CryoSat-2 - SIRAL Calibration with Transponder

Adrián Flores de la Cruz [1], Albert Garcia-Mondéjar [1], Marco Fornari [2], Jerome Bouffard [3], Alessandro Di Bella [3], Mònica Roca [1]

[1] isardSAT; [2] ESTEC, ESA; [3] ESRIN, ESA

isardSAT

esa

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 its 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.

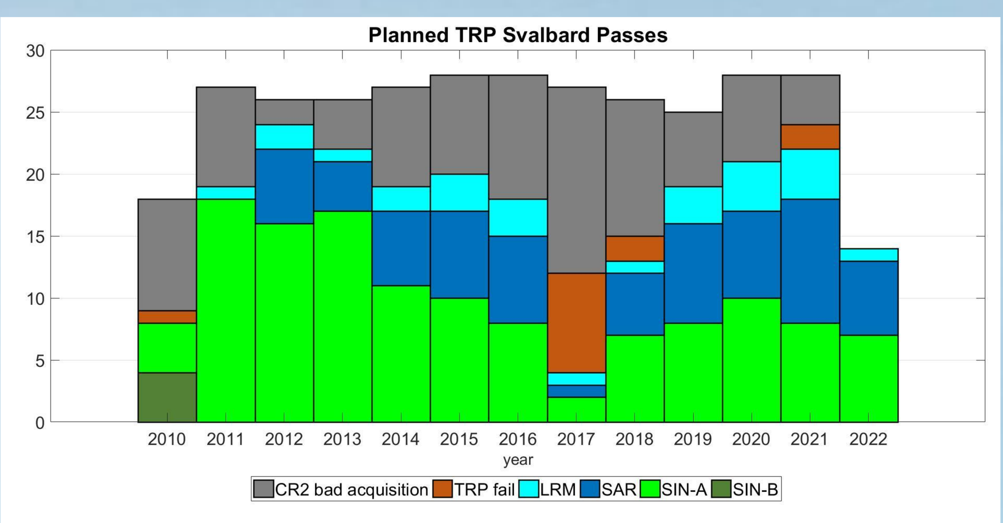
ESA has deployed a transponder available for the CryoSat project (a refurbished ESA transponder developed for the ERS-1 altimeter calibration) at the KSAT Svalbard station. Another transponder was deployed in Greece Technical University of Crete for the Sentinel-3 calibration and then moved to the current location.

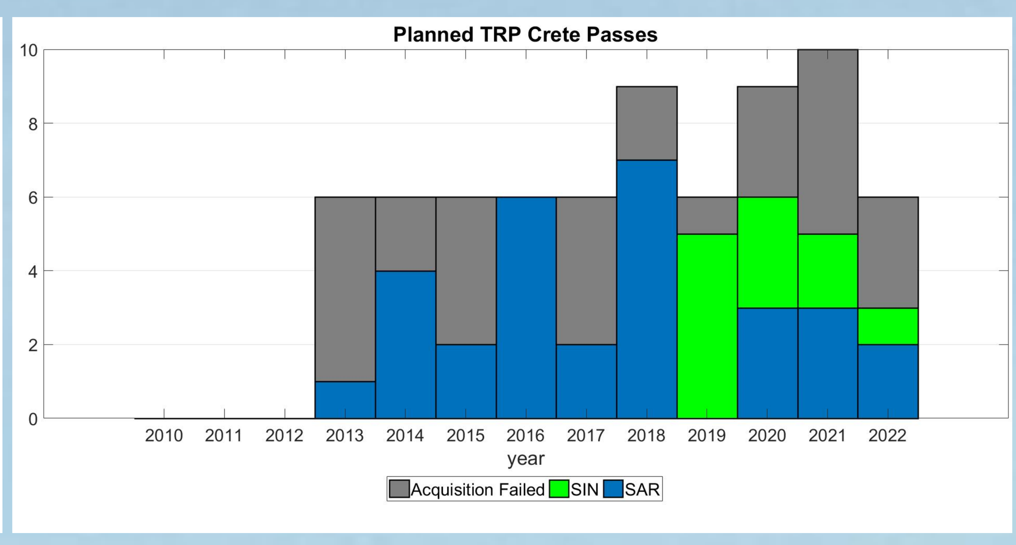
This transponder is also used to calibrate SIRAL's range, datation, and interferometric baseline (or angle of arrival) to meet the mission requirements [2]. Three different type of data are used: the raw Full Bit Rate data, the stack beams before they are multi-looked (stack data) in the Level 1b processor, 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 the error that the instrument introduces when performing its measurement [4]. When this error can be assumed to be constant regardless of the conditions, it will provide the bias of the instrument. 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 using the products processed with **Baseline E**. 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.

DATA – SARIn, SAR & LRM PASSES



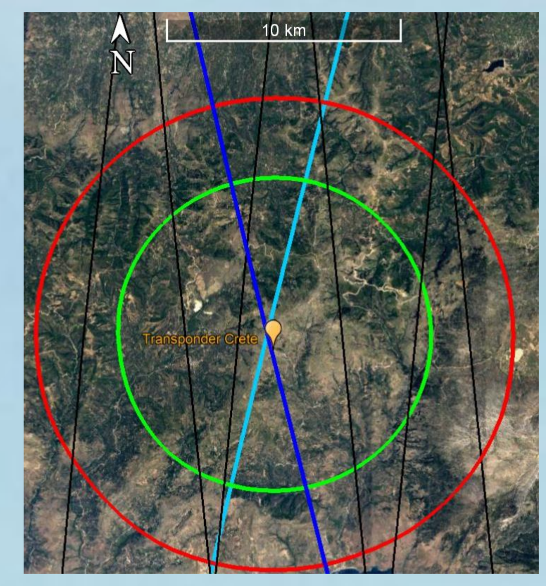


- ~26 CS2 passes planned per year
- Two important anomalies, early 2017 and late 2017 (20 and 6 passes off) related with power supply

- ~6 CS2 passes planned per year
- Several passes failed during the job order generation

THE CRETE SITE

Transponder site being cleared, with GNSS receiver, solar panels and wind generator

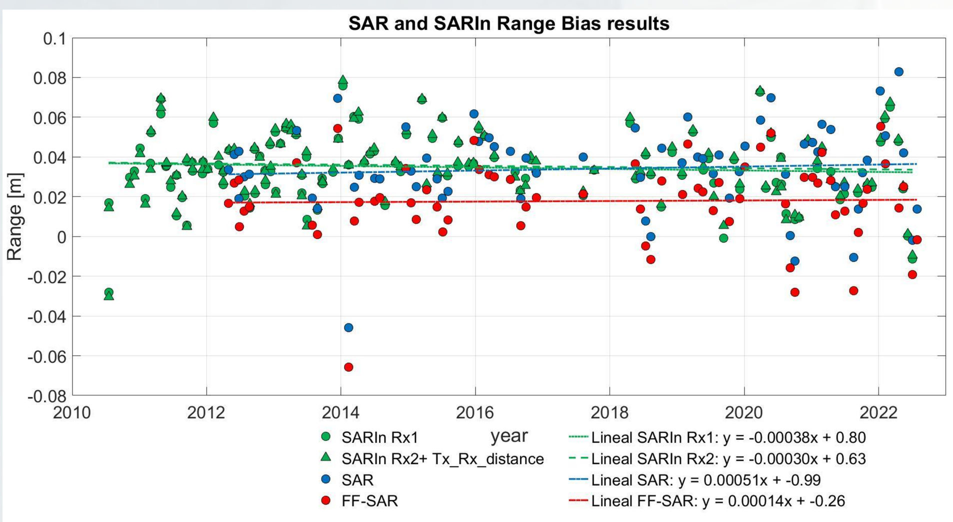


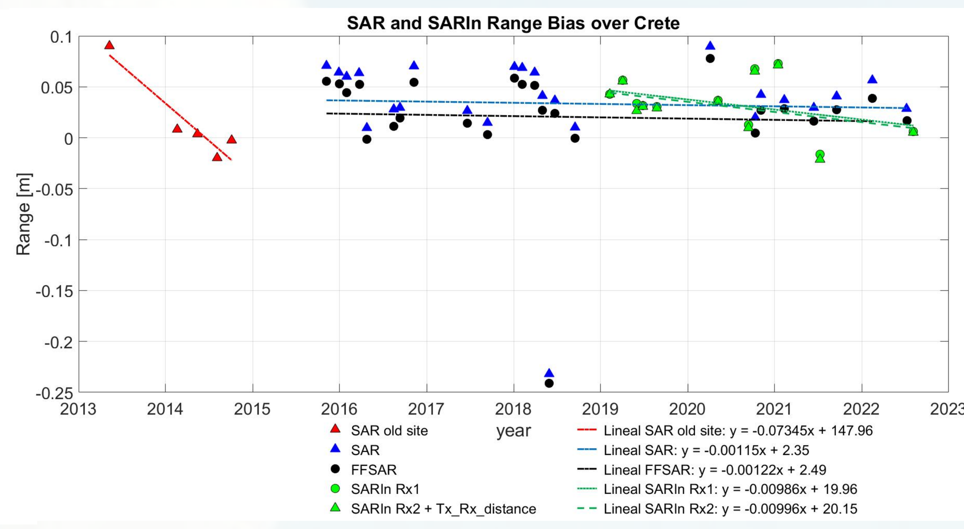
The Crete transponder was developed at the Technical University of Crete for ESA's Copernicus earth observation programme. As well as the Sentinel-3 project, it services the Jason missions as an additional transponder site.

RESULTS

RANGE RESULTS

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

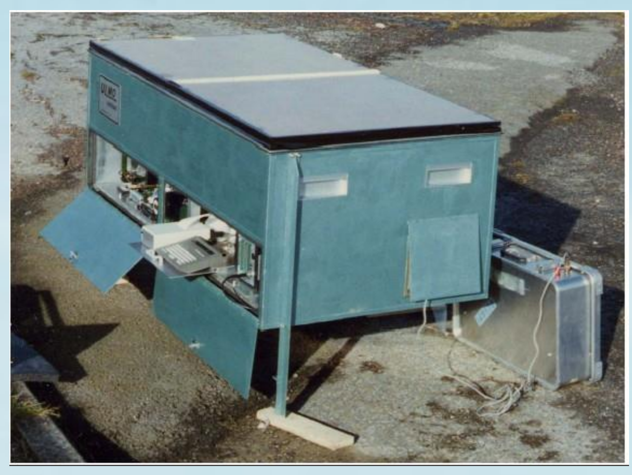




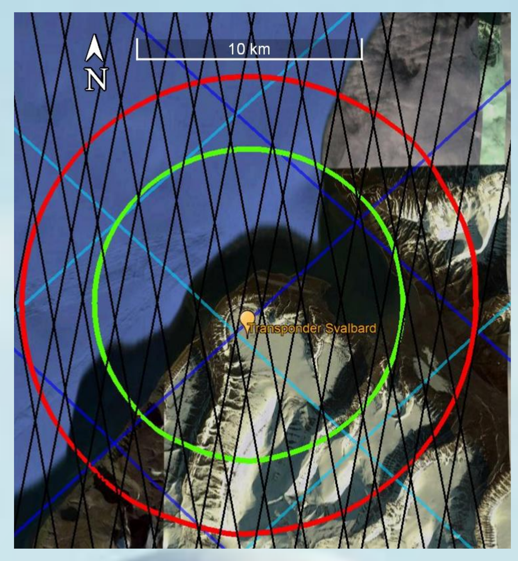
	Svalbard				Crete (CDN1)			
	SARIn		SAR	FF-SAR	SARIn		SAR	FF-SAR
Number of passes	126		66	66	11		25	25
Range average [mm]	35.3	35.3	34.1	17.8	34.0	32.1	44.7	31.4
Range std [mm]	15.7	14.9	21.2	20.4	26.4	25.0	22.3	21.8
Range trend [mm/year]	-0.38	-0.30	0.50	0.14	-9.86	-9.96	-1.1	-1.2

- Range noise results are very stable (less than 1 mm/year) for SARIn, SAR, and FF-SAR (Fully-Focussed SAR) processing and aligned with the absolute range measurements.
- Absolute Range bias difference between Svalbard and Crete (~10 mm) is almost fully related to the internal delay used in Crete.

THE SVALBARD SITE



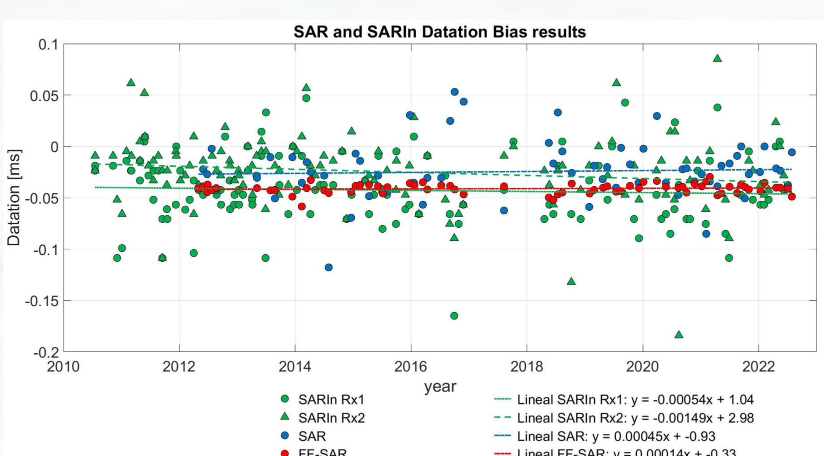
Transponder developed by RAL (UK) in 1987. Refurbished for CS2 calibration (courtesy of ESA)

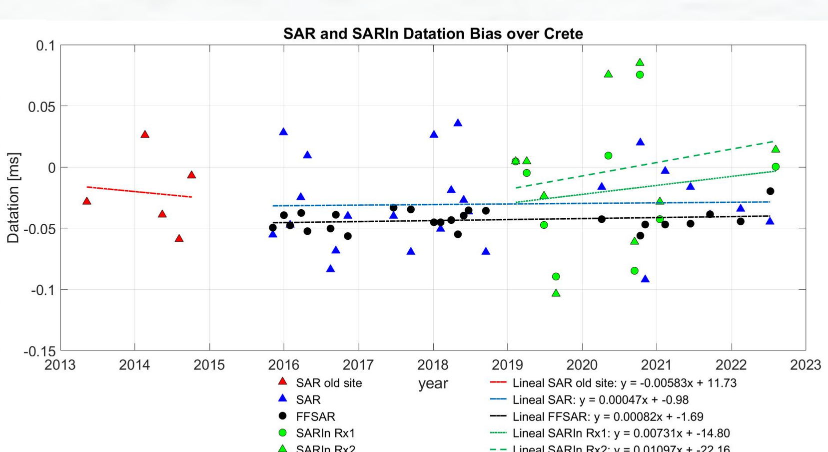


- Transponder location: Svalbard (selected due to its high latitude).
- CS2 orbit repeat cycle is 369 days.
- Passes can be used if the power decay (with respect to the peak) is not greater than ~-7 dB, which implies a separation from the nadir track of ~4 km. Further away passes have been used but need to be carefully considered.

DATATION RESULTS

After the Baseline D and E upgrades, the datation results between SARIn Rx1 and Rx2 is not well aligned: there is a bias ~ 20 µs between both channels. This is already seen in the results between SAR and FF-SAR for both Svalbard and Crete.



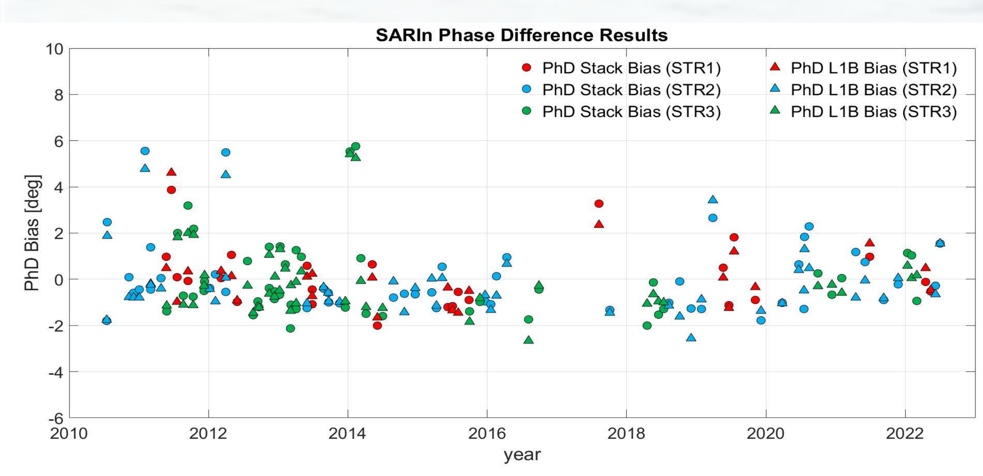


	Svalbard				Crete (CDN1)			
Statistics	SARIn		SAR	FF-SAR	SARIn		SAR	FF-SAR
Number of passes	126		66	66	11		25	25
Datation average [µs]	-40.9	-23.7	-23.8	-41.2	-19.9	-0.03	-30.3	-43.2
Datation std [µs]	34.0	34.1	27.9	4.85	51.8	60.1	34.9	8.34
Datation trend [µs/year]	-0.54	-1.49	0.45	0.14	7.3	10.9	0.47	0.08

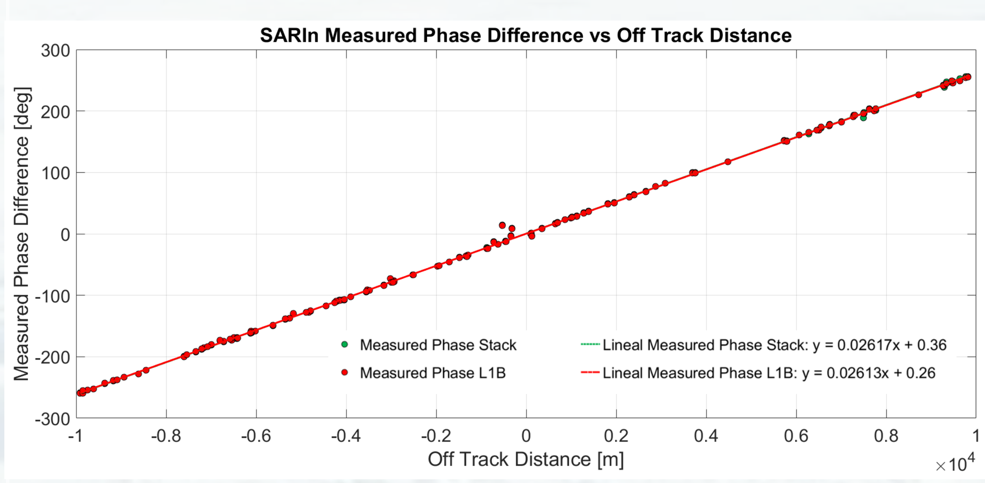
The same bias between the channels, ~20 µs, is seen both in Svalbard and Crete.

INTERFEROMETRIC PHASE RESULTS

Phase bias per STR	STR1	STR2	STR3	all
# passes	25	52	49	126
PhD avg. [deg.]	0.09	0.06	-0.32	0.030
PhD std. [deg.]	1.39	1.63	2.01	1.83

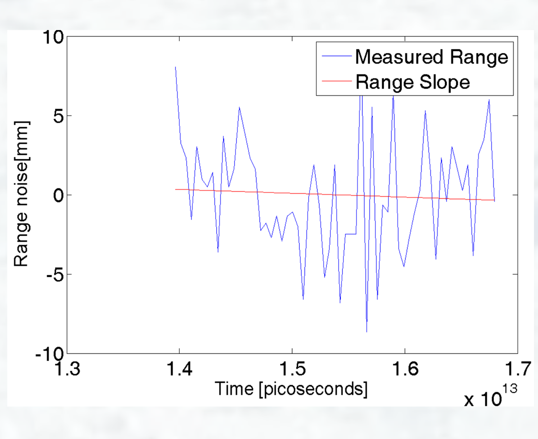


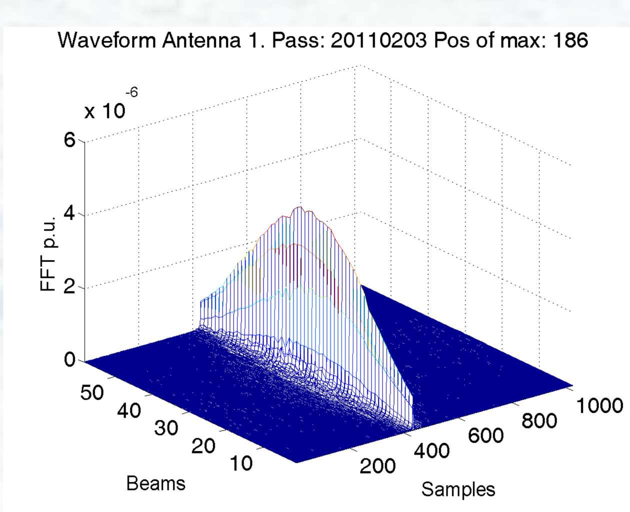
Interferometric phase accuracy and precision depend on the STR used to get the roll. The results regarding the phase difference within the stacks show that the noise is 1.54 degrees. The noise is slightly dependent on the off-track distance. This noise is translated into an uncertainty of 59 meters in the across track geolocation.



Computing the regression line of the Measured Phase Difference for each pass vs the off-track distance, a similar bias is obtained (~0.03 degrees).

RANGE NOISE OVER THE STACKS

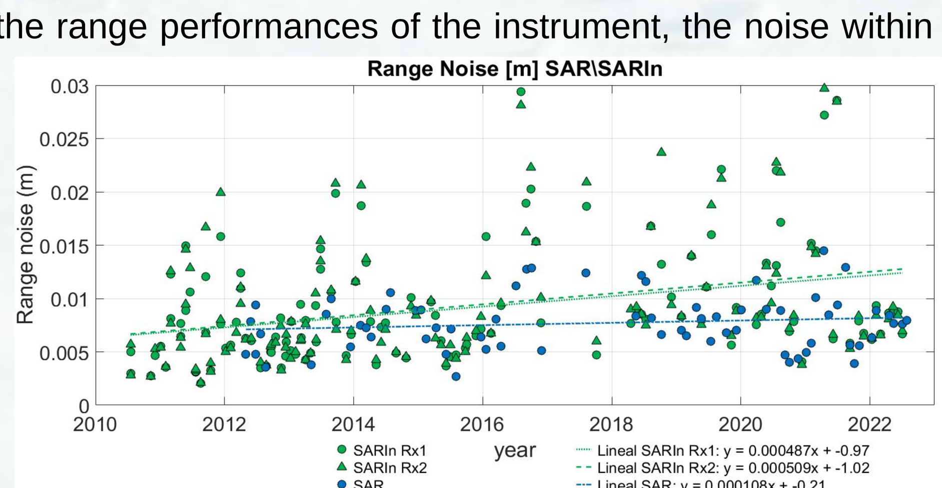




The standard deviation of the independent TRP range errors gives an overall view of the noise of the range measurement, where not only the instrument noise has to be taken into account but also the noise in all the geophysical corrections applied.

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

The range noise results are very stable (less than 1 mm/year) and aligned with the absolute range measurements.



CONCLUSIONS

- Results show consistency among the different types of data used (stack data and L1B).
- The residual range bias observed is about 3.5 cm (SARIn and SAR) . 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. The residual datation bias is about -24 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.)
- 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.

References

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

[2] CryoSat Science and Mission Requirements Document, CS-RS-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.