Why do we need epoch reference frames?

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Motivation

Current ITRS realizations are long-term reference frames (with coordinates and constant velocities), which reflect only secular station motions. The effects caused by various anthropogenic and/or geophysical phenomena (e.g., post-seismic deformations, loading, …) can neither be expressed by such a linear model nor be reduced apriori by applying conventional correction models. As a consequence, the ITRF coordinates may not represent the "real" station positions accurately enough (see Fig. 1 and 2). To overcome this deficiency, so-called epoch reference frames are introduced in this poster.

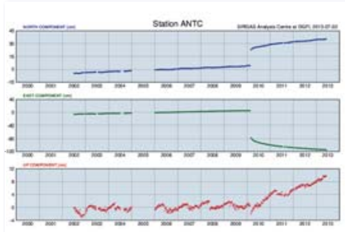

Fig. 1: GNSS station Antofagosta (ANTC), Chile.

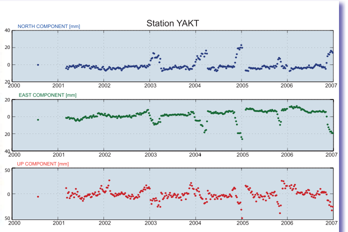

Fig. 2: GNSS station Yakutsk (YAKT), Russia.

Epoch reference frames

The new approach is based on a frequent (e.g., weekly) estimation of station positions and EOP from a combination of epoch normal equations obtained from VLBI, GNSS and SLR observations. The resulting time series of epoch reference frames (ERFs) are studied and compared with the conventional secular approach. The station motion parameterization of both approaches is illustrated in Fig. 3.

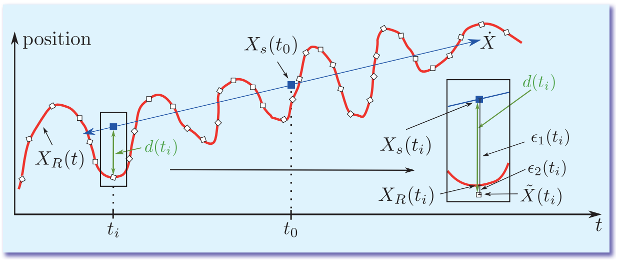

Fig. 3: Station motion parameterization of a secular (blue, continuous linear) and an epoch reference frame (white boxes, discrete). The red line represents the regularized motion of a station position, which is already corrected for conventional models (e.g. Earth tides, ocean tide loading, …).

References

- Bloßfeld, M., Seitz, M., Angermann, D.: Non-linear station motions in epoch and multi-year reference frames, Journal of Geodesy, DOI:10.1007/s00190-013-0668-6, 2013.
- Bloßfeld, M., Seitz, M., Angermann, D.: Epoch reference frames as short-term realizations of the TRS, Recent developments and future challanges, submitted to IAG Symposia Series.
- Rothacher M. et al.: GGOS-D: homogeneous reprocessing and rigorous combination of space geodetic observations. Journal of Geodesy 85(10): 679-705, DOI:10.1007/s00190-011-0475-x, 2011.

Procedure

The computation of global terrestrial reference frames at DGFI is based on the combination of weekly or daily normal equations of the geodetic space techniques VLBI, SLR and GNSS. To ensure consistency between the classical multi-year (MRF) and epoch reference frames (ERFs), the processing is based on identical input data (Tab. 1). Fig. 4 shows the processing chain for both types of reference frame realizations.

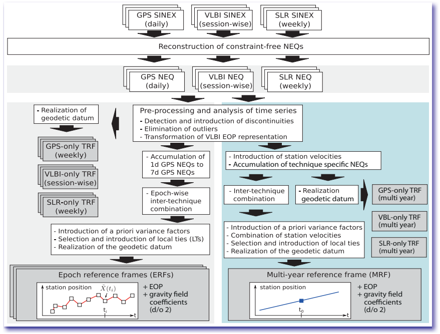

Fig. 4: Processing chain for classical MRF and ERFs.

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

Technique	Solution type	Time span	Temporal solution	Reference
GPS	constrained solution	1994.0 - 2007.0	daily (0h - 0h)	Rothacher et al. (2011)
VLBI	constraint-free NEQ	1994.0 - 2007.0	daily (session-wise)	Rothacher et al. (2011)
SLR	constraint-free NEQ	1994.0 - 2007.0	weekly	Bloßfeld et al. (2013)

Stability of epoch reference frames

We computed ERFs with different time resolutions (7-, 14- and 28-days) to investigate the effect on their datum stability (see Tab. 2). As an example, Fig. 5 shows the time series and the spectra of the x-translations derived from a similarity transformation between the ERFs and the MRF. The stability of the solutions depends strongly on the number, quality and distribution of the local ties. The mean number of local ties for the different sampling intervals is given in Tab. 3.

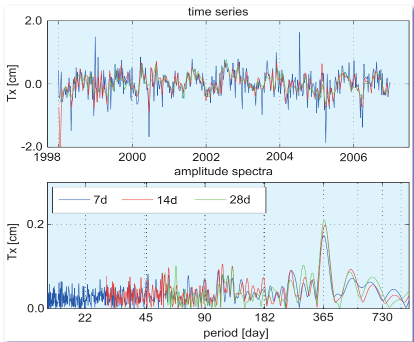

Fig. 5: Time series and spectra of the x-translations for selected GNSS stations of the combined ERFs w.r.t. the combined MRF.

Tab. 2: RMS [mm] of the transformation parameter time series after the reduction of the annual signal (see Fig. 5).

	7d	14d	28d
Tx	3,8	3.2	2.3
Ty	3,9	3.6	2.5
Tz	8,1	6.4	5.6
Rx	1,7	1.6	1.2
Ry	2.2	1.8	1.4
Rz	0.7	0.6	0.3
Sc	3.3	2.6	1.9

Tab. 3: Mean number of different local ties (LT) in the 7-day, 14-day and 28-day solutions.

LT-type	7d	14d	28d
SLR-VLBI	1	2	3
GPS-SLR	9	12	14
GPS-VLBI	8	12	15

Sampling of station motions

As an example, Fig. 6 shows the residual motions for the GNSS station Yakutsk (YAKT), Russia. In total, four different time series are displayed: the daily GPS-only residuals and the three combined ERF residuals (7d, 14d, 28d).

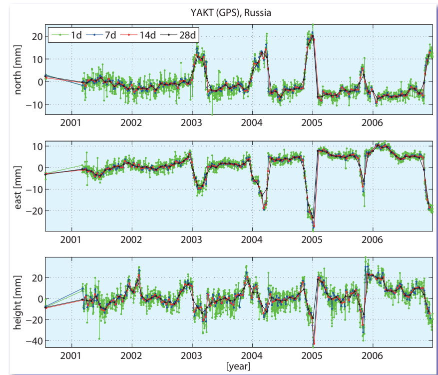

Fig. 6: Time series of residual station motions for GNSS station YAKT obtained from the three different ERF solutions and the daily GPS- only solution (green curve).

Characteristics of different TRF approaches

The characteristics of the ERFs are compared with classical multi-year reference frames (see Tab. 4).

	MRF	ERF
stability	long-term	short-term
parameterization	coord. + const. vel. $x_S(t_0) + \dot{x}\Delta t$	coordinates at epoch t_i $\tilde{X}(t_i)$
estimated positions	precise (formal errors)	accurate (geometry)
position latency	> 2.5 years	few epochs
non-linear station motions	suppressed	frequently sampled
station network	dense	sparse (VLBI, SLR)
number of local ties	high	low, varying

Tab. 4: Characteristics of ERFs in comparison with MRF.

Below we give for both types of realizations some examples for scientific applications, such as the monitoring of various geophysical phenomena, e.g.:

MRF	ERFs
- long-term changes	- 28d: seasonal variations (e.g., loading)
- sea-level rise	- 14d/28d: post-seismic deformations
- secular plate motions	- 7d/14d: abrupt motions, short-term effects

Conclusions

This poster presents a new type of reference frame realizations, called epoch reference frames. This new approach allows to monitor all kind of non-linear station motions, which are caused by various geophysical phenomena and/or other effects. ERFs deliver the „real" site positions at any epoch, which is not the case for secular frames. Another advantage is that the ERFs are available frequently (with short latency) to provide useful coordinates also after abrupt position changes (e.g., due to large earthquakes).

Thus, ERFs are an important supplement to classical ITRS realizations. However, challenges for the epoch combinations are a stable datum realization and the integration of the space techniques due to sparse networks (VLBI, SLR).

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