

**Reports of the Croatian National Committee
of Geodesy and Geophysics
on activities in the period 1999–2002**

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Geodesy in Croatia, 1999-2002

*Report submitted to the International Association of Geodesy
of the International Union of Geodesy and Geophysics*

This report presents the research activities in the field of geodesy in Croatia in the period from 1999 to the end of 2002. We enumerate the research projects funded by Croatian Ministry of Science and Technology. Next, we survey the papers published in Croatian national periodical »Geodetski list«, the papers published on scientific conferences organized in Croatia and the papers published by Croatian geodesists in international journals and conference proceedings during last four years. Finally, a list of selected references is included.

The scientific research was performed exclusively by the experts from the Faculty of Geodesy, University of Zagreb, through the programmes supported by the Ministry of Science and Technology. During this period, former projects (described in previous report) were finished and new projects were accepted after careful review. These projects are the continuation of previous programmes: »Geodetic-geodynamic GPS-projects in the Republic of Croatia« continues on »Physical and Satellite Geodesy in the Republic of Croatia«, »Compatibility of Heights in Croatia« continues »Height Systems in the Republic of Croatia«, »Automated Geodetic Measurement Methods« continues »Measurement Methods in Geodesy and their Automatization«. The new project is »Geomatica Croatica« which stresses the link between various fields of satellite techniques with classical measurements and the importance of physical geodesy. Two other projects related to cadastre and cartography are more related with FIG and ICA, respectively.

Several projects which are going to determine the future of geodesy in Croatia were conducted in cooperation with German Federal Agency for Cartography and Geodesy (BKG): permanent GPS-stations and absolute gravimetric measurements. Two permanent GPS-stations were established in Dubrovnik and Osijek within the frame of the International GPS-Service for Geodynamics (IGS), (Medak and Pribičević, 2001b). With the help of absolute gravimeters from Germany and France as a part of UNIGRACE project, Croatia has established a unified absolute gravity network which is going to be a high quality base network for future gravimetric works (Richter et al. 1999; Čolić et al. 2001).

Significant research has been performed within the project CERGOP (Central European Regional Geodynamic Project), a part of Geodetic and Geodynamic Programmes of the CEI (Central European Initiative). Contribution related to this project are Altiner et al. (2001), Medak and Pribičević

(2001a) and Pribičević et al. (2001a). The new phase of the project started by the end of 2002 through signing the new contract with European Commission within the Fifth Framework of Scientific Programmes. This is very important step for Croatian geodesy, since it was the first time that Croatia was accepted directly in such a project within the field of geodesy.

As usual most of the activities were conducted within the Section I: Positioning. After the establishment of the zero-order 3D Network in 1994 and CROREF Network in 1996, Croatia continued the efforts on densifying the network of GPS-points. In the area of Croatian Capitol, Zagreb, the base GPS-network was re-measured in 2001 in order to obtain quantitative parameters of the motion of the points through time (Medak and Pribičević, 2001c). Interdisciplinary cooperation has been planned with the aim to interpret resulting movements.

After successful publishing of the proceedings of the 2nd International Symposium »Geodynamics of the Alps-Adria Area by means of Terrestrial and Satellite Methods«, held in Dubrovnik, October 1998, under the patronage of IAG another important scientific event took place in Dubrovnik in May 2000: International Workshop on Perspectives of Geodesy in South-East Europe. Proceedings (Moritz et al. 2001) were published in Graz with several papers by Croatian geodesists: Čolić et al. (2001), Car and Medak (2001). The last paper stressed the strong link between classical geodesy and modern trends in geoinformation science. This link was present in several other papers starting with the Ph.D. thesis by Medak (1999a), then by Medak (1999a), Frank and Medak (1999), Medak (2000). Another important multidisciplinary link between several geosciences was stressed in the Ph.D. thesis by Pribičević (2000a).

Croatia participated in events related to the IAG Subcommission for Europe – EUREF, (Bašić and Bašić, 2001; Rožić, 2002a). The foundation of Croatian Geodetic Institute was reported in Rožić (2002b).

Croatian State Geodetic Administration hosted the EUREF-meeting in Dubrovnik in 2001. A number of reports have been submitted to various European organizations: Bašić and Zekušić (2000), Bašić (2001), Bašić et al. (2001), Marjanović and Bašić (2001). Second Croatian Congress on Cadastre, a large national meeting of geodesists was held in Zagreb in November 2001.

Significant progress was made in the area of geoid investigation in Croatia (Bašić and Brkić, 1999; Bašić et al., 1999; Brkić and Bašić, 2000; Brkić and Bašić, 2001; Pribičević and Medak, 2001; Pribičević et al. 2001). Status of height system and leveling was described in Rožić (1999, 2000) and Rožić et al. (2000).

Solarić, N. and M. Solarić (2001) analyzed the result of many years of various geodetic observation techniques applied at Hvar Observatory. That paper serves as a brief history of modern positioning methods in Croatia.

The role of geodesy in ecological engineering was presented in Medak and Pribičević (2002), while an interesting visualization of geodesic was presented in an international Internet conference (Medak et al. 2002).

Finally, Faculty of Geodesy at University of Zagreb celebrated 40 years of independent existence with a large meeting, which resulted with more than 30 papers published in proceedings (Bašić, 2002).

List of publications

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Damir Medak

Geomagnetism and aeronomy in Croatia, 1999–2002

*Report to the International Association of Geomagnetism and Aeronomy
of the International Union of Geodesy and Geophysics.*

The subjects from the field of geomagnetism and aeronomy are taught at the Geophysical Department of the Faculty of Science in Zagreb. Students listen to courses »Terrestrial magnetism« and »Aeronomy« before graduation and to the course »Antropogene changes in the atmosphere« during their postgraduate studies.

In the last period we started a study of relation between the total atmospheric ozone and the ultraviolet radiation, which was measured from summer of 1998 by a biosensor of Scintec make (donation of Neva d.o.o.). Satellite data of total ozone over the geographical position of Zagreb ($f = 45.83^\circ\text{N}$, $l = 15.99^\circ\text{E}$, $h = 195\text{ m}$) were obtained starting from 1978 (satellites NIMBUS, METEOR and EARTH-PROBE). Besides the expected seasonal variation in total ozone, a negative trend of 3.5 % between average values obtained for the two decades, 1978–1988 and 1989–2000 was found (Lisac and Vujnović, 2001). However, in 2001 the ozone level was mostly above the one of 2002. It should be noticed that the solar activity had the maximum in 2001, and that maximum had a double peak, in the relative sunspot number and even more pronounced, in the intensity of 10.7 cm radiation (Vujnović and Lisac, 2002).

In the beginning of December 1999, when total ozone fell below 220 DU, miniozone holes over Zagreb were detected which agrees with findings in the other European countries, as documented in several papers. The relation between interdiurnal differences of erythemal UV and total ozone, categorized into clear and cloudy skies, was also investigated.

In order to prove the quality of the UV data, biosensor was first recalibrated in 2001 (thanking to Prof. M. Blumthaler) by the staff of the Institute of Medical Physics, University of Innsbruck, and then its signals were compared with two empirical models (nowcasts) which relate daily ozone data with the erythemally effective UV radiation. After recalibration, signals came into satisfactory agreement with the nowcasts, being in between the Canadian and the Czech models. This situation lasted until the summer 2001 when discrepancy appeared; it could have been caused by the deterioration of the instrument or of the satellite data, since from this very time, their data were not published any more. Inspection of the quality of data will be continued with new biosensors.

Except for one biosensor in Zagreb, two other monochromatic sensors in Croatia were mounted in the Istria peninsula under the auspices of the State Hydro-Meteorological Department (K. Premec, 2000/1).

One member of the Department of Geophysics, Faculty of Sciences, Zagreb, participated at the IXth IAGA Workshop on Geomagnetic Observatory Instruments, Hurbanovo, Slovakia (12–18 June 2000) and at the International Workshop on »50 Years of the Solar and Ozone Observatory Hradec Kralove«, Hradec Kralove, Czech Republic (23–25 May 2001) with intention to establish the collaboration with colleagues in the other countries. As a result of years-long efforts to re-establish geomagnetic research and measurements in Croatia, a project »Geomagnetism in the region of Croatia« has been granted by the Ministry, offering good prospects for young people who would like to specialize in the field.

Attention was paid to the auroral phenomena in the region of Croatia, but daily values of K_p index were not favourable for our latitudes and aurora was not noticed.

In 2000 and 2001 three B. Sc. theses dealing with problems from this field were defended.

List of publications

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Vladis Vujnović

Meteorology in Croatia, 1999–2002

*Report to the International Association of Geomagnetism and Aeronomy
of the International Union of Geodesy and Geophysics.*

Scientists employed in Meteorological and Hydrological Service of Croatia and in the Geophysical Institute »Andrija Mohorovičić« have been engaged in activities within the research field of meteorology. Most of investigations during the period from 1999 to the middle of 2002, were made within the scientific projects Weather-Climat Forecast along Adriatic-Pannonian Profile, Atmosphere-Sea Interactions and Meteorological Multilanguage Glossary. After the middle of 2002, the studies have continued within the projects: Observation Methods and Meteorological Data Assimilation, Storms and Natural Disasters in Croatia and Atmosphere-Adriatic System.

Within a frame of the first project cited, vertical gradients of evapotranspiration and precipitation amounts have been determined for the Lika and Gorski Kotar area. A correlation between precipitation amounts for the same area and global circulation parameters was established. In addition, a space distribution of seasonal precipitation amounts were studied including some extreme events for shorter time scale. Using a singular spectral analysis procedure, a secular average temperature time series for Zagreb (1862–1999) was studied. Influence of wind and snow cover on infrastructure objects have also been considered. Within the scope of the second project, ground level monthly average Sun's direct, diffuse and global irradiation for Zagreb was modeled. Average monthly temperature anomalies as well as multimonthly precipitation amount anomalies for Zagreb were analysed within a period of 30 years. Monitoring and appropriate interpretation of the ozone layer condition, as well as influence of Sun's irradiation were continuously performed. Some new meteorological notions have been included within the Meteorological Glossary under the third project activities. Research work within the framework of the other three projects is just starting.

Scientists (mainly meteorologists) have been included in activities of more than thirty international and domestic conferences and a number of scientific papers were published covering theoretical and practical topics. The papers are related to the numerical modelling, severe weather study, influence of weather on national electricity infrastructure, traffic and biometeorological research.

Croatia is included in the international meteorological projects such as MAP (Mesoscale Alpine Programme) or MEDEX (Cyclones that Produce High Impact weather on the Mediterranean). The first is focused on the Alpine and the second on the Mediterranean weather events. Croatian scientists presented their results in meetings and conferences devoted to the above projects.

List of publications

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Krešo Pandžić

Physical oceanography in Croatia, 1999–2002

Report submitted to the International Association for the Physical Sciences of the Ocean of the International Union of Geodesy and Geophysics

Between 1999 and 2002 physical oceanographic research in Croatia has been carried out mainly in the following institutions: Institute of Oceanography and Fisheries, Split; Hydrographic Institute of the Republic of Croatia, Split; Center for Marine Research, Rudjer Bošković Institute, Rovinj and Zagreb; and Andrija Mohorovičić Geophysical Institute, Faculty of Science, University of Zagreb.

Altogether, 19 investigators (13 PhD's, 2 MSc's and 4 BSc's), supported by a modest technical staff, were involved in the research. Three research vessels (*Bios*, *Hidra*, *Vila Velebita*) were used in the field work. The oceanographic equipment included several CTD probes (Seabird, Idronaut) and thermistor chains (Aanderaa), a number of current meters (Aanderaa RCM's and RDI ADCP's), tide gauges (Ott analogue instruments and Aanderaa, Ott and Parascientific digital instruments), wave gauges (Datawell, Seabird), and automatic meteo-oceanographic stations (Aanderaa). All institutions had a local computer network with a mainframe computer and a series of personal computers, connected to Internet through Carnet (Croatian Academic Research Network). Moreover, a computer cluster has been acquired, to be used in fine-scale modeling of Croatian coastal waters.

During the four-year interval considered some previously established measurement programs were maintained and some new were started. Thus, hydrographic data were collected on a monthly or seasonal basis all along the east Adriatic coast, as well as along some cross-shore transects (Rovinj-Po, Split-Gargano). Current measurements were performed, mostly on the short-term basis, in the framework of various hydrotechnical projects (Kvarner, Zadar and Šibenik Archipelago, Split, Brač and Mljet Channels, Zrmanja and Krka Estuaries, Dubrovnik area). Tide-gauge measurements were continued at a previously established network of seven stations (Rovinj, Bakar, Zadar, Split-Marjan, Split-Harbour, Sućuraj, Dubrovnik), with some new stations being established recently (Plomin, Susak, Split-Lighthouse, Ploče). Sea-surface temperature was measured daily at a number of coastal stations. Last but not least, automatic meteo-oceanographic stations were maintained at three locations (Veli Rat, Punta Jurana, Sveti Ivan) in order to enable air-sea fluxes to be determined for use in the oceanographic research.

Over the preceding four years Croatian institutions participated in several national projects, in bilateral programs (with Italian partners: ADRICOSM, MAT; with American partners: EACE), and in programs supported by Euro-

pean Community (COST40, ESEAS, MAMA, SEASEARCH). Croatian physical oceanographers also took part in the IOC assemblies, GOOS and GODAR meetings, as well as in a number of international conferences and workshops.

The work done is documented in the publications the list of which is attached to this report. The list contains scientific papers, conference communications published *in extenso*, books and theses. Some attention was paid to fluxes across the air-sea interface. On the basis of monthly averaged coastal meteorological data long-term series (1966–1992) of surface heat, water and buoyancy fluxes in the north Adriatic were computed (Supić, 2000, Supić and Orlić, 1999). These have subsequently been correlated with the current speed (Supić, 2000, Supić et al., 2000, 2001) and with the characteristics of water masses in various areas (Vilibić, 2002a, b, c, Vilibić and Orlić, 2001a, b, 2002). Thus, for example, it was found that the occurrence of the Istrian Coastal Countercurrent during summer in the north Adriatic is more probable if in the preceding winter the transfer of heat from the sea to the atmosphere was lower than usual. Moreover, it was established that the outflow of dense water from the Adriatic shelf usually occurs during spring, four months after weakening of the Po River discharge and two months after high surface buoyancy loss in the north Adriatic. Surface fluxes were also calculated over several months only but using daily or even ten-minute values of input parameters (Supić and Orlić, 1999, Dadić et al., 2001a, Grbec et al., 2001). These calculations showed that the winter transfer of heat from the sea to the atmosphere is dominated by short episodes which last only several days and which are related to the bora wind blowing above the Adriatic. Bone and Grbec (2001) considered a simple solar radiation model to be used in numerical modeling of the Adriatic Sea.

A number of publications dealt with the open Adriatic hydrography and current field variability. Long-term (1966–1992) changes in hydrographic conditions at a station in the open north Adriatic were discussed and qualitatively related to long-term changes of air-sea fluxes (Supić and Ivančić, 2002). Seasonal variations of current field components (inertial oscillations, wind-driven, geostrophic and residual currents) in the north Adriatic were analyzed on the basis of extensive data set (Krajcar, 2001). Bora wind influence on the north Adriatic was studied by the empirical analyses and the meteorological and oceanographic numerical modeling (Beg Paklar, 2000, Beg Paklar et al. 1999, 2001a). Empirical analyses were made on the basis of the current-meter data, satellite sea-surface temperatures and trajectories of satellite-tracked drifters. Numerical simulations were performed with Princeton Ocean Model (POM) forced with wind stress and heat fluxes calculated by bulk method from the winds, air temperatures and humidities obtained by Mesoscale Model 5 (MM5) and ALADIN model and sea-surface temperatures from the oceanographic model as well as with river discharges. The numerical experiments revealed that the offshore spreading of the cold and less saline water from the west coastal area in the form of the narrow fil-

ament after the bora events is a result of a joint action of three external forcings: wind stress, surface heat flux and river discharge, and none of these can be neglected in simulating the observed pattern. These studies represent the first attempt to numerically simulate response of the Adriatic shelf water and the Po River plume to realistic space- and time-variable atmospheric fields, with resolution which enables one to resolve alongshore variability in the wind field and to follow the temporal evolution and decay of the current field. Leder (2002) reported on the occurrence of internal waves near the steep shelf break off the island of Lastovo during summer season, and hypothesized that the waves are excited primarily by the wind action. Transparency decrease at the open sea station Stončica was motivation for including different optical water conditions in the numerical simulations (Beg Paklar et al., 2001b). Different optical types used resulted in changed vertical thermal structures, and the differences, after few days of integration, were higher for the summer than for the winter simulation. Physical studies found application in the investigation of the Adriatic ichthyofauna (Dulčić and Grbec, 2000, Dulčić et al., 1999, Grbec et al., 2002) and in the projects concerned with biodiversity preservation (Požar-Domac et al., 2000).

Coastal oceanography is a discipline that plays a significant role in the Adriatic investigations. Orlić et al. (2000), by comparing CTD data collected before and after a precipitation event and current-meter data measured during the event, demonstrated that the Velebit Channel is strongly influenced by fresh-water input. Leder et al. (1999b) showed that the east part of the Kaštela Bay is influenced more by the wind forcing than the fresh-water outflow. Basic statistical analysis of all available current data from the Kaštela Bay for a period between 1953 and 1990 showed importance of the sirocco wind in generating circulation in the bay (Zore-Armanda et al., 1999a, Beg Paklar et al., 2002). Strong episodes of sirocco reverse the estuarine circulation in the bay inlet. In the bay interior sirocco-induced surface currents turn to the right of the wind direction under the influence of the Coriolis force. Most empirical findings were found to agree with the previously published results of 3D numerical modeling of the Kaštela Bay wind-driven dynamics (Orlić et al., 1999). Some other processes in the Kaštela Bay were modeled by Bone et al. (1999) and by Morović et al. (1999, 2001). Vilibić and Orlić (1999) documented occurrence of barotropic surface seiches (period 2.2 h) and baroclinic Kelvin waves (period 4 days) trapped during the summer season in the semi-enclosed channel off Zadar, by analyzing current-meter series at a large number of stations as well as tide-gauge data collected at Zadar. A number of papers dealt with the physical parameters relevant for the positioning of submarine wastewater sewage disposals off the coastal Croatian cities (Barić et al., 2000, Bojanić et al., 1999, Leder et al., 2000, Smirčić et al., 2001, Vilibić et al., 1999c). Experience gained while analyzing physical phe-

nomena was on several occasions usefully employed in the study of biogeochemical processes (Burić et al., 1999, Viličić et al., 1999).

Sea level also attracted interest of Croatian physical oceanographers over the preceding four years. In a series of publications response of the Adriatic to the planetary-scale atmospheric forcing has been considered (Pasarić, 2000, Pasarić and Orlić, 2001a, b, Pasarić et al., 2000). By applying methods of multiple correlation and regression analysis on the air-pressure and wind data on one hand and the sea-level data on the other it was shown that the previously observed departures from the inverse-barometer effect are due to the wind forcing. Moreover, a simple statistical model was developed in order to demonstrate that in multiple-input linear models with mutually correlated inputs small errors in one of the inputs produce biased estimates of all the response parameters. Climatology of the Adriatic seiches and their role in the appearance of extreme sea levels were examined in detail by Vilibić (2000, 2001). Raicich et al. (1999) considered the Adriatic fundamental mode as recorded in December 1997 at a number of stations distributed along the east coast. Vilibić and Mihanović (2001, 2002) studied the seiches appearing in the Split harbor by examining the data collected at MedGLOSS station recently located there and by using 2D barotropic numerical model. The installation of MedGLOSS station and preliminary analysis of the data was described in the paper by Vilibić et al. (2001). Furthermore, sea-level oscillations in the area of nearby Kaštela Bay were analyzed by Vilibić et al. (1999a), covering the periods from a few hours to decadal ones. Extreme oscillations in the Adriatic were subject of the paper by Vilibić et al. (1999b), whereas Vilibić et al. (2000) considered the impact of storm surges on the coastal infrastructure by analyzing transient episodes (storm at Split on 20 November 1999) and climatological data (1955–1997). An improved formulation of the open-boundary conditions for the Adriatic tidal model was given by Bobanović et al. (2000), and the Adriatic tides were subsequently investigated by Janeković (2001) using numerical simulations and data analysis. In two papers sea-level variability was related to land movements. Orlić and Pasarić (2000) showed, on the basis of tide-gauge data, that tectonic movements bring about a rising of the middle and south Adriatic coast relatively to the north Adriatic coast. Herak et al. (2001) used data and 2D model to show that the Makarska earthquake of 1962 generated a tsunami in the area and that initial disturbance was due to the subsidence of the foot wall of the seismogenetic fault.

Wind waves were considered in several papers. Leder et al. (1999a) estimated maximum wave height of 13.6 m to appear once in 100 years; the result stemmed from the data collected in the years 1978–1986 and 1992 at the waverider buoy located in the open north Adriatic. The analyses of extreme wave episodes based on selected situations were additionally documented by Pršić et al. (1999) and by Smirčić and Leder (1999). Finally, Smirčić et al. (2000) united existing surface wave analyses done for the north, middle and south Adriatic and made an intercomparison of the extreme wave height estimations.

In order to facilitate all these studies procedures for validation, analysis and presentation of oceanographic data were developed (Dadić, 2000, 2001, Dadić and Ivanković, 1999, Dadić et al., 2001b), and Marine Environmental Database of the Adriatic Sea (MEDAS) using Oracle 9i RDBMS and ArcView GIS programming tools was implemented (Ivanković et al., 2000).

Over the past four years several Adriatic-related topics were reviewed by Croatian investigators. Zore-Armanda et al. (1999b) considered classical data on hydrographic characteristics and currents, whereas Gačić et al. (2001) contrasted early findings on the Adriatic physical processes with the results based on modern *in situ* and remote measurements. Orlić (2001a) showed that the Adriatic sea-level variability is controlled by a number of physical phenomena (tides, storm surges and seiches, planetary-scale waves, seasonal and year-to-year variability, interdecadal variability, long-term changes) and reviewed the studies done on each of them. Furthermore, Orlić (2001b) presented a century of research of wind-related dynamics of Croatian coastal sea, distinguishing between direct response of the sea to the wind forcing and barotropic and baroclinic free waves. In the book by Penzar et al. (2001) the review was extended to the air-pressure forcing of the Adriatic, and a section was written on the temperature of the Adriatic Sea and its dependence of the air-sea heat flux, advection and mixing. Finally, Orlić (2002) overviewed development of physical oceanography in Croatia, starting with the first treatise on tides published in 1528.

Overall, the level of scientific activity of Croatian physical oceanographers in the 1999–2002 interval seems to be quite similar to that achieved during the four-year intervals preceding it and described in the previous reports to the International Association for the Physical Sciences of the Ocean*. Recently, intensive cooperation has started between Croatian researchers and their colleagues abroad, resulting in some extensive field programs and state-of-the-art modeling of the Adriatic dynamics. The effects of this cooperation should become evident in future reports.

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Seismology in Croatia, 1999–2002

*Report submitted to the International Association of Seismology
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and Geophysics*

The seismological research in Croatia is carried almost exclusively within the Department of Geophysics, Faculty of Sciences, University of Zagreb. Scientific investigations are mostly organized within the framework of the project »Seismicity of Croatia«, which is financed by the Ministry of Science and Technology of the Republic of Croatia. The staff of Croatian Seismological Survey (a part of the Department) maintain and deploy the network of seismographs and strong-motion instruments, compile the earthquake catalogue and analyse and exchange the seismological data. In this period the number of seismological instruments increased and two new seismological stations were opened (Sisak – SISC and Novalja – NVLJ). Also, two BB stations (DUOK and HVAR) operated in the framework of the MIDSEA project. Most of the existing stations have been upgraded with digital, broad-band instruments.

12 researchers (4 PhD, 6 MSc and 2 BSc) took part in seismological investigations. In the period 1999–2002 they published a total of 39 scientific and conference papers. Croatian seismologists were active in national scientific project as well as in international multilateral and bilateral programs. The research topics included seismic zonation of megacities around the world (UNESCO-IGCP sponsored project coordinated by the Department of Earth Sciences, University of Trieste), interpretation and analysis of historical seismograms (cooperation between Universities of Zagreb and Hamburg), seismic hazard assessment in the Adriatic region GSHAP (UN/IDNDR sponsored project, coordinated by ETH, Zurich in 1997–1999), and investigation of the Earth's mantle in the Europe-Africa region (MIDSEA project, coordinated by ETH, Zurich).

Significant part of seismological studies is related to Croatian seismicity, which was characterized by only a moderate earthquake activity in this period. An overview of Croatian seismicity in period 1997–2001 was presented by Ivančić et al. (2002) and Tomljenović et al. (2001) for NW Croatia. Herak and Herak (2000) presented overall seismicity of the Ston region. Also, the Croatian earthquake catalogue has been regularly updated and currently consists of 18861 records.

Herak M. et al. (2000, 2001) presented numerical modeling of the Ston-Slano (Croatia) aftershock sequence. Thousands of aftershocks after M6 Ston-Slano earthquake of 1996 enabled a sound statistical analysis. The rate

of aftershock occurrence was modeled as the Epidemic Type Aftershock Sequence (ETAS).

Several papers have been dedicated to seismic hazard assessment in Croatia (Herak, M., 1999, Slejko et al., 1999, Markušić et al., 2000, Herak M. et al., 2001, Allegretti and Herak, 2002, Lokmer et al., 2002, Markušić et al., 2002, Panza et al., 2002).

For instance, Markušić et al. (2000) proposed dividing the territory of Croatia and neighboring regions into 17 seismic source zones, considering available seismological and geological data. On this basis, seismic hazard elements (seismicity rate, maximum magnitude, b-value, probabilities of exceedance and return periods for a predefined set of magnitudes) are computed using maximum likelihood method appropriate for treating data sets with variable completeness thresholds. The values of long term expected peak horizontal acceleration obtained by using a combination of the deterministic and the probabilistic procedure are the highest in the Dubrovnik zone, while the Zagreb zone has the highest earthquake hazard in the continental part of Croatia. Papers by Herak et al. (2002) and Markušić et al. (2002) deal with peak ground acceleration (PGA) attenuation in the Dinarides region. The authors proposed PGA attenuation relations to be used in the Dinarides region for distances up to 100 km.

Seismic hazard in several parts of Croatia (Zagreb, some Dalmatian regions) was also estimated by stochastic approach, *i.e.* by Monte-Carlo simulations of earthquake occurrence. The hazard was estimated in terms of peak ground accelerations and expected intensities (I_{max}) computed for various return periods on the basis of statistical analyses of 5000 synthetic 50-years earthquake catalogues. The highest values of PGA are found along the border with Bosnia and Herzegovina with the absolute maximum of 0.35 g in the greater Dubrovnik area (Allegretti and M. Herak, 2002). Lokmer et al. (2002) used a hybrid technique consisting of modal summation and subsequent finite differences modeling for the computation of synthetic accelerograms along a profile crossing the city of Zagreb. According to the results of the paper, the largest amplification of ground motion (exceeding a factor of 3) may be expected beneath the very centre of the city.

Intermediate term earthquake prediction algorithm CN was used by Herak D. et al. (1999a, 1999b) to investigate seismicity prior to 9 strong events in the Southern External Dinarides. They have found that 8 of them were preceded by a time period of increased probability (TIP) of earthquake occurrence.

The papers by Van der Lee et al. (1999a, 1999b, 2000, 2001a, 2001b) describe the results of the MIDSEA project. The goal of this project is to obtain key information on the upper mantle structure in the greater Mediterranean region and Eurasia-Africa plate boundary region.

Historical seismograms recorded in Göttingen and Zagreb were studied by Allegretti et al. (2000). The magnitudes of the largest historical earthquakes in the first half of the 20th century, calculated on the basis of records of Wiechert horizontal seismographs in Göttingen and Zagreb were compared with one another, as well as with the magnitudes reported worldwide. It was shown that systematic trends exist in the data regarding the temporal stability of magnitude estimations in the Göttingen case, as well as the apparent non-linearity of the instrument response in the case of the Wiechert seismograph in Zagreb.

Herak M. et al. (2001) have presented theoretical basis for Ms depth correction. They used modal summation technique to generate 5000, three component theoretical seismograms of surface waves assuming validity of generally accepted global Earth models (PREM-C and AK135F). They observed the theoretical amplitude decay with the source depth in agreement with observational data.

Anisotropy of Pg-wave velocity was considered for two regions: Central External Dinarides and in the hypocentral volume of the Krn Mt. (Slovenia) earthquake sequence (Lokmer and M. Herak, 1999; Herak M. et al., 2002).

The scientific productivity of Croatian seismologists retained the same level as in the previous 4-year period.

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