MONITORING OF STABILITY OF ASG-EUPOS NETWORK COORDINATES

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1. INTRODUCTION

ASG-EUPOS is Polish GNSS (Global Navigation Satellite System) Ground Based Augmentation System. The name stands for Active Geodetic Network European Position Determination System. It is multifunctional system of precise positioning consisting of more than 100 GNSS reference stations (Fig. 1), which constitutes densification of global IGS (International GNSS Service) and regional EPN (European Permanent Network) GNSS (Global Navigation Satellite System) networks. Data collected on those stations are reference for many surveys (real time or postprocessing corrections - differential technology). ASG-EUPOS will fulfill a role of main national geodetic frame and will enable conservation of ETRF (European Terrestrial Reference Frame) in Poland. That is one of the reasons why the system activity has to be monitored and controlled.

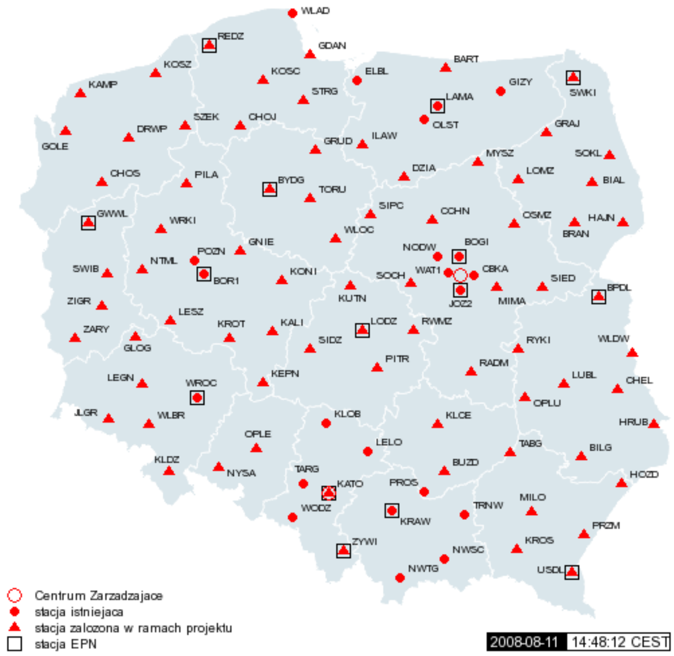

Fig. 1. ASG-EUPOS stations *(http://www.asgeupos.pl)*.

2. PROCESSING OF DATA

Basing on signed agreement with the Head Office of Geodesy and Cartography, which manages the system, Applied Geomatics Centre (Military University of Technology) has an access to all the data that has been gathered since the beginning of the system activity. Processing was made for data from all available Polish stations for foreign, border stations and for some EPN stations. As a reference (datum definition) few EPN stations were used (BOR1, WTZR, METS, POTS, ONSA). The calculations were made for data from November 2006 to February 2009, although most polish stations started to gather data at the end of 2007. Only GPS observations (RINEX format) were used (30 sec for data screening, 180 sec for final solution) with carrier phase as a basic observable. Elevation angle cutoff was 3 degrees and elevation dependent weighting was done using cos(z). Weekly and daily solutions were obtained in SINEX format.

2.1. Strategy of processing (bernese 5.0)

Processing was made using Bernese 5.0 software (Beutler et al., 2006). Strategy of processing was very similar to EPN test reprocessing strategy (Kenyeres et al., in press). As modeled observable double-differences (ionosphere-free linear combination) were used. Absolute model of ground and satellite antenna phase center calibrations for EPN stations was also implemented.
To obtain precise solutions troposphere has to be modeled, but it is also an outcome from the processing. Tropospheric delay (*ZTD*- Zenith Total Delay) is divided into two components: dry (hydrostatic) part – *ZHD* (Zenith Hydrostatic Delay) and wet part – *ZWD* (Zenith Wet Delay). About 90% of tropospheric delay is connected with dry part of the atmosphere and it is easy to be described by a model. Wet part depends on water-vapour content in the atmosphere, so it is hard to model it. Troposphere delay $\Delta\rho$ is a function of zenith distance z (Bosy et al., 2003):

$$\Delta\rho = m(z)\cdot ZTD \tag{1}$$

Function $m(z)$ is called mapping function and it enables determination of delay value for any direction. During the processing Saastamoinen-based dry component mapped with the Dry-Niell mapping function was used as a priori model. The Wet-Niell mapping function was employed to map the wet component (without a priori model). Estimation of zenith delay corrections was made at 1-hour intervals for each station. Horizontal gradient parameter was estimated for each station per day (TILTING) with no a priori constraints. Daily TRO files (files containing troposphere data – processing outcome) with cumulative coordinates input were computed from weekly solution.
For the final adjustment, ionosphere was cancelled out due to ionosphere - free linear combination used, but CODE (The Center for Orbit Determination in Europe) global iono models helped to increase the number of resolved ambiguities in the QIF, the L5/L3 and the L1/L2 ambiguity resolution.
Daily RINEX observation files containing less than 50 percent of possible observation epochs were ignored. To eliminate outliers the two-step preprocessing method was applied. Rejection criterion of L3 outliers was set up as 0.0020 m (normalized L1 zero-difference zenith value).
Satellite clock corrections were not estimated, but biases were eliminated by forming double differences. Receiver clock corrections were estimated as a part of the biases preprocessing using code measurements and finally were eliminated by forming double differences.

Orbits and ERPs (Earth Rotation Parameters) were taken from IGS (International GNSS Service) as a result of IGS network reprocessing (Steigenberger et al., 2006).
Method of ambiguity determination depended on the length of a baseline. For baselines up to 1300 km length QIF strategy in a baseline processing mode using CODE global iono models was used. For baseline lengths shorter than 200 km L5/L3 approach was employed and for baselines shorter than 20 km - L1/L2 approach.

Processing was made using models:
Planetary ephemeris: **DE405**
Ocean tides: **OT_CSRC**
The Earth geopotential is modeled using: **JGM3**
Nutation model: **IAU2000**
Subdaily pole model: **IERS2000**
Tidal displacements:
Solid tides: according to the **IERS 1996/2000** standards
Ocean loading model: **FES2004**

3. WEEKLY SOLUTIONS

As an outcome daily and weekly solutions (North, East, Up components for each station) were achieved. Uniform elaboration (solutions in SINEX format) enables integration and comparison with EPN/IGS solution. Weekly solutions were analyzed using CATREF (Altamimi et al., 1994) software (similarly to EPN solution analysis) and they were used to create cumulative solution. The cumulative solution is a reference for successive weekly solutions by Helmert transformation parameters (translation, rotation, scale) determination. This operation concerns the whole network and it enables to estimate a quality of every weekly solution (Fig. 2).

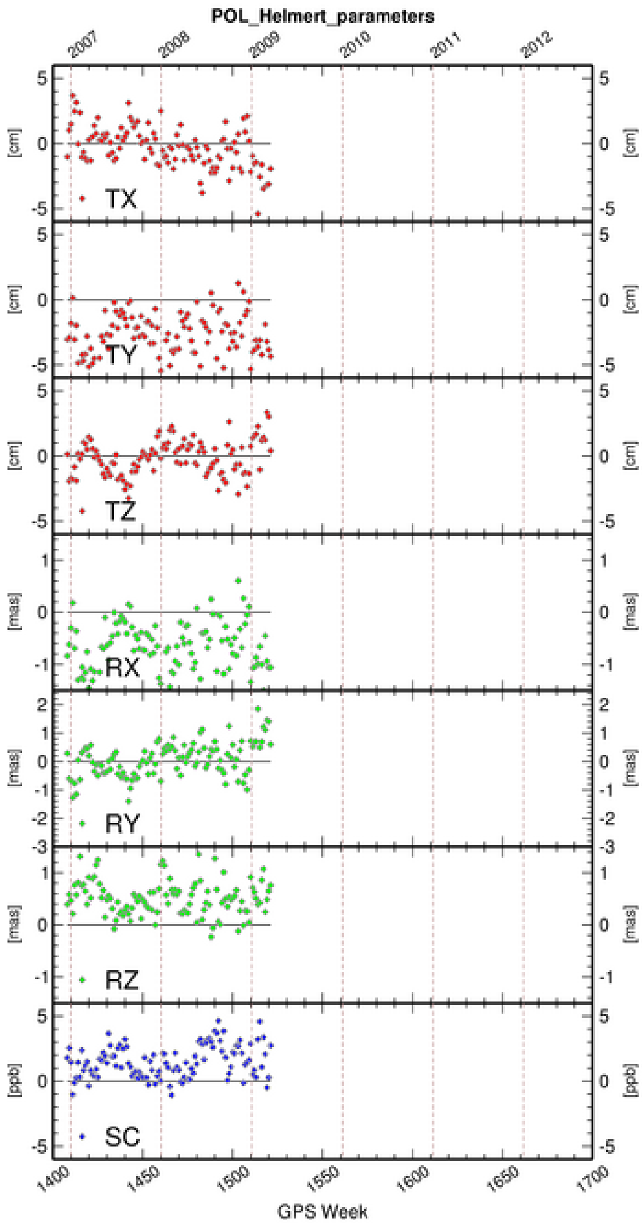

Fig. 2. Helmert transformation parameters (transformation between each weekly solution and cumulative solution).

Another parameter that allows to express solutions accuracy is weekly weighted RMS (Root Mean Square Error). WRMS values for ASG-EUPOS weekly solutions (in reference to cumulative solution) are shown in Fig. 3 separately for North East and Up components. Mean value of 2D WRMS is about 1mm and mean value of Up-WRMS is about 2 mm.

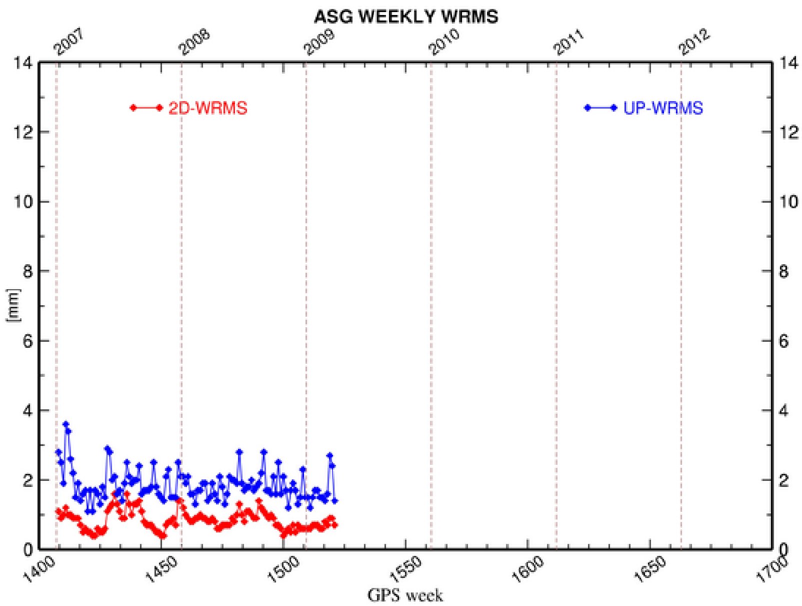

Fig. 3. ASG-EUPOS weekly WRMS.

Solutions from Polish stations (North, East, Up components for each week) can be used to increase density of European velocity field (Dense European Velocity Field - DEVF programme, (Altamimi, 2004)). Currently, kinematic ETRF model is based on data from EPN stations. Solutions from national systems from different countries will supply this model, which enables taking into consideration local Earth's crust movements.
Fig. 4 presents horizontal velocities (North and East components) of polish stations in ITRF. Movement of Eurasian plate can be easily observed here. 2D velocities after movement of Eurasian plate elimination can be seen in Fig. 5 (velocities are referred to ETRF). Vertical velocities are presented in Fig. 6.

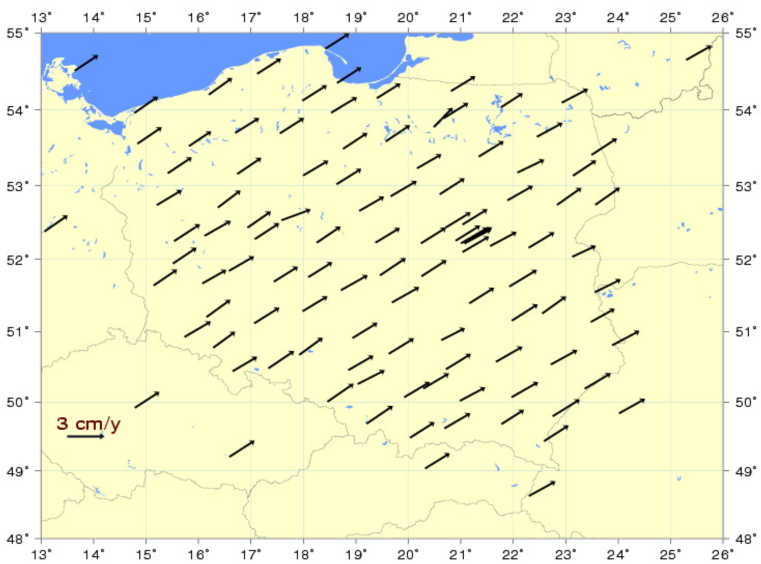

Fig. 4. 2D velocities (ITRF).

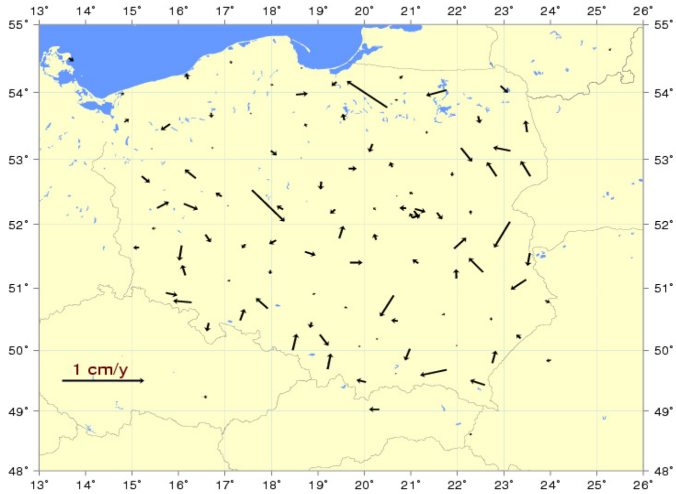

Fig. 5. 2D velocities (ETRF).

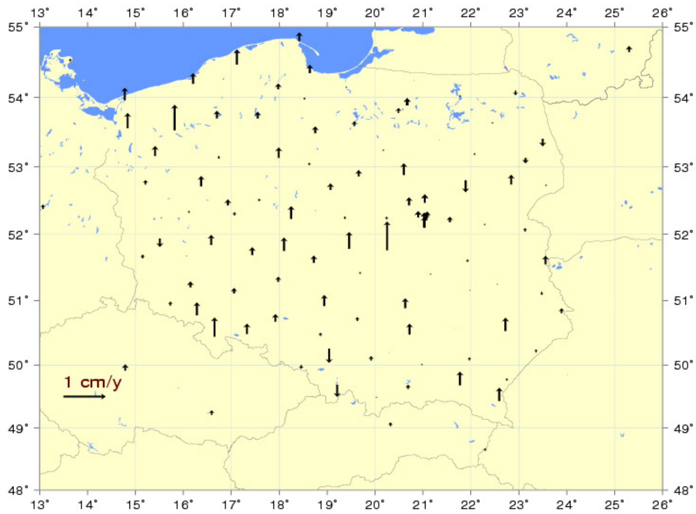

Fig. 6. Vertical movements.

4. DAILY SOLUTIONS

Acceptance of proper reference system and its correct realization is crucial for the whole geodesy. In Poland, horizontal surveys are referred to ETRS. EPN stations that are located in our country determine direct realization of ETRS. ASG-EUPOS is a natural, uniform connection to the European frame. It enables homogenous ETRF densification in Poland. There is a necessity to control whether observations quality and coordinates accuracy are high enough. Station coordinates should be monitored all time to notice any incorrectness as soon as possible to ensure proper activity of system, especially for precise positioning (surveying). Observations must be verified before they are archived in database. Gathering data from a long period to create reliable cumulative solution, monitoring and analysis of daily solutions (North, East, Up time series) will enable obtaining the highest possible accuracy of station coordinates. Fig. 7-10 presents time series of daily solutions residuals (North, East, Up) for selected ASG-EUPOS stations (Fig. 7) after eliminating Eurasian plate movement.

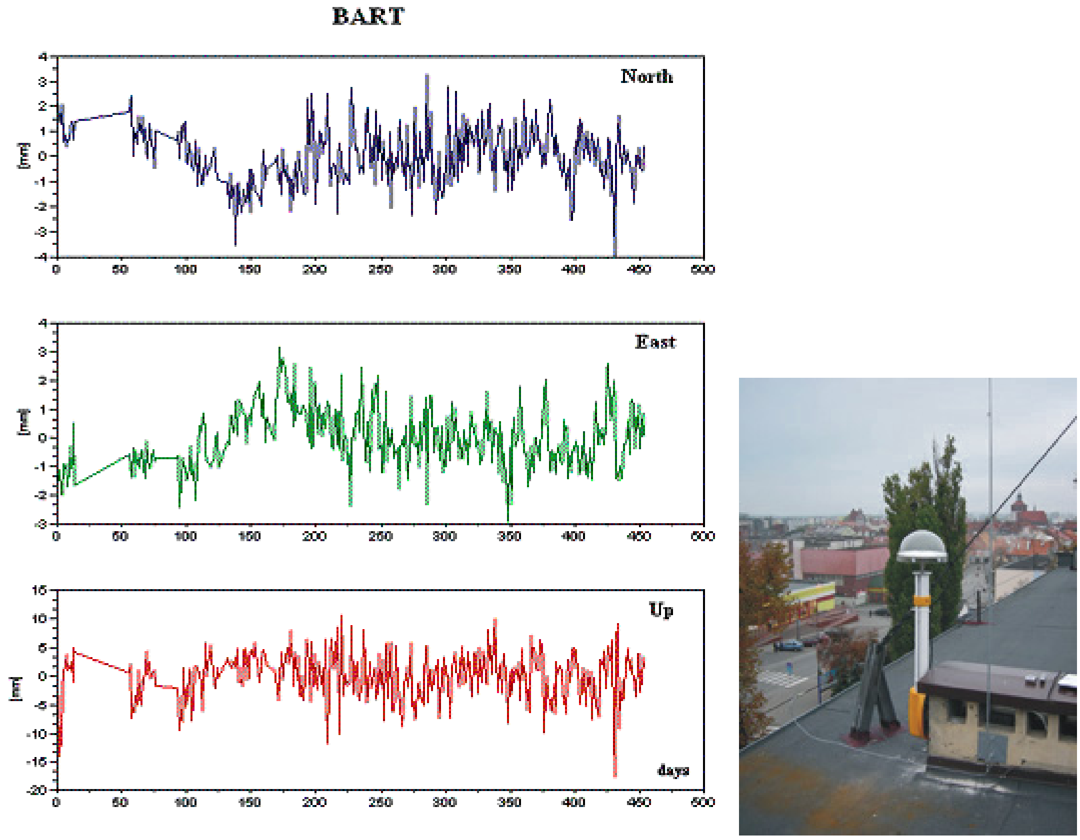

Fig. 7. Station BART (Bartoszyce).

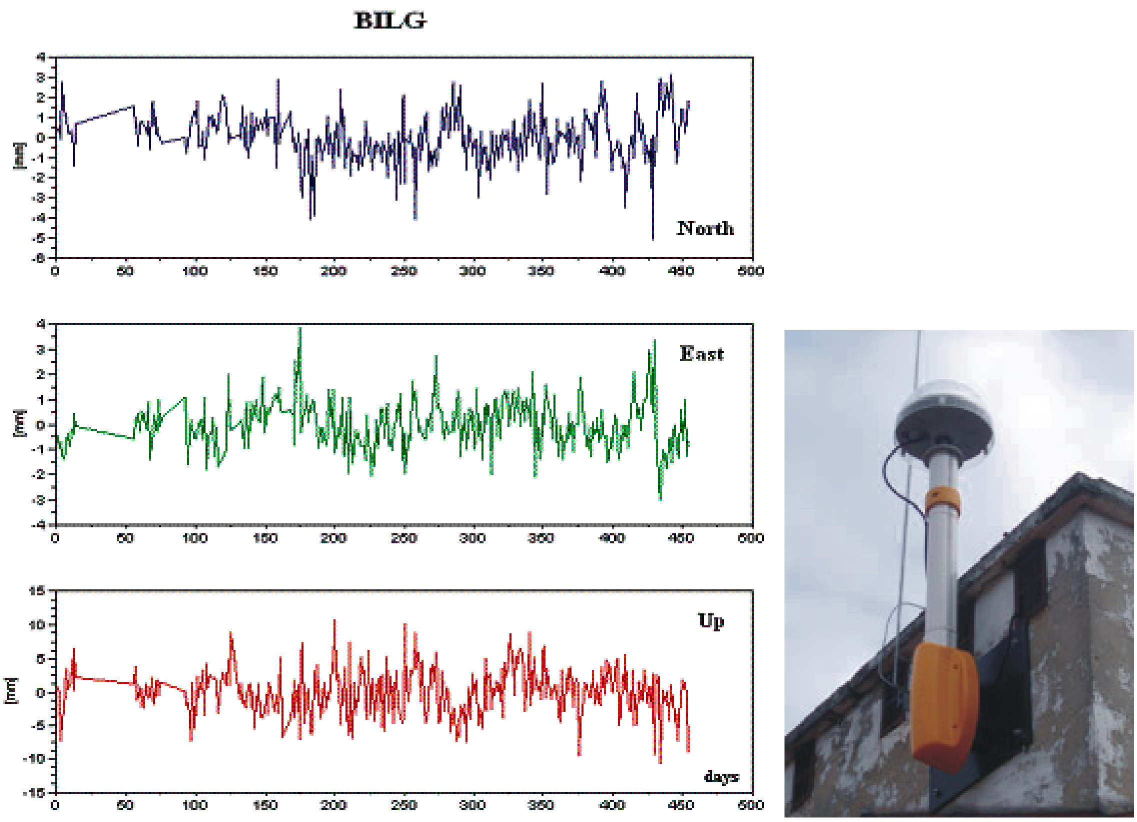

Fig. 8. Station BILG (Biłgoraj).

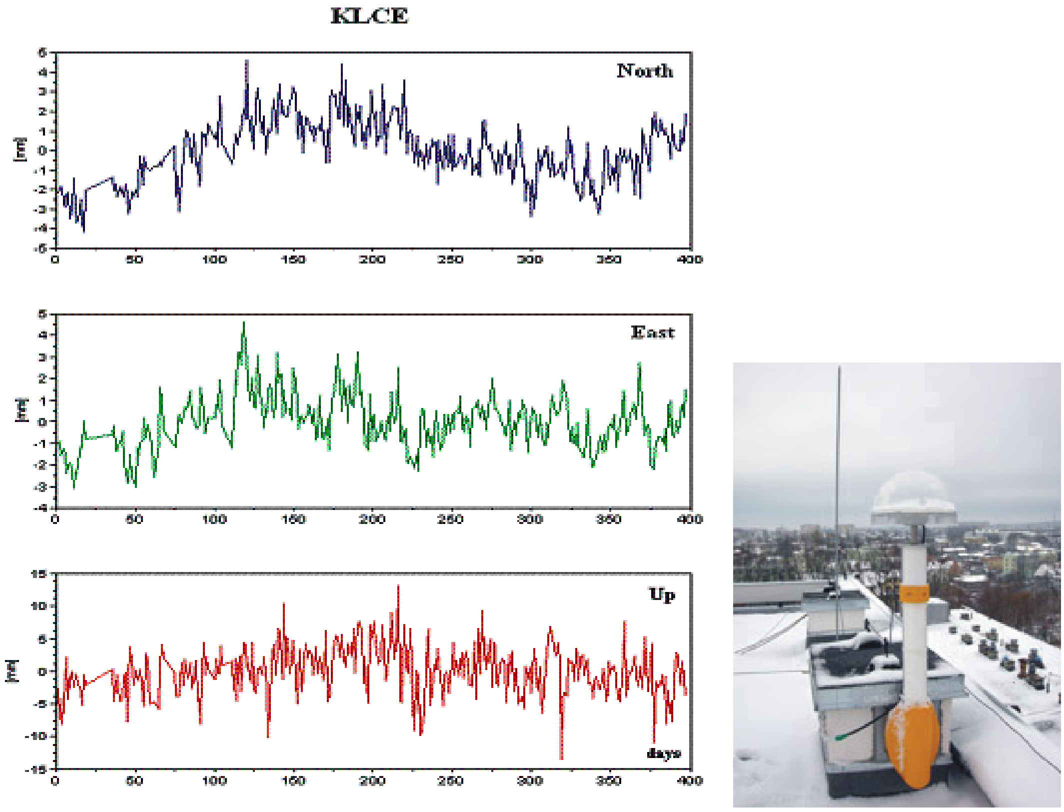

Fig. 9. Station KLCE (Kielce).

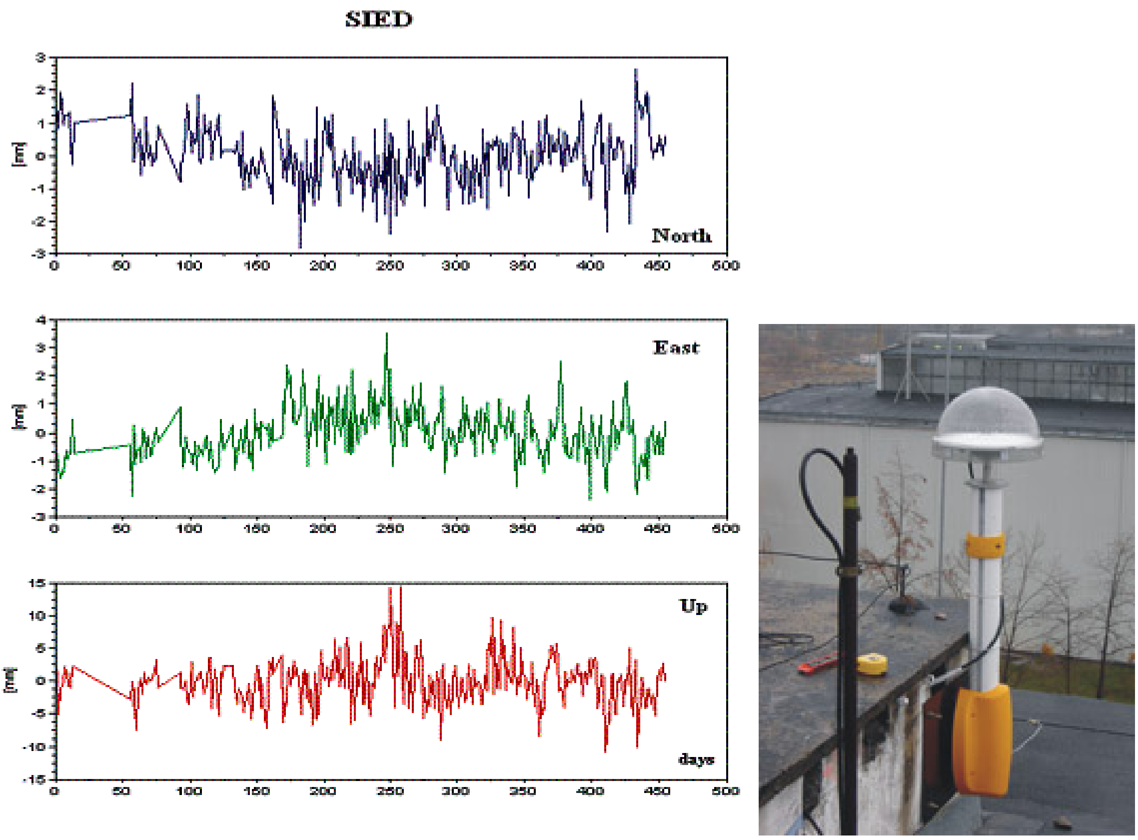

Fig. 10. Station SIED (Siedlce).

Presented time series are based on short period of observations (about 15 months), so it is hard to draw any conclusion about their stability. To obtain higher accuracy and more reliable solutions data from a longer period is needed. To eliminate some periodic factors e.g. oscillation connected with tidal waves or weather conditions, solutions from at least a few years of stations' activity should be analyzed. There are few stations (e.g. TARG and WLAD Fig. 11, 12), on which very strong and regular periodic disturbances in horizontal components can be noticed (those stations gathered data for almost 3 years). Next step is to eliminate different types of factors that are supposed to cause disturbances in order to obtain very precise coordinates and velocities of ASG-EUPOS station, so they can realize reliable and stable datum for the whole country.

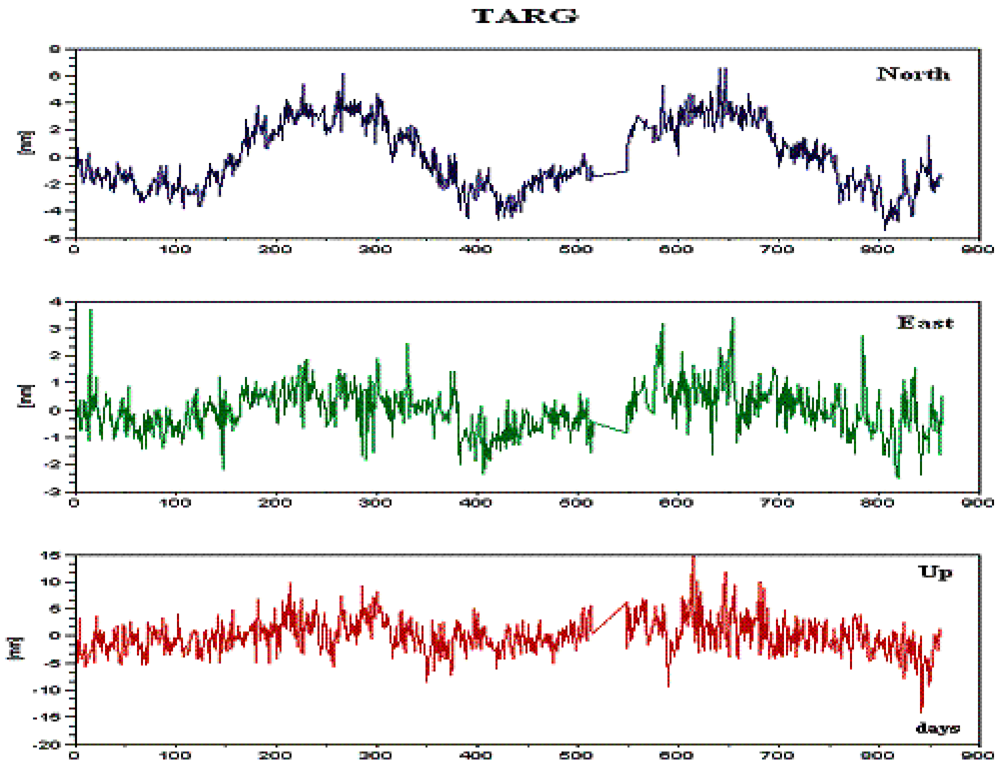

Fig. 11. Station TARG (horizontal oscillation).

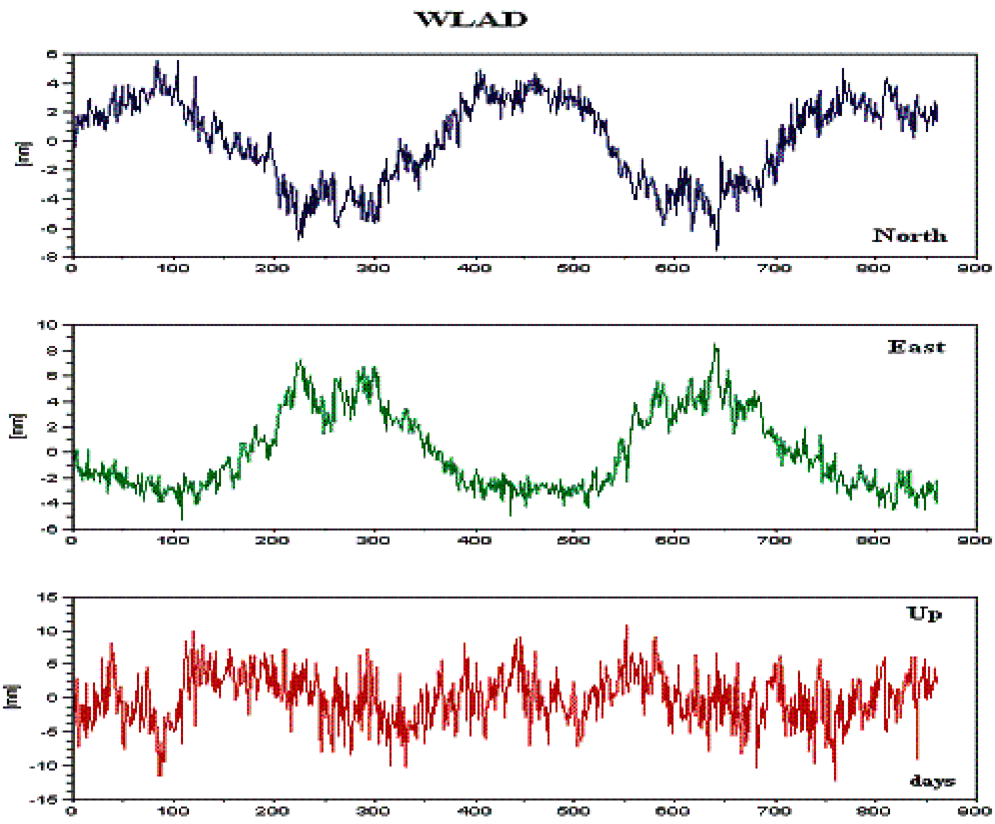

Fig. 12. Station WLAD (horizontal oscillation).

5. CONCLUSIONS

Main aim of reprocessing of the large amount of data gathered by reference stations during long period is to create cumulative solution – reliable and precise coordinates of all involved stations. Cumulative solution is a reference for successive solutions and it constitutes ETRF (ETRS realization) in Poland. Processing made according to EPN resolutions (i.e. joining suitable EPN stations) enable regional network densification (weekly solutions). Afterwards, results of such calculations are verified and validated by EPN Central Bureau. Daily solutions allow to analyze different factors (i.e. geophysical) causing disturbances on stations and estimate proper stations' activity. Described procedures were done for short period of data, more reliable and stable results will be achieved after gathering more observations.

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Pictures of ASG-EUPOS station were taken from http://www.asgeupos.pl.