SWOT River Working Group Splinter

Fabrice Papa[1] & Ernesto Rodriguez[2]
[1]IRD, LEGOS
[2]Jet Propulsion Laboratory, Cal Tech

Agenda,

1. Papa/Rodriguez: Session overview review of River Science activities since the last session (10 minutes)

2. Sherpa/Smith: SWOT observational capabilities in the CalVal phase and Arctic River preliminary results (10 minutes)

3. Fenoglio: SWOT validation activities over German rivers (10 minutes)

4. Rodriguez: SWOT observations over the Congo (10 minutes)

5. Short presentations based on 2-slides from team members not able to attend (5 minutes each):

    a. Moreira: SWOT observations over the Amazon

    b. Garambois et al.: river network modeling

    c. C. Schwatke et al.: SWOT and DAHITI

    d. Ricci, Oubanas, Malaterre: the HYDROS project

    e. Thurmam, Allen: River flow waves with SWOT WSE observations

6. Review of the SWOT River Users poll results (10 minutes)

7. Open discussion of data use/quality feedback and future activities

Session overview review of River Science activities since the last session

Fabrice Papa[1] & Ernesto Rodriguez[2]
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RS Working Group: 2024 activities (since ST in Toulouse 09/2024

Online presentation of ST team project progresses to the group:

02/2024, Benjamin Kitambo: Hydrological science in the Congo from space in the context of SWOT

03/2024, Luisa Vieira-Lucchese: Modeling: suspended sediment concentrations in rivers to combine with SWOT discharge data

06/2024, Sonam Sherpa: Early characterization of SWOT ka-band backscatter behavior for water extent mapping and classification

06/2024 (postpone to later): Simon Mischel, Head GRDC

+ Many discussions/presentations to prepare the current ST (PAG, Moreira, Fenoglio, etc…)

BROWN

Early characterization of SWOT ka-band backscatter behavior for water extent mapping and classification of river

Sonam F. Sherpa and Laurence C. Smith

Institute at Brown for Environment and Society

Department of Earth, Environment and Planetary Sciences

Brown University

Funding support from

NASA

JPL
Jet Propulsion Laboratory

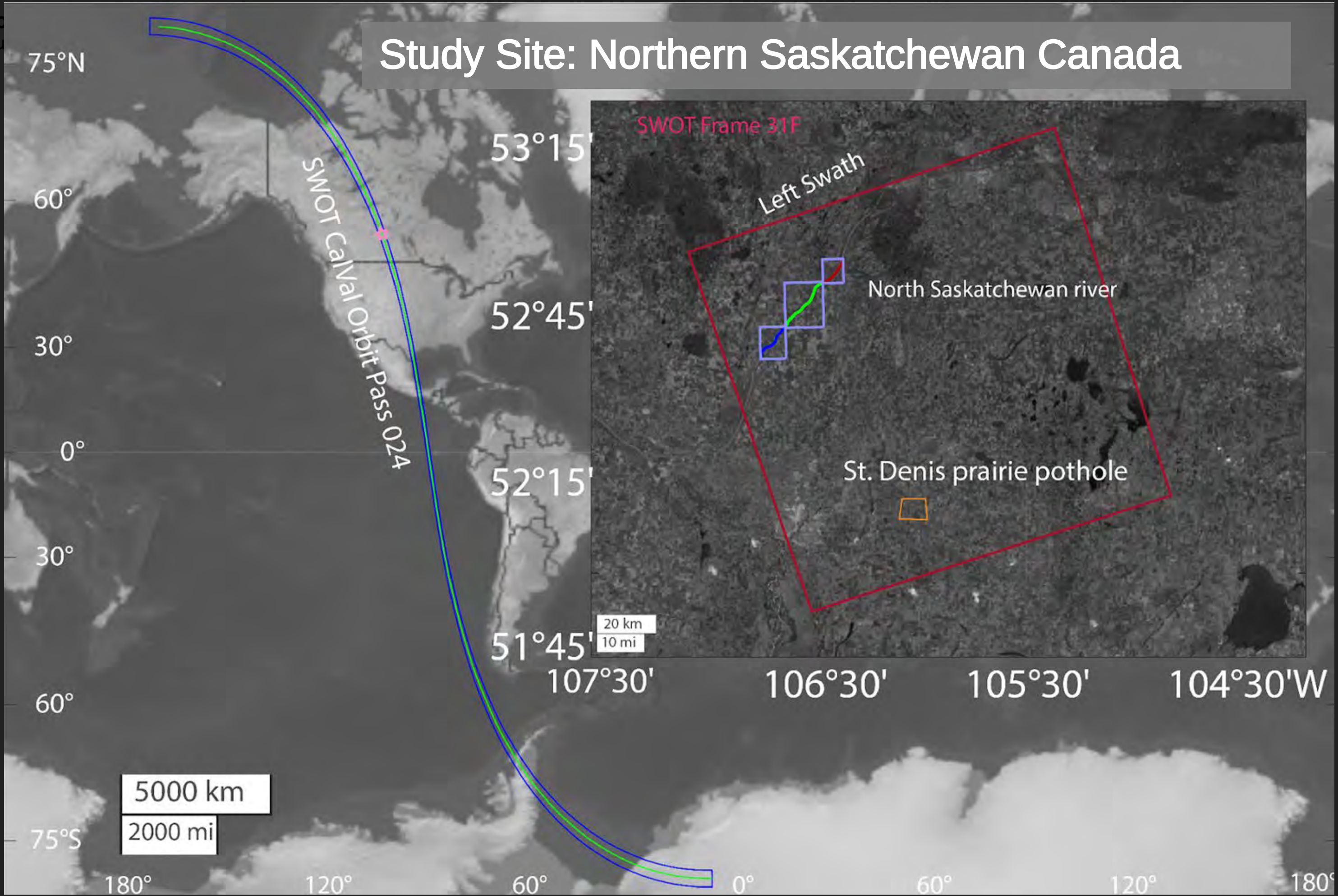
Research Question

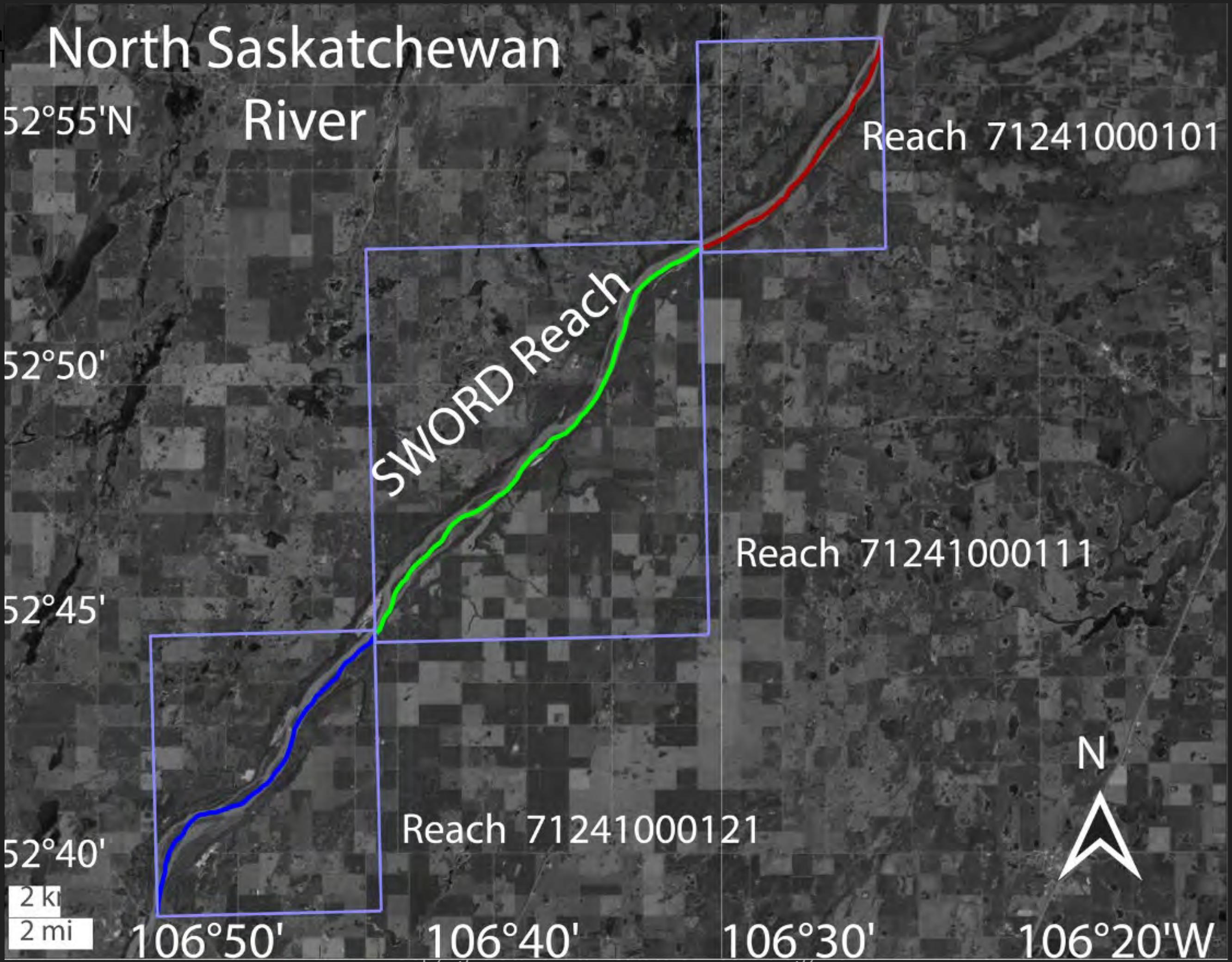
How does the SWOT signal vary over North Saskatchewan River, a tier one Cal/Val site, and thus influence the mapping and classification of water extent?

Objectives

- ❑ Characterize SWOT signal behaviors.
- ❑ Characterize the spatiotemporal variability of SWOT surface water observations (area) during the fast-sampling orbit.

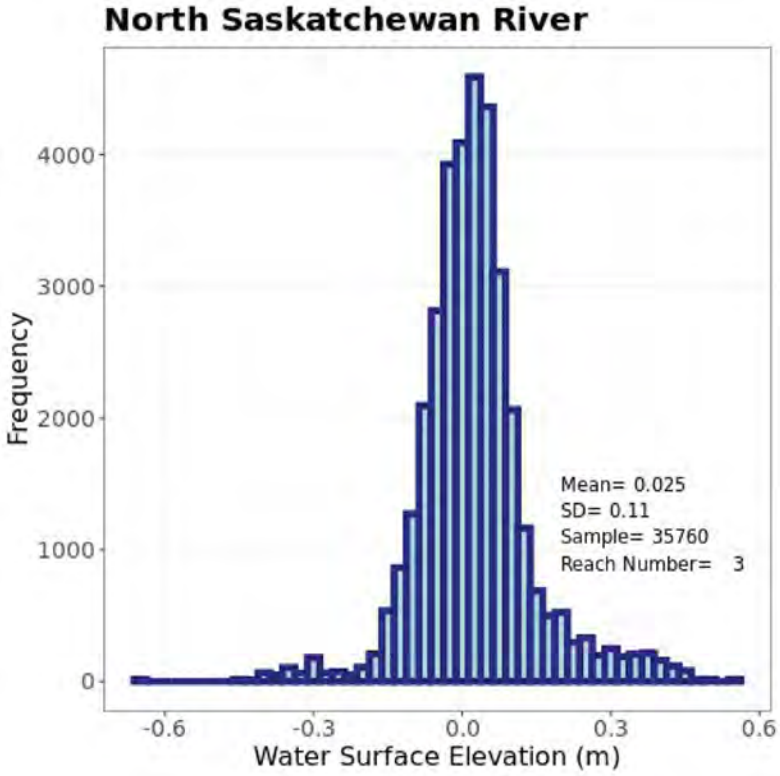
Study Site: Northern Saskatchewan Canada




North Saskatchewan River
52°55'N
52°50'
52°45'
52°40'
SWORD Reach
Reach 71241000101
Reach 71241000111
Reach 71241000121
N
2 mi
106°50'
106°40'
106°30'
106°20'W

GNSS and PT Water Surface Elevation (WSE) differences are within the range of SWOT uncertainty.

WSE GNSS drift data measurement over North Saskatchewan River (Brown University team)



Distribution of relative differences in WSE from GNSS and PT for three Nsask reaches. (Data Version: Summer/Fall 2023): Updated now.

Data

SWOT Pixel cloud product

- Backscatter values (Sig0)
- Classification, classification quality
- Water fraction

Data date: March 9 to July 10, 2023 (Fast sampling orbit)

Optical Measurements

- Pleiades (0.5 m resolution)
- Planet Scope (3 m resolution)
- In-situ gauging station data

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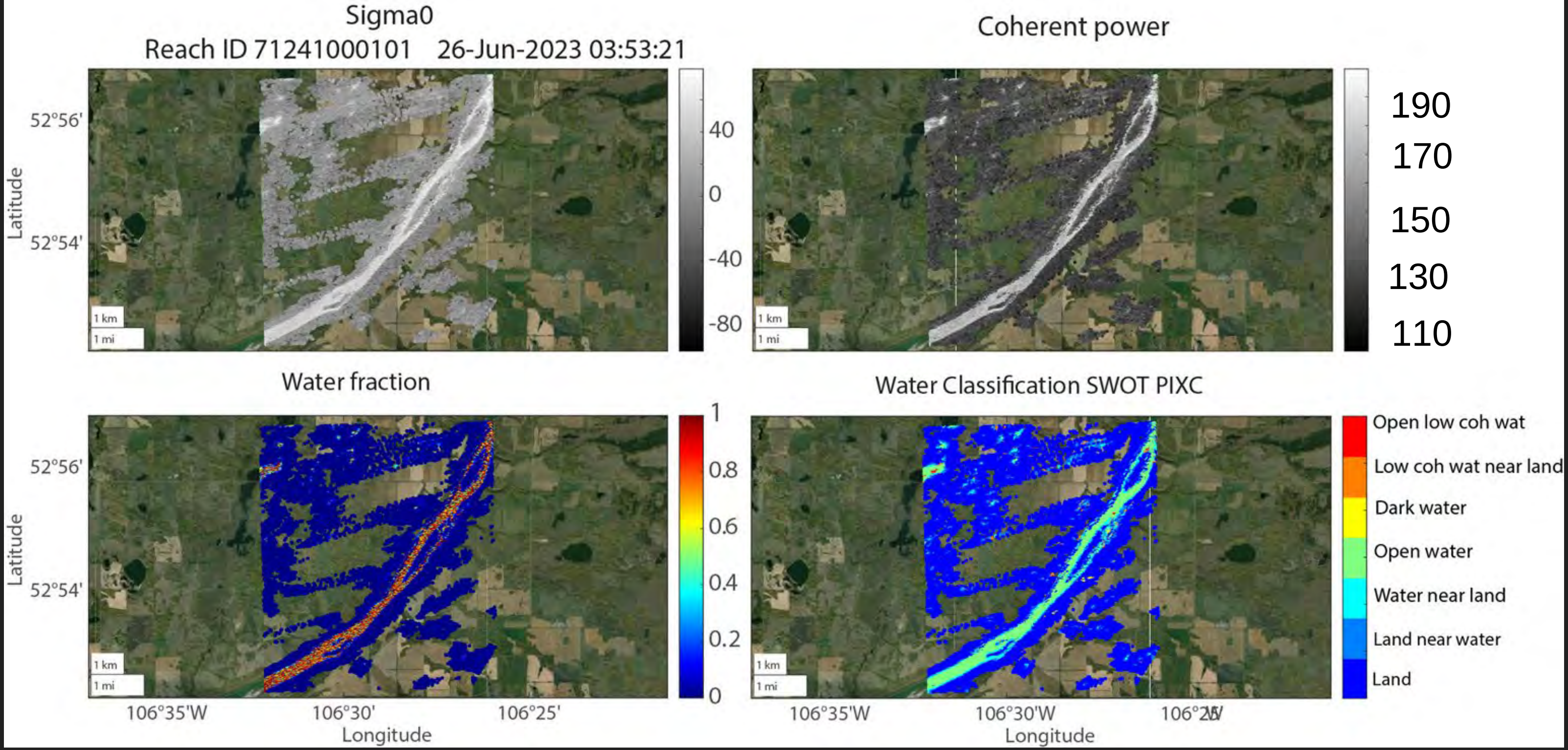
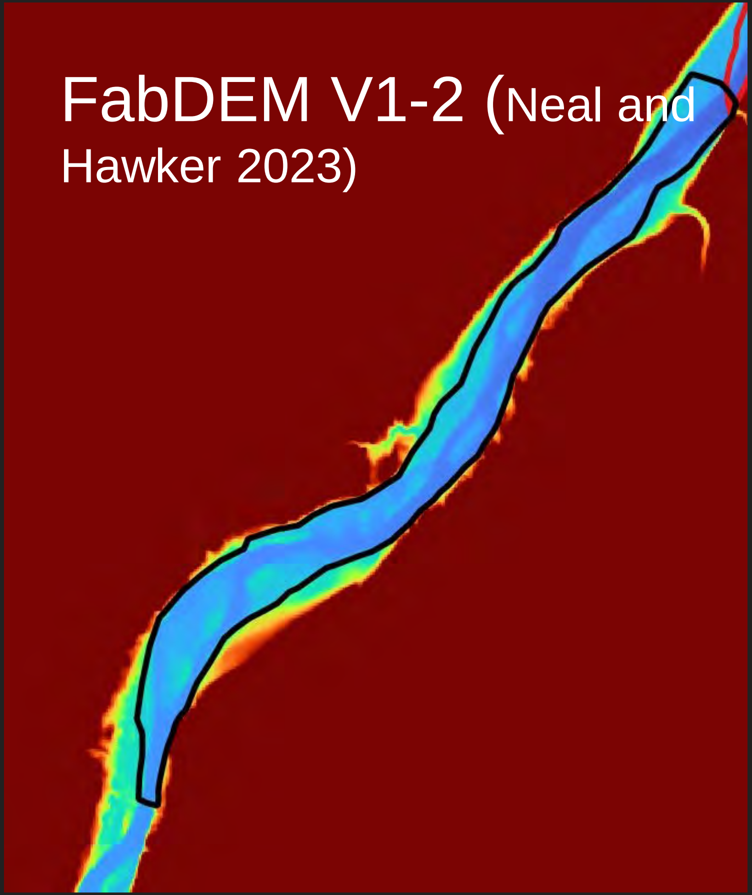
SWOT backscatter and classification on North Sask River.




FabDEM V1-2 (Neal and Hawker 2023)


Planet 27, June, 2023

Methods: SWOT area calculation

Image selection/filtering

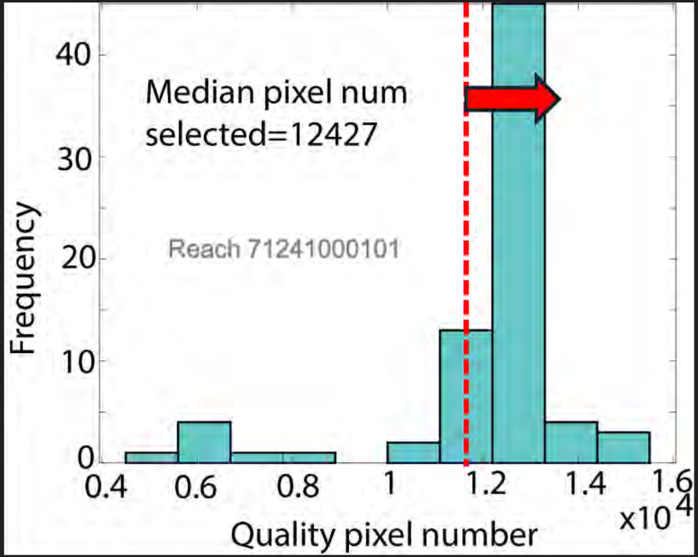
- Obtain median classification qual. value of all images.
- Select images with a median value that is less than <=1.
- Obtain median pix num. Select images with pixel number in the mask >50th percentile.

↓

Compute area

- All water classes as 1 except water near land
- Use mean of water fraction value for water near land
- Keep only Water fraction values within 1 and 0.
- Multiply with pixel area (projected pixel area on the ground)

Identified a median flag of 12427 or higher.



Selection of images with pixel length in the mask >50th percentile

High-Resolution Pleiades Image (Courtesy: Roger Fjortoft)

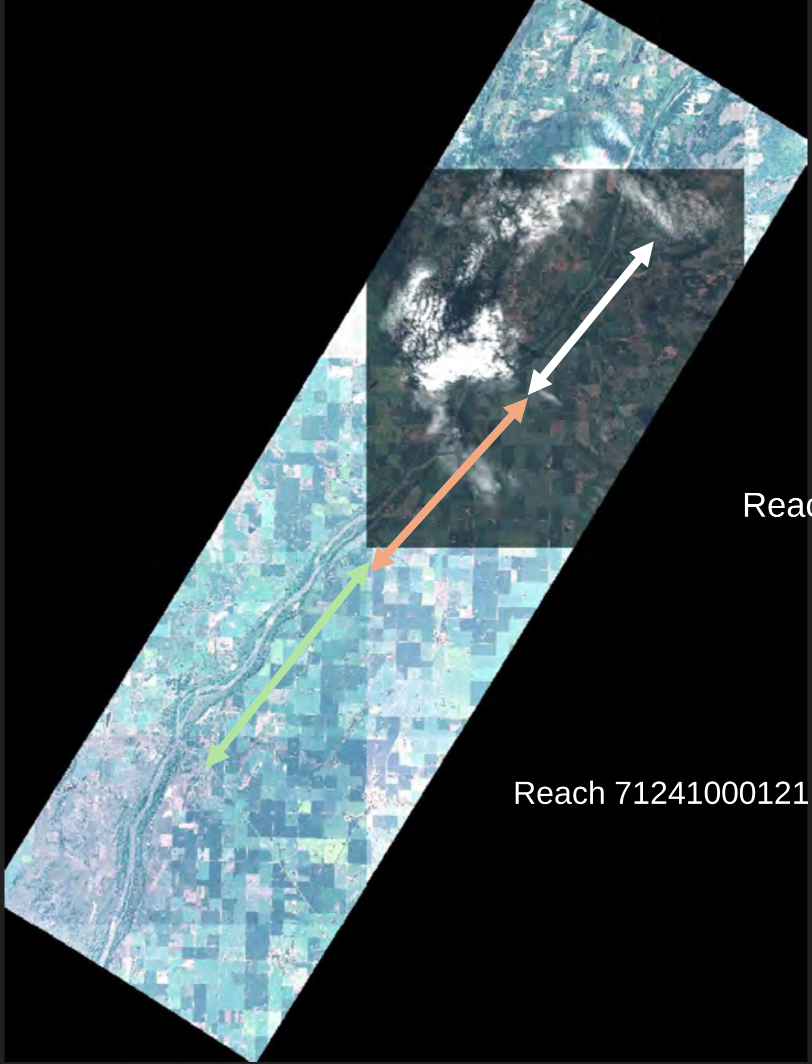


Image date: June 25, 2023

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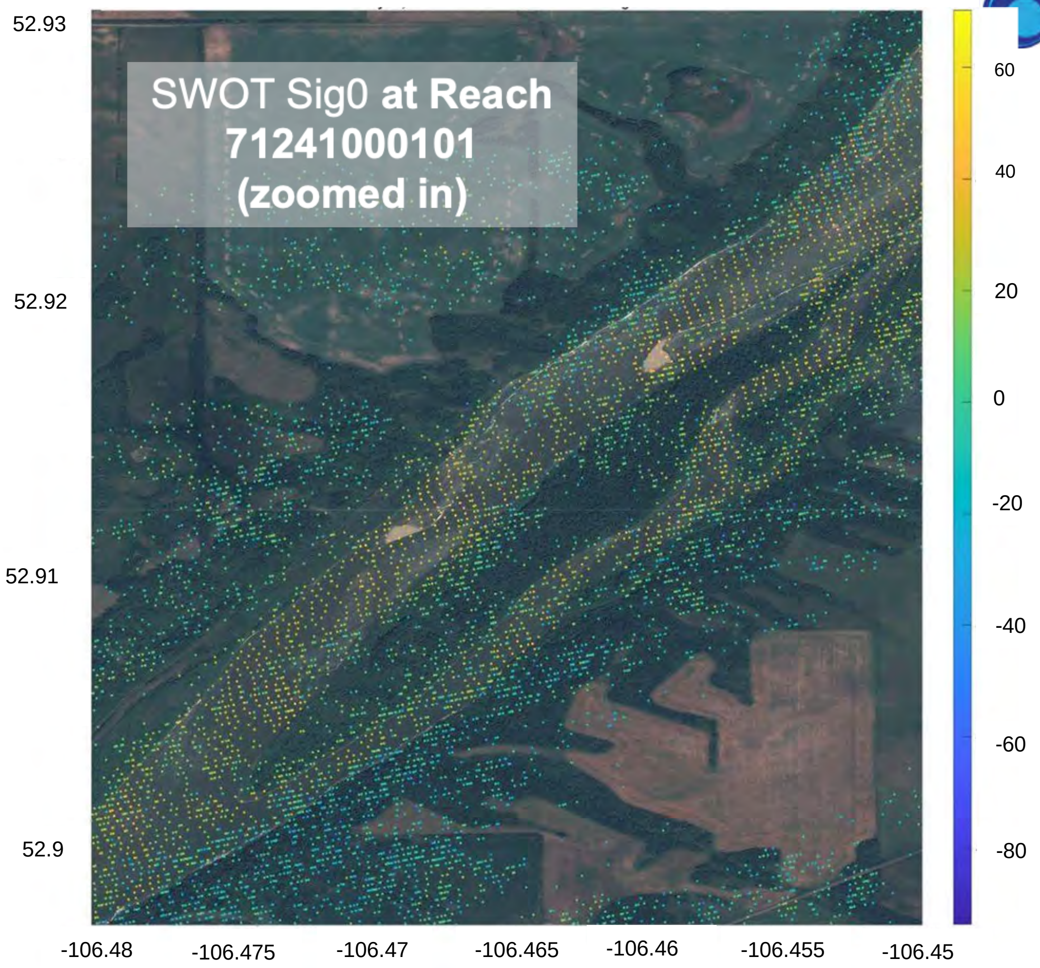
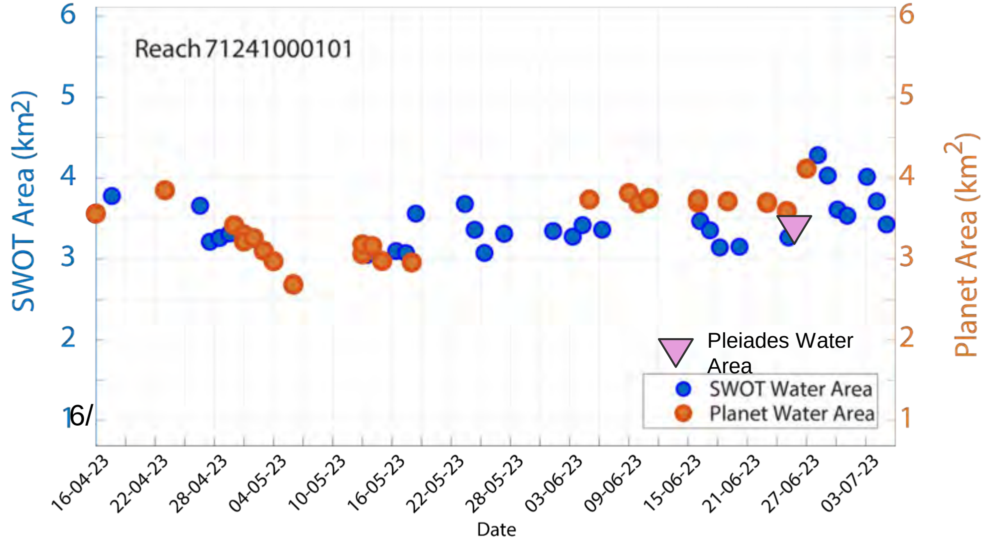
Pleiades and SWOT PIXC on June 25, 2023 are comparable.

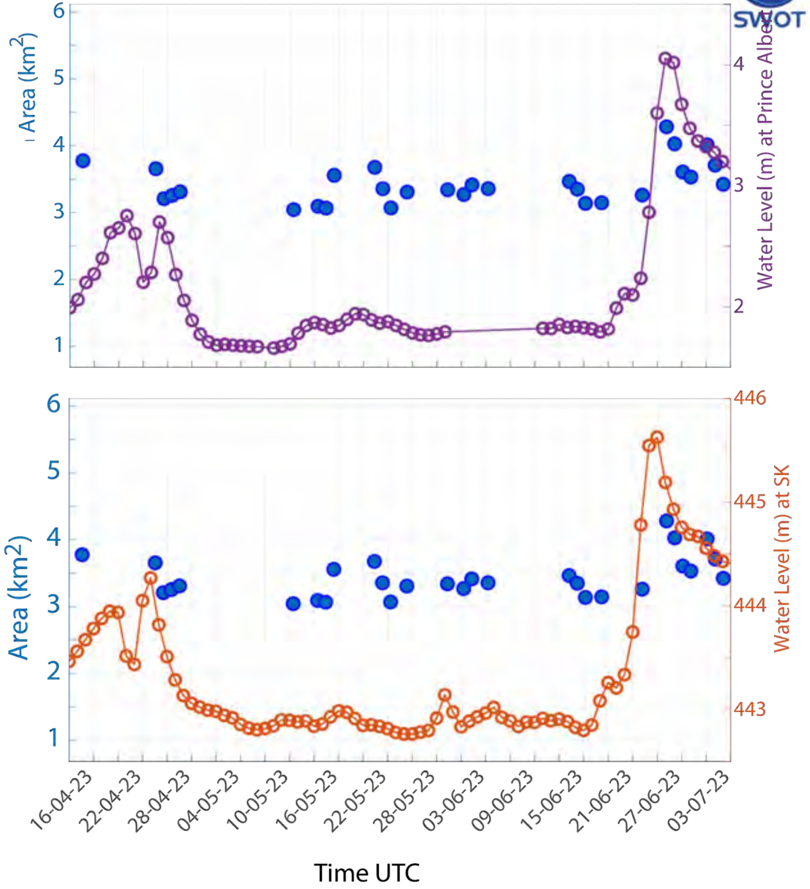
Reach 71241000101
- ❑ Pleiades water area: 3.40 km²
- ❑ SWOT water area: 3.26 km²



Time series of SWOT and Planet water area (km^2)

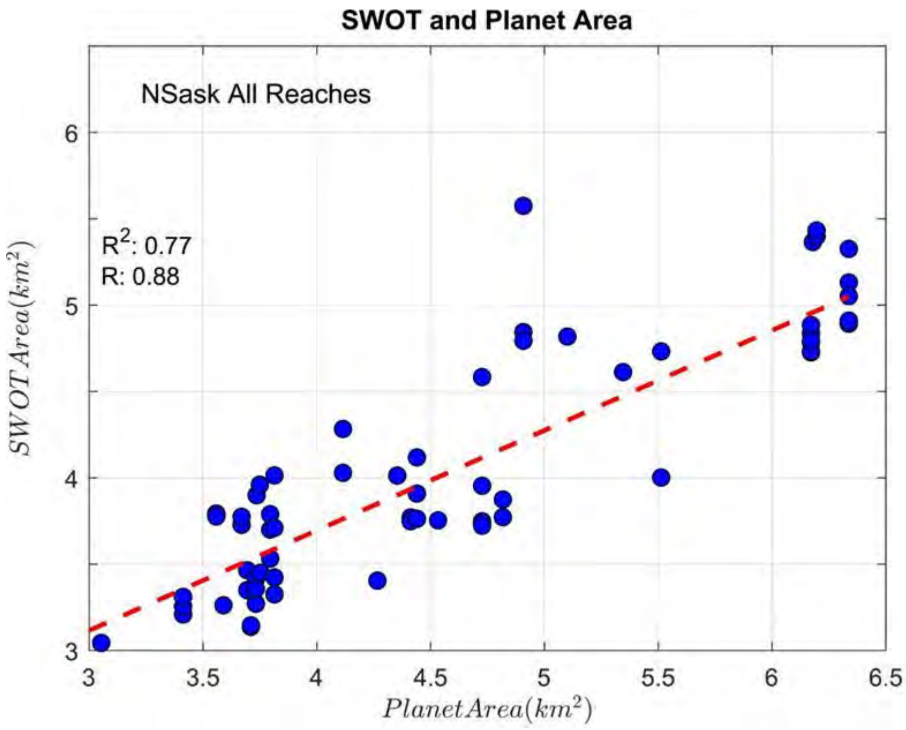


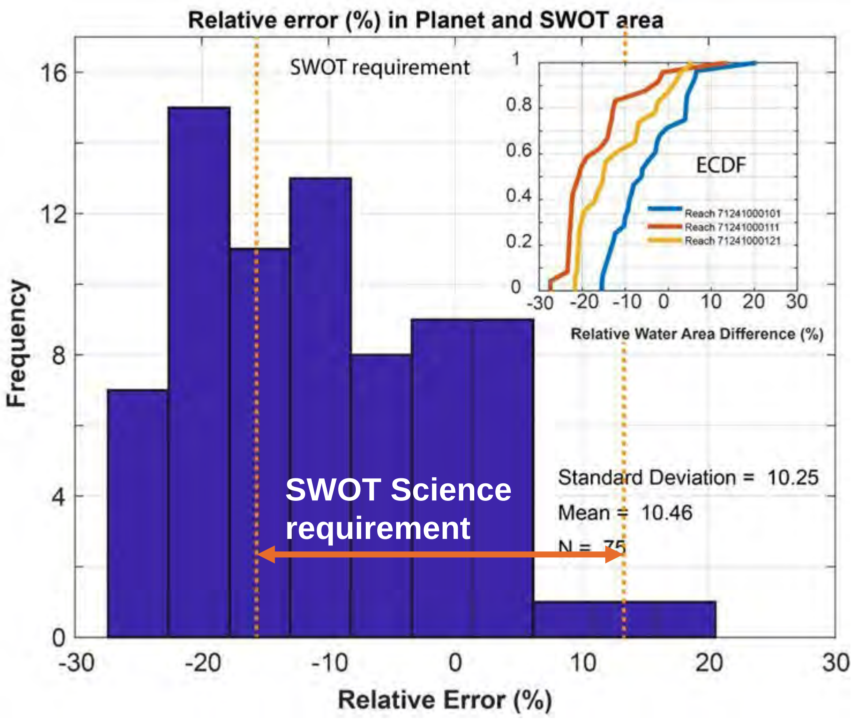
Comparison with Planet Scope water area



Comparison with water level at two gauging stations

North Saskatchewan River SWOT and Planet Area





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SWOT

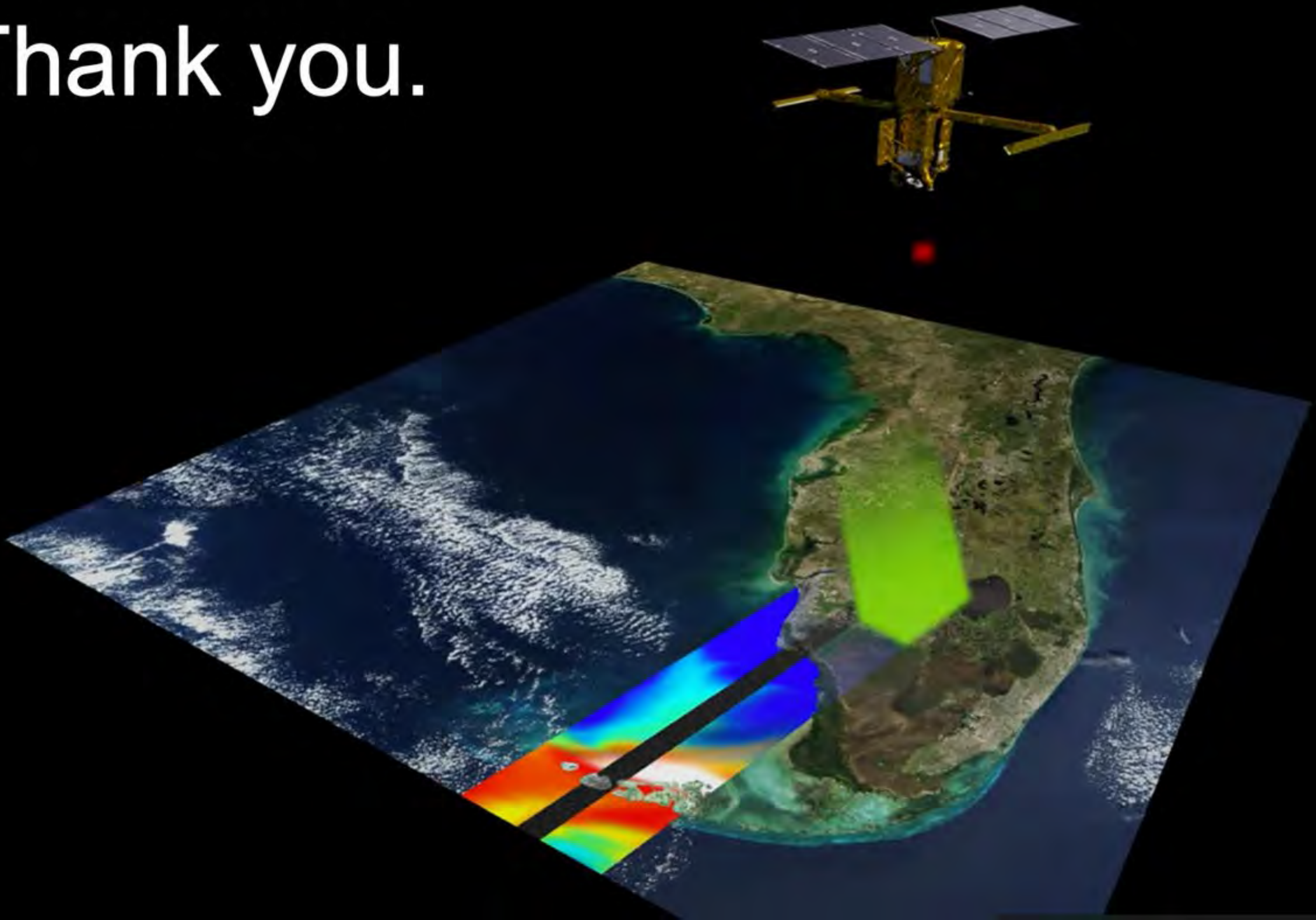
Summary

- ❑ Accurate water classification when Sig0 > ~40 db (qualitative).
- ❑ SWOT river area qualitatively tracks river gauge data.
- ❑ SWOT river area correlates well with Planet area (R = 0.88) and meets science requirements with SD ~10%.
- ❑ Dark water classification may be useful.

Acknowledgments

- SWOT US cal/val team
- CNES (Roger Fjortoft)
- Cassie Stuurman (JPL)
- Funding agents

Thank you.



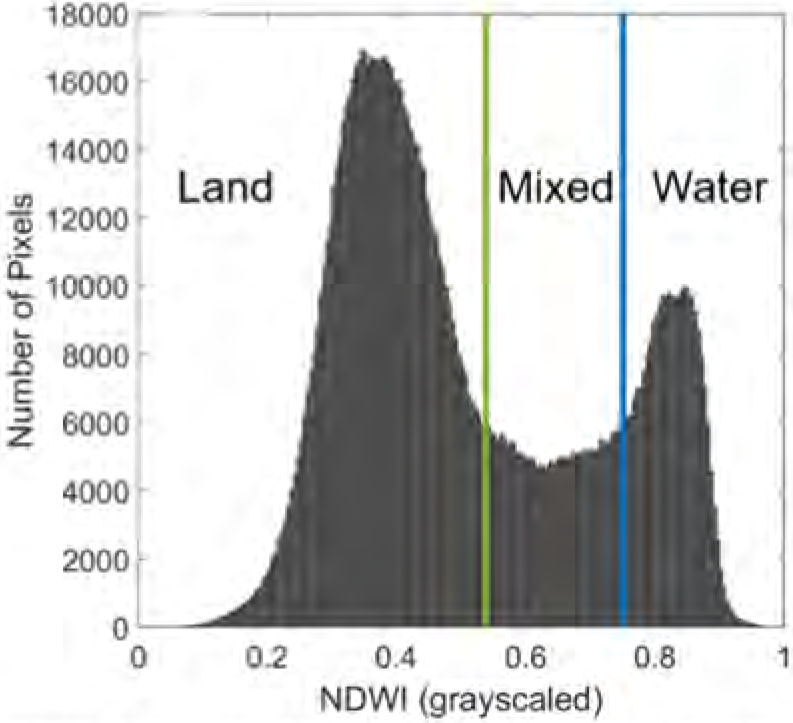
Methods: Planet area calculation

Select images with <5% cloud cover; Exclude snow-covered images.

NDWI = (G-NIR)/(G+NIR) (overlay with mask)

Apply histogram-based thresholding (Cooley et al. 2019).

Select pixels >75% water.



Histogram of land and water pixels contained with the buffered lake mask.

Cooley et al. 2019

SWOT validation activities over German rivers

Fenoglio Luciana, Chen Jiaming

Institute of Geodesy and Geoinformation, University of Bonn, Germany

REFECCT (Rehearsal of EFfective Flood Early warning and decision-support system to strengthen Coping Capacity and adapTation in west Africa)

DETECT-REDS: Impact analysis of Surface water level, Discharge and Storage change

B01-DETECT RHINE

network
reference **DHHN2016, GCG2016 geoid**

RG (> 40) WSE
RG > 10 River discharge
Vortex 4
RPR GNSS-R 8

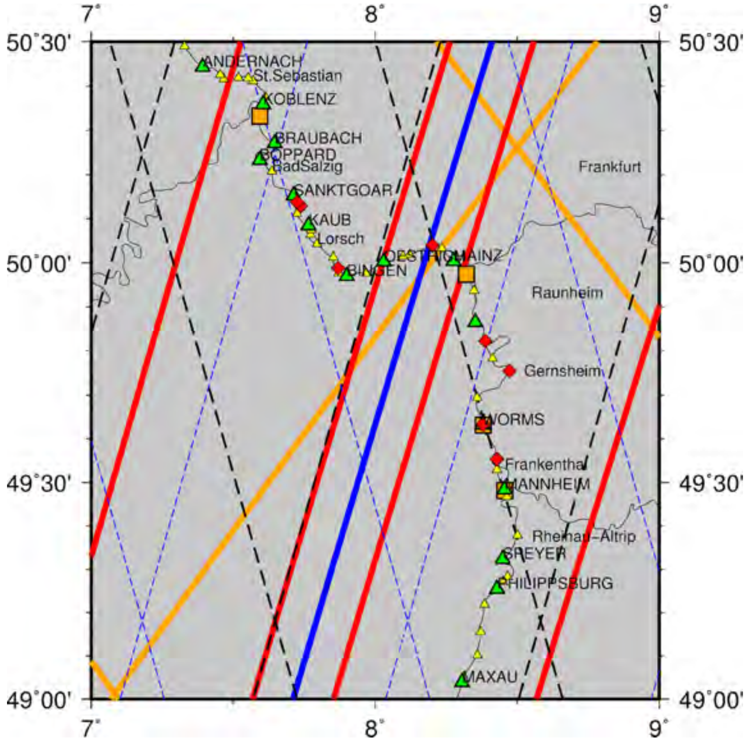


Fig. 1 B01-DETECT Validation region (right) with gauge, Vortex and RPR

Outline

Validation

SWOT WSE PIXC v2.0 vrs gauges & Vortex

SWOT slope PIXC v2.0 vrs gauges

SWOT Discharge RiverSP vrs insitu

Conclusions

Validation of SWOT WSE PIXC v2.0 vrs gauges & Vortex

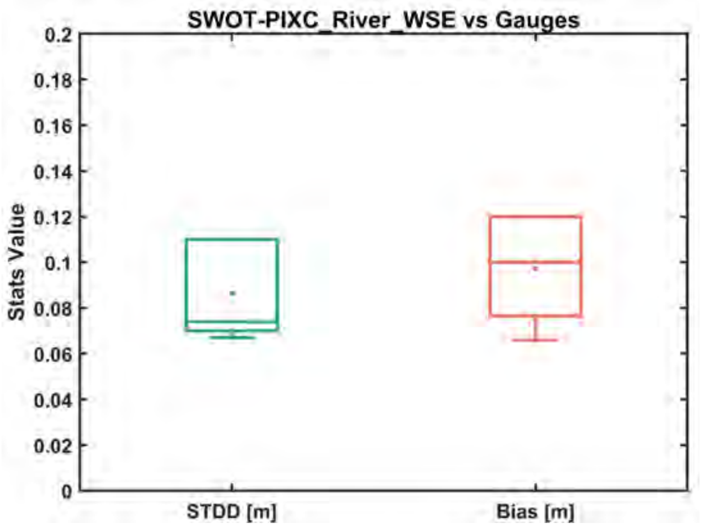


Fig. 1 Large set of stations

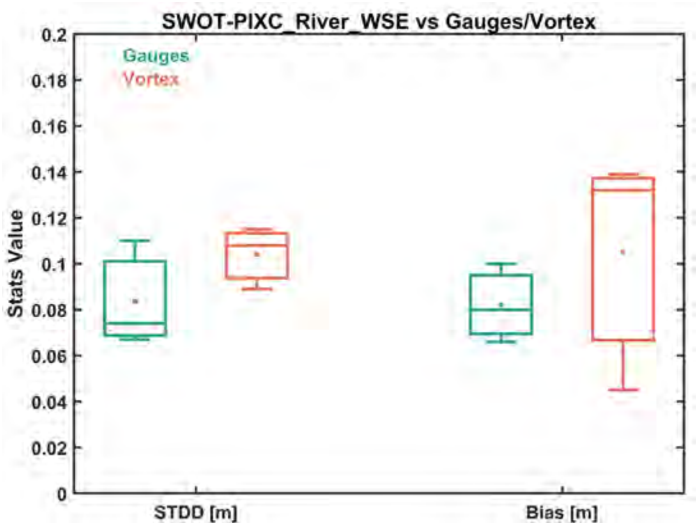
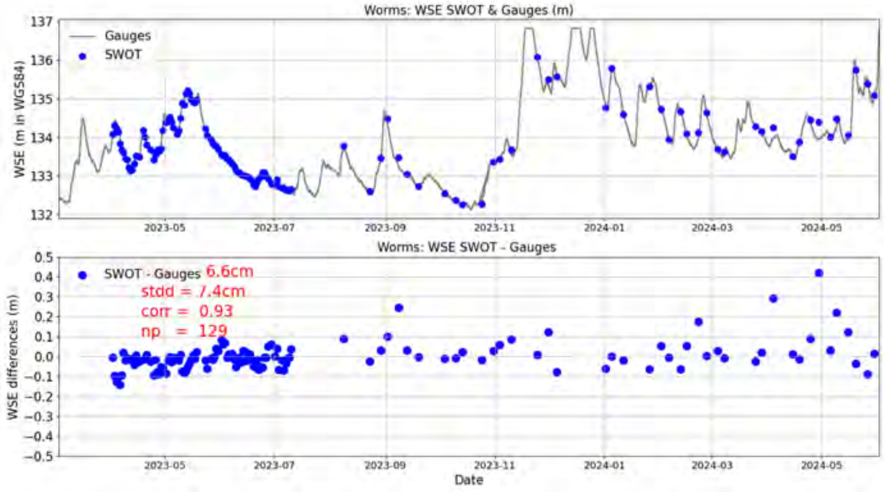
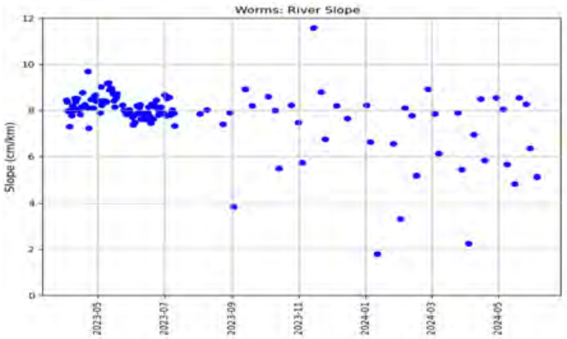


Fig. 2 Three gauges/Vortex: Worms, Mannheim, Koblenz

Worms: SWOT-Karin swath-altimetry vs in-situ

Cal/val phase + science phase

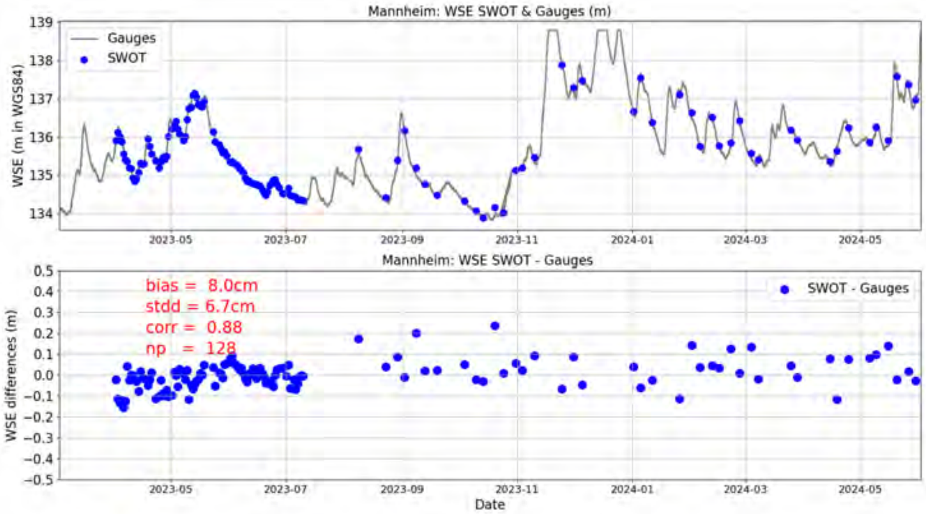




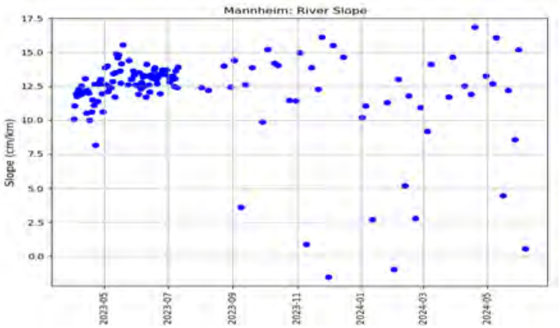
STDD 7.4 cm from PICX SWOT-Karin

Fig. 3 SWOT in Worms over the SWORD reach that includes the gauge and averaging over 0.05 radius

Mannheim: SWOT-Karin swath-altimetry vs in-situ



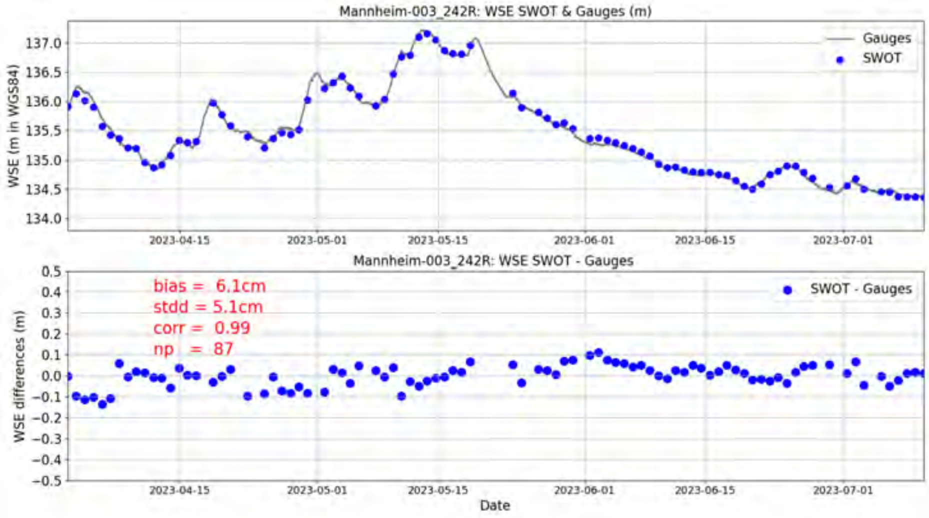
Cal/val phase + science phase



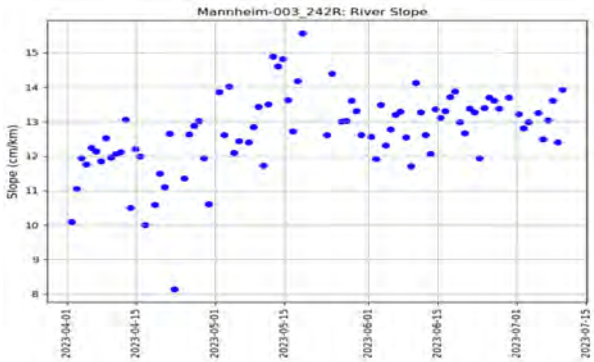
STDD 6.7 cm from PICX SWOT-Karin

Fig. 4 SWOT in Worms over the SWORD reach that includes the gauge and averaging over 0.05 radius

Mannheim: SWOT-Karin swath-altimetry vs gauges



Cal/val phase

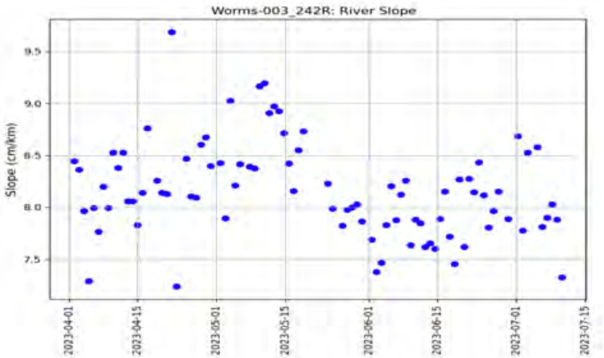


STDD 5.1 cm from PICX SWOT-Karin

Fig. 5 as Fig.4 in cal/val only

Worms: SWOT-Karin swath-altimetry vs in-situ

Cal/val phase

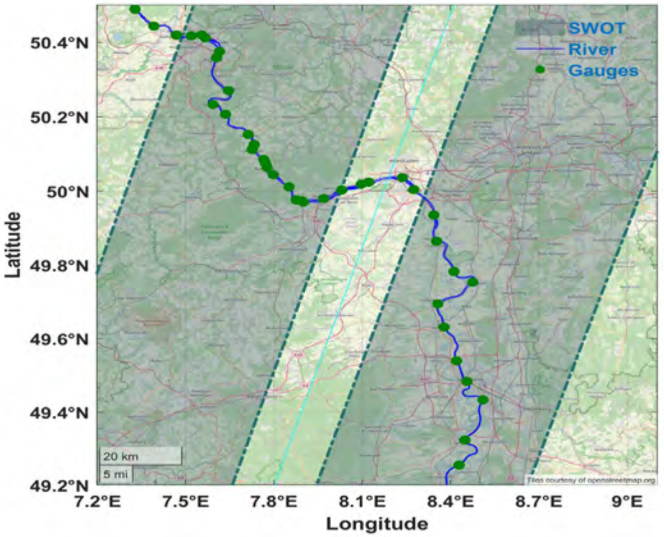


STDD 4.2 cm from PICX SWOT-Karin

Fig. 6 was 7.4 cm in longer inerval

Validation of SWOT SLOPE PIXC v2.0 vrs gauges

Reach-2RG	Bias (cm/km)	Stdd (cm/km)	Corr	Np
Braubach(580km) - Koblenz(592km)	-1.9	0.6	0.91	79
SanktGoar(556km) - Boppard(570km)	-1.4	0.3	0.17	83
Trechtingshausen (535km) -Kaub(546km)	1.9	0.9	0.96	87
Worms(443km) - Gernsheim(462km)	-0.1	0.2	0.94	87
Mannheim(425km) - Worms(443km)	-0.4	0.2	0.88	87
Rheinau(414km) - Mannheim(425km)	0.8	1.2	0.32	81



Koblenz(592km) —> Mannheim(425km)

RIVER SLOPE Accuracy

Validation of SWOT SLOPE PIXC v2.0 vrs gauges

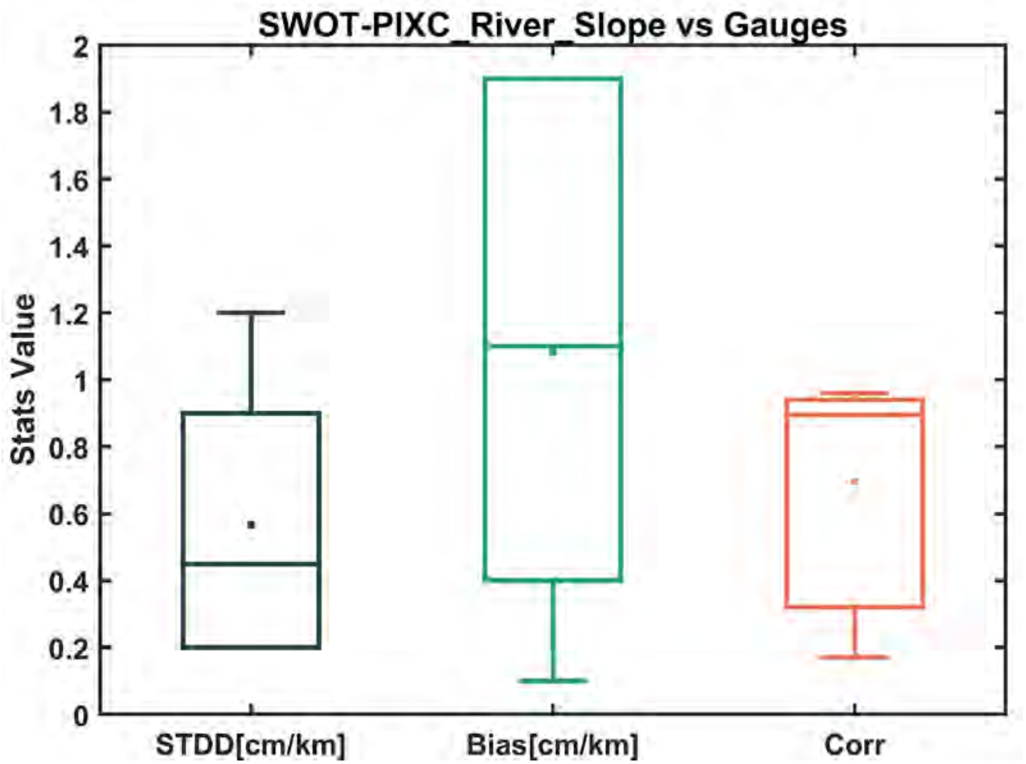


Fig. 7 Large set of stations ST, Abs. of bias, Corr

STDD 0.6 cm/km

Slope SWOT PIXC

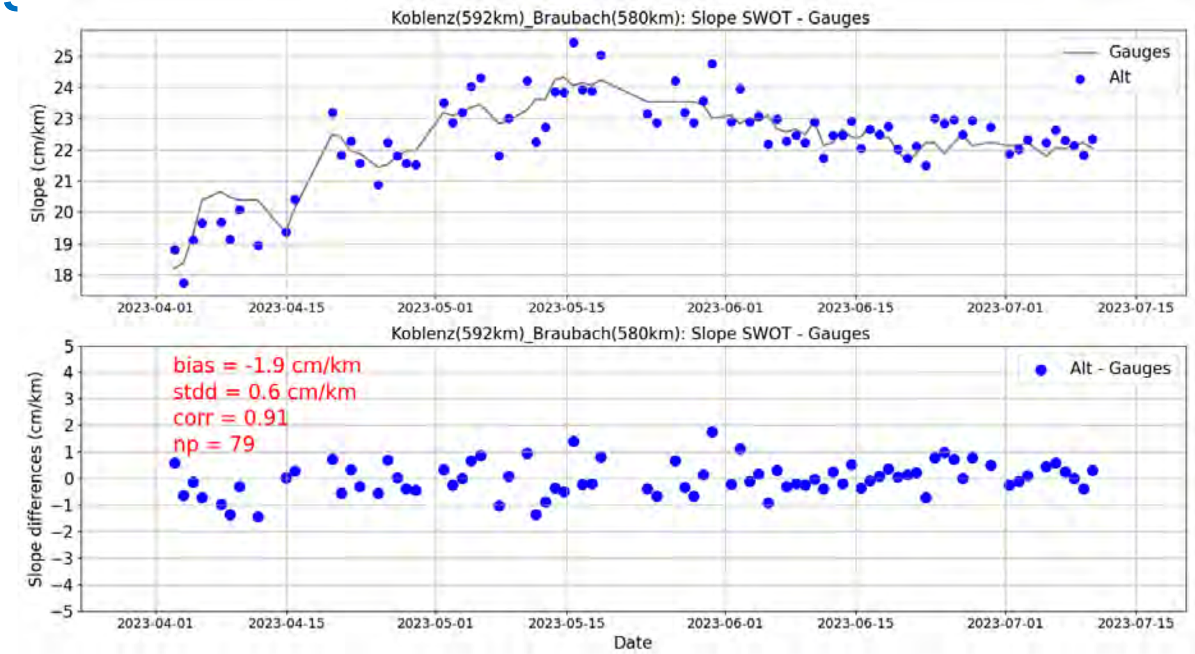


Fig. 8. Slopes **SWOT PIXC** (Koblenz to Braubach km-Rhine) compared to slope **REACH-2RG.**
Second from the WSE of the two gauge (black), first fitting a line to the locations

STDD 0.2 cm/km

Slope SWOT PIXC

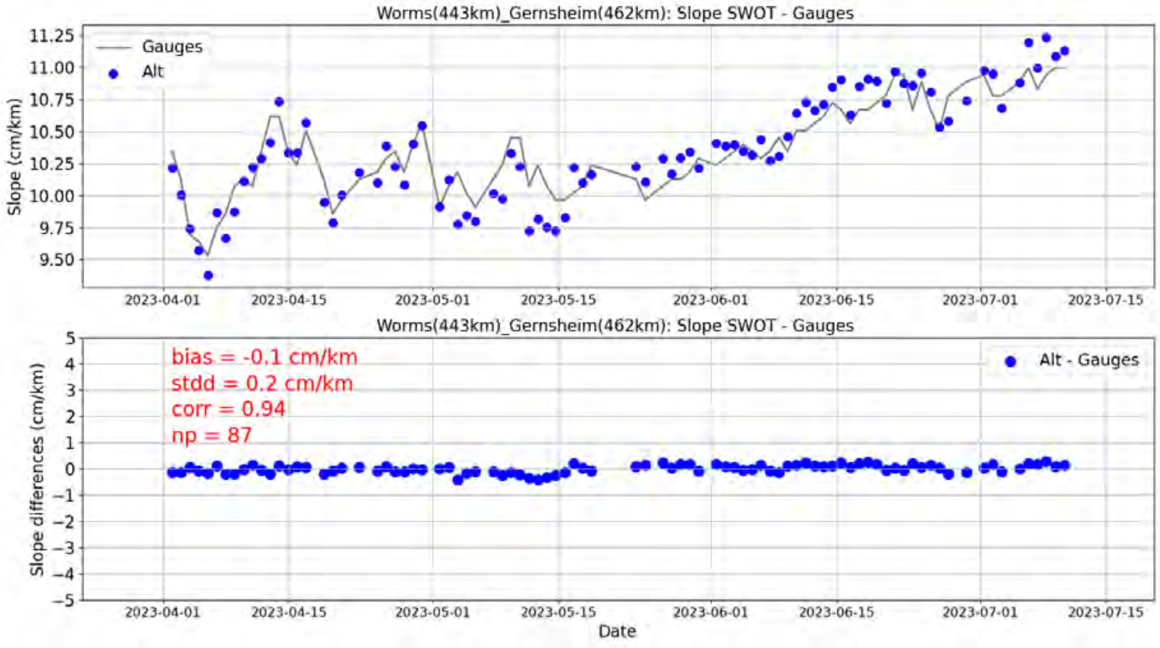
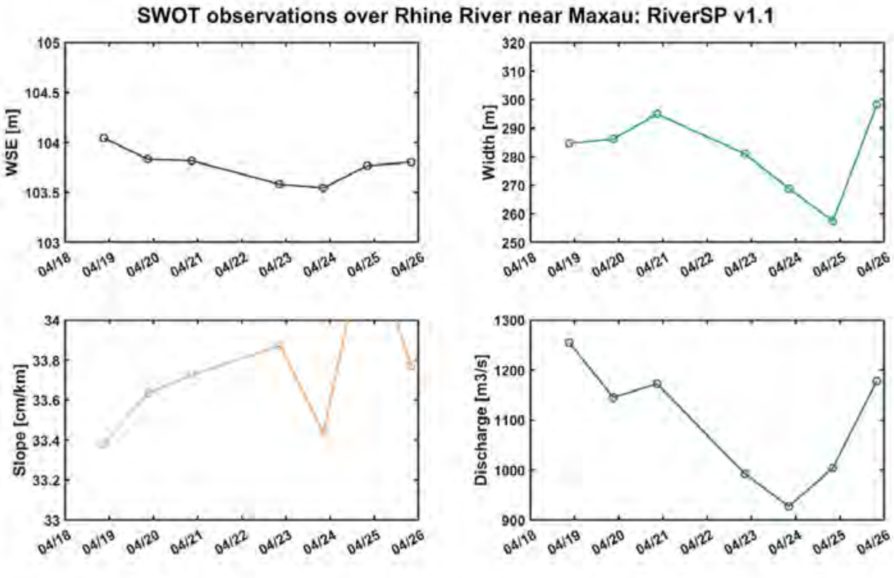


Fig. 9. Slopes **SWOT PIXC** (Worms to Gernsheim compared to slope **REACH-2RG.**
Second from the WSE of the two gauge (black), first fitting a line to the locations

RiverSP Products

$$Q = k_2 W Y^{1.67} S^{0.33}$$

Station	NS	Qnorm	Exp.Width	Exp. depth	Exp. Slope	K
Mainz	0.90	0.16	0.9	1.3	0.54	107.6
Worms	0.92	0.13	1.0	1.4	0.3	8.7
Duisburg	0.91	0.18	0.9	1.3	0.3	13.8
Wesel	0.93	0.15	0.9	1.3	0.3	3.7
Düsseldorf	0.86	0.22	0.9	1.3	0.3	14.9
Duisburg	0.94	0.15	0.9	1.3	0.68	335.8

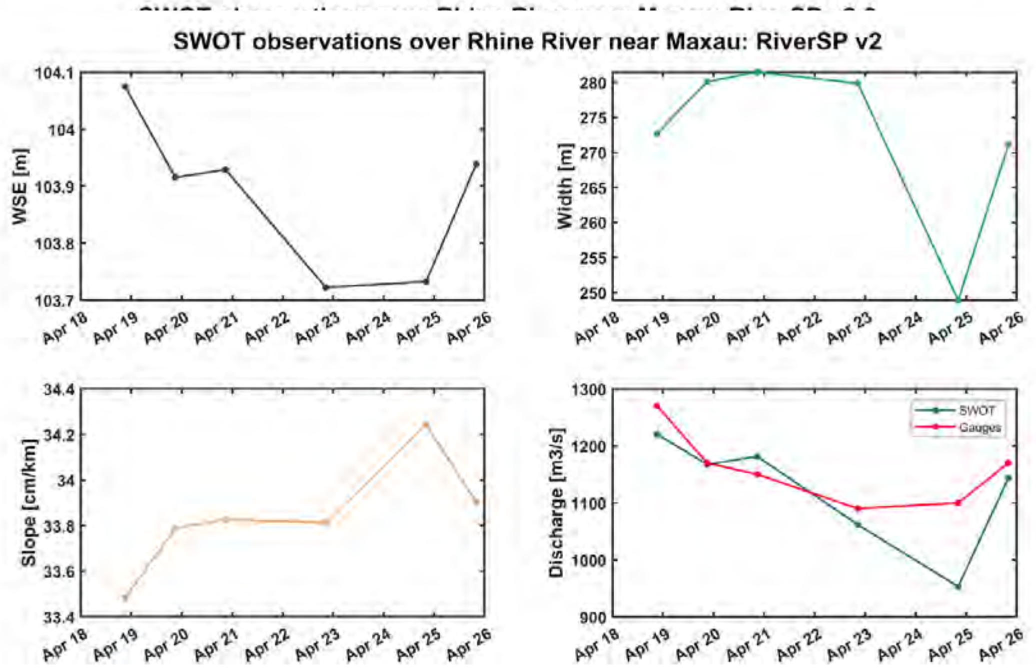


Discharge from Bjerklie2013 Formula (4 coeff. Fixed)

Derived constrained by gauges Q from Sentinel-3 (Fenoglio et al., IUGG 2023)

Fig. 10 Maxau. WSE, Width, Slope– Rhine km 450-440 (see Fig.1 in Andreadis et al. submitted).

The DISCHARGE for SWOT release: version 2.0



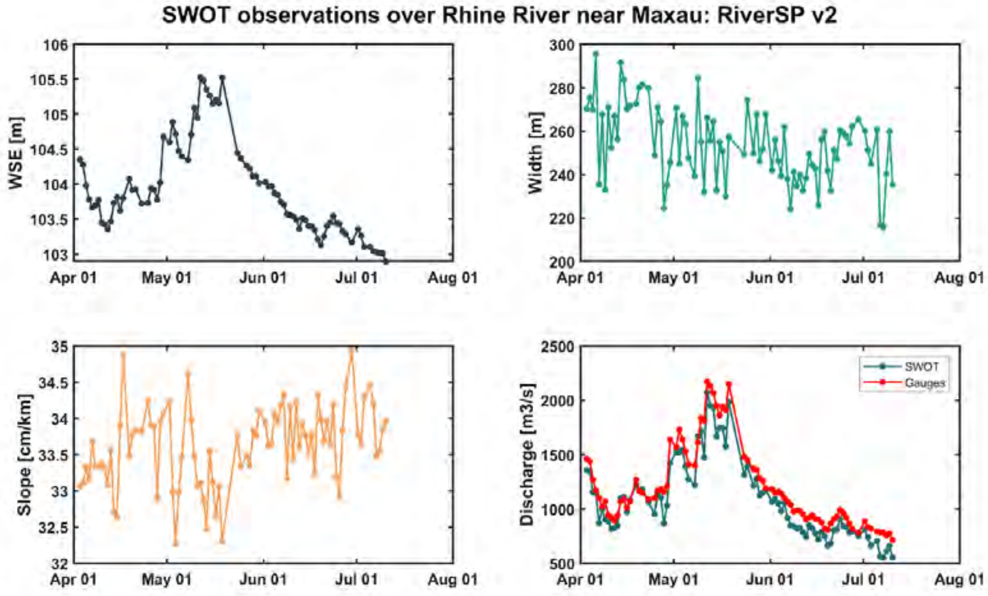
nBias: -3.2%

nRMSE: 4.7%

r: 0.80

Fig. 11 Maxau. WSE and Width in Reach Product – Rhine km 450-440

The DISCHARGE for SWOT release: version 2.0



nBias: -9.7%

nRMSE: 6.4%

r: 0.98

Fig. 12 Maxau. WSE and Width in Reach Product – Rhine km 450-440

Conclusions

Good agreement of WSE from SWOT in rivers compared to river gauges
STDD version 2.0 < **10 cm**

Good agreement of slopes from SWOT in rivers compared to river gauges
STDD 0.2-0.6 < **1.7 cm/km,** bias depends on selected river reach

Good agreement in river discharge from SWOT compared to in-situ discharge with simple equations in the selected gauges in Rhine

Challenge and oulook of our activities River Discharge at ungauged stations

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SWOT

SWOT observations over the Congo

Ernesto Rodriguez
Jet Propulsion Laboratory, Cal Tech

SWOT studies of multi-channel rivers
Ernesto Rodríguez, JPL/CalTech

Nine of the largest 10 rivers in the world exhibit complicated multi-channel (anabranching) geometry.

This makes them very hard to monitor using river gauges, which work well for single-channel rivers. Many of these rivers are not well monitored due to difficult access.

SWOT provides the unique capability of providing numerous virtual gauges that will help understand the complicated hydraulic dynamics.

Many people rely on these large rivers for transportation, water, and food. The SWOT data has the potential of helping large populations in many countries understand and utilize their water resources in a changing planet.

The Congo Cuvette Centrale is an extensive low-slope region that is challenging for SWOT

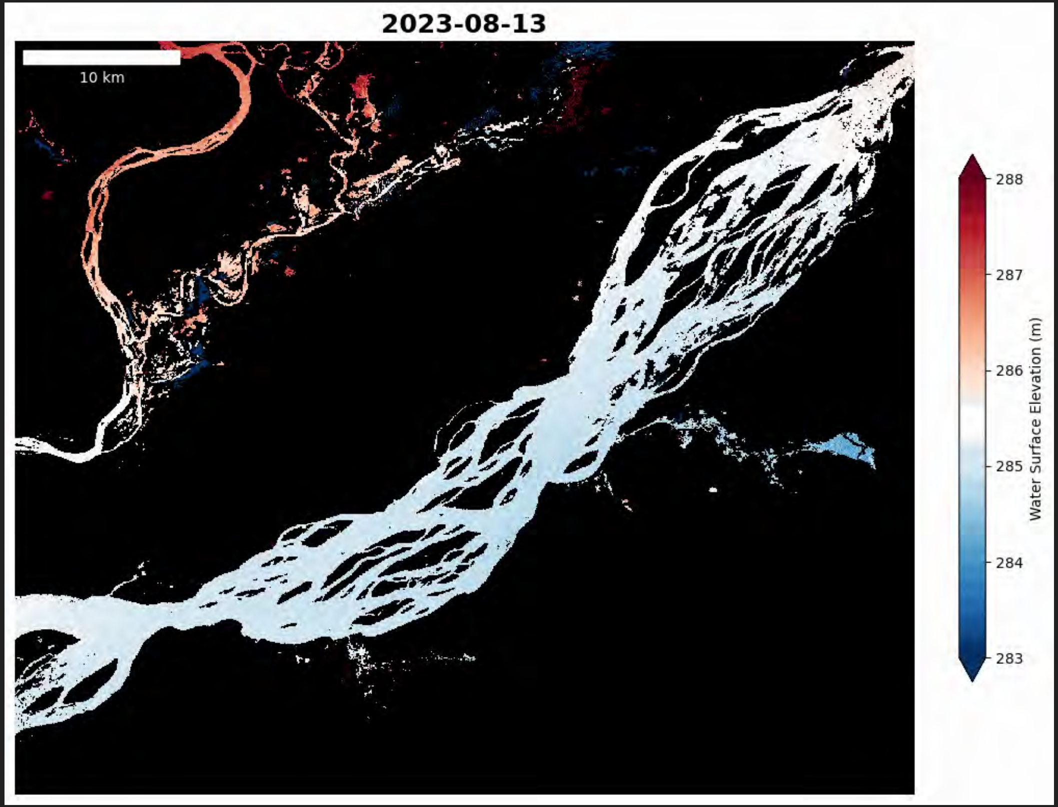
Table 1. World's largest rivers by dominant channel pattern, after Latrubesse [9]

River	Country to the mouth	Mean annual Discharge (m^3/s)	Drainage area (10^3 km^2)	Annual Q_s (Mt/year)	Sediment yield ($t/km^2 year$)	Dominant channel pattern
Amazon	Brazil	209,000	6100	~1000	167	Anabranching
Congo	DR Congo	40,900	3700	32.8	9	Anabranching
Orinoco	Venezuela	35,000	950	150	157.8	Anabranching
Yangtze	China	32,000	1943	970	499	Anabranching
Madeira	Brazil	32,000	1360	450	330	Anabranching
Negro	Brazil	28,400	696	8	11.5	Anabranching
Brahmaputra	Bangladesh	20,000	610	520	852.4	Anabranching
Japura	Brazil	18,600	248	33b	133	Anabranching
Parana	Argentina	18,000	2600	112	43	Anabranching
Mississippi	USA	17,000	3200	330	102	Meandering

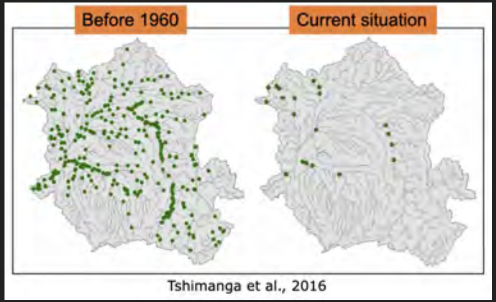
Source: Novetic/United Methodist News
Courtesy B. Kitambo (LEGOS)

Source:CRREBaC/CRuHM/Landry /International Rivers
Courtesy B. Kitambo (LEGOS)

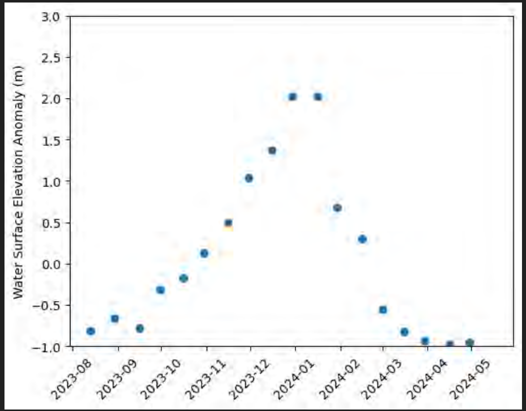
SWOT Water Surface Elevations Provide Many Thousand Virtual Stream Gauges



SWOT raster at 50m derived from PIXC data. This is not the official raster product to look at smaller channels.



This figure shows the number of physical river gauges in the Congo basin



This figure shows the water surface elevation dynamics for just one SWOT channels over the period of nearly one year. The SWOT data captures clearly the annual variations in river stage due to the rainy season.

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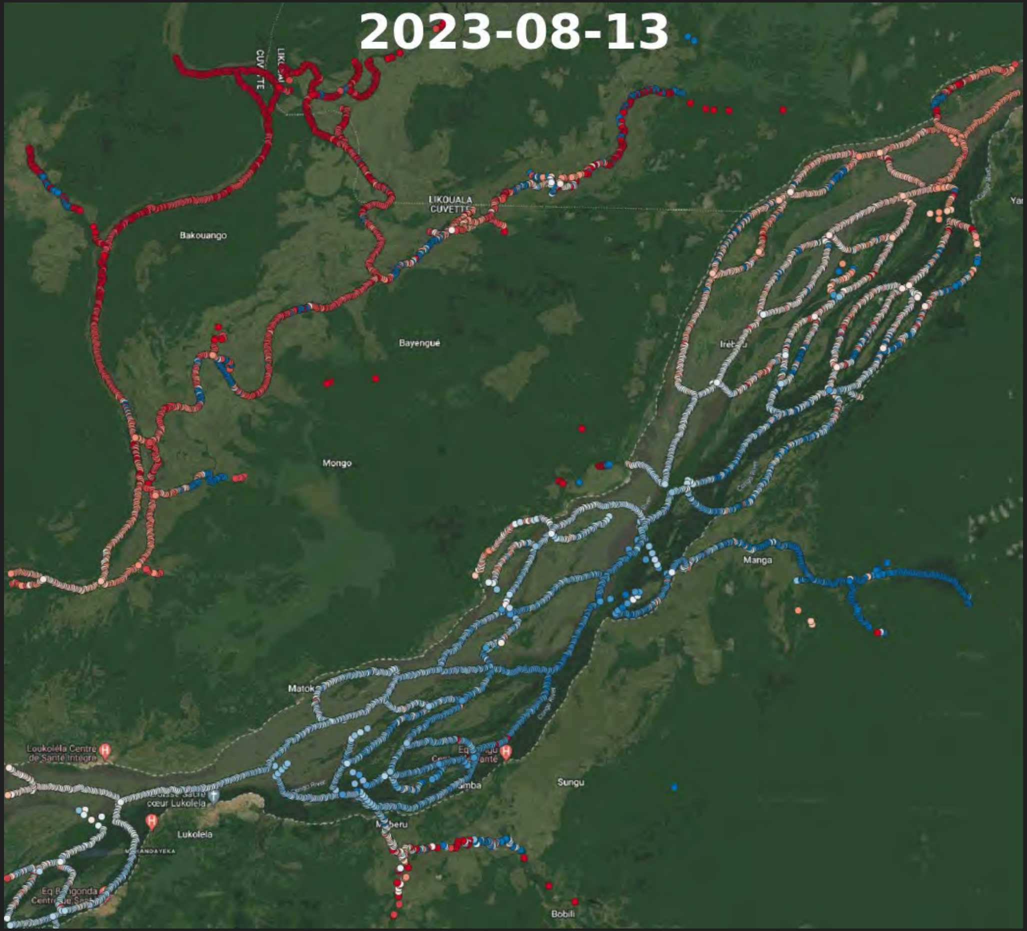
Congo River Nodes



Use Global River Topology (GRIT)* to define *static* channels at high resolution.

SWOT data classification is not sufficient for dynamic channel delineation due to dropouts.

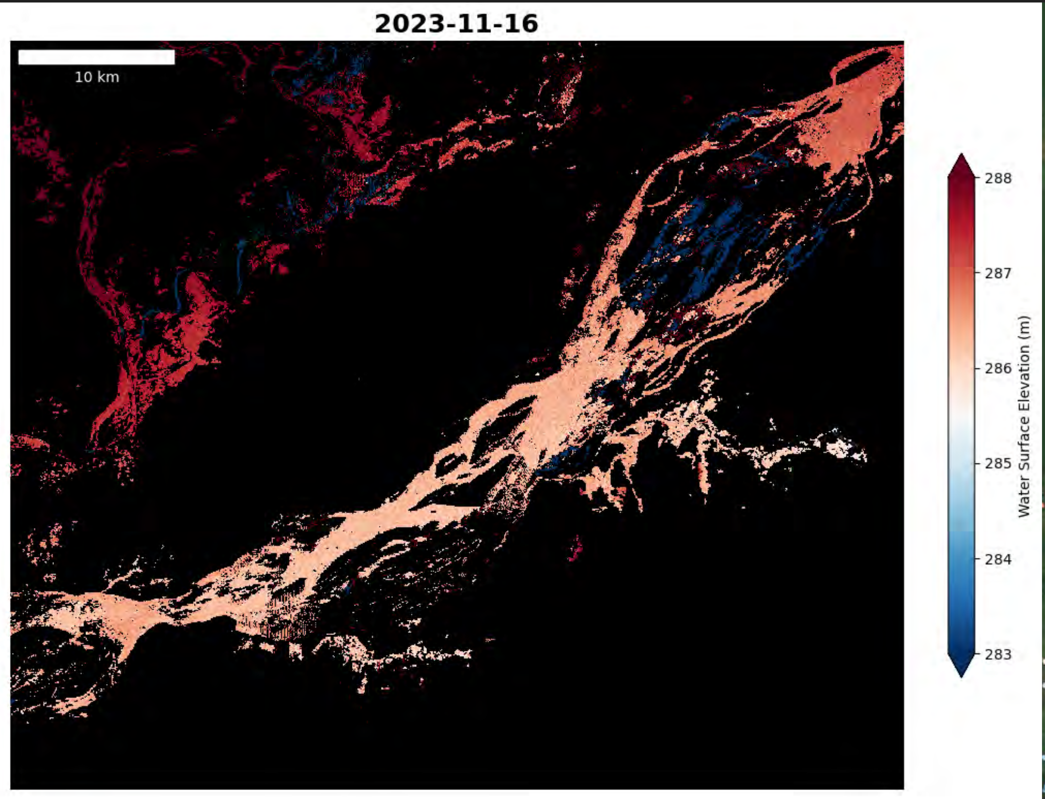
Use modified RiverObs to map raster data to nodes and channels.

Generate updated GRIT channel and a new node dataset as vector data products.

Data available for evaluation/collaboration if you are interested.

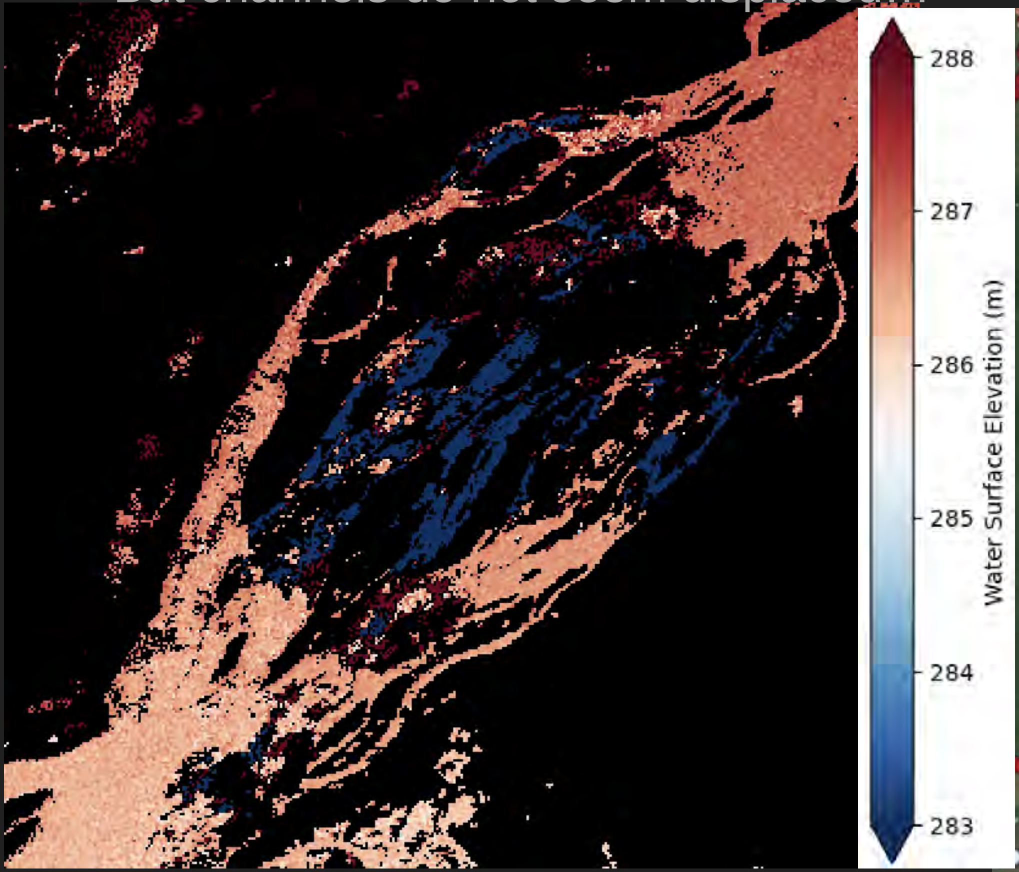
*Wortmann, M. (Creator), Slater, L. (Creator), Hawker, L. (Creator), Liu, Y. (Creator), Neal, J. (Creator) (11 Mar 2024). Global River Topology (GRIT). Zenodo. 10.5281/zenodo.8322965 of the largest 10 rivers in the world exhibit complicated multi-channel (anabranching) geometry. U. Bristol, School of Geographical Sciences, Hydrology

An illustrative example



WSE Anomaly in Large Channels: phase unwrapping errors?

But channels do not seem displaced...



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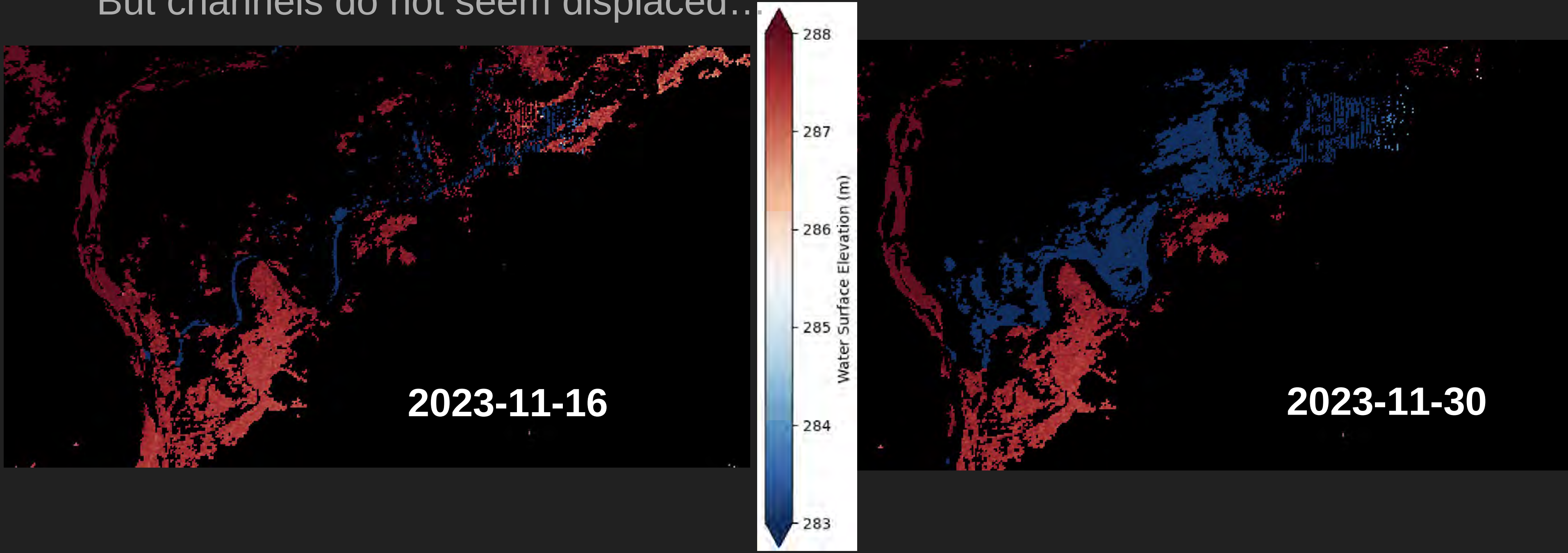
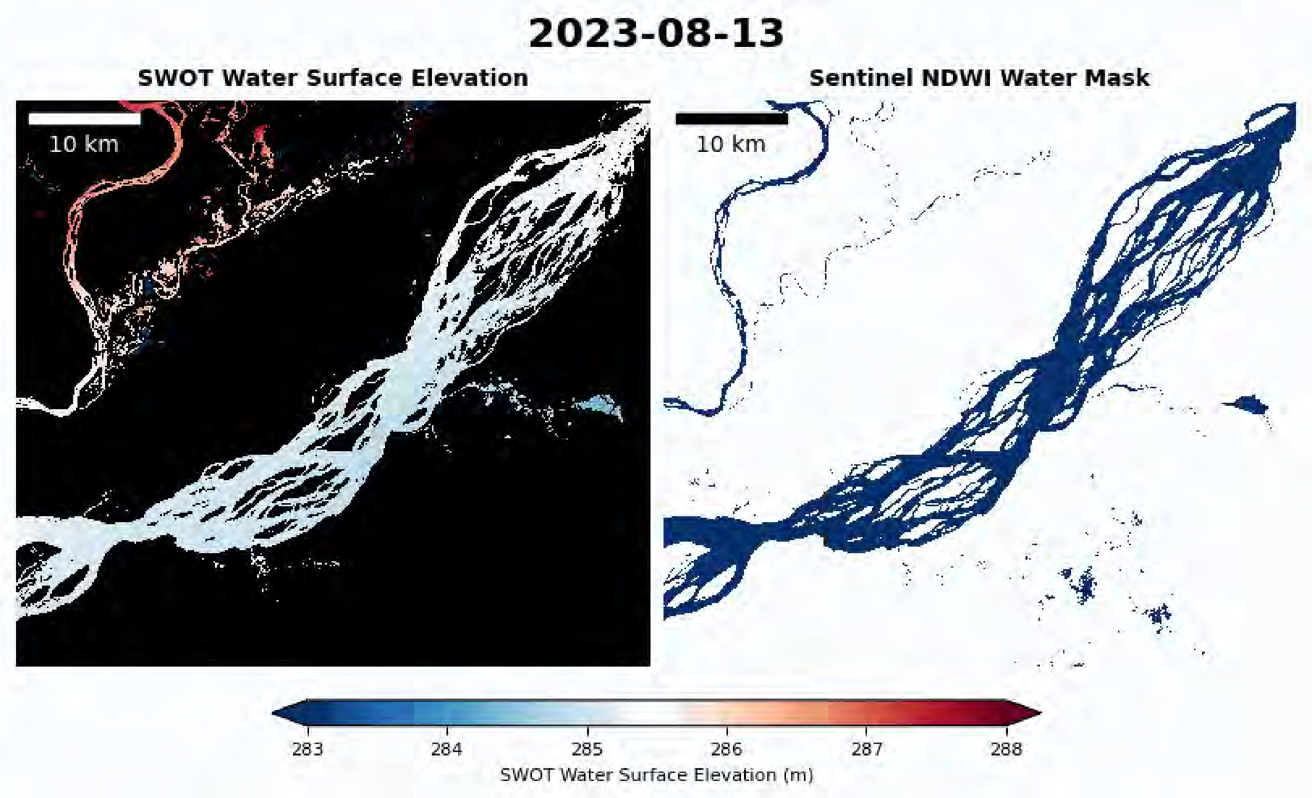
Floodplain/River Dynamics or Phase Unwrapping Error?

But channels do not seem displaced...



SWOT open water classification issues



The Congo basin suffers from cloud coverage, limiting how often it can be imaged by optical sensors.

SWOT can penetrate clouds, but not rain, to provide an independent estimate of flooding extent.

The time series shown here show the limitations of optical and SWOT data to estimate inundation extent by themselves in the rainy season.

The synergistic use of SWOT and optical sensors will result in improved water masks at higher temporal resolution.

Caveat: the SWOT data used here is preliminary and may be improve after the final CalVal exercise and reprocessing.

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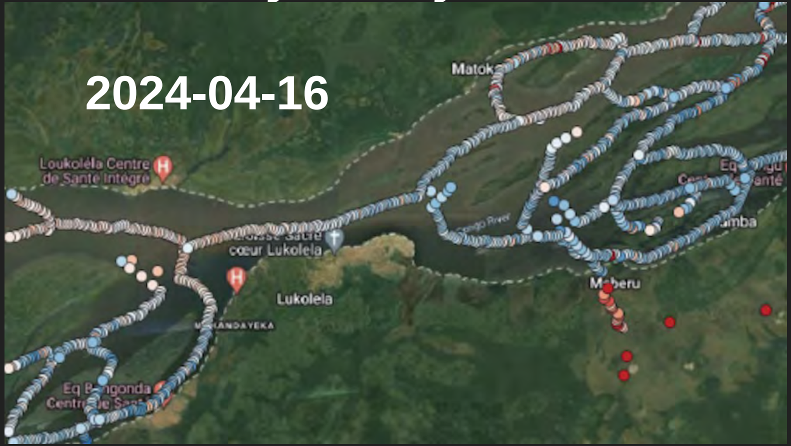
Water flowing uphill: geoid issues? hydrodynamics?



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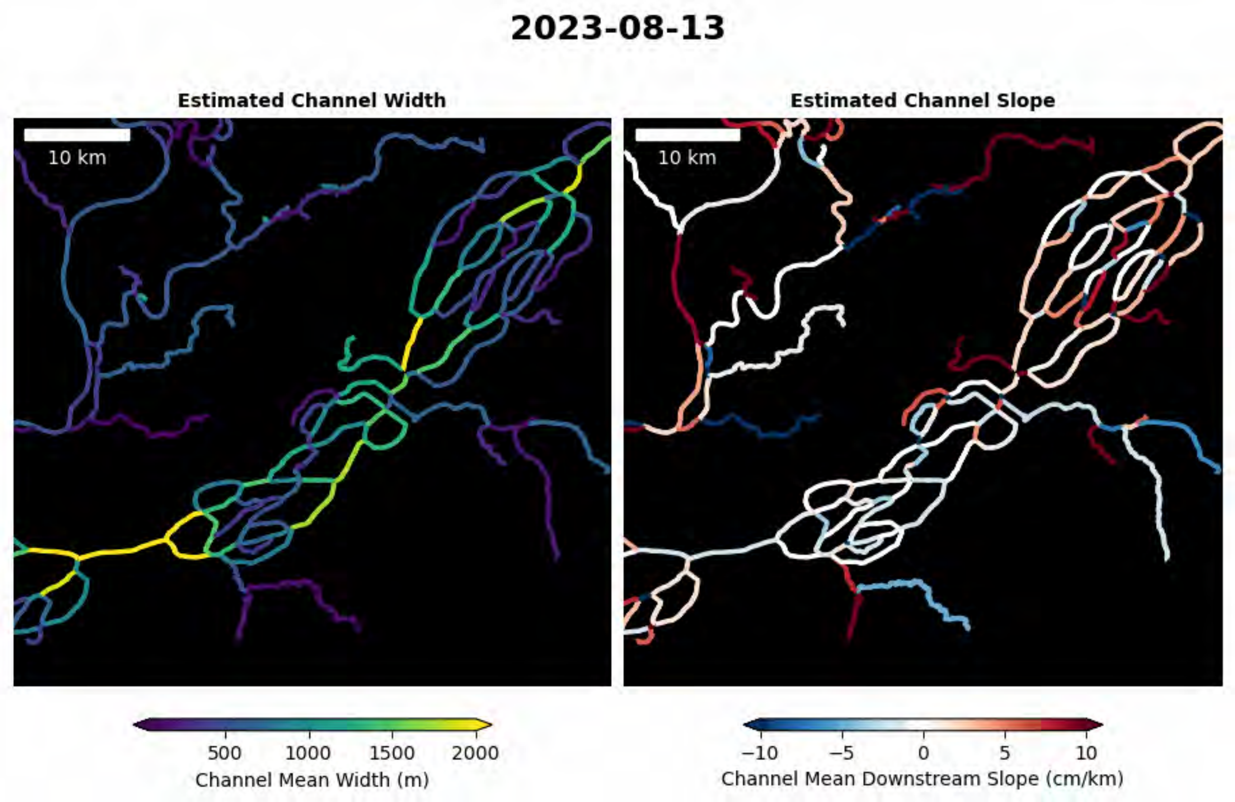
Estimating Multi-channel Hydraulic Variables from SWOT Data



The water surface elevation cannot be used directly to estimate river discharge or dynamics.

Aggregating data into channels, one can estimate channel width and channel slope which are driving parameters hydraulic flow.

Over the Congo, these parameters exhibit complicated variations over time, not consistent with a single channel approximation.

In the future, these observations will be assimilated into hydraulic models, such as Gradually Varied Flow.

The results presented here are still preliminary, as a full quality assessment and validation of the SWOT data are still ongoing.

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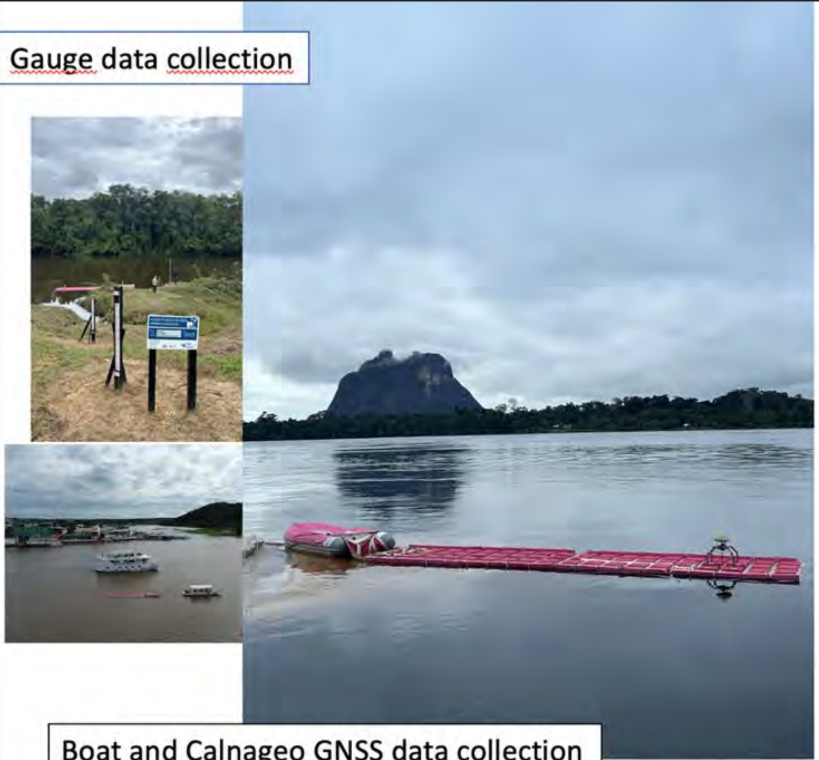
Lightning Talks

Gauge data collection



Boat and Calnageo GNSS data collection

SAMBA SWOT SCIENCE TEAM PROJECT

PIs : Fabrice Papa (IRD/LEGOS) and Daniel Moreira (SGB/GET)

SWOT CAL/VAL results over Negro River and Amazon river

CAL/VAL SITES
(ALREADY SURVEYED AND IN OPERATION)

1- MARONI RIVER (FRENCH GUIANA)

2-NEGRO RIVER (BRAZIL)

3-AMAZON & TAPAJÓS RIVER (BRAZIL)

4-PARAGUAY RIVER (BRAZIL)

5-SÃO FRANCISCO RIVER (BRAZIL)

These cal/val site have the support of :

SGB GEOLOGICAL SURVEY OF BRAZIL · IRD Institut de Recherche pour le Développement FRANCE · cnes · LEGOS · GET · Hydromatters

Moreira et al.

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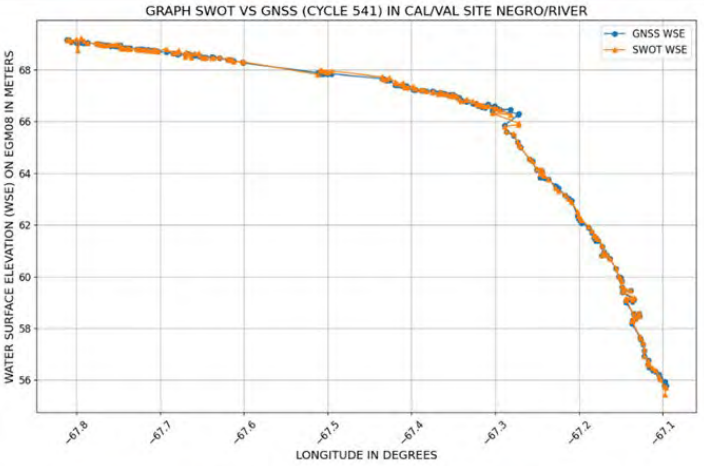
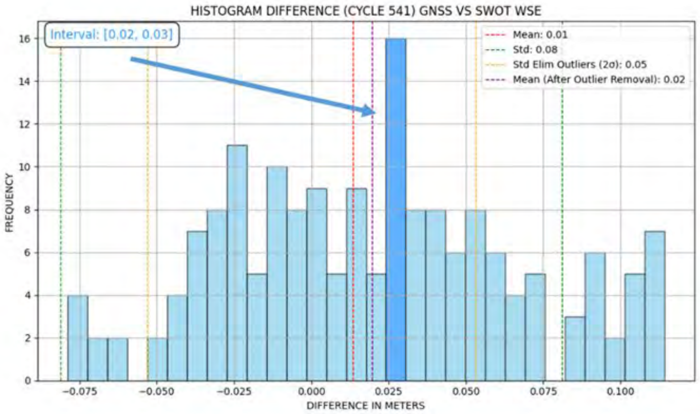
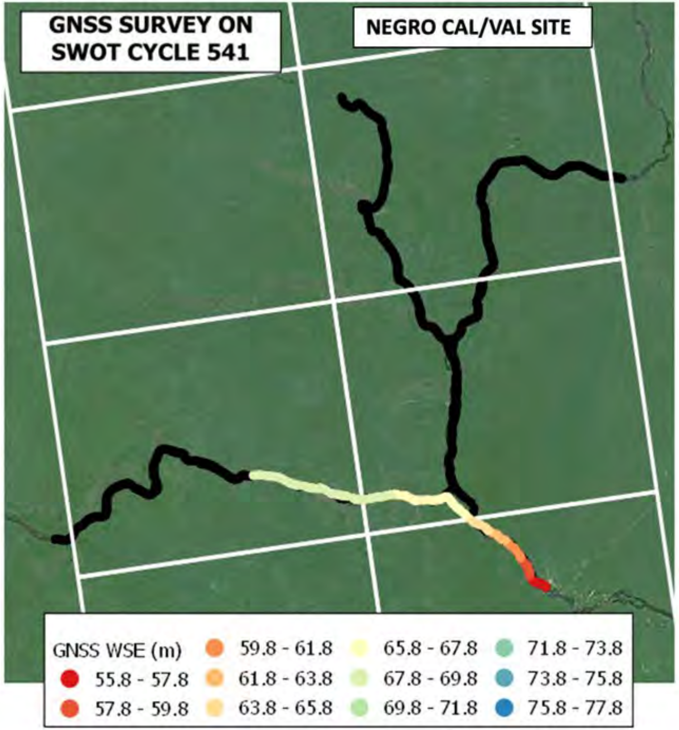






DATA COMPARISION WAS MADE OVER SWOT NODES

SWOT NODE WSE – GNSS WSE TO NEAREST NODE

Moreira et al.

Jet Propulsion Laboratory
California Institute of Technology

SWOT NODES COMPARISION WITH GAUGE STATIONS and BOAT

Statistics

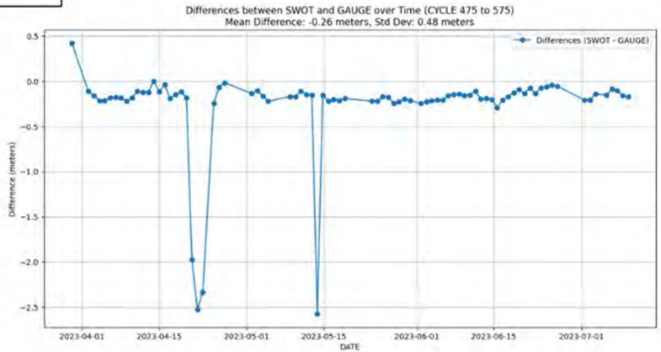
nrcan_trimble_santarem_may_202

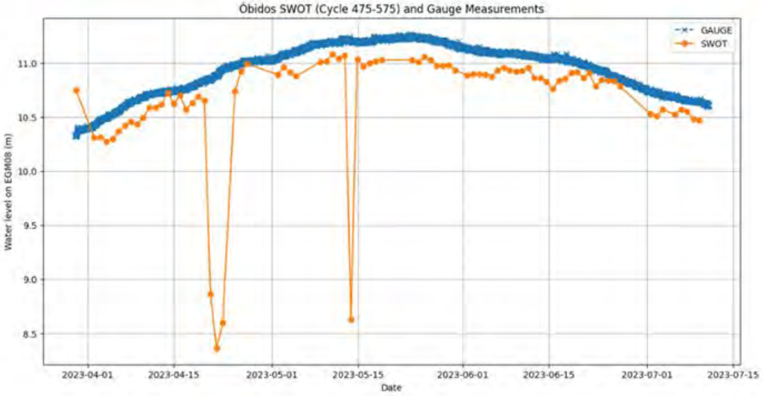
1.2 water_egm

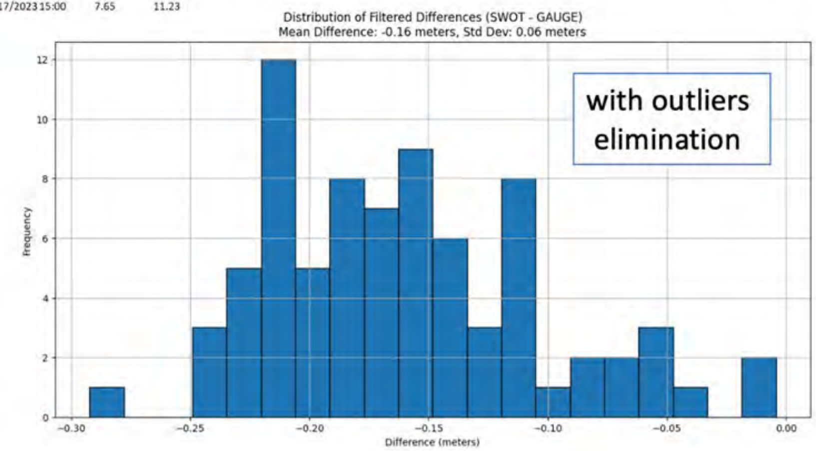
Statistic	Value
Count	23
Sum	258.197
Mean	11.226
Median	11.229
St dev (pop)	0.0148103
St dev (sample)	0.0151432
Minimum	11.181
Maximum	11.254
Range	0.073
Minority	11.181
Majority	11.221
Variety	19
Q1	11.2185
Q3	11.2355
IQR	0.017
Missing (null) values	0

GAUGE MEASURMENTS + 3.58 (THAT'S THE OFFSET TO EGM08 CALCULATE IN 2016)

5/17/2023 9:30	7.63	11.21
5/17/2023 9:45	7.63	11.21
5/17/2023 10:00	7.63	11.21
5/17/2023 10:15	7.62	11.2
5/17/2023 10:30	7.63	11.21
5/17/2023 10:45	7.63	11.21
5/17/2023 11:00	7.64	11.22
5/17/2023 11:15	7.63	11.21
5/17/2023 11:30	7.63	11.21
5/17/2023 11:45	7.65	11.23
5/17/2023 12:00	7.66	11.24
5/17/2023 12:15	7.64	11.22
5/17/2023 12:30	7.67	11.25
5/17/2023 12:45	7.66	11.24
5/17/2023 13:00	7.67	11.25
5/17/2023 13:15	7.67	11.25
5/17/2023 13:30	7.64	11.22
5/17/2023 13:45	7.64	11.22
5/17/2023 14:00	7.64	11.22
5/17/2023 14:15	7.64	11.22
5/17/2023 14:30	7.64	11.22
5/17/2023 14:45	7.62	11.2
5/17/2023 15:00	7.65	11.23







River network hydrological-hydraulic model with assimilation of multi-mission altimetry including SWOT data (article under redaction, MathHydroNum team and collaborators)

Larnier K., Garambois P.-A., Emery C., Pujol L., Monnier J., Gal L., Paris A., Moreira D., Yesou H., Ledauphin T., Calmant S.

Goal: combine SWOT hydraulic visibility with other data to maximize informative feedback to river networks models

Method:

- **Differentiable spatialized hydrological-hydraulic model** for
(1) state-flux consistency and (2) spatio-temporal parameters learning capability from heterogeneous noisy data.
- **Model building from multi-source data**,
WS masks (Sentinel 1 radar images, processing ExtractEO)
WS altimetric profiles (ICESat-2, automatic processing)
- **Variational Data Assimilation at network scale** of multi-mission altimetry and SWOT 1day orbit

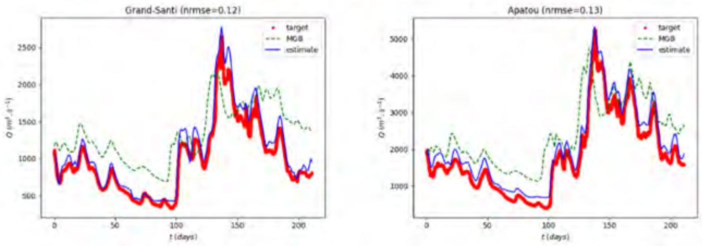
Results: Inferrence of spatially distributed inflow hydrographs on the Maroni basin (cal/val site), friction parameters and effective riverbed elevation in a 1D Saint-Venant model on a full network.

Perspectives: Application to other basins and data sets, 2D zooms for floodplains, integration of neural networks, feedback to hydrology.

References :

Open source codes: https://github.com/DassHydro
HiVDI algo design: Larnier et al. (2023, 2020), Brisset et al. (2018, 2016)
Complex modeling: Garambois et al. 2020, Pujol et al. 2021, Malou et al. 2021)

Hydraulic network (in blue) simulated with DassFlow 1D inflowed by MGB hydrological model (Paiva et al. 2013).



Fit to discharge at gauges within the river nework (result of simultaneous estimation of inflows, bathymetry, friction over the whole network from VDA of multi-mission altimetry

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SWOT

Tosca project to advance river science and learning capabilities from SWOT and multi-source data:
« SWOT-Hydro² -Learning: Learning regionalization of hydrological-hydraulic models and discharge laws over river networks with SWOT and multi-source data assimilation »

PI: Pierre-André Garambois, (INRAE, RECOVER), **Co-PI**: Jérôme Monnier, (INSA-IMT)

Co-I: S. Biancamaria (CNRS-LEGOS), R. Bouclier (INSA-IMT), S. Calmant (HydroMatters), K. Larnier (HydroMatters), T. Ledauphin (SERTIT), J. Maxant (ICUBE-SERTIT), B. Renard (INRAE), O. Roustant (INSA-IMT), H. Roux (IMFT), A. Paris (HydroMatters), H. Yésou (SERTIT).

French consortium: INRAE, INSA-IMT, CNRS/IRD-LEGOS, CNES, HydroMatters, IMFT, ICUBE-SERTIT

US partners: R. Frasson (JPL Caltech/NASA),M. Durand (Ohio State University), H. Lee (Univ. Hawaii Manoa) **Brazil partners:** D. Medeiros-Moreira (SGB-CPRM (Geological Survey of Brazil), Rio de Janeiro), R. Paiva (Universidad Federal de Rio Grande do Sul). **French partner:** F. Pappa (IRD-LEGOS).

Geographical areas of interest: inland; detailed hydrological-hydraulic case studies in France (continental and French Guyana), Brazil (Amazon basin), Africa (Niger basin), US (Ohio basin), and on worlwide rivers for HiVDI discharge algorithm taylored for SWOT (45 river segments worldwide from PEPSI cases; enriched list to be determined).

- **Data analysis,**
- **Uncertainty Quantification,**
- **Discharge estimation algorithm (HiVDI),**
- **Improved basin scale hydrological-hydraulic modeling, (MGB/SMASH - DassFlow)**
- **Hybrid learnable approaches,**
- **Demonstrators ("Digital Twins"),**
- **Operational products**

- **Open source codes** https://github.com/DassHydro
- developped in SWOT context since 2012, by **MathHydroNum research team** https://dasshydro.github.io/
- **Open to new collaborations**, fusions
- **Link with research projects in AI**
  ANITI – Math/AI, co-lead by J. Monnier
  ANR MUFFINS - hybrid flood modeling, lead

Project: **SWOT for Monitoring Terrestrial Water Storage Changes: Quality Assessment and Combination with other Remote Sensing Data (SWOT-DAHITI)**

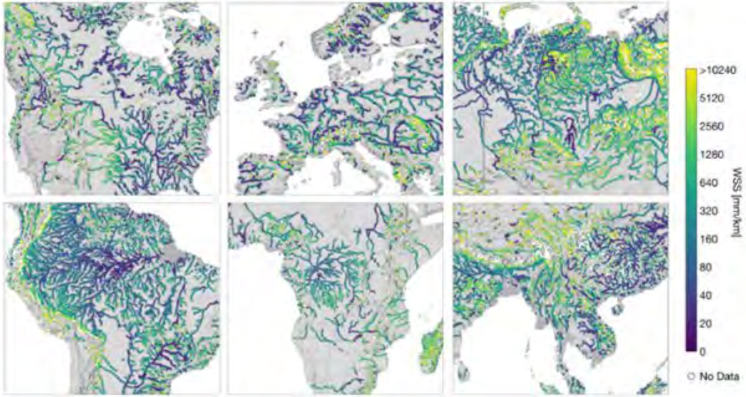
Team: Schwatke Christian, Dettmering Denise, Scherer Daniel

Update of IRISv2.3 Dataset

Global Dataset of Water Surface Slopes

SWORD: **Version 16**

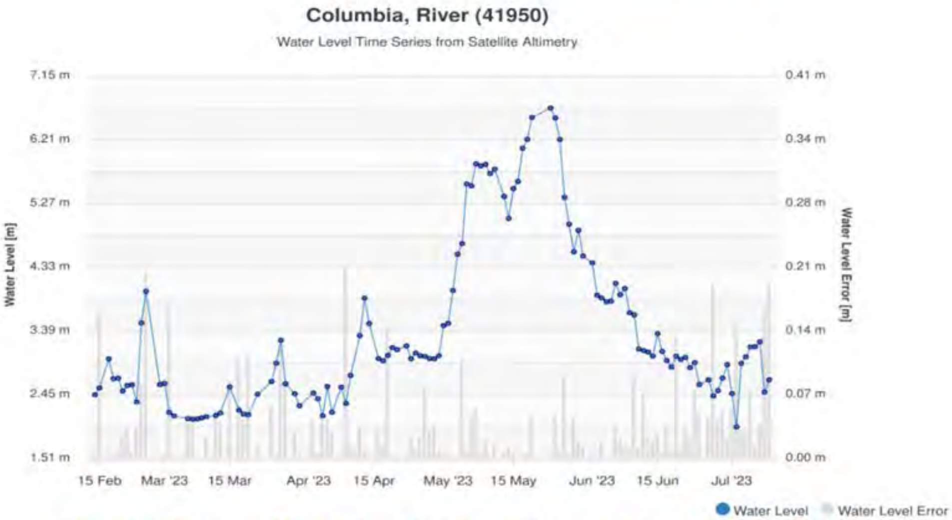
ICESat-2 Data: **ATL13 v6 (Cycle 1-21)**



Next Steps: *Regular updates when new ICESat-2 data or SWORD version will be available*

Integration of SWOT-Nadir Data in DAHITI

SWOT-Dataset: **SWOT_L2_NALT_GDR_2.0**



Next Steps: *Ongoing integration and reprocessing of SWOT nadir data into DAHITI*

Project: **SWOT for Monitoring Terrestrial Water Storage Changes: Quality Assessment and Combination with other Remote Sensing Data (SWOT-DAHITI)**

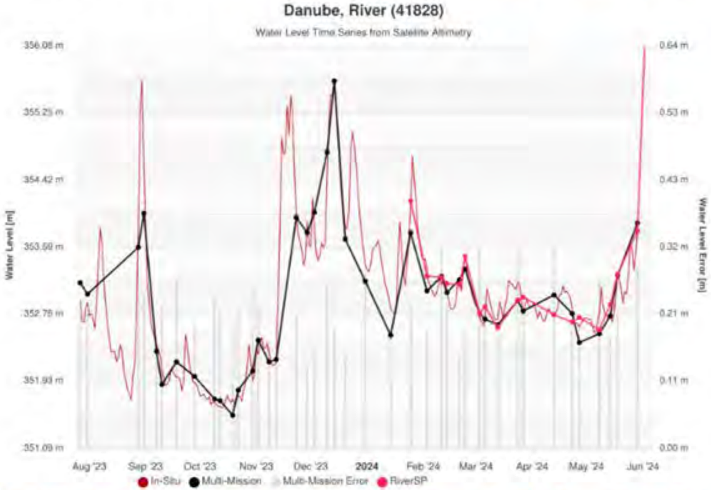
Team: Schwatke Christian, Dettmering Denise, Scherer Daniel

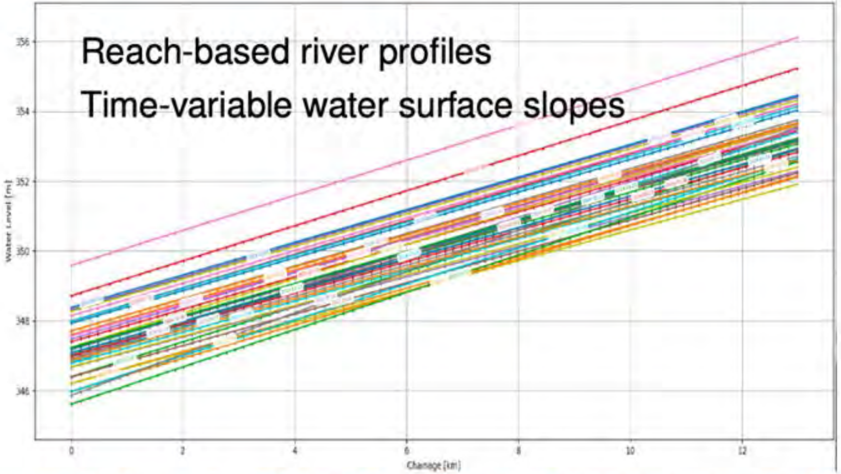
Integration of SWOT KaRIn Measurements for Rivers, Lakes and Reservoirs in DAHITI

A new approach based on histogram analysis and weighted least squares adjustments has been developed.

SWOT-Dataset: **SWOT_L2_HR_PIXC_2.0**

DAHITI-Products: **Water level time series, Time-Variable Water Surface Slopes**





Next steps: *Ongoing validation with in-situ data and comparision with RiverSP product / Preparation of publication*

Oubanas, Ricci et al et al.

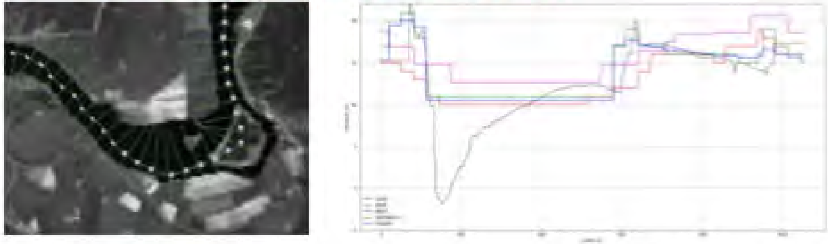
HYDROS : HYdraulic retrievals from Data assimilation: River Observation with Swot

PIs: Hind Oubanas (INRAE) & Sophie Ricci (CECI, CERFACS/UMR5318 CNRS)
Team Members: P.-O. Malaterre, I. Gejadze, D. Quittard (INRAE), C. Emery (CS Group), T.-H. Nguyen (LIST), A. Piacentini , L. Cassan, Q. Bonassies (CECI)

SICFLOW : "**Sic Inverse problem Capabilities for river FLOW dynamics**":

- River system definition
- Data Densification approaches
- FloodPlain DEM Approximation
- Prior/Background Estimation
- Data Assimilation: **SIC4DVar** (Global low cost within CONFLUENCE platform and Local full cost)
- Reanalysis : Historical discharge for climate studies
- Uncertainty Quantification & Error Statistics: Characterization of discharge errors and parameterization of probability density functions.

➔ River FloodPlain DEM from SICFLOW

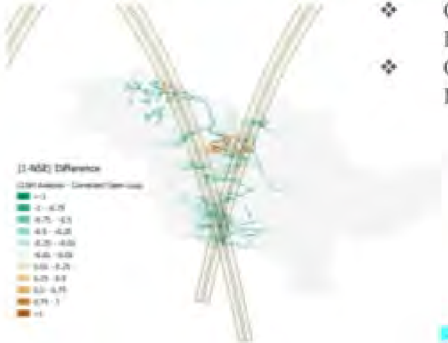


River Floodplain estimation using multi-satellites and inverse problem approaches

➔ SWOT River Discharge from SIC4DVar

➔ Large Scale Hydraulic/Hydrological coupling

- Coupling of SICFLOW and RAPID NASA Model.
- Coupling of SICFLOW and ISBA-CTRIP Model.



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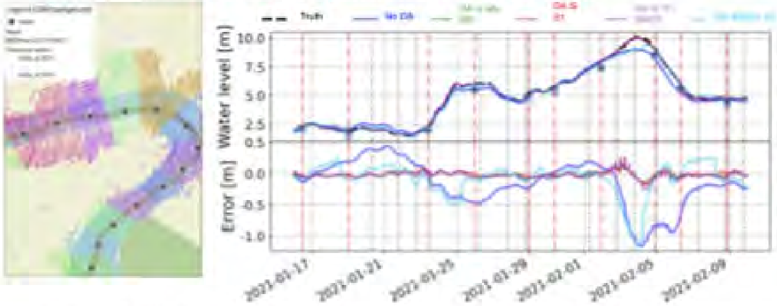
T2DiSURF : "**T**elemac **2D** **i**nverse problem capabilities for water **SURF**ace elevation":

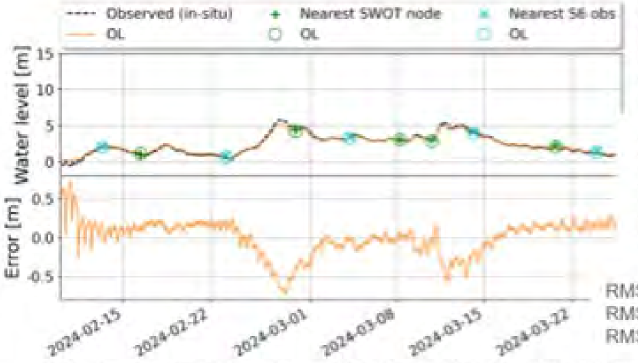
- Generation of hydrocomptible Floodplain DEM from RS
- Generation of RS derived 2D products
  - WSE maps,
  - water extents,
  - synthetical RS data,
- Data Assimilation: **T2DiSURF-EnKF** combines heterogenous in-situ and multi-missions RS data from Sentinel1, Sentinel2, Sentinel6 and SWOT
- Reanalysis for local flood events with High fidelity 2D-hydrodynamic model
- Flood risk assessment (socio-eco impact on industrial, agricultural, urban assets)

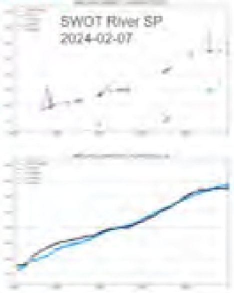
→ Assimilation of SWOT synthetical observation



Assimilation of SWOT-nodes River-SP with in-situ WSE and S1 flood extent (Garonne)

→ Assimilation of real SWOT data for 2D dynamics

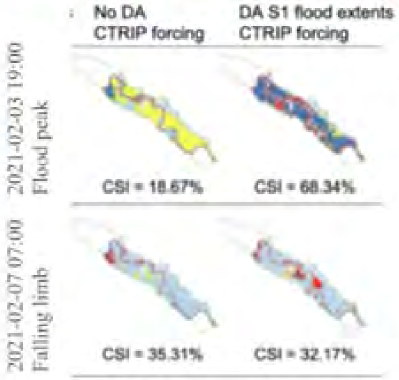




RMSE OL%IS = 0.225 m
RMSE OL%S6 = 0.32 m
RMSE OL%SWOT = 0.66 m

WSE in-situ, SWOT-nodes and S6 02/15/2024-03/22/2024 Garonne Marmandaise

→ Large Scale Hydraulic/Hydrological coupling

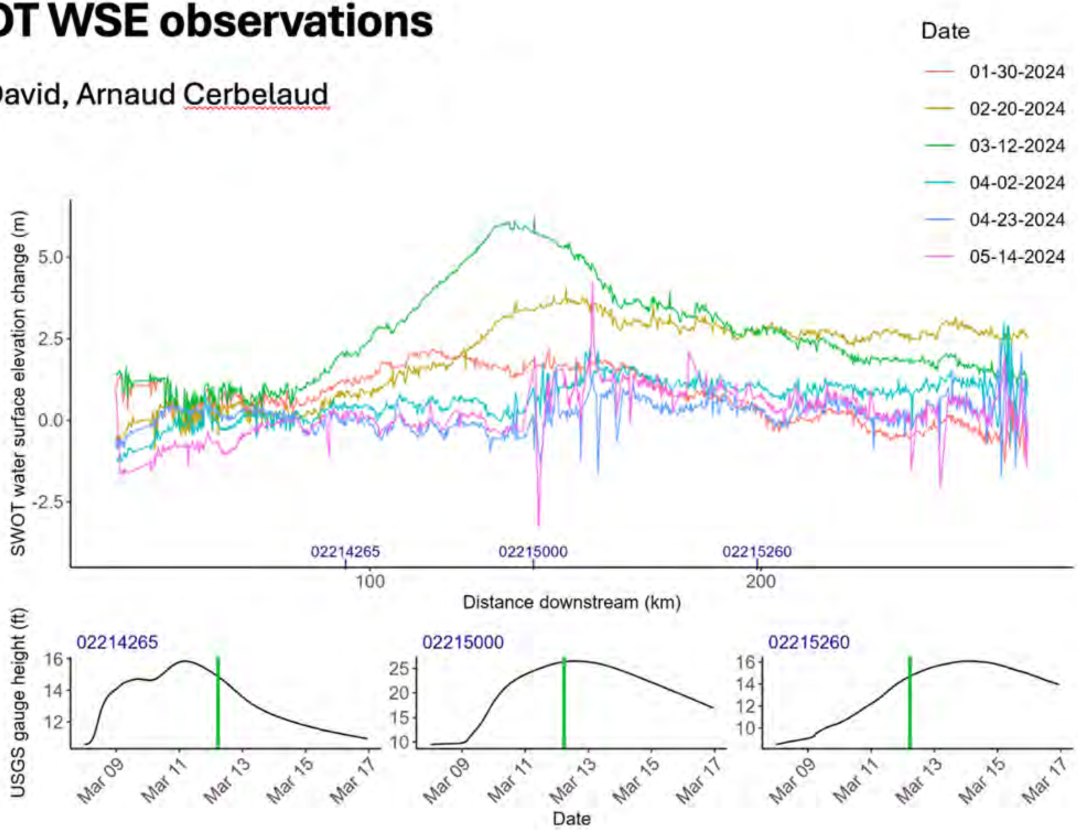


- Coupling of T2DiSURF and RAPID NASA Model.
- Coupling of T2DiSURF and ISBA-CTRIP Model.

River flow waves with SWOT WSE observations

Hana Thurman, George Allen, Cedric David, Arnaud Cerbelaud

- Observing "spatial hydrographs" using SWOT WSE observations in rivers
- Comparing WSE change to gauge data shows that SWOT can capture flow wave dynamics in rivers
- Example (right): Flow wave captured on the Ocmulgee River, March 12, 2024. RiverSP node data with flag 3 data removed. Flow wave can be seen in gauge records along this river reach (lower panels).



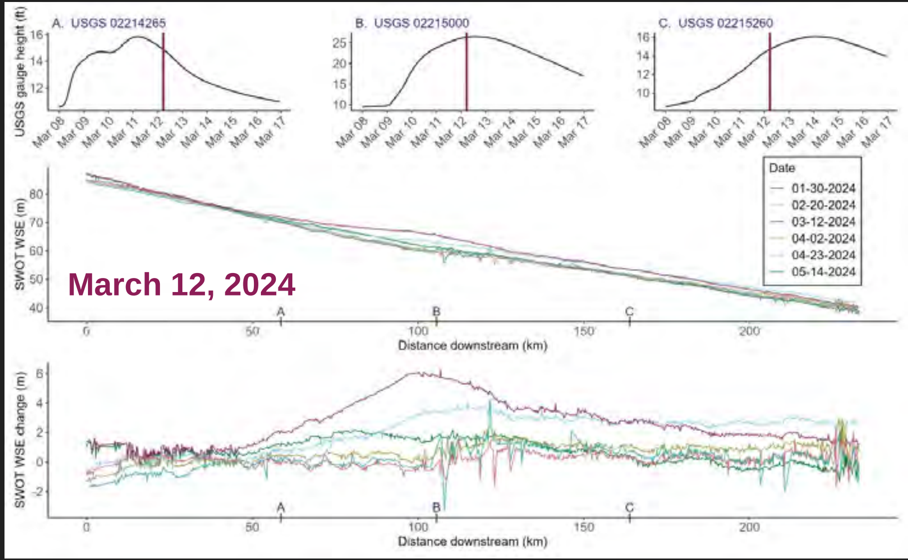
Jet Propulsion Laboratory
California Institute of Technology

Thurman, Allen, et al.,

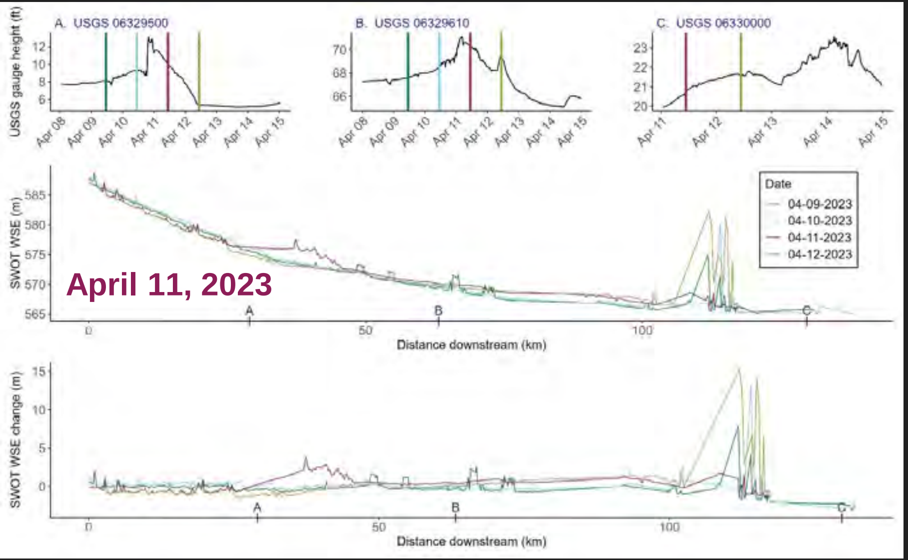
VIRGINIA TECH

SWOT

Science orbit - Ocmulgee River (Georgia)



Cal/val orbit - Yellowstone River (North Dakota/Montana)



Next steps: SWOT observations can potentially be used to study flow wave properties

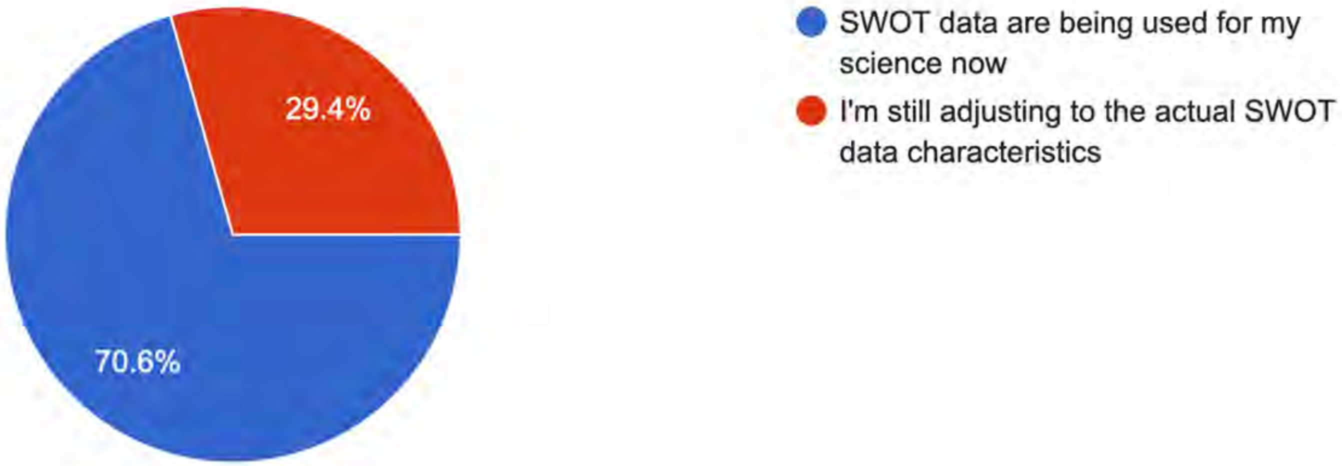
- Measuring flow wave length
- Estimating flow wave celerity from two observations of the same event
- Partitioning flow wave into base flow and storm flow

Review of the SWOT River Users poll results

Ernesto Rodriguez
Jet Propulsion Laboratory, Cal Tech

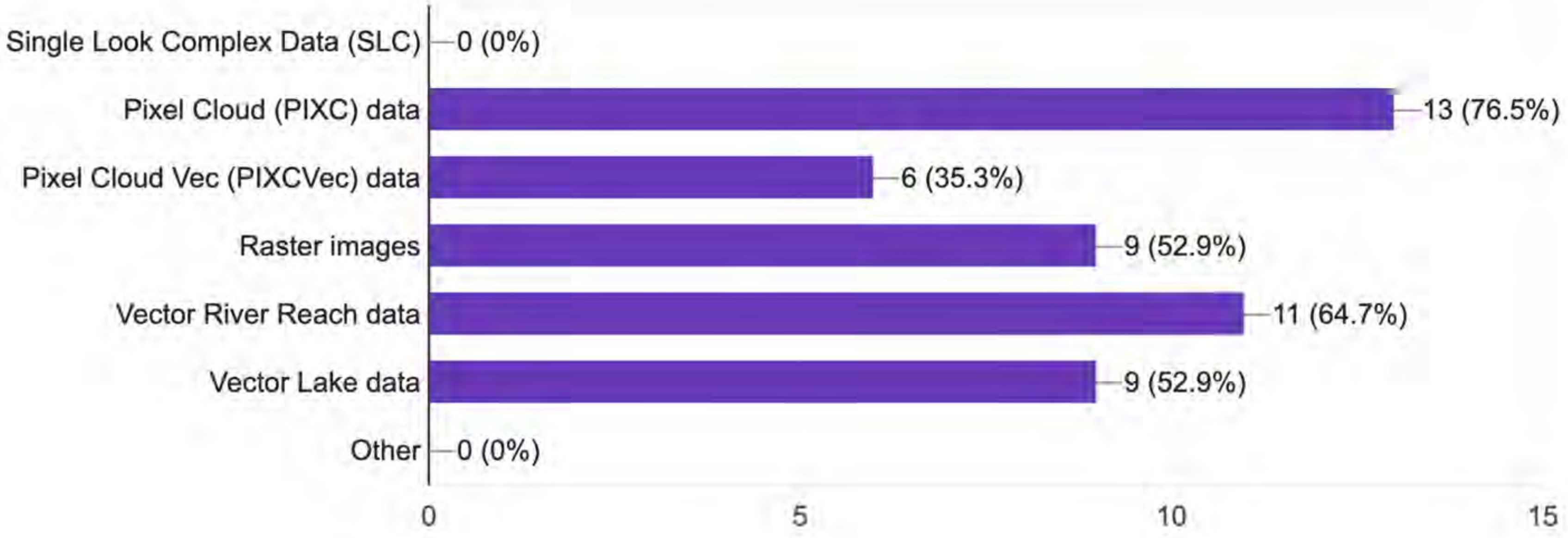
Have you started using SWOT data since its public release for science or are you still adjusting to the characteristics of the SWOT performance?

17 responses



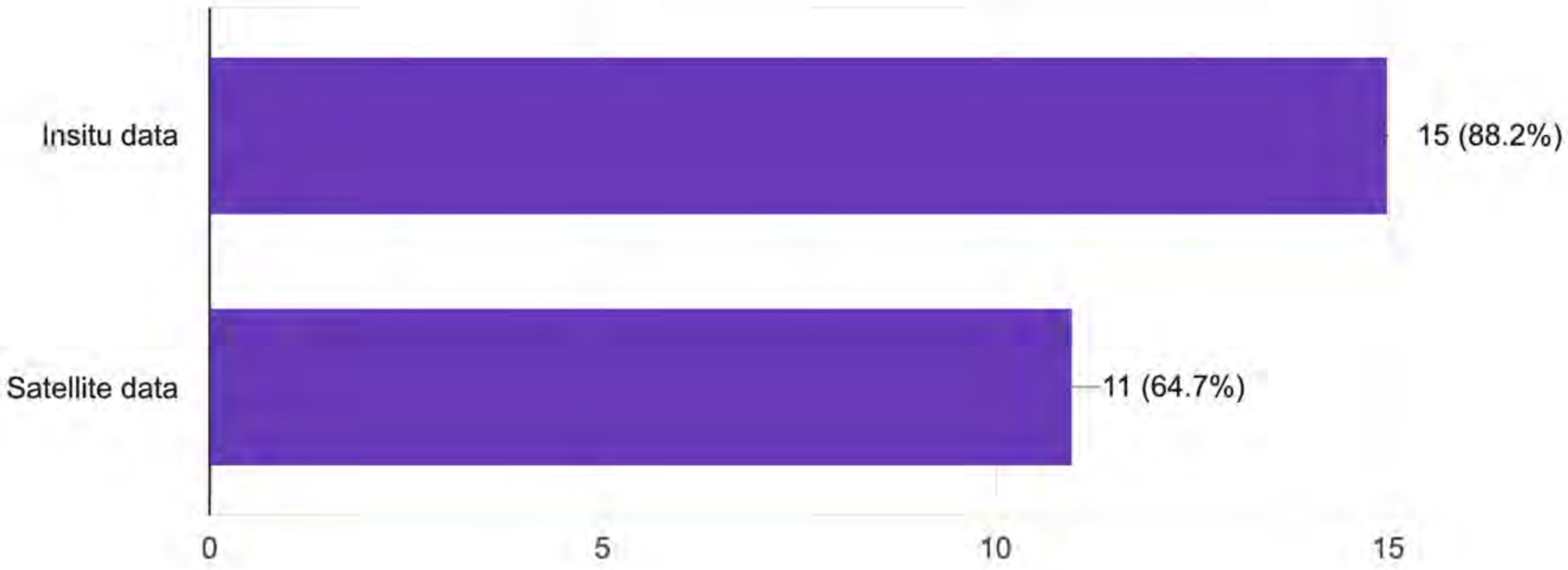
Which SWOT data products are you using? (Check all that apply)

17 responses



How are you assessing SWOT data: with in situ, other satellites or both? Add satellite mission type and name.

17 responses

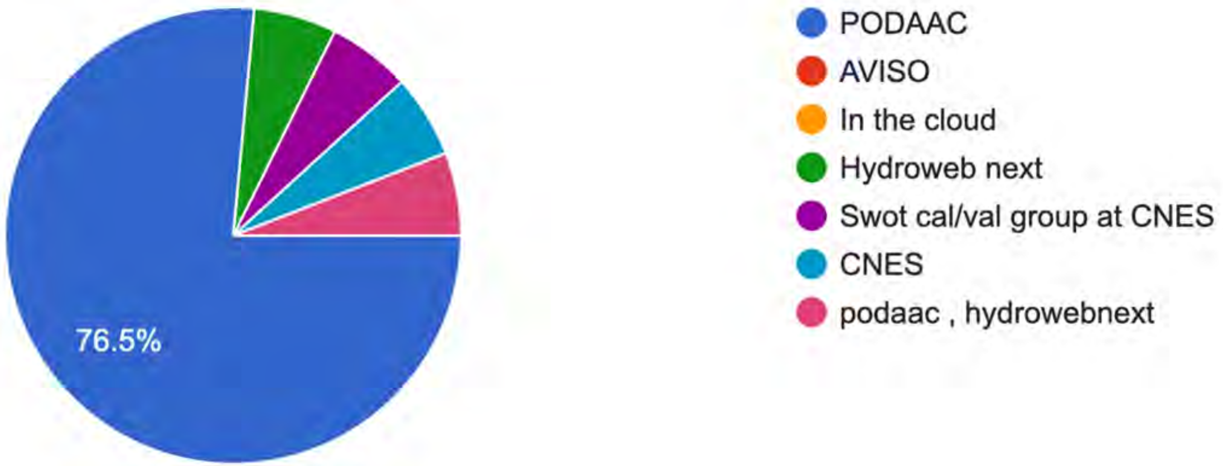


If in situ data, please give a short description
- gages
- available water level in situ data around the world
- wse over small lakes, GNSS vertical profile along rivers
- in situ WS heights, flow lines ; indirectly with discharge at gauges,
- Water level gauges
- We are validating discharge data with USGS river gauge records. We are validating lake WSE using USGS and US Bureau of Reclamation lake gauge data.
- data from WSE collected by GNSS receivers and gauge stations
- in-situ gauges and GNSS-R
- Assessing with gauge station data from Brazilian network.
- Using in situ data that is being collected explicitly for SWOT validation, as well as networks of existing water level gauges in rivers, lakes, and wetlands.
- Using USGS gages
- GNSS surveys, water level gauges
- Publicly available river gauges
- gage data (stage), field measurements
- We are comparing PIXC and LakeSP WSEs against in situ gages for US reservoirs and a few large lakes in China.

If satellite data, please list the satellites used
- Altimetry for wse validation
- WS heights, dynamic water masks
- Sentinel-2, Sentinel-1 and Planet
- with opera for water extent and satellite altimetry for water level
- Sentinel-3
- Landsat, Sentinel 2
- Lansat 8 and Sentinel 2 through the Dynamic Surface Water eXtent distributed by OPERA https://www.jpl.nasa.gov/go/opera
- Planet and Pleiades (mainly Planet)
- Sentinel-2
- ICESat-2, GNSS-R (CYGNSS, Spire), Sentinel-2, Planet
- Planet

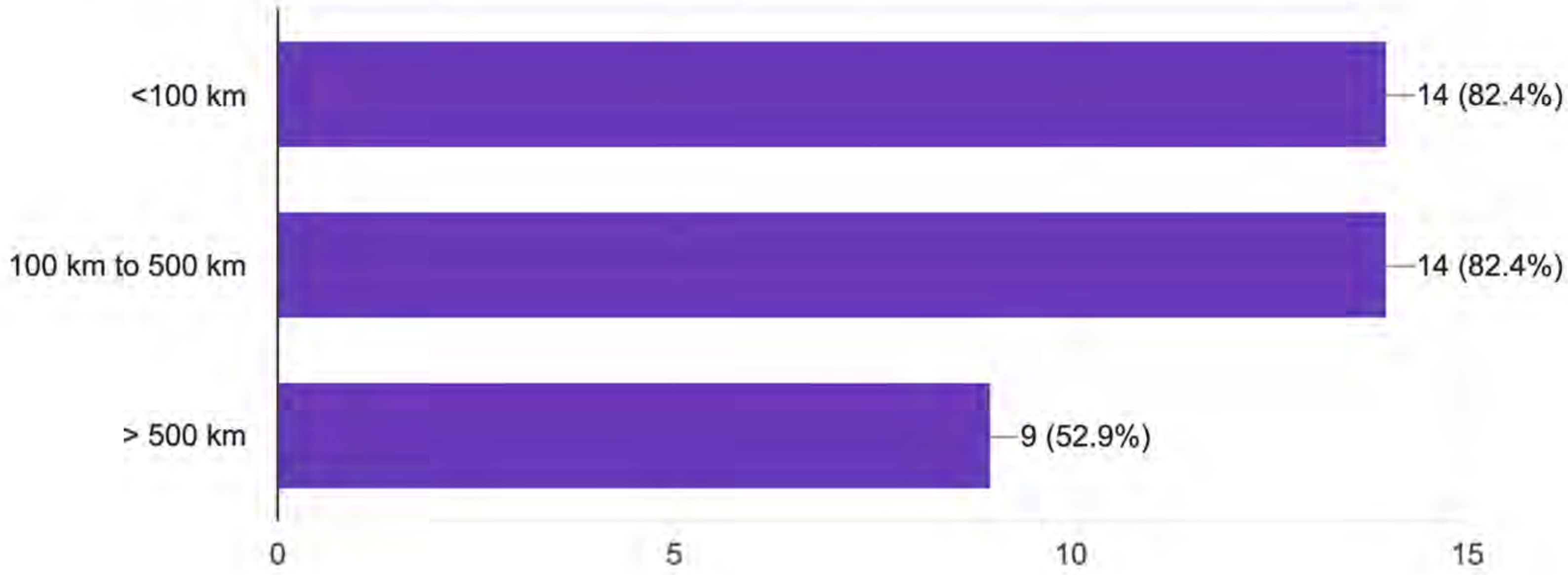
Where do you usually get your data from?

17 responses



What is the size of the rivers/targets and regions you are assessing SWOT data?

17 responses



What are the major positive features that you have found in the SWOT data?
- clear description of data
- not yet enough advanced in my analysis to answer to this question. intuitively, the high number of data on remote areas and over small lakes are going to be more than useful.
- Cartographic coverage with relevant spatial and vertical resolution for river network hydraulic modeling! Slope variations measurements.
- Pixel height
- WSE look good
- Many positives aspects, because we can have data almost everywhere the data is promising, with some work and filtering there is very nice results with comparison within situ
- high spatial resolution
- Vector River Reach data are really useful and simple to use.
- The fundamental SWOT data (e.g. pixel cloud) are generally excellent except in two cases: when there is nadir ringing and where there is dark water. The elevation accuracy is really high overall, especially at the node scale. Slopes are also generally pretty good. Inundation extents/widths are more problematic because many areas that are not part of rivers are bright and get classified as water. Also, SWOT does GREAT in at least some vegetated wetlands (e.g. grassy environments).
- build long river profiles and observe slope dynamics
- heights are less noisy than feared and bright returns from narrower rivers than expected
- The WSE data are high quality for high values of sigma0.
- Really beautiful data in many situations
- WSE accuracy and WSD dynamics seem to be reasonably captured.
- Easy to use, good resolution, really exciting!

What are the major negative features that you have found in the SWOT data?

- size
- Still a lot of uncertainties, spurious data not filtered, strong presence of dark water, some overestimation of water presence...
- tbd
- difficult to query data
- Wrong pixel classification and displacement.
- water extent tends to be overestimated
- the need to work a lot to have clean data for data analysis.
- documentation
- Raster images do not seem to be accurate yet for mapping flood extension.
- See above. Nadir ringing is the big issue that I didn't really anticipate prior to launch. Dark water was expected but is perhaps a bit worse than anticipated prelaunch. There are also intermittent problems with layover (especially in high topography) and phase unwrapping errors. In general, accuracies are higher in the mid- and far range and most problematic in the near range.
- data cannot be used as is. careful reprocessing needed to remove outliers and artifacts
- still learning, but at the moment geolocation errors especially dark water
- The water classification has substantial issues and probably needs to be retrained based on available satellite data (Sentinel-2, OPERA, etc). Instrument artifacts need (e.g., nadir ringing) need to be properly flagged. The flagging and QA of the data need to be improved.
- Some tiles have large amounts of noise that is difficult to decipher
- PIXC water classification can be noisy and erroneous, and the delineated water extents can be over-detected. - Some noise, and still waiting for some cal/val to be reprocessed

What could be done to the SWOT data in future reprocessing to improve the quality of your science?
- short latency
- to have reduced size data covering larger area
- A better filtering and discrimination between 'bad' and 'good' data.
- tbd
- more information about cross-over correction
- Improve pixel classification (water/non-water) and geolocation.
- It would be helpful to have lake height/area/volume change accessible via hydrocron
- Improve the river node calculations, using a better mask to avoid contamination from land, some better outlier removal method that use some constraints maybe testing slopes for closing nodes, or even based to existent knowledge of topography
- more clear indication on time and spatial availability
- Improve raster image quality
- We need to do a better job of combining SWOT with other satellite data to do water classification. We also need to do a better job of flagging nadir ringing. Finally, flagging of dark water doesn't work well in highly mobile rivers (e.g. braided rivers) because it uses a static prior mask, and these rivers are highly dynamic.
- correct the dark water geolocation error problem
- In addition to the PIXC and PIXCVec products, a lower volume product containing just data widely used by science team members should be considered. It is clear that PIXC data are widely used, but they are high volume and strains bandwidth when looking at large areas.
- Data quality flags are great. The new Data Science document helps a lot but having recommended flag settings (e.g. filters) would be very useful.
- (1) consider improving the water classification algorithm, (2) improve the understanding of KaRIn responses to wet soil and wetland (to reduce water over-detection)

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SWOT

Open Discussion