A new adjustment of Poland's national GNSS reference network

Tomasz Liwosz, Jerzy Rogowski

WARSAW UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF GEODESY AND GEODETIC ASTRONOMY
1 POLITECHNIKI SQ., 00-661 WARSAW, POLAND

email: t.liwosz@gik.pw.edu.pl

Abstract

The poster presents results of control adjustment of the Polish national GPS reference network performed at Warsaw University of Technology for the Polish Head Office of Geodesy and Cartography (HOGC). The coordinates obtained in this adjustment will be considered by HOGC as the extension and upgrade of the existing realization of ETRS89 in Poland.

GNSS data from Polish permanent stations and from stations observed in two epoch campaigns (2008 and 2010/2011) were used in these analysis. Analyses have been performed using Bernese GPS Software ver. 5.0. EUREF cumulative solution was used for reference frame realization. The method of expressing combined coordinates in ETRS89 is also presented on the poster.

1 Campaigns

Two measurement campaigns were performed: in **2008** and **2010**:

1. **2008** (18 days: 114–131/2008)
   - 292 points
2. **2010**
   - **2010 part**(36 days: 285–302/2010, 308–317/2010, 341–348/2010)
     – 494 points
   - **2011 part**(12 days: 080–091/2011)
     – 213 points

In final adjustment ~ 700 points.

2 Analyzed network

During the two campaigns, observations were collected on stations belonging to the following Polish networks: EUREF-POL, POLREF, EUVN, 1st class (epoch stations) and ASG-PL (permanent). The distribution of stations used in processing is presented in Figure 1.

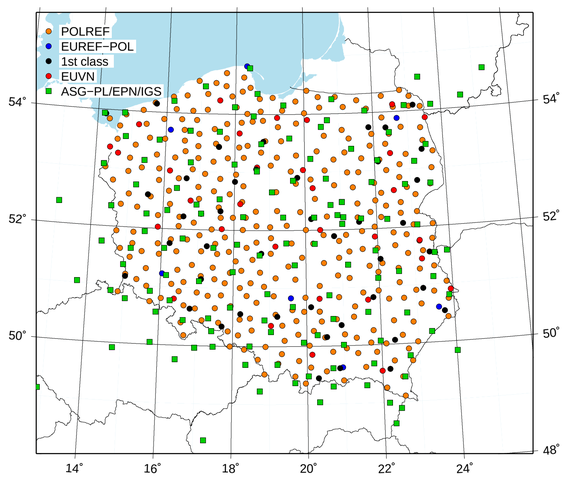


Figure 1: Stations belonging to Poland's national GNSS reference network, non EPN permanent sites from neigbhour countries and IGS/EPN sites (some outside of the map) used in processing

3 Analysis options

The data have been analyzed using Bernese GPS Software ver. 5.0 (Dach et al. 2007).
The analysis options are mostly consistent with EPN LAC guidelines (Bruyninx et al., 2010).

Feature	Value
Software	Bernese GPS Software ver. 5.0
Orbits and ERPs	IGS (GPS)/CODE (GNSS)
Elevation mask	$5°$/$10°$
Satellite system	GPS, GPS+GLONASS
Baseline definition	max. common observations (100 km)
Ambiguity resolution	SIGMA L1&L2 ($L \leq 20$ km)
(GPS satellites only)	SIGMA L5/L3 ($20 < L \leq 200$ km)
	QIF ($L > 200$ km)
Troposphere *a priori* model	Saastamoinen + NMF, dry part
Mapping function for corrections	wet NMF
Interval for troposphere parameters	1 hour
Tropo. horizontal gradients	yes ($5°$), no ($10°$)
Ionosphere model	CODE global
Phase center offsets and variations	absolute (IGS05)
	+ individual (EPN/ASG-EUPOS)
Reference frame	ITRF2005, EPN cumulative (C1600)
Reference frame realization	coordinates: NNT minimum constraints
	velocities: constrained to EPN C1600

4 Analysis Results

Solution types

Data were processed according to three variants: only GPS observations used with elevation mask $5°$, GPS observations with mask $10°$ and GPS+GLONASS (GNSS) observations with elevation mask $5°$. These variants are summarized in Table 2.

Table 2: Variants of data processing

	2008	2010	2011	WUT ASG-PL[a]
GPS mask $5°$	+	+	+	+
GPS mask $10°$	+	+	+	+
GNSS mask $5°$[b]		+	+	

[a] Combined solution
[b] GPS and GLONASS observations used

Intermediate solutions

Intermediate solutions are combinations of daily NEQ solutions separately for 2008, 2010 and 2011.
NNT minimum constraints were used for ~ 35 EPN sites wrt. EPN cumulative solution (C1600).

Table 1: Statistics of intermediate solutions

Year	Solution type	Repeatability (mm) N	E	U	RMS (mm)	Amb. (%)	Number of observations
2008	GPS $5°$	0.97	0.99	2.64	1.30	92.2	10 175 270
	GPS $10°$	1.15	1.23	2.94	1.32	93.9	8 958 888
2010	GPS $5°$	1.30	1.37	3.34	1.29	92.8	21 602 786
	GPS $10°$	1.49	1.38	3.74	1.32	94.3	18 674 394
	GNSS $5°$	1.23	1.31	3.08	1.27	92.8	27 140 216
2011	GPS $5°$	0.85	0.83	2.21	1.29	92.5	6 839 723
	GPS $10°$	0.99	0.83	2.51	1.32	94.2	5 899 616
	GNSS $5°$	0.84	0.82	2.24	1.28	92.4	8 506 863

Combined solution

Combined solution is a combination of all daily NEQ solutions from 2008, 2010 and 2011.
NNT minimum constraints were used for datum definition wrt. EPN cumulative solution (~ 35 sites).
For velocities, the following constraints were applied:

- $\sigma = 0.1$ mm for EPN reference sites wrt. EPN cumulative velocities
- $\sigma = 0.2$ mm for ASG-PL permanent sites wrt. ITRF2005 velocity of Eurasian plate (Altamimi et al., 2007)
- tight constraints to ITRF2005 velocity of Eurasian plate for remaining sites (epoch sites).

Table 1: Statistics of combined solutions

Solution type	Repeatability (mm) N	E	U	RMS (mm)	# of observations
WUT ASG-PL $5°$	1.20	1.23	3.11	1.29	38 617 779
WUT ASG-PL $10°$	1.38	1.30	3.47	1.32	33 532 898

On the basis of estimated velocities V and coordinates at initial epoch $X(t_0)$, two coordinate sets have been generated ($X(t) = X(t_0) + V \cdot (t - t_0)$), as requested by the HOGC:

1. at epoch $t = 2005.0$
2. at epoch $t = 2011.0$

Residual velocity field

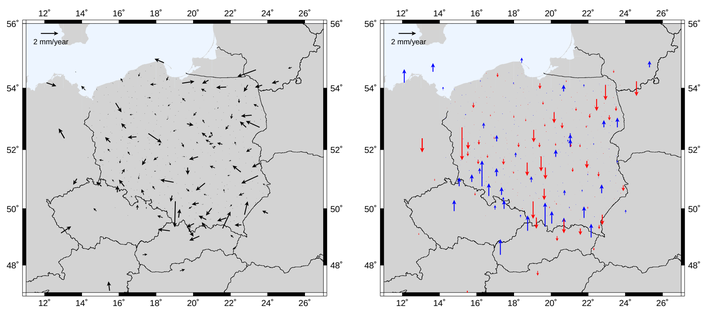
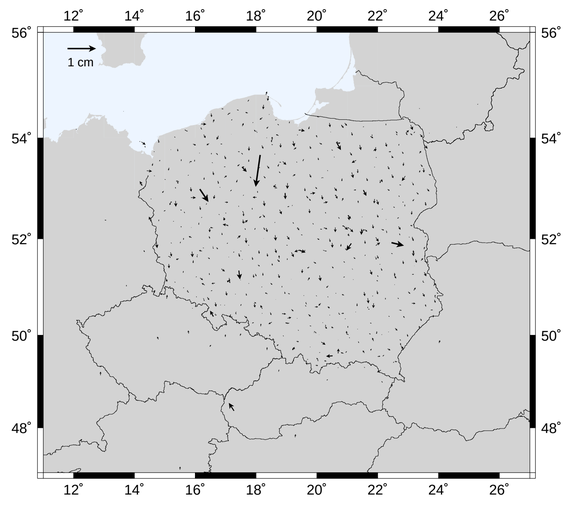
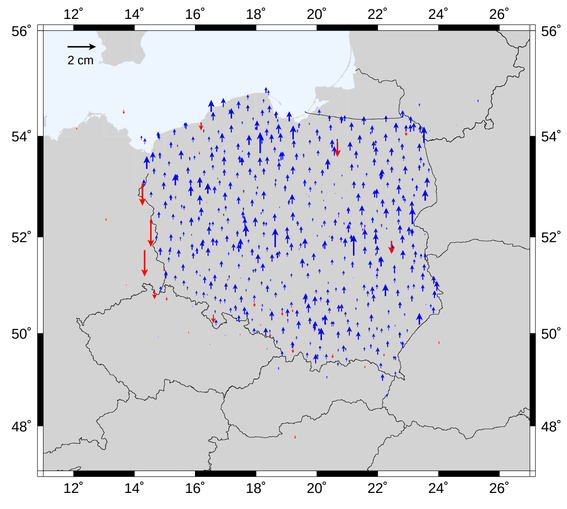


Figure 2: Residual velocity field after removing ITRF2005 velocity for Eurasian plate. Left: horizontal components, Right: up component

Comparison of combined solutions: GPS $5°$ versus GPS $10°$



(a) horizontal components



(b) up component

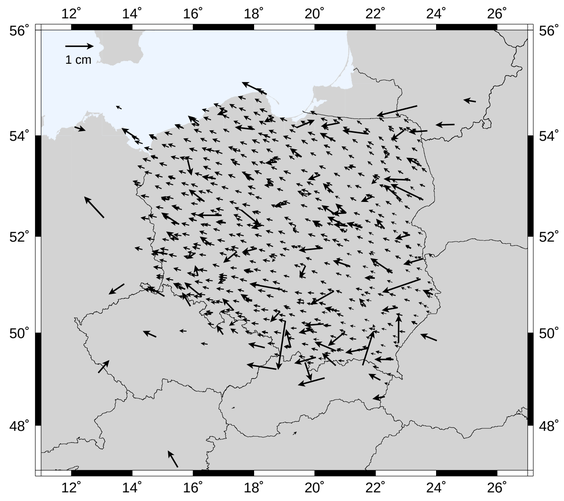
Figure 3: ITRF2005 coordinate differences at epoch 2011.0: solution with mask $5°$ minus solution with mask $10°$

5 ETRS89 relization

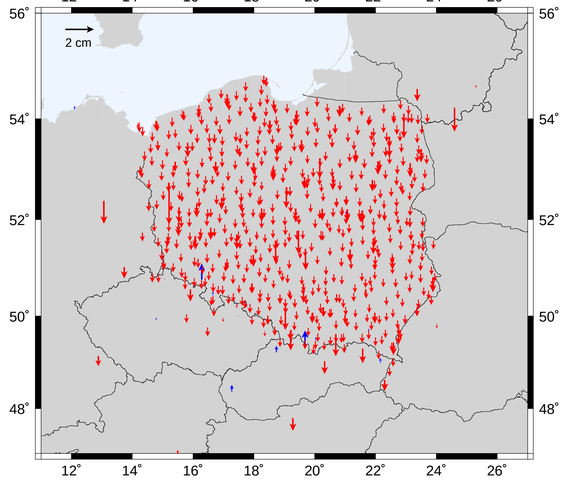
Coordinate given in ITRF2005 have been expressed in ETRF2000 frame using 14-parameter transformation desribed in Memo version 8 (Altamimi and Boucher, 2011):

$$X_{ETRF2000}(t) = X_{ITRF2005}(t) + T(t) + R(t) \cdot X_{ITRF2005}(t)$$

where $T(t)$ and $R(t)$ are translation vector and rotation matrix respectively, evaluated at epoch t.
Taking as input coordinates in ITRF2005 (solution WUT ASG-PL GPS $5°$) at epochs 2005.0 and 2011.0 two coordinate sets in ETRF2000 frame were obtained: at epoch 2005.0 and 2011.0 respectively.
Differences between solutions in ETRF2000 frame at epoch 2005.0 and 2011.0 are presented below in Figure 4 (top: horizontal components, bottom: up component). In addition to residual ITRF2005 velocity field (Figure 2), the effect of transformation between ITRF2005 and ITRF2000 is also visible.



(a) horizontal components



(b) up component

Figure 4: ETRF2000 coordinate differences between epoch 2011.0 and 2005.0 ($X_{ETRF2000}(20011.0) - X_{ETRF2000}(2005.0)$)

6 Conclusions

- GPS $5°$ solution is recommended to be adopted by the HOGC
  – better repeatability and *a posteriori* RMS in comparison with GPS $10°$
  – analysis options used in GPS $5°$ closer to EPN LAC standards (Bruyninx et al., 2010)
- Coordinates expressed in ETRF2000 frame at epoch 20011.0 are recommended to be adopted by the HOGC as extension and upgrade of the ETRS89 system in Poland
- Obtained results indicate good data quality collected during the two measurement campaigns

7 Acknowledgments

We would like to thank our colleagues Marcin Rajner, Michal Kruczyk and Wieslaw Kurka for their valuable work for this project.

8 References

Altamimi, Z., X. Collilieux, J. Legrand, B. Garayt, C. Boucher (2007), *ITRF2005: A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation Parameters*, *J. Geophys. Res.*, 112, B09401, doi: 10.1029/2007JB004949.

Boucher C., Z. Altamimi (2011), Memo: Specifications for reference frame fixing in the analysis of a EUREF GPS campaign, http://etrs89.ensg.ign.fr.

Bruyninx, C., Z. Altamimi, A. Caporali, A. Kenyeres, M. Lidberg, G. Stangl, J.A. Torres (2010), Guidelines for EUREF Densifications, Version 2, http://www.epncb.oma.be

Dach, R., S. Hugentobler, P. Fridez, M. Meindl (eds.) (2007), *Bernese GPS Software Version 5.0*. Astronomical Institute, University of Berne.

EPN (2011) `http://www.epncb.oma.be`

IGS (2011) `http://igs.org/components/prods.html`