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Precise orbit determination of SLR and altimetry satellites using ITRS2020 realizations

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Outline

- The main updates in the ITRS2020 realizations, compared to ITRS2014 realizations
- The setup of precise orbit determination and altimetry crossover tests for SLRF2014 and ITRF2020
- Impact of using the ITRF2020, as compared to SLRF2014, on the SLR observation fits, orbit differences, dynamical and empirical parameters
- SLR range biases estimated using ITRF2020 and SLRF2014
- Results of single-satellite and multi-mission altimetry crossover analysis
- Conclusions and recommendations

The main updates in the ITRS2020 realizations, compared to the ITRS2014 realizations

- 6 year **longer time span of observations** (2015-2020) used

- Use of data from **new tracking stations and satellites**

- **Improvements of station hardware** due to technological advances in measurement methods

- It was attempted to **compensate non-linear station motions** using different approaches:
  periodic signals and post-seismic deformations (PSD) for ITRF,
  non-tidal loading and PSD for DTRF.

- **Improved modelling** of SLR, DORIS, GPS and VLBI data processing

- **The long-term mean biases of the SLR stations** were derived for the period 1993.0 to 2020.5 and substracted from the time series of station positions provided to the ITRS Combination Centers. **However, they have not been published yet.**

The setup of the precise orbit determination and altimetry crossover tests for SLRF2014 and ITRF2020

- Satellites used: TOPEX/Poseidon (1992 – 2005), Jason-1 (2002 – 2013), Jason-2 (2008 – 2019), Jason-3 (2016 – 2021).
- Observation type used: SLR.
- TRF realizations used:
    - SLRF2014,
    - ITRF2020 with annual and semi-annual variations of station positions, and post-seismic deformations.

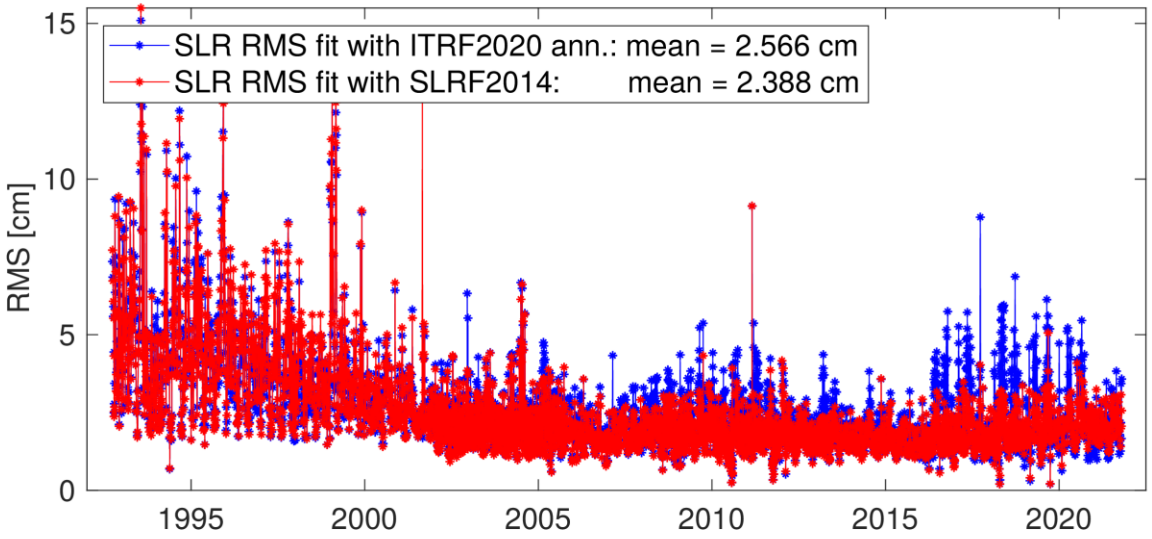
- Dynamical models according to Rudenko et al. (in review).

- ILRS Data Handling file (version 2020/06/16 used):
ftp://edc.dgfi.tum.de/pub/slr/aux_data/ILRS_Data_Handling_File.snx

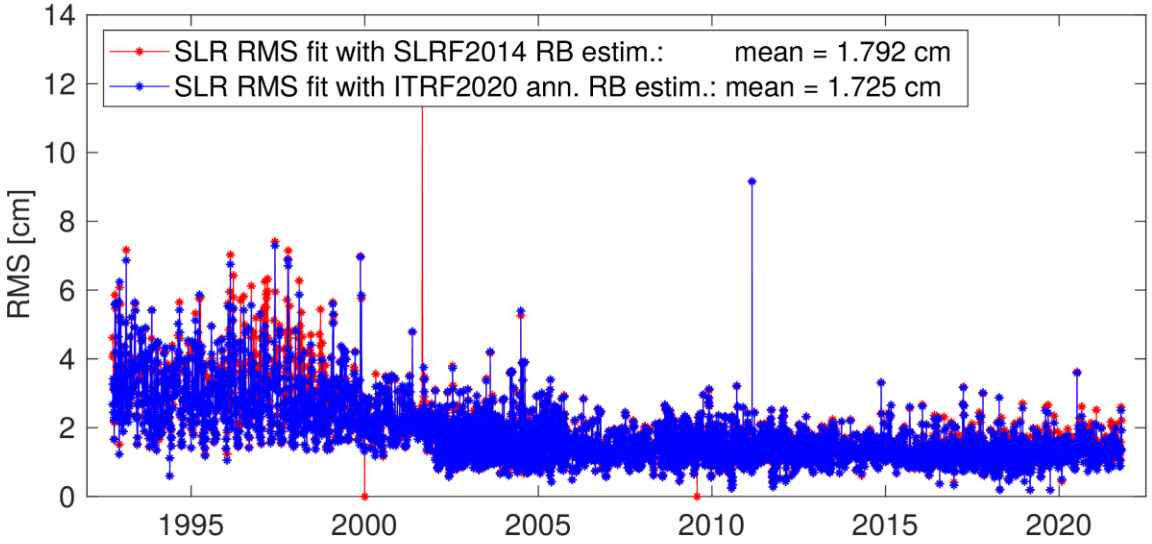
- **No long-term mean biases of SLR stations were applied for ITRF2020**, since they have not been published yet.

- For each TRF realization, two cases are computed: **without and with estimation of SLR range biases for each station** at each 3.5-day orbit arc for each satellite.

RMS fits of SLR observations

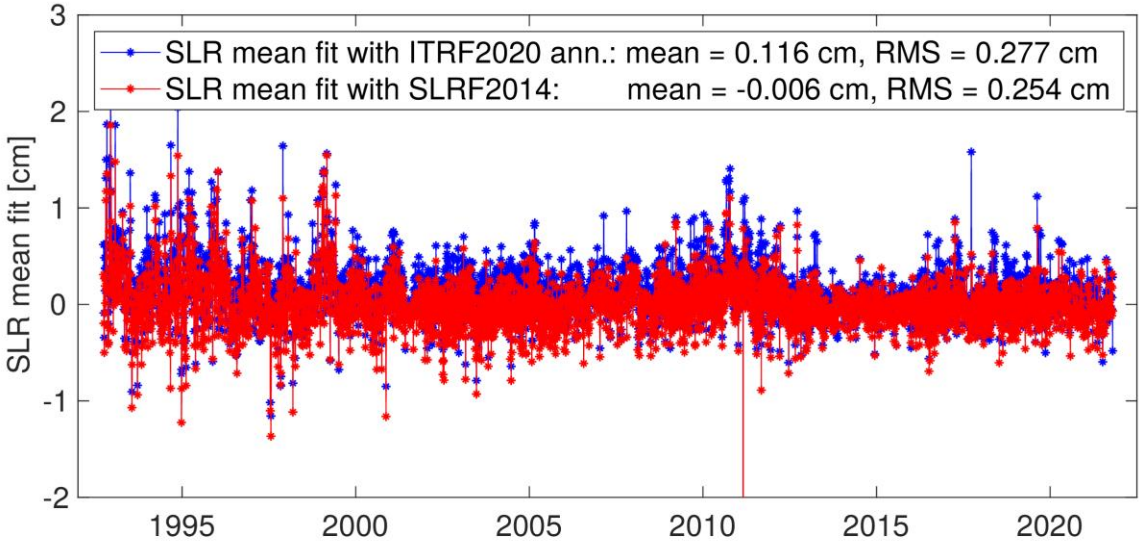


The ITRF2020 results in the **increased RMS fits** of SLR observations in 2007-2011 and 2016-2021, compared to SLRF2014, when no SLR range biases are estimated.

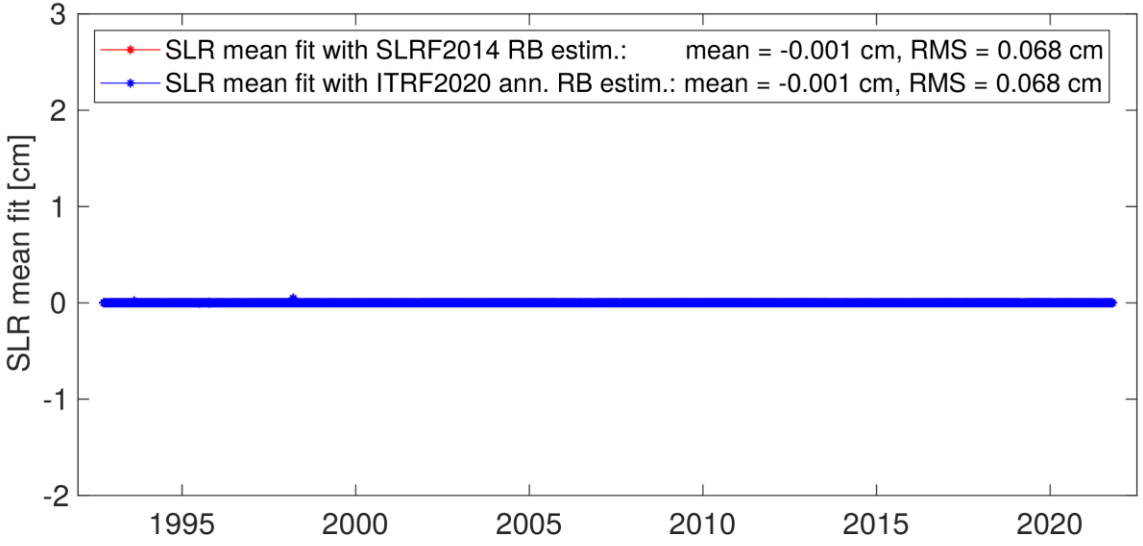


Estimation of SLR range biases reduces RMS fits of SLR observations by 25-33%, so that the ITRF2020 performs better than SLRF2014.

Mean fits of SLR observations

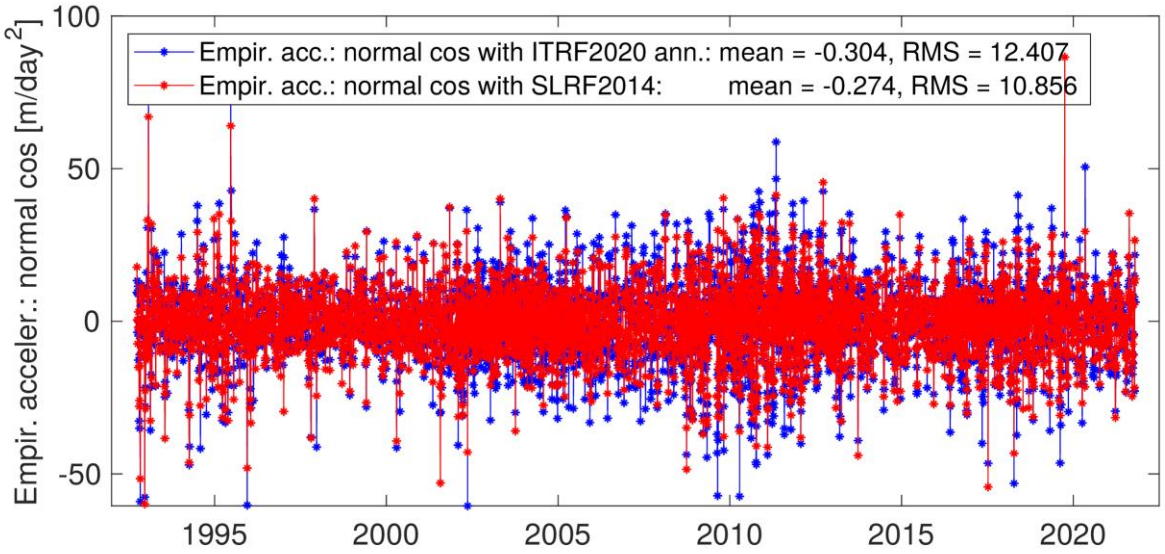


The ITRF2020 results in about **+0.1 cm mean fits of SLR observations**, while SLRF2014 gives the value close to zero, when no SLR range biases are estimated. The ITRF2020 causes a bit larger scatter of mean fits of observations.

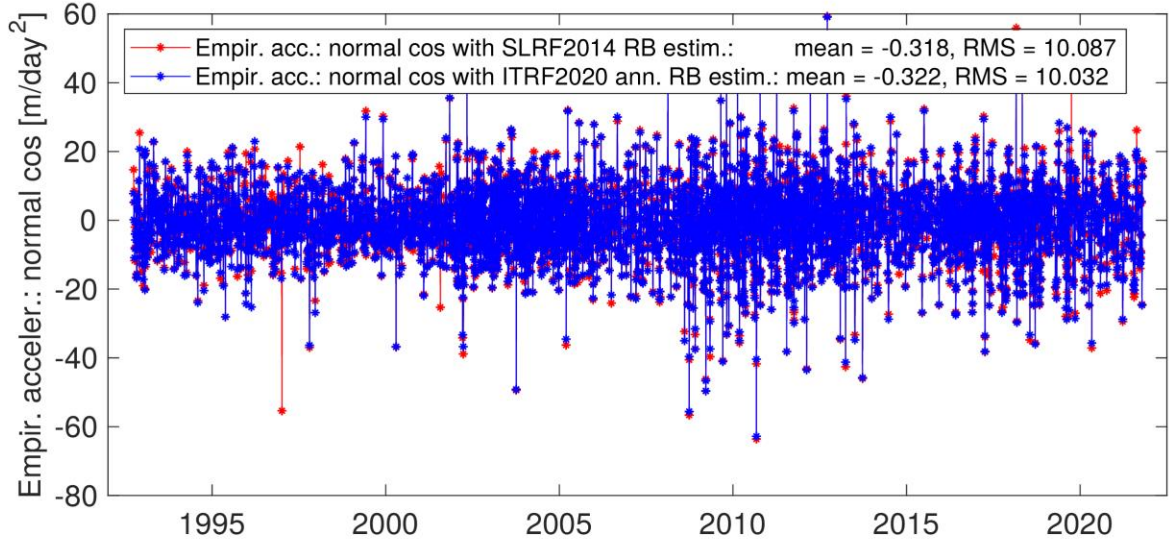


The estimation of SLR range biases brings the mean fits of SLR observations close to zero for both SLRF2014 and ITRF2020.

Empirical acceleration: cosine of the normal term

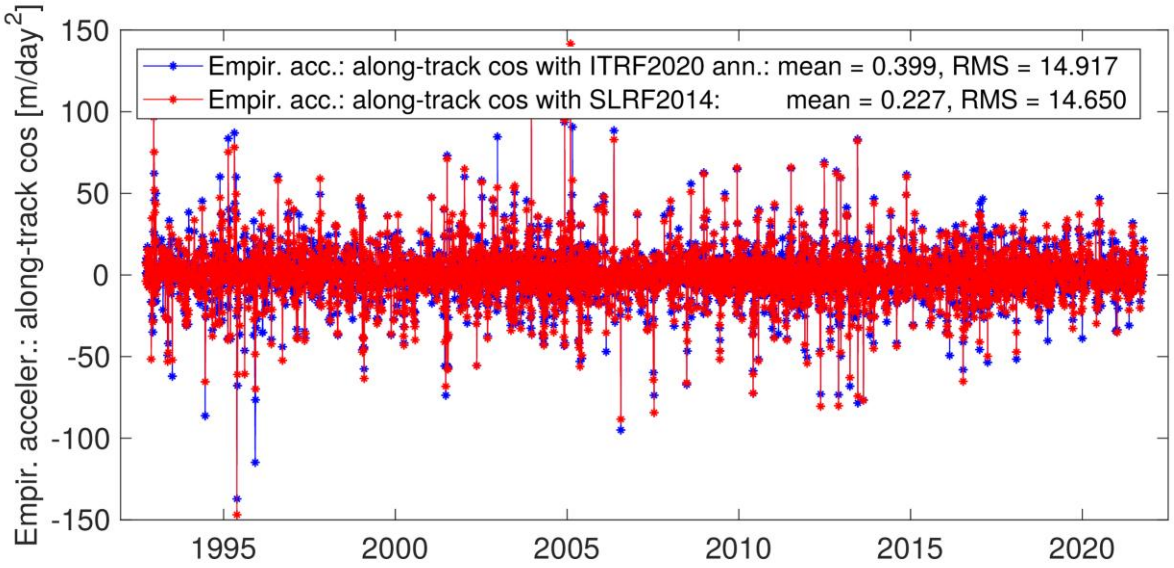


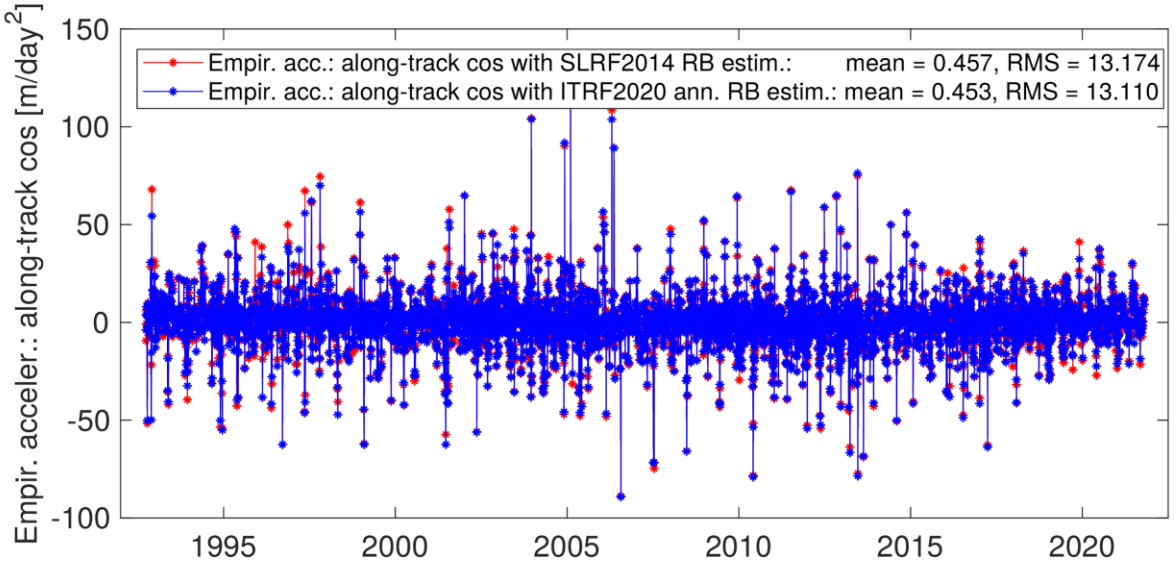
Increased absolute mean and the scatter of the normal term of the empirical acceleration, when using ITRF2020 as compared to using SLRF2014, when no SLR range biases are estimated.



Estimation of SLR range biases reduces the scatter of the normal term of the empirical acceleration for both SLRF2014 and ITRF2020 and gives comparable results of this parameter for both reference frames.

Empirical acceleration: cosine of the along-track term

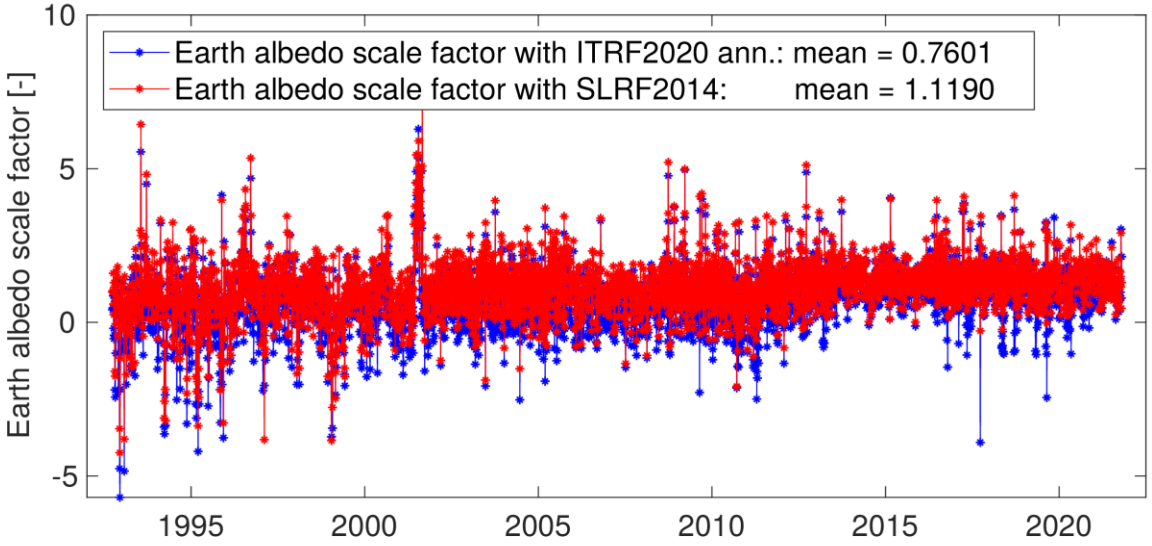


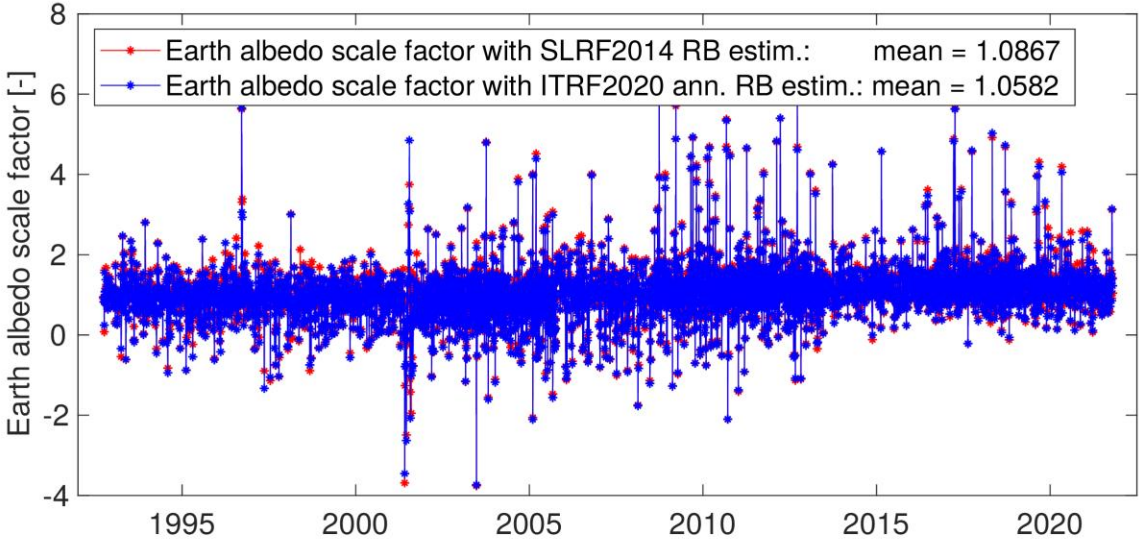


Increased absolute mean and the scatter of the along-track term of the empirical acceleration, while using ITRF2020 as compared to SLRF2014, when no SLR range biases are estimated.

Estimation of SLR range biases reduces the scatter of the along-track term of the empirical acceleration for both SLRF2014 and ITRF2020 and gives comparable results of this parameter for both reference frames.

Earth albedo scale factor





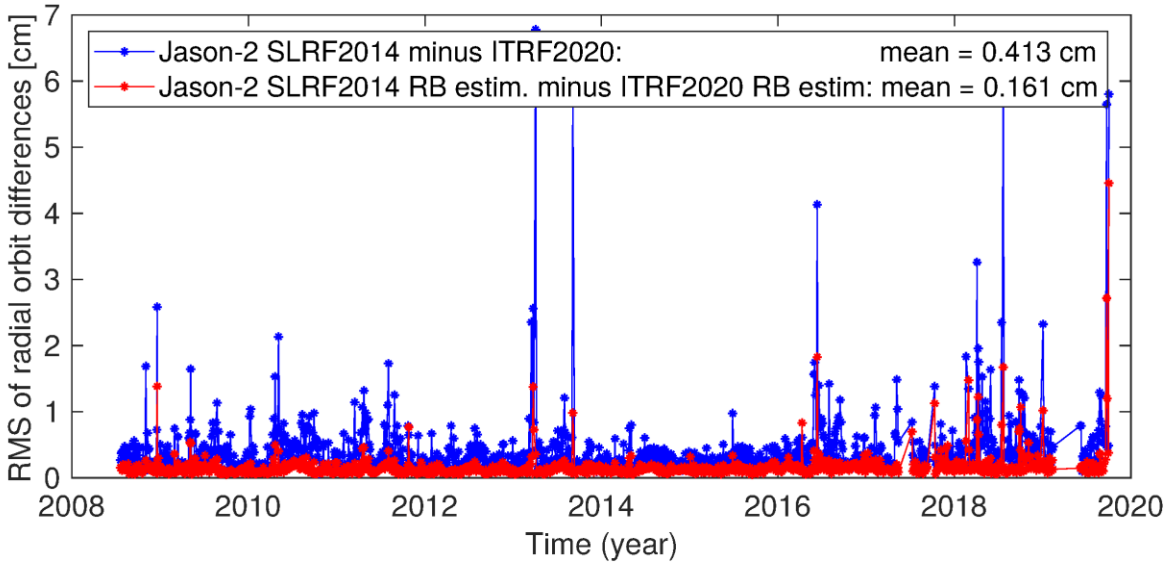
The ITRF2020 gives notably smaller, **shifted (from 1) Earth albedo scale factor (0.76)** than SLRF2014 (1.12), when no SLR range biases are estimated.
Earth albedo acts in the radial direction. **Scale of the SLR solution changed! SLR range biases have direct impact on SLR scale!**

The estimation of SLR range biases brings the Earth albedo scale factor closer to 1: to 1.09 for SLRF2014 and to 1.06 for ITRF2020. **With estimated SLR range biases, the ITRF2020 has a similar scale compared to the SLRF2014.**

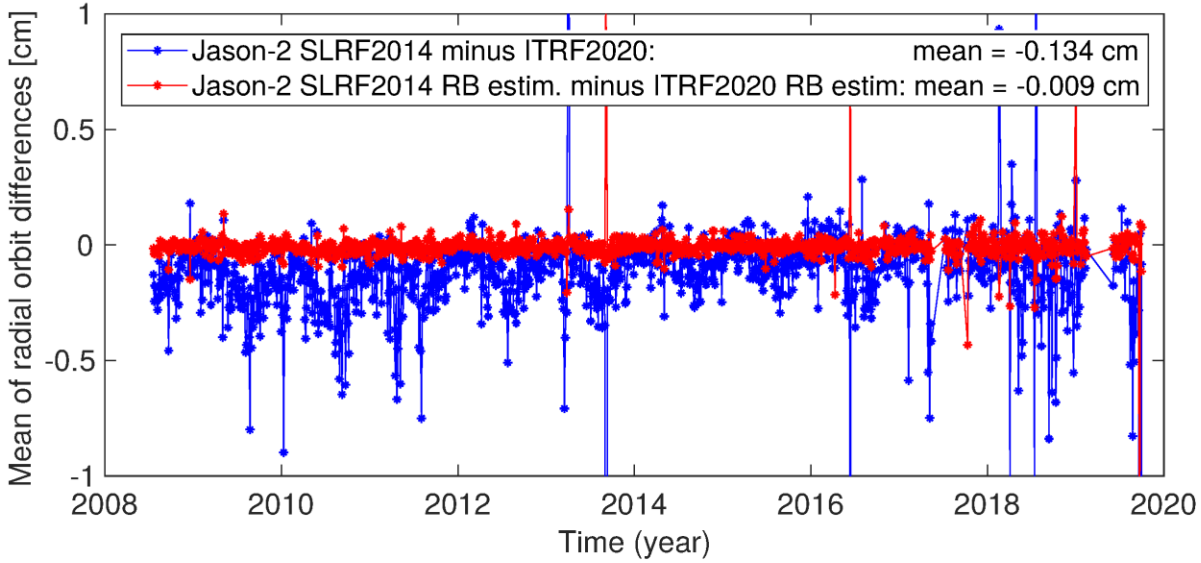
The average values for various test cases

Case	SLR RMS fit (cm)	SLR mean fit (cm)	Earth albedo coefficient	Atmospheric drag coefficient	Solar radiation pressure coefficient
SLRF2014	2.388	-0.006	1.119	0.990	0.976
SLRF2014 RB estimated	1.792	**-0.001**	1.087	0.994	0.975
ITRF2020P	2.530	0.130	0.737	0.995	0.971
ITRF2020	2.574	0.116	0.771	0.991	0.970
ITRF2020, annual and s/a variations	2.566	0.116	0.760	0.993	0.970
ITRF2020, annual and s/a variations, RB estimated	**1.725**	**-0.001**	1.058	0.994	0.974
ITRF2020 RB estimated	**1.725**	**-0.001**	1.062	0.993	0.975

RMS and mean of radial orbit differences

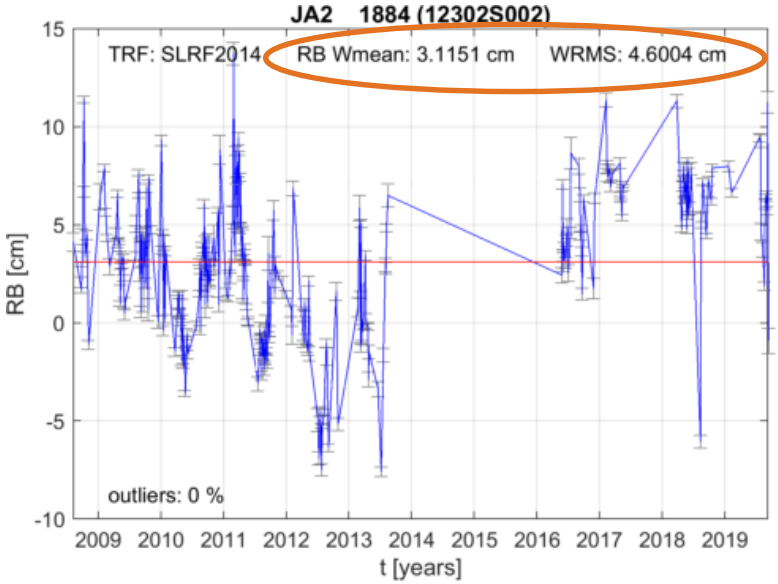


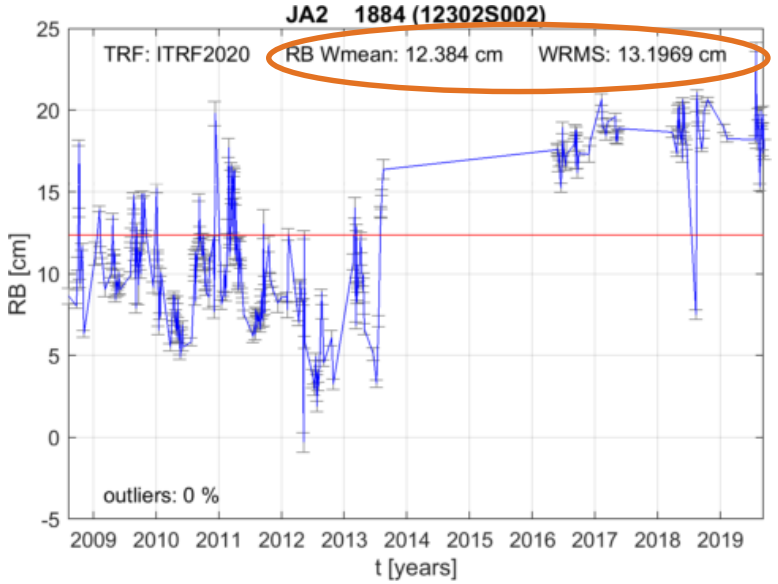
Increased RMS of radial orbit differences between the orbits derived using ITRF2020 and SLRF2014, as compared to the case, when SLR range biases are estimated for orbits of both reference frames.

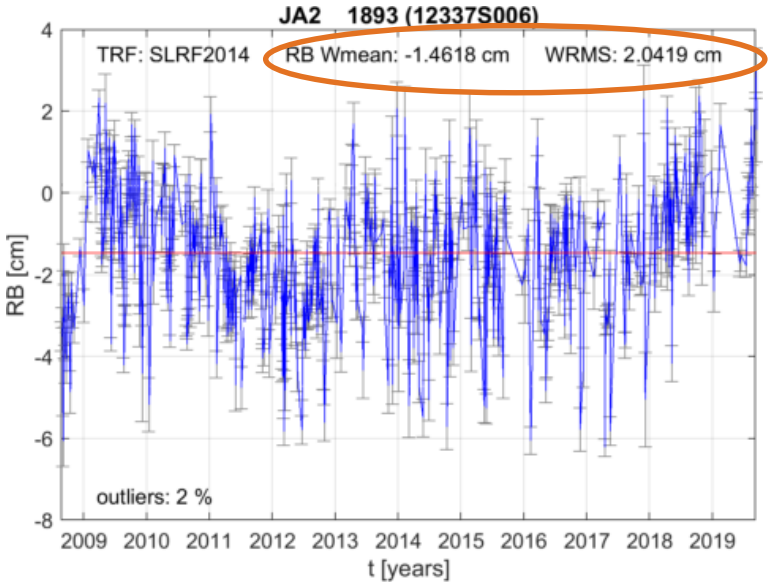


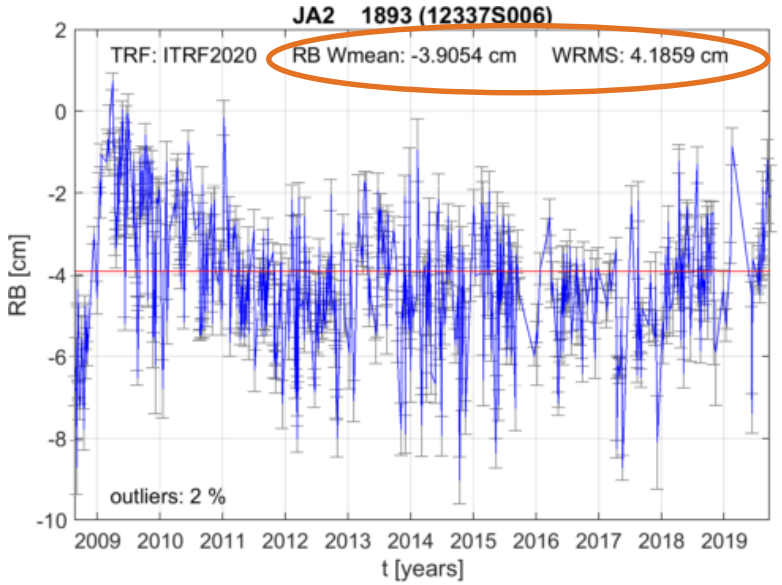
ITRF2020-based **orbits are shifted in the radial direction on average by 1.3 mm** with respect to the SLRF2014-based orbits, when no SLR range biases are estimated.
Estimation of these biases brings the average of these differences to below 0.1 mm.

An example of estimated SLR range biases: stations 1884 (Riga) and 1893 (Katzively)

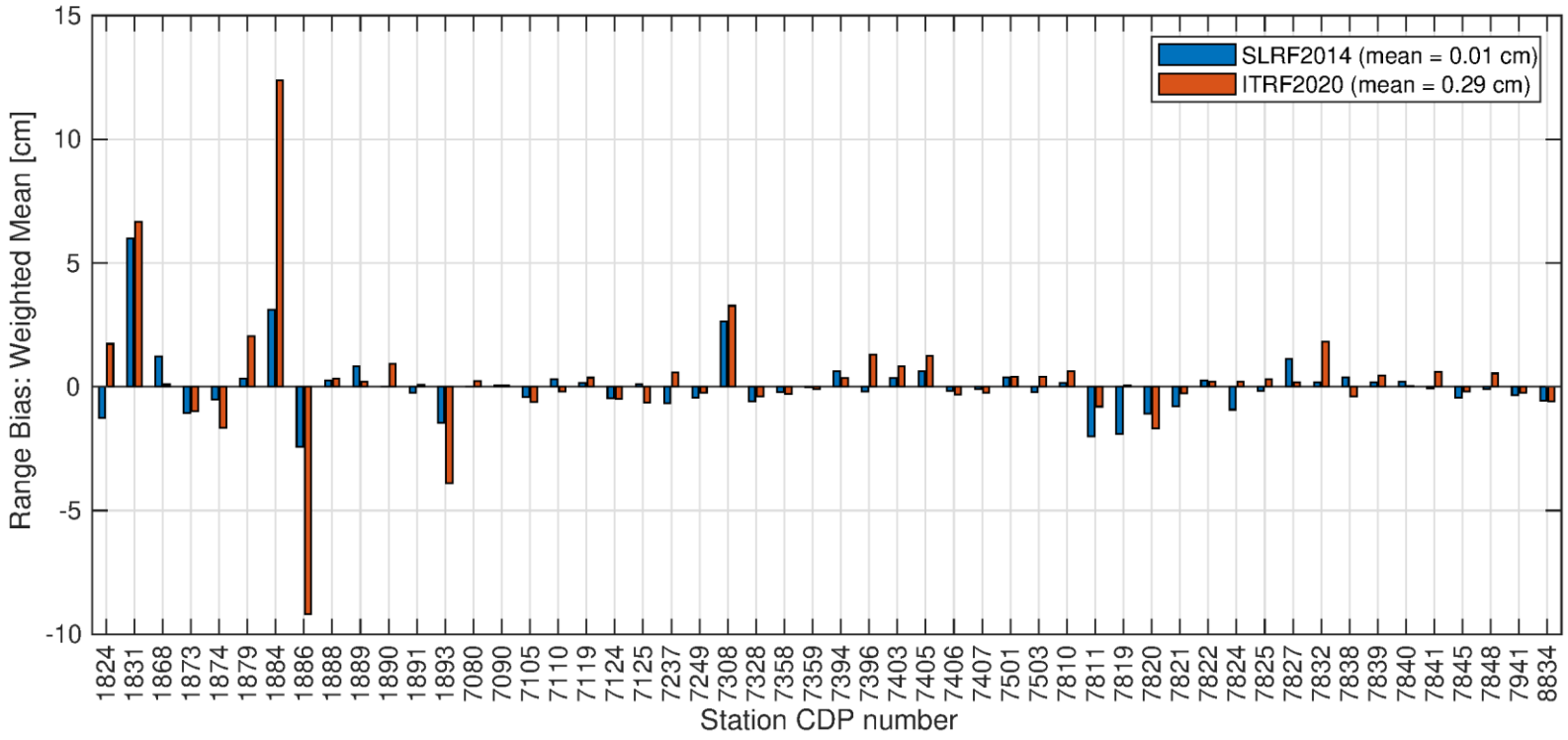






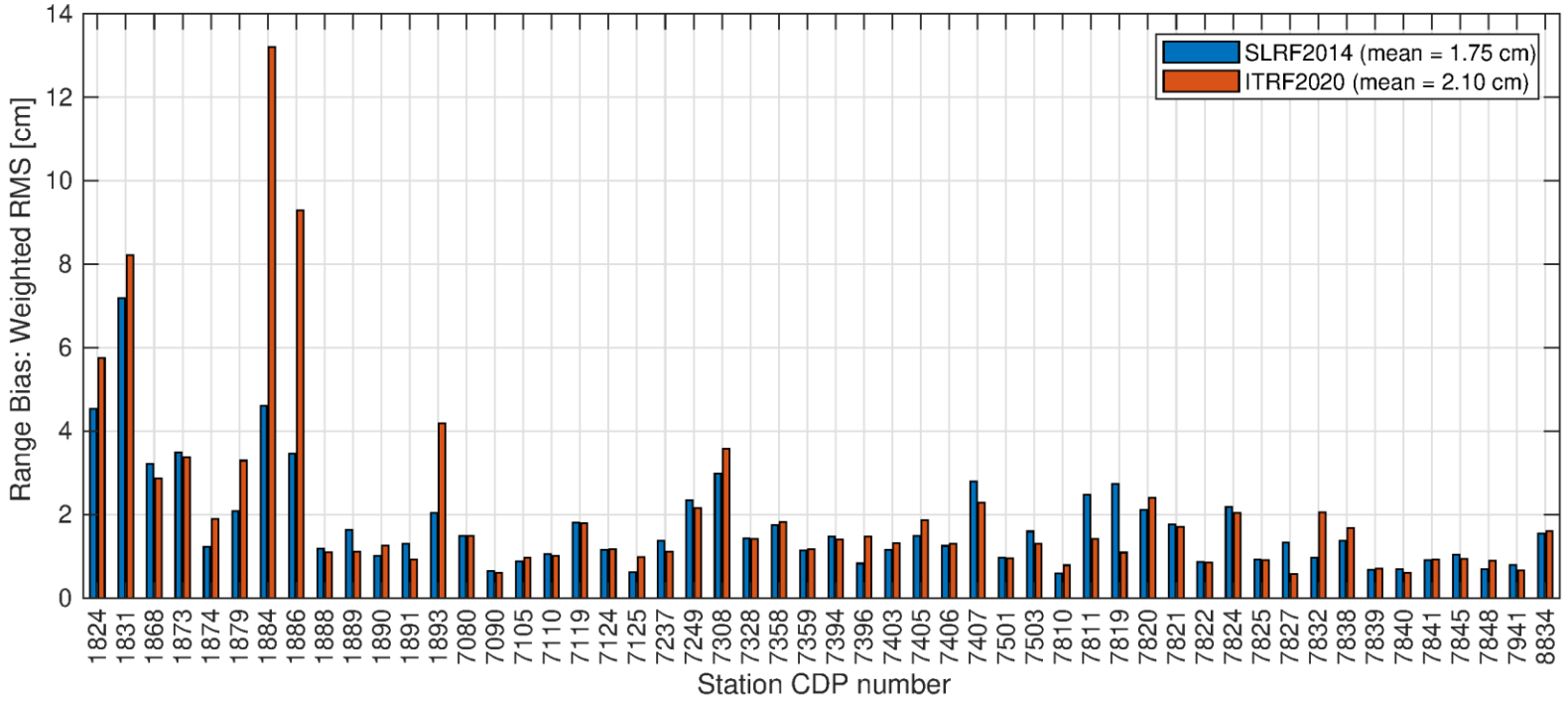


Weighted mean values of the SLR range biases estimated for Jason-2 (2008-2019) using SLRF2014 and ITRF2020



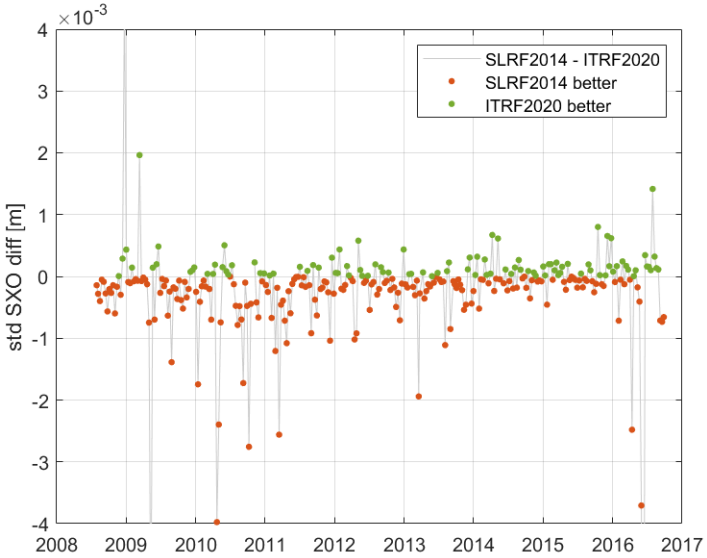
The absolute weighted mean of the SLR range biases of stations 1824 (Golosiiv), 1874 (Mendeleevo 2), 1879 (Altay), 1884 (Riga), 1886 (Arkhyz), 1893 (Katzively), 7308 (Koganei), 7396 (Wuhan), 7832 (Riyadh) notably increased using ITRF2020, as compared to using SLRF2014.

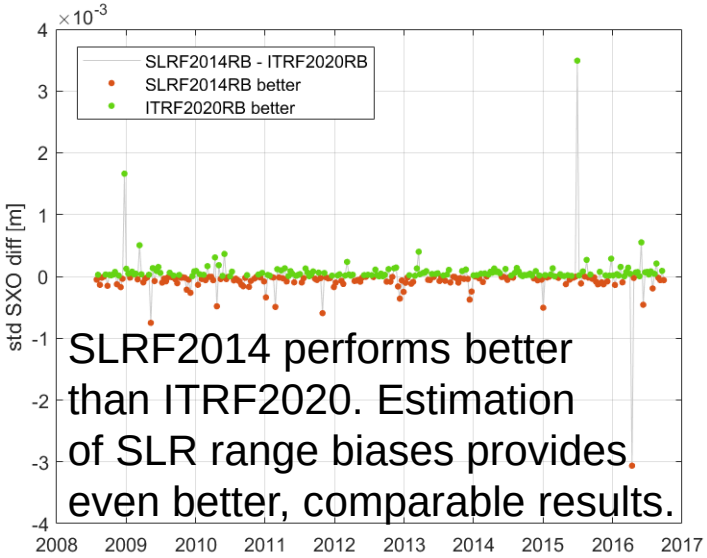
Weighted RMS values of the SLR range biases estimated for Jason-2 (2008-2019) using SLRF2014 and ITRF2020



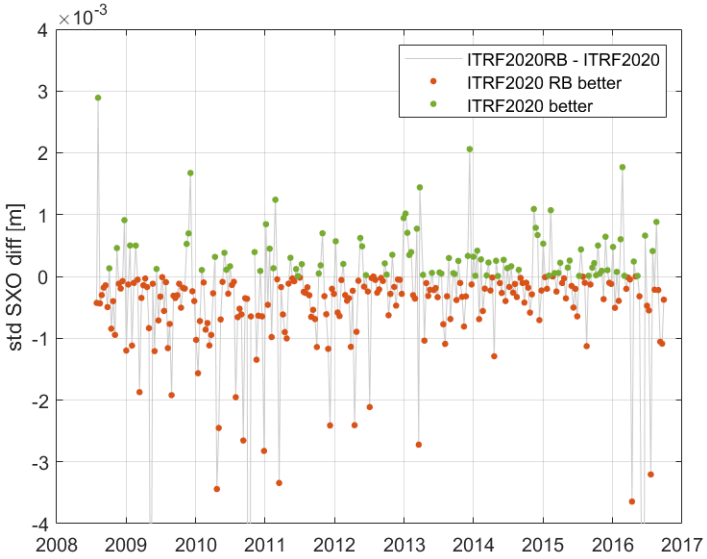
The weighted RMS of the SLR range biases of stations 1824 (Golosiiv), 1831 (Lviv), 1874 (Mendeleevo 2), 1879 (Altay), 1884 (Riga), 1886 (Arkhyz), 1893 (Katzively), 7308 (Koganei), 7396 (Wuhan) and 7832 (Riyadh) notably increased using ITRF2020, as compared to using SLRF2014.

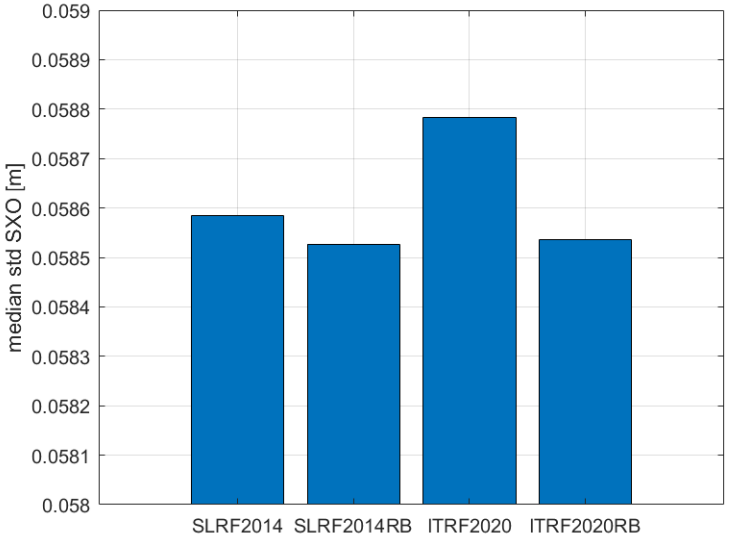
Jason-2 single-satellite altimetry crossover analysis



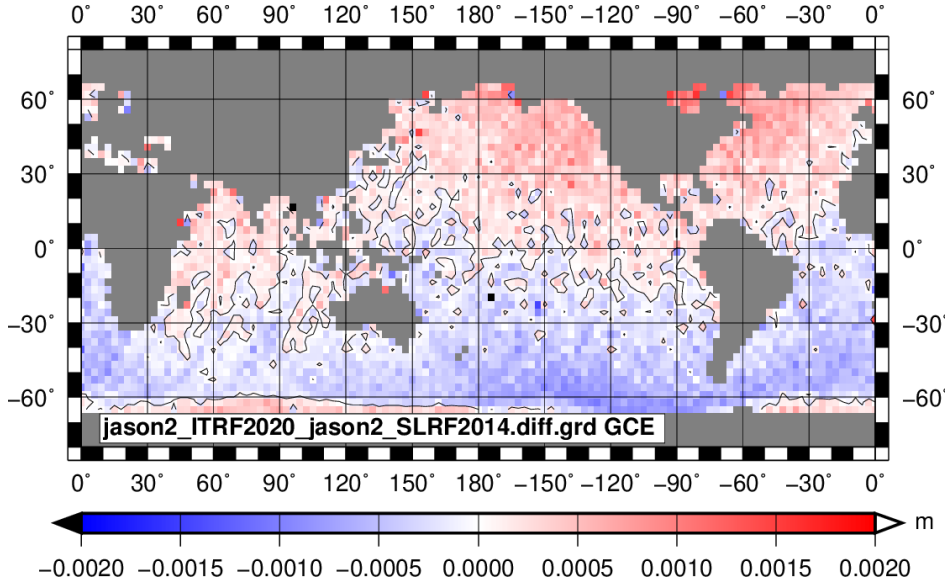


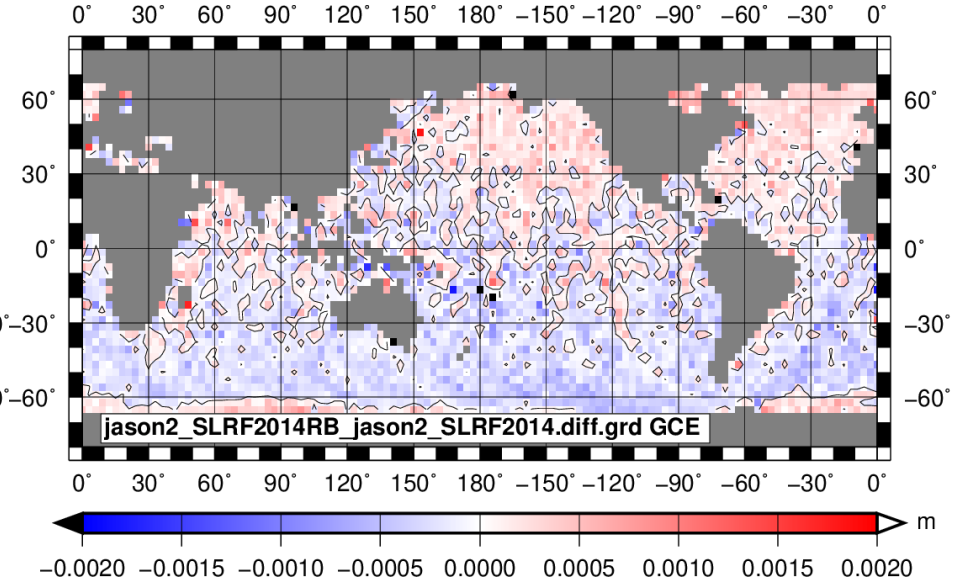
SLRF2014 performs better than ITRF2020. Estimation of SLR range biases provides even better, comparable results.

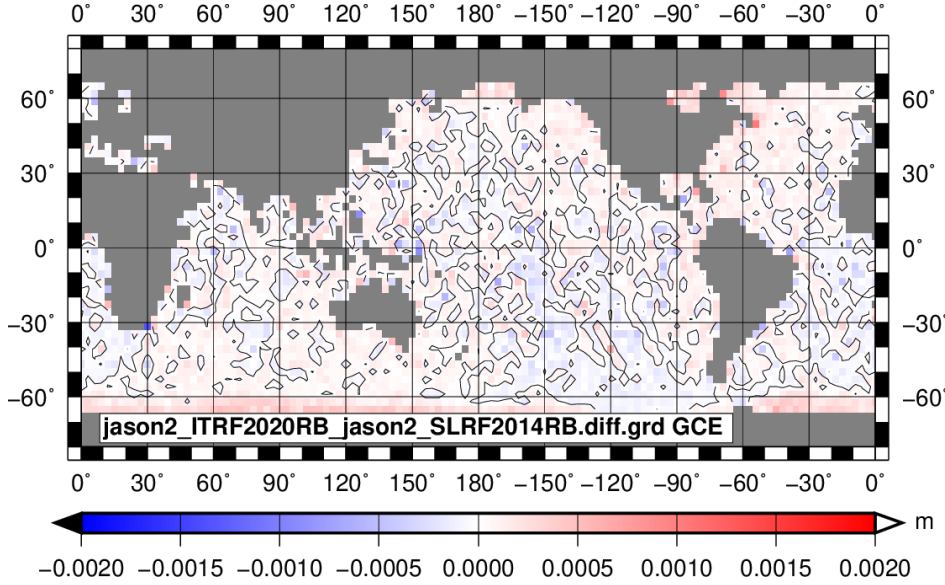


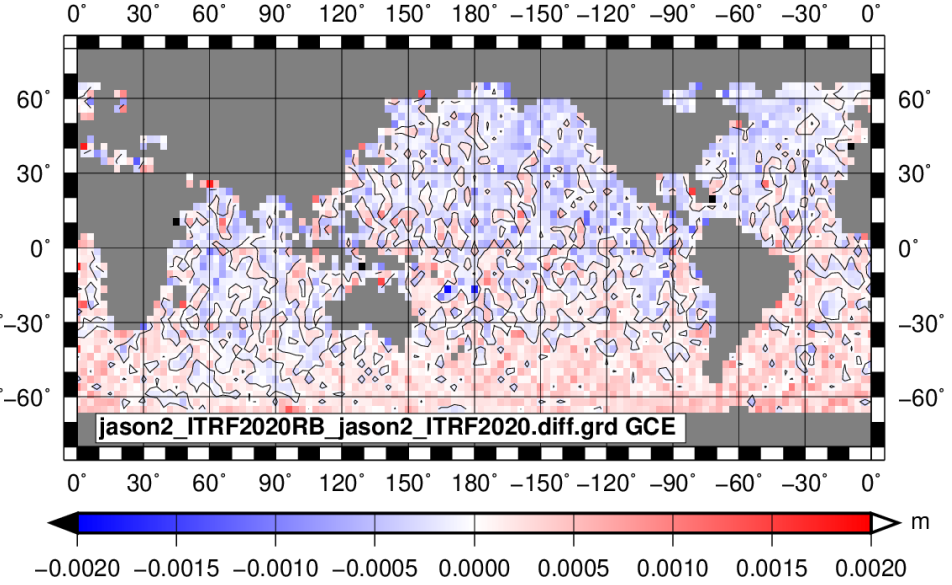


Jason-2 geographically correlated mean error differences

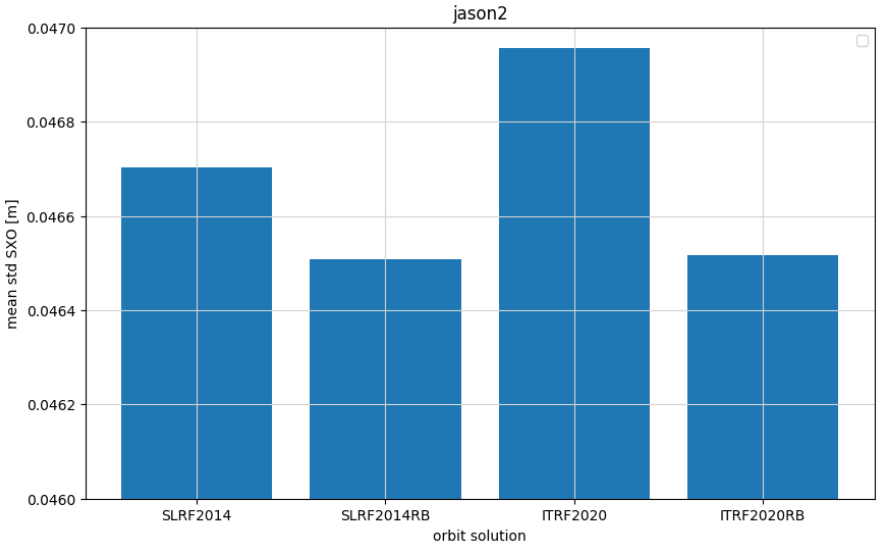


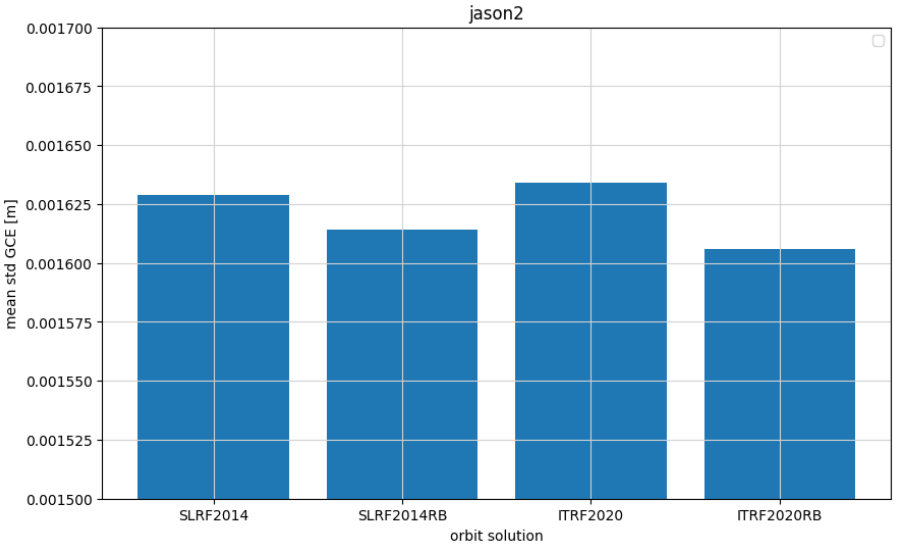


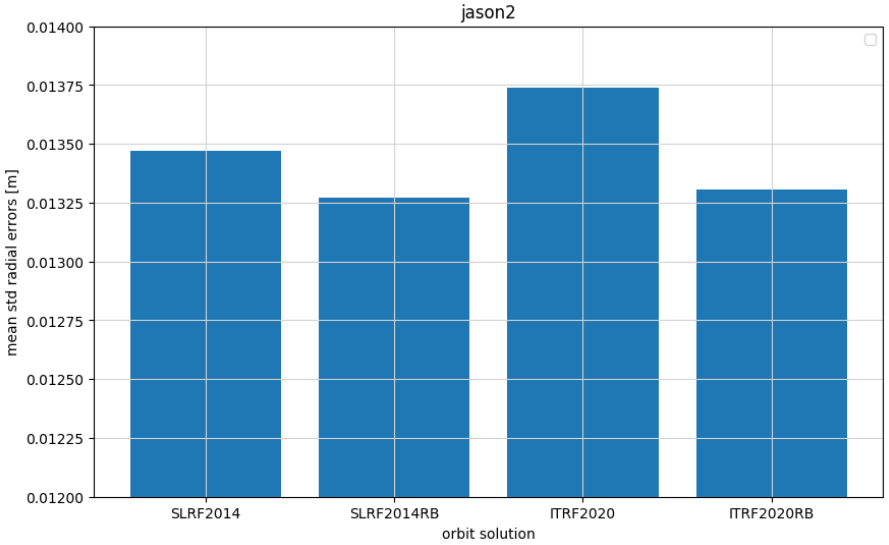




Average of standard deviation of various Jason-2 errors







The largest average values of the standard deviation of all three parameters shown (single-satellite altimeter crossover differences, geographically correlated mean errors and radial errors) **are obtained for ITRF2020,** followed by SLRF2014. Estimation of SLR range biases reduces the values and provides comparable results for both TRF realizations.

Conclusions and recommendations

1. Without the application of the long-term mean biases of SLR stations used to derive the **ITRF2020**, this reference frame realization **provides degraded** orbit quality and altimetry crossover analysis results, as compared to SLRF2014, when no SLR range biases are estimated during orbit determination.

2. **Publication of the long-term mean biases of SLR stations used to derive ITRF2020 is highly desirable.** The biases are necessary to be used also with DTRF2020 and JTRF2020.

3. **Proper evaluation of the ITRS2020 realizations for SLR stations** and use of SLR observations for validation of other space geodetic techniques, like e.g. GNSS and DORIS, with these realizations **can start only after the publication of these biases!**

4. As long as the long-term mean biases of SLR station used to derive ITRF2020 are not published, the only way to derive precise orbits and other products from SLR observations with the ITRS2020 realizations is **to estimate SLR range biases of each station at each orbital arc.** This absorbs the mismodelling caused by missing information on the long-term mean biases of SLR stations.

Reference

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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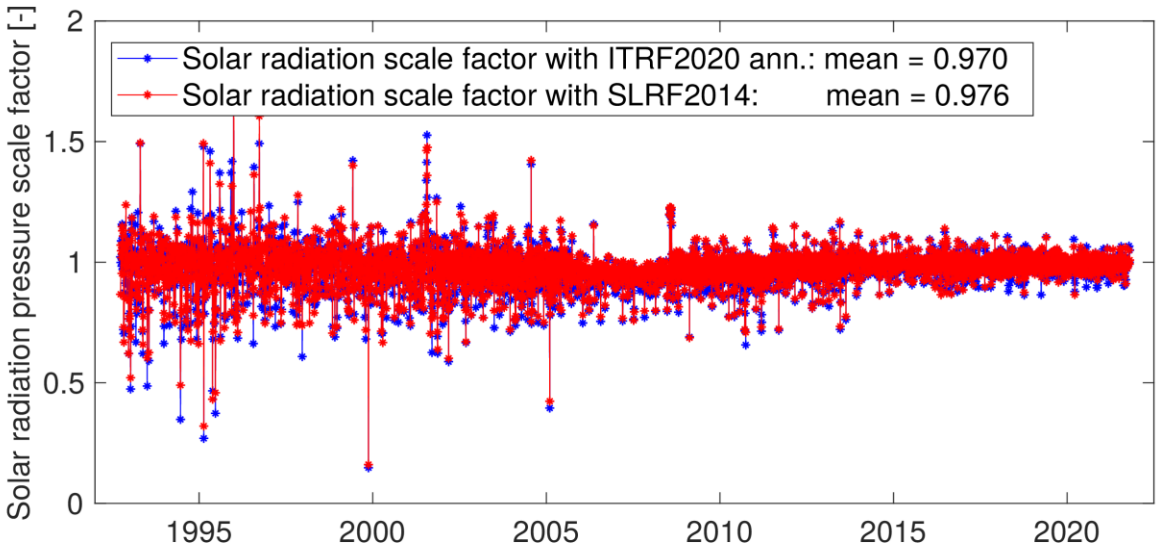
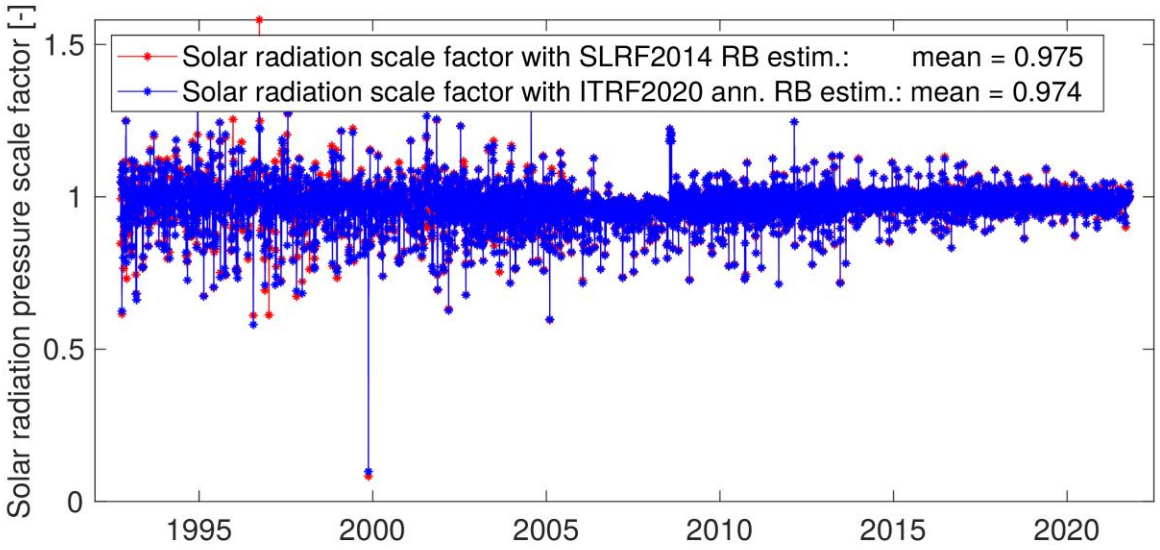
Backup slides

Solar radiation pressure scale factor

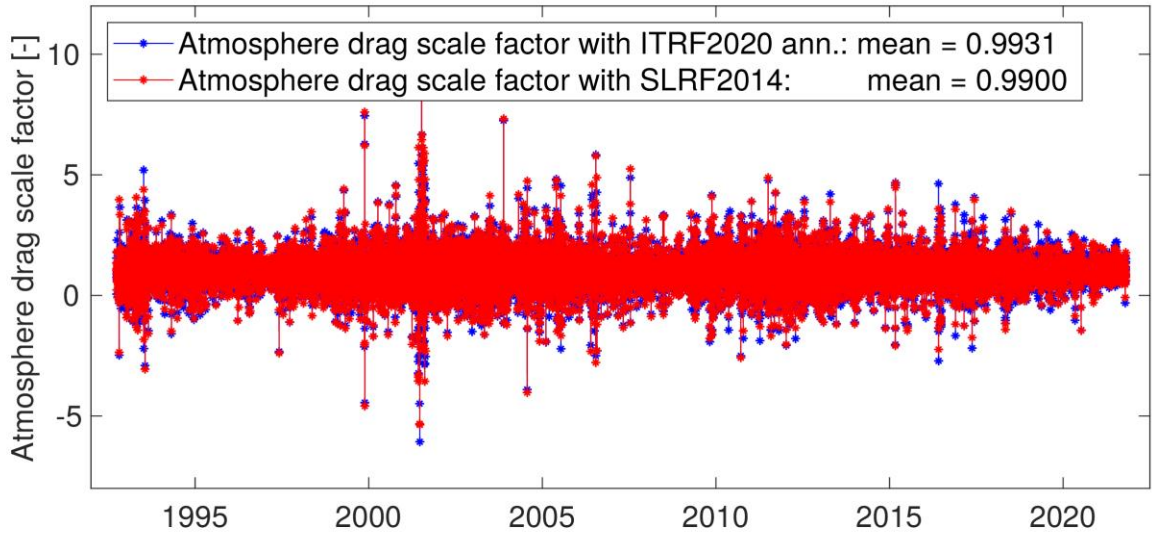


Minor difference, when using ITRF2020 instead of SLRF2014, when no SLR range biases are estimated.

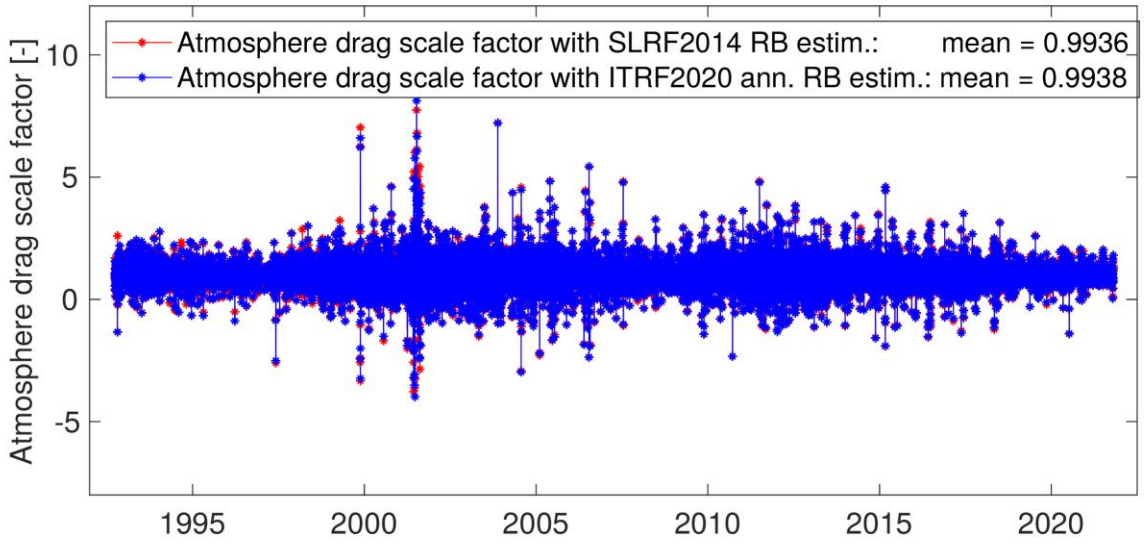


Very comparable values, when using ITRF2020 instead of SLRF2014, when SLR range bias is estimated. Generally, a small impact on this parameter when replacing TRF realizations.

Atmosphere drag scale factor



Minor differences, when replacing SLRF2014 by ITRF2020 for the case, when no SLR range biases are estimated.



The values of this parameter are getting even closer and are comparable when using ITRF2020 instead of SLRF2014, when SLR range biases are estimated.