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

S3 Ocean Validation Cyclic Performance Report				
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Approved by:	G. Quartly, STM ESL Coordinator Authorized by G. Jettou, STM Technical Performance Manager					
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# **Changes Log**

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S3 Ocean Validation Cyclic Performance Report S3A Cycle No. 77/78 – S3B Cycle No. 58

# **1** Introduction

The purpose of this document is to report the major features of the 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 Non Time Critical (NTC) Marine Level 2 products processed by the Marine 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 the period spanning from 07/10/2021 to 03/11/2021 and corresponding to Sentinel-3B cycle 58.





# 2 Cycle Overview

The main metric that describes the data quality is the one derived from the analysis of sea surface variability at crossovers. Using a selection to remove shallow waters (1000 m), areas of high ocean variability and high latitudes (> |60|<sup>°</sup>), the crossover standard deviation is 5.9 cm rms for Sentinel-3A cycle 77 and 5.7 cm rms for Sentinel-3B cycle 58. This first metric is in line with usual values that are obtained on altimetry mission.

Over the period covered by this report (spanning from 07/10/2021 to 03/11/2021), 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 06.50.

The following events occurred over this cycle:

- For Sentinel-3B
  - An out of plane manoeuvre on the 20/10/2021 from 12:40 to 13:15 with impact on off nadir angle platform roll, pitch and yaw and no impact on observations



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# **3** Data coverage and edited measurements

This section presents results that illustrate data quality over Sentinel-3B cycle 58 period. These metrics allow long term monitoring of missing and edited measurements.

## **3.1** Missing measurements

Missing measurements relative to the satellites nominal ground track are plotted on Figure 1. The maps below illustrate 1Hz missing measurements in NTC products for Sentinel-3A (top panel) and Sentinel-3B (bottom panel). Over this cycle, the following tracks/segments of track are missing:

- For Sentinel-3A:
  - Cycle 78, half orbit 259: about 2 min and 30 sec missing
- For Sentinel-3B:
  - Cycle 58, half orbit 760: about 20 sec missing

Figure 2 shows the daily monitoring of available measurements over ocean during the cycle for Sentinel-3A and 3B. The mean percentage is close to 100 % for both missions.



#### Missing measurements





Figure 1: Maps of missing measurements over ocean for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 07/10/2021 to 03/11/2021 (Sentinel-3B cycle 58).



Figure 2: Daily monitoring of the percentage of available measurements for Sentinel-3A (blue curve) and Sentinel-3B (red curve).

### **3.2 Edited Measurements**

The editing criteria are defined as minimum and maximum thresholds for various parameters. Measurements are edited if at least one parameter is found to be outside those thresholds. These thresholds are expected to remain identical for Sentinel-3A and Sentinel-3B and constant throughout



the missions. Therefore, monitoring the number of edited measurements allows a survey of the data quality.

The number and percentage of points removed by each criterion is given in the following table. Note that these statistics are obtained with measurements over ocean only and already edited by ice flag. The percentage of measurements corrupted by sea ice is of 15.39 % for Sentinel-3A and 15.38 % for Sentinel-3B. Over this cycle, Sentinel-3A and Sentinel-3B present equivalent percentages of outliers for each parameter considered.

Over this cycle, the following tracks were partially rejected:

- For Sentinel-3B:
  - Cycle 58, half orbit 361: about 2 min edited
  - Cycle 58, half orbit 362: about 1 min edited



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Parameters	Min threshold	Max threshold	Unit	% rejected Sentinel-3A	% rejected Sentinel-3B
Number of range	10	1000	count	0.05 %	0.07 %
Sea Level Anomaly	-2	2	m	0.38 %	0.40 %
Pole tide height model (Wahr 1985)	-15	15	m	0.00 %	0.00 %
Sea surface height (Orbit - Range)	-130	100	m	0.04 %	0.06 %
Dynamical atmospheric correction (MOGD2)	-2	2	m	0.00 %	0.00 %
Std. deviation of range	0	0.12+0.02*SWH	m	1.35 %	1.34 %
Sea State Bias (Tran 2012)	-0.5	0	m	0.04 %	0.05 %
WTC derived from MWR	-0.5	-0.001	m	0.03 %	0.03 %
Global statistics of edited measurements by thresholds	-	-	-	3.15 %	3.19 %
Std. deviation of sigma0	0	0.7	db	2.69 %	2.66 %
Dry tropospheric correction model (ECMWF Gauss)	-2.5	-1.9	m	0.00 %	0.00 %
Dual frequency ionosphere correction	-0.4	0.04	m	1.13 %	1.25 %
Sigma0	5	28	db	0.11 %	0.12 %
Ocean tide height model (GOT4V10)	-5	5	m	0.01 %	0.01 %
Solid earth tide height model (Cartwright and Tayler 1971)	-1	1	m	0.00 %	0.00 %
Wind Speed	0	30	m	0.06 %	0.07 %

 Table 1: Table of parameters used for editing and the corresponding percentages of edited measurements for

 each parameter for Sentinel-3A and Sentinel-3B, over Sentinel-3B cycle 58.

The measurements rejected during the editing process are shown in Figure 3 (Sentinel-3A: top panel, Sentinel-3B: bottom panel). The two satellites are in perfect agreement. Equatorial wet zones or zones with sea ice appear on the maps as regions with less valid data, as it is also the case for other altimeters: measurements are corrupted by rain or sea ice. They were therefore removed by editing. Since the update of the MWR calibrations pattern for Sentinel-3A (February 2018), less measurements are edited.



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Edited data



Figure 3: Edited measurements for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 07/10/2021 to 03/11/2021 (Sentinel-3B cycle 58).



# 4 Instrumental and geophysical parameter analysis

The monitoring of instrumental and geophysical parameters 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.

## 4.1 Sentinel-3A and 3B Sensors

A detailed assessment of Sentinel-3A and 3B sensors SRAL and MWR is made in separate bulletins:

- S3 SRAL Cyclic Performance Report (S3MPC.ISD.PR.04-77-58).
- S3 MWR Cyclic Performance Report (S3MPC.CLS.PR.05-77-58).

### 4.2 Significant wave height

Figure 4 shows along-track significant wave height derived from altimeter measurements. Wave height may reach several meters. Sentinel-3A SWH is in perfect agreement with Sentinel-3B SWH over this cycle.







*Figure 4: Significant wave height for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 07/10/2021 to 03/11/2021 (Sentinel-3B cycle 58).* 

The SAR parameters are compared to Pseudo Low Resolution Mode (PLRM) processing. The PLRM is an LRM like processing of the SAR observations. It provides a reliable reference to compare with. The daily average of Ku-band SWH for Sentinel-3A and Sentinel-3B SARM and P-LRM is plotted as a function of time on Figure 5. They show similar features. A bias of 12 cm is observed between Sentinel-3A P-LRM and SARM SWH and of 13 cm between Sentinel-3B P-LRM and SARM SWH. Looking at the temporal evolution over this cycle, Sentinel-3A SARM (respectively PLRM) SWH follows the same variation than Sentinel-3B SARM (respectively PLRM) SWH, with only a small bias of about 2 cm between the missions.

For more details concerning the SWH assessment, please refer to the:

S3 Winds and Waves Cyclic Performance Report (ref. S3MPC.ECM.PR.07-77-58)



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Figure 5: Daily monitoring of Ku-band significant wave height for Sentinel-3A and Sentinel-3B (top panel) and the corresponding histograms (bottom panel). Both plots are computed over Sentinel-3B cycle 58.



## 4.3 Backscattering coefficient

Figure 6 shows along-track backscatter coefficient derived from altimeter measurements. Sentinel-3A and Sentinel-3B present similar backscatter coefficient over this cycle.



Figure 6: Backscattering coefficient for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 07/10/2021 to 03/11/2021 (Sentinel-3B cycle 58)..



The daily average of the backscattering coefficient for Sentinel-3A and Sentinel-3B SARM and P-LRM (Ku-band) is plotted as a function of time on Figure 7. There is virtually no bias observed between SARM and P-LRM backscattering coefficient, and the two satellites are in good agreement.



Figure 7: Daily monitoring of backscattering coefficient for Sentinel-3A and Sentinel-3B (top panel) and the corresponding histograms (bottom panel). Both plots are computed over Sentinel-3B cycle 58.



## 4.4 Altimeter wind Speed

Figure 8 shows wind speed estimations derived from along-track altimeter measurements. The wind speed is derived from the one parameter (backscatter coefficient) Saleh Abdalla's algorithm. As for the backscatter coefficient, Sentinel-3A wind speed is consistent with Sentinel-3B.



Figure 8: Altimeter wind speed for Sentinel-3A (top panel) and Sentinel-3B (bottom panel), from 07/10/2021 to 03/11/2021 (Sentinel-3B cycle 58).



The daily average of altimeter wind speed for Sentinel-3A and Sentinel-3B SARM and P-LRM is plotted as a function of time on the top of Figure 9. SARM and P-PLRM wind speed are fully in line, and the two missions are in good agreement.

The histogram is shown on the bottom. A bias of only 0.07 m/s is observed between Sentinel-3A modes and of 0.08 m/s between Sentinel-3B modes. For more details concerning the wind speed assessment, please refer to the:



S3 Winds and Waves Cyclic Performance Report (ref. S3MPC.ECM.PR.07-77-58)

*Figure 9: Daily monitoring of altimeter wind speed for Sentinel-3A and Sentinel-3B (top panel) and the corresponding histograms (bottom panel). Both plots are computed over Sentinel-3B cycle 58.* 



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# **5** Crossover Analysis

### 5.1 Overview

SSH crossover differences are the SSH differences between ascending and descending passes at their crossing point. Crossover differences are systematically analyzed to estimate data quality and the Sea Surface Height (SSH) performances. SSH crossover differences are computed from valid data on a cyclic basis. A maximum time lag of 10 days is set in order to limit the effects of ocean variability which are a source of error in the performance estimation. The mean SSH crossover differences should ideally be close to zero and standard deviation should ideally be small. Nevertheless, SLA varies also within 10 days, especially in high variability areas. Furthermore, due to lower data availability (due to seasonal sea ice coverage), models of several geophysical corrections are less precise in high latitude. Therefore, an additional geographical selection - removing shallow waters, areas of high ocean variability and high latitudes (> |60|) - is applied for cyclic monitoring.

### 5.2 Maps of SSH crossover differences

The maps of the mean differences at crossovers (4 by 4 degree bin) is plotted for Sentinel-3B cycle 58 on Figure 10. Although the results are a little bit noisy because of the short time period (27 days), Sentinel-3A and Sentinel-3B maps do not highlight strong anomalies. The same large geographical patterns are observed, they will be investigated using a larger time period.





Figure 10: Sea Surface Height differences at crossovers, after data editing, applying additional geographical selection (removing shallow waters, areas of high ocean variability and high latitudes (> |60|°)) for Sentinel-3A (top panel) and Sentinel-3B (bottom panel). Maps computed over Sentinel-3B cycle 58.



The map of the mean SSH differences at Sentinel-3A/Sentinel-3B crossovers (4 by 4 degree bin) is plotted for Sentinel-3B cycle 58 on Figure 11. Once again, this map does not show strong anomalies and highlight the consistency between the two Sentinel-3 missions.



Sentinel-3B vs Sentinel-3A Crossover : Mean differences (cm)

Figure 11: Sea Surface Height differences at Sentinel-3A/Sentinel-3B crossovers, after data editing, applying additional geographical selection (removing shallow waters, areas of high ocean variability and high latitudes (> |60|°)). Map computed over Sentinel-3B cycle 58.

### 5.3 Cycle by cycle monitoring

The mean and standard deviation of SSH differences at crossovers are plotted for Sentinel-3A and Sentinel-3B and compared with Jason-3 in function of time on a cyclic basis (Figure 12 top panel). The statistics are computed after data editing and using the geographical selection criteria (|latitude|  $< |60|^\circ$ , bathymetry < -1000m, ocean variability (computed over several years) < 0.2m).

Note that statistics are computed for each cycle (with a repeat period of approximately 27 days for SentienI-3A and 3B and 10 days for Jason-3). Furthermore, figures are computed by averaging in boxes of 4° by 4° resolution. This is done in order to reduce weight of crossover points in high latitudes (there are much more crossover points in high and very high latitudes than in mean and low latitudes).

This long-term diagnosis has been performed using Sentinel-3 2020 reprocessed datasets (IPF SM2-06.18) until the end of 2019, and then the official datasets.

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Over Sentinel-3B period, the two Sentinel-3 satellites present identical mean SSH difference at crossovers. The mean difference is almost null (0.2 cm) proving the consistency between ascending and descending tracks.

The standard deviation metrics show performances close to the Jason-3 ones. A part of the differences observed between Sentinel-3 missions and Jason-3 metrics could be explained by the mean time lag at crossovers. This parameter varies as function of the satellite orbit. For the Jason-3 mission it is around 3 days whereas it reaches more than 4 days for Sentinel-3A and 3B.



Figure 12: Mean and standard deviation of SSH differences at crossovers for Sentinel-3A (blue curve), Sentinel-3B (red curve) and Jason-3 (black curve) as a function of time.



The mean and standard deviation of SSH difference at Sentinel-3A/Sentinel-3B crossovers is plotted on Figure 13. The difference between the satellites remains small in both SARM and P-LRM, and the standard deviation stable in time. The mean temporal evolution shows positive trends (starting at least from January 2020) for both modes. These trends indicate a different behavior of S3B SLA with respect to S3A.



Figure 13: Mean and standard deviation of SSH differences at Sentinel-3A/Sentinel-3B crossovers as a function of time.



## 5.4 Comparison of pseudo time tag bias

The pseudo time tag bias is found by computing at SSH crossovers a regression between SSH and orbital altitude rate (H), also called satellite radial velocity:

 $SSH = \alpha H$ 

This method allows to estimate the time tag bias, but it also absorbs other errors correlated with H as for instance orbit errors. Therefore, it is called "pseudo" time tag bias.

Figure 14 shows the monitoring of the pseudo time tag bias for Sentinel-3A and Sentinel-3B on a cyclic basis. Using SARM data, a value of -52 microseconds is found for Sentinel-3A cycle 77 and of -28 microseconds for Sentinel-3B cycle 58. The variability from one cycle to the other makes difficult the interpretation of this parameter. Dedicated studies are ongoing to characterize the time tag bias more precisely.



Figure 14: Cyclic monitoring of pseudo time tag bias for Sentinel-3A (blue curve) and Sentinel-3B (red curve).



# 6 Along Track Analysis

### 6.1 Mean of along-track SLA

#### 6.1.1 Temporal analysis

The monitoring of mean SLA and its standard deviation (Figure 15) is done in order to detect possible jumps or drifts.

We note:

- A mean bias between SARM and P-LRM Sea Level time series of 0.7 cm for Sentinel-3A and of 1.5 cm for Sentinel-3B
- ✤ A bias of 0.3 cm between Sentinel-3A and Sentinel-3B SARM SLA.
- ✤ A bias of 0.5 cm between Sentinel-3A and Sentinel-3B PLRM SLA.

The monitoring of the SLA standard deviation also highlights the good agreement between the two missions and between the two modes.



Daily mean of Sea Level Anomaly





Figure 15: Daily monitoring of mean (top panel) and standard deviation (bottom panel) of SLA computed using the radiometer wet tropospheric correction (sla\_rad) over Sentinel-3B cycle 58, for Sentienl-3A SARM (blue) and P-LRM (cyan) and Sentinel-3B SARM (red) and P-LRM (orange).

#### 6.1.2 Maps

Figure 16 shows the maps of Sentinel-3A and Sentinel-3B SLA relative to the Mean Sea Surface. Both maps highlight similar geophysical variation.





Figure 16: Along track of Sea level anomaly relative to MSS computed over Sentinel-3B cycle 58 for Sentinel-3A (top panel) and Sentinel-3B (middle panel).. For both maps, an offset equal to the mean value has been applied.



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# 7 Long term monitoring

## 7.1 Significant wave height monitoring

Figure 17 shows the daily average of Ku-band SWH for Sentinel-3A, Sentinel-3B and Jason-3 products as a function of time. For this long-term monitoring diagnosis, Sentinel-3A data have been concatenated with the latest reprocessed dataset (IPF-SM2 V06.18).

The bias between SARM and P-LRM SWH is around 12 cm for Sentinel-3A and 14 cm for Sentinel-3B. Over Sentinel-3B period, the two Sentinel-3 satellites are in perfect agreement. Thanks to the SAMOSA DPM 2.5 SWH fitting routine improvement in the IPF-SM2 V06.18, Sentinel-3A and -3B SARM SWH are in line with Jason-3.



Figure 17: Daily monitoring of Ku-band significant wave height for Sentinel-3A, Sentinel-3B and Jason-3.

# 7.2 Backscattering coefficient monitoring

Figure 18 shows the daily average of the backscattering coefficient for Sentinel-3A, Sentinel-3B and Jason-3 (Ku-band) as a function of time. For this long-term monitoring diagnosis, Sentinel-3A data have been concatenated with the latest reprocessed dataset (IPF-SM2 V06.18).

A bias of ~4 dB is observed between Sentinel-3A and Jason-3. This is expected since Sentinel-3A has been aligned on Envisat mean value. The Sentinel-3A backscatter curves are flat, this traduces the stability of this parameter.

Sentinel-3A and 3B backscatter coefficients are in line and centred around 11dB.





Figure 18: Daily monitoring of backscattering coefficient for Sentinel-3A, Sentinel-3B, and Jason-3.

### 7.3 Altimeter Wind Speed monitoring

Figure 19 shows the daily average of altimeter wind speed for Sentinel-3A, Sentinel-3B and Jason-3 as a function of time. For this long-term monitoring diagnosis, Sentinel-3A data have been concatenated with the latest reprocessed dataset (IPF-SM2 V06.18).

The SARM and P-LRM wind speed features are in agreement but exhibit a mean bias of  $\sim$ 0.4 m/s compared to Jason-3.

Sentinel-3A and -3B wind speeds are stable and consistent.





Figure 19: Daily monitoring of altimeter wind speed for Sentinel-3A, Sentinel-3B, and Jason-3.

### 7.4 Mean of along-track SLA monitoring

The comparison between mean SLA for Sentinel-3A, Sentinel-3B and Jason-3 (Figure 20 top panel) is done in order to detect possible jumps or drifts. For this long-term monitoring diagnosis, Sentinel-3A data have been concatenated with the latest reprocessed dataset (IPF-SM2 V06.18). The sea level is computed using the radiometer wet tropospheric correction.

Between SARM and P-LRM time series, we note a mean bias of 0.6 cm for Sentinel-3A and of 1.5 cm for Sentinel-3B. The Sentinel-3A sea level in SARM is centered around 5.3 cm in average and is consistent with Jason-3 metric (computed with consistent geophysical correction standards). However, Sentinel-3B sea level, while showing similar annual variation , does not present the same temporal trend as Sentinel-3A and Jason-3.

The monitoring of the SLA standard deviation (Figure 20 bottom panel) allows to detect potential changes in the long-term stability of the altimeter's system performances. The metrics for the three satellites are consistent. Over the mission lifetime, Sentinel-3B SARM and P-LRM variances are in perfect agreement with Sentinel-3A SARM and PLRM respectively, both in magnitude and in temporal variation.





Figure 20: Daily monitoring of mean SLA for Sentinel-3A, Sentinel-3B, and Jason-3.



Figure 21: Daily monitoring of SLA standard deviation for Sentinel-3A, Sentinel-3B, and Jason-3.



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# 8 Conclusions

These results over Sentinel-3B cycle 58 highlight a good quality of Sentinel-3A and Sentinel-3B NTC Marine products. The performances observed at crossovers over this cycle are in perfect agreement for Sentinel-3A and Sentinel-3B and close to Jason-3 ones. The sea level and other parameters derived from the altimeter (backscatter coefficient, SWH, wind speed) show good metrics and good consistency between Sentinel-3A and Sentinel-3B, close to Jason-3 performance.



# 9 Appendix A

Other reports related to the Optical mission are:

- S3 SRAL Cyclic Performance Report, S3A Cycle No. 77, S3B Cycle No. 58 (ref. S3MPC.ISD.PR.04-77-58)
- S3 MWR Cyclic Performance Report, S3A Cycle No. 77, S3B Cycle No. 58 (ref. S3MPC.CLS.PR.05-77-58)
- S3 Winds and Waves Cyclic Performance Report, S3A Cycle No. 77, S3B Cycle No. 58 (ref. S3MPC.ECM.PR.07-77-58)
- S3 Land and Sea Ice Cyclic Performance Report, S3A Cycle No. 77, S3B Cycle No. 58 (ref. S3MPC.UCL.PR.08-77-58)

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

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