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EUREF-Czech-2009 Campaign

Final Report

submitted for evaluation by the EUREF Technical Working Group

prepared by

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1 Introduction

The reasons for ETRS89 implementation in the Czech Republic were threefold:

- Harmonization of the surveying and mapping legislation with IAG/CERCO/EuroGeographic and EC recommendations and directives
- Fostering the use of GPS technique and development of GPS based applications by a broad user community
- Improved realization of the classical national user geodetic reference system S-JTSK

The first expansion of the ETRS89 to the east was realized by the EUREF-CS/H’91 campaign in 1991. Eleven stations of the fundamental national geodetic network were observed by the former Institute of Applied Geodesy, Frankfurt am Main (present-day BKG) on the territories of Hungary (5 sites) and the former Czech and Slovak Federal Republic (6 sites). Only three of them (Pecný, Kleť, Přední příčka) are located on the territory of the Czech Republic and today none of them is operated as a permanent GNSS station with the exception of Pecný where the GOPE IGS/EPN station is located about 90 m apart. Note, that in processing of the EUREF-CS/H’91 campaign, which was performed in cooperation between BKG and RIGTC, no precise GPS orbits were available since it had been done in 1992 before a regular IGS operation started. Later, in 1993 the solution was slightly improved after the ideas by W. Gurtner and M. Rothacher by computing ad hoc “precise orbits” using several fiducial European permanent stations. This solution was validated by the EUREF TWG in 1994 as “class B”.

The Czech national user reference system (S-JTSK), which is one of the mandatory geodetic reference systems allowed in the Czech Republic and is used as a principal system for all legal mapping and surveying work, originates in 1927. Besides a wrong placing on the Bessel ellipsoid, wrong orientation and scale the realization of this system (first to fifth order national triangulation network) suffers from inhomogenities and many local deformations so that a large number of the triangulation points with ETRS89 coordinates regularly distributed over the entire territory is necessary to detect and rectify them. In 1992-1994, a sequence of campaigns was carried out to set up a national reference frame for the ETRS89 realization:

- CS-NULRAD (1992) – realization of the Zero-order network (6+13 stations) as a first densification of the frame set up by the EUREF-CS/H’91 campaign in the Czech and Slovak Federal Republic in 1991; processing done by RIGTC-GO Pecný using precise orbits kindly provided by Y. Bock of SIO.
- CS-BRD (1993) – the campaign to connect the GPS networks of the Czech Republic and Germany. Some of CS-NULRAD stations were re-observed, but finally the resulting accuracy of the re-processed coordinates was similar to that of the previous campaign; processing done by RIGTC-GO Pecný using precise IGS orbits.
- DOPNUL (1993-1994) – second order densification of the EUREF based reference frame on the territory of the Czech Republic stemming from the CS-NULRAD and CS-BRD campaigns and resulting in 176 stations (average distance of 25km) with both ETRS89 and S-JTSK coordinates; processing done by RIGTC-GO Pecný using IGS precise orbits.

The above mentioned campaigns represent a hierarchy of the sequential ETRS89 densification on the territory of the Czech Republic. The national CS-NULRAD and DOPNUL campaigns, which were based on the EUREF-CS/H'91 campaign, were not submitted to the EUREF TWG for validation. None of the stations is currently operated as a permanent GNSS station.

The active GNSS positioning system (CZEPOS), which was developed in the Czech Republic from 2004 to 2006, has been after an about one-year provisional operation fully operational since January 1, 2007. In 2008 and 2009, it was upgraded by implementation of the new stations, software tools and services. In April 2010, it consists of 54 permanent GPS/GNSS stations 27 of which are regularly distributed over the territory of the Czech Republic and the remaining 27 are located in the neighbour countries along the Czech border as a part of the national GNSS positioning systems of these countries. CZEPOS uses the data of these stations on the basis of bilateral agreements with their operators.

Because the realization of ETRS89 coordinates in the Czech Republic comes from the early GNSS era, i.e. before the International GNSS Service (IGS) was established, the ETRS89 coordinates of CZEPOS stations were preliminary estimated from the first permanent GPS observations.

A new realization of the reference frame based on the ETRS89 coordinates of permanent GNSS stations in the Czech Republic is described in this report. This represents the first step for a further large scale densification represented by ETRS89 coordinates of about 46 500 points in the Czech Republic with an average distance of 2 km.

2 Campaign configuration

The EUREF-Czech-2009 campaign consists of available permanent GPS stations on the territory of the Czech Republic (44) and EPN stations in other European countries (18). The latter were selected using the following criteria:

- EPN Class A stations with defined coordinates and velocities.
- Station with smooth coordinate time-series in the EPN cumulative solution.
- Fiducial stations within the EPN cumulative solution.
- Location in the close surrounding of the Czech Republic.
- In distance to all directions from the middle of the network (approximately 1000 km).

The remote stations were included to minimize possible biases on the fiducial stations and to support the estimation of absolute values of tropospheric parameters.

All Czech stations are plotted in Figure 1 and additionally introduced EPN stations in Figure 2. All stations instrumentation, monumentation and period of data are listed in Table 1. Only 8 from all the stations were processed for a period shorter than 3 years.

Table 1: Description of all stations included in the EUREF-Czech-2009 campaign.
Individual phase centre variation tables were used for stations with given antenna number.

Name Domes	Full Name	Receiver	Antenna/Radome	Monumentation	Period
CBRU	Bruntál	LEICA GRX1200PRO	LEIAT504 LEIS (#103051)	brick building + steel mast	2005-11-02 – 2008-12-31
CDAC	Dačice	LEICA GRX1200PRO	LEIAT504 LEIS (#102134)	brick building + steel mast	2005-02-08 – 2008-12-31
CDOM	Domažlice	LEICA GRX1200PRO	LEIAT504 LEIS (#102877)	concrete building + steel rod	2005-04-21 – 2008-12-31
CFRM 11525M001	Frýdek Místek	LEICA GRX1200PRO	LEIAT504 LEIS (#103035)	brick building + steel rod	2005-11-01 – 2008-12-31
CHOD	Hodonín	LEICA GRX1200PRO	LEIAT504 LEIS (#103048)	brick building + steel rod	2005-10-13 – 2008-12-31
CJIH	Jihlava	LEICA GRX1200PRO	LEIAT504 LEIS (#102553)	building + steel mast	2005-04-20 – 2008-12-31
CKAP	Kaplice	LEICA GRX1200PRO	LEIAT504 LEIS (#102935)	brick building + steel mast	2005-06-17 – 2008-12-31
CKRO	Kroměříž	LEICA GRX1200PRO	LEIAT504 LEIS (#103037)	building + steel mast	2005-11-01 – 2008-12-07
CKVA	Karlovy Vary	LEICA GRX1200PRO	LEIAT504 LEIS (#102882)	building + steel mast	2005-04-27 – 2008-12-31
CLIB 11526M001	Liberec	LEICA GRX1200PRO	LEIAT504 LEIS (#102943)	concrete building + steel mast	2005-06-25 – 2008-12-31
CLIT	Litoměřice	LEICA GRX1200PRO	LEIAT504 LEIS (#102926)	concrete building + steel mast	2005-04-22 – 2008-12-31
CMBO	Mladá Boleslav	LEICA GRX1200PRO	LEIAT504 LEIS (#102840)	building + steel mast	2005-06-03 – 2008-12-31
CMOK	Morav.Krumlov	LEICA GRX1200PRO	LEIAT504 LEIS (#103058)	building + steel rod	2005-11-06 – 2008-12-31
CPAR 11527M001	Pardubice	LEICA GRX1200PRO	LEIAT504 LEIS (#102546)	building + steel mast	2005-04-20 – 2008-12-31
CPRA	Prachatice	LEICA GRX1200PRO	LEIAT504 LEIS (#102835)	brick building + steel mast	2005-04-15 – 2008-12-31
CPRG	Praha	LEICA GRX1200GGPRO	LEIAT504GG LEIS (#200047)	concrete building + steel mast	2006-12-29 – 2008-12-31
CPRI	Příbram	LEICA GRX1200PRO	LEIAT504 LEIS (#102554)	building + steel mast	2005-02-18 – 2008-12-31
CRAK 11528M001	Rakovník	LEICA GRX1200PRO	LEIAT504 LEIS (#102833)	building + steel mast	2005-04-19 – 2008-12-31
CSUM	Šumperk	LEICA GRX1200PRO	LEIAT504 LEIS (#102941)	brick building + steel mast	2005-10-07 – 2008-12-31
CSVI	Svitavy	LEICA GRX1200PRO	LEIAT504 LEIS (#102549)	building + steel mast	2005-01-11 – 2008-12-31
CTAB 11529M001	Tábor	LEICA GRX1200PRO	LEIAT504 LEIS (#102133)	building + steel rod	2005-01-14 – 2008-12-31
CTRU	Trutnov	LEICA GRX1200PRO	LEIAT504 LEIS (#102937)	concrete building + steel mast	2005-06-25 – 2008-12-31
CVSE	Vsetín	LEICA GRX1200PRO	LEIAT504 LEIS (#103057)	building + steel mast	2005-11-01 – 2008-12-31
GOPE 11502M002	GO Pecný	ASHTECH Z18	ASH701946.3 SNOW	building, concrete mast	2005-01-01 – 2006-07-14
		ASHTECH Z18	TPSCR3_GGD CONE		2006-07-14 – 2008-12-31
TUBO 11503M001	TU Brno	TRIMBLE 4700	TRM29659.00 NONE	building, concrete mast	2005-01-01 – 2005-12-15
		LEICA GRX1200PRO	LEIAT504 LEIS (#102923)		2005-12-15 – 2008-12-31
VSBO 11521M001	VŠB-TU Ostrava	TPS GB-1000	TPSCR3_GGD CONE	concrete building	2005-01-01 – 2007-06-18
		TPS NETG3	TPSCR_G3 TPSH		2007-06-18 – 2008.12.31
PLZE 11523M001	ZČU Plzeň	TPS LEGACY	JPSREGANT_DD_E NONE	concrete building	2005-01-01 – 2005-11-18
		TPS LEGACY	JPSREGANT_E NONE		2005-11-18 – 2006-01-03
		TPS LEGACY	TPSCR3_GGD CONE		2006-01-03 – 2008-12-31
LYSH 11522M001	Lysá hora	TPS GB-1000	TPSCR3_GGD CONE	brick building, iron mast	2005-06-22 – 2008-10-15
KUNZ 11524M001	Kunžak	SEPT POLARX2	TRM41249.00 TZGD	concrete building, iron rod	2005-09-23 – 2008-12-31
POL1	Polom	TRIMBLE NETRS	TRM41249.00 TZGD	concrete mast	2006-11-26 – 2008-06-30
BISK 11520M0001	Biskupská Kupa	ASHTECH Z18	ASH701946.2 SNOW	concrete mast	2005-04-24 – 2008-12-31
BEZD	Bezděčín	TPS GB-1000	TPSCR3_GGD CONE	N/A	2007-01-01 – 2007-12-31
CHOT	Chotěboř	TPS GB-1000	TPSCR3_GGD CONE	N/A	2007-01-01 – 2007-12-31
MARJ 11517M001	Marjánská	ASHTECH Z18	ASH701946.2 SNOW	building, concrete chimney	2005-04-24 – 2008-12-31
POUS 11518M001	Poustka	ASHTECH Z18	ASH701946.2 SNOW	concrete building and mast	2005-10-16 – 2008-12-31
SLUK	Šluknov	TPS GB-1000	TPSCR3_GGD CONE	N/A	2007-01-01 – 2007-12-31
SNEC 11519M001	Sněžka	TPS GB-1000	ASH701946.2 SNOW	building, concrete chimney	2005-04-24 – 2006-03-16
		TPS GB-1000	TPSCR3_GGD CONE		2006-03-16 – 2008-09-20
TEME	Temelín	TPS GB-1000	TPSCR3_GGD CONE	N/A	2007-01-01 – 2007-12-31
VACO 11516M001	Vacov	ASHTECH Z18	ASH701946.2 SNOW	concrete building, mast	2005-04-24 – 2008-12-31

Continuation of Table 1

Name Domes	Full Name	Receiver	Antenna/Radome	Monumentation	Period
TPOD	Podivín	TPS GB-1000	TPSCR3_GGD CONE	N/A	2007-08-09 – 2008-06-30
TPRO	Prostějov	TPS GB-1000	TPSCR3_GGD CONE	N/A	2005-07-01 – 2007-10-24
			JPSLEGANT_E NONE	N/A	2007-10-24 – 2008-03-25
			TPSCR3_GGD CONE	N/A	2008-03-25 – 2008-06-30
TZDA	Ždár n.Sázavou	TPS GB-1000	TPSCR3_GGD CONE	N/A	2005-07-01 – 2008-06-30
TZLI	Zlín	TPS GB-1000	TPSCR3_GGD CONE	N/A	2006-01-01 – 2008-06-30
TZNO	Znojmo	TPS GB-1000	TPSCR3_GGD CONE	N/A	2007-08-09 – 2008-06-30
BOR1 12205M002	Borowiec	ROGUE SNR-8000	AOAD/M_T NONE	EPN compliant (all)	2005-01-01 – 2007-07-08
		TRIMBLE NETRS	AOAD/M_T NONE		2007-07-08 – 2008-12-31
BRUS 13101M004	Brussels	ASHTECH Z-XII3T	ASH701945B_M NONE		2005-01-01 – 2008-12-31
DRES 14108M001	Dresden	TRIMBLE 4000SSI	TRM29659.00 NONE		2005-01-01 – 2007-05-23
		JPS LEGACY	TPSCR3_GGD CONE		2007-05-23 – 2008-12-31
GLSV 12356M001	Kiev	TRIMBLE 4000SSI	TRM29659.00 NONE		2005-01-01 – 2007-11-13
		NOV OEMV3	NOV702GG NONE		2007-11-13 – 2008-12-31
GRAS 10002M006	Caussols	ASHTECH UZ-12	ASH701945E_M NONE		2005-01-01 – 2008-12-31
GRAZ 11001M002	Graz	TRIMBLE NETRS	ASH701945C_M NONE		2005-01-01 – 2005-03-22
		TRIMBLE NETRS	TRM29659.00 NONE		2005-03-22 – 2008-12-31
JOZE 12204M001	Jozefoslaw	TRIMBLE 4000SSE	TRM14532.00 NONE		2005-01-01 – 2008-12-31
LINZ 11033S001	Linz	TRIMBLE NETRS	TRM29659.00 UNAV		2005-09-01 – 2008-12-31
MATE12734M008	Matera	TRIMBLE 4000SSI	TRM29659.00 NONE		2005-01-01 – 2008-11-24
		LEICA GRX1200GGPRO	LEIAT504GG NONE		2008-11-24 – 2008-12-31
MOPI 11507M001	Modra Piesok	TRIMBLE 4000SSI	TRM14532.00 DOME		2005-01-01 – 2008-12-31
ONSA 10402M004	Onsala	JPS E_GGD	AOAD/M_B OSOD		2005-01-01 – 2008-12-31
PENC 11206M006	Penc	TRIMBLE 5700	TRM41249.00 NONE		2005-01-01 – 2007-07-12
		LEICA GRX1200GGPRO	LEIAT504GG LEIS		2007-07-12 – 2008-12-31
POTS 14106M003	Potsdam	AOA SNR-8000 ACT	AOAD/M_T NONE		2005-01-01 – 2008-12-31
RIGA 12302M002	Riga	AOA BENCHMARK ACT	AOAD/M_T NONE		2005-01-01 – 2006-05-20
		AOA or ROGUE SNR-8000	ASH700936D_M NONE		2006-05-20 – 2007-12-16
		LEICA GRX1200PRO	LEIAT504 LEIS		2007-12-16 – 2008-12-31
SOFI 11101M002	Sofia	TPS E_GGD	AOAD/M_T NONE		2005-01-01 – 2008-12-31
WROC12217M001	Wroclaw	ASHTECH Z18	ASH701941.1 SNOW		2005-01-01 – 2007-04-13
		LEICA GRX1200GGPRO	LEIAT504GG LEIS		2007-04-13 – 2008-12-31
WTZR 14201M001	Wettzell	AOA SNR-8000 ACT	AOAD/M_T NONE		2005-01-01 – 2005-05-04
		TPS E_GGD,	AOAD/M_T NONE		2005-05-04 – 2007-05-29
		TPS NETG3	AOAD/M_T NONE		2007-05-29 – 2008-12-31
		LEICA GRX1200GGPRO	AOAD/M_T NONE		2007-05-29 – 2008-12-31
ZIMM 14001M004	Zimmerwald	TRIMBLE 4700	TRM29659.00 NONE		2005-01-01 – 2006-02-22
		TRIMBLE NETRS	TRM29659.00 NONE		2006-02-02 – 2008-12-31

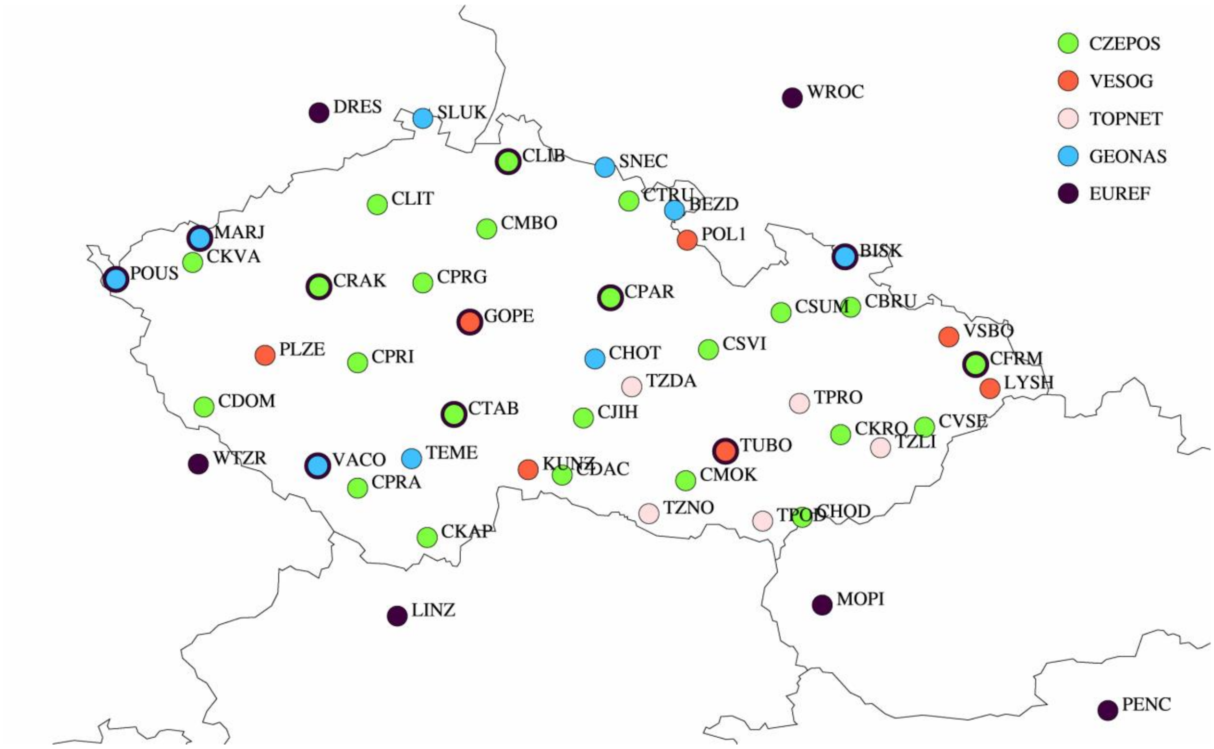

Figure 1: Stations of the EUREF-Czech-2010 campaign on the territory of the Czech Republic

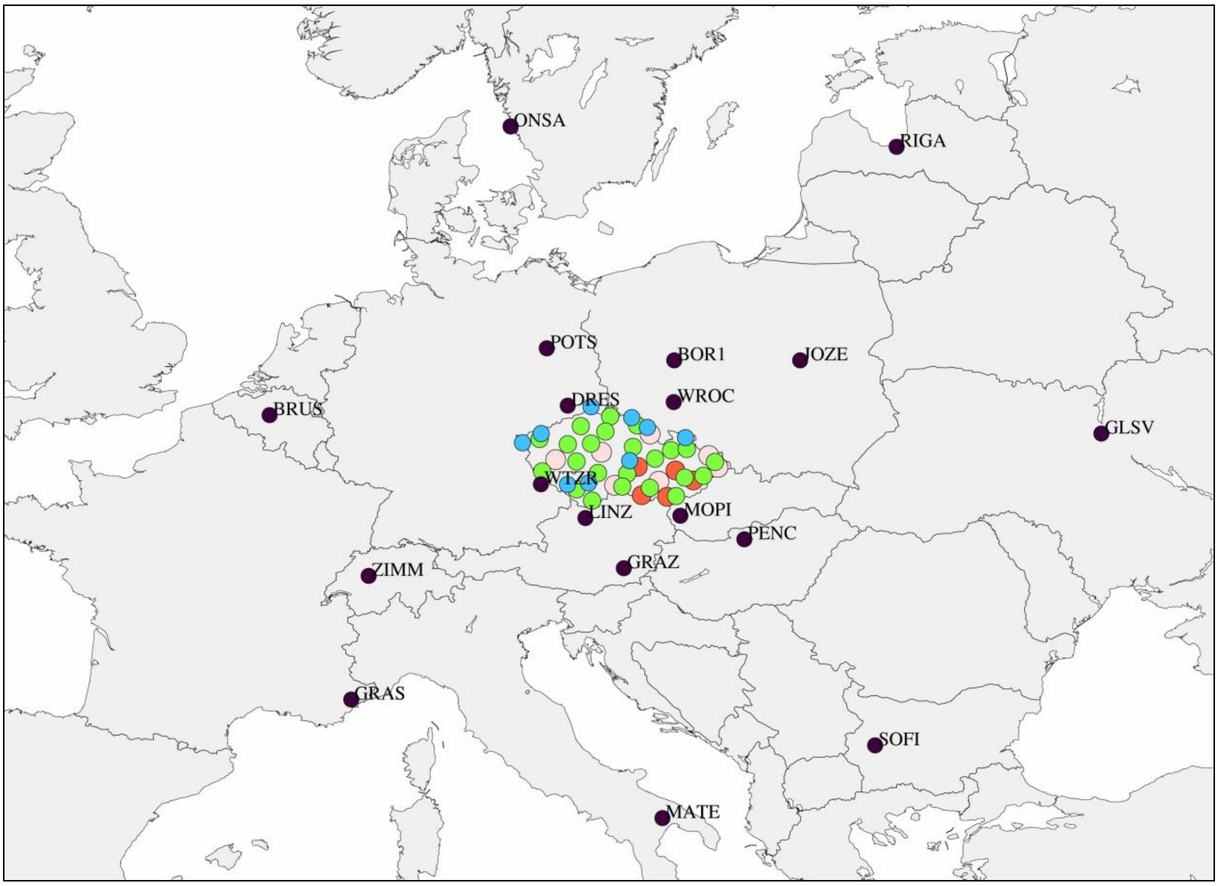

Figure 2: EPN stations outside the Czech Republic (black) included in EUREF-Czech-2010 campaign

The station Sněžka (SNEC) is very well known for its problems during winter periods. The station is located on the top of the highest mountain in the Czech Republic which is well known for extremely severe weather conditions so that from early autumn till late spring its radome is usually covered with snow or, in worst case, even with a few centimetres of ice crust. The effects reached even more than decimetre in horizontal position, see e.g. EUREF CB web page coordinate time-series. For this reason, only data from snow-free periods (June-September, 2005-2009) were included in the daily processing. In 2009, the monumentation (an old building) was destroyed and the station was moved to another pillar. The reason why SNEC had to be included in the campaign was that the baselines using data from this station were observed and calculated in the past and will be probably necessary for selected local densifications.

Similar problems during winter periods can be seen in daily coordinate time-series of two other stations located at the top of high mountains in the region of Moravia – Lysá hora (LYSH) and Biskupská kupa (BISK). Nevertheless, the problems were significantly smaller and the data of winter periods were not excluded in daily processing, but only in the final combination if outliers were detected.

3 Daily processing

The processing was carried out using the Bernese GPS software V5.0 [Dach et al. 2007]. The strategy was based on the system developed at Geodetic Observatory Pecný (GOP) for the EUREF Permanent Network analysis.

Only GPS data were used in the campaign, because only a few stations in the Czech Republic provide GPS+GLONASS observations and these are mostly equipped with problematic ASHTECH Z-18 receivers.

The main steps of the daily processing consist in:

- Data and product conversion and a priori coordinates and input files preparation
- Single point positioning based on pseudo-range observations (receiver clock synchronization)
- Baseline definition using OBS-MAX strategy in clusters and baselines connecting the clusters
- Triple-difference solution applied for data cleaning, cycle slip detection and ambiguity setting
- Ambiguity-float solution for post-fit residual screening and outlier rejection
- Iterative ambiguity-float solution for the selection of fiducial stations (datum definition)
- Integer ambiguity resolution based on the QIF strategy
- Ambiguity-fixed daily solution applying no-net translation (NNT) based on selected fiducial stations

3.1 Processing clusters

To complete data processing of 4 years within a few days a highly optimized processing scheme was prepared. This was achieved by splitting the network into clusters of a suitable size for parallel processing. Small clusters (4-8 stations) were designed for the ambiguity resolution and outlier rejection while large clusters (approximately 20 stations) usually for all others steps. Each processing step running in parallel ended with a combination, checking or summary extraction procedure.

3.2 A priori coordinates

A priori coordinates used in daily processing were prepared by merging the coordinates from three sources applied in a given order with an identification flag:

- Last IGS (or ITRF) realizations converted to the epoch of processed day using velocities consistent with coordinates
- Preliminary coordinates available from any previous solution (no velocities applied)
- Coordinates available in RINEX files (no velocities applied)

The coordinates were expressed in the epoch of processed day according to their velocities if available.

3.3 Orbits and Earth Rotation Parameters

Final IGS orbits and ERPs were fixed in the daily processing. The IGS final product is based on relative models of satellite and receiver antenna phase centre variations (PCV) before GPS week 1400 and on absolute PCV models starting with GPS week 1400. The absolute models were used in the campaign processing over the whole data span whereas the most important was to apply a consistent model for both satellite and receiver antennas.

The satellites with zero accuracy codes (a few cases only) were a priori excluded from the processing. Nevertheless, our procedure independently checks residuals in order to identify any problematic satellite orbits.

3.4 Other external products and models

Applied models were consistent with the IERS 2003 conventions. Table 2 summarises the models and their sources.

Table 2: External products and models used in the campaign

Product/model	Source
IGS final orbits and ERPs	ftp://cddis.gsfc.nasa.gov/gps/products/www/igswwwd.sp3.Z ftp://cddis.gsfc.nasa.gov/gps/products/www/igswww7.erp.Z
Ionospheric model	ftp://ftp.unibe.ch/aiub/CODE/yyyy/CODwwwwd.ION.Z
Antenna PCV	ftp://ftp.epncb.oma.be/pub/general/epn_05.atx http://czepos.cuzk.cz/_paramAnten.aspx
Ocean tide loading	http://www.oso.chalmers.se/~loading/ (model FES2004, no CMC corrections)
IGS05/ITRF2005	ftp://itrf.ensg.ign.fr/pub/itrf/itrf2005/ITRF2005.SNX.gz ftp://igscb.jpl.nasa.gov/pub/station/coord/IGS05.snx
EPN cumulative solution	ftp://epncb.oma.be/epncb/station/coord/EPN/EPN_A_ITRF2005.SSC (EPN_A_ITRF2005_C1570)

3.5 Observation sampling, weighting and elevation cut-off angle

The 3 degree elevation cut-off angle was applied in all steps of the processing, but 10 degrees in the step for integer ambiguity resolution. By including low-elevation angle observations the estimation of horizontal troposphere gradients was supported (see Troposphere modelling). Observations with 30 sec sampling interval and the elevation dependent weighting function were used in pre-processing and 180 sec in final processing.

3.6 Ionosphere modelling

Wherever possible the first-order effect of the ionosphere was eliminated using ionosphere-free linear combination (single point positioning based on code observations, pre-processing for the cycle slip detection and outlier rejection and final modelling of the GPS observations for normal equation generation). The second- and third-order effects were neglected in the processing.

While the estimation of the ionosphere model is also a part of our routine system, in this campaign the final CODE model was introduced to support the ambiguity resolution (see Ambiguity resolution).

3.7 Troposphere modelling

In pre-processing steps the troposphere effects were modelled with site-specific station parameters applying a simple tropospheric model and mapping function.

In all steps requiring the highest accuracy of observation modelling, the following parameterization was applied (gradients were estimated only in the ambiguity-fixed solution):

- A priori model by Saastamoinen (1972), standard atmosphere and Niell dry mapping function (Niell, 1996). Loose constraints (5m) were applied for a priori values.
- Corrections estimated for each station and 60-min interval applying Niell wet mapping function (Niell, 1996). Loose relative constraints (1 m) were applied to subsequent values.
- Tropospheric horizontal gradients estimated for each station and 24-hour interval.

The troposphere parameters were pre-eliminated before saving daily normal equations. Thus, their connection at daily boundaries was not possible in the final combination. Whereas the effect on coordinate estimates in long-term combination is negligible, this approach significantly reduces requirements for the disk space and combination time.

3.8 Data cleaning and outlier rejection

Detection of cycle-slips, removal of incomplete data and setting new ambiguities were done in several clusters using a triple-difference solution. Ambiguity-float solution was then used for post-fit residual screening and outlier detection. A problematic station or satellite could be detected during this step, followed by removal of all relevant data and jump back to the step of baseline definition. The last feature was practically not used in this processing campaign.

3.9 Datum definition

After data cleaning and outlier rejection, the daily combination of ambiguity-float solution was used for fiducial station selection. Stations used as fiducials in the IGS05 reference frame (BOR1, BRUS, GLSV, GRAS, JOZE, MATE, ONSA, POTS, WTZR, ZIMM) were used to define an initial set, while the selection procedure was based on a minimum constrained solution (NNT), which was repeated until the set of fiducial stations provided sufficiently small residuals. Only in a few cases in the whole period an additional iteration was used. The RMS of residuals for the fiducial stations were 2.4, 4.4 and 5.0 mm on average for North, East and Up, respectively. The RMS time-series are plotted in Figure 3.

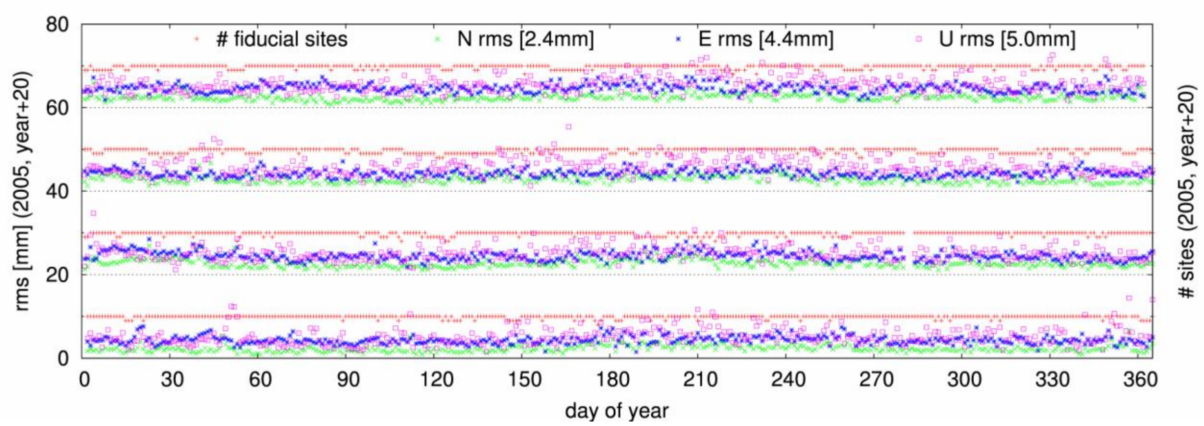

Figure 3: Datum definition realized within daily solutions during 4 years (years shifted) applying no-net translation: total number of fiducial stations and North, East and Up RMS errors from Helmert residuals.

3.10 Ambiguity fixing

The length of all baselines in the network was below 2000 km so that the QIF ambiguity resolution strategy (Mervart, 1996) could be generally applied. The ionospheric model was ready to be estimated within the campaign processing scheme, but finally this was not applied in order to minimize the time for a single day processing. The ionospheric product from the Centre of Orbit Determination in Europe (CODE) was introduced instead, which slightly increased the rate of fixed ambiguities by about 2-3% with respect to the estimated model.

Apart from a priori ionosphere model, stochastic ionospheric parameters were estimated during the ambiguity fixing. The tropospheric parameters and a priori coordinates from daily ambiguity-float solution were introduced from the last iteration of the datum definition. The coordinates of one station were constrained for each cluster during the ambiguity resolution.

On average 84% ambiguities were fixed. Figure 4 shows seasonal variation of the total number of fixed ambiguities per each day over the whole period.

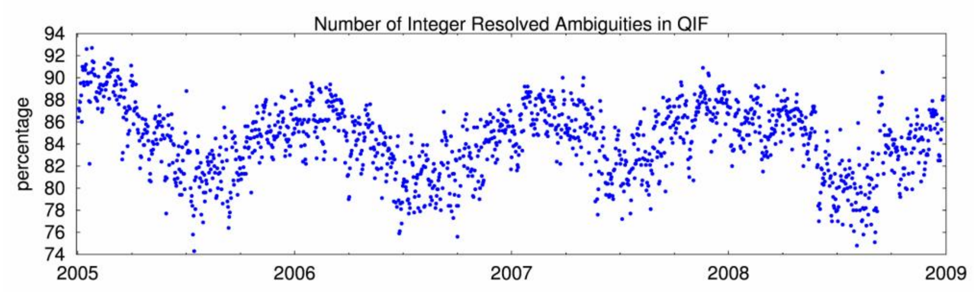

Figure 4: Percentage of integer ambiguities using QIF strategy

3.11 Daily solutions

The final solution of daily processing consists of two steps:

- Correct correlation and modelling in 3-4 clusters (approx. 20 stations) with saving normal equations for each cluster
- Daily normal equation combination into a network solution (neglecting correlations across different clusters) and saving daily network normal equations

These normal equations from the network solution were input in the final 4-year combination. Nevertheless, thanks to well defined datum in daily solutions, we could directly plot daily coordinate differences with respect to simple mean values and immediately identify significant jumps and problems with daily solutions. Typical examples are given in Figure 5. Most of the coordinate differences are within ±1 cm with a standard deviation below 5 mm (including effects such as daily datum realization, antenna changes etc). All time-series are available at http://www.pecny.cz/EUREF-Czech-2009/DAILY-TIMESERIES.

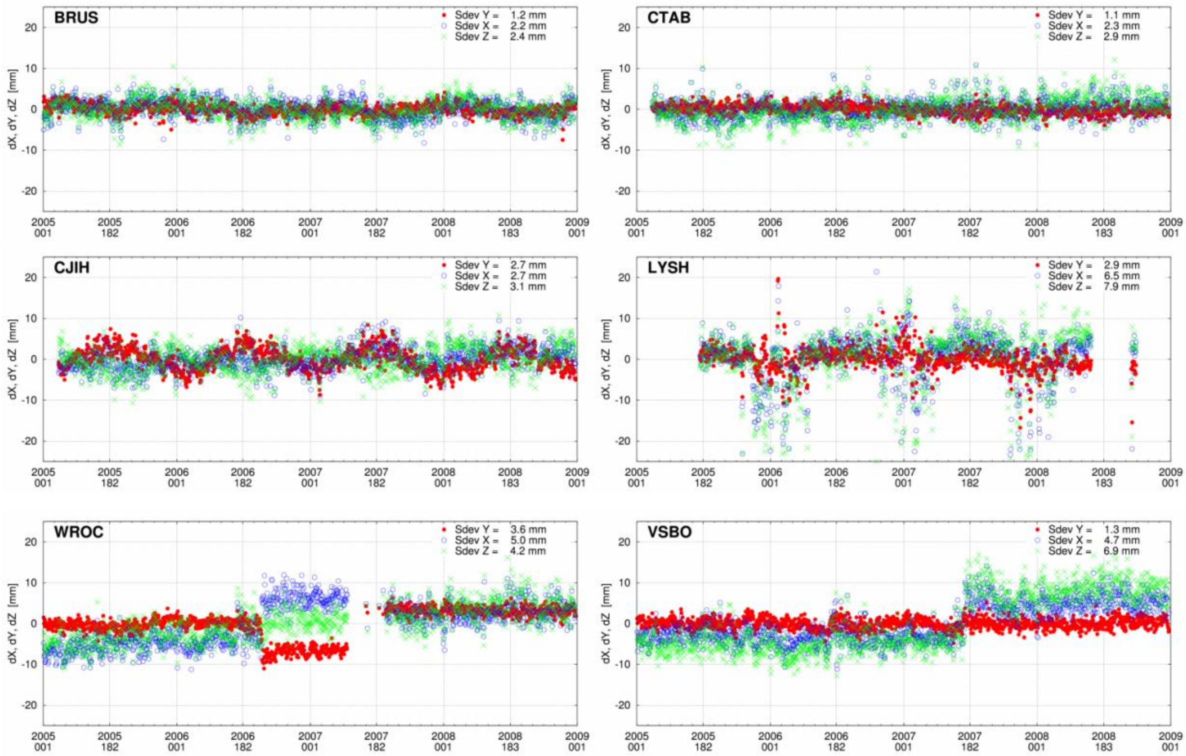

Figure 5: Coordinate differences (X, Y, Z) with respect to mean values based on daily solutions. On the top two examples of clean time-series are given: fiducial station (BRUS) and CZEPOS station (CTAB). In the middle two examples of problematic stations are given: seasonal signal (CJIH) and problems with snow (LYSH). At the bottom two examples of antenna replacements are given: WROC, VSBO.

4 Final combination

The Bernese ADDNEQ2 program was used for the final combination based on stacking daily normal equations (NEQ). Although the network spread over a stable part of Europe, coordinates and velocities were introduced as unknown parameters for this campaign covering the period of 4 years.

The combination step consists in the identification of outliers and jumps, selection of fiducial stations and in setting pre-defined intervals for coordinate and velocity estimation. More different combination variants have been computed in order to achieve the best results.

Because we introduced 24 EPN stations of Class A (6 in the Czech Republic and 18 external) in daily solutions, we didn't need to combine NEQs with EPN weekly solutions. This was confirmed by a stable realization of the IGS05 reference frame on a daily basis, which was visualized in the preliminary time-series of coordinate differences with respect to a simple mean from independent days (Figure 5).

4.1 Fiducial stations

Sufficient number of EPN Class A station candidates was available for the campaign and the selection of the most reliable set resulted in these different variants (full station lists are given in Table 6):

A) 11 EPN (Class A) stations used as fiducial in the EPN cumulative solution
B) 10 IGS/EUREF (Class A) stations used in IGS05 realization (applied in daily solutions)
C) All EPN (Class A) stations with GOPE excluded before GPS week 1400 (24 stations)
D) All EPN (Class A) stations with excluded intervals with larger residuals (23 stations)

4.2 Reference coordinates and velocities

The coordinates and velocities from the EPN cumulative solution *EPN_A_ITRF2005_C1570* were used as a reference for all fiducial stations. During the campaign period, several sets of coordinates were published for most of the stations included in the campaign. These are usually related to the change of antenna or receiver. However, there are many coordinate changes at GPS week 1400, which are related to the changes in the EPN processing strategy – the most important was a switch from the relative to absolute phase centre model. For many stations, this caused a station-specific change in coordinates at a level of millimetres for horizontal position and centimetres in height.

The campaign covered the period both before and after GPS week 1400, while the absolute phase centre variation model was applied for the whole campaign processing period. Since the coordinates in the EPN cumulative solution before GPS week 1400 are based only on the processing that use relative phase centre variation model, we clearly identified jumps in our preliminary coordinates induced by this model change. These artificial jumps were eliminated in our campaign by omitting those sets of EPN coordinates with a time span limited only to a period before GPS week 1400. Instead, the coordinates starting at GPS week 1400 were used also for such station for the period without any instrumentation change. A consistency of the coordinates was thus guaranteed as long as possible also before GPS week 1400 and reference coordinates from the old model were used only in a few short periods at the beginning for these stations – DRES, GOPE, PENC, RIGA, TUBO and

WROC, see Table 1. The summary of all reference coordinates for EPN stations is given in Table 3.

A priori coordinates of all non-EUREF campaign stations could be set up at a decimetre level. Since the campaign covered 4-year period and the processing has been done in a global reference frame, velocities should be estimated as well. For a few stations we tightly constrained these velocities to their a priori values (because of short-time observed period), therefore we set their a priori velocities consistently with the rotation of ETRF2000 with respect to ITRF2005.

Table 3: Reference ITRF coordinates and velocities for all fiducial stations at epoch 2005.00

Station	X [m] and VX [mm/year]	Y [m] and VY [mm/year]	Z [m] and VZ [mm/year]
BISK 11520M001	3898945.9400 -0.0155	1223993.3600 +0.0162	4881826.4440 +0.0102
BOR1 12205M002	3738358.4570 -0.0165	1148173.7100 +0.0154	5021815.7750 +0.0095
BOR1 12205M002B	3738358.4570 -0.0165	1148173.7100 +0.0154	5021815.7740 +0.0095
BRUS 13101M004	4027893.7510 -0.0126	307045.8250 +0.0161	4919475.1220 +0.0112
BRUS 13101M004B	4027893.7510 -0.0126	307045.8250 +0.0161	4919475.1220 +0.0112
DRES 14108M001	3904724.7030 -0.0152	954013.3890 +0.0161	4935789.9920 +0.0108
DRES 14108M001B	3904724.7020 -0.0152	954013.3910 +0.0161	4935789.9940 +0.0108
DRES 14108M001C	3904724.7020 -0.0152	954013.3910 +0.0161	4935789.9940 +0.0108
DRES 14108M001D	3904724.7040 -0.0152	954013.3920 +0.0161	4935789.9930 +0.0108
GLSV 12356M001	3512888.9570 -0.0190	2068979.8800 +0.0141	4888903.2120 +0.0091
GLSV 12356M001B	3512888.9570 -0.0190	2068979.8800 +0.0141	4888903.2120 +0.0091
GLSV 12356M001C	3512888.9540 -0.0190	2068979.8830 +0.0141	4888903.2000 +0.0091
GOPE 11502M002	3979316.1270 -0.0158	1050312.4780 +0.0165	4857067.0950 +0.0104
GOPE 11502M002B	3979316.1240 -0.0158	1050312.4760 +0.0165	4857067.0910 +0.0104
GOPE 11502M002C	3979316.1340 -0.0158	1050312.4780 +0.0165	4857067.1080 +0.0104
GRAS 10002M006	4581690.9040 -0.0131	556114.8360 +0.0186	4389360.7960 +0.0119
GRAS 10002M006B	4581690.9040 -0.0131	556114.8360 +0.0186	4389360.7960 +0.0119
GRAZ 11001M002	4194423.8230 -0.0167	1162702.6910 +0.0176	4647245.4120 +0.0108
GRAZ 11001M002B	4194423.8260 -0.0167	1162702.6990 +0.0176	4647245.4130 +0.0108
GRAZ 11001M002C	4194423.8230 -0.0167	1162702.6970 +0.0176	4647245.4160 +0.0108
GRAZ 11001M002D	4194423.8230 -0.0167	1162702.6970 +0.0176	4647245.4160 +0.0108
JOZE 12204M001	3664940.1670 -0.0173	1409153.8650 +0.0153	5009571.3890 +0.0098
JOZE 12204M001B	3664940.1670 -0.0173	1409153.8650 +0.0153	5009571.3890 +0.0098
LINZ 11033S001	4118898.6610 -0.0151	1048597.3580 +0.0173	4740105.9100 +0.0109
LINZ 11033S001B	4118898.6610 -0.0151	1048597.3580 +0.0173	4740105.9100 +0.0109
MARJ 11517M001	3975132.6960 -0.0143	909950.5410 +0.0166	4888908.1490 +0.0111
MARJ 11517M001B	3975132.6960 -0.0143	909950.5410 +0.0166	4888908.1490 +0.0111
MATE 12734M008	4641949.5550 -0.0176	1393045.4290 +0.0189	4133287.4610 +0.0155
MATE 12734M008B	4641949.5550 -0.0176	1393045.4290 +0.0189	4133287.4610 +0.0155
MATE 12734M008C	4641949.5540 -0.0176	1393045.4250 +0.0189	4133287.4610 +0.0155
MOPI 11507M001	4053737.8870 -0.0156	1260571.6050 +0.0171	4744940.8650 +0.0120
MOPI 11507M001B	4053737.8870 -0.0156	1260571.6050 +0.0171	4744940.8650 +0.0120
ONSA 10402M004	3370658.5460 -0.0128	711877.5460 +0.0144	5349786.9550 +0.0121
ONSA 10402M004B	3370658.5460 -0.0128	711877.5460 +0.0144	5349786.9550 +0.0121
PENC 11206M006	4052449.4720 -0.0176	1417681.1250 +0.0171	4701407.1020 +0.0099
PENC 11206M006B	4052449.4720 -0.0176	1417681.1250 +0.0171	4701407.1070 +0.0099
PENC 11206M006C	4052449.4790 -0.0176	1417681.1250 +0.0171	4701407.1140 +0.0099
POTS 14106M003	3800689.6400 -0.0153	882077.3870 +0.0157	5028791.3220 +0.0100
POTS 14106M003B	3800689.6340 -0.0153	882077.3840 +0.0157	5028791.3180 +0.0100
POUS 11518M001	4002424.6870 -0.0136	872513.0350 +0.0164	4873111.7900 +0.0106
RIGA 12302M002	3183899.1980 -0.0166	1421478.4970 +0.0142	5322810.8010 +0.0100
RIGA 12302M002B	3183899.1990 -0.0166	1421478.4920 +0.0142	5322810.7990 +0.0100
RIGA 12302M002C	3183899.1970 -0.0166	1421478.4920 +0.0142	5322810.8010 +0.0100
SOFI 11101M002	4319372.0910 -0.0167	1868687.7830 +0.0187	4292063.9360 +0.0091
TUBO 11503M001	4001470.2910 -0.0164	1192345.5360 +0.0165	4805795.5310 +0.0103
TUBO 11503M001B	4001470.2820 -0.0164	1192345.5330 +0.0165	4805795.5210 +0.0103
TUBO 11503M001C	4001470.2930 -0.0164	1192345.5320 +0.0165	4805795.5290 +0.0103
TUBO 11503M001D	4001470.2930 -0.0164	1192345.5320 +0.0165	4805795.5290 +0.0103
VACO 11516M001	4062325.8520 -0.0165	992104.6652 +0.0166	4800911.2820 +0.0086
VACO 11516M001B	4062325.8520 -0.0165	992104.6652 +0.0166	4800911.2820 +0.0086
WROC 12217M001	3835751.2980 -0.0157	1177249.9570 +0.0155	4941605.2420 +0.0106
WROC 12217M001B	3835751.3080 -0.0157	1177249.9510 +0.0155	4941605.2460 +0.0106
WROC 12217M001C	3835751.3110 -0.0157	1177249.9530 +0.0155	4941605.2490 +0.0106
WROC 12217M001D	3835751.3080 -0.0157	1177249.9640 +0.0155	4941605.2510 +0.0106
WTZR 14201M010	4075580.5580 -0.0156	931853.7990 +0.0168	4941605.1390 +0.0104
WTZR 14201M010B	4075580.5580 -0.0156	931853.7990 +0.0168	4941605.1390 +0.0104
ZIMM 14001M004	4331297.0650 -0.0131	567555.8810 +0.0179	4801568.9340 +0.0124
ZIMM 14001M004B	4331297.0650 -0.0131	567555.8810 +0.0179	4801568.9340 +0.0124

4.3 Outlier rejection

The final combination was done in an iterative way in order to eliminate outliers. The following criteria were used for the outlier detection:

- 8, 8 and 25 mm in North, East and Up for all EPN sites
- 15, 15 and 40 mm in North, East and Up for all other stations

The number of excluded days in final combination due to these criteria was 182 and 62 on fiducial and other stations, respectively.

Table 4 summarizes several other periods of data excluding due to a significant effect on estimated coordinates and for which in many cases the reason was well known, such as receiver problems, antenna covered by snow or ice etc. The total amount of all eliminated data was less than 0.5% when winter periods from SNEC and LYSH were not accounted for.

Table 4: Periods of manually data exclusion because of a priori known problems

Site	From	To	Length (days)	Problem
JOZE	2005 12 01	2006 02 28	424	systematic outliers
BISK	2005 11 20	2006 03 10	110	winter outliers
BISK	2007 12 12	2007 12 23	12	series of Up outliers
LYSH	2005 10 15	2005 10 25	11	winter 2005/6, part 1
LYSH	2005 11 01	2006 04 15	165	winter 2005/6, part 2
LYSH	2006 10 15	2007 03 20	156	winter 2006/7
LYSH	2007 10 10	2008 02 20	133	winter 2007/8
SNEC	Oct-	-May	~ 60%	all winter periods excluded in daily solutions
KUNZ	2006 01 01	2006 03 07	66	winter 2005/6

4.4 Coordinate and velocity estimation

The coordinates of all stations were estimated in pre-defined intervals according to the jumps identified from residual time-series. Sets of fiducial stations were used for the datum definition using the minimum constrained solution (no-net translation).

The velocities were estimated only for all non-EUREF stations observed over 3 years. Since a priori velocities for such stations originated from a common ETRF2000 trend, we estimated corrections only and whenever more intervals for station coordinates were pre-defined, these corrections were estimated uniquely over the whole interval (there was no reason for splitting velocities during the campaign period).

In variants A, B and C, we have estimated only horizontal velocities in all variants, while vertical velocities were tightly constrained to their a priori values. In variant D, vertical velocities were also estimated for all stations observed over more than 3 years.

The reference velocities of all EPN stations were always tightly constrained since we assumed that they could not be estimated with a higher quality than in the EPN cumulative solution.

5 Campaign results

3D Helmert transformation (translation estimates) was performed for all the combination variants in order to assess the closeness of resulting coordinates to the ETRS89 realization (EPN cumulative product). The estimated translations for each variant using all class 'A' stations are within 1.3 mm in East, North and Up component, see Table 5. This result proved that any selection of ten or more fiducial stations in the campaign is reliable for the realization of the ETRS89 reference system at a millimetre level.

Table 5: Translations and RMS errors from Helmert transformations with respect to the EPN cumulative solution

Variant	Translations [mm] (all "Class A" sites)			Translations [mm] (selected fiducal sites only)			RMS [mm] of Helmert transformation (selected fiducal sites only)			
	North	East	Up	North	East	Up	North	East	Up	Total
A	0.0	-0.9	-0.5	+0.1	-0.1	-0.0	1.0	0.8	3.5	2.1
B	0.0	-0.9	-0.6	+0.1	-0.1	0.0	1.0	0.8	3.6	2.2
C	+0.3	-0.1	-0.9	+0.1	-0.1	-0.1	1.1	2.1	3.2	2.3
D	+0.4	-0.4	-1.3	+0.1	-0.1	-0.0	1.1	1.2	2.5	1.7

The table further shows fulfilled NNT conditions and RMS from coordinate residuals of applied fiducial stations. The solution 'D' shows clearly a superior performance while total RMS of Helmert transformation decreased to 1.7 mm. The solution 'D' was selected as final also because it includes as many as fiducial stations and excluding only three stations (MATE, and partly GOPE, WROC) with residuals larger than 6 mm in any component. Besides the station selection, Table 6 summarizes residuals from the final solution D and Figure 6 plots their geographical distribution.

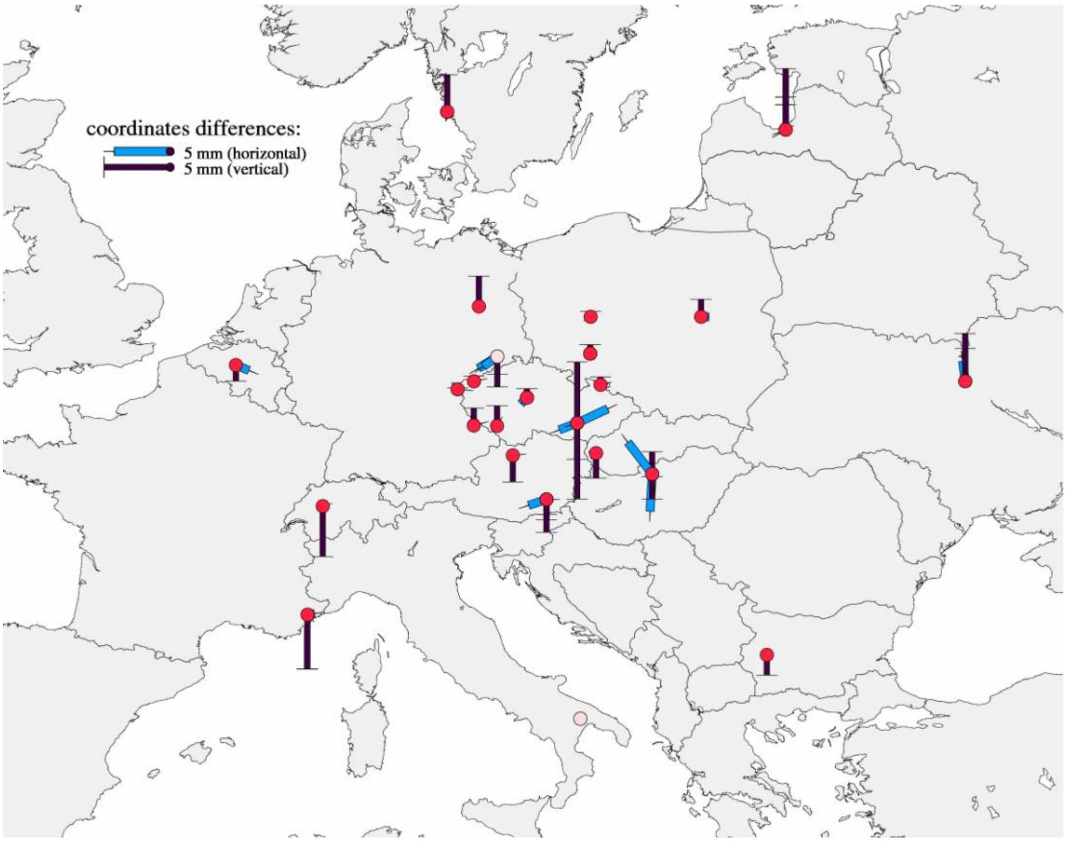

Figure 6: Coordinate residuals at fiducial EPN stations (red) for D variant (non-fiducial EPN stations are plotted with pink).

Table 6 Selection of fiducial stations for different variants. Residuals from Helmert transformation between final variant D and EPN cumulative solution. Stations with flag M were only compared in the transformation.

Station	Fiducal set				D – final solution			
	A	B	C	D	North [mm]	East [mm]	Up [mm]	Flag
BISK 11520M001			✓	✓	0.2	0.8	0.6	
BOR1 12205M002B	✓	✓	✓	✓	-0.3	-0.5	0.4	
BRUS 13101M004B	✓	✓	✓	✓	-0.7	1.7	-1.2	
DRES 14108M001			✓	✓	-1.3	-2.1	-2.3	
DRES 14108M001C			✓	✓	-1.2	-1.7	-1.3	
DRES 14108M001D			✓		2.2	0.0	6.7	M
GLSV 12356M001B	✓	✓	✓	✓	2.3	-0.3	2.5	
GLSV 12356M001C	✓	✓	✓	✓	1.2	0.0	3.6	
GOPE 11502M002					3.2	-1.4	-17.2	M
GOPE 11502M002B					2.7	-1.1	-20.3	M
GOPE 11502M002C			✓	✓	0.1	0.1	0.7	
GRAS 10002M006B	✓	✓	✓	✓	0.2	1.3	-4.1	
GRAZ 11001M002			✓	✓	0.3	0.1	-1.1	
GRAZ 11001M002B			✓	✓	-0.7	-2.1	-2.5	
GRAZ 11001M002D			✓	✓	0.0	1.0	-1.5	
JOZE 12204M001B	✓	✓	✓	✓	0.0	-0.2	1.3	
LINZ 11033S001B			✓	✓	0.1	1.0	-2.0	
MARJ 11517M001B			✓	✓	0.2	1.0	0.4	
MATE 12734M008B	✓	✓	✓		2.4	0.8	-6.5	M
MATE 12734M008C	✓	✓	✓		0.4	1.5	-7.1	M
MOPI 11507M001B			✓	✓	0.1	0.3	-1.9	
ONSA 10402M004B	✓	✓	✓	✓	-0.7	-0.1	2.8	
PENC 11206M006			✓	✓	-3.6	-0.2	-0.2	
PENC 11206M006B			✓	✓	0.2	0.4	1.7	
PENC 11206M006C			✓	✓	3.0	-2.3	-1.9	
POTS 14106M003	✓	✓	✓	✓	-0.3	0.3	2.3	
POUS 11518M001			✓	✓	-0.1	1.2	0.1	
RIGA 12302M002			✓	✓	-0.4	-1.0	1.9	
RIGA 12302M002B			✓	✓	-0.6	-1.0	2.5	
RIGA 12302M002C			✓	✓	0.3	-0.6	4.6	
SOFI 11101M002	✓		✓	✓	0.4	0.3	-1.5	
TUBO 11503M001			✓	✓	-0.8	-2.1	-2.7	
TUBO 11503M001B			✓	✓	1.4	3.0	-5.7	
TUBO 11503M001D			✓	✓	-0.3	-1.0	4.6	
VACO 11516M001B			✓	✓	0.7	0.4	1.5	
WROC 12217M001			✓		0.3	-0.5	-6.3	M
WROC 12217M001C					-0.8	-10.9	-0.9	M
WROC 12217M001D			✓	✓	-0.2	-0.4	0.7	
WTZR 14201M010B	✓	✓	✓	✓	0.3	1.1	1.3	
ZIMM 14001M004B	✓	✓	✓	✓	0.2	0.7	-3.8	
RMS / comp.				✓	**1.1**	**1.2**	**2.5**	
Translations				✓	**0.1**	**-0.1**	**0.0**	

Estimated coordinates and velocities in ITRF2005 and ETRF2000 reference frames are summarized in Appendix. Figure 7 visualizes velocity corrections from the final solution (D) with respect to a priori velocities. Velocity differences are very small (bellow 1mm/year) for all stations, but for SNEC and CPRA.

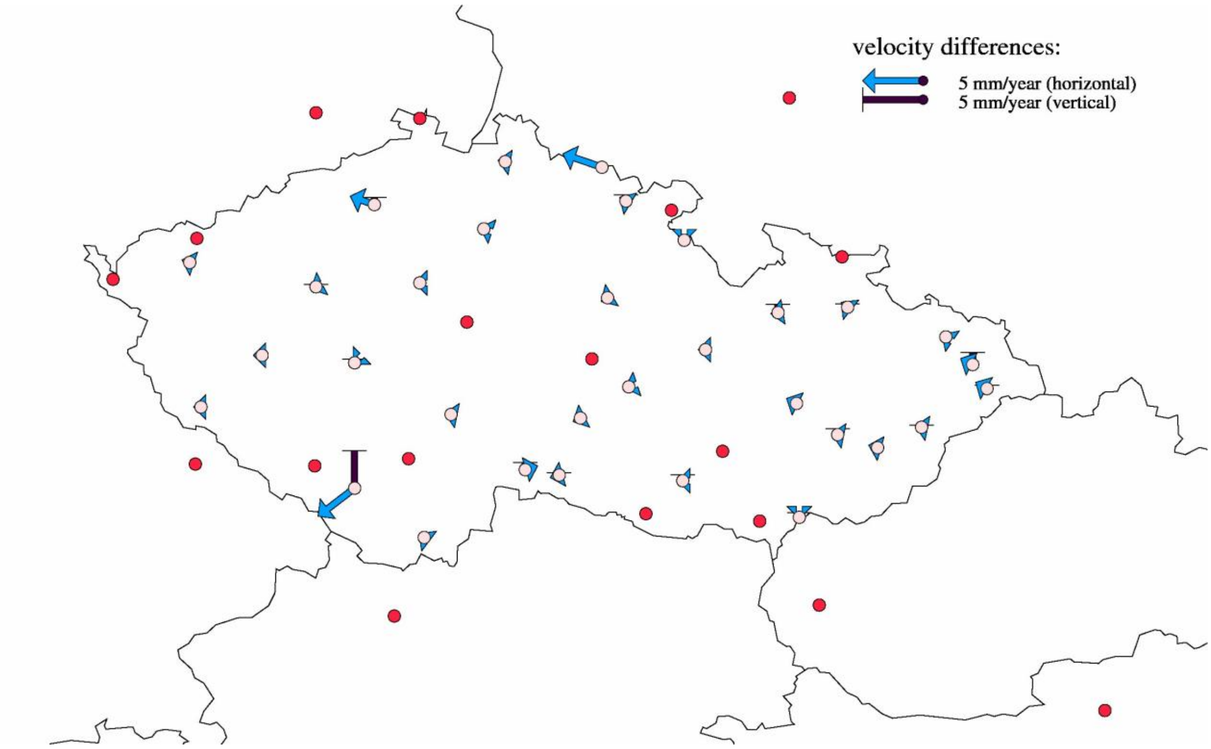

Figure 7: Estimated corrections (variant D) for non-EUREF stations (pink points) to the common ETRF2000 velocity field. For all EPN stations (red points) velocities were constrained to the EPN cumulative solution.

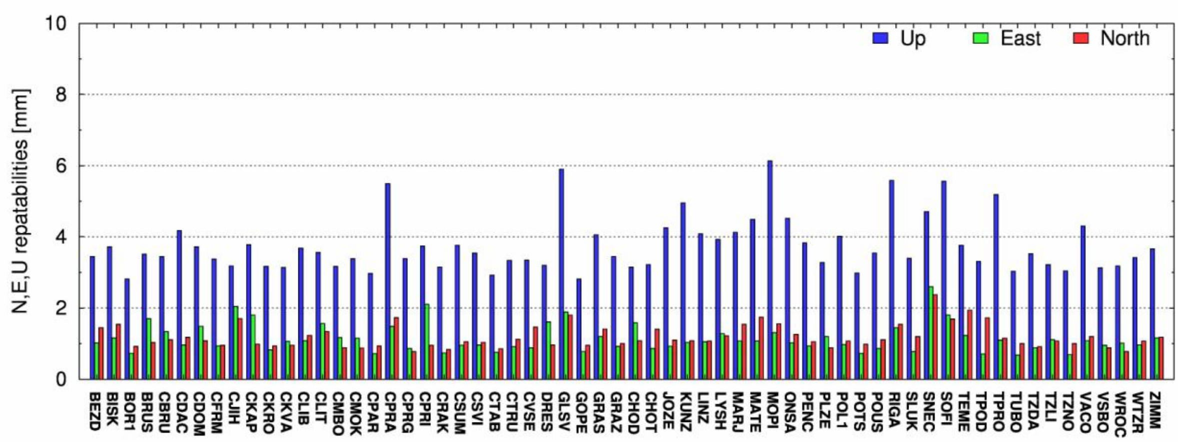

Figure 8: North, East and Up repeatabilities for all stations from the final combination (D variant).

Repeatabilities for all stations were calculated for each variant, but they do not differ significantly – 2mm in horizontal component (only SNEC slightly more) and usually 4 mm in vertical (with a few stations up to 6 mm). Figure 8 shows repeatabilities for final solution (D).

The examples of coordinate time-series from the final combination are given in Figure 9 for three stations – one fiducial (POTS) and two CZEPOS stations (CPAR, CJIH). While CPAR is an example of an excellent performance, CJIH suffers from a seasonal effect probably due to steel mast monumentation. A similar but smaller effect was detected at some other CZEPOS stations with the same type. The time-series of all other stations can be found at http://www.pecny.cz/EUREF-Czech-2009/FINAL-TIMESERIES.

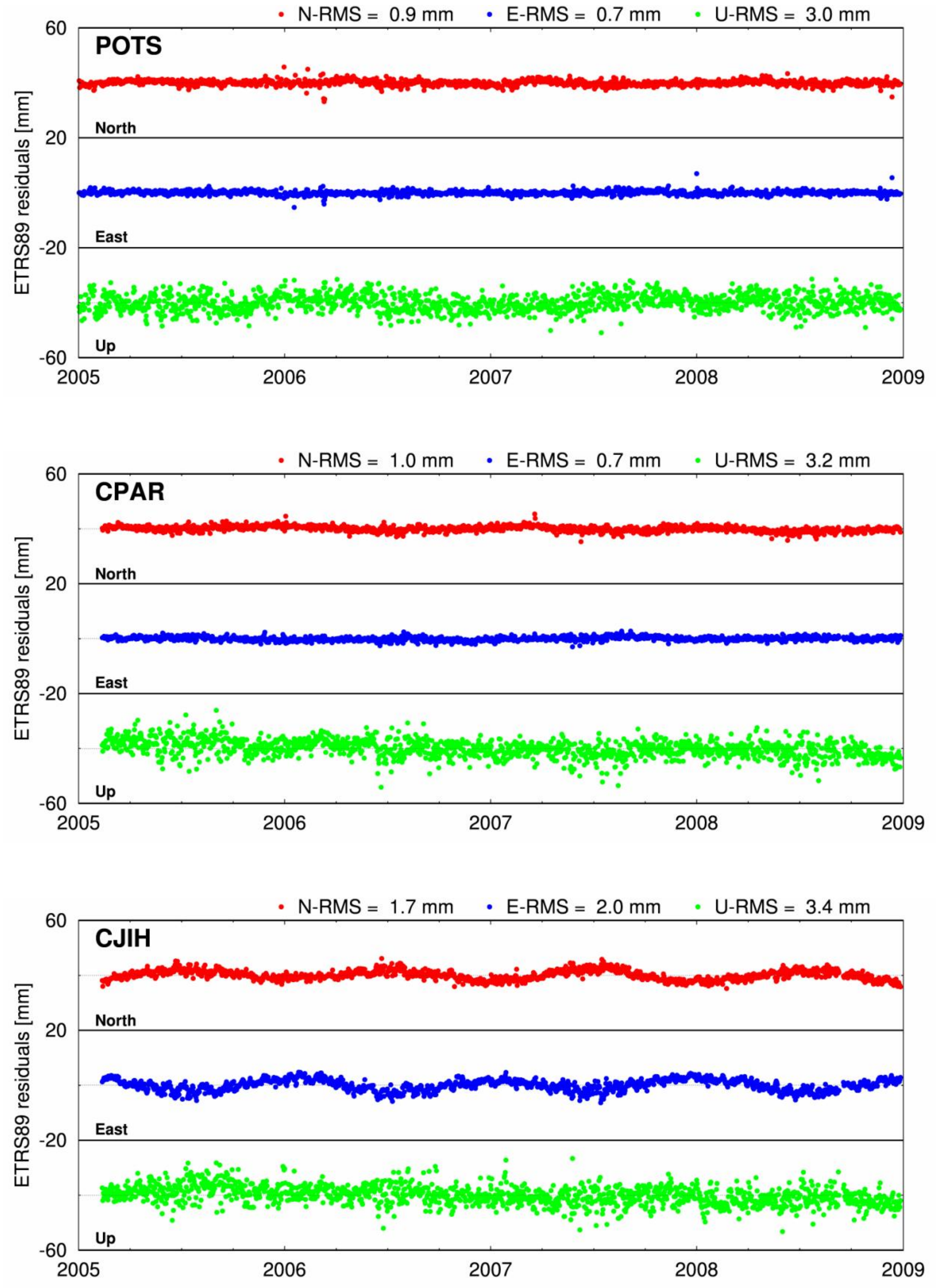

Figure 9: Example residual time-series for station POTS (fiducial), CPAR (estimated) and CJIH (estimated, seasonal signal)

6 Transformation to ETRS89

The final combination was calculated in the International Terrestrial Reference System (ITRS), which requires velocities to express coordinates in different epochs. Resulting coordinates from our combination had to be transformed into the European Terrestrial Reference System (ETRS89) in order to minimize coordinate changes in time. The latest ETRS89 realization based on ITRF2005 is maintained via the cumulative EPN solution (Kenyeres, 2009).

In transformation we followed the procedure described in Memo (Boucher and Altamimi, 2008) using two approaches to transform ITRF2005 coordinates and velocities into the ETRF2000:

a) Two-step transformation: ITRF2005 → ITRF2000 → ETRF2000, see Table 7.

b) Direct transformation using 14-element transformation (three translations, three rotations and scale in basic epoch and their time changes), see Table 8.

Table 7: Transformation parameters from ITRF2005 → ITRF2000, ITRF2000 → ETRF2000 at epoch 2007.0

Parameters	T1 mm	T2 mm	T3 mm	D 10^{-9}	R1 mas	R2 mas	R3 mas
ITRF2005 → ITRF 2000 (2000.0)*	0.0	-1.2	-5.8	0.40	0	0	0
Rates (per year)	-0.2	0.1	-1.8	0.08	0	0	0
ITRF2005 → ITRF 2000 (2007.0)	-1.4	-0.5	-18.4	0.96	0	0	0
ITRF2000 → ETRF2000 (1989.0)	54.0	51.0	-48.0	0	0	0	0
Rates (per year)	0	0	0	0	0.081	0.490	-0.792
ITRF2000 → ETRF2000 (2007.0)	54.0	51.0	-48.0	0	1.458	8.820	-14.256
ITRF2000 → ETRF2000 (2007.0)	**52.6**	**50.5**	**-66.4**	**0.96**	**1.458**	**8.820**	**-14.256**

*** Values 0.1, -0.8, -5.8 and 0.4 for T1, T2, T3 and D, respectively, are available at http://itrf.ensg.ign.fr/ITRF_solutions/2005/tp_05-00.php**

Table 8: Transformation parameters from ITRF2005 → ETRF2000 at epoch 2007.0

Parameters	T1 mm	T2 mm	T3 mm	D 10^{-9}	R1 mas	R2 mas	R3 mas
ITRF2005 → ETRF 2000 (2000.0)	54.1	50.2	-53.8	0.40	0.891	5.390	-8.712
Rates (per year)	-0.2	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2005 → ETRF2000 (2007.0)	**52.7**	**50.9**	**-66.4**	**0.96**	**1.458**	**8.820**	**-14.256**

Table 7 and Table 8 show that transformation coefficients for both approaches do not agree exactly, but they differ only in 0.1 mm and 0.4 mm in T1 and T2, respectively. The difference are caused by rounding errors, because values in Table 7 (first line) are reproduced directly from the Memo (Tables 1 and 2), while they are more accurately given at http://itrf.ensg.ign.fr/ITRF_solutions/2005/tp_05-00.php. Since the latter are used in the EPN web-page (http://epncb.oma.be/_dataproducts/coord_trans) and are fully consistent with Table 8, we finally used them in the transformation. The coordinates and velocities from the final solution 'D' (ITRF2005, ETRF2000) are summarized in Appendix.

7 Comparison with previous ETRS89 realization

This comparison evaluates the quality of older campaigns that contributed to the previous ETRS89 realisations in the Czech Republic than the quality of this campaign. However it is important to consider the discontinuity between previous and current national ETRS89 realisations.

The previous realisation of ETRS89 is described in Section 1. As a result, there exists a set of ETRS89 coordinates for 27 actually processed sites of the CZEPOS network in previous realisation. Table 9 shows translations and RMS errors estimated from Helmert transformation.

Nearly 1 cm offset in the North component is remarkable. Except that, the comparison shows a good agreement on a centimetre level in horizontal direction and a few centimetres in height. Only one station (CPRA) shows more than 15 mm difference in horizontal direction and two stations (CPRG and CMBO) exceed 30 mm in vertical direction.

Table 9: Translations and RMS errors from Helmert transformations with respect to the previous ETRS89 realisation

Number of sites	Translations			RMS of Helmert transformation			
	North [mm]	East [mm]	Up [mm]	North [mm]	East [mm]	Up [mm]	Total [mm]
27	9.9	-1.7	1.1	5.3	6.5	15.6	10.2

8 Conclusions

Altogether 44 Czech national and 18 EPN stations located in other European countries were processed during 4-year campaign and combined coordinates were converted into ETRF2000. For most of the stations 4-year observation time-series were considered, for some shorter time series, but minimally of 1 year. Data from winter periods were excluded for SNEC and LYSH stations located on the top of high mountains.

A high internal consistency of the campaign solution during the whole period is demonstrated by daily coordinate repeatabilities for all stations with a maximum of 2, 2 and 6 mm in North, East and Up component, respectively.

Four variants were tested differing in fiducial station configuration and coordinate and velocities parameterization. No significant difference between the realizations of the ETRS89 was found since all of them agreed within 1.3 mm in three translations.

Finally, 23 fiducial stations were selected for the final realization using a minimum constrained solution (no-net translation) with respect to the EPN cumulative solution (*EPN_A_ITRF2005_C1570)*. Residuals on the fiducial stations demonstrate the consistency of estimated coordinates with ETRS89 at the level of 1.7 mm in total RMS from Helmert transformation and 1.1, 1.2 and 2.5 mm for North, East and Up component, respectively.

An indirect comparison with the previous ETRS89 realization in the Czech Republic could only be applied using coordinates derived in roundabout multi-step approach for all CZEPOS stations (see description of previous realization of ETRS in the Czech Republic in Section 1). The total RMS from the Helmert transformation for 27 stations is 10.2 mm (in 2007.0), while estimated translation parameters were 9.9, -1.7 and 1.1 mm for North, East and Up components, respectively.

The EUREF Technical Working Group is asked to validate the coordinates (not velocities) resulting from this campaign.

Acknowledgments

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- data and products from the EUREF Permanent network (EPN)
  http://epncb.oma.be/
- orbit and clock products from the International GNSS Service (IGS)
  http://igscb.jpl.nasa.gov/
- data from CZEPOS operated by the Land Survey Office (LSO)
  http://czepos.cuzk.cz/
- data from VESOG network operated by the Research Institute of Geodesy, Topography and Cartography in collaboration with University of West Bohemia in Plzeň, Brno University of Technology, VŠB Technical University of Ostrava and Military Geographical and Hydrometeorological Institute
  http://oko.asu.cas.cz/vesog/
- data from GEONAS network operated by the Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic
  http://www.geonas.irsm.cas.cz/
- data from TOPNET network operated by GEODIS, s.r.o. company
  http://www.geodis.cz/produkty/topnet

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References

Bruyninx, C., Altamimi, Z., Caporali, A., Kenyeres, A., Lidberg, M., Stangl, G., Torress, G.A. (2009), Guidelines for EUREF Densifications, Version 1: 26-05-2009, ftp://epncb.oma.be/pub/general/Guidelines_for_EUREF_Densifications.pdf

Boucher, C., Altamimi, Z. (2008), Memo: Specification for reference frame fixing in the analysis of EUREF GPS campaigns. Version 7, http://etrs89.ensg.ign.fr/memo-V7.pdf

Dach, R., Hugentobler, U., Fridez, P., Meindl, M. (eds.) (2007), Bernese GPS software V5.0, Astronomical Institute, University of Bern, Switzerland

IERS Conventions (2003), McCarthy, D., Petit, G. (IERS Technical Note, 32) Frankfurt am Main: *Verlag des Bundesamts für Kartographie und Geodäsie*, 2004, 127 pp. http://www.iers.org/IERS/EN/Publications/TechnicalNotes/tn32.html

Kenyeres, A. (2009), Maintenance of the EPN ETRS89 coordinates, presented at the EUREF TWG Spring Meeting, Feb. 26-27, 2009, Budapest, available from http://www.euref.eu/TWG/EUREF%20TWG%20minutes/49-Budapest2009/03-e-ETRSmaint_TWGrepBP.pdf

Mervart, L. (1995), Ambiguity Resolution Techniques in Geodetic and Geodynamic Application of the Global Positioning System, Ph.D. Thesis, Astronomical Institute, University of Bern

Saastamoinen, J. (1972), Atmospheric correction for the troposphere and stratosphere in radio ranging of satellites, In *The Use of Artificial Satellites for Geodesy, Geophys. Monogr. Ser.*, vol. 15, Henriksen, S.W., Mancini, A., Chovitz ,B.H. (eds.), pp. 247-251, AGU, Washington, D.C.

Niell, A.E. (1996), Global mapping functions for the atmosphere delay at radio wavelengths, *JGR*, 100, pp.3227–3246

Appendix A - Stations List with Validity Intervals

Site Domex	Valid from	Valid to	# days	Comments
CBRU XXXXXXXXX	2005-11-03	2008-12-27	1103	
CDAC XXXXXXXXX	2005-02-09	2008-12-27	1391	
CDOM XXXXXXXXX	2005-04-22	2008-12-27	1320	
CFRM XXXXXXXXX	2005-11-01	2008-12-27	1131	
CHOD XXXXXXXXX	2005-10-14	2008-12-27	1150	
CJIH XXXXXXXXX	2005-02-12	2008-12-27	1392	
CKAP XXXXXXXXX	2005-08-09	2008-12-27	1211	
CKRO XXXXXXXXX	2005-11-01	2008-12-06	1111	
CKVA XXXXXXXXX	2005-04-28	2008-12-27	1317	
CLIB XXXXXXXXX	2005-08-09	2008-12-27	1213	
CLIT XXXXXXXXX	2005-06-22	2005-09-28	95	
CLIT XXXXXXXXXB	2005-11-01	2008-12-27	1132	Antenna replacement
CMBO XXXXXXXXX	2005-06-04	2006-06-02	360	
CMBO XXXXXXXXXB	2006-06-03	2008-12-27	919	Jump in N (confirmed)
CMOK XXXXXXXXX	2005-11-08	2008-12-27	1126	
CPAR XXXXXXXXX	2005-02-12	2008-12-27	1387	
CPRA XXXXXXXXX	2005-04-16	2008-04-22	1086	
CPRA XXXXXXXXXB	2008-04-23	2008-12-27	236	Jump in E
CPRG XXXXXXXXX	2006-12-30	2008-12-27	523	
CPRI XXXXXXXXX	2005-02-19	2008-12-27	1382	
CRAK XXXXXXXXX	2005-04-20	2008-12-27	1318	
CSUM XXXXXXXXX	2005-10-07	2008-12-27	1157	
CSVI XXXXXXXXX	2005-02-12	2008-12-27	1391	
CTAB XXXXXXXXX	2005-02-12	2008-12-27	1388	
CTRU XXXXXXXXX	2005-08-09	2008-12-27	1214	
CVSE XXXXXXXXX	2005-11-01	2008-12-27	1131	
GOPE 11502M002	2005-01-02	2006-01-19	378	Antenna replacement
GOPE 11502M002B	2006-01-26	2006-07-13	169	Antenna replacement
GOPE 11502M002C	2006-07-16	2008-12-27	871	Antenna replacement
KUNZ 11524M001	2005-09-24	2008-12-27	1046	
LYSH 11522M001	2005-06-23	2008-09-28	597	
PLZE 11523M001	2005-03-25	2005-10-07	171	
PLZE 11523M001B	2005-11-19	2006-01-03	46	Antenna replacement
PLZE 11523M001C	2006-01-04	2008-12-27	1071	Antenna replacement
POL1 XXXXXXXXX	2006-11-26	2008-06-28	574	
TUBO 11503M001	2005-01-02	2005-12-14	334	
TUBO 11503M001B	2005-12-17	2006-06-24	188	Antenna replacement
TUBO 11503M001D	2006-06-25	2008-12-24	904	New EPN coordinates
VSBO 11521M001	2005-01-02	2007-06-18	887	Antenna replacement
VSBO 11521M001B	2007-06-19	2008-12-27	548	Antenna replacement
BISK 11520M001	2005-04-24	2008-12-27	1190	
BEZD XXXXXXXXX	2007-01-01	2007-12-30	351	
CHOT XXXXXXXXX	2007-01-01	2007-12-30	362	
MARJ 11517M001B	2005-04-24	2008-12-27	1259	
POUS 11518M001	2005-10-16	2008-12-27	1154	
SLUK XXXXXXXXX	2007-01-01	2007-12-30	354	
SNEC 11519M001	2005-05-30	2005-09-27	116	
SNEC 11519M001B	2006-05-30	2008-09-26	305	Antenna replacement
TEME XXXXXXXXX	2007-01-01	2007-12-30	306	
VACO 11516M001B	2005-04-24	2008-12-27	1293	
TPOD XXXXXXXXX	2007-09-05	2008-06-28	273	
TPRO XXXXXXXXX	2005-07-08	2007-06-20	631	Jump
TPRO XXXXXXXXXB	2007-07-13	2007-10-03	48	Jump
TPRO XXXXXXXXXC	2007-10-24	2007-10-27	4	Antenna replacement
TPRO XXXXXXXXXD	2008-03-25	2008-06-28	66	Antenna replacement
TZDA XXXXXXXXX	2005-07-12	2006-08-27	393	
TZDA XXXXXXXXXB	2006-09-01	2007-01-03	122	Jump (approx. + 5cm in height)
TZDA XXXXXXXXXC	2007-01-04	2008-06-28	536	Jump (approx. - 5cm in height)
TZLI XXXXXXXXX	2006-01-01	2008-06-28	898	
TZNO XXXXXXXXX	2007-08-10	2008-06-28	323	

Station List with Validity Intervals (continuation)

BOR1 12205M002B	2005-01-02	2008-12-27	1436	
BRUS 13101M004B	2005-01-02	2008-12-27	1443	
DRES 14108M001	2005-01-02	2006-06-07	470	
DRES 14108M001C	2006-06-08	2007-05-22	322	New EPN coordinates
DRES 14108M001D	2007-05-25	2008-12-27	577	New antenna (but no crds.in EPN)
GLSV 12356M001B	2005-01-02	2007-11-08	1013	
GLSV 12356M001C	2007-11-22	2008-12-27	368	Antenna replacement
GRAS 10002M006B	2005-01-02	2008-12-27	1333	
GRAZ 11001M002	2005-01-02	2005-03-21	72	
GRAZ 11001M002B	2005-03-22	2005-11-01	223	Antenna replacement
GRAZ 11001M002D	2005-11-02	2008-12-27	1117	New EPN coordinates
JOZE 12204M001B	2005-01-02	2008-12-27	1284	
LINZ 11033S001B	2005-09-25	2008-12-27	1071	
MATE 12734M008B	2005-01-02	2008-11-23	1396	
MATE 12734M008C	2008-11-24	2008-12-27	33	Antenna replacement
MOPI 11507M001B	2005-01-02	2008-12-27	1298	
ONSA 10402M004B	2005-01-02	2008-12-27	1448	
PENC 11206M006	2005-01-02	2006-05-10	486	Antenna replacement
PENC 11206M006B	2006-05-11	2007-06-25	400	Antenna replacement
PENC 11206M006C	2007-07-18	2008-12-27	478	Antenna replacement
POTS 14106M003	2005-01-02	2008-12-27	1426	
RIGA 12302M002	2005-01-02	2006-05-18	492	
RIGA 12302M002B	2006-05-21	2007-12-05	535	Antenna replacement
RIGA 12302M002C	2007-12-18	2008-12-27	371	Antenna replacement
WROC 12217M001	2005-01-02	2006-08-13	571	
WROC 12217M001C	2006-08-14	2007-11-04	103	New EPN coordinates
WROC 12217M001D	2007-11-05	2008-12-27	405	Antenna replacement
WTZR 14201M010B	2005-01-02	2008-12-27	1426	
ZIMM 14001M004B	2005-01-02	2008-12-27	1433	

Appendix B – Coordinates and Velocities in ITRF2005

LOCAL GEODETIC DATUM: ITRF2005 EPOCH: 2007-01-01 0:00:00

STATION NAME	X (M)	Y (M)	Z (M)	VX	VY	VZ (m/y)
BEZDXXXXXXXXXX	3902726.4395	1136008.3366	4899384.0792	-0.0161	0.0167	0.0102
BISK11520M001	3898945.9091	1223993.3917	4881826.4637	-0.0155	0.0162	0.0102
BOR112205M002B	3738358.4234	1148173.7413	5021815.7928	-0.0165	0.0154	0.0095
BRUS13101M004B	4027893.7266	307045.8558	4919475.1457	-0.0126	0.0161	0.0112
CBRUXXXXXXXXXX	3919707.6473	1233461.5991	4862456.5764	-0.0164	0.0163	0.0106
CDACXXXXXXXXXX	4035070.4290	1114232.1783	4796779.1020	-0.0153	0.0166	0.0106
CDOMXXXXXXXXXX	4049956.1794	929357.5134	4823342.2655	-0.0153	0.0167	0.0105
CFRMXXXXXXXXXX	3924572.8201	1301971.2726	4840464.7111	-0.0160	0.0160	0.0113
CHODXXXXXXXXXX	4018665.1641	1238535.2337	4779742.7990	-0.0158	0.0172	0.0107
CHOTXXXXXXXXXX	3979115.0237	1116429.9776	4842575.0492	-0.0159	0.0170	0.0104
CJIHXXXXXXXXXX	4006712.7299	1117669.2024	4819597.9709	-0.0155	0.0166	0.0103
CKAPXXXXXXXXXX	4080537.6204	1054825.2573	4771937.3448	-0.0161	0.0168	0.0103
CKROXXXXXXXXXX	3976868.3107	1246286.2372	4812394.8913	-0.0159	0.0166	0.0108
CKVAXXXXXXXXXX	3986036.7120	908669.7883	4879721.8426	-0.0157	0.0163	0.0101
CLIBXXXXXXXXXX	3903195.1845	1050232.5085	4917869.8610	-0.0160	0.0160	0.0100
CLITXXXXXXXXXX	3938730.0064	992282.9663	4901389.0515	-0.0152	0.0149	0.0113
CLITXXXXXXXXXXB	3938729.9997	992282.9682	4901389.0525	-0.0152	0.0149	0.0113
CMBOXXXXXXXXXX	3935718.3327	1047652.7300	4892416.6423	-0.0164	0.0163	0.0096
CMBOXXXXXXXXXXB	3935718.3376	1047652.7309	4892416.6407	-0.0164	0.0163	0.0096
CMOKXXXXXXXXXX	4019915.8455	1176595.5730	4794332.2629	-0.0156	0.0168	0.0108
CPARXXXXXXXXXX	3949918.7417	1116467.3007	4865832.7637	-0.0160	0.0164	0.0098
CPRAXXXXXXXXXX	4067219.2625	1013765.7227	4792089.3869	-0.0110	0.0153	0.0115
CPRAXXXXXXXXXXB	4067219.2563	1013765.7302	4792089.3814	-0.0110	0.0153	0.0115
CPRGXXXXXXXXXX	3967685.1739	1022867.5895	4872004.4125	-0.0155	0.0166	0.0104
CPRIXXXXXXXXXX	4011991.0488	1000172.4819	4840841.1702	-0.0152	0.0171	0.0107
CRAKXXXXXXXXXX	3982250.9864	972921.5821	4870394.9991	-0.0151	0.0167	0.0106
CSUMXXXXXXXXXX	3931871.6104	1200665.3358	4860559.1594	-0.0156	0.0163	0.0107
CSVIXXXXXXXXXX	3959346.1980	1170655.7515	4845811.5221	-0.0160	0.0163	0.0103
CTABXXXXXXXXXX	4022509.9614	1053801.8688	4820712.4451	-0.0156	0.0167	0.0106
CTRUXXXXXXXXXX	3904532.4386	1112858.1053	4903151.9366	-0.0158	0.0163	0.0107
CVSEXXXXXXXXXX	3960645.4583	1286205.2965	4815446.2190	-0.0163	0.0165	0.0105
DRES14108M001	3904724.6725	954013.4235	4935790.0161	-0.0152	0.0161	0.0108
DRES14108M001C	3904724.6711	954013.4249	4935790.0173	-0.0152	0.0161	0.0108
DRES14108M001D	3904724.6712	954013.4236	4935790.0080	-0.0152	0.0161	0.0108
GLSV12356M001B	3512888.9191	2068979.9087	4888903.2267	-0.0190	0.0141	0.0091
GLSV12356M001C	3512888.9147	2068979.9109	4888903.2146	-0.0190	0.0141	0.0091
GOPE11502M002	3979316.1080	1050312.5163	4857067.1269	-0.0158	0.0165	0.0104
GOPE11502M002B	3979316.1066	1050312.5145	4857067.1256	-0.0158	0.0165	0.0104
GOPE11502M002C	3979316.1021	1050312.5109	4857067.1281	-0.0158	0.0165	0.0104
GRAS10002M006B	4581690.8809	556114.8729	4389360.8227	-0.0131	0.0186	0.0119
GRAZ11001M002	4194423.7906	1162702.7265	4647245.4342	-0.0167	0.0176	0.0108
GRAZ11001M002B	4194423.7931	1162702.7367	4647245.4369	-0.0167	0.0176	0.0108
GRAZ11001M002D	4194423.7909	1162702.7317	4647245.4387	-0.0167	0.0176	0.0108
JOZE12204M001B	3664940.1316	1409153.8957	5009571.4075	-0.0173	0.0153	0.0098
KUNZ11524M001	4037497.7764	1097034.2923	4798909.3434	-0.0158	0.0182	0.0112
LINZ11033S001B	4118898.6324	1048597.3922	4740105.9332	-0.0151	0.0173	0.0109
LYSH11522M001	3934178.1268	1312357.3783	4831238.0546	-0.0165	0.0159	0.0108
MARJ11517M001B	3975132.6677	909950.5734	4888908.1707	-0.0143	0.0166	0.0111
MATE12734M008B	4641949.5258	1393045.4679	4133287.4954	-0.0176	0.0189	0.0155
MATE12734M008C	4641949.5239	1393045.4629	4133287.4971	-0.0176	0.0189	0.0155
MOPI11507M001B	4053737.8572	1260571.6394	4744940.8903	-0.0156	0.0171	0.0120
ONSA10402M004B	3370658.5182	711877.1674	5349786.9774	-0.0128	0.0144	0.0121
PENC11206M006	4052449.4343	1417681.1588	4701407.1242	-0.0176	0.0171	0.0099
PENC11206M006B	4052449.4361	1417681.1587	4701407.1253	-0.0176	0.0171	0.0099
PENC11206M006C	4052449.4466	1417681.1625	4701407.1333	-0.0176	0.0171	0.0099
PLZE11523M001	4019840.9099	954005.6924	4843421.0968	-0.0154	0.0164	0.0103
PLZE11523M001B	4019840.9070	954005.6924	4843421.0890	-0.0154	0.0164	0.0103
PLZE11523M001C	4019840.8995	954005.6917	4843421.0799	-0.0154	0.0164	0.0103
POL1XXXXXXXXXX	3914079.4967	1146206.9431	4888342.9290	-0.0160	0.0168	0.0102
POTS14106M003	3800689.6079	882077.4178	5028791.3403	-0.0153	0.0157	0.0100
POUS11518M001	4002424.6601	872513.0667	4873111.8111	-0.0136	0.0164	0.0106
RIGA12302M002	3183899.1631	1421478.5261	5322810.8197	-0.0166	0.0142	0.0100
RIGA12302M002B	3183899.1636	1421478.5209	5322810.8174	-0.0166	0.0142	0.0100
RIGA12302M002C	3183899.1614	1421478.5192	5322810.8172	-0.0166	0.0142	0.0100
SLUKXXXXXXXXXX	3894883.9962	1004403.5074	4933867.0388	-0.0157	0.0167	0.0103
SNEC11519M001	3894162.7980	1097515.0617	4916280.0384	-0.0159	0.0134	0.0109
SNEC11519M001B	3894162.7909	1097515.0712	4916280.0189	-0.0159	0.0134	0.0109

SOFI11101M002	4319372.0590	1868687.8206	4292063.9550	-0.0167	0.0187	0.0091
TEMEXXXXXXXXX	4047280.1756	1037653.5652	4803656.6307	-0.0155	0.0172	0.0106
TPODXXXXXXXXX	4026475.0610	1219275.5217	4778133.5685	-0.0162	0.0171	0.0105
TPROXXXXXXXXX	3969184.3363	1221886.7913	4824930.3606	-0.0167	0.0160	0.0102
TPROXXXXXXXXXB	3969184.3698	1221886.7989	4824930.3953	-0.0167	0.0160	0.0102
TPROXXXXXXXXXC	3969184.3369	1221886.7873	4824930.3553	-0.0167	0.0160	0.0102
TPROXXXXXXXXXD	3969184.3352	1221886.7826	4824930.3744	-0.0167	0.0160	0.0102
TUBO11503M001	4001470.2587	1192345.5715	4805795.5541	-0.0164	0.0165	0.0103
TUBO11503M001B	4001470.2546	1192345.5646	4805795.5450	-0.0164	0.0165	0.0103
TUBO11503M001D	4001470.2569	1192345.5652	4805795.5462	-0.0164	0.0165	0.0103
TZDAXXXXXXXXX	3986578.8149	1137981.9915	4831512.7814	-0.0159	0.0167	0.0102
TZDAXXXXXXXXXB	3986578.8488	1137982.0014	4831512.8241	-0.0159	0.0167	0.0102
TZDAXXXXXXXXXC	3986578.8138	1137981.9913	4831512.7819	-0.0159	0.0167	0.0102
TZLIXXXXXXXXX	3976492.1443	1267580.1431	4807221.0039	-0.0163	0.0163	0.0105
TZNOXXXXXXXXX	4040134.9329	1162174.0380	4780963.4123	-0.0159	0.0172	0.0106
VACO11516M001B	4062325.8518	992104.6648	4800911.2975	-0.0165	0.0166	0.0086
VSBO11521M001	3916835.9220	1285051.3559	4851126.1374	-0.0170	0.0162	0.0098
VSBO11521M001B	3916835.9307	1285051.3569	4851126.1501	-0.0170	0.0162	0.0098
WROC12217M001	3835751.2706	1177249.9898	4941605.2678	-0.0157	0.0155	0.0106
WROC12217M001C	3835751.2765	1177249.9946	4941605.2713	-0.0157	0.0155	0.0106
WROC12217M001D	3835751.2760	1177249.9953	4941605.2717	-0.0157	0.0155	0.0106
WTZR14201M010B	4075580.5266	931853.8315	4801568.1586	-0.0156	0.0168	0.0104
ZIMM14001M004B	4331297.0415	567555.9170	4633133.9615	-0.0131	0.0179	0.0124

Appendix C – Coordinates and Velocities in ETRF2000

LOCAL GEODETIC DATUM: ETRF2000 EPOCH: 2007-01-01 0:00:00

STATION NAME		X (M)	Y (M)	Z (M)	VX	VY	VZ (m/y)
BEZD	XXXXXXXXX	3902726.7840	1136008.0842	4899383.8587	0.0000	0.0000	0.0000
BISK	11520M001	3898946.2589	1223993.1398	4881826.2439	0.0009	-0.0005	0.0000
BOR1	12205M002B	3738358.7738	1148173.4994	5021815.5795	-0.0001	-0.0007	-0.0003
BRUS	13101M004B	4027894.0147	307045.5938	4919474.9140	0.0004	-0.0012	0.0003
CBRU	XXXXXXXXX	3919707.9969	1233461.3459	4862456.3558	0.0000	-0.0005	0.0004
CDAC	XXXXXXXXX	4035070.7677	1114231.9175	4796778.8755	0.0005	-0.0006	0.0000
CDOM	XXXXXXXXX	4049956.5065	929357.2512	4823342.0371	-0.0001	-0.0006	-0.0002
CFRM	XXXXXXXXX	3924573.1735	1301971.0193	4840464.4907	0.0006	-0.0008	0.0011
CHOD	XXXXXXXXX	4018665.5106	1238534.9743	4779742.5741	0.0004	0.0001	0.0002
CHOT	XXXXXXXXX	3979115.3645	1116429.7203	4842574.8252	0.0000	0.0000	0.0000
CJIH	XXXXXXXXX	4006713.0698	1117668.9434	4819597.7457	0.0004	-0.0005	-0.0002
CKAP	XXXXXXXXX	4080537.9540	1054824.9935	4771937.1160	-0.0006	-0.0006	-0.0004
CKRO	XXXXXXXXX	3976868.6591	1246285.9804	4812394.6683	0.0004	-0.0004	0.0004
CKVA	XXXXXXXXX	3986037.0400	908669.5301	4879721.6169	-0.0005	-0.0007	-0.0004
CLIB	XXXXXXXXX	3903195.5238	1050232.2559	4917869.6398	-0.0002	-0.0007	-0.0003
CLIT	XXXXXXXXX	3938730.3410	992282.7113	4901388.8284	0.0004	-0.0020	0.0009
CLIT	XXXXXXXXXB	3938730.3343	992282.7132	4901388.8294	0.0004	-0.0020	0.0009
CMBO	XXXXXXXXX	3935718.6708	1047652.4753	4892416.4197	-0.0006	-0.0005	-0.0007
CMBO	XXXXXXXXXB	3935718.6757	1047652.4762	4892416.4181	-0.0006	-0.0005	-0.0007
CMOK	XXXXXXXXX	4019916.1884	1176595.3133	4794332.0375	0.0004	-0.0003	0.0003
CPAR	XXXXXXXXX	3949919.0834	1116467.0453	4865832.5410	0.0000	-0.0005	-0.0006
CPRA	XXXXXXXXX	4067219.5941	1013765.4596	4792089.1583	0.0044	-0.0020	0.0008
CPRA	XXXXXXXXXB	4067219.5879	1013765.4671	4792089.1528	0.0044	-0.0020	0.0008
CPRG	XXXXXXXXX	3967685.5094	1022867.3327	4872004.1883	0.0001	-0.0004	0.0000
CPRI	XXXXXXXXX	4011991.3815	1000172.2223	4840840.9440	0.0003	0.0000	0.0001
CRAK	XXXXXXXXX	3982251.3184	972921.3243	4870394.7740	0.0003	-0.0003	0.0001
CSUM	XXXXXXXXX	3931871.9577	1200665.0817	4860558.9380	0.0007	-0.0005	0.0004
CSVI	XXXXXXXXX	3959346.5426	1170655.4956	4845811.2993	0.0001	-0.0006	-0.0001
CTAB	XXXXXXXXX	4022510.2969	1053801.6086	4820712.2188	0.0000	-0.0005	0.0000
CTRU	XXXXXXXXX	3904532.7816	1112857.8527	4903151.7158	0.0002	-0.0004	0.0005
CVSE	XXXXXXXXX	3960645.8096	1286205.0409	4815445.9970	0.0002	-0.0004	0.0002
DRES	14108M001	3904725.0059	954013.1706	4935789.7942	0.0003	-0.0007	0.0005
DRES	14108M001C	3904725.0045	954013.1720	4935789.7954	0.0003	-0.0007	0.0005
DRES	14108M001D	3904725.0046	954013.1707	4935789.7861	0.0003	-0.0007	0.0005
GLSV	12356M001B	3512889.3272	2068979.6842	4888903.0294	0.0006	-0.0010	0.0002
GLSV	12356M001C	3512889.3228	2068979.6864	4888903.0173	0.0006	-0.0010	0.0002
GOPE	11502M002	3979316.4448	1050312.2588	4857066.9024	-0.0001	-0.0005	-0.0001
GOPE	11502M002B	3979316.4434	1050312.2570	4857066.9011	-0.0001	-0.0005	-0.0001
GOPE	11502M002C	3979316.4389	1050312.2534	4857066.9036	-0.0001	-0.0005	-0.0001
GRAS	10002M006B	4581691.1641	556114.5766	4389360.5685	-0.0004	-0.0006	-0.0002
GRAZ	11001M002	4194424.1264	1162702.4558	4647245.2011	-0.0011	-0.0001	-0.0001
GRAZ	11001M002B	4194424.1289	1162702.4660	4647245.2038	-0.0011	-0.0001	-0.0001
GRAZ	11001M002D	4194424.1267	1162702.4610	4647245.2056	-0.0011	-0.0001	-0.0001
JOZE	12204M001B	3664940.4994	1409153.6592	5009571.1992	0.0001	-0.0005	0.0002
KUNZ	11524M001	4037498.1140	1097034.0313	4798909.1167	-0.0001	0.0010	0.0006
LINZ	11033S001B	4118898.9642	1048597.1259	4740105.7026	0.0003	-0.0002	0.0001
LYSH	11522M001	3934178.4806	1312357.1244	4831237.8339	0.0001	-0.0009	0.0006
MARJ	11517M001B	3975132.9962	909950.3159	4888907.9454	0.0009	-0.0004	0.0006
MATE	12734M008B	4641949.8560	1393045.1701	4133287.2443	-0.0023	-0.0003	0.0036
MATE	12734M008C	4641949.8541	1393045.1651	4133287.2460	-0.0023	-0.0003	0.0036
MOPI	11507M001B	4053738.2038	1260571.3778	4744940.6640	0.0006	-0.0001	0.0014
ONSA	10402M004B	3370658.8521	711876.9482	5349786.7770	0.0027	-0.0005	0.0030
PENC	11206M006	4052449.7899	1417680.8977	4701406.8990	-0.0009	-0.0001	-0.0006
PENC	11206M006B	4052449.7917	1417680.8976	4701406.9001	-0.0009	-0.0001	-0.0006
PENC	11206M006C	4052449.8022	1417680.9014	4701406.9081	-0.0009	-0.0001	-0.0006
PLZE	11523M001	4019841.2395	954005.4321	4843420.8699	-0.0001	-0.0008	-0.0003
PLZE	11523M001B	4019841.2366	954005.4321	4843420.8621	-0.0001	-0.0008	-0.0003
PLZE	11523M001C	4019841.2291	954005.4314	4843420.8530	-0.0001	-0.0008	-0.0003
POL1	XXXXXXXXX	3914079.8414	1146206.6900	4888342.7080	0.0001	0.0000	-0.0001
POTS	14106M003	3800689.9402	882077.1713	5028791.1224	0.0001	-0.0007	-0.0001
POUS	11518M001	4002424.9853	872512.8074	4873111.5844	0.0014	-0.0007	0.0000
RIGA	12302M002	3183899.5447	1421478.3207	5322810.6323	0.0016	0.0001	0.0016
RIGA	12302M002B	3183899.5452	1421478.3155	5322810.6300	0.0016	0.0001	0.0016
RIGA	12302M002C	3183899.5430	1421478.3138	5322810.6298	0.0016	0.0001	0.0016
SLUK	XXXXXXXXX	3894884.3330	1004403.2552	4933866.8177	0.0000	0.0000	0.0000
SNEC	11519M001	3894163.1405	1097514.8098	4916279.8180	0.0001	-0.0033	0.0007
SNEC	11519M001B	3894163.1334	1097514.8193	4916279.7985	0.0001	-0.0033	0.0007

SOFI	11101M002	4319372.4285	1868687.5444	4292063.7212	0.0008	0.0007	-0.0019
TEME	XXXXXXXXX	4047280.5093	1037653.3034	4803656.4032	0.0000	0.0000	0.0000
TPOD	XXXXXXXXX	4026475.4062	1219275.2617	4778133.3431	0.0000	0.0000	0.0000
TPRO	XXXXXXXXX	3969184.6836	1221886.5349	4824930.1377	-0.0004	-0.0009	-0.0002
TPRO	XXXXXXXXXB	3969184.7171	1221886.5425	4824930.1724	-0.0004	-0.0009	-0.0002
TPRO	XXXXXXXXXC	3969184.6842	1221886.5309	4824930.1324	-0.0004	-0.0009	-0.0002
TPRO	XXXXXXXXXD	3969184.6825	1221886.5262	4824930.1515	-0.0004	-0.0009	-0.0002
TUBO	11503M001	4001470.6031	1192345.3130	4805795.3296	-0.0003	-0.0006	-0.0002
TUBO	11503M001B	4001470.5990	1192345.3061	4805795.3205	-0.0003	-0.0006	-0.0002
TUBO	11503M001D	4001470.6013	1192345.3067	4805795.3217	-0.0003	-0.0006	-0.0002
TZDA	XXXXXXXXX	3986579.1567	1137981.7338	4831512.5572	0.0001	-0.0003	-0.0002
TZDA	XXXXXXXXXB	3986579.1906	1137981.7437	4831512.5999	0.0001	-0.0003	-0.0002
TZDA	XXXXXXXXXC	3986579.1556	1137981.7336	4831512.5577	0.0001	-0.0003	-0.0002
TZLI	XXXXXXXXX	3976492.4940	1267579.8864	4807220.7810	0.0001	-0.0007	0.0001
TZNO	XXXXXXXXX	4040135.2742	1162173.7770	4780963.1859	0.0000	0.0000	0.0000
VACO	11516M001B	4062326.1823	992104.4019	4800911.0690	-0.0012	-0.0007	-0.0021
VSBO	11521M001	3916836.2747	1285051.1030	4851125.9173	-0.0004	-0.0005	-0.0004
VSBO	11521M001B	3916836.2834	1285051.1040	4851125.9300	-0.0004	-0.0005	-0.0004
WROC	12217M001	3835751.6197	1177249.7418	4941605.0504	0.0007	-0.0010	0.0005
WROC	12217M001C	3835751.6256	1177249.7466	4941605.0539	0.0007	-0.0010	0.0005
WROC	12217M001D	3835751.6251	1177249.7473	4941605.0543	0.0007	-0.0010	0.0005
WTZR	14201M010B	4075580.8529	931853.5677	4801567.9291	-0.0005	-0.0006	-0.0003
ZIMM	14001M004B	4331297.3357	567555.6363	4633133.7184	0.0002	-0.0004	0.0009