S3-A Ocean Validation Cyclic Performance Report

Cycle No. 009

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

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S3-A Ocean Validation Cyclic Performance Report

**Author(s):**
M. Raynal, M. Orsztynowicz, S. Labroue

**Approved by:**
G. Quartly, STM ESL Coordinator

**Authorized by:**
Sylvie Labroue, STM Technical Performance Manager

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1 Introduction

The purpose of this document is to report the major features of the data quality from the Sentinel-3A mission. The document is associated with data dissemination on a cycle per cycle basis. This document reports results from SRAL/Sentinel-3A Near Real Time (NRT) Marine Level 2 products processed by the Marine Centre using the software IPF-SM-2. The version has changed during this cycle, during the 25 first days (from September 17th to October 12th) the processing ran with version 05.03.16, during the 2 last days it ran with the new version 6.03. 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 for cycle 9, from September-17-2016 to October-14-2016.
2 Cycle Overview

The main metric that describes the data quality is the one derived from the analysis of sea surface variability at crossovers. For this cycle, the crossover standard deviation is \(9.7 \text{ cm rms}\) using a selection to remove shallow waters (1000 m), areas of high ocean variability and high latitudes (\(> |60^\circ|\)): This first metric is stronger than usual values that are obtained on altimetry mission. The analysis of data quality presented in this document highlights several anomalies:

- Brightness temperature values for the tracks crossing the Greenwich meridian are set to default values for the 25 first days of this cycle since products where generated with version 05.03.16. This anomaly has been corrected and implemented in IPF version 06.03.xx, therefore the two last days of cycle 9 does not present this anomaly.
- The modeled geophysical corrections derived from ECMWF model are impacted by a processing anomaly.

Cycle 9 spans from September-17-2016 to October-14-2016. Thus SRAL operates in SAR mode.
3 Baseline Processing

The version of the S3-MPC software used to compute the altimeter parameters for this dataset is the IPF-SM-2, version 05.03.16 from September 17th to October 12th and then version 06.03 from October 12th to October 14th.
4 Data coverage and edited measurements

This section presents results that illustrate data quality during cycle 9. These metrics allow long term monitoring of missing and edited measurements.

4.1 Missing measurements

Missing measurements relative to the Sentinel-3A nominal ground track are plotted on Figure 1. The maps below illustrate available 1Hz measurements in the NRT products, with respect to a 1Hz sampling of a nominal repeat track. This figure shows that missing measurement corresponds to one full orbit and a quarter one. These missing measurements are related with the new version installation. Figure 2 shows the daily monitoring of available measurements over Ocean during the cycle. The mean percentage is close to 100% except for the October 12th which corresponds to new version installation.

Figure 1: Map of missing measurements over ocean for cycle 9.
Figure 2: Monitoring of percentage of available measurements per day.

4.2 Edited Measurements

The editing criteria are defined as minimum and maximum thresholds for various parameters. These criteria for editing will be refined for Sentinel-3A mission. Measurements are edited if at least one parameter is found to be outside those thresholds. These thresholds are expected to remain constant throughout the Sentinel-3A mission, so that monitoring the number of edited measurements allows a survey of data quality. In the following, only measurements over ocean are kept.

The number and percentage of points removed by each criterion is given on the following table. Note that these statistics are obtained with measurements already edited by ice flag (20.11 % of points removed).
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min threshold</th>
<th>Max threshold</th>
<th>Unit</th>
<th>Nb removed</th>
<th>% removed</th>
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<tr>
<td>Sea surface height (Orbit - Range)</td>
<td>-130</td>
<td>100</td>
<td>m</td>
<td>2 157</td>
<td>0.18 %</td>
</tr>
<tr>
<td>Orbit - Range - MSS</td>
<td>-10</td>
<td>10</td>
<td>m</td>
<td>2 745</td>
<td>0.22 %</td>
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<tr>
<td>Std. deviation of range</td>
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<td>0.2</td>
<td>m</td>
<td>11 710</td>
<td>0.95 %</td>
</tr>
<tr>
<td>Number of range</td>
<td>10</td>
<td>DV</td>
<td>count</td>
<td>2 090</td>
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<tr>
<td>Dry tropospheric correction model (ECMWF Gauss)</td>
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<td>-1.9</td>
<td>m</td>
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<td>0.00 %</td>
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<td>-0.001</td>
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<td>0.00 %</td>
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<td>0.7</td>
<td>db</td>
<td>27 080</td>
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<tr>
<td>Ocean tide height model (GOT4V10)</td>
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<td>m</td>
<td>212</td>
<td>0.02 %</td>
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<td>Solid earth tide height model (Cartwright and Tayler 1971)</td>
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<td>m</td>
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<td>Pole tide height model (Wahr 1985)</td>
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<td>m</td>
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<tr>
<td>Global statistics of edited measurements by thresholds</td>
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<td></td>
<td></td>
<td>30 589</td>
<td>2.48 %</td>
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</table>

Table 1: Table of parameters used for editing

The measurements rejected during the editing process are shown in Figure 3. Equatorial wet zones or zones with sea ice appear in the plot 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. The sinusoids of edited measurements observed for some of the latitudes are related with granule extremities. The Level 2 products provide 1 Hz duplicates between 2 consecutive granules (S3MPC-926) for the 20 measurements that cover two granules. This means that the 1 Hz average is done with too few 20 Hz observations and thus provides range values to default value.

Figure 3: Edited measurements for cycle 9.
5 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 verification products are produced operationally so that they allow systematic monitoring of the main relevant parameters.

5.1 Sentinel-3A Sensors

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

- STM SRAL N-Cyclic Performance-Report.docx for SRAL assessment (S3MPC.ISD.PR.04-009).
- STM MWR N-Cyclic Performance-Report.docx for MWR assessment (S3MPC.ISD.PR.05-009).

5.2 Significant wave height

Figure 4 shows along-track significant wave height derived from altimeter measurements. Wave height may reach several meters.

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 SARM and P-LRM is plotted as a function of time on Figure 5. They show similar features.
A bias of 3 cm is observed between P-LRM and SARM SWH.

**Figure 5:** Daily monitoring of significant wave height for Sentinel-3A (Ku-band) and Jason-3 (Ku-band) on top and histogram for cycle 9 on bottom (limited to 66° latitude).

### 5.3 Backscattering coefficient

Figure 6 shows along-track backscatter coefficient derived from altimeter measurements.
Figure 6: Backscattering coefficient for cycle 9.

The daily average of the backscattering coefficient for Sentinel-3A SARM and P-LRM (Ku-band) is plotted as a function of time on Figure 7. A bias of 0.08 dB is observed between P-LRM and SARM.
Figure 7: Daily monitoring of backscattering coefficient for Sentinel-3A and Jason-3 on top and histogram for cycle 9 on bottom (limited to 66° latitude).

5.4 Altimeter wind Speed

Figure 8 shows wind speed estimations derived from along-track altimeter measurements.
The daily average of altimeter wind speed for Sentinel-3A SARM and P-LRM is plotted as a function of time on the top of Figure 9. The histogram is shown on the bottom. A mean bias of ~0.2 m/s is observed between SARM and P-LRM.
Figure 9: Daily monitoring of altimeter wind speed for Sentinel-3A and Jason-3 on the left and histogram for cycle 9 on the right (limited to 66° latitude).
6 Crossover Analysis

6.1 Overview

SSH crossover differences are the SSH differences between ascending and descending passes where they cross each other. Crossover differences are systematically analyzed to estimate data quality and the Sea Surface Height (SSH) performances. SSH crossover differences are computed from the valid data set on a one cycle basis, with a maximum time lag of 10 days, 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.

6.2 Maps of SSH crossover differences

The map of the mean differences at crossovers (4 by 4 degrees by bins) is plotted for cycle 9 on Figure 10. Mean and standard deviation statistics are computed over boxes. This map shows strong heterogeneity in the South hemisphere, in the North East Pacific and several along-track patterns. As it has been already mentioned in section 2, these discrepancies are mainly explained by the wrong computation of modeled geophysical correction derived from ECMWF files (pattern observed in the south hemisphere).
Figure 10: After data editing, applying additional geographical selection (removing shallow waters, areas of high ocean variability and high latitudes (> |60|°)).

### 6.3 Cycle by cycle monitoring

The mean and standard deviation of SSH differences at crossovers are plotted for Sentinel-3A and compared with Jason-3 as a function of time on a one cycle per cycle basis on top of Figure 11. The statistics are computed after data editing and using the geographical selection criteria (|latitude| < |60|°, bathymetry < −1000m, ocean variability (computed over several years) < 0.2 m).

Note that statistics are computed for each cycle (with a repeat period of approximately 27 days for Sentinel-3A 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).

The mean difference is slightly negative (-0.5 cm) indicating that there is a bias between ascending and descending tracks.

The standard deviation is quite large since the beginning of the Level 2 NRT Marine production. The statistics are very much degraded compared to Jason-3 due to the anomalies in ECMWF derived fields. The previous cycle statistics was also impacted by the orbit quality since the GPS observations (ROE orbits) were not use everywhere (see previous reports).
6.4 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 us to estimate the time tag bias but it absorbs also other errors correlated with H as for instance orbit errors. Therefore, it is called "pseudo" time tag bias. Figure 12 shows the monitoring of the pseudo time tag bias for Sentinel-3A on a cyclic basis. A value of +202 microseconds is found for this cycle using only the SARM data. Whereas in the light of the
anomalies mentioned and the strong discrepancies observed Figure 10, the level of confidence for the pseudo time tag bias is very low.

![S3A Pseudo time tag bias](image)

*Figure 12: Cyclic monitoring of pseudo time tag bias for Sentinel-3A.*
7 Along Track Analysis

7.1 Mean of along-track SLA

7.1.1 Temporal analysis

The monitoring of mean SLA and its standard deviation (Figure 13) is done in order to detect possible jumps or drifts.

We note a mean bias of 1.4 cm between SARM and PLRM Sea Level time series.

![Mean SLA and Standard Deviation](image)

*Figure 13: Daily monitoring of mean (top panel) and standard deviation (bottom panel) of Sentinel-3A SLA.*
7.1.2 Maps

Figure 14 respectively show the map of Sentinel-3A and Jason-3 SLA relative to the Mean Sea Surface. Along track patterns and strong variability are observed on the Sentinel-3a map, due to the anomalies reported.

![Ku-band SLA using radiometer](image1)

**Sentinel-3a** (2016-09-17 00:00, 2016-10-14 00:00)

![Ku-band SLA using radiometer](image2)

**Jason-3** (2016-09-17 00:00, 2016-10-14 00:00)

*Figure 14: Along track map of Sentinel-3a Sea level anomaly relative to MSS for cycle 9 (top panel). Along track map of Jason-3 Sea level anomaly relative to MSS for Sentinel-3A cycle 9 (bottom panel).*
8 Long term monitoring

8.1 Significant wave height monitoring

Figure 4 shows the daily average of Ku-band SWH for Sentinel-3A and Jason-3 IGDR products as a function of time since the beginning of products availability. They show similar features and a bias of ~15 cm between Sentinel-3A and Jason-3.

![Graph showing SWH monitoring for Sentinel-3A and Jason-3](image)

*Figure 15: Daily monitoring of significant wave height for Sentinel-3A (Ku-band) and Jason-3 (Ku-band).*

8.2 Backscattering coefficient monitoring

Figure 7 shows the daily average of the backscattering coefficient for Sentinel-3A and Jason-3 (Ku-band) as a function of time. Note that the atmospheric attenuation is available in the Sentinel-3A products but the backscatter coefficient is not corrected for it (whereas it is accounted for Jason-3 backscatter coefficient). A bias of ~3 dB is observed between Sentinel-3A and Jason-3. This is expected since Sentinel-3A has been aligned on Envisat mean value.
8.3 Altimeter wind Speed monitoring

Figure 8 shows the daily average of altimeter wind speed for Sentinel-3A and Jason-3 as a function of time. The SARM and P-LRM wind speed features are in agreement with Jason-3 but exhibit a mean bias of ~1 m/s compared to Jason-3.
8.4 Mean of along-track SLA monitoring

The comparison between mean SLA for Sentinel-3A and Jason-3 (Figure 13) is done in order to detect possible jumps or drifts. The sea level is computed using the radiometer wet tropospheric correction.

Strong variations mainly related to the orbit quality are observed on the SLA standard deviation for the previous cycles (Figure 19).

We note a mean bias of 1.3 cm between SARM and PLRM Sea Level time series. The Sentinel-3A sea level in SARM is biased by 10 cm compared to Jason-3 mission.

**Figure 18: Daily monitoring of mean SLA for Sentinel-3A and Jason-3.**

**Figure 19: Daily monitoring of SLA standard deviation for Sentinel-3A and Jason-3.**
These results over cycle 9 highlight a mitigated quality of the Sentinel-3A NRT Marine products. The performances of the sea level are degraded by wrong computation of geophysical corrections derived from ECMWF. The parameters that are not impacted by these errors (backscatter coefficient, SWH, wind speed) show good metrics, close to Jason-3 performance.
Other reports related to the STM mission are:

- S3-A SRAL Cyclic Performance Report, Cycle No. 009 (ref. S3MPC.ISR.PR.04-009)
- S3-A MWR Cyclic Performance Report, Cycle No. 009 (ref. S3MPC.CLS.PR.05-009)
- S3-A Winds and Waves Cyclic Performance Report, Cycle No. 009 (ref. S3MPC.ECM.PR.07-009)

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

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