Geomagnetism and aeronomy in Croatia, 2015–2018

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

Giuliana Verbanac

Department of Geophysics, Faculty of Science, University of Zagreb, Zagreb, Croatia

This report aims to provide an overview of the research, professional and education activities in the field of geomagnetism and aeronomy that have been carried out at the Department of Geophysics, Faculty of Science, University of Zagreb and some other institutions during the time span 2015–2018. The report is organized as follows. First, the research activity is outlined. Second, the professional work is described. The educational engagement follows. Finally the public outreach is reported.

The performed research studies in this period are very interdisciplinary embracing different parts of the geomagnetic field, aeronomy, changes on the Sun, in the interplanetary space and related responses of the Earth's magnetosphere and ionosphere. Accordingly, the research topics are also related to space weather and therefore are of broad interests and applications. Ground based data and data from satellites with orbits both within the magnetosphere and in the interplanetary space are generally employed in the analyses.

The temporal changes in the monthly magnetic observatory biases at 42 stations within the 2000–2009 interval are analysed by employing the model entirely based on geomagnetic observatory data and data provided by the CHAMP satellite. The bias evolution over several years to three decades (long-term trends) as well as its variation on a timescale of several months to one year is investigated. The comparison with biases based on two months of MAGSAT and Ørsted satellite data, related to the 1979.92 and 1992.92 epochs, is performed. The results indicate that the crustal magnetic field has probably not changed over the studied time span. This investigation and the obtained results are presented in the work by Verbanac et al. (2015).

Brajša et al. (2015) investigated the possibility to predict and reconstruct the solar cycle 24 by applying the modified minimum–maximum method, which belongs to the precursor class of methods, to the smoothed monthly sunspot values. A comparison between the observed and predicted amplitude of the 24th solar cycle is performed. The obtained results indicate that the applied mini-

mum–maximum method is a reliable one for the solar cycle prediction and moreover allow to predict the subsequent solar maximum amplitude already three years before the preceding minimum of solar activity.

Relationship between plasmapause, solar wind and geomagnetic activity between 2007 and 2011 is obtained using ACE and CLUSTER satellite data (Verbanac at al., 2015). The time delay of the plasmapause response to solar wind parameters and geomagnetic activity in different magnetic local times (MLT) is obtained by applying the cross-correlation analyses. In the study by Bandić at al. (2016) the MLT plasmapause dependence is further analysed for different phase of the solar cycle using CRRES satellite data. MLT propagation of the plasmapause is inferred from THEMIS satellite data by investigating the cross-corellation curves in each 1 hour MLT bin and the results are given in the study by Bandić at al. (2017).

Verbanac et al. (2018) compared the plasmapause characteristics obtained from THEMIS satellite data with the numerical simulations based on the interchange instability physical mechanism. The global plasmapause characteristics as the MLT sectors of the plasmapause erosion and azimuthal plasmapause motion are derived. This work has shown that the global plasmapause behaviour is indeed in agreement with interchange instability mechanism. The great importance of this study is that it contributes to resolve some of the long-lasting issues related to plasmapause formation and dynamics.

Observations from the European quasi-Meridional Magnetometer Array (EMMA) and their comparison with Dynamic Global Core Plasma Model (DGCPM) are considered by Jorgensen et al. (2017). The DGCPM model is modified in order to better fit the observations. The results suggest faster daytime refilling and nighttime loss.

In the study by Mandić and Korte (2017) the method for automatic estimation of the observatory baselines is presented. It is demonstrated that preparation of definitive geomagnetic data is possible within one year. The performed comparison with the baselines reported on INTERMAGNET DVDs for the period 2009–2011 has shown that the proposed method may be suitable for automatic data processing when automated absolute instruments are placed at remote sites.

Geomagnetic effects of corotating interaction regions from 2005 throughout 2008, the period belonging to the declining phase of Solar Cycle 23 which are characterized by a particularly low number of interplanetary coronal mass ejections, is presented by Vršnak (2017). The statistical relationship between solar wind flow speed, magnetic field and the convective electric field based on the southward magnetic field component is quantified.

Research results were presented at international conferences. Status report related to research activity in the fields was also presented at Europlanet NA1 Annual Meeting and Inclusiveness Forum in 2018 by G. Verbanac. There, the ongoing activities at Geophysical Department were especially emphasized.

The topics related to geomagnetism, aeronomy and space weather in general have been promoted within the Adriatic Aerospace Association since spring 2018 contributing to the professional activity in the fields. Further, the professional work was dedicated to geomagnetic observatory practice. Based on the quality of the data collected at geomagnetic observatory Lonjsko Polje during 2014 and 2015, the observatory took part in the INTERMAGNET network in February 2016. The official IAGA code LON was associated to the observatory. The verification of the quality of the first collected data is documented by Mandić et al. (2016). The observatory has been working almost permanently until today. In 2017 and 2018 the problems with the LEMI-03 magnetometar occurred. Fortunately, the problems were fixed at the end of 2018. Thereafter, the data have been continuously sent to European quasi-Meridional Magnetometer Array (EMMA) network requlary in real time. Additional problems with running the observatory occurred in 2018 caused by natural disasters (flood). Since 2017 the observatory also serves for testing the instrumentation which has been used for reapeat station measurements in the framework of the project "Second Geomagnetic Information Renewal Cycle in the Republic of Croatia" that is led by the Faculty of Geodesy, University of Zagreb. Three workshops were attended (two IAGA and one MagNetE workshops) which contributed to new knowledge and enlarged experience related to observatory practice and instrumentation.

Except for the contacts that have been already put in place, the international collaboration in the fields of geomagnetism, aeronomy, solar physics and generally in planetary science is further extended in the period 2015–2018.

The education is actively performed at the Geophysical Department through the university undergraduate courses: Planetology, Geomagnetism, Aeronomy, Geophysical Practicum as well as university doctoral course: Planetary Magnetism. Important to note is that these courses for the first time in Croatia embrace fundamentals of plasma physics, magnetospheric physics, solar physics, geomagnetism in all aspects, high ionospheric levels (ionosphere and thermosphere) and planetary science in general. Through these courses the students gain diverse knowledge that allow them to easily fit in different international groups. The appropriate examples are the current visits of six months to one year of two students at the very well known international institutions (University of Graz, Austria and Max-Planck institute Goetingen, Germany) where they have so far demonstrated great capability to successfully face with all physical problems and tasks within the fields. Further, within the course Geophysical Practicum student visit to the geomagnetic observatory LON is organized, which helps them to better adopt the knowledge attained at other regular courses. Students acquire additional knowledge in the fields by preparing diploma theses and publications. In the reported period, one doctoral thesis that focused on quality and proposals for improvements in the baseline adaption at geomagnetic observatories was defended (Mandić, 2017).

Last, but not the least, it is important to note that geomagnetism, aeronomy and space science are regularly promoted to the wider audience through public talks, tribunes, festivals, talks at schools and popular scientific articles (e.g., Jerčić and Verbanac, 2018; Andrić and Verbanac, 2017; Majstorović and Verbanac, 2015; Belinić and Verbanac, 2015).

List of publications

Andrić, T. and Verbanac, G. (2017): Pregled unutrašnje građe planeta Sunčeva sustava, Čovjek i svemir, **2**(2), 37–39 (in Croatian).

Bandić, M., Verbanac, G., Moldwin, M. B., Pierrard, V. and Piredda, G. (2016): MLT dependence in the relationship between plasmapause, solar wind and geomagnetic activity based on CRRES: 1990–1991, *J. Geophys. Res. Space Physics*, **121**, 4397–4408, DOI: 10.1002/2015JA022278.

Bandić, M., Verbanac, G., Pierrard, V. and Cho, J. (2017): Evidence of MLT propagation of the plasmapause inferred from THEMIS data, *J. Atmosph. Sol. Terr. Phys.*, **161**, 55–63, DOI: 10.1016/j.jastp.2017.05.005.

Belinić, T. and Verbanac, G. (2015): Unutrašnjosti planeta Sunčevog sustava, Čovjek i svemir, **3**(3), 32–34 (in Croatian).

Brajša, R., Verbanac, G., Sudar, D., Skokic, I., Zic, T., Hanslmeier, A., Woehl, H., Roth, M., Mursula, K. and Zhang, L. (2015): A comparison between the observed and predicted amplitude of the 24th solar cycle, *Cent. Eur. Astrophys. Bull.*, **39**, 135–144.

Jerčić, V. and Verbanac, G. (2018): Jupiterov satelit Io i njegova vulkanska aktivnost, Čovjek i svemir, **3**(3), 26–30 (in Croatian).

Jorgensen, A. M., Heilig, B., Vellante, M., Lichtenberger, J., Reda, J., Valach, F. and Mandić, I. (2017): Comparing the Dynamic Global Core Plasma Model with ground-based plasma mass density observationsm, *J. Geophys. Res. Space Physic*s, **122**, 8, 7997–8013, DOI: 10.1002/2016JA023229.

Mandić, I., Vujić, E., Heilig, B., Pelajić, I. and Herak, D. (2016): Recent efforts toward the establishment of the Lonjsko Polje Geomagnetic Observatory, *Acta Geophys.*, **64**, 5, 1311–1339, DOI: 10.1515/acgeo-2016-0051.

Mandić, I. and Korte, M. (2017): On the possibility of producing definitive magnetic observatory data within less than one year, *Acta Geophys.*, **65**, 275–286, DOI: 10.1007/s11600-017-0026-9.

Mandić, I. (2017): Quality issues and proposals for improvements in the baseline adaption at geomagnetic observatories. Ph.D. Thesis, Faculty of Science, University of Zagreb, Zagreb, 101 pp.

Verbanac, G. and Majstorović, J. (2015): Vulkanizam u Sunčevom sustavu, Čovjek i svemir, **4**(4), 36–37.

Verbanac, G., Pierrard, V., Bandić, M., Darrouzet, F., Rauch, J.-L., Décréau, P. (2015): Relationship between plasmapause, solar wind and geomagnetic activity between 2007 and 2011, *Ann. Geophys. - Special Issue: Dynamic Processes in Geospace*, **33**, 1271–1283, DOI: 10.5194/angeo-33-1271-2015.

Verbanac, G., Mandea, M., Bandić, M. and Subasic, S. (2015): Magnetic observatories: biases over CHAMP satellite mission, *Solid Earth*, **6**, 775–781, DOI: 10.5194/se-6-775-2015.

Verbanac, G., Bandić, M., Pierrard, V. and Cho, J. (2018): MLT plasmapause characteristics: Comparison between THEMIS observations and numerical simulations, *J. Geophys. Res. Space Physics*, **123**, 2000–2017, DOI: 10.1002/2017JA024573.

Vršnak, B., Dumbović, M., Čalogović, J., Verbanac, G. and Poljančić Beljan, I. (2017): Geomagnetic effects of corotating interaction regions, *Solar Phys.*, **292**, A140, 20 pp, DOI: 10.1007/s11207-017-1165-5.