Comparison of time series of DORIS and SLR station coordinates of ITRS 2020 realizations and their updates and their impact on POD of altimetry satellites

Sergei Rudenko[1], Mathis Bloßfeld[2], Manuela Seitz[2] and Julian Zeitlhöfler[2]

[1] Karlsruher Institut für Technologie (KIT), Geodätisches Institut (GIK), Karlsruhe

[2] Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), München

IDS Analysis Working Group Meeting, Athens, Greece

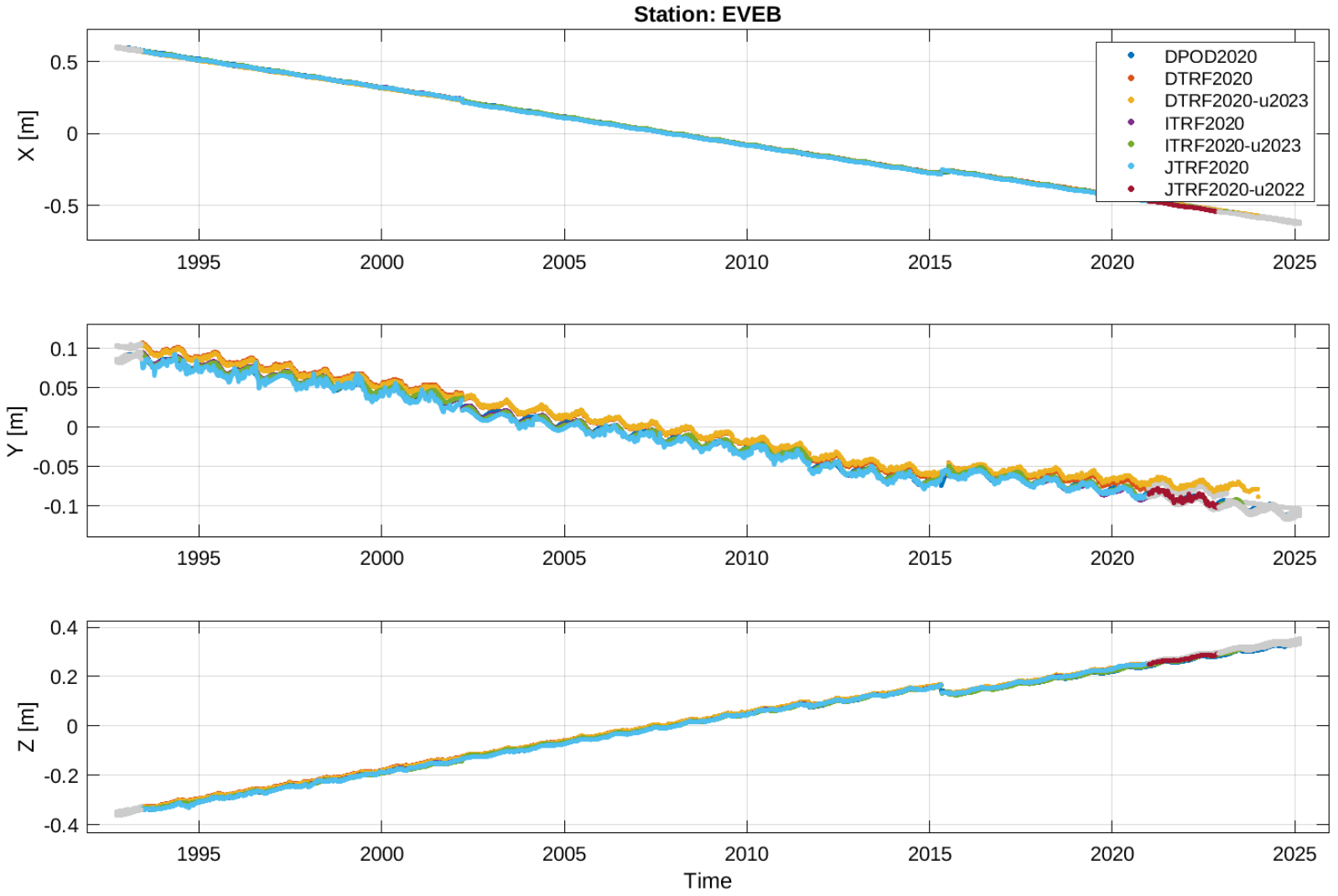
November 6-7, 2025

A description of the ITRS realizations used in the study

Items / ITRS realizations	ITRF2020	ITRF2020-u2023	DTRF2020	DTRF2020-u2023	JTRF2020	JTRF2020-u2022	SLRF2020 (v.250513)	DPOD2020 v4.1
Reference	(Altamimi et al., 2023)	(Altamimi et al., 2023)	(Seitz et al., 2023)	(Seitz et al., 2023)	(Gross et al., 2023)	(Gross et al., 2023)	Pavlis and Luceri (2022)	Moreaux et al. (2023)
Reference epoch of station coordinates (year)	2015.0	2015.0	2010.0	2010.0	daily	daily	2015.0	2000.0
Velocities	Yes	Yes	Yes	Yes	–	–	Yes	Yes
Post-seismic deformation	coefficients of PSD function	coefficients of PSD function	discrete PSD correction time series	discrete PSD correction time series	–	–	coefficients of PSD function	discrete PSD correction time series
Periodic functions in the CM frame: (semi)-annual + GNSS draconitic periods (and harmonics)	Yes	Yes	–	–	–	–	Yes	Yes
Time series for CM atmospheric, oceanic and hydrological non-tidal loading (NTL) corrections (GGFC)	–	–	Yes	Yes	–	–	–	–
SLR network translations	Available (not used)	Available (not used)	Available (not used)	Available (not used)	–	–	–	–
Helmert transformation residuals	Available (not used)	Available (not used)	Available (not used)	Available (not used)	–	–	–	–

Time series of reduced DORIS station coordinates (with respect to the mean value in the DTRF2020-u2023)

An example of a good agreement of trends

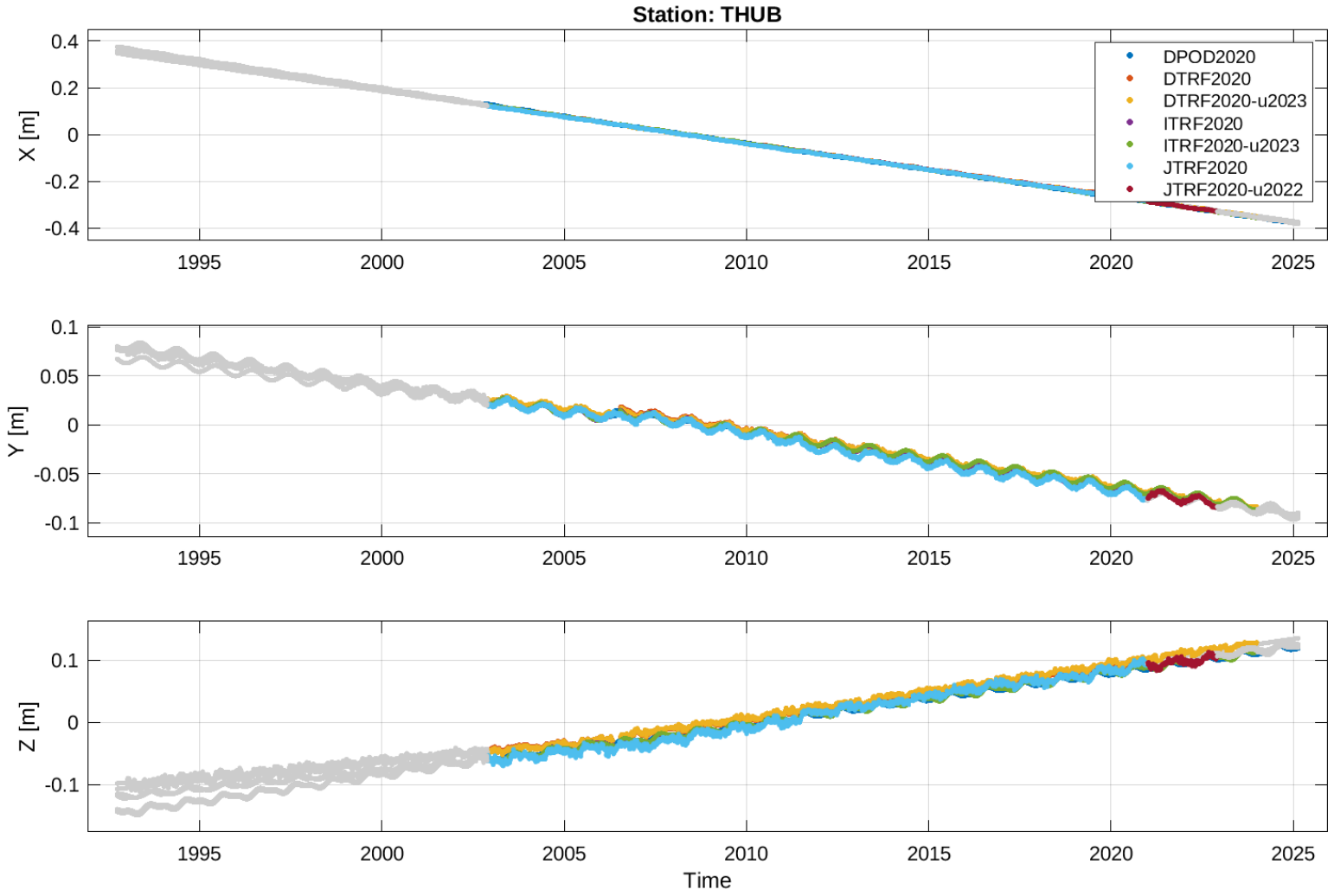


Station EVEB
EVEREST - NEPAL

A good agreement of station coordinate time series was obtained for most DORIS stations

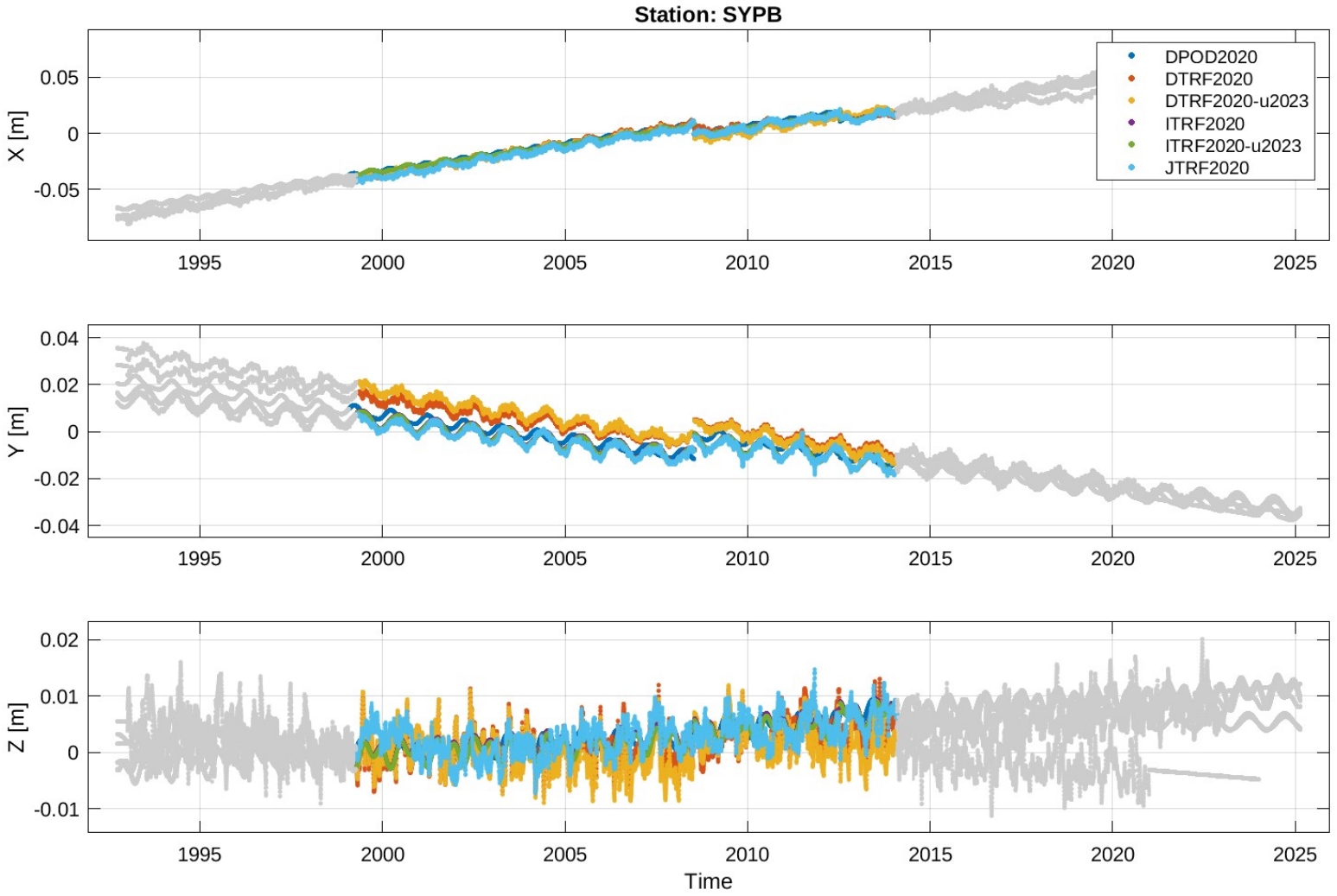
Grey color shows the extrapolated time series outside of the validity interval of the respective ITRS solution for this station

An example of a good agreement



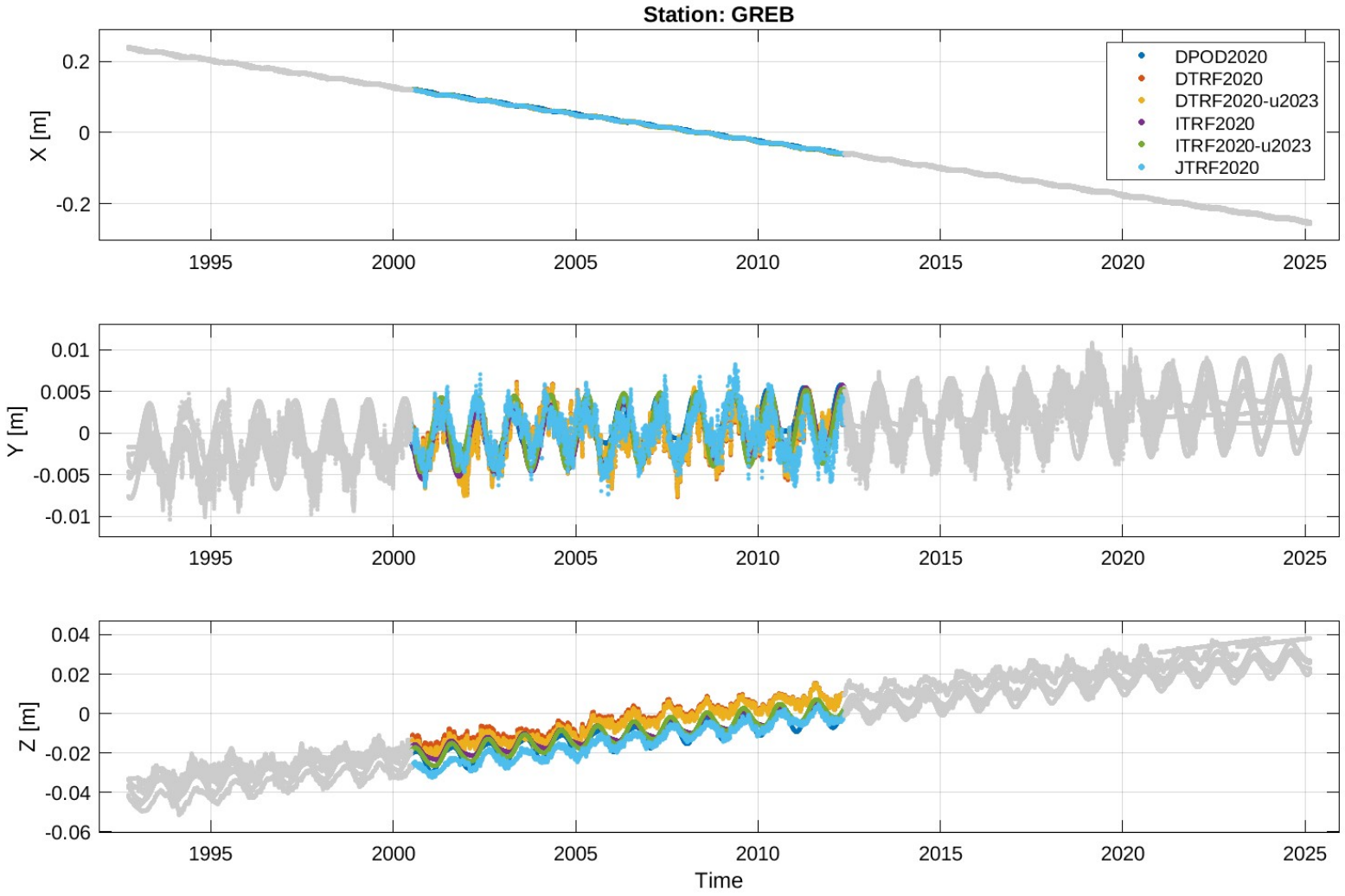
Station THUB
THULE - DENMARK
(Greenland)

An example of small differences



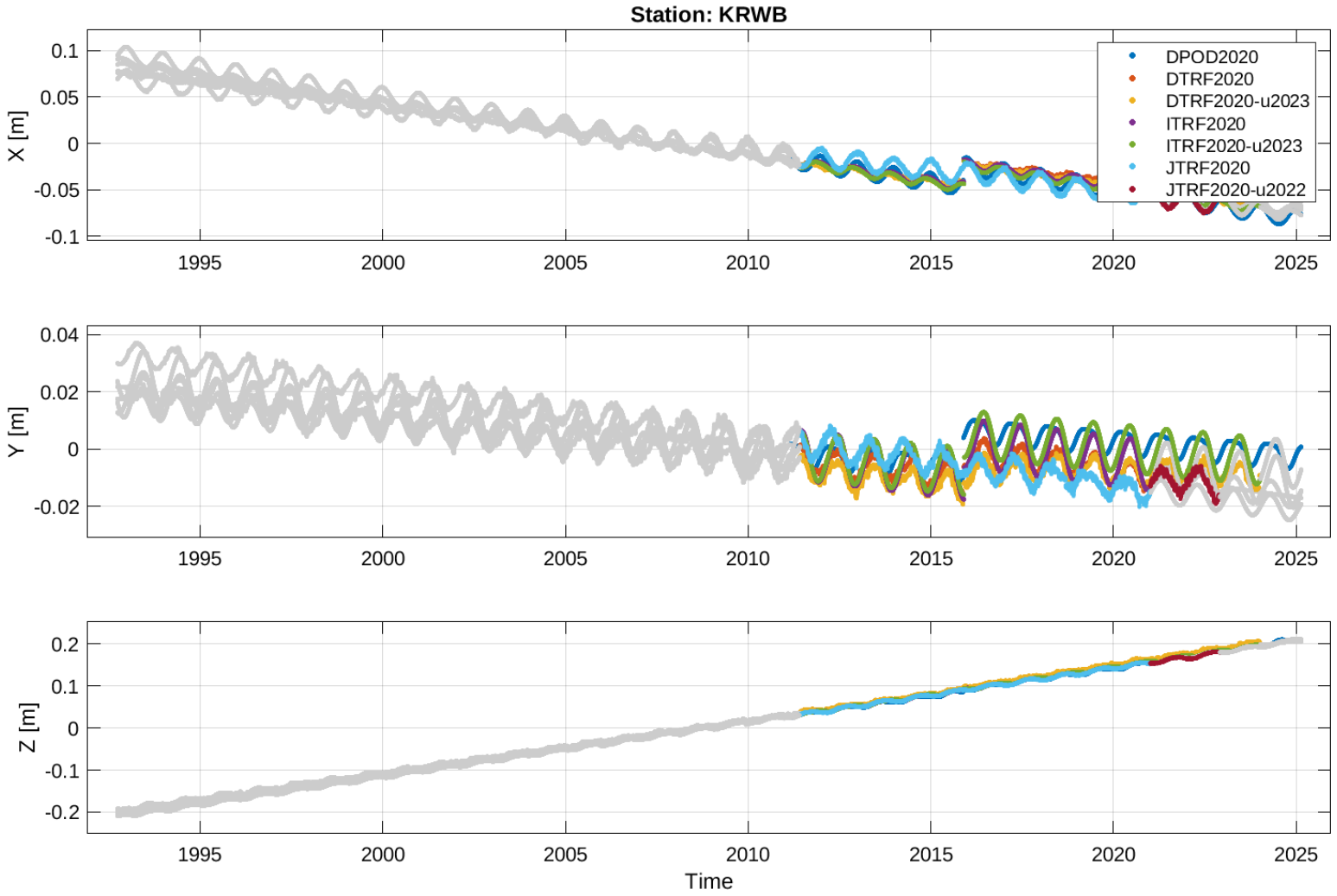
Station SYPB
SYOWA -
ANTARCTICA

An example of a good agreement of annual variations



Station GREB
GREENBELT - U.S.A.

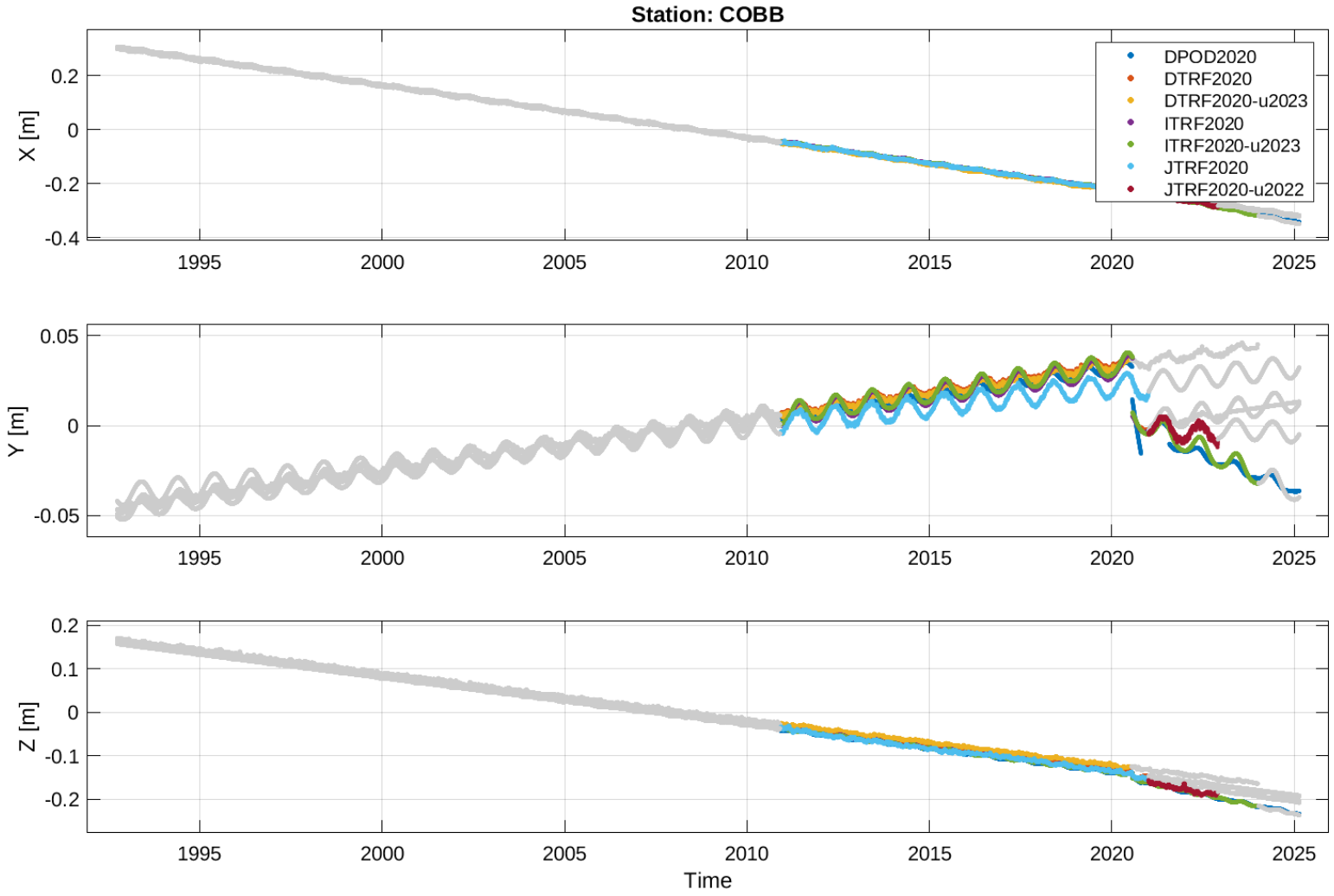
Different modeling of coordinate variations



Station KRWB
KOUROU - FRANCE
(French Guiana)

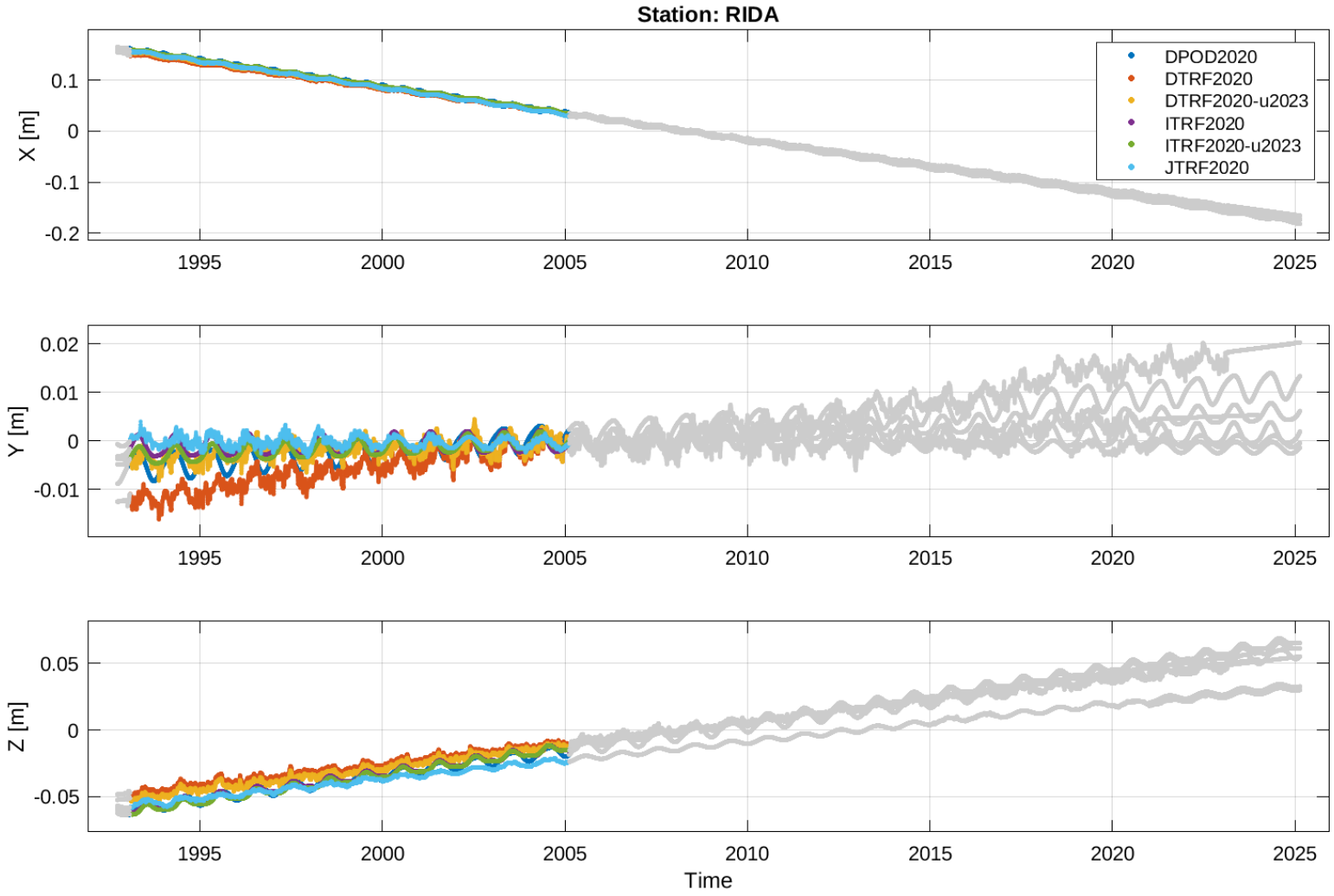
A missing jump of station coordinate time series in JTRF2020 compared to other ITRS realizations

Different modeling of coordinate variations



Station COBB
COLD-BAY - U.S.A.

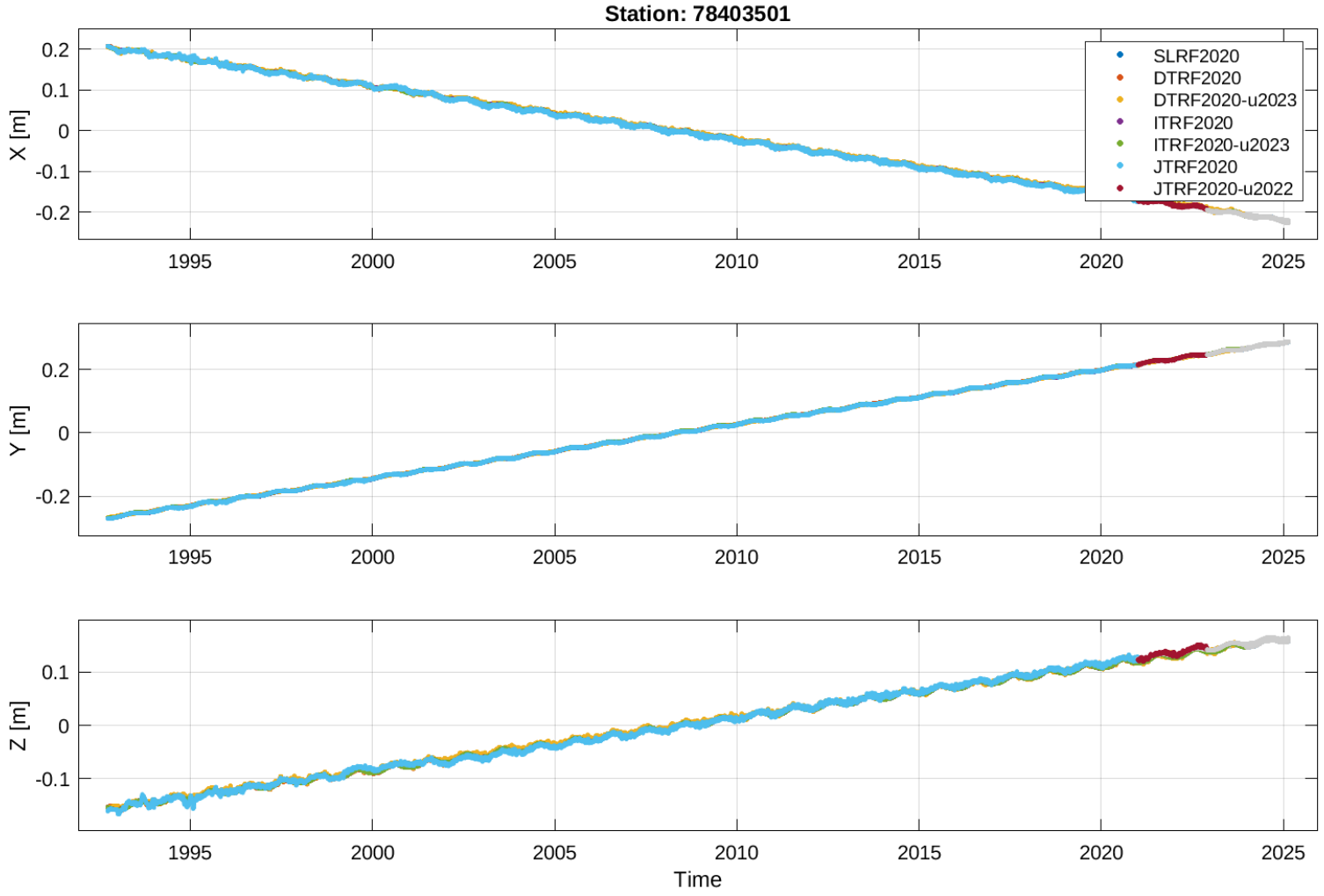
Slightly different velocities



Station RIDA
RICHMOND - U.S.A.

Time series of reduced SLR station coordinates (with respect to the mean value in the DTRF2020-u2023)

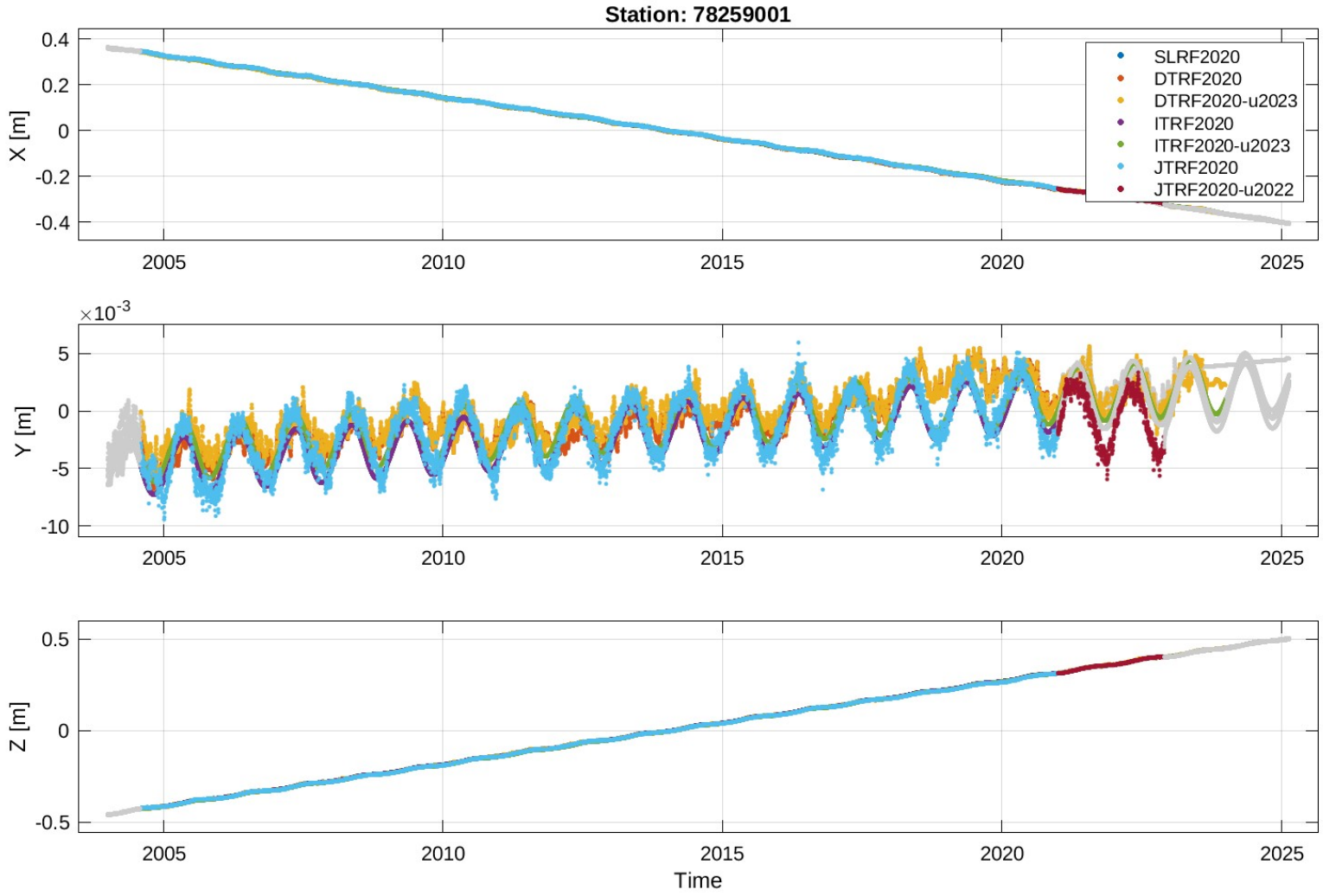
An example of a good agreement of trends



Station 78403501
Herstmonceux, United Kingdom

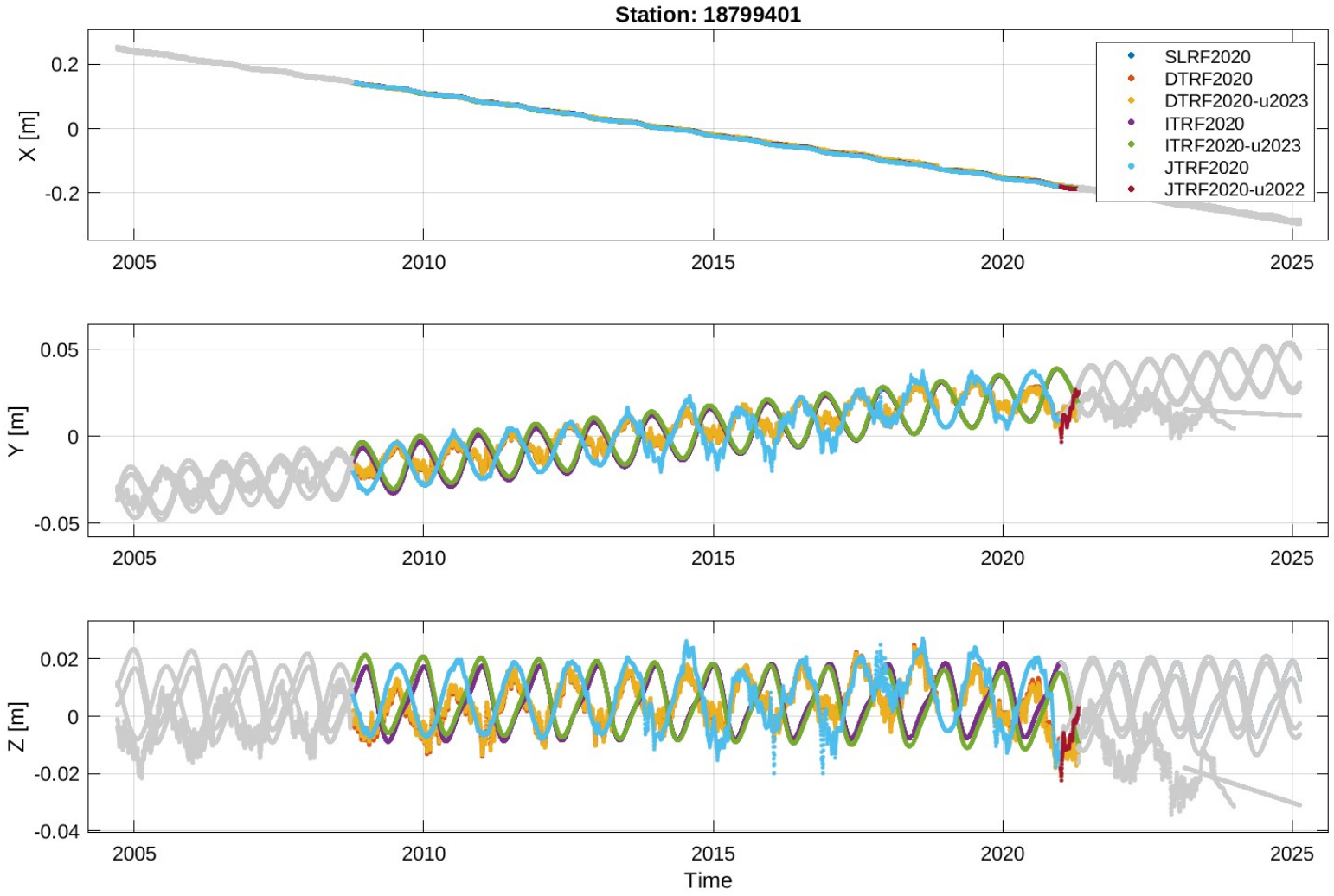
A good agreement of station coordinate time series was obtained for many SLR stations

An example of a good agreement of annual variations



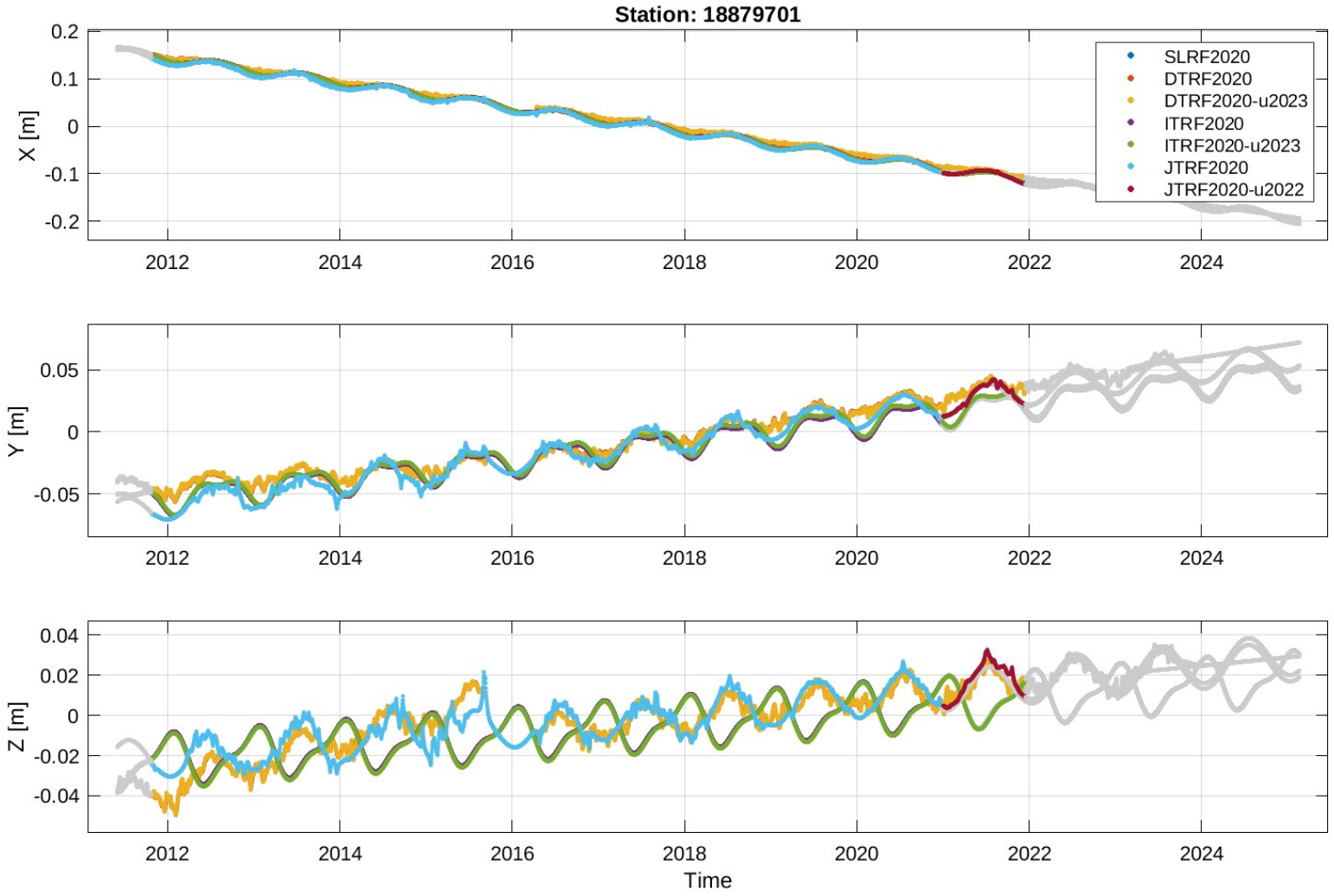
Station 78259001
Mt Stromlo, Australia

An example of a disagreement of annual variations



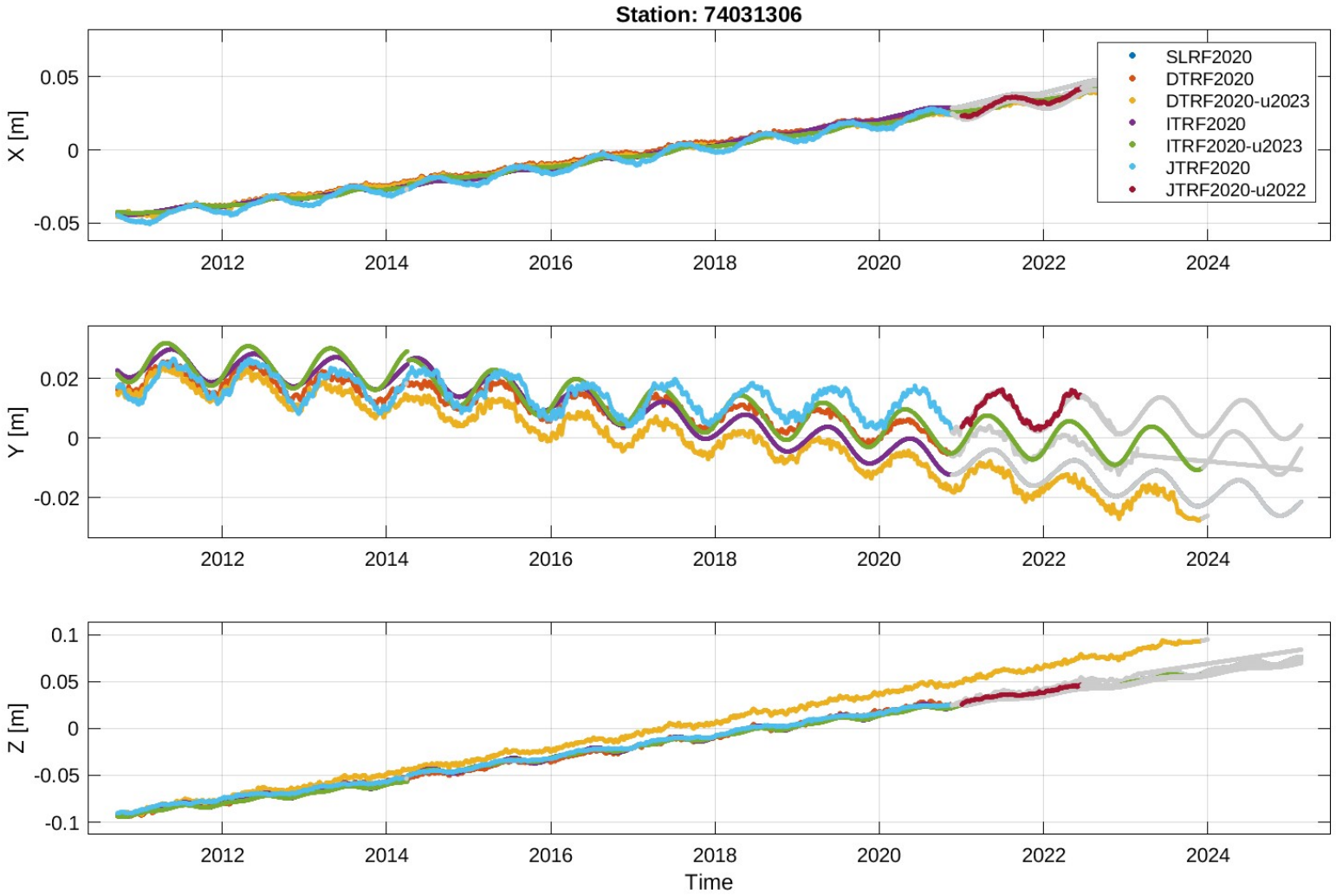
Station 18799401
Altay, Russia

An example of a disagreement of annual variations



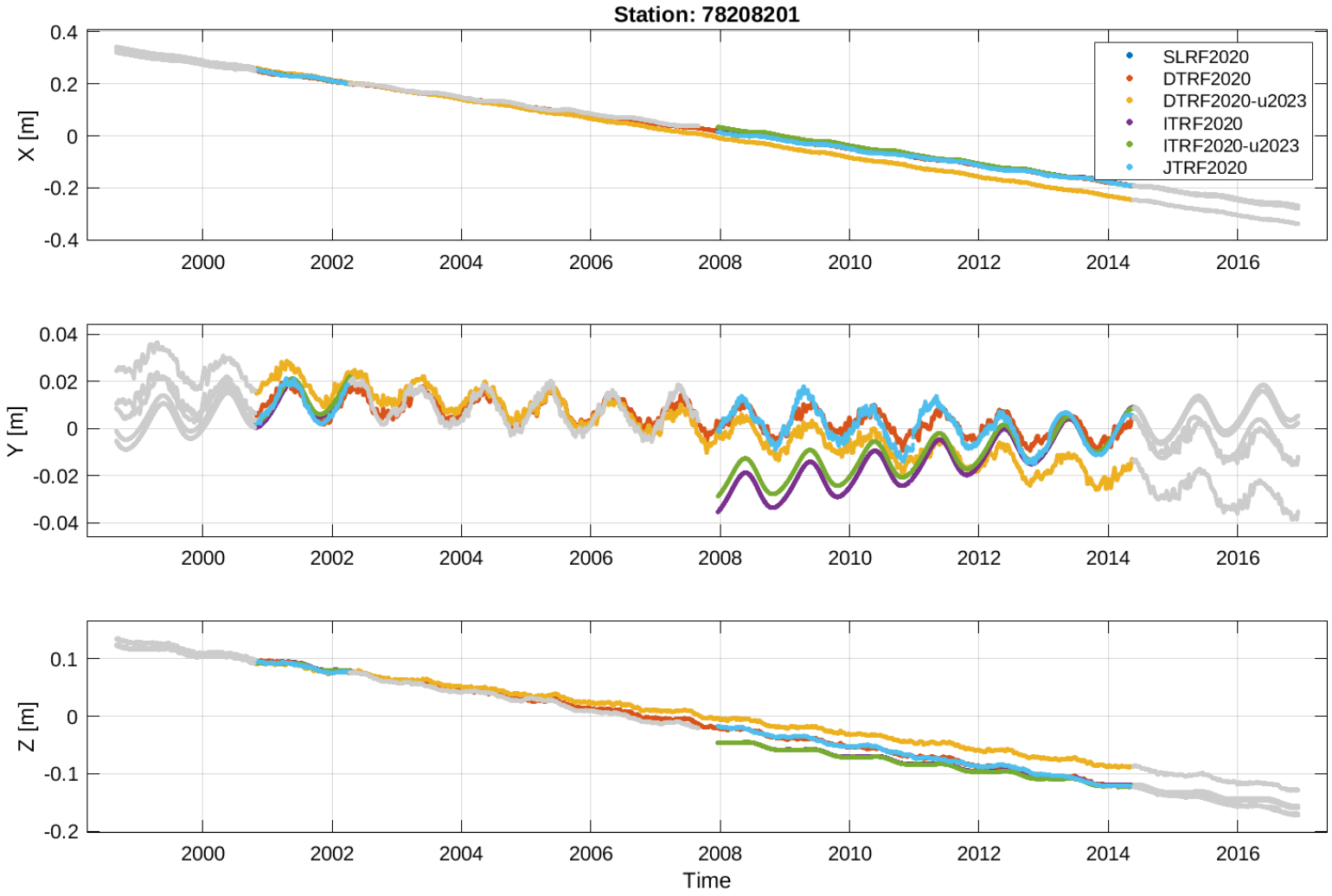
Station 18879701
Baikonur, Kazakhstan

An example of slightly different velocity components



Station 74031306
Arequipa, Peru

An example of different velocity components



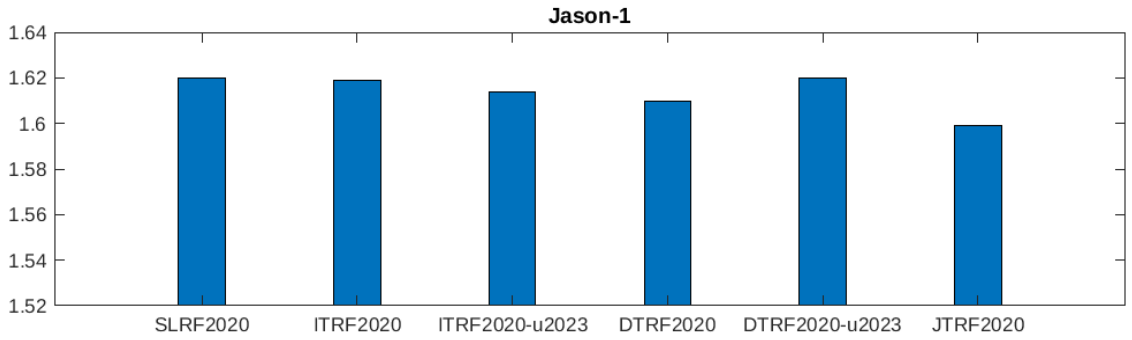
Station 78208201
Kunming, China

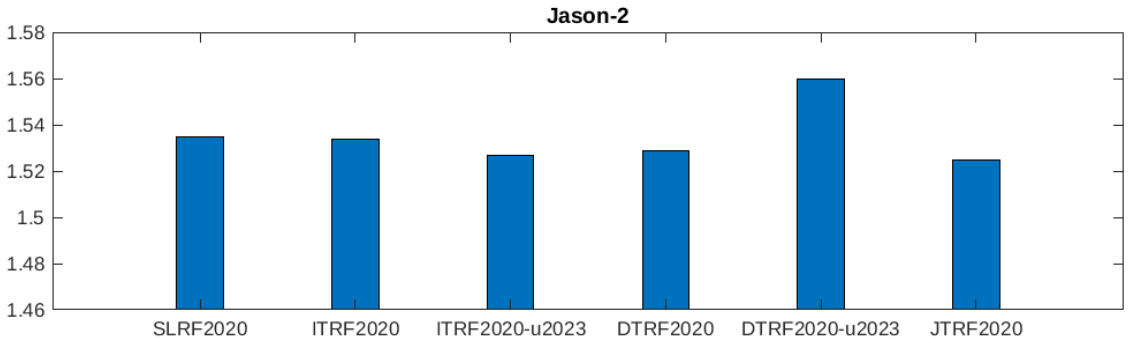
A setup for precise orbit determination (POD) tests

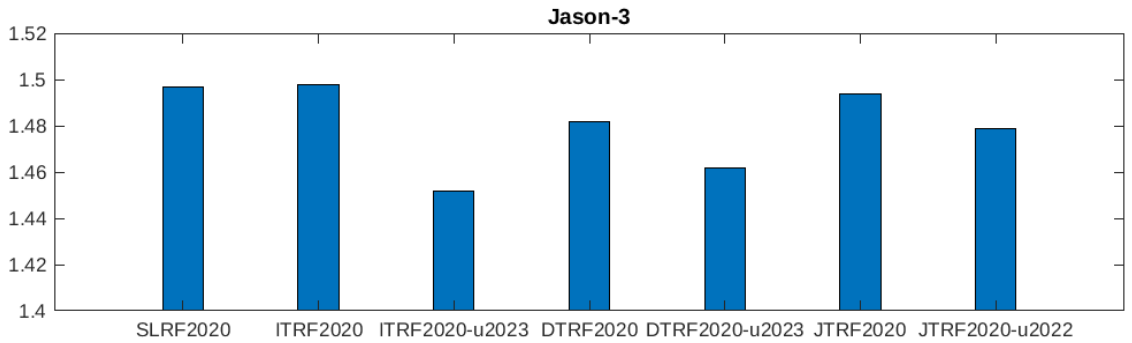
- Seven ITRS realizations containing SLR-station-related information were used (slide 2)
- Observation type used: Satellite Laser Ranging (SLR).
- Satellites used (at the time spans given):
  - TOPEX/Poseidon (Sep. 1992 – Oct. 2005),
  - Jason-1 (Jan. 2002 – Jun. 2013),
  - Jason-2 (Jul. 2008 – Oct. 2019),
  - Jason-3 (Feb. 2016 – Feb. 2025),
  - Sentinel-6A (Nov. 2020 – Feb. 2025).
- Background models are according to Rudenko et al. (2023) for the DGFI-TUM DSO1 orbits. Additionally CNES RL05MF Earth's gravity field model used.
- ILRS Data Handling File for SLRF2020 is used for all ITRS 2020 realizations, according to Rudenko et al. (2025)

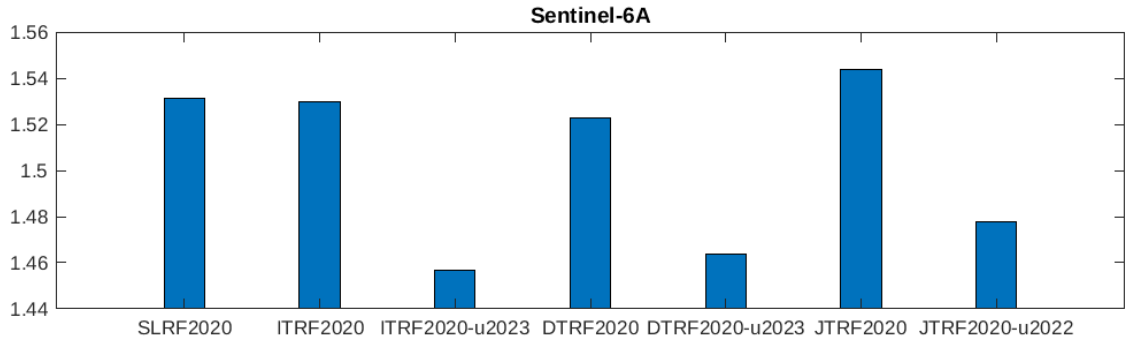
- Orbits are computed primarily at 3.5-day long arcs. Orbit maneuvers are excluded resulting in a bit shorter or longer arcs.
- Reduced-dynamic orbits with loosely constrained estimated parameters were computed.
- Estimated parameters:
  - Keplerian elements (once per arc),
  - Atmospheric drag scale factor (with a 0.5 day step),
  - Solar radiation pressure scale factor (once per arc),
  - Earth's albedo and infrared radiation (once per arc),
  - Empirical accelerations in the along-track and cross-track directions (sine and cosine terms – once per arc, polygon terms – with a 0.5 day step).
- Impact on the following parameters is investigated:
  - RMS values of SLR observation residuals,
  - RMS and mean values of orbit differences in the radial direction.

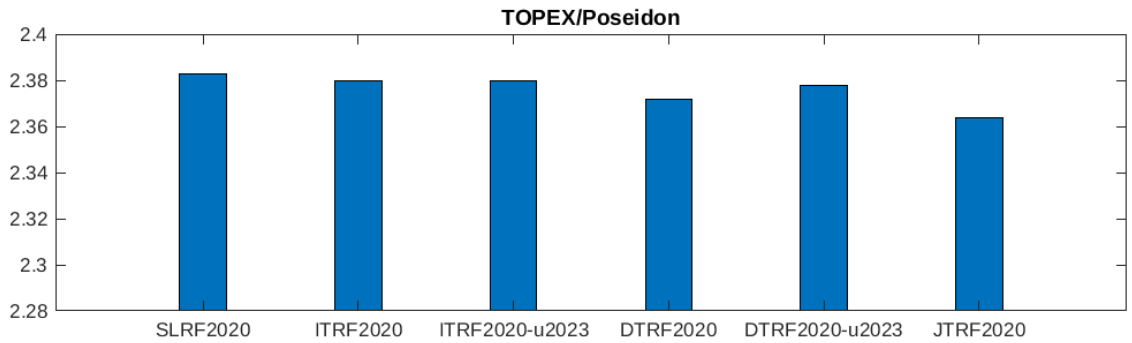
Impact of ITRS 2020 realizations on the RMS fits (cm) of SLR observations





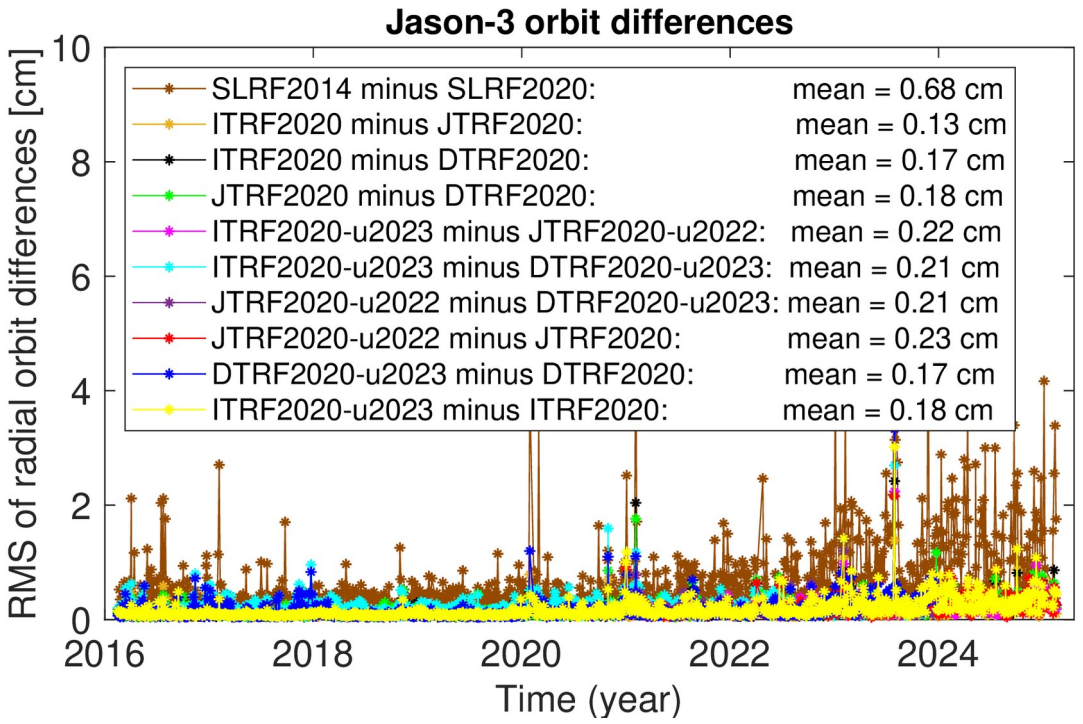


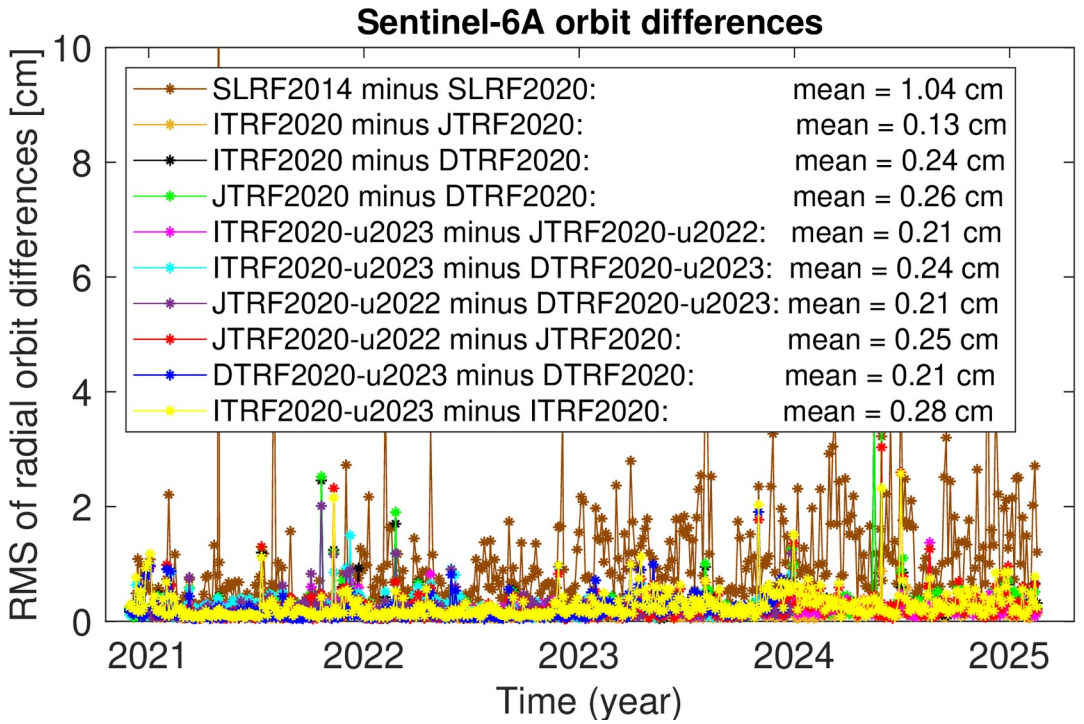




- Updates of ITRS 2020 realizations, namely ITRF2020-u2023, DTRF2020-u2023, JTRF2020-u2022, provide smaller RMS fits than the original ITRS 2020 realizations for currently running missions (Jason-3 and Sentinel-6A), especially at the time spans of ITRS extensions (after 2021.0).

RMS values of radial orbit differences of Jason-3 and Sentinel-6A orbits derived using various ITRS 2020 realizations

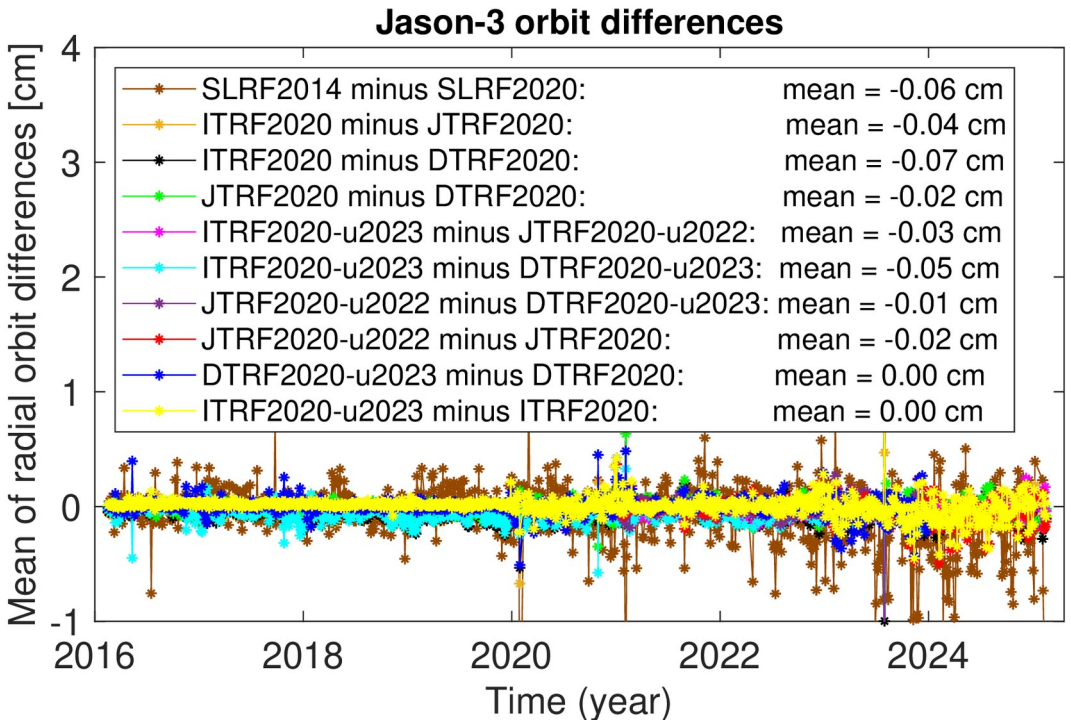


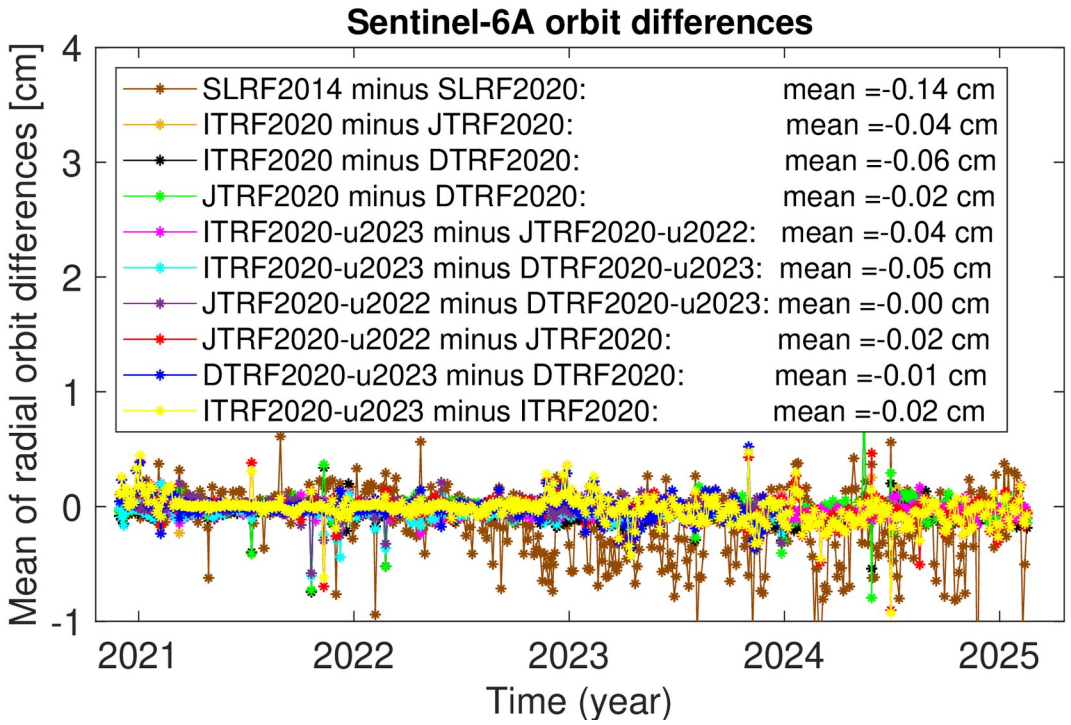


- Satellite positions of the ITRS 2020-based orbits of Jason-3 and Sentinel-6A agree within 0.1 – 0.3 cm in the radial direction.
- Increased orbit differences are seen at the extrapolation interval (after 2021.0) between the original ITRS 2020 realizations and their updates.

- Significantly larger values (up to 0.7 – 1.0 cm) for the “SLRF2014 minus SLRF2020” case show extrapolation errors of SLRF2014 and stress an importance and benefits of regular reprocessing of ITRS realizations.

Mean values of radial orbit differences of Jason-3 and Sentinel-6A orbits derived using various ITRS 2020 realizations





- A good agreement (less than 0.1 cm) of the absolute mean values of orbit differences in the radial direction for the ITRS 2020-based realizations is obtained.
- SLRF2014 causes larger orbit differences due to extrapolation errors.
- Orbits based on the ITRS 2020 updates/extensions and original ITRS 2020 realizations fit better at the time overlaps of the realizations (before 2021.0), since the same input data were used in their generation. More significant effect of new data is seen mainly at the extension and extrapolation time spans of the realizations (after 2021.0).

Conclusions

- Time series of DORIS and SLR stations have been created at the time span from September 1992 until February 2025 using ITRS 2020 realizations (ITRF2020, DTRF2020, and JTRF2020) and their updates (ITRF2020-u2023, DTRF2020-u2023, and JTRF2020-u2022). Most time series show a good agreement. However, differences in periodical variations and velocities have been found for some stations between various realizations.
- ITRS 2020 realizations and their updates have been evaluated using SLR-observation-based POD of five altimetry satellites (TOPEX/Poseidon, Jason-1/-2/-3, and Sentinel-6A) over the complete time interval from September 1992 until February 2025.
- Generally, a good performance of all ITRS 2020 realizations and their updates for SLR-based POD was obtained.
- ITRS 2020 updates show a better performance than the original ITRS 2020 realizations for the current missions (e.g., Jason-3 and Sentinel-6A), especially at the time spans of ITRS extensions (after 2021.0).
- The results obtained show that regular reprocessing and updates of ITRS realizations are important to guarantee high quality of orbits of Earth orbiting satellites.

References

- Altamimi Z., Rebischung P., Collilieux X., Métivier L., Chanard K. (2023) ITRF2020: an augmented reference frame refining the modeling of nonlinear station motions. Journal of Geodesy, 97:47, DOI: 10.1007/s00190-023-01738-w
- Gross R., Abbondanza C., Chin M., Heflin M., Parker J. (2023) JTRF2020: results and next steps, EGU General Assembly 2023, Vienna, Austria, 24-28 Apr. 2023, EGU23-2117, DOI: 10.5194/egusphere-egu23-2117
- Luceri V. and Pavlis E. (2016) The ILRS contribution to ITRF2014. https://itrf.ign.fr/docs/solutions/itrf2014/ILRS-ITRF2014-description.pdf
- Moreaux G., Lemoine F.G., Zelensky N.P., Moyard J., Couhert A. (2023) DPOD2020: a DORIS extension of the ITRF2020 for Precise Orbit Determination, Advances in Space Research, 72(11):4625-4650, DOI: 10.1016/j.asr.2023.10.006
- Pavlis E. and Luceri V. (2022) The ILRS contribution to ITRF2020. https://itrf.ign.fr/docs/solutions/itrf2020/The_ILRS_contribution_to_ITRF2020_description_2022.09.23.pdf
- Rudenko S., Bloßfeld M., Kehm A., Dettmering D., Zeitlhöfler J. (2025) Impact of SLR long-term mean range biases on SLRF2020-based orbits of altimetry satellites. Earth, Planets and Space, 59, DOI: 10.1186/s40623-025-02183-z
- Rudenko S., Dettmering D., Zeitlhöfler J., Alkahal R., Upadhyay D., Bloßfeld M. (2023) Radial orbit errors of contemporary altimetry satellite orbits. Surveys in Geophysics, 44, 705-737, DOI: 10.1007/s10712-022-09758-5
- Seitz M., Bloßfeld M., Angermann D., Glomsda M., Rudenko S., Zeitlhöfler J., Seitz F. (2023) DTRF2020: ITRS 2020 realization of DGFI-TUM (data). Zenodo, DOI: 10.5281/zenodo.8220524

Acknowledgements

This study was partly supported by the Deutsche Forschungsgemeinschaft (DFG) within the project „Exploitation of the Potential of the SLR-tracked altimetry and GNSS satellites for determination of global geodetic parameters (PotS)” (DFG project number 535929798).