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On the accuracy of contemporary orbits of altimetry satellites in the radial direction

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Outline

Significant progress has been achieved in precise orbit determination (POD) of altimetry satellites between 1992 and 2022.

Geophysical Data Records (GDR) orbit standards have been improved from **GDR-A to POE-F**.

Different types of observations have been used for POD of altimetry satellites: SLR, DORIS, GPS, PRARE, Doppler and altimeter crossovers.

In this study, we

a) investigate **radial orbit differences of contemporary orbit solutions** derived in the extended ITRF2014 reference frame realization by various institutions using various types of observations;

b) perform multi-mission crossover analysis:

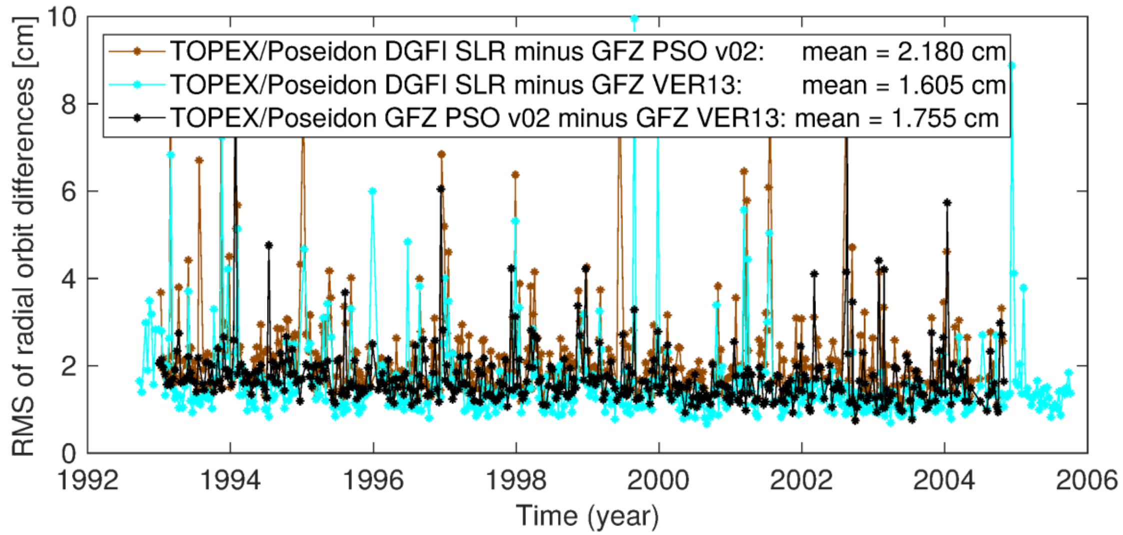
- to investigate **radial and geographically correlated errors (GCE)** of these orbit solutions,
- to investigate **improvements in the radial orbit quality** obtained from GDR-C to POE-F orbit standards.

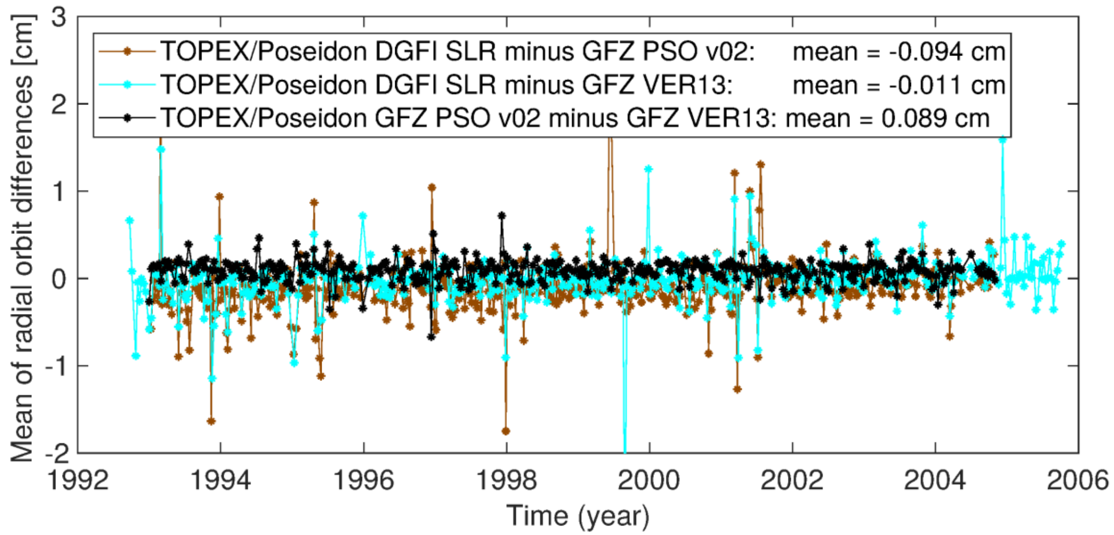
Observation types of the orbit solutions in ITRF2014 used for the analysis

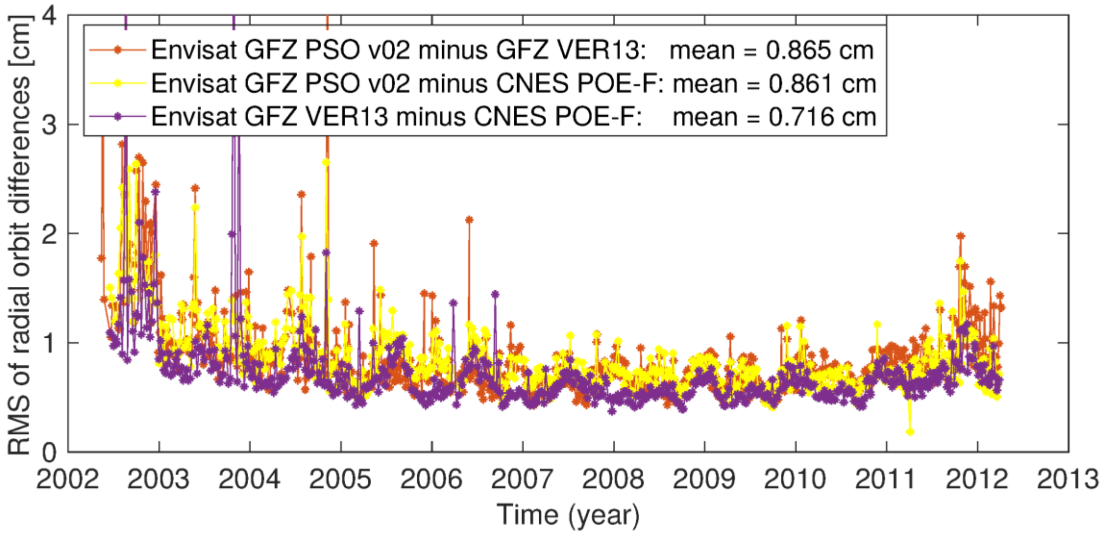
Satellite	CNES POE-F	GFZ VER13	GFZ PSO v02	GSFC ITRF2014	CPOD ITRF2014	JPL IGS14	DGFI RUN8
TOPEX/ Poseidon		DORIS+SLR	DORIS+SLR	DORIS+SLR			SLR
Envisat	DORIS	DORIS+SLR	DORIS+SLR				
Jason-1		DORIS+SLR	DORIS+SLR				SLR
Jason-2	DORIS+GPS	DORIS+SLR	DORIS+SLR	DORIS+SLR		GPS	SLR
Jason-3	DORIS+GPS		DORIS+SLR	DORIS+SLR		GPS	SLR
Sentinel-3A	DORIS+GPS		DORIS+SLR		GPS	GPS	
Sentinel-3B	DORIS+GPS		DORIS+SLR		GPS	GPS	

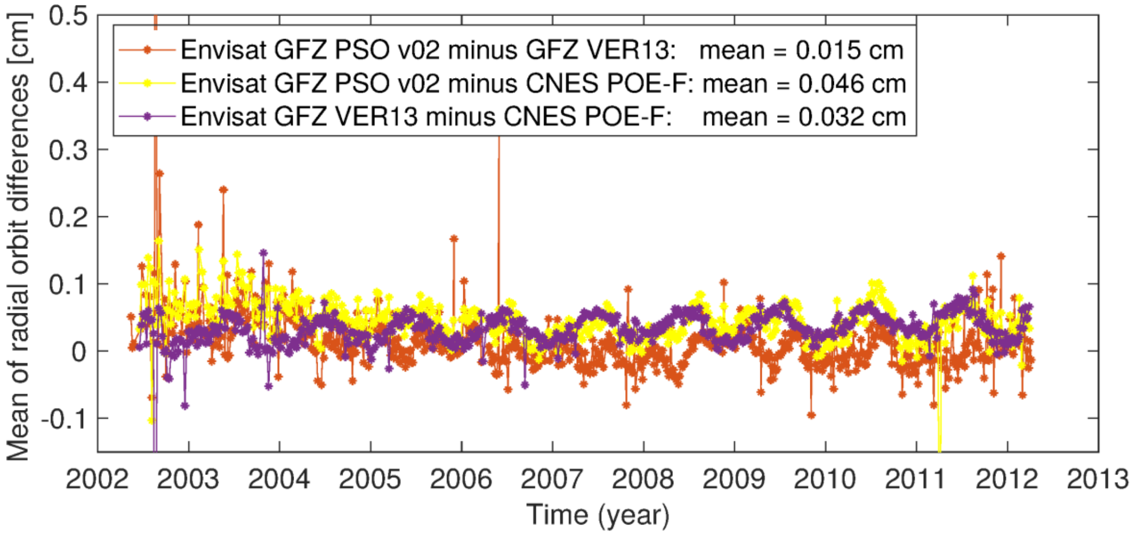
Additionally, we investigate a few orbit solutions of ERS-1, ERS-2, Saral and Cryosat-2.

Radial orbit differences of TOPEX/Poseidon (top) and Envisat (bottom) orbits

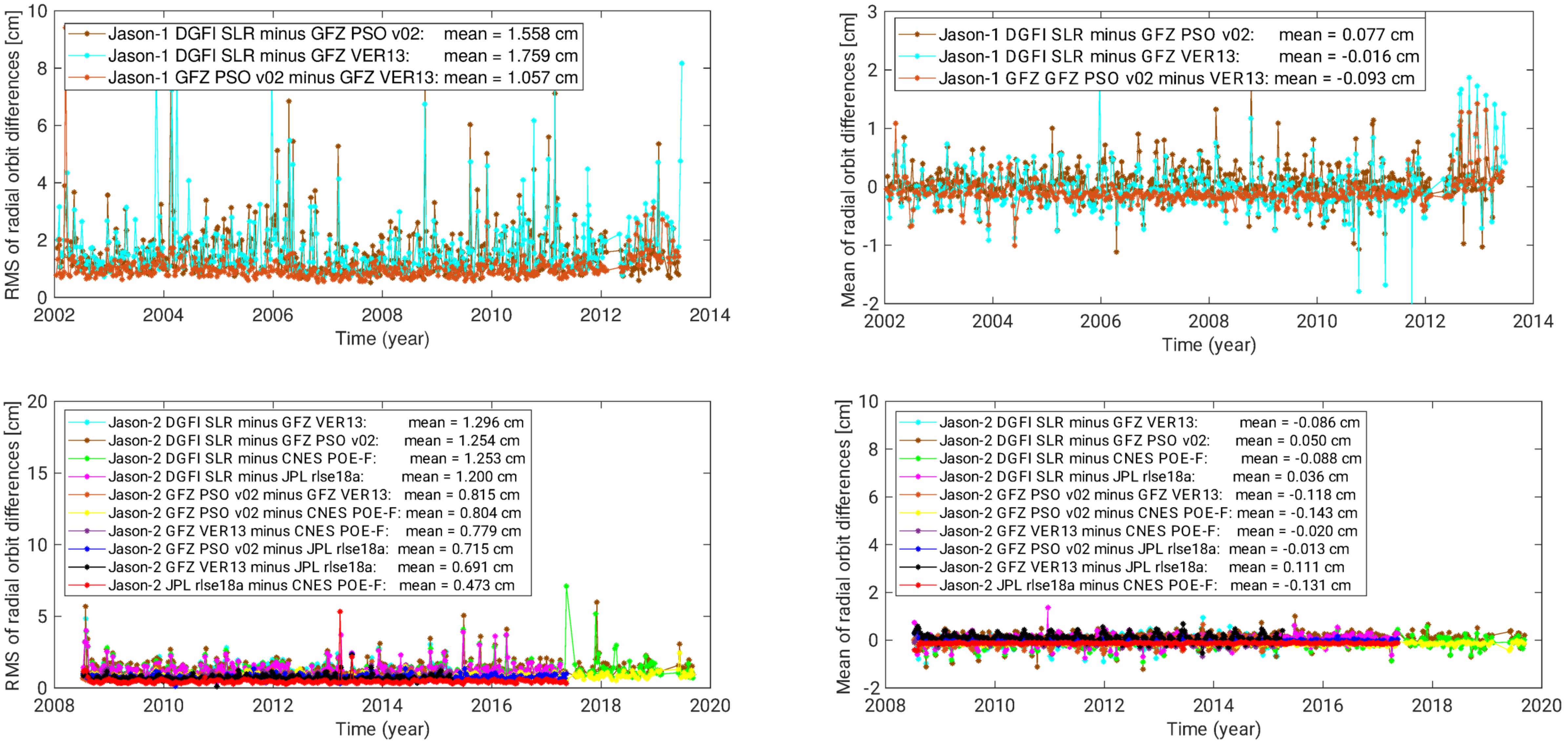




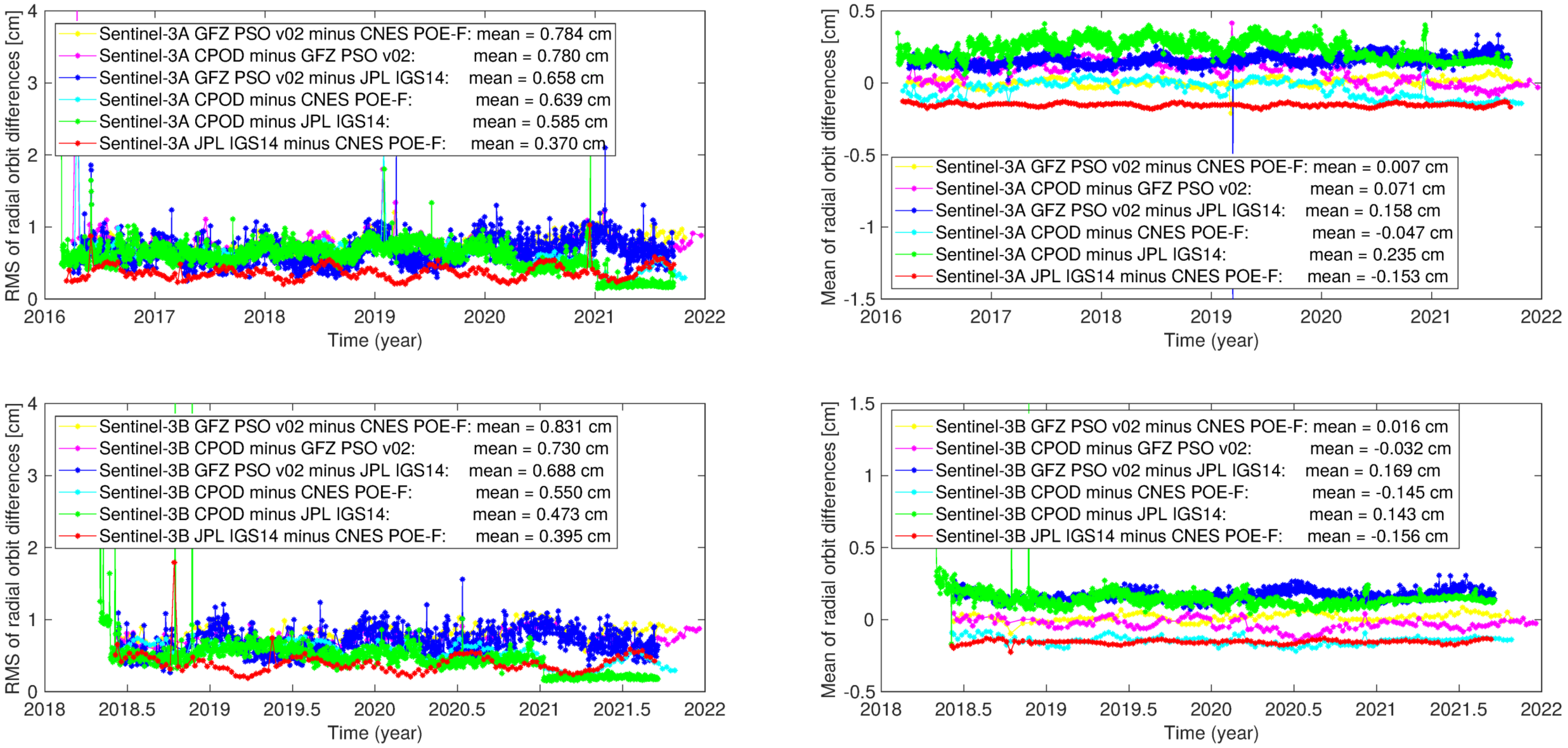




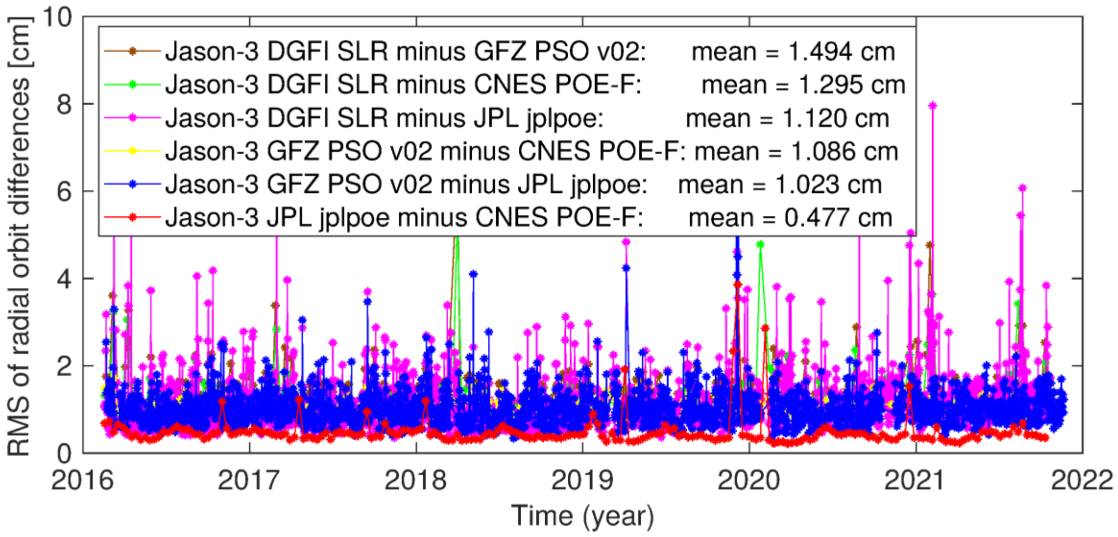
Radial orbit differences of Jason-1 (top) and Jason-2 (bottom) orbits

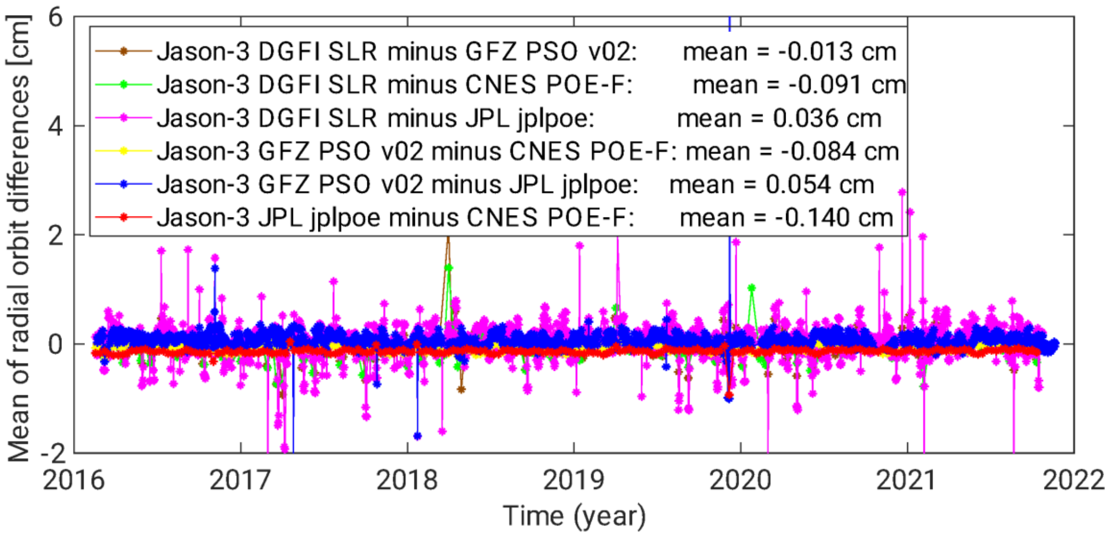


Radial orbit differences of Sentinel-3A (top) and Sentinel-3B (bottom) orbits



Radial orbit differences of Jason-3 orbits

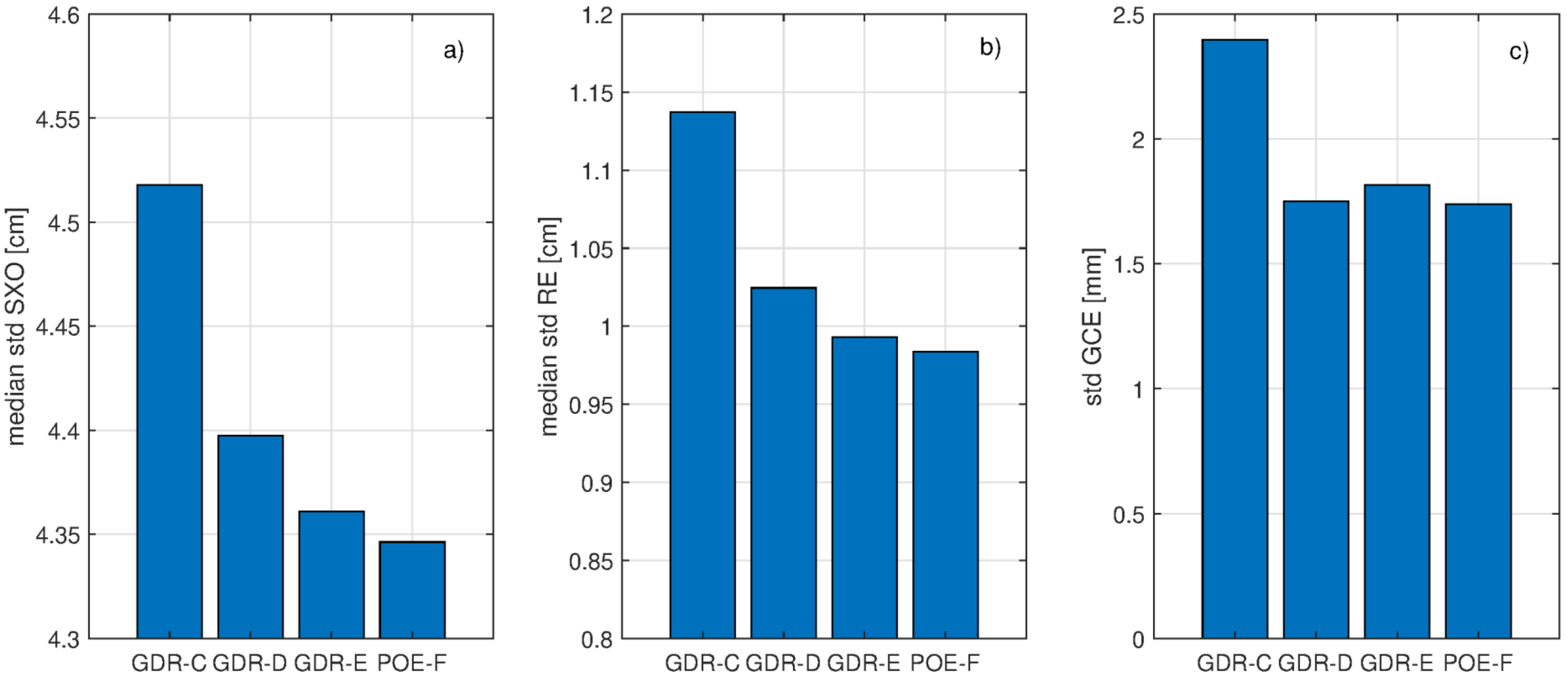




A summary on the RMS and mean values of radial orbit differences of various orbit solutions derived by various institutions using various observation types

Satellite	RMS (cm) DORIS / GPS / SLR	RMS (cm) w. r. t. SLR-only	Mean (cm) DORIS / GPS / SLR	Mean (cm) w. r. t. SLR-only
TOPEX/Poseidon	1.8	1.6 to 2.2	0.09	–0.09 to –0.01
Envisat	0.7 to 0.9	---	0.02 to 0.05	---
Jason-1	1.1	1.6 to 1.7	–0.09	–0.02 to 0.08
Jason-2	0.5 to 0.8	1.2 to 1.3	–0.14 to 0.11	–0.09 to 0.05
Jason-3	0.5 to 1.1	1.1 to 1.5	–0.14 to 0.05	–0.09 to 0.04
Sentinel-3A	0.4 to 0.8	---	–0.15 to 0.24	---
Sentinel-3B	0.4 to 0.8	---	–0.16 to 0.17	---

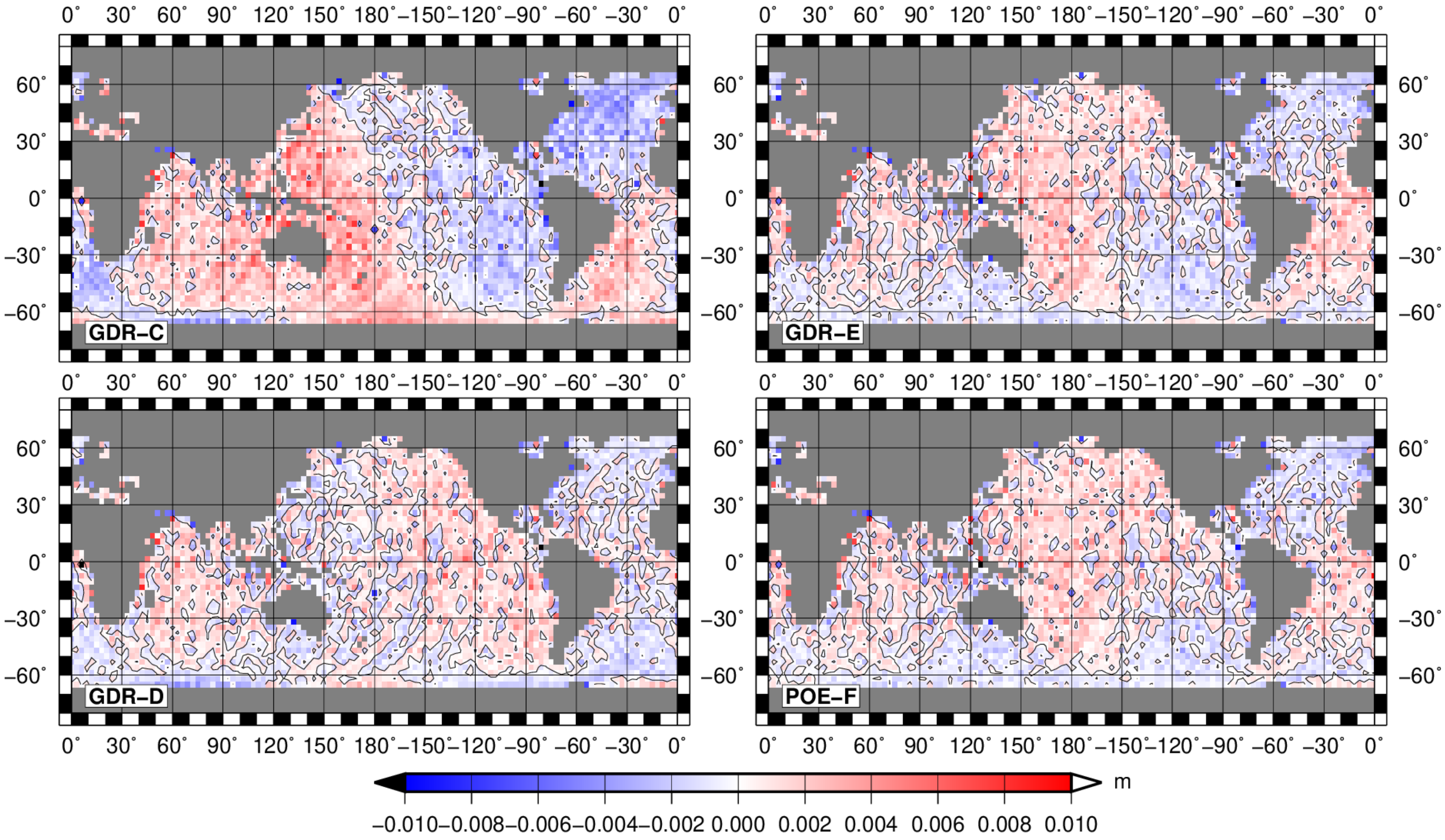
Quality comparison of Jason-2 CNES GDR-C, GDR-D, GDR-E and POE orbit solutions using a multi-mission crossover analysis



a) standard deviation of single-satellite crossover differences,
b) standard deviation of radial errors,
c) standard deviation of geographically correlated errors.

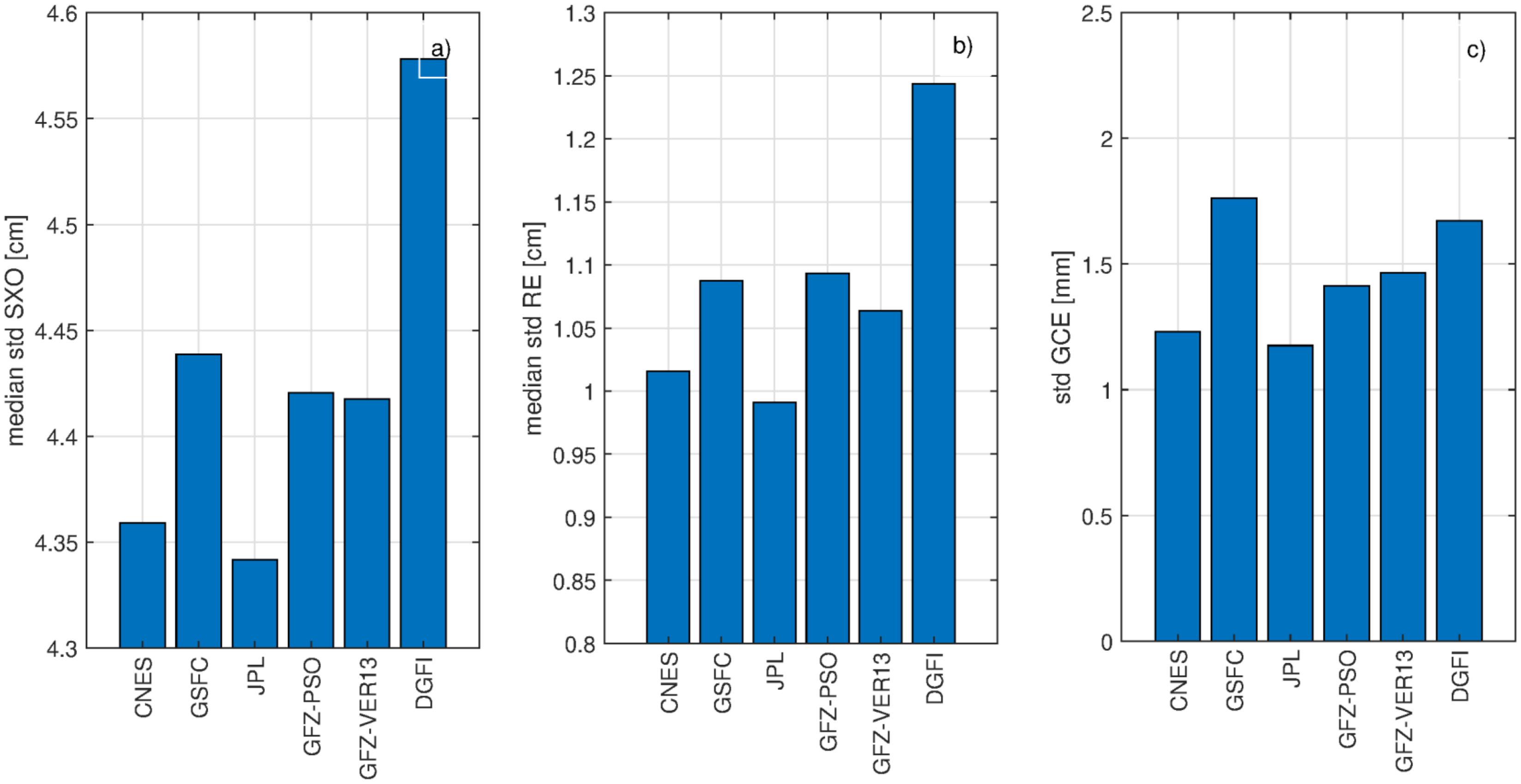
The largest improvement is seen, when switching from the GDR-C to the GDR-D orbit standards.

Geographically correlated errors for Jason-2 CNES GDR-C, GDR-D, GDR-E and POE-F orbit solutions (cycles 67–145)



The largest difference is seen when switching from the GDR-C to the GDR-D orbit standards due to the switch from the EIGEN-GL04S-ANNUAL to the EIGEN-GRGS. RL02bis.MEAN-FIELD **Earth's gravity field model** based on 8 (instead of 2) years of GRACE and LAGEOS data. Also switch from ITRF2005 to **ITRF2008 reference frame realization**.

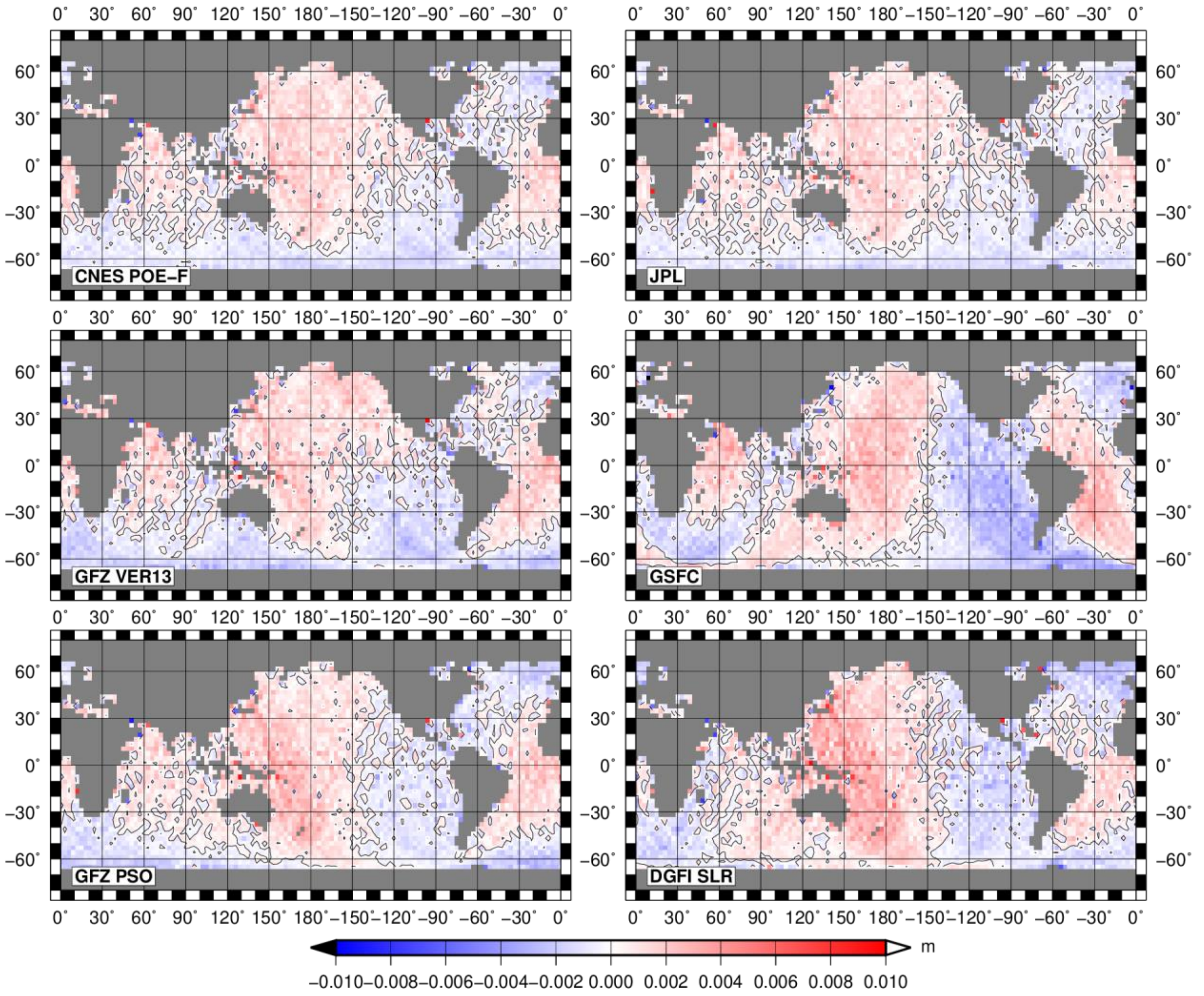
Quality comparison of ITRF2014 Jason-2 orbit solutions from different institutions using a multi-mission crossover analysis

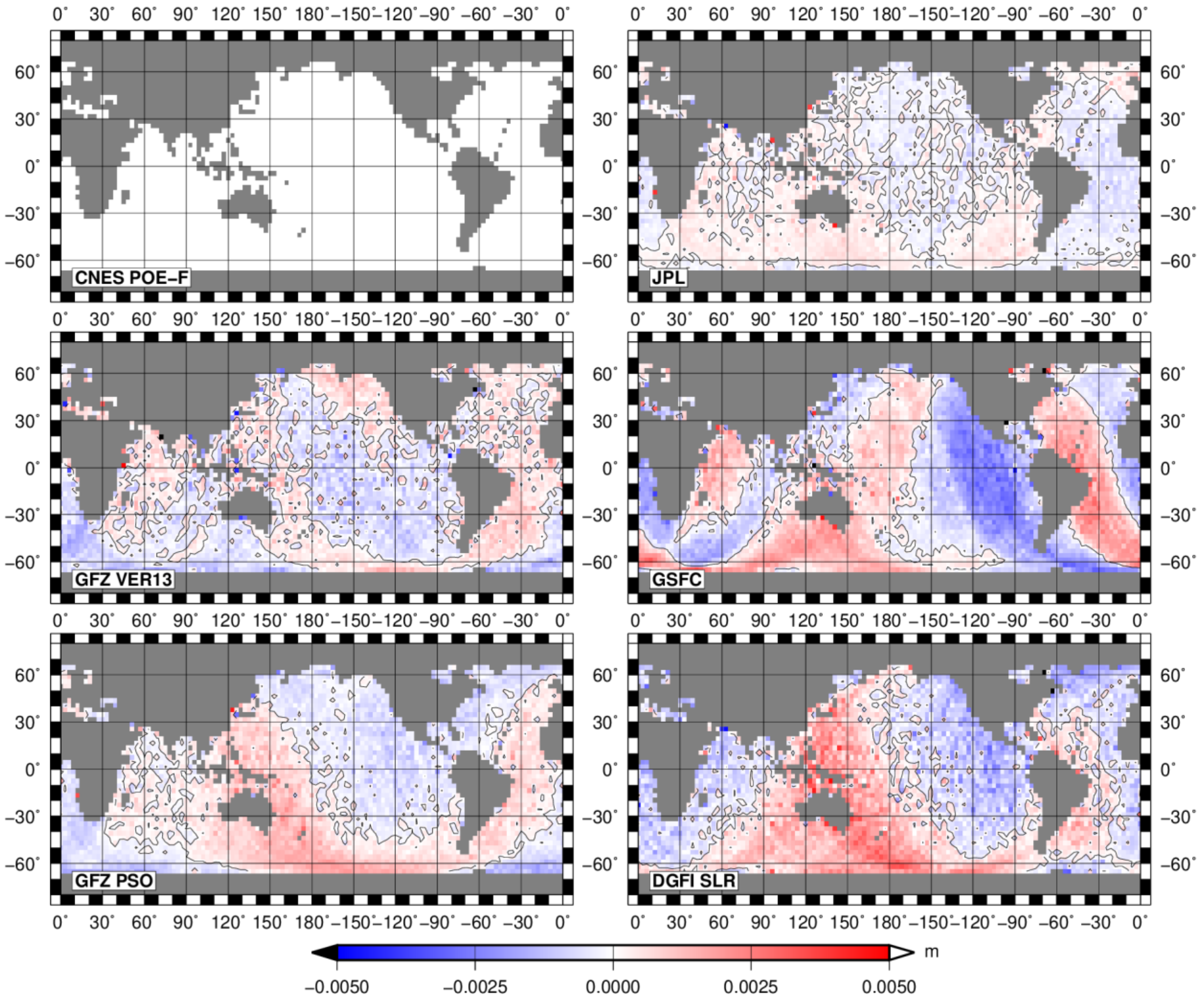


a) standard deviation of single-satellite crossover differences,
b) standard deviation of radial errors,
c) standard deviation of geographically correlated errors;

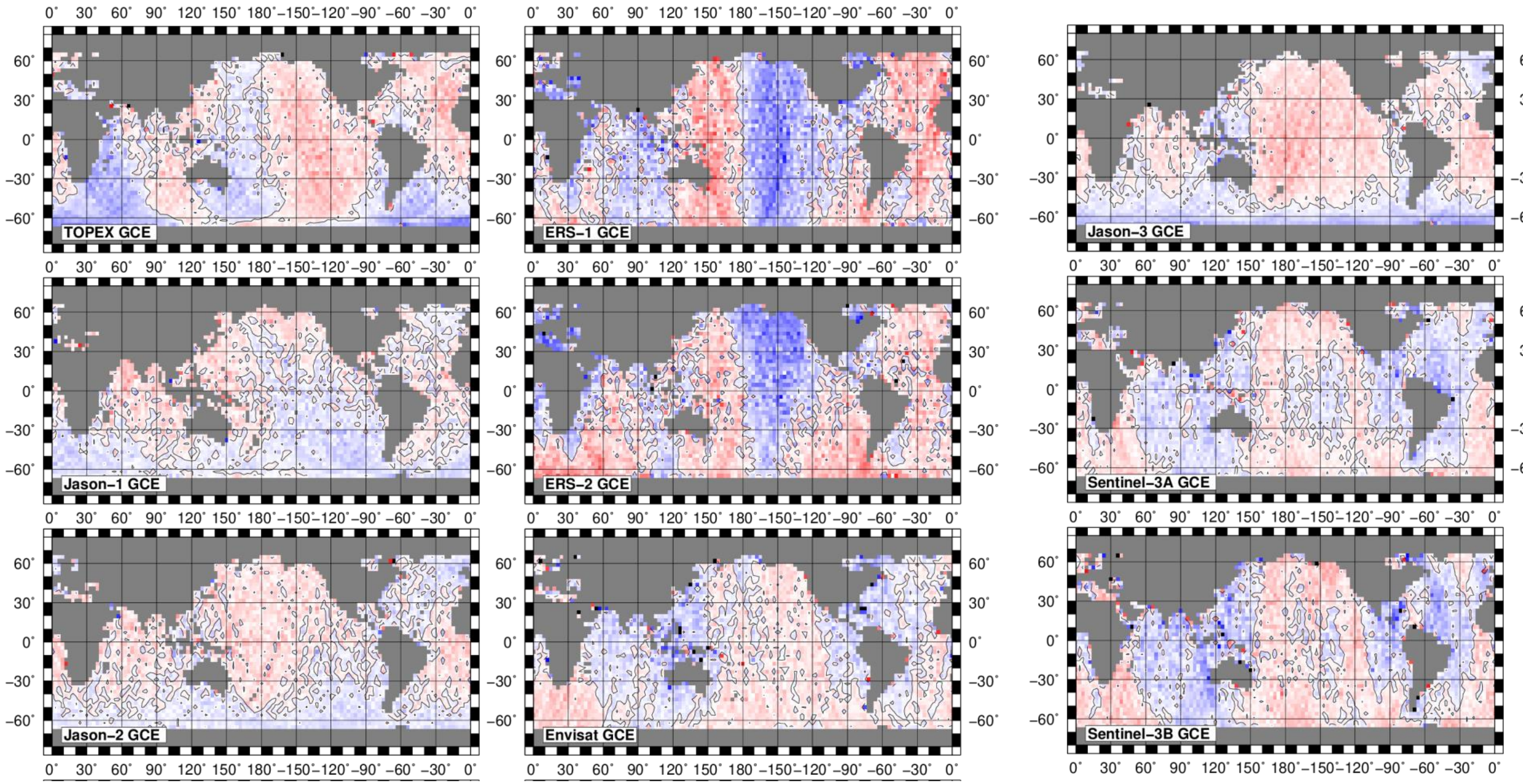
The smallest values are obtained for GPS data based solutions, followed by those based on using DORIS data.

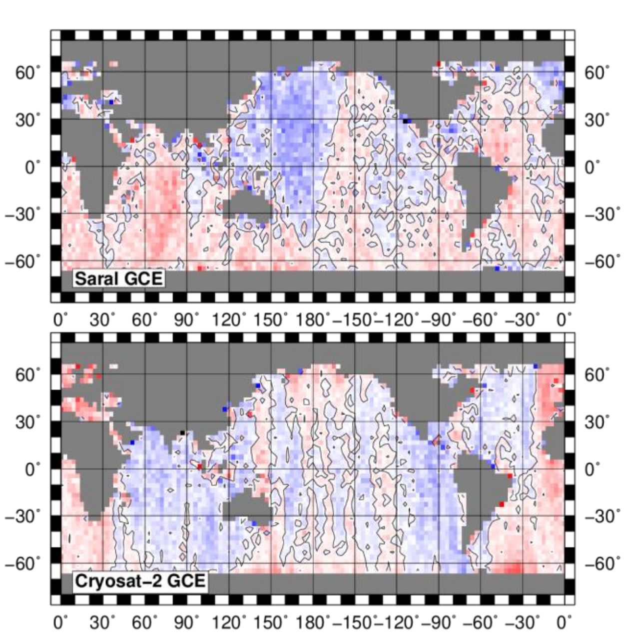
Geographically correlated errors (left) for Jason-2 six different orbit solutions and their differences (right) with respect to the CNES POE-F orbit solution



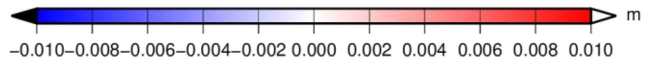


Geographically correlated errors for 11 altimetry missions based on the newest orbit standards (CNES POE-F and GFZ VER13)





Orbits of ERS-1, ERS-2 and Saral show larger GCE than orbits of other satellites.



Conclusions

Comparison of **contemporary orbit solutions** of altimetry satellites derived in the **extended ITRF2014** reference frame has been performed.

Satellite positions of the orbits derived using **DORIS and GPS** observations agree in the radial direction at **0.4–1.0 cm RMS** values for the **Jason and Sentinel-3** missions and of **1.9 cm for TOPEX/Poseidon**.

Orbit solutions derived using only **SLR observations** agree in the radial direction with those derived using DORIS and GPS observations at **1.2–1.8 cm RMS values for the Jason missions** and of **1.6–2.2 cm for TOPEX/Poseidon.**

From the multi-mission altimetry crossover analysis, the standard deviation of radial errors:

- decreased (**improved**) from **1.14 (for GDR-C) to 0.98 cm (for the POE-F** standards-based orbits) of **CNES Jason-2 orbits;**

- is of **0.99–1.09 cm** for the orbits based **on DORIS and/or GPS** observations and of **1.24 cm** for the **SLR-only** orbits.

The standard deviation of **geographically correlated errors** is of **0.12–0.18 cm.**

Though notable improvement of orbit quality has been achieved for altimetry satellites in the past 30 years, **further improvement is desirable** to reduce further radial and geographically correlated errors.

References

S. Rudenko, D. Dettmering, J. Zeitlhöfler, R. Alkahal, D. Upadhyay and M. Bloßfeld. Radial orbit errors of contemporary altimetry satellite orbits, submitted, in review.

Acknowledgements

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