Recent activities on orbit determination for altimetry satellites at DGFI-TUM

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Major DOGS-OC updates in April 2021 – May 2022

- Import and processing of DORIS observations were updated.
- Treatment of wavelength-specific SLR range biases was refined.
- Algorithm for modeling the satellite attitude was further optimized based on Bloßfeld et al. (2020).
- EIGEN-GRGS.RL04.MEAN-FIELD Earth's time-variable gravity field model (Lemoine et al., 2019) was implemented.
- Update of existing and implementation of the new thermosphere model NRLMSIS 2.0 (Emmert et al., 2021) were performed.
- A new station-dependent satellite laser ranging (SLR) measurement correction model for TOPEX/Poseidon has been developed (Zeitlhöfler et al., submitted, in review).
- Observed GFZ geomagnetic storm and solar flux indices (Matzka et al., 2021) are now used.
- Tests on optimal parametrization have been performed.

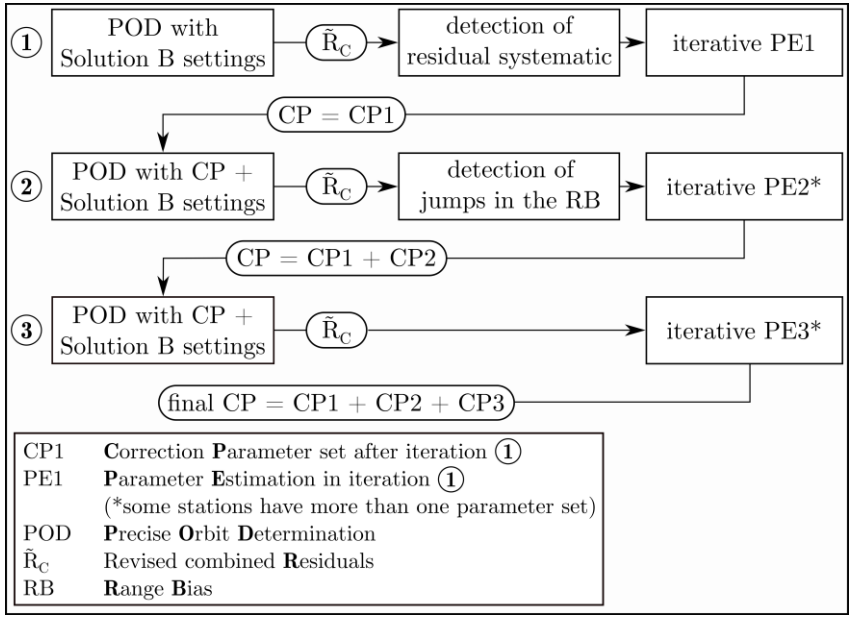
Station-dependent SLR measurement correction model for TOPEX (1)

- The large dimensions of the laser retroreflector array cause the main limiting factor of the POD of TOPEX/Poseidon (T/P)
- Iterative least square adjustment of system-dependent measurement correction functions
- For each CDDIS SOD that tracked T/P, a set of **six parameters** is estimated combined in the correction function $K(x)$:

$$K(x) = \boldsymbol{C_O} + [\boldsymbol{G_0}\cos\alpha + \boldsymbol{G_{90}}\sin\alpha]\sin i + \boldsymbol{X_1}\sin i + \boldsymbol{X_2}\sin^2 i + \boldsymbol{X_3}\sin^3 i \ ,$$

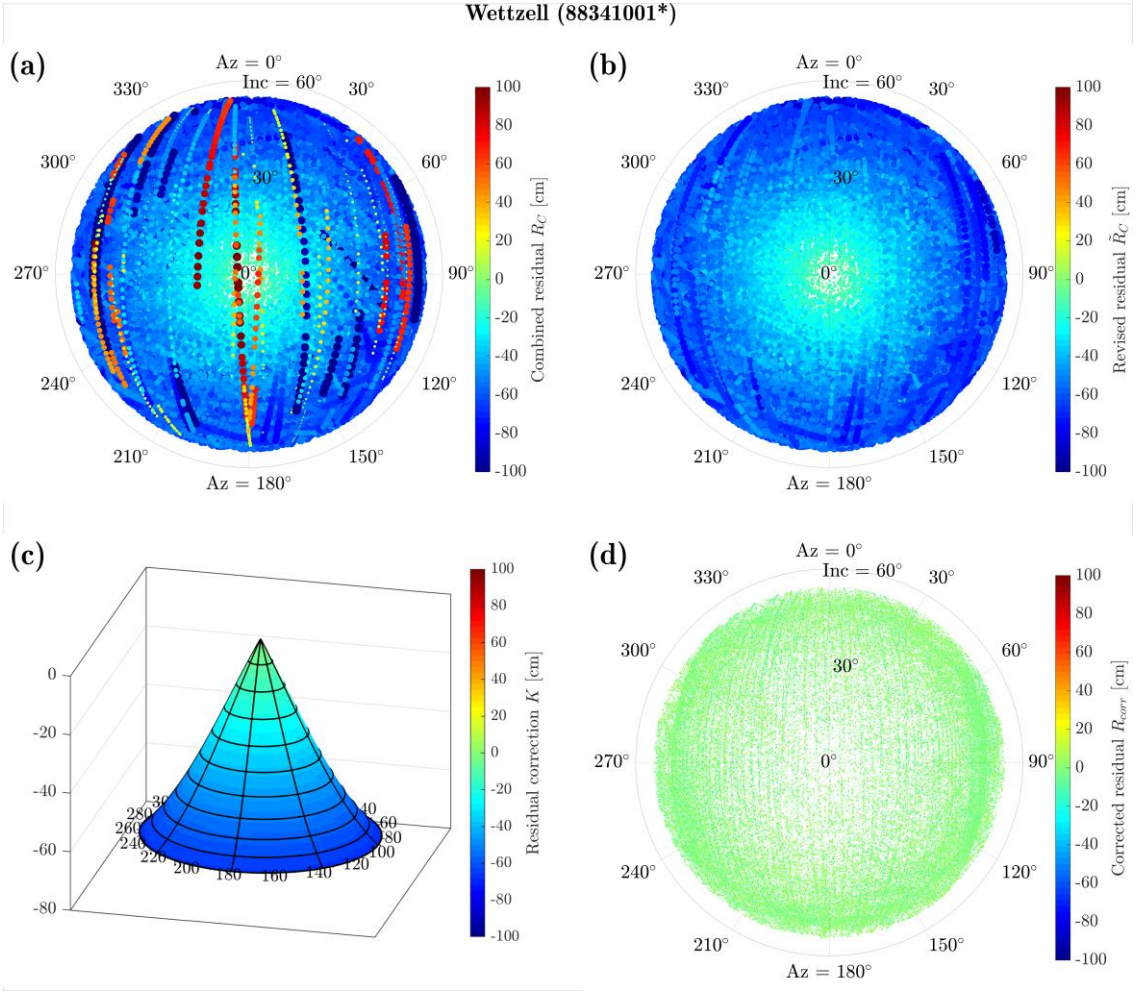
with:

- C_O correction offset [cm]
- G_0 gradient in the 0° azimuth direction in the LRA frame [cm]
- G_{90} gradient in the 90° azimuth direction in the LRA frame [cm]
- $X_{1/2/3}$ coefficient for the linear/quadratic/cubic polynomial of i [cm]
- α, i azimuth and incidence angle of the SLR observation in the LRA frame [°]



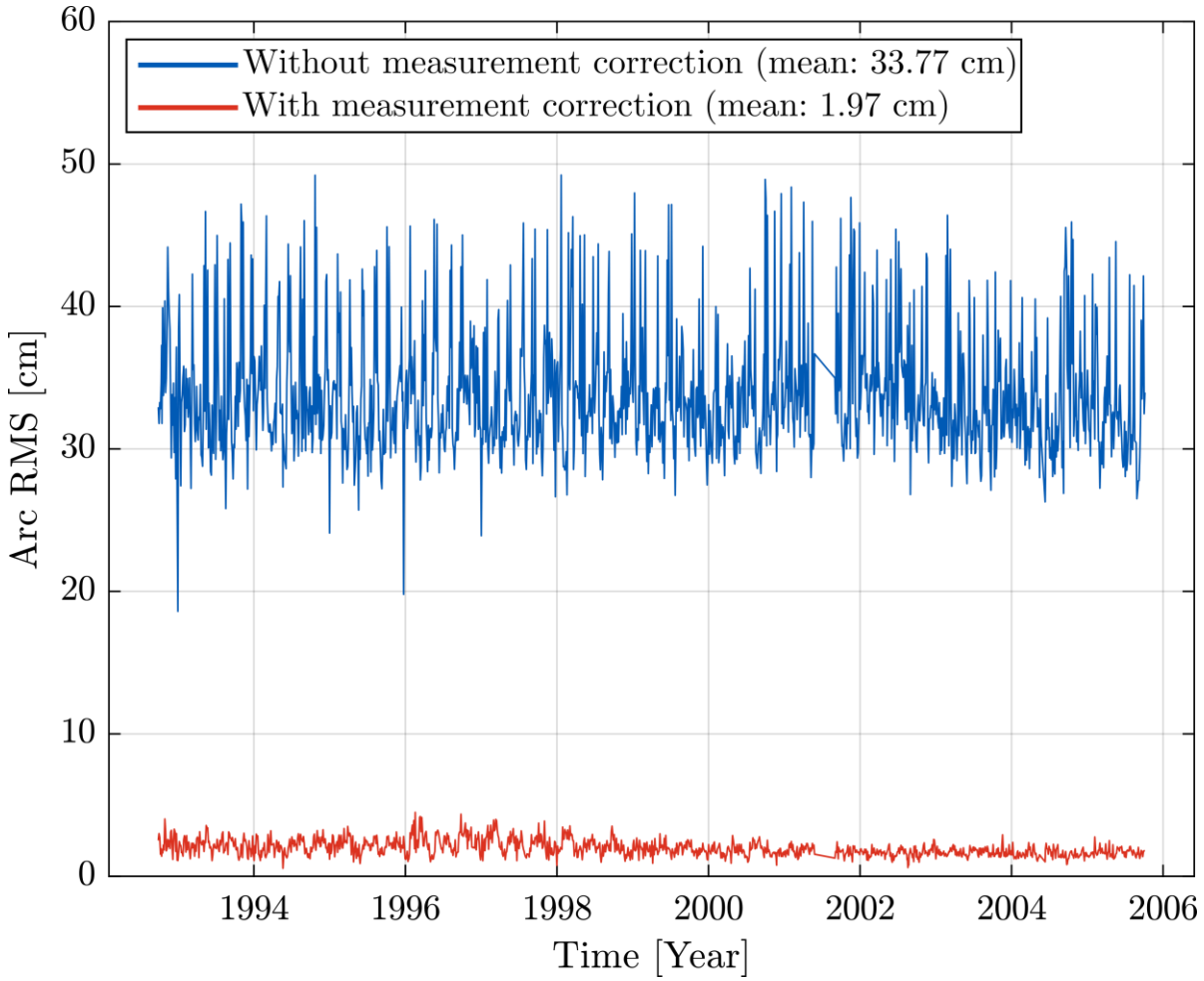
Station-dependent SLR measurement correction model for TOPEX (2)

- The correction function with the system-individual parameters improves the SLR measurement and removes any azimuth or incidence dependency
- (a) residuals of SLR observations of the station Wettzell (88341001) in the LRA frame
- (b) revised residuals (without outliers)
- (c) correction function based on the 6 parameters
- (d) corrected residuals

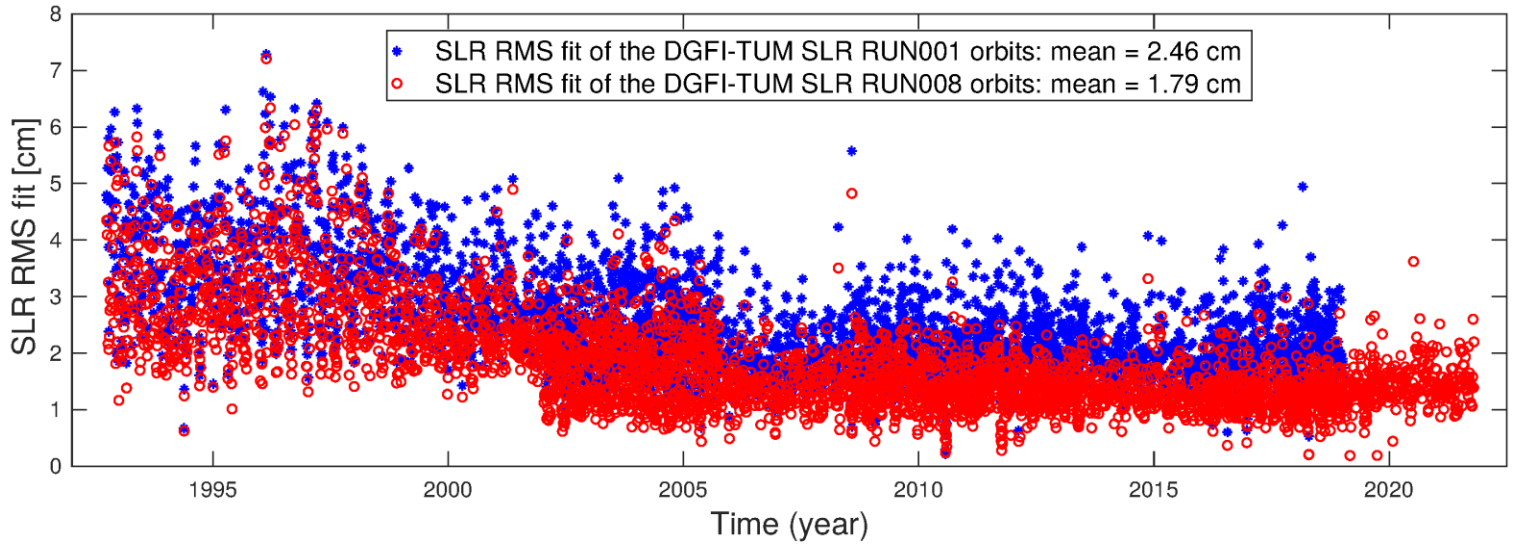


Station-dependent SLR measurement correction model for TOPEX (3)

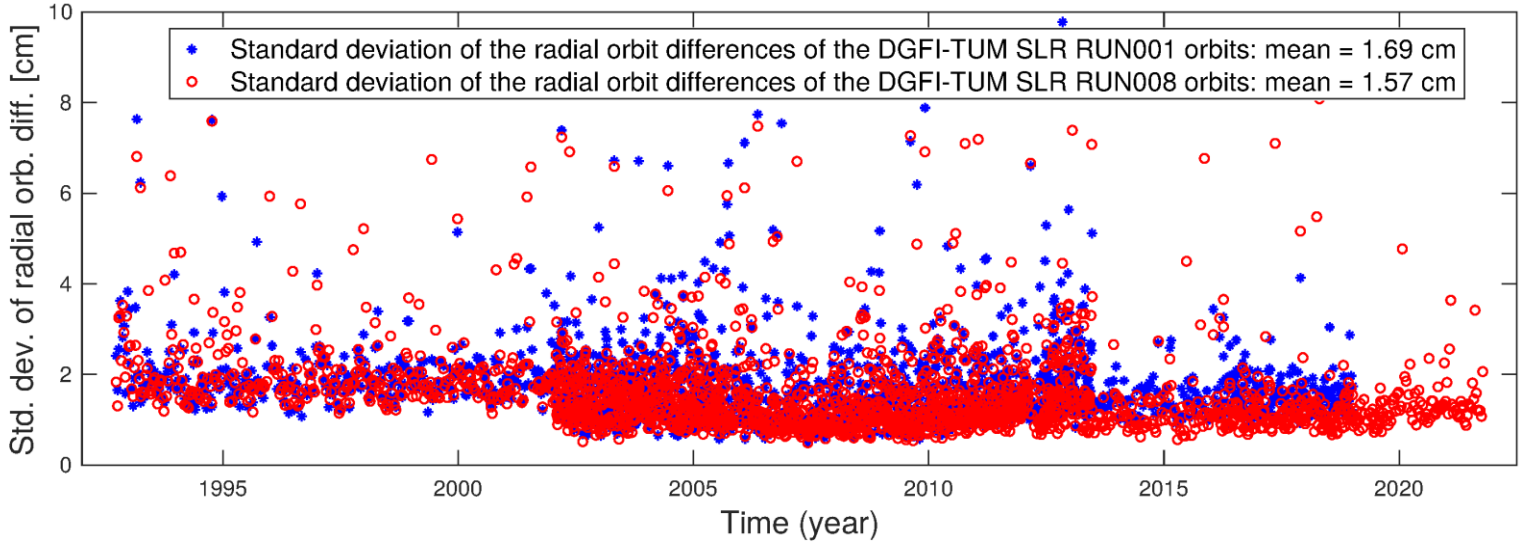
- The uncorrected orbit of T/P has a mean mission RMS of 33.77 cm
- Applying the measurement correction for SLR observations to T/P improves the RMS to 1.97 cm
- Orbit comparisons to external solutions (SLR-only and SLR+DORIS) show good agreement between the solutions. The mean of orbit differences differ only up to 0.2 cm in the radial, transverse, and normal directions.
- A paper is submitted to the journal Advances in Space Research.



Some results on SLR data-based orbits derived at DGFI-TUM

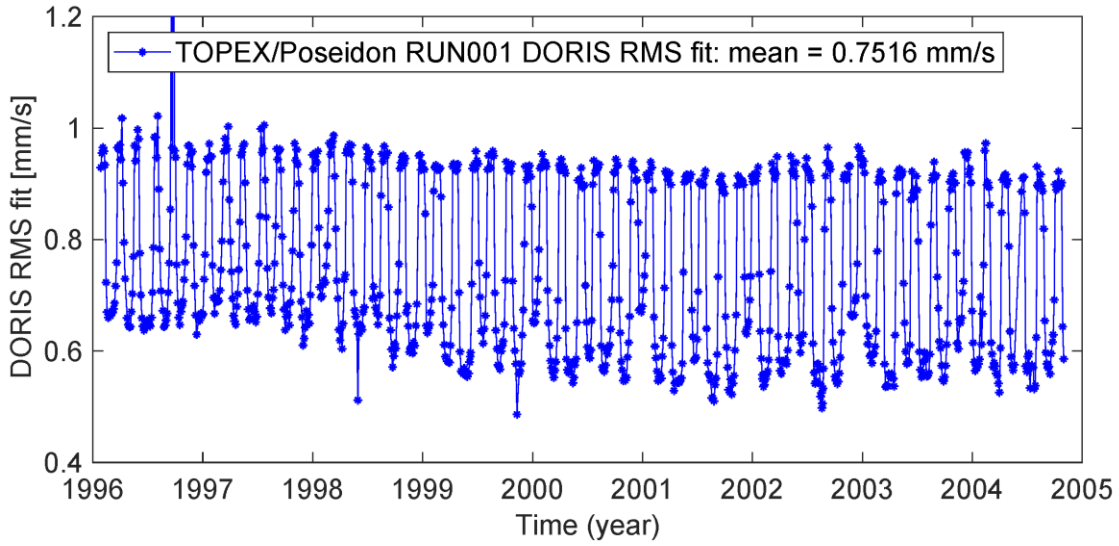


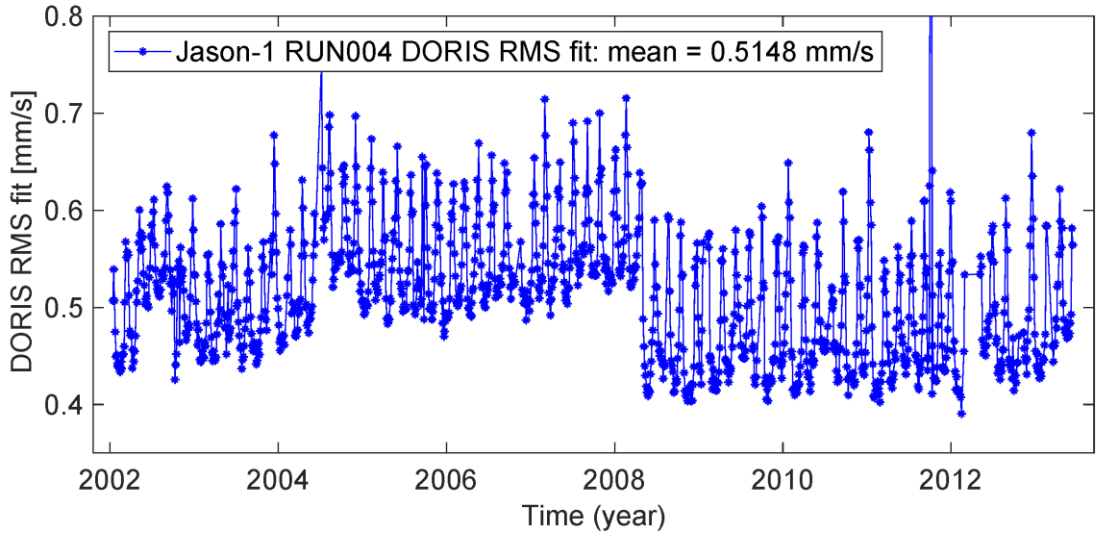
RMS differences of SLR observations of TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3 of DGFI-TUM SLR RUN001 and RUN008 orbits.

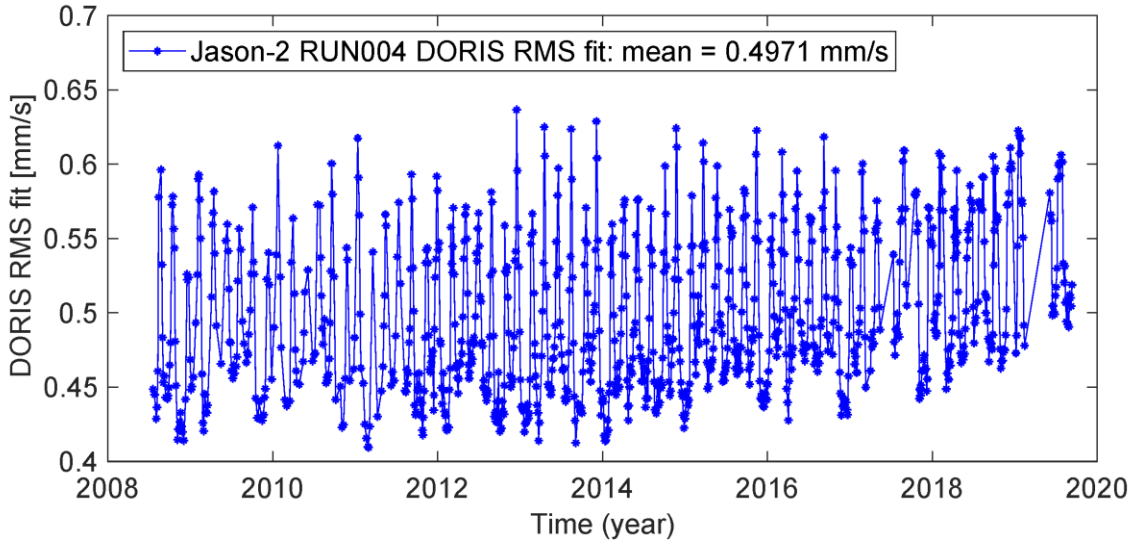


Standard deviation of the orbit differences in the radial direction of DGFI-TUM SLR RUN001 and RUN008 orbits with respect to GFZ VER13 orbits of TOPEX/Poseidon and Jason-1 and CNES POE-F orbits of Jason-2 and Jason-3.

RMS fits of DORIS measurements of DGFI-TUM DORIS data-based orbits







The mean values of the RMS fits of DORIS measurements are:
0.75 mm/s for TOPEX/Poseidon,
0.50-0.51 mm/s for Jason-1 and Jason-2.

A new tool to compute and analyze satellite orbit differences

Formats of orbit files to be used: SP1, SP3c, SP3d.

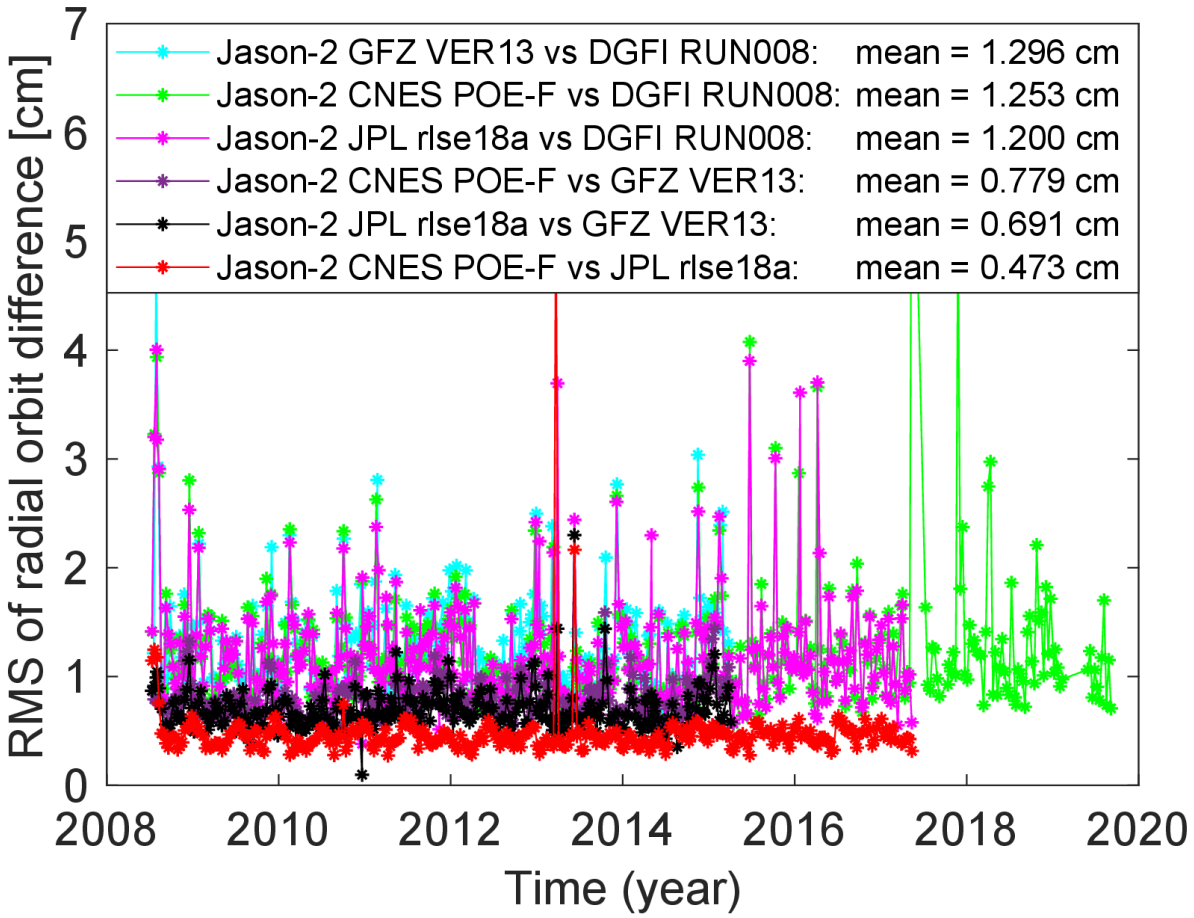
Orbit solutions may have **different time steps**.

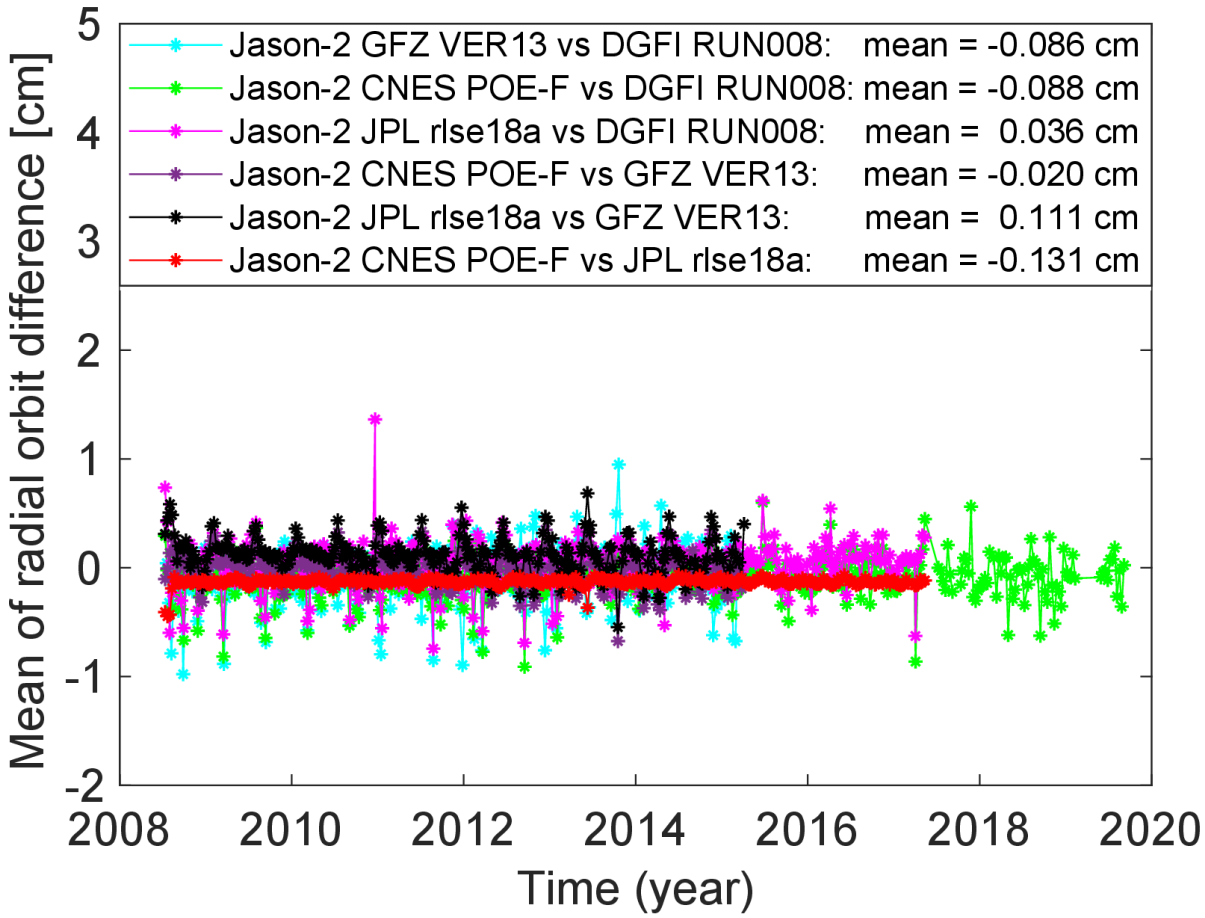
Spline interpolation method is used to interpolate satellite positions.

Various **possibilities** are realized:

- Computation of orbit differences over the orbit file length of the reference solution or over a long **time span**.
- A possibility to **exclude intervals with orbit maneuvers** from the orbit comparison and to define the duration of the time spans to be cut before and after orbit maneuvers (4 minutes used here).
- A possibility to compute and plot orbit differences **in various coordinate systems**: Cartesian (X,Y, Z), RTN (radial, transverse, normal) and ellipsoidal (height, longitude, and latitude).
- A possibility **to mark orbit maneuvers, start and end** of orbit files in the plots of orbit differences.
- A possibility to perform **frequency analysis** of the orbit differences (under development).

Radial orbit differences of Jason-2 various orbit solutions





All orbits agree within 5-13 mm in RMS and ±1.3 mm in mean. CNES POE-F, JPL and GFZ VER13 orbits agree within 5-8 mm in RMS. SLR data-only DGFI RUN008 orbit agrees within 12-13 mm in RMS with DORIS or GPS data derived orbits from CNES, GFZ and JPL.

Conclusions

- DOGS-OC has been **further elaborated** for precise orbit determination of altimetry satellites.
- SLR data-based orbits of TOPEX/Poseidon, Jason-1, Jason-2, Jason-3 have been derived at DGFI-TUM during the complete duration of each mission (by 24 October 2021 for Jason-3). The average values of **RMS fits of SLR observations** for these orbits are 1.97 cm for TOPEX/Poseidon, 1.37 cm for Jason-1, 1.35 cm for Jason-2, and 1.38 cm for Jason-3.
- The average values of the RMS of the **radial orbit differences** between DGFI SLR-data orbits and GFZ VER13 orbits are 2.01 cm for TOPEX/Poseidon, 1.76 cm for Jason-1 and 1.30 cm for Jason-2. The average absolute value of the mean radial orbit differences between these orbits is below 0.1 cm.
- DORIS data-based orbits of TOPEX/Poseidon, Jason-1 and Jason-2 have been derived at DGFI-TUM for the duration of each mission. The mean values of the **RMS fits of DORIS observations** are: 0.75 mm/s for TOPEX/Poseidon, and 0.50-0.51 mm/s for Jason-1 and Jason-2.
- **A new tool for the computation and visualization of orbit differences** has been developed at DGFI-TUM and can be applied for the analysis of various orbit solutions.

References

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