

SWOT

Science Team Meeting

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ARCACHON • France

14-17 OCT. 2025

Performance assessment of the water surface elevation of HR SWOT products based on comparisons with in-situ networks and in-flight nadir altimetry missions



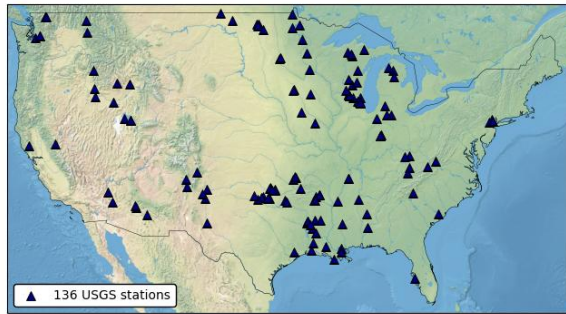
VAYRE Maxime, RENOU Julien, CHAPPELLIER Marie, TABURET Nicolas



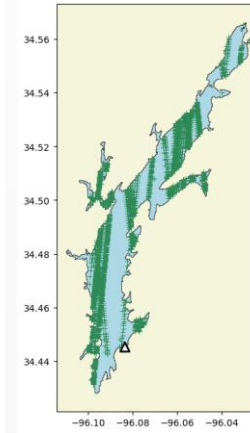
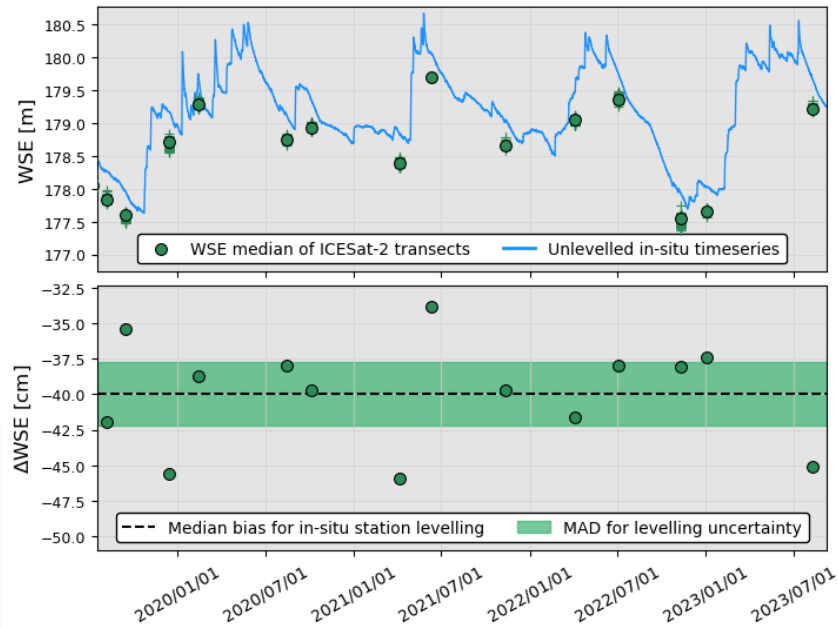
FJØRTOFT Roger, PICOT Nicolas, POTTIER Claire

Levelling of lake in situ data with ICESat-2

Use of the ICESat-2 (ATL13) mission to level in-situ measurements that have regional or unknown WSE levelling



USGS in-situ stations monitoring lakes in the United States



Lake Atoka

- SWOT requirements: $|WSE \text{ error}| < 10 \text{ cm} (1\sigma)$ for water bodies $> 1 \text{ km}^2$
- Need for very precise leveling

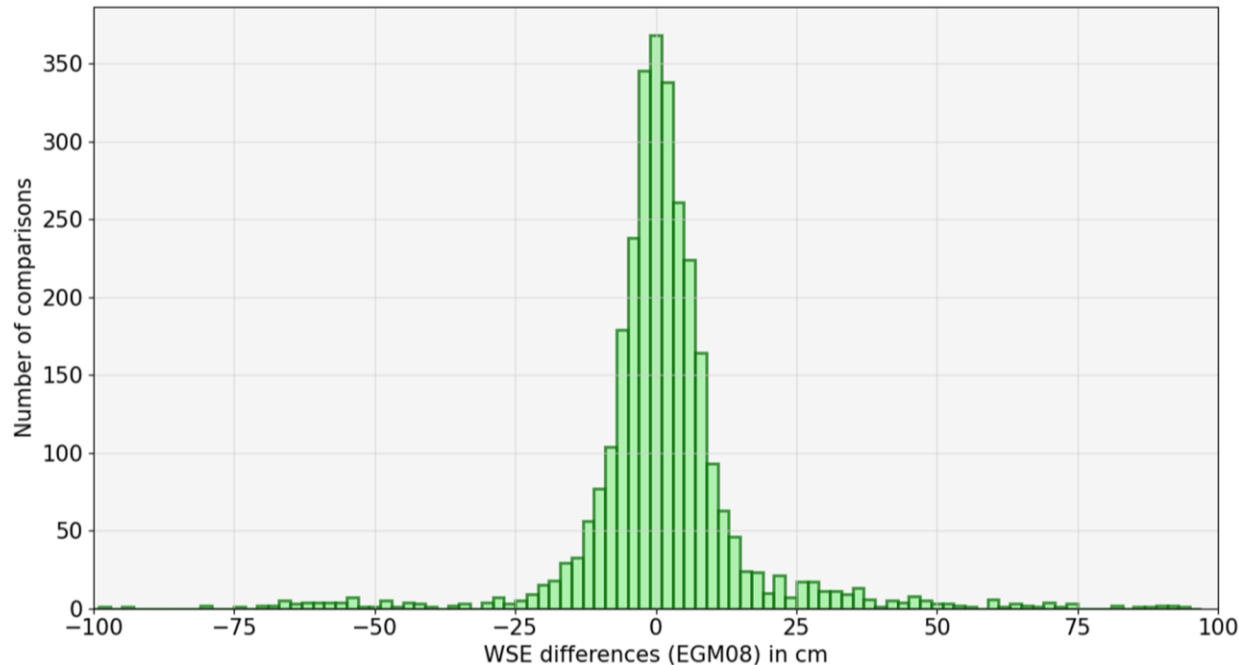
- Example for the USGS network (136 gauges)
- Comparisons of ICESat-2 WSE measurements referenced on EGM2008_mean_tide geoid model with in-situ WSE timeseries
- Estimate of the median bias and median absolute deviation (MAD) for provision of levelling and its uncertainty (124 out of 136 gauges with $MAD < 10 \text{ cm}$)

SWOT LakeSP validation results based on in situ observations

USGS network over lakes



BAFU network over lakes



WSE differences (EGM08) between SWOT LakeSP and USGS + BAFU in situ data (126 lakes and 3038 measurements)

Comparisons w.r.t BAFU ([Switzerland Topic Water \(admin.ch\)](http://www.admin.ch)) and USGS ([US USGS Water Data for the Nation](http://www.usgs.gov)) in situ networks

126 different lakes (PLD reference area > 1 km²)

- Period: Aug 2023 – May 2025 (LAKESP version C)

Use of ICESat-2 data (ATL13 v6) to level in situ measurements when needed (regional or unknown WSE levelling) and detect potential inconsistent gauges

3038 measurements (1-day difference):

- Flag: "quality_f"=0 & "xovr_cal_q"=0
- 1σ |WSE_{Error}| ~8,10 cm (68th percentile)
- Bias: Median value WSE_{Error} ~1,66 cm

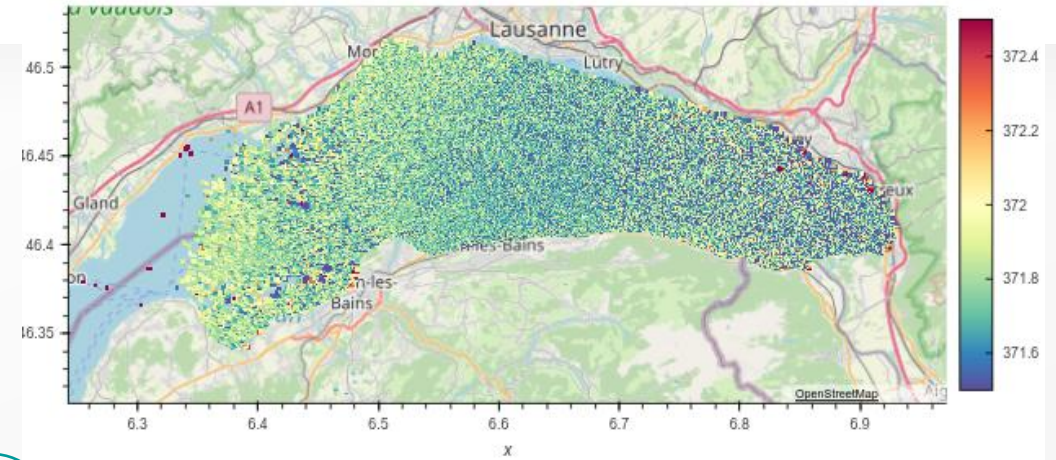
Preliminary validation from PIXC version D products

SWOT products :

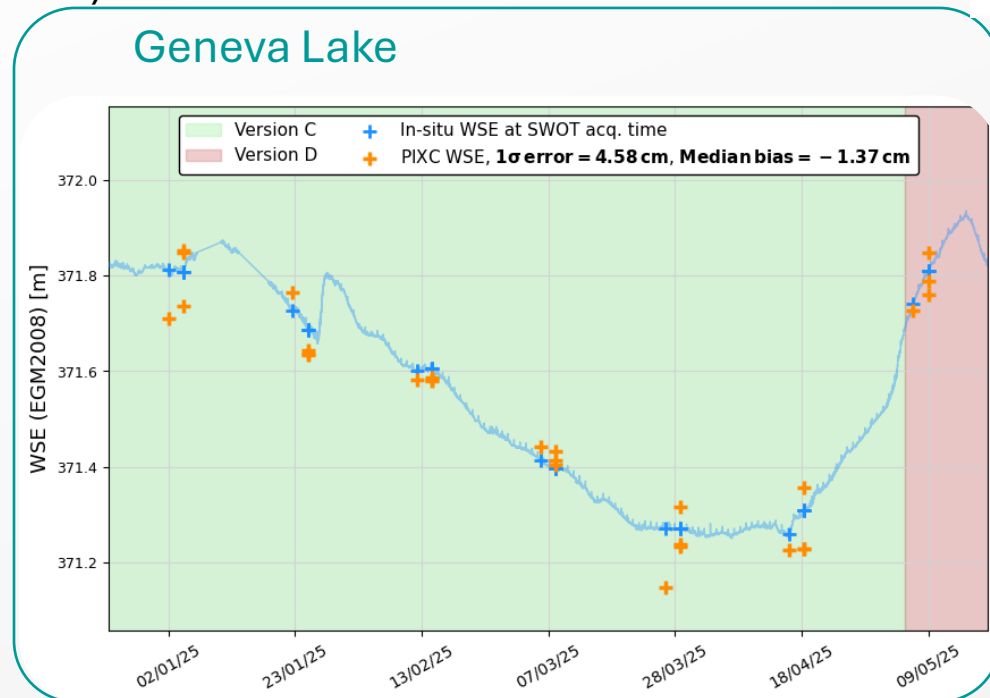
- HR Pixel Cloud (PIXC) - version C
- HR Pixel Cloud (PIXC) - version D : latest version (since May 2025)

In situ products:

- Switzerland network (FOEN/BAFU)
- US network (USGS)



PIXC water level distribution example for PID product (335_236R cycle 35) over the Geneva Lake



Water level time series example over the Geneva Lake with PIXC version C and (green area) and version D (red area)

Method:

- PIXC WSE:
 - Water level selection within the swath (10km-60km) and the lake area (using PLD) and 'classification_flag' = 4
 - WSE computed as the weighted average (based on phase noise estimates)
- Comparisons w.r.t in situ data ($\Delta t < 1\text{day}$)

Preliminary validation from PIXC version D products

Objective : Preliminary evaluation of PIXC version performance compared to in-situ measurements from the first version D products. PIXC version C vs version D w.r.t in situ

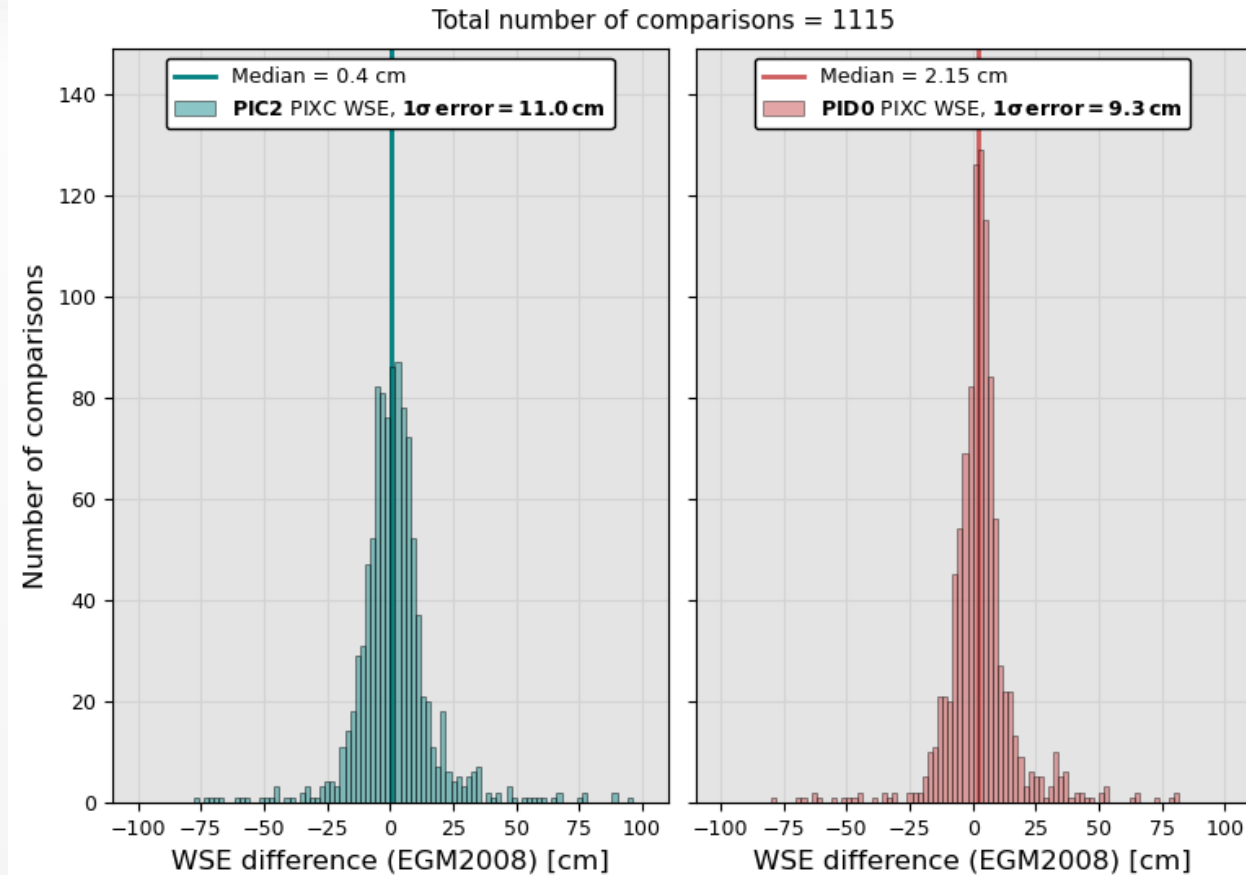
Period: Science phase. 2025 for PIC and May-July 2025 for PID

Dataset: USGS and BAFU in situ data (126 lakes, 1115 comparisons). Different dates for PIC and PID products, but the same number of comparisons and targets is used to assess the performance

	Version C	Version D
Bias	0.4 cm	2.15 cm
1 σ error	11 cm	9.3 cm

Bias: Bias is about 0.4 cm for version C products. Version D bias is consistent with the expected +1.5 cm relative to PIC products, but deviates from zero.

1 σ performance: Preliminary assessment suggests improvements for version D products, could be related to the geoid grid correction applied to SWOT



Distribution of the differences between SWOT PIXC PIC (left panel) and PID (right panel) compared to in situ data (BAFU and USGS)

ICESat-2 to assess SWOT LakeSP performance

Products: SWOT LakeSP version C vs ICESat-2 ATL13 (v6)

ICESat-2 ATL13: Water level computed as the median value using all available estimates within the lake area (PLD v105)

Period: Science Phase, Aug 2023 – Aug 2024

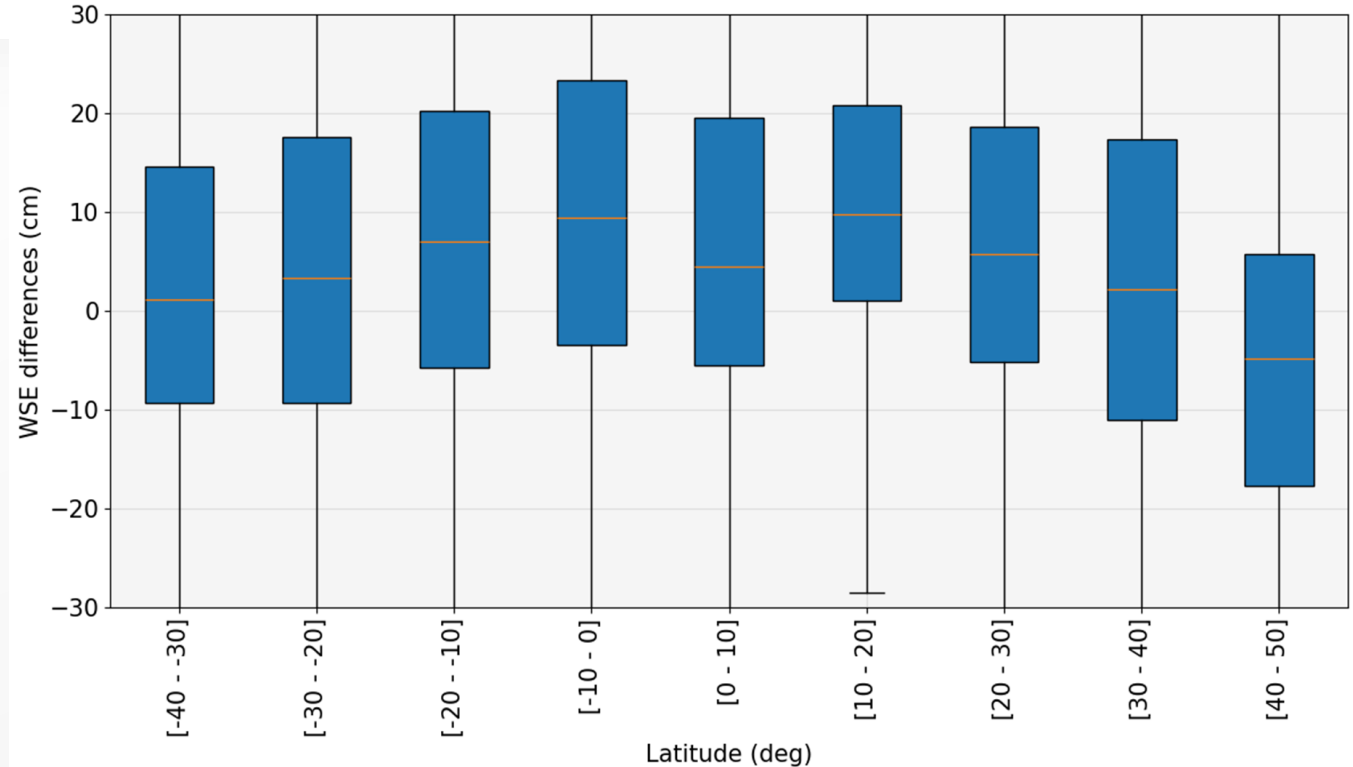
Selection: $\Delta t < 5\text{days}$, $WSE_STD < 0.50\text{ m}$ and latitude $< 50^\circ$ (to keep only low WSE variability and avoid frozen areas) "Flag": "quality_f"=0 & "xovr_cal_q"=0

⇒ ~4.3k lakes and ~13k comparisons

⇒ Clear dependence on latitudes, similar to permanent tide correction (see IERS convention). From -10 cm at high latitudes (70°) to +6 cm near the equator.

Differences between ICESat-2 and SWOT considering permanent tides (solid earth tide correction). Particular attention should be paid to the user handbook and ATBDs

	ICESat-2 vs SWOT LakeSP	
Bias [cm]	(lat<40°)	3.65 cm
	(lat>40°)	-4,80 cm



Distribution of the differences between SWOT LakeSP (version C) and ICESat-2 (ALT13 v6), permanent tide correction not applied

permanent tide correction not applied

ICESat-2 to assess SWOT LakeSP performance

Products: SWOT LakeSP version C vs ICESat-2 ATL13 (v6)

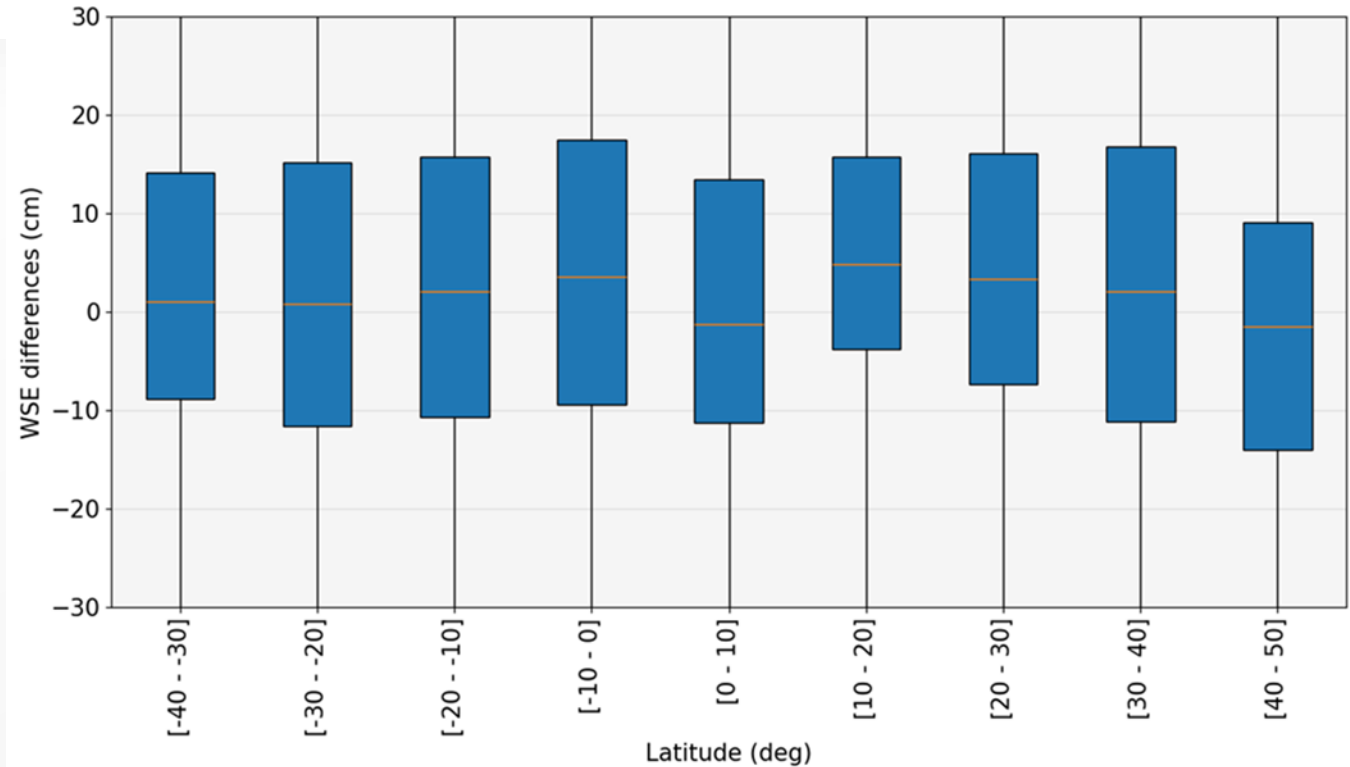
ICESat-2 ATL13: Water level computed as the median value using all available estimates within the lake area (PLD v105)

Period: Science Phase, Aug 2023 – Aug 2024

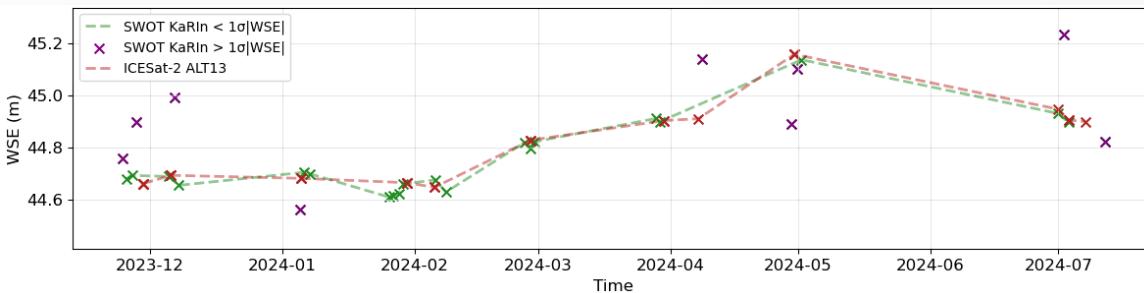
Selection: $\Delta t < 5$ days, $WSE_STD < 0.50$ m and latitude $< 50^\circ$ (to keep only low WSE variability and avoid frozen areas) "Flag": "quality_f"=0 & "xovr_cal_q"=0

⇒ ~4.3k lakes and ~13k comparisons

⇒ Bias: Median value WSE_{Error} -0,2 cm ($1\sigma |WSE_{Error}|$ ~22,8 cm)



Distribution of the differences between SWOT LakeSP (version C) and ICESat-2 (ALT13 v6), permanent tide correction applied



Example ICESat-2 vs SWOT LakeSP over the Vanern (area of 5381 km²). $1\sigma |WSE| = 5,55$ cm and bias = -0,6 cm

permanent tide correction applied

Conclusions and futures perspectives

Ability to level lake in situ stations using ICESat-2 ATL13 data

SWOT KaRIn validation over inland waters highlights good results generally in agreement with the mission requirements (WSE accuracy ~10 cm using BAFU and USGS datasets)

First PIXC version D results (Science phase):

- **Bias:** Bias is about 0.4 cm for version C. The bias of version D is consistent with the expected value of +1.5 cm compared to version C but deviates from zero.
- **1 σ performance:** Preliminary assessment suggests improvements for version D products, could be particularly related to the geoid grid correction applied to SWOT

ICESat-2 to assess SWOT LakeSP performance

- **Highlighting the need to account for the permanent tide**, comparing ICESat-2 with SWOT. More generally, this demonstrates the **complementarity between in situ measurements and altimetry missions (radar and/or lidar)**. Although noisier, they provide estimates over a large number of targets, allowing for the assessment of potential biases and the detection of trends
- Bias is about 0.2 cm using LakeSP version C products and ICESat-2 ATL13 with ~4.3k lakes and 13k comparisons

Perspectives:

- Part of *Performance evaluation of HR SWOT elevation data based on nadir altimetry and in situ comparisons over lakes, Vayre et al. in prep*
- Follow current reprocessing and future versions of SWOT products
- Discuss SWOT validation results, distinguishing **systematic** and **random errors**
- Discuss LakeSP performance using alternative PIXC selection and water level computation methods => PLD-based selection and outlier-robust water level computation
- Use SWOT to derive **mean lake surfaces** and overcome the limitations of existing geoid models



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