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Computation of the EUREF Slovenia 2016 GNSS Campaign

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1 Introduction

Three EUREF GPS campaigns were carried out in the nineties of the last century (i.e. in 1994, 1995, and 1996) in Slovenia. The combined solution of these campaigns was presented in 2003 at the 13th EUREF symposium in Toledo [Berk et al. 2004] and accepted as Class B standard (~1 cm at the epoch of observations). This is the official Slovenian realization of the ETRS89, known as the national terrestrial datum 1996 (ETRS89/D96); the mean epoch of the three campaigns was 1995.55. A total of 49 sites in Slovenia were included into (at least one of) the three campaigns and five of them were accepted as official EUREF sites and put into the EUREF Campaign Database. The lifetime of the current realization of the ETRS89 in Slovenia has already expired [e.g. Caporali et al. 2011, Sterle 2015].

The national GBAS network called SIGNAL (Slovenia-Geodesy-Navigation-Location) was established in 2006 [e.g. Berk et al. 2006]. Nowadays, it consists of 16 permanent GNSS stations. The coordinates of the SIGNAL Network stations were determined via the so-called “Mini EUREF 2007” campaign. Only the (five) official EUREF sites were included into this campaign and the resulting station coordinates might not be fully consistent with the ETRS89/D96 [e.g. Stopar et al. 2008].

The national Combined Geodetic Network – also known as the Zero-Order Network – was established in 2016 as an infrastructure for the high-quality spatial reference system realization in a long term. Ten permanent GNSS stations are installed on six locations; four of them are double stations. The stations are installed on concrete pillars, mounted on well-founded platforms [e.g. Medved et al. 2015, 2016, 2017].

The “EUREF Slovenia 2016” GNSS Campaign (henceforth: the campaign) was conducted 20 years after the last EUREF GPS campaign in Slovenia, 10 years after establishing the SIGNAL Network, and right after establishing the Zero-Order Network. The purpose of this project was:

- to check and improve the consistency of coordinates of points in the EUREF (passive) and SIGNAL (active) Networks in Slovenia,
- to connect EUREF and SIGNAL Networks with the newly established Zero-Order Network to be used for the future realizations of the spatial reference system in Slovenia, and
- to find an evidence for active tectonics in the EUREF densification area (Slovenia).

2 Overview of the EUREF Slovenia 2016 GNSS Campaign

The campaign was carried out from August 22nd to November 10th 2016 (days of year 235–315, GPS weeks 1911–1922). The mean epoch of observations was 2016.7498 (i.e. October 1st 2016, 10:10 UTC, rounded to 2016.75 (i.e. October 1st 2016, 12:00 UTC) or simply 2017 – the campaign solution in the ETRS89 shall be referred to as the national terrestrial datum 2017 (ETRS89/D17).

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Reasons for such a long duration of the campaign were complex logistics due to manpower shortage and difficult access (helicopter support was organised for some high mountain sites) and equipment availability – only five GNSS receivers (plus one as a spare receiver) were at our disposal. Namely, the decision was to use only the newest receivers of the same type and with choke ring antennas.

The campaign consisted of nine series of 72-hour periods (i.e. three consecutive daily sessions for each series) with eight intermediate series resulting in 80 consecutive daily sessions. Each passive EUREF network point was observed within one of the nine series. Of course, the permanent stations collected data for the whole period of the campaign. A regular daily session lasted from 10:00 to 10:00 UTC (next day) and from 11:00 to 11:00 UTC since October 30th 2016 (transition out of daylight saving time). Detailed information on the time periods of daily sessions and series of observations is given in **Appendix 1**.

The points included into the campaign can be divided into several groups as follows:

- 8 permanent stations in the Zero-Order Network installed on 6 network sites[3]: Areh, Kog, Koper[4], Korada, Prilozje, and Šentvid pri Stični;
- 15 additional permanent stations in the SIGNAL Network: Bodonci, Bovec, Brežice, Celje, Črnomelj, Idrija, Ilirska Bistrica, Lendava, Ljubljana[5], Maribor, Nova Gorica, Ptuj, Radovljica, Slovenj Gradec, and Trebnje;
- 20 permanent stations from GBAS networks of neighbouring countries (APOS, CROPOS, GNSSNet.hu, Rete GNSS FVG), also included (or to be included) into the SIGNAL Network;
- 46 EUREF points in Slovenia (from EUREF GPS campaigns in the years 1994–1996), including five official EUREF points: Donačka gora, Korada, Kucelj, Malija, and Velika Kopa;
- 2 official EUREF points in Croatia (also from EUREF GPS campaigns in the years 1994–1996): Brusnik and Pula;
- 32 additional IGS and/or EPN stations used as reference and control stations.

A total of 123 points were selected to be included into the campaign – 48 passive and 75 active network points. More than 6000 daily RINEX files were acquired, because the permanent stations were mostly occupied for all 81 days.

2.1 Subset of Data Used in the Computation (for the Validation by the EUREF GB)

After the first announcement of the new EUREF densification in Slovenia to the EUREF GB[6], we decided to select only a subset of all the sites and daily sessions of the campaign to be used in the computation for the purpose of the validation of this EUREF densification by the EUREF GB. However, it included the most relevant sites occupied in Slovenia. The observation period was the same as for the complete network, the selected reference frame stations were the same, and the configuration of this reduced network was the basis also for the complete network (to be created with the same baselines and further expanded with baselines to additional points). After the adoption of this computation by the EUREF, the same processing strategy will be used for the complete network computation, which will be considered the national densification of this campaign.

[3] Two Zero-Order Network stations (Prilozje and Šentvid pri Stični) were fully operational double stations and another two planned double stations (Areh and Korada) were still operating as single stations in the time of conducting the campaign; the additional stations on these two sites started collecting data a year later (in November 2017).

[4] The Koper station (KOPE 14502M001) is included into both, the Zero-Order and the SIGNAL Networks; it was also an European Sea Level Service (ESEAS) observing site.

[5] The Ljubljana station (GSR1 14501M001) is also a EUREF Permanent GNSS Network (EPN) site.

[6] This topic was discussed with Dr. Kenyeres, the chair of the EUREF GB, at the 4th EUPOS Council and Technical Meeting, which took place in Bratislava, November 21–22, 2017.

The processing of the campaign included:

- 6 permanent stations in the Zero-Order Network (only one station at double stations);
- 15 additional permanent stations in the SIGNAL Network;
- 8 EUREF points in Slovenia, including the five official EUREF points;
- 2 official EUREF points in Croatia;
- 26 additional IGS and/or EPN stations used as reference frame and control stations.

A total of 57 points – 10 passive and 47 active network points – were selected (i.e. 46.3% of points), which were located in 16 European countries, see Figures 1 and 2. According to the periods of observation for the selected passive network points, only seven (out of nine) series of observations were used (1^{st}, 2^{nd}, 3^{rd}, 5^{th}, 6^{th}, 8^{th} and 9^{th} – coloured in Appendix 1), which corresponded to 21 daily sessions (out of 80; i.e. 26.3% of daily sessions). A total of 993 daily RINEX files (i.e. about 16.6% of collected RINEX files) were used in the computation.

A list of sites included into this computation with full names, 4- and 2-char IDs, and domes numbers (i.e. Station Abbreviation Table – Bernese ABB file) is given in **Appendix 2**. An overview of observation periods for sites included into this computation with daily sessions available is given in **Appendix 3**. A list of GNSS equipment used in this computation (i.e. Station Information Table – from Bernese STA file) is given in **Appendix 4**. Most of the GNSS receivers collected GPS + GLONASS data; the exceptions were Genoa, Józefosław, and Zimmerwald. Also, only GPS observations for the Brussels station were used because the Bernese software consistently proposed the connection of this station to Zimmerwald. Additionally, the Ohrid station was considered as GPS only because of some problems encountered in the preliminary solution, which might be caused by the inconsistent individual antenna calibration model for GLONASS satellites (adopted from group mean calibration).

Figure 1: Sites used in the computation – general overview

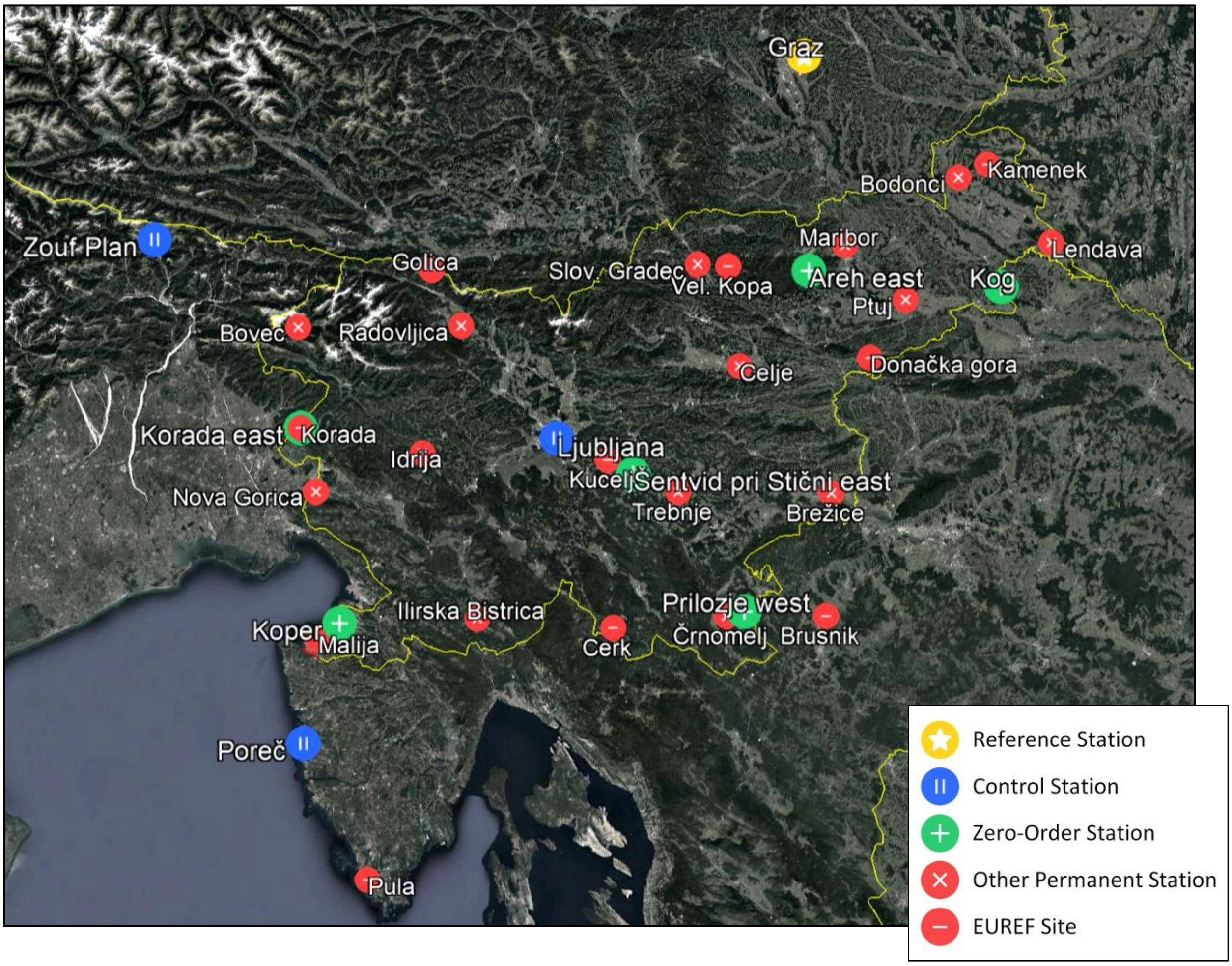


Figure 2: Sites used in the computation – zoom to Slovenia

Two maps showing the sites used in this computation are given as deliverables in kml format (in the .../KML_maps directory), i.e.;

- a map of sites with full location names (EUREF_SVN16-Site_names.kml), and
- a map of sites with 4-char IDs (EUREF_SVN16-Site_IDs.kml).

As can be seen in Appendix 4, all the campaign data for passive GNSS sites were collected with Javad receivers and corresponding choke ring antennas[7] (in Slovenia) and with Trimble receivers and antennas[8] (in Croatia). The 30-second sampling rate was used. The elevation cut-off angle was 10°. Javad JPS2RIN and Trimble TBC Utility Software were used to convert raw data into RINEX format, version 2.11.

The 30-second daily RINEX data for the Zero-Order and SIGNAL Networks were acquired directly from the digital archives. The corresponding log files were taken from the SIGNAL Network web portal [SIGNAL 2016].

The RINEX data for the IGS and EPN stations were taken from ftp servers of the Crustal Dynamics Data Information System [Noll 2010, CDDIS 2016], the Lustbühel Graz Observatory [OLG 2016], and the EPN Central Bureau [EPN CB 2016]. Log files for the IGS stations were taken from the IGS web portal [IGS Network 2016].

[7] The receiver type was JAVAD TR_LS2 and the antenna type was JAV_RINGANT_G3T.

[8] The receiver type was TRIMBLE R8 GNSS and the antenna type was TRMR8 GNSS.

2.2 Other Data Used in the Computation

Both, the precise IGS orbits [IGS Orbits 2017] and the precise CODE orbits [CODE Orbits 2017] were acquired and tested for the period of conducting the campaign. A slightly lower daily medians of total RMSes (for GPS + GLONAS satellites) can be obtained for the precise IGS orbits. For the final computation of the campaign, precise IGS orbits and corresponding Earth rotation parameters were used – also recommended in the guidelines [Bruyninx et al. 2013].

Ocean tide loading displacements for all 57 sites were prepared (FES2004.BLQ file) by using the web service of the Onsala Space Observatory [Onsala 2017]. JPL planetary and lunar ephemeris DE405 were prepared (DE405.EPH file) by using data taken from the National Aeronautics and Space Administration ftp server [NASA 2017]. Global ionosphere model (ION files) was prepared by using data taken from the Astronomical Institute of the University of Berne ftp server [AIUB 2018]. Vienna Mapping Function (VMF1) troposphere model – created from the European Centre for Medium-Range Weather Forecast (ECMWF) data – was prepared (GRD files) by taking data from the Technical University of Vienna ftp server [Boehm et al. 2006, TUW 2018].

General files used in the computation were taken from the Astronomical Institute of the University of Berne ftp server [BSWUSER52 2017]. Station information file for the EPN (including IGS) stations (EUREF52.STA) and the corresponding EPN individual antenna calibration models (EPNC_08.ATX) were taken from the EPN Central Bureau ftp server [EPN CB General 2017]. The latter was used to upgrade the Bernese PCV file (PCV.I08), which was based on the IGS antenna calibration models (IGS08.ATX) and did not include absolute individual antenna calibration models [e.g. Schmid et al. 2016].

Antenna phase centre variations (PCV) for the Zero-Order Network stations and for one SIGNAL Network station (Ptuj) have been analysed and absolute individual antenna calibration models have been created by Geo++ [Wübbena et al. 2006]. The corresponding ATX files are given as deliverables (in the .../ANTEX_files directory). Together with the absolute individual antenna calibration model for the Potsdam station – taken from the EPN Central Bureau ftp server [EPN CB Individual 2017] –, which was missing in the EPNC_08.ATX file, these models were included into the Bernese PCV file, too.

EPN products in the form of cumulative station positions and velocities [Bruyninx et al. 2012] were also used. Coordinates and velocities for the reference frame and control stations (referred to the IGb08, epoch 2005.0) were taken from the EPN cumulative solution with the release name EPN_A_IGb08_C1934[9] [IGb08 2017].

3 Processing of the EUREF Slovenia 2016 GNSS Campaign

Bernese GNSS Software, version 5.2, release 2018-02-28, with the corresponding documentation [Dach et al. 2015] was used for the processing of the campaign. The software was running on Windows 10 Enterprise operating system. Guidelines for EUREF Densifications, version 5 [Bruyninx et al. 2013], were followed. GPS and GLONAS observations were used. The computation was carried out in the ITRF2008/IGb08 [Altamimi et al. 2011, Rebischung et al. 2012], which was the reference frame used at the time of conducting the campaign. The EPN transformation service [ETRF/ITRF 2017] was used for transformation of the results from the IGb08 to the ETRF2000, which follows the latest version (8.0) of the Memo [Boucher and Altamimi 2011]. The frame of the realization of this computation is a solution delivered in IGb08/ETRF2000, which is considered a EUREF densification (improvement) of the ETRS89 in Slovenia referred to as the ETRS89/D17.

[9] This was the last IGb08 release and also the first one, which covered the whole period of the campaign.

3.1 Data Time Span Modification (Day of Year → Daily Session Files)

RINEX data for permanent stations were all available as daily RINEX files (each day of year from 0:00 to 24:00 UTC). A batch procedure was developed to adapt all RINEX files of the campaign (~6000 files). A consecutive pair of daily RINEX files for each station was cut and merged into one daily session RINEX file, beginning and ending in accordance with the daily session definition – see Appendix 1. Resulting daily session RINEX file took the name after the first RINEX file (i.e. day of year for the first epoch of observations).

Similar modifications were performed manually also for precise orbits (SP3/PRE files), IERS pole information (IEP/ERP files), global ionosphere model (ION files), and VMF1 troposphere model (H00–H18/GRD files).

3.2 Selection of Reference Frame Stations and Control Stations

IGS stations were used as reference frame stations of the campaign. These stations should:

- be the core stations – included into the IGS08 network [Rebischung et al. 2012],
- be included into the cumulative solution with the release name EPN_A_IGb08_C1934, and
- have uninterrupted and verified time series [Altamimi 2003] tied to EPN_A_IGb08 – possibly without GNSS equipment changes,
- have no missing daily session RINEX files for the period of the campaign (with the requirement of at least 1200 epochs contained);
- be evenly distributed around the EUREF densification area, and possibly
- be used as a reference also in the previous EUREF GNSS campaigns in a EUREF densification area.

A shortlist of 11 IGS08 stations located closest to Slovenia was prepared. After checking the criteria above, three IGS stations were excluded from this list: Borówiec with antenna change and time series discontinuity in the period of the campaign, Potsdam with missing RINEX data for the first day of the campaign, and Sofia – following the experience from the preliminary computation[10]. It should be mentioned that there was an antenna change in Graz (GRAZ) within the period of the campaign (Figure 3).

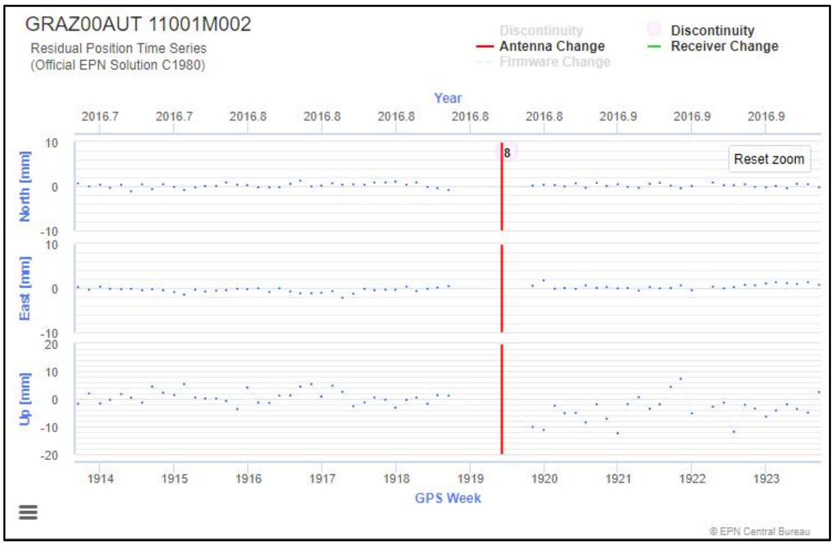


Figure 3: Antenna change in Graz on October 20th 2016 [EPN Position Time Series 2017]

[10] The first computation results of the EUREF Slovenia 2016 GNSS Campaign were presented at the 76th EUREF GB Meeting, which took place in Padua, February 27–28, 2018.

According to the last EPN cumulative solution (in IGb08) with the release name EPN_A_IGb08_C1934 [IGb08 2017], this antenna change did not cause any significant coordinate time series discontinuity. Having in mind that this (Graz station) was the IGS station closest to Slovenia and that it was also a reference for all previous EUREF GPS campaigns, this station was used as a reference frame station despite of the antenna change.

Finally, these eight reference frame stations were selected (Figure 4): Bucharest (BUCU), Grasse (GRAS), Graz (GRAZ), Józefosław (JOZE), Matera (MATE), Uzhgorod (UZHL), Wettzell (WTZR), and Zimmerwald (ZIMM).

The remaining 19 IGb08 Class A stations included into the campaign were used as control stations (also Figure 4): Bolzano (BZRG), Borówiec (BOR1), Brussels (BRUX), Dubrovnik (DUB2), Florence (IGMI), Genoa (GENO), Ljubljana (GSR1), Ohrid (ORID), Pecný (GOPE), Penc (PENC), Poreč (PORE), Potsdam (POTS), Požega (POZE), Rome (M0SE), Sarajevo (SRJV), Sofia (SOFI), Venice (VEN1), Zadar (ZADA), and Zouf Plan (ZOUF).

Figure 4: Selected reference frame and control stations of the campaign

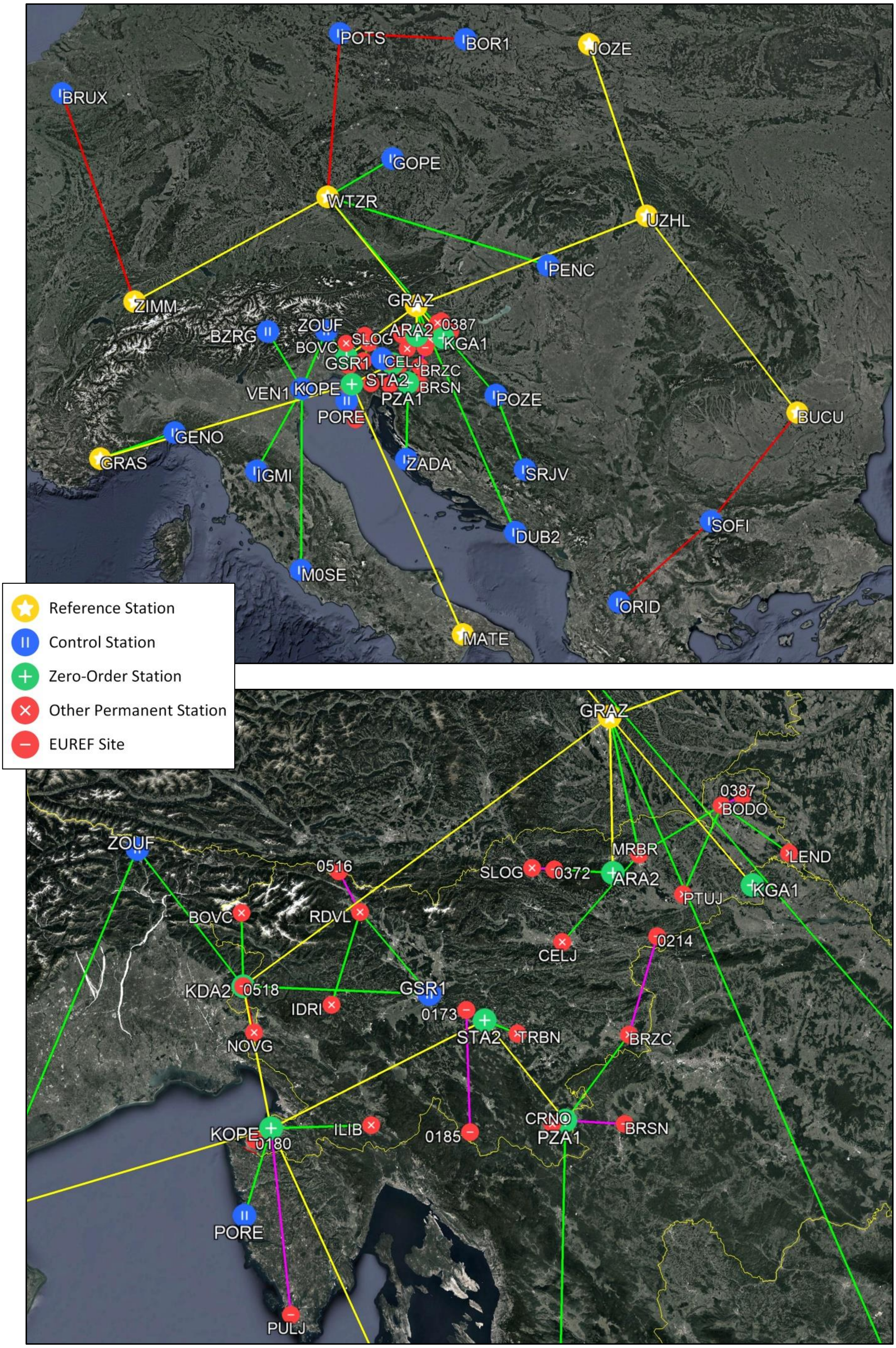
3.3 Network Configuration

A set of baselines with maximum common observations (MAX-OBS strategy) was chosen to create the single-difference observation files. However, some stations were not included into all daily sessions, which would lead into different network configuration for each daily session. This was partly avoided by dividing baseline creation process into phases. In the first phase, the six Zero-Order Network stations[11] were connected between themselves and with the selected eight reference frame stations. This core network was expanded with the connections to other permanent stations with all 21 daily session RINEX files available. Finally, the network was completed with connections to permanent stations with incomplete data and to passive GNSS network points occupied for only three daily sessions each. Maximum common observations strategy was used in all these phases. However, by using the experience from the preliminary computation, some stations with a bit more noisy data formed dead end baselines (e.g. Celje, Dubrovnik, and Poreč). In this way not only the quantity but also the quality of observations was taken into consideration when creating the network.

The core network connecting the Zero-Order Network stations with the selected reference frame stations (yellow baselines) is shown in Figure 5. Final network configuration expanded with other baselines with full 21 daily session data (green baselines), baselines to permanent stations with incomplete daily session data (red baselines), and finally baselines to sites occupied for only three daily sessions (magenta baselines) is shown in Figures 6 and 7.

Figure 5: The core network configuration

[11] The RINEX data for these stations were downloaded daily from the receivers (no gaps caused by real-time data flow interruptions and system breakdowns); the antennas are installed on concrete pillars and have absolute individual calibration models (which should result in less noisy and more continuous time series with low periodic signals).



Figures 6 and 7: The extended network configuration – general overview and zoom to Slovenia

A map showing the baselines created for this computation is given as a deliverable in kml format (in the .../KML_maps directory), i.e.;

- a map of baselines coloured according to the creation phase (EUREF_SVN16_Baselines.kml).

3.4 Processing Procedure

The processing of the campaign was performed by following the example from the tutorial [Dach and Fridez 2017]. The procedure consists of the following steps:

- preparing basic project-specific Bernese files (manually),
- preparing global ionosphere model (manually),
- preparing VMF1 troposphere model (manually),
- preparing a priori station coordinate files (COOVEL + manually),
- preparing station velocity files (NUVELO + manually),
- comparing station velocity files (VELDIF),
- preparing antenna phase centre variation file (ATX2PCV),
- extracting atmospheric tidal loading coefficients (GRDS1S2),
- preparing ocean tidal loading coefficients (web service + manually),
- importing IERS pole information files into Bernese (POLUPD),
- importing/merging precise IGS orbit files for GPS and GLONASS satellites (CCPREORB),
- concatenating precise orbit files for each daily session (CCPREORB),
- creating tabular and standard orbit files (PRETAB, ORBGEN),
- creating observation statistics (RNXGRA),
- importing RINEX files into Bernese (RXOBV3),
- synchronizing receiver clocks (CODSPP),
- creating predefined baseline files (SNGDIF),
- preprocessing phase observations (MAUPRP),
- improving a priori station coordinate file (GPSEST),
- estimating parameters and saving residuals (GPSEST),
- creating residual statistics (RESRMS),
- marking/removing outliers (SATMRK),
- producing first daily network solutions – float (GPSEST),
- resolving ambiguities for long baselines (GPSEST),
- resolving ambiguities for short baselines (GPSEST),
- generating daily mean ambiguity resolution statistics (GPSXTR),
- producing final daily network solutions – fixed (GPSEST),
- producing final daily coordinate/troposphere estimations (ADDNEQ2),
- checking reference coordinates for daily solutions (HELMR1),
- checking repeatability of daily solutions (COMPAR, HELMR1),
- generating normal equations with coordinates only (ADDNEQ2),
- stacking daily network solutions and producing final network solution (ADDNEQ2), and
- checking reference/control coordinates of the final network solution (HELMR1).

After creating a new project, manually were prepared the campaign session table (SES file) – according to the predefined time periods of daily sessions and series of observations – see Appendix 1, the station abbreviation table (ABB file), the list of reference frame stations (FIX file) – see Figure 3, the station information file (STA file), which was based on the station information file for the EPN stations (EUREF52.STA), and the plate definition file (PLD file).

A priori station coordinate files (CRD files) were prepared for the mean epochs of each individual daily session and for the mean epoch of the campaign. Coordinates and velocities of the selected reference frame stations and control stations were available in the reference epoch 2005.0 from the EPN cumulative solution with the release name EPN_A_IGb08_C1934 [IGb08 2017]. These coordinates were transformed into the corresponding epoch in the IGb08 by using the equation [Boucher and Altamimi 2011]:

$$X_{IGb08}(t) = X_{IGb08}(t_0) + \dot{X}_{IGb08}(t - t_0)$$

with:

- t ... the mean epoch of observations,
- t_0 ... the reference epoch (i.e. 2005.0 for the IGb08),
- $X_{IGb08}(t)$ ... coordinate in the mean epoch of observations,
- $X_{IGb08}(t_0)$ ... coordinate in the reference epoch, and
- $\dot{X}_{IGb08}$ ... the corresponding velocity component.

Similarly, the a priori/reference coordinate files for all daily sessions were prepared, i.e. referring to the mean epoch of each individual daily session. Coordinates for the other points included into the campaign were taken from the preliminary campaign solution with the accuracy of a few millimetres.

A priori station velocity file (VEL file) was prepared for all network points. Velocities of the selected reference frame stations and control stations were taken directly from the EPN cumulative solution with the release name EPN_A_IGb08_C1934 [IGb08 2017].

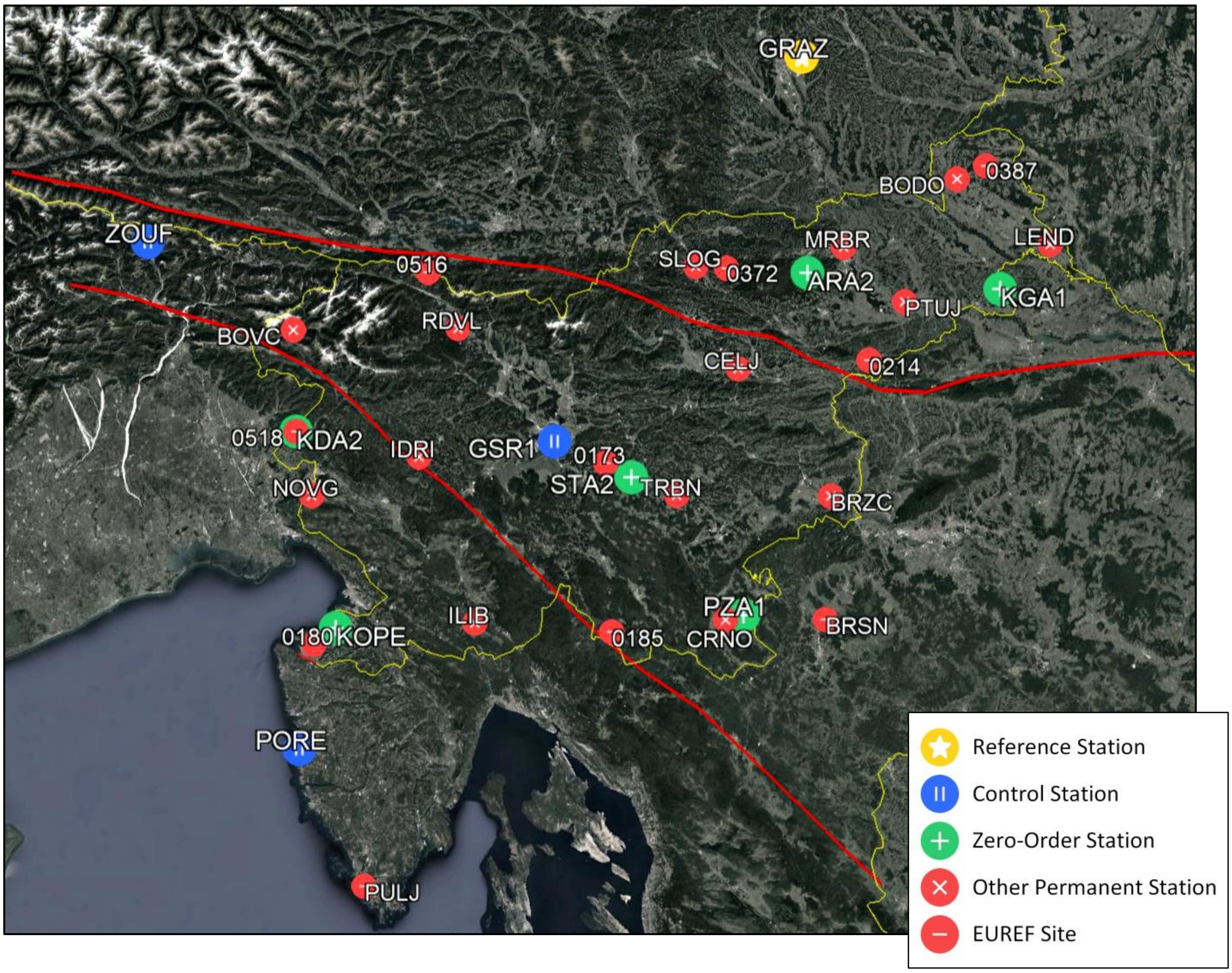


Figure 8: Velocity vectors determination through the adoption from the nearest reference frame or control station, but without crossing the most relevant tectonic faults (in red)

Missing velocities for a site in the network were adopted from the reference frame or control station:

- which is the closest station to this site (to be estimated), and
- which is not divided from this site with an important tectonic fault.

The tectonic subdivision of Slovenia [e.g. Placer 2008] was studied together with the latest geodetic contributions to this issue [Sterle 2015]. The Idrija fault and the Periadriatic fault extended eastward to the Lavanttal fault were chosen here as the most relevant[12] (Figure 8). According to these criteria, velocity vector from Graz (GRAZ) was used for the north-east Slovenia[13], from Ljubljana (GSR1) for the central Slovenia[14], from Zouf Plan (ZOUF) for the north-west Slovenia[15], and from Poreč (PORE) for the south-west Slovenia[16]. Of course, being on the same microplate does not mean having the same velocity vector, but the Euler pole for the Adria microplate, for example, is relatively far away from the EUREF densification area [e.g. Weber et al. 2010], so this misassumption should in our case (up to 40 days from the mean epoch of the campaign) not be essential.

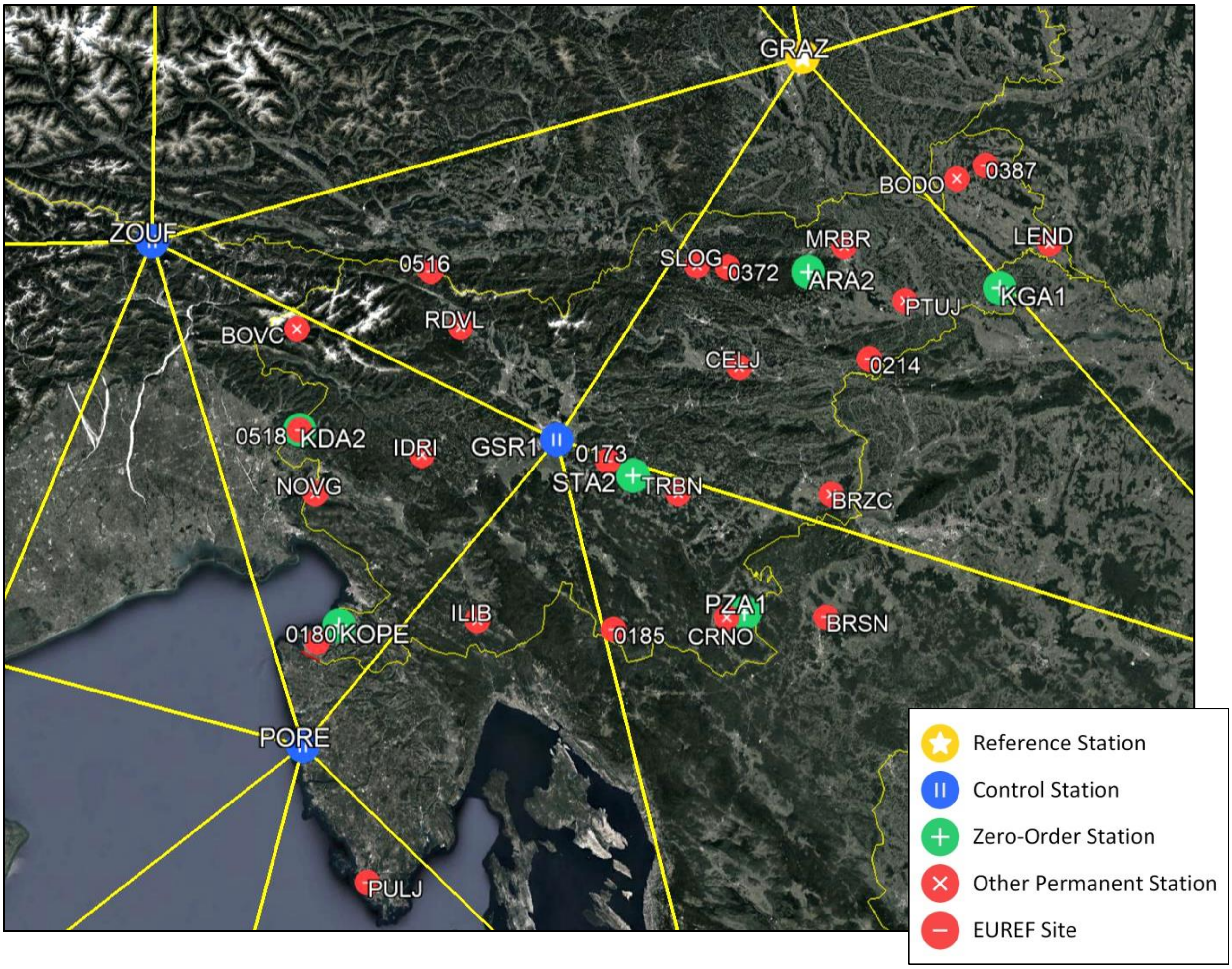


Figure 9: Velocity vectors determination through the linear interpolation of each individual velocity component in a triangulated irregular network (in yellow)

[12] It should be noted that further interdisciplinary research is needed to be able to satisfactory explain the tectonics of this area.

[13] Velocity vector from Graz (GRAZ) was used also for: Areh east (ARA2), Bodonci (BODO), Donačka gora (0214), Kamenek (0387), Kog (KGA1), Lendava (LEND), Maribor (MRBR), Ptuj (PTUJ), Slovenj Gradec (SLOG), and Velika Kopa (0372).

[14] Velocity vector from Ljubljana (GSR1) was used also for: Brežice (BRZC), Brusnik (BRSN), Celje (CELJ), Cerk (0185), Črnomelj (CRNO), Golica (0516), Idrija (IDRI), Kucelj (0173), Prilozje west (PZA1), Radovljica (RDVL), Šentvid pri Stični east (STA2), and Trebnje (TRBN).

[15] Velocity vector from Zouf Plan (ZOUF) was used also for Bovec (BOVC).

[16] Velocity vector from Poreč (PORE) was used also for: Ilirska Bistrica (ILIB), Koper (KOPE), Korada (0518), Korada east (KDA2), Malija (0180), Nova Gorica (NOVG), and Pula (PULJ).

As alternatives, an interpolated velocity model and two global velocity models were created to be able to study the impact of using various velocity models to the final coordinates in the network. Velocities from the EPN cumulative solution were used for the reference frame stations and control stations (Graz, Ljubljana, Poreč, Zouf Plan …) and only missing velocities were estimated. Delaunay triangulation based irregular network was created (Figure 9) and each individual velocity component was interpolated (as being a height) by using the Global Mapper software. The global NUVEL-1 [Argus and Gordon 1991] and NUVEL-1A [DeMets et al. 1994] no-net-rotation (NNR) plate motion models were created by the Bernese software.

The comparisons of the three alternative sets of estimated velocities with the “known” velocities in the EUREF densification area (for the reference frame stations and control stations) or with the corresponding adopted velocities (for all other sites) were carried out (see Section 4.4).

The Bernese antenna phase centre variation file was prepared by including the absolute individual antenna calibration models for nine EPN stations[17] and 11 Slovenian CORS network stations (see also Section 2.2). When using type mean instead of individual phase centre corrections, discrepancies up to 1 cm could be expected in the final positions of some of the stations included in our computation, e.g. for Sofia with LEIAR25.R3 LEIT antenna [Araszkiewicz and Völksen 2017].

The new Empirical CODE Orbit Model (System D2X) for dynamical orbit parameters and 2-hour parameter spacing were used for generating standard orbits [Dach et al. 2015]. Average total RMS errors for the orbit fit were up to about 2 mm for all 21 daily sessions; for most of the GPS and GLONASS satellites, this error was below 5 mm.

Observation statistics obtained after importing RINEX data showed some incomplete daily RINEX files, e.g. for the reference frame station Grasse (GRAS) – daily sessions 2700 (only 1940 epochs out of 3140, i.e. 61.8%) and 2710 (1200 epochs out of 2880, i.e. 41.7%), Požega (POZE) – daily sessions 2350 (1200 epochs out of 3000, i.e. 40.0%) and 2440 (1330 epochs out of 2880, i.e. 46.2%), Sarajevo (SRJV) – daily session 2500 (1200 epochs out of 3120, i.e. 38.5%), and Zadar (ZADA) – daily session 2350 (1200 epochs out of 3000, i.e. 40.0%).

Six Zero-Order Network stations and eight reference frame stations were included in the first phase of baselines creation (see also Section 3.3). Only baselines up to 600 km were allowed. The resulting sets of baselines for all 21 daily sessions were analysed and the core network configuration (Figure 5) was defined by using maximum common observations as the primary criterion. In the core network, the average baseline length was 306 km and the median baseline length was 302 km.

The corresponding list of predefined baselines in the core network (BSL file), which were equal for all 21 daily sessions, was used for further phases of baselines creation. Similarly, baselines were created to other complete (with all 21 RINEX files) and incomplete (with missing RINEX files) stations, and finally to the sites occupied for only three daily sessions. In the extended network, the average baseline length was 174 km and the median baseline length was 74 km. A total of 56 different connections generated 972 actual daily session baselines.

The elevation cut-off angle of 3° was used for the receiver clocks synchronization. The same elevation cut-off angle was used also for the phase observation preprocessing. However, for the baselines to Dubrovnik and Poreč (all daily sessions), to Potsdam (daily sessions 2360 and 2370), and to Celje, Radovljica, and Wettzell (daily session 2420) the cut-off angle was increased to 10° and the maximum (allowed) observed−computed value was decreased from 50 cm to 20 cm. In this way, the RMSes of

[17] The EPN stations used in the computation with an absolute individual antenna calibration model were: Bolzano (BZRG), Brussels (BRUX), Bucharest (BUCU), Ohrid (ORID), Penc (PENC), Potsdam (POTS), Rome (M0SE), Sofia (SOFI), and Wettzell (WTZR).

epoch difference solution were below 2 cm and the estimates for the coordinates in the epoch difference solution only reached up to about 10 cm.

The elevation cut-off angle of 3° and an elevation-dependent weighting were used for estimating parameters and saving residuals. Loose constraints were put on the station coordinates available in the IGb08 [Dach and Fridez 2017], i.e. for the reference frame and control stations; a priori sigmas of 5 mm were used for the north and east components, and 10 mm for the up component. A posteriori sigmas of unit weight up to the expected 1.5 mm were obtained for most of the daily sessions; for only three of them (daily sessions 2350, 2420, and 2510) this value was exceeded. The worst was session 2420 with the a posteriori sigma of unit weight equal to 1.8 mm. For all the baselines in all 21 daily sessions, a posteriori sigmas of unit weight were below 3 mm; the worst was baseline Koper–Poreč with an average value of 2.6 mm. A total of 2.1% of observations were removed in this processing step – from 0.9% (daily session 3140) and up to 7.4% (daily session 2420).

The elevation cut-off angle of 3° and an elevation-dependent weighting were used while producing first daily network solutions (float) in order to store the coordinates and troposphere parameters. Loose constraints were put on the station coordinates available in the IGb08 (reference frame and control stations); a priori sigmas of 1 mm were used for the north, east, and up components [Dach and Fridez 2017]. A posteriori sigmas of unit weight between 1.2 mm (ten daily sessions) and 1.4 mm (daily sessions 2350, 2420, and 2510) – 1.27 mm on average – were obtained.

QIF ambiguity resolution strategy was used for long baselines and sigma ambiguity resolution strategy for short baselines. The elevation cut-off angle of 10° was used. The usual 20 km threshold for long baselines was reduced to 5 km for this computation. A posteriori sigmas of unit weight below 2.0 mm were obtained for all baselines except those to Poreč station (PORE) with an average value of nearly 2.2 mm. Also, it could be observed, that dead end baselines to Celje (CELJ), Dubrovnik (DUB2), Ilirska Bistrica (ILIB) and in Józefosław (JOZE) obtained sigmas above the average.

The elevation cut-off angle of 3°, an elevation-dependent weighting, and correct correlation strategy were used when producing final daily network solutions (fixed) to store normal equations. Loose constraints were put on all the station coordinates [Dach and Fridez 2017]; a priori sigmas of 1 cm were used for the north, east, and up components. About 90% of ambiguities on average were resolved and pre-eliminated before the inversion of the normal equations (see also Section 4.1).

The elevation cut-off angle of 3°, an elevation-dependent weighting, and correct correlation strategy were used while producing final daily coordinate and troposphere estimations. Datum for the station coordinates was defined with the minimum constraint solution by using the selected eight reference frame stations (Figure 4). Translations only were used as minimum constraint conditions. A posteriori RMSes of unit weight between 1.25 mm (daily sessions 3130 and 3140) and 1.58 mm (daily session 2420) – 1.36 mm on average – were obtained.

The 10 mm threshold for the north and east components (N, E) and 30 mm for the up component (U) were used [Dach and Fridez 2017] for outlier detection while checking reference coordinates of daily solutions. At the eight reference frame stations in all 21 daily sessions, absolute coordinate differences up to 3.2 mm for the north and east components (N, E) and up to 14.4 mm for the up component (U) were obtained (see also Section 4.3 and Appendix 6).

Velocities of the selected reference frame and control stations, taken directly from the EPN cumulative solution, and velocities for the other sites, adopted from the nearest reference frame or control station (see Figure 8), were used when checking daily coordinate solution repeatability. The mean epoch of the campaign was chosen as the epoch of comparison. GPS derived unweighted coordinate RMS values up to 2.7 mm for the north and east components (N, E) and up to 6.7 mm for the up component (U) were obtained. For all 57 points in all 21 daily sessions, absolute coordinate differences up to 7.2 mm for the north and east components (N, E) and up to 14.9 mm for the up component (U) were obtained (see also Section 4.2 and Appendix 5).

When generating normal equations (with coordinates only), loose constraints were put on all the station coordinates [Dach and Fridez 2017]; a priori sigmas of 1 mm were used for the north, east, and up components.

Velocities of the selected reference frame and control stations, taken directly from the EPN cumulative solution, and velocities for the other sites, adopted from the nearest reference frame or control station (see Figure 8), were used when stacking daily network solutions and producing the final network solution. Other variants of estimating the missing velocities were used only to study the impact of these velocities to the final coordinates in the network (see Section 4.4).

In the final network solution, datum for the station coordinates was defined with the minimum constraint solution by using the selected eight reference frame stations (Figure 4). Translations only were used as minimum constraint conditions. RMS errors up to 0.03 mm were obtained for the north and east components (N, E) and up to 0.12 mm for the up component (U) for all Slovenian SIGNAL and Zero-Order Network stations. For the EUREF points (with only three daily sessions), RMS errors up to 0.08 mm were obtained for the north and east components (N, E) and up to 0.29 mm for the up component (U). The final result of the Bernese processing were coordinates in the IGb08, epoch 2016.75 (without velocities).

At the eight reference frame stations, absolute coordinate differences up to 0.95 mm for the north and east components (N, E) and up to 2.66 mm for the up component (U) were obtained, when checking reference coordinates of final network solution (see also Section 4.5, Graph 2). At the 19 control stations, absolute coordinate differences up to 2.84 mm for the north and east components (N, E) and up to 4.78 mm for the up component (U) were obtained (see also Section 4.5, Graph 3).

3.5 Transformation Procedure

The final campaign solution in the IGb08, epoch 2016.75, was transformed into the ETRF2000, epoch 2016.75. The procedure consists of the following two steps:

- transformation of coordinates from the ITRF2008 into the ITRF2000 (COOSYS), and
- transformation of coordinates from the ITRF2000 into the ETRF2000 (ETRS89).

The transformation from the ITRF2008 to the ITRF2000 is defined by the equation [Boucher and Altamimi 2011]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2000} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2008} + \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} + \begin{bmatrix} D & -R_z & R_y \\ R_z & D & -R_x \\ -R_y & R_x & D \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2008}$$

The transformation parameters from the ITRF2008 to the ITRF2000 can be determined from the parameters for the epoch 2000.0 [ITRF2008-ITRF2000 2018]:

Transformation parameters from ITRF2008 to:

SOLUTION	Tx	Ty	Tz	D	Rx	Ry	Rz	EPOCH
UNITS---------->	mm	mm	mm	ppb	.001"	.001"	.001"	
	.	.	.	.	.	.	.	
RATES	Tx	Ty	Tz	D	Rx	Ry	Rz	
UNITS---------->	mm/y	mm/y	mm/y	ppb/y	.001"/y	.001"/y	.001"/y	
ITRF2000	-1.9	-1.7	-10.5	1.34	0.00	0.00	0.00	2000.0
rates	0.1	0.1	-1.8	0.08	0.00	0.00	0.00	

The parameters for the epoch t (2016.75) can be calculated as $P(t) = P(2000.0) + \dot{P} \cdot (t - 2000.0)$ and the resulting parameters are as follows:

```
Transformation parameters from ITRF2008 to:
---------------------------------------------------------------------------------------
SOLUTION          Tx       Ty       Tz        D        Rx       Ry       Rz      EPOCH
UNITS----------> mm       mm       mm        ppb      .001"    .001"    .001"
---------------------------------------------------------------------------------------
  ITRF2000      -0.225   -0.025   -40.65     2.68     0.00     0.00     0.00   2016.75
```

The transformation from the ITRF2000 to the ETRF2000 is defined by the equation [Boucher and Altamimi 2011]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ETRF2000} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2000} + \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} + \begin{bmatrix} 0 & -R_z & R_y \\ R_z & 0 & -R_x \\ -R_y & R_x & 0 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2000} \cdot (t - 1989.0)$$

The transformation parameters from the ITRF2000 to the ETRF2000 can be determined from the parameters for the epoch 2000.0 [Boucher and Altamimi 2011]:

```
Transformation parameters from ITRF2000 to:
---------------------------------------------------------------------------------------
SOLUTION          Tx       Ty       Tz        D        Rx       Ry       Rz      EPOCH
UNITS----------> mm       mm       mm        ppb      .001"    .001"    .001"
                  .        .        .         .        .        .        .
       RATES      Tx       Ty       Tz        D        Rx       Ry       Rz
UNITS----------> mm/y     mm/y     mm/y      ppb/y   .001"/y  .001"/y  .001"/y
---------------------------------------------------------------------------------------
  ETRF2000        54.0     51.0    -48.0      0.00     0.891    5.390   -8.712   2000.0
       rates       0.0      0.0      0.0      0.00     0.081    0.490   -0.792
```

The parameters for the epoch t (2016.75) can be calculated as $P(t) = P(2000.0) + \dot{P} \cdot (t - 2000.0)$ and the resulting parameters are as follows:

```
Transformation parameters from ITRF2000 to:
---------------------------------------------------------------------------------------
SOLUTION          Tx       Ty       Tz        D        Rx       Ry       Rz      EPOCH
UNITS----------> mm       mm       mm        ppb      .001"    .001"    .001"
---------------------------------------------------------------------------------------
  ETRF2000        54.0     51.0    -48.0      0.00     2.24775  13.5975  -21.978  2016.75
```

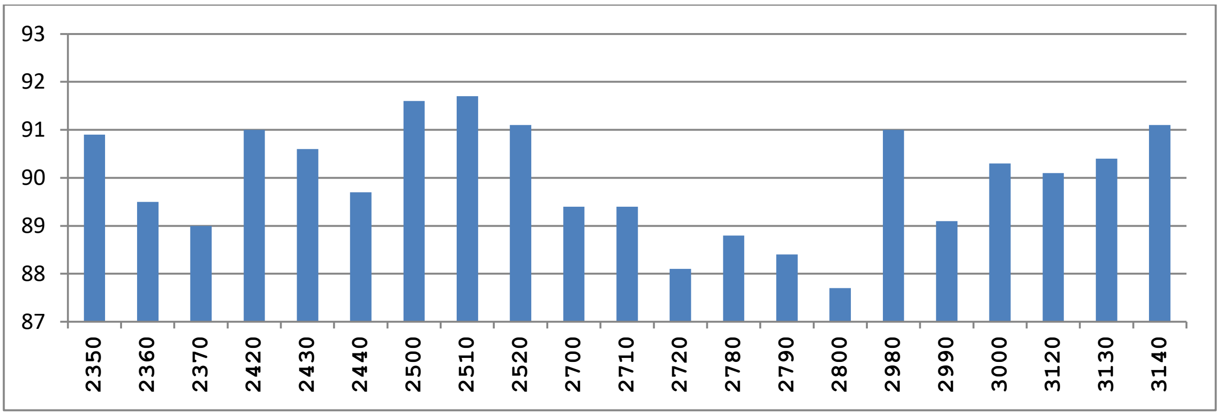
The EPN transformation service [ETRF/ITRF 2017] was used to check these coordinate transformations.

4 Analyses of the Computation Results

Various analyses were performed to check the quality of the results of the campaign solution and to check the coordinate differences between the new and the previous campaign(s).

4.1 Checking of Daily Mean Ambiguity Resolutions Percentages

Mean ambiguity resolution percentages were calculated for each daily session for GPS + GLONAS observations. The results are given in Graph 1.



Graph 1: Mean ambiguity resolutions for all daily sessions [%]

Percentages of resolved ambiguities varied between:

- 87.8% for daily session 2800, and
- 91.7% for daily session 2510.

4.2 Checking of Daily Coordinate Solution Repeatability

The coordinates from each individual final minimum constraint daily solution were compared with the mean/combined coordinates in the mean epoch of the campaign (2016.75) as the epoch of comparison.

Graphs with coordinate differences for each daily session are given in **Appendix 5**.

These extreme coordinate RMSes were obtained:

- 2.5 mm in the north component (N) for Bovec (BOVC),
- 2.5 mm in the east component (E) for Ilirska Bistrica (ILIB), and
- 6.4 mm in the up component (U) for Bovec (BOVC).

These extreme coordinate differences were obtained:

- 4.9 mm in the north component (N) for Bovec (BOVC) in daily session 3000,
- −7.2 mm in the east component (E) for Bovec (BOVC) in daily session 2500, and
- 14.9 mm in the up component (U) for Bovec (BOVC) in daily session 2350.

4.3 Checking Daily Coordinates of Reference Frame Stations

The coordinates of reference frame stations from each individual final minimum constraint daily solution were compared with the (reference) coordinates in the IGb08, epoch 2016.75, transformed from the EPN cumulative solution with the release name EPN_A_IGb08_C1934.

Graphs with coordinate differences for each daily session are given in **Appendix 6**.

These extreme coordinate differences were obtained:

- 3.2 mm in the north component (N) for Józefosław (JOZE) in daily sessions 2720,
- 3.2 mm in the east component (E) for Graz (GRAZ) in daily session 2420, and
- 14.4 mm in the up component (U) for Graz (GRAZ) in daily session 3130.

4.4 Checking the Impact of Different Velocity Models on the Final Coordinates

The coordinates of points without velocities (all except reference frame and control stations) in the final minimum constraint network solution in the IGb08, epoch 2016.75, were determined by using velocities, adopted from the nearest reference frame or control station (see Figure 8). Alternatively, the missing velocities were determined by using:

- the linear interpolation in a triangulated irregular network (Figure 9),
- the global NUVEL-1 NNR plate motion model [Argus and Gordon 1991], and
- the global NUVEL-1A NNR plate motion model [DeMets et al. 1994].

The largest differences between the adopted and interpolated velocities were 1.06 mm/y for Korada (0518) and Korada east (KDA2), 0.88 mm/y for Golica (0516), and 0.82 mm/y for Nova Gorica (NOVG) – all in the north component (N). The maximum absolute coordinate differences obtained when using interpolated velocities reached 0.01 mm in all three components (N, E, U).

For both sets of NUVEL-model-based velocities, an analysis of their quality was carried out by comparison for the stations on the EUREF densification area with "known" velocities (i.e. Graz, Ljubljana, Poreč, and Zouf Plan – see Figure 9).

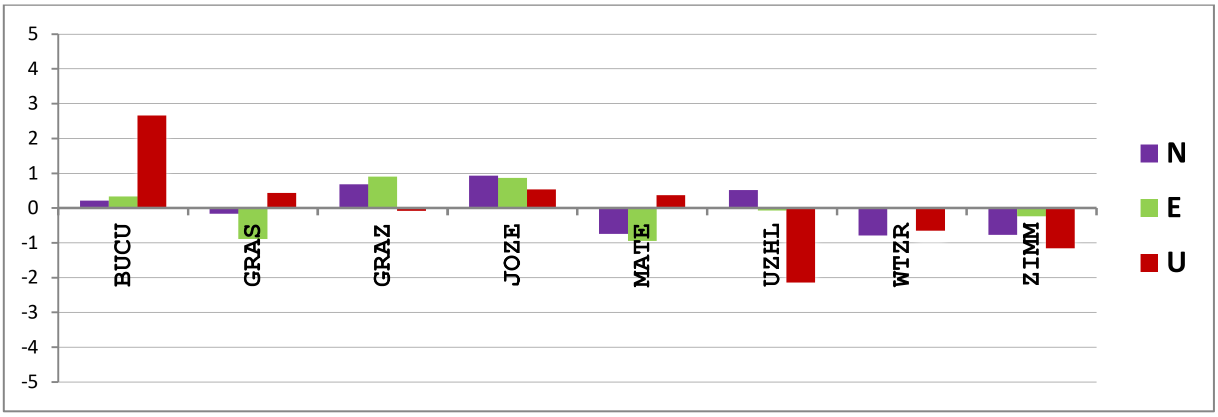
The largest absolute differences between the IGb08/C1934 and NUVEL-1 NNR velocities were 4.19 mm/y (23.1% error) for Poreč (PORE), 3.53 mm/y (20.4% error) for Ljubljana (GSR1), 2.29 mm/y (14.0% error) for Zouf Plan (ZOUF), and 2.16 mm/y (13.7% error) for Graz (GRAZ) – all in the north component (N). The largest coordinate differences obtained when using NUVEL-1 NNR velocities reached 0.17 mm for Malija (180), −0.15 mm for Kamenek (0387), −0.13 mm for Golica (0516), and 0.12 mm for Korada (0518) – all in the north component (N).

The largest absolute differences between the IGb08/C1934 and NUVEL-1A NNR velocities were 4.80 mm/y (26.5% error) for Poreč (PORE), 4.13 mm/y (23.9% error) for Ljubljana (GSR1), 2.90 mm/y (17.7% error) for Zouf Plan (ZOUF), and 2.76 mm/y (17.5% error) for Graz (GRAZ) – all in the north component (N). The largest coordinate differences obtained when using NUVEL-1A NNR velocities reached 0.20 mm for Malija (0180), −0.17 mm for Kamenek (0387), −0.15 mm for Golica (0516), and 0.13 mm for Korada (0518) – all in the north component (N).

The analyses show that there is practically no differences in final coordinates of the network points when using either adopted or interpolated velocities. However, coordinate differences up to 0.2 mm appeared when using velocities, estimated through global NUVEL NNR plate motion models; up to 27% errors were detected in the north component of the velocity vectors.

4.5 Checking Final Coordinates of Reference Frame Stations and Control Stations

The coordinates of reference frame stations and control stations from the final minimum constraint network solution in the IGb08, epoch 2016.75, were directly compared with the (reference) coordinates in the IGb08, epoch 2016.75, transformed from the EPN cumulative solution with the release name EPN_A_IGb08_C1934. The results are given in Graphs 2 and 3.



Graph 2: Coordinate differences at the reference frame stations [mm]

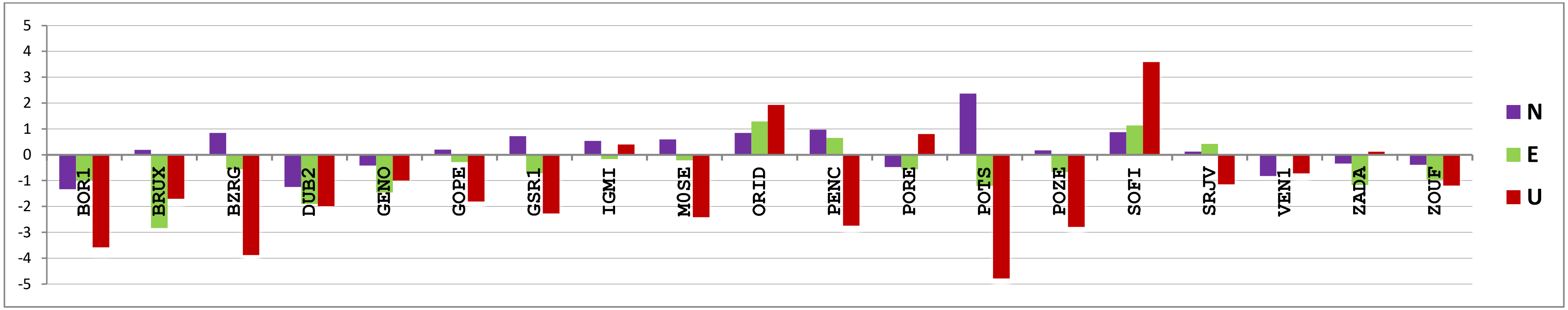
These average absolute coordinate differences were obtained for the reference frame stations:

- 0.60 mm in the north component (N),
- 0.53 mm in the east component (E), and
- 1.00 mm in the up component (U).

These extreme coordinate differences were obtained for the reference frame stations:

- 0.93 mm in the north component (N) for Józefosław (JOZE),
- −0.95 mm in the east component (E) for Matera (MATE), and
- 2.66 mm in the up component (U) for Bucharest (BUCU).

Coordinate differences in Graz (GRAZ), which is the closest reference frame station to the EUREF densification area, reached 0.68 mm in the north component (N), 0.90 mm in the east component (E), and −0.08 mm in the up component (U).



Graph 3: Coordinate differences at the control stations [mm]

These average absolute coordinate differences were obtained for the control stations:

- 0.71 mm in the north component (N),
- 0.91 mm in the east component (E), and
- 2.04 mm in the up component (U).

These extreme coordinate differences were obtained for the control stations:

- 2.37 mm in the north component (N) for Potsdam (POTS),
- −2.84 mm in the east component (E) for Brussels (BRUX), and
- −4.78 mm in the up component (U) for Potsdam (POTS).

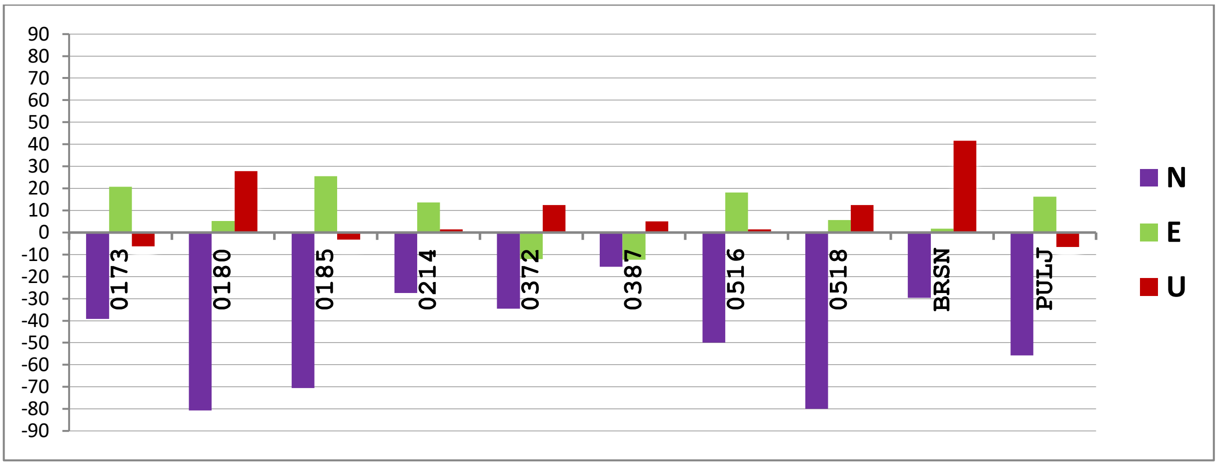
Coordinate differences in Ljubljana (GSR1), which is located in the centre of the EUREF densification area, reached 0.72 mm in the north component (N), −0.72 mm in the east component (E), and −2.27 mm in the up component (U).

4.6 Comparison of Coordinates of EUREF Points from the Previous Densification

The coordinates of EUREF points (already used in the previous EUREF campaigns) from the final network solution in the IGb08/ETRF2000 (ETRS89/D17) were compared with the (official) coordinates in the ITRF96/ETRF96 (ETRS89/D96). Ten points were available, which have both triplets of coordinates (Figure 10).

Figure 10: The selected ten EUREF points used in this computation

Both EUREF points located in Croatia – Brusnik (BRSN) and Pula (PULJ) – were used only as control points[18]. The comparison results are given in Graphs 4–8.



Graph 4: Coordinate differences from the direct comparison [mm]

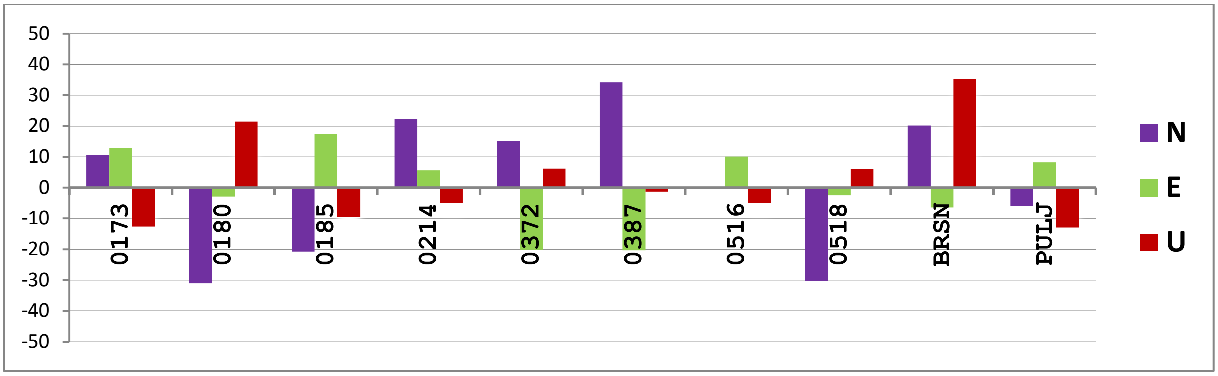
[18] It means that these two points were not involved in defining the transformation parameters (fitting) – see Graphs 5–8 and the final D96↔D17 transformation. This decision was made due to outstanding differences in all three components (N, E, U). Similar comparisons were carried out with sets of coordinates reduced to the surface of the GRS80 ellipsoid (h = 0). Both analyses showed that the presence of Brusnik and Pula would increase RMSes of best-fit D96↔D17 transformations.

These extreme coordinate differences were obtained:

- −80.8 mm in the north component (N) for Malija (0180),
- 25.5 mm in the east component (E) for Cerk (0185), and
- 41.6 mm in the up component (U) for Brusnik (BRSN).

In order to remove the trend caused by the different origin (ITRFs) of both ETRS89 realizations and to (maybe) find some evidence of internal deformations in the area considered, four different transformations were used:

- 3-parametric shifts-only transformation,
- 3-parametric rotations-only transformation,
- 6-parametric 3D rigid transformation, and
- 7-parametric 3D similarity (Helmert) transformation.

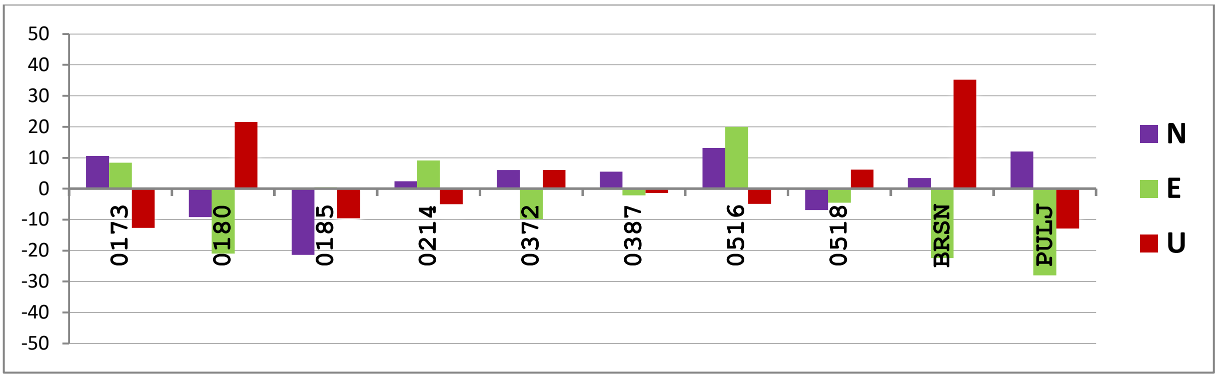


Graph 5: Coordinate differences after best-fit shifts [mm]

These extreme coordinate differences were obtained after best-fit shifts:

- 34.2 mm in the north component (N) for Kamenek (0387),
- −20.4 mm in the east component (E) for Kamenek (0387), and
- 35.2 mm in the up component (U) for Brusnik (BRSN).

The RMS of best-fit shifts-only transformation was 17.7 mm.

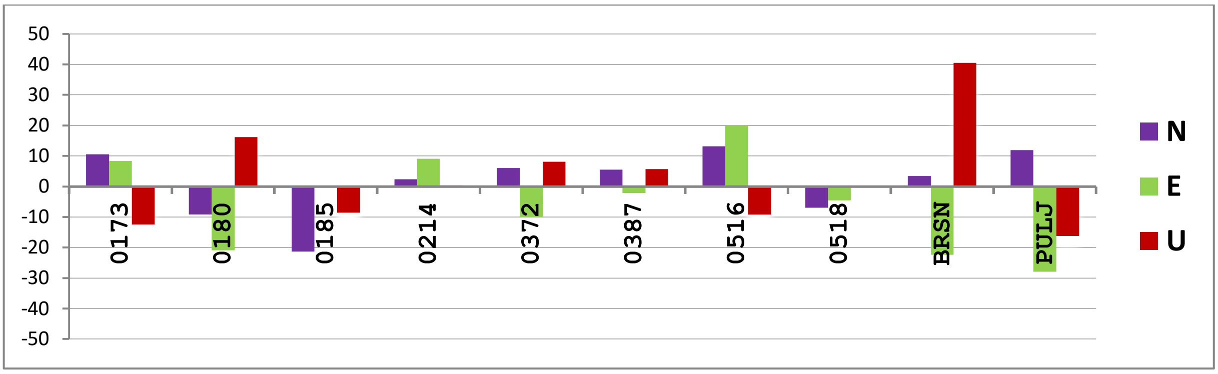


Graph 6: Coordinate differences after best-fit rotations [mm]

These extreme coordinate differences were obtained after best-fit rotations:

- −21.4 mm in the north component (N) for Cerk (0185),
- −28.0 mm in the east component (E) for Pula (PULJ), and
- 35.1 mm in the up component (U) for Brusnik (BRSN).

The RMS of best-fit rotations-only transformation was 12.7 mm.

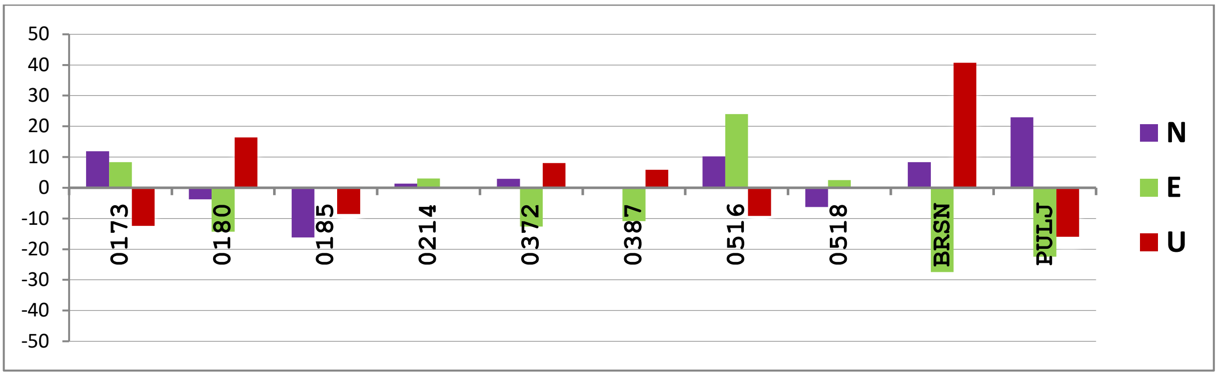


Graph 7: Coordinate differences after best-fit rigid transformation [mm]

These extreme coordinate differences were obtained after best-fit rigid transformation:

- −21.4 mm in the north component (N) for Cerk (0185),
- −27.9 mm in the east component (E) for Pula (PULJ), and
- 40.6 mm in the up component (U) for Brusnik (BRSN).

The RMS of best-fit rigid transformation was 12.3 mm.



Graph 8: Coordinate differences after best-fit similarity transformation [mm]

These extreme coordinate differences were obtained after best-fit similarity transformation:

- 23.0 mm in the north component (N) for Pula (PULJ),
- 24.0 mm in the east component (E) for Golica (0516), and
- 40.6 mm in the up component (U) for Brusnik (BRSN).

RMS of the best-fit similarity transformation was 11.9 mm.

The direct comparison of the two realizations showed coordinate differences exceeding 8 cm, especially featured in the north component (U) with 5 cm on average. However, by applying the best-fit rigid or similarity transformation, the coordinate differences between the two realizations of the ETRS89 (D96 and D17) were reduced for the selected eight Slovenian EUREF points to about 2.4 cm in all three components (N, E, U).

As the connection between the old (D96) and new (D17) realizations of the ETRS89 in Slovenia, the best-fit 7-parametric 3D similarity transformation (see Graph 8) is proposed, following examples used in some other countries [e.g. Häkli et al. 2016, Altiner and Perlt 2018]. The direct parameters are as follows:

```
Transformation parameters from ITRF96/ETRF96 (D96) to:
-------------------------------------------------------------------------------------------
SOLUTION                    Tx        Ty        Tz        D        Rx        Ry        Rz
UNITS---------->            mm        mm        mm        ppb      .001"     .001"     .001"
-------------------------------------------------------------------------------------------
  IGb08/ETRF2000 (D17)    232.96    523.29    331.19    -77.55    24.567    9.042    48.136
```

The inverse parameters are as follows:

```
Transformation parameters from IGb08/ETRF2000 (D17) to:
-------------------------------------------------------------------------------------------
SOLUTION                    Tx        Ty        Tz        D        Rx        Ry        Rz
UNITS---------->            mm        mm        mm        ppb      .001"     .001"     .001"
-------------------------------------------------------------------------------------------
  ITRF96/ETRF96 (D96)    -232.96   -523.28   -331.19    77.55   -24.567   -9.042   -48.136
```

It should be noticed that the EUREF strategy for the future realizations of the ETRS89 is focusing on the cross-boundary consistency based on the homogeneous dense European velocity model [Bruyninx et al. 2017].

5 Summary

First results of the computation of the EUREF Slovenia 2016 GNSS Campaign are presented. Only subsets of all the sites and daily sessions of the campaign were included in the computation for the purpose of the validation of this EUREF densification by the EUREF GB.

The frame of the realization of this computation is a solution delivered in the IGb08/ETRF2000, which is considered a EUREF densification (improvement) of the ETRS89 in Slovenia referred to as the ETRS89/D17. The coordinates from the final network solution in the IGb08/ETRF2000 (ETRS89/D17) were compared with the (official) coordinates in the ITRF96/ETRF96 (ETRS89/D96).

Ten points were available, which have both (D96 and D17) triplets of coordinates. The direct comparison of the two realizations showed coordinate differences exceeding 8 cm. However, when applying the best-fit similarity transformation, coordinate differences between the two realizations of the ETRS89 in Slovenia reached only up to 24 mm in all three components (N, E, U); the RMS of this transformation was 12 mm.

Deliverables of the computation of the EUREF Slovenia 2016 GNSS Campaign are explained in detail in **Appendix 7**.

Acknowledgements

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List of Appendices

Appendix 1

Series and Daily Sessions of the EUREF Slovenia 2016 GNSS Campaign

			Beginning		Ending	
Series	**Session no.**	**Day of year**	**Date**	**UTC**	**Date**	**UTC**
1st	1	235	22.08.2016	09:00	23.08.2016	10:00
1st	2	236	23.08.2016	10:00	24.08.2016	10:00
1st	3	237	24.08.2016	10:00	25.08.2016	10:00
1st intermediate	1	238	25.08.2016	10:00	26.08.2016	10:00
1st intermediate	2	239	26.08.2016	10:00	27.08.2016	10:00
1st intermediate	3	240	27.08.2016	10:00	28.08.2016	10:00
1st intermediate	4	241	28.08.2016	10:00	29.08.2016	08:30
2nd	1	242	29.08.2016	08:30	30.08.2016	10:00
2nd	2	243	30.08.2016	10:00	31.08.2016	10:00
2nd	3	244	31.08.2016	10:00	01.09.2016	10:00
2nd intermediate	1	245	01.09.2016	10:00	02.09.2016	10:00
2nd intermediate	2	246	02.09.2016	10:00	03.09.2016	10:00
2nd intermediate	3	247	03.09.2016	10:00	04.09.2016	10:00
2nd intermediate	4	248	04.09.2016	10:00	05.09.2016	10:00
2nd intermediate	5	249	05.09.2016	10:00	06.09.2016	08:00
3rd	1	250	06.09.2016	08:00	07.09.2016	10:00
3rd	2	251	07.09.2016	10:00	08.09.2016	10:00
3rd	3	252	08.09.2016	10:00	09.09.2016	10:00
3rd intermediate	1	253	09.09.2016	10:00	10.09.2016	10:00
3rd intermediate	2	254	10.09.2016	10:00	11.09.2016	10:00
3rd intermediate	3	255	11.09.2016	10:00	12.09.2016	08:30
4th	1	256	12.09.2016	08:30	13.09.2016	10:00
4th	2	257	13.09.2016	10:00	14.09.2016	10:00
4th	3	258	14.09.2016	10:00	15.09.2016	10:00
4th intermediate	1	259	15.09.2016	10:00	16.09.2016	10:00
4th intermediate	2	260	16.09.2016	10:00	17.09.2016	10:00
4th intermediate	3	261	17.09.2016	10:00	18.09.2016	10:00
4th intermediate	4	262	18.09.2016	10:00	19.09.2016	10:00
4th intermediate	5	263	19.09.2016	10:00	20.09.2016	10:00
4th intermediate	6	264	20.09.2016	10:00	21.09.2016	10:00
4th intermediate	7	265	21.09.2016	10:00	22.09.2016	10:00
4th intermediate	8	266	22.09.2016	10:00	23.09.2016	10:00
4th intermediate	9	267	23.09.2016	10:00	24.09.2016	10:00
4th intermediate	10	268	24.09.2016	10:00	25.09.2016	10:00
4th intermediate	11	269	25.09.2016	10:00	26.09.2016	07:50
5th	1	270	26.09.2016	07:50	27.09.2016	10:00
5th	2	271	27.09.2016	10:00	28.09.2016	10:00
5th	3	272	28.09.2016	10:00	29.09.2016	10:00
5th intermediate	1	273	29.09.2016	10:00	30.09.2016	10:00
5th intermediate	2	274	30.09.2016	10:00	01.10.2016	10:00
5th intermediate	3	275	01.10.2016	10:00	02.10.2016	10:00
5th intermediate	4	276	02.10.2016	10:00	03.10.2016	10:00
5th intermediate	5	277	03.10.2016	10:00	04.10.2016	07:30
6th	1	278	04.10.2016	07:30	05.10.2016	10:00
6th	2	279	05.10.2016	10:00	06.10.2016	10:00
6th	3	280	06.10.2016	10:00	07.10.2016	10:00

			Beginning		Ending	
Series	Session no.	Day of year	Date	UTC	Date	UTC
6th intermediate	1	281	07.10.2016	10:00	08.10.2016	10:00
6th intermediate	2	282	08.10.2016	10:00	09.10.2016	10:00
6th intermediate	3	283	09.10.2016	10:00	10.10.2016	10:00
6th intermediate	4	284	10.10.2016	10:00	11.10.2016	08:00
7th	1	285	11.10.2016	08:00	12.10.2016	10:00
7th	2	286	12.10.2016	10:00	13.10.2016	10:00
7th	3	287	13.10.2016	10:00	14.10.2016	10:10
7th intermediate	1	288	14.10.2016	10:10	15.10.2016	10:00
7th intermediate	2	289	15.10.2016	10:00	16.10.2016	10:00
7th intermediate	3	290	16.10.2016	10:00	17.10.2016	10:00
7th intermediate	4	291	17.10.2016	10:00	18.10.2016	10:00
7th intermediate	5	292	18.10.2016	10:00	19.10.2016	10:00
7th intermediate	6	293	19.10.2016	10:00	20.10.2016	10:00
7th intermediate	7	294	20.10.2016	10:00	21.10.2016	10:00
7th intermediate	8	295	21.10.2016	10:00	22.10.2016	10:00
7th intermediate	9	296	22.10.2016	10:00	23.10.2016	10:00
7th intermediate	10	297	23.10.2016	10:00	24.10.2016	07:50
8th	1	298	24.10.2016	07:50	25.10.2016	10:00
8th	2	299	25.10.2016	10:00	26.10.2016	10:00
8th	3	300	26.10.2016	10:00	27.10.2016	11:40
8th intermediate	1	301	27.10.2016	11:40	28.10.2016	10:00
8th intermediate	2	302	28.10.2016	10:00	29.10.2016	10:00
8th intermediate	3	303	29.10.2016	10:00	30.10.2016	11:00
8th intermediate	4	304	30.10.2016	11:00	31.10.2016	11:00
8th intermediate	5	305	31.10.2016	11:00	01.11.2016	11:00
8th intermediate	6	306	01.11.2016	11:00	02.11.2016	11:00
8th intermediate	7	307	02.11.2016	11:00	03.11.2016	11:00
8th intermediate	8	308	03.11.2016	11:00	04.11.2016	11:00
8th intermediate	9	309	04.11.2016	11:00	05.11.2016	11:00
8th intermediate	10	310	05.11.2016	11:00	06.11.2016	11:00
8th intermediate	11	311	06.11.2016	11:00	07.11.2016	09:00
9th	1	312	07.11.2016	09:00	08.11.2016	11:00
9th	2	313	08.11.2016	11:00	09.11.2016	11:00
9th	3	314	09.11.2016	11:00	10.11.2016	11:20

Appendix 2

Sites Included into the EUREF Slovenia 2016 GNSS Campaign

Station name	4-ID	2-ID	Remark
****************	****	**	**************************************
0173 KUCELJ	0173	07	Kucelj, EUREF 722
0180 MALIJA	0180	12	Malija, EUREF 724
0185 CERK	0185	14	Cerk, EUREF NN
0214 DONAC. G.	0214	16	Donačka gora, EUREF NN
0372 VEL. KOPA	0372	19	Velika Kopa, EUREF 721
0387 KAMENEK	0387	26	Kamenek, EUREF NN
0516 GOLICA	0516	29	Golica, EUREF NN
0518 KORADA	0518	31	Korada, EUREF 723
ARA2 14503M002	ARA2	K1	Areh east, 0-Order Network
BODO BODONCI	BODO	S1	Bodonci, SIGNAL
BOR1 12205M002	BOR1	I1	Borówiec, Poland, IGS
BOVC BOVEC	BOVC	S2	Bovec, SIGNAL
BRSN BRUSNIK	BRSN	G1	Brusnik, Croatia, EUREF 727
BRUX 13101M010	BRUX	I2	Brussels, Belgium, IGS
BRZC BREZICE	BRZC	S3	Brežice, SIGNAL
BUCU 11401M001	BUCU	I3	Bucharest, Romania, IGS
BZRG 12751M001	BZRG	I4	Bolzano, Italy, IGS
CELJ CELJE	CELJ	S4	Celje, SIGNAL
CRNO CRNOMELJ	CRNO	S5	Črnomelj, SIGNAL
DUB2 11901M002	DUB2	E2	Dubrovnik, Croatia, EPN & CROPOS
GENO 12712M002	GENO	I7	Genoa, Italy, IGS
GOPE 11502M002	GOPE	I8	Pecný, Ondřejov, Czechia, IGS
GRAS 10002M006	GRAS	I9	Grasse, Caussols, France, IGS
GRAZ 11001M002	GRAZ	IA	Graz, Austria, IGS
GSR1 14501M001	GSR1	S6	Ljubljana, EPN & SIGNAL
IDRI IDRIJA	IDRI	S7	Idrija, SIGNAL
IGMI 12701M003	IGMI	E3	Florence, Italy, EPN
ILIB I. BISTR.	ILIB	S8	Ilirska Bistrica, SIGNAL
JOZE 12204M001	JOZE	IB	Józefosław, Poland, IGS
KDA2 14504M002	KDA2	K4	Korada east, 0-Order Network
KGA1 14505M001	KGA1	K2	Kog, 0-Order Network
KOPE 14502M001	KOPE	K3	Koper, 0-Order Network & SIGNAL
LEND LENDAVA	LEND	S9	Lendava, SIGNAL
M0SE 12772M001	M0SE	IC	Rome, Italy, IGS
MATE 12734M008	MATE	ID	Matera, Italy, IGS
MRBR MARIBOR	MRBR	SA	Maribor, SIGNAL
NOVG N. GORICA	NOVG	SB	Nova Gorica, SIGNAL
ORID 15601M001	ORID	IG	Ohrid, Macedonia, IGS
PENC 11206M006	PENC	II	Penc, Hungary, IGS
PORE 11907M001	PORE	C4	Poreč, Croatia, EPN & CROPOS
POTS 14106M003	POTS	IJ	Potsdam, Germany, IGS
POZE 11908M001	POZE	E4	Požega, Croatia, EPN & CROPOS
PTUJ PTUJ	PTUJ	SC	Ptuj, SIGNAL
PULJ PULA	PULJ	GD	Pula, Croatia, EUREF 729
PZA1 14506M001	PZA1	K5	Prilozje west, 0-Order Network
RDVL RADOVLJ.	RDVL	SD	Radovljica, SIGNAL
SLOG S. GRADEC	SLOG	SE	Slovenj Gradec, SIGNAL
SOFI 11101M002	SOFI	IK	Sofia, Bulgaria, IGS
SRJV 11801S001	SRJV	E6	Sarajevo, Bosnia and Herzegovina, EPN
STA2 14507M002	STA2	K8	Šentvid p. Stični east, 0-Order Network
TRBN TREBNJE	TRBN	SF	Trebnje, SIGNAL
UZHL 12301M001	UZHL	IL	Uzhgorod, Ukraine, IGS
VEN1 19513M001	VEN1	E7	Venice, Italy, EPN
WTZR 14201M010	WTZR	IM	Wettzell, Bad Kötzting, Germany, IGS
ZADA 11905M001	ZADA	E8	Zadar, Croatia, EPN & CROPOS
ZIMM 14001M004	ZIMM	IN	Zimmerwald, Switzerland, IGS
ZOUF 12763M001	ZOUF	E9	Zouf Plan, Cercivento, Italy, EPN

Appendix 3

Data Availability for Sites Included into the EUREF Slovenia 2016 GNSS Campaign

Site name	4ch	2ch	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314
Kucelj	0173	07																																																																																
Malija	0180	12																																																																																
Cerk	0185	14																																																																																
Donačka gora	0214	16																																																																																
Velika Kopa	0372	19																																																																																
Kamenek	0387	26																																																																																
Golica	0516	29																																																																																
Korada	0518	31																																																																																
Areh east, Zero Order	ARA2	K1																																																																																
Bodonci, SIGNAL	BODO	S1																																																																																
Borówiec, EPN, IGS08, PL	BOR1	I1																																																																															
Bovec, SIGNAL	BOVC	S2																																																																																
Brusnik, HR	BRSN	G1																																																																																
Brussels, EPN, IGS, BE	BRUX	I2																																																																																
Brežice, SIGNAL	BRZC	S3																																																																																
Bucharest, EPN, IGS08, RO	BUCU	I3																																																																																
Bolzano, EPN, IGS, IT	BZRG	I4																																																																																
Celje, SIGNAL	CELJ	S4																																																																																
Črnomelj, SIGNAL	CRNO	S5																																																																																
Dubrovnik, CROPOS, EPN, HR	DUB2	E2																																																																																
Genoa, EPN, IGS, IT	GENO	I7																																																																																
Pecný, Ondřejov, EPN, IGS, CZ	GOPE	I8																																																																																
Grasse, Caussols, EPN, IGS08, FR	GRAS	I9																																																																																
Graz, EPN, IGS08, AT	GRAZ	IA																																																																																
Ljubljana, SIGNAL, EPN	GSR1	S6																																																																																
Idrija, SIGNAL	IDRI	S7																																																																																
Florence, EPN, IT	IGMI	E3																																																																																
Ilirska Bistrica, SIGNAL	ILIB	S8																																																																																
Józefosław, EPN, IGS08, PL	JOZE	IB																																																																																
Korada east, Zero Order	KDA2	K4																																																																																
Kog, Zero Order	KGA1	K2																																																																																
Koper, SIGNAL, Zero Order	KOPE	K3																																																																															
Lendava, SIGNAL	LEND	S9																																																																																
Rome, EPN, IGS, IT	MOSE	IC																																																																																
Matera, EPN, IGS08, IT	MATE	ID																																																																																
Maribor, SIGNAL	MRBR	SA																																																																																
Nova Gorica, SIGNAL	NOVG	SB																																																																																
Ohrid, EPN, IGS, MK	ORID	IG																																																																																
Penc, EPN, IGS, HU	PENC	II																																																																																
Poreč, CROPOS, EPN, HR	PORE	C4																																																																																
Potsdam, EPN, IGS08, DE	POTS	IJ																																																																																
Požega, CROPOS, EPN, HR	POZE	E4																																																																																
Ptuj, SIGNAL	PTUJ	SC																																																																																
Pula, HR	PULJ	GD																																																																																
Prilozje west, Zero Order	PZA1	K5																																																																																
Radovljica, SIGNAL	RDVL	SD																																																																																

Site name	4ch	2ch	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314
Slovenj Gradec, SIGNAL	SLOG	SE																																																																															
Sofia, EPN, IGS08, BG	SOFI	IK																																																																															
Sarajevo, EPN, BA	SRJV	E6																																																																															
Šentvid pri Stični east, Zero Order	STA2	K8																																																																															
Trebnje, SIGNAL	TRBN	SF																																																																															
Uzhgorod, EPN, IGS08, UA	UZHL	IL																																																																															
Venice, EPN, IT	VEN1	E7																																																																															
Wettzell, Bad Kötzting, EPN, IGS08, DE	WTZR	IM																																																																																
Zadar, CROPOS, EPN, HR	ZADA	E8																																																																																
Zimmerwald, EPN, IGS08, CH	ZIMM	IN																																																																																
Zouf Plan, Cercivento, EPN, IT	ZOUF	E9																																																																																	

Appendix 4

GNSS Equipment Used in the EUREF Slovenia 2016 GNSS Campaign

BERNESE V.5.2 STA FILE FOR EUREF GNSS CAMPAIGN PROCESSING 20-MAR-18 15:08

TYPE 002: STATION INFORMATION

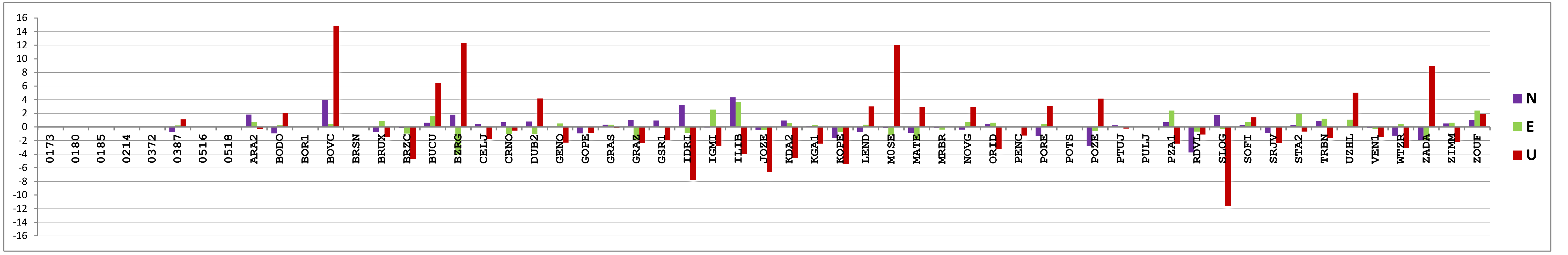
STATION NAME	FLG	FROM	TO	RECEIVER TYPE	RECEIVER SERIAL NBR	REC #	ANTENNA TYPE	ANTENNA SERIAL NBR	ANT #	NORTH	EAST	UP
****************	***	YYYY MM DD HH MM SS	YYYY MM DD HH MM SS	********************	********************	******	********************	********************	******	***.****	***.****	***.****
0173 KUCELJ	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.1205
0180 MALIJA	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.6000
0185 CERK	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.1208
0214 DONAC. G.	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.3107
0372 VEL. KOPA	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.1233
0387 KAMENEK	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.1223
0516 GOLICA	001	2016 08 22 09 00 00	2016 11 10 11 20 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.1250
0518 KORADA	001	2016 10 24 10 00 00	2016 10 27 11 40 00	JAVAD TR_LS2	999999	999999	JAV_RINGANT_G3T NONE	999999	999999	0.0000	0.0000	0.1185
ARA2 14503M002	001	2015 11 16 12 00 00		LEICA GR25	31178	31178	LEIAR20 LEIM	31002	31002	0.0007	-0.0006	0.0800
BODO BODONCI	001	2016 06 02 14 00 00		TRIMBLE NETR9	50227	999999	TRM57971.00 TZGD	999999	999999	0.0000	0.0000	0.0650
BOR1 12205M002	001	2016 10 05 11 00 00	2017 02 21 00 00 00	TRIMBLE NETR9	48510	999999	TRM59800.00 NONE	999999	999999	0.0000	0.0000	0.0622
BOVC BOVEC	001	2008 01 10 10 40 00		TRIMBLE NETR5	05590	999999	TRM55971.00 TZGD	36590	999999	0.0000	0.0000	0.0650
BRSN BRUSNIK	001	2016 08 22 09 00 00	2016 11 10 11 20 00	TRIMBLE R8 GNSS	999999	999999	TRMR8_GNSS NONE	999999	999999	0.0000	0.0000	0.1266
BRUX 13101M010	001	2012 01 31 14 00 00		SEPT POLARX4TR	01376	1376	JAVRINGANT_DM NONE	00464	464	0.0010	0.0000	0.4689
BRZC BREZICE	001	2016 05 31 12 30 00		TRIMBLE NETR9	50001	999999	TRM57971.00 TZGD	17291	999999	0.0000	0.0000	0.0650
BUCU 11401M001	001	2008 10 31 10 00 00		LEICA GRX1200GGPRO	55368	55368	LEIAT504GG LEIS	00456	456	0.0000	0.0000	0.0970
BZRG 12751M001	001	2015 07 17 00 00 00		LEICA GRX1200+GNSS	54401	999999	LEIAR25.R4 LEIT	25220	25220	0.0000	0.0000	0.2120
CELJ CELJE	001	2012 01 09 14 30 00		LEICA GRX1200+GNSS	59190	999999	LEIAR10 NONE	999999	999999	0.0000	0.0000	0.0650
CRNO CRNOMELJ	001	2007 09 13 07 00 00		TRIMBLE NETR5	02873	999999	TRM55971.00 TZGD	999999	999999	0.0000	0.0000	0.0650
DUB2 11901M002	001	2015 07 16 00 00 00	2017 01 23 00 00 00	TRIMBLE NETR5	02946	999999	TRM55971.00 TZGD	999999	999999	0.0000	0.0000	0.0000
GENO 12712M002	001	2013 05 21 14 00 00		TRIMBLE 4700	03888	999999	TRM29659.00 NONE	999999	999999	0.0000	0.0000	0.0000
GOPE 11502M002	001	2009 12 14 10 30 00		TPS NETG3	01308	999999	TPSCR.G3 TPSH	999999	999999	0.0000	0.0000	0.1114
GRAS 10002M006	001	2010 05 19 13 00 00		TRIMBLE NETR5	64043	999999	ASH701945E_M NONE	999999	999999	0.0000	0.0000	0.0350
GRAZ 11001M002	001	2010 05 18 09 00 00	2016 10 20 10 50 59	LEICA GRX1200+GNSS	95524	999999	LEIAR25.R3 LEIT	999999	999999	0.0000	0.0000	1.9640
GRAZ 11001M002	001	2016 10 20 10 51 00		LEICA GRX1200+GNSS	95524	999999	LEIAR25.R4 LEIT	999999	999999	0.0000	0.0000	1.9640
GSR1 14501M001	001	2016 08 03 10 00 00		LEICA GRX1200GGPRO	56151	999999	LEIAT504GG LEIS	00862	999999	0.0000	0.0000	0.0650
IDRI IDRIJA	001	2014 01 17 12 00 00		LEICA GRX1200+GNSS	97035	999999	LEIAR10 NONE	999999	999999	0.0000	0.0000	0.0650
IGMI 12701M003	001	2016 07 21 09 00 00		TPS ODYSSEY_E	00849	999999	TPSCR.G3 TPSH	999999	999999	0.0000	0.0000	0.0015
ILIB I. BISTR.	001	2013 10 16 13 30 00		TRIMBLE NETR9	41176	999999	TRM57971.00 TZGD	16959	999999	0.0000	0.0000	0.0650
JOZE 12204M001	001	2009 05 21 12 00 00		TRIMBLE 4000SSI	27500	999999	TRM14532.00 NONE	999999	999999	0.0000	0.0000	0.1980
KDA2 14504M002	001	2016 01 02 10 00 00		LEICA GR25	31167	31167	LEIAR20 LEIM	27013	27013	0.0008	0.0005	0.0800
KGA1 14505M001	001	2015 06 30 12 00 00		LEICA GR25	31028	31028	LEIAR20 LEIM	31001	31001	0.0000	-0.0004	0.0800
KOPE 14502M001	001	2015 11 06 12 00 00		LEICA GR25	31511	31511	LEIAR20 LEIM	31007	31007	0.0000	0.0000	0.0650
LEND LENDAVA	001	2015 10 16 16 15 00		LEICA GRX1200+GNSS	59182	999999	LEIAT504 LEIS	01279	999999	0.0000	0.0000	0.0650
M0SE 12772M001	001	2013 10 01 00 00 00		LEICA GR25	30126	30126	LEIAR25.R4 LEIT	25219	25219	0.0000	0.0000	0.0000
MATE 12734M008	001	2008 11 24 00 00 00	2017 07 04 09 00 00	LEICA GRX1200GGPRO	55893	999999	LEIAT504GG NONE	999999	999999	0.0000	0.0000	0.1010
MRBR MARIBOR	001	2015 01 26 09 05 00		LEICA GRX1200GGPRO	56161	999999	LEIAT504GG LEIS	00876	999999	0.0000	0.0000	0.0650
NOVG N. GORICA	001	2013 05 29 05 00 00		LEICA GRX1200+GNSS	56151	999999	LEIAR10 NONE	999999	999999	0.0000	0.0000	0.0650
ORID 15601M001	001	2008 11 06 07 00 00		LEICA GRX1200GGPRO	55361	55361	LEIAT504GG LEIS	00627	627	0.0000	0.0000	0.0640
PENC 11206M006	001	2010 12 03 10 35 00		LEICA GRX1200GGPRO	56488	56488	LEIAT504GG LEIS	00219	219	0.0000	0.0000	0.0300
PORE 11907M001	001	2008 12 09 00 00 00		TRIMBLE NETR5	53354	999999	TRM55971.00 TZGD	999999	999999	0.0000	0.0000	0.0000
POTS 14106M003	001	2011 02 15 17 00 00		JAVAD TRE_G3TH DELTA	00205	999999	JAV_RINGANT_G3T NONE	00316	316	0.0000	0.0000	0.1206
POZE 11908M001	001	2008 12 09 00 00 00		TRIMBLE NETR5	11070	999999	TRM55971.00 TZGD	999999	999999	0.0000	0.0000	0.0000
PTUJ PTUJ	001	2015 01 26 11 30 00		LEICA GR10	03208	3208	LEIAR20 LEIM	31025	31025	0.0000	0.0000	0.0650
PULJ PULA	001	2016 08 22 09 00 00	2016 11 10 11 20 00	TRIMBLE R8 GNSS	999999	999999	TRMR8_GNSS NONE	999999	999999	0.0000	0.0000	0.0820
PZA1 14506M001	001	2015 06 05 12 00 00		LEICA GR25	31027	31027	LEIAR20 LEIM	15004	15004	0.0000	0.0002	0.0800
RDVL RADOVLJ.	001	2015 01 29 13 25 00		TRIMBLE NETR9	49372	999999	TRM57971.00 TZGD	18022	999999	0.0000	0.0000	0.0650

STATION NAME	FLG	FROM	TO	RECEIVER TYPE	RECEIVER SERIAL NBR	REC #	ANTENNA TYPE	ANTENNA SERIAL NBR	ANT #	NORTH	EAST	UP
****************	***	YYYY MM DD HH MM SS	YYYY MM DD HH MM SS	********************	********************	******	********************	********************	******	***.****	***.****	***.****
SLOG S. GRADEC	001	2009 12 18 14 05 00		TRIMBLE NETR5	63961	999999	TRM55971.00 TZGD	25515	999999	0.0000	0.0000	0.0650
SOFI 11101M002	001	2010 04 29 13 00 00		LEICA GRX1200GGPRO	56544	56544	LEIAR25.R3 LEIT	60008	60008	0.0000	0.0000	0.2200
SRJV 11801S001	001	2011 10 05 00 00 00		TRIMBLE NETR5	61087	999999	TRM57971.00 NONE	999999	999999	0.0000	0.0000	0.1740
STA2 14507M002	001	2015 11 09 12 00 00		LEICA GR25	31179	31179	LEIAR20 LEIM	31026	31026	-0.0004	-0.0005	0.0800
TRBN TREBNJE	001	2013 05 31 15 30 00		TRIMBLE NETR9	40236	999999	TRM57971.00 TZGD	999999	999999	0.0000	0.0000	0.0650
UZHL 12301M001	001	2013 11 12 07 48 00		NOV OEMV3	50014	999999	NOV702GG NONE	999999	999999	0.0000	0.0000	0.0063
VEN1 19513M001	001	2009 05 15 00 00 00		LEICA GRX1200GGPRO	55701	999999	LEIAT504GG NONE	999999	999999	0.0000	0.0000	0.0000
WTZR 14201M010	001	2014 02 13 12 00 00		LEICA GR25	31022	31022	LEIAR25.R3 LEIT	20031	20031	0.0000	0.0000	0.0710
ZADA 11905M001	001	2015 07 16 00 00 00	2017 01 23 00 00 00	TRIMBLE NETR5	53960	999999	TRM55971.00 TZGD	999999	999999	0.0000	0.0000	0.0000
ZIMM 14001M004	001	2015 12 16 00 00 00	2017 02 06 00 00 00	TRIMBLE NETR9	49141	999999	TRM29659.00 NONE	999999	999999	0.0000	0.0000	0.0000
ZOUF 12763M001	001	2013 10 15 10 41 00		TPS GB-1000	24367	999999	ASH701945C_M SCIT	999999	999999	0.0000	0.0000	0.0083

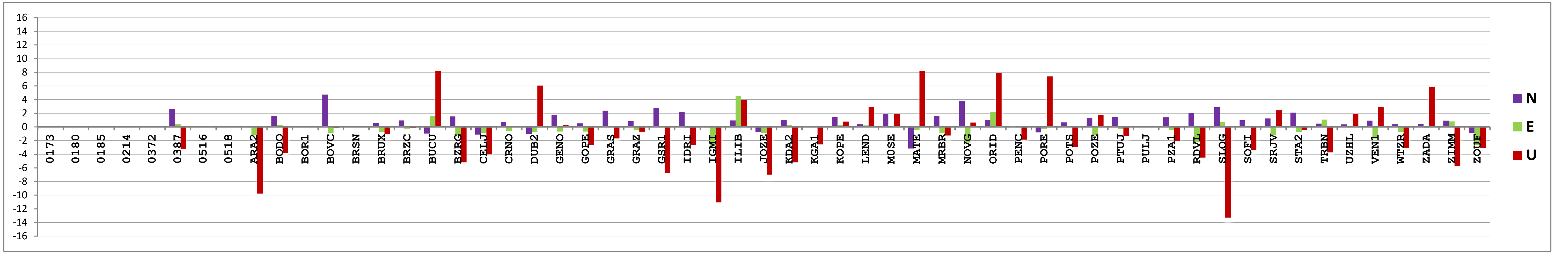
Appendix 5

Daily Coordinate Solution Repeatability in the EUREF Slovenia 2016 GNSS Campaign

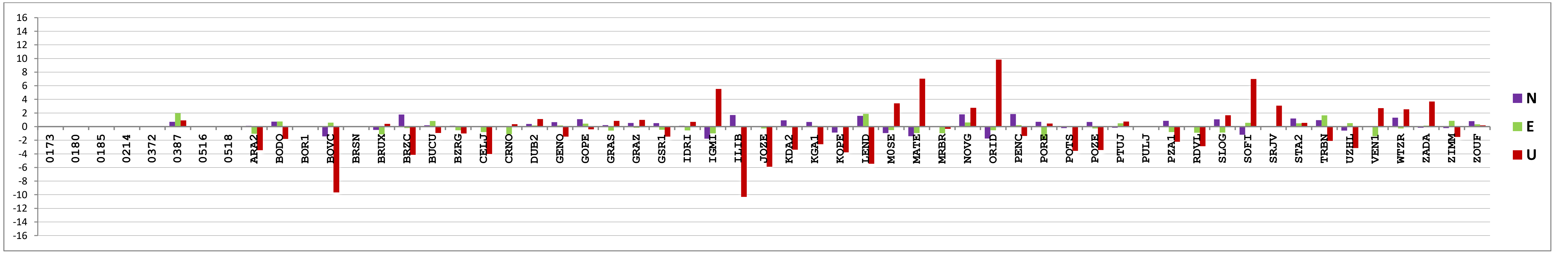
Daily Coordinate Solution Repeatability (1st Series)



Coordinate differences for the daily session 2350 [mm]

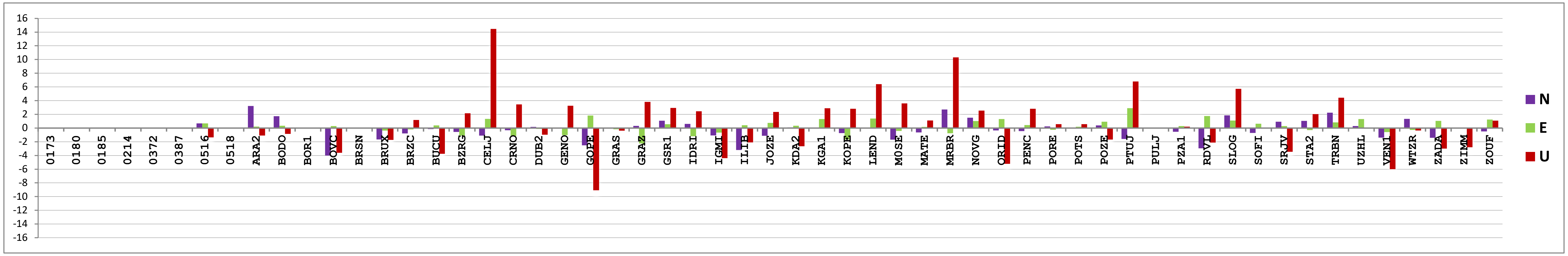


Coordinate differences for the daily session 2360 [mm]

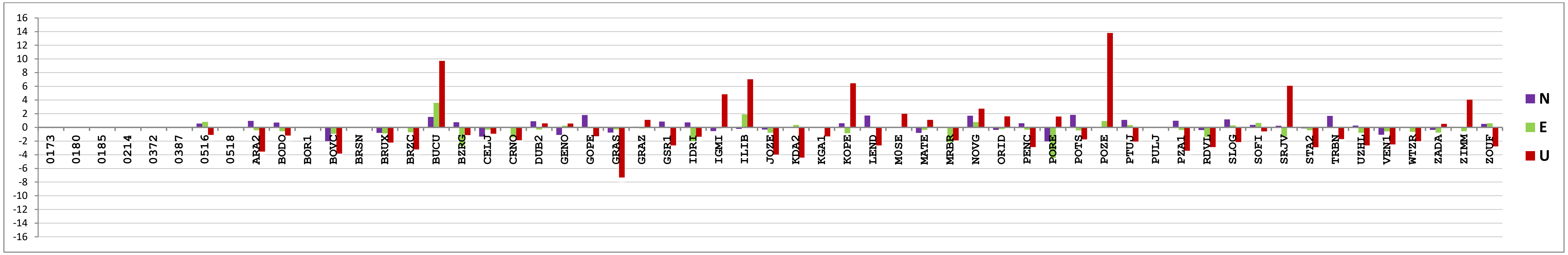


Coordinate differences for the daily session 2370 [mm]

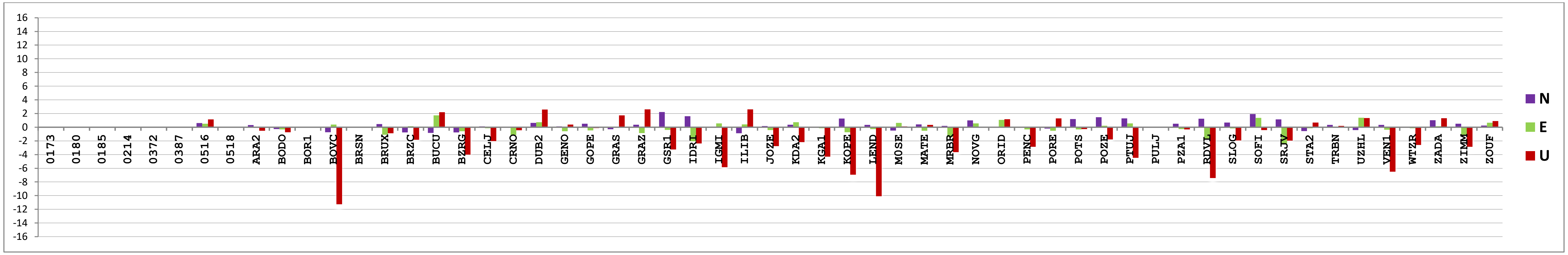
Daily Coordinate Solution Repeatability (2nd Series)



Coordinate differences for the daily session 2420 [mm]

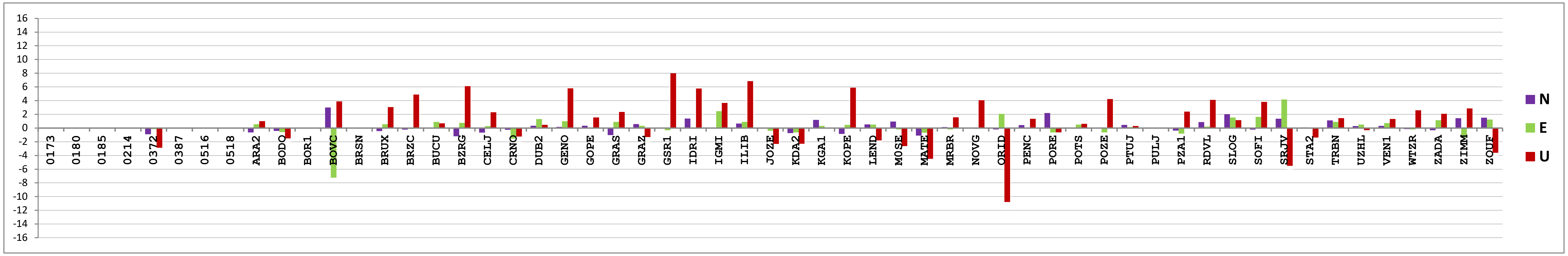


Coordinate differences for the daily session 2430 [mm]

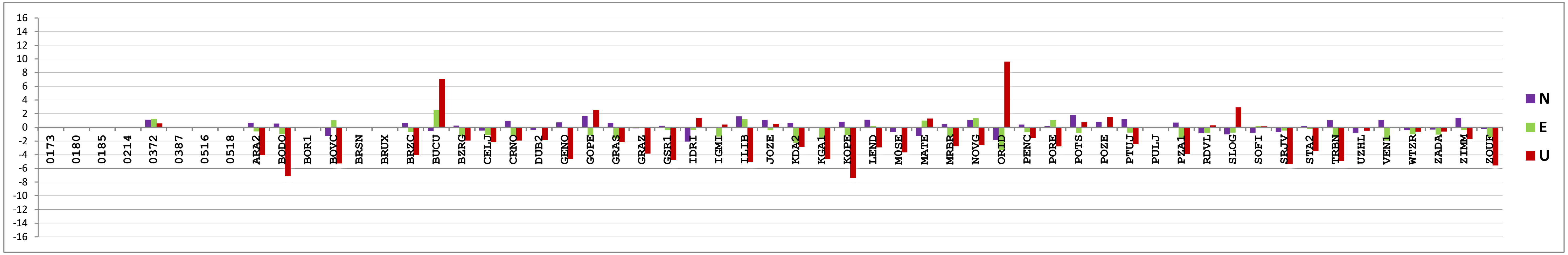


Coordinate differences for the daily session 2440 [mm]

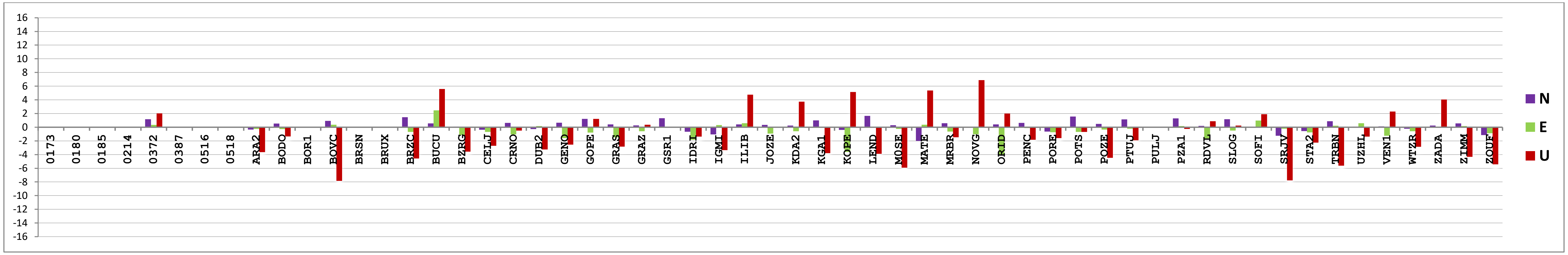
Daily Coordinate Solution Repeatability (3rd Series)



Coordinate differences for the daily session 2500 [mm]

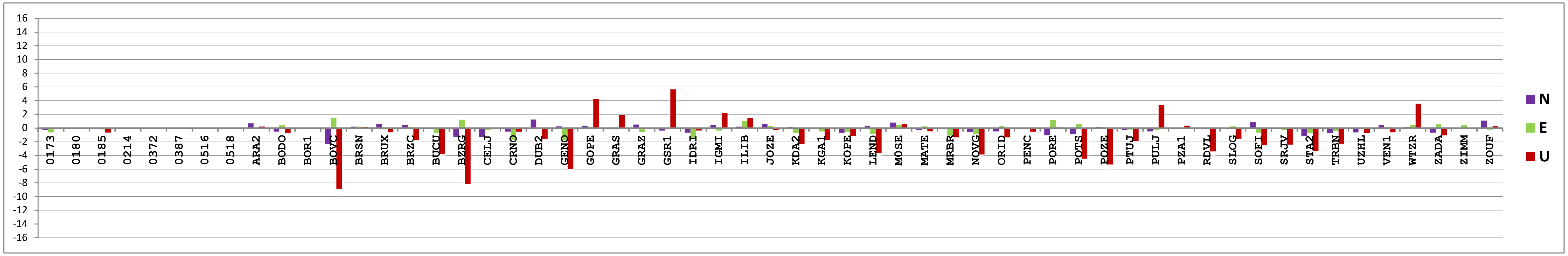


Coordinate differences for the daily session 2510 [mm]

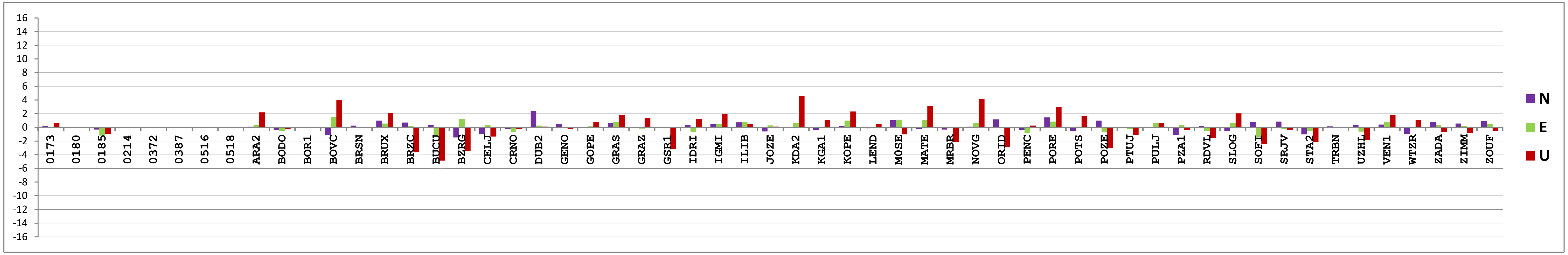


Coordinate differences for the daily session 2520 [mm]

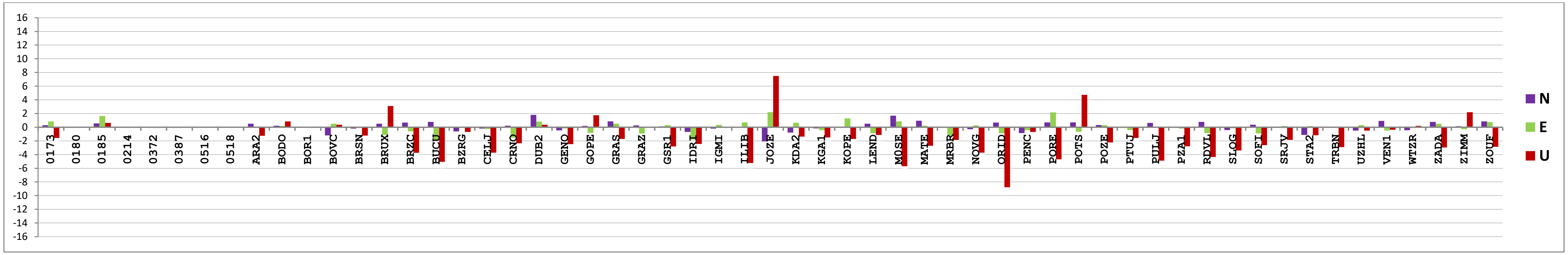
Daily Coordinate Solution Repeatability (5th Series)



Coordinate differences for the daily session 2700 [mm]

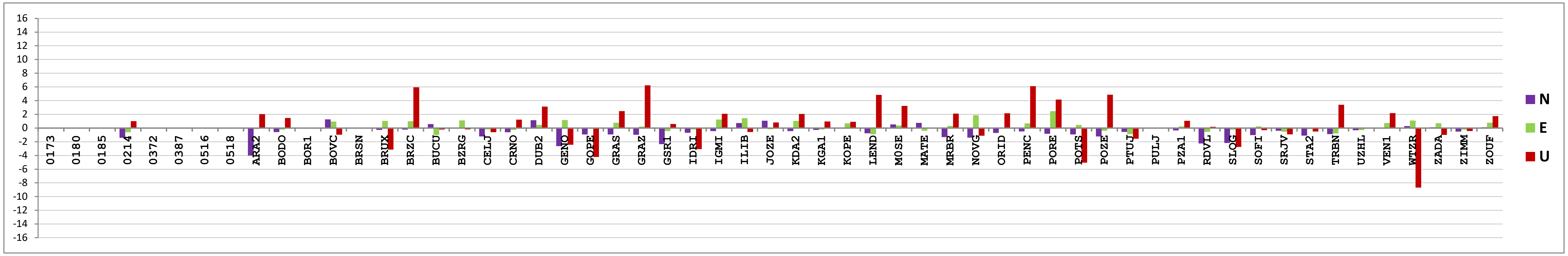


Coordinate differences for the daily session 2710 [mm]

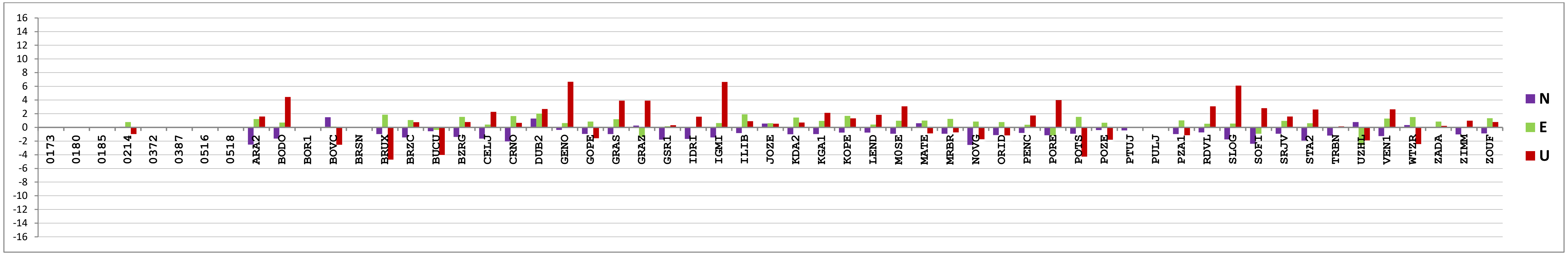


Coordinate differences for the daily session 2720 [mm]

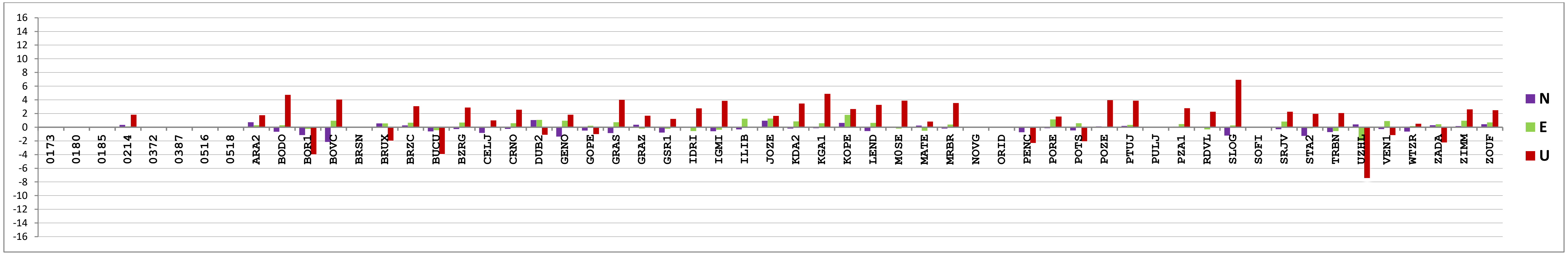
Daily Coordinate Solution Repeatability (6th Series)



Coordinate differences for the daily session 2780 [mm]

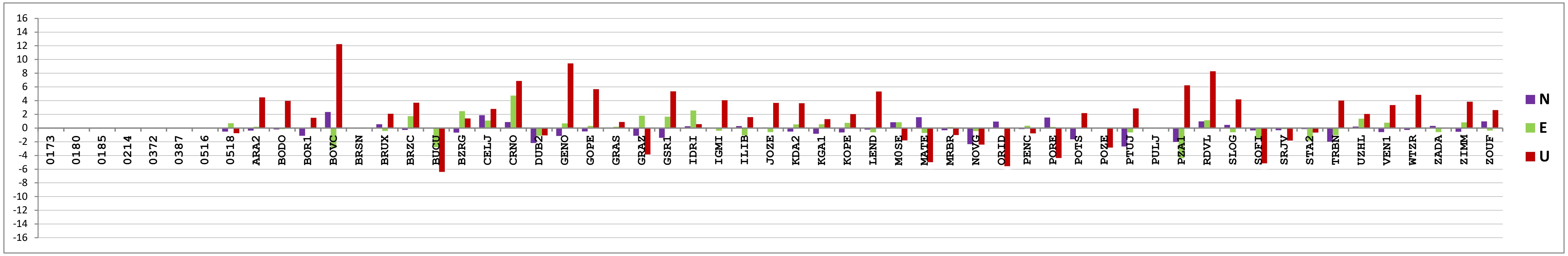


Coordinate differences for the daily session 2790 [mm]

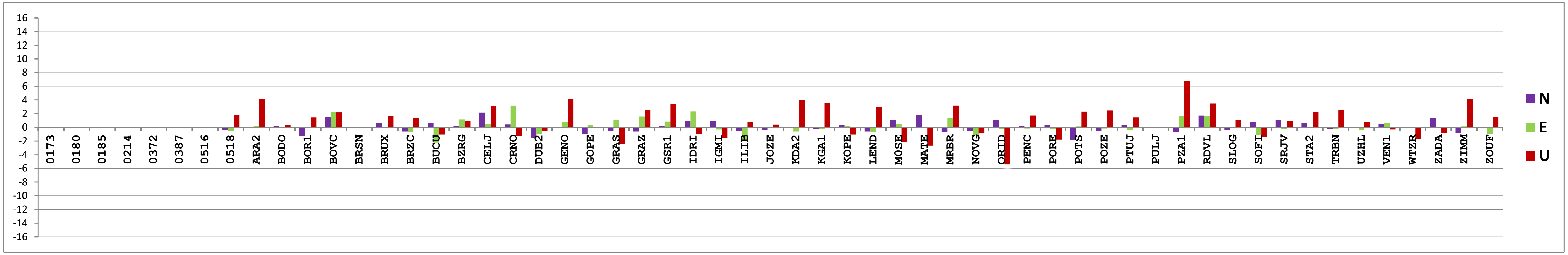


Coordinate differences for the daily session 2800 [mm]

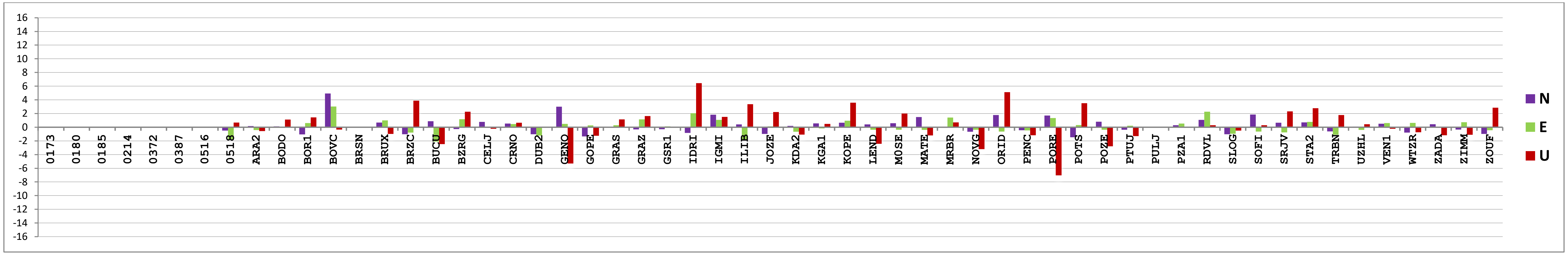
Daily Coordinate Solution Repeatability (8th Series)



Coordinate differences for the daily session 2980 [mm]

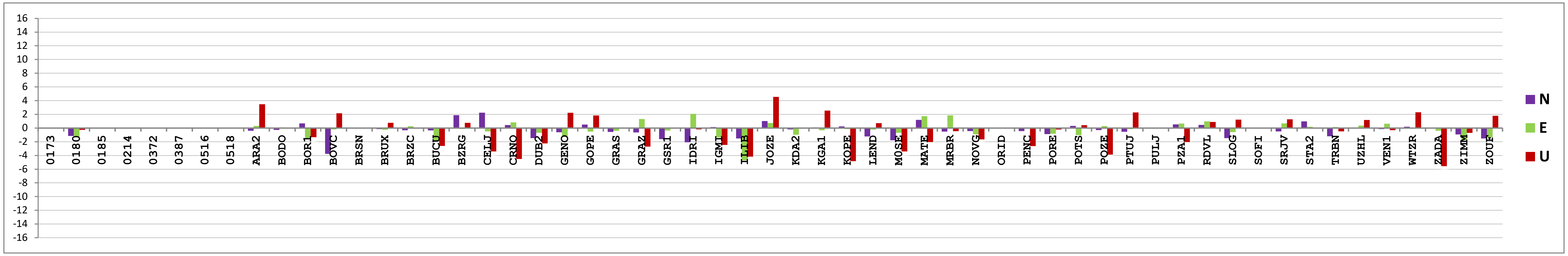


Coordinate differences for the daily session 2990 [mm]

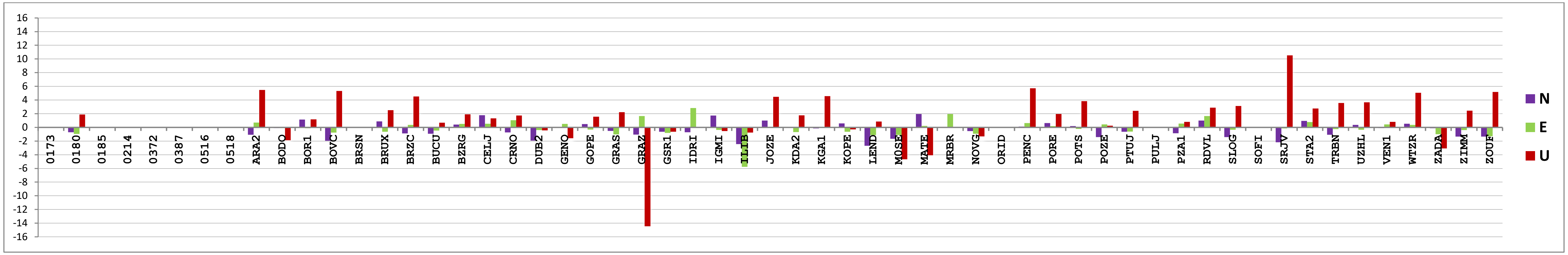


Coordinate differences for the daily session 3000 [mm]

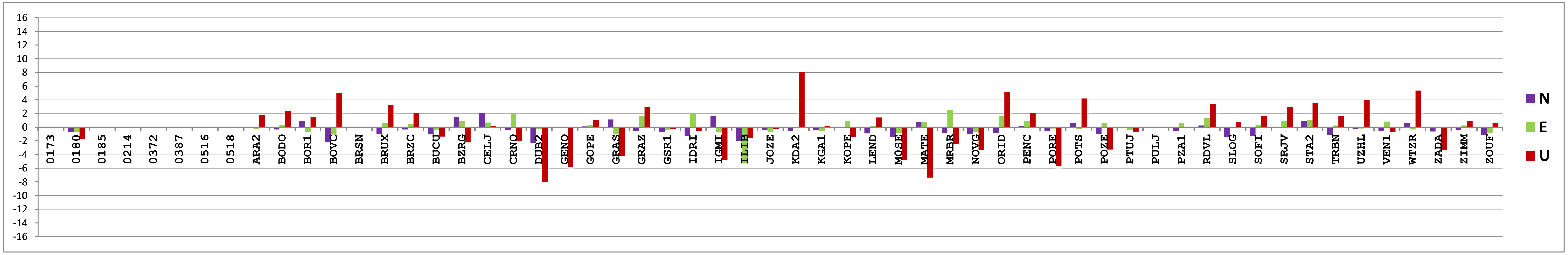
Daily Coordinate Solution Repeatability (9th Series)



Coordinate differences for the daily session 3120 [mm]



Coordinate differences for the daily session 3130 [mm]

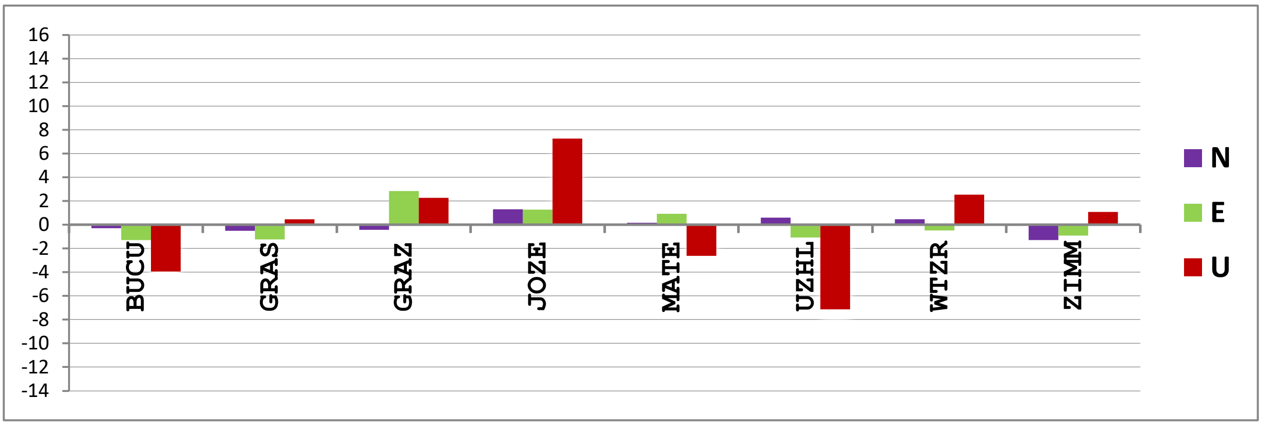


Coordinate differences for the daily session 3140 [mm]

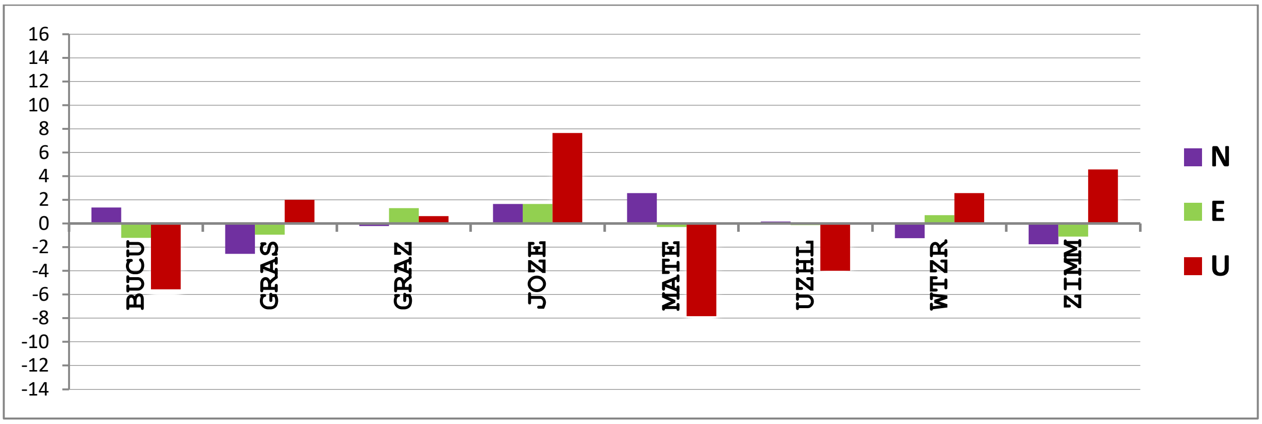
Appendix 6

Daily Coordinate Differences at the Reference Frame Stations in the EUREF Slovenia 2016 GNSS Campaign

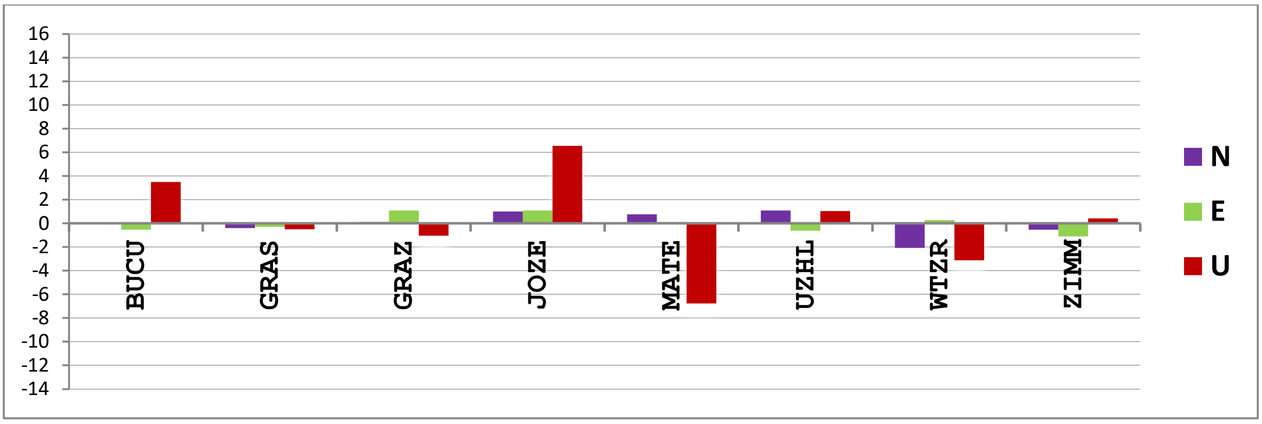
Daily Coordinate Differences at the Reference Frame Stations (1st Series)



Coordinate differences for the daily session 2350 [mm]

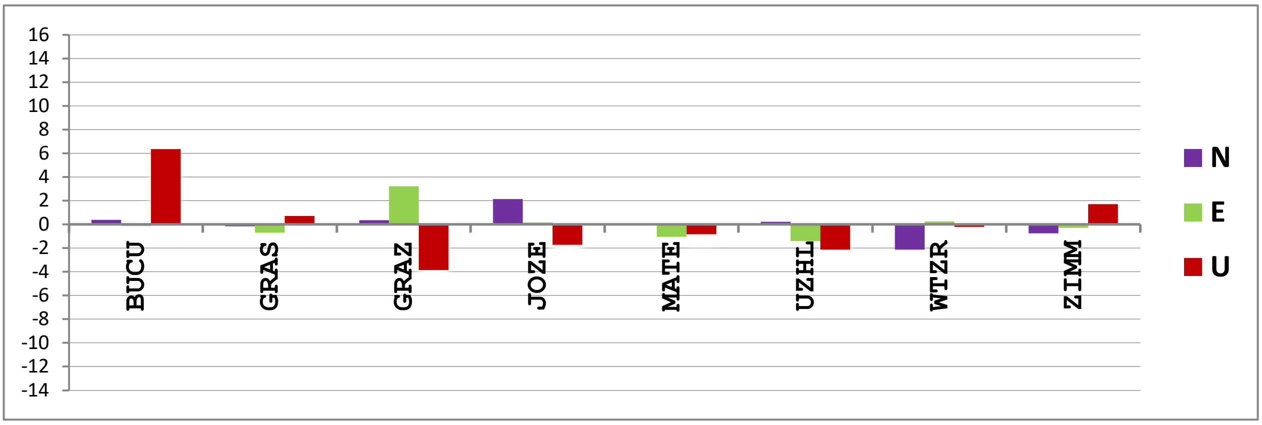


Coordinate differences for the daily session 2360 [mm]

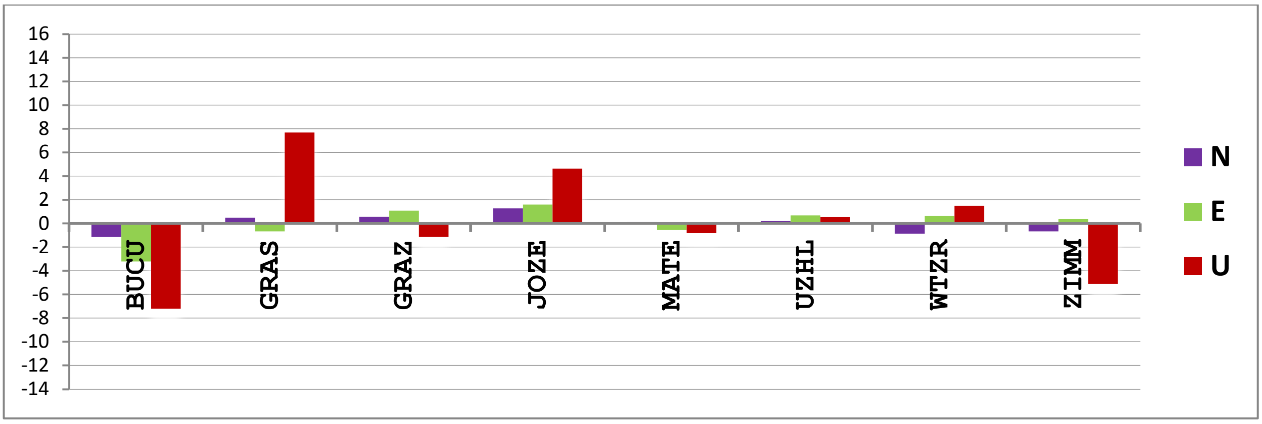


Coordinate differences for the daily session 2370 [mm]

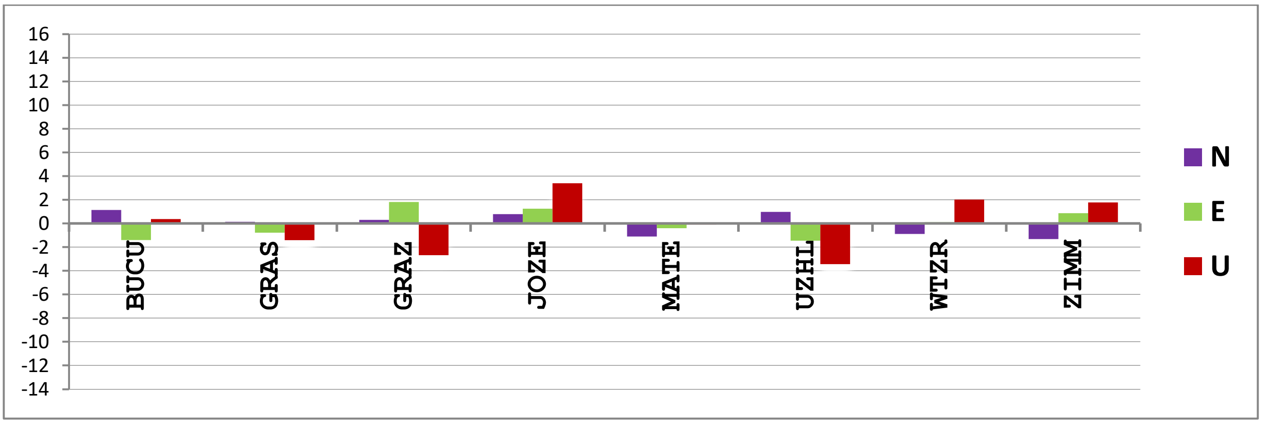
Daily Coordinate Differences at the Reference Frame Stations (2nd Series)



Coordinate differences for the daily session 2420 [mm]

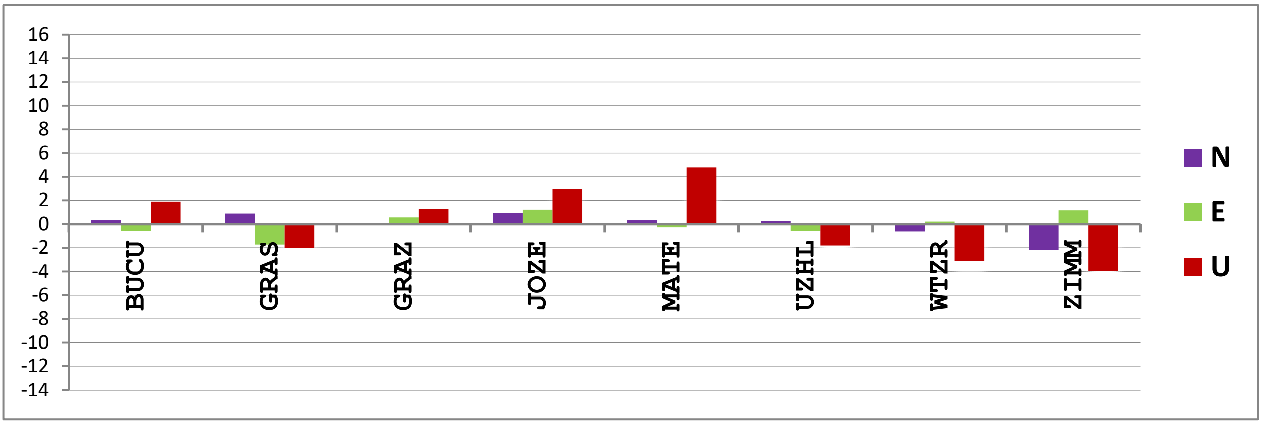


Coordinate differences for the daily session 2430 [mm]

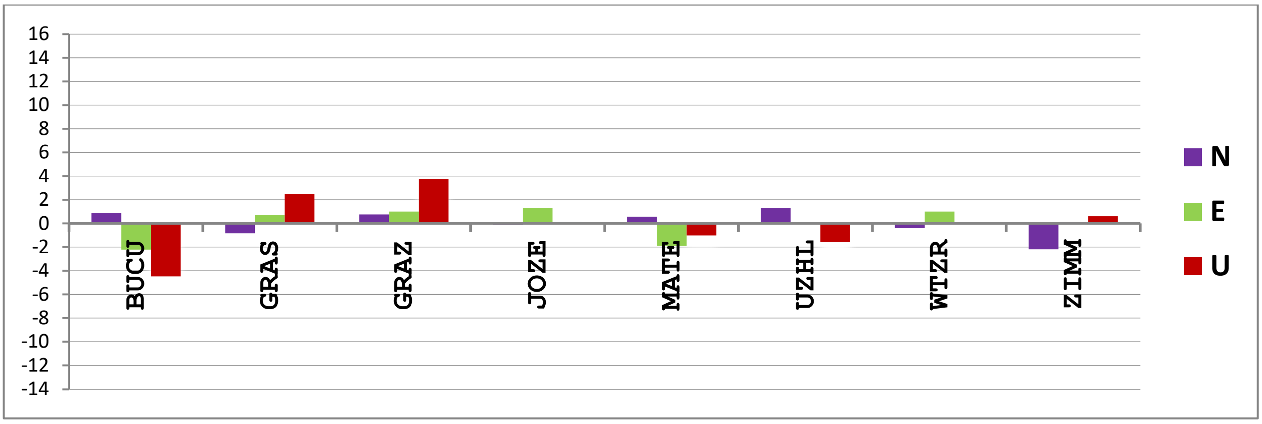


Coordinate differences for the daily session 2440 [mm]

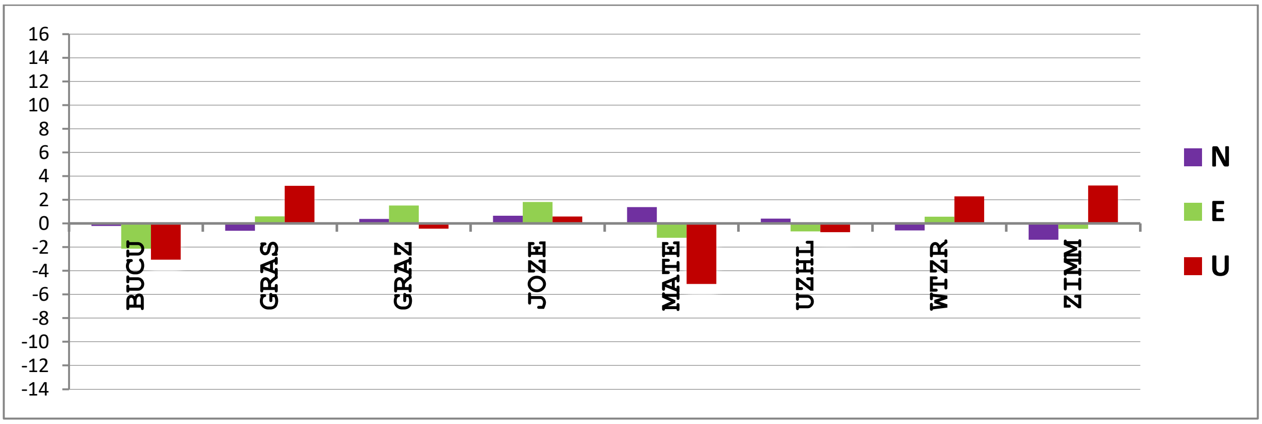
Daily Coordinate Differences at the Reference Frame Stations (3rd Series)



Coordinate differences for the daily session 2500 [mm]

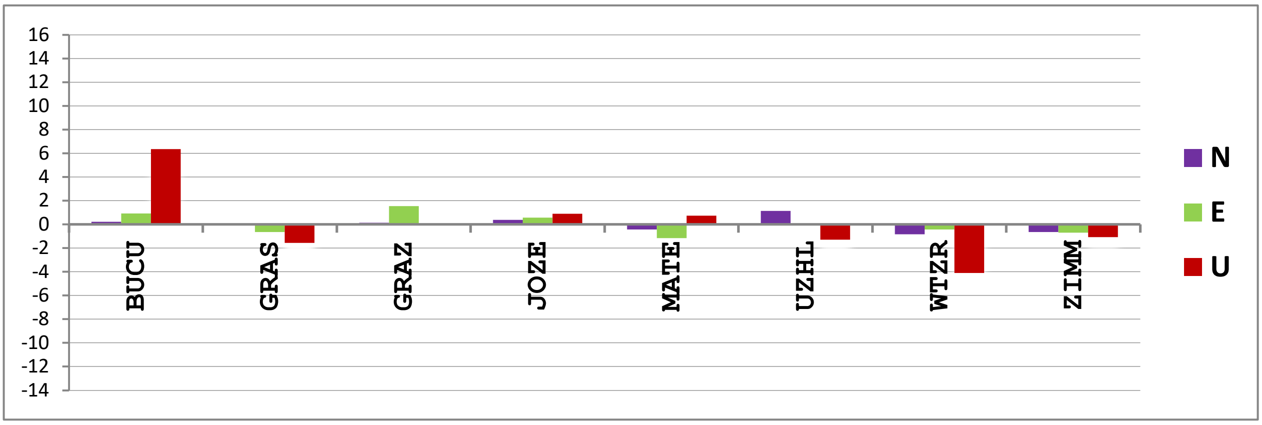


Coordinate differences for the daily session 2510 [mm]

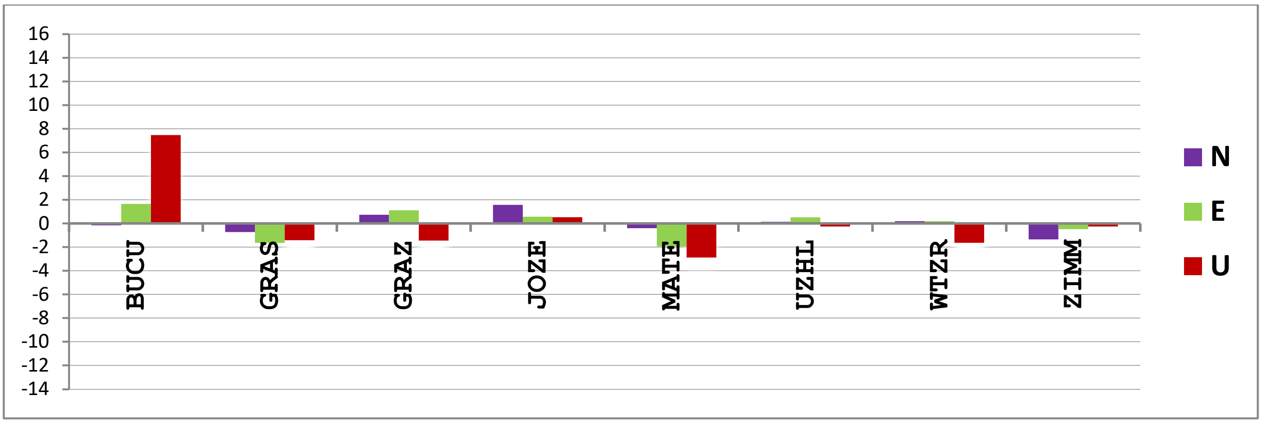


Coordinate differences for the daily session 2520 [mm]

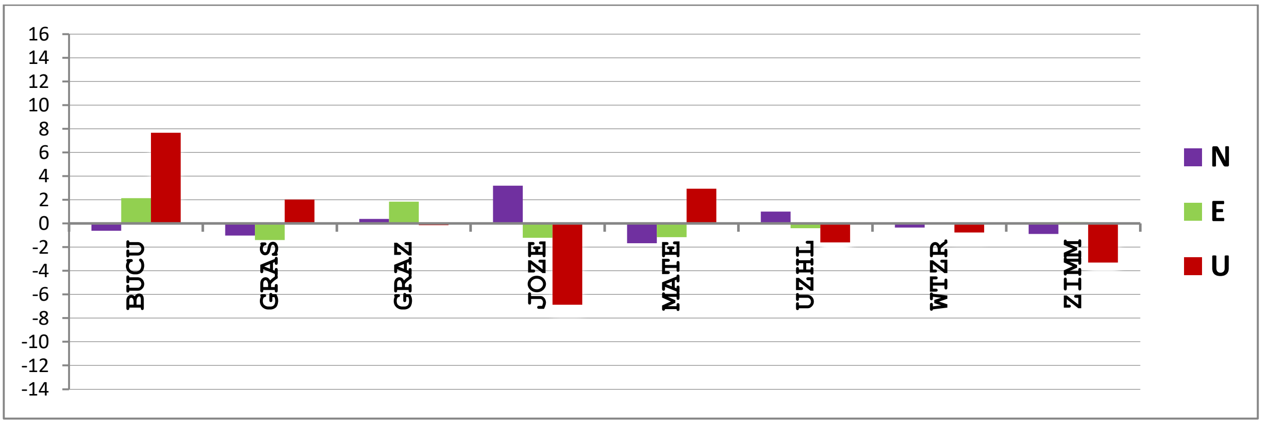
Daily Coordinate Differences at the Reference Frame Stations (5th Series)



Coordinate differences for the daily session 2700 [mm]

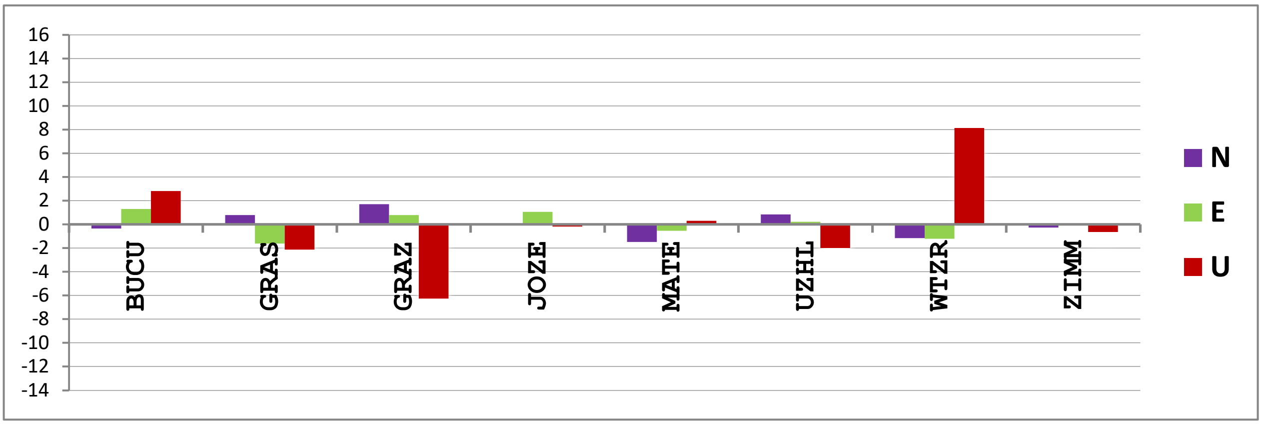


Coordinate differences for the daily session 2710 [mm]

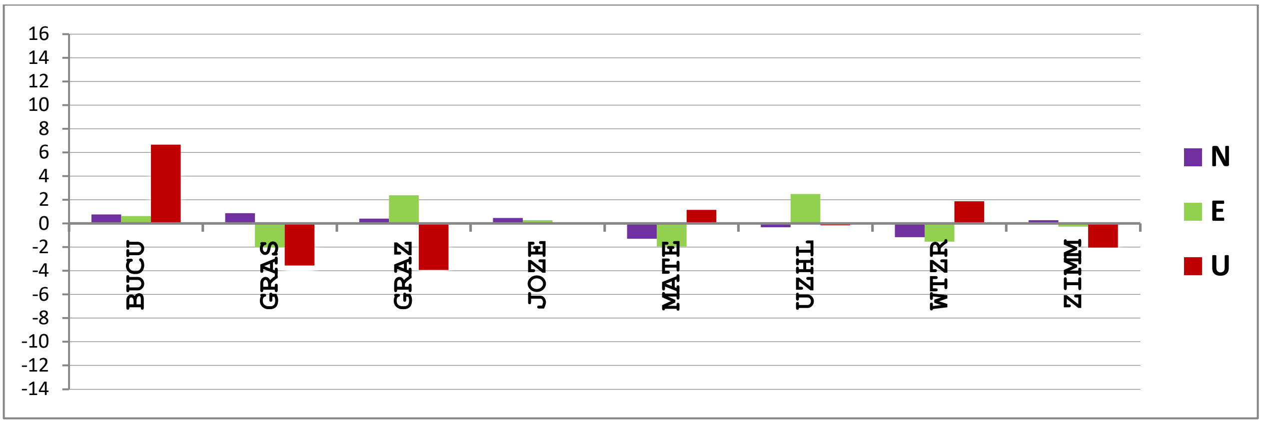


Coordinate differences for the daily session 2720 [mm]

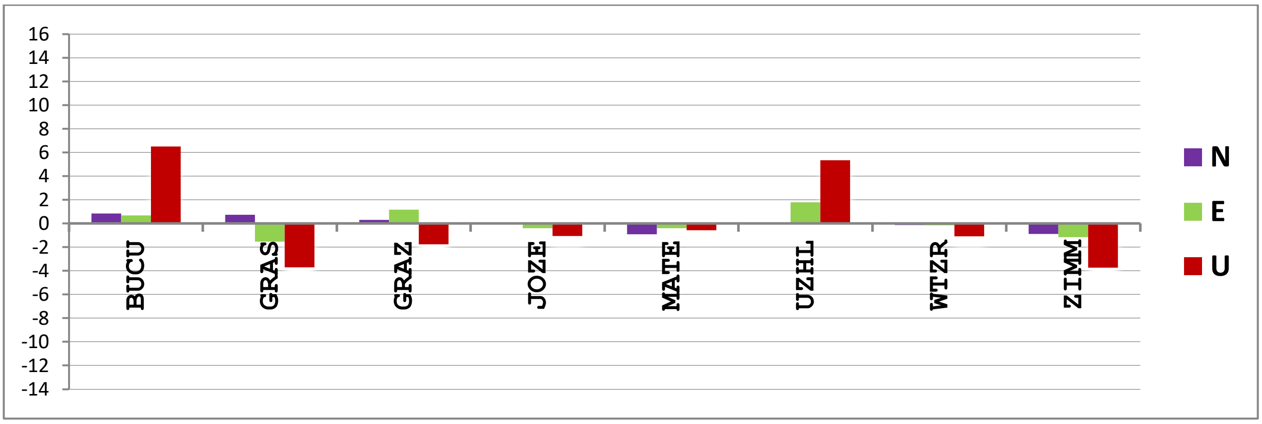
Daily Coordinate Differences at the Reference Frame Stations (6th Series)



Coordinate differences for the daily session 2780 [mm]

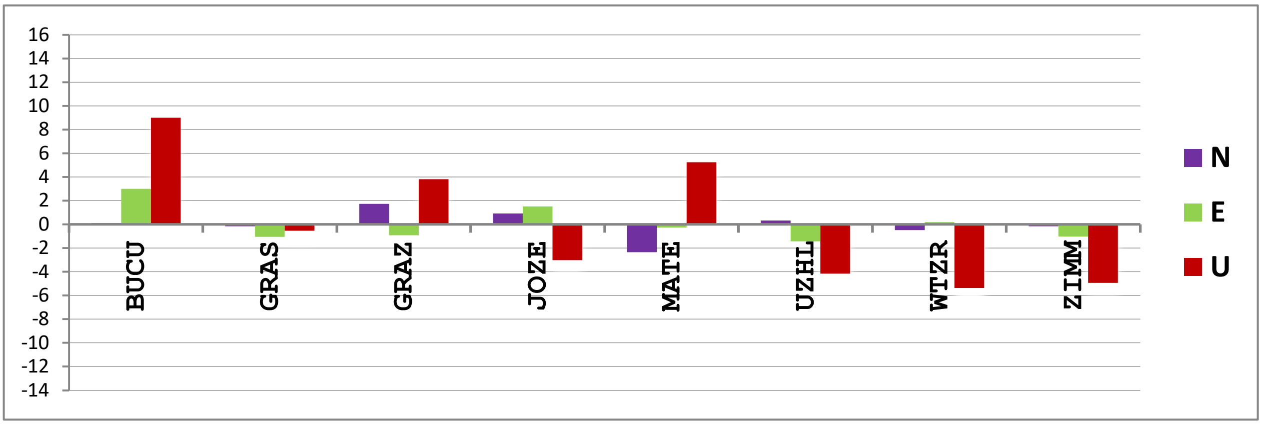


Coordinate differences for the daily session 2790 [mm]



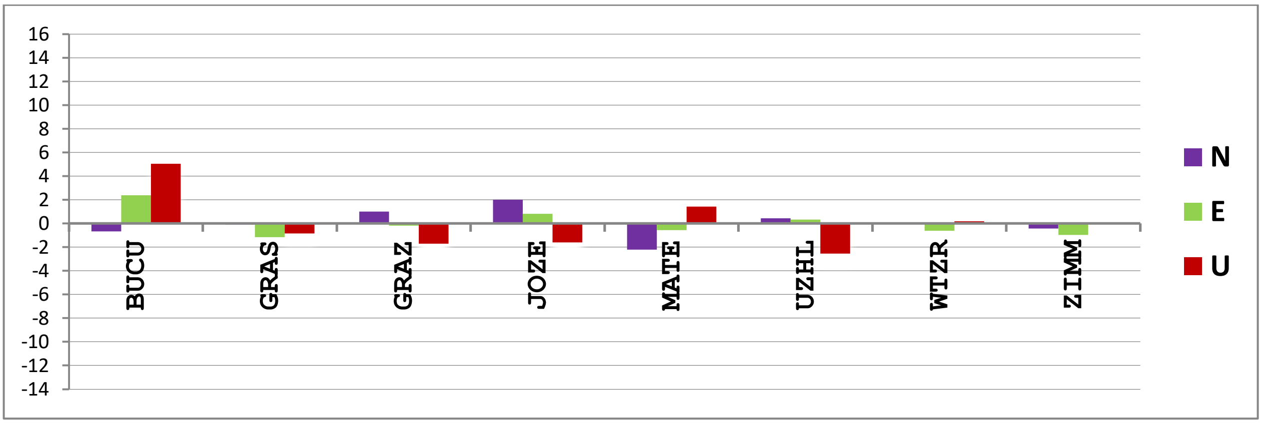
Coordinate differences for the daily session 2800 [mm]

Daily Coordinate Differences at the Reference Frame Stations (8th Series)



Coordinate differences for the daily session 2980 [mm]

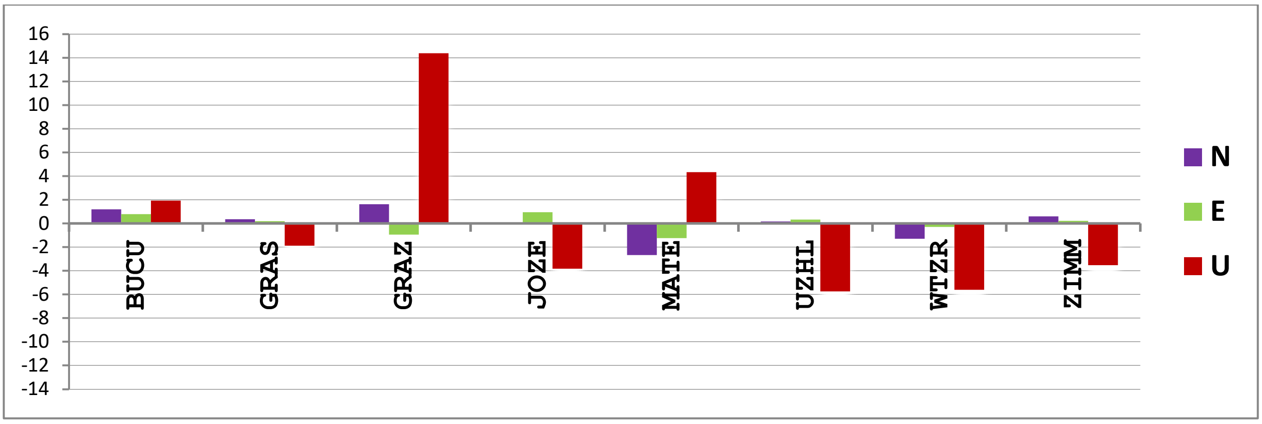
Coordinate differences for the daily session 2990 [mm]



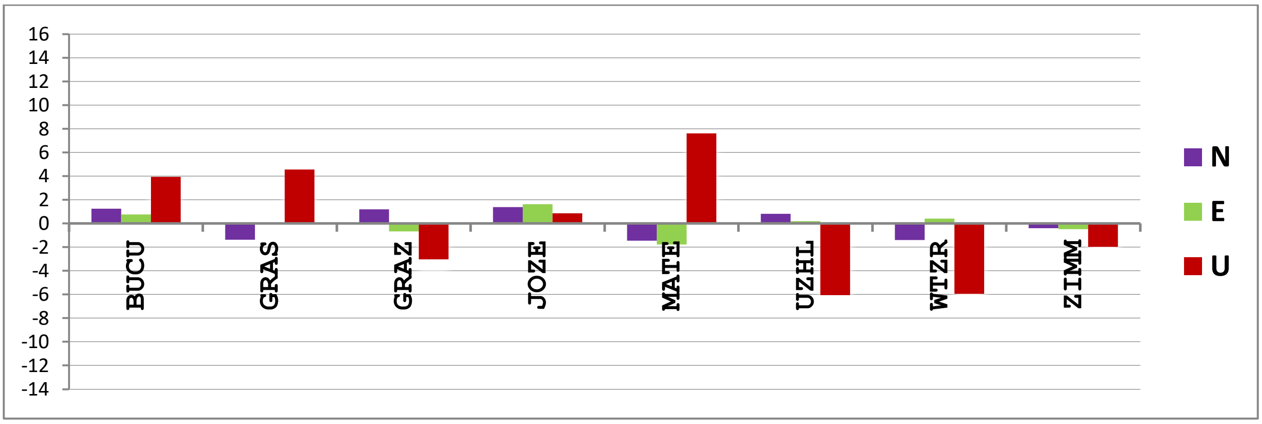
Coordinate differences for the daily session 3000 [mm]

Daily Coordinate Differences at the Reference Frame Stations (9th Series)

Coordinate differences for the daily session 3120 [mm]



Coordinate differences for the daily session 3130 [mm]



Coordinate differences for the daily session 3140 [mm]

Appendix 7

Description of the Deliverables of the Computation of the EUREF Slovenia 2016 GNSS Campaign

Deliverables of the EUREF Slovenia 2016 GNSS Campaign

Deliverables of the project can be found in five directories.

The .../**ANTEX_files** directory contains:

- antenna phase centre variation models for 11 Slovenian permanent stations with absolute individual antenna calibrations (*.ATX) – seven of them were used in the computation.

The .../**Coordinates** directory contains:

- list of coordinates for all network sites in the IGb08, epoch 2016.75, (SVN16MC.CRD) – result of the final minimum constraint network solution,
- list of coordinates for all network sites in the ETRF2000, epoch 2016.75, (SVN16D17.CRD) – result of the transformation of the final minimum constraint network solution into the ETRS89,
- list of a priori coordinates for all network sites in the IGb08, epoch 2016.75, (SVN16AP.CRD) – the coordinates for the reference frame stations and control stations are derived from the EPN cumulative solution with the release name EPN_A_IGb08_C1934,
- list of a priori velocities for all network sites in the IGb08 (SVN16AP.VEL) – the velocities for reference frame stations and control stations are taken from the EPN cumulative solution with the release name EPN_A_IGb08_C1934, velocities for the other sites were adopted from the nearest reference frame or control station.
- list of a priori coordinates for all network sites in IGb08, epoch 2016.75, (SVN16AP.CRD) – the coordinates for the reference frame stations and control stations are derived from the EPN cumulative solution with the release name EPN_A_IGb08_C1934.

The .../**KML_maps** directory contains Google Earth ready:

- map of sites with full location names (EUREF_SVN16-Site_names.kml),
- map of sites with 4-char IDs (EUREF_SVN16-Site_IDs.kml), and
- map of baselines coloured according to the priority (EUREF_SVN16_Baselines.kml).

The .../**SINEX_files** directory contains:

- minimum constraint network solution in the SINEX format (SVN16MC.SNX) and
- list of reference frame stations (SVN16.FIX).

The .../**Site_log_files** directory contains:

- log files of all Slovenian active and passive network sites used in the computation (*.log), which are dispersed into three subdirectories:
  - EUREF_Sites
  - SIGNAL_Stations
  - Zero-Order_Stations