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The EUREF Poland 2015 Campaign

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Chapter 1

Introduction

A network of reference stations called ASG-EUPOS (Active Geodetic Network – European Position Determination System), is the primary national geodetic network in Poland maintained by the Head Office of Geodesy and Cartography (GUGiK).

The development of this permanent GNSS network has forced the introduction of new legal acts in which one of the essential element was the introduction of ETRF2000 as a valid realization of reference frame in Poland. This corresponds to the resolution No. 2 undertaken by the Sub-Commission EUREF at EUREF Symposium in Gävle, Sweden (2nd June 2010) concerning the adoption of ETRF2000 as a conventional reference frame for the realisation of ETRS89.

First EUREF campaign in Poland, EUREF-POL, was carried out in 1992, when 11 fundamental geodetic points were established. This points were used as a reference for further ETRS89 densification on lower level networks. Till now only 4 of them: `JOZE`, `BOR1`, `LAMA` and `BOGO` are useful for current campaign processing as they were redesigned into permanent reference stations. These stations have been working for almost 20 years as part of the EUREF permanent network, and except `BOGO`, also as part of IGS network.

A densification network of EUREF-POL, POLREF, was based on 359 points evenly distributed over country. POLREF and EUREF-POL networks were used to establish and maintain the ETRS89 frame (known as EUREF89). After 16 years, in 2008, with increased usability of GNSS techniques, newly built ASG-EUPOS network has took over the task of national reference frame realization and later become a primary network in Poland. With an increase of the availability of geodetic GNSS equipment, some research institutions and GUGiK, within the development of ASG-EUPOS, have performed actions to include selected sites into the EPN. Nowadays, there are 18 permanent GNSS reference stations in Poland belonging to the EPN, which ensure good geographical distribution and connection within ETRS89.

This report describes the new realization of ETRF2000 for Polish national geodetic network ASG-EUPOS and its comparison with currently adopted realization.

Chapter 2

Campaign configuration

The campaign network consists of 154 permanent GNSS reference stations from which 43 are EPN stations, 91 are non-EPN permanent stations located on the territory of Poland, and 20 are non-EPN permanent stations located in other European countries. The EPN sites for this campaign were selected to include all sites categorized as class A or class B in the densification network area and additional class A stations around Poland enlarging the campaign region. Observations of non-EPN sites from other European countries were processed together in daily sessions but they were finally excluded from the combined solution as they are not Polish reference stations. The spatial distribution of the campaign network is presented on Figure 2.1 and Figure 2.2.

The campaign lasted for a period of 3.7 years, between 17th April 2011 (GPS week 1632/0, DOY 107/2011) and 31th December 2014 (GPS week 1825/3, DOY 365/2014). That gives in total 193.6 GPS weeks – 1355 daily sessions. Sessions are considered to start at 00:00:00 and end at 23:59:30 GPST.

All densification stations were permanent type and almost all stations (92% of non-EPN sites) observed during the whole period of campaign. The exceptions occurred on sites:

- `GDAN`, `RMWZ`, `NWTG` and `TARG` which during campaign had a location problem and were moved to the nearby area. Respectively this sites received new names: `GDA1`, `RWM1`, `NWT1` and `TAR1` (Table 2.1).
- introduction of a new site `MIEL` working since 16th December 2013,
- introduction of a new site `OPNT` working since 1st December 2013,
- introduction of a new site `WIEL` working since 13th February 2013,
- site `CBKA` observed only till 19 June 2013.

Full list of reference stations containing names with domes numbers, with their GNSS equipment sets, equipment changes and campaign observation periods is presented in Appendix A. All densification sites are rooftop with typical mounting based on aluminium post attached to the stable parts of buildings, such as a chimney or main walls, using steel claws, plates or clamping rings.

Equipment of ASG-EUPOS network is not homogeneous; only 50% of stations are capable to observe both GPS and GLONASS. However, data processing was made utilising the GPS+GLONASS observations where possible. Other GNSS systems were not considered. Observational data for all stations was stored in compact RINEX files (derived from RINEX 2.x format) with data sampling of 30 seconds.

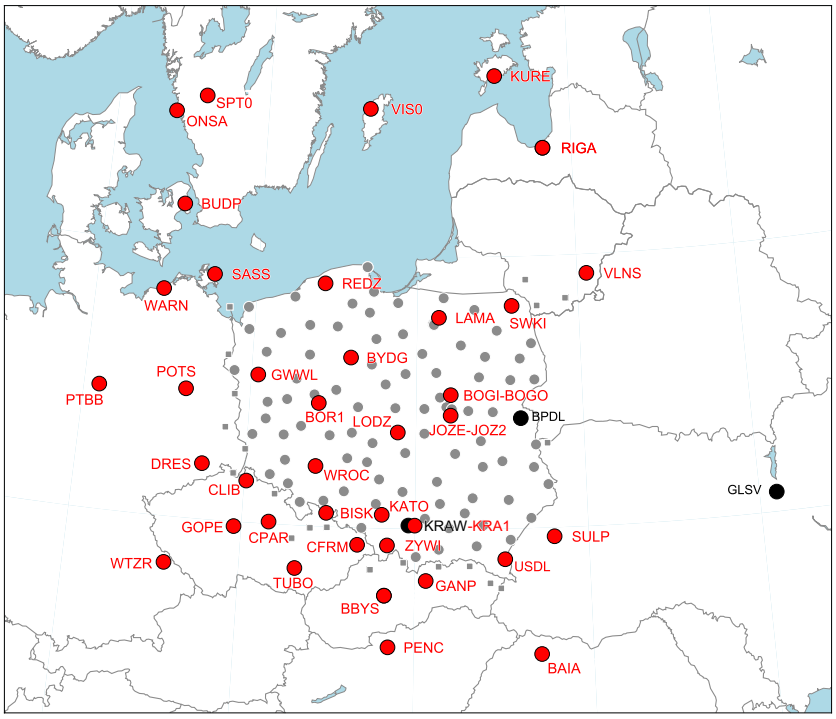


Figure 2.1: Map of the EPN sites used in campaign

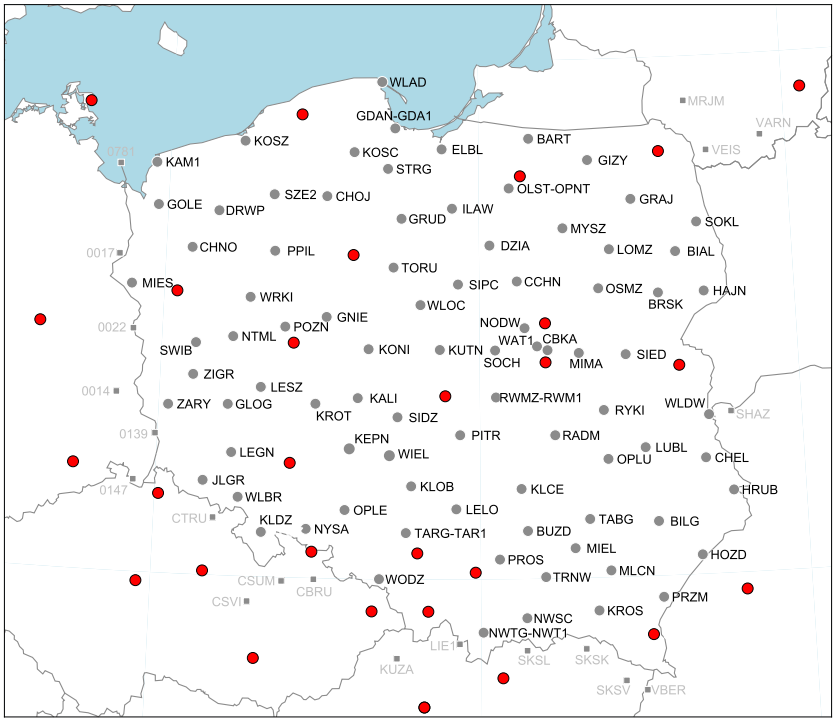


Figure 2.2: Map of the densification sites

Table 2.1: Former and new ASG-EUPOS stations

Site	from date	to date
GDAN	beginning of the campaign	17th December 2014
GDA1	17th December 2014	end of the campaign
NWTG	beginning of the campaign	21th January 2014
NWT1	12th March 2014	end of the campaign
RWMZ	beginning of the campaign	18th November 2014
RMW1	18th November 2014	end of the campaign
TARG	beginning of the campaign	27th December 2012
TAR1	1st January 2013	end of the campaign

2.1 Fiducial site selection

43 EPN stations were selected to cover the densification area. 40 of them are classified as class A and were used for reference frame definition. Selected stations had also acceptable position time series (www.epncb.oma.be). The remaining three stations were included in processing but were not used for reference frame definition:

- BPDL and KRAW are categorized as class B stations, but they are Polish stations and are located inside densification area,
- GLSV – at the beginning of the project (middle of 2014) it was class A station, but since the release of C1800 EPN cumulative solution, GLSV has been classified as class B station. It was decided to retain the station in next phases of GNSS data processing.

The list of stations with their positions and velocities is presented in appendix in Table C.1.

2.2 External data and models

External data files used in the processing are listed below in Table 2.2.

All RINEX observation files from EPN sites has been downloaded from BKG EPN data centre. For all antennas used in the campaign, absolute calibrations were used from igs_08_1830.atx model, completed by EPN individual calibrations and by individual calibrations for non-EPN stations derived by GUGiK. For antennas which individual calibrations were used, 5-digit antenna number is given in "Antenna" field in Appendix A.

For all sites the coefficients for ocean tide loading were used. For EPN sites they were derived from EPN_FES2004.BLQ file available on EPN ftp server. In case of other sites the coefficients were obtained from http://holt.oso.chalmers.se/loading/ web-site (M.S. Bos and H.-G. Scherneck) for FES2004 model without correction for the motion of the centre of mass of the solid Earth.

Table 2.2: External products and models used in the campaign

Product	Source
GNSS orbits and ERPs	
GPS	ftp://cddis.gsfc.nasa.gov/gps/products/wwww/igswwwwd.sp3.Z
GLONASS	ftp://cddis.gsfc.nasa.gov/glonass/products/wwww/iglwwwwd.sp3.Z
ERP	ftp://cddis.gsfc.nasa.gov/gps/products/wwww/igswwww7.erp.Z
Antenna calibrations	
EPN	ftp://epncb.oma.be/pub/station/general/epn_08_1830.atx
non–EPN	additional individual calibrations
Ocean tidal loading	
EPN	ftp://epncb.oma.be/pub/station/general/EPN_FES2004.BLQ
non–EPN	http://holt.oso.chalmers.se/loading/ (FES2004, no CMC)
Ionosphere models	ftp://ftp.unibe.ch/aiub/CODE/yyyy/CODwwwwd.ION.Z
Differential code biases	ftp://ftp.unibe.ch/aiub/CODE/yyyy/P1C1yymm.DCB.Z
EPN cumulative solution	ftp://epncb.oma.be/pub/station/coord/EPN_A_IGb08_C1815.SNX
EPN discontinuities	ftp://epncb.oma.be/pub/station/coord/EPN_discontinuities.snx
EPN RINEX files	ftp://igs.bkg.bund.de/EUREF/obs/ssssddd0.yyd.Z
	ftp://igs.bkg.bund.de/IGS/obs/ssssddd0.yyd.Z
EPN site logs	ftp://igs.bkg.bund.de/EUREF/station/ssss_yyyymmdd.log
	ftp://igs.bkg.bund.de/IGS/station/ssss_yyyymmdd.log

Chapter 3

Processing of daily sessions

GNSS observations collected between 17th April 2011 and 31th December 2014, at stations described in Chapter 2 were processed using Bernese GNSS Software version 5.2 (Dach et al., 2007). Processing strategy was according to the most recent guidelines for EPN Local Analysis Centres (EPN LAC, 2013) and taking into account guidelines for EUREF densification campaigns (Bruyninx et al., 2013).

During processing of GNSS observations, satellite orbits, satellite clocks and Earth rotation parameters were used from the International GNSS Service (IGS). Description of the strategy used for daily data processing is as follows. Receiver clock corrections were computed using GPS code measurements. Then single differences were created between two stations yielding an independent set of baselines for each daily session. Baselines were created using the algorithm that maximizes the number of common single difference observations over all baselines in the network and creation of baselines up to 200 km was favored. Observations of each baseline were screened using triple differences for data cleaning, searching for carrier phase cycle slips, and setting new ambiguities. Ambiguities were resolved for GPS and GLONASS satellites. Three strategies depending on a baseline length were used:

- direct ambiguity resolution on L_1 and L_2 using SIGMA method for baselines shorter than 20 km,
- two-step L_5/L_3 approach was used utilizing SIGMA method for baseline lengths between 20 and 200 km. Unresolved ambiguities were also tried using QIF method.
- two-step L_6/L_3 approach was used utilizing SIGMA method (L_6 denotes Melbourne-Wübbena code and phase linear combination) for baseline lengths between 200 and 2000 km. Unresolved ambiguities were also tried using QIF method.

Mean ambiguity resolution rate in daily sessions for GPS and GLONASS satellites is presented in Figure 3.1. On average, it was possible to resolve 83% of GPS ambiguities, and 63% of GLONASS ambiguities.

After fixing ambiguities, a network solution was computed; previously fixed ambiguities were introduced and unresolved ones were eliminated from observation system. In the network solution also tropospheric parameters were solved for, i.e., zenith delays and horizontal gradients. Zenith tropospheric delays were estimated in one-hour intervals for each station, while horizontal gradients were estimated in 24-hour intervals. The reference frame in daily network solutions was realized by imposing the no-net-translation (NNT) minimum constraint conditions on reference frame defined by coordinates of EPN class A stations from cumulative solution extrapolated to the mean epoch of an observation session. As a result of network solutions, daily normal equations were saved and were further used for computing final long-term solution.

In Table 3.1, a brief description of used processing options is presented.

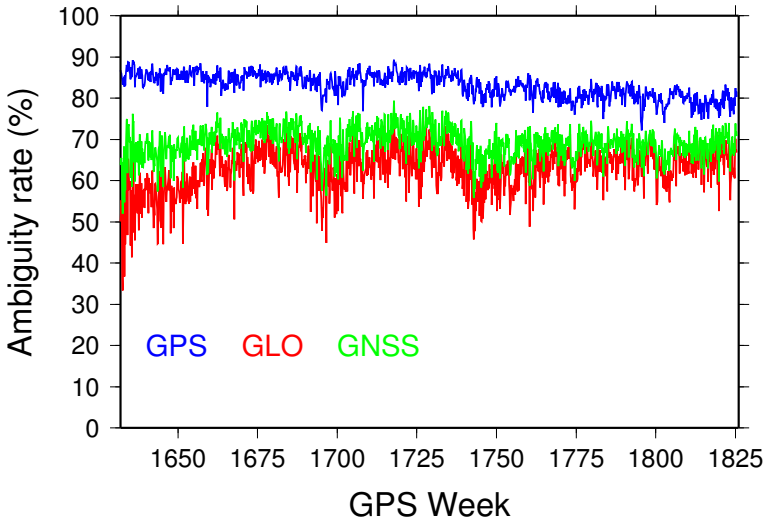


Figure 3.1: Ambiguity resolution rate in daily sessions for GPS and GLONASS satellites

Table 3.1: Characteristics of the processing strategy

Option	Value
GNSS Orbits and ERPs	IGS
GNSS observations	GPS, GLONASS
Elevation mask	3°
Baselines creation	maximum common observations
Ambiguity resolution strategies	$200 < L \leqslant 2000$ km: L6/L3+QIF
depending on baseline length (L)	$20 < L \leqslant 200$ km: L5/L3+QIF
	$L \leqslant 20$ km: direct L1&L2
A priori troposphere model	Saastamoinen + GMF, dry part
Mapping function for corrections	wet GMF
Time resolution for ZTD	1 hour
Interval for troposphere horizontal gradients	24 hours
Ionosphere model	CODE global
Higher order ionosphere corrections	applied
Antenna calibrations	igs_08.atx + individual calibrations
	(EPN, ASG)
Reference frame	IGb08 (EPN cumulative solution)

Chapter 4

Long-term solution

Long-term solution was obtained by stacking daily normal equations from period 2011.3–2015.0 (GPS weeks: 1632–1825). We used ADDNEQ2 program of Bernese GNSS Software ver. 5.2 for computing the long-term solution.

Since our data span 3.7 years, in addition to coordinates, we estimated also velocities for all stations. In the final solution, we only included stations observing for at least 2.7 years. Other stations were propagated to the epoch of minimum position variance (EMPV) and eliminated from final long-term solution. For stations, for which discontinuity in position time series was noticed, the time series were split and new coordinates were estimated. Velocities before and after the discontinuity were constrained to the same value with $\sigma = 10^{-3}$ mm. Discontinuities for EPN reference stations were applied according to the `EPN_discontinuities.snx` file released with the EPN cumulative solution covering data up to GPS week 1815 (C1815); if needed, new discontinuities were introduced after the GPS week 1815 (Table B.1).

We applied minimum constraint (MC) conditions on reference frame defined by coordinates and velocities of 40 class A EPN stations taken from EPN cumulative solution C1815 (`EPN_A_IGb08_C1815.SNX`). Because velocities in C1815 cumulative solution for the same stations (before and after discontinuity) agree at the level of 0.1 mm, we extracted coordinates and velocities from the EPN SINEX file with the precision of 0.1 mm, despite the fact that Bernese version 5.2 allows using input coordinates and velocities with the precision of 0.01 mm. Since we tightly constrained velocities after position discontinuity, we wanted to use the same a priori information to obtain the same estimates for velocities (with 0.01 mm precision). Coordinates and velocities of reference stations used in our analysis are listed in Table C.1.

We computed a long-term solution with applying no-net translation (NNT) MC conditions on reference frame and its rate (solution P1). For comparison, another two solutions were computed: (1) P2: with applying NNT and no-net scale (NNS) conditions, and (2) P3: with applying NNT, NNS, and no-net rotation (NNR) conditions on reference frame.

As a result of daily normal equations stacking, we obtained long-term coordinates, velocities and time series of position residuals between each daily solution and the combined solution for each solution variant. We plotted and inspected time series of each station against discontinuities and outliers. In general, we identified residuals as outliers if they exceeded 10 mm in north or east components, or 20 mm in up component. The procedure of outlier detection was done iteratively. Discontinuities introduced for Polish campaign stations are provided in Table B.1. Quality of reference stations was checked by inspecting residuals of Helmert transformation between C1815 cumulative solution and our solutions at three epochs: at the beginning, in the middle, and at the end of used data. Table 4.2 shows that slightly better agreement between estimated coordinates and reference solution (C1815) has been obtained for P1 solution (only NNT conditions applied). In Table 4.1 the differences between coordinates of solution P1 and reference coordinates at the three epochs are presented. We accepted stations as reference if differences at all epochs did not exceed 4 mm horizontally or 5 mm vertically; we therefore

rejected the following three solutions: BISK (solution number: 1), CFRM (1), and CPAR (1). Coordinate differences of these stations also exceeded above criteria in variants P2 and P3 and were rejected as well.

Transformation parameters between each solution variant and the combined solution at the three epochs are also presented in Table 4.2. The parameters are mostly zero, and only small drift in translation can be observed for solutions P2 and P3. We obtained these results with slightly different ADDNEQ2 settings for MC conditions than default. With the default ADDNEQ2 settings regarding MC conditions, we obtained larger deviations of transformation parameters from zero. For example, after 4-parameter transformation (translation and scale) between P2D solution (P2 variant with default MC settings) and EPN cumulative solution, we obtained a difference in scale equal 0.4 ppb, and plain comparison of coordinates showed mean difference in heights equal 2.7 mm (which corresponds to the difference in scale). Translations for P1D and P2D solutions were at the level of 0.1 mm. We therefore used smaller values for standard deviations of transformation parameters which were used in construction of the MC condition matrix. (We used a value of 10^{-8} for translation and 10^{-9} for rotation and scale in ADDNEQ2 panel in place of "YES" settings; default sigmas are: 10^{-5}, 10^{-4}, 10^{-3}, for translation, rotation and scale).

Maximum absolute differences between estimated velocities and C1815 reference velocities did not exceeded 0.8 mm/y for horizontal velocities, and 2.0 mm for vertical velocities. RMSs of velocity differences between three solution variants and cumulative solutions for accepted reference stations agreed at the 0.1 mm/y level (Table 4.3).

Comparisons of coordinates and velocities obtained in three variants (P1, P2, P3) wrt. EPN cumulative solution show small differences. In the densification area, coordinates of solutions P2 and P3 agree with coordinates of solution P1 at the 0.1 mm level horizontally and at 0.2 mm level vertically; velocities agree at the 0.1 mm/y level. Since for P1 variant, we obtained slightly better agreement of coordinates (Table 4.2) and comparable agreement of velocities (Table 4.3) with the EPN C1815 solution, we choose solution P1 as the final solution of our campaign and ask for validation of its coordinates and velocities at epoch 2013.14. Solution is provided in SINEX file: ASG_A_P1.SNX.

Repeatability for each station from variant P1 is presented in Figure 4.1. Mean repeatability of positions over all stations are: 1.1 mm for north component, 1.0 mm for east component, and 3.2 mm for vertical component. (For other variants repeatabilities for horizontal components were the same, and for vertical component 3.3 mm was obtained for P2 variant, and 3.1 mm for P3 variant.)

It was mentioned that velocities were only estimated for stations having at least 2.7 years of observations, and other stations were eliminated from our final P1 solution. This was a case for 10 stations: GDA1, RWM1, NWT1, TARG, TAR1, MIEL, OPNT, WIEL, CBKA and WLAD. Before eliminating these stations from a long-term solution, theirs coordinates were propagated to the epoch of minimum position variance (EMPV) using velocities and variance-covariance information for coordinates and velocities (Altamimi et al., 2002). Coordinates of these stations expressed in IGb08 reference frame are listed in Table C.3. In addition to coordinate list (Table C.3) we provide SINEX file: ASG_AB_P1.SNX that contains all stations processed within densification area.

Table 4.1: Differences between solution P1 and cumulative EPN solution at three epochs: at the beginning of observations (2011.29), in the middle (2013.14) and at the end (2015.00). Solution numbers (SN) according to `ASG_A_P1.SNX`; second number denotes corresponding SN according to C1815 EPN cumulative solution

Station name	SN	Beginning			Middle			End			Remark
		ΔN (mm)	ΔE (mm)	ΔU (mm)	ΔN (mm)	ΔE (mm)	ΔU (mm)	ΔN (mm)	ΔE (mm)	ΔU (mm)	
BAIA 11406M001	1/2	0.02	−0.18	2.30	−0.59	−0.40	0.91	−1.20	−0.61	−0.47	
BBYS 11514M001	1/2	−0.34	−1.10	0.40	−0.56	−0.96	−1.65	−0.78	−0.82	−3.70	
BBYS 11514M001	2/3	0.17	−1.08	1.34	−0.05	−0.95	−0.72	−0.26	−0.80	−2.76	
BISK 11520M001	1/1	−1.71	1.23	9.99	−2.02	1.47	10.52	−2.34	1.71	11.05	rejected
BISK 11520M001	2/2	0.77	−0.02	−1.27	0.45	0.22	−0.73	0.14	0.47	−0.21	
BOGI 12207M003	1/1	−0.86	−1.12	−0.96	−1.08	−0.22	1.28	−1.30	0.68	3.51	
BOGO 12207M002	1/2	0.05	−0.43	0.25	−0.11	−0.32	0.66	−0.28	−0.22	1.07	
BOR1 12205M002	1/2	−0.11	−0.30	−0.31	−0.36	0.37	0.43	−0.62	1.05	1.16	
BUDP 10101M003	1/1	−0.44	0.51	−0.36	−0.36	0.34	0.97	−0.28	0.16	2.31	
BYDG 12224M001	1/1	−0.21	0.62	0.22	−0.47	0.43	1.14	−0.74	0.24	2.05	
BYDG 12224M001	2/2	1.68	0.22	−1.80	1.42	0.03	−0.88	1.15	−0.16	0.03	
CFRM 11525M001	1/1	3.32	−3.85	−4.53	3.29	−3.69	−7.32	3.26	−3.53	−10.12	rejected
CFRM 11525M001	2/2	0.14	0.05	3.94	0.10	0.21	1.15	0.07	0.37	−1.64	
CLIB 11526M001	1/1	−0.70	−0.78	−2.61	−0.89	−0.89	−1.66	−1.08	−0.99	−0.72	
CLIB 11526M001	2/2	1.35	1.94	−4.08	1.20	1.65	−3.16	1.05	1.37	−2.25	
CPAR 11527M001	1/1	−4.00	0.03	3.59	−4.61	0.02	4.30	−5.22	0.02	5.00	rejected
CPAR 11527M001	2/2	0.10	1.66	−4.59	−0.51	1.65	−3.88	−1.13	1.64	−3.18	
DRES 14108M001	1/4	1.07	0.34	0.80	−0.01	0.22	−0.37	−1.09	0.10	−1.55	
GANP 11515M001	1/2	−0.05	−0.06	0.69	−0.33	−0.21	0.76	−0.61	−0.37	0.83	
GOPE 11502M002	1/6	0.01	0.15	0.50	0.09	0.57	−0.40	0.17	0.99	−1.29	
GWWL 12225M001	1/1	−0.33	0.01	−0.35	0.23	0.16	2.20	0.80	0.30	4.75	
JOZ2 12204M002	1/2	0.26	−0.49	−0.51	−0.56	−0.42	−1.50	−1.38	−0.36	−2.48	
JOZE 12204M001	1/2	0.11	0.19	−0.39	−0.17	−1.05	−1.61	−0.44	−2.30	−2.83	
KATO 12219S001	1/3	−1.11	0.41	1.33	−0.54	−0.58	0.19	0.02	−1.57	−0.96	
KRA1 12218M002	1/1	−0.56	−0.10	3.99	−0.38	0.13	0.34	−0.21	0.36	−3.31	
KURE 10604S001	1/1	−1.48	−0.63	0.08	−1.19	−0.18	1.85	−0.91	0.27	3.62	
LAMA 12209M001	1/4	0.29	−0.27	−0.30	0.03	0.03	1.55	−0.23	0.33	3.39	
LODZ 12226M001	1/1	0.02	0.38	1.37	−0.19	0.57	0.64	−0.39	0.74	−0.09	
ONSA 10402M004	1/2	0.24	0.92	−0.03	0.75	1.15	1.11	1.27	1.38	2.26	
ONSA 10402M004	2/3	−0.38	−0.14	0.02	0.14	0.09	1.16	0.65	0.32	2.30	
ONSA 10402M004	3/4	−0.47	−0.13	0.53	0.05	0.10	1.67	0.56	0.33	2.81	
PENC 11206M006	1/3	0.55	−0.01	0.56	0.71	−0.17	−0.31	0.87	−0.33	−1.18	
POTS 14106M003	1/3	3.91	−0.10	−3.13	3.52	0.09	−1.40	3.13	0.29	0.32	
PTBB 14234M001	1/3	0.77	0.87	−1.96	−0.03	0.52	1.22	−0.83	0.15	4.39	
REDZ 12227M001	1/1	−0.42	0.61	−1.12	−0.18	0.62	1.19	0.06	0.64	3.50	
RIGA 12302M002	1/4	−0.13	−0.59	1.68	−0.36	−0.23	−0.07	−0.59	0.12	−1.82	
RIGA 12302M002	2/5	−0.01	−0.71	4.33	−0.24	−0.35	2.58	−0.47	0.00	0.84	
SASS 14281M001	1/3	−1.04	0.44	−2.98	−0.82	0.36	0.03	−0.60	0.29	3.04	
SPT0 10425M001	1/1	−0.22	1.05	−0.97	−0.27	0.57	−0.35	−0.30	0.08	0.27	
SULP 12366M001	1/1	0.20	−0.29	2.32	0.68	−0.63	−0.37	1.16	−0.97	−3.05	
SULP 12366M001	2/2	−1.10	0.04	2.60	−0.62	−0.30	−0.08	−0.14	−0.64	−2.77	
SWKI 12228M001	1/1	−0.05	−1.92	−1.87	−0.24	−0.82	1.00	−0.44	0.28	3.86	
TUBO 11503M001	1/3	−0.09	−0.33	0.50	−0.39	0.18	−1.55	−0.69	0.68	−3.59	
TUBO 11503M001	2/4	−0.14	−0.44	1.01	−0.44	0.07	−1.04	−0.73	0.57	−3.08	
USDL 12229M001	1/1	0.24	−0.31	0.86	0.05	−0.50	−0.05	−0.14	−0.70	−0.96	
VIS0 10423M001	1/1	0.02	−0.12	−1.13	0.29	−0.15	1.05	0.55	−0.19	3.23	
VLNS 10801M001	1/1	−1.35	−0.89	1.49	−0.13	−0.08	1.31	1.08	0.72	1.14	
WARN 14277M002	1/4	−0.05	1.14	−1.24	−0.49	0.77	−0.40	−0.92	0.40	0.44	
WROC 12217M001	1/4	−0.01	−0.80	−1.75	0.52	−1.23	−2.78	1.06	−1.66	−3.81	
WROC 12217M001	2/5	−0.62	0.18	0.54	−0.08	−0.26	−0.48	0.46	−0.69	−1.52	
WTZR 14201M010	1/2	0.50	−0.15	−1.79	0.70	−0.30	−2.02	0.89	−0.46	−2.26	
ZYWI 12220S001	1/2	1.19	−0.23	0.76	0.63	−0.21	0.53	0.06	−0.18	0.30	
Min:		−1.48	−1.92	−4.59	−1.19	−1.23	−3.88	−1.38	−2.30	−3.81	
Max:		3.91	1.94	4.33	3.52	1.65	2.58	3.13	1.64	4.75	

Table 4.2: RMSs of residuals after Helmert transformation between coordinates of the long-term solution variants (P1, P2, P3) and C1815 EPN solution and values of transformation parameters. All values refer to three epochs: beginning (B), middle, and end (E) of used observations

Solution	RMS/component N	E	U	RMS (mm)	T_X (mm)	T_Y (mm)	T_Z (mm)	D (ppb)	R_X (mas)	R_Y (mas)	R_Z (mas)
P1	0.7	0.6	1.4	1.0	0.00	0.00	0.00	—	—	—	—
P1B	0.8	0.7	1.9	1.3	0.00	0.00	0.00	—	—	—	—
P1E	0.9	0.8	2.5	1.6	0.00	0.00	0.00	—	—	—	—
P2	0.8	0.6	1.5	1.0	0.00	0.00	0.00	0.00	—	—	—
P2B	1.0	0.7	2.1	1.4	0.01	0.00	0.01	0.00	—	—	—
P2E	1.0	0.8	2.5	1.6	−0.02	−0.01	−0.03	0.01	—	—	—
P3	0.9	0.7	1.7	1.2	0.00	0.00	0.00	0.00	0.000	0.000	0.000
P3B	1.0	0.8	2.1	1.5	0.00	−0.01	−0.01	0.00	0.000	0.000	0.000
P3E	1.0	0.8	2.4	1.6	0.00	−0.02	0.02	0.00	0.001	0.000	0.000

Table 4.3: Agreement of velocities between three solution variants and C1815 solution

Solution	MC conditions	Velocity RMS N (mm/y)	E (mm/y)	U (mm/y)	Min/Max Differences N (mm/y)	E (mm/y)	U (mm/y)
P1	NNT	0.2	0.2	0.9	−0.6/0.7	−0.7/0.6	−2.0/1.7
P2	NNT+NNS	0.2	0.2	1.0	−0.6/0.7	−0.7/0.6	−1.9/1.7
P3	NNT+NNS+NNR	0.3	0.2	0.8	−0.7/0.8	−0.7/0.6	−2.0/1.4

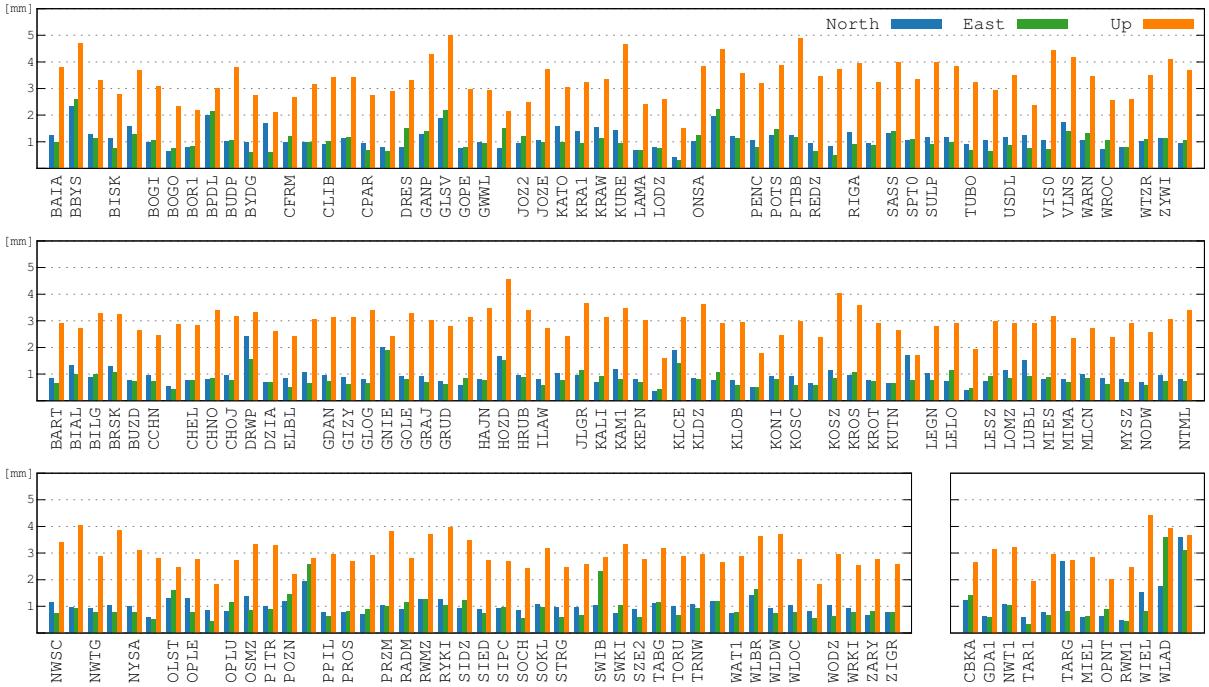


Figure 4.1: Repeatability of position time series of variant P1. Top: repeatability for EPN sites, Middle and Bottom left: repeatability for densification sites, Bottom right: repeatability for shortly observing stations excluded from long-term solution

Chapter 5

Transformation to ETRS89

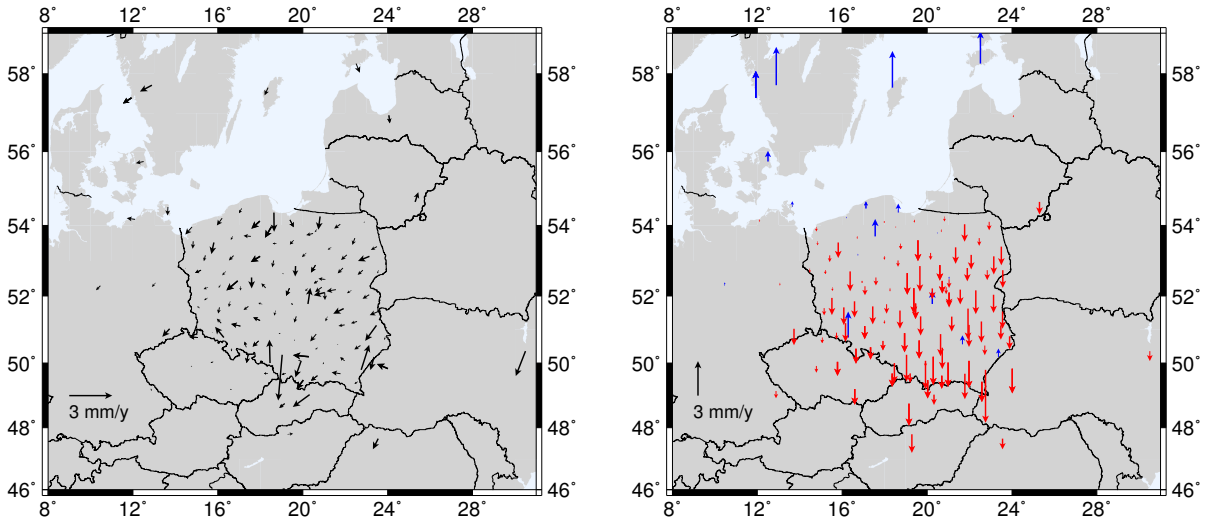
Final long-term coordinates and velocities expressed in IGb08 from solution P1 were transformed to ETRF2000(R08) using 14-parameter transformation model. Transformation parameters were taken from Table 5 of the Memo document, version 8 (Boucher and Altamimi, 2011). Table 5.1 contains the values of official transformation parameters at epoch 2000.0 and their rates, and their values propagated to the mean epoch of the data, i.e., 2013.14. Coordinates and velocities expressed in ETRF2000 at epoch 2013.14 are given in Table C.4. Horizontal and vertical ETRF2000 velocities of solution P1 and EPN cumulative solution C1815 are presented in Figure 5.1.

Residuals on EPN reference stations for coordinates did not exceed 3.5 mm horizontally and 4 mm vertically. For velocities residuals did not exceed 0.7 mm/y horizontally and 2 mm/y vertically (Figure 5.2).

For stations with short observation time span, expressed at epochs of minimum position variance, transformation parameters were computed on epoch of minimum position variance of each station. Coordinates of those stations are given in in Table C.5.

Table 5.1: Transformation parameters from ITRF2008 to ETRF2000

	T_1 mm	T_2 mm	T_3 mm	D 10^{-9}	R_1 mas	R_2 mas	R_3 mas
At epoch 2000.00	52.1	49.3	−58.5	1.34	0.891	5.390	−8.712
Rates	0.1	0.1	−1.8	0.08	0.081	0.490	−0.792
At epoch 2013.14	53.4	50.6	−82.2	2.39	1.956	11.831	−19.122



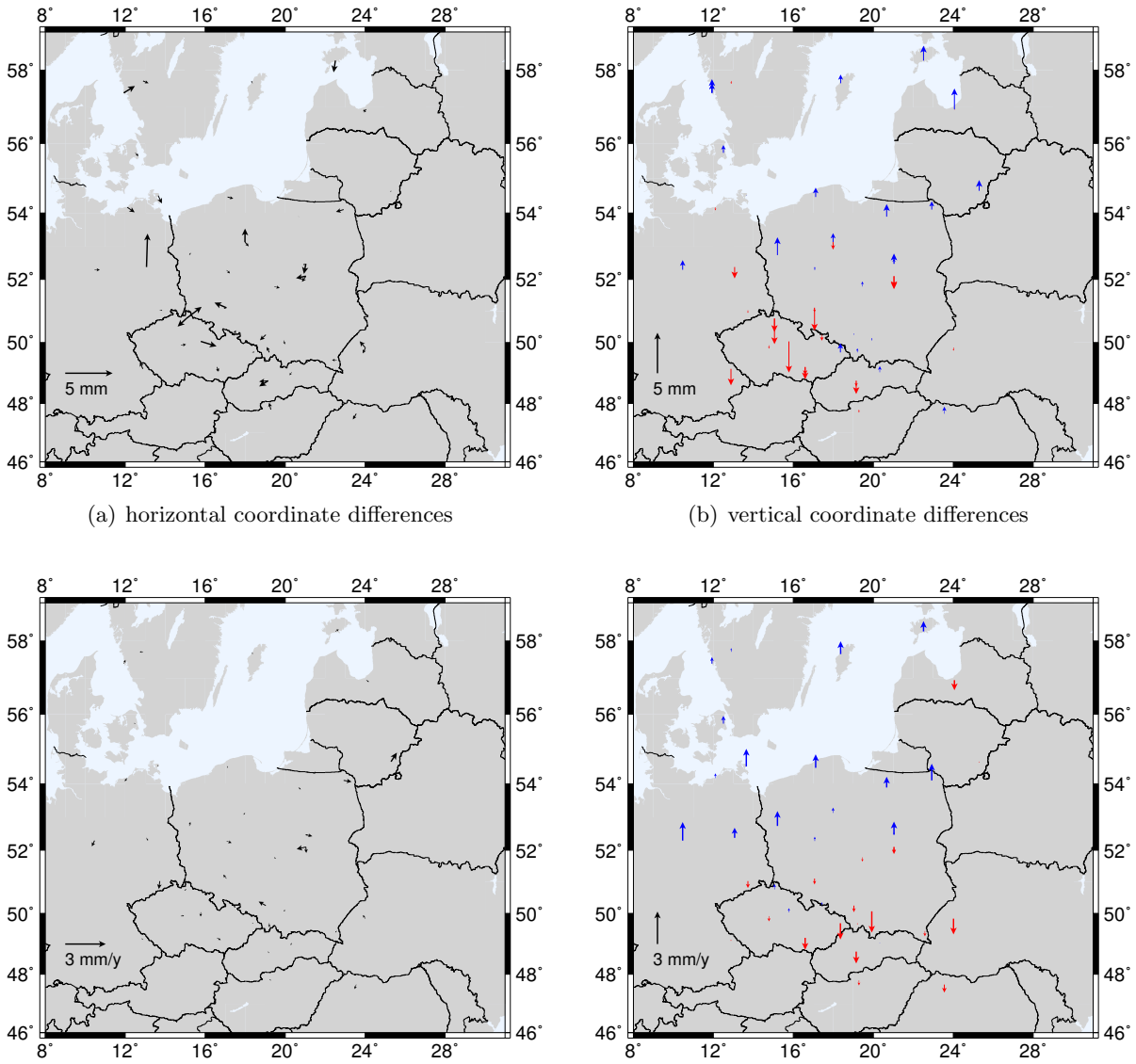
(a) P1 horizontal velocities

(b) P1 vertical velocities

(c) C1815 horizontal velocities

(d) C1815 vertical velocities

Figure 5.1: ETRF2000 velocities of P1 solution and C1815 reference solution



(a) horizontal coordinate differences

(b) vertical coordinate differences

(c) horizontal velocity differences

(d) vertical velocity differences

Figure 5.2: Differences of ETRF2000 coordinates and velocities for accepted EPN reference stations between P1 solution and EPN C1815 cumulative solution

Chapter 6

Comparison with previous campaign

Because of no comparable position set of previous EUREF campaign, this campaign solution is compared to the official, currently adopted ASG-EUPOS catalogue. This catalogue, named PL-ETRF2000 was established during national GNSS campaign preformed between 2008 and 2011. This campaign was divided into three smaller parts and besides the reference stations included also ground points from networks: EUREF–POL, POLREF and EUVN. Its final output comes from cumulative solution expressed in the ETRF2000 at the epoch 2011.00. It should be noted that the previous solution was based on IGS05 frame.

Below we present two types of comparison built on common points represented by reference stations working on the same equipment sets in both campaigns:

- First one, presented on Fig. 6.1, is a direct comparison of new solution reduced to epoch 2011.0 utilising the estimated velocities, with the PL-ETRF2000, expressed at the same epoch.
- Second one, presented on Fig. 6.2, is made by reduction of current solution to the epoch 2011.00 utilising the estimated velocities and preforming 7 parameter Helmert transformation into the PL-ETRF2000 data set.

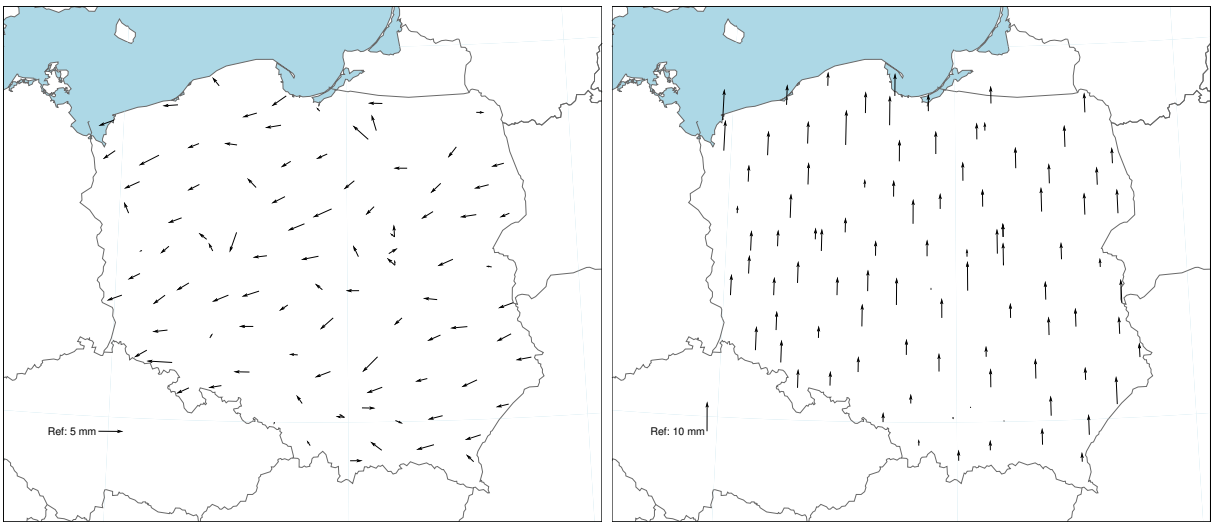


Figure 6.1: Map of position differences between current solution and the official PL-ETRF2000 at epoch 2011.00. Left: horizontal differences. Right: vertical differences.

Presented comparisons show good agreement of both data sets. Maximum differences do not exceed 10 mm and 20 mm respectively for horizontal and vertical component. Transformation parameters and short statistical summaries are presented in tables 6.1 and 6.2.

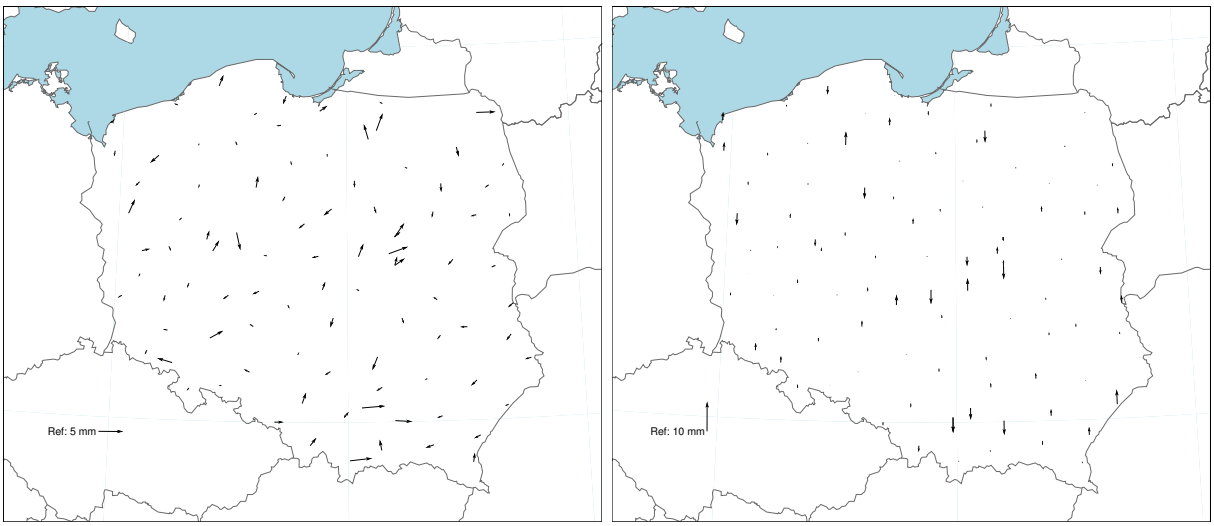


Figure 6.2: Map of position differences at epoch 2011.00 between current solution and the official PL-ETRF2000 after Helmert transformation (7 parameter). Left: horizontal differences. Right: vertical differences.

Table 6.1: Transformation parameters between the new ETRF2000 at epoch 2011.00 and the PL-ETRF2000 at epoch 2011.00

	RMS mm	T_1 mm	T_2 mm	T_3 mm	D 10^{-9}	R_1 mas	R_2 mas	R_3 mas
	1.69	−27.28	−17.08	22.12	1.24	0.459	−1.169	−0.202
uncertainty	—	6.93	6.23	5.96	0.08	0.187	0.247	0.181

Table 6.2: Statistical summary of comparison between the new ETRF2000 and the PL-ETRF2000. New solution was reduced to common epoch 2011.00 using estimated velocities.

	with velocities only			*with velocities and transformation*		
	ΔN (mm)	ΔE (mm)	ΔU (mm)	ΔN (mm)	ΔE (mm)	ΔU (mm)
RMS	1.40	2.54	6.41	1.34	1.39	2.19
MEAN	−0.39	−2.12	5.91	−0.00	−0.00	−0.00
MIN	−4.09	−5.20	−0.73	−3.59	−3.09	−5.28
MAX	3.25	2.72	11.81	3.50	4.69	5.01

Chapter 7

Summary

This document presents a description of the network adjustment and obtained results for Polish 2015 EUREF densification campaign conducted by the Head Office of Geodesy and Cartography and the Warsaw University of Technology.

GNSS observations collected at 91 Polish national stations and 43 EPN stations during 3.7-year campaign were processed in order to obtain combined long-term solution. 10 Polish sites because of shorter observation period were considered as a campaign type and excluded from the main solution. Final coordinates and velocities were expressed in ETRF2000 at the mean epoch of campaign (2013.14).

The resulting accuracy is considered to be very good. Mean repeatability of positions over all stations were: 1.1 mm for north component, 1.0 mm for east component, and 3.2 mm for vertical component. Maximal values of repeatability did not exceed 3.0 mm for horizontal component and 5.0 mm for vertical component.

The agreement of the resulting campaign coordinates with the EPN reference cumulative solution (C1815) in terms of RMS of residuals is at the level of 0.7 mm for north, 0.6 mm for east, and 1.4 mm for up component. For velocities, the consistency is at the level of 0.2, 0.2, and 0.9 mm/y for north, east and up component respectively.

This campaign has also proven a good agreement of national catalogue of coordinates, currently used in national reference station network ASG-EUPOS, with newly obtained results. None of coordinate differences exceed 10 mm for horizontal and 20 mm for vertical component, in case of direct comparison and in case of comparison in the same reference epoch.

This EUREF Poland 2015 campaign solution is presented to EUREF Technical Working Group with a view for positive approval of the positions for 81 points of the densification network.

Acknowledgements

The authors would like to acknowledge the EUREF Technical Working Group for cooperation and valuable suggestions made during preparation of this document.

References

Altamimi Z., P. Sillard, C. Boucher (2002), ITRF2000: A New Release of the International Terrestrial Reference Frame for Earth Science Applications, J. Geophys. Res., 107(B10), 2214

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 (2013), Guidelines for EUREF Densifications, Version 5, `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 LAC (2013), Guidelines for the EPN Analysis Centres. `www.epncb.oma.be/_documentation/guidelines/guidelines_analysis_centres.pdf`

Appendix A

List of equipment sets

Table A.1: List of equipment sets for EPN reference stations used in densification campaign

Station name	Receiver	Antenna		From date	To date
BAIA 11406M001	LEICA GRX1200PRO	LEIAT504	LEIS	2011-04-17	2014-12-31
BBYS 11514M001	TRIMBLE 5700	TRM41249.00	NONE	2011-04-17	2012-09-14
	TRIMBLE NETR9	TRM59800.00	NONE	2012-09-14	2014-12-31
BISK 11520M001	ASHTECH Z18	ASH701946.2	SNOW	2011-04-17	2012-11-07
	TPS NETG3	ASH701946.2	SNOW	2012-11-07	2014-12-31
BOGI 12207M003	JAVAD TRE_G3T DELTA	ASH701945C_M	SNOW	2011-04-17	2014-12-31
BOGO 12207M002	TPS EUROCARD	ASH700936C_M	SNOW	2011-04-17	2014-12-31
BOR1 12205M002	TRIMBLE NETRS	AOAD/M_T	NONE	2011-04-17	2014-12-31
BPDL 12223M001	TRIMBLE NETR5	TRM55971.00	TZGD (36730)	2011-04-17	2014-12-31
BUDP 10101M003	LEICA GRX1200GGPRO	ASH701941.B	UNAV	2011-04-17	2014-12-31
BYDG 12224M001	TRIMBLE NETR5	TRM55971.00	TZGD (36334)	2011-04-17	2014-09-09
	TRIMBLE NETR9	TRM59900.00	SCIS (61485)	2014-09-09	2014-12-31
CFRM 11525M001	LEICA GRX1200PRO	LEIAT504	LEIS (03035)	2011-04-17	2012-01-24
	LEICA GRX1200+GNSS	LEIAT504	LEIS (03035)	2012-01-24	2012-04-25
	LEICA GRX1200+GNSS	LEIAR25.R4	LEIT (25340)	2012-04-25	2014-12-31
CLIB 11526M001	LEICA GRX1200PRO	LEIAT504	LEIS (02943)	2011-04-17	2011-08-31
	LEICA GRX1200+GNSS	LEIAR25.R4	LEIT (61017)	2011-08-31	2014-12-31
CPAR 11527M001	LEICA GRX1200PRO	LEIAT504	LEIS (02546)	2011-04-17	2011-10-25
	LEICA GRX1200PRO	LEIAR25.R4	LEIT (01009)	2011-10-25	2011-11-10
	LEICA GRX1200+GNSS	LEIAR25.R4	LEIT (01009)	2011-11-10	2014-12-31
DRES 14108M001	JPS LEGACY	LEIAR25.R3	LEIT (70015)	2011-04-17	2014-03-19
	JAVAD TRE_G3TH DELTA	LEIAR25.R3	LEIT (70015)	2014-03-19	2014-12-31
GANP 11515M001	TRIMBLE NETR8	TRM55971.00	NONE (37385)	2011-04-17	2012-04-19
	TRIMBLE NETR9	TRM55971.00	NONE (37385)	2012-04-19	2014-12-31
GLSV 12356M001	NOV OEMV3	NOV702GG	NONE	2011-04-17	2014-12-31
GOPE 11502M002	TPS NETG3	TPSCR.G3	TPSH	2011-04-17	2014-12-31
GWWL 12225M001	TRIMBLE NETR5	TRM55971.00	TZGD (37385)	2011-04-17	2014-10-28
	TRIMBLE NETR9	TRM59900.00	SCIS (37385)	2014-10-28	2014-12-31
JOZ2 12204M002	LEICA GRX1200GGPRO	LEIAT504GG	NONE	2011-04-17	2014-12-31
JOZE 12204M001	TRIMBLE 4000SSI	TRM14532.00	NONE	2011-04-17	2014-12-31
KATO 12219S001	TRIMBLE NETR5	TRM57971.00	TZGD (29151)	2011-04-17	2014-12-31
KRA1 12218M002	TRIMBLE NETR5	TRM57971.00	NONE	2011-04-17	2014-12-31
KRAW 12218M001	ASHTECH UZ-12	ASH701945C_M	SNOW	2011-04-17	2014-12-31
KURE 10604S001	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	2011-04-17	2014-12-31
LAMA 12209M001	LEICA GRX1200+GNSS	LEIAT504GG	LEIS	2011-04-17	2014-12-31
LODZ 12226M001	TRIMBLE NETR5	TRM55971.00	TZGD (07789)	2011-04-17	2014-10-30
	TRIMBLE NETR9	TRM59900.00	SCIS (61245)	2014-10-30	2014-12-31
ONSA 10402M004	JPS E_GGD	AOAD/M_B	OSOD	2011-04-17	2013-08-28
	JPS E_GGD	AOAD/M_B	NONE	2013-08-28	2013-11-06
	JPS E_GGD	AOAD/M_B	OSOD	2013-11-06	2014-12-31
PENC 11206M006	LEICA GRX1200GGPRO	LEIAT504GG	LEIS (00219)	2011-04-17	2014-12-31
POTS 14106M003	JAVAD TRE_G3TH DELTA	JAV_RINGANT_G3T	NONE	2011-04-17	2014-12-31
PTBB 14234M001	ASHTECH Z-XII3T	ASH700936E	SNOW	2011-04-17	2014-12-31

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Table A.1: *Continued from previous page*

Station name	Receiver	Antenna		From date	To date
REDZ 12227M001	TRIMBLE NETR5	TRM55971.00	TZGD (36524)	2011-04-17	2014-10-29
	TRIMBLE NETR9	TRM59900.00	SCIS (61156)	2014-10-29	2014-12-31
RIGA 12302M002	LEICA GRX1200PRO	LEIAT504	LEIS	2011-04-17	2013-12-11
	LEICA GR25	LEIAT504	LEIS	2013-12-11	2013-12-11
	LEICA GR25	LEIAR25.R4	LEIT (26676)	2013-12-11	2014-12-31
SASS 14281M001	JPS LEGACY	TPSCR3_GGD	CONE (70155)	2011-04-17	2014-12-31
SPT0 10425M001	JPS E_GGD	AOAD/M_T	OSOD	2011-04-17	2012-01-16
	JAVAD TRE_G3TH DELTA	AOAD/M_T	OSOD	2012-01-16	2014-12-31
SULP 12366M001	TRIMBLE 4700	TRM41249.00	NONE	2011-04-17	2013-03-30
	TRIMBLE 4700	TPSCR.G5	TPSH	2013-03-30	2013-04-05
	TPS NET-G3A	TPSCR.G5	TPSH	2013-04-05	2014-12-31
SWKI 12228M001	TRIMBLE NETR5	TRM55971.00	TZGD (77052)	2011-04-17	2014-11-13
	TRIMBLE NETR9	TRM59900.00	SCIS (61114)	2014-11-13	2014-12-31
TUBO 11503M001	LEICA GRX1200PRO	LEIAT504	LEIS (02923)	2011-04-17	2011-12-12
	LEICA GRX1200+GNSS	LEIAR25.R4	LEIT (01005)	2011-12-12	2014-12-31
USDL 12229M001	TRIMBLE NETR5	TRM55971.00	TZGD (36693)	2011-04-17	2014-10-28
	TRIMBLE NETR9	TRM59900.00	SCIS (61155)	2014-10-28	2014-12-31
VIS0 10423M001	JPS EGGDT	AOAD/M_T	OSOD	2011-04-17	2014-05-22
	JAVAD TRE_G3TH DELTA	AOAD/M_T	OSOD	2014-05-22	2014-12-31
VLNS 10801M001	ASHTECH Z-XII3	ASH700936A_M	NONE	2011-04-17	2013-10-01
	LEICA GRX1200+GNSS	LEIAR25.R4	NONE	2013-10-01	2014-12-31
WARN 14277M002	JPS LEGACY	LEIAR25.R3	LEIT (50002)	2011-04-17	2014-12-31
WROC 12217M001	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	2011-04-17	2012-10-22
	LEICA GR25	LEIAR25.R4	LEIT (25270)	2012-10-22	2014-12-31
WTZR 14201M010	LEICA GRX1200+GNSS	LEIAR25.R3	LEIT (20031)	2011-04-17	2014-02-13
	LEICA GR25	LEIAR25.R3	LEIT (20031)	2014-02-13	2014-12-31
ZYWI 12220S001	TRIMBLE NETR5	TRM55971.00	TZGD (36564)	2011-04-17	2014-08-29
	TRIMBLE NETR9	TRM59900.00	SCIS (61484)	2014-08-29	2014-12-31

Table A.2: List of equipment sets for reference stations of dansification campaign

Station name	Receiver	Antenna		From date	To date
BART 12234M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
BIAL 12235M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
BILG 12236M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
BRSK 12237M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
BUZD 12238M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
CBKA 12221M001	ASHTECH UZ-12	ASH701945E_M	NONE	2011-04-17	2013-06-19
CCHN 12239M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-09-10
	TRIMBLE NETR5	TRM55971.00	TZGD (36334)	2014-09-10	2014-12-31
CHEL 12240M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
CHNO 12241M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
CHOJ 12242M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2013-11-08
	LEICA GR10	LEIAR20	LEIM (41008)	2013-11-08	2014-12-31
DRWP 12243M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
DZIA 12244M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-12
	TRIMBLE NETR9	TRM59900.00	SCIS (61068)	2014-11-12	2014-12-31
ELBL 18991M001	ASHTECH UZ-12	ASH701945C_M	SNOW	2011-04-17	2012-07-06
	TRIMBLE NETR9	TRM59900.00	SCIS (60382)	2012-07-06	2014-12-31
GDA1 12252M002	LEICA GR10	LEIAR20	LEIM (75033)	2014-12-17	2014-12-31
GDAN 12252M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2013-11-19
	LEICA GR10	LEIAR20	LEIM (75033)	2013-11-19	2014-12-17
GIZY 12253M001	ASHTECH UZ-12	ASH701945C_M	SNOW	2011-04-17	2011-08-11
	TRIMBLE NETRS	TRM41249.00	TZGD	2011-08-11	2014-12-31
GLOG 12254M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
GNIE 12255M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
GOLE 12256M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
GRAJ 12245M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
GRUD 12246M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-04

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Table A.2: *Continued from previous page*

Station name	Receiver	Antenna		From date	To date
	TRIMBLE NETRS	TRM55971.00	TZGD (77056)	2014-11-04	2014-11-04
	TRIMBLE NETR5	TRM55971.00	TZGD (77056)	2014-11-04	2014-12-31
HAJN 12247M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
HOZD 12248M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
HRUB 12249M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
ILAW 12250M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-07
	TRIMBLE NETR5	TRM55971.00	TZGD (36524)	2014-11-07	2014-12-31
JLGR 12251M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KALI 12257M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KAM1 12258M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KEPN 12259M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-03
	TRIMBLE NETR9	TRM59900.00	SCIS (61073)	2014-11-03	2014-12-31
KLCE 12260M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KLDZ 12261M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-10-17
	TRIMBLE NETR9	TRM59900.00	SCIS (61052)	2014-10-17	2014-12-31
KLOB 12219M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-10-16
	TRIMBLE NETR9	TRM59900.00	SCIS (61163)	2014-10-16	2014-12-31
KONI 12262M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KOSC 12263M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2013-11-19
	LEICA GR10	LEIAR20	LEIM (74029)	2013-11-19	2014-12-31
KOSZ 12264M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KROS 12265M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-07
	TRIMBLE NETR5	TRM55971.00	TZGD (36693)	2014-11-07	2014-12-31
KROT 12266M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
KUTN 12267M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-14
	TRIMBLE NETR9	TRM59900.00	SCIS (61054)	2014-11-14	2014-12-31
LEGN 12268M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
LELO 12269M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-10-24
	TRIMBLE NETR9	TRM59900.00	SCIS (61241)	2014-10-24	2014-12-31
LESZ 12270M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2011-12-07
	ASHTECH UZ-12	TRM41249.00	TZGD	2011-12-07	2012-01-19
	TRIMBLE NETR9	TRM41249.00	TZGD	2012-01-19	2012-07-04
	TRIMBLE NETRS	TRM41249.00	TZGD	2012-07-04	2014-12-31
LOMZ 12271M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
LUBL 12272M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
MIEL 18967M001	LEICA GR10	LEIAR20	LEIM	2013-12-16	2014-12-31
MIES 18993M001	TRIMBLE NETRS	TRM41249.00	TZGD (87554)	2011-04-17	2014-12-31
MIMA 12273M001	TRIMBLE NETR5	TRM57971.00	TZGD (25319)	2011-04-17	2014-12-31
MLCN 12274M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-10-24
	TRIMBLE NETR9	TRM59900.00	SCIS (61239)	2014-10-24	2014-12-31
MYSZ 12275M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
NODW 12276M001	TRIMBLE NETR5	TRM55971.00	NONE	2011-04-17	2014-12-31
NTML 12277M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
NWSC 12231M001	ASHTECH UZ-12	ASH701945C_M	SNOW	2011-04-17	2011-11-17
	TRIMBLE NETR9	TRM55971.00	TZGD	2011-11-17	2014-12-31
NWT1 12232M002	TRIMBLE NETR9	TRM55971.00	TZGD	2014-03-12	2014-12-31
NWTG 12232M001	TRIMBLE NETRS	TRM29659.00	SCIT	2011-04-17	2011-11-18
	TRIMBLE NETR9	TRM55971.00	TZGD	2011-11-18	2014-01-21
NYSA 12278M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-09-23
	TRIMBLE NETR9	TRM59900.00	SCIS (61489)	2014-09-23	2014-12-31
OLST 12203M001	ASHTECH UZ-12	ASH701945C_M	SNOW	2011-04-17	2014-12-31
OPLE 12283M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-09-24
	TRIMBLE NETR9	TRM59900.00	SCIS (61490)	2014-09-24	2014-12-31
OPLU 12284M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
OPNT 12203M003	TRIMBLE NETR9	TRM59800.00	SCIS (54783)	2013-12-01	2014-12-31
OSMZ 12285M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
PITR 12287M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
POZN 12206M001	ASHTECH UZ-12	ASH701945C_M	SNOW	2011-04-17	2013-10-30
	TRIMBLE NETR9	TRM59900.00	SCIS (61030)	2013-10-30	2014-12-31
PPIL 12286M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31

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Table A.2: *Continued from previous page*

Station name	Receiver	Antenna		From date	To date
PROS 12233M001	TRIMBLE NETRS	TRM29659.00	SCIT	2011-04-17	2011-11-22
	TRIMBLE NETR9	TRM55971.00	TZGD	2011-11-22	2014-12-31
PRZM 12279M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-05
	TRIMBLE NETR5	TRM55971.00	TZGD (36564)	2014-11-05	2014-12-31
RADM 12280M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
RWM1 12281M002	TRIMBLE NETR9	TRM59900.00	SCIS (61098)	2014-11-18	2014-12-31
RWMZ 12281M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-18
RYKI 12282M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
SIDZ 12288M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
SIED 12289M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
SIPC 12290M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-20
	TRIMBLE NETR5	TRM55971.00	TZGD (77052)	2014-11-20	2014-12-31
SOCH 12291M001	TRIMBLE NETR5	TRM57971.00	TZGD (36130)	2011-04-17	2014-12-31
SOKL 12292M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
STRG 18994M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2013-12-11
	LEICA GR10	LEIAR20	LEIM (74006)	2013-12-11	2014-12-31
SWIB 12293M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
SZE2 12294M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
TABG 12295M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
TAR1 12296M002	TRIMBLE NETRS	TRM41249.00	TZGD	2013-01-01	2014-10-31
	TRIMBLE NETR9	TRM59900.00	SCIS (60959)	2014-10-31	2014-12-31
TARG 12296M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2012-12-27
TORU 12202M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-19
	TRIMBLE NETR5	TRM55971.00	TZGD (07789)	2014-11-19	2014-12-31
TRNW 12230M001	TRIMBLE NETRS	TRM29659.00	SCIT	2011-04-17	2011-11-21
	TRIMBLE NETR9	TRM55971.00	TZGD	2011-11-21	2014-12-31
WAT1 12297M001	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	2011-04-17	2014-12-31
WIEL 18968M001	TRIMBLE NETR9	TRM57971.00	TZGD	2013-02-13	2014-12-31
WLAD 12222M001	TRIMBLE 4000SSI	ASH701945E_M	SNOW	2011-04-17	2012-07-05
	TRIMBLE NETRS	ASH701945E_M	SNOW	2012-07-05	2014-01-23
	LEICA GR10	ASH701945E_M	SNOW	2014-01-23	2014-04-01
	LEICA GR10	LEIAR20	LEIM (74005)	2014-04-01	2014-12-31
WLBR 12298M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-10-27
	TRIMBLE NETR9	TRM59900.00	SCIS (61248)	2014-10-27	2014-12-31
WLDW 12299M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
WLOC 18999M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-11-04
	TRIMBLE NETR9	TRM59900.00	SCIS (60989)	2014-11-04	2014-12-31
WODZ 18998M001	TRIMBLE NETR5	TRM57971.00	TZGD (36186)	2011-04-17	2014-12-31
WRKI 18997M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
ZARY 18996M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31
ZIGR 18995M001	TRIMBLE NETRS	TRM41249.00	TZGD	2011-04-17	2014-12-31

Appendix B

Discontinuities in position time series

Table B.1: List of discontinues in position time series occurred in densification campaign

Station name	Date	Reason	Δ N (mm)	Δ E (mm)	Δ U (mm)
EPN sites - discontinuities after 1815 GPS Week					
GWWL 12225M001	28th October 2014	antenna change	0.000	0.002	0.022
LODZ 12226M001	30th October 2014	antenna change	0.001	−0.001	0.014
REDZ 12227M001	29th October 2014	antenna change	0.000	0.000	−0.004
USDL 12229M001	28th October 2014	antenna change	0.000	0.001	0.007
ZYWI 12220S001	29th August 2014	antenna change	0.000	0.000	0.014
Densification sites with long term solution					
CCHN 12239M001	10th September 2014	antenna change	0.000	−0.002	−0.004
ELBL 18991M001	6th July 2012	antenna change	0.000	−0.002	−0.001
GRUD 12246M001	4th November 2014	antenna change	−0.001	−0.001	−0.014
ILAW 12250M001	7th November 2014	antenna change	0.000	0.002	−0.007
KEPN 12259M001	3rd November 2014	antenna change	0.000	0.001	0.012
KLDZ 12261M001	17th October 2014	antenna change	−0.001	0.001	0.010
KLOB 12219M001	16th October 2014	antenna change	0.000	−0.001	0.006
KOSC 12263M001	19th November 2014	antenna change	−0.002	0.000	0.008
KUTN 12267M001	14th November 2014	antenna change	0.000	0.000	0.006
LELO 12269M001	24th October 2014	antenna change	0.000	−0.001	0.005
MLCN 12274M001	24th October 2014	antenna change	0.000	0.000	0.009
NODW 12276M001	15th October 2013	unknown reason	−0.003	−0.004	−0.001
NWSC 12231M001	17th November 2011	antenna change	−0.001	−0.001	−0.009
NWTG 12232M001	18th November 2011	antenna change	0.001	0.003	0.002
NYSA 12278M001	23th September 2014	antenna change	−0.001	−0.001	0.011
OPLE 12283M001	24th September 2014	antenna change	0.000	−0.001	0.010
POZN 12206M001	30th October 2013	antenna change	0.001	0.004	−0.004
PROS 12233M001	22th November 2011	antenna change	0.000	0.006	0.007
STRG 18994M001	11th December 2013	antenna change	0.000	0.001	0.008
TRNW 12230M001	21th November 2011	antenna change	−0.002	0.007	0.009
WLOC 18999M001	4th November 2014	antenna change	−0.001	−0.001	0.012
Densification sites with EMPV solution					
TAR1 12296M002	31th October 2014	antenna change	−0.001	0.005	0.011
WLAD 12222M001	1th April 2014	antenna change	−0.002	0.003	0.014

Appendix C

Catalogues of coordinates and velocities

C.1 Reference EPN coordinates and velocities

Table C.1: Coordinates and velocities of reference stations from cumulative EPN C1815 solution expressed in IGb08 reference frame at epoch 2005.0. Solution numbers (SN), start and end dates according to the `EPN_discontinuities.snx` file

Station name	SN	X (m) V_X (m/y)	Y (m) V_Y (m/y)	Z (m) V_Z (m/y)	Start date	End date
BAIA 11406M001	2	3945839.7800 −0.0179	1720428.2640 0.0166	4691082.7105 0.0097	2006-06-25 00:00:00	
BBYS 11514M001	2	3980358.8015 −0.0173	1382292.0897 0.0164	4772771.9523 0.0096	2005-01-11 00:00:00	2012-09-14 00:00:00
BBYS 11514M001	3	3980358.8170 −0.0173	1382292.0960 0.0164	4772771.9724 0.0096	2012-09-14 00:00:00	
BISK 11520M001	1	3898945.9363 −0.0165	1223993.3578 0.0165	4881826.4404 0.0097		2011-07-10 00:00:00
BISK 11520M001	2	3898945.9443 −0.0165	1223993.3620 0.0165	4881826.4471 0.0097	2011-07-10 00:00:00	
BOGI 12207M003	1	3633815.3456 −0.0182	1397454.1231 0.0151	5035280.9913 0.0088		
BOGO 12207M002	2	3633738.9719 −0.0182	1397434.1333 0.0150	5035353.4763 0.0088	2001-08-17 00:00:00	
BOR1 12205M002	2	3738358.4527 −0.0172	1148173.7092 0.0156	5021815.7718 0.0088	1999-05-31 00:00:00	
BUDP 10101M003	1	3513638.2521 −0.0155	778956.3976 0.0150	5248216.4343 0.0095		
BYDG 12224M001	1	3647216.8721 −0.0171	1184604.2949 0.0152	5079625.1674 0.0088		2014-09-09 00:00:00
BYDG 12224M001	2	3647216.8825 −0.0171	1184604.2993 0.0152	5079625.1766 0.0088	2014-09-09 00:00:00	
CFRM 11525M001	1	3924572.8457 −0.0166	1301971.2355 0.0165	4840464.6859 0.0105		2012-04-25 00:00:00
CFRM 11525M001	2	3924572.8439 −0.0166	1301971.2273 0.0165	4840464.6843 0.0105	2012-04-25 00:00:00	
CLIB 11526M001	1	3903195.2126 −0.0167	1050232.4755 0.0160	4917869.8411 0.0096		2011-08-31 00:00:00
CLIB 11526M001	2	3903195.2182 −0.0167	1050232.4761 0.0161	4917869.8431 0.0096	2011-08-31 00:00:00	
CPAR 11527M001	1	3949918.7739 −0.0174	1116467.2676 0.0164	4865832.7445 0.0093		2011-10-25 00:00:00

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Table C.1: *Continued from previous page*

Station name	SN	X (m) V_X (m/y)	Y (m) V_Y (m/y)	Z (m) V_Z (m/y)	Start date	End date
CPAR 11527M001	2	3949918.7758 −0.0174	1116467.2685 0.0164	4865832.7465 0.0093	2011-10-25 00:00:00	
DRES 14108M001	4	3904724.7003 −0.0162	954013.3918 0.0162	4935789.9885 0.0097	2010-09-22 00:00:00	
GANP 11515M001	2	3929181.5169 −0.0171	1455236.7339 0.0157	4793653.9030 0.0090	2006-08-24 00:00:00	
GOPE 11502M002	6	3979316.1301 −0.0159	1050312.4761 0.0167	4857067.1090 0.0103	2009-12-14 00:00:00	
GWWL 12225M001	1	3734525.8556 −0.0168	1015013.0071 0.0155	5053042.7394 0.0082		2014-10-28 00:00:00
JOZ2 12204M002	2	3664880.5758 −0.0180	1409190.5897 0.0157	5009618.4785 0.0090	2008-03-14 00:00:00	
JOZE 12204M001	2	3664940.1617 −0.0180	1409153.8635 0.0156	5009571.3859 0.0090	2004-12-06 00:00:00	
KATO 12219S001	3	3862992.0333 −0.0157	1332822.8730 0.0173	4881105.6512 0.0065	2010-12-17 00:00:00	
KRA1 12218M002	1	3856938.5976 −0.0175	1397750.4238 0.0161	4867717.5290 0.0096		
KURE 10604S001	1	3107617.4199 −0.0166	1287856.5163 0.0145	5400807.2883 0.0094		
LAMA 12209M001	4	3524522.9249 −0.0182	1329693.6273 0.0148	5129846.3565 0.0082	2007-11-17 18:00:00	
LODZ 12226M001	1	3728601.5508 −0.0179	1317402.4702 0.0159	4987811.3344 0.0090		2014-10-30 00:00:00
ONSA 10402M004	2	3370658.5416 −0.0142	711877.1385 0.0145	5349786.9536 0.0102	1999-02-02 00:00:00	2013-08-28 12:00:00
ONSA 10402M004	3	3370658.5403 −0.0142	711877.1389 0.0145	5349786.9531 0.0102	2013-08-28 12:00:00	2013-11-06 15:08:20
ONSA 10402M004	4	3370658.5414 −0.0142	711877.1389 0.0145	5349786.9545 0.0102	2013-11-06 15:08:20	
PENC 11206M006	3	4052449.4756 −0.0179	1417681.1236 0.0174	4701407.1142 0.0096	2007-06-25 00:00:00	
POTS 14106M003	3	3800689.6364 −0.0163	882077.3855 0.0159	5028791.3267 0.0091	2011-02-15 17:15:00	
PTBB 14234M001	3	3844059.9622 −0.0160	709661.3160 0.0163	5023129.5587 0.0092	2003-08-31 00:00:00	
REDZ 12227M001	1	3550066.6017 −0.0168	1093331.9913 0.0153	5167562.1424 0.0086		2014-10-29 00:00:00
RIGA 12302M002	4	3183899.1929 −0.0177	1421478.4891 0.0143	5322810.7972 0.0088	2007-12-16 12:00:00	2013-12-11 09:00:00
RIGA 12302M002	5	3183899.1937 −0.0177	1421478.4911 0.0143	5322810.7947 0.0088	2013-12-11 09:00:00	
SASS 14281M001	3	3606146.0802 −0.0161	875303.3431 0.0157	5170193.9560 0.0083	2008-01-25 00:00:00	
SPTO 10425M001	1	3328984.5280 −0.0140	761910.2650 0.0146	5369033.6913 0.0113		
SULP 12366M001	1	3765296.9905 −0.0186	1677559.2038 0.0154	4851297.4091 0.0092		2013-03-30 11:16:00
SULP 12366M001	2	3765296.9934 −0.0186	1677559.2025 0.0154	4851297.4097 0.0092	2013-03-30 11:16:00	
SWKI 12228M001	1	3452304.5171 −0.0192	1460314.7910 0.0139	5143362.5900 0.0072		
TUBO 11503M001	3	4001470.2868 −0.0166	1192345.5302 0.0168	4805795.5268 0.0103	2006-06-25 00:00:00	2011-12-12 00:00:00
TUBO 11503M001	4	4001470.2837 −0.0166	1192345.5327 0.0168	4805795.5224 0.0103	2011-12-12 00:00:00	

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Table C.1: *Continued from previous page*

Station name	SN	X (m) V_X (m/y)	Y (m) V_Y (m/y)	Z (m) V_Z (m/y)	Start date	End date
USDL 12229M001	1	3837557.8849 −0.0187	1596303.2485 0.0160	4822409.8368 0.0089		2014-10-28 00:00:00
VISO 10423M001	1	3246470.2522 −0.0156	1077900.5109 0.0147	5365278.0997 0.0100		
VLNS 10801M001	1	3343600.6166 −0.0192	1580417.7386 0.0142	5179337.2930 0.0079		
WARN 14277M002	4	3658785.8047 −0.0162	784470.8794 0.0154	5147870.5950 0.0094	2010-09-15 09:00:00	
WROC 12217M001	4	3835751.3061 −0.0168	1177249.9621 0.0160	4941605.2520 0.0095	2007-04-13 13:12:59	2012-10-22 11:00:00
WROC 12217M001	5	3835751.3019 −0.0168	1177249.9597 0.0160	4941605.2479 0.0095	2012-10-22 11:00:00	
WTZR 14201M010	2	4075580.5487 −0.0158	931853.7980 0.0173	4801568.1328 0.0104	2010-06-30 08:00:00	
ZYWI 12220S001	2	3904632.9813 −0.0176	1360192.0996 0.0162	4840630.9747 0.0098	2007-11-25 00:00:00	2014-08-29 00:00:00

C.2 Final long-term coordinates and velocities in IGb08

Table C.2: Final long-term coordinates and velocities in IGb08 at 2013.14 epoch (22.02.2013). Solution numbers (SN) according to `ASG_A_P1.SNX`; second number, if given, denotes corresponding SN according to C1815 EPN cumulative solution

Station name	SN	X (m)	Y (m)	Z (m)	V_X (m/y)	V_Y (m/y)	V_Z (m/y)
BART 12234M001	1	3490896.49103	1327144.05346	5153172.35123	−0.01721	0.01528	0.00826
BIAL 12235M001	1	3526537.66430	1507014.85772	5079530.15713	−0.01856	0.01431	0.00771
BILG 12236M001	1	3747351.18581	1568978.40906	4900768.93776	−0.01820	0.01557	0.00887
BRSK 12237M001	1	3566372.28384	1501993.69659	5053285.23035	−0.01826	0.01502	0.00839
BUZD 12238M001	1	3805090.88424	1439261.62559	4896192.64615	−0.01852	0.01576	0.00838
CCHN 12239M001	1	3610610.71262	1356983.71873	5062816.76262	−0.01790	0.01520	0.00804
CCHN 12239M001	2	3610610.71133	1356983.71560	5062816.75887	−0.01790	0.01520	0.00804
CHEL 12240M001	1	3678820.04295	1598101.21972	4942832.87854	−0.01790	0.01514	0.00787
CHNO 12241M001	1	3694305.11345	1018555.59110	5081594.40673	−0.01637	0.01589	0.00905
CHOJ 12242M001	1	3608519.65903	1141388.39539	5116893.70798	−0.01595	0.01545	0.01077
DRWP 12243M001	1	3655958.50305	1035736.14732	5105717.32717	−0.01660	0.01565	0.00811
DZIA 12244M001	1	3591708.77216	1319170.02455	5086093.92403	−0.01756	0.01525	0.00874
ELBL 18991M001	1	3530686.49628	1243375.57450	5146944.63585	−0.01720	0.01572	0.00881
ELBL 18991M001	2	3530686.49540	1243375.57214	5146944.63521	−0.01720	0.01572	0.00881
GDAN 12252M001	1	3529800.12923	1190808.01803	5159896.88397	−0.01574	0.01589	0.00916
GIZY 12253M001	1	3486403.04477	1392187.65149	5139218.90449	−0.01837	0.01455	0.00771
GLOG 12254M001	1	3809340.54109	1097658.00440	4979900.97392	−0.01702	0.01613	0.00853
GNIE 12255M001	1	3706493.78730	1174620.11077	5039232.23686	−0.01672	0.01608	0.00872
GOLE 12256M001	1	3670267.67479	972331.73497	5107777.27502	−0.01604	0.01594	0.00913
GRAJ 12245M001	1	3501475.93184	1446945.23389	5113951.94991	−0.01803	0.01507	0.00832
GRUD 12246M001	1	3601223.39646	1222799.52889	5103133.81017	−0.01742	0.01530	0.00909
GRUD 12246M001	2	3601223.39016	1222799.52615	5103133.79786	−0.01742	0.01530	0.00909
HAJN 12247M001	1	3547043.51854	1547151.89738	5053300.87620	−0.01900	0.01501	0.00784
HOZD 12248M001	1	3756466.78915	1622631.37547	4876495.59951	−0.01705	0.01634	0.00968
HRUB 12249M001	1	3693100.19650	1635499.60968	4920024.37461	−0.01881	0.01562	0.00850
ILAW 12250M001	1	3575245.53285	1270835.83442	5109730.41395	−0.01811	0.01500	0.00775
ILAW 12250M001	2	3575245.52776	1270835.83425	5109730.40843	−0.01811	0.01500	0.00775
JLGR 12251M001	1	3878289.29535	1092567.19816	4928218.12784	−0.01670	0.01654	0.00976
KALI 12257M001	1	3760909.34956	1228903.79636	4986013.45702	−0.01743	0.01575	0.00925
KAM1 12258M001	1	3636189.95533	959188.56415	5134372.85528	−0.01597	0.01540	0.00901
KEPN 12259M001	1	3802580.43769	1234329.28450	4953272.40960	−0.01709	0.01579	0.00987
KEPN 12259M001	2	3802580.44500	1234329.28777	4953272.41887	−0.01709	0.01579	0.00987
KLCE 12260M001	1	3774368.38058	1420921.50750	4925093.27712	−0.01819	0.01553	0.00799
KLDZ 12261M001	1	3900141.50443	1166529.98899	4894068.61352	−0.01718	0.01648	0.00908
KLDZ 12261M001	2	3900141.51132	1166529.99249	4894068.61942	−0.01718	0.01648	0.00908
KLOB 12219M001	1	3812245.06050	1307966.86518	4927157.74268	−0.01806	0.01594	0.00861
KLOB 12219M001	2	3812245.06476	1307966.86586	4927157.74807	−0.01806	0.01594	0.00861
KONI 12262M001	1	3718009.44304	1226302.03114	5018514.87649	−0.01737	0.01562	0.00969
KOSC 12263M001	1	3563309.68358	1156523.00371	5144921.13834	−0.01655	0.01505	0.00896
KOSC 12263M001	2	3563309.69108	1156523.00592	5144921.14181	−0.01655	0.01506	0.00896
KOSZ 12264M001	1	3590529.94866	1042990.87081	5150117.91189	−0.01605	0.01541	0.00932
KROS 12265M001	1	3840336.00317	1534054.18642	4840009.63896	−0.01897	0.01528	0.00830
KROT 12266M001	1	3779936.28900	1187254.65475	4981792.62863	−0.01743	0.01572	0.00852
KUTN 12267M001	1	3693480.41173	1298866.78851	5018375.67433	−0.01810	0.01541	0.00756
KUTN 12267M001	2	3693480.41467	1298866.79006	5018375.68027	−0.01810	0.01541	0.00756
LEGN 12268M001	1	3846687.30630	1114288.68176	4947658.90137	−0.01757	0.01587	0.00904
LELO 12269M001	1	3814250.53121	1360360.49052	4911505.15355	−0.01827	0.01598	0.00874
LELO 12269M001	2	3814250.53406	1360360.49093	4911505.15833	−0.01827	0.01598	0.00874
LESZ 12270M001	1	3784869.45987	1126771.68330	4991968.21522	−0.01710	0.01605	0.00860
LOMZ 12271M001	1	3550310.83696	1440214.71748	5082321.75491	−0.01828	0.01486	0.00803
LUBL 12272M001	1	3694474.79513	1534437.78891	4951248.95797	−0.01887	0.01512	0.00806
MIES 18993M001	1	3742653.68528	966298.54566	5056520.45258	−0.01638	0.01613	0.00964
MIMA 12273M001	1	3644974.05782	1440150.22006	5015356.91257	−0.01825	0.01489	0.00841

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Table C.2: *Continued from previous page*

Station name	SN	X (m)	Y (m)	Z (m)	V_X (m/y)	V_Y (m/y)	V_Z (m/y)
MLCN 12274M001	1	3804457.28011	1534915.01011	4867705.75806	−0.01933	0.01538	0.00819
MLCN 12274M001	2	3804457.28649	1534915.01268	4867705.76458	−0.01933	0.01538	0.00819
MYSZ 12275M001	1	3550868.33957	1387537.62907	5096451.60699	−0.01840	0.01493	0.00803
NODW 12276M001	1	3645290.49078	1378210.42406	5032291.81282	−0.01804	0.01531	0.00854
NODW 12276M001	2	3645290.49650	1378210.42202	5032291.80834	−0.01803	0.01531	0.00854
NTML 12277M001	1	3753277.46622	1084607.44419	5024800.71526	−0.01630	0.01613	0.00976
NWSC 12231M001	1	3873461.27695	1462888.48928	4835656.28647	−0.01779	0.01596	0.00894
NWSC 12231M001	2	3873461.27379	1462888.48689	4835656.27841	−0.01779	0.01596	0.00894
NWTG 12232M001	1	3901050.40147	1422373.38201	4826032.56603	−0.01770	0.01602	0.00848
NWTG 12232M001	2	3901050.40026	1422373.38457	4826032.56932	−0.01770	0.01602	0.00848
NYSA 12278M001	1	3882469.38597	1211763.20776	4896966.51279	−0.01761	0.01623	0.00958
NYSA 12278M001	2	3882469.39442	1211763.20936	4896966.52063	−0.01761	0.01623	0.00958
OLST 12203M001	1	3538408.94585	1322052.86025	5122295.98541	−0.01732	0.01500	0.00930
OPLE 12283M001	1	3854337.64211	1246354.55104	4910366.57882	−0.01694	0.01607	0.00918
OPLE 12283M001	2	3854337.64719	1246354.55167	4910366.58677	−0.01694	0.01607	0.00918
OPLU 12284M001	1	3717923.97127	1500320.91031	4944131.24419	−0.01880	0.01517	0.00811
OSMZ 12285M001	1	3585797.35534	1440878.29675	5057302.95405	−0.01818	0.01505	0.00819
PITR 12287M001	1	3754198.19049	1343527.39388	4961743.55495	−0.01797	0.01579	0.00821
POZN 12206M001	1	3728246.62338	1135212.05458	5032258.62709	−0.01609	0.01547	0.00925
POZN 12206M001	2	3728246.61792	1135212.05724	5032258.62553	−0.01609	0.01547	0.00925
PPIL 12286M001	1	3670392.63175	1103842.99295	5081135.35852	−0.01624	0.01569	0.00961
PROS 12233M001	1	3837828.53387	1418780.23695	4876685.87496	−0.01862	0.01482	0.00814
PROS 12233M001	2	3837828.53534	1418780.24439	4876685.88152	−0.01862	0.01482	0.00814
PRZM 12279M001	1	3804695.21195	1595661.17017	4848106.74029	−0.02224	0.01514	0.00743
RADM 12280M001	1	3719233.12611	1439895.07097	4961004.53898	−0.01819	0.01568	0.00844
RWMZ 12281M001	1	3711199.13532	1369172.83167	4986762.49782	−0.01771	0.01610	0.01128
RYKI 12282M001	1	3680882.84732	1481736.72641	4977132.54541	−0.01894	0.01467	0.00721
SIDZ 12288M001	1	3762312.91419	1274760.36862	4973563.86745	−0.01774	0.01588	0.00837
SIED 12289M001	1	3628142.23123	1487581.99560	5013729.49608	−0.01893	0.01497	0.00767
SIPC 12290M001	1	3634432.04269	1298646.73927	5061077.83171	−0.01811	0.01546	0.00732
SOCH 12291M001	1	3673992.27544	1354866.48377	5017845.00131	−0.01786	0.01553	0.00872
SOKL 12292M001	1	3494481.54912	1519135.35524	5097955.01107	−0.01886	0.01449	0.00765
STRG 18994M001	1	3565383.25835	1195036.44626	5134648.91399	−0.01647	0.01526	0.00887
STRG 18994M001	2	3565383.26315	1195036.44869	5134648.91979	−0.01647	0.01526	0.00887
SWIB 12293M001	1	3770280.24281	1048163.59860	5019843.75794	−0.01636	0.01593	0.00959
SZE2 12294M001	1	3624637.84783	1087539.26240	5117214.82361	−0.01662	0.01562	0.00921
TABG 12295M001	1	3772239.00968	1498959.04616	4903535.66191	−0.01733	0.01629	0.01039
TORU 12202M001	1	3643531.83160	1228658.90181	5071868.70763	−0.01708	0.01570	0.00883
TRNW 12230M001	1	3834315.27525	1470638.68400	4864151.00556	−0.01877	0.01591	0.00824
TRNW 12230M001	2	3834315.28198	1470638.69457	4864151.00842	−0.01877	0.01591	0.00824
WAT1 12297M001	1	3655222.68701	1396074.76368	5020262.63379	−0.01762	0.01532	0.00884
WLBR 12298M001	1	3880291.90245	1133212.21368	4917654.81789	−0.01544	0.01630	0.01241
WLDW 12299M001	1	3643580.51911	1588599.69967	4971661.41367	−0.01874	0.01488	0.00809
WLOC 18999M001	1	3664306.42849	1266512.64908	5047682.07675	−0.01827	0.01551	0.00806
WLOC 18999M001	2	3664306.43667	1266512.65098	5047682.08551	−0.01827	0.01551	0.00806
WODZ 18998M001	1	3896698.28874	1300674.04714	4863029.63393	−0.01920	0.01588	0.00987
WRKI 18997M001	1	3715835.91334	1091592.31882	5050832.45703	−0.01732	0.01559	0.00825
ZARY 18996M001	1	3828791.32642	1036393.69030	4978198.55980	−0.01663	0.01616	0.00967
ZIGR 18995M001	1	3796759.63609	1053955.11924	4998889.67293	−0.01704	0.01592	0.00873

C.3 Coordinates of a subset of stations in IGb08 at epochs of minimum position variance

Table C.3: Coordinates of shortly observing stations expressed in IGb08 at the minimum position variance epoch. Solution numbers (SN) according to `ASG_AB_P1.SNX`

Station name	SN	X (m)	Y (m)	Z (m)	Epoch
CBKA 12221M001	1	3654409.56470	1407752.80103	5017577.16985	2012.409
GDA1 12252M002	1	3530093.14260	1190826.33870	5159689.21480	2014.982
MIEL 18967M001	1	3800644.41444	1492364.77829	4883718.78720	2014.600
NWT1 12232M002	1	3901292.92713	1422611.13111	4825779.03109	2014.599
OPNT 12203M003	1	3538856.17992	1324402.65039	5121378.34470	2014.952
RWM1 12281M002	1	3711201.12952	1369169.94166	4986762.25068	2014.945
TAR1 12296M002	1	3851034.14376	1315360.89347	4895201.21635	2013.911
TAR1 12296M002	2	3851034.13252	1315360.91685	4895201.23100	2014.911
TARG 12296M001	1	3851054.48202	1315388.62302	4895186.13005	2012.157
WIEL 18968M001	1	3794719.45399	1274981.00570	4949048.21684	2014.011
WLAD 12222M001	1	3496344.60079	1164350.32953	5188401.92753	2013.386
WLAD 12222M001	2	3496344.58615	1164350.35663	5188401.95192	2014.642

C.4 Final long-term coordinates and velocities in ETRF2000

Table C.4: Final coordinates and velocities in ETRF2000(R08) at epoch 2013.14 (22.02.2013). Solution numbers (SN) according to `ASG_A_P1.SNX`; second number, if given, denotes corresponding SN according to C1815 EPN cumulative solution

Station name	SN	X (m)	Y (m)	Z (m)	V_X (m/y)	V_Y (m/y)	V_Z (m/y)
BART 12234M001	1	3490896.97140	1327143.73475	5153172.09375	0.00051	0.00006	−0.00090
BIAL 12235M001	1	3526538.15721	1507014.53684	5079529.89913	−0.00032	−0.00101	−0.00147
BILG 12236M001	1	3747351.67474	1568978.06955	4900768.66726	−0.00013	−0.00052	−0.00082
BRSK 12237M001	1	3566372.77487	1501993.37225	5053284.96996	−0.00010	−0.00044	−0.00089
BUZD 12238M001	1	3805091.36102	1439261.28046	4896192.37110	−0.00096	−0.00056	−0.00150
CCHN 12239M001	1	3610611.19086	1356983.38985	5062816.49834	−0.00027	−0.00044	−0.00140
CCHN 12239M001	2	3610611.18957	1356983.38672	5062816.49459	−0.00027	−0.00044	−0.00140
CHEL 12240M001	1	3678820.53683	1598100.88624	4942832.61235	0.00037	−0.00070	−0.00165
CHNO 12241M001	1	3694305.56159	1018555.25348	5081594.13449	0.00001	−0.00011	−0.00072
CHOJ 12242M001	1	3608520.12038	1141388.06568	5116893.44190	0.00098	−0.00022	0.00126
DRWP 12243M001	1	3655958.95408	1035735.81307	5105717.05735	−0.00010	−0.00021	−0.00156
DZIA 12244M001	1	3591709.24819	1319169.69712	5086093.66053	−0.00002	−0.00033	−0.00067
ELBL 18991M001	1	3530686.96862	1243375.25196	5146944.37528	0.00018	0.00034	−0.00048
ELBL 18991M001	2	3530686.96774	1243375.24960	5146944.37464	0.00018	0.00034	−0.00048
GDAN 12252M001	1	3529800.59744	1190807.69533	5159896.62298	0.00147	0.00051	−0.00014
GIZY 12253M001	1	3486403.53036	1392187.33349	5139218.64785	−0.00044	−0.00064	−0.00141
GLOG 12254M001	1	3809340.99101	1097657.65727	4979900.69558	−0.00057	−0.00026	−0.00149
GNIE 12255M001	1	3706494.24751	1174619.77279	5039231.96529	0.00016	0.00006	−0.00102
GOLE 12256M001	1	3670268.12009	972331.39922	5107777.00378	0.00022	0.00002	−0.00060
GRAJ 12245M001	1	3501476.42109	1446944.91486	5113951.69286	0.00005	−0.00017	−0.00082
GRUD 12246M001	1	3601223.86455	1222799.20018	5103133.54525	−0.00021	−0.00033	−0.00038
GRUD 12246M001	2	3601223.85825	1222799.19744	5103133.53294	−0.00021	−0.00033	−0.00038
HAJN 12247M001	1	3547044.01371	1547151.57494	5053300.61735	−0.00067	−0.00037	−0.00137
HOZD 12248M001	1	3756467.28168	1622631.03547	4876495.32894	0.00117	0.00023	−0.00002
HRUB 12249M001	1	3693100.69257	1635499.27518	4920024.10790	−0.00045	−0.00026	−0.00104
ILAW 12250M001	1	3575246.00571	1270835.50817	5109730.15099	−0.00071	−0.00053	−0.00164
ILAW 12250M001	2	3575246.00062	1270835.50800	5109730.14547	−0.00071	−0.00053	−0.00164
JLGR 12251M001	1	3878289.74200	1092566.84511	4928217.84538	−0.00039	−0.00010	−0.00043
KALI 12257M001	1	3760909.81188	1228903.45397	4986013.18272	−0.00047	−0.00045	−0.00060
KAM1 12258M001	1	3636190.40086	959188.23127	5134372.58593	0.00030	−0.00040	−0.00064
KEPN 12259M001	1	3802580.89874	1234328.93857	4953272.13288	−0.00018	−0.00056	−0.00008
KEPN 12259M001	2	3802580.90605	1234328.94184	4953272.14215	−0.00018	−0.00056	−0.00008
KLCE 12260M001	1	3774368.85724	1420921.16490	4925093.00372	−0.00063	−0.00068	−0.00182
KLDZ 12261M001	1	3900141.95603	1166529.63442	4894068.33042	−0.00066	−0.00022	−0.00114
KLDZ 12261M001	2	3900141.96292	1166529.63792	4894068.33632	−0.00066	−0.00022	−0.00114
KLOB 12219M001	1	3812245.52690	1307966.51878	4927157.46605	−0.00093	−0.00043	−0.00134
KLOB 12219M001	2	3812245.53116	1307966.51946	4927157.47144	−0.00093	−0.00043	−0.00134
KONI 12262M001	1	3718009.90688	1226301.69242	5018514.60470	−0.00034	−0.00043	−0.00006
KOSC 12263M001	1	3563310.14783	1156522.67796	5144920.87507	0.00050	−0.00046	−0.00044
KOSC 12263M001	2	3563310.15533	1156522.68017	5144920.87854	0.00050	−0.00045	−0.00044
KOSZ 12264M001	1	3590530.40275	1042990.54222	5150117.64599	0.00058	−0.00022	−0.00019
KROS 12265M001	1	3840336.48560	1534053.83878	4840009.36265	−0.00117	−0.00114	−0.00163
KROT 12266M001	1	3779936.74726	1187254.31054	4981792.35283	−0.00063	−0.00056	−0.00139
KUTN 12267M001	1	3693480.88223	1298866.45223	5018375.40464	−0.00080	−0.00054	−0.00210
KUTN 12267M001	2	3693480.88517	1298866.45378	5018375.41058	−0.00080	−0.00054	−0.00210
LEGN 12268M001	1	3846687.75600	1114288.33151	4947658.62097	−0.00113	−0.00065	−0.00106
LELO 12269M001	1	3814251.00157	1360360.14421	4911504.87726	−0.00097	−0.00039	−0.00119
LELO 12269M001	2	3814251.00442	1360360.14462	4911504.88204	−0.00097	−0.00039	−0.00119
LESZ 12270M001	1	3784869.91312	1126771.33839	4991967.93859	−0.00051	−0.00025	−0.00135
LOMZ 12271M001	1	3550311.32389	1440214.39421	5082321.49492	−0.00029	−0.00055	−0.00123
LUBL 12272M001	1	3694475.28362	1534437.45374	4951248.69030	−0.00082	−0.00079	−0.00152
MIES 18993M001	1	3742654.12726	966298.20367	5056520.17701	−0.00026	−0.00005	−0.00027
MIMA 12273M001	1	3644974.54113	1440149.88865	5015356.64699	−0.00041	−0.00086	−0.00108

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Table C.4: *Continued from previous page*

Station name	SN	X (m)	Y (m)	Z (m)	V_X (m/y)	V_Y (m/y)	V_Z (m/y)
MLCN 12274M001	1	3804457.76412	1534914.66554	4867705.48388	−0.00147	−0.00092	−0.00166
MLCN 12274M001	2	3804457.77050	1534914.66811	4867705.49040	−0.00147	−0.00092	−0.00166
MYSZ 12275M001	1	3550868.82243	1387537.30549	5096451.34651	−0.00058	−0.00049	−0.00125
NODW 12276M001	1	3645290.96932	1378210.09231	5032291.54668	−0.00040	−0.00045	−0.00098
NODW 12276M001	2	3645290.97504	1378210.09027	5032291.54220	−0.00039	−0.00045	−0.00098
NTML 12277M001	1	3753277.91737	1084607.10180	5024800.44012	0.00020	−0.00007	−0.00013
NWSC 12231M001	1	3873461.75261	1462888.13844	4835656.00757	−0.00028	−0.00059	−0.00110
NWSC 12231M001	2	3873461.74945	1462888.13605	4835655.99951	−0.00028	−0.00059	−0.00110
NWTG 12232M001	1	3901050.87289	1422373.02861	4826032.28514	−0.00036	−0.00064	−0.00164
NWTG 12232M001	2	3901050.87168	1422373.03117	4826032.28843	−0.00036	−0.00064	−0.00164
NYSA 12278M001	1	3882469.84189	1211762.85491	4896966.23114	−0.00091	−0.00040	−0.00058
NYSA 12278M001	2	3882469.85034	1211762.85651	4896966.23898	−0.00091	−0.00040	−0.00058
OLST 12203M001	1	3538409.42409	1322052.53742	5122295.72508	0.00031	−0.00039	0.00002
OPLE 12283M001	1	3854338.10193	1246354.20075	4910366.29915	−0.00008	−0.00046	−0.00089
OPLE 12283M001	2	3854338.10701	1246354.20138	4910366.30710	−0.00008	−0.00046	−0.00089
OPLU 12284M001	1	3717924.45625	1500320.57295	4944130.97483	−0.00090	−0.00083	−0.00154
OSMZ 12285M001	1	3585797.84098	1440877.97043	5057302.69198	−0.00025	−0.00049	−0.00116
PITR 12287M001	1	3754198.66203	1343527.05262	4961743.28206	−0.00062	−0.00037	−0.00158
POZN 12206M001	1	3728247.07959	1135211.71456	5032258.35389	0.00062	−0.00063	−0.00056
POZN 12206M001	2	3728247.07413	1135211.71722	5032258.35233	0.00062	−0.00063	−0.00056
PPIL 12286M001	1	3670393.08772	1103842.65775	5081135.08845	0.00046	−0.00021	−0.00007
PROS 12233M001	1	3837829.00771	1418779.88892	4876685.59779	−0.00118	−0.00162	−0.00183
PROS 12233M001	2	3837829.00918	1418779.89636	4876685.60435	−0.00118	−0.00162	−0.00183
PRZM 12279M001	1	3804695.70047	1595660.82591	4848106.46663	−0.00419	−0.00115	−0.00239
RADM 12280M001	1	3719233.60646	1439894.73319	4961004.26901	−0.00048	−0.00033	−0.00123
RWMZ 12281M001	1	3711199.61057	1369172.49422	4986762.22770	−0.00021	0.00010	0.00160
RYKI 12282M001	1	3680883.33238	1481736.39213	4977132.27808	−0.00103	−0.00120	−0.00235
SIDZ 12288M001	1	3762313.38005	1274760.02633	4973563.59348	−0.00063	−0.00032	−0.00147
SIED 12289M001	1	3628142.71881	1487581.66588	5013729.23192	−0.00092	−0.00071	−0.00176
SIPC 12290M001	1	3634432.51548	1298646.40806	5061077.56551	−0.00071	−0.00028	−0.00220
SOCH 12291M001	1	3673992.75106	1354866.14944	5017844.73327	−0.00034	−0.00034	−0.00087
SOKL 12292M001	1	3494482.04413	1519135.03719	5097954.75507	−0.00054	−0.00071	−0.00145
STRG 18994M001	1	3565383.72559	1195036.12051	5134648.65094	0.00070	−0.00025	−0.00052
STRG 18994M001	2	3565383.73039	1195036.12294	5134648.65674	0.00070	−0.00025	−0.00052
SWIB 12293M001	1	3770280.69034	1048163.25459	5019843.48147	−0.00001	−0.00033	−0.00035
SZE2 12294M001	1	3624638.30425	1087538.93106	5117214.55610	0.00010	−0.00012	−0.00036
TABG 12295M001	1	3772239.49233	1498958.70415	4903535.38932	0.00048	0.00010	0.00061
TORU 12202M001	1	3643532.29854	1228658.56949	5071868.44027	0.00008	−0.00008	−0.00074
TRNW 12230M001	1	3834315.75317	1470638.33654	4864150.72905	−0.00116	−0.00051	−0.00170
TRNW 12230M001	2	3834315.75990	1470638.34711	4864150.73191	−0.00116	−0.00051	−0.00170
WAT1 12297M001	1	3655223.16654	1396074.43117	5020262.36722	0.00006	−0.00047	−0.00069
WLBR 12298M001	1	3880292.35226	1133211.86064	4917654.53567	0.00100	−0.00034	0.00223
WLDW 12299M001	1	3643581.01367	1588599.36916	4971661.14948	−0.00044	−0.00084	−0.00134
WLOC 18999M001	1	3664306.89760	1266512.31515	5047681.80850	−0.00102	−0.00034	−0.00154
WLOC 18999M001	2	3664306.90578	1266512.31705	5047681.81726	−0.00102	−0.00034	−0.00154
WODZ 18998M001	1	3896698.75099	1300673.69350	4863029.35223	−0.00224	−0.00079	−0.00029
WRKI 18997M001	1	3715836.36654	1091591.97967	5050832.18417	−0.00073	−0.00047	−0.00154
ZARY 18996M001	1	3828791.77061	1036393.34123	4978198.27976	−0.00042	−0.00031	−0.00042
ZIGR 18995M001	1	3796760.08302	1053954.77299	4998889.39495	−0.00071	−0.00044	−0.00128

C.5 Coordinates of a subset of stations in ETRF2000 at epochs of minimum position variance

Table C.5: Coordinates of shortly observing stations expressed in ETRF2000(R08) at epochs of minimum position variance. Solution numbers (SN) according to `ASG_AB_P1.SNX`

Station name	SN	X (m)	Y (m)	Z (m)	Epoch
CBKA 12221M001	1	3654410.03213	1407752.48025	5017576.91043	2012.409
GDA1 12252M002	1	3530093.64243	1190825.98770	5159688.93669	2014.982
MIEL 18967M001	1	3800644.92123	1492364.41010	4883718.49853	2014.600
NWT1 12232M002	1	3901293.42378	1422610.75345	4825778.73546	2014.599
OPNT 12203M003	1	3538856.69021	1324402.29971	5121378.06760	2014.952
RWM1 12281M002	1	3711201.63628	1369169.57540	4986761.96313	2014.945
TAR1 12296M002	1	3851034.62221	1315360.53114	4895200.92978	2013.911
TAR1 12296M002	2	3851034.62806	1315360.53801	4895200.93439	2014.911
TARG 12296M001	1	3851054.93049	1315388.28964	4895185.86110	2012.157
WIEL 18968M001	1	3794719.93333	1274980.64650	4949047.93235	2014.011
WLAD 12222M001	1	3496345.07226	1164350.00590	5188401.66605	2013.386
WLAD 12222M001	2	3496345.07918	1164350.01383	5188401.67884	2014.642

Appendix D

Differences form comparison with national catalogue PL-ETRF2000

Table D.1: Direct comparison of solution P1 with the national solution PL-ETRF2000. Solution P1 was expressed at common epoch 2011.00 using estimated velocities.

Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)	Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)
BOGI 12207M003	2.52	−0.10	4.62	KOSC 12263M001	−0.88	−2.93	7.29
BOR1 12205M002	1.66	−0.91	7.55	KOSZ 12264M001	−0.32	−3.11	6.89
GWWL 12225M001	2.24	−1.06	2.62	KROS 12265M001	−0.90	−3.61	5.68
JOZ2 12204M002	1.10	−0.02	1.05	KROT 12266M001	−1.40	−3.27	6.19
KATO 12219S001	1.74	−1.21	3.30	KUTN 12267M001	−0.68	−3.52	5.67
LAMA 12209M001	3.25	−0.92	2.95	LEGN 12268M001	−0.45	−3.05	6.47
LODZ 12226M001	1.26	−1.51	0.82	LELO 12269M001	−1.17	−3.17	6.25
REDZ 12227M001	1.74	−1.47	4.78	LESZ 12270M001	−1.60	−2.49	7.38
SWKI 12228M001	−0.11	1.64	6.72	LOMZ 12271M001	−1.93	−2.15	6.75
USDL 12229M001	1.57	−1.51	3.32	LUBL 12272M001	−0.17	−3.47	6.34
WROC 12217M001	0.94	0.57	4.18	MLCN 12274M001	−0.66	−3.04	6.76
ZYWI 12220S001	1.08	−0.70	2.18	MYSZ 12275M001	0.08	−2.76	7.18
BOGO 12207M002	0.77	−0.90	4.67	NTML 12277M001	−1.56	−1.71	5.62
JOZE 12204M001	1.54	−1.60	7.70	NWSC 12231M001	1.79	−2.29	3.56
KRAW 12218M001	0.22	−1.78	−0.54	NWTG 12232M001	−0.02	2.53	3.75
BPDL 12223M001	0.25	−1.17	3.09	NYSA 12278M001	−0.49	−2.64	4.96
BYDG 12224M001	1.90	−1.86	2.89	OLST 12203M001	2.86	−3.12	5.67
KRA1 12218M002	0.70	−1.08	−0.73	OPLE 12283M001	0.02	−3.23	5.34
BART 12234M001	0.13	−2.91	5.97	OPLU 12284M001	−1.09	−2.71	6.23
BIAL 12235M001	−0.62	−2.99	6.11	OSMZ 12285M001	−1.40	−2.43	8.26
BILG 12236M001	−1.33	−3.20	4.43	PITR 12287M001	−2.34	−2.68	6.67
BRSK 12237M001	−0.36	−3.32	7.47	POZN 12206M001	1.27	−1.69	3.96
BUZD 12238M001	−1.12	−3.20	6.35	PPIL 12286M001	−1.30	−2.39	7.47
CCHN 12239M001	−1.69	−1.75	5.99	PROS 12233M001	−0.09	2.72	0.57
CHEL 12240M001	−1.38	−2.99	5.88	PRZM 12279M001	−0.90	−3.24	6.97
CHNO 12241M001	−1.55	−3.07	5.74	RADM 12280M001	−1.46	−1.66	5.07
CHOJ 12242M001	0.31	−2.61	11.81	RWMZ 12281M001	0.03	−2.70	9.94
DRWP 12243M001	−2.22	−3.99	8.23	RYKI 12282M001	0.39	−2.85	6.30
DZIA 12244M001	−1.73	−2.17	6.45	SIDZ 12288M001	−1.22	−1.76	9.23
ELBL 18991M001	0.77	−0.70	5.84	SIED 12289M001	−1.27	−3.17	5.80
GDAN 12252M001	−2.10	−2.97	7.68	SIPC 12290M001	−1.68	−3.82	5.37
GLOG 12254M001	−1.92	−2.40	6.14	SOCH 12291M001	2.32	−1.08	2.71
GNIE 12255M001	−4.09	−1.33	5.05	SOKL 12292M001	−0.56	−2.59	5.42
GOLE 12256M001	−1.83	−2.41	10.34	STRG 18994M001	−0.55	−3.22	9.97
GRAJ 12245M001	−2.14	−1.79	7.39	SWIB 12293M001	−0.20	−0.58	6.83
GRUD 12246M001	−1.24	−2.01	7.30	SZE2 12294M001	−1.01	−2.34	7.60
HAJN 12247M001	−0.76	−2.04	8.25	TABG 12295M001	−0.54	−2.46	6.78

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Table D.1: *Continued from previous page*

Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)	Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)
HOZD 12248M001	−0.49	−2.64	9.42	TORU 12202M001	−1.40	−2.74	5.61
HRUB 12249M001	−0.42	−3.21	4.95	TRNW 12230M001	−0.66	1.50	−0.49
ILAW 12250M001	−0.99	−2.26	7.80	WAT1 12297M001	1.06	1.80	8.41
JLGR 12251M001	−1.56	−2.53	8.09	WLBR 12298M001	0.14	−5.20	7.64
KALI 12257M001	−1.15	−3.49	7.26	WLDW 12299M001	−0.97	−3.11	7.99
KAM1 12258M001	−1.32	−3.08	10.48	WLOC 18999M001	−1.37	−3.37	8.34
KEPN 12259M001	−0.03	−2.90	7.65	WODZ 18998M001	−0.54	−0.12	3.39
KLCE 12260M001	−3.04	−3.12	3.73	WRKI 18997M001	−1.13	−2.74	8.19
KLDZ 12261M001	−1.25	−2.54	6.39	ZARY 18996M001	−1.22	−3.00	7.14
KLOB 12219M001	0.13	−1.77	5.41	ZIGR 18995M001	−1.32	−2.43	6.24
KONI 12262M001	−0.37	−2.87	5.18				

Table D.2: Comparison of of solution P1 with the national solution PL-ETRF2000 using Helmert transformation. Solution P1 was expressed at common epoch 2011.00 using estimated velocities. Finally the 7 parameter transformation was applied.

Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)	Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)
BOGI 12207M003	2.77	2.03	−1.47	KOSC 12263M001	−0.42	−0.65	−0.14
BOR1 12205M002	2.21	1.26	1.29	KOSZ 12264M001	0.25	−0.83	−0.74
GWWL 12225M001	2.89	1.15	−4.13	KROS 12265M001	−0.57	−1.73	1.52
JOZ2 12204M002	1.37	2.08	−4.79	KROT 12266M001	−0.86	−1.13	0.35
KATO 12219S001	2.24	0.80	−1.45	KUTN 12267M001	−0.29	−1.38	−0.38
LAMA 12209M001	3.50	1.34	−4.12	LEGN 12268M001	0.19	−0.92	0.84
LODZ 12226M001	1.66	0.60	−4.92	LELO 12269M001	−0.73	−1.14	1.26
REDZ 12227M001	2.25	0.82	−2.95	LESZ 12270M001	−1.01	−0.34	1.36
SWKI 12228M001	−0.05	3.90	−0.36	LOMZ 12271M001	−1.78	0.03	0.25
USDL 12229M001	1.86	0.32	−0.63	LUBL 12272M001	0.01	−1.48	1.17
WROC 12217M001	1.53	2.68	−1.32	MLCN 12274M001	−0.36	−1.14	2.35
ZYWI 12220S001	1.61	1.27	−2.18	MYSZ 12275M001	0.29	−0.56	0.49
BOGO 12207M002	1.02	1.23	−1.42	NTML 12277M001	−0.95	0.47	−0.76
JOZE 12204M001	1.81	0.51	1.86	NWSC 12231M001	2.21	−0.38	−0.64
KRAW 12218M001	0.68	0.19	−5.09	NWTG 12232M001	0.46	4.46	−0.40
BPDL 12223M001	0.34	0.88	−2.58	NYSA 12278M001	0.12	−0.57	−0.08
BYDG 12224M001	2.36	0.36	−3.87	OLST 12203M001	3.13	−0.88	−1.34
KRA1 12218M002	1.15	0.89	−5.28	OPLE 12283M001	0.58	−1.17	0.22
BART 12234M001	0.37	−0.63	−1.34	OPLU 12284M001	−0.85	−0.71	1.09
BIAL 12235M001	−0.56	−0.83	−0.30	OSMZ 12285M001	−1.23	−0.29	2.00
BILG 12236M001	−1.12	−1.28	−0.25	PITR 12287M001	−1.94	−0.61	1.20
BRSK 12237M001	−0.26	−1.19	1.31	POZN 12206M001	1.82	0.49	−2.42
BUZD 12238M001	−0.75	−1.22	1.58	PPIL 12286M001	−0.75	−0.17	0.59
CCHN 12239M001	−1.41	0.43	−0.40	PROS 12233M001	0.33	4.69	−4.04
CHEL 12240M001	−1.28	−1.03	0.84	PRZM 12279M001	−0.66	−1.39	2.79
CHNO 12241M001	−0.92	−0.85	−1.27	RADM 12280M001	−1.17	0.38	−0.29
CHOJ 12242M001	0.79	−0.35	4.64	RWMZ 12281M001	0.38	−0.61	4.27
DRWP 12243M001	−1.62	−1.75	1.02	RYKI 12282M001	0.61	−0.81	0.84
DZIA 12244M001	−1.42	0.03	−0.21	SIDZ 12288M001	−0.76	0.35	3.57
ELBL 18991M001	1.12	1.58	−1.49	SIED 12289M001	−1.11	−1.08	−0.00
GDAN 12252M001	−1.70	−0.68	0.16	SIPC 12290M001	−1.32	−1.64	−1.07
GLOG 12254M001	−1.29	−0.24	0.18	SOCH 12291M001	2.65	1.05	−3.27
GNIE 12255M001	−3.59	0.85	−1.34	SOKL 12292M001	−0.54	−0.41	−1.16
GOLE 12256M001	−1.18	−0.17	3.01	STRG 18994M001	−0.14	−0.96	2.70
GRAJ 12245M001	−2.03	0.43	0.58	SWIB 12293M001	0.44	1.60	0.44
GRUD 12246M001	−0.83	0.22	0.36	SZE2 12294M001	−0.46	−0.09	0.35
HAJN 12247M001	−0.73	0.07	2.13	TABG 12295M001	−0.26	−0.50	2.01
HOZD 12248M001	−0.32	−0.77	5.01	TORU 12202M001	−0.97	−0.54	−1.02
HRUB 12249M001	−0.34	−1.31	0.15	TRNW 12230M001	−0.28	3.43	−4.93

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Table D.2: *Continued from previous page*

Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)	Station name	Δ N (mm)	Δ E (mm)	Δ U (mm)
ILAW 12250M001	−0.65	−0.02	0.86	WAT1 12297M001	1.33	3.92	2.46
JLGR 12251M001	−0.88	−0.40	2.60	WLBR 12298M001	0.80	−3.09	2.30
KALI 12257M001	−0.65	−1.36	1.43	WLDW 12299M001	−0.89	−1.11	2.67
KAM1 12258M001	−0.66	−0.82	2.88	WLOC 18999M001	−0.97	−1.20	1.98
KEPN 12259M001	0.49	−0.79	2.13	WODZ 18998M001	0.02	1.90	−1.24
KLCE 12260M001	−2.68	−1.11	−1.31	WRKI 18997M001	−0.54	−0.54	1.57
KLDZ 12261M001	−0.60	−0.45	1.31	ZARY 18996M001	−0.54	−0.84	1.11
KLOB 12219M001	0.60	0.29	0.22	ZIGR 18995M001	−0.67	−0.25	0.05
KONI 12262M001	0.10	−0.71	−0.95				