PREPARATION AND OPERATIONS OF THE MISSION PERFORMANCE CENTRE (MPC) FOR THE COPERNICUS SENTINEL-3 MISSION

S3 Land Water Validation Cyclic Performance Report

S3-A

Cycle No. 71/72

Start date: 28/04/21

End date: 25/05/21

S3-B

Cycle No. 52

Start date: 28/04/21

End date: 25/05/21



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SENTINEL 3



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Changes Log

Version	Date	Changes
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List of Changes

Version	Section	Answers to RID	Changes



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1 Introduction

The purpose of this document is to report the major features of the inland waters data quality from Sentinel-3A and Sentinel-3B missions. The document is associated with data dissemination on a cycle per cycle basis, based on Sentinel-3B cycle. This document reports results from SRAL/Sentinel-3A and SRAL/Sentinel-3B Short Time Critical (STC) Land Level 2 products processed by the Land Centre using the software IPF-SM-2. The objectives of this document are:

- To provide a data quality assessment.
- To report any change likely to impact data quality at any level, from instrument status to software configuration.
- To present the major useful results over Sentinel-3A cycles 71/72 and Sentinel-3B cycle 52, from 28/04/21 to 25/05/21.

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2 Cycle Overview

The metrics that describe the data quality are derived from the analysis of water surface on the largest lakes worldwide overflown 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.

The metrics are generally applied to the whole set of measurements extracted on the largest lakes, and then to a subset in Open Loop mode and Closed Loop mode. Indeed, the Open Loop mode is the recommended acquisition mode as it theoretically provides the most precise range and water surface height measurements. This mode allows to constrain the onboard tracker to record echoes only in a predefined range. This range is estimated based on Digital Elevation Models.

Similarly, the metrics are generally applied to water surface height estimated from the SAMOSA and the OCOG retrackers 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).

Over the period covered by this report (spanning from 28/04/21 to 25/05/21), SRAL/Sentinel-3A and SRAL/Sentinel-3B both operate in SAR mode.

The version of the S3-MPC software used to compute the altimeter parameters for Sentinel-3A and Sentinel-3B datasets is the IPF-SM-2, version 06.19.

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3 Data Coverage and missing measurements

This section presents results that illustrate data quality over Sentinel-3B cycle 52. These metrics allow long term monitoring of missing and edited measurements.

3.1 Missing and available measurements

Missing measurements relative to the satellites nominal ground track are plotted on Figure 1:. The maps below illustrate 20Hz missing measurements in STC products for Sentinel-3A (top panel) and Sentinel-3B (bottom panel).

Available measurements relative to the satellites nominal ground track are plotted on Figure 2:. The maps below illustrate 20Hz available 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%. Passes 627, 639, 653 (cycle 71) and 129 (cycle 72) of S3A are uncomplete. Passes 346 and 347 for S3B over cycle 51 are missing and passes 345 and 645 are uncomplete as shown in Figure 1.

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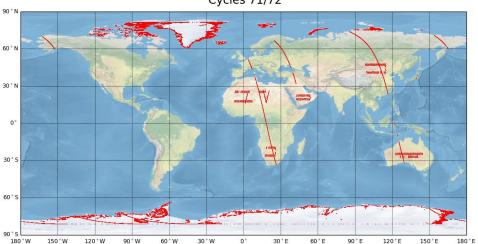
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Sentinel 3 - A: Missing mesurement Cycles 71/72



Sentinel 3 - B: Missing mesurement Cycle 52

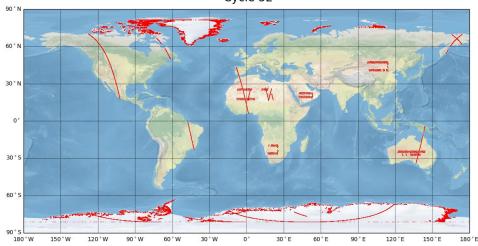


Figure 1: Maps of missing measurements (red dots) over land for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).

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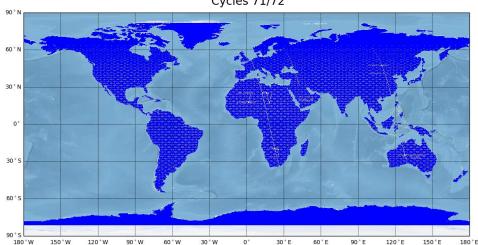
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Sentinel 3 - A: Available mesurement Cycles 71/72



Sentinel 3 - B: Available mesurement Cycle 52

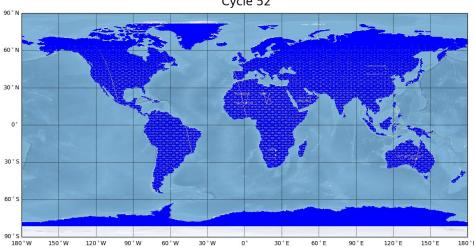


Figure 2: Maps of available measurements (blue dots) over land for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).



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3.2 Valid, edited and default value measurements

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 evolution in time: the water surface height time series is estimated for each lake, including the measurements from the last cycle. Then the time series is low-pass filtered and subtracted to the original time series. The outliers are identified as the values outside a +/- 3 sigma range of this residual. 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	% Edit S3B
Backscatter Coefficient (OCOG)	22		dB	2.68%	3.23%
Backscatter Coefficient (SAMOSA)	7		dB	4.35%	4.55%
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: and Figure 4: synthesize 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. Figure 3: displays the results for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) on the whole set of measurements extracted on the largest lakes for cycle 52 of Sentinel-3B. Figure 4: displays the same metrics for the subset of Open Loop mode only measurements.

In both figures, the Water Surface Height SAMOSA and Water Surface Height OCOG both integrate the editing performed on the other fields. Indeed, 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

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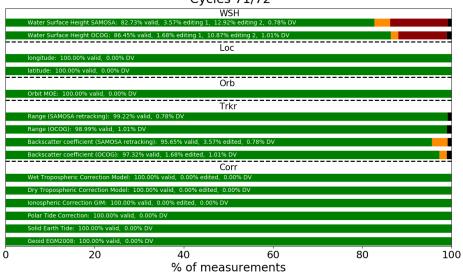
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Sentinel 3 - A: Valid / edited / DV - L2 Land water data Cycles 71/72



Sentinel 3 - B: Valid / edited / DV - L2 Land water data Cycle 52

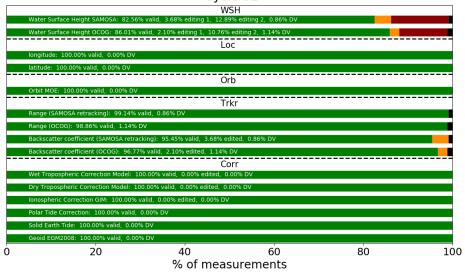


Figure 3: Sentinel-3A (top panel) and Sentinel-3B (bottom panel): Percentage of Valid (green), Edited with technique 1 (orange), Edited with technique 2 (red), and Default Value (black) measurements on the largest lakes worldwide. Statistics are provided for all fields necessary to the water surface height estimation with the SAMOSA and the OCOG retracking algorithms. Statistics estimated on cycle 52 of Sentinel-3B.

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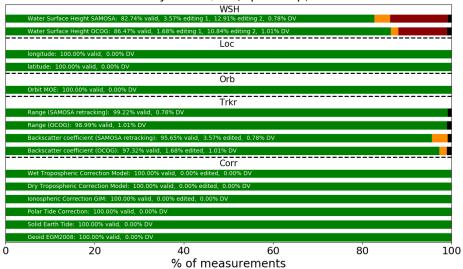
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Sentinel 3 - A: Valid / edited / DV - L2 Land water data Cycles 71/72 (Open loop)



Sentinel 3 - B: Valid / edited / DV - L2 Land water data Cycle 52 (Open loop)

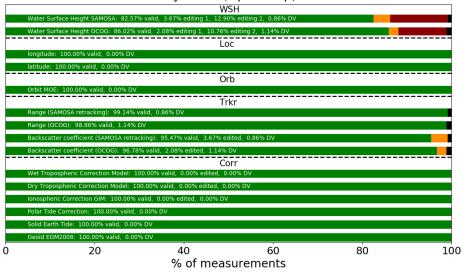


Figure 4: Sentinel-3A (top panel) and Sentinel-3B (bottom panel): Percentage of Valid (green), Edited with technique 1 (orange), Edited with technique 2 (red), and Default Value (black) measurements on the largest lakes worldwide in Open Loop mode. Statistics are provided for all fields necessary to the water surface height estimation with the SAMOSA and the OCOG retracking algorithms. Statistics estimated on cycle 52 of Sentinel-3B.

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4 Large Scale analysis of Water Surface Height

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 5: and Figure 6:, the Mean Water Surface Height for the largest lakes is estimated for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) with the OCOG (Figure 5) or SAMOSA (Figure 6) retrackers, for cycle 52 of Sentinel-3B. 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.

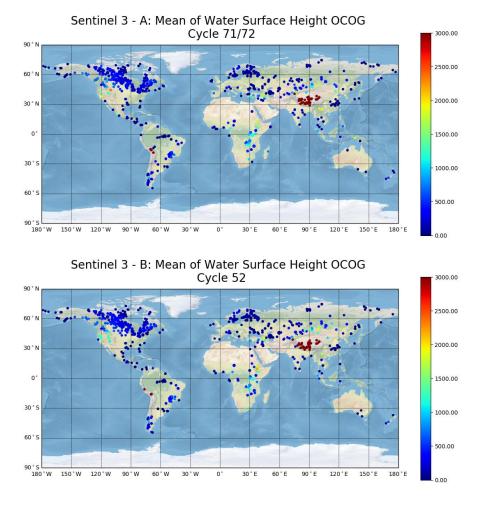


Figure 5: Water Surface Height in meters for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) with the OCOG retracker, from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).



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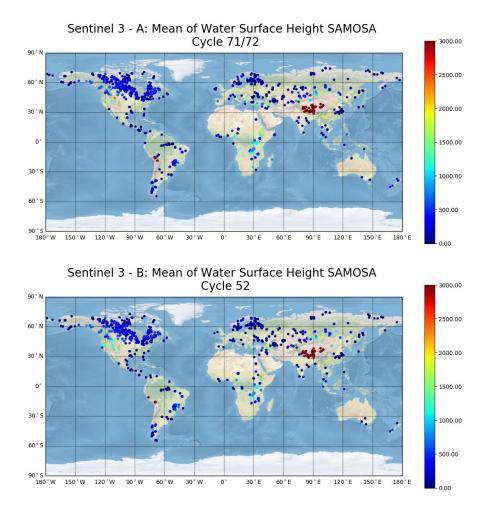


Figure 6: Water Surface Height in meters for Sentinel-3A (top panel) and Sentinel-3B (bottom panel) with the SAMOSA retracker, from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).

When the time period for Sentinel-3A and Sentinel-3B missions will cover a few years, it will be possible to estimate and remove the mean water surface height. In the meantime, Figure 7: 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.



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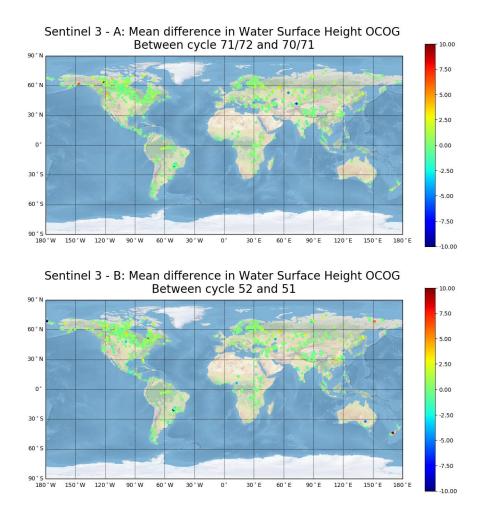


Figure 7: Water Surface Height difference with previous cycle for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), for OCOG retracker, from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).

Since water surface height may be estimated with the OCOG or the SAMOSA retrackers, depending on the size of the target and possible land contamination in the footprint, Figure 8 shows the difference between the two estimates for Sentinel-3A (top panel) and Sentinel-3B (bottom panel). The average difference is of -0.24m 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 retrackers, the products are considered nominal.

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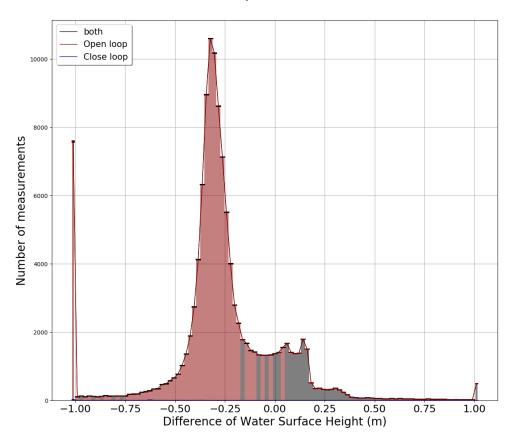
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Sentinel 3 - A: Histogram of WSH SAMOSA - WSH OCOG Cycles 71/72



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Sentinel 3 - B: Histogram of WSH SAMOSA - WSH OCOG Cycle 52

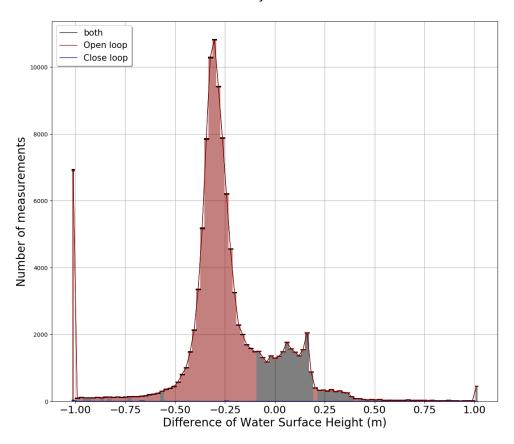


Figure 8: Difference of Water Surface Height estimated with SAMOSA retracker versus OCOG retracker for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).

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5 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 9: 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. Following the SZB update on both S3A and S3B, the area over which S3A&B uses Open Loop tracking mode has been extended further north. Only a few transects remain over lakes observed in Close Loop.

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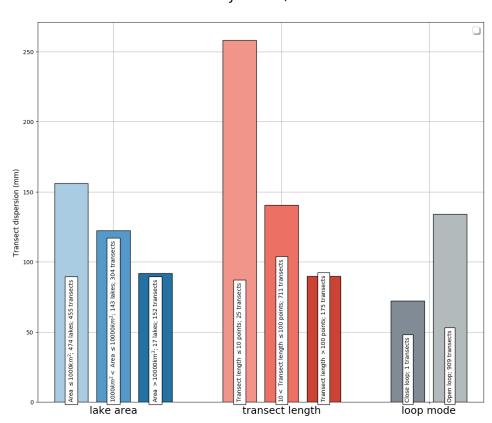
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Sentinel 3 - A: STD of Water Surface Height OCOG (mm) Cycles 71/72



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Sentinel 3 - B: STD of Water Surface Height OCOG (mm) Cycle 52

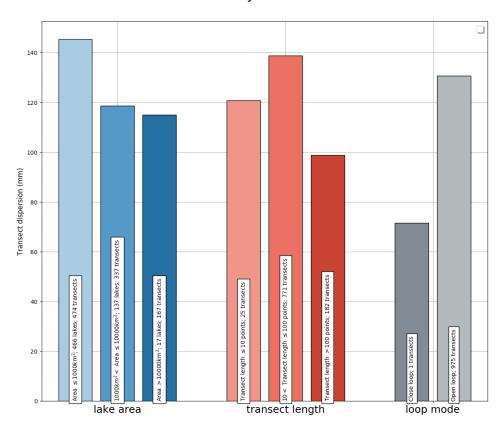


Figure 9: Histogram of Water Surface Height transect dispersion repartition (mm) for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), for OCOG retracker, from 28/04/21 to 25/05/21 (Sentinel-3B cycle 52).



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6 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)

6.1 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 overflown by several tracks of Sentinel-3A and Sentinel-3B passes.

Figure 10: 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.

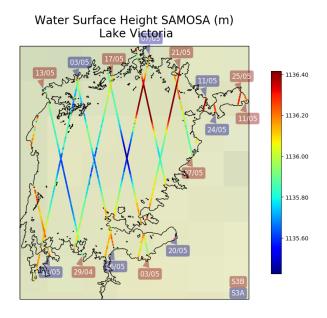


Figure 10: Water Surface Height (m) on Lake Victoria measured by Sentinel-3A and Sentinel-3B)

In Figure 11:, 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 12: presents the median absolute deviation of the 20Hz points along each transect. It is a complementary diagnosis to the previous one that allows understanding potential outliers in Figure 11:



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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.

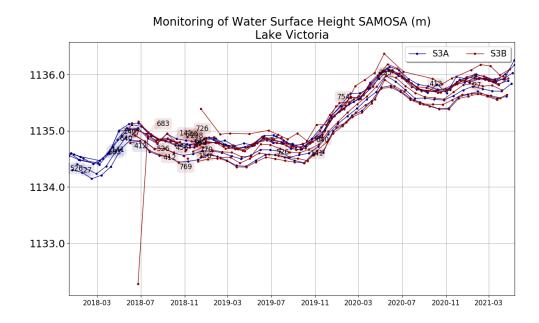


Figure 11: Time series of Water Surface Height (m) on Lake Victoria for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), SAMOSA retracker

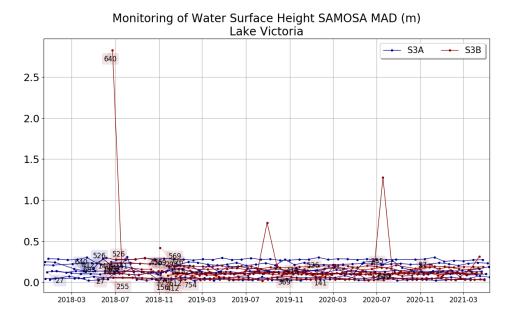


Figure 12: Time series of Water Surface Height deviation (m) on Lake Victoria for the Sentinel-3A transect (blue lines) and Sentinel-3B transects (red lines), OCOG retracker



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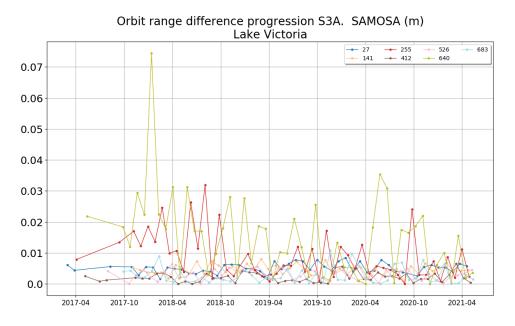
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Figure 13: represent the time series of the median along each transect of the difference of the (orbit-range) quantity between two consecutive 20Hz points for S3A and S3B respectively. This diagnosis tracks the consistency between the high frequency points. A sudden increase is an indicator of a potential retracking issue (from which range is derived).



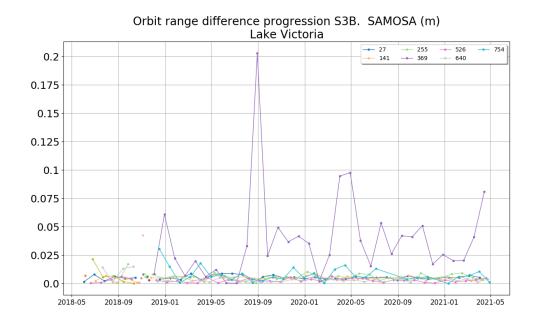


Figure 13: Time series of the difference orbit -range (m) between consecutive points on Sentinel-S3A transects (top figure) and Sentinel-S3B transects (bottom figure) on Lake Victoria



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6.2 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 overflown by several tracks of Sentinel-3A and Sentinel-3B passes.

Figure 14: 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.

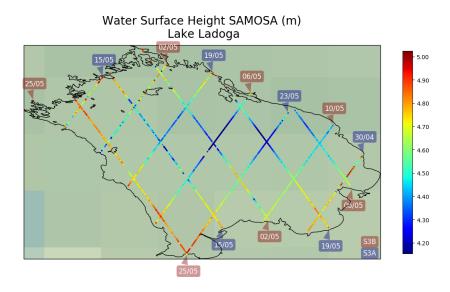


Figure 14: Water Surface Height (m) on Lake Ladoga measured by Sentinel-3A and Sentinel-3B

In Figure 15: Figure 15: 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 16: presents the median absolute deviation of the 20Hz points along each transect. It is a complementary diagnosis to the previous one that allows understanding potential outliers in Figure 15:

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.



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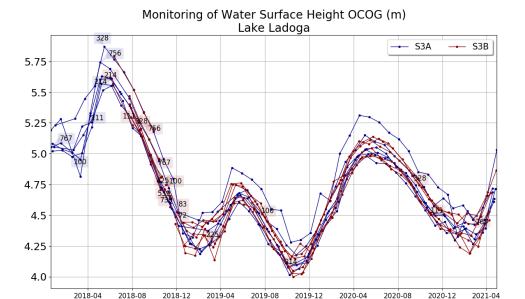


Figure 15: Time series of Water Surface Height (m) on Lake Ladoga for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

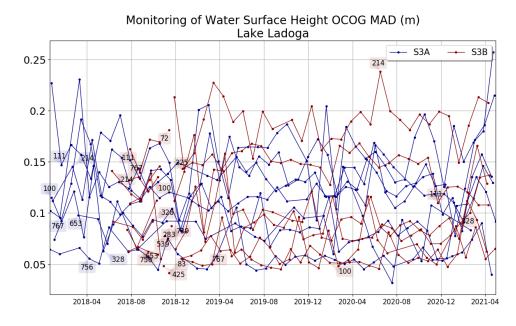


Figure 16: Time series of Water Surface Height deviation (m) on Lake Ladoga for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

Figure 17: represent the time series of the median along each transect of the difference of the (orbitrange) 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).



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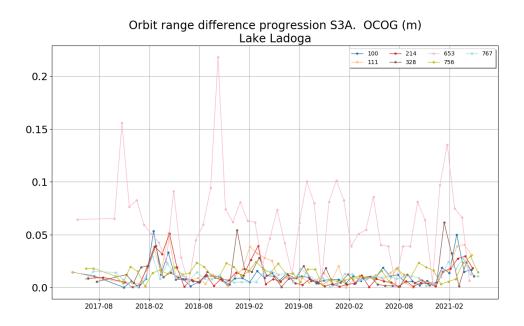
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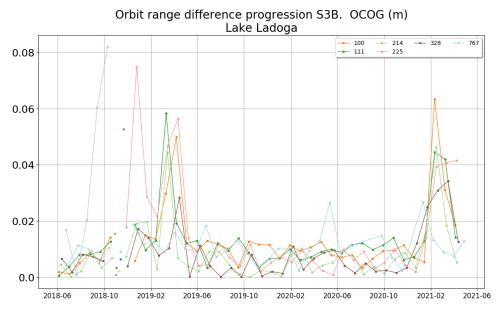
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Time series of the difference orbit -range (m) between consecutive points on Sentinel-S3A Figure 17: transects (top figure) and Sentinel-S3B transects (bottom figure) on Lake Ladoga

Issyk-Kul 6.3

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 overflown by several tracks of Sentinel-3A and Sentinel-3B passes.

SENTINEL 3 Mission Performance

Sentinel-3 MPC

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Figure 18: illustrates the Water Surface Height above geoid (m) for Issyk-Kul, measured by Sentinel-3A (blue labels) and Sentinel-3B (red labels).

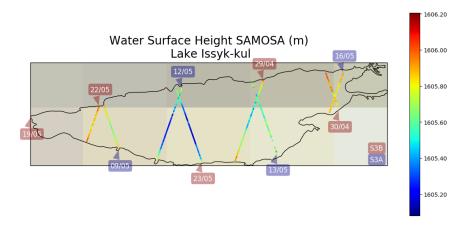


Figure 18: Water Surface Height (m) on Lake Issyk-kul measured by Sentinel-3A and Sentinel-3B

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.

In Figure 19: 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 20: 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 19:

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.

Sentinel-3 MPC

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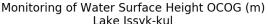
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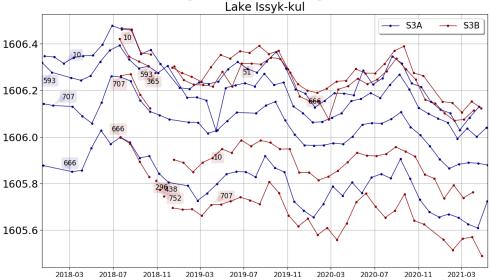


Figure 19: Time series of Water Surface Height (m) on Lake Issyk-kul for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

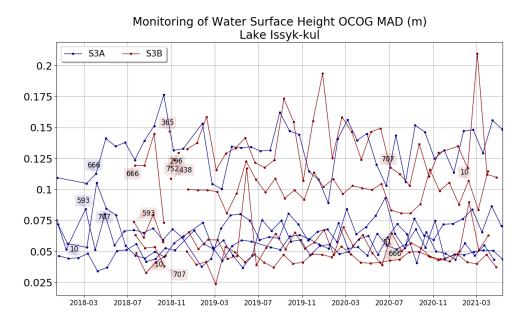


Figure 20: Time series of Water Surface Height deviation (m) on Lake Issyk-kul for the Sentinel-3A transects (blue lines) and Sentinel-3B transects (red lines), OCOG retracker

Figure 21: represent the time series of the median along each transect of the difference of the (orbitrange) quantity between two consecutive 20Hz points for S3A and S3B respectively. This diagnosis tracks



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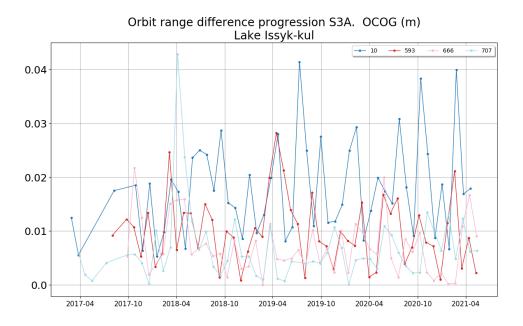
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the consistency between the high frequency points. A sudden increase is an indicator of a potential retracking issue (from which range is derived).



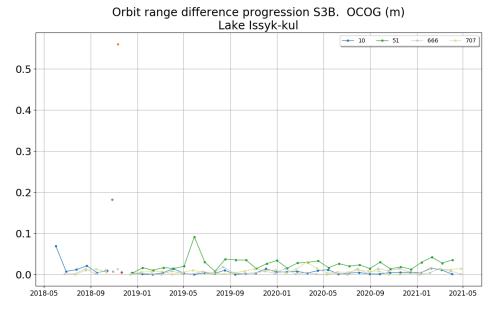


Figure 21: Time series of the difference orbit -range (m) between consecutive points on Sentinel-S3A transects (top figure) and Sentinel-S3B transects (bottom figure) on Lake Issyk-kul

SENTINEL 3 Mission Parformance Centre

Sentinel-3 MPC

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7 Appendix A

Other reports related to the Surface Topography Mission are:

- \$3 SRAL Cyclic Performance Report, S3A Cycle No. 71/72, S3B Cycle No. 52 (ref. S3MPC.ISD.PR.04-71/72-52)
- S3 MWR Cyclic Performance Report, S3A Cycle No. 71/72, S3B Cycle No. 52 (ref. S3MPC.CLS.PR.05-71/72-52)
- S3 Ocean Validation Report, S3A Cycle No. 71/72, S3B Cycle No. 52 (ref. S3MPC.ISD.PR.06-71/72-52)
- S3 Winds and Waves Cyclic Performance Report, S3A Cycle No. 71/72, S3B Cycle No. 52 (ref. S3MPC.ECM.PR.07-71/72-52)
- S3 Land and Sea Ice Cyclic Performance Report, S3A Cycle No. 71/72, S3B Cycle No. 52 (ref. S3MPC.UCL.PR.08-71/72-52)

All Cyclic Performance Reports are available on MPC pages in Sentinel Online website, at: https://sentinel.esa.int

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