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

S3 Land and Sea Ice Cyclic Performance Report				
S3-A S3-B				
Cycle No. 060	Cycle No. 041			
Start date: 25/06/2020	Start date: 05/07/2020			
End date: 22/07/2020	End date: 01/08/2020			



Customer:	ESA	Document Ref.:	S3MPC.UCL.PR.08-060-041
Contract No.:	4000111836/14/I-LG	Date:	07/09/2020
		Issue:	1.0

Project:	PREPARATION AND OPERATIONS OF THE MISSION PERFORMANCE CENTRE (MPC) FOR THE COPERNICUS SENTINEL-3 MISSION				
Title:	S3 Land and Sea Ice Cyclic Perfe	ormance Report			
Author(s):	Land and Sea Ice ESLs				
Approved by:	G. Quartly, STM ESL Coordinator				
Distribution:	ESA, EUMETSAT, S3MPC consortium				
Accepted by ESA	P. Féménias, MPC TO				
Filename	S3MPC_LandSealce-CyclicReport-060-041.doc				





Changes Log

Version	Date	Changes
1.0	07/09/2020	First Version

List of Changes

Version	Section	Answers to RID	Changes



Table of content

1	INTE	IRODUCTION			
2	CYC	LE OVERVIEW	8		
	2.1	Sentinel-3A	8		
	2.2	Sentinel-3B	8		
3	PRO	CESSING BASELINES	9		
4	DAT	A AVAILABILITY & INSTRUMENT MODES	11		
	4.1	Data Availability	11		
	4.2	SRAL INSTRUMENT MODE	12		
5	AVA	ILABILITY OF POLAR GEOPHYSICAL CORRECTIONS	16		
	5.1	AVAILABILITY OF GEOPHYSICAL CORRECTIONS OVER ICE SHEETS (NTC PRODUCTS)	16		
	5.2	AVAILABILITY OF GEOPHYSICAL CORRECTIONS OVER ICE SHELVES (NTC PRODUCTS)	18		
	5.3	AVAILABILITY OF GEOPHYSICAL CORRECTIONS OVER SEA ICE	18		
	5.4	Availability of Snow Density, Snow Depth and Sea Ice Concentration over Sea Ice	20		
6	GEO	PHYSICAL PARAMETER MONITORING FOR LAND ICE	21		
	6.1	20Hz Ku Band Elevation (elevation_ice_sheet_20_ku)	21		
	6.2	20Hz Ku Band Ice Sheet Range (range_ice_sheet_20_ku)	24		
	6.3	20Hz Ku Band Ice Sheet Sigma0 (sig0_ice_sheet_20_ku)	26		
	6.4	20Hz Ku Band OCOG (Ice-1) Elevation (elevation_ocog_20_ku)	27		
	6.5	20Hz Ku Band OCOG (Ice-1) Range (range_ocog_20_ku)	30		
	6.6	20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku)	32		
	6.7	BAND WAVEFORM QUALITY FLAG (WAVEFORM_QUAL_ICE_20_KU)	34		
	6.8	PLRM ICE RANGE (RANGE_ICE_20_PLRM_KU)	39		
	6.9	20Hz Ku Band PLRM Sigma0 (sig0_ice_20_plrm_ku)	41		
	6.10	20Hz Ku Band Surface Class (surf_class_20_ku)	42		
7	SLO	PE CORRECTION	43		
8	GEO	PHYSICAL PARAMETER MONITORING FOR SEA ICE	46		
	8.1	20Hz Ku Band Altimeter Derived Surface Type (surf_type_class_20_ku)	46		
	8.2	20Hz Ku band Freeboard (freeboard_20_ku)	50		
	8.3	20Hz Ku Band Interpolated Sea Surface Height Anomaly (Int_sea_ice_ssha_20_ku)	52		
	8.4	Sea Surface Height Anomaly (sea_ice_ssha_20_ku)	55		
	8.5	20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku)	57		



	8.6	20Hz Ku band Peakiness (peakiness_2_20_ku)	59
9	CRO	SSOVER ANALYSIS	61
10	E١	VENTS AND PROCESSING BASELINE CHANGES	63
11	С	ONCLUSIONS	66
12	A	PPENDIX A	67



List of Figures

Figure 1: Map of SRAL mode over Antarctic ice sheets 1	12
Figure 2: Map of SRAL mode over Greenland ice sheet1	L3
Figure 3: Map of SRAL mode over the Antarctic sea ice1	L4
Figure 4: Map of SRAL mode over the Arctic sea ice 1	۱5
Figure 5: Percentage of Geophysical Correction Non-availability over Antarctic Ice Sheets 1	16
Figure 6: Percentage of Geophysical Correction Non-availability over the Greenland Ice Sheet 1	L7
Figure 7: Availability of Geophysical Corrections over Antarctic Ice Shelves 1	18
Figure 8: % Non Availability of Geophysical Corrections over Sea Ice (NTC) 1	19
Figure 9: Map of elevation_ice_sheet_20_ku over Antarctica and Gridded Parameter Failure 2	22
Figure 10: Map of 20Hz Ku band Ice Sheet Elevation over Greenland and Gridded % Parameter Failure 2	23
Figure 11: Map of range_ice_sheet_20_ku over Antarctica and % Gridded Parameter Failure Rate 2	24
Figure 12: Maps of 20Hz Ku Band Ice Sheet Range (range_ice_sheet_20_ku) over Greenland and Gridde Parameter % Failure Rates 2	
Figure 13: Maps of 20Hz Ku Band Ice Sheet Sigma0 (sig0_ice_sheet_20_ku) 2	27
Figure 14: Map of elevation_ocog_20_ku over Antarctica and % Gridded Parameter Failure Rates 2	28
Figure 15: Map of elevation_ocog_20_ku over Greenland and % Gridded Parameter Failure Rates 2	29
Figure 16: Map of range_ocog_20_ku over Antarctica and % Gridded Parameter Failure 3	30
Figure 17: Map of range_ocog_20_ku over Greenland and % Gridded Parameter Failure 3	31
Figure 18: Map of 20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku) over Antarctica 3	32
Figure 19: Map of 20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku) over Greenland 3	33
Figure 20: Map of Waveform Quality Flag over Antarctica (all tests) 3	35
Figure 21: Maps of Waveform Quality Flag over Greenland (all tests) 3	35
Figure 22: Map of Waveform Quality Flag over Antarctica (T1 power) 3	36
Figure 23: Map of Waveform Quality Flag over Antarctica (T2 noise)	36
Figure 24: Map of Waveform Quality Flag over Antarctica (T3 variance)3	37
Figure 25: Map of Waveform Quality Flag over Antarctica (T4 leading edge test)	37
Figure 26: Map of Waveform Quality Flag over Antarctica (T5 peakiness low) 3	38
Figure 27: Map of Waveform Quality Flag over Antarctica (T6 peakiness high) 3	38
Figure 28: Map of range_ice_20_plrm_ku over Antarctica and % Gridded Parameter Failure 3	39



Figure 29: Map of range_ice_20_plrm_ku over Greenland and % Gridded Parameter Failure	40
Figure 30: Maps of 20Hz Ku Band PLRM Sigma0 (sig0_ice_20_plrm_ku)	41
Figure 31: Maps of 20Hz Ku Band Surface Class (surf_class_20_ku)	42
Figure 32: Maps of Slope Correction Failure Locations over Antarctica	44
Figure 33: Maps of the Failure of the lat_cor_20_c Parameter over Antarctica	45
Figure 34: Maps of surf_type_class_20_ku classes over the Arctic	47
Figure 35: Maps of surf_type_class_20_ku classes over the Antarctic	49
Figure 36: Map of Freeboard (freeboard_20_ku) and Gridded Parameter Failure over Antarctica	51
Figure 37: Map of Freeboard (freeboard_20_ku) and Gridded Parameter Failure over the Arctic	51
Figure 38: Map of Interpolated Sea Ice SSHA (int_sea_ice_ssha_20_ku) and Gridded Parameter Fai over Antarctica	
Figure 39: Map of Interpolated Sea Ice SSHA (int_sea_ice_ssha_20_ku) and Gridded Parameter Fai over the Arctic	
Figure 40: Maps of sea_ice_ssha_20_ku and Gridded Parameter Failure over the Antarctic	55
Figure 41: Maps of sea_ice_ssha_20_ku and Gridded Parameter Failure over the Arctic	56
Figure 42: Maps of 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku) over the Anta Ocean	
Figure 43: Maps of 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku) over Arctic	
Figure 44: Maps of 20Hz Ku band Peakiness (peakiness_2_20_ku) over the Antarctic	59
Figure 45: Maps of 20Hz Ku band Peakiness (peakiness_2_20_ku) over the Arctic	60
Figure 46: Maps of Crossover Difference of OCOG Elevation over Antarctica	61
Figure 47: Maps of Crossover Difference of Ice Sheet Elevation over Antarctica	62



List of Tables

Table 1: Data Availability for NTC	11
Table 2: % Availability of Snow Density, Snow Depth, Sea Ice Concentration over Sea Ice	20



1 Introduction

This document provides a report of the performance and data quality of the Sentinel-3A and Sentinel-3B 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 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 assessment.
- 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 060, from 25/06/2020 to 22/07/2020.
- To present the major useful results for S3B cycle 041, from 05/07/2020 to 01/08/2020.

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



2 Cycle Overview

2.1 Sentinel-3A

This is 27-day cycle 060 (25/06/2020 to 22/07/2020).

Sentinel-3A was launched on 16-February-2016 and entered its routine operational phase in cycle 12 (07-December-2016) following commissioning.

During this cycle 060, Sentinel-3A SRAL operated in SAR mode over land ice and sea ice surfaces.

2.2 Sentinel-3B

This is 27-day cycle 041 (05/07/2020 to 01/08/2020).

Sentinel-3B was launched on 25-April-2018 and entered its routine operational phase in cycle 19 (11-December-2018) following commissioning.

During this cycle 041, Sentinel-3B SRAL operated in SAR mode over land ice and sea ice surfaces.



3 Processing Baselines

A new IPF PB was deployed on 9th July 2020:

- PB2.66 for S3A
- PB1.33 for S3B

The level-2 IPF upgrades to version 06.19, SRAL level-1 to version 06.19

The versions of the Level-1 and Level-2 Instrument Processing Facility software and Product Baseline used to compute the altimeter parameters for the L2 Land (SR_2-LAN) NTC dataset were:

SR_2_LAN NTC				
S3A Cycle	S3B Cycle	Processing Baseline	L2 IPF Versions	L1 IPF Versions
060	041	PB 2.66	SM2 6.19	SR1 6.19

The versions of the Level-1 and Level-2 Instrument Processing Facility software and Product Baseline were used to compute the altimeter parameters for the L2 Marine (SR_2-WAT) NTC dataset were:.

SR_2_WAT NTC				
S3A Cycle	S3B Cycle	Processing Baseline	L2 IPF Versions	L1 IPF Versions
060	041	PB 2.66	SM2 6.19	SR1 6.19

A major change in this baseline is a new land/sea mask ADF

S3___SR_2_MLM_AX_20160216T000000_20991231T235959_20200512T120000____ __MPC_0_AL_004.SEN3

which means all sea ice is covered by the LAN product where it was previously masked to within 100km of land.

2	Sentinel-3 MPC	Ref.: S3MPC.UCL.PR.08-060-041
SENTINEL 3	S3 Land and Sea Ice Cyclic Performance Report	Issue: 1.0
Performance Centre	S3A Cycle No. 060 – S3B Cycle No. 041	Page: 10
		Date: 07/09/2020

In this report, plots of LAN products will appear with parameters masked to within 100km of land in the first part of the cycle (up to the baseline change) and plotted over the full sea ice extent in the last part of the cycle.



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:

Cycle	Product Type	Latency	% Orbits Received
S3A 060	SR_2_LAN	NTC	100%
S3A 060	SR_2_WAT	NTC	100%
S3B 041	SR_2_LAN	NTC	100%
S3B 041	SR_2_WAT	NTC	100%

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 instruments on S3A and S3B 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.

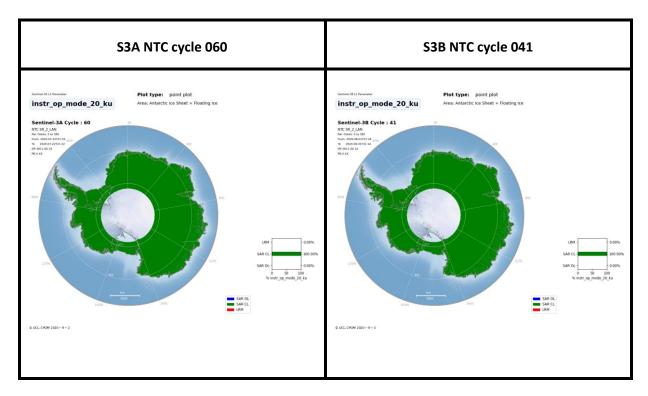


Figure 1: Map of SRAL mode over Antarctic ice sheets



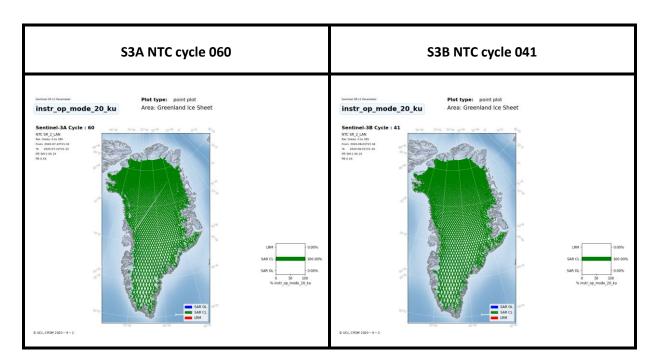


Figure 2: Map of SRAL mode over Greenland ice sheet

2	Sentinel-3 MPC	Ref.: S3MPC.UCL.PR.08-060-041
SENTINEL 3 Mission	S3 Land and Sea Ice Cyclic Performance Report	Issue: 1.0
Performance Centre	S3A Cycle No. 060 – S3B Cycle No. 041	Page: 14
		Date: 07/09/2020

For sea ice and ocean surfaces the S3A and S3B SRAL instruments operated in SAR open loop mode. 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.

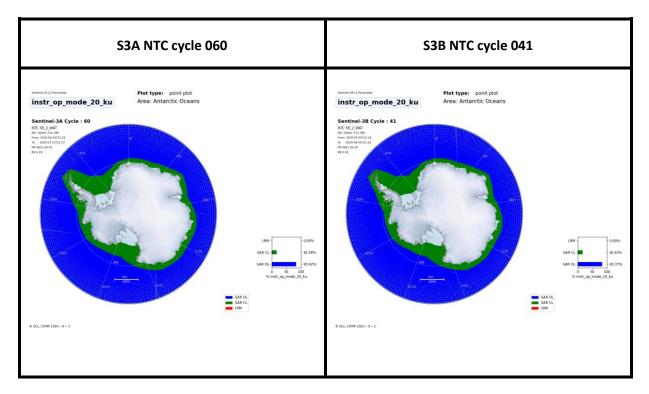
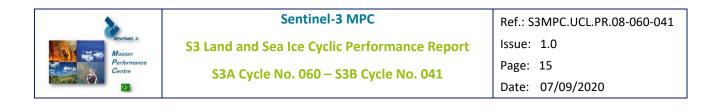


Figure 3: Map of SRAL mode over the Antarctic sea ice



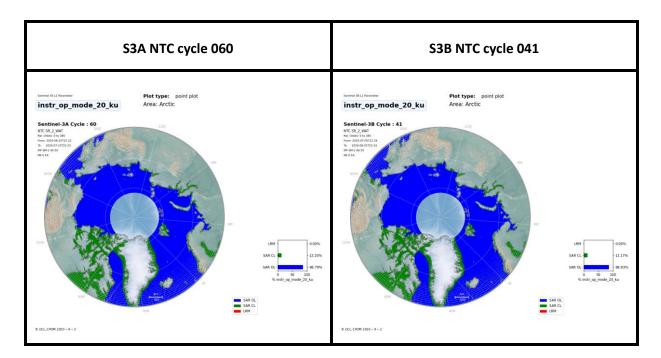


Figure 4: Map of SRAL mode over the Arctic sea ice



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.

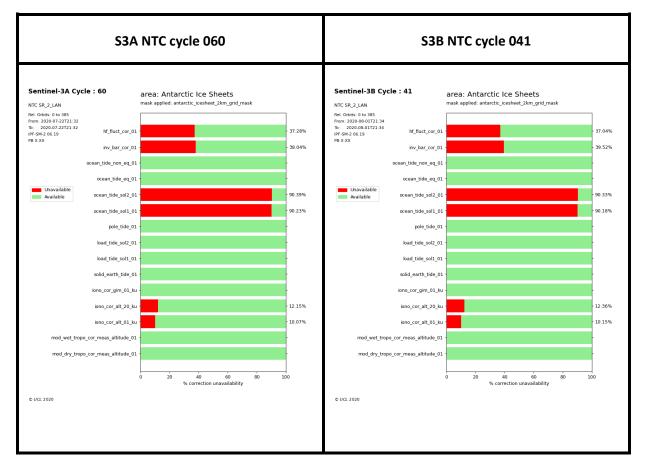


Figure 5: Percentage of Geophysical Correction Non-availability over Antarctic Ice Sheets





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.

The percentage availability of geophysical corrections over Antarctic ice shelves was:

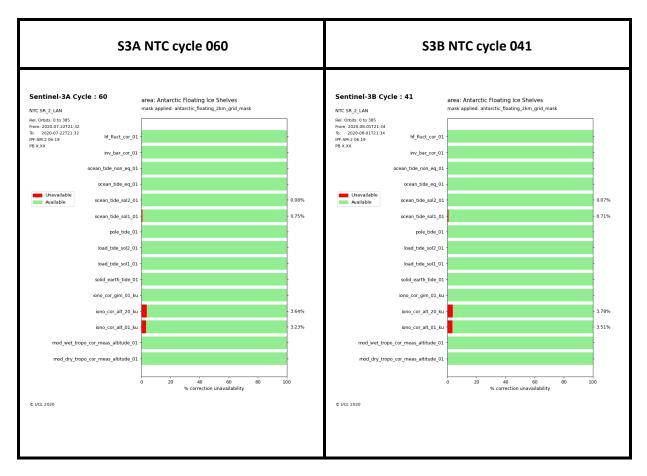
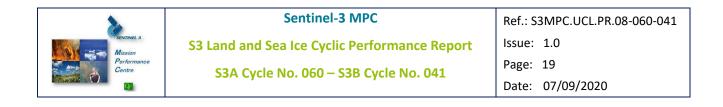


Figure 7: Availability of Geophysical Corrections over Antarctic Ice Shelves

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 NTC L2 Marine product.



The percentage availability of geophysical corrections over sea ice was:



Figure 8: % Non Availability of Geophysical Corrections over Sea Ice (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		
	S3A	S3B	S3A	S3B	
Sea Ice Concentration ³	97.1	97.1	99.7	99.3	
Snow Density ¹	100	100	100	100	
Snow Depth	100	100	100 ²	100 ²	

Table 2: % 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.

In the new baseline there is a change to the sea ice concentration parameter via a new format Sea Ice Concentration ADF.



6 Geophysical Parameter Monitoring for Land Ice

This section shows results and analysis of the primary L2 NTC parameters relating to land ice in S3A cycle 060 and S3B 041.

6.1 **20Hz Ku Band Elevation (elevation_ice_sheet_20_ku)**

20Hz Ku band ice sheet elevation is the primary output of the land ice products over continental ice sheets and ice shelves, processed using a physical ice sheet retracker. Note that in this product baseline a second elevation parameter is also now available processed using an empirical OCOG retracker. The method of OCOG retracking is less sensitive to noise and complex waveform shapes and hence has lower failure rates.

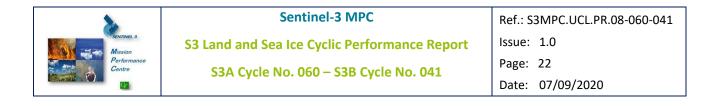
Analysis of the elevation_ice_sheet_20_ku parameter shows that the map of elevation is as expected but there is a higher rate of parameter failure than would be expected over the Antarctica (20%) and Greenland (28%) ice sheets. Failure is predominantly over the ice sheet margins, in areas of high slope (> 0.3 degrees), where failure of 40-50% of measurements is common.

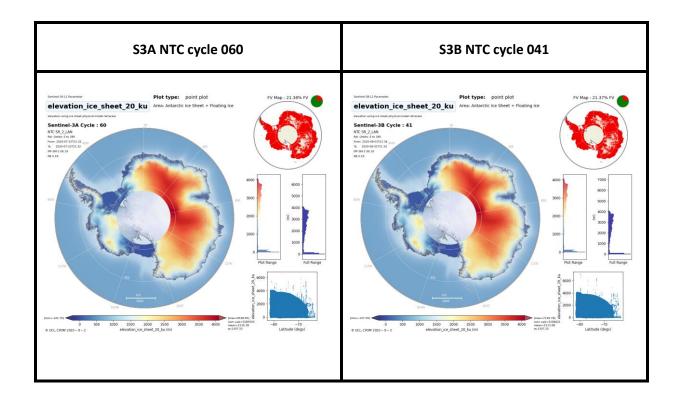
The high failure rate over the margins is caused by

- an issue with the L1 SAR processing (L1 IPF 6.14) 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, outside the ice margin retracker's central fit window, or being truncated. The ice margin retracker has been tuned to reduce such failure rates since IPF 6.10 after which there was a 10% reduction in parameter failure.
- complex SAR waveform shapes (including multi-peaked waveforms) in the margins cause a low goodness of fit to the physical model used in the ice sheet retracker, resulting in retracker failure. Further tuning of the retracker model is planned in the future.

There is a very small increase in failure rate of ~ 2% since IPF 6.15 which is being investigated.

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





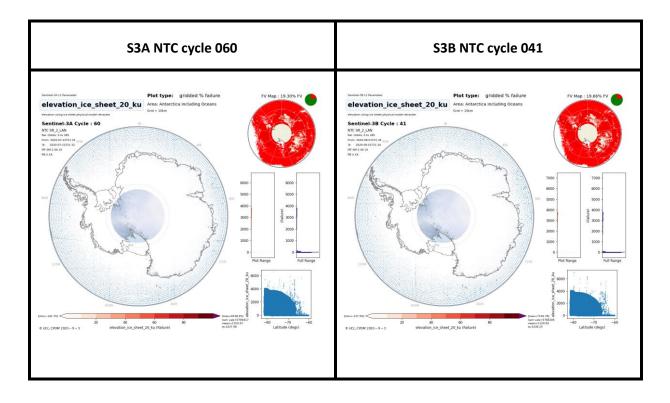


Figure 9: Map of elevation_ice_sheet_20_ku over Antarctica and Gridded Parameter Failure

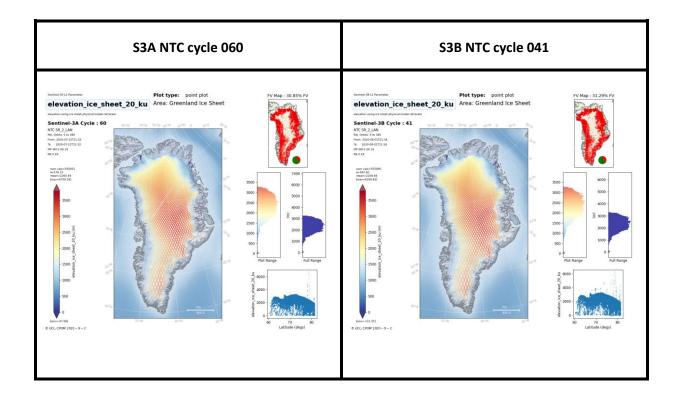


Sentinel-3 MPC

S3A Cycle No. 060 – S3B Cycle No. 041

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 23

Date: 07/09/2020



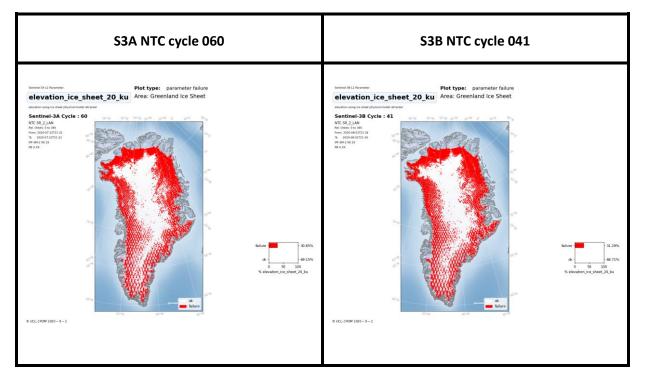


Figure 10: Map of 20Hz Ku band Ice Sheet Elevation over Greenland and Gridded % Parameter Failure



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.

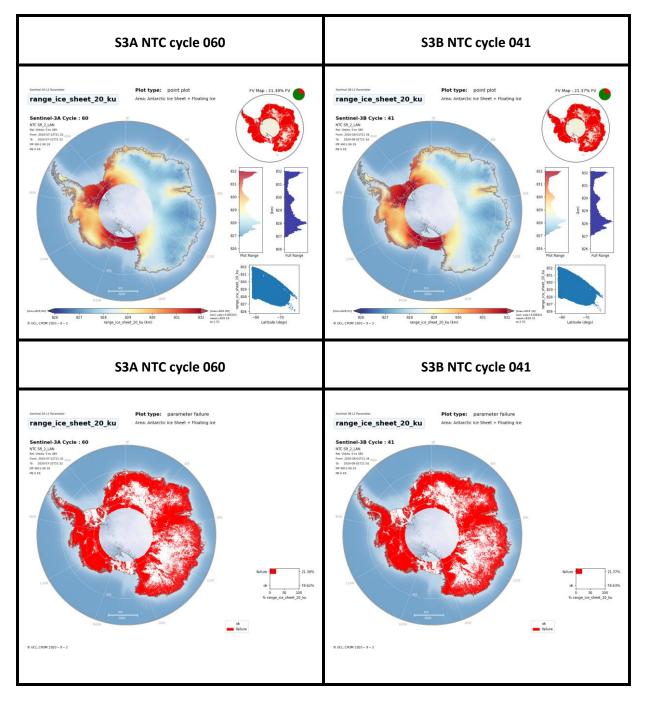


Figure 11: Map of range_ice_sheet_20_ku over Antarctica and % Gridded Parameter Failure Rate



Sentinel-3 MPC S3 Land and Sea Ice Cyclic Performance Report

S3A Cycle No. 060 – S3B Cycle No. 041

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 25 Date: 07/09/2020

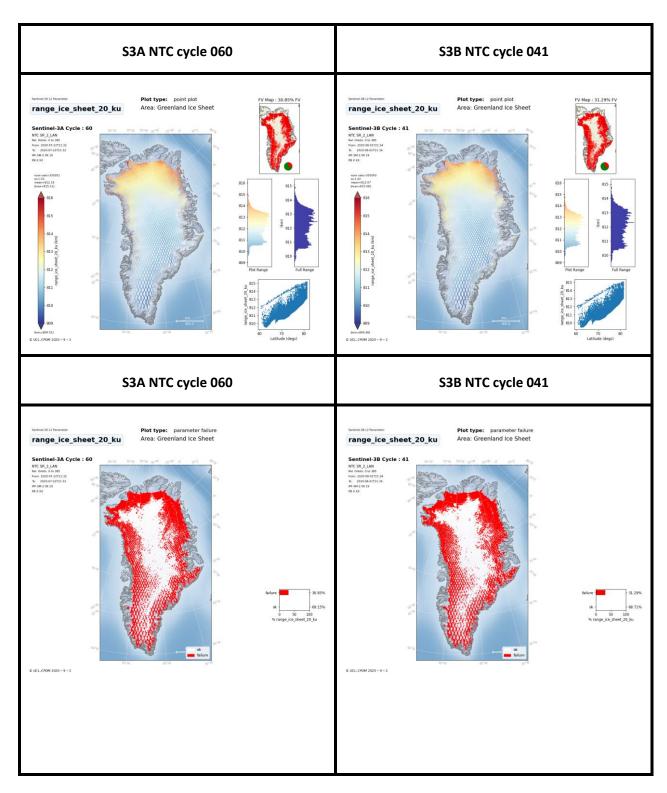


Figure 12: Maps of 20Hz Ku Band Ice Sheet Range (range_ice_sheet_20_ku) over Greenland and Gridded Parameter % Failure Rates

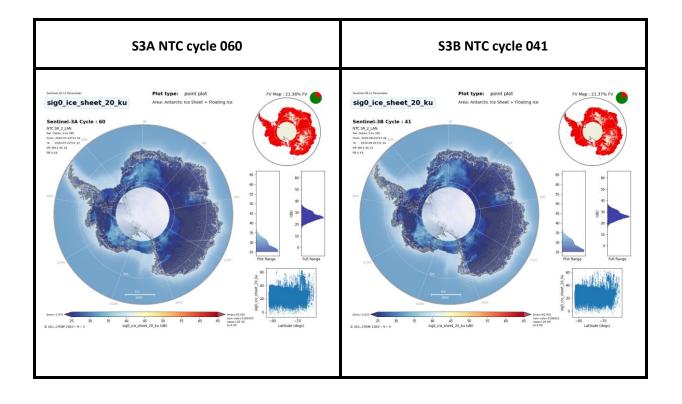


6.3 20Hz Ku Band Ice Sheet Sigma0 (sig0_ice_sheet_20_ku)

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.

The change seen in the sigma0 backscatter parameter since S3A cycle 53 is a result of the IPF upgrade: sigma0 derived from ocog and ice is \sim 18dB lower.

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.



>	Sentinel-3 MPC	Ref.: S3MPC.UCL.PR.08-060-041
SENTINEL 3	S3 Land and Sea Ice Cyclic Performance Report	Issue: 1.0
Performance Centre	S3A Cycle No. 060 – S3B Cycle No. 041	Page: 27
		Date: 07/09/2020

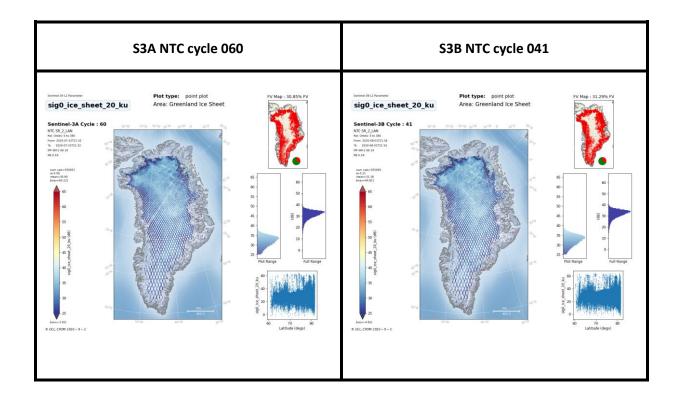


Figure 13: Maps of 20Hz Ku Band Ice Sheet Sigma0 (sig0_ice_sheet_20_ku)

For maps of % gridded parameter failure rates see range_ice_sheet_20_ku

6.4 20Hz Ku Band OCOG (Ice-1) Elevation (elevation_ocog_20_ku)

This parameter is the elevation derived from the OCOG (Ice-1) retracker. Note that there are much lower failure rates (~2%) than for the SAR ice sheet retracked elevation (~20%). This is because the OCOG centre of gravity retracking algorithm will retrack a wider range of waveform shapes and leading edge positions than the physical model fit approach used by the SAR ice margin retracker. This results in greater measurement density, but in some areas lower accuracy.

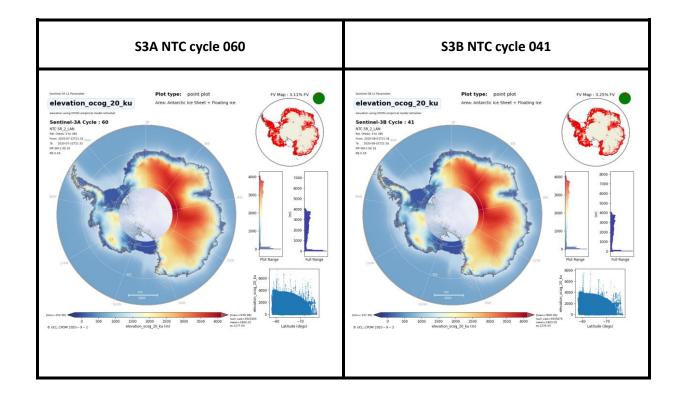


Sentinel-3 MPC

S3 Land and Sea Ice Cyclic Performance Report

S3A Cycle No. 060 – S3B Cycle No. 041

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 28 Date: 07/09/2020



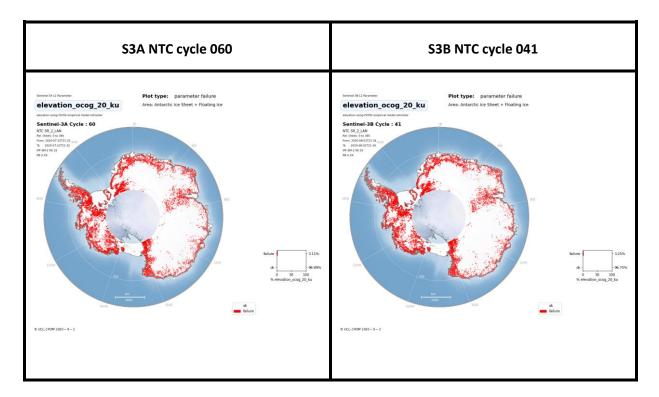


Figure 14: Map of elevation_ocog_20_ku over Antarctica and % Gridded Parameter Failure Rates

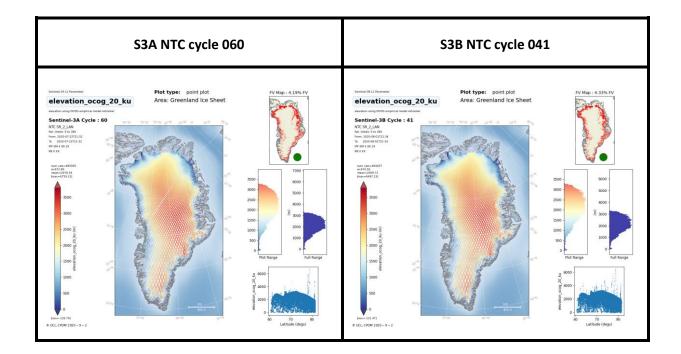


Sentinel-3 MPC

S3A Cycle No. 060 – S3B Cycle No. 041

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 29

Date: 07/09/2020



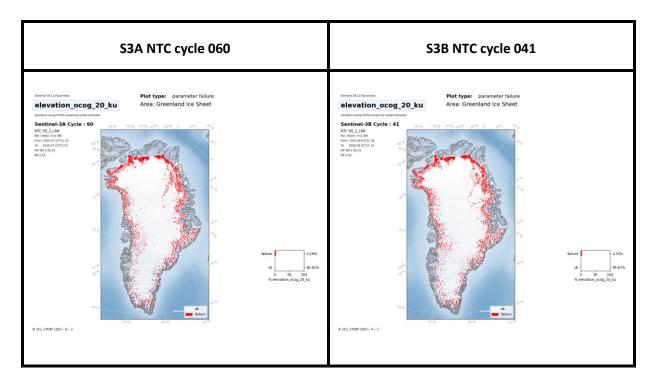


Figure 15: Map of elevation_ocog_20_ku over Greenland and % Gridded Parameter Failure Rates



6.5 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 (\sim 2%) than for the SAR ice margin retracker (\sim 20%) as explained in the section on elevation_ocog_20_ku.

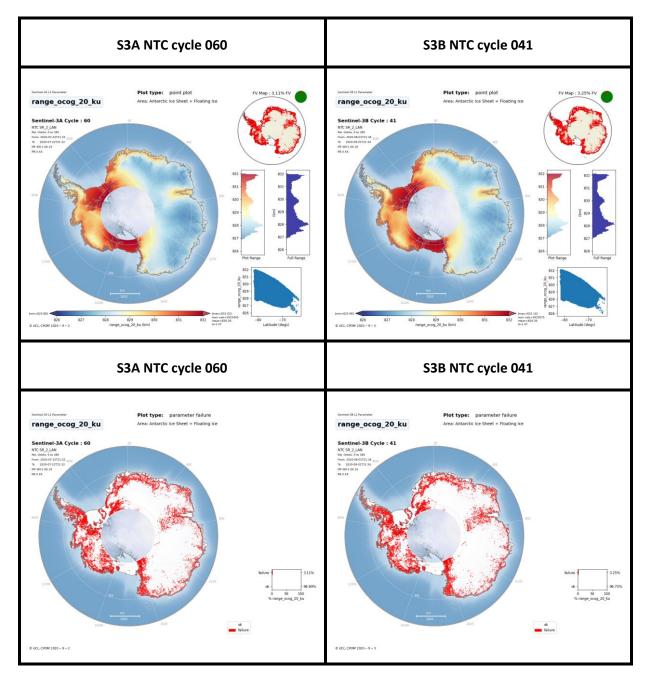
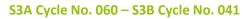


Figure 16: Map of range_ocog_20_ku over Antarctica and % Gridded Parameter Failure



Sentinel-3 MPC S3 Land and Sea Ice Cyclic Performance Report

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 31 Date: 07/09/2020



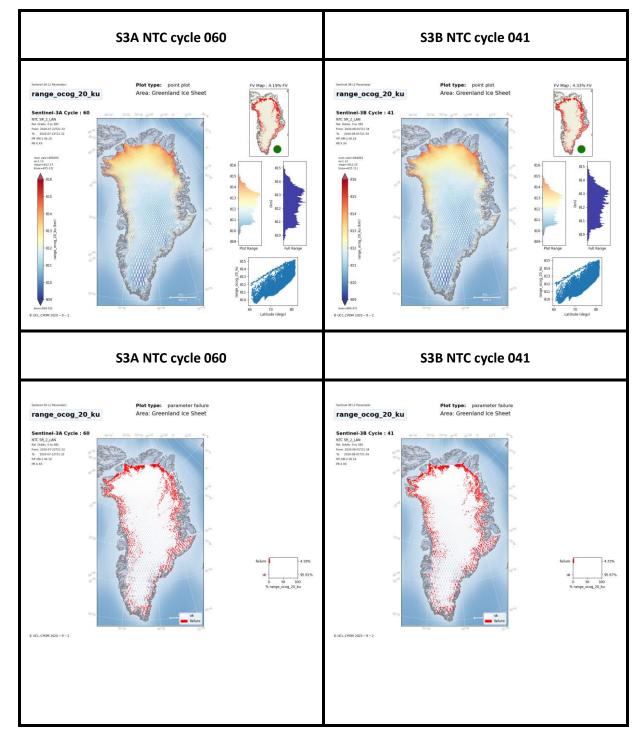


Figure 17: Map of range_ocog_20_ku over Greenland and % Gridded Parameter Failure



6.6 **20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku)**

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.

The change seen in the sigma0 backscatter parameter since S3A cycle 53 is a result of the IPF upgrade: sigma0 derived from ocog and ice is \sim 18dB lower.

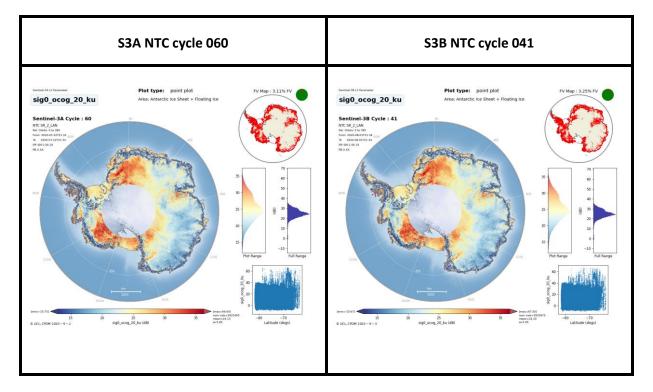


Figure 18: Map of 20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku) over Antarctica

>	Sentinel-3 MPC	Ref.: S3MPC.UCL.PR.08-060-041
SENTINEL 3	S3 Land and Sea Ice Cyclic Performance Report	Issue: 1.0
Performance Centre	S3A Cycle No. 060 – S3B Cycle No. 041	Page: 33
		Date: 07/09/2020

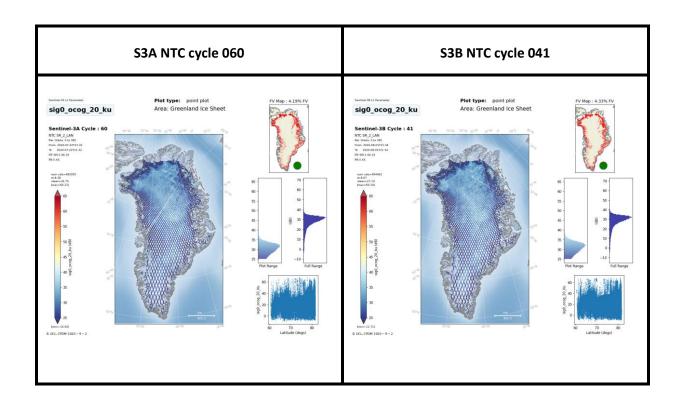


Figure 19: Map of 20Hz Ku Band OCOG (Ice-1) Sigma0 (sig0_ocog_20_ku) over Greenland

For maps of % gridded parameter failure rates, see maps of range_ocog_20_ku.



Band Waveform Quality Flag (waveform qual ice 20 ku) 6.7

The waveform quality flag for ice sheets provides users with an indication of the quality and suitability of the SAR waveform for use in the calculation of range and elevation. Six different tests are performed on each waveform and a separate flag bit value set if any test fails. The value of waveform_qual_ice_20_ku will be zero if all tests are passed.

In IPF 6.14 the thresholds used for each test are:

Test Description	Threshold	Flag Bit Set
Total Power in waveform < threshold	2500	1
Average noise power in gates 6-9* > threshold *Noise gates starts at 0	12.5	2
Variance > threshold	7.0	4
Leading Edge Test > threshold Flag set if power to left of gate 42 > threshold * power to right	1.0	8
Peakiness < Low Threshold	0.9	16
Peakiness > High Threshold	1e12	32

- Elevation_ice_sheet_20_ku and associated range and sigma0 measurements are already filtered (set to fill value) when the waveform quality flag is set to > 0.
- Elevation_ocog_20_ku and associated range and sigma0 measurements are not filtered by the waveform quality flag. Users are recommended to consider their own filtering of measurements based on the waveform quality flag.
- The waveform quality checks are designed for centered waveforms (at L1). In this product baseline there is a L1 anomaly whereby waveforms are not centered and over sloping surfaces the waveform will migrate across the range window. This reduces the effectiveness and accuracy of the waveform quality checks over the ice sheet margins.



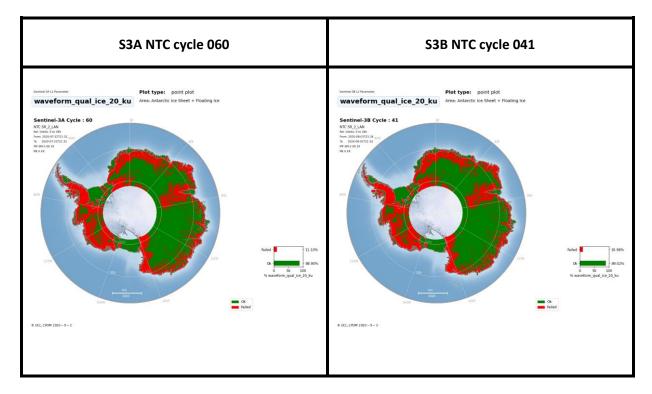


Figure 20: Map of Waveform Quality Flag over Antarctica (all tests)

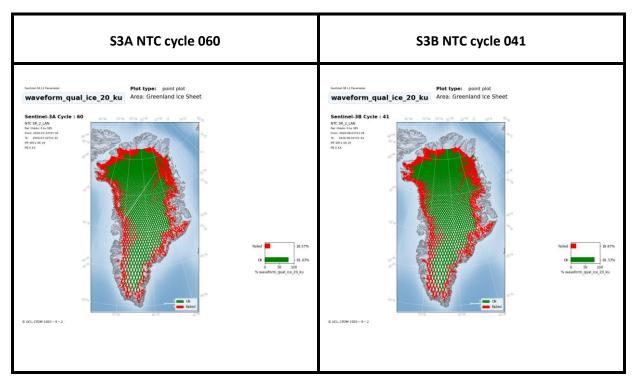


Figure 21: Maps of Waveform Quality Flag over Greenland (all tests)



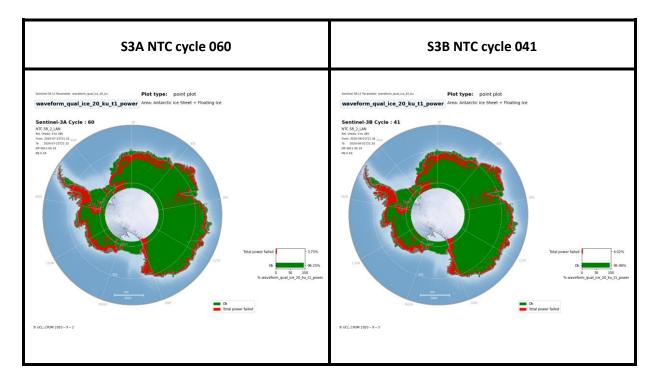


Figure 22: Map of Waveform Quality Flag over Antarctica (T1 power)

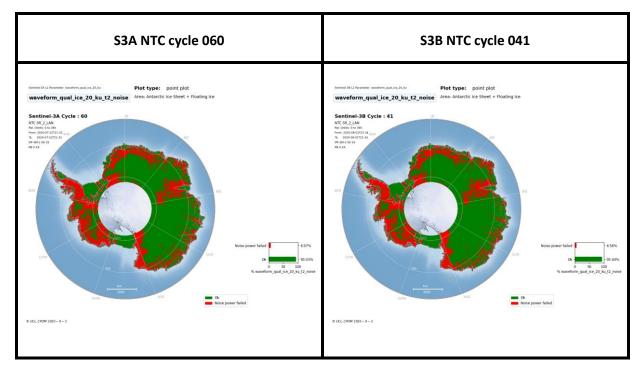


Figure 23: Map of Waveform Quality Flag over Antarctica (T2 noise)



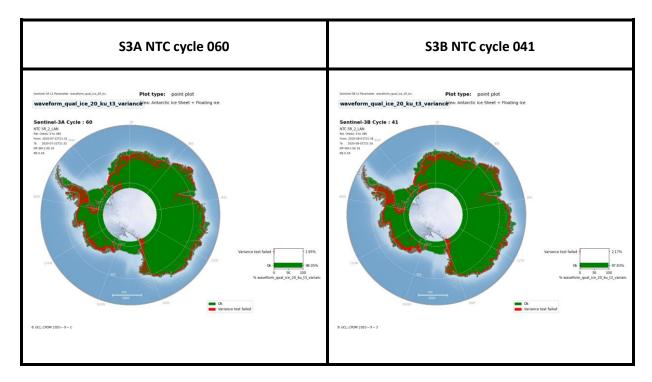


Figure 24: Map of Waveform Quality Flag over Antarctica (T3 variance)

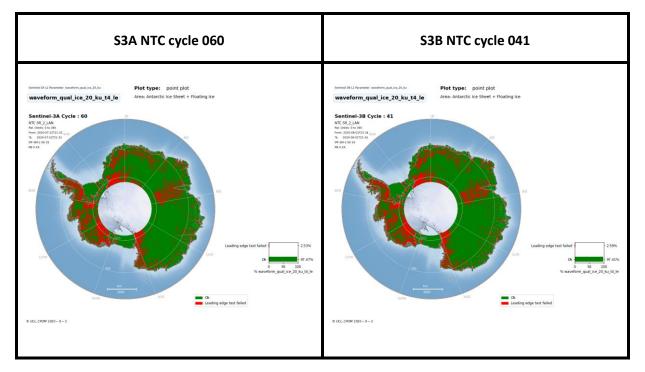


Figure 25: Map of Waveform Quality Flag over Antarctica (T4 leading edge test)



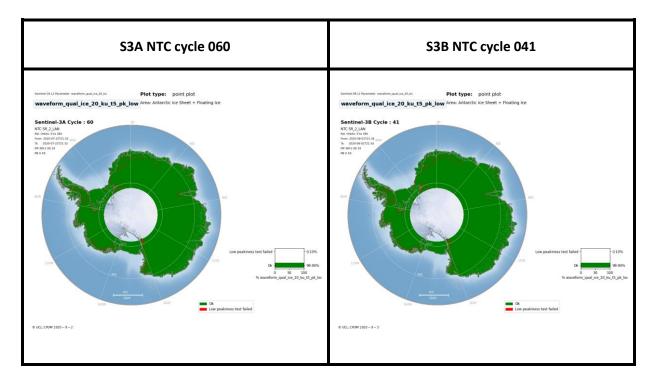


Figure 26: Map of Waveform Quality Flag over Antarctica (T5 peakiness low)

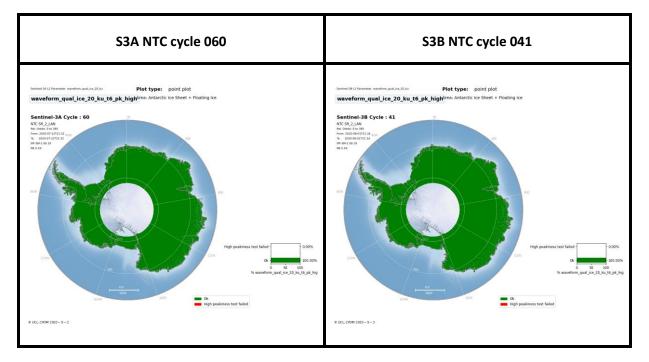


Figure 27: Map of Waveform Quality Flag over Antarctica (T6 peakiness high)



6.8 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.

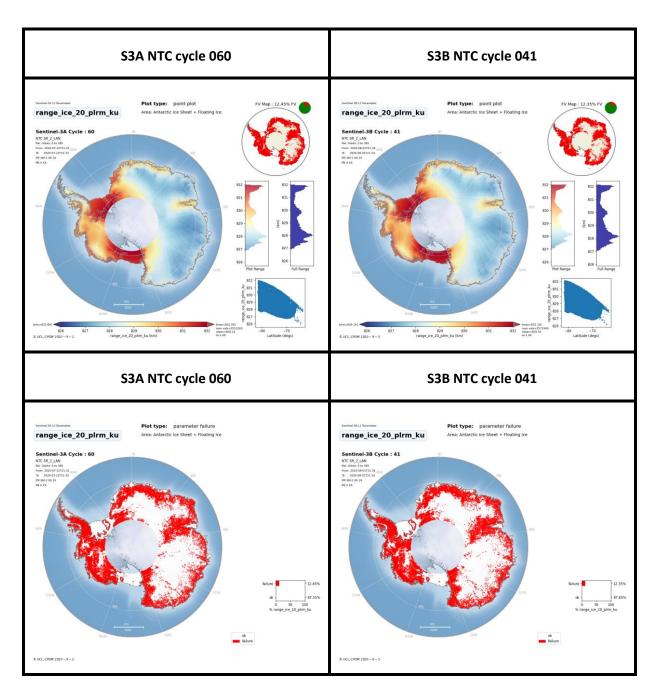
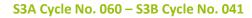


Figure 28: Map of range_ice_20_plrm_ku over Antarctica and % Gridded Parameter Failure



Sentinel-3 MPC

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 40 Date: 07/09/2020



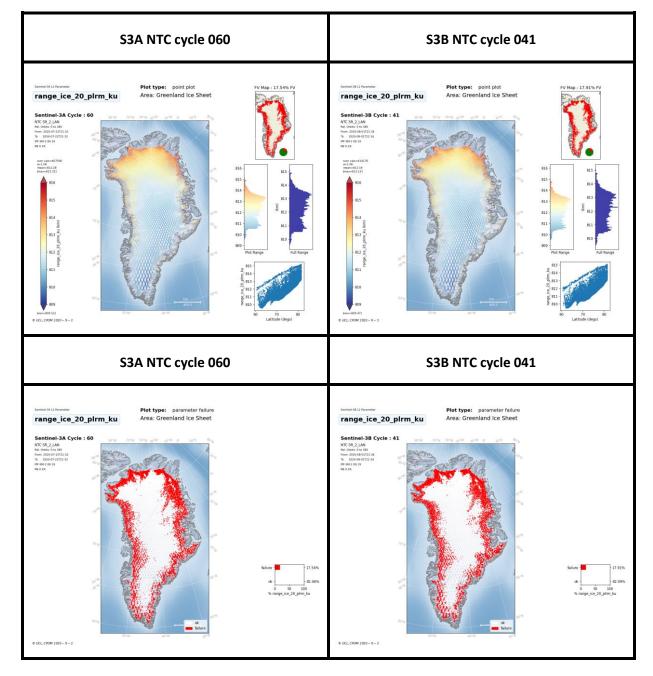


Figure 29: Map of range_ice_20_plrm_ku over Greenland and % Gridded Parameter Failure



6.9 20Hz Ku Band PLRM Sigma0 (sig0_ice_20_plrm_ku)

Backscatter sigma0 derived from the 20Hz Ku PLRM waveforms are shown below.

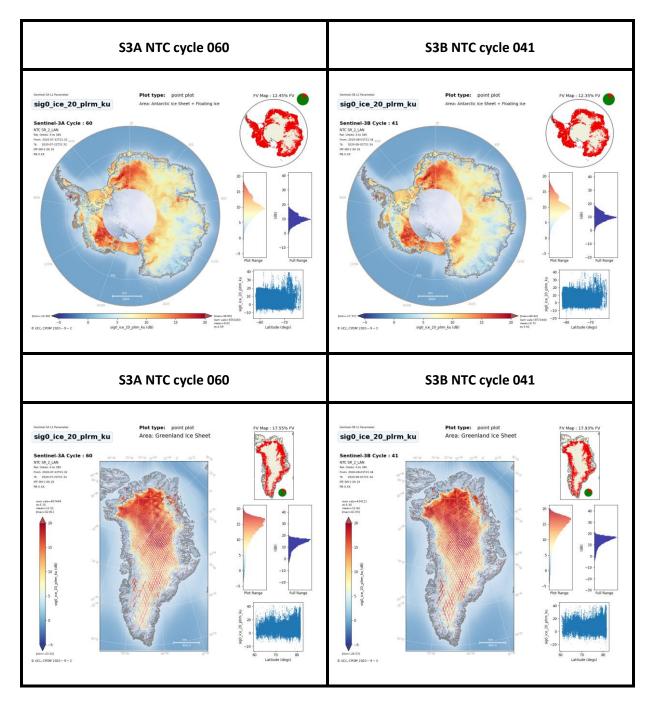


Figure 30: Maps of 20Hz Ku Band PLRM Sigma0 (sig0_ice_20_plrm_ku)



6.10 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.

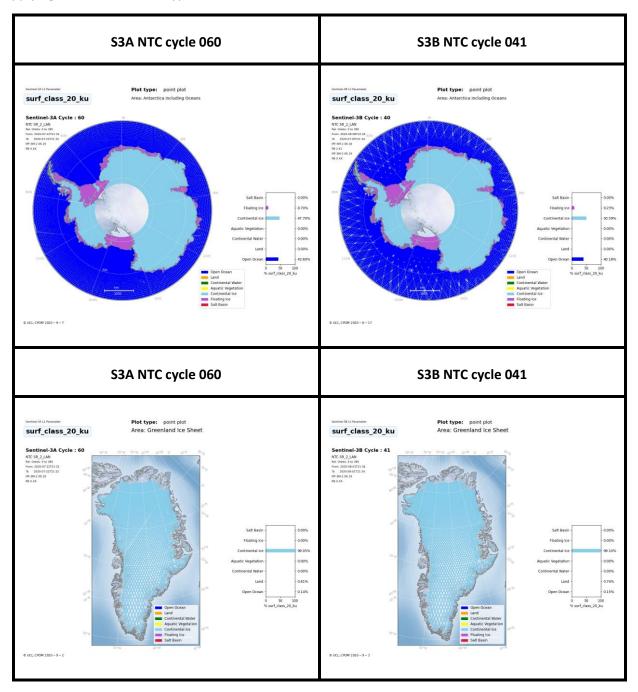


Figure 31: Maps of 20Hz Ku Band Surface Class (surf_class_20_ku)

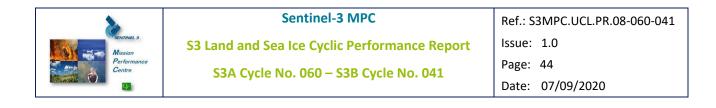


7 Slope Correction

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. The slope corrected locations are stored in parameters lat_cor_20_ku, lon_cor_20_ku. Note that an error in the slope correction was present in all IPF versions <= 6.10. This was corrected in IPF version 6.12.

Maps of where the slope correction is not calculated for the S3A and S3B cycles are shown below.

In the previous version of the IPF there were unexpectedly zero failures indicated for slope correction failure, this is corrected in the current IPF version 6.15.



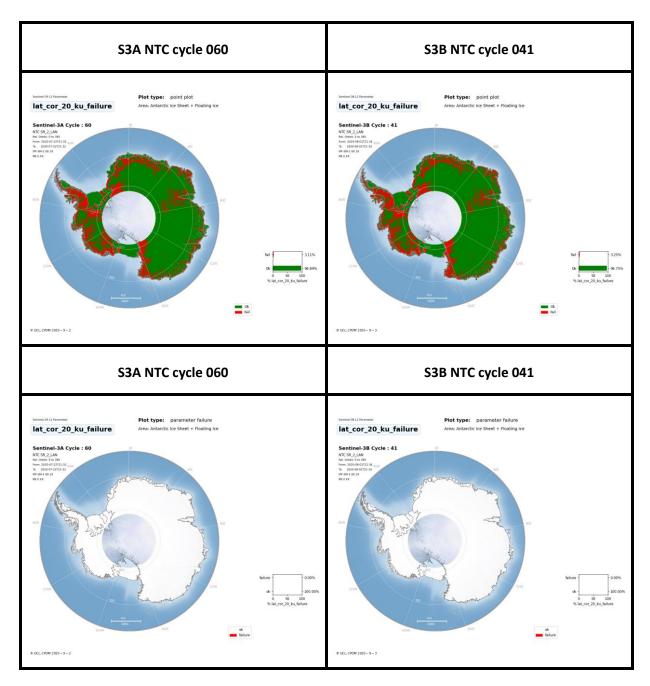


Figure 32: Maps of Slope Correction Failure Locations over Antarctica

Slope corrected locations are also calculated for PLRM parameters:



Sentinel-3 MPC

S3 Land and Sea Ice Cyclic Performance Report

S3A Cycle No. 060 – S3B Cycle No. 041

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 45 Date: 07/09/2020

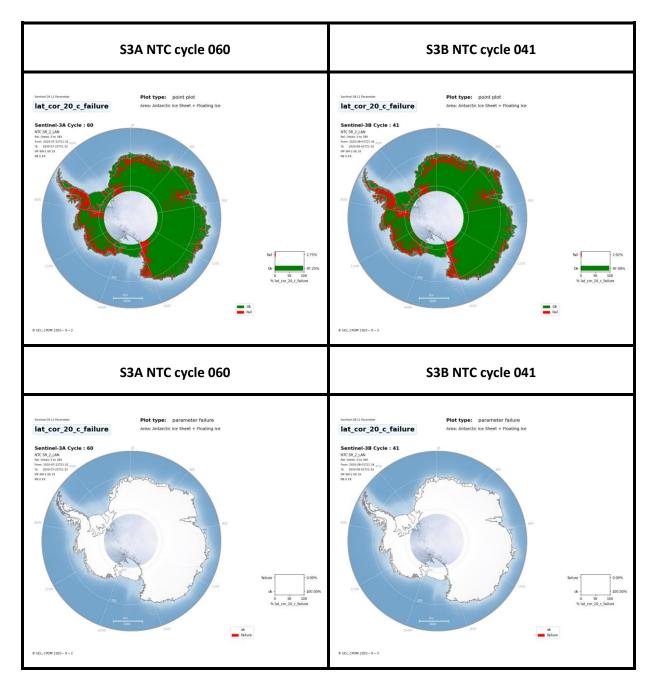


Figure 33: Maps of the Failure of the lat_cor_20_c Parameter over Antarctica

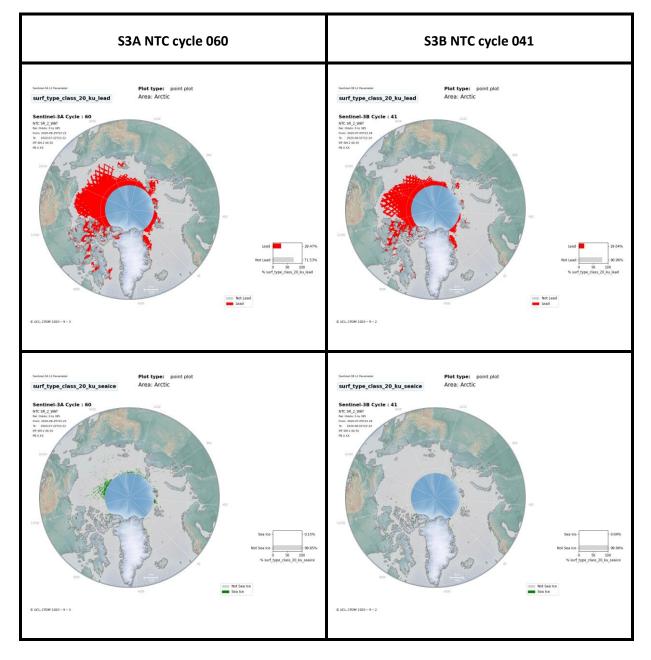


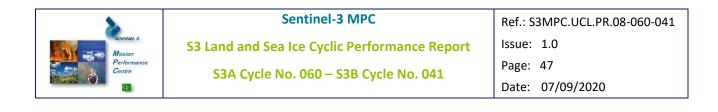
8 Geophysical Parameter Monitoring for Sea Ice

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

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 which classifies each echo as a surface type (lead, sea ice floe, open ocean or unclassified) based on echo shape (peakiness, and SAR stack parameters) and sea ice concentration.





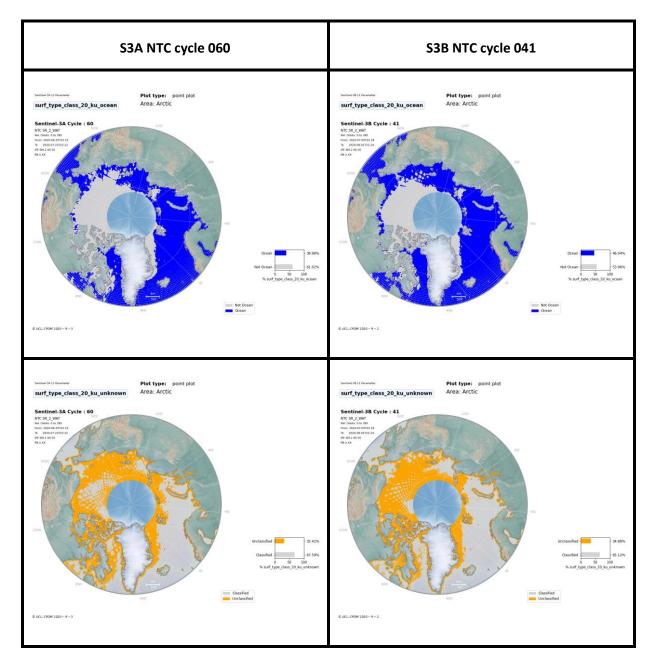
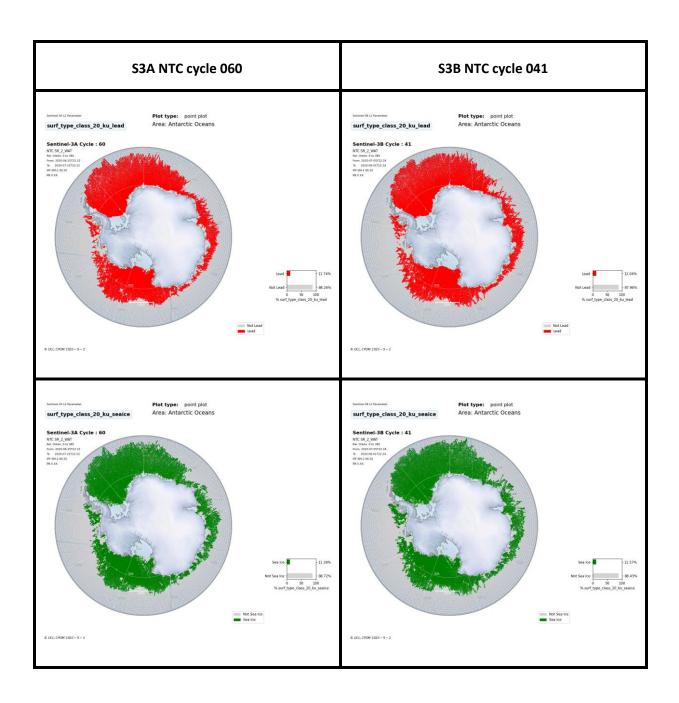
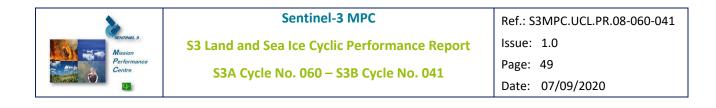


Figure 34: Maps of surf_type_class_20_ku classes over the Arctic







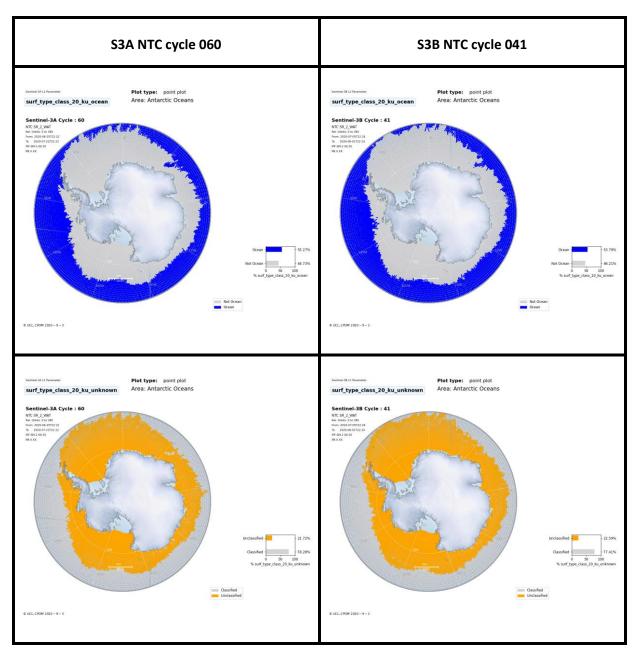


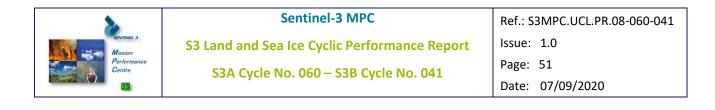
Figure 35: Maps of surf_type_class_20_ku classes over the Antarctic



8.2 **20Hz Ku band Freeboard (freeboard_20_ku)**

Several issues were corrected in IPF 6.15 :

- the performance of the diffuse echo floe retracker in this version of the IPF, resulting in lower than expected sea ice elevation and higher than expected retracker failure.
- an issue with incorrect filtering of sea ice lead returns resulting in higher than expected retracker failure.
- an issue with filtering of SSHA outliers.
- a possible unresolved sea ice lead and floe retracker bias.



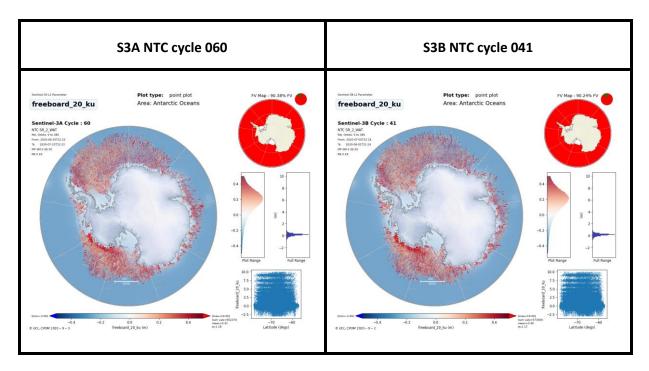


Figure 36: Map of Freeboard (freeboard_20_ku) and Gridded Parameter Failure over Antarctica

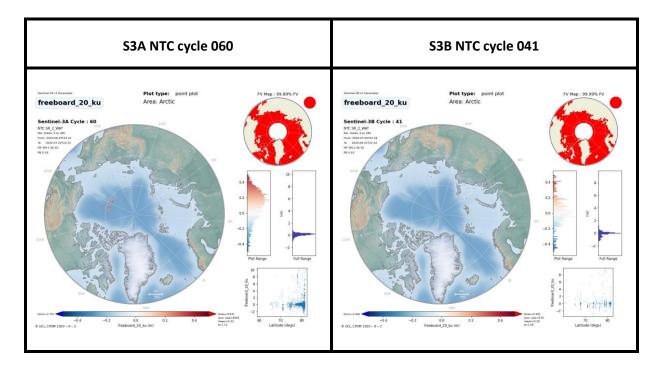


Figure 37: Map of Freeboard (freeboard_20_ku) and Gridded Parameter Failure over the Arctic



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

This parameter is the sea surface height with respect to the mean sea surface interpolated between leads in the sea ice (ie represents the SSHA underneath the sea ice floes). In this version of the IPF 6.15 the previous problem of anomalously large values of interpolated SSHA near the coastline have been corrected.

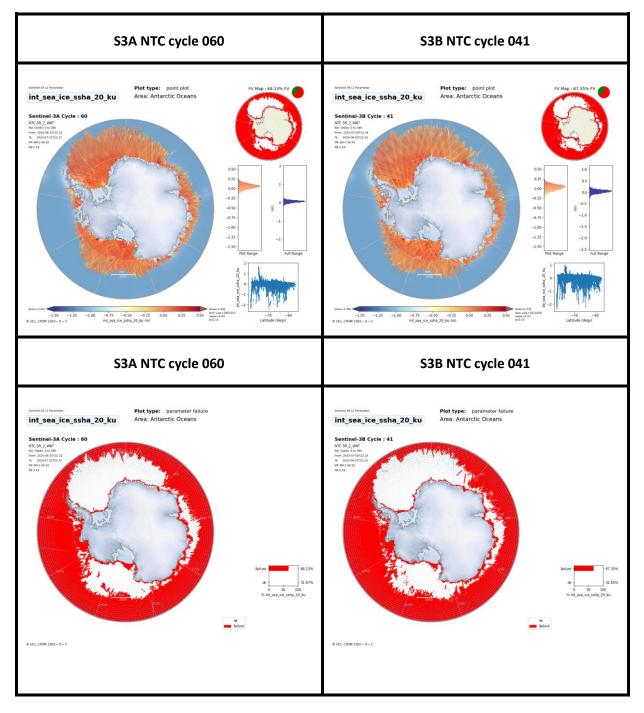


Figure 38: Map of Interpolated Sea Ice SSHA (int_sea_ice_ssha_20_ku) and Gridded Parameter Failure over Antarctica

2	Sentinel-3 MPC	Ref.: S3MPC.UCL.PR.08-060-041
SENTINEL 3	S3 Land and Sea Ice Cyclic Performance Report	Issue: 1.0
Performance Centre	S3A Cycle No. 060 – S3B Cycle No. 041	Page: 53
		Date: 07/09/2020



Sentinel-3 MPC

S3 Land and Sea Ice Cyclic Performance Report

S3A Cycle No. 060 - S3B Cycle No. 041

Ref.: S3MPC.UCL.PR.08-060-041 Issue: 1.0 Page: 54 Date: 07/09/2020

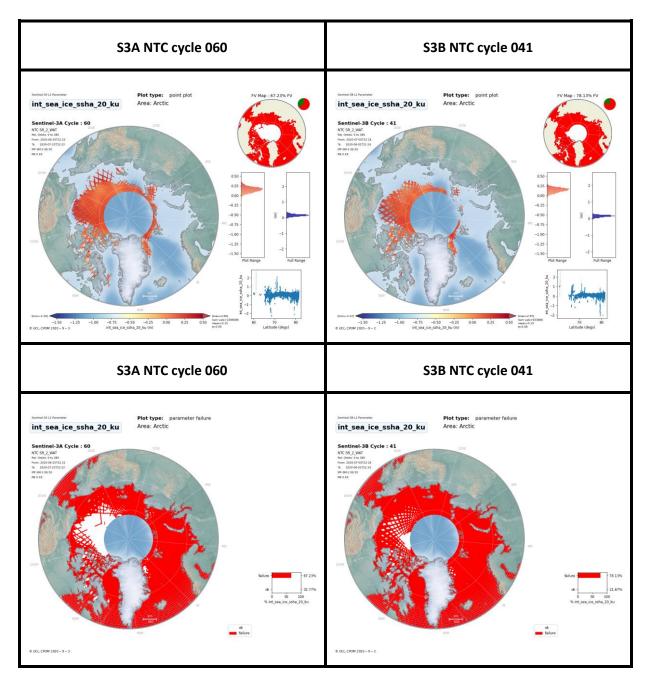


Figure 39: Map of Interpolated Sea Ice SSHA (int_sea_ice_ssha_20_ku) and Gridded Parameter Failure over the Arctic



8.4 Sea Surface Height Anomaly (sea_ice_ssha_20_ku)

This parameter is the sea surface height with respect to the mean sea surface.

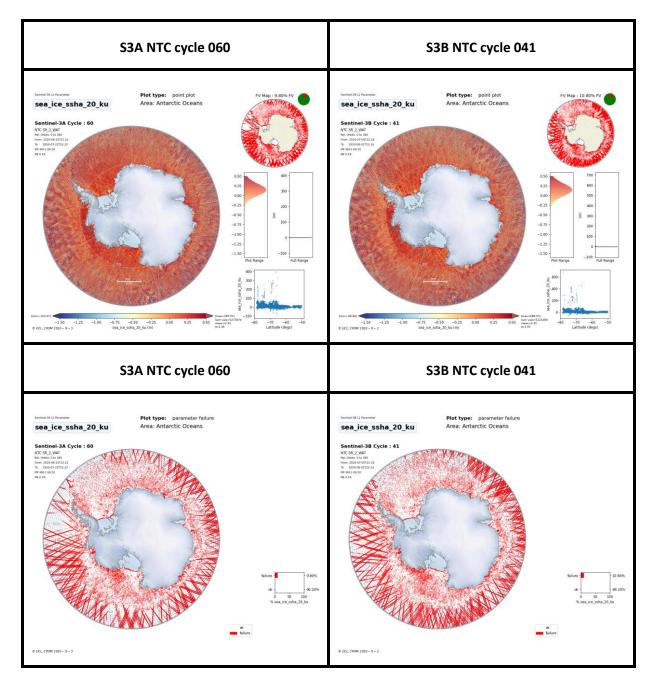
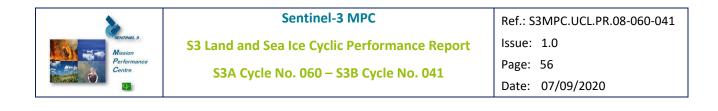


Figure 40: Maps of sea_ice_ssha_20_ku and Gridded Parameter Failure over the Antarctic



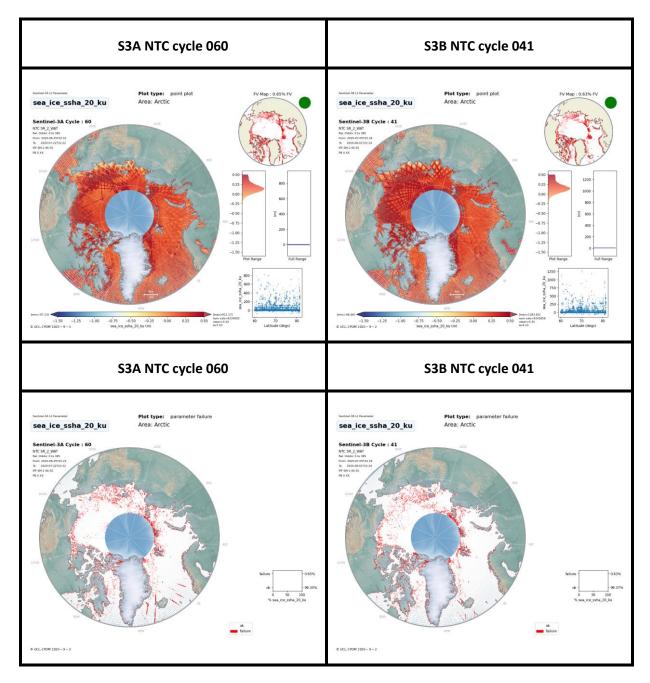


Figure 41: Maps of sea_ice_ssha_20_ku and Gridded Parameter Failure over the Arctic



8.5 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku)

Sea ice concentration data is available in 100% of records in the NTC product in these cycles. 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.

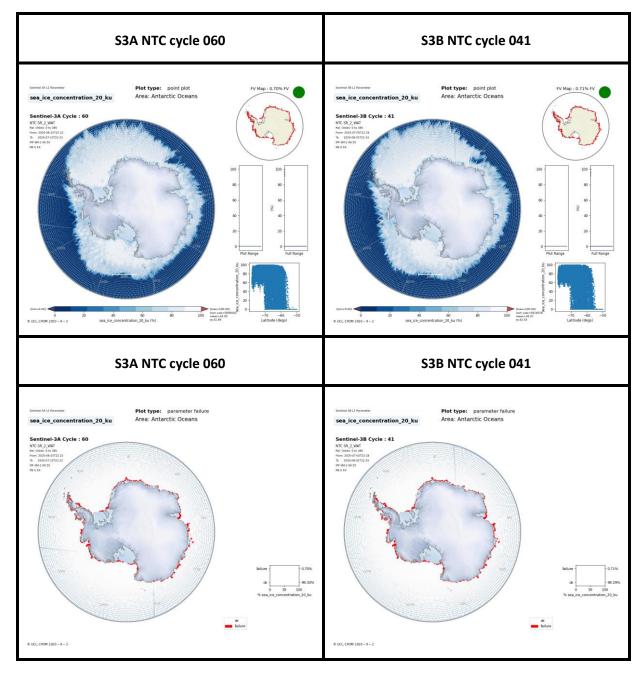


Figure 42: Maps of 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku) over the Antarctic Ocean



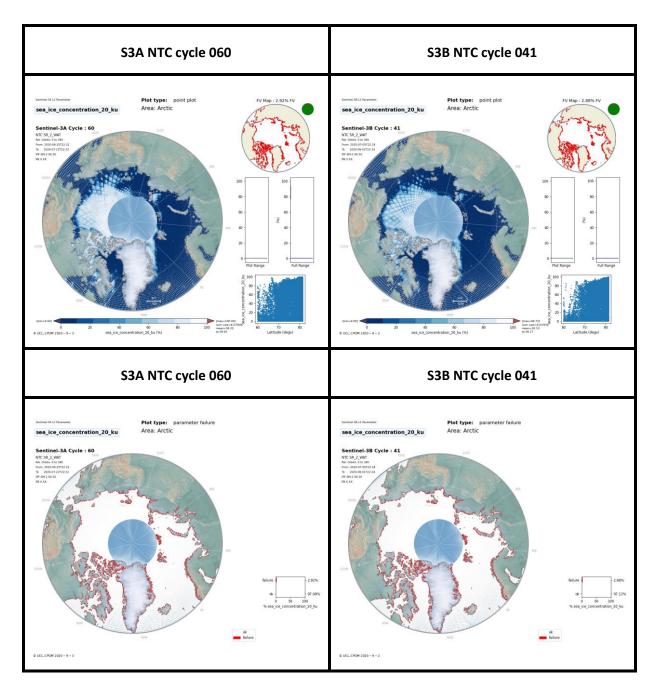


Figure 43: Maps of 20Hz Ku band Sea Ice Concentration (sea_ice_concentration_20_ku) over the Arctic



8.6 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 with peakiness values (< 11).

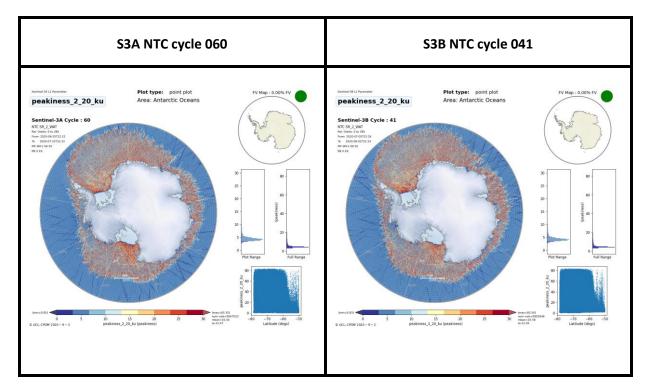
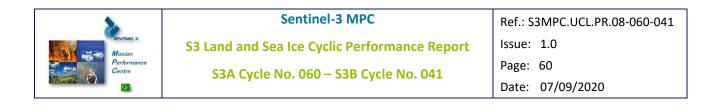


Figure 44: Maps of 20Hz Ku band Peakiness (peakiness_2_20_ku) over the Antarctic



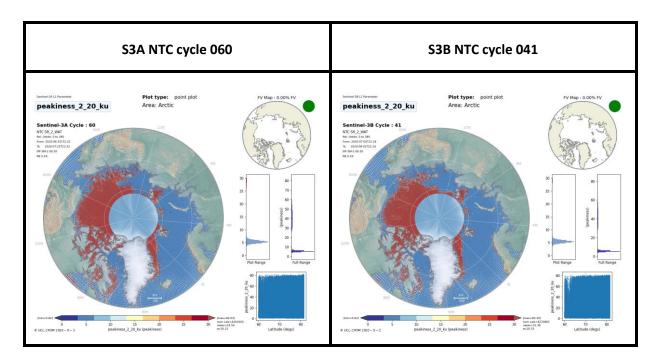


Figure 45: Maps of 20Hz Ku band Peakiness (peakiness_2_20_ku) over the Arctic



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.

The crossover difference of the elevation from both ice sheet retrackers shows a mean of 0.0m and an rms difference of 0.4m+/-0.02 which is in line with previous missions. There are a greater number of crossovers from the OCOG retracker due to its lower failure rate.

The crossover difference from both ice sheet retrackers is reduced and the standard deviation is lower, compared to previous cycles. This is due to the new slope model which was introduced in this IPF 6.18.

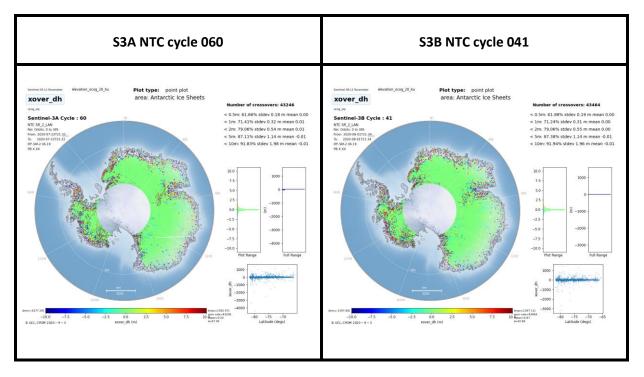
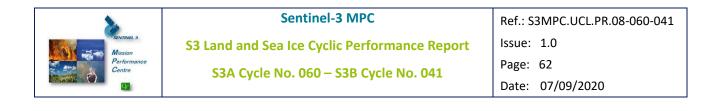


Figure 46: Maps of Crossover Difference of OCOG Elevation over Antarctica



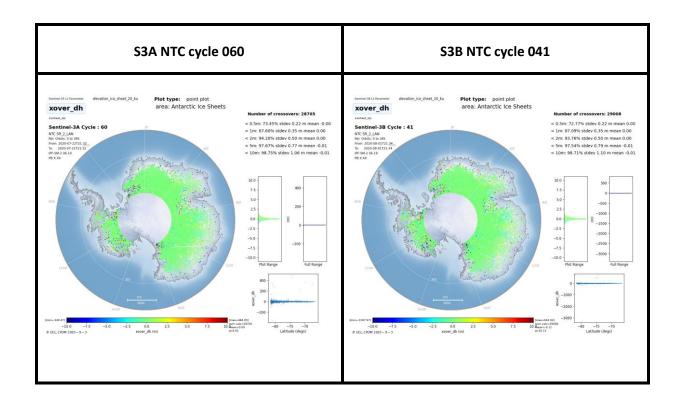


Figure 47: Maps of Crossover Difference of Ice Sheet Elevation over Antarctica



10 Events and Processing Baseline Changes

List of all IPF processing changes and events effecting land and sea ice parameters in this cycle.

Product Baseline	L2 IPF	Operational Since	Land Ice/ Sea Ice	Change Description
PB 2.66	6.19	09/07/2020	L/S	Modification of MLM_AX Land/Sea mask
			L/S	New format SIC ADF which improves SIC around the coastline, removing land contamination
PB 2.61 6	6.18	21/01/2020		
			L	Update of Slope Model for Greenland and Antarctica (from CryoSat-2 DEM (Helm,2014)), S3MPC-3243
			S	Update of Mean Sea Surface to DTU2018
			L/S	Update: sigma0 derived from ocog and ice ~ 18dB lower in this IPF
PB 2.34	6.15	14/02/2019		
			S	Fixed: The freeboard parameter exhibits a mean value centred around -30 cm. It is mainly due to the retracker used for the diffuse echoes which is not optimal to properly retrack the double peak waveforms that are characteristics over floes.
			5	Fixed: The sea ice retracker exhibits a much higher level of failure compared to the other retrackers (ocean, OCOG and ice sheet retrackers), due to the use of a quality check applied on the waveforms. This results in the sea ice retracking not being applied to waveforms for observations that are associated to leads and sea ice, leads being the dominant population where the retracker is not activated.
			L	Fixed: The discrimination flag (surf_type_class_20_ku) which is designed for sea ice is set to ocean over land surfaces
			S	Fixed: Values of interpolated ssha for sea ice (int_sea_ice_ssha) show stronger magnitude than the original sea_ice_ssha parameter, over transition zones between ocean and land areas.
			L	Fixed: Sea_ice_concentration_20_ku is set to zero percent over land but it does not affect the quality of the sea ice parameters using this parameter.
			L/S	Fixed: The output of the OCOG retracker in Ku-band in LRM mode (range_ocog_20_ku and sig0_ocog_20_ku parameters) are very frequently set to fill values, whatever the surface.
PB 2.33	6.14	04/04/2018		

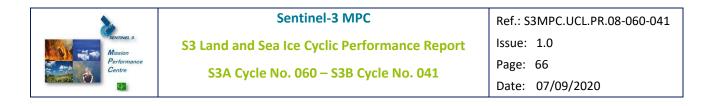


			1	Eivad: DES and Draduct Man descriptions are urong for
				Fixed: PFS and Product Map descriptions are wrong for elevation_ocog_20_ku and elevation_ice_sheet_20_ku (SIIIMPC- 2427)
			L	Fixed : the field "elevation_ocog_20_ku" is always set to Fill Value in LRM mode (SIIIMPC-2477)
			S	Fixed: the field "ssha_20_ku" is always set to Fill Value in LRM mode
			L	Fixed : elevation_ocog_20_ku field set to NaN on standard_measurement.nc only (SIIIMPC-2426)
PB 2.27	6.12	12/01/2018		
			L	Fixed slope model anomaly (SIIIMPC-2074)
			L	Added new OCOG elevation parameter (SIIIMPC-2299)
			L	Noise power anomaly fixed (SIIIMPC-2076)
			S	Wrong value for sea ice range in L2 STM products (SIIIMPC-2067)
			S	When GIM iono is absent, a 3.27m bias appears in SSHA (SIIIMPC- 2271)
PB 2.24	6.10	13/12/2017		
			L	New L2 Parameter: waveform_qual_ice_20_ku
				A flag related to the quality of the waveforms over land ice. This is of interest mainly over land ice to discard data that have corrupted waveforms.
			L	Anomaly relating to large negative elevation values present around ice shelves fixed.
			L/S	New Parameters: Three additional parameters to facilitate the connection between the 1 Hz and 20 Hz fields short index_1hz_meas_20_ku(time_20_ku); int index_first_20hz_meas_01_ku(time_01); short num_20hz_meas_01_ku(time_01);
			S	Implementation of a new Mean Sea Surface model for sea ice SSHA processing: DTU15 models.
				The DTU15 has been selected due to the extended coverage that includes values over some of the large lakes and a small region in the Arctic Ocean whereas the CNES-CLS15 does not provide any value.
				The use of the DTU15 Mean Sea Surface model in sea_ice_ssha parameters because this model performs better over the Arctic



Sentinel-3 MPC S3 Land and Sea Ice Cyclic Performance Report S3A Cycle No. 060 – S3B Cycle No. 041

		Ocean.
	S	Implementation of the FES2014 model in replacement of the FES2004 model, for the computation of the solution 2 tide heights.
	S	the availability of the GIM ionospheric correction in STC products. The systematic coverage now available for this correction allows retrieving the expected values of the sea_ice_ssha parameters.
	S	the evolution of the sea ice classification (Discrimination) parameter (surf_type_class_20_ku).
	L	the increase of the coverage of the outputs of the ice sheet retracker by extending the SAR ice margin retrackers fit window.



11 Conclusions

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

For Level-2 NTC Land products over polar ice sheets there is good data quality using the OCOG elevation parameter over areas of low slope. In areas of high slope (> 0.3 degrees) an issue at L1b resulting in uncentered waveforms affects this cycle, resulting in a lower density of measurements over these areas and a reduction in the quality of the elevation parameters. Users are recommended to use the waveform quality flag to filter OCOG elevation measurements over ice sheets.

L1b processing is also not currently 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.

L1b issues in this cycle are scheduled to be corrected in an optimised thematic land ice and sea ice processing during 2020/2021.



12 Appendix A

Other reports related to the STM mission are:

- S3 SRAL Cyclic Performance Report, S3A Cycle No. 060, S3B Cycle No. 041 (ref. S3MPC.ISR.PR.04-060-041)
- S3 MWR Cyclic Performance Report, S3A Cycle No. 060, S3B Cycle No. 041 (ref. S3MPC.CLS.PR.05-060-041)
- S3 Ocean Validation Cyclic Performance Report, S3A Cycle No. 060, S3B Cycle No. 041 (ref. S3MPC.CLS.PR.06-060-041)

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

End of document