Transformation between the Local and Global Geodetic Datum in Croatia

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Abstract

Thanks to the several GPS campaigns, made in the last six years, it was possible to calculate for the territory of Croatia precise transformation parameters between the existing (old) geodetic reference system, which is based on original one from the Austro-Hungarian Empire (1901), and the new global geodetic datum, like ETRF89 or ITRF94. In this paper, the results of the latest calculations efforts are presented in the form of seven transformations parameters and their error estimates. The significant influence of the recent Croatian geoid solution on the high transformation is elaborated, too.

1. Introduction

Transformation between geodetic datums is necessary because the spatial data become more and more globalized (so that the national datums are no longer convenient), and modern techniques of geodetic measurements (GPS) have started to be applied more widely with their realisations being of higher quality than the local datums

The geodesists in the Republic of Croatia have so far had at their disposal the inherited geodetic references systems from the states that it used to be the part of through the its history. The basis of the present positional geodetic datum was determined then by the works of the Military and Geographic Institute of the Austro-Hungarian Monarchy in Vienna. The fundamental point of this system is Hermanskögel having the position $\phi_0=48^0 16\ 15.29''$, $\lambda_0=33^0 57\ 41.06''$ (from Ferro) i.e. the belonging azimuth $A=107^0 31\ 41.70''$ towards the neighbouring points Hundesheimer Berg, was determined by means of astronomical measurements. As mathematical model for the Earth, Bessel's ellipsoid from 1841 was chosen at that time (MGI, 1901). Thus established I. order triangulation network covered very well the territory of the present day Croatia and it was adjusted according to the measuring conditions in seven separate blocks (see Fig. 5). For brevity sake, let us denote this inherited geodetic datum as HR1901.

Between the two World Wars the Military and Geographic Institute from Belgrade established the I. order triangulation network of Yugoslavia from that time leaning on the existing Austro-Hungarian network, and it was measured anew after the Second World War, but the results of these measurements have never been introduced into the civil usage completely. Three essential deficiencies of the existing triangulation network should be pointed out. First, the elevation of points are determined essentially worse than the horizontal position co-ordinates, which poses a significant problem in the transformation of modern GPS measurements into the existing local datum. The second deficiency lies in the fact that the existing network is very badly documented, and for almost every GPS campaign one has to calculate local transformation parameters in order to minimize the transformation errors. And finally, the permanent markings of these points are rather inconvenient for practical GPS measurements, because they are located mostly on high hills difficult to approach.

2. New geodetic works in the independent Croatia

In 1991, GPS started to be applied in Croatia, but these measurements became significant along with Croatia being included into the European Reference Network EUREF (Seeger, 1993). The measurements were made in the period from the 30. May till the 3. June 1994 (four days with a session lasting 24 hours) at altogether 10 new 0. order points (plus 5 points in Slovenia; Fig. 1). The next was GPS campaign CRODYN94 (22 geodynamic points) carried out in order to determine the reference framework for testing the geodynamics in the area of the Adriatic Sea (Altiner et al., 1995). CROREF96 – CRODYN96 is another EUREF campaign in Croatia. Its successful realisation led to significant densifying of the field of I. order GPS points to about 80 points (Fig. 2). The measurements lasted from the 29. August to the 12. September 1996, and that is, in four phases lasting two days each, and the last phase (CRODYN phase) three days, with the measuring session of 24 hours (ALTINER et al., 1997).

It should be pointed out that these international projects were realized in collaboration with BKG (Bundesamt für Kartographie und Geodäsie; earlier IfAG) from Frankfurt, the State Geodetic Administration of the Republic of Croatia and the Faculty of Geodesy, University of Zagreb. The processing of GPS data was carried out in Frankfurt with the help of Bernese computer program resulting in precise co-ordinates of points in ETRF89, i.e. ITRF94 datum and epoch 1996.7. The accuracy obtained on the basis of daily solutions has been evaluated to ±2 mm for the northern component, ±4 mm for the eastern and ±7 mm for the height component (ibid.).

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Besides the 0. and I. GPS points, the project of reconstructing the II. Order trigonometric network and for establishing adequate homogeneous field of GPS points in the raster 10x10 km was initiated in 1997.

Fig. 1. EUREF94 GPS campaign in Croatia

The measurements were carried out at about 50% of the territory of north-western Croatia covered with altogether 464 points (BAČIĆ and BAŠIĆ, 1999). The final results in the form of three-dimensional GPS co-ordinates have been indicated in ITRF94 datum and the epoch 1997.4, as well as in ETRF89 datum. It should also be highlighted that the continuation at the rest of the territory of southern and eastern Croatia has been planned for this and the next year. On the Fig. 3, one can see the mutual presentation of available 0. and I. Order GPS points. Apart from that, there has been a whole series of city GPS networks measured that should be used also in the cadastre reconstruction, apart from the datum definition.

A significant advance has been made in the last years in the field of determining the Earth's gravity field as well (BAŠIĆ et al., 1999; BAŠIĆ and BRKIĆ, 1999), so that for Croatia (and wider) there is an absolutely oriented geoid HRG98 given at disposal (Fig. 4) with its inner accuracy better than ±4 cm at the entire territory. The geoid is used for the purpose of transformation, as well as for obtaining the orthometric heights on the basis of GPS measurements.

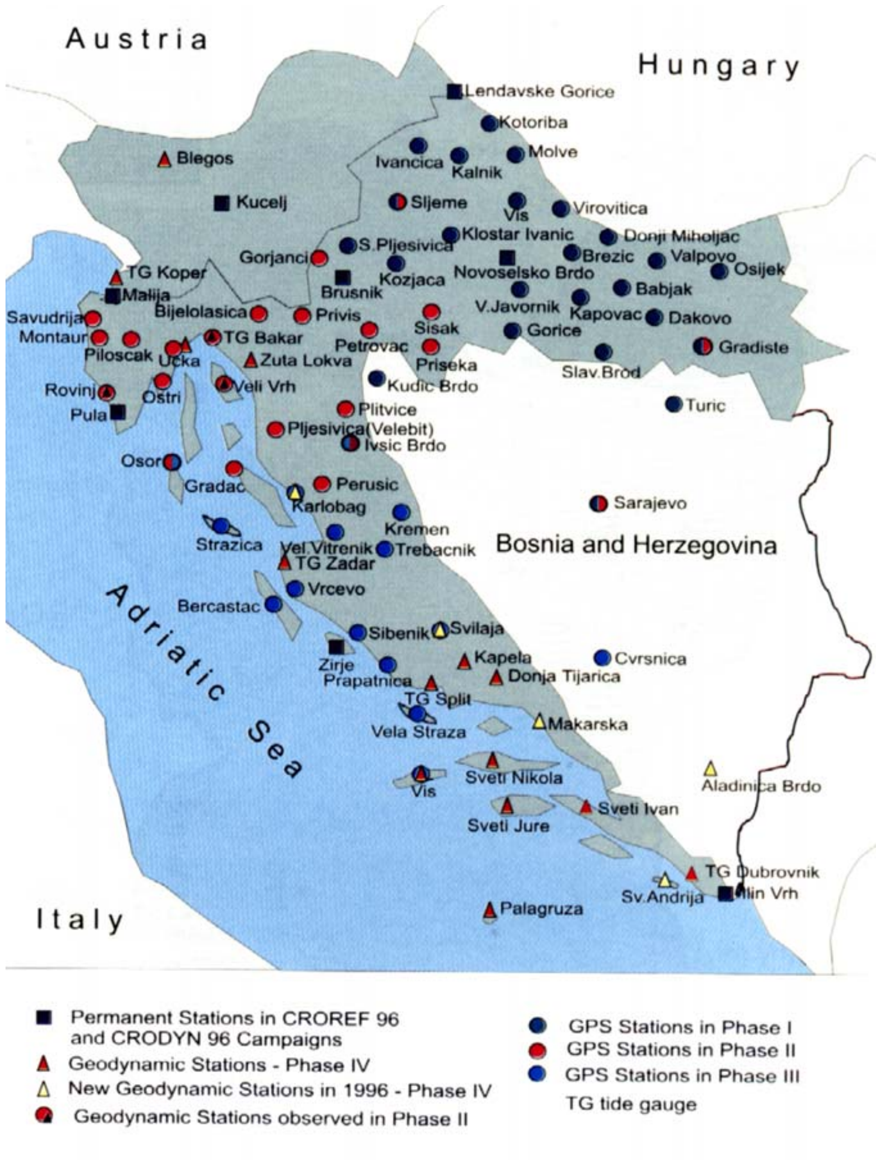

Fig. 2. CROREF96–CRODYN96 GPS campaign in Croatia

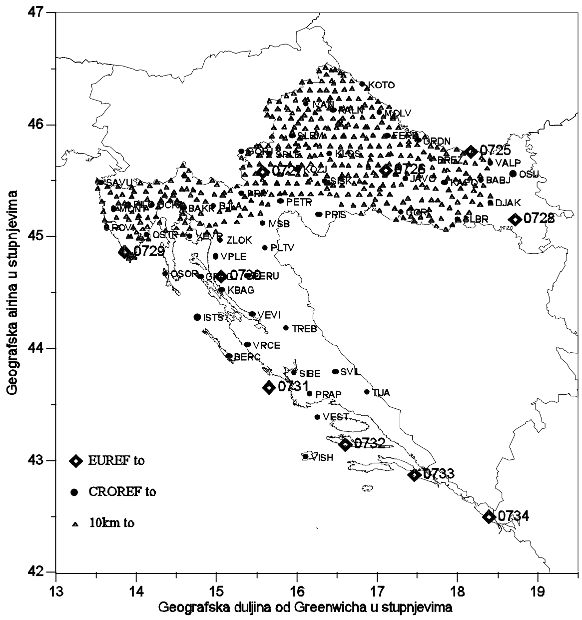

Fig. 3. 0., I. and II. order GPS points in Croatia

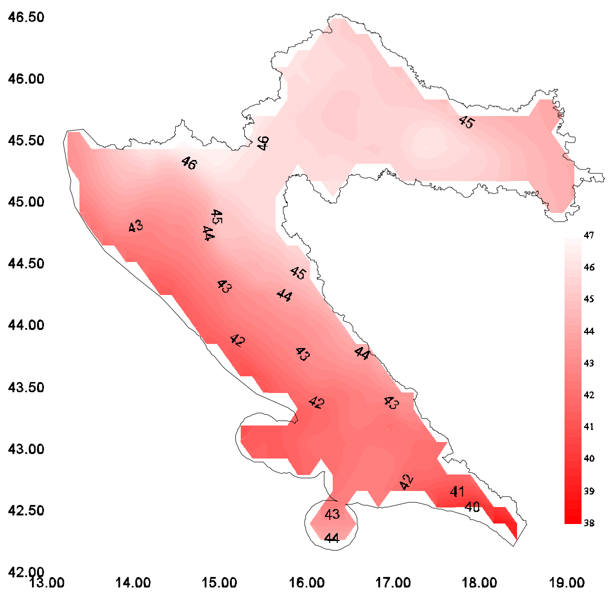

Fig. 4. The newest Croatian geoid HRG98 (meters)

3. Transformation

The problem of the transformation itself between a global and a local datum can be solved very simply providing that both networks are homogeneous, by determining e.g. a set of 7 transformation parameters (3 translations, 3 rotations and 1 scale change). In that case, even relatively more significant «progress» of the inherited Croatian local datum HR1901 with regard to the global datums, of about 17.0" by λ and about 0.7" by ϕ, does not present any difficulties in mathematical sense. There is a bigger problem referring to the fact that the existing triangulation network is actually two-dimensional with very badly determined height component, and on the other hand, the precise heights have got mostly no good positional co-ordinates. The situation becomes additionally complicated due to the fact that the transformation in three dimensions should not be executed without using a geoid. Even when the heights are well determined, the influence of the geoid in the networks having even a little bit larger spreading or containing more considerable variations, can be more significant.

3.1 Transformation between ETRF89 and HR1901

There are the calculations of global transformation parameters presented further in the text on the basis of momentarily available 120 identical point at the level of the entire state (Fig. 5). The following unique transformation parameters and their error estimates have been obtained for Croatia (table 1).

As it can be seen, it is to be deduced on the basis of the obtained residuals in identical points that the accuracy of global transformation parameters for Croatia, indicated in adequate rms values, is ±0.84 m positionally and ±1.34 m spatially in the case when the geoid is not used in the transformation, i.e. ±0.83 m positionally and ±0.87 m three-dimensionally in the case when HRG98 geoid is used. It is more than obvious how significant the usage of geoid is because it results in achieving height transformation accuracy of almost 4 times (!), but by means of that also of the spatial (3D) transformation of about 35%. Although the distribution of identical points for the transformation cannot be considered ideal (Fig. 5), one can still say that the global transformation parameters will be changed very little in the future, as well as their error estimation. On the basis of the data given in the table 1it can be affirmed that the accuracy of the existing positional trigonometric network at the level of entire Croatia belongs to the order of about ±1 m size, but there are also other remarkable inhomogeneities in it (see Fig. 6, and especially Fig. 8). Graphic presentation of the obtained discrepancies in the direction north-south and east-west is visible on the Fig. 6. There is total (absolute) discrepancy of about 2 m by ϕ and of about 3 m by λ. The Fig. 7 shows the discrepancies by height, and that is in the case when the geoid surface is not used (down), and Fig. 8 gives vector presentation of positional discrepancy between global ETRF89 datum and Croatian local HR1901 datum.

Table 1: Transformation parameters between ETRF89 and HR1901 including their error estimates

	Without geoid	With geoid
Translation: Tx	- 514.00 m	- 551.73 m
Ty	- 155.49 m	- 162.86 m
Tz	- 507.05 m	- 467.93 m
Rotation: Rx	5.613852 "	6.037326 "
Ry	3.675670 "	1.957325 "
Rz	- 11.466815 "	- 11.381551 "
Scale: μ	- 2.091013 ppm	4.820429 ppm
Accuracy: in ϕ	±0.522 m	±0.516 m
in λ	±0.653 m	±0.646 m
in h	±1.043 m	±0.280 m
Positional(2D)	±0.836 m	±0.827 m
Three-dimensional (3D)	±1.336 m	±0.873 m

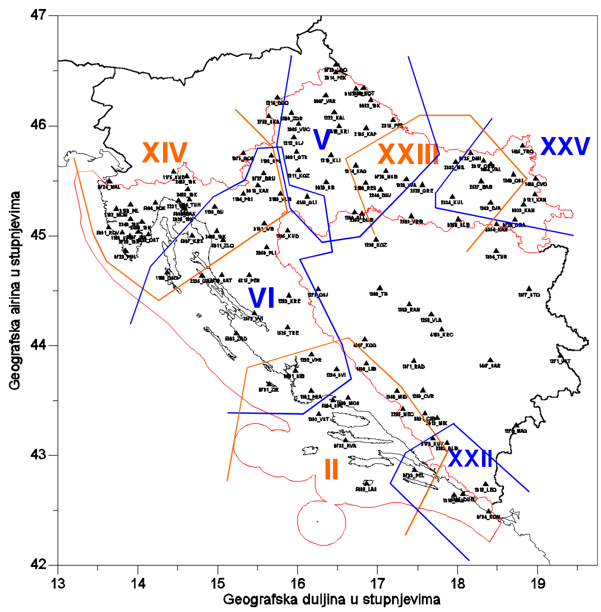

Fig. 5. Identical points and 7 blocks of Austro-Hungarian triangulation

If we do not use the geoid, the occurrence of the height transformation errors is possible at the entire territory of the state amounting even to about a few meters, and if we use the geoid, it will be only a decimeter at the most (Fig. 7). If we compare the figures 5. and 8. we can notice more than clear correlation between them and thus understand better how the existing inhomogeneities in HR1901 network have developed actually. The figure 8 shows very clearly the real reason for the necessity of defining a new official geodetic datum of the Republic of Croatia.

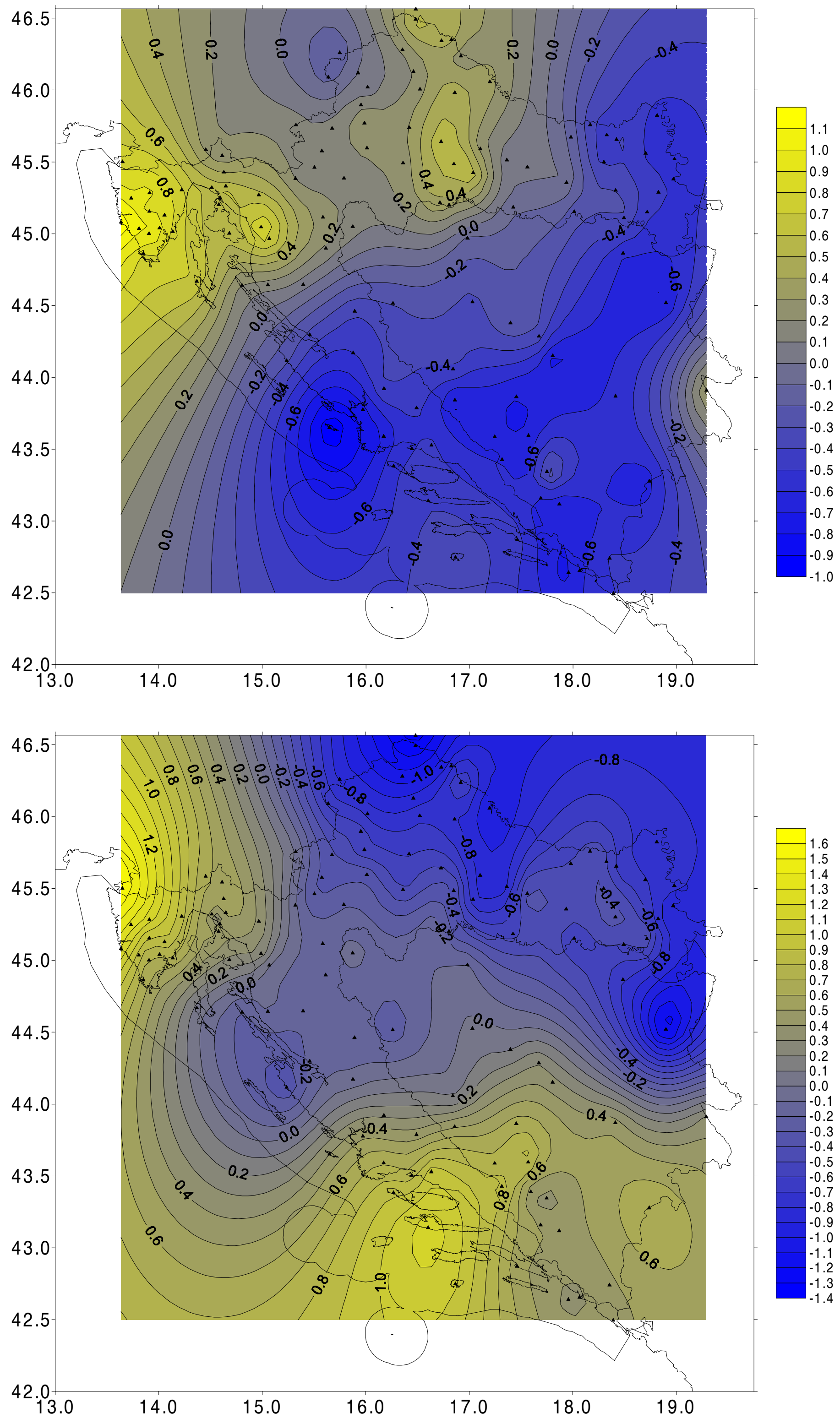

Fig. 6. Residuals in north-south (up) and east-west (down) direction in meters

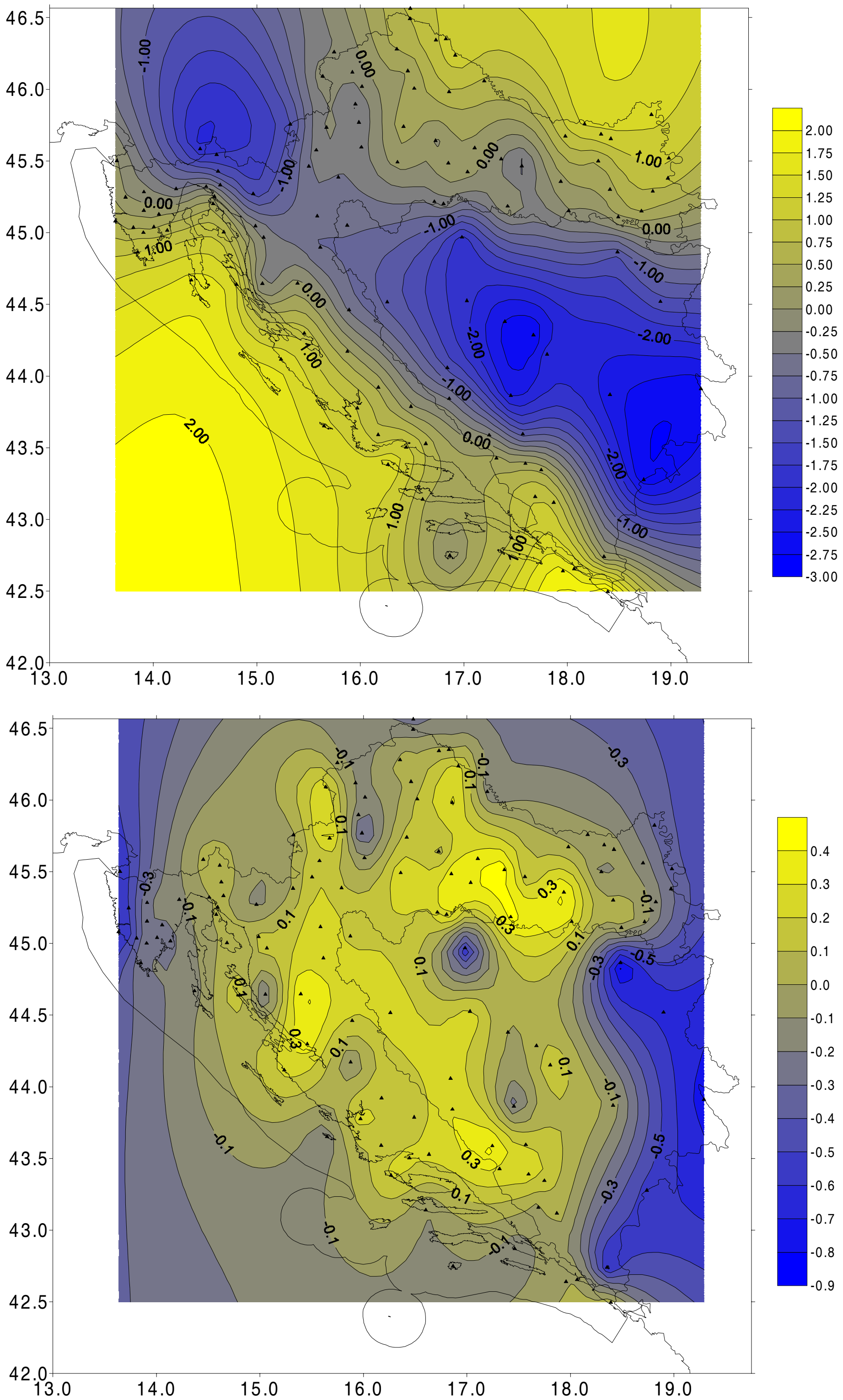

Fig. 7. Height residuals in the case of excluding (up) and including (down) HRG98 geoid in meters

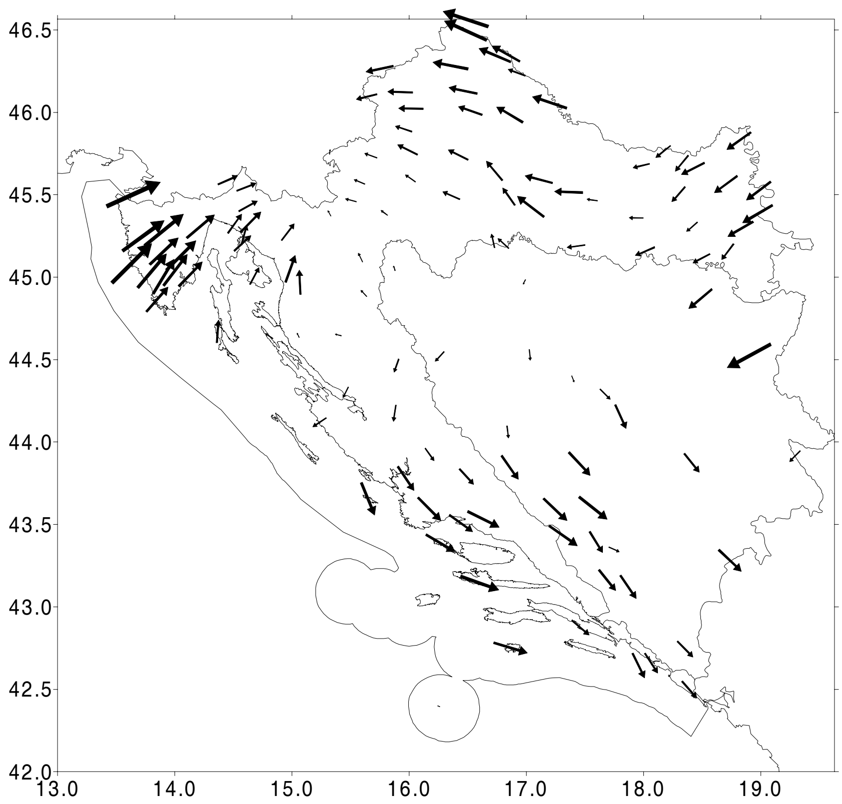

Fig. 8. Vector presentation of the positional discrepancy (rms = ±0.83 m)

3.2 Transformation between ITRF94, in the epoch 1996.7 and ETRF89 datum

Since there were 9 among 10 EUREF points observed (except the point 0730) in both GPS campaigns: EUREF94 and CROREF96, it was rather interesting to calculate direct transformation parameters between ETFR89 datum and ITRF94 datum in the epoch 1996.7 (in which the CROEF96 co-ordinates have been determined), and that is because both global datums are imposed as possible solutions for the new fixed terrestrial reference datum of the Republic of Croatia.

Table 2: Direct transformation parameters between ITRF94 datum, the epoch 1996.7 and ETRF89 datum at the territory of Croatia

		9 EUREF points
Translation:	Tx	- 0.3824 m
	Ty	0.1768 m
	Tz	- 0.0381 m
Rotation:	Rx	- 0.00426503 "
	Ry	- 0.01385051 "
	Rz	0.01125247 "
Scale:	μ	0.03345245 ppm
Accuracy (rms):	po ϕ	±0.003 m
	po λ	±0.003 m
	po h	±0.006 m
Positional (2D)		±0.004 m
Three-dimensional (3D)		±0.007 m

Table 2 gives the amounts of transformation parameters and their error estimates. It is obvious that the accuracy of transformation parameters between these two global datums at the territory of Croatia comes to ±4 mm for horizontal position, and ±7 mm for three-dimensional (!). This high transformation accuracy is in accordance with the accuracies of positional co-ordinates and ellipsoidal heights that resulted from the processing of EUREF9 and CROREF96 GPS campaigns. The transformation between these two datums (and the epoch) is of course possible, using earlier published global transformation parameters for Europe (Boucher et al., 1998).

4. Conclusion

The global transformation parameters between the local geodetic reference system HR1901 and the global ETRF89 datum have been determined for the territory of Croatia, showing an rms accuracy of ±0.83 m in horizontal position and ±0.87 m in spatial position, in the case when HRG98 geoid was applied. When geoid surface was not taken into account, the heigh transformation yielded almost 4 times worse results and the 3D-transformation with ±1.34 m accuracy. The obtained and in this paper published 7 parameters should be accepted as most reliable one at this moment. Those parameters are proposed to become official for Croatia till the end of this year.

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