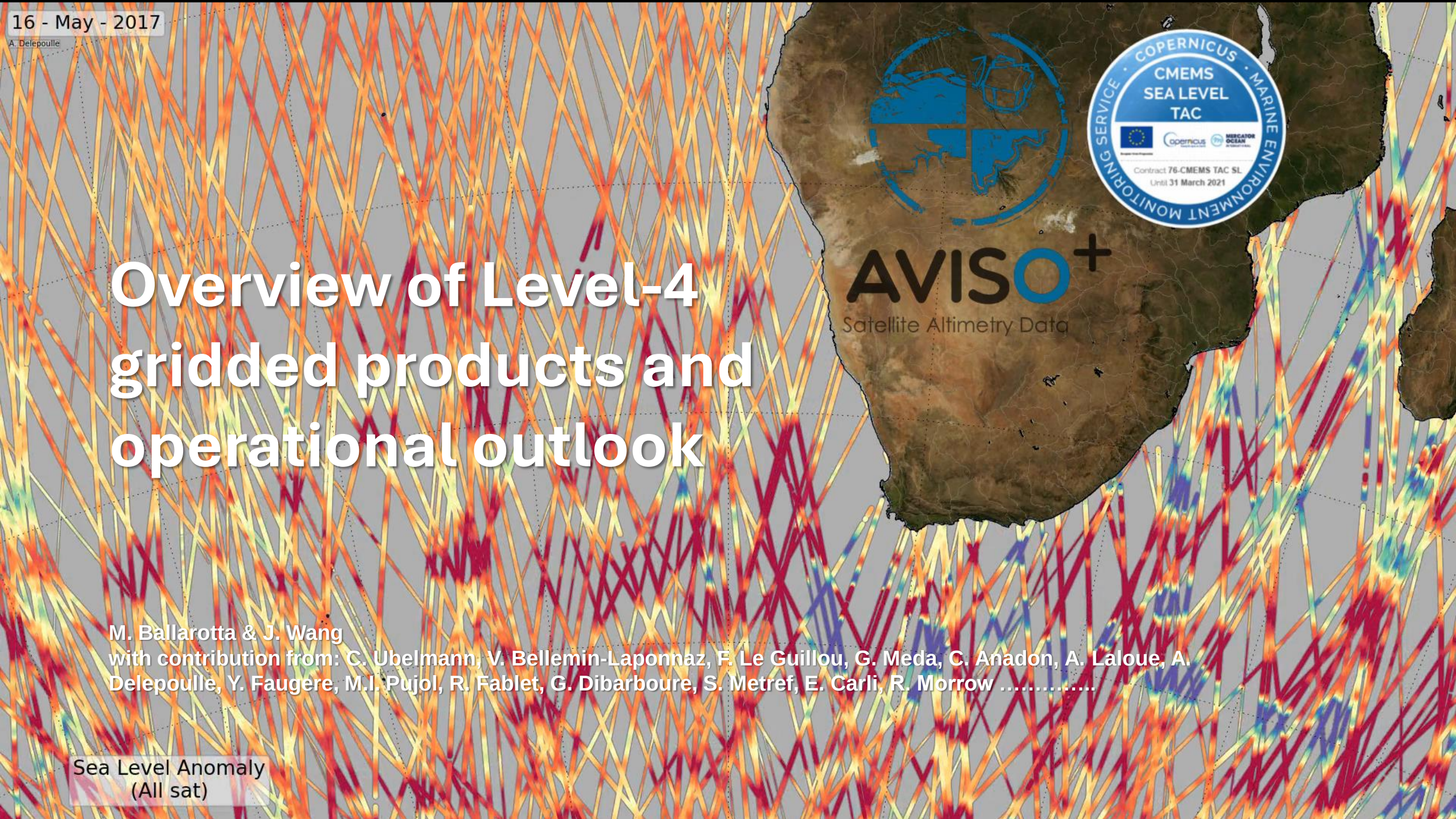


Overview of Level-4 gridded products and operational outlook

M. Ballarotta & J. Wang
with contribution from: C. Ubelmann, V. Bellemin-Laponnaz, F. Le Guillou, G. Meda, C. Anadon, A. Laloue, A. Delepoulle, Y. Faugere, M.I. Pujol, R. Fablet, G. Dibarboure, S. Metref, E. Carli, R. Morrow ……..

Content

- Introduction & context
- First mapping experiment at global/regional scale with SWOT data
- Conclusions
- Future activities

Before April 2023, only simulations through **Observing System Simulation Experiments** (OSSE) have been conducted to study the **contribution of wide-swath systems** (like SWOT) to mapping systems

2015 2016 2017 2018 2019 2020 2021 2022 2023

Dynamic Interpolation of Sea Surface Height and Potential Applications for Future High-Resolution Altimetry Mapping

Clement Ubelmann, Patrice Klein, and Lee-Lueng Fu

Print Publication: 01 Jan 2015

DOI: https://doi.org/10.1175/JTECH-D-14-00152.1

Page(s): 177–184

Article | Peer review | Metrics | Related articles

Research article | 16 Nov 2018

Contribution of future wide-swath altimetry missions to ocean analysis and forecasting

Antonio Bonaduce, Mounir Benkiran, Elisabeth Remy, Pierre Yves Le Traon, and Gilles Garric

Article | Assets | Peer review | Metrics | Related articles

Development and technical paper | 19 Apr 2023

4DVarNet-SSH: end-to-end learning of variational interpolation schemes for nadir and wide-swath satellite altimetry

Maxime Beauchamp, Quentin Febvre, Hugo Georgenthum, and Ronan Fablet

Research Article | Free Access

An Observing System Simulation Experiment for Ocean State Estimation to Assess the Performance of the SWOT Mission: Part 1—A Twin Experiment

Zhijin Li, Jinbo Wang, Lee-Lueng Fu

ORIGINAL RESEARCH article

Front. Mar. Sci., 22 July 2021
Sec. Ocean Observation

Assessing the Impact of the Assimilation of SWOT Observations in a Global High-Resolution Analysis and Forecasting System Part 1: Methods

ORIGINAL RESEARCH article

Front. Mar. Sci., 26 August 2021
Sec. Ocean Observation

Assessing the Impact of the Assimilation of SWOT Observations in a Global High-Resolution Analysis and Forecasting System – Part 2: Results

ELSEVIER

Ocean Modelling

Volume 135, March 2019, Pages 40-55

Quantifying wavelengths constrained by simulated SWOT observations in a submesoscale resolving ocean analysis/forecasting system

Joseph M. D'Addezio, Scott Smith, Gregg A. Jacobs, Robert W. Helber, Clark Rowley, Innocent Souopgui, Matthew J. Carrier

VOLUME 38 JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY APRIL 2021

Mapping Altimetry in the Forthcoming SWOT Era by Back-and-Forth Nudging a One-Layer Quasigeostrophic Model

FLORIAN LE GUILLOU,[a] SAMMY METREF,[a] EMMANUEL COSME,[a] CLÉMENT UBELMANN,[b] MAXIME BALLAROTTA,[c] JULIEN LE SOMMER,[a] AND JACQUES VERRON[b]

[a] *Université Grenoble Alpes, CNRS, IRD, Grenoble INP, IGE, Grenoble, France*
[b] *Ocean Next, Grenoble, France*
[c] *Collecte Localisation Satellites, Ramonville-Saint-Agne, France*

Research Article | Free Access

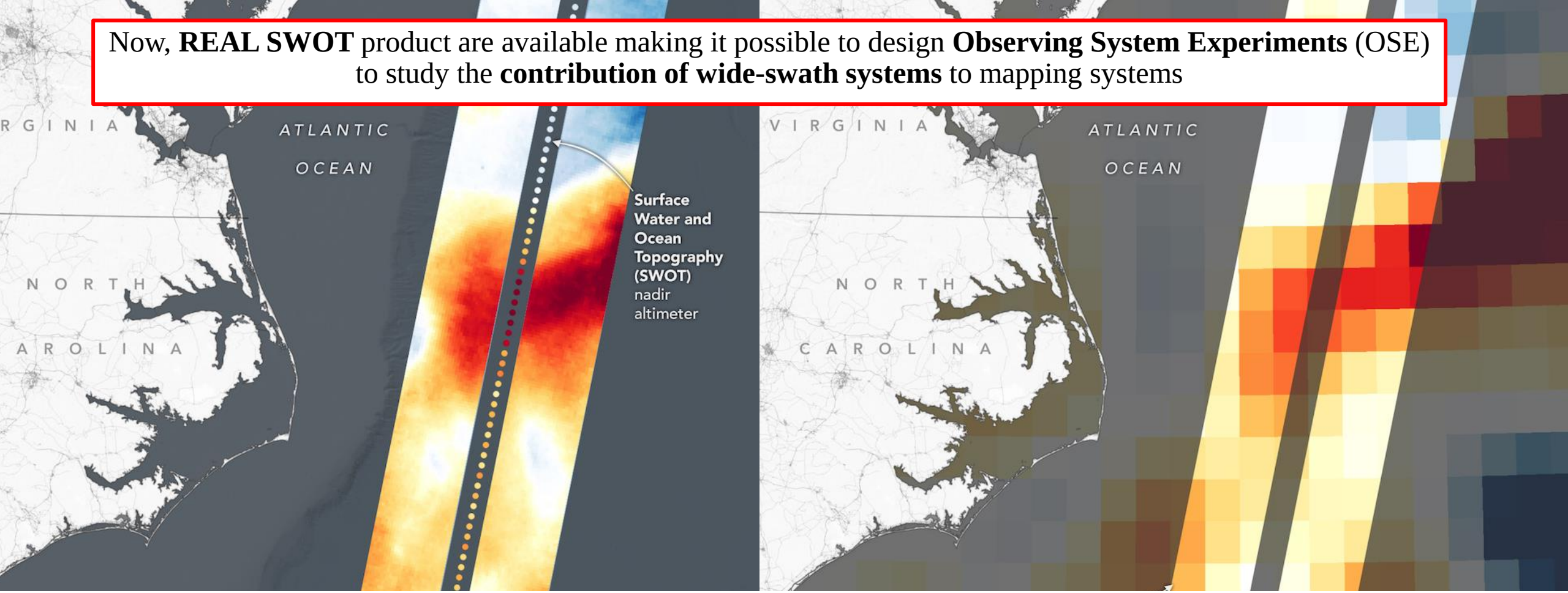
Reconstructing Fine-Scale Ocean Variability via Data Assimilation of the SWOT Pre-Launch In Situ Observing System

Matthew R. Archer, Zhijin Li, Jinbo Wang, Lee-Lueng Fu

On the Development of SWOT In Situ Calibration/Validation for Short-Wavelength Ocean Topography

Jinbo Wang, Lee-Lueng Fu, Bruce Haines, Matthias Lankhorst, Andrew J. Lucas, J. Thomas Farrar, Uwe Send, Christian Meinig, Oscar Schofield, Richard Ray, Matthew Archer, David Aragon, Sebastien Bigorre, Yi Chao, John Kerfoot, Robert Pinkel, David Sandwell, and Scott Stalin

Now, **REAL SWOT** product are available making it possible to design **Observing System Experiments** (OSE) to study the **contribution of wide-swath systems** to mapping systems

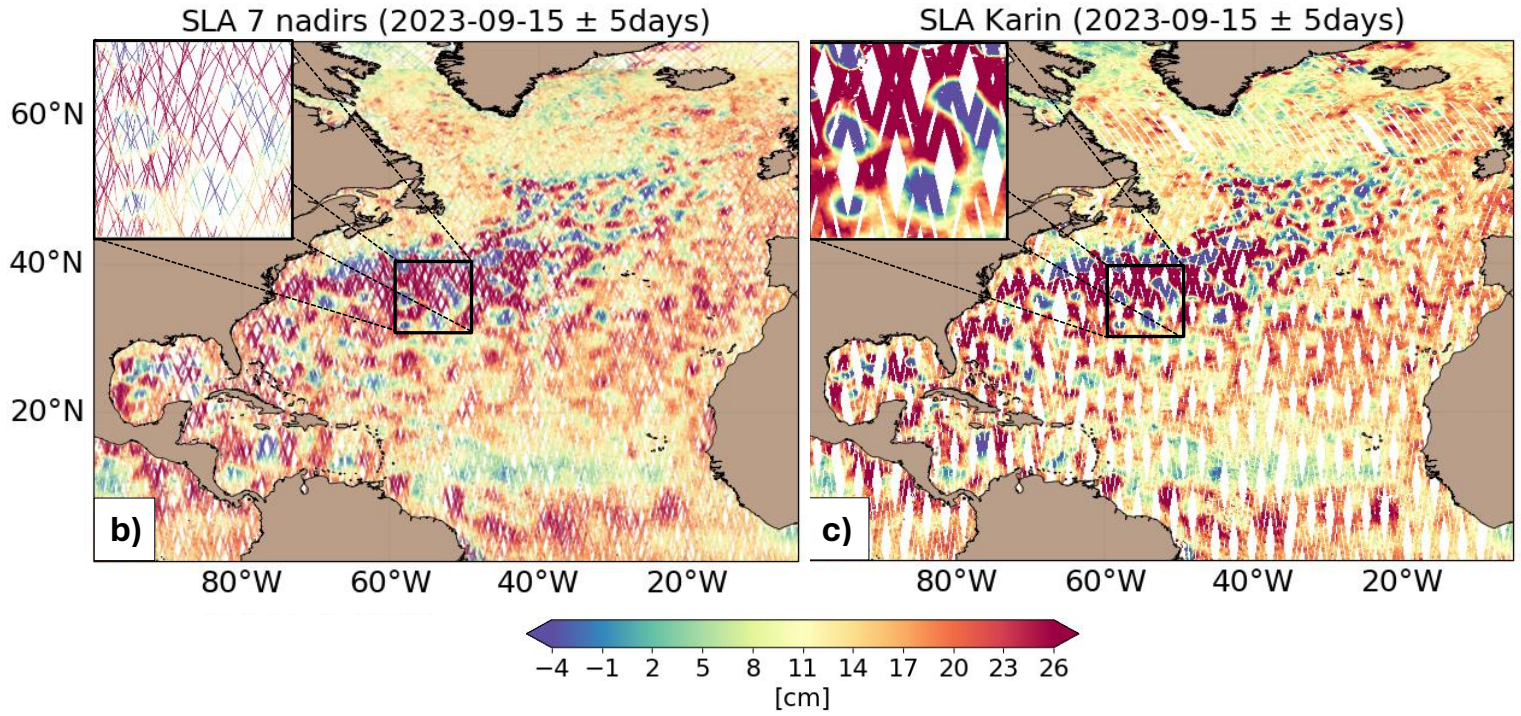


- **=> assess the impact of these new wide-swath data in the current global/regional mapping system through the use of Observing System Experiments (OSE)**
- **=> in various context/application: DT/REP, NRT, Forecasting**
- **=> investigate which mapping method is able to resolve finer oceanic scale**

First mapping experiments at global/regional scale

Input data:

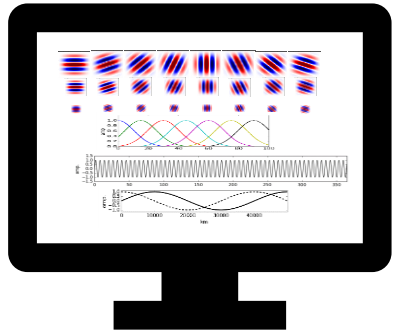
Product type	Nadirs Sea-level anomaly Level 3 products	SWOT Sea-level anomaly Level 3 products
Product ref.	SEALEVEL_GLO_PHY_L3_NRT_008_044	SWOT_L3_SSH
Spatial coverage	[0°E:360°E] [90°S:90°N]	[0°E:360°E] [90°S:90°N]
Temporal coverage	From 2023-07-01 to 2023-12-01	From 2023-07-27 to 2023-11-30



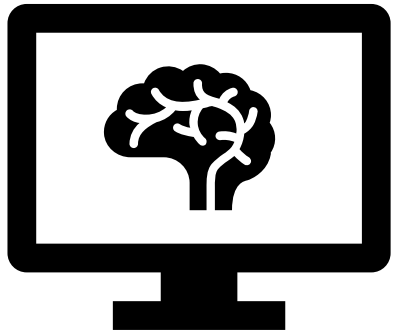
2 Experiments were carried out: 1) using **nadir only**, 2) using **nadir and SWOT**

Three mapping methods are tested:

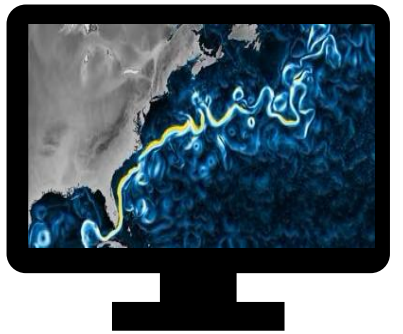
MIOST (Ubelmann et al., 2021): a method accounting for various modes of variability of the ocean surface topography (e.g., geostrophic, barotrope, equatorial waves dynamic …) by constructing several independent components within an assumed covariance model.



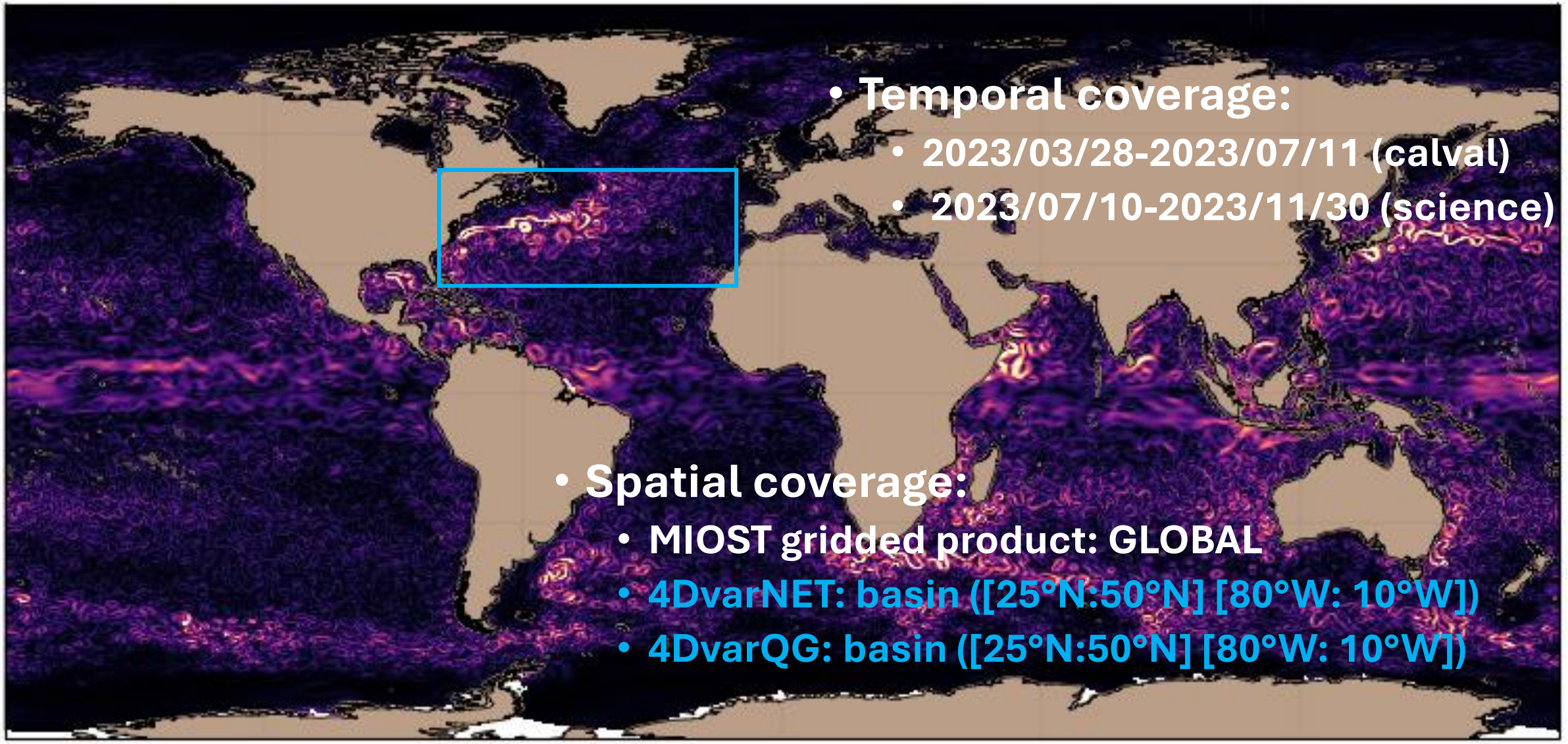
4DvarNET (Fablet et al., 2021): a data-driven approach combining a data assimilation scheme associated with a deep learning framework. This neural network framework involves the joint training of the representation of the ocean dynamic, as well as of the solver of the data assimilation problem.



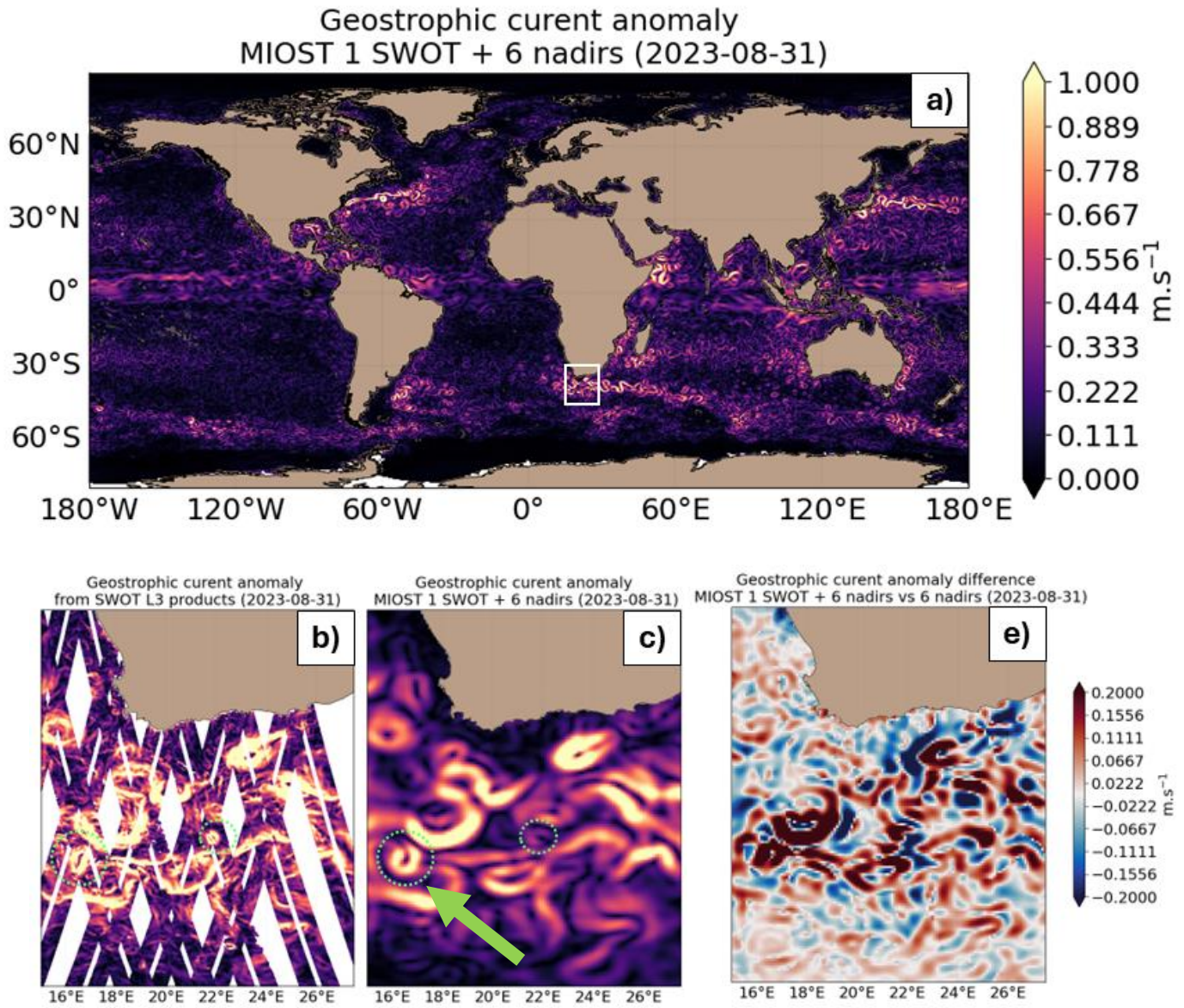
4DvarQG (Le Guillou et al., 2021) : a 4-Dimensional variational (4DVAR) scheme with a Quasi-Geostrophic (QG) model



Experimental Products



Wide swath altimetry enables better positioning of oceanic structures (eddies, fronts, etc...)



Validation metrics:

One altimeter (SARAL/Altika) is excluded from the mapping to assess the mapping error. We focus here on the effective resolution metric, which is given by the wavelength λ_s where the Signal to Noise Ratio SNR(λ_s) is 2, i.e., the wavelength where the SSH_{error} is two times lower than the signal $SSH_{alongtrack}$

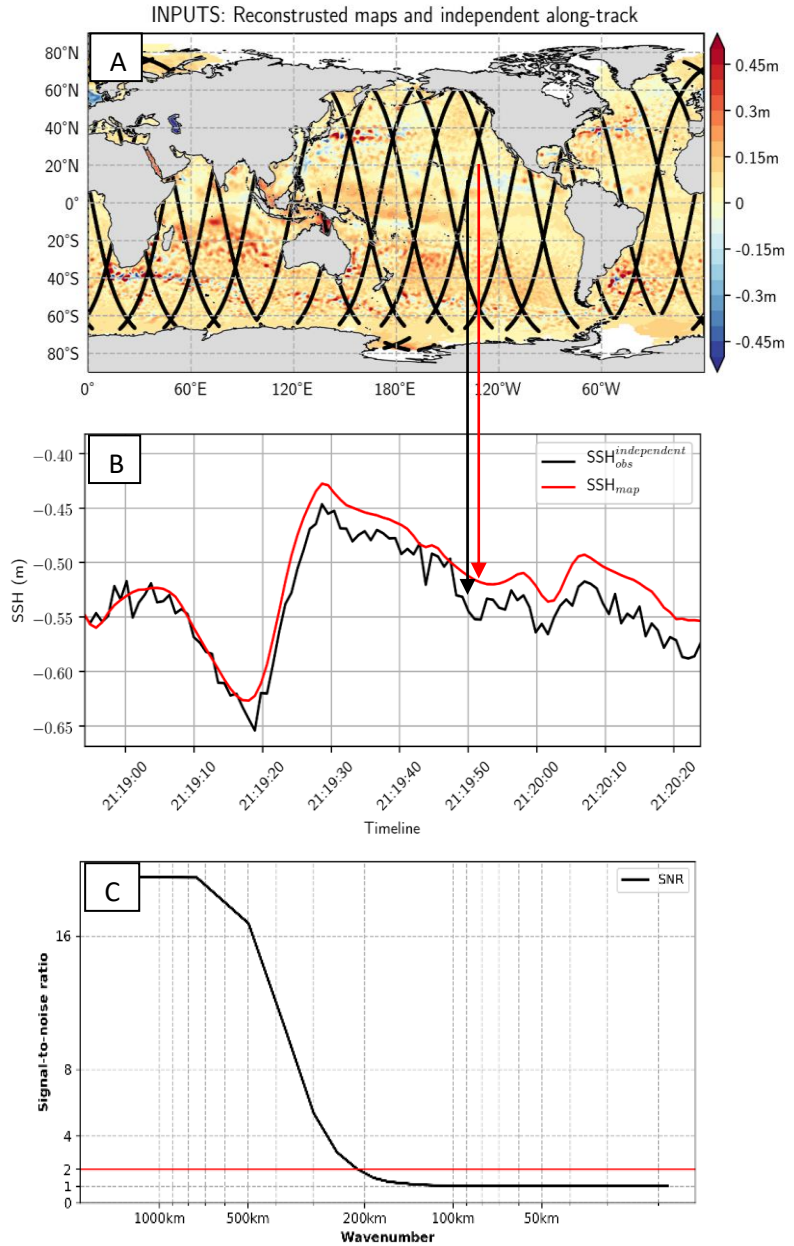
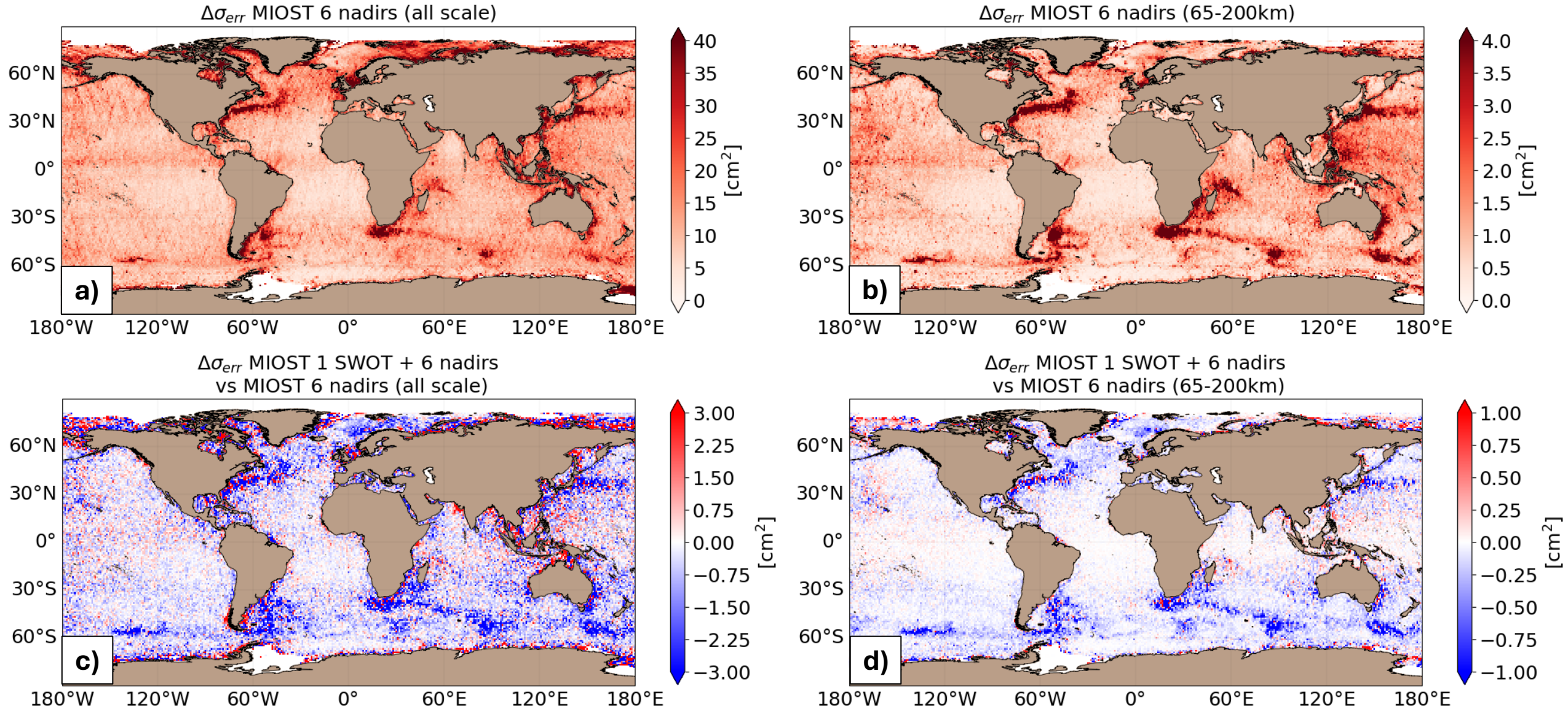


Fig.: Example of spectral analysis: A) inputs SSH gridded and along-track fields, B) colocation gridded SSH and along-track SSH; and C) Signal-to-Noise ratio

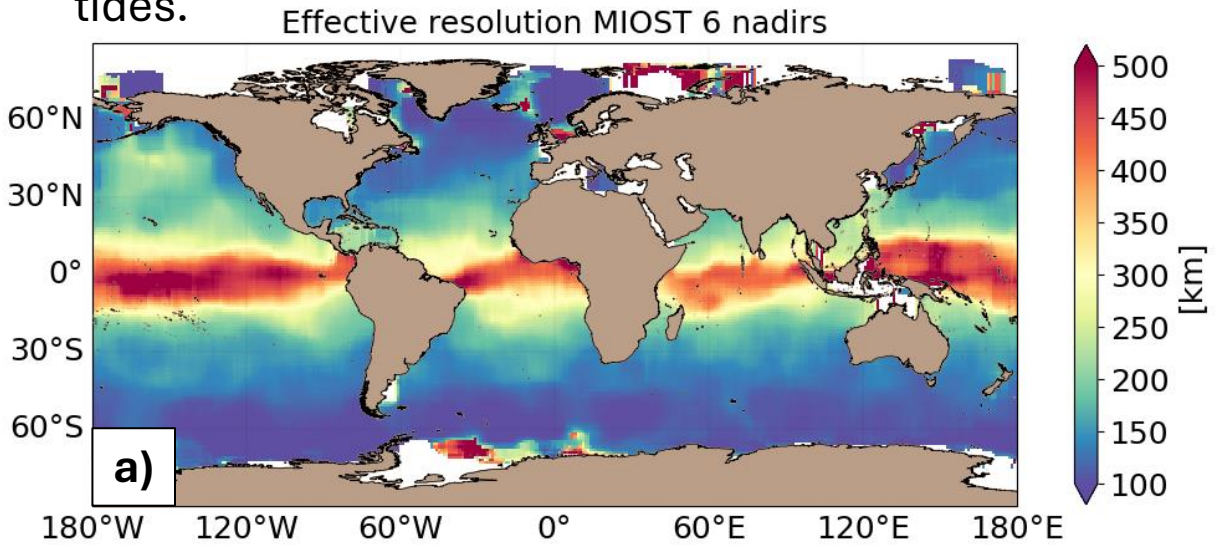
Error variance reduction in energetic currents (Gulfstream, ACC, Kuroshio…) when integrating SWOT into a **6** nadirs altimeter constellation **(~15% error reduction** in high variability, **10% error reduction** in low variability region)



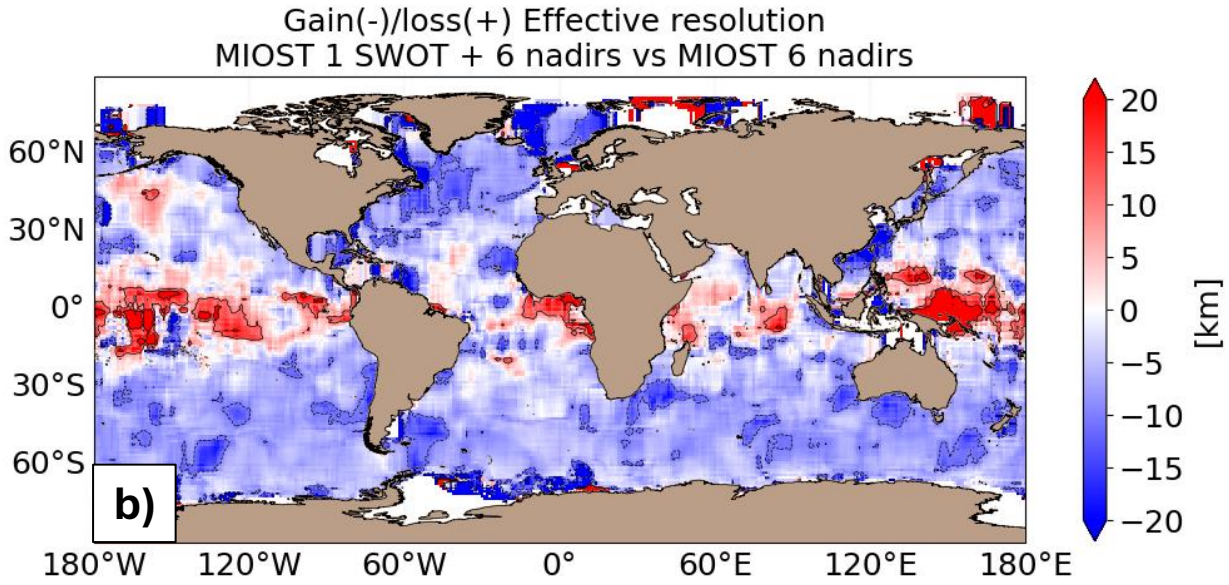
Improved mapping with SWOT

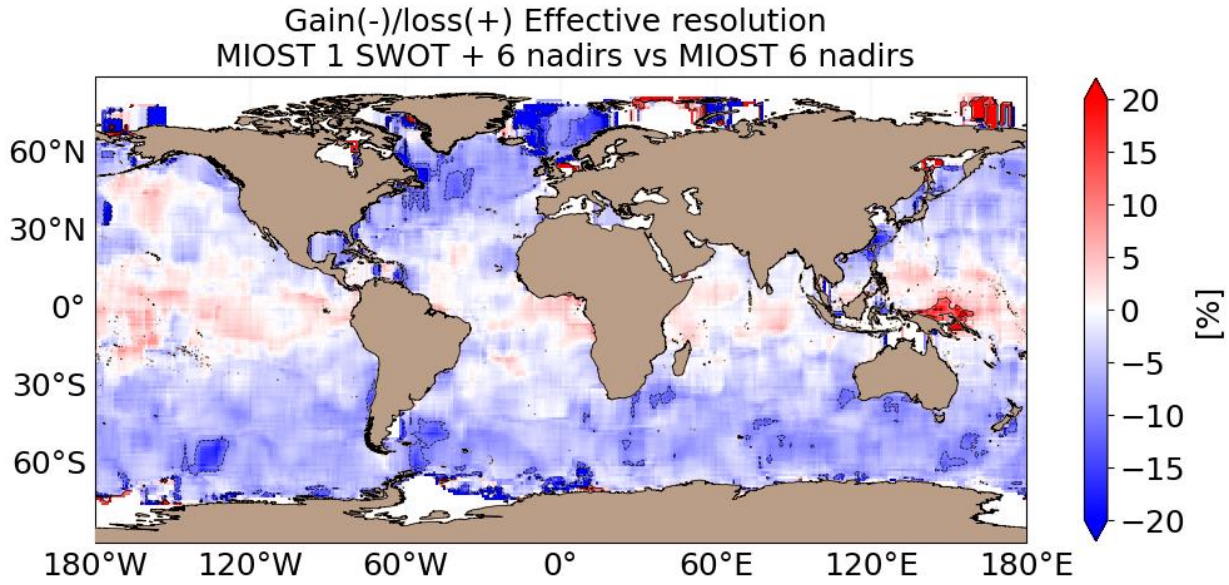
degrade mapping with SWOT

Gain in effective resolution when integrating SWOT into a **6** nadirs altimeter constellation: overall good benefit of SWOT (**finer resolution ~5-10km, 20km locally**) except in regions characterized by specific atmospheric and oceanic conditions, such as tropical rainfall, wet troposphere, as well as areas affected by storm tracks or internal tides.

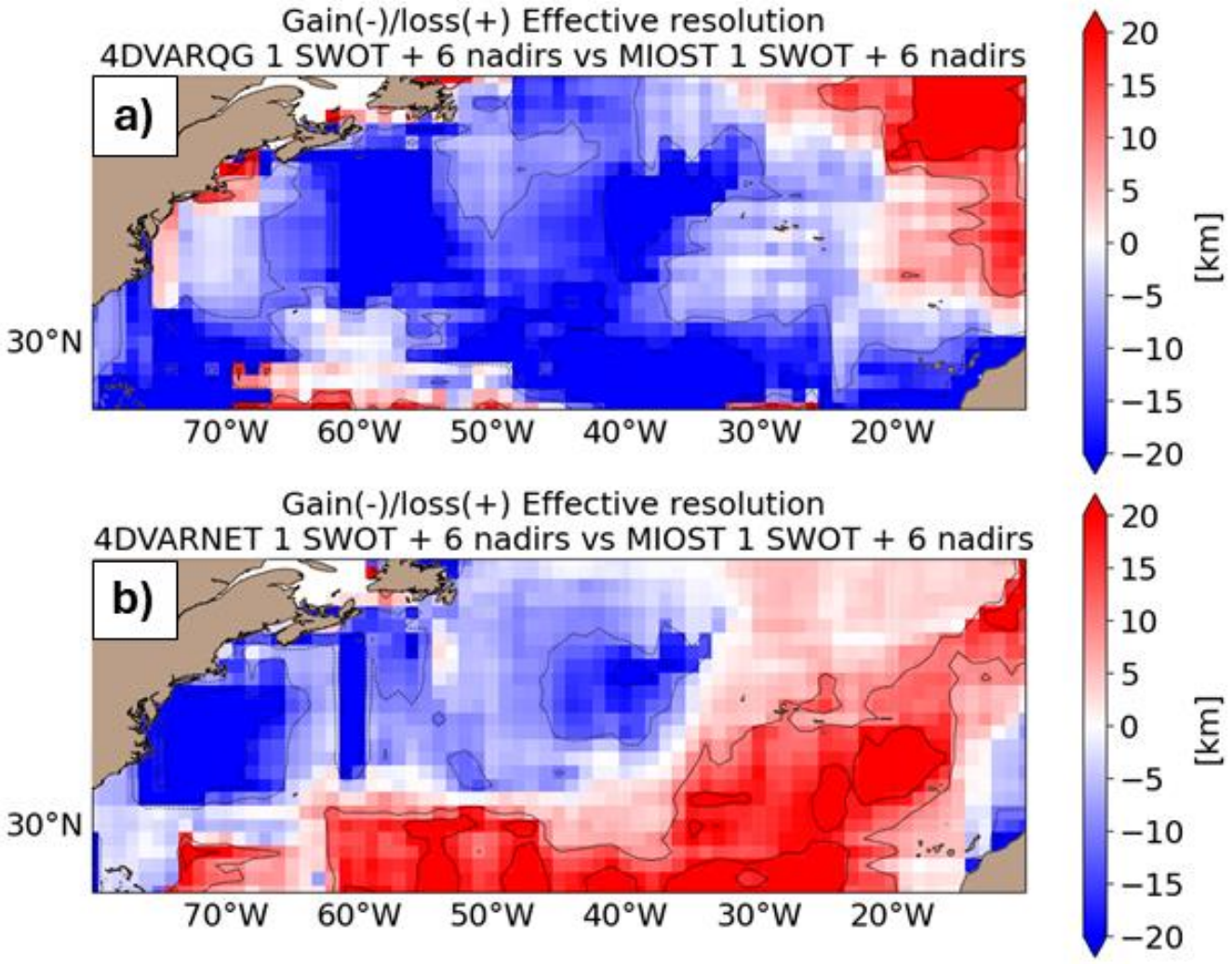


Wide swath altimetry enables finer resolution in maps





Dynamical & Data-driven mapping approaches enable finer resolution



Finer resolution in 4DvarQG than in MIOST products

Coarser resolution in 4DvarQG than in MIOST products

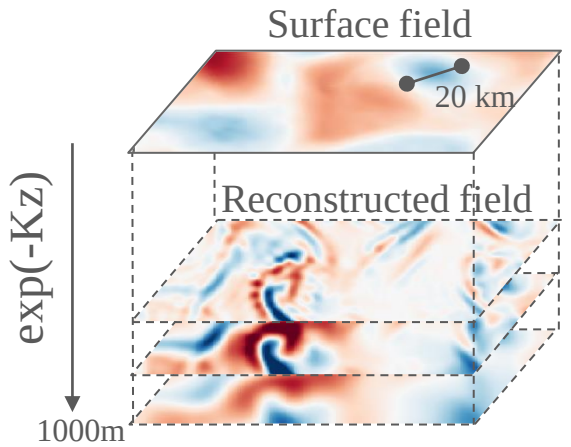
Finer resolution in 4DvarNET than in MIOST products

Coarser resolution in 4DvarNET than in MIOST products

Regional studies/applications: E. Carli et al.

Reconstruction of **3D balanced motions from 2D surface fields** projection at depth

- Mesoscale and large submesoscale structures (>20 km)
- Coherent structures along the water column

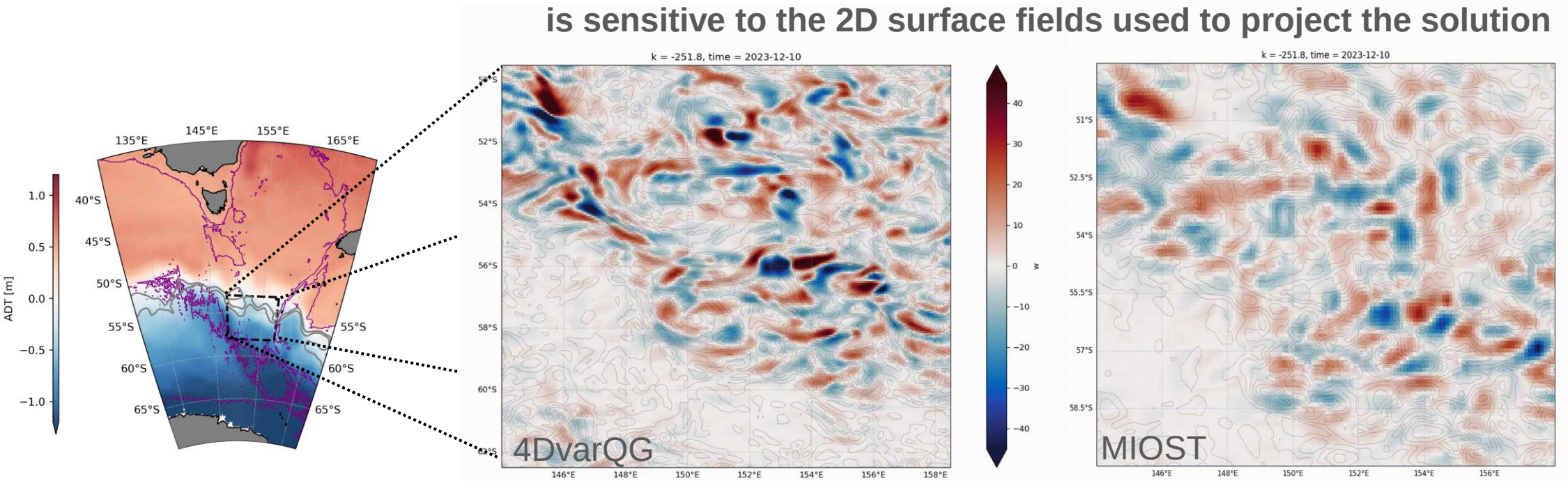


Klein and Lapeyre (2006)
Klein et al. (2009)
Lapeyre (2017)

ASSUMPTIONS

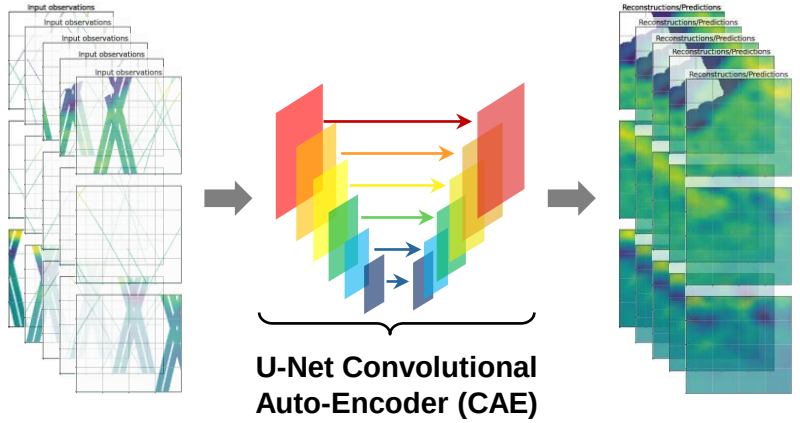
- Exponential decay of the reconstructed fields
- Constant vertical stratification
- Conservation of potential vorticity in the domain
- Horizontal boundaries: double periodic domain
- Vertical boundaries: semi-infinite domain

Vertical velocity w [m/d] @250m with surface strain rate contours is sensitive to the 2D surface fields used to project the solution

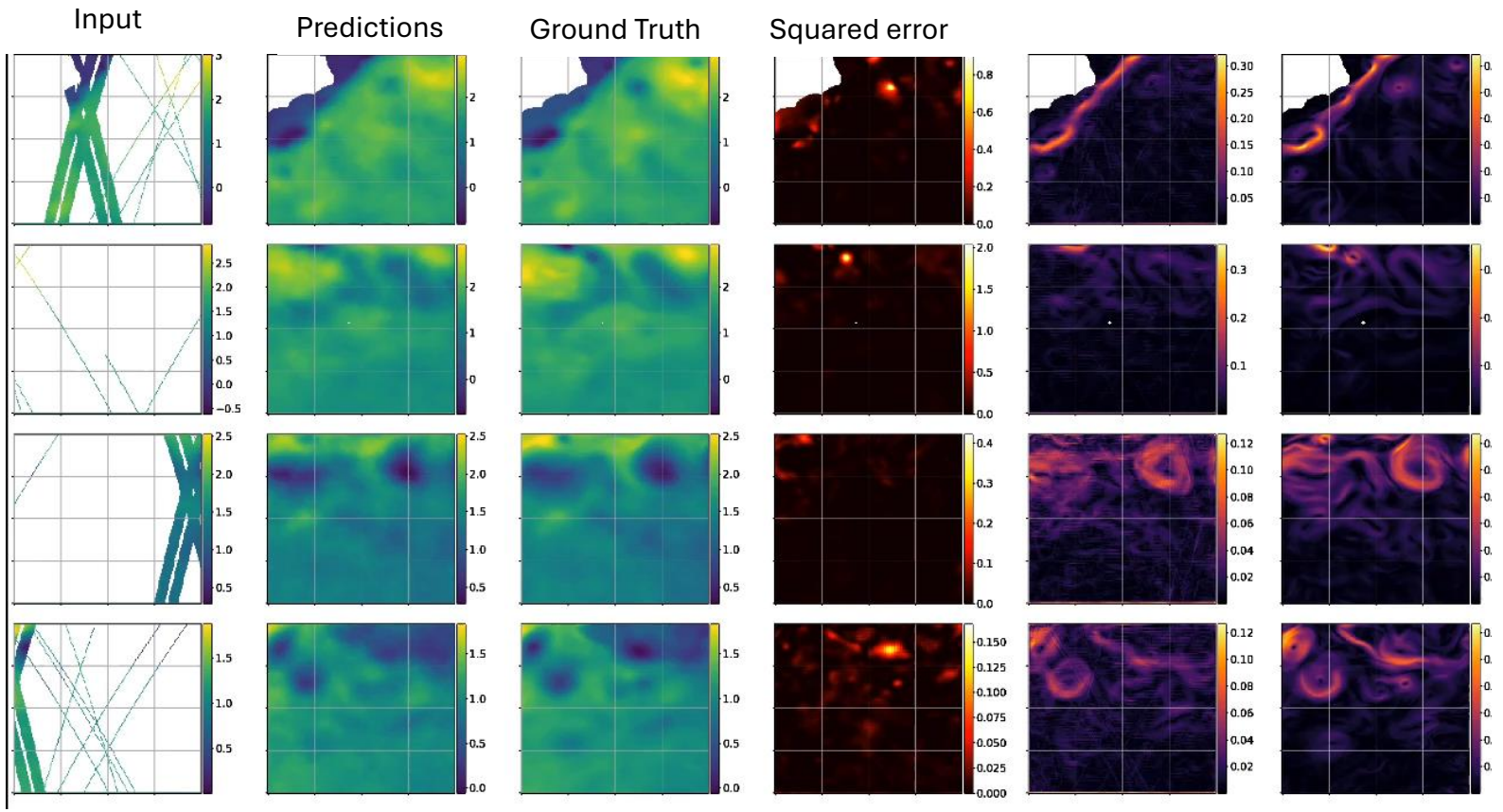


AI-based ultra-resolution satellite data assimilation – working progress

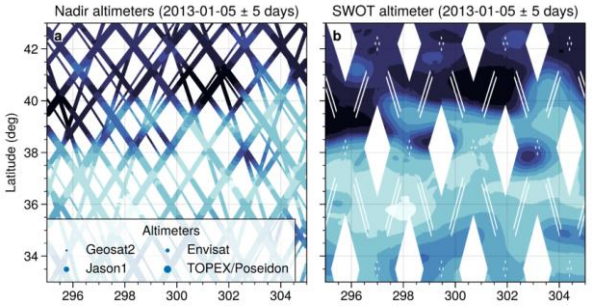
Edwin Goh, Alice Yepremyan, Jinbo Wang, Brian Wilson
Jet Propulsion Laboratory



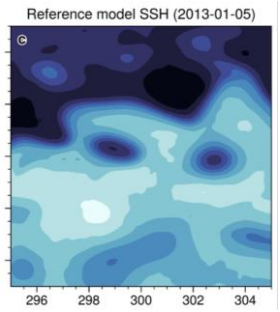
- Based on **2023_SSH_mapping_train_eNATL60_test_NATL60**
- Convolutional Autoencoder (CAE)
- Data: NATL60 high-res ocean simulation (1/20° grid spacing). Consists of SWOT + 4 Nadir.
  - Training: Jan 2, 2013 → Sep 30, 2013
    - Train for 400 epochs
  - Testing: Oct 22, 2012 → Dec 2, 2012



Data availability



The **SWOT_L3_SSH** product, derived from the L2 SWOT KaRIn low-rate ocean data products (NASA/JPL and CNES), is produced and made freely available by AVISO and DUACS teams as part of the DESMOS Science Team project. AVISO/DUACS, 2023. https://doi.org/10.24400/527896/A01-2023.018. The **Near-Real-Time (NRT) Level-3** altimeter satellite **along-track data** are distributed by the EU Copernicus Marine Service (product reference SEALEVEL_GLO_PHY_L3_NRT_008_044, Pujol et al., 2023).



The experimental gridded products (MIOST, 4DvarNET & 4DvarQG) computed with nadirs and wide swath (v0.3) altimetry are also made available on the AVISO+ portal. https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/experimental-multimission-gridded-l4-sea-level-heights-and-velocities-with-swot.html

A collaborative data-challenge focusing on the integration of SWOT data into mapping systems is currently under construction: https://github.com/ocean-data-challenges/2024_DC_SSH_mapping_SWOT_OSE

Conclusions

- SWOT data are available since April 2023 and can now be integrated into mapping systems
- Various mapping algo to test: data-driven, dynamical mapping, classical statistical linear mapping (OI) ….
- First results on the impact of Karin the current L4 product : mapping error reduced by 10-15%, finer resolution (up to 20km locally)
- Data-driven & dynamic resolved finer scale than OI
- Products available on AVISO+
- **Don’t hesitate to give us feedbacks on these experimental products**

  (=> aviso-swot@altimetry.fr)

Future work & Operational outlook

- **Further validations, understand what happen in the equatorial & north pacific regions**

- **Increase collaboration (e.g., regional data-challenge over Californian/Mediterannean Xover)**

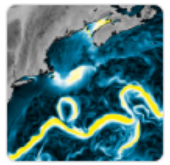
- **Release of L4 product based on the v1.0 L3 Karin SSH product**
  - ⇒ **period from 2023-07-27 to 2024-05-01**

- **MIOST Mapping Algorithm Solution:**
  - Planned as the reference mapping algorithm for upcoming CMEMS Level-4 (L4) altimeter product reprocessing DT24.
  - Will also be used for near-real-time (NRT) L4 products.
  - MIOST L4 product, incorporating Karin data, planned to be distributed through CMEMS from mid-2025.

- **4DvarNET Solution:**
  - Shows good performance for regional products.
  - Requires further refinement for global application before CMEMS integration.

- **4DvarQG Solution:**
  - Good for regional scale applications.
  - Development efforts in progress to extend to a global scale.

- **Exploration of Other Mapping Techniques:**
  - Deep learning approach by Martin et al. (2024) has shown high efficiency in resolving small oceanic features.
  - A global map solution has been successfully processed using SSH only and combined SSH+SST data.
  - Others ?



Ocean Data Challenges

Hosting collaborative data challenges related to oceanography.

29 followers http://ocean-data-challenges.github.io

Unfollow

MORE INFO: https://github.com/ocean-data-challenge

README.md

OCEAN DATA CHALLENGES

The available data challenges are:

Level 3 SWOT processing

- **2024-DC SWOT denoising OSE** By Datlas, CLS and IMEDEA A challenge CNES on removing the uncorrelated KaRIN instrumental noise from the SWOT data.
- **2022-DC SWOT error calibration Gulf Stream** By Datlas, CLS, IMT-Atlantique and MEOM A challenge on the SWOT satellite spatially correlated error calibration in the Gulf Stream region.
- **2022-DC SWOT karin error filtering North Atlantic** By Datlas and CLS A challenge on the SWOT Karin instrumental error filtering in the North-Atlantic basin.

Level 4 SSH processing

- **2024-DC 4DMedSea ESA mapping OSE** By Datlas and CLS A challenge ESA - 4DMedSea project to provide SSH products in the Mediterranean for 4D reconstructions.
- **2023-DC global altimetry mapping OSE** By Datlas and CLS A challenge on real conventional nadir mapping at global scales and in regional zooms.
- **2023-DC SSH HF mapping in California OSSE** By Datlas and MEOM A challenge on mapping high frequency SSH with artificial SWOT and nadir data in the Californian SWOT Xover.

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Get started with tasks that most successful organizations complete.

Discussions

Set up discussions to engage with your community!

Turn on discussions

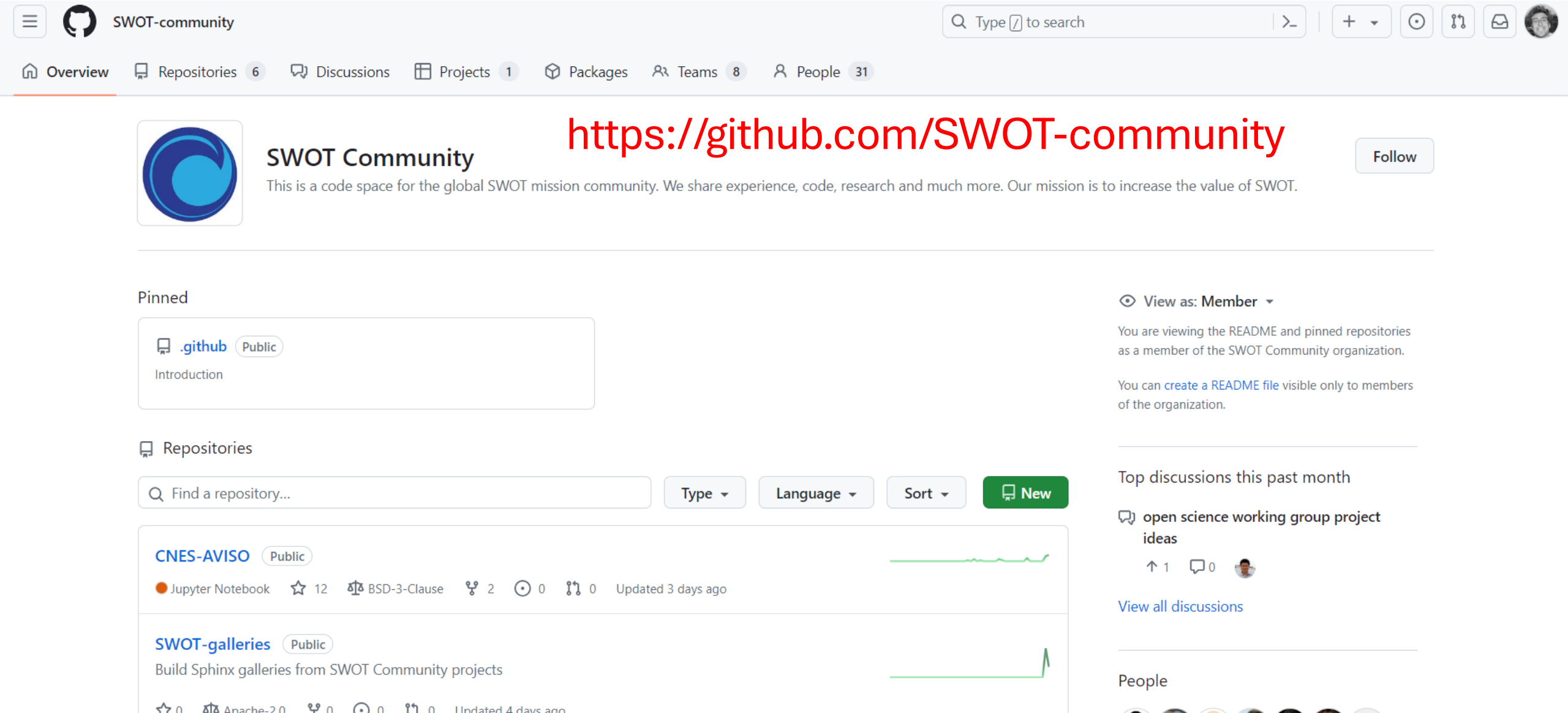
People

Invite someone

Top languages

Jupyter Notebook Python

MORE INFO:
Working group on the topic of “open science, data, and algorithm.”
See Github page



THANK YOU

Conclusions

CONSTELLATION

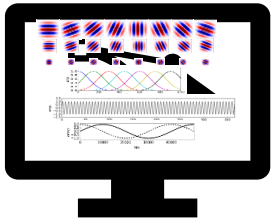
MAPPING SOLUTION

AVERAGED MAP RESOLUTION

7 nadirs

\+

MIOST

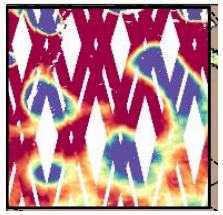


→ **~150km**

7 nadirs

\+

1 SWOT



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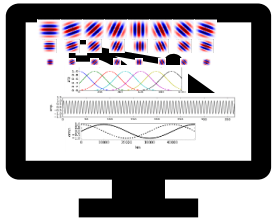
MIOST

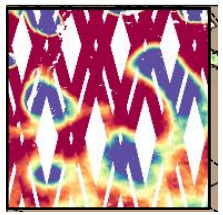


→ **~130-140km**

7 nadirs

\+

1 SWOT



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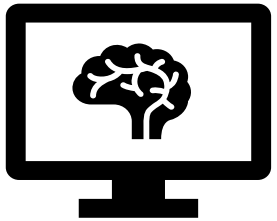
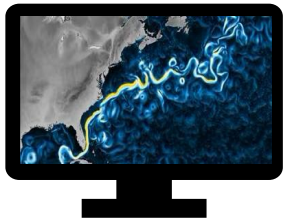
4DVARNET



or

4DVARQG



→ **~100-110km**