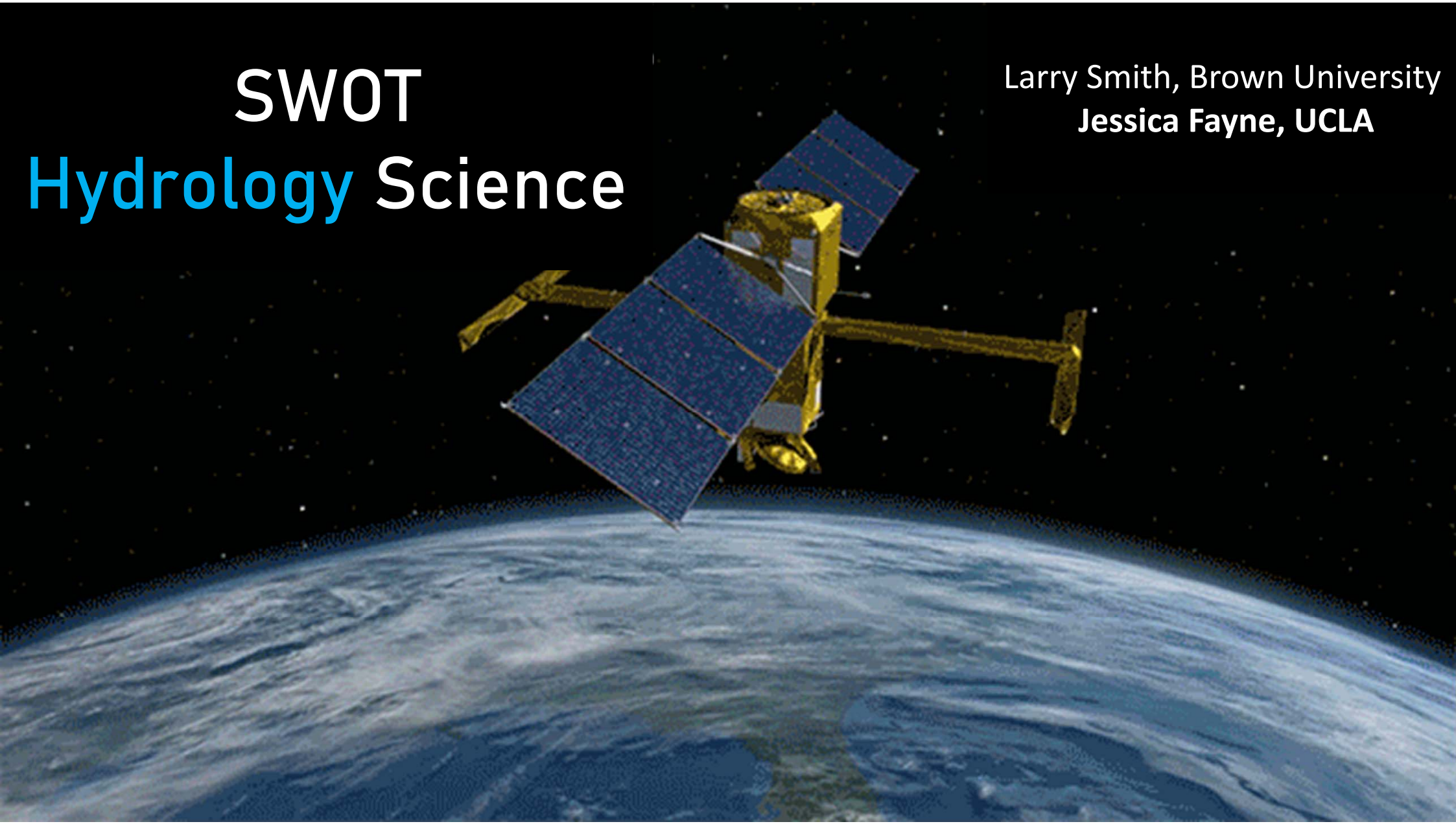
SWOT Hydrology Science

Larry Smith, Brown University
Jessica Fayne, UCLA



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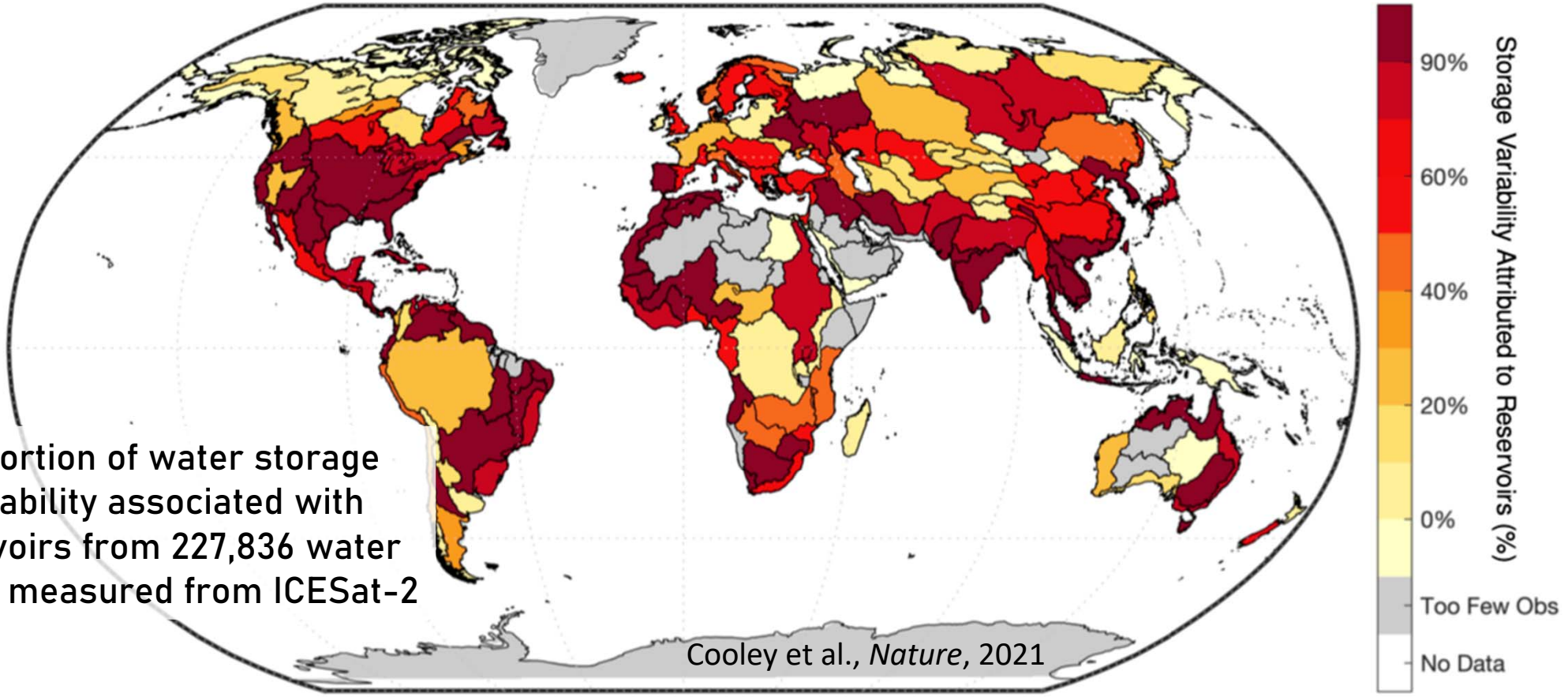
What is the effect of reservoirs on surface water storage variability?

(S. Cooley, J. Ryan, Oregon State, L. Smith, Brown U.)

Knowing the extent of human influence on the global hydrological cycle is essential for the sustainability of freshwater resources on Earth.



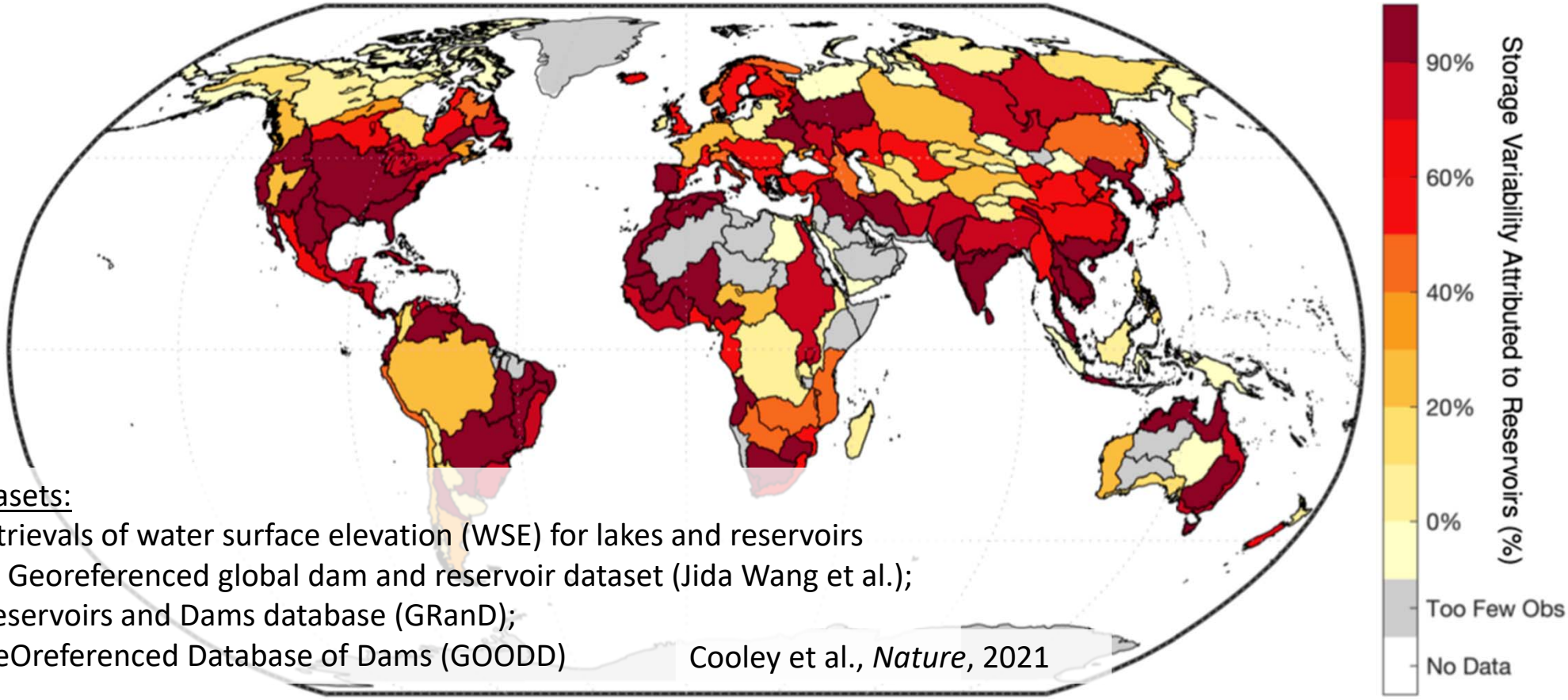
Proportion of water storage variability associated with reservoirs from 227,836 water bodies, measured from ICESat-2

Cooley et al., *Nature*, 2021

What is the effect of reservoirs on surface water storage variability?

(S. Cooley, J. Ryan, Oregon State, L. Smith, Brown U.)

SWOT retrieval of water surface elevation (WSE) will enable tracking of the influence of human impoundments upon the global hydrologic cycle.



Cooley et al., *Nature*, 2021

Core datasets:

SWOT retrievals of water surface elevation (WSE) for lakes and reservoirs

GeoDAR: Georeferenced global dam and reservoir dataset (Jida Wang et al.);

Global Reservoirs and Dams database (GRanD);

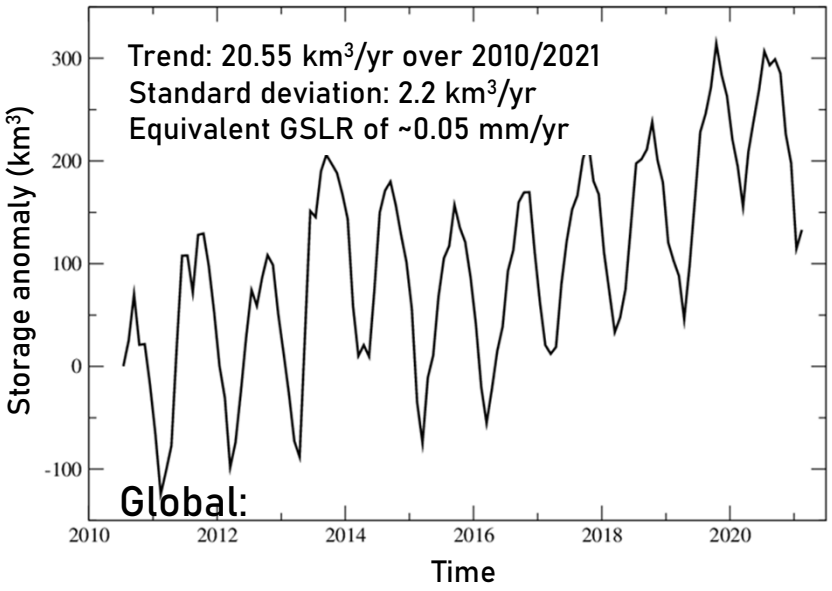
GlObal geOreferenced Database of Dams (GOODD)

What are artificial reservoirs storage change at decal time scales?

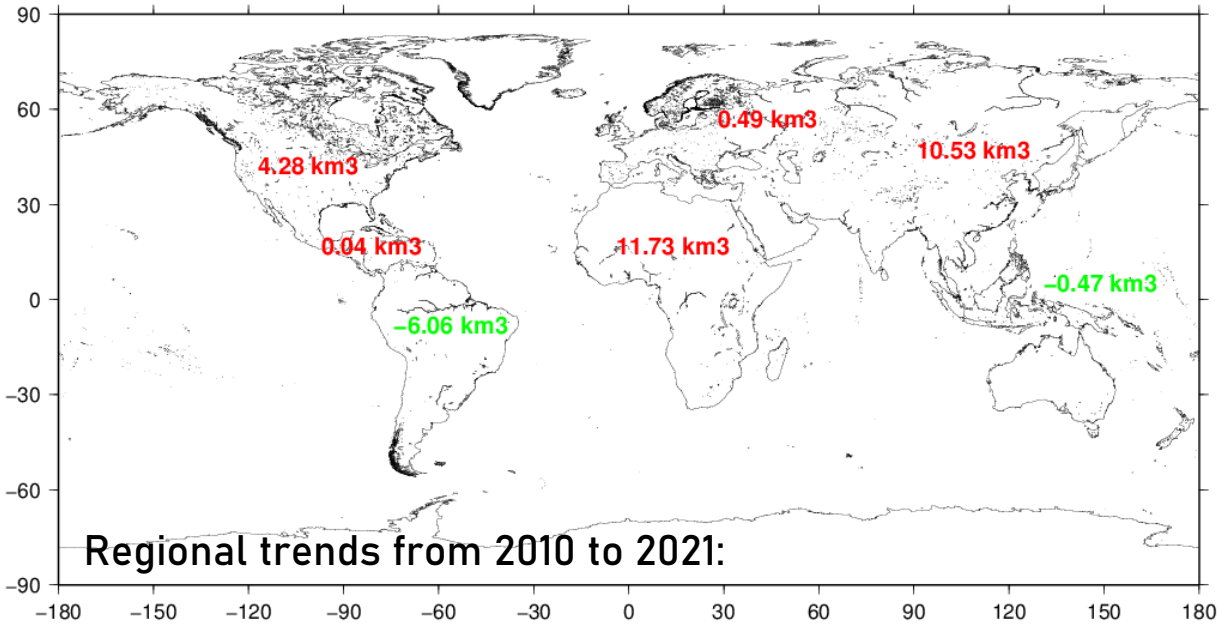
(J.-F Cretaux, M. Berge-Nguyen, and A. Blazquez, LEGOS; J. Wang, KSU; F. Yao, CU Boulder)

Current estimates of reservoir analysis requires combining multiple observations and datasets: Cryosat-2 radar altimetry on 1750 largest reservoirs, Landsat imagery & hypsometry curves on ~200 largest reservoirs, GeoDAR database on reservoirs polygons

Storage change and trend for the 700 largest reservoirs:



Anthropogenic effect: Artificial reservoirs store more waters on land -> global & regional trends?



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SWOT will directly measure 2-D WSE enabling the computation of reservoir storage change and estimate quantity of water artificially stored on lands

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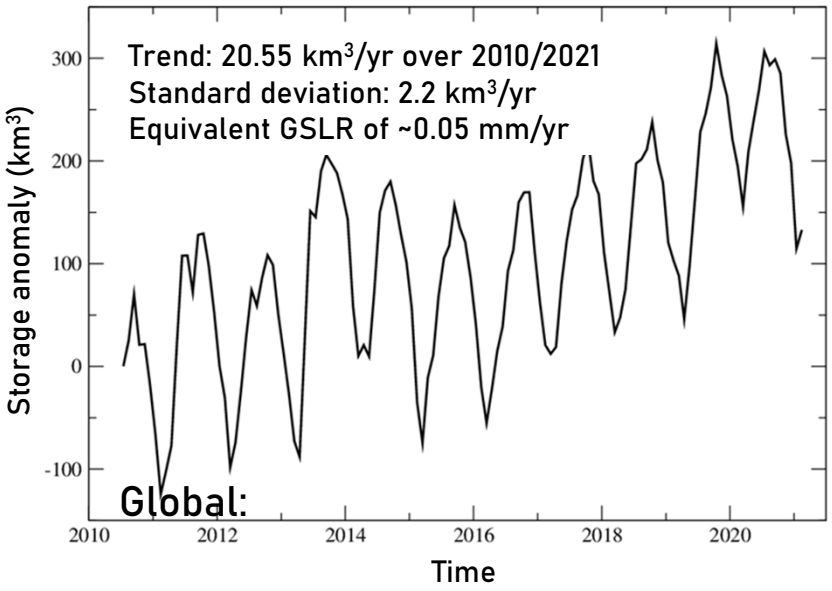

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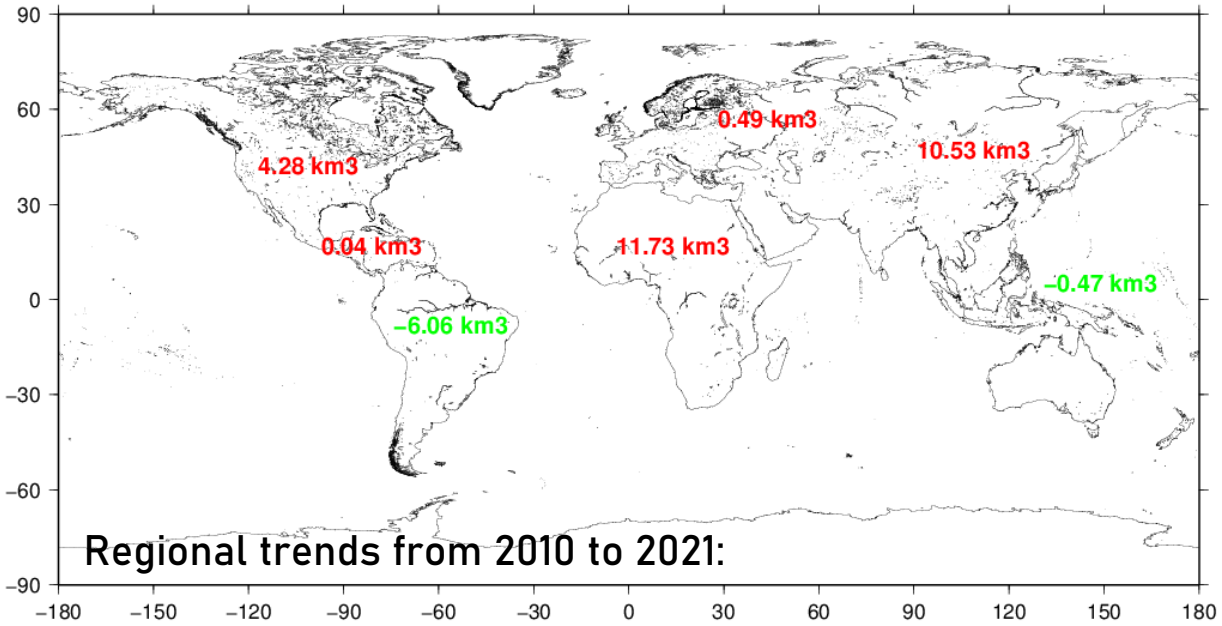
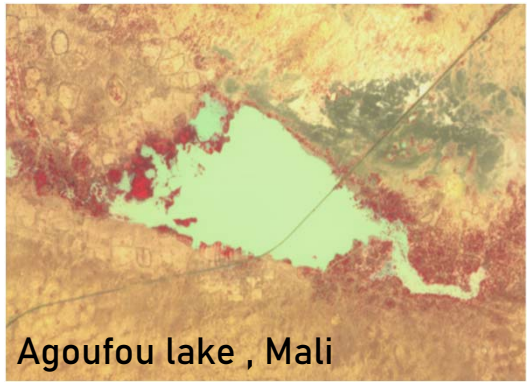
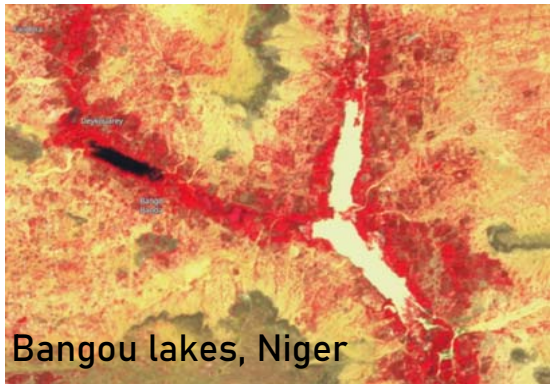


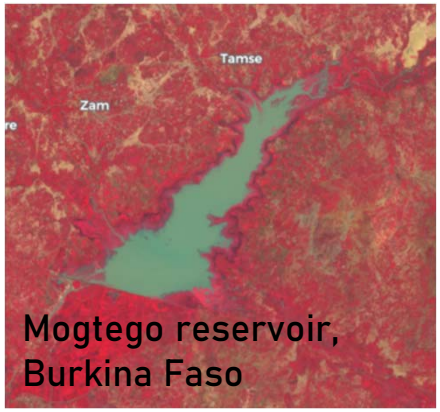
How can SWOT help map small waterbody dynamics and water balance in semi-arid regions?

(M. Grippa, M. de Fleury and SPLASH collaboration)

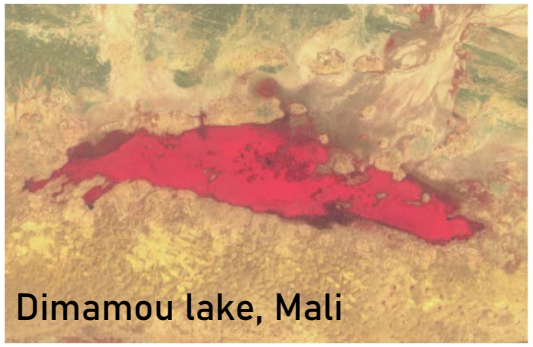

Agoufou lake , Mali


Bangou lakes, Niger

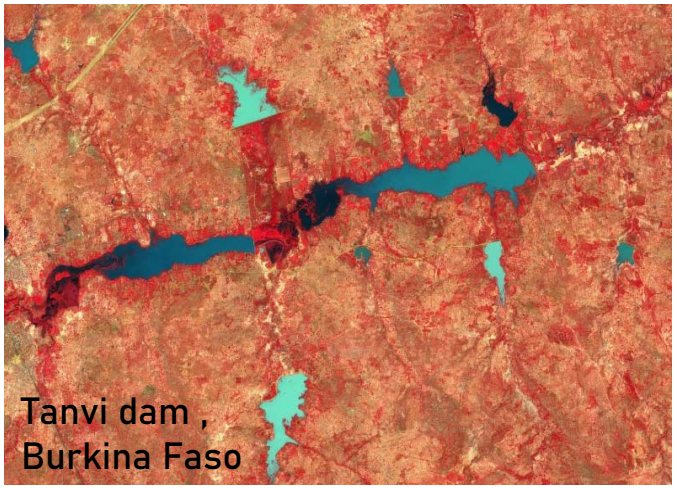

Goubuye lake, Mauritania



Mogtego reservoir, Burkina Faso


Dimamou lake, Mali


Kokorou lake, Niger


Tanvi dam , Burkina Faso

Sentinel-2, False color composite (NIR-R-G) over Sahelian lakes in October -November 2020 (EO Browser)

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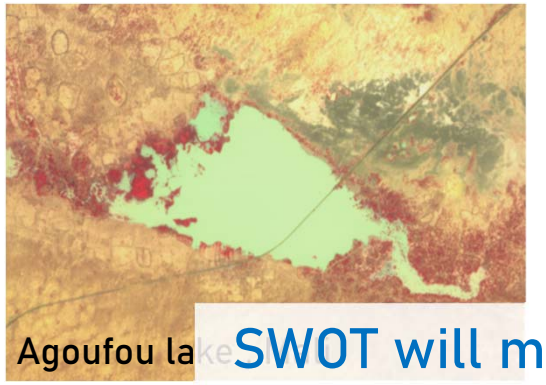
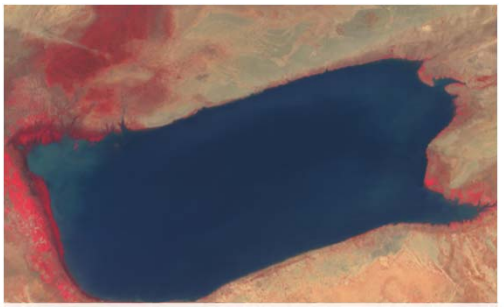

Agoufou la

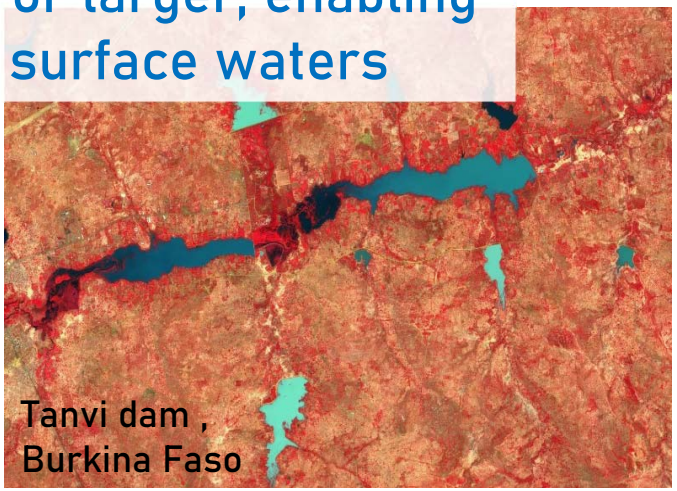


Mogtego reservoir, Burkina Faso

SWOT will map water bodies 250m x 250m or larger, enabling the monitoring of these highly dynamic surface waters


Dimamou lake, Mali


Kokorou lake, Niger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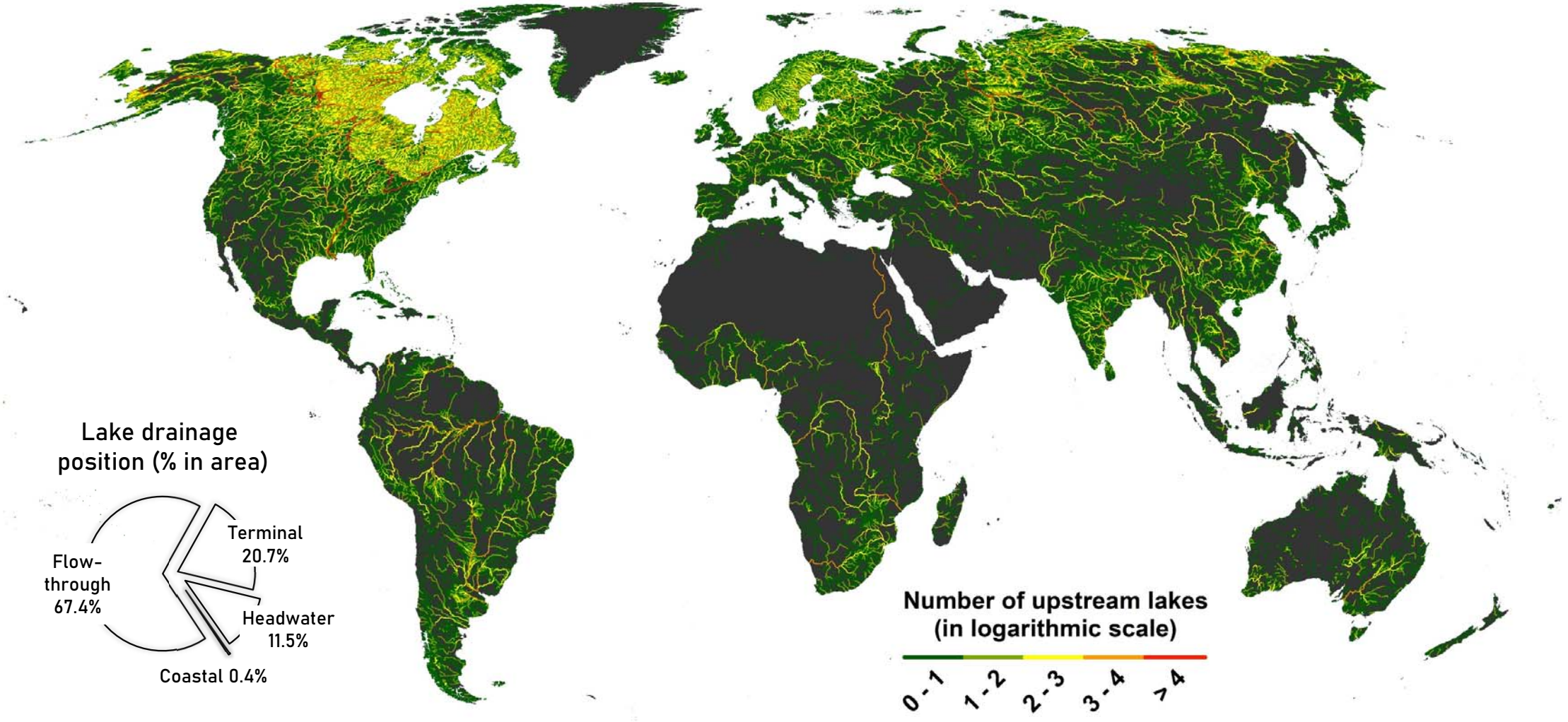
Sentinel-2, False color composite (NIR-R-G) over Sahelian lakes in October -November 2020 (EO Browser)

How are global lakes connected through river networks?

(S. Sikder, J. Wang, Y. Sheng, G. H. Allen, D. Yamazaki, T. M. Pavelsky)



SWOT will observe nearly 2 million lakes, and the constructed lake drainage topology helps us "expand" and "interconnect" the individual observations.

Global lakes that are visible to SWOT are drained from:

- A total catchment area of 80 million square kilometers
- Nearly 60% of the Earth's land surface (excluding Antarctica)
- About 30 times larger than the total SWOT-visible lake area

Storage variations in SWOT-visible lakes affect discharge in:

- More than 3 million river reaches
- Stretching about 10 million kilometers
- At least 4.6 times longer than SWOT-visible river reaches (SWORD)

Next step:

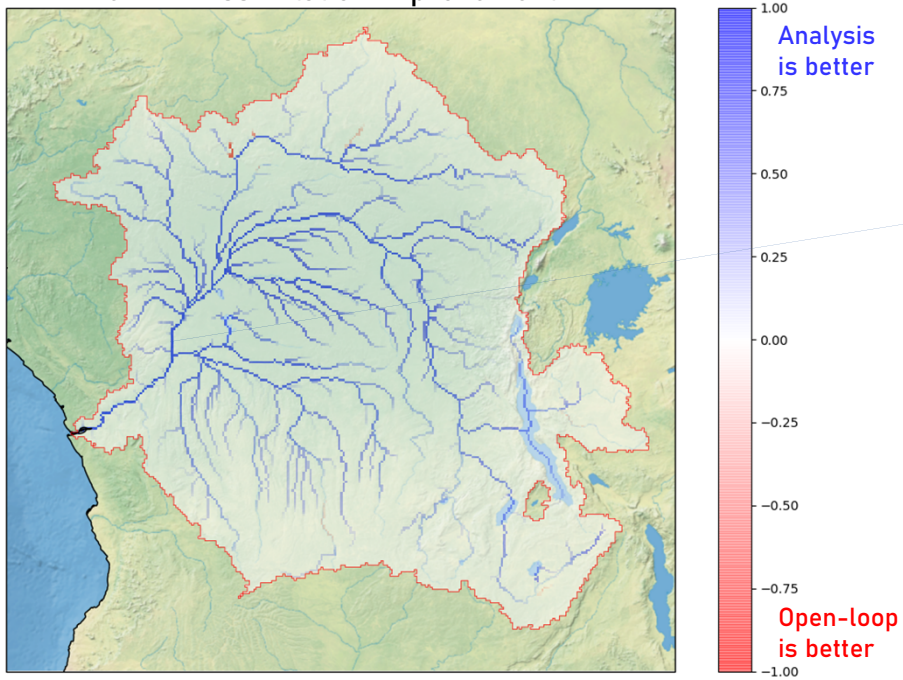
- To fully harmonized the drainage relations between SWOT a priori lake and river databases

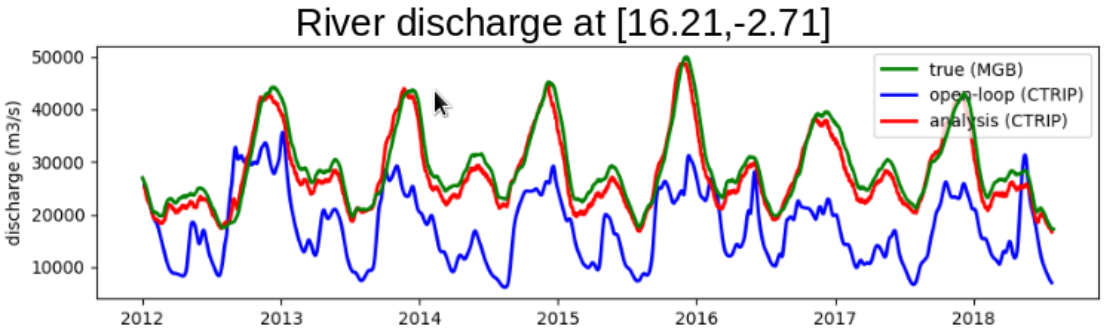
Can SWOT data assimilation into global hydrological models (1/12° resolution) help us to improve the understanding and representation of rivers and groundwater dynamics at the large to global scale?

(A. Boone, S. Munier, P. Le Moigne, C. Ottlé, D. Yamazaki)

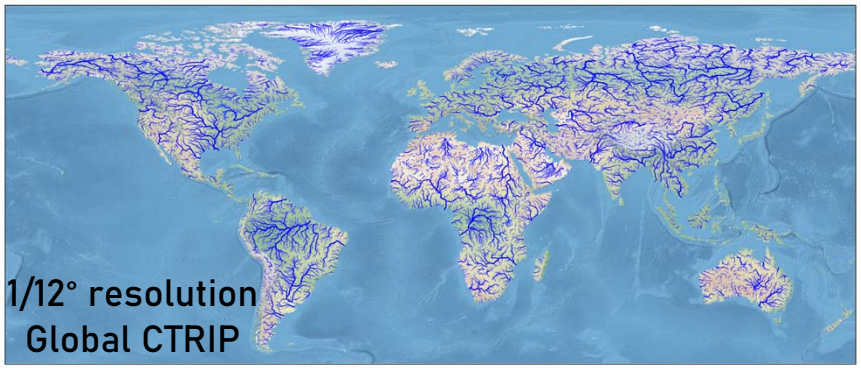
- Method: Test case over the Congo Basin → OSSE-like with independent model (MGB) and meteorological forcing to simulate the *truth*

CTRIP: Assimilation improvement





- Next step: extension to global scale



This work is an extension of the study presented at AGU (2019) and EO for Water Cycle Science 2020 (ESA, GEWEX)
S. Munier, A. Boone, S. Biancamaria, P. Le Moigne, 2020. Assimilation of SWOT discharge into CTRIP-12D over the Ebro Basin.

Key Takeaways:

The spatial resolution of the river network is much smaller than for standard global scale networks (typically 0.5)
→ We are approaching more realistic resolutions which can take much better advantage of SWOT observations

Assimilation in CTRIP of SWOT observations simulated by MGB + noise
→ We have moved away from the identical twin experiments

For the Congo, we see an improvement almost everywhere, and more importantly as we go downstream
→ The improvement (information from assimilation) is "advected" and not just local)

The OL simulation is quite biased compared to truth (MGB), and it is corrected quite well by assimilation

Next step: The coherence of river networks is a real problem, and it's not easy to solve. An algorithm is being developed (S. Munier) to match the CTRIP and MGB networks. We will have to do the same with the SWOT network (RiverObs) and the other models involved in SWOT (CaMaFlood). This could be useful for SWOT overall.

Issues being addressed: The constraints in computing power are great for the passage from a single large basin to the global scale. It will surely be necessary to reduce the size of the ensemble (for the Congo, an ensemble of 127 members was used, but currently this is too much for the global network at 1/12 deg on the supercomputer, notably for memory reasons).

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This study makes significant advancements to SWOT data assimilation at the global scale.

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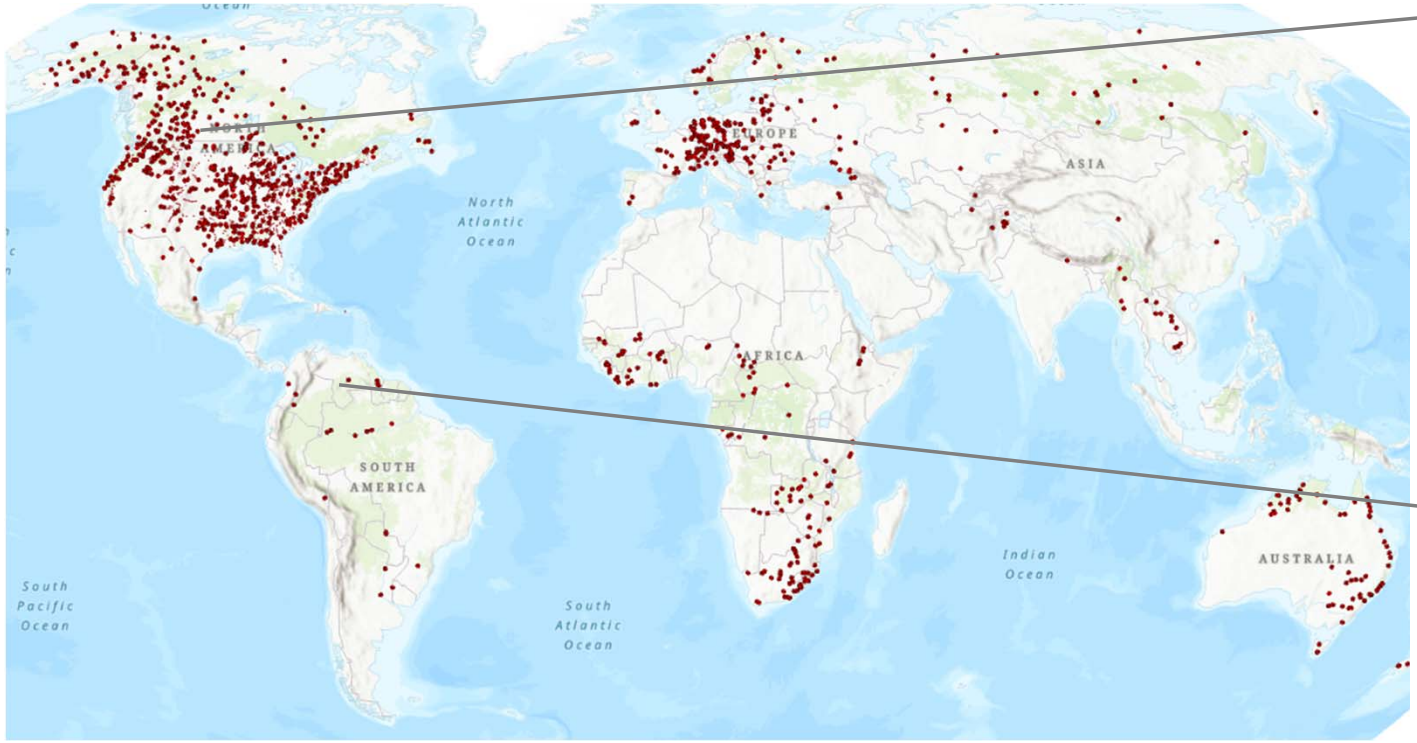
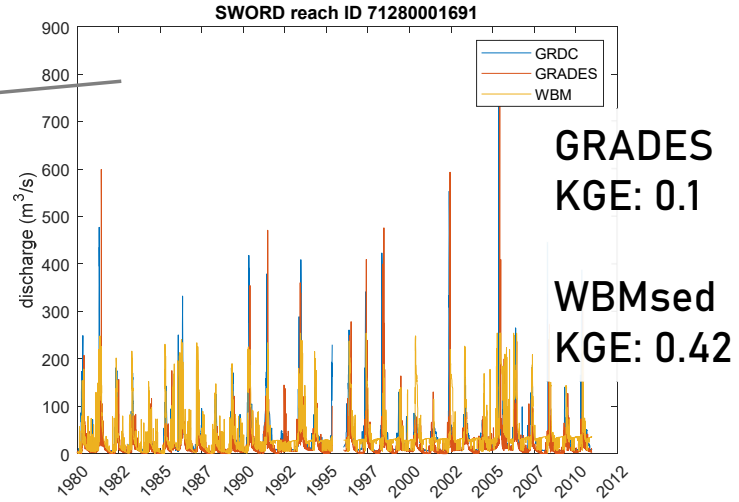
How can SWOT improve global model accuracy?

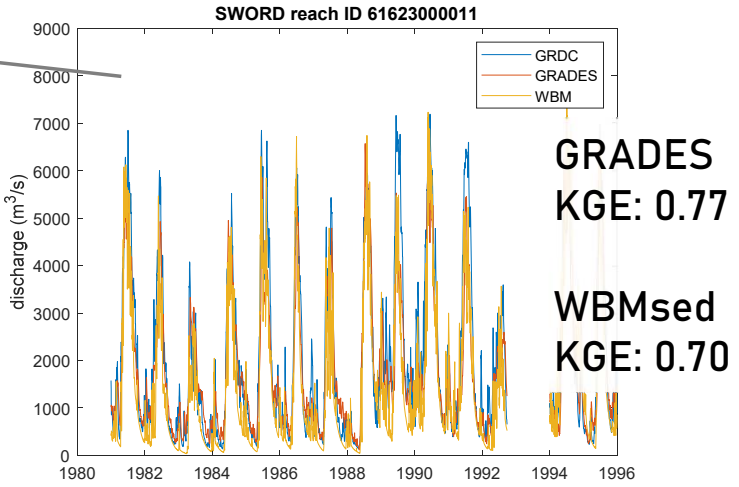
(S. Coss, M. Durand, Ohio State U.)





GRADES
KGE: 0.1

WBMsed
KGE: 0.42



GRADES
KGE: 0.77

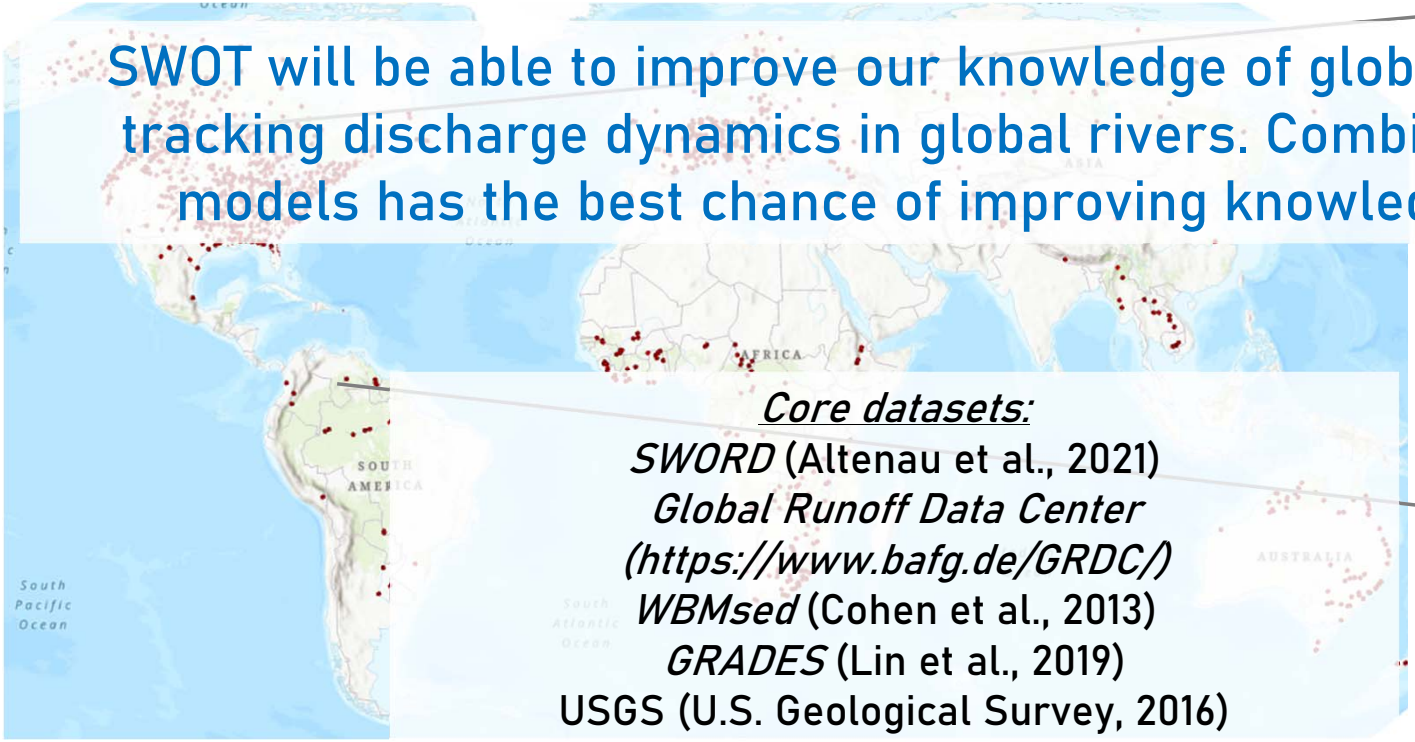
WBMsed
KGE: 0.70

GRDC and USGS gages, and GRADES and WBM models have been connected with SWOT rivers (SWORD) for prior information for discharge algorithms. Two of several thousand example gages shown.

How can SWOT improve global model accuracy?

(S. Coss, M. Durand, Ohio State U.)

SWOT will be able to improve our knowledge of global discharge by accurately tracking discharge dynamics in global rivers. Combining SWOT discharge and models has the best chance of improving knowledge of global discharge.



<u>Core datasets:</u>

SWORD (Altenau et al., 2021)

Global Runoff Data Center (https://www.bafg.de/GRDC/)

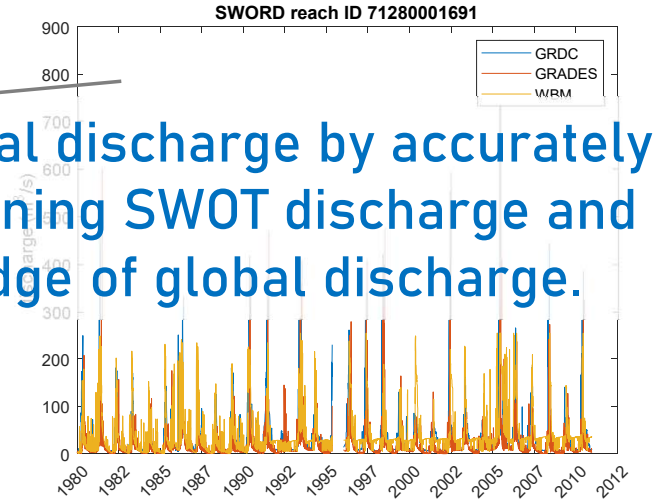
WBMsed (Cohen et al., 2013)

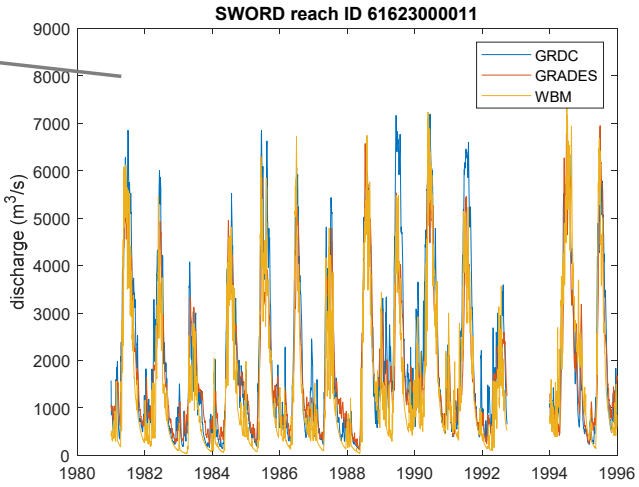
GRADES (Lin et al., 2019)

USGS (U.S. Geological Survey, 2016)

… *others to be added!*

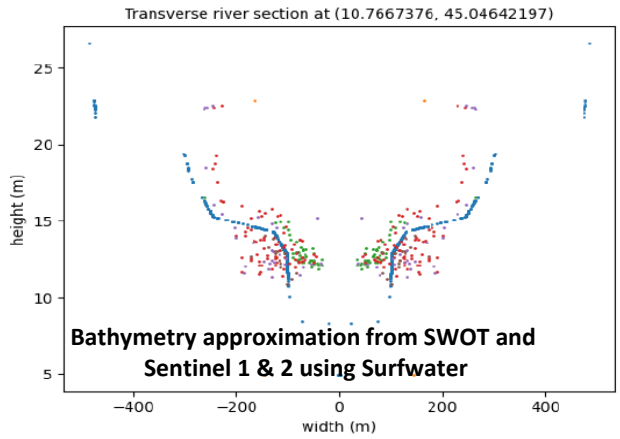
SWOT discharge (Q)

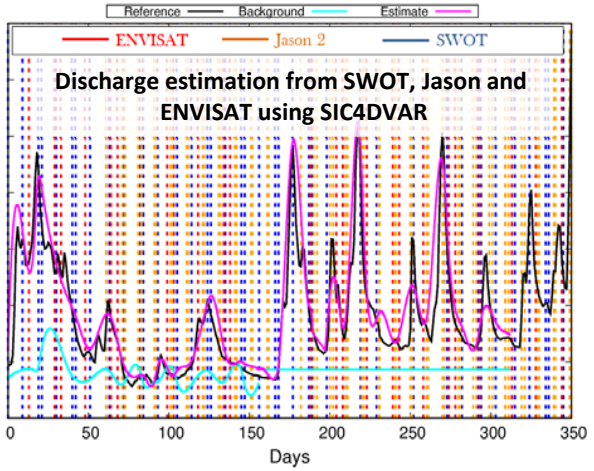




What is the potential of combining SWOT with existing satellites?

(H. Oubanas, INRAE)





- What information can we gather about river Floodplain DEM in ungauged basins?
  - Combination of SWOT and Sentinel 1 & 2 satellite to approximate river bathymetry : Surfwater software.
  - Future products : Floodplain DEM Databases
- How well can river discharge be estimated from SWOT and altimetry/optical observations?
  - Discharge algorithms based on data assimilation (SIC4DVAR, EnKF-Telemac 1D/2D, HiVDi, McFLI, etc.).
    - ➢ More information will be presented in the hydrology splinter.
- Need for SWOT simulated data at the global scale (LR Simulator) or finer scale (HR simulator) :
  - ToolBoxSWOT : generation of synthetic data from a hydraulic scenario for river with known or unknown topography.
  - This tool will be very helpful for other future satellite missions for hydraulics and hydrology.

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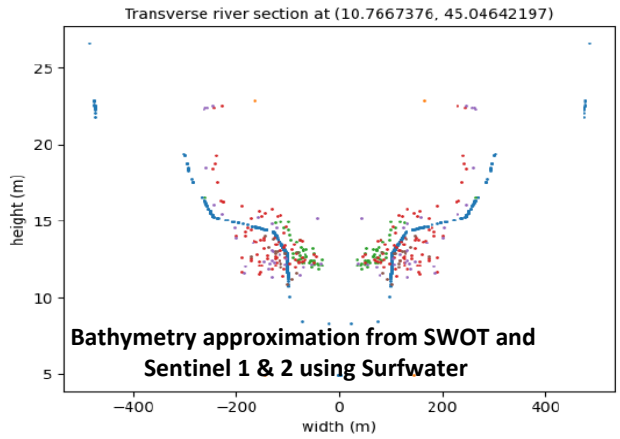

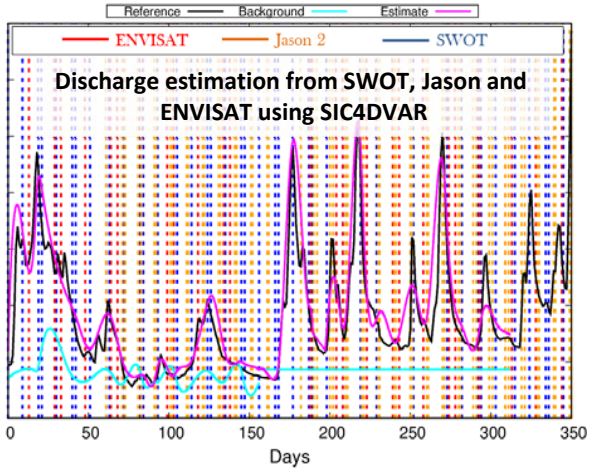

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  - *Future products : Floodplain DEM Databases.*
- *How well can river discharge be estimated from SWOT and altimetry/optical observations?*
  - *Discharge estimation with different algorithms (MOMMA, MetroMan, SIC4DVAR, HiVDi, McFLI, etc.).*
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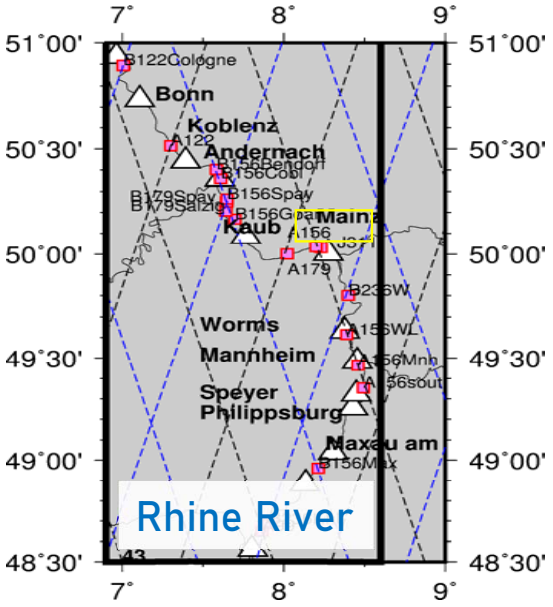
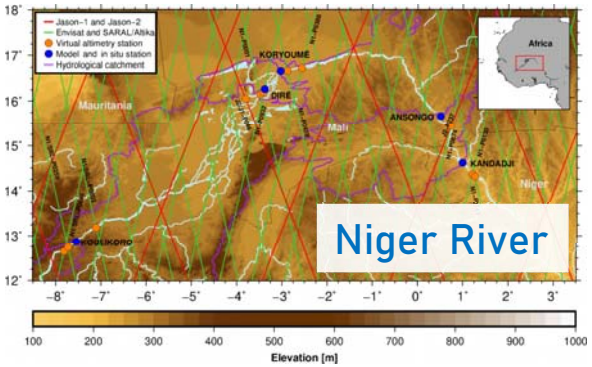
- *Need for SWOT simulated data at the global scale (LR Simulator) or finer scale (HR simulator) :*
  - *ToolBoxSWOT : generation of synthetic data from a hydraulic scenario for river with known or unknown topography.*
  - *This tool will be very helpful for other future satellite missions for hydraulics and hydrology.*

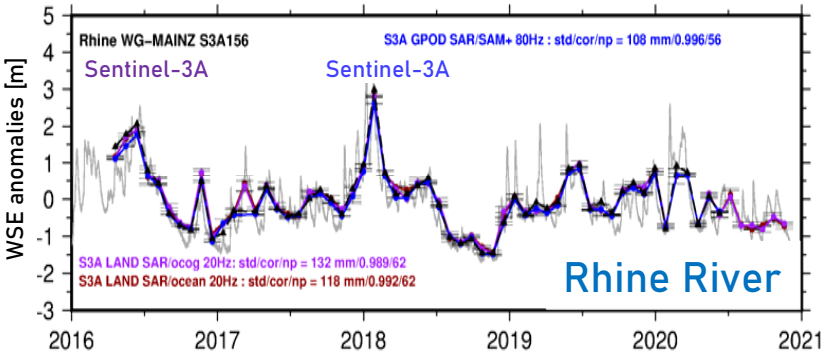
The assimilation of SWOT data will improve the estimates of river discharge and will enable the production of higher accuracy floodplain DEMs.

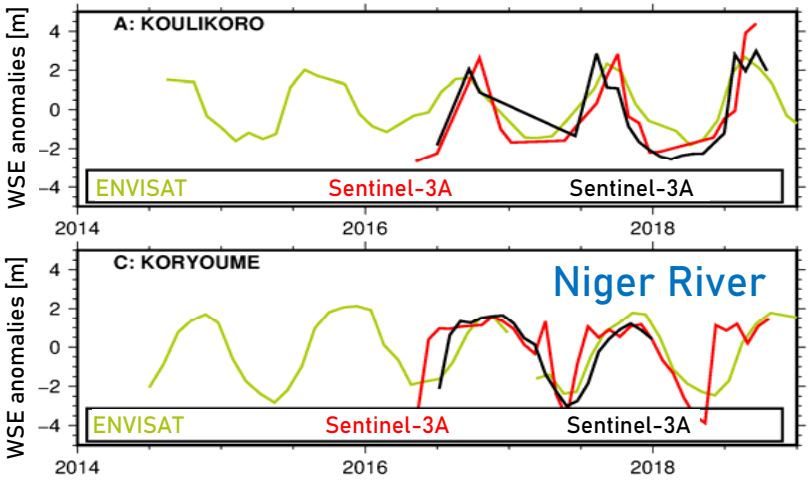
How are hydrology, hydraulics and morphology of rivers linked?

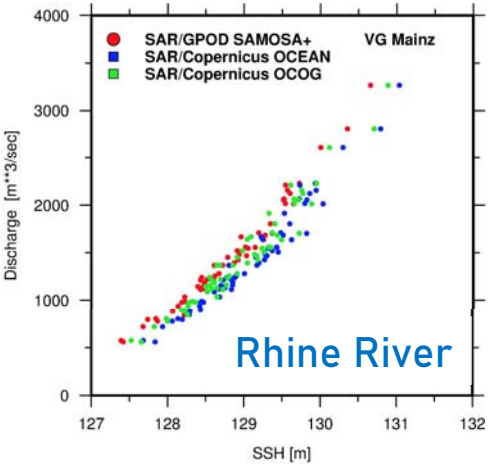
(L. Fenoglio, P. Krahe, T. Artz, S. Martinis, B. Gundlich, M. Evers, J.Kusche)

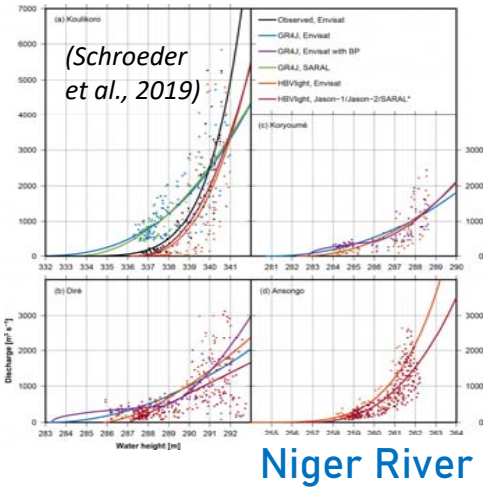












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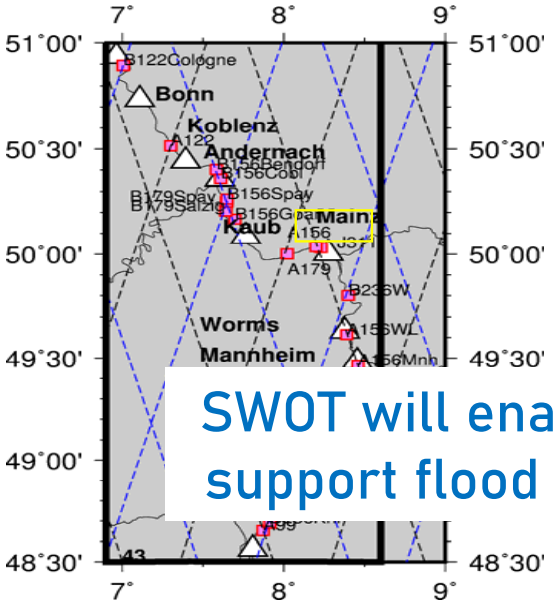
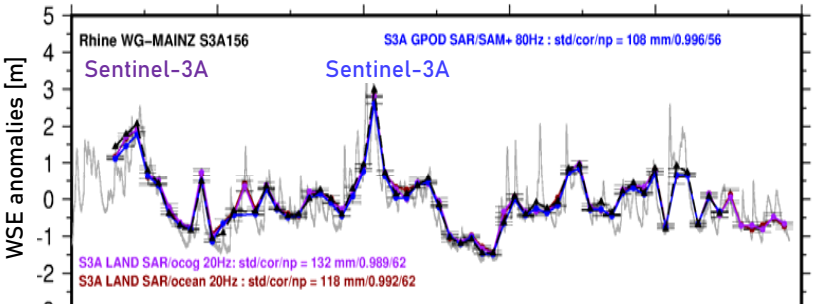
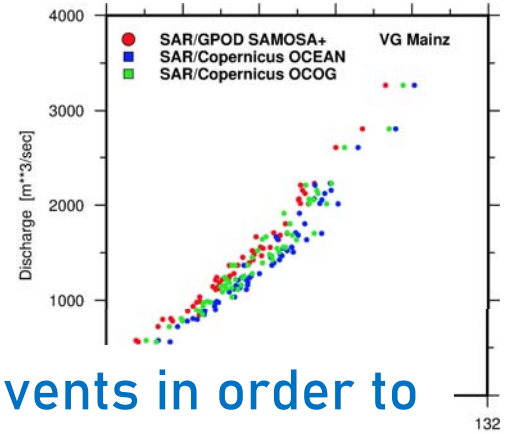
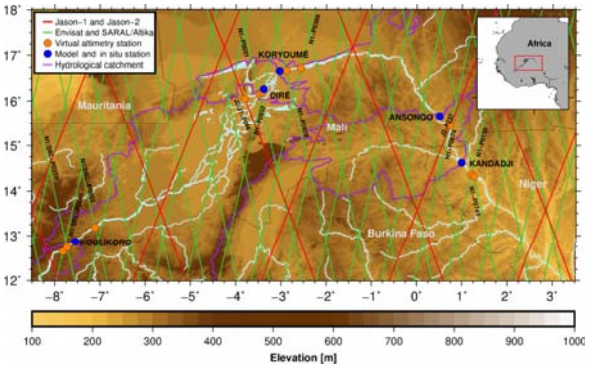
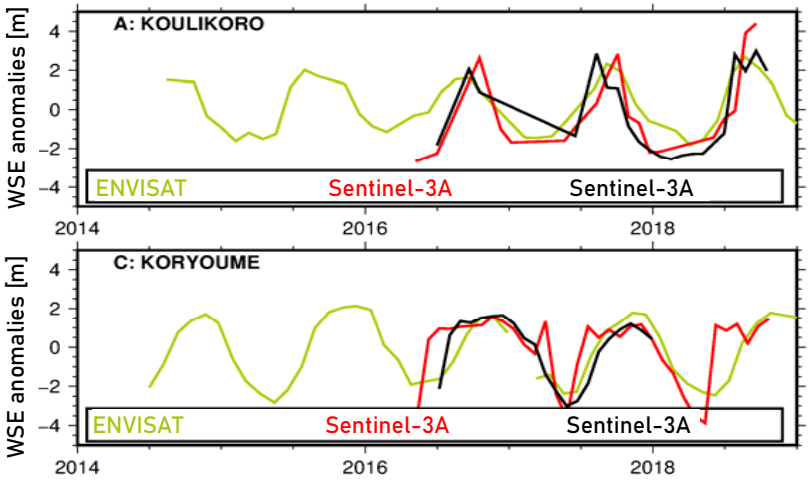


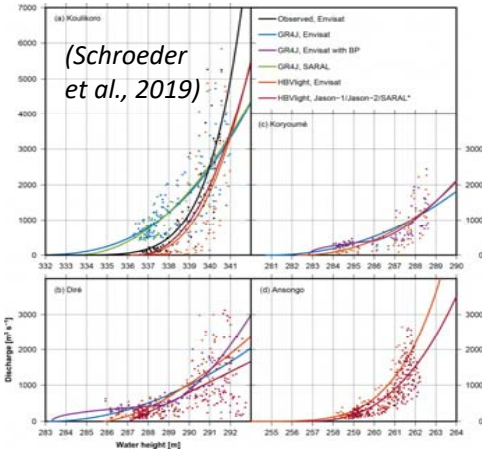




SWOT will enable the tracking of extreme hydrologic events in order to support flood early warning systems for gauged and ungauged basins.



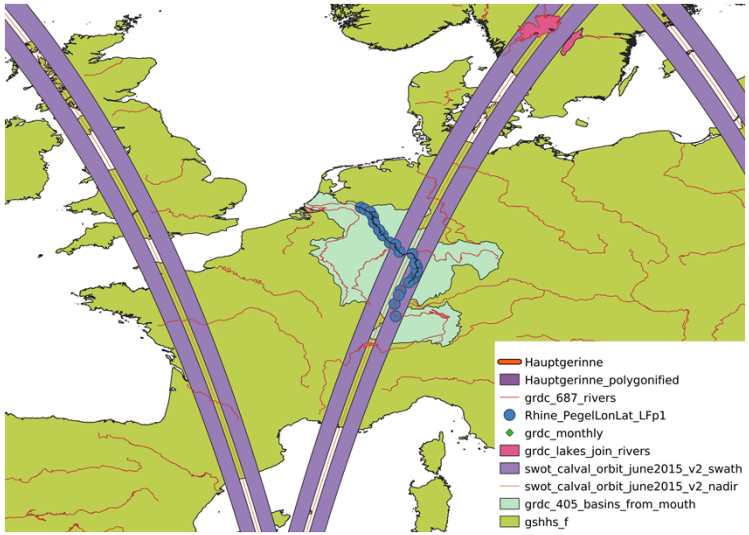




How will SWOT teach us about links on hydrology, hydraulics and morphology of rivers?

The water cycle and climatic conditions constrain the hydrological regimes and define seasonal and daily flow patterns. River hydraulic processes involve discharge, sediment transport, regional and local topographic slope, and bank material cohesive strength, thus hydrology, hydraulics and morphology are strictly related.

- SWOT data will produce highly accurate observations of water surface slope (WSS) and discharge (Q), enabling global analysis and characterization of global hydrologic, hydraulic and morphologic river attributes
- Combining SWOT data with data from existing satellites, in-situ measurements and other ancillary datasets and an understanding of their hydrologic, hydraulic and morphologic attributes will provide useful information for SAR altimetry and imagery to be used outside of the SWOT timeline for additional analysis

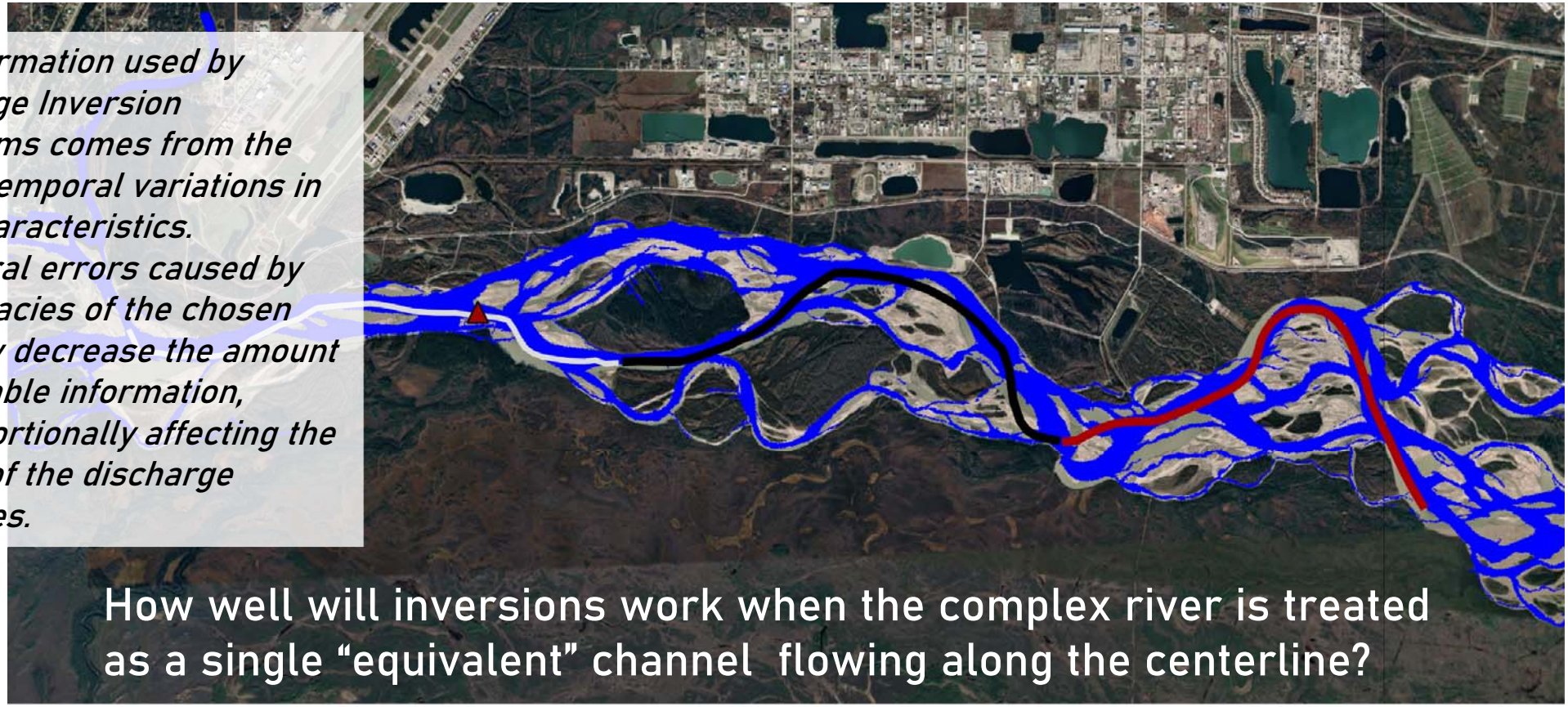


<u>Core datasets:</u>
SWORD (SWOT Mission River Database, Altenau et al., 2021) – available now
Ancillary datasets (e.g. topography, lithology) – available now
SAR altimetry and SAR imaging
SWOT retrievals of water surface slope (WSS), discharge (Q) – post launch

Can the SWOT discharge algorithms work in complex rivers ?

(E. Rodríguez, R. Frasson, JPL)

The information used by Discharge Inversion algorithms comes from the spatio-temporal variations in river characteristics. Structural errors caused by inadequacies of the chosen flow law decrease the amount of available information, disproportionally affecting the quality of the discharge estimates.



How effectively will the SWOT discharge algorithms work in complex rivers?

- We evaluated the ability of the modified Manning's equation used in MetroMan to describe the flows rates observed at an in-situ location managed by the USGS.
- While structural errors appeared to be higher than those in single channel rivers used in previous benchmarking studies, the data collected over the Tanana river contained enough information to allow for successful inversions.
- Upcoming activities will use SWOT data to conduct comprehensive evaluations of invertibility and lead to improved flow laws more appropriate for rivers with complex planforms.

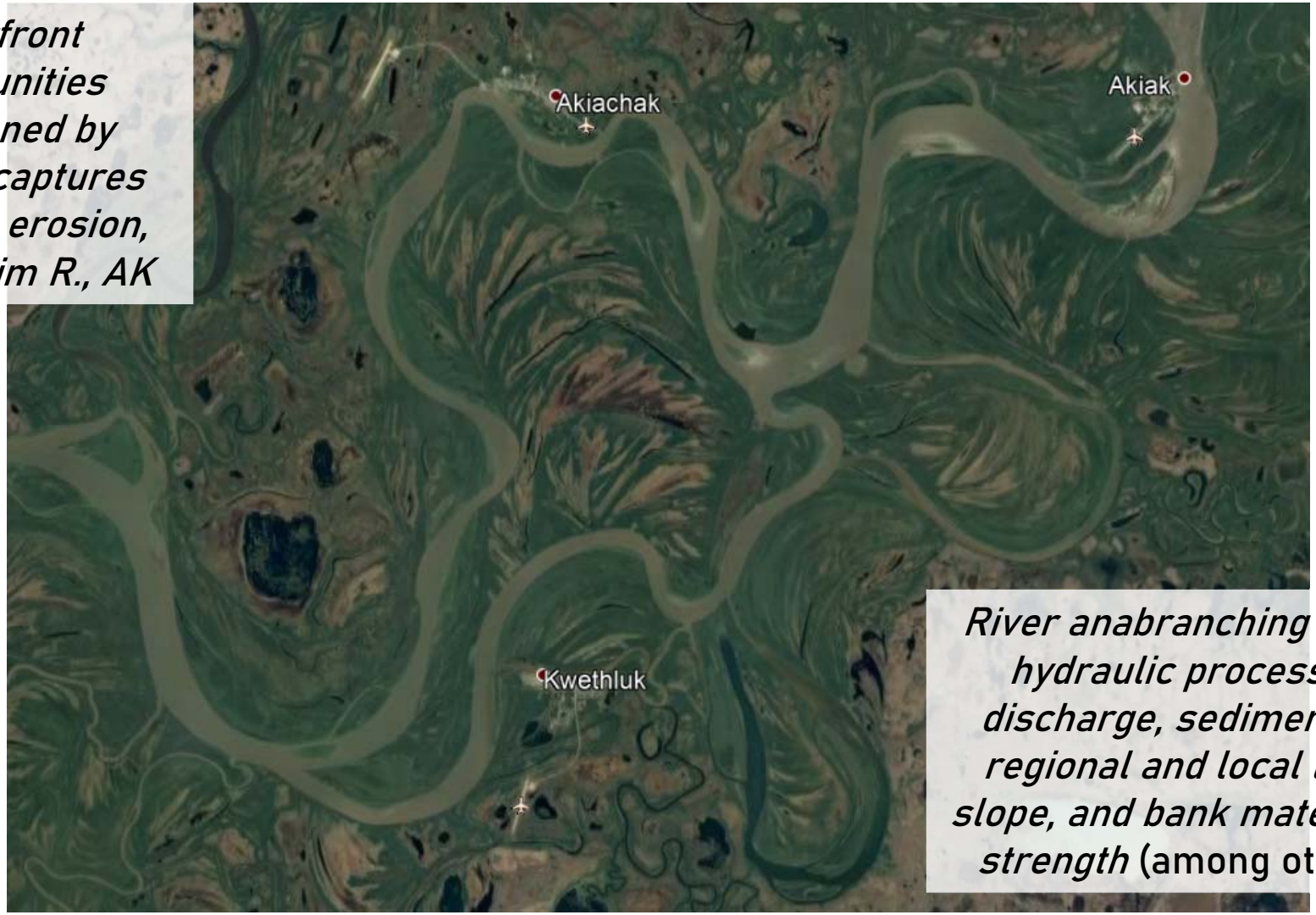
<u>Core dataset:</u>

ArcticDEM measurements over the Tanana River– available soon!

What controls large-river anabranching?

(B. Wang, L. Smith, Brown U.)

Riverfront communities threatened by channel captures and bank erosion, Kuskokwim R., AK

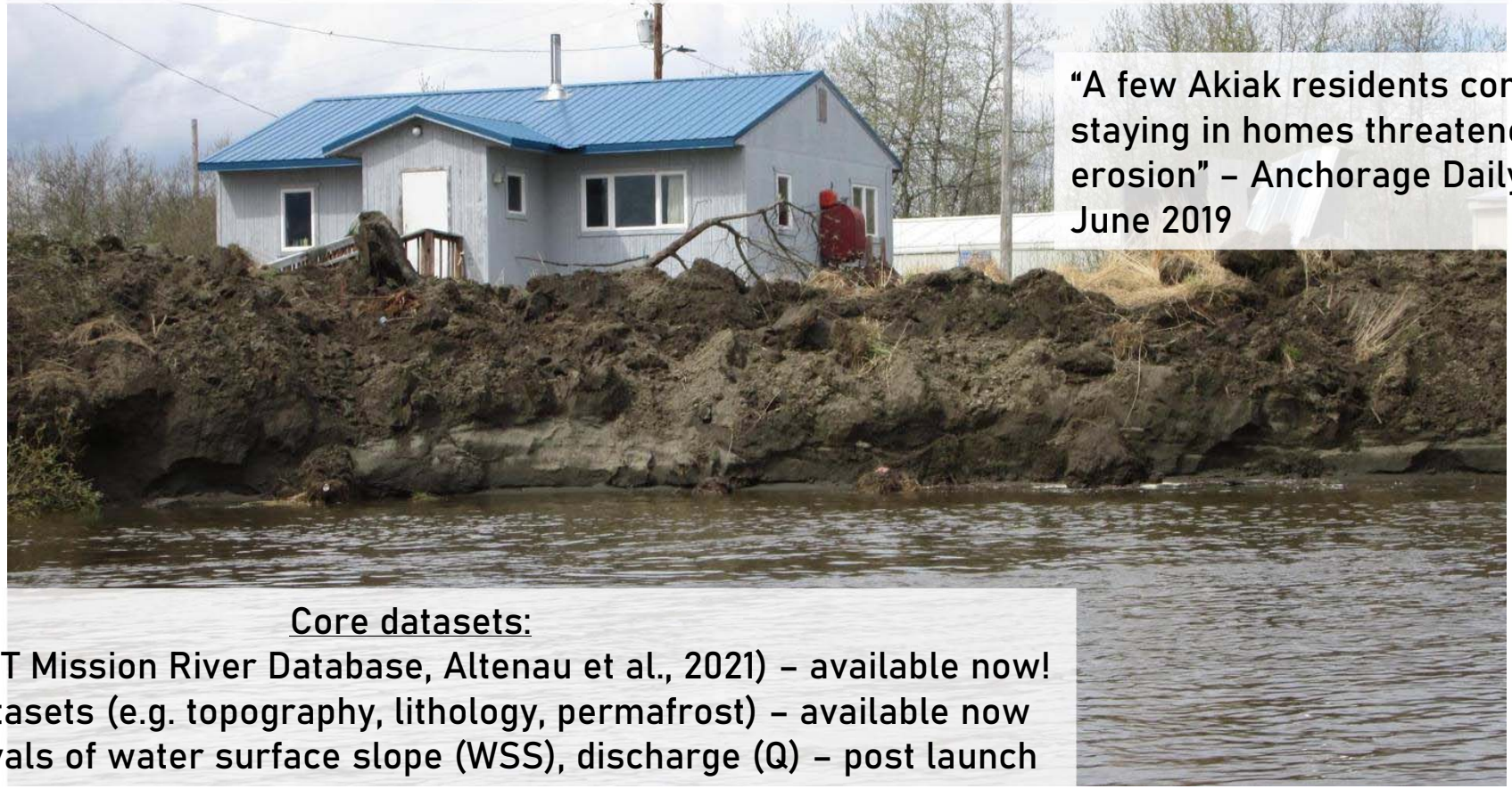


River anabranching is a complex hydraulic process involving discharge, sediment transport, regional and local topographic slope, and bank material cohesive strength (among other factors)

What controls large-river anabranching?

(B. Wang, L. Smith, Brown U.)

SWOT will generate reach-averaged values of water surface slope (WSS) and discharge (Q) enabling empirical testing of their association with anabranching channel planforms and other ancillary datasets.



"A few Akiak residents consider staying in homes threatened by erosion" – Anchorage Daily News, June 2019

Core datasets:

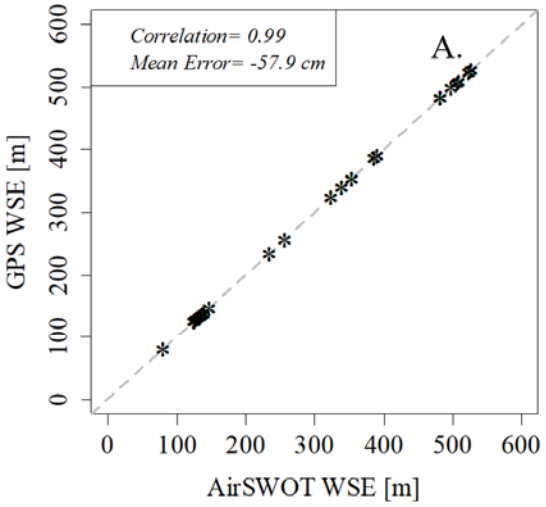
SWORD (SWOT Mission River Database, Altenau et al., 2021) – available now!

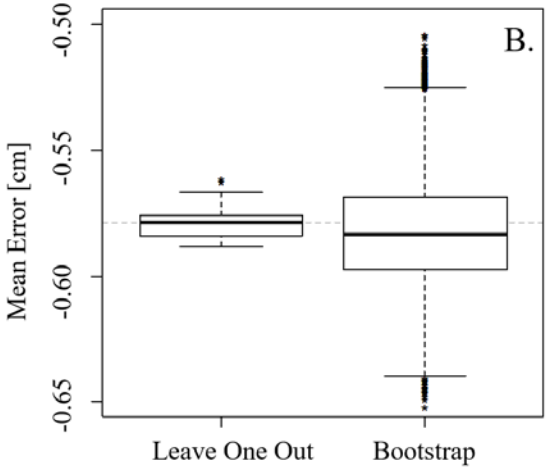
Ancillary datasets (e.g. topography, lithology, permafrost) – available now

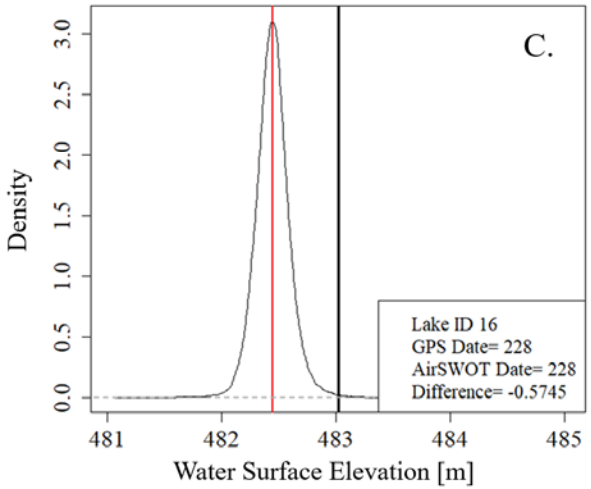
SWOT retrievals of water surface slope (WSS), discharge (Q) – post launch

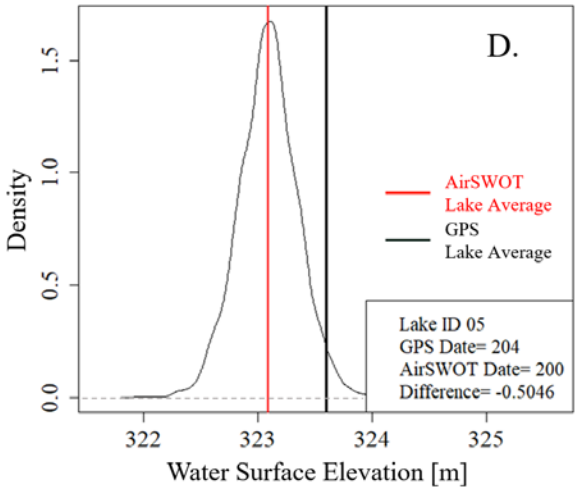
How well does the 2017 AirSWOT ABoVE data measure water surface elevations?

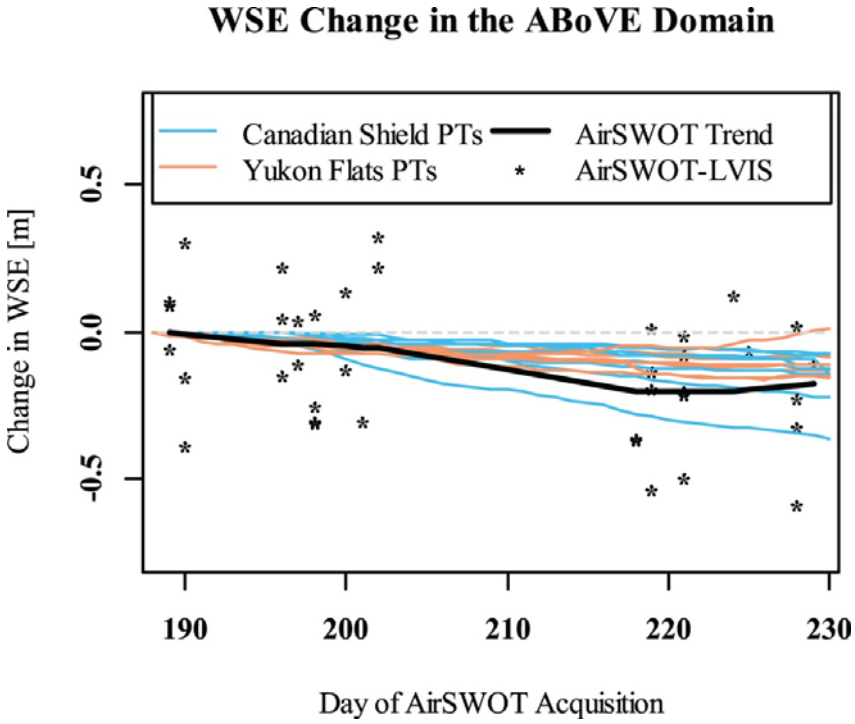
(J. Fayne, UCLA, L. Smith, Brown U., and many others)









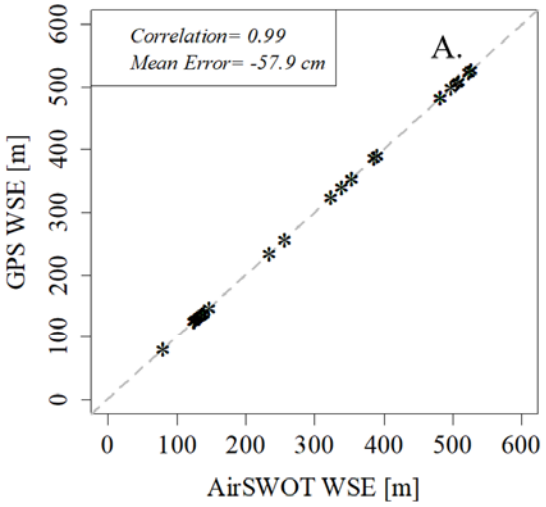


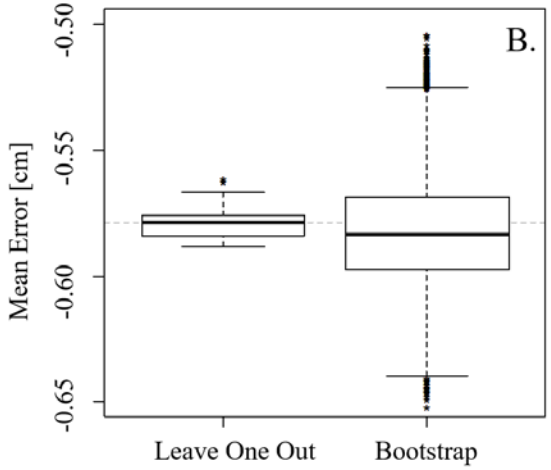
AirSWOT 2017 data has a correctable bias of 0.58 cm, and can effectively measure relative seasonal change in Canada and Alaska

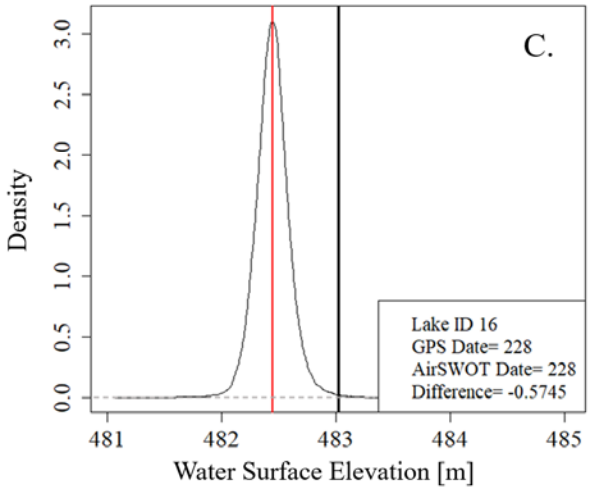
Fayne et al., *ERL*, 2020

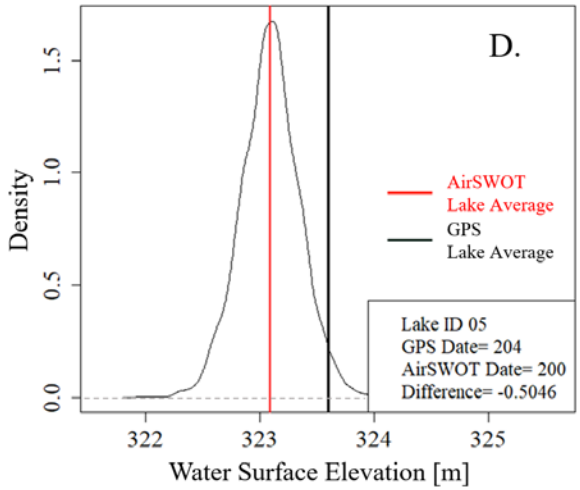
How well does the 2017 AirSWOT ABoVE data measure water surface elevations?

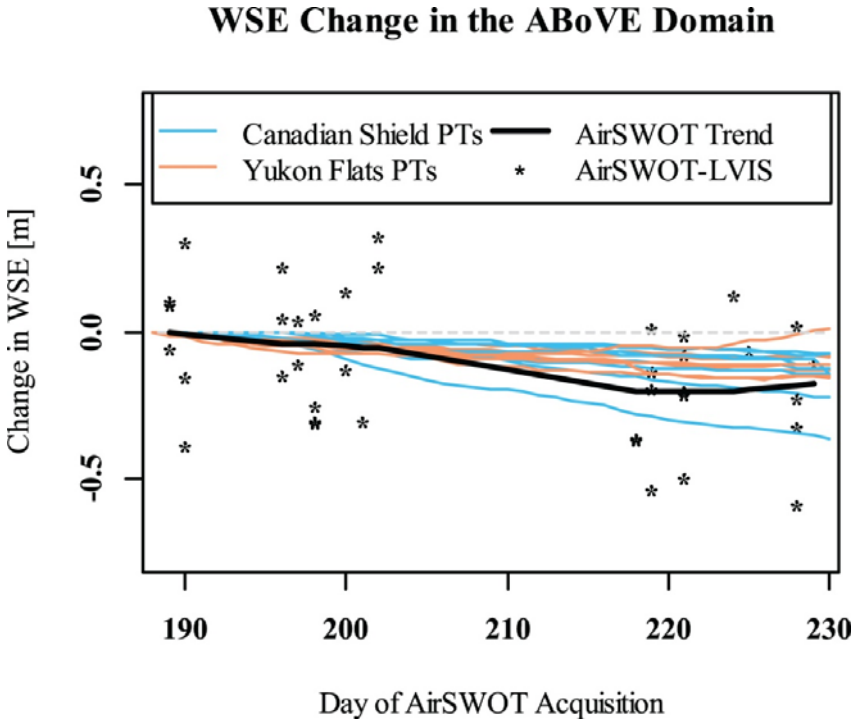
(J. Fayne, UCLA, L. Smith, Brown U., and many others)











SWOT data has more precise calibration than the data presented here, and will be very useful for diverse applications.

Fayne et al., *ERL*, 2020

Thank You