

# Imaging and altimetric multi-mission synergy, including SWOT, Sentinel 6, Sentinel2, for reservoir monitoring: applications to the Grand lacs de Seine reservoirs (France)



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## Context: Information within diamond?

- Assess satellite altimetry for monitoring surface area, water level and volume changes.
- Focus on Der lake (48 km<sup>2</sup>), key reservoir in the Seine flood management system.
- Explore multi-sensors synergy.

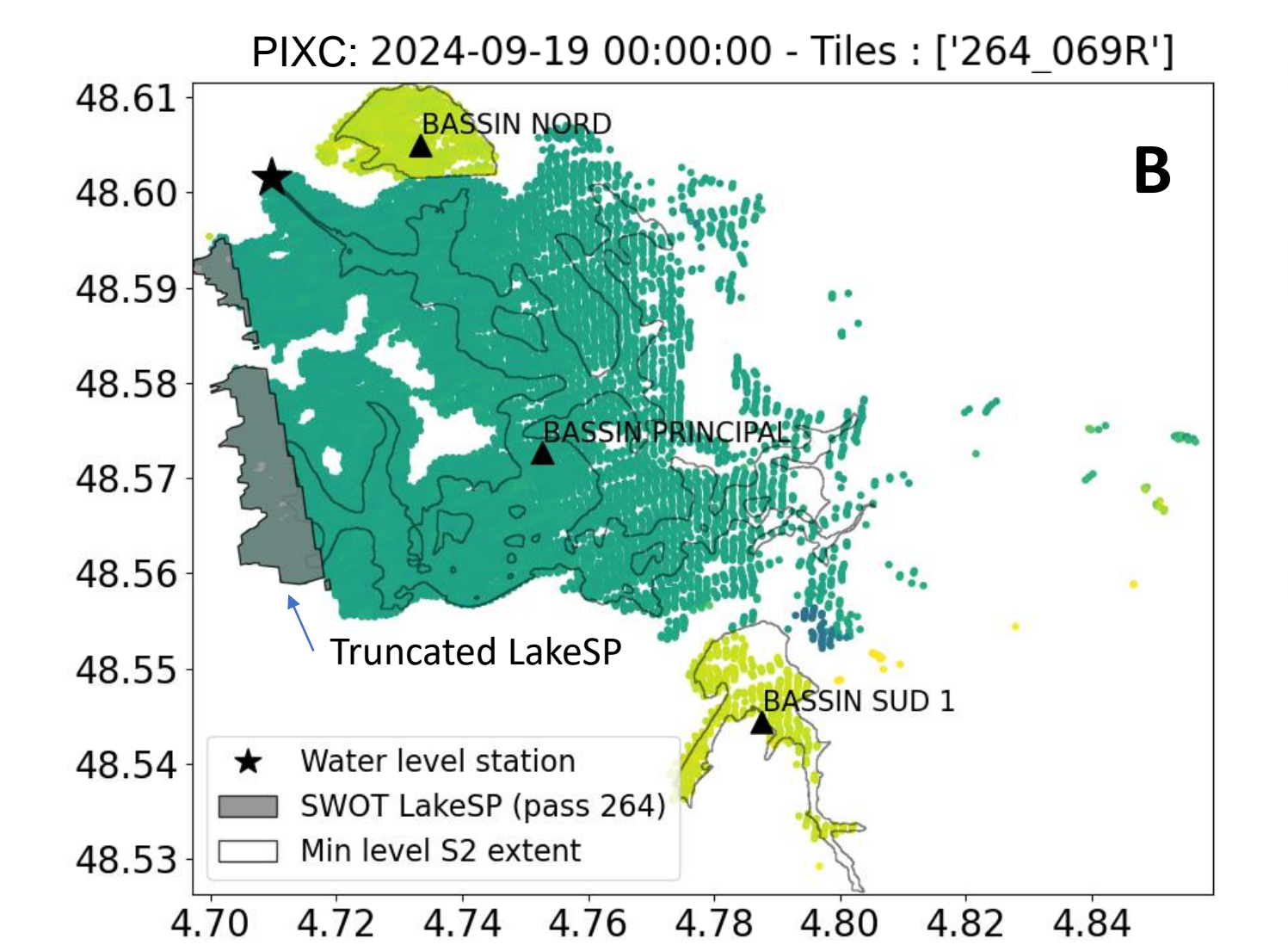
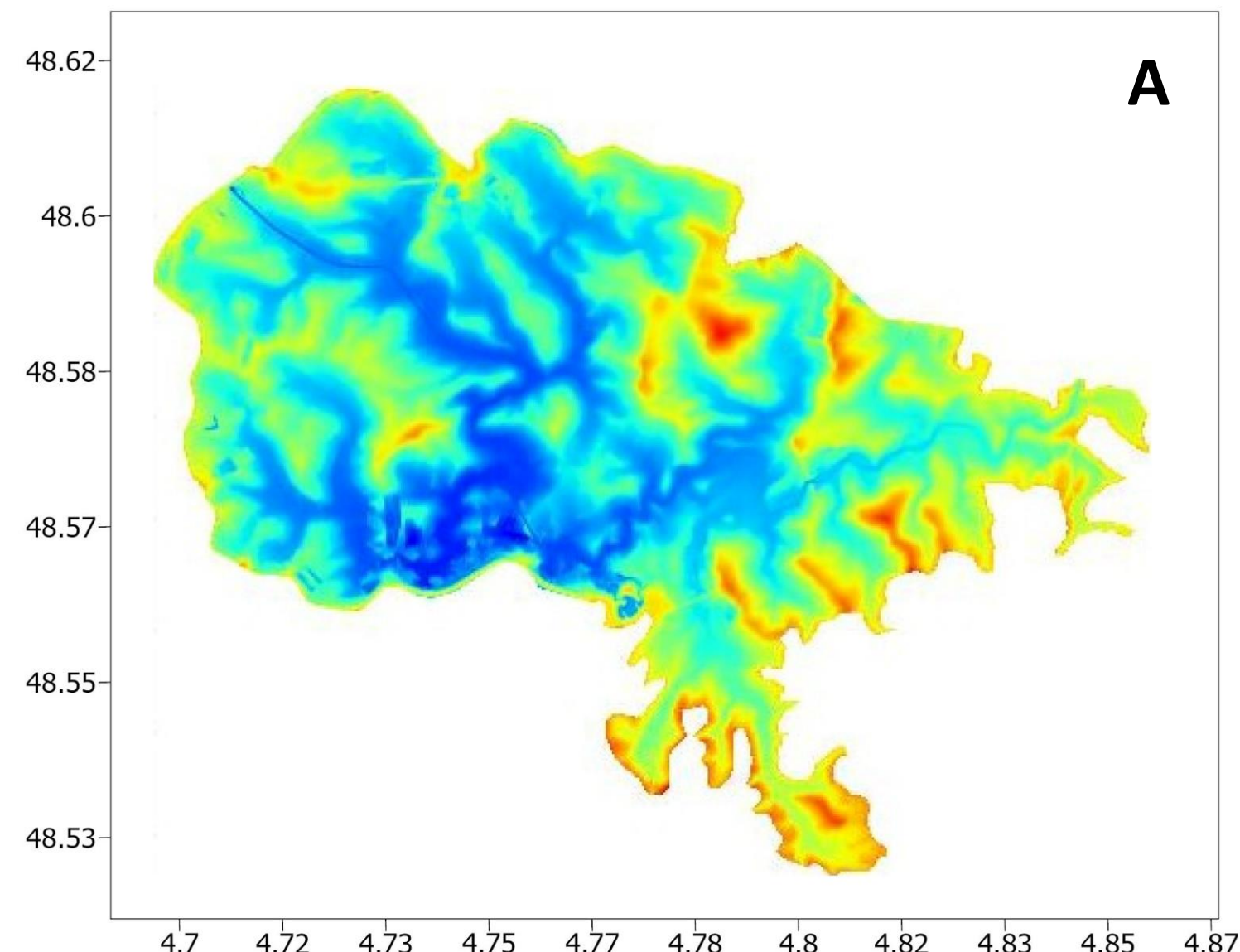


Fig.2: Lake Bathymetry (A). Water surface height (WGS84) from PIXC class 4 (B).

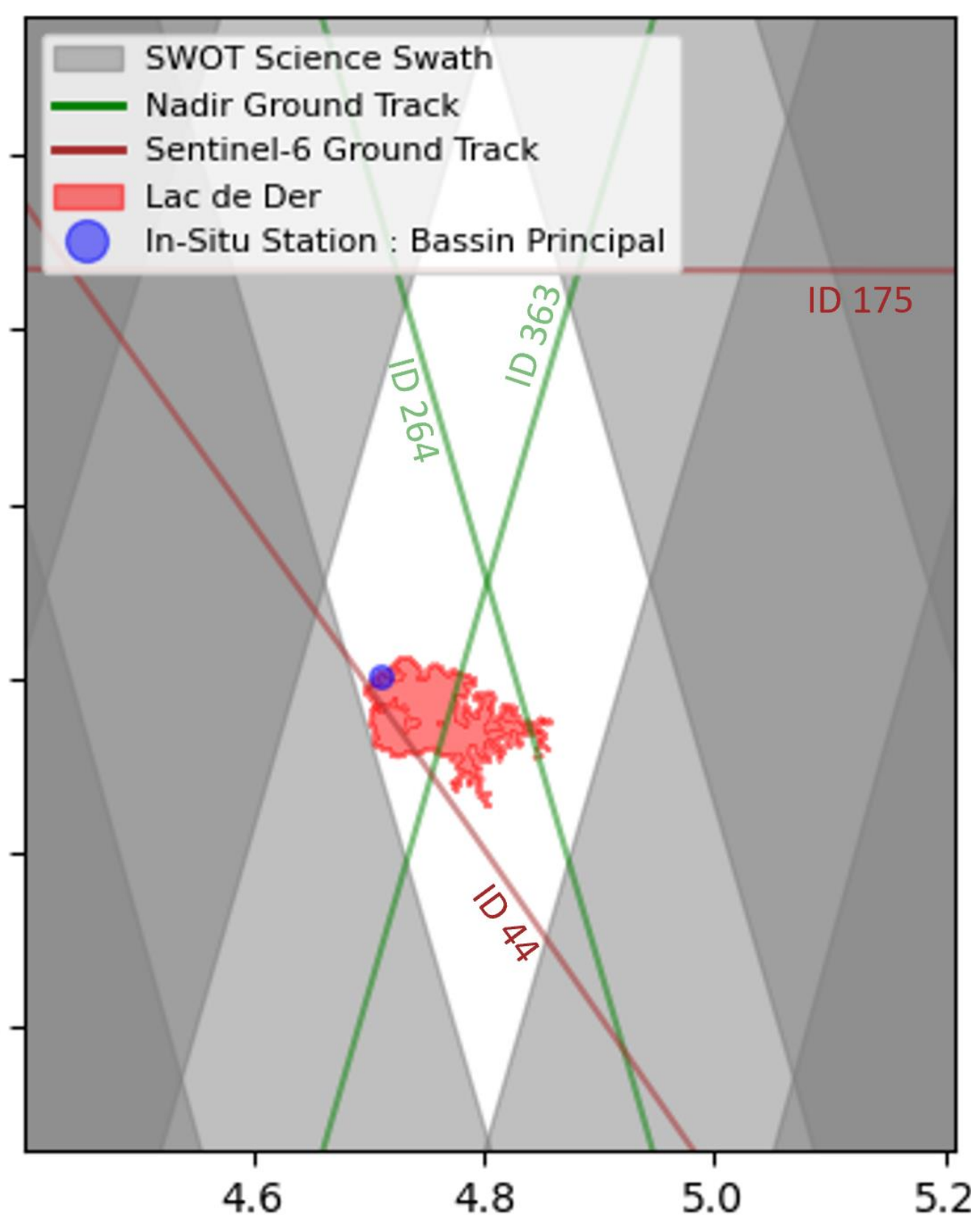


Fig. 1: SWOT diamond over Der lake.

## Satellite and In situ Data

- SWOT L2 High-Rate (HR) Lake products : PIXC and LakeSP Prior (PGCO, PICO, PIC2 and PID0, Science Orbit) from July 2023 to September 2025. The **observed LakeSP water surface areas** are incomplete because the lake is not located within the SWOT's swath (polygon in grey, Fig.2).
- SWOT PIXC class 4 WSH and LakeSP WSH with outliers removed.
- SWOT Nadir, Sentinel-6 (FFSAR) with a dedicated CNES retracker and IceSAT-2 for surface water height (WSH) time series
- Sentinel-2 for lake water extent time series.
- In situ water levels and volumes provided by *Seine Grands Lacs*.
- All water surface heights were converted to WGS84 reference system.

## Lake Water Height Results

- WSH from different missions: same tendency with small shift between the series and different temporal granulometry (Fig.3).
- SWOT height variation  $\approx 8$  m; RMSE PIXC vs in-situ:  $1\sigma = 0.39$  m,  $\sigma = 0.09$  m, bias  $\approx 38$  cm.
- SWOT Nadir data showed limited accuracy in water surface height estimation.
- Sentinel-6 very consistent with in situ but biased, Very good results after bias removed:  $1\sigma = 0.09$  m,  $\sigma = 0.04$
- ICESat-2 height are coherent with SWOT PIXC and LakeSP data.

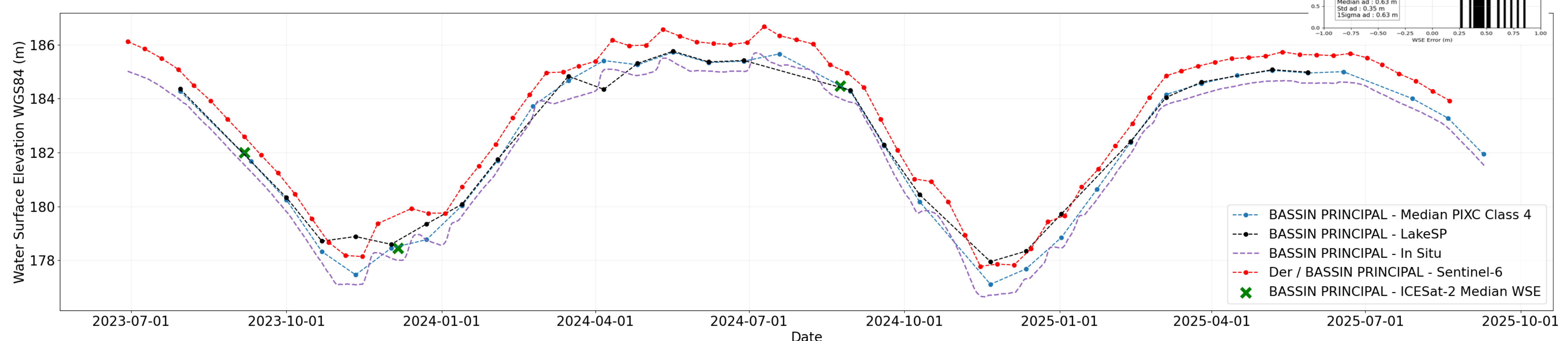


Fig. 3: Monitoring of water surface height (WGS84) over Der Lake based on different altimetry missions.

## Volume Change Results

- Volume variation estimations by combination of water surface (Fig. 4) and height approximating that change in volume can be approximated by a truncated pyramid (1). (Quellec and Cretaux, 2019)
- Coherent results compared to in-situ volume changes and well represented seasonal cycle.
- SWOT PIXC/S2 volume variations more accurate than with SWOT LakeSP/S2.
- SWOT S6/S2 volume variations more accurate than with SWOT PIXC/S2.
- Access to absolute lake volume and more complete volume change estimations using in situ bathymetry data (Fig. 5, B).

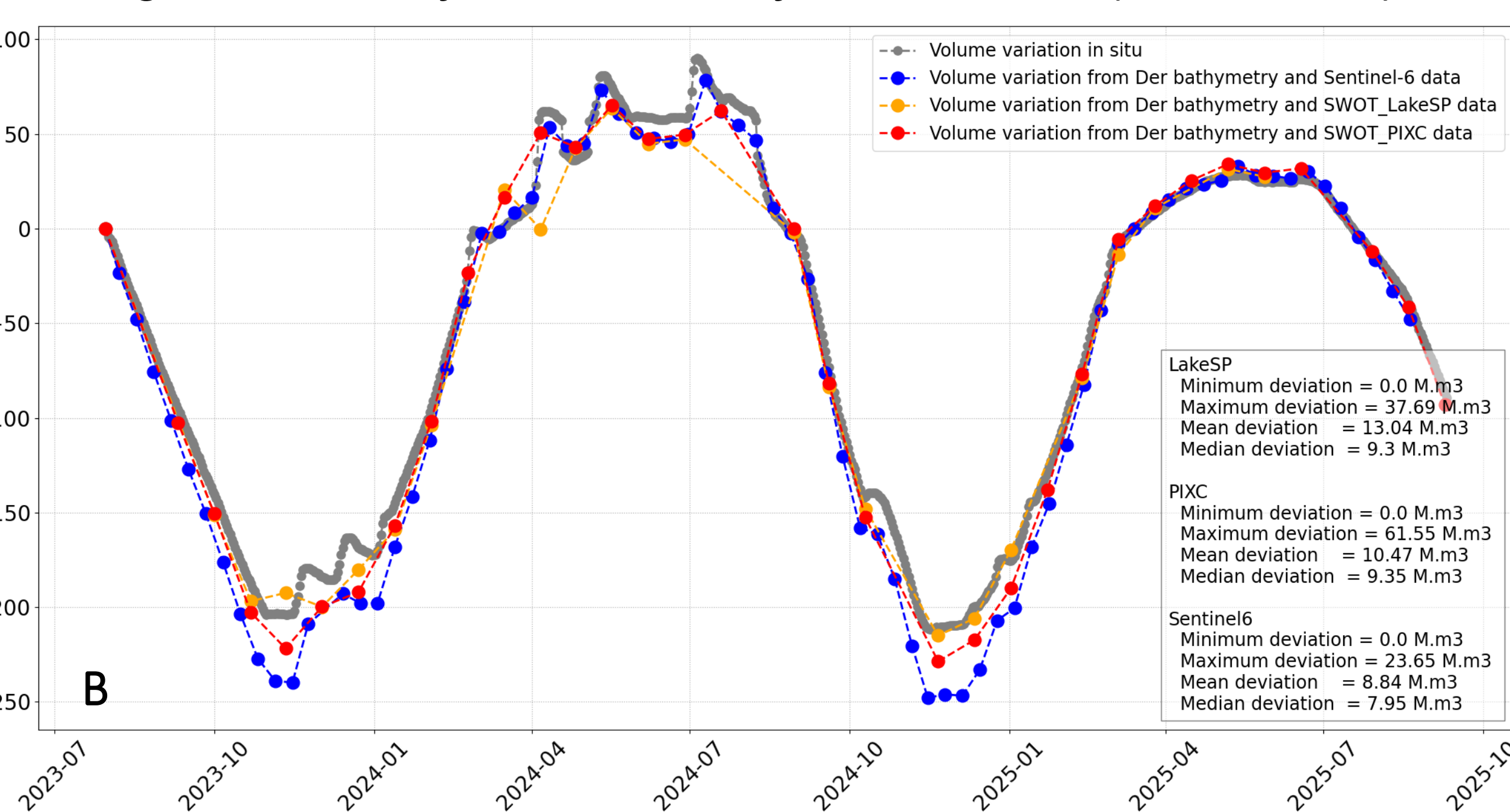
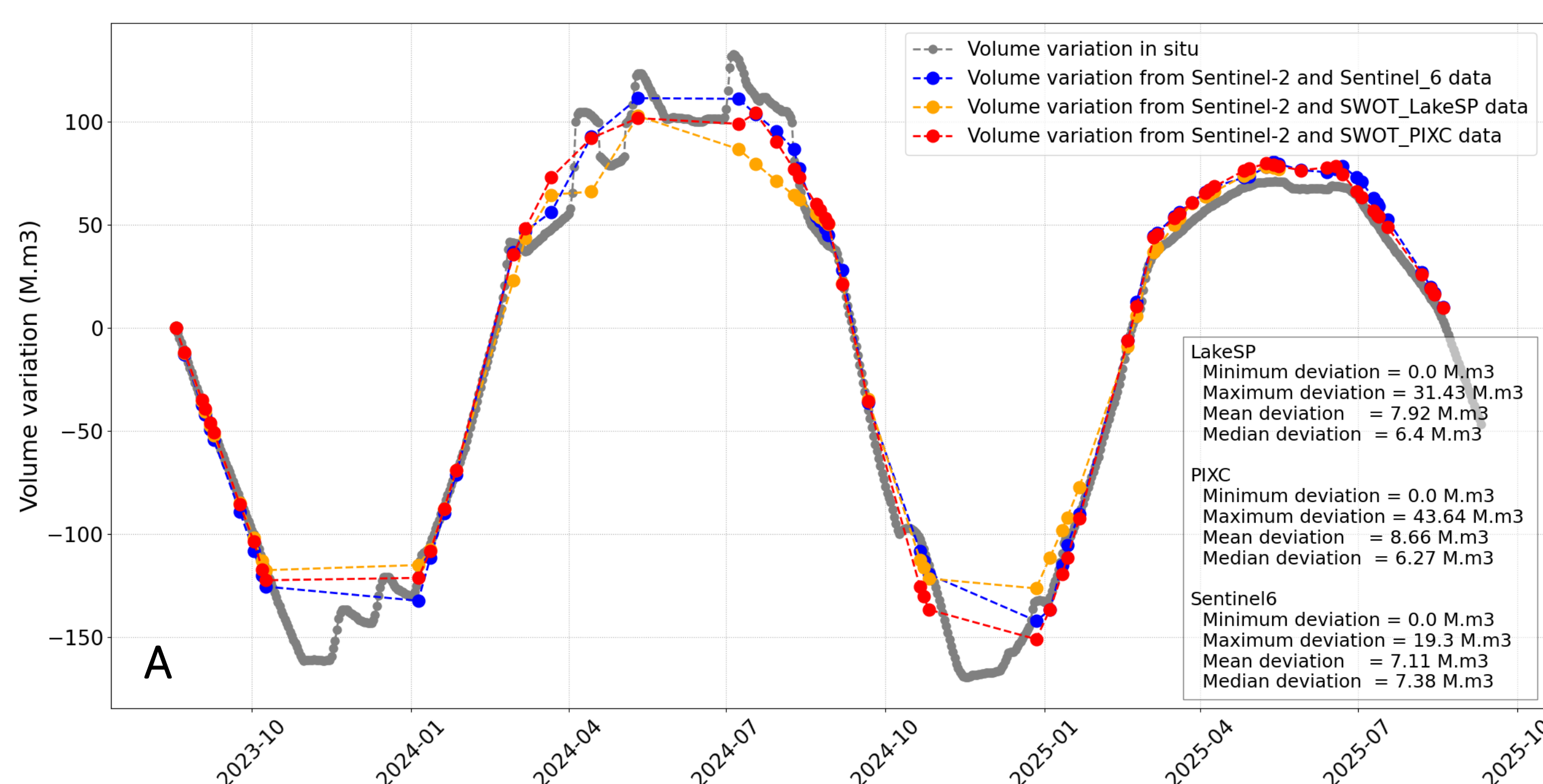


Fig. 4: Water surface time series from Sentinel-2 (2023 – 2025).

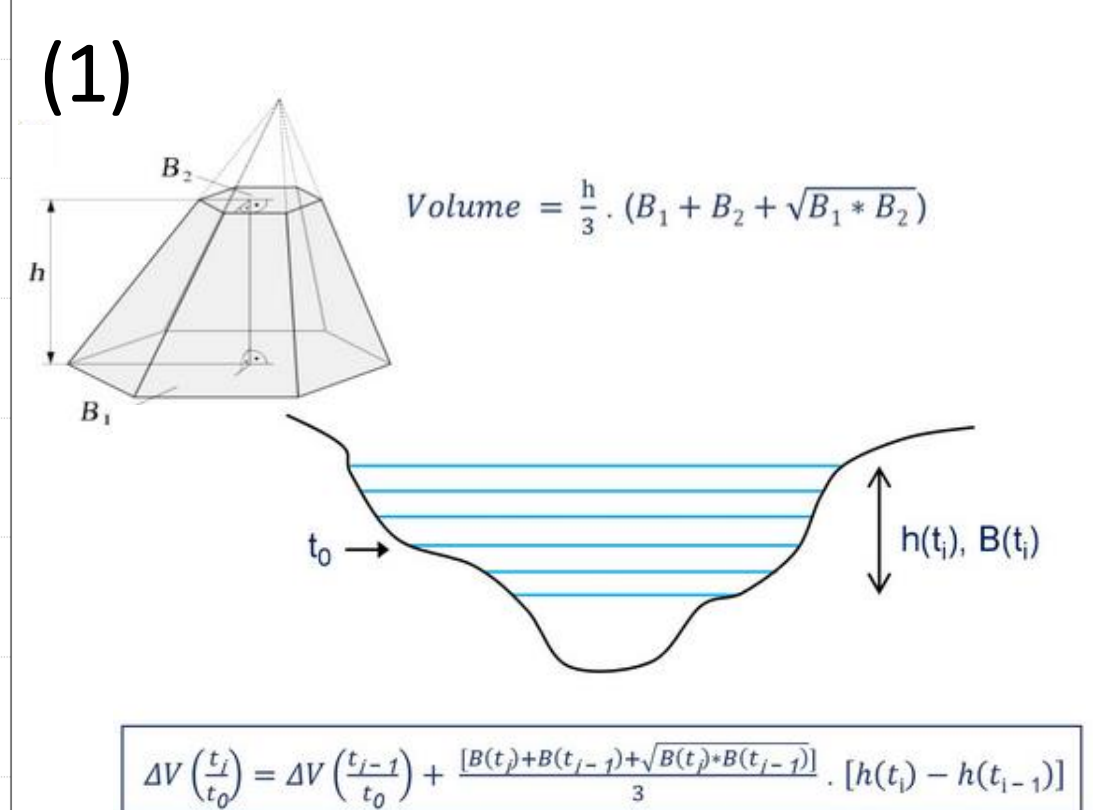


Fig.5: Volume variations analysis:

**A:** using Sentinel-2 areas and Sentinel-6, SWOT PIXC and LakeSP heights.

Temporal granularity depending on exploitable S2 data availability.

**B:** using Der's bathymetry and Sentinel-6, SWOT PIXC and LakeSP heights.

## Conclusion-perspectives

- Diamond could content very valuable information, mostly in PICX products ( $\sigma_{\text{PIXC}/\text{insitu}} = 9$  cm)
- The Nadir SWOT data does not give the expected results because the Nadir SWOT OLTC is incorrectly configured for this lake.
- Multi-sensors exploitation demonstrate strong complementarity for monitoring water height, surface and volume variations in medium-sized reservoirs.
- Sentinel-6 provides superior temporal resolution; SWOT offers high spatial detail.

- Fine-scale height variations captured by S6 during summer 2024, linked to tight water regulation ahead of the Paris Olympics—only detectable thanks to its 10-day revisit.
- Precise monitoring of reservoir volume variations based on S2 lake water surface + SWOT PIXC lake water height.
- Deriving absolute lake volume using SWOT and S6 WSH associated with in-situ bathymetry.