

CONTRIBUTION OF DATA FROM POLAR REGIONS TO THE INVESTIGATION OF SHORT TERM GEODYNAMICS. FIRST RESULTS AND PERSPECTIVES

Jan Krynski, Yevgen Zanimonskiy

Institute of Geodesy and Cartography, Jasna 2/4, 00-950 Warsaw, Poland
tel. +48 22 8270328, e-mail: krynski@igik.edu.pl

ABSTRACT

Perfection of technology and appropriate procedures of geodetic measurements makes it possible to detect and investigate short term regular geodynamic processes in time scale from several hours to several days. Also an increasing need for near real time precise satellite positioning requires to investigate short time variations of station co-ordinates geometrically derived from GPS data. Time series of investigated components of the vectors defined by permanent GPS stations and obtained using bernese software show a distinguished periodic behaviour with periods of 24 hours, 12 hours and shorter ones. Regularity of these variations occur at different levels for the vectors investigated.

An attempt to separate periodic biases into three groups depending on ground segment (receiver, antenna, software and site stability), space segment (orbits and satellites configuration) and environmental segment (troposphere and ionosphere models) was undertaken. It requires an extensive analysis of GPS, gravity and meteo data from the stations located in different regions. The comparative analysis of heterogeneous geodetic, geophysical and meteo data that are affected by the Earth rotation can contribute to the development of short term geodynamics by complementing the knowledge on the interrelations within a range of geophysical and meteorological phenomena. In particular, research on the separation of environmental segment requires data from polar regions due to specifics in the diurnal and sub-diurnal atmospheric variations at high latitudes. Recently obtained results are discussed in the paper.

1. Introduction

GPS positioning with centimetre accuracy requires long observation campaigns on wide spread network of points followed by a laborious data processing. The increase of the length of observing session results in the increase of the number of degrees of freedom and decrease of solution error. That error can additionally be reduced by including it into the solution data collected at the other stations of the network. Twenty four hour long observing sessions are considered as shortest in such calculations. Frequently the station co-ordinates are obtained by averaging solutions from a few consecutive days. The use of sessions lasting as long as 24 hour in processing high precision GPS data is not really constrained by redundancy requirements but it is driven by the need of smoothing the solution through removing from it the non-modelled systematic effects of periodic character. Such an approach concerns also a single vector precise determination from GPS data. Although vectors of 100 km length can already be resolved with fixed ambiguities and high internal precision from a few hour long GPS observing session, the variations of time series of such solutions noticeably exceed the estimated precision of individual solutions.

Research on variability of vector solutions obtained from short GPS observing sessions with use of data collected at Polish permanent stations of the IGS and EUREF networks was initiated in 1999 at the Institute of Geodesy and Cartography, Warsaw. For BOGO-JOZE vector (42 km length) computed with GPPS software using 4h long sessions covering 25 days, the variations in north (N), east (E), up (U) components and vector length (D) did not exceed 5 cm, 10 cm, 10 cm and 4 cm, respectively (Krynski and Cisak, 2000). Calculation of the same vector with bernese software provided variations in N, E, U components and in D within 1 cm, 1 cm, 4 cm and 1 cm intervals, respectively (Krynski et al., 1999). In both time series of solutions generated using different software packages the distinct periodic terms with 12h and 24 h periods occur. Variability of coordinates of JOZE IGS/EUREF permanent GPS station obtained from processing with bernese software 1h observing sessions over 22 days at 29 stations of EUREF network was analysed (Bogusz et al., 2000). Variations within 1 cm, 1 cm and 2.5 cm were obtained for N, E and U components, respectively and a distinct periodicity of 12 hour and 24 hour periods was indicated.

2. Permanent GPS station's data analysis

Time series of vector solutions obtained using data from BOGO, JOZE and LAMA permanent GPS stations of EUREF network were analysed. All three stations are situated on approximately the same meridian. Data from 21 days (260-280 DOY 1999) was processed using Bernese 4.2 software for the vectors BOGO-JOZE, JOZE-LAMA and LAMA-BOGO forming a triangle. The vectors calculated from 4h observing sessions with 75% overlap, i.e. the beginning of next session were shifted by 1 hour with respect to the beginning of the previous one. Variations in the obtained time series of solutions are distinctly regular. Spectral analysis of time series of the solutions shows the evidence of diurnal and semi-diurnal periodic terms (Zanimonskiy and Krynski, 2000). Further, a time series of triangle closure was calculated for each vector component. A variation in those series does not seem to be regular. Their magnitudes are, however

smaller than those in respective components of individual vectors. The amplitude of the variations in vertical component is the largest. Time series for vertical component of BOGO-JOZE vector as well as the respective time series derived from the combination of two vectors remaining in the triangle are shown in Fig. 1.

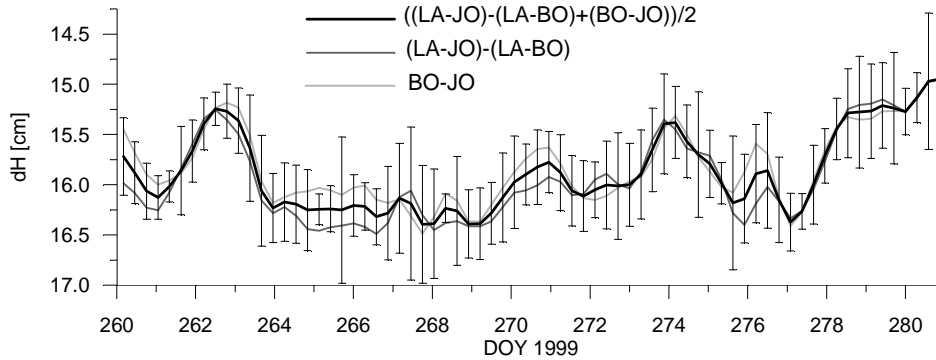


Figure 1. Variations in vertical component of BOGO-JOZE vector, of same vector calculated as the sum of two vectors remaining in the triangle, as well as of the average of two previous solutions

Three curves in Fig. 1 remarkably match to each other. The closeness of the curves indicates that in the solutions based on a few hour long observing sessions there exist systematic effects that were not removed from the data. Moreover, it also indicates that these effects distinctly dominate over random errors of observations in the estimated vector components. Thus, variations in the analysed time series are mainly due to effect of non-modelled biases. Simultaneously rough estimate of random errors corresponds quite well with the estimates provided in the process of individual vector computation.

Most distinguished regularity in time series of obtained vector components corresponds to daily blocks of solutions. Such blocks of solutions for the length of BOGO-JOZE vector for 5 consecutive days are given in Fig. 2.

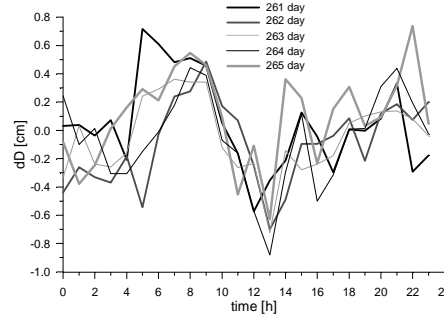


Figure 2. Diurnal regularity of variations of the length of BOGO-JOZE vector

Considering diurnal regularity of variations of vector components the average solution for each hour of the day over 21 days was computed for each component of three vectors analysed. Close agreement in the variations of the corresponding components of the vectors was obtained. Figures 3 and 4 show the variations in vertical component and vector length, respectively.

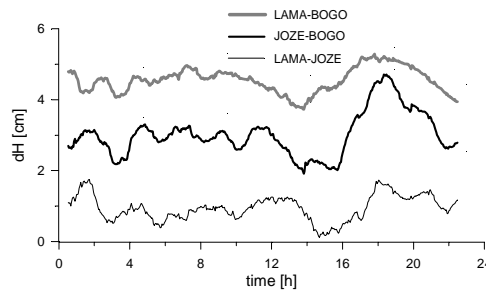


Figure 3. Averaged variations in vertical component

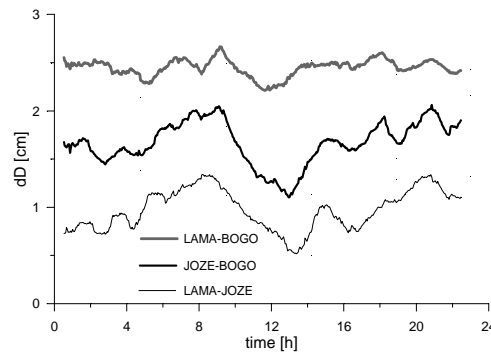


Figure 4. Averaged variations in vector length

Averaged variations obtained for BOGO-JOZE, JOZE-LAMA and LAMA-BOGO vectors that form a prolate triangle are very similar to each other in corresponding co-ordinates. Most distinguished similarity with simultaneously largest dispersion of solutions took place for the vectors BOGO-JOZE (42 km) and LAMA-JOZE (201 km), i.e. vectors with JOZE as a common station. It was found that the number of GPS satellites tracked at JOZE was frequently smaller than that at BOGO and LAMA. It resulted in weaker solution of the vectors containing JOZE and in consequence larger variations in time series of resolved co-ordinates.

Observed variations in time series of vector components determined from GPS data besides random errors of observations consist of resultant of multiple effects caused by deficiency of the models applied. Resulting biases come from different sources. They can be classified in three groups: ground segment (receiver, antenna, software and site stability), space segment (orbits and satellite configuration) and environmental segment (troposphere and ionosphere models). Separation of the individual biases and adequate observation modelling would enable more accurate determination of vector components from much shorter than 24h sessions of GPS data

3. Analysis of GPS data from mini-network at Borowa Gora

In the solutions obtained for a hundred metre long vectors the effects of orbital biases as well as biases due to ionosphere and troposphere are negligible. The solutions for such short vectors obtained from sufficiently long GPS observing sessions are thus affected by satellite configuration bias (including multipath) as well as biases related to ground segment.

GPS observations were conducted at four close to each other stations at Borowa Gora Geodetic-Geophysical Observatory for 5 consecutive days in 2000. Stations 217, OR3 i 3230 are the eccentric points for BOGO permanent GPS station (Fig. 5).

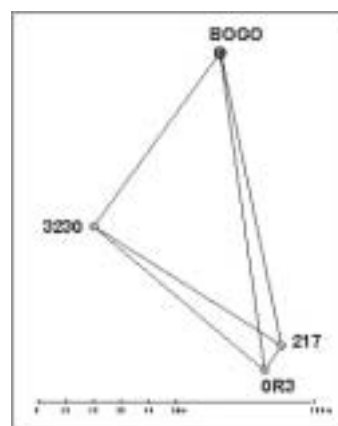


Figure 5. Test mini-network at Borowa Gora Geodetic-Geophysical Observatory

GPS data collected at the points of mini-network (Fig. 5) was processed using PINNACLE software. The vectors were calculated from 1h sessions with 67% overlap, i.e. the beginning of next session was shifted by 20m with respect to the beginning of the previous one. Time series for the components of 6 vectors in the network were obtained. As expected, the agreement in the variations between daily blocks for each component of the vectors was much better than in case of long vectors. The solutions for vertical component of BOGO-217 (107 m) vector over three consecutive days are shown in Fig. 6. Time series for the same component of BOGO-217 vector calculated from a combination of BOGO-3230 i 3230-217 vectors is given in Fig. 7.

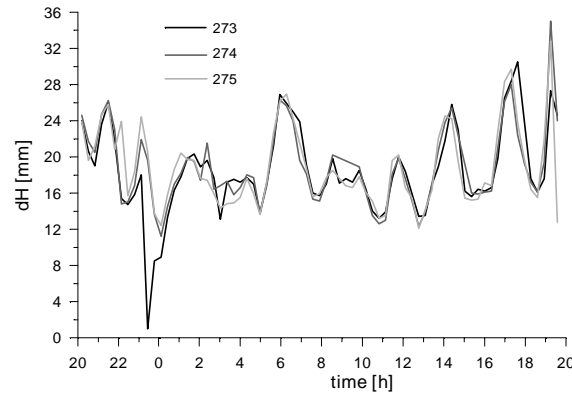


Figure 6. Diurnal regularity of variations of vertical component of BOGO-217 vector (1h sessions with 20m shift)

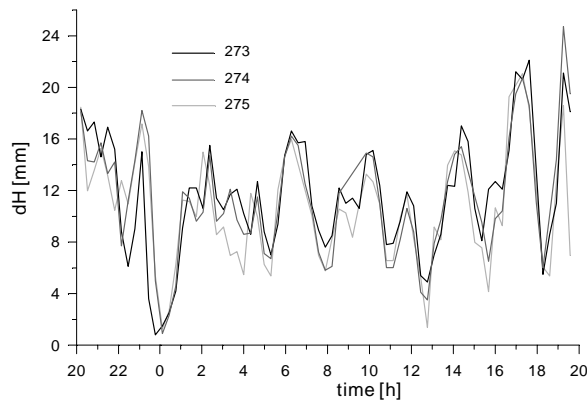


Figure 7. Diurnal regularity of variations of vertical component of BOGO-217 vector calculated as a combination of BOGO-3230 and 3230-217 vectors (1h sessions with 20m shift)

Similarly the solutions for the length of BOGO-217 (107 m) vector over three consecutive days are shown in Fig. 8.

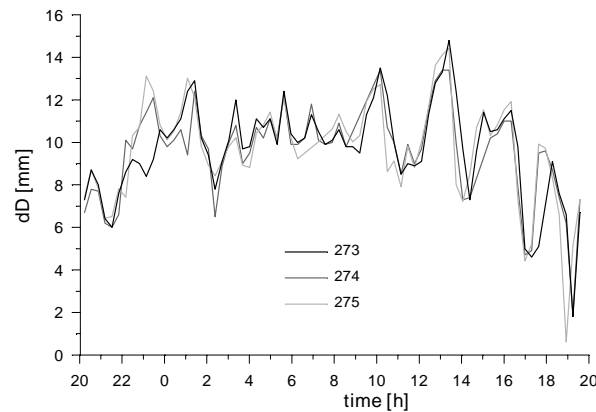


Figure 8. Diurnal regularity of variations of the length of BOGO-217 vector (1h sessions with 20m shift)

The diurnal variations of short vector components (e.g. Fig. 6, Fig. 8) as well as of triangle closure (Fig. 7) is much more regular than those for long vectors (e.g. Fig. 2). It is not surprising since in case of short vectors lots of biases differentiate to a negligible level. Variations of short vector components (Fig. 6, Fig. 8) seem to be chaotic. One can notice in them, however, periodic biases due to multipath and antenna phase centre.

In order to get higher resolution of time series for variations of vector solutions, BOGO-217 vector was calculated from 1h sessions with 98% overlap, i.e. the beginning of next session was shifted by 1m with respect to the beginning of the previous one, over 4h of 273 DOY 2000. The results obtained for vertical component and for vector length on the background of the respective previously discussed more sparse solutions are given in Fig. 9 and Fig. 10.

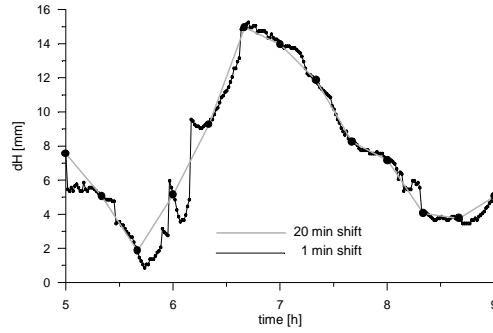


Figure 9. Regularity of variations of vertical component of BOGO-217 vector (1h sessions)

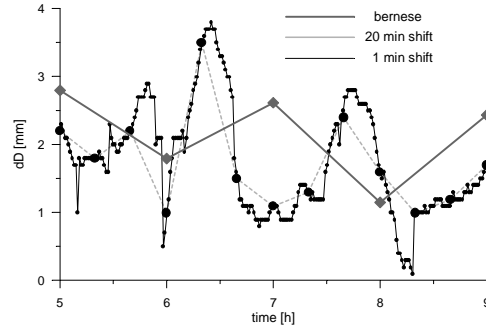


Figure 10. Regularity of variations of the length of BOGO-217 vector (1h sessions)

Variations in the solutions for vertical component and the length of the vector shown in Figures 9 and 10, respectively, similarly to the other vector components, reflect the effect of satellite configuration. This effect affects the solutions through geometry, quality of ambiguity solution, multipath and antenna phase centre.

The solutions presented in Figures 9 and 10 are obtained from processing GPS data covering 120 epochs (30s sampling rate). Since the data used for two consecutive solutions differ by 4 epochs only (1m shift) one could expect smooth variations in calculated vector components. In both figures, however, sudden jumps and peaks occur. They correspond to a case when satellite configuration changes (new satellite is getting observed or/and one of the observed satellites descended below the horizon) between two consecutive observing sessions processed. Sudden changes in N, E, U vector components and D vector length reached 1mm, 1mm, 2mm and 1mm, respectively. They also take place when the same configuration of satellites is observed but the pairs of satellites chosen to form double differences in two consecutive solutions do not match. Jumps at the level of 2mm, 1mm, 5mm and 2mm in N, E, U vector components and D vector length, respectively, occurred.

4. Specifics of GPS data from polar regions in separation of biases in vector determination

Biases that affect vector solutions from short GPS observing sessions in polar regions can also be classified as the effect of ground segment, space segment and environmental segment. Biases due to ground segment in the solutions from polar regions are expected to represent the same behaviour as the ones in medium latitudes. The substantial difference between the variations in GPS solutions in those two geographical regions occurs in the biases due to space segment, i.e. satellite configuration as well as due to environmental segment.

Distribution of tracked GPS satellites in polar region, due to high latitude, is much less homogeneous than at medium latitudes. Thus, besides 12h and 24h periodic variations in GPS solutions a bias due to satellite distribution heterogeneity is expected to occur. The effects of satellite configuration can be investigated by analysing short and medium length vectors obtained from short GPS observing sessions.

At medium latitudes both troposphere and ionosphere biases consist of a distinguished diurnal periodic component with seasonal influence. At high latitudes the effects of Earth rotation on biases in GPS solutions seasonally decrease to the level of negligibility. Therefore periodicity of the environmental bias in polar region is expected to seasonally practically vanish. This unique situation that occurs in polar regions gives an opportunity to better separate environmental biases. Analysis of GPS time series over different seasons together with meteo data will allow to separate the tropospheric bias what further would lead to the extraction of ionospheric bias.

5. Conclusions

Vector components are determined at a sub-centimetre level of accuracy from at least 24h long GPS observing sessions. Shortening observing session leads to the increase of dispersion of results and to lowering their accuracy.

A distinct regularity with daily cycle for the solutions of vector components is noted. Daily blocks of solutions for short vectors almost perfectly coincide. For long vectors daily blocks of solutions also match very well. They are, however, additionally disturbed with biases caused by imperfection of ionosphere and troposphere models as well as satellite orbit models.

The analysis indicates the need of further research on daily regularity of the vector solutions obtained from GPS data and on improvement of ionosphere and troposphere models in order to achieve sub-centimetre accuracy in vector determination from short GPS observing sessions. In such a research an important role plays an analysis of GPS data from polar regions, mainly due to specifics of environmental segment.

Acknowledgements

Research was conducted at the Institute of Geodesy and Cartography, Warsaw, within the project No 8T12E04520 supported by Polish National Committee for Scientific Research. Vectors used for analysis were calculated with Bernese software by P. Wielgosz from the University of Warmia and Mazury, Olsztyn, and with Pinnacle software by L. Zak from the Institute of Geodesy and Cartography, Warsaw.

References

Bogusz, J., Kruczyk, M., Figurski, M., Liwosz, T., Pfeil, M., Rogowski, J.B., (2000): Modelling of the Influence of Geophysical and Atmospheric Effects in Position and Gravity Changes, ION GPS 2000, 19-22 September 2000, Salt Lake City, UT.

Krynski, J., Cisak, J., Wielgosz, P., (1999): Preliminary Analysis of Variations of Borowa Gora – Jozefoslaw Vector Components Determined from GPS Data (in Polish), Presented at the Conference "Methods of precise satellite positioning in geodesy and navigation", 14-15.10.1999, Olsztyn, Poland.

Krynski, J., Cisak, J., (2000): Preliminary Analysis of the GPS Derived Vector Borowa Gora – Jozefoslaw, Proceedings of the Institute of Geodesy and Cartography, Warsaw, Poland, t. XLVII, z. 100.

Zanimonskiy, Y., Krynski, J., (2000): Towards Short Term Geodynamics, Proceedings of the 6th Geodetic Millenium Meeting Poland-Italy, University of Mining and Metallurgy, Faculty of Mining Surveying and Environmental Engineering, Krakow, Poland, 29 June – 1 July 2000, Special Issue of "Reports on Geodesy", Institute of Geodesy and Geodetic Astronomy, Warsaw University of Technology, No. 8(54), 2000.