

New Official Geodetic Datum of Croatia and CROPOS System as its Implementation

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Key words: geodetic datum, national reference network, permanent GNSS network

SUMMARY

On the basis of the Law on State Survey and Real Estate Cadastre, the Government of the Republic of Croatia, made at its meeting on August the 4th 2004 the Decree on establishing new official geodetic datum (horizontal and vertical), gravimetric datum and map projections of the Republic of Croatia. New official geodetic datum and plane map projections will be implemented into the official use gradually until January the 1st 2010 at the latest. The State Geodetic Administration is entrusted with the task of developing a program for implementing new official geodetic datum and map projections into the official use. Within PHARE Project on Modernization & capacity building of integrated land administration system in Croatia a national reference network CROPOS – CROatian POrtitioning System will be established. The purpose of the project is to build a system of reference stations of the Republic of Croatia that would diminish the expenses and accelerate the processes of state survey and real estate cadastre jobs, and enable an efficient introduction of the new geodetic datum and map projections. Implementation of a national GNSS network comprised of 30 reference stations covering the whole territory of Croatia and control centre, which will allow to pass from the current approximation of ± 2.5 m to a level of precision of ± 0.02 m for each positioning in real time. The tender for the CROPOS will be launched in August 2006. In this paper the overview of activities concerning definition and implementation of new geodetic datum and preliminary works for establishment of CROPOS system will be presented.

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1. INTRODUCTION

On the basis of the Law on State Survey and Real Estate Cadastre, on August 4th 2004 the Government of the Republic of Croatia has adopted Decree on establishing new official geodetic datum and map projections for the Republic of Croatia.

Reasons why we have decided to implement new official geodetic reference system are as following:

- By becoming an independent state, Republic of Croatia was found in position to define geodetic datum and map projections toward its own beliefs and national interesting, which was not a case before since prior its independence the existing geodetic networks were developed for the ex-Yu countries' area that today Croatia had been of part too. Defining and introducing unique Croatian official geodetic datum and map projections was based on modern achievement of science and according to European recommendations and trends.
- Second reason for implementation was removing existing obstacles toward more efficient use of modern measuring and GIS technologies and in that way offer the state, economy and citizens uniform, rational and simply applied reference system and frame.
- Further more, in a part that relates to space data implementation was necessary in order to create prerequisites for development of information society in Croatia (e-government, one-stop-shop, ...), as well as to make further development of geodesy and other geo-professions possible.

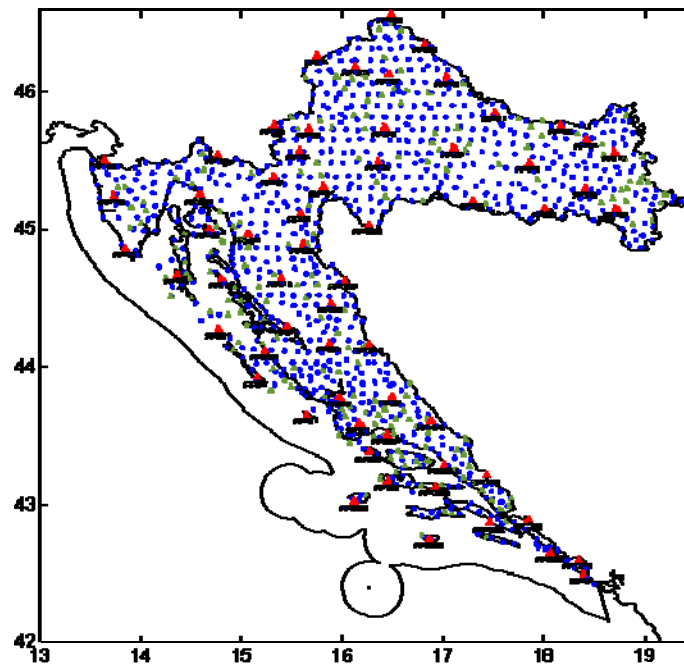
2. NEW OFFICIAL GEODETIC DATUM AND MAP PROJECTIONS OF THE REPUBLIC OF CROATIA

2.1. New Terrestrial Reference System – HTRS'96

New terrestrial reference system of the Republic of Croatia is defined on ETRS89 system, that was taken by majority of European countries as a base for official horizontal datum as recommended by EUREF and EuroGeographics. That reference system uses GRS80 ellipsoid determined by its own intercepts as its mathematical model.

Since the permanently stabilized geodetic control points represent the materialization of geodetic reference systems (Fig. 1), the Decree has defined the basic positional network consisting of 78 permanently stabilized geodetic control points having the coordinates determined by ETRS89, and has been abbreviated as Croatian Terrestrial Reference System 1996,55 - HTRS'96.

Fig. 1: Network of geodetic control points



2.2. New Croatian vertical reference system 1971,5 – HVRS'71

Vertical datum of Croatia is defined with geoid surface as the reference surface used for the computation of heights in Croatia. This surface is defined by mean sea level for epoch 1971.5 on five tide gauges equal set along the Adriatic coast. Although this vertical datum is usually defined with only one tide gauge, this specific approach of defining the geoid surface has shown satisfying results, since the tide gauges and gravimetric measures comparison shows the regular geoid surface along the Adriatic coast. Using this approach height data are in accordance with physical data.

Benchmark of basic levelling network (Fig. 2) known as second level of high accuracy, whose heights are given in accordance to new vertical datum definition, constitutes the materialization of new vertical reference system in Croatia. That system has been given the name Croatian Vertical Reference System 1971,5 – HVRS'71.

2.3. New Croatian gravimetric reference system 2003 – HGRS'03

For the gravimetric datum we have taken the international gravimetric system known as IGSN71 - *International Gravity Standardization Network* that as well uses the same mathematical model for the Earth GRS80 ellipsoid with the belonging set of physical parameters.

Materialization of gravimetric network (Fig. 3) is represented by basic gravimetric network that consists of six permanently stabilized points of absolute gravimetric network and 36 permanently stabilized gravimetric points of the first order gravimetric network and that reference system was given the name Croatian Gravimetric Reference System 03 – HGRS'03..

Fig. 2: Levelling network

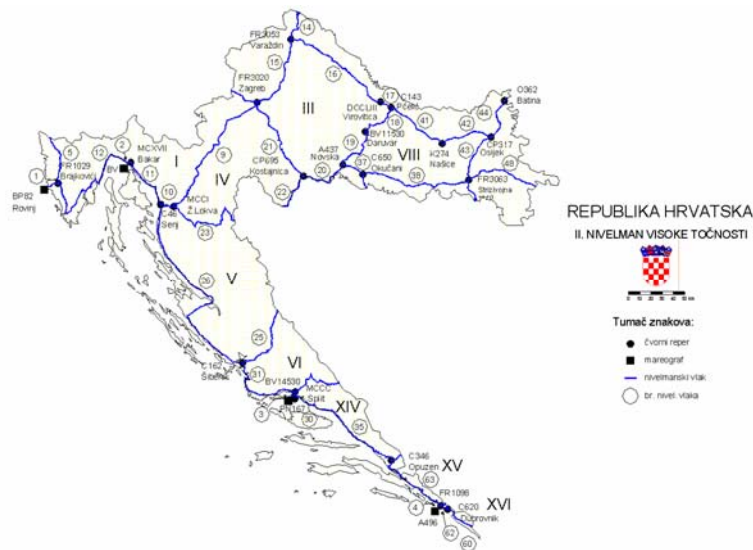
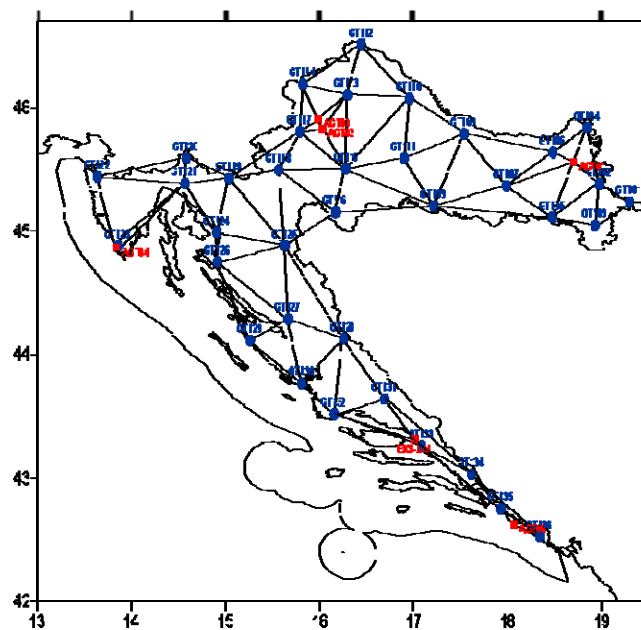


Fig. 3: Gravimetric network



2.4. New Map Projections

Coordinate system of the transverse aspect of Mercator's projection, with the mean meridian $16^{\circ} 30'$ and the linear scale on that meridian 0.9999, is defined to be the projection coordinate system of the Republic of Croatia for the field of cadastre and detailed state topographical cartography.

Coordinate system of the normal aspect of Lambert conformal conical projection (with standard parallels $43^{\circ} 05'$ and $45^{\circ} 55'$), is defined to be the projection coordinate system of the Republic of Croatia for the field of general state cartography.

Both projections are based on GRS80 ellipsoid as a mathematical meaning Croatian Terrestrial Reference System.

Universal transverse Mercator's projection, well known as UTM projection, is adopted as well as the official projection for the needs of Army forces of the Republic of Croatia according the suggestions and obligations towards the NATO.

3. PROGRAM OF IMPLEMENTATION OF NEW OFFICIAL GEODETIC DATUM AND MAP PROJECTIONS

Being aware that implementing new geodetic datum and map projections is a very complex and long process that implies a very good organization and coordination large number of tasks, setting the article five of the Decree, we have regulated its implementation into the official use in steps based on the Program of implementation of new official geodetic datum and map projections.

SGA is in charge to bring the program as well as to end the process of implementing new geodetic datum and map projections by 1st of January 2010.

Program defines the following:

- necessary activities and tasks for implementation of new geodetic datum and map projections in official use,
- modes and due dates of their performance,
- holders and subjects of their performance,
- activities and measures that SGA is to undertake in direction of implementation new geodetic datum and map projections in general use for all space information users with special accent on government bodies and public systems.

The purpose of Program is to:

- introduce the new geodetic reference system in practical use on the all Croatian territory, in all official registries and data bases and execution of work from SGA responsibility,
- ensure the frame of geodetic reference system of Croatia for NSDI establishment,

- create necessary prerequisites and ensure support to implementation of new reference system in all official space referencing registries and data bases of governmental bodies and authorities,
- create necessary prerequisites and ensure support to implementation official geodetic datum and map projections for economy and citizens,
- elaborate adoptions and use necessary rules, standards and technical specifications for Program execution,
- elaborate system of education and training that is to ensure Program's execution.

Holder of Program performance is State Geodetic Administration and Program will be executed through Annual programme of State Geodetic Administration.

Participants in Program's performance besides SGA are:

- Croatian geodetic institute,
- Faculty of Geodesy, University of Zagreb,
- Company licensed to practice jobs of state survey and real estate cadastre,
- International institutions and authoritative organisations of other countries.

Activities and tasks will be conducted according to the time schedule that is a part of the Program. Program will be achieved by conducting chain of tasks divided in few round legislative, technological and organisational units.

3.1. Fundamental geodetic works and state border survey

Basic horizontal network consisting of 78 fundamental permanently stabilized points presents the Croatian reference frame. On that basic horizontal network the 10 x 10 km GPS network is laid that represents base for development of additional networks. Additional networks are developed for bigger cities as for the cadastre municipalities where the cadastre survey has been carried on.

The founded reference system will be overbuilt by establishing system of the national permanent GPS network of Croatia (project CROPOS). Such materialization, new system will enable simpler and more precise defining the coordinate points directly in new system throughout the whole state territory, referring to faster and more efficient geodetic survey performance.

With purpose of transforming the data between the new geodetic reference system and old system a uniform transformation model for all users will be confirmed.

With purpose of constructing better and more accurate transformation from ellipsoid height to orthometric height we will approach to constructing new geoid model for Croatia.

SGA will undertake the reconstruction of permanent points of geodetic base and establish the system of maintaining ordinary network that will serve to collect the data on network condition that will through the base of permanent points be available to wide range of users.

Vertical base Croatian vertical reference system 1971,5 is constituted of vertical network of second levelling order of high accuracy. In the nineties terrain revision of benchmark condition maintenance has done. High percentage of 40% of destroyed benchmark demonstrates the need for systematic renewal of fundamental level network. In the process of vertical base renewal by establishing new levelling figures, its geometric configuration shall adjust to the state territory of Croatia, and systematic gravimetric survey shall be established as well. In addition, within the SGA organization, systematic process of maintaining levelling networks shall be established.

For height transformation towards the new system and back the unique model of transformation will be developed.

Reference frame of new gravimetric reference system consists of absolute gravimetric network and gravimetric network of first order. In order to completely define basic gravimetric network it is necessary to set microgravimetric networks for absolute gravimetric points, expend gravimetric network of first order to the islands, set heights of gravimetric points by geometric levelling, and horizontal coordinates using GPS method.

Parallel with completing the basic gravimetric networks the establishment of gravimetric network of second order will start. In order to rationalize costs and setting the exact geoid model, the second order network will be laid against 10 x 10 km GPS network as well against all other adjusted GPS points that shall at the same time be given their height using the geometric levelling method.

At the moment, Croatia has defined and marked boarder line only with Hungary. As well as other neighbour countries are concerned, terrain establishment and marking the boarder line is still to be undertaken. After the marking is done, coordinates of pillars will be defined in new geodetic reference system.

3.2. Topographic survey and state maps production

In 1996 SGA started the project of constructing topographic map scale 1:25000 for the whole Croatia – 594 sheets, and so far 427 sheets have been done and settled.

In 2003 topographic data base was established and 56 made sheets were arranged to be worked on and put into the base till the end of the year. The whole work of making topographic map scale 1:25000 is done in existing projection system. Upon all sheets are made and complete topographic base is set, the whole base will be transformed into the new system.

DOF in scale 1:5000 is made in existing reference system for 80% of Croatia. After the whole DOF5 has been made and data base will be established for the whole territory that shall transform into the new reference system using the uniform transformation model.

SGA has started the project of vectorisation Croatian base map scale 1:5000. All sheets are scanned and geo referenced in existing reference system. After the vectorisation of sheet's contents is made and the data base is formed, its transformation to the new reference system will be conducted using the uniform model of transformation and new model of height transformation.

3.3. Real estate Cadastre

Implementation of new geodetic reference system into the real estate cadastre we will achieve through conducting new cadastre survey that shall be undertaken into the new projection system without option and through setting data base of digital cadastre plan in new projection coordinate system.

This generates the need for transforming cadastre plan from existing system to new map projections system using the uniform transformation model.

3.4. Registry of space units

SGA is in charge for running central data base of space units. The data on all space units borders are vectorised in an old system on raster data bases that have to be transformed into the new system. Soon after constructing and determining new topographic base the now existing raster base will be replaced by appropriate data from topographic data base.

3.5. Installation cadastre and engineering geodesy

Public companies, other state bodies and institutions, towns and municipalities have for there own needs developed of installation cadastre meaning geo-referencing information systems of different contents. All the data is gathered and done in old coordinate system. Implementing new datum's enhances the transformation of GIS in the new reference system.

SGA shall after the transformation of cartographic bases meaning the cartographic plans, put the same into the official use and inform all the users about it.

Through the program of education, SGA will offer scientific-expertise help all the public and state institutions in transformation of their GIS system into the new geodetic reference system. For that purpose it will be possible for all the employees of such institutions to enrol the education program and in that way they will ensure all needed conditions for undertaking all geodetic works of the new system.

3.6. Education and technical standard legislation

Implementation of new geodetic datum and map projections in daily use asks education and informing to all geodetic professionals with performance of geodetic works in new geodetic reference system, modern methods of survey and transformations between new and old system and back.

Informing and education will carry through:

- informing expertises and the public through the existing publications, as Geodetic Informator and Catalogue of SGA products, as well as in the special brochures, about introducing and implementing new geodetic reference system,
- development and installation of implementation and application of new geodetic reference system modules into the system of education and training for geodetic professionals, GIS and other professionals,
- completing the book of rules to way of fundamental geodetic works performance that will be support new geodetic reference system together with new acceptable and efficient methods of fundamental geodetic works performance,
- completing technical specifications of new map projections – HTRS'96/TM for practical use.

4. CROPOS – CROATIAN POSITIONING SYSTEM

4.1. National GPS network

The development of national GPS network started with EUREF activities in the Republic of Croatia with the first EUREF-1994 Croatia and Slovenia GPS campaign carried out in order to connect Croatian and Slovenian networks to the EUREF-89 reference network. Fifteen new points were included in this campaign (10 in Croatia and 8 in Slovenia). The observations were performed from May 30 to June 3, 1994. In order to establish reference GPS network in Slovenia, the SLOVENIA-1995 GPS campaign was carried out together with CROREF-1995 GPS campaign in Croatia. The GPS network consists of 47 stations in Slovenia and 14 stations in Croatia. The observations were performed from September 25 to October 2, 1995 in two phases with 3 day observation each. The CROREF-1996 GPS campaign was the second EUREF campaign in Croatia and also GPS campaign to determine the first and second order Croatian reference network. The GPS campaign was observed from August 29 to September 12, 1996. The Project of establishment of homogenous GPS-point-network 10 x 10 km started in 1997 and continued in 2002 was completed in the year 2003. After re-computation of EUREF and CROREF GPS campaigns carried out in Croatia and Slovenia in 1994-1996 in ITRF1996, epoch 1995.55 (Marjanović and Bačić, 2002) and new solution was accepted within Resolutions of the EUREF Symposium in Dubrovnik in 2001 as combined EUREF-CRO94/95/96 solution for Croatia new common adjustment of GPS-point-network 10 x 10 km in ITRF1996, epoch 1999.60 were computed (Bačić et al, 2002). The CROREF-05 GPS campaign was carried out in September 2005, in order to re-observe EUREF GPS points measured in the frame of SLOCRO-94 EUREF GPS campaign eleven years ago (Marjanović et al., 2006). After the initial idea, the project expanded later with geodynamics included and other national reference GPS points, also observed in previous campaigns.

The development of GPS methods initiate start of projects needed for successful application in every day practice:

1. In order to provide unified computation procedures of GPS measurements and coordinate transformation State Geodetic Administration contracted Faculty of

Geodesy in Zagreb to develop two computer programs (Bašić et al, 2003). The first program is DAT_ABMO for transformation between ETRS89 and Croatian national coordinate system. The second program is IHRG2000 for computation of geoid undulations for transition from ellipsoidal to orthometric heights. The purpose of program DAT_ABMO is to provide users to transform the coordinates between different coordinate systems, different reference epochs and different geodetic datum. It is possible to transform coordinates by using sets of default transformation parameters or by using transformation parameters computed on the base of identical points in both coordinate systems. The program IHRG2000 is designed for computation of geoid undulations for transition from ellipsoidal heights to orthometric heights. It is possible to compute geoid undulation of any point on the territory of the Republic of Croatia.

2. The Project of development and establishment a central geodetic point database started in year 2002 is finished. The data are stored in Oracle Database System in combination with ESRI ArcGIS software in order to performe connection with the Register of Spatial Units Database and digital maps 1:25000. Within the project the revision process of geodetic points is organized and till the end of 2006 the gathering of field information at almost 65% of all fundamental geodetic points will be finished. After developing process of database model, four different applications were finished:
 - Application for input and updating of data (Intranet Application),
 - Application for Export and Import a large amount of data (Intranet Application),
 - Application for publishing and distribution of data (Intranet ArcGIS Application),
 - Application for publishing and distribution of data through Web portal (Internet Application).
3. Development of the unique transformation model for the coordinate transformation between old system (Bessel) and new system (GRS80) at the territory of the entire state (Bašić and Šljivarić, 2006).

4.2. Application of RTK method

In the application of a classical RTK method and the receipt of RTK data from one station only, the operation is limited within the circle of maximally 10 km from the base station (or less, depending on the ionospheric influence). Various external influences (troposphere, ionosphere, signal multipath, orbit) lead to the limitation of the base station and rover distance and to the problems in solving ambiguities. This disadvantage can be solved through networking of more reference stations the distance of which can be 70 km regarding the technology available today. In order to provide the given accuracy, it is necessary that the raw measuring data from reference station flow continuously into the control centre, where they are checked and analyzed, then the data processing and adjustment are done and real-time corrections calculated. The system provide the GNSS data exchange from the reference stations with the neighbouring countries and the integration of the GNSS data from the closest IGS points (if it is possible considering the technological characteristics of the equipment at individual points).

The GTZ (F. R. Germany) sponsored project “Consultation for the establishment of the cadastral system in Croatia” assisted the SGA to the implementation of a feasibility study for a permanent GNSS network – CROPOS (Bilajbegović and Ludwig, 2005).

The study proved the implementation of CROPOS to be a cost-effective intervention for the implementation of ILAS that will speed up the process of land reform. Several secondary benefits are also expected for the numerous applications of CROPOS. Within project Aufbau eines Katastarsystems in Kroatien - Machbarkeitsstudie für das permanente GNSS-Netz of State Geodetic Administration and Deutsche Gessellschaft für Technische Zusammenarbeit GmbH, a study visit was organized to assist SGA staff in the learning process and to understand demands concerning preparation works, installation and maintenance of the system.

4.3. CROPOS project

The goal of the project is to establish a unique national system of reference GNSS stations of the Republic of Croatia CROPOS (CROatian POsitioning System) that would enable point positioning in real time with an accuracy of ± 2 cm at the territory of the entire state. CROPOS components include GNSS equipment, communication equipment, network equipment, computer equipment and software. Within the CROPOS system, 30 reference stations have to be established at locations spread over the territory of the Republic of Croatia. The reference stations will enable continuous GNSS measurements (CORS - Continuously Operating Reference Station) and measuring data transfer into the control centre, and have the possibility for remote control of reference stations from the control centre.

CROPOS system will have the following basic characteristics:

- collecting the data from the reference stations that will be placed at 30 locations at the territory of the Republic of Croatia (Fig. 4),
- reference station real-time GNSS data exchange with the neighbouring countries,
- connecting the reference stations with control centre,
- networking and computing the real-time correction parameters,
- distribution of measuring data and real-time correction parameters to the users,
- enable users to determine the position of points in real time with the positional accuracy of ± 2 cm at the territory of the entire state,
- monitoring of the system operation and users support,
- 24/7 service availability.

The application of CROPOS system as implementation of new geodetic datum of Croatia will improve surveying practice but also it will be necessary for education of personal for the system maintenance and user support as well as education of surveyors and system users.

The system of reference stations CROPOS should make the following basic services possible for the users:

| CROPOS service | Procedure/ Method | Accuracy |
|--|-------------------------------------|------------------|
| DPS differential positioning | code network solution in real time | ±0.3 m to ±0.5 m |
| VPPS highly precise positioning | phase network solution in real time | ±2 cm |
| GPPS geodetic highly precise positioning | post-processing | ±1 cm |

Fig. 4: Design of the CROPOS system



The CROPOS system will influence future surveying in Croatia because it should provide:

- introduction and application of a new geodetic datum of the Republic of Croatia,
- homogenization of coordinate system,
- the same accuracy of measurement and coordinate determination at the entire territory of the Republic of Croatia,
- utilization of the unique measurement methods,
- standardization in performing of geodetic works,
- faster and more efficient performing of geodetic works.

5. CONCLUSION

Republic of Croatia has defined new geodetic datum and its realisations have been defined. Its implementation will be high tasking, complex and long-lasting work. All together, implementation represents a big challenge, but also a big chance for SGA and all Croatian surveyors to achieve a new level by building new and modern geodetic reference system that will enable the completion of all user requests.

The European Union preliminary mission to Croatia set an accelerated land reform as one of the priority intervention areas. PHARE support to CROPOS will permit to speed up the implementation of an efficient Integrated Land Administration System, a pre-requisite to carry out land reform and overcome current obstacles to the process. All through Europe land measurement is implemented through national GNSS networks in real time, with a high level of precision and low operational cost. CROPOS will be established to comply with EU standards and is expected to be a tool lasting in the long term. Due to the time table within PHARE project it is expected that CROPOS system will be finished and in fully functionality till the end of year 2007.

REFERENCES

- Bašić, T. (2000): Proposal for Official Geodetic Datum of the Republic of Croatia, Faculty of Geodesy, University of Zagreb, 2000.
- Bašić, T. (2001): Study of the Condition and Proposal of the New Gravimetric Network of the Republic of the Croatia, Faculty of Geodesy, University of Zagreb, 2001.
- Bašić, T., Rezo, M., Markovinović, D. (2002): Unique Adjustment of 10 km-GPS Network of the Republic of Croatia, Faculty of Geodesy, University of Zagreb, 2002.
- Bašić, T., Šljivarić, M., Rezo, M., Markovinović, D., Jeličić, J. (2003): Development of Programs for Application of Official Croatian Geoid and Coordinate Transformation between HDKS-a i ETRS-a, Faculty of Geodesy, University of Zagreb, 2003.
- Bašić, T., Šljivarić, M. (2006): Development of Unique Transformation Model HTRS96/HDKS, Faculty of Geodesy, University of Zagreb, 2006.

Bilajbegović, A., Ludwig, O. (2005): Aufbau eines Katastersystems in Kroatien, Machbarkeitsstudie für das permanente GNSS-Netz – CROPOS, Deutsche Gesellschaft für Technische Zusammenarbeit GmbH, 2005.

Brockmann, E., Harsson, B.-G., Ihde, J. (2001): Geodetic Reference System of the Republic of Croatia - Consultants Final Report on Horizontal and Vertical Datum Definition, Map Projection and Basic Networks, 2001.

Feil, L., Rožić, N. (2000): Proposal for Official Height Datum of the Republic of Croatia, Faculty of Geodesy, University of Zagreb, 2000.

Lapaine, M. (2002): Proposal for Official Map Projections of the Republic of Croatia, Faculty of Geodesy, University of Zagreb, 2000.

Marjanović, M., Bačić, Ž. (2002): Computation of the Combined Solution of EUREF GPS Campaigns in the Republic of Croatia, Report on the Symposium of the IAG Subcommittee for the European Reference Frame – EUREF in Dubrovnik, May 16-18, 2001, p. 171-188, Frankfurt/Main, 2002.

Marjanović, M., Bačić, Ž., Bačić, T. (2006): CROREF-05 GPS campaign - preliminary results, Reports on the EUREF Symposium, Riga, 2006.

Official Gazette of the Republic of Croatia, No.:110/04,117/04, Decree on establishing new official geodetic datum and map projections of the Republic of Croatia.

State Geodetic Administration: Program of implementation of official geodetic datum and map projections, Zagreb, 2005.

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