Copernicus Sentinel-3 Surface Topography Mission - Cyclic Performance Report

**SEA ICE**

<table>
<thead>
<tr>
<th>S3A</th>
<th>S3B</th>
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<tr>
<td>Cycle No. 84</td>
<td>Cycle No. 65</td>
</tr>
<tr>
<td>Start date: 04/04/2022</td>
<td>Start date: 14/04/2022</td>
</tr>
<tr>
<td>End date: 01/05/2022</td>
<td>End date: 11/05/2022</td>
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Reference: S3MPC-STM_CPR_0008-084-065

Issue 1.0 – 16/05/2022

Contract: 4000136824/21/I-BG

Open/Public/Público

Disclaimer
The work performed in the frame of this contract is carried out with funding by the European Union. The views expressed herein can in no way be taken to reflect the official opinion of either the European Union or the European Space Agency.
CHRONOLOGY ISSUES

<table>
<thead>
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<th>Written by</th>
<th>Checked by</th>
<th>Approved by</th>
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<tr>
<td>1.0</td>
<td>22/04/2022</td>
<td>Creation</td>
<td>F. Piras</td>
<td>J. Aublanc</td>
<td>G. Jettou</td>
</tr>
</tbody>
</table>

ACCEPTANCE

<table>
<thead>
<tr>
<th></th>
<th>CLIENT: ESA</th>
<th>SUPPLIER: CLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Pierre Féménias</td>
<td>Ghita Jettou</td>
</tr>
<tr>
<td>Function</td>
<td>ESA Technical Officer</td>
<td>MPC Service Manager</td>
</tr>
</tbody>
</table>
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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.

The Level 2 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 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 84, from 04/04/2022 to 01/05/2022.
- To present the major useful results for S3B cycle 65, from 14/04/2022 to 11/05/2022.
2 Cycle overview

Note that the period covered by the S3A and S3B cycles in this report have an offset of 10-days and their orbits are 140 degrees out of phase. Differences in parameters are therefore expected, particularly over sea ice due to the wind induced drift of the sea ice during this period.

The delay-Doppler/SAR processing is currently not fully optimised for sea ice (no zero padding or hamming weighting is applied), and hence users should be aware that freeboard accuracy is sub-optimal in this cycle.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sentinel-3A</th>
<th>Sentinel-3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>Nominal orbit availability</td>
<td>3 missing tracks (553,554,759)</td>
</tr>
<tr>
<td>Availability of geophysical</td>
<td>Nominal geophysical corrections availability</td>
<td>Ionospheric correction available at 97.06%</td>
</tr>
<tr>
<td>corrections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of auxiliary data</td>
<td>Nominal auxiliary data availability</td>
<td>Nominal auxiliary data availability</td>
</tr>
<tr>
<td>Geophysical parameters</td>
<td>Nominal performances of the altimeter-derived</td>
<td>Nominal performances of the altimeter-derived</td>
</tr>
<tr>
<td></td>
<td>geophysical parameters</td>
<td>geophysical parameters</td>
</tr>
<tr>
<td>Specific investigations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>Nominal mission performances on this cycle</td>
<td>Nominal mission performances on this cycle</td>
</tr>
</tbody>
</table>

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

Color legend:

- OK
- Warning
- NOK

Please note that Ice Shelves have not been edited for the Antarctic statistics, which has an impact on the following:

- The sea ice concentration availability is lower on the Antarctic than the Arctic (Table 5).
- Visible Ice shelves on the Sea Ice Concentration NaN maps (Figure 33) and SSHA Antarctic maps (Figure 27 and Figure 28)
3 Processing baseline

Table 2 details the versions of the Processing Baseline (PB), and Level-1 and Level-2 Instrument Processing Facility software used for the products assessed. This is part of the Baseline Collection (BC) 004.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Processing Baseline</th>
<th>IPF SM2 version</th>
<th>IPF SR1 version</th>
<th>IPF MW1 version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentinel-3A</td>
<td>84</td>
<td>2.72</td>
<td>06.19</td>
<td>06.20</td>
</tr>
<tr>
<td>Sentinel-3B</td>
<td>65</td>
<td>1.49</td>
<td>06.11</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Processing baseline and IPF details

The evolutions of the Sentinel-3 STM Processing Baseline since July 2016, end of commissioning phase, are summarized in the “Sentinel Online” Web pages: https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-3-altimetry/processing-baseline

4 Data availability and missing measurements

4.1 Orbit coverage

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Product Type</th>
<th>Latency</th>
<th>% Tracks received</th>
<th>Missing tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentinel-3A</td>
<td>84</td>
<td>SR_2_LAN</td>
<td>STC</td>
<td>100%</td>
</tr>
<tr>
<td>Sentinel-3B</td>
<td>65</td>
<td>SR_2_LAN</td>
<td>STC</td>
<td>99.61%</td>
</tr>
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</table>

Table 3: Orbit coverage pour Sentinel-3A and Sentinel-3B

4.2 Availability of geophysical corrections

Data have been selected over ocean, where the flag surf_type_01 is set to 0.

surf_type_01

<table>
<thead>
<tr>
<th>surface type: 1 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: ocean_or_semi_enclosed_sea</td>
</tr>
<tr>
<td>2: continental_ice</td>
</tr>
</tbody>
</table>
Over sea ice the model dry tropospheric, model wet tropospheric, ionospheric, solid earth tide, pole tide, ocean tide, inverse barometric and ionospheric corrections are available in the STC L2 product.

<table>
<thead>
<tr>
<th>Correction</th>
<th>% Availability Sentinel-3A</th>
<th>% Availability Sentinel-3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>hf_fluct_cor_01</td>
<td>100</td>
<td>99.91</td>
</tr>
<tr>
<td>inv_bar_cor_01</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ocean_tide_non_eq_01</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ocean_tide_sol2_01</td>
<td>99.97</td>
<td>99.97</td>
</tr>
<tr>
<td>ocean_tide_sol1_01</td>
<td>99.90</td>
<td>99.90</td>
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<td>100</td>
</tr>
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<td>solid_earth_tide_01</td>
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<td>100</td>
</tr>
<tr>
<td>iono_cor_gim_01_ku</td>
<td>100</td>
<td>97.06</td>
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<tr>
<td>mod_wet_tropo_cor_meas_altitude_01</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>mod_dry_tropo_cor_meas_altitude_01</td>
<td>100</td>
<td>100</td>
</tr>
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</table>

Table 4: Availability percentage of Geophysical Corrections over Sea Ice. Green=100%; Orange= Between 80% and 100%; Red <80%

### 4.3 Availability of auxiliary data

<table>
<thead>
<tr>
<th>Correction</th>
<th>% Availability Sentinel-3A</th>
<th>% Availability Sentinel-3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>sea ice concentration</td>
<td>Arctic 96.9820  Antarctic 87.9555</td>
<td>Arctic 96.9913  Antarctic 87.8994</td>
</tr>
<tr>
<td>snow density</td>
<td>100 100</td>
<td>100 100</td>
</tr>
</tbody>
</table>

Table 5: Availability percentage of Snow Density and Sea Ice Concentration over Sea Ice

Note that the Snow Density is set to a single value of 400 Kg/m³ in the current version of the IPF.

Snow depth over Antarctic Sea-Ice is set to zero in the current version of the IPF.

Sea Ice Concentration is derived from a dynamic 3-day average of sea ice concentration calculated from SSM/I daily brightness temperature data.
4.4 SRAL instrument modes (mode_id_20_ku and instr_op_mode_20_ku)

This section focuses on the SRAL processing mode (instr_op_mode_20_ku), and the SRAL on-board tracking mode (mode_id_20_ku) The following fields from the SR_2_LAN Level 2 STC products have been used:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>surf_type_20_ku</td>
<td>surface type: 20 Hz Ku band</td>
</tr>
<tr>
<td></td>
<td>0: ocean or semi enclosed sea</td>
</tr>
<tr>
<td></td>
<td>2: continental ice</td>
</tr>
<tr>
<td>mode_id_20_ku</td>
<td>Mode identifier: 20 Hz Ku band</td>
</tr>
<tr>
<td></td>
<td>0: closed_loop</td>
</tr>
<tr>
<td>instr_op_mode_20_ku</td>
<td>Instrument operating mode: 20 Hz Ku band</td>
</tr>
<tr>
<td></td>
<td>0: LRM</td>
</tr>
</tbody>
</table>

Table 6: Fields selected to analyse and monitor the Sentinel-3 instrument modes

Data have been selected over ocean using only points where surf_type_20_ku = 0. Percentages have been obtained by using a combination of the fields mode_id_20_ku and instr_op_mode_20_ku.

As it can be seen in Figure 3 and Figure 5, Sentinel-3A and Sentinel-3B are fully operating in SAR altimetry mode. This is the nominal situation since the end of commissioning phase.

4.4.1 Arctic

![Figure 2: Map of SRAL on-board tracking modes over the Arctic sea-ice (mode_id_20_ku)](image)

Figure 2: Map of SRAL on-board tracking modes over the Arctic sea-ice (mode_id_20_ku)
4.4.2 Antarctic

Figure 3: Percentage of the different SRAL modes over the Arctic sea-ice (combination of mode_id_20_ku & instr_op_mode_20_ku)

Figure 4: Map of SRAL on-board tracking modes over the Antarctic sea-ice (mode_id_20_ku)
This section shows results and analyses of the L2 STC parameters relating to sea ice. For all the analyses of this section, NaN values have been discarded.

The following fields from the SR_2_LAN Level 2 STC products have been used in this section:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
</table>
| surf_type_20_ku              | Surface type: 20 Hz Ku band  
0: ocean_or_semi_enclosed_sea | 1: enclosed_sea_or_lake  
2: continental_ice | 3: land |
| freeboard_20_ku              | Radar freeboard derived from SAR mode altimetry measurements, available at 20 Hz rate |
| surf_type_class_20_ku        | Altimeter-derived surface type classification, available at 20 Hz rate  
0: open_ocean | 1: sea_ice | 2: leads | 3: unclassified |
| int_sea_ice_ssha_20_ku       | Interpolated sea ice sea surface height anomaly, available at 20 Hz rate |
| sea_ice_ssha_20_ku           | Sea ice sea surface height anomaly, available at 20 Hz rate |
| sea_ice_concentration_20_ku  | Sea-ice concentration from MSSL Auxiliary Data Files, available at 20 Hz rate |
| peakiness_2_20_ku            | SAR waveform Peakiness from Laxon's derivation, available at 20 Hz rate |

Data have been selected over ocean, where the flag surf_type_20_ku is set to 0.

All polar maps in this section have been generated using a 25km polar stereographic projection.
5.1 20Hz Ku-band Altimeter Derived freeboard (freeboard_20_ku)

5.1.1 Arctic

Figure 6: Maps of SAR mode Ku-band freeboard for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.

Figure 7: Histograms of Ku-band freeboard for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the one used in the freeboard maps above (Figure 6).

Arctic freeboard values for this cycle are within normal range and show expected behaviour. No anomalies detected.
5.1.2 Antarctic

Figure 8: Maps of SAR mode Ku-band freeboard for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic

Figure 9: Histograms of SAR mode Ku-band freeboard for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the range used in the freeboard map (Figure 8)

Antarctic freeboard values for this cycle are within normal range and show expected behaviour. No anomalies detected.
5.2 20Hz Ku-band Altimeter Derived Surface Type
(surf_type_class_20_ku)

This parameter flags the surface as "sea ice lead", "sea ice floe", "open ocean" or "unclassified", depending on:

- The SAR waveform shape (i.e.: waveform peakiness)
- The sea ice concentration value from the Auxiliary Data File, and interpolated at the altimetry location

Each class has been mapped using a polar stereographic projection and grid pixel values represent the percentage/ratio of occurrence, for each surface classes. Percentages of each class occurrence (Figure 10 and Figure 11) have been computed directly on the 20Hz data.

5.2.1 Arctic

Figure 10: Percentages of each surface class for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.

Figure 11: Maps of "ocean" class occurrences for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.
Figure 12: Maps of “sea-ice floes” class occurrences for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.

Figure 13: Maps of “leads” class occurrences for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.
The distribution of each class (ocean, floes, leads and unclassified) is nominal and shows no anomalies.

5.2.2 Antarctic

Figure 15: Percentages of each surface class for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic.
Figure 16: Maps of "ocean" class occurrences for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic.

Figure 17: Maps of "leads" class occurrences for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic.
The distribution of each class (ocean, floes, leads and unclassified) is nominal and shows no anomalies.
5.3 20Hz Ku-band Interpolated Sea-Ice Sea Surface Height Anomaly (int_sea_ice_ssha_20_ku)

This parameter is the sea surface height with respect to the mean sea surface (mean_sea_surf_sol2_20_ku) interpolated between leads in the sea ice (i.e., represents the SSHA underneath the sea ice floes).

5.3.1 Arctic

![Maps of SAR mode Ku-band interpolated sea-ice for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic](image)

**Figure 20**: Maps of SAR mode Ku-band interpolated sea-ice for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic

![Histograms of Ku-band SAR mode interpolated sea-ice surface height anomaly for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the range used in the freeboard map (Figure 20)](image)

**Figure 21**: Histograms of Ku-band SAR mode interpolated sea-ice surface height anomaly for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the range used in the freeboard map (Figure 20)

Interpolated sea-ice SSHA values on the Arctic for this cycle are within normal range and show expected behaviour. No anomalies detected.
5.3.2 Antarctic

Figure 22: Maps of Ku-band SAR mode interpolated sea-ice SSHA for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic

Figure 23: Histograms of SAR mode Ku band interpolated sea-ice SSHA for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic. Map range corresponds to the range used in the freeboard map (Figure 22)

Interpolated SSHA values on the Antarctic for this cycle are within normal range and show expected behaviour. No anomalies detected.
5.4 20Hz Sea-Ice Sea Surface Height Anomaly (sea_ice_ssha_20_ku)

This parameter is the sea-ice sea surface height anomaly with respect to the mean sea surface (mean_sea_surf_sol2_20_ku).

5.4.1 Arctic

Figure 24: Maps of the SAR mode Ku band sea-ice SSHA for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.

Figure 25: Maps of the SAR mode Ku band sea-ice SSHA NaN values for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic.
Figure 26: Histograms of the SAR mode Ku band sea-ice SSHA for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the range used in the freeboard map (Figure 24).

Sea ice SSHA values on the Arctic for this cycle are within normal range and show expected behaviour. No anomalies detected. Note that the presence of outliers induces a biased mean and std values.

5.4.2 Antarctic

Figure 27: Maps of the SAR mode Ku band sea-ice SSHA for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic.
SSHA values on the Arctic for this cycle are within normal range and show expected behaviour. No anomalies detected. Note that the presence of outliers induces a biased mean and std values. Also, as explained in the cycle overview (section 2), ice shelves were not edited. They are clearly visible on the maps and increase artificially the number of NaN values.
5.5 20Hz Ku-band Sea Ice Concentration (sea_ice_concentration_20_ku)

Sea ice concentration data is available in 100% of records in the STC product in these cycles. Sea Ice Concentration is retrieved from input Auxiliary Data Files (ADF). These ADF are provided by MSSL, they contain sea ice concentration maps derived from a dynamic 3-day average of sea ice concentration calculated from SSM/I daily brightness temperature data. The sea ice concentration values available in the products, and mapped in the Figures below, below are interpolated at each 20 Hz altimetry locations.

5.5.1 Arctic

![Maps of Sea Ice Concentration](image)

**Figure 30**: Maps of Sea Ice Concentration (sea_ice_concentration_20_ku) over the Arctic Ocean

![Maps of Sea Ice Concentration NaN values](image)

**Figure 31**: Maps of Sea Ice Concentration (sea_ice_concentration_20_ku) NaN values over the Arctic Ocean
Sea-Ice concentration values on the Arctic for this cycle are within normal range and show expected behaviour. The NaN values observed along the coastlines are expected, they are due to the absence of valid estimations in the current input ADF. This issue is planned to be fixed in a near future IPF version, with a change of the input ADF. No anomalies detected.

5.5.2 Antarctic

Sea-Ice concentration values on the Antarctic for this cycle are within normal range and show expected behaviour. No anomalies detected.

As explained in the cycle overview (section 2), ice shelves were not edited. They are clearly visible on the maps and increase artificially the number of NaN values.
5.6 20Hz Ku-band peakiness (peakiness_2_20_ku)

Waveform shape peakiness is a primary means of discriminating between sea ice floes and leads. Specular returns over leads have high peakiness values (> 23) and diffuse echoes over sea ice floes and open ocean have a less peaky shape, leading to low peakiness values (< 11).

5.6.1 Arctic

![Maps of 20Hz SAR mode Ku band Peakiness (peakiness_2_20_ku) over the Arctic](image)

*Figure 34: Maps of 20Hz SAR mode Ku band Peakiness (peakiness_2_20_ku) over the Arctic*

![Histograms of SAR mode Ku-band peakiness for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the range used in the peakiness maps (Figure 34)](image)

*Figure 35: Histograms of SAR mode Ku-band peakiness for Sentinel-3A (left) and Sentinel-3B (right) for the Arctic. Map range corresponds to the range used in the peakiness maps (Figure 34)*

Peakiness values on the Arctic for this cycle are within normal range and show expected behaviour. No anomalies detected.
5.6.2 Antarctic

Figure 36: Maps of 20Hz SAR mode Ku band Peakiness (peakiness_2_20_ku) over the Antarctic

Figure 37: Histograms of SAR mode Ku band freeboard for Sentinel-3A (left) and Sentinel-3B (right) for the Antarctic. Map range corresponds to the range used in the corresponding map (Figure 36)

Peakiness values on the Antarctic for this cycle are within normal range and show expected behaviour. No anomalies detected.
Appendix A - Useful links

The Product Format Specification applicable to the 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