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Report on the EPN Analysis

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Abstract

The consistency between the EPN Local Analysis Centers' solutions further improved during the period since the last EUREF symposium in 2002. A new Local Analysis Center located in Bratislava, Slovakia was introduced, and it was started to submit an EPN sub-network solution to the TIGA Pilot Project. The new rotation of the ETRF since the introduction of ITRF2000 could be recovered from the ETRS89 time series. New absolute receiver and satellite antenna phase center variations had been tested in the analysis of an EPN sub-network and demonstrated the station coordinate displacements evoked by this changes in the data analysis.

1 Introduction

This report deals with the further development of the analysis for the period since the last EUREF symposium in June 2002. The basic analysis and combination scheme is described in Habrich (2000). The best possible realization of the ETRS89 reference system asks for a continuously adjustment of the data analysis to state of the art technologies. This effort of EUREF meets with approval from, e.g., the International GPS Service (IGS) through the introduction of EUREF results into the IGS product generation, as well as the consultation of the TWG by various external guests. The contribution of a sub-network of the EUREF GPS Permanent Network (EPN) to the TIGA Pilot Project of the IGS has to be mentioned here too. Motivated by such credit the EPN tracking network was expanded during the last year by accepting new stations and a new local analysis center (LAC). The consistency between the individual LAC solutions improved. Current developments in GPS analysis are carefully watched by EUREF. For that reason new receiver and satellite antennae phase center variation values had been tested for usage in the EPN analyses. Conclusions of these tests are given in the last paragraph.

2 Recent Progress

The number of analysed EPN stations continued to grow, as the formal number of EPN tracking network stations does. Figure 1 shows such development. There was a new Local Analysis Center established at the University of Technology in Bratislava, Slovakia. The acronym 'SUT' is used for this LAC and since GPS week 1182 the sub-network of SUT is included in the EPN combination.

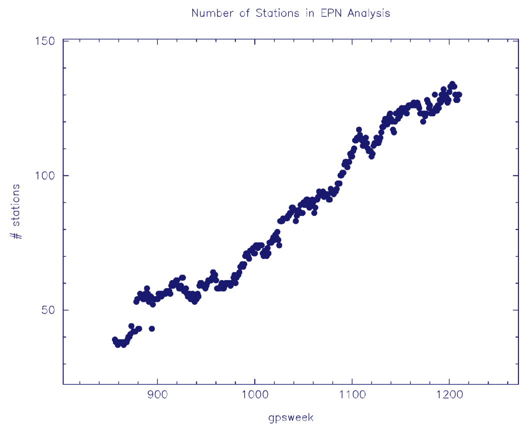

Figure 1: Number of Analysed Stations

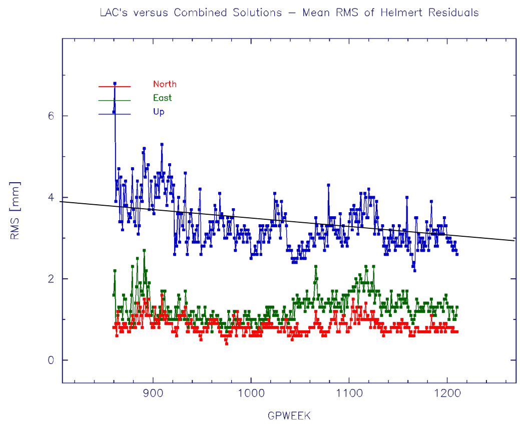

Figure 2: RMS of Helmert Transformations

The consistency between the 16 contributing sub-network solutions may be verified through the calculation of 7-Parameter Helmert residuals between each LAC solution and the combined solution. Figure 2 shows those mean RMS values from all LAC. The upper curve represents the height component, which shows the highest discrepancies. The trend line for this component points to an improvement since the beginning of EPN.

The combination of the sub-network solutions provides for exclusion of individual solutions if they differ more than 5 and 10 mm in the position and height component respectively. It shows up, that recently view stations of the solution of the Delft University of Technology (DEO) were mostly excluded in the combination. Figure 3 shows the percentage of exclusions for such stations for the period of the weeks 1190 to 1210. A detailed investigation of stations with a high exclusion rate could neither detect any specific receiver or antenna type relation nor a network effect based on the location of the stations. It has to be mentioned however, that DEO uses JPL's GIBSY software, whereas most other LACs use the Bernese GPS Software.

3 ETRS89 Time Series

The basic idea for the definition of the ETRS89 was the establishment of a coordinate reference system, which is fixed to the stable part of Europe and therefore the station velocities mainly vanish. The weekly EPN solutions become a realization of ETRS89, called ETRF, after applying the correct transformation formulae to the ITRF coordinates. The EPN Central Bureau (EPN-CB) converts the weekly station coordinate solutions, as given in the weekly SINEX files, from the ITRF to the ETRF. Graphics of ETRF time series are available

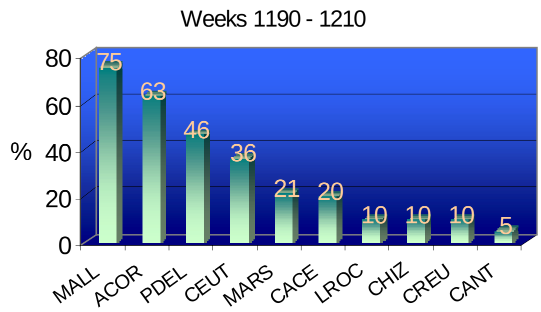

Figure 3: Exclusion of Stations from DEO Sub-Network

on the web page of the EPN-CB. In order to verify the usage of the required transformation formulae, provided by C. Boucher and Z. Altamimi (2001), the BKG repeated those conversions and found a pretty good agreement in the ETRF time series of EPN-CB and BKG.

Since GPS week 1143 the ITRF2000 has been used in the EPN analysis. The transformation from ITRF2000 to ETRF2000 includes a new rotation of the Eurasian plate compared to former realizations as has been presented by Z. Altamimi and C. Boucher (2001). This rotation could be recovered from the ETRF time series derived form EPN solutions by calculation of horizontal position difference vectors between the GPS week 1142 and 1143. Such vectors are given in Figure 4.

4 TIGA Pilot Project

The IGS established a pilot project called "GPS Tide Gauge Benchmark Monitoring Pilot Project (TIGA-PP)" initiated by a call for participation in June 2001. The background of this pilot project is to analyse GPS data from stations at or near tide gauges on a continuous basis. The main objective is to support global vertical geodesy. EUREF submitted a proposal for participation in the TIGA-PP to the IGS. The IGS accepted that proposal which expresses the delivery of (1) validated GPS meta-data information, (2) free access to the GPS data, and (3) weekly coordinate estimates in SINEX format for all EPN stations close to tide gauges. A sub-network of the weekly combined EPN solution is submitted to the TIGA data center located at the Geoforschungszentrum Potsdam (GFZ) in order to carry out that obligation. The sub-network is given in Figure 5. It includes 7 tide gauge and 7 connection stations for GPS week 1211. Additional tide gauge stations will be included, as soon as they fulfil the "TIGA observation station (TOS)" standard. Additional information about TIGA may be found at http://op.gfz-potsdam.de/tiga/.

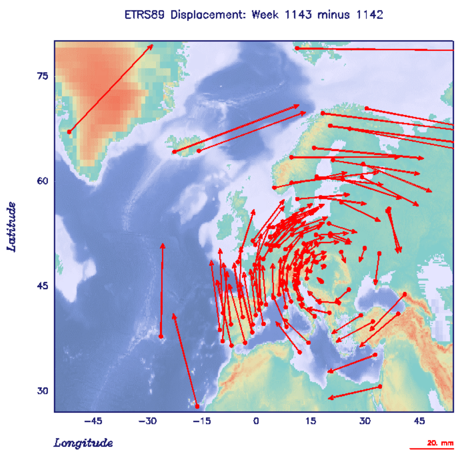

Figure 4: Horizontal Position Differences of EPN

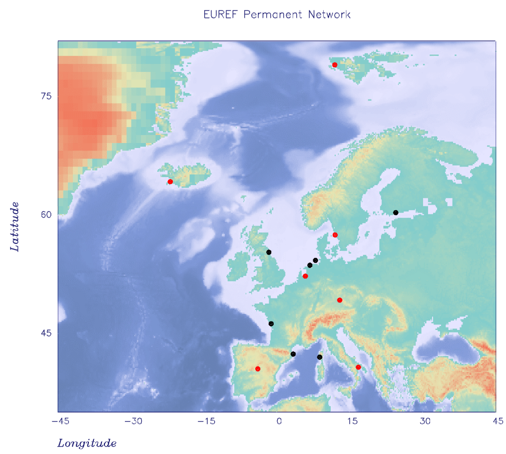

Figure 5: EPN Sub-network for TIGA-PP, week 1211

5 Receiver and Satellite Antenna PCV

Markus Rothacher and Ralf Schmidt provide a test set of absolute antenna phase center variations (PCVs) as announced in IGS-Mail 4324. Peter Franke has introduced these antenna PCVs in the processing of the BKG sub-network of the EPN to study possible coordinate changes. For the satellites just new offsets were used, because it is not possible to introduce variations for satellite antennae in the Bernese GPS Software 4.2, which had been used for the analysis.

Solution	**Receiver PCV**	**Satellite PCV**
X	relative (standard solution)	old
A	absolute, elev.-dependent	old
B	absolute, elev. and azimuth dependent	old
C	absolute, elev. and azimuth dependent	new
Solution	**Datum Definition**	
Free	A priori sigma 1 m for all station coordinates	
Fixed	Coordinates of selected stations fixed	
Minimum-constrained	‘Center-point’ of selected stations fixed	

Table 1: Solution Series for PCV Tests

Table 1 summarizes the series of solutions according to the applied PCVs (solution X, A, B, and C) and to the datum definition (type free, fixed and minimum-constraint). For a regional network (such as the EPN) we expect, that the changes are mainly absorbed by the datum definition strategy. Table 2 shows the results of 7 parameter Helmert transformations between the resulting coordinates of each solution. The estimated parameters for translation in height direction (TH) and the scale are given, following the assumption, that changed antenna PCVs will mainly affect the height and scale parameters.

The free solutions show the smallest RMS, but have no stable datum definition as could be seen in the variation of the estimated TH components. They are therefore not suitable for comparisons of the mean height component of the EPN network. The fixed solutions show large RMS values for A and B, because of the constraints of the reference sites. The height of the network as well as the distances between the reference sites are constrained by fixing various station coordinates. The minimum-constrained solutions show reduced RMS values compared to the fixed solutions. The distances between the stations are no longer constrained, but the height of the network remains constrained, if we interpret minimum-constrained as constraint of a single station, i.e., of the network center. The C solution shows small RMS numbers for free, fixed and minimum-constrained. It confirms the success of the method, to introduce both, satellite and receiver absolute PCVs. It has to be mentioned, that these comparisons suffer from the impossibility to introduce the full variations of the satellite antennae.

It shows, that the minimum-constrained datum definition is most suitable for a comparison to the current standard EPN solution and those results were used to generate the Figures 6 and 7. They illustrate the resulting horizontal displacement for the A and C solutions referenced to the X (standard) solution.

second file / first file	A			B			C		
	RMS mm	TH mm	Scale mm	RMS mm	TH mm	Scale mm	RMS mm	TH mm	Scale mm
Free	3.9	-602.0	10.0	3.9	-593.0	10.0	**3.6**	-385.0	15.0
Fixed	**8.3**	-35.0	-12.0	**8.5**	-36.0	-12.0	**3.5**	-8.0	-2.0
Min-C	6.1	-20.0	-14.0	6.2	-21.0	-14.0	**3.4**	-6.0	-2.0

Table 2: 7 Parameter Helmert Transformation

Significant displacement vectors in radial direction for A (Figure 6) vanish for C (Figure 7). Figures 8 and 9 show the vertical displacements respectively. The comparison between the A solution and the standard solution shows displacements of reference sites in opposite direction than other sites. We may conclude from that, that the height bias, as introduced by the absolute receiver PCVs, is partly absorbed by the datum definition. The comparison between the C solution and the standard solution shows no displacement for reference sites. Other stations show a remaining significant displacement of up to 30 mm.

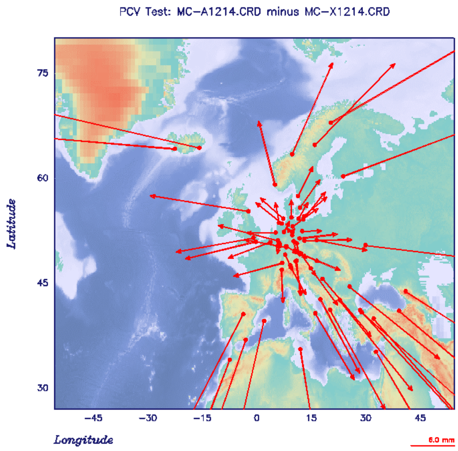

Figure 6: Position changes after introduction of absolute receiver PCV (A minus X)

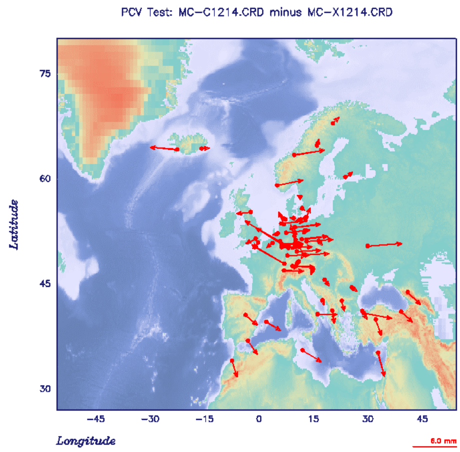

Figure 7: Position changes after introduction of absolute receiver PCV <u>and</u> satellite offset (C minus X)

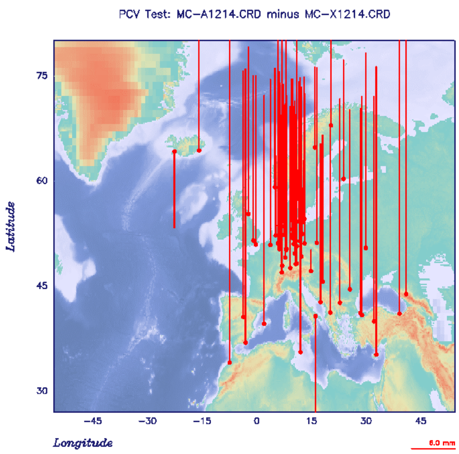

Figure 8: Height changes after introduction of absolute receiver PCV (A mins X)

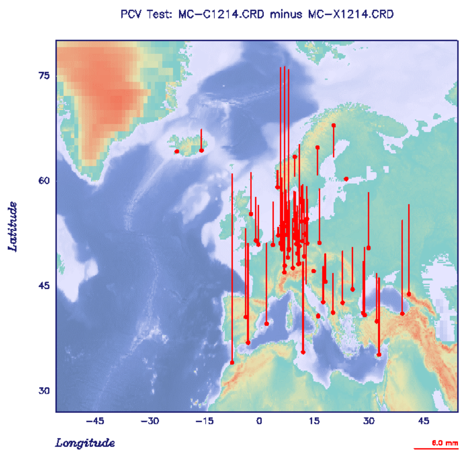

Figure 9: Height changes after introduction of absolute receiver PCV <u>and</u> satellite offset (C minus X)

6 Conclusion and Outlook

Some statistics showed, that the consistency of the EPN data analysis further improved. The significance of EUREF was confirmed by the participation in the TIGA Pilot Project again. New absolute receiver and antenna phase center variations will be used within IGS in the future. This is also planned for national positioning services, e.g., the German SAPOS. The introduction of both, receiver and satellite antenna PCVs, showed negligible displacement for horizontal and up 30 mm for vertical coordinate components in this study. It requires further investigations before introducing the new absolute PCVs in the official EPN solutions.

References:

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Altamimi Z. Boucher C. (2001) :*The ITRS and ETRS89 Relationship : New Results from ITRF2000*, Report on the Symposium of the IAG sub-commission for Europe (EUREF) held in Dubrovnik, 16 – 18 May 2001, published in Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 23, 2002

Habrich H. (2000): *Combining the EUREF Local Analysis Centers' Solutions*, Report on the Symposium of the IAG sub-commission for Europe (EUREF) held in Dubrovnik, 16 – 18 May 2001, published in Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 23, 2002