Results and Comparisons of a Local and a Regional Reprocessed GNSS Network

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Abstract
This paper compares the results obtained from two homogenously reprocessed GNSS networks which are tied to a global conventional frame, namely the ITRF2005, using minimal constraints. The first network (222 stations) comprises the full EUREF Permanent Network (EPN). The second network is a smaller local network consisting of the national dense Belgian network and 38 EPN stations located in and around Belgium. We show that in reason of the network effect, it is impossible to mix the results of both cumulative solutions. Indeed, the position differences between both networks tied to the ITRF2005 using minimal constraints can reach 6.3 mm for the horizontal and 9.6 mm for the vertical. For the velocities, the differences reach 0.5 mm/yr for the horizontal and 2.4 mm/yr for the vertical. In order to mitigate these differences and to obtain a consistent set of station positions and velocities, the two solutions were combined on a weekly basis and then the combined weekly solutions were stacked to obtain a cumulative solution expressed in ITRF2005. The results demonstrate that the network effect on the local solution can be eliminated. This approach is valid thanks to the agreement between the weekly polyhedrons of both solutions as the same data analysis strategy was applied during both reprocessing.

Keywords: Geodesy; Reference Frame; Methodology; GNSS; Velocity Field;

1. Introduction

In a previous study, Legrand and Bruyninx (2009) showed that the network effect can induce biases in the position solutions obtained from a regional GNSS network when tying it to a global conventional frame using minimal constraints (Altamimi 2003). In comparison, global solutions are much more stable and agree within the 2 mm-level. In a subsequent study (Legrand et al, 2010) based on ten years of weekly global GPS solutions, the same problem was evidenced for the velocity solutions. These investigations confirmed that the regional velocity fields show systematic effects with respect to the global velocity field with differences reaching up to 1.3 mm/yr in the horizontal and 2.9 mm/yr in the vertical depending on the geographical extent of the network and the set of regional reference stations. Consequently, it was demonstrated that, in regional networks, the network effect has a significant influence on the estimated velocity field and consequently might cause wrong geodynamical interpretations.

2. Data and Networks, GNSS Reprocessing

The Royal Observatory of Belgium has performed two homogeneous reprocessings. On one hand, the entire EUREF Permanent Network (EPN, Bruyninx, 2004) from 1997 until now, containing 222 stations was reprocessed (Fig. 1). On the other hand, the dense Belgian national GPS network together with 38 EPN stations in and around Belgium (from 1996 until now) was used. This last network, considered as a local network in this study, contains 98 stations (Fig. 2). Both networks have been computed using the Bernese 5.0 software (Dach et al. 2007) and following the EPN Local Analysis Centre guidelines (http://www.epncb.oma.be/_organisation/guidelines/guidelines_analysis_centres.php). Then, CATREF software (Altamimi et al. 2007b) was used to compute weekly SINEX solutions from the daily SINEX solutions, but also to combine the daily or weekly SINEX solutions in order to obtain cumulative position/velocity solutions.

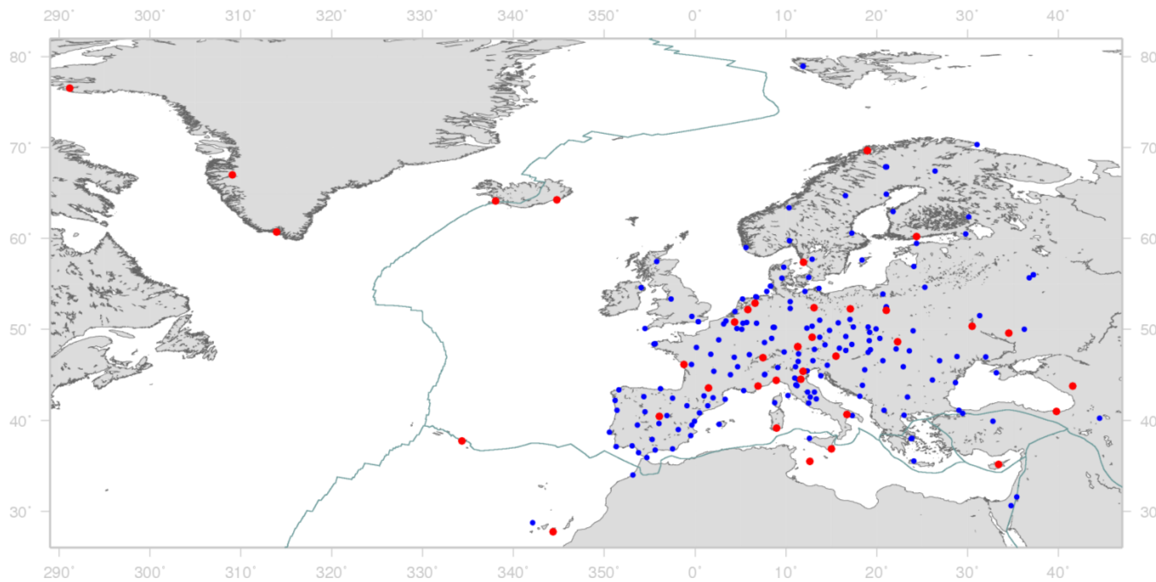

Fig. 1: Regional network. Reference stations used to express the regional solution in ITRF2005 are displayed in red.

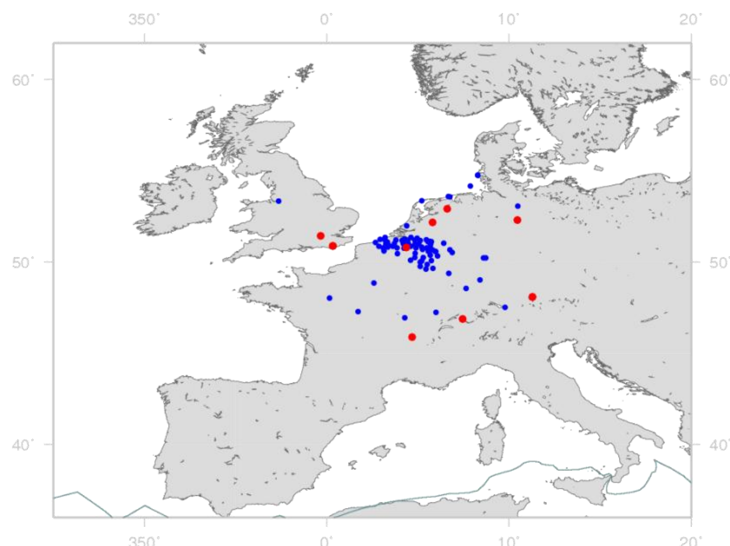

Fig. 2: Local network. Reference stations used to express the local solution in ITRF2005 are displayed in red.

Fig. 3 shows a first result of the data analysis: due to the smaller network size and the fact that generally the quality of the local stations is slightly better than the stations of the regional network, the weekly RMS from the local reprocessing are smaller than from the regional reprocessing. For the regional network, the averaged weekly RMS is 3.4 mm for the up component and 1.3 mm for the horizontal components, while it is 1.7 mm for the up component and 0.8 mm for the horizontal components in the case of the local network.

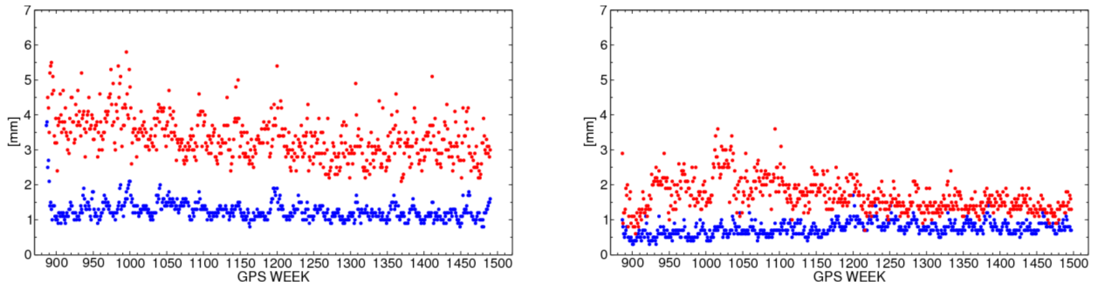

Fig. 3: Weekly RMS (horizontal in blue and vertical in red) of the regional network (left) and the local network (right).

The estimated long-term regional and local solutions (station positions and velocities) are tied to the ITRF2005 (Altamimi et al. 2007a) under minimal constraints using a selected set of reference stations. It is well known that there are too many degrees of freedom when using the translations, the rotations and the scale with a small network and that consequently the parameters are correlated. For that reason, several types of minimal constraints have been investigated: a) 14 parameters (the 3 translations, the 3 rotations, the scale and their rates), b) 12 parameters (the 3 translations, the 3 rotations and their rates), c) 6 parameters (the 3 translations and their rates). The tests showed no significant influence on the conclusions that will be drawn later in the paper. For that reason, only one type of constraints will be presented in the following, namely the minimum constraint method using 14 parameters.

3. Comparison between Local and Regional reprocessed cumulative solutions

3.1. Reference stations and agreement with ITRF2005

The solutions (local and regional) have been expressed in ITRF2005 under minimal constraints using 14 transformations parameters (translations, rotations, scale and their rates) using a selection of ITRF2005 reference stations. In both cases, a maximum number of reference stations showing a good agreement with ITRF2005 and having at least 3 years of data in the solution and in ITRF2005 were retained. Fig. 1 shows the 37 reference stations (in red) used to tie the regional solution to ITRF2005 and Fig. 2 shows the 9 reference stations used to tie the local solution to ITRF2005. As shown in Table 1, thanks to the smaller number of reference stations and the smaller area covered by them, the agreement with ITRF2005 is better for the local solution than for the regional solution. This might lead to the (incorrect) conclusion that the local network is better tied to the ITRF2005 than the regional network.

RMS of the agreement with ITRF2005	#stations	Positions [mm]		Velocities [mm/ yr]	
		Horizontal	Vertical	Horizontal	Vertical
Regional	37	1.8	3.6	0.4	0.7
Local	9	1.2	3.4	0.3	0.5

Table 1: RMS of the agreement of the two solutions with respect to ITRF2005.

3.2. Position and velocity differences between regional and local cumulative solution.

During the stacking of each of the networks, discontinuities have been introduced to account for jumps in the position time series. A new station position is estimated after each discontinuity and the velocities are usually constrained to be equal before and after a discontinuity. For the 38 common stations between the two networks, the same discontinuities and constraints on the velocities have been applied when computing the local and regional cumulative solutions. Due to the introduction of the discontinuities, the 38 common stations lead to 69 positions and 69 velocities estimated in the two networks. For few stations (8 estimates), a major disagreement was found with position differences reaching the cm-level. In some cases, they can be explained by a different data set: in the regional solution, all available data have been processed even if the stations were not active in the EPN, while for the local solution, only EPN stations with an active status were processed). Nevertheless, most of these differences are not explained yet and need further investigation.

After removing these 8 outliers, the agreement (in terms of RMS) between the regional and local solution (Table 2) is 1.2 mm for the horizontal positions (Fig. 4, left and Fig. 6, left and middle), 3.0 mm for the vertical positions (Fig. 4, right and Fig. 6, right), 0.2 mm/yr for the horizontal velocities (Fig. 5, left and Fig. 8, left and middle) and 1.4 mm/yr for the vertical velocities (Fig. 5, right and Fig. 8 right). Despite this good agreement (after removal of the 8 outliers), the network effect (that mainly affects the vertical velocities) makes it impossible to mix the results of both solutions. Indeed, the position differences reach 6.3 mm for the horizontal and 9.6 mm for the vertical. For the horizontal velocities, the differences can reach 0.5 mm/yr. The vertical velocities present a bias of 1.3 mm/yr with differences reaching 2.4 mm/yr. In order to mitigate these differences, the two solutions have been combined on a weekly basis.

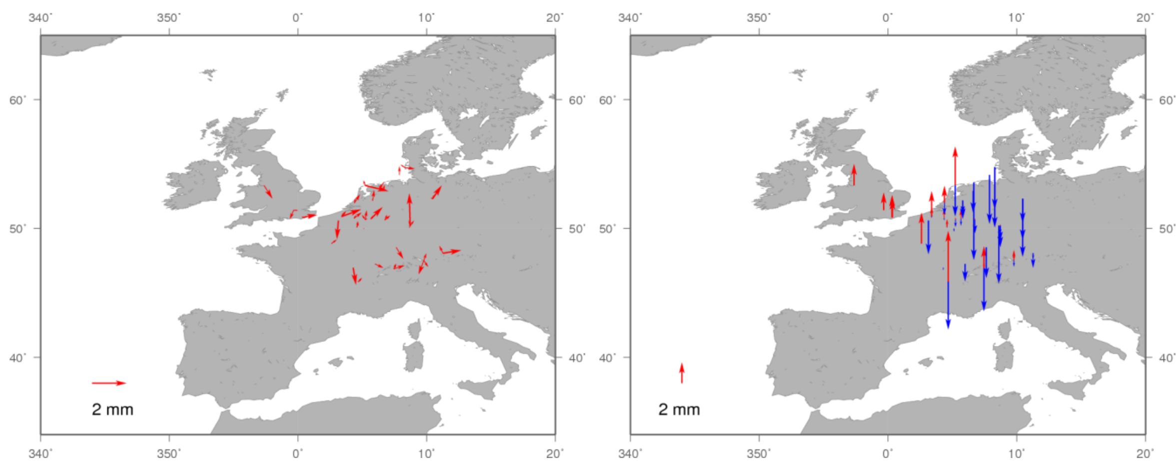

Fig. 4: Difference between EPN and dense Belgian GNSS network positions (mm). Left: horizontal differences, right: vertical differences.

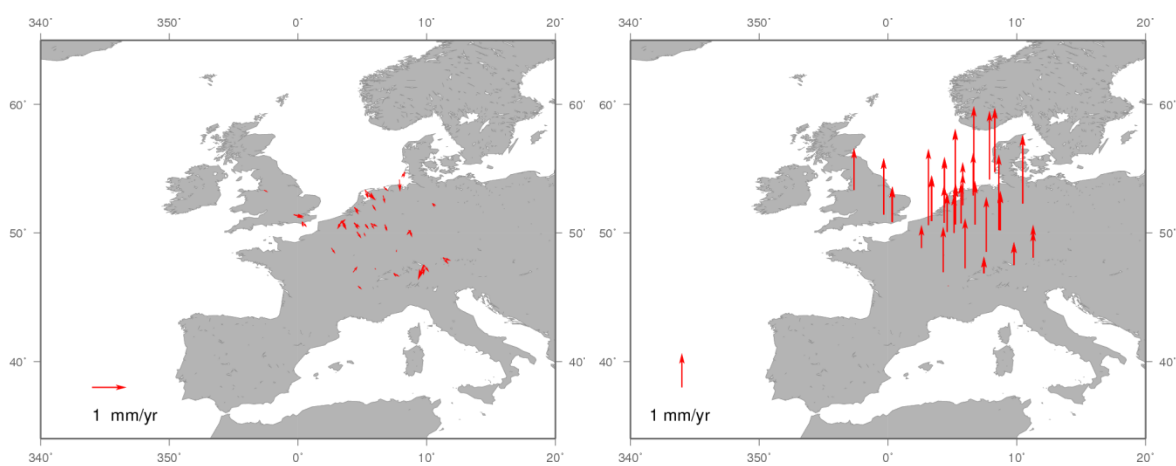

Fig. 5: Difference between EPN and dense Belgian GNSS network velocities (mm/yr). Left: horizontal differences, right: vertical differences.

4. REGIONAL + LOCAL COMBINATION

Each week, the weekly regional and weekly local solutions have been combined in order to obtain a regional + local weekly solution. Then these combined weekly solutions have been stacked in order to obtain a regional + local cumulative solution. This stacking has been done using the same discontinuities and velocity constraints as during the stacking of the local and regional networks. During the combination of the weekly regional and weekly local solutions, only the station positions have been combined and no weighting has been applied. More refined approaches could be to apply different weights on the regional and local solutions and/or to combine also tropospheric parameters.

In the following, the combined cumulative solution (regional+local) is compared to the regional solution (Table 2). For comparison, Fig. 6 shows the histograms of the position differences between the regional and local network assessing the small bias between the horizontal positions and the tilt in the vertical. Fig. 7 (limited to the same stations as Fig. 6) demonstrates that the bias between the regional and local solution has been eliminated after the weekly regional+local network combination.

Differences between		Regional and local			Regional and regional + local		
		Max	RMS	Mean	Max	RMS	Mean
Positions [mm]	East	6.1	1.5	-0.1	1.5	0.3	-0.1
	North	4.6	0.9	0.4	1.1	0.3	-0.1
	Up	9.6	3.0	-0.9	2.1	0.4	0.1
Velocities [mm/yr]	East	0.3	0.1	0.1	0.3	0.1	0.0
	North	0.4	0.2	-0.2	0.2	0.1	-0.0
	Up	2.4	1.4	1.3	0.6	0.1	0.0

Table 2: Statistics (maximum, RMS and mean) of the differences between the regional and the local (resp. the combined regional + local) positions and velocities.

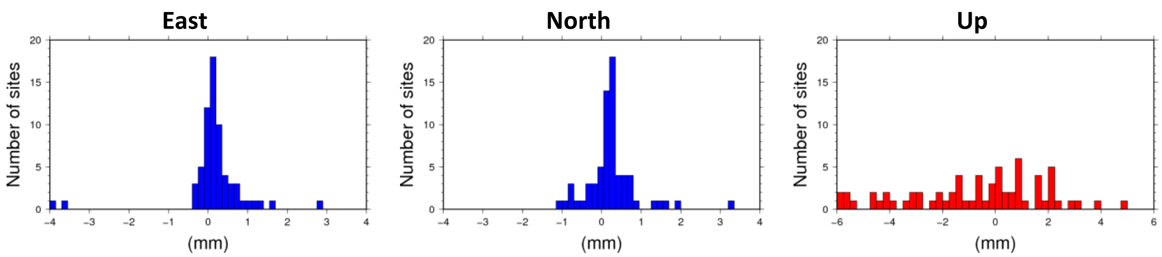

Fig. 6: Histograms of the differences between regional and local positions: East (left), North (middle), and Up (right) component.

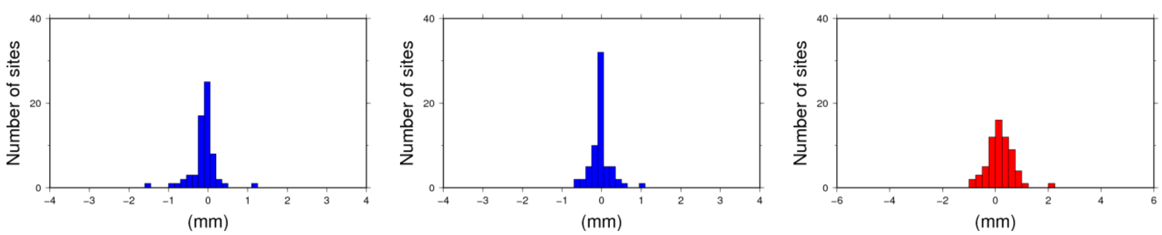

Fig. 7: Histograms of the differences between regional and regional + local positions: East (left), North (middle), and Up (right) component.

The same observations can be made for the velocities. The histograms of the differences between the regional and the local network velocities (Fig. 8) show a small bias between the velocities of 0.1 mm/yr in the East component and -0.2 mm/yr in the North component and 1.3 mm/yr in the vertical. Fig. 9 confirms again that the bias between the regional and the local network has completely disappeared after the weekly regional+local network combination.

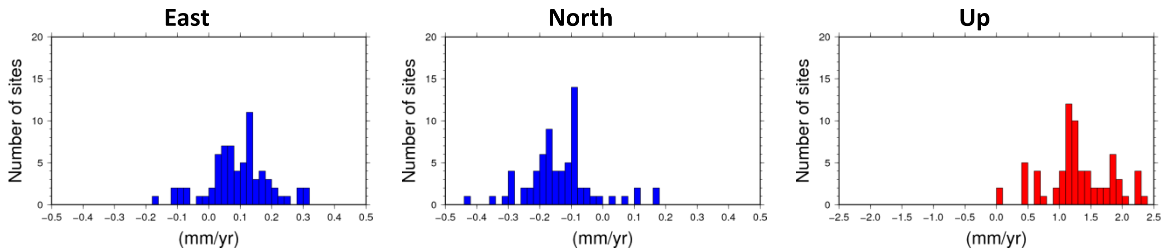

Fig. 8: Histograms of the differences between regional and local velocities: East (left), North (middle), and Up (right) component.

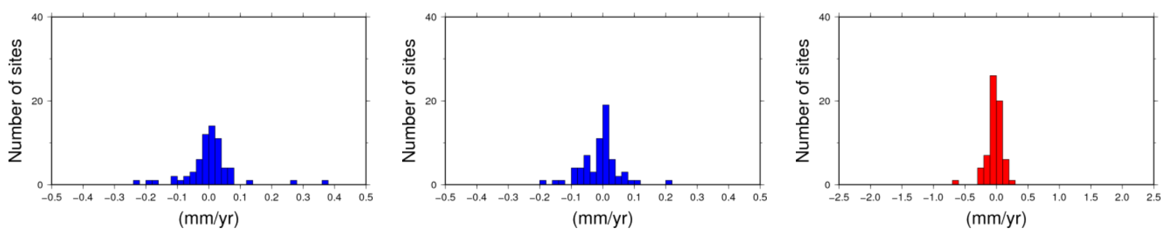

Fig. 9: Histograms of the differences between regional and regional + local velocities: East (left), North (middle), and Up (right) component.

These results show that by combining first, at the weekly level, the solutions of the regional and local networks, and then by stacking these weekly combined solutions to estimate the site positions and velocities, the network effect can largely be eliminated from the local solution. It must be noted however that this approach is successful thanks to the good agreement between the weekly polyhedrons of both solutions due to the usage of an identical processing strategy.

5. Conclusion

We quantified the differences between a local and a regional GNSS network solution, both resulting from a homogeneous reprocessing using an identical analysis strategy and tied to the ITRF2005 using minimum constraints. The position differences reached 6.3 mm for the horizontal and 9.6 mm for the vertical. For the horizontal velocities, the differences were small and reached 0.5 mm/yr. The vertical velocities presented a bias of 1.3 mm/yr with differences reaching 2.4 mm/yr. Consequently, for the considered networks, the network effect affects mainly the vertical velocities, but still remains pretty small because the local network used in this study is already covering a large geographical area.

To get rid off the small bias between the two networks, the regional and local solutions were combined on a weekly basis and then the combined weekly solutions were stacked to obtain a cumulative position and velocity solution expressed in ITRF2005. This step-wise approach guarantees the consistency between discontinuity epochs, solution numbers and the data cleaning in both networks. Using the combined regional+local network, we are able to take advantage of the larger number of ITRF2005 stations in the combined solution which allows to more reliably express the local solution in ITRF2005. This method is however only successful if there is a good agreement between the local and regional solutions (common analysis strategy) and a significant number of common stations.

The tests performed on the combination of a local and regional network showed that by combining first the solution of regional and local networks at the weekly level, and then stacking the weekly combined solutions to estimate the site positions and velocities, the network effect on the local solution is largely eliminated. By applying the same principle on global weekly solutions in good agreement with weekly regional solutions (possibly already integrating the local network), we are convinced that we should be able to more reliably express a regional solution in a global frame by reducing the network effect.

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