2025 SWOT Science Team Meeting

Tuesday, October 14 2025 - Friday, October 17 2025

Nearly three years after its launch, this science team meeting will showcase the extensive scientific advancements achieved using SWOT data, which has been made publicly available on a global scale. SWOT promises to highlight remarkable accomplishments in oceanography, hydrology, estuary studies, cryosphere research, and groundbreaking discoveries, as well as the emergence of new user communities inspired by SWOT.

One particular objective of this event is to assess the L2 products that will be entirely reprocessed in PID0, and available by May 2025.

With SWOT data now open to the public, this meeting marks the first occasion where participation is extended beyond the Science Team members. We are excited to share and discuss the impressive results from broader scientific and end users communities.

The workshop will be held in-person in Arcachon, France from 14 to 17 October, 2025.

Abstracts Book

Abstract list

Oral

Afternoon Plenary Session: Deltas, Estuaries and Coasts

Tue, Oct 14 2025, 14:00 - 18:00 - Plenary session room (Auditorium)

14:00 - 14:20: Hydrodynamic and tide gauge data assimilation modeling of the Gironde Estuary : toward cal/val capabilities?: Florent Lyard et al.
14:20 - 14:40: A Benchmark Dataset of Water Levels and Waves for SWOT Calibration and Validation: Insights from the St. Lawrence Estuary and Saguenay Fjord: Pascal Matte et al.
14:40 - 15:00: Using SWOT Observations to Characterize Hydrodynamics and Hydroperiod in River Deltas and Estuaries: Marc Simard et al.
16:00 - 16:15: SWOT-based intertidal topography retrieval using mission-only data: validation and potential applications: Nushrat Yeasmin et al.
16:15 - 16:30: Predicting flux partitioning in river delta networks using SWOT to produce global delta products and quantify the response of deltas to climate and human-induced change: Paola Passalacqua et al.
16:30 - 16:45: Frontiers in Estuary modeling with SWOT– the tidal Bore in the Severn Estuary revealed from satellite.: Rasmus Lørup Arildsen et al.
16:45 - 17:00: Investigating Barotropic Pressure Gradients in River Plumes Using SWOT: Agata Piffer Braga et al.

Cryosphere: Lakes

Thu, Oct 16 2025, 16:00 - 17:30 - Splinter room for Cryosphere (Banc d'Arguin)

16:08 - 16:18: Tracking Glacial Lake Floods with SWOT: Sonam Sherpa et al.
16:18 - 16:28: Assessing the Potential of the SWOT Mission for the Retrieval of Freshwater Lake Ice and Overlying Snow Properties: Grant Gunn et al.
16:28 - 16:38: Lake and river ice classifications with SWOT: Melanie Trudel et al.

Cryosphere: Sea Ice, SLA and glaciers

Thu, Oct 16 2025, 14:00 - 15:30 - Splinter room for Cryosphere (Banc d'Arguin)

14:05 - 14:15: Towards Improved Mapping of Sea Ice Concentration and Sea Ice Thickness with SWOT: Sammy Metref et al.
14:15 - 14:25: Sea ice classification, concentration and topography using SWOT: Gwenael Jestin et al.
14:25 - 14:35: Sea ice characterization from KaRIn HR data and application to S3NG-T: Laetitia Rodet et al.
14:47 - 14:57: SWOT's Sea Surface Height Observations in Sea Ice Zones: A First Look and Comparison with ICESat-2: Felix Müller et al.
14:57 - 15:07: Using SWOT High-Resolution Raster data to map and monitor rifts on Antarctic ice shelves.: Susan L. Howard et al.
15:07 - 15:17: Surface height extraction over alpine glaciers using SWOT: Cassie Stuurman et al.

Deltas, Estuaries and Coasts

Thu, Oct 16 2025, 09:00 - 12:30 - Splinter room for Deltas, Estuaries and Coasts (Banc d'Arguin)

09:00 - 09:15: First quality assessment of SWOT data in the Gironde estuary: Lucie CAUBET et al.
09:15 - 09:30: Fine scale structures in the coastal zone of Baltic Sea based on nadir-Altimeter and SWOT Data: Luciana Fenoglio et al.
09:30 - 09:45: Assessment of SWOT observations for monitoring nearshore and coastal waves: Md Saiful Islam et al.
09:45 - 10:00: SWOT in the nearshore: Extending HR Pixel cloud product to the surfzone for hyperlocal wave measurements: Tyler Mccormack et al.
10:00 - 10:15: Assessing SWOT Performance to Measure SSH Variability over Rangiroa Atoll, French Polynesia: Ewen Cottour et al.
11:00 - 11:15: Can satellite altimetry observe coastally trapped waves on sub-monthly timescales?: Marcello Passaro
11:15 - 11:30: Integrating SWOT observations with numerical models for investigating water levels in the English Channel: Carlos Lopez Solano et al.
11:30 - 11:45: SWOT to study coastal dynamics: the case of North Current intrusions in the Northwestern Mediterranean Sea: Léna Tolu et al.
11:45 - 12:00: Enhancing surface water extent estimates derived from the SWOT raster product using a Markov Random Field-based algorithm: Omid Elmi et al.
12:00 - 12:15: SWOT-Satellite-Enabled Tidal Data in Estuaries: Paul Bell et al.

Hydrology: Global Hydrology Modeling Working Group

Thu, Oct 16 2025, 16:00 - 17:30 - Splinter room for Hydrology (Ambassadeur)

16:06 - 16:18: Using SWOT to assess and correct global hydrology models: Colin Gleason et al.
16:18 - 16:30: SWOT Derived River Bathymetry for Global Flood Model Applications: Stephen Chuter et al.
16:30 - 16:42: Advancing Global Hydrological Assimilation: First Applications of CTRIP-HyDAS with Real SWOT Observations: KAUSHLENDRA VERMA et al.
16:42 - 16:54: Towards a better understanding of global terrestrial water storage and fluxes through SWOT data assimilation: Augusto Getirana et al.
16:54 - 17:06: Towards Consistent Hydrological-Hydrodynamic Predictions at Large Scale: Multi-Satellite Data Assimilation in the Amazon and the Emerging Role of SWOT Observations: Sly Wongchuig et al.
17:06 - 17:18: SWOT-Hydro2-Learning (tosca project): Learning regionalization of hydrological-hydraulic models and discharge laws over river networks with SWOT and multi-source data assimilation: Pierre-André GARAMBOIS et al.
17:18 - 17:30: Variational Assimilation of SWOT Altimetry into a 1D-2D Porosity-based Hydraulic River Model with Upstream Hydrology: Toward Integrated Hydrological-Hydraulic Discharge Estimation from SWOT: Léo Pujol et al.

Hydrology: HR SWOT Data (Data Validation & Enhancement)
Wed, Oct 15 2025, 14:00 - 17:30 - Splinter room for Hydrology (Ambassadeur)

14:00 - 14:10: Performance assessment of the water surface elevation of HR SWOT products based on comparisons with in-situ networks and in-flight nadir altimetry missions: Maxime Vayre et al.
14:10 - 14:20: Evaluating SWOT inland water surface elevation with gage information in the United States and Canada: Merritt Harlan et al.
14:20 - 14:30: Surface Water and Ocean Topography (SWOT) validation of wide swath interferometry over the lakes in the Pyrénées: Jean-Francois Cretaux et al.
14:30 - 14:40: Validation of SWOT in the Yukon River Basin, Alaska: Camryn Kluetmeier et al.
14:40 - 14:50: Uncertainty assessment of SWOT's systematic errors calibration algorithm: the complementarity of inland and ocean water elevation data: Étienne Jussiau et al.
14:50 - 15:00: Global Validation of SWOT River Widths Using Deep Learning Water Masking of PlanetScope Imagery: Taylor Rowley et al.
15:00 - 15:10: Monitoring smaller water structures using SWOT L2 HR Pixel Cloud: Nicolas Gasnier et al.
16:00 - 16:10: DAHITI – Monitoring of water levels and water slopes surface using SWOT KaRIn measurements over small inland waters: Christian Schwatke et al.
16:10 - 16:20: An Enhanced SWOT River Product (L3) using Densification Approaches: Hind Oubanas et al.
16:20 - 16:30: An Enhanced Framework for Improving SWOT-based Surface Water Level and River Slope Estimations: JIAMING CHEN et al.
16:30 - 16:40: Improving surface type classification in SWOT PIXC Data to enhance inland water monitoring: Mohammad J. Tourian et al.
16:40 - 16:50: Spatial interpolating of SWOT inland water maps based on a hydro/topography-based floodability index and water occurrence: Megumi Watanabe et al.
16:50 - 17:00: SABWAS – Semi-Arid Brazil Water Analysis with SWOT: Advancing Multi-Scale Reservoir Monitoring with Machine Learning and SWOT Products: Rafael OLIVEIRA et al.

Hydrology: Open Science & Applications
Fri, Oct 17 2025, 09:00 - 12:30 - Splinter room for Hydrology (Ambassadeur)

09:00 - 09:10: Progress Update on the SWOT Applications Program: Angelica Rodriguez et al.
09:10 - 09:20: How Well Can We Track Global Reservoir Storage in the SWOT era?: Faisal Hossain
09:20 - 09:30: A global assessment of where SWOT provides new insights for national and transboundary water resource management: Eric Sproles et al.
09:30 - 09:40: Simulating flooding for tropical cyclones in Southern Africa with SWOT: Jeffrey Neal et al.
09:40 - 09:50: What wide swath altimetry has made visible: two case studies of flood events: Nicolas Gasnier et al.
09:50 - 10:00: A comprehensive study of Surface Water and Ocean Topography Pixel Cloud data for flood extent extraction: Quentin Bonassies et al.
11:00 - 11:10: Advancing India's Inland Waterbodies Monitoring with focus on SWOT mission: Pankaj R. Dhote et al.
11:10 - 11:20: Evaluating the Potential of the SWOT Mission for Hydrological Applications in India: Girish Patidar et al.
11:20 - 11:30: Using Surface Water Ocean Topography (SWOT) observations to analyse Land Use Land Cover changes: the case of the Pacific Coast of Ecuador: Valentine Sollier et al.
11:30 - 11:40: SWOT SAR Ka-band Captures Irrigation Events: Cécile Cazals et al.
11:40 - 11:50: Hydrologic impacts on greenhouse gas emissions from streams and rivers: Peter Raymond et al.
11:50 - 12:00: Promoting and explaining a new technology: Swot outreach: Vinca Rosmorduc et al.

Hydrology: River Science Working Group

Thu, Oct 16 2025, 11:00 - 12:30 - Splinter room for Hydrology (Ambassadeur)

11:00 - 11:10: Wide-swath Satellite Altimetry Observes Water Storage Variability in the World's Rivers: Arnaud Cerbelaud et al.
11:10 - 11:20: Assessing and Improving SWOT's Hydraulic Visibility on French narrow rivers (20-100 m): Precision Flow Lines and Slope variation in different flow condition: Thomas LEDAUPHIN et al.
11:20 - 11:30: SAMBA (SWOT for the AMazon BAsin): Fabrice Papa et al.
11:30 - 11:40: Advancing SWOT and Fluvial Geomorphology: River Hydraulics and Sediment Transport: J. Toby Minear et al.
11:40 - 11:50: SWOT River Bathymetry Product: Hind Oubanas et al.
11:50 - 12:00: Detecting river flow waves at large scales with the SWOT satellite: Hana R. Thurman et al.
12:00 - 12:10: Detecting narrow rivers with SWOT: what does detected mean?: Fiona B. Bennitt et al.

Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)

Thu, Oct 16 2025, 09:00 - 10:30 - Splinter room for Hydrology (Ambassadeur)

09:06 - 09:16: All-in-one SWOT lake approach: Volumes, Bathymetry and Uncertainty estimation by Implicit Neural Network Representations: Santiago PENA LUQUE et al.
09:16 - 09:26: Improved SWOT surface water storage monitoring through multi-sensor harmonization: Eric Levenson et al.
09:26 - 09:36: Water volume dynamics in West African lakes and reservoirs by SWOT and optical satellite sensors: Manuela Grippa et al.
09:36 - 09:46: Mapping wetland vegetation using Sentinel-1 and SWOT data: Yannick Duguay et al.
09:46 - 09:56: Global seasonal lake dynamics and phenology revealed by SWOT observations: Jida Wang et al.
09:56 - 10:06: Global Daily Reservoir Evaporation Modeling Augmented by SWOT PIXC Data: Anshul Yadav et al.

Oceanography: Calibration and Validation

Wed, Oct 15 2025, 11:00 - 12:30 - Splinter room for Oceanography (Auditorium)

11:00 - 11:10: SWOT-KaRIn Level-3 Algorithms and Products Overview: Cécile Anadon et al.
11:10 - 11:20: Global assessment of SWOT small-scale performance via synergy with surface chlorophyll observations: Aurelien Deniau et al.
11:20 - 11:30: Extending the Corsica facilities up to SWOT swath: Pascal Bonnefond et al.
11:30 - 11:40: Mediterranean Sea fine-scale dynamics as revealed by SWOT: Louise Rousselet et al.
11:40 - 11:50: Objective Analysis Method for SWOT Microwave Radiometers: Wet Tropospheric Correction for Nadir and Karin altimeters: Marie-Laure Frery et al.
11:50 - 12:00: Strengths and limitations of SWOT geophysical corrections: Francesco Nencioli et al.
12:00 - 12:10: Can the Sentinel-3 Next Generation Topography Altimeter Mission's continuity with Sentinel-3 be assessed with a 4-Hour Tandem Phase?: Noémie Lalau et al.

Oceanography: Inversion/Assimilation

Fri, Oct 17 2025, 09:00 - 10:30 - Splinter room for Oceanography (Auditorium)

09:00 - 09:12: Submesoscale Eddy Dynamics from SWOT and SST via Generative Data Assimilation: Scott Martin et al.
09:12 - 09:24: Short-term neural forecasts of sea surface dynamics: Daria Botvynko et al.
09:24 - 09:36: Mapping SSH with VarDyn: Combining Physics and Variational Techniques for SWOT Data: Florian Le Guillou et al.
09:36 - 09:48: Impact of SWOT assimilation on Mercator Ocean International 's global forecasting system: Mounir Benkiran et al.
09:48 - 10:00: Accounting for observation error correlations for the assimilation of SWOT ocean data: Olivier Goux et al.
10:00 - 10:12: Using SWOT for ocean monitoring and prediction off Canada's west and east coasts: Guoqi Han et al.
10:12 - 10:24: Impact of SWOT data on mesoscale and submesoscale dynamics in a Western Boundary Current: Colette Kerry et al.

Oceanography: Mean Sea Surface

Fri, Oct 17 2025, 11:00 - 12:00 - Splinter room for Oceanography (Auditorium)

11:00 - 11:10: Global Bathymetry Estimation from SWOT Altimetry Using Deep Learning and Integrated Geophysical Features: Farshad Salajegheh et al.
11:10 - 11:20: The new CNES CLS 2025 MSS model leveraging SWOT KaRIn data: Rémy Charayron et al.

11:20 - 11:30: Bathymetry Prediction from SWOT derived gravity using Machine Learning: Bjarke Nilsson et al.
11:30 - 11:40: Enhancing Coastal Bathymetry Prediction by Integrating SWOT and Air-Marine Gravimetry Data with Machine Learning: Biao Lu et al.
11:40 - 11:50: ADVANCING MARINE GRAVITY FIELD RECOVERY IN THE BAY OF BENGAL USING SURFACE WATER AND OCEAN TOPOGRAPHY ALTIMETRY DATA: Milaa Murshan et al.
11:50 - 12:00: The Case for Moving SWOT to an Interlaced Orbit: Ole Baltazar Andersen et al.

Oceanography: Regional Validation

Wed, Oct 15 2025, 14:00 - 17:00 - Splinter room for Oceanography (Auditorium)

14:00 - 14:17: Mapping the Known and Invisible in the age of SWOT: Fine-Scale Ocean Currents from the VERSO/FaSt-SWOT collaboration: Ananda Pascual et al.
14:17 - 14:34: Fine-Scale Upper Ocean Variability in the Kuroshio Extension Region from the Wide-Swath SWOT Measurements: Bo Qiu et al.
14:34 - 14:51: Studying the physical-biogeochemical coupling at fine scale with SWOT : first results of the BioSWOT-Med campaign.: Andrea Doglioli et al.
14:51 - 15:08: The Role Of Fine-Scale Circulation In Shaping The Nutricline Unveiled At The SWOT Era. Insights From BioSWOT-Med.: Aude JOEL et al.
15:08 - 15:25: Fine scale observations in the very dynamic Antarctic Circumpolar Current Polar Front under SWOT over 18 months.: Benoit Legresy et al.
16:00 - 16:17: Ocean Mesoscale Hot-spot at the High Latitudes: the Lofoten Basin: Antonio Bonaduce et al.
16:17 - 16:34: Examining the circulation on the Northwest Atlantic Shelf: along-shelf connectivity and hot spots of shelf-basin exchange: Nicholas Foukal et al.
16:34 - 16:51: Three-dimensional water mass transformation in the Norwegian Sea revealed by SWOT and in-situ data: Leah Johnson et al.
16:51 - 17:08: PATASWOT: Comprehending the physical processes impacting the PATAgonian southwestern continental shelf and adjacent open ocean using SWOT data: Laura Ruiz-Etcheverry et al.
17:08 - 17:25: SWOT in the Cryosphere: Promise, Progress, and Challenges: Tasha Snow et al.

Oceanography: Tides and Inertia-Gravity Waves

Thu, Oct 16 2025, 16:00 - 17:00 - Splinter room for Oceanography (Auditorium)

16:00 - 16:12: Near-inertial wave trapping inside a fine-scale anticyclonic eddy during the BioSWOT-Med 2023 cruise: Turbulence and energy flux: Robin Rolland et al.
16:12 - 16:24: Internal solitary wave activity quantified by SWOT: Matthew Archer et al.
16:24 - 16:36: Tides in complex coastal and polar regions: Michael Hart-Davis et al.
16:36 - 16:48: SWOT observations of the seiche that shook the world: Thomas Monahan et al.
16:48 - 17:00: Mapping internal tides with SWOT and HYCOM: Yadidya Badarvada et al.

Oceanography: Velocities

Thu, Oct 16 2025, 09:00 - 12:30 - Splinter room for Oceanography (Auditorium)

09:00 - 09:13: Reconstruction of Southern Ocean vertical velocities from SWOT and a km-scale regional simulation using 3 independent methods: Elisa Carli et al.
09:13 - 09:26: Ocean Vertical Velocities from Remote Sensing: Eric Dasaro et al.
09:26 - 09:39: High-Resolution Observations from the FaSt-SWOT Campaigns: Validation and Fine-Scale Signal Analysis: Laura Gomez-Navarro et al.
09:39 - 09:52: Signatures of fronts and waves in divergence-vorticity-strain joint probability-density functions created using surface velocities from a high-resolution ocean model: C Spencer Jones et al.
09:52 - 10:05: Between the clouds: An unprecedented view of ocean surface currents: Luc Lenain et al.
10:05 - 10:18: A Practical Separation of Oceanic Vortical and Wavy Motions Entangled in the SWOT Measurements: Zhiyu Liu et al.
11:00 - 11:13: Deciphering Ocean Surface Dynamics with SWOT and drifters: Margot Demol et al.
11:13 - 11:26: Diagnosing the Dynamic Balance of the Surface Ocean Using In-Situ Drifter Observations and SWOT: Andrey Shcherbina
11:26 - 11:39: Assessing submesoscale sea surface height signals from the SWOT mission: Xihan Zhang et al.
11:39 - 11:52: Ocean cyclones from space: Hector Torres et al.
11:52 - 12:05: Vertical velocities and deep subduction events from coincident SWOT and glider observations in the Southern Ocean: Andrew Thompson et al.
12:05 - 12:18: The Horizontal and Vertical structures of sub-10 km Submesoscale Cyclones: Jinbo Wang et al.

Oceanography: Wind and Waves

Thu, Oct 16 2025, 14:00 - 15:30 - Splinter room for Oceanography (Auditorium)

14:00 - 14:15: Submesoscale air-sea interactions as revealed by SWOT: Guillaume Lapeyre et al.

14:15 - 14:30: Orographic waves signatures in SWOT KaRIn data: Perrine Abjean et al.
14:30 - 14:45: Convection within atmospheric storms organized by ocean submesoscale fronts: Félix Vivant et al.
14:45 - 15:00: Leveraging SWOT Radar Data for Machine Learning: Tagging Oceanic and Atmospheric Features at Kilometer Scales: Justin Stopa et al.
15:00 - 15:15: Sizing the largest ocean waves using the SWOT mission: Fabrice Ardhuin et al.

Poster

Cryosphere: Lakes

Tue, Oct 14 2025, 18:00 - 21:00 - Poster session part 1

ST2025CS2_001: Remote sensing of reservoir levels for global water availability assessment: Sarah Esenther et al.
ST2025CS2_002: Ice detection with SWOT data: Louis Kern et al.
ST2025CS2_003: Applying Machine Learning to Analyze SWOT's Potential for Lake Ice Detection: Yanqi Ye et al.
ST2025CS2_004: SWOT mission for study and monitoring of ice-covered rivers and lakes: Elena Zakharova et al.
ST2025CS2_005: Investigating Ice Jams in Arctic Rivers with SWOT's High-Resolution Altimetry: Linda Christoffersen et al.
ST2025CS2_006: Antarctic Ice Shelf Tidal Displacement from SWOT: Zachary Katz et al.
ST2025CS2_007: Machine Learning-Based Mapping of Lake Ice Cover from SWOT KaRIn Backscatter: Preliminary Results: Jaya Sree Mugunthan et al.
ST2025CS2_008: Evaluating SWOT elevation retrieval on lake and river ice cover near Fairbanks, Alaska: Xiao Yang et al.
ST2025CS2_009: Cryosphere Applications for the SWOT SAR Interferometry and Altimetry: Rosemary Willatt et al.

Cryosphere: Sea Ice, SLA and glaciers

Tue, Oct 14 2025, 18:00 - 21:00 - Poster session part 1

ST2025CS1_001: Sea Ice Classification from SWOT Observations: A Preliminary Analysis: Khalil Bakhtiari Asl et al.
ST2025CS1_002: SWOT observations over sea ice: what can we learn for nadir altimetry: Marta Alves et al.
ST2025CS1_003: iSWOT: Project Updates and Initial Results on Cryosphere Monitoring: Mohammed Dabboor et al.
ST2025CS1_004: Multi-frequency radar scattering analysis using SWOT: Imogen Garlick et al.

Deltas, Estuaries and Coasts

Tue, Oct 14 2025, 18:00 - 21:00 - Poster session part 1

ST2025DEC2_001: Enhancing Australian Coastal Bathymetry Using Deep Learning and SWOT-Derived Geophysical Data: Farshad Salajegheh et al.
ST2025DEC2_002: Detecting Mekong River plume fronts using SWOT altimetry and drifter observations : Alexei Sentchev et al.
ST2025DEC2_003: SWOT observations and corrections assesment in the Northeast Atlantic shelf: Florent Lyard et al.
ST2025DEC2_004: Rivers and Tides: a first global analysis from the SWOT satellite mission: Daniel Scherer et al.
ST2025DEC2_005: Evaluation of omission error in FES2022 nonlinear wave spectrum across various coastal areas of the globe: Chafih Skandrani et al.
ST2025DEC2_006: Barotropic tide filtering in SWOT observations through data assimilation: Chafih Skandrani et al.
ST2025DEC2_007: A step forward in the improvement of the SWOT Wet Tropospheric Correction through GPD+ in the coastal zone: Isabel Cardoso et al.
ST2025DEC2_008: ACCURACY ASSESSMENT OF SWOT KaRIn SEA LEVEL DATA: Jesus Gomez-Enri et al.
ST2025DEC2_009: What can we learn about nearshore dynamics from spatial altimetry ? : preliminary results from the TOSCA/POSPOW project: Yann Krien et al.
ST2025DEC2_010: Stream direction reversals in Baltic rivers derived from SWOT water level observations: Dan Jansson et al.
ST2025DEC2_011: The DTU25GRA SWOT derived global gravity field and evaluation with airborne gravity in the Norwegian coastal zone: Bjarke Nilsson et al.

ST2025DEC2_012: Propagation of Ocean Tides and their Influence on Estuarine Systems as Observed by SWOT: Martin Kolster et al.
ST2025DEC2_013: Monitoring interannual evolution of Normandy intertidal areas using spaceborne imagery: A decade of observations with Sentinel-2&1 and SWOT: Simon Déchamps et al.
ST2025DEC2_014: Exploring Estuarine Sea Level Fluctuations and Dynamics Using the Surface Water and Ocean Topography (SWOT) Mission: Resolving Estuaries: Sarah N Giddings et al.
ST2025DEC2_015: SCOEPUS project: on the use of SWOT ocean products in shelf seas and estuaries and for the study of internal tides: Nadia Ayoub et al.
ST2025DEC2_016: Evaluating SWOT in the Estuarine and Nearshore Region: A Comparative Study of the Baltic Sea and the Bay of Bengal: Faruque Abdullah et al.
ST2025DEC2_017: Leveraging SWOT data to estimate hydrologic connectivity between channels and islands in coastal river deltas: Eleanor Henson et al.
ST2025DEC2_018: Observing deltaic surface water elevation with an integrated SWOT-based workflow: Florin Miron et al.

Hydrology: Discharge Algorithms Working Group (DAWG)

Thu, Oct 16 2025, 17:30 - 18:30 - Poster session part 3

ST2025HS4_001: Estimating Discharge–Depth Relationships and Improving Rating Curves in Texas Rivers Using SWOT Data and Machine Learning: Sujana Timilsina et al.
ST2025HS4_002: Typological drivers of SWOT discharge accuracy: Steve Coss et al.
ST2025HS4_003: Estimating river discharge using a SWOT-based statistical approach: Izzy Probyn et al.
ST2025HS4_004: Building an Integrated Satellite-Hydrography Framework for SWOT-Based Discharge Estimation: Heejin An et al.
ST2025HS4_005: Variability in Arctic river discharge, suspended sediment transport, and turbidity: Anastasia Piliouras et al.
ST2025HS4_006: Estimating Daily Discharge Using SWOT Data: Siqi Ke et al.
ST2025HS4_007: Assessing SWOT River Discharge Performance Between Fast Sampling and Science Orbits: Elisa Friedmann et al.
ST2025HS4_008: Estimation of Ungauged River Discharges from SWOT-like Measurements with Uncertainty Quantification: Jerome Monnier et al.
ST2025HS4_009: Global River Discharge from SWOT at Gauging Stations: A Complementary Perspective: Peyman Saemian et al.
ST2025HS4_010: Incorporating SWOT into a deep learning framework of global river discharge.: Theodore Langhorst et al.
ST2025HS4_011: Discharge Algorithm Working Group Update: Michael Durand et al.
ST2025HS4_012: HYdraulic retrievals from Data assimilation: River Observation with Swot (HYDROS Project): Hind Oubanas et al.

Hydrology: Global Hydrology Modeling Working Group

Thu, Oct 16 2025, 17:30 - 18:30 - Poster session part 3

ST2025HS5_001: A Raster-Vector Hydrologic-Hydrodynamic Modeling Framework for Regional Applications with SWOT and Multi-Source Data Integration: Toward Effective Bathymetry Learning: Mohamed Amine BERKAOUI et al.
ST2025HS5_002: Joint training of hydrologic and hydraulic models Using Deep Learning and SWOT Pixel Cloud Data for the Torne River: Simon Jakob Köhn et al.
ST2025HS5_003: Evaluating the potential of reach water surface elevation product from SWOT mission using Assimilation and Hydrodynamic modelling.: Manu K Soman et al.
ST2025HS5_006: SWOT River Database (SWORD) Updates: Elizabeth Altenau et al.
ST2025HS5_007: Towards integrating Pixel Cloud HR SWOT data into a hydrogeological model: Elena GOALIC et al.
ST2025HS5_008: Leveraging SWOT Data to Improve Coupled Lake–River Routing Models: Yuanzhi Ma et al.
ST2025HS5_009: Contribution of SWOT Data to Wetland Hydrological Modelling with HYDROTEL: The Oromocto Watershed Case Study: Anne-Marie Laroche et al.
ST2025HS5_010: Hydrographic Mapping of Chile: SWOT-Based Characterization of National Rivers Through Integrated Hydrological Modeling: Rodrigo Abarca del Rio et al.
ST2025HS5_011: Assessing Global Flood Inundation Model Accuracy with SWOT HR Raster Observations: Stephen Chuter et al.

Hydrology: HR SWOT Data (Data Validation & Enhancement)

Wed, Oct 15 2025, 17:30 - 18:30 - Poster session part 2

ST2025HS1_001: Validation of SWOT Lake water level using in situ measurements: results from a student project at Lake Guerledan (France): Clémence Chupin et al.

ST2025HS1_002: SWOT meets GRDC: Assigning SWORD nodes to in situ stations from the Global Runoff Data Centre: Simon Mischel et al.
ST2025HS1_003: SWOT River Water Surface Elevation Data in the Pantanal: A Sub-Regional Performance Assessment: Jahdy Oliveira et al.
ST2025HS1_004: Validation of Water Surface Elevation and Extent over French lakes using the Surface Water Ocean Topography (SWOT) mission: Cassandra Normandin et al.
ST2025HS1_005: Influence of Bitwise Quality Flags on SWOT Vector Node and Reach Product Accuracy in Indian River Basins: Rucha Sanjay Deshpande et al.
ST2025HS1_006: Investigating SWOT observations for river hydrodynamics: A case study from the Po River: Farid Kurdnezhad et al.
ST2025HS1_007: Assessment of SWOT-RiverSP Data Reliability and Accuracy over Canadian Rivers: Victoria Litalien et al.
ST2025HS1_008: Evaluation of the Water Masks Generated by the SWOT Satellite and Comparison with Optical Sensors: Maurício Cordeiro et al.
ST2025HS1_009: Validation and refinement of water level and water surface estimations from SWOT in floodplains environments: Lucas Sengsourinho et al.
ST2025HS1_010: Field validation of SWOT for measuring water level and inundated areas of geographically isolated wetlands: Frances O'Donnell et al.
ST2025HS1_011: From Field to Swath: Validating and Refining SWOT Water Surface Elevations in Steep Rivers Using Quantile Regression: Trevor Wilkerson et al.
ST2025HS1_012: Assessment of Water Surface Elevation Products of the SWOT Satellite in the Northeast Brazil: Alfredo Ribeiro Neto et al.
ST2025HS1_013: GNSS-IR monitoring of coastal and river water levels in Cameroon for Sentinel and SWOT Altimetry validation: Makan Karegar et al.

Hydrology: Open Science & Applications
Tue, Oct 14 2025, 18:00 - 21:00 - Poster session part 1

ST2025HS6_001: Sentinel-3 Next Generation Topography Mission Performance and Uncertainty Assessment (S3NGT-MPUA): Noemie Lalau et al.
ST2025HS6_002: Assessment of Swath Altimetry Performance for S3NG-T HR Mode Using the Radarspy Simulator: Carlos Yanez et al.
ST2025HS6_003: Analysis of relationships between soil moisture and false water detections in SWOT PIXC products: Maxime Azzoni et al.
ST2025HS6_004: Yangtze intermediate basin lakes and sub-lakes monitoring based on SWOT products: Sabrine Amzil et al.
ST2025HS6_005: Global hydropower potential of world rivers revealed by the SWOT Mission: Jonathan Flores et al.
ST2025HS6_006: Topography of Amazon floodplain lakes from SWOT: preliminary results: Alice Fassoni-Andrade et al.
ST2025HS6_007: Harnessing SWOT observations to advance well water disaster surveillance: Edward Beighley et al.
ST2025HS6_008: Perspectives of Application of SWOT data in South America: Alfredo Ribeiro Neto et al.
ST2025HS6_009: Can SWOT be used to assess Vegetation Structure?: Jessica Fayne
ST2025HS6_010: Operational modes and hydrological implications of cascade reservoirs on major rivers revealed by SWOT observations: Meng Ding et al.
ST2025HS6_011: Deriving Lake Circulation from SWOT: A Physically Constrained, Scalable Approach: Rodrigo Abarca del Rio et al.
ST2025HS6_012: Quantification of Water Resources and Their Evolution: Guillaume HUGUET

Hydrology: River Science Working Group
Thu, Oct 16 2025, 17:30 - 18:30 - Poster session part 3

ST2025HS3_001: Estimation of Discharge and River Channel Parameters through Hydrology–Hydraulic (H&H) Coupling with SWOT Altimetry: Toward Learnable Parameterizations: Pierre-André GARAMBOIS et al.
ST2025HS3_002: Estimation of Bathymetry Profiles For Poorly Gauged River Networks: Jérôme Monnier et al.
ST2025HS3_003: Assessing River Avulsion Risk Ratios with NASA SWOT: Carly Koppe et al.
ST2025HS3_004: Altimetry River Reach Methods (ARRM): Karina Nielsen
ST2025HS3_005: Evaluating the potential of Surface Water and Ocean Topography (SWOT) satellite data for detecting water-surface superelevation in meandering rivers: Tasneem Haq Meem et al.
ST2025HS3_006: Assessment of SWOT estimated hydraulic parameters through hydrological experiments over Ganga River: Shard Chander et al.
ST2025HS3_007: SWOT Validation over the Amazon Basin: Daniel Moreira et al.
ST2025HS3_008: Leveraging SWOT Lake and River Data and Physics-Embedded Machine Learning to Advance Streamflow Simulation: Peijun Li et al.

ST2025HS3_009: Assimilation of SWOT nodes products into basin-scale hydraulic models: Ludovic Cassan et al.
ST2025HS3_010: Global Riverbank Slope Patterns Inferred from SWOT-Derived Hypsometry Curves: J. Daniel Velez et al.

Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Thu, Oct 16 2025, 17:30 - 18:30 - Poster session part 3

ST2025HS2_001: Reservoir monitoring based on SWOT products, comparison with imaging and altimetric multi-mission approach: applications to the Grand lacs de Seine reservoirs (France): Sabrine Amzil et al.
ST2025HS2_002: Lake Shoreline Morphometry Influences the Accuracy of SWOT-Derived Water-Level Estimates: David Lindao Caizaguano et al.
ST2025HS2_003: Lakes and reservoirs storage changes from SWOT and ancillary database in Quebec (Canada): Axel Chuette et al.
ST2025HS2_004: Leveraging SWOT observations for global reservoir monitoring: Elyssa Collins et al.
ST2025HS2_005: Comparing multi-mission altimetry derived reservoir storage changes with SWOT Level 2 Lake Single-Pass product: Abhilasha Garkoti et al.
ST2025HS2_006: Global integration of lake and river hydrology with SWOT and the LakeFlow algorithm: George Allen et al.
ST2025HS2_007: Hydrological dynamics of the floodplains in the Cuvette Centrale (Congo River Basin) using the Surface Water and Ocean Topography (SWOT) mission: Cassandra Normandin et al.
ST2025HS2_008: Monitoring surface water storage in Peruvian Andean lakes and reservoirs with SWOT and Sentinel-1: Toward integrated mountain hydrology: Kimberly Karime Visitacion Bustamante et al.
ST2025HS2_009: Assessing SWOT's capability in characterizing reservoir backwater dynamics: Xinchen He et al.
ST2025HS2_010: Mapping the wetlands of the Amazon and Congo rainforests with PALSAR-2 and SWOT: Paul Senty et al.
ST2025HS2_011: Use of SWOT for understanding dynamics of Amazonian ria lakes and its interaction with the Amazon River: Kei Yamato et al.
ST2025HS2_012: Monitoring water storage change in lakes and reservoirs from space: Luciana Fenoglio et al.
ST2025HS2_013: A SWOT-Based Climatology of Seasonal Variability in Southern Chilean Lakes.: Rodrigo Abarca del Rio et al.

Oceanography: Calibration and Validation
Wed, Oct 15 2025, 17:30 - 18:30 - Poster session part 2

ST2025OS1_001: Atmospheric Gravity Waves signature on the sea surface: Insights from SWOT and OSCAR observations: Adrien Martin et al.
ST2025OS1_002: Assessment of the Wet Tropospheric Correction from the SWOT Radiometer: Thibault Pirotte et al.
ST2025OS1_003: Advances in Sea Level Mapping with SWOT KaRIn Data: Maxime Ballarotta et al.
ST2025OS1_004: KaRIn Noise reduction using a Convolutional Neural Network for the SWOT 2km and 250m ocean product: Gaétan Meis et al.
ST2025OS1_005: Cross-comparison at cross-over between SWOT LR SSH products and Sentinel-3 marine altimetry products: Salvatore Dinardo et al.
ST2025OS1_006: The effects of rain on a Ka-band swath altimeter: lessons learned from the SWOT mission: Bruno Picard et al.
ST2025OS1_007: Sea State Bias on SWOT measurements: Samuel Osina et al.
ST2025OS1_008: A new approach using the Automatic Identification System (AIS) data and SWOT data : a mesoscale study case: Camille Cardot et al.
ST2025OS1_009: SWOT and the drifter's odyssey in the NW Mediterranean Sea: riding current meanders and escaping eddies: Mathilde Cancet et al.
ST2025OS1_010: S3NG-T swath altimetry performance assessments with the CNES simulator Radarspy: Louise Yu et al.
ST2025OS1_011: In situ geometric validation of SWOT satellite observations in Bass Strait, Australia: Andrea Hay et al.
ST2025OS1_012: Contributions to SWOT validation from Bass Strait and the Southern Ocean: Christopher Watson et al.
ST2025OS1_013: Shipborne GNSS atmospheric water vapor retrieval for SWOT radiometer validation in the framework of the Wem-SWOT / C-SWOT dual campaigns: Aurélie Panetier et al.
ST2025OS1_014: Eddy Hunter: a SWOT data mining system to foster altimetry product integration: Federico Scarscelli et al.
ST2025OS1_015: Assessing SWOT-Derived Surface Velocities Against HFR Data: Insights from the Ibiza Channel: Guiomar Lopez et al.
ST2025OS1_016: Level 4 global topography mapping including SWOT data with 4DVarNet: Cecile Anadon et al.

ST2025OS1_017: Using SWOT sea surface height to study coastal eddy dynamics: Luke Kachelein et al.
ST2025OS1_018: SWOT KaRIN Calibration Algorithm: principle, updates and analysis of the absorption of geophysical corrections residues such as tide and sea state bias: Cecile Anadon et al.
ST2025OS1_019: Sub-mesoscale and coastal ocean dynamics in the North Indian Ocean using SWOT and EOS-06/OCM-3 observations: Aditya Chaudhary et al.
ST2025OS1_020: Absolute Calibration and Validation of SWOT Nadir Altimetry Products over the Pertuis Charentais Using In-Situ Observations and Local Model: Audrey Hyeans et al.
ST2025OS1_021: Simulation-informed deep learning for enhanced SWOT observations of fine-scale ocean dynamics: Eugenio Cutolo et al.
ST2025OS1_022: Assessing and Reducing Uncertainty in the Wet Tropospheric Correction for Wide Swath Altimetry: Shannon Brown

Oceanography: Inversion/Assimilation

Wed, Oct 15 2025, 17:30 - 18:30 - Poster session part 2

ST2025OS6_001: Evaluating the impact of SWOT assimilation in Mercator Ocean International's forecasting system: insights from AdAC campaigns: Ergane Fouchet et al.
ST2025OS6_002: Assimilating SWOT Observations into OTIS for Improved Regional Tidal Modeling in the Canadian Arctic Archipelago: Peter Matheston et al.
ST2025OS6_003: Data Assimilation of Surface Geostrophic Currents Derived from SWOT data in the Northwestern Pacific Ocean and marginal seas: Dohyeop Yoo et al.
ST2025OS6_004: Assimilating Nadir SLA at Multiple Resolutions in the Western Mediterranean Sea: Maximo Garcia-Jove Navarro et al.
ST2025OS6_005: Toward an Ocean Foundation Model Integrating SWOT and Conventional Altimetry: Eugenio Cutolo et al.
ST2025OS6_006: Toward Assimilating SWOT Altimetry Data into the Current and Next-Generation GMAO Subseasonal-to-Seasonal Forecast System: David Russell et al.
ST2025OS6_007: Inverse modeling of the internal tide using the Coupled-mode Shallow Water model: Samuel Kelly
ST2025OS6_008: Assessment of High-Resolution Ocean Models Using SWOT Observations: Habib Micael Aguedjou et al.

Oceanography: Mean Sea Surface

Wed, Oct 15 2025, 17:30 - 18:30 - Poster session part 2

ST2025OS7_001: From open ocean to the coastal zone: benefits from SWOT in the mean sea surface: Bjarke Nilsson et al.
ST2025OS7_002: Seamounts from SWOT: Expanding the global catalogue and revealing their interactions with ocean currents: Yao Yu et al.

Oceanography: Regional Validation

Tue, Oct 14 2025, 18:00 - 21:00 - Poster session part 1

ST2025OS2_001: 4D-Var and SWOT: producing a month-long state estimate of the California Current System: Ariane Verdy et al.
ST2025OS2_002: Towards adjoint-based assimilation of SWOT data in a global ocean circulation model: Shoshi Reich et al.
ST2025OS2_003: Super Resolution of DUACS Sea Surface Height near the coast of Norway using SWOT: Antoine Bernigaud et al.
ST2025OS2_004: The spatial organization of Sargassum aggregations by ocean frontal dynamics : insights from SWOT data: Pierre-Etienne Brilouet et al.
ST2025OS2_005: From SWOT Swaths to Global Ocean: A Machine Learning Proof of Concept for Estimating Incoherent Tidal Variability: Ergane Fouchet et al.
ST2025OS2_006: Capsizing and impact wave detection – Case study of iceberg A-76A: Constance Hjort et al.
ST2025OS2_007: Internal solitary waves reflection and diffraction from interaction with eddies on the Amazon Shelf from SWOT: Chloé Goret et al.
ST2025OS2_008: Investigating Mediterranean phytoplankton diversity in fine-scale structures from space.: Théo Garcia et al.
ST2025OS2_009: SWOT data validation on the Patagonian Continental Shelf: Optimized tidal and atmospheric corrections for submesoscale resolution: Sebastián Cornejo-Guzmán et al.
ST2025OS2_010: Evidence and likely mechanisms underlying the existence of fine-Scale frontal phytoplankton communities in the SWOT era: Laurina Oms et al.
ST2025OS2_011: First insights from SWOT fast sampling phase: High Frequency Coastal Trapped Waves over the Patagonian Shelf.: Léa Poli et al.

ST2025OS2_012: Ecological role of fine-scale ocean structures in structuring heterotrophic bacterioplankton communities: BioSWOT-Med campaign: Ludivine Grand et al.
ST2025OS2_013: Heat supply to the fast-thinning Denman glacier in Antarctica: ice and eddies interactions revealed by SWOT and in situ observations.: Benoit Legresy et al.
ST2025OS2_014: New insights on mesoscale activity and associated retention properties from SWOT gridded products in the western Mediterranean Sea: Laura Gomez-Navarro et al.
ST2025OS2_015: Comprehensive studies on sub-mesoscale phenomena; coastal SSHA validations in the Bungo Channel, Japan, and impacts of assimilating SWOT data in ocean and hydrological models: Kaoru Ichikawa
ST2025OS2_016: Unveiling Mediterranean Mesoscale to Sub-mesoscale Dynamics: Insights from WEMSWOT and C-SWOT-2023 Twin Ship Campaigns: Jean-Baptiste Roustan et al.
ST2025OS2_017: Submesoscale Sea Surface Height Mapping Along the East Greenland Coast From SWOT: Sara N. Jensen et al.
ST2025OS2_018: Southern Ocean latent heat flux variability driven by high atmospheric frequencies and oceanic meso- and submesoscale motions: Lucie Reymondet et al.
ST2025OS2_019: Patagonian Shelf Break Front (PSBF): Seabed morphology, water masses and ocean currents: Laura Ruiz-Etcheverry et al.
ST2025OS2_020: Modelling the high-wavenumber ocean dynamics revealed by SWOT in the ACC: Yann-Treden Tranchant et al.
ST2025OS2_021: Submesoscale Eddys Identification and Characterization in the Oceanic Region of Fernando de Noronha and Rocas Atoll Using SWOT Satellite Observations: Diogenes Fontenele et al.
ST2025OS2_022: Surface ocean variability in the northern North Atlantic: Insights from the new SWOT mission: Ingvild Olden Bjerkelund et al.
ST2025OS2_023: Assessment of SWOT satellite observations and integration with high-resolution regional simulations in the Western Mediterranean Sea: Baptiste Mourre et al.
ST2025OS2_024: TROPIC-SWOT: Submesoscale Ocean Currents In The Tropical Pacific: Daniel Whitt et al.
ST2025OS2_025: Fine Scales Structures of the Abrolhos Bank Circulation during the SWOT FSP together with Insitu and Copernicus Data: Fabrice Hernandez et al.
ST2025OS2_026: SWOT-ETAO project : 2D mesoscale/submesoscale dynamics in the Eastern Tropical Atlantic Ocean using the SWOT data with multisensor and modelling approach: Isabelle Dadou et al.

Oceanography: Tides and Inertia-Gravity Waves
Thu, Oct 16 2025, 17:30 - 18:30 - Poster session part 3

ST2025OS5_001: Use of new baroclinic tide models to improve the correction of internal tides in SWOT data: Loren Carrere et al.
ST2025OS5_002: A test case for correcting coherent and incoherent tides in altimetry data using MIOST: Michel Tchilibou et al.
ST2025OS5_003: Combining SWOT and numerical modeling in the Indonesian seas to investigate the internal tides and internal solitary wave interactions: Simon Barbot et al.
ST2025OS5_004: Baroclinic Tides Estimated from SWOT Science Mission Data: Edward Zaron
ST2025OS5_005: Assessment of internal wave propagation through combined observations from SWOT (sea surface height and backscatter coefficient) and Sentinel-1 (surface roughness and Doppler radial velocities): Clément Le Goff et al.
ST2025OS5_006: Capturing the evolution of baroclinic tides into internal solitary waves in the St. Lawrence Estuary with SWOT altimetry: Xavier Chartrand et al.
ST2025OS5_007: The decay of the low-mode internal tide due to near-resonant wave-wave interactions: Maarten Buijsman et al.
ST2025OS5_008: Internal tide energy decay in the Equatorial Pacific: Oladeji Siyanbola et al.
ST2025OS5_009: Mapping Instantaneous Internal Tides from SWOT by An Improved Mapping Technique: Zhongxiang Zhao et al.

Oceanography: Velocities
Thu, Oct 16 2025, 17:30 - 18:30 - Poster session part 3

ST2025OS3_001: Dynamic Mode Decomposition of Geostrophically Balanced Motions from SWOT Cal/Val in the separated Gulf Stream: Takaya Uchida et al.
ST2025OS3_002: Relative dispersion at the surface of the ocean: role of balanced motions and internal waves: Stefano Berti et al.
ST2025OS3_003: Dynamical interpretation of SWOT SSH: an in-situ approach to disentangle balanced and unbalanced motions beneath SWOT swaths: Arne Bendinger et al.
ST2025OS3_004: Observing and understanding internal solitary waves in the Maluku's Sea with SWOT: Aurélien Ponte et al.
ST2025OS3_005: Vertical velocities measurements in fine-scale processes during the BioSWOT-Med cruise: Maxime Arnaud et al.

ST2025OS3_006: Ubiquity and seasonality of deep submesoscales in the Southern Ocean revealed by elephant seals and SWOT: Lia Siegelman et al.
ST2025OS3_007: Energy partition between internal waves and quasi-geostrophic motions in the moderately energetic area of the BioswotMed cruise: Julien Lenne et al.
ST2025OS3_008: Variational method for dynamical reconstruction and separation of Balanced Motions and Internal Tide from SWOT: Valentin Bellemin-Laponnaz et al.
ST2025OS3_009: Revealing the submesoscale structure of subthermocline eddies in the North East Pacific: Giuliana Berden et al.
ST2025OS3_010: Spectral Kinetic Energy Cascades from SWOT Observations in the Kuroshio Region: Jia-Xuan Chang et al.
ST2025OS3_011: Mixed layer mechanisms detected by SWOT: Abigail Bodner et al.
ST2025OS3_012: SWOT reveals fine-scale balanced motions and dispersion in the Antarctic Circumpolar Current: Yann-Treden Tranchant et al.
ST2025OS3_013: Lagrangian characterization of fine-scale processes (1 to 10 km) using an array of surface drifters in the Brazil Current: Candela Lopez Fidel et al.
ST2025OS3_014: Inferring submesoscale transport from SWOT: K.Shafer Smith et al.
ST2025OS3_015: Extrapolating high resolution SWOT SSH fields via deep learning techniques: Tatsu Monkman et al.
ST2025OS3_016: Approaches to estimating heat and transport using sea surface height: Feier Yan et al.
ST2025OS3_017: Assessing the seasonality of ocean macroturbulence in circulation models with SWOT data : first results from a cloud-based, distributed intercomparison study: Julien Le Sommer et al.
ST2025OS3_018: Comparisons between SWOT measurements and surface currents obtained from optical sensors: Nicolas Rascle et al.
ST2025OS3_019: Evaluating SWOT's Performance in Capturing Mesoscale and Submesoscale Currents in the Cape Basin: A. Nathanael Dossa et al.

Oceanography: Wind and Waves

Tue, Oct 14 2025, 18:00 - 21:00 - Poster session part 1

ST2025OS4_001: Wave Spectra from SWOT: Overview of the New Level 3 Wind Wave Product: Beatriz Molero et al.
ST2025OS4_002: Observing Sea State Gradients from SWOT: Preliminary Results and Ongoing Efforts: Bia Villas Boas et al.
ST2025OS4_003: On the assimilation of upgraded L2 SWOT-swath SWH in the wave model MFWAM: Lotfi Aouf et al.
ST2025OS4_004: Spatiotemporal Variability of Ocean Surface Waves in the Argentine Continental Shelf - SWOT Mission Contribution: Leilou LEVARD et al.
ST2025OS4_005: SWOT as a new global ocean imager for air-sea interaction applications in synergy with present and future ocean SAR missions: Doug Vandemark et al.
ST2025OS4_006: The 2025 Drake Passage Tsunami imaged by SWOT: Lucie Rolland et al.
ST2025OS4_007: Observing variability in ocean wave climates with SWOT: Ho Allison et al.
ST2025OS4_008: Wave Observations across Tuamotu Archipelago from Wide Swath Radar Altimetry (SWOT): Taina Postec et al.

Abstract details

Hydrodynamic and tide gauge data assimilation modeling of the Gironde Estuary : toward cal/val capabilities?

Florent Lyard (CNRS/LEGOS, France); Nadia Ayoub (CNRS/LEGOS, France); Lucie Caubet (CNES/Université de Toulouse/LEGOS, France); Pascal Bonnefond (Observatoire de Paris/LTE, France)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
In one hand, estuaries are a permanent challenge for hydrodynamic modeling, because of their highly complex and non-linear dymanic, recurrent flooding, wetting/drying areas and uncertainties on the geometry (including vertical references). In the other hand, some estuaries such as the Gironde estuary are densely monitored by tidal gauges. Using tide gauge data assimilation to model the free surface with a high level of accuracy, it becomes possible to compare SWOT observations not only in a point-wise manner, but as a large portion of the swath with "augmented" tide gauge data, i.e. the data assimilation model output. We investigate here the capabilities of using such a system not only to validate ssh anomalies, but also in an absolute way (calibration), providing model and assimilated data vertical references are consistent and reliable. Actually, vertical reference issue is a key point in our investigations (as Gironde tide gauges are not monitored in terms of land motion), and the Gironde Estuary 2018 GNSS and LIDAR campaign will support the discussion about this point, as well as a new approach based on inferred ocean-at-rest geoid altitude at tide gauge location. This is part of the SWOT ST project SCOEPUS (N. Ayoub and F. Lyard PIs)

Corresponding author:
Florent Lyard (**CNRS/LEGOS**, **France**), florent.lyard@univ-tlse3.fr

A Benchmark Dataset of Water Levels and Waves for SWOT Calibration and Validation: Insights from the St. Lawrence Estuary and Saguenay Fjord

Pascal Matte (Environment and Climate Change Canada, Canada); Marc Simard (Jet Propulsion Laboratory, USA); Alexandra Christensen (Jet Propulsion Laboratory, USA); Xavier Chartrand (Institut des Sciences de la Mer (ISMER), Canada); David Purnell (Precipice Sensors Inc., Canada); Silvia Innocenti (Environment and Climate Change Canada, Canada); Cédric Chavanne (Institut des Sciences de la Mer (ISMER), Canada); Dany Dumont (Institut des Sciences de la Mer (ISMER), Canada); Gabriela Siles (Université Laval, Canada); Mohammed Dabboor (Environment and Climate Change Canada, Canada); Daniel Peters (Environment and Climate Change Canada, Canada)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
The St. Lawrence Estuary and Saguenay Fjord (Quebec, Canada) form a macro-tidal, seasonally ice-covered system exhibiting strong spatial and temporal gradients in water surface dynamics due to the interaction of tides, river discharge, internal waves, and complex bathymetry. During the SWOT mission's Calibration/Validation (Cal/Val) phase (April–July 2023), this region was advantageously located under the fast-sampling orbit, acquiring near-daily, high-resolution KaRIn observations along a ~300 km reach of the estuary.

To support SWOT validation and enable new scientific investigations, we assembled a comprehensive multi-sensor dataset combining in-situ and remote sensing measurements. The dataset includes tide gauges and wave buoys, GNSS-IR sensors, HF radars, ADCPs, airborne LiDAR and AirSWOT measurements, and satellite altimetry (RCM, Sentinel), spanning both the pre- and post-launch Cal/Val and Science phases of SWOT. These observations were co-located in time and space with SWOT overpasses to provide reference measurements of water surface elevation, slope, and surface wave variability under various environmental conditions, including ice and storm events.

Building on this dataset, we apply an advanced harmonic analysis approach tailored to short and/or sparsely sampled SWOT records, blending tide gauge information to achieve super-resolution of non-stationary tides. Particular attention is given to the fluvial–estuarine transition zone (FETZ), where conventional observations are spatially sparse and physical processes are nonlinear and nonstationary.

This curated dataset represents one of the most complete field observation efforts ever conducted in a cold-region estuary for satellite altimetry, offering a valuable resource for validating SWOT performance and improving our understanding of estuarine hydrodynamics. It is designed to support cross-comparisons with models and to advance coastal altimetry applications.
Corresponding author:
Pascal Matte (**Environment and Climate Change Canada**, **Canada**), pascal.matte@ec.gc.ca

Using SWOT Observations to Characterize Hydrodynamics and Hydroperiod in River Deltas and Estuaries

Marc Simard (Jet Propulsion Laboratory, California Institute of Technology, United States); Alexandra Christensen (Jet Propulsion Laboratory, California Institute of Technology, USA); Michael Denbina (Jet Propulsion Laboratory, USA); Pascal Matte (Environment and Climate Change Canada, Canada); Ali Payandeh (Jet Propulsion Laboratory, California Institute of Technology, USA); Cecilia Lopez-Gamundi (Jet Propulsion Laboratory, California Institute of Technology, USA)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
River deltas and estuaries are dynamic transitional zones at the land-ocean interface where freshwater, tides, sediment, and nutrients interact, shaping ecosystems that are both ecologically rich and highly vulnerable to climate change and anthropogenic disturbance. The Surface Water and Ocean Topography (SWOT) satellite mission offers unprecedented opportunities to monitor water surface elevation and hydrodynamics in these complex environments. However, extracting actionable information from SWOT's novel Ka-band radar interferometric measurements—especially in low-slope, tidally influenced coastal regions—requires new approaches tailored to the complex geomorphology and hydrology of deltas and estuaries.

In this study, we developed and applied a framework that aggregates SWOT measurements onto a delta-specific river network graphs to extract hydrodynamic parameters and validate numerical hydrodynamic models in global river deltas and estuaries. The graphs organize SWOT's pixel cloud (PixC) data along channels to allow for a robust non-stationary harmonic analysis (i.e. NS_Tide), which reconstructs hourly tidal constituents from the sparse SWOT measurements. The tidal reconstruction is then used to validate numerical models that are further leveraged to quantify channel-wetland connectivity, which is essential for understanding how water and salinity move across deltaic landscapes. This approach captures temporal variability in tidal dynamics and enables estimation of tidal range and hydroperiod—the duration and frequency of inundation in adjacent wetlands. These parameters are critical for assessing habitat viability, salinity gradients and biogeochemical fluxes.

We applied this methodology across a range of representative coastal systems, including: the Guayas River delta (Ecuador), the Komo River estuary (Gabon), the St. Lawrence estuary (Canada), the Langebaan Lagoon (South Africa), and the Mississippi River Delta (USA). These sites span a spectrum of tidal regimes, channel geometries, and wetland types, offering a comparative view of SWOT's performance across diverse hydro-geomorphological contexts. We evaluated SWOT-derived water levels against in-situ gauges, model outputs, and ancillary remote sensing data, and we assessed the coherence of tidal signals along river-to-ocean transects.

Our results demonstrate that SWOT reliably resolves tidal amplitudes and phases in most estuarine channels, enabling consistent estimation of hydroperiod in adjacent wetlands. SWOT's performance is modulated by regional morphology, including tidal range, channel geometry, vegetation, and bathymetric complexity. SWOT's capacity to detect water surface slopes and variations diminishes in areas with dense vegetation cover, highly fragmented marshes and narrow tidal creeks. Nevertheless, the aggregated PixC-based approach significantly enhances signal quality by reducing noise and increasing spatial-temporal sampling density. The tidal constituents extracted with NS_Tide show strong agreement with in-situ tidal observations, mostly when SWOT accuracy is significantly larger than tidal range. The approach developed here provides a robust framework for leveraging SWOT data in coastal settings, opening new possibilities for long-term monitoring productivity of coastal wetlands, and their vulnerability to sea-level rise, land subsidence, and reduced freshwater discharge, as well as for identifying thresholds where salinity intrusion may begin to impact ecosystem health and function.

Corresponding author:
Marc Simard (**Jet Propulsion Laboratory, California Institute of Technology**, **United States**), marc.simard@jpl.nasa.gov

SWOT-based intertidal topography retrieval using mission-only data: validation and potential applications

Nushrat Yeasmin (LIENSs, UMR 7266, CNRS/La Rochelle Université, La Rochelle, France); Laurent Testut (LIENSs, UMR 7266, CNRS/La Rochelle Université, La Rochelle, France); Valérie Ballu (LIENSs, UMR 7266, CNRS/La Rochelle Université, La Rochelle, France)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
While the SWOT altimetry mission is primarily designed to observe open ocean and inland water bodies, recent studies (Salameh et al., 2024; Shi et al., 2025) have demonstrated its potential for mapping intertidal topography during low tide observations. One of the main challenges in utilizing SWOT for intertidal applications, such as bathymetry extraction, lies in accurately distinguishing intertidal pixels from water pixels. The current SWOT pixel classification does not include any dedicated intertidal class. This study introduces a new methodology for identifying intertidal pixels only using SWOT data, without relying on external datasets.
To validated both the methodology of intertidal classification and the quality of SWOT-derived intertidal topography, we focus on the complex, macro-tidal (1.5 m to 5.5 m tidal range) coastal region of Pertuis Charentais, located within Bay of Biscay, France. This area lies within two SWOT passes (348, 419) with both ocean based LR and inland based HR data coverage and is covered by a rich set of in-situ observations, including high-resolution LiDAR topography and tide gauges. Using the in-situ LiDAR data as a reference, we assessed the accuracy and the reliability of SWOT-derived intertidal topography dataset across a range of intertidal environments within the validation zone. Our findings highlight SWOT's strong potential for capturing the spatiotemporal evolution of the dynamic intertidal zones worldwide. Furthermore, our approach offers a cost-effective pathway for monitoring intertidal bathymetry with accuracy comparable to expensive LiDAR-based measurements. This advancement will significantly enhance coastal monitoring, improved numerical modeling, particularly in the data-sparse regions.
Reference:
Salameh, E., Desroches, D., Deloffre, J., Fjørtoft, R., Mendoza, E. T., Turki, I., Froideval, L., Levaillant, R., Déchamps, S., Picot, N., Laignel, B., & Frappart, F. (2024). Evaluating SWOT's interferometric capabilities for mapping intertidal topography. Remote Sensing of Environment, 314, 114401. https://doi.org/10.1016/j.rse.2024.114401
Shi, H., Jia, D., He, X., Andersen, O. B., & Zheng, X. (2025). SWOT-Based Intertidal Digital Elevation Model Extraction and Spatiotemporal Variation Assessment. Remote Sensing, 17(9), Article 9. https://doi.org/10.3390/rs17091516
Corresponding author:
Nushrat Yeasmin (**LIENSs, UMR 7266, CNRS/La Rochelle Université, La Rochelle**, **France**), nushrat.yeasmin@univ-lr.fr

Predicting flux partitioning in river delta networks using SWOT to produce global delta products and quantify the response of deltas to climate and human-induced change

Paola Passalacqua (The University of Texas at Austin, United States); Eleanor Henson (The University of Texas at Austin, United States); Anastasia Piliouras (Pennsylvania State University , United States); Jon Schwenk (Los Alamos National Laboratory, United States); Michael Lamb (California Institute of Technology, United States); Colin Gleason (University of Massachusetts Amherst, United States)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
River deltas host hundreds of millions of people and provide important ecosystem services, including buffering the effect of storms. In this project, we address critical knowledge gaps in river delta science: (i) How are fluxes of water, solutes, and solids partitioned along delta networks? (ii) How are the delta network structure (topology) and dynamics (fluxes of water, solutes, and solids) characterized across spatial and temporal scales and where and how are they responding to changes in climate and human modifications? And (iii) What mechanisms of hydrological connectivity characterize channel-wetland exchanges in global river deltas? During this first year of the project, we have focused on the extraction of water masks and delta channel networks from Landsat imagery to increase the density and accuracy of river delta networks in SWORD. We extracted water masks with our tool DeepWaterMap, which employs a Convolutional Neural Network approach. From the water masks, we extracted river delta networks with our tool RivGraph, which we modified to add attributes to the network as required by SWORD. The extracted networks will be included in the next release of SWORD. Additionally, in this first year, we have focused on the development of a model for partitioning and decay of nutrients over river delta networks. We based the development on numerical modeling results at the Wax Lake Delta using hydrodynamic modeling with ANUGA and our Lagrangian transport model dorado, which can transport particles of different buoyancy and provide information on their travel paths and residence time. That information, combined with nutrient spiraling theory, forms the basis of a simplified model for nutrient transport in river deltas.
Corresponding author:
Paola Passalacqua (**The University of Texas at Austin**, **United States**), paola@austin.utexas.edu

Frontiers in Estuary modeling with SWOT– the tidal Bore in the Severn Estuary revealed from satellite.

Rasmus Lørup Arildsen (Dr, Denmark); Ole Baltazar Andersen (DTU Space, Denmark); Bjarke Nilsson (DTU Space, Denmark)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
The launch of the Surface Water and Ocean Topography (SWOT) satellite represents a monumental leap in the technology of satellite altimetry. With advanced high-resolution wide swath altimetry and innovative use of the phase difference between dual onboard antennas, SWOT drastically reduces the limitations of traditional radar altimeters. SWOT provides a 2D measurements grid with a detailed 50m grid spacing not degrading towards the coast. This marks a substantial enhancement compared to the 7-km across-track spacing along a 1D trajectory offered by conventional altimetry. This enhancement allows for the precise and detailed monitoring of dynamic coastal phenomena such as tides and tidal bores, even in estuaries. Something that was impossible using conventional 1D altimetry.
Tidal bores, characterized as sudden and powerful water surges against the river's current, are critical for local ecology, navigation, and flood management and exist in around 50 locations worldwide with extensive tidal range. Despite their importance, their dynamic and transient nature has made them challenging to study using conventional methods.
The Bristol Channel, with its extreme tidal range and the presence of the Severn Bore, presents an ideal case study to demonstrate SWOT's capabilities. The tidal Bore is largest during spring tide (march + September), but in April, a substantial tidal bore is also seen. We use SWOT 50-meter pixel cloud data during the 1-day fast sampling repeat period in April 2023 to study the high-resolution tidal signal in the Bristol Channel - Severn Estuary and the Severn tidal bore. The results demonstrate that SWOT can capture the tidal bore sweeping up the Severn River from the mouth of the river and some 20 km upstream. SWOT also reveals the dynamics of the tidal bore as details how the tidal energy is being dissipated during the progress up the Severn River.

SWOT pixel cloud data during the 1-day fast sampling repeat period in April 2023 has been used to study the high-resolution tidal signal in the Bristol Channel - Severn Estuary. The Severn Tidal bore is characterized by a sudden and powerful water surges against the river's current, are critical for local ecology, navigation, and flood management. The tidal bore which reached several meters of amplitude during the period sweeping more than 20 km up the Severn River. The results demonstrate that SWOT can capture the tidal bore sweeping up the Severn River from the mouth of the river and some 20 km upstream. SWOT also reveals the dynamics of the tidal bore as well as details how the tidal energy is being dissipated during the progress up the Severn River.

Corresponding author:
Rasmus Lørup Arildsen (**Dr**, **Denmark**), s174035@student.dtu.dk

Investigating Barotropic Pressure Gradients in River Plumes Using SWOT

Agata Piffer Braga (Scripps Institution of Oceanography (UCSD), United States); Sarah N. Giddings (Scripps Institution of Oceanography (UCSD), United States); Iury Simoes-Sousa (Woods Hole Oceanographic Institution , United States); Angelica Rodriguez (Jet Propulsion Laboratory NASA, United States); Joanna L. Carter (Scripps Institution of Oceanography (UCSD), United States)

Session: Afternoon Plenary Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
River plumes are key agents in the global land-ocean exchange, transporting freshwater, nutrients, sediments, and pollutants into the coastal ocean. Despite decades of research, significant gaps remain in our understanding of how river plumes evolve from gravity currents into geostrophic flows, while it mixes with coastal waters. Among the least observed forcings of plume momentum balance and frontal mixing processes, are the barotropic pressure gradients. Driven by differences in water surface height, barotropic gradients are critical in creating cross-frontal acceleration and plume propagation, enhancing convergence and shear stresses that modulate turbulence within the plume.
In this project, we leverage the high spatial resolution of SWOT's sea surface height data to demonstrate its capability to investigate a river plume's barotropic component. As an example case, we present our analysis of the Rio Grande river plume in southern Brazil. By utilizing the Level 3 Low Rate Unsmoothed (250 m) product, we capture subtle coherent barotropic signatures of the plume, providing unprecedented insights into its dynamics. Expanding this finding we also evaluate SWOT's potential to observe other systems, while also exploring the use of High Rate products for such analysis.
River plumes offer a tractable system with well-defined forcings, making them ideal for investigating fundamental processes that also govern larger-scale oceanic gravity currents and frontal systems, including submesoscale fronts and storm-driven freshwater lenses. By focusing on river plumes, we aim to develop a robust framework for analyzing the evolution of fronts driven by barotropic forcing.

Corresponding author:
Agata Piffer Braga (**Scripps Institution of Oceanography (UCSD)**, **United States**), apifferbraga@ucsd.edu

SWOT-KaRIn Level-3 Algorithms and Products Overview

Cécile Anadon (CLS, France); Anaëlle Treboutte (CLS, France); Gaétan Meis (CLS, France); Robin Chevrier (CLS, France); Antoine Bonnin (CLS, France); Marie-Isabelle Pujol (CLS, France); Clément Ubelmann (Datlas, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
The DUACS system (Data Unification and Altimeter Combination System) produces, as part of the CNES/SALP project, Copernicus Marine Service and Copernicus Climate Change Service, high quality multi-mission altimetry Sea Level products for oceanographic applications, climate forecasting centers, geophysics and biology communities. These products consist in directly usable and easy to manipulate Level-3 (L3; along-track cross-calibrated SSHA) and Level-4 products (L4; multiple sensors merged as maps or time series).

Level-3 algorithms used for nadir altimeters have been extended to handle SWOT's unique swath-altimeter data: upgrades with state-of-the-art Level-2 corrections and models from the research community, a data-driven and statistical approach to the removal of spurious and suspicious pixels, a multi-satellite calibration process that leverages the strengths of the pre-existing nadir altimeter constellation, a noise-mitigation algorithm based on a convolutional neural network. The L3 algorithms process the two resolutions of the L2 product: 2km and 250m. L3 products are freely available via the AVISO+ portal: the 2km product is produced and broadcast in near-real time.

Data reprocessings are carried out twice a year to improve data quality by enhancing Level-3 algorithms in line with the results of carried out studies and user feedback from the community. Major changes in version 2, published in January 2025, include a change of internal tides model, a quick fix of the SSB/SSHA offset in polar transitions, the recovery of eclipse gaps with good quality, an improvement of the coastline especially for estuaries areas and the addition of surface classification (ice/leads) in editing flag in Unsmoothed product. The major changes planned for version 3, to be released in September 2025, are a change of mean sea surface model (CNES/CLS 2025 MSS), an improvement of the neural network denoising, a change of the method used to derive currents and an addition of a technical product that will contain the various separate tidal components, an alternative solution for correcting internal tides, the various calibration components and experimental precipitation rates.

Corresponding author:
Cécile Anadon (**CLS**, **France**), canadon@groupcls.com

Global assessment of SWOT small-scale performance via synergy with surface chlorophyll observations

Aurelien Deniau (Collecte Localisation Satellites, France); Francesco Nencioli (Collecte Localisation Satellites, France); Pierre Prandi (Collecte Localisation Satellites, France); Maxime Ballarotta (Collecte Localisation Satellites, France); Matthias Raynal (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
Currently, one of the main challenges with SWOT observations lies in assessing the nature of the small-scale features detected by KaRIn and determining the extent to which the sea level signals observed at scales below 100 km can be associated with surface ocean currents. To address this challenge, we investigated the spatial correlations between SWOT L3 2 km sea surface height (SSH) from the “Science” Phase (21-day repetitive orbit) and remotely sensed surface Chlorophyll concentration (CHL). Our approach is based on the underlying hypothesis that the spatial patterns of the two fields are closely linked: assuming geostrophic balance, SSH is directly associated with surface velocities, which in turn (at least to a first order) regulate the dispersion and spatial distribution of CHL.

The chlorophyll concentrations used in our study are from the CMEMS GlobColour multi-satellite product. As this product offers kilometer-scale resolution, it has the capability to resolve sea surface structures analogous to those observed by SWOT. A comparison between DUACS SSH and CHL was also included in the analysis and used as a reference.

Our analysis focused on the spatial distribution of the correlation coefficient between SSH (both SWOT and DUACS) and CHL over segments of 120 km along the SWOT swath. Initial results indicated that the correlation patterns were predominantly influenced by the large-scale meridional gradient. Therefore, both altimetry and chlorophyll fields were band-pass filtered to isolate scales between 15 and 100 km.

Our results evidenced that the SSH/CHL correlations obtained for the unfiltered products have overall similar values and geographical patterns for both DUACS and SWOT products. The strongest negative correlations are found over the upwelling regions and western boundary currents, while strong positive ones occur in the subtropical bands of southern Indian and pacific oceans. The same comparison performed with the band-pass filtered fields shows strongly degraded performance for the DUACS product, while the SWOT one maintains higher correlations coefficients and similar geographical distribution. This suggests that SWOT observations better capture small-scale circulation features between 15 and 100 km across most of the global ocean.

A notable exception is the equatorial band where the DUACS product shows stronger correlations. Detailed analysis of the SSH fields indicated that in this band the small scales observed by SWOT are predominantly unbalanced signals (e.g. internal waves) which are not associated with surface currents and, consequently, do not affect the distribution of the surface CHL field.

Corresponding author:
Aurelien Deniau (**Collecte Localisation Satellites**, **France**), adeniau@groupcls.com

Extending the Corsica facilities up to SWOT swath

Pascal Bonnefond (Observatoire de Paris - LTE, France); Olivier Laurain (OCA/Geoazur, France); Michel Calzas (DT-INSU, France); Christine Drezen (DT-INSU, France); Lionel Fichen (DT-INSU, France); Antoine Guillot (DT-INSU, France); Thierry Guinle (CNES, France); Nicolas Picot (CNES, France); Philippe Schaeffer (CLS, France)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
Initially developed for monitoring the performance of TOPEX/Poseidon and follow-on Jason legacy satellite altimeters, the Corsica geodetic facilities that are located both at Senetosa Cape and near Ajaccio have been developed to calibrate successive satellite altimeters in an absolute sense. In anticipation of SWOT, a first phase of extension of the reference surfaces of the Corsica site was carried out in June 2021 (378 nautical miles) and the second in May 2022 (508 nautical miles). The measurements were carried out simultaneously using the instruments developed by DT-INSU as part of FOAM project (CalNaGeo and Cyclopée), which showed very good consistency (a few mm on average and ~20 mm standard deviation). GNSS processing using different software (track, MIT, differential mode / GINS, CNES, iPPP mode) and using the GPS and Galileo constellations jointly or separately have been analyzed. The high degree of consistency, both at processing level and at instrumental level, demonstrates the great maturity acquired thanks to the synergy of the FOAM group. We will present in details, the different phases of processing and preliminary results of the resulting reference surface local ("Mean Sea Surface") covering the SWOT swath of pass #001 (60km along-track and 50km across-track)
Preliminary Calibration and Validation results of both KaRIn and nadir altimeters will be also presented.
Corresponding author:
Pascal Bonnefond (**Observatoire de Paris - LTE**, **France**), Pascal.Bonnefond@obspm.fr

Mediterranean Sea fine-scale dynamics as revealed by SWOT

Louise Rousselet (CNRS, France); Jean-Baptiste Roustan (SHOM, France); Alexandre Barboni (LEGOS, France); Anne Petrenko (MIO, France); Anthony Bosse (MIO, France); Francesco d'Ovidio (LOCEAN, France); Pierre Garreau (IFREMER, France); Franck DUMAS (SHOM, France); Stéphanie Barrillon (MIO, France); Andrea Doglioli (MIO, France)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
Ocean fine-scale dynamics (~10-100 km, days-weeks) are processes driving the distribution of heat, salt and biogeochemical content in the ocean. A comprehensive understanding of fine-scale variability, its vertical extent and its role on the global ocean remains a key objective that has been limited by the lack of observation at these scales. The new SWOT mission, together with the international SWOT-AdAC experiment, provides an unprecedented opportunity to capture fine-scale processes with both in situ and satellite-derived measurements. During the SWOT fast sampling phase, two oceanographic campaigns (C-SWOT/WEMSWOT https://doi.org/10.17600/18002077, and BioSWOT-Med, https://doi.org/10.17600/18002392) extensively sampled the horizontal and vertical dynamics of the northwestern Mediterranean Sea for two months (Apr-May 2023) under SWOT swaths, with both hydrology and velocity measurements. The common objectives were to collect multi-instrument data to participate in the Calibration/Validation process of SWOT data as well as revealing the fine-scale dynamics in this moderately energetic region characterized by a small Rossby deformation radius of about 10 km and where conventional Nadir altimetry was known to perform poorly. In this study, we reconstruct a sea surface height (SSH) signal from combined hydrological and current data acquired with various shipborne (ADCPs) and towed instruments (Seasoar and Moving Vessel Profiler), and complemented by autonomous platforms (gliders). SWOT observations show similar variation as the in situ reconstructed SSH, revealing fine-scale features, down to 20 km, missed by conventional altimetry (multi-mission DUACS product). Globally, SWOT improves the geostrophic current estimation by 30% compared with classical nadir altimetry. It increases to 50% when crossing sharp fronts or small eddies (O(10km)). Cyclostrophic corrections are applied on in situ and satellite-derived velocities to test the relative importance of cyclogeostrophic effects in this region especially across small scale eddies characterized by strong vorticity. The best reference layer for in situ reconstructed SSH and geostrophic velocities is determined at around 250-300 m (Seasoar and MVP), a depth including baroclinic gradients. SWOT-derived geostrophic velocity fields are also shown to best match with in situ total (geostrophic and ageostrophic) currents measured from several ADCPs and integrated over a 20 m layer, a depth typical of the seasonal mixed layer depth in the Mediterranean Sea.

Corresponding author:
Louise Rousselet (**CNRS**, **France**), louise.rousselet@locean.ipsl.fr

Objective Analysis Method for SWOT Microwave Radiometers: Wet Tropospheric Correction for Nadir and Karin altimeters

Marie-Laure Frery (CNES, France); Bruno Picard (Fluctus, France); Gérald Dibarboure (CNES, France); Thibaut Pirotte (CLS, France); Francois Bignalet-Cazalet (CNES, France); Matthias Raynal (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
The SWOT (Surface Water and Ocean Topography) mission, launched in December 2022, aims to enhance the observation of water surfaces and oceans through its advanced instruments, including two onboard microwave radiometers. SWOT carries two altimeters: first the advanced instrument Karin is a Ka-band wide-swath interferometric altimeter; second a conventional altimeter in Ku and C band (Poseidon-C) pointing at nadir between the two swaths. Two microwave radiometers, similar in design to the radiometers onboard Jason-2 and Jason-3, are combined to the altimeters. These radiometers are pivotal for providing wet tropospheric corrections for each swath, which are subsequently interpolated to supply corrections for both the nadir altimeter and the Ka-band Radar Interferometer (KaRIn). Two different interpolation schemes are used for Karin and nadir wet tropospheric corrections (WTC). For the nadir correction, the algorithm is distance-based and performs an average of swaths measurements within a defined radius from nadir point. For the Karin correction, the algorithm processes line by line with a linear interpolation.
In most cases, the computed corrections have been qualified as accurate and stable (see Pirotte et al presentation). However, some cases of degraded situations have shown the limits of these methods and highlights the need for a new interpolation scheme.
This presentation introduces an application of Objective Analysis method as proposed by Stum et al (2011) tailored for the SWOT radiometer data. Objective Analysis is a statistical method to retrieve the value of a field at a given position, starting from a first guess and using measurements in the vicinity. In our case, we will use PD estimated from both AMR as the measurements. ERA5 model derived water vapor path delay is used as the first guess. This method has the great advantage that it can be applied to retrieve both Nadir and Karin corrections. Statistics variables are required by the OA scheme such as the variance and correlation function of the anomaly (radiometer minus first guess) or the observation error variance. In Stum et al, these statistics variables are provided by monthly maps.
First step of this study is to implement and assess the potential of the OA to provide a solution as accurate than the current corrections but without the observed limitations. We will test the system sensitivity to the statistics variables fixed to constant variables and check its behavior in nominal situations and in degraded situations. Comparisons with corrections provided in the product as well as external references such as GPM/GMI will be performed.
If the interest for this method is confirmed, a second step will be to compute updated version of the statistical variables monthly maps. This will allow the application of OA to a long time series of SWOT data and assess its performance as a correction of the altimeter range to retrieve the sea surface height through difference of variance at crossover points.

Corresponding author:
Marie-Laure Frery (**CNES**, **France**), marie-laure.frery@cnes.fr

Strengths and limitations of SWOT geophysical corrections

Francesco Nencioli (Collecte Localisation Satellites, France); Matthias Raynal (CNES, France); Pierre Prandi (Collecte Localisation Satellites, France)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
Analysis of SWOT observations collected during the early phase of the mission has confirmed that KaRIn is meeting many of its pre-launch expectations over the oceans. Mesoscale and submesoscale processes, including unbalanced dynamics, can now be successfully resolved down to spatial scales of just a few tens of kilometers. Moreover, the two-dimensional nature of KaRIn measurements enables improved representation of the shape and position of these structures. However, early studies have also revealed that some of the geophysical corrections applied to KaRIn observations may introduce errors with spatial characteristics similar to those of sea surface height anomalies (SSHA) at wavelengths below 100 km. Consequently, a major challenge in the current phase of the mission is to distinguish the true geophysical variability from residual measurement errors in the small-scale SSH signal observed by KaRIn.

Here we present a global assessment of the performance of KaRIn geophysical corrections, focusing specifically on Sea State Bias (SSB), Wet Tropospheric correction (WTC), Dynamic Atmospheric correction (DAT) and ocean tides. Our analysis is based on KaRIn Level-2, 2-km PGC0 observations from both Cal/Val and Science orbit phases. For SSB and WTC corrections, the performance of the KaRIn-based corrections is also compared against that from the model-based solutions. The study is complementary to others presented at this ST focusing on KaRIn corrections: in particular P. Abjean et al. (tropospheric signature), L. Carrere et al. (baroclinic tides), M. Tchilibou et al. (coherent and inchoerent tides) and C. Anadon et al. (xcal correction).

The first part of the analysis focused on the spatial characterization of correction performance. For each correction, the variance of uncorrected and corrected SSHA was computed over bins of 1° by 1°. The difference between these variances was used to quantify the proportion of SSHA variability absorbed by each correction, providing insights into its effectiveness and spatial variability, including across the KaRIn swath.

In the second part of the analysis, correction performance was assessed in the spectral domain. Specifically, along-track power spectral densities of the corrected SSHA, uncorrected SSHA, and the correction fields themselves were computed. Correction performance at different spatial scales was quantified by comparing the spectral energy reduction in the corrected versus uncorrected SSHA. This analysis was repeated across different oceanic regions to evaluate geographic variability. For corrections expected to exhibit cross-track variability, the analysis was also repeated at different cross-track distance within the KaRIn swath.

Overall, our results offer new insights into the geographical regions and dynamical conditions under which KaRIn geophysical corrections are most and least effective. This improved understanding can provide a decisive contribution for assessing the reliability of KaRIn observations in resolving small-scale oceanic variability.

Corresponding author:
Francesco Nencioli (**Collecte Localisation Satellites**, **France**), fnencioli@groupcls.com

Can the Sentinel-3 Next Generation Topography Altimeter Mission's continuity with Sentinel-3 be assessed with a 4-Hour Tandem Phase?

Noémie Lalau (Magellium, France); Thomas Vaujour (Magellium, France); Michaël Ablain (Magellium, France); Gérald Dibarboure (CNES, France); François Boy (CNES, France); Nicolas Picot (CNES, France); Alejandro Egido (ESA, Netherlands); Craig Donlon (ESA, Netherlands); Robert Cullen (ESA, Netherlands)

Session: Oceanography: Calibration and Validation
Presentation type: Oral

Abstract:
Since 1993, satellite altimetry missions have consistently provided long-term records of Sea Surface Height (SSH) measurements. Tandem flight phases have been crucial in verifying and ensuring consistency between successive altimetry missions. These phases have played a key role in both reference missions (Topex/Poseidon, Jason-1, Jason-2, Jason-3, Sentinel-6 Michael Freilich) and complementary altimetry missions (such as Sentinel-3A and Sentinel-3B).
During a tandem phase, two consecutive altimetry missions closely follow each other on the same ground track with a time interval shorter than a minute. As they observe the same ocean simultaneously, measurement differences primarily reflect relative errors. These errors arise from instrumental variations in altimeter characteristics (e.g., altimeter noise), measurement processing (e.g., retracking algorithm), precise orbit determination, and mean sea surface. By averaging relative errors over periods exceeding 100 days, systematic instrumental differences can be accurately determined, enabling precise calibration of the two altimeters.
For the future altimetry constellation, Copernicus Sentinel-3 Next Generation Topography (S3NG-TOPO) will succeed Sentinel-3 (S3), supporting various Copernicus applications. The S3NG-TOPO mission aims at maintaining the continuity of existing S3 nadir-altimeter measurements while enhancing measurement capabilities and performance. A tandem phase between S3 and S3NG is expected to evaluate this continuity. Due to design constraints, S3NG satellites will be launched into a sun-synchronous orbit with a Local Time of Ascending Node (LTAN) at 6 pm, differing from the current S3 constellation's 10 pm LTAN. As a result, the tandem phase between S3 and S3NG satellites will have a 4-hour separation instead of the current few seconds. This study evaluates the impact of the 4-hour tandem phase on the assessment of S3NG-TOPO's continuity with S3. Using the exceptional distribution of crossovers measurements between SWOT KaRIn (swath) and S3 (nadir), we analyzed the variance of ocean variability and altimetry errors at 4-hours intervals. Additionally, we simulated a 4-hour tandem phase between S3A and S3B by adding random noise due to ocean variability and altimetry errors at 4 hours to the SSH differences of the real tandem phase between S3A and S3B (separated by a few seconds).
Our findings indicate that the 4-hour tandem phase offers intermediate continuity performance between a classical tandem phase and a non-tandem scenario. For example, at regional scales of about 1000 km, a 4-hour tandem phase of 6 months would achieve an offset uncertainty of +/- 5 mm (at 1-sigma), while a classical tandem phase gives a result close to +/- 2 mm (at 1-sigma), and a non-tandem configuration would be above +/- 20 mm (at 1-sigma). This finding highlights the 4-hour tandem phase's potential to meet continuity requirements, depending on user needs. Moreover, this study emphasizes the crucial role of SWOT data in characterizing oceanic variability and improving altimetry performance and continuity assessments.
Corresponding author:
Noémie Lalau (**Magellium**, **France**), noemie.lalau@magellium.fr

Performance assessment of the water surface elevation of HR SWOT products based on comparisons with in-situ networks and in-flight nadir altimetry missions

Maxime Vayre (CLS, France); Julien Renou (CLS, France); Marie Chapellier (CLS, France); Nicolas Taburet (CLS, France); Roger Fjortoft (CNES, France); Nicolas Picot (CNES, France); Claire Pottier (CNES, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission, conducted by CNES and NASA was successfully launched on 16 December 2022. It provides unprecedented 2D observations of the sea-surface height and mesoscale structures as well as water surface elevation over continental water surfaces. An interferometric SAR altimeter, the Ka-band Radar Interferometer (KaRIn), is designed to cover two 50-km cross-track swaths. The first seven months were dedicated to Calibration/Validation (Cal/Val) with a 1-day orbit over limited areas. The nominal phase (Science phase) follows with its 21-day repeat cycle and global spatial coverage up to 78° latitude.

This study is part of the performance assessment of the SWOT over inland water led by CNES on the French side. The High Rate (HR) mode of KaRIn, dedicated to hydrology, provides several HR SWOT products. Their performance is assessed by comparison with reference measurements. Although specific in-situ Cal/Val sites have been equipped for the validation of HR SWOT products over lakes and rivers, the existing in-situ networks are essential, especially for statistical validation that requires a significant number of comparisons. In addition, nadir altimetry measurements (Sentinel-3A/B, Sentinel-6, ICESat-2, etc.) can be used as external measurements on a large number of lakes and rivers, or to level existing gauges.

Our analysis consists of using data from the French (SCHAPI), Swiss (BAFU) and American (USGS) in situ networks to estimate the performance of SWOT HR elevation data (PIC and PID versions). In addition, we use measurements from current nadir altimetry missions (Sentinel-3A/B, Sentinel-6, ICESat-2) to assess performance over a large number of water bodies. SWOT HR data are compared with the station networks available on the Copernicus Global Land Service. ICESat-2 data (ATL13) completes the analysis of tens of thousands of lakes. We have also set up an innovative method for levelling existing gauges with ICESat-2 (ATL13), increasing the number of in situ references on which the accuracy of KaRIn can be estimated.

We will first focus on lakes and rivers, observed daily by SWOT during the Cal/Val phase, to assess the performance of HR SWOT products for monitoring short timescale variation of the water surface elevation. We will then take advantage of the global spatial coverage of the SWOT mission during the Science phase for broader statistical analysis.
Corresponding author:
Maxime Vayre (**CLS**, **France**), mvayre@groupcls.com

Evaluating SWOT inland water surface elevation with gage information in the United States and Canada

Merritt Harlan (U.S. Geological Survey, United States); David Bjerklie (U.S. Geological Survey, United States); Jack Eggleston (U.S. Geological Survey, United States); Dongmei Feng (University of Cincinnati, United States); Ryan Riggs (U.S. Geological Survey, United States); Cécile Cazals (CS Group France, France); Robert Dudley (U.S. Geological Survey, United States); Elisa Friedmann (University of Massachusetts Amherst, United States); Megan Garner (Environment and Climate Change Canada, Canada); Colin Gleason (University of Massachusetts Amherst, United States); Yuta Ishitsuka (University of Massachusetts Amherst, Japan); James Leach (Environment and Climate Change Canada, Canada); J. Toby Minear (Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, United States); Hind Oubanas (INRAE, France); Tamlin Pavelsky (University of North Carolina Chapel Hill, United States); Taylor Rowley (University of Massachusetts Amherst, United States); Cassie Stuurman (Jet Propulsion Laboratory, California Institute of Technology, United States); Catalina Tagliatela (Jet Propulsion Laboratory, United States); Jacob Zwart (U.S. Geological Survey, United States)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission enables transformative approaches to water resources management by offering high-resolution water surface elevation data and extents from novel satellite radar technology. This study presents the first large-scale assessment of SWOT water surface elevation data across the United States and Canada, evaluating elevation accuracy against in situ gage data. We compare SWOT Level 2 Hydrology data products (Version C) to in situ timeseries of water elevation using 421,677 paired observations across 2,143 river and 659 lake and reservoir gages. Data accuracy and temporal coverage of SWOT observations are explored as functions of various data quality filters. Paired measurements (median-normalized) of SWOT and in situ observations resulted in 68th percentile absolute elevation differences of 18.32 cm, 17.08 cm, and 7.79 cm for river reach, river node, and lake data, respectively, with an overall combined difference of 16.97 cm for filtered observations (79,909; 19% of total potential data volume). Here we emphasize the importance of applying quality filters (both self-reported and exogenous) to SWOT Version C data, with 68th percentile absolute elevation differences ranging from 61.23 cm to 75.93 cm for the full dataset. Filtering also improves the correlation statistics between SWOT and in situ water surface elevation data, increasing R2 values from 0.04 to 0.83. Overall, we find that SWOT river and lake elevations meet SWOT data accuracy requirements (elevation accuracies within 10 and 25 cm) with adherence to SWOT quality flags.

Corresponding author:
Merritt Harlan (**U.S. Geological Survey**, **United States**), mharlan@usgs.gov

Surface Water and Ocean Topography (SWOT) validation of wide swath interferometry over the lakes in the Pyrénées

Jean-Francois Cretaux (CNES/LEGOS, France); Tamlin Pavelsky (University of North Carolina, Chapel Hill, United States of America); Claire Pottier (CNES, France); Damien Desroches (CNES, France); Emmanuel Chapron (GEODE, Université Toulouse Jean-Jaures, France); Arthur Compin (LEF, Toulouse, France); Matthias Raynal (CNES, France); Manon Delhoume (CS Soprasteria Group, France); Grant Parkins (University of North Carolina, Chapel Hill, United States of America); Paul-Gérard Gbetkom (CNRS/LEGOS, France); Muriel Berge-Nguyen (CNES/LEGOS, France); Daniel Moreira (SGB, Rio de Janeiro, Brazil); Roger Fjortoft (CNES, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission, launched in December 2022 is aiming to produce Water Surface Elevation (WSE) over lakes larger than 250*250 m, globally, with high accuracy better than 25 cm (1σ). Water extent of lakes is also measured with requirements to perform it with a relative accuracy better than 15% of the total lake extent. Calibration / Validation (C/V) of the mission is therefore necessary on a large number of lakes including a high variety of geographical and morphological situations. WSE of lakes in mountain areas are generally hardly measured from satellite, and using SWOT data is a new opportunity to understand how this type of lakes is responding to climate changes and how they are contributing to the water cycle on the Earth. In the framework of the SWOT's C/V, a set of gauges have been instrumented over lakes in the Pyrenees mountain, with ruler allowing to measure the water level manually and to report them in the C/V database for further comparison with SWOT lake products. For some of the lake chosen for this study, they were observed by SWOT during the one-day (1-D) fast sampling phase of the six first months, while some others were observed by SWOT only when the satellite shifted to its final so-called science orbit with a repeat cycle of 21-days. Data from the rulers were collected and transmitted to the C/V teams by citizens (hikers, fishermen, some local authorities) within a NASA project named LOCSS and fully based on the citizen for science initiative gathering several networks of lakes worldwide. WSE over the lakes in the Pyrenees measured by SWOT meet the requirement for WSE and water extent, with however a rate of lost measurements which is more pronounced during the science phase than the 1-D fast sampling ones. The small size of the lakes chosen in the Pyrenees have led to determine the limit of the performances under such condition: all lakes larger than 6 ha are meeting the requirement once some strict editing was applied (use of several flags contained in the data records). Smaller lakes present all a high rate of missing data and much lower accuracy. Results obtained during the 1-D fast sampling were better than during the science phase.

Corresponding author:
Jean-Francois Cretaux (**CNES/LEGOS**, **France**), jean-francois.cretaux@cnes.fr

Validation of SWOT in the Yukon River Basin, Alaska

Camryn Kluetmeier (Duke University, United States); Tamlin Pavelsky (University of North Carolina at Chapel Hill, United States); Taylor Rowley (University of Massachusetts Amherst, United States); William Tooley (University of Colorado Boulder, United States); Audrey Turcotte (University of Colorado Boulder, United States); Fiona Bennitt (University of Massachusetts Amherst, United States); Audrey Thellman (University of North Carolina at Chapel Hill, United States); Sarah Cooley (Duke University, United States)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
Validation of the newly launched Surface Water and Ocean Topography (SWOT) satellite mission is necessary to understand the precision and accuracy of SWOT water surface elevation, slope, and inundation extent measurements in global river, lake, and wetland environments. The upper Yukon and Porcupine river catchments, Alaska, were selected as a validation site due to a high diversity of river morphologies, sizes, and varying adjacent topography at a high latitude, resulting in more repeat SWOT overpasses during the 21-day orbit cycle. Seventy pressure transducers (PTs) were deployed from July through August 2024 in five distinct clusters of reaches, covering a heavily braided section of the Yukon adjacent to low topography, a single-channel section of the Yukon adjacent to high topography, the relatively steep and braided Chandalar River, and two confluences of small (~50m width) rivers with the Porcupine River. Initial results at the node scale suggest that there is ~15 cm difference in water surface elevation at the absolute 68% percentile between SWOT RiverSP and PT measurements. Approximately 30 GNSS long profiles of water surface elevation were collected coincident with SWOT overpasses, facilitating cross-swath evaluation of SWOT data quality and evaluation of reach and node scale products. Initial results at the node scale suggest that there is ~ 19 cm difference in water surface elevation at the absolute 68% percentile between SWOT RiverSP and GNSS measurements. Comparison of in-situ and SWOT water surface elevation and inundation extent data in the Yukon and Porcupine river catchments will help assess the accuracy of SWOT as a new tool for quantifying river slope and discharge. Additionally, two digital elevations models (DEMs) collected over river ice on the Tanana River in April and March, 2025 show ice surface elevation differences of ~ 25 cm at the absolute 68% percentile when compared against SWOT PIXC data aggregated to the node scale.

Corresponding author:
Camryn Kluetmeier (**Duke University**, **United States**), camryn.kluetmeier@duke.edu

Uncertainty assessment of SWOT's systematic errors calibration algorithm: the complementarity of inland and ocean water elevation data

Étienne Jussiau (CLS, France); Benjamin Flamant (CLS, France); Pierre Prandi (CLS, France); Matthias Raynal (CNES, France); Cécile Anadon (CLS, France); Clément Ubelmann (Datlas, France); Gérald Dibarboure (CNES, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The KaRIn instrument onboard the SWOT mission represents a technological breakthrough in radar altimetry, delivering high-resolution two-dimensional water elevation profiles over both oceans and inland waters. However, KaRIn's innovative radar interferometry brings new challenges, as systematic errors largely dominate the mission's error budget. Specifically, KaRIn data are particularly sensitive to our imperfect knowledge of the satellite's roll angle, baseline dilation caused by changing thermal conditions, antenna group delay, and interferometric phase errors.

To address these issues, the level-2 cross-calibration (L2 XCal) algorithm was developed. It operates in two main steps: First, it estimates systematic errors from sea surface height (SSH) mismatches at crossover points; second, it interpolates between estimates to produce a continuous correction over time. Although primarily designed for hydrological applications, a global assessment of the algorithm's performance over inland waters remains a challenge due to the limited amount of independent water elevation data records available for calibration inland and the differing characteristics of SWOT's data over oceanic versus continental water surfaces.

The height correction produced by the L2 XCal algorithm inland relies on distant oceanic estimates. As such, it is crucial for hydrology to also produce an estimate of the uncertainty of this correction. This uncertainty is expected to depend on both algorithmic parameters and external factors such as the satellite's beta angle, which characterizes its illumination conditions.

This work explores data-driven approaches to quantify the uncertainty of the XCal correction. We perform experiments to quantify how much signal may leak from ocean to continents. To complement this analysis, we introduce so-called "fake continents"—large areas in the open ocean where SSH data are artificially masked—to mimic inland conditions. By comparing the height correction produced by the algorithm with and without fake continents, we derive a model to estimate height correction uncertainty when propagated over land. We also examine crossovers between SWOT and other nadir missions and stable inland areas inland that regularly yield SSH; situations where natural variability cancels out or is small and observed variations are mostly due to residual systematic errors. These variations constitute empirical realizations of such errors, which we compare to the L2 XCal algorithm output. These results contribute to a better understanding of the dynamics of SWOT's systematic error correction and help enhance the reliability of SWOT data over inland water surfaces.

The level-3 cross-calibration (L3 XCal) algorithm was initially developed for oceanographic applications but is also used for hydrology during the Calval phase since the scarcity of crossovers for this orbit leads to a degraded L2 calibration. Enhancements to the L3 XCal algorithm are planned to improve interpolation over continents for inland water applications: an abacus of the height correction dependence on beta angle and local time has been produced. This approach reduces the magnitude of dynamically computed corrections, thereby lowering calibration errors over landmasses. Moreover, an optimal interpolation scheme based on the measured covariances of KaRIn systematic errors has been implemented to further improve interpolation and generate uncertainties to be provided to users.
Corresponding author:
Étienne Jussiau (**CLS**, **France**), ejussiau@groupcls.com

Global Validation of SWOT River Widths Using Deep Learning Water Masking of PlanetScope Imagery

Taylor Rowley (University of Massachusetts, United States); Rangel Daroya (UMass Amherst, United States); Jonathan Flores (UMass Amherst, United States); Colin Gleason (UMass Amherst, United States); Subhransu Maji (UMass Amherst, United States)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The SWOT satellite mission provides unprecedented hydrological measurements of water surface elevation and slope, and inundation extent of rivers globally. While water surface elevation and slope have been validated extensively, inundation extent and width have relied heavily on manually digitized water surfaces from aerial orthophotos, where labeling takes several hours per image, and thus, there are fewer samples to validate. To address this, our team developed a deep learning algorithm (RiverScope) that masks surface water in PlanetScope images. The algorithm was trained on 1,145 manually labeled PlanetScope images of rivers across the globe and the model was applied to masking a global sample of ~5000 SWORD reaches. Each reach has coincident SWOT and PlanetScope data within +12 hours of each other from April 1, 2023 – April 1, 2025, covering a total area of ~ 30 million square kilometers. Using the RiverScope masked images, we calculated effective width for each reach through time, using the SWORD reach length and area of water pixels. Preliminary results, using ~300 reaches within the Yukon River Basin, show that SWOT-derived widths from the RiverSP product have a mean average error (MAE) of 48% and 16% for RiverScope. This presentation will build on the preliminary results, highlighting the range of performance observed across the global sample.

Corresponding author:
Taylor Rowley (**University of Massachusetts**, **United States**), throwley@umass.edu

Monitoring smaller water structures using SWOT L2 HR Pixel Cloud

Nicolas Gasnier (CNES, France); Lionel Zawadzki (CNES, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
While the SWOT mission's scientific goals for hydrology aimed for rivers wider than 50 meters and water bodies larger than 100 meters by 100 meters, the first data showed that much smaller structures were visible and that it was possible to estimate their height. This has provided new opportunities, both for monitoring a larger number of small rivers and natural lakes and for monitoring human-operated water infrastructure. This last application responds to particularly critical issues in areas where water is a scarce resource and where the available data is insufficient on the volumes of water stored in small (less than a few hectares) reservoirs and the flow circulation through canals.

This ability to estimate the water elevation for small objects in water still has limitations related to signal level (dark water due to very smooth water, particularly in sheltered areas) and the presence of man-made structures with high reflectivity in the environment. The resolution of SWOT images also does not allow for precise estimation of the extent of the water in very small objects. For applications that require this information, it must be obtained from another source or derived from the water height.

As these very small objects are typically absent from the SWOT prior Lake and River databases, their monitoring requires using the Level-2 HR Pixel Cloud product. To this end, we have developed pre-processing methods to filter the pixel cloud points corresponding to the object of interest. These methods are based on geometric information and pixel properties. The points thus extracted can, for example, be used to derive the storage change time series for a small reservoir, or the temporal evolution of the slope in a small channel.

An implementation of the Pixel Cloud preprocessing and filtering methods, as well as some case studies, are now available in the PixieDust library : https://github.com/SWOT-community/PixCDust

These filtration methods could still be improved by a better understanding of the phenomenology of the observation and, in particular, of the signal coming from the surrounding areas. Another promising direction toward the extraction of water elevation in even smaller objects may be to improve the processing from the SLC data, for example through an early detection of the small water structures and a dedicated phase unwrapping step.

Finally, a key priority for the adoption of Wide Swath Altimetry data for monitoring small water structures, both for scientific or public water management applications, will be to improve the propagation of uncertainties from pixel cloud data to the final information.
Corresponding author:
Nicolas Gasnier (**CNES**, **France**), nicolas.gasnier@cnes.fr

DAHITI – Monitoring of water levels and water slopes surface using SWOT KaRIn measurements over small inland waters

Christian Schwatke (DGFI-TUM, Germany); Daniel Scherer (DGFI-TUM, Germany); Denise Dettmering (DGFI-TUM, Germany)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
Classical satellite altimetry has been successfully used to monitor the water levels of inland waters, such as rivers, lakes and reservoirs, for more than three decades. In December 2022, a new generation of altimeter mission called Surface Water and Ocean Topography (SWOT) was successfully launched. SWOT is equipped with a classical nadir radar altimeter similar to that on Jason-3, as well as a new Ka-band Radar Interferometer (KaRIn). KaRIn uses the principle of SAR interferometry and, thanks to its 120 km wide swath and 21-day repeat science orbit, has the capability to monitor almost every inland water body worldwide.

In this contribution, we present two new methods for deriving hydrological parameters over inland waters. Water level time series are derived for around 2,000 lakes and reservoirs in Germany. For around 200 river reaches, however, we have derived not only water levels, but also time-varying water surface slopes from the high-resolution SWOT pixel cloud dataset. This dataset enables us to monitor the water levels of very small water bodies. We use SWOT data measured during the fast sampling orbit (03/2023 – 07/2023, 1-day repeat cycle) and the science orbit (since 07/2023, 21-day repeat cycle). This contribution also discusses the challenges due to measurement noise, data gaps, and dark water pixels when using SWOT KaRIn data and how the new approach addresses these challenges.

To assess the quality, the resulting time series of water levels and water surface slopes are validated against in-situ data and compared with the official LakeSP and RiverSP SWOT products. The validation of 99 lakes and reservoirs results in a median RMSE of 6.1 cm. The validation of 153 river reaches results in a median RMSE 9.5 cm. Compared with the official LakeSP and RiverSP products, the results of the new approach show higher accuracy and more data points. All time series of water levels and surface water slopes are freely available on the web portal of the „Database of Hydrological Time Series of Inland Waters„ (DAHITI, https://dahiti.dgfi.tum.de).
Corresponding author:
Christian Schwatke (**DGFI-TUM**, **Germany**), christian.schwatke@tum.de

An Enhanced SWOT River Product (L3) using Densification Approaches

Hind Oubanas (INRAE, France); Céciles Cazals (CS Group, France); Igor Gejadze (INRAE, France); Isadora Rezende (INRAE, France); Pierre-Olivier Malaterre (INRAE, France); Quittard Dylan (INRAE, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
SWOT provides, for the first time, dense spatial coverage that enables the observation of continuous water surface profiles along rivers. However, SWOT observations are subject to errors caused by factors such as dark water, specular ringing, and others. As a result, the use of quality flags is necessary to filter the data, which can significantly reduce the volume of usable observations and limit their applicability in various contexts. In this work, we propose an approach for processing SWOT RiverSP observations of water surface elevation and river width. Our method involves several steps tailored to the nature of SWOT data and its revisiting swaths. Initially, a data pre-processing step is applied to remove inconsistencies through outlier detection and smoothing. This is followed by a densification step to fill in missing observations in areas such as the nadir gap or regions affected by dark water, provided that swath overlaps are available. The densification relies on a Bayesian framework that leverages the spatial and temporal variability of water surface profiles, accounting for different flow regimes. A similar approach is also used to densify river width observations. The proposed methodology is validated over CALVAL sites.
Corresponding author:
Hind Oubanas (**INRAE**, **France**), hind.oubanas@inrae.fr

An Enhanced Framework for Improving SWOT-based Surface Water Level and River Slope Estimations

JIAMING CHEN (Univeristy of Bonn, Germany); Luciana Fenoglio (Univeristy of Bonn, Germany); Jürgen Kusche (Univeristy of Bonn, Germany)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite, launched in 2022, provides unprecedented observations of water surface elevation (WSE), river width, and slope for global rivers.
The project DETECT-REDS (DETECT-REfecct-Discharge-Storage) continues the REFECCT project of the SWOT Science Team 2020-2023. The central hypothesis is that SWOT and SAR altimetry outperform conventional altimetry with new products to monitor surface water and study hydrodynamic processes. The main objective is to evaluate the scientific usability of the SWOT data in inland waters, with a specific focus on applications related to river discharge and storage change.
In the DFG-founded DETECT project, we evaluate the applicability of SWOT in medium and small size rivers and lakes to determine spatial and temporal detection limits of the space techniques. Standard SWOT products (RiverSP and LakeSP) exhibit constrained accuracy and spatial definitions. Building upon SWOT Pixel Cloud (PIXC) and Raster products, we develop an enhanced framework to overcome these limitations for estimating surface water level, incorporating quality flags and gaussian mixture distribution clustering.
For lake and reservoir from Raster product, our approach achieves 4 cm median STDD with 1 cm bias against Swiss in situ gauges, effectively extending SWOT's observational capacity to sub-1 km² water bodies. For river applications, pixel cloud processing enables 6 cm height accuracy and 0.65 cm/km slope uncertainty along the Rhine River, also successfully detecting 50m-wide rivers – half the width threshold of SWOT's operational RiverSP specifications.
Additionally, we extend our framework to whole-European scale to analyze spatiotemporal variations in surface water level, assessing the combined impacts of climate-driven hydrological changes and anthropogenic disturbances (e.g., dam operations, irrigation). To ensure robustness, the derived dataset is undergoing multi-source validation against Hydroweb-next and DAHITI reference databases, enabling cross-comparison of SWOT-based retrievals with in situ gauges, nadir-altimetry.

Corresponding author:
JIAMING CHEN (**Univeristy of Bonn**, **Germany**), chenjiaming@uni-bonn.de

Improving surface type classification in SWOT PIXC Data to enhance inland water monitoring

Mohammad J. Tourian (University of Stuttgart, Institute of Geodesy, Germany); Danyang Zhao (University of Stuttgart, Institute of Geodesy, Germany); Omid Elmi (University of Stuttgart, Institute of Geodesy, Germany); Junyang Gou (Institute of Geodesy and Photogrammetry, ETH Zurich, Zurich, Switzerland, Switzerland)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission, through its Ka-band Radar Interferometer (KaRIn), provides high-resolution observations of surface water extent and elevation, offering new opportunities for hydrological applications. However, the standard surface type classification in SWOT's pixel cloud (PIXC) product can be unreliable over complex inland water bodies. Misclassification, caused by high noise levels, and the challenge of defining the extent of the water body based on the classes can impair the accurate estimation of key hydrological variables, including river water surface elevation, slope, and width, as well as lake water height and surface area, as provided in the vector products (RiverSP and LakeSP).
To improve classification accuracy, we developed and evaluated a series of deep learning models that vary in both architecture and input features. These models account for different pixel cloud sizes and incorporate combinations of SWOT observables, such as coherence, backscatter power (Sigma0), phase noise standard deviation, surface height, and auxiliary indicators derived from satellite imagery. We assessed model performance over rivers and lakes in Germany by generating modified RiverSP and LakeSP products based on the reclassified PIXC data and comparing them against results from the original classification.
For rivers in particular, we analyzed the water surface profile at each time epoch by extracting longitudinal river profiles and assessing variability after removing the static river shape. The model with the lowest root mean square error (RMSE) in profile fluctuation was considered the best-performing. Preliminary results over the Peene and Warnow rivers show an average RMSE improvement of approximately 1 m compared to the original classification.
All tested models so far outperformed vector products derived from the original SWOT classification in capturing river and lake features. Models that incorporate multiple observables consistently outperformed those relying on a single feature. In particular, approaches that include spatial context and surface elevation information yielded the most reliable classifications. We test and show more results at the Science Team meeting.
These findings highlight the importance of refined classification strategies, including the development of machine learning and deep learning methods, for enhancing the hydrological value of SWOT data products.

Corresponding author:
Mohammad J. Tourian (**University of Stuttgart, Institute of Geodesy**, **Germany**), tourian@gis.uni-stuttgart.de

Spatial interpolating of SWOT inland water maps based on a hydro/topography-based floodability index and water occurrence

Megumi Watanabe (LIRA, Paris Observatory/IIS, The University of Tokyo, France); Victor Pellet (Laboratoire de Météorologie Dynamique, École Polytechnique, France); Filipe Aires (LIRA, Paris Observatory, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
One expectation for the SWOT (Surface Water and Ocean Topography) satellite is that it can provide information on surface waters, including beneath clouds and possibly vegetation, at high spatial resolution, which optical sensors cannot achieve. However, SWOT observation errors do exist, e.g., due to specular reflection. It is necessary to filter these errors. This data filtering can amount up to 44% of the considered pixels in this study. They drastically limit the use of the SWOT data. Consequently, filtered pixels need to be filled in some way, to obtain clean and spatially continuous water extent maps from SWOT. We developed an approach to interpolate SWOT data so that all the SWOT observation time steps can be exploited. We focus on a part of the Negro River in the Amazon basin. First, pixels are filtered using echo nadir and specular ringing of the water area fraction variable, from the L2 KaRIn high-rate raster product under conditions of low coherence, degraded classification information, and incident angle. Second, we interpolate the filtered pixels using 1) a hydro/topography-based "Floodability Index" (FI), a proxy for the probability of a pixel being inundated compared to its adjacent pixels (Nguyen and Aires, 2023) and 2) a water occurrence derived by SWOT observation. To do so, we determined spatio-temporally varying thresholds (on the FI and water occurrence) to be the water/non-water pixels, based either on a ROC-curve analysis or on a water area-based optimization. The quality of this spatial interpolation is assessed using a confusion matrix that compares the actual SWOT estimates with the interpolated values. Our interpolation method improves the true positive water detection rate from 62% to 85-86% when compared to the simple adjunction of permanent water, meaning that it is able to capture dynamic information from the SWOT available pixels. The interpolation reduced the difference in water area between the descent and ascent paths. This could enable a clearer detection of temporal dynamics in surface water. The new interpolated SWOT water maps can better capture the seasonality of flooded/saturated or forested riverine wetlands and peatlands (based on the "The Global Lakes and Wetlands Database" (Lehner et al., 2024)). The new, interpolated and completed SWOT water maps can more easily be used by the hydrology community. We expect to improve the interpolation strategy in the future and apply it at the global scale.

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Corresponding author:
Megumi Watanabe (**LIRA, Paris Observatory/IIS, The University of Tokyo**, **France**),
megumi.watanabe@obspm.fr

SABWAS – Semi-Arid Brazil Water Analysis with SWOT: Advancing Multi-Scale Reservoir Monitoring with Machine Learning and SWOT Products

Rafael OLIVEIRA (Funceme/GET, Brazil); Marielle Gosset (IRD, France); Eduardo Martins (Funceme, Brazil)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Oral

Abstract:
The semiarid region of Ceará, in Northeastern Brazil, is characterized by a dense network of over 20,000 reservoirs, ranging from large state-monitored systems to numerous small farm dams under 0.01 km². These water bodies are crucial for water security, particularly in the context of recurrent droughts and climate variability. However, their monitoring remains a major challenge due to the dispersed and fragmented nature of the storage infrastructure.

The Surface Water and Ocean Topography (SWOT) mission offers a transformative opportunity for inland water monitoring with its KaRIn instrument providing high-resolution altimetry data. This study parts of the SWOT-ST project SABWAS (Semi-Arid Brasil Water Analysis with Swot) evaluates the performance of SWOT products for hydrological monitoring of reservoirs in the Crateús watershed, one of the designated cal/val regions in Brazil. The analysis included six state-monitored reservoirs from the Ceará water resources agency and eight additional small reservoirs not-monitored. The methodology involved assessing the L2_HR_LakeSP and L2_HR_PIXC (PixelCloud) products, covering observations from both the calibration/validation and the nominal mission phase. Initially, geolocation matching between datasets was performed, followed by time-series comparison and altimetric bias correction for the monitored reservoirs. In addition, for the smaller not-monitored, a Machine Learning analysis using Random Forest was conducted to improve understanding of the altimetry data and to enhance the pixcloud filtering process by evaluating the relative importance of each variable in predicting an acceptable water surface elevation (WSE) outcome. Performance metrics were calculated using RMSE and 1σ standard deviation after outlier removal.

Results indicate excellent agreement for large reservoirs (area > 5 km²), with errors ranging from 0.06 m to 0.25 m. These large monitored reservoirs exhibited strong temporal coherence with SWOT-derived water level time series for the LakeSP product. However, this coherence tends to diminish with decreasing reservoir size, and in smaller water bodies, errors often exceeded the mission's 10 cm altimetric precision target. The assessment of eight small reservoirs (with surface areas typically under 1 km²), monitored in the field, also revealed significant variability in product performance. However, the comparison between products revealed a better performance of the PixelCloud data relative to LakeSP, especially when more robust filtering processes were applied. RMSE improvements were substantial in many cases (6 to 90%). These results highlight the difficulty of small lake detection, but also demonstrate the potential of machine learning–based filtering approaches to improve WSE retrievals. The potential superior performance of the filtered PIXC product highlights the need to continue investigations focused on more region-specific processing strategies for semi-arid environments. These efforts should also consider the incorporation of more recent product versions, which are currently being processed and released by the satellite operating agencies, in order to refine and expand the applicability of SWOT data for small reservoir monitoring.

In conclusion, SWOT demonstrates robust capabilities for operational water level tracking in major reservoirs and sets a foundation for future integration of smaller systems into regional water management networks. Calibration and assimilation of SWOT altimetry with local geodetic benchmarks remain key to unlocking the full potential of the mission in semi-arid regions.

Corresponding author:
Rafael OLIVEIRA (**Funceme/GET**, **Brazil**), reis.rafaeu@Gmail.com

Mapping the Known and Invisible in the age of SWOT: Fine-Scale Ocean Currents from the VERSO/FaSt-SWOT collaboration

Ananda Pascual (IMEDEA(CSIC-UIB), Spain); Baptiste Mourre (IMEDEA(CSIC-UIB), Spain); Elisabet Verger-Miralles (IMEDEA(CSIC-UIB), Spain); Laura Gómez-Navarro (IMEDEA(CSIC-UIB), Spain); Bàrbara Barceló-Llull (IMEDEA(CSIC-UIB), Spain); Daniel Tarry (APL-UW, US); Eugenio Cutolo (IMT-Atlantique, France); Guiomar López (SOCIB, Spain); Emma Reyes (SOCIB, Spain); Nikolaus Zarokanellos (SOCIB, Spain)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The VERSO SWOT science team project builds on previous work to advance the understanding of oceanic mesoscale and submesoscale features—fronts, eddies, filaments, and meanders—through an integrated approach combining satellite data, in-situ observations, and high-resolution modeling. Focusing on spatial scales from 10 to 100 km, traditionally unresolved by conventional altimetry, it leverages the novel capabilities of the SWOT satellite to study fine-scale ocean dynamics in the Western Mediterranean Sea, a natural laboratory for globally relevant processes.

The investigation follows two main lines: first, it analyzes data from the FaSt-SWOT field campaigns, conducted during SWOT's fast-sampling phase in Spring 2023. These campaigns, supported by the Spanish Ministry of Science and Innovation, featured a multi-platform experiment targeting a small anticyclonic eddy north of Ibiza, integrating ship-based CTD and ADCP measurements, gliders, drifters, and satellite-guided sampling strategies. Second, it develops advanced 3D reconstruction techniques using deep learning and data assimilation, applied to both 1-day and 21-day SWOT orbit datasets. Preliminary results from the FaSt-SWOT campaigns are particularly compelling: SWOT accurately detected the surface signature of a ~25 km-radius anticyclonic eddy, confirmed by multi-platform in-situ observations as intrathermocline. Maximum velocities of 30 cm/s were recorded at 175 m depth by ADCP, and biconvex isopycnals observed by gliders confirmed the eddy's structure. Comparisons demonstrated SWOT's exceptional performance, reducing sea level representation errors by 33% (vs. gliders), horizontal velocity errors by 41% (vs. ADCP), and velocity magnitude and direction errors by 44% and 10%, respectively, (vs. surface drifters). These findings unequivocally highlight SWOT transformative capacity to resolve mesoscale and submesoscale dynamics.

Beyond in-situ and satellite data, complementary numerical simulations support the interpretation of observations and help quantify ageostrophic motions, with a particular focus on the estimation of vertical velocities from SWOT-derived surface fields, combined with glider and model data. Additional analyses include high-frequency radar data to assess dominant spatial and temporal variability in coastal regions and support SWOT resolution assessment. Tools for Lagrangian diagnostics, eddy tracking, and neural-network-based 3D reconstructions of ocean states will be expanded, contributing novel methodologies for SWOT-era of oceanography. Active involvement in the SWOT Adaptive Campaigns Consortium (formerly Adopt-A-Crossover) and the regional validation working group further underscores our commitment to international coordination and scientific progress.

VERSO/FaSt-SWOT collaboration

- B. Barceló-Llull – IMEDEA (CSIC-UIB), Spain
- A. Bonilla – IMEDEA (CSIC-UIB), Spain
- B. Casas – SOCIB, Spain
- V. Combes – IMEDEA (CSIC-UIB), Spain
- E. Cutolo – IMT Atlantique, France
- L. Díaz – SOCIB, Spain
- A. Doglioli – Aix-Marseille Université, France
- F. D'Ovidio – LOCEAN-IPSL, France
- R. Fablet – IMT Atlantique, France
- T. Farrar – WHOI, USA
- L. Gómez-Navarro – IMEDEA (CSIC-UIB), Spain
- J. Fernández – SOCIB, Spain
- J. Le Sommer – IGE, France
- I. Lizarán – SOCIB, Spain
- G. López – SOCIB, Spain

- R. Morrow – LEGOS, France
- B. Mourre – IMEDEA(CSIC-UIB), Spain
- A. Pascual – IMEDEA (CSIC-UIB), Spain
- E. Reyes – SOCIB, Spain
- Ll. Ribot – SOCIB, Spain
- R. Rodríguez – SOCIB, Spain
- D.R. Tarry – APL, UW, USA
- J. Tintoré – IMEDEA (CSIC-UIB) & SOCIB, Spain
- D. Vega-Giménez – IMEDEA (CSIC-UIB), Spain
- E. Verger-Miralles – IMEDEA (CSIC-UIB), Spain
- J. Wang – JPL / TAMU, USA
- N. Zarokanellos – SOCIB, Spain

Cruise plan and cruise report:

https://doi.org/10.20350/digitalCSIC/15276
https://doi.org/10.20350/digitalCSIC/16077

Raw Dataset:

https://doi.org/10.20350/digitalCSIC/16511

Outreach material:

http://hdl.handle.net/10261/351719
http://hdl.handle.net/10261/350728
https://doi.org/10.20350/digitalCSIC/16660
https://doi.org/10.20350/digitalCSIC/16661

Corresponding author:
Ananda Pascual (**IMEDEA(CSIC-UIB)**, **Spain**), ananda.pascual@imedea.uib-csic.es

Fine-Scale Upper Ocean Variability in the Kuroshio Extension Region from the Wide-Swath SWOT Measurements

Bo Qiu (University of Hawaii, United States); Shuiming Chen (University of Hawaii, United States)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
Fine-scale upper ocean variability in the 15 ~ 150 km range of the Kuroshio Extension region is investigated using the wide-swath sea surface height (SSH) data of the Surface Water and Ocean Topography (SWOT) mission from August 2023 to December 2024. The regional SSH wavenumber spectrum in this fine-scale range follows the k^(-11/3) power law, suggesting the control by the surface quasi-geostrophic dynamics. Distinct asymmetric dependence on polarity of the large-mesoscale vorticity field is detected for the fine-scale eddy kinetic energy (EKE) and strain signals due to the ageostrophic secondary circulation and departure from balanced dynamics. As a result of winter mixed layer instability, the fine-scale EKE shows a seasonal enhancement from January to April and its spatial extent is observed to cover the broad interior ocean beyond the Kuroshio Extension jet. We find the length scale separating the forward and inverse energy cascades at 50 km, smaller than the 150-km scale estimated from the gridded nadir altimetry data. Temporally, the inverse cascade amplitude is found to be controlled by the total EKE level in the region, whereas the forward cascade amplitude depends on the areal abundance of the quantity for departure of balanced dynamics: A-S<0, where A is absolute vorticity and S is strain rate.

Corresponding author:
Bo Qiu (**University of Hawaii**, **United States**), bo@soest.hawaii.edu

Studying the physical-biogeochemical coupling at fine scale with SWOT : first results of the BioSWOT-Med campaign.

Andrea Doglioli (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France); Francesco d'Ovidio (Sorbonne Université, CNRS, IRD, MNHN, Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN-IPSL), Paris, France); Gérald Grégori (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France); and the BioSWOT-Med Collaboration (*, *)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The oceanic fine scales (1-100 km) have relatively short lifetimes (days to weeks) but crucially affect ocean physics and ecology up to the climate scale, due to intense gradients created by their energetic dynamics. These gradients can be associated with enhanced vertical transport connecting the ocean's upper layer to its interior. Moreover, the temporal scale associated with the fine-scale dynamics is similar to that of many important oceanic processes including biogeochemical cycles, biodiversity, fish distribution, and even foraging strategies of mega-fauna.

Over the past few decades, numerical studies with physical and biophysical configurations for km-scale processes allowed significant progress in characterizing this regime. However, in situ observations of the physical-biogeochemical coupling at fine scales are particularly challenging to obtain due to the ephemeral nature of the dynamical structures and the complexity and multidisciplinarity of the processes. A few in situ surveys have shown the structuring role of fine-scale dynamics on plankton communities, but most of these studies were conducted in highly productive and energetic regions.

During the BioSWOT-Med cruise (21/4 – 14/5 2023, R/V L'Atalante, https://doi.org/10.17600/18002392) we targeted a moderately energetic front (the North-Balearic Front) in an oligotrophic region (the Western Mediterranean Sea).
Guided by the first bidimensional altimetry data transmitted by the novel SWOT satellite, we used an adaptive Lagrangian strategy to conduct high-resolution multi-disciplinary sampling and deploy several autonomous platforms.

The front consisted of a strong meandering jet, separating cold, salty and more productive waters in the north from warmer, fresher and more oligotrophic waters in the south.
Within a region approximately 50 kilometers wide we performed a series of 24-hour stations in three distinct dynamical features: a cyclonic circulation to the north, an anticyclonic eddy to the south, too small to be clearly detected by conventional altimetry, and the front itself.
Two consecutive northerly wind events created challenging conditions for shipboard operations but allowed us to observe and characterize the generation and propagation of strong near-inertial waves. Microstructure measurements revealed how trapping mechanisms of those waves lead to enhanced turbulence mixing within the anticyclone.
Drifters revealed the significant role of wind and sea-surface height in driving local surface circulation and showed an alternating pattern of vertical velocities within the anticyclone.
Innovative methods allowed us to estimate nutricline depths and nutrient concentration gradients at high resolution and precision. Significant variability of nutricline depths and nutrient gradients across the front, equivalent to basin-scale variability, were observed.
A 24-hour continuous water sampling within the front with automated high frequency flow cytometry was crucial to unveiling a distinct frontal phytoplankton community, where the relative contribution of non-dominant phytoplankton groups increased relative to the one of the adjacent water masses.
Within the frontal area total mesozooplankton abundance and biovolume had values lower than adjacent waters. Within the upper 100 meters the taxonomic composition of the front waters differed from the adjacent ones. Then, with depth, a progressive homogenization of community structure was observed.
Multidisciplinary analyses of the large dataset collected are in progress to explain underlying mechanisms of these observations.

The BIOSWOT-Med campaign showcases the new opportunities for biophysical experiments opened by the combination of SWOT observations and dedicated sampling strategies. Moreover, as the Mediterranean sea shares several physical and biogeochemical conditions with several other regions of the world ocean where fine scale activity is mostly undocumented, this research acquires a global significance.

(*,*) BioSWOT-Med Collaboration Members:
https://people.mio.osupytheas.fr/~doglioli/BioSWOT-Med_MailingList.png
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Cruise Report:
https://doi.org/10.13155/100060

Cruise Metadata: https://people.mio.osupytheas.fr/~doglioli/BioSWOT/BioSWOT-Med_2023/BioSWOT-Med_metadata.pdf

Popularization Book: Doglioli A., Ballerini T. (eds), 2025. People, science and instruments of the BioSWOT-Med Campaign. https://doi.org/10.13155/105690

Corresponding author:
Andrea Doglioli (**Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille**, **France**), andrea.doglioli@univ-amu.fr

The Role Of Fine-Scale Circulation In Shaping The Nutricline Unveiled At The SWOT Era. Insights From BioSWOT-Med.

Aude JOEL (MIO, France); Andrea Doglioli (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France., France); Anthony Bosse (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France., France); Léa Buniak (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France., France); Francesco D'Ovidio (Sorbonne University, CNRS, IRD, MNHN, Oceanography and Climate Laboratory: Experiments and Numerical Approaches (LOCEAN-IPSL), 75005, Paris, France, France); Ricardo Martellucci (National Institute of Oceanography and Applied Geophysics – OGS, Sgonico (TS), Italy., Italy); Thierry Moutin (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France., France); Sandra Nunige (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France., France); Massimo Pacciaroni (National Institute of Oceanography and Applied Geophysics – OGS, Sgonico (TS), Italy., Italy); Elvira Pulido-Villena (Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France., France)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The SWOT satellite mission, during its CalVal phase, provided a unique opportunity to study oceanic fine-scale circulation and its interactions with biogeochemical processes. In low-to-moderate energy systems and oligotrophic regions—representing the majority of the global ocean—numerical models have suggested how physical features such as eddies, fronts, and filaments influence the vertical distribution of nutrients, playing a key role in shaping phytoplankton diversity and distribution. Until SWOT, these interactions remained poorly characterized empirically due to the transient nature of fine-scale structures and the challenges associated with tracking and sampling them in situ.

In spring 2023, as part of the SWOT-AdAC consortium, the BioSWOT-Med campaign (doi:10.17600/18002392) investigated the influence of fine-scale circulation on biogeochemical processes and phytoplankton biodiversity in the North Balearic Front located in the Western Mediterranean Sea. The campaign leveraged the unprecedented spatial resolution of sea surface height measurements provided by SWOT, combined with an adaptive Lagrangian sampling strategy. Within a ~50 km-wide area, three distinct fine-scale features were targeted, including a frontal zone separating an anticyclonic eddy from a cyclonic circulation structure, encompassing contrasting water masses. A comprehensive dataset of nitrate and phosphate concentrations was generated based on Niskin bottle rosette samples (nitrate and phosphate profiles down to 500 m) and automated measurements performed in situ by a BGC-Argo float (nitrate profiles down to 400 m).

Nutrient profiles typically exhibit near-zero concentrations in surface waters and increasing concentrations with depth, separated by the nutricline—a transition layer marked by sharp or gradual changes in nutrient concentrations. The depth of the nutricline and its strength (vertical concentration gradient) are key factors controlling nutrient fluxes into the photic layer, which are critical for sustaining new primary production. Estimating these parameters at an unprecedented spatial scale was complicated by uncertainties related to near-zero nutrient concentrations in surface waters and the discrete nature of the sampling. To address these limitations, statistical approaches and innovative data processing techniques were applied.

For the first time at this scale, a significant variability across the front was observed with in situ data: concentration gradients were steepest within the cyclonic feature, which exhibited the shallowest nutricline depths, and weakest within the anticyclonic feature, where the nutricline was deepest. These results highlight the strong coupling between fine-scale oceanic structures—detectable thanks to SWOT—and distinct patterns in vertical nutrient distribution. Ongoing investigations aim to disentangle the contributions of biological activity, episodic wind forcing, and near-inertial wave dynamics to the observed variability. This study opens promising perspectives on nutrient supply to the photic layer driven by fine-scale circulation in oligotrophic regions, and its implications for structuring phytoplankton communities in the SWOT era.

Corresponding author:
Aude JOEL (**MIO**, **France**), aude.joel@mio.osupytheas.fr

Fine scale observations in the very dynamic Antarctic Circumpolar Current Polar Front under SWOT over 18 months.

Benoit Legresy (CSIRO, Australia); Yann-Treden TRANCHANT (University of Tasmania, Australia); Ash PARKER (CSIRO, Australia); Bea PENA-MOLINO (CSIRO, Australia)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The FOCUS (Fine-scale Observations of the Antarctic Circumpolar Current Under SWOT) project is a regional validation study conducted in support of the SWOT mission. FOCUS targeted an energetic region of the Antarctic Circumpolar Current thought to contribute disproportionately to meridional heat transport and ocean ventilation. A voyage on the R/V Investigator collected data with CTD casts, towed profiler and deployed multiple ocean gliders, floats, and drifters it also deployed a 3.4km tall mooring. The mooring was recovered in May 2025 and has 18month of data under heavy SWOT coverage during the period. This presentation will focus on this longer-term observation dataset and show the temporal variability and the vertical extent of features observed by SWOT snapshots and passing through the mooring. At the time of this abstract submission the Mooring data have not been quality processed, but the first checks indicate we have a rich dataset with higher resolution in the top 1000m of the water column and the bottom 500m. The mooring was designed and instrumented to sustain the strong variability (+-2m/s) in current and properties right at the polar front. The temporal variability with depth will be characterised and put in perspective of SWOT spatial variability. The flow equilibration analysed in concomitance with other voyage datasets and related analysis and the high-resolution FOCUS model (Tranchant et al.) to describe the finer scale dynamics at the polar front.

Corresponding author:
Benoit Legresy (**CSIRO**, **Australia**), benoit.legresy@csiro.au

Ocean Mesoscale Hot-spot at the High Latitudes: the Lofoten Basin

Antonio Bonaduce (NERSC, Norway); Artem Moiseev (NERSC, Norway); Le Guillou Florian (Datlas, France); Hart-Davis Michael (DGF-TUM, Germany); Roshin Raj (NERSC, Norway); Fabio Mangini (NERSC, Norway); Johnny Johannessen (NERSC, Norway)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The SWOT-NOR science team project presents new insights into ocean mesoscale eddies in the Nordic Seas, focusing on highly dynamic regions such as the Lofoten Basin—recognized as a hotspot of high-latitude mesoscale activity. As SWOT extends the capability of nadir altimeters to two-dimensional mapping and sampling of the ocean surface at an unprecedented spatial resolution, this has opened the opportunity to constrain better the mesoscale variability in areas with a reduced number of the available altimetry missions and small Rossby radii. The results presented in this work rely on the science phase of the SWOT mission to show a comparison of KaRIn retrievals with conventional altimeters and characterize the representation of the mesoscale field emerging from the different altimetry concepts. The assessment of the eddy population also builds on the collocation between the altimetry retrievals at the surface and Argo profiling floats in the vertical to characterize the three-dimensional structure of the eddies in the Lofoten Basin. The mesoscale features are then collocated with high-resolution remote-sensing retrievals to characterize the contribution of eddies to the upper ocean dynamics. A key focus is on the synergy between SWOT and Sentinel-1 SAR Doppler data, which enables the partitioning of geostrophic and ageostrophic components of mesoscale dynamics.

Corresponding author:
Antonio Bonaduce (**NERSC**, **Norway**), antonio.bonaduce@nersc.no

Examining the circulation on the Northwest Atlantic Shelf: along-shelf connectivity and hot spots of shelf-basin exchange

Nicholas Foukal (Skidaway Institute of Oceanography, United States); Svenja Ryan (Woods Hole Oceanographic Institution, USA); W. Gordon Zhang (Woods Hole Oceanographic Institution, USA); Dihya Chaal (Skidaway Institute of Oceanography, USA)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
In this project we are studying the connectivity of the circulation on the Northwest Atlantic shelf. The motivation for this project is two-fold: (1) to understand the fate of fresh water entering the shelf region from the Arctic and Greenland Ice Sheet through Davis Strait and its effect on the AMOC, and (2) to improve predictability of ocean properties in the Gulf of Maine/Mid-Atlantic Bight region that is home to one of the most productive ecosystems globally and has recently experienced dramatic swings in temperature and salinity. The project is divided into three work packages, and in this talk, we will present an update on the first work package focused on validation of the SWOT-derived surface geostrophic velocities. Comparisons between the SWOT velocities and two sets of moored data on the Newfoundland and Labrador Shelf, as well as moorings and a regular ship transect in the Mid-Atlantic Bight will be presented. Furthermore, we will present first results from comparisons of SWOT sea surface height data with data from Pressure Inverted Echo Sounders (PIES) deployed at the northern edge of the Gulf Stream for additional validation of SWOT in an eddy-rich region. For this analysis, we will also assess the impact of different spatial filters when deriving geostrophic velocities. In addition, the SWOT velocities and SSH fields are compared to high-resolution SST and chlorophyll products of the region. The goal of this validation work is to determine the processes resolved by SWOT, including the representation of narrow currents such as coastal currents and the shelf break jet, so that we can move forward in the project with confidence that the shelf-basin exchange is accurately resolved by the SWOT data. The goal of this project is to eventually build on these validation results to quantify the shelf-basin exchange along the Northwest Atlantic Shelf and test the hypothesis that this shelf basin exchange has been increasing through time.

Corresponding author:
Nicholas Foukal (**Skidaway Institute of Oceanography**, **United States**), nicholas.foukal@uga.edu

Three-dimensional water mass transformation in the Norwegian Sea revealed by SWOT and in-situ data

Leah Johnson (University of Washington, United States); Alejandra Sanchez-Rios (University of Hawaii, USA); Leo Middleton (University of Gothenburg, Sweden); Harper Simmons (University of Washington, USA); Jennifer MacKinnon (Scripps Institution of Oceanography, USA); Ilker Fer (University of Bergen, Norway); Ailin Brakstad (University of Bergen, Norway)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
Satellite altimetrically derived velocity fields have provided valuable insights into horizontal stirring and tracer transport at the ocean surface, as well as mixing along isopycnals in the ocean interior. Here, we present novel results demonstrating the powerful capability of SWOT to resolve the connectivity between surface-layer stirring and subsurface isopycnal mixing in the Nordic Seas, a region of critical climatic importance, where warm, saline North Atlantic waters mix with cold, fresh polar waters to form North Atlantic Deep Water that feeds the lower limb of the Atlantic Meridional Overturning Circulation. By combining SWOT-derived velocity fields with in-situ observations of a subducted warm water mass in the Jan Mayen channel, we trace the evolution of these flows across the Arctic front and along isopycnal surfaces from the surface to the interior.
Understanding the role of mesoscale and submesoscale eddies in water mass transformation in the Nordic Seas has been limited by the coarse resolution of geostrophic velocities derived from conventional nadir altimetry at high latitudes. The finer-scale velocity fields provided by SWOT, in combination with high resolution in-situ measurements, reveal the critical role of small-scale eddies in stirring tracers in these seas. The in-situ data resolve the structure of warm, saline Atlantic water that was subducted beneath colder polar waters along the boundary of the Arctic front and was being transported away from the front by eddying flows. Dynamic height inferred from density profiles agrees with SWOT observations, and the patchy structure of the subducted water suggests stirring by eddies with horizontal scales of ~20 km that are consistent with those resolved by SWOT. Synthetic sea surface temperature (SST) fields advected using SWOT velocities reproduce stirring patterns seen in the observations. However, these patterns align not with satellite-observed SST, but rather with the along-isopycnal temperature structure of the subducted water mass. Together, these results support a scenario in which surface waters are stirred, subducted in regions of strong lateral gradients, and continued to be advected below the surface by SWOT-resolved eddying flows. Estimates of along isopycnal diffusivity from in-situ observations (~300 m^2/s) closely match those derived from the advected tracer fields and lie within the range of previous drifter-based estimates (O(100–500 m^2/s)). These findings offer new insight into the role of small-scale processes and three-dimensional transport in Nordic Seas water mass transformation, and highlight a new frontier in the use of SWOT to understand stirring by small-scale upper-ocean macroturbulence.

Corresponding author:
Leah Johnson (**University of Washington**, **United States**), leahjohn@uw.edu

PATASWOT: Comprehending the physical processes impacting the PATAgonian southwestern continental shelf and adjacent open ocean using SWOT data

Laura Ruiz-Etcheverry (CIMA/CONICET-UBA, Argentina); Laura Saraceno (CIMA/CONICET-UBA, Argentina); Florence Birol (LEGOS, France); Maristella Berta (CNR-ISMAR, Italy); Alberto Piola (University of Buenos Aires, Argentina); Claudia Simionato (CIMA/CONICET-UBA, Argentina); Silvia Romero (Servicio de Hidrografía Naval, Argentina); Giuliana Berden (University of Victoria , Canada); Nicolas Bodnariuk (IPSL-CNRS, France); Valeria Guinder (Instituto Argentino de Oceanografía , Argentina); Matias Dinápoli (CIMA/CONICET-UBA, Argentina); Carola Ferronato (Instituto Argentino de Oceanografía , Argentina); Sebastian Cornejo-Guzmán (CIMA/CONICET-UBA, Argentina); Melina Martinez (CIMA/CONICET-UBA, Argentina); Urricariet Milagro (CIMA/CONICET-UBA, Argentina); Fernando Becker (Servicio de Hidrografía Naval, Argentina); Ornella Silvestri (Servicio de Hidrografía Naval, Argentina); Martin Rivarossa (INIDEP, Argentina); Fernando Ramirez (Instituto Argentino de Oceanografía , Argentina); Candela López Fidel (Universidad de Buenos Aires, Argentina); Celeste Antieco (Servicio de Hidrografia Naval , Argentina)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The main objective of PATASWOT is to enhance our understanding of the physical processes affecting the Patagonian continental shelf and adjacent open ocean using SWOT data, traditional satellite altimetry, in situ observations and model outputs. This objective is guided by the following key research questions: (Q1) What are the main physical drivers underlying the high biological activity observed over the Patagonian shelf and slope? (Q2) Does the Malvinas Current (MC) act more as a blender or as a barrier between open ocean and shelf waters? (Q3) How are the lower levels of the trophic web, –nutrients and phytoplankton- structured within the water column and how are these distributions associated with the physical characteristic of water masses on the Patagonian shelf, slope, and beyond the MC into the open ocean? To address these questions, we propose the following specific objectives: i) Validate SWOT data and geophysical correction against in situ data in the Patagonian continental shelf and open ocean; ii) Identify the physical processes measured by SWOT during the initial 1-day repeat orbit; Iii) Characterize the water exchange between the Patagonian shelf and open ocean; iv) Discern submesoscale dynamics that modulate the distribution of surface chlorophyll, heat and carbon fluxes; v) Assess the short-term evolution of the phytoplankton community composition and biomass. The required data will be obtained through Eulerian and Lagrangian experiments. These experiments will be conducted during an oceanographic cruise on R/V Falkor (too) scheduled for September-October 2025 on the upper slope of the shelf-break. The Eulerian experiment will include physical observations (temperature, pressure, salinity, currents) using three fixed moorings. The Lagrangian experiment will involve deploying a dense array of drifters (N = 54) drogued at depths of 50 cm and 15 m. The research vessel will track the drifters, and multiple water column samples will be collected at various depths. Additionally, time series of in situ current velocities and sea level measurements are already available to validate SWOT observations during the Cal/Val period over the Patagonian shelf, as well as 23 Lagrangian trajectories collected in the Brazil Current.

Corresponding author:
Laura Ruiz-Etcheverry (**CIMA/CONICET-UBA**, **Argentina**), lruiz@cima.fcen.uba.ar

SWOT in the Cryosphere: Promise, Progress, and Challenges

Tasha Snow (University of Maryland, United States); Cassie Stuurman (Jet Propulsion Laboratory, California Institute of Technology, United States); Sara Fleury (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, Centre National de la Recherche Scientifique (LEGOS/CNRS), France); Mohammed Dabboor (Science and Technology Branch, Environment and Climate Change Canada, Government of Canada, Canada); Laurie Padman (Earth and Space Research, United States); Susan Howard (Earth and Space Research, United States); Zachary Katz (Department of Geophysics, Colorado School of Mines, United States); Sonam F. Sherpa (Institute at Brown for Environment and Society, Brown University/School of Environment, Society, and Sustainability, University of Utah , United States); Ellianna Abrahams (Department of Geophysics and Stanford Data Science Institute, Stanford University, United States); Matthew R. Siegfried (Department of Geophysics, Colorado School of Mines, United States); Imogen Garlick (UCL Department of Space & Climate Physics, United Kingdom); Rosemary Willatt (UCL Department of Earth Sciences, United Kingdom); Felix L. Müller (Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), TUM School of Engineering and Design, Technical University of Munich, Germany); Antonio Bonaduce (Nansen Environmental and Remote Sensing Center (NERSC) , Norway); Andrew Thompson (Environmental Science and Engineering, California Institute of Technology , United States); Camryn Kluetmeier (Department of Earth, Marine, and Environmental Sciences, University of North Carolina at Chapel Hill, United States); Pierre Rampal (Institut de Géophysique de l'Environnement, Centre National de la Recherche Scientifique (IGE/CNRS), France); Khalil Bakhtiari Asl (Centre Eau Terre Environnement, Institut National de la Recherche Scientifique, Canada); Sahra Kacimi (Jet Propulsion Laboratory, United States)

Session: Oceanography: Regional Validation
Presentation type: Oral

Abstract:
The SWOT mission launched in December 2022 with the goals of delivering the first global inventory of Earth's surface water, high-resolution ocean topography, and temporal variability of water bodies. Although SWOT's primary objectives targeted terrestrial hydrology and oceanography, SWOT's ~78° latitude orbital turnaround results in up to sub-weekly observations, unaffected by clouds, in many critical polar regions. SWOT may, therefore, also make significant contributions to cryospheric science. To capitalize on this potential, a dedicated Cryosphere Working Group was formed from the 2024 Science Team to explore and expand SWOT's cryospheric applications. The group's early efforts yielded the first high resolution (HR) tasking over Antarctica, adding to HR acquisitions for other key Arctic regions. Other promising advancements include a demonstration that KaRIn backscatter enables robust discrimination between sea ice and icebergs, a long-standing challenge for automated classifiers, and that the combination of sea surface height anomaly (SSHA) and backscatter supports a novel SWOT-based classification of sea ice and leads. A preliminary examination of SWOT LR data against ICESat-2 provides confidence in the feasibility of retrieving the first truly two-dimensional estimates of sea ice freeboard. SSHA observations of the Antarctic coastal margin provide, for the first time, the potential to observe variability of major surface currents across multiple timescales. HR data also provide the first frequent repeats of the 3-D structure of rifts on some Antarctic ice shelves. Additionally, the initial assessment of SWOT observations offers valuable insights into the mission's potential for monitoring freshwater ice. Preliminary comparisons of HR PIXC data with two days of concurrent DEMs collected over river ice show ice surface elevation differences of ~25 cm. For each of these applications, however, significant challenges remain. Errors in geoid, mean sea surface, and tide corrections, and ongoing issues with crossover corrections hinder the retrieval of accurate coastal SSHA values. For ice shelves, our initial studies of HR data reveal many regions where measured elevations experience jumps, some of which may be attributed to errors in the underlying digital elevation model (DEM) from changing ice shelf fronts and rifts, and from large voids in the v1.1 100m REMA DEM. Artifacts in both HR and LR products, combined with complications introduced by onboard and ground-based processing pipelines, present further obstacles to retrieving reliable surface heights in polar regions. Ongoing work aims to resolve these issues — taking advantage of collaborations with other working groups — and establish SWOT as a powerful tool for observing cryosphere processes.

Corresponding author:
Tasha Snow (**University of Maryland**, **United States**), tsnow03@umd.edu

First quality assessment of SWOT data in the Gironde estuary

Lucie CAUBET (LEGOS laboratory, CNRS/UPS/CNES/IRD, France); Florent LYARD (LEGOS laboratory, CNRS/UPS/CNES/IRD, France); Nadia AYOUB (LEGOS laboratory, CNRS/UPS/CNES/IRD, France); Robin CHEVRIER (CLS, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
Estuaries are part of the so-called land/ocean continuum, thereby making the link between the continent and the ocean. They are places for intense sediment exchanges between muddy river fluxes and the adjacent continental shelf as well as for mixing between freshwater and salty water. In addition, these environments are in many cases highly anthropized with diverse human activities (marine trade, agriculture, aquaculture and fisheries, industries,…), so that monitoring water quality (turbidity, salinity…), as well as discharge and water level variations is a major concern. However, understanding the estuarine dynamics remain quite challenging as they are driven by both hydrological (i.e river discharge, …) and oceanic processes (tides, surges, waves,…) which interact between each other. In particular, the river discharge acts as a tide amplitude and a phase modulator and may create strong tidal signal distortion, making tide prediction difficult to achieve. Yet, tides and river discharge along with their interactions occur on a wide range of temporal (from minutes to both seasonal and interannual variabilities) and spatial scales, thereby requiring a large number of measurements to capture the whole dynamics.
In this sense, the SWOT mission represents an incredible opportunity to get additional and unique observations, as well as new insights on these dynamics. By carrying an innovative altimetry radar which combines SAR and interferometry techniques, SWOT is able to provide two dimensional snapshots of water level at high spatial resolution over 50 km wide swaths, which represents a substantial improvement with respect to conventional altimetry in terms of sampling and coverage for coastal and estuarine regions.
A first step consists to verify the quality and the relevance of the existing SWOT products for the ocean (LR products) and for continental waters (HR products), especially as none of these products were specifically designed for estuaries. For this purpose, the Gironde estuary, including the adjacent continental shelf of the Bay of Biscay, is a very suitable area since it is monitored by several tide gauge stations. Besides, realistic simulations of water level and 2D dynamics by the hydrodynamic model T-UGOm are available to us (see Lyard et al. presentation). In this study, we focus more particularly on the validation of the Level 2 Unsmoothed product at 250 metres posting, which corresponds to the LR product with the highest resolution. Indeed, it both has a sufficient spatial resolution for an estuary that is maximum 12km wide compared to the 2km LR product and already includes correction of sea state bias unlike HR product, which remains important in areas undergoing significant waves. As this product is generated through algorithms primarily designed for ocean applications, some processing, corrections or flags may be not fully appropriated in coastal regions.
The first objective of our study is therefore to assess the relevance of the SWOT quality flag by examining total water level ('ssh' variable) and backscatter ('sigma0' variable) measurements and their corrections. We compute dynamic land/sea masks which change according to the phase of tides based on two different methods. The first one can be used to provide a dynamic surface classification including the identification of intertidal areas, while the second one appears to be more robust to edit spurious anomalies in the data. We find that the ssh quality flag provided in the LR products can be too severe in the upper estuary by removing a too large number of ssh measurements while not capturing certain well-known anomalies, such as swell/wave induced decorrelation at the inner edges of the swaths. In addition, the presented SWOT editing methodology is found to be easier to use than the quality flag and could be applicable in other estuaries throughout the world.
This editing is therefore applied to provide a first SWOT sea surface height error budget by comparing with in-situ and model data. Overall, SWOT deviations remain of the order of ten centimetres along the whole estuary which is quite impressive. Moreover, the comparison with the model enabled to detect some potential errors in the model that could not have been revealed in tide gauge comparisons alone. Yet, there is still a work in progress to explain the remaining bias between SWOT and in-situ/model data which may be linked to vertical movement of the Earth's crust or/and to residual errors from altimetry corrections. In particular, we start to explore the sensitivity to the cross-track correction which is required to avoid deviations that can reach several tens of cm exceeding sometimes one metre.
This study is a contribution to the SCOEPUS (SWOT Coastal Ocean and Estuarine Products Usability Study) project of the SWOT Science Team.
Corresponding author:
Lucie CAUBET (**LEGOS laboratory, CNRS/UPS/CNES/IRD**, **France**), lucie.caubet@univ-tlse3.fr

Fine scale structures in the coastal zone of Baltic Sea based on nadir-Altimeter and SWOT Data

Luciana Fenoglio (University of Bonn, Germany); Volker Mohrholz (IOW , Germany); Anna Bulczak (IOPAN, Poland); Peng Feng (Chalmers University of Technology, Sweden); Jiaming Chen (University of Bonn, Germany); Marco Rivera (University of Bonn, Germany); Faruque Abdulla (University of Bonn, Germany); Jaromir Jakacki (IOPAN, Poland); Christopher Buckhaupt (CISESS/UMD, College Park, Maryland , US); Ulf Graewe (IOW, Germany); Jürgen Kusche (University of Bonn, Germany)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
The project CONWEST-DYCO2 continues project CONWEST-DYCO in the Elbe estuary and Baltic Sea and extends the analysis to two other two regions. The central hypothesis is that hydrodynamic processes of the river-to-ocean continuum and of the mesoscale in coastal zone are today at best resolved and understood by combining SWOT and SAR-satellite altimetry observations. The main objectives is to evaluate the contribution of SWOT to analyse coastal processes. Our focus is on small scale processes in the transition zone from land to sea, that is in estuaries and in coastal zone.

For this purpose, the SWOT data products are analysed separately and then merged to data of nadir-altimeters in 2-dimensional maps with measurements from other satellite altimeter missions, and will be analyzed against in-situ and modeling results.

In this work we investigate the data quality and the temporal evolution of fine scale structures along coast and estuaries of the Baltic Sea in the time interval from April 2023 to December 2024. For this scope we have constructed daily maps of sea level height above a reference mean sea surface by merging data of Sentinel-3 and Sentinel-6 SAR nadir- with and without SWOT wide-swath altimeter missions using an Optimal Interpolation (OI) algorithm. The geostrophic ocean currents are derived from the maps of absolute and relative dynamic topography. The altimeter heights and few selected environmental corrections are validated at few in-situ locations.

The nadir-altimeter mission data along-track have been processed with unfocused (UF-SAR) and focused (FF-SAR) techniques to increase the data density near the coast. For each gauge an altimeter time-series is constructed by selecting for each cycle the nearest altimeter point to the gauge at a minimum distance to the coast. The mean of the standard deviation difference of the pair of time-series is larger than 10 cm for all the Baltic Sea sub-regions. The FFSAR and the LSAR (UF-SAR) reduced at the same frequency of 20 Hz are comparable. The SWOT data product LR L3 Expert data version 2.0.1. in a 2 km x 2 km grid have been selected. For each gauge an altimeter time-series is constructed by selecting for each cycle the nearest SWOT point to the tide gauge at a minimum distance to the coast. The mean of the standard deviation difference of the pair of time-series is smaller than 10 cm for all the Baltic Sea sub-regions. This indicated that the gridded SWOT products are more accurate than the along-track nadir-altimetry. The time-series are smoother.

Daily maps are constructed by merging nadir-altimeters and SWOT data over the cal/val and science phase. Several OI input parameters are used to best match the fine spatial scales observed by SWOT and the less fine spatial scales present in the CMEMS maps. Compared to in-situ data, the accuracy on nadir-only maps is lower than for the CMEMS grids and larger than 10 cm. Conversely, a better agreement with in-situ is obtained for the daily merged grids, which variability is higher than the variability of the standard CMEMS grid products. Along-track data are assimilated in a CEMS regional ocean model run at IOPAN. The IOW ocean model is further used for comparison.

Changes relative to land and coastal impacts are studied in the three key areas of the Kattegat-Danish Straits, Baltic Proper and Gdansk Basin. In the Gotland Basin we follow the mesoscale circulation structure observed between April 18 and April 28 during the SWOT-ADAC campaign showing the good agreement with the steric heights from the CTDs measurements.

Corresponding author:
Luciana Fenoglio (**University of Bonn**, **Germany**), fenoglio@geod.uni-bonn.de

Assessment of SWOT observations for monitoring nearshore and coastal waves

Md Saiful Islam (University of Rouen Normandy, M2C , Rouen, France); Emma Imen Turki (University of Rouen Normandy, CNRS, M2C, Rouen, France); Carlos Lopez Solano (University of Rouen Normandy, CNRS, M2C, Rouen, France); Pascal Matte (Meteorological Research Division, Environment and Climate Change Canada, Quebec , Canada); Xavier Chartrand (Meteorological Research Division, Environment and Climate Change Canada,Institut des Sciences de la Mer de Rimouski, Université du Québec à Rimouski, Rimouski, Québec, Canada); Laurent Froideval (University of Caen Normandy, CNRS, M2C, Caen, France); Edward Salameh (University of Rouen Normandy, CNRS, M2C, Rouen, France); Benoit Laignel (University of Rouen Normandy, CNRS, M2C, Rouen, France); Nicolas Picot (CNES, Toulouse, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
Coastal zones are considered one of the Earth's most dynamic environments, hosting more than 35% of the global population within 100 km of the coastline. These regions are more vulnerable and exposed to increasing risks induced by extreme waves during high-energy events and storms, produced at short scales, combined with the long-term effects of sea-level rise. Accurate estimation of wave parameters is crucial for accurate estimation and requires high-resolution monitoring from ocean to nearshore and coastal areas.
Although in situ wave buoys and coastal radar systems offer fast and precise wave monitoring, the spatial coverage is strictly limited, and the quality of the Lagrangian measurement of wave buoys relies strongly on the mooring configuration and the absence of biofouling. Numerical modeling addresses this data gap, yet it relies on empirical spectral relationships that are ill-defined for transient water from the deep ocean to shallow nearshore areas, fetch, and ambient conditions. Satellite radar altimetry is therefore one realistic means to provide a quantitative near-global mapping of the wave field, but much effort needs to be devoted to work around the decreasing accuracy closer to the coastline due to land contamination and complex coastal wave states. The Surface Water and Ocean Topography (SWOT) mission significantly advances nearshore observations by providing sea surface height (SSH) and significant wave height (SWH) measurements with unprecedented accuracy.
This work investigates the use of SWOT low-rate (LR) and high-rate (HR) observations for monitoring changes in surface gravity wave patterns in nearshore and coastal areas, which are novel capabilities of SWOT compared to previous altimeters. We estimate from SWOT the SWH at different spatial and temporal scales, including interdaily, monthly, and seasonal scales, using a series of statistical and spectral analyses to explore different SWOT LR and HR products and raster maps, together with in situ wave buoys. The obtained results demonstrate the ability of SWOT to capture realistic significant wave height and other key parameters that include peak period, peak direction, and wavelength in nearshore and coastal zones after applying some correction to LR products (example: beta-angle corrections), which significantly enhances the wave estimation.
This methodological approach has been applied to the English Channel and coastal areas for the first time. Further work expanded our approach to the Saint Lawrence Gulf and Estuary as well. This study presents the first comprehensive analysis to evaluate the SWOT accuracy for wave monitoring in shallow waters, which is crucial for improving boundary conditions and calibrating hydrodynamic models.

Corresponding author:
Md Saiful Islam (**University of Rouen Normandy, M2C , Rouen**, **France**), md-saiful.islam@univ-rouen.fr

SWOT in the nearshore: Extending HR Pixel cloud product to the surfzone for hyperlocal wave measurements

Tyler Mccormack (Northeastern University, United States); Edward Beighley (Northeastern University, United States)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
The nearshore region experiences rapidly changing wave conditions in time and space, making it critical, albeit challenging to measure coastal processes. In this study, we leverage the SWOT High Rate (HR) pixel cloud product to explore potential SWOT derived wave measurements in the nearshore. Using data from the US Army Corps of Engineers Field Research Facility in Duck, North Carolina, USA, we assess SWOT water surface elevation (WSE) measurements, and use WSE to derive and assess wave height, period and direction in the nearshore using the HR pixel cloud. The in-situ data includes 20 water level sensors and current meters ranging from 50 m to 16 km offshore, with the majority (17) less than 600 m offshore. Preliminary results show that single pixel WSE measurements from the HR pixel cloud product are accurate even in the presence of shoaling, breaking, and broken waves with a root mean square error (RMSE) of 0.37 m compared to the NOAA water level gauge located 500 m offshore. Nearshore wave height estimates also show good agreement with in-situ wave gauges. SWOT derived wave height accuracy increases as a function of number of pixels included and decreases as a function of wave height. Overall, the results demonstrate the ability of SWOT to quantify wave properties in the nearshore with the HR pixel cloud product.

Corresponding author:
Tyler Mccormack (**Northeastern University**, **United States**), mccormack.ty@northeastern.edu

Assessing SWOT Performance to Measure SSH Variability over Rangiroa Atoll, French Polynesia

Ewen Cottour (IFREMER, France); Guillaume Dodet (IFREMER, France); Clémence Chupin (ENSTA, France); Taina Postec (CNRS, France); Laurent Testut (LIENSs, France); Lisa Maillard (CNES, France); Swen Jullien (Laboratoire d'Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France, France); Frédéric Bouchette (Université de Montpellier, CNRS, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
Atoll reef islands are highly vulnerable to oceanic climate changes due to their low elevation, high exposure to oceanic swells, and strong dependence on the coral reef health. The dynamics of atoll water levels is directly influenced by tide- and wind-generated waves. Incident swells generate a super-elevation of the lagoon water levels through wave setup and inward flows across the shallow reef sections as a result of wave breaking and bottom friction. Tidal wave propagating through the narrow shallow passes induce strong nonlinear tidal distortion, which modify the relative duration of ebb and flood tides and the lagoon flushing capacity. Finally, resonant processes may also occur in (semi-)enclosed lagoons as a result of long-wavelength oceanic (e.g., infragravity waves) or atmospheric forcings (e.g., wind setup). Due to sparse measurements and the limitations of local sensors, spatial variations in sea surface height within large atolls have been understudied. The most extensive studies to date rely on high-resolution modelling systems combining atmospheric, circulation, and wave models, although these models are rare and typically validated at only a few sites with available in situ measurements. The Rangiroa atoll, located in the Tuamotu Archipelago, is the world's second-largest atoll. Recent analyses of SWOT LR 2km gridded maps of sea surface height (SSH) in Rangiroa have revealed significant gradients within the lagoon, between the atoll's exterior and interior, as well as between the northern and southern regions. These spatial gradients align with observed water level variations between lagoon tide gauge measurements and simulated water levels on the atoll's southern and northern sides. However, discrepancies exist between SWOT observations and tide gauge data, possibly due to uncertainties in the vertical datum, geoid spatial gradients, or inaccuracies in atmospheric and sea state bias corrections. In this study, we further analyze SWOT L2 and L3 products over Rangiroa atoll in order to reconstruct accurate SSH, mean sea surface (MSS) and SSH anomaly (SSHA) maps at 250-m resolution and investigate the different source of uncertainties in SWOT products. The high-resolution SSHA maps reveal uniquely observed spatial features that illustrate the complex interactions between tides and waves at Rangiroa atoll. These observations are validated against tide gauge data as well as static and cinematic GNSS SSH data acquired during an extensive field campaign conducted in May 2025. The major source of uncertainties are presented based on the combined analysis of this new dataset.
Corresponding author:
Ewen Cottour (**IFREMER**, **France**), ewen.cottour@ifremer.fr

Can satellite altimetry observe coastally trapped waves on sub-monthly timescales?

Marcello Passaro (DGFI-TUM, Germany)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
Coastally trapped waves (CTWs) are a major driver of sub seasonal coastal sea level variability. Although they have mostly been studied using numerical models, observational evidence remains limited due to the sparse spatial coverage of tide gauge networks and the limitations of gridded satellite altimetry products, which rely on the interpolation of sparse along track data.
Recent developments such as the simultaneous operation of multiple altimetry missions, advances in processing technologies, the introduction of wide swath altimetry, and the creation of new interpolation techniques offer the potential to significantly improve the monitoring of CTWs.
In this study, which is currently under review (preprint available at https://doi.org/10.5194/egusphere-2025-809), I analyze three months of satellite altimetry sea level data to evaluate new capabilities for detecting sub monthly variability. The results are compared with tide gauge observations and an ocean model in Eastern Australia, a region where CTWs are known to dominate at these time scales.
The focus is on the improvement achieved by combining SWOT Karin sea level data with along track estimates from the nadir altimetry constellation using the MIOST interpolation scheme. This product is currently available as an experimental dataset from AVISO. It is compared to the latest DUACS DT2024 daily gridded sea level product, which is based on nadir altimeters and MIOST, and to the older DUACS DT2021 product, which uses nadir altimeters with a more traditional optimal interpolation scheme.
The results show that in the study area, the correlation between tide gauges and coastal daily sea level grids from satellite altimetry exceeds 0.5, even when the time series are filtered to isolate sub monthly variability. CTWs are generally well detected, although some discrepancies remain, particularly in amplitude.
This study suggests that with the increasing availability of MIOST data in the SWOT era, it is feasible to establish an altimetry based monitoring system for CTWs using filtered time series at selected grid points as virtual stations. This approach would complement and enhance existing studies based on sparse in situ observations, where available, and numerical simulations. It could also lead to a better understanding of how CTWs influence upwelling and productivity in coastal regions.

Corresponding author:
Marcello Passaro (**DGFI-TUM**, **Germany**), marcello.passaro@tum.de

Integrating SWOT observations with numerical models for investigating water levels in the English Channel

Carlos Lopez Solano (Universite de Rouen Normandie, France); Emma Imen Turki (Universite de Rouen Normandie, France); Md Saiful Islam (Universite de Rouen Normandie, France); Edward Salameh (Universite de Rouen Normandie, France); Ernesto Tonatiuh Mendoza (Universite de Caen Normandie - Cerema, France); Benoit Laignel (Universite de Rouen Normandie, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
Several low-lying coastal and estuarine communities are facing potential threats, like water level variability and more frequent and intense extreme events, driven by climate change and the growing human activity in these areas. The effects of extreme events on coastal environments include erosion of beaches, coastal infrastructure damage, or flooding, among other impacts. Hence, substantial efforts have been devoted to better understanding the natural processes that govern hydrodynamic variability across multiple scales to produce more accurate estimation of their fluctuations and ensuring reliable coastal risk assessments.

In the context of the increasing coastal risks driven by climate change, a numerical modelling approach has been implemented at both regional and local scales from the English Channel to the Normandy coasts (López Solano et al., 2024; 2025). This approach has been explored in the framework of the SWOT mission to improve the monitoring of water levels from the open ocean to the nearshore and coastal areas by integrating in-situ measurements, SWOT products and numerical models.

In this work, comparative analyses between in-situ water level measurements and SWOT observations have been performed along the UK and Normandy coasts to assess the accuracy of estimations across different times, spatial scales and product types. Subsequently, the different water level observations were used to validate the overall numerical simulations provided by the regional modelling approach. This correlated dataset is explored for a subsequent calibration of the model covering the English Channel (Figure 1). This work provides first insights for developing a data assimilation methodology based on SWOT altimetry observations in nearshore and coastal areas.

Figure 1. Bathymetry map of English Channel with the localization of in-situ measurements in French and UK coasts. The positions of SWOT tracks are displayed

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Corresponding author:
Carlos Lopez Solano (**Universite de Rouen Normandie**, **France**), carlos.lopez-solano@univ-rouen.fr

SWOT to study coastal dynamics: the case of North Current intrusions in the Northwestern Mediterranean Sea

Léna Tolu (CNRS LEGOS, France); Mathilde Cancet (CNRS LEGOS, France); Florence Birol (LEGOS - University of Toulouse, France); Claude Estournel (CNRS LEGOS, France); Maxime Arnaud (Aix Marseille Univ., University of Toulon, CNRS, MIO, France); Anne Petrenko (Aix Marseille Univ., University of Toulon, CNRS, MIO, France); Fabien Léger (CNRS LEGOS, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
The monitoring of ocean currents is a key component in many coastal applications, ranging from biogeochemical resources to marine pollution or search and rescue. During the last three decades, satellite altimetry has played an essential role in the understanding and monitoring of ocean currents at global scale. However, its use is still limited in coastal areas due to both the lower data quality in this environment and the spatiotemporal data resolution, which is not suited to the short scales of coastal dynamics. The importance of ageostrophic currents in coastal regions also raises some limitations of the altimetry measurements.

Nonetheless, many recent studies addressing the different issues related to the derivation and exploitation of altimeter-derived coastal current velocities have shown that they efficiently complement coastal velocity fields retrieved from in-situ data (e.g., hydrographic observations, surface drifter, and moored or ship-based acoustic Doppler velocities) or from shore-based HF radars. Indeed, one of the major advantages of this measurement technique is to provide long time series (i.e., more than 30 years) of spatially and temporally homogeneous information about the circulation, and to be available at near-global scale. The coastal altimetry data quality problem can be partially overcome thanks to dedicated processing with adequate corrections. Merging data from multiple missions has shown to improve the spatial and temporal resolutions. Finally, altimetry-derived geostrophic currents remain a substantial contribution to coastal circulation systems.

The SWOT mission represents the beginning of a new class of satellite altimeters, providing for the first time highly accurate 2D information at unrivalled resolution. In this study, we analyze and quantify the ability of SWOT to observe highly-dynamic coastal features associated with the North Current (a slope current located in the Northwestern Mediterranean Sea) during the Fast-Sampling Phase. We focus on particular events: the coastal intrusions of the current on the Gulf of Lion continental shelf. Through comparisons with in situ velocity measurements at the JULIO (Judicious Location for Intrusion Observation) station, and with outputs from a numerical simulation in the area, we show that SWOT-Karin provides unprecedented 2D current observations of such processes in the coastal strip.

Corresponding author:
Léna Tolu (**CNRS LEGOS**, **France**), lena.tolu@univ-tlse3.fr

Enhancing surface water extent estimates derived from the SWOT raster product using a Markov Random Field-based algorithm

Omid Elmi (Institute of Geodesy, University of Stuttgart, Germany); Ettehadieh Soheil (Institute of Geodesy, University of Stuttgart, Germany); Tourian Mohammad J. (Institute of Geodesy, University of Stuttgart, Germany)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission presents groundbreaking opportunities to monitor inland water bodies at various spatial scales, ranging from a narrow river reach using a Pixel Cloud (PIXC) product to an entire river basin using the raster product. While the SWOT raster product is provided as geographically fixed and uniform grid images, conducting large-scale temporal analysis of inland water bodies using this product presents challenges, primarily due to noise in SWOT observations. Since the raster product is derived from the PIXC product, potential quality issues in the PIXC data (such as misclassification, dark water issues, specular rings, bright land, phase unwrapping artifacts, etc.) can propagate into the raster product.
In this study, we aim to improve surface water extent estimates derived from the SWOT raster product in the Low-Elevation Coastal Zones (LECZs) of the Mississippi River Delta. Water bodies in this region are characterized by intricate channel networks and complex terrain, and the highly dynamic nature of water surfaces, driven by factors such as tides and wind, poses challenges for SWOT KaRIn in accurately measuring extent. Vegetation cover further complicates observations, as the Ka-band wavelength used by KaRIn has limited penetration through emergent vegetation like mangroves and salt marshes, which are prevalent in LECZs.
Our analysis begins by evaluating the impact of different quality flags on the accuracy and reliability of both surface water levels and water fraction in the raster product. We then develop a Markov Random Field framework that incorporates spatial and temporal dependencies, along with additional information sources such as digital elevation models and water occurrence data from satellite imagery. The optimization problem is subsequently solved using the max-flow algorithm to generate an enhanced water mask.
Corresponding author:
Omid Elmi (**Institute of Geodesy, University of Stuttgart**, **Germany**), omid.elmi@gis.uni-stuttgart.de

SWOT-Satellite-Enabled Tidal Data in Estuaries

Paul Bell (National Oceanography Centre, United Kingdom); Clive Neil (National Oceanography Centre, United Kingdom); Christine Sams (National Oceanography Centre, United Kingdom); Dougal Lichtman (National Oceanography Centre, United Kingdom); Christine Gommenginger (National Oceanography Centre, United Kingdom)

Session: Deltas, Estuaries and Coasts
Presentation type: Oral

Abstract:
Remote sensing methods are increasingly able to resolve the complex behaviour of estuaries, but accessing tidal water level data at the fine spatial and temporal scales needed for such work has usually required high resolution tidal models that rely on imperfect, incomplete and ever-changing bathymetry maps.
The Surface Water and Ocean Topography (SWOT) satellite's high resolution scanning altimeter data is now allowing simplified approaches to observing and deriving tidal data in estuaries.
Three months of daily overpass data from the SWOT satellite were compared with and validated against in-situ tide gauge data across the Liverpool Bay area. These data were then used to estimate the tidal phase lag on a 250m grid across the 120km wide swath of the SWOT overpass.
This simple tidal phase lag was then used as a first order correction to tidal elevation data from the Liverpool Gladstone Dock tide gauge for the purpose of mapping the extensive and highly dynamic intertidal regions of the Mersey Estuary using the Temporal Waterline Method.
More sophisticated spatially varying corrections to the tidal curve shape and amplitude are also shown to be possible using these data, which will provide further enhancements to the tidal input of NOC's intertidal mapping algorithms.
This work was conducted as part of a UK Space Agency SBRI contract number UKSAC23_0099-007 and the SWOT-UK project under NERC grant number NE/V009168/1
Corresponding author:
Paul Bell (**National Oceanography Centre**, **United Kingdom**), psb@noc.ac.uk

All-in-one SWOT lake approach: Volumes, Bathymetry and Uncertainty estimation by Implicit Neural Network Representations

Santiago PENA LUQUE (CNES, France); Dawa DERKSEN (CNES, France); Laetitia LALLA (CS-Soprasteria, France); Benjamin TARDY (CS-Soprasteria, France)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Oral

Abstract:
A novel approach for deriving dynamic 3D models of lakes (dry-bathymetry) and their flood basins from Surface Water Ocean Topography (SWOT) pixel cloud data is proposed. Supported by recent advances in Implicit Neural Representations (INR) and Physics-Inspired Machine Learning (PIML), we leverage physical biases regarding the geometric and temporal behavior of water and ground surfaces to learn a continuous implicit 4D model of the lake surface water and its surrounding area. Our experimental results show that despite high levels of noise in the pixel cloud - particularly in ground areas - our proposed model is able to 1. extract a static Digital Elevation Model of the dry bathymetry, 2. estimate the evolution of water height, area, volume, as well as their relations to each other, and 3. generate 2d water masks with no prior label information. We take inspiration from Bayesian Neural Networks and implement a probabilistic framework wherein the model outputs are provided with uncertainty estimations that take into account the level of noise in the SWOT pixel cloud data.

The main advantage of the method is the independency on PIXC Classification attribute. Instead, it takes advantage of 3D information, like in the case of precise dry bathymetry geolocation of PIXC on sandbanks (frequently misclassified as water). This also allows an independent estimation of water levels and areas based only on 3D information and the calculation of dry-bathymetry through the consistency of pixels' geolocations along all available PIXC observations.

The proposed approach has been validated on Ebro reservoir, using local water manager gauge data on water resources monitoring assessment (water surface elevation and volume stock change timeseries). Furthermore, we have validated our dry bathymetry estimate with 1-meter resolution DEM from Pleiades-stereo acquisitions during a low water period.

Current research is focused on expanding the method to a larger number of reservoirs, implying a complete automated pipeline with no human intervention or calibration. We hope that the proposed approach might be reused on the future FloodPlainDEM product generation by SWOT Algorithm Definition Team.

Corresponding author:
Santiago PENA LUQUE (**CNES**, **France**), santiago.penaluque@cnes.fr

Improved SWOT surface water storage monitoring through multi-sensor harmonization

Eric Levenson (University of Oregon, United States); Sarah Cooley (Duke University, United States); Elizabeth Webb (Duke University, United States); Camryn Kluetmeier (Duke University, United States)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Oral

Abstract:
We developed a novel multi-sensor approach that integrates observations from SWOT, Sentinel-2, and MODIS/VIIRS satellite sensors into harmonized time series for individual lakes and river reaches. Our primary research objective is to evaluate whether incorporating Sentinel-2's frequent 10 m resolution water surface area measurements and MODIS/VIIRS' daily cloud observations with SWOT altimetry can reduce uncertainty and increase the temporal resolution of water storage measurements. To do this, we first assembled a benchmark dataset of 315 gaged lakes and reservoirs across the US. For each of these water bodies, we produced a harmonized satellite-based time series using the SWOT single pass lake product, Sentinel-2 derived water surface area, and MODIS/VIIRS observed cloud properties. We utilized the 134 water bodies in the benchmark dataset that only have in situ water level data to produce an observation filtering model designed to filter poor SWOT-based water surface elevation measurements that were not captured by the lake product's quality flags. Using the remaining gaged water bodies, we compared the performance of water storage time series from the filtered and unfiltered SWOT single pass lake product to our storage calculations that leverage Sentinel-2 water surface area. Our results suggest that combining satellite sensors leads to (a) improved SWOT water surface elevation observation filtering; (b) reduced uncertainty in water surface elevation – area relationships; and (c) improved temporal resolution and the ability to reconstruct historical surface water storage trends. We also demonstrate this multi-sensor approach in river reaches, which has the potential to support SWOT-based discharge estimation.

Corresponding author:
Eric Levenson (**University of Oregon**, **United States**), elevens2@uoregon.edu

Water volume dynamics in West African lakes and reservoirs by SWOT and optical satellite sensors

Manuela Grippa (GET, France); Felix Girard (Géosciences Environnement Toulouse, France); Hedwige Nikiema (Ki-Zerbo University, Ouagadougo, Burkina Faso); Cheikh Faye (Assane Seck University, Ziguinchor, Senegal); Amadou Abdourahame Toure (Abdou Moumouni University, Niamey, Niger); Ibrahim Mainassara (Abdou Moumouni University, Niamey, Niger); Maxime Wubda (Ki-Zerbo University, Ouagadougo, Burkina Faso); Laurent Kergoat (Géosciences Environnement Toulouse, France)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Oral

Abstract:
Lakes, reservoirs, and small water bodies play a pivotal role in West African drylands. They are widely spread all over the landscape, which makes them a primary source of water for people and livestock. However, given their usually small size and their significant temporal variability, their hydrological dynamics remain poorly known at the regional scale. Also, these water bodies are very reactive to climate and human forcing, with a complex and sometimes unexpected dynamics, which questions their future evolution in a context of environmental changes and demographic increase.

This work heavily relies on SWOT data to explore the dynamics of water volumes in the thousands of lakes included in the study area. SWOT performance is evaluated using 1) in-situ data collected in Niger, Burkina Faso, and Senegal, and 2) other satellite estimates by altimetery data (Sentinel-3 and ICESat-2) for the lakes below the orbit, and high-resolution Digital Surface Models(Pleiades) acquired when water levels are at their minimum (Girard et al., 2025a).

We show that SWOT water surface elevations are in excellent agreement with in-situ data and with water level estimations by other satellite sensors (Girard et al., 2025b). SWOT-derived water levels are used to analyze the spatial distribution of water stocks and their seasonal dynamics, including water withdrawals from anthropogenic activities, which is poorly known at the regional scale.

Regarding water surface area, SWOT estimates show a general overestimation compared to Sentinel-2 estimates, which makes volume retrievals by SWOT alone challenging in the study region. Water volume changes are therefore estimated by combining SWOT-dervied water levels with water areas estimated by a deep learning approach applied to optical imagery (de Fleury et al., 2025).

Finally, the elevation-area-volume relationships obtained are used to reconstruct past changes in water volume from water area derived from the Landsat archives (1984 to present) over more than 2000 lakes and reservoirs. This reveals changes and trends in the hydrological long-term evolution in relation to environmental changes (i.e., precipitation, temperature, and vegetation cover) and anthropogenic activities (i.e., reservoir management and land use).

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Corresponding author:
Manuela Grippa (**GET**, **France**), manuela.grippa@get.omp.eu

Mapping wetland vegetation using Sentinel-1 and SWOT data

Yannick Duguay (Centre de géomatique du Québec, Canada); Mélanie Trudel (Université de Sherbrooke, Canada); Axel Chuette (Université de Sherbrooke, Canada); Anne-Marie Laroche (Université de Moncton, Canada); Alain N. Rousseau (Institut national de la recherche scientifique, Canada)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Oral

Abstract:
Flooded vegetation mapping is critical for disaster response, ecological monitoring, wetland mapping and effective water resources management, yet it remains a significant challenge due to the limitations of optical remote sensing in detecting inundation beneath dense canopies and cloud cover. Monitoring of the dynamics of wetlands and flooded areas can help improve hydrological modeling and forecasting by providing accurate and timely information on water storage within a watershed. This study presents a methodology for the automated segmentation and classification of flooded vegetation by combining Sentinel-1 Synthetic Aperture Radar (SAR) data with Surface Water and Ocean Topography (SWOT) mission observations. Previous research has demonstrated the potential of Sentinel-1 SAR for mapping wetlands and delineating flood extents. The proposed method leverages the complementarity between high-resolution spatial information from Sentinel-1 and hydrodynamic information provided by SWOT to map flooded vegetation with an object-based image analysis (OBIA) approach.

The method is tested on two study areas, one in the Oromocto River basin in New Brunswick, Canada (45.78 N, 66.55 W) and the other is located around the Mamawi Lake in northern Alberta, Canada (58.66 N, 111.50 W). The first area focuses on wetlands along the Oromocto River which are prone to flooding during the spring freshet and heavy rainfall events. The second area is located within the Peace-Athabasca Delta, which is a complex system of interconnected lakes and wetlands and one of the current test sites for the SWOT and NORthern laKeS (SNORKS) project. Sentinel-1 Interferometric Wide images are selected in alignment with SWOT overpass dates within a 48-hour interval. Observations of high-water levels (including a major flood event for Oromocto) and low-water levels are used to test the algorithm. Preprocessing is applied to Sentinel-1 Ground Range Detected images comprised of radiometric calibration, terrain correction and speckle filtering on both VV and VH polarisations. An image segmentation based on the Mean Shift algorithm is then performed on the dual band images (VV and VH) using the Orfeo Toolbox to create polygons with uniform backscattering behaviour. The SWOT Raster products are then sampled within the segmented polygons to extract statistics of Water Surface Elevation (WSE) and Water Fraction (WF). All polygons with WF greater than 70% and WSE quality rating of 0 or 1 are considered flooded or open water. The segmentation outputs will be validated against flood extent maps provided by Natural Resources Canada where available, as well as maps produced by visual interpretation. Performance is benchmarked using standard metrics such as overall accuracy, class-specific IoU, precision, and recall. Maps produced by visual interpretation are also validated with in situ water gauges to validate water levels measured at the time the images were taken, along with high-resolution Digital Terrain Models (LiDAR), which are used to estimate water extents.

The proposed method provides:
• High-resolution, temporally consistent maps of flooded vegetation, supporting hydrological and hydraulic modelling and long-term environmental monitoring.
• Enhanced understanding of flood propagation dynamics in vegetated landscapes and wetlands to help improve hydrological assessments.
• A transferable methodological framework that leverages the complementary strengths of Sentinel-1 SAR and SWOT data, facilitating scalable flood mapping in diverse geographic and climatic contexts.

By proposing a simple, automated, and robust method for the detection and classification of inundated vegetation, this project advances the state of flood mapping science and provides critical information for applications in hydrology, hydrodynamics and environmental monitoring, especially in remote areas.
Corresponding author:
Yannick Duguay (**Centre de géomatique du Québec**, **Canada**), yannick.duguay@cgq.qc.ca

Global seasonal lake dynamics and phenology revealed by SWOT observations

Jida Wang (University of Illinois Urbana-Champaign, United States); Md Safat Sikder (University of Illinois Urbana-Champaign, United States); George Allen (Virginia Tech, United States); Sylvain Biancamaria (Université de Toulouse, Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS) (CNES/CNRS/IRD/UT3), Toulouse, France, France); Casey Brown (University of Massachusetts Amherst, United States); Jean-François Crétaux (Université de Toulouse, Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS) (CNES/CNRS/IRD/UT3), Toulouse, France, France); Huilin Gao (Texas A&M University, United States); Colin Gleason (University of Massachusetts Amherst, United States); Tamlin Pavelsky (University of North Carolina at Chapel Hill, United States); Laurence Smith (Brown University, United States); Chunqiao Song (Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing, China, China); Mélanie Trudel (University of Sherbrooke, Canada)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Oral

Abstract:

Lakes and reservoirs are among the most widespread inland water repositories. A conservative estimate from the SWOT Prior Lake Database (PLD) identifies nearly 6 million permanent and intermittent lakes larger than 1 ha worldwide, of which at least 8-9% are artificial reservoirs. These water bodies span diverse landscapes and climate zones, with their storage dynamics reflecting a complex interplay of hydrological processes and human interventions. However, the sheer number of lakes presents a significant observational challenge for geodetic satellites. Consequently, most global studies on lake storage dynamics have focused either on interannual trends in a limited number of large lakes (typically a few thousand) or on intra-annual variability across a broader set of lakes but with sparse temporal resolution (often averaging few than five observations per lake per year). While tracking interannual trends remains essential, improving intra-annual observations is critical for capturing the role of lakes in regulating seasonal flow regimes, buffering terrestrial water storage, and mediating carbon and energy fluxes. For reservoirs, tracking intra-annual variability is especially important for inferring operational practices and mitigating seasonal water disparities.

Here, we leverage the first two years of SWOT science data to advance the understanding of Earth's transient seasonal water storage in millions of lakes and reservoirs, through two complementary typological frameworks: origin-based and behavior-based. First, we adopt a conventional, origin-based typology, which differentiates among reservoirs, glacial lakes, and other natural lakes, to assess intra-annual storage dynamics across these predefined lake classes. This approach helps reveal spatial patterns and aids interpretation of their underlying mechanisms. However, we argue that origin-based typology alone is insufficient to capture the intertwined complexity of global lake behaviors. To address this limitation, we introduce the first global lake typology based on observed water level phenology. This behavior-based typology provides a novel lens for understanding the diverse ways in which lakes respond to, and modulate, regional hydroclimatic variability and anthropogenic influences. Together, these two perspectives demonstrate SWOT's unprecedented capability to illuminate nuanced dimensions of seasonal lake dynamics, offering an essential step forward for limnological science and the monitoring of lacustrine environments at the global scale.

Corresponding author:
Jida Wang (**University of Illinois Urbana-Champaign**, **United States**), jidaw@illinois.edu

Global Daily Reservoir Evaporation Modeling Augmented by SWOT PIXC Data

Anshul Yadav (Texas A&M University, United States); Huilin Gao (Texas A&M University, United States); Yinuo Zhu (Texas A&M University, United States); George Allen (Virginia Polytechnic Institute and State University, United States); Jida Wang (University of Illinois at Urbana-Champaign, United States)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Oral

Abstract:
Open-water evaporation can exceed 10% of annual reservoir storage, imposing significant constraints on water-supply reliability and hydropower generation, especially in arid and semi-arid regions. Robust and effective reservoir management practices require evaporation estimates at daily resolution; however, conventional approaches still rely predominantly on monthly Class A pan measurements, which do not account for critical factors like heat storage and wind-fetch effects.

To address this gap, we integrate the physically based Daily Lake Evaporation Model (DLEM)—an advanced Penman energy-balance formulation explicitly accounting for heat storage and wind fetch—with dynamic reservoir geometry derived from the Surface Water and Ocean Topography (SWOT) mission's KaRIn pixel-cloud (PIXC) product. This integrated approach will potentially allow us to produce daily evaporation estimates for more than 21,000 reservoirs globally, as cataloged in the GeoDAR v1.1 dataset, for the period 2020–2024.

For every SWOT overpass, reservoir surface area and elevation are retrieved from PIXC observations and subsequently used to estimate mean reservoir depth. These morphological parameters are interpolated to a daily resolution and, along with meteorological forcing from ERA5-Land reanalysis data, drive DLEM simulations. Validation of the DLEM outputs against eddy-covariance station measurements demonstrates good model accuracy, with coefficient of determination (R^2) values ranging from 0.56 to 0.79 and root mean square errors (RMSE) between 1.27- and 2.52-mm day^{-1}.

To evaluate the role of SWOT data in enhancing the reservoir evaporation modeling, this dataset is also compared with another version which is not augmented by SWOT observations.
This comprehensive evaporation dataset holds promise for refining operational water management strategies and informing adaptive policies in response to evolving hydro-climatic conditions. It can also benefit other SWOT projects related to reservoirs and flow regulations.

Corresponding author:
Anshul Yadav (**Texas A&M University**, **United States**), anshulya@tamu.edu

Reconstruction of Southern Ocean vertical velocities from SWOT and a km-scale regional simulation using 3 independent methods

Elisa Carli (European Aerospace Agency (ESA), Italy); Yann-Treden Tranchant (Australian Antarctic Program Partnership, University of Tasmania, Australia); James Wyatt (University of Tasmania, Australia); Lia Siegelman (Scripps Institution of Oceanography (SIO), United States); Andrew Thompson (California Institute of Technology , United States); Benoit Legresy (Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia); Marie-Helene Rio (European Aerospace Agency (ESA), Italy)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
The Southern Ocean plays an outsized role in the air-sea exchange of heat, carbon, nutrients and other tracers. These quantities are transported between the ocean surface and interior via currents spanning a broad range of spatial scales. Vertical velocities (O(1-10) km) are key to this transport but are notoriously hard to measure directly in the ocean.

In this study, we take advantage of the Surface Water and Ocean Topography (SWOT) satellite to reconstruct these vertical velocities. This study builds upon our previous work (Carli et al., 2024; Carli et al., 2025), in which we demonstrated that vertical velocities derived from SWOT using the effective Surface Quasi Geostrophy (eSQG) framework have a magnitude twice as large as those estimated from conventional altimetry. We use the FOCUS high-resolution forced regional model developed as part of the SWOT validation effort in the Antarctic Circumpolar Current (ACC), with a nested approach from 2.5 km to 800 m resolution (see poster from Tranchant et al.). We compare the eSQG with two other methods: the quasi-geostrophic omega equation, and the density conservation. We assess their applicability to SWOT-like observations during the 1-day repeat phase in an energetic region of the ACC south of Tasmania, exploring their potential and limitations across a range of spatial scales. While the eSQG tends to distribute vertical velocities across coherent mesoscale features, the omega-equation focuses them into narrow frontal regions.We then leverage two years of SWOT passes to provide first seasonal and spatial assessments of vertical transport in this region. This work lays a foundation for constraining tracer fluxes in the Southern Ocean, with downstream implications for closing heat and carbon budgets in this key climate region of the world's Oceans.

Corresponding author:
Elisa Carli (**European Aerospace Agency (ESA)**, **Italy**), elisa.carli@esa.int

Ocean Vertical Velocities from Remote Sensing

Eric Dasaro (University of Washington, United States); Ernesto Rodriguez (Jet Propulson Laboratory, United States)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
Simultaneous observations of ocean vertical velocity from two independent platforms—the NASA airborne DopplerScatt Ka-band pencil-beam Doppler scatterometer and an upward-looking Doppler sonar mounted on a neutrally buoyant float—demonstrate that surface horizontal velocity divergence fields can be used to estimate subsurface vertical velocities when appropriately averaged. These measurements were collected in a region of active mesoscale and submesoscale variability off the coast of California during the Sub-Mesoscale Ocean Dynamics Experiment (SMODE). The float data reveal that the largest vertical velocities are due to surface waves and to internal waves with buoyancy frequencies near the buoyancy period (5–20 minutes). Lower-frequency components become apparent only after multi-hour averaging. Vertical velocities estimated from DopplerScatt divergence fields multiplied by a suitable vertical scale, show significant correlation with float-derived velocities when averaged over several DopplerScatt passes. Typical time-averaged vertical velocities are on the order of 1 mm/s.

These results support theoretical expectations that vertical velocity fields are dominated by small spatial and temporal scales, making instantaneous measurements poor indicators of lower-frequency motions. Estimates of vertical velocity from SWOT data will therefore need to carefully define the spatial and temporal averaging scales assumed in the analysis. The magnitude of the computed velocity is likely to strongly depend on these scales.

Corresponding author:
Eric Dasaro (**University of Washington**, **United States**), dasaro@apl.washington.edu

High-Resolution Observations from the FaSt-SWOT Campaigns: Validation and Fine-Scale Signal Analysis

Laura Gomez-Navarro (IMEDEA (UIB-CSIC), Spain); Daniel R. Tarry (Applied Physics Laboratory, University of Washington, USA); Elisabet Verger-Miralles (IMEDEA (UIB-CSIC), Spain); Diego Cortes-Morales (IMEDEA (UIB-CSIC), Spain); Barbara Barcelo-Llull (IMEDEA (UIB-CSIC), Spain); Diego Vega-Gimenez (IMEDEA (UIB-CSIC), Spain); Nikolaos D. Zarokanellos (SOCIB, Spain); Lara Diaz-Barroso (SOCIB, Spain); Emma Reyes (SOCIB, Spain); Irene Lizaran (SOCIB, Spain); Baptiste Mourre (IMEDEA (UIB-CSIC), Spain); Ananda Pascual (IMEDEA (UIB-CSIC), Spain)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
During the SWOT fast-sampling phase, two field campaigns were conducted (April-May 2023) to perform a multi-platform in situ experiment in the western Mediterranean Sea in the frame of the FaSt-SWOT project. In situ observations combining ship-based instruments and autonomous platforms (surface drifters and gliders) together with complementary satellite data (SST, ocean colour, and conventional nadir altimetric products) provided a comprehensive view of the surface dynamics in our study area. These measurements allowed us to characterize a small-scale eddy observed by SWOT, and to trace its evolution.

In this study, we focus on two complementary components that provide continuous, high-resolution observations during and beyond the FaSt-SWOT campaigns:

(1) glider-based observations, which resolve the vertical and temporal evolution of a targeted eddy;

(2) surface drifter trajectories, which provide detailed insights into surface circulation, vorticity and the validity of the geostrophic assumption.

Two gliders were programmed to repeatedly perform back-and-forth sections over a 3-week period, with a 1-day delay between them. This strategy provided the opportunity to evaluate the temporal variability of ocean fields at a frequency comparable to SWOT's fast-sampling phase repeat cycle, offering valuable insights into the evolution of fine-scale structures. Quantification of temporal variability from both gliders shows a good agreement, laying the groundwork for further analyses of high-frequency signals present in both SWOT absolute dynamic topography and glider-derived dynamic height.

Using surface currents from 40 surface (~1 m depth) and 6 subsurface (~15 m depth) drifters, we infer Differential Kinematic Properties (DKP) like vorticity, to compare them with the SWOT-derived counterparts. These results allow us to confirm the validity of the geostrophic assumption in our study region, with Rossby numbers < 1. The extended continuity of the drifter dataset beyond the campaign period enables further evaluation of the SWOT-derived velocity fields and the surface dynamics these represent. Compared to nadir altimetric products (e.g. the DUACS-OI dataset), SWOT velocities show significant improvements.

The in situ observations confirm SWOT's significantly improved capability in detecting sea level signature of small-scale eddies and their temporal variability. Beyond Cal/Val activities, this FaSt-SWOT dataset helps to better characterize and understand the fine-scale dynamics in this region, characterized by a small Rossby radius of deformation. We also highlight the implications of SWOT swath corrections on characterizing small mesoscale structures, and underscore how wide-swath altimetry introduces both new challenges and transformative opportunities for understanding previously unresolved dynamics.
Corresponding author:
Laura Gomez-Navarro (**IMEDEA (UIB-CSIC)**, **Spain**), laura.gomez@uib.es

Signatures of fronts and waves in divergence-vorticity-strain joint probability-density functions created using surface velocities from a high-resolution ocean model

C Spencer Jones (Texas A&M University, United States); Thomas Nicolas (Earthmover.io, United States); Dhruv Balwada (Lamont Doherty Earth Observatory, United States); Shafer Smith (New York University, United States); Julius Busecke (Columbia University, United States); Ryan Abernathey (Earthmover.io, United States)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
Several groups are attempting to use machine learning to infer ocean surface velocities from SWOT sea surface height measurements. Divergence-vorticity-strain joint probability-density functions are a useful tool for assessing which small-scale features are captured in these machine learning predictions, but until now, no-one has explored the range of ocean surface features that create identifiable patterns in divergence-vorticity-strain space. In this work, we divided the surface velocity field of a high-resolution ocean model (the LLC4320 setup of the MITgcm) into 5 degree by 5 degree regions and calculated the vorticity-strain joint probability density function in each region. We find that, as expected, we see signatures of waves, which tend to have high strain but low vorticity, in the summer hemisphere, and signatures of fronts, which have high strain and high vorticity, in the winter hemisphere. We also plot the divergence conditioned on vorticity and strain and see some surprising results, including a strong convergence at high strain that is associated with nonlinear waves.

Corresponding author:
C Spencer Jones (**Texas A&M University**, **United States**), spencerjones@tamu.edu

Between the clouds: An unprecedented view of ocean surface currents

Luc Lenain (Scripps Institution of Oceanography - UCSD, United States); Nick Pizzo (URI, United States); Roy Barkan (TAU/UCLA, United States); Kaushik Srinivasan (UCLA, United States)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
A major outstanding problem in physical oceanography is resolving high resolution spatio-temporal information of the ocean currents and scalars like temperature. Currents facilitate the flux of mass, momentum and energy, strongly modulating Earth's weather and climate and the transport of marine debris. Traditional approaches are limited by point measurements (e.g. a ship) or snapshots in time (e.g. traditional satellites). Geostationary satellites offer high resolution broadband spatial measurements of the thermal structure of the surface of the ocean, though obscured by clouds. Until now, these satellites have not been used to derive information about surface currents. Here, we present a novel approach leveraging state of the art and novel machine learning techniques to derive the surface velocity field from ocean basin scales to the submesoscale with sub-hour temporal resolution. These results substantially improve the predictability and understanding of global ocean surface currents. By combining these products with collocated and coincident SWOT observations collected during the post-launch CalVal, we show that we can begin to unravel the transition from balanced to unbalanced motion.
Corresponding author:
Luc Lenain (**Scripps Institution of Oceanography - UCSD**, **United States**), llenain@ucsd.edu

A Practical Separation of Oceanic Vortical and Wavy Motions Entangled in the SWOT Measurements

Zhiyu Liu (Xiamen University, China); Chuanyin Wang (Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), China)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
The recently launched Surface Water and Ocean Topography (SWOT) satellite provides an unprecedented two-dimensional measurement of the sea surface height down to the oceanic submesoscale of 1–10 km. Using this measurement to make substantial progress requires the separation of vortical and wavy motions owing to their contrasting ramifications for the energy transfer; however, the separation is extremely challenging due to the long-repeat period of the SWOT satellite. Here we propose a dynamics-based separation inspired by the initialization technique in numerical weather prediction. This separation utilizes the fundamental property that wavy motions induce no potential vorticity anomaly, and requires velocity data in addition to sea surface height. With concurrent measurements of sea surface height and velocity respectively from SWOT and the offshore high-frequency radar system, the proposed separation proves valid and useful. This study is expected to stimulate new discoveries associated with oceanic multiscale interactions and energy transfers.

Corresponding author:
Zhiyu Liu (**Xiamen University**, **China**), zyliu@xmu.edu.cn

Deciphering Ocean Surface Dynamics with SWOT and drifters

Margot Demol (Ifremer, France); Aurelien Ponte (Ifremer, France); Pierre Garreau (Ifremer, France); Jean-François Piolle (Ifremer, France); Gwenael Caer (Ifremer, France); Cyril Germineaud (CNES, France)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
If SWOT provides for the first time sea level observations at scales below 100km, several outstanding questions remain: what is the dynamics of oceanic surface motions at the newly resolved scales, in particular how well does geostrophy hold ? What is the content of dynamical signals (e.g. related to the ocean circulation) versus non-dynamical signals (e.g. instrumental noise, geophysical noise, …) in the various products proposed (e.g. calibrated/filtered, unsmoothed, 2km)? What is the added value of SWOT compared to mainstream altimetric products (e.g. L4 AVISO)?

We provide partial answers to these questions by collocating SWOT observations with surface drifter trajectories and wind reanalysis. This enables the reconstruction of instantaneous surface momentum balances. A novel methodology opens the door for the estimation of balanced vs unbalanced/noise contributions to the momentum closure for each dynamical term (e.g. inertial and Coriolis accelerations, pressure gradient, turbulent stress divergence). We conduct targeted statistical conditioning, sensitivities to filtering (temporal/spatial) and data products in order to partially answer the questions listed above. The core of the analysis is focused on the Western Mediterranean sea and the fast sampling phase when four different in-situ campaigns of the SWOT-Adac Consortium (C-SWOT-2023, WEMSWOT, FaSt-SWOT and BIOSWOT-Med) led to the deployment of numerous in situ instruments, including drifters, in order to sample the upper ocean underneath SWOT tracks. We also provide preliminary results for analysis at the global scale which broadens the range of dynamical regimes and instrumental conditions considered.

Corresponding author:
Margot Demol (**Ifremer**, **France**), margot.demol@ifremer.fr

Diagnosing the Dynamic Balance of the Surface Ocean Using In-Situ Drifter Observations and SWOT

Andrey Shcherbina (Applied Physics Laboratory, University of Washington, United States)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
The SWOT mission enables unprecedented observations of sea surface height (SSH) at smaller scales, where the ocean's dynamic balance becomes more nuanced and ageostrophic effects become increasingly important. However, our understanding of the interplay among submesoscale processes and their expression in SSH remains limited, largely due to the challenges of resolving the full submesoscale momentum budget using traditional in-situ analyses.
To address this challenge, we assess the dynamic balance in the ocean surface layer by evaluating the terms in the Lagrangian momentum equation using satellite-tracked surface drifter trajectories. This approach enables a direct, scale-free diagnosis of the forces acting on near-surface parcels, including the pressure gradient force, wind stress, Coriolis acceleration, and friction. The resulting estimates of pressure gradients and their variability can be directly compared with concurrent SWOT observations.
We apply this analysis to data from the 2023 NASA S-MODE field campaign, which deployed over 100 drifters near a SWOT Cal/Val crossover site off the coast of California. Preliminary results highlight the spatial and temporal variability of unbalanced dynamics associated with submesoscale frontal activity and wind forcing. These findings offer new insight into the interpretation of SWOT Level 2 SSH products in dynamically active regions. Ongoing work focuses on refining these diagnostics and developing tools for the operational integration of Lagrangian and SSH observations to improve our understanding of surface current dynamics.

Corresponding author:
Andrey Shcherbina (**Applied Physics Laboratory, University of Washington**, **United States**), shcher@uw.edu

Assessing submesoscale sea surface height signals from the SWOT mission

Xihan Zhang (California Institute of Technology, United States); Jörn Callies (California Institute of Technology , United States)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
The sea surface height (SSH) field measured by Surface Water and Ocean Topography (SWOT) mission's wide-swath altimeter is analyzed with a focus on submesoscale features. Along-track wavenumber spectra of SSH variance are estimated for the global ocean using the 1-day repeat period from March 26 to July 10, 2023. In regions with an energetic mesoscale eddy field, the spectra have a mesoscale plateau, a steep drop-off due to balanced submesoscale turbulence, and a much flatter power-law tail at small scales. These spectra are characterized by fitting a spectral model. For the balanced signal, this fit yields a spectral slope between -4 and -6 for most regions, consistent with expectations and previous observations. The amplitude of the distinct small-scale signal, which typically dominates at wavelengths less than 30 to 50 km, is strongly correlated in time and space with the height of surface gravity waves, suggesting aliased wave signals as the most likely source. A simple method is proposed to isolate the balanced signal in regions with negligible internal tides. Maps of the balanced signal in the Antarctic Circumpolar Current show compact cyclones with geostrophic relative vorticities frequently in excess of the local planetary vorticity, challenging the quasi-geostrophic framework commonly used to interpret altimetric data.

Corresponding author:
Xihan Zhang (**California Institute of Technology**, **United States**), xihanz@caltech.edu

Ocean cyclones from space

Hector Torres (Jet Propulsion Laboratory, United States); Matthew Archer (Jet Propulsion Laboratory, California Institute of Technology, USA); Patrice Klein (Jet Propulsion Laboratory, California Institute of Technology, USA); Lia Siegelman (Scripps Institution of Oceanography, UCSD, USA); Andrew Thompson (Caltech, USA); Dimitris Menemenlis (San Jose State University, USA); Lee-Lueng Fu (Jet Propulsion Laboratory, California Institute of Technology, USA); Jinbo Wang (Texas A&M University, USA)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
Satellite observations using advanced wide-swath altimetry reveal, for the first time, that mid-latitude oceans are densely populated with cyclones spanning 5–10 km in size. These features, called submesoscale cyclones, are significantly smaller than the well-known mesoscale eddies (50–-200 km) and are associated with intense surface geostrophic currents reaching up to 1 m/s. They exhibit spin rates on the order of a few hours, much shorter than the multi-day timescales typical of mesoscale eddies. Despite arising from distinct physical mechanisms, these compact cyclones display remarkable structural and dynamical similarities to atmospheric hurricanes.
Leveraging a numerical model with unprecedented spatial resolution over a large domain in the Western Pacific, we show that these numerous submesoscale cyclones emerge from instabilities within strongly sheared mesoscale currents. They are associated with vertical velocities exceeding 500 m/day at a depth of 40 m, driving upward heat fluxes surpassing 800 W/m^2 in the upper 200 m of the ocean. Through their vigorous vertical motions, this widespread population of submesoscale cyclones is expected to play a crucial role not only in upper-ocean dynamics and air–sea exchanges, but also in carbon sequestration and nutrient redistribution, thereby shaping marine ecosystems and potentially influencing the climate system

Corresponding author:
Hector Torres (**Jet Propulsion Laboratory**, **United States**), Hector.Torres.Gutierrez@jpl.nasa.gov

Vertical velocities and deep subduction events from coincident SWOT and glider observations in the Southern Ocean

Andrew Thompson (California Institute of Technology, United States); Lilian Dove (Brown University, United States); Yann-Treden Tranchant (University of Tasmania, Australia); Patrice Klein (California Institute of Technology, United States); Beatriz Peña Molino (CSIRO, Australia); Laura Herraiz Borreguero (CSIRO, Australia); Benoit Legresy (CSIRO, Australia); Elisa Carli (Laboratoire d'É́tudes en Geophysique et Oć eanographie Spatiale (LEGOS), France); Lia Siegelman (Scripps Institution of Oceanography, United States)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
The FOCUS (Fine-scale Observations of the Antarctic Circumpolar Current Under SWOT) project is a regional validation study conducted in support of the SWOT mission. FOCUS targeted an energetic region of the Antarctic Circumpolar Current thought to contribute disproportionately to meridional heat transport and ocean ventilation. A five-week cruise on the R/V Investigator collected data with a towed profiler and deployed multiple ocean gliders, floats, and drifters.

Through a combination of high-resolution in situ observations from the FOCUS campaign and observations collected from SWOT, we describe an approach to estimate vertical velocities, and potentially vertical tracer transport, using the quasi-geostrophic (QG) omega equation. First, we show that there is a tight relationship between local sea surface height (SSH) and vertical density profiles as collected from a pair of ocean gliders. This relationship holds at O(10-km) scales, and allows for the inference of a three-dimensional interior density field (to a depth of 1000 m) from two-dimensional SSH fields from SWOT. The reconstructed density field is combined with surface velocity estimates and the thermal wind relationship to produce fields of buoyancy and velocity gradients, which then enable an estimate of ocean vertical velocities using the QG omega equation.

A strong cyclonic eddy, sampled by the FOCUS gliders, has horizontal upper ocean velocities that exceed 1 m/s and a Rossby number > 1. The QG omega equation predicts vertical velocities associated with this cyclone that exceed many hundreds of meters per day and extend to depths of 800 m. These elevated velocities are confined to sharp density gradients around the periphery of the eddy. The magnitude of the vertical velocity is larger and the spatial distribution is more compact as compared to vertical velocities inferred from altimetry using surface QG (SQG) approaches in previous studies. Enhanced vertical velocities coincide with glider-observed deep tracer anomalies, such as optical backscatter, consistent with rapid subduction events. The QG omega approach is also tested using numerical model output, sampled similarly to the glider and SWOT observations, which confirms that these estimates capture a large fraction of the total vertical velocity. Finally, we explore the ability to extend the QG omega approach to other regions of the Southern Ocean using Argo float and other hydrographic data.

Corresponding author:
Andrew Thompson (**California Institute of Technology**, **United States**), andrewt@caltech.edu

The Horizontal and Vertical structures of sub-10 km Submesoscale Cyclones

Jinbo Wang (Texas A & M University, United States); Hector Torres (Jet Propulsion Laboratory , USA); Patrice Klein (Caltech, USA); Matthew Archer (Jet Propulsion Laboratory , USA); Eugenio Cutolo (IMT Atlantique, France); J. Thomas Farrar (Woods Hole Oceanographic Institute, USA); Bo Qiu (University of Hawaii , USA); Lee-Lueng Fu (Jet Propulsion Laboratory , USA)

Session: Oceanography: Velocities
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission's Ka-Band Radar Interferometer (KaRIn) has surpassed prelaunch expectations by 2–4 times, delivering sea surface height (SSH) observations that resolve small-scale oceanic structures down to spatial scales below 10 km. Among these are submesoscale cyclones, with diameters as small as 5 km. This presentation begins with a case study of submesoscale cyclones in the California Current System, analyzing their horizontal and vertical structures using SWOT KaRIn SSH, high-resolution sea surface temperature (SST) from the VIIRS sensor, in-situ mooring data, and synthetic aperture radar (SAR) imagery. We then explore machine learning approaches for global detection and analysis of these submesoscale structures, leveraging SWOT's high-resolution 2D data. Finally, we discuss challenges and opportunities in using SWOT for studies of sub-10km processes.
Corresponding author:
Jinbo Wang (**Texas A & M University**, **United States**), jinbo.wang@tamu.edu

Wide-swath Satellite Altimetry Observes Water Storage Variability in the World's Rivers

Arnaud Cerbelaud (Jet Propulsion Laboratory, Caltech, United States); Jeffrey Wade (Jet Propulsion Laboratory, Caltech, United States); Cédric David (Jet Propulsion Laboratory, Caltech, United States); Michael Durand (School of Earth Sciences, and Byrd Polar and Climate Research Center, The Ohio State University, United States); Renato P. M. Frasson (Jet Propulsion Laboratory, Caltech, United States); Tamlin Pavelsky (Department of Earth, Marine and Environmental Sciences, University of North Carolina, United States); Hind Oubanas (INRAE, France)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
Despite only making up a fraction of total inland surface water storage, rivers are among Earth's most critical renewable and accessible freshwater resources. Yet, global estimates of river water storage magnitude and variability remain scarce and highly uncertain, largely due to limited understanding of surface water balance, unknown channel bathymetry, and sparse observations. Existing estimates rely on either uncertain hydrological routing models or spatially limited remote sensing observations. Here we present the first global observational dataset of reach-specific river volume variability derived from the first year (10-2023 to 09-2024) of the Surface Water and Ocean Topography (SWOT) mission's science orbit at 126,674 reaches worldwide. Clear seasonal patterns and hotspots of variability emerge in major basins such as the Amazon, Ob, Orinoco, Congo, and Ganges-Brahmaputra. The global river volume anomaly observed by SWOT is estimated at 321.6 km^3, approximately 30% lower than the lowest known modeled estimates for the same reaches. This discrepancy likely reflects both the Amazon's 2024 record drought and previous limitations in our understanding of the shape of river beds. Additionally, this underlines key opportunities for improving the fundamental representation of surface water dynamics in global models.

Note: These authors contributed equally: Wade Jeffrey, Cerbelaud Arnaud.

Corresponding author:
Arnaud Cerbelaud (**Jet Propulsion Laboratory, Caltech**, **United States**), arnaud.cerbelaud@jpl.nasa.gov

Assessing and Improving SWOT's Hydraulic Visibility on French narrow rivers (20-100 m): Precision Flow Lines and Slope variation in different flow condition

Thomas LEDAUPHIN (ICUBE-SERTIT, France); Pierre-André Garambois (INRAE, RECOVER, Aix-Marseille University, France); Kevin Larnier (Hydro Matters, France); Maxime Azzoni (ICUBE-SERTIT, France); Amanda Samine Montazem (INRAE, RECOVER, Aix-Marseille University, France); Sabrine Amzil (ICUBE-SERTIT, France); Nicolas Picot (CNES, France); Roger Fjortoft (CNES, France); Jérôme Maxant (ICUBE-SERTIT, France); Hervé Yésou (ICUBE-SERTIT, France)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
The high accuracy of SWOT in capturing river surface elevations, slopes, and hydraulic dynamics was evaluated using a comprehensive in situ dataset over the Franco-German Rhine, with elevation accuracy exceeding expectations (Ledauphin et al., 2025). The analysis of products from PIXC to reach-averaged scales demonstrates SWOT's effectiveness in depicting river surface topography and detecting fine spatial hydraulic signatures driven by longitudinal hydraulic controls including meter-scale sequences of riffles and pools, sandbanks, meanders, and man-made structures as well as dynamic phenomena such as flood wave propagation, intumescence, and a rare submersion wave slope.
This study focuses on evaluating SWOT's accuracy in capturing hydraulic signatures over narrower rivers (20–100 m wide), including the Meurthe (30-40m), Moselle (50-100m), Ill (20-30m), and Sarre (20-30m, major flood in May 2024) in France's Grand Est Region. By leveraging data from the nominal science orbit and applying advanced hydraulic-preserving filters to improve slope computation (Montazem et al., 2019), we assess SWOT's performance near the limits of its design specifications, with up to four revisits per 21-day cycle enabling the observation of key hydrological events such as floods.
Each river's morphology consists in a mix of natural and modified reaches, sampled at a different positions relative to the SWOT swath and in the overpass dates in the 21-days revisit cycle. This dataset enables evaluation of multi-path observations and the impact of cross-track distance on measurement quality.
These rivers benefit from dense in situ gauge networks with long historical records, complemented by field data (drone flights, bathymetric surveys), making them ideal for analysis the capacity of SWOT over narrow rivers. In the absence of full RiverSP coverage (except for parts of the Moselle), we focus on exploiting PIXC pixel cloud classes 3 and 4, corresponding to water-near-land and open water, respectively.
Preliminary results are promising. For example, the absolute water surface height differences between PIXC-derived and gauge data on the Moselle show a 1-sigma of 16 cm for the science phase to date. Continued comparison with high-resolution lidar topo-bathymetric DEMs are underway, aiming to quantify the imprint of riverbed topography on WSE which acts as a low-pass filter for bottom slope breaks (cf. Montazem et al., 2019).
After analyzing SWOT observations for several hydrological events of varying magnitudes, alongside data acquired during normal flow conditions, the initial results confirm that SWOT's precision is high, even on small rivers. A large number of events have already been observed, including variations in the water surface elevation related to flow changes, their connection with bathymetry, and fluctuations during exceptional flood events. Each time, we have attempted to validate these observations using available exogenous datasets for each site, such as gauge time series, high-resolution bathymetry and drone flights;
For these narrow rivers, the limits of SWOT's capability for direct use of raw data are approached, as measurement profiles can be noisy depending on acquisition conditions. To address this, a filtering approach for SWOT data that preserves hydrological characteristics has been developed and studied at fine scales to ensuring consistent and accurate computation of local water surface slopes (cf. Montazen et al., 2019). We also evaluate the impact of this filtering on water surface profiles by comparing the results with in situ measurements
The accuracy of SWOT measurements demonstrated in this study, along with the spatially distributed nature of WSE and slopes, highlight the potential of such data for depicting local hydraulic signatures and inform spatially distributed hydraulic models and regional hydrological models (e.g. Larnier et al. 2025). Such accurate data could also be of interest to support hydraulic structures operations and reinforce the inferrence of bathymetry with additional data.

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Corresponding author:
Thomas LEDAUPHIN (**ICUBE-SERTIT**, **France**), tledauphin@unistra.fr

SAMBA (SWOT for the AMazon BAsin)

Fabrice Papa (LEGOS/IRD, France); Daniel Moreira (SGB, Brazil); Ayan S. Fleischmann (Mamiraua Institute, Brazil); Frédéric Frappart (ISPA/INRAE, France); Alice Fassoni (University of Brasilia, Brazil); Jean-Francois Crétaux (LEGOS/CNES, France); Adrien Paris (Hydro Matters, France); Maurício Cezar Rebello Cordeiro (ANA, Brazil); Santiago Pena Luque (CNES, France); Fernando Jaramillo (Stockholm University, Sweden); Rodrigo Paiva (IPH-UFRGS, Brazil); George Allen (Virginia Tech, USA); Etienne Fluet-Chouinard (Pacific Northwest Nat. Lab., USA); Jefferson Santana Melo (SGB-Rio, Brazil); Michel Calzas (DT INSU/CNRS, France); Sly Wongchuig (CNES-LEGOS, France); Benjamin Kitambo, (Institute of Geodesy, University of Stuttgart, Germany); Marie-Paule Bonnet (ESPACEDEV/IRD, France); Rodrigo Abarca del Rio (University Conception, Chile); Charlotte Blondel (LEGOS/CNRS, France); Andre Martinelli (SGB, Brazil); Pierre-André Garambois (INRAE/RECOVER, France); Stéphane Calmant (LEGOS/IRD, France)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
The SAMBA (SWOT for the AMazon BAsin) project builds upon the precursor project “SWOT for SOUTH AMERICA”, which was part of the 2020-2023 SWOT Science Team, and covered several thematic areas dealing with the water cycle, hydrology and hydroclimatology of South America. These projects have the overall objectives of advancing water sciences in the context of SWOT and connecting the community working on “hydrology from space” across South America. SAMBA builds upon these past efforts (Fassoni et al., 2021, Cretaux et al., 2023) and achievements (Frappart et al., 2019; Fleischmann et al., 2022; 2023), now with SWOT observations, at the scale of the Amazon basin. Its scientific objectives are twofold: 1) make use of SWOT measurements to improve the benefits of SWOT products for hydrology; 2) work towards answering cutting edge research questions with SWOT observations.
As the largest watershed on Earth, the Amazon indeed plays a key role at a range of scales on the water, energy and carbon cycles, while also supporting an incredible biodiversity and many human communities across the basin. It contributes to about 20% of the total freshwater input from the continents to the global oceans annually. Now affected by multiple cumulative stressors, including changes in regional and global climate superimposed on human disturbances, observing and understanding the Amazon hydrology and its changes is of primary importance.
SAMBA explores SWOT measurements, along with a variety of other satellites, in situ and numerical modeling contributions to progress our understanding of the hydrology and water cycle of the region at different spatio-temporal scales, from basin to regional/local scales at several regions of interest (Mamiraua floodplains, Rio Negro, Curuai-Obidos-Tapajos) to address key scientific questions regarding river science, Amazon floodplains connectivity, hydrological processes during extreme events and the development of new tools such as the assimilations of SWOT data in hydrological models (Wongchuig et al., 2024).
Here, we present recent SAMBA advances and results, including the first characterisation of the widespread and exceptional reduction in river water levels across the Amazon Basin during the 2023 extreme drought revealed by satellite altimetry and SWOT (Moreira et al., 2025).
In late 2023, the Amazon River Basin indeed experienced one of its most severe drought and gauges that were still functioning recorded the lowest river water levels (RWL) ever. We use satellite observations, especially from nadir altimetry and SWOT to reveal the spread and timing of extremely low RWL across the entire river system. Nadir altimeter observations show that the 2023 minimum RWL in the Central Amazon were 3 m or more below their annual average, representing two to three times its mean variability. SWOT also clearly captures the basin-scale reduction in RWL with a spatial resolution of 200 m and how the riverdrought propagates with time. Large-scale evaluation with gauges suggests that SWOT outperforms classical altimetry in estimating RWL, despites differences that need further investigations. Our study shows that SWOT offers a new opportunity to understand hydroclimatic extremes and their broad impacts on the environment of the Amazon. It represents a first and important step to other planned activities in the SAMBA various WorkPackages.

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Corresponding author:

Fabrice Papa (**LEGOS/IRD**, **France**), fabrice.papa@ird.fr

Advancing SWOT and Fluvial Geomorphology: River Hydraulics and Sediment Transport

J. Toby Minear (University of Colorado, Boulder, United States); Joel Johnson (University of Colorado, Boulder, USA); Michael Lamb (California Institute of Techology, USA); Taylor Rowley (University of Massachusetts, Amherst, USA)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
Sediment transported by large rivers is a critical component of the global sediment cycle and is central to a broad range of fundamental processes of the Earth system, including sediment supply to the coast, coastal land loss, nutrient and adsorbed contaminant transport, river flooding and floodplain dynamics. Yet, monitoring of bed sediment and sediment transport in large rivers occurs only rarely, if ever. As such, for nearly all large rivers on earth we do not understand sediment dynamics or how they change with time nor are we able to quantify with certainty the effects of human alteration. This has important implications for the SWOT mission, particularly because sediment transport dynamics and river hydraulics are not independent -- they are a tightly coupled system. Bed forms and grains create hydraulic resistance that determines the river velocity and depth, which in turn determines the amount of sediment transport and the composition of the bed. Presently, SWOT discharge algorithms do not incorporate these interlinked effects.

For this work, we build on previous efforts by making use of field measurement data collected routinely by water agencies at in situ gaging stations, including bed sediment data. We use gaging station data where discharge is already known, combined with SWOT KaRIn data, to solve hydraulic resistance equations for the coefficient of friction. We also solve for the total depth to the bed and channel cross-sectional area. From these calculations, we can then derive an expression for hydraulic resistance, area and depth, directly from SWOT data. Similarly, the relationship of hydraulic resistance to grain size is a well-known problem that can be resolved with SWOT combined with in-situ data. These relationships are used to estimate bed shear stress, and bedload sediment transport, when combined with SWOT water surface elevations, extent and slope data. By deriving a model for both hydraulic resistance and sediment transport, formulated for and driven by SWOT data, we are attempting to both improve SWOT discharge products and estimate bed sediment transport in large rivers globally. Our hope is that this work will provide improvements to our understanding of the hydraulics and sediment transport in large rivers and seeks to fill important gaps in our understanding of SWOT discharge algorithms, as well as the global hydrology and sediment cycles.

Corresponding author:
J. Toby Minear (**University of Colorado, Boulder**, **United States**), tminear@colorado.edu

SWOT River Bathymetry Product

Hind Oubanas (INRAE, France); Pierre-Olivier Malaterre (INRAE, France); Michael Durand (Ohio State University, USA); Igor Gejadze (INRAE, France); Isadora Rezende (INRAE, France); Tamlin Pavelsky (University of North Carolina, USA); Daniel Jose (University of North Carolina, USA); Paul Bates (Bristol University, United Kingdom); Jeffrey Neal (Bristol University, United Kingdom); Stephen Chuter (Bristol University, United Kingdom); Colin Gleason (University of Massachusetts Amherst, USA)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
The accuracy of satellite-based hydrodynamic models, and their simulations of water flow through river networks, as well as the resulting hazard assessments, strongly depends on the quality of the local river floodplain topography that defines the water pathways. Recent advancements in open-access spaceborne digital surface models, such as the Copernicus DEM, have significantly improved the underlying elevation data available for representing river networks and mapping flood hazards. A major breakthrough in floodplain observation and bathymetry estimation has been the Surface Water and Ocean Topography mission, which uniquely enables simultaneous observations of water surface elevation and extent at high spatial resolution. This represents a critical step forward in the global monitoring of inland water bodies.
Several methodologies originally developed for river discharge estimation have integrated bathymetry estimation as a foundational step. This includes approaches using SWOT and or other remote sensing observations such as DEMs. To construct the bathymetry for a given river, most algorithms follow a two-step process: 1- Estimation of the 'dry bathymetry' : the topography visible to satellites under non-flooded conditions. 2- Estimation of the 'wet bathymetry': the submerged topography, not observed through remote sensing techniques. These steps rely on distinct methodologies that continue to evolve as more data sources become available, with a strong emphasis on algorithmic robustness and adaptability.
In this context, our goal is to formalize a Level-4 SWOT bathymetry product designed for a broad range of hydrological applications. This product will provide a standardized, high-quality representation of river bathymetry, enabling improved hydrodynamic modeling, flood risk assessment, and water resource management at both regional and global scales.
Corresponding author:
Hind Oubanas (**INRAE**, **France**), hind.oubanas@inrae.fr

Detecting river flow waves at large scales with the SWOT satellite

Hana R. Thurman (Department of Geosciences, Virginia Tech, United States); Arnaud Cerbelaud (Jet Propulsion Laboratory, California Institute of Technology, United States); Cedric H. David (Jet Propulsion Laboratory, California Institute of Technology, United States); George H. Allen (Department of Geosciences, Virginia Tech, United States)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
Flow waves are long river waves driven by rising discharge from rainfall, snowmelt, or reservoir operations. With its dense spatial sampling of global river water surface elevations, the Surface Water and Ocean Topography (SWOT) satellite is uniquely positioned to capture flow waves as they propagate downstream. Complementing the hydrologic time series collected by gauges, SWOT records “space series" that can show detailed variations in river heights over downstream distance during a flow wave. Through previous research, we identified several examples of flow waves recorded by both SWOT and gauges and showed how SWOT observations could be used to estimate flow wave properties. Here, we build upon this effort to record and analyze flow waves at a larger scale. We develop a tool to automate and expand the flow wave detection process, gathering a dataset of the peak flow events SWOT has observed within the Mississippi River basin during its lifetime. We also estimate multiple properties of these flow wave events, such as their spatial extents, amplitudes, and celerities. In the future, our tool could be applied beyond the Mississippi basin to detect flow waves anywhere on Earth, supporting global-scale studies. Collectively, results from this work can inform assessments of river water storages and flows, improve river routing model parameter estimates, support flood control and reservoir operations, and help refine sampling requirements for future satellite missions.

Corresponding author:
Hana R. Thurman (**Department of Geosciences, Virginia Tech**, **United States**), hanathurman@vt.edu

Detecting narrow rivers with SWOT: what does detected mean?

Fiona B. Bennitt (University of Massachusetts Amherst, United States); Colin J. Gleason (University of Massachusetts Amherst, United States); Brent A. Williams (Jet Propulsion Laboratory, California Institute of Technology, United States); Craig B. Brinkerhoff (Yale University, United States); Tamlin M. Pavelsky (University of North Carolina, United States); Cassie Stuurman (Jet Propulsion Laboratory, California Institute of Technology, United States); Jonathan A. Flores (University of Massachusetts Amherst, United States); Elisa Friedmann (University of Massachusetts Amherst, United States); Travis T. Simmons (University of Massachusetts Amherst, United States)

Session: Hydrology: River Science Working Group
Presentation type: Oral

Abstract:
The SWOT mission is required to measure rivers > 50 m wide—however, much narrower rivers are visible in Level 1 SWOT Single-Look Complex (SLC) imagery. These narrow rivers comprise almost 90% of global river length, and having SWOT RiverSP products for these would be a boon for greenhouse gas exchange and discharge studies. While detection of narrow rivers in the SLC remains a viable path, we seek to first characterize the performance of higher-level SWOT products. We present here an evaluation of the Level 2 SWOT Pixel Cloud (PIXC) product over the four distinct regions of CONUS: specifically, the 2-digit hydrologic units (HUC2) 01, 08, 15, and 17. We use the National Hydrography Database Plus High Resolution river database to mask filtered PIXC data from July 2023 to May 2025 and generate coverage statistics and estimate water surface elevation for more than 4.2 million reaches. To understand what the narrowest river SWOT can detect is, we ask: what does detected mean? Preliminary results suggest that rivers down to 30 m are detected as reliably as rivers 50 m wide, but a smaller number of these narrow reaches yield quality heights. This conclusion is highly sensitive to the definition of 'detection,' and we will explore these sensitivities in this presentation.

Corresponding author:
Fiona B. Bennitt (**University of Massachusetts Amherst**, **United States**), fbennitt@umass.edu

Towards Improved Mapping of Sea Ice Concentration and Sea Ice Thickness with SWOT

Sammy Metref (Datlas, France); Sara Fleury (LEGOS, Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France); Pierre Rampal (Université Grenoble Alpes, CNRS, IRD, IGE, Grenoble, France); Gwenaël Jestin (LEGOS, France); Florian Le Guillou (Datlas, France); Clément Ubelmann (Datlas, France)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Oral

Abstract:
Observing sea ice concentration (SIC) and thickness (SIT) remains a key challenge for climate monitoring and modeling. Satellite altimetry provides measurements of ice and sea level anomaly from which can be estimated SIC, sea ice freeboard, and ultimately SIT. An accurate and well-resolved gridded estimation of these quantities would significantly improve our ability to quantify sea ice volume and its variability, support short- to medium-term forecasting of sea ice conditions and, more generally, improve our understanding of sea ice dynamics. But, as it is often the case, the mapping process is hampered by the sparsity of valid observations. Traditional methods based on monthly gridding or averaging introduce biases in dynamical regions and fail to capture sharp SIT gradients, especially near the ice edge or in ridged ice areas.
In this study, we develop a novel reconstruction approach: VarDyn, based on a spatio-temporal basis decomposition, inspired by recent advances in sea surface height mapping. The method expresses SIC or SIT as a linear combination of basis functions defined over multiple spatial and temporal scales. Several families of basis (e.g., Gaussian, Haar, wavelets) and combinations thereof are tested. A variational framework is then used to constrain the SIC/SIT reconstruction to best fit available SWOT observations, while promoting physically plausible structures. Preliminary results in a synthetic experiment setting over the PanArctic region demonstrate improved representation of both large-scale SIT gradients and localized features such as ridges. Against model truth, VarDyn performs well compared to standard averaging approaches in terms of RMS error and outperforms them in terms of spatial and temporal spectral scores.
In addition, we present the first daily gridded SIC maps using the VarDyn framework and derived from the SWOT lead/floe Level 3 classification. The use of SWOT's high-resolution observations enables the detection of leads and floes with unprecedented detail. The resulting gridded reconstruction hence captures fine-scale structures of the sea ice cover and provides temporally consistent information at high resolution.
A promising avenue for future development is the integration of sea ice drift as a dynamical constraint within the VarDyn variational formulation. Incorporating this constraint would enhance the temporal coherence of the gridded reconstructions. Overall, this work opens new perspectives for generating SWOT-based high-resolution SIC and SIT Level 4 products.
Corresponding author:
Sammy Metref (**Datlas**, **France**), sammy.metref@datlas.fr

Sea ice classification, concentration and topography using SWOT

Gwenael Jestin (LEGOS / CNRS, France); Sara Fleury (LEGOS / CNRS, France); Fanny Piras (CLS, France); Marta Alves (CLS, France); Sammy Metref (DATLAS, France); Inès Benabdillah (CNES, France); Matthias Raynal (CNES, France); Nicolas Picot (CNES, France); Gérald Dibarboure (CNES, France)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Oral

Abstract:
Sea ice plays a major role in climate, these changes are of great concern to scientists, who are seeking to forecast its behavior and understand their causes and effects. The most common techniques employed to monitor sea ice rely on 2D space imagery in a wide range of frequencies and techniques (optical, thermal, radiometric, SAR imagery). However, we now know that the evolution of sea ice over the course of days or seasons is governed more by its thickness than by its extent. Thickness is therefore an essential parameter to determine the condition of the ice and its ability to withstand particular climatic events (wind, heat waves) or oceanic events (waves, swells, upwelling of warm waters, etc.). Thickness also provides access to volume and mass variations, quantifying freshwater inflows and the effects of stratification on ocean circulation.
The main technique for measuring sea ice thickness is based on nadir altimeters. The result is a series of point measurements of the sea ice taken vertically along the satellite track. This loose sampling between tracks means that we have to wait for about a month of data to provide a sufficiently dense spatial representation to be exploitable. Relative to the current sparse observations, SWOT's scan width (120km) offers enormous potential to analyze sea ice conditions and dynamics on much shorter time scales and with much higher coverage and density.
This mission, whose primary objective is continental hydrology, was given little consideration by the sea ice scientific community, as we felt that the viewing angle (+- 2.7°) would not allow us to obtain feedback on water surfaces in highly specular sea ice fractures. Without this water reference, ice freeboard and thickness cannot be measured. But initial tests carried out by CNES on atypical surfaces, including sea ice, have revealed quality measurements not only on ice, but also in leads, albeit less systematically on these watery.

We have developed a technique that distinguishes between ice floes and open water in cracks in the ice (the leads) and in polynyas. This classification is now available in the CNES L3 250m v2 product distributed by AVISO. This makes it possible to measure the SLA in sea ice leads in continuity with the open ocean, as well as measuring the freeboard of the ice and, ultimately, its thickness. We propose to present the classification method developed, the first sea ice concentration maps derived from this classification, and the sea ice freeboards in both hemispheres. These results will be compared with reference products for sea ice concentration and sea ice freeboard to illustrate SWOT's strong potential for monitoring sea ice.

Corresponding author:
Gwenael Jestin (**LEGOS / CNRS**, **France**), gwenael.jestin@univ-tlse3.fr

Sea ice characterization from KaRIn HR data and application to S3NG-T

Laetitia Rodet (CLS, France); Louise Yu (CNES, France); Pierre Dubois (CLS, France); Gwenaël Jestin (LEGOS, France); Sara Fleury (LEGOS, France); Laiba Amarouche (CLS, France); Thomas Moreau (CLS, France); Fanny Piras (CLS, France); François Boy (CNES, France); Matthias Raynal (CNES, France); Nicolas Picot (CNES, France)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Oral

Abstract:
The launch of the Surface Water Ocean Topography mission (SWOT) in December 2022 represented a major breakthrough in satellite altimetry. Its primary instrument is the Ka-band Radar Interferometer KaRIn, which uses synthetic-aperture radar (SAR) and interferometry to provide a fine resolution both along and across-track. KaRIn data are processed in two different chains: low-rate (LR), which is applied everywhere and provides one measurement every 2-km-side square tiles (250-m-side for the “unsmoothed” product), and high-rate (HR), which provides ~30-m-resolution pixel clouds (PIXC) on specific 60-km-side square tiles. The HR mask is primarily designed for hydrology and thus covers mostly the continents. However, a seasonal winter mask has been implemented in the arctic ocean, allowing for the characterization of sea ice from both LR and HR data. Although sea ice exploration is not a priority of the SWOT mission, initial results show that it still provides detailed images of both the topography and scattering properties of the ice floes and leads (the fractures between the floes). This is promising for the future Copernicus mission Sentinel-3 Next Generation Topography (S3NG-T) that will provide altimetry measurements over the whole globe almost up to latitude 82°. With both a nadir and a wide swath (with LR and HR modes) altimeter, it will therefore be able to provide enhanced observations of the polar oceans, including sea ice monitoring.

Ensuring the continuity of sea level measurements as well as quantifying the time-varying surface and height of sea ice in polar regions has been a continuous challenge. Since in-situ explorations are difficult in such hostile regions, dedicated space missions (Cryosat-2, SARAL/AltiKa, Sentinel-3, IceSat-2) have recently improved our knowledge and given a first estimate of the sea level and the thickness of the ice [1]. With its unique 2D measurement capabilities, SWOT can provide unprecedented information on the surface classifications of the ice covered oceans (mainly leads and floes) as well as the topography of both the water and ice floes. This was shown in various investigations last year [2, 3], and a classification product computed from SWOT LR “unsmoothed” data is currently being implemented following these studies.

In this work, we propose to show the advantages and limitations of HR data on sea ice. The improved resolution and posting rate allow for the characterization of finer details, but the pre-summing of the raw data and the nature of the surface (ice, snow, dark water) significantly increases the noise, which impacts the topography measurement performance. Learning from the capabilities of SWOT in sea ice is essential to the success of future missions such as S3NG-T. We propose to show comparisons of SWOT HR and LR “unsmoothed” data on sea ice, as well as simulations of both S3NG-T and SWOT, to show the impact of the different instrumental specificities on the performance. Overall, swath altimetry opens a new era for the global understanding and monitoring of sea ice, also contributing to the enhancement of sea level measurements in polar oceans, which is one of the key mission objectives.

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Corresponding author:
Laetitia Rodet (**CLS**, **France**), lrodet@groupcls.com

SWOT's Sea Surface Height Observations in Sea Ice Zones: A First Look and Comparison with ICESat-2

Felix Müller (Deutsches Geodätisches Forschungsinstitut (DGFI), Germany); Denise Dettmering (DGFI-TUM, Germany); Maria Pisareva (DGFI-TUM, Germany)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Oral

Abstract:
In the framework of the SWOT Science Team project "SWOT for Marine Applications in the Polar Seas (SMAPS)" SWOT's capabilities for sea surface height (SSH) determination in the ice-covered ocean up to a latitudinal limit of 78°N are assessed. In the case of the Arctic Ocean, the SWOT L2 LR Unsmoothed swath observations represent the predominant observation mode and will be used from the end of March 2023 to the end of April 2024. In order to assess the quality of the novel 2D-SSH data, they are compared with laser altimetry observations from ICESat-2. The comparison is carried out based on sea level anomalies (SLA). To ensure the most coherent assessment possible, both datasets are referenced to the same mean sea surface (i.e., DTU21), and consistent geophysical corrections are applied as far as possible. The greatest challenge, however, is to find simultaneous measurements of overlapping areas. This is particularly important in the sea-ice covered ocean because of rapidly changing sea ice conditions within a few hours. For this reason, a maximum acquisition time gap of 30 minutes has been set, leading to about 550 suited Arctic-wide crossover locations. In the next step, the SWOT wide-swath data is interpolated to ICESat's individual laser beams, enabling point-by-point quantitative comparisons. Moreover, visual comparisons with Sentinel-1 radar images are performed in order to evaluate the extent to which sea ice surface features, such as ice floes or leads, are mapped by SWOT. Different spatial resolutions are considered by applying spatial low-pass filtering to ICESat-2 and Sentinel-1.
For all crossover locations, point-by-point comparisons are performed, and statistical analyses of the differences are conducted. In general, the differences in SLA show a mean standard deviation of 8 cm when taking all surface conditions into account and 6 cm by limiting the pointwise comparison to open water (i.e., leads). Discrepancies, resulting from the SWOT internal cross-correction, may cause significant height deviations of tens of centimetres between the left and right SWOT swath. Visual comparisons clearly show good accordance between minimum heights and dark pixel values, indicating leads and open water spots. Limitations can be found in the representation of smaller ice-floes or narrow leads, and ridges not showing clear height variations in the swath data.

Corresponding author:
Felix Müller (**Deutsches Geodätisches Forschungsinstitut (DGFI)**, **Germany**), felix-lucian.mueller@tum.de

Using SWOT High-Resolution Raster data to map and monitor rifts on Antarctic ice shelves.

Susan L. Howard (Earth and Space Research, Seattle, WA, United States); Matt R. Siegfried (Department of Geophysics, Colorado School of Mines, Golden, CO, United States); Laurie Padman (Earth and Space Research, Corvallis, OR, United States); Tasha Snow (NASA Goddard Space Flight Center and ESSIC, University of Maryland, United States); Zachary S. Katz (Department of Geophysics, Colorado School of Mines, Golden, CO, United States); Ellie Abrahams (Stanford University, Stanford, CA, United States)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Oral

Abstract:
About fifty percent of the mass loss from the Antarctic Ice Sheet occurs through iceberg calving along the fronts of Antarctic ice shelves, the floating extensions of glaciers. Most of these icebergs form through the extension of rifts (crevasses extending through the full thickness of the ice shelf), emphasizing the importance of mapping existing rifts and monitoring three-dimensional changes in rift geometry. SWOT is the first altimetry mission with the potential to map ice shelf rifts at sub-kilometer scales, both along- and across-track, on at least monthly time scales regardless of cloud cover. SWOT's swaths extend south to a latitude limit of about 78 degrees, which covers many of the most rapidly changing ice shelves. In the fall of 2024, the SWOT Cryosphere Working Group developed a High-Resolution (HR) acquisition mask targeting several major Antarctic ice shelves at varying degrees of swath overlap set by downlink constraints. Here, we demonstrate the potential, and current limitations, of SWOT rift mapping using HR 100-m Raster data. We use along-track ICESat-2 laser altimetry measurements, advected to account for lateral ice motion between the time-separated SWOT and ICESat-2 records, as precise validation data for SWOT's elevation accuracy. Examples from several ice shelves with different surface characteristics are used to explore the strengths and limitations of SWOT mapping of rifts, and to demonstrate the symbioses between SWOT and ICESat-2 missions for ice shelf studies.
Corresponding author:
Susan L. Howard (**Earth and Space Research, Seattle, WA**, **United States**), showard@esr.org

Surface height extraction over alpine glaciers using SWOT

Cassie Stuurman (Jet Propulsion Laboratory, California Institute of Technology, United States); Laurence Smith (Department of Earth, Environmental, and Planetary Sciences, Brown University, United States)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Oral

Abstract:
Early results from SWOT have demonstrated potential to produce coherent interferograms over mountain glaciers. Glaciers are an extraordinarily important freshwater resource as well as a contributor to sea level rise, motivating the measurement of their melting surfaces through remote sensing techniques.

While initial results are promising, InSAR height extraction in alpine environments remains challenging due to steep slopes, layover effects, and the variable brightness of snow and ice surfaces. This project will evaluate SWOT's ability to measure ice surface elevations over mountain glaciers in selected critical water resource regions, and, where possible, quantify
height performance. Our objectives are to:

1. Assess SWOT's capability to acquire usable interferograms and generate Digital Elevation Models (DEMs) over the complex terrain of alpine glaciers.
2. Quantify the accuracy and precision of SWOT-derived ice surface elevations.
3. Evaluate the potential for using SWOT data, alone or in combination with other datasets, to detect changes in glacier surface elevation over time and connect those changes to local hydrology.

This work will explore modified techniques for SWOT processing specific to mountain environments, such as bespoke prior elevations or corrections to phase unwrapping. We will determine the feasibility and limitations of utilizing SWOT data for alpine glacier monitoring, providing valuable insights into climate change impacts on global water resources.

Corresponding author:
Cassie Stuurman (**Jet Propulsion Laboratory, California Institute of Technology**, **United States**), cassie.stuurman@jpl.nasa.gov

Submesoscale air-sea interactions as revealed by SWOT

Guillaume Lapeyre (Laboratoire de Meteorologie Dynamique, France); Mohamed Kaouah (LMD & LEGOS, France); Lionel Renault (LEGOS, France)

Session: Oceanography: Wind and Waves
Presentation type: Oral

Abstract:
At midlatitudes, air-sea interactions have been documented in numerical models, in situ campaigns and satellite observations down to the ocean mesoscales. Such interactions are characterized by a coupling of surface winds with sea surface temperature anomalies or with ocean currents. However little is known for scales of a few kilometers (the submesoscales) and we rely mostly on high-resolution numerical simulations.
SWOT provides not only sea surface height at kilometers scales, but also surface wind speeds at the same resolution (through the measurement of the backscatter coefficient, related to ocean roughness). Here, we take profit of this new dataset to examine the potential of the satellite to detect correlations between surface winds and SST.
Different regions of the world ocean were examined during the fast sampling phase. In this talk, we present a particular situation in the Gulf Stream area during which scatterometer winds, SST and Chlorophyll at kilometer scales were available at the same time. A good correspondence between winds from SWOT, scatterometers and ECMWF forecast is found at the mesoscales. More importantly, we show that SWOT detects submesoscale features of 10 km scales, correlated with SST anomalies and Chlorophyll. We also present other situations in different ocean regions indicating that SWOT is a valuable tool for air-sea interactions studies through its surface wind measurements.

Corresponding author:
Guillaume Lapeyre (**Laboratoire de Meteorologie Dynamique**, **France**), glapeyre@lmd.ipsl.fr

Orographic waves signatures in SWOT KaRIn data

Perrine Abjean (CLS, France); Loren Carrere (CLS, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Wind and Waves
Presentation type: Oral

Abstract:
The new Surface Water and Ocean Topography (SWOT) altimetry mission launched at the end of 2022 is an opportunity to access ocean variability at scales extending below 30 km and to better understand the high-frequency dynamic processes involved. The analysis of SWOT 2-dimensions observations during the Calval (1-day orbit) allowed detecting in several regions, very small-scale patterns both visible in the retrodiffusion coefficient and in the SSHA of the smoothed and unsmoothed products.
The study described here focuses on the SWOT track 16 from CALVAL orbit located north of Baleares Islands in the Mediterranean Sea. We analyzed the very small-scale patterns detected in SWOT SSHA and the correlation with the local meteorological parameters and the global Dynamic Atmospheric Correction (DAC) signal.
The sigma0 and surface patterns appear correlated with strong winds coming from northern Spain's coast and are likely forced by atmospheric Lee waves. The atmospheric corrections provided in the L3 V2.0.2 products are based on the ECMWF global model and they do not have enough spatial resolution to represent such small phenomena. Some very high-resolution meteorological model outputs (AROME, Météo-France) avec been used and reveal the presence of similar small-scale waves signatures in several atmospheric parameters: pressure, wind and the integral column water vapor. AROME data allowed calculating the inverse barometer correction (IB), the wet troposphere correction (WTC) and some wind-effects all showing a good correlation with the SWOT SSHA patterns, although model wavelengths are slightly longer than those observed in SWOT.
Some complementary investigations are on-going to analyze the KaRIn Significant Wave Height parameter and new estimations of the SWOT KaRIn Sea State Bias correction: both show similar small-scale patterns but more verifications are needed to check the realism of these signals.
We propose to present a summary of the study carried out and the investigations in progress.
Corresponding author:
Perrine Abjean (**CLS**, **France**), pabjean@groupcls.com

Convection within atmospheric storms organized by ocean submesoscale fronts

Félix Vivant (LMD-IPSL, France); Lia Siegelman (Scripps Institution of Oceanography, USA); Patrice Klein (LMD-IPSL, JPL-Caltech, USA); Torres Hector (JPL-Caltech, USA); Dimitris Menemenlis (SJSU, JPL-Caltech, USA); Andrea Molod (NASA Goddard Space Flight Center, USA)

Session: Oceanography: Wind and Waves
Presentation type: Oral

Abstract:
The dynamics of mid-latitude storms are driven by moisture processes, convection, and associated precipitation. Over the past two decades, studies have emphasized the role of western boundary currents in the ocean, such as the Gulf Stream and the Kuroshio Extension, in providing moisture to the atmosphere, thereby intensifying convective activity (e.g., clouds and rain) and storms intensity. While the influence of oceanic mesoscale (~200 km-size) and larger scales on storm tracks is relatively understood, the impact of oceanic submesoscale fronts (~10-20 km-size), characterized by strong sea surface temperature gradients of 5°C per 10 km, remains unknown. Using a global coupled ocean-atmosphere simulation at a km-scale resolution, we show that half of latent heat flux variability at the air-sea interface is driven by oceanic motions at the mesoscale (~40%) and submesoscale (~10-20 km-size, <10%) in the Kuroshio Extension during winter. The analysis further demonstrates that ocean submesoscale fronts drive a secondary circulation, extending above the planetary boundary layer up to 4 km within the troposphere, which enhances diabatic processes and convective precipitations within storms. In the warm sector of storms, ocean submesoscale fronts locally account for half of the total diabatic heating and half of the total precipitations, averaging 14 mm/day over five days. In contrast, diabatic heating and precipitations associated with submesoscale fronts are respectively three and twelve times smaller in the cold sector. As such, ocean submesoscale fronts pump moisture from the ocean to the atmosphere and have the potential to affect storms intensification. Overall, these results suggest that SWOT can identify the influence of ocean fine-scales on weather systems by measuring air-sea exchanges down to the submesoscales.

Reference: Vivant, F., Siegelman, L., Klein, P., Torres, H. S., Menemenlis, D., & Molod, A. M. (2025). Ocean submesoscale fronts induce diabatic heating and convective precipitation within storms. Communications Earth & Environment, 6(1), 69. https://doi.org/10.1038/s43247-025-02002-z
Corresponding author:
Félix Vivant (**LMD-IPSL**, **France**), felix.vivant@lmd.ipsl.fr

Leveraging SWOT Radar Data for Machine Learning: Tagging Oceanic and Atmospheric Features at Kilometer Scales

Justin Stopa (The University of Hawaii at Manoa, United States); Yannik Glaser (The University of Hawaii at Mano, USA); Doug Vandemark (The University of New Hampshire, USA); Alexis Mouche (IFREMER, France); Ralph Foster (The University of Washington, USA); Bertrand Chapron (IFREMER, France)

Session: Oceanography: Wind and Waves
Presentation type: Oral

Abstract:
Radar imaging of the sea surface captures information from a wide range of oceanic and atmospheric processes related to air-sea interactions. The new NASA/CNES radar aboard the Surface Water and Ocean Topography (SWOT) satellite provides the most extensive global ocean coverage of any Earth-observing radar system to date. With continuous swath coverage, SWOT collects global sea surface roughness data day or night, regardless of cloud cover, for both scientific and monitoring applications. This dataset represents an unprecedented compilation of imagery capturing mesoscale to sub-mesoscale oceanic, atmospheric, and wave phenomena. A long-term objective of the mission is to develop a new product capable of detecting features at kilometer scales, such as atmospheric rolls and cells, absence of such structures, rain, cold pools, atmospheric and oceanic internal waves, sea ice, icebergs, and surface slicks. Given the vast number of SWOT scenes, automated methods are essential to fully leverage this growing archive. This work establishes a strategy for tagging phenomena within SWOT imagery, laying the groundwork for the development of an automated machine learning model to detect such features. The model aims to classify phenomena in both the ocean (e.g., swell, internal waves, mesoscale and sub-mesoscale fronts) and the atmosphere (e.g., organized turbulent structures, rain and associated cold pools, atmospheric gravity waves, and air-mass boundaries). Although our tagging approach is designed to accommodate any SWOT scene, interpreting Ka-band data remains challenging due to the influence of rain and atmospheric moisture. To address this, we utilize three channels of information: (1) calibrated high-resolution backscatter, (2) scaled high-resolution backscatter to enhance texture visualization, and (3) sea surface height anomalies. We illustrate the range of phenomena observed in SWOT imagery and discuss how our tagging strategy can inform downstream machine learning efforts. Preliminary results highlight SWOT's unique observational capabilities, including the simultaneous detection of atmospheric turbulence during synoptic weather transitions, evolving turbulence across strong current systems, and routine observation of atmospheric gravity waves. These efforts support the broader goal of advancing our understanding of air-sea boundary processes and the connections between mesoscale variability and air-sea interactions.

Corresponding author:
Justin Stopa (**The University of Hawaii at Manoa**, **United States**), stopa@hawaii.edu

Sizing the largest ocean waves using the SWOT mission

Fabrice Ardhuin (LOPS, France); Taina Postec (LOPS, France); Accensi Mickael (LOPS, FR); Jran-François Piolle (LOPS, France); Guillaume Dodet (LOPS, France); Marcello Passaro (TUM, Germany); Marine De Carlo (CLS, France); Romain Husson (CLS, France); Gilles Guirron (OceanDataLab, France); Fabrice Collard (OceanDatalab, France)

Session: Oceanography: Wind and Waves
Presentation type: Oral

Abstract:
Winds generate waves over the oceans with a wide range of heights and lengths. The heights and periods of the largest waves are important parameters in the design of marine structures. Extreme waves also play an outsize role in air-sea fluxes and coastal dynamics, and leave imprints on seismic and sediment records. Rare events have
so far escaped measurements, with few wave heights from satellite altimeters exceeding 16 m, and no associated measurement of wave periods. Here we use swells radiated from the largest storms to reveal wave properties in the storms, and their generation mechanism. Long swells are systematically resolved in the Surface Water and Ocean Topography (SWOT) satellite global LR sea level measurements. Patterns of increasing swell wavelength and decreasing swell height away from storms are consistent with a nonlinear transfer of energy from short to long period waves. The spectral shapes commonly used to represent the roll-off of energy towards long periods are not consistent with this inverse energy cascade, overestimating the energy level by a factor 20 at periods 1.2 to 1.4 times the peak period. We propose an updated spectral shape that is consistent with SWOT swell measurements, and we use it to estimate storm wave periods from swell heights. These results holds up to a new record for measured significant wave heights in Storm Eddie (21 december 2024), at 19.7±0.3m, with a corresponding peak period of 20.1±0.5s. These new observations of long period swells should have a wide range of applications from coastal dynamics to seismology. In terms of wave modelling, the SWOT data shows that better parameterizations of wave-wave interactions are needed to correct swell arrival biases.

These large swell events also give rise the large infragravity waves: data in cycle 025 track 580 off the Oregon coast suggest that the SSH at scales under 20 km can be dominated by infragravity waves with a 10 km dominant wavelength and 10 cm height. Fortunately for most SWOT applications this occurence is extremely rare and typical infragravity wave heights are expected to be under 1 cm.
Corresponding author:
Fabrice Ardhuin (**LOPS**, **France**), ardhuin@ifremer.fr

Tracking Glacial Lake Floods with SWOT

Sonam Sherpa (Institute at Brown for Environment and Society, Brown University, Providence, RI, USA/School of Environment, Society and Sustainability, University of Utah, UT, USA, United States); Laurence Smith (Institute at Brown for Environment and Society, Brown University, Providence, RI, USA, United States); Bo Wang (Department of Earth and Atmospheric Sciences, Saint Louis University, St. Louis, MO, USA, United States); Cassie Stuurman (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, United States)

Session: Cryosphere: Lakes
Presentation type: Oral

Abstract:
Glacial Lake Outburst Floods are a major geohazard in the Himalayas and other mountainous environments. However, high-resolution identification and tracking of such flooding hazards are limited by their extreme environment, inaccessibility, and moderate spatiotemporal resolution of traditionally available satellite programs. Recent technological breakthroughs, including high-resolution Commercial Satellite Data and NASA/CNES/CSA/UKSA Surface Water and Ocean Topography (SWOT) interferometric radar, have the potential to assist in this effort. Using a 16 August 2024 unexpected glacial lake outburst flood of Nepal Himalaya as a case study, we show that multisource satellite observations (Landsat, Sentinel-2, Planet, SWOT) detect source lake's growing area, turbidity, and water surface elevation and storage change before and after the glacial lake outburst. We found that increased glacier meltwater runoff caused rapid, unnoticed growth of this remote glacial lake since 2008. The lake then overtopped its basin, eroding a ~95–150 m wide outlet channel that abruptly drained the lake, releasing a catastrophic flood down-valley, destroying parts of Thame village. Assimilating SWOT with other remote observations, we found that abrupt drainage of the lake caused a 5-meter drop in its water level, a 47% decrease in water area, and a 510,000 cubic meters storage change after the flood, which flowed into the downstream lake, causing it to also breach and fail. This secondary lake drainage triggered an additional 11-meter water level drop, a 72% decrease in lake area, and a 370,000 cubic meter water storage loss, further exacerbating the flood. Sentinel-2 derived Normalized Difference Turbidity Index (NDTI) retrievals over glacial lake outburst flood source area reveal the highest turbidity in the uppermost lake (NDTI= -0.04), signifying a glacial meltwater source. Water levels from this uppermost lake were not present in SWOT LakeSP but were available in the SWOT Pixel Cloud product. We conclude that SWOT observations can aid early detection of potential flood hazards for prioritization in field-based hazard assessments and mitigation strategies.

Corresponding author:
Sonam Sherpa (**Institute at Brown for Environment and Society, Brown University, Providence, RI, USA/School of Environment, Society and Sustainability, University of Utah, UT, USA**, **United States**), u6066134@utah.edu

Assessing the Potential of the SWOT Mission for the Retrieval of Freshwater Lake Ice and Overlying Snow Properties

Grant Gunn (University of Waterloo, Canada); Claude Duguay (University of Waterloo, Canada); Jennifer Fatt (University of Waterloo, Canada); Hayley Kavanagh (University of Waterloo, Canada)

Session: Cryosphere: Lakes
Presentation type: Oral

Abstract:
The properties of ice-covered lakes, namely ice thickness and extent provide a proxy for monitoring climate and are an indicator of climate change. Changing snow patterns and quantity expected in Arctic regions may affect ice cover duration and thickness, indicating the need for better quantification of snow water equivalent (SWE) on lakes across the Northern Hemisphere. The Surface Water Ocean Topography (SWOT) mission offers the potential to retrieve ice thickness and snow parameters through the use of temporally coincident Ku-band altimetry and Ka-band Interferometric SAR (KaRIn), respectively. This project highlights two specific objectives, to 1) assess and improve the accuracy of freshwater ice thickness retrievals using Ku-band altimetry, and 2) quantify the influence of the snow cover overlaying lake ice on Ka-band pixel cloud product interferometric observations to aid in developing snow water equivalent (SWE) retrieval algorithms. While lake ice thickness has been shown to be possible using altimetry in the past, the added information of the overlying snow cover has commonly been assumed or a fitted parameter within thermodynamic modeling of lakes. This presentation highlights altimetry and KaRIn acquisitions on Kluane Lake, Yukon in winter seasons with contrasting snow regimes where some winters presented a considerable snowpack on the ice (2022-23, 2023-24), and others where the ice was nearly bare (2024-25). Variation in lake ice parameter retrieval capacity is also explored for SWOT's Fast Sampling phase (1-day repeat) in 2023, and Science Data Collection phase (21 day repeat) in 2024.

Corresponding author:
Grant Gunn (**University of Waterloo**, **Canada**), g2gunn@uwaterloo.ca

Lake and river ice classifications with SWOT

Melanie Trudel (Universite de Sherbrooke, Canada); Gabriela Siles (Universite Laval, Canada); Samuel Foucher (Universite de Sherbrooke, Canada); Sylvain Biancamaria (LEGOS, France); Anthony Mandeville (Universite de Sherbrooke, Canada); Toumia Ghribi (Universite de Sherbrooke, Canada)

Session: Cryosphere: Lakes
Presentation type: Oral

Abstract:
Lake and river ice play an essential role in northern latitudes, contributing to various human activities (such as transportation and fishing), weather regulation, aquatic ecosystems and as an indicator of climate change. Remote sensing data are increasingly used to monitor lake and river ice due to the scarcity of in situ observations, but significant challenges remain due to some limitations of optical and C, L, and X-band radar sensors. More accurate and frequent measurements of ice dynamics are also required. The SWOT satellite, with its Ka-band radar interferometer and high spatial and temporal coverage, offers an unprecedented opportunity to monitor lake and river ice. With SWOT data available since March 2023, we now have two whole winter seasons to study the signal on lake and river ice.

As backscatter (sig0) decreases but interferometric coherence remains high (or phase noise standard deviation remains low), ice-covered areas can be detected. However, the signal also varies with the incident angle, requiring the development of an algorithm that takes sig0, coherence, phase noise standard deviation,and incident angle into account. Pixel-by-pixel classification with a random forest allows the monitoring of the spatial variability of ice cover. Pixels are classified into four categories: Water (original SWOT classes 3 and 4), Darkwater (class 5), Low-Coherence (classes 6 and 7) and Ice. The figure below shows an example for Richardson Lake in Canada in spring 2025.

The pixel-by-pixel classification is then used in a second random forest to develop a dynamic ice flag for the HR_LakeSP product. The lake-scale classification was developed on lakes in Canada (15 lakes) and Norway (9 lakes) and tested on independent lakes (45 in Canada and 30 in Norway) during the 2024-2025 winter season, achieving an precision of more than 92% when compared to the visual interpretation of Sentinel-2 images, regardless of incident angle, lake size, or region. This classification will be applied to lakes in other regions (e.g. Alaska and Tibetan Plateau) in the next months to validate its global application. A similar classification for rivers is currently being developed at HR_RiverSP node level, again using pixel-by-pixel classification and random forest.

Corresponding author:
Melanie Trudel (**Universite de Sherbrooke**, **Canada**), melanie.trudel@usherbrooke.ca

Using SWOT to assess and correct global hydrology models

Colin Gleason (UMass Amherst, United States); Paul Bates (Univeristy of Bristol, United Kingdom); Paper Team The SWOT Global Hydrology Assessment (28 authors, from around the world)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
Basic global river knowledge is modelled, not measured, and models calibrated on <1% of global rivers reify into freshwater knowledge past, present, and future. We use the Surface Water Ocean Topography (SWOT) satellite to assess our understanding of the global river system represented by six simulations of global rivers [including both ML and physics-based]. In rivers with enough sufficient high-quality SWOT data, representing 33% of global flow (8,200 km3/yr) and 19% of global rivers, SWOT suggests that up to 5,400km3/yr of modelled flows may be in error. Attribution of extreme errors suggests models struggle with dams, Arctic Freshets, and wetland systems. A SWOT proxy map of likely global model skill resembles a map of a human hydrologic activity, suggesting adding to suggestions that current basic hydrology knowledge does not reflect humanity's role in the water cycle. Finally, we prove SWOT measurements can correct model errors as anticipated, and ultimately SWOT's primary data suggest 'naturalized' models ignoring human action can should now be abandoned. As SWOT continuously improves, future models, and therefore future basic global knowledge, will improve.

Corresponding author:
Colin Gleason (**UMass Amherst**, **United States**), cjgleason@umass.edu

SWOT Derived River Bathymetry for Global Flood Model Applications

Stephen Chuter (Fathom, United Kingdom); Jeffrey Neal (University of Bristol, United Kingdom); James Savage (Fathom, United Kingdom); Paul Bates (University of Bristol, United Kingdom); Oliver Pollard (Fathom, United Kingdom); Peter Uhe (Fathom, United Kingdom)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
Accurately parameterising river channel geometry, in particular river bathymetry, remains a key uncertainty and bottleneck for improved accuracy in flood inundation models. Whilst channel bathymetry cannot be directly observed using Earth Observation (except for limited cases of clear and shallow water), we can infer it based on observations of river water surface elevation (w.s.e) and discharge. Historically, these data have been spatiotemporally sparse globally (and declining), preventing bathymetry from being estimated beyond a few localised test cases. SWOT, since its launch in 2022, has provided direct w.s.e measurements for all major global rivers (>50m width) every 21-days; presenting an opportunity to address this current major model limitation. Our recent proof-of-concept for the River Severn, UK, demonstrated that a flood inundation model built with SWOT-conditioned bathymetry had comparable accuracy to a local scale engineering model conditioned on observed field observations (Neal et al, 2025), demonstrating the potential of the approach on a test-case deemed to be at the limit of SWOT detection capability (40-70m river width).

Here, we advance on this proof-of-concept to show how SWOT can be used to develop a consistent global channel bathymetry data set for large rivers, using the SWOT HR Level 2 RiverSP Node product. We present an overview of the methodological approach required to utilise SWOT data for bathymetry inversion for large complex river hydrographies. This will include a focus on the further development of the quality filtering approach developed for the River Severn proof-of-concept, in order for it to be generally applicable for global scale applications. Additionally, we will present an analysis of how the SWOT-based approach for determining bathymetry compares to the current bank height based approaches used in the current generation of flood inundation models. Finally, we will discuss how future planned SWOT processing developments can enhance this work further, such as future evolution of the SWORD hydrography, the changes upcoming in the Version D product and possibility of using SWOT-derived discharges.

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Corresponding author:
Stephen Chuter (**Fathom**, **United Kingdom**), s.chuter@fathom.global

Advancing Global Hydrological Assimilation: First Applications of CTRIP-HyDAS with Real SWOT Observations

KAUSHLENDRA VERMA (CNRM, Université de Toulouse, Meteo-France, CNRS, Toulouse, France, France); Simon Munier (CNRM, Université de Toulouse, Meteo-France, CNRS, Toulouse, France, France); Aaron Boone (CNRM, Université de Toulouse, Meteo-France, CNRS, Toulouse, France, France); Patrick Le Moigne (CNRM, Université de Toulouse, Meteo-France, CNRS, Toulouse, France, France)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
Leveraging the capabilities of SWOT, our study presents a novel approach for estimating global river discharge by integrating SWOT observations into the CTRIP river routing model using the Hydrological Data Assimilation System (CTRIP-HyDAS) and the Local Ensemble Transform Kalman Smoother (LETKS) technique. Building on our recent development and OSSE-based validation of the global CTRIP-HyDAS data assimilation framework, we now extend its application to real SWOT observations. The system is currently being tested with SWOT Version C-2 at the reach scale, using both water surface elevation (WSE), directly observed by SWOT, and derived discharge products in separate assimilation experiments. These efforts represent the first steps in transitioning the framework from simulation to real-world operation. Preliminary results from selected river basins with high-quality overpasses highlight practical challenges related to observation filtering, uncertainty treatment, spatial representation, and model–observation alignment. These early tests help assess the system's robustness and identify priorities for future refinement, including observation selection strategies, mapping between SWORD and the CTRIP river network, and localization design. Looking ahead, the availability of a complete one-year record in SWOT Version D will enable extended assimilation experiments and support ongoing development toward joint assimilation of WSE and discharge. This work represents a key step toward operational global assimilation of SWOT hydrology products and advancing discharge predictions in data-scarce regions.

Corresponding author:
KAUSHLENDRA VERMA (**CNRM, Université de Toulouse, Meteo-France, CNRS, Toulouse, France**, **France**), kaushlendra.verma@meteo.fr

Towards a better understanding of global terrestrial water storage and fluxes through SWOT data assimilation

Augusto Getirana (NASA Goddard Space Flight Center, United States); Yeosang Yoon (NASA Goddard Space Flight Center, USA); Elyssa Collins (NASA Goddard Space Flight Center, USA); Sujay Kumar (NASA Goddard Space Flight Center, USA)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
Optimally integrating the measurements from the Surface Water and Ocean Topography (SWOT) satellite into hydrological models has been a challenge that the scientific community has been working on way before the satellite was launched. Many attempts using synthetic data have been presented in the literature, and most of them focus on SWOT discharge data assimilation (DA). In order to avoid known high errors in discharge data, we adopt a slight different approach where water surface elevation (WSE) is assimilated instead. This approach comes with other challenges. Here, we summarize and discuss the challenges and opportunities in integrating SWOT WSE into NASA's Land Information System (LIS). We focus on NASA Goddard's efforts related to (1) riverbed elevation tunning, (2) data assimilation and representation of human impacts on surface waters. We provide particular insights and preliminary results on addressing the elevation bias between satellite measurements and models, which is an existing limitation when assimilating SWOT WSE. We tackle that issue with a methodology to fit global riverbed elevations to SWOT measurements, which substantially reduces bias between datasets. We anticipate that the these efforts, in combination with synergetic NASA on multivariate DA, will provide an improved representation of the global terrestrial water storage variability and fluxes, and anthropogenic impacts.

Corresponding author:
Augusto Getirana (**NASA Goddard Space Flight Center**, **United States**), augusto.getirana@nasa.gov

Towards Consistent Hydrological-Hydrodynamic Predictions at Large Scale: Multi-Satellite Data Assimilation in the Amazon and the Emerging Role of SWOT Observations

Sly Wongchuig (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France, France); Fabrice Papa (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France , France); Charlotte Blondel (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France , France); Rodrigo Paiva (Instituto de Pesquisas Hidráulicas IPH, Universidade Federal do Rio Grande do Sul UFRGS, Brazil, Brazil); Vinícius Siqueira (Instituto de Pesquisas Hidráulicas IPH, Universidade Federal do Rio Grande do Sul UFRGS, Brazil, Brazil); Ayan Fleischmann (Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, AM, Brazil , Brazil); Sylvain Biancamaria (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France , France); Adrien Paris (Hydro Matters, 1 Chemin de la Pousaraque, 31460 Le Faget, France, France); Stéphane Calmant (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France , France)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
The Amazon Basin, the world's largest hydrological system, plays a critical role in regulating the global water cycle, climate feedbacks, and biogeochemical fluxes such as carbon and methane. However, it remains one of the most challenging regions to model hydrologically due to sparse in-situ data and complex floodplain dynamics typical of low-gradient terrains. In our recent study (Wongchuig et al., 2024), we introduced a large-scale hydrological-hydrodynamic modeling framework using the MGB model ("Modelo de Grandes Bacias") combined with a Multi-Observation Local Ensemble Kalman Filter (MoLEnKF). This approach enables the simultaneous assimilation of satellite-derived variables, including soil moisture, terrestrial water storage, flood extent, and water surface elevation, into model state variables. This integration improves the accuracy of discharge and water level estimates across the Amazon Basin, surpassing the performance of referenced hydrologic-hydrodynamic models within this region. This study builds on previous experiments (Wongchuig et al., 2020) using synthetic SWOT observations, in which the ability of SWOT-like data to reduce model uncertainty and improve hydrologic estimates was demonstrated under uncalibrated global model settings. The integration of real SWOT data, which is now available from nearly two full hydrological years since the satellite launch in December 2022, signifies the subsequent phase in this progression.
The SWOT mission provides high-resolution measurements of river surface elevation, inundation extent, and slope for rivers wider than 100 meters. However, the efficacy of its discharge retrieval algorithms is constrained by the presence of uncertainties associated with bathymetry, roughness, and river network topology. In this context, the incorporation of SWOT data into conceptual-physically-based models such as MGB through data assimilation offers a robust alternative, blending physical principles with observational constraints. The development of the SWORD database further supports this integration by providing a standardized, satellite-compatible river network. As noted by Altenau et al. (2021), aligning SWOT-derived reaches with model structures is key to effective assimilation.
As emphasized by Häfliger et al. (2019) and Andreadis et al. (2020), SWOT's global perspective is essential for closing data gaps and advancing predictions in ungauged basins worldwide. The objective of this study is to demonstrate the feasibility and added value of integrating real SWOT data (e.g., water surface elevation anomaly and river slope) and complementary satellite/in-situ data into a large-scale hydrological-hydrodynamic model through multi-observation data assimilation. In addressing this objective, the study will also examine key challenges such as observation uncertainty and river network inconsistency. Beyond the Amazon, this scalable approach has the potential to improve predictions in other data-scarce tropical basins such as the Congo and Mekong. The integration of SWOT's high-resolution observations with dynamic modeling enhances our capacity to monitor, predict, and manage freshwater systems in the face of accelerating environmental change.

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Wongchuig, S., Paiva, R
Corresponding author:
Sly Wongchuig (**Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France**, **France**), sly.wongchuig-correa@univ-tlse3.fr

SWOT-Hydro2-Learning (tosca project): Learning regionalization of hydrological-hydraulic models and discharge laws over river networks with SWOT and multi-source data assimilation

Pierre-André GARAMBOIS (INRAE, RECOVER, Aix-Marseille University, France); Jérôme Monnier (INSA, IMT, Toulouse University, France); Sylvain Biancamaria (LEGOS-CNRS, Toulouse University, France); Robin Bouclier (INSA, IMT, Toulouse University, France); Mouad Ettalbi (INRAE, RECOVER, Alix-Marseille University; Aiway, France); Truyen Huynh (INRAE, RECOVER, Aix-Marseille University, France); Kevin Larnier (Hydro Matters, France); Thomas Ledauphin (Icube-Sertit, Strasbourg University, France); Jérôme Maxant (Icube-Sertit, Strasbourg University, France); Bao Ngoc (INRAE, RECOVER, Alix-Marseille University, France); Adrien Paris (Hydro Matters, France); Olivier Roustant (INSA, IMT, Toulouse University, France); Hélène Roux (IMFT, INPT-ENSEEIHT, Toulouse University, France)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
Accurate flood and low-flow forecasting amid climate change requires advanced numerical tools that ensure realistic and consistent spatio-temporal flow simulations. Improving the representation of continental water storage and fluxes across scales remains challenging due to complex, nonlinear, multi-physical processes and limited, heterogeneous observations. The SWOT satellite's unprecedented hydraulic visibility of river surfaces, combined with other in situ and satellite data, offers great potential for estimating uncertain river hydraulic quantities (bathymetry-friction, discharge) and improving hydrodynamic modeling from reach to basin scales, with feedback to catchment hydrological models where scale-relevant laws may be discovered.
The overarching goal of SWOT-Hydro2-Learning project is to develop disruptive approaches to maximize information extraction from SWOT and multi-source data for river properties inferences, discharge estimations, and Hydrological-Hydraulic (HH) modeling at high resolution and catchment-river network scale. The proposed approaches are based on the combination of variational data assimilation, deep learning and uncertainty quantification methods, on top of consistent hydrological-hydraulic coupling with built-in regionalization. High quality demonstrators (which may be considered as "digital twins") will be developped on basins with contrasted physical properties and in situ gauging networks of varying density.
Since its recent beginning, the project contributed to several advances such as:
- SWOT data analysis and validation (Ledauphin et al. revised, Larnier et al. in prep.) and wavelet-based denoising and segmentation of node-based flowlines with hydraulic feature preservation (Larnier et al., final redaction).
- Improved Discharge Estimation algorithm HiVDI, including Bayesian UQ and Machine Learning (Larnier et al., final redaction).
- New methods and formulations to estimate effective river batymetries from SWOT like observations. (Levillain et al., final redaction ; Henderson et al. In prep.)
- Network scale inversion of discharge-bathymetry-friction in a HH model from SWOT (Larnier et al. 2025a) and feedback to hydrological model calibration (Pujol et al. in prep) with learnable regionalization (Huynh et al. 2024).
- A Raster-Vector Coupling Framework for Multi-Scale H&H modeling (Berkaoui et al. in prep).
- Development and validation of H&H solver in PyTorch for hybridization with neural networks and forward-inverse computational efficiency over large domains (after Ettalbi et al. final redaction).

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• Larnier K. et al. "Hybrid Bayesian-Neural Network-Variational estimations of river discharge from SWOT data". (final redaction)

• Larnier K. et al. Hydraulic-Preserving Filtering and Segmentation of SWOT Flowlines Using a Wavelet-Based Automatic Algorithm Adapted to the Node Product. (final redaction)

• Levillain J., Monnier J. A robust method to estimate effective river batymetries from surface water observations at reach scale. (final redaction)

Corresponding author:

Pierre-André GARAMBOIS (**INRAE, RECOVER, Aix-Marseille University**, **France**), pierre-andre.garambois@inrae.fr

Variational Assimilation of SWOT Altimetry into a 1D-2D Porosity-based Hydraulic River Model with Upstream Hydrology: Toward Integrated Hydrological-Hydraulic Discharge Estimation from SWOT

Léo Pujol (INRAE RECOVER, France); Pierre-André Garambois (INRAE RECOVER, France); Jérôme Monnier (INSA-IMT, France)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Oral

Abstract:
The high spatial density of SWOT data products enables unprecedented access to small scale variations of water surface elevation (WSE) of worldwide rivers. The informative content carried by such observations has great potential for the calibration of high resolution basin-scale hydraulic-hydrological (H&H) models of river networks and could allow the estimation of reach and cross-section scale geometry parameters and distributed inflows. However, estimating river discharge solely from WSE altimetry data remains a notoriously ill-posed inverse problem if bathymetry-friction are unknown (see Larnier et al., 2020). In this context, H&H modeling frameworks that integrate variational data assimilation (VDA) have shown promise in providing hydrologic closure to this under-constrained problem and also enable the estimation of high-dimensional spatio-temporal H&H parameters. To address these challenges, we employ a robust H&H variational data assimilation (VDA) framework proposed in Pujol et al. (2022), consisting in 1D-2D effective hydraulic model (DassFlow) integrating the GR4H state-space hydrological model (Santos et al. 2018), to assimilate SWOT altimetry for (i) optimizing sequentially or simultaneously effective hydraulic parameters and hydrological parameters and (ii) improving model realism and finally discharge estimation.
To model sub-cell cross-sectional variability in a 1Dlike model (Pujol et al. (2022)), an effective depth-independent porosity parameter was implemented based on Guinot and Soares-Frazão (2006). This parameter is key to the effective modelling of hydraulic controls and signal propagation through a river network hydraulic model based on the 1Dlike modelling approach. It can be estimated from local bathymetry surveys, channel geometry databases, but remains model-dependent and must be calibrated.
Our methodological framework enables the simultaneous inference of distributed hydraulic parameters (bathymetry, friction coefficients, longitudinal riverine porosity) and upstream hydrological parameters or inflow time series. Notably, the H\&H model is integrated into the VDA framework such that information feedback from hydraulic observables to the hydrological model can be achieved. This is key for integrated H&H discharge estimation based on SWOT observations.

The approach was tested on the Garonne river between Tonneins and La Réole (around 50km of river length). Knowledge on the real geometric variabilities of the minor bed is provided by a high-resolution expertised DEM. A 1Dlike hydraulic model of the river was built based on this accurate bathymetry data.
10 SWOT passes over the 2024-02-16 and 2024-04-21 period (65 days) provide snapshots of the waterline for a range of non-flooding upstream discharges. Assimilated SWOT data is in the format of single WSE observation points every 200m at the centerline (RiverObs algorithm output) and covers the whole reach.
A series of inference experiments were designed to evaluate the capability of the VDA method to extract informative content from SWOT WSE. Sought parameters are distributed friction and porosity, as well as hydrological parameters of the lumped upstream hydrological model. Results show improvement of the fit of the modeled waterlines to altimetry observations thanks to the calibration of finely distributed parameters and establishes a robust H&H approach for SWOT discharge estimation.
Low computation costs achieved through the 1Dlike modeling approach make it clear that this method could be scaled to larger river networks, opening the way toward leveraging the full informative content of basin-scale SWOT altimetry through our H&H VDA framework.

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Corresponding author:
Léo Pujol (**INRAE RECOVER**, **France**), leob.pujol@gmail.com

Near-inertial wave trapping inside a fine-scale anticyclonic eddy during the BioSWOT-Med 2023 cruise: Turbulence and energy flux

Robin Rolland (LOCEAN - SU, France); Pascale Bouruet-Aubertot (LOCEAN - SU, France); Yannis Cuypers (LOCEAN - SU, France); Anthony Bosse (MIO - CNAP, France); Anne Petrenko (MIO - AMU, France); Aurélien Ponte (LOPS - IFREMER, France); Tancrède Maytie (MIO, France); Stéphanie Barrillon (MIO - CNRS, France); Maristella Berta (ISMAR - CNR, Italy); Ananda Pascual (IMEDEA - CSIC, Spain); Baptiste Mourre (IMEDEA - SOCIB, Spain); Lloyd Izard (LOCEAN - CNRS, France); Xavier Capet (LOCEAN - CNRS, France); Gérald Grégori (MIO - CNRS, France); Francesco d'Ovidio (LOCEAN - CNRS, France); Andrea Doglioli (MIO - AMU, France)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Oral

Abstract:
The breaking of near-inertial waves (NIWs) trapped in anticyclones after strong wind events is a well-known pathway for kinetic energy dissipation below the mixed layer in the ocean and one of the mechanisms by which the ocean responds to modified wind patterns under climate change. In the Mediterranean Sea, where turbulence is generally low far from topographic boundaries, NIW trapping has been documented only in a few large (>100 km) and energetic mesoscale features. Whether NIW trapping is restricted to these few isolated and semi-permanent features or is a more widespread phenomenon remains a key open question, whose answer is hindered by the difficulty of tracking, in space and time, typical Mediterranean eddies characterized by both low energy and small radii.
Here we present an in-situ experiment conducted during the BioSWOT-Med 2023 cruise (doi.org/10.17600/18002392) that addressed this problem by surveying a moderately energetic small meander (<50 km, Ro ≈ 0.5) of the North Balearic front assisted by the first high-resolution SSH images of the SWOT mission. We explore how the fine scales control the spatio-temporal variability of turbulence (the dissipation of turbulent kinetic energy) around a fine-scale front in a moderately energetic area (compared to western boundary current and upwelling systems) after experiencing two consecutive strong wind events. We show that the turbulence remains low in the front and its cyclonic side while turbulence is greatly enhanced in the anticyclonic side. The latter side is dominated by a small anticyclone (~25 km in diameter) that trapped NIWs down to 300 m, generating intense shear and turbulence reaching up to several 10-8 W/kg. The vertical kinetic energy flux induced by NIWs is estimated from Acoustic Doppler Current Profiler (ADCP) and drifter's data. The flux reaches 10 mW/m2 at 60 m and 5 mW/m2 at 200 m. This is about one order of magnitude stronger than previous estimations outside anticyclones (0.5 to 2.5 mW/m2) and about 1 to 3 times previous estimations inside large and energetic mesoscale anticyclones (3 to 10 mW/m2). The wind power input to inertial motions, estimated from a high-resolution data-assimilative simulation (WMOP), reached 25 mW/m2. In the context of the Mediterranean Sea, where this kind of eddies are widespread, this work raises the question of the contribution of this process to the turbulence budget of the Mediterranean Sea. More generally, these results suggest that moderately energetic fine-scale fronts and eddies are as important to structure turbulence as strong fronts and eddies found in western boundary current and upwelling systems, addressing new challenges for their parameterization in Earth system models.

Corresponding author:
Robin Rolland (**LOCEAN - SU**, **France**), robin.rolland@locean.ipsl.fr

Internal solitary wave activity quantified by SWOT

Matthew Archer (JPL, United States); Lee-Lueng Fu (JPL, USA); Maarten Buijsman (USM, USA); Gautier Bardi de Fourtou (MIT, USA); Thomas Lu (JPL, USA); Jinbo Wang (Texas A & M, USA); Aurelien Ponte (IFREMER, France)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Oral

Abstract:
Internal solitary waves (ISWs) are some of the most striking oceanic signals seen in SWOT imagery. While ISWs have been observed for a long time, we have not had systematic global measurements of their amplitudes, until now. Because SWOT measures sea surface height — a variable that provides dynamical insight — we can explore beyond their kinematics toward quantifying the magnitude and space-time variability of their energy fluxes. ISWs are the result of the direct forcing of tidal currents over bottom topography, as well as the nonlinear steepening of the larger-scale internal tide. While we generally know the energy input into the internal tides, the energy input into the ISWs is less well constrained. Ultimately, this energy contributes to ocean mixing. In this presentation, we first focus on the Mascarene Plateau in the Indian Ocean, where ISWs radiate from an underwater sill with SSH amplitudes up to 30 cm and wavelengths of 10 to 20 km. We map the time and space variability of the ISWs using both CalVal and science orbits and characterize the decay of the ISWs from rough topography and radial spreading. Next, we zoom out to explore global ISW activity, based on a deep learning approach to detect ISWs in the SWOT data.
Corresponding author:
Matthew Archer (**JPL**, **United States**), archer@jpl.nasa.gov

Tides in complex coastal and polar regions

Michael Hart-Davis (DGFI-TUM, Germany); Ole Andersen (DTU Space, Denmark); Richard Ray (NASA, USA); Maximilian Lippert (Technical University of Munich, Germany); Edward Zaron (Oregon State University, USA); Rasmus Arildsen (DTU Space, Denmark); Antonio Bonaduce (NERSC, Norway); Christian Schwatke (Technical University of Munich, Germany); Denise Dettmering (Technical University of Munich, Germany)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Oral

Abstract:
The SWIFT-CORE science team project will present findings on the observation of tides in complex coastal and polar regions from SWOT. Historically, coastal and polar regions have been a challenge for global tide models, due to the limited spatial coverage of conventional satellite altimetry measurements. As SWOT provides unprecedented spatial coverage at high resolution, this has opened the door to the investigation of tidal physics within coastal regions such as estuaries and inlets, as well as challenging polar regions such as within the marginal ice zone and within fjords. The first part of the results to be discussed here will evaluate the estimation of tidal constituents across the land-ocean-aquatic continuum. Here, regions are studied that have historically been challenging for conventional satellite altimetry-based models, including estuaries and archipelagos. The observation of tidal dynamics within fjords is also presented, focusing on Sognefjord in Norway. Fjords are regions where the tidal dynamics are one of the key drivers of variability, but typically, tide models do not provide estimations within these regions due to insufficient spatial resolution and rely on interpolation techniques and in situ measurements. Here, results for the Sognefjord will be presented from SWOT products and contrasted with the latest global tide models and in situ measurements. Finally, a look at the estimation of tides in the polar regions, the Arctic and Antarctic regions, from SWOT ocean products will be discussed.

Corresponding author:
Michael Hart-Davis (**DGFI-TUM**, **Germany**), michael.hart-davis@tum.de

SWOT observations of the seiche that shook the world

Thomas Monahan (University of Oxford, United Kingdom); Tianning Tang (University of Manchester, UK); Stephen Roberts (University of Oxford, UK); Thomas Adcock (University of Oxford, UK)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Oral

Abstract:
On September 16th, 2023, an anomalous 10.88 mHz seismic signal was observed globally, persisting for 9 days. One month later an identical signal appeared, lasting for another week. Several studies have theorized that these signals were produced by seiches which formed after two landslide-generated mega-tsunamis in an East Greenland fjord. This theory is supported by seismic inversions, and analytical and numerical modeling, but no direct observations have been made. Here, we present primary observations of this phenomenon using data from the Surface Water Ocean Topography mission. Other oceanographic processes such as tides are ruled out through direct tidal estimates made from the SWOT data which are compared to FES2022 and in-situ gauge observations. These gauge observations are also used to rule out Ekman transport. We validate the seiche theory of previous authors and independently estimate its initial amplitude at 7.9 m using Bayesian machine learning and seismic data. This study demonstrates the value of SWOT for studying fast oceanic processes and extreme events, while also highlighting the need for specialized methods to address the altimetric data's limitations, namely temporal sparsity. We highlight some of the challenges of using SWOT in narrow fjords and share our procedure for post-processing these data. The SWOT data and approaches will help in understanding future unseen extremes driven by climate change.

Corresponding author:
Thomas Monahan (**University of Oxford**, **United Kingdom**), thomas.monahan@eng.ox.ac.uk

Mapping internal tides with SWOT and HYCOM

Yadidya Badarvada (University of Michigan, United States); Brian Arbic (University of Michigan, United States); Jay Shriver (Naval Research Laboratory , United States); Edward Zaron (Oregon State University, United States); Maarten Buijsman (University of Southern Mississippi, United States); Loren Carrère (CLS, France); Michel Tchilibou (CLS, France)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Oral

Abstract:
Internal tides, which manifest as sub-surface gravity waves with observable sea surface height changes, pose a unique opportunity for the SWOT mission to deepen our understanding of oceanic processes at the mesoscale and submesoscale levels. We assesses the capability of the data-assimilative HYCOM forecast system in accurately identifying and resolving both phase-locked and non-phase-locked internal tides during the both Cal/Val and SCIENCE orbits. We compare HYCOM's performance to the HRET22 model, which is limited to accounting for phase-locked tides. During the SCIENCE orbit, HYCOM globally captures 20% more sea surface height variance related to phase-locked internal tides compared to HRET22, highlighting its enhanced predictive capability. The key advantage of using HYCOM lies in its proficiency at predicting non-phase-locked component of internal tides, where it accounts for an additional 30% of the variance. During Cal/Val period, HYCOM effectively reduces up to 60% of the total variance for phase-locked tides and further minimizes 10-20% of non-phase-locked signals in SWOT observations at the M2 frequency. Forecast models uniquely address the challenge of predicting both phase-locked and non-phase-locked parts by effectively enhancing internal tide mapping, leading to significant improvements in altimetric data correction in the SWOT-era of oceanography.

Corresponding author:
Yadidya Badarvada (**University of Michigan**, **United States**), yadidyabadarvada@gmail.com

Progress Update on the SWOT Applications Program

Angelica Rodriguez (JPL, United States); Matthew Bonnema (NASA Jet Propulsion Laboratory, Caltech, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Novel Ka-band radar interferometer observations from the SWOT satellite bring a unique and unprecedented data source to the fields of hydrology, oceanography, cryospheric sciences, and coastal research, providing an entirely new way to understand surface water heights around the world. Moreover, they have the potential to enable new frameworks for incorporating space-based observations into actionable information. The goal of the SWOT Applications Program has historically been to maximize user readiness for SWOT data, and continues striving to ease access to, and use of, new SWOT data products in order to accelerate the uptake of SWOT data for societal benefits. To date, the NASA and CNES SWOT Applications teams have been providing continued support to applied users who are now incorporating SWOT data into their operational or decision-support workflows. Here, we will share examples of applications facilitated by the SWOT Early Adopters (EA) Community, ranging broadly from reservoir monitoring to global ocean modeling. SWOT EAs are users from government agencies, academia, private sectors, and nonprofits organizations around the world who are demonstrating the high potential for satellite remote sensing to benefit a variety of applications where water elevation is a tangible variable from which derived products and decisions can be formed. In this presentation, we will also share information about community resources and additional SWOT Applications Program activities.

Corresponding author:
Angelica Rodriguez (**JPL**, **United States**), angelica.rodriguez@jpl.nasa.gov

How Well Can We Track Global Reservoir Storage in the SWOT era?

Faisal Hossain (University of Washington, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Satellite remote sensing has long been used for tracking, modeling and estimation of reservoir state in regulated rivers before the advent of the Surface Water and Ocean Topography (SWOT) mission. Most such methods using single or multiple sensors relied on ad hoc approaches to estimate storage change as simultaneous measurement of areal extent and elevation was not available from any sensor. Now that we are in the SWOT era with unprecedent capability to simultaneously track both water extent and elevation, our study asks the question "How well can we track global reservoir relative to the pre-SWOT era or non-SWOT sensors?" We carried out this study over 245 reservoirs around the world with highly accurate storage data overlapping SWOT observations from mid-2023 to end of 2024. We used a multi-sensor (non-SWOT) reservoir storage algorithm called TMS-OS based on optical (Landsat, Sentinel-2) and microwave (Sentinel1) sensors as the non-SWOT baseline for comparison. Our study revealed that SWOT can yield an order of magnitude better estimation of absolute storage with the use of in-situ reservoir bathymetry information. SWOT's performance holds up across climate, elevation, shape and capacity, demonstrating a consistent reliability for global use. Trends in reservoir storage change are also better and more consistently captured than what is possible with non-SWOT sensors. Building on this very promising finding, our future study goal is to apply SWOT data to create accurate reanalysis of global reservoir storage data from the 1980s, improve capacity loss monitoring due to sedimentation of reservoirs and understand how harmful algal blooms (HAB) behave in regulated river systems by building synergy between SWOT and the recently launched PACE (Plankton, Aerosol, Cloud, ocean Ecosystem) satellite mission. With a large water practicing community now eager to benefit from SWOT, our future study will usher the community to improved water management practices where reservoir operations can be optimized for long-term sustainability and ecosystem function goals with SWOT data.

Corresponding author:
Faisal Hossain (**University of Washington**, **United States**), fhossain@uw.edu

A global assessment of where SWOT provides new insights for national and transboundary water resource management

Eric Sproles (Montana State University, United States); Trevor Wilkerson (Montana State University, United States); Cascade Tuholske (Montana State University, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Sound water management relies on consistent and reliable data on the timing and quantity of freshwater resources—information that is currently unevenly distributed, often with a paucity of streamflow measurements in developing economies. The Surface Water and Ocean Topography (SWOT) satellite mission represents a significant advancement in our ability to measure and understand the storage and movement of freshwater across the Earth and within the global water cycle. In addition to its scientific gains, SWOT offers essential socio-technical insights that can support better-informed water resource management for an individual country and across international borders. By enhancing observational capacity, SWOT has the potential to improve decision-making and reduce conflict over shared water resources. In this study, we integrate data from SWORD (SWOT River Database), the Global Stream Gage database, and global gridded population datasets to estimate the number of people living within 5 km and 20 km of SWORD river segments that lack a streamflow gage. Globally, SWOT can provide streamflow measurements to 1.65 billion people who live within 5km of a stream without a gage, and 3.64 billion who live within 20km of a stream without a gage. At the continental scale, Africa, Asia, and South America are projected to benefit most from increased streamflow observations enabled by SWOT. At the national level, countries such as Guatemala, Iran, and Sudan see up to a 100% increase in streamflow observation capacity. When these analyses are applied to transboundary (international) river basins, they reveal that SWOT could significantly enhance data availability in regions in the Glob(international) ersheds with high potential for hydropolitical tension (Nile, Amu Darya). Incorporating SWOT-derived products into water planning and policy offers a promising path forward—reducing uncertainty, increasing adaptability, and especially benefiting areas with limited existing monitoring systems.

Corresponding author:
Eric Sproles (**Montana State University**, **United States**), eric.sproles@montana.edu

Simulating flooding for tropical cyclones in Southern Africa with SWOT

Jeffrey Neal (University of Bristol, United Kingdom); Xiaoli Su (University of Bristol, United Kingdom); Laurence Hawker (University of Bristol, United Kingdom)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Southern Africa has recently been impacted by flooding from a series of devastating tropical cyclones, including Idai in 2019 and Freddy in 2023. Estimating the risk of flooding from these extreme weather events has been hampered by a lack of observation data in the region, especially with respect to river flows and water levels. We present research from the REPRESA project, funded by the UK and Canadian governments under their climate adaptation and resilience (CLARE) program, which aims to improve the simulation of present-day and future tropical cyclone flooding in Southern Africa.
Specifically, we present a flood inundation model driven by tropical cyclone simulations from kilometre-scale convection-permitting climate models, which has been calibrated to SWOT water height data.
To set up the model, weather reanalysis from ERA5 and a hydrological model were used to simulate river discharge in the region. Given these discharges, river bathymetry was estimated from all available SWOT River SP node heights, providing a means to calibrate a large-scale LISFLOOD-FP flood inundation model. To facilitate the simulation of complex river systems with multi-threaded rivers, we link SWOT River SP node data to the recently released Global River Topology (GRIT) river network and Fathom DEM. Compound flooding along the coastline was simulated by linking to an ocean tide and surge model (ADCIRC). The resulting model was validated against flood extents observed by Sentinel 1 from Tropical Cyclone Idai.
Corresponding author:
Jeffrey Neal (**University of Bristol**, **United Kingdom**), j.neal@bristol.ac.uk

What wide swath altimetry has made visible: two case studies of flood events

Nicolas Gasnier (CNES, France); Lionel Zawadzki (CNES, France)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Even though the SWOT's revisit time in its nominal 21-day cycle makes it inadequate for most operational applications in flood mapping and early warning, its data have opened up new perspectives for improving our understanding of floods using swath altimetry. Firstly, the two-dimensional map of water surface elevation makes visible small spatial variations in the water level that provide new information about the event. For example, in the Saint-Omer flood event case study, the difference in water surface elevation (WSE) between two adjacent flooded areas highlighted the role of a small dike that isolated them at the beginning of the flooding.

Combined with accurate topographic data, local water depth derived from SWOT's WSE is also very valuable information because it is directly related to the socioeconomic impact of the flood.

Finally, the 1-day cycle Cal/Val phase provided an opportunity to observe major flood events such as the Kakhovka Dam destruction in 2023. At these large spatial scales, the 1-day time series of WSE maps reveals the temporal dynamics of flood propagation.

The exploitation of SWOT data for flood applications requires using the Level-2 HR Pixel Cloud product, or even the upstream SLC products if necessary. Work to improve the flood-specific treatment of the Pixel Cloud is still ongoing, especially to improve data filtering in urban areas. Beyond that, the key challenge will now be to figure out how to extract useful information from these water level maps. In this context, recent and upcoming developments in high-revisit SAR imaging and nadir altimetry constellations, as well as high-resolution global and updated Digital Elevation Models (CO3D mission), open up promising possibilities for synergies with Wide Swath altimetry data.

Our presentation will focus on 3 case studies including consolidated results from the 2023 Kakhovka Dam and 2024 Saint Omer floods (France) events presented at the 2024 EGU conference [Gasnier et al, 2024]

Gasnier, N., Fjørtoft, R., Zawadzki, L., Desroches, D., Pena Luque, S., Claire, P., Barroso, T., and Nicolas, P.: Leveraging SWOT's water elevation pixel cloud to comprehend analyse the spatial dynamics of flood events, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-13278
Corresponding author:
Nicolas Gasnier (**CNES**, **France**), nicolas.gasnier@cnes.fr

A comprehensive study of Surface Water and Ocean Topography Pixel Cloud data for flood extent extraction

Quentin Bonassies (CECI, Université de Toulouse, CERFACS/CNRS/IRD, Toulouse, France); Christophe Fatras (Collecte Localisation Satellites, Ramonville-Saint-Agnes, France); Santiago Pena Luque (CNES, Toulouse, France); Pierre Dubois (Collecte Localisation Satellites, Ramonville-Saint-Agnes, France); Ludovic Cassan (CECI, Université de Toulouse, CERFACS/CNRS/IRD, Toulouse, France); Andrea Piacentini (CERFACS, Toulouse, France); Sophie Ricci (CECI, Université de Toulouse, CERFACS/CNRS/IRD, Toulouse, France); Nguyen Thanh Huy (Luxembourg Institute of Science and Technology (LIST), Luxembourg)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
The Copernicus Emergency Management Services (EMS), specifically the Emergency Rapid Mapping (ERM) service, requires the rapid generation of flood maps within hours of receiving remote sensing data. This data may be derived from optical or Synthetic Aperture Radar (SAR) sensors, each with distinct properties, such as wavelength, resolution, and band availability, which influence flood detection accuracy. Currently, the process is semi-automatic to reduce misclassification, but large-scale coverage necessitates an accurate automated first guess that can be manually refined. Machine learning (ML) approaches are being developed to assist in flood detection for both optical and SAR data, although challenges remain in regions with low sensor visibility, particularly forests and urban environments. SAR signals in flooded forests are affected by factors such as tree height and canopy density, complicating ML efforts.

In December 2022, the Surface Water and Ocean Topography (SWOT) satellite, equipped with the Ka-band Radar Interferometer (KaRIn), began providing high-quality radar data, offering at least one high-resolution pixel-cloud (PIXC) observation per 21-day repeat cycle over 97 % of the Earth's surface. Along with 2D water level estimation, SWOT provides backscattering, coherent power coefficients, interferometric coherence, and Signal-to-Noise Ratio (SNR) values—key variables for flood detection. Initially, SWOT's Ka-band data was not designed for high-resolution observations under vegetation and let alone in urban areas. However, this study explores SWOT's performance during four significant flood events worldwide: Farkadona (Greece, September 15, 2023), Chinon (France, March 31, 2024), Porto Alegre (Brazil, May 5, 2024), and Owensboro (USA, February 20, 2025). Each event is paired with Sentinel-1 or Sentinel-2 imagery within a 3-hour timeframe, providing a valuable opportunity to compare and evaluate SWOT's flood detection capabilities.

The study demonstrates that SWOT-like satellites show great promise in detecting flooded vegetation and urban areas, using the combined information from the aforementioned radar variables. Additionally, SWOT can detect floods even in regions with high snow cover. However, limitations are observed during the flood recession phase, as wet soils can cause signal saturation, leading to less reliable flood extent estimation. These findings highlight the potential of SWOT-like satellites for improving global flood mapping, as well as the need for further exploration to address current limitations and enhance flood monitoring capabilities in the near future.
Corresponding author:
Quentin Bonassies (**CECI, Université de Toulouse, CERFACS/CNRS/IRD, Toulouse**, **France**), bonassies@cerfacs.fr

Advancing India's Inland Waterbodies Monitoring with focus on SWOT mission

Pankaj R. Dhote (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Praveen K. Thakur (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Vaibhav Garg (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Hind Oubanas (G-EAU, INRAE, Montpellier, France, France); Pierre-Olivier Malaterre (G-EAU, INRAE, Montpellier, France, France); Shubhangam Garg (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Kartikeya Gaur (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Kshiitij Srivastava (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Harish Karnataka (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Pramod Kumar (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India); Raghavendra P Singh (Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun, India)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Monitoring inland water bodies is essential for understanding the hydrological cycle, as well as broader environmental and atmospheric processes within the Earth system. Accurate estimation of river discharge plays a key role in water resource management, ecosystem sustainability, and hydrological modeling. With a global decline in in-situ monitoring stations, remote sensing techniques are increasingly being adopted for estimating river, lake, and reservoir fluxes. The Surface Water and Ocean Topography (SWOT) mission, equipped with a Ka-band radar interferometer, aims to capture global hydrological fluxes through high-precision water surface elevation (WSE) measurements. This study evaluates the characteristics and uncertainties of SWOT observations over diverse Indian inland water bodies—including rivers, reservoirs, glacial lakes, and hydraulic structures—during both calibration-validation (cal/val) and science orbit phases, using in-situ and satellite altimetry datasets. Our findings indicate that the SWOT node product generally yields slightly more accurate WSE estimates compared to the raster product when validated against GNSS, in-situ, and radar altimetry data, although quality filtering reduces the temporal resolution. Conversely, the raster product captures two-dimensional WSE variability, improving spatial representation in wide river cross-sections. To further harness SWOT's potential, we developed a geo-portal to monitor water level and storage changes across major Indian reservoirs. The mission's ability to simultaneously capture spatiotemporal variations in water surface slope (WSS), strong backscatter from permanent river channels for river width estimation, and WSE provides a valuable dataset for hydrological modeling. Our analysis underscores SWOT's significant potential for inland hydrodynamic applications, while also emphasizing the need for continued evaluation in complex riverine and reservoir systems.

Corresponding author:
Pankaj R. Dhote (**Indian Institute of Remote Sensing, Indian Space Research Organisation, Dehradun**, **India**), pdh@iirs.gov.in

Evaluating the Potential of the SWOT Mission for Hydrological Applications in India

Girish Patidar (Indian Institute of Technology Bombay, India); Jayaluxmi Indu (Indian Institute of Technology Bombay, India); Subhankar Karmakar (Indian Institute of Technology Bombay, India)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission, launched in December 2022, provides a transformative view of surface water dynamics by delivering high-resolution measurements of water surface elevation (WSE), width, and slope for rivers wider than 100 m. This study evaluates the utility and performance of SWOT data for hydrological applications across India, addressing four key questions: (a) Can SWOT data improve flood mapping? (b) How effective is SWOT-based discharge in calibrating hydrological models? (c) Is SWOT performing as expected post-launch? and (d) Can SWOT data be reliably used for discharge estimation?
To assess SWOT's flood monitoring capability, we simulate orbital overpasses and compare them with flood events from the Indian Flood Inventory (IFI). SWOT would have captured 49% of total flood events and 21% of single-day flood events, demonstrating meaningful potential for augmenting flood mapping in India.
To evaluate hydrological model calibration, we generate proxy-SWOT discharge data from in-situ observations, adding mission-recommended uncertainty. Using the Mahanadi River basin as a case study, we find that SWOT-like discharge inputs support effective model calibration, especially under high-flow conditions.
We also present a first-hand validation of SWOT WSE data across 419 ground stations from April 2023 to December 2024, encompassing 14,892 observations. Results show high fidelity for rivers wider than 100 m, with Spearman's ρ_s exceeding 0.88 for the 68th percentile and a WSE error of 18 cm. SWOT also performs well for narrower rivers and shows robust accuracy over reservoirs (RE ~11–14 cm, $\rho_s > 0.65$).
Finally, we address challenges in SWOT width uncertainties for discharge estimation by testing three discharge algorithms at 10 stations using DEM-derived widths. At least one algorithm per station meets SWOT's discharge accuracy target (<30%), and the Mean Flow with Constant Roughness (MFCR) algorithm achieves reliable performance in 80% of cases. These results underscore the feasibility of using SWOT data, augmented with DEM-based widths, for accurate discharge estimation. Together, these findings establish a strong foundation for leveraging SWOT data in operational hydrology and flood management across India.
Corresponding author:
Girish Patidar (**Indian Institute of Technology Bombay**, **India**), gp14@iitbbs.ac.in

Using Surface Water Ocean Topography (SWOT) observations to analyse Land Use Land Cover changes: the case of the Pacific Coast of Ecuador

Valentine Sollier (INRAE, France); Frédéric Frappart (INRAE, UMR1391 ISPA, 33140 Villenave d'Ornon, France, France); Luc Bourrel (GET, UMR 5563, Université de Toulouse, CNRS/IRD/OMP/CNES, Toulouse, France., France); Bertrand Ygorra (INRAE, UMR1391 ISPA, 33140 Villenave d'Ornon, France, France); Cassandra Normandin (INRAE, UMR1391 ISPA, 33140 Villenave d'Ornon, France, France); Luis Huaraca (SCA, Ministerio de Ambiente Agua y Transición Ecológica, Quito, Ecuador, Ecuador); Jean-Pierre Wigneron (INRAE, UMR1391 ISPA, 33140 Villenave d'Ornon, France, France)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
The Surface Water Ocean Topography (SWOT) mission was originally launched to provide continuous spatio-temporal monitoring of water levels on oceans and land with unprecedented spatial resolution that surpasses the limitations of conventional altimetric missions (Fu et al., 2024). This study shows that the advanced capabilities of SWOT pave the way for new applications. Thus, we showed that SWOT data is also sensitive to LULC changes in Pacific Coast of Ecuador. The three study areas chosen according to a north-south gradient allow to represent climatic and landscape diversity. In the north, with a humid tropical climate and limited human presence, the area is home to mostly wet tropical forests (Area A). In the middle of the Pacific Coast, the region is home to seasonal tropical forests, more affected by anthropogenic pressures characterized mainly by the presence of the Peripa Daule hydroelectric dam (Area B). The last zone in the south, largely anthropized, is characteristic of the cultivated areas of the Pacific coast of the country (Area C). In this study, we analyzed the backscatter coefficient (noted Sig0, σ0) available in the SWOT gridded product at 100m spatial resolution for the year 2024. First, the SWOT data was pre-processed to obtain two layers: the number of occurrences of each pixel and the average value of the backscatter coefficient over the year 2024. Then, these two layers are used as input of a machine learning model (Support Vector Machine - SVM) to classify the SWOT detections. The SWOT detections were automatically classified with an SVM into three categories: city (1), river (2) and no forest (3) for Area A and four categories: city (1), river (2), road (3), cropland (4) for Area B and C. Finally, this classification of the SWOT data was then compared to three other data sources: LULC maps from the Ecuadorian Ministry of the Environment (MAATE, 2017), the RADD alerts (Reiche et al., 2021) and output results of the CuSum change detection algorithm (Ygorra et al., 2021). The first results show a good correlation with the maps of the Ministry with accuracy between 0.81 and 0.90 depending on the area considered. The results of the data classification also show that SWOT observations can provide information on agricultural parcel boundaries and road networks (Area C), on the deforested areas and the opening of deforestation fronts mainly along communication routes (Zone A), as well as on the state of agricultural parcels (Zone B). The results also highlight SWOT detections in areas affected by large and difficult-to-access topography, which would make it possible to fill out a lack of information on LULC changes in these regions. The SWOT data could therefore be a complementary source of information to existing LULC change products.

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Corresponding author:
Valentine Sollier (**INRAE**, **France**), valentine.sollier@inrae.fr

SWOT SAR Ka-band Captures Irrigation Events

Cécile Cazals (CS GROUP, France); Hassan Bazzi (UMR TETIS, University of Montpellier, AgroParisTech, INRAE, CIRAD, CNRS, France); Nicolas Baghdadi (UMR TETIS, University of Montpellier, AgroParisTech, INRAE, CIRAD, CNRS, France); Cécile Cazals (CS GROUP, France); Sami Najem (UMR TETIS, University of Montpellier, AgroParisTech, INRAE, CIRAD, CNRS, France); Damien Desroches (CNES, France); Frédéric Frappart (ISP INRAE, France); Mehrez Zribi (CESBIO, UMR 5126 Université Toulouse UT3/CNRS/IRD/CNES, USC INRAE, France); François Charron (G-EAU Unit, University of Montpellier, AgroParisTech, CIRAD, INRAE, Institut Agro, IRD, Domaine du Merle, France)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
While primarily designed for ocean and inland water monitoring through Interferometric SAR (InSAR) technology, the SWOT Ka-band SAR sensor also presents potential for agricultural applications. This study offers a novel perspective of SWOT mission by exploring the sensitivity of SWOT's Ka-band backscatter to soil moisture variations, focusing on detecting irrigation events. Using the daily calibration/validation time series data from the SWOT Level 1B High-Rate Single-look Complex product over an experimental irrigated grassland site, we examined backscatter variations in response to irrigation events and rainfall. The analysis included first evaluating the stability of SWOT Ka-band backscatter signal, the temporal responses to both irrigation and rainfall, and the influence of vegetation density on Ka-band SAR signal penetration. Main findings showed that the Ka-band SAR data was sensitive to soil moisture variation due to irrigation, inducing an increased backscattering signal by an average of 4.3 dB after irrigation events. Despite the Ka-band's short wavelength, typically limiting canopy penetration, SWOT's near-vertical incidence angle appears to enhance its ability to penetrate dense vegetation cover reaching the soil surface and detecting soil moisture dynamics. These findings open new perspectives for leveraging daily SWOT acquisitions to map irrigated areas and support agricultural water management.

Corresponding author:
Cécile Cazals (**CS GROUP**, **France**), cecilecazals@gmail.com

Hydrologic impacts on greenhouse gas emissions from streams and rivers

Peter Raymond (Yale, United States); Dongmei Feng (Univ Cincinatti, USA); Craig Brinkerhoff (Yale, USA); Minhui Li (Yale, USA)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Streams and rivers are important to the exchange of all 3 greenhouse gases. Early scaling estimates noted higher fluxes in wetter regions. More recently, it was demonstrated that a greater percentage of terrestrial CO2 is stripped in regions with greater water throughput. The mechanisms that drive stream and river responses to hydrologic variability is, however, complex. Regional emissions are calculated using estimates of the concentration gradient, gas transfer velocity, and surface area and all 3 of these variables vary with discharge. Here we will present the knowledge base of hydrologic drivers of GHG evasion across scales. We will also discuss how this knowledge base might be incorporated into scaling, and how the SWOT mission might contribute to future advancements.

Corresponding author:
Peter Raymond (**Yale**, **United States**), peter.raymond@yale.edu

Promoting and explaining a new technology: Swot outreach

Vinca Rosmorduc (CLS, France); Nicolas Picot (CNES, France)

Session: Hydrology: Open Science & Applications
Presentation type: Oral

Abstract:
Swot KaRIn instrument is a completely new concept. Some pieces of explanations existed through the CNES space technology training courses, some had been posted on the JPL & Cnes project web pages, but more could be done and made available -- and has been, with a major focus on hydrology, but not forgetting the ocean, and the complementarity with currents techniques, including nadir altimetry. Series of ppt slides have been developed and released during the past 5 years, they have now been updated with real Swot data, and will continue to be. With those data available, a portfolio of the early images is posted and updated on Aviso web site.

Communication on results, articles and other publications is also done, in order to promote Science Team work, and also to get would-be users familiar with the data, pinpoint their differences with classical and delay-Doppler altimetry alike and give glimpses of what new uses and applications could be developped from those data.
This presentation will also be the occasion to discuss your need in the field
Corresponding author:
Vinca Rosmorduc (**CLS**, **France**), vrosmorduc@groupcls.com

Submesoscale Eddy Dynamics from SWOT and SST via Generative Data Assimilation

Scott Martin (University of Washington, United States); Georgy Manucharyan (University of Washington, United States); Patrice Klein (California Institute of Technology, United States)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) mission offers an unprecedented view of submesoscale ocean eddy dynamics from space, with the potential to transform our understanding of the role of submesoscale eddy turbulence in transport and energy dissipation. However, diagnosing eddy dynamics from SWOT sea surface height (SSH) alone is challenging due to the superposition of balanced and unbalanced motions in SWOT measurements and the relatively long 21-day orbit repeat cycle—much longer than typical submesoscale time scales. Satellite sea surface temperature (SST) offers daily global coverage of submesoscale features, though gaps due to cloud cover and its indirect relation to dynamics make interpretation challenging. Combining SWOT SSH with SST thus presents a promising avenue for inferring submesoscale surface dynamics.

We leverage generative data assimilation [1–3]—a recently proposed deep learning framework for simulation-informed inverse problems—to estimate submesoscale surface currents from SWOT SSH and satellite SST. Specifically, we train a score-based diffusion model on high-resolution output from a submesoscale-permitting ocean simulation (LLC4320). This model learns to generate physically realistic surface ocean states, including both observed variables (SSH, SST, salinity) and unobserved ones (surface currents), capturing their joint structure.

Once trained, the model is guided at inference by sparse satellite observations of SSH, SST, and salinity to produce state estimates that match available measurements while respecting the learned physical prior. We demonstrate that this approach enables: (1) estimation of ageostrophic surface currents by synergizing SSH and SST, (2) gap-filling of SWOT SSH using SST to achieve high-resolution reconstructions between passes, and (3) enhanced resolution of satellite salinity fields. As the diffusion prior is learned from numerical simulation output, the accuracy of the state estimates depends on the physical realism of the training data and may reflect any inherent biases in the simulation due to limited resolution or imperfect parameterizations. We discuss the strengths and limitations of generative data assimilation for advancing submesoscale oceanography and improving observationally constrained estimates of ocean eddy dynamics.

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Corresponding author:
Scott Martin (**University of Washington**, **United States**), smart1n@uw.edu

Short-term neural forecasts of sea surface dynamics

Daria Botvynko (IMT Atlantique, France); Pierre Haslée (IMT Atlantique, France); Clément de Boyer Montégut (IFREMER, France); Bertrand Chapron (IFREMER, France); Lucile Gaultier (Oceandatalab, France); Anass El Aouni (Mercator Ocean, France); Julien Le Sommer (Univ. Grenoble Alpes, France); Ronan Fablet (IMT Atlantique, France)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
Recent advances in machine learning have significantly improved data-driven Earth system modeling and forecasting, with architectures ranging from 3D convolutional networks [Bi et al., 2023] to graph-based models [Lam et al., 2022] and ocean-specific neural emulators [Wang et al., 2024; Martin et al., 2023]. In this study, we benchmark model-based, neural emulators and observation-based neural ocean forecasting approaches for short-term prediction of sea surface height and surface currents.
Within a standardized ocean forecasting benchmark, we evaluate multiple observation-driven neural architectures—including 4DVarNet [Fablet et al., 2021, 2023] and UNet variants—trained end-to-end on sparse observational inputs to forecast gap-free SSH and geostrophic velocity fields up to seven days ahead. Our results demonstrate that these models consistently outperform the operational GLO12 model-based forecast baseline in terms of normalized root mean square error (nRMSE) for SSH, as well as geostrophic velocity angle and direction scores.
The model training and evaluation are conducted within a standardized benchmarking environment inspired by OceanBench project [Johnson et al., 2023]. This environment provides machine learning–ready datasets, reproducible workflows, and open-source evaluation protocols. It integrates diverse data sources, including ocean reanalyses, sparse and gap-free satellite products and in situ observations. Future work will incorporate SWOT swath altimetry data, which has demonstrated significant improvements in sea surface height (SSH) reconstruction, enhancing space–time resolution by up to 50% relative to nadir-only configurations [Beauchamp et al., 2023]. Its integration is anticipated to further improve short-term sea surface dynamics forecasting accuracy over the current nadir-based approach.
Corresponding author:
Daria Botvynko (**IMT Atlantique**, **France**), daria.botvynko@imt-atlantique.fr

Mapping SSH with VarDyn: Combining Physics and Variational Techniques for SWOT Data

Florian Le Guillou (Datlas, France); Valentin Bellemin-Laponnaz (IGE, France); Sammy Metref (Datlas, France); Maxime Ballarotta (CLS, France); Clément Ubelmann (Datlas, France); Emmanuel Cosme (IGE, France)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
For over three decades, sea surface height (SSH) gridded products derived from altimetry have been indispensable for numerous oceanographic applications. The Surface Water and Ocean Topography (SWOT) mission, with its unprecedented kilometric spatial resolution, offers a transformative capability to observe fine-scale ocean processes. However, its relatively low temporal revisit poses significant challenges for capturing fast-evolving phenomena such as short mesoscale structures and internal tides.
To address these challenges, recent research has focused on developing innovative mapping algorithms that fully exploit SWOT's potential. In this presentation, we introduce VarDyn, a hybrid variational mapping methodology that seamlessly integrates simple physical principles into advanced variational inversions. VarDyn leverages a Quasi-Geostrophic (QG) model constraint to guide the reconstruction of SSH fields, enabling it to surpass the performance of existing operational products using both conventional altimetry and SWOT data on a global scale.
Moreover, we demonstrate that VarDyn's design allows the combination of the QG model with a linearized Shallow Water model, enabling the simultaneous mapping and separation of balanced ocean motions from internal tides. This hybrid approach offers a promising avenue for enhancing the resolution and fidelity of SSH products, ultimately advancing our understanding of ocean dynamics at multiple scales.
Corresponding author:
Florian Le Guillou (**Datlas**, **France**), florian.leguillou@datlas.fr

Impact of SWOT assimilation on Mercator Ocean International 's global forecasting system

Mounir Benkiran (Mercator-Ocean International, France); ergane fouchet (Mercator-Ocean International, France); Pierre-Yves Le Traon (Mercator-Ocean International, France)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
Mercator Ocean International (MOi) has conducted several Observing System Simulation Experiments (OSSEs) to assess the potential of SWOT and more generally swath altimetry for ocean forecasting. The results have shown that the complementarity of SWOT with night-time data improves the quality of ocean forecasts. The launch of the SWOT satellite took place on 16 December 2022. We used the last version of SWOT (v2.0.1) data (nadir+karin) to carry out the assimilation of these data in our global (1/12°) forecasting system. We highlight the contribution of SWOT to global system forecasting. A new data assimilation technique with scale separation has been tested at MOi. Adding SWOT observations to those of others nadir altimeters globally reduces the variance of Sea Level Anomaly by 20%, respectively. We present the impact of SWOT (21-days Orbit) data assimilation on ocean forecast quality. We test new metrics to highlight the impact of SWOT data using independent data.
Corresponding author:
Mounir Benkiran (**Mercator-Ocean International**, **France**), mbenkiran@mercator-ocean.fr

Accounting for observation error correlations for the assimilation of SWOT ocean data

Olivier Goux (CERFACS/CECI, Afghanistan); Anthony Weaver (CERFACS/CECI, France); Andrea Piacentini (CERFACS/CECI, France); Selime Gürol (CERFACS/CECI, France)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
Data assimilation consists of a range of methods which can be used to correct a prior estimate of the state of a system, called the background state, with observations of this system. In particular, for the physical ocean, the state is typically defined as the values of temperature, salinity, sea surface height and velocity at every point on a three-dimensional grid. In order for this correction to be statistically optimal, it is crucial to specify correctly the covariance matrices of the respective errors of the background state and observations. While many sophisticated methods are available to model background error covariances, the assumption of uncorrelated observation errors is commonly made for numerical convenience in ocean forecast and reanalysis systems. However, this assumption becomes problematic when dealing with certain observation types, notably high-resolution satellite data such as SWOT data.

Neglecting observation error correlations during assimilation often results in suboptimal analyses, where observations tend to be overfit at large spatial scales and underfit at small scales. Conventional mitigation strategies include thinning — assimilating only a subset of spatially separated observations — and inflating variances to mitigate overfitting at large scales. Both methods inhibit the extraction of small-scale features from observations and thus limit the potential of high-resolution data. In this poster, we describe developments for modelling correlated error in altimeter data for the ocean data assimilation system NEMOVAR (used operationally by the ECMWF and UK Met Office). The approach is based on a diffusion operator which provides a cost-effective and flexible framework for modelling the inverse observation-error correlation operator with unstructured data. We explore the influence of the observation-error correlations on the quality of the analysis, and provide insights into how the choice of an observation-error correlation model must reflect a balance between computational efficiency and accuracy.

Corresponding author:
Olivier Goux (**CERFACS/CECI**, **Afghanistan**), goux@cerfacs.fr

Using SWOT for ocean monitoring and prediction off Canada's west and east coasts

Guoqi Han (Fisheries and Oceans Canada, Canada); Gregory Smith (Environment and Climate Change Canada, Canada)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
Surface Water and Ocean Topography (SWOT) sea surface height anomaly (SSHA) data were used for ocean monitoring and prediction off Canada's west and east coasts. For the ocean monitoring, a method was developed to reconstruct weekly, monthly and seasonal SSHA fields on a regular spatial grid. Surface geostrophic current anomalies were derived from the reconstructed SSHA fields. Experiments were carried out to refine the reconstruction method and to assess temporal and spatial scales in which SSHA and current features can be reconstructed properly. The mean surface circulation field from a coastal ocean model was added to the SWOT surface current anomalies to produce the absolute currents. For the ocean prediction, after successful Observing System Simulation experiments, real SWOT data were assimilated in the Regional Ice Ocean Prediction System demonstrating significant improvements in SSHA statistics. Further efforts to investigate how to constrain small-scale features from SWOT are being pursued in a 1/36th degree resolution configuration for the Northwest Atlantic Ocean.
Corresponding author:
Guoqi Han (**Fisheries and Oceans Canada**, **Canada**), Guoqi.Han@dfo-mpo.gc.ca

Impact of SWOT data on mesoscale and submesoscale dynamics in a Western Boundary Current

Colette Kerry (UNSW Sydney, Australia); Shane Keating (UNSW Sydney, Australia); Moninya Roughan (UNSW Sydney, Australia); Marina do Valle Chagas Azaneu (UNSW Sydney, Australia)

Session: Oceanography: Inversion/Assimilation
Presentation type: Oral

Abstract:
Ocean state estimates that represent mesoscale and submesoscale dynamics are crucial for climate research and ocean forecasting. Accurate submesoscale representation in ocean models is a current challenge due to the rapidly evolving flow and lack of observations at suitable scales. The SWOT satellite provides a step change in ocean surface measurements at kilometre-scale resolution. We use a regional 4DVar data assimilation scheme to demonstrate the impact of SWOT observations on circulation estimates in a high-resolution hydrodynamic model of a Western Boundary Current. We show that assimilating SWOT data improves representation and prediction of the larger-scale mesoscale motions and improves representation --- but not prediction --- of the fine-scale dynamics. Increased relative vorticity variance with SWOT assimilation is widespread in space and time (away from SWOT observations) and projected to depth. Using data observed by SWOT in a realistic ocean model, we show enhanced representation of ocean processes across scales, essential for better climate projections and real-time forecasts.

Corresponding author:
Colette Kerry (**UNSW Sydney**, **Australia**), c.kerry@unsw.edu.au

Global Bathymetry Estimation from SWOT Altimetry Using Deep Learning and Integrated Geophysical Features

Farshad Salajegheh (The University of Newcastle, Australia); Xiaoli Deng (School of Engineering, University of Newcastle, Newcastle, Australia, Australia); Ole Baltazar Andersen (DTU Space, Technical University of Denmark, Lyngby, Denmark., Denmark); Richard Coleman (Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Tasmania, Australia, Australia)

Session: Oceanography: Mean Sea Surface
Presentation type: Oral

Abstract:
We introduce BathDNN25, a deep neural network model purpose-built to enhance global bathymetric prediction using satellite-derived gravity data. The model is trained on shipborne bathymetry and leverages geophysical inputs derived from the Surface Water and Ocean Topography (SWOT) mission's wide-swath altimetry, including gravity anomalies, deflections of the vertical (DoV), vertical gravity gradients (VGG), and their band-pass filtered variants.

BathDNN25 is specifically designed to overcome limitations posed by sparse in-situ data and complex geological variability. A key architectural innovation is the integration of both raw and band-pass filtered VGG features, enabling the model to resolve subtle and multi-scale seafloor features such as ridges, escarpments, trenches, and seamounts. Through adaptive feature extraction and multi-scale learning, the model generalizes effectively across geologically diverse marine regions.

Extensive validation shows BathDNN25 significantly outperforms existing models, achieving residual standard deviations of 97 m for shipborne data and 205 m for seamounts. These results represent accuracy improvements exceeding 55% and 74%, respectively, over state-of-the-art methods (Harper and Sandwell, 2024).

BathDNN25 demonstrates the potential of deep learning to transform bathymetric mapping by fusing satellite altimetry with carefully engineered geophysical features. Its scalability, precision, and robustness offer a valuable tool for advancing global ocean modeling, geophysical interpretation, and marine resource exploration.

Corresponding author:
Farshad Salajegheh (**The University of Newcastle**, **Australia**), farshad.salajegheh@newcastle.edu.au

The new CNES CLS 2025 MSS model leveraging SWOT KaRIn data

Rémy Charayron (CLS, France); Philippe Schaeffer (CLS, France); Maxime Ballarotta (CLS, France); Antoine Delepoulle (CLS, France); Marie-Isabelle Pujol (CLS, France); Gerald Dibarboure (CNES, France)

Session: Oceanography: Mean Sea Surface
Presentation type: Oral

Abstract:
The mean sea surface (MSS) represents the mean of the sea surface height (SSH) over a given period. It allows to define the so-called sea surface height anomaly (SSHA) in use for plenty of ocean applications ranging from geostrophic currents determination to extreme events detection or climate change monitoring. Errors in the mean sea surface are automatically reflected as sea surface height anomaly errors, which affects the performance of the applications. The data provided by the Ka-band Radar Interferometer (KaRIn) from the Surface Water and Ocean Topography (SWOT) mission is expected to bring a revolution to the altimetry field, and mean sea surface is no exception. SWOT KaRIn strength relies on two key advantages: its outstanding precision and its 2-dimensional swath data. The improvement of precision should make possible the resolution of small-scale ocean features previously unattainable. The 2-dimensional measurements will reveal the spatio-temporal coherence of the oceanic features, not only along-track but also across-track. In this work, we deliver a new MSS model: the CNES CLS 2025. Starting from a MSS first guess for the long wavelengths, the new model takes advantage of SWOT KaRIn data to improve the lower-mesoscale accuracy. It also benefits from the long-term temporal stability of thirty years of nadir altimetric data used through the static part of a Multiscale Inversion of Ocean Surface Topography (MIOST) mapping. The CNES CLS 2025 MSS unveils seamounts or other geodetic structures never seen before and outperforms state-of-the-art MSS model on many metrics of interest. These results using SWOT data underline the potential of swath altimetry for the future of ocean topography.

Corresponding author:
Rémy Charayron (**CLS**, **France**), remy.charayron@laposte.net

Bathymetry Prediction from SWOT derived gravity using Machine Learning

Bjarke Nilsson (Technical University of Denmark, DTU Space, Denmark); Biao Lu (Technical University of Denmark, DTU Space, Denmark); Farshad Salajegheh (School of Engineering, University of Newcastle, Callaghan, NSW, Australia); Benjamin J. Phrampus (United States Naval Research Laboratory, Stennis Space Center, MS, USA); Jonathan Kirby (Technical University of Denmark, DTU Space, Denmark); Paul Elmore (Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA); Xiaoli Deng (School of Engineering, University of Newcastle, Callaghan, NSW, Australia); Luis Altamirano (The University of Southern Mississippi, Division of Marine Science, MS, USA); Yao Yu (Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA); Walter H. F. Smith (8 Center for Satellite Applications and Research, National Oceanographic and Atmospheric Administration, College Park, MD, USA); Ole B. Andersen (Technical University of Denmark, DTU Space, Denmark); David Sandwell (Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA)

Session: Oceanography: Mean Sea Surface
Presentation type: Oral

Abstract:
The introduction of high-resolution sea surface observations provided from the Surface Water and Ocean Topography (SWOT) satellite has enabled the generation of marine gravity fields at 8-km resolution with 1-2 mGal accuracy using just one year of data, representing a major improvement over 30 years of conventional nadir altimetry. The low noise in the short-wavelength observations from SWOT is critical for bathymetric inversion, where gravity precision strongly impacts seafloor predictions. To take full advantage of the possibilities provided with the new data from SWOT, an international workshop at the Technical University of Denmark (DTU) was held in November 2024 with the goal of utilizing the high-resolution gravity field from SWOT, together with Machine Learning models, to provide the best possible bathymetric maps from ocean gravity.

We present key results from this workshop, including:
1. Bathymetry predictions produced by five research groups using different ML architectures. All models demonstrated significant global improvements in accuracy (20–30%) compared to the previous bathymetry release (V32), with the largest enhancements over continental shelves and deep ocean trenches.
2. Cross-model comparisons that revealed how different ML design choices affect predictive performance and identified persistent challenges posed by the sparse distribution of ship-based depth soundings, which serve as training labels.
3. Comparison with conventional physics-based inversions, showing that machine learning methods resolve nonlinear components in the gravity-topography transfer function, which improve prediction over seamount summits.

Corresponding author:
Bjarke Nilsson (**Technical University of Denmark, DTU Space**, **Denmark**), bjarke@space.dtu.dk

Enhancing Coastal Bathymetry Prediction by Integrating SWOT and Air-Marine Gravimetry Data with Machine Learning

Biao Lu (DTU Space, Technical University of Denmark, Denmark); Bjarke Nilsson (DTU Space, Denmark); Andreas Stokholm (DTU Space, Denmark); Bjørnar Dale (DTU Space, Denmark); Tim Jensen (DTU Space, Denmark); Gabriel Strykowski (DTU Space, Denmark); Jonathan Kirby (DTU Space, Denmark); René Forsberg (DTU Space, Denmark); Ole Andersen (DTU Space, Denmark); Walter Smith (Laboratory for Satellite Altimetry, National Oceanic and Atmospheric Administration (NOAA), United States); David Sandwell (Scripps Institute of Oceanography, United States)

Session: Oceanography: Mean Sea Surface
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite mission provides unprecedented, high-resolution gravity signals over the world's oceans, offering new opportunities for detailed seafloor mapping, particularly in shallow and complex coastal regions. In this study, we integrate air-marine gravimetry with SWOT-derived gravity signals to improve bathymetric prediction in coastal areas using machine learning techniques. The SWOT gravity data are first cross-validated against available air-marine gravimetry, then combined to produce enhanced multi-source gravity datasets. We systematically assess the predictive contributions of various gravity-derived inputs, including gravity anomalies commonly used in the Nettleton method, gravity gradients, and vertical deflections, while evaluating the impacts of different filtering strategies. Our approach addresses key challenges in multi-source data fusion and nonlinear modeling, enabling the resolution of fine-scale seafloor features undetectable by conventional altimetry-based gravity products. Preliminary results demonstrate that our bathymetric models improve seafloor depth predictions by 20–30% compared to traditional techniques in representative coastal regions, including areas off Malaysia and Greenland. These findings highlight the potential of combining SWOT data with air-marine gravimetry and machine learning to advance regional bathymetric mapping and reveal previously unresolved seafloor structures.

Corresponding author:
Biao Lu (**DTU Space, Technical University of Denmark**, **Denmark**), bialu@space.dtu.dk

ADVANCING MARINE GRAVITY FIELD RECOVERY IN THE BAY OF BENGAL USING SURFACE WATER AND OCEAN TOPOGRAPHY ALTIMETRY DATA

Milaa Murshan (IIT Bombay, India); Indu Jayaluxmi (IIT Bombay, India); Ropesh Goyal (Indian Institute of Technology (BHU), Varanasi, India)

Session: Oceanography: Mean Sea Surface
Presentation type: Oral

Abstract:
Recovering the marine gravity field from satellite altimetry is essential for geoid modeling and for understanding ocean circulation, tectonic activity, seabed dynamics, and seafloor topography. Among available techniques, the Inverse Vening Meinesz Method (IVM)—which utilizes Deflection of the Vertical (DoV) components—has proven to be a robust alternative to the Inverse Stokes' Integral Method (ISM), which relies on geoid heights. The accuracy of the IVM method is highly dependent on the precision of the DoV inputs.

This study enhances marine gravity field estimation in the Bay of Bengal using the IVM, with DoV components derived from observations collected over 19 cycles of the Surface Water and Ocean Topography (SWOT) mission. Unlike earlier studies limited to simulated or single-cycle SWOT data, this work significantly improves temporal coverage and captures both static and dynamic gravity features. High-resolution DoV components were computed on a fine spatial grid, targeting improved precision in the recovered gravity field.

Validation is performed using shipborne gravity data and comparisons with established global gravity models, including EGM2008, SSv29.1, and DTU21GRA. To further ensure reliability, the SWOT-derived results are cross-validated with data from other satellite altimetry missions (e.g., Jason series, CryoSat-2). This multi-mission integration leverages SWOT's high spatial resolution and the long-term consistency of traditional altimeters, facilitating both bias correction and enhanced temporal coverage.

Building upon prior work in the Bay of Bengal, this study demonstrates the benefits of multi-cycle SWOT data in refining marine gravity estimates. The results are expected to significantly improve regional geoid modeling and offer insights into subsurface density variations. The proposed methodology is also adaptable to other geophysically complex regions, laying a foundation for broader application across the Indian Ocean, particularly in areas with weak geoid signals.

This research helps advance marine geophysics by showing how SWOT data can be used effectively to recover gravity fields. The findings support enhanced oceanographic studies, improved navigation, and a more profound understanding of the interactions between oceanic and geophysical processes in coastal regions.

Keywords: Surface Water and Ocean Topography, Bay of Bengal, Marine Gravity, Deflection of the Vertical, Satellite Altimetry, Gravity Field Recovery

Corresponding author:
Milaa Murshan (**IIT Bombay**, **India**), milaa.murshan@gmail.com

The Case for Moving SWOT to an Interlaced Orbit

Ole Baltazar Andersen (Professor, Denmark); Bjarke Nilsson (DTU Space, Denmark); Jon Kirby (DTU Space, Denmark); Farshad Salajeghed (University of Newcastle, NSW, Australia); Benjamin J Phrampus (United States Naval Research Laboratory, Stennis Space Center, USA); Paul Elmore (Applied Physics Laboratory, Johns Hopkins University, USA); James Beale (National Geospatial-Intelligence Agency, St Louis, , USA); Roberts Jamie (National Geospatial-Intelligence Agency, St Louis, , USA); Luis Parez (The University of Southern Mississippi, USA); Yao Yu (Scripps Institution of Oceanography, University of California San Diego, USA); David Sandwell (Scripps Institution of Oceanography, University of California San Diego, USA); Walter Smith (Center for Satellite Applications and Research, National Oceanographic and Atmospheric Administration, USA)

Session: Oceanography: Mean Sea Surface
Presentation type: Oral

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite mission is currently providing sea surface height observations with unprecedented detail. The marine gravity field, the mean sea surface (MSS), and gravity-derived bathymetry are being improved by SWOT in ways that are truly phenomenal and revolutionary. However, these improvements are non-uniformly distributed over the oceans due to two factors: (1) SWOT's 21-day orbit leaves diamond-shaped gaps in the coverage of the oceans, and (2) SWOT has optimal sampling resolution close to the center of each swath, with higher noise moving closer to the edges. This limits the area covered by the highest possible resolution obtained from SWOT These two limitations have left a clear visible impact on the MSS and gravity with non-uniform accuracy and resolution. If SWOT continues on the same 21-day repeat orbit, further improvements in the MSS & gravity will be marginal at best.
Shifting the orbit of SWOT to a new ground track that interlaces the current orbit will provide high-resolution SWOT in all diamond-shaped holes (in the present field) and will result in major gains in accuracy and resolution of the resulting MSS, gravity and derived bathymetry. More important is that these will all have uniform accuracy and resolution globally.
Shifting the ground-track to an interlaced orbit will have the largest effect at low latitudes where the diamonds are largest (up to >100 km in the north-south direction). At mid and high latitudes, where the diamond decreases in size the effect is smaller until

Spatial resolution determined from spectral coherence between the new mean sea surface model (DTU25) that contains SWOT data. Current state of the art models (DTU21, CLS22 and Hybrid MSS) as well as 93 cycles of an independent SWOT pass from the Calibration and Validation (CalVal) orbit configuration.
Using data from the selected CalVal orbit, which is shifted compared with the Science orbit, we can determine the difference between along-track segments that are affected by diamond gaps, and along-track segments that are not affected by diamond gaps in the Science orbit.

Corresponding author:
Ole Baltazar Andersen (**Professor**, **Denmark**), oa@space.dtu.dk

Atmospheric Gravity Waves signature on the sea surface: Insights from SWOT and OSCAR observations

Adrien Martin (NOVELTIS, France); Eva Le Merle (NOVELTIS, FRANCE); David McCann (NOC, United-Kingdom); Christine Gommenginger (NOC, United-Kingdom); José Da Silva (University of Porto, Portugal); Mahmoud El Hajj (NOVELTIS, FRANCE); Francesco D'OVIDIO (LOCEAN-IPSL, FRANCE); Tania Casal (ESA-ESTEC, Netherlands); Gérald Dibarboure (CNES, France); Yannice Faugère (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_001

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite mission, launched in December 2022, delivers groundbreaking 2D and high-resolution observations of oceanic dynamics with centimeter-level precision in Sea Level Anomaly (SLA) measurements. Additionally, SWOT measures the ocean surface roughness (Normalized Radar Cross Section - NRCS), which is highly complementary to SLA to interpret processes at the interface between the ocean and the atmosphere.

During the SWOT Cal/Val 1-day repeat orbit in 2023, several campaigns were conducted under the Adopt a Crossover (AdaC) consortium. In the Western Mediterranean Sea, the BioSWOT-Med campaign focused on biogeophysical processes at the core and edge of an eddy north of Minorca. In parallel, OSCAR, the airborne demonstrator of the satellite mission concept SeaSTAR, was deployed below the western sub-swath of SWOT Track 3 during the Cal/Val period. OSCAR measures the roughness and the Doppler shift in phase of the ocean surface with a pixel of 8m and derives the ocean surface current and wind at 100m resolution. Three flights were conducted on the 5th, 7th and 8th of May 2023.

On the 8th of May, waves of about 2km wavelength are visible in SWOT SLA and NRCS. In SWOT SLA data, these waves have an amplitude of about 2 cm, corresponding to a direct inverse barometric effect of 2hPa. These waves are clearly visible in OSCAR data across the three antennas in both NRCS and phase. Météo-France AROME (resolution of ~1km) numerical model outputs confirm the existence of the wave, although the model does not reproduce the wavelength (>5km) and the amplitude (~0.2hPa). The signature visible by the SWOT and OSCAR radars on the surface roughness (NRCS) is directly due to oscillation of increased/decreased wind speed, without significant change in the wind direction.
This paper provides a comprehensive overview of the atmospheric gravity waves signature on the sea surface, highlighting the SWOT's unparalleled capability to produce 2D maps of SSH with km-scale resolution and centimeter-level precision.

Corresponding author:
Adrien Martin (**NOVELTIS**, **France**), adrien.martin@noveltis.fr

Assessment of the Wet Tropospheric Correction from the SWOT Radiometer

Thibault Pirotte (CLS, France); Marie-Laure Frery (CNES, France); Bruno Picard (Fluctus, France); Laiba Amarouche (CLS, France); Hélène Roinard (CLS, France); François Bignalet-Cazalet (CNES, France); Gérald Dibarboure (CNES, France); Matthias Raynal (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_002

Abstract:
The aim of the SWOT mission is to measure ocean topography and hydrological water level at high precision and spatial resolution. It carries a Ka-band wide-swath interferometric altimeter (KaRIn) and a conventional Ku and C-band nadir altimeter (Poseidon-C). SWOT also includes two microwave radiometers (MW) to correct the measurements of the two altimeters KaRIn and Poseidon-3C for the delay due to the water vapor content in the troposphere. This is known as the Wet Tropospheric Correction (WTC) and it is necessary for accurate sea surface height measurements. Unlike conventional nadir-looking radiometers, the SWOT radiometer features two beams oriented on both sides of the nadir track. This configuration was specifically developed to match the wide swath coverage of the KaRIn altimeter. The WTC applied along both the nadir altimeter track and across the KaRIn swath is then derived through spatial interpolation of WTC measurements from these two off-nadir beams by two distinct interpolation algorithms designed respectively by CNES/CLS and JPL.
Comparisons with different independent references, either from geophysical models (ECMWF) or other instruments such as GPM/GMI (Global Precipitation Measurement Microwave Imager) or Sentinel-6 AMR-C, indicate that the interpolated SWOT Wet Tropospheric Correction delivers accurate and stable global correction over open ocean, consistent with mission requirement, and better than the Wet Tropospheric Correction computed with the operational model provided by ECMWF, especially in water vapor front zones.
However, several degraded situations have been identified and analyzed. These include data loss in the interpolated WTC where the radiometer measurements are rejected on one beam (due either to precipitation, presence of land, or presence of ice), increased noise in coastal areas due to land contamination, and a lack of sensitivity to fine-scale spatial variations in atmospheric water vapor.
These limitations highlight the challenges of retrieving reliable WTC in complex environments for new altimeter geometries and suggest directions for future improvements in data processing or radiometer instrumental design for future altimetry missions implying wide-swath altimeter.
We propose in this presentation to summarize the main results of this work.

Corresponding author:
Thibault Pirotte (**CLS**, **France**), tpirotte@groupcls.com

Advances in Sea Level Mapping with SWOT KaRIn Data

Maxime Ballarotta (CLS, France); Clément Ubelmann (DATLAS, France); Antoine Delepoulle (CLS, France); Florian Le Guillou (DATLAS, France); Cécile Anadon (CLS, France); Alice Laloue (CLS, France); Sammy Metref (DATLAS, France); Anaelle Treboutte (CLS, France); Marie-Isabelle Pujol (CLS, France); Ronan Fablet (IMT, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_003

Abstract:
In 2024, a new generation of gridded sea surface height (SSH) products was developed by integrating observations from the current constellation of nadir altimeters and the Surface Water and Ocean Topography (SWOT) mission.

These enhanced Level 4 multi-mission products are freely available via the AVISO+ portal and have recently undergone evaluations aimed at quantifying the added value of SWOT's KaRIn instrument to the existing altimeter constellation. Notably, incorporating KaRIn data has led to an average reduction of approximately 10% in SSH mapping errors in regions characterized by energetic meso- and submesoscale dynamics. However, certain areas—particularly those affected by intense tropical rainfall, complex tropospheric conditions, storm tracks, or strong internal tide signals—exhibit anomalous responses to KaRIn integration, highlighting the need for improved processing in this complex atmospheric and oceanic variability.

To address these challenges, an experimental update of the multi-mission gridded product has recently been released, featuring enhanced error characterization within the mapping algorithms. Preliminary validation indicates significant improvements. Concurrently, substantial efforts have been made to extend data-driven, dynamic mapping approaches—initially developed for the North Atlantic region—to a global scale. These new methodologies now offer promising perspectives for generating enriched SSH products on a global grid.

This presentation will highlight these validation results and discuss the methodological advancements underpinning these improved gridded products.
Corresponding author:
Maxime Ballarotta (**CLS**, **France**), mballarotta@groupcls.com

KaRIn Noise reduction using a Convolutional Neural Network for the SWOT 2km and 250m ocean product

Gaétan Meis (Collecte Localisation Satellite CLS, France); Anaëlle Tréboutte (CLS, France); Marie-Isabelle Pujol (CLS, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_004

Abstract:
The recent launch of the new altimetric satellite SWOT (Surface Water and Ocean Topography) was a revolution in oceanography. It can observe ocean dynamics at mesoscale and submesoscale by measuring the Sea Surface Height (SSH) using two KaRIn (Ka-band Radar Interferometer) instruments. It provides two-dimensional measurements of Sea Surface Height (SSH) at high resolution: 2 km and 250 m (also known as Unsmooth product). For each product, SSH field is impacted by a noise that comes from the instrument and is referred to as KaRIn noise. Although the Karin noise is lower than initially expected (Fu et al, 2024), it does present some limitations to the use of the data, particularly when looking at SSH-derived components. A few millimeters of noise can be rapidly amplified by derivatives of order 1 and above, making the result difficult to exploit in terms of physical signal analysis.

Here, we present the denoising method applied to a KaRIn L3 production available on AVISO+. For the 2km product a neural network model based on a U-Net architecture was developed, and it was trained and tested with simulated data in the North Atlantic. The U-Net described in Tréboutte et al. (2023) gives satisfying results on real SWOT data except where the waves heights are important (Dibarboure et al., 2024). Improvements of the U-Net are ongoing and the method was recently consolidated to fix some limitations observed in previous versions. A validation benchmark has also been developed to evaluate the quality of the denoising. The U-Net methodology was also adapted on KaRIn unsmooth production.

REF:

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Corresponding author:
Gaétan Meis (**Collecte Localisation Satellite CLS**, **France**), gmeis@groupcls.com

Cross-comparison at cross-over between SWOT LR SSH products and Sentinel-3 marine altimetry products

Salvatore Dinardo (EUMETSAT, Italy); Bruno Lucas (EUMETSAT, Germany); Carolina Nogueira Loddo (EUMETSAT, Germany)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_005

Abstract:
SWOT is an Earth-Observation science mission dedicated to measuring surface water and ocean topography and jointly developed by NASA and CNES, in partnership with the Canadian Space Agency and UK Space Agency. The primary payload on board SWOT is a Ka-Band swath radar altimeter (KaRIn) which is covering the ocean in Low-Rate (LR) operation mode. A Ku-band Poseidon-Class nadir radar altimeter and a microwave radiometer is also embarked to support and complement the KaRIn swath measurements.

Over the ocean, the SWOT Science Team provides the user community with the LR L2 SSH (Sea Surface Height) forward-processed products via the NASA and CNES distribution centres. These products are delivered on a 2x2 km geographically fixed grid with a short latency (usually few days) and they are now in version D, spanning the time-frame 28-April-2025 onward.

In this work, we assess the performance and data quality of this SWOT L2 D SSH dataset at cross-over points with the Copernicus Sentinel-3 altimeter marine data in term of variance and bias at the cross-over location. The cross-over time difference will be chosen as short as possible (< 2 hours) to limit the impact of the natural ocean variability and both satellites S3A/B will be used to improve the geographic coverage. Also, special case of collinear tracks between Sentinel-3 and SWOT will be analysed, if any.

The Sentinel-3 marine altimetry dataset to be used is an operational non-time-critical (NTC) dataset from baseline collection BC006.01 that was updated on 2024-12-04 to latest GDR-G standards.

In the cross-comparison exercise, we take care that the same “standards” are used in both datasets. The objective is to identify any residual long wavelength error or systematic sea-state bias dependency error which may be still persisting after the KaRIn cross-over calibration application.

Corresponding author:
Salvatore Dinardo (**EUMETSAT**, **Italy**), salvatore.dinardo@eumetsat.int

The effects of rain on a Ka-band swath altimeter: lessons learned from the SWOT mission

Bruno Picard (Fluctus SAS, France); Aurélien Colin (CLS, France); Romain Husson (CLS, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_006

Abstract:
The Surface Water and Ocean Topography (SWOT) mission provides unprecedented Ka-band swath altimetry measurements via its KaRIn instrument but remains highly sensitive to precipitation-induced signal attenuation. This study characterizes KaRIn's radiometric response under rain, with emphasis on the normalized radar backscatter coefficient (sigma0). A three-regime decibel conversion scheme was applied to linear sigma0 values, including negative returns, and a wind-dependent angular correction was implemented. Comparisons with KaPR (GPM) and AltiKa showed consistent angular trends and systematic biases of +2.3 dB and +3.3 dB, respectively, over wind speeds from 3 to 13 m/s—representative of 85% of global oceanic conditions.

Two rain retrieval methods were developed from KaRIn sigma0: a physical attenuation inversion based on the ITU-R gamma-R model, and a supervised random forest (RF) classifier trained with NEXRAD radar data. The RF model achieved 89.2% accuracy and 82.5% detection probability for rain rates above 5 mm hr-1 , outperforming the ITU-based method. Rain rates exceeding 5 mm hr-1 or attenuations above 10 dB led to significant degradation of KaRIn sea surface height (SSH) retrievals, with over 95% of these observations flagged as invalid by Level-3 editing filters.

Beyond SWOT, these methods lay the foundation for Ka-band altimetry in future missions. Sentinel-3 Next Generation will benefit from improved rain detection for calibration and quality control. The ODYSEA mission—a CNES–NASA Doppler scatterometer—will require effective rain filtering to isolate geophysical signals. The dual-method retrieval strategies and statistical characterization of Ka-band attenuation presented here are essential to enabling reliable Ka-band remote sensing in dynamic meteorological environments.

Corresponding author:
Bruno Picard (**Fluctus SAS**, **France**), bpicard@satobsfluctus.eu

Sea State Bias on SWOT measurements

Samuel Osina (LOPS, France); Frederic Nouguier (LOPS, France); Alejandro Bohe (CNES, France); Fabrice Ardhuin (LOPS, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_007

Abstract:
Since the launch of SWOT in December 2022, astonishing bi-dimensional maps of highly resolved Sea-Surface Height (SSH) have been revealed showing the complex structure of the ocean and the multi-scaled processes occurring at its surface. The highly resolved data provided by KaRIn provides a unique opportunity to monitor, study, and quantify such structures.

One important source of error in altimetry, related to the presence of surface waves, is the so called Sea State Bias (SSB) that induces a negative shift in the measured surface height of the order of several percent of the significant wave height (SWH). The SSB is the signature of various complex physical properties of the ocean waves, among which their non-Gaussian nature and the fact that the local roughness (mean square slope) varies along the wave profile due to non-linear interactions between the waves (hydrodynamical modulation), inducing differences in the electromagnetic signal backscattered to the radar that bias the measurement (electromagnetic bias). In the context of conventional (or SAR) nadir altimetry, empirical corrections (essentially derived by tabulating differences between height measurements at cross-overs as a function of sea state parameters) are used to reduce the error due to SSB.

The measurement principle used by KaRIn (interferometry) is significantly different from that of nadir altimetry and as a result, the SSB created by waves could be different. Studies before launch using somewhat simplified wave physics (gaussian waves and a simple model for the backscatter modulation) concluded that the SSB would be similar enough to the one affecting nadir altimetry to allow the usage, as the initial correction (used in the operational processing since launch), of the empirical table derived from the AltiKa mission (also in Ka band). In this work, we revisit this issue using refined wave physics. Since KaRIn's processing uses a SAR compression to achieve its azimuth resolution, we pay particular attention to the impact of surface motion, which has recently been shown to be an important contributor to SSH errors on sensors using Doppler processing (Buchhaupt et al 2021, Marié et al 2024).

We first derive an analytical model for the bias affecting an interferometric SAR instrument like KaRIn in the presence of waves, which are characterized by their four-dimensional (elevation, slopes and vertical velocity) joint probability density functions (PDFs). We use our model to compute the SSB as a function of cross-track distance and doppler beam for a variety of sea state conditions (Significant wave height, wind speed, wind direction, ...). This allows us to quantitatively investigate the impact of instrument characteristics (PTR, pointing...) and wave physics ingredients to the SSB. Our analysis includes the effect of the non-linear interactions and couplings between the slopes and velocities of the large waves, while higher-order effects are left for future work. Specifically, we have derived and used the waves PDFs under second-order Eulerian and first-order Lagrangian approximations.

We will present the results of these analyses, comparing and analyzing the dependences of the predicted SSB on cross-track distance, wind speed, wind direction and wave doppler. By understanding the impact of each wave physics ingredient, we aim to progress toward a more complete SSB model that can be used for correction in the long term.
Corresponding author:
Samuel Osina (**LOPS**, **France**), samuel.osina@ifremer.fr

A new approach using the Automatic Identification System (AIS) data and SWOT data : a mesoscale study case

Camille Cardot (LEGOS/eOdyn, France); Isabelle Dadou (LEGOS, France); Gwenaele Jan (eOdyn, France); Clement Le Goff (eOdyn, France); Yves Morel (LEGOS, France); Habib Micael Aguedjou (CNES, France); Louise Rousselet (LOCEAN/LEGOS, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_008

Abstract:
The aim of this study is to characterize the meso and submesoscale dynamics in the western Mediterranean Sea with a focus on the Gulf of Lion. This region is dominated by a strong current where we can note the presence of strong fronts observed in the in situ data (i.e. ADCP or CTD) or high resolution model, not detected by the nadir altimetry data (e.g. Jason, Sentinel). We used the SWOT mission using the fast sampling phase to have access to the 2D Sea Level Anomalies (SLA) at fine scale. In this work, we used jointly the SWOT data and the AIS data (Automatic Identification System) to study the dynamics of the meso and submesoscale currents (O[2 - 5km]) in this region. The AIS data offer high spatio-temporal resolution of the total currents in coastal area and along the main maritime road across the ocean. So, it is unique data set, that can be combined with several data such as Chlrophyll_a or sea surface temperature, allows us to study the submesoscale dynamic in the area. We highlight that both SWOT or AIS data can detect and study a submesoscale event in coastal area. We then focus on one event and study its dynamical properties and the mechanism allowing its formation. Then, thanks to one year of AIS and 4 months of daily SWOT datasets, we analyze the recurrence of this kind of coastal submesoscale events and especially the new information gained with these two datasets.
Corresponding author:
Camille Cardot (**LEGOS/eOdyn**, **France**), camille.cardot@univ-tlse3.fr

SWOT and the drifter's odyssey in the NW Mediterranean Sea: riding current meanders and escaping eddies

Mathilde Cancet (CNRS LEGOS, France); Florence Birol (LEGOS, University of Toulouse, France); Claude Estournel (CNRS LEGOS, France); Léna Tolu (CNRS LEGOS, France); Louise Rousselet (CNRS LOCEAN, France); Fabien Léger (CNRS LEGOS, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_009

Abstract:
Understanding, monitoring and predicting the sea level changes from regional to local scales are critical issues for coastal populations and ecosystems, and the 30-year record of satellite altimetry observations is an outstanding tool to address them. Yet, interpreting small-scale, rapidly varying nearshore coastal ocean dynamics remains a challenge with the 1-D conventional altimetry measurements. The 2-D SWOT measurements of sea surface heights and derived currents are expected to provide unprecedented insights on small-scale ocean dynamics. They will also enable us to revisit our understanding of the 1-D altimetry physical content and how it captures such processes, finally leading to the improvement of long altimetry time series for regional and coastal studies. This presupposes a clear understanding of the signals captured by SWOT, using the observations and models available.

Here, we explore SWOT L3 sea surface height and current measurements in the Northwestern Mediterranean Sea, at regional and local scales. We take advantage of the wealth of multiplatform data available in the region, such as in situ observations, model simulations, nadir altimetry, and other remote sensing observations (Sea Surface Temperature, Ocean Color, SAR images…) to analyze specific events.

Starting from the one-year odyssey of a drifter throughout the Northwestern Mediterranean Sea basin, carried by current meanders, eddies and fronts, we explore the coherency of its velocity and trajectory with the geostrophic currents derived from SWOT observations, and also compare with the currents obtained from a Symphonie numerical simulation in the area. This 15m-drogued drifting buoy was launched in May 2023 under the SWOT Phase Sampling Phase track 3 within the frame of the SWOT Calval campaigns, and ended its journey in June 2024 in the Tyrrhenian Sea. It thus offers the opportunity to explore different aspects of SWOT sampling, with 1-day and 21-day repeat periods. In addition, the Rossby radius of deformation is about 10 km in the region, which is close to the intrinsic spatial resolution of SWOT measurements, meaning that SWOT geostrophic currents are estimated at the limit of the geostrophy approximation frame. The numerical simulation provides useful insights on geostrophy and ageostrophy contributions in the region to better understand the content of SWOT current estimates at the scale of the basin.

One of the most striking ocean dynamics features encountered by the drifter during its journey is an anticyclonic eddy located around the Capraia Island in the Corsica Channel, where it remains stuck for more than a month. This eddy, with a diameter of about 50 km, including the small Capraia Island at its center, is known to have seasonal characteristics, appearing during Summer and lasting until Fall. It has been sampled by SWOT at the beginning of the Science Phase, which provides an opportunity to investigate the quality of SWOT SSH and current estimates in a more coastal and local domain. Two tracks of the historic Topex-Jason nadir altimetry suite also pass over the Capraia Island, which provides a long time series of coastal altimetry observations in the region. This configuration is thus a very nice opportunity to revisit nadir altimetry at the light of SWOT and analyze how the various instruments (including SWOT nadir altimeter) capture the Capraia Island eddy.
Corresponding author:
Mathilde Cancet (**CNRS LEGOS**, **France**), mathilde.cancet@univ-tlse3.fr

S3NG-T swath altimetry performance assessments with the CNES simulator Radarspy

Louise Yu (CNES, France); François Boy (CNES, France); Alejandro Bohé (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_010

Abstract:
The Sentinel-3 Next Generation - Topography (S3NG-T) mission, led by the European Space Agency (ESA), aims to succeed the currently-flying Sentinel-3 operational altimetry mission, using the recent swath altimetry technique pioneered by the SWOT mission. Following the successes of the latter, ESA has adopted SAR interferometry for S3NG-T and the mission is set to enter phase B2 soon, with a scheduled launch in 2033.

This presentation details some oceanography performance estimates, derived from the CNES in-house simulator Radarspy, using simulations over various sea states. The swath altimetry instrument aboard S3NG-T, called SAOOH (Swath Altimeter for Operation Oceanography and Hydrology), differs from SWOT/KaRIn mainly in its 3-meter baseline, its multiple receptors to flatten the gain pattern, and a closed-burst observation pattern that alternates bursts of 192 radar pulses between left and right swaths, at a 10-kHz pulse repetition frequency. Furthermore, SAOOH will feature a Wave mode, providing modulation cross-spectra for wavelengths between ~40 m and ~7 km across-track, averaged over 4.5-km along-track distances.

Our simulations test both SAOOH's Low-Rate mode (similar to KaRIn's) and Wave mode, over scenes with wind seas and swells with varying significant wave heights (SWH). We also utilize Radarspy's capability to either simulate moving scenes or represent hydrodynamic backscatter modulation with a simple model. Thus, this work contributes to evaluating SAOOH's capabilities in terms of topography restitution, SWH estimates, and sea surface spectra over open oceans.

Corresponding author:
Louise Yu (**CNES**, **France**), louise.yu@cnes.fr

In situ geometric validation of SWOT satellite observations in Bass Strait, Australia

Andrea Hay (University of Tasmania, Australia); Christopher Watson (University of Tasmania, Australia); Benoit Legresy (CSIRO, Australia); Matt King (University of Tasmania, Australia); Boye Zhou (University of Newcastle, Australia); Jack Beardsley (University of Tasmania, Australia); Alejandro Bohé (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_011

Abstract:
The Bass Strait altimeter validation facility provides a complementary validation target for SWOT situated in a coastal shelf sea environment, with heritage back to the launch of TOPEX/Poseidon. Here we present results from our validation of SWOT sea surface height (SSH) products over the fast-sampling phase using a novel array of nine GNSS buoys. We demonstrate the GNSS buoys can provide reliable SSH estimates with a differential-SSH uncertainty of ~4.6 mm. Over the shortest separation distances within our array of 10 km, we find an upper bound for the KaRIn SSH noise of 7.0 mm from the standard SWOT product with 2 km pixel size, and an upper bound of 13.0 mm from the unsmoothed product with 250 m pixels. Errors increase with larger separation distances, which we can partially attribute to errors in the present set of product geophysical corrections. The relative magnitude of these errors compared to instrument noise highlights that care must be taken when interpreting SWOT SSH and SSH anomaly fields. Finally, we find an absolute height bias of KaRIn SSH of -10.3 mm (standard deviation of 33 mm) and an RMSE of significant wave heights of 0.22 m, further demonstrating the outstanding performance of the KaRIn instrument over the challenging coastal environment of Bass Strait.
Corresponding author:
Andrea Hay (**University of Tasmania**, **Australia**), andrea.hay@utas.edu.au

Contributions to SWOT validation from Bass Strait and the Southern Ocean

Christopher Watson (University of Tasmania, Australia); Andrea Hay (University of Tasmania, Australia); Benoit Legresy (CSIRO, Australia); Matt King (University of Tasmania, Australia); Boye Zhou (University of Newcastle, Australia); Jack Beardsley (University of Tasmania, Australia); Alejandro Bohé (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_012

Abstract:
Located within the SWOT fast-sampling phase track, the long-term Bass Strait altimeter validation facility (-40.6°S, 145.6°E) and the Southern Ocean Flux Station (SOFS, -47°S, 142°E), provide two important validation targets in geographically diverse locations in the southern hemisphere. In preparation for SWOT, both sites were augmented with GNSS instrumentation enabling the validation of SWOT satellite observations including sea surface height (SSH), significant wave height (SWH) and tropospheric wet path delay. Commencing with the SOFS location, we review results validating SWOT wave parameters in this highly energetic region of the Southern Ocean. Shifting focus to the Bass Strait facility, we review the geometric approach to validation which is enabled through the deployment of an array of GNSS equipped buoys, with moored oceanographic sensors proving complementary information. We first present results investigating signal delay induced by water vapor in the troposphere. Over short spatial scales (<~80 km), we find that this signal is not well-captured by SWOT radiometer observations and hence may bias geophysical interpretation. We then review our SSH and SWH validation results which provide independent in situ measurement evidence of the outstanding performance of the KaRIn instrument. We conclude with perspectives on the utility of the geometric approach to the validation of future wide-swath altimeter missions.

Corresponding author:
Christopher Watson (**University of Tasmania**, **Australia**), cwatson@utas.edu.au

Shipborne GNSS atmospheric water vapor retrieval for SWOT radiometer validation in the framework of the Wem-SWOT / C-SWOT dual campaigns

Aurélie Panetier (CNES, Toulouse, Shom, Brest, France); Félix Mercier (ENSG-Géomatique, Marne-la-Vallée, ENSTA, Brest, France); Pierre Bosser (ENSTA, Brest, France); Clémence Chupin (ENSTA, Brest, France); Jean-Baptiste Roustan (Shom, Brest, France); Aurélien Ponte (Ifremer, Plouzané, France); Pierre Garreau (Ifremer, Plouzané, France); Franck Dumas (Shom, Brest, France); Félix Perozans (CNES, Paris, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_013

Abstract:
The Surface Water and Ocean Topography (SWOT) mission allows sub-mesoscale ocean processes to be investigated with great precision. The SWOT KaRin capability to access oceanic scales of about 20 km involves new error sources that were orders of magnitude smaller for classical altimetry. In particular, small-scale atmospheric effects may affect the sea surface height (SSH) product. Water vapor is measured through two radiometers onboard the satellite, measuring at the center of each of the two KaRIn interferometers on each side of the Swot nadir. Hay et al. (2025) highlighted some irregularities in the KaRIn dataset due to the spatial variations of the wet troposphere correction not sensed by the wide footprint and single measurement correction applied to both KaRIn swaths.
This research is conducted within the framework of the dual campaigns WEMSWOT, led by the Shom, and C-SWOT-2023, led by Ifremer, in March and April 2023, involving two research vessels (RVs), each carrying geodetic GNSS antennas. The two RVs were sailing along the KaRIn footprint every day during 20 days of the CalVal period of the SWOT mission. We propose to use the GNSS retrieval of water vapor content with state of the art method to qualify the SWOT nadir measurement of the water vapor used for the correction of the altimetric measurements of SWOT. Indeed, the water vapor sensing of the atmosphere from shipborne geodetic GNSS antennas has been assessed in the literature with an accuracy reaching 2 kg.m-². Assessing the radiometer accuracy in the coastal area, ~50 km from the coast, where the radiometer is less performant, is especially relevant. During the twin campaigns, both ships crossed a small yet intense atmospheric cyclone within the SWOT swath, potentially introducing biases in the SSH product. These effects will be thoroughly documented. To achieve this, we compare the water vapor sensing from the GNSS with external datasets, such as reanalysis, radiosondes launched from Ile du Levant, and reference GNSS antennas when the RVs are close to harbors. Then, we compare the SWOT radiometer dataset to the shipborne GNSS-retrieved water vapor. Taking into account the time difference between SWOT and in situ GNSS measurements, we evaluate the capabilities of the SWOT radiometer, which could introduce small-scale atmospheric variations into the SSH product.

Corresponding author:
Aurélie Panetier (**CNES, Toulouse, Shom, Brest**, **France**), aurelie.panetier@ensta-bretagne.org

Eddy Hunter: a SWOT data mining system to foster altimetry product integration

Federico Scarscelli (GEOMAR, Germany); Florian Schütte (GEOMAR, Germany); Claudius Zelenka (Kiel University, Germany); Peer Kröger (Kiel University, Germany)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_014

Abstract:
The SWOT mission has opened a new chapter in understanding mesoscale and sub-mesoscale ocean dynamics, providing a constantly growing amount of high resolution Sea Surface Height (SSH) observations. However, this extremely valuable repository of data is still not fully exploited by researchers, largely due to technical reasons and the novelty of the product. In particular, the KaRIn altimeter's limited spatial coverage and the long orbit cycle duration impose challenges for eddy detection and tracking using SWOT data, while having a reliable source of high resolution eddy signals would be extremely valuable in order to understand small-scale features of eddy dynamics.

On the other hand, traditional satellite altimeters have served as the backbone of mesoscale eddy research for over 30 years, providing reliable SSH data, characterized by a wide spatio temporal coverage. To some extent, these well known data sources can be considered "complementary" to SWOT measurement, offering a possible solution to some of its aforementioned limitations. Therefore, we aim to provide a system capable of overcoming the eddy detection and tracking limitations of KaRIn altimetry data. We pursue this goal by leveraging the integration between SWOT and conventional SSH satellite altimetry, adopting an information retrieval approach to identify high resolution eddy signals similar to a low resolution counterpart.

To do so, the Eddy Hunter System (EHS) integrates the Mesoscale Eddy Trajectory Atlas (META) and SWOT Level 3 products. The core of the system is provided by a PostgreSQL database, while Python is used to manage the interaction between the DB, META, aviso.altimetry FTP server and locally stored SWOT data, lastly, a Streamlit-based Graphical User Interface (GUI) facilitates user interaction.
The EHS works by extracting a spatio-temporal Region Of Interest (ROI) from every eddy observation present in the META dataset. Subsequently, it computes the possible relevant SWOT passages that could contain signals related to the original observation. Finally, the intersection between the ROI and the candidate passages' ground tracks is computed: in case of a non-empty result, a high resolution signal of the original observation is found and stored in the database.

The development and deployment of the proposed system can enhance scientific research in two distinct applications: firstly, it provides a data mining tool to retrieve useful information from a complex data source, fostering new discoveries regarding mesoscale and sub-mesoscale physical oceanography; secondly, it allows to build an extensive repository of high resolution eddy signals, allowing for advancements in applied AI and ML methods in oceanography, like eddy clustering or generative-AI interpolation of the SWOT data.

Corresponding author:
Federico Scarscelli (**GEOMAR**, **Germany**), fscarscelli@geomar.de

Assessing SWOT-Derived Surface Velocities Against HFR Data: Insights from the Ibiza Channel

Guiomar Lopez (SOCIB, Spain); Emma Reyes (SOCIB, Spain); Ananda Pascual (IMEDEA (UIB-CSIC), Spain); Baptiste Mourre (IMEDEA (UIB-CSIC), Spain); Joaquín Tintoré (SOCIB, IMEDEA (UIB-CSIC), Spain)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_015

Abstract:
The Surface Water and Ocean Topography (SWOT) mission offers an unprecedented view of Sea Surface Height (SSH) at significantly higher spatial resolution (~10 times) than conventional altimetry. This capability reveals previously unobserved submesoscale eddies and fronts. However, at these scales, the assumption of geostrophic balance, commonly used to derive current velocities from SSH, is not always valid. Consequently, it is vital to evaluate SWOT-derived velocities against independent high-resolution observations. The FaSt-SWOT project team has already contributed to this global effort by comparing the satellite measurements against a comprehensive dataset built from multi-platform in-situ data collected in the Balearic Sea throughout two oceanographic campaigns during SWOT's fast-sampling phase, in April and May 2023.

Within this context, we now extend the evaluation by comparing geostrophic velocities derived from SWOT SSH against High-Frequency Radar (HFR) surface current measurements collected in the Ibiza Channel. This dynamically complex area, characterised by an intricate topography and significant mesoscale activity, including energetic eddies and filaments, constitutes an ideal natural laboratory for studying fine-scale processes where deviations from geostrophic balance are anticipated. In order to describe the temporal and spatial variability of the surface circulation in the area, we analysed two years of HFR-measured current velocities. Calculated Eddy Kinetic Energy (EKE) spectra present peaks at the diurnal, inertial, and semi-diurnal frequencies, which show high seasonal variability. Wavelet coherence analysis evidenced the importance of wind as a primary driver of surface currents in the area.

SWOT's remarkable ability to detect fine-scale ocean dynamics is evidenced in a snapshot from 26 January 2025 that shows two counter-rotating submesoscale eddies with centres ~ 45 km apart. The eddies are clearly visible in the HFR-derived velocities and exhibit remarkable spatial coincidence with SWOT's SSH Anomaly (SSHA) signal. However, the geostrophic velocities distributed with the SWOT L3 expert v2.0.1 product overestimate the filtered HFR velocities for the cyclonic eddy characterised by a SSHA of 10 cm and a ~10 km radius. Geostrophic velocities derived from SSH reached values exceeding 30 cm/s, whereas the HFR velocities extracted from 1-month time series in January 2025 and filtered using a second order 25-h Butterworth filter, remained below 20 cm/s. The Rossby number calculated from the HFR measurements over this eddy is 0.6, indicating a clear deviation from geostrophic balance. Hence, we applied the cyclogeostrophic balance approximation to SWOT observations (Penven et al., 2014, Tranchant et al., 2025), and obtained velocities which were on average 15 cm/s lower, and much closer to the HFR measurements. This empirical validation highlights the critical importance of verifying the scales and conditions for which the geostrophic balance approximation breaks down when deriving submesoscale currents from high-resolution SSH.

Ongoing work focuses on extending the comparison between SWOT and HFR-derived velocities over a longer period, covering both the Ibiza Channel and the Delta del Ebro region.

Corresponding author:
Guiomar Lopez (**SOCIB**, **Spain**), glopez@socib.es

Level 4 global topography mapping including SWOT data with 4DVarNet

Cecile Anadon (CLS, France); Anaëlle Treboutte (CLS, France); Hugo Georgenthum (IMT Atlantique, France); Alice Laloue (LEGOS, France); Daniel Zhu (IMT Atlantique, France); Ronan Fablet (IMT Atlantique, France); Marie-Isabelle Pujol (CLS, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_016

Abstract:
The study of mesoscale oceanic eddy dynamics requires regular, high-resolution space-timegrids of topography observations. However, most observations come from the constellation of altimetry satellites, which measure the topography along very fine and still very sparse tracks, and surface currents must therefore be calculated using level 4 topography maps. These level 4 maps used operationally are produced by methods based on objective analysis, such as DUACS, or variational resolution, such as MIOST, but their spatial resolution limits the scales of dynamics that can be resolved. While DUACS and MIOST can capture mesoscale dynamics down to approximately 150–200 km, sub-mesoscale features remain inaccessible with these methods.

Recent advancements in neural network-based mapping models have the potential to refine the resolution of mesoscale topography reconstruction. The NeurOST model developed by S. A. Martin (2024), for instance, improves the spatial resolution by 30% compared with existing conventional methods like DUACS, establishing itself as a state-of-the-art technique in level-4 topography mapping. However, the NeurOST model is currently only applicable to nadir data and cannot effectively take SWOT KaRIn data as input.

In this study, we leverage the 4DVarNet model, developed by R. Fablet and Q. Febvre at IMT Atlantique (2023), to estimate global surface current maps from both conventional nadir altimetry and SWOT KaRIn swath data. Different learning methods have been tested: training on simulated data with GLORYS12V1 reanalysis data and training on real data with 30 years of nadirs L3 altimetry data and two years of L3 SWOT KaRIn data. Moreover, SWOT's contribution to global topographic mapping depends on the mapping method used ; SWOT's contribution with the 4DVarNet neural network method will be presented.

Corresponding author:
Cecile Anadon (**CLS**, **France**), canadon@groupcls.com

Using SWOT sea surface height to study coastal eddy dynamics

Luke Kachelein (Jet Propulsion Laboratory, California Institute of Technology, United States); Jinbo Wang (Texas A&M University, United States); Patrice Klein (Jet Propulsion Laboratory, California Institute of Technology, United States); Andrew Thompson (California Institute of Technology, United States)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_017

Abstract:
SWOT has shown the capability of resolving order 10 km and smaller eddies due to its unprecedented low-instrument error and wide-swath. Its use for deriving ocean circulation at tens of kilometer scales is a significant advance in the state of the art over conventional altimetry. The lack of direct observations of surface currents in most of the global ocean, however, limits validation of SWOT velocities derived using geostrophic or cyclogeostrophic balance. Our study focuses on the northern California coast, a region where it is possible to compare dense Eulerian observations of surface currents from high-frequency radar and daily-repeat SWOT passes during the 2023 Cal/Val orbit. Comparing these two data sets, as well as satellite SST data, allows us to examine the predictability of currents from SWOT in a coastal region. These two velocities are significantly correlated in time at most coastal locations, though disagreement at large velocity magnitudes suggests cyclogeostrophic balance may be required to estimate submesoscale eddy velocities from SWOT. Historically, altimetry has performed poorly near the coast, and recent studies have investigated SWOT-derived velocities in energetic regions of open ocean. We aim to examine optimal strategies for SWOT-derived velocities in low-energy coastal regions in order to help facilitate global studies of coastal dynamics using SWOT.

Corresponding author:
Luke Kachelein (**Jet Propulsion Laboratory, California Institute of Technology**, **United States**), luke.kachelein@jpl.nasa.gov

SWOT KaRIN Calibration Algorithm: principle, updates and analysis of the absorption of geophysical corrections residues such as tide and sea state bias

Cecile Anadon (CLS, France); Clément Ubelmann (DATLAS, France); Perrine Abjean (CLS, France); Michel Tchilibou (CELAD, France); Emeline Cadier (CLS, France); Marie-Isabelle Pujol (CLS, France); Loren Carrere (CLS, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_018

Abstract:
The images provided by KaRIn can be biased or skewed by a few centimeters to tens of centimeters. The main source of these errors is an uncorrected satellite roll angle, which explains why KaRIn images are mainly composed of a linear variation based on cross-track distance. There are various other sources of errors such as interferometric phase biases or thermo-elastical distortions in the instrument baseline and antennas. To mitigate these topography distortions, a calibration mechanism is applied.

Two variants of KaRIn calibration have been developed: the SWOT mono-mission or Level-2 algorithm, and the multi-mission or Level-3 algorithm. The L2 algorithm is used in the SWOT ground segment and is based on SWOT data only, because a ground segment cannot depend on external satellites. In contrast, the Level-3 algorithm was designed to leverage better algorithms and external satellites: not only Sentinel-6, the so-called climate reference altimeter, but also all other altimeters in operations (Sentinel-3A/3B, HY2B/C, SARAL, CRYOSAT-2). The L3 correction is generally more robust and stable than the Level-2 variant thanks to the thousands of daily multi-mission crossover segments provided by the constellation. The L3 algorithm is updated regularly with the different product versions (v1.0.2, v2.0.1, v3): the addition of a static component improves calibration for geodetic applications; the reduction of the number of parameters allows less residual signal to be absorbed; a change of interpolation methodology improves calibration in polar areas and on continents for hydrology.

A drawback of calibration is the absorption of geophysical correction residues. Indeed, the harmonic analysis of the calibration highlights the absorption of tide residues in the calibration. This absorption by the calibration is problematic for users who want to analyze the tide signal in coastal areas and for users who are subject to the projection of these errors via calibration; for example, in hydrology, coastal tide error is projected onto continents. A study is conducted to analyze the strongly impacted regions and the amount of signal absorbed for the different calibrations available (Level-2 calibration, Level-3 v1, v2 and v3 calibration) and for degraded calibrations that absorb less signal but that correct systematic errors less effectively. In addition, a study on the absorption of sea state bias by the calibration has been carried out: the dependence of calibration on wind and sea wave height highlights the absorption of sea state bias in the calibration. The use of a calibration that includes only a harmonic roll correction avoids the absorption of sea state bias.

Corresponding author:
Cecile Anadon (**CLS**, **France**), canadon@groupcls.com

Sub-mesoscale and coastal ocean dynamics in the North Indian Ocean using SWOT and EOS-06/OCM-3 observations

Aditya Chaudhary (Space Applications Centre, ISRO, India); Neeraj Agarwal (Space Applications Centre, ISRO, India); Rashmi Sharma (Space Applications Centre, ISRO, India)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_019

Abstract:
High resolution sea level observations from Surface Water and Ocean Topography (SWOT) mission has enabled us to observe the small scale sea level and circulation features that play an important role in dynamics of the ocean. SWOT provides sea level observations at the 2km resolution over the 120 km swath with a middle gap of 20 km. This enables us to derive geostrophic currents over the similar grid. At these smaller scales, there is mix of balanced motions such as mesoscales, submesoscales and unbalanced motions such as internal waves. Circulation features at smaller scales additionally have cyclostrophic components in addition to the pressure gradient and coriolis, which make the geostrophic assumptions invalid. In addition to the small-scale circulation features in the open ocean, sea level observations in the coastal regions is also a focus of SWOT mission. Coastal areas are highly dynamic because of several coastal processes like coastal jets, tidal circulation, high-density gradients, wind generated dynamics, internal waves etc. SWOT observations can help to reveal some of these dynamics. In this study, we firstly validate the SWOT sea levels observations over the Indian regions through coastal tide gauge observations and argo floats. Validation results show an error of 3-9cm based on multiple tide gauge observations. The coastal observations for the SWOT is also shown to have more valid observations in the 0-8 km coastal band as compared to along-track nadir observations. SWOT show 17% more variability with respect to the standard seal level gridded products. The RMSD between the SWOT and standard seal level gridded products is nearly 3.3 cm; however, there are considerable differences near the coast, where SWOT sea levels depict significantly higher difference (~5cm RMSD). Detailed results will be presented in the meeting.
Secondly, we analyse the covaribility of the chlorophyll form EOS-06/OCM3 and the circulation features derived from the SWOT. A scheme to correct the SWOT circulation for the cyclostrophic features has also proposed. We show several test cases of SWOT and chlorophyll to show the improvements in using the proposed scheme. Detailed results will be presented in the meeting.
Corresponding author:
Aditya Chaudhary (**Space Applications Centre, ISRO**, **India**), aditya.iist@gmail.com

Absolute Calibration and Validation of SWOT Nadir Altimetry Products over the Pertuis Charentais Using In-Situ Observations and Local Model

Audrey Hyeans (LIENSs, France); Laurent Testut (LIENSs, France); Valérie Ballu (LIENSs, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_020

Abstract:
Satellite altimetry has revolutionized the observation of ocean dynamics and the monitoring of global mean sea level. However, in coastal zones, standard open-ocean processing techniques often fall short due to land contamination, complex bathymetry (limited knowledge of geoid), and dynamic coastal processes. In recent years, dedicated coastal altimetry products such as XTRACK (Birol et al., 2022) and ALTICAP (Birol et al., 2023) have significantly improved the retrieval of sea surface height (SSH) near the coast.

Despite these advances, retrieving precise sea level height from altimetry products in last kilometers of the coast remain challenging. This study focuses on the absolute calibration and validation (Cal/Val) of Geophysical Data Record (GDR) nadir altimetry products of SWOT mission over the Pertuis Charentais coastal region in Bay of Biscay - France, along track 419. SSH at 20 Hz is computed by refining key geophysical corrections, including wet tropospheric and ionospheric delays, dynamic atmospheric correction (DAC), sea state bias, and tidal effects.

Our validation framework integrates a comprehensive network of in-situ observations. GNSS (Global Navigation Satellite System) ground stations are used to improve the estimation of tropospheric and ionospheric delays. Tide gauges, pressure sensors, and the high-resolution local hydrodynamic model SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model) are employed to enhance tidal and DAC corrections. These datasets enable the assessment and reduction of residual errors in altimetric measurements, particularly in the final kilometers before the coast.

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Corresponding author:
Audrey Hyeans (**LIENSs**, **France**), audrey.hyeans@univ-lr.fr

Simulation-informed deep learning for enhanced SWOT observations of fine-scale ocean dynamics

Eugenio Cutolo (IMT Atlantique, France); Carlos Granero Belinchon (IMT Atlantique, France); Ptashanna Thiraux (IMT Atlantique, France); Jinbo Wang (Texas AM University, USA); Ronan Fablet (IMT Atlantique, France)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_021

Abstract:
Oceanic processes at fine scales are crucial yet difficult to observe accurately due to limitations in satellite and in-situ measurements. The Surface Water and Ocean Topography (SWOT) mission provides high-resolution Sea Surface Height (SSH) data, though noise patterns often obscure fine scale structures. Current methods struggle with noisy data or require extensive supervised training, limiting their effectiveness on real-world observations. We introduce SIMPGEN (Simulation-Informed Metric and Prior for Generative Ensemble Networks), an unsupervised adversarial learning framework combining real SWOT observations with simulated reference data. SIMPGEN leverages wavelet-informed neural metrics to distinguish noisy from clean fields, guiding realistic SSH reconstructions. Applied to SWOT data, SIMPGEN effectively removes noise, preserving fine-scale features better than existing neural methods. This robust, unsupervised approach not only improves SWOT SSH data interpretation but also demonstrates strong potential for broader oceanographic applications, including data assimilation and super-resolution.

Corresponding author:
Eugenio Cutolo (**IMT Atlantique**, **France**), eugenio.cutolo@imt-atlantique.fr

Assessing and Reducing Uncertainty in the Wet Tropospheric Correction for Wide Swath Altimetry

Shannon Brown (JPL, United States)

Session: Oceanography: Calibration and Validation
Presentation type: Poster
Poster number: ST2025OS1_022

Abstract:
Uncertainty in the wet tropospheric path delay correction (WPD) has a one-to-one mapping to sea surface height uncertainty. For SWOT, the WPD correction is performed using a dual-beam radiometer operating between 18-34 GHz. The two radiometer beams are pointed a few degrees off-nadir to either side of the ground track and roughly centered in each of the two KaRIn swaths. The radiometer provides path delay only at these two discrete locations in the swath. A separate algorithm is required to map those two measurements into the best representation of the water vapor field over the swath. We will discuss a performance evaluation of several algorithms to map the two measurements to a 2D swath product. We assess the 2D SWOT path delay performance relative to other co-incidence observations from imaging sensors.

We first inter-compare two simple interpolation approaches, linear and nearest neighbor interpolation, which are the highest order interpolators that can be considered with just two beams. The nearest neighbor approach simply assigns the along-track WPD from each radiometer beam to the respective 60km swaths on either side of nadir. The other approach is to linearly interpolate across-track between the WPD samples from each of the two swaths that are spatially closest. The linear algorithm requires extrapolation at the swath edge beyond the boresight of the radiometer, roughly from 30-60km across-track.

The interpolation approaches are only able to remove linear variations in path delay which can led to cm-level errors in the presence of certain atmospheric features. More advanced approaches are required to reduce uncertainties when the cross-track WPD is highly non-linear. Morphing algorithms are class of algorithm that have been developed to fill in data gaps between satellites observations globally using some knowledge of how the particular quantity of interest transforms in time and space. Water vapor is particularly well suited for a morphing algorithm as it is nearly a conserved quantity on hourly times scales, meaning it advects with the mean atmospheric flow. This is particularly true for larger scale structures. We show a comparison of the advective morphing approach of Wimmers and Velden (2011) to the WPD from the simple interpolation algorithms.

Corresponding author:
Shannon Brown (**JPL**, **United States**), shannon.t.brown@jpl.nasa.gov

Validation of SWOT Lake water level using in situ measurements: results from a student project at Lake Guerledan (France)

Clémence Chupin (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France, France); Pierre Bosser (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Séverine Enet (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Clémentine Beau (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Scott Bédart (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Zoé Besnard (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Lola Henneuse (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Kim Monoury—Homet (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Siméon Ridel (Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France); Jules Faguet (École Nationale des Sciences Géographiques, France / Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France , France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_001

Abstract:
With a wide swath of 120 km, the SWOT mission's KaRin interferometric radar can track rivers and lake dynamics anywhere on Earth with unprecedented resolution [1]. The first “Pixel Cloud” datasets [2] provide information on reservoirs too small to be tracked by traditional space altimetry [3,4], but key to understand local hydrological processes.

As part of an engineering student project, we test KaRin's abilities on one of Brittany's largest freshwater bodies: the Guerlédan dam lake. Since 2015, this lake is the playground for hydrography and robotics students at the École Nationale Supérieure des Techniques Avancées (ENSTA) [5]. This year, six students were responsible for the lake’s instrumentation to monitor water levels, with the aim of comparing the collected data with SWOT observations in the area. The project took place over five months in partnership with Shom (French naval hydrographic and oceanographic service),and included two weeks of field acquisition in October 2024 and February 2025.

The project focused on two main aspects:

1. Lake in-situ instrumentation: design of a measuring scheme to monitor changes in lake level and enable sensors inter-comparison. Several sensors were deployed :

-> Pressure gauges were moored in various locations on the lake over a 5-month period for long-term water level monitoring. GNSS buoys were deployed at the lake's surface to ensure the sensors' absolute position.

-> Low-cost GNSS & acoustic altimeter system was developed and deployed for spatial water level monitoring.

-> A fixed GNSS antenna was installed for water level measurement using GNSS interferometric reflectometry (GNSS-IR).

-> An EPONIM autonomous radar tide gauge [6] was installed on the top of the dam to allow inter-comparison of all systems.

2. SWOT data analysis: processing and analysis of SWOT HR Raster 100m data [7] in the area (flag, correction parameters, etc.), and spatial and temporal comparison with in-situ data.

All instrumental deployments were successful, and the coupled GNSS & acoustic altimeter system enabled space-based acquisitions on the lake. In-situ sensors provide consistent water levels evolutions, despite inter-sensor biases in the range 4-10 cm which are still under investigation. SWOT observations could be retrieved on the lake, but an in-depth analysis of the corrections is required to explain the absolute biases observed with in-situ measurements. For future students' surveys, attention will be paid to the air draft of each sensor and their

positioning to avoid any possible shifts. Satellite data analysis will be completed by adding Sentinel-3a observations over the lake.

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Corresponding author:

Clémence Chupin (**Ecole Nationale des Sciences et Techniques Avancées (ENSTA) / IP Paris, Campus de Brest, France**, **France**), clemence.chupin@ensta.fr

SWOT meets GRDC: Assigning SWORD nodes to in situ stations from the Global Runoff Data Centre

Simon Mischel (Federal Institute of Hydrology, Germany, Germany); Henning Plessow (Federal Institute of Hydrology, Germany); Claudia Zentis (Federal Institute of Hydrology, Germany); Mohammadjavad Tourian (Institute of Geodesy, University of Stuttgart, Germany); Peyman Saemian (Institute of Geodesy, University of Stuttgart, Germany); Omid Elmi (Institute of Geodesy, University of Stuttgart, Germany)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_002

Abstract:
River systems are an integral part of the global water cycle, which are linked to many processes on local, regional, and global scales. Terrestrial monitoring of rivers is fundamental for the sustainable management of available water resources on a regional or catchment scale.

The Global Runoff Data Centre (GRDC) operates under the auspices of the World Meteorological Organization (WMO) at the German Federal Institute of Hydrology (BfG). It holds the most substantive collection of quality-assured river discharge data on a global scale. Established in 1988 to support research on global and climate change and integrated water resources management, GRDC has been a key partner in several data collection and data management projects. It connects national hydrological and hydrometeorological services, the primary providers of river discharge data and associated metadata, with the scientific research community utilizing this unique data collection. Currently, the GRDC contains river discharge data collected at daily or monthly intervals from more than 10,000 stations in 160 countries. GRDC archives international data up to 200 years old, with an average record length of 40 years.

GRDC has been actively supporting the calibration and validation of satellite-based data, thereby strengthening the bridge between in-situ monitoring and satellite-derived data products. This includes support for the Surface Water and Ocean Topography (SWOT) satellite mission, which enhance observations of river water surface elevation (WSE), width, and slope. For rivers, the prior database, known as the SWOT River Database (SWORD), combines multiple global river- and satellite-related datasets to define the nodes and reaches that will constitute SWOT river vector data products. Each SWORD node can be identified and accessed via its individual SWORD ID, which provides valuable information about the node's topology and type.To facilitate a wide range of new analyses with flexibility, the SWOT mission provides a range of relevant data products. One product of the SWOT mission is the river vector product, stored in shapefile format for each SWOT overpass. The SWOT vector data products will be most broadly useful if they allow multitemporal analysis of river nodes and reaches covering the same river areas. The HYDROCRON website provides easy access via API to the data to produce timeseries (https://podaac.github.io/hydrocron/intro.html).

To facilitate the use of SWOT data in the vicinity of GRDC data, here we present a dataset that assigns the nearest SWORD reach ID to each GRDC gauge. Compare WISP for similar functionality for the US (WISP https://apps.usgs.gov/wisp). The coordinates of the GRDC dataset are pour-point corrected. This correction has been used for the station-based catchment calculation which snaps the stations to the river network of HydroSHEDS or MERIT Hydro (Färber et al. 2024). The corrected coordinates can be reused to assign the nearest SWORD ID to the GRDC station. This allows easy access to GRDC stations with SWOT data. The dataset is available for download at the GRDC website (https://grdc.bafg.de)

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Corresponding author:
Simon Mischel (**Federal Institute of Hydrology, Germany**, **Germany**), mischel@bafg.de

SWOT River Water Surface Elevation Data in the Pantanal: A Sub-Regional Performance Assessment

Jahdy Oliveira (National Institute for Space Research, Brazil); Alice Fassoni-Andrade (University of Brasilia (UnB), Brazil); Evlyn Márcia Leão de Moraes Novo (National Institute for space research, Brazil)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_003

Abstract:
The Pantanal, the world's largest tropical wetland, is characterized by its diverse hydrological dynamics across its 11 sub-regions and its very flat topography. These sub-regions are defined by their flooding patterns, topography, soil types, and vegetation. Accurate data on water surface elevation (WSE) are crucial for managing this ecosystem, particularly given increasing threats from extreme hydrological events. However, in situ monitoring is limited. This study assesses the potential of the Surface Water and Ocean Topography (SWOT) mission by evaluating the accuracy of the Level 2 KaRIn high-rate river single-pass vector product (L2_HR_RiverSP), specifically the reach subproduct, for WSE monitoring in the Pantanal. For the assessment, we utilized SWOT-derived WSE time series (2022–2024), which were compared with data from 24 in situ stations of the Brazilian National Water Agency (ANA), covering ten sub-regions and eight rivers. To ensure data quality, both datasets underwent outlier removal using Isolation Forest and min-max normalization. Performance was evaluated using R^2, RMSE, MAE, and BIAS, calculated using only coincident SWOT and in situ measurements. The results revealed significant spatial variability in the performance of the SWOT L2_HR_RiverSP reach subproduct across the Pantanal. The São Lourenço River (Barão de Melgaço sub-region) showed the best agreement with in situ data (RMSE = 0.065 m, $R^2 = 0.94$, bias = 0.01 m), while the Cuiabá River (also in Barão de Melgaço) exhibited the poorest performance (RMSE = 0.61 m, $R^2 = 0.32$). At the sub-regional level, Nabileque and Paiaguás displayed the highest average correlations ($R^2 > 0.49$) and lower errors. In comparison, Aquidauana and Abrobral showed larger discrepancies (RMSE > 0.37 m). These findings highlight the importance of considering sub-regional and river-specific factors when using SWOT data in the Pantanal. The observed variability suggests that local factors, such as river morphology, vegetation cover, and complex hydrological processes, can impact the accuracy of SWOT-derived WSE. Further research should explore the potential of alternative SWOT subproducts (e.g., the node product) and on developing calibration or bias-correction strategies tailored to specific sub-regions. A more comprehensive analysis of the characteristics of these sub-regions could help explain the observed errors. This study provides a critical baseline for future SWOT data applications in the Pantanal, contributing to improved water resource management and conservation efforts in this ecologically significant region.

Corresponding author:
Jahdy Oliveira (**National Institute for Space Research**, **Brazil**), jahdy.moreno@gmail.com

Validation of Water Surface Elevation and Extent over French lakes using the Surface Water Ocean Topography (SWOT) mission

Cassandra Normandin (INRAE, France); Frédéric Frappart (INRAE, France); Christophe Moisy (INRAE, France); Nicolas Baghdadi (TETIS, INRAE, France); Bertrand Ygorra (INRAE, France); Luc Bourrel (GET, France); Philippe Maisongrande (CNES, France); Delphine Leroux (CNES, France); Jean-Pierre Wigneron (INRAE, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_004

Abstract:
Natural lakes and artificial reservoirs—collectively referred to as lakes—are a fundamental component of terrestrial hydrology and play a vital role in supporting ecological processes, sustaining terrestrial biodiversity, regulating biosphere functioning, and facilitating a wide range of human activities (Wang et al., 2025). Furthermore, lakes act as significant carbon sinks (Bar-On et al., 2025), contributing to the regulation of terrestrial carbon fluxes. In recognition of their importance, lakes have been designated as Essential Climate Variables (ECVs) by the Global Climate Observing System (GCOS) of the World Meteorological Organization (WMO). Despite their critical role, the monitoring of lakes at global scales remains challenging—particularly due to the scarcity and uneven spatial distribution of in situ observations. The deployment and maintenance of in situ monitoring infrastructure are often cost-prohibitive, and where such stations do exist, accessibility may be limited by logistical or environmental constraints.
Over the past few decades, satellite remote sensing has emerged as a valuable tool for observing lake dynamics at regional to global scales, offering temporal revisit compatible with hydrological processes. However, traditional satellite missions have typically provided either surface water extent from multispectral sensors or elevation data from nadir altimeters. The launch of the Surface Water and Ocean Topography (SWOT) mission in December 2022 represents a paradigm shift, as it is the first satellite mission dedicated specifically to continental hydrology. SWOT enables the simultaneous observation of surface water extent and elevation at high spatial resolution, allowing estimate of surface water volume, using its Ka-band Radar Interferometer (KaRIn) instrument. A recent study has demonstrated the potential of SWOT to accurately monitor surface water elevation over large lakes (Bazzi et al., 2025).
This study aims to evaluate and validate SWOT-derived surface water extents and elevations over a selection of lakes in France, encompassing a variety of sizes, geographic locations, and elevations. We utilize the Level-2 KaRIn High-Rate (HR) Lake Single-Pass (SP) vector product during both the calibration phase (April 2023) and the scientific phase (since July 2023). SWOT water level data were compared with both in situ gauge measurements and conventional radar altimetry. Comparison with in situ observations across 30 lakes revealed a weak correlation ($R^2 = 0.0159$) and a root mean square error (RMSE) of 0.025 m. This low correlation is likely influenced by lake size, which plays a significant role in determining measurement accuracy. In contrast, comparisons with conventional radar altimetry over 27 lakes showed strong agreement, with a correlation coefficient of $R^2 = 0.899$ and a RMSE of 0.023 m. Additionally, we assessed SWOT-derived surface water extents for 509 lakes using the Global Water Watch database, which is based on Landsat and Sentinel-2 optical imagery. This comparison shows a correlation of $R^2 = 0.81$ and a RMSE of 0.004 km². When applying the “good pixel” quality flag, the correlation improved significantly to $R^2 = 0.906$.

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Corresponding author:
Cassandra Normandin (**INRAE**, **France**), cassandra.normandin@gmail.com

Influence of Bitwise Quality Flags on SWOT Vector Node and Reach Product Accuracy in Indian River Basins

Rucha Sanjay Deshpande (Indian Institute of Technology Kanpur, India); Tajdarul Hassan Syed (Indian Institute of Technology Kanpur, India)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_005

Abstract:
The Surface Water and Ocean Topography (SWOT) Mission provides high-resolution measurements of key parameters such as water surface elevation, channel width, and slope over inland rivers globally. The information provided through its node and reach products is crucial for estimating changes in river discharge, improving hydraulic and hydrological models, and providing reliable flood forecasts. Validating SWOT observations is a first step to ensure their reliability for water resource management, as it helps identify potential errors and quantify measurement uncertainties. Bitwise quality flags assess the quality of pixel cloud data used to generate SWOT's reach and node products. Each bit flag corresponds to a source of error. This study evaluates the accuracy of SWOT Water Surface Elevation (WSE) measurements using bitwise quality flags, validated against in-situ gauge stations in five Indian river basins: Narmada, Mahanadi, Godavari, Krishna, and Cauvery. The performance of individual and combined bitwise filters on Node and Reach products is evaluated by minimizing median RMSE and maximizing the number of stations retained in each basin. This study demonstrates that excluding observations with Flag 19 (geolocation_quality_degraded) in the node product significantly improves the median RMSE across all basins while retaining approximately 70% of the stations. The accuracy improves further upon excluding the narrower channels (Width < 100 m) from the analysis. While the reach product yields a lower median RMSE than the node product in the Godavari, Krishna, and Cauvery basins upon excluding Flag 19 observations, it retains only ~30% of stations overall, making it less robust than the node product. This study provides improved optimization of SWOT data, enabling users to enhance accuracy while retaining the maximum number of viable observations.

Corresponding author:
Rucha Sanjay Deshpande (**Indian Institute of Technology Kanpur**, **India**), rucha22@iitk.ac.in

Investigating SWOT observations for river hydrodynamics: A case study from the Po River

Farid Kurdnezhad (DICAM – School of Civil Engineering, University of Bologna and Research Institute for Geo-Hydrological Protection, National Research Council, Italy); Angelica Tarpanelli (Research Institute for Geo-Hydrological Protection, National Research Council, Italy); Alessio Domeneghetti (DICAM, School of Civil Engineering, University of Bologna, Italy)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_006

Abstract:
This study advances the evaluation of the Surface Water and Ocean Topography (SWOT) mission for monitoring of riverine hydrodynamics in Italy. Given the recent launch of the SWOT mission, its application to riverine hydrology remains relatively new and requires thorough validation. To date, only a limited number of studies have systematically assessed its capability to observe riverine dynamics. This study evaluates SWOT Water Surface Elevation (WSE) and slope data over its entire operational period, by comparing them with in-situ measurements and hydrodynamic model simulations, over a 165-km stretch of the Po River in Northern Italy, starting from Boretto gauging station. A 1D/2D HEC-RAS model, incorporating cross-sections extracted from the most recent LiDAR and bathymetric surveys, is used to dynamically simulate hydrodynamic variables along the river. Preliminary results from the analysis of SWOT River Single Pass product reveal systematic errors in its observations. In addition, when compared with model simulations, the findings underscore the critical importance of quality-aware filtering for the reliable use of SWOT observations. Good-quality WSE data generally show strong agreement with both in-situ measurements and hydrodynamic model simulations, typically within ±0.5–0.8 meters. In contrast, lower-quality observations exhibit significantly larger discrepancies, with deviations reaching several meters. However, only a small fraction of the available data is classified as good quality, presenting challenges for comprehensive analysis. Moreover, results suggest that SWOT accuracy is spatially correlated with geophysical and orbital factors.

To address these limitations, the study expands to use other quality indicators, including bitwise flags, enables the extraction of data with improved quality and coverage. Additionally, complementary SWOT products such as Pixel Cloud datasets are leveraged. These products provide higher spatial detail but being less processed, require thorough preprocessing, such as spatial filtering and noise/outlier removal, to derive reliable hydrodynamic information. Where systematic biases are observed, statistical corrections are applied to enhance SWOT data consistency. The study also explores the spatial and temporal performance of SWOT observations in relation to a range of influencing factors, including: (i) distance from nadir track, (ii) satellite pass orientation, (iii) river planform geometry (e.g., straight vs. meandering), and (iv) flow regime (e.g., rising limb, peak, recession, or low flow).

Although based on a single case study, the analysis contributes to illustrating both the potential and limitations of SWOT products for riverine applications. It highlights the importance of quality-aware data integration with physically based models to support operational hydrology, long-term water monitoring, and decision-making for flood and drought risk mitigation in inland-to-coastal environments. The methodology is also extendable to other riverine systems for inter-basin comparative assessments under varying hydraulic regimes.

Corresponding author:
Farid Kurdnezhad (**DICAM – School of Civil Engineering, University of Bologna and Research Institute for Geo-Hydrological Protection, National Research Council**, **Italy**), farid.kurdnezhad@unibo.it

Assessment of SWOT-RiverSP Data Reliability and Accuracy over Canadian Rivers

Victoria Litalien (Université de Sherbrooke, Canada); Yanis Papin (Université de Sherbrooke, Canada); Cheick Doumbia (Université de Sherbrooke, Canada); Anne-Marie Laroche (Université de Moncton, Canada); Mélanie Trudel (Université de Sherbrooke, Canada)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_007

Abstract:
Launched in December 2022, the SWOT (Surface Water and Ocean Topography) mission represents a major breakthrough in global surface water monitoring. Leveraging Ka-band radar interferometry, SWOT can observe water surface elevation (WSE) in rivers wider than 50 m, covering more than 150,000 km of linear river across Canada. While the scientific potential of SWOT is substantial, its operational use hinges critically on their reliability and accuracy of the data. In this context, a study was conducted to assess the quality of SWOT data comparing the RiverSP product with multiple reference sources across Canadian territory.
The first component of this work compares SWOT-derived WSE with ground truth across diverse hydrological contexts, using records from national hydrometric stations. Approximately 100 stations located on rivers with known elevation datum were selected and properly converted to the SWOT datum. Each station was then matched to the nearest SWOT RiverSP node within a 200-meter range, allowing for direct comparison between in situ and SWOT WSE measurements.
The second component is based on field campaigns conducted between 2023 and 2025 on four rivers: the Nashwaak (New Brunswick), Saint-François (Québec), Chaudière (Québec), and Au Saumon (Québec). High-precision GNSS measurements were performed from riverbank or by boat to measure WSE along the rivers during SWOT overpasses. These ground-based measurements were then compared to the nearest SWOT nodes, providing an opportunity to validate SWOT outputs under known conditions, while considering factors such as river width, slope, discharge, and environmental influences including vegetation and infrastructure.
The third component examines the reliability of the SWOT-RiverSP product by analyzing the factors that influence the availability of high quality data. It was observed that certain areas consistently yield high-quality nodes (node_q < 2), while others regularly produce poor quality nodes (nod_q > 1). These factors are divided into three categories: 1) those associated with the sensors, such as cross-track distance, flow angle, or cross-over calibration, 2) those associated with river characteristics, such as width, the presence of canopy on the bank or rock in the river, proximity to a bridge, meanders, and slope; and 3) finally, those related to hydroclimatic conditions, such as lack of wind (which affects dark water), precipitation, discharges, and ice cover. A Random Forest model is used to rank the relative importance of these variables in predicting node reliability.
The analysis is performed on rivers in New Brunswick and Québec where discharge data are available (from stations or hydrological models), as well as LiDAR data for river characterization. Wind and precipitation conditions are derived from ERA5-Land datasets, whereas vegetation analysis is assessed from aerial imagery. In addition, field campaigns have also been carried out in specific areas of concern to better understand the factors that may affect the SWOT signal.
Overall, this study aims to assess the reliability and accuracy of SWOT data across Canadian rivers by integrating satellite observations, hydrometric stations, and field measurements. It lays the groundwork for the informed use of SWOT in hydrological modeling, flood forecasting, and freshwater resource management.

Corresponding author:
Victoria Litalien (**Université de Sherbrooke**, **Canada**), victoria.litalien@usherbrooke.ca

Evaluation of the Water Masks Generated by the SWOT Satellite and Comparison with Optical Sensors

Maurício Cordeiro (National Water and Sanitation Agency (ANA), Brazil); Santiago Pena-Luque (CNES, France); Renato Frasson (JPL, US); Mohammad J. Tourian (University of stuttgart, Germany); Tati de Almeida (UNB, Brazil); Daniel Moreira (SGB, Brazil); Fabrice Papa (IRD, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_008

Abstract:
The Surface Water and Ocean Topography (SWOT) mission, a collaboration between NASA and CNES, offers a novel opportunity to advance the monitoring of inland water bodies through high-resolution elevation and extent data, even under persistent cloud cover. This is particularly relevant to Brazil, a country with extensive freshwater resources but significant challenges in monitoring water bodies at scale due to accessibility, cost, and the limitations of traditional methods. SWOT's Ka-band Radar Interferometer (KaRIn) overcomes many of these constraints by enabling high-resolution, cloud-independent measurements of water surface extent and elevation. While promising, the utility of many SWOT science products will depend directly on the quality of the water classification available in the PixelCloud. Initial studies indicate that the classification accuracy can be challenged under certain conditions, such as in the presence of specular ringing, dark water, and highly reflective surfaces like sandbanks.
In this context, this project proposes a systematic evaluation of water masks derived from the SWOT PixelCloud product, comparing them with established optical-based products such as OPERA (NASA/JPL) and SURFWATER (CNES). The analysis will encompass a range of global regions representing different environmental conditions, with a primary focus on the Amazon Basin. The methodology involves the spatio-temporal co-location of SWOT and Sentinel-2 data, rasterization of SWOT point clouds, and pixel-based comparisons. Classification agreement will be assessed using the kappa coefficient, and accuracy will be validated against reference samples derived from high-resolution optical imagery. To further validate classification accuracy, reference samples will be generated through the visual interpretation of high-resolution imagery from Pléiades, where available.
Additional analyses aim to explore both intrinsic (e.g., viewing geometry, signal-to-noise ratio) and extrinsic (e.g., land cover, water body size) factors influencing classification performance. Although the study is ongoing, preliminary results will be available by the time of the meeting. The findings will support SWOT users in adopting its products for reservoir monitoring and flood analysis and contribute to broader strategies for integrating radar and optical approaches in water resources management.
Corresponding author:
Maurício Cordeiro (**National Water and Sanitation Agency (ANA)**, **Brazil**), cordmaur@gmail.com

Validation and refinement of water level and water surface estimations from SWOT in floodplains environments

Lucas Sengsourinho (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France, France); Edward Salameh (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France, France); Frédéric Frappart (ISPA, UMR1391 INRAE Bordeaux Science Agro, F-33140, Villenave d'Ornon, France, France); Cassandra Normandin (ISPA, UMR1391 INRAE Bordeaux Science Agro, F-33140, Villenave d'Ornon, France, France); Valentine Sollier (ISPA, UMR1391 INRAE Bordeaux Science Agro, F-33140, Villenave d'Ornon, France, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_009

Abstract:
River floodplains play a major role in water, carbon, and biogeochemical cycles. They serve as an interface between the catchment and the main river channel and are characterized by a complex water dynamic (e.g. multiple water sources and pathways, hydrological connectivity, interactions with groundwater). As such, they require accurate monitoring to better understand their seasonal variability, manage flood risks, and assess their ecological functioning in a changing climate. The Surface Water and Ocean Topography (SWOT) satellite, equipped with a Ka-band Radar Interferometer (KaRIn), offers high-resolution altimetric data with unprecedented potential for monitoring water surface elevation and extent. This study aims to assess the performance of SWOT in measuring water level and detecting water surfaces over floodplains of two river systems with contrasted characteristics: the Parana and the Ob Rivers, located respectively in temperate and boreal climates. The assessment is performed using the L2_HR_PIXC and the L2_HR_Raster products which provide geolocated water surface elevation, backscattering coefficients, pixel classification, and other relevant parameters. For the Paraná River Floodplains, in situ water level measurements were retrieved from the Argentine National Water Information System (SNIH) providing water level records. For water extents, the accuracy of SWOT water detection was validated using two datasets, the Global Land Analysis and Discovery (GLAD) product and water masks extracted from MODIS observations. SWOT Water levels were compated to in situ measurements from multiple stations along the Parana River and its tributaries. The mean absolute error (MAE) reached 20 cm while correlation coefficients (R) exceeded 0.97 for most stations, demonstrating SWOT consistency despite the complexity of the environment. Regarding water surfaces, a good agreement is generally found over inland water (i.e., rivers, lakes and floodplains) when compared to inundation maps from GLAD with overall accuracies ranging between 66% and 81%. Furthermore, water detected by SWOT occurred over agricultural areas in the Parana basin. This represents both a limitation due to misclassification generating an overestimation of water surfaces, but also an opportunity to monitor irrigation periods for agricultural areas. We also detected low backscatter signals classified as water over urban areas, which are likely due to strong reflections from buildings and other urban structures. This highlights the need for further refinement of SWOT algorithms to reduce false positives in urban environments. Parallel analyses are ongoing on the Ob River floodplains to evaluate SWOT's performance across contrasting climatic and hydrological contexts.

Corresponding author:
Lucas Sengsourinho (**Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France**, **France**), lucas.sengsourinho@univ-rouen.fr

Field validation of SWOT for measuring water level and inundated areas of geographically isolated wetlands

Frances O'Donnell (Auburn University, United States); Suranjana Chatterjee (Auburn University, United States); Emma Marzolf (The Jones Center at Ichauway, United States); Steven Brantley (The Jones Center at Ichauway, United States); John Beck (The University of Alabama in Huntsville, United States)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_010

Abstract:
Geographically isolated wetlands (GIWs), which are not connected to a river, lake or ocean, are widespread and provide many societal benefits, including flood prevention, wildlife habitat, and water quality improvement. This project explores the potential of SWOT observations used with other water-focused satellite missions to monitor and improve understanding of GIWs. The first objective of our project, which will be discussed in the presentation, is to compare SWOT raster and pixel cloud data to field-measured water surface elevation and inundated area. We upgraded and expanded an existing monitoring network of 20 GIWs on the Dougherty Plain of Southwest Georgia, USA. The monitored wetlands range in size from (70 m)2 – (350 m)2 or 0.5 – 12 ha when full. A range of wetland vegetation types are represented, including grass and sedge marshes, cypress-gum swamp, and open water with occasional free-floating vegetation coverage. The contributing areas of the GIWs include a mix of forested and agricultural land covers. Water level is measured in the deepest part of the wetland at 15-minute intervals with HOBO water level recorders. We developed bathymetric maps by merging sonar depth readings with ground-based and airborne lidar that provide precise depth-area-volume relationships for these wetlands. Inundated area is determined in a subset of two to three GIWs on the date of each SWOT pass by walking wetted perimeter with a high-resolution (sub-meter) GPS. SWOT level-2 raster-derived water surface elevations were extracted for the raster cells containing the deepest point of three large GIWs and compared to field-measured water level over a one-year period during which the wetlands experienced a large range of variability in water level. Results showed that the raster product is affected by data quality issues leading to frequent overestimation of peak water levels and poor capture of seasonal drawdown periods, with SWOT-reported elevations exceeding field observations by up to 6 meters. This highlights limitations in vegetated or low-coherence conditions. Given these limitations, ongoing work is developing methods for estimating GIW water level and inundated area with SWOT Pixel Cloud Level 2 data. We developed scripts to retrieve and process pixel cloud data over the study wetlands. Initial analyses showed that a large proportion of pixels within wetland boundaries were classified as “land” or transitional types (e.g., land-near-water), especially along vegetated margins, though water was detected through both herbaceous and forested wetland vegetation. These findings demonstrate both the potential and limitations of SWOT for monitoring small inland wetlands. Ongoing work will develop a hybrid framework combining bathymetric modeling, field validation, and pixel filtering to improve wetland hydroperiod estimation.

Corresponding author:
Frances O'Donnell (**Auburn University**, **United States**), fco0002@auburn.edu

From Field to Swath: Validating and Refining SWOT Water Surface Elevations in Steep Rivers Using Quantile Regression

Trevor Wilkerson (Montana State University, United States); Eric Sproles (Montana State University, United States); Kathryn Plymesser (Montana State University, United States); Pablo Iribarren (Universidad Austral de Chile, Chile); Toby Minear (University of Colorado, United States)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_011

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite mission provides novel global water surface elevation (WSE) and discharge estimates, offering new opportunities for monitoring rivers in ungauged and data-scarce regions. However, accurately estimating river slope from WSE remains a challenge, especially in steep, complex terrains where elevation gradients are highly variable. Methods such as ordinary least squares (OLS) regression are sensitive to outliers, which can lead to biased slope estimates. In this field-based study, we introduce a quantile regression filtering approach to systematically identify and remove slope-influencing outliers, improving slope estimation robustness. Using in situ Global Navigation Satellite System (GNSS) data collected along the Río Petrohué (-42.3°, -72.4°), a steep, rapidly varying river in southern Chile, we validate SWOT-derived slopes from the L2_HR_PIXC product (PIC0 release) and assess WSE trend stability. Our results highlight that quantile-based filtering improves agreement between SWOT and ground-based slope estimates using the L2_HR_PIXC data product. This approach lays the groundwork for future automated filtering algorithms with implications for hydrologic modeling, flood forecasting, and water resource management. Additionally, we propose a method for smoothing the SWOT PIXC point cloud rather than aggregating it, as well as quantile regression-based segmentation to detect slope transitions, offering a pathway to preserve spatial fidelity while enabling automated hydraulic analysis across complex river networks.

Corresponding author:
Trevor Wilkerson (**Montana State University**, **United States**), tjwilkerson97@gmail.com

Assessment of Water Surface Elevation Products of the SWOT Satellite in the Northeast Brazil

Alfredo Ribeiro Neto (Federal University of Pernambuco, Brazil); Jonas Santos de Souza (Federal University of Pernambuco, Brazil); Mayara Silva de Oliveira (Federal University of Pernambuco, Brazil); Marielle Gosset (Institut de Recherche pour le Développement, France)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_012

Abstract:
Water level monitoring is crucial for water resource management and addressing the challenges of climate change. The new Surface Water and Ocean Topography (SWOT) mission provides unprecedented spatial and temporal resolution estimates of water surface elevation (WSE) for water bodies worldwide. This study evaluated the accuracy of WSE SWOT estimates over a set of reservoirs and river reaches in the Northeast Brazil. The water bodies are located, part in the Pernambuco state and part in the São Francisco river basin, one of most important in the region. The products evaluated included L2_HR_LakeSP Prior, L2_HR_RASTER 100m and L2_HR_RiverSP Node. The products were compared with observed data from stations for the period between April/2023 and March/2025. The accuracy of the WSE SWOT values was evaluated through the Pearson correlation coefficient r, Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). The results showed that the WSE SWOT time series obtained a good fit to the in-situ water level monitoring, with Pearson's r correlation coefficient greater than 0.9 in most stations. On the other hand, in some cases, WSE SWOT data have difficulty to represent properly the in-situ time series. Satellite measurement errors may be due to instrumental, atmospheric, and geophysical factors. Overall, the SWOT products showed good potential for use in monitoring water elevation in the rivers and lakes selected for assessment, with good accuracy and trend detection capabilities. Better filtering of outliers and improved accuracy in river reaches with sandbars would help to increase the accuracy of the products.

Corresponding author:
Alfredo Ribeiro Neto (**Federal University of Pernambuco**, **Brazil**), alfredo.ribeiro@ufpe.br

GNSS-IR monitoring of coastal and river water levels in Cameroon for Sentinel and SWOT Altimetry validation

Makan Karegar (University of Bonn, Germany); Loudi Yap (Research Laboratory in Geodesy, National Institute of Cartography, Cameroon, Cameroon); Jiaming Chen (Institute of Geodesy and Geoinformation, University of Bonn, Germany , Germany); Jürgen Kusche (Institute of Geodesy and Geoinformation, University of Bonn, Germany , Germany); Abdou Nasser Ngouh (Research Laboratory in Geodesy, National Institute of Cartography, Cameroon, Cameroon); Chrétien Ngouanet (Research Laboratory in Geodesy, National Institute of Cartography, Cameroon, Cameroon); Ludovic Houetchak Kandé (Research Laboratory in Geodesy, National Institute of Cartography, Cameroon, Cameroon); Paul Gautier Kamto (Research Laboratory in Geodesy, National Institute of Cartography, Cameroon, Cameroon)

Session: Hydrology: HR SWOT Data (Data Validation & Enhancement)
Presentation type: Poster
Poster number: ST2025HS1_013

Abstract:
In-situ surface water monitoring networks are crucial for calibrating and improving forecast models, validating satellite altimetry data and developing early-warning flood systems. While satellite remote sensing offer the potential to gauge remote river and coastal areas and provide valuable data for hydrological forecasting, their effective use still requires expertise in processing algorithms and access to in-situ validation data. Cameroon's coastal region, located at the base of the Gulf of Guinea, is highly vulnerable to natural hazards such as erosion, flooding, storms and sea-level rise. Despite the growing risks posed by climate change, there is no dedicated water-level monitoring system along the coast or for the major rivers in the country. In the CAMEO-WAGST project, funded by the Earth Observation Africa Research and Development Facility through the European Space Agency (ESA), we use innovative, low-cost and low-power sensors based on Global Navigation Satellite System Interferometric Reflectometry (GNSS-IR). These sensors, known as Raspberry Pi Reflectors (RPRs), have been deployed to establish a monitoring network of eight RPRs for river and sea level measurements in Cameroon, with the aim of achieving two key objectives. The first objective is to develop a prototype of cost-effective and low-maintenance infrastructure that can be adopted across Africa for operational early warning flood and drought systems. The second objective focuses on validating altimetry data from SWOT and Sentinel-3 and Sentinel-6 satellites. Fieldwork began in May and June 2025 with the installation of four RPRs in Cameroon. Two RPRs were installed along the Sanaga River - one in Song Mbengué, where a major hydropower dam is planned, and another at the Edea Dam. Two RPRs were deployed along the coastline: one in the Wouri Estuary near the city of Douala, a large tidal estuary where several rivers converge, and the other in Limbé. The remaining RPRs were installed along the coastline of the Gulf of Guinea. These efforts will be supported by the development of reusable, open-source EO algorithms and applications, tailored to address African challenges with African solutions particularly relevant for managing hydrological extremes and mitigating hazards such as floods and droughts.

Corresponding author:
Makan Karegar (**University of Bonn**, **Germany**), karegar@uni-bonn.de

4D-Var and SWOT: producing a month-long state estimate of the California Current System

Ariane Verdy (UCSD, United States); Sarah Gille (UCSD, United States); Matthew Mazloff (UCSD, United States); Bruce Cornuelle (UCSD, United States)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_001

Abstract:
SWOT's high-resolution measurements detect ocean features that are small enough to include ageostrophic or unbalanced motions, which necessitates refinements to data assimilation strategies. Using 4D-Var, observations from SWOT and the Global Ocean Observing System are assimilated into a regional model of the California Current System. This is achieved through a regional 2-km configuration of the MIT general circulation model (MITgcm) and its adjoint, with a 31-day assimilation window. The assimilation is run during the SWOT Cal-Val period (May 1-31, 2023). The first-guess model run is initialized with GLORYS ocean state and forced with ERA5 hourly atmospheric state; those fields are adjusted through iterative adjoint model runs to fit the observational constraints. Provided that the initial state is generally consistent with the SWOT observations at large scale, the 4D-Var method can successfully reduce model-data misfits over the month-long assimilation window, despite intrinsic nonlinear variability and instability in the high-resolution model. Assimilating SWOT improves the fit to independent (not assimilated) observations from Cal-Val mooring and gliders, as well as high-frequency radar; withholding the data allows us to quantify its impact. Because of the dynamical propagation of adjoint sensitivities over 31 days, surface observations help constrain the interior ocean state. Oxygen, carbon, and other biogeochemical fields are simulated using the optimized ocean state.

Corresponding author:
Ariane Verdy (**UCSD**, **United States**), averdy@ucsd.edu

Towards adjoint-based assimilation of SWOT data in a global ocean circulation model

Shoshi Reich (Oden Institute, University of Texas at Austin, United States); Patrick Heimbach (Oden Institute, University of Texas at Austin, United States)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_002

Abstract:
The Surface Water and Ocean Topography (SWOT) mission offers unprecedented spatial resolution capable of resolving fine-scale ocean features such as internal tides and mesoscale eddies. However, its 21-day repeat cycle introduces significant spatiotemporal gaps, limiting its ability to capture the rapid evolution of these small-scale processes. To fully exploit SWOT's high-resolution measurements and reconstruct the evolving ocean state, data assimilation is essential. Sequential, filter-based methods often introduce abrupt adjustments to the model state, violating the equations of motion and conservation laws. In contrast, adjoint-based methods enforce dynamical consistency. This work aims to advance eddy and tide-admitting baroclinic four-dimensional variational (4DVar) data assimilation to the global scale in order to produce an ocean state estimate constrained by SWOT observations. Resolving internal tides and mesoscale eddies seen in SWOT data requires a high-resolution global model, but the nonlinearities and computational cost of global 4DVar at these scales are prohibitive. To address this challenge, this work introduces a multi-grid adjoint approach for ocean state estimation. The forward model runs at high resolution to resolve the fine-scale features observed by SWOT, while the adjoint model runs on a coarser grid to approximate sensitivities more efficiently. Preliminary results show that this coarse-grid adjoint improves numerical stability, reduces computational cost, and retains the essential dynamics needed to constrain the model trajectory to observations. Developed within an automatic differentiation framework, this method enables dynamically consistent assimilation of SWOT and other high-resolution datasets in global ocean models. Additionally, to account for the high spatial resolution but temporally sparse nature of SWOT data, a new model-data misfit operator is developed for efficient comparison with irregularly sampled observations. SWOT's high-resolution observations offer a new window into small-scale ocean dynamics, which are vital for understanding the ocean's kinetic energy balance and vertical transport. While we have not yet applied the framework to SWOT data, the assimilation of sea surface height observations from SWOT is expected to tightly constrain initial and surface boundary conditions, shedding light on mesoscale eddy activity and its role in energy exchange. A global state estimate that assimilates SWOT observations at eddy- and internal wave-permitting scales will mark a significant step forward in ocean modeling, enabling deeper insight into the dynamics operating at scales newly accessible through SWOT.

Corresponding author:
Shoshi Reich (**Oden Institute, University of Texas at Austin**, **United States**), sreich@utexas.edu

Super Resolution of DUACS Sea Surface Height near the coast of Norway using SWOT

Antoine Bernigaud (NERSC, Norway); Julien Brajard (NERSC, Norway); Antonio Bonaduce (NERSC, Norway)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_003

Abstract:
Presenting author: Antonio Bonaduce

The goal is to increase the resolution of the DUACS data set consisting of full, Low Resolution (LR) fields of SSH with a neural network using the new SWOT SSH fields consisting of sparse, High Resolution (HR) fields of SSH.

Because the difference in resolution between the two products is high (approximately a factor 12 in both horizontal and vertical dimension), we chose a generative neural network. Indeed many HR images can correspond to one LR one. A standard U-Net architecture tends to average all of these possible realizations and thus struggles to produce high frequency features (new eddies, internal waves …), whereas a generative network can output individual possible HR realizations.

We therefore trained a Conditional Generative Adversarial Network (CGAN) on matching pairs of DUACS and SWOT images. To tackle the sparsity of data available in SWOT, those images are small patches localized along the satellite paths. The full super resolution of the DUACS data is then done patch by patch.

We are able to match the spectral quality of the HR data, i.e. we can produce out of a DUAC image several high resolution images that “look like” SWOT data, although the RMSE with the truth can decrease.
Corresponding author:
Antoine Bernigaud (**NERSC**, **Norway**), antoine.bernigaud@nersc.no

The spatial organization of Sargassum aggregations by ocean frontal dynamics : insights from SWOT data

Pierre-Etienne Brilouet (LEGOS - IRD, France); Julien Jouanno (LEGOS - IRD, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_004

Abstract:
Unprecedented massive landings of Sargassum floating algae have been observed since 2011 in large amounts off the coasts of the Lesser Antilles, Central America, Brazil and West Africa with tremendous negative environmental and socioeconomic impacts.

Satellite remote sensing is essential for observing, understanding and forecasting the extent of Sargassum blooms in the Atlantic. Currently, Sargassum detection by remote sensing is mainly based on ocean color indexes which rely on the difference in optical properties between Sargassum and the surrounding waters. At the Tropical Atlantic basin scale, the observability of Sargassum is assessed with the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Ocean and Land Colour Instrument (OLCI) sensors with spatial resolution of 1 km and 300 m, respectively. However, the acquisition of those optical data is only available during the day and is deeply afected by clouds and their shadows which are prevalent over the region of interest.

In this context, we propose an innovative approach based on Synthetic Aperture Radar (SAR) images to improve the detection of Sargassum rafts and better understand the structuration of the mats in the open ocean. Indeed, the SAR allows to probe high resolution observations of the ocean surface during day and night, regardless of weather conditions and cloud cover. The SAR backscatter signal captures the sea surface roughness signature ot the Sargassum mats, most probably because they inhibit the small waves at the ocean surface. The capacity of the SAR to detect Sargassum is verified using a multi-sensor approach, through comparison with ocean color based Sargassum detections.

In this study, the emphasis is on the recent Surface Water and Ocean Topography (SWOT) mission. Indeed, SWOT mission is a breakthrough in radar remote sensing, as the onboard sensors provide on a same wide-swath, the sea surface height (SSH) and the backscatter signal at high resolution (250m). This provides an invaluable framework for investigating the spatial organization of Sargassum mats and the associated frontal ocean dynamics. Once our Sargassum identification algorithm has been validated, we have focused on selected case studies in order to improve basic knowledge of the processes driving Sargassum transport and aggregation, especially the relative contribution of oceanic frontal dynamics and winds in shaping the Sargassum mats at the ocean surface.

Corresponding author:
Pierre-Etienne Brilouet (**LEGOS - IRD**, **France**), pierre-etienne.brilouet@ird.fr

From SWOT Swaths to Global Ocean: A Machine Learning Proof of Concept for Estimating Incoherent Tidal Variability

Ergane Fouchet (Ergane FOUCHET, France); Jerome Chanut (Mercator Ocean International, France); Clément Bricaud (Mercator Ocean International, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_005

Abstract:
The unprecedented high-resolution, two-dimensional mapping of Sea Surface Height (SSH) provided by SWOT comes with trade-offs: spatial gaps between swaths during the 1-day repeat Cal/Val phase, and temporal gaps between revisits during the 21-day repeat Science phase. One of the key challenges for SWOT-based studies is therefore to propagate observed structures in space and time to produce complete global maps. In this study, we investigate the potential of machine learning techniques to extrapolate information collected during the SWOT Cal/Val phase—covering roughly 9% of the ocean—to the global ocean.

Incoherent internal tides emerge from the interaction of coherent baroclinic tides with mesoscale eddies. Unlike coherent tides, which have predictable amplitudes and phases at fixed locations, incoherent tides are temporally and spatially variable and therefore characterized by unpredictability. The high temporal sampling of the SWOT Cal/Val phase has provided valuable insights into both coherent and incoherent tidal signals, in regions such as the Amazon Shelf and New Caledonia. In this study, we explore the potential to extrapolate these signals globally.

Coherent and incoherent tidal variances have been estimated from ORCA12 model simulations with tidal forcing. We present a proof of concept to assess the ability of machine learning algorithms to predict incoherent tides variance beyond SWOT swaths. Assuming that coherent internal tide variance is globally known and that the variance from incoherent tides has been estimated along SWOT tracks, we test whether machine learning models can reconstruct these signals elsewhere. We evaluate several regression models—including linear regression, support vector regression (SVR), random forests, neural networks, XGBoost, and k-nearest neighbors—and combinations of input features such as bathymetry and mesoscale variability, to identify the key drivers of accurate extrapolation.

Corresponding author:
Ergane Fouchet (**Ergane FOUCHET**, **France**), efouchet@mercator-ocean.fr

Capsizing and impact wave detection – Case study of iceberg A-76A

Constance Hjort (DTU Space, Denmark); Ole Andersen (DTU Space, Denmark); Bjarke Nilsson (DTU Space, Denmark)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_006

Abstract:
The breakup and capsizing of large tabular icebergs contribute to significant oceanic wave events that threaten coastal regions. Despite continuous monitoring near glacier walls, monitoring these processes in open ocean environments has remained challenging due to the unpredictable nature and limited access of the capsizing events. We present a pioneering case study of the London-sized iceberg A-76A, whose final months of fragmentation and capsizing were captured by the SWOT satellite as it approached South Georgia Island in 2023. Our findings highlight SWOT's unique ability to provide two-dimensional, large-scale views of iceberg-induced waves.

We successfully described the waves by their physical characteristics: wavelength (L), wave height (H), and water depth (h). These parameters together define the wave regime, a combination of linearity and dispersiveness, and thus guide the level of complexity required in the wave model. Immediately following the iceberg's impact, waves are expected to be highly nonlinear due to the extreme nature of the generation mechanism. As they propagate outward, these waves undergo energy loss, and their nonlinearity decreases. Over distance and time, wave trains typically become more regular and linear, with longer wavelengths travelling farther from the origin due to dispersion. We use SWOT to verify the regime of the observed waves. We also use a combination of wavelet transformation and the dispersion relationship to estimate the time that has passed since the impact. Investigating the relation between the wave's propagation time and regime.

This study establishes foundational methods for wave characterisation from the SWOT mission, enhancing understanding of iceberg break-up dynamics and their impact on ocean surface topography.

Corresponding author:
Constance Hjort (**DTU Space**, **Denmark**), s214510@dtu.dk

Internal solitary waves reflection and diffraction from interaction with eddies on the Amazon Shelf from SWOT

Chloé Goret (CECI CNRS/Cerfacs/IRD, Université de Toulouse, France); Ariane Koch-Larrouy (CECI CNRS/Cerfacs/IRD, Université de Toulouse, France); Jorge Manuel Magalhães (Interdisciplinary Centre of Marine and Environmental Research & Department of Geosciences, Environment and Spatial Planning, University of Porto (CIMAR/CIIMAR), Portugal); José Carlos Bastos da Silva (Interdisciplinary Centre of Marine and Environmental Research & Department of Geosciences, Environment and Spatial Planning, University of Porto (CIMAR/CIIMAR), Portugal); Fabius Kouogang (CECI, Université de Toulouse, CERFACS/CNRS/IRD ; Departamento de Oceanografia, Universidade Federal de Pernambuco (DOCEAN/UFPE), France / Brazil); Carina Regina de Macedo (LEGOS, Université de Toulouse, CNRS, OMP, IRD ; Univ. Littoral Côte d'Opale, CNRS, Univ. Lille, IRD, UMR 8187 – LOG – Laboratoire d'Océanologie et de Géosciences ; Earth Observation and Geoinformatics Division, National Institute for Space Research (INPE), France / Brazil); Michel Tchilibou (Collecte Localisation Satellites (CLS), France); Camila Artana (Laboratoire LOCEAN-IPSL, Sorbonne Universités, UPMC, Univ. Paris 6-CNRS-IRD-MNHN, France); Isabelle Dadou (LEGOS, Université de Toulouse, CNRS, OMP, IRD, France); Antoine Delepoulle (Collecte Localisation Satellites (CLS), France); Maxime Ballarota (Collecte Localisation Satellites (CLS) , France); Loren Carrère (Collecte Localisation Satellites (CLS), France); Simon Barbot (LEGOS, Université de Toulouse, CNES, CNRS, IRD, UPS,); Alex Costa (Departamento de Oceanografia, Universidade Federal de Pernambuco (DOCEAN/UFPE) , Brazil); M'hamdi Amine (LEGOS, Université de Toulouse, CNRS, OMP, IRD ; Departamento de Oceanografia, Universidade Federal de Pernambuco (DOCEAN/UFPE) ; CECI CNRS/Cerfacs/IRD, Université de Toulouse , France - Brazil)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_007

Abstract:
Off the Amazon shelf, mesoscale eddies interact with internal solitary waves (ISWs), altering their characteristics. For the first time, these interactions are observable through repeated, direct measurements by the Surface Water and Ocean Topography (SWOT) mission, combined with MODIS and NOAA-20 sunglint imagery. This study aims to analyze ISWs observable from SWOT's Absolute Dynamic Topography (ADT) and to characterize the changes in their properties when interacting with eddies. The analysis focuses on three cases: ISW propagation in the absence of eddies, ISW refraction refraction by a cyclonic eddy, and ISW diffraction by an anticyclonic eddy. Using a spectral analysis method combined with band-pass filtering, ISWs crests were detected and extracted. This approach enabled the accurate tracking of ISW features, such as propagation direction, distances between individual ISWs crest, and wavefront geometry. Prior to ISW-eddy interaction, mode-1 ISWs propagated without changes in propagation direction and with plane wavefronts. A key finding was that different ISW responses were observed after interaction with eddies. In the first case, without the eddy, the passage of ISWs over a seamount led to energy transfer from mode-1 ISWS to mode-3 ISWs, although the propagation direction remained unchanged. In the second case, with a cyclonic eddy over the seamount, ISW trajectories were deflected westward by approximately 50°. In addition, the wavefront curvature was increased, and shifts to mode-3 ISWs were observed. In the third case, at the western edge of an anticyclonic eddy near the seamount, ISWs were diffracted into two distinct direction. One part was refracted westward (~42°), exhibiting wavefront flattening and a reduction in the distances between crests. The second propagated eastward (~15°) along the anticyclone's edge, with surface manifestation of wave packet structures and increased wavefront curvature. These results demonstrate that the proposed method effectively captures the complex dynamics of ISWs. The results provide new insights into the nonlinear behavior of ISWs and their interactions with (sub)mesoscale oceanographic features.

Corresponding author:
Chloé Goret (**CECI CNRS/Cerfacs/IRD, Université de Toulouse**, **France**), goret@cerfacs.fr

Investigating Mediterranean phytoplankton diversity in fine-scale structures from space.

Théo Garcia (Institut de Mathématiques de Marseille (I2M) - UMR 7373, 3 place Victor Hugo Case 19, 13331 Marseille Cedex 3, France); Louise Rousselet (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Toulouse, France); Laurina Oms (Aix-Marseille Université, Université de Toulon, CNRS/INSU, IRD, Mediterranean Institute of Oceanography (MIO), UM 110, Campus universitaire de Luminy, Marseille, France); Xavier Milhaud (Institut de Mathématiques de Marseille (I2M) - UMR 7373, 3 place Victor Hugo Case 19, 13331 Marseille Cedex 3, France); Andrea Doglioli (Aix-Marseille Université, Université de Toulon, CNRS/INSU, IRD, Mediterranean Institute of Oceanography (MIO), UM 110, Campus universitaire de Luminy, Marseille, France); Monique Messié (Monterey Bay Aquarium Research Institute, Moss Landing, CA, USA); Claire Lacour (Laboratoire d'analyse et de mathématiques appliquées, Université Gustave Eiffel, 5 boulevard Descartes, 77454 Marne-la-Vallée Cedex 2, France); Pierre Vandekerkhove (Laboratoire d'analyse et de mathématiques appliquées, Université Gustave Eiffel, 5 boulevard Descartes, 77454 Marne-la-Vallée Cedex 2, France); Francesco d'Ovidio (Sorbonne Université, CNRS, IRD, MNHN, Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN-IPSL), Paris, France); Julien Le Sommer (CNRS, IRD, Grenoble INP, IGE, Univ. Grenoble Alpes, Grenoble, France); Gérald Grégori (Aix-Marseille Université, Université de Toulon, CNRS/INSU, IRD, Mediterranean Institute of Oceanography (MIO), UM 110, Campus universitaire de Luminy, Marseille, France); Denys Pommeret (Institut de Mathématiques de Marseille (I2M) - UMR 7373, 3 place Victor Hugo Case 19, 13331 Marseille Cedex 3, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_008

Abstract:
Fine-scale structures (1–100 km, days to weeks) are ubiquitous physical features that drive the physics, chemistry and ecology of the ocean. By creating significant heterogeneity in salinity and temperature, fine-scale structures shape diverse habitats that sustain phytoplankton diversity in the ocean. However, the ephemeral nature of fine-scale structures makes them difficult to study using in situ campaigns. Therefore, aside from a few in situ studies, the relationship between fine-scale structures and the distribution of phytoplankton diversity has mostly been investigated through modelling studies. Nevertheless, understanding the extent to which fine-scale structures influence phytoplankton diversity globally based on observations remains a critical challenge. Satellite-derived observations, particularly the combination of altimetry and ocean colour, have been widely used to study the distribution of phytoplankton according to physical features in the global ocean. The launch of the Surface Water and Ocean Topography (SWOT) satellite in 2022 helps to observe the smallest fine-scale structures that were not visible in conventional altimetry thanks to its unprecedented resolution.
In this study, we present the results obtained from satellite data analysis in the western basin of the Mediterranean Sea (5 May 2023). Our interest lies in (i) the phytoplankton community structure, characterised by the relative biomass of five phytoplankton functional types (i.e. diatoms, dinophytes, haptophytes, green algae and prochlorophytes, and prokaryotes - derived from ocean colour data), and (ii) the fine-scale structures (identified from SWOT-based altimetry data). Our objective is to characterise the phytoplankton communities across the entire study area and then compare their structure with that of the phytoplankton communities found within the fine-scale structures.
To characterize phytoplankton communities, we used Gaussian mixture models, which aimed at estimating the parameters of multivariate Gaussian distribution (i.e. average biomass and variance of the phytoplankton functional types) for several Gaussian components (i.e. within each community). On a first hand, we applied Gaussian mixture models on the whole study area on phytoplankton data to find how many communities are present. Then, using SWOT-based altimetry data, Finite Time Lyapunov Exponents were calculated to highlight fine-scales structures. Finally, Gaussian mixture models were applied a second time on phytoplankton data only in fine-scales structures.
Five communities were observed throughout the Western Mediterranean Sea (hereafter referred to as 'global communities'). Overall, there was a good correspondence between the spatial distribution of these communities and the presence of fine-scale structures. Five communities were observed in the fine-scale structures (hereafter referred to as 'fine-scale communities'). Comparing the relative biomass composition of these communities, it was found that four communities were similar between the global and fine-scale communities. The fine-scale communities that were common with the global communities were slightly less prevalent in fine-scale structures (between 14% and 27%) than in the entire Western Mediterranean Sea (between 21% and 29%). One community was only observed in the Western Mediterranean Sea. This community was mostly associated with coastal areas and represented approximately 2% of observations in the Western Mediterranean Sea. One community was only observed in the fine-scale structures. This community represented up to 22% of those observed in fine-scale structures.

Our results suggest that local environmental conditions in fine-scale structures allow a new community to emerge. Overall, these preliminary results highlight the importance of fine-scale structures in the spatial distribution of phytoplankton communities. This approach will be applied to a global dataset.

Corresponding author:
Théo Garcia (**Institut de Mathématiques de Marseille (I2M) - UMR 7373, 3 place Victor Hugo Case 19, 13331 Marseille Cedex 3**, **France**), theo.garcia@univ-amu.fr

SWOT data validation on the Patagonian Continental Shelf: Optimized tidal and atmospheric corrections for submesoscale resolution

Sebastián Cornejo-Guzmán (DCAO-CIMA, IFAECI, Argentina); Martín Saraceno (DCAO-CIMA, IFAECI, Argentina); Laura Ruiz Etcheverry (DCAO-CIMA, IFAECI, Argentina); Juan Pablo Pisoni (CESIMAR, Argentina); Juan Gabriel Vázquez (CESIMAR, Argentina); Matías G. Dinapoli (DCAO-CIMA, IFAECI, Argentina); Claudia G. Simionato (DCAO-CIMA, IFAECI, Argentina)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_009

Abstract:
The Patagonian Continental Shelf presents unique challenges for SWOT altimetry validation due to complex tidal dynamics, intense atmospheric forcing, and distinctive bathymetric characteristics. This study advances beyond preliminary structure identification to establish rigorous validation protocols through comprehensive in situ measurements and optimized correction algorithms during SWOT's Cal/Val period.
We deployed a multi-platform observational network along KaRIn/nadir track #007, including: (1) bottom pressure recorder at San Matías Gulf (41°S), (2) deep-water lander at 52°S equipped with SBE37 and Aquadopp current/pressure profiler, (3) Puerto Deseado tide gauge (48°S), and (4) three offshore platform WaveRadars (53°S). Trajectories of three surface drifters that crossed the validation track during few days were also analyzed. This configuration enabled systematic evaluation of SWOT L3 products against high-quality reference measurements across diverse shelf environments.
Our analysis demonstrates that standard SWOT corrections significantly underperform in this complex, poorly-measured region. Through comprehensive intercomparison of tidal models (FES2022b, TPXO10v2, GOT5.5, EOT20, and regional barotropic solutions), we identified FES2022b as optimal for harmonic analysis. More critically, replacing SWOT's global Dynamic Atmospheric Correction (DAC) with a regional barotropic model and ERA5-based inverted barometer corrections yielded substantial improvements: correlation coefficients increased from values below 0.5 (at some stations below 0.2) to correlations above 0.8, even exceeding 0.9 for sea level anomaly values.
The optimized correction framework reveals hydrodynamic features undetectable under standard L3 product configuration, with enhanced variability resolution that demonstrates improved capability for detecting coastal submesoscale processes. Comparison with high-frequency regional model outputs further reveals temporal aliasing effects in SWOT measurements that could lead to misinterpretation of oceanographic phenomena; despite daily coverage during the Cal/Val period, the highly dynamic nature of continental shelf processes requires sub-daily sampling to fully capture rapid oceanographic variability. These enhanced capabilities achieve centimeter accuracy essential for resolving coastal submesoscale processes, establishing a robust methodological framework for SWOT validation in continental shelf regions with complex dynamics.
This approach provides critical insights for global Cal/Val efforts and operational oceanographic applications in tidally-complex environments.

Acknowledgments
This work was supported by Pampa Azul B6, SWOT-PATASWOT, and OSTST TOSTO projects. TOTAL Energies provided offshore observational data.

Corresponding author:
Sebastián Cornejo-Guzmán (**DCAO-CIMA, IFAECI**, **Argentina**), sebastian.cornejo@cima.fcen.uba.ar

Evidence and likely mechanisms underlying the existence of fine-Scale frontal phytoplankton communities in the SWOT era

Laurina Oms (Aix Marseille Univ., Toulon University, CNRS, IRD, MIO UM 110, Marseille, 13288, France;, France); Monique Messié (Monterey Bay Aquarium Research Institute, Moss Landing, CA, USA;, US); Léo Berline (Aix Marseille Univ., Toulon University, CNRS, IRD, MIO UM 110, Marseille, 13288, France; , France); Marco Bellacicco (Institute of Marine Science, National Research Council of Italy, Via Fosso del Cavaliere, 100, 00133, Rome, Italy, Italy); Gérald Grégori (Aix Marseille Univ., Toulon University, CNRS, IRD, MIO UM 110, Marseille, 13288, France; , France); Andrea Doglioli (Aix Marseille Univ., Toulon University, CNRS, IRD, MIO UM 110, Marseille, 13288, France; , France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_010

Abstract:
Phytoplankton communities, composed of diverse species, exhibit significant variability across the global ocean. Their composition plays a key role in the marine carbon cycle and ecosystem functioning. As drifting organisms, phytoplankton are carried by ocean currents, and several numerical studies have highlighted the key role of fine-scale physical structures (1-100km, day-weeks) in shaping their distribution and influencing their behavior. However, fine-scale in situ studies have long been limited due to the difficulty of observing at sufficiently high resolution the physical environment in which phytoplankton is living. In particular, studying front-phytoplankton interactions remains challenging because of the complexity in simultaneously tracking fronts and their phytoplankton response in space and time. The few available in situ studies concerning front-phytoplankton interactions have been conducted in highly energetic and productive regions, whereas low energetic and oligotrophic regions, constituting the majority of the ocean and expanding with global warming, remain poorly explored.

The launch of the SWOT satellite in 2022 opened the doors to the "SWOT era," in which the fine-scale component of ocean dynamics is now observable. These new observations provide essential insights for designing adapted oceanographic cruises and for gaining a more comprehensive understanding of the physical environment that shapes phytoplankton communities, even in oligotrophic and low energetic regions.

In 2023, the BioSWOT-Med cruise (doi: 10.17600/18002392) took advantage of the SWOT Cal/Val phase by integrating daily SWOT images into an adaptive, multidisciplinary Lagrangian sampling strategy aimed at accurately targeting and sampling fine-scale physical structures in the oligotrophic Mediterranean Sea. In particular, we carried out, for the first time, high-resolution spatial and temporal sampling across and within the North Balearic Front identified thanks to SWOT imagery. We discovered a specific frontal phytoplankton community, characterized by a higher contribution of non-dominant phytoplankton types and a lower contribution of dominant phytoplankton types. We suggest that this community results from the specific interplay between frontal physical and biological processes.

To investigate this hypothesis, we combined a Lagrangian physical model, to evaluate passive transport by currents, with an NPZ (nutrient–phytoplankton–zooplankton) model, to assess the effect of nutrient supply and zooplankton grazing on phytoplankton. The horizontal velocity fields derived from SWOT were used as input of the Lagrangian model to resolve the North Balearic Front at fine-scale. We show that passive advection of a water mass hosting the frontal community largely explains its presence at the front. However, the age of this advected water mass within the front is shorter than that of the frontal community, suggesting that additional processes contribute to its persistence. We propose a framework where the dynamic synergy between passive transport, nutrient supply, and predation at fine-scale explains the sustained existence of the frontal phytoplankton community.

Findings from the BioSWOT-Med cruise and the coupled Lagrangian-NPZ modeling supported by the new fine-scale ocean overview of the SWOT era, provide evidence for a mechanistic understanding of the subtle and complex dynamics governing phytoplankton community in an oligotrophic and physically heterogeneous region. These results represent a key step toward a more comprehensive understanding of the global ecological implications of fine-scale ocean structuring.

Corresponding author:
Laurina Oms (**Aix Marseille Univ., Toulon University, CNRS, IRD, MIO UM 110, Marseille, 13288, France;, France**), laurina.oms@mio.osupytheas.fr

First insights from SWOT fast sampling phase: High Frequency Coastal Trapped Waves over the Patagonian Shelf.

Léa Poli (Mercator Ocean International, France); Camila Artana (Laboratoire LOCEAN-IPSL, CNRS, IRD, MNHN, Sorbonne Universités, Paris, France, France); Christine Provost (Laboratoire LOCEAN-IPSL, CNRS, IRD, MNHN, Sorbonne Universités, Paris, France, France); Alba Le Dissez (Laboratoire LOCEAN-IPSL, CNRS, IRD, MNHN, Sorbonne Universités, Paris, France, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_011

Abstract:
The wide and highly productive Patagonian Shelf hosts a variety of waves. The study of coastal trapped waves with periods smaller than 20 days has been limited by the temporal resolution of satellite altimetric data. The fast sampling phase of the recently launched SWOT satellite revisits specific areas once a day and provides an unprecedented opportunity to examine rapidly changing signals over the Patagonian Shelf. SWOT provides evidence of waves with wavelengths larger than 4000 km and periods between 8 and 10 days which propagate with speeds of 5-6 m/s over the Pacific side and 10-13 m/s over the Patagonian Shelf. They represent a major feature of the the 20-day high-pass filtered sea surface height anomaly variability of the fast sampling phase. Wind bursts along the Pacific side probably contribute to their generation.

Corresponding author:
Léa Poli (**Mercator Ocean International**, **France**), leapoli1@yahoo.fr

Ecological role of fine-scale ocean structures in structuring heterotrophic bacterioplankton communities: BioSWOT-Med campaign

Ludivine Grand (Institut Méditerranéen d'Océanologie, France); Aude Barani (Institut Méditerranéen d'Océanologie, France); Marceau Dupin (Institut Méditerranéen d'Océanologie, France); Elvira Pulido (Institut Méditerranéen d'Océanologie, France); Andrea Doglioli (Institut Méditerranéen d'Océanologie, France); Gérald Grégori (Institut Méditerranéen d'Océanologie, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_012

Abstract:
Fine-scale oceanic structures (1–100 km), although short-lived (lasting from days to weeks), play a central role in marine chemical and biological dynamics. By generating intense horizontal gradients and associated vertical movements, they influence biogeochemical cycles and the structuring of planktonic biodiversity, even affecting the behavior of megafauna. However, these processes remain largely understudied in many oceanic regions, especially in oligotrophic and moderately energetic basins. The BioSWOT-Med campaign (https://doi.org/10.17600/18002392), conducted in spring 2023 in the area of the oligotrophic North Balearic Front (northwestern Mediterranean), forms part of the international effort to exploit data from the SWOT (Surface Water and Ocean Topography, NASA-CNES) mission, the first altimeter to provide two-dimensional sea surface observations at high spatio-temporal resolution.

The BioSWOT-Med campaign targeted three contrasting dynamic structures: a cyclonic recirculation in the north, an anticyclonic eddy in the south, and an eastward frontal jet separating them. An innovative, adaptive, and Lagrangian sampling strategy was implemented, combining several multi-disciplinary and high-frequency measurements. The collected data enabled a fine-scale characterization of the physical structure of water masses and their influence on the distribution of planktonic communities. While many studies have focused on phytoplankton, whose responses to physical ocean structuring are relatively well documented, heterotrophic bacterial communities (named “bacteria” hereafter) have long been understudied in such contexts, due to the challenges of taxonomic and functional identification without omics tools. Yet, bacteria play a key role in marine biogeochemical cycles, particularly in organic matter degradation, nutrient remineralization, and the regulation of carbon, nitrogen, phosphorus and iron cycles. Using flow cytometry to investigate the diversity and abundance of bacterial communities between 0 and 500 meters depth, alongside analyses of the physical and chemical characteristics of water masses, the study revealed changes in community composition and structure across the three oceanic features.

Functional statistical analyses showed that, interestingly, when comparing relative and absolute abundances, the front’s relative community structure appears intermediate between adjacent water masses, whereas its absolute abundances reveal a distinct pattern. This suggests that the front functions not only as a transitional zone, but also as a hotspot of bacterial accumulation or growth. Notably, this front is dominated by small-cell populations. The cyclonic recirculation is characterized by high variability and the presence of large-cell bacterial groups absent from the other structures. The southern anticyclonic eddy, by contrast, shows low variability due to its trapping nature and its low nutrient availability, and exhibits a deeper bacterioplanktonic signature throughout the water column. Finally, redundancy analysis indicates that a large part of the variance observed in bacterial community composition can be explained by the physico-chemical parameters measured (nutrients, fluorescence, temperature, salinity), highlighting the environmental structuring of these communities.

By integrating high-resolution coupled observations of physics, biogeochemistry, and biology, the BioSWOT-Med campaign demonstrates the potential of the SWOT satellite to link fine-scale ocean dynamics to biodiversity patterns. Conducted in a Mediterranean region representative of many global oligotrophic and low energetic systems, the campaign underscores the importance of integrating physical, biogeochemical, and biological dynamics to understand and model the functioning of marine ecosystems. These results provide a foundation for future global-scale research and emphasize the need for multi-scale and multi-disciplinary observations to understand the structuring of the oceanic biological landscape.
Corresponding author:
Ludivine Grand (**Institut Méditerranéen d'Océanologie**, **France**), ludivine.lucie.grand@gmail.com

Heat supply to the fast-thinning Denman glacier in Antarctica: ice and eddies interactions revealed by SWOT and in situ observations.

Benoit Legresy (CSIRO, Australia); Laura HERRAIZ BORREGUERO (CSIRO, Australia); Ole RIEKE (University of Tasmania, Australia); Yuhang LIU (University of Tasmania, Australia); Annie FOPPERT (University of Tasmania, Australia); Matthis AUGER (University of Tasmania, Australia); Yann-Treden TRANCHANT (University of Tasmania, Australia); Bea PENA-MOLINO (CSIRO, Australia); Maxim NIKURASHIN (University of Tasmania, Australia)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_013

Abstract:
Fine scale observations in the Antarctic Shelf in front of the fast-thinning Denman Glacier with SWOT and in situ observations reveal strong coastal current and sub-mesoscale eddies capable of deep water-masses modification.
The Denman is one of the fastest thinning glaciers in Antarctica. This has been informed by remote sensing observations, and it has been pointed to ocean driving a great deal of the mass loss by models. The glacier area had however never been visited by oceanographic vessels until very recently. The Denman Marine Voyage on-board RSV Nuyina visited the region in March-April 2025 and deployed a significant oceanographic investigation with some datasets already showing stunning small scale ocean processes. SWOT observations suggest very strong currents in the vicinity of the glacier and induced very small and strong instabilities and eddies. This was difficult to assess given the presence of the ice tongue, icebergs and seaice, all prone to contaminate and corrupt sea level anomalies. We developed ways to compute the balanced motion currents from swot at smaller scales (O10km). The ship ADCP data and iceberg drifts confirmed the strength of the currents and small, short-lived eddies. Those sub-mesoscale dynamics are effectively reproduced by a local high-resolution model. This presentation will show the results of this analysis and the inferred deep penetration of surface waters in presence of these sub-mesoscale eddies, the interaction with icebergs and water masses modification. This study highlights the step change of the critical coastal Antarctic observability brought by SWOT.

Corresponding author:
Benoit Legresy (**CSIRO**, **Australia**), benoit.legresy@csiro.au

New insights on mesoscale activity and associated retention properties from SWOT gridded products in the western Mediterranean Sea

Laura Gomez-Navarro (IMEDEA (UIB-CSIC), Spain); Ananda Pascual (IMEDEA (UIB-CSIC), Spain); Diego Cortes-Morales (IMEDEA (UIB-CSIC), Spain); Maxime Ballarotta (CLS, France); Marie-Isabelle Pujol (CLS, France); Laura Fortunato (Università degli studi di Napoli Parthenope, Italy); Baptiste Mourre (IMEDEA (UIB-CSIC), Spain)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_014

Abstract:
In this study we investigate the improvements in monitoring surface mesoscale activity in the western Mediterranean Sea enabled by the new wide-swath altimetry data from the SWOT mission. We compare the recently released high-resolution surface current product (MIOST v2.0.1 and previous versions), which integrates SWOT KaRIn observations during the 2023–2024 science phase, with the operational Copernicus Marine DUACS product (optimal interpolation method). Eddy fields are analyzed using an eddy identification and tracking algorithm, the py-eddy-tracker. We observe differences between the number of eddies identified, especially in coastal regions. The differences in eddy characteristics—such as radius, amplitude, and kinetic energy—are quantified by identifying eddies present in both datasets. To complement this Eulerian approach and to assess the practical implications of these differences, we conduct Lagrangian simulations using OceanParcels to evaluate the retention capacity of Algerian eddies and their role in transporting marine debris. This case study focused on the Cabrera National Park shows that including the SWOT KaRIn data affects the detection of mesoscale pathways relevant to pollution exposure. We quantify the differences in retention capacity of Algerian eddies identified in both fieldsets, observing significant differences in retention strengths, and even opposite effects (retention vs leakage). These findings help us to quantify the improvements provided by including the SWOT KaRIn data in gridded altimetric products. Moreover, this application highlights the added value of SWOT data for advancing operational ocean monitoring, with direct implications for marine conservation, pollution risk assessment, and sustainable maritime operations.

Corresponding author:
Laura Gomez-Navarro (**IMEDEA (UIB-CSIC)**, **Spain**), laura.gomez@uib.es

Comprehensive studies on sub-mesoscale phenomena; coastal SSHA validations in the Bungo Channel, Japan, and impacts of assimilating SWOT data in ocean and hydrological models

Kaoru Ichikawa (Kyushu University, Japan)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_015

Abstract:
The Japanese SWOT science team is an inclusive group for comprehensive studies on sub-mesoscale phenomena in the western North Pacific and marginal seas. (1) We compare coastal SSH variations in the Bungo Channel, Japan, with records of moored pressure gauges and GNSS height observations along ferry tracks. Although temporal changes in SSH at fixed points agree with in situ observations, spatial SSH anomaly distributions are physically unrealistic, mainly due to an insufficient coastal geoid model. (2) The 3D-Var assimilation of six conventional altimeters to the J-COPE model fails to represent locations and shapes of eddies that are detected by both the SWOT instantaneous SSH maps and trajectories of 115 surface drifters deployed east of Izu-Ogasawara Ridge (around 30N and 142E). However, temporal interpolation by the 4D-Var assimilation has relaxed this problem. (3) Compared with the 100-m depth temperature observed by ships and Argo drifters, the MOVE-JPN assimilation model using SWOT KaRIn data was worse than that with nadir data, especially in the Kuroshio Extension and eastern tropical Pacific. Possibly, conversion functions for the vertical thermal profiles from SSH are not well established for sub-mesoscale phenomena. (4) Assimilated results of river discharges from SWOT, based on its river widths and water surface elevation and slope observations, are better than those from Landsat's river widths data, mainly due to the higher observation frequency of SWOT. However, in the areas well represented by the baseline model, the higher spatial resolution of Landsat results in better results.

Corresponding author:
Kaoru Ichikawa (**Kyushu University**, **Japan**), ichikawa@riam.kyushu-u.ac.jp

Unveiling Mediterranean Mesoscale to Sub-mesoscale Dynamics: Insights from WEMSWOT and C-SWOT-2023 Twin Ship Campaigns

Jean-Baptiste Roustan (Shom, France); Valérie Garnier (LOPS, France); Pierre Garreau (LOPS, France); Franck Dumas (Shom, France); Aurélien Ponte (LOPS, France); Alexandre Barboni (LEGOS, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_016

Abstract:
The twin field experiments C-SWOT-2023 and WEMSWOT took place in the North-Western Mediterranean sub-basin during the period of March to April 2023. The primary objective was to support the calibration and validation of the observations provided by the new-generation SWOT altimeter. Indeed, the satellite's daily overflights from Minorqua to Marseille offered a unique opportunity to provide a novel perspective on the regional ocean dynamics: bounded by the North Current and the Balearic Front, the cyclonic gyre is the site of winter convection events during where numerous mesoscale eddies and submesoscale instabilities develop and interact.

The originality of this field experiment lies in the mobilisation of two research vessels (the R/V Thetys II for C-SWOT-2023 and the R/V Atalante for WEMSWOT) that sailed in tandem for more than 600 NM. This enables access to the full tensor constraint statistics (vorticity, strain, divergence) in both surface and at depth, which are rarely accessible in fine-scale in situ observations.

After a short overview of the dataset consisting in joint observations of velocity, temperature and salinity within the first three hundred meters underneath the sea surface, analyses focus on the observed mesoscale to sub-mesoscale dynamics. In situ measurements of vorticity and strain are derived and compared with values derived from SWOT data assuming geostrophy. This comparison highlights SWOT's ability to capture mesoscale to submesoscale turbulent dynamics, even in relatively quiescent regions like the Mediterranean Sea far from western boundary currents. The added value of the cyclogeostrophic approximation over classical geostrophy for characterizing small, yet intense, eddy structures is also discussed.
To complement these analyses, SWOT and in situ observations are compared with CROCO numerical simulations at two different resolutions (400 m and 1.8 km). The idea is to evaluate how well the submesoscale dynamics is represented in numerical models at scales well resolved by SWOT. Conversely, at finer scales, the numerical ocean simulations help identify which parts of the submesoscale turbulent cascade may be captured with SWOT-derived geostrophic and cyclogeostrophic currents.

Corresponding author:
Jean-Baptiste Roustan (**Shom**, **France**), jean.baptiste.roustan@shom.fr

Submesoscale Sea Surface Height Mapping Along the East Greenland Coast From SWOT

Sara N. Jensen (Dr, Denmark); Ole baltazar Andersen (DTU Space, Denmark); Bjarke Nilsson (DTU Space, Denmark)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_017

Abstract:
The recently launched Surface Water Ocean and Water Topography (SWOT) mission provides Sea Surface Height (SSH) observations over a 120 km wide swath at 2 km resolution. This presents a unique opportunity to map the mesoscale and submesoscale ocean dynamics that are not currently resolved by conventional altimetry. The aim of this project is to produce high resolution maps of the SSH field that are consistent in time and space along the East Greenland coast. From the SSH field, geostrophic currents and relative vorticity can be derived and used to study the mesoscale (20km-200km) and submesoscale (200m-20km) dynamics developing in the East Greenland Current (EGC) and along the Polar Front. The submesoscale is associated with vertical exchanges of nutrients, heat, and carbon, and is thus particularly important for understanding the effects of the warming and freshening the region is experiencing due to climate change. Because of its location at high latitudes, the study area benefits from small Rossby number and short satellite revisit time. However, in the period between November and June a large part of the East Greenland shelf is covered by Arctic sea ice that has been transported south by the EGC. To overcome the problem of limited altimetry observations in these months, SWOT data in the marginal ice zone will be exploited by masking individual ice floes. The linear Optimal Interpolation (OI) methods traditionally used on conventional altimetry is not able to fully exploit the high-resolution content of the SWOT observations because the decorrelation time of the small-scale dynamics are much smaller than the satellite revisit time. Thus, a Dynamical Optimal Interpolation (DOI) method based upon conservation of potential vorticity in a quasi-geostrophic framework is applied to assimilate SWOT and conventional altimetry data. The spatial resolution is significantly increased compared to the DUACS products which are based on OI of conventional altimetry data. Moreover, the coverage is significantly increased in coastal and sea-ice covered areas. The capability of the DOI method of capturing mesoscale and submesoscale features will be validated with Sea Surface Temperature (SST) data. This project illustrates how combining high resolution SWOT data with a dynamic model can increase both the accuracy and the spatial and temporal resolution of SSH mapping.

Corresponding author:
Sara N. Jensen (**Dr**, **Denmark**), sanje@space.dtu.dk

Southern Ocean latent heat flux variability driven by high atmospheric frequencies and oceanic meso- and submesoscale motions

Lucie Reymondet (Scripps Institution of Oceanography, University of California San Diego, United States); Lia Siegelman (Scripps Institution of Oceanography, University of California San Diego, United States); Luc Lenain (Scripps Institution of Oceanography, University of California San Diego, United States); Dimitris Menemenlis (Moss Landing Marine Laboratories, San José State University, United States); Andrea Molod (NASA Goddard Space Flight Center, United States)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_018

Abstract:
The Southern Ocean plays an outsized role in air-sea exchanges of heat and other climatically-relevant tracers. In particular, Latent Heat Fluxes (LHF) are the gateways through which moisture is transferred between the ocean and the atmosphere. Air-sea fluxes are known to be modulated by atmospheric variability and oceanic motions. In this study we aim to better understand the contributions of high-frequency atmospheric motions and fine ocean scales (e.g., submesoscales and high-latitude mesoscales) in the Southern Ocean.
We use a global, coupled ocean-atmosphere simulation that admits ocean submesoscales and atmospheric clouds, the so-called GEOS/ECCO C1440-LLC2160 simulation that has ~7-km horizontal grid spacing in the atmosphere and 2–4-km grid spacing in the ocean. The simulation reveals that LHF variability is primarily driven by atmospheric high frequencies (≳2days, e.g. up to 30% in Agulhas retroflection) and oceanic meso- and submesoscales (O(10–100 km) scales, e.g., up to 70% in Agulhas retroflection), with high spatial heterogeneity and distinct seasonal patterns throughout the Southern Ocean. By way of contrast, we also show that the commonly used LHF from ERA5 underestimate LHF variability by 20% on average across the entire Southern Ocean. These results highlight the potential of using SWOT data, in combination with high resolution SST observations, to more accurately diagnose high-latitude heat fluxes at the air-sea interface, fluxes that are at present especially poorly constrained.

Corresponding author:
Lucie Reymondet (**Scripps Institution of Oceanography, University of California San Diego**, **United States**), lureymondet@ucsd.edu

Patagonian Shelf Break Front (PSBF): Seabed morphology, water masses and ocean currents

Laura Ruiz-Etcheverry (CIMA/CONICET-UBA, Argentina); Silvia Romero (Servicio de Hidrografía Naval , Argentina); Graziella Bozzano (Servicio de Hidrografía Naval , Argentina); Ornella Silvestri (Servicio de Hidrografía Naval , Argentina)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_019

Abstract:
This is a project that aims to generate new knowledge on the interaction between submarine morphology associated with submarine canyons on the Argentine Continental Margin (ACM) and the oceanographic dynamics linked to the Malvinas Current (MC), in two key sectors of the shelf break: the Patagonian region (from now on Southern System, 44-45°S) and the Bonaerense region (from now on Northern System, 40-41°S). Research activities are scheduled between September 22 and October 22, 2025, on board the oceanographic vessel Falkor (too). The scientific team is composed entirely of Argentine researchers, led by members of the Servicio de Hidrografía Naval (SHN) and the Centro de Investigación del Mar y la Atmósfera (CIMA-UBA-CONICET). The remaining participants form a multidisciplinary group with extensive experience in oceanography, marine geology, and biology. The central hypothesis is that the submarine valleys associated with the canyons, especially where their head incises the continental shelf, alter the circulation of water masses, promoting the intrusion of slope waters from the MC—cold, saline, and nutrient-rich—onto the continental shelf. This input of deep waters would enhance the fertilization of shelf waters—warmer and less saline—thus supporting high biological productivity and sustaining abundant fishery resources along the shelf-break of the Argentine Sea. The precise location of the canyon heads will be determined using high-resolution geomorphological data acquired with a multibeam echo sounder and a sub-bottom profiler. For the first time, these environments will be explored through dives conducted by the ROV, allowing direct visual characterization of habitats. Hydrographic and biological measurements will be carried out around the canyon heads through water sampling and plankton net tows, with the goal of understanding the coupled physical-biological dynamics in these areas. Additionally, in the Northern System, in the framework of PATASWOT project and a PhD thesis, current meters will be deployed on two landers and a moored surface buoy (Wavescan type) with meteorological and subsurface instruments to generate time series of current velocity, temperature and salinity, and GPS-tracked surface drifters, to study the trajectories and hydrographic characteristics of the currents as they cross the area to verify the surface circulation patterns generated by the interaction with the submarine canyon. This project represents a significant step forward in understanding oceanographic processes and their coupling with seafloor morphology and biological systems, through an interdisciplinary approach that has not yet been developed at this level of detail in Argentine waters. It will constitute the first comprehensive, high-resolution study of submarine canyons on the Argentine continental margin, in a region of high ecological and economic value due to the presence of key fishery resources. The fortunate combination of advanced technologies and integrated methodologies presents a unique opportunity to carry out this study. The expected outcome is the generation of critical knowledge on the dynamics of nutrient availability on the Argentine shelf, its implications for the trophic web, and its influence on commercially important species.

Corresponding author:
Laura Ruiz-Etcheverry (**CIMA/CONICET-UBA**, **Argentina**), lruiz@cima.fcen.uba.ar

Modelling the high-wavenumber ocean dynamics revealed by SWOT in the ACC

Yann-Treden Tranchant (Australian Antarctic Program Partnership, University of Tasmania, Australia); Benoit Legresy (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia); Clothilde Langlais (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia); Paul Sandery (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia); Darren Engwirda (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia); Mike Herzfeld (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_020

Abstract:
The recently launched SWOT (Surface Water and Ocean Topography) satellite provides a new and detailed view of ocean dynamics globally and at scales down to a 15 km wavelength. With the advent of SWOT, there is a critical need to connect high-resolution SSH observations with interior ocean dynamics to estimate key climate-relevant budgets such as vertical heat fluxes. Addressing this challenge involves two complementary strategies: (1) conducting Observing System Simulation Experiments (OSSEs) to develop and validate diagnostic methods and proxies from SSH observations, and (2) assimilating SWOT data into high-resolution ocean models to reconstruct the full 3D ocean circulation. Both approaches require kilometre-scale models capable of capturing realistic ocean dynamics across the full wavenumber spectrum revealed by SWOT.

The SWOT launch has motivated international validation efforts with in-situ campaigns in key dynamic regions. One such validation campaign, the Fine-scale Ocean Currents Under SWOT (FOCUS) voyage, provided a full three-dimensional dataset in an energetic meander of the Antarctic Circumpolar Current (ACC) south of Tasmania, a known hotspot for Eddy Kinetic Energy (EKE) and small-scale motions. This poster presents and validates the FOCUS model, a high-resolution implementation of COMPAS (Coastal Ocean Marine Prediction Across Scales), designed to investigate fine-scale fluxes, conduct OSSEs, and support SWOT data assimilation in the ACC meander. We evaluate the effects of horizontal resolution using a nested grid approach (2.5 km to 800 m), assess the impact of viscosity parameterizations, and explore different vertical discretization to mitigate grid-scale noise. The model's ability to reproduce a realistic energy cascade is assessed using wavenumber spectra derived from SWOT observations and in situ measurements collected during the FOCUS voyage, including hydrographic and ADCP transects.

Corresponding author:
Yann-Treden Tranchant (**Australian Antarctic Program Partnership, University of Tasmania**, **Australia**), yanntreden.tranchant@utas.edu.au

Submesoscale Eddys Identification and Characterization in the Oceanic Region of Fernando de Noronha and Rocas Atoll Using SWOT Satellite Observations

Diogenes Fontenele (Universidade Federal do Ceará, Brazil); Antonio Geraldo Ferreira (Universidade Federal do Ceará, Brazil); Fabrice Hernandez (Institut de Recherche pour le Développement, France); Eduardo Savio Martins (Fundação Cearense de Meteorologia e Recursos Hídricos, Brazil)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_021

Abstract:
Oceanic islands are regions of high primary productivity and biodiversity. These characteristics also apply to the Fernando de Noronha Archipelago and the Rocas Atoll, even though the area is located in the western portion of the Tropical Atlantic, where waters are highly oligotrophic. Studies on ocean dynamics in the region suggest the occurrence of subsurface eddies near the islands, associated with upwelling processes and primary productivity. However, the presence of surface eddies is still not well characterized due to the insufficient spatial resolution of available data. In this context, advancements in altimetric data collection with the launch of the SWOT mission have provided information with higher spatial resolution, enabling the identification of submesoscale eddies. This study uses data from SWOT 21-day repeat orbit to assess surface eddies near these islands, aiming to characterize submesoscale ocean dynamics in the region. SWOT altimetric KaRin data were used to estimate geostrophic currents in the western Tropical Atlantic. This information was compared to currents from the DUACS L4 products, estimated using all existing satellite altimetry missions. Chlorophyll and SST data were also used to identify relationships with local primary productivity. Preliminary results indicate that SWOT data are able to characterize flow in the western Tropical Atlantic in greater detail compared to DUACS data. Additionally, semi-permanent eddies were identified around Fernando de Noronha and Rocas Atoll. The association of this information with chlorophyll and SST is ongoing; however, it is already possible to observe relationships between the eddy cores and anomalies in these variables.

Corresponding author:
Diogenes Fontenele (**Universidade Federal do Ceará**, **Brazil**), diogenesfontenele13@gmail.com

Surface ocean variability in the northern North Atlantic: Insights from the new SWOT mission

Ingvild Olden Bjerkelund (Norwegian Meteorological Institute, Norway); Pål Erik Isachsen (University of Oslo, Norway); Jonathan M. Lilly (Planetary Science Institute, USA); Marina Durán Moro (Norwegian Meteorological Institute, Norway); Martina Idžanovic (Norwegian Meteorological Institute, Norway); Antonio Bonaduce (NERSC, Norway)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_022

Abstract:
The new Surface Water and Ocean Topography (SWOT) mission has marked a significant advancement in altimetry, demonstrating a substantial increase in resolution, capturing variability down to the submesoscale. What separates the SWOT mission from previous altimeters is its two-dimensional measurements of the sea surface. This offers a completely new dataset, where geostrophic velocities can be obtained in both directions. In this study, as part of the SWOT-NOR science team project, we use SWOT to look at the variability in the northern North Atlantic, including variance ellipses to assess the anisotropic part of the variability in surface geostrophic velocities. This has never been done along-track before, as previous altimeters only provided one-dimensional measurements. We use the operational ocean and sea-ice forecast model, Barents-2.5 to compare with SWOT sea surface height, geostrophic currents, and eddy kinetic energy in the Barents Sea and Svalbard region. This intercomparison study aims to evaluate the model's bias relative to SWOT high-resolution observations, as a preparatory step toward its future assimilation into the operational forecasting system.
Corresponding author:
Ingvild Olden Bjerkelund (**Norwegian Meteorological Institute**, **Norway**), ingvild.o.bjerkelund@met.no

Assessment of SWOT satellite observations and integration with high-resolution regional simulations in the Western Mediterranean Sea

Baptiste Mourre (Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB), Spain); Jen-Ping Peng (Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB), Spain); Elisabet Verger-Miralles (Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB), Spain); Laura Gómez-Navarro (Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB), Spain); Máximo García-Jove (Balearic Islands Coastal Observing and Forecasting System, ICTS SOCIB, Spain); Eugenio Cutolo (IMT-Atlantique, France); Bàrbara Barcelo-Llull (Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB), Spain); Daniel R. Tarry (Applied Physics Laboratory, University of Washington, USA); Nikolaos Zarokanellos (Balearic Islands Coastal Observing and Forecasting System, ICTS SOCIB, Spain)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_023

Abstract:
SWOT sea level observations and derived estimates of surface currents and vorticity fields are evaluated based on in-situ observations collected during two sea trial experiments conducted in the Balearic Sea (Western Mediterranean) during the initial fast-sampling phase of the satellite in April-May 2023. Measurements from ship-based instruments (CTD, Moving Vessel Profiler, thermosalinograph, ADCP) and autonomous platforms (surface drifters and gliders) allowed us to characterize the thermohaline and kinematic properties of a ~20-25km-radius intrathermocline anticyclonic eddy detected under the swath of the satellite, approximately 60 km from the coast of Mallorca and Ibiza Islands. In addition, high-resolution numerical simulations were developed to support the cruise planning, help data analysis and provide a complementary view of the small-scale ocean variability. These include a 2-km resolution data-assimilative model run in both predictive and retrospective modes, as well as 650m-resolution nested simulations.

We evaluate both SWOT observations and high-resolution regional simulations using this unique in-situ dataset. On the one hand, SWOT is found to significantly improve the representation of the signature of this small-scale eddy with respect to conventional altimetry, both in terms of observed sea level and derived geostrophic currents. SWOT, together with glider observations, also reveal a significant temporal variability at a daily timescale. On the other hand, the simulations represent a small-scale anticyclonic eddy in the study area showing similarities with the observed eddy in terms of dimension and vertical structure, yet with a 25km spatial offset. The simulations are used to better understand the observed daily variability and evaluate the importance of ageostrophic processes during the study period.

This assessment of SWOT and model uncertainties paves the way for the integration of SWOT observations into the simulations through data assimilation. We provide here initial results about the contribution of SWOT observations to the improvement of the representation of ocean variables in these high-resolution regional simulations after assimilation using an Ensemble Optimal Interpolation approach.

Corresponding author:
Baptiste Mourre (**Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB)**, **Spain**), bmourre@imedea.uib-csic.es

TROPIC-SWOT: Submesoscale Ocean Currents In The Tropical Pacific

Daniel Whitt (NASA Ames, United States); Kydd Pollock (The Nature Conservancy, USA); Dimitris Menemenlis (San Jose State University/Moss Landing Marine Lab, USA); Santha Akella (NOAA, USA); Brian Arbic (University of Michigan, USA); Morgan Gilmour (NASA Ames, USA)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_024

Abstract:
This project advances understanding of how submesoscales (~10–500 km) contribute to equatorial Pacific Ocean circulation and ENSO variability using SWOT KaRIn sea-surface height observations, high-resolution ocean simulations, and in situ drifter-based measurements of surface currents. We quantify submesoscale sea-level variability across the tropical Pacific, focusing on its modulation by the 2023–2024 ENSO event. Detailed analyses focus on the north central equatorial Pacific and especially the vicinity of Palmyra Atoll, where 32 drifters have been released in clusters during eight deployments from August 2024 to June 2025 and about 100 drifter releases are planned over 18 deployments through at least June 2026. The local analysis of the relationship between currents and heights also contributes to a NASA ecological conservation project aimed at forecasting drifting fish aggregating device (dFAD) trajectories to protect coral reef ecosystems. The broader investigation of the role of submesoscales in the regional ocean circulation and ENSO aims to develop quantitative constraints on submesoscale processes that can guide the development of improved global atmosphere-ocean models.
Corresponding author:
Daniel Whitt (**NASA Ames**, **United States**), daniel.b.whitt@nasa.gov

Fine Scales Structures of the Abrolhos Bank Circulation during the SWOT FSP together with Insitu and Copernicus Data

Fabrice Hernandez (IRD, France); Alex Costa (UFPE/DOCEAN, Brazil); Ramilla Vieira de Assunçao (UFPE, Brazil)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_025

Abstract:
In the frame of the SWOT satellite cal/val initiative in Brazil, the University Federal of Pernambuco ship Ciencias do Mar IV has performed the SWOT-Abrolhos campaign with two successive survey in May and September 2023 over the Abrolhos Bank (17-20°S along the Brazilian coast). In situ measurements (CTDs, shipborne ADCP, TSG), as well as moored data (AWAC instrument) have been collected, in order to be compared to SWOT sea surface height retrievals obtained from daily passes of Karin track #20. Copernicus Marine Service operational products in quasi-real time of current are also used to establish the energy distribution at the mooring location, strongly influenced by tidal and subinertial dynamics. This part of the Brazilian coast is dominated by the poleward Brazil Current along the shelf, that meanders and generates seasonal eddy patterns that influences the upper circulation on the shelf. Underneath, equatorward Antarctic Intermediate Waters circulate below the thermocline. The objective of this work are two-fold. First characterize the coastal to open ocean continuum of ocean variability in this shallow area during the surveys. And second evaluate both the SWOT and operational oceanography products in providing realistic representation of the high frequency scales. The first results show the dominance of the tidal dynamics over the Banks, and the influence of the wind and the sea-state variability. However, the Brazil Current patterns and associated mesoscales features are well captured by satellite data and models. Further work will evaluate the benefit of SWOT short scale information to improve our understanding of meso to submesoscale interactions in the area.
Corresponding author:
Fabrice Hernandez (**IRD**, **France**), fabrice.hernandez@ird.fr

SWOT-ETAO project : 2D mesoscale/submesoscale dynamics in the Eastern Tropical Atlantic Ocean using the SWOT data with multisensor and modelling approach

Isabelle Dadou (LEGOS, France); Gaël Alory (LEGOS, France); Micaël Aguedjou (CNES, France); Yves Morel (LEGOS, France); Camille Cardot (LEGOS, eOdyn, France); Karim Thiam (LEGOS, france); Pierre-Etienne Brilouet (LEGOS, France); Guillaume Morvan (LEGOS, France); Clément Le Goff (LEGOS, France); Séréna Illig (LEGOS, France); Florent Gasparin (LEGOS, France); Julien Jouanno (LEGOS, France); Yann Krien (LEGOS, France); Florent Lyard (LEGOS, France)

Session: Oceanography: Regional Validation
Presentation type: Poster
Poster number: ST2025OS2_026

Abstract:
The main objective of this project is to evaluate the improvement brought by the new 2D SWOT data to describe and study the 2D mesoscale/submesoscale dynamics in the Eastern Tropical Atlantic Ocean (ETAO). This mesoscale activity is not well known in the ETAO because of a lack of observations and because altimetric signal is more difficult to interpret in the equatorial region. In our previous SWOT-GG project (2020-2024), we based our analysis on numerical simulations to prepare the present project. The tools and results we obtained are applied to the SWOT data. We have shown that most surface vortices are generated near the coast, their radius remains below 50 km and their lifetime is also short (less than 3 months) (Aguedjou et al., 2019; 2021, 2023; Assene et al., 2020; Napolitano et al., 2022). In addition, these vortices interact with a broad range of processes such as the large-scale circulation, the coastal and equatorial waves and other near-coastal bathymetric or dynamical features (intensification of the tidal signal, generation of internal tides, upwelling/downwelling, etc.). This makes them difficult to observe with classical altimetry. SWOT data provide high resolution 2D quasi-synoptic altimetric maps allowing a description of the variability and eddy activity, at high resolution of particular interest in the equatorial region to identify dynamical features such as vortices. Combining SWOT data with other remotely sensed data, high-resolution numerical models, in situ data as well as AIS data, we evaluate the “Observability” of 2D meso-submesoscale activity with SWOT from the coastal regions to the open ocean in this equatorial region (WP1). We study this high-resolution meso-submesoscale activity in the coastal ETAO area along the African coast and islands (WP2) using the SWOT data. We study the meso-submesoscale and wave dynamics in the open equatorial ocean of ETAO (WP3) with SWOT data. We present the main results of the first year of the SWOT-ETAO project. We used daily SWOT (cal/val) at 2km resolution as well as DUACS and MIOST sea level anomalies (SLA), sea surface temperature, salinity and chlorophyll satellite data (SST, SSS, Chl). The Congo river plume and its mesoscale/submesoscale dynamics are analyzed using the SWOT data. A mesoscale anticyclone with a two-year lifespan is also examined using the daily SWOT data over one month. These SWOT data reveal submesoscale vortices around the mesoscale eddy, which were not detected by the nadir altimetry data. Various submesoscale diagnostics are employed to characterize these dynamics, which are observed for the first time, thanks to the SWOT data. Another study from the SWOT-ETAO project is also presented on internal waves offshore off the Congo river using the 250m SWOT data (Le Goff et al., in this meeting).

Corresponding author:
Isabelle Dadou (**LEGOS**, **France**), isabelle.dadou-pinet@univ-tlse3.fr

Enhancing Australian Coastal Bathymetry Using Deep Learning and SWOT-Derived Geophysical Data

Farshad Salajegheh (The University of Newcastle, Australia); Xiaoli Deng (School of Engineering, University of Newcastle, Newcastle, Australia., Australia); Ole Baltazar Andersen (DTU Space, Technical University of Denmark, Lyngby, Denmark., Denmark); Richard Coleman (Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Tasmania, Australia, Australia)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_001

Abstract:
Accurate bathymetric mapping in coastal zones is essential for marine navigation, environmental monitoring, and geophysical modeling. However, the complexity of shallow-water environments—combined with sparse in situ measurements and the limitations of traditional inversion methods—poses a significant challenge, particularly along Australia's extensive and geologically diverse coastlines.

This study presents a deep learning approach tailored to improve coastal bathymetry estimation in Australian waters using geophysical data derived from the Surface Water and Ocean Topography (SWOT) mission. The model integrates shipborne bathymetric measurements with a suite of SWOT-based geophysical features, including marine gravity anomalies, vertical gravity gradients (VGG), and geoid slopes. These features are processed and fused within a deep neural network (DNN) to capture both large-scale and fine-scale variations in seafloor topography.

By focusing on the Australian coastal zone, the model addresses regional complexities such as continental shelf breaks, reef structures, and sediment-heavy margins. Validation against independent shipborne datasets reveals substantial improvements in prediction accuracy, especially in shallow waters, where global models often underperform. The results demonstrate the importance of integrating multiple geophysical features and tailoring machine learning frameworks to specific regional settings.

This work highlights the potential of SWOT altimetry, when coupled with advanced deep learning techniques, to significantly enhance coastal bathymetric mapping in data-sparse regions. The approach provides a scalable framework that can be extended to other coastal zones globally.

Corresponding author:
Farshad Salajegheh (**The University of Newcastle**, **Australia**), farshad.salajegheh@newcastle.edu.au

Detecting Mekong River plume fronts using SWOT altimetry and drifter observations

Alexei Sentchev (Univ. Littoral Cote d'Opale, UMR8187 LOG, France); Stefano Berti (Univ. Lille, Unité de Mécanique de Lille (UML), France); Nadia Ayoub (Univ. Toulouse, UMR5566 LEGOS , France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_002

Abstract:
The dynamics of the Mekong river plume, one of the largest river systems in Southeast Asia, is investigated using the data from the Surface Water and Ocean Topography (SWOT) satellite mission, complemented by surface drifter observations collected during PLUME oceanographic campaign in June 2024. We employ a variational method of velocity interpolation to reduce the impact of errors propagating through the derivatives of SWOT sea surface height (SSH) which often appears noisy, affected by gaps and small-scale artifacts. The complexity of the SSH signal arises from large buoyancy input supplied by multiple estuaries which generates highly dynamic regional circulation in this shallow water region, further influenced by strong wind forcing.
The velocity field obtained through variational interpolation is not in geostrophic balance but likely provides a synoptic view of unbalanced mesoscale motions. This conclusion is supported by comparisons with velocities obtained from 16 surface drifter trajectories and acoustic Doppler current profiler (ADCP) measurements. The analysis of SWOT-derived velocities revealed consistent surface circulation patterns and indicated the presence of submesoscale frontal structures within the plume body. The frontal zone identification method is based on the extraction of Lagrangian Coherent Structures (LCS) from the surface velocity field using finite-size Lyapunov exponents (FSLE). Large values in the attracting FSLE field (ridge lines) enable the identification of zones of enhanced shear along outflowing manifolds, which are crucial for understanding plume dynamics and mixing within the plume body. FSLE ridge lines revealed diverse geometries of frontal zones, such as semi-spherical or hook-like shapes, and enabled characterization of plume morphology and its offshore expansion. The convergence of real drifters within frontal zones identified from SWOT measurements provides evidence that, in the study region, SWOT-derived velocities at the submesoscale are not in geostrophic balance. This has promising implications for future assessments of horizontal dispersion, vertical motions, and mixing processes in river plume systems which have major ecological and economic importance in coastal ocean regions.

Corresponding author:
Alexei Sentchev (**Univ. Littoral Cote d'Opale, UMR8187 LOG**, **France**), alexei.sentchev@univ-littoral.fr

SWOT observations and corrections assesment in the Northeast Atlantic shelf

Florent Lyard (CNRS/LEGOS, France); Nadia Ayoub (CNRS/LEGOS, France); Lucie Caubet (CNES/Université de Toulouse/LEGOS, France); Michel Tchilibou (CLS, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_003

Abstract:
We investigate some of the challenging corrections applied to SWOT observations in shelf and coastal areas, using the Northeast Atlantic shelf as a benchmark region. In particular, we assess the accuracy of the DAC and tides corrections in this macro-tidal region, and we are questioning the quality of the L3 cross-track correction in a place where the SWOT swath cover continental or islands regions, with large uncertainties on the adjustment to other nadir observations. Both fast-sampling and Science orbits data are examined in our investigations. Empirical adjustment of the L3 cross-track correction will be assessed, using SWOT SHHA variance reduction as a quality metric, despite it is biased by the SSHA data dependency of the SWOT native correction, and comparisons with tide gauge observations. This is part of the SWOT ST project SCOEPUS (N. Ayoub and F. Lyard PIs)

Corresponding author:
Florent Lyard (**CNRS/LEGOS**, **France**), florent.lyard@univ-tlse3.fr

Rivers and Tides: a first global analysis from the SWOT satellite mission

Daniel Scherer (DGFI-TUM, Germany); Michael G. Hart-Davis (DGFI-TUM, Germany); Christian Schwatke (DGFI-TUM, Germany); Tamlin M. Pavelsky (UNC, United States); Audrey H. Sawyer (OSU, United States); Richard D. Ray (NASA, United States); Denise Dettmering (DGFI-TUM, Germany); Florian Seitz (DGFI-TUM, Germany)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_004

Abstract:
Coastal rivers are ecologically and economically vital transition zones between land and sea that are tidally influenced but fresh for much of their length. Tides in coastal rivers affect carbon and nitrogen cycling, sediment storage, and salinity, but the extent of tidal influence is generally unknown over most of the world's rivers. Tidal propagation is sensitive to local morphologic and hydrologic factors, and only a limited number of rivers have tide gauges globally. In the coastal and open ocean regions, tidal modelling efforts have successfully relied on conventional nadir altimetry for decades, but the method is less reliable in narrow river systems and inland water bodies due to land contamination of radar returns. Here, we use the recently launched SWOT satellite, which provides wide-swath elevation measurements at unprecedented scales, to produce a global empirical atlas of tidal influence in rivers for the first time. Tidal constituents are estimated based on the pixel cloud and RiverSP products and validated against in-situ river and tide gauges. Over 150,000 river kilometers are influenced by tides globally, and over 250 million people live near and depend on these coastal transition zones. Manmade and natural obstacles, such as dams, limit tidal propagation in an estimated 15% of all tidal rivers. These results demonstrate further opportunities to use wide-swath measurements to advance the understanding of tidal dynamics in these critical areas.

Corresponding author:
Daniel Scherer (**DGFI-TUM**, **Germany**), daniel.scherer@tum.de

Evaluation of omission error in FES2022 nonlinear wave spectrum across various coastal areas of the globe

Chafih Skandrani (NOVELTIS, France); Florent Lyard (LEGOS, France); Loren Carrere (CLS, France); Mahmoud El hajj (NOVELTIS, France); Gérald Dibarboure (CNES, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_005

Abstract:
Errors of omission in the construction of tidal atlases, such as FES (Finite Element Solution), are often linked to the neglect or approximation of important non-linear processes within tidal modelling. These errors typically arise when interactions between tidal constituents or the intrinsic non-linearity of the ocean surface are insufficiently represented, leading to inaccuracies in tidal amplitude and phase predictions, particularly in coastal and estuarine areas where such effects are most pronounced.
This study assesses the omission errors associated with the non-linear tidal wave spectrum in the latest FES2022 tidal atlas across various coastal regions worldwide. The methodology involves selecting multiple tide gauges in diverse coastal settings, performing harmonic analyses on the recorded time series, and extracting the amplitudes and phases of both major (e.g., M2, K1) and minor (e.g., MS4) tidal constituents.
The contribution of each constituent is then evaluated to identify minor waves that might have non-negligible effects on tidal reconstructions. Omission errors are quantified by comparing the residuals of tidal series reconstructed using a limited number of constituents (e.g., 8 waves, then 50) against a reference reconstruction. The difference in residual signal provides a direct measure of the loss of tidal information due to omissions.
The results from this analysis show the importance of including a broader spectrum of tidal constituents in operational tidal modelling, underlining the non-negligible role of minor and non-linear waves, particularly in complex coastal dynamics.

Corresponding author:
Chafih Skandrani (**NOVELTIS**, **France**), chafih.skandrani@noveltis.fr

Barotropic tide filtering in SWOT observations through data assimilation

Chafih Skandrani (NOVELTIS, France); Florent Lyard (LEGOS, France); Loren Carrere (CLS, France); Mahmoud El hajj (NOVELTIS, France); Gérald Dibarboure (CNES, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_006

Abstract:
Recent analyses performed on harmonic constants derived from SWOT satellite observations, including data from both the Cal/Val phase and the Science orbit, have revealed the presence of significant non-tidal signals. These signals manifest as small to medium-scale spatial structures characteristic of surface ocean circulation, illustrating the challenge of accurately isolating the tidal component in these observations.
To address this issue, the present study uses the FES2022 tidal ensembles combined with the SpEnOI (Spectral Ensemble Optimal Interpolation) assimilation method. This approach offers the potential for highly precise filtering of the spurious ocean circulation signals by leveraging the spatial scale separation provided by the tidal ensembles. Through this assimilation technique, the fine-scale non-tidal structures is effectively isolated and excluded from the assimilation process, ensuring a cleaner retrieval of the tidal signal.
Our analysis focuses on both coastal areas, where tidal dynamics interact strongly with complex bathymetry and coastal processes, and offshore regions, where mesoscale and submesoscale ocean variability dominate. By evaluating the performance of this method across these diverse environments, the study assesses its capacity to improve tidal signal extraction and reduce omission errors in the context of SWOT-derived tide data. The outcomes are expected to contribute to enhancing the quality and reliability of tidal products derived from high-resolution satellite altimetry missions.

Corresponding author:
Chafih Skandrani (**NOVELTIS**, **France**), chafih.skandrani@noveltis.fr

A step forward in the improvement of the SWOT Wet Tropospheric Correction through GPD+ in the coastal zone

Isabel Cardoso (Universidade do Porto, Portugal); Clara Lázaro (Universidade do Porto, Portugal); Telmo Vieira (Universidade do Porto, Portugal); M. Joana Fernandes (Universidade do Porto, Portugal)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_007

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite, equipped with a 120-km-wide swath Ka-band radar interferometer (KaRIn) and a Poseidon-3C type altimeter, uses advanced radar technology to provide high-resolution observations of the ocean, coastal and inland waters. However, radar signals are delayed due to the water vapor and cloud liquid water content in the troposphere, so the correctness of the radar surface height measurements is strongly influenced by the accuracy of the wet tropospheric correction (WTC) to account for those delays. SWOT WTC at each location is currently being derived by the linear interpolation of the two ~70 km spaced measurements at the center of each KaRIn half-swath, acquired by two independent onboard Advanced Microwave Radiometers (SWOT AMR - SAMR). The fact that only two SAMR are available to retrieve the WTC over the whole KaRIn swath and that these observations are optimized for ocean conditions, various improvements to the current SWOT WTC can be foreseen. In particular, areas close to land (< 25 km) and inland waters still present some challenges for acquiring valid and accurate WTC observations. In this study, the GNSS-derived Path Delay Plus (GPD+) algorithm adapted for SWOT is implemented to estimate the WTC at locations along the Poseidon-3C altimeter track and the KaRIn swath, which are subsequently compared with the WTC values available in the SWOT products and those derived from the ERA5 model. The focus of the current study is the impact of the new GPD+ WTC in the coastal regions. The results show that GPD+ allows the retrieval of WTC at locations where these values are absent or flagged as invalid in the SWOT products. In addition, GPD+ also improves the WTC accuracy, particularly at locations close to land and whenever the interpolation between observations is not possible because one of the two onboard SAMR measurements is invalid. The comparison with global navigation satellite system (GNSS) data, although not independent from GPD+, provides relevant information about land contamination in the various analyzed WTC. Thus, the root mean square (RMS) of the WTC differences between GNSS and the values provided by the various considered datasets (SWOT products, GPD+ and ERA5) were analyzed as a function of distance from the coast. Results for latitudes in the range of 50°N-50°S show that GPD+ can reduce the RMS of the differences up to 0.5 cm, particularly closer to land. The impact of GPD+ on the WTC accuracy is also explored through the sea level anomaly (SLA) variance analysis. These findings highlight the worth of the GPD+ methodology to increase the number of locations with valid WTC information and its respective accuracy. The outcome of this improved WTC is then reflected in the sea level anomaly calculation which, in turn, will impact the solidness of future sea level variability analysis. Ongoing and future work envisages the impact of GPD+ on the spatial variability of the WTC and corresponding SLA values along the KaRIn swath, over the coastal and open ocean. Since GPD+ incorporates a set of external observations, apart from the already reported increase in the number of valid observations, it is expected to observe variability not present in the current SWOT WTC.

Corresponding author:
Isabel Cardoso (**Universidade do Porto**, **Portugal**), isabel.cardoso@fc.up.pt

ACCURACY ASSESSMENT OF SWOT KaRIn SEA LEVEL DATA

Jesus Gomez-Enri (Associate Professor, Spain); Barbara Arribas-Rodríguez (Graduate student, Spain); Begoña Tejedor (Associate Professor, Spain); Oscar Alvarez (Associate Professor, Spain); Carlos Jose Gonzalez (Assistant Professor, Spain); Stefano Vignudelli (Research staff, Italy)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_008

Abstract:
In this work, we present the results of the accuracy assessment of time series of SWOT KaRIn Sea Surface Height Anomaly (SSHA) along the Spanish coasts. We used three tide gauges from Puertos del Estado (https://www.puertos.es/servicios/oceanografia) located at Huelva (eastern Gulf of Cadiz), Barcelona (northwestern Mediterranean Sea) and Bilbao (eastern North Atlantic Ocean). We assessed 1.5 years (from July 2023 to February 2025) of Level 2 KaRIn Low Rate (LR) SSHA data product available at: https://hitide.podaac.earthdatacloud.nasa.gov/. SWOT data in LR give regular grids of 2 km x 2 km resolution; they were selected considering a radius of 100 km respect to the location of the tide gauges. We analysed one ascending and one descending orbit at each location. We estimated the standard deviation of the differences (SDD) between time series of KaRIn-dervied SSHAs and tide gauge measurements. The possible use of the ECMWF wet tropospheric correction (EMCWF_wet tropo) instead of the correction derived from the advanced microwave radiometer (AMR_wet_tropo) measurements was analysed. EMCWF_wet tropo showed the same level accuracy as AMR_wet_tropo, but the number of valid grids with ECMWF_wet_tropo was higher than AMR_wet_tropo. We also compared the accuracy of SSHAs by applying the tidal model (FES) with respect to the GOT model. We found that the SDD with FES is slightly better than with GOT. Once the best set of corrections were selected to compute the SSHA from SWOT, we estimated the average SDD at the three study areas. Overall, the SDD ranges between 7.3 cm (Bilbao) and 10.7 cm (Barcelona). We compared the SWOT accuracy with the SSHA from Sentinel-3A (S3A). We selected the closest S3A tracks to the tide gauge locations and estimated the SDD along a track segment of 100-km long. The SDD from SWOT was interpolated to the S3A along-track positions. The mean SDD of S3A / SWOT (two tracks) was: 7.1 (#322) / 8.1 (#154) - 9.1 (#447) cm (Huelva); 9.6 (#356) / 10.2 (#320) - 10.5 (#363) cm (Barcelona); and 6.8 (#051) / 7.8 (#141) - 8.6 (#376) cm (Bilbao). We conclude that S3A shows a better performance than SWOT at all the locations and tracks (considering a radius of 100 km respect to the tide gauge location). More efforts are still needed in the processing of SWOT data to achieve the same accuracy as S3A, but the preliminary results obtained from SWOT are promising. The high SDD observed at Barcelona will be discussed in terms of the hydrodynamic conditions in that area.

Corresponding author:
Jesus Gomez-Enri (**Associate Professor**, **Spain**), jesus.gomez@uca.es

What can we learn about nearshore dynamics from spatial altimetry ? : preliminary results from the TOSCA/POSPOW project

Yann Krien (LEGOS, University of Toulouse, France); Florence Birol (LEGOS, France); Jamal Khan (LEGOS, IRD, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_009

Abstract:
Improving our understanding of hydrodynamics very close to the shore -at depths of just a few meters- is crucial for better predicting and anticipating coastal flooding, shoreline erosion, and pollutant transport. While spatial altimetry has proven effective in accurately measuring water levels or waves in coastal areas, it generally remains limited to distances several kilometers offshore, and has yet not been used to investigate dynamics in the surf zone, where wind waves strongly interact with the bottom. The emergence of new technologies on recent space missions such as SWOT has the potential to change this situation.

As part of the CNES-funded TOSCA/POSPOW project, we are taking advantage of the exceptional morphological features of a unique geographical region -the Ganges delta- to explore the potential of spatial altimetry to capture hydrodynamic processes in the surf zone. The Ganges delta is indeed characterized by an exceptionally flat clinoform, resulting in water depths of less than 10 meters even tens of kilometers offshore.

Building upon a decade of work conducted by the POSPOW team in the study area, that resulted in particular in a state-of-the-art 3D wave-current coupled numerical model, we conduct intercomparisons between altimetric data (SWOT, LRM), numerical reanalysis, and estimates of currents or wave heights derived from alternative methods such as Doppler shift (Sentinel 1) and optical imagery (Sentinel 2).

We will present very preliminary results of these intercomparisons that demonstrate the potential of SWOT to capture physical processes in nearshore waters, and also point the way for future improvements.

Corresponding author:
Yann Krien (**LEGOS, University of Toulouse**, **France**), yann.krien@univ-tlse3.fr

Stream direction reversals in Baltic rivers derived from SWOT water level observations

Dan Jansson (Stockholm University, Sweden); Jaramillo Fernando (Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden., Sweden)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_010

Abstract:
Using Surface Water and Ocean Topography (SWOT) measurements, we investigated water surface elevation differences between the Baltic Sea near river mouths and upstream locations to identify instances where sea levels were significantly higher than inland waters. These directional reversal events have until now been poorly characterized in the Baltic, due to limited observational data of water levels and river flow directions. The recent launch of SWOT enables new ways to interpret river flow direction. By analyzing SWOT data, we explore how coastal riverine processes influence inland water transport and ecosystems, challenging assumptions of coastal boundary extents in the Baltic.
To investigate inland water dynamics near the Baltic Sea, we analyzed river profiles in 41 of the largest rivers draining into the Baltic Sea wider than 100 m. Each river was subsetted based on its width according to the SWOT river database. For each of the selected rivers, Level-2 pixel-cloud data were extracted for the period between September 1, 2023, and April 1, 2025. The data were filtered to ensure that no errors were flagged in the quality flags, indicating good data quality. Additionally, an interquartile range filter was applied to remove outliers in the datasets. After filtering, valid data points were projected onto the corresponding river centerlines to determine their upstream distance from the river mouth. We then compared sea level elevations of the Baltic Sea near the river mouth with inland river water levels to identify instances when coastal water levels exceed water levels further upstream, indicating bilateral flow.
Our analysis reveals upstream flow reversal events, suggesting the inland movement of water from the coastal zones, in 70 percent of the analyzed rivers. These flow anomalies challenge the conventional assumption of unidirectional river flow in Baltic rivers and indicate that coastal influences may extend far beyond traditional estuarine boundaries.
Since the Baltic Sea experiences little to no effect from tidal events, the observed directional changes are plausibly an effect of periods of elevated atmospheric pressure, increasing sea levels and wind speeds. Our findings raise important questions about the potential permeability of coastal boundaries and their influence on freshwater systems, with implications for nutrient transport, habitat integrity, and the management of ecosystems affected by the Baltic Sea.

Corresponding author:
Dan Jansson (**Stockholm University**, **Sweden**), Dan.jansson@natgeo.su.se

The DTU25GRA SWOT derived global gravity field and evaluation with airborne gravity in the Norwegian coastal zone

Bjarke Nilsson (Dr, Denmark); Ole Baltazar Andersen (DTU Space, Denmark); Bjørnar Dala (DTU Space, Denmark); Rene Forsberg (DTU Space, Denmark); Tim jensen (DTU Space, Denmark); Ove Omang (Statens Kartverk, Norge)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_011

Abstract:
The observations from the Surface Water and Ocean Topography (SWOT) satellite have shown to be revolutionary in spatial resolution and precision. With the introduction of wide-swath altimetry sampled at a spacing of 250 m by 250 m, we are able to get reliable and accurate observations in more complex coastal zones than ever before. Traditional gravity fields have always relied on conventional nadir-looking satellite altimetry. Even with the introduction of Synthetic Aperture Radar (SAR) altimeters, the altimetric gravity field was always degraded in the coastal zone due to smoothing and/or extrapolation.
To utilize the high spatial resolution of SWOT, the new DTU25 GRA utilizes the ocean SWOT product (2 km spacing) in the open ocean, but uses the high-sampling of 250 m spacing in the coastal zones globally within the closest 10km.
The airborne gravity data were used for comparison with satellite altimetry-derived gravity models from several sources, including the most recent model DTU25GRA, which includes new high-resolution data from SWOT. We present the results of evaluating the SWOT derived gravity with gravity measured by a strapdown gravimetry campaign using an iMAR iCORUS-01 temperature-stabilized IMU along the south-western coast of Norway conducted in the fall of 2024.
The obtained results are assessed with respect to distance from the coast to quantify the accuracy of satellite altimetry, which has been a challenge for conventional altimetry. We demonstrate how the Inclusion of SWOT data sampled at high resolution (250 meters) results in higher consistency closer to the coast. The findings will be used to determine a distance-based threshold for relative weighting of the different datasets to be used in geoid computations, especially relevant for the computation of the new Scandinavian NKG geoid planned to be released in 2026.

Corresponding author:
Bjarke Nilsson (**Dr**, **Denmark**), Bjarnil@space.dtu.dk

Propagation of Ocean Tides and their Influence on Estuarine Systems as Observed by SWOT

Martin Kolster (University of Colorado, United States); R. Steven Nerem (University of Colorado, United States); J. Toby Minear (University of Colorado, United States)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_012

Abstract:
Tidal propagation directly influences salinity gradients, sediment transport and habitat dynamics in estuarine ecosystems. This study investigates the spatial and temporal dynamics of tidal propagation and the influence of ocean tides and sea level change within the Delaware and Chesapeake Bay estuarine systems. The Surface Water and Ocean Topography (SWOT) satellite mission provides a new technique for monitoring water surface elevations in estuarine systems. The primary SWOT data products used in this analysis are the 100x100m and 250x250m raster products and the pixel cloud (PixC) product. Following cross-validation with in-situ measurements from NOAA tide gauges and USGS stream gauges, we quantify signal attenuation and phase changes of ocean tide propagation and the spatial reach within riverine-estuarine systems. We evaluate how bay geometry and local bathymetry modulate tidal harmonics and flow dynamics by relating these metrics to observed spatial variations. Furthermore, the tidal range profile is evaluated for each estuarine reach. Preliminary results reveal amplification of tidal signals in upstream reaches of both systems, and identify reach-scale zones that may become tidally flood-prone under projected sea level change.

Corresponding author:
Martin Kolster (**University of Colorado**, **United States**), martin.kolster@colorado.edu

Monitoring interannual evolution of Normandy intertidal areas using spaceborne imagery: A decade of observations with Sentinel-2&1 and SWOT

Simon Déchamps (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Edward Salameh (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Erwin Bergsma (CNES, 18 Avenue Edouard Belin, CEDEX 9, 31401 Toulouse, France , France); Frédéric Frappart (ISPA, UMR 1391 INRAE/Bordeaux Science Agro, 33140 Villenave-D'Ornon, France, France); Ernesto Tonatiuh Mendoza (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Imen Turki (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Tatiana Goulas (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Julien Deloffre (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Sophie Le Bot (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France); Benoit Laignel (Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France , France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_013

Abstract:
Intertidal flats act as a natural buffer between the sea and the land, protecting against coastal hazards such as storm surges. These dynamic environments are characterized by significant topographic variations driven by major processes and stressors, including tides, waves, freshwater inflow, storms, human activities, and climate change, all of which influence ongoing sediment redistribution. This emphasizes the growing need for accurate, up-to-date intertidal topographic maps. Spaceborne remote sensing is an efficient tool for monitoring these evolving landscapes and enables regular monitoring. As part of the SCO EO4Intertopo project, this study uses Sentinel-2, Sentinel-1 and SWOT observations to investigate changes in the intertidal topography of the Normandy coast over the past ten years. Sentinel-2 and Sentinel-1 DEMs were generated using a method that relates the inundation frequency of pixels to their corresponding elevations, while the SWOT_HR_PIXC product provides direct elevation measurements. Annual DEMs were generated from 2015 to 2024 using Sentinel-2, supplemented by Sentinel-1, and from 2024 to 2025 using SWOT. Comparing these with airborne LiDAR-derived DEMs at three specific sites (the Bay of Veys, Utah Beach and the Seine Estuary) showed mean absolute errors (MAE) ranging from 0.25 to 0.49 meters and root mean squared errors (RMSE) ranging from 0.41 to 0.70 meters. Validation was also performed using ICESat-2 laser altimetry observations covering the entire Normandy region. Correlation coefficients higher than 0.7 were obtained. Computing DEMs of difference (DoDs) has enabled the quantification of annual volumetric morpho-sedimentary changes (erosion, accretion and stable areas) at a regional scale along the Normandy coastline. Channel migrations and beach slopes were detected and analyzed in relation to hydrodynamic forcings and sedimentary characteristics linked to substrate types. These results demonstrate the potential of combining multi-source satellite observations, including SWOT, for long-term monitoring and understanding of intertidal morphodynamics in response to physical drivers.

Corresponding author:
Simon Déchamps (**Univ Rouen Normandie, Univ Caen Normandie, CNRS, M2C, UMR 6143, F-76000 Rouen, France** , **France**), simon.dechamps@univ-rouen.fr

Exploring Estuarine Sea Level Fluctuations and Dynamics Using the Surface Water and Ocean Topography (SWOT) Mission: Resolving Estuaries

Sarah N Giddings (UCSD Scripps Institution of Oceanography, United States); Angelica Rodriguez (JPL, CalTech, United States); Joanna L Carter (Scripps Institution of Oceanography, UCSD, United States); Agata Piffer Braga (Scripps Institution of Oceanography, UCSD, United States); Iury Simoes-Sousa (WHOI, United States)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_014

Abstract:
Serving as economic hubs with large population densities, coastal environments are critical to society. They are also some of the most dynamic domains within the Earth system at the nexus of complex and interconnected ocean-land processes that have strong impacts on both societal function and ecosystem responses. The flow of water between rivers and the ocean closes the critical hydrologic loop that transports fresh water back to the large ocean basins from which it was derived. The intricacies of these processes are often observable through the dynamic signal of water elevation, or sea surface height. Our research aims to advance the use of SWOT data in complex estuarine environments and improve understanding of estuarine dynamics that lead to changes in estuarine sea surface height. The novel SWOT dataset yields a new way of observing estuarine sea-level fluctuations across the estuary expanse and cross-shore signal propagation at tidal, synoptic, seasonal, and interannual time scales.

We are utilizing realistic regional ocean simulations and in-situ water level sensors across a range of estuary types and scales along with SWOT data from both the fast-sampling phase and the nominal orbit phase in order to: 1) determine the range of estuary sizes SWOT can resolve, 2) assess and improve tidal corrections in a subset of globally representative, dynamically distinct estuarine systems and 3) elucidate what spatial and temporal scales of estuarine dynamics SWOT resolves. In particular we expect to be able to evaluate estuarine-oceanic connectivity via propagation of sea level signals into estuaries and characterize a comprehensive set of estuarine dynamic signals and scales observed by SWOT. This work will provide bounds on the utility of SWOT observations within estuarine environments for research questions relevant to both the scientific community and for coastal applications.

We have found that the vC Level 3 (L3) Low Rate (LR) unsmoothed, 250 m resolution data products are able to successfully resolve most of our estuaries of interest, especially those of intermediate size (surface area O~100-1000 km2). In the smallest target estuaries (San Diego Bay and Humboldt Bay with surface areas of ~50 km2), we are working to assess the current data flags to maximize LR coverage while removing land contamination. Interestingly, SWOT's ability to resolve the largest target estuary, the Salish Sea (surface area O~10,000 km2), is complicated by multiple issues. First, its complex geometry means that for much of the estuary, even within the main passage to the ocean, Strait of Juan de Fuca, the vC LR products are masked out, thus necessitating use of the HR products. Second, its large size requires multiple passes to cover even just the Strait. Thus, careful processing of larger estuaries will need to be considered that take into account spatial and temporal variability to represent the system using multiple passes and the HR products. We anticipate further data availability with the new version D processing, as the algorithms have been further refined, and additional developments in the L3 processing are refining the coastal land masks. We are currently working to incorporate updated algorithms and examine HR data in the estuaries of interest. Our next steps will include comparing SWOT sea surface heights and tidal corrections to in situ data and high resolution numerical regional estuarine coastal models to examine the tidal correction errors within these enclosed embayments.

Corresponding author:
Sarah N Giddings (**UCSD Scripps Institution of Oceanography**, **United States**), sgiddings@ucsd.edu

SCOEPUS project: on the use of SWOT ocean products in shelf seas and estuaries and for the study of internal tides

Nadia Ayoub (LEGOS/CNRS, France); Florent Lyard (LEGOS/CNRS, FRance); Moussa Aw (LOPS, France); Simon Barbot (LEGOS, France); Loren Carrère (CLS, France); Lucie Caubet (LEGOS/Univ de Toulouse, France); Alexis Chaigneau (USTH/IRD, Vietnam); Guillaume Charria (LOPS/IFREMER, France); Pierre De Mey-Frémaux (LEGOS/CNRS, France); Noémie Ferdinand (LEGOS/Univ de Toulouse, France); Marine Herrmann (LEGOS/IRD, France); Yann Krien (LEGOS/Univ de Toulouse, France); Maud Martinez Almoyna (LOPS, FRance); Patrick Marsaleix (LEGOS/CNRS, France); Florence Toublanc (LEGOS/CNRS, France); Alexei Sentchev (LOG/Univ du Littoral Cote d'Opale, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_015

Abstract:
The main objectives of the SCOEPUS project are (1) to evaluate SWOT products (data, corrections, flags) on the shelf and in estuaries and coastal lagoons, (2) to explore the contribution of SWOT and multi-sensor data to the study of water level variability in estuaries and coastal lagoons and of the ocean circulation, (3) to study the observability of internal tides. The regions of interests are the Bay of Biscay and Gironde estuary, the South-East Asian seas with a focus on the Vietnamese coasts, on the Red River delta and on the Gulf of Tonkin and two lagoons (Benin and Vietnam).
This poster presents a brief overview of the work in progress, mostly with ocean products. It summarizes the main results which are presented in details in the other SCOEPUS presentations (from Barbot et al., Carrère et al., Caubet et al., Lyard et al., and Sentchev et al.) and shows some more preliminary work in the Gulf of Tonkin, Bay of Biscay and in the Nokoué Lagoon.
In these regions, available observations (HF radars, buoys, other satellite data) and numerical simulations serve as reference to decipher the the signals in SWOT sea surface elevation and its gradients for different L2/L3 products and to quantify discrepancies when possible. Additionally, L4 products are used to test the representation of small-scale coastal processes in the simulations. By conducting our investigations on several regions, we aim at sampling physical processes of different nature and features, but also to develop a fairly generic common approach for the adequate use of SWOT products.

Corresponding author:
Nadia Ayoub (**LEGOS/CNRS**, **France**), nadia.ayoub@univ-tlse3.fr

Evaluating SWOT in the Estuarine and Nearshore Region: A Comparative Study of the Baltic Sea and the Bay of Bengal

Faruque Abdullah (Institute of Geodesy and Geoinformation, University of Bonn, Germany); Marco Rivera (Institute of Geodesy and Geoinformation, University of Bonn, Germany); Md Jamal Uddin Khan (LEGOS/UT/IRD, Toulouse, France); Jiaming Chen (Institute of Geodesy and Geoinformation, University of Bonn, Germany); Christopher Buchhaupt (CISESS/UMD, College Park, Maryland, United States); Luciana Fenoglio (Institute of Geodesy and Geoinformation, University of Bonn, Germany); Jürgen Kusche (Institute of Geodesy and Geoinformation, University of Bonn, Germany)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_016

Abstract:
Although traditional satellite altimetry has significantly advanced our knowledge of global sea level variability, it faces major challenges in nearshore and estuarine zones due to land contamination and coarse spatial resolution. The Surface Water and Ocean Topography (SWOT) mission brings a unique opportunity to observe the coastal region and the land-ocean continuum with an unprecedented spatial resolution. However, its quality, consistency, and capabilities in this complex zone requires thorough evaluation. We are exploring these questions in the framework of two related projects – CONWEST-DYCO2, and COSWOT.

The project CONWEST-DYCO2 continues project CONWEST-DYCO in the Elbe estuary and Baltic Sea and extends the analysis to two other regions i.e. the waters around Indonesia and the Bay of Bengal. The central hypothesis is that hydrodynamic processes of the river-to-ocean continuum and of the mesoscale in coastal zone are today at best resolved and understood by combining SWOT and SAR-satellite altimetry observations. The main objective is to evaluate the contribution of SWOT to analyze coastal processes. Our focus is on small scale processes in the transition zone from land to sea, that is in estuaries and in coastal zone.

In the COSWOT project funded by DFG, we evaluate the scientific usability of SWOT satellite altimetry in coastal zones, focusing on small-scale processes in land-sea transition areas and estuaries, as well as on the coastal water cycle and related extreme events. For this purpose, various data products of SWOT are processed, compared and merged with measurements from other altimeter missions. In addition, the merged data products are to be compared with in-situ and with regional modeling results. Altogether the project covers three regions- the Baltic Sea, Indonesian waters, and the Bay of Bengal. In this poster we focus on the contrasting hydrodynamic settings of the micro-tidal Baltic Sea and the macro-tidal Bay of Bengal. Comparing SWOT's performance across these two distinct regimes is expected to reveal its strengths and limitations, demonstrating its potential to monitor coastal and estuarine hydrodynamics more accurately in data-scarce areas under varying tidal conditions.

This study evaluates the capabilities of the SWOT observations during its science phase to estimate coastal sea level, river discharge, water level in rivers and longitudinal water surface gradient from upstream to downstream in the estuarine zones. The comparison approach is first developed and validated in the Baltic Sea, leveraging its dense network of in-situ observations, including tide gauges and discharge records. This validated framework is then adapted for the Bay of Bengal, where limited in-situ data and complex tidal dynamics require methodological adjustments and dedicated corrections. The Baltic Sea enables direct validation with abundant ground-truth data, while the Bay of Bengal requires model-based tidal corrections to reduce errors in the distributed products. Both high- and low-resolution SWOT products are systematically compared and merged with established along-track altimetry missions (Jason-3, Sentinel-3A/B, and Sentinel-6A) from Hydroweb-next, CMEMS, RADS and FFSAR database. Beyond estuarine conditions, the study also investigates the potential of Sea Surface Height (SSH) derived from low-resolution (LR_L3_v2.0.1) and high-resolution pixel-clouds (L2_HR_PIXC) SWOT products to reveal fine-scale nearshore processes in both regions.

In the Baltic Sea, we applied Optimal Interpolation (OI) to map more accurate and reliable sea level anomaly (SLA) fields, with multiple along-track satellite altimetry datasets, considering SWOT science phase (2023-08-11 to 2024-09-26). Preliminary results show that adding SWOT synthetic along-track data to traditional altimetry sources significantly improved their performance when validating against in situ tide gauge measurements in the central Baltic, such as at Visby and Landsort Norra. For instance, using RADS alone resulted in a correlation of 0.793, a standard deviation of 0.097 m, and a bias of -0.006 m at Visby; after adding SWOT, the correlation improved to 0.808, with a standard deviation of 0.094 m and a bias of -0.007 m. By further utilizing the

combination of FFSAR, CMEMS, and SWOT, the correlation at Visby further improved to 0.812, with a standard deviation of 0.093 m and a bias of -0.011 m. However, OI still smooths out finer SLA variability and has some limitations when extrapolating into data-sparse areas. Currently, we are exploring strategies to address these shortcomings, which will enable us to apply this enhanced OI approach to more complex and data-poor coastal regimes, such as the Bay of Bengal.

Corresponding author:
Faruque Abdullah (**Institute of Geodesy and Geoinformation, University of Bonn**, **Germany**), fabdulla@uni-bonn.de

Leveraging SWOT data to estimate hydrologic connectivity between channels and islands in coastal river deltas

Eleanor Henson (The University of Texas at Austin, United States); Paola Passalacqua (The University of Texas at Austin, United States); Jon Schwenk (Los Alamos National Laboratory, United States); Anastasia Piliouras (Pennslyvania State University , United States)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_017

Abstract:
Coastal river deltas are dynamic hydrologic systems that present unique challenges for study and modeling. Their channel networks exhibit extremely low topographic gradients, allowing coastal forces such as winds and tides to generate bidirectional flow and create loops within channel structures. Although more difficult to model than tributary networks, recent research has increasingly focused on simulating exchanges between these loopy channel systems and adjacent deltaic islands. Delta networks are inherently leaky systems—at Wax Lake Delta (LA, USA), for example, up to 54% of water can be lost from primary channels into island complexes (Hiatt and Passalacqua, 2015). Accurately representing these exchanges is essential for predicting how sediments, solutes, and nutrients are partitioned and processed across the delta landscape.

Widely used hydrodynamic models like Delft3D and ANUGA, which solve the depth-integrated shallow-water equations, have been employed to estimate hydrologic connectivity in deltas and wetlands. However, these models typically require extensive field data to calibrate and validate parameters governing connectivity. Other recent advances in modeling approaches have utilized graph-theory to represent channel networks as a series of nodes (junctions) and links (channels). Sediments, solutes, and nutrients can then be partitioned along this extracted series of nodes and links through remotely sensed estimates of channel widths and available discharge data. This method offers advantages by relying solely on remotely sensed data, eliminating the need for intensive fieldwork. However, traditional graph-based models conserve mass along links, assuming no material loss from the delta apex to its outlets, which is inherently limited.

This research introduces a new methodology to estimate channel-island connectivity—or channel “leakiness”—in coastal river deltas using reported water surface elevations and pixel cloud classifications from the SWOT Level-2 High Resolution Pixel Cloud product. The approach will first be applied to Louisiana’s Wax Lake Delta, where extensive field data are available for validation. Ultimately, this methodology will be extended to deltas worldwide and integrated into graph-based network extraction techniques.

Corresponding author:
Eleanor Henson (**The University of Texas at Austin**, **United States**), elle.henson@utexas.edu

Observing deltaic surface water elevation with an integrated SWOT-based workflow

Florin Miron (University of Bucharest, Romania); Florin Zăinescu (Aix-Marseille University, University of Bucharest, Romania); Florin Tătui (University of Bucharest, Romania); Edward J Anthony (Aix-Marseille University, University of Bucharest, France)

Session: Deltas, Estuaries and Coasts
Presentation type: Poster
Poster number: ST2025DEC2_018

Abstract:
The launch of the Surface Water and Ocean Topography (SWOT) satellite mission offers unprecedented opportunities for surface hydrology in deltas, particularly those containing large flooded vegetation surfaces. SWOT reveals delta plain-river connectivity, crucial for sea level rise adaptation through sedimentation and is promising as a calibration/validation data source in these data sparse regions. However, the raster product often suffers from degraded and unusable data from various errors including spectral ringing effects that hinders the immediate use of the raster product (L2_HR_RASTER). This work presents the development and application of a comprehensive methodological workflow for processing SWOT Level 2 Pixel Cloud (L2_HR_PIXC) data to characterize in detail the hydrological dynamics of several deltas and wetlands (e.g., Rhône, Danube, and Mississippi deltas). The workflow is implemented entirely in Python, and addresses the full processing chain from data acquisition to error removal and final analytical products and is available on GitHub. A classification algorithm is applied to the point data to refine the distinction between water and land, improving the standard raster product classification particularly in thin ridge areas such as levees, beach ridges and coastal barriers, often misclassified as water. Water-surface elevation points are first filtered for errors through local outlier removal and the application of weighted flags. These filtered points are then interpolated into a regular 30 m grid using a hybrid k-nearest neighbors (KNN) approach and aggregated into a spatio-temporal data cube, forming the basis for multi-temporal analyses. Key final products derived from this data cube include maps of mean water level; temporal variability highlighting areas with the greatest fluctuations; a spatially weighted water-frequency map; anomaly maps; and minimum and maximum water height and extent maps, which, when integrated with wind speed and direction, river discharge, and wave conditions, allow us to better understand water dynamics and ongoing processes. The final accuracy of the water-surface elevation estimates is quantitatively assessed through validation against water-level data measured at in situ stations. Initial validation of SWOT data against these in situ measurements revealed a high level of accuracy ($R^2 > 0.8$). Finally, we show the validation of a numerical model using SWOT data for the Danube Delta. This demonstrates SWOT's crucial role in creating reliable models for poorly monitored areas, which is essential for understanding these systems and predicting their response to climate change.

Corresponding author:
Florin Miron (**University of Bucharest**, **Romania**), florin.miron@s.unibuc.ro

Reservoir monitoring based on SWOT products, comparison with imaging and altimetric multi-mission approach: applications to the Grand lacs de Seine reservoirs (France)

Sabrine Amzil (ICUBE-SERTIT, France); Carlos Yanez (CNES, France); Thomas Ledauphin (ICUBE-SERTIT, France); Maxime Azzoni (ICUBE-SERTIT, France); Nicolas Picot (CNES, France); Émilie Mangold (ICUBE-SERTIT, France); Claire Pottier (CNES, France); Jérôme Maxant (ICUBE-SERTIT, France); Hervé Yésou (ICUBE-SERTIT, France)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_001

Abstract:
Reservoirs are key tools in the management of water resources. They provide a means of reducing the effects of inter-seasonal and inter-annual flow fluctuations, thereby facilitating water supply, flood control, power generation, recreation and other water uses. For more than 20 years, satellite radar altimetry has been an effective technique for monitoring variations in the elevation of continental surface waters, such as inland seas, lakes and reservoirs, rivers and, more recently, wetlands.
This study presents the capabilities of SWOT to monitor water surfaces, heights and variations in water stocks. It also highlights the contribution of multi-sensor synergy and the combination of current imaging and altimetry satellites.
The demonstration of this potential is ongoing over the largest French reservoir, the Lac du Der. With 48 km2, the Lac du Der-Chantecoq, also known as the Marne reservoir, is the largest man-made lake in mainland France. Together with the Orient, Amance and Auzon lakes, it is part of the system of large Seine lakes intended to protect Paris from flooding. Water is drawn from the Marne from November to June, filling the reservoir. From July to October, water is released to support the flow of the rivers. As a result, the water surface area changes considerably throughout the year, from about forty square kilometers during the high-water period to less than ten square kilometers during the very low-water period. In addition to its specific dynamics, this lake is tracked by several altimetry satellites.
Regarding SWOT data, this reservoir is theoretically located in the No Acquisition diamond area, but the signal from this large water body is clearly visible in the SWOT PIXC, the Lake SP products and the SWOT NADIR track that passes over the lake. An analysis of the heights measured by SWOT sensors was carried out both on the PIXC and the Lake SP products over a period of more than one year, from July 2023 to mid-September 2024. Both types of products reproduce well the hydrological evolution of the central reservoir, with a decrease in water levels from September to December, then an increase in levels with water storage and a maximum reached during the summer. These SWOT water level values were compared with in-situ data, to validate the observed phenomenon. For this period, an RMSE of 0.09 m and at 1 sigma 0.30 m were obtained.
Lac du Der is also tracked by the Sentinel-6, since March 2021 with a ten-day frequency. These Sentinel-6 data were first processed using FFSAR to achieve fine resolution of the radargram in the along-track direction, and then a retracker specially designed for this focused data was applied to estimate the water height. Comparison of the in-situ water level data and the relative Sentinel-6 data over 14 months of data shows an impressive consistency of the data, with a RMS of 0.02 m (Median and 1 sigma at 0.03 m). A detailed analysis of the Sentinel-6 data over time also revealed a specific phenomenon, reflecting a reservoir management strategy involving frequent alternation between water release and storage, linked to the needs associated with the Paris Olympic Games.
Another part of this study focuses on evaluating the combination of Sentinel-2 surfaces and altimetry data from SWOT, Sentinel-6 and ICESAT-2 missions to generate a surface/height hypsometric curves for the lake, and to monitor volume variations. These results were also compared with in-situ volume variations provided by the lake operators.
The results obtained illustrate the strong current capabilities of altimetry satellite data such as SWOT and Sentinel-6, combined or not with optical data from Sentinel-2, to access water surfaces, heights and volumes over relatively small reservoirs.
Corresponding author:
Sabrine Amzil (**ICUBE-SERTIT**, **France**), s.amzil@unistra.fr

Lake Shoreline Morphometry Influences the Accuracy of SWOT-Derived Water-Level Estimates

David Lindao Caizaguano (Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden., Sweden); Fernando Jaramillo (Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden., Sweden)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_002

Abstract:
Accurate, spatially comprehensive measurements of lake water surface elevation are key for assessing the hydrological impacts of climate change. Yet, ground-based gauges exist on only a fraction of the world's lakes. The Surface Water and Ocean Topography (SWOT) satellite, launched in December 2022, addresses this gap by mapping inland water levels at high resolution from a dual-swath Ka-band radar interferometer.

Most SWOT accuracy studies have focused on sensor physics, surface conditions, and viewing geometry (incidence angle, layover). Far less attention has been paid to lake morphology and the influence of two-dimensional shoreline characteristics derived from area and perimeter. Metrics such as circularity, elongation, compactness, and lemniscate ratio have thus far undergone limited systematic investigation.

Sweden provides an ideal natural laboratory for exploring these effects. We evaluate SWOT's first-year performance over 62 Swedish lakes spanning 0.01–5 000 km² and a wide spectrum of morphometry. After harmonizing reference frames and applying a multi-stage quality-control filter to the Level-2 pixel-cloud product, we compare satellite-derived water levels with daily observations from the Swedish Meteorological and Hydrological Institute. SWOT attains a median root-mean-square error of 10.2 cm for lakes > 1 km² and 19.1 cm for smaller lakes, remaining within the 25 cm mission requirement for 250 m × 250 m water bodies. Lake area shows a weak negative correlation with error ($r = -0.19$). Three shoreline descriptors, compactness, circularity, and elongation ratio, collectively explain 38 % of the residual variance.

These results emphasize the complexity of shoreline shapes as a significant factor affecting SWOT-derived water-level estimates and provide new insights into performance across diverse lake morphologies.
Corresponding author:
David Lindao Caizaguano (**Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden.**, **Sweden**), david.lindao@natgeo.su.se

Lakes and reservoirs storage changes from SWOT and ancillary database in Quebec (Canada)

Axel Chuette (Université de Sherbrooke, Canada); Melanie Trudel (Université de Sherbrooke, Canada); Sylvain Biancamaria (CNRS/LEGOS, France); Manon Delhoume (CS, France); Mathilde De Fleury (CS, France); Gabriela Siles (Université Laval, Canada)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_003

Abstract:
Authors: Axel CHUETTTE, Mélanie TRUDEL, Sylvain BIANCAMARIA, Manon DELHOUME, Mathilde DE FLEURY, Gabriela SILES

Estimating lakes and reservoirs storage time dynamics is extremely important for multiple aspect of the water and carbon cycle. This study aims to compute and assess accuracy of lake storage change from SWOT data, for some lakes and reservoirs in Quebec, Canada (especially, the Aylmer, Grand Lac Saint-François, and Louise lakes). SWOT simultaneous measurements of lake extent and water surface elevations (WSE) are unique and can be used to estimate lakes/reservoirs storage change at global, continental, basin and local scales. Validation against in situ measurements in Quebec (Canada) showed SWOT meets the requirements on WSE and at some locations outperforms them. If SWOT also meets its requirements of 15% accuracy on lake extent measurements (impact of phenology set aside), for some lakes with extent variations smaller than 15% it is not accurate enough. Besides, lake extent from SWOT is affected by different source of errors (dark water, specular ringing, wetland near lakes, vegetation, layover…). It is therefore needed to combine SWOT data with other satellite data to improve lake extent time series. It is done in this study using Sentinel-1 and Sentinel-2 satellites data. The radar and optical images are selected if they are within + or – three days from SWOT observations. Once lake extent time series from SWOT/Sentinel-1/Sentinel-2 and WSE time series from SWOT have been computed, an hypsographic curve (lake extent versus WSE) is computed. It will allow to get consistent lake extent and WSE at the same measurement times.
Then, lake storage change is computed using the incremental approach from the L2_HR_LakeSP product Algorithm Theoretical Basis Document (ATBD; Pottier and Stuurman, 2023). Accuracy of these estimates are evaluated using lake storage change computed using the lake bathymetry and in situ WSE, that are available for the studied lakes. These lakes are also ice-covered during winter. SWOT data and an ice-flagging algorithm developed at Université de Sherbrooke are used to handle ice on lakes.
Lake/reservoir storage dynamic can be investigated using the lake water mass balance equation. Lake storage change is equal to the water mass flowing to it (from incoming rivers, direct water runoff from rain and snow melt, and potentially from the connected aquifer) minus water mass leaving it (water flowing out through downstream river network, evaporation, and potentially from the connected aquifer). SWOT estimates of lake storage change provides one part of this mass balance equation and will help to estimate inputs and outputs fluxes. For the studied lakes, information on water levels and outflow from the lakes/reservoirs are available freely through Quebec Government. It is therefore a perfect test case for lake/reservoir mass balance study. Assuming that contribution of connected aquifer is negligible, it will be possible to assess water mass lost via evaporation and quantify this mass loss compared to other term of the equation. This component (evaporation) is largely unknown and currently is only estimated as a byproduct of hydrological models. Deriving water balance components from in-situ and satellite observations will help to obtain a better knowledge of the water fluxes at high latitudes. For these lakes, quality of the SWOT discharge product may be assessed and water budget for other lakes/reservoirs without or partial in situ monitoring possibly computed. The approach will be tested on the studied lakes and estimate the benefits from SWOT data for mass balance computation.
This study is done at Université of Sherbrooke (Canada), LEGOS (France), CNES (France) and C-S Group (France) within the context of the SNORKS2 project, funded by the CNES TOSCA program and ASC/CSA.
Corresponding author:
Axel Chuette (**Université de Sherbrooke**, **Canada**), sylvain.biancamaria@univ-tlse3.fr

Leveraging SWOT observations for global reservoir monitoring

Elyssa Collins (NASA GSFC / UMD ESSIC, United States); Augusto Getirana (NASA GSFC/SAIC, United States); Sujay Kumar (NASA GSFC, United States); Yeosang Yoon (NASA GSFC/SAIC, United States); Chi-Hsiang Huang (Texas A&M University, United States); Huilin Gao (Texas A&M University, United States); Fuad Yassin (Environment and Climate Change Canada, Canada)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_004

Abstract:
Global evaluation of historical and future water security requires models that can accurately simulate reservoir operations, including reservoir storage and release. Reservoir models rely on time series of reservoir operation patterns (inflow, storage, and release) as inputs to estimate key model parameters; however, such in-situ data is limited and therefore spatially scarce. Satellite remote sensing and hydrological modeling offer another avenue for determining reservoir operation patterns. Recently, advances in satellite technology for the Surface Water and Ocean Topography (SWOT) satellite mission have substantially increased the spatial coverage of globally observed reservoirs. Here, we leverage water surface elevation (WSE) observations from SWOT and simulated flows from the Hydrological Modeling and Analysis Platform (HyMAP) to evaluate a globally applicable framework for simulating reservoir operations. In a case study focused on reservoirs in Brazil, we perform a set of experiments to characterize the error of simulated reservoir operations when using different combinations of in-situ, altimeter, and modeled data sources to optimize reservoir model parameters. To have a baseline, we also compare results using SWOT for parameter optimization to results using the global water measurements (GWM) satellite altimeter dataset, which has less spatial coverage but longer WSE time series. Our results indicate that incorporating satellite observations into reservoir parameterization improves simulated releases compared to using HyMAP naturalized flow alone for both SWOT and GWM. We find that using GWM for parameter optimization results in better performance compared to SWOT; however, further analysis suggests that the performance of reservoir operations using SWOT may increase with a longer observation record. Overall, our study suggests that incorporating satellite observations into hydrological models enhances simulated surface water dynamics, and that SWOT holds promise for the global assessments of reservoir operations.

Corresponding author:
Elyssa Collins (**NASA GSFC / UMD ESSIC**, **United States**), elyssa.l.collins@nasa.gov

Comparing multi-mission altimetry derived reservoir storage changes with SWOT Level 2 Lake Single-Pass product

Abhilasha Garkoti (Indian Institute of Technology, Kanpur, India); Aditya Sati (Indian Institute of Technology, Kanpur, India); Balaji Devaraju (Indian Institute of Technology, Kanpur, India)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_005

Abstract:
Reservoirs are artificial water bodies controlled by human operations, unlike natural lakes or rivers driven primarily by climate and catchment processes. Their levels, storage, release, and seasonal behavior make separate analysis essential for understanding their behavior and impact. Satellite radar altimetry provides water surface elevation (WSE) estimates, but factors such as altimetry pass location, variability in surface water area, and topographic conditions can influence accuracy. The Surface Water and Ocean Topography (SWOT) mission introduces co-located observations of WSE, surface water area, and derived storage changes, offering a framework for integrated reservoir monitoring. This study presents a workflow to estimate reservoir storage change using data from Sentinel-6, Sentinel-3A/3B, and SWOT (nadir) altimetry missions, combined with surface water extent derived from Sentinel-1 Synthetic Aperture Radar (SAR) imagery. The workflow includes the selection of virtual stations based on altimetry track distribution, dynamic surface masking using auxiliary datasets, and integration of multi-mission altimetry for WSE estimation. Storage change is calculated by combining the WSE and the area time series. We apply this workflow to five Indian reservoirs: Gandhisagar, Nathsagar, Shivajisagar, Somasila, and Ukai, which differ in shape, size, and topography. The results are compared against the SWOT Level 2 Lake Single-Pass Vector Data Product (SWOT_L2_HR_LakeSP), evaluating WSE, area, and storage estimates. The analysis examines the consistency between SWOT observations and multi-mission satellite-based methods and assesses the ability of SWOT to capture spatial and temporal changes in reservoirs.

Corresponding author:
Abhilasha Garkoti (**Indian Institute of Technology, Kanpur**, **India**), garkotiab20@iitk.ac.in

Global integration of lake and river hydrology with SWOT and the LakeFlow algorithm

George Allen (Virginia Tech, United States); Hana Thurman (Virginia Tech, USA); Ryan Riggs (United States Geological Survey, USA); Travis Simmons (University of Massachusetts Amherst, USA); Anshul Yadav (Texas A&M University, USA); Huilin Gao (Texas A&M University, USA); Jida Wang (University of Illinois Urbana-Champaign, USA)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_006

Abstract:
SWOT's unique observations of lakes and rivers enables new approaches to monitor lake-river interactions at the global scale. The LakeFlow algorithm uses SWOT's simultaneous observations of lakes and rivers to estimate the discharge of large rivers flowing in and out of lakes/reservoirs. LakeFlow assumes that lake storage change is equal to river inflows minus river outflows while accounting for lateral/tributary inflows and evaporative loss. Specifically, LakeFlow uses a modified version of Manning's equation to estimate discharge of rivers flowing in and out of lakes, while also accounting for lake storage change between SWOT overpasses. Here we present progress applying LakeFlow globally using SWOT's observations to estimate lake inflows and outflows. We also present the integration efforts of LakeFlow into the Confluence river discharge platform. To run LakeFlow at the global scale, we have parallelized, optimized, and containerized LakeFlow code for high-performance computing. As of May 2025, we have successfully run LakeFlow on 2.97 thousand lakes globally using SWOT observations and are currently in the process of validating and analyzing results from the first global LakeFlow run. A preliminary analysis of LakeFlow results across 1.06 thousand lakes in North America indicates that SWOT can characterize lake-river dynamics including the operational timing of actively managed reservoirs. We find that the outflows of actively managed reservoirs have significantly more variability than the outflows of natural lakes in North America. We also present the recent integration of LakeFlow into the Confluence river discharge platform, to be run operationally by PO.DAAC. This containerized version of the LakeFlow algorithm was optimized to run on Amazon Web Services and its outputs were assimilated into the Confluence pipeline to provide flow law parameter estimates of rivers adjacent to lakes. Confluence outputs can also be used by the Confluence Mass Optimization Integrator to account for processes like lake storage change, tributary inflows, and evaporative loss.

Corresponding author:
George Allen (**Virginia Tech**, **United States**), geoallen@vt.edu

Hydrological dynamics of the floodplains in the Cuvette Centrale (Congo River Basin) using the Surface Water and Ocean Topography (SWOT) mission

Cassandra Normandin (INRAE, France); Frédéric Frappart (INRAe, France); Bertrand Ygorra (INRAE, France); Valentine Sollier (INRAE, France); Julie Betbeder (CIRAD, France); Valéry Gond (CIRAD, France); Fabrice Papa (LEGOS, France); Benjamin Kitambo (Université de Stuttgart, Germany); Averti Ifo Suspens (Université Marien N'GOUABI à Brazzaville, Republic of Congo); Serge Razianoff (VisioTerra, France); Jean-Pierre Wigneron (INRAE, France)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_007

Abstract:
Climate change is exerting significant pressure on all components of the Earth system, with surface water reservoirs—such as lakes, rivers, wetlands, and floodplains—being particularly affected. Within this hydrological compartment, wetlands, including floodplains, play a critical role in modulating hydrological processes. These systems function as natural buffers, storing substantial volumes of water over timescales ranging from weeks to months, thereby regulating river discharge, enhancing evapotranspiration, influencing regional energy and moisture fluxes and have a key role in the carbon cycle (Bar-on et al., 2025). Despite their importance, the spatio-temporal dynamics of floodplains remain inadequately characterized at both regional and global scales. This gap in understanding is primarily attributed to the high spatial resolution observations of inundation extent and surface water elevation.

In response to these limitations, the Surface Water and Ocean Topography (SWOT) mission—jointly developed by CNES and NASA, launched in December 2022—represents a major advancement. For the first time, this mission enables direct, high-resolution (~100 m) and temporally consistent (21-day repeat cycle) observations of surface water extent and elevation over inland water bodies, including floodplains. This study aims to exploit the SWOT observations to monitor the hydrological dynamics of the Central Cuvette floodplain, a key component of the Congo Basin's hydrological system. The Central Cuvette is located in the core of the Congo Basin in Central Africa with an area of approximately 1,176,000 km². The region's climate is characterized by a humid tropical climate with bimodal rainfall distribution, featuring two pronounced precipitation maxima: one in October and a second in April. Consequently, the region exhibits a bimodal flooding regime, with peak inundation typically occurring during November–December and May–June, and low-flow periods observed in August and February–March (Betbeder et al., 2014 ; Normandin et al., 2024). The amplitude of surface water level fluctuations varies across the basin, with lower variability observed in the Cuvette Centrale, where annual changes range from approximately 1.5 to 4.5 meters (Kitambo et al., 2022a. Moreover, recent studies have provided quantitative estimates of surface water storage within the basin, reporting varying values, and have examined the influence of incorporating floodplains into surface water storage assessments (Becker et al., 2018; Frappart et al., 2021 ; Kitambo et al.,2022b).

More recently, a study conducted in the Congo Basin demonstrated the strong potential of the SWOT mission for measuring river slopes, even on rivers narrower than 100 meters (Normandin et al., 2024). This promising first step now allows us to focus on a more detailed analysis of floodplains in order to better quantify surface water storage and assess the full potential of the SWOT mission. The methodological approach involves the extraction and analysis of radar backscatter coefficients to delineate surface water bodies, followed by a comparative assessment with Synthetic Aperture Radar data from the Sentinel-1 satellite (Bossy et al., 2025). Preliminary results from this stage are currently under evaluation. Subsequent analyses will focus on the derivation and interpretation of water level and coherence maps, with the goal of improving our understanding of floodplain hydrodynamics in the Cuvette Centrale.

Corresponding author:
Cassandra Normandin (**INRAE**, **France**), cassandra.normandin@gmail.com

Monitoring surface water storage in Peruvian Andean lakes and reservoirs with SWOT and Sentinel-1: Toward integrated mountain hydrology

Kimberly Karime Visitacion Bustamante (ISPA - INRAE, France); Santiago Pena Luque (CNES, France); Nafissa Sfaksi (MEOSS, France); Pedro Rau (CITA-UTEC, Peru); Marie Paule Bonnet (ESPACE-DEV, Univ Montpellier, IRD, France); Luc Bourrel (GET, UMR 5563 CNRS/IRD/UPS, France); Frederic Frappart (ISPA-INRAE, France)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_008

Abstract:
Monitoring surface water storage in high-altitude regions remains challenging due to sparse in-situ data. This study evaluates a multi-sensor approach to estimate lake volume changes in three Andean water bodies: Lake Junín, Lake Sibinacocha, and the Yuracmayo reservoir by integrating surface elevations from the SWOT mission with surface areas derived from Sentinel-1 SAR imagery.
The SWOT Lake Vector product (L2_HR_LakeSP) was successfully applied to Yuracmayo, where compact morphology and well-defined shorelines enabled accurate elevation retrieval. Estimated volumes correlated well with in-situ data ($R = 0.80$), capturing both seasonal variation and abrupt changes from reservoir operations (9–49 hm^3). In contrast, the vector product was unsuitable for Junín and Sibinacocha due to shoreline complexity: wetlands in Junín and narrow, fragmented geometry in Sibinacocha impeded consistent elevation extraction. For these sites, elevation retrieval was obtained from SWOT pixel cloud (L2_HR_PIXC). Elevation retrieval from the pixel cloud involved spatial filtering and classification to isolate valid water surfaces.
Volume dynamics observed in 2024 revealed distinct hydrological regimes across the three study sites. Lake Junín exhibited a pronounced wet-season peak, with volumes rising from 59 hm^3 in January to 350 hm^3 in May, then declining below 65 hm^3 by November characteristic of a precipitation-driven system. Sibinacocha showed a slower, more gradual increase from 50 to 94 hm^3 by June, reflecting sustained inputs from glacial melt. Yuracmayo displayed abrupt, stepwise changes in storage, increasing from 18 hm^3 in December 2023 to 49 hm^3 in April, then dropping to 9 hm^3 by November, consistent with managed releases for water supply.
These contrasting dynamics demonstrate SWOT's capacity to resolve diverse storage behaviors when product selection is adapted to lake morphology and observation conditions. While the Lake Vector product proved effective in Yuracmayo, accurate elevation retrieval in Junín and Sibinacocha requires processing from the pixel cloud due to shoreline complexity. The SWOT and Sentinel-1 framework thus offers a flexible and scalable solution for monitoring surface water storage in data-scarce, high-mountain basins.

Corresponding author:
Kimberly Karime Visitacion Bustamante (**ISPA - INRAE**, **France**), kimberly.visitacion@inrae.fr

Assessing SWOT's capability in characterizing reservoir backwater dynamics

Xinchen He (University of Illinois Urbana-Champaign, United States); Jida Wang (University of Illinois Urbana-Champaign, United States); George Allen (Virginia Tech, United States); Huilin Gao (Texas A&M University, United States)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_009

Abstract:
River-lake interfaces prevail across global hydrological systems and host unique processes for modulating flow and sediment regimes. In particular, the inlet corridor where a river flows into a lake is often characterized by an "M1" surface-water profile, or the so-called backwater curve, where water elevation transitions asymptotically from the sloping river flow upstream to the horizontal lake surface downstream. This phenomenon is pronounced when a low-gradient, subcritical river flows into a large reservoir, where backwater effect can be expressed tens of kilometers upstream. The scale and location of the backwater curve vary seasonally, reflecting the dynamic interactions between inflow regimes and reservoir regulations. Characterizing backwater dynamics is important not only because it helps accurately locate the shifting inlet boundary of a reservoir, but also because it contributes to the estimation of the reservoir "wedge water storage", i.e., the additional volume of water superelevated by backwater. This wedge storage is critical for reservoir water management but has been largely ignored due to observation challenges.

The Surface Water and Ocean Topography (SWOT) satellite mission, with its repeated wide-swath, fine-resolution water surface elevation data, offers unprecedented potential for capturing river-lake hydrodynamics. In this study, we leverage multiple SWOT L2 data products, including pixel cloud and standard vector datasets, to retrieve multi-temporal surface-water profiles along the inflow corridors of selected reservoirs worldwide. Using principles from open-channel hydraulics, we decompose each retrieved profile into horizontal, static, and wedge storage zones, which enables more accurate estimation of dynamic reservoir extents and storage changes. We further investigate how surface-water profiles evolve throughout reservoir operation cycles, highlighting seasonal amplification of backwater effects and their implications for water management.

This study demonstrates SWOT's unique capability in capturing complex river-lake interactions and highlights the critical importance of resolving backwater dynamics for improved reservoir monitoring. It also serves as a proof of concept for our global application of SWOT data in generating L4 reservoir products that explicitly account for backwater effects.

Corresponding author:
Xinchen He (**University of Illinois Urbana-Champaign**, **United States**), xinchenh@illinois.edu

Mapping the wetlands of the Amazon and Congo rainforests with PALSAR-2 and SWOT

Paul Senty (DHI & University of Copenhagen, Denmark); Cécile Kittel (DHI, Denmark); Fabrice Papa (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université Toulouse, IRD, CNRS, CNES, France); Monica Coppo Frias (DHI & University of Copenhagen, Denmark); Rasmus Fensholt (Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark); Stéphanie Horion (Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_010

Abstract:
The wetlands of the Amazon and Congo rainforests are significant hotspots for methane emissions. These emissions are driven by the seasonal and inter-annual dynamics of flooding, yet the extent of flooded forests and savannas is poorly understood. This is due to a lack of in-situ data, the remoteness of these wetlands, and the vegetation that obscures the surface water, leading to discrepancies across existing flood extent datasets.

Synthetic Aperture Radars (SAR), such as PALSAR-2 and the KaRIn instrument on the SWOT satellite, are particularly effective for mapping tropical wetlands, thanks to their ability to penetrate clouds and vegetation. In this analysis, we used the whole archive of PALSAR-2 imagery to map the flood extent of both rainforests, and differentiate between permanent, seasonal, and occasional flooding. Over 2,000 altimetric stations were used to delineate hydrologically homogeneous sub-regions, within which the maximal and minimal river stages are reached at similar times. For each sub-region, we generated high-resolution composites representing different river stages, enabling the classification of forests as permanently, seasonally, occasionally, or never flooded.

Our maps of maximum flood extent show strong agreement with existing datasets in the Amazon. The interpretation of our results in the Congo is more challenging due to the limited number of existing datasets, and disagreements appear over the Cuvette Centrale peatlands, which are associated with smaller backscatter variations and are usually rain-fed. While PALSAR-2 and its longer wavelength is more adapted to map flooded forests, the SWOT satellite has complementary strengths, especially its ability to map flooded savannas at high resolution. Combined, these satellite datasets offer a powerful approach for comprehensive wetland mapping in tropical forest ecosystems.

Acknowledgement
This research is part of the Global Wetland Center funded by the Novo Nordisk Foundation. More info: https://globalwetlandcenter.ku.dk/
Corresponding author:
Paul Senty (**DHI & University of Copenhagen**, **Denmark**), pase@dhigroup.com

Use of SWOT for understanding dynamics of Amazonian ria lakes and its interaction with the Amazon River

Kei Yamato (University of Illinois Urbana-Champaign, United States); Jida Wang (University of Illinois Urbana-Champaign, United States); James Best (University of Illinois Urbana-Champaign, United States)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_011

Abstract:
Ria lakes are widespread in the Amazon River basin, where they comprise a crucial component of the Amazon ecosystem. These lakes, formed as flooded river valleys due to post-glacial sea level rise, remain poorly understand in terms of their hydrodynamic interactions with the Amazon River. Yet, understanding such lake-river interactions is essential for assessing functional connectivity and seasonal dynamics in water and sediment fluxes across the Amazon freshwater system. With the Amazon River experiencing its most severe drought in two consecutive years in 2023-2024, further stresses on lake-river connectivity are expected, which is further compounded by dam construction and deforestation under a changing climate in the region. To investigate this connectivity, we integrate multiple SWOT data products, including LakeSP, RiverSP and PIXC, along with optical images collected from Sentinel-2, PlanetScope, and Landsat-9, to evaluate the relationship between each ria lake and the adjacent Amazon River. By examining the seasonal dynamics of the lake-river relationship since July 2023, we aim to obtain a detailed understanding of the role of the Amazon River in controlling the behavior of ria lakes.

To date, we have analyzed 21 ria lakes along the Amazon River mainstem, which exhibit an average annual water surface elevation (WSE) amplitude of 10 meters. The WSE hydrographs of these ria lakes show a temporal lag from upstream to downstream along the Amazon mainstem, confirming the central control of the Amazon River. Among the 21 ria lakes, 20 display a strong 1:1 relationship between lake and adjacent river WSE, either consistently throughout the observed period or until the water level falls below a threshold “sill” level. This “sill effect” is observed in 19 of the lakes, and is likely driven by: (1) a functional disconnection of the lake with the Amazon River below this sill (hydrogeomorphic control), or (2) a shift in dominant influence from the downstream river to the upstream lake catchment (hydrodynamic control). We further test these mechanisms using SWOT-derived longitudinal water surface profiles along the ria lakes and their adjacent Amazon River mainstem, in combination with water surface connectivity interpreted from optical imagery. These findings offer new insights into the intricate controls of the ria lake system, and lay the foundation for advancing our understanding of sediment dynamics and refining the typology of the Amazonian lakes.

Corresponding author:
Kei Yamato (**University of Illinois Urbana-Champaign**, **United States**), kyamato2@illinois.edu

Monitoring water storage change in lakes and reservoirs from space

Luciana Fenoglio (Chalmers University of Technology, University of Bonn, Sweden); Jiaming Chen (University of Bonn, Germany)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_012

Abstract:
DETECT-REDS investigates in its second phase the impact of water use change on the water cycle in different climate zones in Europe between 2016 and 2025. We consider as sub-regions the Alps, Southern-, Central-, Northern- and Eastern-Europe. Water surface elevations from swath-, SAR nadir- and icesat altimetry cross-validated and validated against in-situ, are merged in a time-series for each lake. Seasonal and intra-annual variability of surface water storage are investigated for lakes of area larger than 0.5 km**2.

Nadir altimetry data are processed with Fully Focused SAR algorithm (FFSAR) at 80 Hz for Sentinel-3 and 140 Hz for Sentinel-6. For Swath-altimetry we choose the HR products PICX of 60 meters resolution and the Raster products. We observe that 1/8 of the water bodies observed by SWOT are seen from nadir altimetry. The sub-regions Alps and Northern-Europe are the most reach in water, with natural lakes and man-made reservoirs.

Reservoirs for hydropower generation have the highest variation in water level.
The accuracy of water heights is assessed against in-situ, bathymetry and Sentinel-1 images and found to be higher with SWOT that with nadir-altimetry. Is better than 15 cm in all water bodies and the surface area has a mean accuracy of 10%. In the Alps the water surface elevation (WSE) varies by more than 10 meters, with changes up to 100 m in hydroelectric and up to 10 m in irrigation reservoirs. Switzerland has more than 70 reservoirs for hydropower of area larger than 0.5 Km**2 and with annual minima in April. Annual minima is in November for irrigation reservoirs and annual maxima in summer for natural lakes. In hydroelectric reservoirs the seasonal amplitude of storage change is 70% higher than in irrigation reservoirs and 80% higher than in natural lakes. The water storage change (WSC) is estimated from area and height change and is combined to precipitation and evaporation and runoff to verify the water balance. Runoff and snowmelt from a land model that does not include irrigation and hydropower are compared with.
In Northern Europe the variation of water surface elevation in reservoirs is smaller than in Switzerland and varies by less than 10 meters in all the lakes.
This study highlights the relevance of the new satellite altimeter observations to study the effect of water use. Similar methodology can be applied to monitor lakes in areas where in situ measurements are not available and to improve water management.

This study is partly funded by the German Research Foundation (DFG) as sub-project B01 of CRC 1502 (https://sfb1502.de).

Corresponding author:
Luciana Fenoglio (**Chalmers University of Technology, University of Bonn**, **Sweden**), fenoglio@geod.uni-bonn.de

A SWOT-Based Climatology of Seasonal Variability in Southern Chilean Lakes.

Rodrigo Abarca del Rio (Department of Geophysics (DGEO), Faculty of Physical and Mathematical Sciences, University of Concepción, Concepción, Chile); Javier Andrade-Jiménez (Department of Geophysics (DGEO), Faculty of Physical and Mathematical Sciences, University of Concepción, Concepción, Chile, Chile); Jean-Francois Cretaux (Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, Toulouse, France)

Session: Hydrology: SWOT Lakes, Estuaries and Wetlands (SLEW)
Presentation type: Poster
Poster number: ST2025HS2_013

Abstract:
Lakes in southern Chile, spanning latitudes 38°S to 46°S, are sensitive indicators of hydroclimatic variability, reflecting seasonal shifts in snowmelt, glacial runoff, and precipitation. Despite their hydrologic and ecological significance, a regional-scale understanding of their seasonal behavior remains elusive due to the scarcity of consistent, high-resolution observations. Leveraging the Surface Water and Ocean Topography (SWOT) mission, this study presents the first climatology of seasonal lake variability in this complex Andean region, based solely on SWOT data.
We analyze a network of lakes—ranging from large systems like Llanquihue, Ranco, and General Carrera to smaller bodies exceeding 100 m²—using SWOT Level 2 LakeObs products. These provide spatially detailed, temporally discrete observations of water surface elevation (WSE) and lake extent, enabling the characterization of seasonal dynamics across multiple hydrologic years.
Our methodology includes: (1) extraction of SWOT-observed WSE and surface area for each SWOT pass; (2) construction of climatological profiles based on the aggregation of seasonal signals from multiple overpasses; and (3) spatial comparison of seasonal amplitude and phase across the lake network to identify latitudinal and topographic gradients in hydrologic response.
This SWOT-exclusive climatology captures seasonal variability with unprecedented spatial resolution, revealing the characteristic timing and magnitude of lake-level fluctuations across southern Chile. These results provide critical baseline information for future assessments of hydrologic change, and demonstrate the power of SWOT for monitoring lacustrine dynamics in mountainous, data-scarce environments.

Corresponding author:
Rodrigo Abarca del Rio (**Department of Geophysics (DGEO), Faculty of Physical and Mathematical Sciences, University of Concepción, Concepción**, **Chile**), rabarcadelrio.univ@gmail.com

Dynamic Mode Decomposition of Geostrophically Balanced Motions from SWOT Cal/Val in the separated Gulf Stream

Takaya Uchida (Moscow Institute of Physics and Technology, Russia); Badarvada Yadidya (University of Michigan, United States of America); Karl Lapo (Universitat Innsbruck, Austria); Xiaobiao Xu (Florida State University, United States of America); Jeffrey Early (NorthWest Research Associates, United States of America); Brian Arbic (University of Michigan, United States of America); Dimitris Menemenlis (San Jose State University, United States of America); Luna Hiron (Florida State University, United States of America); Eric Chassignet (Florida State University, United States of America); Jay Shriver (Naval Research Laboratory, United States of America); Maarten Buijsman (University of Southern Mississippi, United States of America)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_001

Abstract:
The decomposition of oceanic flow into its geostrophically balanced and unbalanced motions carries theoretical and practical significance for the oceanographic community. These two motions have distinct dynamical characteristics and affect the transport of tracers differently from one another. The launch of the Surface Water and Ocean Topography (SWOT) satellite provides a prime opportunity to diagnose the surface balanced and unbalanced motions on a global scale at an unprecedented spatial resolution. Here, we apply dynamic-mode decomposition (DMD), a linear-algebraic data-driven method, to tidally-forced idealized and realistic numerical simulations at submesoscale-permitting resolution and one-day-repeat SWOT observations of sea-surface height (SSH) in the Gulf Stream downstream of Cape Hatteras, a region commonly referred to as the separated Gulf Stream. DMD is able to separate out the spatial modes associated with sub-inertial periods from super-inertial periods. The sub-inertial modes of DMD can be used to extract geostrophically balanced motions from SSH fields, which have an imprint of internal gravity waves (IGWs). We utilize the statistical relation between relative vorticity and strain rate as the metric to gauge the extraction of geostrophy.
Corresponding author:
Takaya Uchida (**Moscow Institute of Physics and Technology**, **Russia**), takachanbo@gmail.com

Relative dispersion at the surface of the ocean: role of balanced motions and internal waves

Stefano Berti (Unité de Mécanique de Lille J. Boussinesq, Université de Lille, France); Michael Maalouly (Unité de Mécanique de Lille J. Boussinesq, Université de Lille , France); Apolline Dekens (Unité de Mécanique de Lille J. Boussinesq, Université de Lille , France); Guillaume Lapeyre (LMD/IPSL, CNRS, Ecole Normale Supérieure, PSL Research University, Paris, France); Aurélien L. S. Ponte (Ifremer, Université de Brest, CNRS, IRD, Laboratoire D'Océanographie Physique et Spatiale, IUEM, Brest, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_002

Abstract:
Ocean flows at scales smaller than few hundreds of kilometers display rich dynamics, mainly associated with nearly-balanced, meso and submesoscale turbulence, and internal gravity waves. Although these processes may act on comparable lengthscales, the former are considerably slower than the latter, which take part in the ocean fast variability. Understanding how their effects overlap is crucial for several fundamental and applied questions, including the interpretation and exploitation of new, high-resolution satellite altimetry data, such as those from SWOT, and the characterization of material transport at fine scales.

In this study we investigate these points by examining Lagrangian pair-dispersion statistics in a high-resolution global-ocean numerical simulation resolving both submesoscale and high-frequency motions, such as internal gravity waves. In particular, we aim at assessing the sensitivity of the particle relative-dispersion process on the latter, fast and strongly ageostrophic fluid motions. For this purpose we select a study area close to Kuroshio Extension, in which the relative importance of internal waves and balanced motions varies in summer and winter, and focus on the seasonal variability of the Lagrangian dynamics.

We find that in winter pair dispersion is predominantly influenced by meso and submesoscale motions. In this case, the behavior of the different Lagrangian indicators considered is in overall agreement with their predictions based on the shape of the kinetic energy spectrum, as in quasi-geostrophic turbulence. Conversely, in summer, when high-frequency motions gain importance and submesoscales are less energetic, the situation is found to be more subtle, and the usual relations between dispersion properties and spectra do not seem to hold. We explain this apparent inconsistency relying on a decomposition of the flow into nearly-balanced motions and internal gravity waves. Through this approach, we show that while the latter contribute to the kinetic energy spectrum at small scales, they do not impact relative dispersion, which is essentially controlled by the nearly-balanced, mainly rotational, flow component at larger scales. Our results then also suggest that high-resolution data from SWOT should allow predicting Lagrangian transport and dispersion properties via the advection of synthetic drifters, provided the satellite-derived, nearly- balanced flow component is sufficiently accurate.

Corresponding author:
Stefano Berti (**Unité de Mécanique de Lille J. Boussinesq, Université de Lille**, **France**), stefano.berti@polytech-lille.fr

Dynamical interpretation of SWOT SSH: an in-situ approach to disentangle balanced and unbalanced motions beneath SWOT swaths

Arne Bendinger (LOPS, France); Clément Vic (LOPS, France); Sophie Cravatte (IRD, New Caledonia); Lionel Gourdeau (LEGOS, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_003

Abstract:
The Surface Water Ocean Topography (SWOT) satellite altimetry mission provides sea surface height (SSH) at unprecedented spatial scales encompassing mesoscale to submesoscale dynamics as well as internal gravity waves motion. While SWOT offers new opportunities to study energy redistribution, momentum transfer, and nonlinear scale interactions, a key challenge lies in accurately disentangling the SSH signal to attribute variability to different dynamical regimes. In 2023, an extensive in-situ experiment was conducted in the southwestern tropical Pacific focusing on the deployment and recovery of mooring lines in an internal tide generation and propagation hotspot located beneath both SWOT swaths during the fast-sampling phase. The region's strong mesoscale and submesoscale activity, combined with energetic internal tides, makes it an ideal site to separate near-geostrophic (balanced) and wave-driven (unbalanced) motions. Using a time-filtering technique, we decompose the moored observations into distinct dynamical flow regimes. Our results reveal the coexistence of mesoscale dynamics and semidiurnal internal tides, the latter associated with vertical isopycnal displacements of up to 150 m and steric SSH variations of up to 20 cm. Steric SSH estimated from the moorings shows good agreement with the daily-aliased SWOT SSH. These mooring observations provide crucial insight into the vertical structure of fine-scale ocean dynamics and how they manifest at the surface, helping to unravel the complex signals captured by SWOT.

Corresponding author:
Arne Bendinger (**LOPS**, **France**), arne.bendinger@univ-brest.fr

Observing and understanding internal solitary waves in the Maluku's Sea with SWOT

Aurélien Ponte (Ifremer, France); Noé Lahaye (Inria, france)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_004

Abstract:
One of the new and relatively unexpected features appearing in SWOT sea level observations are internal solitary waves (ISW). This study reports on the Maluku Sea where ISW were systematically observed during SWOT fast sampling phase, with typical sea level anomaly of 20 cm and spatial extent of the front of a few kilometers. We systematically describe the occurrence of these waves and its relationship with the phase of the tidal cycle, the geometrical shape of the wave packets, its propagation speed, as well as the shape of each individual wave. These observations are compared against analytical and numerical predictions from simplified ISW dynamical models (KdV style). Using semi-analytical solutions of ISW trains to fit the observations, we show that one can extract quantitative information on the amplitude and shape of the ISW train, and extrapolate its structure at depth (deviation of isopycnals and currents). These results support the high potential of SWOT data in providing unprecedented measures of ocean dynamics at the submesoscale.
Corresponding author:
Aurélien Ponte (**Ifremer**, **France**), aurelien.ponte@ifremer.fr

Vertical velocities measurements in fine-scale processes during the BioSWOT-Med cruise

Maxime Arnaud (Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France, France); Stéphanie Barrillon (Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France, France); Jean-Luc Fuda (Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France, France); Robin Rolland (Sorbonne Université, CNRS, IRD, MNHN, LOCEAN-IPSL, 4 place Jussieu, Paris, 75005, France, France); Gérald Grégori (Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France, France); Andrea Doglioli (Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France, France); Francesco d'Ovidio (Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN-IPSL), Sorbonne, France); Ananda Pascual (Mediterranean Institute for Advanced Studies, IMEDEA, (CSIC-UIB), Esporles, Spain, Spain); Anne Petrenko (Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_005

Abstract:
Ocean fine-scale dynamics such as (sub)mesoscale processes (1-100 km / days to weeks) can significantly impact biogeochemistry and particularly phytoplankton production and distribution. Although difficult to sample due to their short space and time extent, fine-scale processes can induce substantial vertical velocities of a few mm/s.

The SWOT mission, launched in 2022, provides a new tool to better detect fine-scale features from altimetry at an unprecedented resolution, reaching a spatial resolution of 15km (versus >100km for previous missions). The SWOT CalVal phase provided daily data in specific areas. Therefore, the BioSWOT-Med cruise (DOI: 10.17600/18002392) took place in one of these areas in the western Mediterranean Sea, from April to May 2023, and combined modelling, in situ and satellite data to study fine-scale dynamics. Indeed, the North Balearic front between dense saline older Atlantic waters and light fresh newer Atlantic waters and a small but strong anticyclonic eddy were extensively sampled both physically and biologically.

The challenging vertical velocities measurement has been conducted using several in situ instruments and methodologies. The conventional vessel-mounted ADCPs (Acoustic Doppler Current Profilers) provide 3D velocity transects covering the entire cruise period. Two other original methods developed by our group have also been used: the Free-Fall ADCP (FF-ADCP) at stations, and the autonomous Vertical Velocity Profiler (VVP). The FF-ADCP consists of a downward-looking ADCP, connected to the boat by a loose rope, letting the ADCP drop by gravity and make measurements free of the ship's movements. The VVP is inspired from the methodology developed for gliders, using the comparison to a flight model to estimate the direction and intensity of the vertical velocities. In order to focus on physics-driven oceanic vertical velocities, we developed a method to identify and isolate biology-induced vertical velocities. The intensity and variability of the physics-driven vertical velocities have been studied in the frontal zone and in the anticyclonic eddy, dominated by near-inertial internal waves.

In addition to the innovative part of this work using three different methods to measure vertical velocities during this interdisciplinary cruise, it unlocks perspectives for inter-validation of vertical velocities between in situ measurements and sea surface height derived velocities in the context of the SWOT era.

Corresponding author:
Maxime Arnaud (**Aix Marseille Univ., Université de Toulon, CNRS, MIO, 13288, Marseille, France**, **France**), maxime.arnaud@mio.osupytheas.fr

Ubiquity and seasonality of deep submesoscales in the Southern Ocean revealed by elephant seals and SWOT

Lia Siegelman (UCSD, United States); Patrice Klein (Caltech, United States); Christophe Guinet (CEBC CNRS, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_006

Abstract:
Ocean submesoscale fronts with a size of 1-20 km have been extensively documented within the surface mixed layer but little is known about their existence below it. Here, we analyze an extensive record of 133 598 dives performed by instrumented Southern Elephant Seals over several years in the Indian sector of the Southern Ocean with a sub-km resolution. Results show that submesoscale motions are intensified below the mixed layer and are present year-round from the surface down to depths of at least 500 m. They exhibit a seasonal cycle with an austral spring (Sep-Oct-Nov) intensification and a weakening in fall (Mar-Apr-May).
These deep submesoscales have a weak signature on sea surface temperature and salinity and conventional altimetry. However, they are detectable in high-resolution SWOT sea surface height due their significant steric height signal at submesoscale. Results show that these deep submesoscales are generated by subsurface intensified eddies (with a size > 50 km) and follow their seasonality. Since submesoscales are known to be associated with strong vertical velocities, these results suggest that vertical exchanges of heat and nutrient at depth may be more important than commonly assumed. Overall, these results highlight the potential of SWOT for detecting subsurface features and quantifying their role in ocean transport.
Corresponding author:
Lia Siegelman (**UCSD**, **United States**), lsiegelman@ucsd.edu

Energy partition between internal waves and quasi-geostrophic motions in the moderately energetic area of the BioswotMed cruise

Julien Lenne (LOCEAN, France); Pascale Bouruet-Aubertot (Sorbonne université, France); Yannis Cuypers (Sorbonne université, France); Anne Petrenko (Mediterranean Institute of Oceanography, France); Léo Berline (Mediterranean Institute of Oceanography, France); Anthony Bosse (Mediterranean Institute of Oceanography, France); Robin Rolland (Sorbonne université, France); Louise Rousselet (Sorbonne université, France); Ananda Pascual (IMEDEA, Spain); Francesco D'Ovidio (Sorbonne université, France); Andrea Doglioli (Mediterranean Institute of Oceanography, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_007

Abstract:
The considerable refinement of SWOT measurements compared to classical altimetry, extending the spatial resolution to the finescale range (including meso and submesoscales 1-100km) has raised the question of the contribution of ageostrophic motions to the SSH signature. These fine-scales which include frontal structures, vortices and filaments are conducive of various instabilities feeding the direct energy cascade to small-scale turbulence, but also a reverse cascade to large-scale turbulence. The question of the transition scale between direct and reverse cascades is fundamental as a virtual boundary between “balanced” and “unbalanced” movements. This transition scale is highly dependent on fine-scale dynamics and the eddy kinetic energy level. In addition, the interaction of sub-mesoscale structures with internal waves acts as a catalyst for the energy cascade, whether internal tidal waves or wind-generated near-inertial frequency waves.
Our study area is that of the BIOSWOT-MED cruise, near the North Balearic front. The dynamics, characterized by a moderate eddy kinetic energy level and an insignificant tidal signal. These features make it a specific case study for characterizing wind generated near inertial waves and vorticity structures interactions and how they impact the transition scale and reinforce the energy cascade. The analysis is based upon vertical section of currents (acoustic Dopler current profiler) and density measurements (Moving Vessel Profiler). The energy partition between internal waves (IW) and quasi-geostrophic (QG) motions in 2D wavenumber space is inferred from two methods : the Helmoltz decomposition and a Burger decomposition (Vladoiu et al, 2024). The energy partition between QG motions and IW is contrasted and depends upon the wind forcing events and the sign of the background vorticity field. The largest IW total energy is observed along vertical section crossing anticyclonic structures which is consistent with the inertial chimneys evidenced by Rolland et al (2025). Implications regarding the interpretation of SWOT measurements are under present investigation and will be discussed.
Corresponding author:
Julien Lenne (**LOCEAN**, **France**), julien.lenne@locean.ipsl.fr

Variational method for dynamical reconstruction and separation of Balanced Motions and Internal Tide from SWOT

Valentin Bellemin-Laponnaz (Institut des Géosciences de l'Environnement, Université Grenoble Alpes, France); Florian Le Guillou (Datlas , France); Clément Ubelmann (Datlas, France); Eric Blayo (Laboratoire Jean Kuntzmann, Université Grenoble Alpes, France); Emmanuel Cosme (Institut des Géosciences de l'Environnement, Université Grenoble Alpes, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_008

Abstract:
Mapping Sea Surface Height (SSH) from satellite altimetry is crucial for numerous scientific and operational applications. At the fine scales observed by wide-swath altimeters, SSH variations are primarily driven by two types of dynamics: nearly geostrophic balanced motions and the wavy motion of the internal tide. These two processes influence ocean dynamics in different ways and their contributions to SSH variations must be separated for applications. While this separation is now standard practice with high-frequency outputs of numerical simulations, it remains an unresolved challenge for SSH maps derived from satellite observations, which are sparse in both space and time.

This study introduces an innovative method to separate balanced motions and internal tide components in SSH altimetric observations, including SWOT. The method is based on a data assimilation system combining two models: a quasi-geostrophic model for the balanced motions and a linear shallow-water model for the internal tide. The inversion is performed using a weak-constraint four-dimensional variational (4DVar) approach, with two different sets of control parameters adapted to each regime. The method produces hourly SSH and surface velocity fields for both components over a specified domain.

The method is applied to real SWOT SSH measurements, with the Californian Current System 1-day phase crossover serving as a case study. As this work forms part of a PhD project, the most recent results will be presented at the conference.

Corresponding author:
Valentin Bellemin-Laponnaz (**Institut des Géosciences de l'Environnement, Université Grenoble Alpes**, **France**), valentin.bellemin-laponnaz@univ-grenoble-alpes.fr

Revealing the submesoscale structure of subthermocline eddies in the North East Pacific

Giuliana Berden (University of Victoria, Canada); Jody Klymak (University of Victoria, Canada); Tetjana Ross (Institute of Ocean Sciences, Fisheries and Oceans Canada (DFO), Canada); Guoqi Han (Institute of Ocean Sciences, Fisheries and Oceans Canada (DFO), Canada)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_009

Abstract:
The california undercurrent in the Northeast Pacific interacts with the shelf break creating instabilities associated with the generation of sub surface eddies called Cuddies. These subthermocline eddies are key agents in offshore transport of heat, salt, oxygen and nutrients, yet their limited surface expression has historically hindered their detection via traditional satellite altimetry. In this study, we investigate the vertical and horizontal structure of a Cuddy, using underwater glider observations and satellite data, including the high-resolution Surface Water and Ocean Topography (SWOT) mission. Glider transects reveal a subsurface-intensified lens at ~250 m depth, characterized by warm and salty Pacific Equatorial Waters. SWOT captures the eddy with greater intensity and finer-scale structure than conventional altimetry (DUACS), resolving submesoscale features and spiral-shaped internal jets not seen in DUACS. In addition, SWOT-derived geostrophic velocities were compared with surface velocities inferred from satellite chlorophyll imagery showing high correlation (R2 = 0.78). These results highlight SWOT's unique capability to detect the submesoscale surface imprint of subsurface eddies, enhancing our understanding of eastern boundary current dynamics and cross-shelf exchange

Corresponding author:
Giuliana Berden (**University of Victoria**, **Canada**), gberden@uvic.ca

Spectral Kinetic Energy Cascades from SWOT Observations in the Kuroshio Region

Jia-Xuan Chang (University of Michigan, United States); Brian Arbic (University of Michigan, United States)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_010

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite provides two-dimensional sea surface height (SSH) measurements at sub-10 km resolution. We use SWOT Level 3 SSH data in the Kuroshio region to investigate surface kinetic energy transfers and the validity of balance assumptions at submesoscales. The SSH field is separated into wave and eddy components using a recent method. The eddy component is used to compute velocities under both geostrophic and cyclogeostrophic assumptions, allowing us to assess how balance choices affect inferred flows. We compute relative vorticity and the Jacobian of streamfunction and vorticity from the filtered SSH, forming the basis for spectral flux diagnostics, following the approach of Arbic et al. (2013, JPO). The goal is to identify the direction of kinetic energy cascades, inverse and forward, based on SWOT observations. Results from SWOT will be compared with AVISO altimetry and MITgcm LLC simulations to evaluate the consistency of observed and modeled energy transfers.

Corresponding author:
Jia-Xuan Chang (**University of Michigan**, **United States**), jiaxc@umich.edu

Mixed layer mechanisms detected by SWOT

Abigail Bodner (Massachusetts Institute of Technology, United States); Bianca Champenois (Massachusetts Institute of Technology, United States); Leah Johnson (University of Washington, United States)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_011

Abstract:
Submesoscale O(1-10km) dynamics are known for their role in impacting stratification and the vertical structure of the upper ocean. In this work, we evaluate the relationship between the sea surface height (SSH) signal measured by SWOT and the vertical structure in the oceanic mixed layer. We use data from cross-over regions where SWOT, surface temperature and salinity measurements are available alongside in-situ data from moorings and Argo. We derive the vertical modes based on principal component analysis and compare with signatures of submesoscale restratification in isopycnal tilting. We identify clear relationships between SSH and the vertical modes, highlighting the significance of fine-scale features from SWOT to reconstruct submesoscale contributions of ocean mixed layer dynamics.

Corresponding author:
Abigail Bodner (**Massachusetts Institute of Technology**, **United States**), abodner@mit.edu

SWOT reveals fine-scale balanced motions and dispersion in the Antarctic Circumpolar Current

Yann-Treden Tranchant (Australian Antarctic Program Partnership, University of Tasmania, Australia); Benoit Legresy (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia); Annie Foppert (Australian Antarctic Program Partnership, University of Tasmania, TAS, Australia); Beatriz Peña Molino (Commonwealth Scientific and Industrial Research Organisation, TAS, Australia); Helen Phillips (University of Tasmania, TAS, Australia)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_012

Abstract:
The Southern Ocean and its main feature, the Antarctic Circumpolar Current (ACC), plays a key role in heat and carbon exchanges. Recent studies have emphasized the role of smaller-scale processes in tracer exchanges within the ACC. The new SWOT satellite enhances the capability of observing ocean dynamics down to a 15 km wavelength and will help understand the role of smaller-scale features in redistributing tracers in the ocean. SWOT data are affected by instrumental noise and unbalanced components in the observed SSH field, affecting geostrophic velocity estimation.

In this presentation, we assess the velocities derived from high-resolution SSH measurements from the SWOT satellite using Lagrangian drifters deployed during the FOCUS SWOT-validation voyage in an energetic meander of the ACC. We show that SWOT's ability to resolve sharper SSH gradients results in more intense and accurate velocity estimates that match remarkably with in-situ observations. In the region, we find that SWOT SSH is valid to infer balanced dynamics at scales as small as 15 km, with a 25 km length scale found to be a trade-off between suppressing errors due to unbalanced SSH while preserving fine-scale balanced motions in the region. At these scales, geostrophic balance alone becomes insufficient, and nonlinear terms in the momentum balance make a significant contribution to the drifter velocities. Pair-statistics computed from drifters and virtual particles further reveal that SWOT-derived velocities accurately capture dispersion properties over the 5-200 km scale, comparing well and unprecedently to those calculated from drifters, observational evidence that balanced motions are dominant in driving dispersion at these scales.

Corresponding author:
Yann-Treden Tranchant (**Australian Antarctic Program Partnership, University of Tasmania**, **Australia**), yanntreden.tranchant@utas.edu.au

Lagrangian characterization of fine-scale processes (1 to 10 km) using an array of surface drifters in the Brazil Current

Candela Lopez Fidel (University of Buenos Aires, Argentina); Martín Saraceno (CIMA/CONICET-UBA, Argentina); Sebastián Cornejo Guzmán (CIMA/CONICET-UBA, Argentina); Laura Ruiz Etcheverry (CIMA/CONICET-UBA, Argentina)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_013

Abstract:
The study of oceanic submesoscale processes represents a challenge for both in situ observations and satellite data. In recent years, the use of drifting buoys has gained importance as a Lagrangian tool to investigate these processes, enabling an analysis that follows the flow and examines its properties while removing the advective component. During a research cruise in January 2025, a set of 5 drifters anchored at 15 m depth (type A) and 18 drifters anchored at 50 cm depth (type B) were deployed in the Uruguayan shelf-break, under the influence of the Brazil Current. Type A drifters also measured surface temperature and temperature and conductivity at 12 m depth. The buoys drifted for 36 hours transmitting its position every 30 minutes (A) and 10 minutes (B). The drifter trajectories revealed distinct circulation patterns between the two drifter types. For type B drifters, we examined the influence of Ekman transport, tides, and inertial motions. Reconstructed trajectories—obtained by subtracting each drifter's mean velocity and the tidal current—highlight inertial oscillations as the dominant residual signal. Type A drifters displayed trajectories coherent with geostrophy. The observed trajectories will be used to compare conventional Level-4 altimetry products with datasets enhanced with SWOT observations. Additionally, vertical transport is to be estimated from kinematic properties at two depth levels, with the aim of advancing toward a Lagrangian characterization of submesoscale processes in the Southwestern Atlantic. This work has been made possible thanks to the Pampa Azul B6, OSTST TOSTO, and SWOT PATASWOT projects.

Corresponding author:
Candela Lopez Fidel (**University of Buenos Aires**, **Argentina**), candelaslf@gmail.com

Inferring submesoscale transport from SWOT

K.Shafer Smith (kss3@nyu.edu, United States); Abigail Bodner (MIT, USA); Dhruv Balwada (Columbia University, USA); Spencer Jones (Texas A&M University, USA); Leah Johnson (U Washington , USA); Tatsu Monkman (NYU, USA); Ryan Shijie Du (NYU, USA)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_014

Abstract:
Learning submesoscale surface velocities from SWOT observations presents a challenge for at least two reasons: (1) submesoscale dynamics are characterized by O(1) Rossby number and exhibit a wide range of ageostrophic motions, including convergent fronts and strong vortical asymmetry; and (2) inertia-gravity waves (IGWs) strongly influence SSH at these scales. These wave motions are ageostrophic, and moreover, their O(1 day) timescales make it infeasible to remove them from the 21-day repeat cycle SWOT data using temporal filtering. Alternate methods, not relying on geostrophy or temporal filtering, need to be developed if we wish to quantify submesoscale transport from SWOT.

Our SWOT Science Team is focused on estimating the submesoscale, non-wave, ageostrophic velocity field from SWOT KaRin snapshots, in conjunction with other satellite and in situ data. In this presentation, I will discuss our team's approach to this problem, covering results from work over the past six years, emphasizing how they fit together and provide parts of the solution to this puzzle, and ending with a presentation of our current efforts and plans going forward. Highlights include the development of deterministic inversion methods to recover surface and subsurface balanced velocities using higher-order balanced models; use of joint probability distributions of vorticity, strain and divergence in the LLC4320 simulation to reveal statistical flow patterns as a function of region and season; using machine learning approaches to estimate wave-filtered SSH fields; and a newly-begun effort to use generative diffusion models to estimate surface velocities, along with their uncertainty quantification.

Corresponding author:
K.Shafer Smith (**kss3@nyu.edu**, **United States**), kss3@nyu.edu

Extrapolating high resolution SWOT SSH fields via deep learning techniques

Tatsu Monkman (New York University, United States); K. Shafer Smith (New York University, USA); Dhruv Balwada (Columbia University, USA); Spencer Jones (Texas A&M University, USA)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_015

Abstract:
Since the start of data collection in 2023, the Surface Water and Ocean Topography (SWOT) mission has exceeded its original requirements and revealed exciting potential for studying previously unresolved submesoscale processes and the upper-ocean kinetic energy cycle. However, significant challenges remain in fully exploiting SWOT's sea surface height (SSH) data, particularly with respect to estimating and validating submesoscale surface and subsurface currents and vertical velocities. One key limitation is the temporal and spatial sparsity of SWOT observations, which complicates the use of traditional dynamical reconstruction methods such as those based on quasi-geostrophic (QG) theory that require SSH data on a uniform grid.
To address this challenge we aim to generate and validate a realistic, high-resolution 2D SSH field by extrapolating SWOT observations onto a regularly spaced grid using deep learning techniques. Our long-term objective is to create SSH fields suitable for enabling higher-order, QG-based submesoscale velocity reconstructions in the upper ocean. We evaluate several approaches for extrapolating SWOT SSH data beyond the SWOT swath, including modified versions of the video inpainting method behind NeurOST, as well as a score-based data assimilation method that leverages high-resolution model priors. As an initial validation step we assess each method’s performance in reconstructing SSH by evaluating physical metrics such as power spectral density and upper-ocean transport using high-resolution model data.

Corresponding author:
Tatsu Monkman (**New York University**, **United States**), tm3076@nyu.edu

Approaches to estimating heat and transport using sea surface height

Feier Yan (Lamont-Doherty Earth Observatory, Columbia University, United States); Dhruv Balwada (Lamont-Doherty Earth Observatory, Columbia University,, United States); Tatsu Monkman (Courant Institute of Mathematical Sciences, New York University, United States); Shafer Smith (Courant Institute of Mathematical Sciences, New York University, United States)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_016

Abstract:
Estimating mesoscale and submesoscale driven eddy heat transport in global ocean circulation remains challenging due to the lack of fine-resolution and co-located velocity and tracer observations. Different satellites provide broad spatial coverage for resolving eddy dynamics across different observable variables, but inferring true surface currents and the corresponding tracer transport based on the satellite data is nontrivial.

To address this, we propose a method utilizing diffusion models and other approaches to downscale and transform sea surface height (SSH) and tracer data into higher-resolution surface velocity and tracer flux estimates. As a proof of concept, we are currently testing our approach in idealized quasi-geostrophic models, and comparing the machine learning (ML) approaches with traditional data driven optimal interpolation and stochastic filtering strategies. We hope to develop a hierarchy of approaches that would be capable of providing us refined tracer transport estimates using SWOT and other eddy resolving satellites.
Corresponding author:
Feier Yan (**Lamont-Doherty Earth Observatory, Columbia University**, **United States**), fy2331@columbia.edu

Assessing the seasonality of ocean macroturbulence in circulation models with SWOT data : first results from a cloud-based, distributed intercomparison study

Julien Le Sommer (IGE/CNRS, France); Marcela Contreras (IGE/CNRS, France); Micaël Aguedjou (CNES, France); Amine Ouehechou (IGE/CNRS, France); Flavien Gouillon (CNES, France); Aurélie Albert (IGE/CNRS, France); Takaya Uchida (MIPT, Russia); Cyril Germineaud (CNES, France); Eric Chassignet (COAPS, USA)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_017

Abstract:
Ocean macro-turbulence significantly influences the transport of heat, carbon, and nutrients, playing a critical role in regulating Earth's climate and sustaining marine ecosystems. Therefore, accurately representing these processes in ocean models and forecasting systems is essential. A key challenge lies in particular in capturing the pronounced seasonal and spatial variability of (sub)mesoscale ocean processes. Satellite altimeter data provides crucial observational constraints for evaluating and improving the representation of these scales in ocean models.

The SWOT mission offers an unprecedented opportunity to observe the full spectrum of ocean macroturbulence with high spatial resolution on a global scale. When combined with in-situ measurements from the SWOT-AdAC field campaign, this dataset provides a powerful tool for evaluating the realism of (sub)mesoscale dynamics represented in ocean circulation models across different resolutions. Such comprehensive observations are essential for improving model accuracy and advancing our understanding of ocean circulation.

But in practice, fully leveraging the potential of SWOT ocean data is challenging due to the large data volume, and the unique characteristics of wide-swath altimetry. Additional complexity arises from the diversity of model data sources, the differences in ocean model grids and naming conventions. These factors make a systematic intercomparison difficult, especially when aiming for a workflow that is fully open and reproducible across different models and research groups.

In this presentation, we report on an ongoing effort to simplify the intercomparison of ocean models at various resolutions using SWOT data. We describe an open workflow leveraging cloud computing resources where research groups can contribute seamlessly with their ocean model data. The workflow, tools and instructions for contributing are hosted openly on GitHub.

We present initial results from a pilot study assessing the space-time variability of sea surface height (SSH) wavenumber spectra across a range of ocean circulation models with various grid resolution and parameters. We aim to better understand how different models represent the seasonality of ocean macroturbulence and kinetic energy cascades.

Corresponding author:
Julien Le Sommer (**IGE/CNRS**, **France**), julien.lesommer@univ-grenoble-alpes.fr

Comparisons between SWOT measurements and surface currents obtained from optical sensors

Nicolas Rascle (IFREMER, France); Renaud Binet (CNES, France); Erwin Bergsma (CNES, France)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_018

Abstract:
We present comparisons between surface currents derived by optical sensors (using Sentinel-2) and SWOT measurements. The sigma0 from SWOT, the SSH, the MDT, the level-3 current and higher order gradients like the vorticity are discussed on selected collocated cases.
As obtained, the sigma0 and the SSH contain information on the dynamics at kilometer scale, which should help to better reconstruct the current and its vorticity at those scales.
Corresponding author:
Nicolas Rascle (**IFREMER**, **France**), nicolas.rascle@ifremer.fr

Evaluating SWOT's Performance in Capturing Mesoscale and Submesoscale Currents in the Cape Basin

A. Nathanael Dossa (Rosenstiel School of Marine, Atmospheric and Earth Sciences, University of Miami, Miami, FL, USA, United States); M. Lisa Beal (Rosenstiel School of Marine, Atmospheric and Earth Sciences, University of Miami, Miami, FL, USA, United States); Guillaume Novelli (Rosenstiel School of Marine, Atmospheric and Earth Sciences, University of Miami, Miami, FL, USA, United Sates); J. Thomas Farrar (Woods Hole Oceanographic Institution, Woods Hole, MA, USA, United States)

Session: Oceanography: Velocities
Presentation type: Poster
Poster number: ST2025OS3_019

Abstract:
Launched in December 2022, the SWOT (Surface Water and Ocean Topography) satellite provides unprecedented sea surface height (SSH) observations at a spatial resolution of 2 km × 2 km. However, SSH measurements from SWOT may include contributions from unbalanced motions, which can pose challenges when estimating surface currents and vorticity. This study aims to investigate submesoscale variability in the Cape Basin by combining SWOT data with traditional altimetry, sea surface temperature (SST), chlorophyll-a, and in situ measurements from Shipboard ADCP and X-band Radar collected during the QUICCHE campaign in March 2023. This integrated approach highlights SWOT's potential to resolve fine-scale ocean dynamics in the region. To assess the accuracy of surface velocity and vorticity estimates, two SSH-based derivation methods were applied: finite-difference (stencil) derivatives and a fitting kernel method using multiple spatial windows (3 km, 5 km, 7 km, 9 km, 11 km, and 13 km). The fitting kernel method with a 9 km window provided the best results, capturing finer-scale structures with reduced noise. Velocities derived using this method showed good agreement with in situ observations, with root-mean-square errors (RMSE) of 0.20 m/s for ADCP velocities and 0.22 m/s for X-band radar velocities.

Corresponding author:
A. Nathanael Dossa (**Rosenstiel School of Marine, Atmospheric and Earth Sciences, University of Miami, Miami, FL, USA**, **United States**), nath2dossa@gmail.com

Estimation of Discharge and River Channel Parameters through Hydrology–Hydraulic (H&H) Coupling with SWOT Altimetry: Toward Learnable Parameterizations

Pierre-André GARAMBOIS (INRAE, RECOVER, AIx-Marseille University, France); Kevin Larnier (Hydro Matters, France); Léo Pujol (INRAE / INSA-IMT, France); Jérôme Monnier (INSA-IMT, France)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_001

Abstract:
The unprecedented hydraulic visibility of river surface deformation provided by the SWOT satellite offers a wealth of information for enhancing hydrological-hydraulic (H&H) models and improving discharge estimations worldwide. However, estimating uncertain or unknown parameters in hydraulic models—such as inflow discharges, riverbed bathymetry, and friction parameters embedded in the momentum equation and subject to equifinality—constitutes a high-dimensional inverse problem that remains ill-posed when based solely on altimetric observations. To address this challenge, we couple a river network hydraulic model with regional hydrological modeling, leveraging physically consistent inflow estimates at upstream boundaries and lateral contributions to constrain the solution space and improve parameter identifiability across the river network (after Pujol et al. 2020). A robust variational data assimilation (VDA) of water surface elevation (WSE) observations into the 1D Saint-Venant river network model DassFlow 1D enables the joint inference of inflow hydrographs, effective bathymetry, and spatially distributed friction at the network scale starting from prior parameters infered with HiVDI (Larnier et al. 2020, Larnier and Monnier 2023).
This approach is demonstrated on the large, complex, and poorly gauged Maroni basin in French Guiana (Larnier et al., 2025). The pre-processing chain includes: (i) constructing effective hydraulic geometry using drifting ICESat altimetry and Sentinel-1-derived river widths; and (ii) filtering noisy SWOT Level 2 WSE data prior to assimilation. Results show systematic
improvements in both the fit to assimilated WSE data—achieving an 85% cost reduction—and discharge validation at five gauges across the network. When assimilating SWOT data alone, 70% of WSE residuals fall within the [–0.25; 0.25 m] range, and normalized root-mean-square error (NRMSE) of discharge estimates ranges from 0.05 to 0.18, representing an improvement of 18% to 71% over prior estimates. The dense spatial coverage of SWOT WSE observations enables the inference of detailed spatial variability in riverbed elevation, friction coefficients, and inflow time series.
Next, the hybrid physics–AI hydrological model SMASH (Huynh et al. 2024, 2025) is coupled with DassFlow 1D (Brisset et al. 2018). This numerical integration of two differentiable models enables VDA to provide information feedback from hydraulic observables to the hydrological model (after Pujol et al., 2022). This feedback capability is demonstrated on the Maroni River by calibrating the hydrological model directly from SWOT-derived WSE observations. The approach is currently being adapted to the Garonne basin, where the methodology of Pujol et al. (2022)—embedding a hydrological model within a seamless 2D–1D-like hydraulic framework—is also under investigation.
This work is part of the SWOT-Hydro2Learning TOSCA project, which develops disruptive H&H modeling and discharge inversion methods by coupling differentiable models with data assimilation and machine learning, leveraging SWOT, multi-source Earth observation, and in situ data.

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Corresponding author:
Pierre-André GARAMBOIS (**INRAE, RECOVER, AIx-Marseille University**, **France**), pierre-andre.garambois@inrae.fr

Estimation of Bathymetry Profiles For Poorly Gauged River Networks

Jérôme Monnier (INSA-Mathematics Institute of Toulouse, France); Jessie Levillain (CNES / INSA-Mathematics Institute of Toulouse, France); Kevin Larnier (Hydro-Matters / INSA-Mathematics Institute of Toulouse, France)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_002

Abstract:
Knowledge of water depth h(x,t) [m] in rivers, more precisely the cross-sectional area A(x,t) [m^2], or equivalently the bathymetry b(x) [m] once a geometrical wetted cross-sections model is fixed, is indispensable data for setting up river dynamics models. However, river bathymetry is unknown for a large number of rivers worldwide: it is difficult to measure on a large scale and cannot be done remotely. Knowledge of river bathymetry is important in itself, but also for estimating the river discharges Q(x,t) [m^3/s] of ungauged rivers, as shown, for example, in [1]. Estimating river bathymetry from water surface measurements alone is an ill-posed problem. Given a single measurement b_ref, effective bathymetry profiles b(x) of river portions can be estimated from SWOT-like measurements, as seen in [2], by using the so-called Low-Froude flow equation, highlighted in [3]. However, the use of this equation can be problematic with sparse and noisy data, especially for long portions. This is due to a drift in the estimation that is intrinsic to such an Ordinary Differential Equation.
Given a geometrical wetted-cross section model compatible with SWOT measurements, under flow assumptions (including the low-Froude assumption (1-Fr^2) \approx 1, one can derive a PDE relating the water surface elevation H(x) to the bathymetry profile b(x) only, [4]. This provides an "altimetry-to-bathymetry model" valid for a great majority of worldwide rivers at approximately 1 km reach scale. This model enables robust estimations against noise and without drifting phenomena in the estimation. Moreover, one can derive a formulation adapted to networks, enabling the estimation of bathymetry profiles of a complete river network given a single measurement in the network, [5]. The method has been tested on the synthetic Pepsi rivers and synthetic river networks. Moreover, within its domain of applicability, this method can improve the estimation of the river discharge Q(x,t) presented in [6].

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Corresponding author:
Jérôme Monnier (**INSA-Mathematics Institute of Toulouse**, **France**), jerome.monnier@insa-toulouse.fr

Assessing River Avulsion Risk Ratios with NASA SWOT

Carly Koppe (Saint Louis University, United States); Bo Wang (Saint Louis University , United States)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_003

Abstract:
River avulsions, the abrupt relocation of channels, are fundamental fluvial processes that build landscapes but pose significant hazards. Predicting these events is challenging. Particularly in dynamic, high-sediment rivers like Nepal's Koshi, these shifts threaten extensive populations and critical infrastructure, where traditional monitoring methods often fall short due to the vast scale and rapid changes involved. This study addresses the need for enhanced, quantitative avulsion risk assessment by leveraging new satellite datasets. Here we demonstrate, using synergistic analysis of SWOT (Surface Water and Ocean Topography) water surface elevations and FABDEM (Forest And Buildings removed Copernicus DEM) topography, that distinct reaches of the 70-km upper Koshi River exhibit quantifiable high risk of future avulsion. We calculated four indicators—Scv /Sdv (cross-valley slope/down-valley river slope), Ls /Sdv (levee slope/down-valley river slope), superelevation (derived from SWOT-inferred river depth using extreme low flow conditions and high-flow water surface elevation), and a composite metric (Y∗B, here Y*B is Ls/Sdv * Superelevation)—which pinpoint reaches 8 and 14 as most susceptible. The high risk in reach 8, located downstream of the 2008 Koshi avulsion in reach 7, validates our indicators' ability to identify areas primed for channel change by capturing conditions such as progressive superelevation. This approach offers a significant advance over previous qualitative or data-limited assessments by providing spatially explicit, data-driven vulnerability metrics. These findings establish a crucial, replicable framework for proactive avulsion hazard management in Koshi and other large, sediment-rich river systems globally.

Corresponding author:
Carly Koppe (**Saint Louis University**, **United States**), carly.koppe@slu.edu

Altimetry River Reach Methods (ARRM)

Karina Nielsen (DTU Space, Denmark)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_004

Abstract:
Satellite altimetry is an important supplement for water level monitoring. Water level time series are traditionally reconstructed at virtual stations (VS), where the satellite ground track intersects the river. The Surface Water and Ocean Topography (SWOT) mission provides a nearly complete spatial coverage, which allows us to study changes in the surface water profile along river reaches. The temporal resolution is approximately 10 days or better, depending on the latitude. However, if we combine SWOT with the traditional nadir altimetry, we can increase the temporal resolution and extend the water level time series back in time.

Here, the R package “Altimetry River Reach Methods” (ARRM) is presented. The core functionality of ARRM is to reconstruct a water level time series using all available satellite altimetry data over a river reach, unlike the classical VS approach, where only one mission is applied. A Gaussian Markov Random Field is used to reconstruct the reach-based water level. ARRM exploits the river center lines from the SWOT River Database (SWORD), ensuring an easy connection with the SWOT data, e.g., the RiverSP product. Here, the functionality of the R packages is demonstrated via examples from different rivers

Corresponding author:
Karina Nielsen (**DTU Space**, **Denmark**), karni@space.dtu.dk

Evaluating the potential of Surface Water and Ocean Topography (SWOT) satellite data for detecting water-surface superelevation in meandering rivers

Tasneem Haq Meem (University of Illinois Urbana-Champaign, United States); Bruce L Rhoads (University of Illinois Urbana-Champaign, United States); Jida Wang (University of Illinois Urbana-Champaign, United States)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_005

Abstract:
Lateral water-surface superelevation, i.e., the rise in water level along the outer bank, is a common phenomenon in meandering rivers caused by the curvature-induced centrifugal force. Accurate data on water-surface superelevation are critical for modeling the hydrodynamics of meandering rivers, including free surface deformation and prediction of mean velocity near bends. Despite its significance, superelevation has been studied in only a limited number of cases, primarily in laboratory curved channels. Field measurement of superelevation remains challenging due to water surface disturbance and temporal variability associated with changing hydrological conditions. This study aims to evaluate the potential of high-rate data from the Surface Water and Ocean Topography (SWOT) satellite mission to accurately detect superelevation of the water surface in large meandering rivers. The lateral variation in water-surface elevation (WSE) was evaluated for bankfull flows in a series of sharply curved bends at three sites - two on the Mississippi River and one on the Wabash River. A grid-based spatial-averaging model was applied to determine lateral variation in WSE at discrete cross sections from SWOT pixel cloud data. Plots of lateral WSE gradients at cross-sections around the bends show that distinct superelevation is evident on the Mississippi River bends with the pattern of superelevation varying directly with the pattern of bend curvature. Data for the Wabash River, which is only about one-third as wide as the Mississippi reaches, is less conclusive. Mean flow velocities estimated from the WSE gradients are consistent with estimated velocities based on data for nearby gaging stations. Overall, the results suggest that SWOT is capable of accurately detecting superelevation of the water surface in bends of large rivers, providing a promising foundation for global assessments of lateral gradients in WSE in large meandering rivers.

Corresponding author:
Tasneem Haq Meem (**University of Illinois Urbana-Champaign**, **United States**), tmeem2@illinois.edu

Assessment of SWOT estimated hydraulic parameters through hydrological experiments over Ganga River

Shard Chander (Space Applications Centre ISRO, India); Ritesh Agrawal (Space Applications Centre, India); Amit Dubey (Space Applications Centre, India); Rohit Pradhan (Space Applications Centre, India); Ashwin Gujrati (Space Applications Centre, India); Shishir Gaur (Indian Institute of Technology (BHU), India); Anurag Ohri (Indian Institute of Technology (BHU), India); Praveen Kumar Gupta (Space Applications Centre, India)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_006

Abstract:
River discharge is one of the important hydrological essential climate variables (ECV) that is a key for understanding the water cycle and prevention strategies for efficient water resources. In this study, we investigate the Ka band Radar Interferometer (KaRIn) sensor data of Surface Water Ocean Topography (SWOT) mission to estimate river discharge over Ganga River exclusively from remotely sensed hydraulic observations. A series of field campaigns were carried out in-synchronous with the SWOT Cal-Val orbit (track 10, daily repetivity) and Science orbit (pass 36 & 273, 21 day's cycle) during April-2023 to June 2024. More than 15000 kinematic observations were collected using DGPS to monitor spatial variability of the water stage within the 120 km of swath altimetry during Cal-Val and science phase. The observation from Acoustic Doppler Current Profiler (ADCP) was also collected simultaneously at various locations to estimate river discharge for calibration/validation purposes. SWOT Level 2 Water Mask Pixel Cloud Data Product, Version C and River Single-Pass Vector Data Product, Version 2 was downloaded from PODAAC. For analyzing the long time series, we utilized the Hydrocron-API. For our selected ROI, in total 16 reaches and 1142 nodes were found on the main stream of Ganga River. The PIX-C product contains multiple attributes such as: Geolocated elevations, geophysical range corrections, tidal corrections, Classification mask and Surface areas that was used estimating WSE. Prior to analysis, WSE were preprocessed for estimating the land contaminated pixels, we use the following flags: geolocation quality flag (geolocation_qual), Classification mask (water/land flags, and water fraction), interferogram flag and Sigma0 >15 dB. This step has significantly reduced the number of valid observations. SWOT data release is still in the commissioning phase and recently distributed version D data may reduce these erroneous observations. To remove the erroneous pixels, we also make use of maximum extent of wetland boundaries. The National Wetland Inventory and Assessment (NWIA) database at 1:12500 scale is a pan India database, developed by the Space Applications Centre (ISRO) that integrates data from the Resourcesat-2/2A LISS-IV of spatial resolution 5.6 meter. SWOT WSE observations were interpolated at 60 meter intervals to prepare the surface elevation maps.

WSE along with river width and water slope are the three hydraulic variables essential for river discharge computation. SWOT retrieved WSE during Cal-Val phase is validated using in-situ hydrological observations. During the experiment the water stage was found to be varying between 53.37 m - 73. 94 m with respect to mean sea surface and the river discharge value were sound to be varying between 430 m3/s to 1658 m3/s. The in-situ water stage during experiment was observed to be between 63.28 - 69.53 meter with corresponding river discharge of 510-1409 m3/s. The water surface profile fitted linearly and the slope was estimated (8.09 cm/Km). Similar order of variation in the water levels was observed by SWOT observations, with root mean square error (RMSE) of the order of 25 cm. The SWOT derived river slope (8.89 cm/ Km) as shown in figure 1e was also in good agreement with the GPS observations. To evaluate the capability of SWOT observations in estimating river discharge, the extreme downstream location of the ROI was selected. GloFAS model estimated river discharge was used to compare the SWOT estimated discharge. The integration of SWOT measured high-resolution WSE along with river width with a modified Manning's equation has provided a scalable approach for estimating discharge without relying on traditional in situ measurements. SWOT estimated river widths were highly erroneous, varying between 400-3000 meters without any seasonal pattern. In this work, river width was estimated using Landsat-8/9 in Google Earth Engine (GEE). River depth and slope is inferred from WSE by subtracting a reference bed elevation (minimum WSE as an approximation) and from the gradient along the river's reach. With these parameters in hand, Manning's equation is applied to estimate discharge with n (0.018 for natural rivers).

The results demonstrate that SWOT-derived discharge successfully captures seasonal variations and large-scale hydrological trends with R2 0.8368, RMSE 2418.43 m3/s and NSE of 0.82. The overall correlation between altimetry measured river discharge with GloFAS data, reinforcing the reliability of SWOT observations under natural flow conditions. This study generated a reliable dataset to validate the SWOT observations along with the

estimated river discharge data set of the Ganga River near Varanasi with the aim of enhancing the accuracy of swath altimeter products. Initial results from swath altimetry measurements have added a new dimension in the field of land hydrology.

Corresponding author:
Shard Chander (**Space Applications Centre ISRO**, **India**), sharad.isro@gmail.com

SWOT Validation over the Amazon Basin

Daniel Moreira (SGB - Geological Survey of Brazil, Brazil); Fabrice Papa (IRD/LEGOS, France); Fabrice Papa (IRD/LEGOS, France); Alice Fassoni-Andrade (Unb, Brazil); Ayan Fleischmann (Mamirauá Institute, Brazil); Jefferson Melo (SGB, Brazil); Leandro Guedes (SGB, Brazil); Charlotte Blondel (CNES/LEGOS, France); Sly Wongchuig (CNES/LEGOS, France); Adrien Paris (Hydro-Matters, France); Andre Santos (SGB, Brazil); Jean-Francois Cretaux (CNES/LEGOS, France); Stéphane Calmant (IRD/LEGOS, France)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_007

Abstract:
The Amazon Basin experiences extreme hydrological variability, with annual water level fluctuations often exceeding 16 meters. These seasonal changes shape not only the lives and economy of millions across the region but also the local ecology. When more severe than expected, such events can isolate communities, disrupt wildlife habitats, cause economic losses, and lead to shortages of essential supplies. To mitigate these risks, institutions like the Geological Survey of Brazil (SGB) continuously monitor the basin, forecasting the magnitude of annual flood and drought peaks. However, the existing in-situ network lacks the spatial density needed to cover this vast area of approximately 7 million km².

To expand monitoring capacity, SGB, IRD, and partners—with support from CNES—have been leveraging satellite-based observations. In this context, SWOT represents a major opportunity. Recent results (Moreira et al., 2025) have demonstrated SWOT's strong potential for capturing extreme events, such as the severe 2023 Amazon drought. Recognizing SWOT's importance for operational hydrological monitoring, SGB, IRD, and collaborators have conducted an extensive validation program. Since May 2023, during SWOT's Cal/Val phase, field campaigns using GNSS have been collecting water surface elevation (WSE) data. These efforts include evaluations at both pixel cloud and river product levels, focusing on accuracy, uncertainty, and product limitations.

This work presents key validation results, including direct comparisons between SWOT-derived WSE and GNSS measurements, as well as cross-comparisons with continuous in-situ monitoring and other satellite altimetry missions (e.g., hydrologyfromspace.org/hfs-app). The goal is to assess SWOT's integration potential with both conventional and satellite-based hydrological networks, offering insights into data quality, uncertainties, known issues, and possible solutions to improve future SWOT products.

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Corresponding author:
Daniel Moreira (**SGB - Geological Survey of Brazil**, **Brazil**), daniel.moreira@sgb.gov.br

Leveraging SWOT Lake and River Data and Physics-Embedded Machine Learning to Advance Streamflow Simulation

Peijun Li (Pennsylvania State University, United States); Chaopeng Shen (Pennsylvania State University, US); Colin Gleason (University of Massachusetts, Amherst, US); Theodore Langhorst (University of Massachusetts, Amherst, US); Kostas Andreadis (University of Massachusetts, Amherst, US); Casey Brown (University of Massachusetts, Amherst, US)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_008

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite, launched in December 2022, has introduced transformative capabilities for monitoring surface water dynamics. We present an early investigation of the information value of using SWOT-derived lake and river data across the conterminous United States (CONUS) for streamflow simulation. Two distinct approaches — a data-driven model and a physically-based model — were first employed to “reconstruct” sparse SWOT observations (2023-2025) into continuous daily data from 2017 to 2024. In other words, we simulated a time series in response to meteorological forcings in a highly consistent way to SWOT-like data. These reconstructions were then integrated into a data-driven modeling framework to simulate final gauge-observed discharge. Our results demonstrate that incorporating SWOT-related lake and river data can improve streamflow long-term simulation by better informing either the physical parameters or data-driven networks. The improvement is most noteworthy for median flows, presumably due to observational frequency. Notably, absolute values of the SWOT lake water surface elevation data without de-meaning provided more substantial improvements, and applying a roughness penalty during the reconstruction of SWOT lake signals also proved beneficial. Incorporating hydrological prior knowledge was beneficial to effectively extracting and utilizing information from SWOT observations. Expanded temporal coverage of SWOT data expected to enhance our simulations' precision. By demonstrating the readiness of differentiable modeling for global hydrological applications, this study also lays the foundation to assimilate SWOT data for streamflow prediction.
Corresponding author:
Peijun Li (**Pennsylvania State University**, **United States**), shen.chaopeng@gmail.com

Assimilation of SWOT nodes products into basin-scale hydraulic models

Ludovic Cassan (Univ Toulouse, CNRS/CERFACS/IRD, CECI, France); Hind Oubanas (INRAE, France); Pierre-Olivier Malaterre (INRAE, France); Sophie Ricci (Univ Toulouse, CNRS/CERFACS/IRD, CECI, France); Quentin Bonassies (Univ Toulouse, CNRS/CERFACS/IRD, CECI, France); Igor Gejadze (INRAE, France); Andrea Piancentini (Univ Toulouse, CNRS/CERFACS/IRD, CECI, France); Thanh Huy Nguyen (LIST, Luxembourg); Patrick Matgen (LIST, Luxembourg); Marco Chini (LIST, Luxembourg)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_009

Abstract:
This study leverages the innovative capabilities of the SWOT, especially its river node products, to enhance the accuracy of riverine flood reanalysis, performed on a 50-km stretch of the Garonne River (France). The experiments incorporate various data assimilation strategies, based on the ensemble Kalman filter, which allows for sequential updates of hydraulic model parameters based on available observations. The assessments with respect to a reference simulation in OSSE mode (using synthetical SWOT-like observations) as well as with respect to Sentinel-1 and Sentinel-6 data for a real event, show that while SWOT data alone offers some improvements. In addition, combining SWOT river node products with in-situ water level measurements provides the most accurate representation of flood dynamics, both at gauge stations and along the river. Similar analyses are also carried out over other challenging catchments such as Ohio and Mississippi Rivers (US) and Severn River (UK). It was demonstrated that the assimilation of SWOT offers promising prospects for future river dynamics and flood monitoring systems making the most of various and complementary strengths of Earth Observation data. In addition, we explore the combined assimilation of SWOT WSE and altimetry satellite data to estimate river discharge over a set of study areas to improve the temporal frequency. These estimates can then be assimilated into global hydrological/routing models (RAPID, ISBA-CTRIP) to further enhance the estimates at finer scales.

Corresponding author:
Ludovic Cassan (**Univ Toulouse, CNRS/CERFACS/IRD, CECI**, **France**), ricci@cerfacs.fr

Global Riverbank Slope Patterns Inferred from SWOT-Derived Hypsometry Curves

J. Daniel Velez (University of North Carolina at Chapel Hill, United States); Tamlin Pavelsky (University of North Carolina at Chapel Hill, United States)

Session: Hydrology: River Science Working Group
Presentation type: Poster
Poster number: ST2025HS3_010

Abstract:
Riverbank slopes are a key geometric attribute that governs channel-floodplain connectivity, cross-sectional shape, and overbank flow behavior, with significant implications for hydrodynamic modeling and ecohydrological processes such as hyporheic exchange, riparian inundation, and floodplain residence times. However, riverbank slopes remain largely unquantified on a global scale, constrained by the limited capacity of remote sensing to capture near-bank topography and the infeasibility of applying high-resolution topobathymetric modeling across broad river domains.

The Surface Water and Ocean Topography (SWOT) satellite provides global observations of river width and water surface elevation (WSE), but not channel depth, slope geometry, or cross-sectional area. To overcome this gap, we explore the use of width-elevation hypsometry curves, monotonic relationships between SWOT-derived width and elevation, as a proxy to infer riverbank slope. This approach builds on hydraulic geometry theory, which posits that observable covariates, such as width and elevation, can inform estimates of unseen hydraulic behavior.

We applied this approach a at global scale by constructing hypsometry curves using SWOT node products at 200 m spacing across a broad set of river systems. To validate the method and assess its robustness, we focused on eight rivers in the USA, Colombia, France, and Italy, which span a range of climatic, geomorphic, hydraulic, and anthropogenic conditions, including systems with significant channel modification and hydraulic infrastructure. The shape, slope, and regression behavior of the hypsometric curves were analyzed to estimate the effective riverbank slope. This global analysis demonstrates that satellite-derived hypsometry can serve as a practical proxy for riverbank slope, enabling scalable assessments of channel geometry in support of hydrologic, hydraulic, and geomorphic applications using SWOT data alone.

Corresponding author:
J. Daniel Velez (**University of North Carolina at Chapel Hill**, **United States**), davelez@unc.edu

Sea Ice Classification from SWOT Observations: A Preliminary Analysis

Khalil Bakhtiari Asl (Centre Eau Terre Environnment, Institut National de la Recherche Scientifique, Canada); Mohammed Dabboor (Science and Technology Branch, Environment and Climate Change Canada, Canada); Saeid Homayouni (Centre Eau Terre Environnment, Institut National de la Recherche Scientifique, Canada)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Poster
Poster number: ST2025CS1_001

Abstract:
Sea ice mapping in the Canadian Arctic is essential for monitoring climate change impacts and supporting safe navigation. Synthetic Aperture Radar (SAR) missions such as RADARSAT Constellation Mission (RCM) and Sentinel-1 have proven effective for ice typing since they provide high spatial resolution and weather independence. Conversely, the Surface Water and Ocean Topography (SWOT) satellite offers complimentary altimetric measurements with the potential to provide two-dimensional surface elevation maps.
This study proposes a machine learning approach for sea ice classification using Ka-band SAR imagery from the SWOT mission. We investigate the influence of SWOT's radar incidence angle on classification performance. Several locations in the Canadian Arctic are selected as case studies. In addition, classification results are compared with sea ice types derived from co-located imagery from the RCM and Sentinel-1 satellites. Through this study, we aim to support the ice flags in SWOT products by incorporating information on different sea ice types.

Corresponding author:
Khalil Bakhtiari Asl (**Centre Eau Terre Environnment, Institut National de la Recherche Scientifique**, **Canada**), khalil.bakhtiari-asl@inrs.ca

SWOT observations over sea ice: what can we learn for nadir altimetry

Marta Alves (CLS, France); Fanny Piras (CLS, France); Gwenaël Jestin (LEGOS, France); Sara Fleury (LEGOS, France); Matthias Raynal (CNES, France); Filomena Catapano (ESA/ESRIN, Italy)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Poster
Poster number: ST2025CS1_002

Abstract:
Spatial altimetry, although initially dedicated to ocean observation, is particularly well-suited to monitor the polar regions. Since the ERS missions, the polar ice caps have been observable from space but with rather limited exploitation until 2010 due to the operational mode used. Indeed, the low-resolution (LRM) mode is appropriate for ocean studies but much less for the analysis of ice-covered surfaces. Synthetic aperture radar (SAR) altimetry, which significantly reduces the along-track resolution, has been a true revolution, first with CryoSat-2 and later with Sentinel-3 providing the first consistent estimation of freeboard and sea ice thickness. The IceSat-2 mission launched in 2018 is also innovative thanks to its lidar altimeter that not only provides excellent ground resolution, but also does not penetrate the snow layer, making it complementary to Ku-band instruments such as those on board CryoSat-2 and Sentinel-3.

Despite the variety of available missions, processing sea ice observations remains extremely challenging. The diversity of surface types (open water, sea ice, leads, melt ponds…) and the different surface properties (presence of snow, ice type, etc.) significantly affect the radar signal and are only partially accounted for in current retracking models. This has a substantial impact on the estimated geophysical parameters and several studies are currently on-going to better account for these effects (e.g. [1] and references therein). Moreover, given the particularly hostile nature of the polar regions, there are relatively few in-situ datasets available to validate altimetric data. Notable examples include the annual BGEP mooring campaigns, which provide regular estimates of ice draft (the submerged part of the sea ice), but always in the same limited area.

The Ka-band radar interferometer (KaRIn) onboard the SWOT satellite is a significant innovation as it provides 2D topography and roughness information covering 50 km-wide swaths on each side of the nadir measurement provided by Poseidon-3C. The first KaRIn images over sea ice showed promising results exceeding expectations, given that this surface was not the primary objective of the mission. The combination of the 2D topography and roughness information, which is independent of any physical or empirical retracker, opens new windows in the study of sea ice. Not only will it allow us to determine the nature of the sampled surface and to estimate sea ice parameters (e.g. [2], [3]) but also to potentially validate and better understand signals from nadir altimetry. The advances made based on SWOT data will in addition be highly valuable for the preparation of future similar missions such as Sentinel-3 Next Generation Topography.

In this talk we present different analyses based on the first global sea ice surface classification performed on KaRIn data at 500 m resolution [4]. We perform a quantitative comparison of the surface classification over crossover points with Sentinel-3 and IceSat-2, finding a general good agreement. We investigate how KaRIn can help us reconcile the different classification methods provided by different agencies/research teams for altimetric data, namely for Sentinel-3. We also look, for the first time, at the sea ice surface height distribution given by KaRIn. Indeed, lognormal and exponentially modified Gaussian distributions have been recently found to better fit laser swath observations of sea ice elevation ([1], [5]), as opposed to the classical Gaussian law used in physical retracking models. Here we investigate the input of larger scale swath measurements, at Ka band, for the current modelling of the sea ice roughness, an important parameter in the analysis of nadir altimeter data.

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Corresponding author:
Marta Alves (**CLS**, **France**), malves@groupcls.com

iSWOT: Project Updates and Initial Results on Cryosphere Monitoring

Mohammed Dabboor (Environment and Climate Change Canada, Canada); Adrienne Tivy (Science and Technology Branch, Environment and Climate Change Canada, Canada); John Mackay (Defence Research and Development Canada, Canada); Jose Lagunas-Morales (Defence Research and Development Canada, Canada); Mathieu Plante (Science and Technology Branch, Environment and Climate Change Canada, Canada); Pascal Matte (Science and Technology Branch, Environment and Climate Change Canada, Canada); Daniel Peters (Watershed Hydrology and Ecology Research Division, Environment and Climate Change Canada, Canada); Saeid Homayouni (Institut national de la recherche scientifique, Canada); Christine Gommenginger (National Oceanography Centre, UK); adrien Martin (Noveltis, France)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Poster
Poster number: ST2025CS1_003

Abstract:
Monitoring sea ice is critical for advancing our understanding of climate change, maintaining polar ecosystems, and ensuring safe navigation in the Arctic and Antarctic regions. The SWOT (Surface Water and Ocean Topography) satellite mission aims to provide high-precision measurements of the Earth's water bodies, including oceans, lakes, and rivers. SWOT uses radar interferometry to accurately measure water surface elevation, which helps in understanding and monitoring changes in water levels, currents, and other hydrological dynamics on a global scale. Early findings from the SWOT mission indicate the prospect of new discoveries, extending beyond its main goals in oceanography and hydrology to encompass emerging applications such as cryosphere. This is particularly significant due to SWOT's wide-swath radar altimeter, which offers unparalleled high-resolution two-dimensional maps of surface elevation. The iSWOT project (ice-SWOT: Unlocking Impacts and Opportunities) is one of the initiatives selected under the new International SWOT Science Team. Its primary objective is to explore innovative cryosphere applications by leveraging the high-resolution data products of the SWOT mission to enhance ice monitoring and characterization in the Canadian Arctic. The project also incorporates Synthetic Aperture Radar (SAR) data from the Canadian RADARSAT Constellation Mission (RCM) to support multi-sensor analysis and validation efforts.
This presentation provides first results and key insights from the analysis of SWOT data over sea ice in several experimental sites in Canada. We present results from field measurements in Nain over landfast sea ice. Field measurements include the ice temperature profile and thickness. We also include comparison analysis of sea ice types with RCM imagery over the Canadian Arctic and Beaufort Sea. We also provide preliminary results demonstrating the potential of SWOT for monitoring lake ice and detecting open water in Lake Athabasca, supported by comparisons with RADARSAT Constellation Mission (RCM) and Sentinel-2 imagery. The expedition will take place in the Labrador Sea during the winter, and in the Parry Channel as well as the surrounding channels, sounds, and straits near Prince of Wales Island—including Barrow Strait—during the summer.
Corresponding author:
Mohammed Dabboor (**Environment and Climate Change Canada**, **Canada**), Mohammed.Dabboor@ec.gc.ca

Multi-frequency radar scattering analysis using SWOT

Imogen Garlick (UCL Department of Earth Sciences, Afghanistan); Rosemary Willatt (UCL Department of Earth Sciences, London, UK, United Kingdom)

Session: Cryosphere: Sea Ice, SLA and glaciers
Presentation type: Poster
Poster number: ST2025CS1_004

Abstract:
Our study focuses on the radar scattering behaviour across Ka-, Ku-, and C-band frequencies over sea ice, particularly in the Weddell Sea area. Using data collected from SWOT's KaRIn and nadir altimeters, we explore frequency-dependencies, looking at variables such as radar backscatter, sea surface height (SSH), and range.

The goal is to examine how these variables differ across radar frequencies, and therefore how this effects the estimation of the sea ice freeboard. For example, we compare radar penetration and scattering at Ku- and C-band and find that they range to the same point over leads, but differ over snow and sea ice. By analysing these datasets, including frequencies and retracker choices, we can identify characteristics of radar frequencies for measuring snow and ice depths and surface characteristics over sea ice.

Our findings contribute to a better understanding and interpretation of SWOT observations in the cryosphere and support the improvement of satellite-derived sea ice freeboard measurements. This enhances our understanding of how the cryosphere is responding to climate change and the rate at which it's doing so. By exploiting the single platform of SWOT with KaRIn and nadar altimeters, we can also provide insights into interpretation of data from other existing (e.g. CryoSat and AltiKa) and future (e.g. CRISTAL) satellite missions.

Our work contributes to the CASSIA (Cryosphere Applications for SWOT SAR Interferometry and Altimetry) project, given that it assesses the ability of SWOT's instruments in providing reliable and accurate measurements for cryosphere monitoring.

Corresponding author:
Imogen Garlick (**UCL Department of Earth Sciences**, **Afghanistan**), imogen.garlick.24@ucl.ac.uk

Estimating Discharge–Depth Relationships and Improving Rating Curves in Texas Rivers Using SWOT Data and Machine Learning

Sujana Timilsina (University of Texas at Austin, United States); Paola Passalacqua (University of Texas at Austin, United States)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_001

Abstract:
Accurate streamflow prediction and flood inundation mapping are critical components of early warning systems that help prevent loss of life and property during storm events. Traditional empirical approaches, such as the Height Above Nearest Drainage (HAND), based on Synthetic Rating Curves (HAND-SRC), are widely used to estimate flood depths from streamflow due to their simplicity and ease of implementation. However, these methods often rely on generalized assumptions about channel geometry and hydrodynamics, which can result in significant inaccuracies, particularly in topographically and hydrologically complex regions. This study explores the potential of Surface Water and Ocean Topography (SWOT) derived hydrologic variables such as water surface elevation (WSE), channel slope, and river width measurements to improve the accuracy of rating curves in Texas rivers. Our initial comparisons of water depths at USGS-gauged sites show that SWOT-derived water depths exhibit stronger agreement with observed data compared to those estimated from the HAND method, highlighting the capability of satellite-based measurements to overcome the limitations of empirical models. Building on this insight, we develop a machine learning model that integrates SWOT observations with digital elevation models (DEMs), remotely sensed hydrologic variables, river geometry from the National Hydrography Dataset (NHD), and in-situ discharge and stage data from USGS gauges, to estimate discharge–depth relationships, and thus rating curves in the ungauged rivers across Texas. By learning the complex interactions among hydrologic and geomorphic variables, the machine learning model shows potential to estimate more accurate and scalable rating curves and improve flood modeling capabilities in the ungauged rivers of Texas.

Corresponding author:
Sujana Timilsina (**University of Texas at Austin**, **United States**), sujanatimilsina@utexas.edu

Typological drivers of SWOT discharge accuracy

Steve Coss (School of Earth Sciences, Ohio State University, Columbus, OH, USA Byrd Polar and Climate Research Center, Columbus, OH, USA, United States); Michael Durand (School of Earth Sciences, Ohio State University, Columbus, OH, USA Byrd Polar and Climate Research Center, Columbus, OH, USA, United States)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_002

Abstract:
We have made substantial progress towards characterizing SWOT discharge accuracy. In a recent working group paper, we characterized three increasingly restrictive data quality filtering groups and describe how these groupings could be used to infer discharge accuracy in the predominantly un-gauged reaches of the world. We show a preference here for accuracy statistics that separate bias and correlation, as the former is driven by systematic uncertainty, particularly in the prior, while the latter should perform well when FLPEs are working, regardless of bias. What we find is that bias is somewhat higher than originally expected, but that the Consensus algorithm has increasing skill in correlation across these groupings. Most notably, we find that 11,274 ungauged reaches globally can be expected to perform in accordance with the “mid-filter” group, based on the restrictions used to select that group. While we believe that SWOT data quality will always be a driving factor in discharge accuracy, we have moved our main area of focus on to characteristics inherent to river reaches that are associated with high and low discharge accuracy. In our investigation of typological drivers of SWOT discharge accuracy, we are exploring the characteristics as described by SWORD, near-river landcover, topography, and the presence of manmade features, such as dams. We have already seen that some of these features play a large roll in discharge accuracy. We find that urban landcover and high elevation variation (nearby extreme topography) both have a dramatic impact on discharge correlation but not bias we see in the result. An interesting finding from this work is that the impact is most notable with the mid-filter group. Using Jenks breaks to group classes of urban landcover the median Pearson correlation is 0.76 where there is less than 1% urban landcover, and that median monotonically decreases to 0.56 in (20%) in the urban cover >34% group. Similarly median Pearson correlation monotonically decreases in the mid-tier data from 0.74 (elevation std<9.88m) to 0.49 (25% reduction at elevation std>36.01m). These patterns are not apparent with the least-filtered group and are less dramatic with the highly-filtered group. It’s likely that this demonstrates the intersection of filter quality and the inherent qualities of the reach. It’s likely that the impact of urban land cover is obscured by low data quality in least-filtered data, but as filtering is made more restrictive the impact is more substantial. Interestingly, with the highly-filtered requirement, the urban impact is less dramatic, which may indicate that enforcing hydraulic consistency (one of the requirements) counters much of the error driven by urban land cover, while the elevation std medians still span 30% in the CH data. Overall, we find that given the correct SWOT data criteria and some inherent reach properties, we can infer what accuracy we can expect from most of the worlds ungauged river reaches.

Corresponding author:
Steve Coss (**School of Earth Sciences, Ohio State University, Columbus, OH, USA Byrd Polar and Climate Research Center, Columbus, OH, USA**, **United States**), coss.31@osu.edu

Estimating river discharge using a SWOT-based statistical approach

Izzy Probyn (University of Bristol, United Kingdom); Jeff Neal (University of Bristol, United Kingdom); Stephen Chuter (Fathom, United Kingdom); Paul Bates (University of Bristol, United Kingdom)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_003

Abstract:
Estimating river discharge using a SWOT-based statistical approach

Authors: Izzy Probyn, Jeff Neal, Stephen Chuter, Paul Bates

Accurate estimates of river discharge are critical for a variety of applications including global hydrological and hydraulic models, flood forecasting, and water resources management. A key limitation for many of these models is the limited availability of observations, such as data records from gauging stations. The availability and reliability of discharge estimates, particularly in data-scarce regions, could be substantially improved by increased hydrological observations. The SWOT mission provides an opportunity to advance these models due to the unpreceded global data on water surface elevation (WSE), and the resolution and accuracy of the measurements taken. Releasing WSE measurements from all rivers exceeding 100m (and in many cases 50m) in width, with a repeat cycle of 21 days, it allows the incorporation of data into models as forcing or prior information in many locations where there has never been access to these measurements before, as well as providing regular, and consistent, data to add to what is already available.
The Discharge Algorithm Working Group has been using SWOT RiverSP data to calculate discharge for these rivers using a variety of different physical methods (Durand et al., 2023). All these algorithms involve solving hydrodynamical equations with SWOT observations as the driving data. However, the problem is ill-posed and unconstrained, and there is no exact solution to the equations that will fully satisfy the input observations. The algorithms are always going to need additional prior data to converge on a realistic discharge timeseries. Subsequently, the different algorithms have had varying degrees of success, with each sensitive to the input data in different ways. This is due to several reasons; the present unreliability of the width variable produced by SWOT, uncertainty in the WSE variable, but also in the conditions that must be met by the input data for these algorithms to be run.
Here we present a complimentary methodological approach to the problem using a statistical as opposed to empirical methodology. This statistical method produces a level-duration curve for each SWORD reach by linking quantiles of SWOT WSEs to global discharge distributions constructed from GRADES-HydroDL (Yang et al., 2023), essentially creating a level-discharge rating curve for each SWORD reach. By generating pairs of level-duration and flow-duration curves, one for each reach, a simple look-up from a SWOT reach observation to produce discharge should provide as much insight as a physical model, reducing compute time and resources without compromising on accuracy.
With promising results, we believe this method could be a useful addition to the Confluence workflow, with differing strengths from the current set of algorithms. Ultimately, this could be scaled to form an extensive and reliable series of virtual network of gauges to better inform models across hydrology, hydraulics, forecasting and many other areas.

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Corresponding author:
Izzy Probyn (**University of Bristol**, **United Kingdom**), izzy.probyn@bristol.ac.uk

Building an Integrated Satellite-Hydrography Framework for SWOT-Based Discharge Estimation

Heejin An (University of Massachusetts Amherst, United States); Colin J. Gleason (University of Massachusetts Amherst, United States)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_004

Abstract:
As access to SWOT data increases, hydrologists face the challenge of transforming SWOT observations into accurate and practical discharge estimates. Unlike traditional hydrologic models that may overlook anthropogenic influences, SWOT enables the estimation of more realistic discharge trends by relying on direct observations. However, current discharge algorithms depend heavily on priors derived from ancillary data and strict filtering criteria, which introduces spatial limitations.

To overcome these limitations, we aim to build a framework that integrates multiple hydrography datasets and relevant satellite observations from multiple missions. Our first step is to construct a unified hydrography by combining key features from SWORD, HydroSHEDS, and MERIT Hydro. This integrated river network will serve as the spatial foundation for linking SWOT RiverSP data and various Earth observation products. We will collect river width, slope, and water surface elevation from SWOT, and supplement these with satellite-derived environmental variables. These include MODIS (surface temperature and NDVI), Landsat and Sentinel-2 (high-resolution land cover and albedo), and SMAP (soil moisture). All datasets will be spatially and temporally aligned with the unified hydrography to provide reach-scale inputs for discharge estimation. Our ultimate goal is to develop a distributed Long Short-Term Memory (LSTM) model that incorporates both static features (e.g., river slope, upstream catchment area, stream order) and dynamic time-series data from satellites. The hydrography-satellite dataset constructed through this project will also support “X vs Y” experiments, enabling the comparison of different model structures and feature sets to identify optimal strategies for satellite-based discharge estimation.
We plan to complete data integration and initial model development by the end of this summer. In future work, we will explore whether some variables should be used directly as inputs or handled through model design choices. Additionally, we plan to consider human impacts such as dam operations to further improve model performance.

Corresponding author:
Heejin An (**University of Massachusetts Amherst**, **United States**), heejinan@umass.edu

Variability in Arctic river discharge, suspended sediment transport, and turbidity

Anastasia Piliouras (Penn State University, United States); Xiwei Guo (Penn State University, United States); Nynaeve Phillipson (Penn State University, United States); Ben Crosby (Idaho State University, United States)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_005

Abstract:
Rising temperatures are drastically impacting Arctic river dynamics; yet for many of these rivers, we lack a good baseline to understand their current hydrology. Information about sediment fluxes is even more stark and almost entirely missing from most Arctic rivers. Understanding the timing and controls on river discharge, suspended sediment transport and changes in river turbidity is important both for impacts to marine ecosystems and locally to the people who depend on the river for food and water resources. This project aims to fill these knowledge gaps by quantifying variability in river discharge, suspended sediment transport, and turbidity on the ungauged Noatak River in Alaska. This project integrates field measurements with multiple satellite-based observations to achieve three goals: (1) provide measurements of river discharge timed with SWOT satellite overpasses to reduce uncertainty in SWOT discharge estimates on an ungauged river; (2) quantify monthly, seasonal, and annual variability in river discharge, suspended sediment flux, and turbidity and their interrelationships; and (3) estimate seasonal and annual suspended sediment fluxes and associated changes in turbidity for the Noatak River.

In the first two years of this project, we have been collecting field measurements of river discharge, suspended sediment concentrations (SSC), and turbidity over the open water season. River discharge has been collected coincident with multiple SWOT overpasses and shared on HydroShare for incorporation into Confluence to support discharge estimates from SWOT data. In addition to our field measurements, we have prioritized investigating seasonality of river turbidity from remotely sensed data, utilizing daily imagery from Planet to quantify turbidity for all available cloud-free days over the Planet record. We examined various metrics of remotely sensed turbidity so that we can determine which metric best characterizes actual turbidity and suspended sediment concentration in the Noatak. Preliminary results show that turbidity is consistently highest in May, coinciding with the spring melt season. Turbidity in summer and fall is temporally and spatially variable, with lowest values typically occurring in September-October, but short-term increases occurring sporadically, likely following rain events. Our first field season coincided with a summer rainstorm, allowing us to directly observe changes in discharge, turbidity, and suspended sediment transport over short timescales. These types of observations, combined with river discharge estimates from SWOT, will enable us to explore the variability of Arctic river fluxes over event-based, seasonal, and annual timescales. Understanding the variability in discharge, turbidity, and SSC, and in their interrelationships, will provide critical insights as to processes affecting Arctic river discharge, sediment supply, and sediment transport in these rapidly changing systems.

Corresponding author:
Anastasia Piliouras (**Penn State University**, **United States**), apiliouras@psu.edu

Estimating Daily Discharge Using SWOT Data

Siqi Ke (Institute of Geodesy, University of Stuttgart, Germany); Mohammad J. Tourian (Institute of Geodesy, University of Stuttgart, Germany); Pierre-Olivier Malaterre (INRAE, UMR G-eau, Montpellier, France); Colin Gleason (Department of Civil and Environmental Engineering, University of Massachusetts Amherst, Amherst, USA); Michael Durand (School of Earth Sciences, Ohio State University, Columbus, USA)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_006

Abstract:
The SWOT satellite mission is the first to conduct a global survey of the Earth's surface waters, measuring water surface height, river width, and water surface slope, based on which river discharge is estimated. At mid-latitudes, the repeat orbit design of SWOT only allows a sampling of twice per repeat cycle, which is considered too low for most hydrological applications. To address the spatiotemporal limitations of SWOT, we develop a method, based on a Kalman Filter, that assimilates SWOT observations across continuous reaches within a single-branch river network to obtain daily discharge estimates. The Kalman filter solves a linear dynamic system, which includes a process model based on a physically based spatiotemporal discharge correlation model and observation equations that utilize SWOT products. Our test analysis over the Rhine River shows that the estimated discharge reaches a median correlation of 0.70, a median NSE of 0.46, and a median rRMSE of 18% when using the MOMMA discharge product, whereas with the SIC4DVar product, the correlation remains the same, but the NSE drops to 0.32 and the rRMSE increases to 22%. For the Science Team meeting presentation, we plan to apply the method to multiple rivers in the SWOT development set (Devset) using real SWOT measurements. Devset is a set of reaches defined within the SWOT Discharge Algorithm Working Group for calibration and validation. To further enhance our method and improve the accuracy of the discharge estimates, we also consider incorporating other satellite-based discharge products.

Corresponding author:
Siqi Ke (**Institute of Geodesy, University of Stuttgart**, **Germany**), kesiqi96@163.com

Assessing SWOT River Discharge Performance Between Fast Sampling and Science Orbits

Elisa Friedmann (UMass Amherst, United States); Colin Gleason (UMass Amherst, United States); Cécile Cazals (CNES, France); Michael Durand (The Ohio State University, United States); Stephen Coss (The Ohio State University, United States); Jonathan Flores (UMass Amherst, United States); Merritt Harlan (USGS, United States)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_007

Abstract:
The Surface Water Ocean Topography (SWOT) satellite mission returns terrestrial surface water height, width, and slope, parameters that in turn are used to invert river discharge at a global scale in the Confluence framework. SWOT estimates discharge under two orbits with spatial and temporal tradeoffs: the initial, semi-global, 90-day 'Fast Sampling Orbit' ('FSO') from April to August 2023 and the primary, global, 21-day cycled 'Science Orbit' ('SO') from mid-August until end of lifetime. The reaches included in both orbits provide an opportunity to assess SWOT global discharge performance between orbits and its capabilities for discharge regime capture in both gauged and ungauged basins at a hydrologically relevant timescale. To characterize temporal sampling effects on river discharge characterization, we ran the Confluence framework 'offline' on all 22,777 FSO reaches. We tested discharge performance reaches from FSO only, SO only, both continuous orbits ('continuous'), and FSO sampled like SO ('sampled') in time for these reaches to isolate the effect of the orbit, focusing especially on hydrologic regime capture as well as variability during the April-July FSO time period. While all configurations generally show low bias and evenly distributed global discharge differences, the FSO alone slightly underestimates discharge at any magnitude compared to 'continuous' data especially in Arctic regions whereas SO only data overestimates low discharge and underestimates high discharge especially in Arctic regions compared to 'continuous' data.

Corresponding author:
Elisa Friedmann (**UMass Amherst**, **United States**), efriedmann@umass.edu

Estimation of Ungauged River Discharges from SWOT-like Measurements with Uncertainty Quantification

Jerome Monnier (INSA - Mathematics Institute of Toulouse, France); Kevin Larnier (Hydro-Matters / INSA-Mathematics Institute of Toulouse, France); Olivier Roustant (INSA - Mathematics Institute of Toulouse, France)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_008

Abstract:
Estimating discharges Q(x,t) of ungauged rivers, particularly those with unknown bathymetry profiles, from altimetric measurements and fluid flow models only, has been demonstrated to be an ill-posed inverse problem [1]. This central property of the problem explains the biased estimations obtained with the few existing algorithms [2, 3, 4], which can be of very different nature. The obtained bias depends on the priors (intrinsic or not) of the employed algorithm, typically a first guess value. Inversions based on Variational Data Assimilation (VDA) approaches, such as the HiVDI algorithm [5,1] or others, enable accurate estimations of spatio-temporal variations of the discharge, but still with a potential bias scaling the overall estimate. The latter is drastically diminished if starting the iterative VDA process from a good first guess. The latter may be estimated by deep learning considering the drainage area of the river portion (information available in global datasets), such as in [5].
We here adopt another strategy based on a preliminary Bayesian estimation, providing the first guess of the VDA process. Key ingredients of the Bayesian analysis are the detection of uncorrelated variables and a physics-informed likelihood. The resulting latest version of the HiVDI algorithm [6] enables estimations with still less than 30% of errors for a huge majority of reaches, accompanied with Uncertainty Quantification, e.g., quantile envelopes. However, the error is still dominated by bias : the intrinsic ill-posed problem characteristics remains. Possible closure informations, including original ones, have been identified. Finally, as with its previous version, this latest HiVDI algorithm version enables estimations from newly acquired WS measurements in real-time. Numerical experiments are analysed both for synthetic and real SWOT measurements, for ≈ 50 heterogeneous worldwide river portions, corresponding to ≈ 400 reaches.

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Corresponding author:
Jerome Monnier (**INSA - Mathematics Institute of Toulouse**, **France**), jerome.monnier@insa-toulouse.fr

Global River Discharge from SWOT at Gauging Stations: A Complementary Perspective

Peyman Saemian (Institute of Geodesy, University of Stuttgart, Germany); Siqi Ke (Institute of Geodesy, University of Stuttgart, Germany); Omid Elmi (Institute of Geodesy, University of Stuttgart, Germany); Benjamin M. Kitambo (Institute of Geodesy, University of Stuttgart, Germany); Fabrice Papa (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France); Mohammad J. Tourian (Institute of Geodesy, University of Stuttgart, Germany)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_009

Abstract:
River discharge is a fundamental component of the global water cycle and an Essential Climate Variable (ECV), yet its observation remains spatially and temporally sparse. The Surface Water and Ocean Topography (SWOT) mission provides unprecedented high-resolution (~100 m) observations of water surface elevation over global rivers and lakes, offering a unique opportunity to enhance our understanding of surface water dynamics. Building on these new observations, we present an ongoing effort to estimate river discharge during the SWOT mission period by using an unprecedented available of historical and contemporary in situ discharge measurements (over 52,000 gauges) and SWOT-derived water level observations. SWOT's broad spatial coverage allows us to use more gauges than previous satellite-based studies (e.g., SAEM, RSEG, etc), enhancing the geographic and hydrological reach of discharge estimation. Using the non-parametric quantile mapping (NPQM) approach introduced by Elmi et al. (2021), we derive discharge time series from SWOT water levels across a wide range of hydrological and climatic regimes. We also develop a near-real-time (NRT) framework, in which SWOT water surface elevation is converted into discharge using the derived non-parametric rating curve.

Preliminary results show encouraging consistency in several regions, suggesting the potential value of these estimates for supporting SWOT-related studies. We compare our estimates with outputs from SWOT discharge algorithms, including neoBAM, HiVDI, MetroMan, MOMMA, SAD, SIC4DVar, and the consensus product. Our discharge estimates can serve as a complementary source for validating discharge algorithms, provide prior information to infer the flow law parameters, and also support hydrological modeling and data assimilation. We aim to stimulate discussion and foster collaboration within the SWOT community to improve global discharge characterization and make the most of SWOT's observational capabilities.

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Corresponding author:
Peyman Saemian (**Institute of Geodesy, University of Stuttgart**, **Germany**), peyman.saemian@gis.uni-stuttgart.de

Incorporating SWOT into a deep learning framework of global river discharge.

Theodore Langhorst (University of Massachusetts Amherst, United States); Colin Gleason (University of Massachusetts Amherst, United States); Konstantinos Andreadis (University of Massachusetts Amherst, United States)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_010

Abstract:
SWOT provides the opportunity to improve hydrologic models of river discharge by incorporating real-time data on surface water fluxes and storages. Traditionally, we would need to either first invert discharge from SWOT observations (i.e, from the DAWG) and then assimilate these estimates into a model or have a model capable of representing water surface heights and widths as the global state variable. The latter approach is rare and difficult globally, so the former is expected. However, the DAWG's discharge inversions necessarily add error to SWOT's high quality information. If our goal is discharge estimation from a model, it is best to use SWOT's primary measurements together with meteorological data. Now, more than two years into the mission, we have enough data to try a nontraditional approach: train deep learning models that can use the primary SWOT observations directly. We combine a Long Short-Term Memory model (LSTM; which has been shown to be very effective in global, large-scale hydrologic modeling) with a cross-attention transformer (which is commonly used in multi-modal and language translation models) to take full advantage of SWOT data. Preliminary results on 130 basins unseen during training shows improvement in median Kling Gupta Efficiency from 0.05 to 0.34 as a result of including SWOT data in the model. We hypothesize that these improvements will not be uniform across locations, but correlate with the amount of human modification to river systems (i.e. where climate forcings alone are not sufficient to predict discharge). In addition to improving prediction accuracy of models, we will investigate the model's learned use of measurement quality flags to evaluate how much information is lost by these different sources of error.

Corresponding author:
Theodore Langhorst (**University of Massachusetts Amherst**, **United States**), tmlanghorst@umass.edu

Discharge Algorithm Working Group Update

Michael Durand (Ohio State University, United States); Colin Gleason (University of Massachusetts , United States); Kevin Larnier (Hydro Matters, France); Pierre Olivier Malaterre (INRAE, France)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_011

Abstract:
Discharge estimates derived from SWOT data are potentially transformative for human understanding of global hydrology, provided these estimates attain a reasonable level of accuracy. At the 2025 Science Team meeting, the Discharge Algorithm Working Group reports on progress towards global estimates of river discharge, in four areas of interest to the Science Team in general.

First, we report a first estimate of the accuracy of SWOT discharge, based on mid-2024 SWOT discharge estimates, and recently published in Geophysical Research Letters. We show that SWOT discharge tracks discharge variations, but is subject to bias, which is consistent with pre-launch studies. Bias is larger than expected based on pre-launch studies, and we explore reasons for this difference.

Second, the Confluence software has reached a new level of maturity, with major advances on multiple fronts. Confluence is now running operationally at PO.DAAC, overseen by software engineers, with both input and independence from the Science Team; Confluence will be run globally on a regular schedule going forward. Confluence has been modified to include several new modules, including the ability to process lakes alongside rivers. Confluence now can be run in “offline mode”, with many groups globally performing their own Confluence runs to estimate SWOT discharge.

Third, multiple groups have assessed the impact of various aspects of SWOT data quality on SWOT discharge accuracy. These groups have explored the impact of such factors as dark water, layover, prior bias, temporal revisit and data completeness and related to SWOT ability to tease out discharge variations. This analysis improves SWOT discharge maturity and points the way towards flags to alert users to expected SWOT discharge precision on a reach/pass basis.

Fourth, we describe work that explores the upper limit or ceiling of SWOT accuracy. We calibrate SWOT data directly to in situ gages, and show that SWOT discharge estimates follow prelaunch expectations and expected SWOT error in height width and slope, with discharge error ranging between 15-20% across hundreds of gages. We compare SWOT version C and D. Defining this ceiling provides a target for ongoing efforts to aim at.

In addition to these four advances, we provide a short update on the timeline of expected discharge estimate availability for those estimates computed by the space agencies (Level 2), and those produced by the Science Team (Level 4).

Corresponding author:
Michael Durand (**Ohio State University**, **United States**), durand.8@osu.edu

HYdraulic retrievals from Data assimilation: River Observation with Swot (HYDROS Project)

Hind Oubanas (INRAE, France); Sophie Ricci (Cerfacs, France); Pierre-Olivier Malaterre (INRAE, France); Cassan Ludovic (Cerfacs, France); Igor Gejadze (INRAE, France); Piacentini Andrea (Cerfacs, France)

Session: Hydrology: Discharge Algorithms Working Group (DAWG)
Presentation type: Poster
Poster number: ST2025HS4_012

Abstract:
Following nearly a decade of rigorous preparations for the SWOT mission and its successful launch in December 2022, substantial methodological and algorithmic advancements have been made to enable the estimation of the SWOT discharge product and essential hydraulic properties of the river. The HYDROS project aims at leveraging the SWOT satellite's capabilities to provide comprehensive insights into hydraulic and hydrological systems, of different scales including global. The project is tailored to specific objectives, ensuring a holistic approach to river system analyses.
The project emphasizes the estimation and validation of hydraulic variables derived from the SWOT solely, concurrently assessing the statistical errors. Following this foundational stage, we focus on refining SWOT products through integration of multiple data sources in order to enhance accuracy of hydraulic retrievals. This step requires methodological advancements combining hydraulic modeling, data assimilation approaches as well as reanalysis. A significant milestone involves the integration of hydrological and hydraulic systems. This coupling is essential to transfer information across different time and space scales, ensuring a complete understanding of the river network. Culminating these rigorous developmental phases, the project transitions to an operational stage through applications on key basins targeting societal challenges and emphasizing the potential of SWOT mission. The main scientific objectives can be summarized into six intersecting objectives:

- SWOT Discharge estimation and validation within the DAWG during the CalVal and nominal orbits in addition to discharge uncertainty assessment.
- River FloodPlain Digital Elevation Model as well as its 2-dimensional dynamics using SWOT and muli-satellite data.
- SWOT in a multi-mission framework through multi-satellite data assimilation for hydraulic retrievals as well as investigation of ‘what if’ scenarios for future missions design.
- SWOT in a multi-satellite and reanalysis framework in order to recreate historical records.
- Hydraulic and hydrological coupling at the catchment scale for improved discharge simulations in smaller tributaries as well as extending the forecast lead time.
- SWOT applications and societal challenges in key basins with socio-economic implications

Corresponding author:
Hind Oubanas (**INRAE**, **France**), hind.oubanas@inrae.fr

Wave Spectra from SWOT: Overview of the New Level 3 Wind Wave Product

Beatriz Molero (CLS, France); Molero Beatriz (CLS, France); Ardhuin Fabrice (LOPS,Univ.Brest,CNRS,IRD,Ifremer,IUEM, France); Nigou Adrien (CLS, France); Dibarboure Gérald (CNES, France); Postec Taina (LOPS,Univ.Brest,CNRS,IRD,Ifremer,IUEM, France); Chevrier Robin (CLS, France); Bohé Alejandro (CNES, France); Germineaud Cyril (CNES, France); Mertz Françoise (CLS, France); Mahler Léa (CLS, France); Anne-Sophie Tonneau (CELAD, France); Romain Husson (CLS, France); Marine De Carlo (CLS, France); Ollivier Annabelle (CLS, France); Daniel Sandrine (CLS, France)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_001

Abstract:
The new SWOT KaRIn Level-3 Wind Wave product (L3_LR_WIND_WAVE) is an innovative dataset that provides wave spectra and related wave parameters derived from 250-meter KaRIn sea surface heights (based on the Unsmoothed L3_LR_SSH product: https://doi.org/10.24400/527896/a01-2024.003). This product is built upon the methodology developed by Ardhuin et al. (2024).
In this presentation, we introduce the SWOT KaRIn Level-3 Wind Wave product to the scientific community, detailing its main features, including processing algorithms, spatial coverage, data structure, and preliminary validation. The wave spectra provided in the product resolve wavelengths longer than approximately 500 meters, with centimeter-level precision (Ardhuin et al., 2024). These long waves are rare in the open ocean and entirely absent in marginal seas, yet they are closely associated with extreme storm events and play a critical role in coastal dynamics.
The spectral estimates are computed as power spectral densities (PSD) of sea surface height anomalies (SSHA), using a Welch (1967) method. This involves dividing SSHA "boxes" into smaller overlapping tiles, which are averaged to reduce spectral noise. Multiple configurations of box and tile sizes are available, allowing users to select a balance between spectral noise, spectral resolution, and wavelength range appropriate for their application. The product also includes a "swell mask" that identifies coherent wave systems (wave partitions) along with their integrated parameters: significant wave height (H18), dominant wavelength (L18), and direction (phi18). A correction is applied to the spectrum using an approximation of the KaRIn transfer function. This correction assumes linear processing and does not yet include all possible instrument or processing artifacts.
In parallel, alternative wave spectra partitioning methods without any a priori are considered, with a specific focus on the capability to retrieve longest swell signatures. These swell "forerunners" can only be seen by Karin but can help reviewing swell inversion methods and limitations from other sensors (e.g. S1, SWIM) to improve the processing of such low energetic swell.
Finally, we present preliminary examples and a limited validation of this first version of the product. Early comparisons with independent datasets suggest that the derived wave spectra and parameters are generally consistent with observations and models under favorable conditions, especially when KaRIn noise is low. However, this validation is exploratory, and further assessment is needed to better characterize the product's accuracy and guide algorithm improvements. We encourage the scientific community to contribute to this effort by providing feedback and participating in future validation work. Understanding the properties of long-wavelength ocean waves is crucial for improving global wave forecasts, quantifying their impacts on coastal infrastructure, and advancing research in ocean-atmosphere interactions and seismology.

Corresponding author:
Beatriz Molero (**CLS**, **France**), bmolero@groupcls.com

Observing Sea State Gradients from SWOT: Preliminary Results and Ongoing Efforts

Bia Villas Boas (Colorado School of Mines, United States); Alejandro Bohé (CNES, France); Gwendal Marechal (LEGOS, France); Han Wang (University of Hamburg, Germany); Ryan Dù (Colorado School of Mines, United States); Momme Hell (WHOI, United States); Luc Lenain (Scripps Institution of Oceanography, United States)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_002

Abstract:
SWOT’s Ka-band Radar Interferometer (KaRIn) enables high-resolution mapping of sea surface height (SSH) and significant wave height (SWH), revealing new details of ocean surface variability at meso- and submesoscales. We present early results showing that the KaRIn-derived 2D SWH fields capture sharp sea state gradients associated with eddies, jets, and submesoscale turbulence, as well as fine-scale features linked to wave group modulation. Comparisons with airborne lidar observations from the MASS instrument during the SWOT cal/val campaign demonstrate strong agreement with KaRIn's observations. To help interpretation of these gradients, we introduce the U2H map, an analytical tool that relates SWH anomalies from swells to underlying surface currents through a linear convolution operator. This approach reproduces key features observed in both SWOT and model outputs. We show examples of its application to SWOT scenes and discuss ongoing work to separate the effects of wave groups and currents.

Corresponding author:
Bia Villas Boas (**Colorado School of Mines**, **United States**), villasboas@mines.edu

On the assimilation of upgraded L2 SWOT-swath SWH in the wave model MFWAM

Lotfi Aouf (Météo-France, DIROP-CNRM, France); Ferraton Léon (Météo France, DIROP/MAR, france); Wagner-Luiz Langer-Cosat (Météo France, DIROP/MAR, Italy)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_003

Abstract:
The wave data from SWOT-swath have demonstrated significant benefit for sea state forecasting during extreme storm events. Recently, improvements concerning Level 2 (L2) processing of Significant Wave Heights (SWH) from SWOT-swath have been developed in the latest version called “PIC2”. The objective of this work is to assess the impact of the assimilation of SWH retrieved from SWOT Level 2 processing (PIC2) on the forecasting of wave parameters both globally and in regional coastal area such as IBI (Iberian-Biscay-Ireland).
Wave model runs using the MFWAM model in a global configuration have been conducted with and without the assimilation of SWOT wave data over the recent period from December 2024 to March 2025. The validation of these results was performed using independent altimeter SWH data, as well as drifting buoys of the MELODI type from EODYN deployed in the Indian Ocean.
Results indicate a substantial impact of SWOT-swath assimilation, with a significant reduction in bias and scatter index of SWH compared to altimeter data. Notably, the bias reduction is consistent across all ranges of SWH values.
This work also presents a combined data assimilation approach, integrating SWOT SWH with recent wave spectra derived from L3 wave data with wavelengths exceeding 500 meters, developed within the SWOT mission framework. Additional simulations incorporating combined assimilation of CFOSAT wave spectra has been also investigated, and the impact on integrated wave parameters forecasts will be analyzed.
Finally, we will evaluate the validation of these recent assimilation experiment using MELODI and OMB buoys wave data collected during the “One Ocean Expedition” summer school organized by ESA.
Corresponding author:
Lotfi Aouf (**Météo-France, DIROP-CNRM**, **France**), lotfi.aouf@meteo.fr

Spatiotemporal Variability of Ocean Surface Waves in the Argentine Continental Shelf - SWOT Mission Contribution

Leilou LEVARD (LEGOS, France); Martin SARACENO (University of Buenos Aires , Argentina); Yann KRIEN (LEGOS, France); Florence BIROL (LEGOS, France)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_004

Abstract:
Abstract poster:
Waves are a key parameter in ocean dynamics. Studies of wave dynamics are essential for many domains, such as navigation, coastal design, or biodiversity management. However, such knowledge is limited or remains insufficient along the southeastern South American coast, mostly because of a lack of accurate in situ measurements to validate model and satellite data. This study aims to evaluate the performance of models and several satellite altimetry missions to measure significant wave heights (SWH) thanks to in situ datasets collected from 2019 to 2025 at four offshore platforms located between 11 km and 80 km from the coast in southern Patagonia. Special attention is given to the recent SWOT mission, including its CalVal and Science phases. Several statistical metrics were computed, and their comparisons show strong agreement between model/satellite data and in situ observations (up to 0.99 correlation, down to 0.14 RMSE), especially at offshore sites. Seasonal analyses reveal higher SWH in winter than in summer, and spatial variability shows stronger offshore waves. By comparing waves and wind roses, the results reveal a constant wind direction year-round but a changing wave direction seasonally, suggesting dominance of wind waves in summer and swell in winter. A winter swell event was analysed using wave period criteria and backtracking techniques. Future work will focus on understanding swell origin more precisely, exploring tide-wave interaction, particularly at the stations closer to the coast, and current-wave interactions. This research highlights the potential of the SWOT mission for wave monitoring and improves our understanding of wave climate in a poorly observed but dynamically complex region. This work is a contribution to the TOSTO OSTST project.
Corresponding author:
Leilou LEVARD (**LEGOS**, **France**), leilou.levard@univ-tlse3.fr

SWOT as a new global ocean imager for air-sea interaction applications in synergy with present and future ocean SAR missions

Doug Vandemark (Univ. of New Hampshire, United States); Justin Stopa (U. Hawaii, USA); Ralph Foster (Univ. of Washington/APL, USA); Bertrand Chapron (IFREMER, France); Ryan Eastman (Univ. of Washington, USA)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_005

Abstract:
A new joint NASA/CNES imager aboard the Surface Water and Ocean Topography (SWOT) satellite is now providing the widest global ocean coverage of any earth observing radar system yet launched. It's been known since the early SEASAT synthetic aperture radar (SAR) mission that radar imaging of the sea surface can reveal a wide range of air-sea interaction processes with applications that span from search and rescue to ocean wave and weather prediction. This study describes central characteristics of ocean radar backscatter imagery collected using SWOT's primary ocean sampling mode including the scope of oceanic, atmospheric and air-sea interaction phenomena that the radar can resolve. SWOT Ka-band interferometric SAR images differ substantially from previous satellite SAR measurements in four key respects including spatial resolution (500 m), operating frequency (36 GHz), and incidence angle (near-nadir). The final difference is maritime environment spatial coverage, and this is arguably the most important. SWOT imagery is provided continuously along the satellite track over a nearly 120 km swath opening new opportunities to systematically investigate sub-mesoscale air-sea interaction embedded within synoptic weather systems as well as over regions of strong ocean-atmosphere exchange such as western boundary current systems. We illustrate and discuss the benefits and limitations of SWOT using an observational investigation of SWOT versus SAR measurements, this using comparison between coincident SWOT and Sentinel-1 C-band SAR WV mode imagery. It is expected that image interpretation of wind-wave signatures is simplified using these low-incidence angle Ka-band data. We will show that SWOT offers several new capabilities to the earth observing system and provide a first list of potential applications using this new sensor.

Corresponding author:
Doug Vandemark (**Univ. of New Hampshire**, **United States**), doug.vandemark@unh.edu

The 2025 Drake Passage Tsunami imaged by SWOT

Lucie Rolland (Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, IRD, Géoazur, France); Antoine Delepoulle (CLS, France); Faugère Yannice (CNES, France); Mauricio Fuentes (Universidad de Chile, Programa Riesgo Sismico, Chile); Hélène Hébert (CEA, France); Gabriela Herrera Malig (Universidad de Chile, Programa Riesgo Sismico, Chile); Jean Roger (Earth Structure and Processes Department, GNS Science, Lower Hutt, Aotearoa New Zealand, New-Zealand); Patricio Toledo (Universidad de Chile, Programa Riesgo Sismico, Chile); Francisco Uribe (Universidad de Chile, Programa Riesgo Sismico, Chile)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_006

Abstract:
Two years after the first image of a tsunami in the Southwest Pacific Ocean (Faugère et al., 2024), SWOT has caught new tsunami wave features in the South Atlantic Ocean on 2 May 2025, combining the unprecedented resolution and accuracy of the KaRIn instrument (Ka-band Radar Interferometer) and tsunami predictions. The satellite sea-surface height observation and the tsunami simulation show clear and similar wave-like structures and planar wavefronts. The tsunami was initiated about 5 hours earlier within the Drake passage ~100 km off Cape Horn, the southernmost tip of Chilean Patagonia, by a rare Mw 7.4 earthquake. To prevent a potentially severe impact on the coastal populations mainly associated to limited knowledge of tsunamis in the region, Hydrographic Service of Chilean Navy issued an evacuation alert in South of Chile and Antarctica. This alert was cancelled a couple of hours later.

In the Drake Passage, a remote region of the globe, seismic and tsunami in-situ measurements remain severely sparse with a bad azimuthal coverage, despite the existing active tectonic features bordering the Scotia Plate, including the Shackleton fracture zone to the west. In this presentation, we show how, by analyzing the SWOT dataset, the complex source processes that triggered the tsunami can be better constrained, notably comparing the 2D tsunami wave field photographed by SWOT with multiple tsunami numerical models. SWOT could help better understand the tectonic peculiarities of a poorly known tectonic zone and indirectly improve the warning systems.

Corresponding author:
Lucie Rolland (**Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, IRD, Géoazur**, **France**), lrolland@geoazur.unice.fr

Observing variability in ocean wave climates with SWOT

Ho Allison (Jet Propulsion Laboratory, California Institute of Technology, United States); Jinbo Wang (Texas A&M University, United States); Bruce Haines (Jet Propulsion Laboratory, California Institute of Technology, United States); Andy Wu (Jet Propulsion Laboratory, California Institute of Technology, United States); Scott Stalin (NOAA PMEL, United States)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_007

Abstract:
SWOT's unprecedented two-dimensional interferometric measurements offer new opportunities to observe variability in ocean surface wave conditions. We evaluate SWOT's significant wave height (SWH) product via comparison to an array of in situ wave measurements off Central California during SWOT's Cal/Val orbit and find that SWOT SWH measurements resolve wave conditions with high fidelity (CC>0.99, RMSE<0.2 m), performance consistent in additional comparison to a network of coastal wave buoys. SWOT accurately resolves gradients over short spatial scales (20-70 km). These wave height gradients can arise from interactions with mesoscale and submesoscale ocean currents. We identify SWH gradients associated with strong Western Boundary Currents and characterize the intermittency in these gradients related to both the background circulation and incident wave conditions. Consistent with previous numerical modeling work, SWOT observes amplification of SWH over the Gulf Stream as high as 2 meters when waves propagate from the northwest. The sensitivity to incident wave direction leads to seasonality in wave-current interactions tied to the Atlantic wave climate. Overall, these findings demonstrate the use of SWOT's wide-swath observations as a powerful tool for observing and understanding ocean surface wave conditions and their connection to both ocean circulation, atmospheric variability, and regional wave climatology.

Corresponding author:
Ho Allison (**Jet Propulsion Laboratory, California Institute of Technology**, **United States**), allison.ho@jpl.nasa.gov

Wave Observations across Tuamotu Archipelago from Wide Swath Radar Altimetry (SWOT)

Taina Postec (Laboratoire d’Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France, France); Guillaume Dodet (Laboratoire d’Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France, FRANCE); Fabrice Ardhuin (Laboratoire d’Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France, FRANCE); Swen Jullien (Laboratoire d’Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France, France); Lisa Maillard (Laboratoire d’Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France, France)

Session: Oceanography: Wind and Waves
Presentation type: Poster
Poster number: ST2025OS4_008

Abstract:
The Tuamotu Archipelago is the largest group of atolls worldwide, composed of 84 atolls, each with diverse morphological and hydrodynamical characteristics, and located in the middle of the South Pacific Ocean (French Polynesia). This archipelago is exposed to high energy northern and southern swells, and it has a strong impact on wave propagation iat regional scale, with shadowing and refraction phenomena around the atoll islands. These phenomena are a major source of errors for numerical wave modeling, as wave models are sensitive to the geometry and resolutions of the computational grids, as well as to the implemented numerical schemes and the parameterization of wave obstruction. Observing the effect of atolls or islands on the propagation of open sea swells helps identify local model errors in the case of resolved or unresolved islands. Given the limited in-situ observations in these environments,the improved resolution and 2D spatial mapping offered by SWOT appear particularly useful to analyze swell propagation at both local and regional scales.

In this study, we explore long swell (wavelength > 500m) transformation while propagating across the Tuamotu Archipelago thanks to SWOT 250m- gridded sea surface height (SSH) maps. These SSH maps enable PSD spectrum computation, which gives opportunity to quantify swell transformation through spectrum analysis both along-track and cross-track. Then, we investigate the capacity of SWOT LR 2km gridded significant wave height (Hs) maps to monitor Hs variability across the archipelago. These Hs measurements represent fairly accurately island regional shadowing even if instrumental noise (mostly along swath edges) may require specific correction before analyzing Hs maps. We take advantage of two recently moored Sofar spotter buoys deployed on the southern and northern side of Rangiroa atoll during the FUTURISKs field campaign of May 2025, to sharpen our swell transformation analysis. Finally, these new insights are used to diagnose wave model accuracy in modelising island sheltering effects, regarding their computational grids, numerical scheme and their parameterization of wave obstruction. SWOT measurements help to spot limitations of operational models and reanalysis, through Hs transects or integrated swell parameters analysis which show discrepancies between satellite data versus model results for both Tuamotu Archipelago and specific atolls shadowing.

Corresponding author:
Taina Postec (**Laboratoire d’Océanographie Physique et Spatiale (LOPS), Univ. Brest, CNES, CNRS, IRD, Ifremer, IUEM, Brest, 29200, France**, **France**), taina.postec@ifremer.fr

Remote sensing of reservoir levels for global water availability assessment

Sarah Esenther (Institute at Brown for Environment and Society (IBES)/Department of Earth, Environmental, and Planetary Sciences (DEEPS), Brown University, United States); Seth N. Goldstein (Institute at Brown for Environment and Society (IBES), USA); Laurence Smith (Department of Earth, Environmental, and Planetary Sciences, Brown University, United States)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_001

Abstract:
A growing body of research describes water security using quantitative indices combining physical and government-reported human factors. Few of these indices are updated regularly at the global scale given a variety of data availability challenges. Here, we show that the correlation between remotely sensed SWOT seasonal reservoir level changes and regional Precipitation - Evaporation (P - ET) offers a global measure of water availability independent of a traditional report-based water security indices. Anticorrelation between changes in reservoir water level and P - ET (negative Reservoir Water Balance Correlation or RWBC; Ryan et al., 2020) reflects water resource management with operational independence from climatic water input, while positive correlation (positive RWBC) signifies operational dependence on climatic water inputs. We find that countries with negative RWBC have high water availability as measured by the traditional Global Water Security Index (GWSI; Gain et al., 2016). Countries with positive RWBC can have high or low water availability as measured by the GWSI, with differences largely explainable by two readily obtainable metrics (remotely sensed P - ET and national GDP per capita). Our study affirms the potential of satellite remote sensing for tracking reservoir operations, and for enhancing insight into the water security of nations with limited data availability.

Corresponding author:
Sarah Esenther (**Institute at Brown for Environment and Society (IBES)/Department of Earth, Environmental, and Planetary Sciences (DEEPS), Brown University**, **United States**), laurence_smith@brown.edu

Ice detection with SWOT data

Louis Kern (Magellium, France); Matthieu Denisselle (Magellium, France); Thomas Vaujour (Magellium, France); Noémie Lalau (Magellium, France); Michaël Ablain (Magellium, France)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_002

Abstract:
The Surface Water Ocean Topography (SWOT) mission launched in December 2022 started a new era of spatial altimetry and hydrology. Its objectives are to characterise ocean mesoscale and submesoscale circulation, and to characterise spatial and temporal variations in surface waters. Two types of topography data are generated: Low Rate (LR) data over the oceans, with a spatial resolution from 250 m to 2 km, and High Rate (HR) data over inland waters, with a spatial resolution from 10 to 60 m. The study of glaciated regions, whether located in the open ocean or inland, still represents major scientific and technical challenges. However, the groundbreaking performance of the SWOT mission could allow us to study them in detail. Indeed, already available SWOT data show the potential for detecting ice over continental areas as well as sea ice.

This study develops an ice detection algorithm for lakes and rivers based on SWOT HR data. A first study showed the ability to discriminate between ice and water over lakes at the Swedish/Norwegian border using the Level 2 Pixel Cloud Product: by combining σ0, height and coherence information, water-filled cracks in ice layers (called leads) were detected. Based on these findings, segmentation algorithms were tested on a scene featuring lake Athabasca in Canada in May 2023, when the ice-cover started to break up in pieces. Unsupervised machine learning algorithms were implemented, taking as input 2D images of σ0, height and coherence values. After some preprocessing steps, a Principal Component Analysis (PCA) followed by a clustering algorithm separates the points into several groups. Based on their σ0 and coherence values, each cluster in the image is classified as either ”ice” or ”water.” The output is a 2-D water and ice mask matching the sampling of the input products. In order to quantify the performance of each algorithm, a small dataset of hand-labelled Sentinel-2 optical images was created.

The results of this study demonstrate the potential of SWOT data to detect ice. The existing algorithm should be refined in the future by adapting it to SWOT version D products and making it more robust to different ice and water conditions. The updated algorithm could then be used to train a Machine Learning model able to detect sea ice. Being able to detect ice both on the ocean surfaces and on inland waters is a key issue for numerous scientific and socio-economic topics.

Corresponding author:
Louis Kern (**Magellium**, **France**), louis.kern@magellium.fr

Applying Machine Learning to Analyze SWOT's Potential for Lake Ice Detection

Yanqi Ye (Brown University, United States); Laurence C. Smith (Brown University, United States); Thomas Howard (Brown University, United States); Cassie Stuurman (NASA JPL, United States)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_003

Abstract:
Accurately monitoring the seasonal freeze-thaw state of lakes and rivers is essential for understanding water resources and climate feedback in cold regions. However, observing lake ice transitions across remote high-latitude regions remains challenging, emphasizing the need for reliable satellite-based approaches. The Surface Water and Ocean Topography (SWOT) satellite mission provides high-resolution measurements of water surface elevations for lakes and rivers across the globe, offering new opportunities to enhance our understanding of freshwater dynamics. In high-latitude regions, interpreting SWOT's measurements requires distinguishing between open-water and ice-covered water surfaces, yet SWOT lacks a reliable native method for this discrimination. This study evaluates the capability of SWOT data (i.e., backscatter, water surface elevation, and incidence angle) to effectively differentiate between ice-covered and open-water lakes in Alaska. We show that machine learning classifiers (e.g., random forest, gradient boosting) accurately distinguish ice-covered from open-water lakes, with backscatter emerging as the most informative predictor. Our findings affirm SWOT's potential to detect lake ice cover and extend its utility beyond water level monitoring. More broadly, this work highlights the value of integrating new satellite observations with machine learning to advance the monitoring of Earth's changing freshwater systems.

Corresponding author:
Yanqi Ye (**Brown University**, **United States**), yanqi_ye@brown.edu

SWOT mission for study and monitoring of ice-covered rivers and lakes

Elena Zakharova (EOLA, France); Alexei Kouraev (LEGOS/UPS, France); Inna Krylenko (IWP RAS, Russia); Nicholas Hall (LEGOS/UPS, France); Jean-Francois Crétaux (LEGOS/CNES, France)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_004

Abstract:
Many rivers and lakes in the Northern Hemisphere are seasonally ice-covered. Ice presence is long and may last for almost half of the year. Ice cover dramatically affects energy exchange between water and atmosphere. Ice formation and break-up, as well as ice thickness, are good indicators of regional and large-scale climate variability. River ice is a key component of the river hydrology as it affects streamflow via immobilization/release, modification of the water velocity field, creation of a backwater during freezing and melting. For lakes, ice thickness and duration of ice period affect timing of vertical overturning, duration of summer warming period and thus water temperature and evaporation rate. Ice is also important for establishing transport on ice, for fishing activities and tourism.
Satellite monitoring of river and lake ice is a rapidly developing area. At the same time for active microwave remote sensing the presence of ice significantly affects the returning radar signal and could result in erroneous interpretation of satellite altimetry measurements. We present results of comparison of field observations on ice and snow structure done on Lake Hovsgol (Mongolia) in winter with SWOT measurements and use complementary satellite imagery in different bands to help the interpretation of spatial heterogeneity of SWOT observations.
In the Middle Lena River we compare the SWOT water level measurements with in situ observations at the gauging stations and with the simulations of the hydrodynamic model STREAM 2D along 300 km-long river reach. We put a specific focus on the winter period.
This research was supported by the CNES TOSCA Lakeddies, Lakeddies II, TRISHNA and SWIRL projects, and RAS Governmental Order FMWZ-2025-0003 for IWP.
Corresponding author:
Elena Zakharova (**EOLA**, **France**), zavocado@gmail.com

Investigating Ice Jams in Arctic Rivers with SWOT's High-Resolution Altimetry

Linda Christoffersen (Technical University of Denmark, Denmark); Karina Nielsen (Technical University of Denmark, Denmark)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_005

Abstract:
This research examines the effectiveness of the Surface Water and Ocean Topography (SWOT) mission in detecting and characterising ice jams in Arctic rivers, utilising both SWOT altimetry and optical satellite data. Arctic rivers, which remain ice-covered for much of the year, undergo a rapid and complex breakup each spring. This process can lead to the formation of ice jams—accumulations of ice that obstruct river flow—resulting in significant alterations to the river's surface profile and slope. The primary objective of this study is to evaluate SWOT's capability to observe such events and to contribute to improved monitoring and prediction of associated hydrological changes.

Ice jams typically form during spring breakup when dislodged ice accumulates and blocks the river channel, causing water to back up and potentially raising the upstream water surface elevation by several meters. This can trigger severe flooding and necessitate the evacuation of communities along the riverbanks. Due to the extreme environmental conditions and short-lived nature of ice jams, they have historically been poorly monitored. However, SWOT's high spatial resolution, wide-swath coverage, and relatively frequent revisit intervals—down to every few days in polar regions—make it uniquely suited for capturing these ephemeral yet high-impact events. The level of detail achievable with SWOT far exceeds that of conventional satellite radar altimetry missions (Biancamaria et al., 2016).

During the calibration and validation (cal/val) phase of the SWOT mission, the satellite captured a ~15 km long ice jam on the Peace River that persisted for several days. Thanks to the daily revisit capability of the cal/val orbit, the ice jam was observed multiple times before its complete breakup. Combined with high-resolution optical imagery from Sentinel-2 (Drusch et al., 2012) and PlanetScope (Planet Labs PBC, 2025), the SWOT observations enabled a detailed analysis of the temporal evolution of both water surface elevation (WSE) and water surface slope (WSS) upstream of the jam. Comparisons with data from traditional altimetry missions, including Sentinel-3A/B (Seitz et al., 2010) and ICESat-2 (Neumann et al., 2019), reveal that these sensors lack the spatial and temporal resolution necessary to detect the full complexity of ice jam dynamics—highlighting the substantial leap forward that SWOT represents.

The transition from a fully ice-covered state to jammed flow and ultimately to an ice-free river contributes valuable insight into the hydrological and cryospheric processes operating in Arctic river systems. These findings underscore the transformative potential of SWOT data for advancing the understanding, monitoring, and prediction of extreme events in cold-region hydrology.

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Corresponding author:
Linda Christoffersen (**Technical University of Denmark**, **Denmark**), lindchr@space.dtu.dk

Antarctic Ice Shelf Tidal Displacement from SWOT

Zachary Katz (Department of Geophysics, Colorado School of Mines, Golden, CO, United States); Matthew Siegfried (Department of Geophysics, Colorado School of Mines, Golden, CO, United States); Susan Howard (Earth and Space Research, Seattle, WA, United States); Laurie Padman (Earth and Space Research, Corvallis, OR, United States); Ellianna Abrahams (Department of Geophysics and Stanford Data Science Institute, Stanford University, Stanford, CA, United States); Tasha Snow (NASA Goddard Space Flight Center and ESSIC, University of Maryland, United States)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_006

Abstract:
Southern Ocean tides impact the cryosphere and global climate system, for example altering ice shelf basal melt rates, sea ice concentration, and production of Antarctic Bottom Water. Southern Ocean tides also drive ice stream and ice shelf velocity variability on daily to monthly timescales. However, models of tides around Antarctica are less accurate than models of subpolar ocean tides, due to lack of in situ tide gauges and complications in interpreting satellite altimetry data at high latitudes. In particular, improved observations of interactions between tides and ice shelves are necessary to analyze and project the coupled tide-ice shelf system. NASA/CNES's Surface Water and Ocean Topography (SWOT) mission is the first satellite that favorably aliases major tidal harmonics, reaches far enough south (~78°S) to provide data over several critical Antarctic ice shelves, and obtains data regardless of cloud cover. We explore the potential for SWOT elevation change data over ice shelves to improve our understanding of Antarctic tides, including accurately determining ice elevation in regions of complex topography via comparison to satellite laser altimetry data from NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) mission and identifying supraglacial water features on cloudy days via comparison to Sentinel-2 optical imagery. We demonstrate the feasibility of using SWOT to observe tides underneath ice shelves through elevation-change comparisons to ICESat-2 data and regional tide models. Accurate ice-shelf elevations are currently limited to areas covered by SWOT's high resolution data product, which is only available over certain ice shelves since November 2024 after adjustments to the high resolution mask proposed by the SWOT Cryosphere Working Group. We discuss challenges associated with correcting the low-resolution data over ice shelves, which would lead to more extensive spatial coverage and a longer time series necessary for calculating tidal constituents. Despite these challenges, SWOT provides revolutionary new polar tide observations, important for improved understanding of tidal interactions with ice shelves and how tides impact ice stream flow.

Corresponding author:
Zachary Katz (**Department of Geophysics, Colorado School of Mines, Golden, CO**, **United States**), zachary_katz@mines.edu

Machine Learning-Based Mapping of Lake Ice Cover from SWOT KaRIn Backscatter: Preliminary Results

Jaya Sree Mugunthan (H2O Geomatics, Canada); Claude Duguay (University of Waterloo and H2O Geomatics, Canada)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_007

Abstract:
Lakes are key components of the global freshwater system, playing a crucial role in climate regulation, hydrological cycling, and maintaining ecological balance. As highly sensitive indicators of climate change, lakes are recognized by the Global Climate Observing System (GCOS) as an essential climate variable (ECV), with lake ice cover (LIC) and lake ice thickness (LIT) identified as two of its thematic products. In the Northern Hemisphere, many lakes develop seasonal ice cover, which significantly influences local energy balance, ecosystem function, and socio-economic activities such as transportation, fishing, recreation, and tourism.

Understanding the spatial distribution and temporal dynamics of the lake surface conditions is essential for numerous applications. For instance, accurate mapping of ice cover dynamics in lakes is crucial for predicting lake ice phenology, estimating ice thickness, and assessing the impacts of climate change on lake ecosystems. Due to the steady decline in long-term in situ observations of lake ice and overlying snow properties in recent decades, there is an increasing reliance on satellite remote sensing. These spaceborne approaches provide an effective alternative for investigating lakes at regional and global scales, providing a comprehensive and cost-effective means of monitoring these dynamic water bodies.

The Surface Water and Ocean Topography (SWOT) mission, launched in December 2022, introduces the Ka-band Radar Interferometer (KaRIn), which offers high-resolution measurements of both surface water elevation and backscatter. While primarily designed for hydrological and oceanographic studies, SWOT's KaRIn backscatter data have shown sensitivity to surface conditions, suggesting potential applications in cryospheric monitoring. Our analyses demonstrate that KaRIn backscatter is sensitive to lake surface conditions and exhibits a clear distinction between ice-covered and open-water areas, providing a basis for classification efforts.

Building on these initial findings, we develop a Random Forest classification model to distinguish between lake ice and open water using SWOT KaRIn backscatter data. Random Forest is a robust machine learning algorithm known for its effectiveness in handling complex, nonlinear relationships and has been widely used in remote sensing classification studies. The study focuses on five lakes in the Northern Hemisphere: Lake Teshekpuk in Alaska, as well as Kluane Lake, Great Slave Lake, Lake Athabasca, and Great Bear Lake, all located in Canada. Lake Teshekpuk and Kluane Lake are consistently observed during both the Cal/Val and Science phases of the SWOT mission, while Great Slave Lake, Lake Athabasca, and Great Bear Lake were partially covered during the Cal/Val phase, with full spatial coverage during the Science phase. The time period considered for performing the classification spans from March 30 to July 10, 2023 (Cal/Val phase), and from September 1, 2023, to July 15, 2025 (Science phase). To support classification and provide accurate labelling, we use supplementary satellite datasets including Sentinel-1 SAR, Sentinel-2 MSI, MODIS Aqua/Terra, and Landsat 8/9. These datasets provide additional information on surface conditions to ensure accurate reference labelling. By leveraging SWOT's high-resolution data and the capabilities of machine learning, this study aims to enhance the monitoring of lake ice phenology. It offers valuable insights into the value of Ka-band for mapping lake ice.

Corresponding author:
Jaya Sree Mugunthan (**H2O Geomatics**, **Canada**), jayasree.mugunthan@h2ogeomatics.com

Evaluating SWOT elevation retrieval on lake and river ice cover near Fairbanks, Alaska

Xiao Yang (Southern Methodist University, United States); Sunwoo Yoon (Department of Earth Sciences, Southern Methodist University, Dallas, TX, USA, United States); Christopher Arp (Water and Environmental Research Center, University of Alaska Fairbanks, Fairbanks, AK, USA, United States); Allen Bondurant (Water and Environmental Research Center, University of Alaska Fairbanks, Fairbanks, AK, USA, United States); Tamlin Pavelsky (Department of Earth, Marine and Environmental Sciences, University of North Carolina at Chapel Hill, NC, USA, United States)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_008

Abstract:
Over terrestrial environments, the Surface Water and Ocean Topography Mission (SWOT) is designed to retrieve elevation over lakes and rivers globally. It is estimated that globally, the majority of satellite resolvable lakes and rivers experiences seasonal ice cover, which limits SWOT hydrology application over a large portion of its target water bodies during the winter. Some preliminary studies have demonstrated SWOT's ability to detect the presence of ice/snow and estimate ice surface elevation over both inland water ice cover and sea ice. To date, most evaluation studies have compared SWOT-retrieved elevation over ice with elevation from altimeters. In this work, we aim to conduct a field-based study to evaluate ice elevation from SWOT. To capture the complexity of the lake/river ice environment, we conducted a four-day field study near Fairbanks, Alaska. We collected dense GNSS data over morphologically complex ice cover using Trimble R12i with its RTX service. The data were collected at 1 second interval by towing a GNSS receiver behind a snow machine over an accumulated distance of ≥120 miles, covering two segments of the Tanana River, Healy Lake, and Harding Lake. The RTX service provides data with ~5 cm vertical accuracy to be compared with SWOT's reported elevation. The data will be converted to SWOT's reference frame before comparing with SWOT's pixel cloud and raster product. We expect the results will be useful in further demonstrating SWOT's applicability in cryosphere studies. And given the complexity of the river/lake environment, the resulting evaluation will likely provide a lower bounds for SWOT's ice elevation retrieval accuracy over various snow/ice conditions in terrestrial environments.

Corresponding author:
Xiao Yang (**Southern Methodist University**, **United States**), xnayang@smu.edu

Cryosphere Applications for the SWOT SAR Interferometry and Altimetry

Rosemary Willatt (UCL, United Kingdom); Connor Burke (UCL, UK); Imogen Garlick (UCL, UK)

Session: Cryosphere: Lakes
Presentation type: Poster
Poster number: ST2025CS2_009

Abstract:
The Cryosphere Applications for SWOT SAR Interferometry and Altimetry (CASSIA) project explores the potential of SWOT data to provide novel, advanced observations of the cryosphere. We explore SWOT data collected over cryosphere regions for the study of floating and grounded ice in both hemispheres. While the primary objectives of the mission focus on measuring ocean surface dynamics and terrestrial surface water storage, the possibilities to use SWOT's innovative payload to improve satellite measurements over the Polar Regions have been clear from early SWOT data onwards.

This study compares SWOT data at C-, Ku- and Ka-band frequencies and the V- and H polarisations from both SWOT's interferometer and altimeter instruments over both sea ice and land ice. Over sea ice we show that retrieved range differences between the nadir C- and Ku-band altimeters are ~constant over leads but highly variable over sea ice, indicating variable scattering depths. These scattering depths and especially their variability are difficult to observe in non-spatially-coincident altimeters i.e. on separate platforms, making SWOT an ideal mission for this intercomparison. Using intercomparisons between nadir altimeter and KarIn datasets, we are able to indicate that the nadir altimeters pick up leads and floes reliably and that retrieved freeboards show a strong frequency dependence. Similar to our study over sea ice, over land ice we compare SWOT KarIn and nadir altimeter data, observing characteristics of the radar penetration and scattering over ice sheets and ice shelves, showing results over Antarctic and Greenland. the implications of the physics revealed by SWOT and the implications for retrieval of Essential Climate Variables will be highlighted.

We show SWOT's unique capability to make spatially and temporally coincident measurements both for geophysical observations of Essential Climate Variables. We also contextualise our findings and show how these are relevant for both planning of novel concept missions (e.g. PoSARA) and interpretation of data from other existing missions (e.g. CryoSat) including missions approaching launch (e.g. CRISTAL). We summarise the status, outlook and suggestions for development in relation to SWOT data products over the cryosphere.
Corresponding author:
Rosemary Willatt (**UCL**, **United Kingdom**), r.willatt@ucl.ac.uk

A Raster-Vector Hydrologic-Hydrodynamic Modeling Framework for Regional Applications with SWOT and Multi-Source Data Integration: Toward Effective Bathymetry Learning

Mohamed Amine BERKAOUI (Institut de Mécanique des Fluides de Toulouse (IMFT), Université de Toulouse, CNRS, Toulouse, France); Mohamed Saadi (Institut de Mécanique des Fluides de Toulouse (IMFT), Université de Toulouse, CNRS, Toulouse, France); Pierre-André Garambois (INRAE, Aix-Marseille Université, RECOVER, Aix-en-Provence, France); François Colleoni (INRAE, Aix-Marseille Université, RECOVER, Aix-en-Provence, France); Truyen Huynh (INRAE, Aix-Marseille Université, RECOVER, Aix-en-Provence, France); Kevin Larnier (Hydro Matters, Toulouse, France); Ludovic Cassan (CERFACS, Toulouse, France); Hélène Roux (Institut de Mécanique des Fluides de Toulouse (IMFT), Université de Toulouse, CNRS, Toulouse, France)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_001

Abstract:
Accurate simulation of flood propagation and submersion at regional to continental scales requires proper representation of river channel and floodplain geometry, which significantly influences fluvial hydrodynamics. However, detailed bathymetric data (e.g., channel storage, thalweg elevation, bank slope) are often unavailable across large domains, leading to a simplified representation of river bathymetry in hydrological-hydrodynamic modelling applications. This poor representation of river bathymetry introduces uncertainties in model outputs (e.g., peak time and magnitude, depth, inundation extent), particularly during extreme flooding events. The increasing availability of multi-scale remote sensing altimetry data (e.g., SWOT, LIDAR) offers a valuable opportunity to fill this gap in data-sparse regions. By assimilating these remote sensing observations (e.g., water surface elevation) into integrated hydrological-hydrodynamic modeling frameworks, hydraulic model parameters such as bathymetry and roughness can be refined through inverse modeling enabling more accurate flood prediction in data-sparse regions. To address these challenges, this work introduces a hybrid raster-vector hydrologic-hydrodynamic modeling framework combining grid-based hydrological modeling with vector-based river routing. This approach provides the spatial structure needed for effective assimilation of remote sensing observation data. We developed a fully automated preprocessing workflow that requires minimal inputs: a fine-resolution digital elevation model (DEM) and a reference vector hydrography. The preprocessing workflow consists of four sequential steps: (1) DEM conditioning through stream burning and depression filling; (2) flow direction computation at the DEM's native resolution followed by upscaling to target hydrological model resolution; (3) coarse-scale hydrography delineation by tracing reference vector river pathways along upscaled flow directions rather than using the conventional support area threshold approach; and (4) coupling the hydrological grid to the DEM-derived hydrography through direct cell-to-cell index matching. This workflow preserves the fine-scale river features through a subgrid-scale representation of the river network at the native DEM resolution, thereby overcoming dependency on the grid resolution of the hydrological model. The preprocessing workflow was implemented within SMASH (Spatially distributed Modelling and ASsimilation for Hydrology), a computational software framework for hydrological modeling. We evaluated the workflow on the Garonne basin in France using MERIT DEM and the SWORD river network across three spatial resolutions (approximately 250m, 500m, and 1 km). The quality of the DEM-derived subgrid network was assessed through two metrics: mean separation distance (MD) and length ratio (LR). Results showed excellent performance across all resolutions, with the subgrid network maintaining close spatial alignment to the SWORD reference network (MD of 16-17 m) while successfully preserving fine-scale features (LR consistently at 1). A modeling numerical experiment was conducted within SMASH on the Garonne basin at 1 km resolution coupling the grid-based conceptual GR hydrological model to a vector-based routing model solving a simplification of the 1D shallow water equation without convective acceleration terms (sufficient approximation for low Froude regimes in SWOT context). For this experiment, river channels were represented using a simple rectangular geometry with width and depth parameters estimated from drainage area-based empirical relationships. The results demonstrated excellent mass balance conservation between the hydrological grid and the vector network, with very low errors. This high precision confirms the effectiveness of the cell-to-cell index matching approach for spatial coupling between raster and vector domains. This hybrid raster-vector modeling framework provides a flexible and scalable foundation for large-scale hydrological-hydrodynamic applications, enabling effective assimilation of satellite river observations to enhance modeling accuracy in data-sparse regions. Ongoing work aims to extend the framework for inferring effective bathymetry-friction (Larnier et al 2025) using parameterized shapes and geomorphological constraints, within a learnable regionalization framework (Huynh et al. 2025) enabling optimal integration of SWOT and LiDAR elevation data, along with in situ measurements when available.

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Corresponding author:
Mohamed Amine BERKAOUI (**Institut de Mécanique des Fluides de Toulouse (IMFT), Université de Toulouse, CNRS, Toulouse**, **France**), amine.berkaoui@imft.fr

Joint training of hydrologic and hydraulic models Using Deep Learning and SWOT Pixel Cloud Data for the Torne River

Simon Jakob Köhn (DTU Space, Denmark); Karina Nielsen (DTU Space, Denmark); Peter Bauer-Gottwein (KU, Denmark); Cécile Kittel (DHI, Denmark); Connor Chewning (DHI, Denmark)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_002

Abstract:
Floods are among the most devastating natural disasters, affecting both developed and developing regions. However, developing countries often lack sufficient monitoring and early warning systems, making them more vulnerable. The ESA EO4FLOOD project seeks to enhance flood forecasting by integrating satellite data with hydrologic and hydraulic models (Tarpanelli et al., 2025). Within this effort, we introduce a novel, joint modelling framework that couples hydrologic and hydraulic models using a deep learning (DL) approach.

The Surface Water and Ocean Topography (SWOT) mission is the first satellite to provide 2D spatially distributed water surface elevation (WSE) data globally, complimenting the global water gauge network through its ability to produce spatially continuous and consistent WSE measurements (Pavelsky et al. 2014). It has a 21-day orbit, with more frequent revisit times depending on latitude. SWOT's ability to deliver consistent measurements of WSE, water surface slope (WSS), and river width enables a new era in discharge estimation (Durand et al., 2023).

Our framework leverages physics-informed deep learning to integrate large-scale Earth observation (EO) data while maintaining physical consistency. The hydrologic and hydraulic models are trained against SWOT pixel cloud data, using the output of the hydrologic model as the input to the hydraulic model. Joint training allows both models to benefit from the information contained in the SWOT data (WSE, WSS), and, potentially, satellite earth observations of additional state variables (e.g., soil moisture, evapotranspiration, terrestrial water storage).

We demonstrate this approach on the Torne River, located between northern Sweden and Finland. With extensive in-situ data, Torne provides an ideal case for validation. Our joint model supports accurate water level and discharge forecasting, aiding flood preparedness, informing local adaptation strategies, and enhancing climate resilience. This proof of concept highlights the method's global potential under the EO4FLOOD initiative.

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Corresponding author:
Simon Jakob Köhn (**DTU Space**, **Denmark**), sijko@space.dtu.dk

Evaluating the potential of reach water surface elevation product from SWOT mission using Assimilation and Hydrodynamic modelling.

Manu K Soman (Indian Institute of Technology Bombay, India); Indu Jayaluxmi (Indian Institute of Technology Bombay, India)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_003

Abstract:
Spatiotemporally consistent quantification of river discharge is a persistent problem in the field of hydrology. The current generation of technologically advanced satellite sensors provide reliable alternatives to the conventional gauge monitoring system. In this study, we utilize the Water Surface Elevation (WSE) measurements from the recently released river products from the Surface Water and Ocean Topography (SWOT) mission. We integrate the reach WSE measurements into a distributed hydrodynamic model through an assimilation system to study its contribution towards enhancing the modelled discharge over an entire river basin. Assimilation is implemented using both synthetic and real SWOT reach WSE measurements, where the former is generated using a new method involving the CNES Large Scale SWOT Hydrology Simulator and the NASA Jet Propulsion Laboratory's (JPL) RiverObs toolkit. The study using synthetic data is conducted for a 3-year period, whereas that using real measurements are implemented based on the availability during the science phase of the mission. Real measurements from the SWOT mission are affected by the presence of outliers that are filtered prior to assimilation to ensure consistent improvements corresponding to each satellite overpass date over the study region. SWOT reaches are accurately connected to the river network grid before initiating the assimilated model run. Results reveal notable improvement in modelled discharge after assimilation, with the NSE values exceeding 0.6 and 0.4 for the synthetic and real SWOT data-based experiments, respectively. The improvements, though pronounced towards the downstream reaches, are evident at all validation stations across the basin.

Corresponding author:
Manu K Soman (**Indian Institute of Technology Bombay**, **India**), manuks@iitb.ac.in

SWOT River Database (SWORD) Updates

Elizabeth Altenau (UNC Chapel Hill, United States); Tamlin Pavelsky (UNC Chapel Hill , United States)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_006

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite mission, which launched in 2022, provides unprecedented observations of river water surface elevation (WSE), width, and slope for global rivers. For practical application of SWOT vector products, a global prior database of river networks and reaches is required. The SWOT River Database (SWORD) was introduced in 2021 and is the foundation for the SWOT river single-pass vector products. SWORD was produced by combining seven different global databases to create one congruent hydrography database that incorporates over 45 hydrologic and SWOT-relevant variables including topology. SWORD has three different spatial resolutions: The centerline resolution at ~30 m point spacing, the node resolution at ~200 m point spacing, and the reach resolution at ~10 km polyline spacing on average. To create the SWOT river vector products, the SWOT pixel cloud elevations are mapped onto the SWORD nodes and reaches based on several SWORD attributes including proximity to the centerline, maximum distance thresholds, and connectivity. Therefore, while SWORD is not the primary factor involved in SWOT river vector product accuracy, the database does play a large role in the vector product outcomes. SWORD is a complex database with many different sources and is constantly undergoing updates based on user feedback and algorithm development in order to improve the SWOT vector products. Updates to SWORD v17 revolved around improving topology to create a better user experience with SWOT vector products, improve discharge algorithm implementation, and ease the use of hydrologic modeling or routing along the SWORD centerline network. Planned updates for version 18 focus on expanding SWORD to include narrower rivers based on MERIT Hydro Vector, improving centerline representations in complex river channels, and adjusting centerline offsets.
Corresponding author:
Elizabeth Altenau (**UNC Chapel Hill**, **United States**), ealtenau@unc.edu

Towards integrating Pixel Cloud HR SWOT data into a hydrogeological model

Elena GOALIC (CNES - Centre national d'études spatiales, France); Jean-Pierre VERGNES (BRGM, France); Anne JOST (METIS, France); Nicolas GASNIER (CNES, France); Marcello DE MICHELE (BRGM, France)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_007

Abstract:
In the presence of climate change and population growth, hydrogeological models become essential for monitoring and managing freshwater resources and to prevent and mitigate the consequences of flood events. These models integrate a wide range of geomorphological data and need field measurements that are not always sufficient. The SWOT satellite mission therefore appears very attractive as a complement to in situ data on surface waters. The aim of this study is to assess the feasibility of using SWOT data as a complementary tool for building and evaluating regional hydrogeological models, in particular their relation with groundwater level. To this end, we identify hydrogeological models which represent areas with high surface water and groundwater interactions isssues, for which our knowledge can be improved. For now, three French study areas are targeted : the lakes and canals of the Landes region, the Boutonne watershed, and the Tarn-et-Garonne watershed. On the second hand, we develop a method for processing Pixel Cloud HR SWOT products based on the PixC Dust library (outlier isolation, temporal chronicle, linear along the watercourse, assessment of satellite data reliability) with the aim of linking SWOT satellite data to simulated surface water, and indirectly to simulated groundwater levels through river-groundwater exchanges. To do so, Pixel Cloud HR SWOT products undergo various filtering operations (geographical and based on the pixel classification and sigma-0) to eliminate outliers. SWOT temporal and spatial chronicles are evaluated against in situ river flow and water height time series available from the French Hydroportail portal. Among the three chosen study areas, first results from the SWOT data processing show a very good representation of lake extents and surface water elevation variations in the Landes canals, perfectible representation on certain narrow rivers (30m wide) like the Boutonne river likely due to water level not buffered by lakes, and an accurate estimation of the water surface elevations over the Tarn and the Garonne rivers. Next step will be to link those SWOT results to the available hydrogeological models in these areas in order to assess the capability of SWOT to improve the simulated surface water representation and hence the simulated piezometric levels.

Corresponding author:
Elena GOALIC (**CNES - Centre national d'études spatiales**, **France**), e.goalic@externe.brgm.fr

Leveraging SWOT Data to Improve Coupled Lake–River Routing Models

Yuanzhi Ma (University of Illinois Urbana-Champaign, United States); Md Safat Sikder (University of Illinois Urbana-Champaign, United States); Jida Wang (University of Illinois Urbana-Champaign, United States)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_008

Abstract:
Lakes and reservoirs store a large portion of the Earth's surface water and play a crucial role in the terrestrial water cycle. As an integral part of the global drainage network, lakes significantly influence river systems through hydrological connections. Especially, including reservoirs in hydrological routing is essential for accurate estimations of river discharge in regulated basins. In data-driven routing approaches, the observed lake/reservoir outflow is used as a model input, while in non-data-driven approaches, the outflow is calculated using parameterized/calibrated lake/reservoir schemes. Both approaches need an accurate representation of the lake-river drainage topology and associated catchments. Traditional gridded routing networks struggle to accurately represent the topology of water bodies, whereas vector-based routing networks offer greater compatibility and accuracy.

Here, we experiment to build an integrated lake-river model based on a high-resolution vector-based lake-river network. This network is extended from the latest version of Lake-TopoCat (Sikder et al., 2023), which registers 6 million SWOT prior lakes (Wang et al., 2025) into the global drainage network. By further harmonizing PLD-TopoCat with the SWOT River Database (SWORD; Altenau et al., 2021) and MERIT Hydro Vector (Lin et al., 2021), a globally congruent lake-river network is formed, with key advantages to be consistent with the spatial units of SWOT vector data products. The model employs a flexible routing framework to simulate river discharge and lake inflow/outflow. SWOT-observed lake storage changes can be used as inputs for data-driven methods or to calibrate lake scheme parameters in data assimilation approaches. Preliminary results indicate that, compared to the conventional scheme-driven approach, the data-driven method better captures the seasonal variations of rivers influenced by lakes and reservoirs in headwater regions, revealing its potential in improving hydrological simulations within complex lake-river systems. Our goals are to enhance modeling capacities that leverage SWOT data to advance understanding of the roles of lakes and reservoirs in catchment processes, and to better constrain uncertainties of tributaries inflows to SWOT-observed rivers.

Corresponding author:
Yuanzhi Ma (**University of Illinois Urbana-Champaign**, **United States**), ym35@illinois.edu

Contribution of SWOT Data to Wetland Hydrological Modelling with HYDROTEL: The Oromocto Watershed Case Study

Anne-Marie Laroche (Université de Moncton, Canada); Mélanie Trudel (Université de Sherbrooke, Canada); Yannick Duguay (Centre de géomatique du Québec, Canada); Alain N. Rousseau (Institut national de la recherche scientifique, Canada); Arij Messai (Université de Moncton, Canada)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_009

Abstract:
The SWOT (Surface Water and Ocean Topography) mission offers significant potential for hydrological modelling in ungauged or sparsely monitored watersheds. It is expected to enhance the representation of wetlands, whose hydrological dynamics are often poorly parameterized in current models. One of the major challenges that remains is the accurate simulation of their storage, connectivity, and water release mechanisms, which are still not understood well.

This study explores the use of SWOT-derived products to inform the wetland modules of HYDROTEL, a semi-distributed, deterministic hydrological model. The modules govern the interactions between isolated and riparian wetlands and other hydrological components, using surface variables such as water-covered area as well as maximum and average storage estimates.

The Oromocto River watershed (New Brunswick, Canada) was selected for its high density of wetlands and the presence of a stream gauge located near the outlet, making it a suitable site for assessing the added value of SWOT satellite observations. The watershed presents a favourable hydrological context for studying the buffering effect of wetlands on flood regimes and offers reliable calibration data for a strategic portion of the network.

To this end, the HYDROTEL model was first calibrated and validated using interpolated meteorological data from the Daymet database, along with observed streamflow records. The calibration focused on key model parameters over the period 2000–2009, while the validation was conducted for 2010–2019. Standard performance metrics, including the Nash–Sutcliffe Efficiency (NSE) and the Kling–Gupta Efficiency (KGE), were used to evaluate the goodness-of-fit of the simulations.

Following this phase, three simulation scenarios were developed to analyze the differential impacts of how wetlands are represented in the model:
1. A baseline scenario that incorporates wetland data from the provincial GeoNB geospatial database;
2. A scenario using a wetland map derived from SWOT imagery, combining spatial and altimetric information; and
3. A scenario that does not explicitly include wetlands.

These scenarios allow the isolation of the specific influence of different wetland data sources on the simulated hydrological dynamics, particularly regarding peak flow regulation and the gradual release of water. The comparative approach is designed to assess the contribution of SWOT-derived information under real-world conditions, focusing on a partially gauged sub-watershed where wetland-related temporary storage processes play a key role in flow regulation.

Preliminary results suggest that SWOT imagery can improve hydrological modelling in ungauged watersheds, particularly by enhancing the representation of wetlands. Comparisons of peak flows, low flows, and flow duration curves indicate that the model incorporating SWOT data slightly attenuates high flows and alters the simulation of low flows. These effects suggest enhanced water retention and delayed release mechanisms when wetlands are characterized using SWOT-derived variables. However, the accuracy of low flow simulations remains uncertain and warrants further investigation to ensure a reliable representation of dry-season dynamics. In addition, a partial validation was carried out using SWOT-derived water level measurements in lakes and wetlands within the Oromocto River watershed. SWOT data provide new insights into the dynamics of water storage and release within the basin, offering an opportunity to advance our understanding of the interactions between isolated and riparian wetlands and other hydrological components. These findings underscore the need for further analysis to fully assess the contribution of SWOT data to hydrological modelling in ungauged basins.

Overall, this study presents an operational framework for using SWOT products within a semi-distributed hydrological model. It explores how SWOT data support hydrological modelling in wetland-rich watersheds, particularly where observational data are limited. It contributes to the core objectives of the SWOT mission and aligns with the scientific priorities of the SWOT Science Team by advancing data-driven approaches to representing wetlands in semi-distributed, deterministic hydrological models.

Corresponding author:
Anne-Marie Laroche (**Université de Moncton**, **Canada**), anne-marie.laroche@umoncton.ca

Hydrographic Mapping of Chile: SWOT-Based Characterization of National Rivers Through Integrated Hydrological Modeling

Rodrigo Abarca del Rio (Department of Geophysics (DGEO), University of Concepción, Chile); Cristobal Caro (Doctoral Program in Environmental Sciences, University of Concepción, Chile); Fernando Campos (Doctoral Program in Applied Sciences with a Specialization in Mathematical Engineering, University of Concepción, Chile); Oscar Link (Department of Civil Engineering, University of Concepción, Chile); Mauricio Sepulveda (Department of Mathematical Engineering, University of Concepción, Chile)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_010

Abstract:
Chile's river systems are fundamental to national ecological integrity, water security, and socio-economic resilience. However, the country's hydrological monitoring network remains limited in spatial coverage and temporal resolution due to the sparse distribution of hydrometric stations. This study proposes a transformative approach to Chilean hydrography by leveraging high-resolution satellite observations from the Surface Water and Ocean Topography (SWOT) mission, coupled with state-of-the-art hydrological modeling frameworks.

The research targets a representative array of major river basins, including the Loa, Bío-Bío, Baker, Maipo, Aconcagua, Maule, Cautín, Valdivia, and Imperial Rivers, with a focus on reaches exceeding 100 meters in width, for which SWOT provides optimal observational coverage. The methodology is structured into three principal stages: (1) identification and characterization of stationary hydrological cycles, including water surface elevation (WSE) and inferred discharge patterns, from SWOT observations; (2) integration and calibration of SWOT-derived variables with distributed hydrological models to enhance spatiotemporal continuity; and (3) development of a prototype system for continuous, satellite-based river monitoring at the national scale.

To assess the reliability and added value of satellite-based observations, we perform a comparative analysis between SWOT-derived hydrological metrics and outputs from the ERA5-Land reanalysis. Specifically, we evaluate consistency in seasonal discharge dynamics, runoff timing, and spatial gradients, highlighting both the complementary strengths and limitations of reanalysis-based hydrology in mountainous, data-scarce basins. This cross-validation helps identify biases in land-surface model outputs and informs improved parameterization for large-scale hydrological forecasting.

A key deliverable of the project is the establishment of an open-access hydrological database, encompassing validated time series, statistical summaries, and geospatial visualizations. This resource is designed to support scientific inquiry, water governance, and infrastructure planning.

By addressing critical data gaps in Chile's freshwater monitoring capabilities, this project provides a foundational framework for long-term riverine observation and risk assessment. Moreover, it enhances national capacity to detect and respond to extreme hydrometeorological events—an increasingly urgent need under evolving climate regimes.

Corresponding author:
Rodrigo Abarca del Rio (**Department of Geophysics (DGEO), University of Concepción**, **Chile**), rabarcadelrio.univ@gmail.com

Assessing Global Flood Inundation Model Accuracy with SWOT HR Raster Observations

Stephen Chuter (Fathom, United Kingdom); Oliver Wing (Fathom, United Kingdom); Colin Gleason (University of Massachusetts, Amherst, USA); Paul Bates (University of Bristol, United Kingdom); Jeffrey Neal (University of Bristol, United Kingdom); James Savage (Fathom, United Kingdom)

Session: Hydrology: Global Hydrology Modeling Working Group
Presentation type: Poster
Poster number: ST2025HS5_011

Abstract:
Evaluating the accuracy of flood inundation models at global scales is a challenging endeavor given the highly transient nature of flood events, the limited availability of ground truth observations (e.g. high-water marks) and the presence of cloud cover preventing the use of optical imagery. Significant progress in determining flood extent using Synthetic Aperture Radar (SAR) and Optical Imagery has been made over the last decade, with the proliferation of automated water detection threshold mapping techniques (e.g. Copernicus Global Flood Monitoring service) and the combination of complimentary satellite constellations (NASA DSWx OPERA product) to reduce revisit times, increasing the chances of capturing the flood event peak. However, the inability to capture the flood event elevation (and therefore depth) in areas where ground truth observations are not available, is a key inhibitor of assessing global flood model accuracy. Given that flood depth is a key determinant of flood vulnerability and the economic impact of a given flood event on infrastructure, more extension observations of flood height are critical for thorough model evaluation.

SWOT, with its novel swath KaRin instrumentation, has provided comprehensive monitoring of both flood extent and surface elevation every 21-days since its launch in December 2022. This offers the chance, for the first time, to evaluate a global flood inundation model's extent and depth simultaneously. Here, we use the NASA SWOT High Rate Raster Product (L2_HR_Raster) to compare with the full set of Return Periods (RP's) from Fathom's (www.fathom.global) industry leading Global Flood Map V3 (Wing et al, 2023), for a set of global flood events since the launch of the mission. The L2_HR_Raster is ideally suited for this purpose, with its focus on ease of use and application of higher level quality filtering. This presentation will firstly assess SWOT's capability in observing flood event extent and elevation, including how to best discern fluvial flood events from other observed water surfaces (such as wet fields and surface water flooding). Secondly, we will discuss how the quality filters can be used to remove spurious observations and provide the most physically comparable set of observations with Fathom's V3 flood hazard layers. Finally, we will show a comparison between SWOT observations and the flood hazard maps, highlighting the areas of agreement and differences between the two; with a focus on how both datasets can compliment each other.

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Corresponding author:
Stephen Chuter (**Fathom**, **United Kingdom**), s.chuter@fathom.global

Use of new baroclinic tide models to improve the correction of internal tides in SWOT data

Loren Carrere (CLS, France); Mei-Ling Dabat (CLS, France); Michel Tchilibou (CLS, France); Perrine Abjean (CLS, France); Florent Lyard (LEGOS/CNRS, France); Clément Ubelmann (DATLAS, France); Gérald Dibarboure (CNES, France)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_001

Abstract:
Altimeter measurements are corrected from several geophysical parameters in order to isolate the oceanic variability and the tide correction is one of the most critical. Global ocean and loading tide models GOT and FES are used in present altimeter GDRs to remove the barotropic tide component, and the internal tides signatures can also be partly corrected with specific models since a few years.
Internal tides (IT) have a surface signature of several cm with wavelengths about 50-250 km for the first mode and smaller for higher modes. With the new higher resolution missions giving access to ocean small scale variability, the correction of these small-scale signals becomes mandatory for many applications.
As demonstrated in previous studies, using global IT models to correct the stationary IT signal allows a significant altimeter variance reduction on ocean regions where internal tides are generating and propagating (Zaron, 2019; Ubelmann, 2021, Carrere et al. 2021), although non-stationary IT signal due to seasonal variability of the ocean conditions and the interactions with mesoscales and other ocean waves is more difficult to estimate.
The new Surface Water and Ocean Topography (SWOT) altimetry mission launched at the end of 2022 is an opportunity to access ocean variability at a scale extending to 15-30 km and to better understand high-frequency dynamic processes such as the internal tide (IT). The analysis of SWOT 2-dimensions observations during the Calval (1-day orbit) has allowed producing a new specific IT solution for SWOT in the Amazon area (Tchilibou et al 2025). The present study proposes an evaluation of some new global IT models for the removal of the stationary IT variability in SWOT and nadir altimeter measurements. We have studied several new IT models: HRET14 and HRET22 (Zaron 2024), ZHAO30yr (Zhao 2025) and MIOST-IT24 (Tchilibou et al. 2025). Results are presented here and they indicate an improvement of the recent models which permit reducing further the residual sea level variance on ocean regions impacted by IT.
Corresponding author:
Loren Carrere (**CLS**, **France**), lcarrere@groupcls.com

A test case for correcting coherent and incoherent tides in altimetry data using MIOST

Michel Tchilibou (CLS, France); Loren Carrere (CLS, France); Gérald Dibarboure (CNES, France); Maxime Ballarotta (CLS, France); Clement Ubelmann (Datlas, France)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_002

Abstract:
An internal tide (IT) is an internal wave that varies at the tidal frequency and can be observed by altimetry. There are two types of internal tide: a coherent or stationary internal tide, which is in phase with the barotropic tide; and an incoherent or non-stationary internal tide, which results from the interaction between the internal tide and its propagation environment. This work aims to contribute to the improvement of the knowledge and the correction of the non-stationary part of IT in the ocean and is within the scope of several projects (Tide-SALP and TOSCA-SCOEPUS).

In this study, we present a test case for correcting the coherent and incoherent internal tides in the altimetric SLA (Sea Level Anomaly) i.e. an internal tide correction in two stages. The 2023 SLA from six missions (S3a, S3b, C2, H2b and J3) are used as reference data, while the Saral/Altika and SWOT nadirs are used as independent data. Firstly, the HRET22 (High-Resolution Empirical Tide 22) internal tide atlas is used to remove the coherent internal tide from the SLA of referenced missions. Secondly, the MIOST (Multivariate Inversion of Ocean Surface Topography, Ubelmann et al.,2022) inversion method is employed to evaluate the incoherent tide in the SLA residual from the first step. Various time windows are tested to evaluate the incoherent tide. All these tests show that MIOST can capture nonstationary internal tide amplitudes between 2 and 5 cm i.e. 20–40% more variability compared to the HRET22 coherent internal tide amplitude. On independent missions, combining coherent and incoherent solutions improves the quality of the correction as shown in the Indonesian region of the Pacific.

Corresponding author:
Michel Tchilibou (**CLS**, **France**), mtchilibou@groupcls.com

Combining SWOT and numerical modeling in the Indonesian seas to investigate the internal tides and internal solitary wave interactions

Simon Barbot (Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3), France); Florent Lyard (Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3), France); Michel Tchilibou (CLS, France); Patrick Marsaleix (Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3), France); Marine Herrmann (Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3), France)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_003

Abstract:
The internal tides are generated when the barotropic tides pass through a steep slope, perturbing the stratification of the ocean. With complex bathymetry, deep semi-closed seas, shallow straits, and a strong spring-neap tide cycle due to similar diurnal and semi-diurnal tides, the Indonesian seas are the realm of internal tides. The specific shape of the straits also leads to a rapid degeneration of the internal tides into internal solitary waves (Qiu et al., 2024). The numerous sites of generation around the same sea result, for the surface elevation, in a complex pattern mixing a wide range of wavelengths and directions. In the scope of TOSCA-SCOEPUS project, we aim to distinguish the internal solitary waves from the internal tides in SWOT observations.
On one hand, the SWOT Unsmoothed observations are unprecedented in characterizing the internal solitary waves, e.g. sampling down to 1 km wavelengths in places where these waves are the most energetic. On the other hand, the time sampling and the duration of the time series can only provide information on the internal tides through harmonic analysis (ITkar method; Tchilibou et al., 2025) during the CalVal phase. In contrast, numerical modeling (SEA simulation; Garinet et al., 2024) cannot resolve the internal solitary waves but is used to characterize the theoretical regime of internal tides. To compare both approaches, new high-resolution bathymetry and coastlines have been used in the model to improve the tidal circulation and match most of the generation sites. The combined approach leads to the quantification of the internal tides dissipation that the numerical models lack and could be used to validate the wave-wave and wave-circulation interactions simulated.
Corresponding author:
Simon Barbot (**Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3)**, **France**), simon.barbot@univ-tlse3.fr

Baroclinic Tides Estimated from SWOT Science Mission Data

Edward Zaron (Oregon State University, United States)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_004

Abstract:
The duration of the Science Mission is now sufficient to resolve and map baroclinic tides at the dominant semidiurnal frequencies of M2 and S2. New estimates are derived from SWOT using a remove/restore strategy to identify features of the baroclinic tides not resolved in older baroclinic tide models. Tidal predictions based on the new estimates typically explain from 3% to 20% more SSH variance than HRET8.1 as judged against the CryoSat-2 observations, which are used for validation. Based on regions examined thus far, the largest accuracy gains are achieved in areas with complex coastlines and large-amplitude internal tides, such as the Banda Sea. There is evidence from parts of the North Pacific that SWOT-based tidal estimates capture interannual variability of baroclinic tides, since the predictions are less accurate for CryoSat-2 data collected in years prior to SWOT launch. Development of the tidal estimates is an ongoing exercise, since results are sensitive to residual long-wavelength errors and data flagging/selection, aspects of the SWOT data which are evolving in different product releases. Results also depend on assumptions used to smooth SWOT-derived harmonic constants and interpolate them into data gaps between swaths.

Corresponding author:
Edward Zaron (**Oregon State University**, **United States**), edward.d.zaron@oregonstate.edu

Assessment of internal wave propagation through combined observations from SWOT (sea surface height and backscatter coefficient) and Sentinel-1 (surface roughness and Doppler radial velocities)

Clément Le Goff (LEGOS (CNES/CNRS/IRD/UT), OMP 14, avenue Édouard Belin,31400 TOULOUSE, France); Bertrand Chapron (IFREMER centre de Brest, 1625 Rte de Sainte-Anne, 29280 Plouzané, FRANCE); Isabelle Dadou (LEGOS (CNES/CNRS/IRD/UT), OMP 14, avenue Édouard Belin,31400 TOULOUSE, FRANCE)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_005

Abstract:
Until recently, the study of internal waves (IWs) in the ocean has primarily relied on high-resolution imagery, such as Synthetic Aperture Radar (SAR) and optical sensors. However, prior to the launch of the Surface Water and Ocean Topography (SWOT) mission, detecting the sea surface height (SSH) perturbations associated with these waves was challenging due to the limited spatial resolution of conventional nadir altimeters. As a swath-based SAR interferometer, the Ka-band Radar Interferometer (KaRIn) onboard SWOT provides not only SSH measurements but also the backscatter signal (sigma0), which can be directly compared to sigma0 or surface roughness products derived from Sentinel-1 SAR data.

In this study, we present a novel analysis conducted in the coastal region offshore of the Congo River mouth, based on the synergistic use of SWOT (250 m) and Sentinel-1 (10 m) observations. On both sides of the submarine canyon associated with the Congo River (north and south), internal waves are clearly detected in both the SSH and sigma0 products from KaRIn. On October 24th, 2023, Sentinel-1 sampled the region approximately 2.5 hours after the SWOT overpass. By tracking the internal wave fronts in both SWOT sigma0 and Sentinel-1 roughness maps, we estimated the phase velocity of the waves.

Two distinct phase velocities were identified: a slower propagation (~0.3 m/s) north of the canyon and a faster one (~0.8 m/s) to the south. These differences likely result from variations in environmental conditions, including stratification, bathymetry, and background currents. For instance, Doppler-derived radial velocities from Sentinel-1 reveal opposing ocean currents of up to 0.5 m/s in the northern region, which counteract internal wave propagation. In contrast, southern currents are weaker and aligned with the direction of wave propagation, likely facilitating faster wave speeds.

Moreover, in the case of internal waves, simultaneous knowledge of the phase velocity and sea surface height (SSH) along the direction of propagation is particularly valuable, as these parameters are linearly related to the orbital surface velocities (Gill, 1982). Analyzing the spatial gradients of SSH along the wave crest allows the identification of convergence and divergence zones at the surface, potentially related to vertical velocities of the waves. These dynamic features correspond to modulations in surface roughness and are reflected in the variations of the backscatter signal (sigma0) observed by SWOT. These waves are also detected in the 2km SWOT SLA data.

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Corresponding author:
Clément Le Goff (**LEGOS (CNES/CNRS/IRD/UT), OMP 14, avenue Édouard Belin,31400 TOULOUSE**, **France**), clement.le-goff@univ-tlse3.fr

Capturing the evolution of baroclinic tides into internal solitary waves in the St. Lawrence Estuary with SWOT altimetry

Xavier Chartrand (Université du Québec à Rimouski - Institut des sciences de la mer, Canada); Cédric Chavanne (Université du Québec à Rimouski - Institut des sciences de la mer, Canada); Pascal Matte (Environment and Climate Change Canada - Meteorological Research and Development, Canada)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_006

Abstract:
The Surface Water and Ocean Topography (SWOT) mission will significantly improve and expand near-global mapping of tidal cycles that contribute significantly to sea-level variability by collecting, at an unprecedented resolution, sea-level elevation measurements in nearshore areas that were poorly mapped by previous altimetric missions. Despite SWOT's limitations in capturing tides due to undersampling, mapping tides is a prerequisite for distinguishing them from other physical processes that occur on comparable scales, such as mesoscale and submesoscale eddies and fronts, which are key targets for SWOT. The mechanisms by which energy moves from barotropic and baroclinic tides to smaller scales have been extensively researched in the global ocean. However, tracking the tidal energy budget in coastal shallower areas remains challenging due to the complex nonlinear deformation of sinusoidal tidal waves caused by bathymetric gradients, water discharge, and ambient stratification. Using numerical modeling and SWOT observations, we seek to decipher the tidal energetics of the St. Lawrence Lower Estuary, a major stratified North American waterway strongly driven by tides, and that also received additional attention during SWOT calibration-validation stage and AirSWOT campaign. Our primary finding is that SWOT can observe the prominent surface elevation signal of internal solitary waves generated by the nonlinear steepening of the low-mode baroclinic tide propagating in the St. Lawrence Estuary, which periodically redistributes the tidal energy toward scales of one or a few kilometers. This reveals the potential of SWOT to capture tidal variability at much finer scales previously missed by its predecessors. Future work will focus on understanding the key mechanisms and physical parameters that control the decay of baroclinic tides into internal solitary waves, which could lead to improved detection of baroclinic tides using altimetry.
Corresponding author:
Xavier Chartrand (**Université du Québec à Rimouski - Institut des sciences de la mer**, **Canada**), xavier.chartrand@uqar.ca

The decay of the low-mode internal tide due to near-resonant wave-wave interactions

Maarten Buijsman (University of Southern Mississippi, United States); Dheeraj Varma (University of Southern Mississippi, United States); Mujeeb Abdulfatai (University of Southern Mississippi, United States); Miguel Solano (Sofar Ocean, United States)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_007

Abstract:
The decay of the internal tide contributes to watermass mixing in the global ocean, which is relevant for the overturning circulation and the dispersal of biogeochemial tracers. In this study, we report on an understudied decay mechanism due to near-resonant interactions between low-mode internal tides. These interactions cause cross-scale energy transfers from the internal tide to higher harmonic waves. The phase locked harmonics cause the aggregate wave form to steepen and eventually form into solitary waves, which are easily detected in SWOT measurements.

We diagnose a 30-day forward global ocean model simulation with a 4-km grid spacing and 41 layers. This simulation is forced with realistic tides and atmospheric fields. We decompose the 3D fields into tidal and supertidal (>2.5 cycles per day) vertical modes and quantify their energetics. The supertidal band is dominated by the higher harmonics of the diurnal and semidiurnal tides. Its higher harmonic energy projects on the internal wave dispersion curves in frequency-wavenumber spectra and is captured mostly by the terdiurnal and quarterdiurnal mode-1 waves. Terdiurnal modes are mostly generated in the west Pacific, where diurnal internal tides are strong. In contrast, quarterdiurnal modes occur at all longitudes near strong semidiurnal generation sites.

The supertidal energy as a fraction of the tidal energy is elevated along semidiurnal internal wave beams in the tropics. We attribute this to near-resonant mode-mode interactions, which are enhanced for low f. We quantify the cross-scale energy transfers with a coarse-graining method. These transfers are enhanced in regularly spaced banding patterns due to the constructive superposition between mode 1 and mode 2 waves. A peculiarity is that weakly nonlinear theory only predicts resonant interactions between semidiurnal modes of the same mode number and not between mode 1 and mode 2 waves.

We plan to run nonhydrostatic simulations to better understand these modal interactions and compare the resulting wave forms with SWOT observations, for example along the Amazon beam.

Corresponding author:
Maarten Buijsman (**University of Southern Mississippi**, **United States**), maarten.buijsman@usm.edu

Internal tide energy decay in the Equatorial Pacific

Oladeji Siyanbola (University of Southern Mississippi, United States); Maarten Buijsman (University of Southern Mississippi, United States); Roy Barkan (Tel Aviv University, Israel); Michal Shaham (Tel Aviv University, Israel)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_008

Abstract:
Accurately representing sea surface temperature in the Equatorial Pacific, particularly the spatial extent and intensity of the equatorial cold tongue, is critically important, as biases in this region can lead to substantial errors in global climate projections. The accuracy of these predictions hinges critically on correctly modeling the vertical distribution of mixing, a process in which internal tides may play a pivotal role. Model simulations and satellite altimetry data of the Equatorial Pacific indicate a pronounced decay of internal tides radiating from the Hawaiian and French Polynesian Islands. We aim to understand the causes of this decay and how this energy loss affects ocean mixing in the region. We analyze a 2-km horizontal resolution Regional Ocean Modeling System (ROMS) simulation of the Equatorial Pacific. The 2-km resolution ROMS simulation is nested from a 6-km resolution parent's run of the Equatorial Pacific, which has realistic stratification, surface tidal and atmospheric forcing. We will validate the surface tides with TPXO and the decay of the internal tides using the SWOT CAL/VAL daily repeat cycles. The transfer of internal tide energy to high wavenumbers and frequencies is quantified using a coarse-graining framework. We hope to determine what mechanisms contribute to the internal tide decay: interactions with the background flows, e.g., tropical instability waves, and/or or nonlinear steepening due to wave-wave interactions, which are enhanced in the tropics.

Corresponding author:
Oladeji Siyanbola (**University of Southern Mississippi**, **United States**), oladeji.siyanbola@usm.edu

Mapping Instantaneous Internal Tides from SWOT by An Improved Mapping Technique

Zhongxiang Zhao (University of Washington, United States); James Girton (University of Washington, United States)

Session: Oceanography: Tides and Inertia-Gravity Waves
Presentation type: Poster
Poster number: ST2025OS5_009

Abstract:
We have recently developed a 3-step mapping technique that consists of two rounds of plane wave analysis with spatial bandpass filtering in between. Our technique is to construct and decompose the internal tide field from satellite altimetry, which samples the global sea surface topography irregularly with insufficient spatial and temporal resolution. Our technique extracts internal tides in three rounds of temporal and spatial filtering and thus can significantly suppress model errors. On a global average, model errors are as low as <0.5 mm in ZHAO30yr, our latest model based on 30 years of nadir altimetry data. The low model errors also allow us to extract minor constituents K2, P1 and Q1, which have not been tackled in previous empirical internal tide models.

We map internal tides from SWOT by our improved mapping technique. The new SWOT mission samples sea surface topography along a 120-km swath with a 2-km spatial resolution. The combination of our improved technique and SWOT data yields unprecedented details of the global internal tide field. In our 2024 JGR-Oceans paper, we demonstrated that we can extract M2 internal tides using as short as 75 days of SWOT data. In some regions (the tropical South Atlantic Ocean, the central North Pacific Ocean, and the Melanesian region), the 75-day model performs better than our 30-year model. Evaluation using seasonally subsetted altimetry data reveals that internal tides have significant temporal variations. The 75-day model performs the best in fall, because the model is constructed using SWOT data largely in fall. We suggested that the large phase anomalies in the 75-day model can be used to better make internal tide correction to SWOT. In 2025, we further applied our mapping technique to two years of SWOT data. We mapped instantaneous M2 and K1 internal tides using 3-cycle subsetted SWOT data (~63 days). The resulting time series of internal tide fields demonstrate significant seasonal and year-to-year variations. We separated a few long-range internal tidal beams and quantified their along-beam spatiotemporal variations. The coherence of internal tides is studied using the time series instantaneous internal tide fields.

Corresponding author:
Zhongxiang Zhao (**University of Washington**, **United States**), zzhao@uw.edu

Sentinel-3 Next Generation Topography Mission Performance and Uncertainty Assessment (S3NGT-MPUA)

Noemie Lalau (Magellium, France); Thomas Vaujour (Magellium, France); Michael Ablain (Magellium, France); Clement Ubelmann (DATLAS, France); Lucile Gaultier (ODL, France); Fabrice Collard (ODL, France); Nicolas Taburet (CLS, France); Julien Renou (CLS, France); Maxime Vayre (CLS, France); Emma Woolliams (NPL, United Kingdom); Sajedeh Behnia (NPL, United Kingdom); Frederic Nouguier (Ifremer, France); François Boy (CNES, France); Louise Yu (CNES, France); Alejandro Egido (ESA, Netherlands); Craig Donlon (ESA, Netherlands); Robert Cullen (ESA, Netherlands)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_001

Abstract:
The Sentinel-3 Next Generation Topography (S3NGT) mission is designed to ensure the continuity of the existing Copernicus Sentinel-3 nadir-altimeter measurements from 2030 to 2050 while also improving measurement capabilities and performance. This mission consists of two large spacecrafts equipped with an across-track interferometer swath altimeter (SAOOH), a synthetic aperture radar (SAR) nadir altimeter (Poseidon-5 (POS-5)), a multi-channel microwave radiometer, and a precise orbit determination suite. The SAOOH instrument builds upon the swath altimetry advancements pioneered by the Surface Water and Ocean Topography (SWOT) mission, launched in December 2022 with the KaRIn instrument. However, the SAOOH instrument differs from KaRIn in several key aspects, including a shorter baseline (3 m instead of 10 m) and a different Signal-to-Noise-Ratio (SNR) of the antenna compared to SWOT/KaRIn's. Given these differences, it is imperative to pay utmost attention to the performance of the S3NGT mission before its launch to ensure its success.

The ESA-supported S3NGT preliminary mission performance and uncertainty assessment (S3NGT-MPUA) study is ongoing. In this study, we have made significant progress since its initiation in May 2023. Here, we outline the key achievements for each objective of this project.

The first objective of the study is to conduct a preliminary assessment of the performance of S3NGT Level-2 products before the mission's launch. This assessment focuses on ocean surfaces and inland waters. To achieve this, we first developed a strategy to generate S3NGT-like data. For ocean surfaces, we employed a strategy that utilized inflight data from the SWOT mission (level-3 products) to create a first dataset and an Ocean General Circulation Model (OGCM) to simulate S3NGT-like data for a second dataset. We introduced S3NGT-specific instrumental uncertainties into the OGCM data and SWOT inflight level-3 data using a scientific simulator developed by ODL. These two complementary approaches provide respectively lower and upper bounds of S3NGT performances. Additionally, we evaluated the behavior of swath measurements for high sea state conditions by degrading SWOT Level-1B data with instrumental characteristics that are similar to SAOOH ones. For inland waters, we developed a similar strategy to generate S3NGT-like data from SWOT L2 Pixel cloud products, incorporating specific S3NGT uncertainties. All these three SWOT-derived datasets are examples of applications of SWOT data and help gain knowledge in swath altimetry. This activity also included defining key metrics to describe the mission's performance for several variables including sea surface height, sea state, systematic errors, and inland water surface elevation. We evaluated these metrics with our generated S3NGT-like data and compared these results to the S3NGT Mission Requirements Document (MRD). This approach provides valuable insights into the expected capabilities of S3NGT products and highlights areas where the mission design can be refined to meet operational requirements.

The second study objective is to develop a comprehensive uncertainty model and budget following established metrological principles. The first part entails a metrological assessment of the S3NGT mission, while the second part focuses on verifying and validating the S3NGT uncertainty budget. This has involved creating a clear metrological traceability diagram representing the Swath altimeter and using this to identify (and later quantify) individual sources of uncertainty.

The third study objective is to evaluate options for in-orbit calibration of the S3NG-TOPO mission. This includes methods such as using orbit crossovers to correct for known systematic errors in water elevation over the ocean and inland water bodies. The evaluation must consider the different latencies of the S3NG-TOPO products. Indeed, given the stricter latency requirements for the S3NG-TOPO mission than for SWOT, the number of available orbit crossovers for cross-calibration measurements is limited.

The final study objective is to assess the uncertainty in cross-calibrating S3NG-TOPO with the current S3 constellation and reference mission (S6) using established or innovative methods. The primary goal is to ensure the continuity of S3NGT measurements, including an effective cross-calibration between the current S3 constellation and the future S3NG-TOPO constellation, particularly for the nadir altimeter system incorporating the microwave radiometer (MWR).

Corresponding author:
Noemie Lalau (**Magellium**, **France**), noemie.lalau@magellium.fr

Assessment of Swath Altimetry Performance for S3NG-T HR Mode Using the Radarspy Simulator

Carlos Yanez (CNES, France); François Boy (CNES, France); Louise Yu (CNES, France); Damien Desroches (CNES, France); Julien Bosman (CS, France)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_002

Abstract:
We present the contribution of CNES to the Sentinel-3 Next Generation – Topography (S3NG-T) project. Building on the legacy of the SWOT mission, which was the first to demonstrate the use of SAR interferometry for surface water altimetry, the European Space Agency (ESA) has committed to the swath altimetry approach for the successor to the current Sentinel-3 (S3) operational mission. This new approach, commonly referred to as swath altimetry, enables the retrieval of two-dimensional characteristics of water surfaces with significantly improved spatial coverage compared to conventional nadir altimetry (as employed on Sentinel-3). However, its operational implementation requires a rigorous assessment of performance and compliance with accuracy requirements across diverse observation scenarios.

To support the performance assessment of S3NG over oceanic and inland water surfaces, we enhanced Radarspy, the CNES in-house swath altimetry simulator. The swath altimeter onboard S3NG-T, designated SAOOH (Swath Altimeter for Operational Oceanography and Hydrology), introduces several key differences relative to SWOT's instrument: notably, a reduced interferometric baseline of 3 meters, the use of multiple receivers (four per swath side—left and right—to flatten the antenna gain pattern), and an closed-burst mode, wherein bursts of 192 radar pulses are alternately transmitted to the left and right swaths.

We present the outcomes of simulation campaigns conducted using Radarspy, evaluating SAOOH's performance across scenes with varying surface reflectivity and under different instrument operating conditions. These simulations provide insight into the High-Resolution (HR) mode capabilities and inform the trade-offs between on-board data volume constraints and compliance with user requirements for hydrology applications.
Corresponding author:
Carlos Yanez (**CNES**, **France**), carlos.yanez@cnes.fr

Analysis of relationships between soil moisture and false water detections in SWOT PIXC products

Maxime Azzoni (ICUBE-SERTIT, France); Thomas Ledauphin (ICUBE-SERTIT, France); Hervé Yésou (ICUBE-SERTIT, France)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_003

Abstract:
This study investigates the relationship between soil moisture conditions and false water detections observed in SWOT's class 4 "water" products over agricultural areas. The analysis addresses spurious water classifications that occur in SWOT PIXC data, particularly over temporarily saturated agricultural parcels following precipitation events.
The methodology leverages pre-existing soil moisture products generated by INRAE (UMR TETIS) using combined Sentinel-1/2 observations (El Hajj et al., 2017; Baghdadi et al.) covering agricultural parcels and grasslands at ~0-5 cm depth. The study focuses on cross-analysis between SWOT PIXC classifications (classes 2, 3, and 4), soil moisture conditions, and meteorological data (ERA5 precipitation) across two sites in France (Alsace Plain, Lorraine Plateau) from March 2023 to January 2024.
SWOT PIXC data analysis was performed using 183 soil moisture maps (100 for Alsace Plain, 83 for Lorraine Lakes area), with statistical correlation performed between soil moisture temporal evolution and PIXC classification patterns. The study incorporated precipitation data, pedological constraints (focusing on poorly-drained soils), and land cover differentiation between grasslands and crops to understand detection sensitivity variations.
Key findings reveal that SWOT effectively detects temporarily water-saturated agricultural parcels as "water" following significant precipitation events. Critical thresholds were identified: ~11% volumetric soil moisture content and 6mm precipitation levels trigger increased false water detections (for the observed area and study period). A significant temporal shift in PIXC class distribution was observed, with class 2 (land-near water) decreasing from ~70% to ~50% and class 4 (open water) increasing from ~5% to ~25% during periods of rapid soil moisture recovery following precipitation events. The relationship between soil moisture and false water detections follows a non-linear pattern, with detection frequency increasing dramatically above critical moisture thresholds. The phenomenon affects crops more than grasslands, though this observation must be considered within the context of the study area's land cover distribution (fewer grasslands than crops in the analyzed parcels). Cross-correlation analysis demonstrates strong temporal correspondence between precipitation events, soil moisture peaks, and SWOT class 4 detection spikes, particularly on poorly-drained agricultural soils with limited vegetation cover (NDVI < 0.7, corresponding to the soil moisture detection method applicability threshold). These results provide insights for SWOT data quality assessment and suggest that soil moisture and precipitation context could be considered when interpreting water detection products over agricultural landscapes. The study contributes to understanding SWOT's detection behavior and provides preliminary quantitative thresholds that may help identify potential false positive water detections in similar agricultural areas.

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Corresponding author:
Maxime Azzoni (**ICUBE-SERTIT**, **France**), azzoni@unistra.fr

Yangtze intermediate basin lakes and sub-lakes monitoring based on SWOT products

Sabrine Amzil (ICUBE-SERTIT, France); Thomas Ledauphin (ICUBE-SERTIT, France); Maxime Azzoni (azzoni@unistra.fr, France); Hervé Yésou (ICUBE-SERTIT, France)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_004

Abstract:
Lakes in the basin of the Yangtze River, play a fundamental role in regional bio-geochemical cycles and provide major services to the communities, provisioning services (drinking water, fishing) and biodiversity keeping. However, the extreme temporal and spatial variability of these massive but extremely shallow ecosystems prevents a reliable quantification of their dynamics with respect to changes in climate and land use.
Three sets of water bodies presenting diverse hydrological context and all having rich biodiversity are taken into account:
- The Poyang lake and it's interconnected sub-lakes of the Poyang (PLNR) and of Nanjishan Natural Reserves.
- The Xiaoxi, Daxi, Caisang sub-lakes located into the Western Dongting lake, Hunan Province.
- The disconnected lakes of the Anhui Province Caizi lake (~175 Km2), Baidang Lake (~73 Km2), Shengjin Lake (~ 120 Km2) and Wuchang Lake (~ 73 Km2).

A first step of the study carried out within the framework of the ESA MOST DRAGON program consisted in setting up a reference database in terms of water extent and height, over the different targets, in order to be able to characterize the dynamics of these areas, their interrelationship as well as the maximum extent of these water bodies.
Water extents were derived from Sentinel-2 time series, i.e. based on the analysis of about 150 images for each of the Anhui province lakes, as well as a few additional SAR datasets, Sentinel-1, IceEye, Radarsat-2, allowing to cover some critical periods such as the 2020 severe flood event giving access to the water maximum extent mask. Altitude information was derived from Sentinel-3 times series, as well as a few ICESat-2 data. It is noticeable that the spatial coverage of altimetry data is very weak and only a few lakes were covered by Sentinal-3 tracks. A particular attention was paid over the Baidang and Shengjin Lakes.
In a second step, the SWOT Orbit Science data were analyzed. Based on two SWOT products to retrieve water height levels and lake surface areas: L2_HR_PIXC and L2_HR_LakeSP during the scientific phase starting from July 2023. In this paper we present only the altitude assessment work during the filling period, some LakeSP observations tend to incorporate neighbouring bodies with the main water extraction of the lake, resulting in incorrect/spoiled surface areas. Water surface elevations were generated from the L2_HR_PIXC products by computing the mean height of PIXC class 4 points (Open Water) per acquisition over the polygons defining the 7 and 6 sub-lakes both for the Nanjishan Natural reserve and Poyang lake National reserve.
The analysis of SWOT products was carried out as follows:
- Evaluation of the accuracy of the PIXC classes (water only, land and water, dark water, etc).
- Outliers removal.
- Exploitation of Bright Land and Dark Water flags.

The first step was to check whether SWOT could be used to monitor the filling/emptying cycles of the sub-lakes, bearing in mind that during the dry season these sub-lakes are at different altitudes within the same sub-set constituting the Natural reserves.
At all the sites, the SWOT data clearly identifies the sub-assemblies during the dry season, highlighting the differences in altitude (between the different sub-lakes: i.e. 2 m of elevation difference for the Nanjishan case, 4 m in the case of PLNR sub-lakes. When the water level rises during the rainy season, there is a clear homogenization of altitudes, corresponding to the sub-lakes flooding, forming a single vast complex. In addition, in the Dongting lake sector, the sub-systems are clearly distinct, with Caising lake separated from Dongting lake and the other sub-lakes by a high dyke.

In terms of accuracy, the SWOT altitudes were compared with water elevation derived from ICESat-2 and Sentinel-3. Based on this, accuracy is better than 10 cm (at 1 sigma).
In addition it was possible to access to in-situ water level from DuChang station, corresponding to the central area of the lake. These data were referenced in Wusong Datum for which the transposition in WGS84 is not so simple and accurate. We can observe that the lake water elevation dynamics derived from the SWOT PIXC and the in situ data are very similar, presenting the same peaks and trends but with a mean residual bias of 1.48 m. When this bias is removed the two curves are merged.

This work presents the first exploitation of SWOT products over Chinese sensitive and threatened ecosystems. Over these complex hydrographical systems, SWOT allows a unique monitoring of LWE and LWL sub-lake by sub-lake with never unreached accuracy and revisit. Therefore SWOT LakeSP is very sensitive to the neighborhood of these wetlands and complicated lakes inducing incorrect/spoiled surface areas.

Corresponding author:
Sabrine Amzil (**ICUBE-SERTIT**, **France**), s.amzil@unistra.fr

Global hydropower potential of world rivers revealed by the SWOT Mission

Jonathan Flores (University of Massachusetts, United States); Colin Gleason (University of Massachusetts, United States); Casey Brown (University of Massachusetts, United States); Jida Wang (University of Illinois Urbana-Champaign, United States); Rangel Daroya (University of Massachusetts, United States); Fiona Bennitt (University of Massachusetts, United States); Elisa Friedmann (University of Massachusetts, United States); Dongmei Feng (University of Cincinnati, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_005

Abstract:
Dams control a substantial portion of global river systems. Numerous efforts have been made to create comprehensive data on their location and hydropower capacity. However, to date, these dam databases remain incomplete, particularly in regions where validation from remote sensing approaches and ground-based observations is limited. This study presents a deep learning framework to detect dams using direct observations from the recently launched Surface Water and Ocean Topography (SWOT) satellite mission. By analyzing node-level river profiles of water surface elevation, surface area, and width, we trained a one-dimensional convolutional neural network to classify dammed reaches based on Global Dam Watch, GeoDAR, and Global River Obstructions Database. The best dam detection model from our initial tests achieved an average accuracy of 0.83, with precision, recall, and F1-score of 0.82, 0.85, and 0.83, respectively. From this model, we can identify undocumented dams missing from existing databases, and also differentiate hydropower-producing dams from non-hydropower dams. Then, we will estimate the potential hydropower generation of rivers globally based on SWOT-estimated discharge and hydraulic head taken from height observations on either side of dams, which is expected to reveal the untapped capacity in underreported basins and the currently tapped but unreported capacity. This study will offer a reproducible method for monitoring dam infrastructure and evaluating hydropower resources without relying on national reporting or in-situ data. Our findings will highlight the potential of SWOT to advance global dam mapping and hydropower assessment.

Corresponding author:
Jonathan Flores (**University of Massachusetts**, **United States**), jflores@umass.edu

Topography of Amazon floodplain lakes from SWOT: preliminary results

Alice Fassoni-Andrade (University of Brasília, Brazil); Deborah Correia-Lima (UnB, Brazil); Fabrice Papa (IRD, France); Daniel Moreira (SGB, Brazil); Fleischmann Ayan (IDSM, Brazil)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_006

Abstract:
SWOT mission provides multiple and simultaneous observations of water surface elevation (WSE) and water extent. In addition to raster products with spatial resolutions of 100 m and 250 m, the mission will also provide a lake topography product at ~50 m resolution after several acquisition cycles over natural and artificial lakes. Here, we tested the Flood2Topo method (Fassoni-Andrade et al., 2020a) to derive the topography of Amazon floodplain lakes using only SWOT data. The method is based on a flood frequency map derived from water extent raster using quality flags (0 for good, 1 for suspect), combined with WSE duration curves obtained from SWOT observations. The bottom elevation at each pixel is defined as the WSE with an exceedance probability equal to the flood frequency. This transforms the flood frequency map into an elevation map (EGM08) using a raster-based approach, avoiding the need for interpolation, as required by the traditional waterline method. Preliminary results for the Lago Grande de Curuai floodplain in the lower Amazon River show an RMSE of 2.53 m, Pearson correlation of 0.48, R^2 of 0.23, and a bias of 2.02 m when compared with estimated (mean 6.37 m) and observed (mean 4.36 m) bathymetry. These errors are lower than those of the SRTM DEM (RMSE = 3.55 m; R^2 = 0; Fassoni-Andrade 2020b), which represents floodplain lakes as flat surfaces. However, the errors are higher than those obtained using the same method with Landsat images and in situ WSE observations (RMSE = 1.30 m; R^2 = 0.59; Fassoni-Andrade 2020b). The extreme droughts of 2023 and 2024 in the central Amazon provided an opportunity to map the drainage network and lakes in detail using only SWOT observations from July 2023 to April 2025. Larger errors are found in areas dominated by macrophytes, where SWOT likely detected water presence, but the elevation corresponded to the vegetation surface. Importantly, no bias was observed in relation to satellite nadir distance. The Flood2Topo method shows strong potential for generating lake topography using SWOT data and may contribute significantly to the mission's official topography product.

Fassoni-Andrade, A. C., De Paiva, R. C. D., & Fleischmann, A. S. (2020a). Lake topography and active storage from satellite observations of flood frequency. Water Resources Research, 56(7), e2019WR026362.
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Corresponding author:
Alice Fassoni-Andrade (**University of Brasília**, **Brazil**), alice.fassoni@unb.br

Harnessing SWOT observations to advance well water disaster surveillance

Edward Beighley (Northeastern University, United States); Reza Jamshidi (Northeastern University, United States); Yuyang Li (Northeastern University, United States); Jenna Brooks (Northeastern University, United States); Kelsey Pieper (Northeastern University, United States); Nate Jones (University of Alabama, United States); Wilson Mize (North Carolina Dept. of Health and Human Services, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_007

Abstract:
A significant fraction of the global population is reliant on unregulated private wells for drinking water, which lack routine monitoring of water quality. However, many of these users are at risk of well water contamination due to surface water flooding. Our research advances well water surveillance after disasters by enhancing identification of well users at-risk of flood-related contamination using NASA Surface Water and Ocean Topography (SWOT) satellite observations. Our study is focused on North Carolina in collaboration with the State's Department of Health and Human Services. In this presentation, we present updates on our near real-time flood inundation mapping system. First, SWOT derived water surface elevations are assessed at USGS gauge locations throughout the state. Next, given that SWOT is not intended to capture peak flood conditions within our surveillance systems, observations for a range of river discharges are used to calibrate and validate our mapping system. To assess the value of integrating SWOT data into our systems, calibrated model results are compared to output from previously calibrated HEC-RAS hydraulics models (elevations and extents) and water extents derived from Sentinel-1. To illustrate the capabilities of our surveillance system, results for a recent flood event (Hurricane Helene, September 2024) are presented.

Corresponding author:
Edward Beighley (**Northeastern University**, **United States**), r.beighley@northeastern.edu

Perspectives of Application of SWOT data in South America

Alfredo Ribeiro Neto (Federal University of Pernambuco, Brazil); Rodrigo Abarca del Rio (University of Concepción, Chile); Oliver Saavedra Valeriano (Universidad Privada Boliviana, Bolivia); Rômulo Oliveira (Hydro Matters, France); Paula Pacheco Mollinedo (Espace-dev, France)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_008

Abstract:
The global climate system is undergoing profound changes, primarily driven by increasing concentrations of greenhouse gases. One of the most impacted components is the freshwater system, as disruptions in the global water cycle are intensifying. These are particularly visible in the increasing frequency and severity of hydrological extremes (droughts and floods) with major social, environmental, and economic consequences. South America is experiencing these changes firsthand. In Brazil, unprecedented floods in the state of Rio Grande do Sul (2024–2025) displaced hundreds of thousands. In Bolivia, concurrent droughts and floods have impacted water security, while glacier retreat in the Andes threatens long-term water availability. In Chile, recurrent droughts and changing snowmelt patterns have disrupted water resources and increased flash flood risks in mountainous areas. These diverse climatic pressures highlight the need for robust monitoring and forecasting tools across contrasting hydrological environments. A collaborative research initiative, involving institutions from Brazil, Bolivia, Chile, and France has been designed to address these challenges by leveraging the capabilities of remote sensing products, in particular the validation of SWOT (Surface Water and Ocean Topography) data across diverse basins in South America. Traditional monitoring systems are limited in remote, data-scarce regions, where high spatial and temporal resolution are crucial. Satellite remote sensing, particularly SWOT, offers effective alternatives to fill these gaps and provide actionable information. This tool supports more accurate risk assessments for floods and droughts, as well as better water resource planning and climate adaptation strategies. The partnership aims to strengthen regional early warning systems and promote sustainable water management through scientific collaboration and capacity building. The first applications of SWOT data in the central Chile and Northeast of Brazil have shown promising results, demonstrating the potential of the mission to provide subsidies for water resources management.

Corresponding author:
Alfredo Ribeiro Neto (**Federal University of Pernambuco**, **Brazil**), alfredo.ribeiro@ufpe.br

Can SWOT be used to assess Vegetation Structure?

Jessica Fayne (University of Michigan, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_009

Abstract:
Vegetation disturbance events from pestilence, drought, and fires are expected to increase significantly with climate change. Wildfires and drought are increasingly causing extensive ecosystem damage, evidenced by changes to the vegetation morphology of the dominant plant functional type (PFT) or a transition of the PFT to another type. Severe burn events are rapid disturbance events, where the current ecosystem is burned, and the dominant ecosystem may not recover. Drought disturbance events are relatively slow in comparison, where trees are forced to adapt during water-limited periods to conserve energy and water, leading to dead branches after many seasons and finally resulting in mortality.

The NASA Surface Topography and Vegetation (STV) Incubation Study, in response to the Decadal Survey, identified Vegetation Structure as a designated observable, drawing additional attention to the importance of studying vegetation structure for understanding ecosystem dynamics, as well as carbon, hydrological, and energy fluxes and disturbance events such as for fires and droughts. However, the study notes that the systems and sensors necessary for observing vegetation structure are not yet well-developed, calling specialized attention to radar, a technology that has been used increasingly to study vegetation structure. “While radar approaches for characterization of 3D vegetation structure are emerging, there are gaps in how to best accomplish this and what retrieval accuracies could be achieved.”

Observations from spaceborne radar and lidar from GEDI, NISAR, and BIOMASS all aim to characterize vegetation structure, though the spatial resolutions of these products are more coarse than desired for improved understanding of 3D vegetation dynamics at the 1-hectare scale. Additionally, these instruments have high vegetation-penetration capabilities, an ideal condition for observing the ground beneath vegetation and through thick canopies. This benefit is a detriment to the fine-scale study of foliar vegetation, which changes on more rapid seasonal and subseasonal time scales due to water availability and seasonal phenological patterns.

The SWOT mission was designed to measure surface water–having characteristics that are flat and wet. In contrast, vegetation surface geometries and relatively lower dielectric values result in different scattering signals in comparison to water, yielding complex scattering coefficients associated with diverse vegetation structure and vegetation water (which includes vegetation-rainfall interception and within-leaf water).

This presentation provides an incremental update to a multi-year process to investigate the feasibility and utility of using SWOT data to observe vegetation structural dynamics. The aim of this work is to provide ‘a piece of the puzzle’ through foliar vegetation structural assessments, in support of vegetation structure and evapotranspiration communities. In turn, this work also aims to aid in the monitoring and prevention of climate change and anthropogenically driven ecosystem damage.

Corresponding author:
Jessica Fayne (**University of Michigan**, **United States**), jfayne@g.ucla.edu

Operational modes and hydrological implications of cascade reservoirs on major rivers revealed by SWOT observations

Meng Ding (Kansas State University, United States); Jida Wang (University of Illinois Urbana-Champaign, United States)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_010

Abstract:
With the increasing frequency of extreme climate events and rising water demand, the spatial and temporal distribution of surface water resources has become increasingly uneven. This variability highlights the essential role of reservoir systems in water allocation and hydrological regulation. Along many major rivers, cascade reservoirs, which are multiple reservoirs constructed and operated in sequence, play a key role in water supply, flood control, and hydropower generation. However, their operational modes and cumulative impacts on downstream rivers, particularly in transboundary river reaches, remain insufficiently observed and poorly quantified. Our study focuses on the cascade reservoir systems along the Yangtze and Mekong Rivers, aiming to reveal their operational behaviors and associated hydrological impacts. We utilize high-resolution, wide-swath remote sensing data from the Surface Water and Ocean Topography (SWOT) satellite mission, which provides repeated observations at least every 21 days. This high temporal resolution enables the detection of short-term changes in water surface elevation (WSE), thereby improving the accuracy of characterizing intra-annual dynamics of reservoirs and identifying their operational modes over time. Based on the WSE time series of reservoirs derived from SWOT observations, we apply wavelet analysis to examine the data in the frequency, time, and phase domains, aiming to reveal the correlations among reservoirs across seasonal and multiple frequency scales, as well as their operational modes. Building on this, we further convert WSE data into water storage estimates to quantify the regulation intensity and temporal characteristics of each cascade reservoir systems. To evaluate downstream hydrological responses, we analyze the impacts of cascade reservoir operations on mainstem discharge, with particular attention to how reservoir operations within the Chinese section of the Mekong River influence inflows to Southeast Asian countries, as well as how these upstream reservoirs affect discharge volumes in the Mekong Delta. This research advances our understanding of the operational modes of cascade reservoir systems, particularly in transboundary river regions, and provides scientific support for sustainable regional water management and international river governance.

Corresponding author:
Meng Ding (**Kansas State University**, **United States**), mengding@ksu.edu

Deriving Lake Circulation from SWOT: A Physically Constrained, Scalable Approach

Rodrigo Abarca del Rio (Department of Geophysics, Faculty of Physical and Mathematical Sciences, University of Concepción, Concepción, Chile, Chile); Jean-Francois Cretaux (Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, IRD, CNRS, CNES, UPS, Toulouse, France)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_011

Abstract:
Despite the growing importance of inland water bodies in climate, hydrology, and biogeochemistry, large-scale observations of lake circulation remain virtually nonexistent. The SWOT (Surface Water and Ocean Topography) satellite mission offers, for the first time, the spatial continuity and resolution required to resolve such dynamics at synoptic scales, directly from water surface geometry.
Lake circulation, shaped by size, depth, and morphology, controls key processes such as heat redistribution, nutrient transport, and oxygenation, yet remains largely undocumented across systems. The SWOT mission offers a unique opportunity to observe and compare these internal dynamics globally, opening new avenues for understanding lake function and diversity.
We investigate the capacity of SWOT data to reconstruct horizontal circulation patterns in large lakes by combining interferometric elevation measurements with precise geoid referencing and high-resolution bathymetry. This configuration enables the derivation of physically consistent surface flow fields, without the need for external forcing or in-situ observations. Elevation gradients, when interpreted relative to the geoid, reveal pressure surfaces that can drive internal redistribution of mass, while bathymetric features modulate the spatial structure of the flow.
Applied to Lake Titicaca and Lake Issyk-Kul, this methodology forms part of a broader, multi-phase project aiming to establish transferable strategies for deriving lake circulation patterns from satellite observations. Future developments will explore the integration of physical modeling, data assimilation techniques, and physically informed learning approaches, enabling deeper comparisons across lakes and dynamic reconstruction of circulation under diverse forcing scenarios. Ultimately, this framework offers a scalable foundation for dynamic lake monitoring worldwide, paving the way for a new generation of physically informed, satellite-driven freshwater circulation models.
Corresponding author:
Rodrigo Abarca del Rio (**Department of Geophysics, Faculty of Physical and Mathematical Sciences, University of Concepción, Concepción, Chile**, **Chile**), rabarcadelrio.univ@gmail.com

Quantification of Water Resources and Their Evolution

Guillaume HUGUET (ATOS, France)

Session: Hydrology: Open Science & Applications
Presentation type: Poster
Poster number: ST2025HS6_012

Abstract:
During the last five years, water resources have been heavily impacted by unusual climate situations, especially in the south of Europe, and in many other places around the World.

This leads to unprecedent tense situation, or even competition, between water users, urging heart-breaking prioritization between human drinking water supply, preservation of ecosystems, agriculture irrigation needs and industrial use.

In this situation, and through the coming years during which this tense will probably repeat and grow, the need for automated estimation and monitoring of water resources becomes compelling. The monitoring solution shall answer to the concerns of any kind of stakeholders, including resource administrators, regulatory institutions, environmental NGOs and users.

Moreover, this monitoring shall be systematic, unbiased, impartial, and dispassionate, in order to bring to local or country level decision makers the proper information to make their decisions and the levers to justify their prioritization decisions.

Earth Observation provides unprecedent data to this matter. For water bodies of scale starting from 1 ha, being either lakes, dams or reservoirs, either natural or man-made, Earth Observation is the perfect tool to monitor water resources at large scale, region wide or even country wide.

The combination of the results of different research, published during the last years, allows now to overcome the challenge of monitoring water bodies, for both surface and volume, only based on satellite data.

Inspired by those scientific papers, Atos has designed and developed on online service that automates water bodies monitoring based on the combination of different satellite sources, without the need of onsite data. The project is led in the scope of the agricultural and environmental services based on Atos' Copernicus DIAS, Mundi Webservices https://mundiwebservices.com/

For each water body to be monitored, a first theoretical model is built from DEM data (for example Copernicus Digital Elevation Model) and geophysical local parameters. In a second step, the theoretical model is tuned by shore evolution timeseries based on optical and SAR data (for example Copernicus Sentinel 1 & 2). A third step is applied to fine tune the model, with water level altitude calibration thanks to specialised altimetry missions dedicated to water bodies (for example CNES SWOT).

Once a collection of water bodies has been modelled, the proposed service is ready to automatically monitor this collection. This systematic monitoring of water bodies is achieved through optical and SAR data (including Sentinel 1 &2), with weekly revisit, monitoring both surface and volume. The service also provides past years analysis, and real-time monitoring and alerting.

This first service level addresses mainly water management institutions and all kinds of water resources users.

Despite not being in all the regions the main user of water, agriculture is usually the main consumer if it, meaning that water used by agriculture is not reinjected in the cycle of available water. In the scope of a region wide monitoring, the water bodies monitoring service can be combined with Earth Observation based irrigation detection. It is eased by region providing crop parcels inventory, and if not, this requires a parcel detection process, as a preparation phase. This service allows the correlation of water bodies volume variation, previous years rainfall in the area (for example based on ERA5 data) and evolution of irrigated surfaces among cultivated areas.

In a further step, Atos is planning to add a forecast level to the service, making use of Destination Earth digital twin data. DestinE will provide an unprecedent data source of temperature and rainfalls evolution forecast, and the ability to calculate their impact on available water volumes and irrigation needs.

This second service level addresses more specifically agricultural regulation institutions and farmers' crop strategy.

The goal of this poster is to sketch the proposed water resources monitoring process, detail the expected results and advantages, and highlight the challenges still to overcome.

Corresponding author:
Guillaume HUGUET (**ATOS**, **France**), guillaume.huguet@atos.net

Evaluating the impact of SWOT assimilation in Mercator Ocean International's forecasting system: insights from AdAC campaigns

Ergane Fouchet (Ergane FOUCHET, France); Mounir Benkiran (Mercator Ocean International, France); Pierre-Yves Le Traon (Mercator Ocean International, France)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_001

Abstract:
Many social and economic sectors directly depend on the ability to describe and predict ocean conditions at any time, location, and depth. With its unprecedented spatial resolution, the SWOT mission now enables global measurements of sea surface height (SSH) and the characterization of ocean dynamics down to the submesoscale. However, ocean models and data assimilation systems remain essential to dynamically propagate this surface information in time, in depth, and across other physical variables. Assimilating SWOT KaRIn global, high-resolution, and two-dimensional SSH observations thus offers strong potential for improving the representation and forecasting of small mesoscale features.

Ahead of the operational assimilation of SWOT Science Phase data into Copernicus Marine products, we analyze the response of the Mercator Ocean assimilation system to three months of daily observations from the Cal/Val phase. Our assessment is based on comparisons with in situ measurements from the SWOT-AdAC Consortium, which deployed a wide range of instruments directly beneath the satellite tracks. We focus on the QUICCHE and SMODE campaigns, in the Agulhas and California Currents respectively, to evaluate the assimilation of SWOT in dynamically different regions.

Surface drifters provide high-temporal-resolution trajectories and velocities, capturing a broad spectrum of ocean motions across scales. They are besides independent of both the model and assimilated satellite data, making them a valuable reference for model validation. We compare observed drifter trajectories with those of virtual Lagrangian particles seeded in the model velocity fields, both with and without SWOT assimilation. This approach allows us to assess the added value of SWOT assimilation for surface current dynamics and transport.

Corresponding author:
Ergane Fouchet (**Ergane FOUCHET**, **France**), efouchet@mercator-ocean.fr

Assimilating SWOT Observations into OTIS for Improved Regional Tidal Modeling in the Canadian Arctic Archipelago

Peter Matheston (The Ohio State University, United States); Jason Otero-Torres (NGA, USA); CK Shum (Ohio State University, USA)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_002

Abstract:
Recent work by Hart-Davis et al. (2024) has demonstrated that sea surface height anomalies (SSHAs) derived from SWOT (Surface Water and Ocean Topography) satellite measurements capture coherent tidal signals across a range of complex coastal environments, including estuaries and marginal seas. In addition, SWOT orbit is designed to minimize theoretical ocean tidal aliasing. These measurements provide a new opportunity to incorporate SWOT observations into regional tidal modeling frameworks to improve tide prediction accuracy and spatial resolution in challenging nearshore environments. Building on this foundation, we propose to extend the OTIS (Oregon State University Tidal Inversion Software) framework to assimilate SWOT SSHAs alongside conventional satellite altimetry and in situ tide gauge measurements.

Our study focuses on the Canadian Arctic Archipelago (CAA), characterized by narrow straits, fjords, complex bathymetry, and a highly modulated tidal regime. The CAA represents a particularly challenging environment for tidal modeling due to sparse in situ observations, sea ice variability, and limitations of classical along-track altimetry in coastal zones. The SWOT wide-swath capabilities offer unprecedented spatial coverage in these regions, providing an opportunity to improve tidal model fidelity significantly.

SWOT Level-2 SSH products will be processed to isolate the barotropic tidal signal before data assimilation. Isolating the tidal signal involves removing non-tidal variability through atmospheric pressure corrections, internal tide removal based on empirical models, and spatiotemporal filtering designed to suppress mesoscale and submesoscale noise. Harmonic analysis will be performed to extract major tidal constituents, including M2, S2, K1, and O1 using OTIS. SWOT-derived tidal amplitudes and phases will then be mapped onto the OTIS representer framework, treating each SWOT observation as a data constraint linked to the model solution at corresponding grid locations.

The OTIS inversion will be adapted to accommodate SWOT measurements' higher density and twodimensional spatial structure. Modifications will be made to the representer weighting and observational error covariance structure to reflect SWOT's variable noise characteristics, particularly near complex coastlines and regions of variable land/sea ice contamination. Assimilation will proceed via a least-squares inversion that balances observational fit with hydrodynamic consistency, as enforced by OTIS's linearized shallow water equations.

The resulting SWOT-enhanced tide model will be validated with tide gauge records and vertical displacement measurements from continuous GPS stations within the CAA. GPS-based estimates of tidal loading effects offer an independent means of validating the modeled ocean tide signal, particularly in regions where direct tide gauge observations are limited or seasonally unavailable. Comparisons will also be made against existing tidal models that assimilate conventional altimetry data, such as TPXO9v5 and FES2014b, to assess improvements attributable specifically to SWOT assimilation.

SWOT ground tracks converge at high latitudes and frequently overlap between swath crossovers throughout the CAA. This spatial redundancy enhances tidal estimation by providing multiple independent observations of sea surface height anomalies at closely spaced locations and varying phases of the tidal cycle. Such overlap improves signal-to-noise through ensemble averaging, increases spatial resolution in narrow straits and fjords, and strengthens harmonic analysis of major tidal constituents. It also provides more robust constraints for the OTIS inversion framework, allowing better resolution of localized tidal dynamics in regions where conventional altimetry is degraded. These advantages are especially critical in the CAA, where sharp tidal gradients and limited in situ observations challenge existing modeling approaches.

Based on the findings of Hart-Davis et al. (2024) and the increased spatial coverage afforded by SWOT, we anticipate that incorporating SWOT SSHAs into OTIS will reduce coastal tidal misfits and better resolve small-scale spatial variability in the CAA relative to models constrained solely by alongtrack altimetry. We expect improvements in narrow channels and near complex coastal boundaries, where traditional satellite altimetry lacks

sufficient resolution to resolve key dynamical features. This work aims to demonstrate the potential of wide-swath altimetry to transform regional tidal modeling in polar regions, with implications for scientific understanding of Arctic oceanography and operational forecasting in regions vulnerable to tidal forcing and sea ice variability.

Corresponding author:
Peter Matheston (**The Ohio State University**, **United States**), peter.matheston@proton.me

Data Assimilation of Surface Geostrophic Currents Derived from SWOT data in the Northwestern Pacific Ocean and marginal seas

Dohyeop Yoo (Department of Oceanography, Chonnam National University, Gwangju, Republic of Korea, South Korea); Byoung-Ju Choi (Department of Oceanography, Chonnam National University, Gwangju, Republic of Korea, South Korea)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_003

Abstract:
Previous studies have primarily focused on assimilating Sea Level Anomalies (SLA) observed by SWOT altimetry. However, direct assimilation of surface geostrophic currents derived from SWOT SLA data into ocean circulation models is rare. This study evaluates the impact of assimilating surface geostrophic currents derived from high resolution SWOT altimetry data into a regional ocean circulation model.

Data assimilation experiments were conducted for 2024 using the Regional Ocean Modeling System (ROMS). The Ensemble Optimal Interpolation (EnOI) method was applied, with a hindcast simulation spanning 1993–2022 used for the estimation of background error covariance. Two experiments were carried out to examine the effects of assimilating surface geostrophic currents. The control experiments assimilated satellite-observed sea surface temperature data, low resolution gridded surface geostrophic currents, and in-situ temperature and salinity profiles. The second experiment used the same configuration, but additionally assimilated high resolution surface geostrophic currents derived from SWOT altimetry.

The experiment that assimilated SWOT-derived surface geostrophic currents reproduced mesoscale eddy structures in the East Sea and the Kuroshio Extension regions, dominated by geostrophic flow. Spectrum analysis revealed that increased energy at scales between 40km and 140km, indicating that assimilating SWOT-derived surface geostrophic currents enhances representation of mesoscale eddies. The root mean square errors (RMSEs) in temperature profiles decreased by 0.36 %, while those in salinity profiles decreased by 0.01%, indicating that the assimilation of high-resolution geostrophic currents had minimal impact on the overall temperature and salinity structures. However, RMSE in temperature decreased by 23.35% in the East Sea from March to May.

These results suggest that high resolution surface geostrophic currents can improve the accuracy of mesoscale eddy representation. Nevertheless, this study applied a spatially and temporally uniform observation error. In the future work, time varying observation errors will be considered and the effects on the salinity and temperature profiles will be investigated.

This Research was supported by Korea Institute of Marine Science & Technology Promotion (KIMST) funded by the Ministry of Oceans and Fisheries, Korea (RS-2025-02217872)

Corresponding author:
Dohyeop Yoo (**Department of Oceanography, Chonnam National University, Gwangju, Republic of Korea**, **South Korea**), toaeh@naver.com

Assimilating Nadir SLA at Multiple Resolutions in the Western Mediterranean Sea

Maximo Garcia-Jove Navarro (Balearic Islands Coastal Observing and Forecasting System (SOCIB), Palma, Spain, Spain); Baptiste Mourre (Instituto Mediterráneo de Estudios Avanzados (IMEDEA (CSIC-UIB)), Esporles, Spain, Spain); Nikolaos Zarokanellos (Balearic Islands Coastal Observing and Forecasting System (SOCIB), Palma, Spain, Spain); Emma Reyes (Balearic Islands Coastal Observing and Forecasting System (SOCIB), Palma, Spain, Spain); Joaquín Tintoré (1) Balearic Islands Coastal Observing and Forecasting System (SOCIB), Palma, Spain 2) Instituto Mediterráneo de Estudios Avanzados (IMEDEA (CSIC-UIB)), Esporles, Spain, Spain)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_004

Abstract:
Traditionally, ocean data assimilation (DA) systems have been constrained to broader, mesoscale structures due to limited observational resolution. However, the advent of very high-resolution satellite missions, such as Surface Water Ocean Topography (SWOT) and Sentinel-6A, open the door to enable the assimilation of critically important smaller-scale features. This abstract details recent advancements in Western Mediterranean Operational Forecasting (WMOP) DA component, including the integration of Sentinel-6A Sea Level Anomaly (SLA) altimeter data. WMOP, based on the ROMS numerical model, uses an Ensemble Optimal Interpolation (EnOI) DA scheme to incorporate a diverse range of multi-platform observations, which was initially designed to constrain the mesoscale fields. Its operational configuration features a 2 km horizontal resolution and 32 sigma vertical layers, delivering 3-hourly and daily forecasts. To investigate the impact of assimilating smaller-scale features on ocean state estimation, we conducted an Observing System Experiment (OSE) in the Balearic Sea in the Western Mediterranean. We performed five distinct DA simulations using: (i) a free control run without data assimilation; (ii) a run assimilating a comprehensive suite of conventional observations including satellite SLA, sea surface temperature (SST), high-frequency radar surface currents (HFR), and temperature/salinity (T/S) profiles from Argo floats and moorings; (iii) a run specifically 1 Hz (~7 km) SLA; (iv) a run focusing on assimilation of 5 Hz (~1km) and 20 Hz (~0.3km) SLA observations; and (v) a run implementing a nested, multi-scale assimilation system combining both mesoscale and submesoscale SLA data. The performance of each setup focused on the surface and subsurface was evaluated by assessing its ability to represent small-scale features using independent high-resolution SWOT and in-situ observations from gliders. Preliminary results from the assimilation experiments described in (ii) indicate that incorporating high-resolution SLA data into WMOP does not yet significantly enhance submesoscale forecast skill. However, experiments currently underway, specifically employing a multi-scale assimilation system (Experiment v) will be analyzed to evaluate their capacity to reduce SLA variance errors at smaller spatial scales and to enhance model performance. Recent publications highlight the transformative potential of high-resolution altimetry in coastal ocean forecasting, offering critical insights for future developments aimed at improving the accuracy of submesoscale predictions.

FOCCUS is funded by the European Union (Grant Agreement No. 101133911). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HaDEA). Neither the European Union nor the granting authority can be held responsible for them.

Corresponding author:
Maximo Garcia-Jove Navarro (**Balearic Islands Coastal Observing and Forecasting System (SOCIB), Palma, Spain**, **Spain**), mgarciajove@socib.es

Toward an Ocean Foundation Model Integrating SWOT and Conventional Altimetry

Eugenio Cutolo (IMT Atlantique, France); Jinbo Wang (Texas A&M University, USA); Ananda Pascual (IMEDEA, Spain); Carlos Granero Belinchon (IMT Atlantique, France); Ronan Fablet (IMT Atlantique, France)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_005

Abstract:
The Surface Water and Ocean Topography (SWOT) satellite provides daily global sea-surface-height measurements at kilometre-scale resolution, generating petabytes of data that surpass the processing capabilities of traditional oceanographic workflows. To overcome this data-volume challenge, deep learning, particularly unsupervised architectures, offers promising complementary tools to conventional numerical models and data assimilation frameworks.
We introduce an Ocean Foundation Model primarily trained on SWOT's high-resolution surface-height fields, demonstrating its ability to effectively integrate additional datasets such as global ocean circulation simulations and traditional nadir altimeter measurements. By embedding these heterogeneous sources into a unified latent space, the model enables efficient similarity searches and rapid generation of ensemble outputs for spatiotemporal gap filling. Furthermore, this generative AI framework provides probabilistic uncertainty estimates comparable to those from traditional data-assimilation methods.
The unified latent representation significantly accelerates the extraction of key oceanic dynamics, such as eddy interactions and SST-SSH coupling, from SWOT's extensive archives providing a powerful method for obtaining global statics. Our results illustrate how deep-learning foundation models can leverage SWOT observations to enhance oceanographic research and help advance towards an ocean digital twin.
Corresponding author:
Eugenio Cutolo (**IMT Atlantique**, **France**), eugenio.cutolo@imt-atlantique.fr

Toward Assimilating SWOT Altimetry Data into the Current and Next-Generation GMAO Subseasonal-to-Seasonal Forecast System

David Russell (University of Maryland / NASA, United States); Eric Hackert (NASA, USA); Doruk Ardag (Science Systems and Applications, Inc. / NASA, USA); Cheng Da (University of Maryland / NASA, USA)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_006

Abstract:
At NASA's Global Modeling and Assimilation Office (GMAO), efforts are underway to assimilate wide-swath ocean altimetry data from the new Surface Water and Ocean Topography (SWOT) satellite's Ka-band Radar Interferometer (KaRIn) instrument into our suite of coupled earth system models. To pave the way for such new observation types into coupled data assimilation (DA), the next version of the Goddard Earth Observing System Subseasonal-to-Seasonal (GEOS-S2S) prediction system will transition from legacy DA systems for the individual Earth system components to the new Joint Effort for Data assimilation Integration (JEDI) system, which provides a unified framework for multiple DA methods across various Earth system components.

As a first step, assimilation of conventional altimetry data from SWOT's Jason-class nadir altimeter is being tested within both GEOS-S2S version 3 (S2S-3) and JEDI's marine interface Sea-ice, Ocean and Coupled Analysis (SOCA). For ocean DA, S2S-3 uses a modified version of the local ensemble transform Kalman filter (LETKF), whereas SOCA testing at GMAO has thus far been limited to the 3DVar and 3D-FGAT methods. In this work, the impact of SWOT nadir data on analyses and forecasts in the two DA systems is explored using Observing System Evaluation (OSE) experiments. Each OSE is comprised of two component experiments: One in which the SWOT data are assimilated (i.e., the SWOT experiment), and one in which the SWOT data are withheld (i.e., the CONTROL). For both experiments, all other conventional data are assimilated (e.g., Argo, other nadir altimeters, satellite SSS, etc.), as would be the case in operational prediction scenarios. The impact of assimilating SWOT data is assessed by comparing the SWOT and CONTROL experiments for both the S2S-3 and SOCA DA systems, as well as long-range (e.g., ENSO) forecasts initialized from the two experiments.

Beyond SWOT nadir assimilation, for future work, we intend to show progress towards assimilation of wide-swath KaRIn data, which will likely require new methods which account for two-dimensional spatial correlations in the observation error covariance.

Corresponding author:
David Russell (**University of Maryland / NASA**, **United States**), david.s.russell@nasa.gov

Inverse modeling of the internal tide using the Coupled-mode Shallow Water model

Samuel Kelly (University of Minnesota Duluth, United States)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_007

Abstract:
A new generalized inverse model is developed to predict both stationary and nonstationary internal tides. Model dynamics are based on the Coupled-mode Shallow Water model (CSW), which includes topographic and mean-flow effects. Data assimilation is performed by minimizing errors in boundary conditions, initial conditions, and forcing. First, the 30-year Nadir altimetry record is used to optimize a frequency-based model of the stationary tide. Forcing errors from these solutions are attributed to uncertainties in stratification, topography, and internal-tide dissipation. Next, SWOT KaRIn data are used to optimize a time-dependent model over a 21-day assimilation period. Numerical experiments are used to quantify the performance of the generalized inverse in a regional domain, highlighting the impacts of model resolution, error covariances, and computational methods. Conclusions focus on how to best scale the prediction system from a regional to global domain.
Corresponding author:
Samuel Kelly (**University of Minnesota Duluth**, **United States**), smkelly@d.umn.edu

Assessment of High-Resolution Ocean Models Using SWOT Observations

Habib Micael Aguedjou (CNES, France); Flavien Gouillon (CNES, France); Eric Chassignet (FSU/COAPS, USA)

Session: Oceanography: Inversion/Assimilation
Presentation type: Poster
Poster number: ST2025OS6_008

Abstract:
Modeling ocean circulation is a fundamental step in understanding physical processes and interactions between spatial and temporal scales. However, accurately modeling different processes remains a real challenge. The validation of ocean models is therefore crucial for ensuring the accuracy of ocean simulations, particularly in regions with complex dynamics like the Gulf Stream. Altimetry data from space missions, notably SWOT (Surface Water and Ocean Topography), provide an invaluable opportunity for model validation due to their high spatial resolution and global coverage. This study compares models output circulations with SWOT measurements in the Gulf Stream region, focusing on sea surface height, current velocities, and circulation patterns. The goal is to quantify discrepancies between model outputs and observations, and to assess how differences in model resolution and ocean process representation affect simulations of the Gulf Stream. Preliminary results suggest that SWOT data offers precise validation for this region, highlighting its potential for improving oceanographic predictions and enhancing our understanding of Gulf Stream dynamics.

Corresponding author:
Habib Micael Aguedjou (**CNES**, **France**), habibmicael.aguedjou@cnes.fr

From open ocean to the coastal zone: benefits from SWOT in the mean sea surface

Bjarke Nilsson (Technical University of Denmark, DTU Space, Denmark); Ole Baltazar Andersen (Technical University of Denmark, DTU Space, Denmark); Per Knudsen (Technical University of Denmark, DTU Space, Denmark)

Session: Oceanography: Mean Sea Surface
Presentation type: Poster
Poster number: ST2025OS7_001

Abstract:
The observations from the Surface Water and Ocean Topography (SWOT) satellite has shown to be revolutionary in spatial resolution and precision. With the introduction of wide-swath altimetry at sample spacing of 250 m by 250 m we are able to get reliable and accurate observations in more complex coastal zones than ever before. Traditional mean sea surface (MSS) reference fields, critical for oceanography, have always relied on conventional nadir-looking satellite altimetry. Even with the introduction of Synthetic Aperture Radar (SAR) altimeters, this lead to most coastal zones in the resulting MSS being degraded due to land-contamination in the underlying observations. Subsequent smoothing or extrapolation might yield acceptable values in low-complexity areas, but have found to be less accurate in more complex areas, such as fjords, archipelagos, lagoons, atolls or similar features.

To utilize the high spatial resolution of SWOT, the new DTU25 MSS utilizes the ocean SWOT product (2 km spacing) in the open ocean, but uses the high-sampling of 250 m spacing in the coastal zones globally, to provide the spacial resolution needed to resolve the most complex coastal features. While providing little benefit in areas with a simple coastline, we see a large effect at coastal features with small enclosed waters, such as atolls with lagoons down to 1 km width. We show a global analysis of the effect of introducing the 250 m data product from SWOT in the MSS models, and subsequent consequences for oceanographic and coastal studies, as well as possible benefits and case-studies for going further inland with higher resolution products from SWOT.

Corresponding author:
Bjarke Nilsson (**Technical University of Denmark, DTU Space**, **Denmark**), bjarke@space.dtu.dk

Seamounts from SWOT: Expanding the global catalogue and revealing their interactions with ocean currents

Yao Yu (UCSD, United States); David Sandwell (University of California San Diego, United States); Martin Hawks (University of California San Diego, United States); Sarah Gille (University of California San Diego, United States)

Session: Oceanography: Mean Sea Surface
Presentation type: Poster
Poster number: ST2025OS7_002

Abstract:
Two years of SWOT data enable the construction of marine gravity fields at an 8-km spatial resolution, allowing for the detection of small seamounts approximately 1 km in height at a typical ocean depth of 4 km. These seamounts, formed by off-ridge volcanism, often exhibit a Gaussian circular shape with a characteristic height-to-radius ratio of 0.25. Using vertical gravity gradient (VGG) maps derived from SWOT's two-year ocean height observations, we present an updated global seamount catalogue, identifying approximately 14,000 previously uncharted ones (with counting still ongoing), expanding upon the previously published catalogue of ~43,000 seamounts. Beyond their tectonic importance, seamounts also act as biodiversity hotspots, where ocean currents trap nutrients and larvae. We report observations of localized sub-mesoscale ocean dynamics adjacent to seamounts, including features consistent with Taylor columns, lee waves, and wake formations.

Corresponding author:
Yao Yu (**UCSD**, **United States**), yaoyu.9404@gmail.com