Comparison within the WG

Goals:

- Share WG assessments on SWOT's performance on lakes, reservoirs, and wetlands
- Complement the Cal/Val team with Tier-3 results
- Provide additional insight on whether SWOT is meeting mission requirements
- Synthesize and inter-compare results to offer WG suggestions

Mission requirements and goals

Baseline Science Mission specifications for **non-vegetated surface water**:

Area
• Requirement: relative error <15% (1σ) for lakes >$(250\ m)^2$
• Goal: relative error <25% (1σ) for lakes >$(100\ m)^2$

WSE
• Requirement: relative error <10 cm (1σ) for lakes >1 km^2, and
• relative error <25 cm (1σ) for lakes >$(250\ m)^2$

Flags
Requirement: accuracy > 68% for rain flag, layover flag, and frozen water flag

Note:

• "*Only non-vegetated water bodies in regions of moderate topographic relief (i.e., where layover contamination is negligible) are to be used to assess SWOT performance*." JPL-D-61923

• Hydrography requirement after crossover calibration for topography is 7.4 cm RMS for roll and phase errors, and the hydrography requirement after crossover calibration for slope is 1.7 μrad RMS. JPL D-79084

Baseline Science Mission specifications for **vegetated water and wetlands**:

Due to complexity and variation of vegetation characteristics, "*it is not possible to set specific performance target for wetland. However, it is important that SWOT wetland capabilities be assessed for a range of different wetland types*."

SWOT **definition** of vegetated wetland:

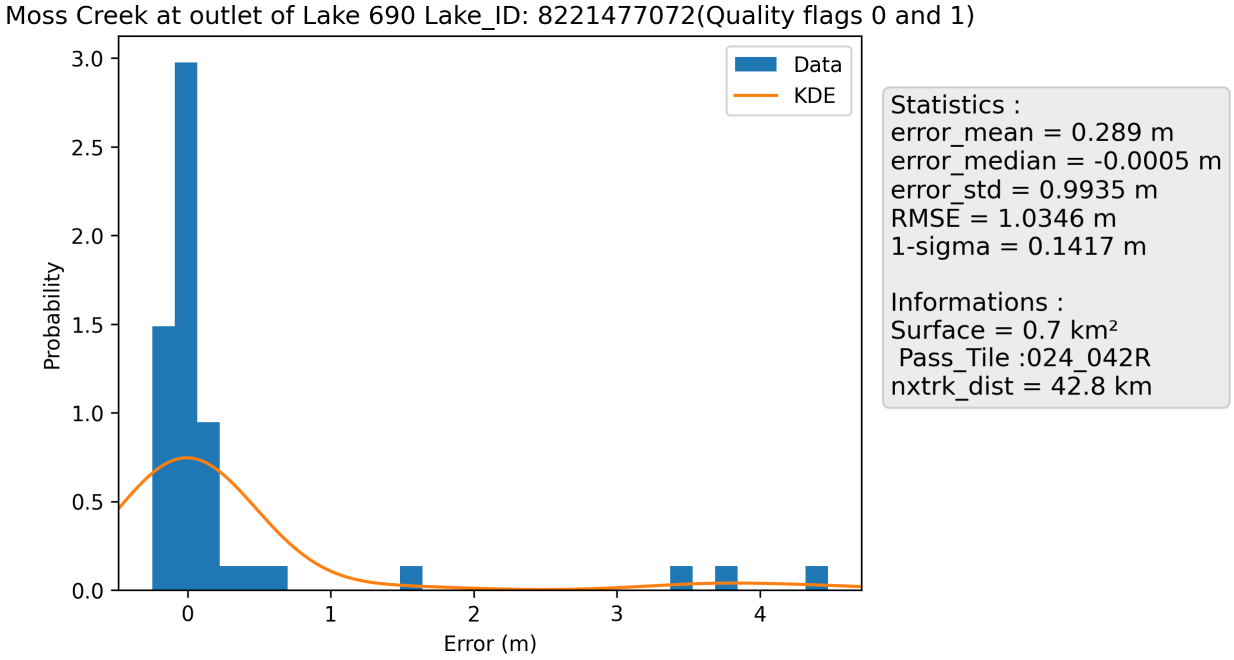
"*(1) it does not appear in either the lake or river a priori databases, and*

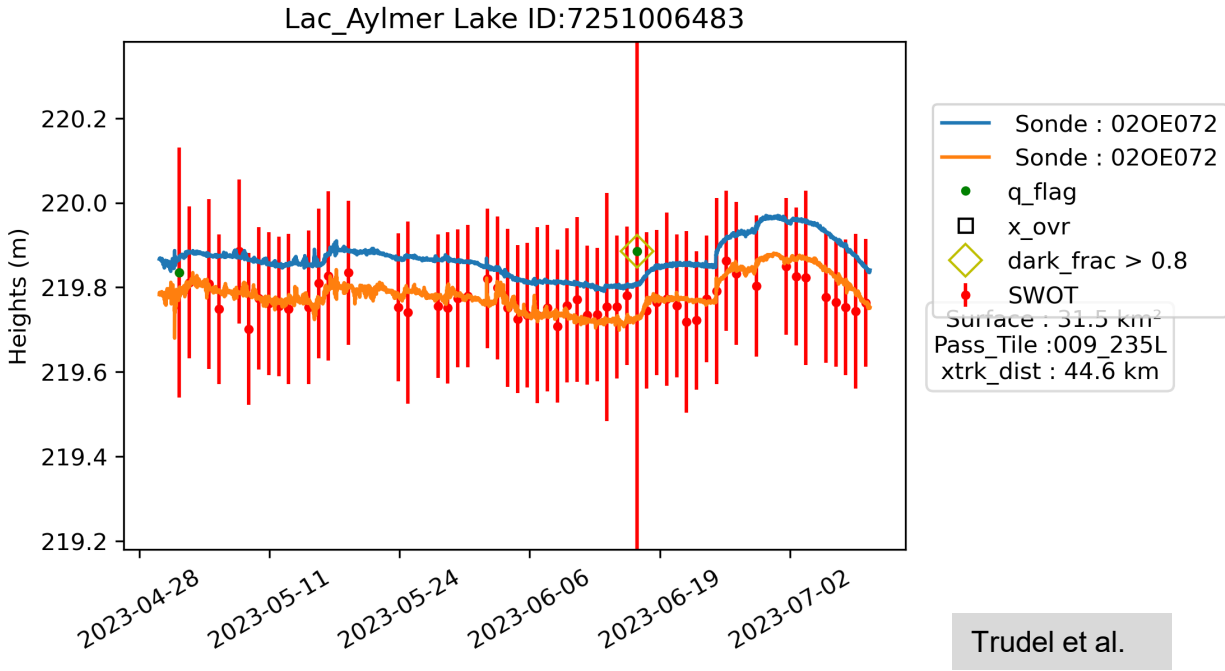
(2) it comprises an area of open, non-vegetation water smaller than $(250\ m)^2$ in area and has a mean width of open, non-vegetated water <100 m. Margins of rivers and lakes that contain dense, flooded vegetation can be considered wetlands." JPL-D-61923

*"SWOT Project Science Requirements Document (Rev B)" (particularly, **Section 2.8**)*

Water Surface Elevation (WSE)

Assessment	Region/object	Team
• Lakes in Zone 1 (sizes > 1 km^2) well meet requirements: 1-sigma error from **5-9 cm**, and the dynamics are also well characterized. • Lakes in Zone 2 (sizes < 1 km^2), after removal of the bad quality flag, met requirements: 1-sigma from **14-19 cm**. So, the quality flag needs to be considered. • For lakes with a WSE gradient or substantial WSE variation, the variation across the same lake is bounded by WSE_u. So, considering WSE_u is important.	Lakes across Canada: Zone 1 near Sherbrook with lake size from 1 to 50 km^2 Zone 2 much northern, with lake size also smaller, from 0.2 to 6 km^2	Mélanie Trudel, Gabriela Siles, Manon Delhoume, Sylvain Biancamaria, Daniel Peters, and others

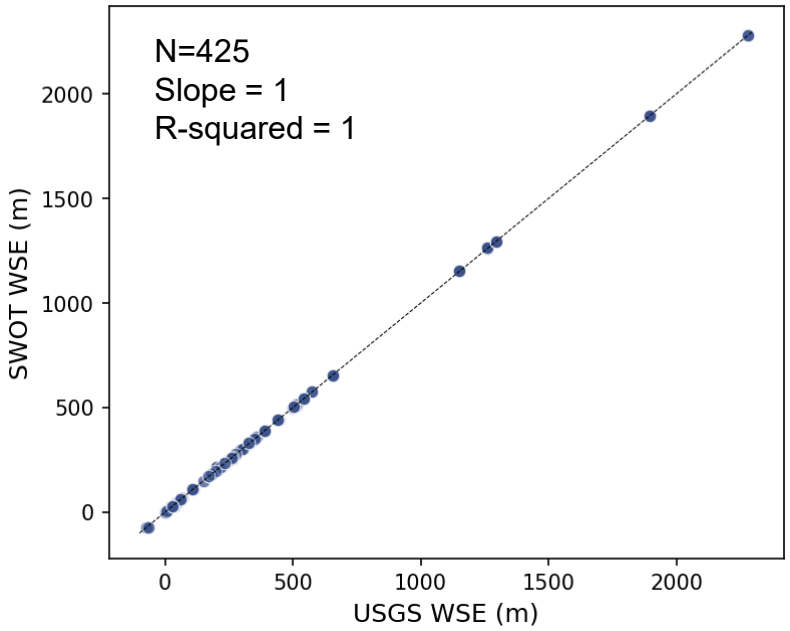


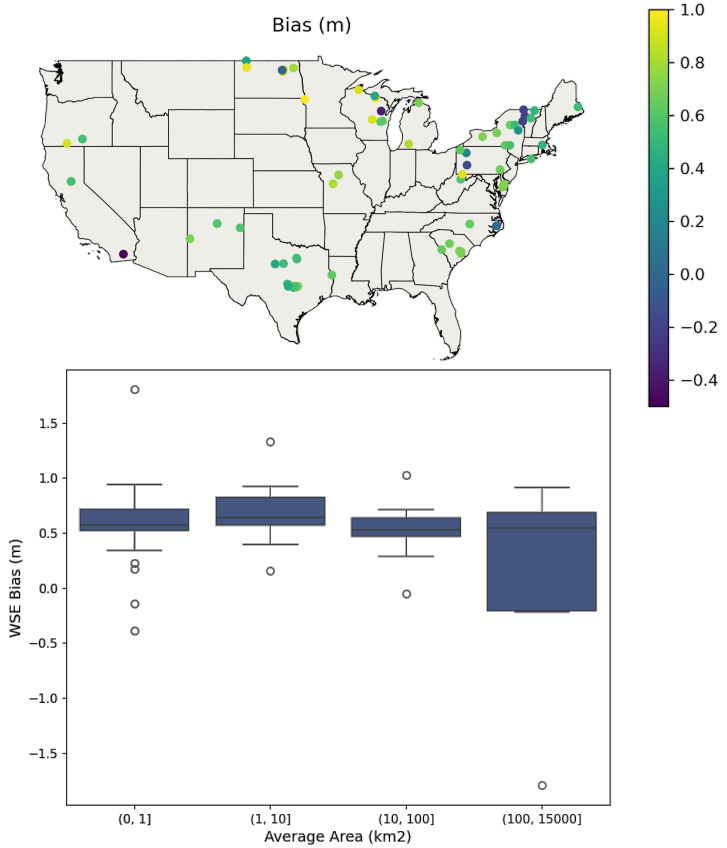


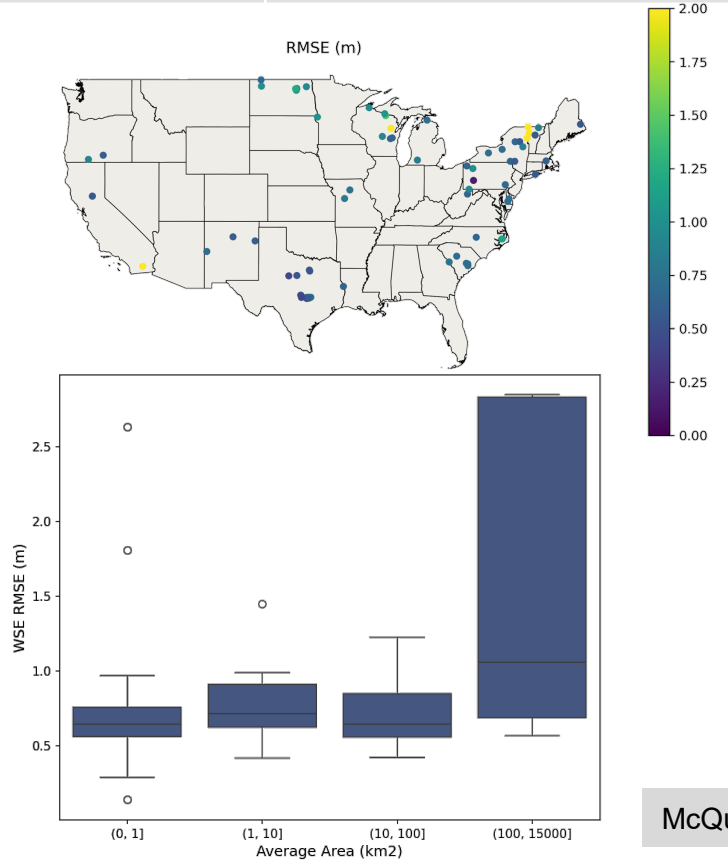
Trudel et al.

Water Surface Elevation (WSE)

Assessment	Region/object	Team
• WSE in LakeSP (v2.0) for 78 gages on 73 US lakes shows a high agreement with gage measurement, with **a slope of 1.0 and R-squared of 1.0** (N=433). • LakeSP WSE shows **a positive median bias of 58 cm and a median RMSE of 69 cm**. • Lakes of different size categories show similar **positive median biases of ~50-70 cm**, although biases for large lakes (> 100 km2) also have a greater variation (IQR). • Lakes of smaller size categories show **similar median RMSEs (~60-70 cm),** whereas RMSEs for lakes > 100 km^2 are significantly larger, with a median of ~1 m and an IQR from ~0.6-2.7 m. • Lakes of different crossover calibration qualities do not show too much difference in WSE accuracy.	Lakes/reservoirs covered by ~90 USGS gages, with sizes ranging from 0.01 to 12,789 km^2	Katie McQuillan, George Allen, Jessica Fayne, Huilin Gao, Jida Wang, Safat Sikder



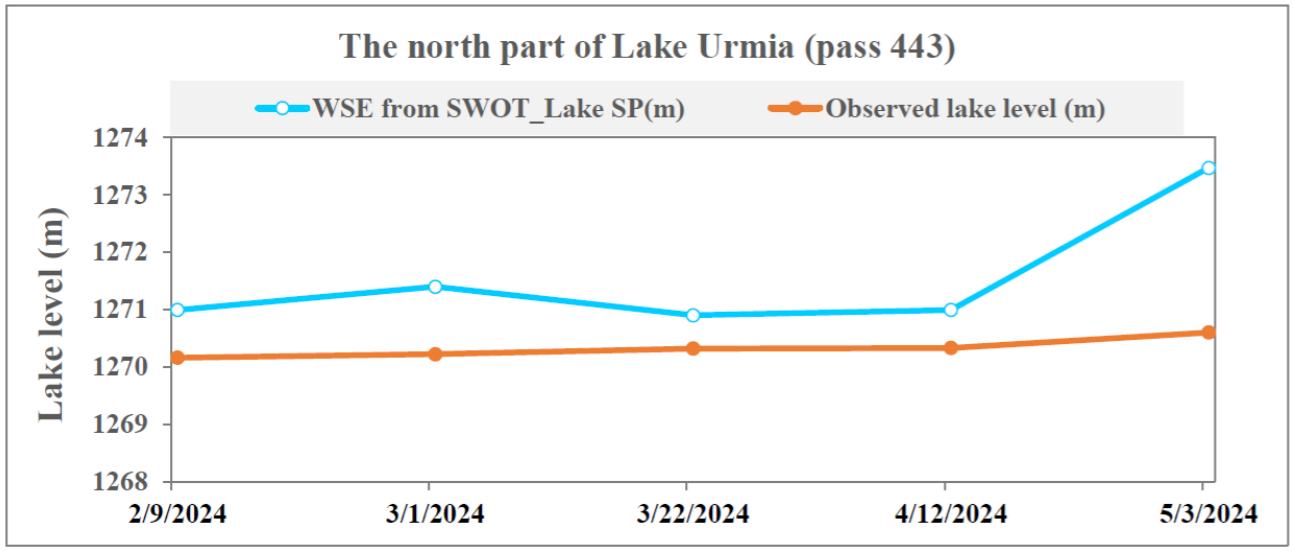


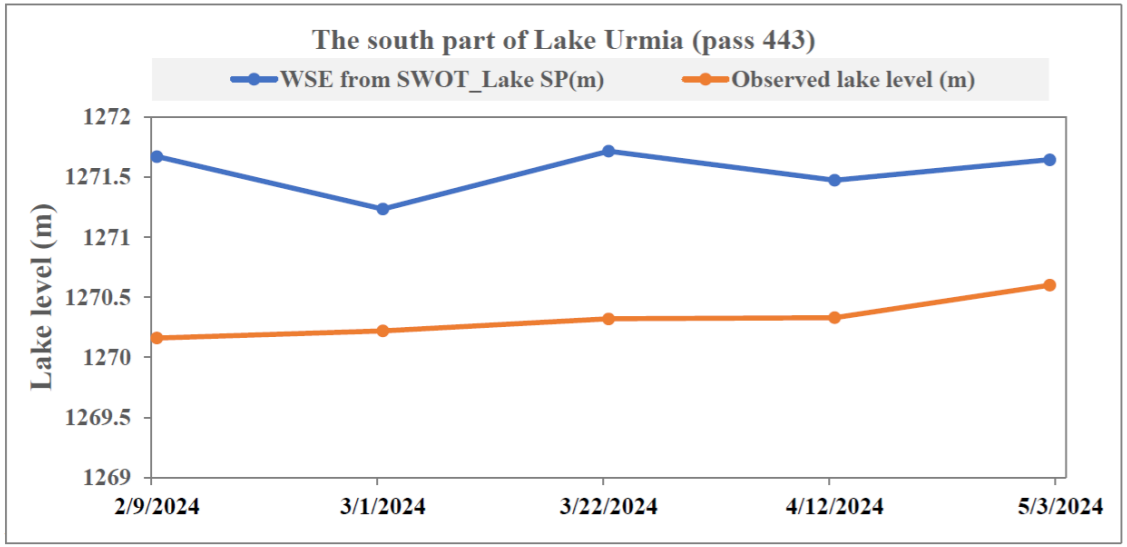


McQuillan et al.

Water Surface Elevation (WSE)

Assessment	Region/object	Team
• WSE obtained by SWOT overestimates Lake Urmia's level measured by **1 to over 3 m** (both with reference to WGS1984) • The overestimation of WSE is probably caused by the misclassification of bare and salt lands at the lake coasts as water areas. Note both biases are positive, indicating SWOT overestimates the water extents. • The overestimation in the lake's southern part is more pronounced than the north part due to the vaster area and higher desiccation	Lake Urmia	Somayeh Sima, Jean-francois Cretaux

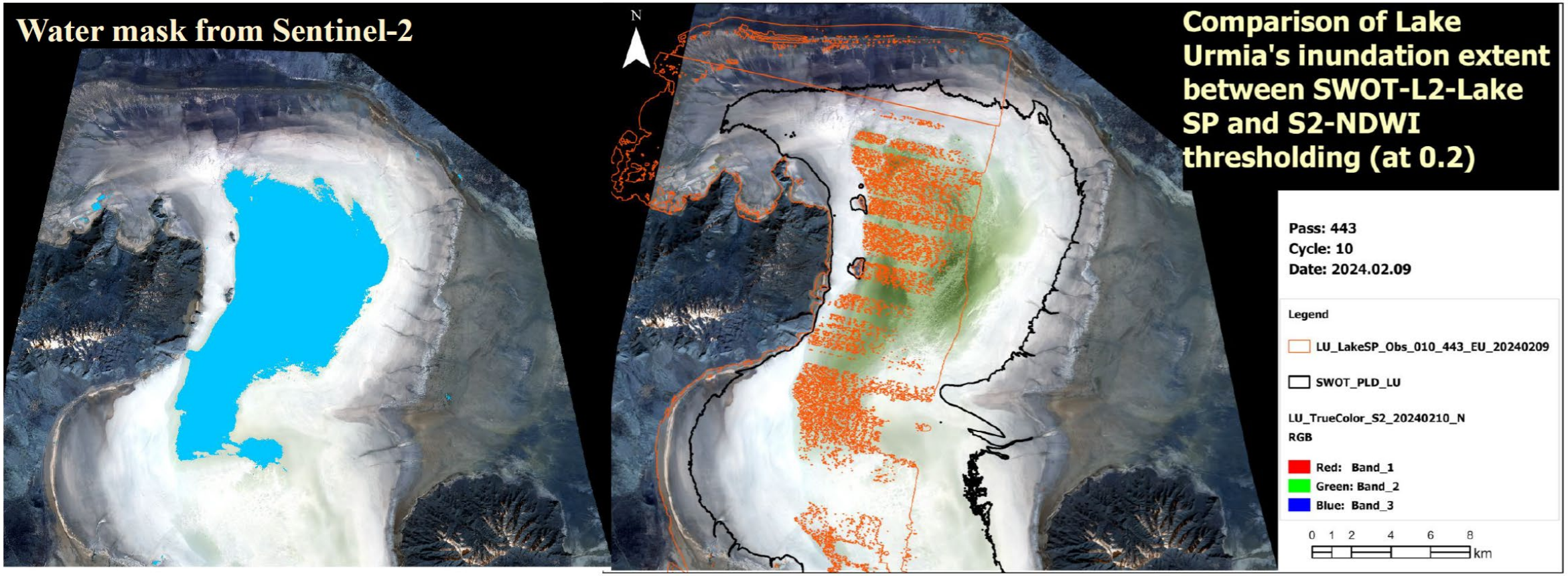




Sima and Cretaux

Water Area

Assessment	Region/object	Team
Substantial misclassification of bare and salt lands at the lake coasts as water areas, leading to overestimation of WSE as well.	Lake Urmia	Somayeh Sima and Jean-francois Cretaux



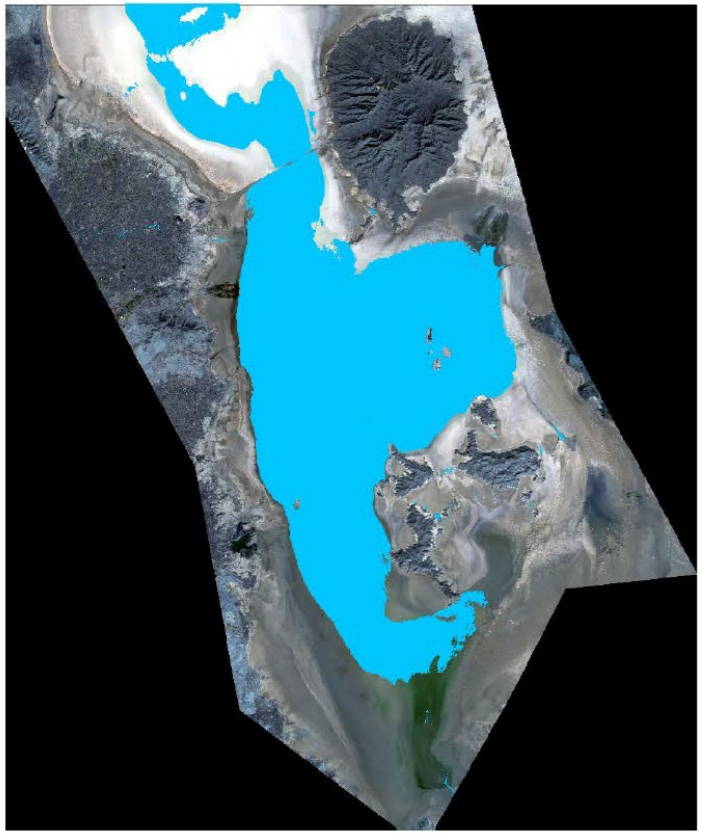
NDWI >0.2 water mask

Sima et al. (2023) *https://doi.org/10.1016/j.jglr.2023.09.010*

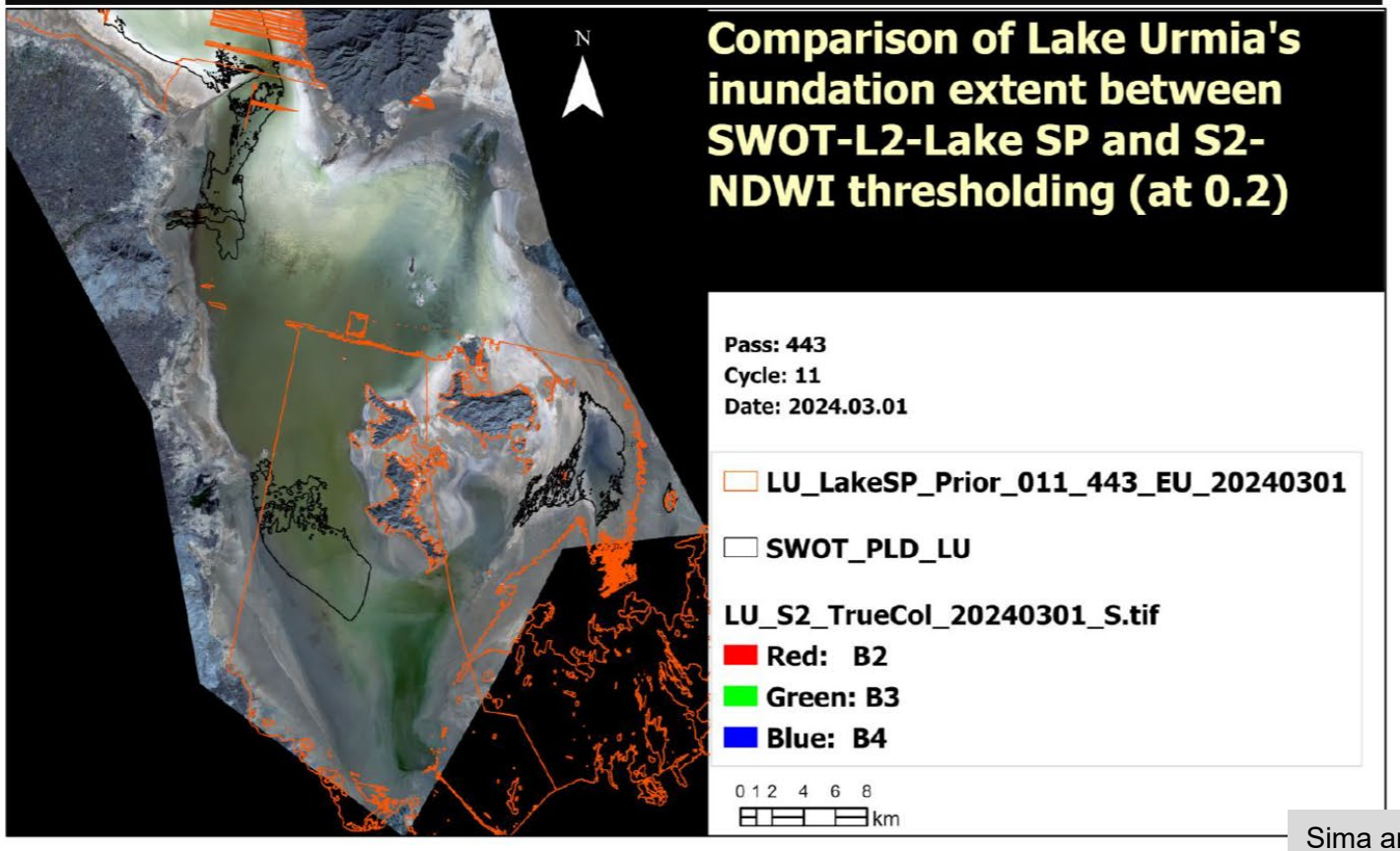
Water Area

Assessment	Region/object	Team
Substantial misclassification of bare and salt lands at the lake coasts as water areas, leading to overestimation of WSE as well.	Lake Urmia	Somayeh Sima and Jean-francois Cretaux

Water mask from Sentinel-2



Overestimation of the lake-inundated areas in SWOT-L2-Lake SP



Sima and Cretaux

Separate small ponds on the lake shores

Rugged salty coasts that create speckles

Sima and Cretaux

Floating salt patches

Wet salt lands

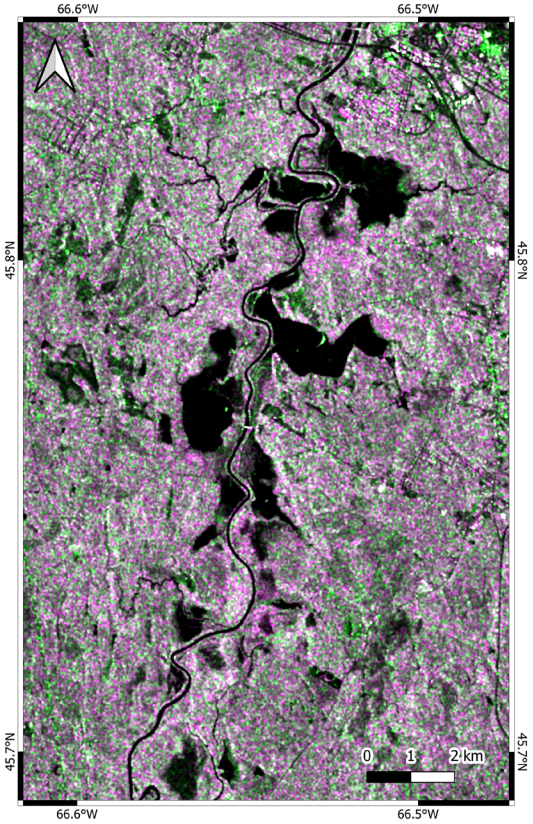
Sima and Cretaux

Wetland

Assessment	Region/object	Team
• SWOT backscatter variability can be attributed to surface moisture and vegetation density. • Skin-surface moisture (e.g., top 1 cm) is strongly correlated with Ka-band backscatter (based on AirSWOT experiments), but the strong relationship is also seen for KaRIn backscatter. • Backscatter-moisture relationships are sensitive to land cover which is affected by vegetation structure and density. • The relationship between backscatter, moisture, and wetland can be modeled. Examples are the Ka-band Phenomenology Scattering (KaPS) model which simulates backscatter and the companion Ka-band Radar Wet-Likelihood (KaRWL) model which retrieve surface moisture and vegetation structure.	Water and wetland phenomenology: **soil moisture and vegetation** (AirSWOT tracks; visual explorations for Okavango Delta, Botswana)	Jessica Fanye, Etienne Fluet-Chouinard, George Allen, Katie McQuillan, Duncan Jurayj
SWOT is able to detect both extents and WSE of the inundated vegetation (~2 m water) together with open water fairly well.	Oromocto watershed, New Brunswick, Canada	Mélanie Trudel (U Sherbrook), Sylvain Biancamaria (CNES), et al.

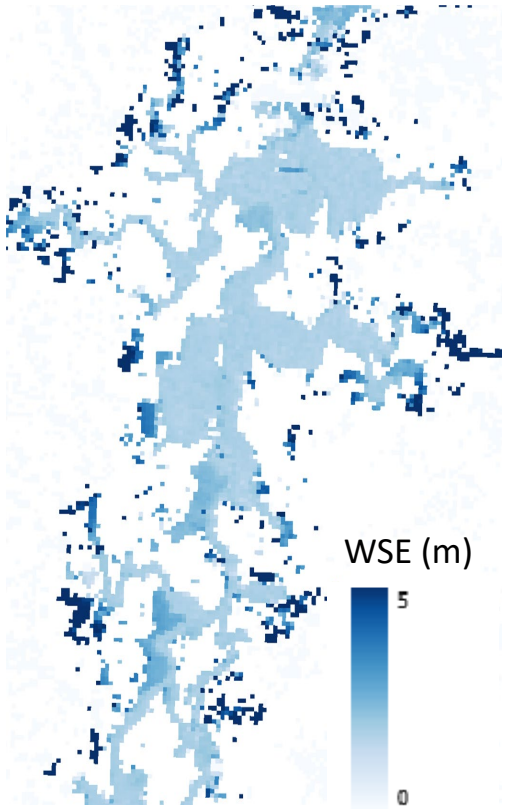
SWOT observed water levels and extents on inundated wetlands

Sentinel 1
November 29, 2023

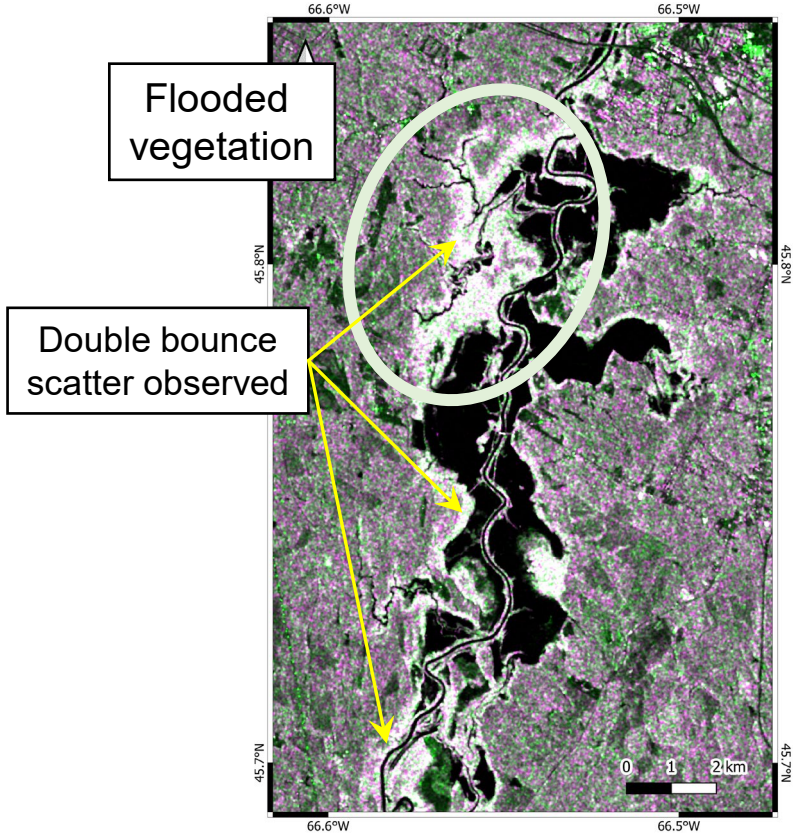


Sig0 VV : Red + Blue
Sig0 VH : Green

SWOT L2_HR_Raster
December 1st, 2023

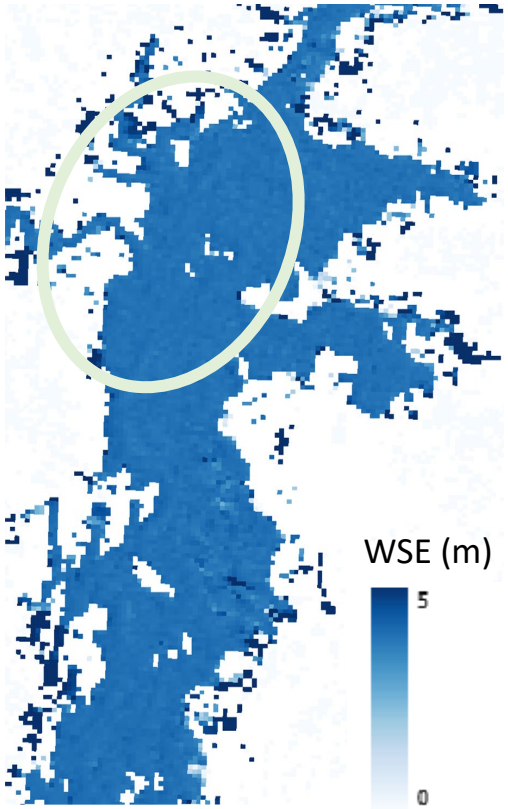


Sentinel 1
December 23, 2023



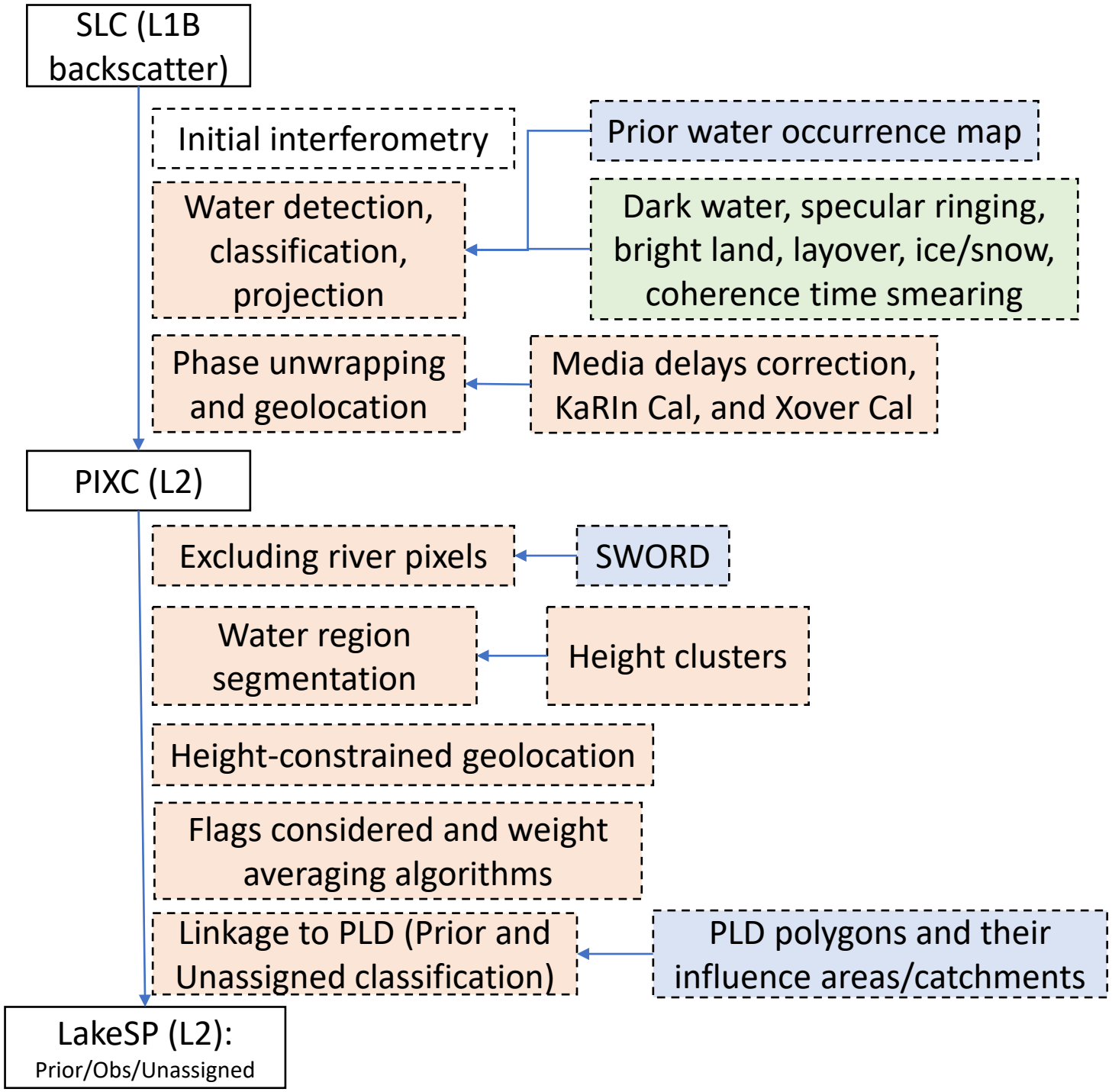
Sig0 VV : Red + Blue
Sig0 VH : Green

SWOT L2_HR_Raster
December 21st, 2023



Oromocto watershed, New Brunswick, Canada

Mélanie Trudel (U Sherbrook), Sylvain Biancamaria (CNES), et al.



Error sources

Phenomenology

Algorithms

Prior data

WG suggestions: WSE

- Requirements (even the goals) for WSE are largely met in canonical scenario, i.e., open water without substantial vegetation cover, thick ice cover (WSE error can be up to ~5 m), major layover, or significant water over-detection due to wet field, bright land, snow cover, and salt speckles.
- It is important to utilize the quality flag and understand the field conditions and data quality before using it.
- It is recommended to take into account WSE_u, area_u, and other uncertainty attributes in interpreting science results.
- For large lakes, caveats should be given to the accuracy of the geoid.

WG suggestions: water area

- The accuracy of lake water extents is more sensitive to PIXC classification errors and other disturbing factors ranging from over-detection (e.g., caused by wet soil and sometimes layover), dark water, littoral ice/snow, and specular ringing.
- While LakeSP WSE is overall good, the above issues (which directly affect water area measurements) will affect the computation of water storage changes. Improving SWOT's water areas, such as through ancillary water area estimates, is one of the most imminent priorities.
- SWOT's capability of observing small lakes and rivers, inundated wetlands and floodplains, and thin-ice-covered lakes (particularly useful for alpine and high-latitude regions) are promising.

WG suggestions: water area

- Riparian vegetation and wetlands, although not considered for mission requirements, will affect the accuracy of water storage change estimates, which is scientifically important.
- Early results show that at least part of inundated wetland can be observed by SWOT with reasonable WSE accuracy. The issues are: down to what inundation level can SWOT still see the wetland extent, and how SWOT capability for wetland varies among different wetland types.
- There was no or few hypersaline lakes among pilot lakes for cal/val. It is probably worth investigating the issues associated with saline lakes, e.g., wet soil and salt pans, salt speckles, floating salt patches, small salt lake patches, as reported for Lake Urmia.

WG suggestions: water area

- Water over-detection in PIXC is one of the key challenges. Investigations are needed to improve the water classification algorithm.
- Some WG suggestions for improving water mask algorithm:
  - Using the Harmonized Landsat and Sentinel-2 (HLS) to increase the frequency of image acquisition
  - Using synergy of altimetry data with the optical Landsat & Sentinel imageries
  - Utilizing prior E-A relationship to confine lake extents
  - Checking the suitability of the water mask thresholds for multiple cases, e.g., using an adaptive sig0 threshold, with reference to other auxiliary data

WG suggestions: others

- Crossover cal/val is necessary, and confirmation is required once fully validated SWOT data is available.
- Asia is the main contributor to the residual topography error (after crossover calibration) due to large landmass being far from the ocean. More scientific validation is needed for Asian lakes.
- We need a better understanding of the impact of ice and snow, such as through more field measurements.
- We noticed that the current ice flag (based on climatology) can report more ice than observed. It will be helpful to develop an ice flag directly based on SWOT's sig0 and coherence observations.