Surface Water & Ocean Topography (SWOT) Applications

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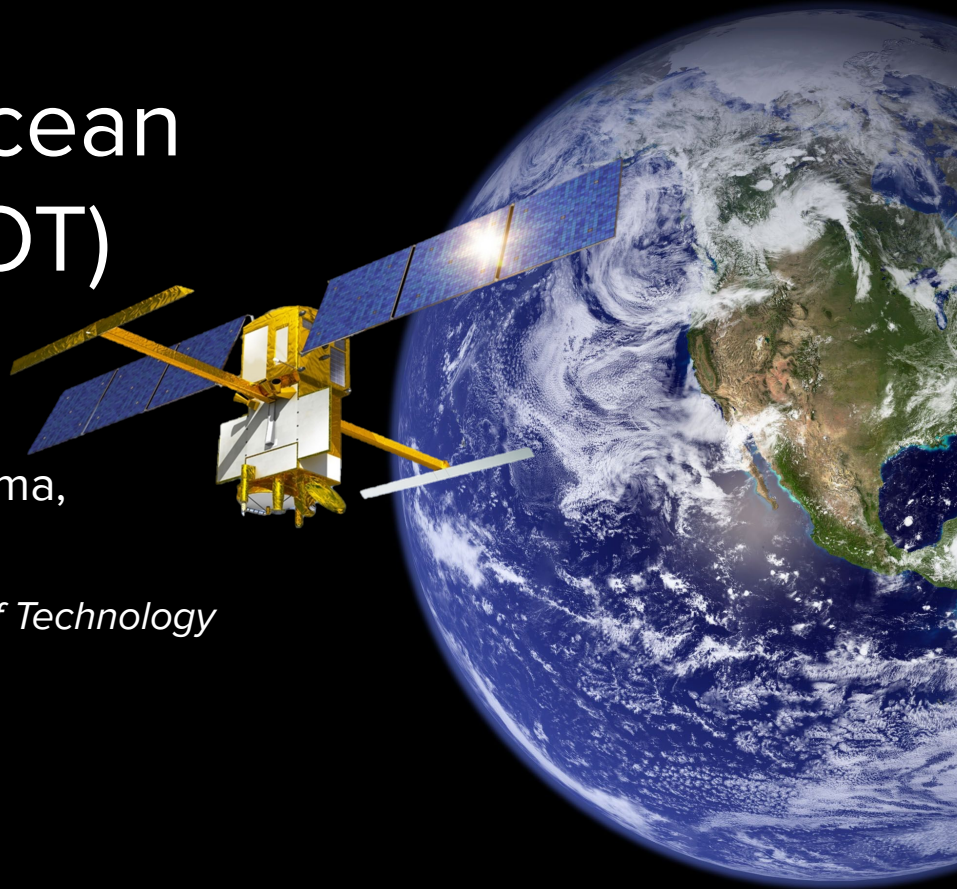
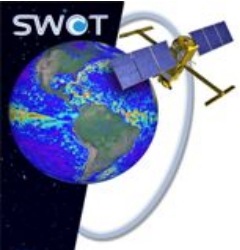
Jet Propulsion Laboratory, California Institute of Technology

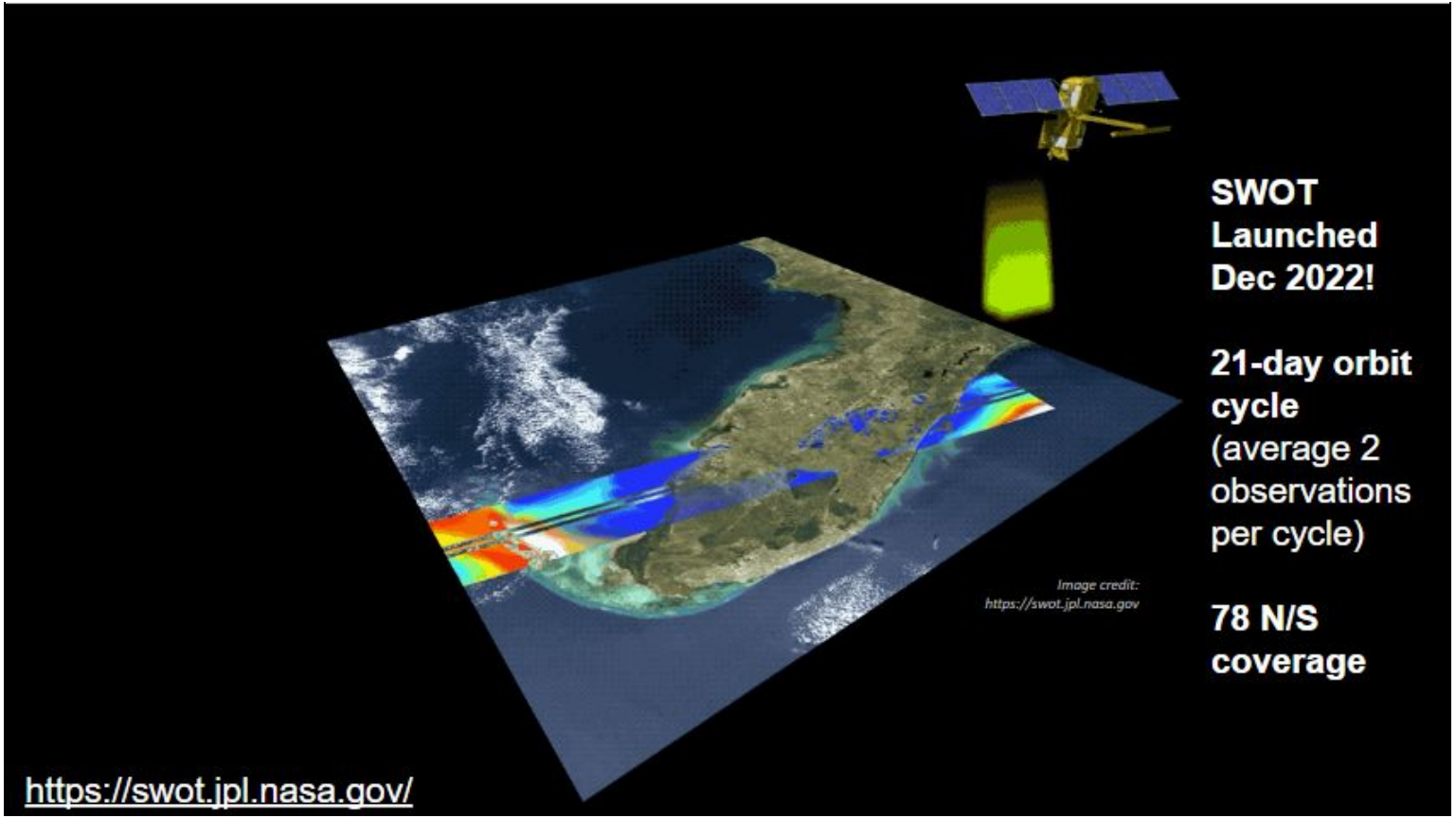
2024 Annual Meeting of the
Western Water Applications Office (WWAO)
May 1, 2024



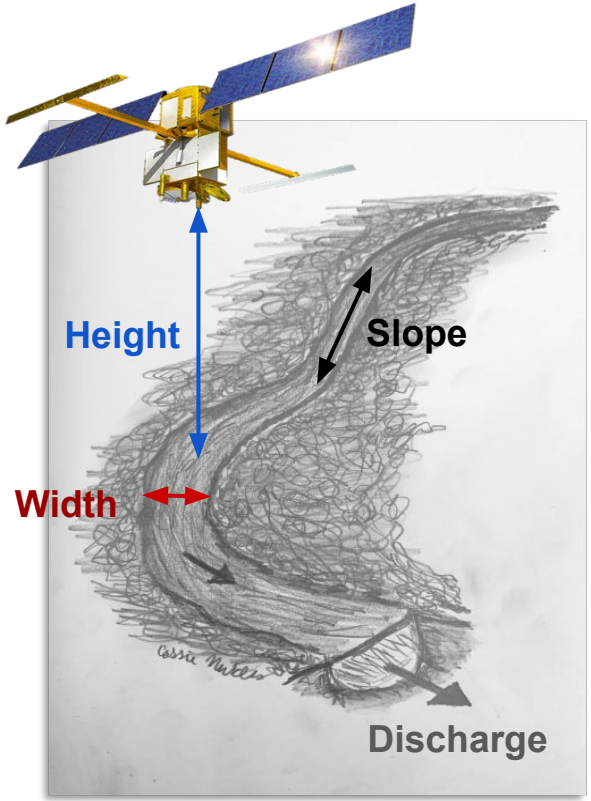
Credit: NASA Blue Marble

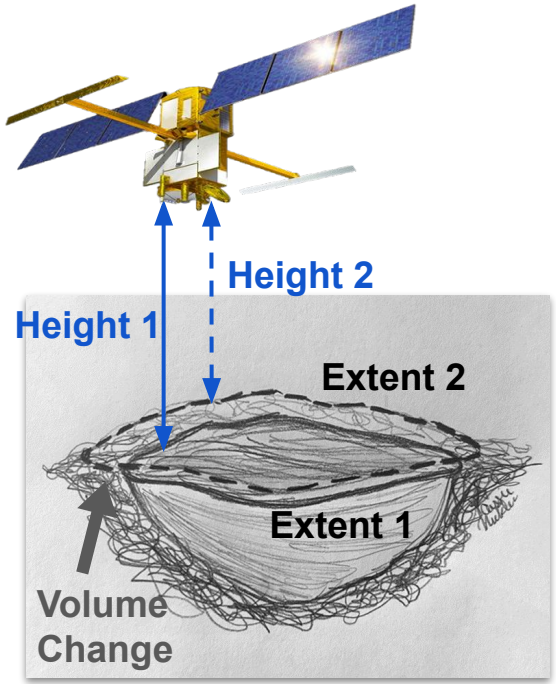


SWOT measures global **ocean** surface topography and **land surface water** extents & elevation with great accuracy using interferometry.



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

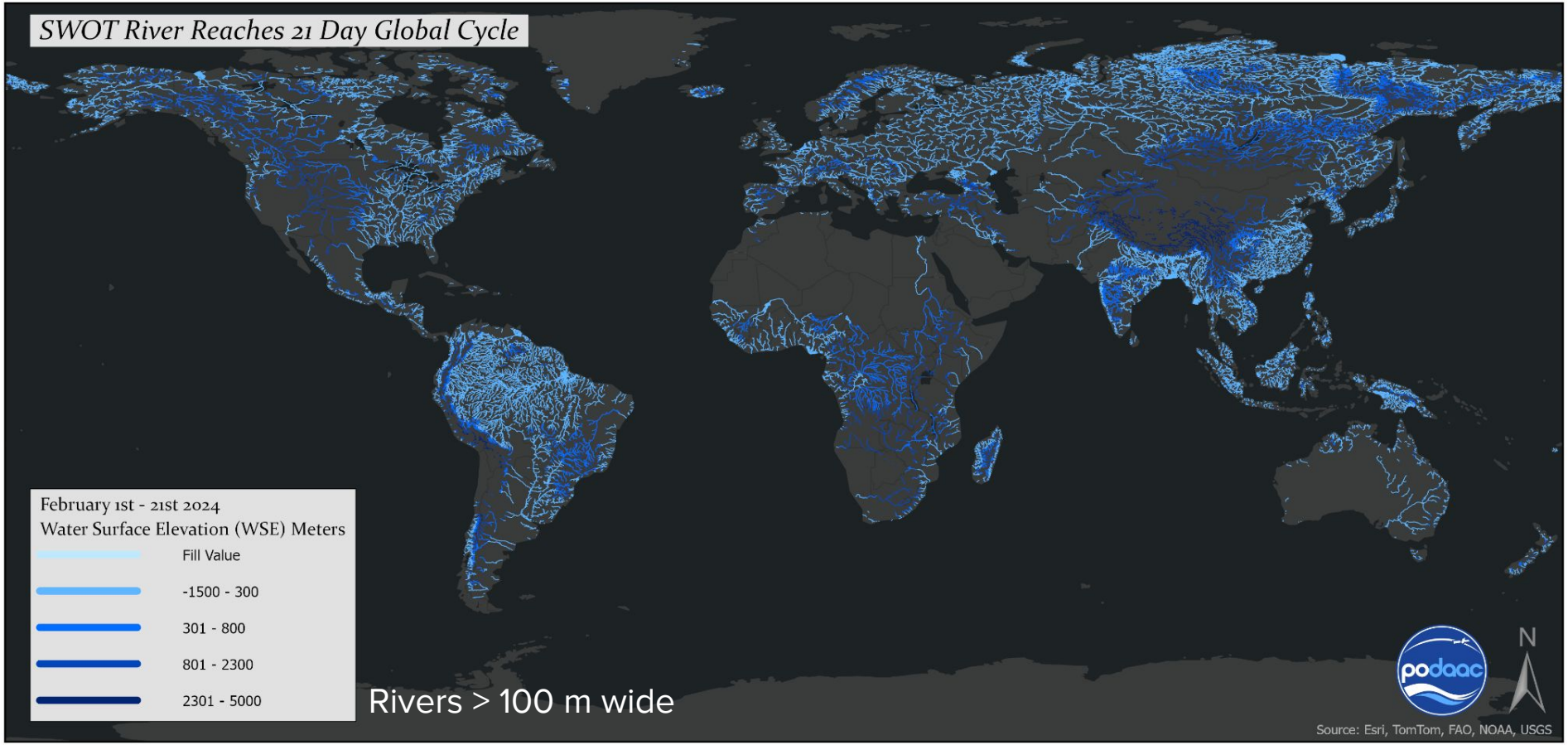
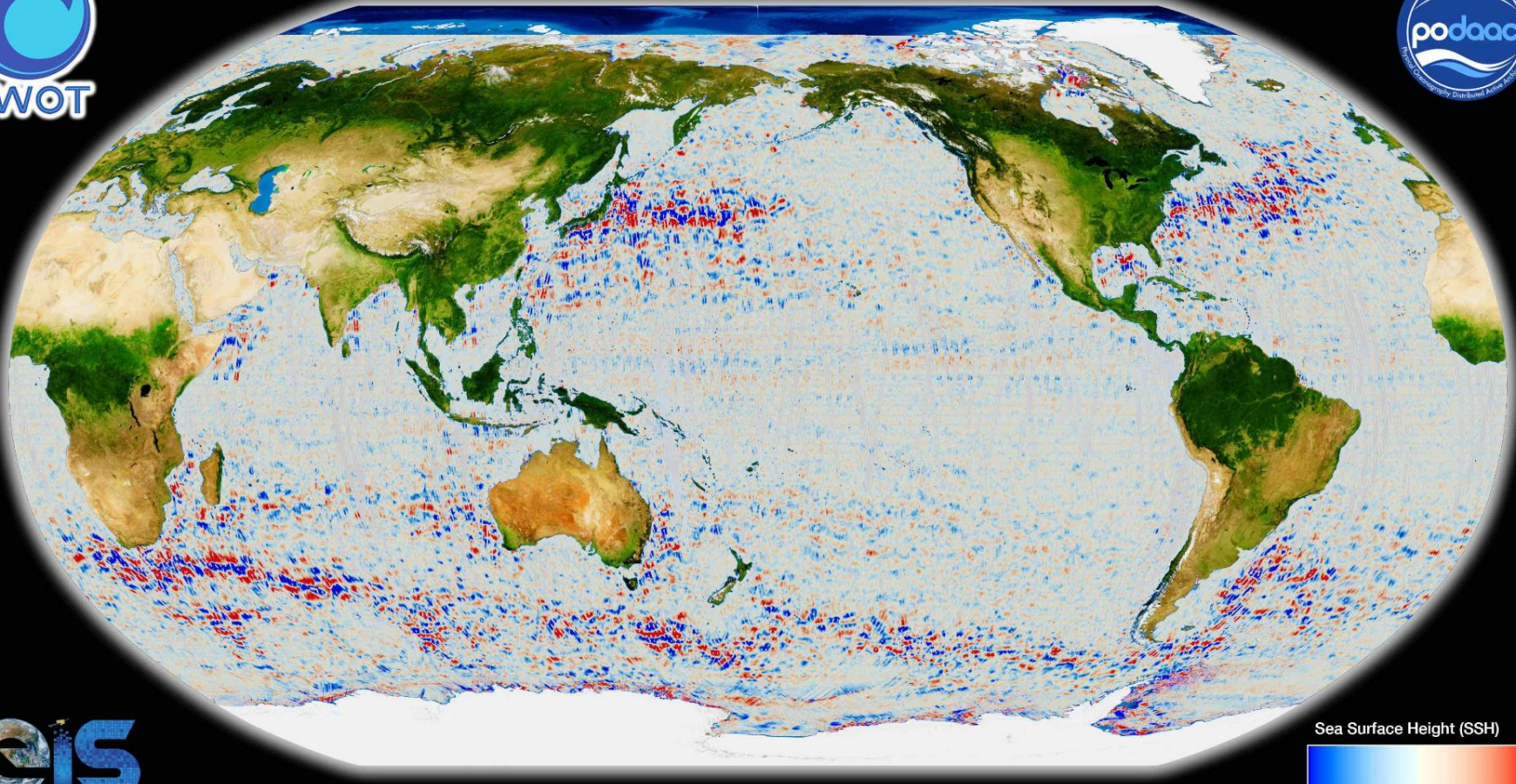


Image Credit: N. Tarpinian

Oceanography - Sea Surface Height



Resolutions below 10 km!

Data start: 2023-07-26T14:12:39
end: 2023-08-16T14:17:18

SWOT Applications Areas

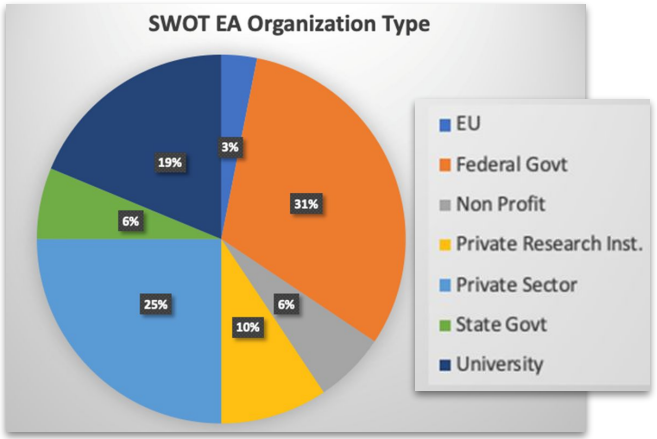
https://swot.jpl.nasa.gov/applications/applications-areas/

SWOT Early Adopters Program

- SWOT Applications Program since 2012
- 40 SWOT Early Adopters
- U.S. and International leadership – NASA/CNES

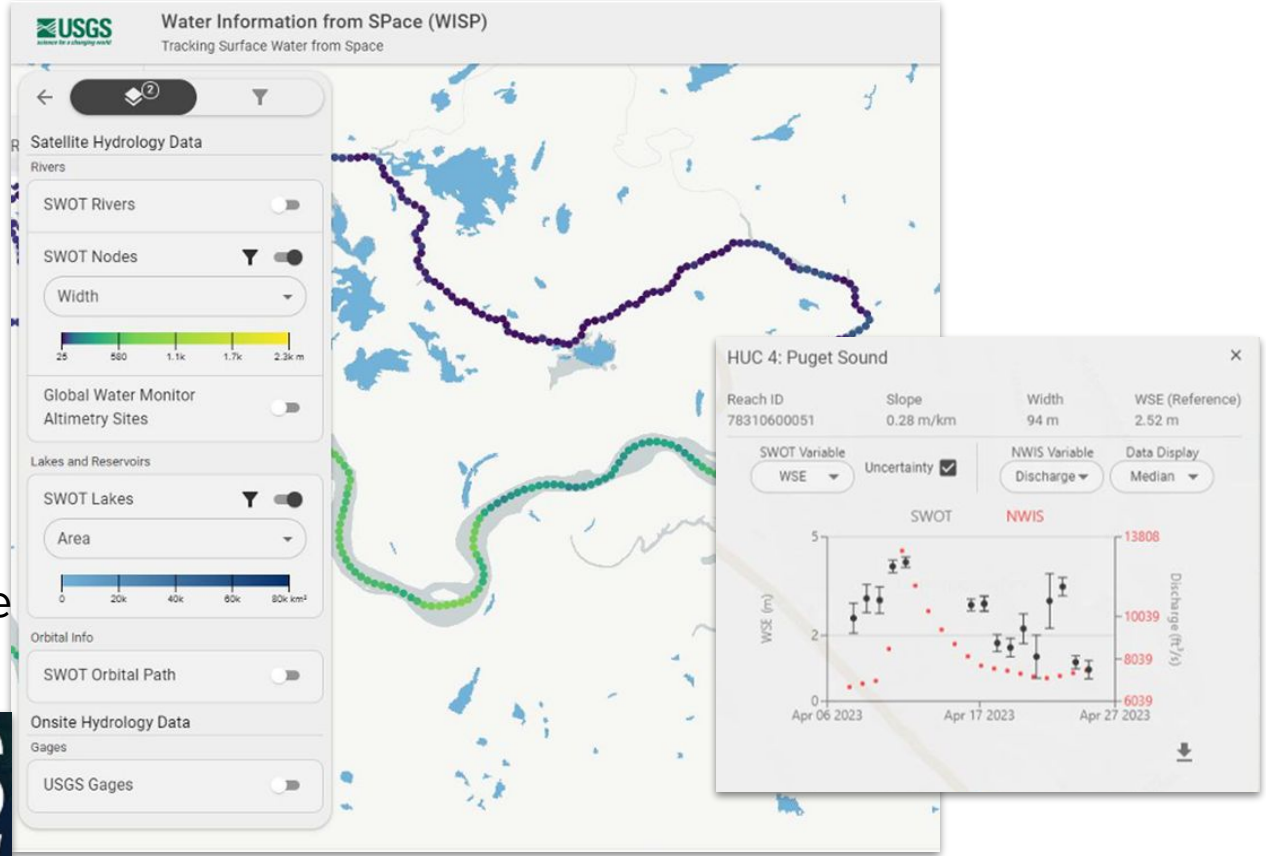
https://swot.jpl.nasa.gov/applications

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.*



Water Information from SPace (WISP) Dashboard

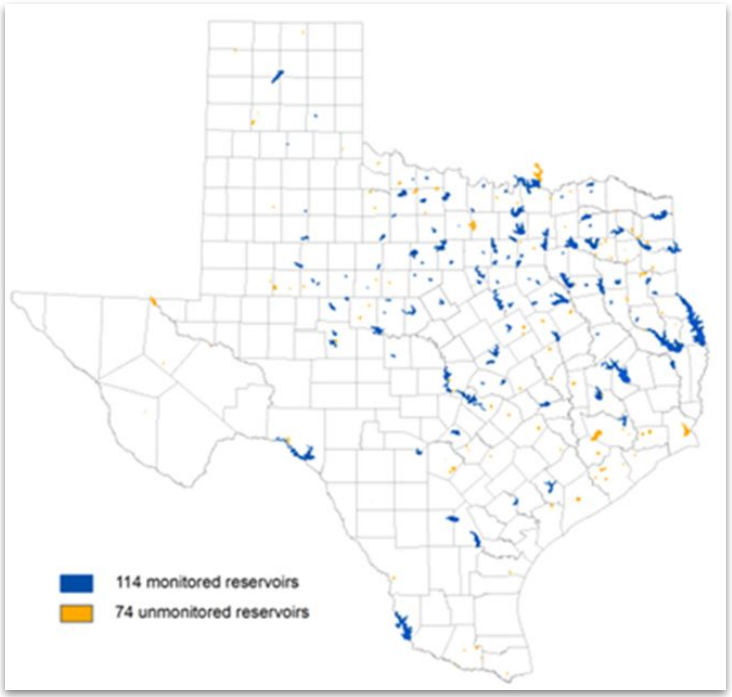
- SWOT River data timeseries alongside USGS gauge data
- Uses Hydrocron tool developed by PO.DAAC
- Not yet publicly available, but in the works!



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.



IIT - Bombay

Work in Progress:

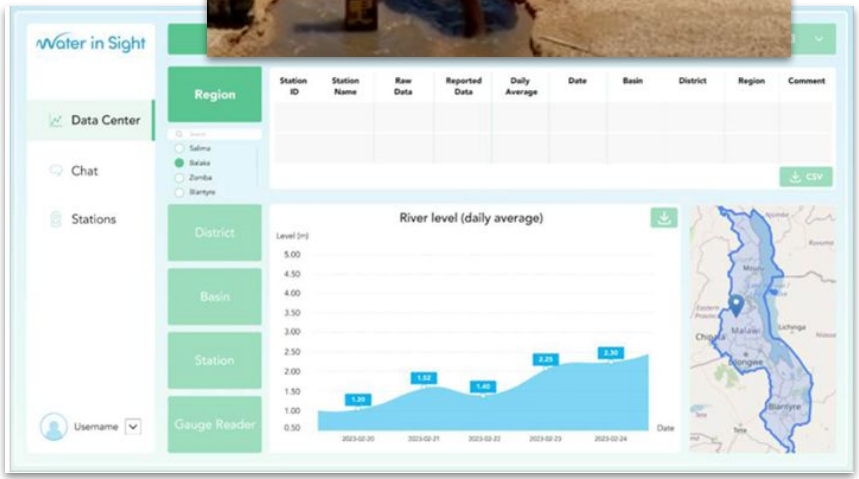
- Lake Data Inventory
- Floods on Indian Rivers through Discharge Estimation
- Extending historical gauge network over Indian river reaches
- Hydrologic model calibration over the Indian Basin
- Sentinel-1 based Inland water dynamics Mapping System (SIMS) Toolkit

Leads: Indu Jaya & Manu Soman

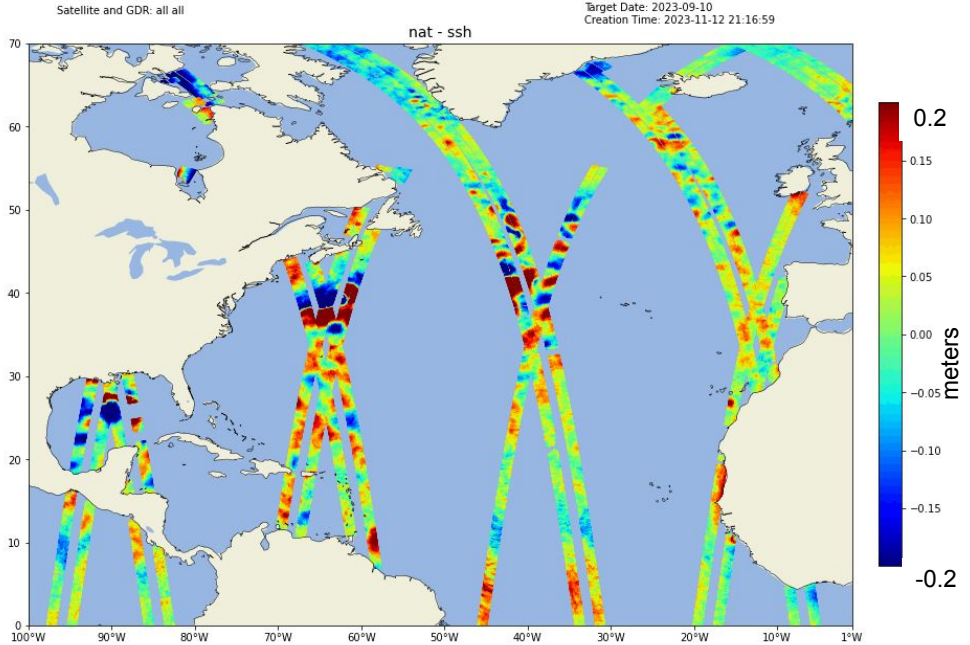
Water in Sight

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



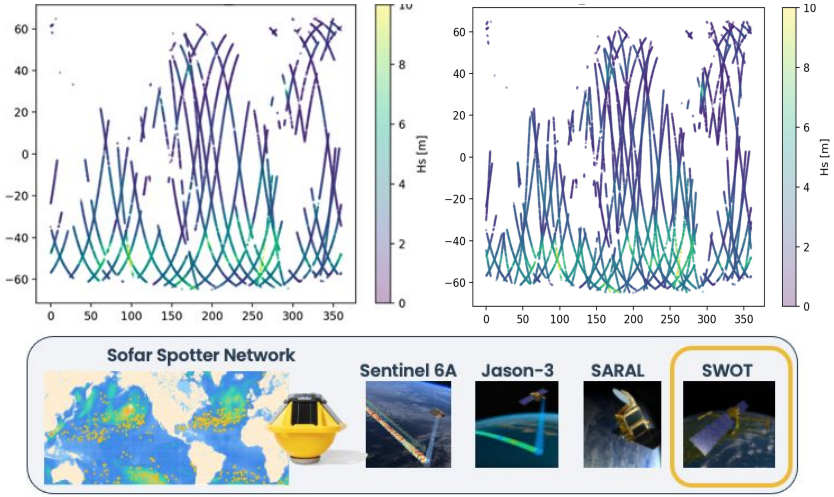
SWOT Ocean Early Adopters



- **SWOT Ocean swath data and nadir data already integrated!**

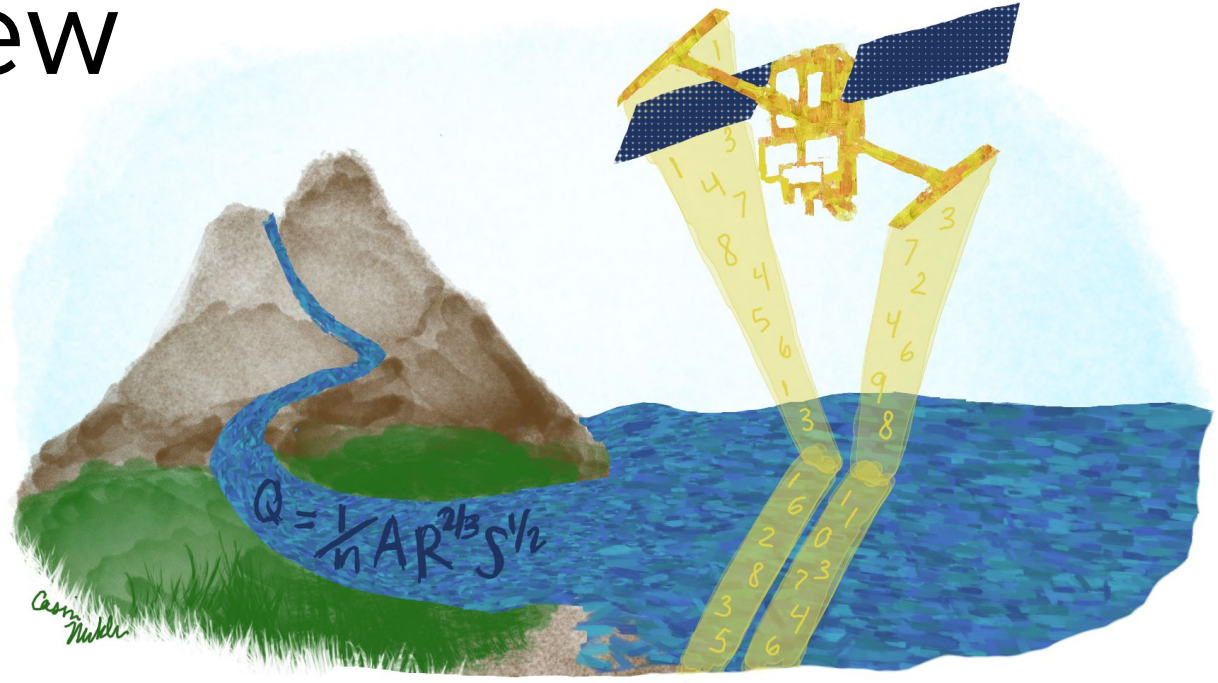
24 hrs Altimeter Data
11,962 obs

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**

Data Products Overview



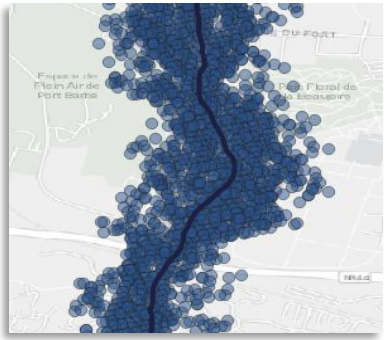
Hydrology-Relevant Level 2 SWOT Products

Water Mask Pixel Cloud NetCDF	**L2_HR_PIXC**
Pixel Cloud Vector Attribute NetCDF	**L2_HR_PIXCVec**
Raster NetCDF	**L2_HR_Raster**
River Vector Shapefile	**L2_HR_RiverSP**
Lake Vector Shapefile	**L2_HR_LakeSP**
Cycle Average River Vector Shapefile	**L2_HR_RiverAvg**
Cycle Average Lake Vector Shapefile	**L2_HR_LakeAvg**
Floodplain Digital Elevation Model	**L2_HR_FPDEM***

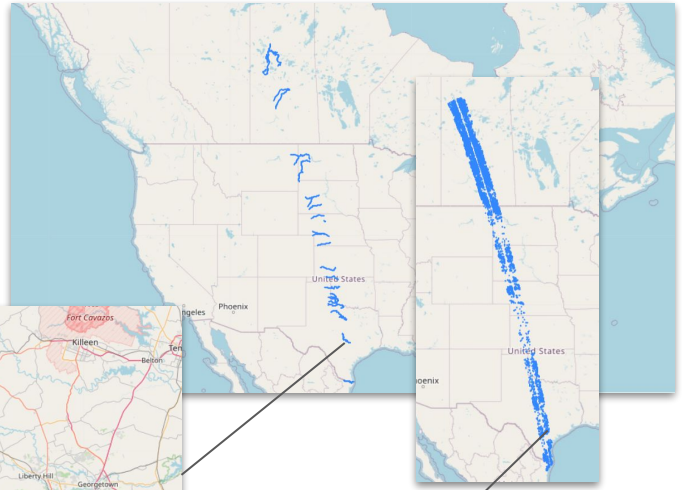
* available ~2 years after launch

Hydrology-Relevant Level 2 SWOT Products

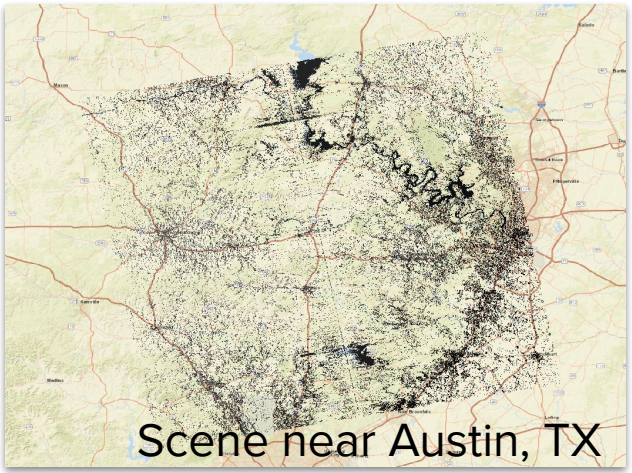
Pixel Cloud NetCDF



River Vector Shapefile

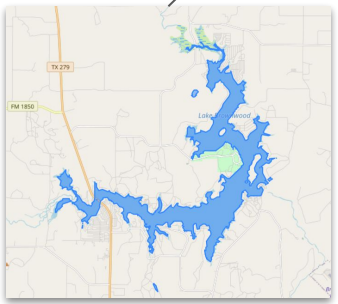


Raster NetCDF



Scene near Austin, TX

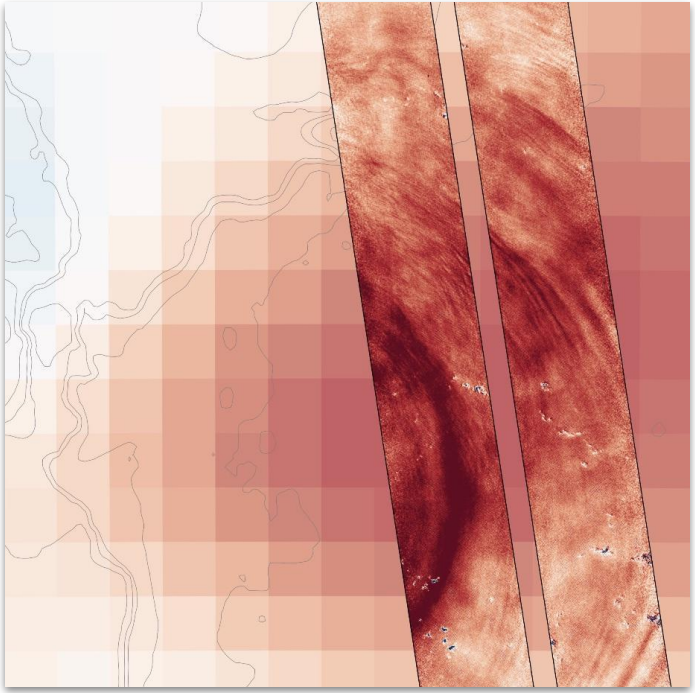
Lake Vector Shapefile



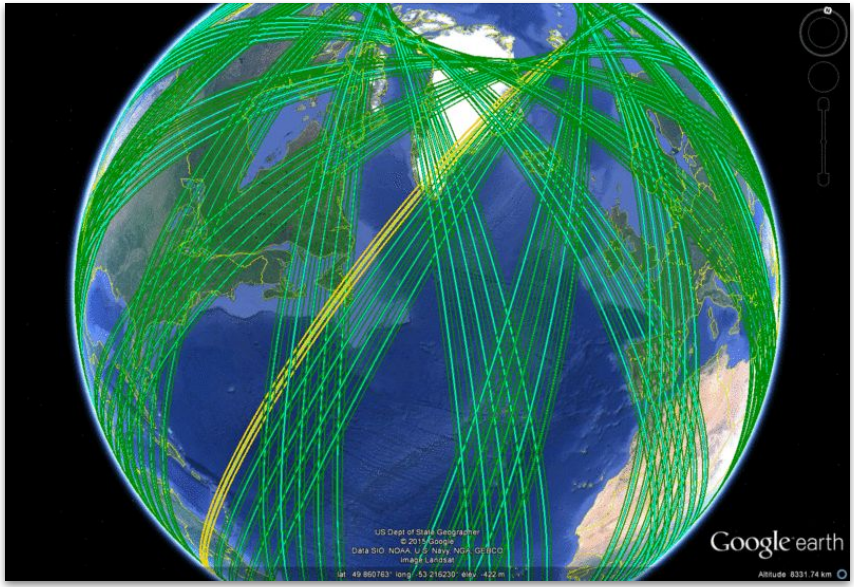
Oceanography-Relevant SWOT Products

• Operational Radiometer NetCDF	**L2_RAD_OGDR**
• Interim Radiometer NetCDF	**L2_RAD_IGDR**
• Radiometer NetCDF	**L2_RAD_GDR**
• Operational Nadir Altimetry NetCDF	**L2_NALT_OGDR**
• Interim Nadir Altimetry NetCDF	**L2_NALT_IGDR**
• Nadir Altimetry NetCDF	**L2_NALT_GDR**
• KaRIn Sea Surface Height NetCDF	**L2_LR_SSH**

Oceanography-Relevant SWOT Products



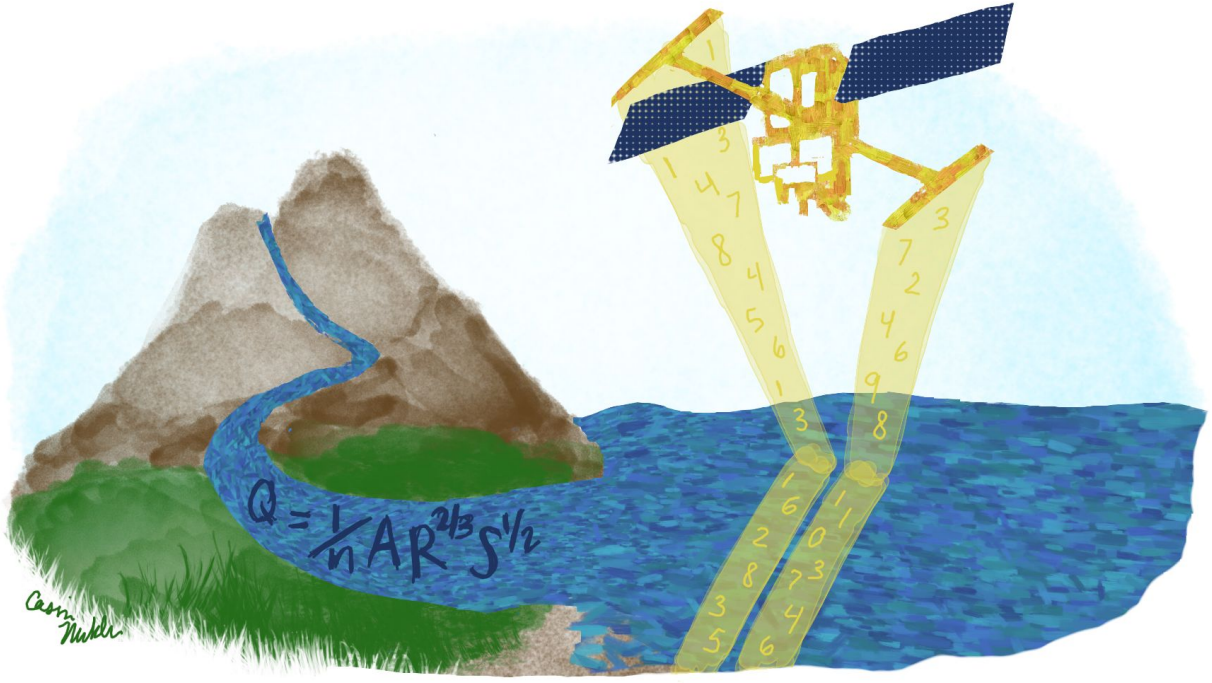
KaRIn Sea Surface Height



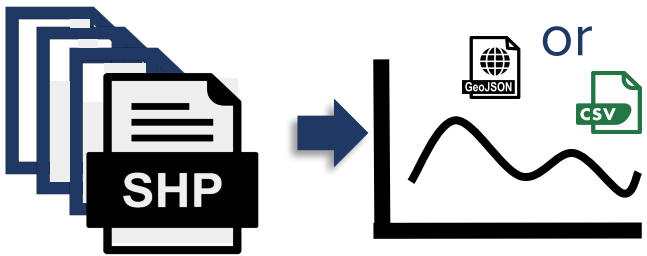
Radiometer & Nadir products

credit: M. Archer

Tools & Resources



Hydrocron Timeseries API

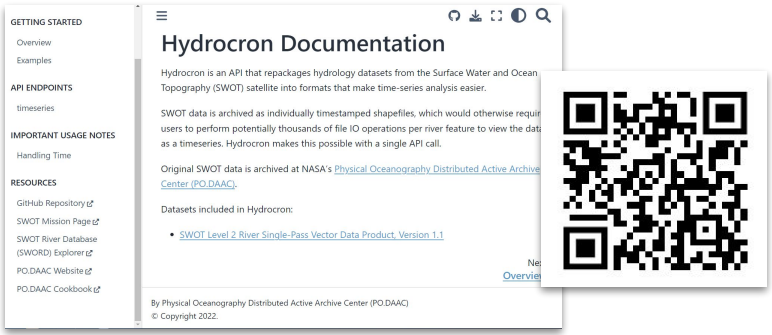


podaac/hydrocron

Input: Water feature ID (SWOT River reach, node)
Future: lake ID, or geospatial bounding box

Output: timeseries in CSV or GeoJSON

Example Applications: populate time series in a web dashboard for a river reach, ingest time series into models, faster analysis in programmatic workflows



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.

Python 29 Apache-2.0 7 0 1 Updated 2 weeks ago

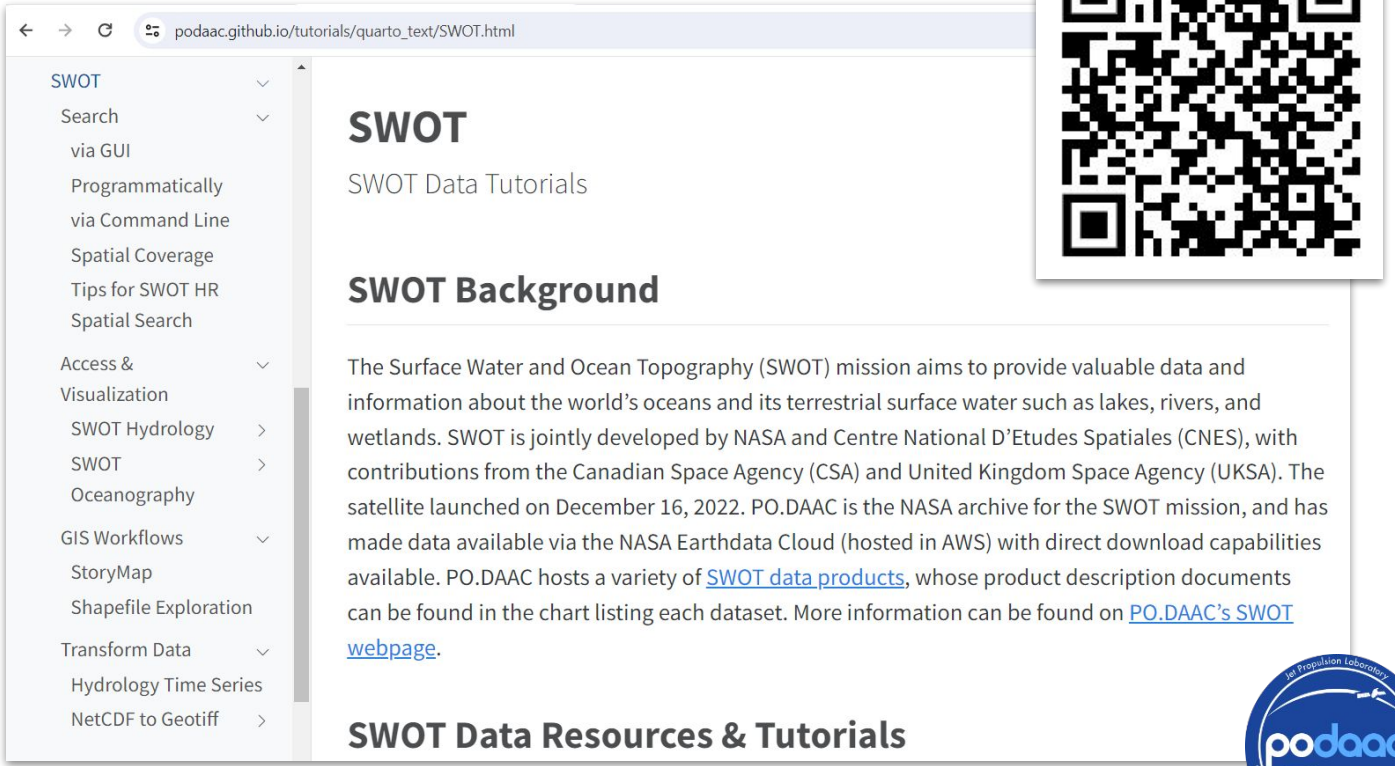
CNES-AVISO Public

Jupyter Notebook 7 BSD-3-Clause 1 0 0
Updated 3 weeks ago

https://github.com/SWOT-community

Resources, Tips, & Tutorials!

PO.DAAC Cookbook: SWOT Chapter



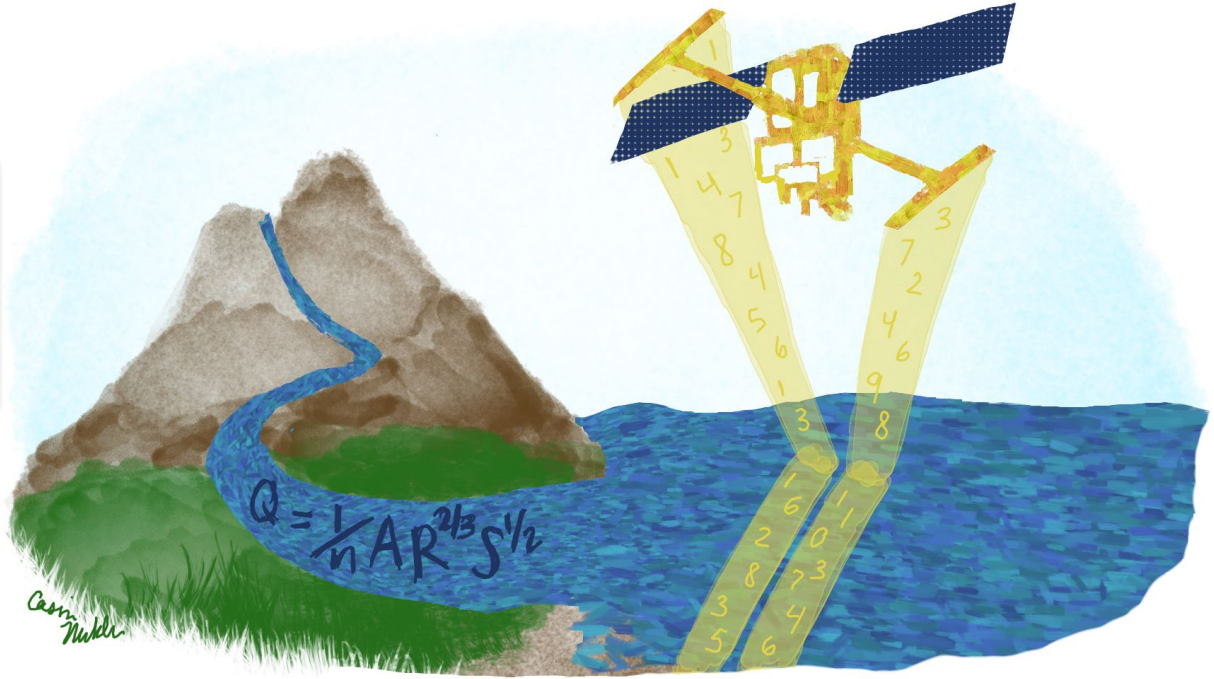
https://podaac.github.io/tutorials/quarto_text/SWOT.html

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

Thank you!

Questions?

Contact:
cassandra.l.nickles@jpl.nasa.gov
matthew.g.bonnema@jpl.nasa.gov
angelica.rodriguez@jpl.nasa.gov



Extra Slides

Tools for accessing SWOT data - Cheatsheet

Ocean Hydro Coast

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/

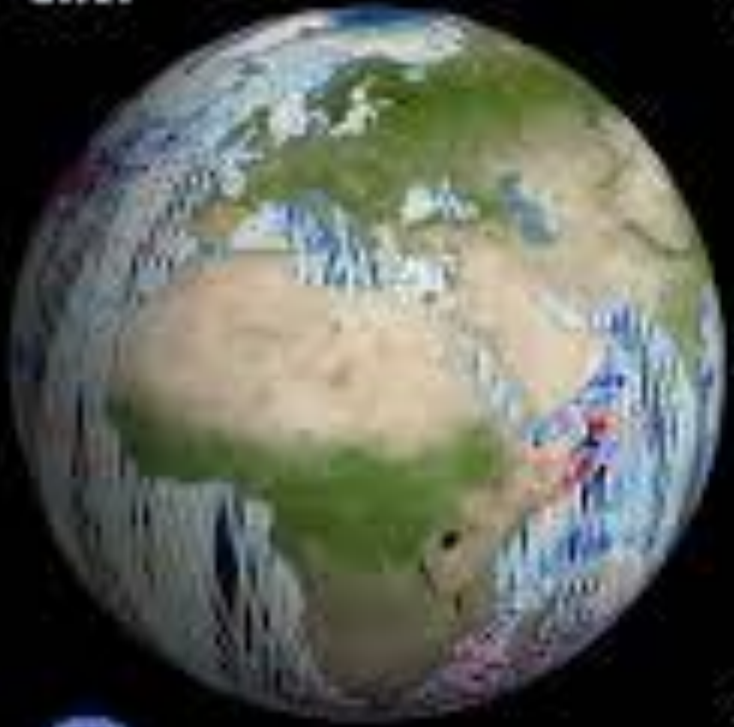
Access - Cloud native, Big data, ML

- 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*

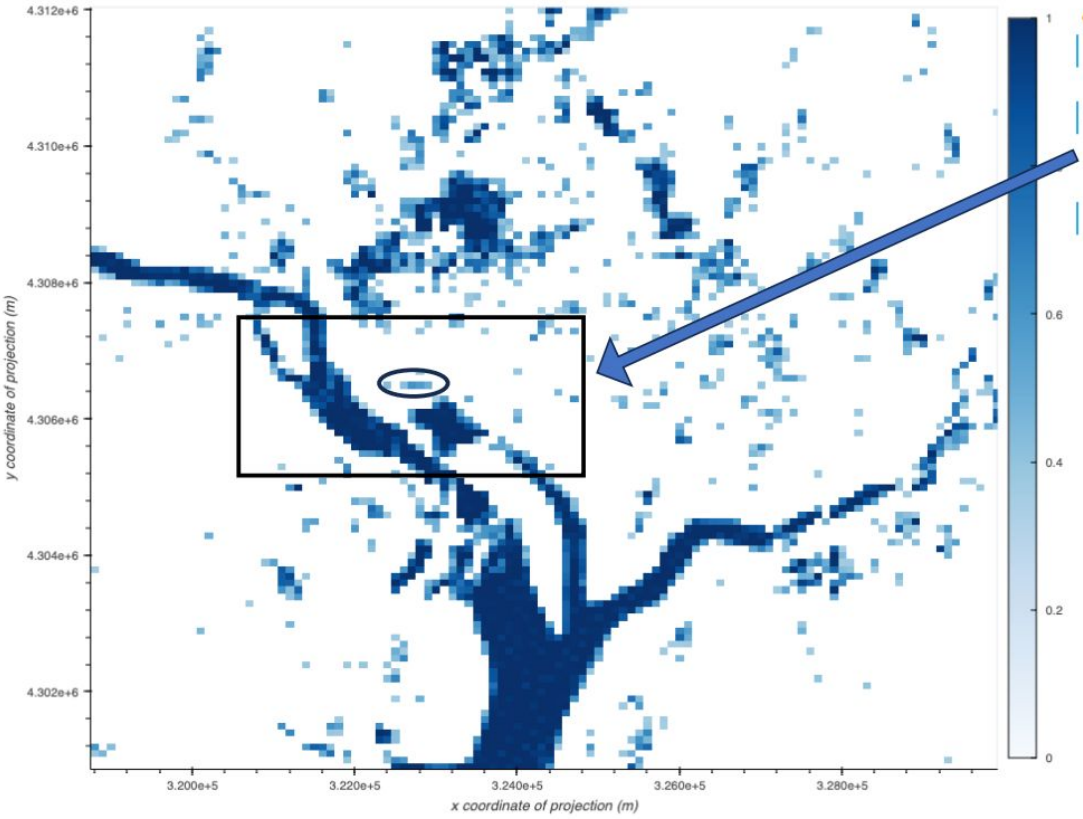
Sea surface height anomaly (SSHA) from SWOT Ka-band Radar Interferometer (KaRIn) over one full 21-day cycle
Same field, difference perspectives



2023-08-24 10:43

Pass: 374

DC Reflective Pool

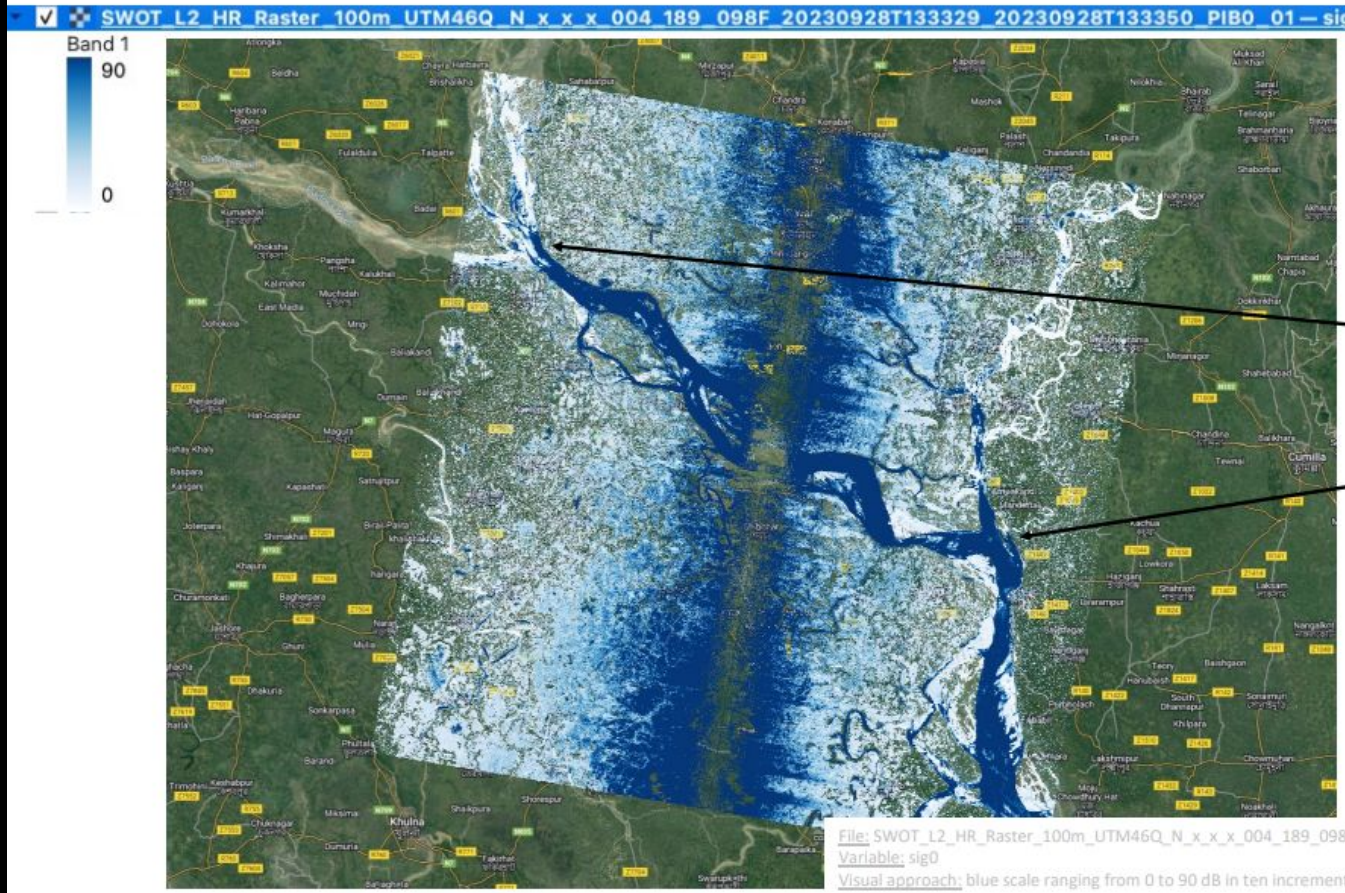


Cycle: 007
Pass: 091
Scene: 112F
Date: 26 Nov 2023

Approach: Blue scale ranging of "water fraction" from 0 to 1

Credit: C. David, J. Wade, A. Cerbelaud, M. Tom

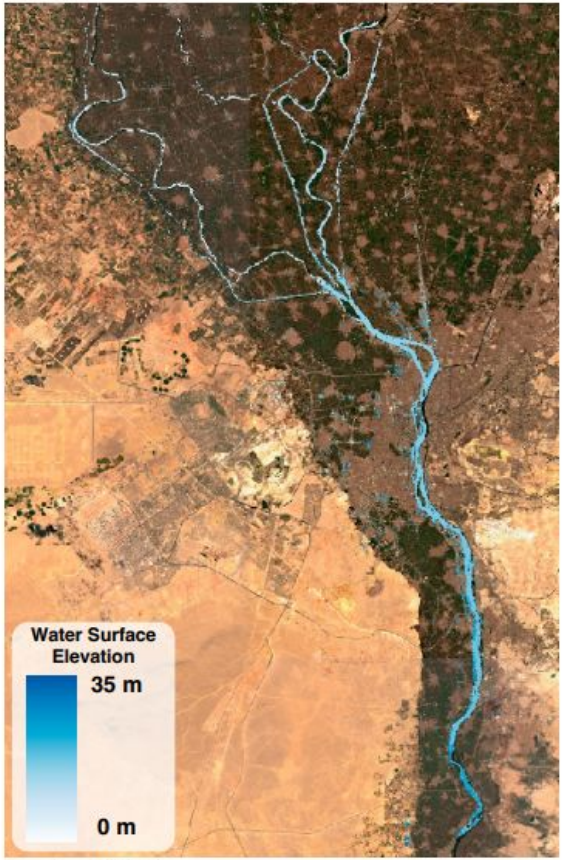
Confluences of Ganges, Brahmaputra, and Meghna rivers in Bangladesh



These are South Asia's biggest rivers and together flow to the Bay of Bengal. Flooding is guaranteed every year with the monsoon season

Credit: C. David, J. Wade, A. Cerbelaud, M. Tom

SWOT Captures the Nile River Flowing Through Cairo, Egypt



File Information:
- **Cycle:** 001
- **Pass:** 318
- **Scene:** 051F
- **Date:** 08-01-2023
- **Time:** T133912 – T133933

Processing Approach:
Show Water Surface Elevation where:
[Dark_frac > 0 *OR* Sigma0 > 100]
AND
[Cross_track > 23,000]

Credit: C. David, J. Wade, A. Cerbelaud, M. Tom

March 6, 2024 SWOT Data Release, v2.0

https://podaac.jpl.nasa.gov/announcements/2024-03-06-SWOT-KaRIn-Science-Data-Products-Release

Forward stream and reprocessed SWOT KaRIn Science Data Products Release:

Encourage users to review the **Release Note** closely to familiarize themselves with the details of the release.

*Tip: **these** are data product shortnames!*

Section 6: Known Features and Issues - Helpful!

This release includes:

1. **Reprocessed global low rate (LR)** ocean products spanning **Nov 23, 2023 – Jan 25, 2024 and forward processing** from the science phase (21-day orbit).
2. **Forward processing reprocessed global high rate (HR)** hydrology products from **Jan 25, 2024 onward** from the science phase (21-day orbit).
3. Reprocessing of science data products from March 30, 2023 to January 25, 2024 is ongoing and will be released as they become available.

The LR products include:

1. Level 1B KaRIn Low Rate Interferogram Data Product (**SWOT_L1B_LR_INTF_2.0** (DOI: 10.5067/SWOT-INTF-2.0))
2. Level 2 KaRIn Low Rate Sea Surface Height Data Product (**SWOT_L2_LR_SSH_2.0** (DOI: 10.5067/SWOT-SSH-2.0))

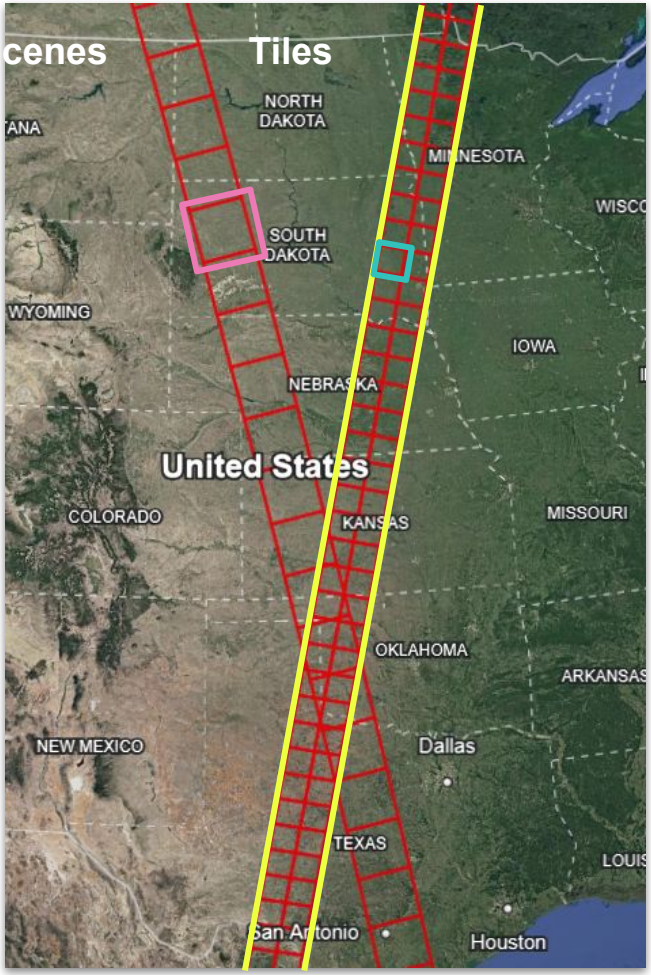
The HR products include:

1. Level 1B KaRIn High Rate Single Look Complex Product (**SWOT_L1B_HR_SLC_2.0** (DOI: 10.5067/SWOT-SLC-2.0))
2. Level 2 KaRIn High Rate Water Mask Pixel Cloud Product (**SWOT_L2_HR_PIXC_2.0** (DOI: 10.5067/SWOT-PIXC-2.0))
3. Level 2 KaRIn High Rate Water Mask Pixel Auxiliary Cloud Product (**SWOT_L2_HR_PIXCVec_2.0** (DOI: 10.5067/SWOT-PIXCVEC-2.0))
4. Level 2 KaRIn High Rate River Single Pass Vector Product (**SWOT_L2_HR_RiverSP_2.0** (DOI: 10.5067/SWOT-RIVERSP-2.0))
5. Level 2 KaRIn High Rate Lake Single Pass Vector Product (**SWOT_L2_HR_LakeSP_2.0** (DOI: 10.5067/SWOT-LAKESP-2.0))
6. Level 2 KaRIn High Rate Raster Product (**SWOT_L2_HR_Raster_2.0** (DOI: 10.5067/SWOT-RASTER-2.0))
1. Level 2 KaRIn High Rate River Average Vector Product (**SWOT_L2_HR_RiverAvg_2.0** (DOI: 10.5067/SWOT-RIVERAVG-2.0))
2. Level 2 KaRIn High Rate Lake Average Vector Product (**SWOT_L2_HR_LakeAvg_2.0** (DOI: 10.5067/SWOT-LAKEAVG-2.0))
3. Level 2 KaRIn High Rate Floodplain DEM Product* (**SWOT_L2_HR_FPDEM_2.0**
*available after one year of science orbit products released

Spatial Extent Formats

- Swath - half-globe orbit track
- Tile - 64x64 km^2; half swath width
- Scene - 128x128 km^2, georeferenced; full swath width

scene number x 2 = tile number



Tip: more here
https://podaac.github.io/tutorials/quarto_text/SWOT.html#tips-for-swot-hr-spatial-search

File Naming Conventions!

Product (organized by...)	File Naming Convention	Notes
L2_HR_RiverSP L2_HR_LakeSP (continent-level swaths)	PPP_CC	PPP = pass number (valid range: 001-584) CC = continent code (options listed below) AF - Africa EU - Europe and Middle East SI - Siberia AS - Central and Southeast Asia AU - Australia and Oceania SA - South America NA - North America and Caribbean AR - North American Arctic GR - Greenland *Ex: 013_NA = pass 013, North America*
L2_HR_PIXC L2_HR_PIXCVec L1B_HR_SLC (tiles)	PPP_TTTC	PPP = pass number (valid range: 001-584) TTT = tile number (valid range: 001-308) C = character L or R corresponding to left or right swaths *Ex: 001_120R = pass 001, right swath, tile 120*
L2_HR_Raster (scenes)	PPP_SSS	PPP = pass number (valid range: 001-584) SSS = scene number (valid range: 001-154) Scenes correspond to 2 x 2 sets of tiles **scene number x 2 = tile number** *Ex: 001_060 = pass 001, scene 60, corresponding to the same location as the PIXC/PIXCVec tile example above.*

Find this info in the PO.DAAC Cookbook:
https://podaac.github.io/tutorials/quarto_text/SWOT.html#tips-for-swot-hr-spatial-search

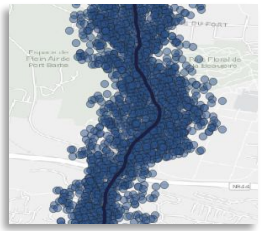
SWOT_L2_HR_PIXC (netCDF)

Description: Point cloud of water mask pixels (“pixel cloud”)

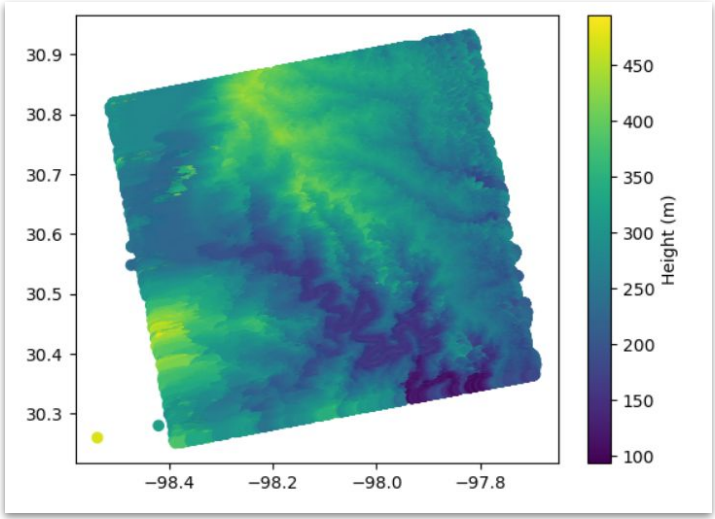
Spatial Extent Format: Tile (64x64 km^2)

Select Variables: geolocated heights, backscatter, geophysical fields, and flags

Subcollections: N/A



Example river pixels



Colorado River near Austin, TX

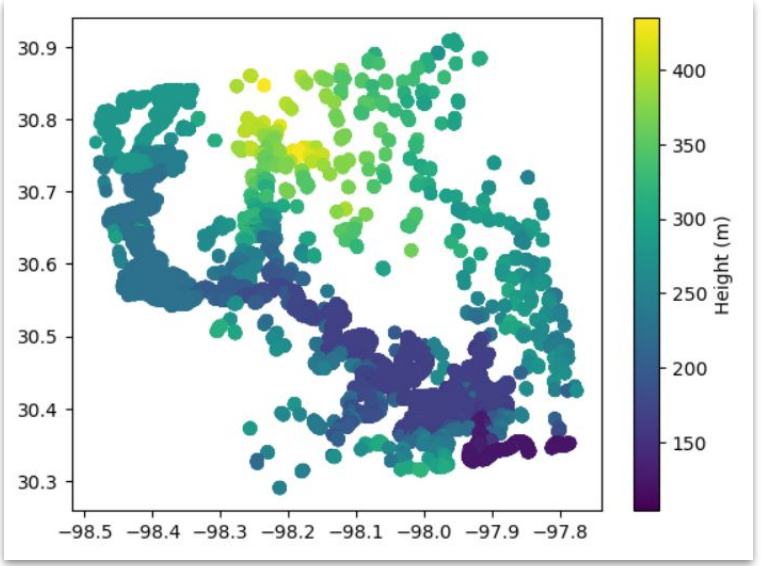
SWOT_L2_HR_PIXCVec (netCDF)

Description: Auxiliary info for pixel cloud product indicating water bodies pixels are assigned

Spatial Extent Format: Tile (64x64 km^2)

Select Variables: height-constrained pixel geolocation after reach- or lake-scale averaging.

Subcollections: N/A



Colorado River near Austin, TX

SWOT_L2_Raster (netCDF)

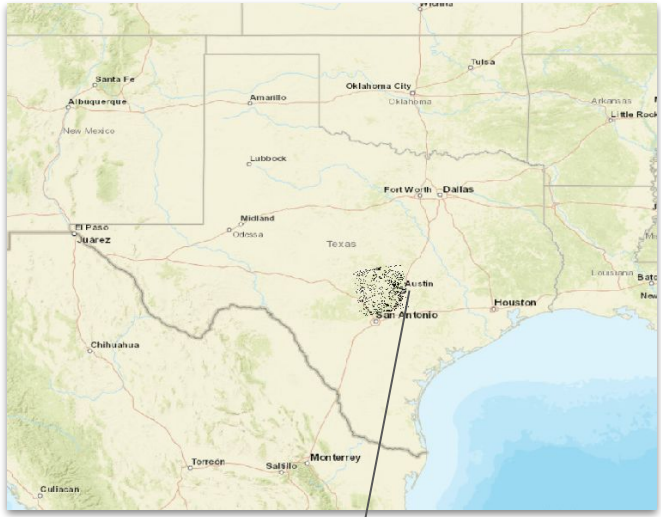
Description: Geographically fixed rasterized water surface elevation and inundation extent.

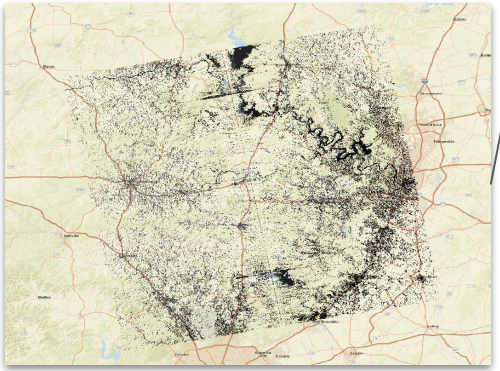
Spatial Extent Format: Scene (128x128 km^2)

Select Variables: water surface elevation, area, water fraction, backscatter, geophysical information

Subcollections:

- SWOT_L2_Raster_100m
- SWOT_L2_Raster_250m





Scene near Austin, TX

SWOT_L2_RiverSP (shapefile)

Description: Vectors of river reaches (~10 km long) and nodes (~200 m spacing) in prior river database.

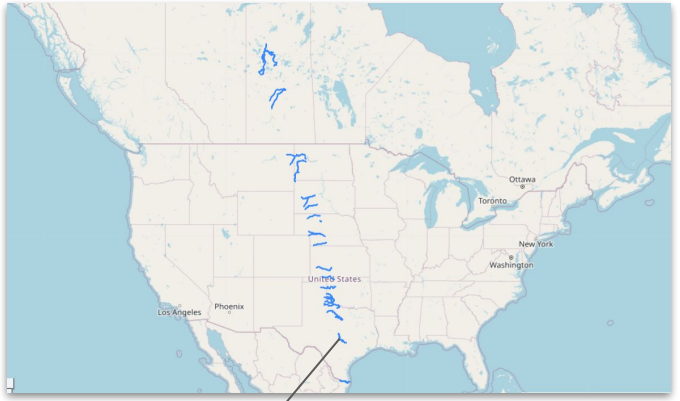
Extent Format: continent-scale swath

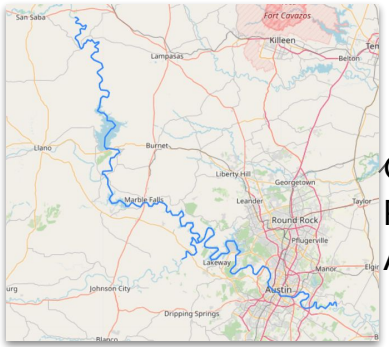
Variables: water surface elevation, slope, width, derived discharge*

Subcollections:

- SWOT_L2_RiverSP_reach
- SWOT_L2_RiverSP_node

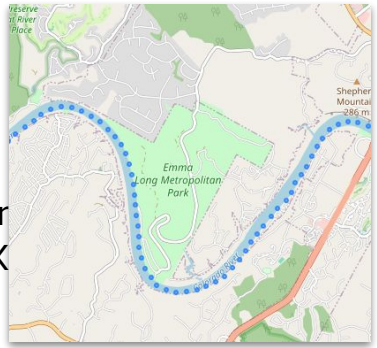
*included ~2 years after launch





Reach file

Colorado River near Austin, TX



Node file

SWOT_L2_LakeSP (shapefile)

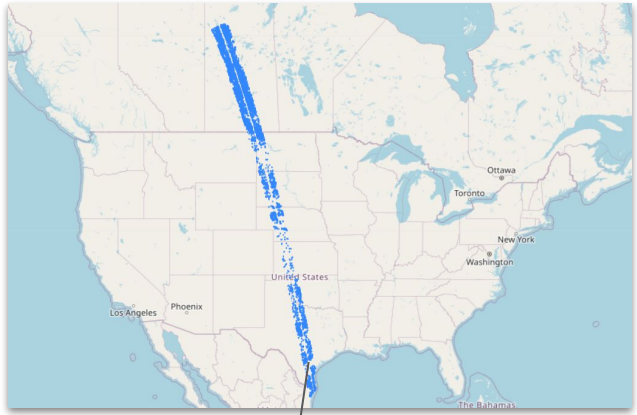
Description: Vectors of lakes in prior lake database and detected features not in the prior river or lake databases.

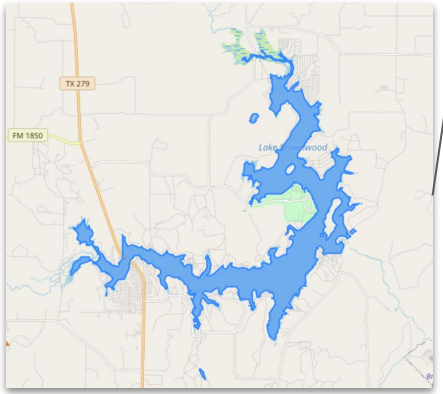
Extent Format: continent-scale swath

Select Variables: water surface elevation, area, derived storage change

Subcollections:

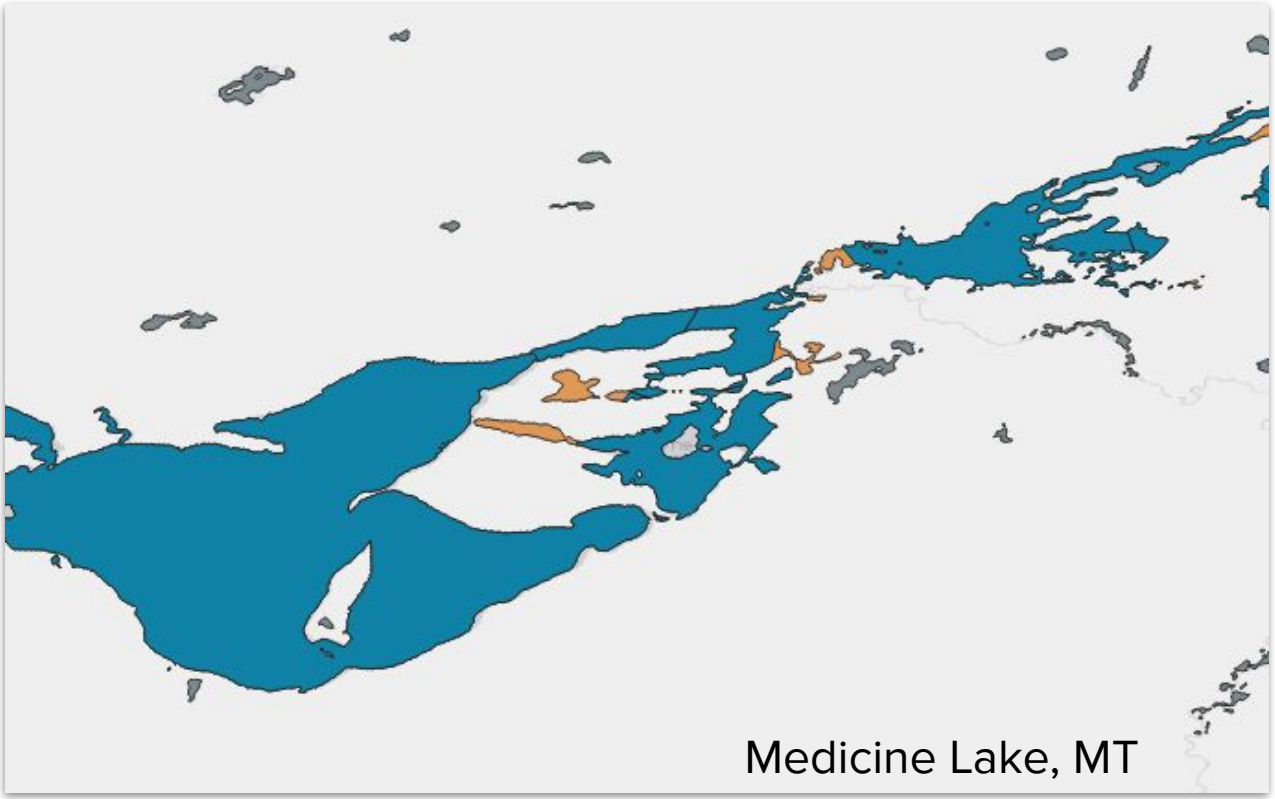
- SWOT_L2_LakeSP_obs
- SWOT_L2_LakeSP_prior
- SWOT_L2_LakeSP_unassigned





Lake Brownwood, TX

Observed, Prior & Unassigned Lakes



L2_HR_RiverAvg (shapefile)

Cycle average and aggregation of river reach pass data within predefined hydrological basins.

L2_HR_LakeAvg (shapefile)

Cycle average and aggregation of lake pass data within predefined hydrological basins.

L2_HR_FPDEM* (netCDF)

Flood Plain Digital Elevation Map in raster format, derived from multiple cycles of SWOT acquisitions. (~50m resolution). Provides height and quality flag for each pixel.

*available ~2 years after launch

SWOT_L2_RAD_(O/I)GDR (netCDF)

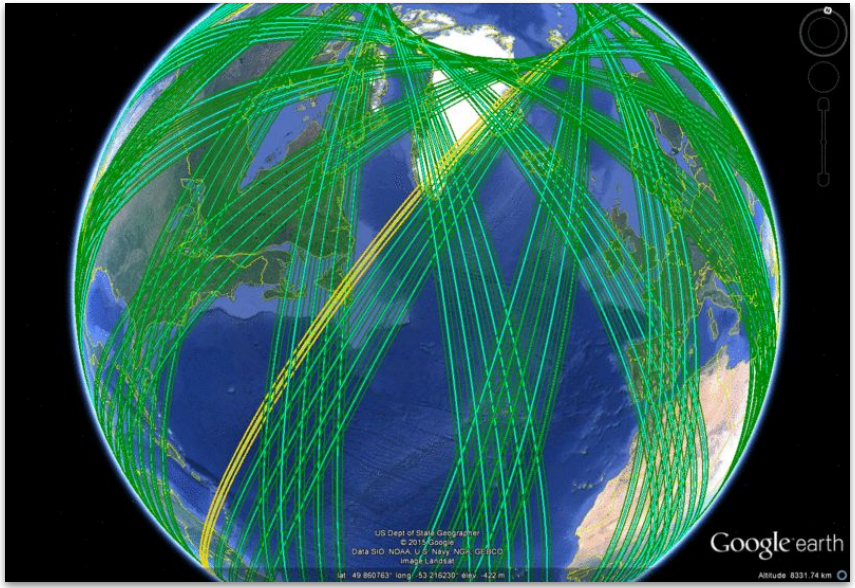
Description: Radiometer brightness temperature and troposphere correction data product - (operational/interim) geophysical data record

Spatial Extent Format: nadir track -

Left and right sides

Select Variables: radiometer wet troposphere correction

Subcollections: N/A



SWOT_L2_NALT_OGDR (netCDF)

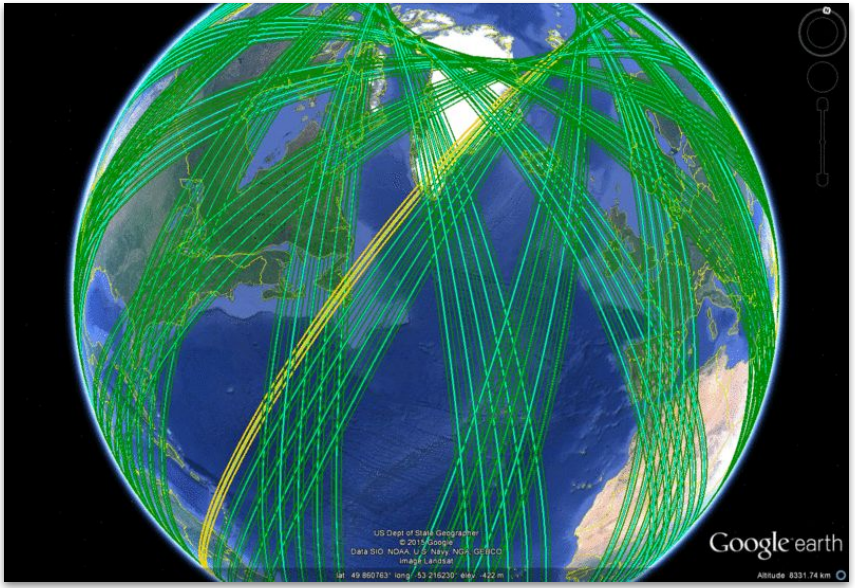
Description: Nadir altimetry operational geophysical data record

Spatial Extent Format: nadir track

Select Variables: sea surface height anomaly, significant wave height

Subcollections:

- SWOT_L2_NALT_OGDR_SSHA
- SWOT_L2_NALT_OGDR_GDR



SWOT_L2_NALT_IGDR (netCDF)

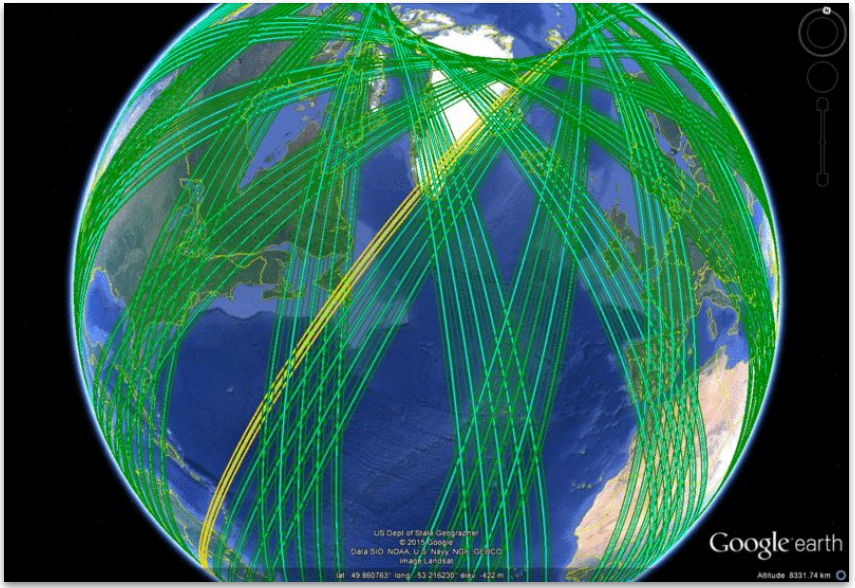
Description: Nadir altimetry interim geophysical data record

Spatial Extent Format: nadir track

Select Variables: sea surface height anomaly, significant wave height

Subcollections:

- SWOT_L2_NALT_IGDR_SSHA
- SWOT_L2_NALT_IGDR_GDR
- SWOT_L2_NALT_IGDR_SGDR



SWOT_L2_NALT_GDR (netCDF)

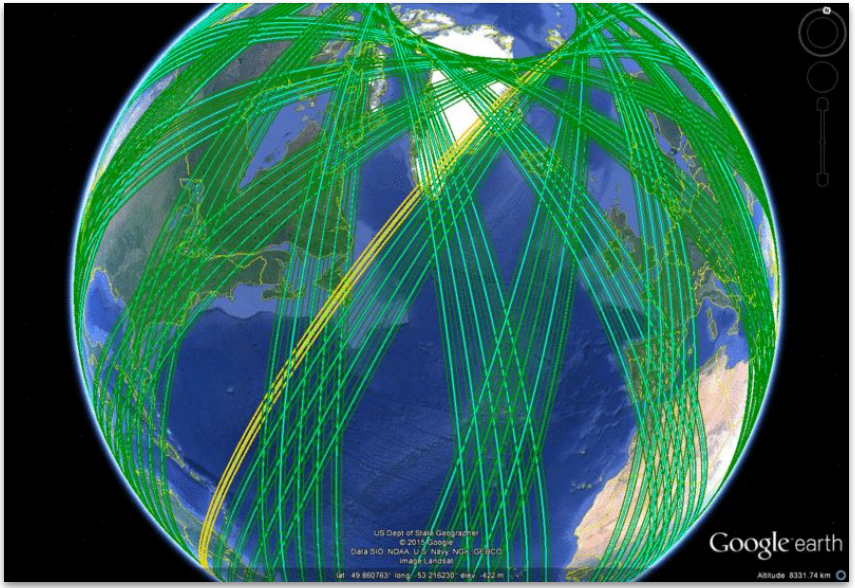
Description: Nadir altimetry geophysical data record

Spatial Extent Format: nadir track

Select Variables: sea surface height anomaly, significant wave height

Subcollections:

- SWOT_L2_NALT_GDR_SSHA
- SWOT_L2_NALT_GDR_GDR
- SWOT_L2_NALT_GDR_SGDR



SWOT_L2_LR_SSH (netCDF)

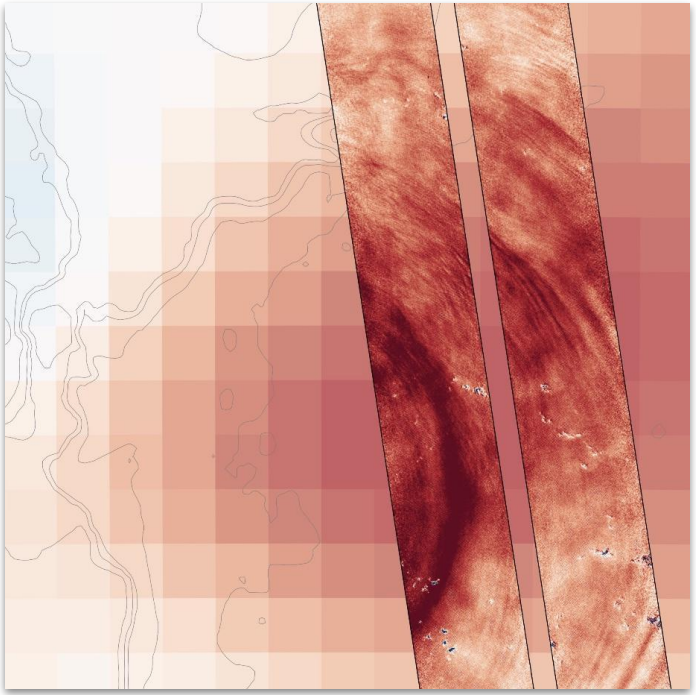
Description: Sea surface height (SSH) and significant wave height (SWH) over oceans

Spatial Extent Format: 2 km fixed-grid swath (and unsmoothed; 250 m native grid)

Select Variables: SSH, SWH

Subcollections:

- SWOT_L2_LR_SSH_Basic
- SWOT_L2_LR_SSH_WindWave
- SWOT_L2_LR_SSH_Expert
- SWOT_L2_LR_SSH_Unsmoothed



Thumbnail image credit: M. Archer

Quality Flags!

SWOT Product	Quality Flag Identifier	Values and Meanings
L2_HR_RiverSP L2_HR_RiverAvg	Var + '_q' Overall Quality Variables: 'reach_q' or 'node_q' Bitwise: Var + '_q_b'	0 = good 1 = suspect - may have large errors 2 = degraded - likely to have large errors 3 = bad - may be nonsensical and should be ignored *For discharge parameters: (e.g., 'dschg_c_q')* 0 = valid 1 = questionable 2 = invalid
L2_HR_LakeSP L2_HR_LakeAvg	Overall quality Variable: 'quality_f'	0 = good 1 = bad
L2_HR_Raster	Var + '_qual' Ex: 'wse_qual' Bitwise: Var + '_qual_bitwise'	0 = good 1 = suspect - may have large errors 2 = degraded - likely to have large errors 3 = bad - may be nonsensical and should be ignored

L2_NALT_GDR L2_NALT_IGDR L2_NALT_OGDR L2_RAD_GDR L2_RAD_IGDR L2_RAD_OGDR L2_FPDEM	Var + '_qual' Ex: 'rad_water_vapor_qual'	0 = good 1 = bad
L2_LR_SSH L2_HR_PIXC L1B_HR_SLC L1B_LR_INTF	Var + '_qual'	Varies, see PDDs

Find this info in the PO.DAAC Cookbook:
https://podaac.github.io/tutorials/quarto_text/SWOT.html#tips-for-quality-flags

More Detailed Information

Product Description Documents (PDDs)

Dataset	Description	Coverage	Format	Product Description Document (PDD)	Algorithm Theoretical Basis Document (ATBD)
L2_HR_PIXC	Point cloud of water mask pixels (“pixel cloud”) with geolocated heights, backscatter, geophysical fields, and flags.	Point cloud over tile (approx 64x64 km^2); half swath (left or right side of full swath)	netCDF	L2_HR_PIXC Product Description Document	L2_HR_PIXC Algorithm Theoretical Basis Document

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https://podaac.jpl.nasa.gov/SWOT?tab=datasets-information&sections=about