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

S3-A Land and Sea Ice Cyclic Performance Report

Cycle No. 021

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Author(s):	Land and Sea Ice ESLs		
Approved by:	G. Quartly, STM ESL Coordinator	Authorized by	Sylvie Labroue, STM Technical Performance Manager
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Disclaimer

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Changes Log

Version	Date	Changes
1.0	05/12/2017	First Version

List of Changes

Version	Section	Answers to RID	Changes



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1 Introduction

This document provides a report of the performance and data quality of the Sentinel-3A SRAL Level 2 data products over land ice (polar ice sheets, ice shelves, and ice caps) and sea ice surfaces.

For land ice the SR_2_LAN Level 2 NTC (Non Time Critical) products which contain the final orbit and geophysical corrections are assessed. These are produced by the S3 Instrument Processing Facility (IPF) at CNES.

For sea ice, we assess the SR_2_WAT Marine Level 2 NTC (Non Time Critical) products, produced by the S3 Marine Centre.

The objectives of this document are :

- To provide a data quality assessement.
- 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 cycle 21, from 07 August 2017 to 03 September 2017.



2 Cycle Overview

This is 27-day cycle 21 (07-Aug-2017 to 03-Sep-2017), the eighth cycle since Sentinel-3A entered its routine operational phase following commissioning. Sentinel-3A was launched on 16-February-2016.

During this cycle, Sentinel-3A SRAL operated in SAR mode over land ice and sea ice surfaces.



3 Processing Baselines

During this cycle there was no Instrument Processing Facility (IPF) software version change for SR_2_LAN NTC products.

One version of the IPF was used to compute the altimeter parameters for the L2 Land (SR_2-LAN) NTC dataset during this cycle. This was IPF-SM-2, version 06.07.

SR_2_LAN NTC			
Cycle	Processing Baseline	L2 IPF Versions	L1 IPF Versions
21	PB 2.12	SM2 6.0.7 (since 12/04/2017 10:37 UTC)	SR1 06.11

One version of the IPF was used to compute the altimeter parameters for the L2 Land (SR_2-WAT) NTC dataset during this cycle. This was IPF-SM-2, version 06.07.

SR_2_WAT NTC			
Cycle	Processing Baseline	L2 IPF Versions	L1 IPF Versions
21	PB 2.12	SM2 6.0.7 (since 12/04/2017 10:54 UTC)	SR1 06.11



4 Data Availability & Instrument Modes

4.1 Data Availability

The percentage of L2 product orbits received during this 27 day cycle by the MPC and contributing to this report were:

Product Type	Latency	% Orbits Received
SR_2_LAN	NTC	100.0
SR_2_WAT	NTC	99.7%

Table 1: Data Availability for NTC

Note that these are percentages of products received by the Mission Performance Centre at the time of report issue, and may be lower than the final data availability if there have been processing centre delays.



4.2 SRAL Instrument Mode

Over land ice surfaces the SRAL instrument operated in SAR closed loop during this cycle. Closed-loop is the autonomous form of surface tracking typically used for altimetry missions, as compared with open-loop which depends on a pre-computed DEM stored onboard.

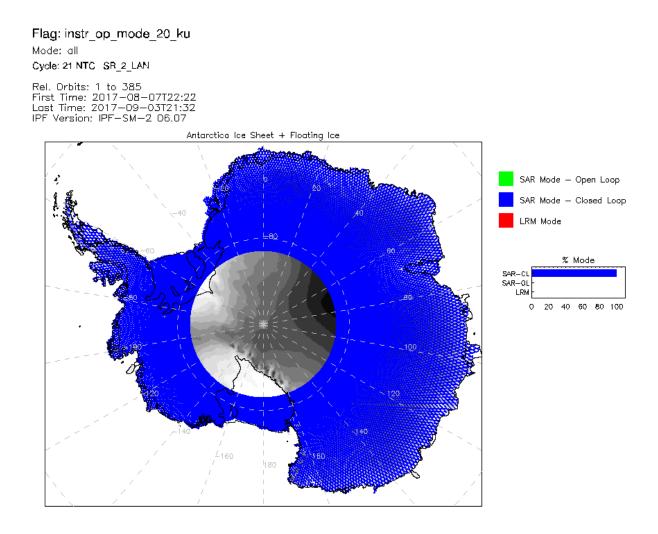


Figure 1 : Map of SRAL mode over Antarctic ice sheet and ice shelves for cycle 21 NTC



Flag: instr_op_mode_20_ku Mode: all Cycle: 21 NTC_SR_2_LAN

Rel. Orbits: 1 to 385 First Time: 2017-08-07T22:22 Last Time: 2017-09-03T21:32 IPF Version: IPF-SM-2 06.07

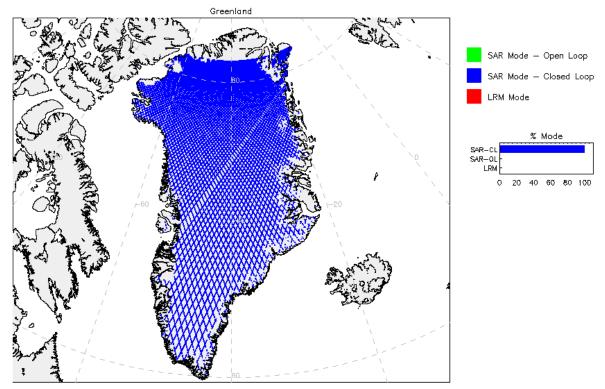


Figure 2: Map of SRAL mode over Greenland ice sheet for cycle 21 NTC

For sea ice and ocean surfaces the SRAL instrument operated in SAR open loop mode during this cycle. Note that the mode mask is fixed and does not dynamically change from cycle to cycle. In open loop the range window is positioned using a 1-D along track DEM with a-priori knowledge of the surface height.



Flag: instr_op_mode_20_ku Mode: all Cycle: 21 NTC_SR_2_WAT

Rel. Orbits: 1 to 385 First Time: 2017–08–07T22:22 Last Time: 2017–09–03T21:27 IPF Version: IPF–SM–2 06.07

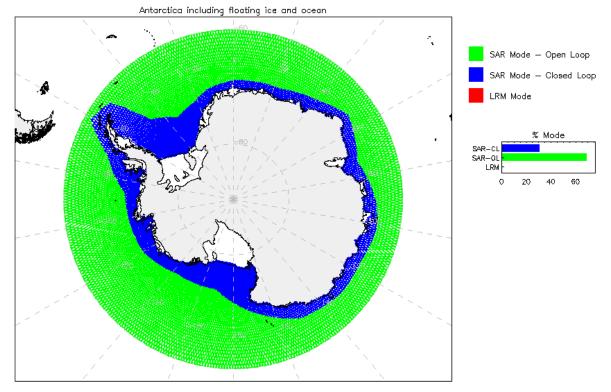


Figure 3: Map of SRAL mode over the Antarctic sea ice for cycle 21 NTC



Flag: instr_op_mode_20_ku Mode: all Cycle: 21 NTC_SR_2_WAT

Rel. Orbits: 1 to 385 First Time: 2017-08-07T22:22 Last Time: 2017-09-03T21:27 IPF Version: IPF-SM-2 06.07

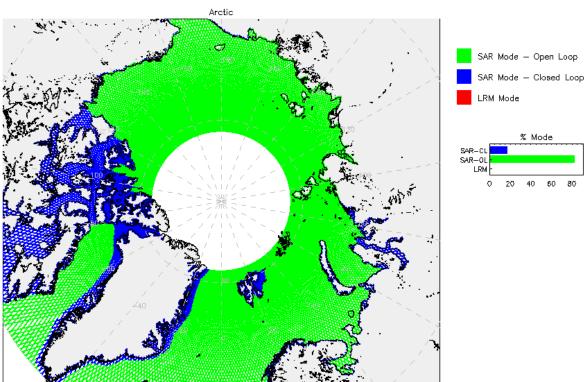


Figure 4: Map of SRAL mode over the Arctic sea ice for cycle 21 NTC



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5 Availability of Polar Geophysical Corrections

In this section the availability of geophysical corrections to altimeter range contained in the L2 products over ice sheets, ice shelves and sea ice are analysed for this cycle. Missing or invalid geophysical corrections can cause errors in the final L2 elevation parameters, and erroneous steps in derived time series of ice sheet surface elevation change or sea ice freeboard.

5.1 Availability of Geophysical Corrections over Ice Sheets (NTC Products)

For polar ice sheets, the primary geophysical corrections applied to the range are model dry tropospheric, model wet tropospheric, GIM ionospheric, solid earth tide, pole tide and ocean loading tide. We would normally expect 100% availability of all corrections except the altimeter derived ionospheric corrections (iono_cor_alt_01_ku, iono_cor_alt_20_ku).

For cycle 21 NTC the percentage of non-available geophysical corrections over Antarctic ice sheets was:

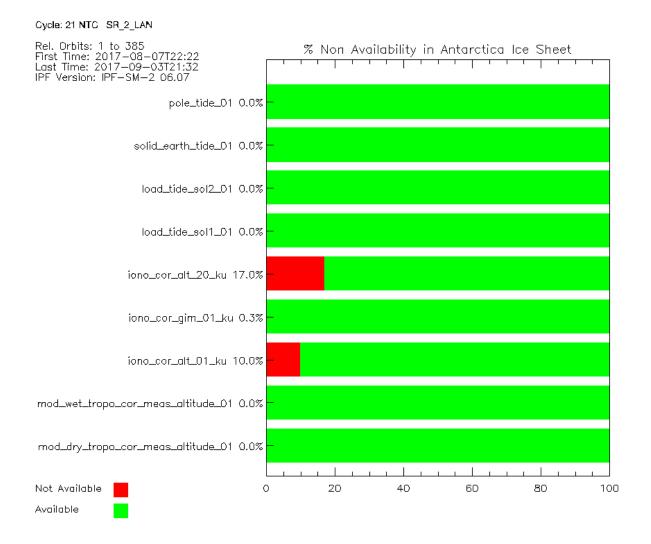


Figure 5: Percentage of Geophysical Correction Non-availability over Antarctic Ice Sheets



For cycle 21 NTC the percentage of non-available geophysical corrections over the Greenland ice sheet was:

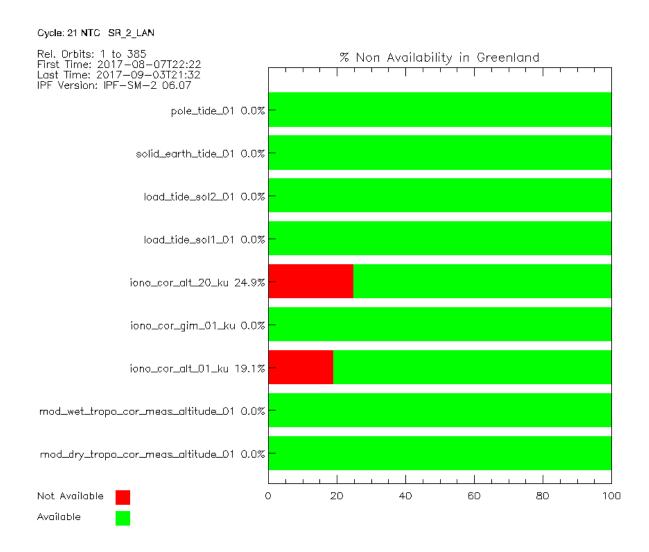


Figure 6: Percentage of Geophysical Correction Non-availability over the Greenland Ice Sheet

5.2 Availability of Geophysical Corrections over Ice Shelves (NTC Products)

For polar ice shelves, the primary geophysical corrections applied to the range are as for ice sheets plus ocean tide and inverse barometric corrections.

For cycle 21 NTC the percentage availability of geophysical corrections over Antarctic ice shelves was:



Cycle: 21 NTC SR_2_LAN

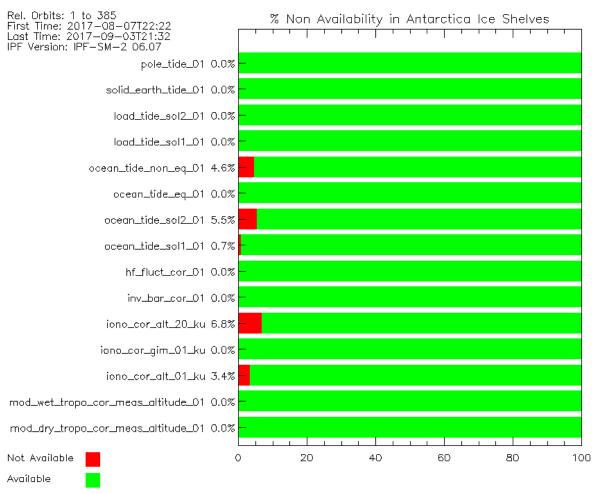
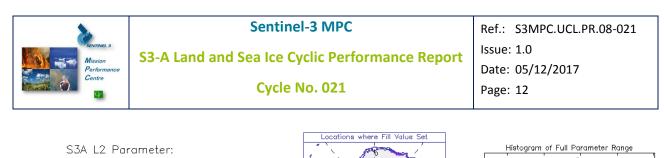


Figure 7: Availability of Geophysical Corrections over Antarctic Ice Shelves

¹For ice shelf studies it is recommended that users replace the ocean tide correction (Ocean Tide Solution 2 in cycle 21) where it is valid in the L2 NTC products over Antarctic ice shelves with a more accurate high resolution circumpolar ocean tide model correction such as the Circum Antarctic Tidal Simulation (CATS 2008a), *Padman et al* (2008).

Note that the % non availability of ocean tide fields shown appear to be predominantly due to use of a different glacier grounding line (GLL) mask in the S3A processing as compared to the reports test mask which uses the Rignot 2016 GLL.



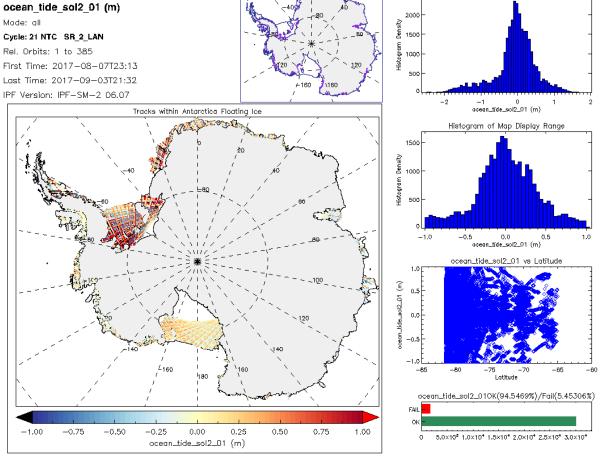


Figure 8: Map of Ocean Tide Correction (sol. 2) over Antarctic ice shelves in cycle 21 NTC

5.3 Availability of Geophysical Corrections over Sea Ice

Over sea ice the model dry tropospheric, model wet tropospheric, ionospheric, solid earth tide, pole tide and ocean tide and inverse barometric corrections are applied in the STC L2 Marine product.

For cycle 21 NTC the percentage availability of geophysical corrections over sea ice was:



Cycle: 21 NTC SR_2_WAT

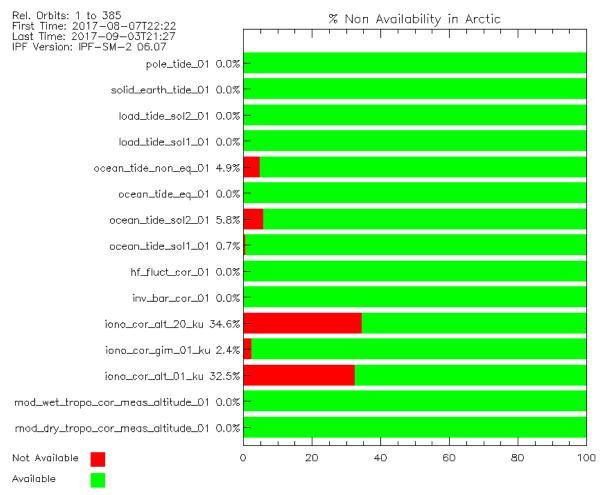


Table 2: % Non Availability of Geophysical Corrections over Sea Ice (NTC)

The Ocean Tide solutions over the Arctic show missing values only very close to the coast:



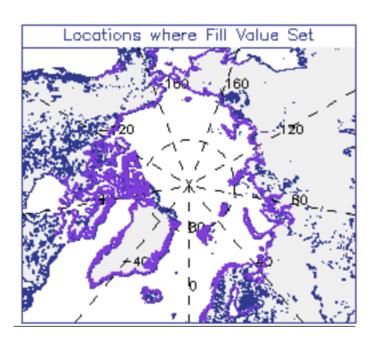


Figure 9: Map of Ocean Tide Correction (sol. 2) Failure Locations over Arctic in cycle 21 NTC

5.4 Availability of Snow Density, Snow Depth and Sea Ice Concentration over Sea Ice

Correction	% Availability Arctic Sea Ice	% Availability Antarctic Sea Ice
Sea Ice Concentration ³	100	100
Snow Density ¹	100	100
Snow Depth	100	100 ²

Table 3: % Availability of Snow Density, Snow Depth, Sea Ice Concentration over Sea Ice

¹Snow Density is set to a single value of 400 Kg/m³ as expected.

² Snow depth over Antarctic sea ice is set to zero as expected.

³Sea Ice Concentration is derived from a dynamic 3 day average of sea ice concentration calculated from SSM/I daily brightness temperature data.



6 Geophysical Parameter Monitoring for Land Ice

This section shows results and analysis of the primary L2 NTC parameters relating to land ice in cycle 21.

6.1 20Hz Ku Band Elevation (elevation_ice_sheet_20_ku)

20Hz Ku band surface elevation is the primary output of the land ice products over continental ice sheets and ice shelves.

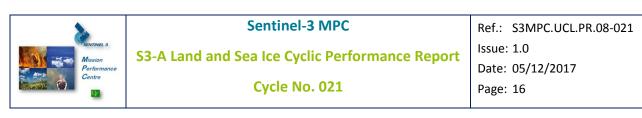
Analysis of this parameter shows that the map of elevation is as expected but there is an unexpectedly high rate of parameter failure over the whole ice area in both Antarctica (32%) and Greenland (43%). This is currently under investigation by the MPC and ESA but it is believed to be due to two main reasons:

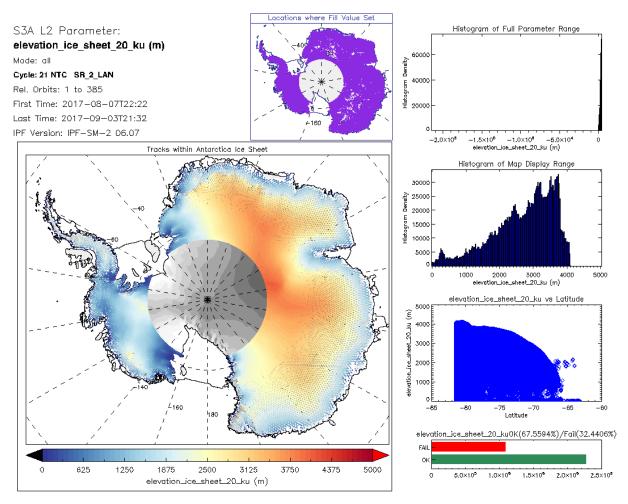
- 1. An issue with the L1 SAR processing over areas of sloping terrain. This affects the stability of the waveform positioning within the range window, particularly in the continental margins. This results in waveforms being located towards the edge of the range window or being truncated.
- 2. A SAR ice margin retracker tuning issue over areas of low slope.

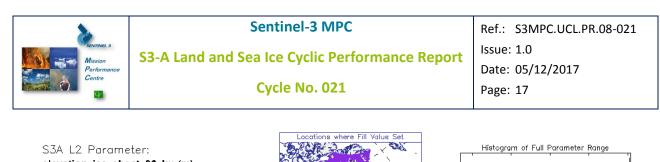
Additionally, tests indicate that an error in the slope correction is present in this version of the IPF processing which will cause a resulting error in the elevation (of 30cm to several meters, dependent on slope) and to the location of the echo.

A small number of anomalous large negative values are also present. This is under investigation by the MPC.

The following maps show the 20Hz Ku band Elevation parameter plotted for the complete cycle.







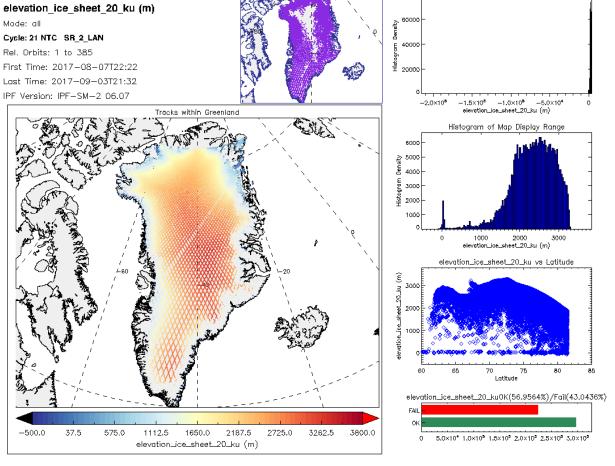


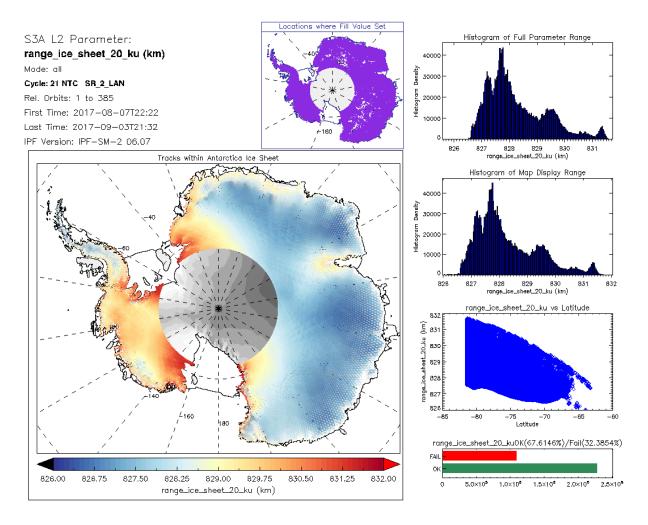
Figure 10: Map of 20Hz Ku band Ice Sheet Elevation over Antarctica and Greenland for cycle 21



6.2 20Hz Ku Band Ice Sheet Range (range_ice_sheet_20_ku)

The ice sheet range is retracked using the SAR ice margin retracker and is the primary range used to calculate elevation in the L2 product.

There are higher than expected rates of failure in this parameter over all ice areas. An explanation of this is given in the preceding section on ice sheet elevation.



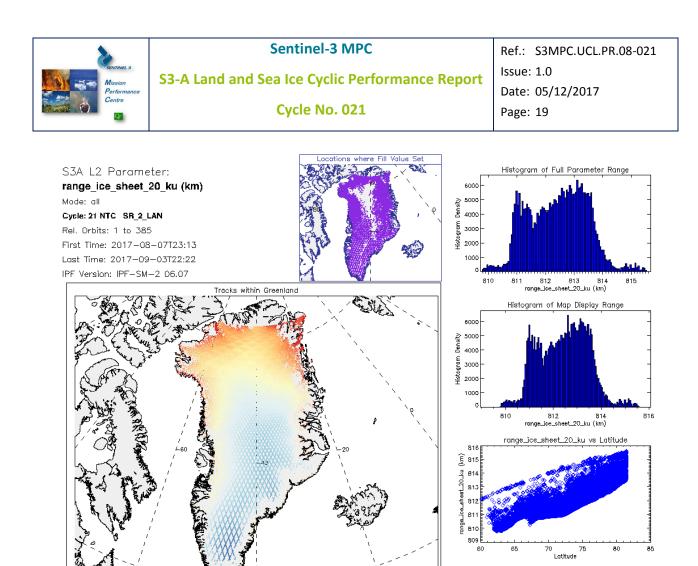


Figure 11: Maps of 20Hz Ku Band Ice Sheet Range (range_ice_sheet_20_ku)

815.1

816.0

814.2

809.0

809.9

810.8

812.5

range_ice_sheet_20_ku (km)

811.6

813.4

range_ice_sheet_20_ku0K(56.8538%)/Fail(43.1462%)

5.0×10* 1.0×10* 1.5×10* 2.0×10* 2.5×10* 3.0×10*

FAIL

0



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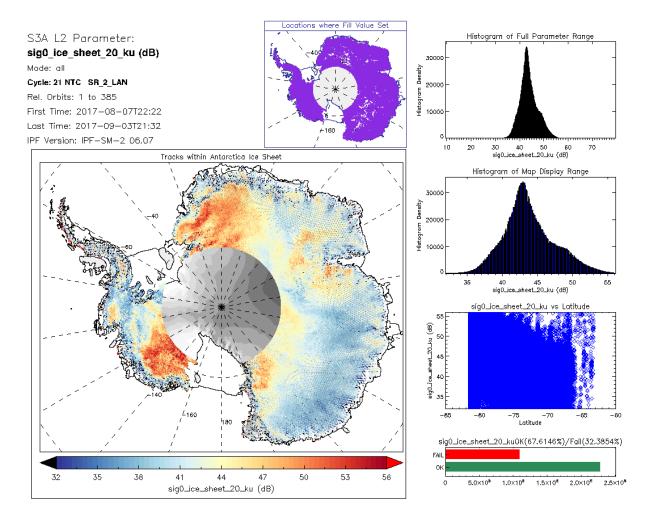
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6.3 20Hz Ku Band Ice Sheet Sigma0 (sig0_ice_sheet_20_ku)

The Ku band ice sheet sigma0 backscatter parameter is derived from the SAR ice margin retracker. The map of sigma0 over the ice sheets shows similar patterns of backscatter values to previous missions. Backscatter values are controlled by surface roughness characteristics, surface slope and differences in surface and volume echo. Over the ice sheet margins backscatter is low due to high surface slope, and over the East Antarctic ice sheet it is also low due to strong winds causing high surface roughness. Over the West Antarctic ice sheet and areas of Dronning Maud land there are high backscatter returns due to very smooth surfaces. In Greenland the ice sheet surface is smoother due to lower winds and regular melt events causing higher backscatter values.

There are higher than expected rates of failure in this parameter over all ice areas. An explanation of this is given in the preceding section on ice sheet elevation.





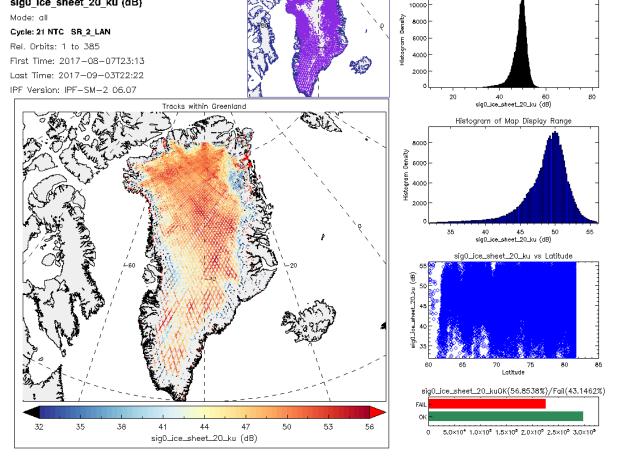


Figure 12: Maps of 20Hz Ku Band Ice Sheet Sigma0 (sig0_ice_sheet_20_ku)



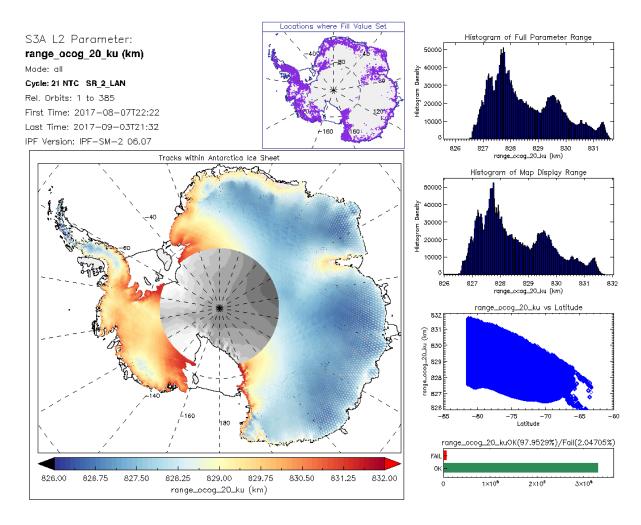
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6.4 20Hz Ku Band OCOG (Ice-1) Range (range_ocog_20_ku)

This parameter is the range derived from the OCOG (Ice-1) retracker. Note that there are much lower failure rates (~2%) than for the SAR ice margin retracker (32%). This is because the OCOG centre of gravity retracking algorithm will retrack a wider range of waveform shapes and leading edge positions than the model fit approach used by the SAR ice margin retracker. This results in greater measurement density, but in some areas lower accuracy.





815

80

5×10⁸

4×10⁵

85

75

ue o Cycle: 21 NTC SR_2_LAN 6000 Rel. Orbits: 1 to 385 First Time: 2017-08-07T23:13 2000 Last Time: 2017-09-03T22:22 IPF Version: IPF-SM-2 06.07 810 811 812 813 814 range_ccog_20_ku (km) Fracks within Greenland Calle -Histogram of Map Display Range 10000 800 Density 6000 4000 2000 810 812 814 range_ccog_20_ku (km) range_ocog_20_ku vs Latítude 816 」16 (長 男) (長) ocog_20_ku 813 812 811 5 5 610 809 60 65 Latitude range_ocog_20_kuOK(96.1911%)/Fail(3.80887%) FAIL Ωk 809.9 813.4 814.2 815.1 816.0 809.0 810.8 811.6 812.5 o 1×10⁸ 2×10⁵ 3×10³ range_ocog_20_ku (km)

Figure 13: Maps of 20Hz Ku Band OCOG (Ice-1) Range (range_ocog_20_ku)

20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku) 6.5

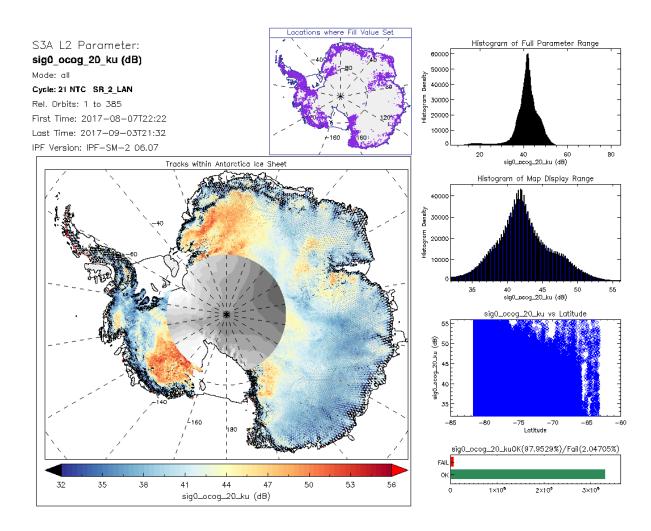
The Ku band OCOG sigma0 backscatter parameter is derived from the OCOG (Ice-1) retracker. The map of sigma0 over the ice sheets shows similar patterns of backscatter values to previous missions. Backscatter values are controlled by surface roughness characteristics, surface slope and differences in surface and volume echo. Over the ice sheet margins backscatter is low due to high surface slope, and over the East Antarctic ice sheet it is also low due to strong winds causing high surface roughness. Over the West Antarctic ice sheet and areas of Dronning Maud land there are high backscatter returns due to very smooth surfaces. In Greenland the ice sheet surface is smoother due to lower winds and regular melt events causing higher backscatter values.

There are higher than expected rates of failure in this parameter over the margins, West Antarctica and the Antarctic Peninsula, but much lower failure rates than for the SAR ice margin retracker. This is because the OCOG centre of gravity retracking algorithm will retrack a wider range of waveform shapes than the model fit approach used by the SAR ice margin retracker. This results in greater measurement density, but in some areas lower accuracy.



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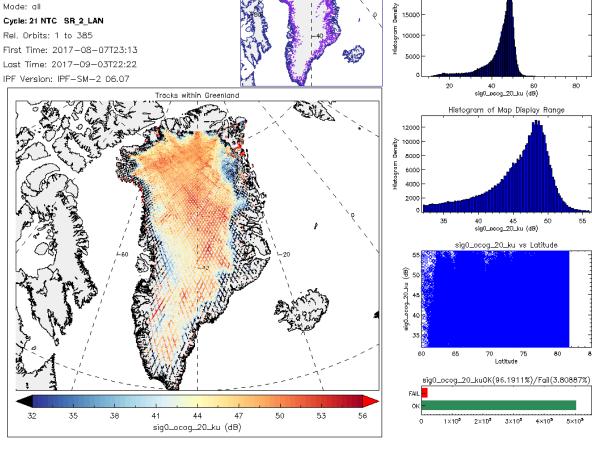


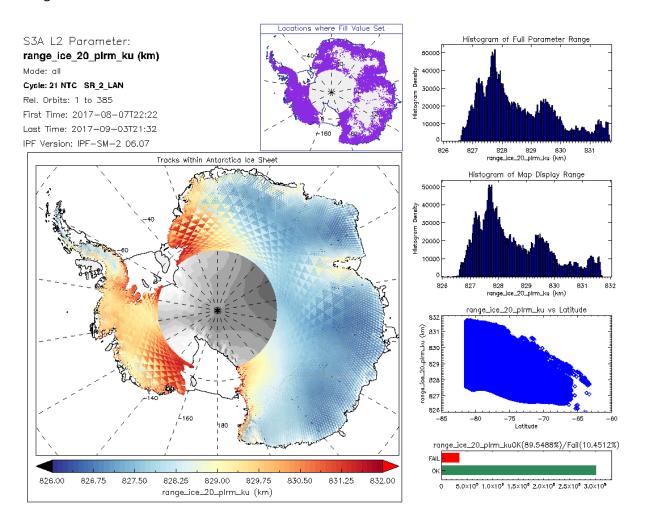
Figure 14: Maps of 20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku)



6.6 20Hz Ku Band PLRM Ice Range (range_ice_20_plrm_ku)

Range measurements derived from the PLRM waveforms and retracker show similar but slightly higher failure rates than for the SAR OCOG retracked range.

There is a strong orbit directional bias in the PLRM range over ice sheet surfaces. This is under investigation.

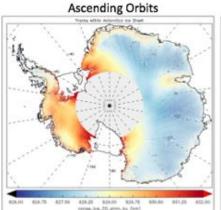


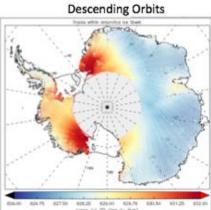


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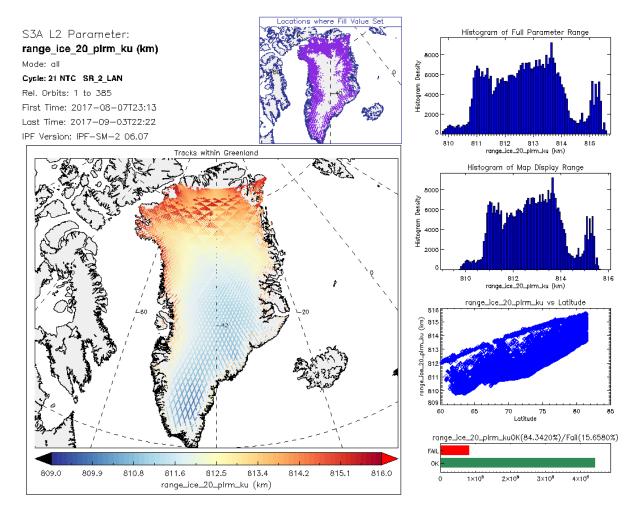
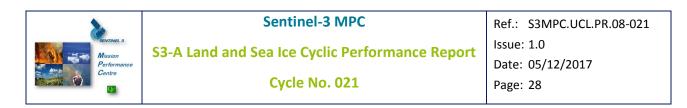


Figure 15: Maps of 20Hz Ku Band PLRM Ice Range (range_ice_20_plrm_ku)

A plot of 20Hz altitude – PLRM range show a similar pattern of directional bias.



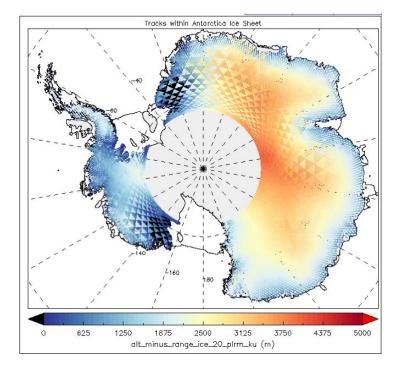
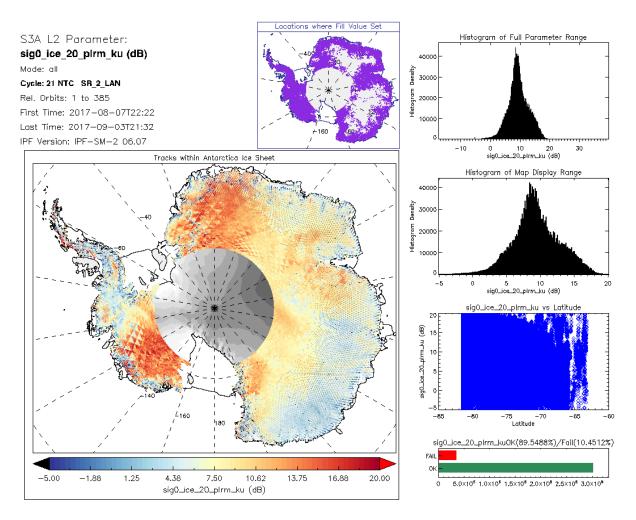


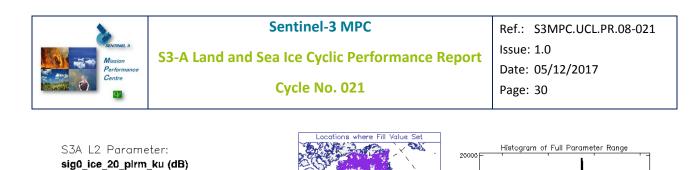
Figure 16: Plot of 20Hz Altitude - PLRM range over Antarctic Ice Sheets



6.7 20Hz Ku Band PLRM Sigma0 (sig0_ice_20_plrm_ku)

Backscatter sigma0 derived from the 20Hz Ku PLRM waveforms are shown below. There is a strong orbit directional bias over the ice sheets as discussed above in the section on PLRM range.





Cycle: 21 NTC SR_2_LAN Rel. Orbits: 1 to 385 First Time: 2017-08-07T23:13 Last Time: 2017-09-03T22:22 IPF Version: IPF-SM-2 06.07 within Greenland

Mode: all

-5.00

-1.88

1,25

4.38

1000 listo 5000 -20 0 20 sig0_ice_20_plrm_ku (dB) Cold Star Histogram of Map Display Range 1500 Density 10000 Histogro 5000 0 5 10 sig0_ice_20_plrm_ku (dB) 15 sig0_ice_20_plrm_ku vs Latitude 20 9 202 60 65 70 75 Latitude 80 85 sig0_ice_20_plrm_ku0K(84.3311%)/Fail(15.6689%) FAII ٥ŀ 7.50 10.62 13.75 16.88 20.00 o 1×10⁵ 2×10⁵ 3×10⁸ 4×10⁵ sig0_ice_20_plrm_ku (dB)

Density 1500

Figure 17: Maps of 20Hz Ku Band PLRM Sigma0 (sig0_ice_20_plrm_ku)

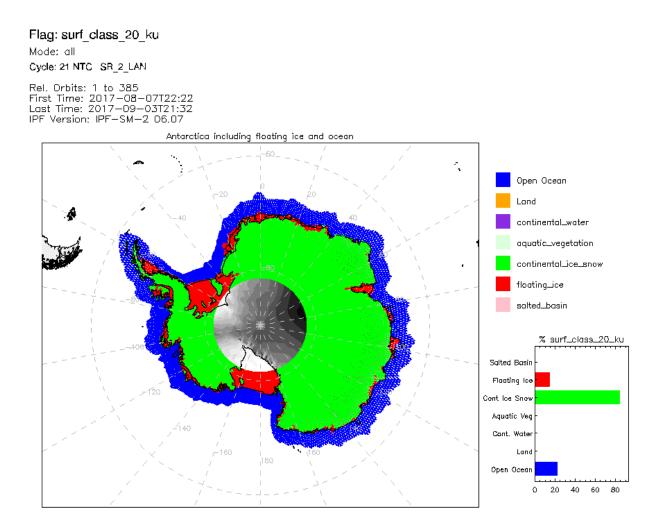


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6.8 20Hz Ku Band Surface Class (surf_class_20_ku)

The 20Hz Ku surface classification parameter is derived from MODIS and GlobCover data. Users of the data requiring high resolution ice sheet glacier grounding line and calving front locations should consider applying their own surface type masks.





Flag: surf_class_20_ku Mode: all Cycle: 21 NTC_SR_2_LAN

Rel. Orbits: 1 to 385 First Time: 2017-08-07T22:22 Last Time: 2017-09-03T21:32 IPF Version: IPF-SM-2 06.07

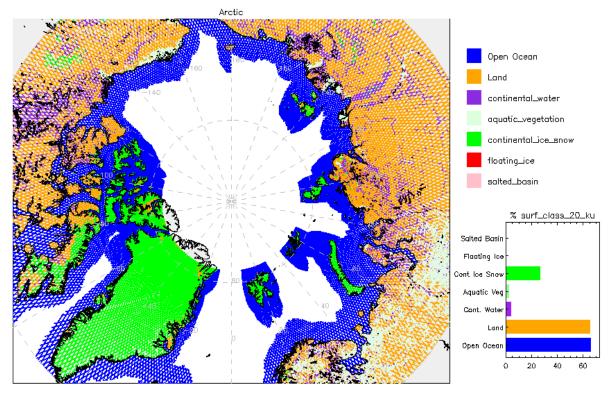


Figure 18: Maps of 20Hz Ku Band Surface Class (surf_class_20_ku)



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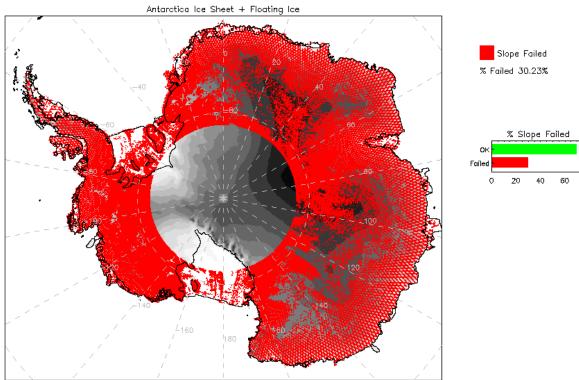
7 Slope Correction Assessment

A slope correction is applied to 20Hz Ku band elevation over ice sheets to relocate the SAR echo to the point of closest approach across track.

In cycle 21, due to the high failure rate of the SAR Ice Margin retracker, the slope correction is not performed on more than 30-42% of range measurements over the ice sheets.

Flag: slope_failure Mode: all Cycle: 21 NTC SR_2_LAN

Rel. Orbits: 1 to 385 First Time: 2017-08-07T22:22 Last Time: 2017-09-03T21:32 IPF Version: IPF-SM-2 06.07





Flag: slope_failure Mode: all Cycle: 21 NTC SR_2_LAN

Rel. Orbits: 1 to 385 First Time: 2017-08-07T23:13 Last Time: 2017-09-03T22:22 IPF Version: IPF-SM-2 06.07

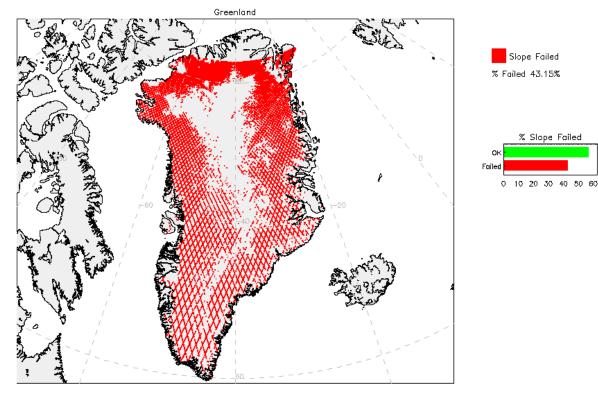


Figure 19: Maps of Slope Correction Failure Locations

Tests of the SAR mode slope correction (of measurements that are retracked) in this cycle indicate that there is an **error in the echo direction calculation in the current IPF processing**. This results in an erroneous relocation down slope of the nadir track. As a result a slope dependent error in the resulting elevation measurement of approximately 30cm to several meters is present. Users are advised to consider this additional error if using the 20Hz elevation parameter over land ice. This slope error should be fixed in the next IPF version.

A full assessment of the slope correction will be added to the report once the failure rate has been reduced.

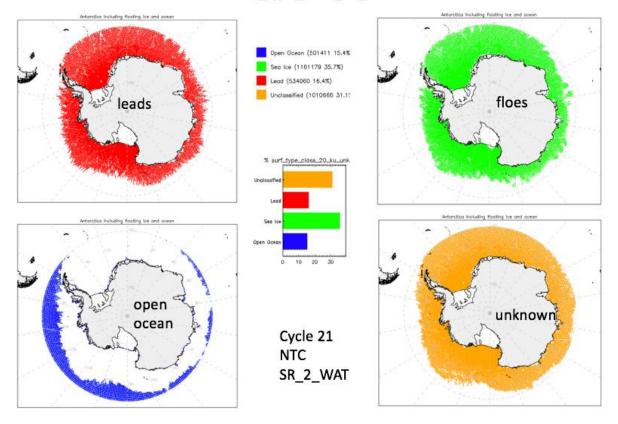


8 Geophysical Parameter Monitoring for Sea Ice

This section shows results and analysis of the primary L2 NTC parameters relating to sea ice in cycle 21.

8.1 20Hz Ku Band Altimeter Derived Surface Type (surf_type_class_20_ku)

This parameter is the output of the sea ice echo discriminator. Whilst the maps of surface type looks reasonable, validation of the data has shown that the discriminator requires some further tuning (with too few leads identified) and that results from this parameter should not be used for this product version of cycle 21.



surf_type_class_20_ku



surf_type_class_20_ku

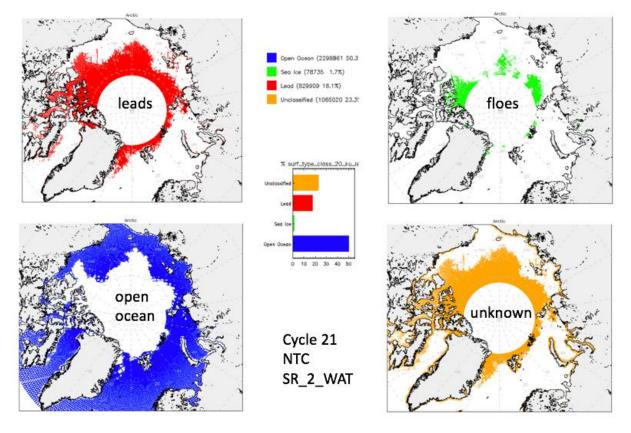
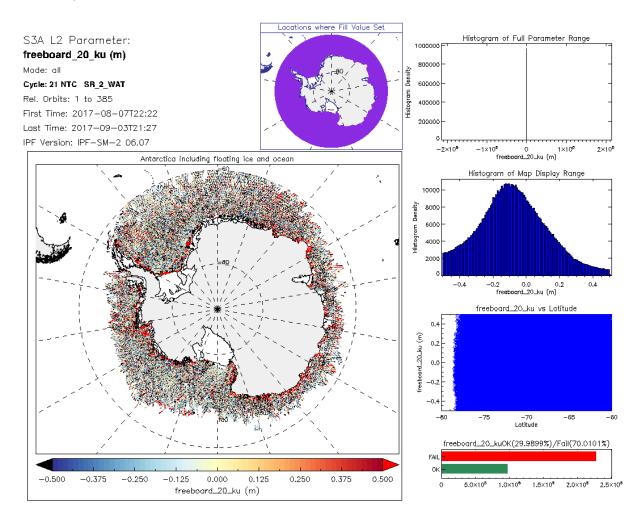


Figure 20: Maps of 20Hz Ku Band Altimeter Derived Surface Type (surf_type_class_20_ku)



8.2 20Hz Ku band Freeboard (freeboard_20_ku)

The histogram of freeboard results from this cycle show a greater proportion of negative freeboard values and a wider spread of freeboard than would be expected. Although negative freeboard is possible due to snow loading, this spread of values is likely to be erroneous. This is most likely to due to incomplete tuning of the surface type discriminator algorithm causing incorrect classification of leads as floes and a possible unresolved sea ice lead and floe retracker bias.





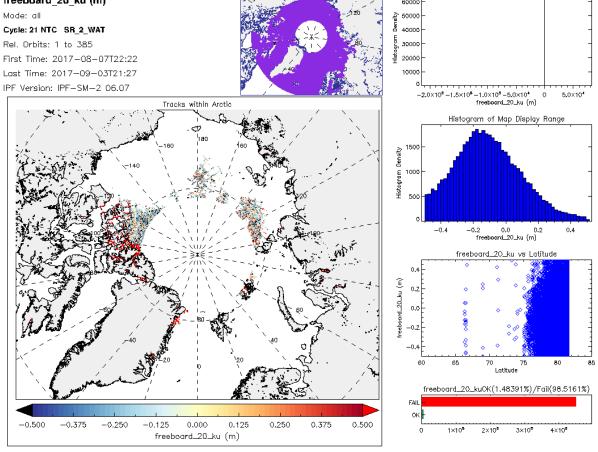


Figure 21: Maps of 20Hz Ku band Freeboard (freeboard_20_ku)



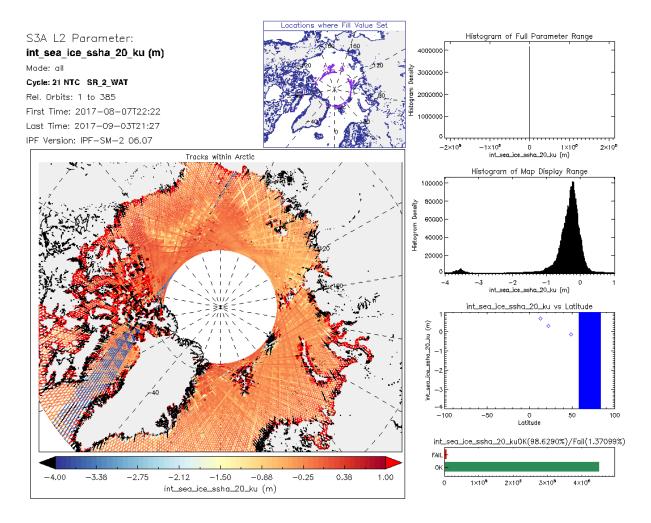
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8.3 20Hz Ku Band Interpolated Sea Surface Height Anomaly (int_sea_ice_ssha_20_ku)

The interpolated sea surface height anomaly is an estimate of the height of the sea surface in the absence of sea ice, interpolated along track between sea ice leads. Note that in this version of the IPF processor there is an error resulting in a -3.27m bias in locations where the GIM ionospheric correction was flagged as missing. This can be seen in the strip to the west of Greenland. Interpolate SSHA in this cycle shows a predominantly negative histogram, an anomaly that is under investigation.



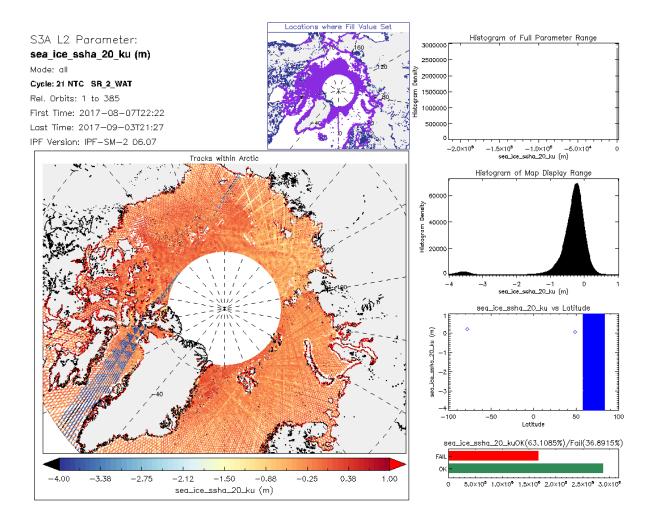


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8.4 Sea Surface Height Anomaly (sea_ice_ssha_20_ku)

The sea surface height anomaly is the height of the sea surface relative to the mean sea surface (MSS). Note that in this version of the IPF processor there is an error resulting in a -3.27m bias in locations where the GIM ionospheric correction was flagged as missing. This can be seen in the strip to the west of Greenland. Interpolate SSHA in this cycle shows a predominantly negative histogram, an anomaly that is under investigation.



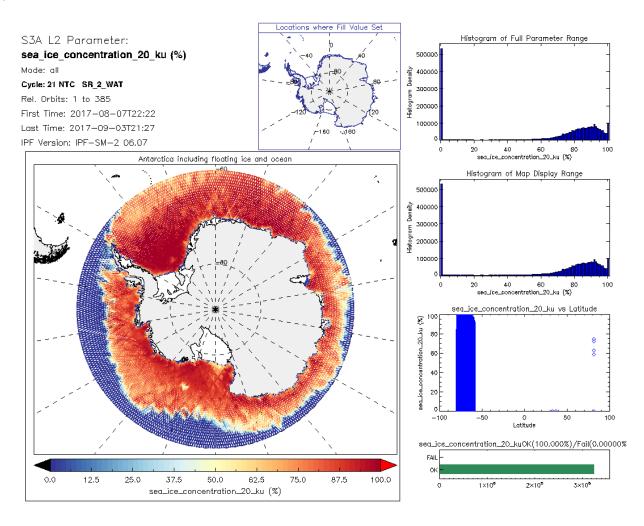


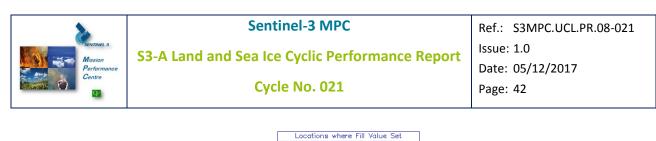
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8.5 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku)

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Sea ice concentration data is available in 100% of records in the NTC product in cycle 21. Sea Ice Concentration is derived from a dynamic 3 day average of sea ice concentration calculated from SSM/I daily brightness temperature data and this map is consistent with external sea ice extent maps for this period.





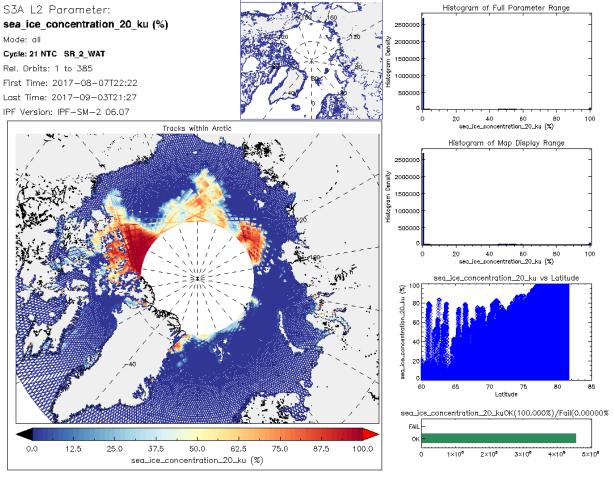


Figure 22: Maps of 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku)



9 Crossover Analysis

Measuring the elevation residual at orbit crossover points is a primary method of assessing the performance of the altimeter and the processing chain. Over time intervals where there is no expected change in the surface elevation, the elevation difference at a crossover provides a measure of altimeter and chain performance, height error and antenna polarity issues.

Due to the reported high failure rates with the 20Hz Ku band Elevation parameter in this cycle, the density of measurements is too low to produce meaningful crossover results that can be compared with previous missions. As soon as the failure rate is reduced to nominal levels then a crossover analysis result will be reported in this section for this cycle.





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10 Repeat Track Analysis

Repeat track analysis is a method of processing several years of operational altimetry data to produce gridded maps of temporal change in the ice sheet's surface elevation and mass balance since the start of mission. These can be validated against known ice sheet dynamics and other external sources of temporal change data.

Since cycle 21 is the 8th cycle since the start of the operational phase there is not a long enough time series of stable measurements to produce a repeat track analysis. This analysis will be added to reports from cycles in 2018 once at least a year of stable data is available.



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11 Long Term Monitoring

In this section the long term performance statistics of Sentinel-3A parameters over land ice and sea ice will be analysed to indicate the stability of the instrument and ground processing. As cycle 21 is the 8th cycle in the routine operations phase, no long term statistics are available for this cycle.



12 Events

List of all events happened during the cycle affecting the Land and Sea Ice validation:

1. There were no changes in IPF versions which affect measurement density or quality for land ice or sea ice products in this cycle.



13 Conclusions

For Level-2 NTC Land products over polar ice sheets, maps of L2 ice sheet elevation and sigma0 backscatter show expected patterns of spatial variability over the ice sheet topography and surface types as compared to previous missions, but there are 32-42% higher than expected levels of retracker and tracker failure in the primary 20Hz Ku band ice sheet elevation and range parameters over all areas (ice sheet interior and margins) resulting in lower than expected measurement density. There is also an error in the slope correction in the current IPF affecting accuracy of the calculated elevation over sloping surfaces. This is currently under investigation by the MPC and ESA.

For Level-2 NTC Marine products, the sea ice freeboard and surface discrimination parameters requires further tuning and we recommend that they are not used in this cycle.



14 Appendix A

Other reports related to the STM mission are:

- S3-A SRAL Cyclic Performance Report, Cycle No. 021 (ref. S3MPC.ISR.PR.04-021)
- S3-A MWR Cyclic Performance Report, Cycle No. 021 (ref. S3MPC.CLS.PR.05-021)
- S3-A Ocean Validation Cyclic Performance Report, Cycle No. 021 (ref. S3MPC.CLS.PR.06-021)
- S3-A Land and Sea Ice Cyclic Performance Report, Cycle No. 021 (ref. S3MPC.UCL.PR.08-021)

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

End of document