Evaluation of ITRF2014 Solutions

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Introduction

For the most recent International Terrestrial Reference Frame (ITRF) realization three insitutions have provided solutions. They significantly differ in the way how they have been generated and in their parametrizations:

- Deutsches Geodätisches Forschungsinstitut at TU Munich (DGFI-TUM, Germany), (Seitz et al. 2016)
  DTRF2014: based on a classical modelling of time series by station coordinates and linear velocities (after correcting for loading effects)
  DTRF2014L: corrections for atmospheric pressure loading and hydrological effects are reapplied
- Institut national de l'information géographique et forestière (IGN, France) (Altamimi et al. 2016)
  ITRF2014: based on coordinate, linear velocities, and empirical post-seismic deformation corrections (together with annual/semi-annual periodic functions in the background)
  ITRF2014P: periodic functions recovered
- Jet Propulsion Laboratory (JPL, USA) (Wu et al. 2015)
  JTRF2014: based on a filter approach

The authors are grateful to the groups for providing their reference frame solutions and accompanying information used for this evaluation study. Thanks go in particular to Z. Altamimi (IGN, France), C. Abbondanza (JPL, USA) as well as M. Bloßfeld and M. Seitz (DGFI-TUM, Germany).

Background on the GNSS Data Processing

Consistent GNSS solutions have been established for each of the five reference frame coordinate sets. They were derived from an identical set of normal equations where the IGS08-ANTEX antenna phase center corrections were still used. Consequently, the scale for these solutions is consistent to the repro2 solution of the International GNSS Service (IGS) and therefore with the reference frame solutions. The modelling of the GNSS data is derived from the processing standards of the CODE analysis center (Center for Orbit Determination in Europe) of the IGS as they were used in summer 2015 (Dach et al. 2016a).
According to the practice within the IGS, a no-net-translation condition has been applied for datum defintion. In this way the center of mass (relevant, e.g., for the satellite orbit modelling) is forced to coincide with the origin of the reference frame solution.

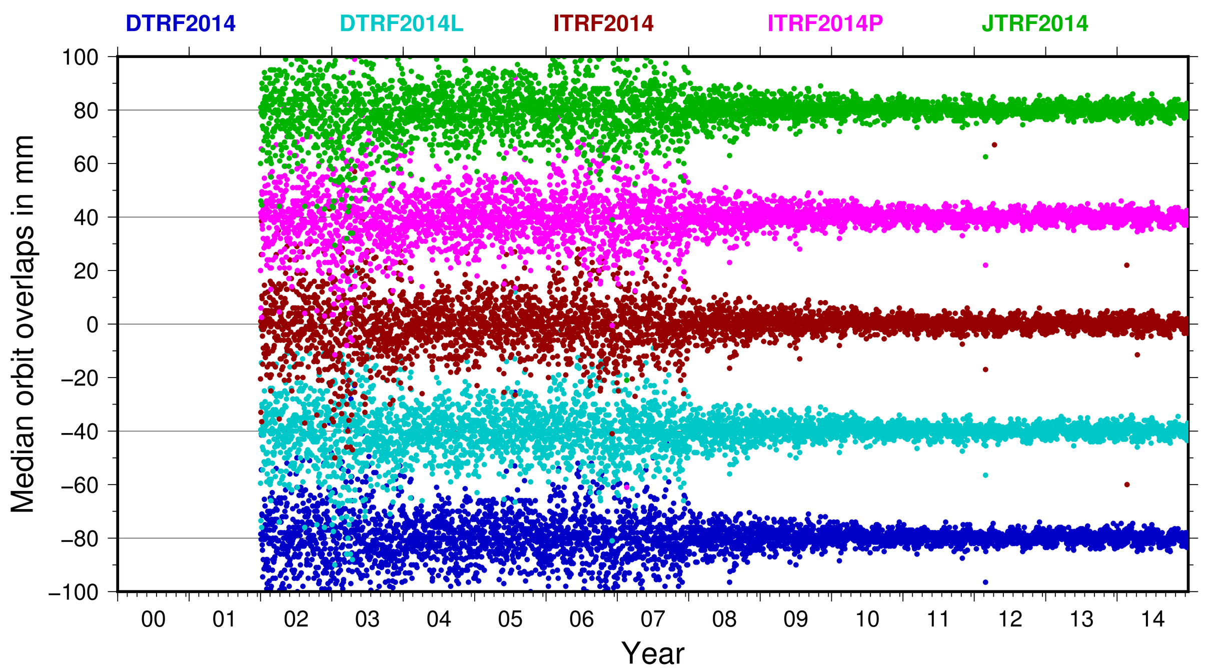


Figure 1: Median of the orbit overlaps for all GLONASS satellites in the Earth-fixed coordinate system, Z-component is shown as example (shifted by 20 mm between solutions).

The orbit overlaps are commonly used to assess the quality of GNSS orbits. The median of the Z-component for all GLONASS satellites are provided in Figure 1, the order of magnitude for the other components is comparable. The improvement of the station network configuration for GLONASS is clearly visible. For GPS satellites the value is of the order of 5 mm as for GLONASS in the last years.

Description of the SLR Solution

Coordinate series for all five reference frame solutions were derived for the SLR stations as well. The positions of the GNSS satellites are extracted from the corresponding solution based on the GNSS microwave measurements (discussed by Dach et al. 2016b). The resulting distances are directly compared with the SLR measurements after applying the usual corrections (e.g., for troposphere). No further parameters (e.g., SLR range biases or coordinates of the SLR tracking stations) were estimated.

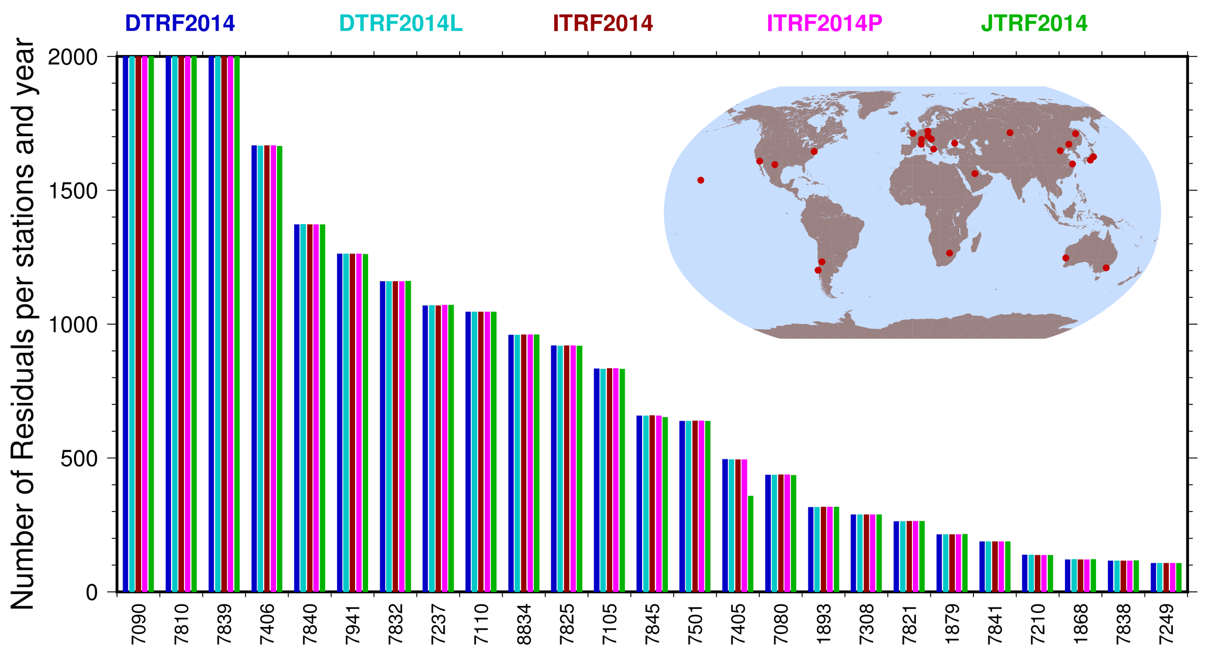


Figure 2: Mean number of SLR observations per year for stations with at least 100 measurements per year on average. The map shows their geographic distribution.

About 10 stations (in the early years even fewer) provide SLR measurements to GPS and GLONASS satellites whereas only sites with coordinates in the related reference frame solutions are considered (station 7406, San Juan, Argentina is not contained in the JPL solution for a certain interval).

SLR Residuals for Satellites

The time series of SLR residuals for one of the GPS satellites are shown in Figure 3 using all five reference frame solutions for the GNSS orbit determination as well as for the SLR analysis. At the beginning of the time series an annual signal is visible that becomes a general scatter in the later years. More stations were able to track GNSS satellites in the second part of the time interval, but the number of stations tracking GNSS satellites during day-time increased as well. Therefore, geomtry effects of the SLR tracking network became less pronounced towards the end of the experiment. At the same time the dependency on the elevation of the Sun above the orbital plane becomes better visible.

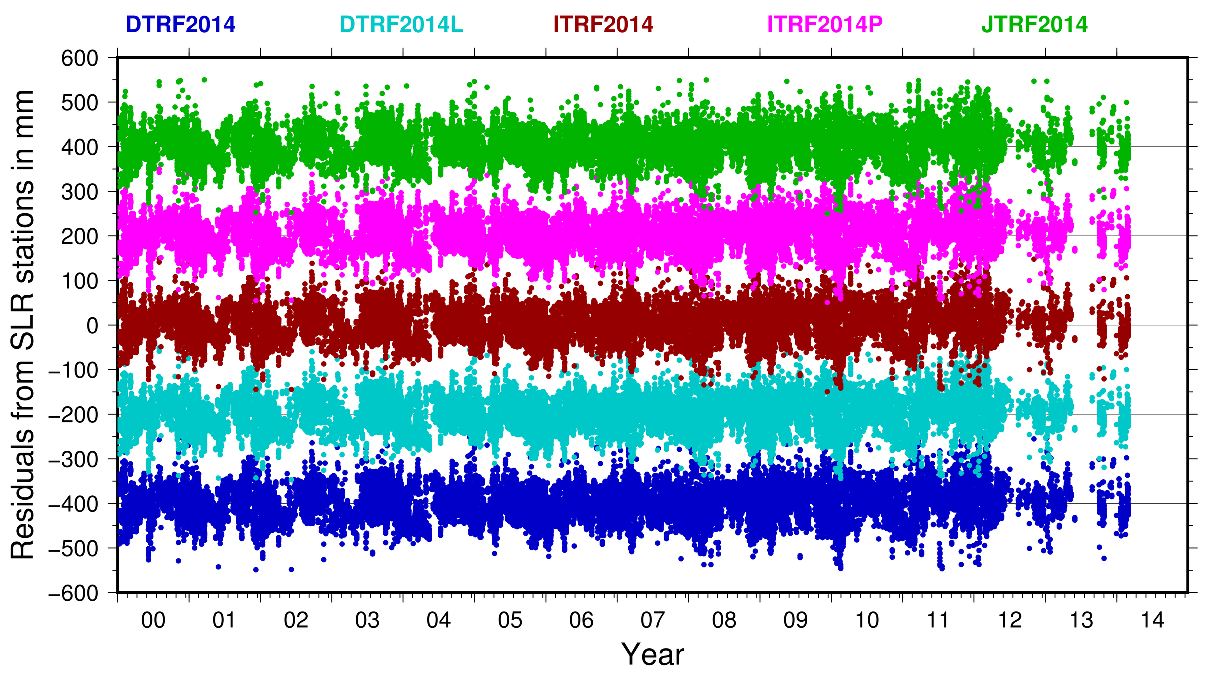
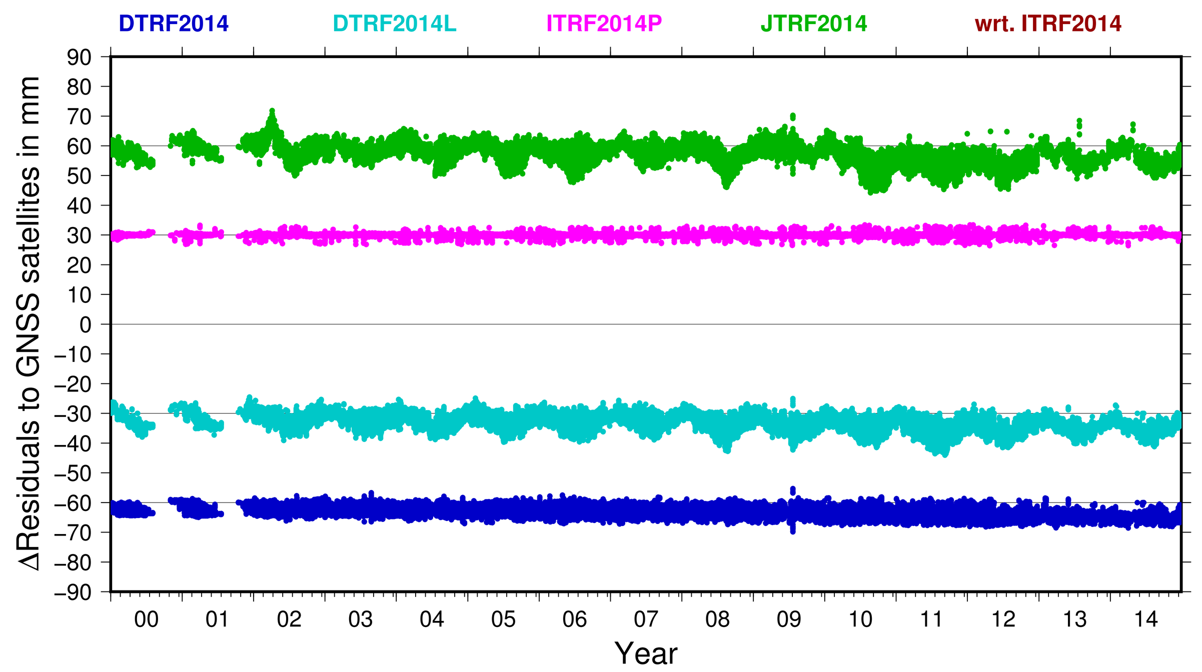


Figure 3: Time series SLR residuals to satellite GPS 036 (shifted by 20 cm between solutions).

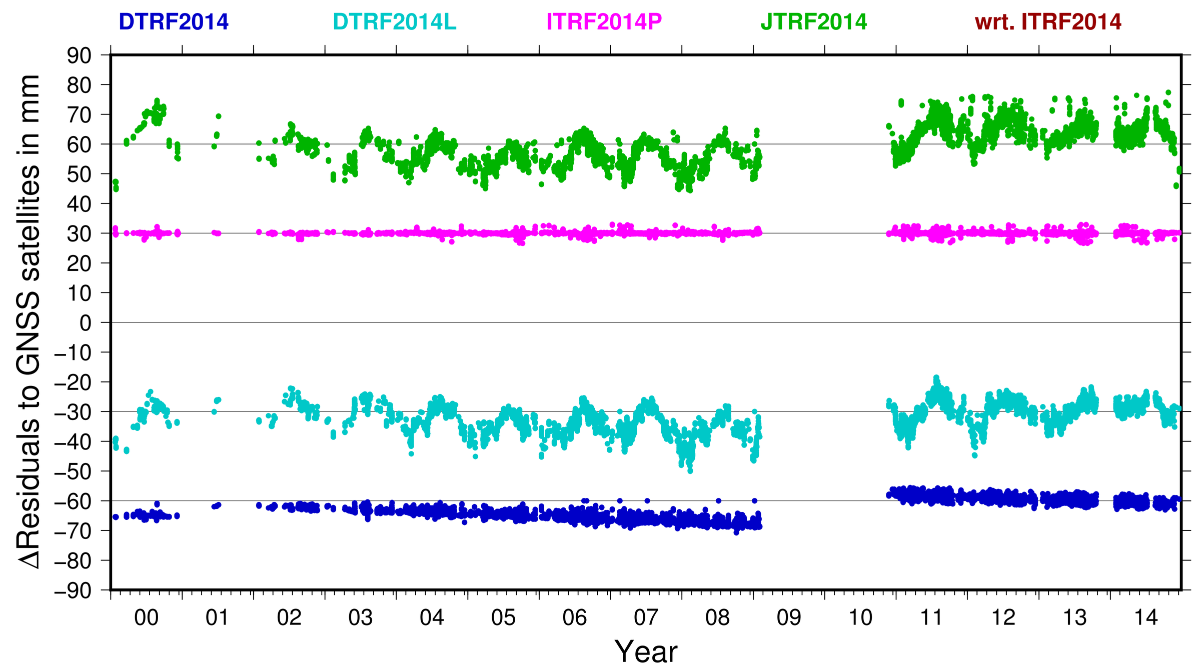
The scatter for the GLONASS satellites is even larger than for the GPS satellite in Figure 3 meaning that the differences between the five reference frame solutions are smaller than the effects from orbit modelling, station-/satellite-specific effect introduced by the SLR technology (as for instance described by Sośnica et al. 2015). Assuming that such systematic effects are the same in all five reference frame solutions, it is worth to study the differences of the SLR residuals.

Comparison of SLR Residuals for Stations

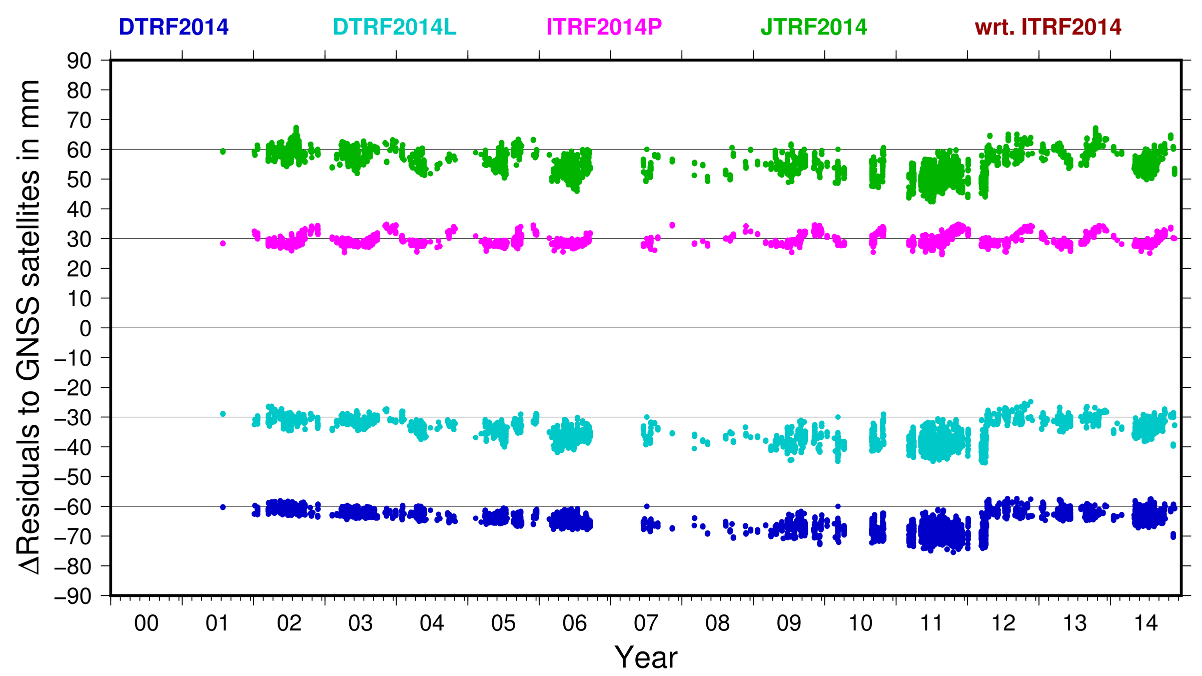
The differences of the SLR residuals for selected stations are shown in Figure 4. One of the solutions is selected as the reference – without any preference (e.g., ITRF2014).



a) SLR station: Yarragadee, Australia (number 7090)



b) SLR station: Wettzell, Germany (number 8834)



c) SLR station: Hartebeesthoek, South Africa (number 7501)

Figure 4: Differences between the SLR residuals obtained from different reference frame solutions with respect to the ITRF2014 solution for selected SLR Stations (shifted by 30 mm between solutions).

For many stations the differences of the residuals show a similar pattern as for station Yarragadee (top plot in Figure 4): consistent residuals between ITRF2014 and DTRF2014 solution; seasonal variations in the differences for solutions containing periodic coefficients (ITRF2014P), loading corrections (DTRF2014L), or allow for empirical variations due to the filter characteristics (JTRF2014). Seasonal variations are usually in phase for all stations in one region (e.g., Europe). For some stations other systematic effects (drifts or discontinuities) are found (as shown for example for Wettzell and Hartebeesthoek in the middle and bottom plots of Figure 4).

Summary and Conclusions

The standard deviations of the SLR resdiuals per station are in the order of magnitude of 3 cm. Comparing the values between the reference frame solutions in Figure 5 they are smallest for the JTRF2014 solutions followed in most cases by the DTRF2014L solution. This is consistent with the distorsion of the network geometry in the GNSS solutions (Dach et al. 2016b).

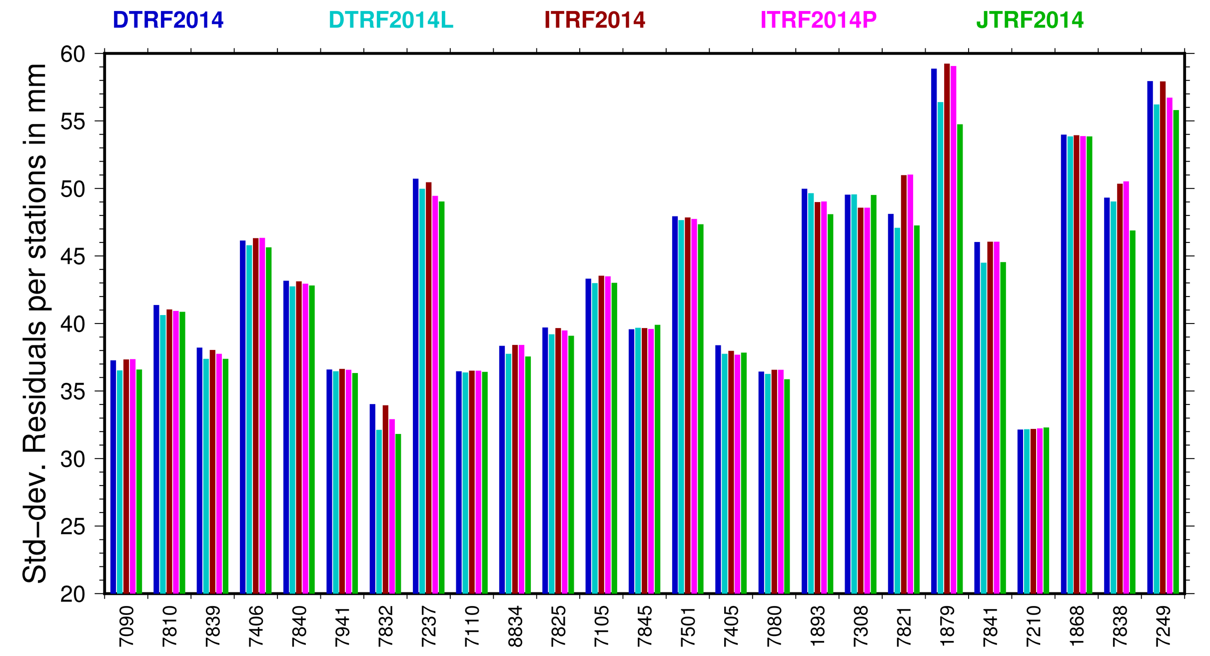


Figure 5: Standard deviations of all SLR residuals to GNSS satellites per station for each of the reference frame solutions. Note that the ordinate axis starts with 20 mm in order to amplify the differences between the reference frame solutions.

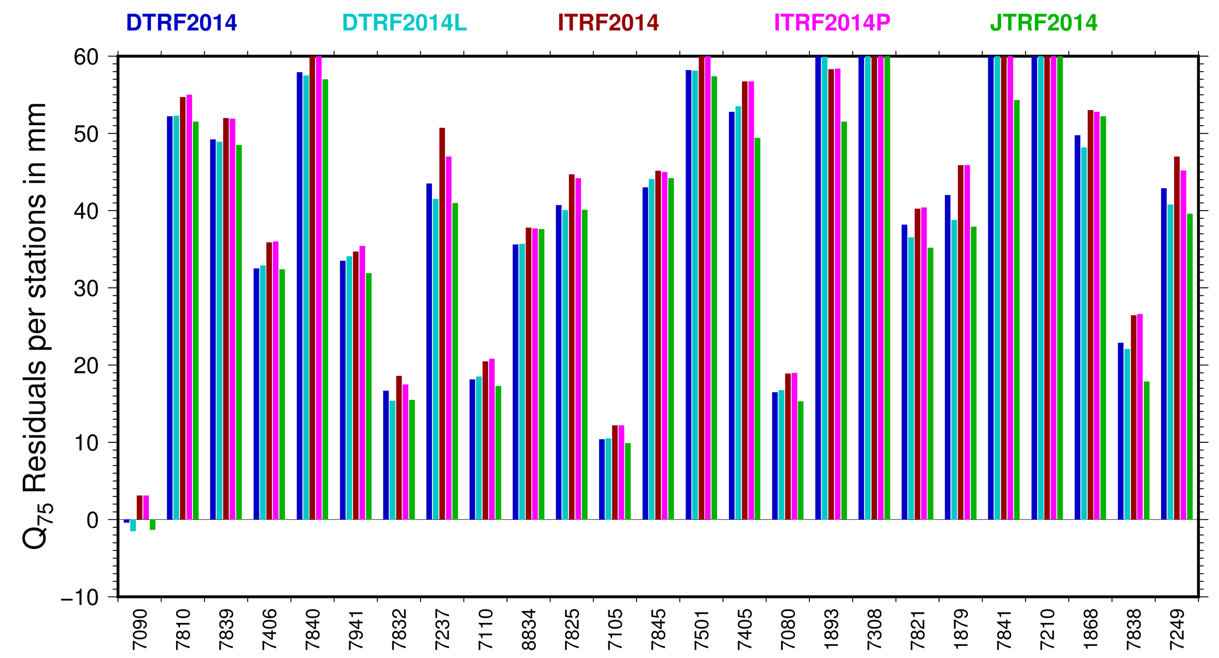


Figure 6: Quantile 75% of all SLR residuals to GNSS satellites per station for each of the reference frame solutions.

The observation from Figure 4 that the SLR residuals for the two ITRF2014 and ITRF2014P solutions are about 3 mm bigger than for the other solutions is confirmed by Figure 6 for most sites. The smaller 75% quantile values in Figure 6 are in general obtained for stations outside of Europe. A network effect, therefore, cannot be excluded.

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