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Reference frame definition in a regional GNSS network: Global or regional?

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1. Introduction

Regional GNSS networks are used today for tectonic studies as well as for reference frame densifications. With the improving computing facilities and GNSS data analysis software, more people have now the possibility to also process a global GNSS network. Therefore now the question is posed: "**Is it necessary to add global GNSS stations to a regional GNSS network in order to reliably fix the reference frame?**".

The method we use to express our global or regional GNSS network solution in a conventional reference frame is the **minimum constraint approach**. The reason for this choice is that minimal constraints preserve the original characteristics of the solution [Altamimi 2003] and do not deform the original network geometry. The minimum constraints (MC) approach can be summarized as follows [Altamimi et al. 2007b]:

The linearized form of the standard 7 helmert parameter transformation between two reference frames X1 and X2 can be written as:

$$X2 = X1 + A\theta \quad \text{with} \quad A = \begin{pmatrix} 1 & 0 & 0 & X1 & 0 & -Z1 & Y1 \\ 0 & 1 & 0 & Y1 & Z1 & 0 & -X1 \\ 0 & 0 & 1 & Z1 & -Y1 & X1 & 0 \end{pmatrix}$$

and $\theta = {}^T(TX \;\; TY \;\; TZ \;\; D \;\; RX \;\; RY \;\; RZ)$ with (TX, TY, TZ) the 3 translations, D the scale factor and (RX, RY, RZ) the 3 rotations.

The minimum constraint approach consists in expressing X1 and X2 in the same frame (i.e. θ = 0).

A least squares adjustment yields solution for θ as follows: $\theta = (A^T A)^{-1} A^T (X2 - X1)$ and consequently the MC condition can be imposed by adding the following constraint: $0 = B(X2 - X1)$ with $B = (A^T A)^{-1} A^T$

The 7 columns of the design matrix A correspond to the 7 datum parameters. Therefore this matrix can be reduced to those parameters which need to be defined.

Two conventional reference frames are commonly used: ITRF2005 [Altamimi et al. 2007a] and IGS05 [Ferland 2006]. The GNSS contribution to the ITRF2005 was based on relative antenna phase center models. To accommodate more recent GNSS data processing using absolute antenna phase center variations, the IGS05 was created by correcting the ITRF2005 for station-dependent coordinate differences between the absolute and relative antenna phase center models. After that, this so-called "corrected ITRF2005" was re-aligned with the ITRF2005 through a 7-parameter transformation (Ferland 2006) using more than 130 IGS reference frame stations to form the IGS05. Consequently, on the **global level, IGS05** and **ITRF2005** are the **same frame. However, the question we pose is if this is also the case on the regional level.**

We will compare the differences between the coordinates obtained when processing a **regional** network with respect to the coordinates obtained when the regional network is extended with a set of well-chosen **global** IGS reference stations.

In addition, we will also investigate the differences between the coordinates obtained when tying the network to the **IGS05** [Ferland 2006] wrt to the **ITRF2005** [Altamimi et al. 2007a].

2. Methodology

Networks

We have processed two GNSS networks:

- A **regional network** (Figure 1): 42 GNSS stations (part of the EUREF Permanent Network) of which 24 also belong to IGS05.
- A **global network** (Figure 2): the regional network extended with 47 global IGS05 reference stations.

Figure 1: Regional Network

Data Processing

~ 1 year of data: from GPS week 1400 (Nov. 2006) to week 1445 (Sep. 2007)

- ionosphere-free double differences in a network approach,
- BERNESE software version 5.0 [Dach et al., 2007],
- absolute antenna phase center corrections,
- IGS final orbits and ERPs,
- Troposphere: wet-Niell mapping function, 1h ZTD corrections, daily horizontal gradient parameter,
- Baselines: regional network baselines are saved and introduced as a priori to process the global network.

⇨ Daily Free network SINEX.

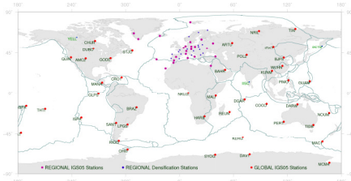

Figure 2: Global Network

Reference Frame Realization

The daily Free Network solutions outcome of the Bernese 5.0 are the basis for all the following computations.

The **combination software CATREF** [Altamimi et al.2007b] is used to:

- express the GNSS daily solutions in the conventional reference frame under minimum constraints,
- combine daily Free Network SINEX in order to obtain:
  - weekly station positions,
  - cumulative station positions.

These solutions are expressed in a conventional reference frame (**IGS05 or ITRF2005)** under **minimum constraints** using a subset of reference stations:

- The MC are applied with conditions on **translation**, **rotation** and **scale**.
- The stations showing large discrepancies (more than 7 mm in horizontal components and more than 1.5 cm in Up component) with the 2 reference solutions (IGS05 and ITRF2005) are not used as reference stations.

As computations cover only ten months, velocities are not reliable and are removed from the solution.

Of course, all the comparisons are done at the same epoch, which is the mean epoch of the computations for cumulative solutions.

This poster will investigate the sensitivity of the stations positions:

- when expressing the GNSS solution in **ITRF2005** instead of **IGS05**,
- when processing a **global** instead of a **regional** network,
- when using different sets of **reference stations**.

3. IGS05 vs ITRF2005

Comparison of IGS05 and ITRF2005:

Today two global reference frames are made available: IGS05 and ITRF2005. The position differences between both are given in Figure 3.

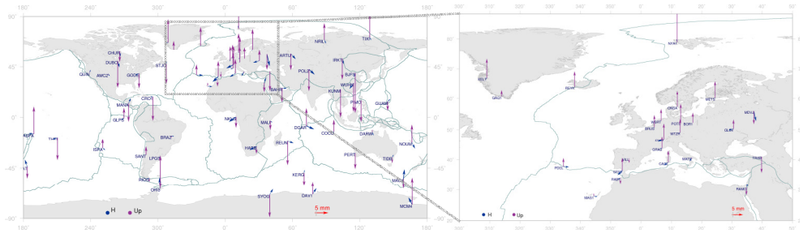

Figure 3: Position differences between IGS05 and ITRF2005 for the stations used in the computations.

Comparison of our cumulative global/regional solutions expressed in IGS05 and in ITRF2005 :

As explained in the introduction, both frames are **equivalent** on the **global level**.

⇨ confirmed by sub-mm coordinate differences (Figure 4) between two global cumulative solutions, where one is tied to the IGS05 and the other to the ITRF2005.

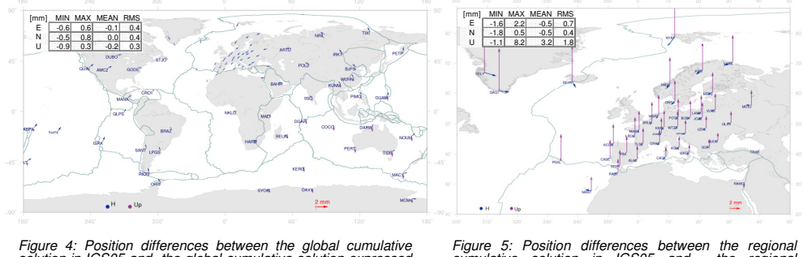

Figure 4: Position differences between the global cumulative solution in IGS05 and the global cumulative solution expressed in ITRF2005

Figure 5: Position differences between the regional cumulative solution in IGS05 and the regional cumulative solution expressed in ITRF2005

However, at the **regional level**, the situation is different. Figure 5 shows the coordinate differences between the regional cumulative solution tied to IGS05 and the regional cumulative solution tied to ITRF2005.

⇨ differences in station coordinates reach up to **8.2 mm in the vertical**, with a mean **bias** of about **3 mm**. Comparison with Figure 3 could explain this effect.

5. Conclusions

We have investigated different ways of fixing, using minimum constraints, the datum of a GNSS network computed originally as a free network. We have distinguished between regional and global solutions. We have used both the IGS05 and ITRF2005 as reference datum.

IGS05 vs ITRF2005:

- Comparison of two global solutions expressed in ITRF2005 or IGS05 (using MC on translations, rotations and scale with CATREF): no significant differences. The two frames are **identical in the global sense** (Figure 4).
- Comparison of two regional solutions expressed in ITRF2005 or IGS05 (using MC on translations, rotations and scale with CATREF): due to the **regional effect** in Europe **between IGS05 and ITRF2005** (Figure 3), differences reach up to 8 mm in the vertical and show a **tilt** and a **bias** of about 3 mm (Figure 5).

Regional vs Global:

- No significant deformation of the cumulative solutions.
- Comparison between regional and global position solutions depends on whether the solution is tied to IGS05 (Figure 8) or to ITRF2005 (Figure 9).
- Difference between global and regional station position solutions is strongly dependent on the reference stations used to define the geodetic datum (Figures 6 and 8 or Figures 7 and 9).
- In a regional network, the datum definition is highly sensitive to the reference frame and reference stations used.
- In a regional network, a special care has to be paid to the selection of the fiducial stations, especially the border stations.
- In addition, it is **not possible to define** a standard set of values for the 7 **helmert parameters** which can be applied to **transform a regional solution into a global solution**.

In our tests, **different regional solutions can show biases (up to the cm-level) with respect to each other**.

Our future work will, using a longer time span, analyze also the effect on site velocities.

4. REGIONAL vs GLOBAL

Is it necessary to add global GNSS stations to a regional GNSS network to reliably fix the reference frame ?

Comparison of the regional and global solutions:

we have compared the coordinates of:

- the global cumulative solutions, considered as the ground truth,
- the regional cumulative solutions.

Regional and global solutions have been computed in such a way that the analysis-related coordinate differences are minimized (see Section 2 "Methodology").

Both solutions are expressed in IGS05 and in ITRF2005 using minimum constraints.

First step: all the European IGS05 stations are taken as reference station, see Figure 6 and 7.

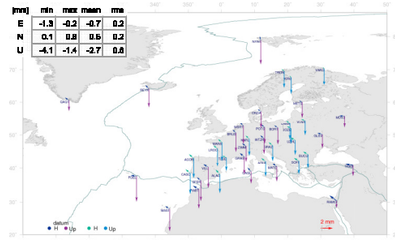

Figure 6: Difference in positions between the global cumulative solution in IGS05 and the regional cumulative solution in IGS05

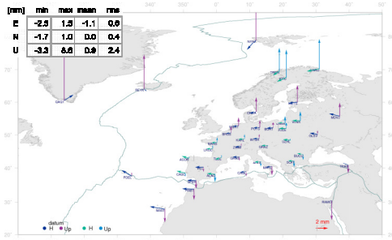

Figure 7: Difference in positions between the global cumulative solution in ITRF2005 and the regional cumulative solution in ITRF2005

In the case of ITRF2005, the station NYA1 shows a difference with ITRF2005 of 2.2 cm in the up component.

Second step: After rejecting the station NYA1, we obtain Figure 8 (IGS05) and Figure 9 (ITRF2005).

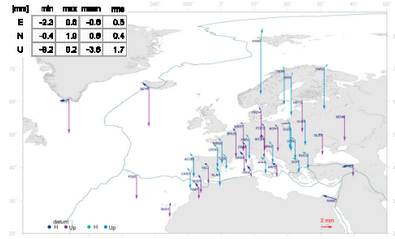

*Figure 8: Difference in positions between the global cumulative solution in IGS05 and the regional cumulative solution in IGS05 **without NYA1***

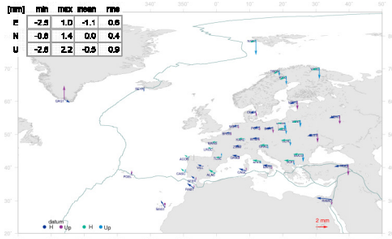

*Figure 9: Difference in positions between the global cumulative solution in ITRF2005 and the regional cumulative solution in ITRF2005 **without NYA1***

At the regional level, due to these different behaviors, the choice whether to tie a network to the IGS05 or ITRF2005 is an important choice:

- Case IGS05: the position differences between the regional solution and the global solution reach up to 9 mm in the up component with a tilt and a bias of about 3 mm (Figure 8).
- Case ITRF2005: pretty good agreement between regional and global ITRF2005 solutions if outlier NYA1 is rejected of the fiducial station list.

The datum definition is highly sensitive to the reference frame and reference stations used. Consequently, in our tests, **different regional solutions can show biases (up to the cm-level) with respect to each other**.

Border stations play a crucial role in the datum definition. As reference station, they have a non negligible impact on the coordinates of the other stations in the network. Moreover, they are the most sensitive to the datum definition.

Definition of a standard set of 7 helmert parameters to transform regional into global solution ?

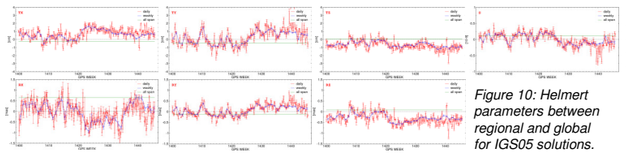

Figure 10: Helmert parameters between regional and global for IGS05 solutions.

	TX	TY	TZ
RX		0.8	
RY	-0.8		0.7
RZ		-0.7	
S	-0.5		-0.6

Table 1: Correlation between highly correlated (more than 0.5) parameters

Figure 10 shows the 7 parameters between the regional and the global network for the daily, weekly and cumulative solutions tied to IGS05. These parameters have no physical meaning as they are highly correlated (Table 1). Nevertheless, these graphs show that it is not possible to define a standard value for the 7 parameters which can be applied to transform a regional solution into a global solution.

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