CryoSat-2 - SIRAL Calibration with Transponders and Corner Reflectors

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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).

Transponders and Corner Reflectors are commonly used to calibrate absolute range from conventional altimeter waveforms because of its characteristic point target radar reflection. The waveforms corresponding to these Point Targets 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 (CDN1).

The Gavdos transponder was deployed in 2021 to support the calibration of Sentinel-6 MF, serving as an additional calibration point for the Sentinel-3 mission. This transponder was designed to support absolute calibration, not only for the range, but also for the backscatter coefficient (sigma-naught).

A trihedral corner reflector has been designed and tested to assess the capability of passive reflectors to calibrate radar altimeters such as the Poseidon-4 altimeter on board Sentinel-6A. The current facility, located within an astronomical observatory at the top of a mountain ridge, has shown to be idoneous for S6, S3B and CS-2 monitoring

All of these instruments are also used to calibrate SIRAL's range, datation, and interferometric baseline (or angle of arrival) to meet the mission requirements. 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.

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. 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.

CALIBRATION SITES

SVALBARD

- Transponder location: Svalbard (selected due to its high latitude).
- CS2 orbit repeat cycle is 369 days.
- ~26 passes planned per year.
- Transponder developed by RAL (UK) in 1987. Refurbished for CS2 calibration (courtesy of ESA)

CRETE

- The Crete transponder was developed at the Technical University of Crete for ESA's Copernicus earth observation programme.
- It was relocated from the University of Crete to its current position in 2015.
- ~8 passes planned per year.

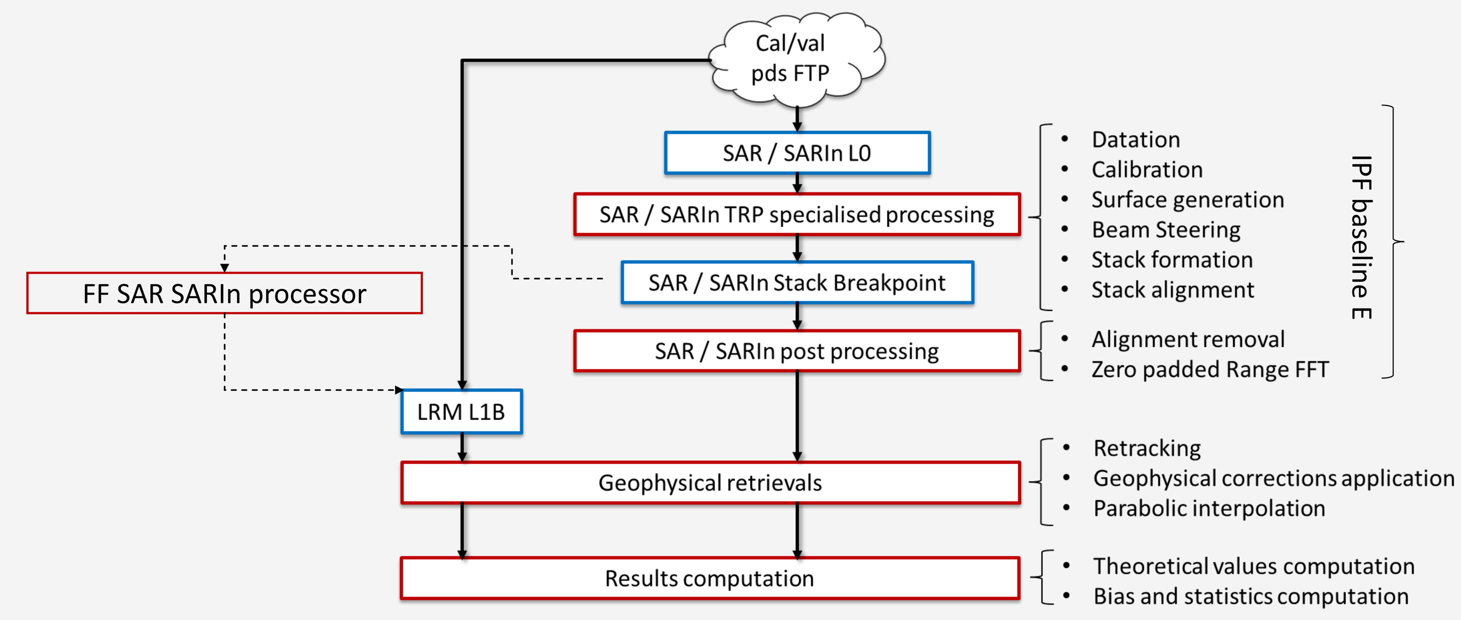
GAVDOS

- Its design, manufacturing, characterization, testing, and installation took place in the period February 2020–October 2022
- Dual operation for range and sigma-naught calibration
- ~8 passes planned per year.

MONTSEC

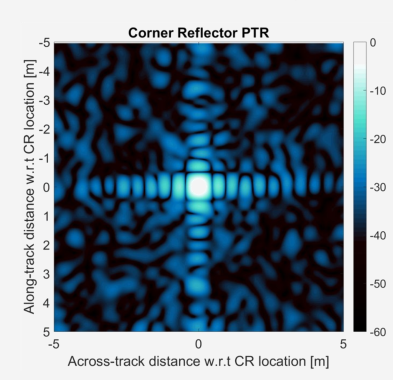
- Corner Reflector deployed by isardSAT in 2021. The chosen location was the Montsec Astronomical Observatory facility around 1600 m, in the southern side of the Pyrenees
- Since February 2023, a GNSS station is providing independent tropospheric corrections.
- ~10 passes planned per year.

PROCESSING METHODS

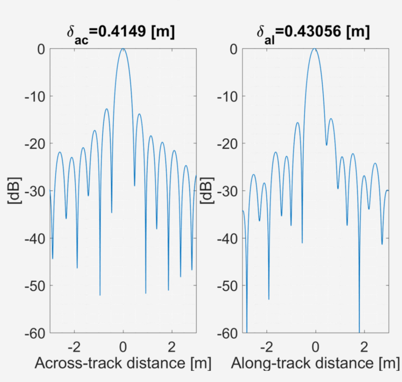


L1b processing chain main steps.

Fully Focussed Processing

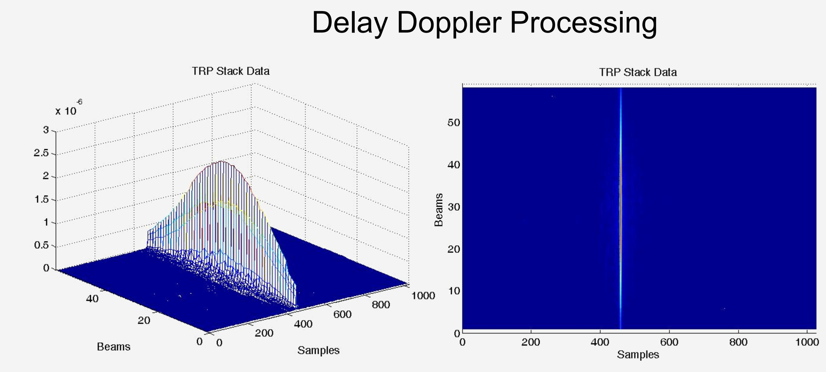


Centred radargram with the 2-D impulse response function of the CRF



(Left) Across track impulse response. (Right) Along track impulse response.

Delay Doppler Processing

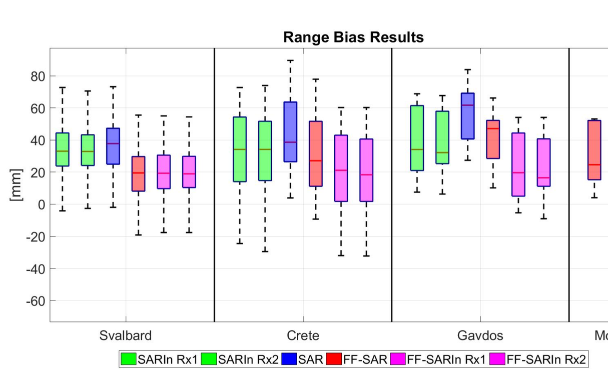


After the slant correction, the waveforms of each beam are aligned with the TRP reference position, we can note the waveforms correctly aligned respect to the TRP signal.

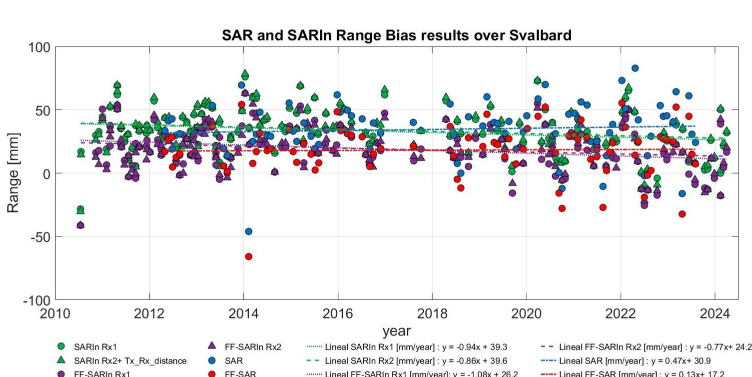
RESULTS

RANGE

The range bias analysis at all calibration sites reveals a good stability but a uniform difference between UF-SAR and FF-SAR processing results (~15 mm).



The box plot shows a consistent misalignment across both modes (SAR and SARIn) when using both processors (UF-SAR and FF-SAR).



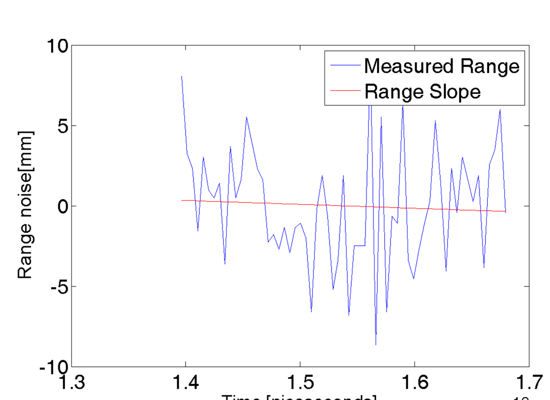
In Svalbard, the correction of the terrain motion was added to the other geophysical corrections to get the proper deviation of the instrument range bias. Resulting in a drift of less than 1 mm/year.

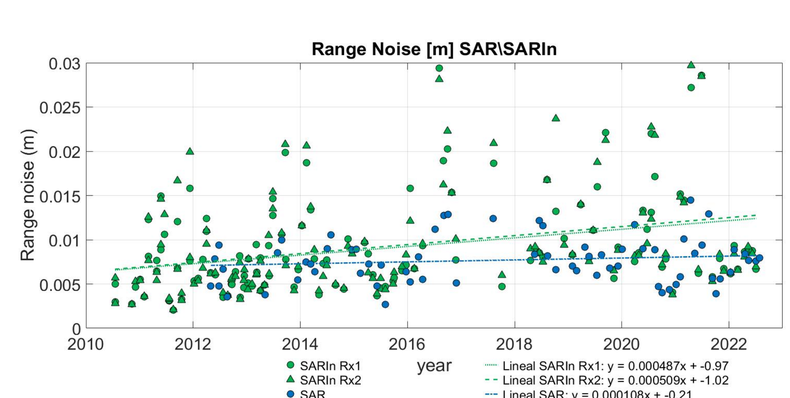
RANGE NOISE

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.

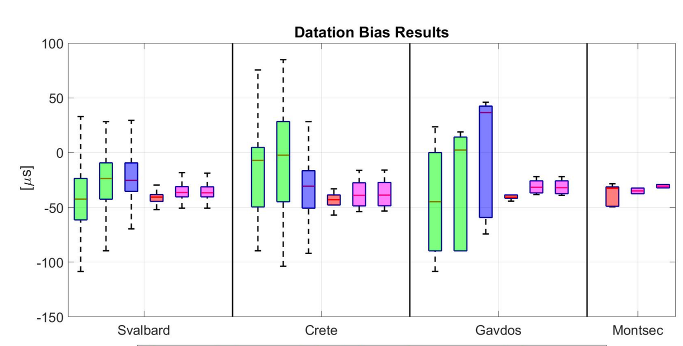
The range noise results are very stable (less than 1 mm/year) and aligned with the absolute range measurements.



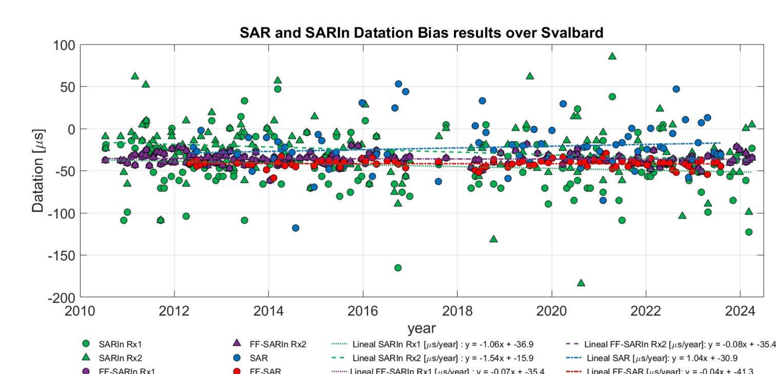


DATATION

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 channel misalignment is not observed in the Fully Focused SAR analysis.

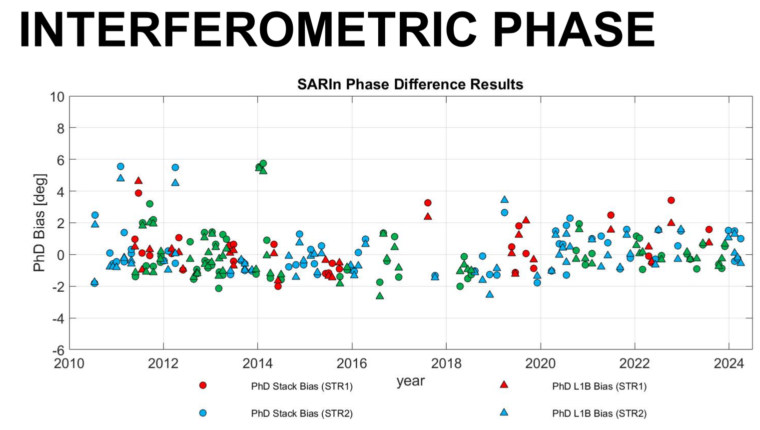


The UF-SAR analysis is influenced by the accuracy of the parabolic approximation derived from the stack measurements, which can introduce variability if the parabolic fitting is not optimal.

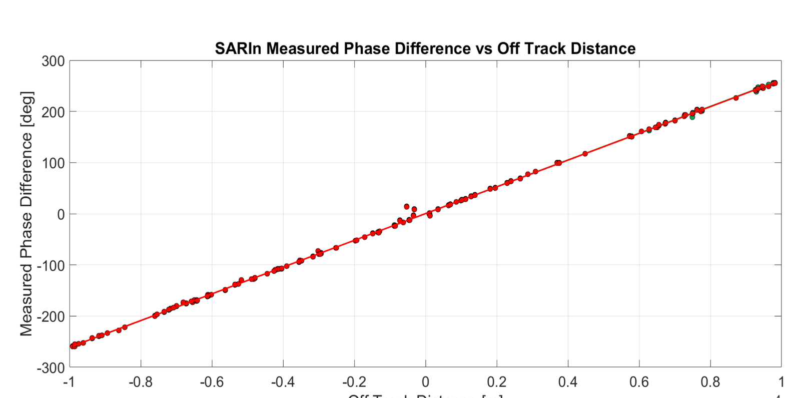


Fully Focused (FF) analysis exhibits a drift of approximately 0 μs/year. Conversely, the stack analysis reveals a slightly higher drift, approximately 1 μs/year.

INTERFEROMETRIC PHASE



- After the Baseline D changes, the results were reduced from 2 degrees to residual values (0.034 degrees).
- No STR dependency is observed anymore
- The phase difference noise within the stack increases when going further 6 km off-track.
- No drift or increased degradation is observed



- 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).

CONCLUSIONS

- Results show consistency among the different types of data used (L1BS and L1B).
- Range Bias related to Rx1-RX2 is measured for each pass within the UF-SAR/SARIn processing.
- The FF-SARIn processing has been added as nominal analysis.
- Some differences between processing methods have been quantified.
- 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)
- Range, datation and phase difference results are not presenting any worsening over time.
- Data over Montsec CRF are being analysed since 2022-12-05; its results are useful in preparation for the CRISTAL commissioning and Cal/Val planning

SUMMARY

		Svalbard				Crete				Gavdos				Montsec	
		SARIn	FF-SARIn	SAR	FF-SAR	SARIn	FF-SARIn	SAR	FF-SAR	SARIn	FF-SARIn	SAR	FF-SAR	FF-SARIn	FF-SAR
# passes		145	145	78	78	17	17	31	25	6	6	6	6	2	5
Range [mm]	mean	33	19	34	18	30	18	40	28	38	21	62	47	27	30
	std	17	17	21	20	28	27	23	23	23	23	25	24	7	21
Datation [μs]	mean	-35	-36	-22	-41	-20	-40	-31	-43	-35	-32	7	-39	32	41
	std	26	7	28	5	45	11	36	7	54	8	56	4	4	12
Phase difference [deg.]	mean	0.06				0.10				0.65				0.38	
	std	1.71				1.25				1.43				0.80	

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