Paper presented at the 19th EUREF Symposium held in Florence, Italy, 27–30 May 2009

NATIONAL REPORT OF SLOVENIA

B. STOPAR[1], B. KOLER[1], M. KUHAR[1], B. MOZETIČ[2], K.MEDVED[2], S. BERK[3], D. RADOVAN[3]

1 Introduction

This paper is the review of activities regarding the adoption the new national reference system in Slovenia, during the period 2008–2009.

2 The Project of the Establishment of the Network of GPS-Stations and European Spatial Reference System in Slovenia

According to the Recording of the Real Estate Act Slovenia established a contemporary national reference system and reference frame, which is realization of European Spatial Reference System (ESRS) at the territory of Slovenia. The purpose of introduction the new national reference system is to establish high quality reference for positioning for the sustainable development needs.

Surveying and mapping Authority of Republic of Slovenia (SMARS) succeed at a call for proposals for the European Economic Area and Norwegian Financial Mechanism with the project "The Establishment of the network of GPS Stations and European Spatial Reference System in Slovenia". The Grant Offer was signed in October 2006 and the project started in February 2007. The duration of the project is 33 months and 23 activities will be completed in this period.

3 The SIGNAL positioning service

The SIGNAL (SlovenIa-Geodetics-NAvigation-Location) positioning service represents the most important (fundamental) infrastructure of the new national horizontal reference system, based on ETRS89. The whole system consists of 15 Slovenian, 5 Austrian, 1 Hungarian and currently 2, but in plans for the future 7 Croatian permanent GNSS stations and of Control Center (Figure 2). Owner of the SIGNAL is Surveying and Mapping Authority of the Republic of Slovenia and the SIGNAL network, and the Control center consisted by operational, analytical and data center is managed by the Geodetic Institute of Slovenia. 1 station is part of EPN and 1 is part of ESEAS. Currently, the SIGNAL data is available free of charge with nearly 500 registered users. 250 regular users are mostly surveyors and app. 50 different users are using the SIGNAL positioning service products every day. Products of SIGNAL service are intended for positioning within the SIGNAL network in real time and post processing mode.

Products for real time positioning are DGPS corrections and RTK data of the single base station of the whole network, RINEX data at 1 sec. recording interval are available for post processing. Users are using the real time products at the portions: RTK VRS 3.0 62%, RTK VRS 2.3 31%, RTK single base station 6% and DGPS 1% (Figure 1).

---

[1] University of Ljubljana, Faculty of Civil and Geodetic Engineering
[2] Surveying and Mapping Administration of Slovenia
[3] Geodetic Institute of Slovenia

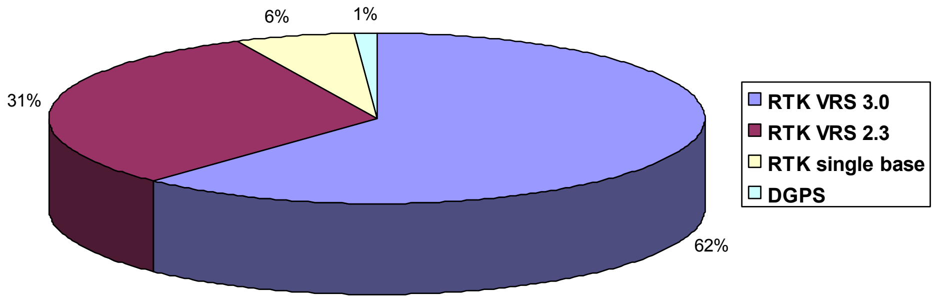

Figure 1: The usage of real time services

The SIGNAL positioning service is currently in process of renovation of the hardware equipment at permanent stations where GPS receivers are substituted with the GNSS ones. The new permanent station in Idrija was installed and is used for testing VRS positioning (rover integrity monitor). Beside hardware renovation at the stations also upgrade of software for GNSS service and parallel GNSS server was established. The peripheral equipment on all permanent stations (eg. UPS-device) is also being changed.

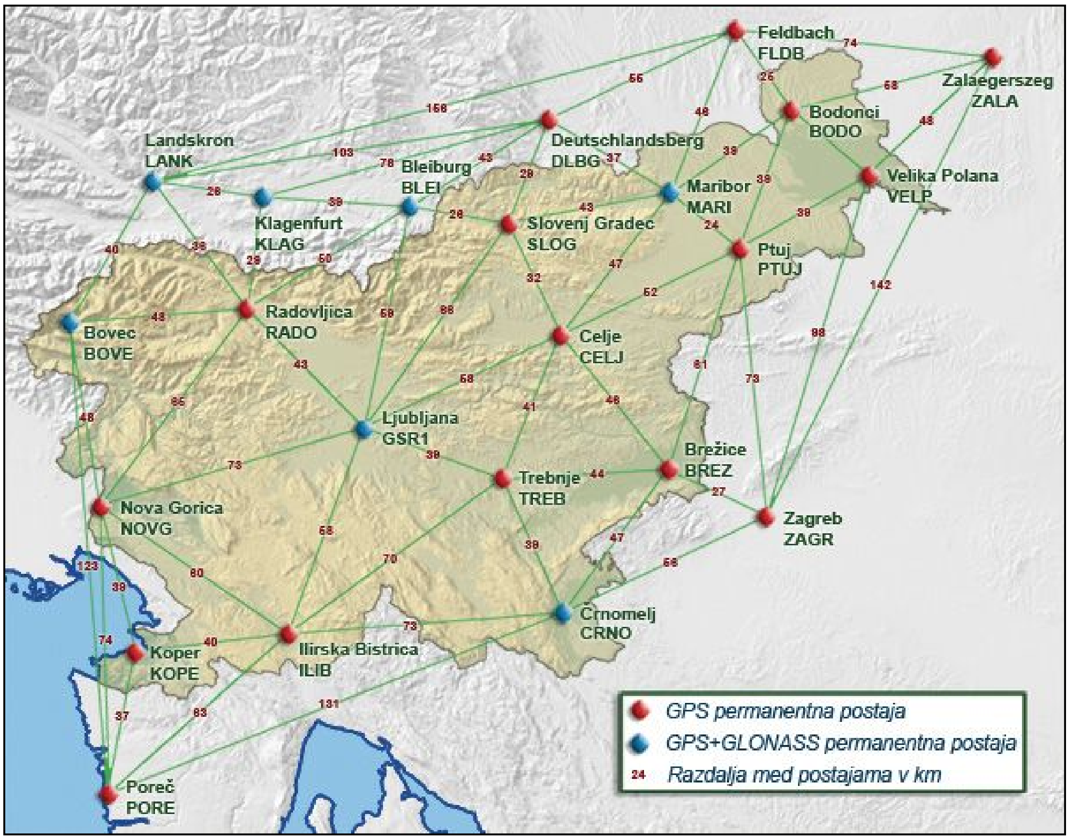

Figure 2: The SIGNAL network

4 Horizontal reference system

For the transformation purposes between old and new national reference system further densification of points in new reference system was performed. At the moment we have app. 2000 geodetic points with coordinates in both systems of good quality. On the basis of theese points many transformations for testing purposes were performed. As a result of theese testing transformations we marked the regions of inhomogenous quality of the old system where the transformation procedure of existing data to the new reference system should be done with special care. Another result of theese test tranformations is the selection of tie points, i.e. points with high quality coordinates in both systems. 560 tie points will be used for transformation of official national spatial data bases to the new reference system. The transformation method which will be used is based on planar affine transformation which is based on Delaunay triangules formed among theese 560 tie points. The tie points and Delaunay triangles formed among theese points are presented at Figure 3.

Establishment of the new reference system in Slovenia is based on the assumption that long term stability of reference system will be assured. Since the area of Slovenia is located on geodynamical active area, we have initiated the study which should gave us an overview of possibilities to assure the long term positional stability of connection between active GNSS network SIGNAL and passive GNSS network. Our goal within this research is to ensure (realize) the reference frame which will be able to ensure the coordinates which will be statistically equal, regardless of using active or passive GNSS network as a reference for geodetic survey purposes.

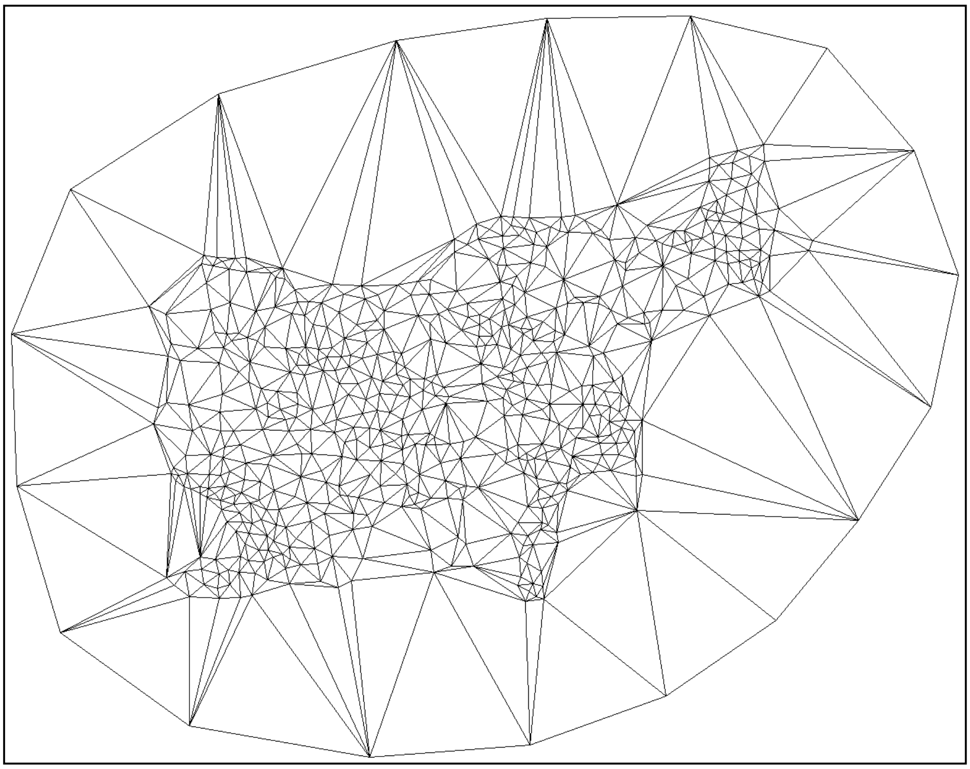

Figure 3. Tie points and Delaunay triangles for the transformation of official national geodetic data bases from an old to the new reference system

5 The Height System

For the purpose of establishment of the new height system, 230 km of the first order levelling lines were reobserved till the end of 2008. Gravimetric surveys were also performed along these new leveling lines for the purpose of determination of geopotential numbers.

6 The quality analysis of the existing geoid model

Existing geoid model is not homogenous in the country regarding the quality of GNSS-leveling. Detailed analysis could not be performed beacuse the existing GPS/leveling points are not evenly distributed. In some regions the discrepancies are up to several decimeters.

Surveying and Mapping Authorities of Republic of Slovenia (SMARS) maintanes the data base of all natioanl GPS/leveling points. There are 2005 point int the data base, but most of the orthometric heights were determined by trigonometric leveling. For the purpose of the analysis of geoid model, 879 GPS/leveling points were used; its distribution is presented at Figure 4.

The analysis is based on the comparison of computed orthometric height from measured ellipsoidal height and interpolated geoid height with measured (leveled) orthometric height. The differences on some points were too large and these points were removed from the data base. The final analysis was made with 781 ponts. Heights of 248 points were determined by geometric leveling, the rest were determined by trigonometric leveling.

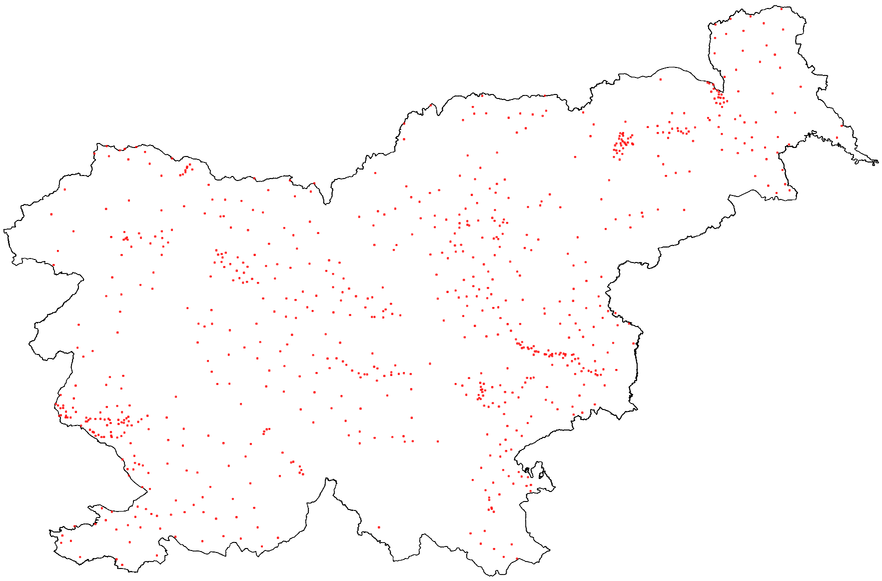

Figure 4: Distribution of GPS/leveling points used in the analysis of geoid model

Differences vary between -0,122 m and 0,262 m for the points whose heights were determined by geometric leveling, and between -0,22 m and 0,28 m for the points determined by trigonometric leveling.

6.1 The test area in western Slovenia

The special quality analysis of geoid were carried out in the western part of Slovenia along the leveling line Nova Gorica - Most na Soči. Some of the benchmarks in the line were stabilised recently in the years 2007 and 2008. The leveling, gravity survey and GPS observations were performed in the same years. Also the GPS-permanent stations Nova Gorica was inclued in the research.

The differences vary between 0,295 m and 0,489 m. The average difference is 0,394 m and agree well with the diiference determined at permanent GPS station Nova Gorica 0,383 m.

The results of the analysis at the test area show that existing geoid model could not be used for the GNSS-leveling in the western Slovenia. Differences between "interpolated" and "measured" heights are too large for the all surveying tasks. The reason for such big discrepancies could be errors in the geoid model or problems with the natioanl leveling network. Further research is neccessary to give the correct answer.

7 The Gravity System

In the year 2008 the project of establishment of the new gravity network of Slovenia was completed. Realization of the network has been done in two phases. The first phase represents monumentation and absolute gravity measurements on 6 absolute gravimetric points, which represent zero-order gravimetric network. This phase was completed in '90s. The second phase represented the monumentation and relative gravimetric measurements on 29 relative gravimetric stations of the first-order gravimetric network. The relative gravimetric measurements in the network were performed with two Scintrex gravimeters in the year 2006. The network is connected to one austrian and four croatian points. Austrian point (A abs on the Figure 5) is an excenter of the austrian absolute point. Points H-112, H-122, H-120 H-117 (Figure 5) are points of the croatian first order gravity network. The gravimetric network is sketched in Figure 5.

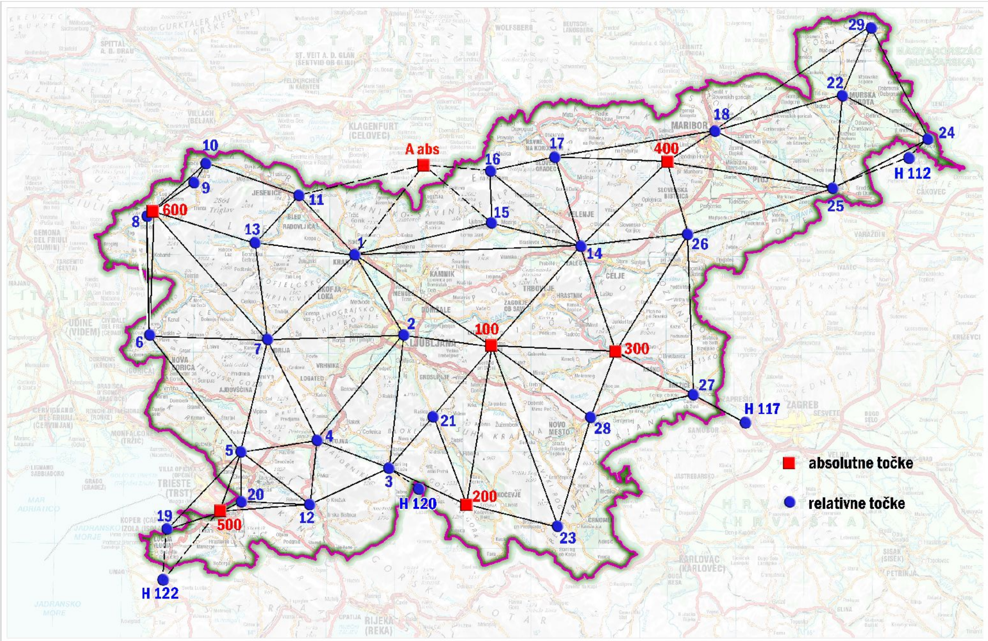

Figure 5: New gravity network of Slovenia

The final adjustment of relative gravimetric network were finished at the end of 2007. In our opinion the observations in the network were performed with acuracy which suits valid standards for national gravity networks. The a posteriori standard deviations obtained from the adjustment are as follows: $\sigma_{0\ SGU1} = 7{,}7*10^{-8}\ ms^{-2}$ for gravimeter SGU1 and $\sigma_{0\ HGI1} = 7,\ 2*10^{-8}\ ms^{-2}$ for the gravimeter HGI1. The adjustment of all observations performed with both gravimeters yielded a posteriori standard deviation $\sigma_{0(SGU1+HGI1)} = 9{,}5*10^{-8}\ ms^{-2}$.

Gravity values on the points of the first-order gravity network are based on the final adjustment of the observations in the network. Estimated standard deviations on the points range from $3{,}0*10^{-8}\ ms^{-2}$ to $6{,}2*10^{-8}\ ms^{-2}$.

New gravity network of Slovenia represents very good basis for all further activities regarding the gravity field research in Slovenia.

8 Introducing the new coordinate system into the national spatial databases

Work on introducing the new national horizontal coordinate system is going on. The Surveying and Mapping Authority of the Republic of Slovenia is continuing with activities on the field of the national cartographic/topographic system. After adopting the new national map projection, the map index system was changed for all basic scale levels (scales from 1:500 up to 1:10,000). Map sheet formats (dimensions) remain unchanged for all scale levels, but were virtually shifted for about 600 meters in south-east direction.

Figure 6: Virtual shift of the map sheet

The rule for new map sheet nomenclatures is based on the principle, that no map sheet from the old map index system could be mistaken for the one from the new map index system. The new orthophoto (adequate to map scale 1:5,000) is already produced in this new system.

The step-by step transformation of spatial data into the new coordinate system is carrying on. From the year 2008, all the maps of scale 1:25,000 and 1:50,000 (raster and vector data) are available in both – the old and new coordinate systems. Submeter accuracy of transformation was achieved. The transformed map sheets preserved the old map index system (covering the same area).

Detailed protocol of transforming all spatial data from the national spatial database has been prepared. The main goal is to assure the distribution of all spatial data in the new coordinate system as soon as possible. In the transitional period, all the data will be available in the old coordinate system, too.

9 References

BAJEC K., BERK S., FAJDIGA D., KLANJŠČEK M., LIKOVIČ D, MAHNIČ D, MESNER N, RADOVAN D., KOLER B., KOZMUS TRAJKOVSKI K., KUHAR M., STERLE O., STOPAR B. (2007): Razvoj državnega geodetskega sistema – Prehod na nov koordinatni sistem, 203p + 70 supplements, Geodetic Institute of Slovenia, Ljubljana.

BERK S., KOMADINA Ž., MARJANOVIĆ M., RADOVAN D., STOPAR B. (2003): *The Recomputation of the EUREF GPS Campaigns in Slovenia*, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Toledo, June 4–7, 2003. Reports of the EUREF Technical Working Group (TWG), No. 13. Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, 2004, pp. 132–149.

BERK S., BAJEC K., TRIGLAV ČEKADA M., FAJDIGA D., MESNER N., ŽAGAR T., KETE P., VODOPIVEC A., KLANJŠČEK M., RADOVAN D., STOPAR B., KOLER B., KUHAR M., KOZMUS TRAJKOVSKI K., PAVLOVČIČ PREŠEREN P., STERLE O. (2008): *Razvoj državnega geodetskega sistema – Prehod na nov koordinatni sistem, (Development of national geodetic system – Introduction of new coordinate reference system)* 202 pp. + 54 supplements, Geodetic Institute of Slovenia, Ljubljana.

BOUCHER, C., ALTAMIMI, Z. (2007): *Memo: Specification for reference frame fixing in the analysis of a EUREF GPS compaign*, http://lareg.ensg.ign.fr/EUREF/memo.pdf

KUHAR M., BARIŠIČ B., LIKER M., MEDVED K., KOLER, B. (2007): *The survey of the Slovenian gravimetric network*, presented at Slovenian Association of Geodesy and Geophysics annual meeting, Ljubljana, January 18, 2007.

STOPAR B., REŽEK J., *National Report of Slovenia*.: TORRES, Joao Agria (ed.), HORNIK, Helmut (ed.). Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Toledo, 4–7 June 2003. Reports of the EUREF Technical Working Group (TWG): IAG, Subcommission for Europe (EUREF), (Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Bd. 33), (EUREF Publication, No. 13). Frankfurt am Main: Verlag des Bundesamtes für Kartographie und Geodäsie, 2004, pp. 281–282.

STOPAR B., *National Report of Slovenia*: TORRES, Joao Agria (ed.), HORNIK, Helmut (ed.). Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Bratislava, 2–5 June 2004. Reports of the EUREF Technical Working Group (TWG): IAG, Subcommission for Europe (EUREF), (Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Bd. 35), (EUREF Publication, No. 14). Frankfurt am Main: Verlag des Bundesamtes für Kartographie und Geodäsie, 2004, pp. 266–268.

STOPAR B., *National Report of Slovenia*: TORRES, Joao Agria (ed.), HORNIK, Helmut (ed.). Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Vienna, 1–4 June 2005. Reports of the EUREF Technical Working Group (TWG): IAG, Subcommission for Europe (EUREF), (Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Bd. 38), (EUREF Publication, No. 15). Frankfurt am Main: Verlag des Bundesamtes für Kartographie und Geodäsie, 2005, pp. 278–280.