Recent Geodynamical GPS-projects in Croatia

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Abstract

ABSTRACT: This paper summarizes recent research activities on application of contemporary geodetic methods for determination of geodynamic activities in Croatia. During the period of five years starting in 2000, two IGS stations were operable in Dubrovnik and Hvar. The project CERGOP2/Environment resulted in valuable datasets about the movements of several long term epoch sites: Brusnik and Hvar, recently Pula and Zagreb permanent stations. Several GPS-campaigns were performed in the City of Zagreb area, which is the boundary zone of Eastern Alps, Dinnarides and Pannonian Basin. Due to the proximity of Croatian capitol, special attention has been paid to the effects of possible hazard on construction code. All these results are combined with geologic measurements and results of seismic activity studies in order to give more detailed and more accurate picture of the current situation in the tectonically very active region of Dinnarides. The future of geodynamical geodesy is discussed as well.

Introduction

Research on the regional structure fabric, structural classifications and deep geological structure of Dinnarides was summarised in numerous papers (Dewey et al., 1973; Martinis, 1975; Premru, 1976; Herak, 1986; Aljinovic et al., 1987; Skoko et al., 1987; Horvath, 1984; Mantovani et al., 1992, 1995; Prelogovic et al. 1997; Moors & Twiss, 1995; Decker & Peresson, 1996). Several papers from the NATO Workshop confirmed that the geology, tectonics and geodesy should closely cooperate in solving the hypotheses of movements in the area of Adriatic micro-plate and Dinnarides (Pinter et al. 2006). Since 1960, the movement of the Earth's litospheric plates has been explained by the analysis of global ocean floor spreading rates, transform fault systems and earthquake slip vectors. According to this theory, the Earth's crust consists of 14 to 16 major litospheric plates, floating on the fluid astenosphere.

The major role in geodynamics of Croatia belongs to the Adriatic Microplate and Dinnarides. Figure 1 shows the structural map of Croatia. Movements of the Adriatic micro-plate are crucial in formation of the recent structure fabric. Pushed by the African plate it is being indented into the European continent thus causing deformation of the Earth’s crust and gradual shaping of the Alpine-Dinarides orogenic belt.

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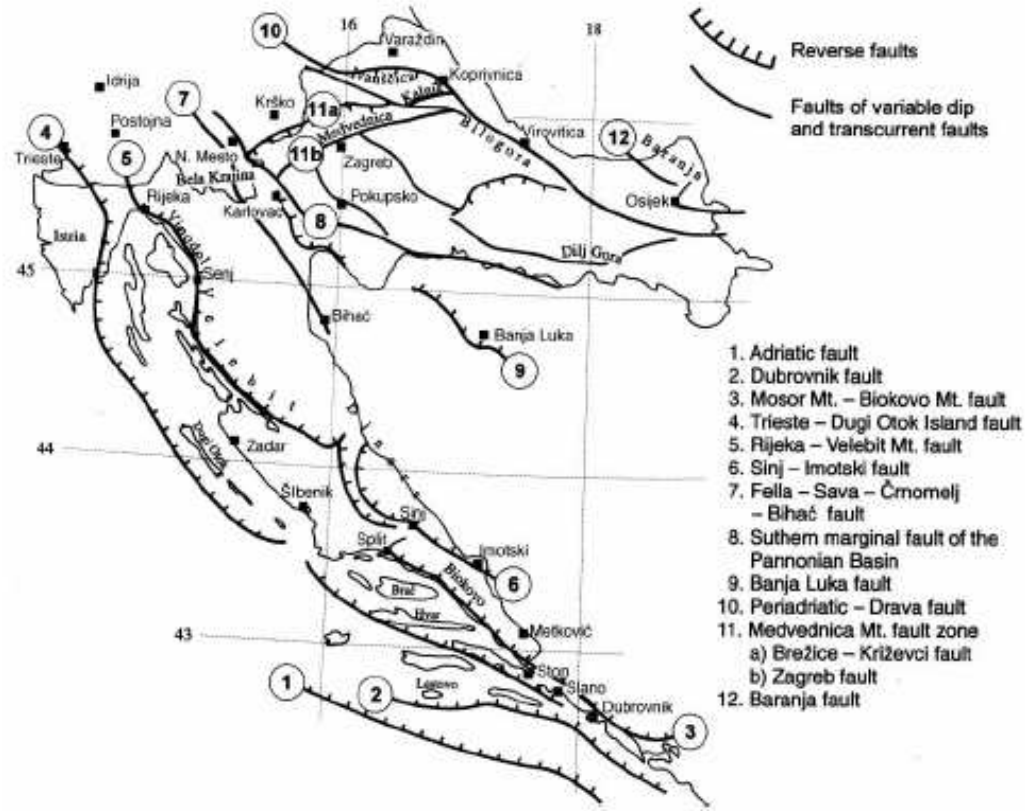

Figure 1 - Map of major faults in Croatia related to the tectonic activity

Geodetic GPS-measurements

Since 1960, the movement of the Earth's litospheric plates has been explained by the analysis of global ocean floor spreading rates, transform fault systems and earthquake slip vectors. According to this theory, the Earth's crust consists of 14 to 16 major litospheric plates, floating on the fluid astenosphere.

At the mid-oceanic ridge hot magmatic material emerges, spreading the ocean floor apart. By this spreading the plates are shifted on their boundaries and begin to move. The horizontal motions of the litospheric plates generally range from a few to more than 150 mm/yr.

The NUVEL-1 model describes motions of 14 major plates relative to the fixed Pacific Plate (DeMets et al., 1990). The NNR-NUVEL1 model (no net rotation) gives absolute angular velocities of the plates (Argus and Gordon, 1991). Tectonic development of the Adriatic Sea area was and still is a very interesting puzzle for scientists. Some of them believe that the Adriatic Microplate is a promontory of the African Plate (Mantovani et al., 1995), asserting that this promontory moves in the northwest direction with the velocity of cca. 5 mm/yr.

On the other hand, other scientists explain the earthquakes that are frequently occurring in this area as an internal deformation of the Adriatic microplate (Anderson and Jackson, 1987). The measurement of such small movements between points that are far away from each other has been made possible by the development of the space techniques like Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR) and recently with GPS.

Since the late 1980s, the U.S. Global Positioning System (GPS) constellation of satellites has come to play a major role in regional and global studies of Earth. In the face

of continued growth and diversification of GPS applications, the worldwide scientific community has made an effort to promote international standards for GPS data acquisition and analysis, and to deploy and operate a common, comprehensive global tracking system.

IGS stations in Croatia

In order to enable precise ground control for GPS measurements, a multi-purpose international network has been established: International GPS-Service for Geodynamics (IGS). Besides the controlling of measurement accuracy for the whole system (orbit determination and correction), the role of such a network is substantial in the determination of the movement of the Earth's crust. Croatian geodesy joined to this world project in 2000 through establishing of two permanent GPS-stations (Dubrovnik and Osijek) within the EUREF Permanent subproject of IGS Network. Activity of these stations should have contributed to our knowledge of motions of the Adriatic Microplate as an important successor of the CRODYN project (Altiner, 1999; Altiner et al. 2001).

In 1998, several reconnaissance campaigns were undertaken in order to determine which sites suit the needs of potential GPS Permanent sites. The shape of the Croatian territory dictated the choice: one point in the north-east and one point in the south-east. Finally, the experts from BKG agreed with Croatian colleagues to set up the stations in Osijek and Dubrovnik. According to the guidelines for European Permanent Network that were valid at that time (Gurtner, 1992), the area in north-east Croatia was not particularly suitable since it was not possible to set up the marker onto a bedrock foundation. Therefore, the building of the Geodetski zavod Osijek was chosen for stabilization of the marker. In Dubrovnik, the station was placed in an ancient fortress named Imperial, located at the Mount Srdj, the hill dominating the area. Special construction for antenna support was erected to achieve better angle for low-elevation satellites.

Figure 2 - The monument at DUBR station.

The stations were operating since October 2000 to December 2005. Unfortunately, due to the custom regulations, the equipment had to be returned to German owners (Bundesamt

für Kartographie und Geodäsie). On the other hand, the State Geodetic Administration finally funded the re-establishment of both stations, and these are going to continue the operation in the beginning of 2007.

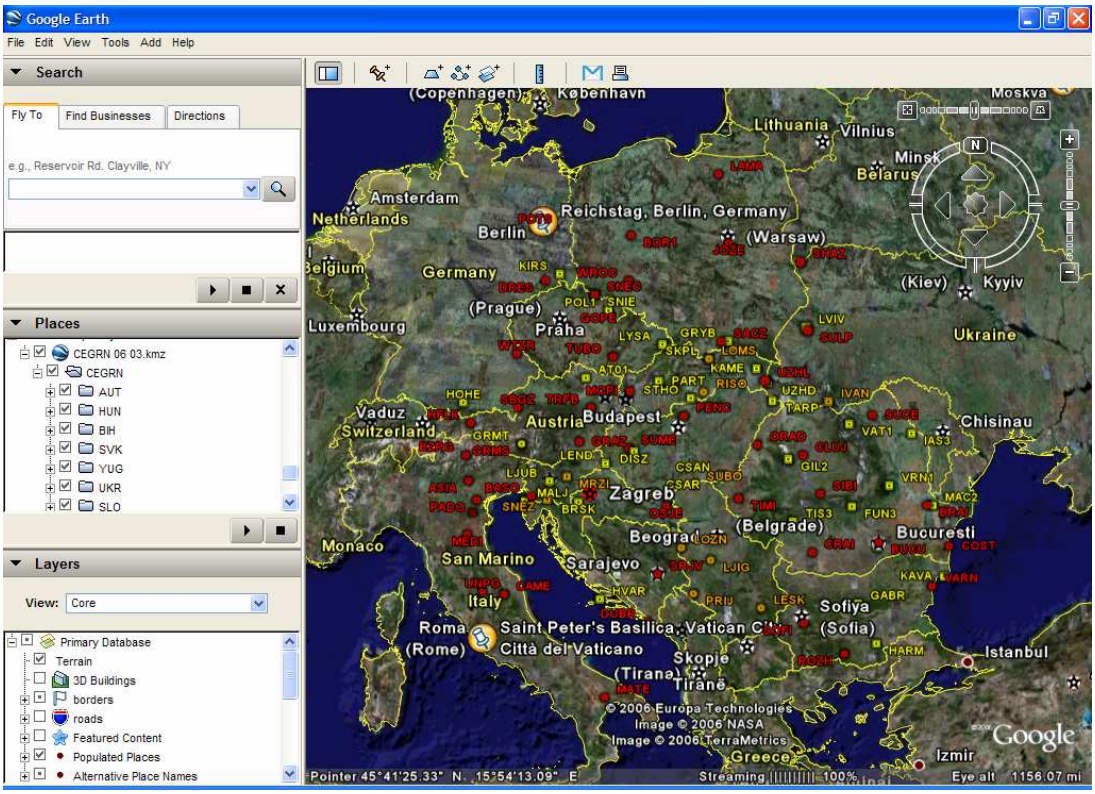

Figure 3 - GoogleEarth map of IGS stations in EUREF permanent tracking network and CEGRN sites.

Figure 3 shows the IGS stations in EUREF permanent tracking network as in April 2006. To encourage the installation of EPN stations in less dense regions, the EUREF Technical working group has adopted a new guideline concerning the station location: a minimal distance of 300 km to already existing EPN stations is required, accepting the interest of each nation to have at least one EPN station.

Two another permanent stations, in Zagreb and Pula, are operating for even longer time, but these stations were not included into international projects so far. Because of their location and good stabilization, their inclusion in international projects has been recently considered.

One such project is CERGOP2/Enviroment funded by European Union Fifth Framework Programme. CERGOP2 is based on CERGOP1 (the Central Europe Regional Geodynamics Project) which lasted from 1994 to 1998, (Reinhart and Becker, 1998). Afterwards it was decided by the participants to continue the long term project resulting in CEGRN - a dense network of geodynamic GPS-network in 14 European countries. Faculty of Geodesy, University of Zagreb organized the measurements on two sites of the network: Brusnik and Hvar. Measurements were performed without difficulties and all data has been transferred to Graz after obtaining the data from permanent stations in Zagreb (CAOP) and Pula.

GPS-Network of the City of Zagreb

The station in Zagreb is operated by the City Cadastre and located on an independent part of the building of the City Computing Centre. This station had an important role in both geodynamical GPS-campaigns within the project Geodynamic GPS-Network of the City of Zagreb (Medak and Pribicevic 2001).

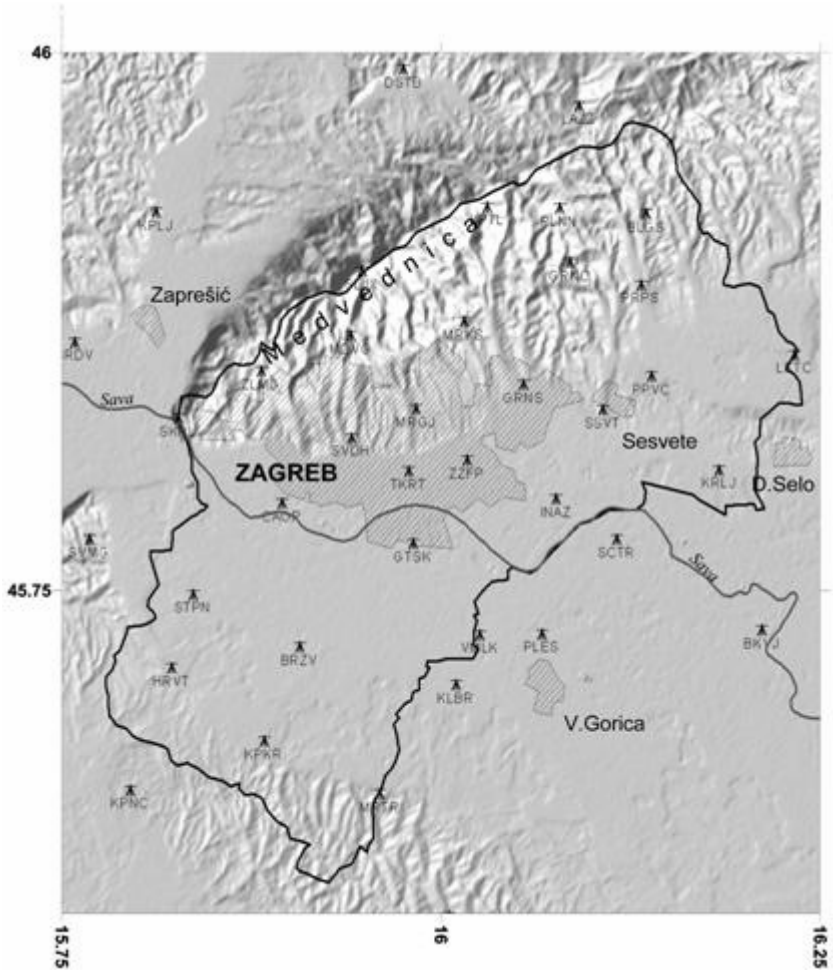

Figure 4 - Distribution of points in the Zagreb Geodynamic Network

Through the realization of the project GPS-network for Zagreb, a well-founded network of points, shown on Figure 4, was established (Medak and Pribicevic, 2001). All 43 points in the base network had special stabilization that fulfilled all criteria for geodynamic research. During the choice of point locations scientists from other disciplines were included: geologists, geophysicists, seismologists and civil engineers. The stability of points was the most important issue during the preparatory phase of the project. All pillars are equipped with forced centering screws. Since the area is mainly gravel, special stabilization is constructed and checked with precise leveling after a couple of years to determine if the pillars are vertically stable with respect to nearby leveling points. Locations are chosen with respect to fault zones to optimally describe motions. Several other criteria were important: nearby leveling points, durability with respect to landslides, engineering works, vehicle accessibility and, clear sky view at 10-15° elevation and above, especially in S, SW and SE direction. Sources of strong radio-emission, and reflective

surfaces were avoided. Altogether, 33 points were stabilized with special pillars, while the rest of the points had other marks for forced centering of GPS-antennas.

The first measurements were carried out in 1997. The purpose of the network was twofold: to be used for the state survey and to monitor tectonic movements. The first goal was fulfilled in 1998, as the homogenous field with more than 4000 GPS-points in Zagreb area was measured and adjusted. The second goal, geodynamic monitoring is a long-term project involving repeated observations every 2 years. Figure 5 shows the damaging effects of tectonic activity in the area of Kasina, where the most seismic activity is recorded.

Figure 5 - Examples of damages on houses in the epicentral area near Zagreb.

Aside from CEGRN GPS-campaigns, researchers from the Faculty of Geodesy, University of Zagreb are performing precise GPS-measurements on the Geodynamic Network of the City of Zagreb since 1997. First results has been presented in (Medak and Pribicevic 2001), and a comprehensive description of achievements can be found in (Medak and Pribicevic 2006).

Future of Geodynamics in Croatia

An important contribution to the application of GPS-technology in geodynamic research is the implementation of virtual reference networks. This process improves not only positioning and state survey, but also the possibility of better and more detailed contribution of geodesy to geodynamic research. The situation in neighbouring countries is quite good: in Slovenia there is the network SIGNAL with 15 stations (Stopar 2004) fully operable in 2006; in Serbia there is the network AGROS - Active Geodetic Referent Network of Serbia (maintained by the Republic Geodetic Authority - Republic of Serbia) with 34 stations, operable in 2006. In Croatia, the network CROPOS with 30 stations is planned for testing in 2007. We hope that this project shall open new epoch of GPS-technology in Croatia, both for practical and research purposes.

Conclusion

The zone of Dinnarides delineated by the Alps in the north, the Adriatic in the south west, and with the Pannonian basin in the north-east is seismically and tectonically very active area, which deserves further interdisciplinary research. Geodesy is contributing a lot with precise GPS-measurements which yield very accurate displacements even on local or regional level. The CEGRN network observed several times in this region has proven the hypothesis that Dinnarides are an important research area. Several campaigns performed on the Geodynamic GPS-Network of the City of Zagreb confirm the hypothesis that the movement of Eastern Alps toward Dinnarides and Pannonian basin is causing significant tectonic activity in the Mount Medvednica area. Further measurements and interdisciplinary and international cooperation is necessary in order to track these potential hazard movements. Wider usage of GPS-technology in Croatia depends on the implementation of the virtual reference stations network, which is scheduled for the end of 2007.

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