CryoSat-2 - SIRAL Calibration with Transponder

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ABSTRACT

The CryoSat mission is designed to determine fluctuations in the mass of the Earth's land and the marine ice fields. Its primary payload is a radar altimeter that operates in different modes optimised depending on the kind of surface: Low resolution mode (LRM), SAR mode (SAR) and SAR interferometric mode (SARin). This radar is named SIRAL: Synthetic aperture interferometer radar altimeter [1].

Transponders are commonly used to calibrate absolute range from conventional altimeter waveforms because of it characteristic point target radar reflection. The waveforms corresponding to the transponder distinguish themselves from the other waveforms resulting from natural targets, in power and shape.

ESA has deployed a transponder available for the CryoSat project (a refurbished ESA transponder developed for the ERS-1 altimeter calibration). It is deployed at the KSAT Svalbard station: SvalSAT. Another transponder has been deployed in Greece Technical University of Crete for the Sentinel 3 calibration.

We are using the transponder to calibrate SIRAL's range, datation, and interferometric baseline (or angle of arrival) to meet the missions requirements [2]. In these calibrations, we are using 3 different type of data: the raw Full Bit Rate data, the stack beams before they are multi-looked (stack data) in the Level 1b processor, and the Level 1b data itself [3].

Ideally the comparison between (a) the theoretical value provided by the well-known target, and (b) the measurement by the instrument to be calibrated; provides us with the error the instrument is introducing when performing its measurement [4]. When this error can be assumed to be constant regardless the conditions, it will provide the bias of the instrument. And if the measurements can be repeated after a certain period of time, it can also provide an indication of the instrument drift.

This poster presents the analysis and results of this calibration. The work presented here has been carried out under an ESTEC/ESA contract, to calibrate CryoSat-2 during the Commissioning phase. It was later extended with an ESRIN/ESA contract, for continue monitoring and including further analysis.

Acknowledgments: The authors of this poster would like to thank Walter Smith for providing the terrain motion data over the Svalbard region which has been a key to understand the long term range results evolution.

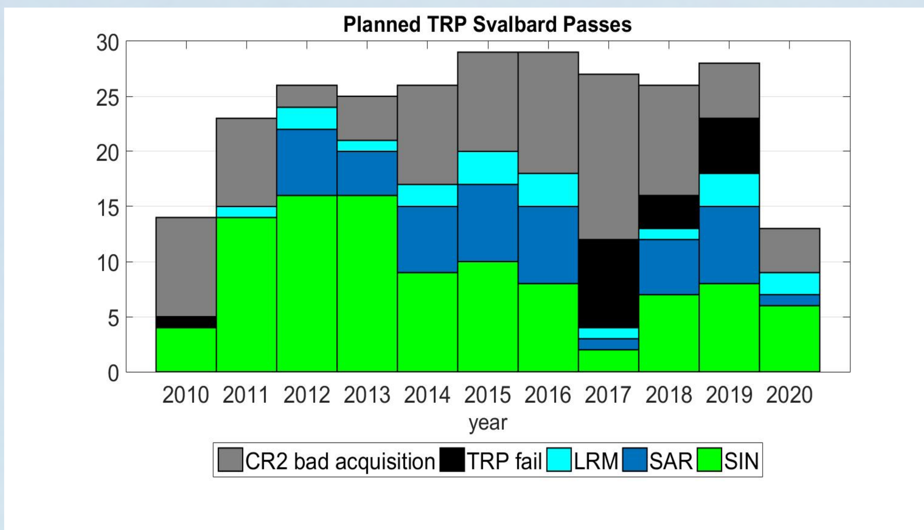
[1] C.R. Francis, "CryoSat Mission and Data Description", CS-RP-ESA-SY-0059.

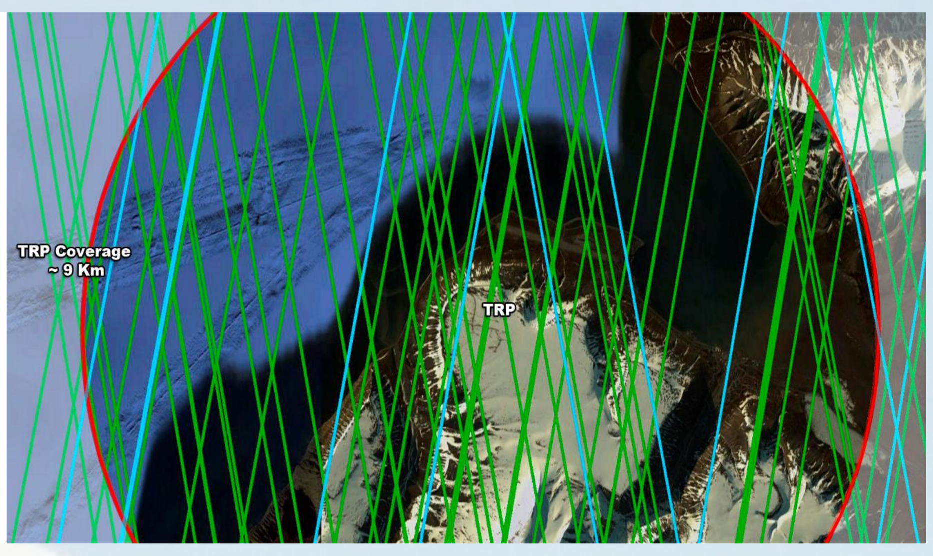
[2] CryoSat Science and Mission Requirements Document, CS-RP-UCL-SY-001.

[3] D.J.Wingham, et al.: "CryoSat: A mission to determine the fluctuations in Earth's land and marine ice fields", Advances in Space Research 37 (2006) 841–871.

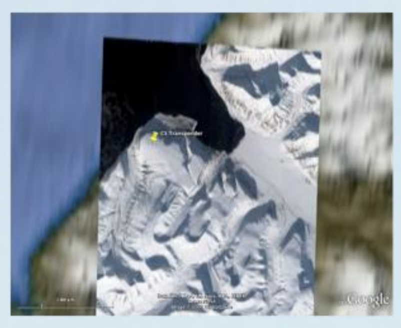
[4] SIRAL2 Calibration using TRP: Detail Processing Model – DPM; ISARD_ESA_CR2_TRP_CAL_DPM_030.

DATA – SARIn, SAR & LRM PASSES





THE SVALBARD SITE



- Transponder location: Svalbard (selected due to its high latitude).
- CryoSat Orbit repeat cycle is 369 days.
- The passes can be used so long as the power decay (with respect to the peak) is not greater than about -7dB, which implies a separation from the nadir track of about about 4 km.
- Further away passes have been used, but need to be carefully considered.

THE TRP CHARACTERISTICS

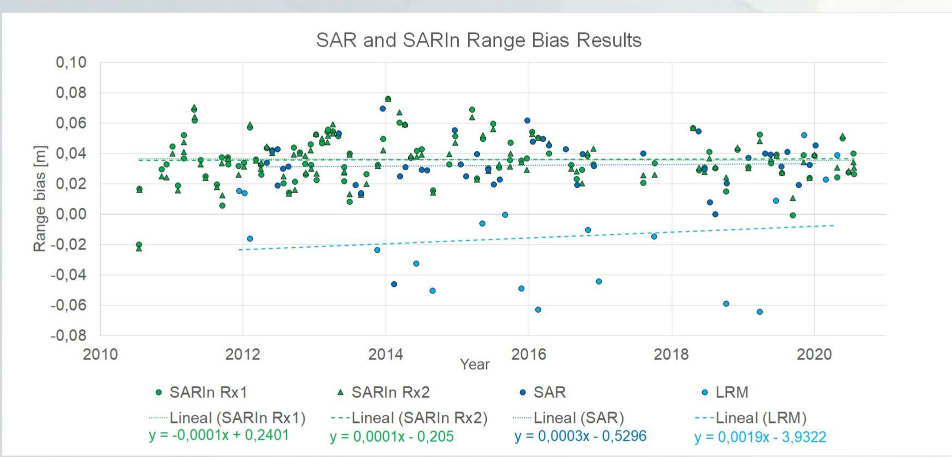
Antenna diameter	0.61 m
Radar cross section ($\sigma = G_{ant1} \times G_{ant2} \times G_{sys} \times \lambda^2/4\pi$)	44.5 – 104.5 dB
Beam width	2.5º
Beam co-linearity	+-0.1 º
Beam pointing	+-0.1º
Antenna gain	35.8 dB
Inter-antenna isolation	105 dB
Amplifier frequency rang	13.2 – 14.1 GHz
Amplifier gain	17-77 dB
Amplifier gain variation across band	<+-0.5 dB
Amplifier 1dB suppression point	20 or 23 dBm
Amplifier phase linearity across band	+-7º
Internal gain monitoring precision	+-0.05 dB
Internal path-length monitoring precision	+-0.5 mm
Nominal internal path length	9.88 m
Path-length stability over temperature	0.1 mm/º

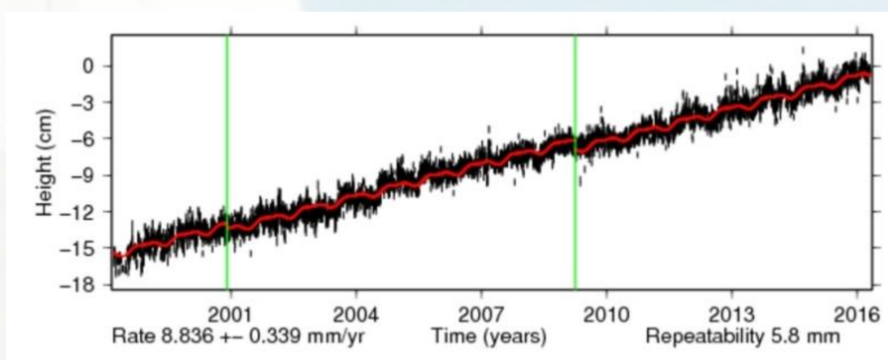
Transponder developed by RAL (UK) in 1987
Refurbished for CryoSat calibration, curtsey of ESA

RESULTS

RANGE RESULTS

The correction of the terrain motion was added to the other geophysical corrections in order to get the proper deviation of the instrument range bias.





Terrain motion (height component) in Ny-Ålesund, Svalvard JPL

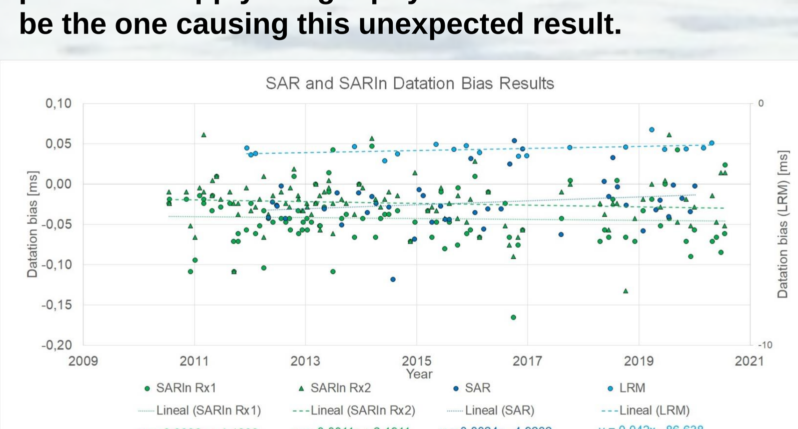
	SARIn Rx1	SARIn Rx2	SAR	LRM	Overall SAR/SARIn
# measurements	101	101	44	19	246
Bias	36.1 mm	35.8 mm	32.3 mm	-14.83 mm	34.73 mm
Std	15.3 mm	14.9 mm	18.4 mm	34.84 mm	16.20 mm
Drift	-0.10 mm/year	0.12 mm/year	0.28 mm/year	1.94 mm/year	0.1 mm/year

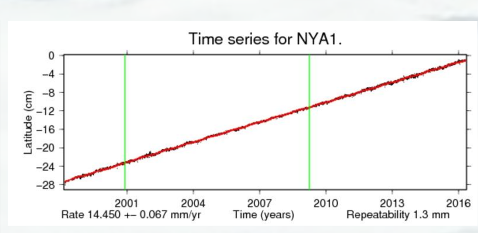
The range noise results are very stable as well considering residual variation less than 1mm / year for SARIn and SAR, and aligned with the absolute range measurements.

DATATION RESULTS

The results for SAR and SARIn have been referenced to the left vertical axis and the LRM ones to the right due mismatching between LRM results. The slope of the regressions shows a variation around -0.85 µs / year.

After the Baseline D upgrade, the datation results between SARIn Rx1 and Rx2 are not well aligned. There is a bias between them around 20 microseconds. The Baseline D changes in the application of CAL1 and the USO correction will be reviewed in case there are related with this anomaly. Additionally, the datation results obtained for LRM do not match with the datation results obtained with the studies over ocean. The process to apply the geophysical corrections in the LRM needs to be reviewed as should be the one causing this unexpected result.





Terrain motion (latitude component) in Ny-Ålesund, Svalvard, by JPL

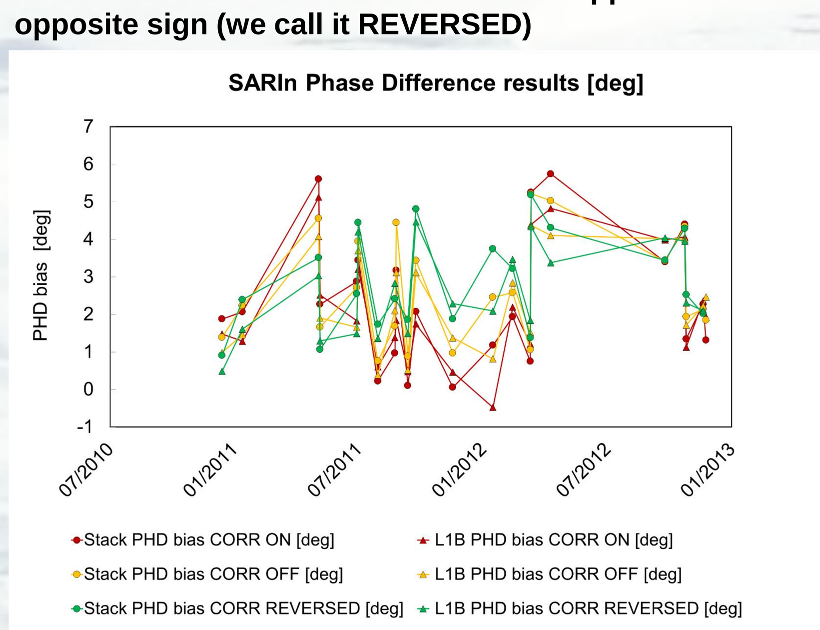
The datation trend around -0.85 µs / year is related with the motion northward. As the coordinates for the TRP position are fixed during the processing of all passes, the datation error should be varying according to the movement of the terrain in that direction.

	SARIn Rx1	SARIn Rx2	SAR	LRM	Overall SAR/SARIN
# measurements	101	101	44	19	246
Bias	-42.5 µs	-23.6 µs	-22.9 µs	-1.88 ms	-29.66 µs
Std	34.2 µs	29.9 µs	30.8 µs	0.27 ms	31.63 µs
Drift	-0.6 µs/year	-1.1 µs/year	+2.4 µs/year	+42.0 µs/year	-0.85 µs/year

INTERFEROMETRIC PHASE RESULTS

An analysis has been made in order to investigate if the "aberration correction" applied to the attitude measurements computed with the Star Trackers was correctly applied or with an opposite sign.

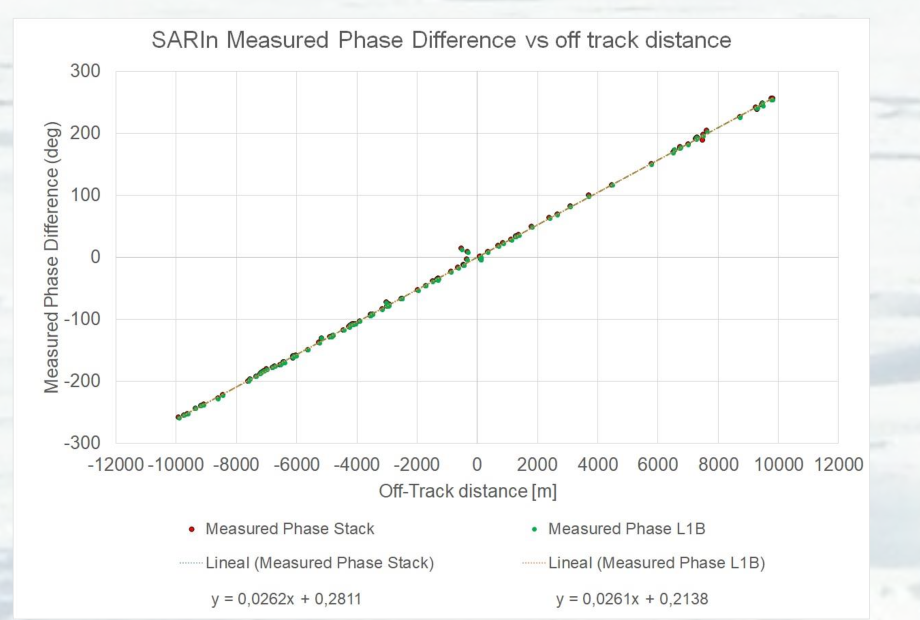
The procedure was to process the data from L0 to L1B with 3 different attitude files. The first one with the aberration correction applied as it was done in the past (we will call it ON) the second one with the aberration correction not applied (we will call it OFF) and the last one with the aberration correction applied with the opposite sign (we call it REVERSED)



It can be appreciated that the phase results obtained with the data processed with the REVERSED aberration correction, green line, are the ones with a lower standard deviation, around 1.2 degrees, while the ones obtained with the aberration correction ON seem to be noisier, standard deviation around 1.6 degrees.

The phase results for each STR are summarized in the table bellow. An average bias around -0.15 degrees has been obtained.

	STR1		STR2		STR3	
	average	std	average	std	average	std
Stack data	0.05	1.53	-0.05	1.66	-0.35	1.87
L1B data	0.15	1.50	-0.26	1.45	-0.46	1.75

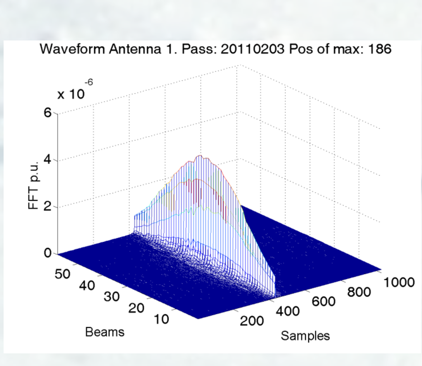


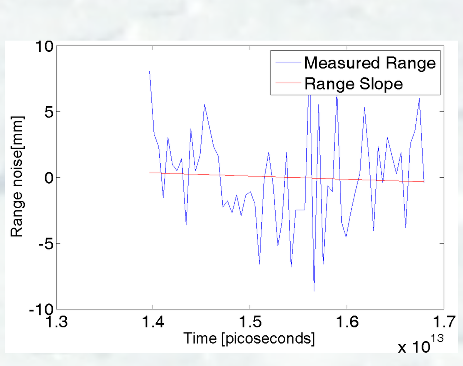
A similar bias is obtained from another point of view. This time we are computing the regression line of the Measured Phase Difference for each pass vs the off track distance. We obtain a bias around 0.2 degrees

RANGE NOISE OVER THE STACKS

The standard deviation of the independent TRP range errors gives us an overall view of the noise of the range measurement, where not only the instrument noise has to be taken into account but also the noise in all the geophysical corrections applied.

In order to evaluate as closer as possible the range performances of the instrument, the noise within the aligned stacks is computed.





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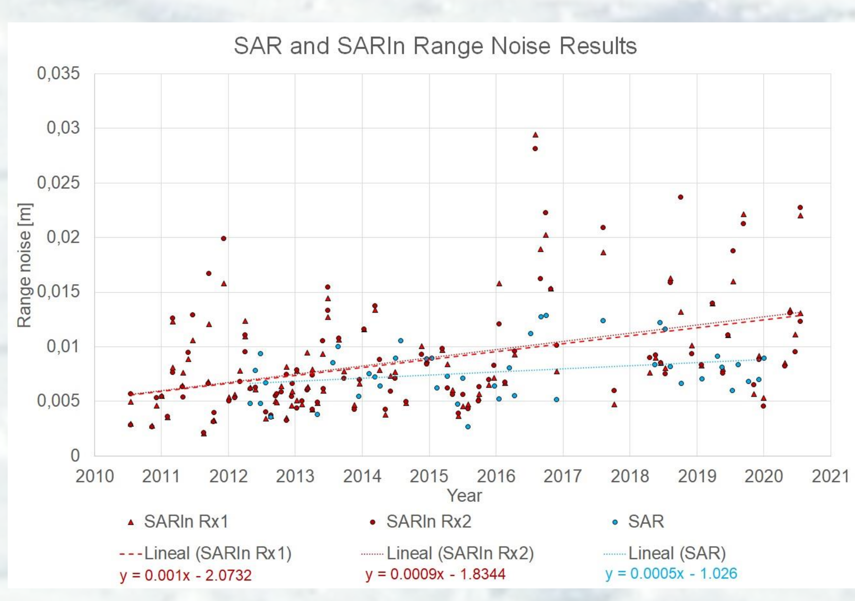

CONCLUSIONS

- Results show consistence among the different types of data used (Stack data and L1B).
- The residual range bias observed is about 3.5 cm . A trend of 0.1 mm/year is observed in the range results over Svalbard after compensating with the terrain motion monitored with a GPS ground station.
- After the correction of the datation biases found in Baseline A&B, the datation bias could be considered negligible in the SAR/SARIn cases. But with the Baseline D upgrade, the datation bias between the channels is not well aligned. The residual datation bias is around -23 µs for SAR/SARIn (channel 2) while for SARIn (channel 1) is -42 µs. Note: The pre-launch system datation testing showed a random error of a few µs. There is also a trend of – 0.85 µs / year that could be linked with the latitude component of the terrain motion in Svalbard.
- After the Baseline D changes, the phase results have been reduced from 2 degrees to residual values (-0.1 degrees).
- The phase results are still noisier when the STR selection is not done properly by the on-board system. In some passes STR ATT_REF does not provide the best phase result.