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CaVaMuMi:
Calibration and Validation of altimeter observations and models by means of global multi-mission crossover analysis

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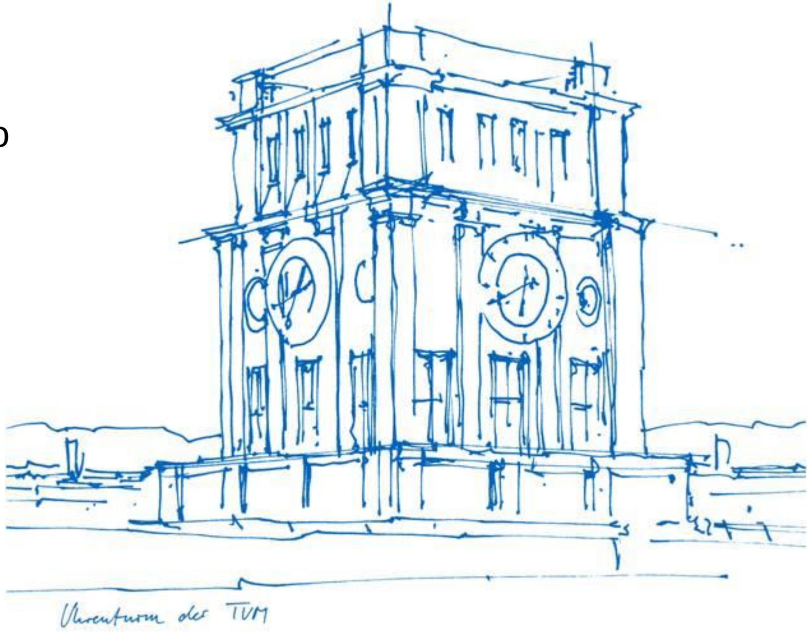

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Introduction

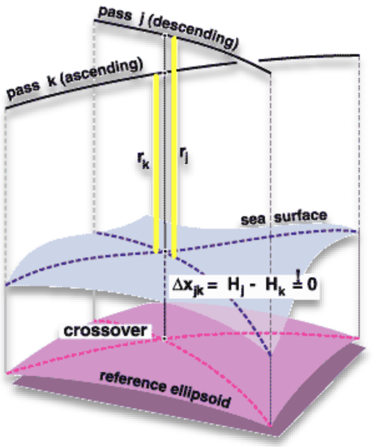
A consistent long-term sea level data record is a fundamental requirement for many applications, especially for climate studies. However, combining satellite altimetry missions with different instruments and different sampling capabilities requires a careful pre-processing and calibration of all altimeter systems. This can be done by means of a global cross-calibration of all missions. In addition, this technique is able to provide information on the quality of single missions and to reveal e.g. instrument drifts or differences in the center-of-origin realization of satellite’s orbits.

The project conducts inter-calibrations of contemporaneous altimeter systems based on extended crossover analyses on a global scale. It uses an extended multi-mission crossover analysis approach in order to assess the performance of each mission. The cross-calibration is realized globally by adjusting an extremely large set of single- and dual-satellite sea surface height (SSH) crossover differences. The analysis yields time series of radial errors of each mission and can be used to derive inter-mission biases, to identify potential altimeter drifts, as well as to extract information on the quality of precise orbit determination (POD) and geophysical corrections.

This presentation shows selected results of the project from the past 4 years.

Multi-mission crossover analysis (MMXO)

- ❑ building single- and dual satellite SSH crossover differences in all combinations ($\Delta t < 2$ days); without coastal regions and sea-ice areas
- ❑ minimizing crossover differences **and** along-track consecutive differences in a least squares adjustment; estimation of radial errors at all crossover points
- ❑ automated mission weighting by variance component estimation (VCE)
- ❑ TOPEX (later Jason-1, Jason-2, Jason-3) taken as reference mission



Bosch et al., 2014

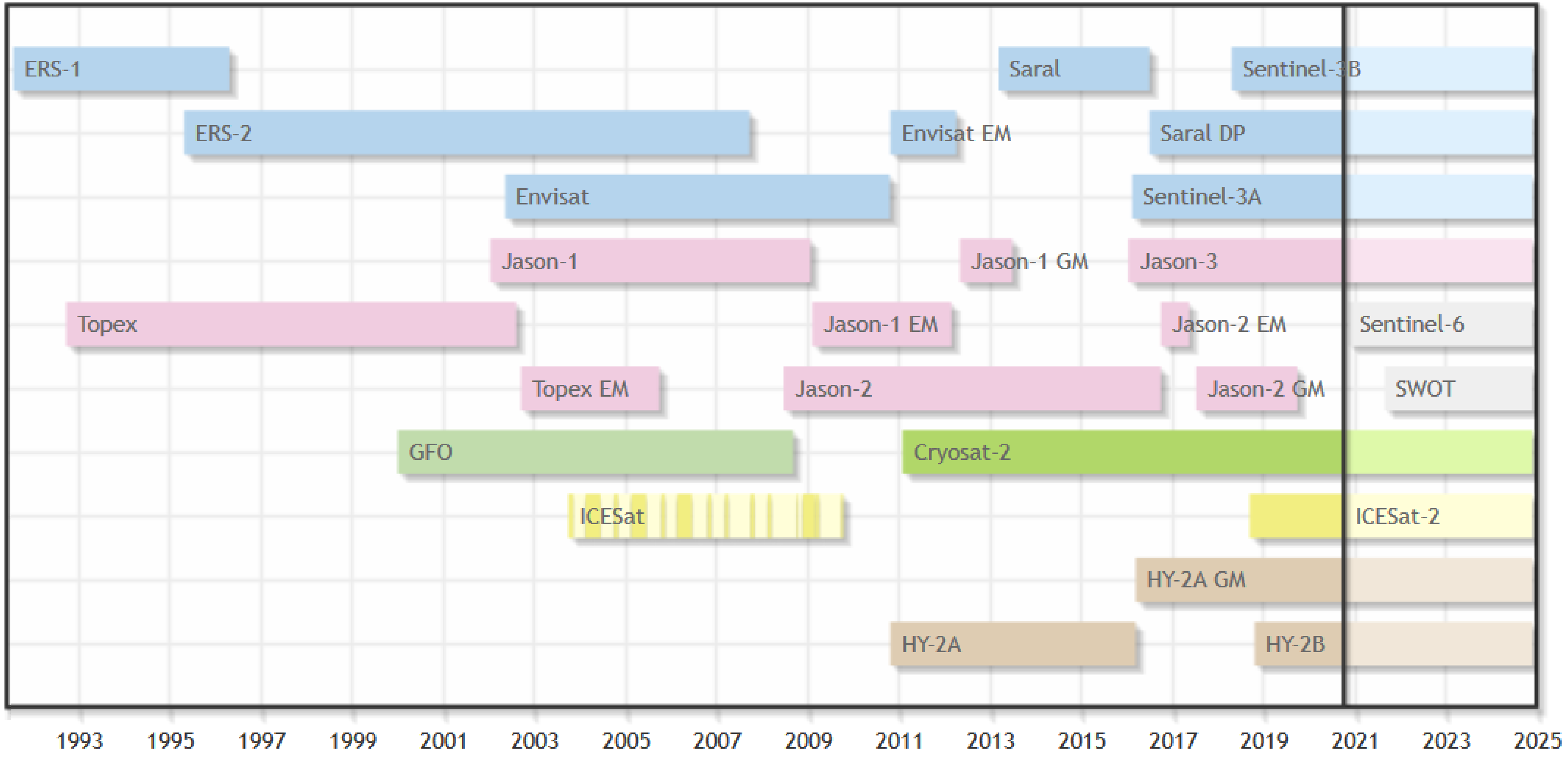
Main output:

- time series of radial errors => applied as corrections to each measurement

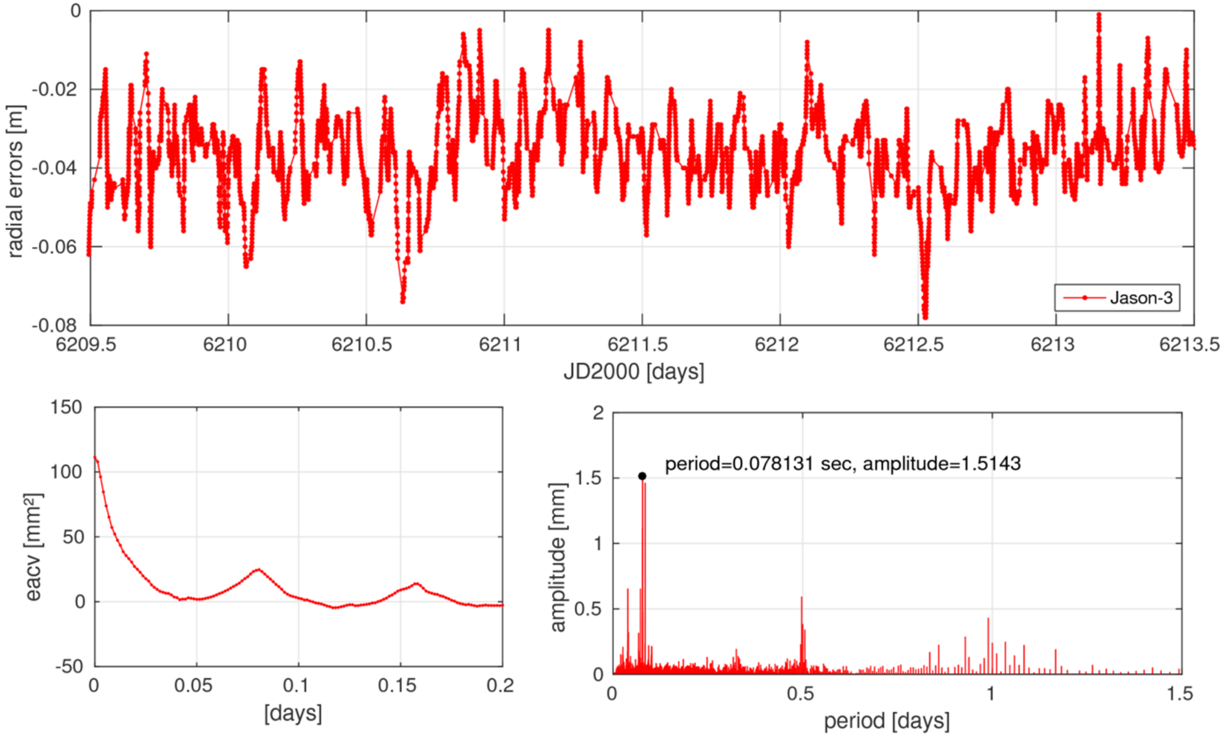
Additional outputs (derived from radial errors):

- relative range biases (global mean and per cycle)
- relative instrument drifts
- geographically correlated SSH errors

Altimetry missions



Jason-3 radial errors



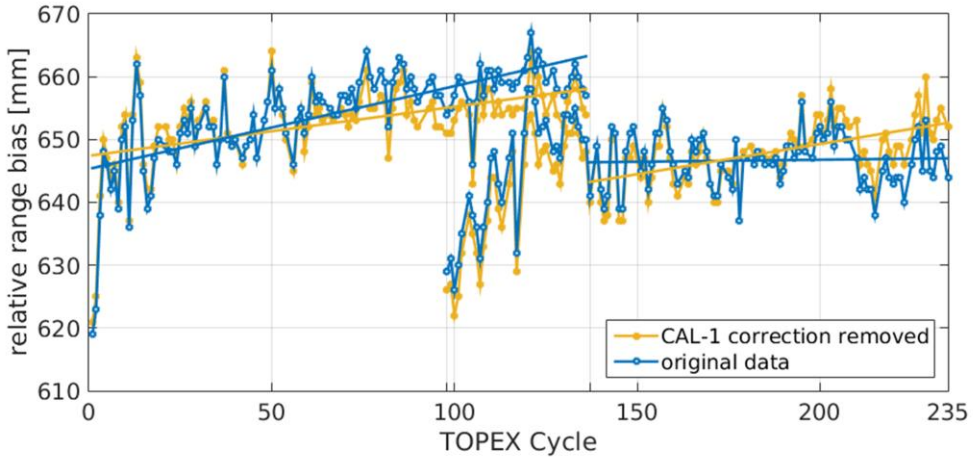
Radial errors for Jason-3 (top), its empirical covariance function (bottom left) and its frequency spectrum (bottom right).

Dettmering & Schwatke, OSTST 2017

ERS relative drifts w.r.t. TOPEX

Dettmering & Schwatke, OSTST 2018

Relative range bias ERS-TOPEX per 10-day cycle



Bias and Trends between TOPEX and ERS for different time periods (green: ERS-1; red: ERS-2)

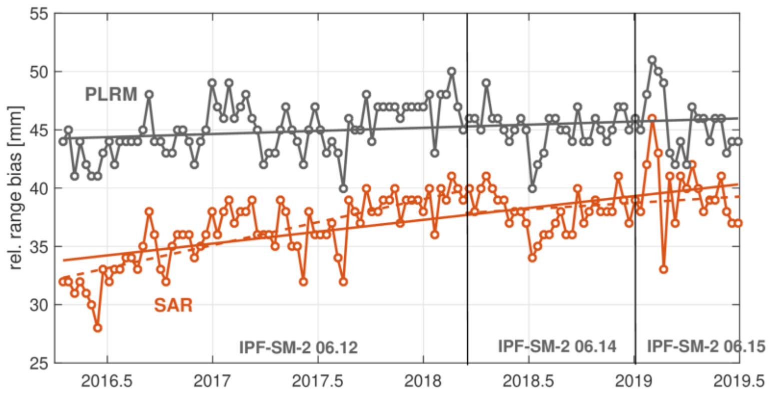
Cycles	Bias [cm]	Trend [mm/year]
000-136 (original)	65.41 ± 0.74	4.8 ± 0.4
000-136 (cal-1)	65.26 ± 0.62	2.9 ± 0.4
137-235 (original)	64.69 ± 0.42	0.2 ± 0.6
137-235 (cal-1)	64.79 ± 0.52	3.5 ± 0.6

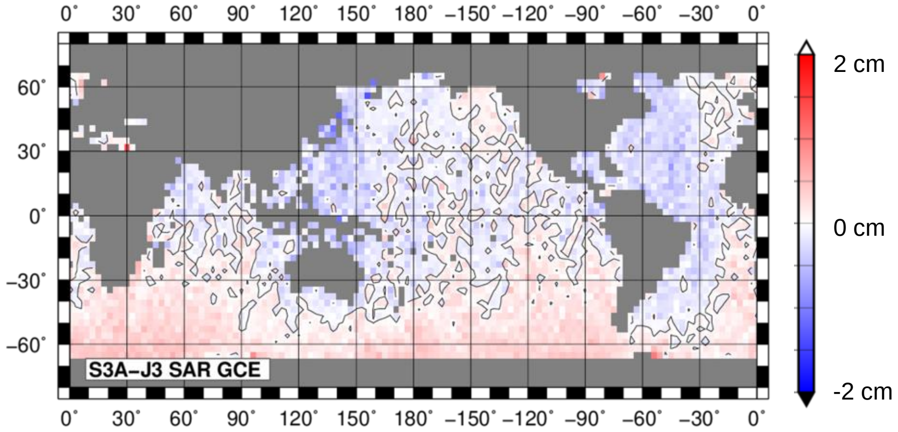
- **Significant drifts between TOPEX and ERS are detectable.**
- **Removing the CAL-1 correction from the TOPEX data decreases the trend differences in the first period but increases the trend difference in the second period of TOPEX-A.**
- **Due to the relative calibration method and the unknown stability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

Sentinel-3A: drift with respect to Jason-3

Relative drift between Sentinel-3A and Jason-3 for different data types and processing baselines.

(Sentinel-3A data: Level 2 WAT Rep V6 until Dec. 2018, CODA afterwards)



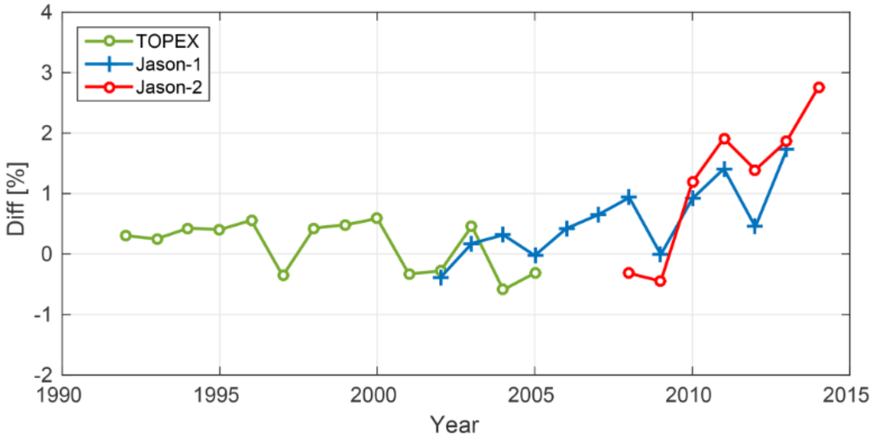


- **Significant drift between Jason-3 and Sentinel-3A SAR sea surface heights, especially until March 2018. No trend detectable between Sentinel-3B (core orbit) and Jason-3.**
- **Differences in the realization of the origin in z-component (offset and annual oscillation) for both Sentinel-3 missions. These effects also reduces when using PLRM instead of SAR.**

Dettmering & Schwatke, 2019

Impact of reference system realization: ITRF2008 => ITRF2014

Relative differences (between solutions ITRF2008-ITRF2014 orbit) in the standard deviation of radial errors per year for TOPEX (green), Jason-1 (blue), and Jason-2 (red)



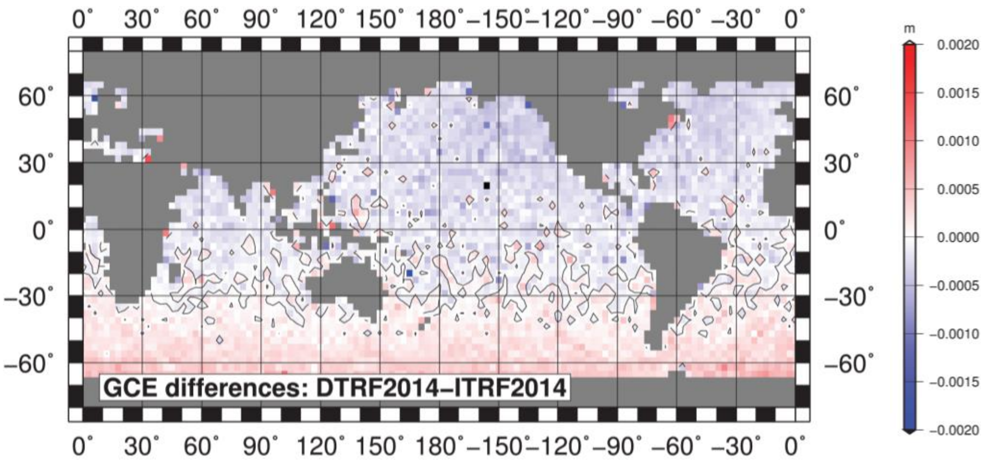
Positive values indicate improvements induced by ITRF2014 orbits

Rudenko et al., 2019

- **For all three missions, slight improvements in the standard deviations of radial errors are obtained through the use of ITRF2014 orbits.**
- **This behavior is time-dependet: After 2010, clear improvements for all missions are visible reaching a maximum of nearly 3 % for Jason-2 in 2014.**

Impact of reference system realization: ITRF2014/DTRF2014

Geographically correlated error differences for **Jason-2** when using SLR-orbits based on two different reference frames: ITRF2014 and DTRF2014



Mean and Standard Deviations of the Radial Errors for Jason-2 Orbits Based on Different Reference Frame Realizations

TRF realization	Radial errors mean [mm]	Radial errors std [mm]	Difference w.r.t. SLRF2008 mean [mm]	Difference w.r.t. SLRF2008 std [mm]
SLRF2008	1.943	15.723	–	–
ITRF2014	1.939	15.748	−0.004	+0.025
DTRF2014	1.947	15.649	+0.004	−0.074
JTRF2014	1.937	15.772	−0.006	+0.049

Rudenko et al., 2018

- **The impact of the different reference frames is below 1mm and in the order of about 10% of the total GCE effect.**
- **The main influence is visible in a North-South error distribution indicating differences in the realization of the z-component of the origin.**

Summary

DGFI-TUM’s multi-mission crossover analysis (MMXO) provides…

- ✓ radial range correction for each individual altimetry measurement
- ✓ mean relative range biases between different missions
- ✓ information on relative drift behaviors between different missions
- ✓ information on orbit performance and its impact on sea level determination, especially
    - geographically correlated mean errors
    - center-of-origin realization differences
- ✓ empirical auto-covariance functions of radial errors (useful for describing stochastic properties of altimeter measurements)

We will be happy to continue our work during the next OSTST period, and to extend the approach to observations of new missions, such as Sentinel-6 and SWOT.

References

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