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National Report of Slovenia
to the EUREF 2019 Symposium in Tallinn

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1 Introduction

This report is a short review of activities regarding national geodetic reference frames, CORS networks and activities related to EUREF in Slovenia for the period 2018–2019.

2 Terrestrial Reference Frame

The EUREF Slovenia 2016 GNSS campaign and its computation have already been presented in the previous national reports (Medved et al., 2017 and 2018a) as well as in a separate contribution to the last EUREF symposium in Amsterdam (Berk et al., 2018b). However, only subsets of all the sites and daily sessions of the campaign were included in the computation for the purpose of the validation by the EUREF GB. The results were accepted as Class B standard (EUREF 2018 Resolution No. 3). The solution was delivered in the IGb08/ETRF2000 and is considered a EUREF densification (improvement) of the ETRS89 in Slovenia referred to as the ETRS89/D17. Afterwards, a complete campaign computation was carried out, based on 117 sites (48 passive and 69 active GNSS network stations) and all 80 consecutive daily sessions (Figure 1).

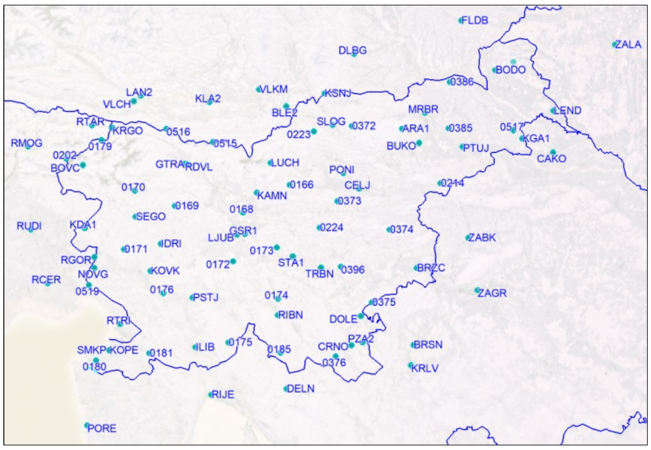

Figure 1: Sites included into the EUREF Slovenia 2016 GNSS campaign (complete network computation).

A total of 5554 daily RINEX files were used in the computation. The Guidelines for EUREF Densifications (Bruyninx et al., 2013) were followed. The decision was taken to keep the official horizontal geodetic datum D96 (based on the EUREF GPS campaigns from years 1994–1996) until further update, which is supposed to be a semi-kinematic geodetic datum (Poutanen and Häkli, 2018; Medved et al., 2018b and 2019a). The new realization of ETRS89 (after more than two decades) provided high quality coordinates of points included into the computation. An optimal 3D rigid (6-parameter) transformation from the D17 into the D96 was determined by considering official coordinates of EUREF sites and the coordinates used for stations in the SIGNAL Network. As expected, coordinates within the passive and active GNSS networks (mean epochs of the campaigns were 1995.55 and 2007.26, respectively) weren't really consistent. The optimal solution – referred to as the D96-17 – retains the inner geometry of the new realization (D17) and, at the same time, stays as much as possible close to the current coordinates in both networks. This solution offers a set of coordinates for passive and active GNSS networks in Slovenia, which is as much as possible consistent with all GNSS based coordinates acquired till now (Figure 2).

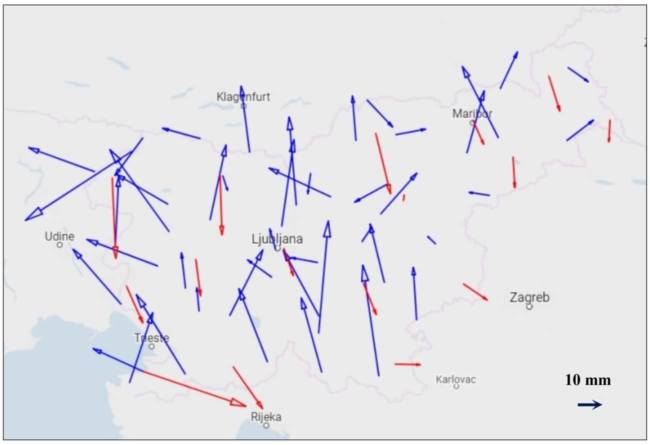

Figure 2: Horizontal correction vectors of EUREF sites (blue) and SIGNAL stations (red) to achieve consistent realization of the ETRS89/D96-17; the median horizontal correction is 23.1 mm.

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The benefit of this pragmatic solution is an improvement of the quality of the horizontal coordinate reference system in Slovenia without bothering the cadastral community.

A significant displacement of the KOPE station (Koper) was detected in the 2011–2017 multi-year solution of the CEGRN project (Zurutuza et al., 2018). The transformation of the SIGNAL stations from D17 into D96 confirmed a position discontinuity for this station. RMS of transformation (without involving the Koper station) was 6.0 mm and the estimated movement of the Koper station was about 36 mm towards east (Figure 3, bottom left).

Figure 3: Horizontal residual vectors for the optimal 3D rigid (6-parameter) transformation of SIGNAL stations from the ETRS89/D17 into the ETRS89/D96.

Large coordinate residuals at the Koper station are supposed to be a result of a non-permanent local movement caused by the harbour reconstruction works in the immediate vicinity of the station, which started in April, 2013.

The EUREF Slovenia 2016 GNSS campaign was the fifth GNSS campaign in Slovenia, which was computed in accordance with the EUREF guidelines. With this campaign, more than 40 EUREF sites obtained coordinate time series for the period of 21 years or longer. Final ITRFyy coordinates of those campaigns were collected (Berk et al., 2004; Mesner et al., 2007; Sterle and Stopar, 2007; Berk et al., 2018b):

- EUREF Croatia and Slovenia 1994 in ITRF96, epoch 1994.41,
- EUREF Slovenia 1995 in ITRF96, epoch 1995.74,
- EUREF Croatia 1996 in ITRF96, epoch 1996.68,
- Mini EUREF Slovenia 2007 in ITRF2005, epoch 2007.26, and
- EUREF Slovenia 2016 in IGb08/ITRF2008, epoch 2016.75.

The final ITRFyy coordinates were transformed into the ITRF2014, keeping the original mean epochs of each campaign. The resulting sets of coordinates were used for the time series analysis with Bernese GNSS Software, Version 5.2, (Dach et al., 2015) and the ITRF2014 velocities of the selected EUREF sites were estimated (Figure 4). Finally, the ITRF2014 velocities were transformed into the ETRF2000 velocities (Figure 5).

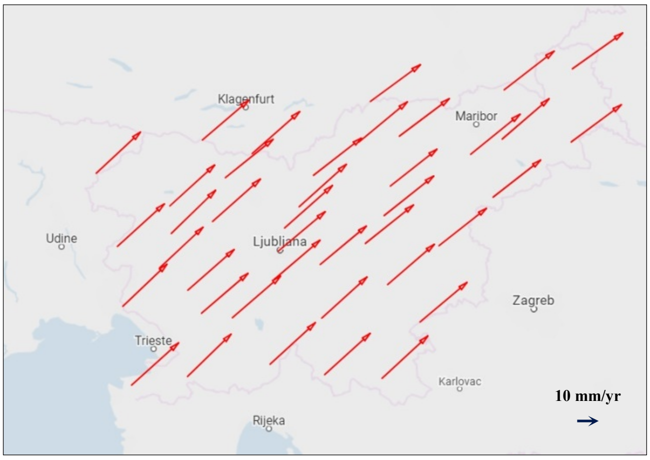

Figure 4: Horizontal velocity vectors of the selected EUREF sites in Slovenia in the ITRF2014; the median horizontal velocity component is 27.6 mm/yr and the median azimuth is 49.3°.

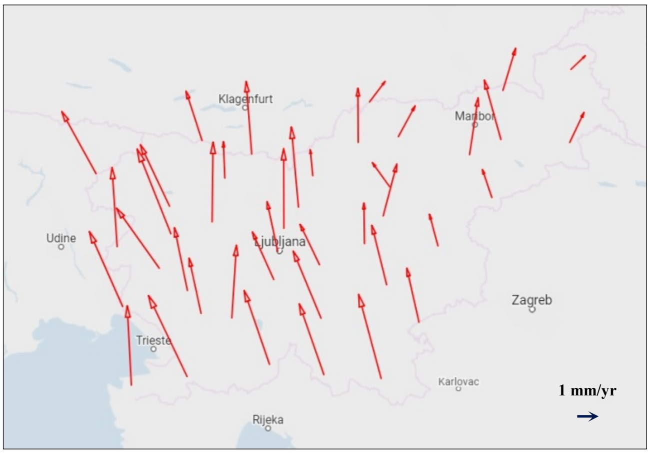

Figure 5: Horizontal velocity vectors of the selected EUREF sites in Slovenia in the ETRF2000; the median horizontal velocity component is 2.7 mm/yr and the median azimuth is −12.2°.

The EUREF Technical Note 1 (Altamimi, 2018) was followed to perform the above-mentioned transformations. There was no recomputation of the past campaigns and 78% of the sites were included only in the two largest campaigns (1995 and 2016). However, the coordinate time series periods exceed 20 years for the selected 40 sites and these velocities are available at the moment, e.g. for future campaign computations. Following a EUREF initiative (Brockmann et al., 2017; EUREF 2017 Resolution No. 2), this preliminary solution was also delivered to the Working Group on European Dense Velocities (WG EDV, 2019).

3 National CORS Networks

The national Combined Geodetic Network – the Zero-Order Network – consists of 10 GNSS stations set up at six locations, four of them as double stations (Medved et al., 2018a). The Zero-Order Network is operational since 2016. Performance analysis for the zero-order station in Kog, which is operational since the beginning of 2016, showed good quality of data. The coordinate time series analysis confirmed Kog as a stable station (Oven et al., 2019).

The national GBAS Network – the SIGNAL Network – consists of 16 GNSS stations in Slovenia and additional 14 GNSS stations in the neighbouring countries: four in Austria, one in Hungary, six in Croatia and three in Italy (Figure 6).

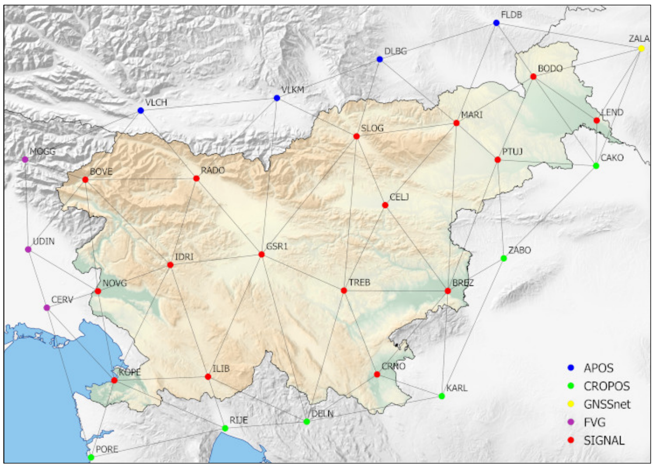

Figure 6: The new configuration of the SIGNAL network.

A few changes of the network configuration were made since last year:

- three new Italian stations from the Rete GNSS Friuli - Venezia Giulia were included into the SIGNAL network: Cervignano del Friuli (CERV), Moggio Udinese (MOGG), and Udine (UDIN);
- three Austrian stations from the APOS network were removed: Bleiburg (BLEI), Landskron (LANK), and Klagenfurt (KLAG);
- two new Austrian stations replaced the removed ones: Villach (VLCH) and Völkermarkt (VLKM).

Equipment changes (receivers + antennas) were made at three SIGNAL stations: Bovec (BOVE), Črnomelj (CRNO), and Slovenj Gradec (SLOG). Recently, DOMES numbers were acquired for the SIGNAL network stations and for some of them their 4-character abbreviations had to be changed (BOVE → BOVC, BREZ → BRZC, CRNO → CRNM, MARI → MRBR, RADO → RDVL, TREB → TRBN).

A new SIGNAL service was started in February 2019 – the Trimble Online Processing or the TOP Service. It offers automatic post-processing of static and fast static surveys. The users simply upload their RINEX files and receive the processing reports with the coordinates and estimated accuracies for each site in the national coordinate reference system. This service is especially convenient for cadastral surveys in areas of weak GSM signal – as a substitute of RTK surveys (Fabiani and Ritlop, 2019).

The SIGNAL Network is fully operational since 2007. A study of the network's performance during the period from 2007 to 2017 was made in the scope of the national research project V2-1729. It showed that the quality and availability of products and services improved significantly in those ten years. The decline in annual number of events is clearly visible (Figure 7).

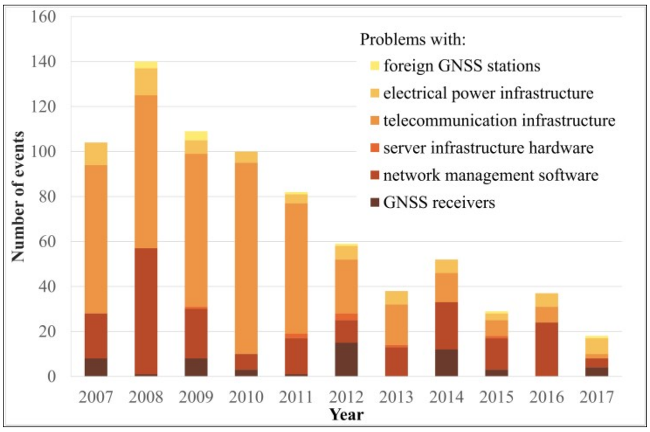

Figure 7: Problem events in the SIGNAL network in years 2007–2017.

The number of events is shown separately for problems related to:

- foreign GNSS stations in the SIGNAL network,
- electrical power infrastructure,
- telecommunication infrastructure,
- server infrastructure hardware,
- network management software, and
- GNSS receivers.

The most abundant problems covering 54% of all documented events were telecommunication infrastructure problems, followed by problems associated with network management software covering 27% (Ritlop et al., 2018).

A decision for processing all GNSS observations from CORS networks had also taken place. The processing started in the middle of 2016. Data for almost three years have already been processed. Two different tools are being used: Bernese GNSS Software, Version 5.2, (Dach et al., 2015) and gPPP software that utilizes PPP concept, which is a self-made application (Sterle et al., 2014; Sterle, 2015). The geodetic network consists of the SIGNAL and the Zero-Order Networks, as well as IGS stations in Europe and most of the EPN stations in the surrounding countries. Altogether, around 100 stations are included in the processing of GNSS data on a daily basis.

The processing strategy follows as much as possible all IGS and EPN recommendations on the state-of-the-art analysis methods. In case of Bernese-based processing, the solution is obtained on a basis of GPS+GLONASS observations. On the other hand, several methods are applied in case of gPPP-based processing, mostly for testing purposes. Various GPS only and GPS+GLONASS solutions are produced. Although, stations coordinates are obtained directly with PPP, 3-, 4-, 6-, and 7-parameter transformations are applied for fitting PPP coordinates at the IGS stations to assure appropriate geodetic datum of the results.

The processing results were coordinate time series generated with the two available software solutions (gPPP and Bernese GNSS Software) and different processing strategies (in case of gPPP). There is a high level of congruence between the gPPP- and Bernese GNSS Software-based results, with differences on a level of observation precision.

The level of repeatability for coordinates computed with the Bernese GNSS Software is around 2 mm for E/N and 5 mm for the height component. On the other hand, the level of repeatability of coordinates computed with gPPP software is around 2.5 mm for E/N and 6 mm for the height component, but in case of additional spatial transformation, the repeatability reach the same level as with the Bernese GNSS Software. The coordinate differences between both solutions are 1–2 mm for E/N and 3 mm for the height component.

4 Local to ETRS89 Datum Transformation

At the beginning of 2019, the transformation of spatial datasets into a new horizontal coordinate reference system has been completed in accordance with the National Geodetic Reference System Act (ZDGRS, 2014). All spatial datasets maintained by the Surveying and Mapping Authority of the Republic of Slovenia are now georeferenced in this new system, which is referred to as D96/TM. This is important information for everyone dealing in with national spatial data. With this transformation, positions of points ‘moved’ for about 600 m towards north-west (Vugrin and Petek, 2018). The performed activities have a direct impact on surveyors’ work, especially in the maintenance of cadastral datasets (Medved et al., 2019a). The local to ETRS89 datum transformation model, version 4.0, was made public in 2017 – together with freeware transformation tools – as already presented in the previous national reports (Medved et al., 2017 and 2018a).

Recently, some missing EPSG codes for Slovenian coordinate systems, coordinate reference systems (reference frames), geodetic datums, and coordinate transformations (datum transformations) were added to the EPSG Geodetic Parameter Registry (Berk et al., 2018a). Nowadays, it contains about 30 coordinate reference systems and about 40 coordinate transformations, which are relevant for the GIS community in Slovenia (Portal Prostor, 2019).

5 Vertical Reference Frame

The Slovenian height system 2010, also referred to as SVS2010, has officially replaced the old one, referred to as SVS2000 (Decree, 2018). The new system is based on the 1st order levelling network measurements conducted in the last decade. The network consists of 13 levelling loops with 2036 bench marks; the total length of the levelling lines is 1960 km. Gravimetric survey was conducted for more than 85% of all bench marks, which enabled the adjustment of the levelling network in the system of geopotential numbers. Geopotential numbers were used to compute the normal heights, which are now the official heights in Slovenia and replace the old normal-orthometric heights (Koler et al., 2019b; Medved et al., 2019a).

The new height reference system also brings a new national height datum. It is based on the tide gauge measurements at the national tide gauge station in Koper for one 18.6-year cycle. The mean epoch of observations is 10. 10. 2010 (Sterle and Koler, 2019). The Koper height datum replaced the old Trieste height datum, which dated back to 1875. A new height reference surface (quasi-geoid model) was determined, denoted by SLO_VRP2016/Koper. The new regional gravimetric survey significantly improved its quality (Medved et al., 2019b). All lower order levelling networks were recomputed in the new height reference system and all the bench marks maintained in the dataset of geodetic points obtained new official heights. The differences of heights in the old and new height reference systems vary from 5.3 cm to 21.0 cm; the mean difference is 12.8 cm (Figure 8).

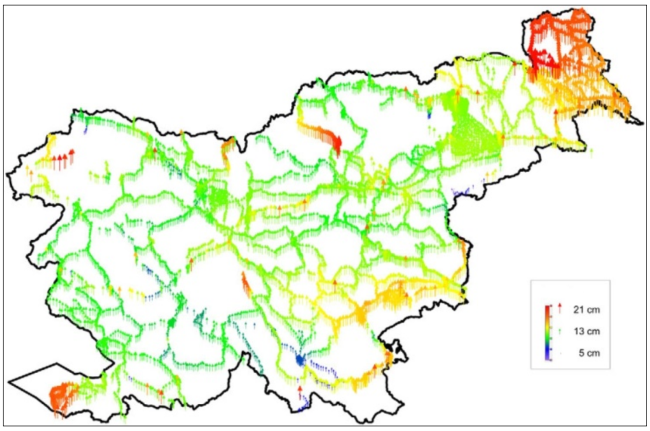

Figure 8: Differences between heights referred to the old and new height reference systems of Slovenia.

Simultaneously with the new height reference system, the new depth reference system – also referred to as the vertical offshore reference frame – was established. The new chart datum for the Slovenian sea is based on the same period of tide gauge observation dataset (18.6-year cycle at the tide gauge station in Koper with the mean epoch of 10. 10. 2010). The new height datum is now 70 cm above the chart datum. The latter is defined as the mean lower low water spring (Koler et al., 2019a).

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