Overview of the Surface Water and Ocean Topography Mission

Renato Frasson, on behalf of:
Matthew Bonnema and Angelica Rodriguez

Jet Propulsion Laboratory, California Institute of Technology

NASA Western Water Action Office, Annual Meeting
15 May 2025

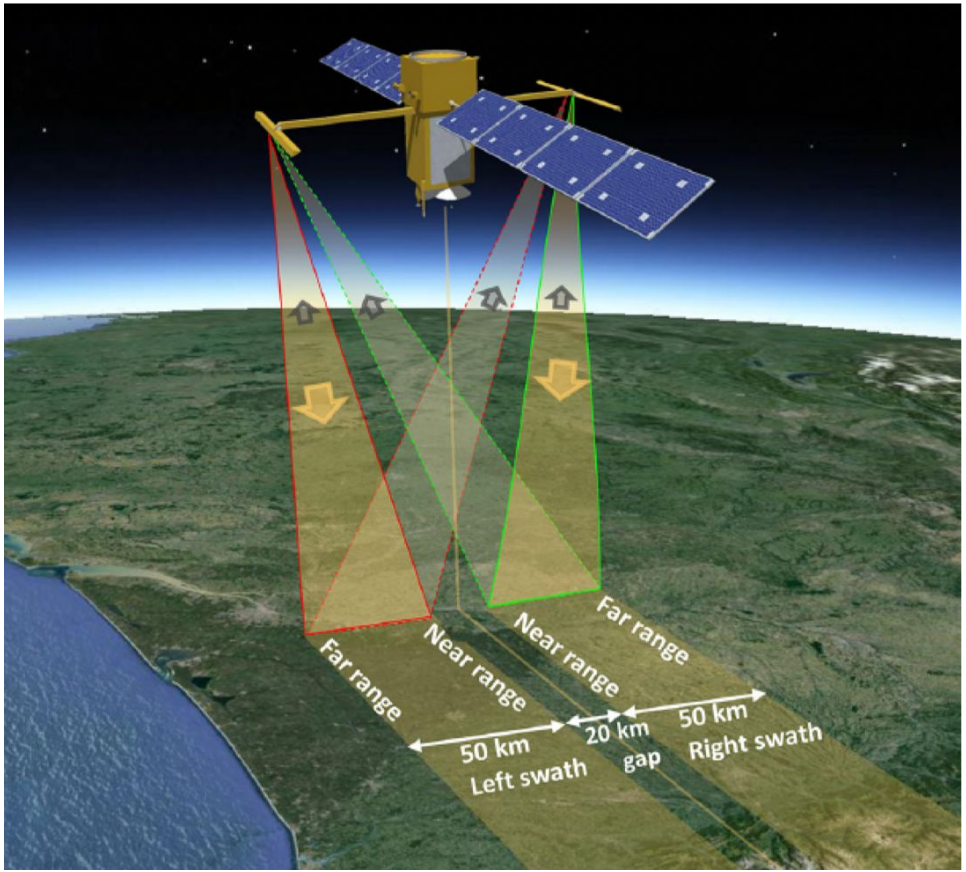
Credit: NASA Blue Marble

The Surface Water and Ocean Topography Mission

National Aeronautics and Space Administration

The SWOT satellite uses **radar interferometry** technology to provide "**spatially continuous**" observations of water surface extent, elevation, and slope:

- Launched Dec. 16, 2022
- Observations every 10 days, on average
- Covers 78°N to 78°S
- Data latency goal of <3 days
- 3.5 year nominal mission lifetime (we hope for longer)
- Partnership between NASA, CNES (France), Canadian Space Agency, and UK Space Agency



Biancamaria, Lettenmaier, and Pavelsky, *SoG*, 2016

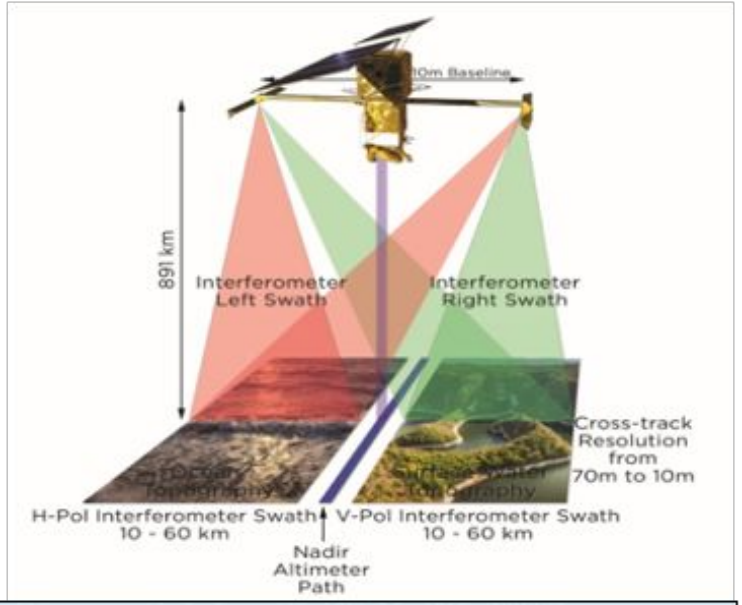
https://swot.jpl.nasa.gov/
www.nasa.gov

Mission Science Objectives

Oceanography: Characterize the ocean mesoscale and sub-mesoscale circulation at **spatial resolutions of 15 km** and greater.

Hydrology: To provide a global inventory of all terrestrial water bodies whose **surface area exceeds (250m)^2 (lakes, reservoirs, wetlands) and rivers whose width exceeds 100 m (rivers).**

- To measure the global storage change in fresh water bodies at sub-monthly, seasonal, and annual time scales.
- To estimate the global change in river discharge at sub-monthly, seasonal, and annual time scales.



- Ka-band SAR interferometric (KaRIn) system with 2 swaths, 50 km each, 20 km gap
- Produces heights and co-registered all-weather imagery
- Use conventional Jason-class altimeter for nadir coverage, radiometer for wet-tropospheric delay, and GPS/DORIS/LRA for POD.
- On-Board interferometric SAR processing over the ocean (500m^2 resolution) for data vol. reduction.

- Partnered mission with CNES, CSA, UKSA
- Science mission duration - 3 years
- Cal orbit: 857 km, 77.6° Incl., 1 day repeat
- Science orbit: 891 km, 77.6° Incl., 21 day repeat
- Flight System: ~2400kg, ~2100W
- Launch Vehicle: SpaceX Falcon 9, VAFB
- Cat 2 Project, Risk Class: C; Current Phase D
- Launched : 16 Dec 2022

https://swot.jpl.nasa.gov/
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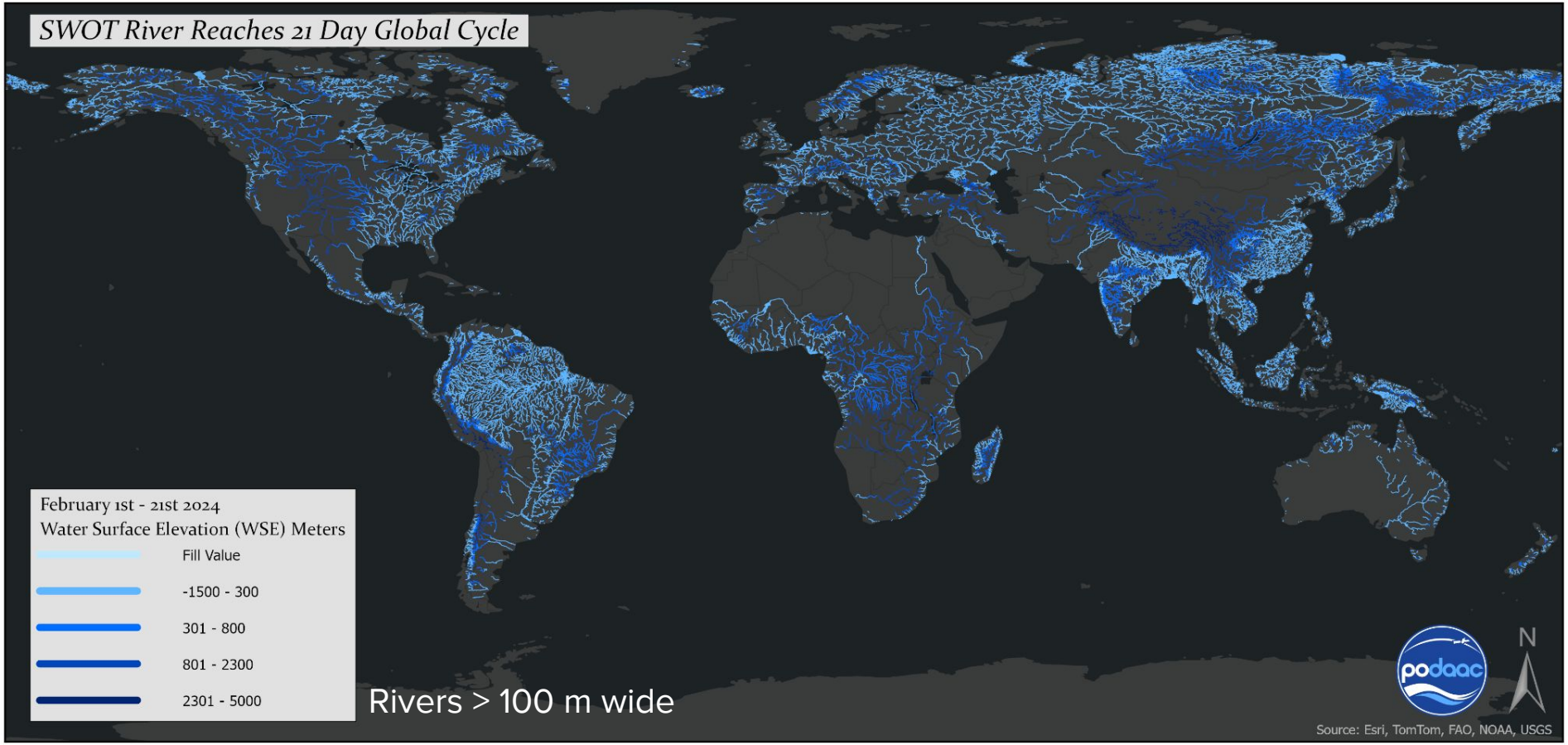
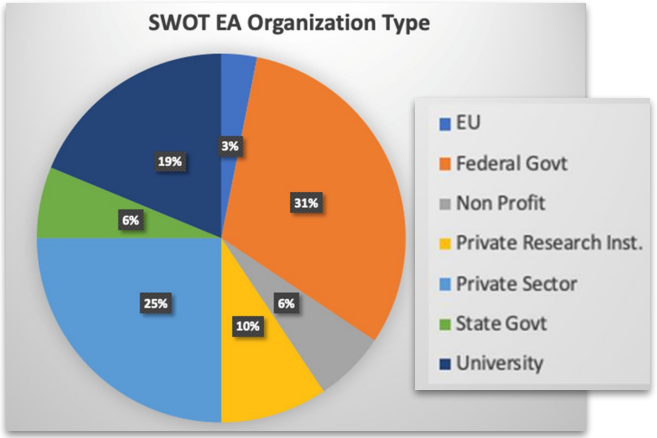


Image Credit: N. Tarpinian

SWOT Early Adopters Program

- SWOT Applications Program since 2012
- 41 SWOT Early Adopters
- U.S. and International leadership – NASA/CNES
- Building toward early SWOT applications success stories!

Figure 2. *Forty SWOT Early Adopter teams span the globe with a wide range of operational and applied science project topics. Visit swot.jpl.nasa.gov/applications/early-adopters/ for information about all SWOT EA projects.*



https://swot.jpl.nasa.gov/applications

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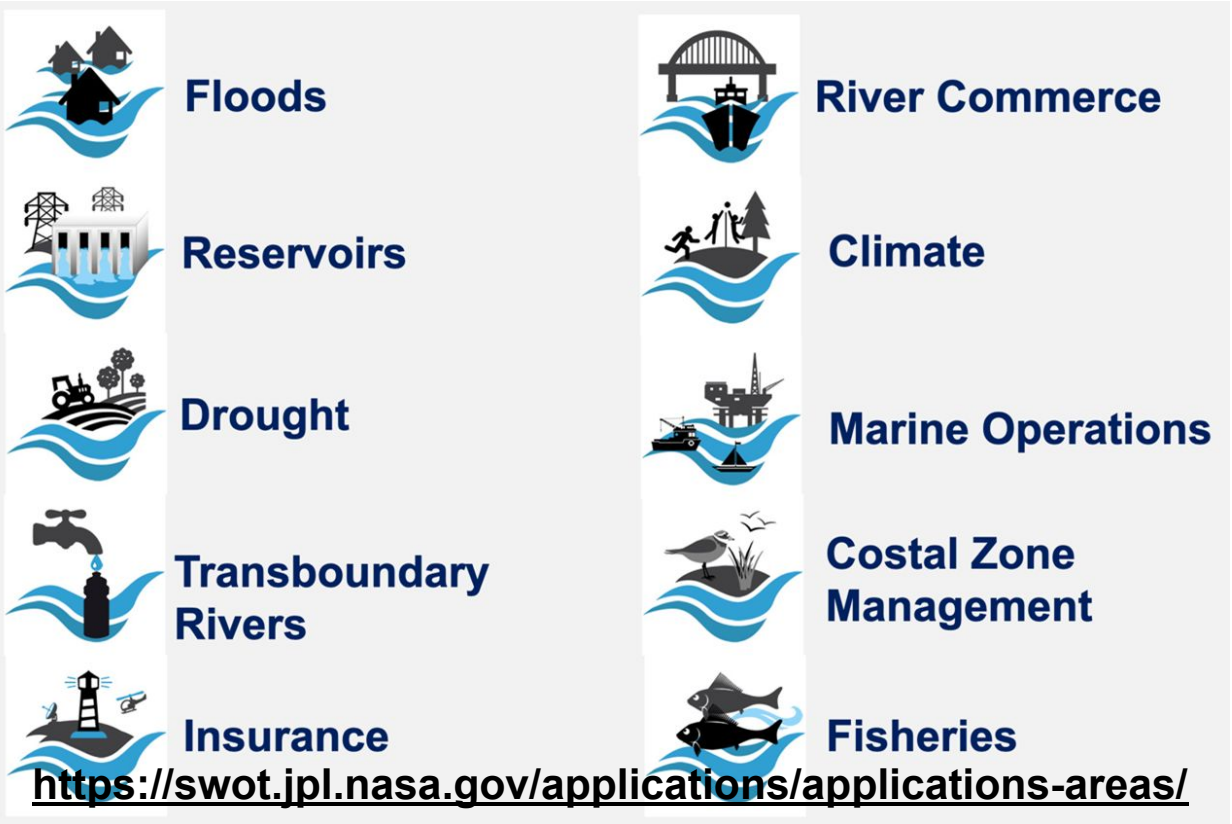
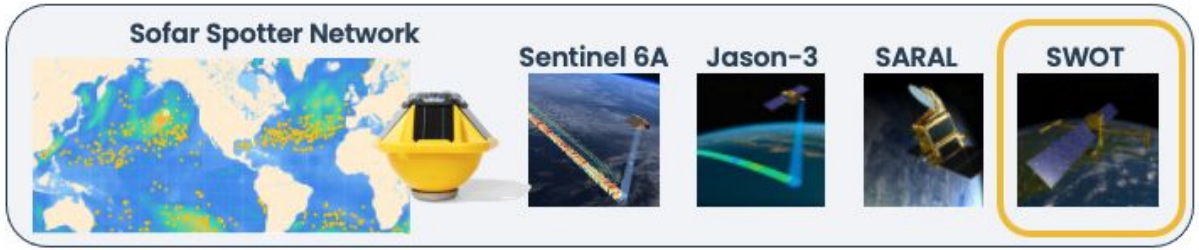
SWOT Applications Areas

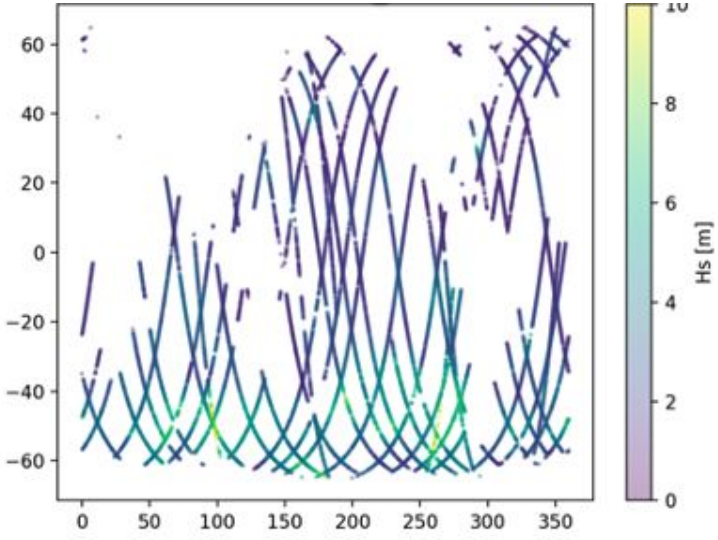


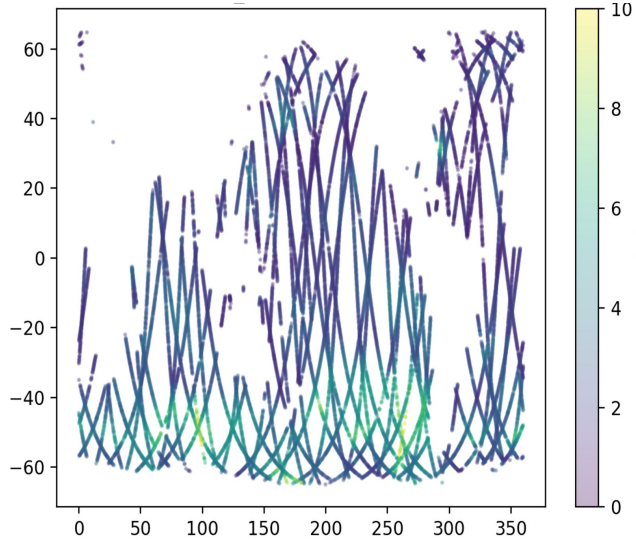
https://swot.jpl.nasa.gov/applications/applications-areas/

SOFAR Ocean



24 hrs Altimeter Data
11,962 obs





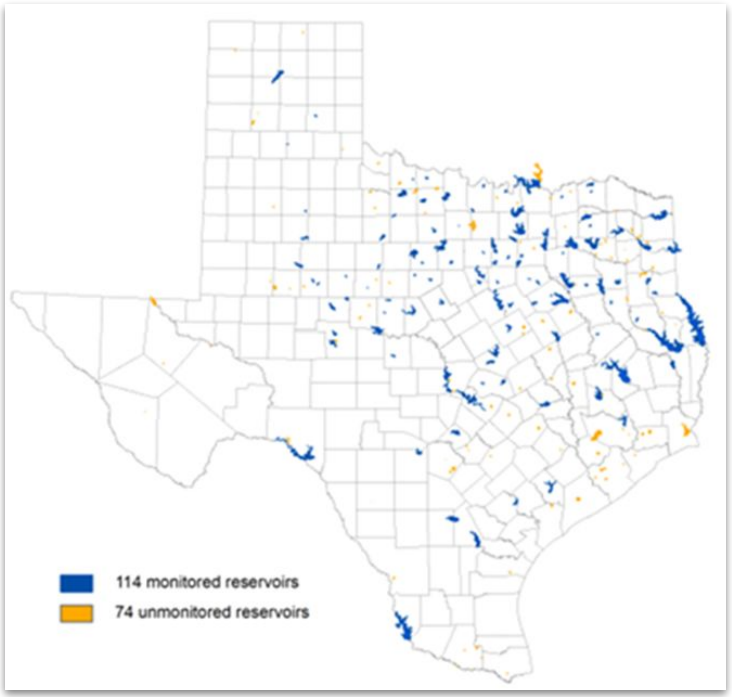
24 hrs Altimeter Data with SWOT
19,303 obs

- Ocean weather forecasts to reduce fuel and emissions for maritime shipping
- Adding SWOT gives 50-100% more observations
- Researching KaRIn data implementation and Earth System modeling applications

Texas Water Development Board (TWDB), Austin, TX

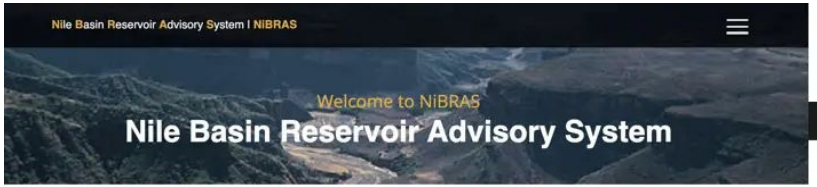
- Estimation of Volumetric Evaporative Water Loss from Unmonitored Reservoirs in Texas
- SWOT provides surface area for reservoirs and TWDB plans to compute “statewide” evaporation losses (evaporation - precipitation)
- Leads: Nelun Fernando & John Zhu

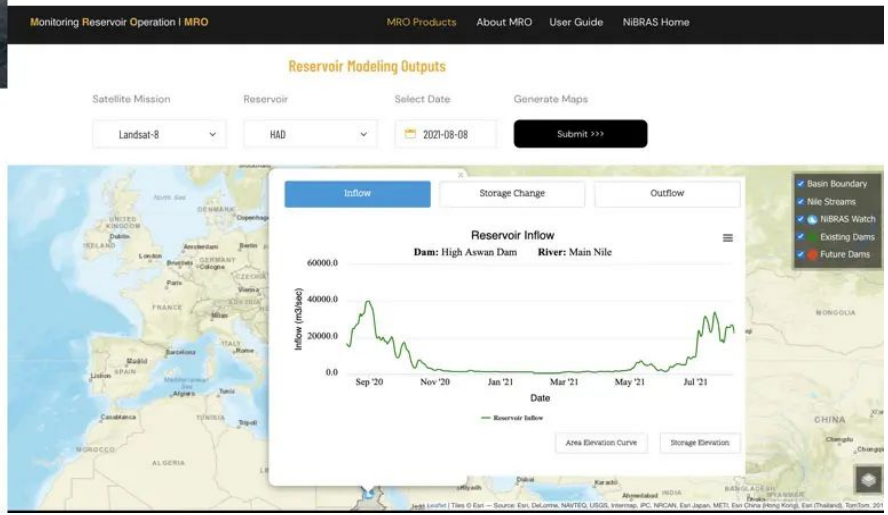
Major Texas reservoirs (capacity is greater than 5,000 acre-feet); ~200.



Alexandria University, Egypt

Improving dam operations and building stronger capacity for using SWOT observations in monitoring surface water resources in the Nile River basin





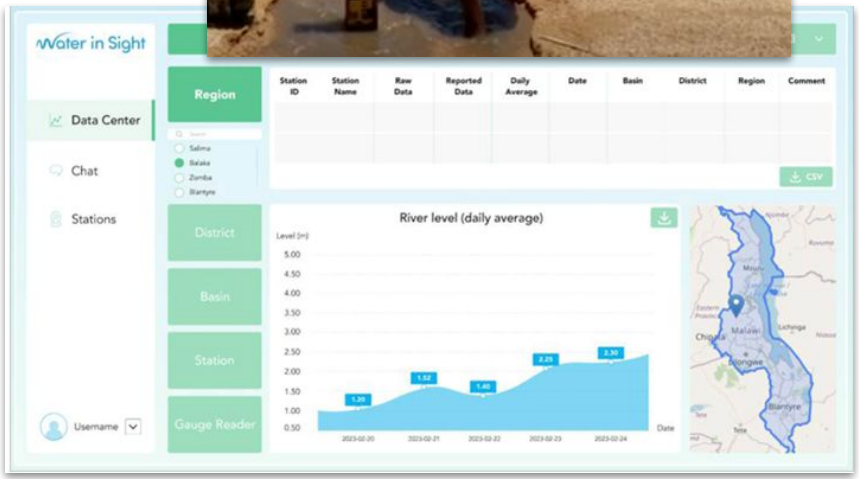
Goals: 1) to test/apply SWOT synthetic data for lake water balance analysis and modeling with focus on Lake Nasser (HAD reservoir);
2) to test the integration of SWOT data/products into the operational Nile Basin Reservoir Advisory System or (NiBRAS).

NiBRAS is a satellite-based framework to facilitate the understanding of the water management issues associated with reservoir operation in the NRB and provide a basis for evaluating potential solutions.

Water in Sight

Swedish startup

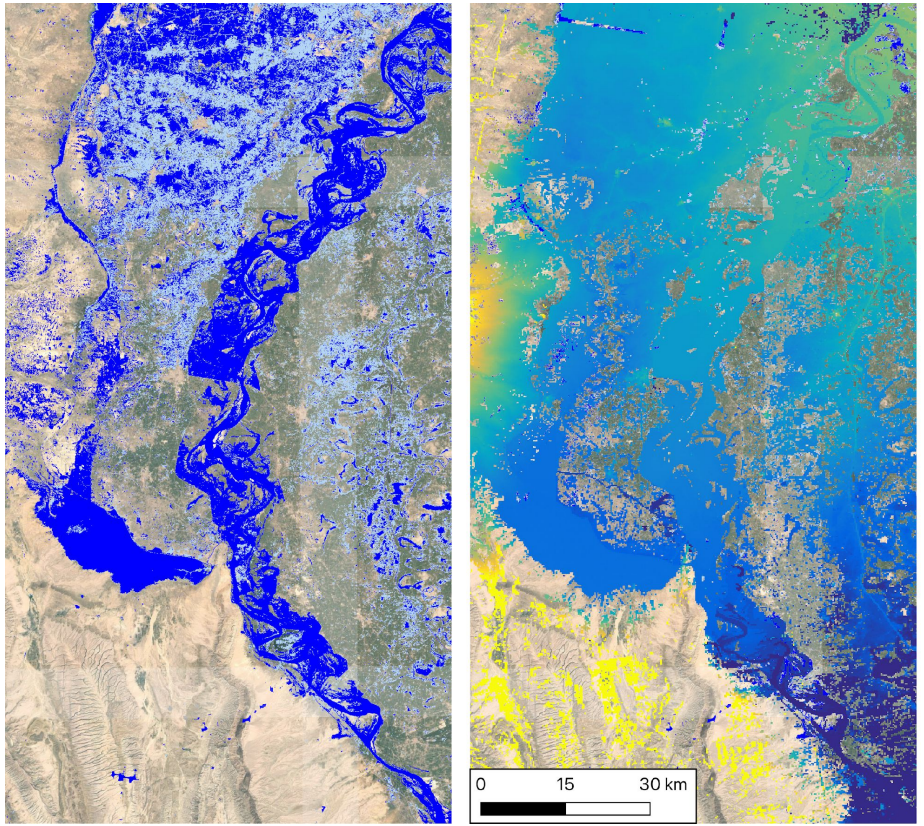
- Developed SMS & WhatsApp for hydro gauge readers in Least Developed Countries (LDC)
- SWOT EA project area – Africa (Malawi, Mozambique, Sierra Leone)
- Smartphone observations of river & rainfall levels sent to database for govt operational agencies, compare to SWOT
- Flood thresholds & equipment inventory



SWOT adds a new dimension: Pakistan 2024

National Aeronautics and Space Administration

- Left: Optical inundation extent August 1st to 31st
- Right: Water surface elevation seen by SWOT August 1st to 27th
- Water surface gradient from north to south very well captured
- Filtering extent by other masks to solve over detection
- Combining extent with elevation enables estimates of volume, damage assessments, guiding design of future flood protection infrastructure, many more



Open water
Partial water
Clouds

SWOT Raster 250m resolution
Water Surface Elevation
60
30

Challenges and barriers for adoption

National Aeronautics and Space Administration

- Product is very **complex**. The shapefile contains 125 fields! Original vision anticipated a **Basic** and **Expert** versions.
- Not quite Analysis Ready. **Simpler**, **cleaner**, **leaner** product is needed.
- Not all fields are populated. Discharge debut should happen closer to 2025's AGU.
- Cookbooks, dashboards, tools to increase data friendliness are available, with more to come.
- Product is under continuous development:
    - **Today's extensive QA before use will not be always be needed**!
- Product version D was just launched! The first version D products were expected to start appearing May 13th! Many bugs were resolved. This is the first that includes **retrospective** processing! This means, consistent product quality dating back to data collected in 2023!

Tools for accessing SWOT data - Cheatsheet

Ocean Hydro Coast

REF

Learn/Information

- PO.DAAC Dataset Mission Page and Landing Pages https://podaac.jpl.nasa.gov/SWOT?sections=data
- PO.DAAC Cookbook - SWOT Chapter https://podaac.github.io/tutorials/quarto_text/SWOT.html

Find Data - Map GUI interface

- Search & Access in *Earthdata Search* https://search.earthdata.nasa.gov/search?q=SWOT%20HR&long=-0.0703125

Access - Command line/automated scripts

- Subscriber/Downloader https://podaac.github.io/tutorials/quarto_text/SWOT.html

Access & Subset - GUI

- HiTIDE https://hitide.podaac.earthdatacloud.nasa.gov/

Access - Cloud native, Big data, ML

- in-cloud access available: example for LR ocean, example for HR hydro

Access & Explore - In development or planning phase:

- Hydrocron Timeseries API
- SWODLR On-demand Raster - *in development (Beta, Spring 2024)*
- GIS-friendly, e.g. web services (e.g. WFS) - *in development (Beta, mid-2024)*
- QGIS and ArcGIS - local: download and open - *works now*
- Exploratory Analysis in SOTO by Worldview - *early 2025*

Thank you!

Questions?

https://swot.jpl.nasa.gov/applications
https://swot.cnes.fr/en/search/site/SWOT

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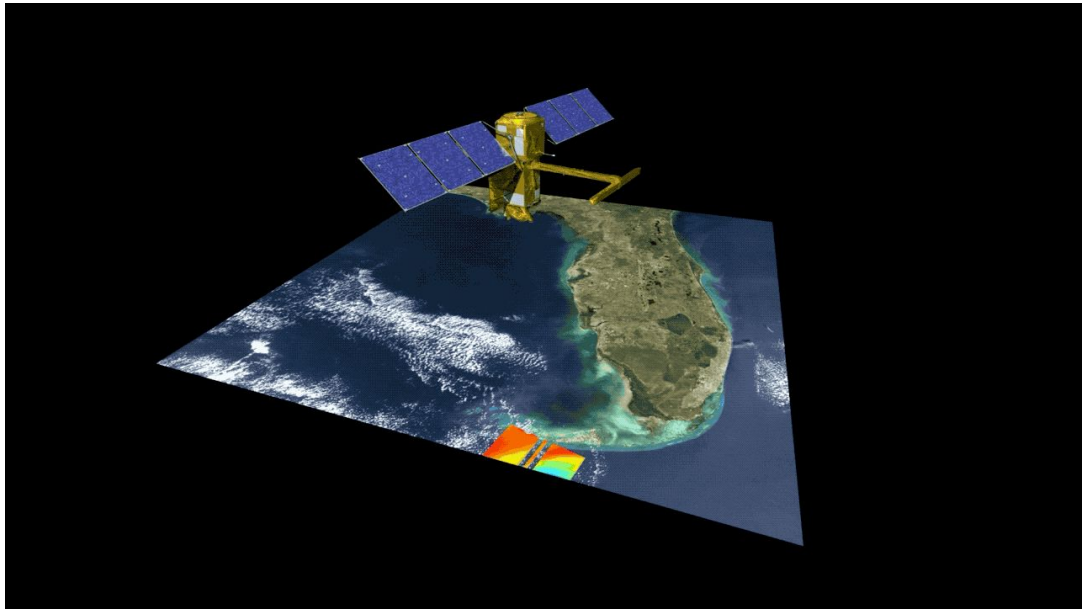


Extra Slides

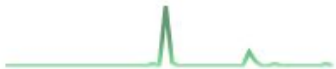
GitHub Collaboration Space

SWOT Community

This is a code space for the global SWOT mission community. We share experience, code, research and much more. Our mission is to increase the value of SWOT.

SWOT-OpenToolkit Public

Community codes for processing SWOT data. This is a community code repo, does not include the algorithms that belong to the project.



SWOT-Hydrology Public

Hydrology-relevant tutorials and resources for the Surface Water and Ocean Topography (SWOT) Mission

Jupyter Notebook ☆ 9 MIT 1 1 0 Updated last month

SWOT-Oceanography Public

Jupyter Notebook ☆ 17 BSD-3-Clause 2 1 0 Updated on Jul 16

https://github.com/SWOT-community

You're Invited!

SWOT Applications Working Group (SAWG)

Purpose

- **Build connections** and awareness among ST members that are participating in **applications work related to SWOT**
- **Spread expert knowledge** on how data should be used and communicated (**videos!**)
  - **Best practices** for quality flags and filtering the data, etc.
  - **Open science**! (synergies with open science, data, and algorithm WG)
- Working group to move **beyond understanding the data** and toward using it for **societal benefit**

What does this look like **practically**?

- Quarterly virtual gatherings to communicate what we're already doing in application spheres and brainstorming ways to synergize & spread the word
- Contact us if interested!

IIT - Bombay

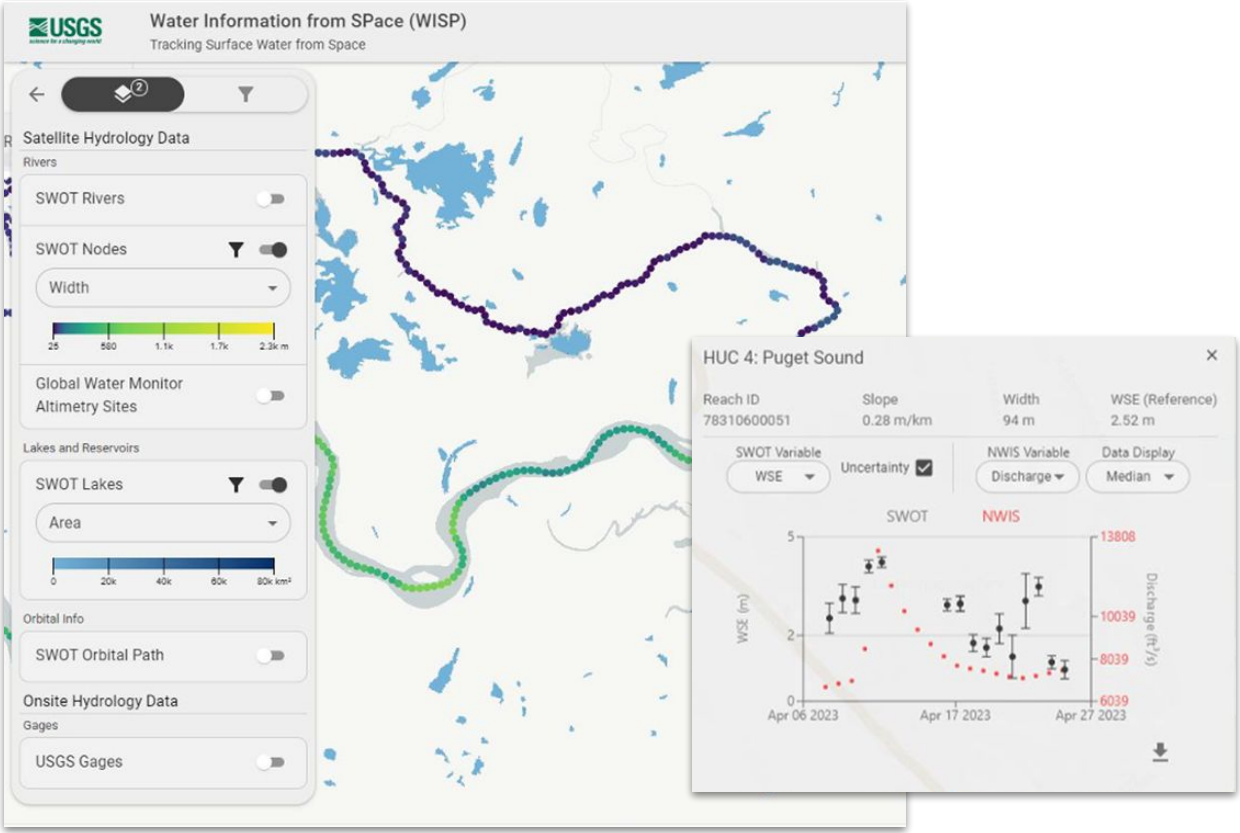
Work in Progress:

- Lake Data Inventory
- Floods on Indian Rivers through Discharge Estimation
- Extending historical gauge network over Indian river reaches
- Hydrologic model calibration over the Indian Basin
- Sentinel-1 based Inland water dynamics Mapping System (SIMS) Toolkit

Leads: Indu Jaya & Manu Soman

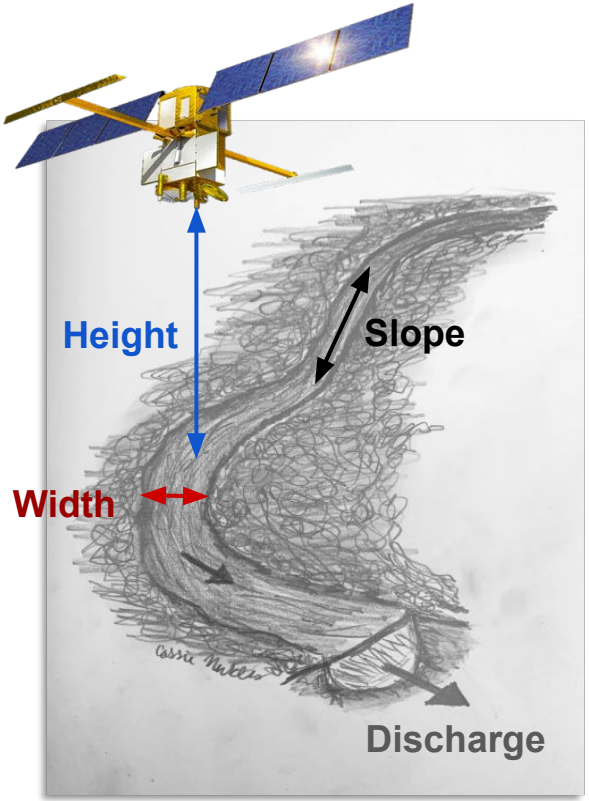
Water Information from SPace (WISP) Dashboard

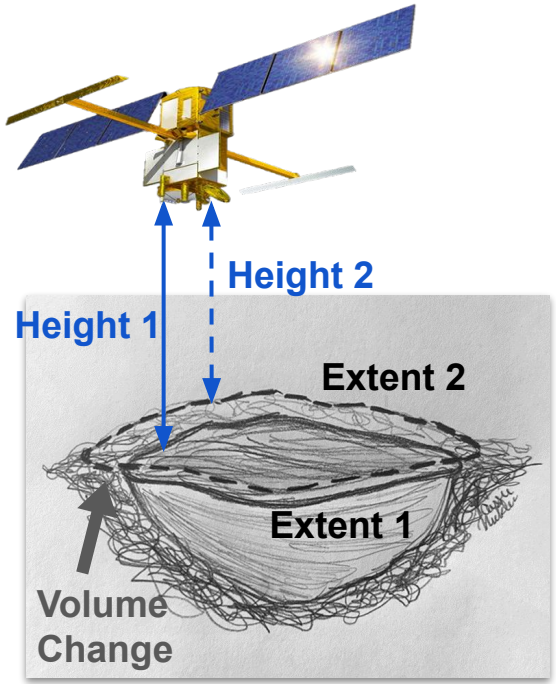
- SWOT River data timeseries alongside USGS gauge data
- Uses Hydrocron tool developed by PO.DAAC
- Approaching publicly availability



This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information."

Hydrology Measurements Simplified





Requirements:
Rivers > 100 m wide
Lakes > 250 m^2

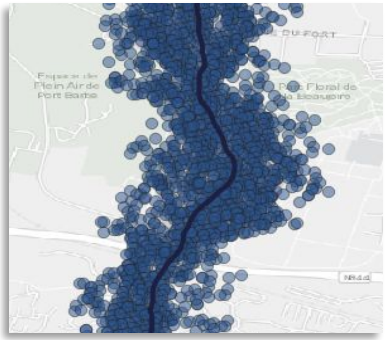
Future Derived Products:

- River flow (i.e. discharge)
- Lake/ reservoir volume change

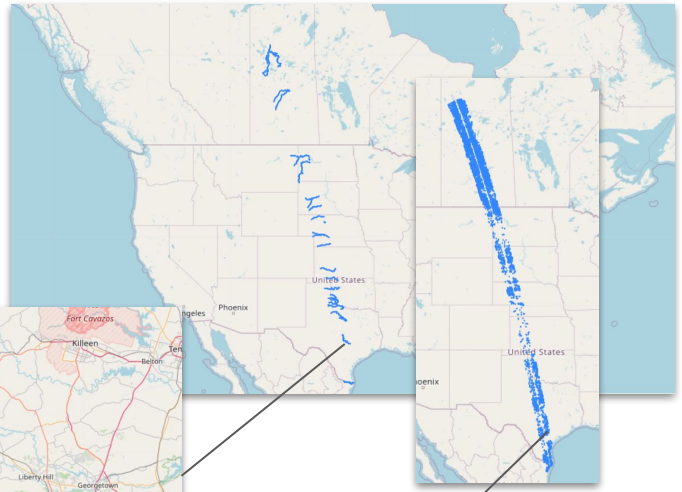
Image Credit: C. Nickles

Hydrology-Relevant Level 2 SWOT Products

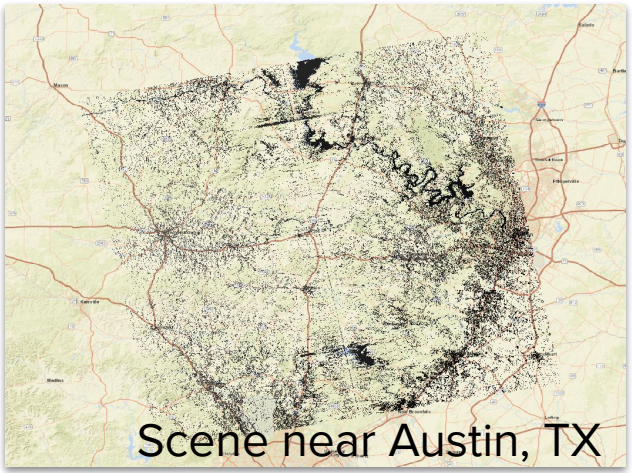
Pixel Cloud NetCDF



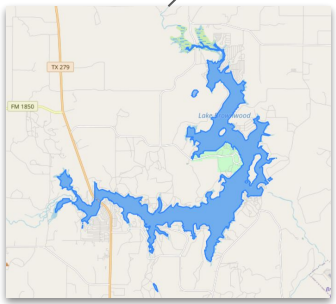
River Vector Shapefile



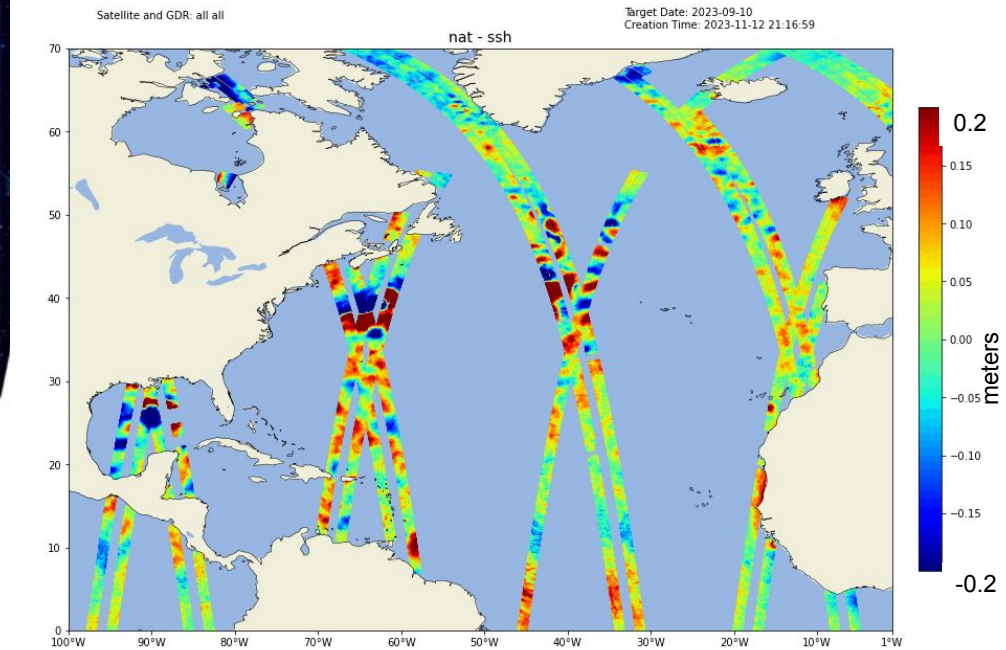
Raster NetCDF



Lake Vector Shapefile



U.S. Naval Research Laboratory

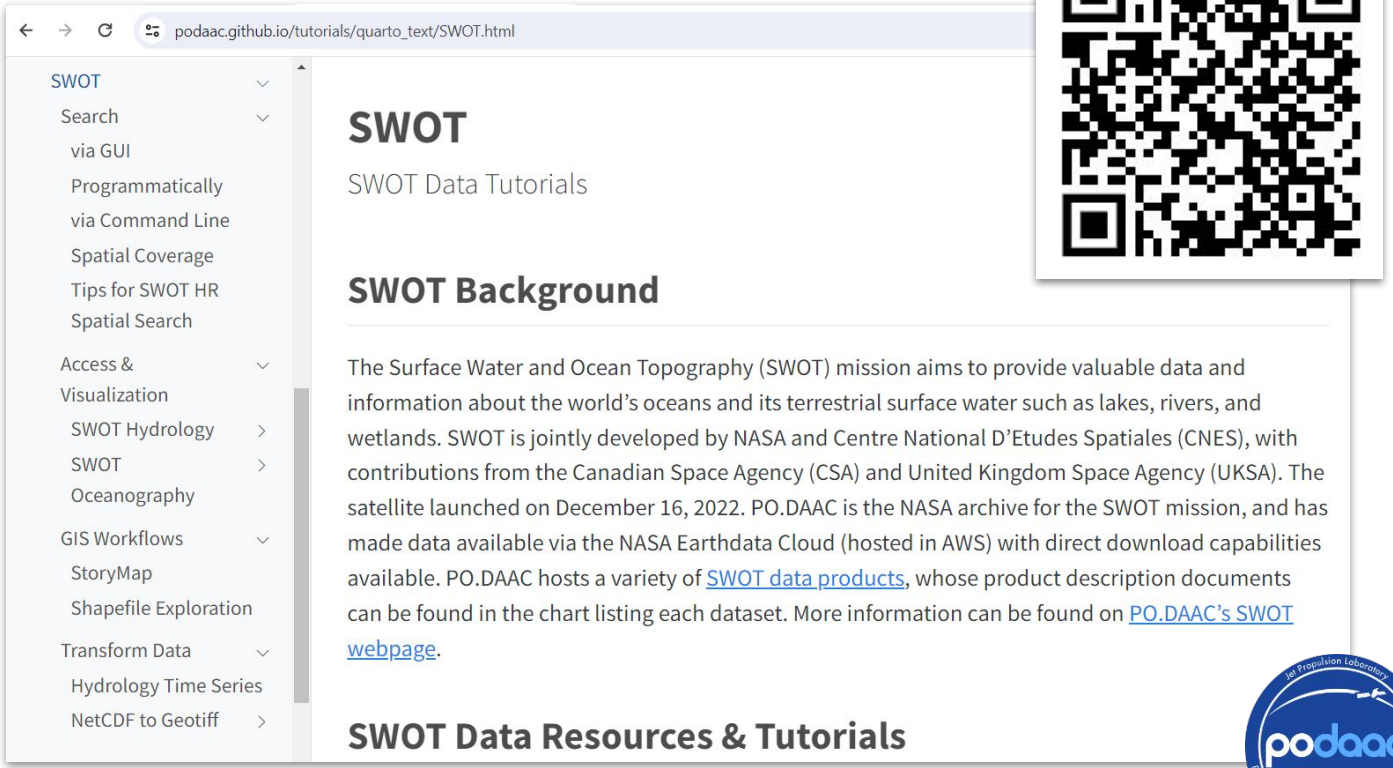


Data-assimilating ocean forecasts
Contacts: Gregg Jacobs; Joseph D'Addezio

- Apart of the reconstruction, mapping, inversion, assimilation working group
- SWOT observations resolve features at much higher resolutions than prior observing systems, and many prior assumptions of data distribution and ocean features are no longer valid. We must address these prior assumptions and the manner in which observations correct the ocean forecasts changes.
- Assimilations have been conducted using nadir altimeter data, nadir + moorings, nadir + KaRIn data
- KaRIn data adds skill above just nadir data
- Challenge: Realizing full SWOT resolution value (Super-obbing/thinning, T/S realtionships in small-scale physics)

Resources, Tips, & Tutorials!

PO.DAAC Cookbook: SWOT Chapter



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