CWRA 2026 MIDTERM CONFERENCE CONNECTING THE DROPS : WATER MANAGEMENT IN AN EVOLVING WORLD

SWOT AND HEIGHT REFERENCE

Mélanie Trudel, Gabriela Siles, Samuel Foucher, Victoria Litalien

January 29, 2026

UNIVERSITÉ LAVAL
UDS Université de Sherbrooke
CANADIAN SPACE AGENCY AGENCE SPATIALE CANADIENNE

Download the presentation here:
https://github.com/sfoucher/SWOT-Canada

SWOT

WELCOME

SWOT, un nouveau satellite pour le suivi de l'eau mondiale – Rêves d'Espace

Mélanie Trudel

Professor, Faculty of Engineering
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Research Topics

- Remote Sensing
- Water resources
- Hydrological modeling
- Hydraulic modeling

Qualifications
(2010-2013). Post-doctoral. Civil engineering. Université de Sherbrooke. Sherbrooke, Canada.
(2006-2010). Ph.D. Civil engineering. École de Technologie Supérieure. Montreal, Canada.
(2004-2006). M.Sc. Remote Sensing. Université de Sherbrooke. Sherbrooke, Canada.
(2001-2004). B.Sc. Physics. Université de Montréal. Montreal, Canada.

Academic experiences
Professor. (2017-). Université de Sherbrooke. Sherbrooke, Canada.
Research Assistant. (2013-2017). Université de Sherbrooke. Sherbrooke, Canada.

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Research Topics

- Remote Sensing
- Water resources
- River Ice

Qualifications
(2021-2023). M.Sc. Applied geomatics and remote sensing. Université de Sherbrooke. Sherbrooke, Canada.
(2020-2021). Graduate Microprogram in Geomatics. Université Laval. Québec, Canada.
(2016-2019). B.Env. Environmental studies. Université de Montréal. Montreal, Canada.

Academic experiences
Research profesionnal. (2023-). Université de Sherbrooke. Sherbrooke, Canada.

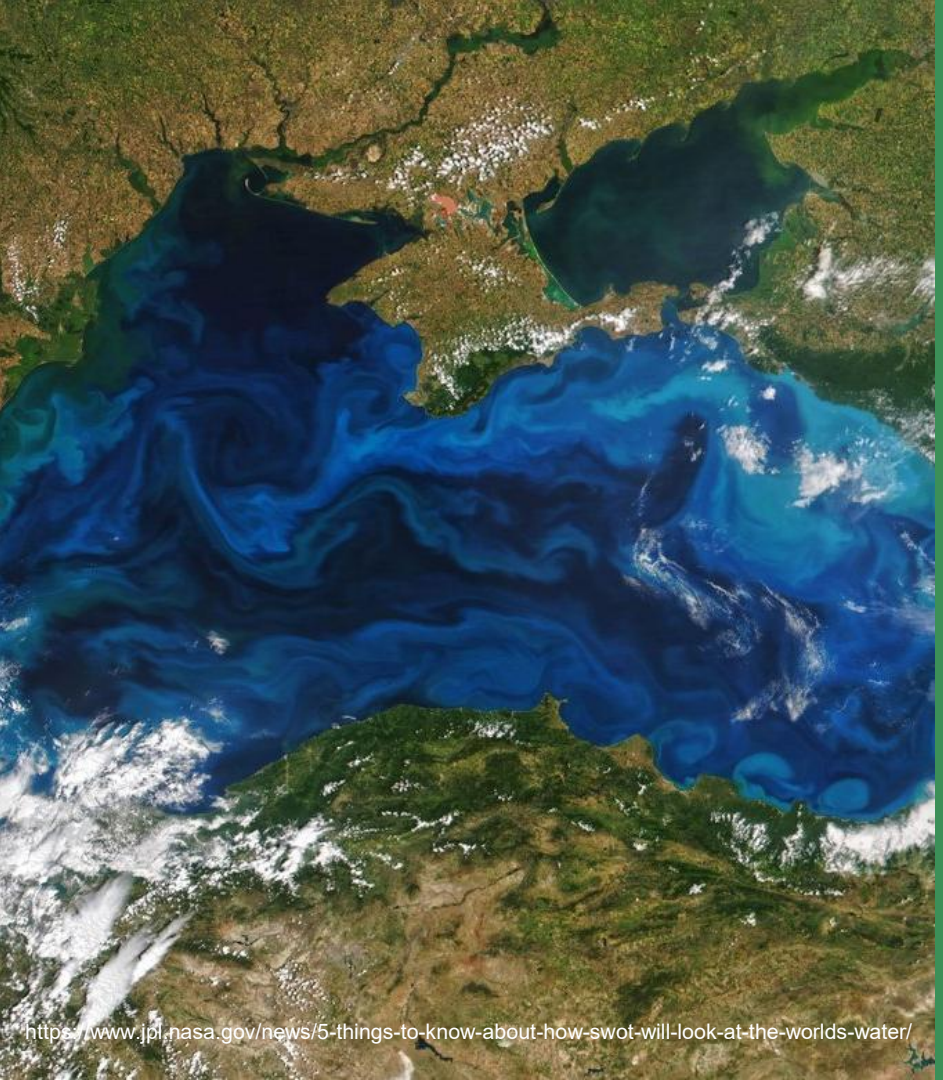
Océans, rivières et lacs dans la mire du satellite SWOT | OHdio | Radio-Canada

Today's agenda

- Ice breaker
- SWOT and height reference presentation
- Break
- Workshop – Part I

- Lunch

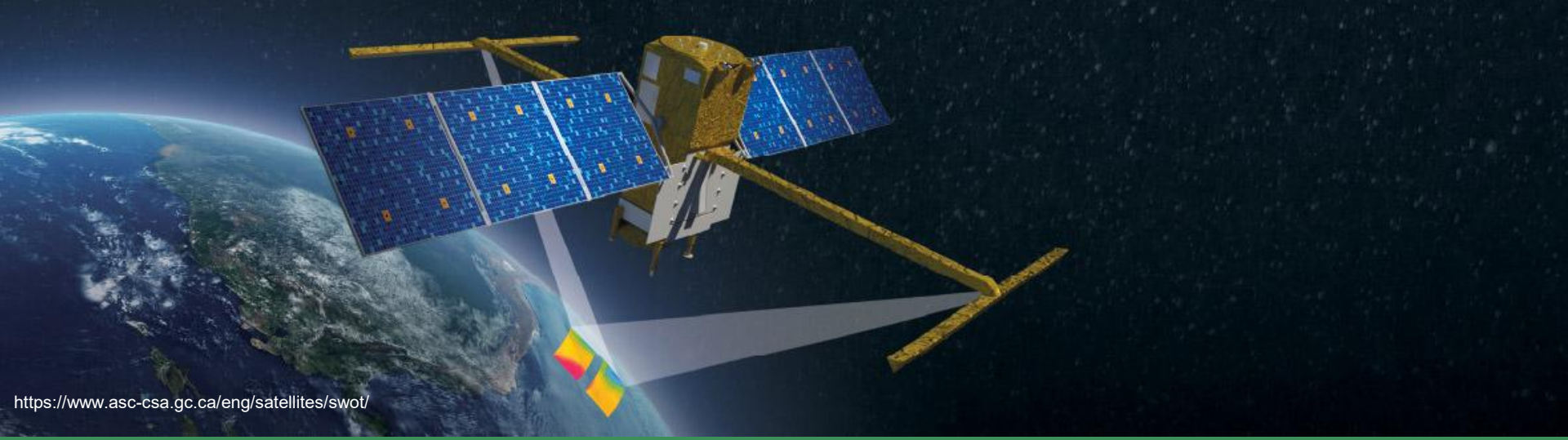
- Workshop – Part II
- Assessment of SWOT-RiverSP Data presentation



https://www.jpl.nasa.gov/news/5-things-to-know-about-how-swot-will-look-at-the-worlds-water/

Ice breaker

- Have you used SWOT before?
- What is your main interest in using SWOT?
- What do you hope to get from this workshop?



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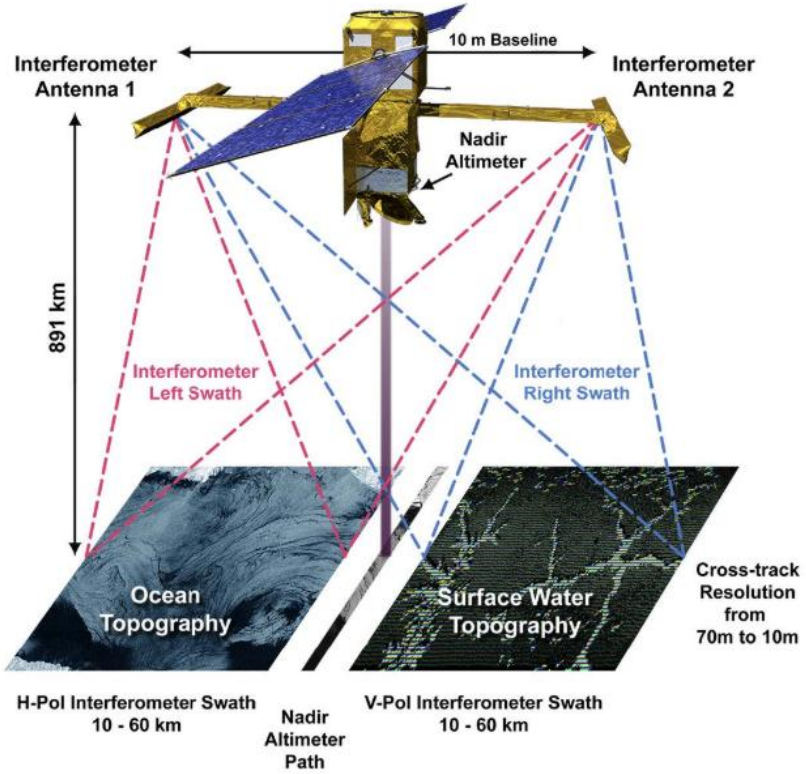
A) SWOT mission overview
B) SWOT HR products
C) Challenges and opportunities

A) SWOT MISSION OVERVIEW

SWOT overview

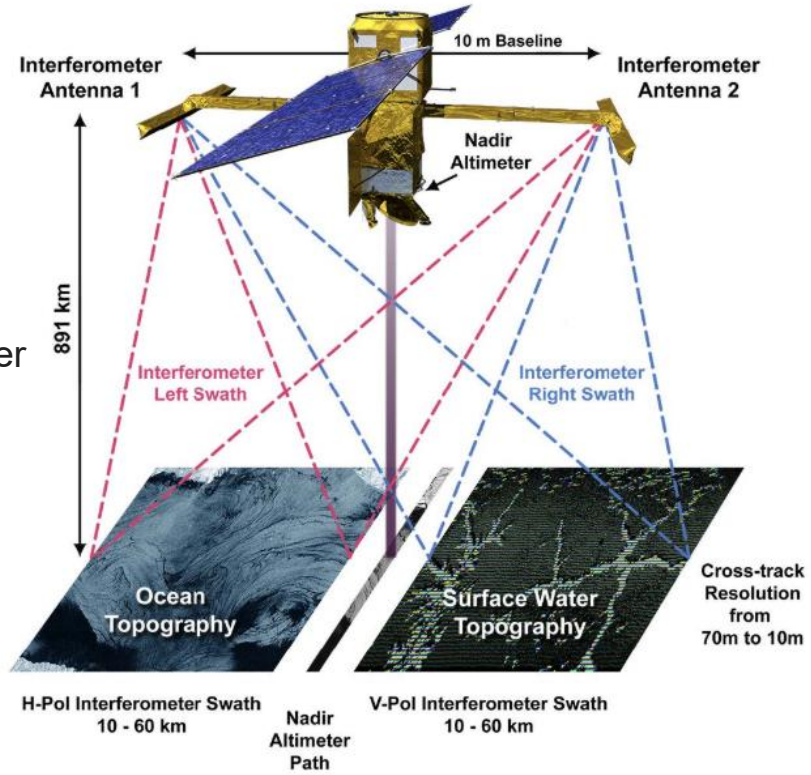
- Partnership between NASA and CNES, with contributions from CSA and UKSA
- Launch: December 2022
- Main instrument: Ka-band Radar Interferometer (KaRIn)
- Angle of incidence near nadir
- Mission duration: 3 to 5 years
- Revisits every 21 days, with the possibility of multiple passes over the same water body



SWOT overview

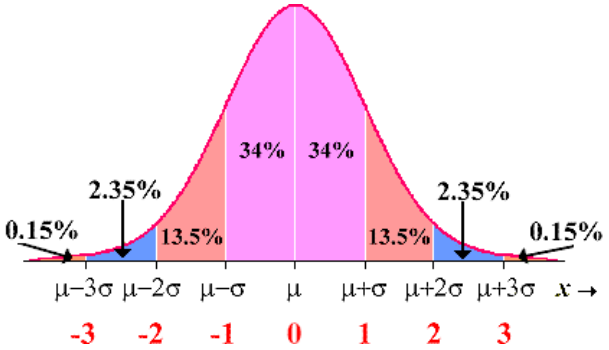
Mission objectives:

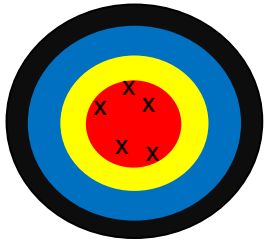
- Provide a global inventory of :
  - all terrestrial water bodies with an area larger than $(250\ m)^2$ (goal: $(100\ m)^2$, threshold: $1km^2$) (lakes, reservoirs, and wetlands)
  - rivers wider than 100m (goal: 50m, threshold: 170m)
- Measure global changes in water storage in terrestrial water bodies at sub-monthly, seasonal, and annual timescales.
- Estimate global river discharge changes at sub-monthly, seasonal, and annual timescales.



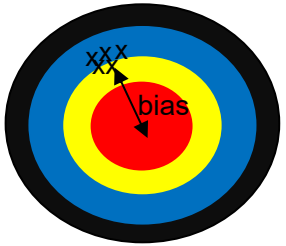
SWOT HR requirements

- What does 1σ mean?

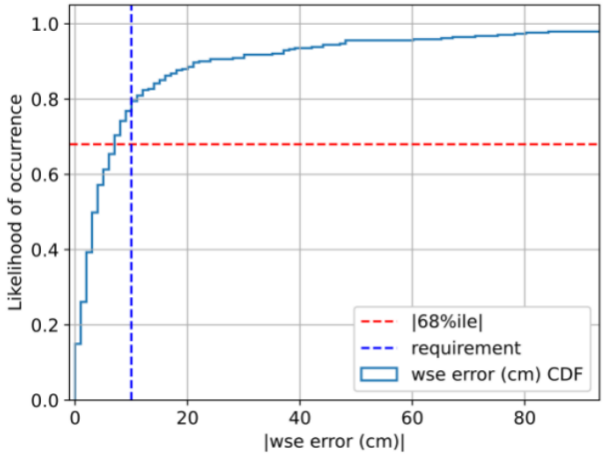




Accurate but not precise



Precise but not accurate



- For a Gaussian, 68% of values lie within one standard deviation (1σ).

SWOT HR requirements

Water Surface Elevation (WSE) (1σ) :

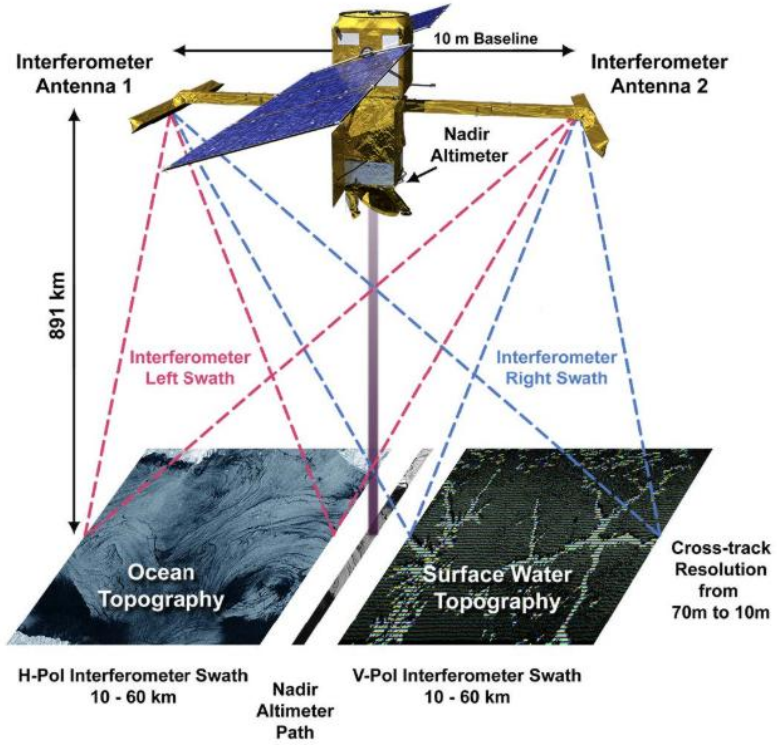
- > 1 km² : 10 cm or better
- between (250m x 250 m) and 1 km² : 25 cm or better

Surface area (1σ) :

- Relative error < 15 % (1σ)
  - water bodies > (250m x 250 m)
  - river segments with average width > 100 m and length > 10 km

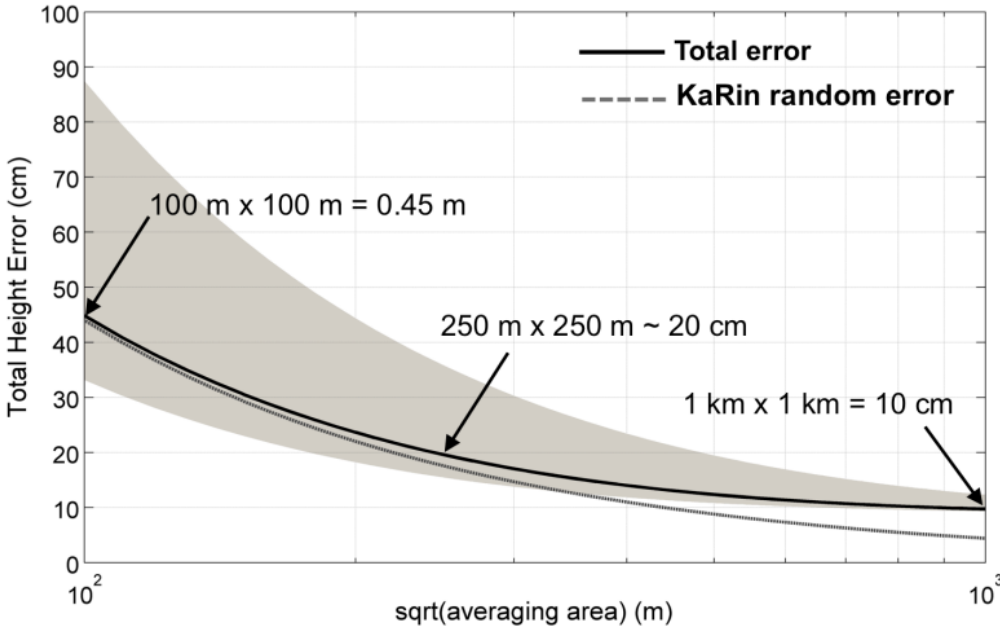
River slope :

- For rivers wider than 100 m : precision of 17 µrad (1.7 cm/km) after averaging over ≤ 10 km downstream

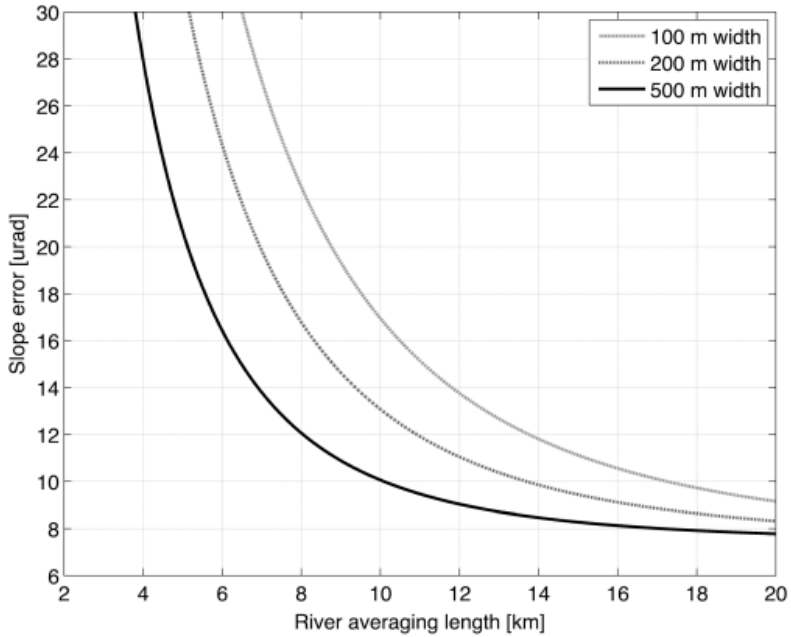


SWOT HR requirements

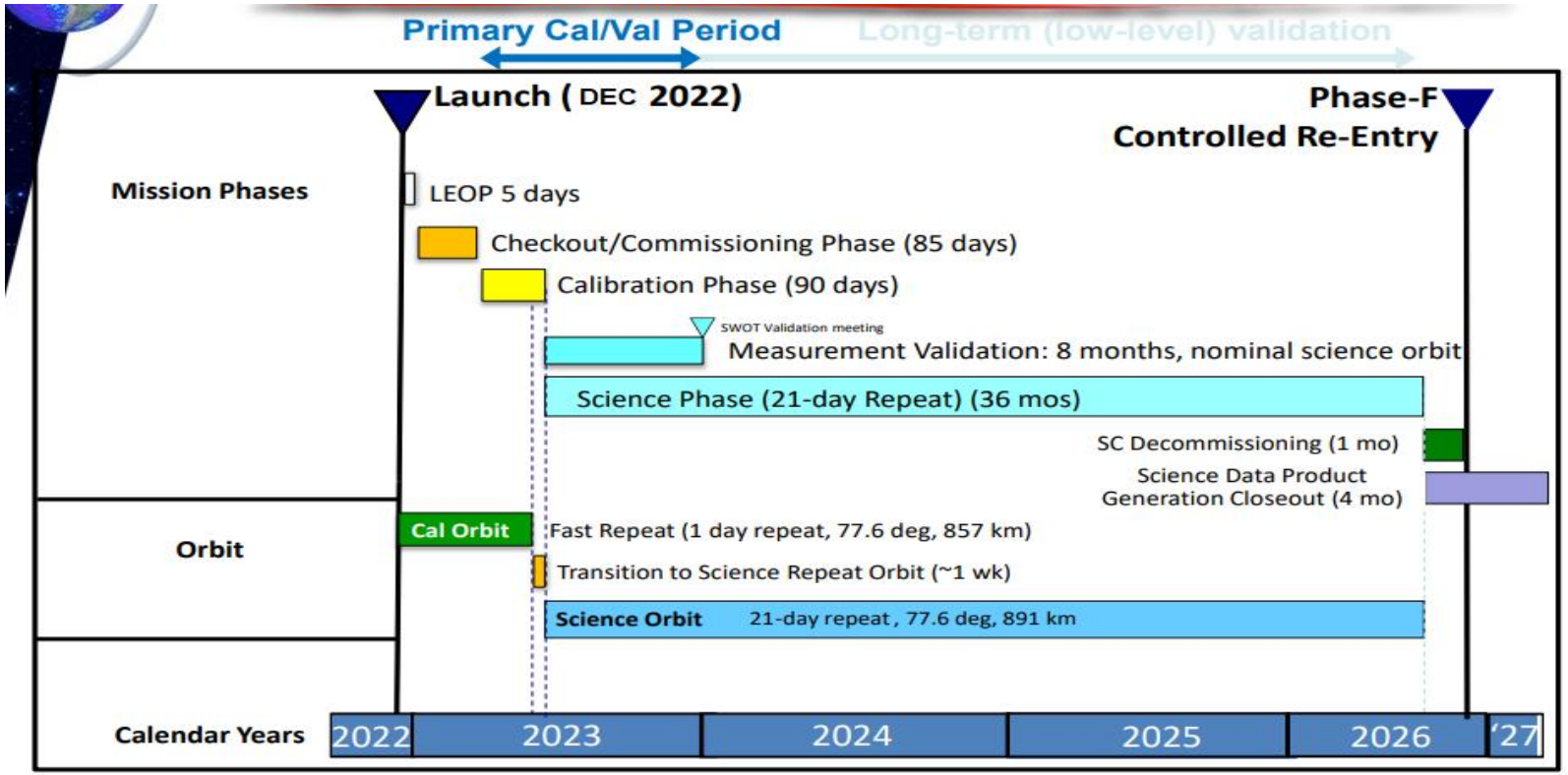
WSE



SLOPE



SWOT over time



SWOT over time

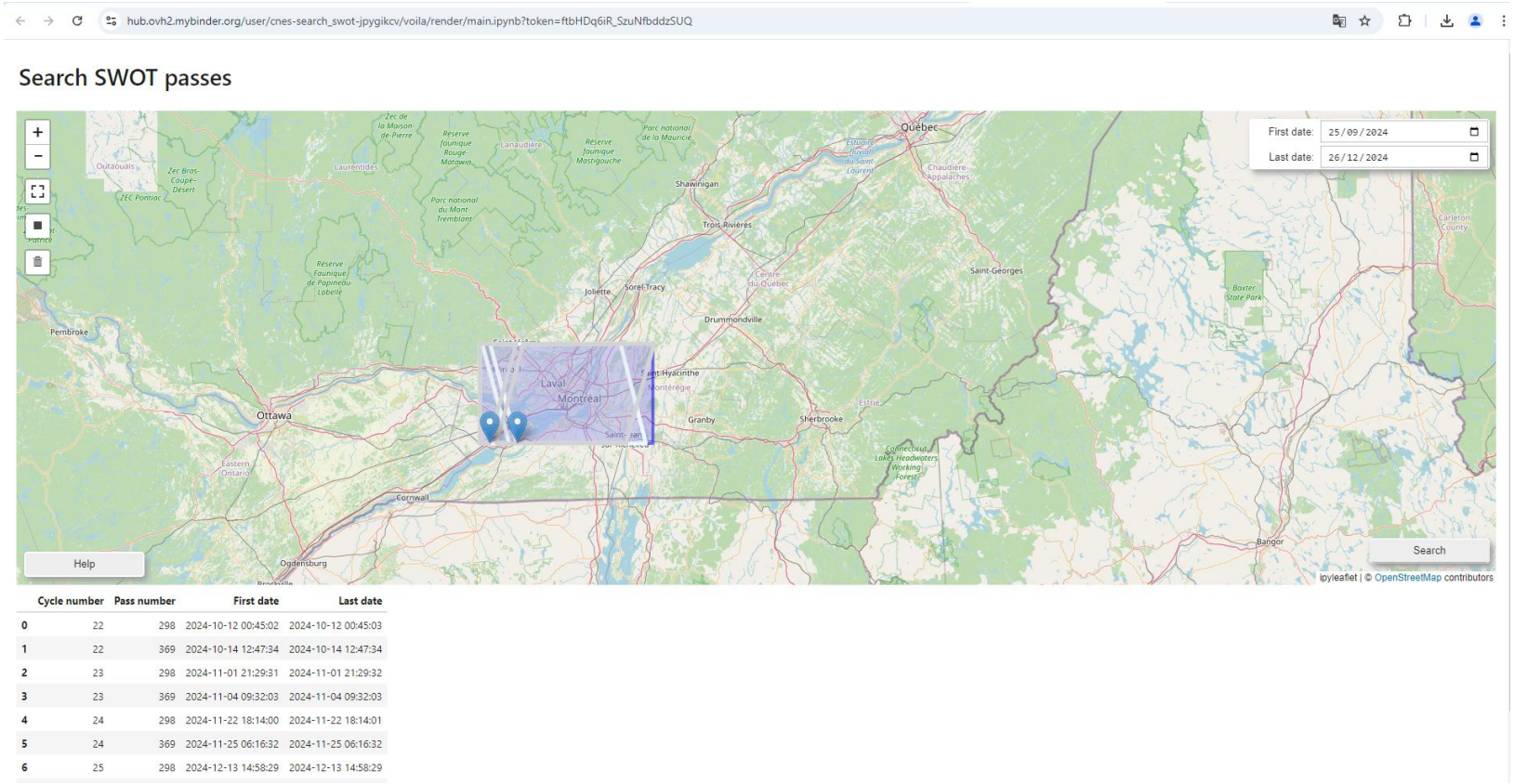
Currently, Version C :
PGC0 : Data reprocessing (CAL/VAL and Science)
PIC0 : Forward, Processing within days of acquisition
PIC2 : Forward, Since October 16, 2024
PID0 : Forward, Since May 6, 2025

Global reprocessing (PGD0) on the way (CAL/VAL completed).

Check out the known issues in the Product Release Notes.

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

SWOT over time

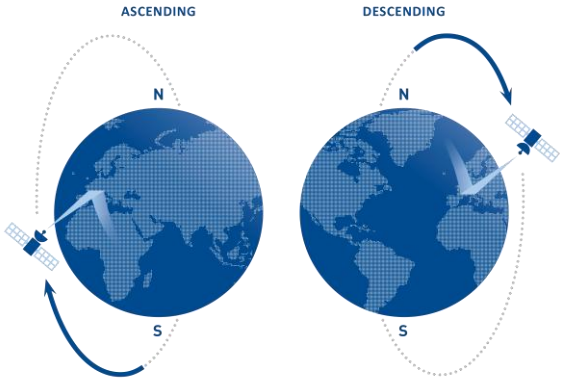


	Cycle number	Pass number	First date	Last date
0	22	298	2024-10-12 00:45:02	2024-10-12 00:45:03
1	22	369	2024-10-14 12:47:34	2024-10-14 12:47:34
2	23	298	2024-11-01 21:29:31	2024-11-01 21:29:32
3	23	369	2024-11-04 09:32:03	2024-11-04 09:32:03
4	24	298	2024-11-22 18:14:00	2024-11-22 18:14:01
5	24	369	2024-11-25 06:16:32	2024-11-25 06:16:32
6	25	298	2024-12-13 14:58:29	2024-12-13 14:58:29

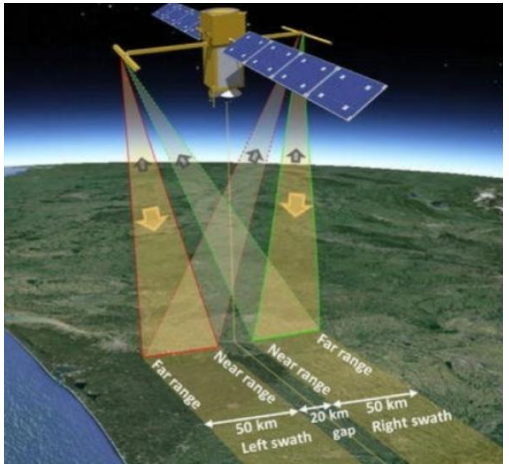
https://swot.jpl.nasa.gov/mission/swath-visualizer/

B) SWOT HR PRODUCTS

File subdivision



Pass (1 to 584) - SWOT follows the same ground track every 21 days over 292 orbits around the Earth. Each orbit includes an ascending pass (flight north) and a descending pass (flight south).



Swath - Land area covered by the KaRIn instrument

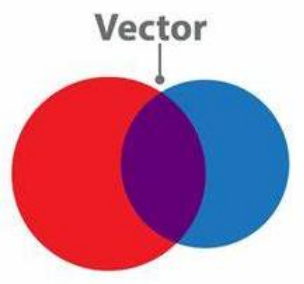
Tile – Each pass is divided into 64 × 64 km tiles, one on the left and one on the right. No usable data is available within 20 km of the nadir or beyond 64 km from the nadir.

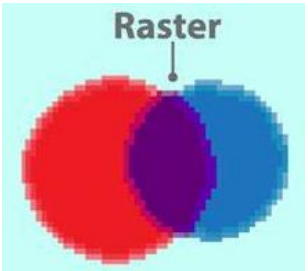
Scene – 4 tiles (2 L and 2 R): 128 × 128 km

https://github.com/sfoucher/SWOT-Canada/tree/main/Data
https://site.tre-altamira.com/insar/

File types

	Vector	Raster
Shape	Points, Lines & Polygons	Pixel
Format	NetCDF4 (.nc), Shapefile (.shp)	NetCDF4 (.nc)
Files	L2_HR_PIXC L1B_HR_SLC L2_HR_LakeSP L2_HR_RiverSP	L2_HR_Raster

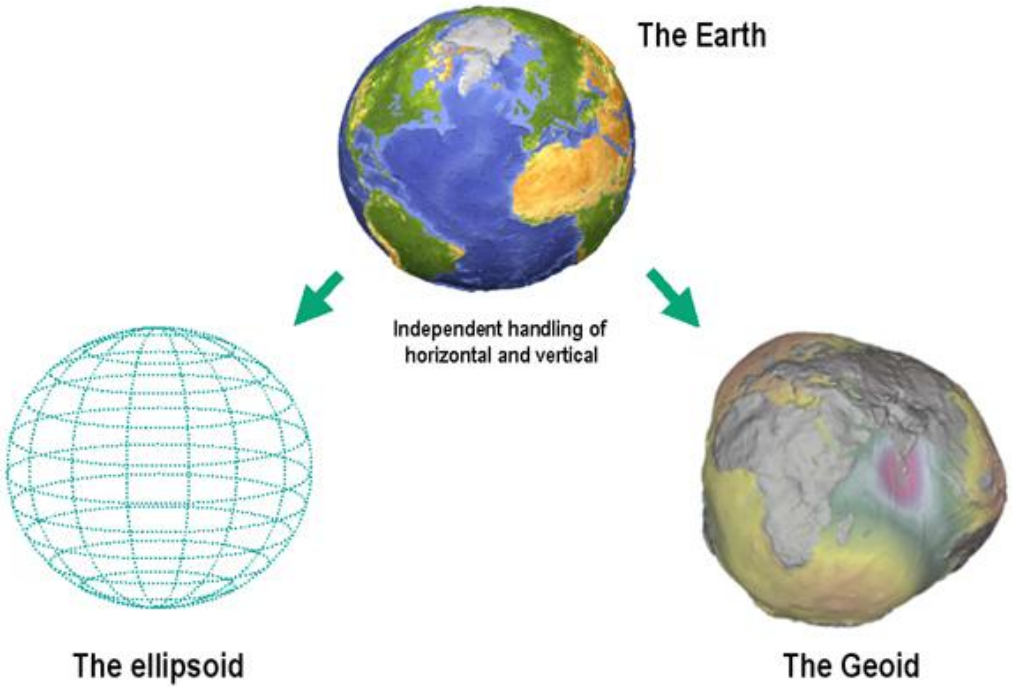




How SWOT measures elevation: Geoid vs Ellipsoid

When we talk about elevation, there are two common reference surfaces: the geoid and the ellipsoid.

The ellipsoid is a mathematical approximation of the Earth's shape. Elevations measured relative to the ellipsoid are called ellipsoidal heights.

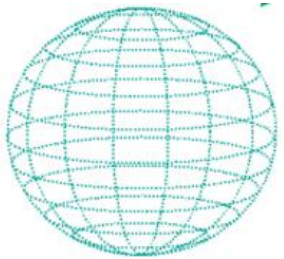


The geoid is a model of the Earth based on mean sea level. Elevations measured relative to the geoid are called orthometric heights.

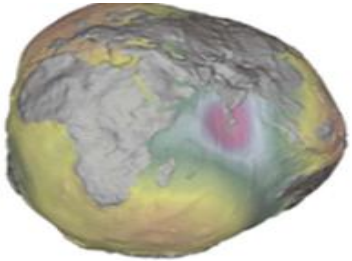
https://unstats.un.org/unsd/geoinfo/ungegn/docs/_data_icacourses/_HtmlModules/_Selfstudy/S06/S06_03a.html

How SWOT measures elevation: Geoid vs Ellipsoid

SWOT defines ellipsoidal height (h) as “height”



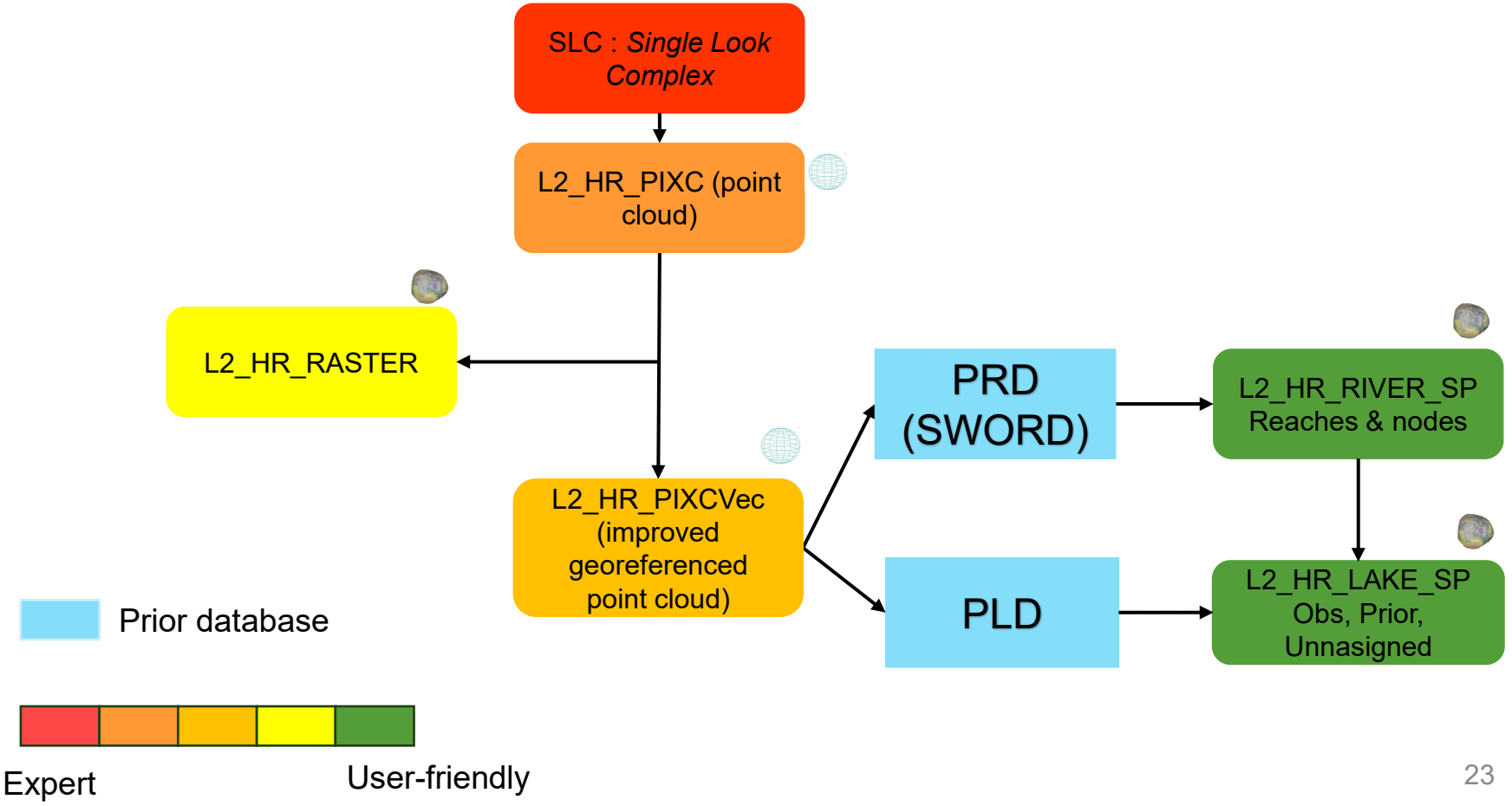
and orthometric height (geoid, H) as “WSE.”



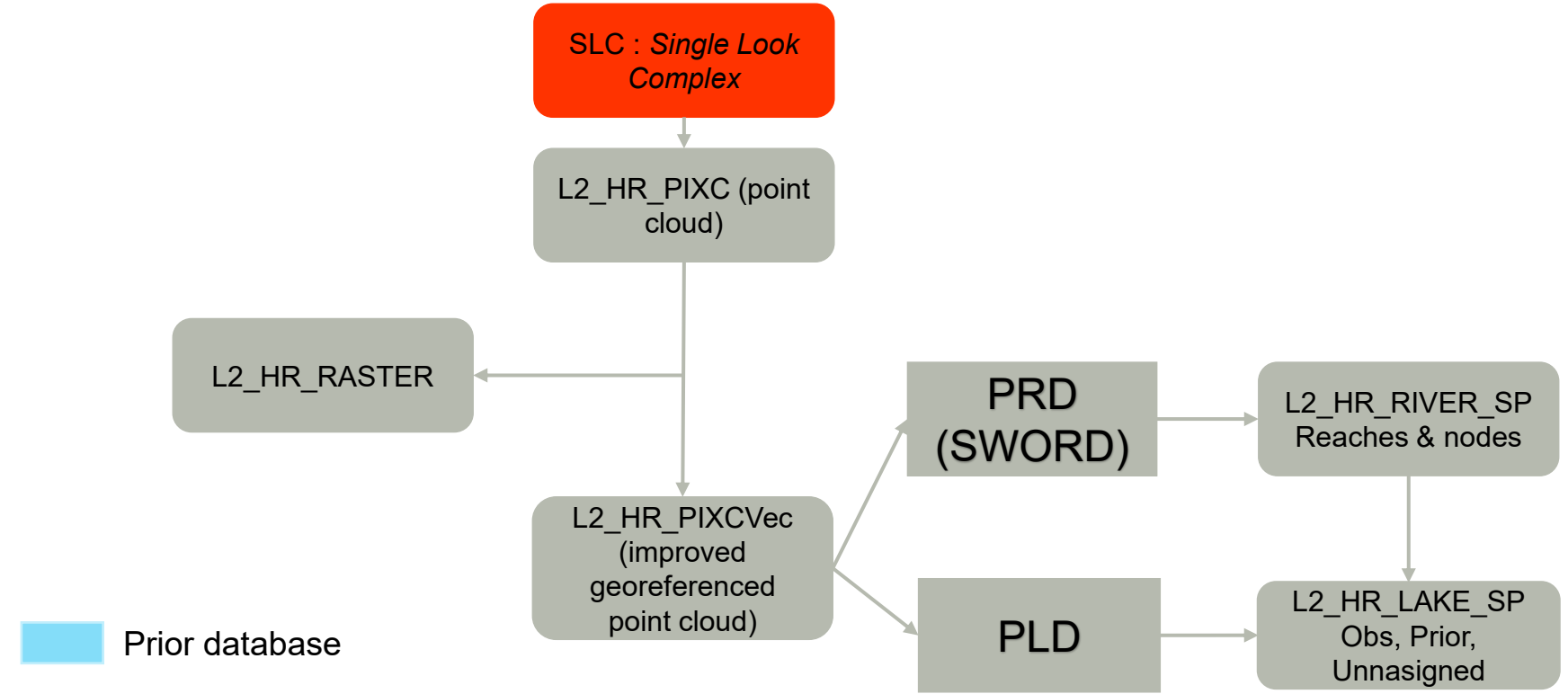
So whenever you see “height,” think ellipsoid,

and when you see “WSE,” think geoid!

SWOT HR PRODUCTS

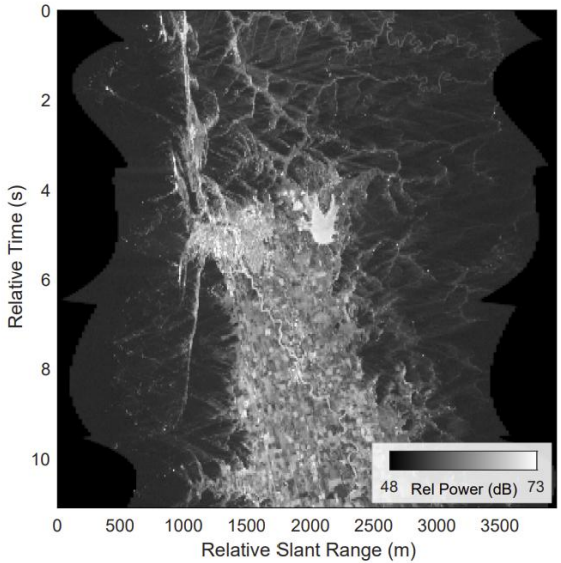


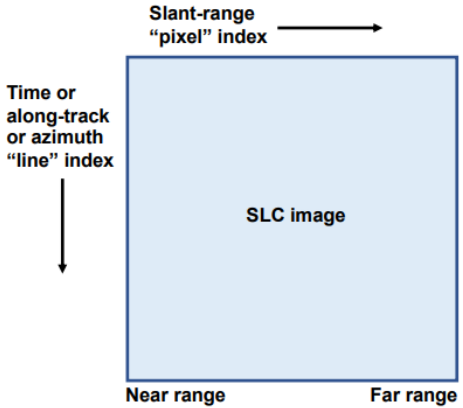
SWOT HR PRODUCTS



L1B_HR_SLC

For expert user who wish to apply their own specialized algorithms





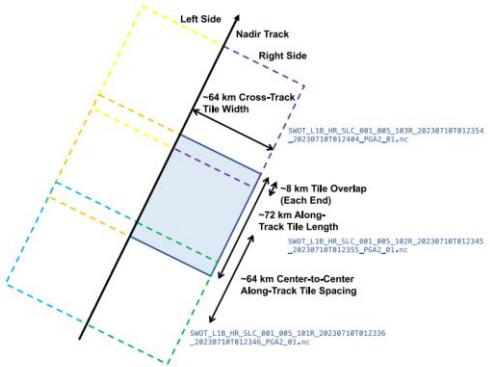


Image in radar slant-plane coordinates. It shows the data as they are measured, according to the satellite's viewing angle.

The image follows the satellite path, so is not geolocated.

Divided in tiles

L1B_HR_SLC

	SLC
File Name	SWOT_L1B_HR_SLC_<Cycle>_<Pass>_<Tile>[L/R]_<BeginningDateTime>_<EndingDateTime>_<CRID>_<ProductCounter>.nc
Format	NetCDF4 (.nc)
Time	UTC
Latency from data collection	At most 45 days
File organization	One NetCDF file with 5 groups : slc, xfactor, noise, tvp, grdem
Included informations	• Wavelength • Polarization • slc_plus_y, slc_minus_y • xfactor_plus_y, xfactor_minus_y • noise_plus_y, noise_minus_y • roll, pitch, yaw, velocity_heading • height • Quality flags (ice, …)

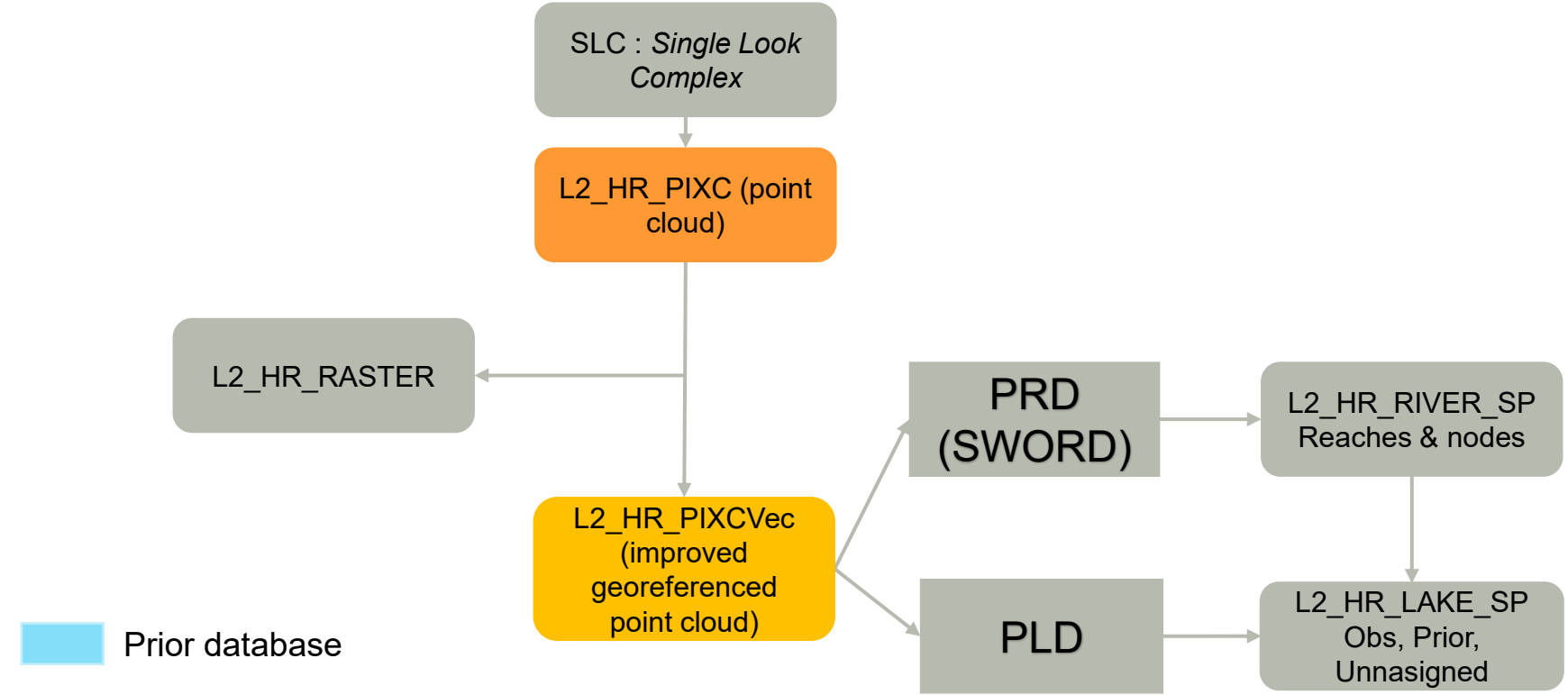
L1B_HR_SLC

Bit (from LSB)	Decimal	Hex	slc_qual	sc_event_flag	tvp_qual
0	1	1	tvp_suspect	yaw_flip_maneuver	good
1	2	2	sc_event_suspect	gyro_calibration_maneuver	
2	4	4	small_karin_gap	orbit_control_maneuver	
3	8	8		solar_array_rotation	
4	16	10		eclipse_entry	orbit_estimated_during_a_maneuver
5	32	20	tvp_bad	eclipse_exit	orbit_interpolated_over_data_gap
6	64	40	sc_event_bad	karin_bad_due_to_eclipse_event	orbit_extrapolated_for_a_duration_less_than_1_day
7	128	80	large_karin_gap	karin_bad_due_to_non_eclipse_ev	orbit_extrapolated_for_a_duration_between_1_to_2_days
8	256	100			orbit_extrapolated_for_a_duration_greater_than_2_days
9	512	200			
10	1024	400			attitude_suspect
11	2048	800			
12	4096	1000			
13	8192	2000			
14	16384	4000			attitude_suspect_and_orbit_estimated_during_a_maneuver
15	32768	8000			attitude_suspect_and_orbit_interpolated_over_data_gap
16	65536	10000			attitude_suspect_and_orbit_extrapolated_for_a_duration_less_than_1_day
17	131072	20000			attitude_suspect_and_orbit_extrapolated_for_a_duration_between_1_to_2_days
18	262144	40000			attitude_suspect_and_orbit_extrapolated_for_a_duration_greater_than_2_days
19	524288	80000			
20	1048576	100000			attitude_bad
21	2097152	200000			
22	4194304	400000			
23	8388608	800000			
24	16777216	1000000			attitude_bad_and_orbit_estimated_during_a_maneuver
25	33554432	2000000			attitude_bad_and_orbit_interpolated_over_data_gap
26	67108864	4000000			attitude_bad_and_orbit_extrapolated_for_a_duration_less_than_1_day
27	134217728	8000000			attitude_bad_and_orbit_extrapolated_for_a_duration_between_1_to_2_days
28	268435456	10000000			attitude_bad_and_orbit_extrapolated_for_a_duration_greater_than_2_days

Do not use

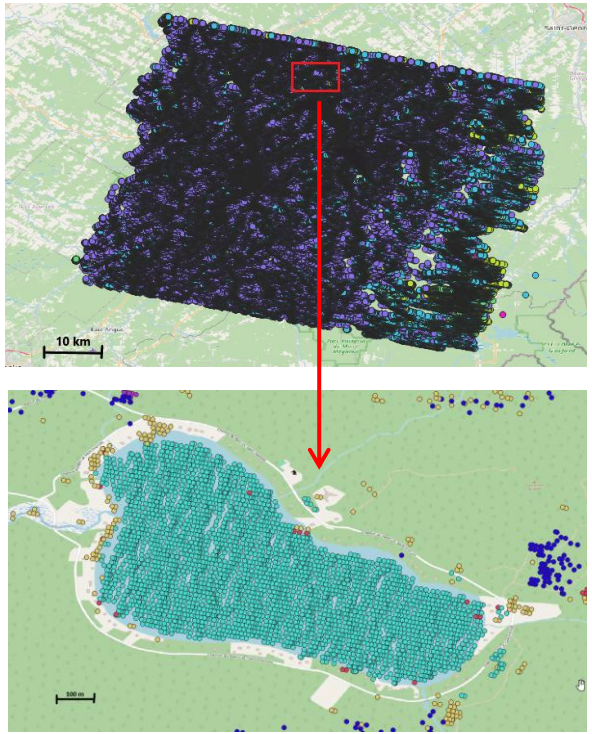
Additionnal data : quality flags

SWOT HR PRODUCTS



L2_HR_PIXC

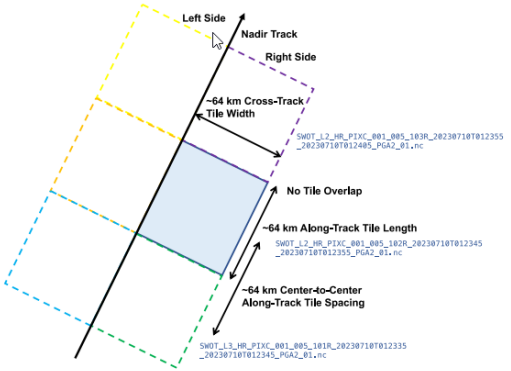
Geolocated height measurements derived from the SLC



This product also includes a classification for each pixel.

Class	Definition
1	Land
2	Land near water
3	Water near land
4	Open water
5	Dark water
6	Low-coherence water near land
7	Open low-coherence water

Divided in tiles



The PIXCVec product is derived from the PIXC product and is used as an intermediate step to build the river and lake products and gives better pixel location and ice information.

L2_HR_PIXC

	PIXC
File Name	SWOT_L2_HR_PIXC_<Cycle>_<Pass>_<Tile>[L/R]_<BeginningDateTime>_<EndingDateTime>_<CRID>_<ProductCounter>.nc
Format	NetCDF4 (.nc)
Time	UTC
Latency from data collection	At most 45 days
File organization	3 groups of data in one file : **pixel_cloud**, tvp, and noise
Pixel_cloud informations	• Classification • Height (WGS84 ellipsoidal) • water_area • water_frac • Quality flags (ice, dark_fraction…) • Sig0 (radar backscatter) • cross_track (signed distance to the nadir) • Inc (Incidence angle)

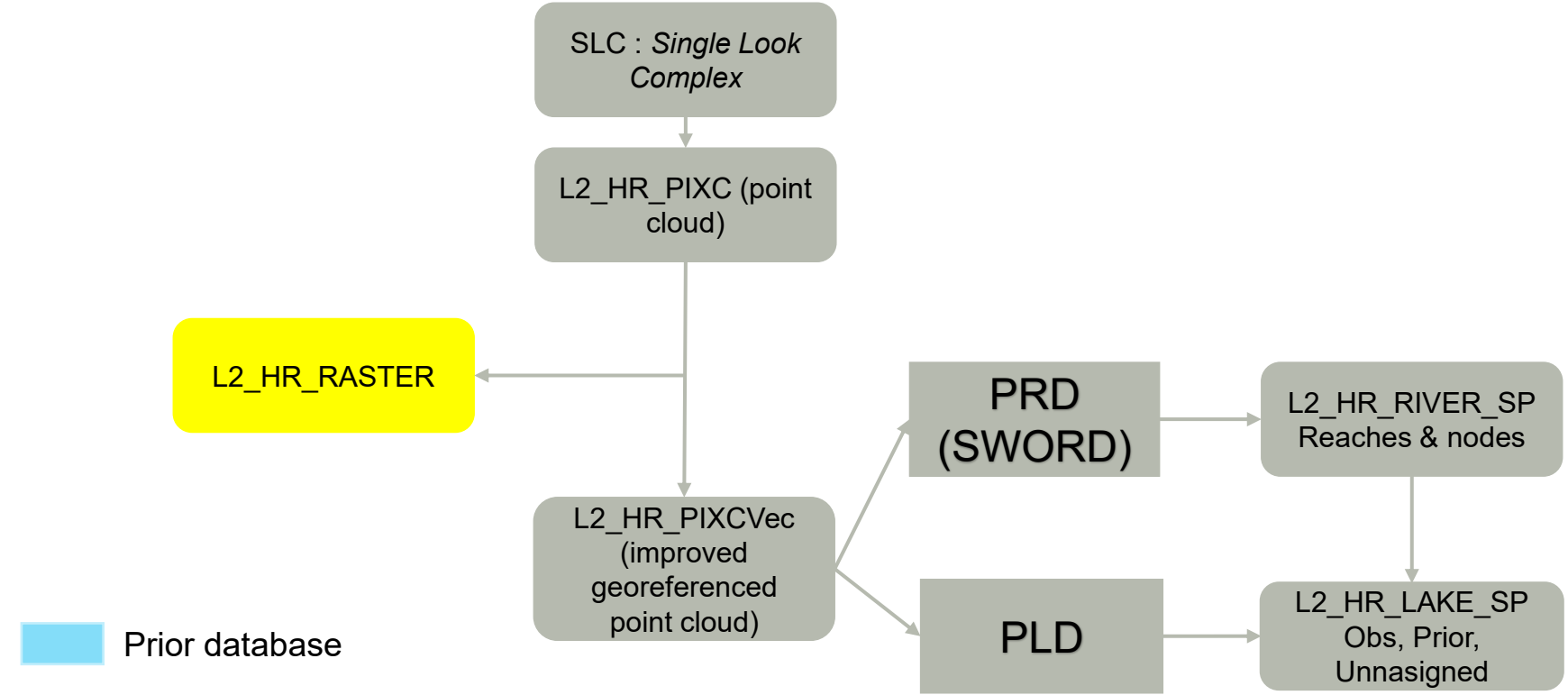
L2_HR_PIXC

Bit (from LSB)	Decimal	Hex	interferogram_qual	classification_qual	geolocation_qual	sig0_qual	pixc_line_qual
0	1	1		no_coherent_gain	layover_significant	sig0_uncert_suspect	not_in_tile
1	2	2		power_close_to_noise_floor	phase_noise_suspect	sig0_cor_atmos_suspect	
2	4	4		detected_water_but_no_prior_water	phase_unwrapping_suspect	noise_power_suspect	
3	8	8		detected_water_but_bright_land	model_dry_tropo_cor_suspect	xfactor_suspect	
4	16	10		water_false_detection_rate_suspect	model_wet_tropo_cor_suspect		
5	32	20			iono_cor_gim_ka_suspect		
6	64	40			xovercal_suspect		
7	128	80					
8	256	100					
9	512	200					
10	1024	400					
11	2048	800	rare_power_suspect	coherent_power_suspect		rare_power_suspect	
12	4096	1000	rare_phase_suspect		medium_phase_suspect		
13	8192	2000	tvp_suspect	tvp_suspect	tvp_suspect	tvp_suspect	tvp_suspect
14	16384	4000	sc_event_suspect	sc_event_suspect	sc_event_suspect	sc_event_suspect	sc_event_suspect
15	32768	8000	small_karin_gap	small_karin_gap	small_karin_gap	small_karin_gap	small_karin_gap
16	65536	10000					
17	131072	20000					
18	262144	40000	in_air_pixel_degraded	in_air_pixel_degraded		in_air_pixel_degraded	
19	524288	80000	specular_ringing_degraded	specular_ringing_degraded	specular_ringing_degraded	specular_ringing_degraded	
20	1048576	100000			model_dry_tropo_cor_missing	sig0_cor_atmos_missing	
21	2097152	200000			model_wet_tropo_cor_missing		
22	4194304	400000			iono_cor_gim_ka_missing		
23	8388608	800000			xovercal_missing		
24	16777216	1000000			geolocation_is_from_refloc		
25	33554432	2000000				noise_power_bad	
26	67108864	4000000				xfactor_bad	
27	134217728	8000000	rare_power_bad	coherent_power_bad	no_geolocation_bad	rare_power_bad	
28	268435456	10000000	rare_phase_bad		medium_phase_bad		
29	536870912	20000000	tvp_bad	tvp_bad	tvp_bad	tvp_bad	tvp_bad
30	1073741824	40000000	sc_event_bad	sc_event_bad	sc_event_bad	sc_event_bad	sc_event_bad
31	2147483648	80000000	large_karin_gap	large_karin_gap	large_karin_gap	large_karin_gap	large_karin_gap

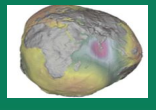
Do not use

Additionnal data : quality flags

SWOT HR PRODUCTS

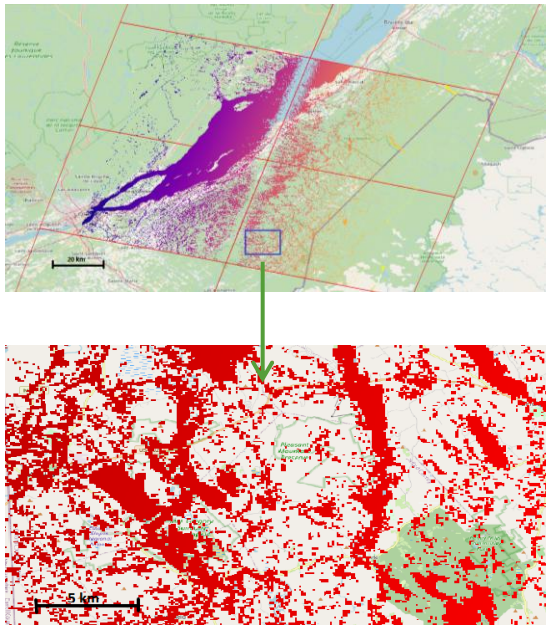


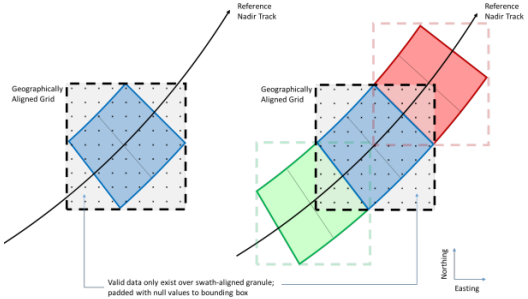
L2_HR_Raster



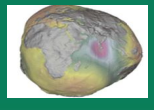
WSE (EGM2008), inundation extent, and backscatter on a regular 2-D geographic grid.

Divided in scenes



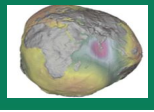


L2_HR_Raster



	Raster
File Name	SWOT_L2_HR_Raster_<DescriptorString>_<Cycle>_<Pass>_<Scene>_<BeginningDateTime>_<EndingDateTime>_<CRID>_<ProductCounter>.nc
Format	NetCDF4 (.nc)
Time	UTC
Latency from data collection	At most 45 days
File organization	One NetCDF file with 1 group containing both an UTM and geodetic lat-lon grids
Included informations	• Wse (water surface elevation) (orthometric elevation EGM2008) • water_area • water_frac • Quality flags (ice, dark_fraction…) • Sig0 (radar backscatter) • cross_track (signed distance to the nadir) • Inc (Incidence angle)

L2_HR_Raster

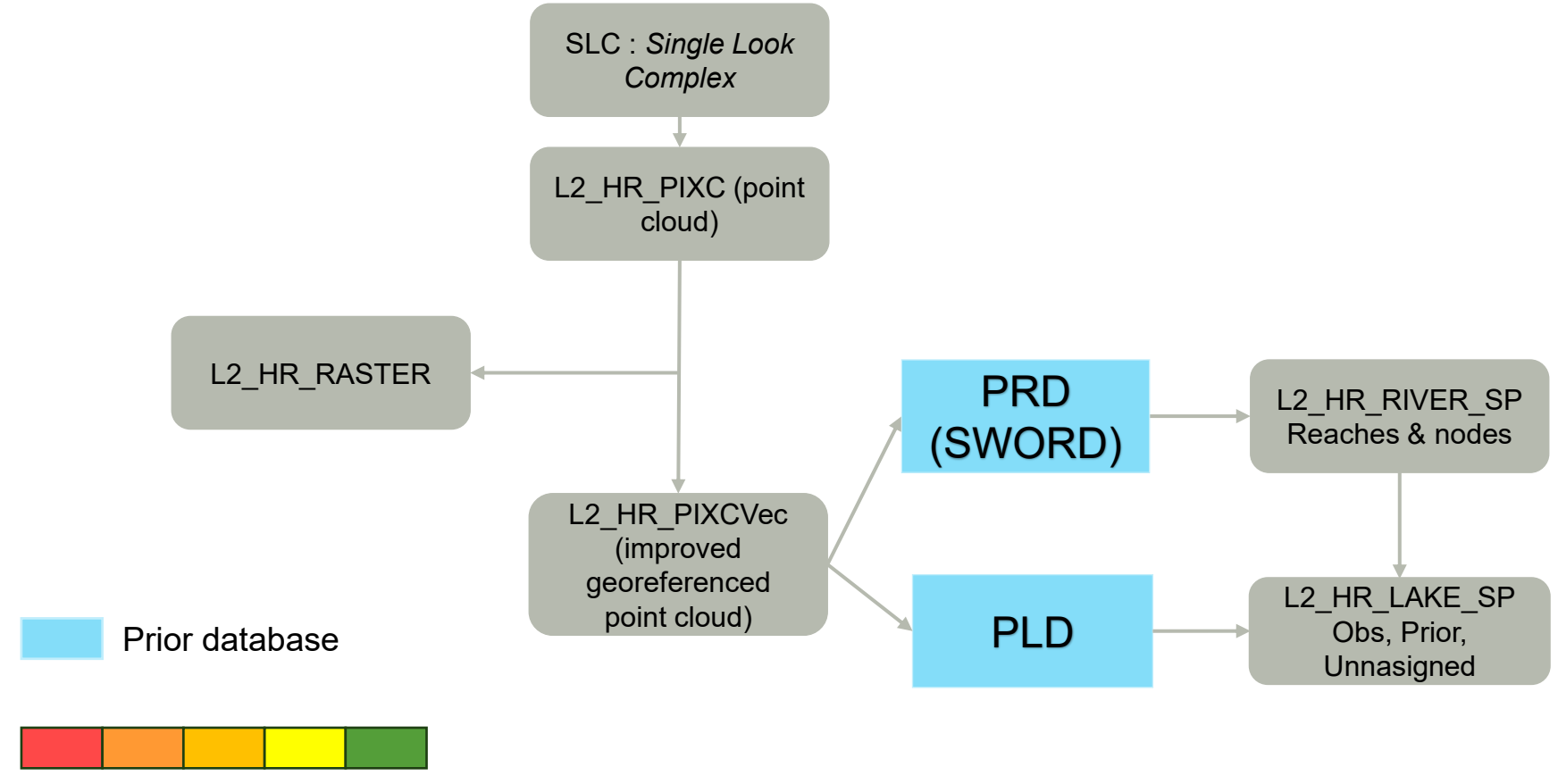


Bit (from LSB)	Decimal	Hex	wse_qual_bitwise	water_area_qual_bitwise	sig0_qual_bitwise
0	1	1			sig0_qual_suspect
1	2	2	classification_qual_suspect	classification_qual_suspect	classification_qual_suspect
2	4	4	geolocation_qual_suspect	geolocation_qual_suspect	geolocation_qual_suspect
3	8	8		water_fraction_suspect	
4	16	10			
5	32	20	large_uncert_suspect	large_uncert_suspect	large_uncert_suspect
6	64	40			
7	128	80	bright_land	bright_land	bright_land
8	256	100		low_coherence_water_suspect	low_coherence_water_suspect
9	512	200			
10	1024	400			
11	2048	800			
12	4096	1000	few_pixels	few_pixels	few_pixels
13	8192	2000	far_range_suspect	far_range_suspect	far_range_suspect
14	16384	4000	near_range_suspect	near_range_suspect	near_range_suspect
15	32768	8000			
16	65536	10000			
17	131072	20000			sig0_qual_degraded
18	262144	40000	classification_qual_degraded	classification_qual_degraded	classification_qual_degraded
19	524288	80000	geolocation_qual_degraded	geolocation_qual_degraded	geolocation_qual_degraded
20	1048576	100000			
21	2097152	200000	low_coherence_water_degraded		
22	4194304	400000			
23	8388608	800000			
24	16777216	1000000	value_bad	value_bad	value_bad
25	33554432	2000000			
26	67108864	4000000			
27	134217728	8000000			
28	268435456	10000000	no_pixels	no_pixels	no_pixels
29	536870912	20000000	outside_scene_bounds	outside_scene_bounds	outside_scene_bounds
30	1073741824	40000000	inner_swath	inner_swath	inner_swath
31	2147483648	80000000	missing_karin_data	missing_karin_data	missing_karin_data

Do not use

Additionnal data : quality flags

SWOT HR PRODUCTS



File types

PRD (SWORD)

Nodes (points)
Reachs (lines)

http://gaia.geosci.unc.edu/SWORD/

Altenau, E. H., Pavelsky, T. M., Durand, M. T., Yang, X., Frasson, R. P. D. M., & Bendezu, L. (2021). The Surface Water and Ocean Topography (SWOT) Mission River Database (SWORD): A global river network for satellite data products. *Water Resources Research*, https://doi.org/10.1029/2021WR030054

File types

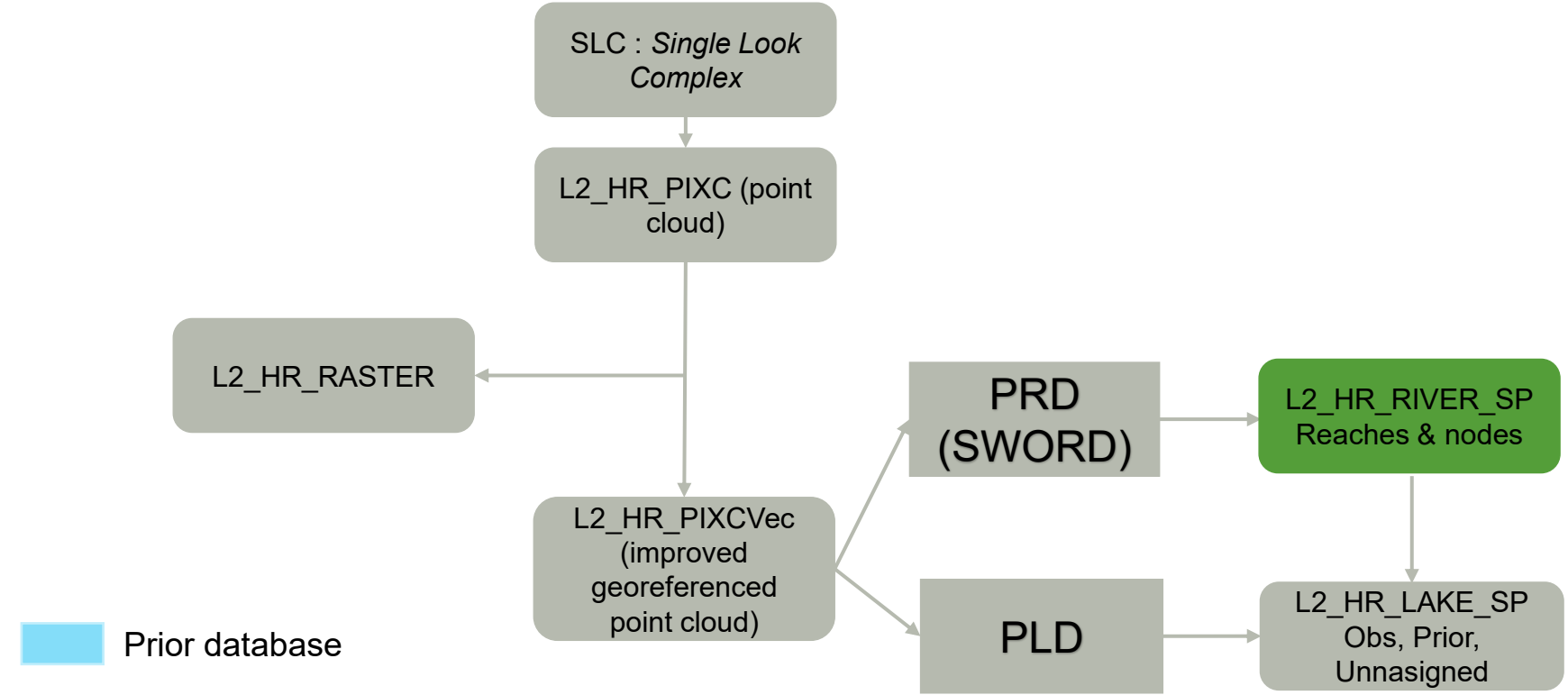
PLD

Polygones

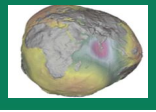
https://hydroweb.next.theia-land.fr/

Wang, J., Pottier, C., Cazals, C., Battude, M., Sheng, Y., Song, C., ... & Pavelsky, T. M. (2025). The Surface Water and Ocean Topography Mission (SWOT) Prior Lake Database (PLD): Lake Mask and Operational Auxiliaries. *Water Resources Research*, https://doi.org/10.1029/2023WR036896

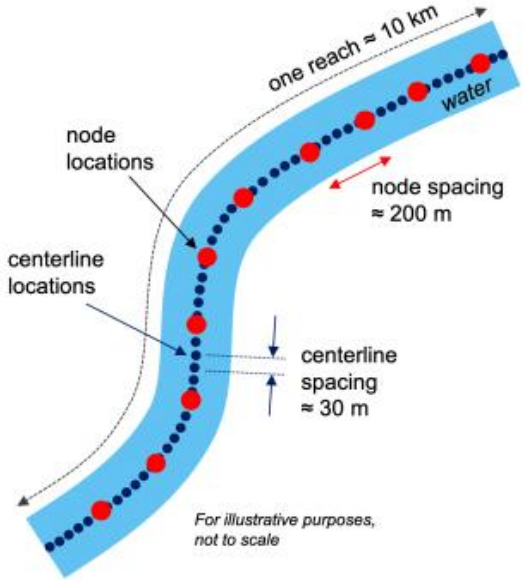
SWOT HR PRODUCTS

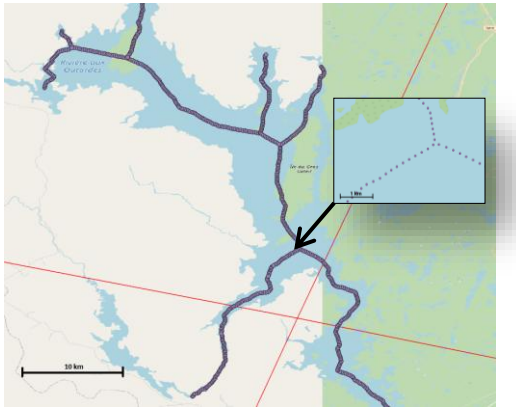


L2_HR_RiverSP



An algorithm links the right pixels to each river reach and node from the prior database, then aggregates the pixel measurements.

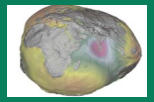




Node : points

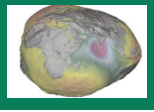
Reach : lines

L2_HR_RiverSP



	RiverSP
File Name	SWOT_L2_HR_RiverSP_<FileIdentifier>_<Cycle>_<Pass>_<Continent>_<BeginningDateTime>_<EndingDateTime>_<CRID>_<ProductCounter>.<extension>
Format	Shapefile (.shp) (and other extensions : .shx, .dbf, .prj, or .shp.xml)
Time	UTC
Latency from data collection	At most 45 days
File organization	2 Shapefiles (and their associated extensions) : Reach , Node
Included informations	• Ids (reach, nodes) • Wse (water surface elevation) (EGM2008) • Area_total • Width • Slope • xtrk_dist (distance to the nadir track) • Water_frac • Quality flags (ice, …) • geoid_hght (height for the geoid model EGM2008) • …

L2_HR_RiverSP



```
0 = good
1 = suspect - may have large errors
2 = degraded - very likely do have large errors
3 = bad -  may be nonsensicial and should be ignored
```

Prefix and suffix meaning :

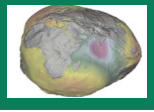
- **p_** : information taken from the PLD
- **_c** : correction
- **_f** : flag
- **_q** : quality flag
- **_u** : uncertainty (1sigma or 68th-percentile uncertainty estimates)

Bit (from LSB)	Decimal	Hex	dschg_q_b / dschg_gq_b	reach_q	node_q	p_low_slp	ice_clim_f	ice_dyn_f	partial_f	xovr_cal_q
0	1	1	reach_qual_suspect	good	good	low_slope_false	no_ice_cover	no_ice_cover	covered	good
1	2	2	big_slope_unc	suspect	suspect	low_slope_true	uncertain_ice_cover	partial_ice_cover	partially_covered	suspect
2	4	4		degraded	degraded		full_ice_cover	full_ice_cover		bad
3	8	8	metro_dxa_bad	bad	bad					
4	16	10	bam_dxa_bad							
5	32	20	hivdi_dxa_bad							
6	64	40	momma_b_gt_momma_h							
7	128	80	sads_dxa_bad							
8	256	100	sic4dvar_dxa_BAD							
9	512	200								
10	1024	400								
11	2048	800	incomplete_consensus							
12	4096	1000								
13	8192	2000								
14	16384	4000								
15	32768	8000								
16	65536	10000								
17	131072	20000								
18	262144	40000	reach_qual_degraded							
19	524288	80000								
20	1048576	100000								
21	2097152	200000								
22	4194304	400000	reach_qual_bad							
23	8388608	800000	no_discharge_outputs							
24	16777216	1000000	negative_slope							
25	33554432	2000000								
26	67108864	4000000								
27	134217728	8000000								
28	268435456	10000000								

Do not use

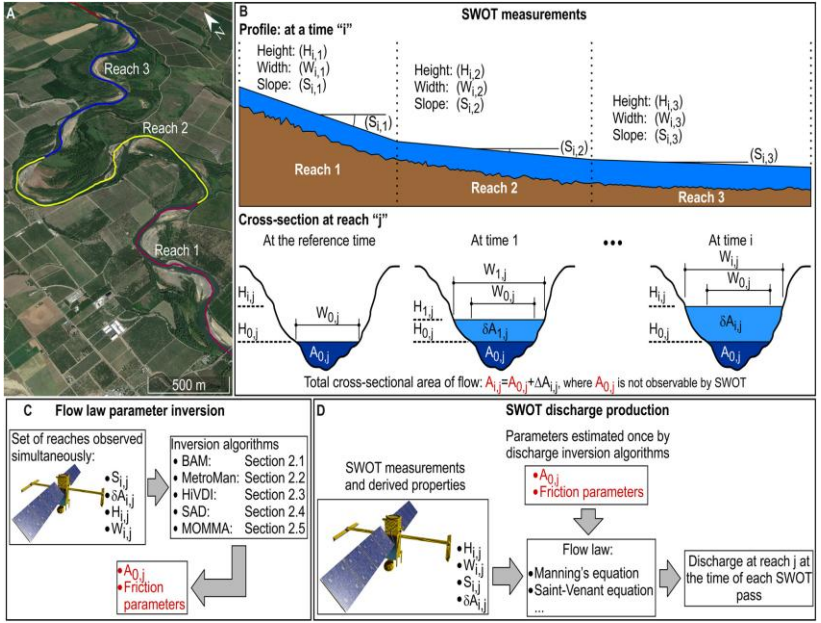
Additionnal data : quality flags

L2_HR_RiverSP



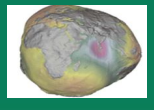
The L2_HR_RiverSP product will includes discharge estimates.

- The SWOT mission measure river width, water surface elevation, and slope.
- These measurements make it possible to estimate river discharge using simple hydraulic relationships.



Frasson et al. (2021). Exploring the factors controlling the error characteristics of the Surface Water and Ocean Topography mission discharge estimates. *Water Resources Research*, https://doi.org/10.1029/2020WR028519

L2_HR_RiverSP

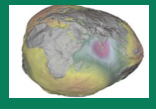


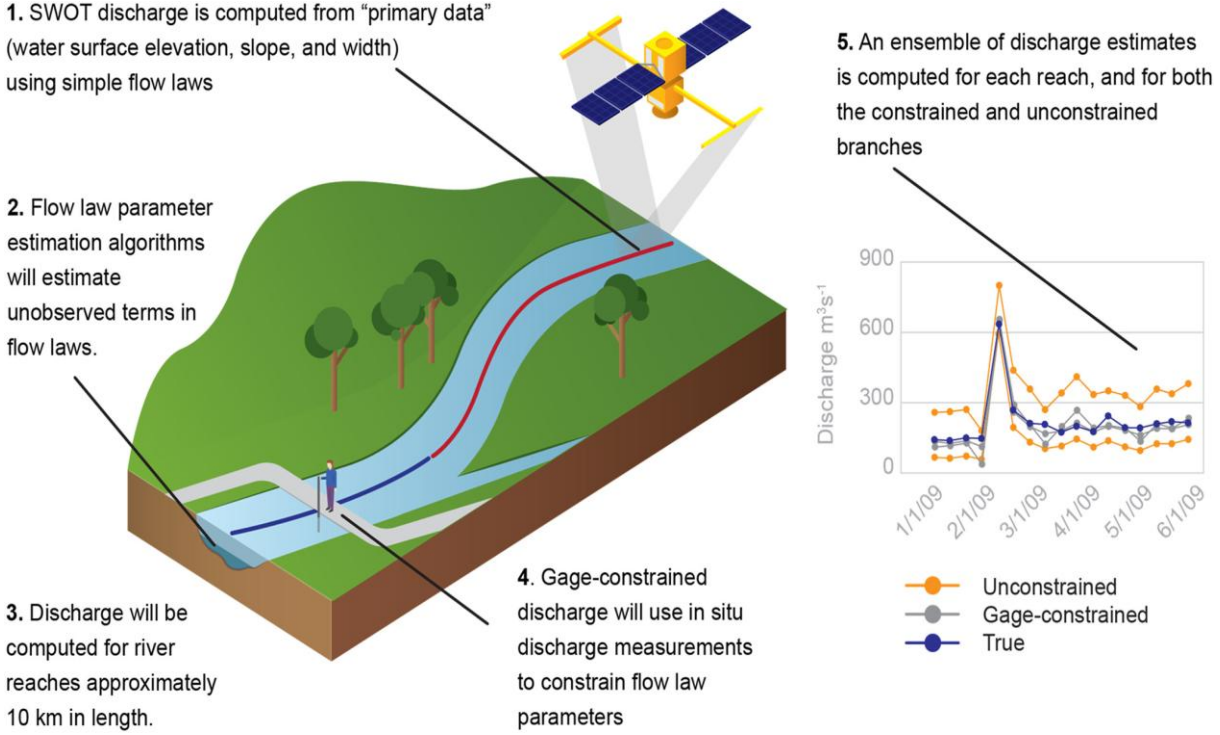
Several algorithms are used to estimate discharge :

1. Metropolis-Manning (MetroMan) [1]
2. Bayesian AMHG-Manning (BAM) [2]
3. Hierarchical Variational Discharge Inference (HiVDI) [3]
4. Modified Manning Method Algorithm (MOMMA) [4]
5. SWOT Assimilated DiScharge (SADS) [5]
6. SIC 4D Var [6]

[1] Durand et al. "Estimating reachaveraged discharge for the River Severn from measurements of river water surface elevation and slope," Journal of Hydrology, 2014, https://doi.org/10.1016/j.jhydrol.2013.12.050
[2] Hagemann et al., "BAM: Bayesian AMHG-Manning Inference of Discharge Using Remotely Sensed Stream Width, Slope, and Height," Water Resources Research, 2017, https://doi.org/10.1002/2017WR021626
[3] Garambois et al., "Variational estimation of effective channel and ungauged anabranching river discharge from multi-satellite water heights of different spatial sparsity," Journal of Hydrology, 2020, https://doi.org/10.1016/j.jhydrol.2019.124409
[4] Bjerklie et al., "Satellite Remote Sensing Estimation of River Discharge: Application to the Yukon River Alaska," Journal of Hydrology, 2018, https://doi.org/10.1016/j.jhydrol.2018.04.005
[5] Andreadis et al., "Constraining the assimilation of SWOT observations with hydraulic geometry relations," Water Resources Research, 2020, https://doi.org/10.1029/2019WR026611
[6] Oubanas et al., "Discharge Estimation in Ungauged Basins Through Variational Data Assimilation: The Potential of the SWOT Mission," Water Resources Research, 2018; https://doi.org/10.1002/2017wr021735

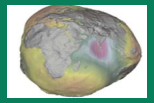
L2_HR_RiverSP





Durand et al. (2023). A framework for estimating global river discharge from the surface water and ocean topography satellite mission. Water Resources Research, https://doi.org/10.1029/2021WR031614

L2_HR_RiverSP

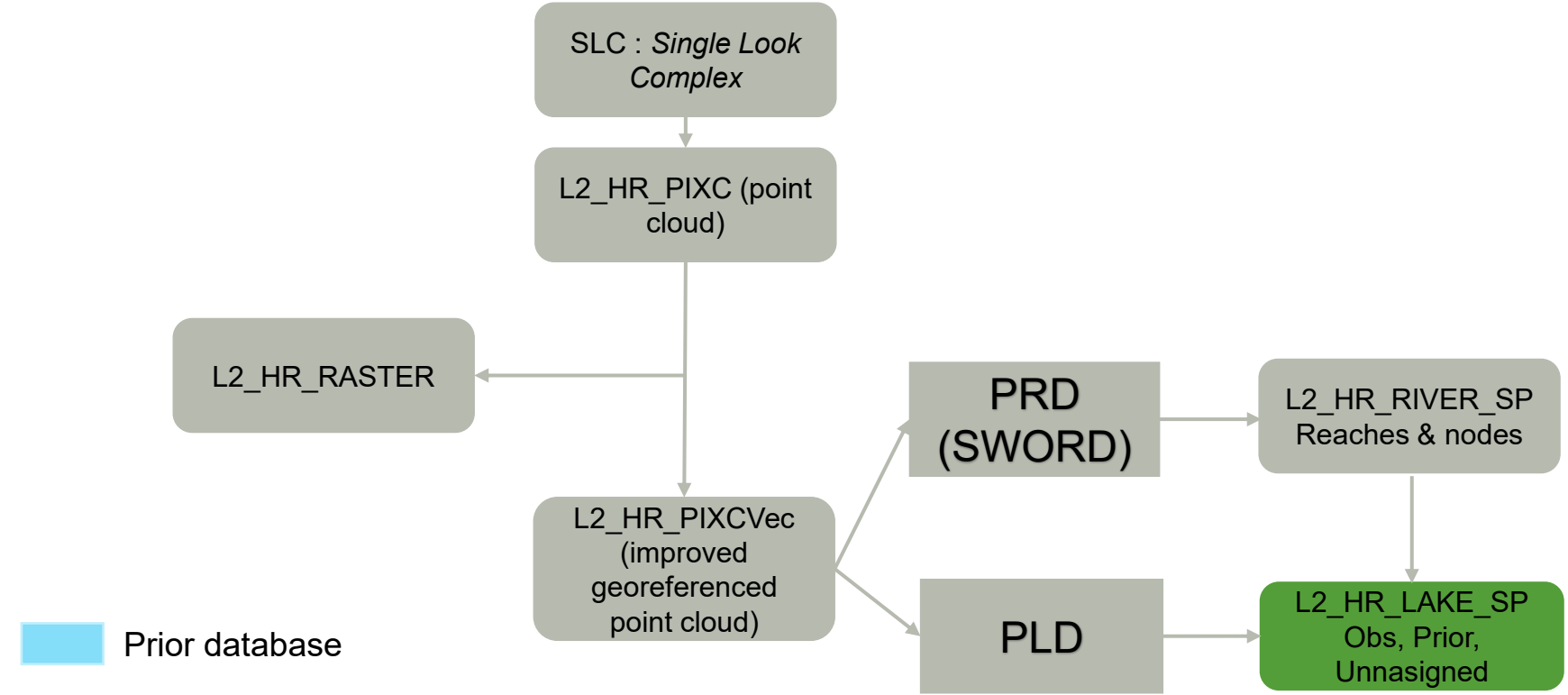


“Note that discharge estimates are not provided in the PID0 and PGD0 products. They will be provided after the reprocessing of Version D products is complete. The reprocessed Version D products will be used to compute discharge parameters that are consistent with the Version D products.”

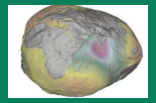
An L4 version has been available since December 1, 2025.

https://podaac.jpl.nasa.gov/dataset/SWOT_L4_HR_DAWG_SOS_DISCHARGE_V3

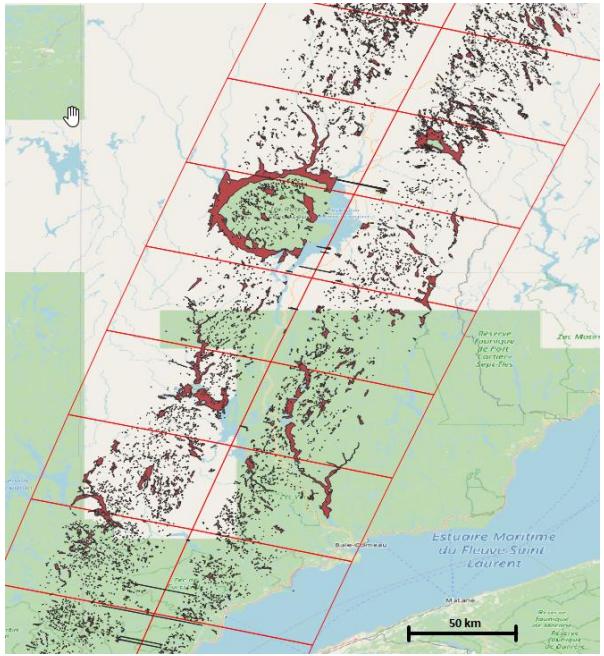
SWOT HR PRODUCTS



L2_HR_LakeSP



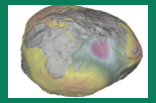
An algorithm selects the PIXC pixels for each lake in the database and averages the data.



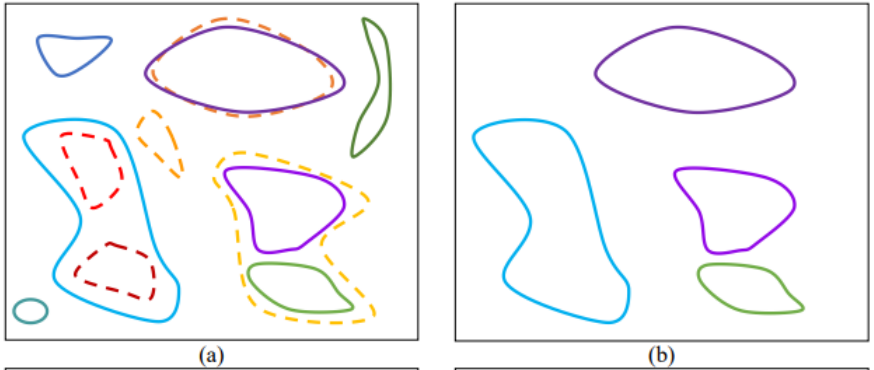
Three types of file :
Obs
Prior
Unassigned

We recommend to used this one!

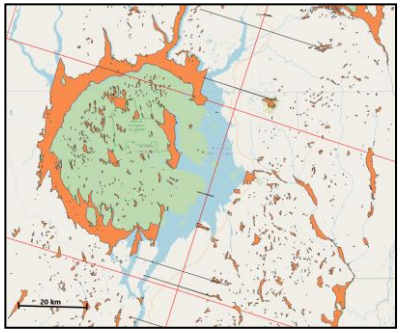
L2_HR_LakeSP

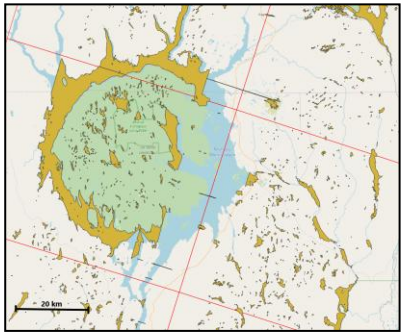


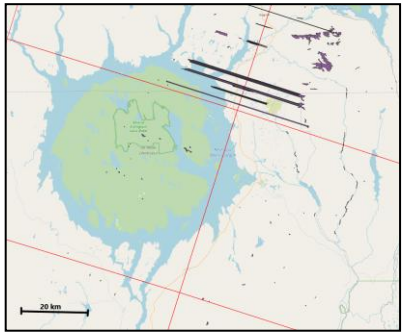
Obs is what we see, Prior is what we expect, and Unassigned is what doesn't fit the database



(a) All
(b) Obs
(c) Prior
(d) Unassigned

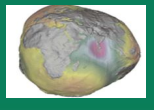






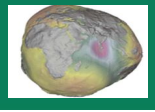
(a) All observed features (solid polygons) and PLD lakes (dashed polygons) in an area. Different colors = different observation ids or PLD ids.
(b) Polygons of the observation-oriented lake shapefile.
(c) Polygons of the PLD-oriented lake shapefile (where the unobserved PLD lake is an empty shape).
(d) Polygons of the observation-oriented unassigned features shapefile.

L2_HR_LakeSP



	LakeSP
File Name	SWOT_L2_HR_LakeSP_<FileIdentifier>_<Cycle>_<Pass>_<Continent>_<BeginningDateTime>_<EndingDateTime>_<CRID>_<ProductCounter>.<extension>
Format	Shapefile (.shp) (and other extensions : .shx, .dbf, .prj, or .shp.xml)
Time	UTC
Latency from data collection	At most 45 days
File organization	3 Shapefiles (and their associated extensions) : Obs (observation-oriented lake shapefile), Prior (PLD-oriented lake shapefile), Unassigned (unassigned features)
Included informations	• lds (lake, obs, reservoir, name, …) • Wse (water surface elevation) • area_total • xtrk_dist (distance to the nadir track) • Water_frac • Quality flags (ice, …) • geoid_hght (height for the geoid model EGM2008) • …

L2_HR_LakeSP



PIC2 and later version

Bit	Decimal	Hex	Flag meaning
0	1	1	classification_qual_suspect
1	2	2	geolocation_qual_suspect
2	4	4	
3	8	8	few_open_water_suspect
4	16	10	
5	32	20	wse_std_suspect
6	64	40	diff_from_pld_area_suspect
7	128	80	
8	256	100	xovr_cal_suspect
9	512	200	
10	1024	400	no_prior_suspect
11	2048	800	water_false_detection_rate_suspect
12	4096	1000	
13	8192	2000	
14	16384	4000	
15	32768	8000	classification_qual_degraded
16	65536	10000	geolocation_qual_degraded
17	131072	20000	
18	262144	40000	low_coh_degraded
19	524288	80000	specular_ringing_degraded
20	1048576	100000	
21	2097152	200000	
22	4194304	400000	
23	8388608	800000	low_coh_bad
24	16777216	1000000	xovr_cal_bad
25	33554432	2000000	
26	67108864	4000000	specular_ringing_bad
27	134217728	8000000	
28	268435456	10000000	

Do not use

Prefix and suffix meaning :

- **p_** : information taken from the PLD
- **_c** : correction
- **_f** : flag
- **_q** : quality flag
- **_u** : uncertainty
- **_std** : standard deviation within the lake

PIC0

Bit (from LSB)	Decimal	Hex	Quality_f	ice_clim_f	ice_dyn_f	partial_f	xovr_cal_q
0	1	1	good	no_ice_cover	no_ice_cover	covered	good
1	2	2	bad	uncertain_ice_cover	partial_ice_cover	partially_covered	suspect
2	4	4		full_ice_cover	full_ice_cover		bad

Additionnal data : quality flags

SWOT reference system

	Station (Quebec)	Station (Canada, NB, NS, NL)	SWOT WSE
Datum	NAD83 SRCS	NAD83 SRCS	ITRF2014
Epoch	1997	2010	Acquisition date
Geoid	CGVD1928 (HT2)	CGVD2013	EGM08
Tide	Tide-free	Tide-free	Mean-tide

To compare SWOT data with ground data, like hydrometric station, we need to **convert them in the same reference system**.

SWOT reference system

SWOT defines ellipsoidal height (h) as “height” and orthometric height (geoid, H) as “WSE.” The general conversion equation is:

$$H = h - N$$

The geoid_hght field in SWOT products includes the EGM08mt geoid undulation (N). This geoid is mean-tide, meaning it includes the permanent tide. Therefore, it is possible to convert SWOT WSE to height using the equation:

$$height_{SWOT} = WSE_{SWOT} + geoid\_hght$$

The resulting height is tide-free because geoid_hght includes the permanent tide correction. If an EGM08 geoid is used, for example with GPS-H, it is also tide-free, so the permanent tide must likewise be accounted for.

$height_{SWOT}$ must then be converted to to the station ellipsoidal height ($h_{ITRF2014\_now}$ to $h_{NAD83SCRS\_2010}$), using TRX or the csrsppy Python package.

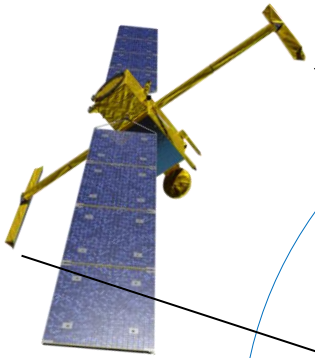
Finally, the station geoid is removed (CGVD2013).

$$H_{station} = h_{NAD83SCRS\_1997} - N_{CGVD2013}$$

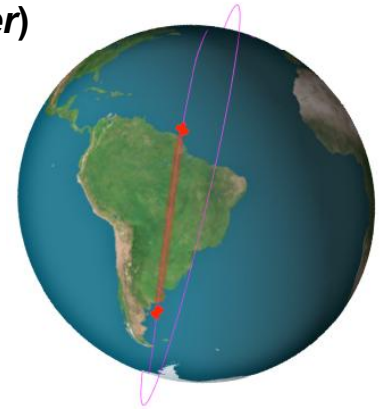
DON’T WORRY, THERE IS A PYTHON CODE THAT DOES ALL OF THIS AUTOMATICALLY!

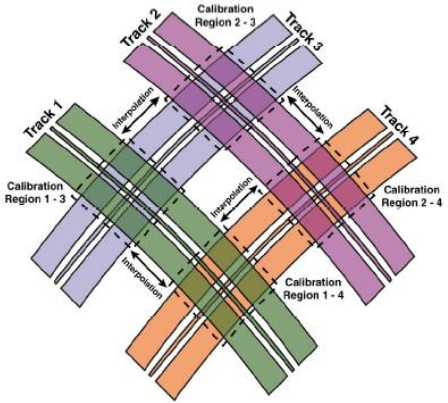
C) CHALLENGES AND OPPORTUNITIES

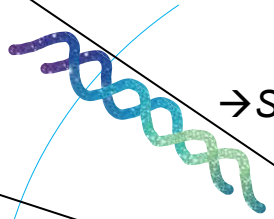
SWOT ERROR BUDGET



→**Satellite's position (*cross-over*)**





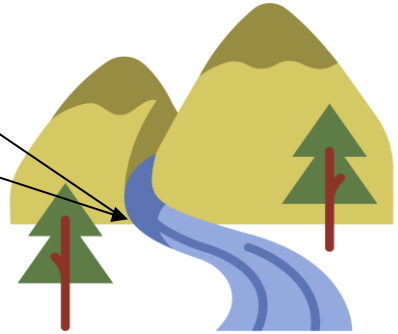


→*Speckle*

Ionosphere

→Ionosphere and troposphere

Troposphere



→ *Layover*

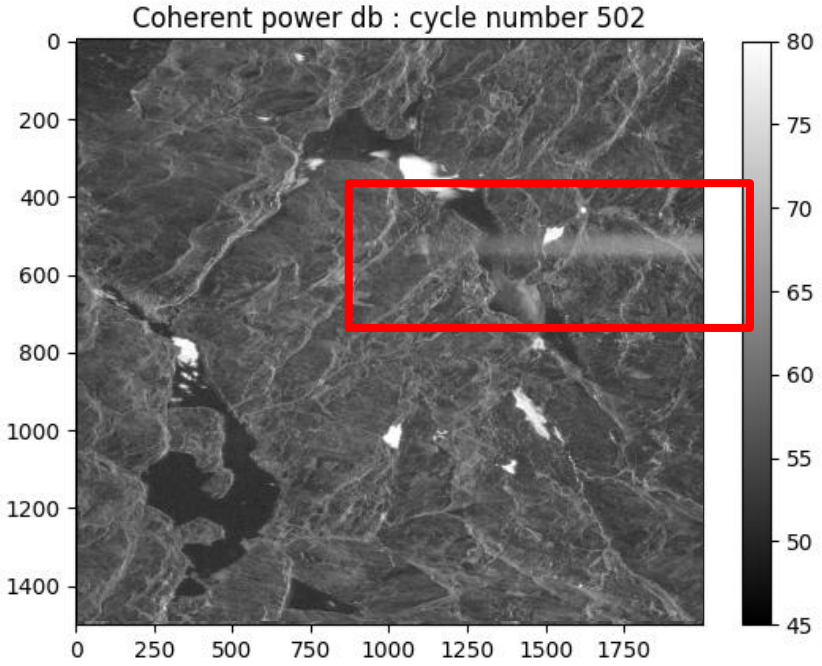
→*Dark Water* : no signal return (light wind or attenuation)

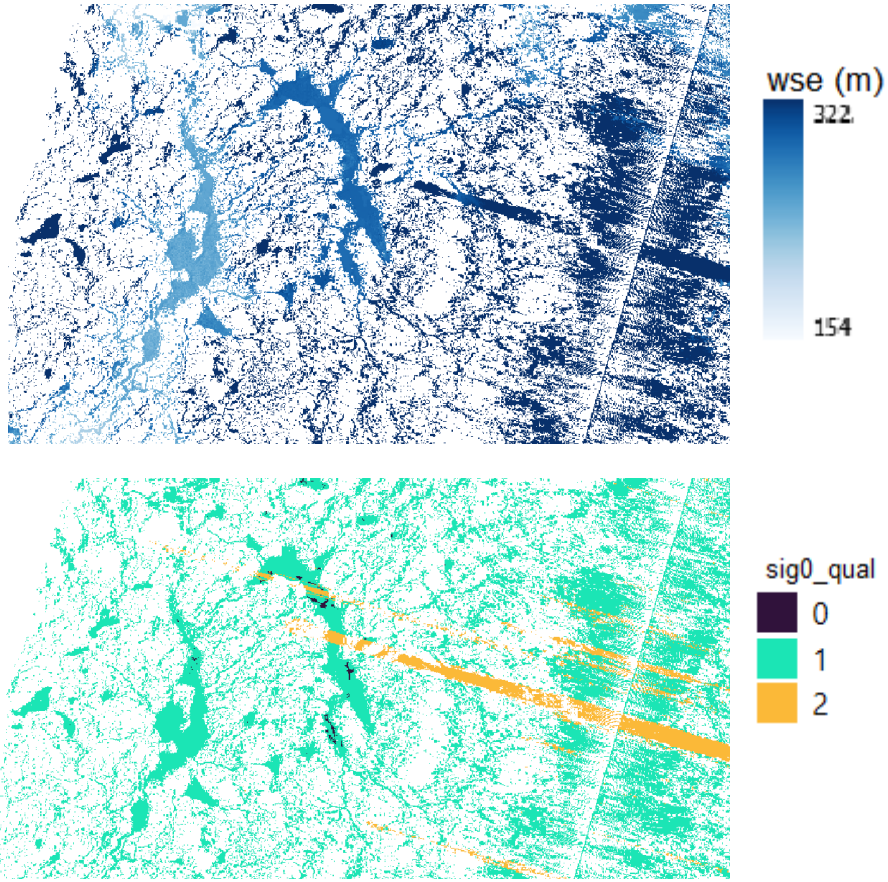
→ Classification

→ Geolocation

Challenges

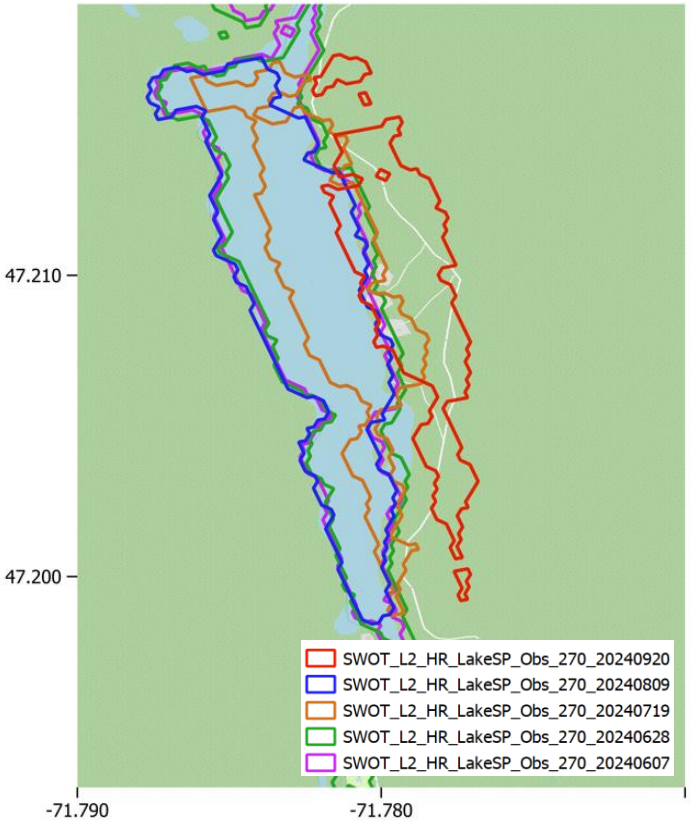
Specular ringing





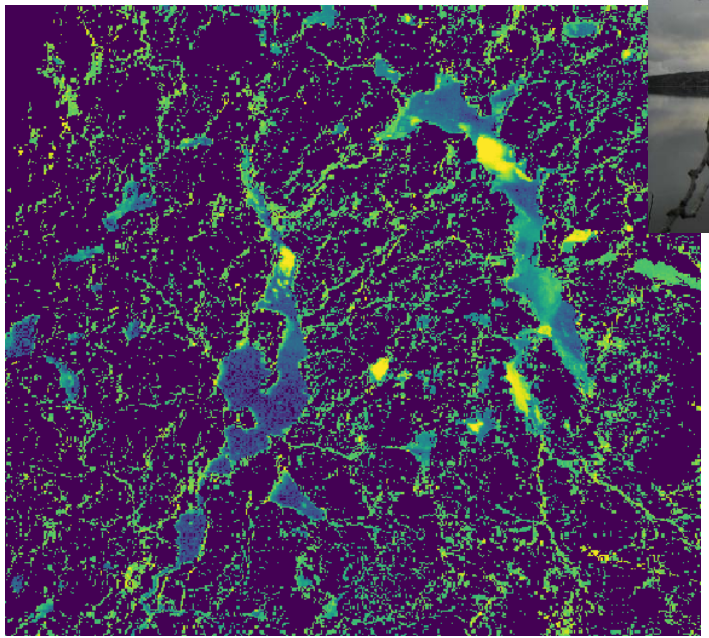
Challenges

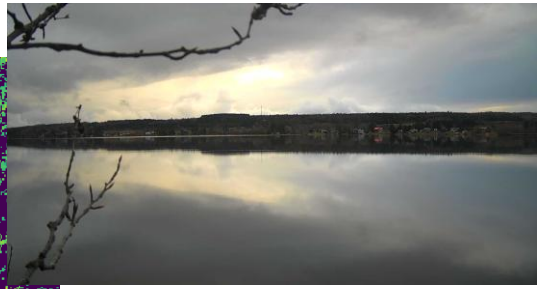
Geolocalisation



Challenges

Dark Water





Caution: the PIC0 version presents several issues in areas with dark water—see the Release Notes.

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

Challenges

Prior lake database (PLD)

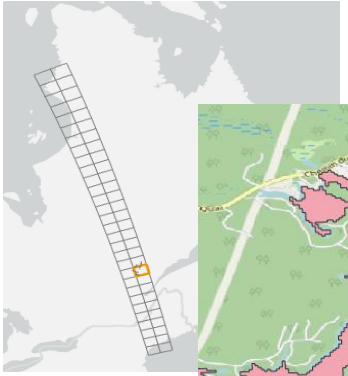
Témiscaming lake in PLD

Modified Témiscaming lake

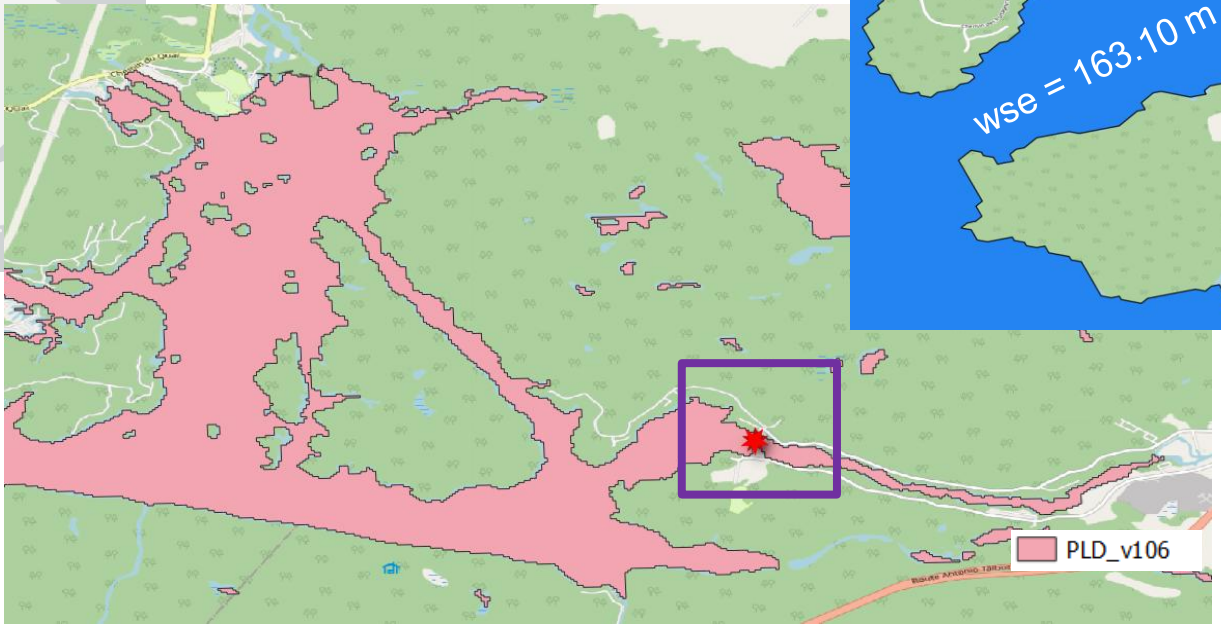
Challenges

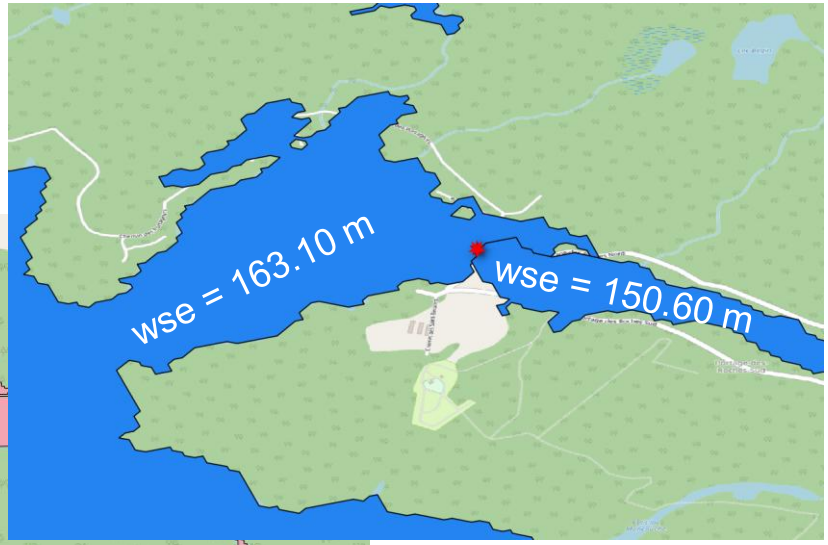
Prior lake database (PLD)

Pass 548



Lake Kénogami



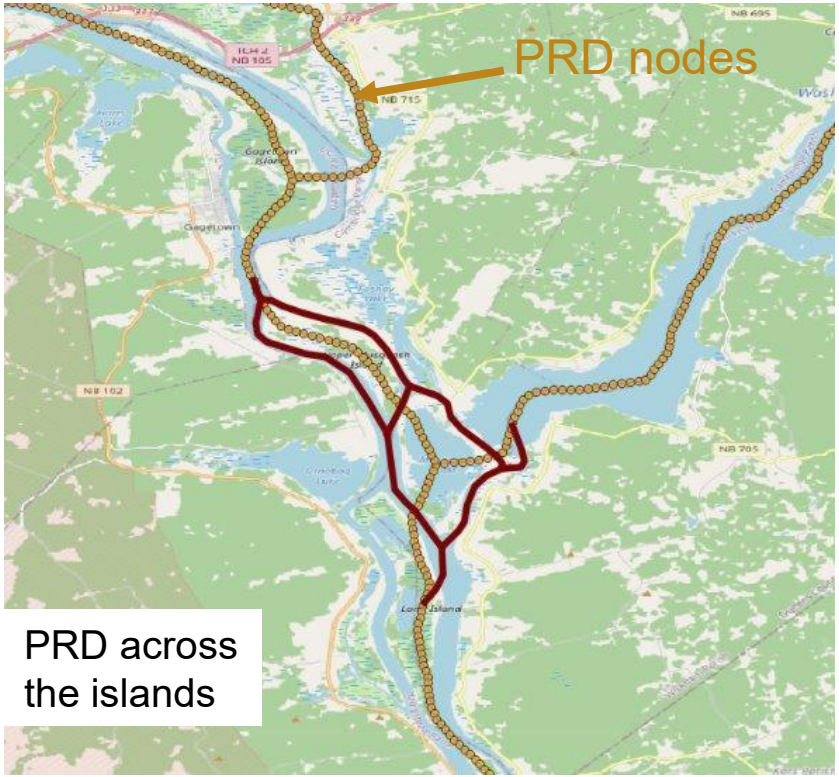


LakeSP_Obs

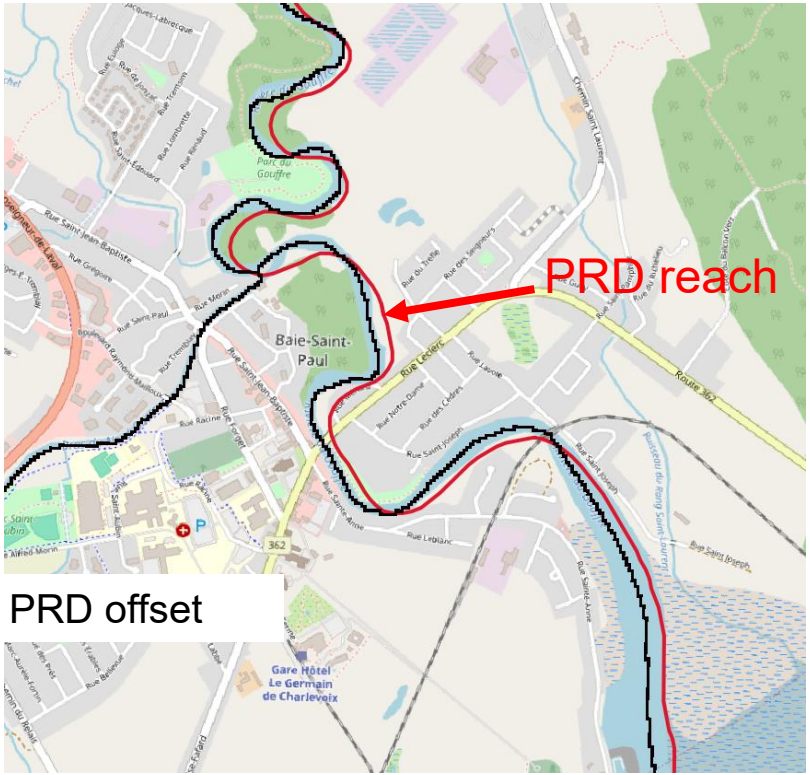
Dam

Challenges

Prior River Database (PRD, SWORD)



PRD across the islands

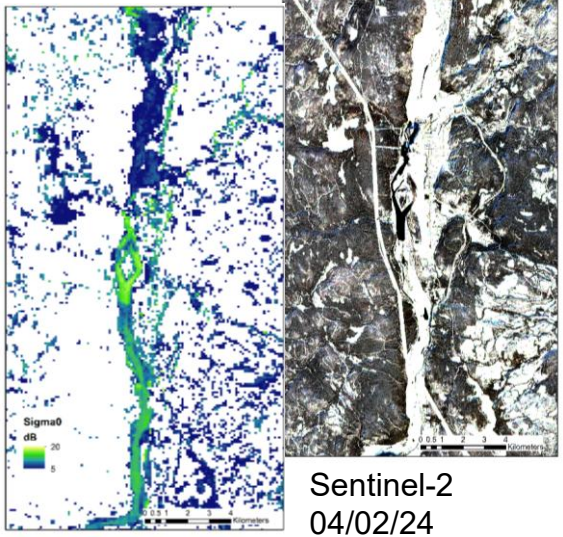


PRD offset

Challenges/opportunities

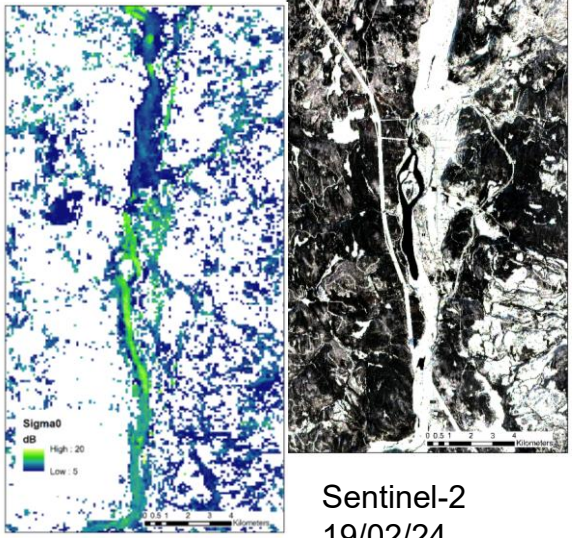
River ice

SWOT – 27/01/24



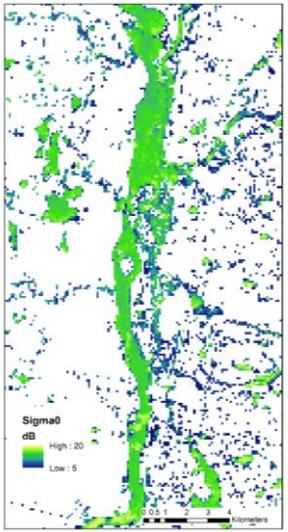
Sentinel-2
04/02/24

SWOT – 17/02/24



Sentinel-2
19/02/24

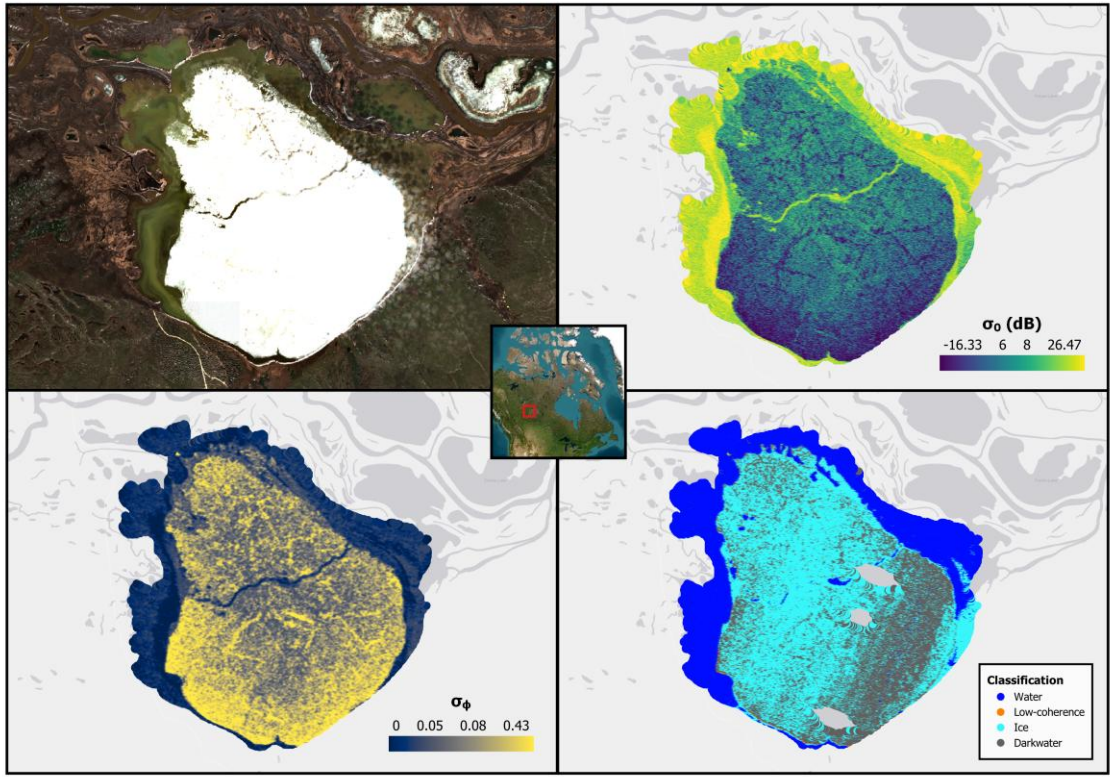
SWOT – 19/04/24



Sentinel-2
09/04/24

Challenges/opportunities

Lake ice



Challenges/opportunities

How exactly does the signal interact with ice?

A study underway


TIME FOR A
BREAK

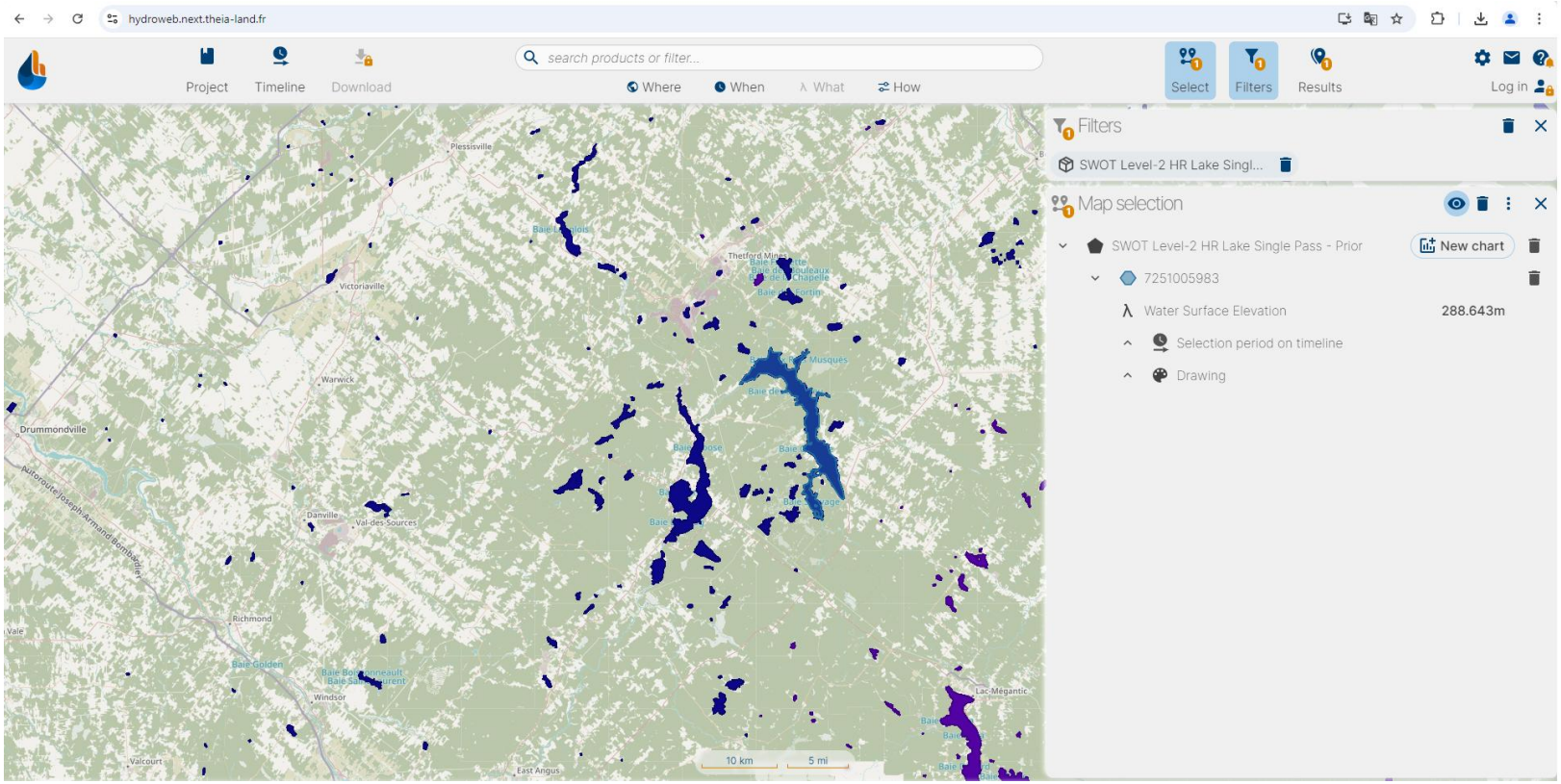
WORKSHOP

PART I

WHAT YOU'LL NEED

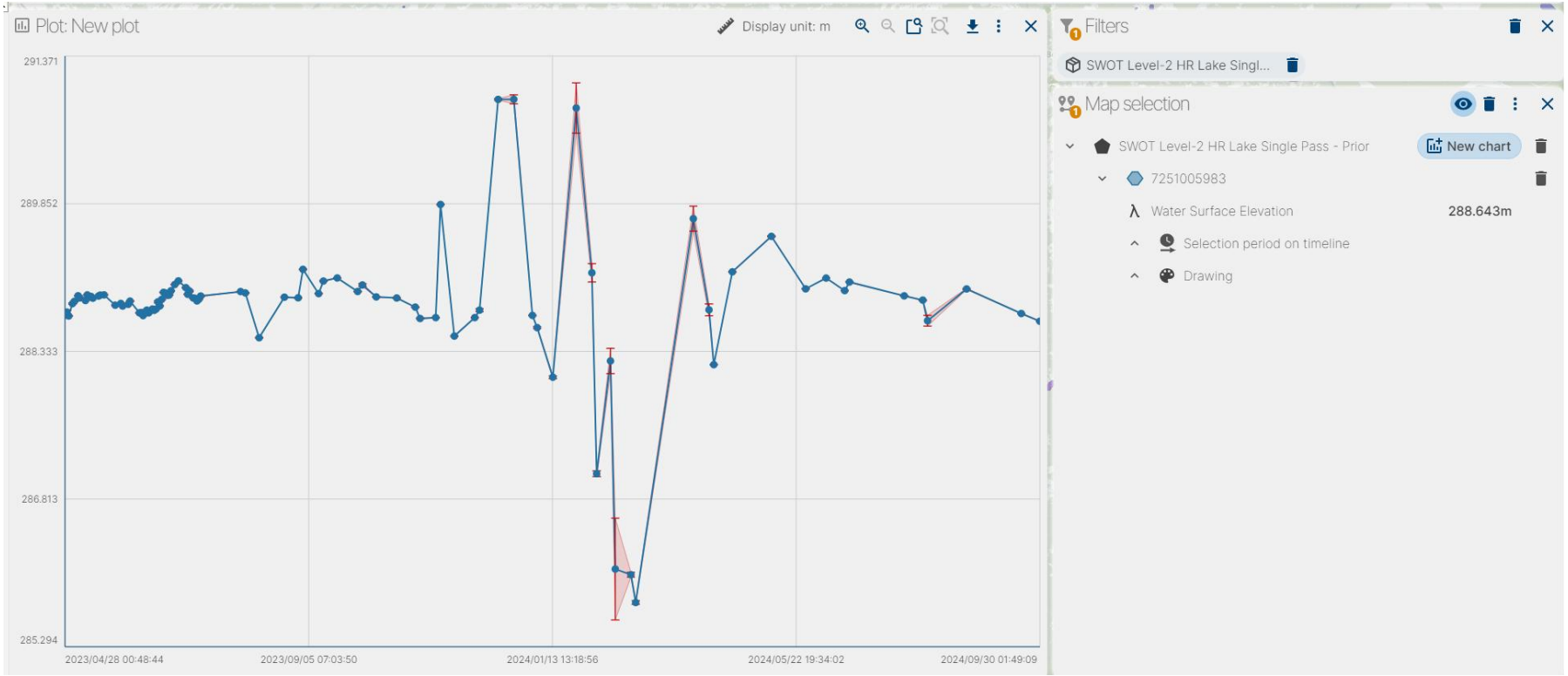
- EARTHDATA ACCOUNT
- GOOGLE COLAB
- QGIS

Data access



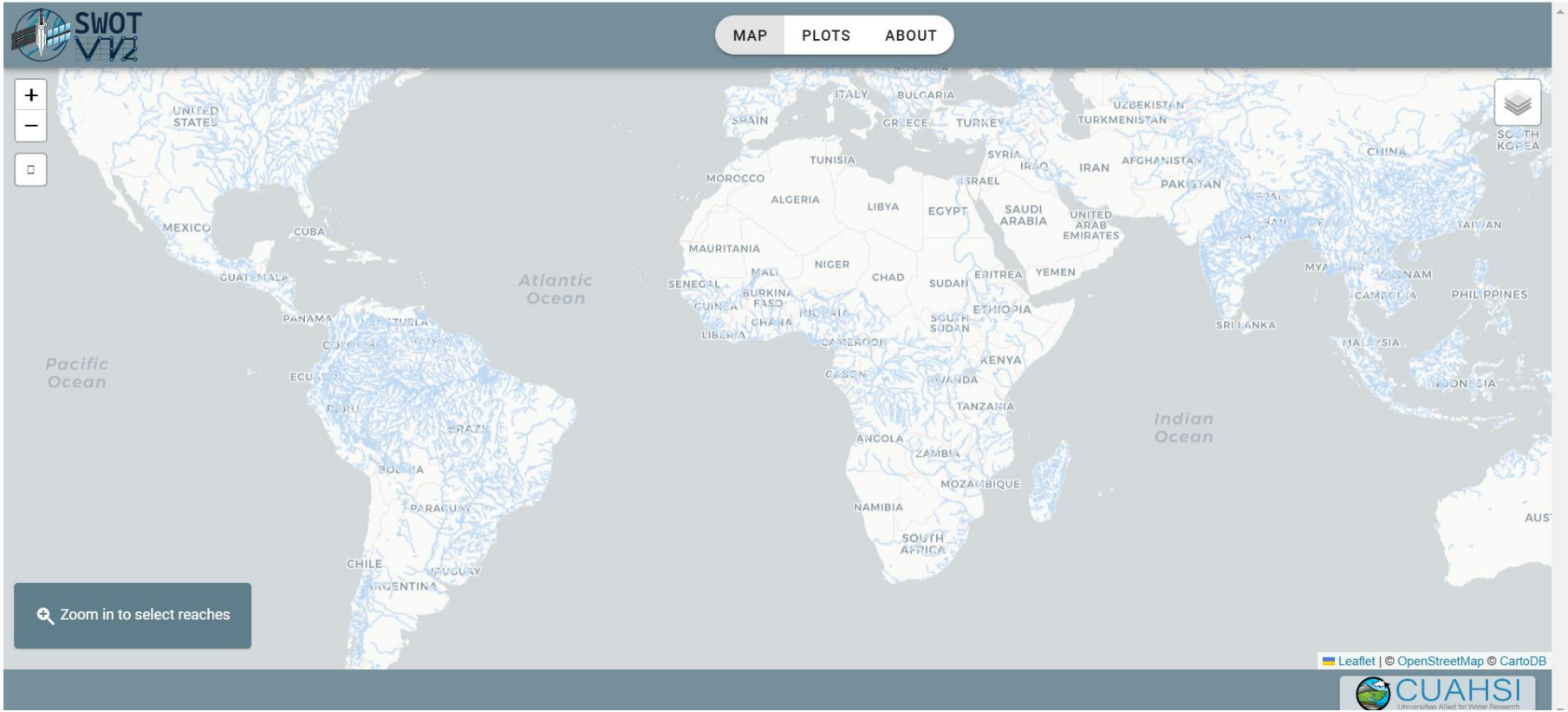
https://hydroweb.next.theia-land.fr/

Data access



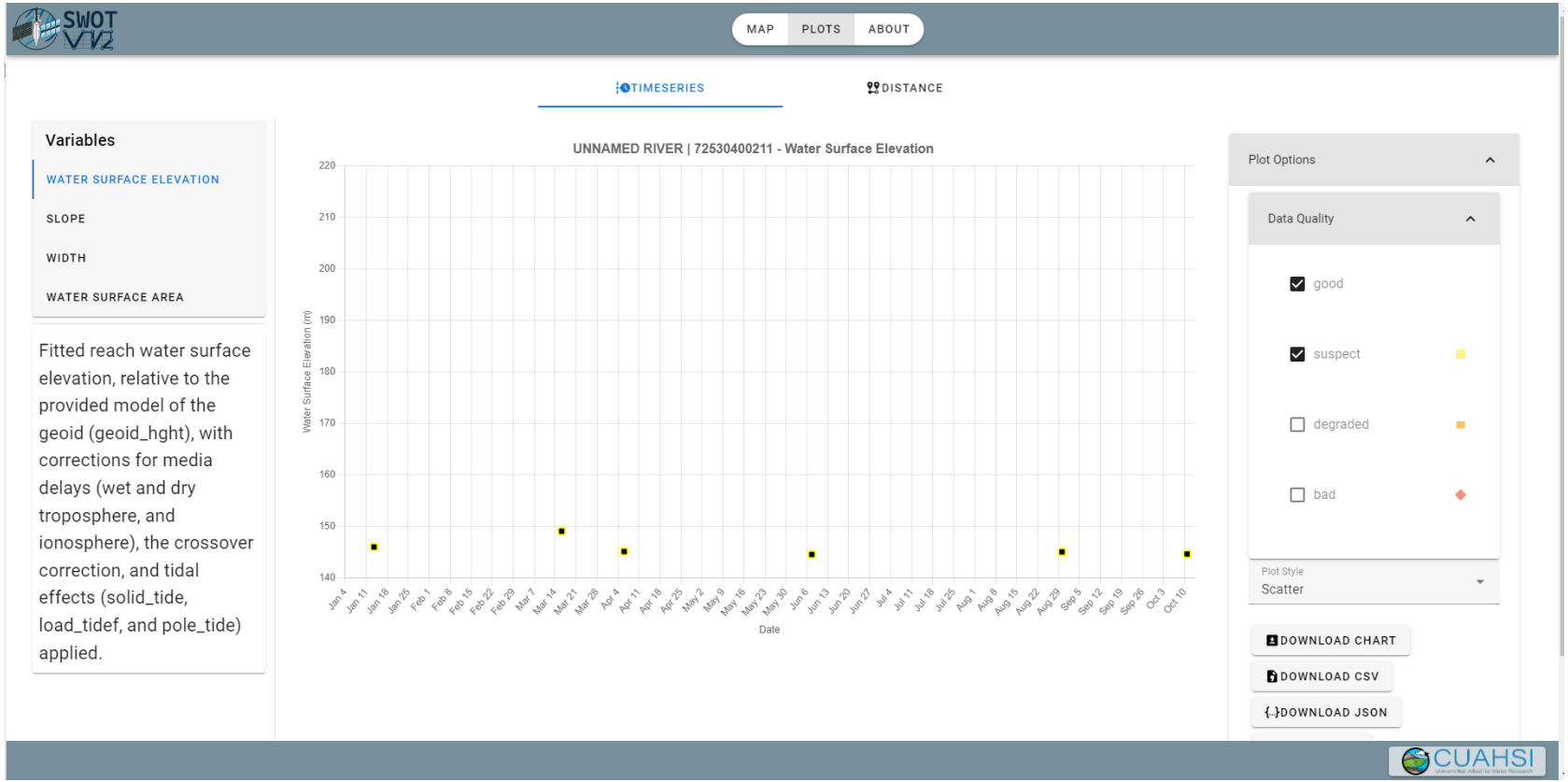
https://hydroweb.next.theia-land.fr/

Data access



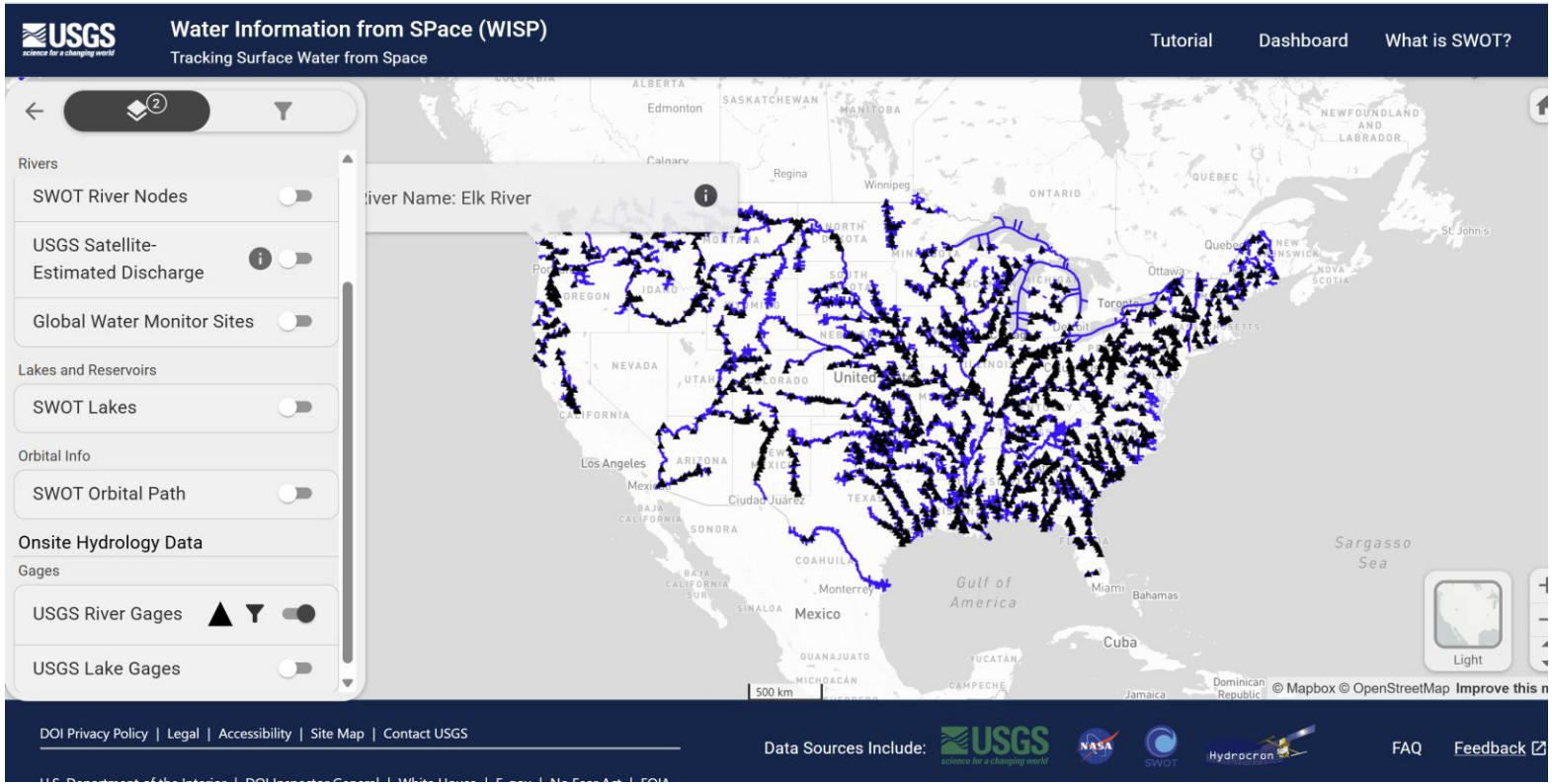
https://swotvis.cuahsi.io/#/

Data access



https://swotvis.cuahsi.io/#/

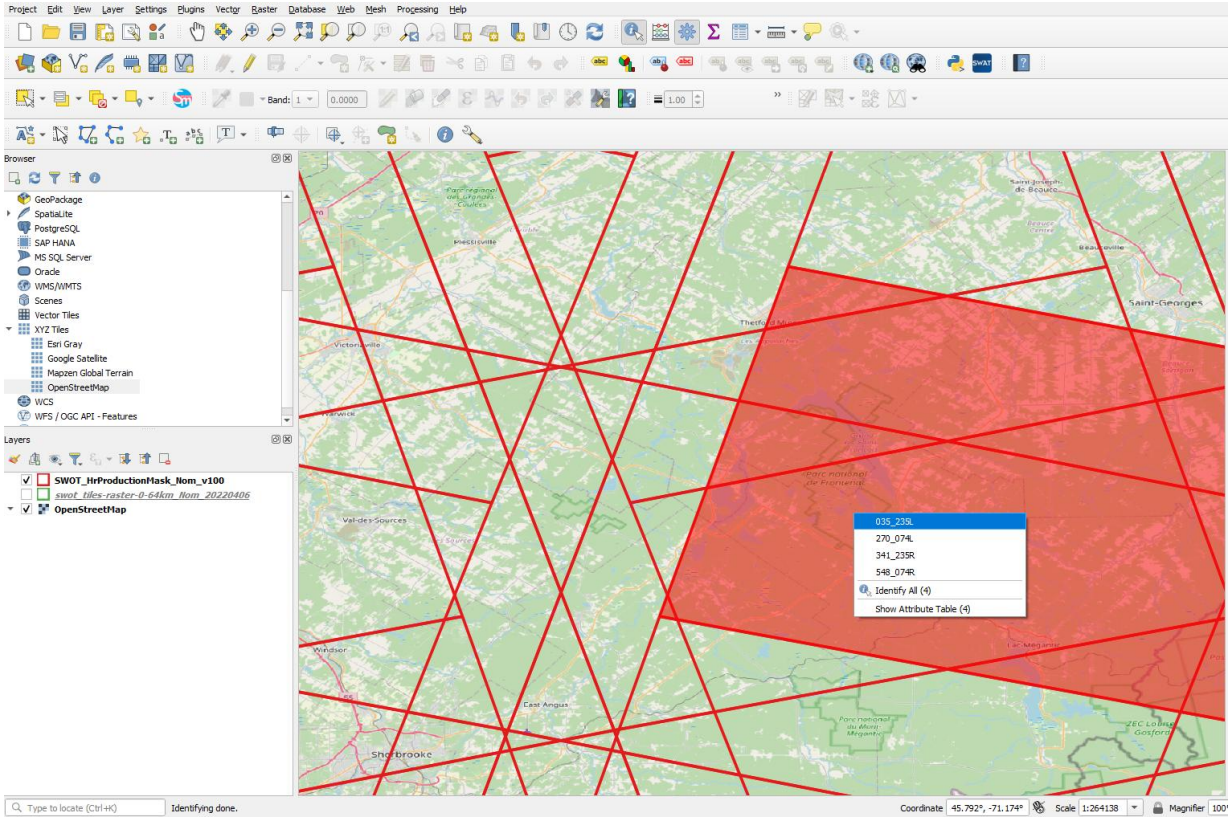
Data access



https://apps.usgs.gov/wisp

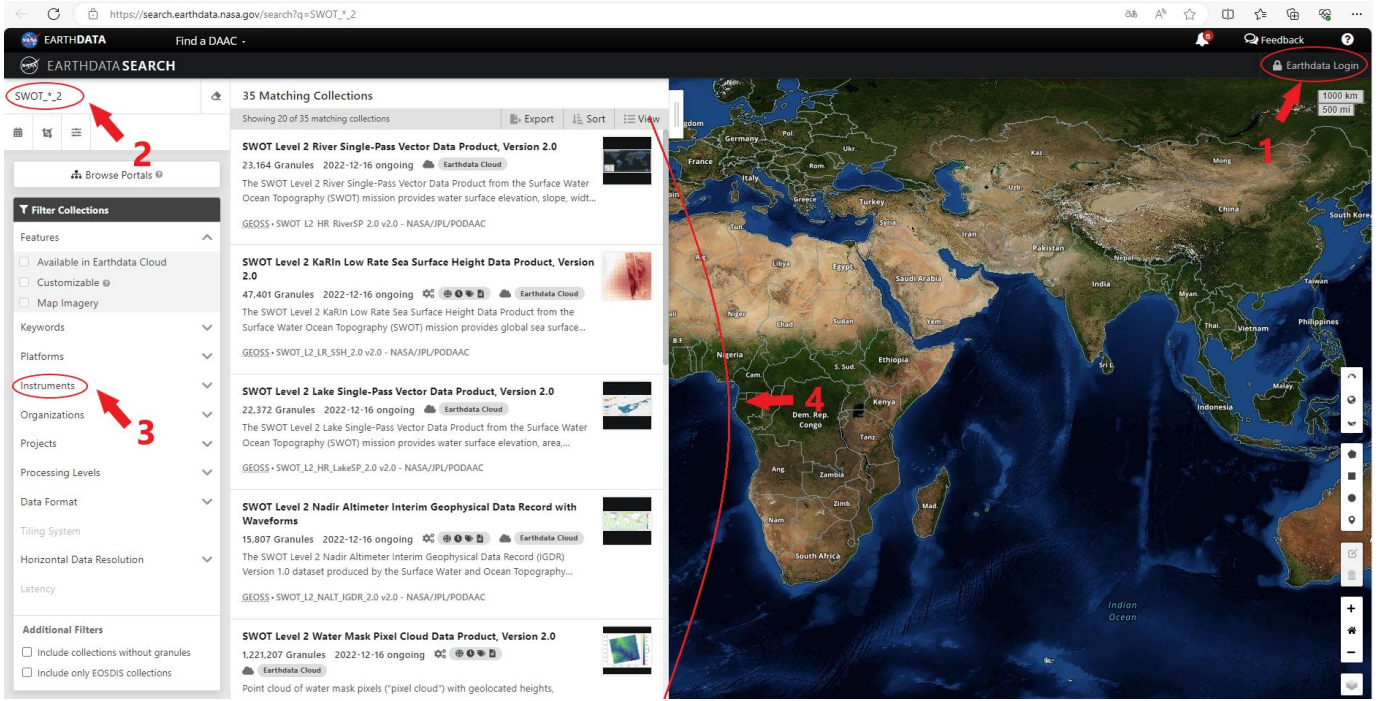
Data access

- Find the tile or scene : https://github.com/sfoucher/SWOT-Canada/tree/main/Data



Data access

Earthdata Search : https://search.earthdata.nasa.gov/search?q=SWOT_L2_HR

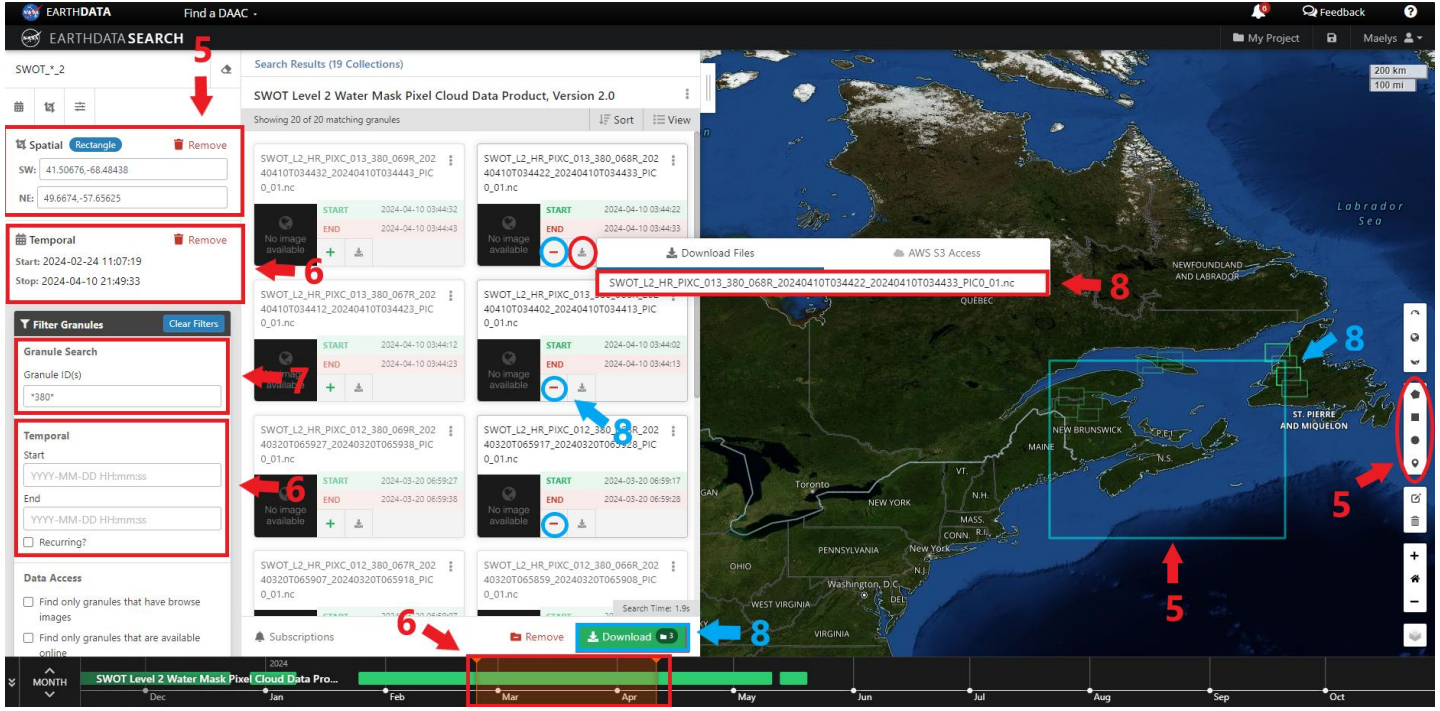


1 - Create an account and log in
2 - Type « SWOT_L2_HR » in the search bar
3 - Choose KaRIn Instrument
4 – Choose the data product you want to extract

This method enables only extracting files from the same data product. For extractions of many products, use the next method with code.

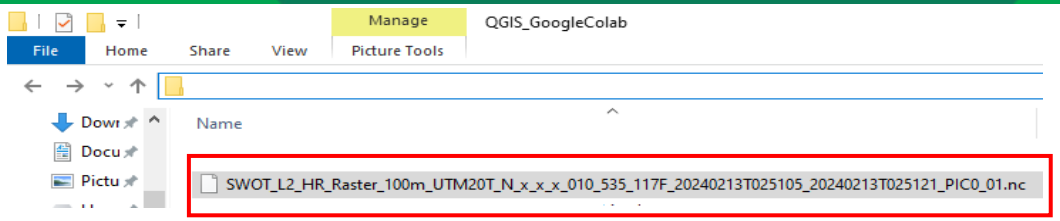
Data access

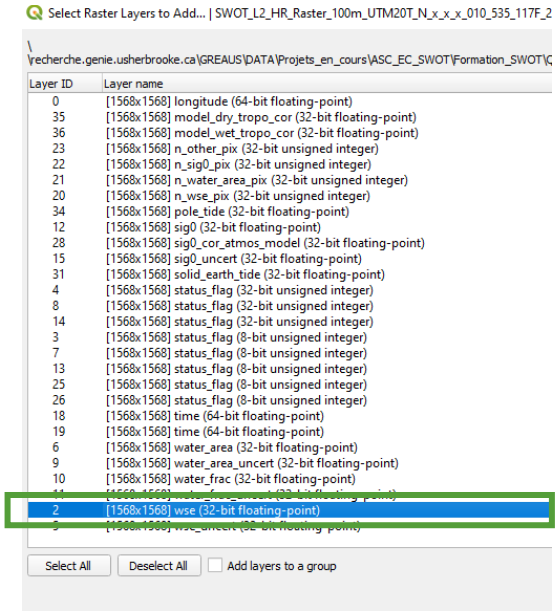
Earthdata Search : [Earthdata Search | Earthdata Search (nasa.gov)]

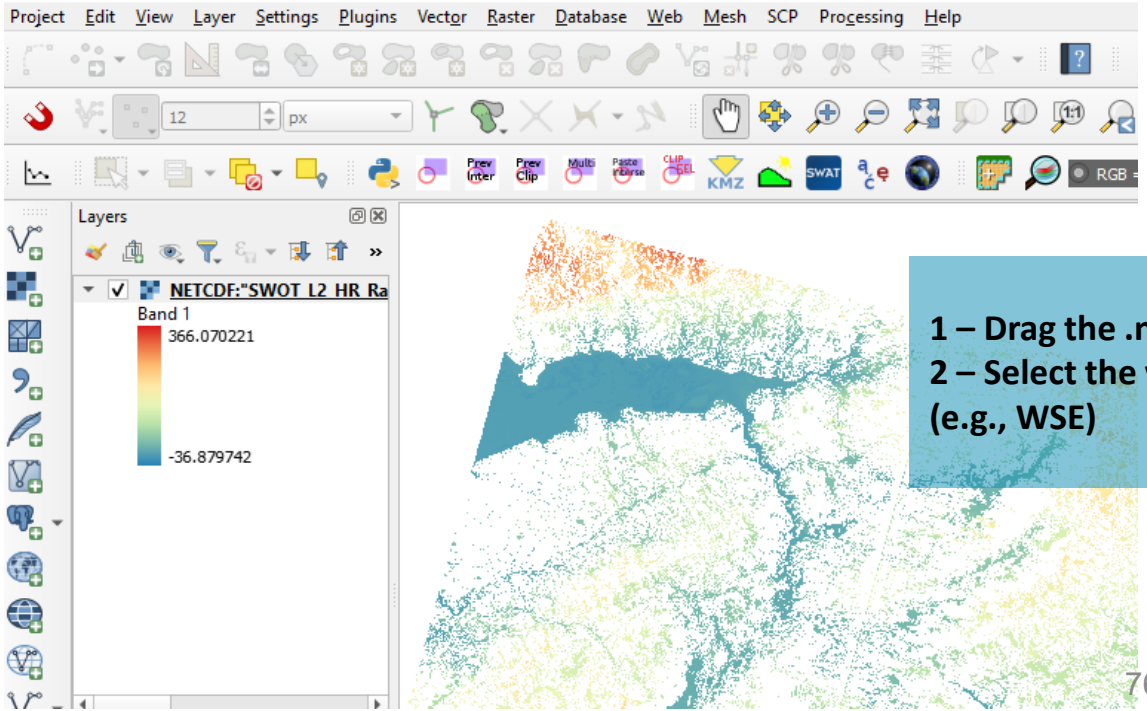


5 - Spatial selection (many methods)
6 - Temporal selection (many methods)
7 – Name filtering (put an *cycle(or tile or pass)* to select one particular cycle, tile or pass)
8 – Download the data (one fil in red, all the selection in blue)

QGIS

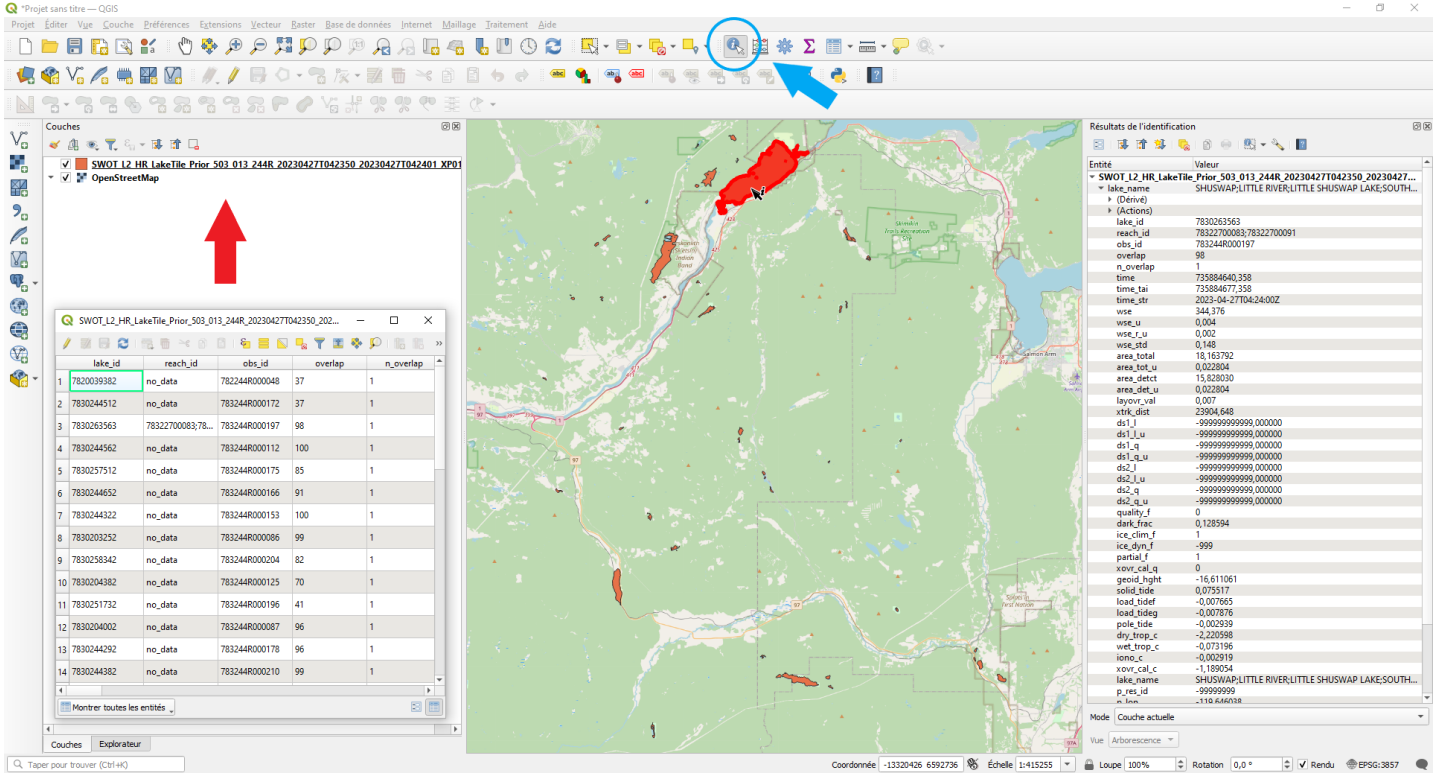






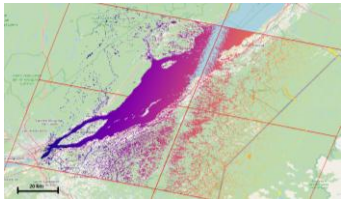
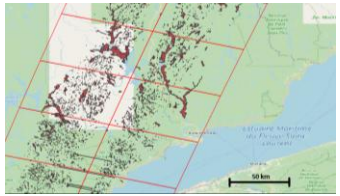
1 – Drag the .nc file
2 – Select the variable (e.g., WSE)

QGIS


Couches
SWOT_L2_HR_LakeTile_Prior_503_013_244R_20230427T042350_20230427T042401_XP01
OpenStreetMap
Résultats de l'identification
Entité
Valeur
Couches
Explorateur

QGIS

QGIS : a simple open-source software to visualize data (and other actions)

Raster	✓	
PIXC	✗	A code treatment is needed before opening it in QGIS
LakeSP	✓	
RiverSP	✓	
SLC	✗	A code treatment is needed before opening it in QGIS

CONCLUSION

PART I


TIME FOR
LUNCH

WORKSHOP

PART II

Python code

Google colab

Google collab link : https://colab.research.google.com/drive/1goHI-4-iscumrM4F2jcmixuLTwEo_23X?usp=sharing

Make a copy of the project

GitHub for users without Google Colab

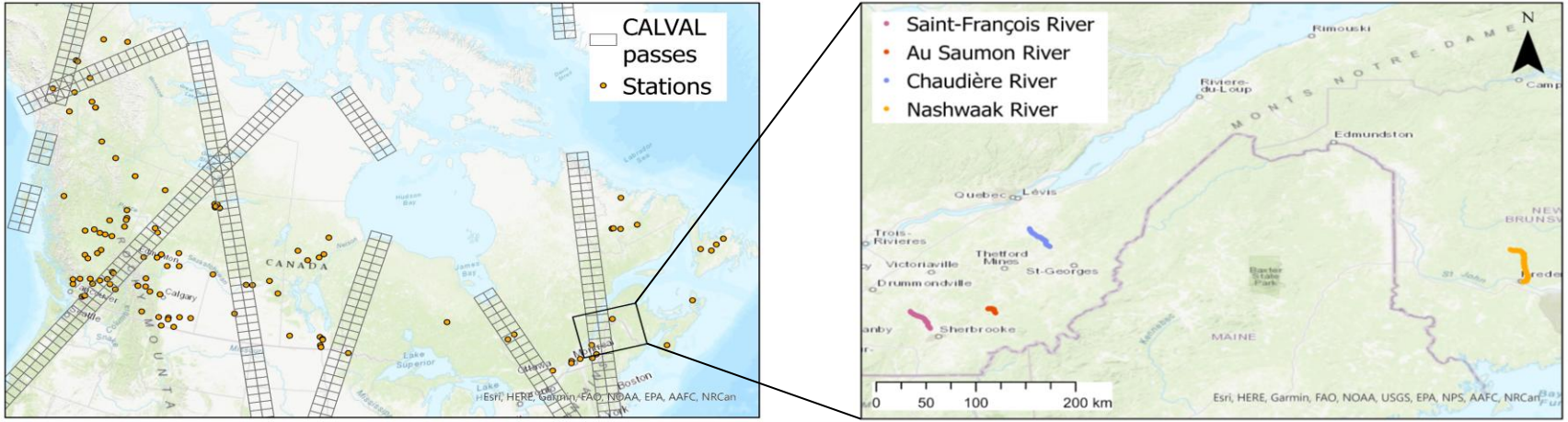
https://github.com/sfoucher/SWOT-Canada/tree/main/Workshops

ASSESSMENT OF SWOT-RIVERSP DATA PRESENTATION

OUR RESEARCH QUESTIONS

- What is the accuracy of WSE at the node scale ?
- What factors affect the quality of the nodes ?

WHAT IS THE ACCURACY OF WSE AT THE NODE SCALE ?



A total of 110 leveled gauge stations in Canada were used. Only nodes with a node_id ending in 1 (i.e., not associated with lakes or dams) were retained.

For four Canadian rivers, profiles were obtained either through boat surveys or from shore-based WSE measurements.

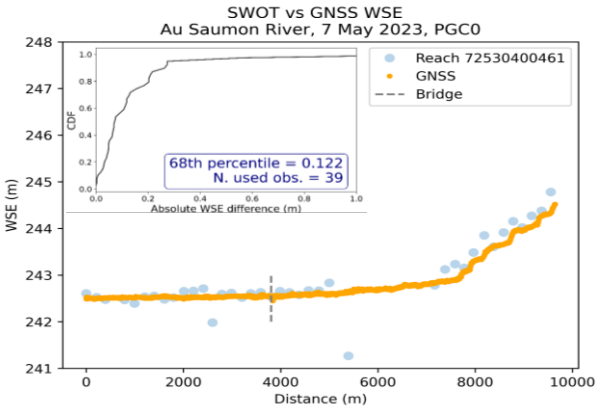
WHAT IS THE ACCURACY OF WSE AT THE NODE SCALE ?

Version	Absolute wse difference (m) 68e percentile	node_q = 3 (%)	node_q = 2 (%)	node_q = 1 (%)	node_q = 0 (%)	N obs	N stations
All data							
CALVAL – C	0.43	11	16	66	7	1179	17
CALVAL – D	0.38	15	6	44	35	1540	17
Science - C	0.42	14	16	65	5	6593	110
Science – D	0.25	13	9	45	33	2090	108
Ice free (ice_clim_f=0), and node_q < 3							
CALVAL – C	0.26					784	17
CALVAL – D	0.24					998	17
Science - C	0.23					2971	110
Science - D	0.21					1779	108

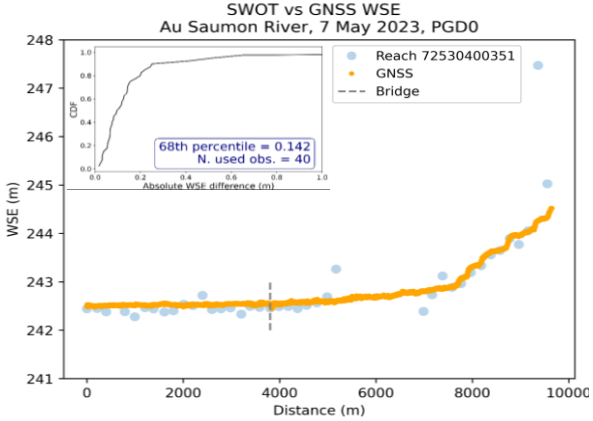
*Water Surface Elevation (Élévation de la surface de l’eau)

WHAT IS THE ACCURACY OF WSE AT THE NODE SCALE ?

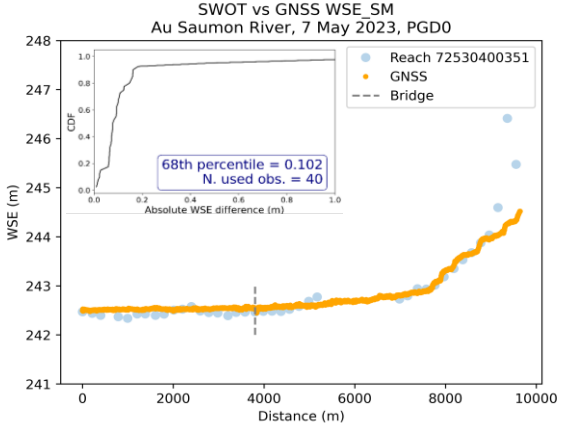
CALVAL



WSE VERSION C



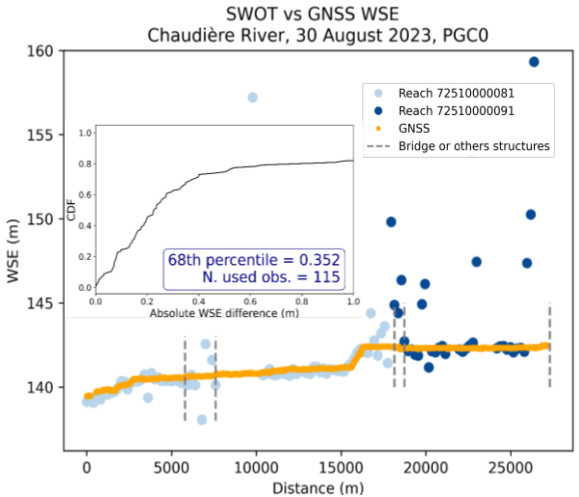
WSE VERSION D

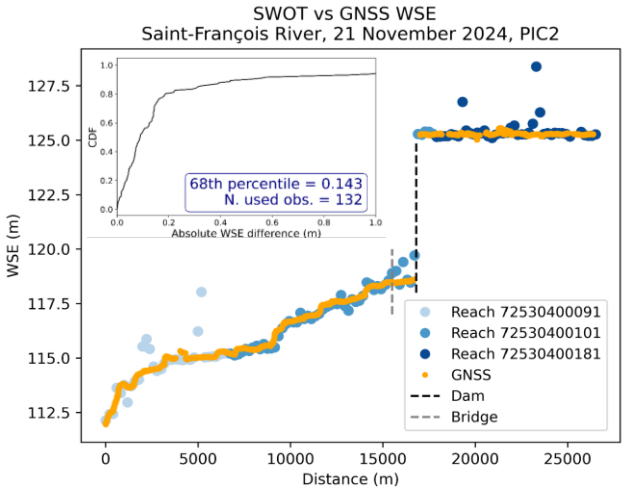


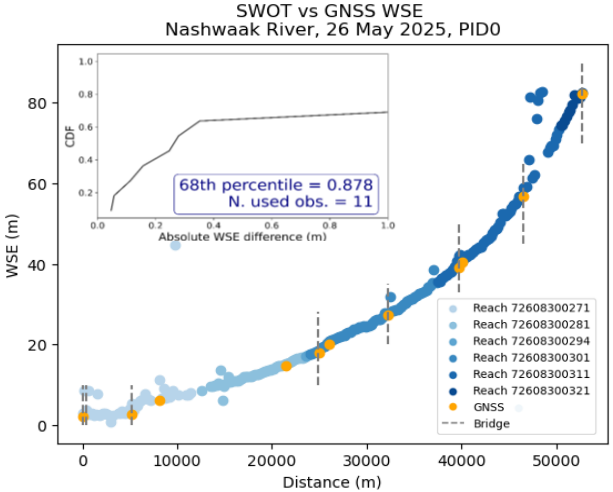
WSE_SM VERSION D

WHAT IS THE ACCURACY OF WSE AT THE NODE SCALE ?

SCIENCE

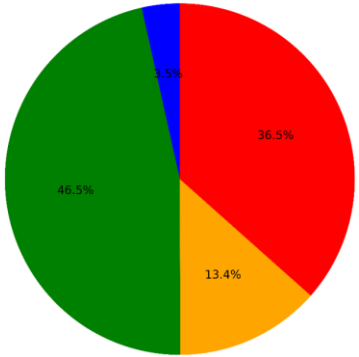




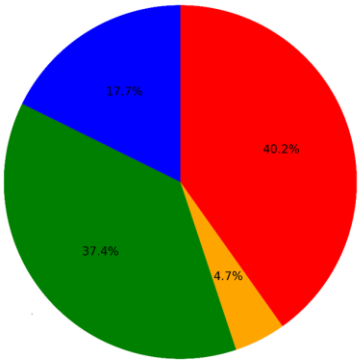


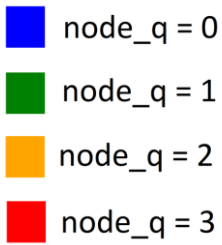
WHAT FACTORS AFFECT THE QUALITY OF THE NODES ?

Version C

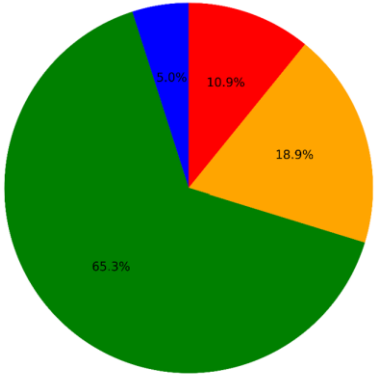


Version D

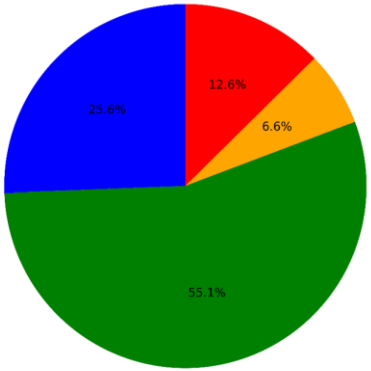




Version C



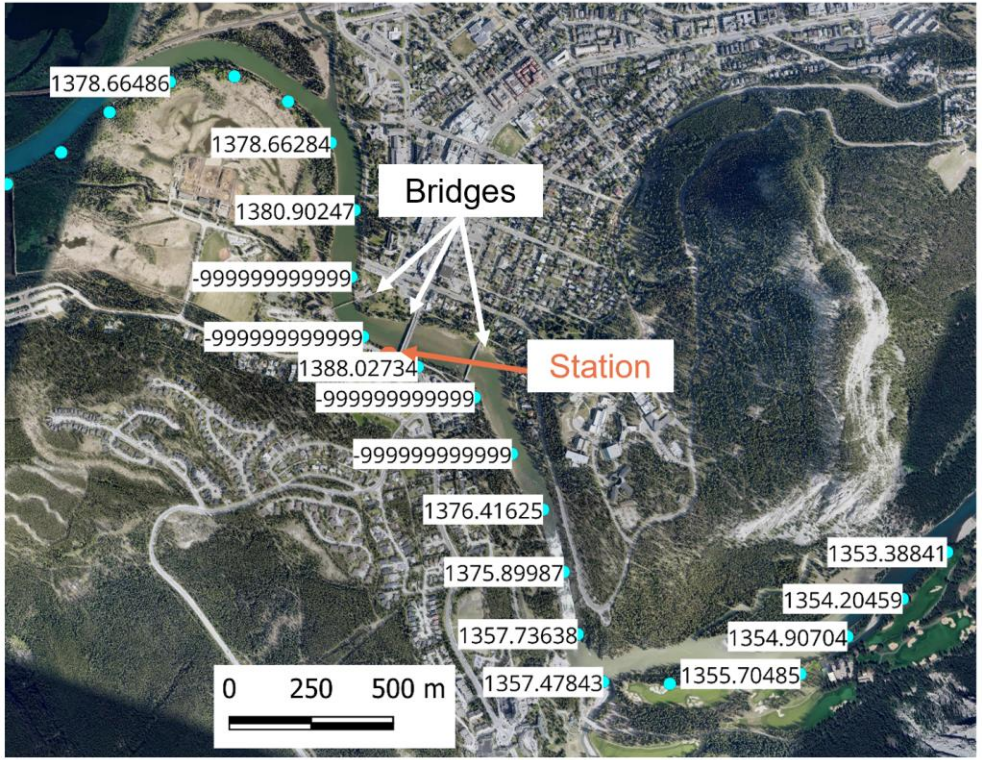
Version D



A total of 1,200 nodes were randomly selected across Canada during the Science orbit.

Excluding nodes associated with lakes or dams (node_id ending in 3 or 4) leads to a marked decrease in nodes with node_q = 3, indicating these are important factors affecting node quality.

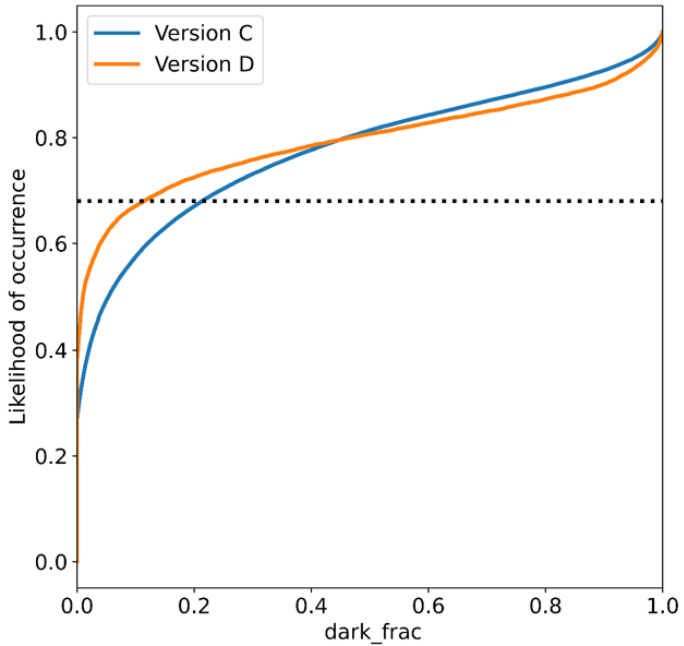
WHAT FACTORS AFFECT THE QUALITY OF THE NODES ?



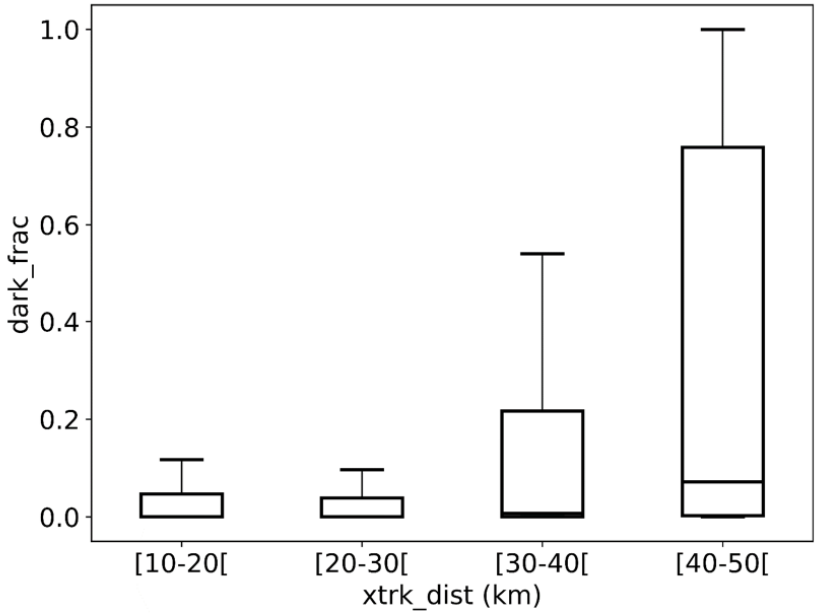
WHAT FACTORS AFFECT THE QUALITY OF THE NODES ?

Dark Water

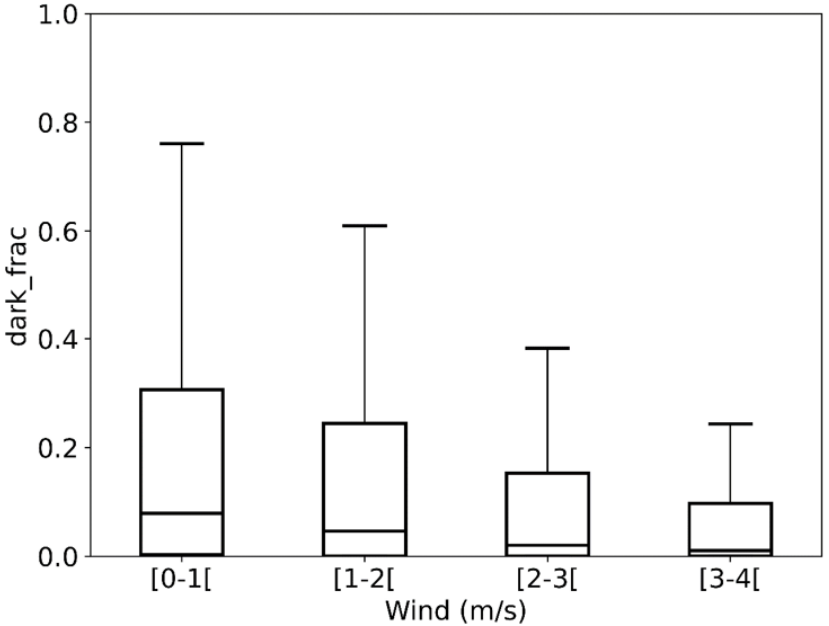
- Smooth water, without wind or waves.
- Acts like a mirror and deflects the radar signal.
- Little signal returns to the radar.



WHAT FACTORS AFFECT THE QUALITY OF THE NODES ?



Dark water is more common in remote areas (xtrk_dist > 40 km).



For nodes with xtrk_dist < 40 km, dark water appears more frequently when wind speeds are low.

CONCLUSION

- Version D performs slightly better than version C (by a few centimeters).
- Infrastructure appears to affect data quality.
- When wind speeds are low, dark water increases when the distance perpendicular to the satellite's trajectory is low (< 40 km).
- Other factors are planned to be studied: sinuosity, width, slope, precipitation, and layover.

REFERENCES

Important links and documents:

- All technical notes for SWOT data products : https://podaac.jpl.nasa.gov/SWOT?tab=datasets-information&sections=about
- Earthdata Search : search.earthdata.nasa.gov/search?q=SWOT_*_2
- To download the KMZ file, for the science 21-day orbit, click here.
- For the Beta Pre-validated data KMZ that used the cal/val 1-day orbit, click here.
- More data on SWOT : Home – NASA SWOT
- How to find the number of the pass/tile and see an animation : SWOT in Space and Time | Mission – NASA SWOT

CONCLUSION

PART II

THANK YOU!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