GEOKINEMATICAL IMPLICATIONS INFERRED FROM ANALYSIS OF PERMANENT STATIONS IN CENTRAL EUROPE REGION

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ABSTRACT

GPS permanent stations situated in Central Europe region are systematically analyzed in order to investigate behaviour of long-term monitoring of horizontal position and ellipsoidal height. On the basis of data from more than 30 sites the quality of the station is evaluated. Stability of station is measured by variety of parameters: jumps and discontinuities of known but also of unknown origin, seasonal variations amplitudes and phases and diurnal coordinate variations. We estimate for each network station its main deterministic characteristics including identification of eventual jumps, their time of occurrence and magnitude, annual variations and site velocities. The set of criteria for defining "stable" permanent station is proposed.

1. INTRODUCTION

The activities of Work-Package 5 of the CERGOP-2/Environment "GPS data analysis and the definition of reference frames" are based on systematically processing of permanent GNSS stations in Central Europe region. Main task of the work-package is realisation and maintenance of reference frame suitable for geo-kinematical monitoring in the region. The frame is realised by set of long-term monitored permanent GNSS stations. Regional network processing started at Slovak University of Technology in January 2003 in the network consisting of 32 stations, the present status comprising of 54 stations in shown in Fig. 1. On the basis of analysis of evolution of station coordinates from various aspects the aim is to set criteria for definition of stable reference stations. The main attributes of processing, referencing and analysis are summarized in (Hefty et al., 2004, Hefty, 2004). We emphasise here, that the actual stations coordinates are referenced to mean of the selected set of stations (13 stations were used as reference in this paper, namely BOR1, BOGO, BOGI, GOPE, JOZE, LAMA, POTS, WROC, BZRG, GSR1, TUBO, WTZR, UZHL). It means, that all the derived quantities are relative values related to mean of this set of stations and represent the intraplate behaviour of the stations. In this paper we will present results from analysis of 3-year interval from 2003.0 to 2006.0. Following aspects will be discussed:

- **Continuity of series, expected and unexplained jumps, outliers.**
- **Intraplate motion characteristics.**
- **Seasonal variations of station coordinates.**

- **Diurnal and sub-diurnal variations.**
- **Short-term station stability – daily repeatability.**

Fig. 1 Status of network of permanent stations included in the analysis in 2006. o – stations processed more than 3 years, ■ – stations processed approximately 2 years, + - stations processed one year or less.

2. CONTINUITY OF LONG-TERM OBSERVATION SERIES

The continuity and homogeneity of long-term observations of spatial position is the most important phenomenon affecting the velocity estimation and consecutively the selection of reference stations. There are two kinds of discontinuities or jumps in the coordinate time series observed:

- **Expected discontinuities due to known reasons, like antenna or receiver alteration, monumentation modification, radome mounting, new obstacles in satellite visibility or removal of obstacles, etc. Such events are usually reported in station log sheets. If the epoch of such expected discontinuities is known, its magnitude is estimated by least squares adjustment.**
- **Discontinuities of unknown origin and instant of occurrence. In the coordinate series are occasionally visible jumps even the reason of such event was not reported. It is question of discussion if such events have to be eliminated from the series. We**

developed an algorithm for identification of such events which is based on comparison of actual observed weekly positions with its forward or backwards prediction. This method allows to identify jumps exceeding 3 mm in horizontal coordinates and 6 mm in height. The applied mathematical model will be published elsewhere. We detected unexpected jumps in GANP, WTZR, NYIR, SNEC and BISK series. Further investigation of these phenomena are necessary.

3. HORIZONTAL AND VERTICAL VELOCITIES

Relative horizontal velocities of permanent stations which have in the time span 2003 – 2005 the observational history longer than two years were estimated from weekly time series simultaneously with seasonal variations amplitudes and discontinuity characteristics. The obtained horizontal velocities are shown in Fig. 2. Their uncertainties are evaluated using the coloured noise modelling (Williams, 2003, Hefty, 2006). At some sites these velocities are compared with velocities obtained from other available sources: ITRF 2000 velocities (Boucher et al., 2004), reduced for APKIM velocities (Drewes, 1998), EPN velocities (Kenyeres, 2006) and CERGOP velocities evaluated from epoch observations (Hefty and Gerhátová, 2006). All these values represent in some manner the intraplate velocities. Examples of such comparison are in Fig. 3.

Fig. 2 Horizontal intraplate velocities of permanent station in Central Europe

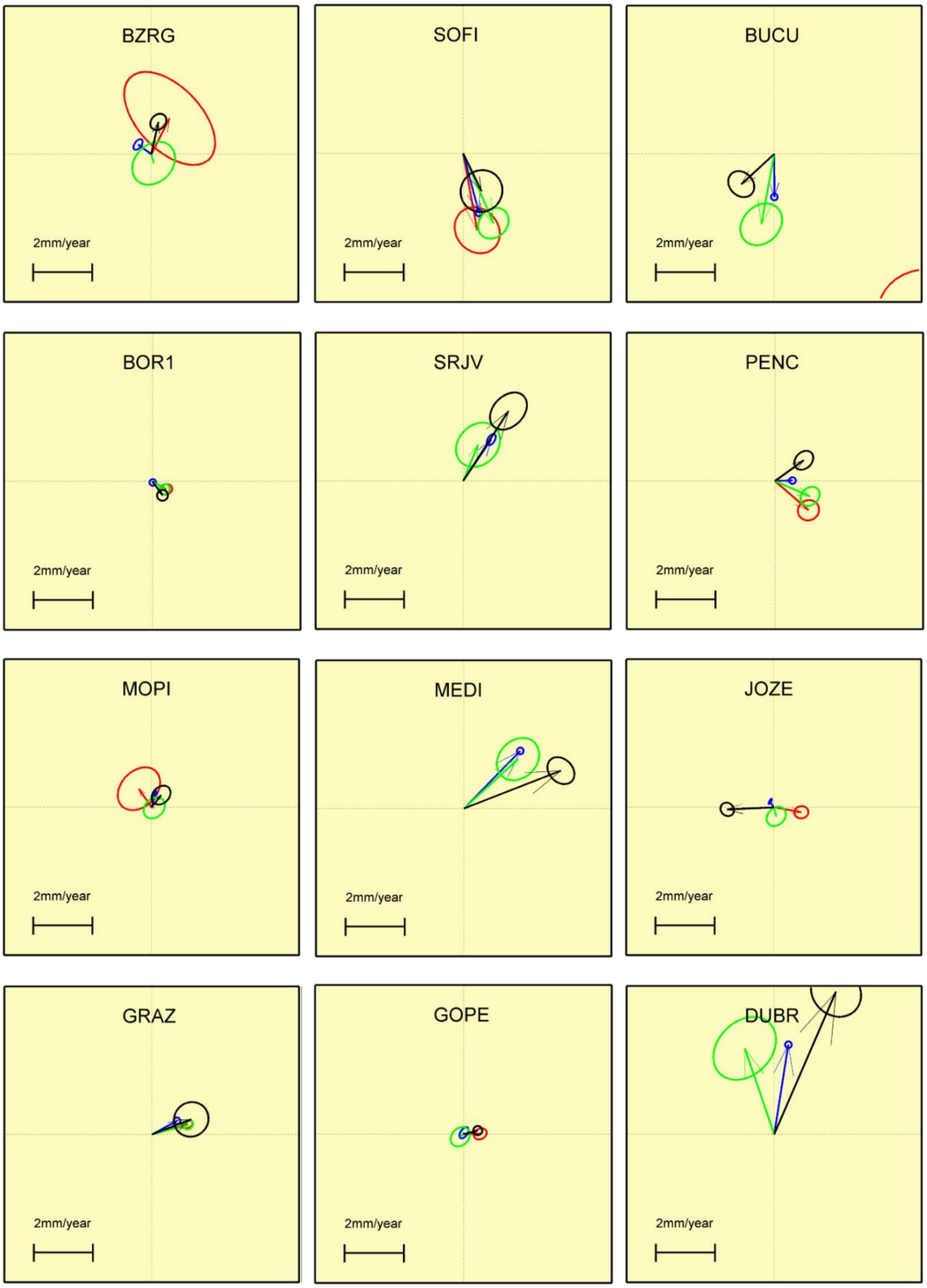

Fig. 3 Comparison of intraplate velocities estimated from analysis of 3-year interval of permanent stations in Central Europe (black lines), with ITRF 2000 velocities reduced for APKIM 2000, CERGOP velocities from epoch observations and EPN velocities.

Velocities obtained from Central Europe permanent stations analysis and referenced to mean of the stable stations are at most sites consistent with other velocity estimates. There are few anomalies observed, like large KATO velocity or discrepancies among various estimates at JOZE, PENC and BUCU. The detailed analysis will be topic of other paper.

The estimated vertical velocities are shown in Fig. 4. Their uncertainties are about 1.2 mm/year when considering the coloured noise model. At the present time the geodynamical implications of these information is disputable.

Fig. 4 Estimated relative vertical velocities from permanent GPS observations in Central Europe

4. SEASONAL VARIATIONS

Periodic variations of horizontal coordinates and ellipsoidal height are besides the long-term drift the most pronounced phenomenon of permanent station behaviour. The origin of seasonal variations with amplitudes reaching from 1 to 5 mm is not clearly explained. It is partly regional phenomenon with some local anomalies. Figs 5 and 6 document amplitudes and phases of annual variations in north-south and east-west components. The orientation of vectors is giving the phase of the variation with east direction indicating maximum in January and west direction corresponds to maximum in July.

Fig. 5 Amplitudes of annual variations in north-south direction. The orientation of vectors gives phases - direction to east means maximum in January, orientation to east maximum in July.

Fig. 6 Amplitudes of annual variations in east-west direction. The orientation of vectors gives phases - direction to east means maximum in January, orientation to east maximum in July.

Local anomalies are characteristic for station PADO, KRAW and DRES which show variations with amplitudes above 3 mm and their phases are not consistent with the regional phases.

5. DIURNAL AND SUB-DIURNAL VARIATIONS

The spectra of coordinate time series evaluated for 3-hour batches clearly indicate that for the majority of network stations are dominating variations with diurnal and semidiurnal tidal periods S_1, K_1, O_1, S_2, K_2, M_2 with amplitudes up to 2 mm. As an example we show in Figs. 7 and 8 amplitudes and phases of variations S_1 with strictly diurnal period (P = 1.000 day) in north-south and east-west components. Regional pattern is visible with no clear delimitation. The geodynamical reasons are not confirmed at this moment.

Fig. 7 Amplitudes and phases of S_1 variations in north-south horizontal coordinate

6. DAILY REPEATABILITY IN HORIZONTAL POSITION AND IN HEIGHT

After eliminating jumps and discontinuities, linear drift and seasonal terms from daily coordinate series we can evaluate the station repeatability on the basis of residual RMS errors of each network station. Fig. 9 shows RMS of horizontal coordinates obtained for the period 2003.0 – 2006.0 and Fig. 10 shows RMS of height determination.

Fig. 8 Amplitudes and phases of S_1 variations in east-west horizontal coordinate

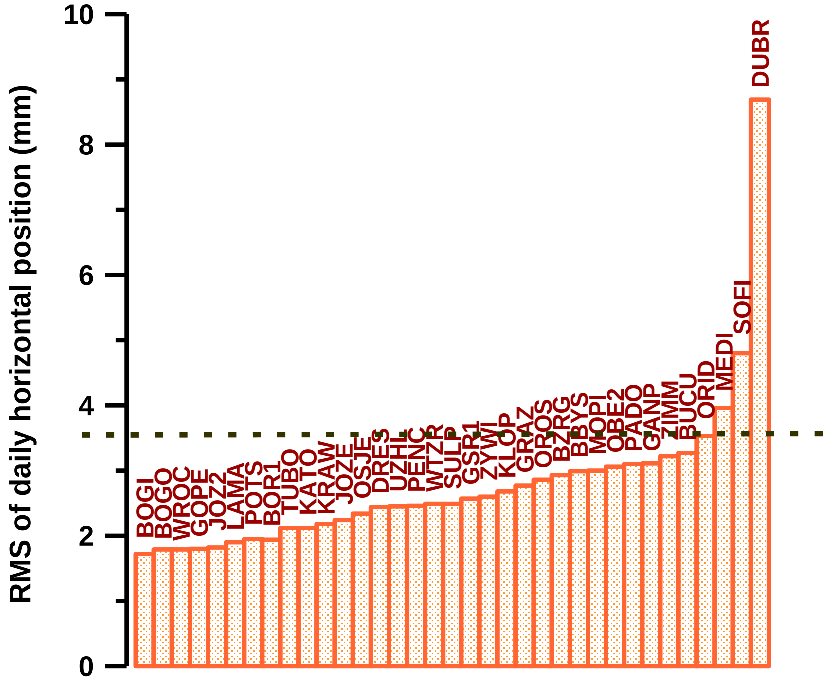

Fig. 9 RMS of daily determination of horizontal position in the network of Central Europe permanent stations. The dashed line is indicating the limit of RMS which can be for relevant stations exceeded only with 0.005 probability.

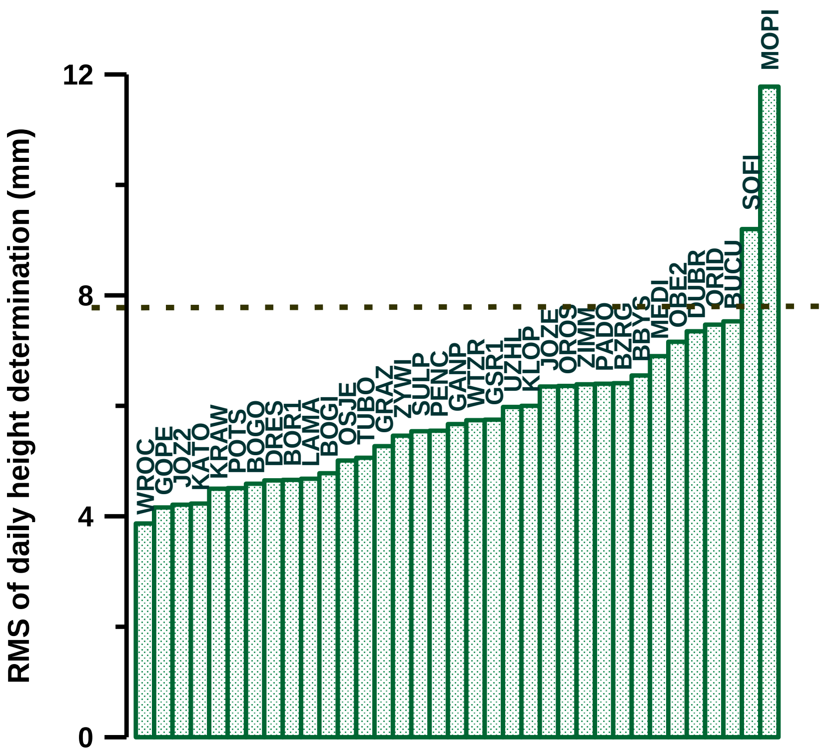

Fig. 10 RMS of daily determination of height in the network of Central Europe permanent stations. The dashed line is indicating the limit of RMS which can be for relevant stations exceeded only with 0.005 probability.

The values on the graphs document that the daily repeatability is not uniform and reflects the combined effect of at least two phenomena: the station instrument and environment influence and geographical position of the station concerning the network geometry.

The RMS of horizontal position is generally less than 4 mm and only occasionally is exceeding this limit. In height component is the general limit 8 mm. Dashed lines in both graphs show the values indicating confidence limits which can be exceeded with only 0.005 probability according to χ^2 distribution.

7. CONCLUSIONS

The results from analysis of 3-year interval of permanent observations in Central Europe region showed that:

- **Unexplained jumps in series are occasionally occurring, their elimination is inevitable for reliable velocity estimation.**
- **Three-year observation time span in the regional network is good base for intraplate horizontal velocities estimation, however is not sufficient for vertical velocities evaluation. Seasonal variations with amplitudes 1-2 mm are observed at majority of stations. Larger amplitudes occur, but quite seldom. The geodynamical interpretation of annual variations is not proved.**
- **Diurnal and semidiurnal variations with amplitudes 0.5 – 1.5 mm are characteristic for majority of stations. Origin of these coordinate oscillations with tidal frequencies is not clearly explained. Based on results of the performed analyses we can formulate**

recommendations for selection of reliable permanent stations as the reference sites in the Central Europe region:

- **No unexplained statistically significant jumps in the station coordinate time series.**
- **Intraplate horizontal velocities below 4 mm/year.**
- **If seasonal variations are with amplitude above 2 mm, it is necessary to include them in station model.**
- **Criteria for daily repeatability after eliminating deterministic terms are: RMS for horizontal position < 4 mm, RMS for height < 8 mm.**

Stations which will be considered as reference for local and regional geodynamical investigations have to fulfil at least these criteria. Of course their completion and specification is expected in future.

Acknowledgement: This work was supported by grant No. 1/1033/04 of the Grant Agency of Slovak Republic VEGA and by the CERGOP-2/Environment EU contract.

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