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GNSS RTK-networks: The significance and issues to realize a recent reference coordinate system

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INTRODUCTION

The upcoming release of the new global reference frame ITRF2013 will provide high accurate reference station positions and station velocities at the mm- and mm/year level, respectively. ITRF users benefit from this development in various ways. For example, this new frame allows for embedding high accurate GNSS baseline observations to an underlying reference of at least the same accuracy. Another advantage is that the IGS products are fully consistent with this frame and therefore all GNSS based zero-difference positioning results (Precise Point Positioning (PPP)) will be aligned to the ITRF2013.

On the other hand the transition to a new frame (or just to a new reference epoch) implies also issues in particular for providers and users of real time positioning services. In this contribution we highlight all significant steps and hurdles, which have to be jumped over when introducing a new reference frame from point of view of a typical regional RTK-reference station network provider.

THE IMPACT OF THE CHOOSEN REFERENCE FRAME ON PRECISE GNSS POSITIONING

A. PROCESSING ETRF COORDINATES

European RTK-networks typically realize either the ITRS or the ETRS89. Both realizations have their advantages and drawbacks, which have to be balanced to guarantee the user-community a largely easy access and utmost accuracy. In case the network is tied to an ITRS realization, ETRF coordinates can be derived in post-processing by following the steps defined in guidelines [1]. The model postulates the use of the precise orbit information provided by IGS, which refers to the current ITRF frame at the epoch of the day.

- The first procedure step contains the propagation from a set of ITRF reference coordinates of sites, which are part of the campaigns´ network and which are avaiable in the current ITRF realization, to the epoch of the GNSS observation.

- Secondly, the motion of the continental plates has to be considered. To express coordinates in ETRS89, the transformation formula, valid for the stable part of the Eurasisan plate is:

$$\boldsymbol{X}^{E}(t_c)=\boldsymbol{X}^{I}_{\boldsymbol{YY}}(t_c)+\boldsymbol{T}_{\boldsymbol{YY}}+\begin{pmatrix}0 & -\dot{R}3_{YY} & \dot{R}2_{yy}\\ \dot{R}3_{YY} & 0 & -\dot{R}1_{yy}\\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0\end{pmatrix}\times\boldsymbol{X}^{I}_{\boldsymbol{YY}}(t_c)\cdot(t_c-1989.0)$$

$X^{E}(t_c)$......Position of a point in $ETRF_{YY}$ at observation epoch t_c

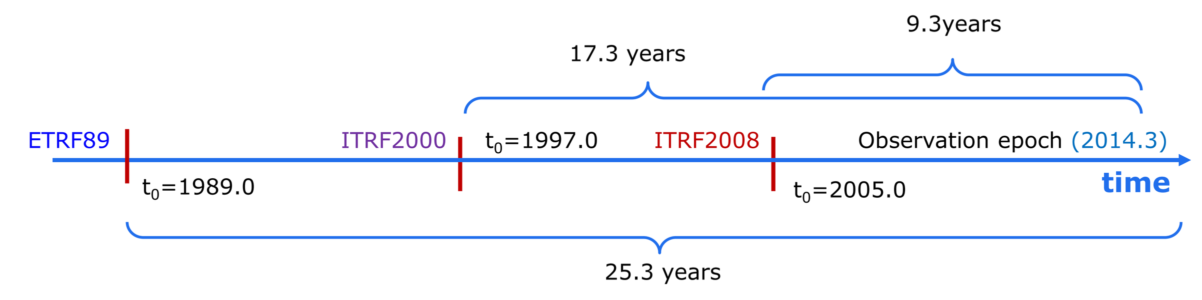
$X^{I}_{YY}(t_c)$......Position of a point in $ITRF_{yy}$ at observation epoch t_c

T_{YY} ....Translation shift between $ITRF_{yy}$ and $ETRF_{YY}$

R_{YY} ....Angular velocity of the Eurasian plate

B. CONCURRENT USE OF DIFFERNET RFERENCE SYSTEMS/-FRAMES

For many technical applications varying ITRF coordinates (epoch of date), which directly map the global tectonics may not be practicable. In contrast ITRF coordinates fixed to a reference epoch or ETRF coordinates are ‚stable in time' and therefore frequently utilized. In Europe the use of the continental reference system/reference frame ETRS89/ETRF2000 is, due to cross-national guidelines, recommended by most national mapping authorities.
The concurrent use of different reference frames and reference epochs to which the satellite coordinates and coordinates of the terrestrial sites are aligned degrades the accuracy of the processed GNSS baselines.
Assuming an approximative annual motion of 2.5 cm for the European plate w.r.t. the ITRS the systematic difference between station coordinates and satellite coordinates in ITRF2008 (either at reference epoch 2005 or epoch of day) are exemplary estimated and visualized below. The resulting coordinate offset on surface on earth corresponds to an orbit error in space. Applying the rule of thumb (Bauersima) the error of the derived baseline length can be obtained.



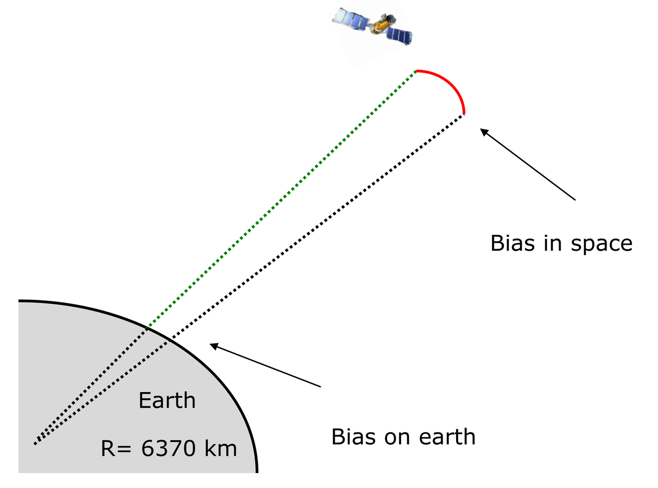


Figure 1

The table below visualizes the inferred coordinate offsets (in space and on earth) as well as the consequential baseline errors (the lenght of the baseline is assumed with 200km) in case the data processing introduces reference site coordinates in ETRF2000 but satellite orbits in ITRF2008 (epoch 2014.3).

	Bias on earth	Bias in space	Baseline error
ETRF2000	63 cm	2.5 m	20 mm
ITRF2000	43 cm	1.7 m	14 mm
ITRF2008	23 cm	0.9 m	7 mm

RTK-NETWORKS IN AUSTRIA

In Austria several real time positioning services are active, operated either by the national Mapping authority or private companies. An example of a typical RTK-network, which covers whole of the Austrian territory is illustrated in Figure 2.

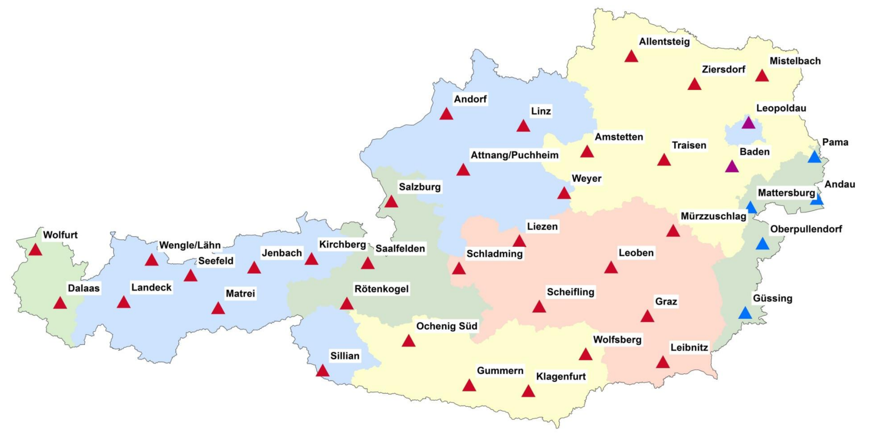


Figure 2

EPOSA (Echtzeit Positionierung Austria)-netwok

TRANSITION TO A NEW FRAME

Recent PPP techniques allow for a determination of station coordinates at the 1-2 dm level almost close to real-time. The underlying reference frame is the most recent ITRF (epoch of date). Therefore coordinate offsets inferred due to out-dated ITRS realizations (or ETRS89 realizations) of the reference network are easy detectable by an growing number of users employing ‚single-point'-positioning techniques. The transition to a new frame is therefore a must for the RTK-provider. But this implies also issues for providers and users of this real time positioning services. The following steps are a minimum list to be considered.

- Calculate coordinates of the network sites within the new frame (or just a new epoch) derived from data of an observation period of at least a couple of weeks) and readjust the coordinates of the sites in your network software (optimally utilizing a parallel test environment).
- Update the transformation information from the homogenous GNSS coordinate frame to the national datum. This implies for RTK 3.1 users also the update of the gridded information describing the distortions of the national control coordinates.
- Extensive testing phase within all areas of the providers service area.
- Information of clients about changes and significant adjustments (at least 4 months in advance).
- Establish a web application for coordinate transformation between old and new frame.
- Establish a regional velocity model of reference sites (w.r.t. to ITRF and ETRF). For example see site motion map of Eastern part of Austria (velocities are calculated from 4 years GNSS data) -> the output is of course also of interest for geodynamic investigations.

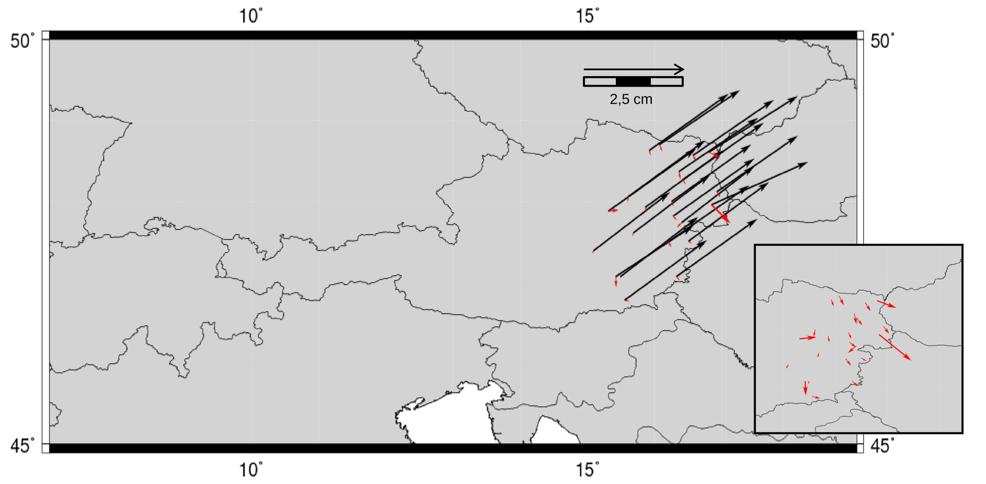


Figure 3

REFERENCES

[1] Boucher C., Altamimi Z. (1993-2011): Memo: Specifications for reference fixing in the analysis of a EUREF GPS campaign, available from http://etrs89.ensg.ign.fr/memo-V8.pdf.