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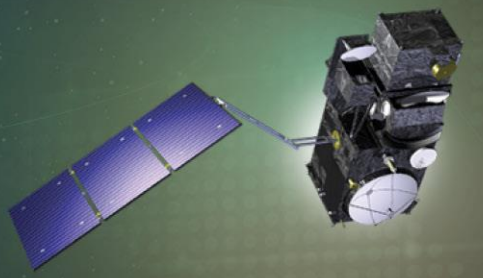


7th Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

Sentinel-3 Land STM MPC: Performance and Thematic products over Inland Waters

Taburet N.[1], Renou J. [1], Nielsen K. [2], Aiche A. [3]

Jettou G.[1], Aublanc J.[1], Femenias P. [4], Crétaux J.F. [5]

[1] CLS, [2]DTU, [3]Celad/CLS, [4]ESA-ESRIN, [5]CNES-LEGOS

Presentation content

1. Quality of PDGS products

2. OLTC update first feedback

3. Thematic Inland Water products : processing improvements that are expected to impact the most the Quality

4. Quality of Thematic Inland Water products

Comparisons with PDGS products

5. Proposed roadmap for the T-IPF products evolutions

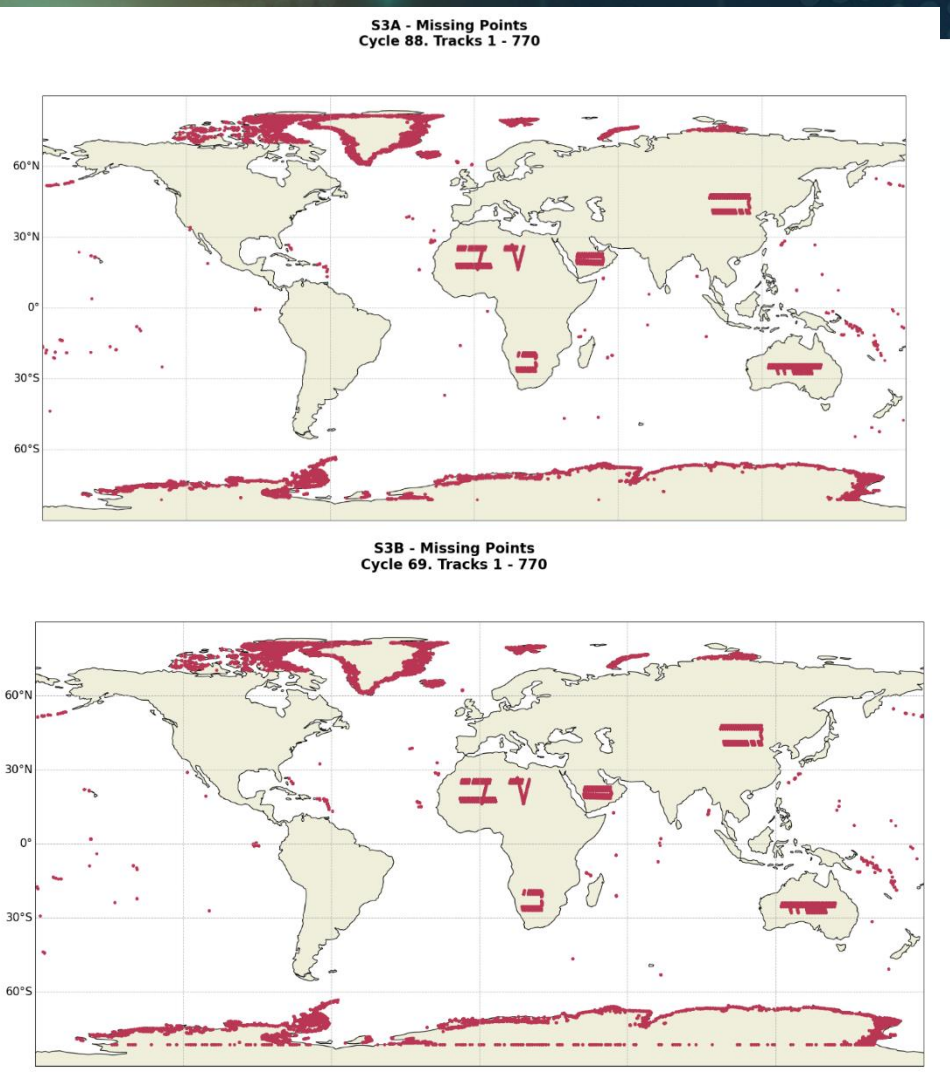
1. PDGS products quality over Inland Waters

1.1 Coverage / data availability

Missing data are mainly situated in calibration / closed loop areas
Expected as in closed loop tracking mode the altimeter repositions its receiving window when backscattered signal is lost

Missing passes over the past cycles (STC L2 PDGS Land)

Cycle S3A		Cycle S3B	
81	None	62	None
82	None	63	None
83	None	64	456,457,458,459,583
84	None	65	Pass 554 almost fully incomplete
85	None	66	None
86	None	67	Late delivery 763,764
87	294, 295	68	None
88	None	69	None
89	None	90	None



Example of missing data (STC L2 PDGS Land) for S3A cycle 88 / S3B cycle 69

1. PDGS products quality over Inland Waters

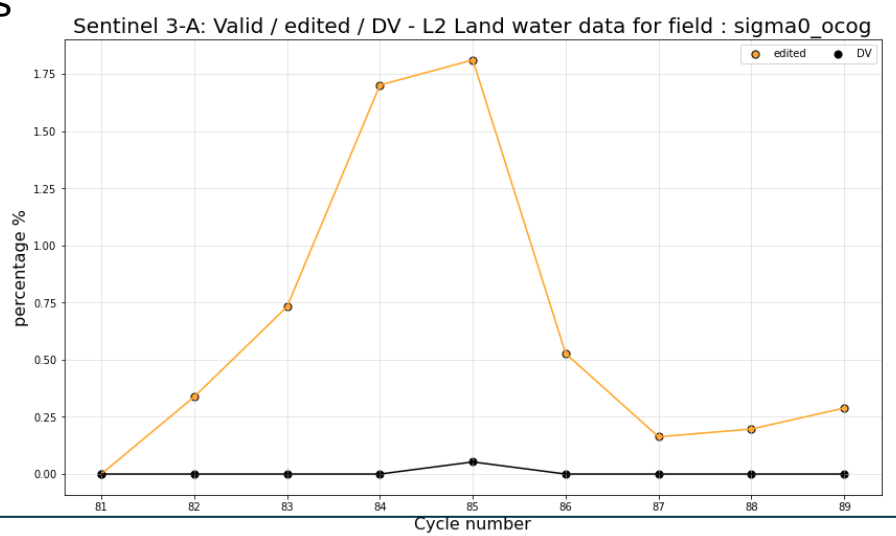
1.2 Data validity

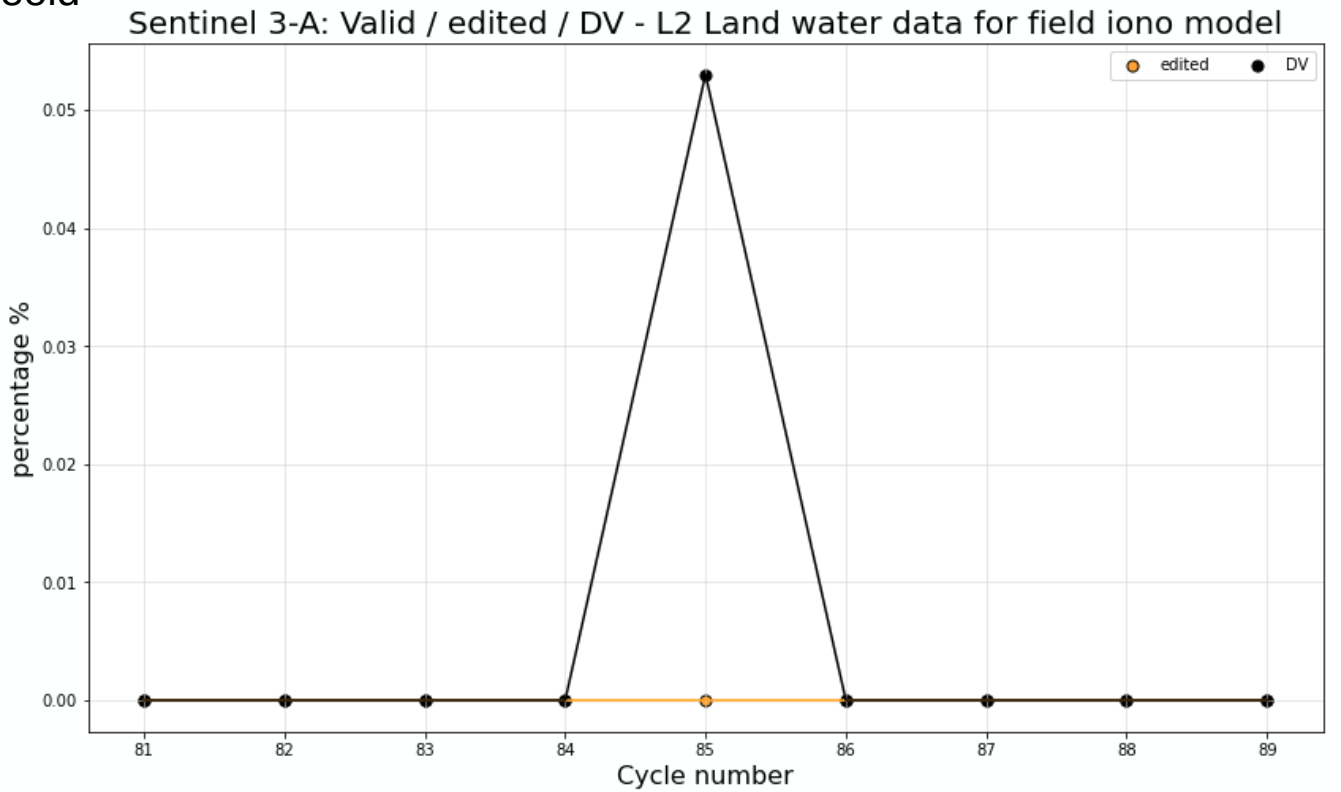
Water Surface Height is estimated as follows:
WSH = orbit - range - wet_tropospheric_correction - dry_tropospheric_correction - ionospheric_correction - polar_tide_correction - solid_earth_tide_correction - geoid

Monitoring of the validity of these fields

All cyclic reports available on https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-3-altimetry/data-quality-reports

Exemple of missing iono correction on some passes, documented in the cyclic reports



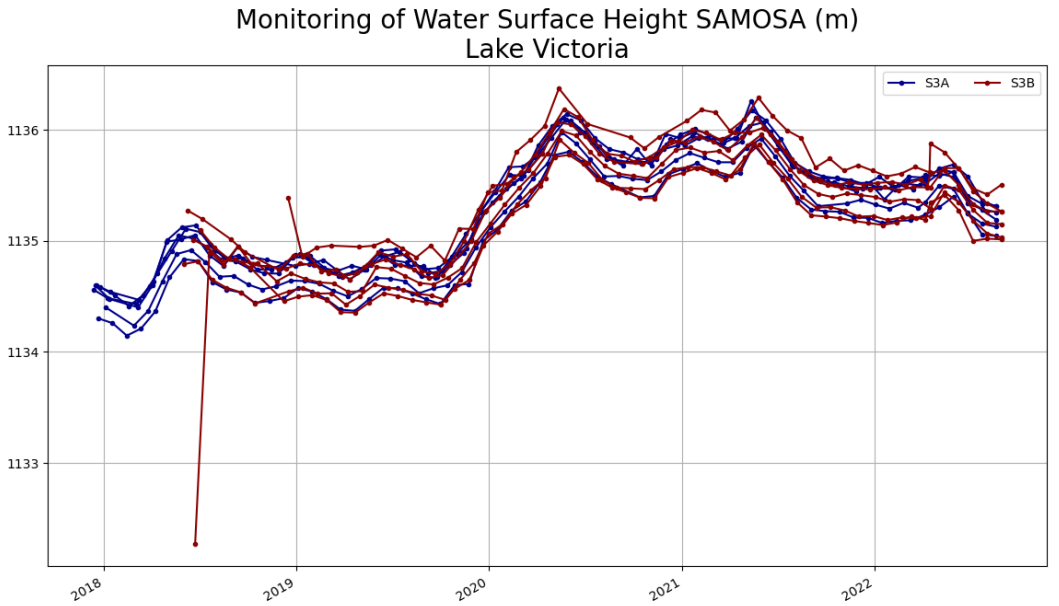


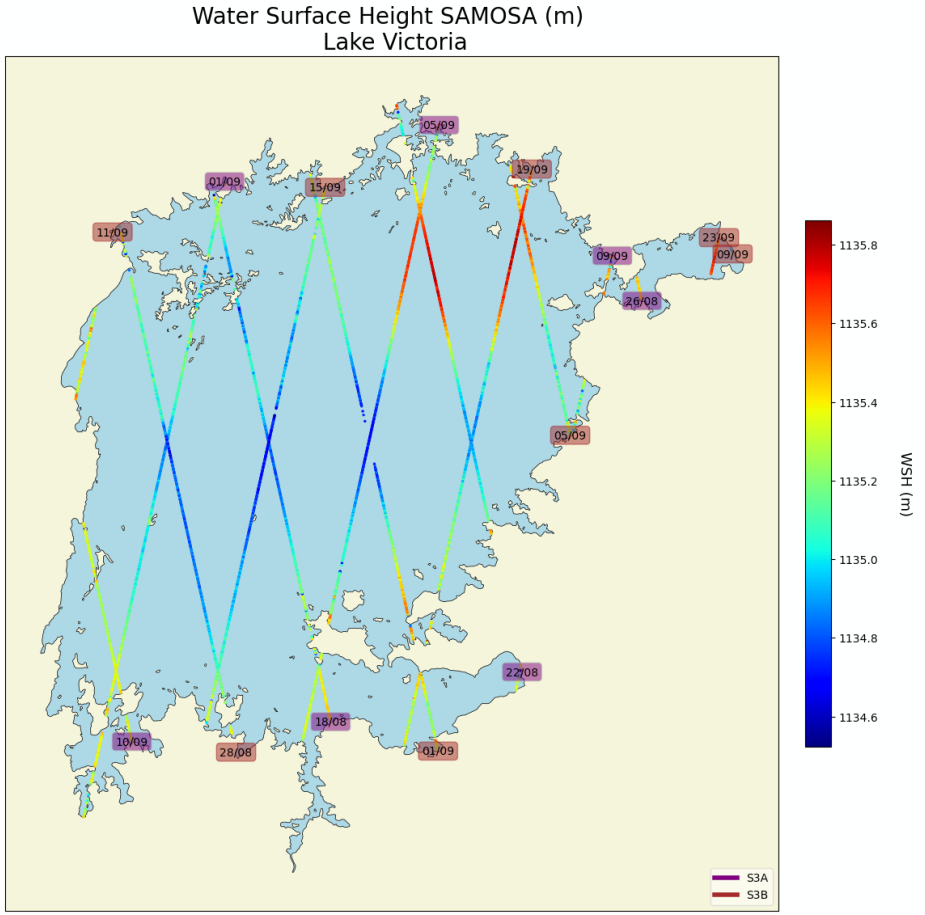
1. PDGS products quality over Inland Waters

1.3 Cyclic monitoring over lakes

Monitoring of inter tracks consistency inter and intra missions

- Spatially at Xovers. Expected along track variation (geoid fluctuations)
- Temporally: centimetric consistency in between the water level timeseries estimated on the different tracks



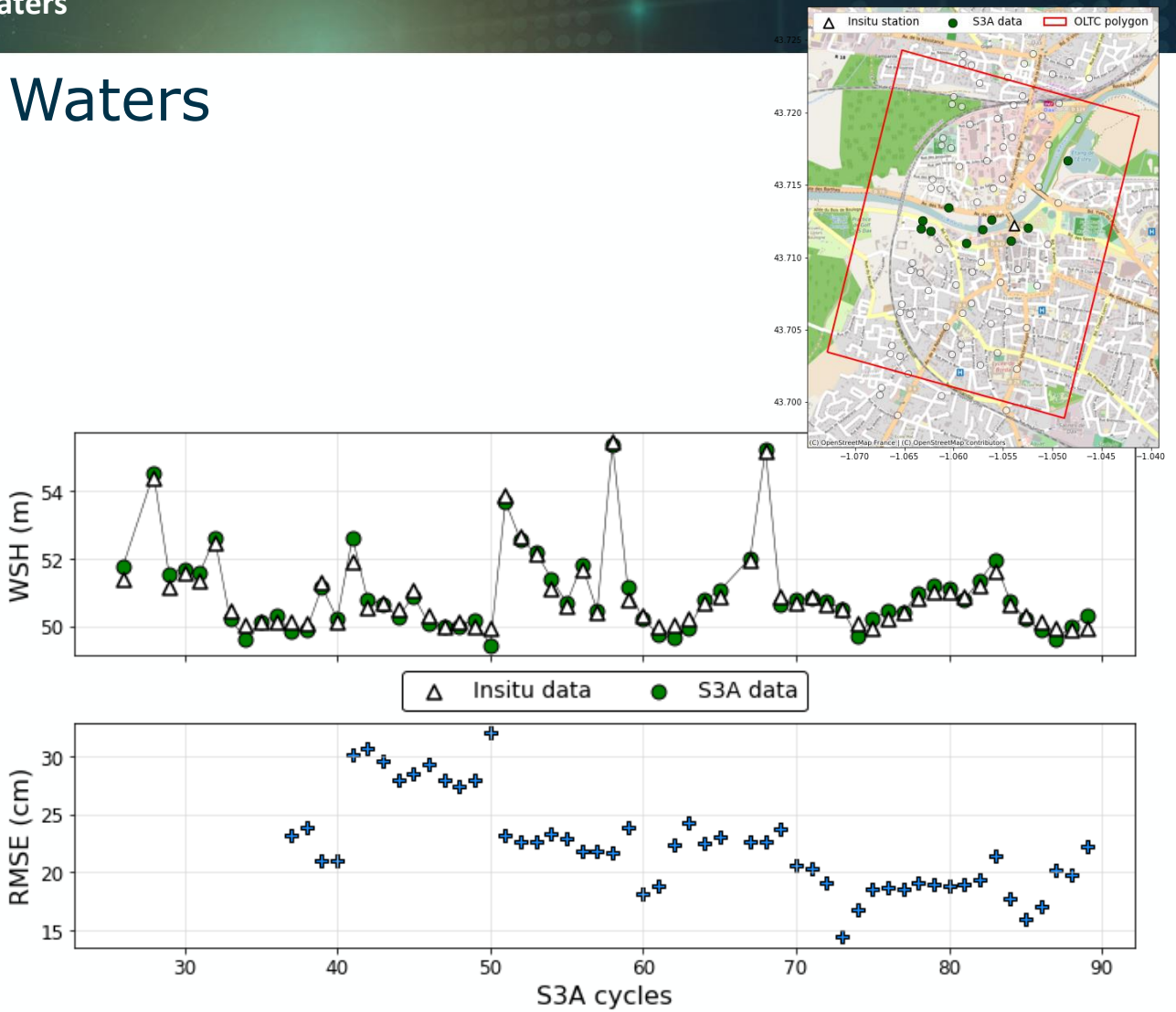


1. PDGS products quality over Inland Waters

1.4 Cyclic monitoring over rivers

- Comparison to InSitu dataset newly integrated in cyclic reports
- Based on French SCHAPI in situ data re-referenced to the same ellipsoid reference (WGS 84) as the S3 data
- Ongoing work in synergy with St3tart project

- RMSE (absolute) of the order of 20-25cm (11cm/km river slope not accounted for)

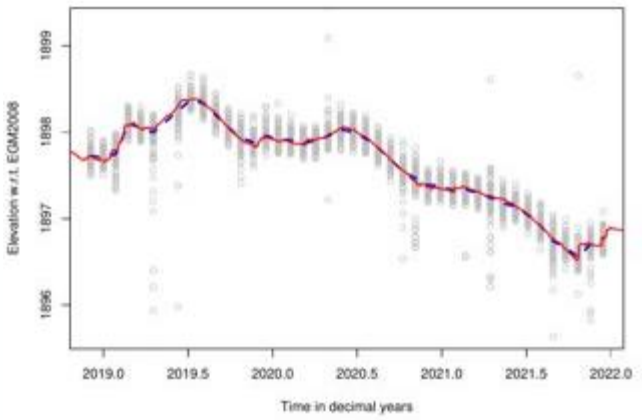


Time series of the insitu and S3A data on the Adour river (top). RMSE value computed for each cycle using data from the 10 last cycles (bottom). Retracker used = OCOG

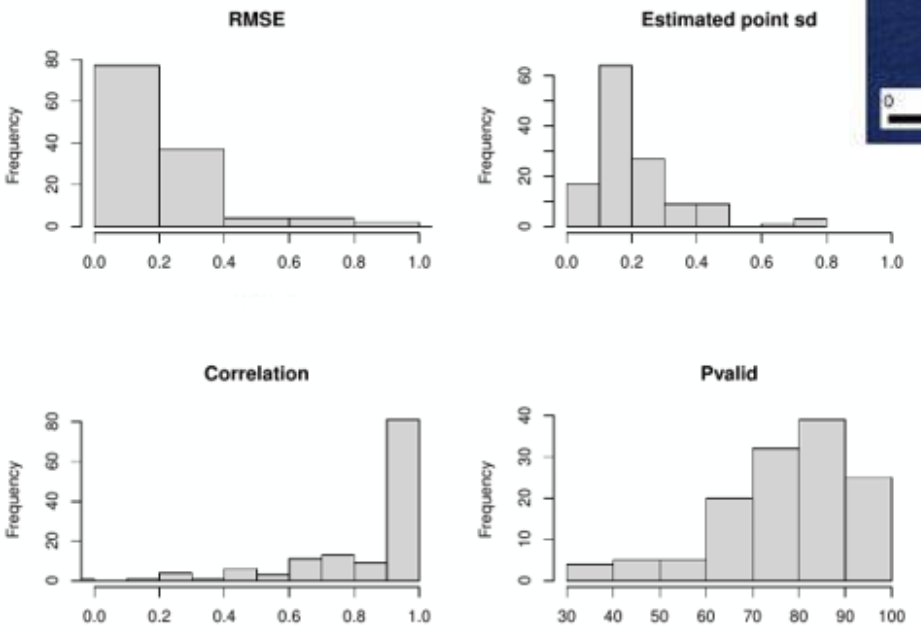
1. PDGS products quality over Inland Waters

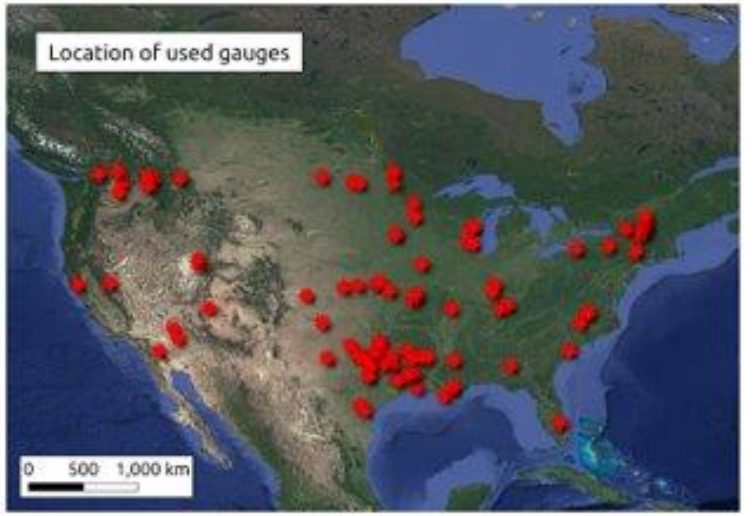
1.5 Extensive comparisons over lakes with InSitu references

- The evaluation is based on comparison with gauge data over 83 lakes with an area between 20-6500 km2
- The Root mean squared error (RMSE) is generally below 20 cm
- Poor RMSE values are often related to errors in the range window
- We find the OCOG retracker most suitable for inland water applications



gauge data (red line), time series model (blue line), observations (gray points)





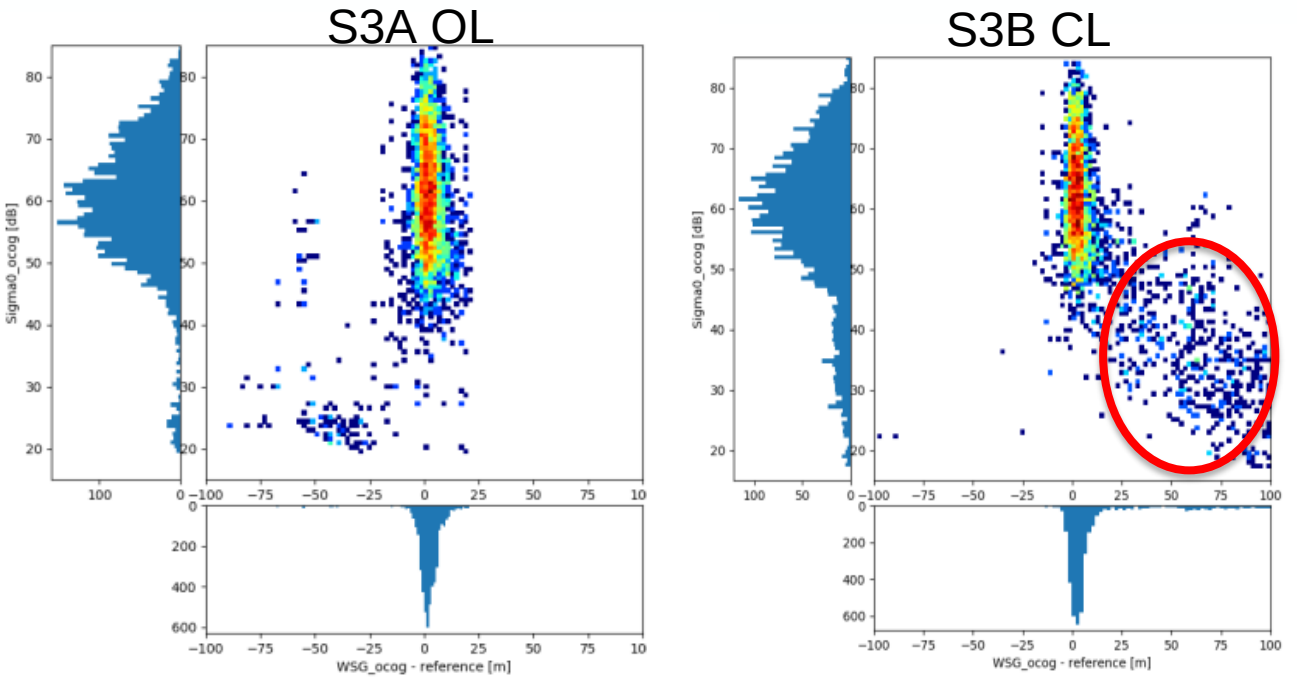
2. OLTC

2.1 Why are Open Loop and associated OLTC essential to measure inland water levels ?

- In Closed Loop the altimeter positions its receiving window (about 60m wide) based on previous echoes
- In Open Loop it used a priori information from onboard DEM named Open Loop Tracking Command

Previous studies have shown that

- CL properly tracks a large fraction of the water bodies
- BUT also hooks on other reflecting targets (|WSH-reference elevation| >20m) either not at the altimeter nadir or with low reflectivity
- 16% CL points correspond to tracking another target



Density of 20Hz points in the sigma0 0C0G / (WSH estimate –reference) space during the tandem phase.

Several papers emphasized the benefits of OLTC over Inland Waters

- Biancamaria et al. Validation of Jason-3 tracking modes over French rivers. Remote Sens. Environ. 2018, 209, 77–89
- Le Gac et al. Benefits of the Open-Loop Tracking Command (OLTC): Extending conventional nadir altimetry to inland waters monitoring. Adv. Space Res. 2019
- Taburet et al., S3MPC: Improvement on Inland Water Tracking and Water Level Monitoring from the OLTC Onboard Sentinel-3 Altimeters. Remote Sens. 2020, 12, 3055.

2. OLTC

2.2 September 2022 OLTC update first feedback

SRAL onboard DEM Updates

- from the 5th to 8th of September for S3A : v6.1 to v6.2
- from the 12th to 15th of September for S3B : v3.1 to v3.2

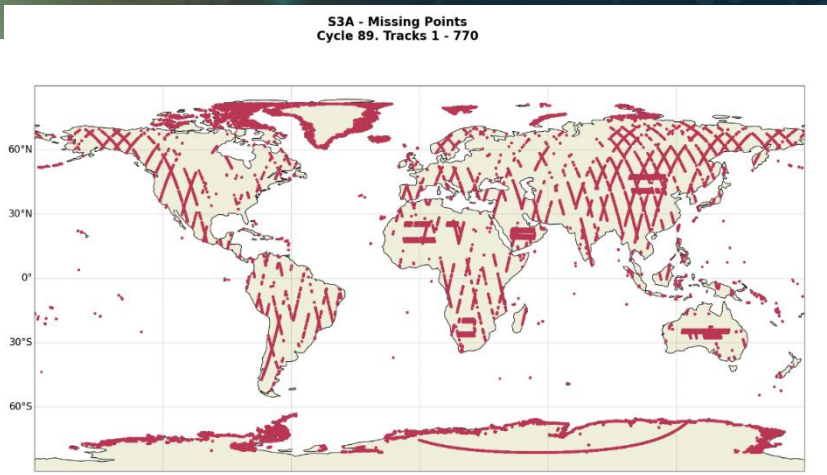
Acquisition mode has been temporarily turned into closed loop over these periods

⇒ Yields more missing points (3.66% over S3A cycle 89, while it was of 2.09% over cycle 88)

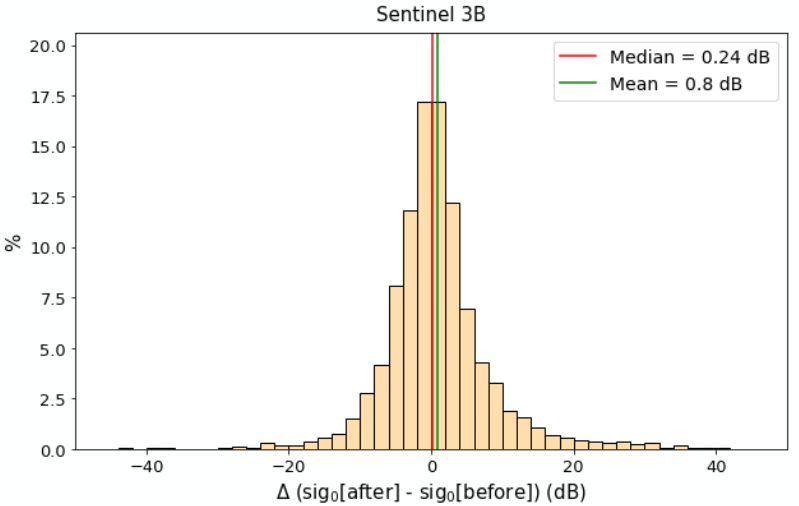
Update consisted in

- Changing the command over 4256 S3A targets (including 5 new)
- Changing the command over 4048 S3B targets (including 2 new)

⇒ Overall consistency in Sigma0 values
⇒ Significant improvement for 95 targets both on S3A and S3B
⇒ Possible degradation over 11 and 30 targets (ongoing investigations)



Missing data (STC L2 PDGS Land) for S3A cycle 89



Distribution of differences on Sigma0 OCOG values in between v3.2 and v3.1 over the 4048 water targets for which the command was modified on S3B

3. Thematic Inland Water products : what are the new important features ?

0-padding

This processing allows to improve the waveform sampling in range by a factor of 2 compared to PDGS products

Hamming windowing

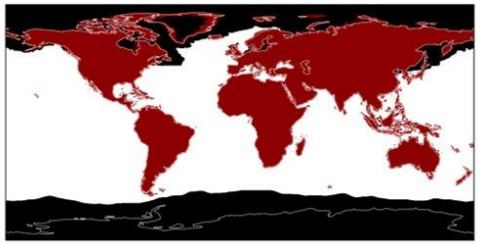
It avoids secondary lobes contamination in the azimuth direction resulting in restraining the energy contribution to the WF within the SAR band.

Thematic mask

Data selection results from the application of both

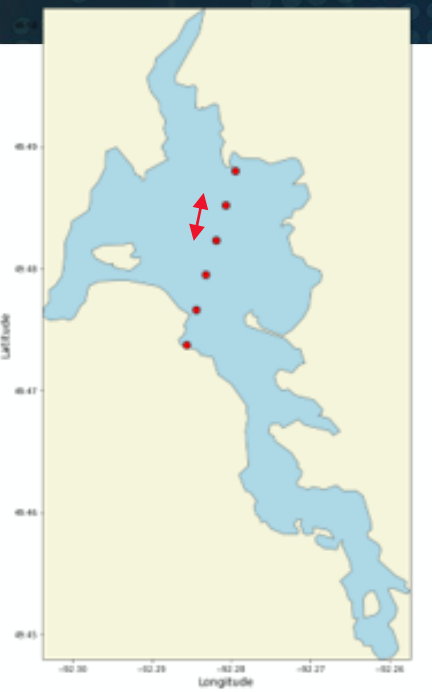
- the Marine Land Mask that defines the extension of the Marine and Land products.
- The thematic mask that defines the areas for Inland waters / land ice / sea ice products

Should your area of interest not being covered by them, data will not appear in the thematic products
MPC ESL Hydro has already provided feedbacks, inland water thematic mask has been extended to cover Greenland, Iceland….



Thematic Hydro products mask, see J. Aublanc presentation

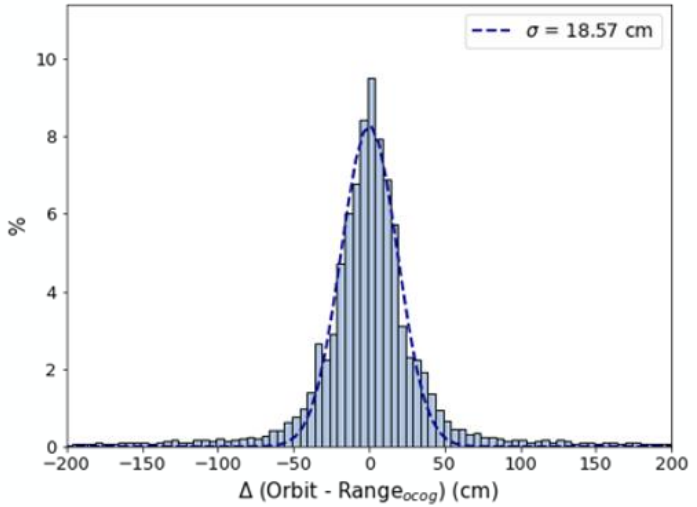
4. Quality of Thematic Inland Water product

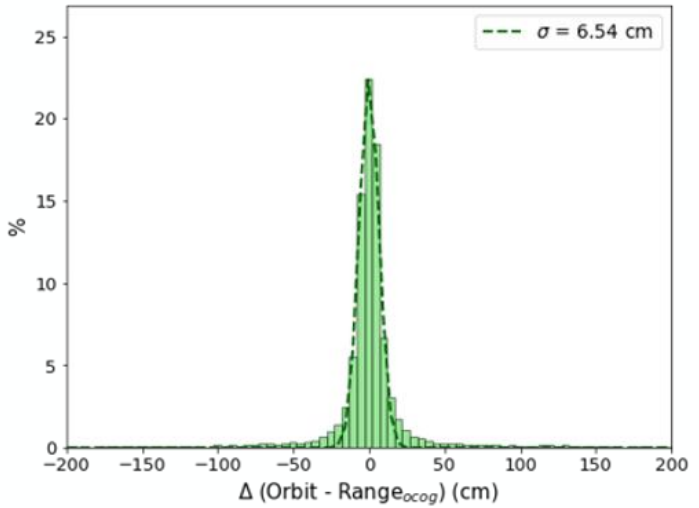


4.1 Assessment of the benefits of 0-padding over one cycle reprocessed with the thematic Hydro products and comparison with current PDGS products

Retracking noise estimate

The metric used is (Orbit – range) difference in between consecutive points:
$(Orbit – Range)_n - (Orbit - Range)_{n+1} = \Delta(Orbit - Range)$
Over lakes to avoid slope issues, small to be representative of peaky waveforms (OCOG retracking)



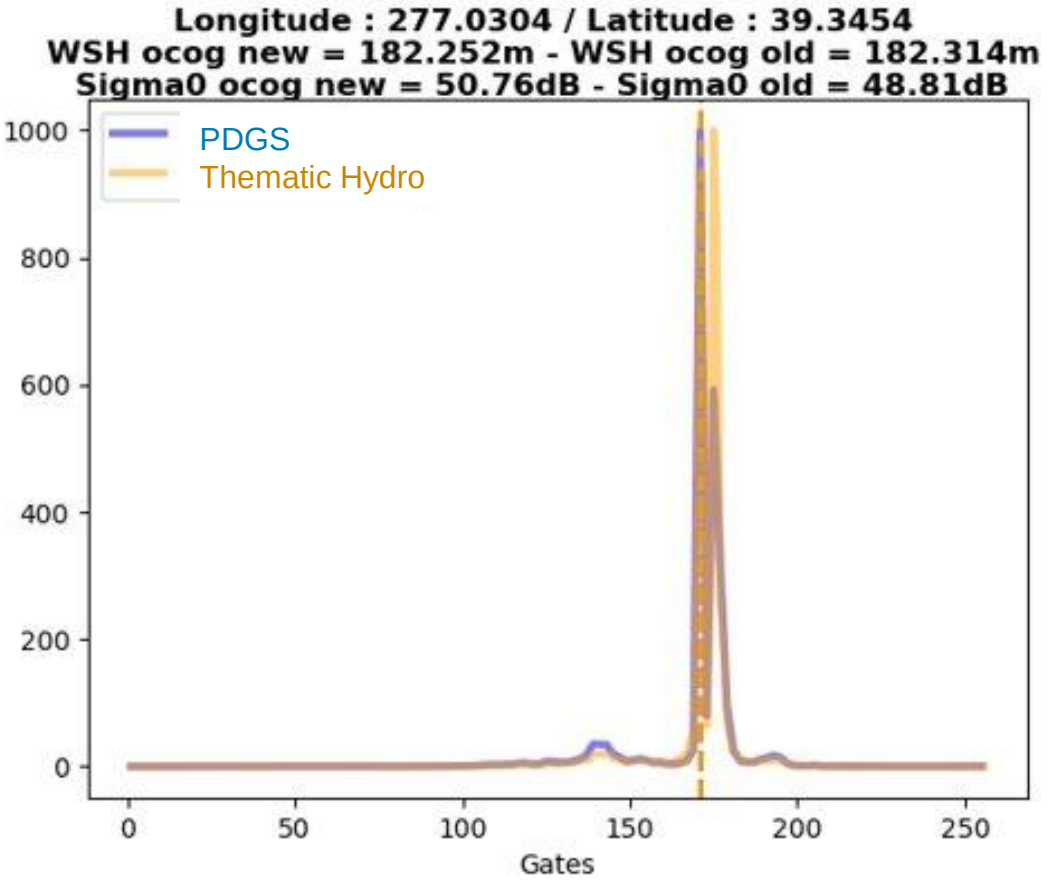


0-padding processing improves epoch estimation for steep leading edges, the retracking noise decreases from 18.6cm to 6.5cm over small lakes.

4. Quality of Thematic Inland Water product

4.2 Assessment of the benefits of Hamming processing in the thematic Hydro products and comparison with current PDGS products

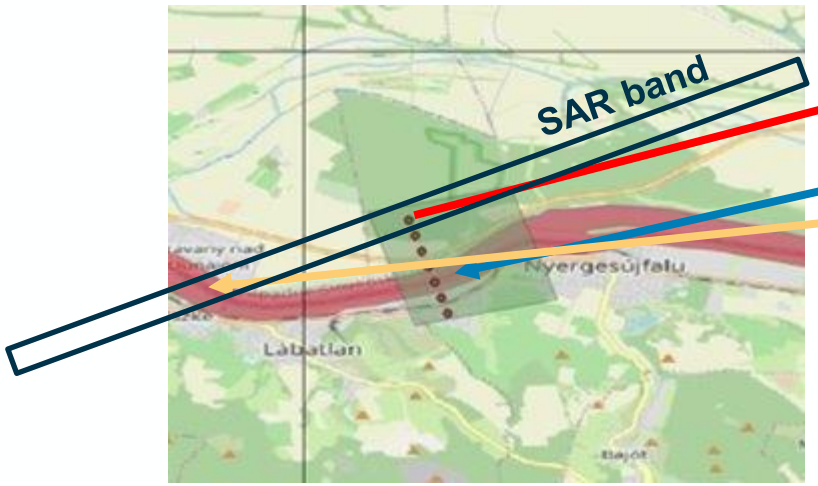
At river nadir
Sigma0 consistency and retracking of the same leading edge

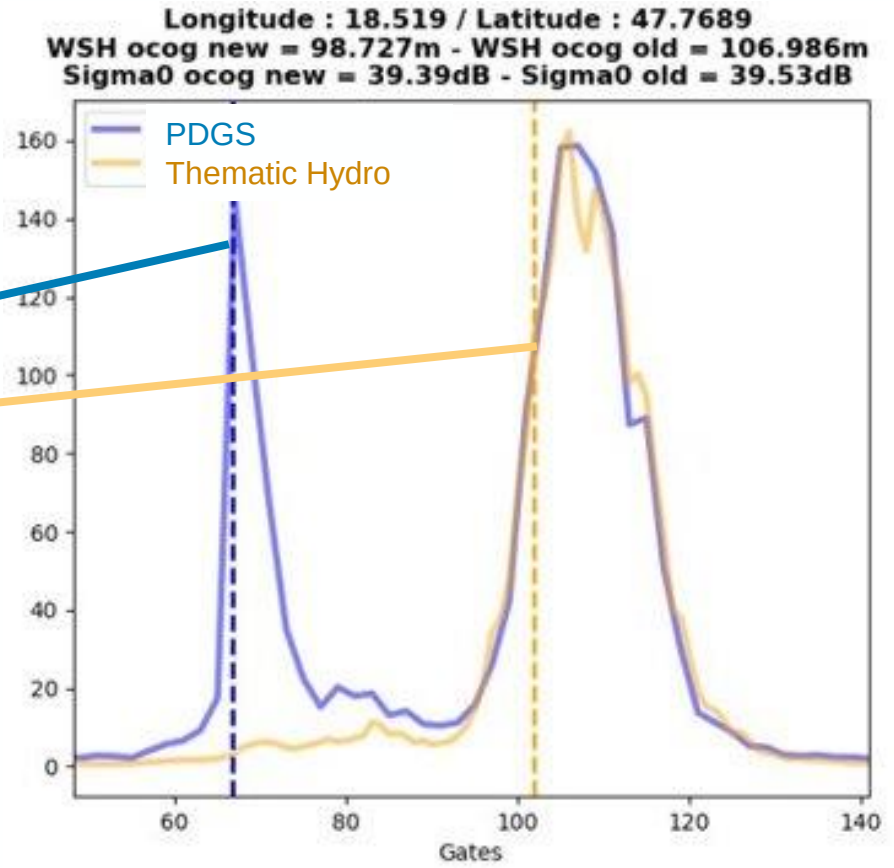


4. Quality of Thematic Inland Water product

4.2 Assessment of the benefits of Hamming processing in the thematic Hydro products and comparison with current PDGS products

Slightly off nadir the effect of Hamming is clearly visible : Thematic product is focused on signal coming from the SAR band, while PDGS waveform (blue) presents two echos, from the river and the westerm meandre.



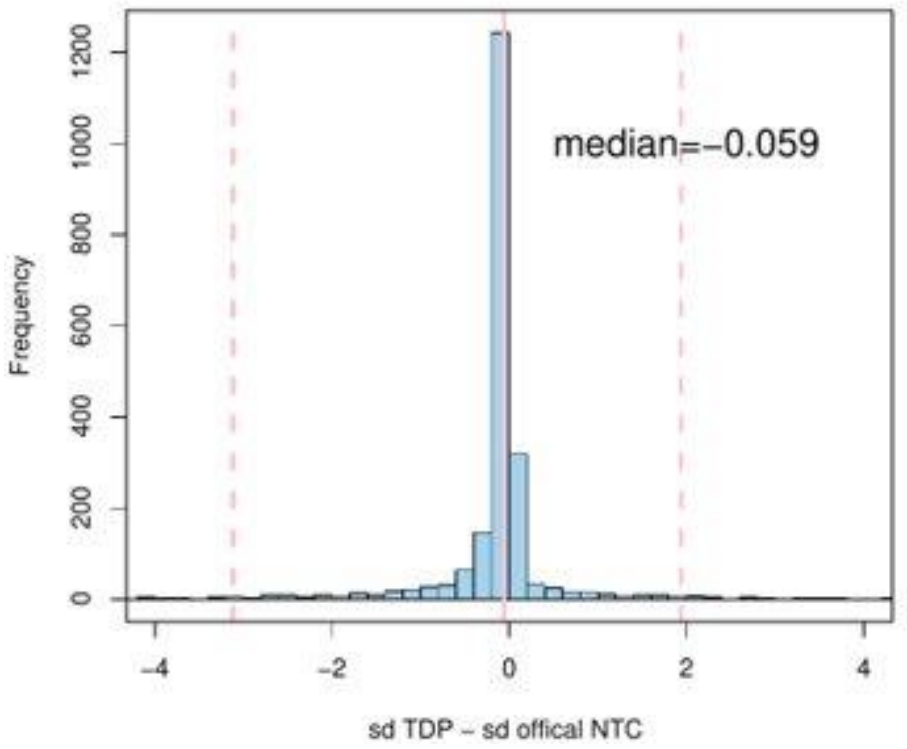


The epoch point does not have the same location in both products as Hamming filter focuses the along track footprint on the SAR band.

⇒ Across track signal emerges : other targets or other positions over river can be measured.

4. Quality of Thematic Inland Water product

4.3 Comparisons over lakes



The median track sd is ~6 cm smaller in the TDP, and can via bootstrap be shown to be significant at 5%

- 2185 globally distributed lakes were applied for the comparison
- A robust mean and standard deviation for each track were estimated
  - Evaluation of precision: Analyse the difference in the estimated point standard deviation (sd)
  - Evaluation of accuracy: Compare the estimated robust mean with ICESat-2 data

5. Proposed roadmap for the T-IPF products evolutions

5.1 Evolutions planned at short term (2023-2024)

	Description	Impact in Land Ice level-2 products	Recommenda-tion source
OLTC quality flag	Flag describing for each L2 data point if it is associated to a water target over which the OLTC was fine tuned or not.	New variable	QWG
Water surface mask information	Based on GSWE (Pekel et al. 2016)	New surface flag in L2 products	MPC ESL
Waveform classification from Neural Network	A waveform classification, based on a Neural Network algorithm using different waveform parameters (geometrical and/or geophysical when possible), to assign a class number to the radar waveform. **(Poisson et al., 2018)**	New variables giving information about waveform shape	QWG & ESL

5. Proposed roadmap for the T-IPF products evolutions

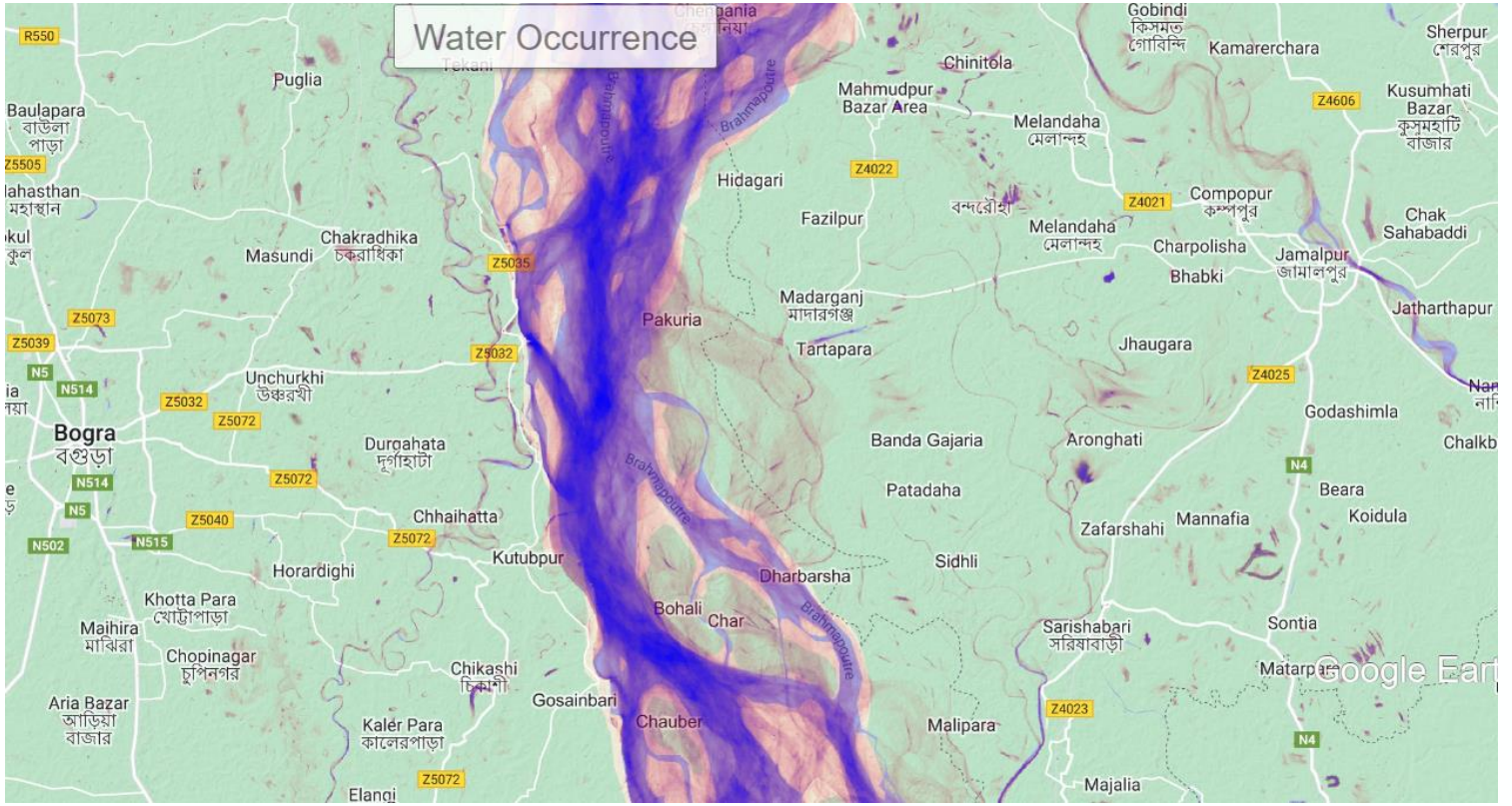
5.1 Evolutions planned at short term (2023-2024)

OLTC targets can be found (+ you can contribute) on https://altimetry-hydro.eu

5. Proposed roadmap for the T-IPF products evolutions

5.1 Evolutions planned at short term (2023-2024)

Global Surface Water occurrence

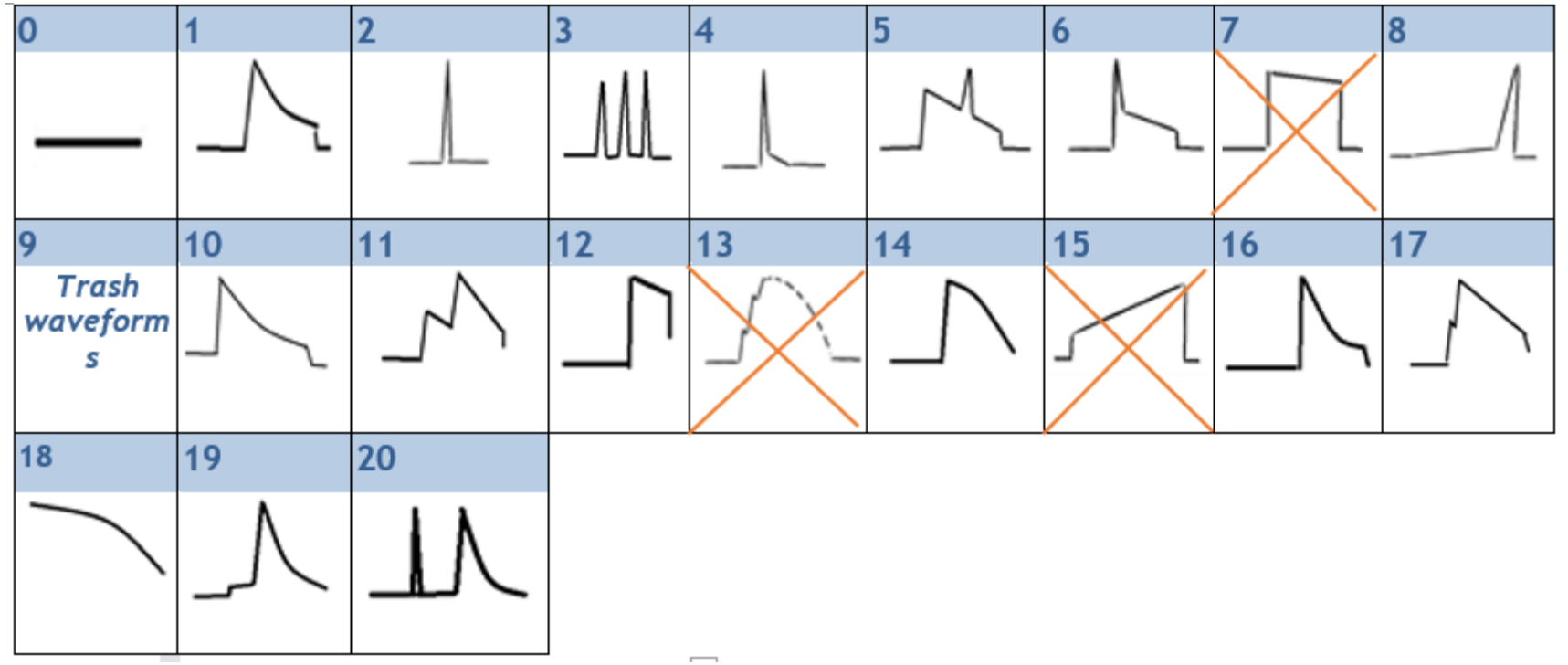


https://global-surface-water.appspot.com/map

5. Proposed roadmap for the T-IPF products evolutions

5.1 Evolutions planned at short term (2023-2024)

Waveform classification



5. Proposed roadmap for the T-IPF products evolutions

5.2 Mid term strategy main priorities

UnFocused-SAR at 80 Hz

To increase the posting rate (on-ground sampling). Preliminary investigations in studies funded by ESA / CNES showed improvements on L3 derived products when using 80Hz data. In addition, several FRM sites currently being defined in St3tart are over <300m rivers

Retracking improvements

Need of retrackers adapted to the target characteristics (size, roughness). Assessments/benchmarks are needed to review the possible current solutions (SAMOSA+/++, numerical retracker with mean square slope, sinc retracker, others?…). How to benefits from innovative processings ?

River information from external data (slope, width …)

Based on Tamlin et al. Database, will benefit from SWOT contribution. Slope correction is critical to build L3 time series and for validation activities. River width will be complementary information to GSWE mask.

5. Proposed roadmap for the T-IPF products evolutions

5.2 Mid term strategy main priorities

UFSAR 80Hz

Preliminary investigations in studies funded by ESA ESTEC / CNES

- Code to produce 80Hz data exists (SMAP)
- No specific auxiliary data file, needed input L1A and CAL2
- Increase by factor of 4 in CPU time
- Code complexity : important changes in IPF

Justifications

- 4 times higher sampling. Of particular interest for <300m wide rivers, having more than 1 point over 300-600m rivers
- Copernicus Land requirement : threshold 300m rivers, target 100m
- FRM are defined over <200m rivers (e.g; Garonne), need to have points at the nadir
- Performances. First results show that 80Hz improves L3 quality (from 8cm to 2cm error bars)

5.2 Mid term strategy other priorities

	Title	Maturity (High/Medium/Low)	Priority/Need (High/Medium/Low)
3	River Width information	High	High
5	Tunning OCOG over Inland Water surfaces	High	Medium
6	Tunning of Sigma0 for all retrackers	High	Low
7	Unfocused SAR processing at 80Hz	Medium	High
8	Physical Retracking	Medium	High
9	Uncertainty characterization	Medium	High
10	Lake Ice Thickness	Medium	Medium
11	Fully Focused SAR processing	Medium	Medium
12	Radiometer related corrections over large lakes	Low	Medium
13	Capability of the IPF to apply a specific processing over some selected areas	Medium	Medium
14	Sea State Bias correction over large lakes	Low	Low

Summary

- Current PDGS Land products
  - Quality consistent in time
  - Root mean squared error (RMSE) is generally below 20 cm over lakes
  - Absolute RMSE over rivers is of the order of 20-25cm. Ongoing work in synergy with St3tart project
- Open Loop tracking mode benefits confirmed
- September 2022 OLTC update is applied (from v6.1 to v6.2 for S3A, v3.1 to v3.2 for S3B)
  - We confirm the improvement over some targets previously degraded in the previous version
  - Few cases to investigate deeper/
- Thematic Hydro products are coming in 2023
  - Retracking noise is being reduced thanks to 0-padding : expected from ~18cm in PDGS down to ~7cm
  - Hamming windowing: across track signal emerges when not exactly at the nadir of water, beware of measurements interpretations when switching from PDGS to Thematic products
- Thematic Hydro products evolution roadmap
  - New fields to help data use/interpretation : OLTC flag, Global Surface Water Occurrence, Waveform classification
  - Mid term strategy is to propose higher sampling, retracking improvements, as well as metadata necessary for data interpretation and validation (rivers slope, width)