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

S3-A SRAL Cyclic Performance Report

Cycle No. 016

Start date: 25/03/2017

End date: 21/04/2017

SENTINEL 3

Mission Performance Centre

Ref.: S3MPC.ISR.PR.04-016
Issue: 1.0
Date: 26/04/2017
Contract: 4000111836/14/I-LG

Customer:	ESA	**Document Ref.:**	S3MPC.ISR.PR.04-016
Contract No.:	4000111836/14/I-LG	**Date:**	26/04/2017
isardSAT Doc. Ref.:	ISARD_ESA_S3_MPC_RP_534	**Issue:**	1.0

Project:	PREPARATION AND OPERATIONS OF THE MISSION PERFORMANCE CENTRE (MPC) FOR THE COPERNICUS SENTINEL-3 MISSION		
Title:	S3-A SRAL Cyclic Performance Report		
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Distribution:	ESA, EUMETSAT, S3MPC consortium		
Accepted by ESA	P. Féménias, MPC TO		
Filename	S3MPC.ISR.PR.04-016 - i1r0 - SRAL Cyclic Report 016.docx		

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Changes Log

Version	Date	Changes
1.0	26/04/2017	First Version

List of Changes

Version	Section	Answers to RID	Changes

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1 Introduction

1.1 Applicable Documents

AD. 1	PREPARATION AND OPERATIONS OF THE MISSION PERFORMANCE CENTRE (MPC) FOR THE COPERNICUS SENTINEL-3 MISSION, S3MPC.ISR.PR.04-016, issue 1.1, 26/05/2015.

1.2 Acronyms

ADF	Auxiliary Data File
Cal/Val	Calibration / Validation
CNES	Centre National d'Études Spatiales
DEM	Digital Elevation Model
ESA	European Space Agency
ESL	Expert Support Laboratory
ESTEC	European Space Technology Centre
HKTM	House Keeping Temperatures Monitoring
IOCR	In-Orbit Commissioning Review
LRM	Low Resolution Mode
MPC	Mission Performance Centre
PTR	Point Target Response
SAR	Synthetic Aperture Radar
SCCDB	Satellite Calibration and Characterisation Database
SCT	Satellite Commissioning Team
SRAL	Synthetic Aperture Radar Altimeter
TBD	To Be Done

1.3 Scope of the document

This document is dedicated to the cyclic monitoring report of the SRAL calibration parameters within the Sentinel-3 MPC project. Also a whole mission analysis is given.

It will be distributed during the Routine Operations Phase to the MPC team on a cyclic basis. The MPC team is in charge of its official delivery to ESA and EUMETSAT.

2 SRAL Internal Calibration Monitoring.

2.1 Introduction

The SRAL instrumental calibration is assessed during the mission. Several parameters are monitored and analysed in detail in order to characterise the altimeter performance along the mission lifetime.

Two main groups of calibration parameters are monitored.

The first is derived from the Point Target Response (PTR) calibration in CAL1 mode. The PTR signal follows the same circuitry path as the science waveforms within the calibration loop. The delay caused by the travel through the calibration path can be measured and afterwards compensated in the total range computation. The attenuation suffered by the signal when traveling through the instrument also needs to be monitored and the science waveforms need to be compensated for this power variations. Moreover, there are a collection of other parameters to be checked, such as the PTR width and the secondary lobes features. These CAL1 parameters are produced separately for LRM and SAR modes, as they follow different instrumental paths, and also they are duplicated for Ku-band and C-band. Moreover there are different options for characterising the delay and power of the closed loop signal, such as the PTR maximum power or PTR maximum position.

The second is related to the Instrument Transfer Function, measured by the CAL2 mode. The science waveforms spectra is distorted by the on-board instrumental hardware sections. Therefore, in order to retrieve the original echo shape, we need to compensate for this effect. Several parameters are derived from the analysis of the CAL2 waveforms for characterizing it and dissect any feature along the mission lifetime. The CAL2 waveform is the same for both modes LRM and SAR, but there is a distinction between bands Ku and C.

Additionally, for SAR mode, the two intra-burst corrections are monitored: they are the power and phase progressions within a burst. Science pulses within a burst are to be corrected for these expected variations in the burst. Some characteristics are computed for describing and following up their behaviour along the S3 mission.

It is also of major importance the monitoring of the on-board clocks. The altimeter clock counter, responsible for computing the echo travel time, has a multiplicative impact in the range determination. The platform clock is responsible for the overall platform instruments datation. Their stability and performance are to be supervised along the mission.

Finally, the data coming from the thermistors located in the different sections of the on-board HW (HKTM products), are to be analysed in order to check the relation of any calibration parameters anomaly with the thermal behaviour, and find solutions for modelling the instrument characterisation (for instance orbital oscillations) if needed.

An important remark is to be made: although we can see a certain drift of a specific calibration parameter along the mission, this is not to be considered as a warning for the quality of the science data, as long as the instrumental calibration is correctly applied during the science data processing. A warning shall be raised in the scenario of a calibration parameter value approaching the mission requirement bounds.

2.2 Cyclic In-Flight Internal Calibration.

In this chapter, the monitoring of all calibration modes main parameters is depicted in figures. An analysis of the cycle results is developed in chapter 2.3.

2.2.1 CAL1 LRM

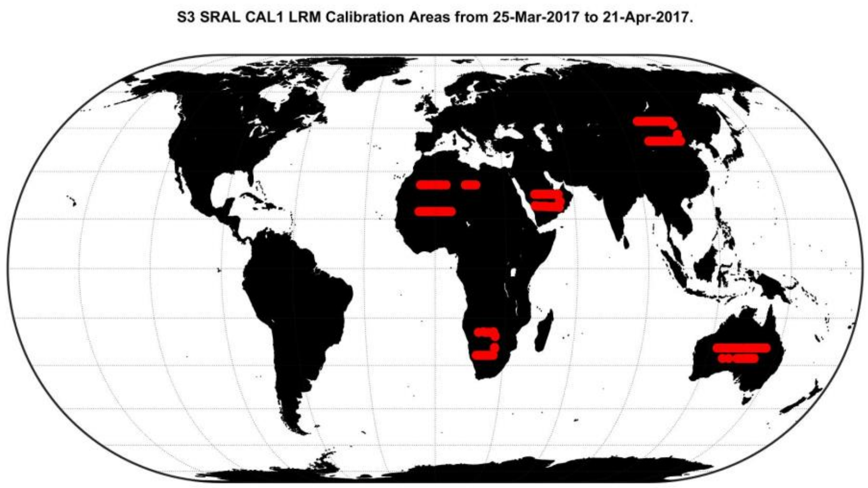

Figure 2.2-1. Location of the CAL1 LRM measurements.

Period trend of all CAL1 PTR Delay related variables for LRM mode.

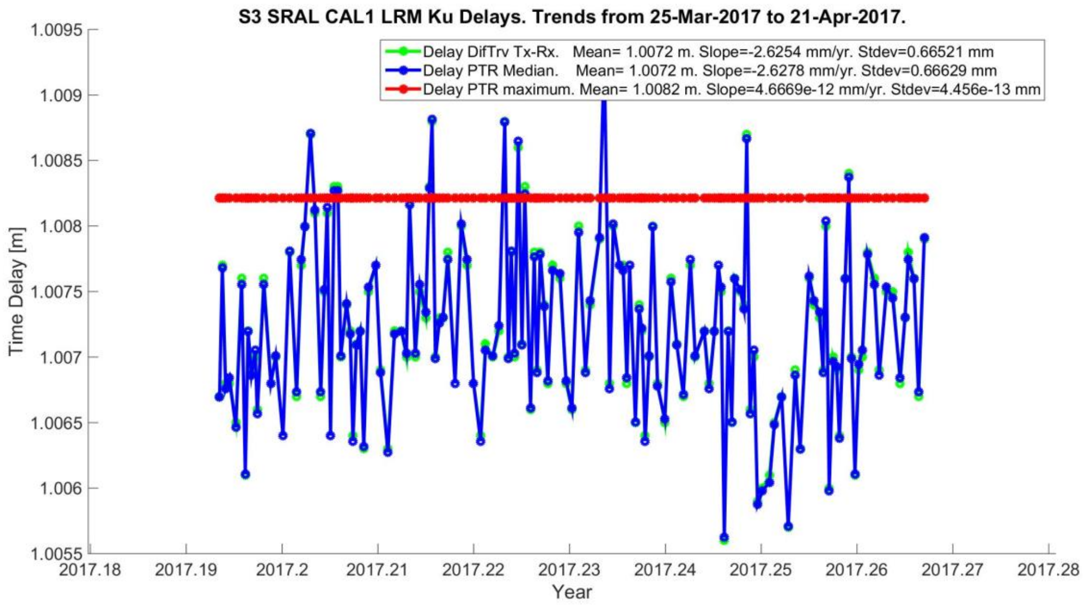

Figure 2.2-2. CAL1 LRM Ku Time Delay related variables trend. The green line (Diff of travel between Tx & Rx lines) is hidden below the blue line (PTR Median Delay).

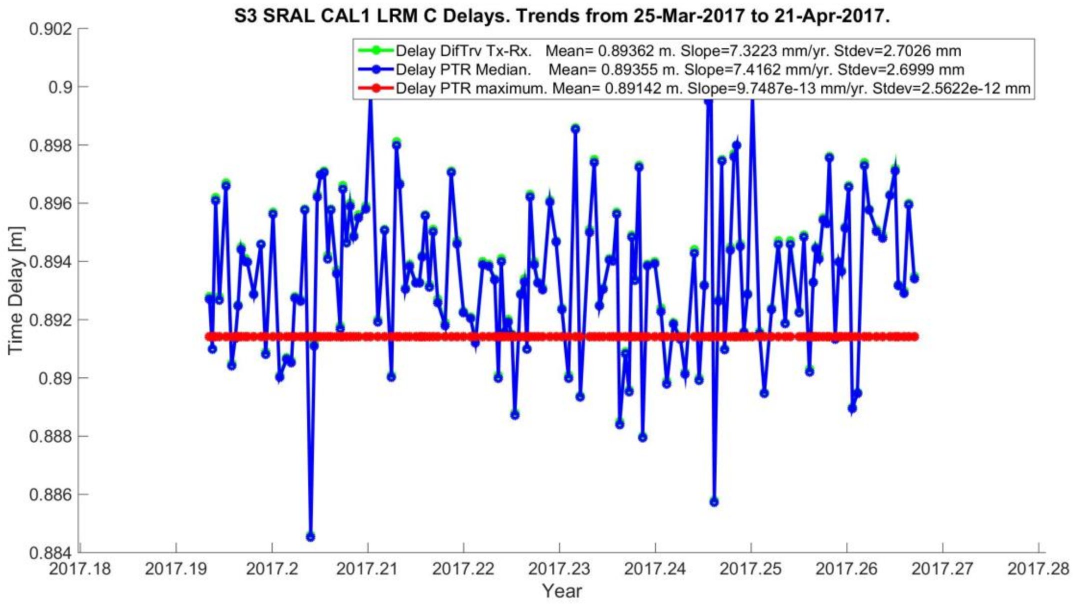

Figure 2.2-3. CAL1 LRM C Time Delay related variables trend.

Period trend of the PTR Total and Maximum Power for LRM mode.

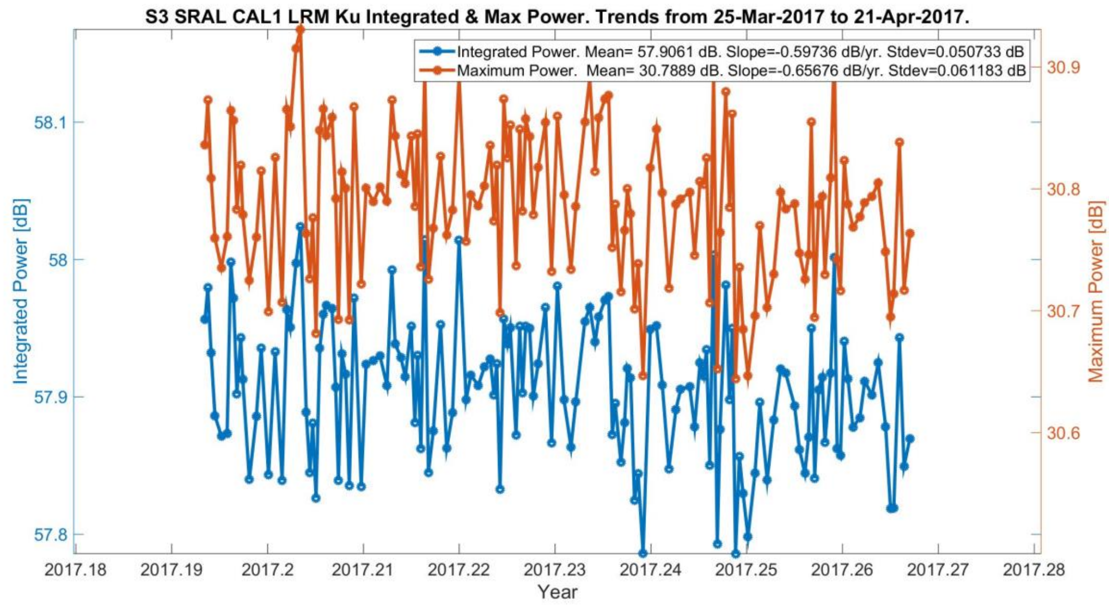

Figure 2.2-4. CAL1 LRM Ku Power Trend.

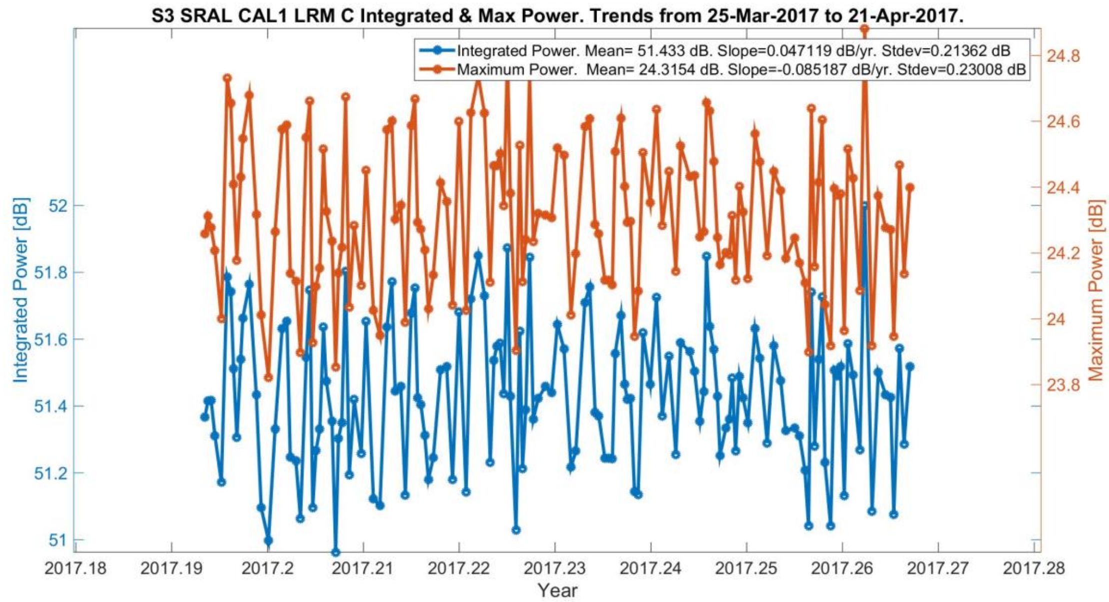

Figure 2.2-5. CAL1 LRM C Power Trend.

Period trend of the CAL1 PTR width for LRM mode.

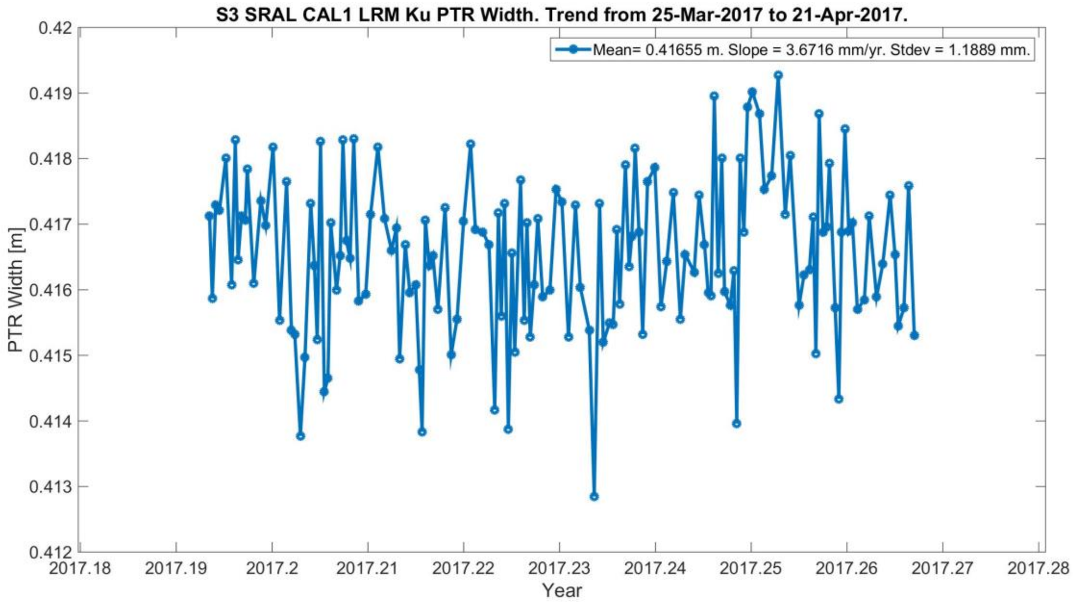

Figure 2.2-6. CAL1 LRM Ku PTR width trend.

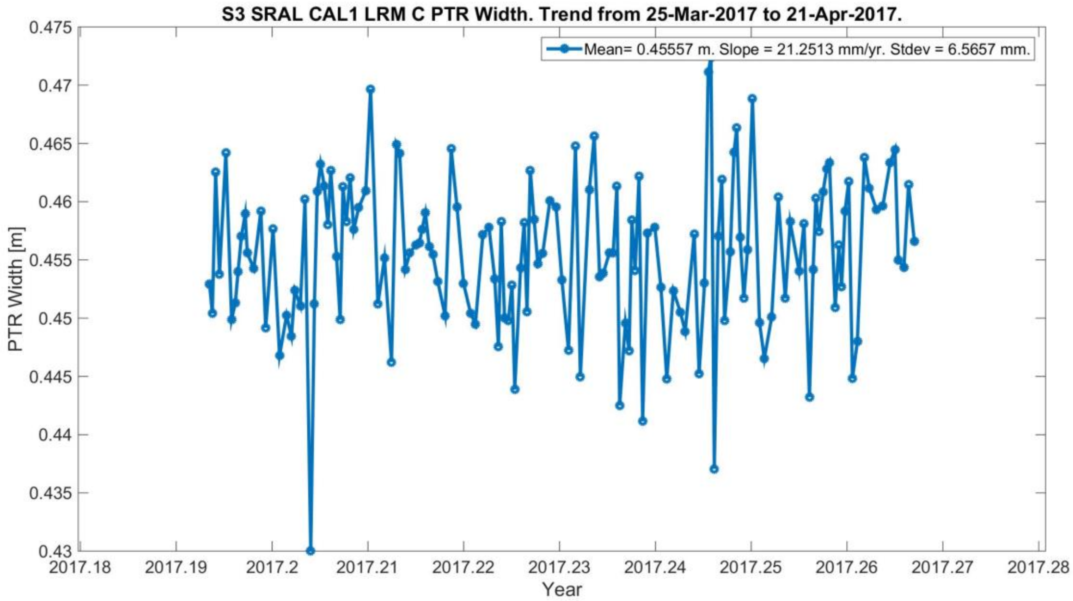

Figure 2.2-7. CAL1 LRM C PTR width trend.

Distribution of the PTR secondary lobes within the CAL1 PTR waveform for LRM mode.

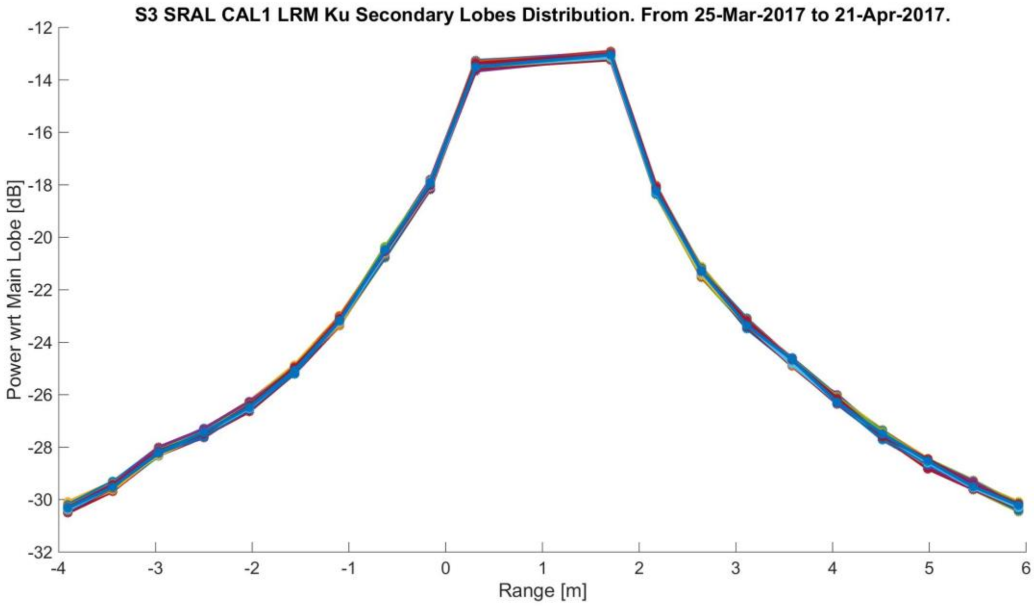

Figure 2.2-8. CAL1 LRM Ku PTR secondary lobes Power and Position within the PTR waveform.

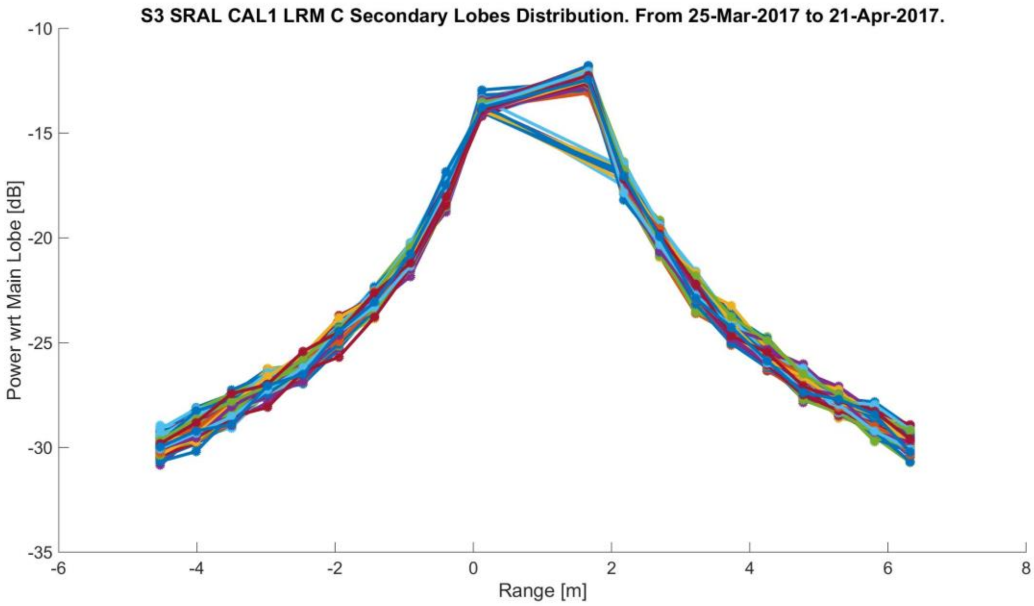

Figure 2.2-9. CAL1 LRM C PTR secondary lobes Power and Position within the PTR waveform.

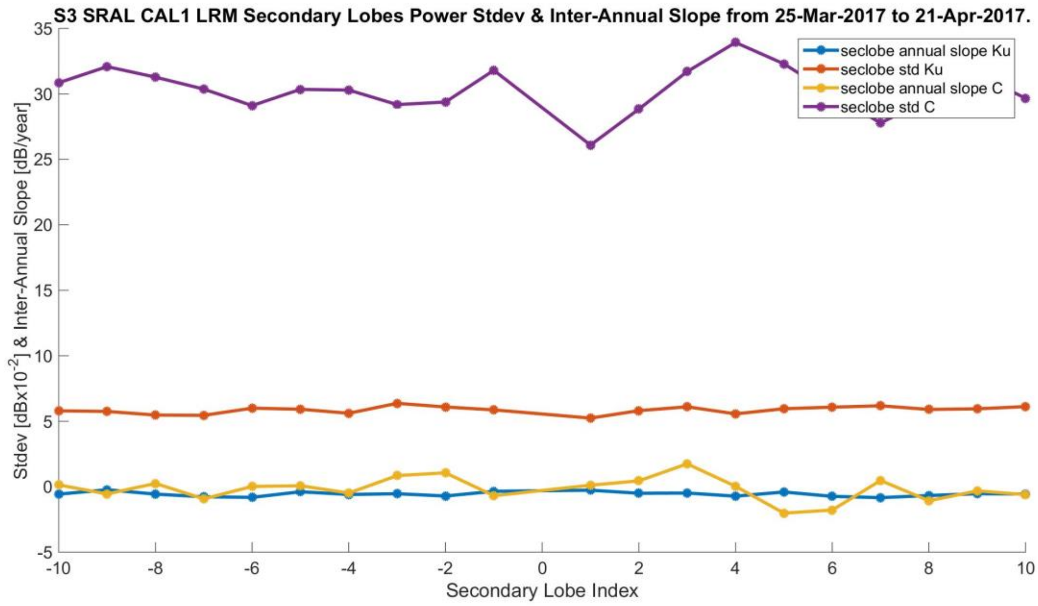

Figure 2.2-10. CAL1 LRM PTR secondary lobes characterisation. The inter-annual slope (in dB/year) and standard deviation (in dBx10^-2) of each of the secondary lobes during the period are shown.

2.2.2 CAL1 SAR

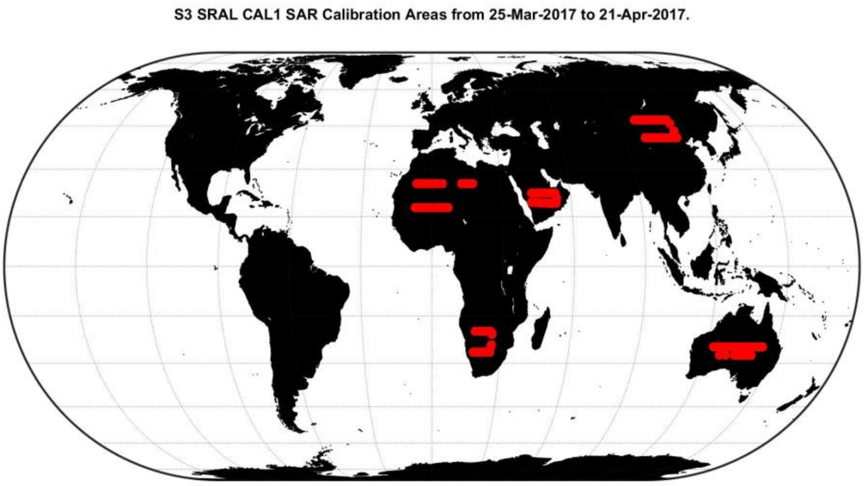

Figure 2.2-11. Location of the CAL1 SAR measurements.

Period trend of all CAL1 PTR Delay related variables for SAR mode.

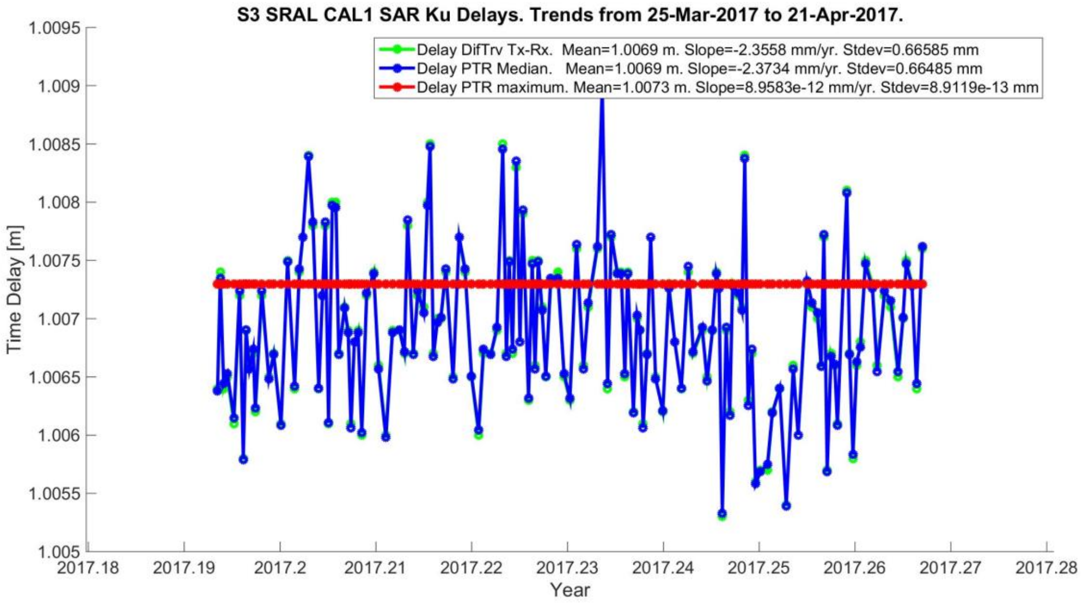

Figure 2.2-12. CAL1 SAR Ku Time Delay related variables trend.

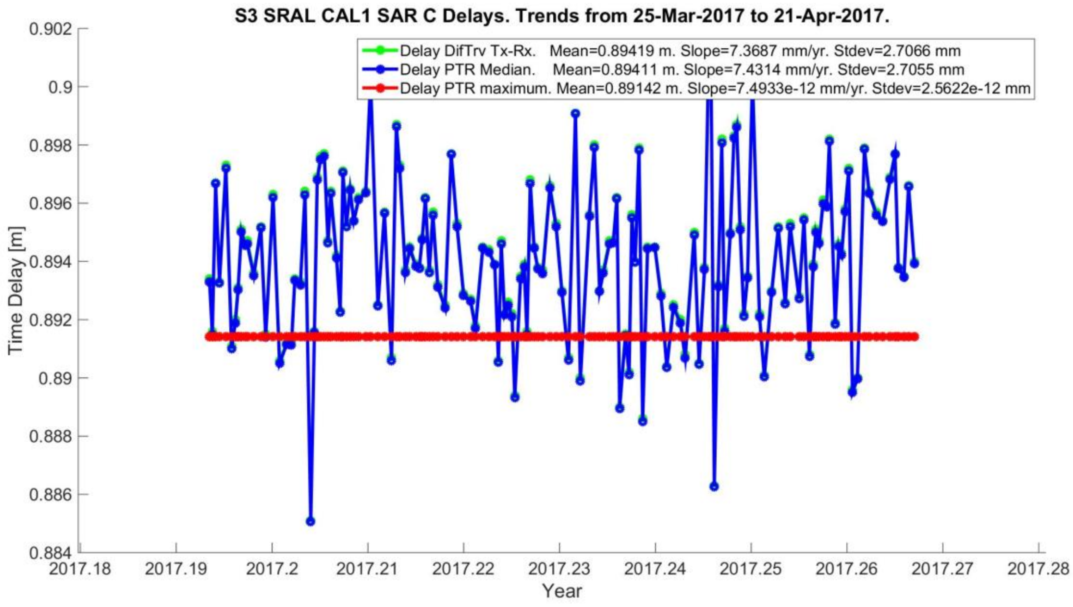

Figure 2.2-13. CAL1 SAR C Time Delay related variables trend. The green line (Diff of travel between Tx & Rx lines) is hidden below the blue line (PTR Median Delay).

Period trend of the PTR Total and Maximum Power for SAR mode.

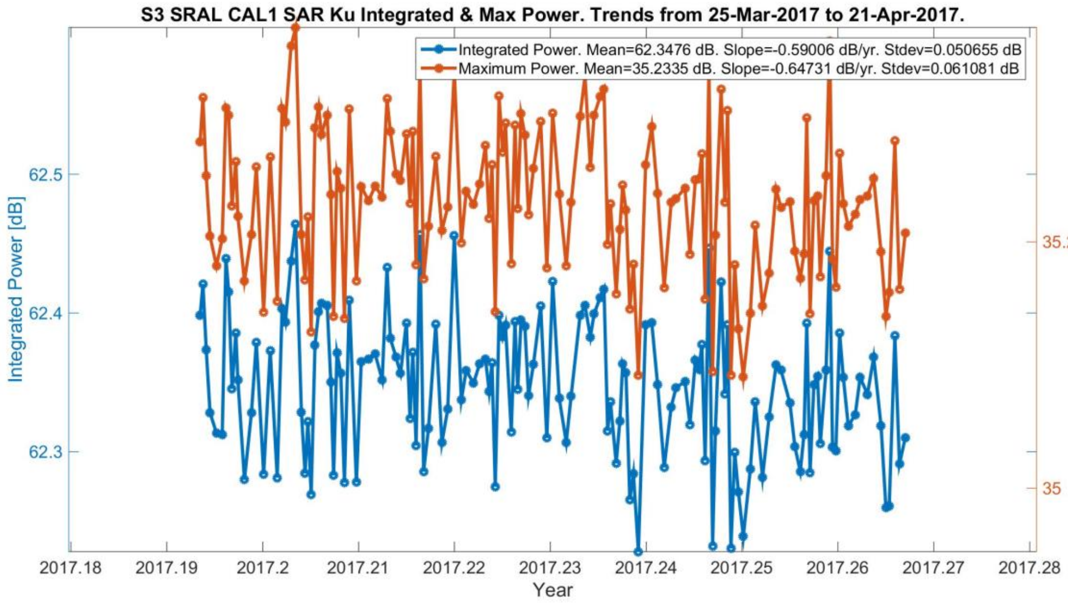

Figure 2.2-14. CAL1 SAR Ku Power Trend.

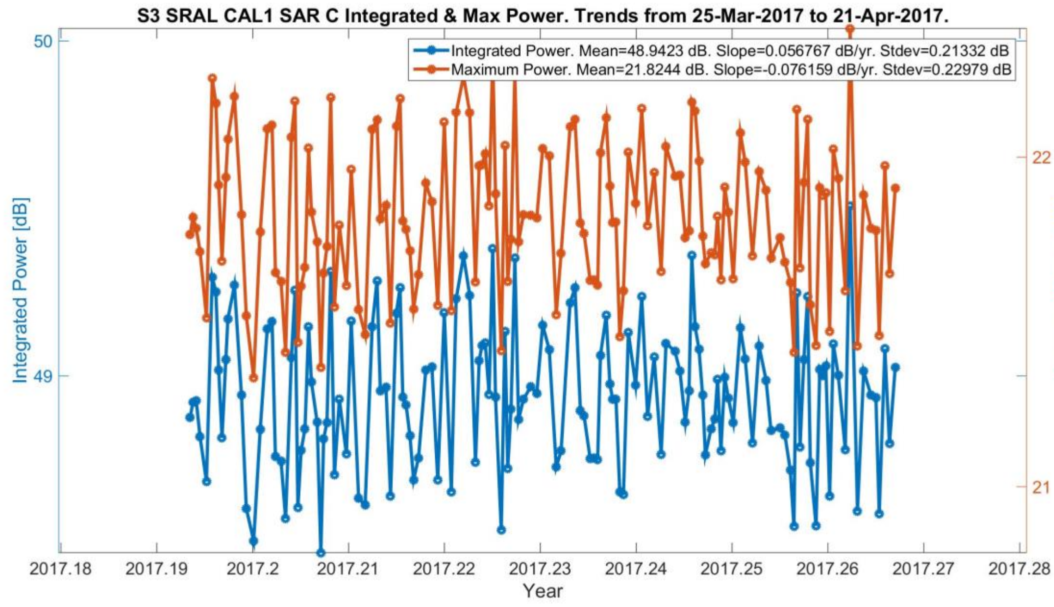

Figure 2.2-15. CAL1 SAR C Power Trend.

Period trend of the CAL1 PTR width for SAR mode.

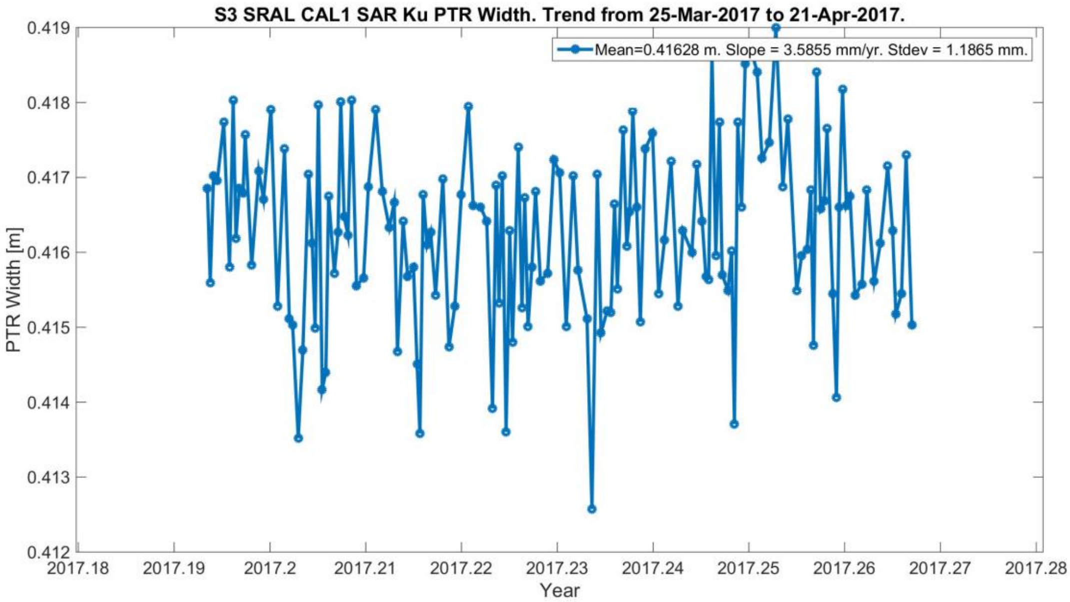

Figure 2.2-16. CAL1 SAR Ku PTR width trend.

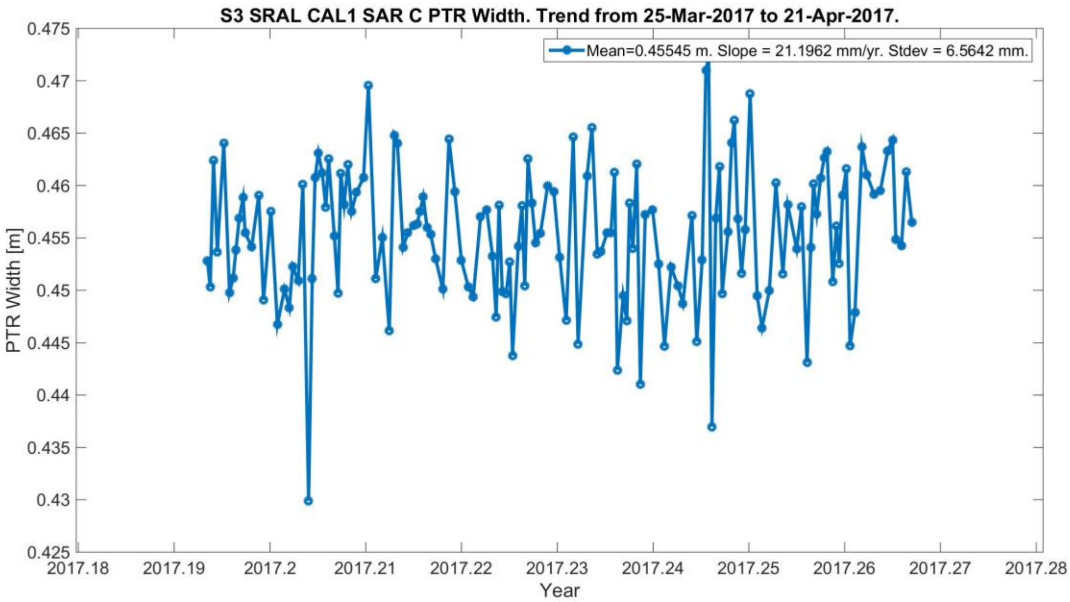

Figure 2.2-17. CAL1 SAR C PTR width trend.

Distribution of the PTR secondary lobes within the CAL1 PTR waveform for SAR mode.

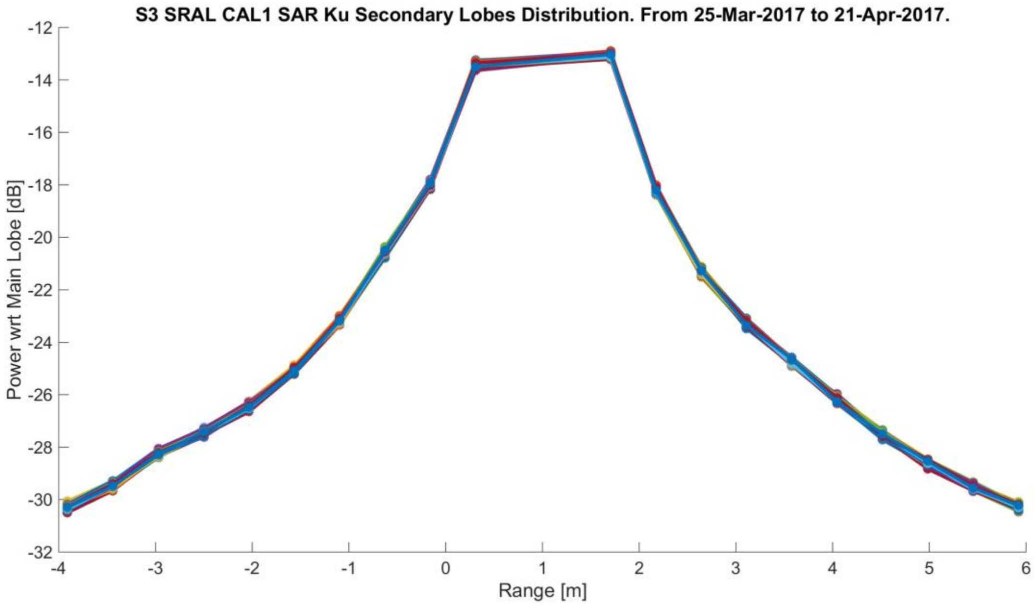

Figure 2.2-18. CAL1 SAR Ku PTR secondary lobes Power and Position within the PTR waveform.

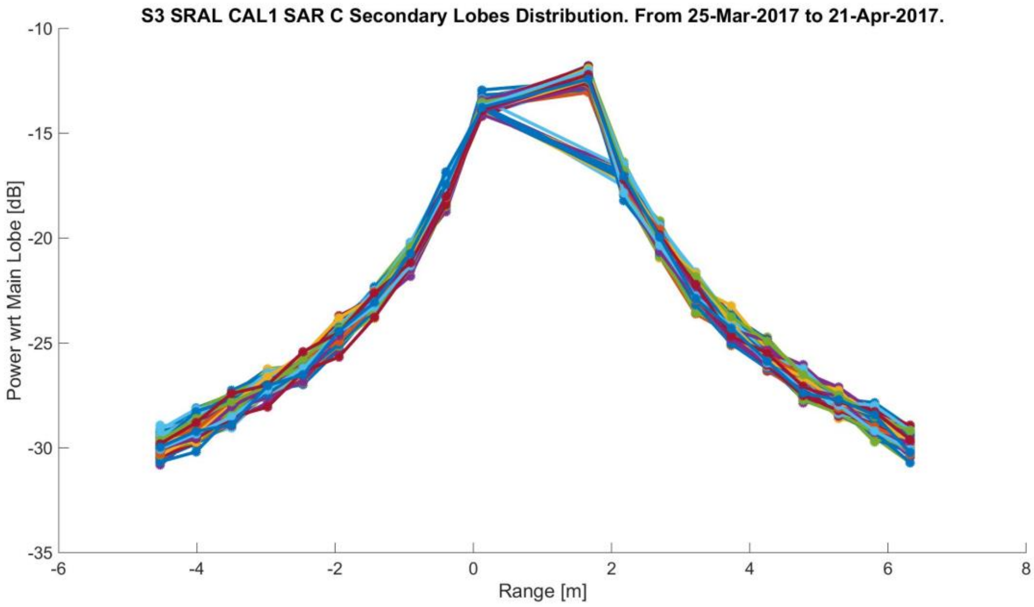

Figure 2.2-19. CAL1 SAR C PTR secondary lobes Power and Position within the PTR waveform.

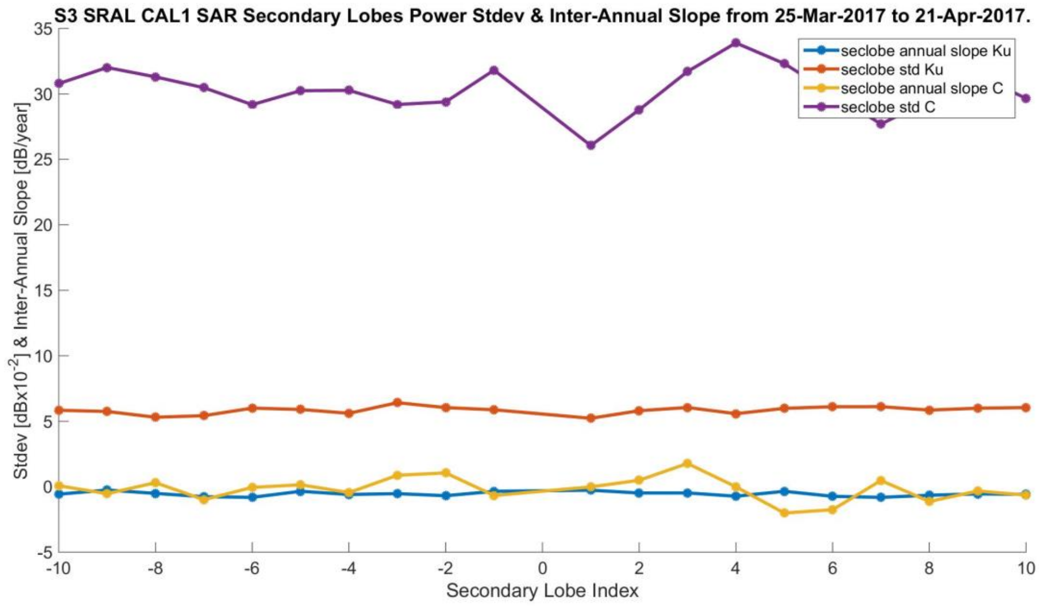

Figure 2.2-20. CAL1 SAR PTR secondary lobes characterisation. The inter-annual slope (in dB/year) and standard deviation (in dBx10^-2) of each of the secondary lobes during the analysed period are shown.

CAL1 SAR mode Ku intra-burst corrections: Power and Phase.

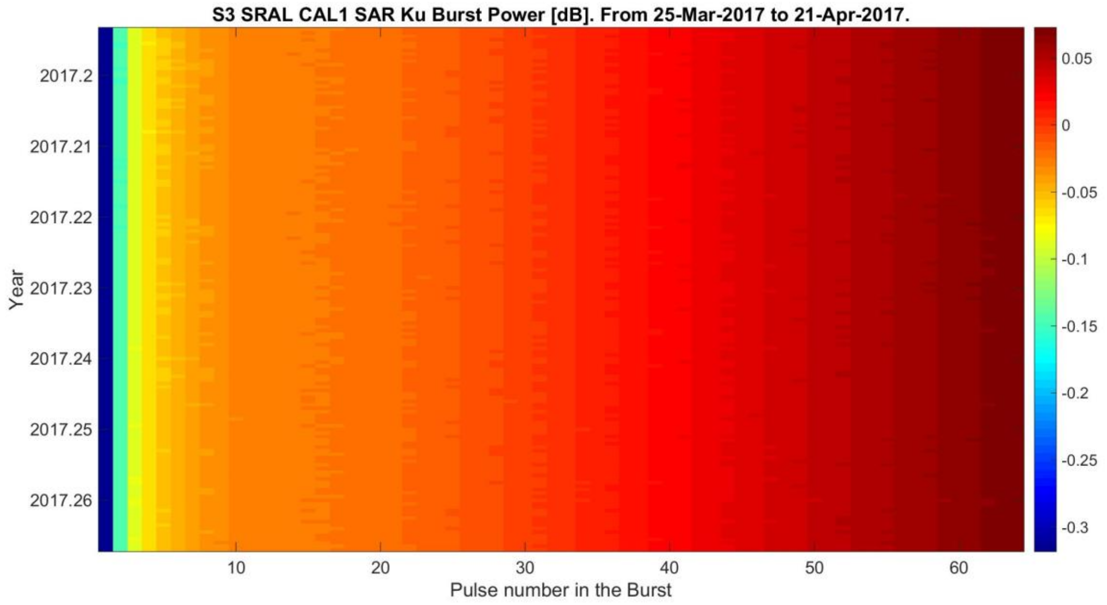

Figure 2.2-21. CAL1 SAR Ku Power intra-burst correction along the period.

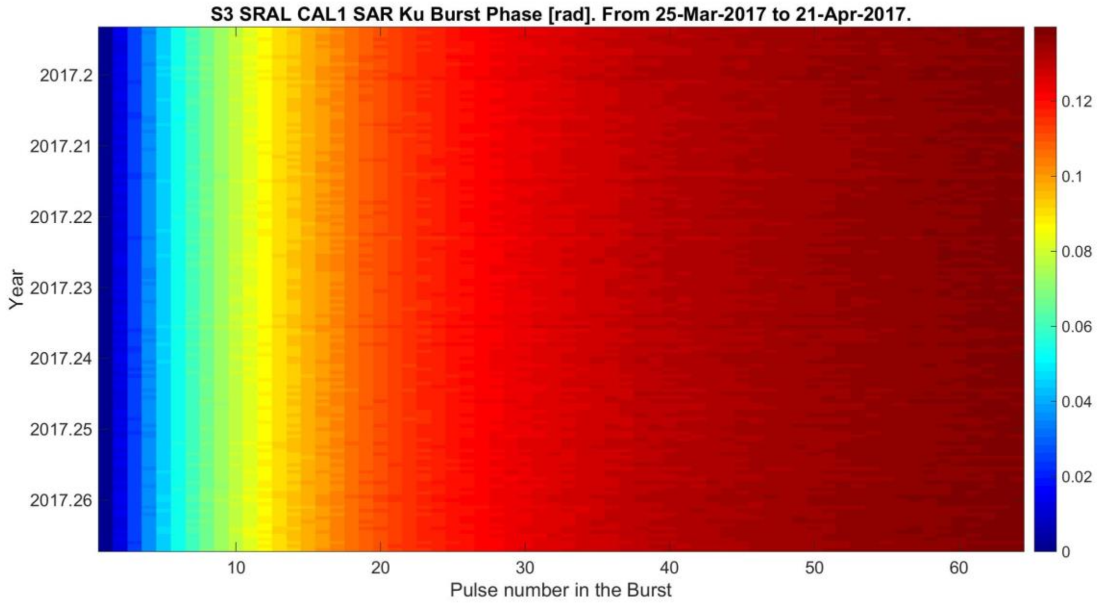

Figure 2.2-22. CAL1 SAR Ku Phase intra-burst correction along the period.

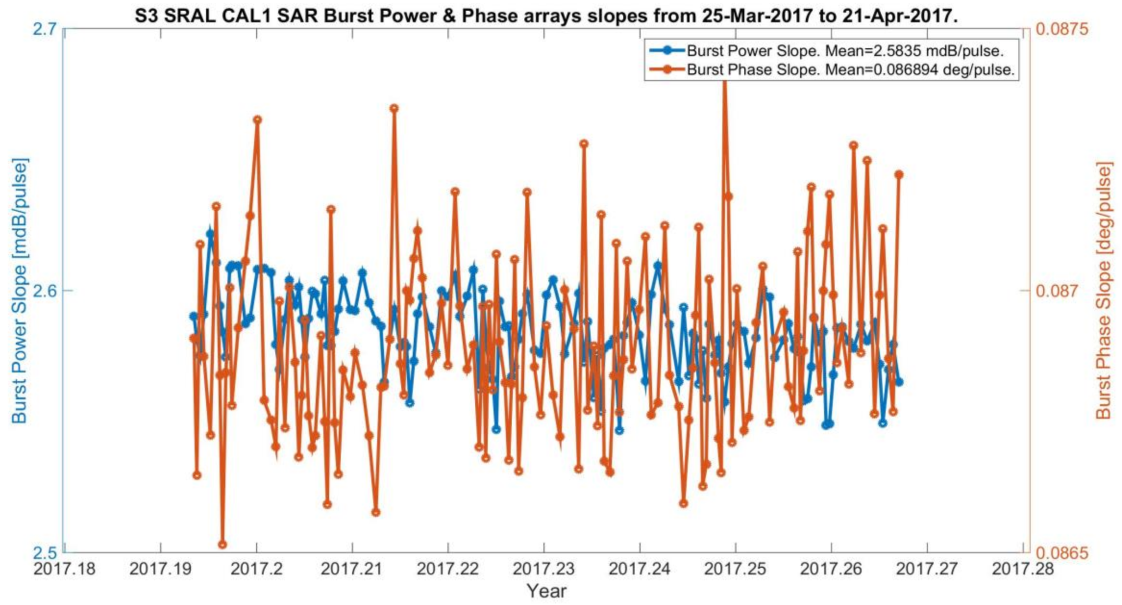

Figure 2.2-23. CAL1 SAR Ku Phase & Power intra-burst corrections slopes over the analysis period.

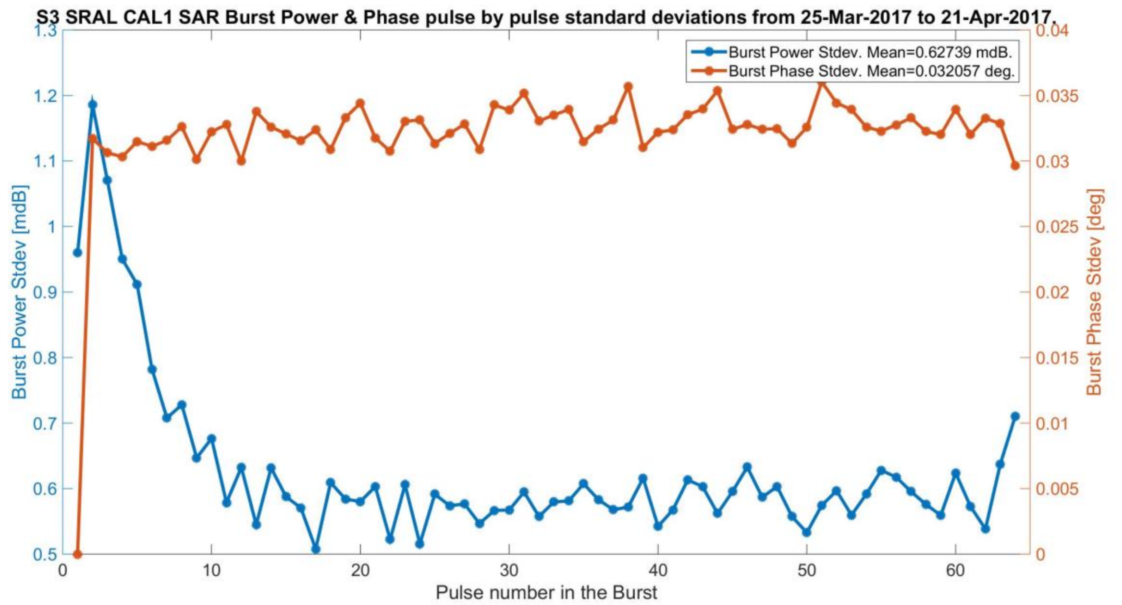

Figure 2.2-24. Pulse by pulse standard deviations of the CAL1 SAR Ku Power and Phase intra-burst corrections.

2.2.3 System Transfer Function (CAL2)

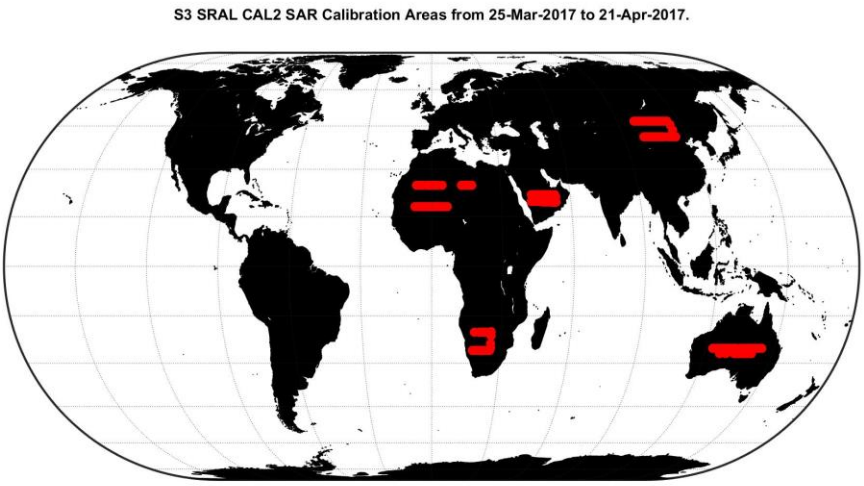

Figure 2.2-25. Location of the CAL2 measurements.

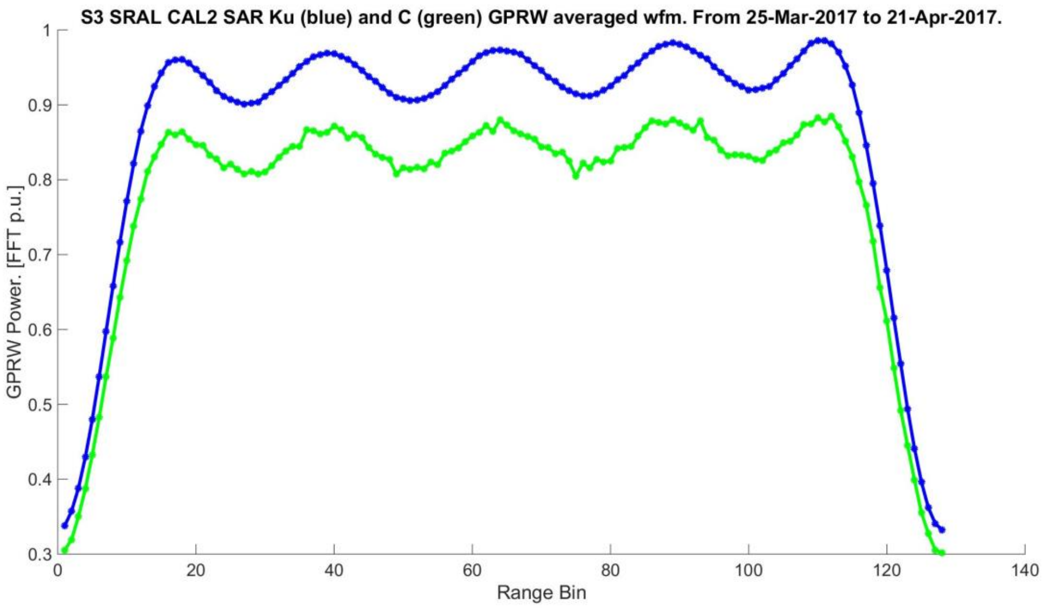

Figure 2.2-26. Averaged CAL2 Ku and C waveforms over the period.

Mesh of CAL2 waveforms.

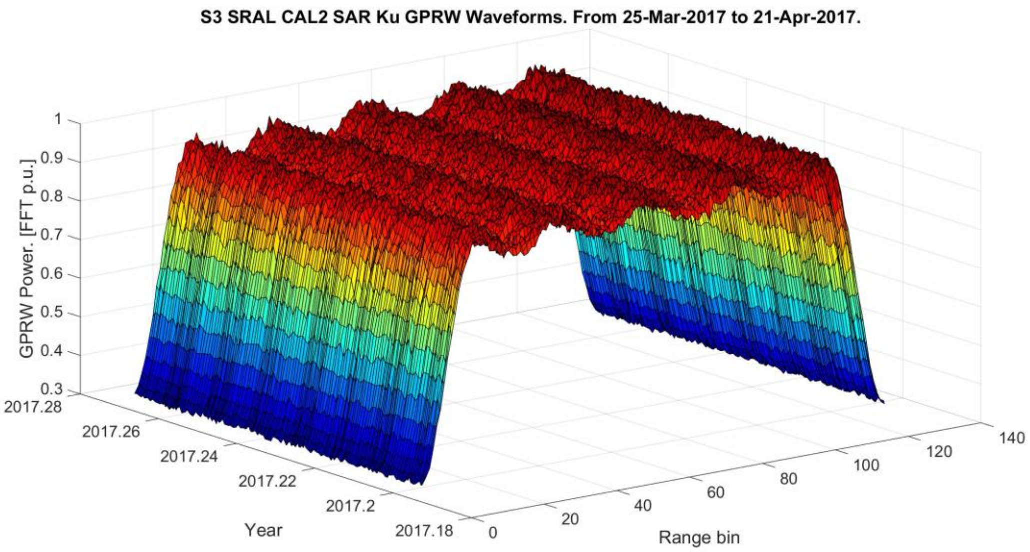

Figure 2.2-27. CAL2 Ku waveforms over the period.

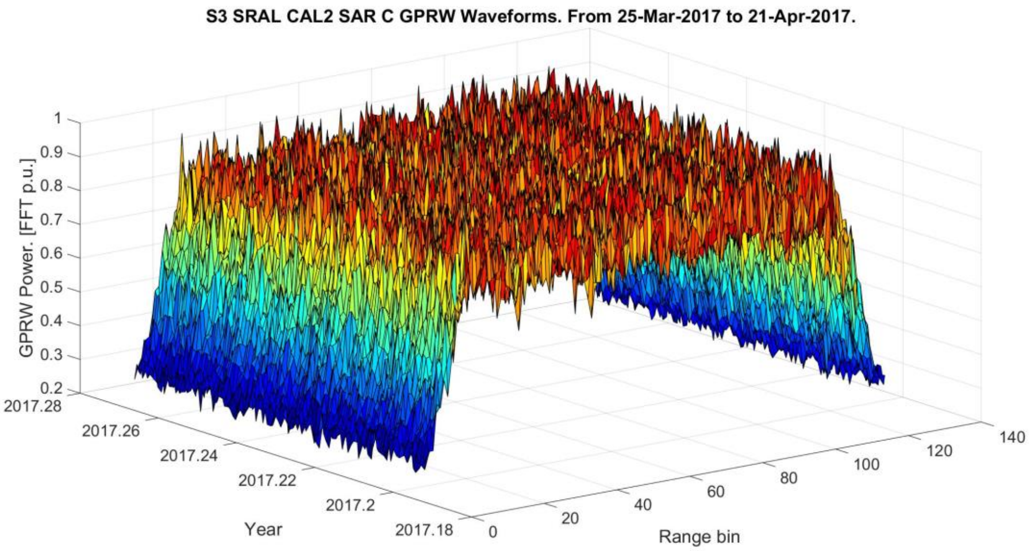

Figure 2.2-28. CAL2 C waveforms over the period.

Time series of CAL2 waveforms right and left sides Slope.

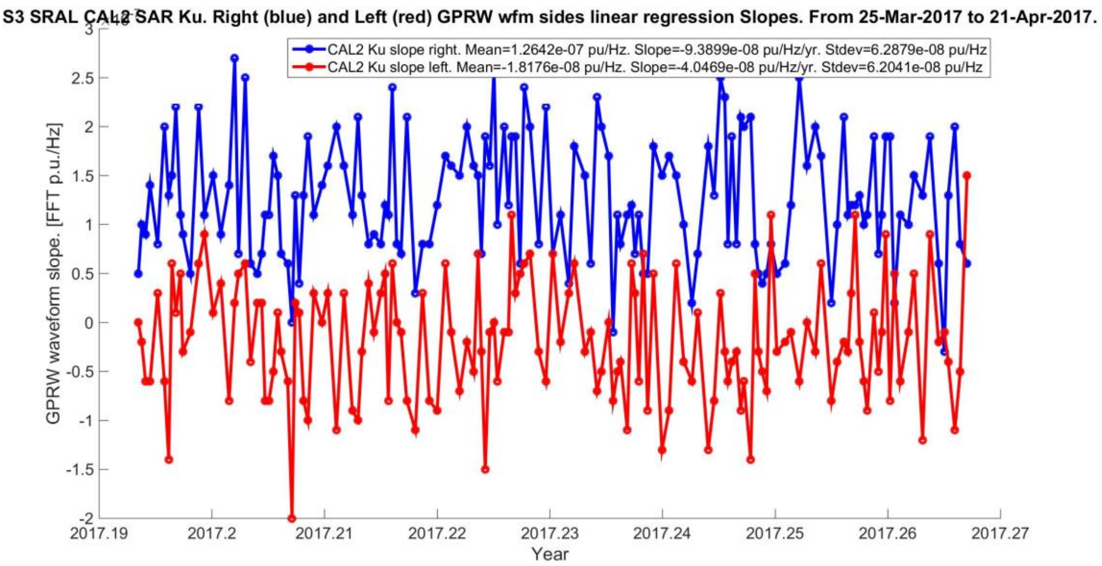

Figure 2.2-29. CAL2 Ku waveforms right (blue) and left (red) sides Slope over the period.

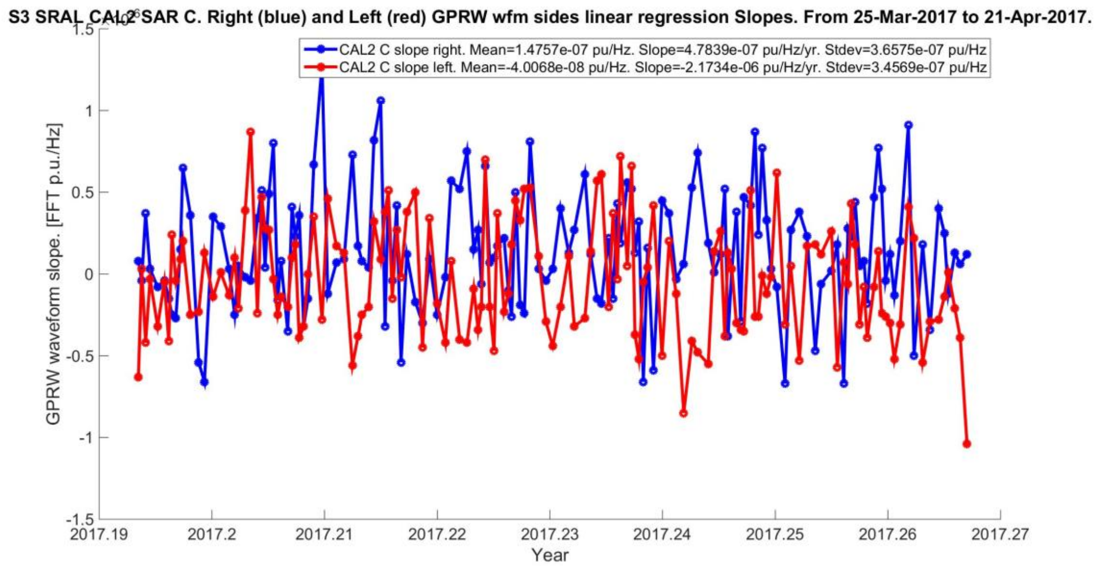

Figure 2.2-30. CAL2 C waveforms right (blue) and left (red) sides Slope over the period.

Time series of CAL2 waveforms right and left sides Standard Deviation.

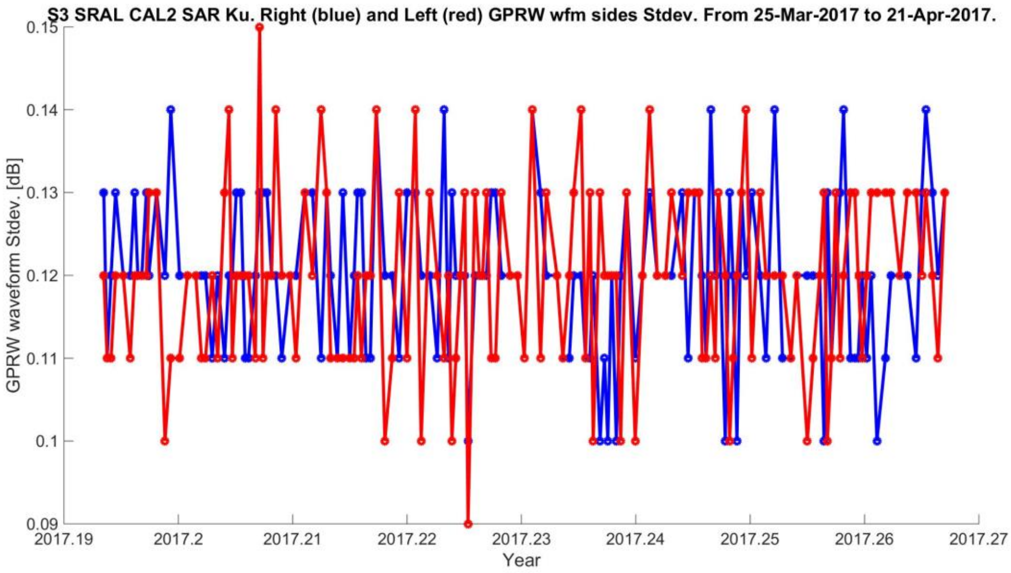

Figure 2.2-31. CAL2 Ku waveforms right (blue) and left (red) sides Standard Deviation over the period.

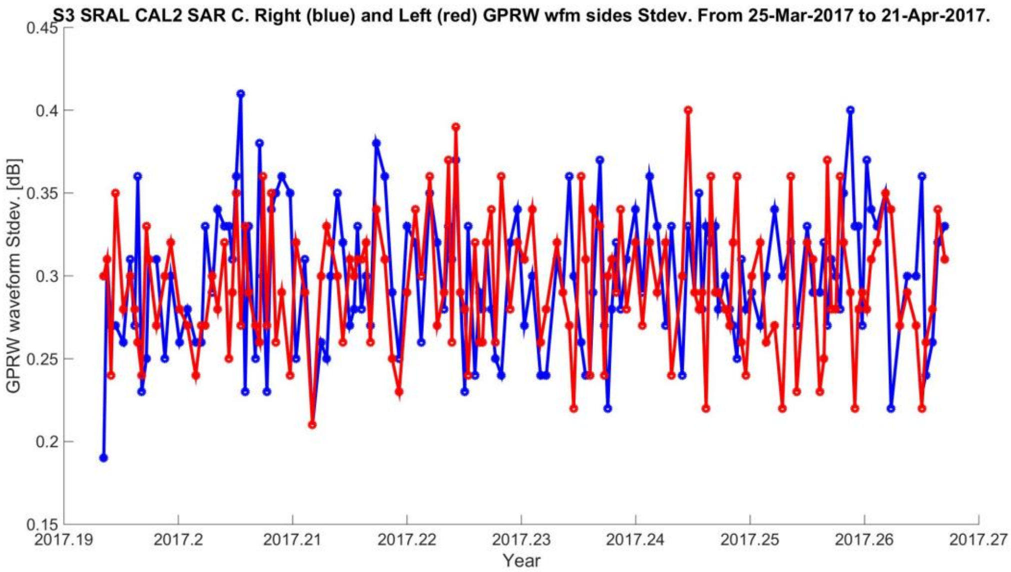

Figure 2.2-32. CAL2 C waveforms right (blue) and left (red) sides Standard Deviation over the period.

2.2.4 AutoCAL (CAL1 SAR Auto)

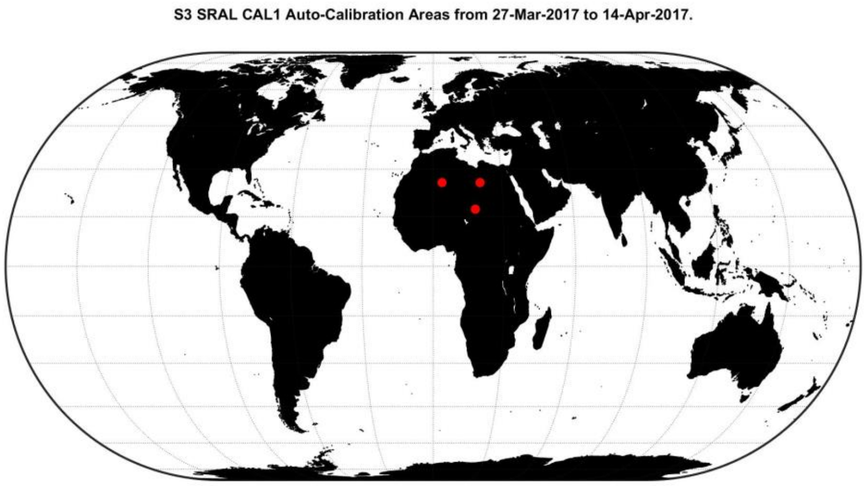

Figure 2.2-33. Location of the AutoCal measurements.

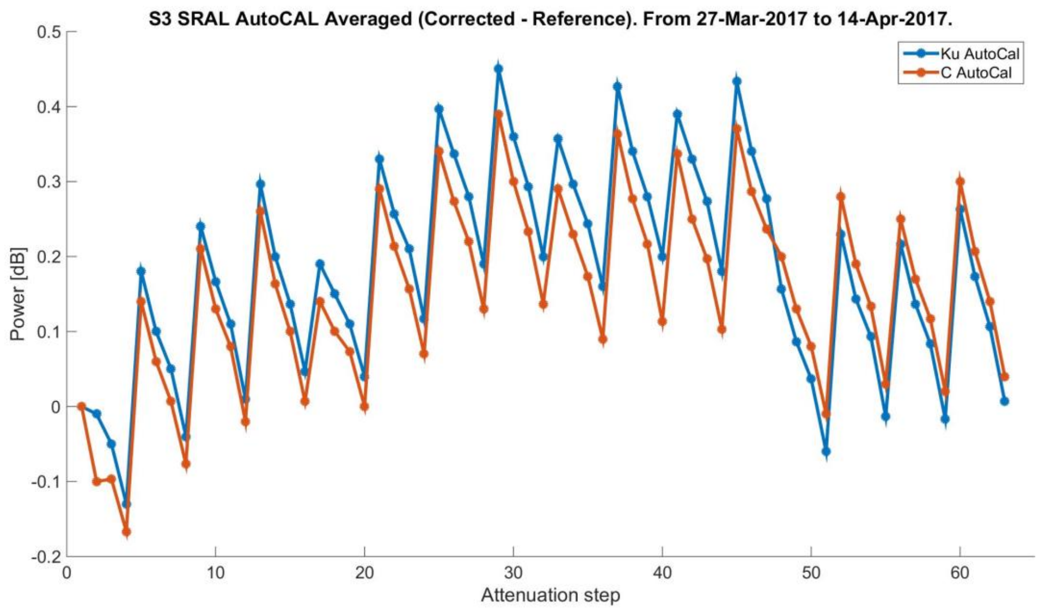

Figure 2.2-34. AutoCal measurements: Corrected - Reference. Averaged over the analysis period.

2.2.5 On-board Clock Performance

The altimeter and platform clock frequencies will be here below depicted and analysed when the USO auxiliary files are available. Their assessment is very important for the identification of the range anomalies causes, all along with calibration parameters such as the PTR time delay, and the datation issues during the mission. It has a multiplicative impact in the final range.

2.2.6 Housekeeping Temperatures

Time series of thermistors temperatures on CAL1 LRM IQ mode over the analysed period.

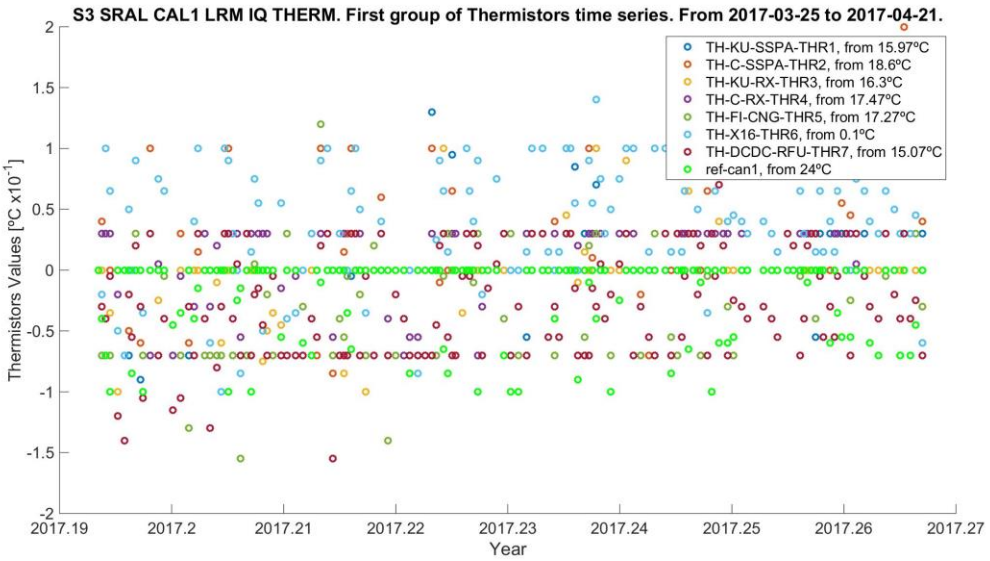

Figure 2.2-35. First group of Thermistors time series on CAL1 LRM IQ mode. The temperatures are averaged for each calibration product over the analysis period.

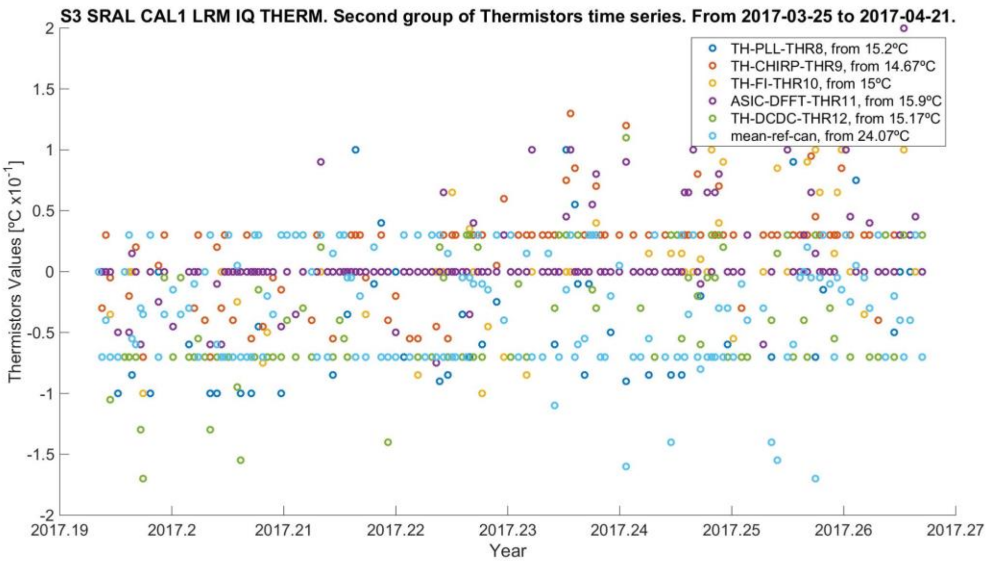

Figure 2.2-36. Second group of Thermistors time series on CAL1 LRM IQ mode. The temperatures are averaged for each calibration product over the analysis period.

Time series of thermistors temperatures on CAL1 SAR mode over the analysed period.

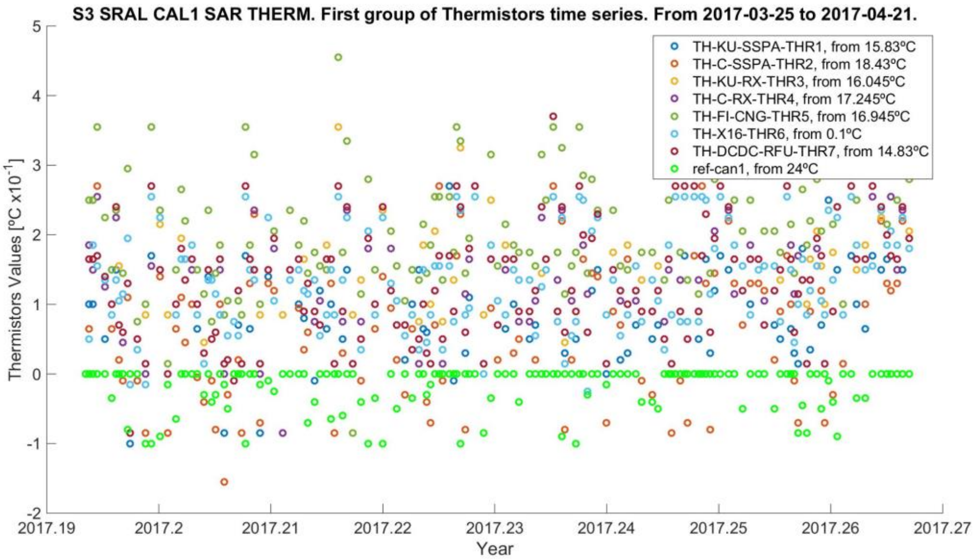

Figure 2.2-37. First group of Thermistors time series on CAL1 SAR mode. The temperatures are averaged for each calibration product over the analysis period.

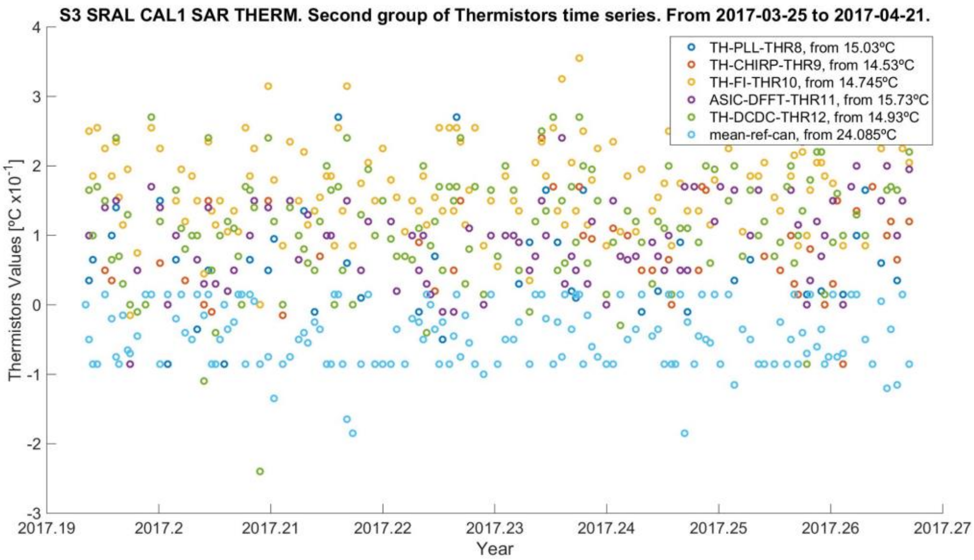

Figure 2.2-38. Second group of Thermistors time series on CAL1 SAR mode. The temperatures are averaged for each calibration product over the analysis period.

Time series of thermistors temperatures on CAL2 mode over the analysed period.

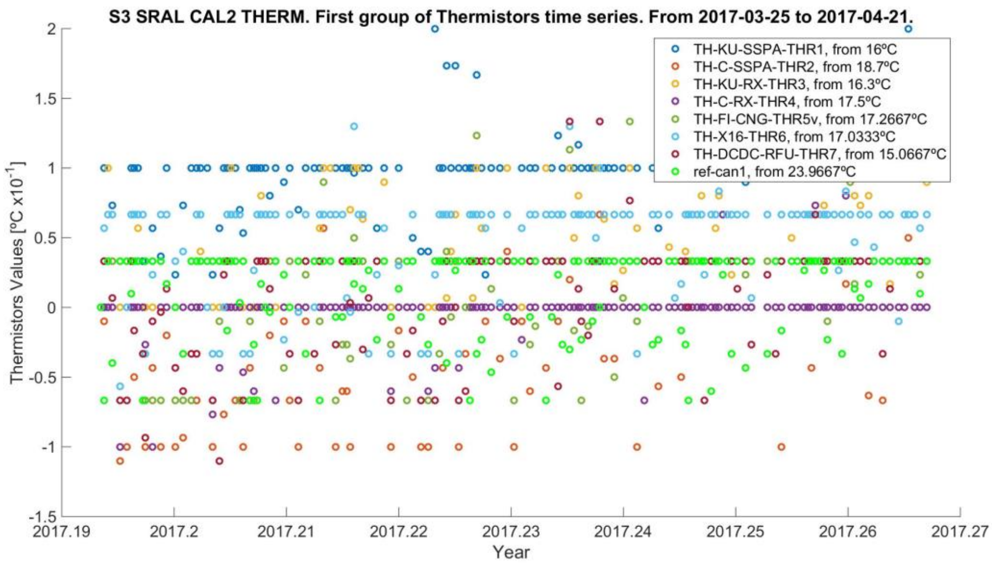

Figure 2.2-39. First group of Thermistors time series on CAL2 mode. The temperatures are averaged for each calibration product over the analysis period.

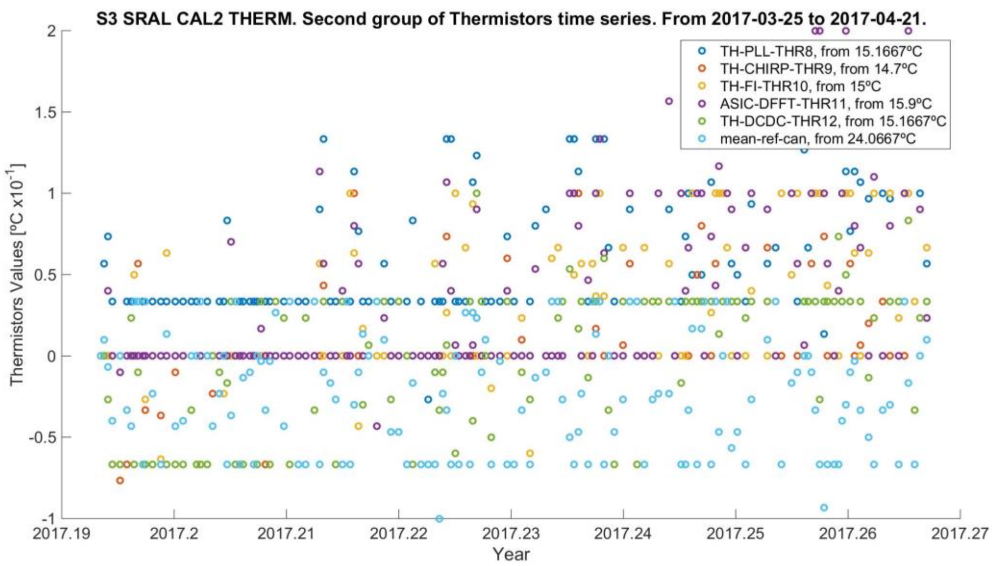

Figure 2.2-40. Second group of Thermistors time series on CAL2 mode. The temperatures are averaged for each calibration product over the analysis period.

2.3 Cyclic SRAL Status Summary

This section is dedicated to a summary of the cyclic performances and status of the altimeter parameters exposed in section 2.2.

For the analysed period, none of the calibration parameters is showing a significant anomalous behaviour. Nonetheless some specific observations are explained here below.

As expected, the Ku band (SAR science main band) calibration parameters performances are better than the ones from the C band. The calibration data dispersion is higher for the C band.

In general, the LRM and SAR performances are similar for a given band (Ku or C).

In Table 2-1 the main CAL1 parameters statistics are detailed.

Calibration Parameter	Ku band			C band		
	mean	annual slope	standard deviation	mean	annual slope	standard deviation
LRM CAL1 time delay	1.0072 m	-2.63 mm	0.67 mm	0.8936 m	7.32 mm	2.70 mm
SAR CAL1 time delay	1.0069 m	-2.36 mm	0.67 mm	0.8942 m	7.37 mm	2.71 mm
LRM CAL1 power	57.91 dB	-0.60 dB	0.05 dB	51.43 dB	0.05 dB	0.21 dB
SAR CAL1 power	62.35 dB	-0.59 dB	0.05 dB	48.94 dB	0.06 dB	0.21 dB
LRM CAL1 PTR width	0.4166 m	3.67 mm	1.19 mm	0.4556 m	21.25 mm	6.57 mm
SAR CAL1 PTR width	0.4162 m	3.59 mm	1.19 mm	0.4555 m	21.20 mm	6.56 mm

Table 2-1. Collection of calibration parameters statistics for all modes and bands covering the cycle period.

The CAL1 power trend for Ku band is no longer close to -1 dB/yr as at the first cycles of the mission (see section 2.4). It follows a decreasing trend, slightly steeper than the one of cycle 15.

The CAL1 power trend for C band is positive, its trend sign has been changing in the last cycles.

The Ku band CAL1 time delay has a decreasing trend, steeper than the one of the previous cycle. The change in the trend absolute value is significant: twice for the C band, and 1.6 times for Ku-band. This slope variations are a usual situation along the mission.

For the CAL1 width, the trend values are following the same magnitude of changes along the mission, with absolute values two orders of magnitude below the PTR width value. These cyclic trends have been changing along the mission between positive and negative values.

This is the first full cycle after a L1B IPF code fix on the CAL1 intra-burst corrections. The overall cycle statistics show a new figure. The Burst Power correction noise is highly reduced (from 80mdB to 0.6mdB), and the Burst Phase correction is reversed with respect to the previous version. A much more stable value of the burst power slope is now revealed, around 2.58 mdB/pulse.

CAL2 and Autocal parameters are stable.

The thermistors values are showing a stable series over the analysed period, although a slight increase is generally observed.

All these observations are related to the different SRAL calibration parameters during this cycle. A whole mission observation is developed in section 2.4.

2.4 Mission SRAL Status Summary

The main L1b calibration parameters series are gathered and plotted in this section, in order to observe their whole mission behaviour. For the sake of simplicity, the C band and the LRM mode have been excluded.

The plotted calibration parameters are:

- CAL1 time delay
- CAL1 power
- PTR width
- Burst corrections (power and phase) and their slopes
- CAL2 waveform ripples shape, plus the waveforms slopes and detrended standard deviations
- Autocal averaged differences and attenuation progression

Also the SAR mode thermistors series is plotted.

Whole mission trend of the PTR time delay.

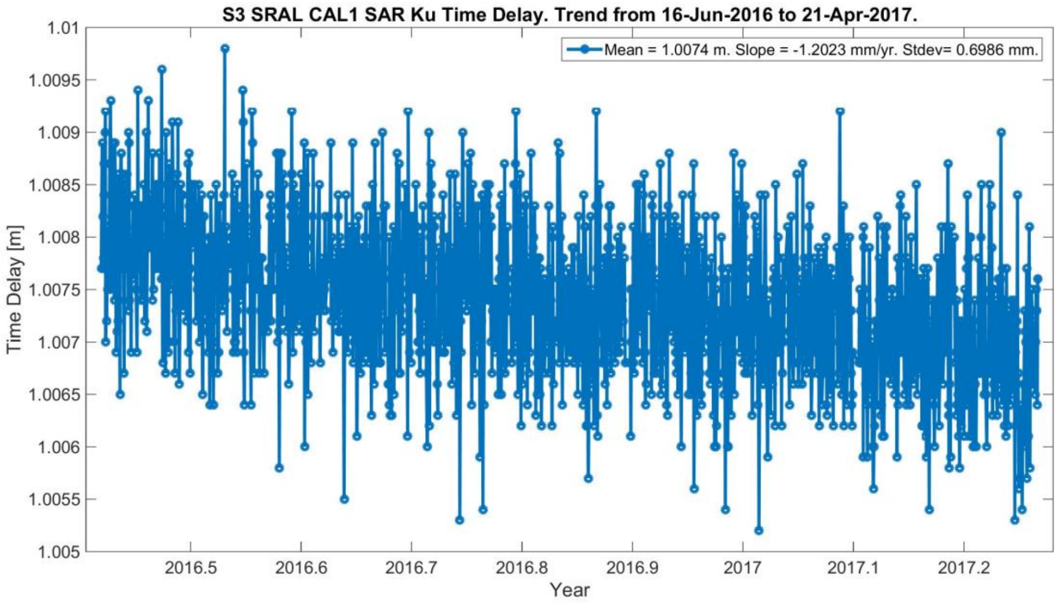

Figure 2.4-1. CAL1 SAR Ku Time Delay Whole Mission Trend.

Whole mission trend of the PTR Total and Maximum Power.

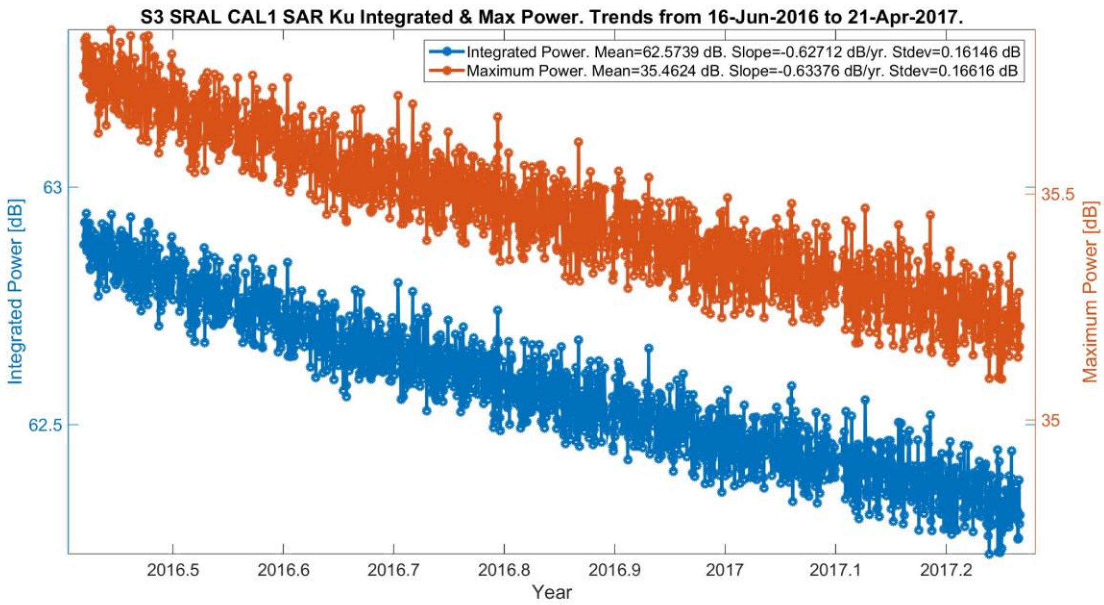

Figure 2.4-2. CAL1 SAR Ku Power Whole Mission Trend.

Whole mission trend of the CAL1 PTR width.

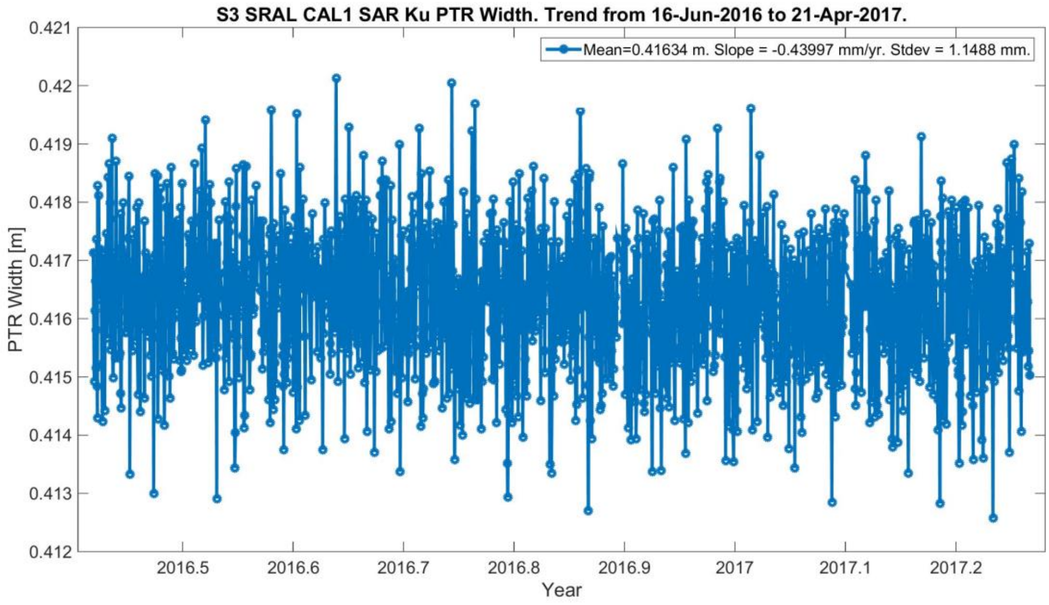

Figure 2.4-3. CAL1 SAR Ku PTR Width Whole Mission Trend.

Slopes of CAL1 SAR intra-burst corrections.

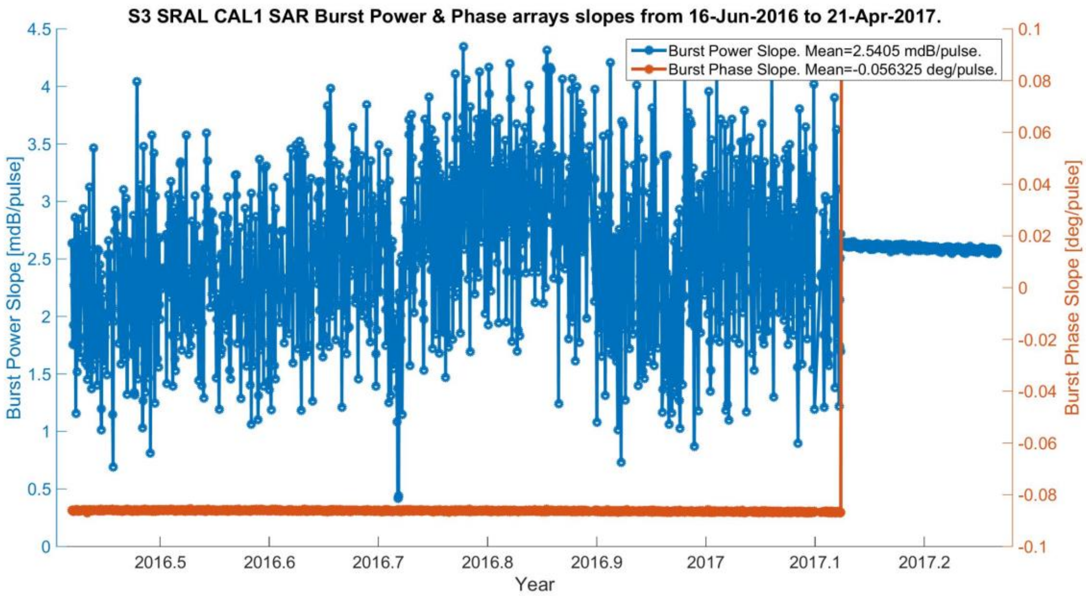

Figure 2.4-4. CAL1 SAR Ku Phase & Power intra-burst corrections slopes along the whole mission.

CAL1 SAR mode Ku intra-burst corrections: Power and Phase.

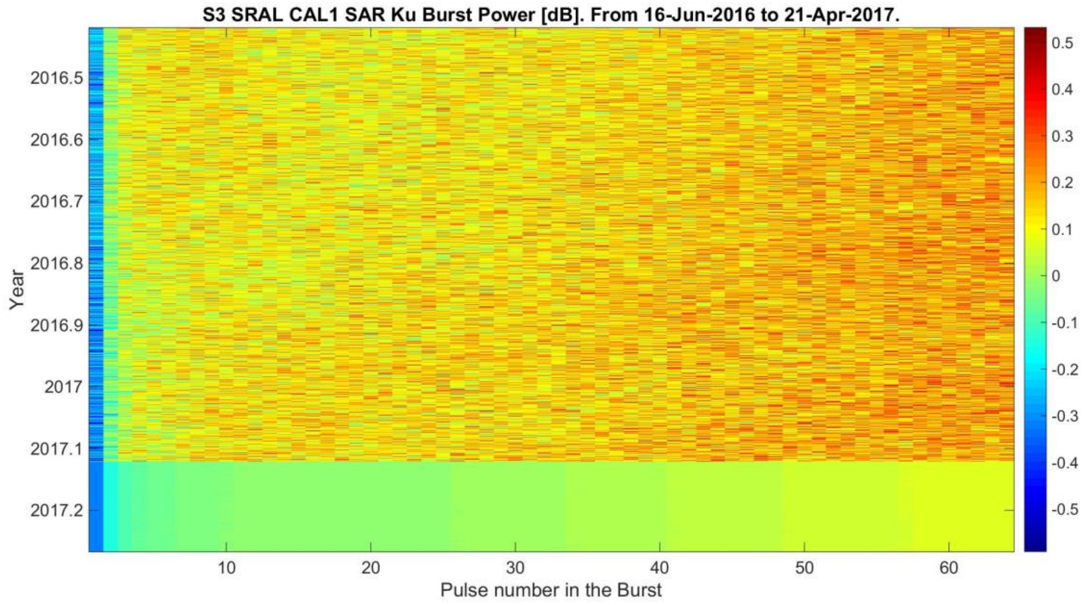

Figure 2.4-5. CAL1 SAR Ku Power intra-burst correction along the whole mission.

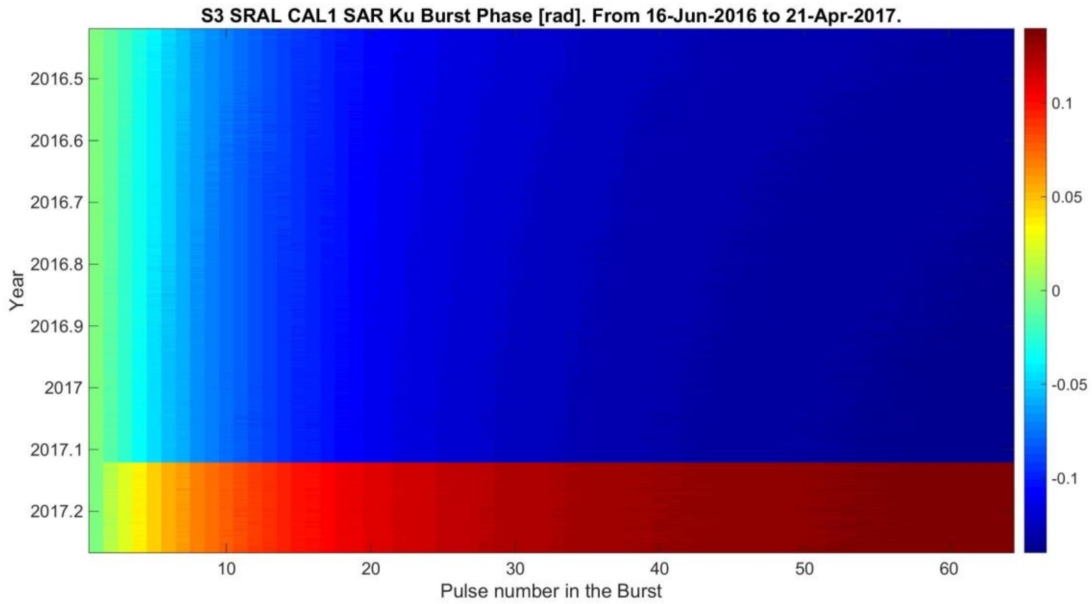

Figure 2.4-6. CAL1 SAR Ku Phase intra-burst correction along the whole mission.

Ripples of CAL2 waveforms.

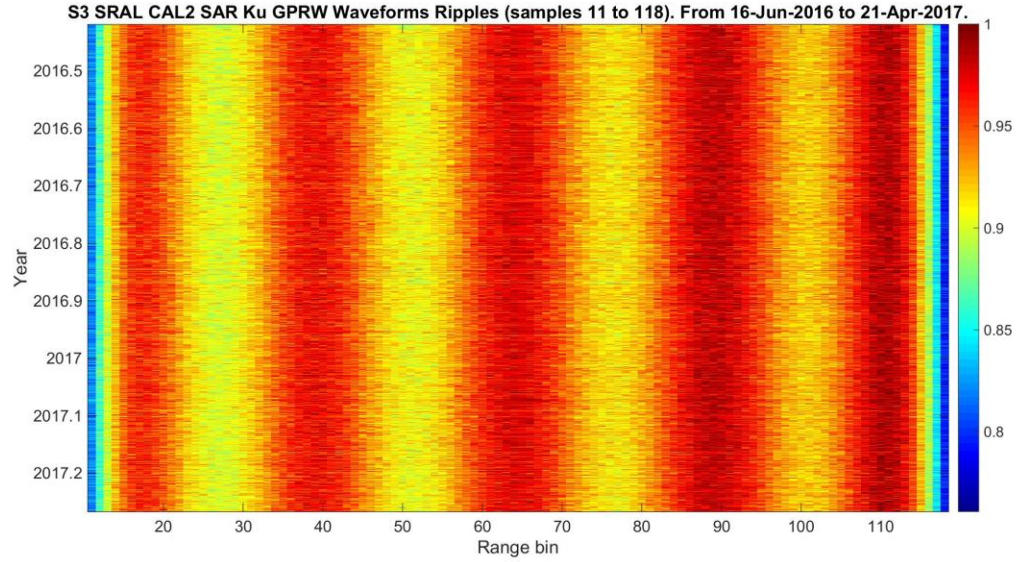

Figure 2.4-7. CAL2 Ku waveforms ripples over the whole mission.

Slope at each side of the CAL2 waveform.

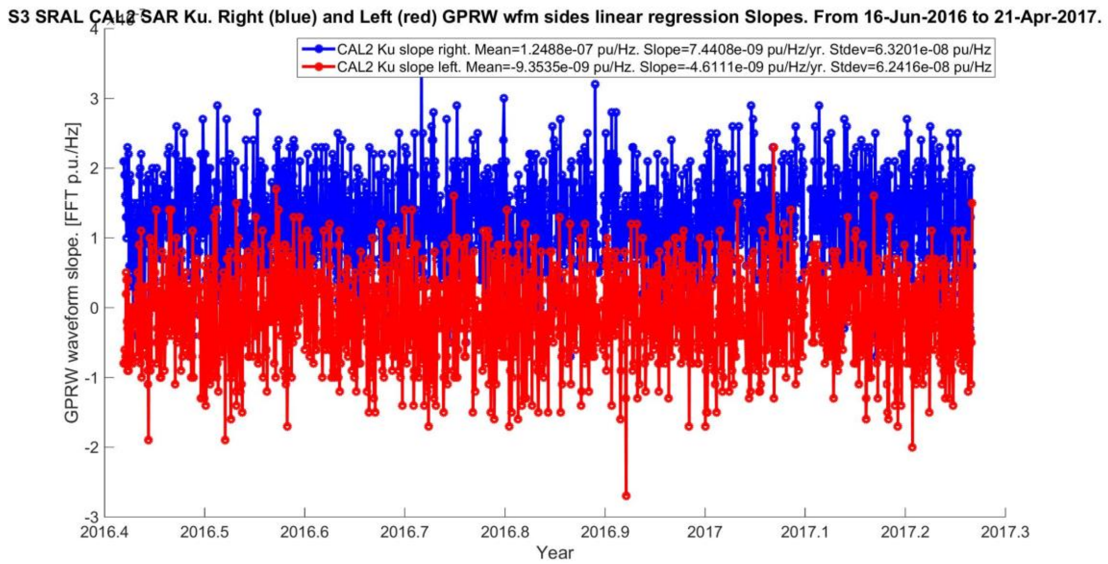

Figure 2.4-8. Slope at each side of the CAL2 Ku waveform, averaged over the whole mission.

Detrended Standard Deviation at each side of the CAL2 waveform.

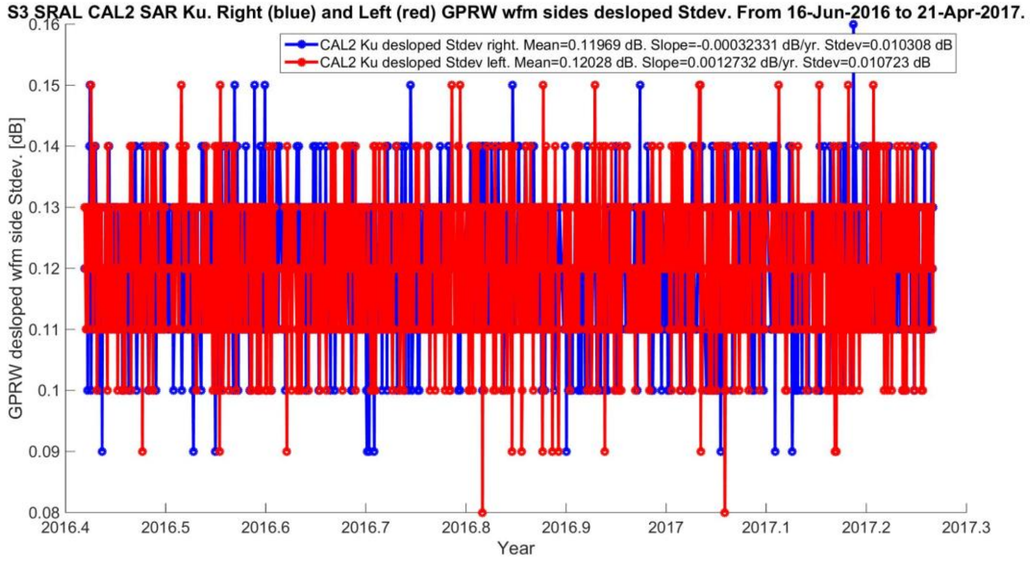

Figure 2.4-9. CAL2 Ku waveform standard deviation at each side after compensating by the slope, averaged over the whole mission.

Averaged Autocal differences.

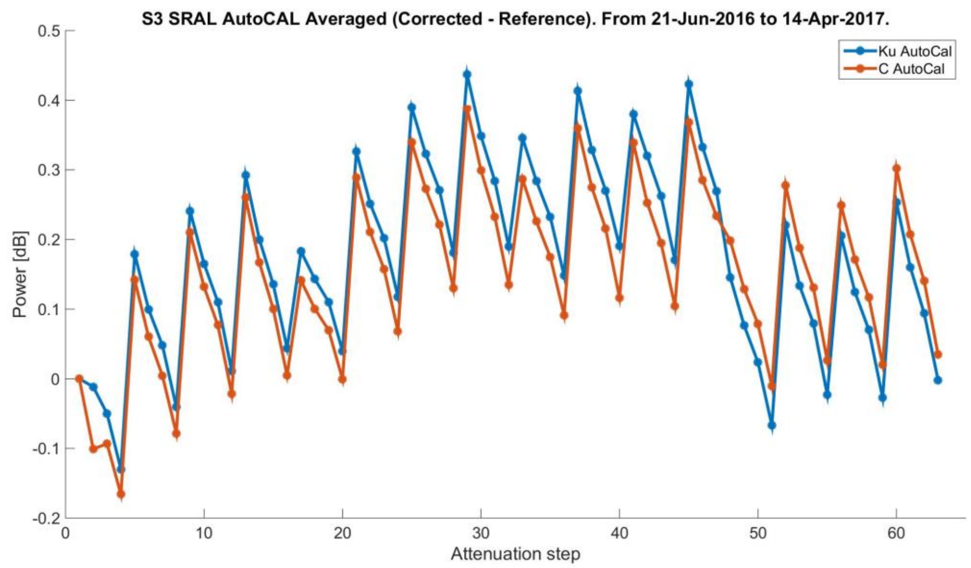

Figure 2.4-10. Autocal measurements: Corrected - Reference. Averaged over the whole mission.

AutoCAL attenuation progression series.

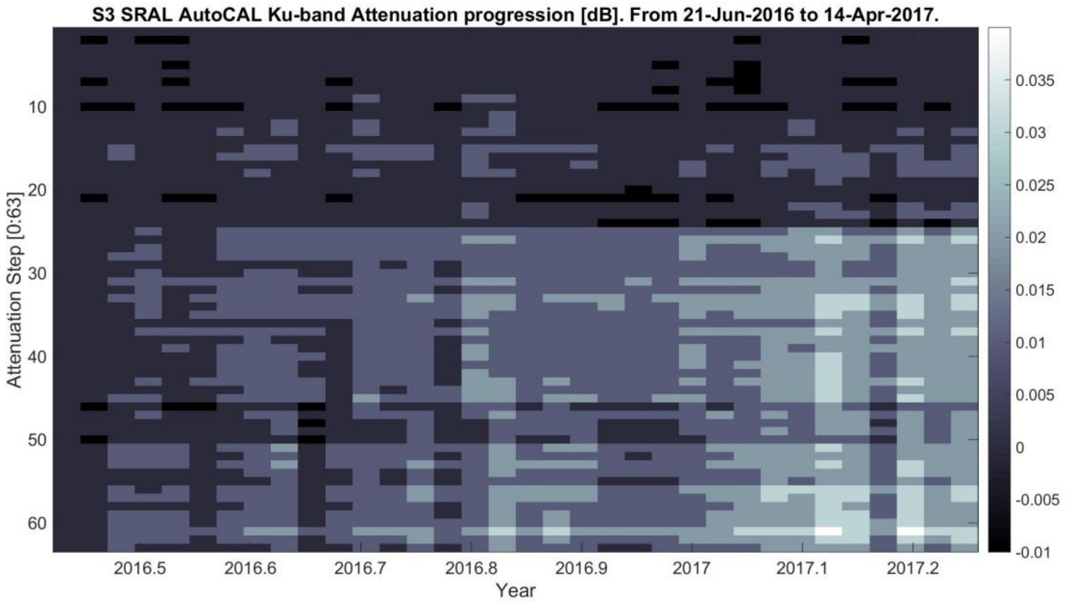

Figure 2.4-11. AutoCAL attenuation whole mission progression for Ku-band. Difference in dB with respect to the previous attenuation value, for each attenuation step.

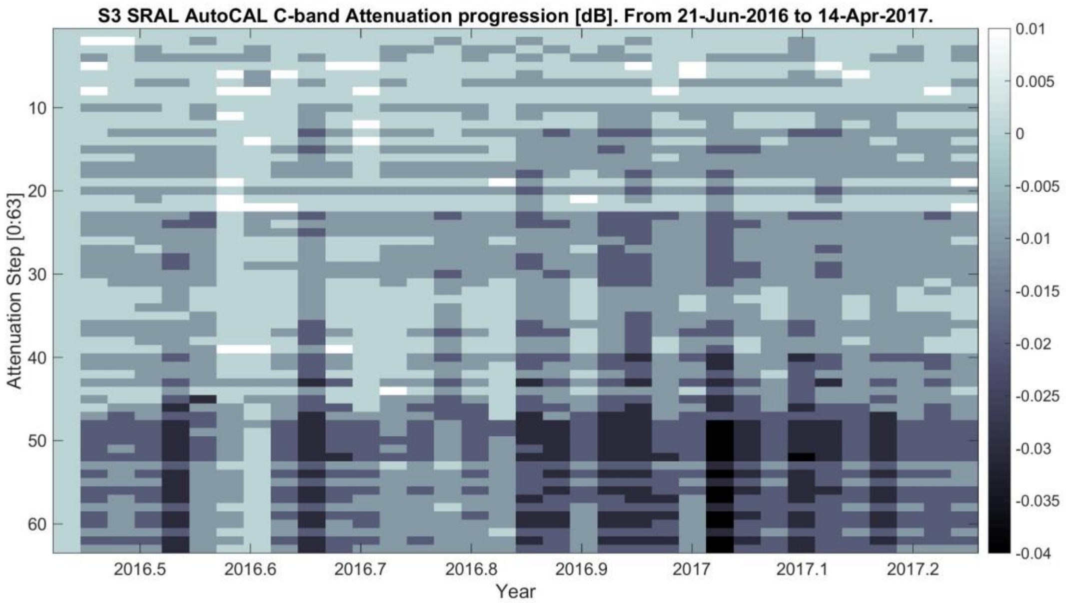

Figure 2.4-12. AutoCAL attenuation whole mission progression for C-band. Difference in dB with respect to the previous attenuation value, for each attenuation step.

CAL1 SAR thermistors series.

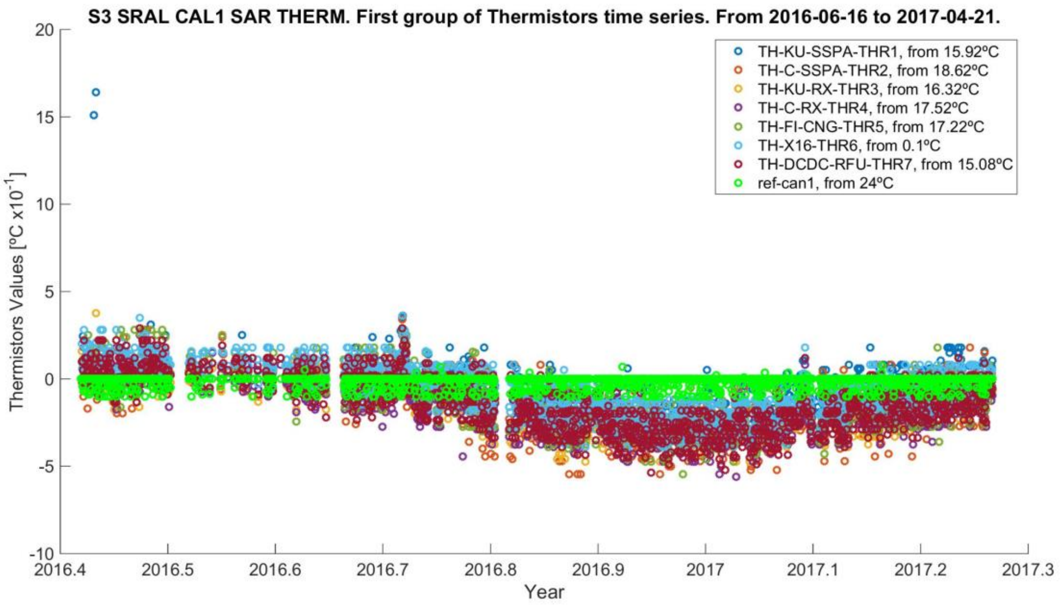

Figure 2.4-13. CAL1 SAR thermistors series along the whole mission. First group.

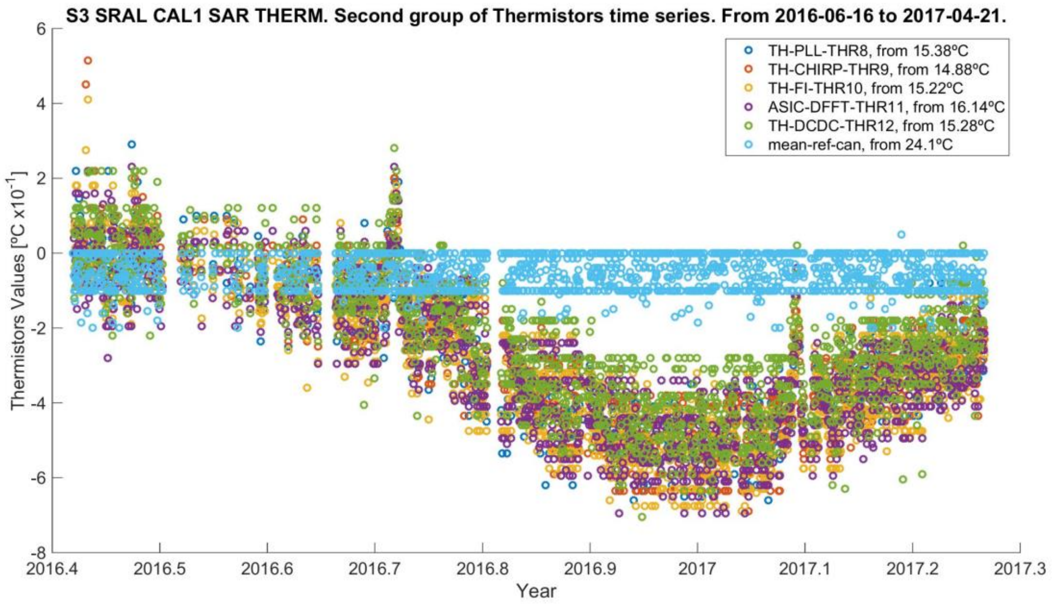

Figure 2.4-14. CAL1 SAR thermistors series along the whole mission. Second group.

So far the only clear and notable drift observed in the whole mission series is in the CAL1 Ku Power series, where we observe a significant power decay. Anyhow, it has decreased the observed trend in the last cycles. In cycles 8, 12 and 16 the whole mission SAR Ku Total Power trend in absolute values was respectively of 0.89, 0.70, and 0.63 dB/year. Hence, we can state a slow stabilisation of this parameter.

Also the PTR time delay has decreased its negative trend. In cycles 8, 12 and 16 the whole mission SAR Ku Time Delay trend in absolute values was respectively of 2.02, 1.32 and 1.20 mm/year.

The PTR width for the Ku band has a negative trend around 0.44 mm/year, three orders of magnitude below its absolute value.

The attenuation steps progression in dB is shown in Figure 2.4-11 and Figure 2.4-12, where we can check, for each attenuation step, the delta in attenuation with respect to the previous value in time. The tendencies are visible for specific attenuations in each band case, with small drifts (see colour code at right hand side) of up to 0.04 dB.

In terms of intra-burst corrections, the new L1B code version, implemented during cycle 15, causes a drastic change in the series. Their slopes along the mission are quite stable. A new whole mission CAL L1B reprocessing campaign shall be done to show the new series for both intra-burst corrections without mixing the two versions.

The CAL2 parameters behaviour is stable along the mission.

The thermistors data series are generally showing a decreasing slope up to the beginning of 2017, as shown in Figure 2.4-13 and Figure 2.4-14. In 2017 it begins a new phase of temperatures increase.

Finally, the collection of statistics for the main calibration parameters is depicted in Table 2-2 for both modes and bands. Once more we observe the better performance (less standard deviation) of the Ku band with respect to the C band, and the general similar values and trends between modes (with some exceptions such as the time delay slope and the power absolute values).

Calibration Parameter	Ku band			C band		
	mean	annual slope	standard deviation	mean	annual slope	standard deviation
LRM CAL1 time delay	1.0078 m	-1.66 mm	0.75 mm	0.8935 m	-0.68 mm	2.85 mm
SAR CAL1 time delay	1.0074 m	-1.20 mm	0.70 mm	0.8940 m	-0.48 mm	2.85 mm
LRM CAL1 power	58.13 dB	-0.61 dB	0.16 dB	51.43 dB	0.09 dB	0.22 dB
SAR CAL1 power	62.57 dB	-0.63 dB	0.16 dB	48.94 dB	0.09 dB	0.22 dB
LRM CAL1 PTR width	0.4166 m	-0.44 mm	1.15 mm	0.4547 m	-0.38 mm	7.01 mm
SAR CAL1 PTR width	0.4163 m	-0.44 mm	1.15 mm	0.4546 m	-0.40 mm	7.01 mm

Table 2-2. Collection of calibration parameters statistics for all modes and bands covering the whole mission.

The long term drift for the time delay and power variables is higher in absolute terms for the Ku band than for the C band, while the standard deviation is always lower for the Ku band. This means that, although the Ku band chain performance is better than the one from C band, the Ku band ageing is faster than the one from C band, probably caused by the more stressed Ku band instrumental operations (e.g. bursts transmission & reception only in Ku band).

The PTR width standard deviation for the C band is around 6 times higher than the one from the Ku band, for both operational modes.

As a general observation, we can say that the behaviour of all calibration parameters is nominal. Nevertheless the different values shall be compared to the official S3 mission SRAL instrumental requirements in order to make a final statement. Once they are gathered, the calibration performance check versus requirements will be made, and warnings will be raised accordingly.

2.5 SRAL Dedicated Investigations

This chapter is devoted to the investigations derived from observations along the mission. The on-going investigations results will be updated in each new version of the report; solved issues will be dismissed from the report.

- The flagging of some L1b CAL2 parameters (slope, mean and standard deviation over the slope) is reversed. This issue is not impacting the quality of the science data.
- Some duplicated products have been detected in the MPC ftp site. This situation is to be solved, in order to contribute having a unique consolidated database.

3 Events

A L1B IPF code fix has been implemented in cycle 15, causing the intra-burst corrections to change. The noise on the Burst Power correction has been reduced. The Burst Phase correction has been reversed.

No SRAL special events have been observed during this cycle.

4 Appendix A

Other reports related to the STM mission are:

- S3-A MWR Cyclic Performance Report, Cycle No. 016 (ref. S3MPC.CLS.PR.05-016)
- S3-A Ocean Validation Cyclic Performance Report, Cycle No. 016 (ref. S3MPC.CLS.PR.06-016)
- S3-A Winds and Waves Cyclic Performance Report, Cycle No. 016 (ref. S3MPC.ECM.PR.07-016)
- S3-A Land and Sea Ice Cyclic Performance Report, Cycle No. 016 (ref. S3MPC.UCL.PR.08-016)

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

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