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Validation of DTRF2014, ITRF2014 and JTRF2014 by precise orbit determination of SLR and altimetry satellites

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Summary

We have tested three new realizations of the International Terrestrial Reference System (ITRS), namely, DTRF2014 (Seitz et al. 2016), ITRF2014 (Altamimi et al., 2016) and JTRF2014 (Wu et al., 2015) for precise orbit determination (POD) of ten high and low Earth orbiting geodetic satellites equipped with satellite laser ranging (SLR) retroreflectors (LAGEOS-1, LAGEOS-2, Etalon-1, Etalon-2, LARES, Larets, Ajisai, Starlette, Stella and Jason-2). We have computed orbits of these satellites using SLR observations at 1993.0−2017.0 using 7-day orbital arcs for each satellite, but 3.5-day arcs for Jason-2 using these ITRS realizations and compared the orbits and results with those computed using a previous ITRS realization, namely, SLRF2008 (Pavlis, 2009).

Using new ITRS realizations reduces station-specific weekly range biases, as compared to using SLRF2008, especially after 2015.0, when estimated.

The mean values of SLR RMS fits reduce (improve), on average over all satellites tested, by 3.0, 3.6, 8.1 and 7.7% in the **interpolation interval** (1993.0–2015.0) when using ITRF2014, DTRF2014, DTRF2014 with non-tidal loading and JTRF2014 realizations, respectively, as compared to using SLRF2008. The improvement of the RMS fits is even larger in the **extrapolation interval** (2015.0–2017.0): 14.0 and 15.5% using ITRF2014 and DTRF2014, respectively, as compared to using SLRF2008.

Altimetry analysis of Jason-2 orbits indicates improvements of the scatter and mean of single-satellite sea surface crossover differences for orbits derived using JTRF2014 and DTRF2014 with non-tidal loading corrections, as compared to SLRF2008.

From our analysis, we conclude that JTRF2014 and DTRF2014 with non-tidal loading corrections show the best performance among the ITRS realizations for the satellites tested and are recommended to use.

International Terrestrial Reference System (ITRS) realizations used for the analysis

– SLRF2008 (version of 8 August 2016) provides station positions and velocities,
– ITRF2014 provides station positions, velocities and postseismic deformation models,
– JTRF2014 provides weekly positions from 28 November 1979 till 14 February 2015,
– DTRF2014 provides station positions, velocities, atmospheric and hydrological non-tidal loading (NT-L) corrections available by 2015.0, SLR origin and residual station motions.

Impact on the estimated mean station-specific weekly range biases

In general, the SLRF2008 causes the largest range biases. The DTRF2014 solution causes some smaller biases in Europe whereas the ITRF2014 performs slightly better on the southern hemisphere.

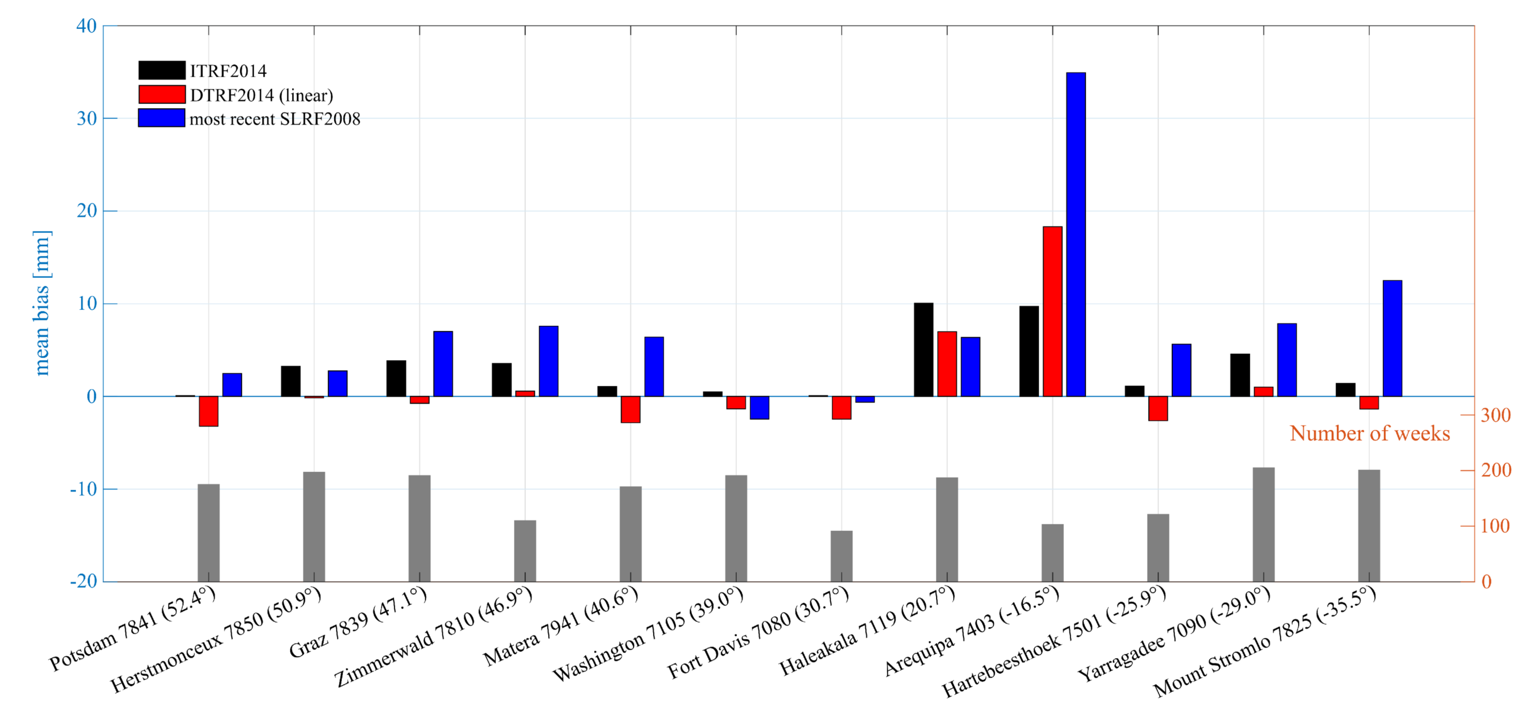

Fig. 1. Estimated mean station-specific weekly range biases for different ITRS realizations in the period 2015.0−2017.0 for LAGEOS-1. In addition, the number of processed weeks is shown for each station.

Impact on the RMS and mean fits of SLR observations

The analysis of the RMS and mean fits of SLR observations of ten satellites shows (Tables 1-2) that the smallest absolute values are obtained for the most satellites using JTRF2014 and DTRF2014 with non-tidal loading corrections at 1993.0–2015.0 and using DTRF2014 at 2015.0–2017.0.

	Lageos-1	Lageos-2	Etalon-1	Etalon-2	LARES	Larets	Ajisai	Starlette	Stella	Jason-2
1993–2014										
SLRF2008	1.72	1.72	2.59	2.52	3.07	4.34	3.81	3.59	4.08	2.42
ITRF2014	1.63	1.62	2.56	2.48	2.85	4.30	3.77	3.27	4.07	2.28
DTRF2014	1.62	1.62	2.54	2.48	2.83	4.30	3.70	3.16	4.05	2.24
DTRF2014+ NTL	**1.47**	**1.48**	2.53	2.47	**2.82**	4.21	3.65	**3.11**	3.35	2.24
JTRF2014	1.55	1.57	**2.49**	**2.44**	2.83	**4.20**	**3.64**	3.17	**3.32**	**2.20**
2015–2016										
SLRF2008	2.31	2.35	2.92	3.18	3.50	**5.73**	3.85	3.96	5.06	
ITRF2014	1.48	1.62	2.49	2.86	3.20	**5.73**	3.42	3.65	**4.74**	
DTRF2014	**1.41**	**1.52**	**2.44**	**2.82**	**3.19**	**5.73**	**3.31**	**3.64**	**4.74**	

Table 1. Mean values of RMS fits of SLR observations in [cm] obtained using various TRF realizations for two periods: 1993.0–2015.0 and 2015.0–2017.0. The smallest values for each satellite and each period are marked in blue.

	Lageos-1	Lageos-2	Etalon-1	Etalon-2	LARES	Larets	Ajisai	Starlette	Stella	Jason-2
1993–2014										
SLRF2008	0.10	0.18	0.18	0.21	0.11	0.26	1.31	0.10	**0.00**	0.06
ITRF2014	0.12	0.19	0.19	0.22	**0.05**	0.25	1.33	0.12	0.03	0.08
DTRF2014	0.03	0.08	0.12	0.15	−0.15	**0.07**	**1.16**	−0.05	−0.13	**−0.04**
DTRF2014+ NTL	**−0.02**	0.03	0.12	0.16	−0.13	**0.07**	**1.16**	−0.05	−0.14	**−0.04**
JTRF2014	−0.03	**0.02**	**0.09**	**0.13**	−0.13	**0.07**	**1.16**	**−0.04**	−0.10	**−0.04**
2015–2016										
SLRF2008	0.20	0.41	0.38	0.40	0.24	0.21	1.69	0.33	0.22	
ITRF2014	0.24	0.38	0.32	0.32	0.19	0.19	1.54	0.21	0.14	
DTRF2014	**0.00**	**0.11**	**0.20**	**0.19**	**−0.01**	**0.02**	**1.35**	**0.02**	**−0.06**	

Table 2. Mean values of mean fits of SLR observations in [cm] obtained using various TRF realizations for two periods: 1993.0–2015.0 and 2015.0–2017.0 The smallest absolute values for each satellite and each period are marked in blue.

Impact of the ITRS realizations on the geographically correlated mean sea surface height (SSH) errors computed using Jason-2 orbits

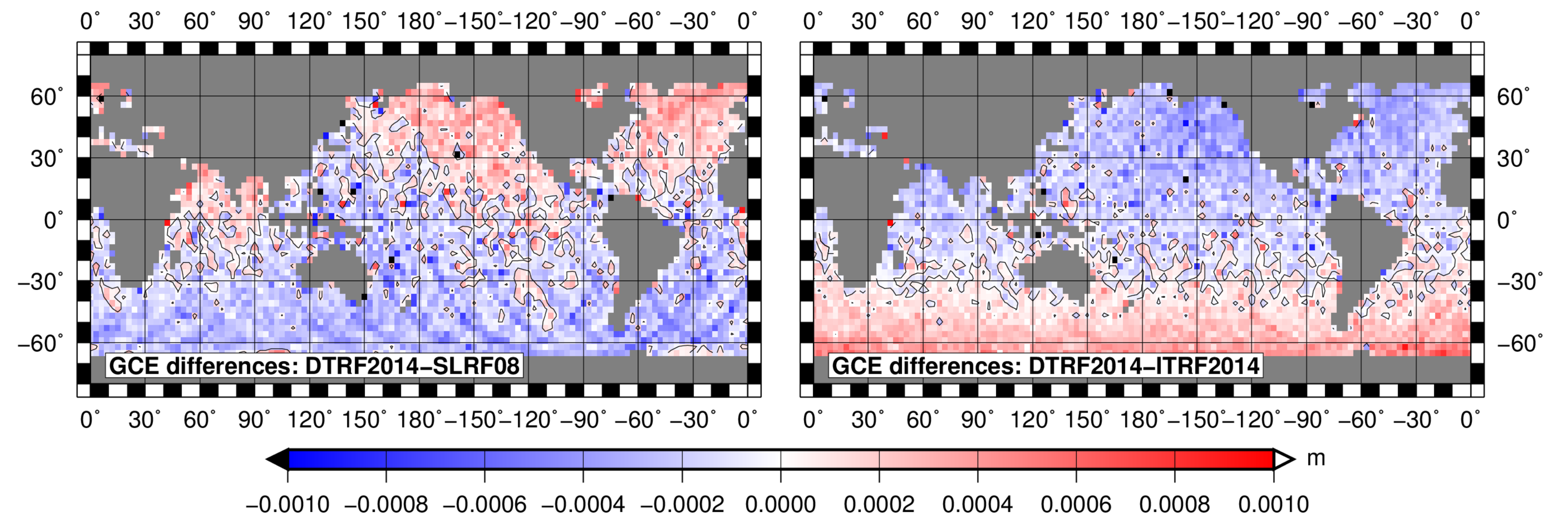

Fig.2. Differences of of geographically correlated mean SSH errors computed using Jason-2 orbits derived with DTRF2014 and SLRF2008 (left) and DTRF2014 and ITRF2014 (right) terrestrial reference frame realizations.

Impact of the ITRS realizations on the running average of the RMS and mean fits of SLR observations

The smallest 50-week running average of the RMS fits and absolute mean fits of SLR observations of high-orbit satellite LAGEOS-1 and low-orbit satellite Starlette over the time interval 1993−2017 are obtained by using JTRF2014 and DTRF2014 with non-tidal loading corrections (Fig. 3-4). ITRF2014 and SLRF2018, on the contrary, show a trend in the mean fits of observations.

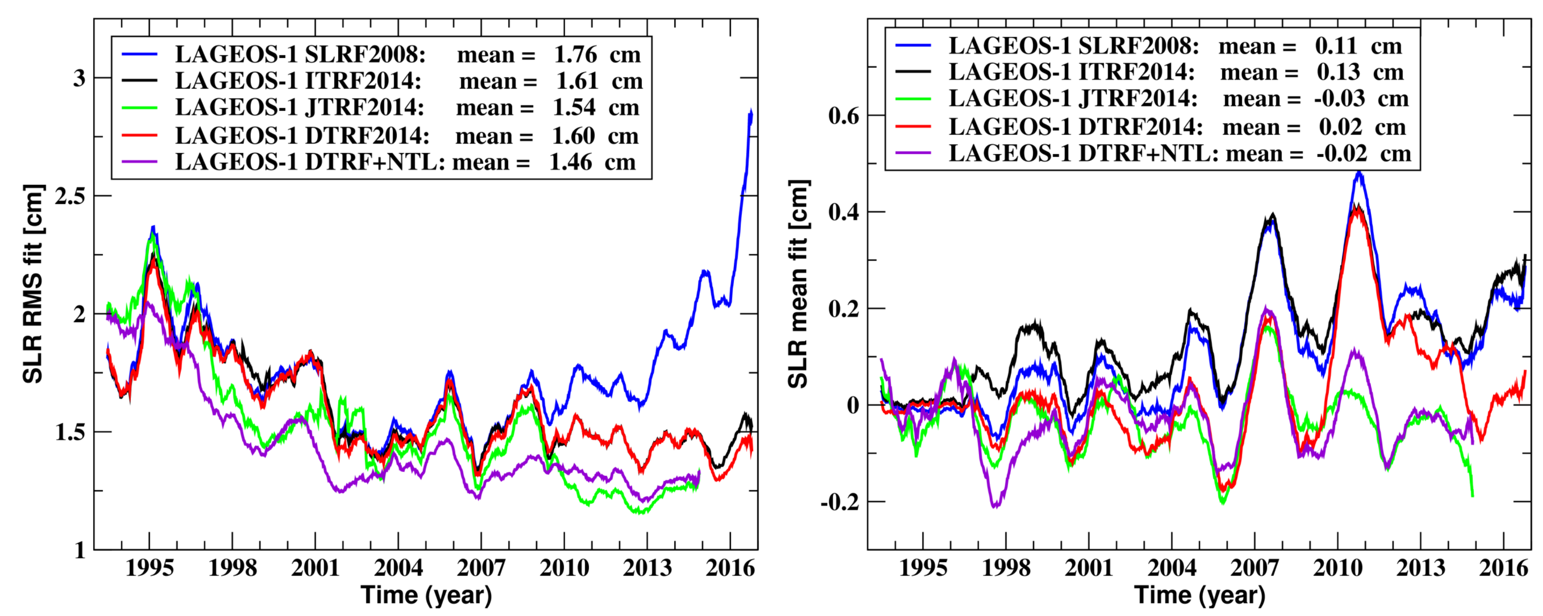

Fig. 3. 50-week running average of the RMS (left) and mean (right) fits of SLR observations for LAGEOS-1 orbits derived using SLRF2008, ITRF2008, JTRF2014, DTRF2014 linear and DTRF2014+NT-L realizations.

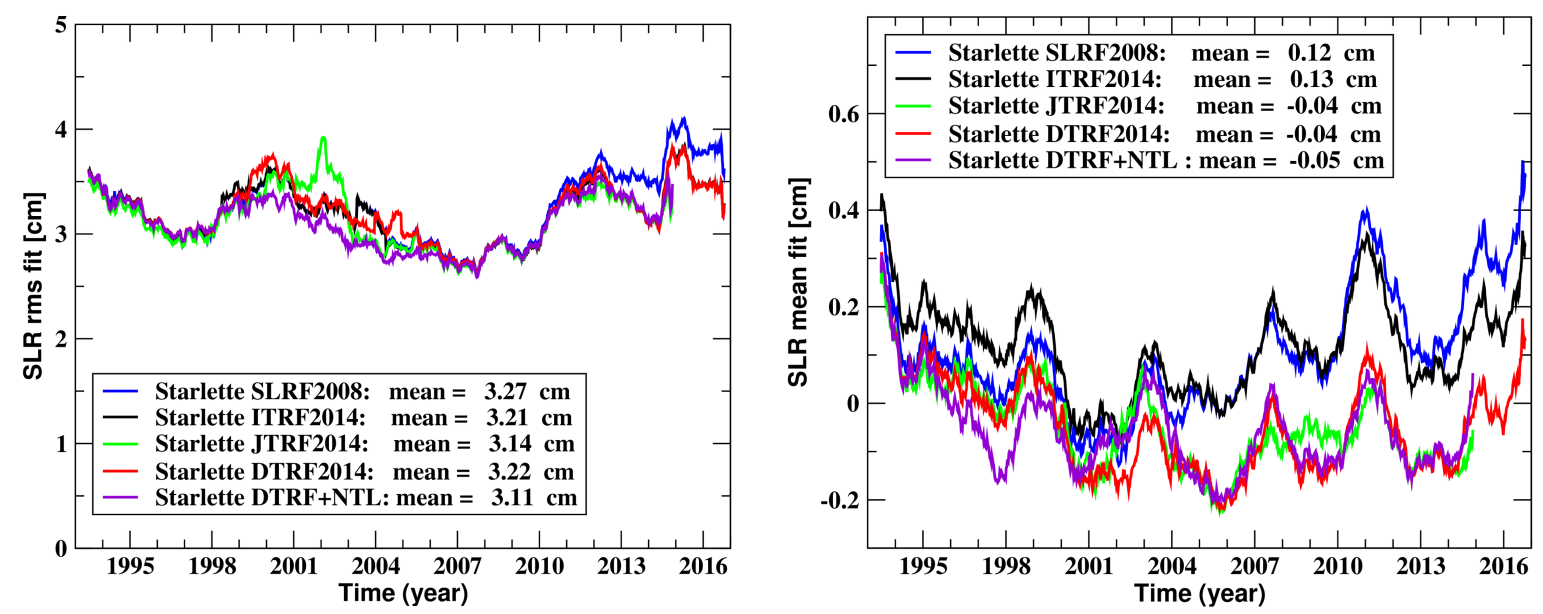

Fig. 4. 50-week running average of the RMS (left) and mean (right) fits of SLR observations for Starlette orbits derived using SLRF2008, ITRF2008, JTRF2014, DTRF2014 linear and DTRF2014+NT-L realizations.

Impact of the ITRS realizations on single-satellite SSH crossover differences for Jason-2

ITRS realization	SXO mean (mm)	SXO RMS (cm)	Diff. w.r.t. SLRF2008 mean (mm)	Diff. w.r.t. SLRF2008 RMS (mm)
SLRF2008	1.00	5.95	–	–
ITRF2014	0.80	5.95	−0.2	0.0
DTRF2014	0.68	5.94	−0.3	−0.1
DTRF2014+ NT-L	0.64	5.94	−0.4	−0.1
JTRF2014	0.62	5.92	−0.4	−0.3

Table 3. 10-day single-satellite sea surface height (SSH) crossover differences for Jason-2 for orbits based on different reference frame realizations.

References

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