

Sentinel-3

Mission Performance Cluster

of Surface Topography Mission



Copernicus Sentinel-3 Surface Topography Mission - Cyclic Performance Report

LAND WATER

S3A

Cycle No. 100

Start date: 10/06/23

End date: 07/07/23

S3B

Cycle No. 81

Start date: 20/06/23

End date: 17/07/23

Reference: S3MPC-STM_CPR_0009_100_081

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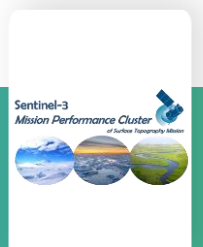
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1 Introduction

The purpose of this document is to report on the performance and data quality of the Copernicus Sentinel-3 Surface Topography Mission (STM) LAND products. The constellation currently includes Sentinel-3A and Sentinel-3B altimetry satellites. This document is associated with data dissemination on a cyclic basis and is generated a few days after the end of Sentinel-3B cycle.

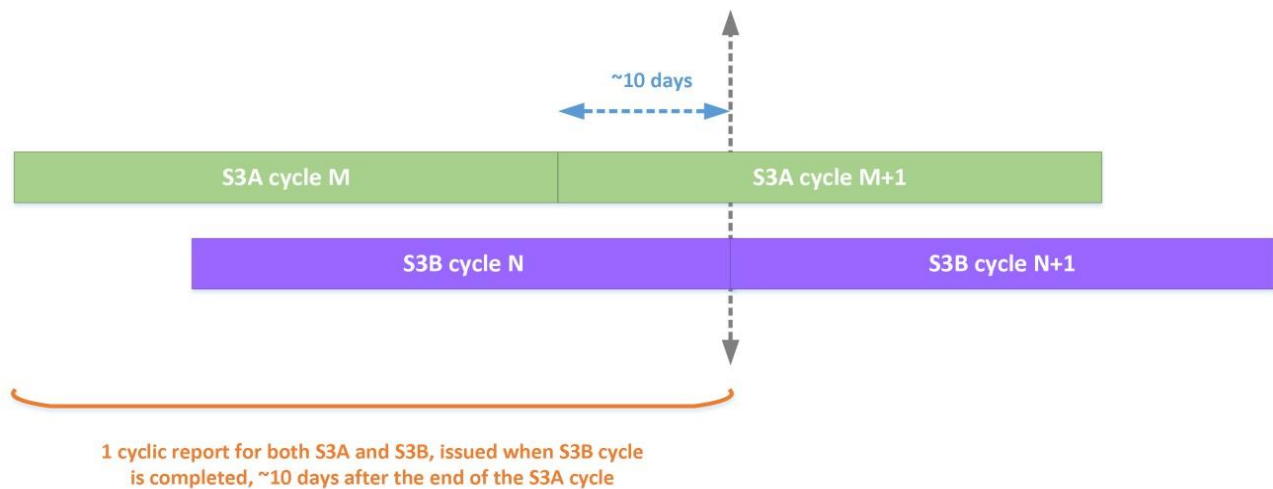


Figure 1 : S3A and S3B cycles chronology

The Inland Water Level 2 STC (Short Time Critical) products assessed hereafter are produced by the ESA Sentinel-3 LAND Processing Centre. One of the main goals of the cyclic report is to detect and report as quickly as possible any events, or anomaly, impacting the data quality. Subsequently, the assessments are made on the Short Time Critical (STC) products, generally delivered 48 hours after data acquisitions. Differences are expected with the Non Time Critical (NTC) products, for which the orbit data and several geophysical corrections are consolidated.

The main objectives of this document are:

- To provide a data quality assessment of the Sentinel-3 Inland Water Level 2 STC products
- To report on any changes likely to impact data quality at any level, from instrument status to software configuration.
- To present the major useful results for S3A cycle 100, from 10/06/23 to 07/07/23.
- To present the major useful results for S3B cycle 81, from 20/06/23 to 17/07/23.

2 Cycle overview




The performances obtained for cycles 100 (S3A) and 81 (S3B) are nominal:

- There are no full missing pass files. Some missing data are detected in closed loop mode and in calibration areas, which remains consistent with previous cycles.
- The mean percentage of available measurements over the targets measured in Open Loop is close to 100%
- The percentage of valid geophysical corrections is 100 %
- The percentage of valid Water Surface Height estimates over the considered targets is nominal
- The performances over lakes Victoria Ladoga and Issy-kul are nominal.

The following table summarizes the behaviour during the cycle with the main characteristics in terms of orbit, auxiliary data, geophysical corrections and geophysical parameters.

Parameter:	Sentinel-3A	Sentinel-3B
Orbit	Nominal orbit availability	Nominal orbit availability
Availability of geophysical corrections	Nominal geophysical corrections availability	Nominal geophysical corrections availability
Availability of auxiliary data	Nominal auxiliary data availability	Nominal auxiliary data availability
Geophysical parameters	Nominal performances of the altimeter-derived geophysical parameters	Nominal performances of the altimeter-derived geophysical parameters
Specific investigations		
Status	Nominal mission performances on this cycle	Nominal mission performances on this cycle

Table 1: General overview of the data availability and mission performances for the S3A and S3B cycles evaluated

- **Color legend:**
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-  NOK

3 Processing baseline

Table 2 details the versions of the Processing Baseline, and Level-1 and Level-2 Instrument Processing Facility software used for the products assessed hereafter.

	Cycle	Processing Baseline	IPF SM2 version	IPF SR1 version	IPF MW1 version
Sentinel-3A	100	3.05	06.20	06.20	06.13
Sentinel-3B	81				

Table 2: Processing baseline and IPF details

4 Data availability and missing measurements

4.1 Orbit coverage and missing measurements

Missing measurements relative to the satellites nominal ground track are plotted on Figure 2. The maps below illustrate 20Hz missing measurements in STC products for Sentinel-3A (top panel) and Sentinel-3B (bottom panel).

The missing measurements are mainly in the closed Loop mode areas for both satellites and at the transition to calibration zones. In Open Loop mode, the mean percentage of available measurements is close to 100%. As explained in Part 2, acquisition mode has been turned into closed Loop during three days for both missions, which results in abnormally high percentage of missing measurements over land for these periods.

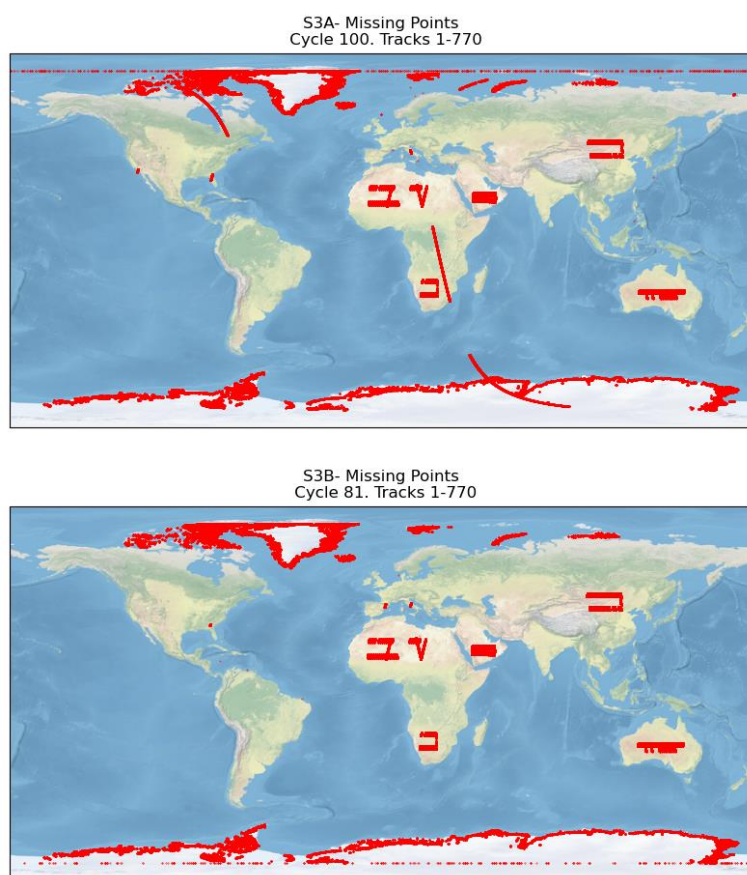


Figure 2: Maps of missing measurements (red dots) over land for Sentinel-3A (top panel) from 10/06/23 to 07/07/23 (cycle 100), and for Sentinel-3B (bottom panel) from 20/06/23 to 17/07/23 (cycle 81).

4.2 Validity of geophysical corrections, auxiliary data and altimetry parameters

The Water Surface Height is estimated as follows:

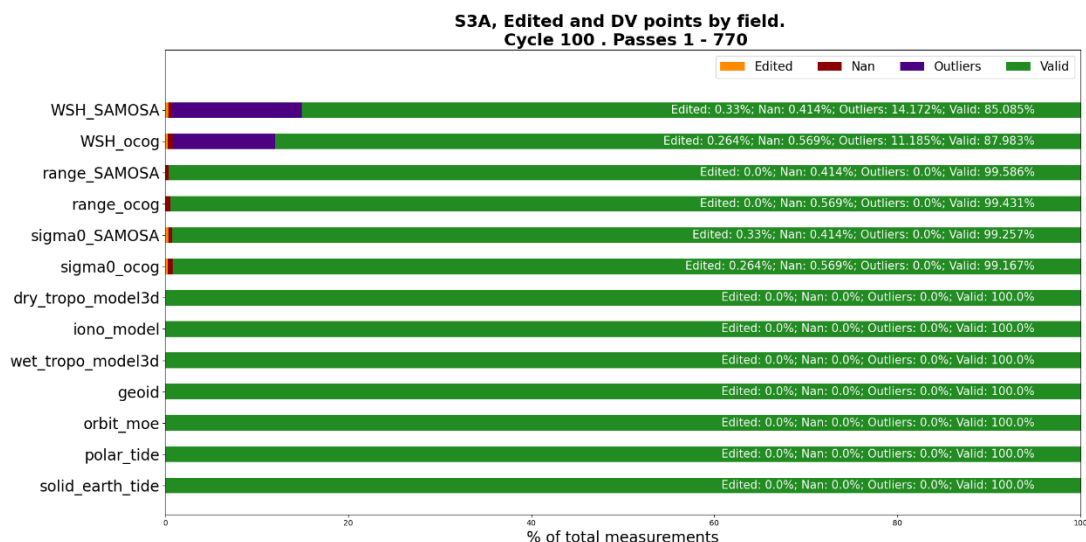
$$WSH = orbit - range - wet_tropospheric_correction - dry_tropospheric_correction - ionospheric_correction - polar_tide_correction - solid_earth_tide_correction - geoid$$

To assess the validity of the measurements of interest for Water Surface Height computation, an editing is defined. The editing criteria are twofold. The first technique (editing 1) is based on minimum and maximum thresholds for various parameters. Measurements are edited if at least one parameter is found to be outside those thresholds. The second technique (editing 2) is based on a statistical analysis of the water surface height. The standard deviation of the WSH per transect is computed and the points outside +/- 3 sigma from the median are flagged. The percentage of outliers with both techniques is expected to remain similar for Sentinel-3A and Sentinel-3B and consistent throughout the missions. Therefore, monitoring the number of edited measurements allows a survey of the data quality.

The thresholds used to identify outliers with the first technique are given in the following table.

Parameters	Min threshold	Max threshold	Unit	% Edit S3A	% Edit S3B
Backscatter Coefficient (OCOg)	22	--	dB	0.833%	0.87%
Backscatter Coefficient (SAMOSA)	7	--	dB	0.743%	0.811%
Wet tropospheric correction model (ECMWF Direct)	-0.8	0.01	m	0.00%	0.00%
Dry tropospheric correction model (ECMWF Direct)	-2.5	-1.2	m	0.00%	0.00%
Ionospheric correction model (GIM)	-0.4	0.04	m	0.00%	0.00%

Figure 3 synthesizes the percentage of available measurements (green), edited measurements (editing 1, orange), edited measurements (editing 2, red) and Default Value (DV) measurements (black) for all fields necessary for water surface height estimation. It displays the results for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) on the whole set of measurements extracted on the largest lakes.



S3B, Edited and DV points by field.
Cycle 81 . Passes 1 - 770

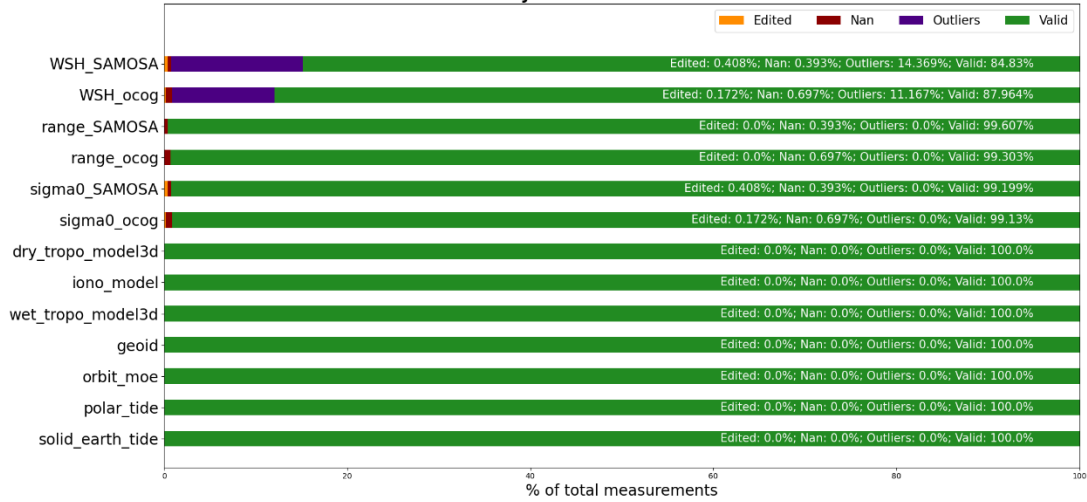


Figure 3: Percentage of Valid (green), Edited with technique 1 (orange), Edited with technique 2 (red), and Default Value (black) measurements on the largest lakes worldwide. Statistics are provided for all fields necessary to the water surface height estimation with the SAMOSA and the OCOG retracking algorithms. Sentinel-3A (top panel) and Sentinel-3B (bottom panel).

5 Geophysical parameters monitoring

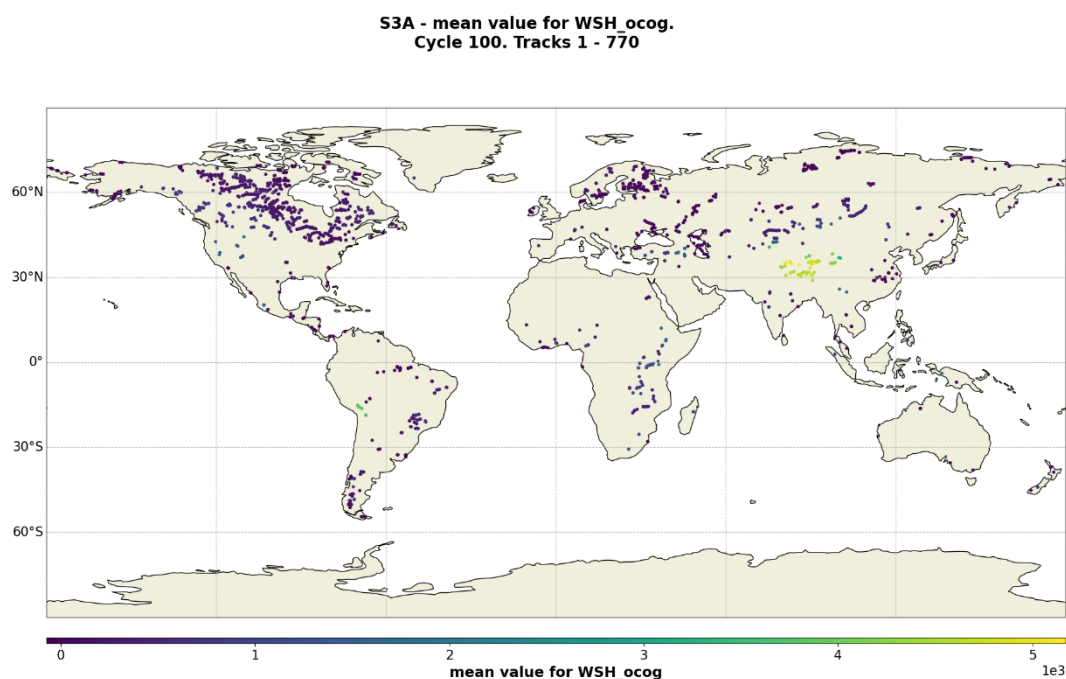
The metrics that describe the data quality are derived from the analysis of water surface on the largest lakes worldwide overflowed by Sentinel-3A and Sentinel-3B missions. The main metrics are the consistency between consecutive cycles and the along-track variability of the water surface height.

Similarly, the metrics are generally applied to water surface height estimated from the SAMOSA and the OCOG retracers as both may be of interest for users, depending on the inland water target of interest. Indeed, the SAMOSA retracker is a physical retracker dedicated to Brownian echoes (larges lakes, no land contamination) while the OCOG retracker is an empirical retracker dedicated to peaky echoes (small lakes, rivers or other echogenic surfaces).

5.1 Global scale analyses

The global monitoring of water surface height is crucial to detect potential drifts or jumps in long-term time series. These verifications are produced operationally so that they allow systematic monitoring of the main relevant parameters used in the estimation of water surface height.

In Figure 4 and Figure 5, the Mean Water Surface Height for the largest lakes is estimated for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) with the OCOG and SAMOSA retracking algorithms respectively. The diversity in the altitude of these induces a large range of water surface height estimations, from -50 to 3000m. These synthetic maps thus mainly show the surrounding topography and allows to identify major drifts or jumps.



**S3B - mean value for WSH_ocog.
Cycle 81. Tracks 1 - 770**

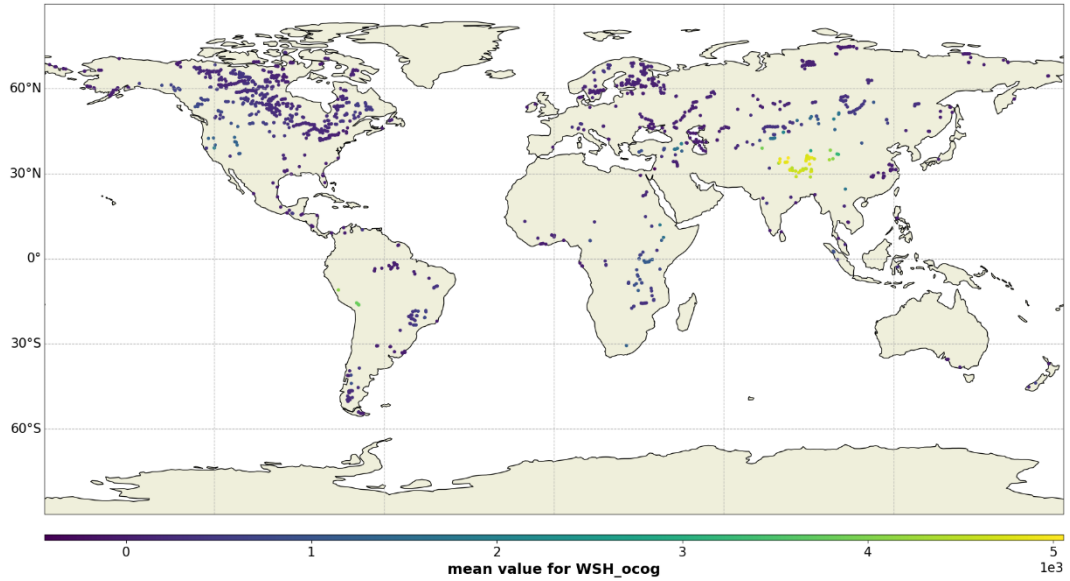
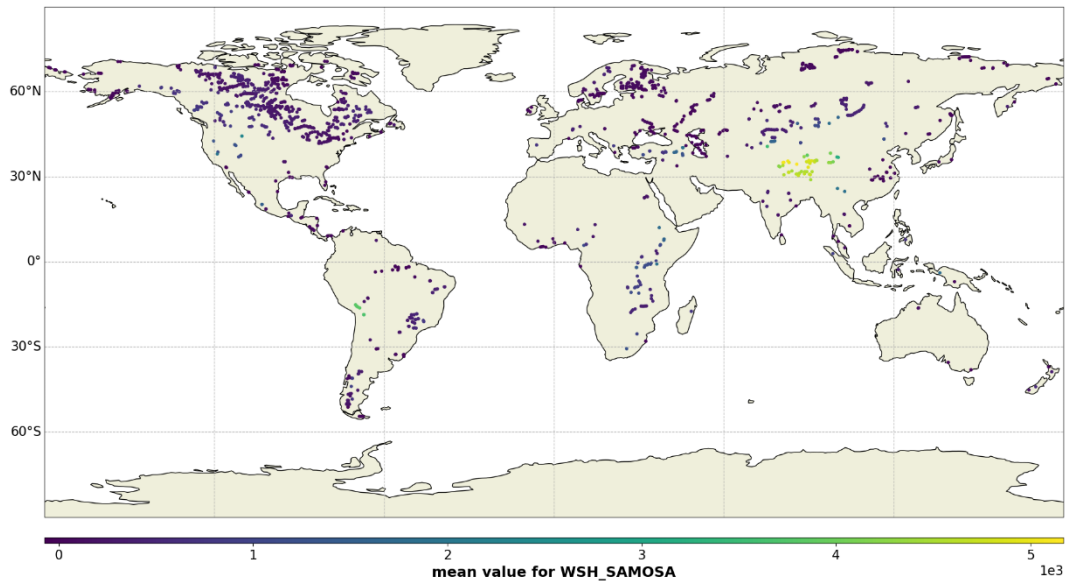


Figure 4: Water Surface Height in meters for Sentinel-3A (top panel) from 10/06/23 to 07/07/23 (cycle 100), and for Sentinel-3B (bottom panel) from 20/06/23 to 17/07/23 (cycle 81) with the OCOG retracker.

**S3A - mean value for WSH_SAMOSA.
Cycle 100. Tracks 1 - 770**



**S3B - mean value for WSH_SAMOSA.
Cycle 81. Tracks 1 - 770**

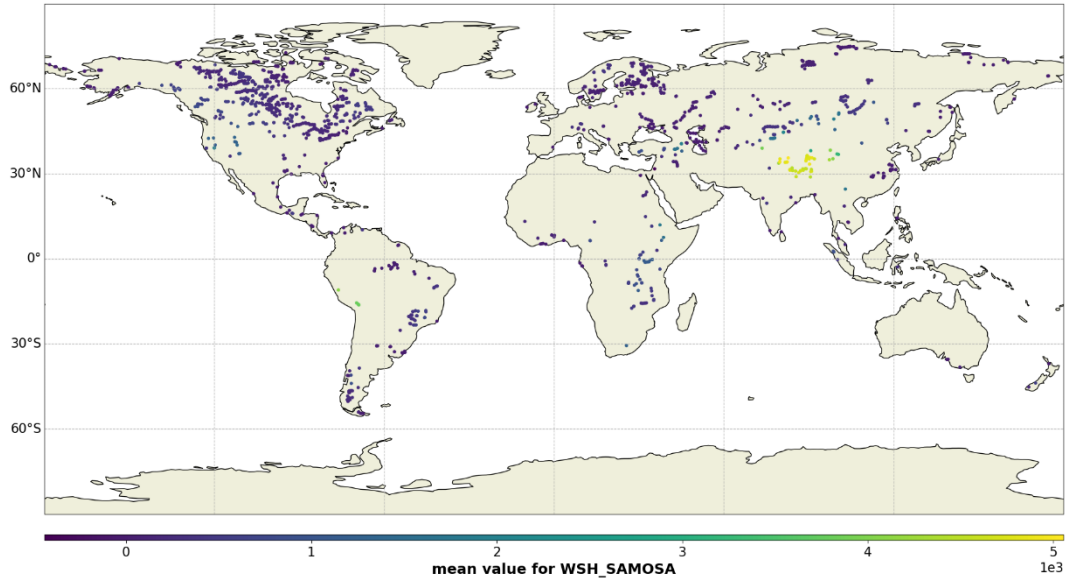
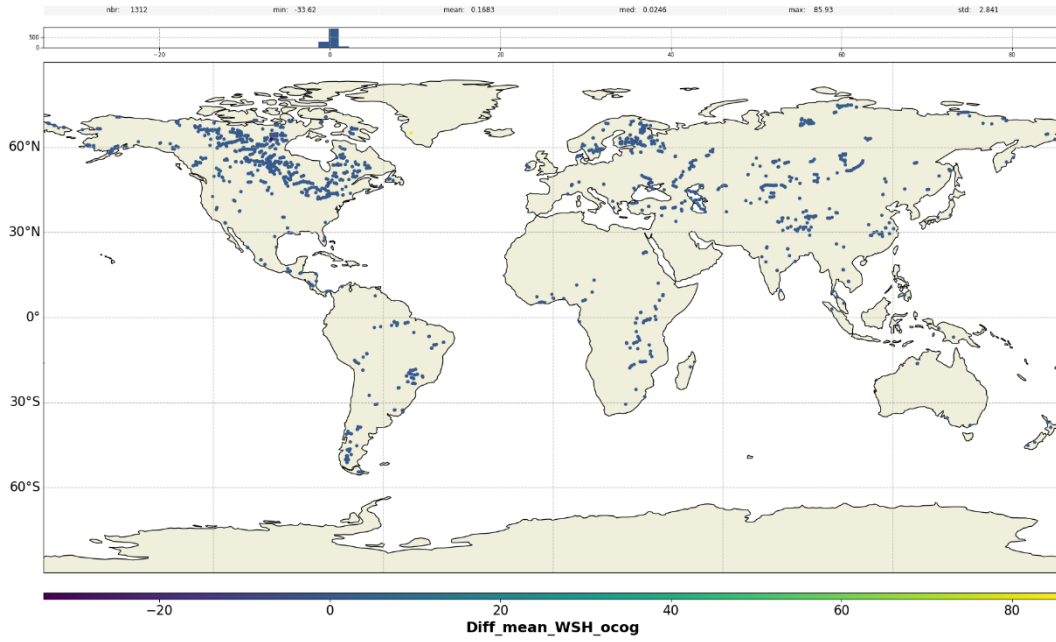


Figure 5: Water Surface Height in meters for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) with the SAMOSA retracker, from 10/06/23 to 07/07/23 (cycle 100), and for Sentinel-3B (bottom panel) from 20/06/23 to 17/07/23 (cycle 81)

Figure 6 proposes an approximation to approach this future diagnosis based on the difference between two consecutive Sentinel-3A (top panel) or Sentinel-3B (bottom panel) cycles, for OCOG retracker. Except for a few lakes where the differences are mainly due to the large uncertainty of the water surface height extraction and estimation or the dynamic of the lake water surface height itself, the agreement between two consecutive cycles is globally nominal.

**S3A - Mean difference in WSH_ocog
Between Cycles 100 and 99 (Tracks 1-770)**



**S3B - Mean difference in WSH_ocog
Between Cycles 81 and 80 (Tracks 1-770)**

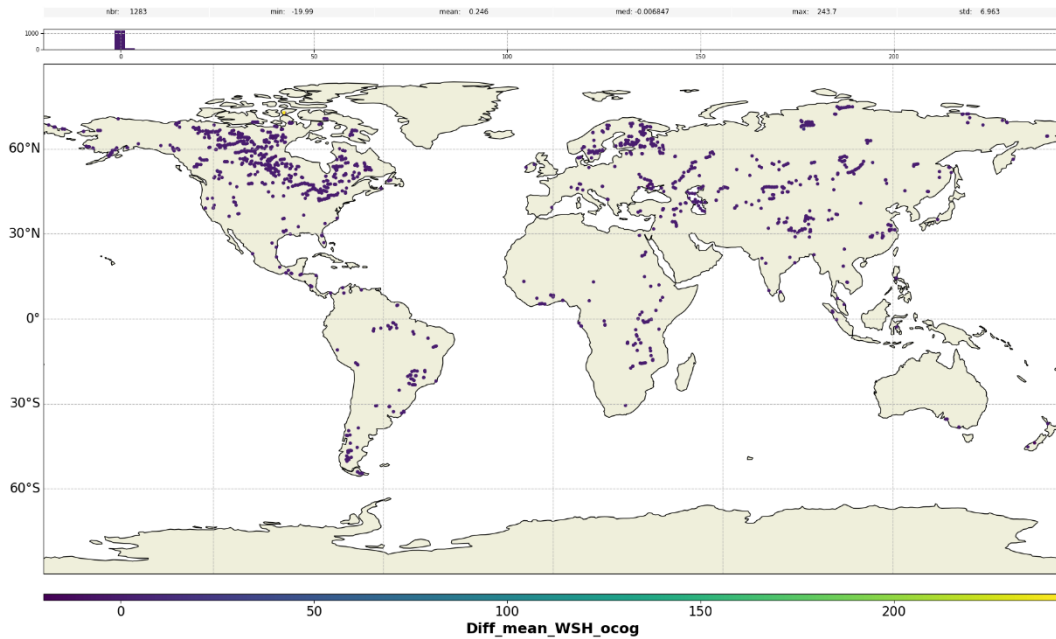


Figure 6: Water Surface Height difference with previous cycle for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), for OCOG retracker, from 10/06/23 to 07/07/23 (cycle 100), and for Sentinel-3B (bottom panel) from 20/06/23 to 17/07/23 (cycle 81).

Since water surface height may be estimated with the both available OCOG or the SAMOSA retracker, depending on the size of the target, surface roughness and possible land contamination in the footprint, Figure 7 shows the difference between the two estimates for Sentinel-3A (top panel) and Sentinel-3B (bottom panel). The average difference is of -0.27m and due to the difference of methodology between the empirical retracker OCOG and the physical retracker SAMOSA. With decimetric differences between the water surface height estimated with these two retracker, the products are considered nominal.

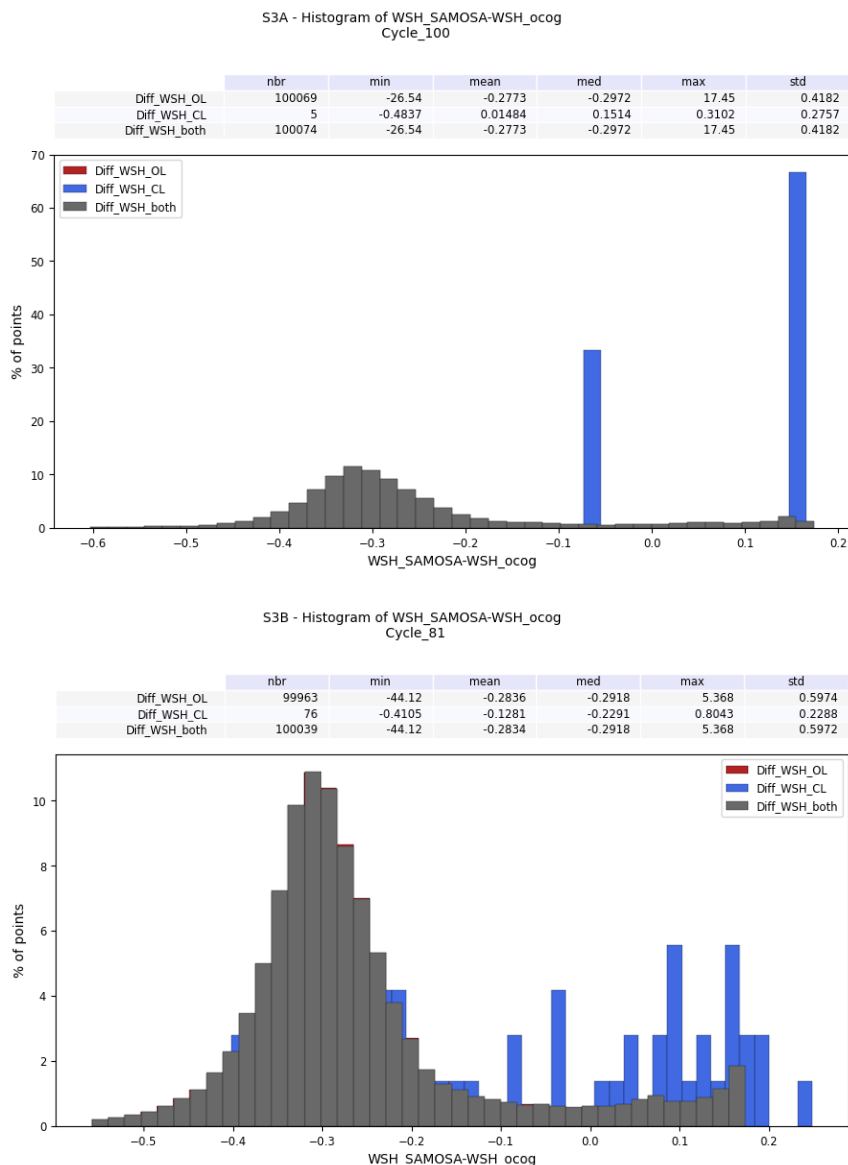


Figure 7: Difference of Water Surface Height estimated with SAMOSA retracker versus OCOG retracker for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 10/06/23 to 07/07/23 (cycle 100), and for Sentinel-3B (bottom panel) from 20/06/23 to 17/07/23 (cycle 81).

5.2 Along-track analysis of Water Surface Height

The along-track analysis of Water Surface Height is necessary to monitor the performance of the product, mainly in terms of:

- its capability to measure nadir water echoes without the contamination of off-nadir echogenic targets (mostly on small lakes and banks)

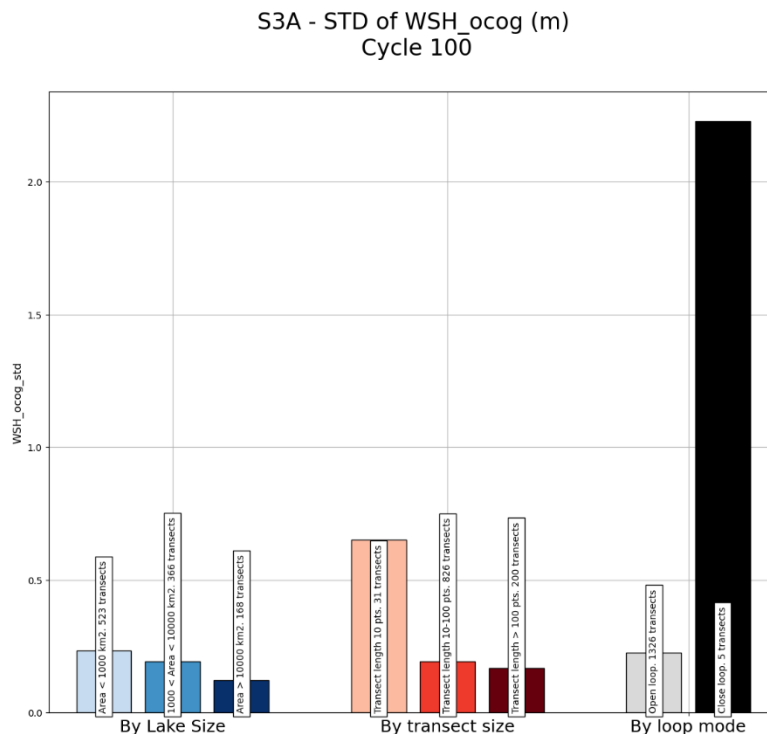
- the resolution and precision of the geoid model

The dispersion is estimated for the water surface height on each transect. A transect is defined as the union of the intersection of a single ground-track with a lake delineation. In many cases, there are several intersections of the same track with one lake (presence of islands, concave shapes...etc) and the union of these intersections defines the transect.

The dispersion contains both the performance of the altimeter itself but also of each correction and particularly the geoid that contains errors of 20cm in average. However, geoid errors are generally constant from one cycle to another for one transect, apart from the cross-track drift of the orbit (specification: lower than 1km w.r.t the theoretical ground track in 95% cases). The transect dispersion must thus be considered as a relative level that is designed to be compared between two cycles, for the same transect. However, the global statistics calculated with this metric provides an overview of the performance of the product.

Figure 8 shows the repartition of the Water Surface Height transects dispersion for several classes: lake area, transect length and open loop or closed loop mode. The dispersion is expected to be significantly larger on small lakes and small transects, mainly because the number of samples within the transects is low and proportionally more contaminated by non-water off-nadir surfaces. On larger transects, the dispersion provides a better knowledge of the performance of the product and is expected to be below 15cm in open loop mode. This dispersion is however significantly driven by the geoid errors.

Results for Sentinel-3A and Sentinel-3B are in good agreement. The dispersion is larger in closed Loop mode as the altimeter is more likely to measure off-nadir echoes which results in a higher dispersion



S3B - STD of WSH_ocog (m)
Cycle 81

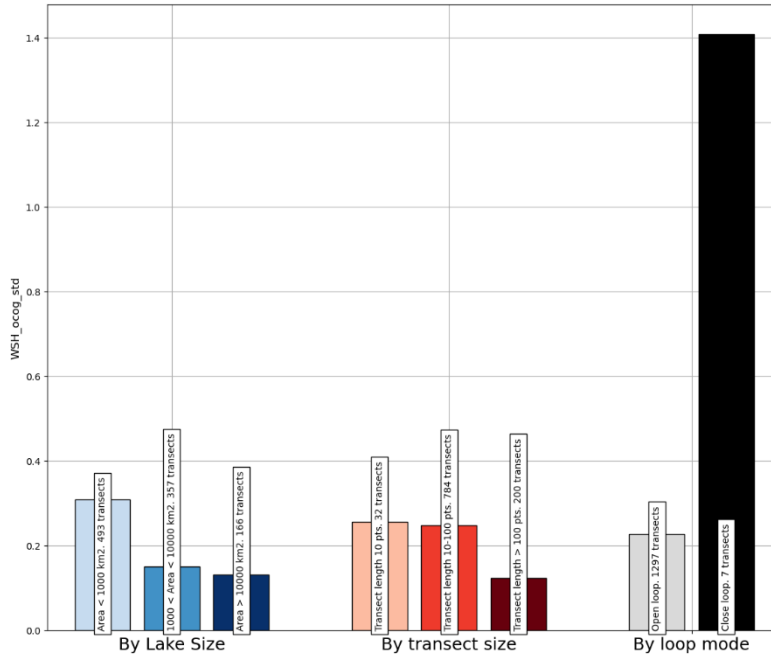


Figure 8: Histogram of Water Surface Height transect dispersion repartition (mm) for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), for OCOG retracker, from 10/06/23 to 07/07/23 (cycle 100), and for Sentinel-3B (bottom panel) from 20/06/23 to 17/07/23 (cycle 81)

5.3 Specific Cyclic Monitoring of Water Surface Height for three large Lakes

In this section, we propose to illustrate the quality of the products on three well-known large lakes distributed worldwide: Lake Victoria (Africa), Lake Ladoga (Europe) and Lake Issyk-kul (Asia)

5.3.1 Lake Victoria

Lake Victoria is Africa's largest lake by area (appr. 60 000km²), and is located 0° 59' 46" S, 33° 03' 29" E, divided among Kenya, Tanzania and Uganda. It is overflowed by several tracks of Sentinel-3A and Sentinel-3B passes.

Figure 9 illustrates the Water Surface Height above geoid (m) for Lake Victoria, measured by Sentinel-3A (blue labels) and Sentinel-3B (red labels). The maps show large-scale along-track and across-track variations with an amplitude of 50-to-100cm. This is induced by the low resolution of the geoid model in the product that does not allow to correct these short wavelengths geoid signals.

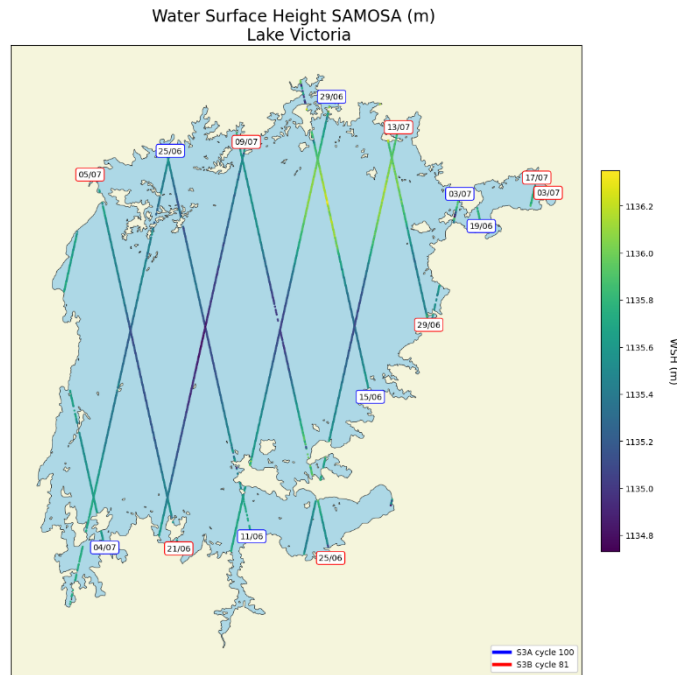


Figure 9: Water Surface Height (m) on Lake Victoria measured by Sentinel-3A and Sentinel-3B

In Figure 10, the median value of each transect is estimated and represented in time for Sentinel-3A (blue lines) and Sentinel-3B (red lines). The long-term water surface height variation is nominal and overall consistent between the two altimeters. It suggests no drift or jumps in the product. The biases between the transects result mainly from the geoid errors.

Figure 11 presents the median absolute deviation of the 20Hz points along each transect. It is a new complementary diagnosis to the previous one that allows understanding potential outliers in Figure 10.

The individual points measured by Sentinel-3B in October/November 2018 result from the drifting phase of the satellite between the tandem phase to the nominal orbit: these tracks locations only crossed the lake once.

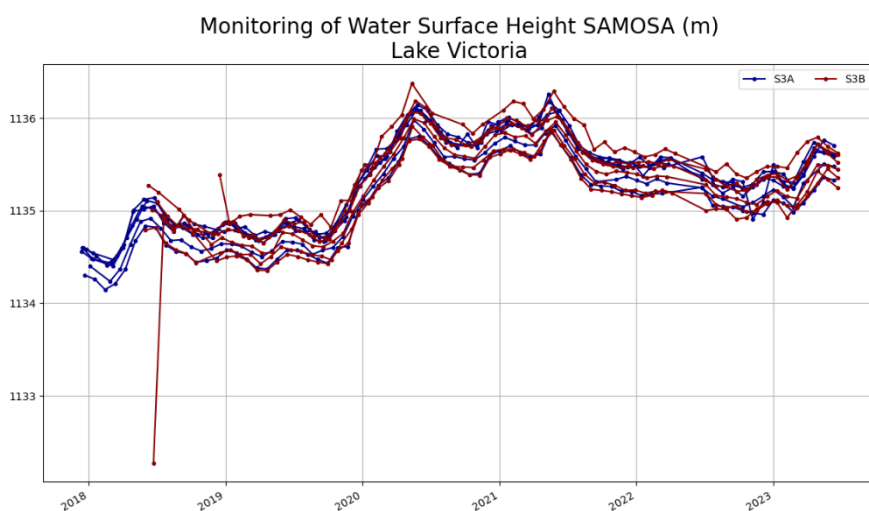


Figure 10: Time series of Water Surface Height (m) on Lake Victoria for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), SAMOSA retracker

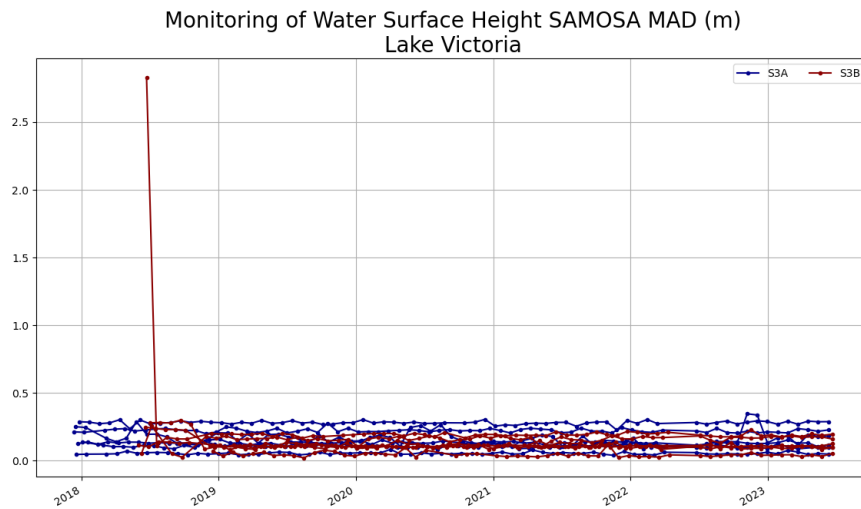
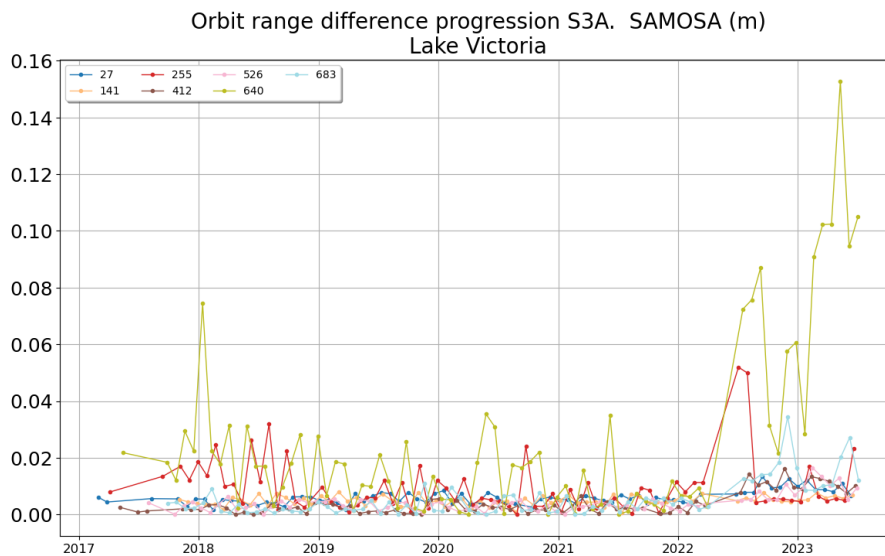


Figure 11: Time series of Water Surface Height deviation (m) on Lake Victoria for the Sentinel-3A transect (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

Figure 12 represents the time series of the median along each transect of the difference of the (orbit-range) quantity between two consecutive 20Hz points for S3A and S3B respectively. This diagnosis tracks the consistency between the high frequency points. A sudden increase is an indicator of a potential retracking issue (from which range is derived).



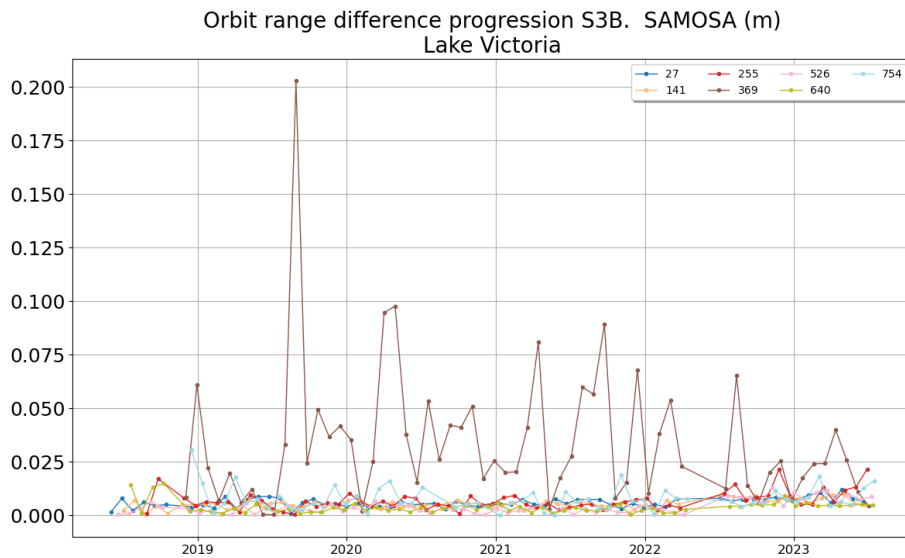


Figure 12: Time series of the difference orbit -range (m) between consecutive points on Sentinel-S3A transects (top figure) and Sentinel-S3B transects (bottom figure) on Lake Victoria

5.3.2 Lake Ladoga

Lake Ladoga is Europa's largest lake by area (appr. 17 700km²) and is located 61°00'N 31°30'E, divided among Russia and Finland. It is overflowed by several tracks of Sentinel-3A and Sentinel-3B passes.

Figure 13 illustrates the Water Surface Height above geoid (m) for Lake Ladoga, measured by Sentinel-3A (blue labels) and Sentinel-3B (red labels). The maps show large-scale along-track and across-track variations with an amplitude of 50-to-100cm. This is induced by the low resolution of the geoid model in the product that does not allow to correct these short wavelengths geoid signals.

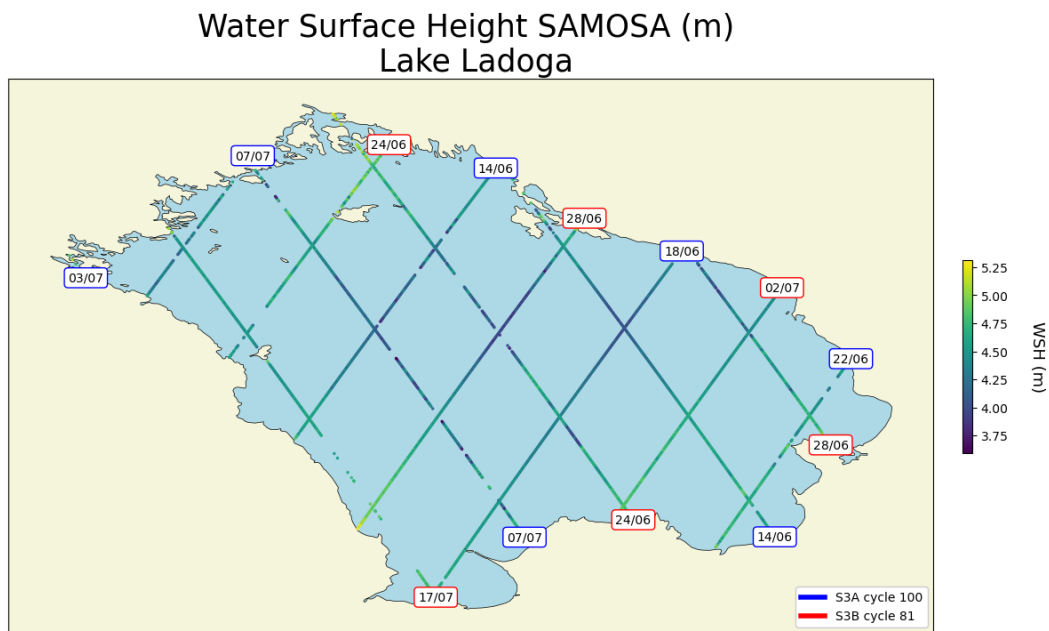


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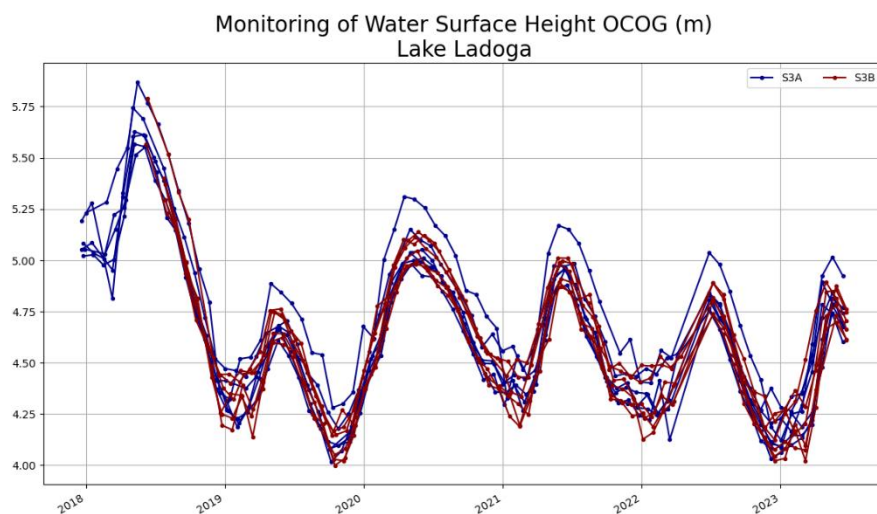


Figure 14: Time series of Water Surface Height (m) on Lake Ladoga for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

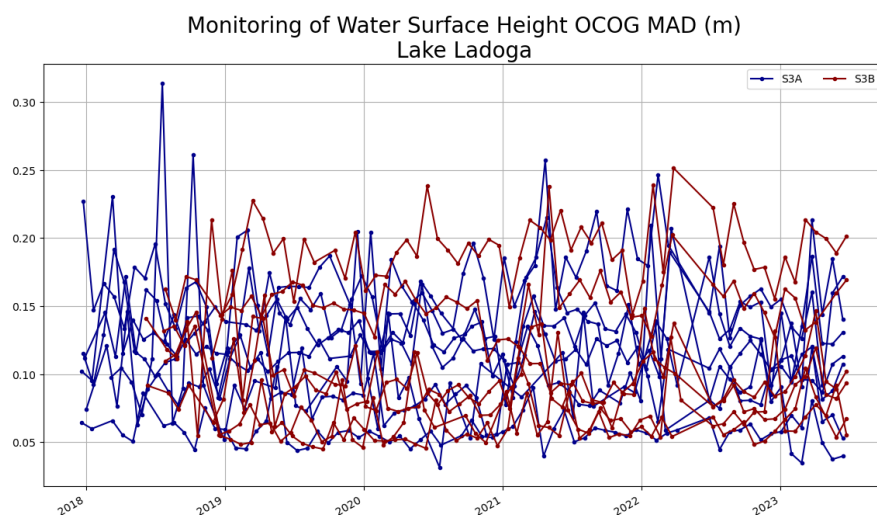


Figure 15: Time series of Water Surface Height deviation (m) on Lake Ladoga for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

Figure 16 represents the time series of the median along each transect of the difference of the (orbit-range) quantity between two consecutive 20Hz points for S3A and S3B respectively. This diagnosis tracks the consistency between the high frequency points. A sudden increase is an indicator of a potential retracking issue (from which range is derived).

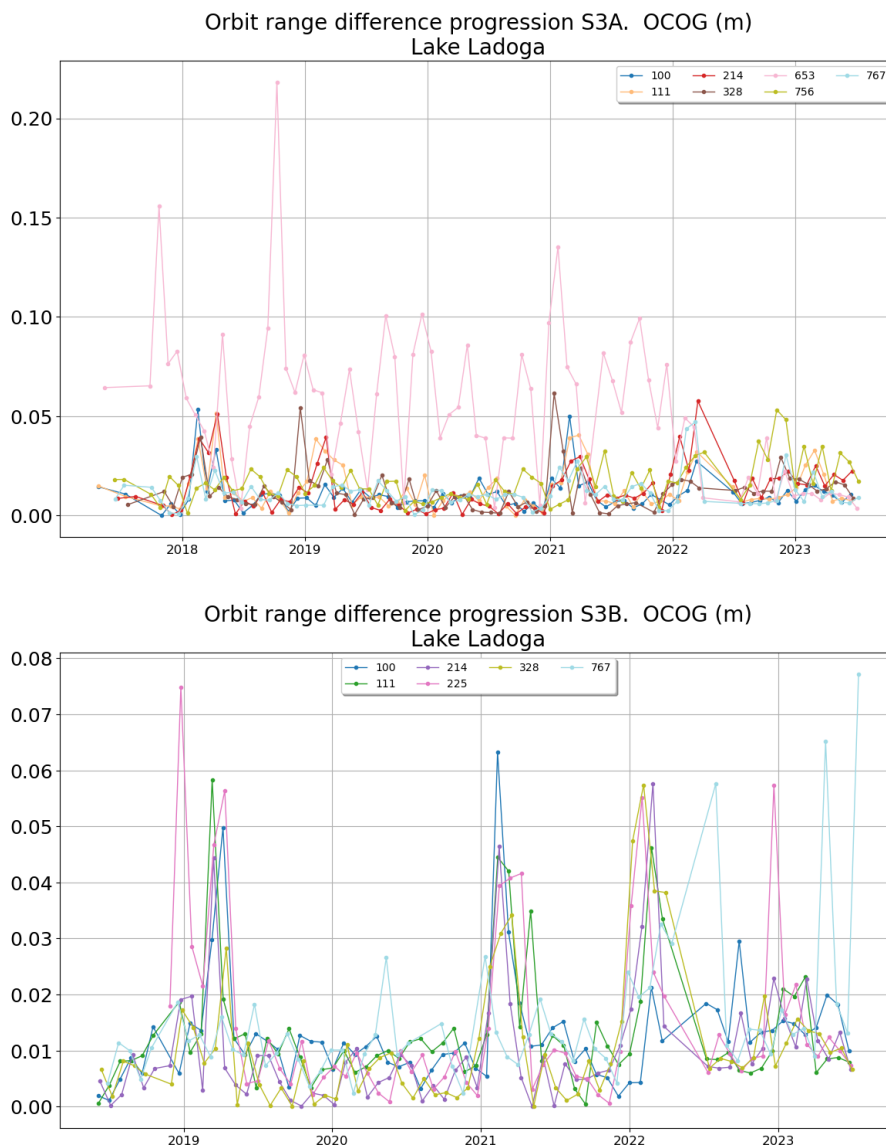


Figure 16: Time series of the difference orbit -range (m) between consecutive points on Sentinel-S3A transects (top figure) and Sentinel-S3B transects (bottom figure) on Lake Ladoga

5.3.3 Issyk-Kul



Lake Issyk-Kul is an endorheic lake, the seventh deepest lake in the world, tenth largest lake by volume, with an area of appr. 6 500 km²) and is located 42° 25'N 77° 15'E, in Kyrgyzstan. It is overflowed by several tracks of Sentinel-3A and Sentinel-3B passes.

0 illustrates the Water Surface Height above geoid (m) for Issyk-Kul, measured by Sentinel-3A (blue labels) and Sentinel-3B (red labels).

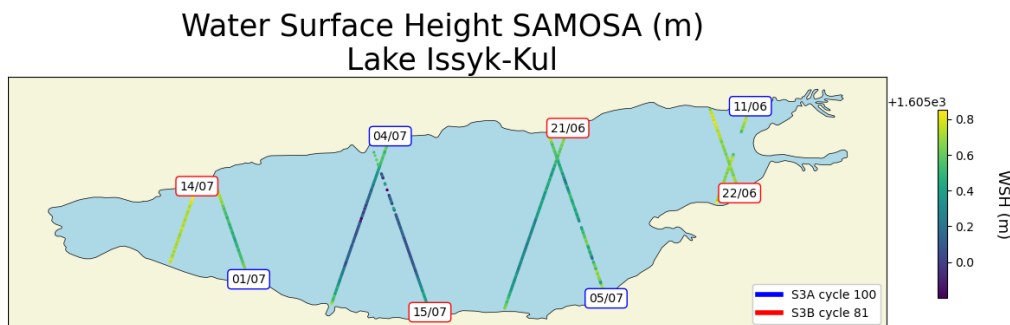


Figure 17 Water Surface Height (m) on Lake Issyk-kul measured by Sentinel-3A and Sentinel-3B

In Figure 17 the median value of each transect is estimated and represented in time for Sentinel-3A (blue lines) and Sentinel-3B (red lines). The long-term water surface height variation is nominal and overall consistent between the two altimeters. It suggests no drift or jumps in the product. The biases between the transects result mainly from the geoid errors.

In Figure 18 the median value of each transect is estimated and represented in time for Sentinel-3A (blue lines) and Sentinel-3B (red lines). The long-term water surface height variation is nominal and overall consistent between the two altimeters. It suggests no drift or jumps in the product. The biases between the transects result mainly from the geoid errors.

Figure 19 presents the median absolute deviation of the 20Hz points along each transect. It is a new complementary diagnosis to the previous one that allows understanding potential outliers in 0

The individual points measured by Sentinel-3B in October/November 2018 result from the drifting phase of the satellite between the tandem phase to the nominal orbit: these tracks locations only crossed the lake once.

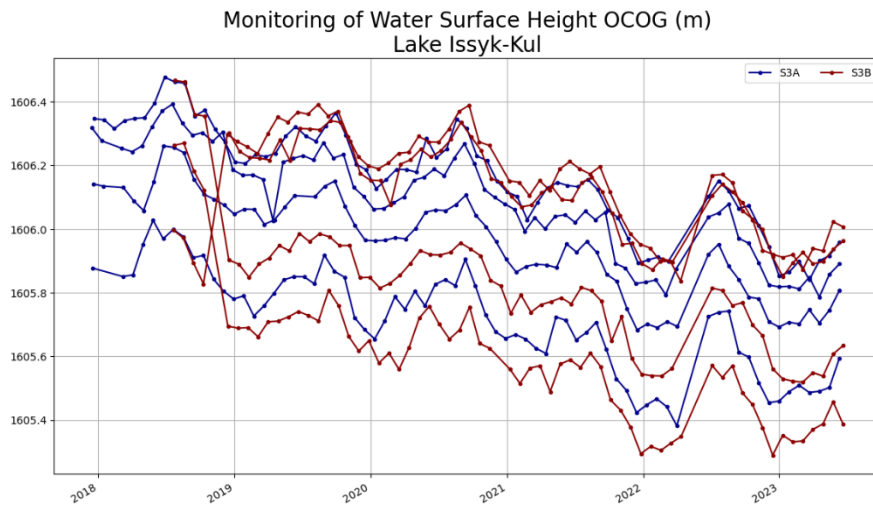


Figure 18 Time series of Water Surface Height (m) on Lake Issyk-kul for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

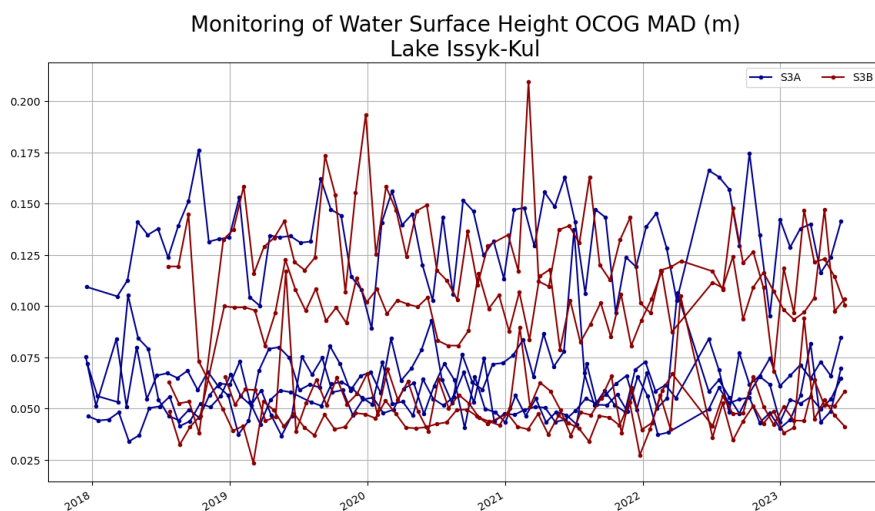


Figure 19: Time series of Water Surface Height deviation (m) on Lake Issyk-kul for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

Figure 20 represents the time series of the median along each transect of the difference of the (orbit-range) quantity between two consecutive 20Hz points for S3A and S3B respectively. This diagnosis tracks the consistency between the high frequency points. A sudden increase is an indicator of a potential retracking issue (from which range is derived).

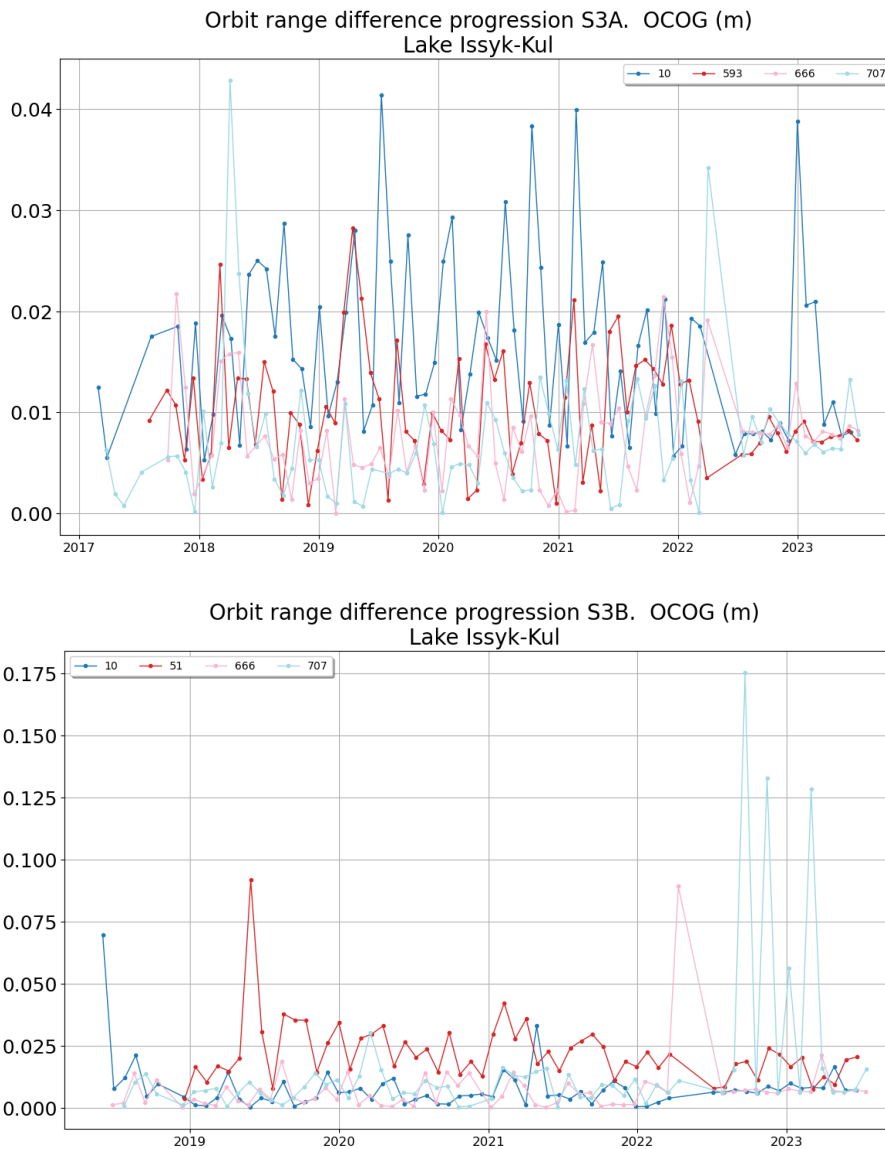


Figure 20: Time series of the difference orbit -range (m) between consecutive points on Sentinel-S3A transects (top figure) and Sentinel-S3B transects (bottom figure) on Lake Issyk-kul

5.4 Specific Cyclic Monitoring of Water Surface Height for one river

In this section, we propose to illustrate the quality of the products on one river in which in-situ data are available in the French database of the hydrologic surfaces (SCHAPI). In-situ data are re-referenced to the same ellipsoid reference (WGS 84) as the Sentinel data in order to perform an accuracy analysis.

5.4.1 Comparison with in-situ data on river Adour

As shown in Figure 21a, the in-situ station of Dax on the river Adour is located below a S3A OLTC polygon. For each cycle, we select in the transect the nearest point to the river centerline, that we further compare to the in-situ data at the same date. The timeseries in the top panel of the Figure 21b represents this selection for the in-situ and S3A data (white triangles and green dots, respectively). At a given cycle, the performance of the product is quantified by computing the Root Mean Square Error (RMSE) using the ten

last data of the timeseries (bottom panel in Figure 21b). A large difference between in-situ and the product for the last cycle will for example result in a higher RMSE value.

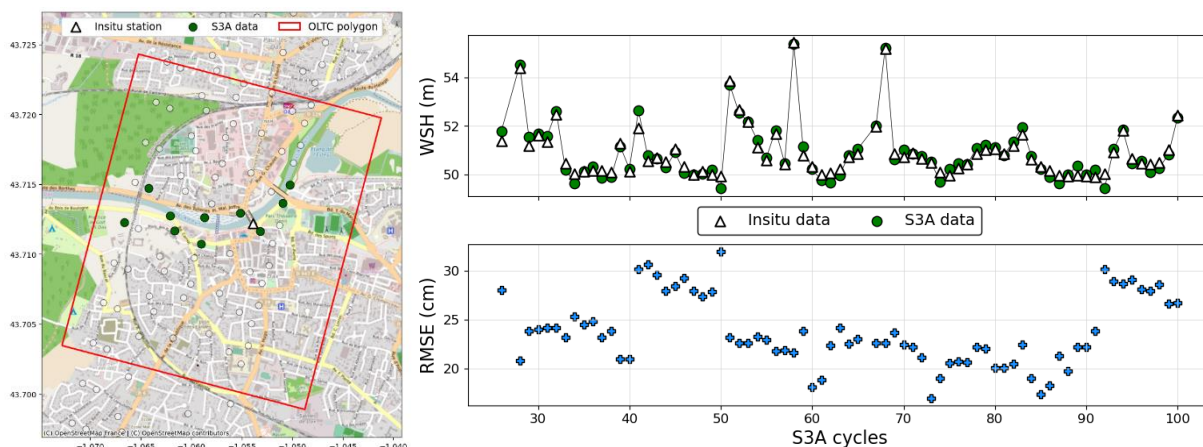


Figure 21a): Map of the Dax in-situ station (white triangle) on the Adour river with S3A data of the 10 last cycles (green dots).
 Figure 21b): Time series of the in-situ and S3A data (top). RMSE value computed for each cycle computed using data from the 10 last cycles (bottom)

Appendix A - Useful links

The Product Format Specification applicable to the Inland Water Level 2 products assessed in this report is available in Sentinel Online, version 2.15:

<https://sentinel.esa.int/documents/247904/2753172/Sentinel-3-Product-Data-Format-Specification-Level-2-Land.pdf/a176f07a-d9bd-4589-8c29-92c3487a9c7b?t=1611592513420>