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

**S3-A SRAL Cyclic Performance Report** 

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Approved by:	G. Quartly, STM ESL Coordinator Authorized by Sylvie Labroue, STM Tech Performance Manager					
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# **1** Introduction

## **1.1** Scope of the document

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

### 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
нктм	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** Processing Baseline Version

IPF	IPF / Processing Baseline version	Date of deployment
SR1	06.13 / 2.25	CGS: 14/02/2018 10:31 UTC PAC: 14/02/2018 10:18 UTC
SR1	06.14 / 2.33	CGS: 04/04/2018 10:09 UTC PAC: 04/04/2018 10:09 UTC



# **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

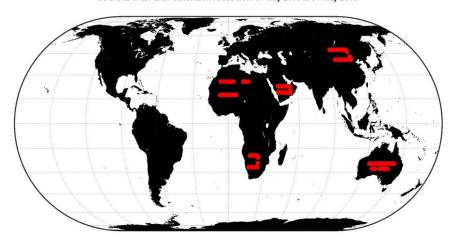


data, as long as the instrumental calibration is correctly applied during the science data processing. A warning shall be raised in the scenario of a calibration parameter value approaching the mission requirement bounds.

## 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.

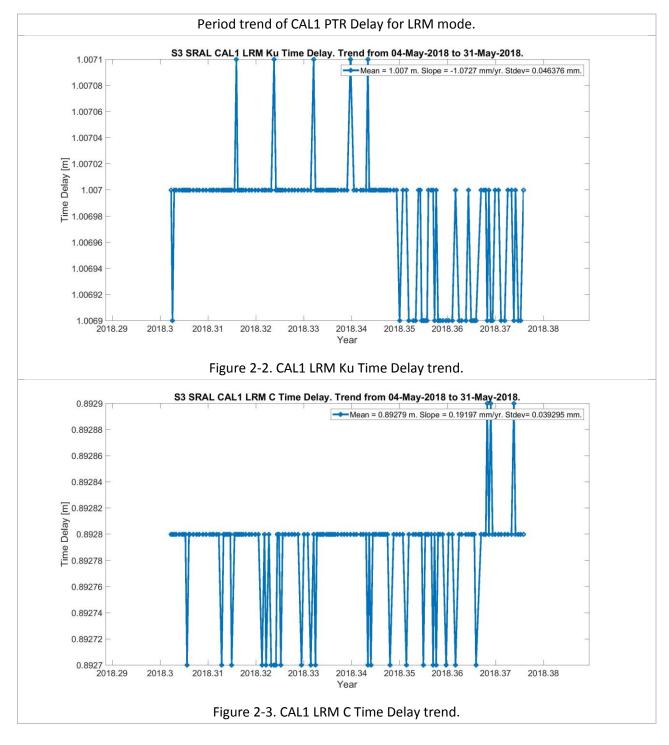
### 2.2.1 CAL1 LRM



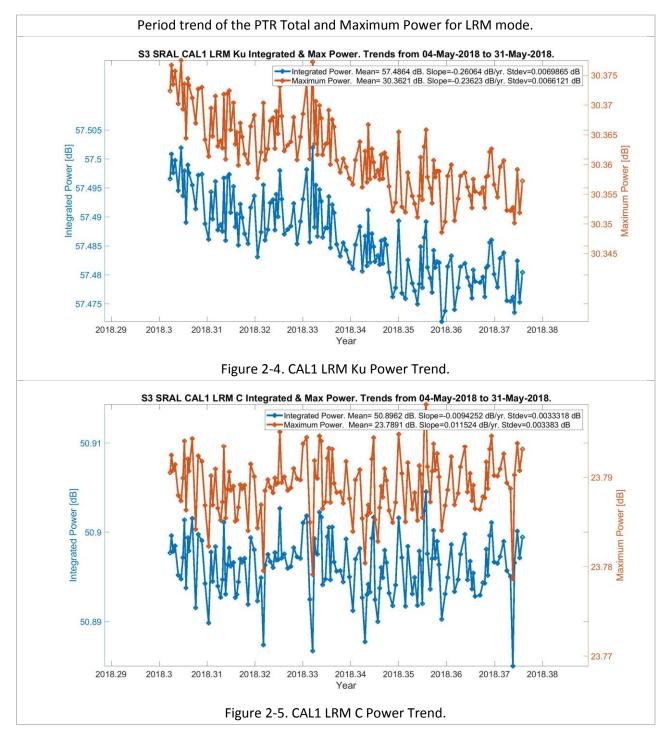
S3 SRAL CAL1 LRM Calibration Areas from 04-May-2018 to 31-May-2018.

Figure 2-1. Location of the CAL1 LRM measurements.

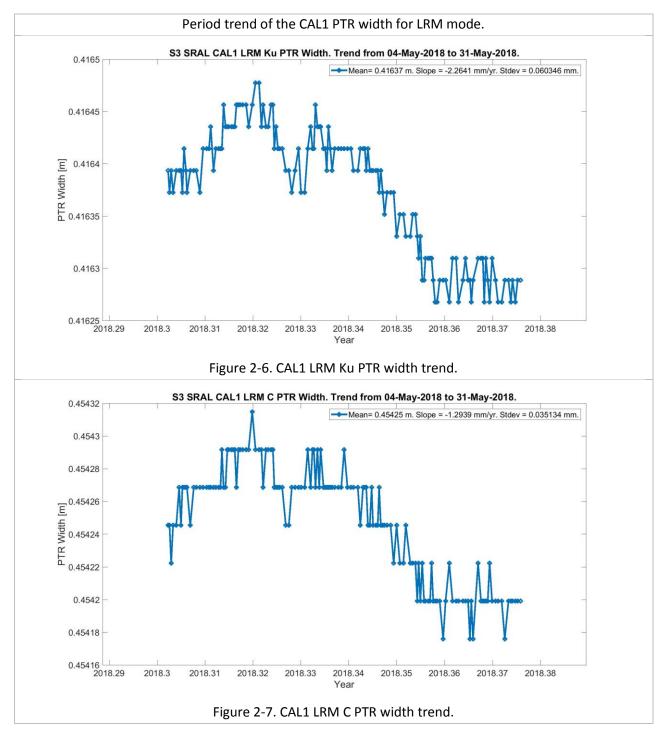




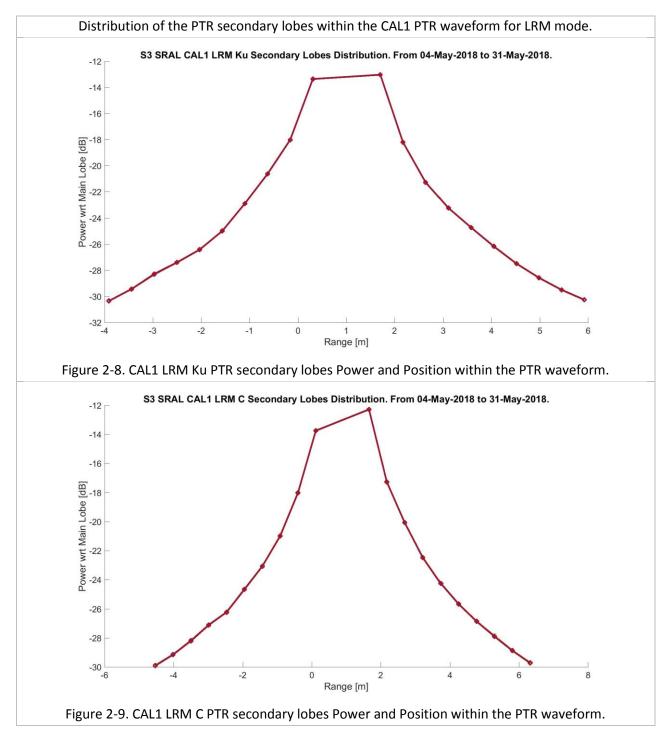




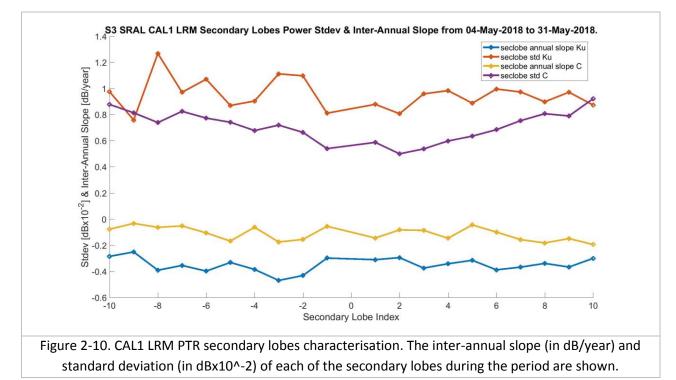














#### 2.2.2 CAL1 SAR

S3 SRAL CAL1 SAR Calibration Areas from 04-May-2018 to 31-May-2018.

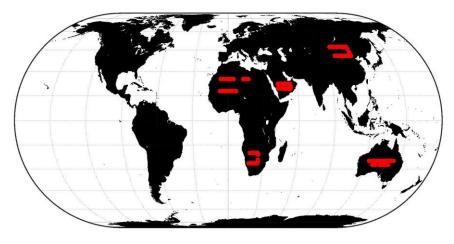
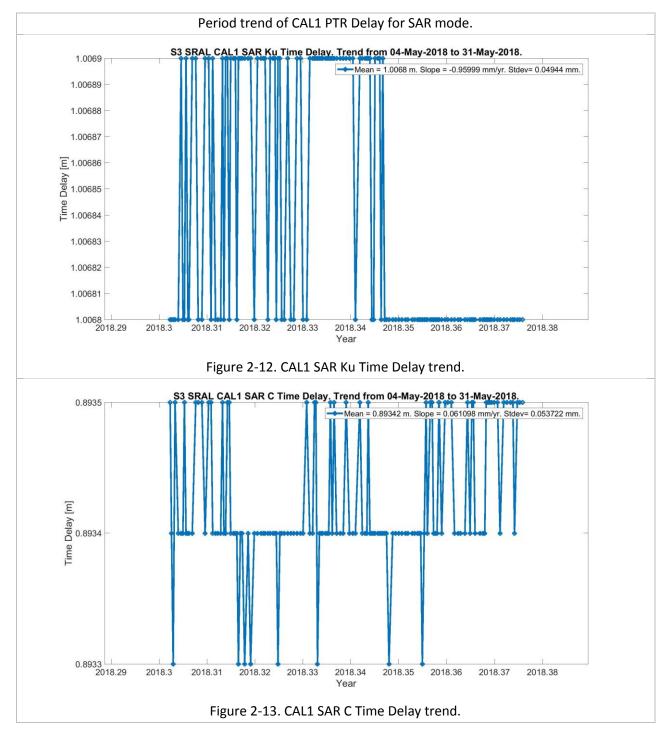
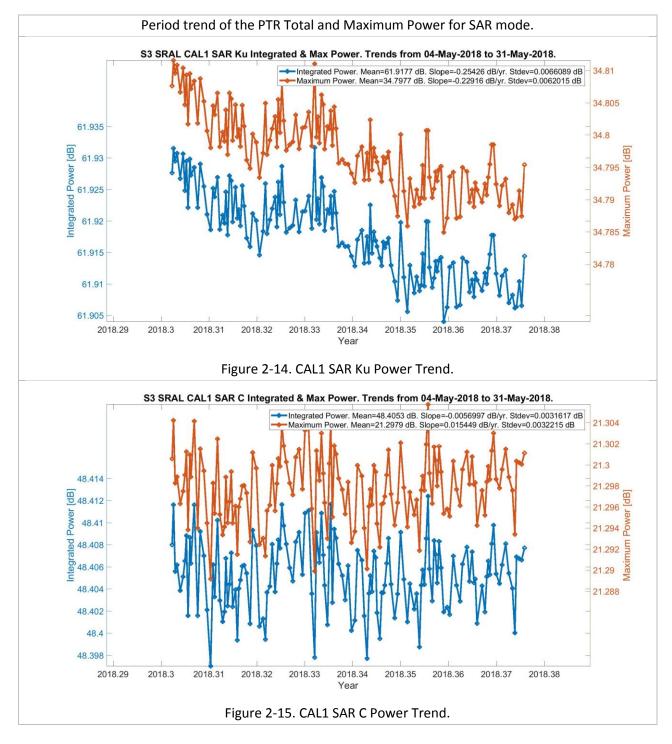


Figure 2-11. Location of the CAL1 SAR measurements.

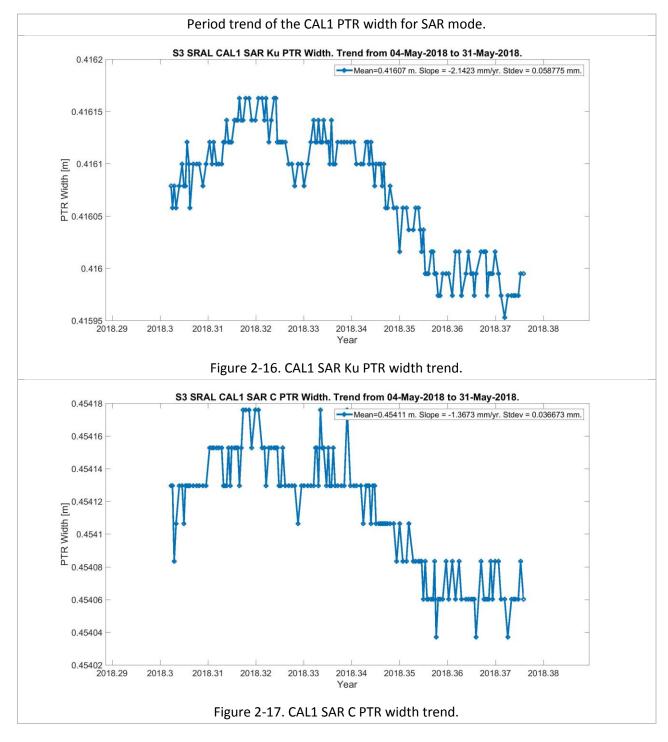




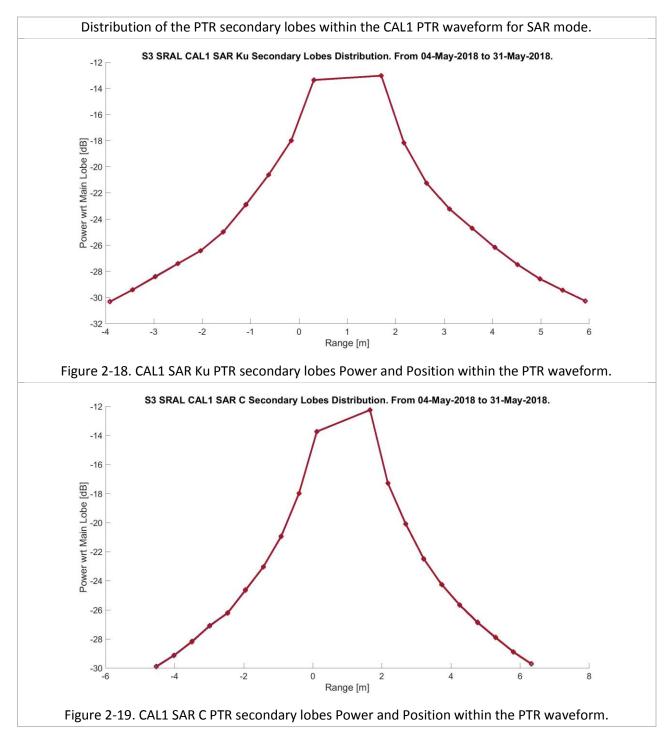




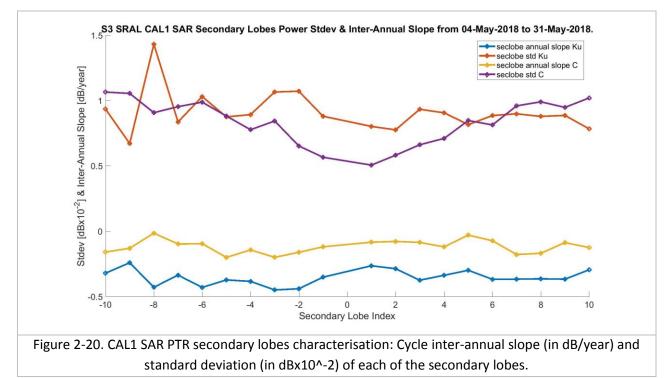




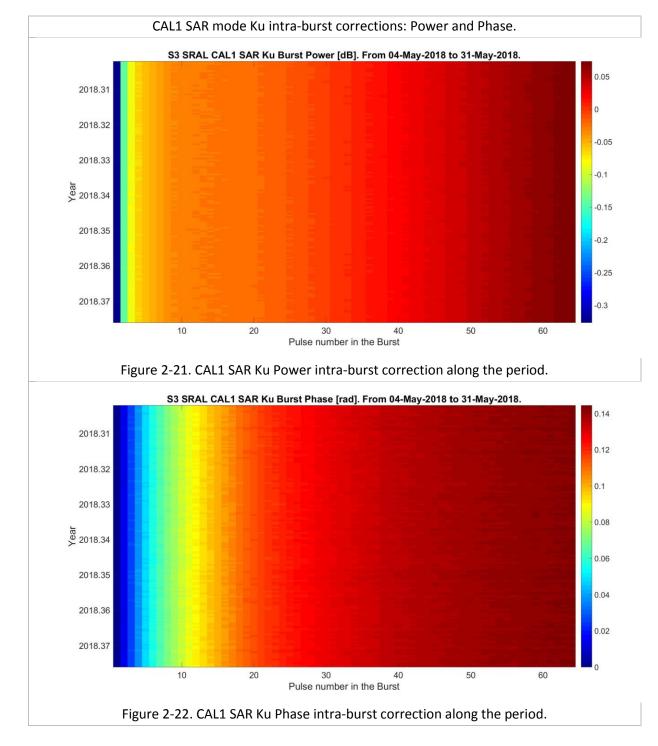




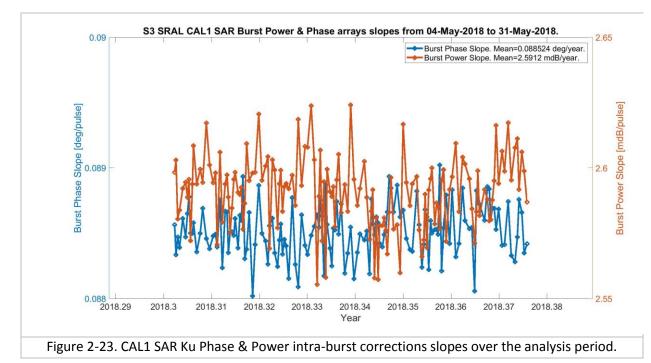


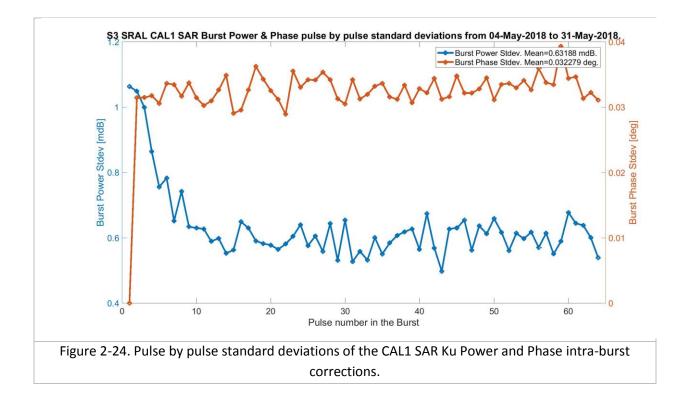














#### 2.2.3 System Transfer Function (CAL2)

S3 SRAL CAL2 SAR Calibration Areas from 04-May-2018 to 31-May-2018.

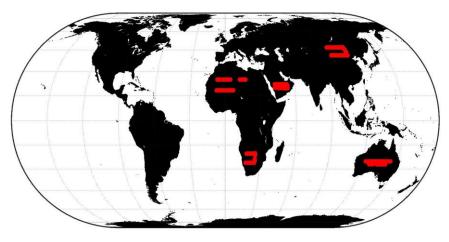
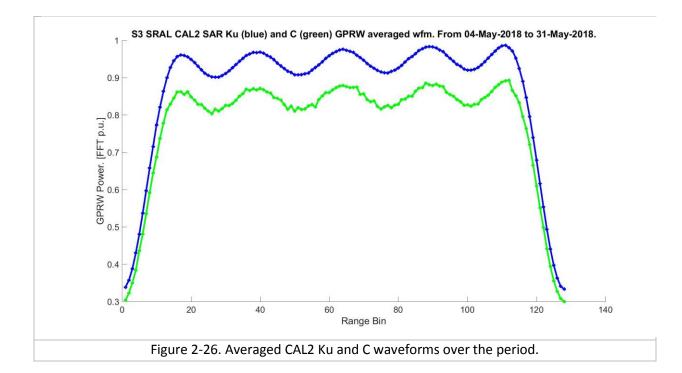


Figure 2-25. Location of the CAL2 measurements.

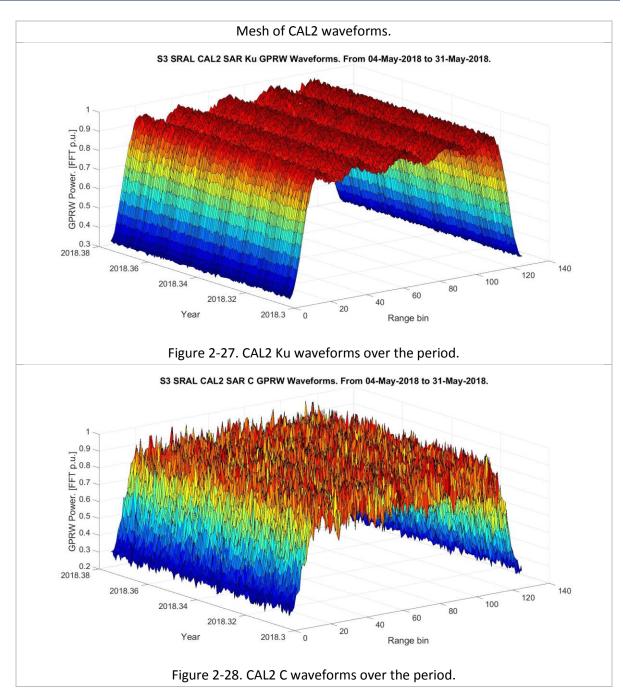




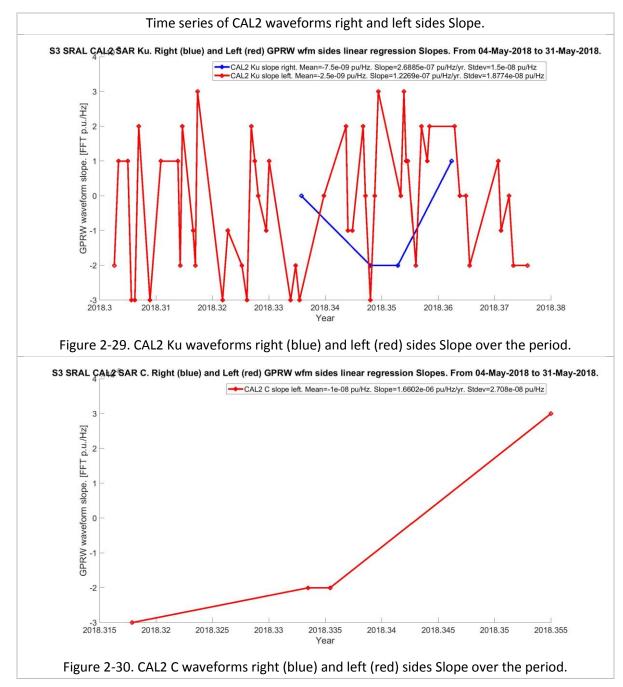
# Sentinel-3 MPC S3-A SRAL Cyclic Performance Report

Cycle No. 031

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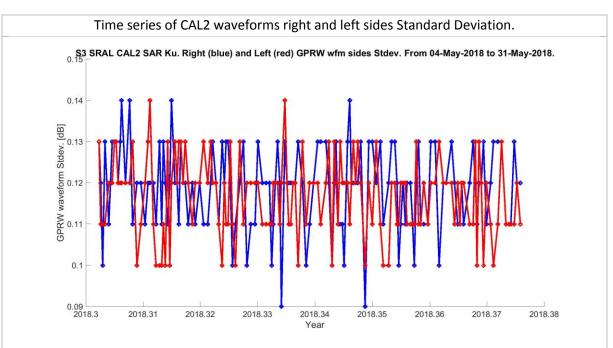
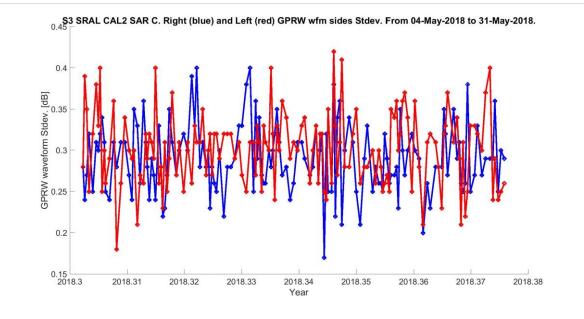


Figure 2-31. CAL2 Ku waveforms right (blue) and left (red) sides Standard Deviation over the period.







#### 2.2.4 AutoCAL (CAL1 SAR Auto)

S3 SRAL CAL1 Auto-Calibration Areas from 06-May-2018 to 24-May-2018.

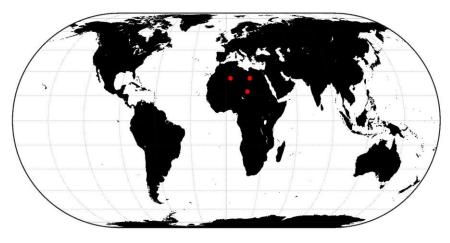


Figure 2-33. Location of the AutoCal measurements.

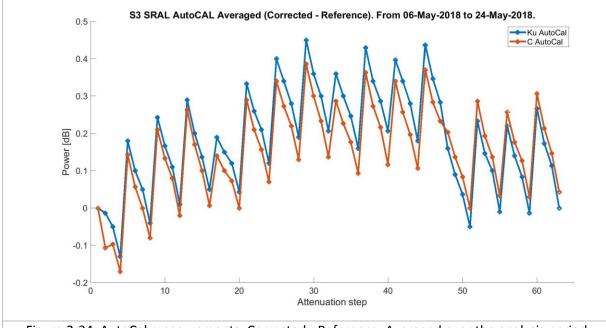


Figure 2-34. AutoCal measurements: Corrected - Reference. Averaged over the analysis period.



#### 2.2.5 Housekeeping Temperatures

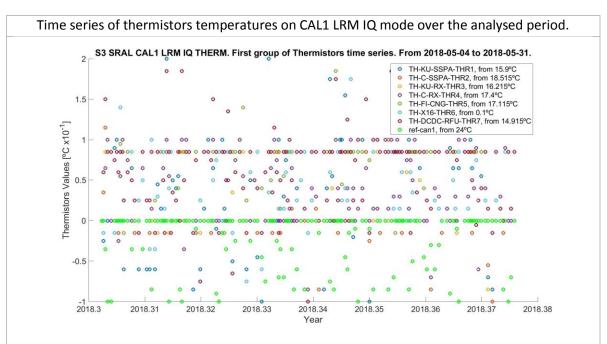
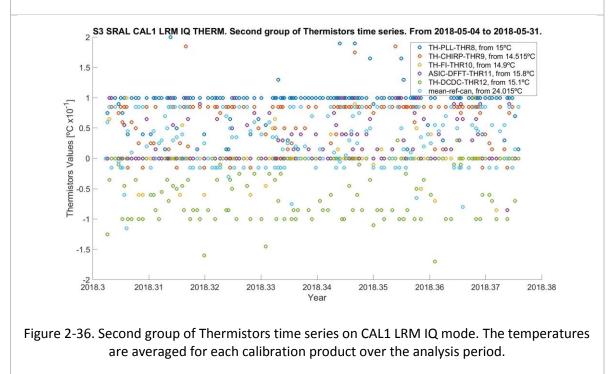
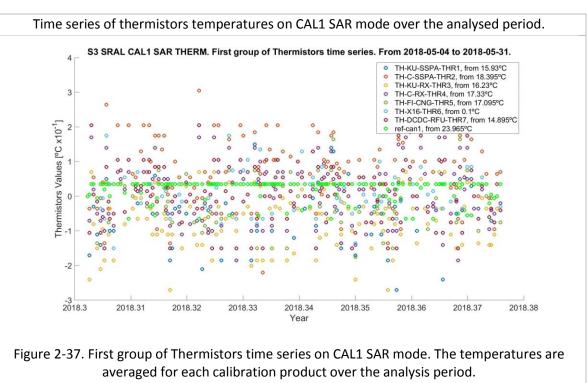
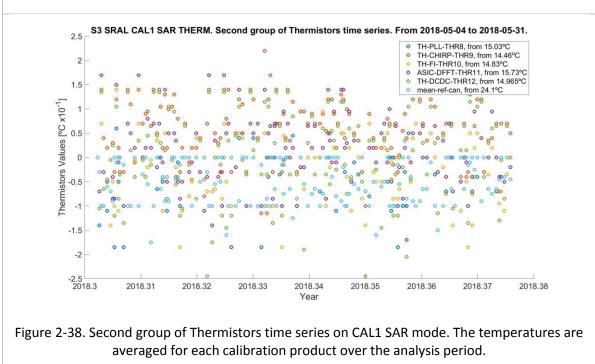


Figure 2-35. First group of Thermistors time series on CAL1 LRM IQ mode. The temperatures are averaged for each calibration product over the analysis period.











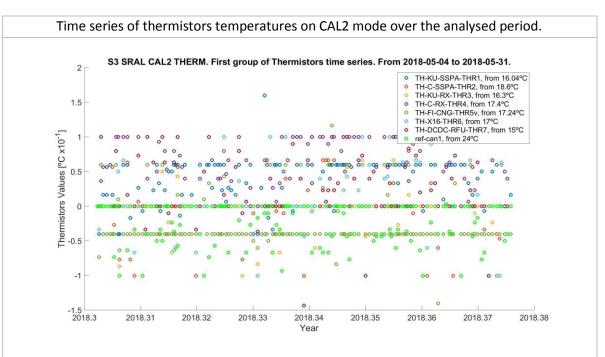
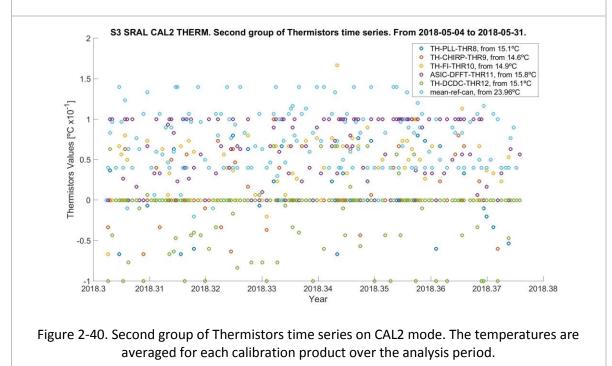


Figure 2-39. First group of Thermistors time series on CAL2 mode. The temperatures are averaged for each calibration product over the analysis period.





## 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.

The current 2.27 processing baseline changes with respect to the previous are:

- The use of an averaged (over 27 days) CAL2 waveform for the CAL1 waveform correction
- The use of the CAL2 Ku band waveform for correcting both Ku and C bands CAL1 waveforms.

The new processing baseline reduces the CAL1 variables noise considerably with respect to previous cycle reports.

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

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.

	Ku band			C band		
Calibration Parameter	mean	annual slope	standard deviation	mean	annual slope	standard deviation
LRM CAL1 time delay	1.0070 m	-1.07 mm	0.05 mm	0.8928 m	0.19 mm	0.04 mm
SAR CAL1 time delay	1.0068 m	-0.96 mm	0.05 mm	0.8934 m	0.61 mm	0.05 mm
LRM CAL1 power	57.49 dB	-0.26 dB	0.01 dB	50.90 dB	-0.01 dB	0.0
SAR CAL1 power	61.92 dB	-0.25 dB	0.01 dB	48.41 dB	-0.01 dB	0.00 dB
LRM CAL1 PTR width	0.4164 m	-2.26 mm	0.06 mm	0.4542 m	-1.29 mm	0.04 mm
SAR CAL1 PTR width	0.4161 m	-2.14 mm	0.06 mm	0.4541 m	-1.37 mm	0.04 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. It presents a decreasing trend but less negative than at BOM. The CAL1 power trend for C band is very low in absolute values, changing its sign from cycle to cycle.



The CAL1 time delay slope has been changing its trend sign along the mission, with values in the order of few mm/year.

The Ku band CAL1 width inter-annual drift is several orders of magnitude below the nominal PTR width value (Ku-band).

CAL2 and Autocal parameters are stable. Some CAL2 parameters present validity flags problems, causing less data to be plotted. This is a known issue, with a solution to be implemented.

The thermistors values are showing a stable series over the analysed period.

All these observations are related to the different SRAL calibration parameters during this cycle. A whole mission monitoring 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.

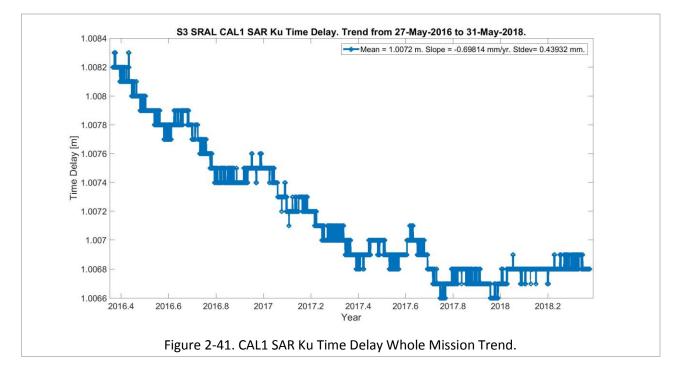
The plotted calibration parameters are:

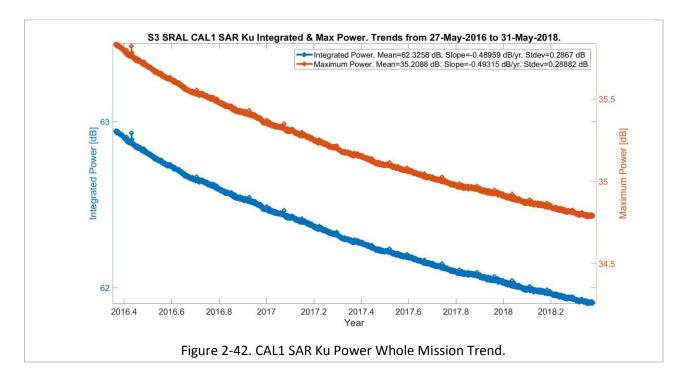
- CAL1 time delay
- CAL1 power
- PTR width
- Burst corrections (power and phase) and their slopes
- CAL2 waveform ripples shape, plus the waveforms slopes and de-trended standard deviations
- Autocal averaged differences and attenuation progression

Also the SAR mode thermistors series is plotted.

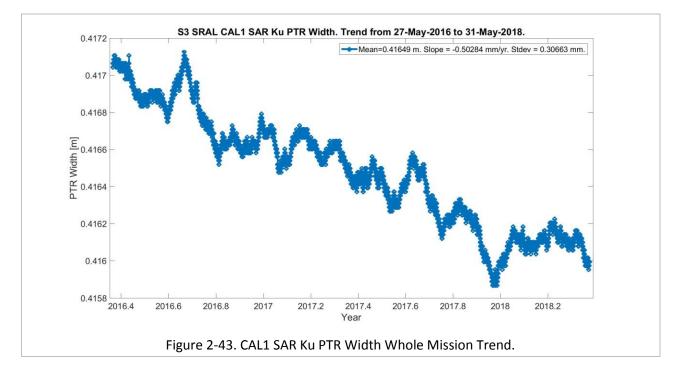
The processing with the new PB2.27 put in operations the 14<sup>th</sup> of February is completed. The previous reports combined results from 2 different processing baselines, impacting some monitored values. This is now solved, and the figures show only the last reprocessed products along the mission.

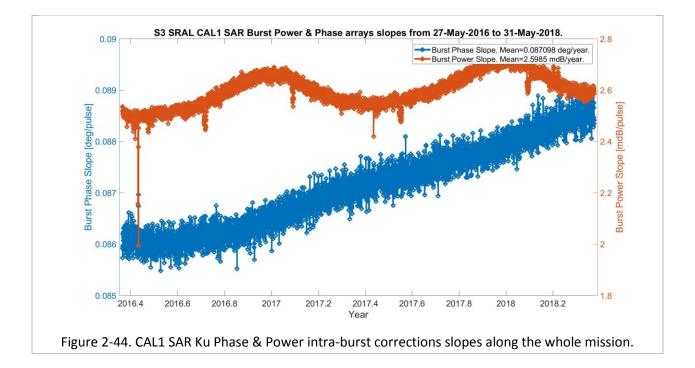




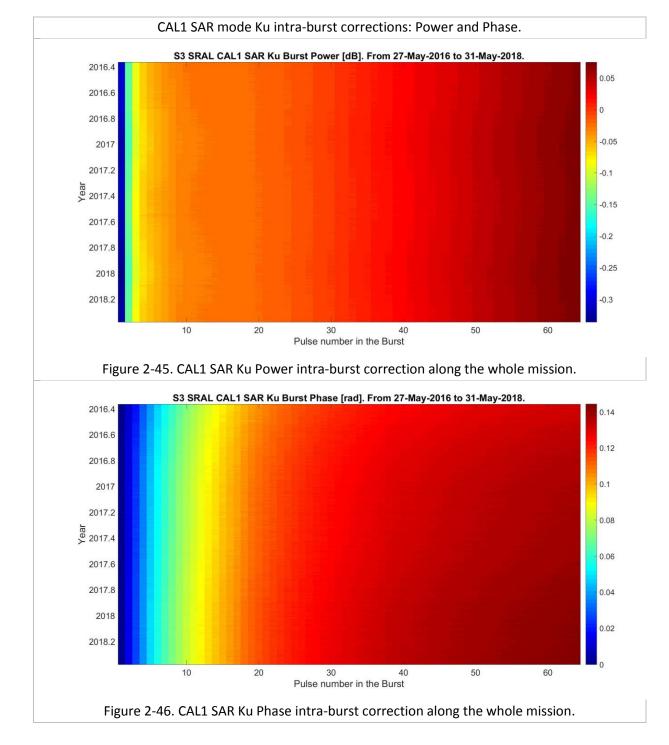




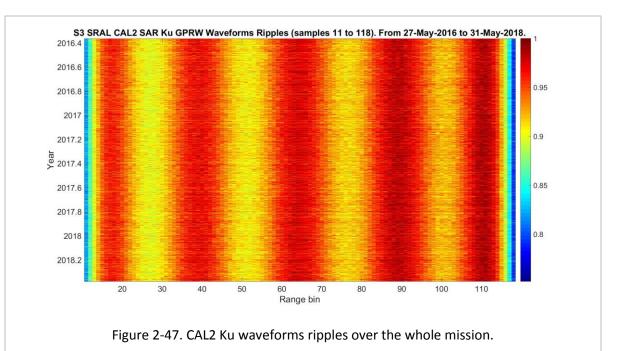


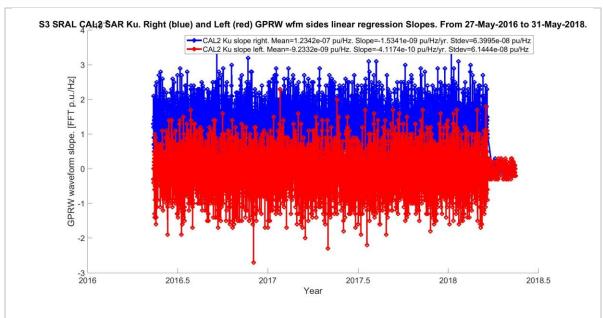


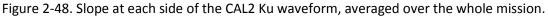














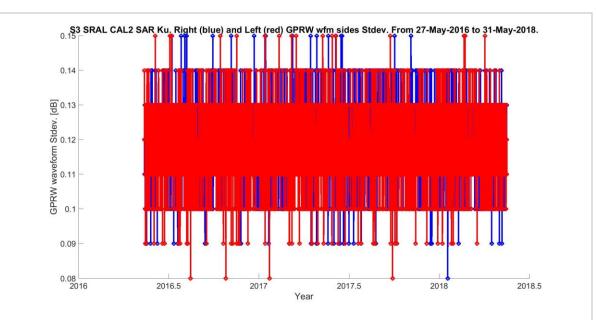
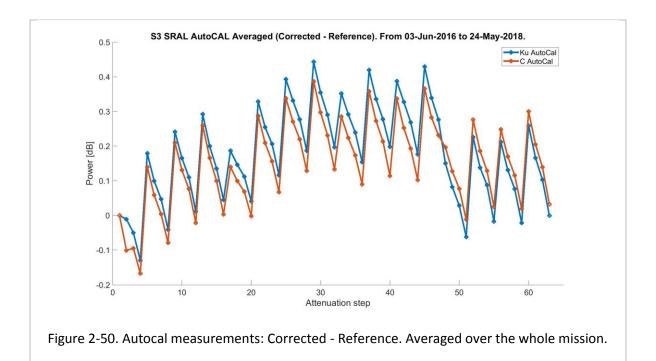


Figure 2-49. CAL2 Ku waveform standard deviation at each side after compensating by the slope, averaged over the whole mission.





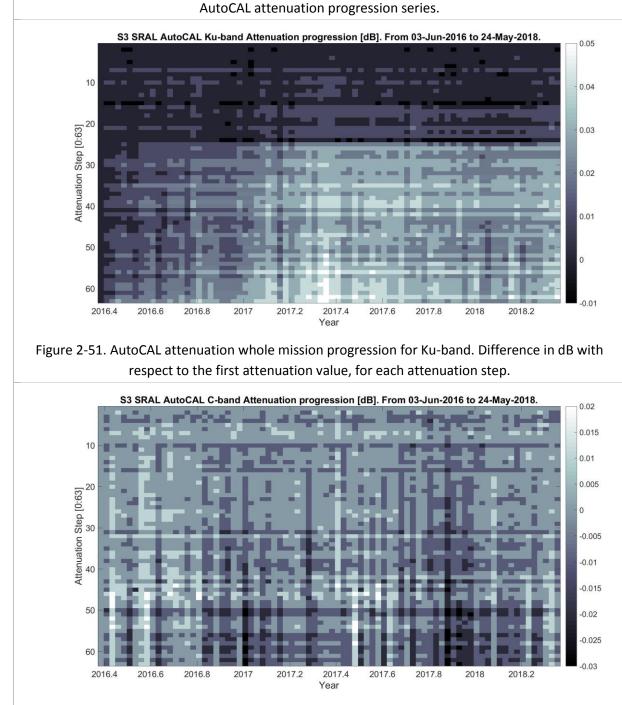
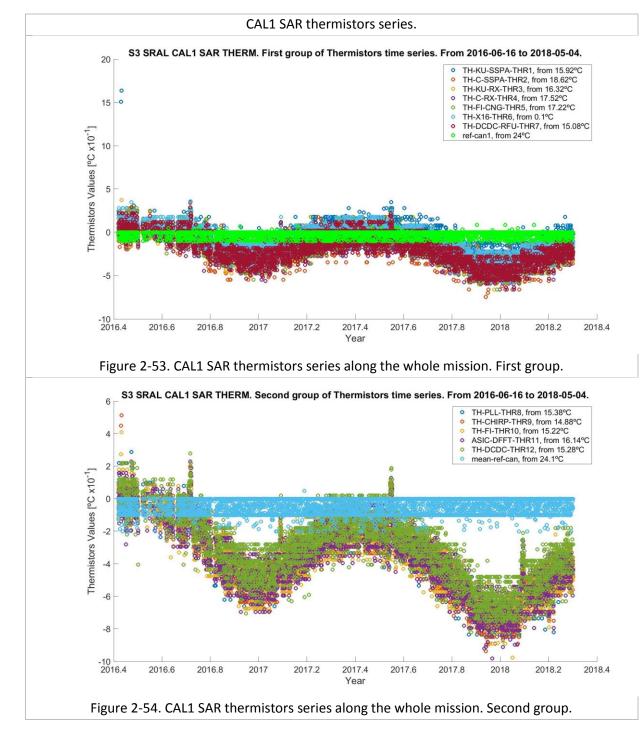


Figure 2-52. AutoCAL attenuation whole mission progression for C-band. Difference in dB with respect to the first attenuation value, for each attenuation step.





The most important and notable drift observed in the whole mission series is the CAL1 Ku Power series, presenting a significant power decay, especially at BOM. Anyhow, it has decreased in absolute values the observed trend along the mission. In cycles 10, 20 and 31 the whole mission SAR Ku Total Power trend in absolute values was respectively of 0.91, 0.68, and 0.49 dB/year. Hence, we can state a slow stabilisation of this parameter.



Also the PTR time delay has decreased its negative trend. In cycles 10, 20 and 31 the whole mission SAR Ku Time Delay trend in absolute values was respectively of 1.94, 1.29 and 0.70 mm/year.

The Ku band PTR width has a trend that is three orders of magnitude below its absolute value, and similar to its standard deviation.

The attenuation steps progression in dB are shown in Figure 2-51 and Figure 2-52, 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 less than 0.1 dB.

The intra-burst corrections along the mission are quite stable. The burst power slope shows a clear annual behaviour and a sensibility to instrumental thermal changes. The burst phase slope is increasing along the mission, around 1 mdeg./pulse per year.

The CAL2 parameters behaviour is stable along the mission. There is a change of signature of the CAL2 slopes in the last weeks due to the deployment of the L1B processing code version "IPF SR1 6.14 - Baseline 2.31". It includes changes in the CAL2 slope flagging, which needs a further correction in the characterisation auxiliary file for its proper flagging.

The thermistors data series are showing an annual behaviour, and a long term negative drift, as shown in Figure 2-53 and Figure 2-54. Around decimal year 2016.7, 2017.1, 2017.55 and 2018.1, there is an increase of the thermistors values of around 0.2 °C, returning after several orbits to its precedent values.

	Ku band			C band			
Calibration Parameter	mean	annual slope	standard deviation	mean	annual slope	standard deviation	
LRM CAL1 time delay	1.0075 m	-0.95 mm	0.59 mm	0.8932 m	-0.41 mm	0.26 mm	
SAR CAL1 time delay	1.0072 m	-0.70 mm	0.44 mm	0.8938 m	-0.29 mm	0.20 mm	
LRM CAL1 power	57.89 dB	-0.48 dB	0.28 dB	50.93 dB	-0.01 dB	0.02 dB	
SAR CAL1 power	62.33 dB	-0.49 dB	0.29 dB	48.44 dB	-0.01 dB	0.02 dB	
LRM CAL1 PTR width	0.4168 m	-0.48 mm	0.30 mm	0.4544 m	-0.09 mm	0.07 mm	
SAR CAL1 PTR width	0.4165 m	-0.50 mm	0.31 mm	0.4542 m	-0.11 mm	0.08 mm	

Finally, the collection of statistics for the main calibration parameters is depicted in Table 2-2 for both modes and bands.

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



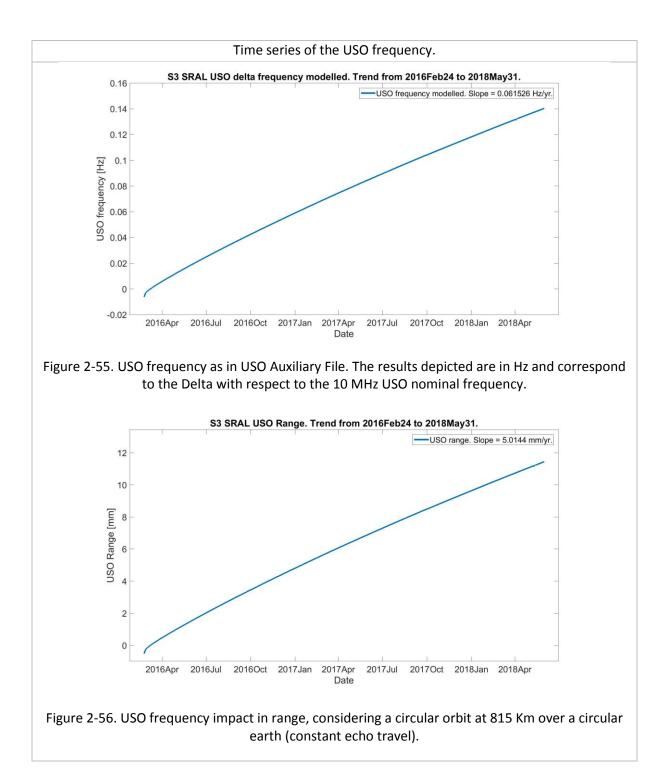
The long term drift for the time delay and power variables is higher in absolute terms for the Ku band than for the C band, the Ku band ageing is faster than the one from C band, probably caused by the more stressed Ku band instrumental operations (e.g. bursts transmission & reception only in Ku band).

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 On-board Clock Performance

The altimeter USO clock frequency has a major multiplicative impact in the determination of the altimeter range. The USO clock is the one that drives the chirp generation and controls the acquisition time (window delay or tracker range) of the returned echo signal. Here below are depicted the USO frequency long term monitoring (Figure 2-55) and its impact on the altimeter range (Figure 2-56).





The USO clock frequency impact in the range has a constant trend of about 5 mm per year.

The USO impact in the range can change around an orbit considering an elliptical orbit and the variations on the surface elevations, but these differences are far below the nominal absolute values.

Also the temperatures on-board can make the clock suffer frequency fluctuations, but as we can see in the previous figures, no visible effects of this kind has been observed so far.



### 2.6 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 (mean, slope and standard deviation over the slope) seems to be reversed. This issue is not impacting the quality of the science data. An investigation has been done by the S3-MPC team. The cause is related to the use of wrong units in the variables written in the characterisation file. Also the impact of a low absolute error in the final relative error computation has been addressed. Updated nominal and redundant characterization ADFs have been delivered. There is a remaining issue about the auxiliary files update, which have an impact in some figures such as the CAL2 slope, to be solved.



#### Cycle No. 031

## **3** Calibration with Transponder

isardSAT has processed the TRP data from a list of L1A products. Passes with IPF-SR-1 Version 06.13 (cycle 3 to 23) use reprocessed L1A and L2 data provided on the ftp.s3rep.acri-cwa.fr FTP server. Passes from cycle 24 to 31 increase in IPF-SR-1 Version as newer ones become available, up to Version 06.14 for the most recent passes.

The range bias results are of the order of millimetres. The datation bias is of the order of hundreds of microseconds.

The passes on cycles 13 and 21 (2017/08/08) have not been analysed because the transponder was not switched on due to extreme climate conditions.

Table 3-1 and Figure 3-1 to Figure 3-4 present the results from the TRP passes processing. The range bias is computed as measured minus theoretical. The results show a positive measured range, 7.44 mm larger than expected (elevation 7.44 mm shorter than expected), and a datation bias of -174.97 microseconds, both extracted from the minimisation of the RMS between theoretical and measured series, and from the stack misalignment estimation. They also show a ~0.85 mm stack noise.

The regression line in Figure 3-1 shows a drift of 1.08 mm/year, but it has a very low significance.

In Figure 3-5 and Figure 3-6 it is shown a comparison between the two processing baselines. We can see that there are no significant differences in range and datation bias.

2	Sentinel-3 MPC	Ref.:	S3MPC.ISR.PR.04-031
SENTINEL 3	S3-A SRAL Cyclic Performance Report	Issue:	1.0
Mission Performance Centre		Date:	05/06/2018
	Cycle No. 031	Page:	41

Cycle	Date	Range bias [mm]	Datation bias [microseconds]	Alignment [mm/beam]	Noise [mm]	IPF-SR-1 Version
3	2016/04/09	0.33	-114.61	-0.08	0.81	06.13
4	2016/05/06	14.29	-127.34	-0.07	0.78	06.13
5	2016/06/02	-3.91	-165.54	-0.09	0.86	06.13
6	2016/06/29	1.00	-140.07	-0.06	0.92	06.13
7	2016/07/26	-2.84	-152.77	-0.07	1.01	06.13
8	2016/08/22	-0.50	-127.32	-0.09	0.81	06.13
9	2016/09/18	1.19	-203.73	-0.13	0.71	06.13
10	2016/10/15	8.83	-178.28	-0.12	0.66	06.13
11	2016/11/11	19.89	-127.32	-0.09	0.79	06.13
12	2016/12/08	21.13	-140.07	-0.07	0.82	06.13
13	Transponder not switched of	on due to heavy	r snow.		I	
14	2017/01/31	26.38	-140.07	-0.09	0.72	06.13
15	2017/02/27	2.74	-165.54	-0.10	0.86	06.13
16	2017/03/26	-0.24	-216.48	-0.13	0.79	06.13
17	2017/04/22	14.70	-165.54	-0.13	1.05	06.13
18	2017/05/19	28.66	-127.34	-0.06	1.11	06.13
19	2017/06/15	-4.15	-203.74	-0.09	1.28	06.13
20	2017/07/12	-15.89	-127.34	-0.09	0.70	06.13
21	Transponder not switched of	sponder not switched on due to high temperatures.		I		
22	2017/09/04	26.32	-165.54	-0.12	0.69	06.13
23	2017/10/01	19.51	-152.81	-0.10	0.70	06.13
24	2017/10/28	0.31	-229.21	-0.15	0.92	06.11
25	2017/11/24	15.63	-203.74	-0.15	0.83	06.12
26	2017/12/21	-1.81	-216.48	-0.14	0.80	06.12
27	2018/01/17	10.20	-203.74	-0.14	0.94	06.12
28	2018/02/13	13.89	-229.21	-0.15	0.75	06.13
29	2018/03/12	-1.69	-203.74	-0.17	0.95	06.14
30	2018/04/08	4.78	-229.21	-0.16	0.82	06.14
31	2018/05/05	2.01	-241.94	-0.14	0.89	06.14
Mean		7.44	-174.97	-0.11	0.85	-



Cycle	Date		Datation bias [microseconds]			IPF-SR-1 Version
Standa	rd Deviation	11.29	38.78	0.03	0.14	-

Table 3-1. Results of TRP passes processing

Regarding the geophysical corrections, the ionospheric and wet/dry tropospheric corrections were extracted from the transponder auxiliary files provided by the MPC team.

Then, the solid earth, geocentric tide and ocean loading corrections are selected from the L2 products. A table with the Geophysical corrections used is shown in Table 3-2. The TRP internal delay is 4.954 meters.

Cycle	Date	Dry Tropo [m]	Wet Tropo [m]	lono [m]	Solid Earth [m]	Geocentric Tide [m]	Ocean Loading [m]
3	2016/04/09	-2.02600	-0.08710	-0.02418	-0.12970	0.00290	0.00310
4	2016/05/06	-2.04220	-0.07140	-0.03489	-0.04410	0.00230	0.01020
5	2016/06/02	-2.05024	-0.12316	-0.03851	0.03480	0.00100	0.00900
6	2016/06/29	-2.05184	-0.11006	-0.02995	-0.00030	-0.00060	0.00250
7	2016/07/26	-2.04933	-0.07117	-0.02432	-0.08820	-0.00260	-0.00200
8	2016/08/22	-2.05343	-0.07527	-0.02265	-0.12310	-0.00380	-0.00140
9	2016/09/18	-2.05799	-0.12541	-0.02411	-0.03270	-0.00470	0.00360
10	2016/10/15	-2.06529	-0.06351	-0.01800	0.13620	-0.00470	0.00680
11	2016/11/11	-2.06734	-0.07036	-0.01639	0.19500	-0.00400	0.00310
12	2016/12/08	-2.07943	-0.01087	-0.01453	0.09160	-0.00270	-0.00300
14	2017/01/31	-2.06552	-0.01138	-0.01913	-0.08110	0.00060	-0.00220
15	2017/02/27	-2.05001	-0.09089	-0.01818	-0.00790	0.00200	0.00310
16	2017/03/26	-2.05115	-0.06735	-0.01618	0.11520	0.00270	0.00520
17	2017/04/22	-2.04841	-0.04449	-0.02672	0.13670	0.00270	0.00160
18	2017/05/19	-2.05320	-0.03910	-0.03295	0.03340	0.00210	-0.00260
19	2017/06/15	-2.05731	-0.07789	-0.02817	-0.08180	0.00080	-0.00230
20	2017/07/12	-2.05252	-0.08288	-0.02232	-0.11870	-0.00080	0.00190
22	2017/09/04	-2.05777	-0.00013	-0.02142	0.02520	-0.00370	0.00900
23	2017/10/01	-2.06119	-0.06361	-0.02128	0.05060	-0.00440	0.00510

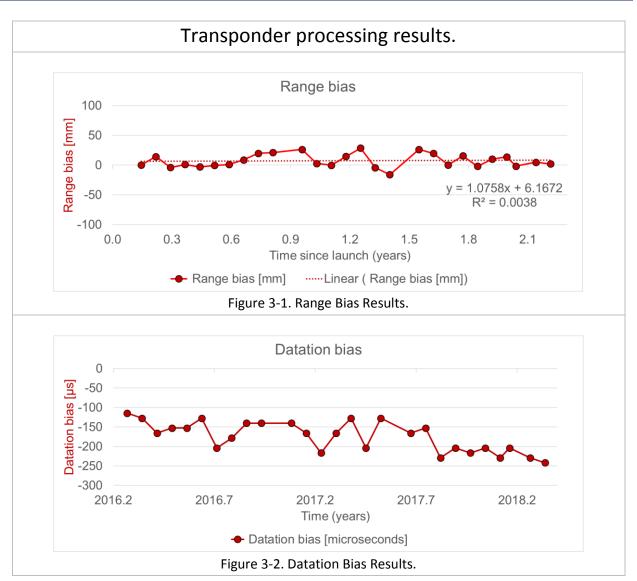
2	Sentinel-3 MPC	Ref.:	S3MPC.ISR.PR.04-031
SENTINEL 3	S3-A SRAL Cyclic Performance Report	Issue:	1.0
Mission Performance Centre	33-A Share Cyclic I erformance heport	Date:	05/06/2018
	Cycle No. 031	Page:	43

Cycle	Date	Dry Tropo [m]	Wet Tropo [m]	lono [m]	Solid Earth [m]	Geocentric Tide [m]	Ocean Loading [m]
24	2017/10/28	-2.03975	-0.12175	-0.01537	0.00120	-0.00440	-0.00040
25	2017/11/24	-2.06119	-0.06461	-0.01486	-0.03940	-0.00340	-0.00270
26	21/12/2017	-2.05275	-0.12315	-0.01603	-0.00760	-0.00160	-0.00150
27	2018/01/17	-2.03678	-0.06282	-0.01587	0.08640	-0.00020	0.00100
28	2018/02/13	-2.04978	-0.04902	-0.01518	0.17020	0.00130	0.00130
29	2018/03/12	-2.04591	-0.11249	-0.01673	0.16230	0.00170	-0.00130
30	2018/04/08	-2.05024	-0.06556	-0.02125	0.05600	0.00160	-0.00350
31	2018/05/05	-2.04203	-0.02587	-0.03728	-0.06510	0.00100	-0.00200

Table 3-2. Geophysical Corrections of TRP passes processing



Cycle No. 031





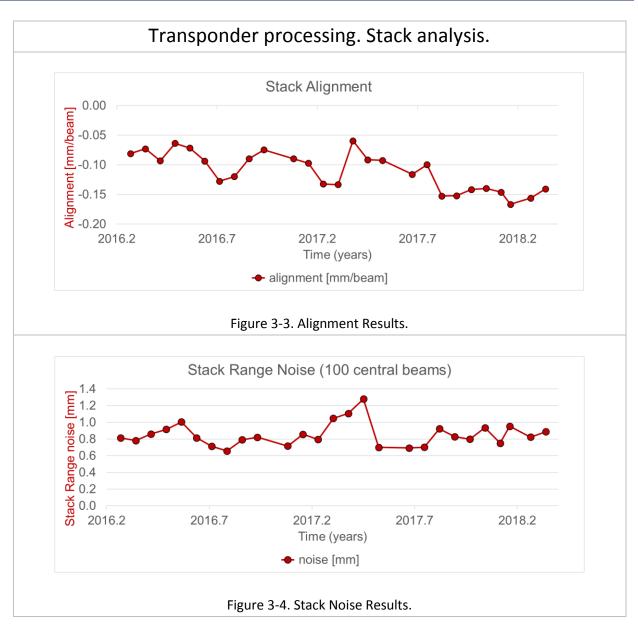
Cycle No. 031

 Ref.:
 S3MPC.ISR.PR.04-031

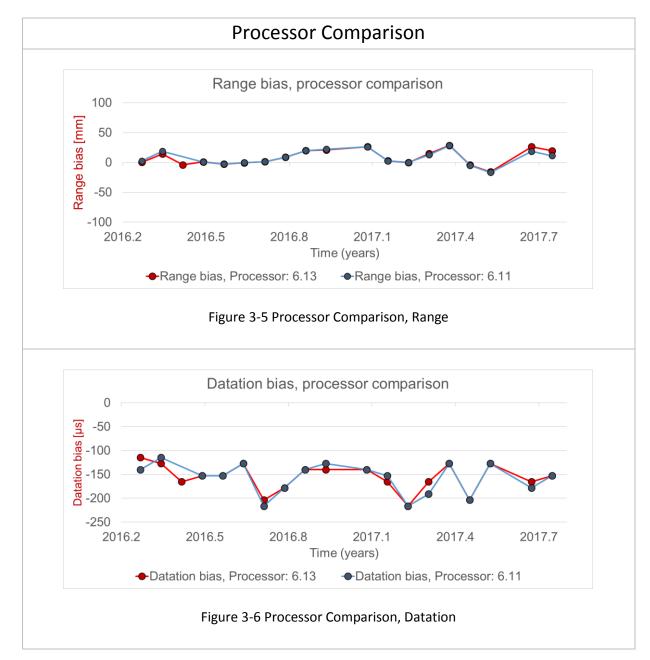
 Issue:
 1.0

 Date:
 05/06/2018

 Page:
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## 4 Events

No SRAL special events have been observed during this cycle.



# 5 Appendix A

Other reports related to the STM mission are:

- S3-A MWR Cyclic Performance Report, Cycle No. 031 (ref. S3MPC.CLS.PR.05-031)
- S3-A Ocean Validation Cyclic Performance Report, Cycle No. 031 (ref. S3MPC.CLS.PR.06-031)
- S3-A Winds and Waves Cyclic Performance Report, Cycle No. 031 (ref. S3MPC.ECM.PR.07-031)
- S3-A Land and Sea Ice Cyclic Performance Report, Cycle No. 031 (ref. S3MPC.UCL.PR.08-031)

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

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