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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 witching 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 Bačić, 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: Bačić and Zekušić (2000), Bačić (2001), Bačić et al. (2001), Marjanović and Bačić (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

Altiner, Y., Marjanović-Kavanagh, Medak, D., Medić, Z., Prelogović, E., Pribičević, B., Seliškar, A. (2001): Is Adria a Promontory or does it exist as an Independent Microplate? Proceedings of the EGS G9 Symposium »Geodetic and Geodynamic Programmes of the CEI (Central European Initiative)«, Nice, France 25–30 March 2001. Reports on Geodesy No.2. Sledzinski, Janusz (ed.). Warsaw, Poland: Warsaw University of Technology, 225–229.

Bačić, Ž. (2001): National Report of Republic of Croatia. 1st General Assembly of Eurogeographics, Dublin, Ireland, September 2–5, 2001.

Bačić, Ž., Zekušić, S. (2000): National Report of Republic of Croatia. CERCO General Assembly, Malmø, Sweden, October, 2–4, 2000.

Bačić, Ž., Bosiljevac, M., Marjanović, M. (2001): National Report of Republic of Croatia. Proceedings of the Symposium of the IAG Subcommission for Europe (EUREF), Dubrovnik, Croatia, May 2001.

Barković, Đ. (2002): Comparison of Levelling Staves by means of Sealed Linear Encoder (in Croatian). University of Zagreb – Faculty of Geodesy, Ph. D. thesis.

Bašić, T., editor (2002): Proceedings of the Faculty of Geodesy University of Zagreb on the Occasion of the 40th Anniversary of Autonomous Activities 1962–2002, ISBN 953-6082-07-1, 1–332, Zagreb 2002.

Bašić, T., Brkić, M. (1999): The Latest Efforts in Geoid Determination in Croatia. 2nd Joint Meeting of the International Gravity Commission and the International Geoid Commission, Trieste, 7–12 September 1998, In: Bollettino di Geofisica Teorica ed Applicata, 40, N. 3–4, 379–386, Osservatorio Geofisico Sperimantale, Trieste 1999.

Bašić, T., Brkić, M., Sünkel, H. (1999): A New, More Accurate Geoid for Croatia. EGS XXIII General Assembly, Nice, 20–24 April 1998, In: Physics and Chemistry of the Earth (A), Vol. 24, No. 1,: Solid Earth and Geodesy, Special Issue: Recent Advances in Precise Geoid Determination Methodology, I. N. Tziavos and M. Vermeer (Eds.), 67–72, Elsevier Science Ltd. 1999.

Bašić, T., Bačić, Ž. (2001): Transformation between the Local and Global Geodetic Datum in Croatia. Proceedings of the Symposium of the IAG Subcommission for Europe (EUREF), Trømsø, Norway, June 21–24, 2000. In: Mittelungen des Bundesamtes für Kartographie und Geodäsie, 229–236, Frankfurt am Main.

Brkić, M., Bašić, T. (2000): Relief correction calculation in spatial and spectral domain (in Croatian). Geodetski list 54 (77), 4, 259–273, Zagreb 2000.

Brkić, M., Bašić, T. (2001): Terrain correction by means of simple spatial density model. EGS XXVI General Assembly, Nice, 25–30 March 2001, G7 Session: Regional and local gravity field approximation, Published in International Geoid Service (IGeS) Bulletin N. 13, Special Issue, I. N. Tziavos and R. Barzaghi (Eds.), 62–73, Milano, September 2002.

Car, A. and D. Medak (2001): GIS in 2000 and beyond. Proceedings of the International Workshop on Perspectives of Geodesy in South-East Europe, Dubrovnik, Croatia, May 2–6, 2000. (H. Moritz, D. Medak, B. Pribičević, eds.) Mitteilungen der geodätischen Institute der Technischen Universität Graz, Folge 89, Graz 2001, 73–80.

Čolić, K., Solarić, M. (1999): Application of GPS and DGPS in Croatia, Reports on Geodesy, No 44 (3), Sledzinski, Janusz (ur.).Warsaw, Poland: Warsaw University of Technology, 1999. 67–72.

Čolić, K., Pribičević, B., Švehla, D. (1999): 3-D Geodynamic Network of Broader Area of City of Zagreb. 2nd International Symposium »Geodynamics of the Alps-Adria Area by means of Terrestrial and Satellite Methods«, Dubrovnik, Zagreb and Graz, 1999 (75–86).

Čolić K., B. Pribičević, D. Medak, A. Đapo (2001): Absolute Gravity Measurements in Croatia. Proceedings of the International Workshop on Perspectives of Geodesy in South-East Europe, Dubrovnik, Croatia, May 2–6, 2000. (H. Moritz, D. Medak, B. Pribičević, eds.) Mitteilungen der geodätischen Institute der Technischen Universität Graz, Folge 89, Graz 2001, 101–104.

Frank, A.U. and D. Medak (1999): Formal Model of a Spatiotemporal Database. In Proceedings of the 19th annual conference on the current trends in databases and information systems DATASEM99. Brno, Czech Republic, October 24–26, 1999, (Karel Richta, ed.), pp. 117–130.

Marjanović, M., Bačić, Ž. (2001): Computation of the Combined Solution of EUREF GPS Campaigns 1994–96 in the Republic of Croatia. Proceedings of the Symposium of the IAG Subcommission for Europe (EUREF), Dubrovnik, Croatia, May 2001 (in print).

Medak, D. (1999a): Lifestyles – a new Paradigm in Spatio-Temporal Databases. Ph.D.-thesis. Technical University of Vienna, p. 1–169.

Medak, D. (1999b): Lifestyles – an Algebraic Approach to Change in Identity. In »Spatio-temporal Database Management, International Workshop STDBM'99«, Edinburgh, Scotland, September 10–11, 1999, (Böhlen, M.H., Jensen, C.S., and Scholl, M.O., eds.), Lecture Notes in Computer Science Vol. 1678, Springer Verlag, Berlin-Heidelberg-New York, pp. 19–38.

Medak, D. (2000): Applications of GIS in geodesy and geophysics, Raziskave s področja geodezije in geofizike 2000 – zbornik radova (F. Vodopivec, ed.), Slovensko združenje za geodeziju in geofiziku, Ljubljana, pp. 37–44.

Medak, D., Pribičević, B. (2001a): Dynamic Three-dimensional Model of the National Park Plitvice Lakes, Barriers and Tributary Streams, UNESCO, Pariz.

Medak, D. and B. Pribičević (2001b): Programe of Geodynamic and Environmental Studies in the Region of Plitvice Lakes. Proceedings of the EGS G9 Symposium »Geodetic and Geodynamic Programmes of the CEI (Central European Initiative)«, Nice, France 25–30 March 2001. Reports on Geodesy No.2. Sledzinski, Janusz (ur.). Warsaw, Poland: Warsaw University of Technology, 219–224.

Medak, D. and B. Pribičević (2001c): *Geodynamic GPS-Network of the City of Zagreb – First Results*. The Stephan Mueller Topical Conference of the European Geophysical Society: Quantitative Neotectonics and Seismic Hazard Assessment: New Integrated Approaches for Environmental Management, September 22–26, 2001, Balatonfuered, Hungary.

Medak, D., Pribičević, B. (2001d): Croatian Permanent Stations within International GPS-service for Geodynamics. Hvar Obs. Bull. 25 (2001) 1, 61–73.

Medak, D., Pribičević, B. (2002): Modern geodetic technologies and environment protection. First Croatian Ecological Engineering Conference, Plitvice Lakes, October 2002.

Medak, D., Pribičević, B., Medved, I. (2002): Geodesic in Java – Enhancing the Presence of Geodesy in the Internet. Proceedings of the 4th Carnet Users Conference.

Moritz H., D. Medak, B. Pribičević (2001): Proceedings of the International Workshop on Perspectives of Geodesy in South-East Europe, Dubrovnik, Croatia, May 2–6, 2000. Mitteilungen der geodätischen Institute der Technischen Universität Graz, Folge 89, Graz 2001, 206 pages.

Pribičević, B. (2000): Uporaba geološko – geofizičnih in geodetskih baz podatkov za računanje ploskve geoida Republike Slovenije, Ph.D.-thesis. University of Ljubljana, Faculty of Civil Engineering and Geodesy, Ljubljana, 1–172.

Pribičević, B. and D. Medak (2001): Influence of close-surface masses of the Earth's surface on geoid undulations (in Croatian). Geodetski list, Vol. 55(78) 1, Zagreb 2001, pp. 19–31.

Pribičević, B., D. Medak, M. Ratkajec (2001): Astrogeodetic works on determination of new geodial points in the Republic of Croatia (in Croatian). Geodetski list, Vol. 56(79) 2, pp. 77–98.

Pribičević, B., Medak, D., Domandžić, D. (2001): Research on geodynamics of the Adriatic micro-plate. Raziskave s področja geodezije in geofizike 2001 – zbornik radova (F. Vodopivec, ed.), Slovensko združenje za geodeziju in geofiziku, Ljubljana, 29–38.

Pribičević, B., Medak, D., Prelogović, E. (2001): Usage of the Geoid Surface with Geological-geophysical Data for Interpretation of Recent Crustal Movements Determined by GPS. Proceedings of the EGS G9 Symposium »Geodetic and Geodynamic Programmes of the CEI (Central European Initiative)«, Nice, France 25–30 March 2001. Reports on Geodesy No.2. Sledzinski, Janusz (ur.). Warsaw, Poland: Warsaw University of Technology, 213–217.

Richter, B., Wilmes, H., Lothhammer, A., Falk, R., Čolić, K., Pribičević, B. (1999): Absolute gravity measurements in Croatia – a standardized base net for geodynamic, height and gravity studies. Proceedings of the Second International Symposium: Geodynamics of Alps-Adria Area by means of Terrestrial and Satellite Methods, (Eds. K. Čolić and H. Moritz, University of Zagreb and Technical University Graz), Dubrovnik, Croatia, September 28 – October 2, 1998, 263–270.

Rožić, N. (1999): Erhaltung der Reperepunkte im Österreichischen Präzisionsnivellement auf dem Gebiet der Republik Kroatien. Österreichische zeitschrift für Vermessung & Geoinformation, Heft 4, 188–195.

Rožić, N. (2000): Fundamental levelling networks and height datums at the territory of the Republic of Croatia. Acta Geodaetica et Geophysica Hungarica, Budapest, Vol. 36 (2), 231–243.

Rožić, N. (2002a): Accuracy of geometric levelling networks at the territory of Croatia. Veröffentlicungen der bayerischen Kommission für die Internationale Erdemessung der Bayerischen Akademie der Wissenschaften, Report on the Symposium of the IAG Subcommission for Europe (EUREF), Ponta Delgada, Portugal, 5.–9. Jun 2002, München.

Rožić, N. (2002b): Croatian Geodetic Institute. Mittelungen des Bundesamtes für Kartographie und Geodäsie, Band 23, EUREF Publication No. 10, Frankfurt am Main, 2002, 211–212.

Rožić, N., Feil, L., Pavičić, S. (2000): Review of activities on levelling works in the Republic of Croatia 1999–2000. Veröffentlichungen der Bayerischen Kommission für die Internationale Erdemessung der Bayerischen Akademie der Wissenschaften, Report on the Symposium of the IAG Subcommission for Europe (EUREF), Trømsø, Norway, June 21.–24. 2000, München, 2000, Heft Nr. 61, 362–365.

Solarić, N., Solarić, M. (2001): Analysis of Scientific Results Obtained in Geodetic Positioning of the Hvar Observatory (in Croatian). Geodetski list 55 (78), 2, 79–104, Zagreb 2001.

Špoljarić, D. (2002): The Automation of Simultaneous Determination of Astronomical Coordinates on Geoid Points (in Croatian). University of Zagreb – Faculty of Geodesy, Ph. D. thesis.

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 °N, l = 15.99 °E, h = 195 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, cathegorized 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 penninsula 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 Kp 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

Herceg-Bulić, I. (2000/1): Erythemally effective UV radiation in Zagreb during May 1999., Hrv. meteorološki časopis, **35/36**, 37–44.

Premec, K. (2000/1): Ultraljubičasto Sunčevo zračenje i njegov značaj (Ultraviolet Solar radiation and its significance), Hrv. meteorološki časopis, **35/36**, 45–54.

Lisac, I. (2001): Overview of scientific activities in geomagnetism and aeronomy in Croatia, Acta Geod. Geoph. Hung., **36**(2), 245–255.

Lisac, I. and Vujnović, V. (2001): Atmosferski ozon i Sunčevo UV zračenje nad područjem Hrvatske (Atmospheric ozone and Solar UV radiation over Croatia), IInd Croatian Symp. »Aromatherapy and…«, Opatija 26–28.IX.2001., Contributed papers 145–154.

Vujnović, V. and Lisac, I. (2001): Prostiranje Sunčeva zračenja kroz atmosferu i eritemalno učinkovito ultraljubičasto zračenje u Hrvatskoj (Solar radiation transfer through the atmosphere and erythemally effective ultraviolet radiation in Croatia), Conference on Health tourism, Veli Lošinj 7–9. Sept. 2001, Contributed papers (ed. Ivanišević, G.), Zagreb, 136–46.

Vujnović, V. and Marić, K. (2001): An overview of measurement activities in geomagnetism in Croatia, Contrib. Geoph. Geod., **31**(1), 29–32.

Vujnović, V. and Lisac, I. (2001): Usporedba ukupnog atmosferskog ozona nad Zagrebom i mjerenog UV zračenja (Comparison of total atmospheric ozone above Zagreb and measured UV radiation), Third Conference of Croatian Physical Society, Zagreb, 5–7. December 2001., Contributed abstracts, Zagreb, 41.

Vujnović, V. and Lisac, I. (2002): Prilog poznavanju odnosa između ukupnog ozona i Sunčevog UVE zračenja u Hrvatskoj (A contribution to the study of total ozone over Croatia and corresponding UVE radiation), Conference on Health tourism, Veli Lošinj 6–8. Sept. 2002, Contributed papers (ed. Ivanišević, G.), Zagreb, 165–170.

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-Climate 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

Antonić, O., Križan, J., Marki, A., Bukovec, D. (2001): Spatio-temporal interpolation of climatic variables over large region of complex terrain using neural networks, *Ecological Modelling,* **138**, 255–263.

Antonić, O., Marki, A., Hatić, D., (1998/1999): Climatic variables modelling as part of a dendroecological study in the Repaš forest, Prekodravlje, Croatia, Hrvatski meteorološki časopis, **33/34,** 39–51.

Antonić, O., Marki, A., Križan, J. (2000): A global model for monthly mean hourly direct solar radiation. Ecological Modelling**, 129**; 113–118.

Antonić, O., Bukovec, D., Križan, J., Marki, A., Hatić, D. (2000): Spatial distribution of major forest types in Croatia as a function of macroclimate, Natura Croatica, **9**, 1; 1–13.

Bajić, A., Vučetić, V., Peroš, B., Žibrat, Z. (2001): Metetorološka podloga za hrvatske norme – opterećenje vjetra. Građevinar, **53**, 495–505.

Bénard, P., Marki, A., Neytchev, P. N., Telišman Prtenjak, M. (2000): Stabilization of nonlinear vertical diffusion schemes in the context of NWP models, Monthly Weather Review, **128**, 1937–1948.

Bencetić Klaić, Z. (2001): Weather types and traffic accidents, *Collegium Antropologicum,* **25**, 245–254.

Bencetić Klaić, Z., Nitis, T., Kos, I. and Moussiopoulos, N. (2002): Modification of the local winds due to hypothetical urbanization of the Zagreb surroundings, *Meteorology and Atmospheric Physics*, **79**, 1–12.

Cesarec, K., Beraković, B. (2002): Extraordinary summer flood in a karst area: Case Study in Croatia – The extremes of the extremes: Extraordinary floods, IAHS publication No. 271, 133–139.

Cesarec, K., Blažeković, Z. (2001): Examples of the transboundary water activities on the rivers Drava and Mura-Hydrological chalanges in transboundary water resources management, IHP/OHP-477-481, International Conference, Koblenz, Germany, 2001.

Cvitan, L., Šinik, N. and Bencetić Klaić, Z. (2002): Two simple wind speed models for practical application under stable conditions, Meteorological Applications, **9**, 423–432.

Đuričić, V. (2001): Atmospheric Input of Inorganic Nitrogen to the Adriatic Sea*,* Report du 36e Congres de la CIESM, **36**., 59–59.

Đuričić, V., Vidič, S., Šojat, V. (1999): Atmosferski doprinos problemu eutrofikacije sjevernog Jadrana*,* Drugi hrvatski znanstveno-stručni skup »Zaštita zraka '99« Šibenik, Hrvatska, 22–25 rujna 1999., 331–338.

Đuričić, V., Šojat, V., Vidič, S., Guerzoni, S. (2001): Atmospheric Input of Inorganic Nitrogen to the Adriatic Sea*,* MAP Technical Report Series, No.133, (Atmospheric Transport and deposition of Pollutants into the Mediterranean Sea, Final Reports on Research Projects), UNEP/MAP, Athens, 86–112.

Gajić-Čapka, M., Ivančan-Picek, B. (2000): Assessment of heavy rainfall, *European Conference on Applied Climatology ECAC2000*, 16–20 October 2000, Pisa, Italy, Book of abstracts, 290, (CD ROM, Abs.Pos-7).

Gajić-Čapka, M. (1999): Duljina normalnog niza za kratkotrajne oborine u Hrvatskoj, Hrvatske vode, **29,** 217–235.

Gajić-Čapka, M. (2000): Metode klimatološke analize kratkotrajnih oborina velikog intenziteta. Sveučilište u Zagrebu, Prirodoslovno matematički fakultet, Zagreb, str 131, (Ph. D. thesis).

Gajić-Čapka, M. (2000): Normal Length Of Maximum Short-term precipitation Series. 5th International Workshop on Precipitation in Urban Areas, From Precipitation Measurements to Design and Forecasting Modelling, Preprints of papers, Ed. P. Burlando and Th. Einfalt, IHP-V / Technical Documents in Hydrology, UNESCO, 177–182.

Gajić-Čapka, M. (2000): Secular trends of precipitation amount, frequency and intensity in Croatia. Meteorology at the Millennium, 10–14 July 2000, Cambridge, UK, Book of abstracts, 83.

Gajić-Čapka, M. (2001): Regionalno modeliranje maksimalnih dnevnih oborina. Hrvatske vode, **36**, 275–356.

Gajić-Čapka, M. (2002): Regionalna analiza učestalosti ekstremnih oborina, Okrugli stol: Urbana hidrologija, Split, 25. i 26. travnja 2002, 91–100.

Gajić-Čapka, M., Zaninović, K. (1999): Estimation of rainfall rates for the road design. Proceedings of the 4th European Conference on Applications of Meteorology (ECAM 99), 13–17 November 1999, Norrköping, Sweden, CD- ROM, P027.

Gajić-Čapka, M., Ivančan-Picek, B. (2000): Assessment of havy rainfall. 3rd European Conference on Applied Climatology, 16–20 Oct. 2000, Pisa, Italy, Book of abstracts, 290, (CD ROM, Abs. Pos-7).

Gajić-Čapka, M., Perčec Tadić, M., Patarčić, M. (2002): Digitalna klimatska oborinska karta Hrvatske. Hrvatski meteorološki časopis, 37, u tisku.

Gajić-Čapka, M., Zaninović, K. (2002): Thermal effects on buildings – meteorological input data for Croatian standards. 4th European Conference on Applied Climatology, 12–15 Nov. 2002, Brussels, Belgium, Book of abstracts.

Gajić-Čapka, M., Zaninović, K., Androić, B., Džeba, I., Dujmović, D. (2001): Termičko djelovanje na građevine – meteorološka podloga za hrvatske norme, Građevinar, 53, 431–441

Glasnović, D., Ivančan-Picek, B. (1999): MAP SOP – diagnosis and forecast of vertical atmospheric structure by HRID and ALADIN/LACE. *Proceedings of the 7th International ALADIN Workshop, Ljubljana, 17–19 November 1999.*

Glasnović, D., Ivančan-Picek, B. (2001): Another look into the direct NWP model output. *Fifth European Conference on Applications of Meteorology ECAM 2001*, Book of Abstracts, 24–28 September 2001, Budapest, pp. 15.

Herceg Bulić, I. (2000/2001): Eritemally effective UV radiation in Zagreb during May 1999. Croatian Meteorological Journal, **35/36**, 37–44.

Hrabak-Tumpa, G., I. Vuković, Ivatek-Šahdan, S. (1999): Klimatski čimbenici kao podloga projektiranja HE Podsused. Zbornik radova, II Hrvatska konferencija o vodama Hrvatske vode od Jadrana do Dunava, Dubrovnik 19.–22.05.1999., R 4.47., 845–852.

Hrabak-Tumpa, G., Ivatek-Šahdan, S. (1999): Meteorološki čimbenici i dalekovodna mreža Hrvatske. Zbornik radova, IV savjetovanje HK CIGRE, Cavtat, 17–21.10.1999., 22–06, 57–64. (CD ROM)

Hrabak-Tumpa, G., Ivatek-Šahdan, S., Delonga, A. (1999): Meteorološki čimbenici i nadzemna elektroenergetska mreža Hrvatske siječnja 1998. godine. Zbornik radova, IV savjetovanje HK CIGRE, Cavtat, 17–21.10.1999., 22–09, 81–89. (CD ROM)

Hrabak-Tumpa, G., Ivatek-Šahdan, S., Smirčić, A. (2001): Režim vjetra na području TS Meline. Zbornik radova, V savjetovanje HK CIGRE, Cavtat, 04–08.11.2001., 22–10, 89–94. (CD ROM)

Hrabak-Tumpa, G., Ivatek-Šahdan, S., Sijerković, M. (1999): Elektroenergetski sustavi, meteorološki čimbenici i zaštita okoliša. Zbornik radova, II hrvatski znanstveno-stručni skup Zaštita zraka '99, Šibenik-Solaris, 22.–25.09.1999., 425–432.

Ivančan-Picek, B. (2000): Fizika atmosfere – meteorologija na prijelazu stoljeća. *Zbornik, 16. ljetna škola mladih fizičara*, Božava, 18–24.lipnja 2000., *Hrvatsko fizikalno društvo.*

Ivančan-Picek, B., Glasnović, D. (2002): Synoptic and mesoscale environments conductive to heavy precipitation during MAP IOP5. *4th EGS Plinius Conference on Mediterranean Storms,* Book of Abstracts, 2–4 October 2002, Mallorca, pp.27.

Ivančan-Picek, B., Glasnović, D., Tutiš, V. (2000): MAP SOP heavy precipitation event – diagnosis by HRID and ALADIN/LACE. 26th Internationa Conference on Alpine Meteorology, 11–15 September 2000., Innsbruck, *Oesterrechische Beitraege zu Meteorologie und Geophysik*. Heft Nr.23/ Publ.Nr.392. (CD ROM).

Ivančan-Picek, B., Glasnović, D., Tutiš, V. (2000): MAP SOP heavy precipitation event – diagnosis by HRID and ALADIN/LACE. *MAP Meeting*, 24–26 May 2000., Bohinjska Bistrica, Slovenia.

Ivančan-Picek, B., Glasnović, D., Tutiš, V. (2000): MAP SOP heavy precipitation event – diagnosis by HRID and ALADIN/LACE. *MAP newsletter*, no.13, october 2000., 16–18.

Ivančan-Picek, B., Jurčec, V. (2001): Ciklogeneza mezorazmjera nad Jadranom. Jadranska meteorologija, **XLVI**, 11–17.

Ivančan-Picek, B., Jurčec, V. (2002): Adriatic vortex generation predicted by the mesoscale ALADIN/LACE model. Croatian Meteorological Journal, (in print).

Ivančan-Picek, B., Jurčec, V. (2002): Atmospheric mesoscale Adriatic vortex generation. Idojaras, (in print).

Ivančan-Picek, B., Pandžić, K., Trninić, D. (2001): Heavy rain in Croatian mountainous region in September 1993 with an empirical insght, Proceedings of the 3th EGS Plinius Conference held at Baja Sardinia, Italy, October 2001, 297–304.

Ivančan-Picek, B., Tutiš, V. (1999): Mezoskalni alpski program (MAP). *Knjiga sažetaka. Drugi znanstveni sastanak Hrvatskog fizikalnog društva,* Zagreb, 1–3.prosinca 1999.

Ivančan-Picek, B., Tutiš, V. (1999): Mezoskalni alpski program (MAP). *Knjiga sažetaka. Drugi znanstveni sastanak Hrvatskog fizikalnog društva,* Zagreb, 1–3. prosinca 1999.

Ivatek-Šahdan, S., Hrabak-Tumpa, G. (1999): Projektiranje dalekovoda i meteorološki čimbenici. Zbornik radova, IV savjetovanje HK CIGRE, Cavtat, 17–21.10.1999., 22–07, 65–72. (CD ROM)

Ivatek-Šahdan, S., Hrabak-Tumpa, G. (2001): Projektiranje dalekovoda i meteorološki čimbenici. Zbornik radova, V savjetovanje HK CIGRE, Cavtat, 04–08.11.2001., 22–09, 81–88. (CD ROM)

Juras, J. (2000): Comments on »Probabilistic predictions of precipitation using the ECMWF ensemble prediction system«. Weather & Forecasting, 15, 365–366.

Juras, J., Vakula, Z. (2000): Kratkoročne prognoze vremena, Pomorska meteorologija, **XLV**, 29–33.

Lisac, I. (1999): Geomagnetism and aeronomy in Croatia, 1995 – 1998, Geodetski list, **53**.

Lisac, I. (2000): Znanstveni rad akademika Stjepana Škreba, Spomenica preminulim akademicima »Stjepan Škreb 1879.–1952.« / Meštrov, Milan (ur.). Zagreb: Hrvatska akademija znanosti i umjetnosti, 2000. 12–29.

Lisac, I., Zelenko, B., Marki, A., Trošić, Ž. (1998/1999): Wind rose frequency analysis for the jugo wind in the Adriatic, Hrvatski meteorološki časopis. **33/34**,19–37.

Marki, A., Antonić, O. (1999): Annual models of monthly mean hourly direct, diffuse and global solar radiation at ground, Meteorologische Zeitschrift, **8**, 91–95.

Mokorić M., Glasnović, D. (1999): Local weather forecast in forest fire protection, Proceedings of International Symposium Forest Fires: Needs & Innovations, 18–19 November1999, Athens, Greece, 370–375.

Mokorić, M., Vakula Z. (1999): The evaluation of ALADIN/LACE minimum and maximum temperature in regard to weather types, Abstracts of 4th ECAM 99, Norrkoping, Sweden, 13–17 November 1999, Norrköping, Sweden, CD-ROM, P027.

Orlić, M. (2000): Izložba dokumentacije, radova i fotografija akademika Stjepana Škreba, Spomenica preminulim akademicima »Stjepan Škreb 1879.–1952.« / Meštrov, Milan (ur.). Zagreb: Hrvatska akademija znanosti i umjetnosti, 2000. 10–11.

Pandžić, K. (2002): *Analiza meteoroloških polja i sustava*, HINUS, Zagreb,314 pp.

Pandžić, K., Trninić, D. (1999.): Primjena prognostičkih produkata modela ALADIN na slivu rijeke Kupe. Zbornik radova: 2. Hrvatska konferencija o vodama, Dubrovnik, 585–588.

Pandžić, K., Trninić, D. (1999/2000): Relationship between monthly precipitation, the Sava river discharge and large-scale circulation, Geofizika, **16/17**, 53–63.

Pandžić, K.,Vuković, I. (1999): Vertikalni gradijenti evapotranspiracije na području Like i Gorskog kotara, Hrvatske Vode, **28**, 203–216.

Peljto, A., Bencetić Klaić, Z., (1999/2000): Accidental release of hydrogen sulfide in Nagylengel, Hungary on November 14, 1998 – A trajectory study, Geofizika, **16/17**, 43–51.

Penzar, I., Penzar, B. (2000): *Agrometeorologija,* Školska knjiga, Zagreb, 222 pp

Penzar, I., Poje, D., (1999/2000): Review of meteorological research in Croatia – survey of situation up to 1997, Geofizika., **16/17**, 1–32.

Penzar, B., Penzar, I., Orlić, M. (2001): *Vrijeme i klima hrvatskog Jadrana.* Feletar, Hrvatski hidrografski institut, Zagreb-Koprivnica-Split, 258 pp.

Perčec Tadić, M., Gajić-Čapka, M., Patarčić, M. (2002): Geostatistical methods in producing mean annual precipitation map for Croatia. 4th European Conference on Applied Climatology, 12–15 Nov. 2002, Brussels, Belgium, Book of abstracts.

Perić, M., Bace, M., Žibrat, Z. (2002): The Empirical-Stochastical Model of Irradiance for the Simulation of the Solar Systems, EuroSun 2002, The Fourth ISES-Europe Solar Congress, Bologna, 23–26. 06. 2002.

Sijerković, M., Ivatek-Šahdan, S., Hrabak-Tumpa, G., Šojat, V. (1999): Onečišćenje zraka i magla u Zagrebu. Zbornik radova, II hrvatski znanstveno-stručni skup Zaštita zraka '99, Šibenik-Solaris, 22.–25.09.1999., 323–329.

Sijerković, M., Žibrat, Z., Glasnović, D., Dvornik, A. (1999): Vjetar na Masleničkom mostu, Drugi hrvatski kongres o cestama 1999, Cavtat, 24–27.10.1999.

Srnec, L. (2001): *Modelling climate changes for Croatia*. In: Brunet, M. and López, D. (Editors), Detecting and modelling Regional Climate Change, Springer-Verlag, Germany, 501–514.

Srnec, L. (2001): *Scenariji klimatskih promjena*, Prvo nacionalno izvješće Republike Hrvatske prema Okvirnoj konvenciji Ujedinjenih naroda o promjeni klime (UNFCCC), Ministarstvo zaštite okoliša i prostornog uređenja, Zagreb, 167–175.

Šojat, V., Borovečki, D., Đuričić, V. (1999): Atmosferski unos anorganskog dušika u hrvatsko priobalje, II hrvatska konferencija o vodama, Dubrovnik, Hrvatska, 19.–22. svibnja 1999.

Telišman Prtenjak M., Zitouni, M., Srnec, L. (2002): A modelling study of the universal stability functions in simple numerical model simulations over idealised urban surface, Croatian Meteorological Journal, (in press).

Telišman Prtenjak, M., Grisogono, B. (2002): Idealised numerical simulations of diurnal sea breeze characteristics over a step change in roughness, Meteorologische Zeitschrift, **11**, 501–516.

Trninić, D. (2000): Drugi svjetski forum o vodama: Voda u rijekama, Hrvatske vode, **32**, 253–258.

Trninić, D. (2000): Hidrološki podaci o površinskim vodama u funkciji izrade vodnogospodarske osnove. Zbornik radova: Sabor hrvatskih graditelja 2000 – graditelji u razvoju RH, Cavtat, 861–868.

Trninić, D. (2002): Climate Change Assessment and Hydrological Draught in Croatia. Abstracts – International Conference on drought mitigation and prevention of land desertification, Bled.

Trninić, D. (2002): Obilježja nanosa nekih bujica sliva Drave i predviđene klimatske promjene. Hrvatske vode, **38**, 33–40.

Trninić, D. (2002): Obnova mreže hidroloških stanica na području Plitvičkih jezera. Zbornik radova: Ekoinženjerstvo 2002., Plitvička jezera.

Trninić, D., Bošnjak, T. (2000.): Prilog hidrološkoj analizi malih voda na rijeci Savi u RH. Zbornik radova: Okrugli stol – Hidrologija i vodni resursi Save u novim uvjetima, Slavonski Brod, 169–177.

Trninić, D., Cerar, K., Tropan, Lj., Benić, N., Milković, J. (2000.): Education of Hydrology Personnel – Needs and Possibilities. Conference Abstracts XX Conference of the Danubian Countries on Hydrological Forecasting and Hydrological Bases of Water Management, Bratislava, 156–161.

Tutiš, V., Ivančan-Picek, B., Glasnović, D. (2000): MAP SOP severe Adriatic bora event. 26th Internationa Conference on Alpine Meteorology, 11–15 September 2000., Innsbruck, *Oesterrechische Beitraege zu Meteorologie und Geophysik*. Heft Nr.23/ Publ.Nr.392. (CD ROM).

Volarić, B. (2000): Značenje Stjepana Škreba za razvoj geofizike u Hrvatskoj, Spomenica preminulim akademicima »Stjepan Škreb 1879.–1952.« / Meštrov, Milan (ur.). Zagreb : Hrvatska akademija znanosti i umjetnosti, 30–43.

Volarić, B., Lisac, I. (2000): Popis radova akademika Stjepana Škreba, Spomenica preminulim akademicima »Stjepan Škreb 1879.–1952.« / Meštrov, Milan (ur.). Zagreb: Hrvatska akademija znanosti i umjetnosti, 55–61.

Vučetić M., Vučetić, V. (1999): Požari u različitim vremenskim situacijama, Vatrogasni vjesnik, Glasilo za zaštitu od požara i vatrogastvo, **12/99,** 12–14.

Vučetić M., Vučetić, V. (1999): Different types of the forest fires on the Croatian coast, Symposium Forest Fires: Needs and Innovations, DELFI99, Atena-Grčka, 17–20. studenog 1999. 365–369.

Vučetić M., Vučetić, V. (1999): Vodni režim područja spaljenog šumskim požarom, Zbornik radova 2. hrvatske konferencije o vodama, Dubrovnik, 19–22. svibnja 1999, 117–122.

Vučetić M., Vučetić, V. (2002): *Vrijeme na Jadranu – Meteorologija za nautičare*, Fabra d.o.o., Zagreb, 129 pp.

Vučetić V. (1999): Wind variability and wind energy potential estiamation in Croatia, Zbornik radova European Wind Energy Conference, Nica – Francuska, 1–5. ožujka 1999.1132–1135.

Vučetić V. i M. Vučetić, 1999: Varijacije vodne ravnoteže u morskim parkovima, Zbornik radova 2. hrvatske konferencije o vodama, Dubrovnik, 19–22. svibnja 1999, 111–116.

Vučetić V.,Vučetić, M. (2000): The role of climatic variations on the establishment of the Adriatic marine parks, Periodicum Biologorum, **102**, 489–498.

Vuković, I., Hrabak-Tumpa, G., Ivatek-Šahdan, S. (1999): Oborinske prilike i proizvodnja električne energije u hidroelektranama Dalmacije. Zbornik radova, II Hrvatska konferencija o vodama Hrvatske vode od Jadrana do Dunava, Dubrovnik 19.–22.05.1999., 859–864.

Vuković, I., Ivatek-Šahdan, S. (1999): Meteorološke podloge projektiranja dalekovoda 2x400 kV Žerjavinec-Mađarska. Zbornik radova, IV savjetovanje HK CIGRE, Cavtat, 17–21.10.1999., 22–08, 73–79. (CD ROM).

Zaninović, K., Gajić-Čapka, M., Srnec L. (2001): *Prvo nacionalno izvješće o promjeni klime – klima i zdravlje*, Klimatske promjene i njihov utjecaj na zdravlje, Hrvatski lječnički zbor, Hrvatsko društvo za zdravstvenu ekologiju, Zagreb.

Zaninović, K. (2000): Climatic change in extreme temperature events in Croatia, Meteorology at the Millennium, 10–14. July 2000, Cambridge, Book of Abstracts, 190.

Zaninović, K. (2000): Climatological Basis for Snow Load Standards, Proceeding of the 3rd European Conference on Applied Climatology, 16–20 Oct. 2000, Pisa, CD-ROM, Abs. Pos.-5., Book of Abstracts, 266.

Zaninović, K. (2000): Klimatske i bioklimatske prilike Skrada, Paediatria Croatica, Vol. 44, 37–39.

Zaninović, K., Patarčić, M. (2002): The snowfall climate zones in Croatia. 4th European Conference on Applied Climatology, 12–15 Nov. 2002, Brussels, Belgium, Book of abstracts.

Zaninović, K. (1999): The influence of weather on asthmatic attacks in children, in R.J de Dear, J. D. Kalma, T. R: Oke and A. Auliciems: Biometeorology and Urban Climatology at the Turn of the Millennium: Selected Papers from the Conference ICB-ICUC'99, Sydney, 8–12. November 1999, WCASP-50, WMO/TD No. 1026, 123–126

Zaninović, K. (1999): Utjecaj vremena na astme, Zbornik radova s II hrvatskog znanstveno-stručnog skupa »Zaštita zraka 99«, Šibenik, 22–25. rujna 1999, 393–400.

Zaninović, K., Gajić-Čapka, M. (1998/1999): Climatological basis for prediction of temperature regime on ground, Hrvatski meteorološki časopis, **33/34**, 71–78.

Zaninović, K., Gajić-Čapka, M. (2000): Changes in Components of the Water Balance in the Croatian Lowlands. Theoretical and Applied Climatology, **65**,1–2, 111–117.

Zaninović, K., Gajić-Čapka, M., Androić, B. (2001): Snow load standards in Croatia – climatological background, 5th European Conference on Applications of Meteorology, 24–28 September 2001, Budapest, Extended abstract, CD-ROM, Book of Abstracts, 202.

Zaninović, K., Gajić-Čapka, M., Androić, B., Džeba, I., Dujmović, D. (2001): Određivanje karakterističnog opterećenja snijegom, Građevinar, **53**, 363–378.

Zaninović, K., Gajić-Čapka, M., Žibrat, Z., Šimetin, V. (2001): Meteorološki parametri u projektiranju energetski efikasne toplinske zaštite zgrada, Građevinar, 53, 619–629.

Zaninović, K., Patarčić, M. (2002): The snowfall climate zones in Croatia, 4th European Conference on Applied Climatology, 12–15 Nov. 2002, Brussels, Belgium, Book of abstracts.

Zaninović, K., Raos, M. (2002): Utjecaj meteoroloških parametara na astmatične napadaje u djece, Hrvatski meteorološki časopis, **37**, (in press).

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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List of publications

Barić A., V. Dadić and B. Grbec (2000): Marine research undertaken for the design of submarine outfall of the Split-Solin seawerage system, International Conference MWWD 2000 – Marine Waste Water Discharges, Bologna, 343–358.

Beg Paklar G. (2000): Bora wind forcing of the northern Adriatic – simulations with the meteorological and oceanographic models (in Croatian), Ph. D. Thesis, Faculty of Science, University of Zagreb, 210 pp.

* M. Orlić (1994): Physical oceanography in Croatia, 1991–1994, *Geofizika*, **11**, XXXIX–XLIV; M. Orlić (1999): Physical oceanography in Croatia, 1995–1998, *Geodetski list*, **53**, XXIII–XXXI.

Beg Paklar G., V. Isakov, D. Koračin, V. Kourafalou and M. Orlić (1999): Observation and modelling of the Po River inflow to the northern Adriatic (The case of 16–20 January 1987), Oceanography of the Eastern Mediterranean and Black Sea, International Conference, Athens, 183.

Beg Paklar G., V. Isakov, D. Koračin, V. Kourafalou and M. Orlić (2001a): A case study of bora-driven flow and density changes on the Adriatic shelf (January 1987), Continental Shelf Research, **21**, 1751–1783.

Beg Paklar G., M. Morović and M. Bone (2001b): The role of optical properties for the dynamics at the open sea station Stončica, Rapports et proces-verbaux des reunions CIESMM, **36**, 52.

Beg Paklar G., M. Zore-Armanda and V. Dadić (2002): Currents in the Kaštela Bay: empirical analysis and results of numerical model, Acta Adriatica, **43 (1)**, 33–64.

Bobanović J., I. Janeković and M. Kuzmić (2000): The Adriatic Sea tidal open boundary conditions via data assimilation: exploring the altimetry contribution, In: V. Barale, J. F. R. Gower, and L. Alberotanza (Eds), Oceans from Space »Venice 2000« Abstracts, European Commission, Venice, 131.

Bojanić F., N. Leder, A. Smirčić and I. Vilibić (1999): Oceanographic and hydrographic investigations for the projecting of submarine sewage outfalls (in Croatian), Proceedings of 2nd Croatian Water Conference, Dubrovnik, 335–341.

Bone M. and B. Grbec (2001): A simple solar radiation model applicable in numerical hydrodinamical modeling on seasonal time-scale, Acta Adriatica, **42(1),**15–22.

Bone M., B. Grbec, G. Beg Paklar and M. Morović (1999): Modelling of heat exchange and fresh water inflow in the Kaštela Bay (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 351–354.

Burić. Z., D. Viličić, M. Orlić, A. Smirčić, F. Kršinić, Z. Gržetić and K. Caput (1999): Thermohaline properties and distribution of phytoplankton in the Zrmanja Estuary (October 1998), Proceedings of 2nd Croatian Water Conference, Dubrovnik, 277–282.

Dadić V. (2000): Vertical interpolation of oceanographic data on standard levels, 42nd ELMAR International Syposium, Zadar, 349–353.

Dadić V. (2001): An application of kriging method in objective analysis of randomly distributed oceanographic data, 43rd ELMAR International Symposium, Zadar, 98–102.

Dadić V. and D. Ivanković (1999): Automatic meteo-oceanographic measurements and data transmission in real time to Internet, 41st ELMAR International Syposium, Zadar, 114–118.

Dadić V., B. Grbec, D. Ivanković, F. Matić and M. Morović (2001a): Some results from the automatic met-ocean station Split Marjan-cape, Rapports et proces-verbaux des reunions CIESMM, **36**, 57.

Dadić V., M. Srdelić and Z. Gržetić (2001b): Analysis of oceanographic properties of the Adriatic Sea by GIS technique, 20th International Cartographic Conference, Beijing, 575–584.

Dulčić J. and B. Grbec (2000): Climatic change and Adriatic ichthyofauna, Fisheries Oceanography, **9(2)**, 187–191.

Dulčić J., B. Grbec and L. Lipej (1999): Information on the Adriatic ichthyofauna – effect of water warming? Acta Adriatica, **40(2)**, 33–43.

Gačić M., P.-M. Poulain, M. Zore-Armanda and V. Barale (2001): Overview, In: B. Cushman-Roisin et al. (Eds), Physical Oceanography of the Adriatic Sea, Kluwer, Dordrecht, 1–44.

Grbec B., V. Dadić, D. Ivanković, M. Morović and F. Matić (2001): The first year of the Automatic Metocean Station Split Marjan Cape – preliminary results, Acta Adriatica, **42(1)**, 23–34.

Grbec B., J. Dulčić and M. Morović (2002): Long-term changes in landings of small pelagic fish in the eastern Adriatic – possible influence of climate oscillations over the Northern Hemisphere, Climate Research, **20**, 241–252.

Herak M., M. Orlić and M. Kunovec-Varga (2001): Did the Makarska earthquake of 1962 generate a tsunami in the central Adriatic archipelago? Journal of Geodynamics, **31**, 71–86.

Ivanković D., V. Dadić and M. Srdelić (2000): Marine environmental database of the Adriatic Sea with application for managing and visualisation of data. ENVIROSOFT International Conference: Computer Techniques to Environmental Studies VIII, Bilbao, 398–406.

Janeković I. (2001): The tides of the Adriatic Sea – numerical model and empirical analysis (in Croatian), M. Sc. Thesis, Faculty of Science, University of Zagreb, 153 pp.

Krajcar V. (2001): Empirical analysis of annual current variability in the northern Adriatic (in Croatian), Ph. D. Thesis, Faculty of Science, University of Zagreb, 235 pp.

Leder N. (2002): Wind-induced internal wave dynamics near the Adriatic shelf break, Continental Shelf Research, **22**, 445–463.

Leder N., A. Smirčić and I. Vilibić (1999a): Extreme values of surface wave heights in the northern Adriatic, Geofizika, **15**, 1–13.

Leder N., Z. Gržetić, A. Smirčić and I. Vilibić (1999b): Some results of oceanographic measurements in the eastern part of the Kaštela Bay (Vranjic area) (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 359–366.

Leder N., A. Smirčić and I. Vilibić (2000): The role of physical oceanography research in the process of marine environmental assessment – example of Cavtat, Periodicum Biologorum, **102**, Supplement 1, 107–114.

Morović M., B. Grbec and M. Bone (1999): The analysis of the influence of global radiation and optical sea properties on dynamics of the Kaštela Bay (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 346–350.

Morović M., M. Bone, B. Grbec and G. Beg Paklar (2001): The role of optical properties for the Kaštela Bay dynamics, Rapports et proces-verbaux des reunions CIESMM, **36**, 75.

Orlić M. (2001a): Anatomy of sea level variability – an example from the Adriatic, In: F. El-Hawary (Ed.), The Ocean Engineering Handbook, CRC Press, Boca Raton (USA), 1.1–1.14.

Orlić M. (2001b): Croatian coastal waters, In: B. Cushman-Roisin et al. (Eds), Physical Oceanography of the Adriatic Sea, Kluwer, Dordrecht, 189–214.

Orlić M. (2002): Four centuries of physical oceanography in Croatia, In: K. R. Benson and P. F. Rehbock (Eds), Oceanographic History – The Pacific and Beyond, University of Washington Press, Seattle, 280–286.

Orlić M. and M. Pasarić (2000): Sea-level changes and crustal movements recorded along the east Adriatic coast, Il Nuovo Cimento C, **23**, 351–364.

Orlić M., M. Kuzmić and Z. Pasarić (1999): Modelling wind-driven currents in the Kaštela Bay (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 367–372.

Orlić M., N. Leder, M. Pasarić and A. Smirčić (2000): Physical properties and currents recorded during September and October 1998 in the Velebit Channel (East Adriatic), Periodicum Biologorum, **102**, Supplement 1, 31–37.

Pasarić M. (2000): Variations of sea level in the Adriatic caused by slowly changing air pressure and wind (in Croatian), Ph. D. Thesis, Faculty of Science, University of Zagreb, 113 pp.

Pasarić M. and M. Orlić (2001a): Long-term meteorological preconditioning of the North Adriatic coastal floods, Continental Shelf Research, **21**, 263–278.

Pasarić M. and M. Orlić (2001b): Effects of mean sea-level rise on the flooding of the North Adriatic coast, In: I. Vilibić, H.-P. Plag and M. Orlić (Eds), Book of Abstracts of the Final Workshop of COST Action 40, Croatian Hydrographic Institute, Dubrovnik, 80–82.

Pasarić M., Z. Pasarić and M. Orlić (2000): Response of the Adriatic sea level to the air pressure and wind forcing at low frequencies (0.01–0.1 cpd), Journal of Geophysical Research, **105**, 11423–11439.

Penzar B., I. Penzar and M. Orlić (2001): Weather and Climate of the Croatian Adriatic (in Croatian), Feletar, Croatian Hydrographic Institute, Zagreb-Koprivnica-Split, 258 pp.

Požar-Domac A., D. Zavodnik, A. Jaklin, E. Zahtila, A. Smirčić, A. Pallaoro, N. Leder, G. Sinovčić, M. Radošević, G. Olujić, P. Kružić, N. Zavodnik, A. Žuljević, T. Bakran-Petricioli, M. Juračić and B. Antolić (2000): Project »Biodiversity preservation in the Adriatic Sea« – Specially protected area »Palagruža«, Periodicum Biologorum, **102**, Supplement 2, 49–57.

Pršić M., A. Smirčić and N. Leder (1999): Adriatic high sea state characteristiscs, Proceedings of the International MEDCOAST Conference on Wind and Wave Climate of Mediterranean and Black Sea, Antalya, 277–293.

Raicich F., M. Orlić, I. Vilibić and V. Malačič (1999): A case study of the Adriatic seiches (December 1997), Il Nuovo Cimento C, **22**, 715–726.

Smirčić A. and N. Leder (1999): Surface wave characteristics generated by bora wind in the Kaštela Bay (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 355–358.

Smirčić A., I. Vilibić and N. Leder (2000): The characteristics of surface waves in the Adriatic Sea (in Croatian), In: Z. Kulenović et al. (Eds), Proceedings of the High Maritime School in Split, High Maritime School, Split, 37–46.

Smirčić A., N. Leder and I. Vilibić (2001): An analysis of diffusion characteristics in the harbour area (Split harbour, Adriatic Sea), Rapports et proces-verbaux des reunions CIESMM, **36**, 81.

Supić N. (2000): Interannual variability of surface fluxes and geostrophic flow in the northern Adriatic (in Croatian), Ph. D. Thesis, Faculty of Science, University of Zagreb, 171 pp.

Supić N. and I. Ivančić (2002): Hydrographic conditions in the northern Adriatic in the relation to surface fluxes and the Po River discharge rates (1966–1992), Periodicum Biologorum, **104**, 203–209.

Supić N. and M. Orlić (1999): Seasonal and interannual variability of the northern Adriatic surface fluxes, Journal of Marine Systems, **20**, 205–229.

Supić N., M. Orlić and D. Degobbis (2000): Istrian Coastal Countercurrent and its year-to-year variability, Estuarine, Coastal and Shelf Science, **51**, 385–397.

Supić N., M. Orlić and D. Degobbis (2001): Istrian Coastal Countercurrent in the year 2000, Rapports et proces-verbaux des reunions CIESMM, **36**, 82.

Vilibić I. (2000): A climatological study of the uninodal seiche in the Adriatic Sea, Acta Adriatica, **41 (2)**, 89–102.

Vilibić I. (2001): Adriatic extreme sea levels: the role of the seiches, In: I. Vilibić, H.-P. Plag and M. Orlić (Eds), Book of Abstracts of the Final Workshop of COST Action 40, Croatian Hydrographic Institute, Dubrovnik, 83–86.

Vilibić I. (2002a): Long term changes in Adriatic thermohaline properties, CIESMM Workshop Series 16 »Tracking Long-term Hydrological Change in the Mediterranean Sea«, Monaco, 57–59.

Vilibić I. (2002b): An analysis of dense water production on the North Adriatic shelf, Estuarine, Coastal and Shelf Science, **55**, in press.

Vilibić I. (2002c): Objective analysis of the Adriatic water masses (in Croatian), Ph. D. Thesis, Faculty of Science, University of Zagreb, 148 pp.

Vilibić I. and H. Mihanović (2001): High-frequency sea level oscillations observed and modelled in the Split harbour (Adriatic Sea), Rapports et proces-verbaux des reunions CIESMM, **36**, 88.

Vilibić I. and H. Mihanović (2002): A study of seiches in the Split harbor (Adriatic Sea), Acta Adriatica, **43 (2)**, 59–68.

Vilibić I. and M. Orlić (1999): Surface seiches and internal Kelvin waves observed off Zadar (east Adriatic), Estuarine, Coastal and Shelf Science, **48**, 125–136.

Vilibić I. and M. Orlić (2001a): Least-squares tracer analysis of water masses in the South Adriatic (1967–1990), Deep-Sea Research I, **48**, 2297–2330.

Vilibić I. and M. Orlić (2001b): An estimation of water mass fractions in the Middle and South Adriatic, Rapports et proces-verbaux des reunions CIESMM, **36**, 87.

Vilibić I. and M. Orlić (2002): Adriatic water masses, their rates of formation and transport through the Otranto Strait, Deep-Sea Research I, **49**, 1321–1340.

Vilibić I., N. Leder and A. Smirčić (1999a): Long-term sea level oscillations in the Kaštela Bay (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 373–377.

Vilibić I., N. Leder and A. Smirčić (1999b): Extreme variations of the Adriatic sea level (in Croatian), Proceedings of 2nd Croatian Water Conference, Dubrovnik, 319–324.

Vilibić I., A. Smirčić, N. Leder and Z. Gržetić (1999c): Sewage outfalls in the channel area: the Zadar and Pašman Channels (east Adriatic), In: P. Anagnostopoulos and C. A. Brebbia (Eds), Water Pollution V: Modelling, Measuring and Prediction, WIT Press, Southampton, 85–94.

Vilibić I., N. Leder and A. Smirčić (2000): Storm surges in the Adriatic Sea: an impact on the coastal infrastructure, Periodicum Biologorum, **102**, Supplement 1, 483–488.

Vilibić I., N. Leder, H. Mihanović, A. Smirčić and Z. Gržetić (2001): MedGLOSS pressure gauge in the Split harbour: installation and preliminary analysis of the data, Rapports et proces-verbaux des reunions CIESMM, **36**, 97.

Viličić D., M. Orlić, Z. Burić, M. Carić, N. Jasprica, F. Kršinić, A. Smirčić and Z. Gržetić (1999): Patchy distribution of phytoplankton in a highly stratified estuary (the Zrmanja Estuary, October 1998), Acta Botanica Croatica, **58**, 105–125.

Zore–Armanda M., V. Dadić, G. Beg Paklar and N. Leder (1999a): Analysis of current measurement results in the Kaštela Bay (in Croatian), Proceedings »Kaštela – the cradle of Croatia«, Kaštela, 338–345.

Zore-Armanda M., B. Grbec and M. Morović (1999b): Oceanographic properties of the Adriatic Sea – a point of view, Acta Adriatica, **40**, 39–54.

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Seismology in Croatia, 1999–2002

Report submitted to the International Association of Seismology and Physics of the Earth's Interior of the International Union of Geodesy 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 (*Imax*) 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 Gottingen 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.

List of publications

Allegretti, I., Herak D., Herak M., S.J. Duda (2000): Consistency of magnitudes of the largest historical earthquakes of the first half of 20th century determined on the basis of Gottingen and Zagreb Wiechert seismograms. Studia Geophysica et Geodaetica **44**, 13–25.

Allegretti, I., M. Herak (2000): Influence of uncertainties of input parameters on earthquake hazard for the city of Zagreb estimated by Monte-Carlo simulations, European Seismological Commission (ESC), XXVII General Assembly, Lisbon, Portugal, 10–15 September 2000, Book of Abstracts and Papers, 95.

Allegretti, I., M. Herak (2002): Seismic hazard in Dalmatia (Croatia) estimated by Monte-Carlo simulations, European Seismological Commission (ESC), XXVIII General Assembly, Genoa, 1–6 September 2002, Italy, 124.

Herak D., M. Herak (1999a): Application of the CN earthquake prediction algorithm to Croatian and neighbouring territories, 24th General Assembly of the European Geophysical Society, Nice, France, April, 1999, Geophysical Research Abstracts, **1**, 108.

Herak D., Herak M., Panza G.F., G. Costa (1999b): Application of the CN intermediate term earthquake prediction algorithm to the area of the Southern External Dinarides. PAGEOPH, **156**, 689–699.

Herak D., M. Herak (2000): Seizmičnost Stonskog područja. Dubrovnik, **XI**, 192–198

Herak, D., M. Herak (2001): Lapse-time and frequency dependence of coda-Q in the Adriatic region, EGS XXVI General Assembly, Nice, France, 25–30 March 2001, Geophysical Research Abstracts.

Herak, M. (1999): Principal contributor for Croatia in Giardini D., Grunthal G., Shedlock K., P. Zhang. (Eds.): Global seismic hazard map (GSHAP Project). Attachment to Annali di Geofisica, 42.

Herak, M., M. Orlić, M. Kunovec-Varga (1999): Tsunami excitation and propagation in the Central Adriatic archipelago – the case of Makarska earthquake (1962), 24th EGS General Assembly, The Hague, Netherlands, 19–23 April, 1999.

Herak M., Herak D., Markušić S., I. Ivančić (2001): Numerical modeling of the Ston-Slano (Croatia) aftershock sequence. Studia Geophysica et Geodaetica, **45**, 251–266.

Herak M., D. Herak, S. Markušić, I. Ivančić (2000): Numerical modeling of aftershock activity in Southern External Dinarides, XXVII General Assembly of the European Seismological Commission (ESC), Lisbon, Portugal, 10–15 September 2000, Book of Abstracts and Papers, 59–60.

Herak, M., Markušić, S., I. Ivančić (2001): Attenuation of peak horizontal and vertical acceleration in the Dinarides area, Studia Geophysica et Geodaetica, **45**, 383–394.

Herak, M., G. F. Panza, G. Costa (2001): Theoretical and observed depth correction for MS, PAGEOPH, **158**, 1517–1530.

Herak, M., Orlić, M., Kunovec-Varga, M. (2001): Did the Makarska earthquake of 1962 generate a tsunami in the central Adriatic archipelago?, Journal of Geodynamics, **31**, 71–86.

Herak M., M. Živčić, D. Herak (2002): Pg-wave velocity anisotropy in the hypocentral volume of the Krn Mt. (Slovenia) earthquake sequence. 10. International Workshop on Seismic Anisotropy, Tutzing, April 14–19, 2002, 33.

Herak M., M. Živčić, D. Herak (2002): Pg-wave velocity anisotropy in the hypocentral volume of the Krn Mt. (Slovenia) earthquake sequence. European Seismological Commission (ESC), XXVIII General Assembly, Genoa, 1–6 September 2002, Italy, 109.

Herak M., Skoko D., D. Herak (2002): Seismology in Croatia. IASPEI International Handbook of Earthquake and Engineering Seismology (Eds.: P. Jenning, H. Kanamori, W. Lee), Part X, (National Centennial Report) (in press).

Ivančić, I., I. Allegretti (1999): Newsletter CSEM, **14**, 2.

Ivančić, I., Herak, D., Markušić, S., Sović, I., M. Herak (2002): Seismicity of Croatia in the period 1997–2001, Geofizika **18/19**, 17–29.

Jurak, V., Kvasnička, P. Dujmić, D. Kuk, V. (1999): Zbornik radova znanstvenog skupa »Andrija Mohorovičić – 140. obljetnica rođenja«, Bajić, A. (ed.). Zagreb: DHMZ, 1999. 125–139.

Lokmer, I., M. Herak (1999): Anisotropy of P-wave velocity in the upper crust of the central External Dinarides, Studia Geophysica et Geodaetica, **43**, 345–356.

Lokmer, I., M. Herak, G. F. Panza, F. Vaccari (2002): Amplification of strong-ground motion in the city of Zagreb, Croatia, estimated by computation of synthetic seismograms, Soil Dynamics and Earthquake Engineering, **22**, 105–113.

Markušić S., M. Herak (1999): Seismic zoning of Croatia, Natural Hazards, **18**, 269–285.

Markušić, S., Suhadolc, P., Herak, M., Vaccari, F. (2000): A contribution to seismic hazard assessment in Croatia from deterministic modeling. PAGEOPH, **157**, 1/2, 185–204.

Markušić S., Herak M., Herak D., I. Ivančić (2002): Peak horizontal-to-vertical acceleration ratio and local amplification of strong ground motion. Studia Geophysica et Geodaetica, **46**, 83–92.

Pamić, J., D. Balen., M. Herak (2002): Origin and geodynamic evolution of Late Paleogene magmatic associations along the Periadriatic-Sava-Vardar magmatic belt, Geodynamica acta, **15**, 209–231.

Panza, G. F., Alvarez, L., Aoudia, A., Ayadi, A., Benhallou, H., Benouar, D., Bus, Z., Chen,Y-T., Cioflan, C., Ding, Z., El-Sayed, A., Garcia, J., Garofalo, B., Gorshkov, A., Gribovszki, K., Harbi, A., Hatzidimitriou, P., Herak, M., Kouteva, M., Kuznetzov, I., Lokmer, I., Maouche, S., Marmureanu, G., Matova, M., Natale, M., Nunziata, C., Parvez, I., Paskaleva, I., Pico, R., Radulian, M., Romanelli, F., Soloviev, A., Suhadolc, P., Szeidovitz, G., Triantafyllidis, P.and F. Vaccari: (2002): Episodes, **25**, No. 3, 160–180.

Prelogović E., D. Skoko, M. Herak (1999): Contributions to cognition of relation between recent tectonic movements and seismic activity of Dinarides in Croatia. EUG 10, Journal of Conference, Abstracts, **4/1** (ISSN 1362–0886), EUG, 450.

Prelogović, E., Kuk, V., Buljan, R., Tomljenović, B., Skoko, D. (1999): Proceeding of the 2nd Int. Simp. Geodynamics of the Alps-Adria Area by Means of Terrestrial and Satellite Methods, Čolić, K., Moritz, H. (eds.), 255–262.

Prelogović, E., Kuk, V. (1999): , Zbornik radova znanstvenog skupa »Andrija Mohorovičić« (Bajić, A., ed.), Zagreb, 115–124.

Skoko D., Herak M. (2002): Andrija Mohorovičić (1857–1936). IASPEI International Handbook of Earthquake and Engineering Seismology (Eds.: P. Jenning, H. Kanamori, W. Lee), Part XI, chpt. 89 (in press).

Slejko D., Camassi I., Cecić I., Herak D., Herak M., Kociu S., Kouskouna V., Lapajne J., Makropoulos C., Meletti C., Muco B., Papaioannou C., Peruzza L., Rebez A., Scandone P. Sulstarova E., Voulgaris N., Živčić M., P. Zupančič (1999): Seismic hazard assesment for Adria. Annali di Geofisica, **42**, 1085–1107.

Tomljenović B., Csontos L., Herak M., D. Herak (2001): Neogene-quaternary structures and recent seismicity in NW Croatia (Hrvatsko Zagorje and Karlovac Basins). The Stephan Mueller Topical Conference of the European Geophysical Society. Quantitative neotectonics and seismic hazard assesment: New integrated approaches for environmental management. Balatonfured, September 22–26, 2001, Hungary, 63.

Van der Lee, S.,, F. Marone, M. van der Meijde, D. Giardini, C. Chiarabba, M. Herak, R. Ortiz, A. Ugalde Aguirre, A.S. Suleiman, G. Chouliaras, J.M. Davila (1999a): New broadband stations for imaging crust and upper mantle structure of the Mediterranean region. XXV General Assembly EGS, Nice, France, 25–29 April 1999.

Van der Lee, F. Marone, M. van der Meijde, D. Giardini, C. Chiarabba, M. Herak, R. Ortiz, A. Ugalde Aguirre, A.S. Suleiman, G. Chouliaras, J.M. Davila (1999b): New broadband stations for imaging crust and upper mantle structure of the Mediterranean region. American Geophysical Union Spring Meeting, May 30–June 3, Washington D.C.

Van der Lee, S., F. Marone, M. van der Meijde, D. Giardini, A. Deschamps, C. Chiarabba, M. Herak, R. Ortiz, A.U. Aguirre, G. Chouliaras, A.S. Suleiman, J.M. Davila (2000): MIDSEA: New plate-boundary broadband stations from Greece to the Azores, XXVII General Assembly of the European Seismological Commission (ESC), Lisbon, Portugal, 10–15 September 2000, Book of Abstracts and Papers, 30.

Van der Lee, S., F. Marone, M. van der Meijde, D. Giardini, A. Deschamps, C. Chiarabba, M. Herak, R. Ortiz, Ugalde, A., Chouliaras, G., Suleiman, A.S., Eshwehdi, A., Davila, M., Yelles, K. (2001a): MIDSEA: New broadband stations for imaging crust and upper mantle structure of the Mediterranean region, EGS XXVI General Assembly, Nice, France, 25–30 March 2001, Geophysical Research Abstracts.

Van der Lee, S., F. Marone, M. van der Meijde, D. Giardini, A. Deschamps, L. Margheriti, P. Burkett, S. C. Solomon, P. M. Alves, M. Chouliaras, A. Eshwedi, A.S. Suleiman, H. Gashut, M. Herak, R. Ortiz, J.M. Davila, A. Aguirre, J. Vila, K. Yelles (2001b): Eurasia-Africa Plate Boundary Region Yields New Seismographic Data. EOS Trans. AGU, **82**, 637–646.

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