Preliminary results of processing EUREF network observations using a non-fiducial strategy

Z. M. Malkin, A. V. Voinov

Institute of Applied Astronomy, nab. Kutuzova 10, St.Petersburg 191187, Russia

Camera-ready Copy for

???

Manuscript-No. ???

Preliminary results of processing EUREF network observations using a non-fiducial strategy

Z. M. Malkin, A. V. Voinov

Institute of Applied Astronomy, nab. Kutuzova 10, St.Petersburg 191187, Russia

Received: ??? – Accepted: ???

Abstract. Analysis of the official EUREF (European reference GPS network) weekly solution series reveals some systematic seasonal errors, especially in the height component. We suspect that the standard fiducial processing strategy causes these errors. In this investigation a non-fiducial strategy has been used to process a subnetwork of 21 EUREF stations for GPS weeks 969-1042: free weekly solutions obtained as Helmert-based combinations of daily solutions followed by Helmert transformation to ITRF97. Bernese, PyGPS and GROSS packages were used. Comparison with the official EUREF solution shows that obtained coordinate time series most likely are free from seasonal errors. The authors consider it important for such a solution to accompany the official one. A comparison of EUREF and VLBI solutions is planned.

1 Introduction

The main goal of this paper is a search for an optimal strategy for processing GPS observations collected from the EUREF network to obtain continuous coordinate time series.

At the moment two EUREF coordinate time series are publicly available: a series computed at the Bundesamt für Kartographie und Geodäsie (early at the Center for Orbit Determination in Europe, Astronomical Institute of the University of Bern, Switzerland) and distributed as SINEX files (hereafter referred as official EUREF solution) and a series computed by the EUREF Central Bereau (EUREF CB) at Royal Observatory of Belgium (ROB) and distributed as plots through the EUREF CB web site.

The former solution is computed using the “standard” strategy by fixing coordinates of a set of selected fiducial stations. Unfortunately, it is affected by a periodic change of reference system and the set of fiducial stations used. Besides, as one can see below, this coordinate time series is evidently affected by serious systematic errors. This makes the official EUREF solution taken “as is” unsuitable for scientific use.

The EUREF CB solution is computed by removing constraints from official solution and provides a much more stable coordinate time series but it is not distributed in SINEX files. This also makes it impossible to use this solution in scientific researches.

Therefore we tried to obtain, using the non-fiducial strategy, an independent solution, which would be more stable and free of network distortion. Basic theoretical background of using non-fiducial approach to processing GPS networks can be found in (Blewitt, 1992; Heflin, 1992; Zumberge, 1997; Dong, 1998).

2 Processing strategy

33 stations were selected for this research. These are, first of all, Russian stations, then, stations located in Fennoscandia, stations collocated with VLBI and several stations added for better network geometry. This paper presents results of processing 22 stations over a 105 week interval plus 11 more stations over a 42 week interval obtained up to the moment — we have still difficulties in obtaining observations of these latter stations. We have still problems with some stations, especially with TROM and NYAL. Evidently, they will be replaced by TRO1 and NYA1 at the next stage of

this work.

We have used a non-fiducial strategy in this research as described below. The motivation of such a choice of processing strategy is the following. Fiducial strategy presupposes that coordinates of fiducial stations precisely follow a linear model of an accepted terrestrial reference system, e.g. ITRF. Errors in coordinates of fiducial stations, peculiar station motion, local displacements, equipment change, etc. may result in errors distributed over the whole processed network.

In more detail, if one uses more than one fiducial stations with tight constraints (e.g. a priori sigma 0.01 mm is used by EUREF) to build a network solution and instability of fiducial stations is greater than used constraints, one can expect that the resulting solution will be distorted. This distortion will increase towards the edges of the network, especially if fiducial stations are concentrated near the center of the network. Such a deformation of the network evidently is not linear and cannot be removed by "standard" de-constraining procedure, in our opinion. An idea of this analysis is not to use tight constrains at all to avoid non-linear deformations of coordinate system.

On the other hand, non-fiducial strategy has some advantages in our opinion:

1. Such a solution does not cause a distortion of the network.

2. More stations can be used for orientation of a network which makes final orientation of the solution more reliable and dependant to a lesser degree on unmodelled errors in coordinates of fiducial stations.

3. Such a solution can be easily transformed to any reference system and re-transformed to another one using a much simpler procedure than that needed for removing constraints.

This strategy was successfully tested during processing of the Baltic Sea Level 1993 and 1997 GPS campaigns (Springer and Malkin, 1995; Voinov and Malkin, 1999). Therefore we tried to use the same approach to the processing of the EUREF network.

1. *Computation of a daily free network (non-fiducial) solution.* Orbits and Earth orientation parameters were fixed to the IGS (International GPS Service) final values. Optimal baseline configuration was chosen using a combination of one of the strategies provided by Bernese with an original method of iterating rejection of "bad" baselines using results of preprocessing and ambiguity resolution (Voinov, 1999, 2000). Such a method enables one to avoid manual station and baseline selection and prevents unnecessary automatic rejection.

2. *Computation of a weekly free network solution.* This processing was done in several convergent iterations repeated independently for every week.

First, a day with maximum number of stations is chosen, and all other days are aligned to it using a seven parameter Helmert transformation.

Then the average X, Y, Z are computed for each station for all available reduced day solutions. For each day an average is computed without this day. If this day deviates from that average by more than 3 sigma, then it is discarded. After such a cycle over all days the final average is computed without outlier days.

After having obtained the average for all the stations, this set of average coordinates is taken as a new reference for the Helmert transformation (instead of the aforementioned day with maximum number of stations) and the entire iteration is repeated.

3. *Transformation of weekly free network solution to ITRF97.* Seven parameter Helmert transformation was used on this step, and two possibilities were explored: to use nine fiducial stations, or to use all stations present in both the ITRF definition and our list. Our preliminary conclusion is that the second method provides more stable results.

Observations were analyzed using the PyGPS package (Voinov, 1999, 2000) which provides a powerful tool to combine the Bernese package with the data processing package GROSS and MAL library (Malkin et al., 1999) to enable both to automate the overall control over the GPS data processing and to apply some custom data analysis methods.

3 Results and comparisons

Resulting coordinate time series (vertical component) along with some statistics are presented in Figure 1 in comparison with the series obtained from the official EUREF weekly solution. It is clear that only stations that are not used as fiducial in the EUREF solution can be compared here.

Using Allan variance for estimation of week-to-week repeatability seems reasonable here because it doesn't require an estimation of a systematical trend (in our case, when week-to-week systematic change of coordinates is much less than random variations) or defining a reference series.

One can see that some stations showing seasonal terms in EUREF coordinates are free from them in the non-fiducial solution. The latter coordinate time series is very similar to the EUREF CB one. Unfortunately, detailed comparison is impossible, because the latter is not available in numerical files.

Acknowledgments

The authors are very grateful to Tim Springer and Carine Bruyninx for valuable discussion and Angelyn Moore for assistance in presentation of this paper at the IGS Network Workshop 2000.

References

Blewitt, G., Heflin, M., Bertiger, W., Webb, F., Lindqwister, U., Malla, R., Global Coordinates With Centimeter Accuracy In The International Terrestrial Reference Frame Using The Global Positioning System, Geophys. Res. Lett., **19**, 853–856, 1992.

Dong, D., Herring, T. A., King, R. W., Estimating regional deformation from a combination of space and terrestrial geodetic data, Journal of Geodesy, **72**, 200–214, 1998.

Heflin, M. B., Bertiger, W. I., Blewitt, G., Freedman, A., Hurst, K., Lichten, S. M., Lindqwister, U., Vigue, Y., Webb, F., Yunck, T, Zumberge, J., Global Geodesy Using GPS Without Fiducial Sites, Geophys. Res. Lett., **19**, 131–134, 1992.

Malkin, Z., Voinov, A., Skurikhina, E., Software for Geodynamical Researches Used in the LSGER IAA, Presented at ADASS IX Conference, Hawaii, October 3–6, 1999.

Springer, T. A., Malkin, Z. M., Analysis of the Baltic Sea Level 1993 GPS Campaign, In: J. Kakkuri (ed.), Final Results of the Baltic Sea Level 1993 GPS Campaign. Rep. Finn. Geod. Inst., **95:2**, 87–104, 1995.

Voinov, A. V., GPS data processing automation with the use of Python scripting language, In: M. Poutanen, J. Kakkuri (eds.), Final results of the Baltic Sea Level 1997 GPS Campaign. Rep. Finn. Geod. Inst., **99:4**, 75–84, 1999.

Voinov, A. V., PyGPS: a GPS data processing automation package, 2000, this issue.

Voinov, A. V., Malkin, Z. M., Preliminary Results of the BSL 1993 and 1997 GPS Campaigns, In: M. Poutanen, J. Kakkuri (eds.), Final results of the Baltic Sea Level 1997 GPS Campaign. Rep. Finn. Geod. Inst., **99:4**, 51–68, 1999.

Zumberge, J., Heflin, M., Jefferson, D., Watkins, M., Webb, F., Precise Point Positioning for the Efficient and Robust Analysis of GPS Data from Large Networks, J. Geophys. Res., **102**, 5005–5017, 1997.

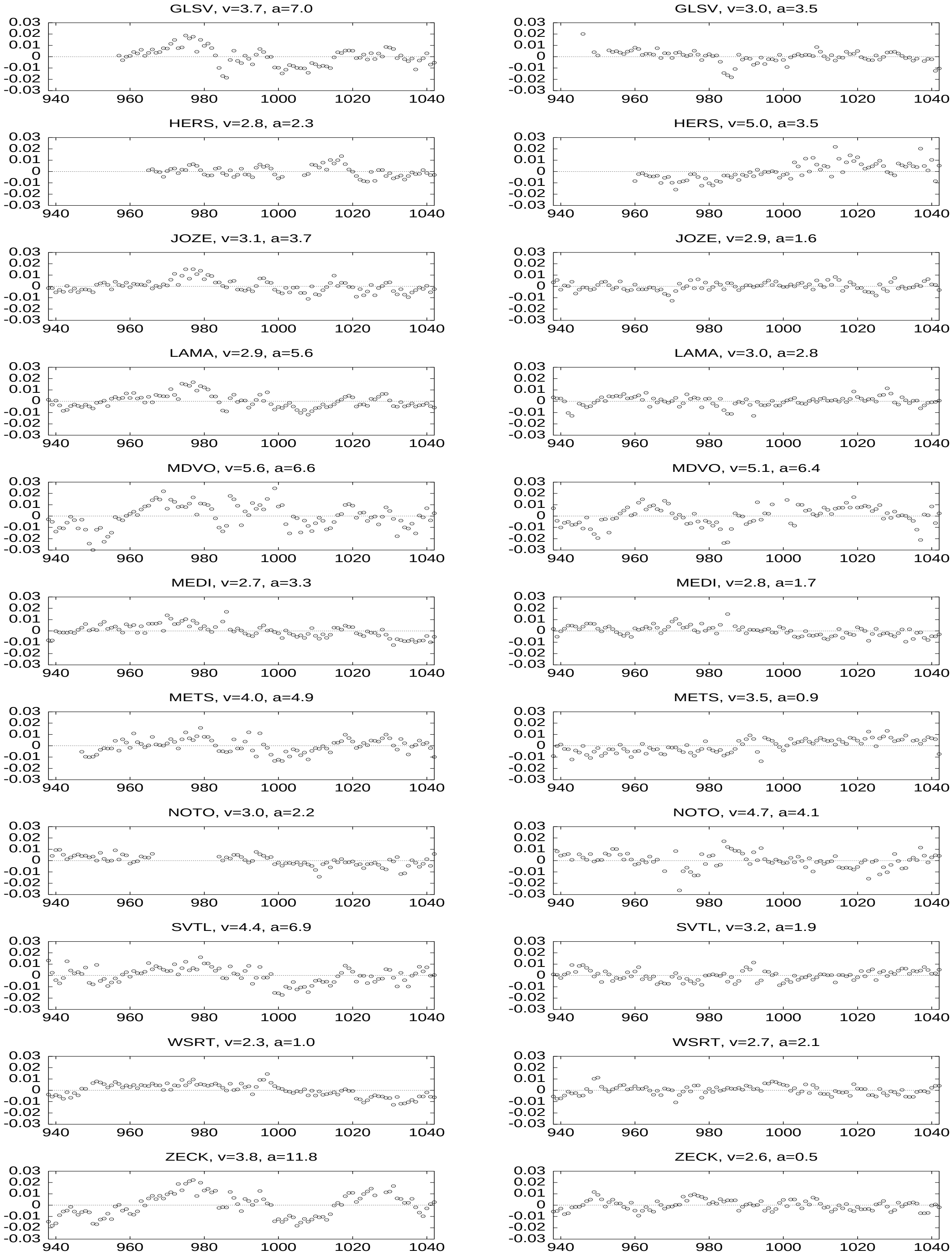

Fig. 1. Height component of station displacement, m (EUREF solution on the left and IAA solution on the right), v — Allan variance, mm, a — amplitude of annual term, mm.

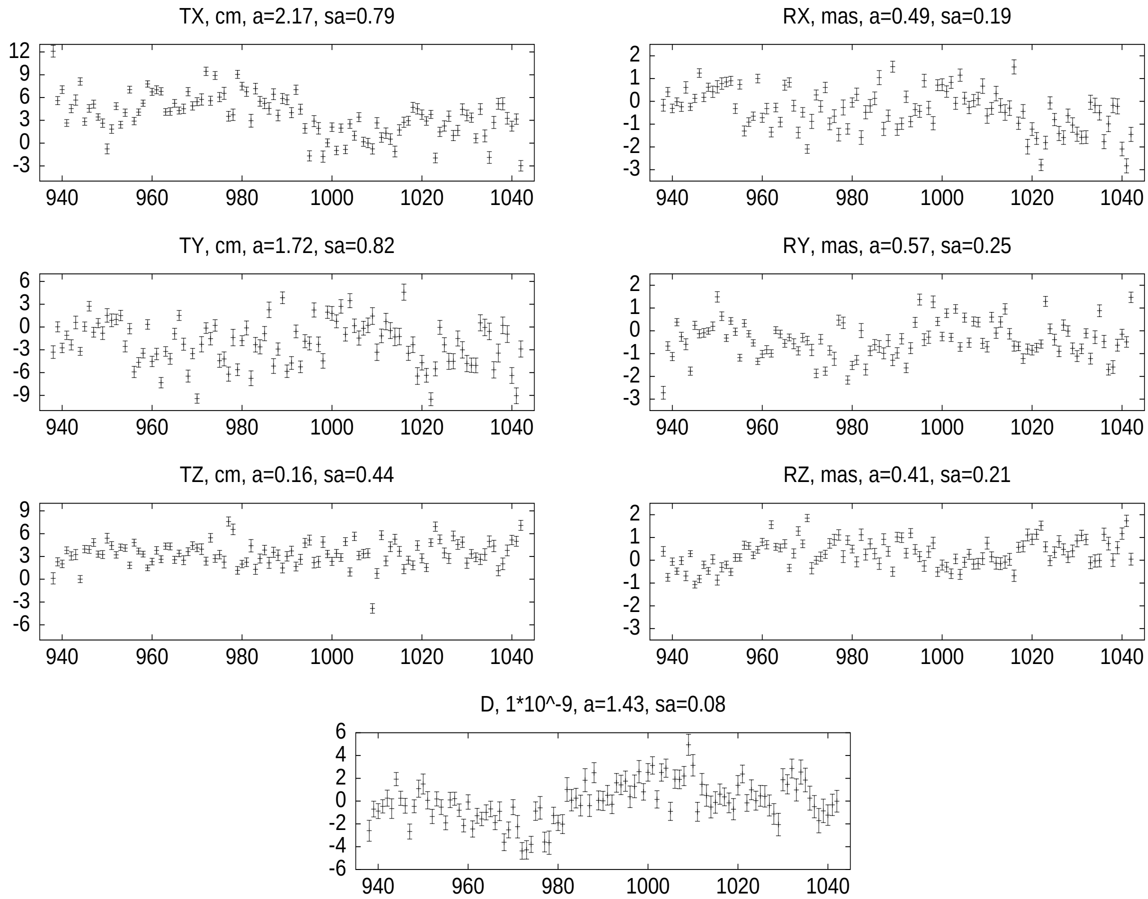

Fig. 2. Time series of transformation parameters between free weekly solutions and ITRF97, a — amplitude of annual term, sa — amplitude of semiannual term.