DENSIFICATION ITRF08 INTO UKRAINE AREA

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Abstract

According to the fast development and distribution of GNSS technologies all over the world, the large numbers of reference GNSS stations have appeared in Ukraine. These stations are included in the state and several private networks. The permanent GNSS observations gathered within these networks are processed and analysed by the Centre of Lviv Polytechnic National University. A cumulative solution (coordinates expressed at the specified epoch and velocities of all stations) was estimated by using the GAMIT-GLOBK software. The authors made several numerous tests using certain configuration of fiducial stations which belong to the EPN A class to transfer ITRF08 frame into Ukraine area and choose the best strategy of alignment of the Ukrainian national GNSS network to the EPN. Three different solutions with cretin tolerance set for Ukrainian GNSS network were estimated and each time the different set of coordinates was obtained. The differences reached several millimetres. Also for verification, our solution was compared with EPN solution. Received coordinates and velocities could have a geophysical interpretation and provide very useful information for local geodesy tasks.

Key words: reference GNSS station, cumulative solution, GAMIT-GLOBK software, national densification

Introduction

The realization of ITRF is based on five techniques: Very Long Baseline Interferometry (VLBI), Lunar and Satellite Laser Ranging (LLR and SLR), Global Navigation Satellite System (GNSS) and Doppler Orbitography Radio - positioning Integrated by Satellite (DORIS). ITRF coordinates were obtained by combination of individual solutions computed by analysis centres using the observations from networks of stations located on sites covering the whole Earth. For regional and local research station density of global network is not sufficient. For densification the network and improvement of the availability of ITRF regional networks were organized. From the geodetic point of view, densification of the ITRF is meant for the expression of station positions (and velocities) of a regional or local network in the ITRF. The GNSS, compared to other techniques, has the advantage of being the most efficient one for the ITRF densification purpose, given its easy use, low cost and the availability of the IGS products for all users (Altamimi, 2003). An example of such densification of the ITRF is EUREF Permanent GNSS Network (EPN) (http://www.epncb.oma.be). Also almost all countries have their national GNSS networks: Romania - ROMPOS (http://www.rompos.ro), Poland - ASG-EUPOS (http://www.asgeupos.pl), Finland - FinnRef (http://euref-fin.fgi.fi), Italy – RDN (Barbarella et al. 2009) etc. All these networks also have their own Analysis Centres, which estimate cumulative solutions (coordinates expressed at the specified epoch and velocities of all stations) using three different GNSS analysis packages (GIPSY, Bernese, GAMIT-GLOBK) (Dach et al. 2015; Herring et al. 2016; Lichten et al. 1995). For example, the Italian network RDN (100 permanent stations) was processed by Military Geographical Institute (IGMI) and computed with Bernese software (Caldera, 2010). Poland network ASG-EUPOS (130 permanent stations) was processed by the Centre of Applied Geomatics of Military University of Technology, which is one of the EPN Local Analysis Centres (Araszkiewicz et al. 2011) with Bernese software. Strategy of processing was very similar to EPN test reprocessing strategy (Kenyeres et al. 2008). Designated solution is expressed in the reference frame implemented by given reference stations. Reference frame is transferred by introducing a minimum number of constraints (Szafranek, Bogusz, Figurski, 2014). ASG - EUPOS fulfils the role of the main national geodetic frame and enable conservation of ETRF (European Terrestrial Reference Frame) in Poland. Also daily and weekly solutions will help to monitor and control whole system activity (Szafranek et al. 2009).

In Ukraine we also have large numbers of reference GNSS stations (~150), which observations are processed and analysed in Lviv Polytechnic National University, Department of Geodesy and Astronomy. The aim of this research is the estimation of a cumulative solution and selection of the optimal alignment strategy of Ukraine GNSS network to EPN.

Methodology of research and materials

The primary aim of this research was to align the Ukrainian national GNSS network to the EPN, the Guidelines for EUREF Densifications (Bruyninx et al. 2013) were followed. In particular, we used final IGS orbits and Earth Rotation Parameters, the same antenna calibration values as the EPN analysis centres, also GNSS observations collected by the Ukrainian GNSS network (Fig. 1) since 2013 (including 1721-1929 GPS weeks) have been processed in GAMIT - GLOBK software which are based on a classical double-difference approach.

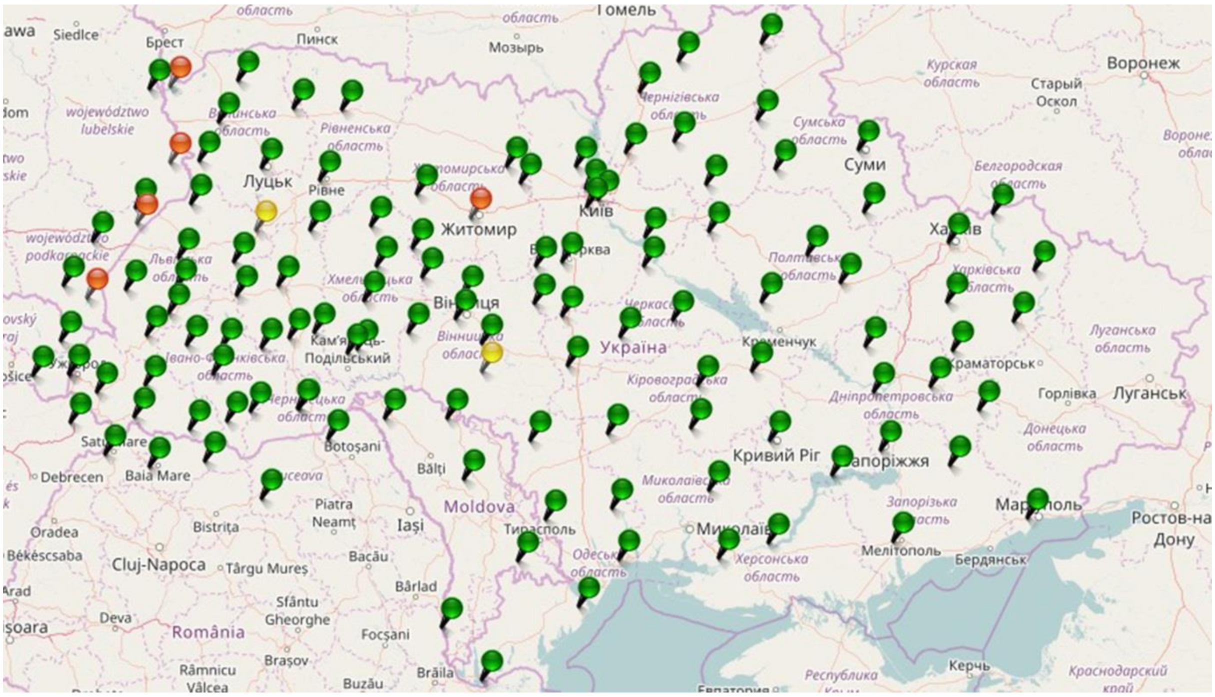

Fig. 1. Ukrainian GNSS network

To ensure a reliable alignment, data from 24 EPN stations class A (Kenyeres, 2009) (Fig.2): BBYS (Slovakia), TUBO (Czech Republic), BAIA, BUCU (Romania), BYDG, JOZ2, LAMA, USDL (Poland), GRAZ (Austria), IGEO (Republic of Moldova), MATE (Italy), MDVJ, ZECK (Russian Federation), POTS, WTZR (Germany), RIGA (Latvia), SOFI (Bulgaria), VLNS (Lithuania) i CNIV, GLSV, MIKL, POLV, SULP, UZHL (Ukraine) distributed around the processed network was used. This configuration of fiducial stations was chosen as optimal from the previous research (Doskich, 2016).

The relation between a regional solution (X_R) and ITRF (X_1), over selected stations could be written as (Altamimi, 2003):

$$X_1 = X_R + A1 \tag{1}$$

where A and 1 are respectively the design matrix of partial derivatives and the vector of 7 transformation parameters:

$$A = \begin{pmatrix} . & . & . & . & & . & . \\ 1 & 0 & 0 & x_a^i & 0 & z_a^i & -y_a^i \\ 0 & 1 & 0 & y_a^i & -z_a^i & 0 & x_a^i \\ 0 & 0 & 1 & z_a^i & y_a^i & -x_a^i & 0 \end{pmatrix} \tag{2}$$

$$1 = \left(T_x, T_y, T_z, D, R_x, R_y, R_z\right)^T$$

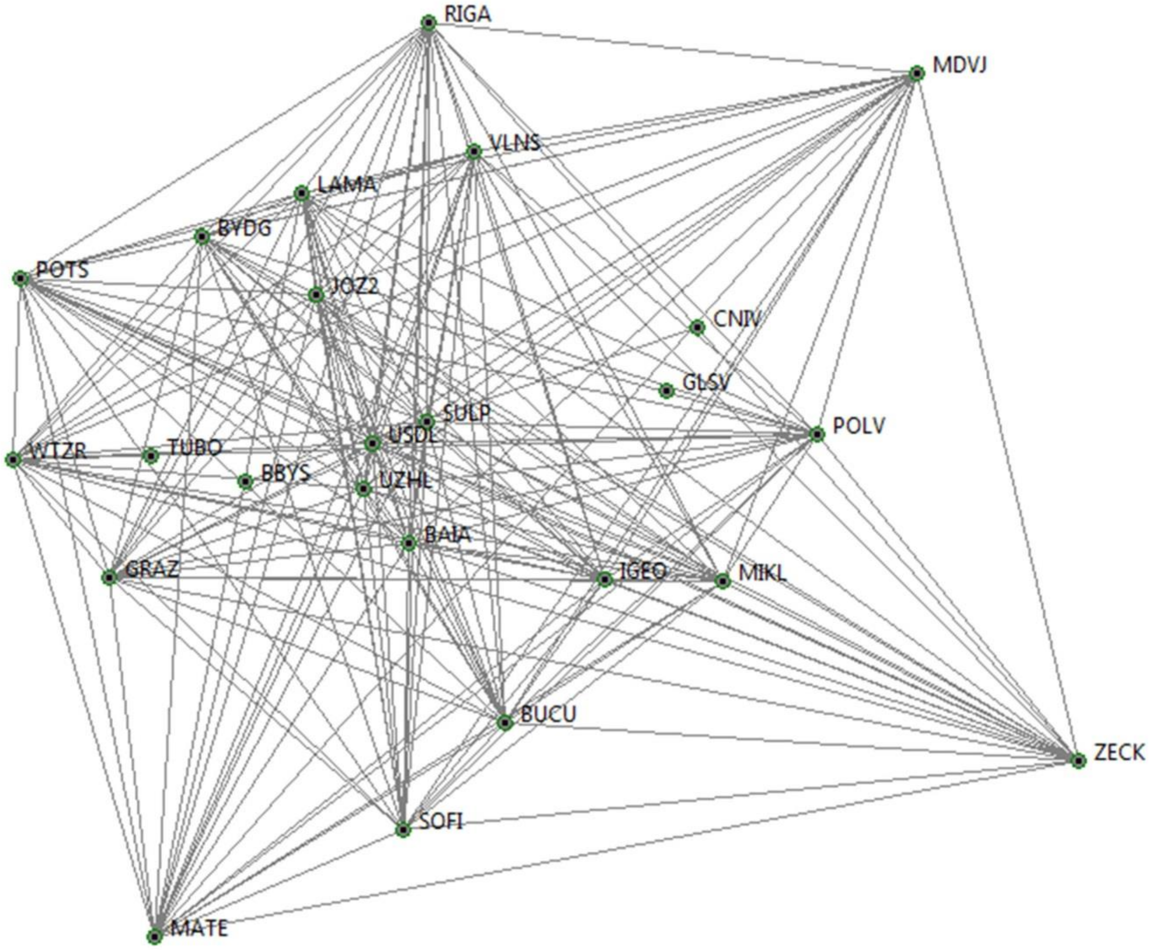

Fig. 2. Scheme of the fiducial stations network

During the alignment GAMIT-GLOBK also compared the estimated values of the parameters to the a priori. If they differ, it is more than the tolerance set (max_chii), ”bad” data are automatically excluded. Max chii has three arguments to specify the maximum chi-square increment, the maximum prefit residual (m) and the maximum rotation (mas). To choose the best tolerance set for our network, we made several numerous tests using certain max_chii: max_chii1=13 3 100; max_chii2=100 5 20000; max_chii3=20 10000 10000.

For verification of the achieved result, we compared our cumulative solution from GAMIT-GLOBK with EPN solution.

Discussions and results

When a cumulative solution (observation of 1721-1929 GPS weeks) from GAMIT-GLOBK software was estimated, several stations have “bad” values of coordinates and velocities. We have investigated that the reasons for this “bad” values have several factors:

1. Some stations had incorrectly indicated a receiver’s antenna. The reason for this is an error during transmission of data to our Centre. The server of private network automatically recorded the wrong antenna.
2. The length of the time interval of the station observations were small. Figure 3 illustrates diagrams of the time interval of the problematic station observation for 4 years (1461 days).
3. Some stations have incorrect input data.

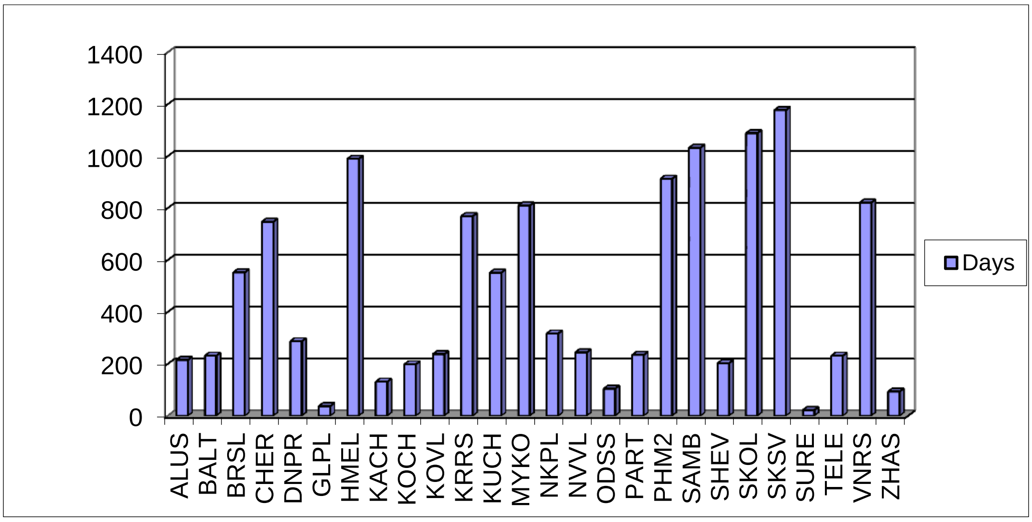

Fig. 3. The time interval of the stations observation

Table 1

The difference of coordinates between certain tolerance sets

Stations	**max_chii1-max_chii2**			**max_chii1-max_chii3**			**max_chii2-max_chii3**		
	ΔX, mm	**ΔY, mm**	**ΔZ, mm**	**ΔX, mm**	**ΔY, mm**	**ΔZ, mm**	**ΔX, mm**	**ΔY, mm**	**ΔZ, mm**
ALUS	0	0	0	0	0	0	0	0	0
BALT	0	0	0	-1	0	0	0	0	0
BRSL	0	-1	0	-1	0	0	0	0	0
CHER	0	0	0	1	0	2	1	0	2
DNPR	0	0	0	0	0	1	0	0	0
GLPL	-1	0	0	-2	-1	-1	-1	-2	-1
HMEL	0	0	0	0	0	1	0	0	0
KACH	0	0	0	1	-2	1	0	-1	1
KOCH	0	0	0	-1	0	0	0	0	0
KOVL	0	0	1	0	0	0	0	0	0
KRRS	-4	3	3	-4	3	3	0	0	0
KUCH	0	0	0	0	1	1	0	0	0
MYKO	1	0	1	1	-1	-1	0	-1	-2
NKPL	-1	0	0	-2	0	0	-1	1	0
NVVL	0	1	0	3	-4	-2	4	-6	-1
ODSS	-3	-2	-4	-9	-6	-13	-6	-4	-8
PART	-2	-1	-1	-8	1	-2	-6	1	-1
PHM2	0	0	0	0	0	0	0	0	0
SAMB	1	0	0	-2	0	-3	-2	0	-3
SKOL	1	0	1	-2	-2	-3	-2	-1	-4
SKSV	9	4	11	13	6	16	4	2	5
SHEV	-1	0	0	-1	0	0	0	0	0
SUDA	0	0	0	0	0	0	0	0	0
SURE	-1	-2	0	-1	-1	0	0	0	1
TELE	0	0	0	0	0	1	0	0	0
VNRS	0	0	0	-1	1	0	0	0	0
ZHAS	0	1	0	0	1	0	0	0	0

The next step of our research was to select the optimal tolerance set (max_chii) for our network. For this task we estimated 3 different cumulative solutions with a certain value max_chii (max_chii1=13 3 100; max_chii2=100 5 20000; max_chii3=20 10000 10000). From these solutions, we calculated the number of days for 4 years (1461 days). We received such results: max_chii1=1164 days, max_chii2=1177 days, max_chii3=1044 days and compared the coordinates obtained from all variants of tolerance set in Table 1.

The best result is shown by max_chii2 (1177 of 1461 days), so this tolerance set would be used to estimate a comulative solution in the future.

To investigate accuracy and correctness of our cumulative solutions, it was compared with EPN solutions by common station, and coordinates differences were determined (Fig.4). EPN solutions were taken from EPN_A_IGb08.SSC (http://www.epncb.oma.be/_productsservices/coordinates/). Coordinates have been calculated on the same epoch as in our solution.

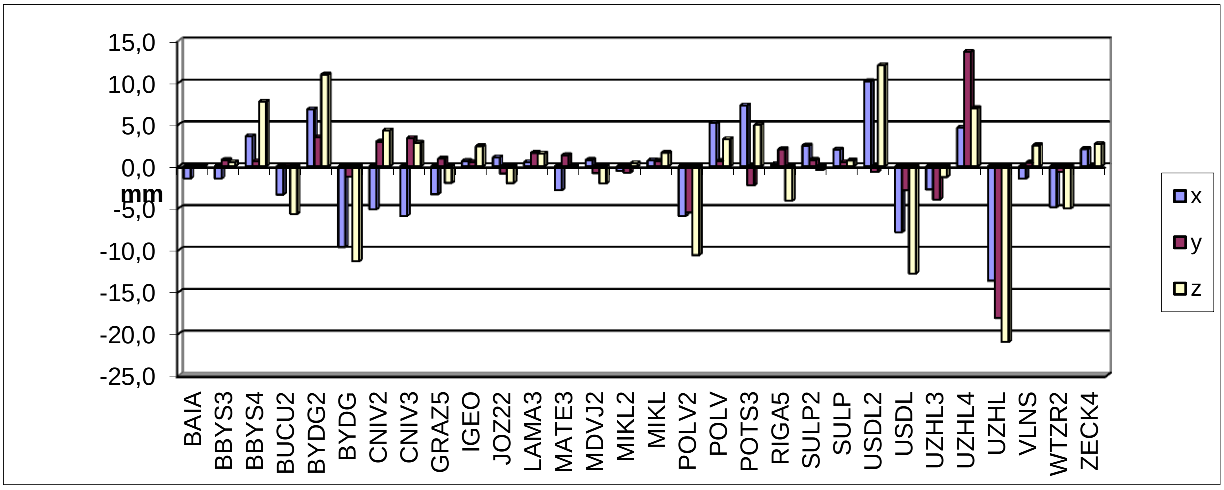

Fig. 4. Comparison of common sites coordinates from EPN and Ukraine solutions

Table 2 shows the statistical summary of the differences.

Table 2

Statistical result of the differences EPN-Ukraine solutions

St. dev	X	Y	Z
mm	5.2	4.6	6.9

The comparison made between solutions obtained in national processing and official EPN solution gave good results since differences do not exceed 1 cm.

Conclusions and proposals

1. The tests allowed to examine the impact of observation period on the reliability of the realization of the ITRF08 in Ukraine and select the optimal tolerance set (max_chii2=100 5 20000), which was used in software GAMIT-GLOBK to determine the reference coordinates and velocities.
2. For verification the achieved cumulative solution was compared with a cumulative solution from EPN. The comparison gave good results (differences do not exceed 1 cm), so it shows that procedures were done correctly.
3. The received cumulative solution (coordinates and velocities) may be further used for regional and local geodynamic studies, geophysical interpretation and for many practical applications in geodesy.

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