Relative range bias drifts revealed by a multi-mission crossover analysis: from TOPEX to Sentinel-3

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Abstract

A global multi-mission cross-calibration enables the combination of different altimetry missions with various sampling characteristics and measurement periods. In addition, a cross-calibration is able to provide information on the quality of single missions and to reveal, e.g., instrument drifts or geographically correlated error patterns. DGFI-TUM is performing multi-mission altimeter crossover analysis (MMXO) on a regular basis in order to estimate relative radial errors between the different altimeter systems operating simultaneously.

Data

Data from TOPEX-A (MGDR-B), ERS (Reaper), Jason-3 (GDR-D), and Sentinel-3A (NTC R6) are used in this study, as well as Jason-2 (GDR-D) and SARAL (GDR-T).

Identical models are applied to all mission to correct the altimeter ranges (ECMWF for troposphere, NIC09 for ionosphere, EOT11a for ocean tides, DAC for atmosphere loading).

Method – Multi-Mission Crossover Analysis (MMXO)

The cross-calibration is realized globally by minimizing a large set of single- and dual-satellite sea surface height (SSH) crossover differences computed between all contemporaneous altimeter systems. The total set of crossover enables a robust estimate of radial errors with a dense sampling for all altimeter systems analyzed. An iterative variance component estimation is applied to obtain an objective relative weighting between the different altimeter systems. The method requires the definition of one reference mission, whose absolute level is fixed. Thus, only relative range biases and relative drift behavior is detectable, and a systematic effect can not be related to one mission. This is of extreme importance in time period when only two missions are available (e.g. TOPEX and ERS).

Reference: *Bosch W., Dettmering D., Schwatke C.: Multi-mission cross-calibration of satellite altimeters: constructing a long-term data record for global and regional sea level change studies. Remote Sensing 6(3): 2255-2281, 10.3390/rs6032255, 2014*

Results – TOPEX A drift w.r.t. ERS

A clear trend is visible between TOPEX and ERS-1, which can be reduced significantly when the so-called CAL-1 correction (see Fig. 2) is not applied to the data set (subtracted from the MGDR ranges).

Between TOPEX and ERS-2 almost no trend is detectable when analyzing data between June 1996 and February 1999 (Cycles 137-235). However, removing the CAL-1 correction introduces a trend of about 3.5 mm/year.

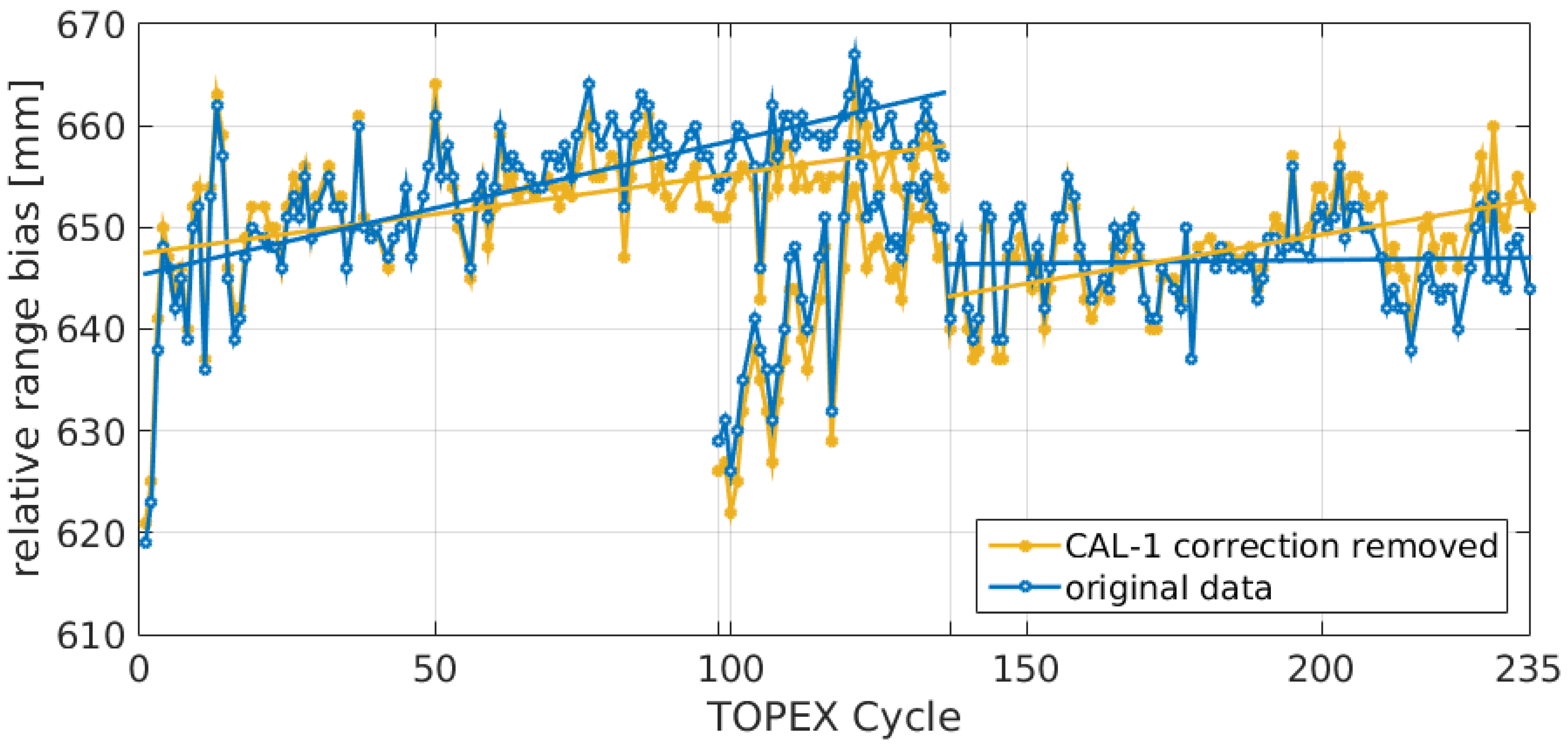

Figure 1: Relative range bias ERS-TOPEX per 10-day cycle

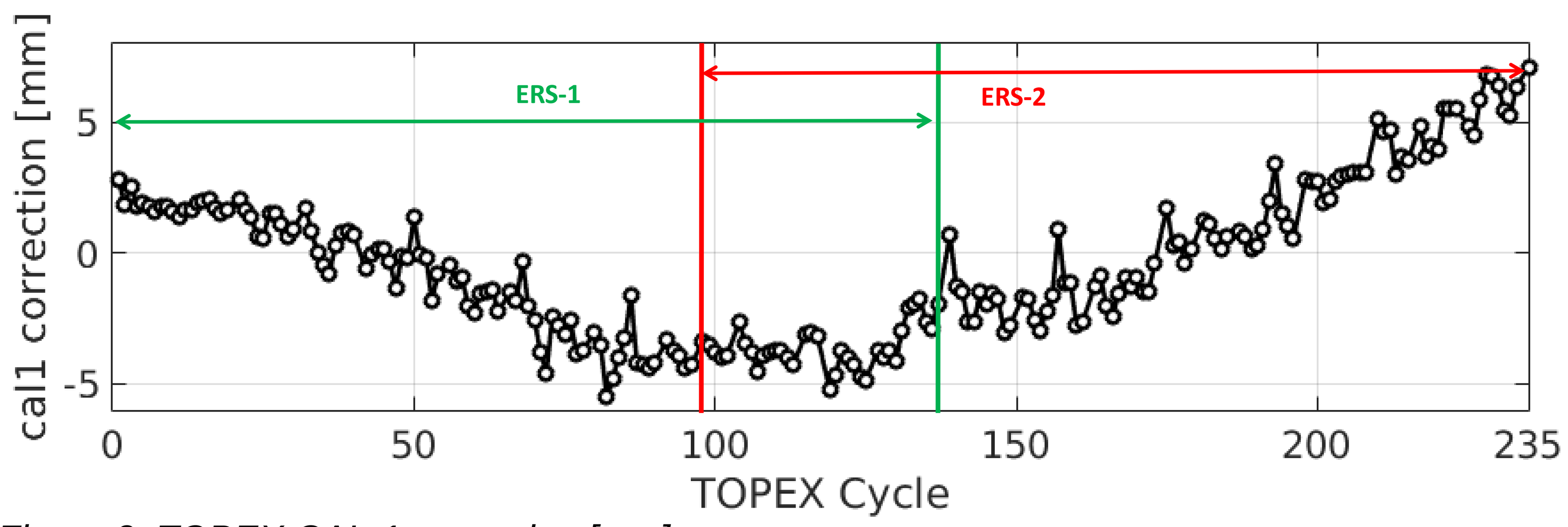

Figure 2: TOPEX CAL-1 correction [mm]

Comparing ERS-1 and ERS-2 in the period between May 1995 and June 1996 reveals a clear systematic drift difference of more than 18 mm/year. Even when taking the short time period of only about one year into account (resulting in trend uncertainties of more than 3 mm/year), this shows that ERS data can not be taken as stable.

Table 1: Bias and Trends between TOPEX and ERS for different time periods

Cycles	Bias [cm]	Trend [mm/year]
000-136 (original)	65.41 ± 0.74	4.8 ± 0.4
000-136 (cal-1)	65.26 ± 0.62	2.9 ± 0.4
137-235 (original)	64.69 ± 0.42	0.2 ± 0.6
137-235 (cal-1)	64.79 ± 0.52	3.5 ± 0.6

- **Significant drifts between TOPEX and ERS are detectable.**
- **Removing the CAL-1 correction from the TOPEX data decreases the trend differences in the first period but increases the trend difference in the second period of TOPEX-A.**
- **Due to the relative calibration method and the unknown stability of the ERS missions, no conclusions on absolute TOPEX drifts can be drawn.**

Results – Sentinel-3A drift w.r.t. Jason-3

The relative range bias between Sentinel-3A and Jason-3 is plotted in Fig. 3 (March 2016 until December 2017). When neglecting the very first period (before J3 cycle 7, April 2016), in which Sentinel-3A provides only very few valid data sets, a clear trend behavior between the two missions is visible. This can be reduced significantly if PLRM data is used in the computation instead of SAR data.

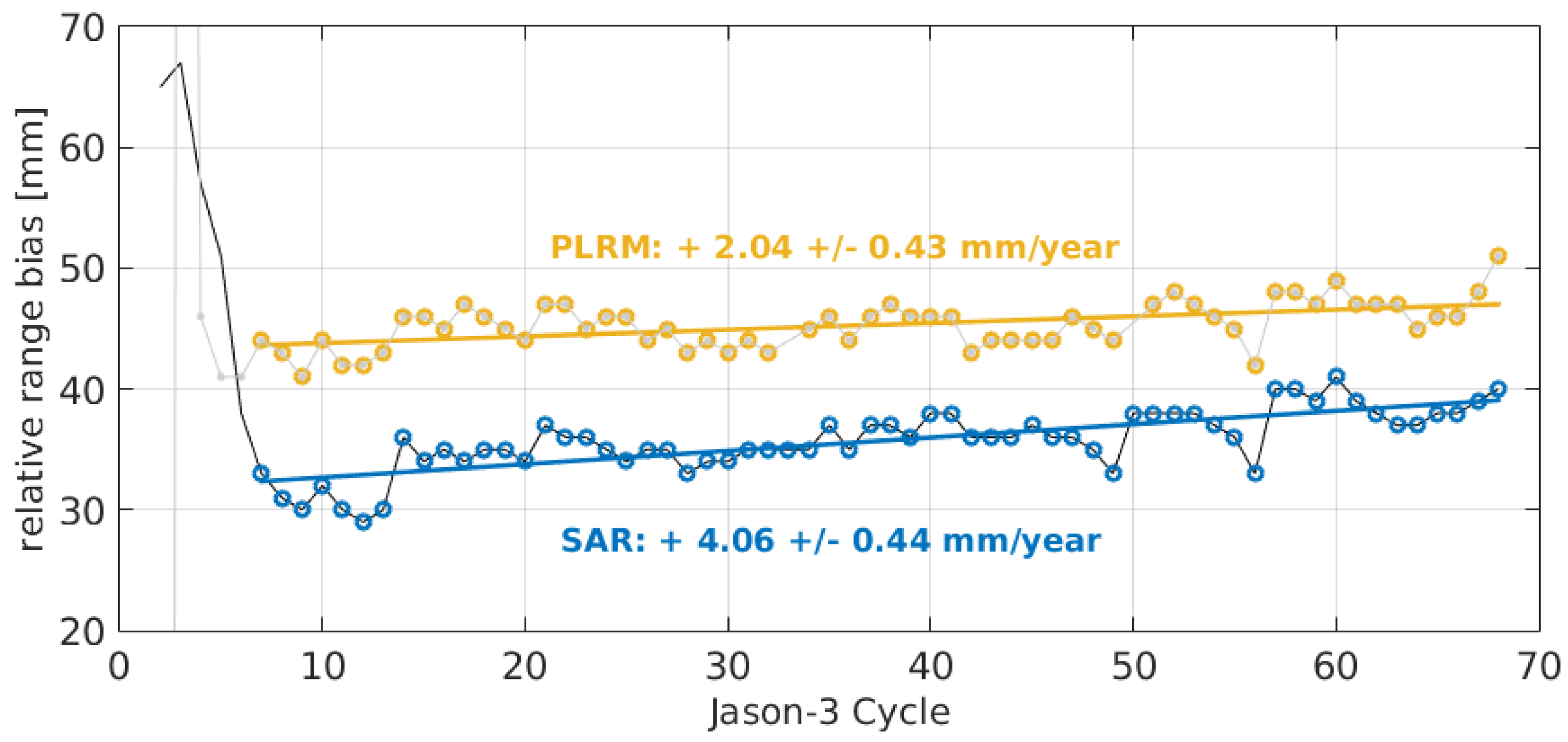

Figure 3: Relative range bias Sentinel-3A-Jason-3 per 10-day cycle

Since in the last years additional altimetry missions are available and included in the calibration process, Sentinel-3A can also be compared to Jason-2 and SARAL (only until the end of Jason-2 repeat mission in May 2017). These tests show that the drift behavior of Sentinel-3A is also detectable with respect to Jason-2 and SARAL.

Table 2: Bias and Trends between Sentinel-3A and three other missions for two time periods

S-3A mode	Mission	Cycles	Bias [cm]	Trend [mm/year]
SAR	**Jason-3**	**7-68**	**3.57 ± 0.26**	**4.0 ± 0.4**
PLRM	**Jason-3**	**7-68**	**4.53 ± 0.19**	**2.0 ± 0.4**
SAR	Jason-3	7-46	3.46 ± 0.22	5.3 ± 0.8
SAR	Jason-2	7-46	1.18 ± 0.23	4.3 ± 1.0
SAR	SARAL	7-46	6.40 ± 0.27	5.0 ± 1.1
PLRM	Jason-3	7-46	4.46 ± 0.15	0.9 ± 0.8
PLRM	Jason-3	7-46	2.19 ± 0.18	0.3 ± 0.9
PLRM	SARAL	7-46	7.45 ± 0.22	1.1 ± 1.1

It is important to keep in mind, that the drift information should be interpreted tentatively since a 1.5 year period is certainly not long enough for providing reliable numbers. Instead, they should be taken as an indication, that some systematic effects are inherent in the data set, which should be pursued in the future.

- **A systematic difference between Sentinel-3A and Jason-3 is visible between April 2016 and December 2017.**
- **The relative drift of about 4 mm/year can be reduced when using PLRM data instead of SAR data.**
- **Similar drifts are visible with respect to Jason-2 and SARAL.**