
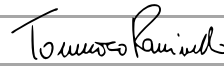


Known biases in CryoSat Level1b products

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1 Introduction

The following known biases that affected CryoSat Level1b products before BaselineC are hereafter considered:

- Datation biases
- Range biases
- Mispointing angle biases

By definition, a bias error is defined as a residual fixed offset that is stable throughout the time. Biases given throughout this document are defined as the estimated offset in the CryoSat Level1b product with respect to the correct value, so that

$$\text{Corrected_value} = \text{product_value} - \text{bias} \quad (1)$$

It has to be remarked here that the BaselineC L1b products are already corrected for the biases discussed in this document, so that no further actions are needed by the user.

1.1 Purpose

This document aims at providing the list and the values of all known biases that affected the CryoSat BaselineB L1b products and that have been thus compensated in CryoSat BaselineC L1b products. Additionally, throughout the document are presented the residual errors which have been evaluated on the CryoSat BaselineC L1b products where the known biases have been compensated.

Known biases are here categorized depending on the acquisition mode and the Baseline that the products are referred to.

For a general description of the Cryosat Mission refer to [RD-03]. For general description of the CryoSat Products refer to CryoSat Product Handbook [RD-03]. For a detailed description of the Level1b products, refer to [RD-04].

1.2 Reference documents

RD-01 Datation bias IPF1 vk1.0, Marco Fornari, 2nd of August 2012

RD-02 IPF1 Baseline B range errors, Tech-Note-130425, issue 2.0, 5th of June 2013

RD-03 [Cryosat Product Handbook](#), February 2013 – Available on Cryosat Wiki¹

RD-04 [CryoSat FBR and L1b Product Format Specification](#) – Available on CryoSat Wiki

RD-05 Galin, N. and Wingham, D., *Estimating Pitch Angle of CryoSat-2 using the Power Distribution of the Synthetic Aperture*, presented at SAR Altimetry Expert Group Meeting, Southampton UK, June 25-27, 2013.

¹ CryoSat Wiki: <https://wiki.services.eoportal.org/tiki-index.php?page=CryoSat%20Wiki>

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- RD-06 Smith, W.H.F. and Scharroo, R., *Retracking range, SWH, sigma-naught, and attitude in CryoSat conventional ocean data*. In proceedings of Ocean Surface Topography Science Team Meeting. San Diego, October 19-21, 2011.
- RD-07 Aresys, [Main evolutions and expected quality improvements in Baseline C Level1b products](#), C2-TN-ARS-GS-5154, Issue 1.3, Feb. 2015 – Available on CryoSat Wiki
- RD-08 IsardSAT, CryoSat-2 Calibration with Transponder Results, ISARD_ESA_CS2_EXT_CAL_TN_289, Issue 3.a, June 2016
- RD-09 Scagliola, M.; Fornari, M.; Tagliani, N., "Pitch Estimation for CryoSat by Analysis of Stacks of Single-Look Echoes," in *Geoscience and Remote Sensing Letters, IEEE* , vol.12, no.7, pp.1561-1565, July 2015

2 Biases and residual errors on Level1b products

2.1 Datation

The datation bias is here intended as the offset that affects the timestamp referred to each Level1b waveform. For more details on the definition of the timestamps for the different acquisition modes refer to [RD-02].

In Tab.1 are listed the known datation biases for the Baseline B Level1b products according to [RD-01]. The sources of those systematic offsets have been identified and have been solved in Baseline C through a new release of the CryoSat IPF1 [RD-07]. As a consequence Level1b users do not have to correct any datation bias on the Baseline C Level1b products.

Datation biases			
Baseline	LRM	SAR	SARIn
Baseline B	4.7 ms	-0.5195 ms	-0.5195 ms

Tab.1 Datation biases in Baseline B Level1b products.

CryoSat acquisitions over the calibration transponder have been analyzed in order to assess the residual datation accuracy and precision of Baseline C Level1b products. The residual datation errors in the sense of average and standard deviation, denoted by μ and σ respectively, are listed in Tab.2 for Baseline C Level1b products, according to [RD-08]. These results are in line with what expected from [RD-07] for SAR and SARIn modes while further investigations are on-going to verify the residual datation errors obtained by analysis of acquisition over the transponder for LRM mode.

Residual datation errors: $\mu \pm \sigma$			
Baseline	LRM	SAR	SARIn
Baseline C	Further investigations on-going	-0.029 ± 0.033 ms	-0.022 ± 0.024 ms

Tab.2 Residual datation errors in Baseline C Level1b products.

2.2 Range

The range bias is here intended as the offset that affects the one-way range measurement in each Level1b waveform. The one-way range at the middle of the range window is computed from the window delay according to following formula:

$$1\text{-way_range} = \text{window_delay} * 1.0\text{e-}12 * \text{speed_of_light} / 2 \quad (2)$$

The range bias is then applied to the 1-way_range according to equation (1) to get the correct value of the latter.

In Tab.3 are listed the known range biases for Baseline B Level1b products according to [RD-02]. The sources of those systematic offsets have been identified and have been solved in Baseline C through a new release of the CryoSat IPF1 [RD-07]. As a consequence Level1b users do not have to correct any range bias on the Baseline C Level1b products,

Range biases			
Baseline	LRM	SAR	SARIn
Baseline B	0.2046 m	0.6730 m	0.6730 m

Tab.3 Range biases in Baseline B Level1b products.

CryoSat acquisitions over the calibration transponder have been analyzed in order to assess the residual range accuracy and precision of Baseline C Level1b products. The residual range errors in the sense of average and standard deviation, denoted by μ and σ respectively, are listed in Tab.4 for Baseline C Level1b products, according to [RD-08]. These results are in line with what expected from [RD-07].

Residual range errors: $\mu \pm \sigma$			
Baseline	LRM	SAR	SARIn
Baseline C	-22 \pm 23 mm	47 \pm 40 mm	17 \pm 35 mm

Tab.4 Residual range errors in Baseline C Level1b products.

2.3 Mispointing angle

The mispointing angle bias is here intended as the offset that affects the angle between the antenna pointing, i.e. the direction of the actual antenna beam, and the nadir direction. A bias has been observed for both the pitch and roll angle, and it has been addressed to an error in the rotation matrices that are applied to the Star Tracker quaternions to convert them to attitude angles with respect to the CryoSat reference frame [RD-05]

In the Level1b product, the roll and the pitch angle are annotated in the Time and Orbit Group (field#15 and field#16 respectively in Level1b product [RD-04]). It is worth underlining that the mispointing angle biases are independent of the acquisition mode.

In Tab.5 are listed the known mispointing angle biases for the Baseline B Level1b products. As it can be here noticed, two figures were known for the pitch and roll bias since two independent but different methods have provided two different results. For details on the estimation methods for the mispointing biases refer to [RD-05], [RD-09] and [RD-06]. It is worth noticing that in Baseline B, according to [RD-02], the L1b SARIn *Phase Difference* waveforms were already corrected for the roll bias. This correction was applied through the External Phase Correction (that is written in field#31 in Level1b product [RD-04]).

In Baseline C, as described in [RD-07], a pitch bias of 0.520 deg and a roll bias of 0.1062 deg have been applied to the mispointing angles and the External Phase Correction has been set to zero, so that the L1b SARIn *Phase Difference* waveforms are no more corrected for the roll bias. As a consequence Level1b users do not have to correct the pitch and roll bias on the Baseline C Level1b products.

Further analyses are still ongoing to assess the residual pitch bias and the residual roll errors in Baseline C Level1b products.

Mispointing angle biases		
Baseline	Pitch	Roll
Baseline B	0.0520 deg	0.1054 deg
	0.0962 deg	0.0848 deg

Tab.5 Mispointing angle biases in Baseline B Level1b products.

3 Summary of residual errors in CryoSat Baseline C Level1b products

The following table summarizes the residual errors, in the sense of accuracy and precision, which have been evaluated in CryoSat Baseline C Level1b products and have been discussed in this document.

Baseline	Quantity	Mode	Value $\mu \pm \sigma$	Reference	Comment
Baseline C	Datation	LRM	To be assessed	[RD-08]	Further analyses are still ongoing
		SAR	-0.029 ± 0.033 ms	[RD-08]	
		SARIn	-0.022 ± 0.024 ms	[RD-08]	
	Range	LRM	-22 ± 23 mm	[RD-08]	
		SAR	47 ± 40 mm	[RD-08]	
		SARIn	17 ± 35 mm	[RD-08]	
	Pitch	LRM/SAR/SARIn	To be assessed		Further analyses are still ongoing
	Roll	LRM/SAR/SARIn	To be assessed		Further analyses are still ongoing

Tab.6 Summary of residual errors in CryoSat BaselineC Level1b products.