# CryoSat Monthly Quality Report #137

## 19th December 2021 - 17th January 2022

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*QA4EO-VEG-OQC-REP-4515* *Issue 1.0* *09 March 2022*

## AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

| ISSUE | DATE | REASON |
|---|---|---|
| 1.0 | 09 March 2022 | First issue of report |

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# 1. INTRODUCTION

## 1.1 Purpose and Scope

This CryoSat Quality Report is distributed by the QA4EO team to keep the CryoSat community informed of the overall mission performance, the status of the SIRAL instrument as well as the data quality of the ***CryoSat Ice Products***.

Complementary analysis of the CryoSat Ocean Products is performed by the National Oceanography Centre in Southampton (NOCS). Cyclic Reports for the Ocean Products are also generated and are made available at the following web address: https://earth.esa.int/eogateway/instruments/siral/quality-control-reports

The report is based on a 30-day reporting period, which has been defined by the data Quality-Analysis (QA) Team of UCL/MSSL since the mission Transfer to Operations (TTO), as part of their routine QA monitoring activity. This 30-day cycle has been defined purely for the purpose of statistic reporting and does not correspond to an official 30-day sub cycle. The actual repeat cycle for CryoSat is 369 days, which consists of 5344 orbits.

This document reports on Offline Ice data (LRM, SAR and SARIn). This document is also available online at the following web address: https://qras.earth.esa.int/

Further product parameter time series, on both a cyclic and weekly basis, are available on the MSSL Quality Monitoring website: http://cryosat.mssl.ucl.ac.uk/qa/mode.php

## 1.2 Definition of Terms

The following terms have been used in this report with the meanings shown.

| Term | Definition |
|---|---|
| QA4EO | Quality Assurance for Earth Observation, reporting to the ESA Data Quality and Algorithms Management Office (EOP-GMQ). This is a consortium responsible for quality of data provided to users including the data calibration and validation, the data processing algorithms, and the routine instrument and processing chain performances. |
| QA4EO team | In this document, the “QA4EO team” refers to the QA4EO CryoSat team, which can be reached via the following email address: cryosat@eo-sppa.org. |
| ADF | Auxiliary Data File which is needed by the CryoSat processors to process Level 0 or Level 1B data to higher level products. |

## 2. EXECUTIVE SUMMARY

| Cycle Number | 137 |
|---|---|
| Cycle Start Date | 19th December 2021 |
| Cycle End Date | 17th January 2022 |
| Instrument Status | NOMINAL |
| Data Quality Status | NOMINAL |
| Processor Updates | None |
| ADF Updates | None |

The health of the SIRAL instrument was found to be nominal during cycle #137.

During the reporting period there were two period during which the SIRAL data was unavailable; a platform anomaly and a planned orbit manoeuvre. Further information on data unavailability during the reporting period can be found in Section 3.2.1.

There were no changes to Processor Configurations or any Auxiliary Data File updates during the reporting period.

**The data quality of Level 1B (L1B) and Level 2 (L2) data products was found to be nominal throughout this reporting period.**

# 3. INSTRUMENT HEALTH

SIRAL parameters are extracted from the Level 0 Data Products and monitored on a daily basis in order to check the health and status of the SIRAL instrument.

## 3.1 SIRAL Loss of Surface Track

It is expected that the SIRAL altimeter can lose track of the surface over land areas, and this is a nominal feature of the instrument. However, this surface tracking is monitored to ensure there is no loss of track over large areas of ocean as this could indicate a potential issue with the SIRAL instrument. Figure 1 and Figure 2 show global and polar plots from January 2022, presenting areas where the instrument has lost track of the surface, for each SIRAL mode.

During this reporting period, the loss of SIRAL track was **nominal** for all three SIRAL modes.

Plot to be updated.

**Figure 1 – Global plot showing areas of loss of track in all SIRAL modes L0 data during January 2022**

Plot to be updated.

**Figure 2 - Polar plots showing areas of loss of track in all SIRAL modes L0 data during January 2022.**

## 3.2 Instrument and Data Availability

### 3.2.1 Recorded Periods of Instrument Unavailability

The following unavailability periods have been noted for SIRAL during this reporting period:

**Table 3-1 - SIRAL unavailability periods for Cycle #137**

| UTC Start | UTC Stop | Planned | Reason | Mode |
|---|---|---|---|---|
| 2021-12-16 08:29:13 | 2021-12-20 16:53:09 | Unplanned | Platform Anomaly | All |
| 2021-12-22 11:48:01 | 2021-12-22 13:38:40 | Planned | Orbit Manoeuvre | All |

As reported in the previous report for cycle 136, there was an **unplanned platform anomaly** from 16th – 20th December, during which the instrument was switched off. An operation to patch the latest On

Board Control Procedures lead to a memory corruption which triggered the Control and Data Management Unit to reboot and enter safe mode. By re-writing the affected procedures, the memory was once again accessed successfully without further issues, and the system was rebooted.

During the reporting period there was also one **planned orbit manoeuvre** on the 22nd December, during which the SIRAL instrument was unavailable.

### 3.2.2 L1 & L2 Offline Data Availability

During this reporting period there were no significant periods of Offline data unavailability, which cannot be associated to known periods of SIRAL unavailability already provided in Table 3-1.

Processing anomalies are responsible for a small percentage of data product gaps within L1, L2, and GDR offline production. For further information on the current known processing anomalies please see the CryoSat Ice Data Quality Status documentation, available to download from https://earth.esa.int/eogateway/instruments/siral/quality-control-reports.

In the case of occasional GDR anomalies/ failures, users should use the equivalent L2 products, which remain available and do not contain any degradation in quality.

# 4. OFFLINE DATA QUALITY STATUS

## 4.1 Offline Data Quality Overview

The overall quality of Offline data processed during this reporting period is **nominal**.

During cycle #137, a number of CryoSat Offline products may have been affected by instrument and/or processing issues, which have had a detrimental effect on the data quality of some of the data records within the product. For a full list of the products affected on a particular day please see the relevant Daily Performance Report, available to download from https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat/daily-performance-reports.

**Table 4-1 - CryoSat products affected by instrument and/or processing issues during cycle #137**

| Affected Products | Reason |
|---|---|
| 1 products with warnings on 21/12/2021 | The Cal1 correction missing flag is set in a product for 1 or more records. |
| 1 products with warnings on 31/12/2021 | The Cal1 correction missing flag is set in a product for 1 or more records. |
| 2 products with warnings on 02/01/2022 | The Cal1 correction missing flag is set in a product for 1 or more records. |

The Cal1 Correction Missing Flag is set by the L1B processor during the processing of the data. The flag indicates that one or more record in the product was processed without the Cal1 Correction file and has instead been taken from the IPF database.

Users are advised to take note of flags in the products, but to be aware that the flags may only relate to one or a few individual records inside the product, meaning that the product may still be useable.

## 4.2 SIRAL Mode

CryoSat is designed to acquire continuously whilst switching automatically between its three nominal measurement modes, LRM, SAR and SARIn, according to a Geographical Mode Mask. The mask is the basis of the CryoSat mission planning and defines the mode switching of the SIRAL instrument while the satellite revolves around the Earth. The latest operational mask can be viewed on the CryoSat Webpage; https://earth.esa.int/web/guest/-/geographical-mode-mask-7107

### 4.2.1 SIRAL Mode Map

Figure 3 shows global and polar plots of the SIRAL Modes acquired during cycle #137. These plots are generated from offline L2 Geophysical Data Record (GDR) data, which includes a SIRAL mode indicator for each 20 Hz record (field #2). The region in grey is a defined calibration zone where SIRAL is commanded in Calibration (CCAL1) mode each time CryoSat overflies.

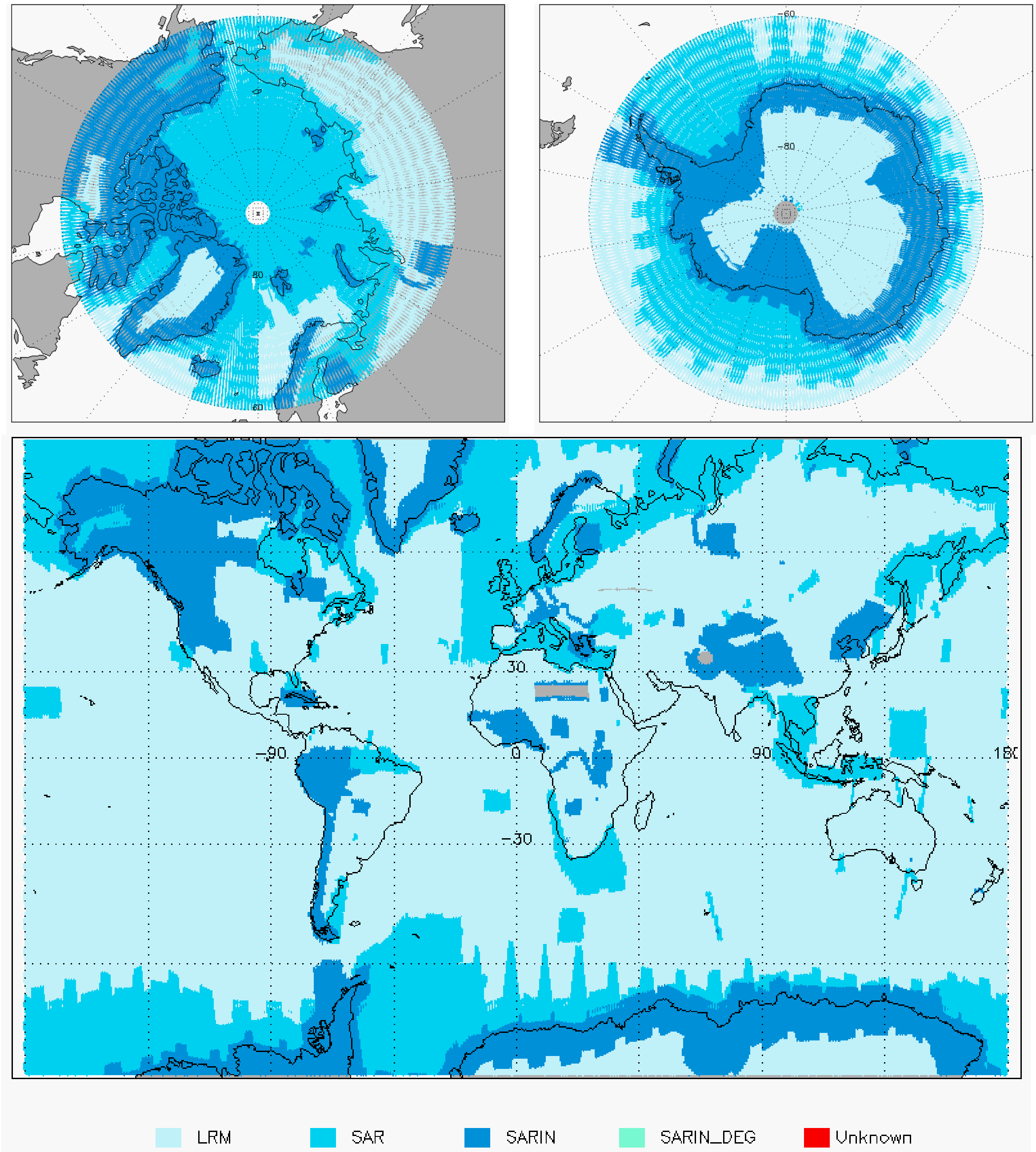


**Figure 3 - Global and Polar plots of SIRAL Modes for cycle #137.**

## 4.3 Attitude Parameters

### 4.3.1 L1B Roll, Pitch and Yaw

Figure 4 shows the Spacecraft Attitude Parameters; Roll (field #15), Yaw (field #16) and Pitch (field #17), extracted from L1B products during cycle #137.

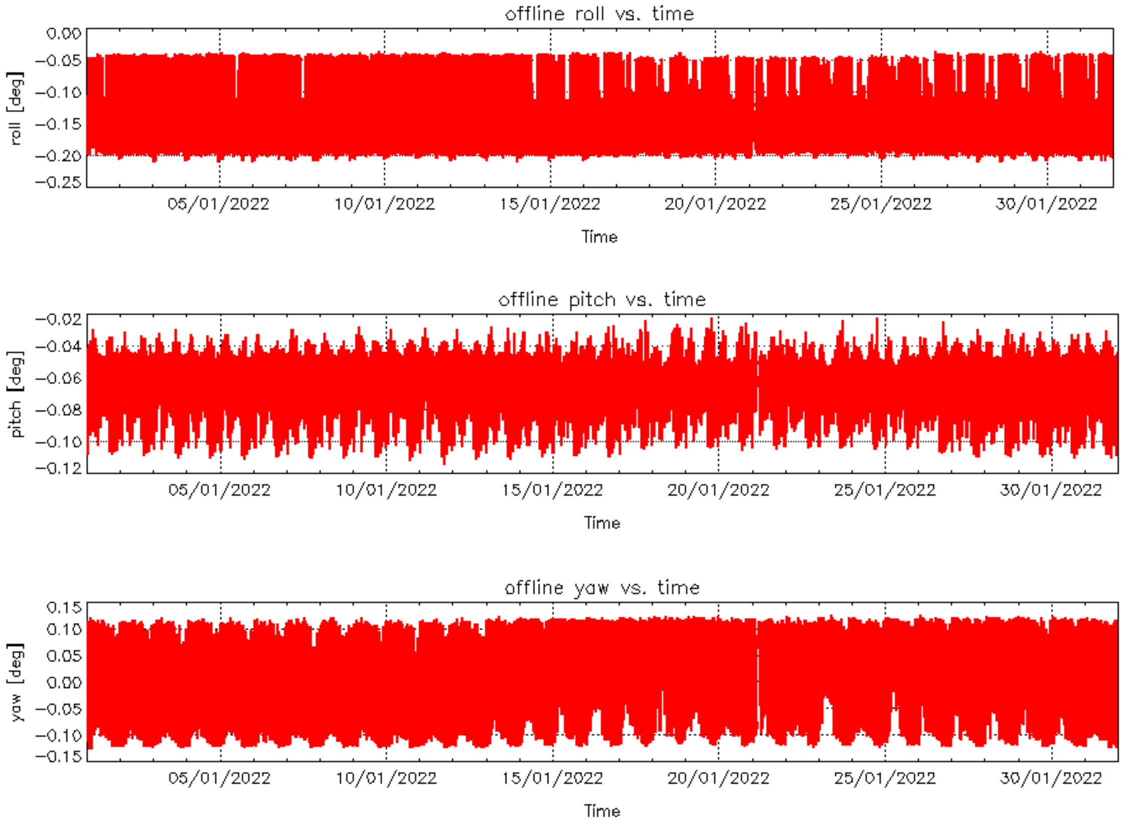


**Figure 4 – Roll (top), Pitch (middle) and Yaw (bottom) values for L1B Products during cycle #137.**

Figure 4 shows that during this reporting period the attitude parameters were provided continuously in the L1B products.

## 4.4 SIRAL Measured Product Parameters

### 4.4.1 Freeboard

CryoSat L2 data includes a SAR mode computed Sea Ice Freeboard calculation (Field #43) for each 20 Hz record, discriminated as 'Sea Ice' by the SAR discriminator flag. Freeboard is defined as the difference in height between sea ice and adjacent water and is used for the calculation of sea ice thickness.

Freeboard values can be negative if there is heavy snow load on thin ice and are calculated using UCL04 model values for snow depth and density.

Figure 5 and Figure 6 show the associated histograms and polar plots of 10km gridded freeboard values from L2 SAR products from cycle #137. No histogram or plot is available for the Antarctic, since there are limited freeboard data points over this region during the Antarctic summer.

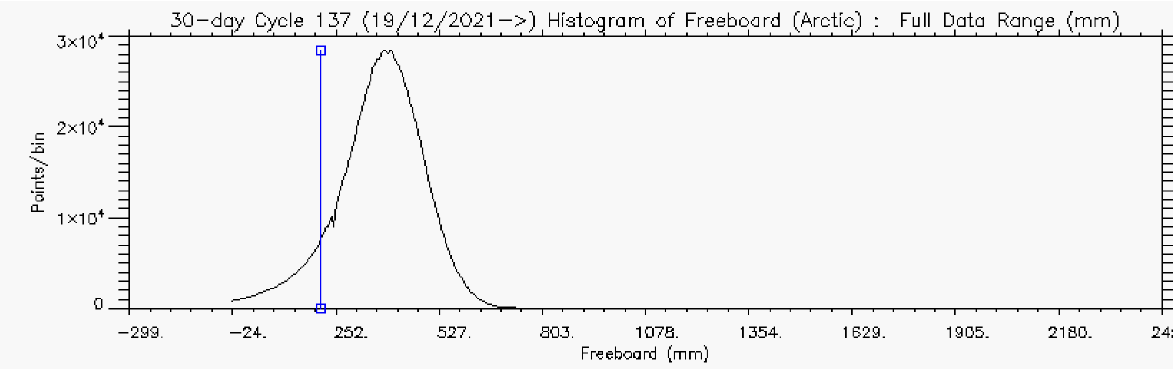


**Figure 5 – Histogram of Freeboard for Arctic (above) and Antarctic (below) for cycle #137**

**During the reporting period, there were no unexpected Quality Flags or errors associated with the computation of the Freeboard values in L2 SAR products.**

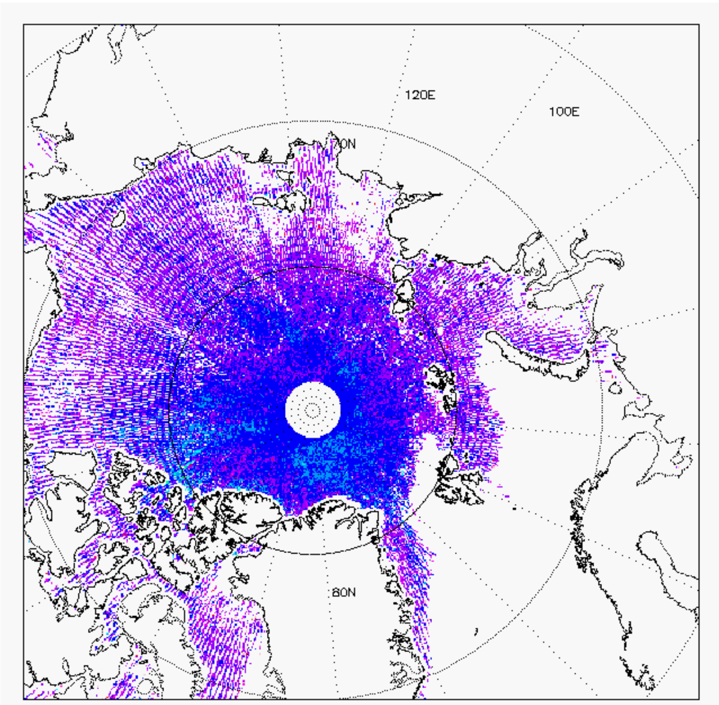


**Figure 6 - Polar plots of 10km Gridded Freeboard values from L2 SAR products in cycle #137.**

### 4.4.2 Sea Surface Height Anomaly

CryoSat L2 data provides the Interpolated Sea Surface Height Anomaly (SSHA) (field #44) for each 20Hz measurement record. The SSHA value is used to compute the Freeboard in the sea-ice processing within the SAR chain; therefore it is not currently output for LRM or SARIn mode.

Figure 7 shows polar plots of the SIRAL SSHA values from L2 products during cycle #137. The values in red indicate areas where SSHA is not provided in SAR mode, over land areas.

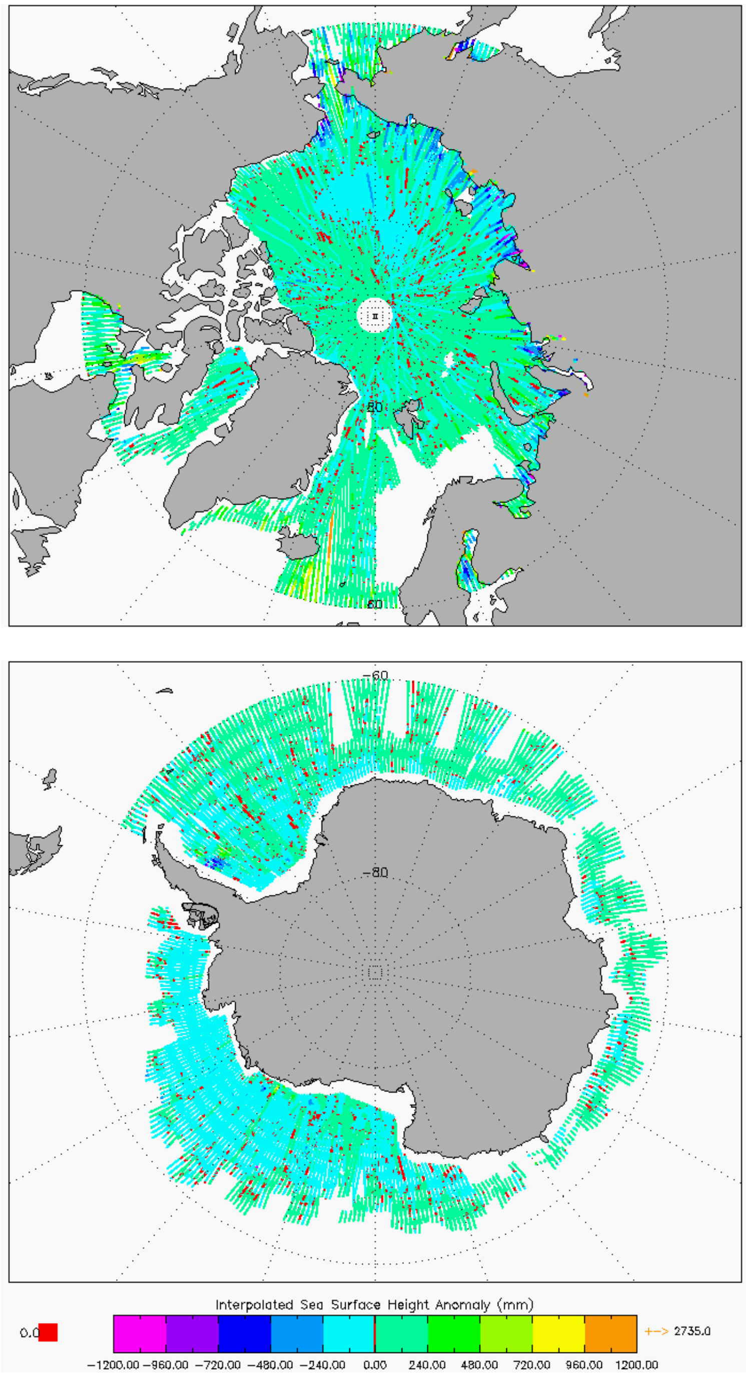


**Figure 7 –Polar plots of SSHA for cycle #137.**

**The values for this reporting period are all within the expected range and no issues are highlighted for this reporting period.**

## 4.5 Retracker Failure Analysis

The table below summarises the retrackers currently used for the CryoSat Baseline-C processing:

**Table 4-2 - Current CryoSat Retrackers in Baseline-C**

| Retracker ID | LRM | SAR | SARIn |
|---|---|---|---|
| 1 | Ocean CFI Model Fit | Laxon/Ridout Sea Ice Model Fit | Wingham/Wallis Model Fit |
| 2 | UCL Land-Ice (LIRT) | | |
| 3 | OCOG | | |

CryoSat L2I products include a Retracker Failure Flag for each 20Hz measurement record (field #75, bits 20, 21, 22) which indicates the overall success or failure of the retracker algorithm for that measurement waveform.

Table 4-3 shows the statistics of retracker failures for this reporting period, cycle #137.

**Table 4-3 - Statistics of Global Retracker Failures for Cycle #137**

| LRM CFI Failed | LRM LIRT Failed | LRM OCOG Failed | SAR Failed | SARIn Failed |
|---|---|---|---|---|
| 16.81 % | 13.85 % | 4.82 % | 1.70 % | 6.75 % |

Figure 8 shows the global retracker failure time series for each of the CryoSat retrackers, from L2I products since the beginning of the mission.

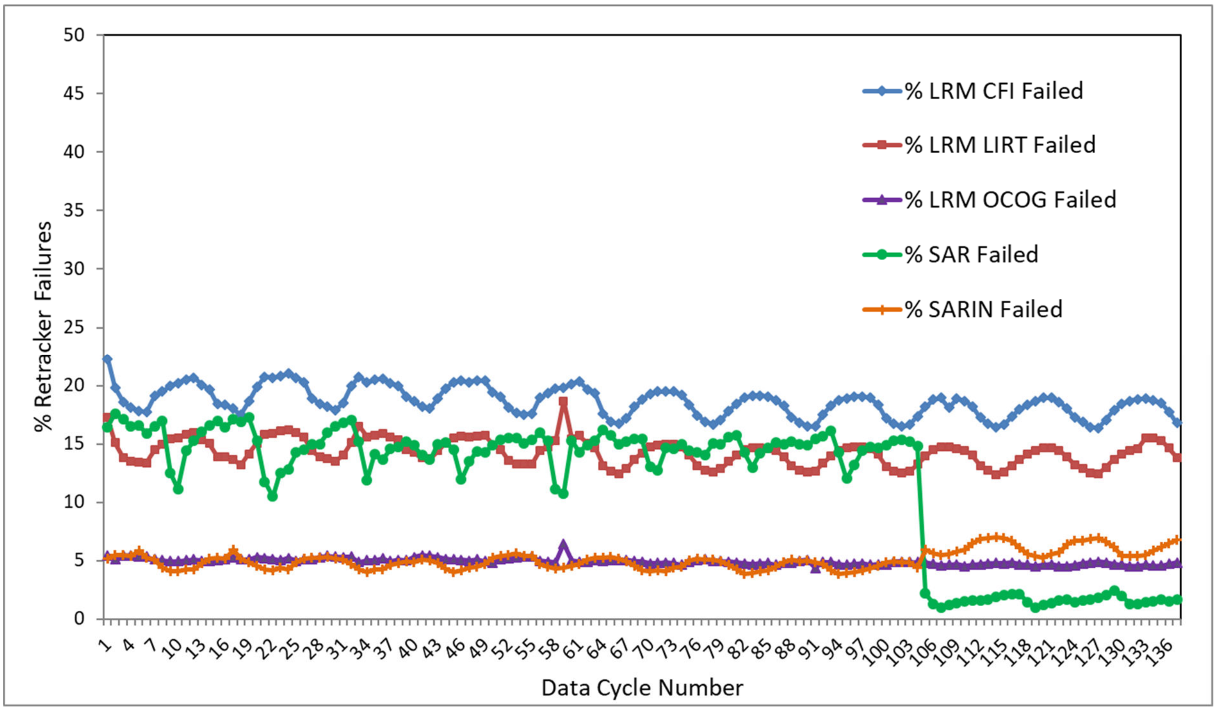


**Figure 8 – Time Series for Retracker Failure Flags**

Figure 9 compares the occurrence of the L2 LRM Retracker Failure Flag (field #75, bits 20,21,22) for each of the LRM Retrackers for cycle #137.

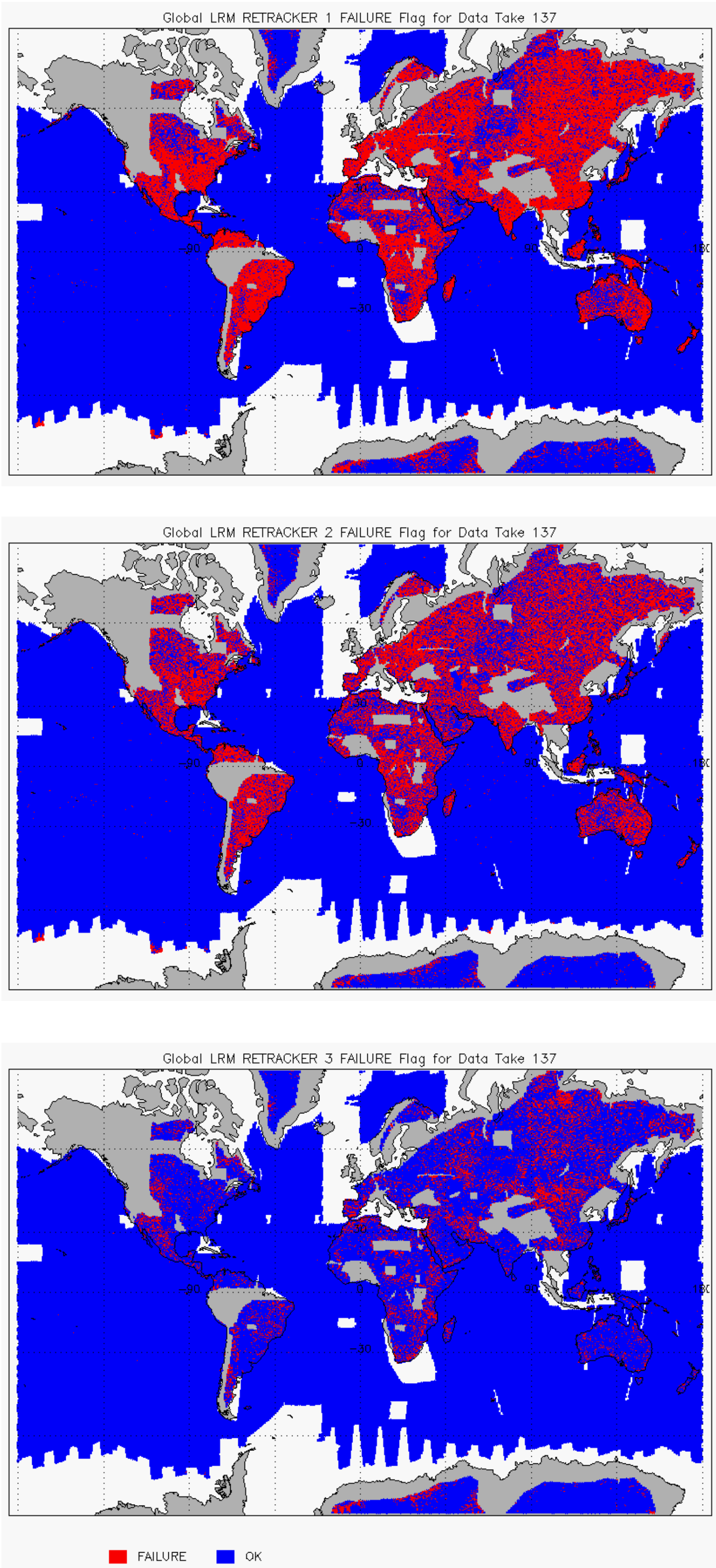


**Figure 9 – Global plots showing Retracker Failure Flags for LRM mode for cycle #137:**

**LRM CFI (top), LRM LIRT (middle), LRM OCOG (bottom)**

Figure 9 shows that the main difference between the failure rates of each of the LRM retrackers is due mainly to failures over land areas for which the OCOG retracker has the least number of failures, followed by the LIRT and then the CFI retracker, which has the most failures over land areas. **This is currently in line with the expected performance of the current LRM retrackers.** Figure 10 and Figure 11 show the occurrence of the L2 SAR and SARIn Retracker Failure Flags (field #75, bit 20) for cycle #137.

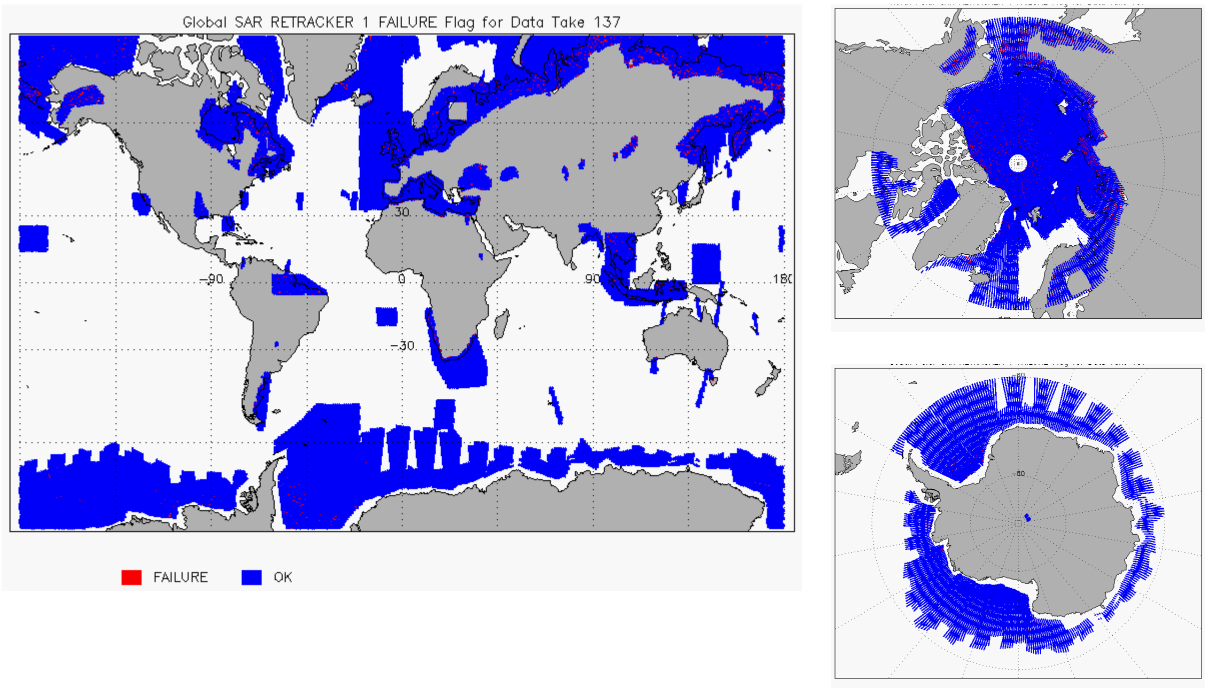


**Figure 10 - Global plots showing Retracker Failure Flags for SAR mode for cycle #137**

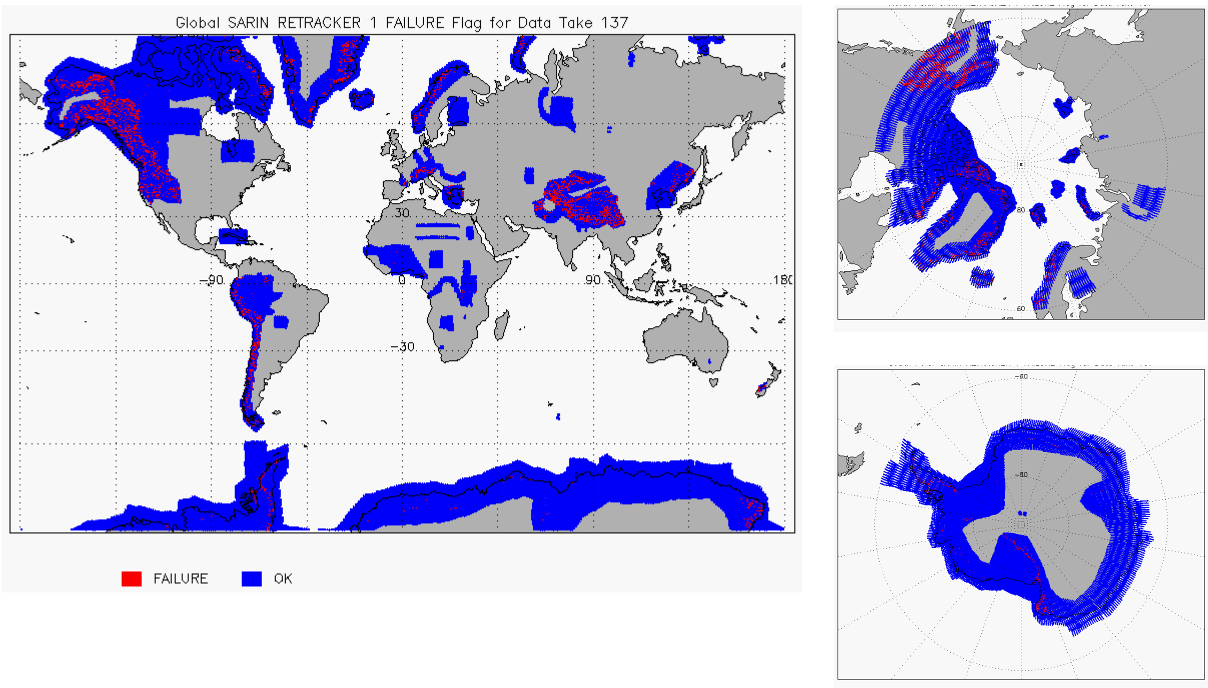


**Figure 11 – Global plots showing Retracker Failure Flags for SARIn mode for cycle #137**

**The retracker failure flags shown above are currently in line with the expected performance of the current SAR and SARIn retrackers.**

## 4.6 Orbit Crossover Derived Parameters

This section provides results from crossover processing of offline L2 data from cycle #137.

The crossover elevations presented in the sections below are calculated by interpolating pairs of slope corrected elevation measurements of ascending and descending arcs to the crossover point and calculating the difference.

It should be noted that the DEM is not removed for this analysis and as L2 data is used in input, the crossover elevations are calculated using the range corrected L2 elevation values. The use of the retracker in the elevation calculation depends on the SIRAL mode; please refer to Table 4-2.

### 4.6.1 Crossover Elevation Statistics and Time Series

Table 4-4 below provides r.m.s elevation difference and the mean difference at crossover, in different modes and areas, from the crossovers generated from L2 data from cycle #137.

**Table 4-4 - Statistics of surface elevation crossover processing for LRM and SARIn data for cycle #137**

| Location | Statistic | LRM | SARIn |
|---|---|---|---|
| **Antarctica (Land)** | **r.m.s (m)** | 0.42 m | 1.82 m |
| | **Mean Difference (m)** | 0.01 m | -0.01 m |
| | **% of xovers < 10.0m** | 60.4 % | 83.1 % |
| **Greenland (Land)** | **r.m.s (m)** | 0.30 m | 1.85 m |
| | **Mean Difference (m)** | 0.02 m | 0 m |
| | **% of xovers < 1.0m** | 81.7 % | 71.9 % |
| **Global Oceans** | **r.m.s (m)** | 0.121 m | |
| | **Mean Difference (m)** | 0.00 m | |
| | **% of xovers < 1.0m** | 98.7 % | |

Figure 12 shows the time series for crossover r.m.s values of surface elevation from CryoSat products since the beginning of the mission for LRM and SARIn modes over Antarctica, Greenland and Global Oceans.

Figure 13 shows the time series of Mean Difference in elevation values at crossovers from CryoSat products since the beginning of the mission for LRM and SARIn modes over Antarctica, Greenland and Global Oceans.

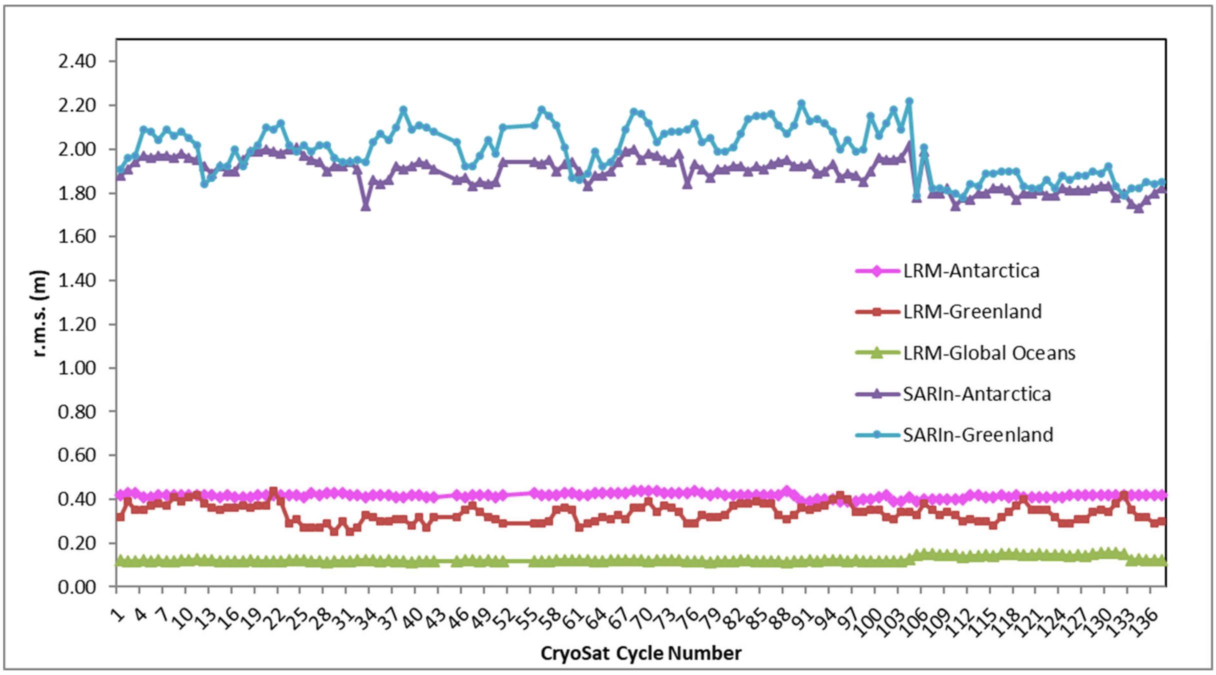


**Figure 12 - Time series for crossover elevation r.m.s values from beginning of the mission**

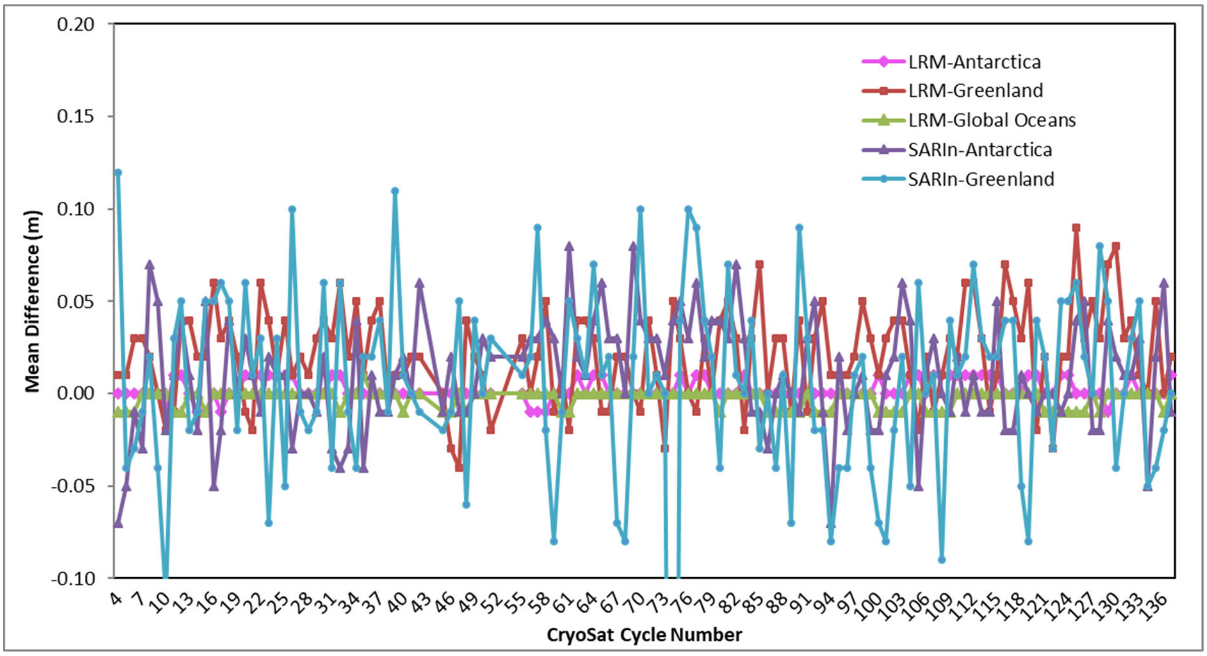


**Figure 13 - Time series for Mean Difference in elevation at crossovers from beginning of the mission**

The mean difference in elevation values at crossovers is expected to be as close to zero as possible. Although Figure 13 shows the values of mean difference to be fluctuating since the beginning of the mission, the mean difference values all remain within the expected range.

In SARIn mode, over Antarctica and especially over Greenland, there is a higher fluctuation in the mean difference; a higher standard deviation would be expected in SARin mode due to the smaller footprint – it is more likely that a slightly different part of the surface is being observed at the crossover point.

In addition, for SARIn mode the footprint is also different for ascending and descending tracks. On the other hand the larger LRM footprint has a smoothing effect and is not dependent on track direction.

### 4.6.2 Crossover Elevation Maps

Figure 14 and Figure 15 show spatial polar maps of elevation differences calculated at crossover per 10 km$^2$ grid cells for L2 products from cycle #137

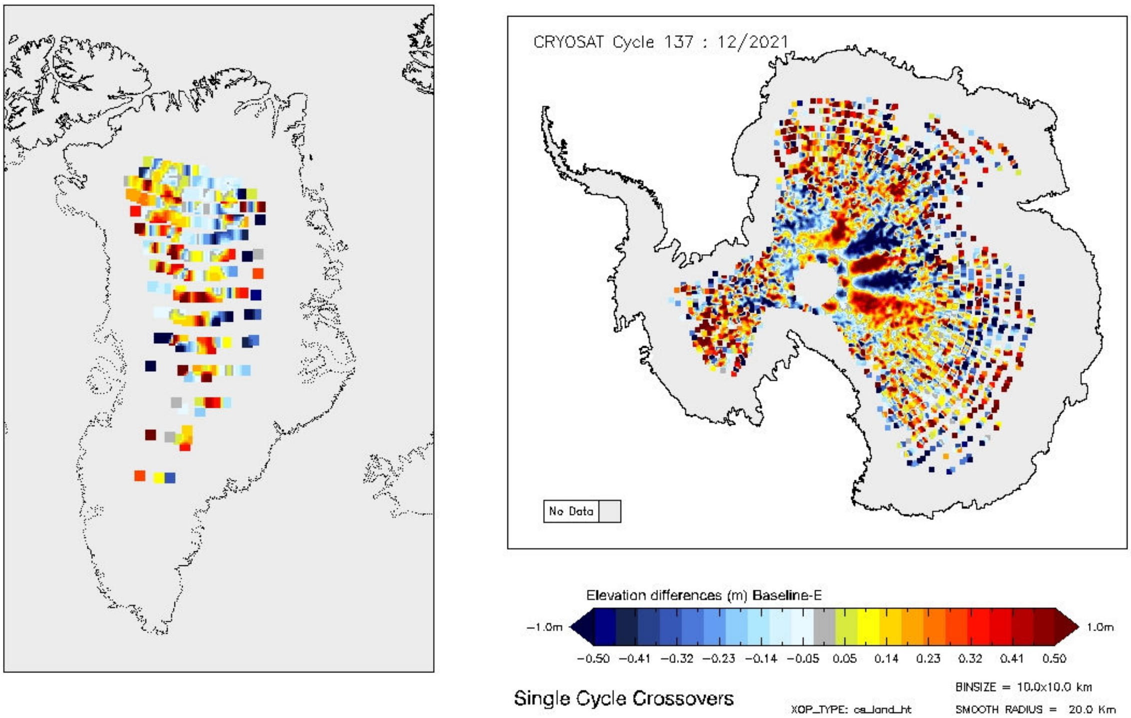


**Figure 14 - Greenland and Antarctica maps of LRM elevation differences for cycle #137.**

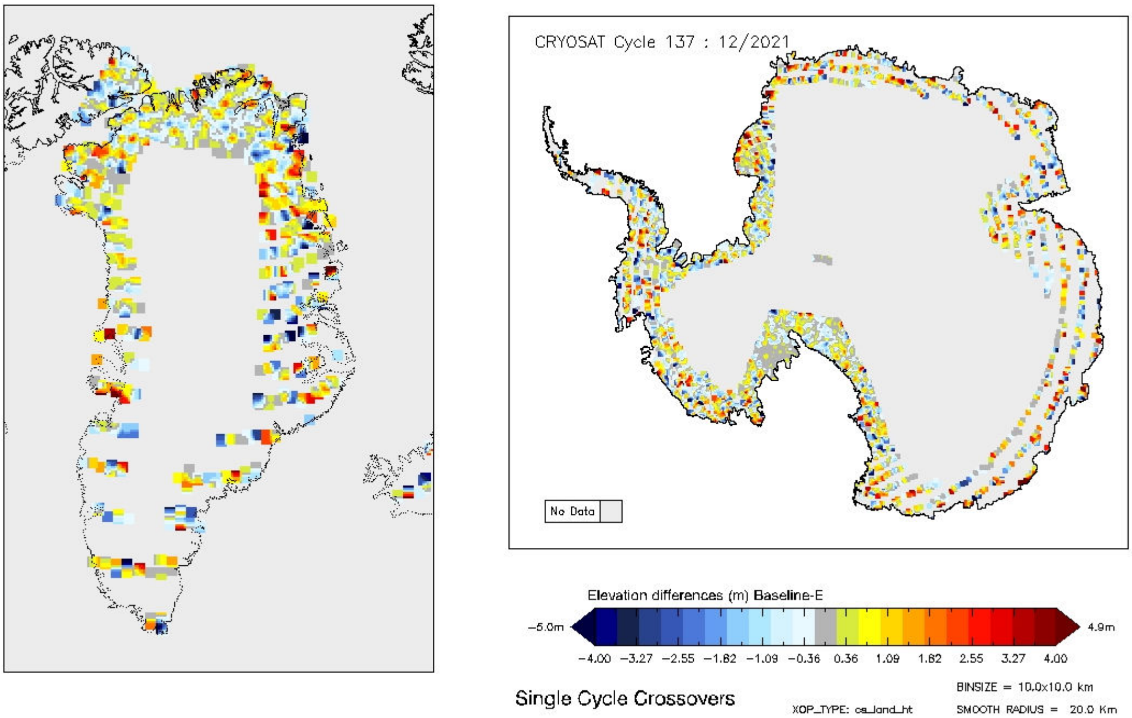


**Figure 15 - Greenland and Antarctica maps of SARIn elevation differences for cycle #137.**

Figure 14 shows an unusual pattern in the ice sheet's elevation near central Antarctica. This static pattern is an artefact arising from the interaction of the polarisation of CryoSat's antenna with the structure of the ice surface induced by wind. Further details can be found at the following webpage: http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat/CryoSat_detects_hidden_Antarctic_pattern

Since the pattern is static, it can be removed by can be removed by users applying an elevation correction (see Armitage *et al.*, 2013, "Meteorological Origin of the Static Crossover Pattern Present in Low-Resolution-Mode CryoSat-2 Data over Central Antarctica"). However, this elevation correction is not currently applied in the CryoSat processing and is therefore not applied in the spatial polar maps above.

## 4.7 L2 Quality Flags

The CryoSat offline L2 data products include a Quality Flag word (field #50) for each 20 Hz measurement record. The bit values of this flag indicate an assessment of the measurement quality by the CryoSat processing chains.

The table below provides the statistics of the main Quality Flags during this reporting period, which can be used to indicate a data quality issue. CryoSat data users should ensure the Quality Flags are checked in the CryoSat data products they are using. In some cases data records which have a Quality Flag set should be discarded by the user prior to any data analysis.

Table 3-1 shows the Quality Flags which were flagged over each surface area during this reporting period; **during cycle #137 there has been no unexpected Quality Flags set in the CryoSat L2 products.**

**Table 4-5 - Percentage of Quality Flags set in L2 products during Cycle #137**

| Quality Flag | LRM Ice | LRM Land | LRM Ocean | SARIn Ice | SARIn Land | SAR Ocean |
|---|---|---|---|---|---|---|
| **Height Error** | 16.93 % | 72.75 % | 0.33 % | 8.43 % | 18.36 % | 1.29 % |
| **Backscatter Error** | 16.69 % | 72.05 % | 0.33 % | 8.39 % | 18.24 % | 1.29 % |

The large number of “Height Error” and “Backscatter Error” Quality Flags, especially over Land and Land Ice, are due to the failure of the altimeter to track the surface over rough surface terrain – this is expected behaviour of the altimeter.

From looking at the plots provided in Section 4.5, it is clear the presence of the Quality Flags shown in Table 4-5 coincide with the failure of the Retrackers in both LRM and SARIn modes.

All users are advised to manually review the quality of the waveforms within their products by looking at the Quality Flags and rejecting any waveforms which have the Height/Backscatter Error Flags set.

## 4.8 External Auxiliary Corrections

Surface Height measurements, which are provided in offline L2 products, are corrected for atmospheric propagation delays and geophysical surface variations.

Table 4-6 provides the r.m.s value and availability of each external correction in the L2 products for cycle #137.

**Table 4-6 – r.m.s value and availability of each external auxiliary correction in the L2 products for cycle #137**

| | Dry Tropospheric Correction | Wet Tropospheric Correction | Inverse Barometric Correction | Dynamic Atmospheric Correction |
|---|---|---|---|---|
| **Availability (%)** | 100% | 100% | 100% | 100% |
| **r.m.s value (mm)** | 2215.69 | 148.277 | 186.825 | 123.667 |

**During this reporting period there were no issues with the availability of auxiliary corrections in the processing of CryoSat products.**

The following sections provide global and polar maps of the value of each correction for cycle #137. Furthermore, the global trend from each 30-day cycle, since the beginning of the mission is also provided.

### 4.8.1 Dry Tropospheric Correction

The Dry Tropospheric Correction is the correction for refraction due to the dry gas component of the atmosphere, which generates a path delay in the radar return signal. For CryoSat, this correction is not received via a direct ADF input, but is computed by the CryoSat processors using dynamic mean surface pressure ECMWF Meteo grids. Figure 16 shows, geographically, the Dry Tropospheric Correction values, applied to the L2 data during cycle #137 and Figure 17 shows the trends in r.m.s values since the beginning of the mission.

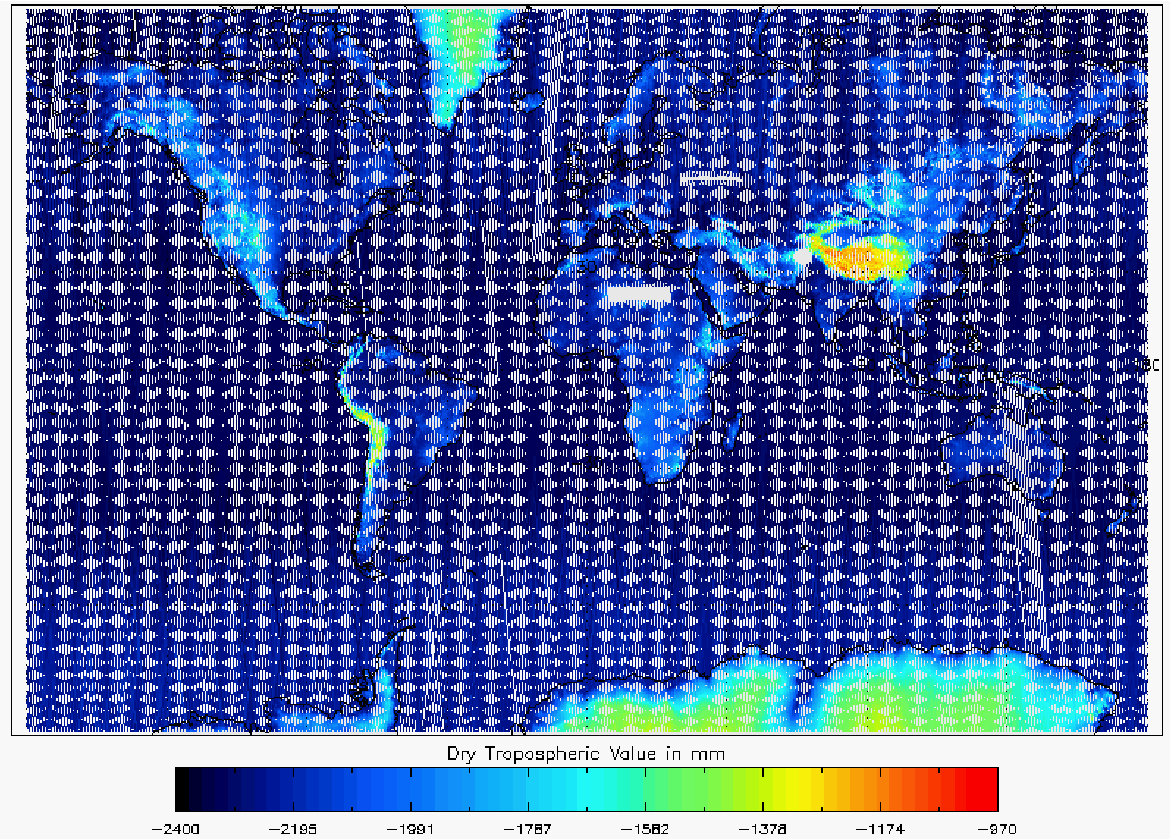


**Figure 16 - Global plot of Dry Tropospheric Correction for cycle #137**

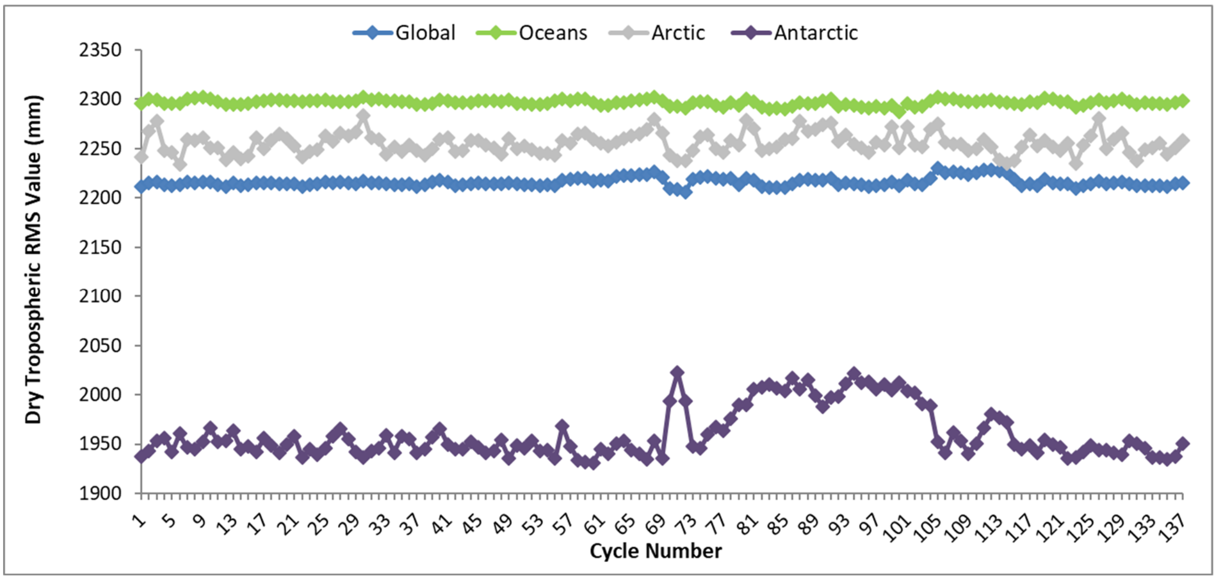


**Figure 17 - Dry Tropospheric Correction RMS value trend from beginning of mission**

### 4.8.2 Wet Tropospheric Correction

The Wet Troposphere Correction is the correction for the path delay in the radar return signal due to liquid water in the atmosphere. Unlike the Dry Tropospheric Correction, the Wet Tropospheric Correction is retrieved as a direct input from ECMWF analysed grids, and is then formatted to the CryoSat PDS file standard before being used by the processor. Figure 18 shows, geographically, the Wet Tropospheric Correction values, applied to the L2 data during cycle #137 and Figure 19 shows the trends in r.m.s values since the beginning of the mission.

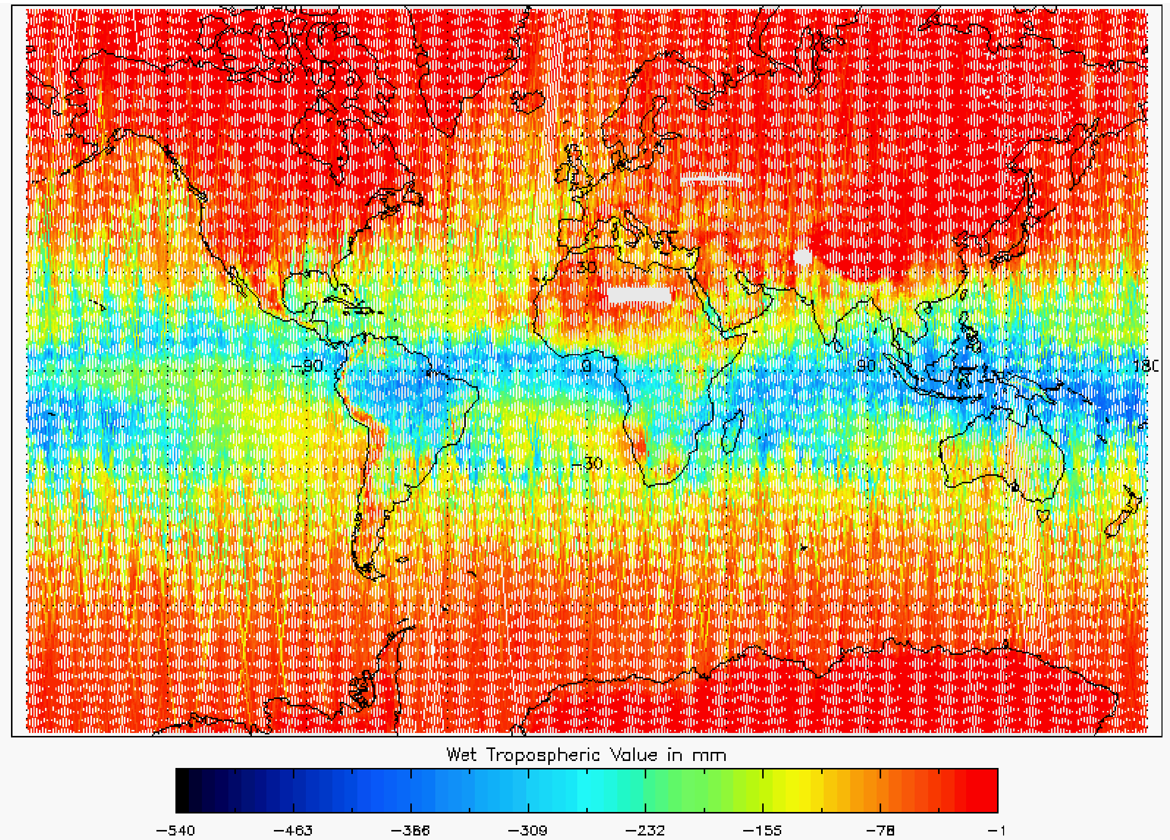


**Figure 18 - Global plot of Wet Tropospheric Correction for cycle #137**

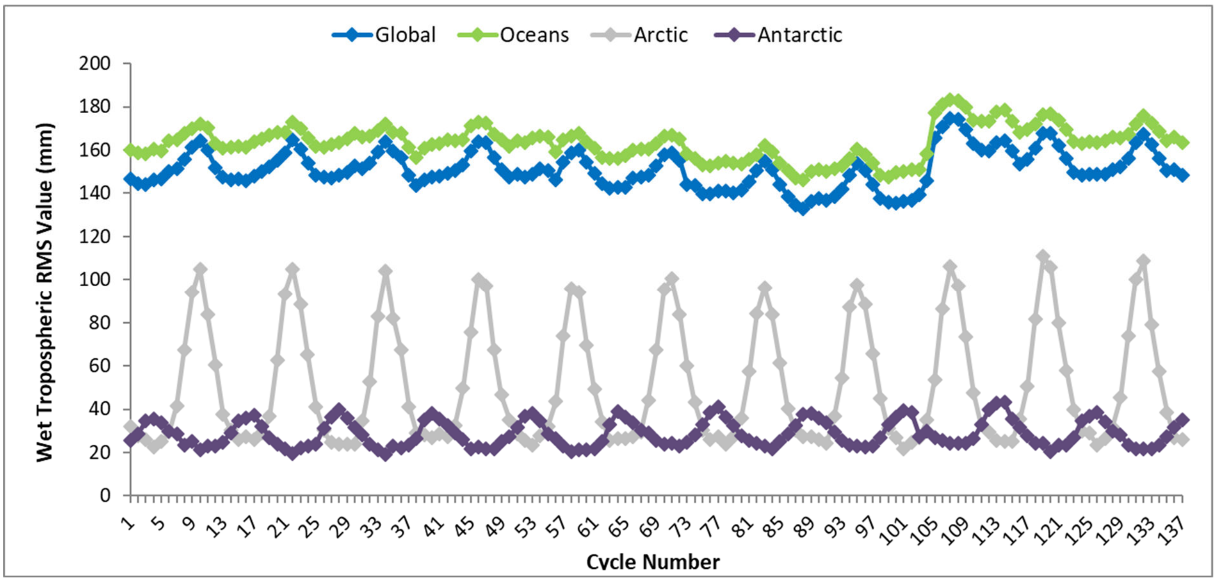


**Figure 19 – Wet Tropospheric Correction RMS value trend from beginning of mission**

### 4.8.3 Inverse Barometric Correction

The Inverse Barometric Correction compensates for variations in sea surface height due to atmospheric pressure variations (atmospheric loading). For CryoSat this is calculated using dynamic surface pressure based on ECMWF outputs. The correction is only used in SAR mode over sea ice and when the surface type is “Open Ocean”. Figure 20 shows, geographically, the value of the Inverse Barometric Correction, applied to the L2 data during cycle #137 and Figure 21 shows the trends in r.m.s values since the beginning of the mission.

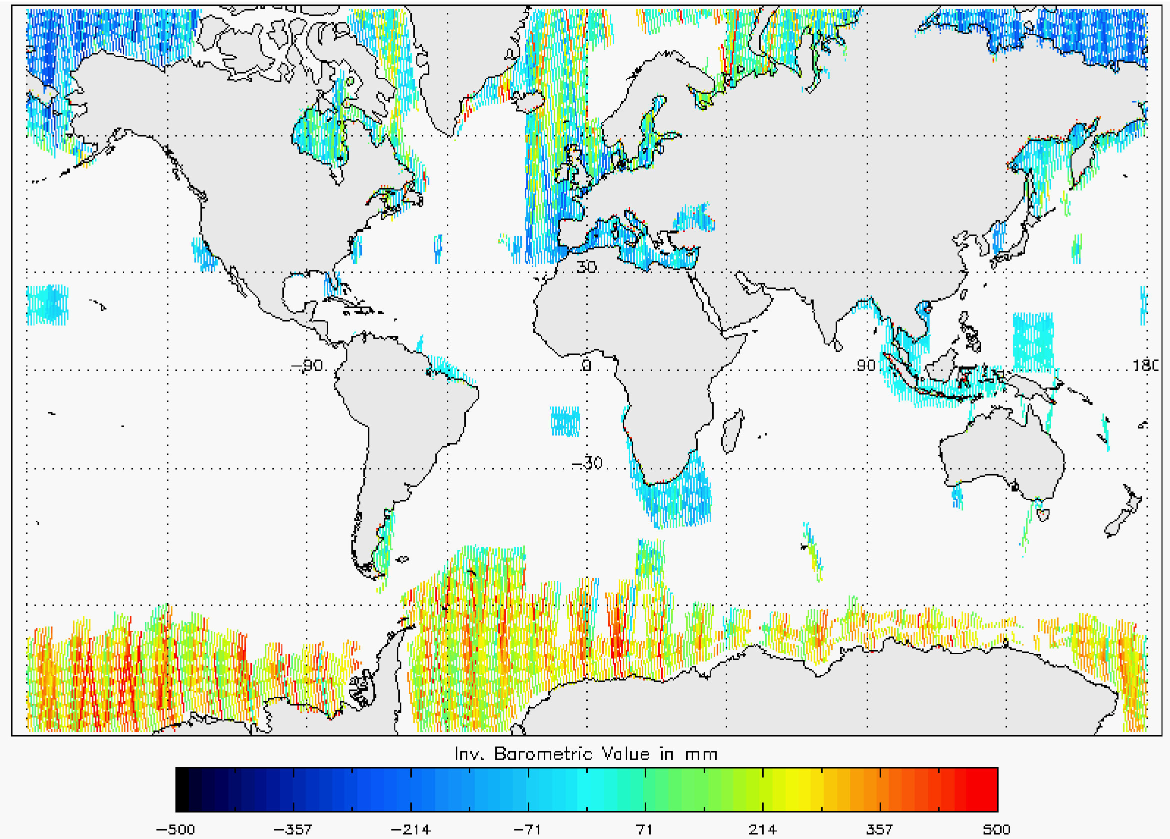


**Figure 20 - Global plot of Inverse Barometric Correction for cycle #137**

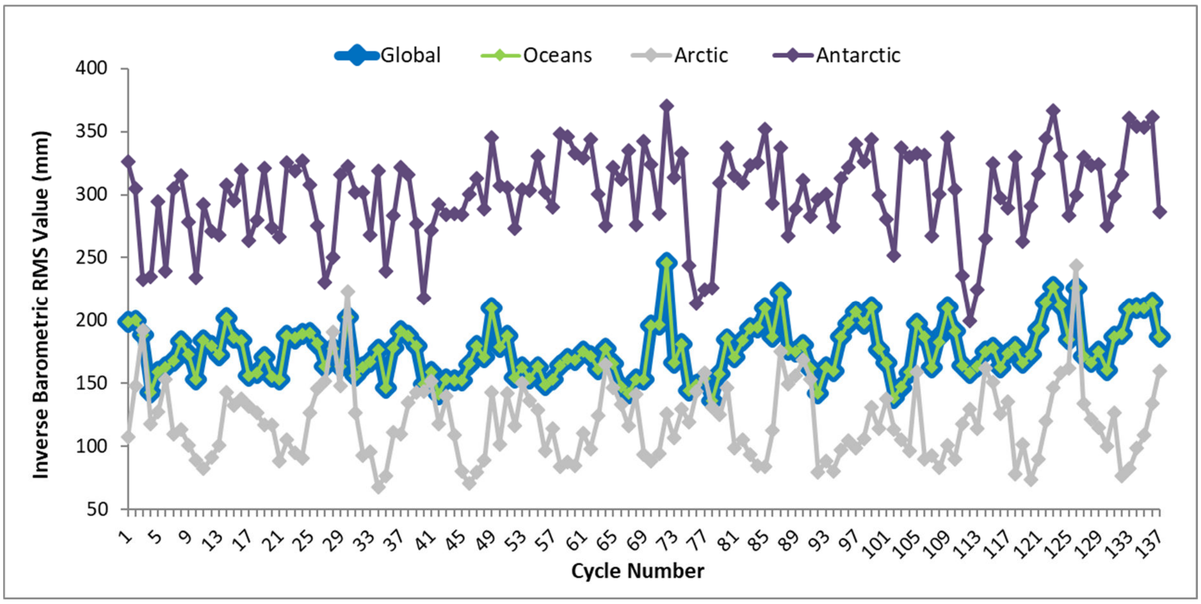


**Figure 21 – Inverse Barometric Correction RMS value trend from beginning of mission**

### 4.8.4 Dynamic Atmospheric Correction

The Dynamic Atmospheric Correction (DAC) is needed to correct for the depression of the ocean surface caused by the local barometric pressure and wind effects. This is provided by Meteo grids and is a combination of the high frequency, high resolution 2D Gravity Waves Model (MOG2D), an ECMWF ocean model, and the low frequency Inverse Barometric (IB) Correction. The correction is used over ocean only where there is no sea-ice cover, i.e. for LRM and in a few cases for SARIn mode when the surface type is "Open Ocean". Figure 22 shows, geographically, the DAC values, applied to the L2 data during cycle #137 and Figure 23 shows the trends in r.m.s values since the beginning of the mission.

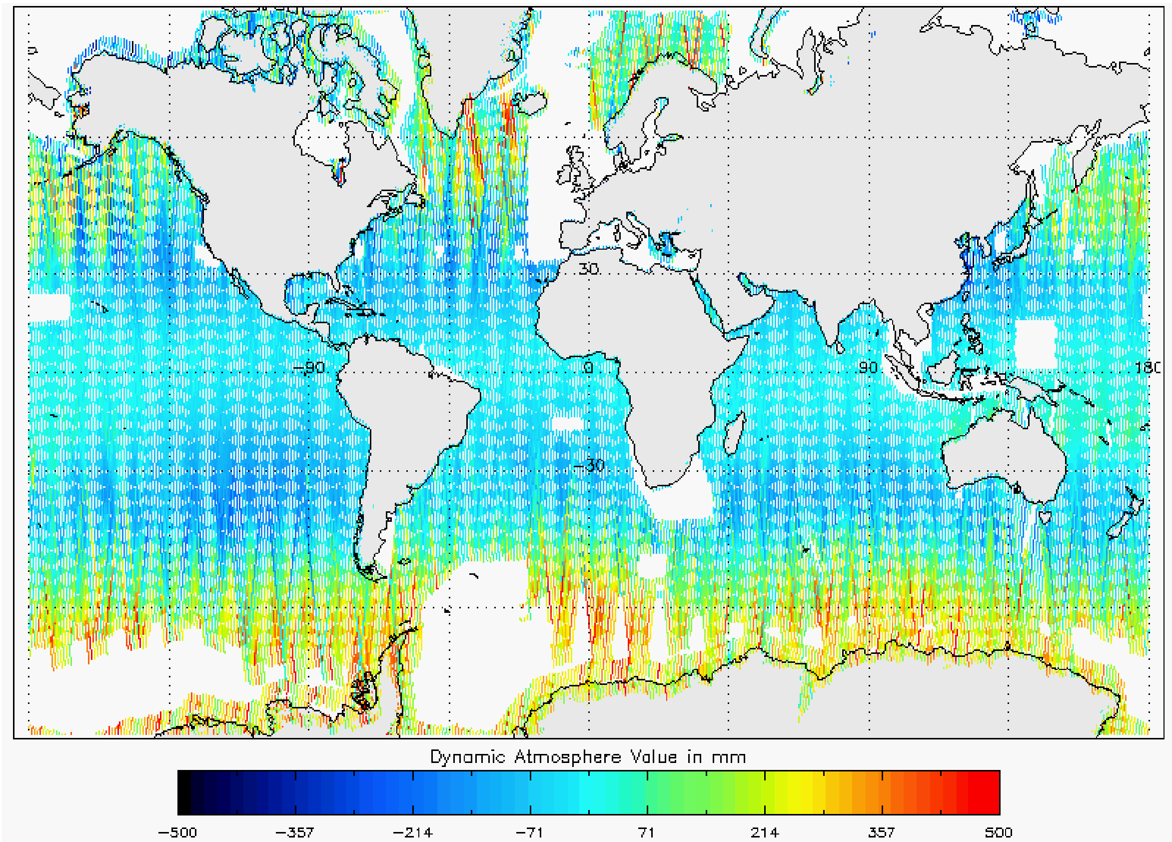


**Figure 22 - Global plot of Dynamic Atmospheric Correction for cycle #137**

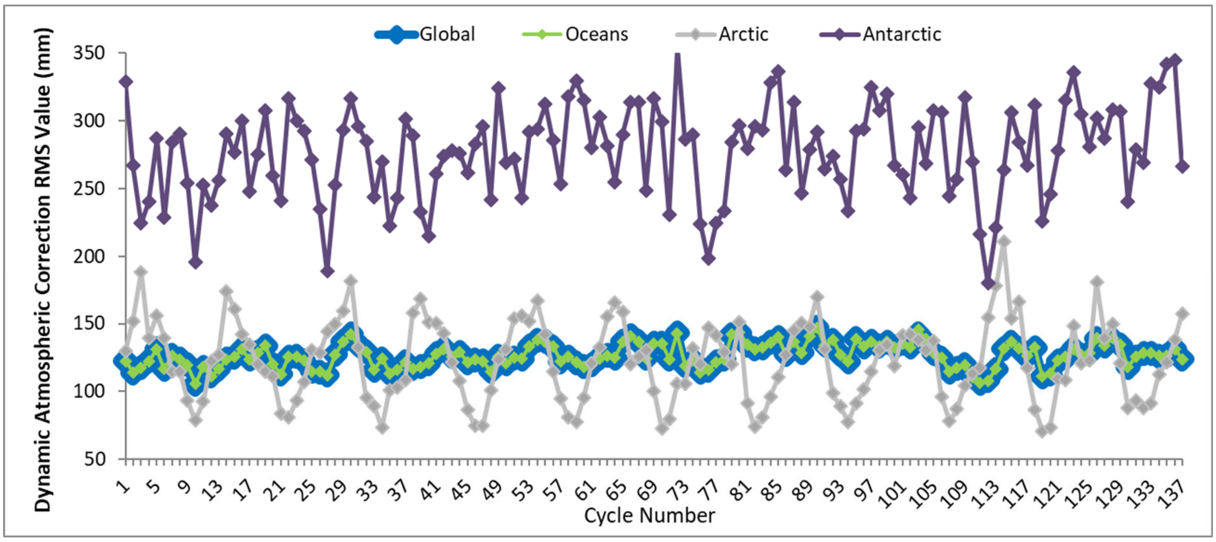


**Figure 23 – Dynamic Atmospheric Correction RMS value trend from beginning of mission**

# 5. ANOMALY REPORTS AND PRODUCT QUALITY DISCLAIMERS

An updated list of ***all known anomalies*** that have been opened and tracked on the IPF and affect the quality of the distributed data products, is provided at the link below:

https://earth.esa.int/eogateway/documents/20142/37627/CryoSat-Ice-Product-Status.pdf