Global Multi-Mission Crossover Analysis

Wolfgang Bosch
Deutsches Geodätisches Forschungsinstitut (DGFI), München
bosch@dgfi.badw.de

Forschungsgruppe
Satellitengeodäsie

Objectives

A discrete crossover analysis (DCA) is used to perform a rigorous cross-calibration of all altimeter satellites operating simultaneously, namely ERS-1, TOPEX, Poseidon, ERS-2, GFO, Jason1, and ENVISAT. The total set of nearly simultaneous single- and dual-satellite crossovers implies a dense sampling of the orbits of all satellites and realizes a rigid network with high redundancy to obtain reliable estimates of the radial error components.

The analysis is performed for a sequence of 10 day periods (covering the TOPEX life time) with 3 days overlap to neighbouring periods. The concatenated time series of radial errors allows estimating auto-covariance functions for all satellites. The errors are averaged and decomposed in a mean (geographically fixed) and a variable error pattern. TOPEX is not used as reference but adjusted just as all other altimeter systems. The radial errors are also used to calculate time series of relative range biases and centre-of-origin-shifts between all altimeter systems.

Table 1. Altimeter mission data used for the present analysis

Mission (Phase)	Cycles	Period	Source	Replacements
TOPEX/Poseidon	001-481	1992/09/23-2005/10/08	MGDR-C AVISO	Chambers SSB correction, FES2004
Jason1	001-135	2002/01/15-2005/09/14	GDR-A PODACC	FES2004
ERS-1 (C & G)	083-101 144-155	1992/04/14-1993/12/20 1995/03/24-1996/04/28	OPR-V6 CERSAT	DEOS orbits, FES2004, pole tide
ERS-2	000-087	1995/04/29-2003/09/15	OPR-V6 CERSAT	DEOS orbits, FES2004, pole tide
ENVISAT	010-040	2002/09/30-2005/09/19	GDR ESA/CNES	FES2004
GFO	100-122	2003/01/01-2003/12/31	GDR NOAA	FES2004

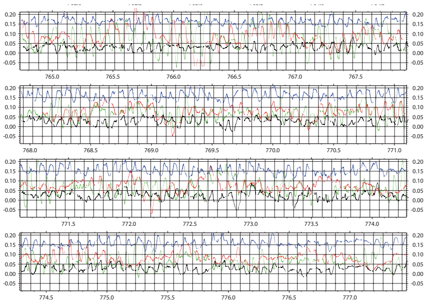


Fig. 2: *Subset of analysis period with the radial error estimates of TOPEX (black), ERS-2 (red), GFO (green) and Jason1 (blue).*

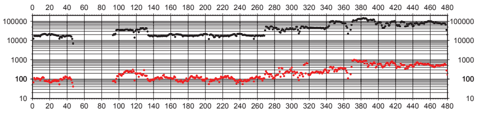


Fig. 1: *The total number of crossovers (in black) treated for all analysis periods (coinciding with TOPEX cycles plus 2×3 days overlap). The crossover adjustment was iterated once skipping crossovers whose residuals exceed a 3σ-criteria (less than 1%, shown in red).*

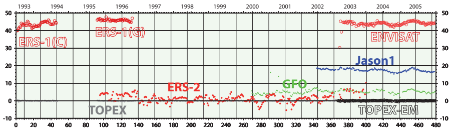


Fig. 2: *Relative range biases (cm) for all missions and 10-day periods analysed. The range biases are relative to TOPEX (later T/P-EM) because the sum of TOPEX (T/P-EM) errors was forced to zero. Note, all biases show weak annual oscillations with similar phasing and amplitude for ENVISAT, Jason1, and GFO since late 2002 – an indication for systematic variations in the TOPEX (T/P-EM) orbits.*

Discrete Crossover Analysis (DCA)

Crossover differences $d' = [\cdots, \Delta x_{ij}, \cdots]$ are modelled by the radial errors x_i and x_j of the two passes intersecting at a crossover location. To avoid uncontrolled jumps of the errors, consecutive differences are considered in addition and - together with the crossover differences - minimized by the weighted least squares approach:

$$\min_{k'x=0} \left\| \begin{bmatrix} D \\ A \end{bmatrix} x = \begin{bmatrix} 0 \\ d \end{bmatrix} \right\|_P^2$$

The combined system (right hand) has a rank defect of 1 which is solved by a single constraint $k'x = 0$ applied to all errors x_i or any subset of these errors. Here, the sum of all TOPEX errors was forced to be zero.

Weighting

With growing time difference Δt, both „observation“, Δx and x_i - x_{i+1} are down weighted - using different half-weight-width. Additional weights for the crossover differences are derived from their standard deviation and by cosφ compensating the increasing number of crossovers at high latitude.

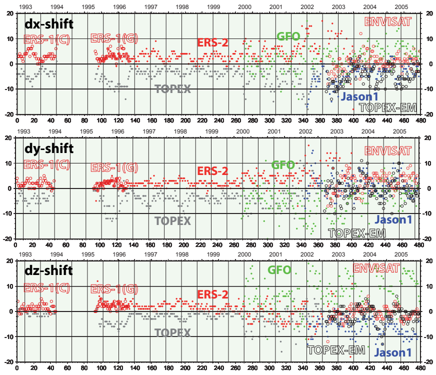
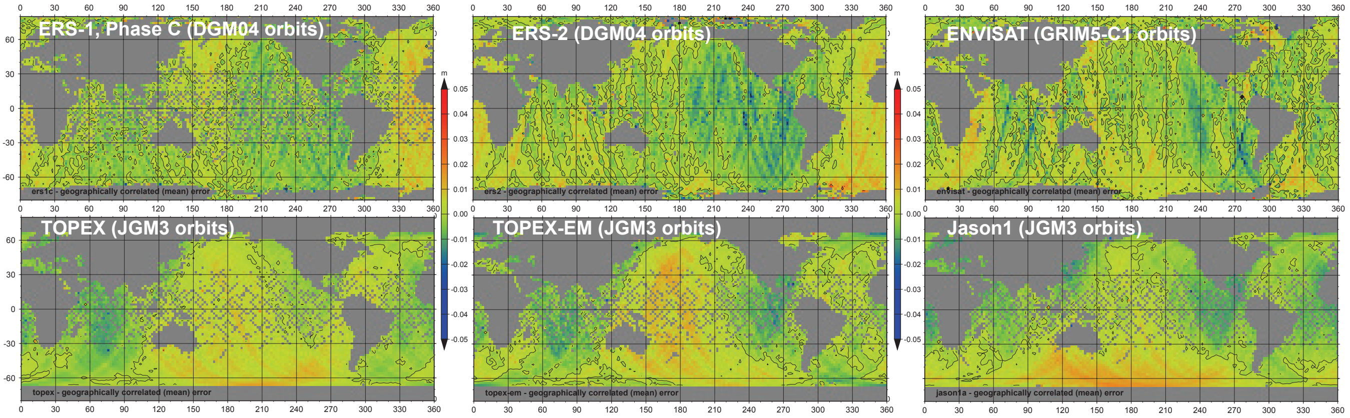


Fig. 3: *Centre-of-origin shifts (mm) derived for every 10-day analysis period from the radial error estimates of each mission. Notable the reversed shifts of ERS-2 and TOPEX. The scatter of the shifts increases significantly from 2000 on. Striking the large z-shifts for GFO - possibly caused by sea state bias errors in the southern ocean.*

Geographically correlated (mean) errors of all altimeter missions


ERS-1, Phase C (DGM04 orbits)
ERS-2 (DGM04 orbits)
ENVISAT (GRIM5-C1 orbits)
TOPEX (JGM3 orbits)
TOPEX-EM (JGM3 orbits)
Jason1 (JGM3 orbits)

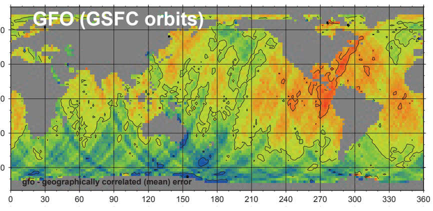

GFO (GSFC orbits)

Fig. 4: *Geographically correlated mean errors (meter) for ERS-1, phase C (phase G is similar and not shown), ERS-2 and ENVISAT (top row from left to right), TOPEX, TOPEX-EM, and Jason1 (second row from left to right), and for GFO (right). The mean error pattern for TOPEX and TOPEX-EM are – as expected – very similar. However the mean error of Jason1 differs significantly from TOPEX although Jason1 orbits are also based on JGM3. This is an indication that not only gravity field errors but also other errors (e.g. for sea state bias) map into the mean error. GFO exhibits the most outstanding mean error pattern with up to 4-5 cm around central America and negative values (between -2 and -4 cm) at all southern oceans.*

Mean errors of retracked data for the TOPEX/Jason1 tandem phase

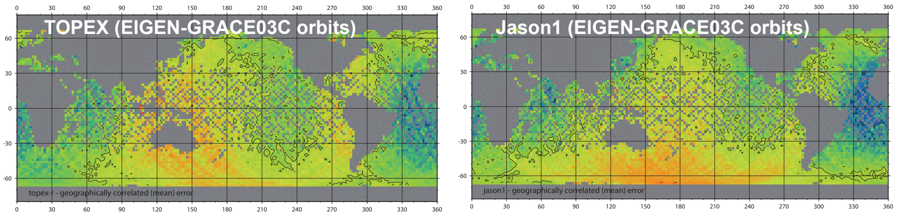

TOPEX (EIGEN-GRACE03C orbits)
Jason1 (EIGEN-GRACE03C orbits)

Fig. 6: *Pattern of mean errors for TOPEX (left) and Jason1 (right). derived from crossover analysis of retracked data acquired during the tandem phase (cycle 344-364). Surprisingly the amplitude are equal or even higher than the values shown in Figure 4 above*

Conclusions

Global multi-mission crossover analysis was performed for up to five contemporary altimeter satellites. The total set of single- and dual-satellite crossovers creates a strong network with high redundancy and enables a reliable and dense sampling of the radial errors of all satellites.
The error time series allows to assess the spectral properties of the radial component, captures relative range biases and indicates systematic variations of the centre-of-origin realisations. Most challenging is the capability to estimate for all altimeter systems the geographically correlated mean error.

References

Bosch, W. (2006) Discrete crossover analysis (DCA). IAG Symposia, Vol. 13?, Springer (in press)

Bosch, W. and R. Savchenko (2006): Satellite Altimetry: Multi Mission Cross Calibration. IAG Symposia, Vol. 13?, Springer (in press)

Ocean Surface Topography Science Team, Venice, 16.-18. March 2006