Influence of latest orbit reprocessing on multi-mission altimetry

Denise Dettmering & Wolfgang Bosch

Deutsches Geodätisches Forschungsinstitut (DGFI)
Centrum für Geodätische Erdsystemforschung (CGE)
Munich, Germany
email: *dettmering@dgfi.badw.de*

Outline

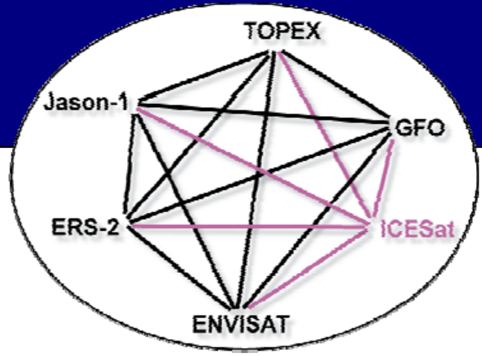
- Multi-Mission Crossover Analysis

- Orbit solutions
  - ESOC EIGEN-6C solutions (Jason-1/2, Envisat)
  - REAPER Orbits (ERS-1/2)
  - GFO GSFC std0905

- Investigations
  - Geographically correlated errors
  - Center-of-Origin (first degree harmonics)
  - Orientation of the rotation axis (second degree harmonics)

- Conclusion

Multi-Mission Cross-Calibration (MMXO)



Basics

- single- and dual satellite crossover differences in all combinations
- using only crossovers close in time (Δt < 2 days)
- least squares adjustment of radial errors minimizing crossover and the along-track consecutive differences
- Weighting of missions done by variance component estimation (VCE)
- TOPEX (later Jason1) taken as reference mission
- Segmentation into 10-day cycles of reference mission plus 2 days overlap (errors in the overlap differ by mm only)
- up to 120000(240000) crossovers (unknowns) per segment
- iterative solution with conjugate gradient algorithm

Results

- time series of radial errors per mission (w.r.t. to reference mission)
- range bias (per 10 days period) *=> Cal/Val Session*
- geographically correlated error pattern
- differences in the realization of the origin of reference frame (first order harmonics)
- differences in the realization of the rotation axis (second order harmonics)

mainly due to orbit errors

Used orbit solutions

ESOC sol3 & sol8 orbits (Jason-1/2 & Envisat)

- EIGEN-6C (including GOCE)
- ITRF2008

Michiel Otten; ftp://dgn6.esoc.esa.int

ERS-1/2 REAPER Orbits

- ESA project “Reprocessing of Altimeter Products for ERS” (REAPER)
- Combined solution from three processing centers (DEOS,ESOC,GFZ)
- EIGEN-GL04S
- LPOD2005

S. Rudenko, M. Otten, P. Visser, R. Scharroo, T. Schoene
New improved homogeneous orbits of ERS-1 and ERS-2 satellites, Advances in Space Research, submitted

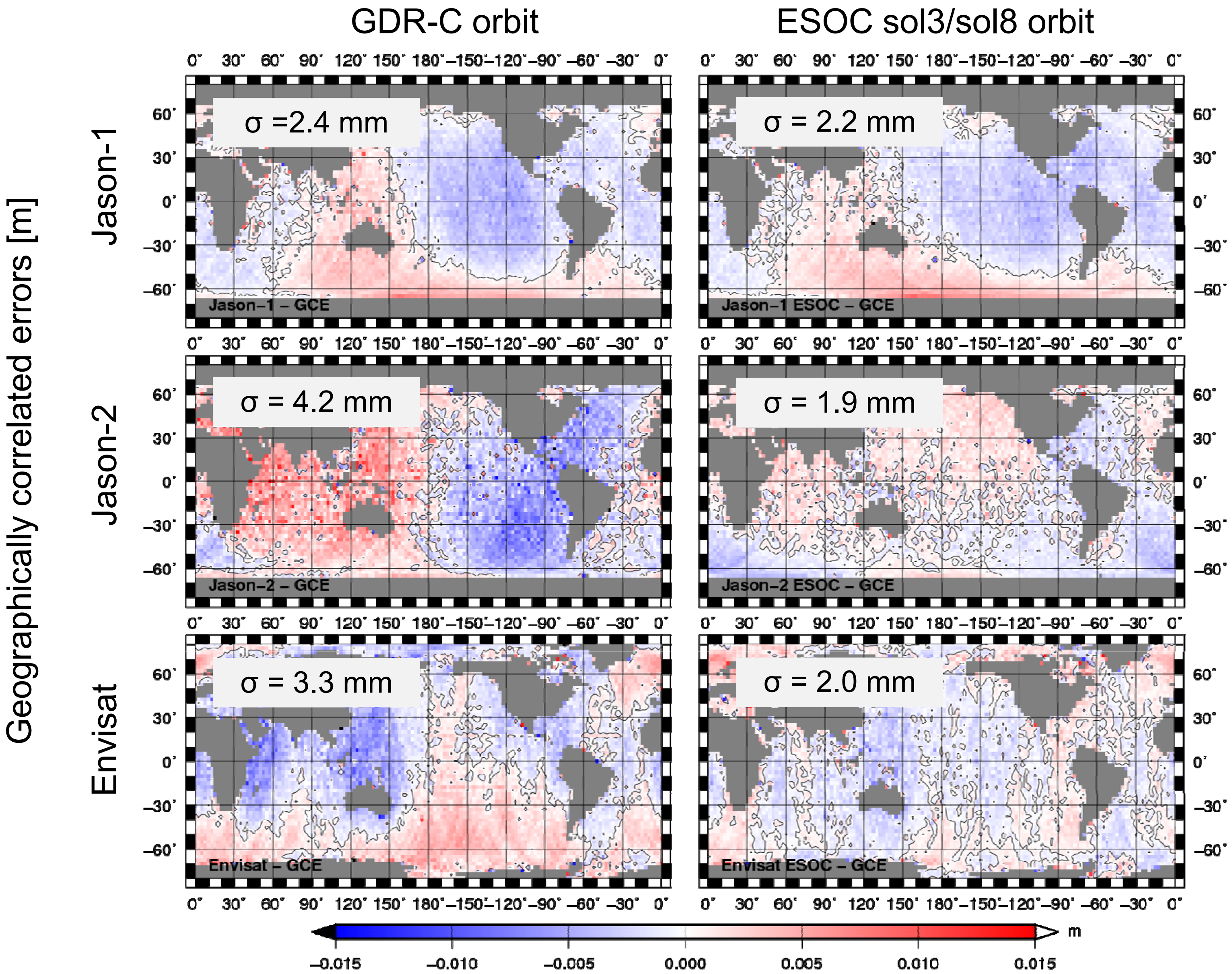
GFO GSFC std09/05 Orbits

- EIGEN-GL04S (120)
- ITRF2005

Lemoine F.G., Zelensky N.P., Chinn D.S., Beckley B.D., Lillibridge J.L.
Towards the GEOSAT Follow-On Precise Orbit Determination Goals of High Accuracy and Near-Real-Time Processing, Proceedings of AIAA/AAS Astrodynamics Specialist Conference 2006

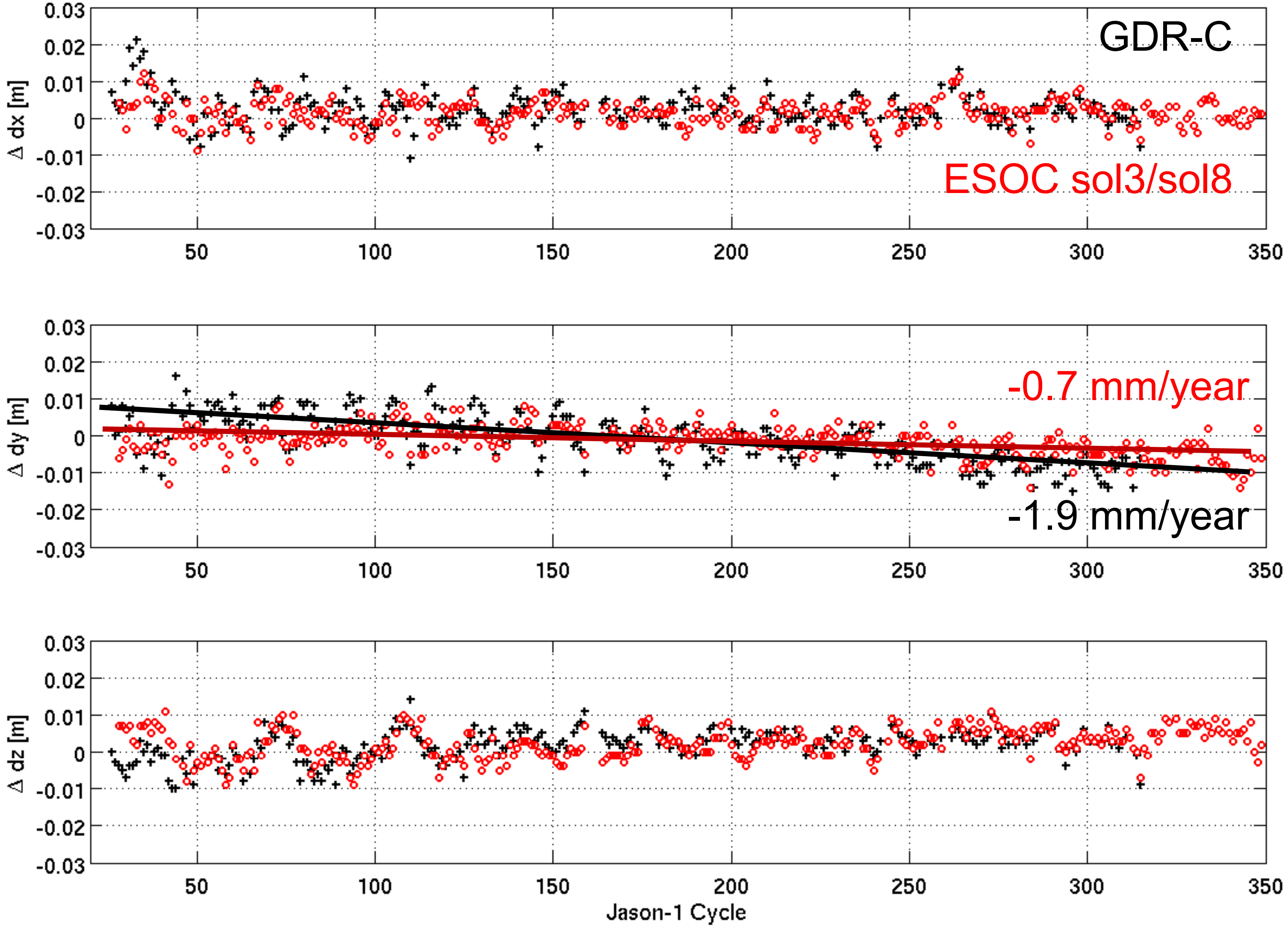
ESOC EIGEN-6C orbits

ESOC EIGEN-6C orbits – GCE



ESOC EIGEN-6C orbits – Center of origin

Relative differences in center-of-origin realization: Envisat-Jason1



2.2 ± 4.2 mm
1.2 ± 3.4 mm

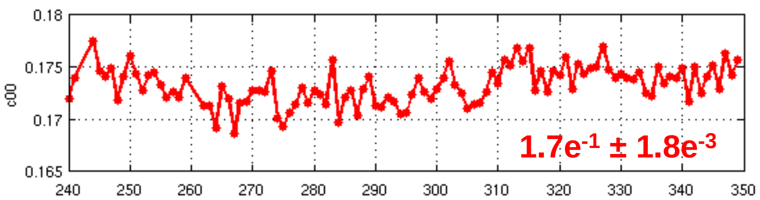
-1.0 ± 6.3 mm
-1.6 ± 4.0 mm

1.8 ± 4.0 mm
2.3 ± 4.0 mm

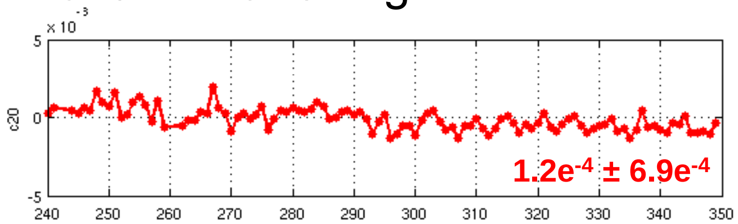
Jason-2 – Low degree harmonics (ESOC sol3 orbit)

$$radial\ errors(\theta,\lambda)=\sum_{n=0}^{2}\sum_{m=0}^{n}\left[\bar{c}_{nm}\bar{P}_{nm}(\cos\theta)\cos m\lambda+\bar{s}_{nm}\bar{P}_{nm}(\cos\theta)\sin m\lambda\right]$$

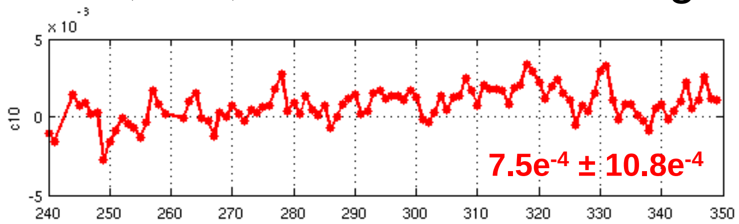
c00 => range bias

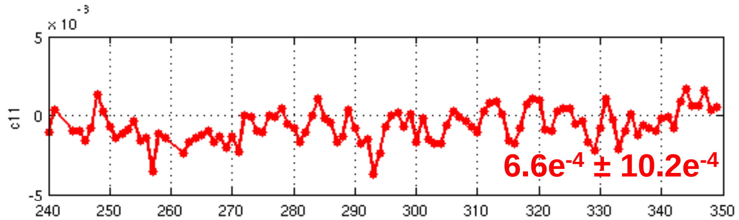


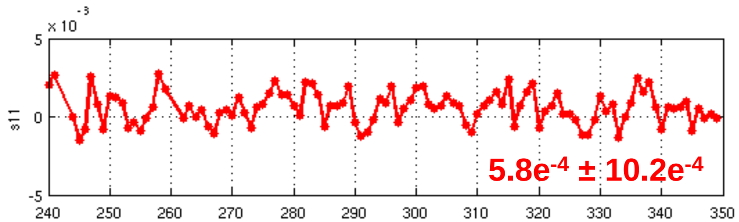
c20 => flattening



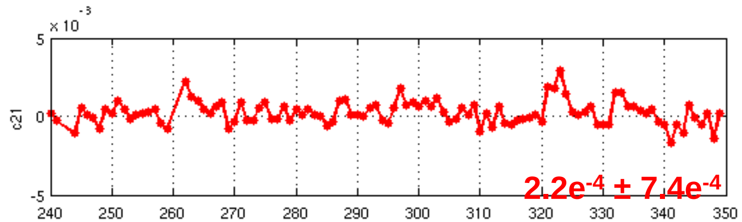
c10, c11, s11 => center-of-origin

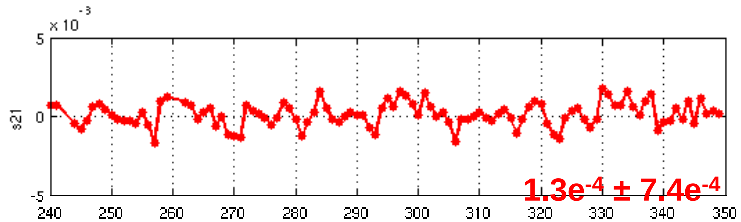






c21, s21 => orientation of the rotation axis

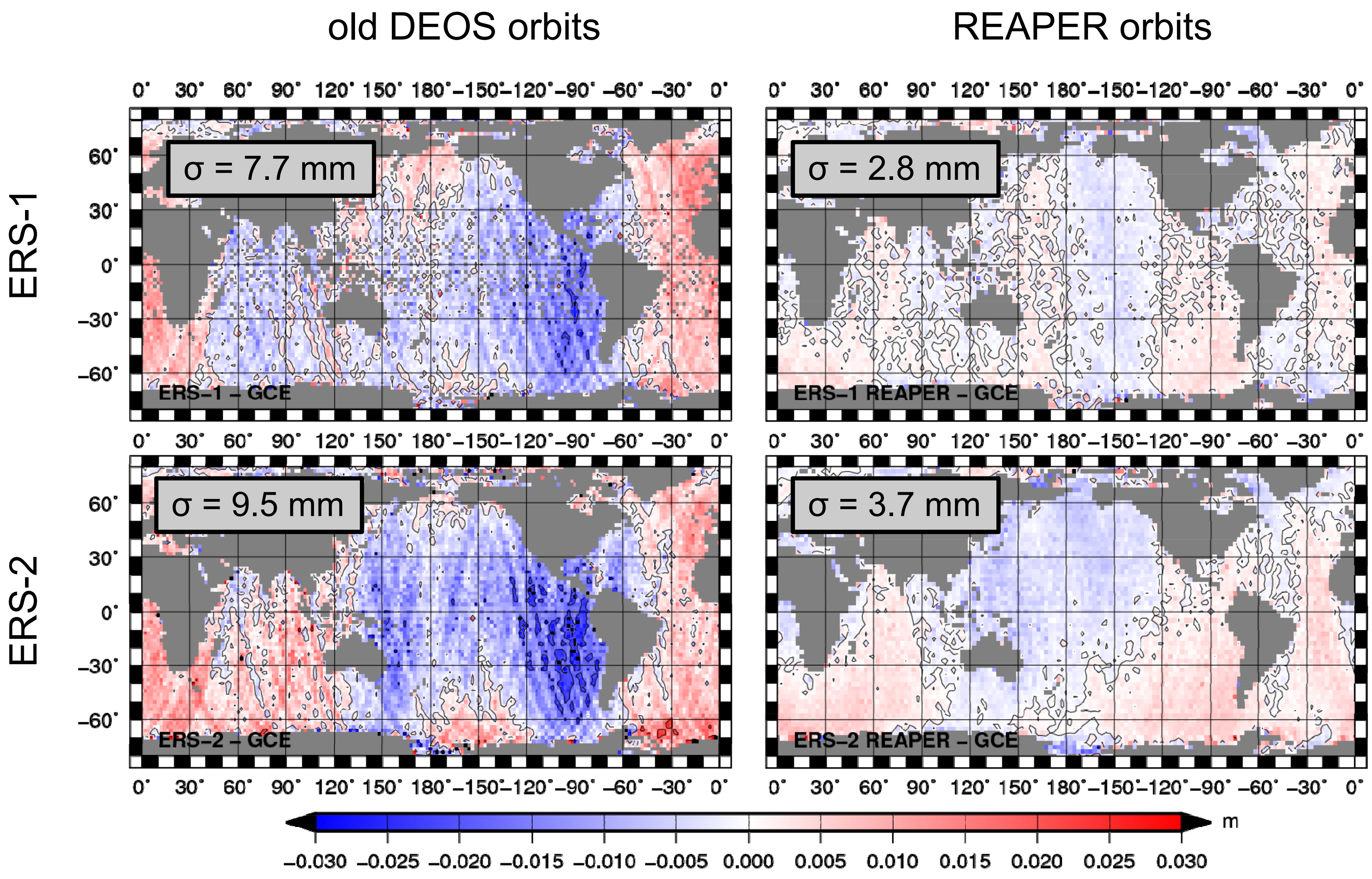




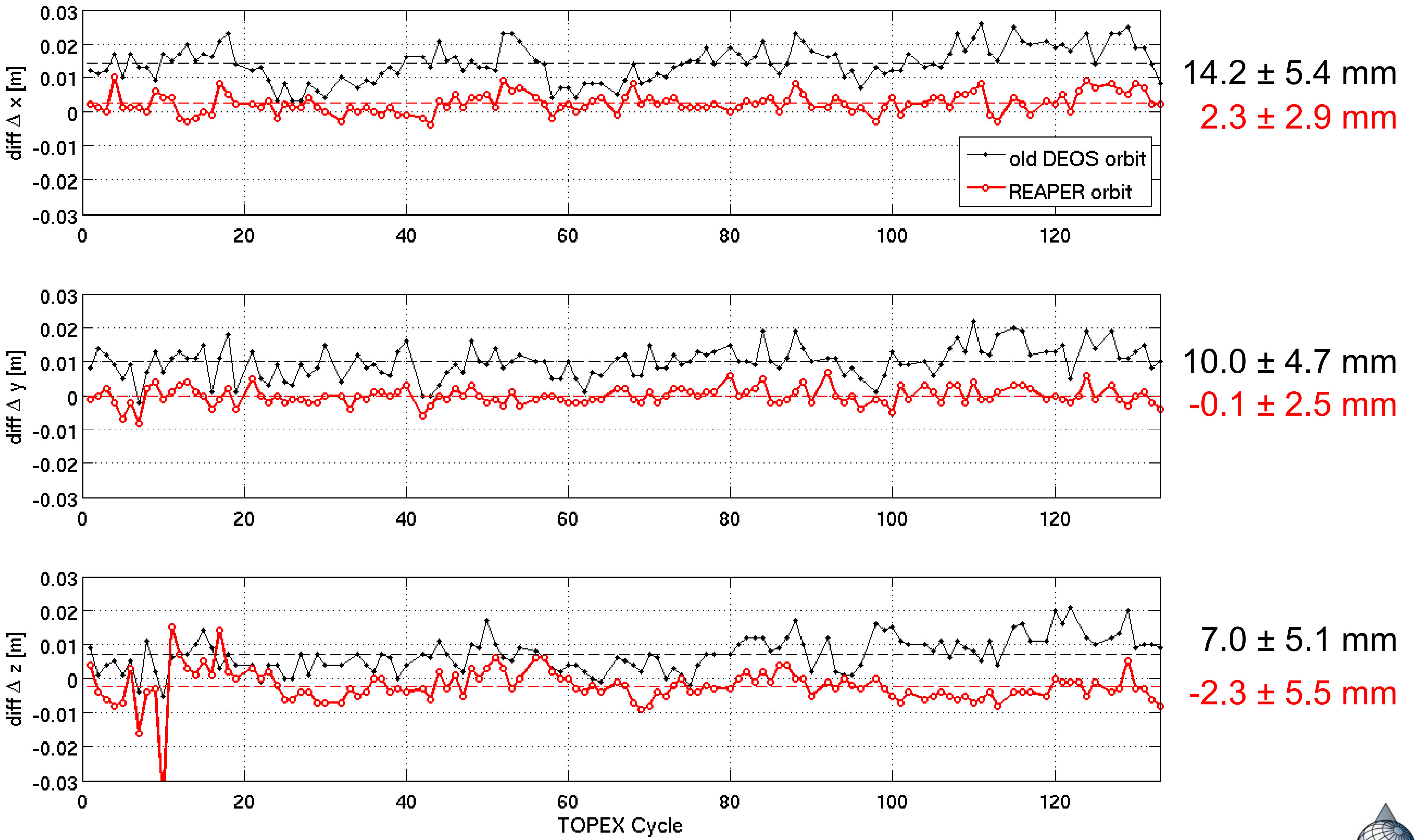
=> significant range bias w.r.t. Jason-1
=> all other coefficients not significant

ERS REAPER orbits

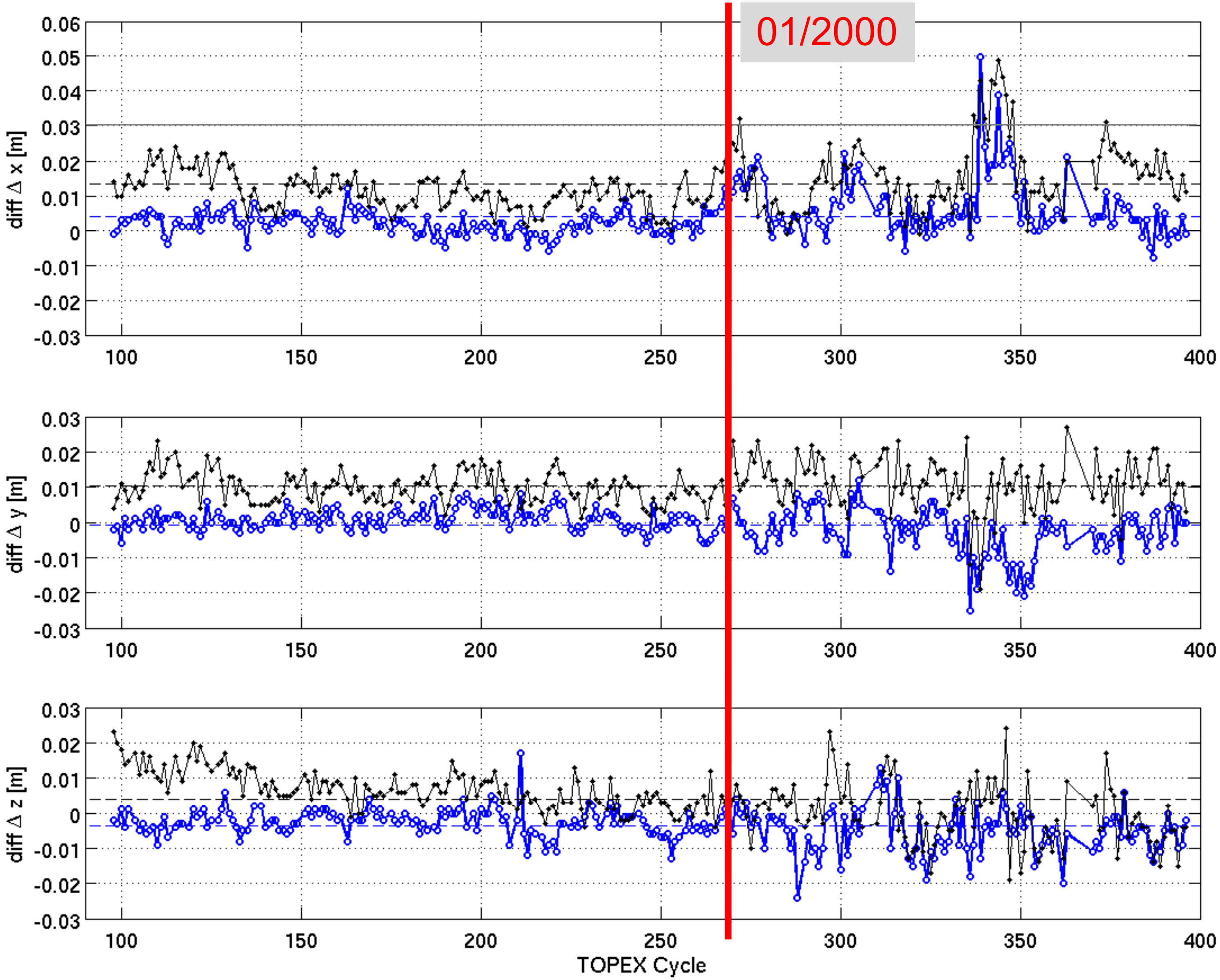
ERS – geographically correlated errors



Differences in Center-of-Origin realization: ERS1-TOPEX



Differences in Center-of-Origin realization: ERS2-TOPEX



13.4 ± 8.2 mm
4.0 ± 6.6 mm

10.4 ± 5.8 mm
-0.8 ± 5.3 mm

3.9 ± 7.7 mm
-3.6 ± 5.3 mm

ERS – center of origin

	ERS-1	ERS-2
dx	2.3 ± 2.9	4.0 ± 6.6
dy	-0.1 ± 2.5	-0.8 ± 5.3
dz	-2.3 ± 5.5	-3.6 ± 5.3

differences to TOPEX in [mm]

⇒ No significant differences in the center-of-origin realization between ERS REAPER orbits and TOPEX

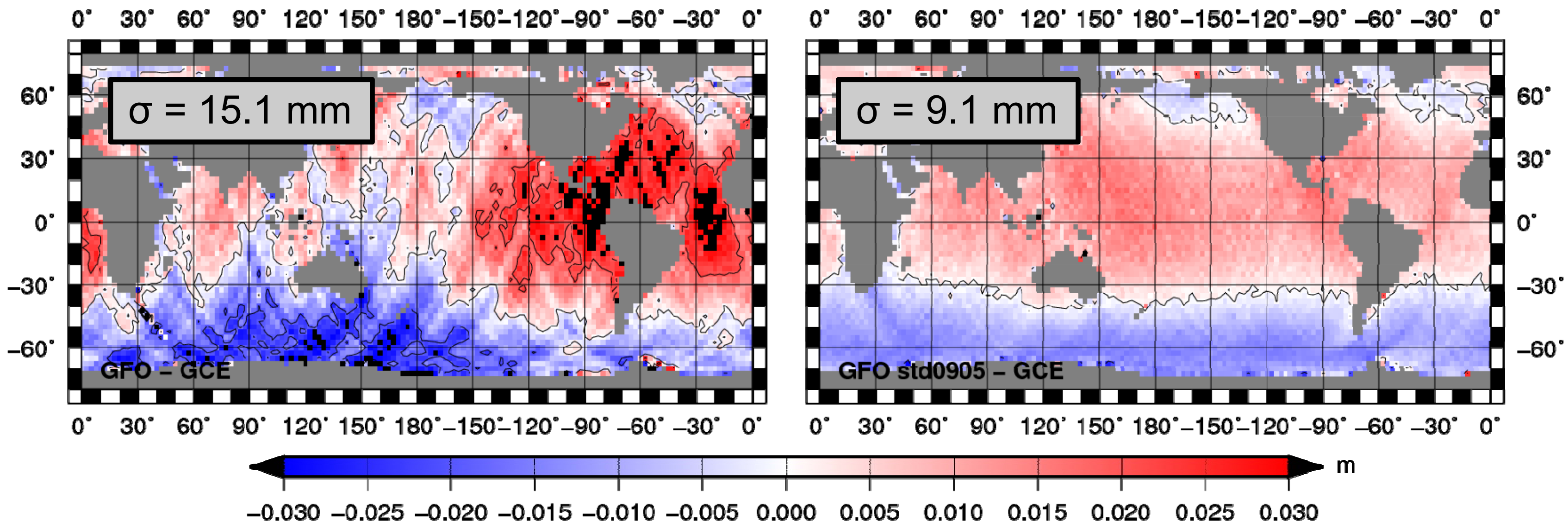
⇒ ERS-2 higher variations due to increased solar activity (~2000 to 2003)

⇒ no significant differences in the second order terms (rotation axis)

GFO GSFC std0905

GFO – geographically correlated errors

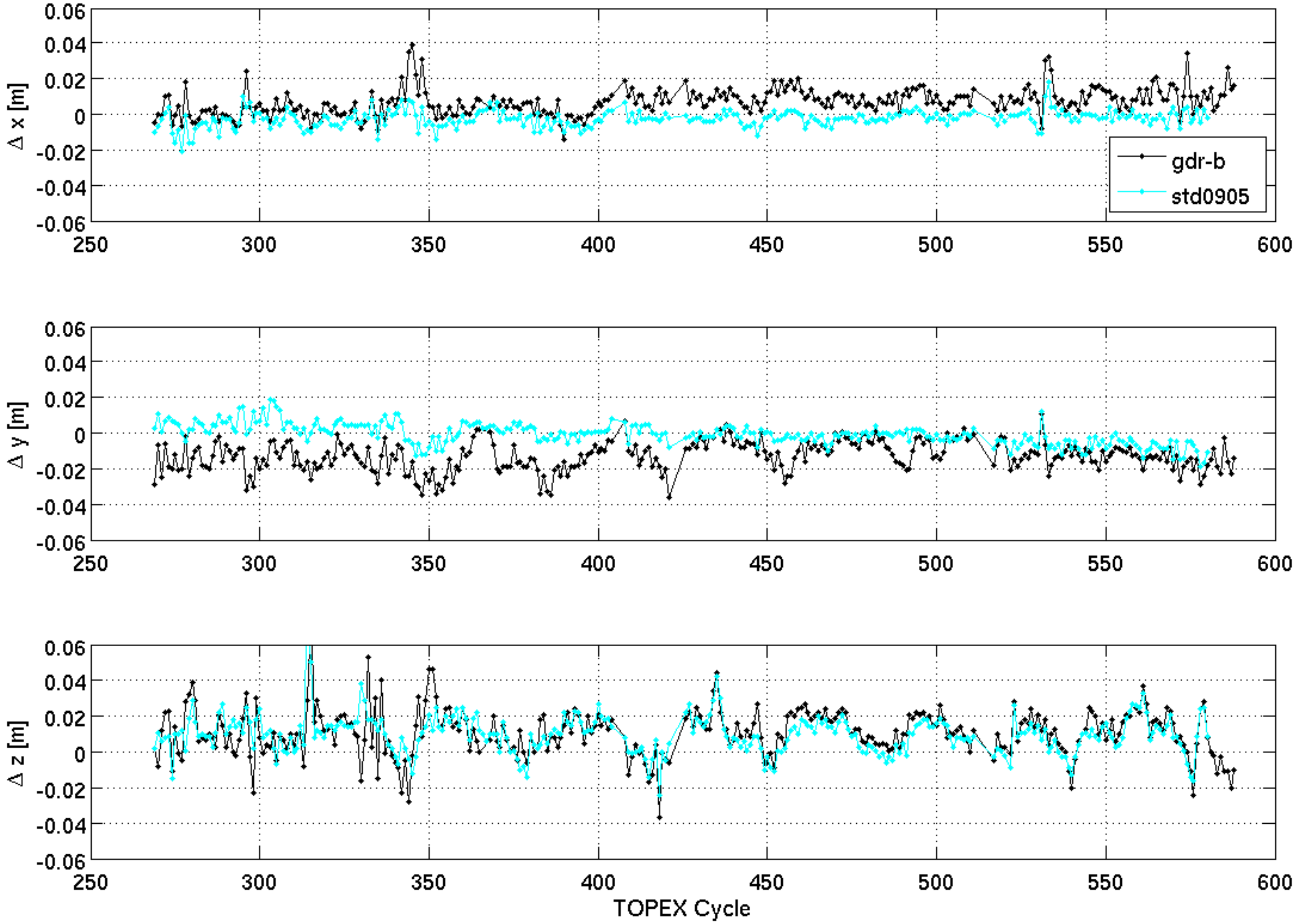
GDR orbit　　　　std0905 orbit



⇒ significant improvement

⇒ still some systematic effects left => J2 ?

GFO – center of origin



7.0 ± 7.5 mm
-2.6 ± 4.6 mm

-0.6 ± 6.0 mm
-13.0 ± 8.3 mm

10.8 ± 13.3 mm
9.9 ± 10.8 mm

GFO – Low degree harmonics (w.r.t TOPEX mission)

	gdr-b	std0905
c_{00}	21.6 ± 5.3	23.9 ± 4.5
c_{10}	5.7 ± 7.5	5.2 ± 6.2
c_{11}	4.3 ± 3.9	-0.9 ± 2.4
s_{11}	-6.5 ± 4.4	0.8 ± 2.9
c_{20}	-8.6 ± 2.6	-6.4 ± 2.1
c_{21}	-0.8 ± 1.4	0.2 ± 1.1
s_{21}	1.4 ± 2.1	0.7 ± 1.4

range bias

center-of-origin

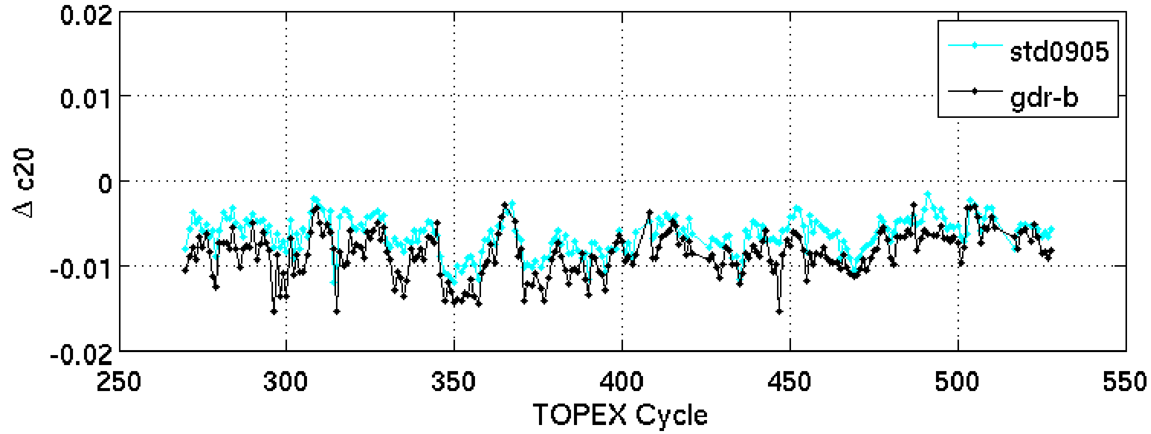
flattening

orientation of the rotation axis

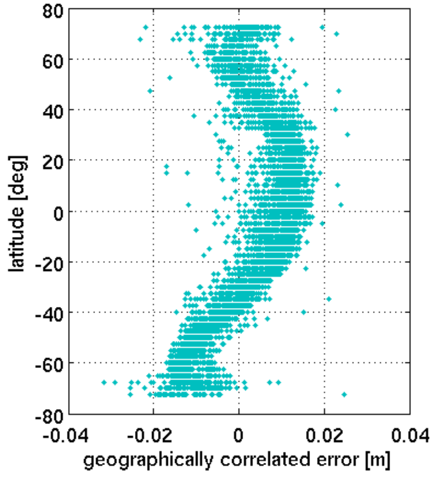
⇒ center-of-origin differences reduced by std0905 orbit

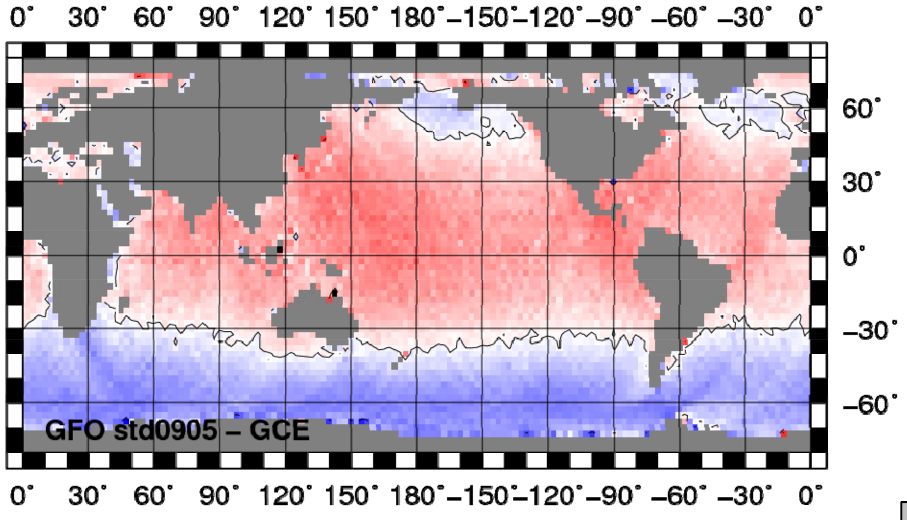
⇒ significant difference in c_{20} (oblateness of the Earth) w.r.t. TOPEX remains

GFO – flattening c20



geographically correlated errors





Conclusion

✓ ESOC EIGEN-6C orbits: improved GCE and better consistency between **Jason** and **Envisat** (temporal gravity field, visible as Δy)

✓ Geographically correlated errors of **ERS** now in the same order of magnitude as TOPEX and Jason (2-3 mm RMS), thanks to REAPER!

✓ **GFO** orbits show significant improvement; some problems left: J2 systematic? Time tag bias?

THANK YOU !

Computation of geographical correlated errors

Radial Errors are available for ascending and descending tracks.

From the differences between ascending and descending errors
(mean values per 2.5° by 2.5° region) the mean GCE can be computed:

$$\Delta\gamma = (dr^{asc} + dr^{desc})/2$$

[Rosborough, 1986]

dr^{asc}	average of the radial errors (mean reduced) of all asc. passes
dr^{desc}	average of the radial errors (mean reduced) of all desc. passes
$\Delta\gamma$	mean of ascending and descending errors, GCE per cell

Center-of-Origin Shifts

Separation of radial errors into range bias and center-of-origin shifts

Least square adjustment for each 10-day cycle

$$x_i + \varepsilon_{x_i} = \Delta r + \Delta x \cos\varphi_i \cos\lambda_i + \Delta y \cos\varphi_i \sin\lambda_i + \Delta z \sin\varphi_i$$

input: radial errors x_i at location φ_i, λ_i

output: mean range bias Δr

mean center-of-origin shifts Δx, Δy, Δz

Computation of low degree harmonics

radial errors

$$f(\theta,\lambda)=\sum_{n=0}^{2}\sum_{m=0}^{n}\left[\bar{c}_{nm}\bar{P}_{nm}(\cos\theta)\cos m\lambda+\bar{s}_{nm}\bar{P}_{nm}(\cos\theta)\sin m\lambda\right]$$

$\bar{c}_{00}$	range bias	$\bar{c}_{20}$	flattening
	center-of-origin		
$\bar{c}_{10}$	z	$\bar{c}_{21}$	rotation axis
$\bar{c}_{11}$	x	$\bar{s}_{21}$	
$\bar{s}_{11}$	y		

$\bar{s}_{22}$ $\bar{c}_{22}$: for most missions estimation not possible