Different realizations of the ITRS and consequences for the terrestrial pole coordinates

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Motivation

In the IERS Conventions 2010, the instantaneous station position $X_I(t)$ is defined to be the sum of a regularized position $X_R(t)$ and n conventional high-frequency reduction terms

$$X_I(t) = X_R(t) + \sum_n \Delta X_n(t)\,. \tag{1}$$

Thereby, $X_R(t)$ is parameterized by a linear model with a position at a reference epoch t_0 and a constant velocity $\dot{X}$. The reduction terms $\sum_n \Delta X_n(t)$ are used to correct for various geophysical and instrumental effects such as Earth tides, ocean loading and thermal deformation of the VLBI antenna. Due to several reasons, these models cannot account perfectly for all non-linear station motions. Additionally, some effects (e.g. atmospheric and hydrologic loading) are neglected so far and therefore, the linear model recommended in the conventions (multi-year reference frame, MRF) is not adequate enough.

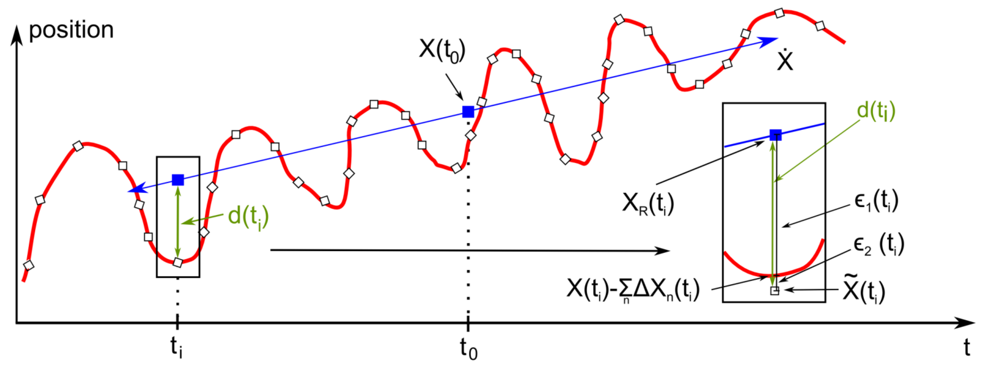
In this study, we present an alternative parameterization of the station coordinates. The regularized station position is estimated frequently with a weekly time interval. This kind of reference frame is called hereafter epoch reference frame (ERF).

Station parameterization

Fig. 1 emphasizes that the alternative ERF approach is a more realistic representation of the "real" (residual) station motion, than using a constant velocity for extrapolation. Therefore, the approximation error ε_1 of the ERF approach is much smaller than the approximation error ε_2 of the MRF approach.

$$X_R(t_i) + \varepsilon_1 = X_I(t_i) - \sum_n \Delta X(t_i) = \tilde{X}(t_i) + \varepsilon_2 \tag{2}$$

Fig. 1: Approximation of the residual station motion by a multi-year and an epoch reference frame. The differences between the two parameterizations are the sum of the two approximation errors.



Procedure

The computation of global terrestrial reference frames at DGFI is based on the level of normal equations. Therefore, time series of the geodetic space techniques GPS, VLBI and SLR are combined. To ensure consistency between the reference frame realizations, both types are based on identical input data (Tab. 1).

Tab. 1: Input data for both reference frame realizations (NEQ denotes normal equation system).

technique	solution type	time span	temporal resolution	reference
GPS	constrained solution	1994-2007	daily (0h to 0h)	Rothacher et al. (2011)
VLBI	constraint-free NEQ	1994-2007	daily (session-wise)	Rothacher et al. (2011)
SLR	constraint-free NEQ	1994-2007	weekly	this study

Fig. 2 shows the processing chain for the MRF and the ERF computation starting from the SINEX files until the final solutions.

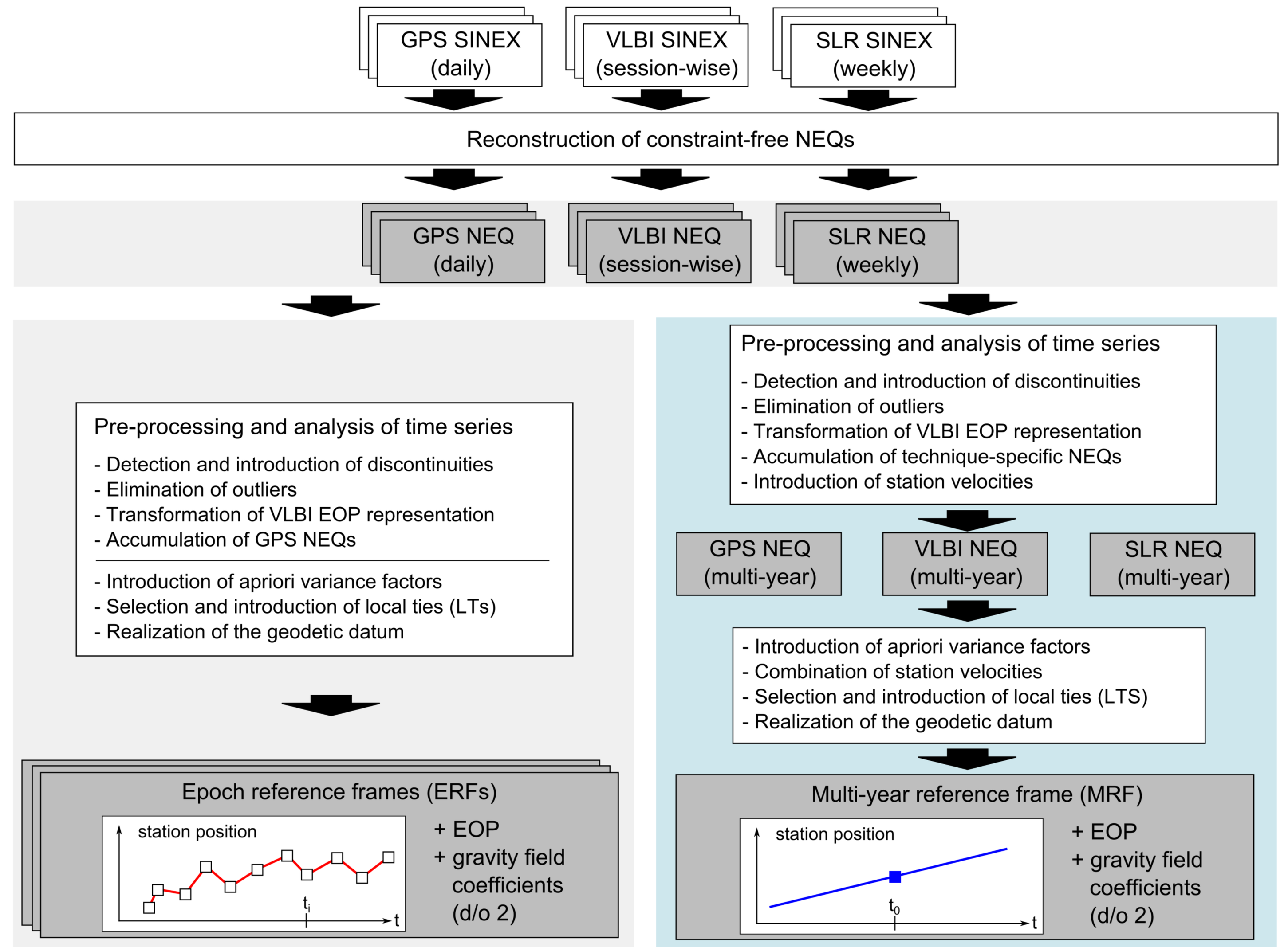


Fig. 2: Processing scheme for MRF and ERF.

Comparison of the station coordinates

For validating the reference frames, the MRF solutions are transformed with a 14 parameter similarity transformation to the DTRF2008 whereas for the ERF validations, 7 parameter similarity transformation were used. All transformation parameters are clearly below the 5 mm level and mostly even below the 1 mm level. This shows the good agreement of all solutions with the official ITRS realizations.

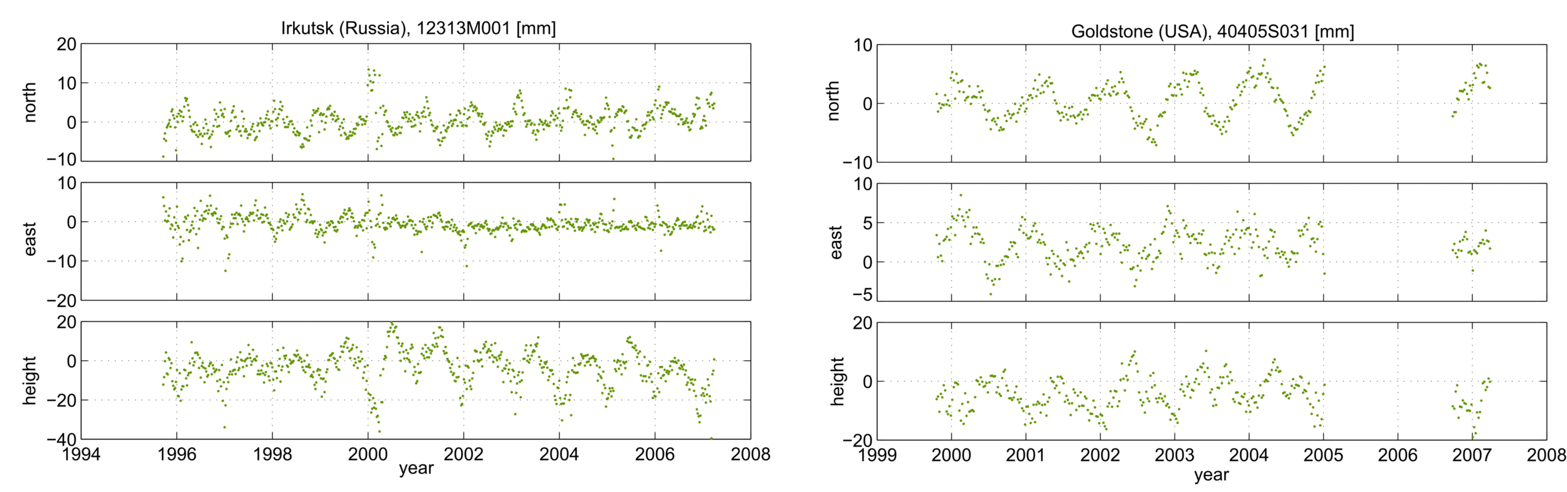


Fig. 3: Residual position differences between the MRF and ERF solutions for the GPS stations Irkutsk (3a) and Goldstone (3b).

The residual station coordinates of the ERF solutions are compared to the MRF coordinates (see Fig. 3). As expected, the dominating signal in the differences has an annual period (due to neglected non-tidal loading effects). Tab. 2 shows the occurrence of annual amplitudes in the position differences of all GPS stations. More than half of the GPS stations show height differences with an amplitude larger than 2 mm.

coordinates	1.0 < a < 2.0	2.0 < a
north	28.9%	17.5%
east	23.5%	6.8%
height	10.9%	53.4%

Tab. 2: Occurrence of annual amplitudes a [mm] in GPS station position differences.

Comparison of the terrestrial pole coordinates

To study the effect of the station parameterization on the terrestrial pole coordinates, two different types of ERFs are computed:

(1) The orientation of the ERF is realized by a NNR condition. This solution is the standard ERF solution (left panel in Fig. 2).

(2) All station coordinates are fixed to their a priori values. This solution is an epoch-wise reconstruction of the MRF solution.

The pole coordinates of these solutions are subtracted from the MRF solutions. Fig. 4 shows the amplitude spectra of the GPS-only and SLR-only differences.

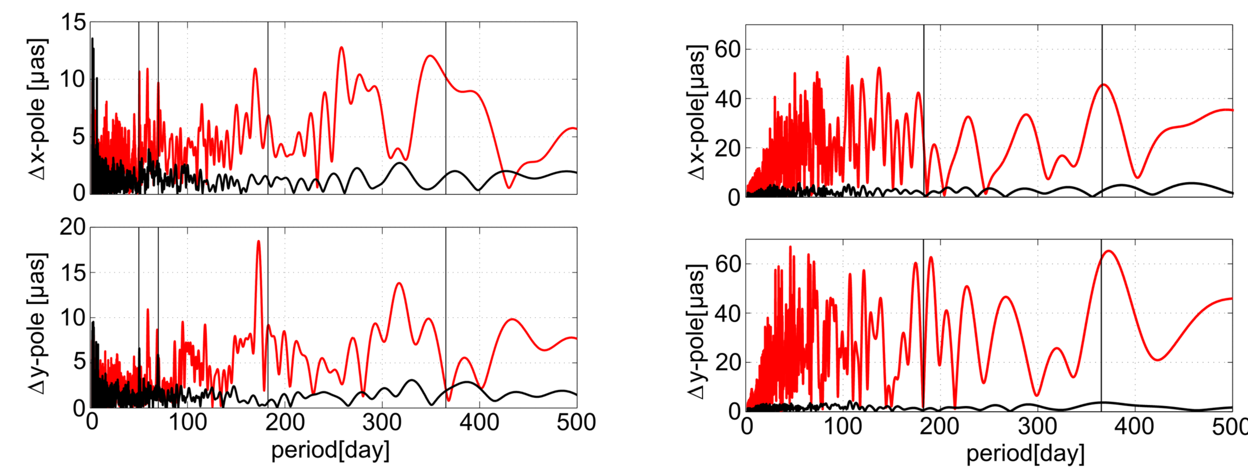


*Fig. 4: Amplitude spectra of the time series of differential terrestrial pole coordinates of the solutions **(1)** and **(2)**. (left panels) GPS-only differences, (right panels) SLR-only differences.*

As it was expected, the solutions **(2)** show no significant signals in the pole differences. However, if the station coordinates are estimated in the ERFs **(1)**, the pole coordinates are affected with periodic signals up to 0.6 mm in the GPS-only differences and 2.0 mm in the SLR-only differences w.r.t. the MRF EOP series.

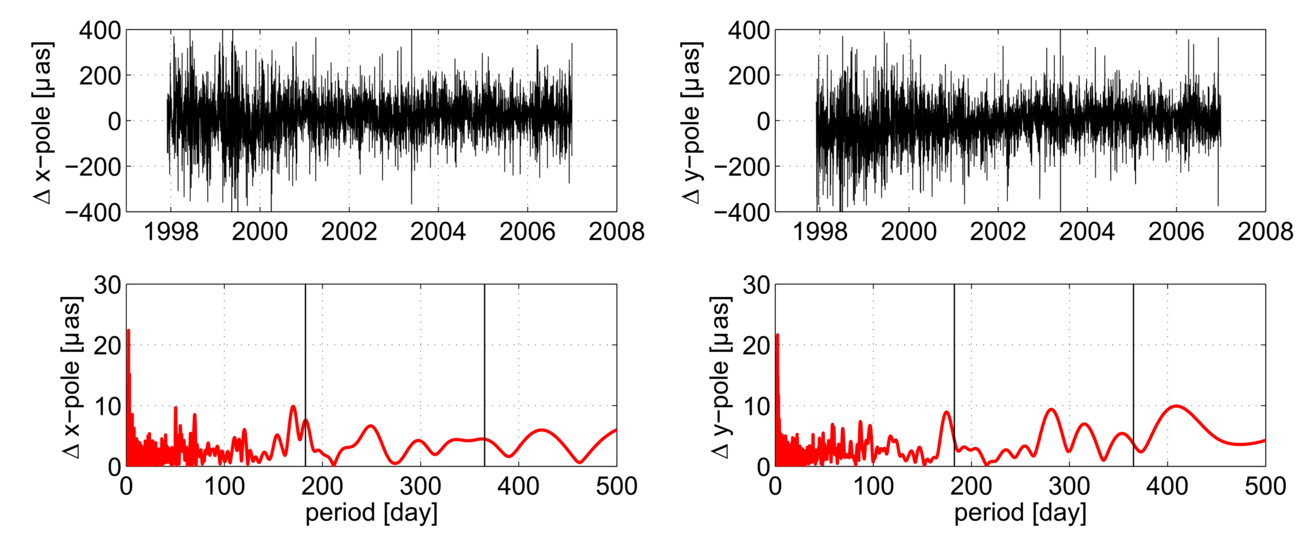


Fig. 5: Differential time series of pole coordinates obtained from the combined solution (upper part) and their amplitude spectra (lower part).

Fig. 5 shows the differences of the combined ERFs of solution type **(1)** and their amplitude spectra. For the combined ERFs, the periodic differences in the pole coordinates w.r.t. the combined MRF are below 0.3 mm. The small amplitudes can be explained by the fact, that the combined solution benefits from the combination of the techniques but also is partly dominated by GPS.

Conclusions

In this study, an alternative realization of the ITRS is presented. The computation of the MRF and the ERF solutions is based on identical input data and was done following the recommendations of the IERS. To quantify the effect of non-linear station motions on the terrestrial pole coordinates, the differences in the pole coordinates are analyzed. The results show that the effect of the station coordinate parameterization on the pole coordinates is less than 0.3 mm in the combined solution but of periodic nature.

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