National Report of Slovenia

B. STOPAR, M. KUHAR[1]

1 Introduction

This paper is the review of geodetic activities in Slovenia during the period 1998–2000, with special emphasis on activities and participation of Slovenia within European projects.

2 The use of EUREF network in Slovenia

The development of a new reference coordinate system in Slovenia that should comply all the needs of the contemporary geodesy regarding state and unified European coordinate system, started with the connection of the first order horizontal network of Slovenia with the EUREF. This connection is based on GPS observation campaigns performed in 1994 and 1995. Both campaigns were performed with the substantial contribution of the Institut für Angewandte Geodäsie, Frankfurt (now Bundesamt für Kartographie and Geodäsie) to the Surveying and Mapping Authority of the Republic of Slovenia. The EUREF-CRO-SLOV '94 GPS observation campaign was performed at 8 first order points (among these were 5 points chosen as "real" EUREF points) during the 5 days of permanent GPS observations. The results were published in 1995 (ALTINER et al., 1998).

The purpose of the second EUREF campaign at the territory of Slovenia, under the name SLOVENIA '95 Campaign, was to densify the existing EUREF points at the territory of Slovenia. Slovenia is placed in tectonical and seismological active part of Europe and Surveying and Mapping Authority of Slovenia wanted to connect the project of the establishment of new reference coordinate system with the monitoring the strain accumulation in south-eastern part of the Alps region and in the northern part of the Adriatic Plate. The second observation campaign in 1995 was performed at all 34 (35) first order points, at 2 stations of the triangulation base lines network (Bukovec and Radovljica) included in the first order network; at 1 second order point, and at 12 geodynamic points. GPS observation were carried out for six days, in two blocks with 3 day of 24 hours of observations each. The final coordinates of the Slovenia '95 Campaign are given in the ITRF93 epoch 1995.7, respectively in the ETRS89 epoch 1989.0. Unweighted RMS values with respect to the combined solutions are 2 mm in north direction, 2 mm in east direction and 6 mm in height direction. At the moment became available also the common solution of the three GPS observation Campaign performed at the territory of Slovenia and the surrounding area (Y. ALTINER et al., 1998). Namely in 1996 there was another GPS observation campaign CROREF-CRODYN '96, with the duration of 15 days, where 68 points were observed. The purpose of this campaign was the enlargement the EUREF reference frame into the continental part of Croatia, and to establish dense geodynamic network covering the area around the Adriatic sea. At this campaign 5 EUREF points in Slovenia and 10 points in Croatia were observed once more.

2.1 Astrogeodetic network of Slovenia and ETRS89

As we already mentioned, the astrogeodetic network of Slovenia is classical triangulation network. In classical triangulation networks angles are observed with much higher accuracy than the baseline lengths and in general all such networks exhibit quite large scale errors. The another reason for the systematic errors in the astrogeodetic network is the fact that the impact of the deflection of the vertical and the impact of the geoidal heights to the observed quantities were not taken into account. Some previous investigations (Jenko, 1986) confirmed the hypothesis that the situation is the same also in the astrogeodetic network of Slovenia.

In the situation where besides the official coordinates in the national coordinate system, also the positions in ETRS89 coordinate system are available, some considerations of the national coordinate system became possible. The 27 of the first order triangulation points with positions given in both system in Figure 1 are marked with the filled circles and squares.

We have performed the 7-parameter similarity and 6-parameter similarity (orthogonal) transformation of ETRS89 coordinate system to the national coordinate system. These types of transformations give us an overall impression about the relative point positions in the coordinate system, and can also serve as starting point for the detailed assessment of the coordinate system.

The 7-parameter similarity transformation of the whole astrogeodetic network shows the residuals of the transformed point positions in the amount up to 1 m. The interesting fact is that the largest residuals occur at the points located on lower part of the country i.e. at the east and at the south-west. Residuals of the transformed coordinates are given in Figure 2 (left).

[1] Bojan Stopar, M. Kuhar: University of Ljubljana, Faculty of Civil and Geodetic Engineering, Geodetic Department, Jamova cesta 2, SLO 1000 Ljubljana, Slovenia, Fax: 386 - 1 - 4 250 704, Tel.: 386 - 1 - 4 768 500, E-mail: bstopar@fgg.uni-lj.si

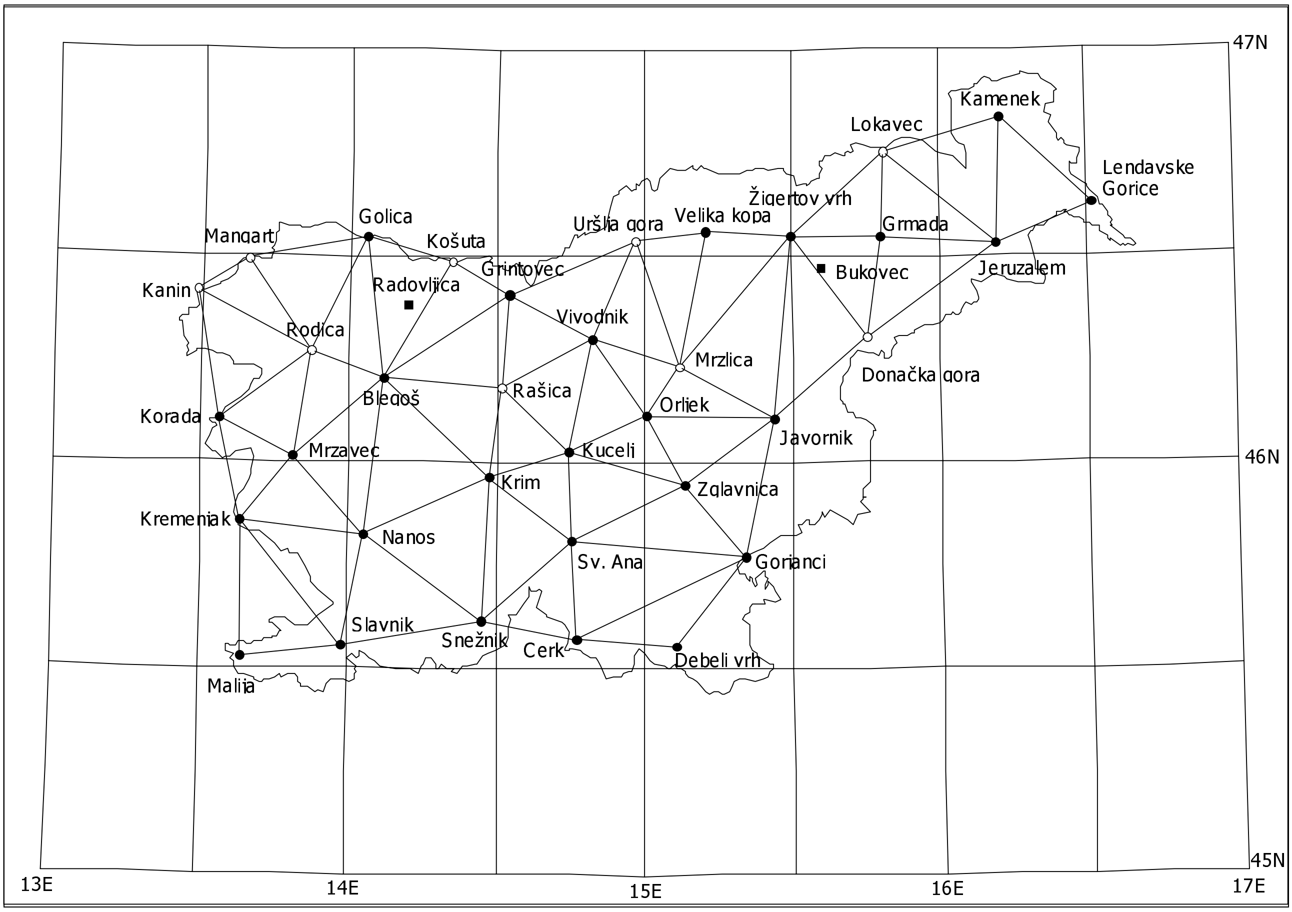

Fig. 1: Astrogeodetic network of Slovenia

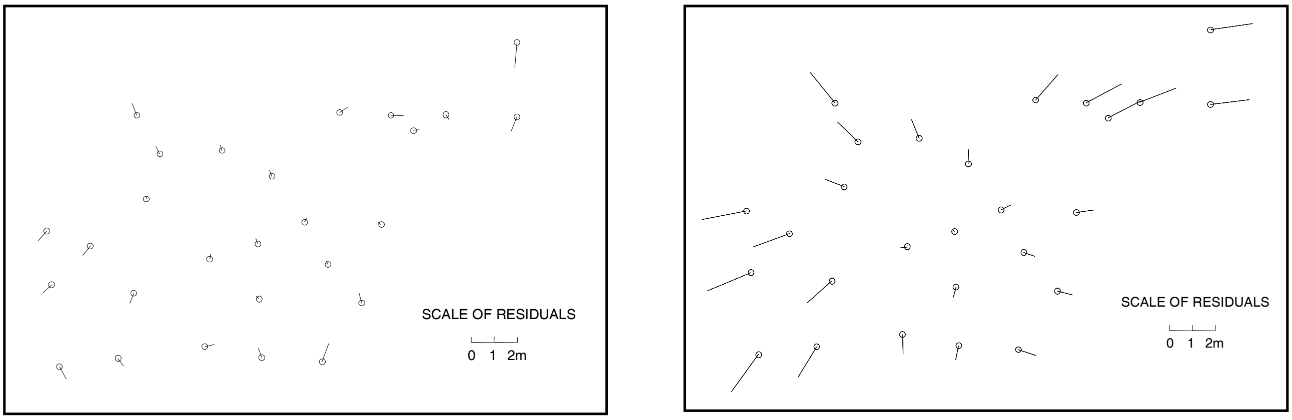

Fig. 2: Residuals in the astrogeodetic network of Slovenia after the 7–parameter (left) and after the 6–parameter (right) similarity transformation

With the 6-parameter coordinate transformation we compare coordinate systems under the presumption of equal scale in both systems. Such transformation is not very common procedure, since coordinate system which should be transformed, results from different measuring procedures or measuring techniques, what is also the reason for the need of transformation. In general it is possible to accept that different measuring techniques produce coordinate systems which are rotated, shifted to each other and of different scale.

The residuals after the 6-parameter orthogonal transformation of the ETRS89 coordinate system to the national coordinate are in the amount to the 2 m. The residual vectors are now increasing with the increased distance from the centre of the gravity of the network. The residual vectors of the border points at the eastern and western part of the network exhibit large components up to 2 m in the E-W direction. Concerning the opposite direction and the almost parallel direction of the residual vectors at these points, it is possible to say that the distance between eastern and western part of the network are for about 4 meters too short. We can say that the territory of the Republic of Slovenia, as presented in the official coordinate system, is for the same amount i.e. for 4 meters too short in E-W direction, and for about 2 m too short in N-S direction. Residuals of the 6-parameter transformation are given in Figure 2 (right).

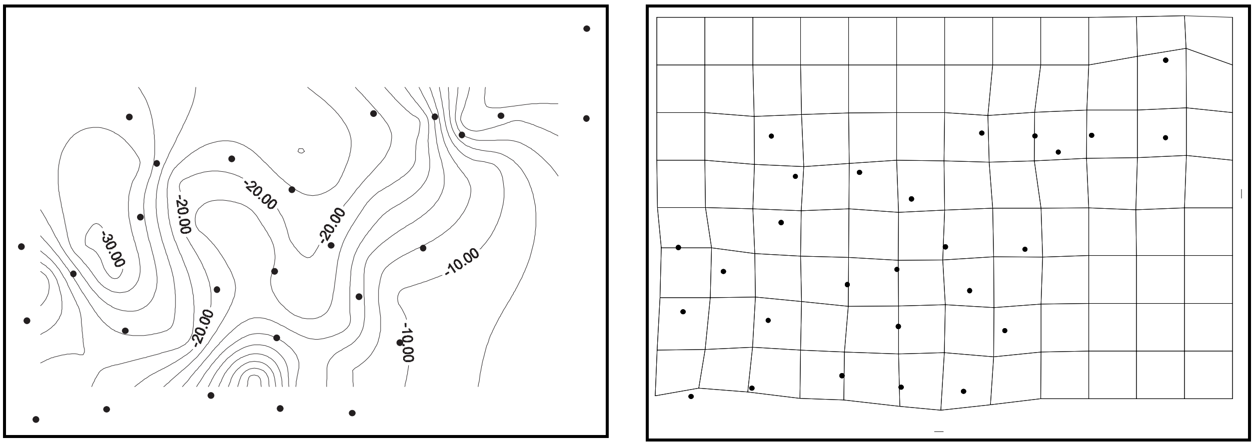

Fig. 3: Scale deformation of the astrogeodetic network of Slovenia in mm/km (left) and the distortions of the national coordinate system of Slovenia computed using the collocation method (right)

Besides the displacements of the points in the national coordinate system we tried to estimate the scale (the unit length) in the national coordinate system as a function of a position in the coordinate system. For the scale assessment we formed 37 triangles connecting 27 points in the net. In each triangle the scale factor was estimated with the similarity 7-parameter transformation. Scale factor as function of the position in the net reach the values from -0.02 mm/km to -30.85 mm/km. Interpolated scale of the official network in the mm/km is shown on the Figure 3 (left). Practical value of the computed scale factor is that the correctly measured distances should be corrected according to the scale factor deformation valid for the measured distance position in the net. Such distance could be then included into the existing coordinate system with the non-homogenous scale without difficulties.

2.2 Transformation using least squares collocation

At he end the least squares collocation was used as a mean by which we tried to model the distortions of the official (horizontal) coordinate system. Because of only having 27 observation points, covariance function was not determined empirically. Characteristic distance of the covariance function is chosen to be the minimum distance in the network. With the choice of the characteristic distance equal to the minimum distance in the net we tried to simulate the situation where the error in the position in certain point has no influence to the position error in the neighbouring points, which is certainly not very close to the reality.

Residuals after the 7-parameters transformation of the national coordinate system into the ETRS89 coordinate system were used for the computation of the signal in computation points. The distortions of the national coordinate system of Slovenia computed using the collocation method are sketched in Figure 3 (right).

3. The geoid in Slovenia

In the year 2000 a completely new geoid for the territory of Slovenia was determined (PRIBIČEVIĘ, 2000). It is a combined astro-geodetic & gravimetric solution. Together 99 astro-geodetic points in Slovenia and in border area with Austria, Croatia, Hungary and Italy, together with some 4000 point gravity values were used. The least squares collocation was employed with known remove–restore technique. The transformation of collocation solution was done using almost 200 GPS/levelled stations.

Figure 5 shows the 2000 year solution together with differences with the European gravimetric geoid (quasi-geoid) EGG97, (DENKER et al., 1997), where gravimetric undulations were transformed to the Slovenian height system.

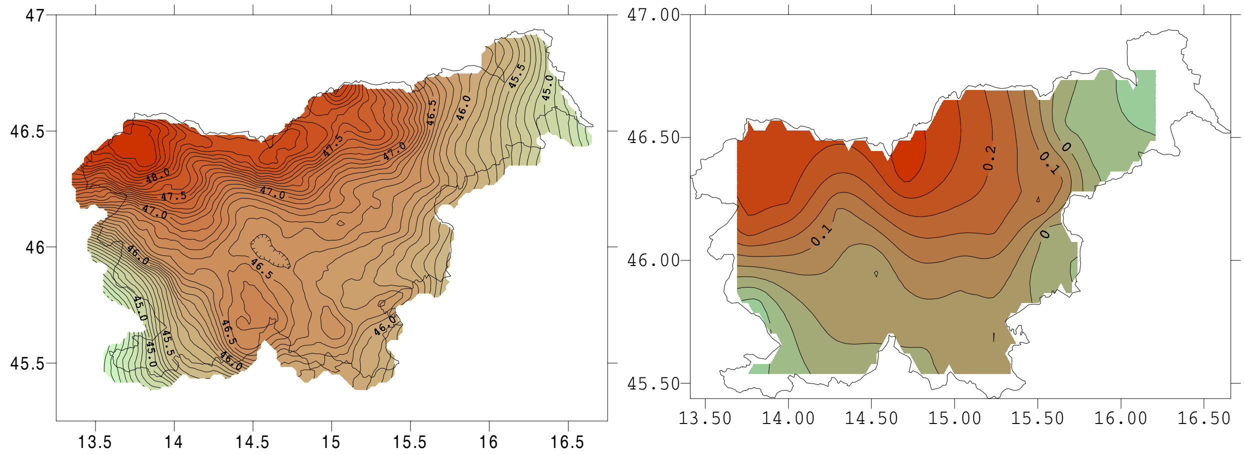

Fig. 5: the latest geoid solution (2000) and differences with EGG97

4. Participation in EUVN

The following points were included in the EUVN97 campaign: Velika Pirešica, Lendavske gorice (EUREF point) and Malija (EUREF point). Levelling measurements have been carried out between the UELN nodal bench marks and EUVN GPS markers, using first order precise levelling methods.

In order to compute geopotential number differences, gravimetric measurements had been performed in May 2000 with the support of from BEV (Bundesamt für Eich und Vermessungswesen) Austria (RUESS, 2000). All data and results together with the documentation sheets were forwarder to BKG–Leipzig.

5. UELN95/Vertical Control Network

In the year 2000 the re-computation of the Slovenian first-order levelling network was completed. The network was a part of a united first-order levelling network of former Yugoslavia, so the re-computation and adjustment was done in such a way that all levelling lines homogeneously cover the territory of Slovenia, what was not the case in the past.

6. Participation in project UNIGRACE

Slovenian station in the project UNIGRACE is Bogenšperk ca 30km away from CEGRN site Ljubljana. The point is stabilized in the underground room of the mediaeval castle Bogenšperk. Stations fulfil all the criteria for selection and implementation of absolute gravity stations. The measurements of the first campaign were carried in December 9–11, 1998 by Dr. Mäkinen from Finnish Geodetic Institute (FGI) (MÄKINEN, 1999). The measurements of the second campaign were performed by Dr. Ruess from BEV in May 24–25, 2000 (RUESS, 2000).

7. References

ALTINER Y., ČOLIĘ K., GOJČETA B., HABRICH H., LIPEJ B., NEUMAIER P., MARJANOVIĘ M., MEDIĘ Z., MIŠKOVIĘ D., PRIBIČEVIĘ B., RAŠIĘ L., SEEGER H., SELIŠKAR A. AND TAVČAR D. (1998): *Results of a Recomputation of the EUREF GPS Campaigns in Croatia and Slovenia*, Proceedings of the Symposium of the IAG Subcommission for Europe (EUREF), Bad Neuenahr–Ahrweiler, June 10–13, 1998, eds. Gubler E. and Hornik H., Verlag des BGK, 79–89.

DENKER H., TORGE W. (1997): *The European Gravimetric Quasigeoid EGG97 – an IAG supported continental enterprise*. In: IAG Symp. Proceed., IAG Scient. Ass. Rio de Janeiro, 1997, Springer, Berlin.

JENKO M. (1986): *Works on the Astrogeodetic Network in the Years 1975–1982*, Inštitut GZ SRS, Ljubljana.

MÄKINEN J. (1998): *UNIGRACE COPERNICUS Programme, Progress Report 1998 for Finland*, Annual Progress and Financial Report 1998 for the UNIGRACE PROJECT.

PRIBIČEVIĘ B. (2000): *The Use of Geological, Geophysical and Geodetical Databases in Determination of the Shape of Geoid in the Republic of Slovenia*, Doctoral Thesis, Faculty of Civil and Geodetic Engineering, University of Ljubljana.

RUESS D. (2000): *Gravimetric measurements in Slovenia 2000*, BEV, Vienna, Austria (personal communications)