

GEODESY IN CROATIA 1991–1994*

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ABSTRACT. This is the first brief review of the achievements made by the Croatian geodetic scientists so far, within the scope of single fields covering all 5 sections of IAG. For the period from 1991 to 1994, it has taken into consideration the results of the work done by 41 authors operating in the geodetic activity of the Republic of Croatia accompanied by the collaboration of 13 experts from abroad.

It must be pointed out at the beginning that the Croatian geodesists and geophysicists have continuously participated in the most of General Assemblies of the International Union of Geodesy and Geophysics (IUGG), and that they also organised very successfully the first international symposium on “Gravity Field Determination and GPS-Positioning in the Alps Adria Area” in Dubrovnik and Hvar, October, 1–7, 1989. The subsequent symposium was not held because of the war events.

However, our geodetic experts got the opportunity to participate actively with their works as representatives of the sovereign Republic of Croatia in Vienna in 1991. The prominent geodetic experts from Croatia, Čolić, Bašić and others, were immediately or a little bit later selected into some Special Study Groups or even into the Commissions within the frame of IAG. Due to a very broad international recognition of our independent state, at the beginning of 1992 it was finally provided for Croatia to achieve its long wished appointment as provisional member of IUGG, with the Croatian Academy of Sciences and Arts as an Adhering Body and also a representative of a young state in the International Council of Scientific Unions (ICSU), (Čolić, 1993a). In this case, as well as in the foundation of the National Committee for Geodesy and Geophysics of Croatia, the great support by Professor H. Moritz, the president of IUGG, was a decisive one, (Čolić, 1993b).

The foundation of the Croatian Geodetic Society (Božićnik, 1993) has provided the possibility for our geodesists to be presented in FIG as well, afterwards in ICA etc. On the other hand, the State Geodetic Authorities put a lot of effort into the promotion of the whole geodetic activity in Croatia, (Gojčeta, 1993), and at the same time it supports the development of the international collaboration through the membership in CERCO and other organisations.

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We hope that all these efforts will result in electing Croatia by the Council to be full member of the Union in 1995 at the General Assembly in Boulder (USA).

This report presents interesting activities of the Faculty of Geodesy at the University of Zagreb and the published papers of Croatian geodetic researches, as well as those realised in collaboration with the colleagues from abroad. Altogether there were 41 investigators from Croatia participating in the research of interest to IAG in the period between 1991 and 1994, i.e.: 17 doctors, among which there is also the first geodesist ever elected to be full member of the Croatian Academy of Sciences and Arts, namely Prof. Krešimir Čolić (Solarić et al., 1993), together with 9 masters of sciences and 15 qualified engineers of geodesy, accompanied by 13 colleagues from abroad as well (Austria, Bosnia and Herzegovina, Tschech Republic, Germany, USA, Slovakia and Slovenia).

Actually, a smaller number of Croatian authors deals with geodesy exclusively as geoscientific discipline, but the most of them take it as the engineering and technical one. The majority of papers were published in Croatian (regularly with an abstract in English), in *Geodetski list* – the only Croatian geodetic journal with international reputation. In 1991 Prof. Frančula et al. compiled the Bibliography of Relevant Papers published in *Geodetski list* in the period between 1947 and 1990. However, our authors have been publishing their papers in some well known world geodetic journals, and also not rarely in the proceedings of the eminent IAG Symposiums.

In the period from 1991 till 1994 the Croatian geodesists have defended three doctoral thesis: Dr. Petrović, 1991 in Graz, dr. Kapović, 1993 in Zagreb, Dr. Roić 1994 in Vienna, and a number geodetic master's thesis have been submitted to the University in Zagreb.

There was also a book published in 1991 (Bilajbegović et al.) intended for students of geodesy and our experts in the practice. It was realised through the support of two Austrian colleagues and analyses of the problems within the area of the Basic Geodetic Works – Modern methods – GPS. The publication (Čolić, 1993d) deserves to be mentioned here, in which the geodetic work of Ruder Bošković, one of the very few pioneers of geodesy in the 18th century, is presented in German. There is also a work by Čolić (1994) devoted to the historical geodetic topic, i.e. to the famous Croat Gjurjo Pilar who lived in the 19th century. The modern geodesy in Croatia, especially in the course of the 20th century, is dealt with by Prof. Lovrić (1994).

In the area of Positioning (IAG Section I), very few articles of Croatian geodesists deal with the triangulation and levelling problems, while most of them present the modern GPS technology. In the paper Cigrovski-Detelić (1991), the *a priori* accuracy for a part of the 2nd order triangulation of the territory network of Croatia is analysed, showing that the existing measurements are inhomogeneous. Moreover, the existing three spatial points coordinates of the 1st order trigonometric network in Croatia, and in smaller extent in the neighbouring Slovenia, with always good basis originating from the old Austria-Hungary, have been recently tested through GPS measurements.

With regard to the vertical reference systems the initial report has been given in the paper by Bilajbegović et al. (1993b) about the reference of the precise levelling at the territory of the neighbouring and independent countries Croatia, Bosnia and Herzegovina and Slovenia. Immediately after that, the review of works accomplished on the precise levelling on the territory of the Republic Croatia, also with a special attention to the second precise levelling (II NVT) which was accepted as the basic extension network for the execution of the lower order

levelling works, was presented first by Prof. Feil et al. (1993b) and then in German by Feil et al. (1993c).

The subject of the papers Benčić and Lasić (1992 and 1994) is the atmospheric influence on geodetic measurements, and the specific topic of the new metrological activity in the Republic Croatia is considered by Benčić et al. (1994). In this respect the work of Prof. Solarić et al. (1992) about projecting and extensive works on the establishment of the calibration base Zagreb is very significant. The problems of geodetic measurements accuracy are dealt with in the articles by Šimičić (1992), Novaković (1993) and others.

After some experiences with Achtech receiver on the calibration base in Zagreb was gained (Bilajbegović and M. Solarić, 1991), the first GPS measurements have been made at the points of the upper part of the 1st order tigonometric network at the border of Croatia and Slovenia, (Bilajbegović et al. 1992a). In Bilajbegović et al. (1993a) the preliminary results for a part of Croatia have been presented. The paper by Bilajbegović et al. (1992b) deals with the application of

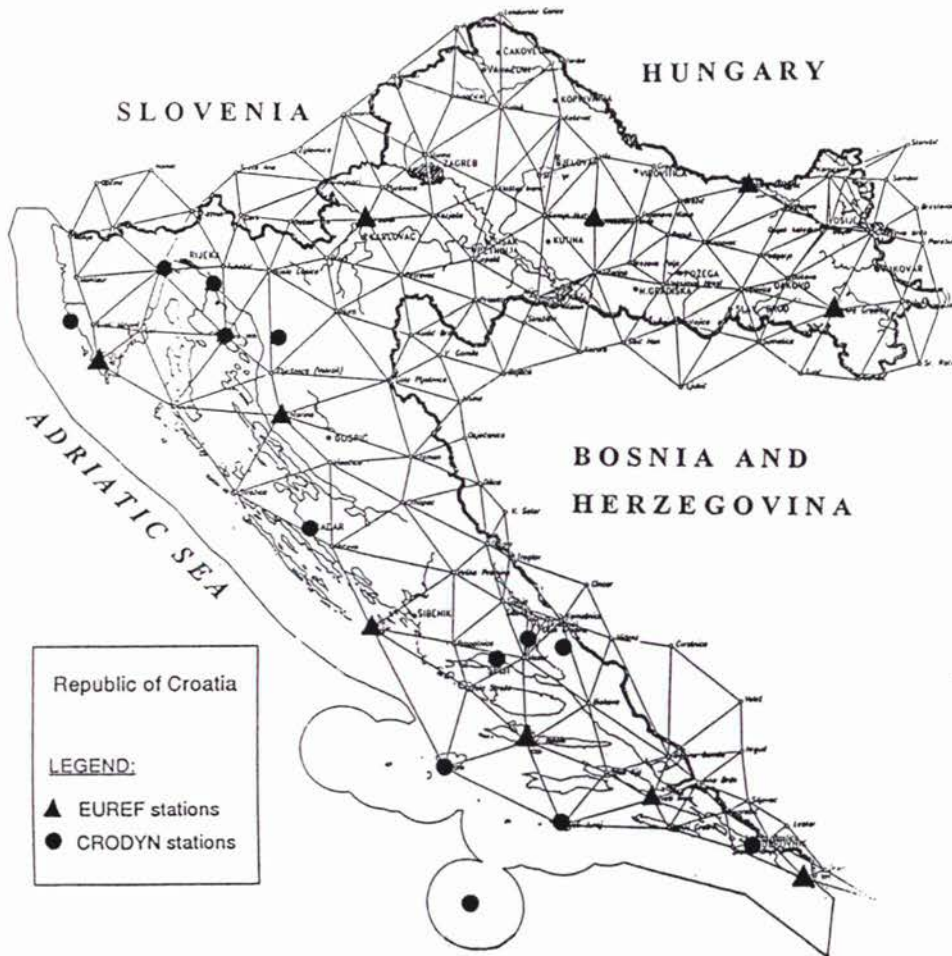


Fig. 1: EUREF'94 (10 points) and CRODYN'94 (13 points) GPS-Campaigns in Croatia.

GPS in the local geodetic networks in urban areas, and the interesting topic of the integration of GPS data into GIS is considered in (Galić, 1994), while the curves for the transformation from WGS84 coordinates into the state coordinates system are offered in the paper by Bilajbegović and Podunavac (1994).

Finally, with the support of the German Institut für Angewandte Geodäsie (Frankfurt on Main) a very important step has been realised: together with Slovenia, Croatia participated in the campaign EUREF'94, so the necessary GPS measurements with Trimble 4000 SSE receivers were all very successfully executed at 15 first order trigonometric points (Čolić et al., 1994). Leaning on this campaign, the first series of GPS measurements in the Croatian geodynamic project – CRODYN has been realised and presented in the same paper, with altogether 17 points: 13 new points (5 gauges and 8 geodynamic stations) and 4 permanent EUREF-points, see Fig. 1. At the same time additionally two points were observed in Slovenia and two in Italy (gauge Trieste and Bazovica).

Referring to other contributions connected to the positioning, not only in geometric, but also in the physical sence, it should be pointed out that in the

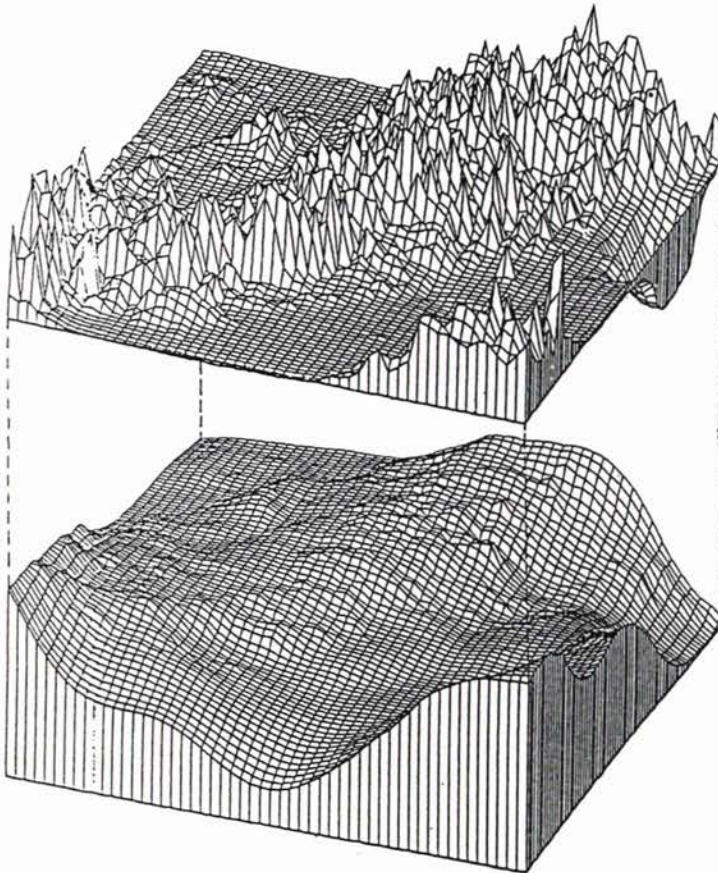


Fig. 2. 3D-view of the gravimetric geoid seen from SW (down) with corresponding topographic model for the entire territory of Croatia (up).

Republic of Croatia they come from geodetic astronomy (partly associated to the Section III). The problem of automatic time recording in determination of astronomical coordinates is dealt with in the works by Solarić (1991a, 1993a), Solarić and Špoljarić (1993a, b, c), and worth mentioning is also the work of Terzić (1993). The improvements of astronomical azimuth determination are analyzed by Solarić (1991b), Solarić and Špoljarić (1992) and Solarić et al. (1994). In the last paper the original method of passing from azimuth to the grid azimuth has been suggested, although the components of deflections of the vertical are not known. In the paper by Solarić (1993b) all automations are presented that have been developed at the Faculty of Geodesy, University of Zagreb, in the last twenty years in geodetic astronomy and surveying.

OSU-Report No416, (Bašić and Rapp, 1992), in which an oceanwide prediction of gravity anomalies and sea surface heights using altimeter and bathymetric data is presented, can above all be classified into the area of Advanced Space Techniques (Section II). Our works belonging to the IAG problem area of Determination of the Gravity Field (Section III) are also obviously more or less related to these important problems. In this research area the Croatian geodesists have given the most valuable contributions, along with the above mentioned GPS technology. They have been made within the framework of the scientific project "Gravity field in geodesy, geophysics and geodynamics". The preliminary gravimetric results in the gravity field determination for the territory of Croatia are presented by Prof. Bašić and Prof. Čolić (1993), see Fig. 2. The researchers from the Faculty of Geodesy in Zagreb have also conducted the astrogeodetic networks in the neighbouring Republic Slovenia (Čolić, 1992b, 1992c). The entire review of

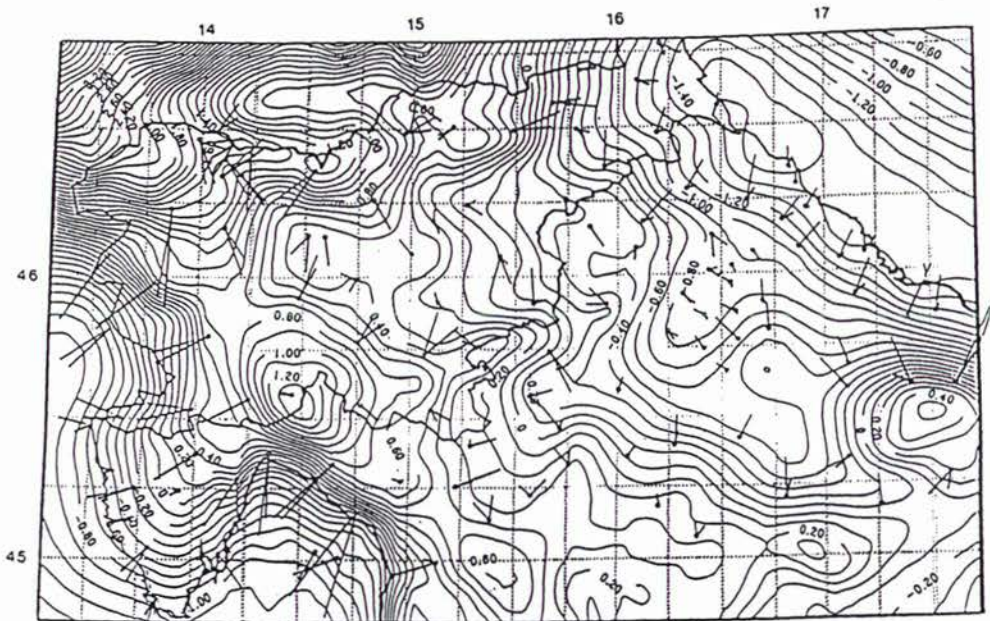


Fig. 3: Relatively oriented astrogeodetic geoid model together with 117 used vertical deflection points, C.I. = 10 cm.

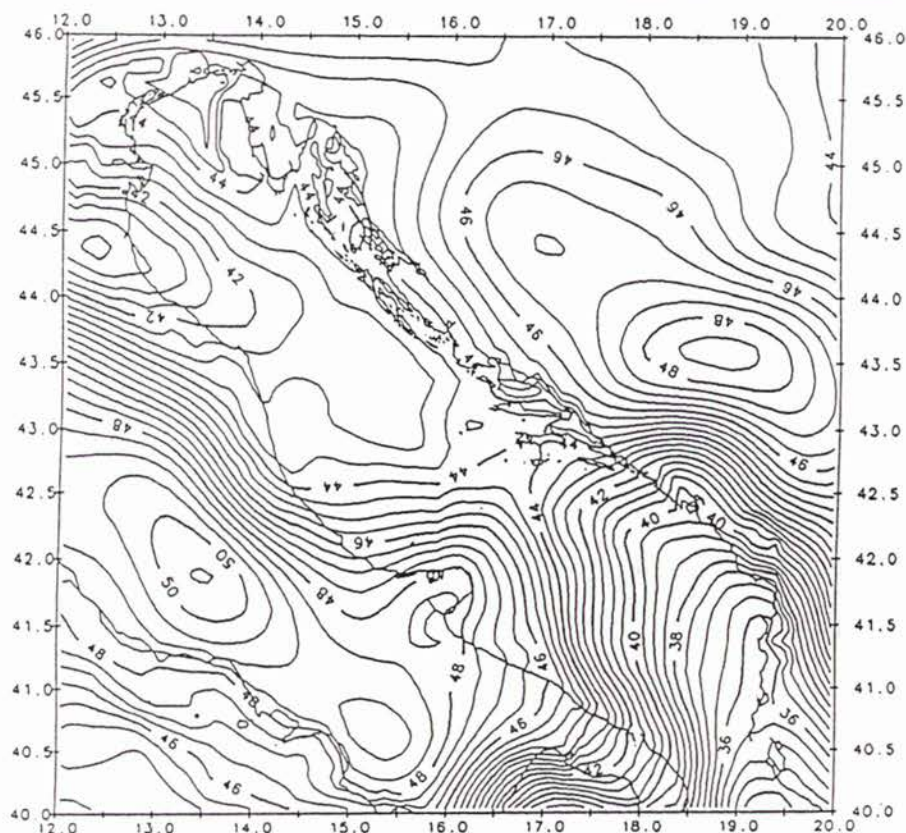


Fig. 4: Altimetric geoid in the Adriatic Sea area, C.I. = 50 cm.

Earth's gravity field investigations in Croatia and Slovenia is given in Čolić et al. (1993a), while the improvement of the astrogeodetic geoid solution for the same area can be found in Čolić et al. (1993c, 1993e), see Fig. 3. Finally, the last status report on the gravity field determination for the last four years in Croatia has been presented in the paper by Čolić et al. (1994a).

In the area of the satellite altimetry for the purpose of determining gravitation anomalies and the surface of the geoid, a special significant activity has been accomplished by Bašić in the published papers which were made during his postdoctoral stay at Ohio State University, Columbus, USA: Bašić and Rapp (1992), and Rapp and Bašić (1992). On this occasion the geoid and free-air gravity anomalies were calculated globally, i.e. for all world oceans and greater seas. After his return to Zagreb, Bašić (1993) applied the same methodology on the area of the Adriatic Sea representing almost the half of the entire territory of the Republic Croatia, see Fig. 4.

For the XXIst General Assembly of IUGG in Boulder 1995, the paper "Gravity Field solution for Croatia CRO95" was prepared (authors: T. Bašić, K. Čolić, B. Pribičević and D. Medak) in which the astrogeodetic, gravimetric and

altimetric solution of the geoid surface through the application of the data from GPS campaign EUREF 94 is reported.

Thus, in this report we reach the Section IV (General Theory and Methodology). In the field of the geometrical geodesy one should point out the work of Lapaine (1991) in which the new direct solution for transforming the Cartesian into the ellipsoide coordinates has been given. Lapaine and Frančula (1992) reviewed the most important results about solving the spherical triangle, the orthodrome, the loxodrome, the isometric latitude, the length of the meridian arc, the area of the ellipsoid surface in researches which have been carried out at the Faculty of Geodesy, University of Zagreb, within the framework of the scientific project *Cartography and Geoinformation Systems*. The new and very simple definition of the isometric latitude is established on the basis of the relation between the loxodrome and the isometric latitude on the sphere (Lapaine, 1993). The efficiency of algorithms for computing the geodetic latitude from the isometric latitude have been investigated and presented (Lapaine and Frančula 1993). In Lapaine (1994) all possible main geodetic problems along a meridian and along a parallel are specified and the algorithms for their numerical solution are given.

The problems of the functional adjustment models of geodetic measurements are dealt with by Hećimović (1991) and Rožić (1994). The comment of the accuracy criteria of geodetic networks is given in Ivković and Barković (1992). A very interesting and original methodology of applying the criteria of maximum correlation in adjustment, with special contributions exactly to the physical geodesy and geophysics has been brought out by Petrović (1991, 1993a). The most updated application of GIS in navigation is shown in the work of Car and Frank (1994), which investigates the general principles of hierarchical spatial reasoning theory and gives the example of their application to wayfinding in large networks.

The contribution of the Croatian geodesists in the field of Section V (Geodynamics) can by no means be neglected. The review of the first modern determinations of vertical Earth' crust movements in the land part of Croatia is given by Feil et al. (1993), and a more complete presentation by Feil et al. (1992). Kapović and Narobe (1993) investigate the efficiency of the Hannover model in determination of bench marks movements of the levelling network, while the thesis of Kapović (1993) adresses the temperature effects on the motions and deformations of bridges. In the doctoral thesis (Ročić, 1994) the observation of 3D structures with the help of theodolite is primarily elaborated.

The above mentioned method of maximum linear correlation coefficients has been realized as the result of the intention to investigate and use the interrelation of geoid surface and the Mohorovičić's discontinuity (Petrović, 1993b). After the previous works by the Croatian authors referring to the area of Dinarides, see also Petrović (1991), the work of Burda et al. (1991) relating to the area of the Western Carpathians was published. Afterwards, the similarities and differences among three mountain belts (Dinarides, Eastern Alps and Western Carpathians) are analysed.

The problem of determining the density of surface close masses of the Earth's crust in the part of Croatia and Slovenia is dealt with in the work by Čolić et al. (1992). Determination of the leap in the density at the passing from the Earth's crust and the cover for all three just mentioned mountain chains at the edge of Pannonian basin in the Central Europe is documented by Petrović and Čolić (1994). The new formula and the mean value of $0,22 \text{ gcm}^{-3}$ differing from previous hypothesis were given. This was also reflected in the report by Čolić (1993b). The

improved method of modelling the density of the Earth's crust layers is proposed by Brkić (1994).

The group for physical geodesy of the Faculty of Geodesy, University of Zagreb (K. Čolić, T. Bašić, B. Pribičević and D. Medak) has prepared for XXIst General Assembly of IUGG the work: "Geodetic-gravimetric method for better modelling of geological structures in the test area of Croatia", which is based on the researches of carbon hydrogen findings carried out for an oil company.

We would like to conclude our report by emphasising only three most important works among those planned for the coming period: a) accomplishment of CROREF'95 (Croatian Reference Frame) leaned on EUREF'94 with almost 40 new GPS points (mainly the first order trigonometric points, and to the smaller extent the second order ones); b) establishment of an absolute gravimetric network (up to seven points) and beginning of relative measurements within the scope of the wide network of Croatia; c) the improved model of geoid of subdecimeter accuracy for the whole territory of Croatia based on all possible data sources (deflections of vertical, gravity anomalies, satellite altimetry and topography/bathymetry).

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GEODEZIJA U HRVATSKOJ 1991–1994

Ovo je dosad prvi sumarni pregled dostignuća hrvatskih geodetskih znanstvenika iz područja koje pokrivaju svih 5 selekcija u sklopu IAG. U njemu su za vremenski period 1991.–1994. uzeti u obzir rezultati rada 41 geodetskog djelatnika iz Hrvatske, uz suradnju i 13 eksperata iz inozemstva.

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