ROMANIAN ACADEMY

ROMANIAN NATIONAL COMMITTEE
OF GEODESY AND GEOPHYSICS

NATIONAL REPORT

ON GEODETIC AND GEOPHYSICAL ACTIVITIES IN ROMANIA

2019 – 2022

Prepared for the 28th IUGG General Assembly
Berlin - GERMANY
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2023

FOREWORD

The National Report of the Romanian Committee of Geodesy and Geophysics (RNCGG) for the 28th General Assembly of IUGG aims to present the main directions and results of newly initiated and/or developed scientific research conducted by Romanian geoscientists. These research efforts are carried out and supported by all scientific associations of the Romanian Committee and focus on the interdisciplinary study of planet Earth.

The sections of the RNCGG's report presents the involvement of Romanian scientists and specialists in significant national and international research projects being produced under the guidance of national correspondents. The report also highlights the organization of important conferences and symposia, as well as the main topics discussed by Romanian participants.

An important part of each contribution in the National Report is a selective bibliography. It enables interested readers to continuously follow the development of research projects and the involved working groups, with the aim of establishing mutually beneficial contacts in the near future.

The present report covers the period from 2019 to 2022, since the last IUGG General Assembly held in Montreal, Canada.

During this period, we have strived to raise the quality of RNCGG activities to higher standards through continuous improvement of the organizational structure, appointment of new members, and new secretaries of the committees of scientific associations. The report also contains information about these improvements.

We would like to extend our heartfelt gratitude for the outstanding efforts and dedicated work of Dr. Constantin Stefan Sava, Secretary General of RNCGG, and Dr. Anisoara Irimescu, the editor-in-chief of the RNCGG Report, as well as all the associate editors. We acknowledge and deeply appreciate their invaluable contributions.

The National Report pays tribute to our esteemed professors and former presidents of the Romanian National Committee of Geodesy and Geophysics, who were the pioneers of the Romanian school of geophysics: Academicians Sabba S. Stefanescu and Liviu Constantinescu, as well as Prof. Dr. Dorel Zugravescu, Corresponding Member of the Romanian Academy and former RNCGG President. We also honor the legacy of Prof. Dr. Dorel Zugravescu as the founder of the "Sabba S. Stefanescu" Geodynamic Institute of the Romanian Academy.

Acad. Prof. Nicolae Panin,
President of the Geonomical Sciences Section
of the Romanian Academy

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IACS ACTIVITIES IN ROMANIA

2019-2023

NATIONAL REPORT ON CRYOSPHERE

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Content:

PART I: ORGANIZATION

The Romanian IACS Committee is supported by members from the National Meteorological Administration (Bucharest), West University of Timișoara, and Emil Racovita Institute of Speleology (Cluj).

The National Meteorological Administration (NMA) is the national service in the field of meteorology and climatology. The Director General of NMA is the Permanent Representative of Romania with the World Meteorological Organization (WMO). The main activities developed within NMA are: basic operational activity (weather forecast including nivologic alerts and observation system including snow-related data), research activity (numerical modeling, climate variability and climate change, physics of the atmosphere, air pollution, remote sensing and remote sensing), education and training and international cooperation.

The team of **West University of Timisoara, Department of Geography**, coordinated by Professor Petru Urdea has contributed to Data and Information Service for CliC (http://clic.npolar.no/). Also, researchers from the West University of Timisoara have an extensive expertise on avalanches.

The team of **Emil Racovita Institute of Speleology,Romanian Academy (Cluj)** is involved in studies related to cryosphere and caves.

The Romanian Meteorological Society also supports the IACS activities in Romania.

Romanian IACS Activities:

- Snow and Avalanches;
- Continental Glaciers/ Permafrost;
- Cryosphere, Atmosphere and Climate.

Institutions:

- National Meteorological Administration (Bucharest)
- West University of Timișoara
- Emil Racovita Institute of Speleology (Cluj)

Professional Organizations:

- Romanian Meteorological Society

National Conferences:

- Annual Scientific Session of the National Meteorological Administration
- The Romanian National Symposium on Geomorphology

National Publications:

- Romanian Journal of Meteorology
- Romanian Reports in Physics
- Romanian Journal of Physics

PART II: PROFESSIONAL ACTIVITY

1. Research

1.1. Snow and Avalanches

The monitoring of snow cover evolution in the mountain area of Romania contributes to the protection of lives, properties, and infrastructure. Avalanche risk has been identified in the Romanian mountains and risk assessment studies are continuously updated. The program of snow-related meteorology which started in the National Meteorological Administration in February 2004 (under the coordination of “Centre d’Etudes de la Neige”, Grenoble) has been carried out to meet the demand for information related to snow cover avalanche conditions. The National Meteorological Administration (http://www.meteoromania.ro) through the Regional Forecasting Center in Sibiu, the Department of Geography of the West University of Timișoara and the Faculty of Geography from the University of Bucharest are the leading institutions in the avalanche monitoring and research.

Past avalanches analysis provides the knowledge to document the hazard component of the avalanche risk. Snow avalanches change landscapes and frequently disturb forest stands. Tree-growth anomalies (e.g., scars, callus tissues, the onset sequences of tangential rows of traumatic resin ducts, compression wood, growth suppression and release sequences) related to snow avalanche disturbance identified within tree rings serve to reconstruct past events (Decaulne et al., 2020). Such disturbances in trees have been used to date past avalanches, study their extent, and document their triggers by the tree-ring analyses. The dendrogeomorphological approach combined with snow-related analysis using meteorological data have provided the tools to reconstruct past avalanche activity (e.g., Todea et al., 2020; Gavrilă et al., 2022). Todea et al. (2020) have reconstructed snow–avalanche history with tree rings along a path located below Cârja Peak (2405 m a.s.l.) in Parâng Mountains (Southern Carpathian, Romania). Gavrilă et al. (2022) have reconstructed snow-avalanche (SA) activity along three adjacent avalanche paths in the northern part of the Rodna Mountains (Eastern Carpathians, Romania).

Remote sensing data have been also used to detect and make an avalanche inventory for areas in Carpathian Mountains.

Studies regarding avalanche-related impact components and risk assessments have been also carried out.

Studies on snow related to winter tourism have been also carried out. Romania has 44 ski resorts with about150 ski lifts, 20% of which have been installed or renewed in the last 15 years (Bacoş and Gabor, 2021).

1.2. Continental Glaciers/ Permafrost

Some of activities carried out by Romanian scientists have focused on glacial/periglacial geomorphology and permafrost detection. Several studies used combined physical and geomorphological approach to characterize the permafrost presence in the mountain areas in Romania (e.g., Popescu et al., 2022). Onaca et al. (2020) have investigated, for the first time, the permafrost occurrence within 13 rock glaciers in the Balkan Peninsula where active and/or inactive rock glaciers are likely to occur in the highest mountains of Bulgaria (e.g., Rila and Pirin Mountains) above 2450 m (Onaca et al., 2020).

Also, the past glaciation and deglaciation processes and associated climate changes have been investigated using palaeoenvironmental analysis based on a multiproxy approach in lacustrine and peat deposits from the Carpathians and the Cosmic Ray Exposure (CRE) dating methods (e.g., Ruszkiczay-Rüdiger et al., 2021; Urdea et al., 2023).

An important research area refers to the Ice Cave Scărişoara located in the Western Carpathians (e.g., Perșoiu and Onac, 2019). The Carpathian Mountains across Slovakia and Romania are home of several ice caves located at elevations between 700 and 1200 m above sea level. The Scărișoara Ice Cave (Romania) which is in the Apuseni Mountains at 1165 m above sea level hosts one of world's largest and oldest underground glacier.

1.3. Cryosphere, Atmosphere and Climate

Bojariu et al. (2021) updated the trend analysis for snow depth in Romania. The evolution and the associated trend of spatially-averaged snow depth at low altitude (up to 800 m) in the cold season (October-April 1961-2021) is presented in figure 1. However, it is interesting to note that there is an intermonthly difference in the trends of mean snow depth. Downward trends are present in December, January, February and March and the magnitude of the downward trend is largest in February (0.5 cm/decade).

The study of Amihăesei et al. (2022) documented the trends in number of days with snow cover in Romania. Their results provide further evidence of a declining snow cover regime, with slight differentiations induced by the elevation. About 59% of stations experience significant ($p<0.05$) declines. The country-wide average change is ~0.33 days/decade, with a slightly higher decrease in the lowlands (with a maximum of ~0.74 days decade-1) than in the highlands (~0.25 days decade-1) (Amihăesei et al., 2022).

Amihăesei et al. (2023) have also analyzed the changes in the monthly snow-to-liquid precipitation ratio (SLPR) over the October-May interval in Romania, based on daily precipitation, air temperature and snow depth data provided by 114 weather stations from the national meteorological monitoring network, over the 1961-2021 period. The observed trends showed a country-wide and significant decline in SLPR. The most notable decline is observed during the late winter and early spring months

(February-March), with decreasing trends at over 70% of the weather stations, although only 20% suggest statistically significant changes (p value < 0.05). The autumn months (October and November) depict no statistically trends. Evidence of elevation dependency of SLPR trends has been found in spring. The results show that the SLPR declines with altitude, especially in April (R2 = .30) and May (R2 = .67), when the correlations are statistically significant (p<0.05) (Amihăesei et al, 2023).

Caian and Andrei (2019) have documented a mechanism involved in snow-related severe weather events such as blizzard. These types of events that are occurring in eastern and southeastern Romania are often associated with extratropical cyclones over western Black Sea, generally of Mediterranean origin. This study serves the forecasting system and gives insights to help in documenting how climate change background could impact severe blizzard events in middle spring when socio-economic impacts are very high.

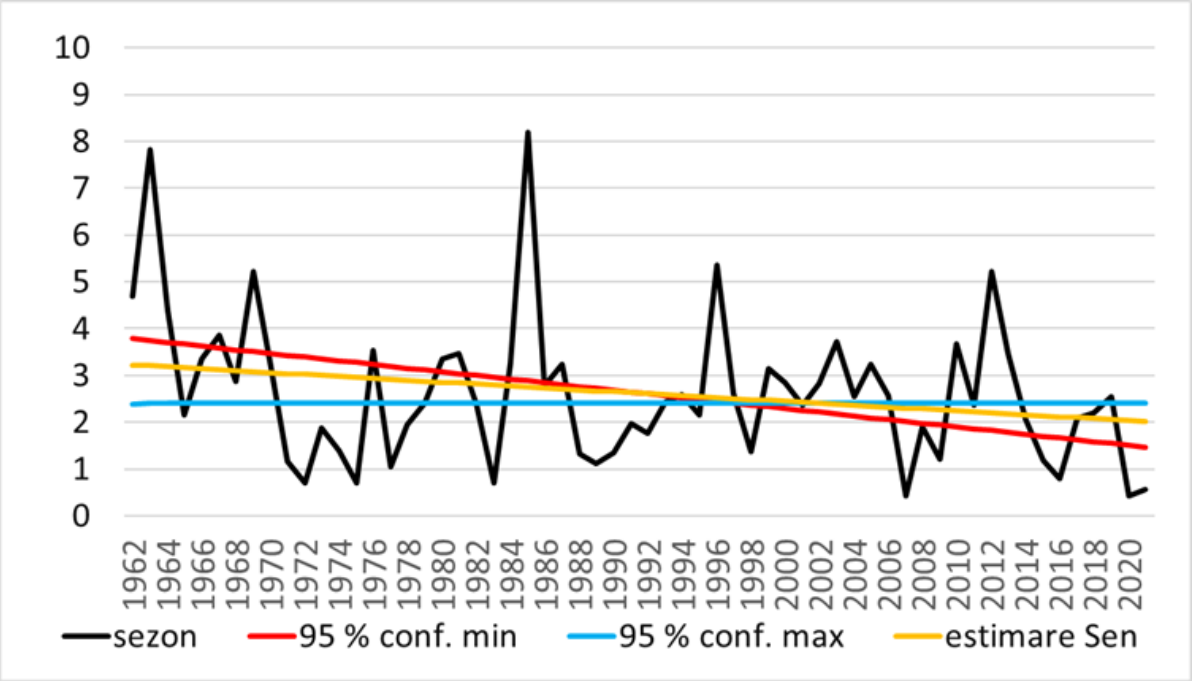

Figure 1. The evolution of the average snow layer depth (in cm/month), at the level of Romania (average of observations from 88 stations (mountain stations are excluded - those at altitudes higher than 800 m) and the linear trend associated (in orange), along with values in the 95% confidence interval (in red and blue), for the period October - April 1961-2021. From Bojariu et al. (2021).

Numerical experiments with regional climate models have been used to investigate in more detail the physical mechanisms involved in regional response to present and future global warming. A general trend of decreasing snowfall amounts, mean snow depth and snow cover duration was observed for major urban areas of Romania and under scenarios RCP4.5 and RCP8.5 (Hrițac et al., 2023). The results of Hrițac et al. (2023) have also suggested an increasing number of years lacking snowfall and snow cover, especially after 2050 in the high concentration scenario (RCP8.5). An increased variability was also documented: extreme snowfall events have been identified even in the latter half of this century.

2. Participation of the Romanian specialists in international projects or programs

- Joint research project 09-AUF, ‘‘Activité des avalanches de neige dans les Carpates Orientales Roumaines et Ukrainiennes - ACTIVNEIGE’’, co-funded by the Agence Universitaire de la Francophonie (AUF) and Institutul de Fizică Atomică (IFA), Romania.

3. Participation of the Romanian specialists in the international symposiums and conferences

Romanian researchers have presented most of their results related to IACS topics in the EGU General Assemblies.

4. Publications

4.1. Peer-reviewed publications

Bacoş, I-B and Gabor M R. (2021). "Tourism Economy. Mountain Tourism: Quantitative Analysis of Winter Destinations in Romania" *ECONOMICS*, vol.9, no.1, 2021, pp.143-159. https://doi.org/10.2478/eoik-2021-0005

Caian, M, and M. D. Andrei. (2019). "Late-Spring Severe Blizzard Events over Eastern Romania: A Conceptual Model of Development" *Atmosphere* 10, no. 12: 770. https://doi.org/10.3390/atmos10120770

Gavrilă, I.G., Kholiavchuk, D., Holobâcă, I.H. et al. Tree-ring records of snow-avalanche activity in the Rodna Mountains (Eastern Carpathians, Romania). (2022) *Nat Hazards* 114, 2041–2057.https://doi.org/10.1007/s11069-022-05458

Ruszkiczay-Rüdiger Z., Z. Kern, P. Urdea, B. Madarász, R. Braucher,(2021) Limited glacial erosion during the last glaciation in mid-latitude cirques (Retezat Mts, Southern Carpathians, Romania), Geomorphology, Volume 384, 107719, ISSN 0169-555X, https://doi.org/10.1016/j.geomorph.2021.107719.
(https://www.sciencedirect.com/science/article/pii/S0169555X21001276)

4.2. Other journals articles and Proceedings papers

Amihăesei, V.-A., Micu, D-M, ApostoL, L., Dumitrescu, A., Cheval, S. Changes in number of snow cover days over Romania in the last 60 years. In: *Present Environment and Sustainable Development*, Ed. 17, 3 iunie 2022, Iași: 2022, Ediția 17, R, pp. 86-87.

Amihăesei, V.-A., Micu, D. M., Dumitrescu, A., Cheval, S., Bîrsan, M.-V., and Sfîcă, L.: Observed trends in the snow-to-liquid precipitation ratio over Romania, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-10305, https://doi.org/10.5194/egusphere-egu23-10305, 2023.

Bojariu, R., Velea, L., Irimescu, A., Craciunescu, V. and Puiu, S., (2021). Climate services for winter tourism in Romanian mountains (No. EGU21-11216). *Copernicus Meetings*.

Decaulne, A., Răchită, I.-G., Hotea, M., Chiş, V. T., and Pop, O. T.: Reconstructing snow-avalanche activity with tree rings in Maramureş Mountains (Eastern

Carpathians, Romania), 2020. EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-20060, https://doi.org/10.5194/egusphere-egu2020-20060

Hrițac, R., Sfîcă, L., Breabăn, I.-G., and Amihăesei, V.-A.: The expected effect of climate change on snowfall amounts and snow depth in the major urban areas of Romania, *EGU General Assembly 2023*, Vienna, Austria, 24–28 Apr 2023, EGU23-12497, https://doi.org/10.5194/egusphere-egu23-12497, 2023. 6

Popescu, R., Filhol, S., Etzelmüller, B., Șandric, I., Pleșoianu, A., Vîrghileanu, M., Săvulescu, I., Vasile, M., Cruceru, N., Vespremeanu-Stroe, A., Westermann, S., Sîrbu, F., Onaca, A., Mihai, B., and Nedelea, A. (2022): Permafrost distribution in the Southern Carpathians, Romania, derived from statistical modeling, *10th International Conference on Geomorphology*, Coimbra, Portugal, 12–16 Sep 2022, ICG2022-655, https://doi.org/10.5194/icg2022-655, 2022.

Todea, C. and Pop, O.: Tree-ring reconstruction of snow avalanches in Şureanu Mountains (Southern Carpathians, Romania), *EGU General Assembly 2021*, online, 19–30 Apr 2021, EGU21-14504, https://doi.org/10.5194/egusphere-egu21-14504, 2021.

4.3. Books and book chapters

4.3.1. Books

Bojariu R, Chitu Z., Dascălu SI, Gothard M, Velea L, Burcea R, Dumitrescu A, Burcea S, Apostol L., Amihaesei V., Marin L, Crăciunescu VS, Irimescu A, Mătreata M, Niţă A., Bîrsan MV (2021): Climate change – from physical basis to impact and adaptation (in Romanian with abstract in English). Updated edition. Editura Printech, București, 222 p, ISBN: 978-606-23-1275-6.

Perşoiu, A., Onac, B.P. (2019). Ice Caves in Romania. In: Ponta, G., Onac, B. (eds) Cave and Karst Systems of Romania. Cave and Karst Systems of the World. Springer, Cham. https://doi.org/10.1007/978-3-319-90747-5_52

4.3.2. Book chapters

Perșoiu A., and B. P.Onac, 2019: Chapter 66 - Ice in caves In: *Encyclopedia of Caves (Third Edition)*, 553-558, https://doi.org/10.1016/B978-0-12-814124-3.00066-2

Urdea P., F, Ardelean, M. Ardelean, A. Onaca, (2023). Chapter 36 - The Romanian Carpathians: glacial landforms during Bølling–Allerød Interstadial (14.6–12.9 ka), Editor(s): David Palacios, Philip D. Hughes, José M. García-Ruiz, Nuria Andrés, European Glacial Landscapes, Elsevier, pp 347-353, ISBN 9780323918992, https://doi.org/10.1016/B978-0-323-91899-2.00010-3.

Urdea P., F. Ardelean, M. Ardelean, A. Onaca, O. Berzescu,(2023). Chapter 54 - The Romanian Carpathians: glacial landforms from the Younger Dryas, Editor(s): David Palacios, Philip D. Hughes, José M. García-Ruiz, Nuria Andrés, European *Glacial Landscapes*, Elsevier, Pages 517-524, ISBN 9780323918992, https://doi.org/10.1016/B978-0-323-91899-2.00059-0.

IAG ACTIVITIES IN ROMANIA

2019-2022

NATIONAL REPORT ON GEODETIC AND GEOPHYSICAL ACTIVITIES

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PART I: ORGANIZATION

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The Faculty of Geodesy in Bucharest is a leading institution renowned for its expertise in geodesy. Part of Technical University of Civil Engineering Bucharest, its rooftop is home to the BUCU permanent GNSS station, a crucial asset for collecting precise satellite positioning data in Romania. This cutting-edge facility enables students and researchers to conduct advanced studies in geodetic surveying, satellite geodesy, and navigation systems. The faculty offers modern laboratories, geodetic instruments, and geospatial software, fostering hands-on experience in data acquisition and analysis. The Faculty of Geodesy actively engages in national and international projects, providing students with opportunities to contribute to the field of geodesy, photogrammetry, cartography, remote sensing and GIS research.

The National Cartography Center, part of the National Agency for Cadastre and Land Registration, is a vital institution for geodesy and mapping in Romania. It modernizes national geodetic networks, provides data for the national GNSS permanent stations system, conducts geodetic and topographic works, and creates and updates the official map of Romania. The center contributes to the national spatial data infrastructure, processes photogrammetric and remote sensing data, manages geodetic and cartographic databases, and offers specialized services and products. It participates in research, supports the national cadastre program, and maintains the Romanian Position Determination System (ROMPOS). The center plays a significant role in ensuring accurate geospatial information for various applications across the country.

The Institute of Geodynamics "Sabba S. Stefanescu" conducts research on various aspects of geodynamics. It focuses on studying the relative displacements between blocks in the Vrancea region, optimal sensor placement for monitoring geodynamic activity, evolution of geomagnetic, gravity, and geothermal fields, electromagnetic variations for understanding tectonic blocks' geometry, connections between volcanism and geodynamic processes, nonlinear analysis of geodynamic systems, and tectonic hazard studies. The institute's work contributes to a better understanding of geodynamic phenomena and helps mitigate risks associated with earthquakes, volcanic eruptions, and other geohazards.

The National Research-Development Institute for Marine Geology and Geoecology - GeoEcoMar is the national pole of excellence in geological, geophysical and geoecological research and advice on marine, coastal and inland waters, being a reference center for the study of Marine and Earth Sciences. The

addressed scientific fields include geological, geophysical and geoecological aspects of the river-sea systems in general and of the Danube-Danube Delta-Black Sea macro-system in particular.

Romanian IAG Activities:

- **Positioning and reference frames**
- **Advanced Space Geodesy**
- **Determination of the Gravity Field**
- **General Theory and Methodology**
- **Geodynamic studies**

Romanian IAG products and services

Based on GNSS observations, real-time and post-processing services provided through ROMPOS (Romanian Position Determination System) and other similar networks are available in Romania. ROMPOS services are available for a fee according to the provisions of Government Decision no. 16/2019 and can be accessed on the web platform.

Coordinates of the points included in the National Geodetic Network are available at National Centre for Cartography (NCC).

A gravimetric quasigeoid at the national level will be available in 2023 with an accuracy of about 10 cm.

Maps and plans at different scales and thematic content it is available also at NCC.

Orthphoto products for the Romanian territory there are available and updated at about five years time interval.

NACLR it is coordinating the INIS (National Infrastructure of Spatial Informations) according to the INSPIRE Directive of the European Union from 2007. A National geoportal it is available.

Maintenance of the Coordinate and Reference Systems in Romania according to European an National standards (ETRS89/ETRF, EVRS/EVRF, former S42 reference system with Stereographic 1970 projection and Black Sea 1975 leveling datum) and their connections by official transformations. For ETRS89 and S42 a connection was realized through the versions of software tools like TransDatRO and ShapeTransDatRO, designed for coordinate transformations of measured points and shape files, and implementing the NTv2 transformation in ArcGIS Desktop. These updates are published on the institution's website.

Institutions:

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- The National Cartography Center (CNC)
- The Institute of Geodynamics "Sabba S. Stefanescu"
- National Institute for Research and Development of Marine Geology and Geoecology (GeoEcoMar)

Professional Organizations:

- Romanian Surveyors Union (UGR)

International Conferences:

- 19th International Multidisciplinary Scientific GeoConference SGEM 2019, 30 June - 6 July 2019, Albena, Bulgaria;
- Working Party on the Standardization of Technical and Safety Requirements in Inland Navigation, Fifty-ninth session, Geneva, 23–25 June 2021;
- 21st International Multidisciplinary Scientific GeoConference SGEM 2021, June 26 – July 05, 2022, Albena, Bulgaria
- 22nd International Multidisciplinary Scientific GeoConference SGEM 2022, June 26 – July 05, 2022, Albena, Bulgaria;
- 4 – 10 July, 2022
- FIG Congress 2022, “Volunteering for the future - Geospatial excellence for a better living”, Warsaw, Poland, 11–15 September 2022;
- DISC 2022 – Danube Information System Conference, 14-15 Decembre 2022, Bucharest, Romania;
- EUREF Symposium 2019, 21–24 May 2019,Tallinn, Estonia;
- EUREF Symposium 2021 (online), 26–28 May 2021, Ljubljana, Slovenia
- EUREF Symposium 2022, May 31 - June 03, 2022, Zagreb, Croatia
- The XVII th Edition of the Scientific Symposia, “Technological Progress – Result of the Research”, General Association of the Romanian Engineers, April 27, 2023

Publications:

- Journal of Applied Engineering Sciences (JAES) , published by Faculty of Constructions and Architecture, in University of Oradea Publishing House;
- RevCAD Journal of Geodesy and Cadastre, edited by Department of Topography, „1st Decembre 1918” University of Alba Iulia, Romania;
- Nova Geodesia , an open access and quarterly peer-reviewed journal under the aegis of Society of Land Measurements and Cadastre from Transylvania;
- Journal of Geodesy, Cartography and Cadastre, Edited by Faculty of Geodesy, T.U. of Civil Engineering, Bucharest, ISSN: 1454-1408.

PART II: PROFESSIONAL ACTIVITY

1. Research orientation

1.1. Positioning and reference frames

1.1.1. Introductory

For the time interval 2019-2022 geodetic activities in Romania were in progress according to the economy and social situation. Economic development in our country after integration into European Union concluded to some positive effects mainly for the time interval 2007-2009. The professional bodies reorganized and for geodetic activities the Geodesists Order was created by Law 17/2006 for organizing the geodesist's profession according to the Law 7/1996 – Cadastre and Real Estate law. A drawback on this activity was done by suspending the Geodesists Order Law. At present the situation still remains the same even efforts to unlock were done especially by professional body – Romanian Geodesists Union (UGR) and at present the law it is to be reviewed by Romanian Parliament.

The National Agency for Cadastre and Land Registration (NACLR) under Ministry of Regional Development and Administration is the state responsible institution for geodetic and mapping activities in Romania. From a budget financing public institution NACLR was transformed since 2014 in a self-financing institution. NACLR includes the national mapping activities and 42 Cadastre and Land Registration Offices. As research and production institution acts the National Centre for Cartography (former National Centre for Geodesy, Cartography, Photogrammetry and Remote Sensing). Due to the difficult economic situation, in 2009 and 2010, NACLR was reorganized by decreasing the employees number, but after September 2014, it comes back to previous financial form.

1.1.2. Global Navigation Satellite System (GNSS) Network

According to the global and European trends in the field of modern geodetic networks, Romania followed this trend by promotion and implementation of a new high accurate geodetic network in the time interval 2007-2012. The new geodetic network it is built as an active continuously operating network. As technological equipments the GNSS (GPS/GLONASS) receivers are included into the network. Galileo and Beidou GNSS technology started to be implemented.

Starting 1999, when it was installed the first GPS permanent station in Romania at the Faculty of Geodesy - Technical University of Civil Engineering Bucharest (BUCU) in cooperation with Federal Agency for Cartography and Geodesy Frankfurt a.M. (Germany), the new methods of global satellite positioning were introduced in Romania.

In 2001 the National Office for Cadastre, Geodesy and Cartography (reorganized in 2004 as National Agency for Cadastre and Land Registration) installed 5 GPS permanent stations in Braila, Suceava, Cluj, Sibiu, Timisoara (BRAI, SUCE, CLUJ, SIBI, TIMI) as a necessity for the precise geodetic measurements in the area. Romania as a CERGOP (Central European Regional Geodynamic Project) country

member installed two GPS permanent stations in Craiova and Constanta in 2004 (CRAI, COST). In 2005 the continuously modernization of the National GNSS Permanent Network consisted in the installation of 5 new GPS permanent stations in Bacau, Deva, Baia Mare, Oradea and Sfântu Gheorghe (BACA, DEVA, BAIA, ORAD, SFGH). With their own funds or from PHARE and World Bank the GNSS network was continuously extended by the National Agency for Cadastre and Land Registration (NACLR) in 2007-2010. At the end of 2010 the Romanian GNSS permanent network included 60 GPS and GNSS permanent stations installed by NACLR and one GNSS permanent station installed at the Faculty of Geodesy, Technical University of Civil Engineering Bucharest. The EUREF (EPN) station BUCU was introduced into the IGS network since 2005 and was modernized in 2008 with the help of the Federal Agency for Cartography and Geodesy Frankfurt a. M. (Germany). Other 6 stations were modernized in 2009 by replacing old equipments (Leica System 530) with new equipments (Leica 1200 GNSS+, AR25 antennas). In 2012, the last 15 GNSS permanent stations were installed increasing the GNSS permanent network up to 74 stations. In the last four years, GNSS equipments were modernized by including GALILEO signals for a part of the network. By end of 2023 it is planned that all the stations to be able to track four GNSS constellations: GPS, GALILEO, GLONASS and BEIDOU as well as EGNOS satellites. The RINEX 3.x format it is generally implemented as GNSS data format.

Romania it is member of the EUPOS (European Position Determination System) organization contributing to the standards adopted by members from Central and East European countries and EUPOS infrastructure by realizing *ROMPOS (Romanian Position Determination System)* based on the 74 GNSS permanent stations.

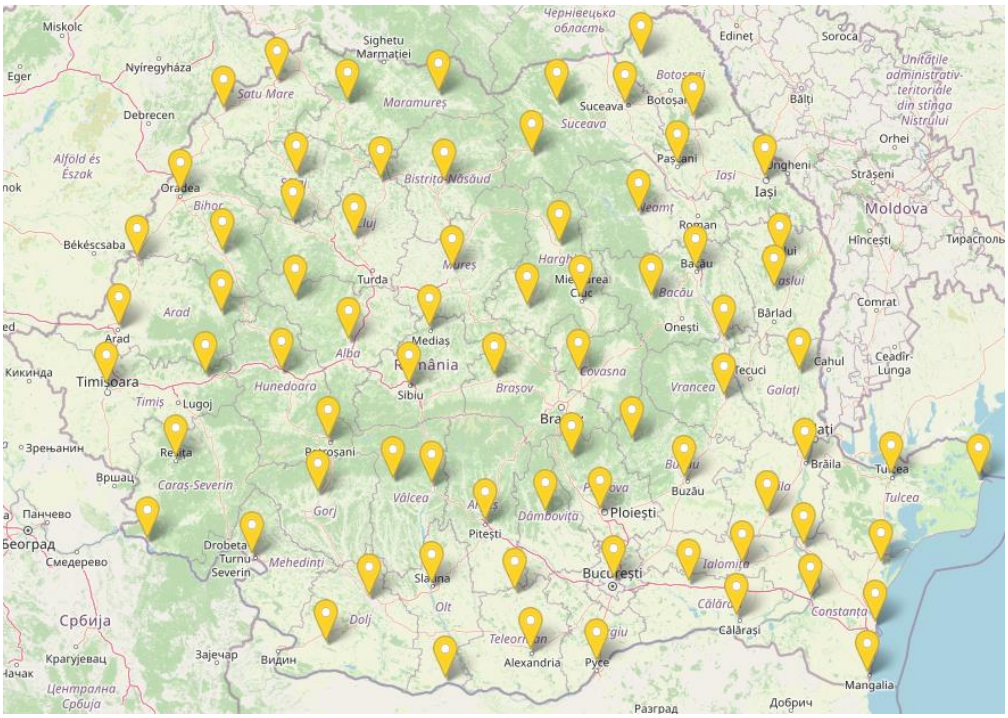

Figure 1.1: Romanian National GNSS Permanent Network (ROMPOS) – 2022

In January 2006, the NACLR integrated in the EUREF-EPN (European Permanent Network) 4 new GPS permanent stations: BACA, BAIA, COST and DEVA as a contribution to the European reference frame maintenance and other special projects. The EUREF-EPN GPS station in Constanta (COST) it is located near to a tide gauge and it is connected with this by precise leveling. The accuracy for the coordinates of the stations are better than +/- 1cm.

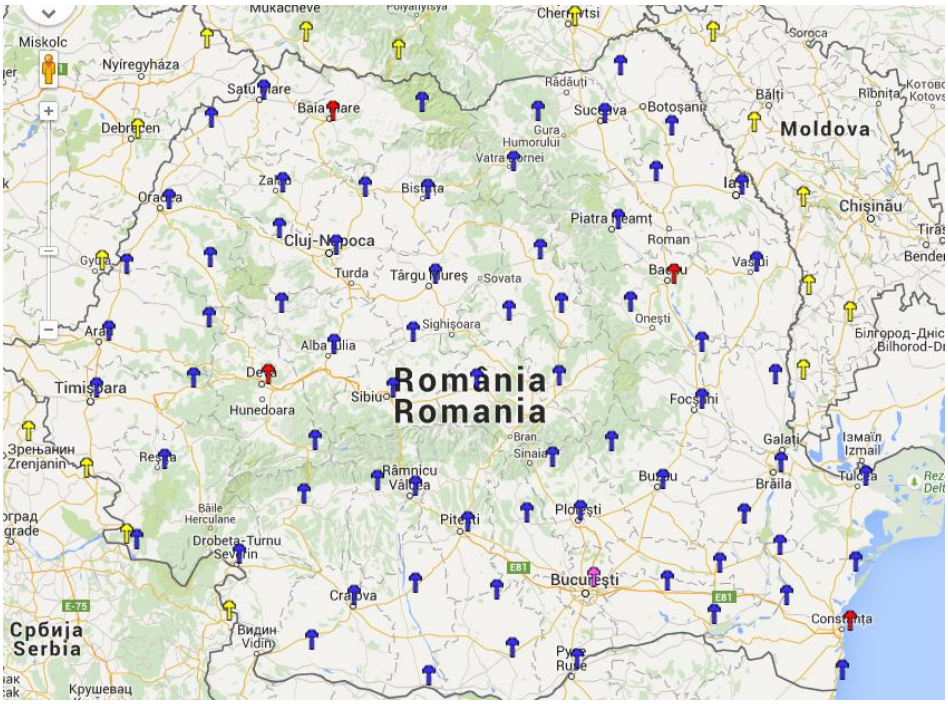

Figure 1.2: ROMPOS – including neighbor countries stations (red – IGS/EUREF/EUPOS sites; yellow included stations from HU, MD, SR and UA)

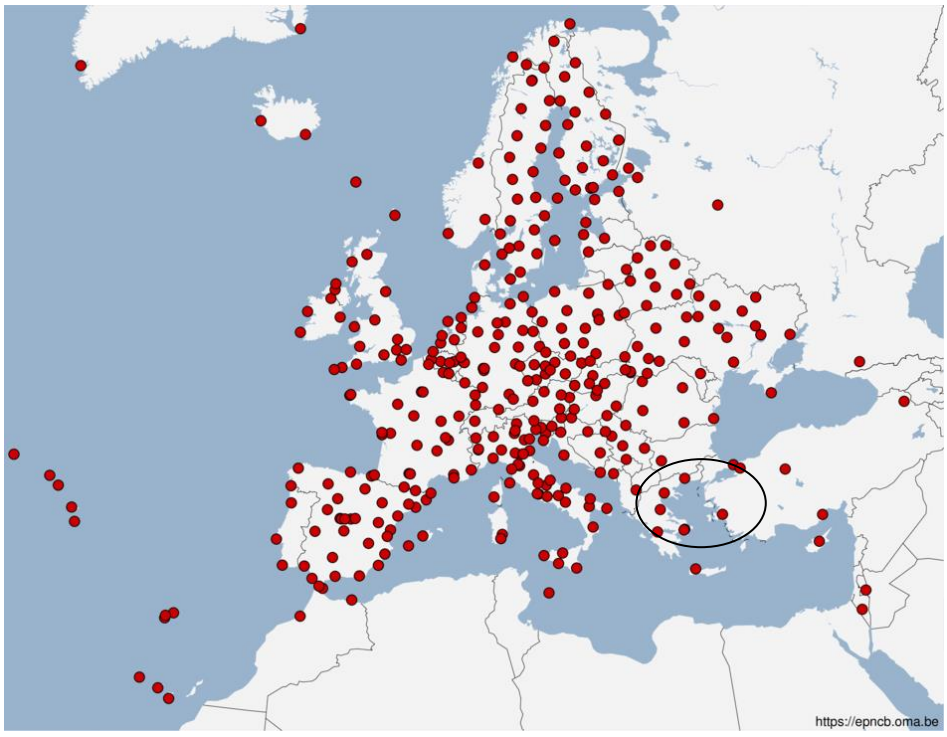

Figure 1.3: EUREF-EPN stations in Romania (Bucu, Baca, Baia, Cost, Deva)

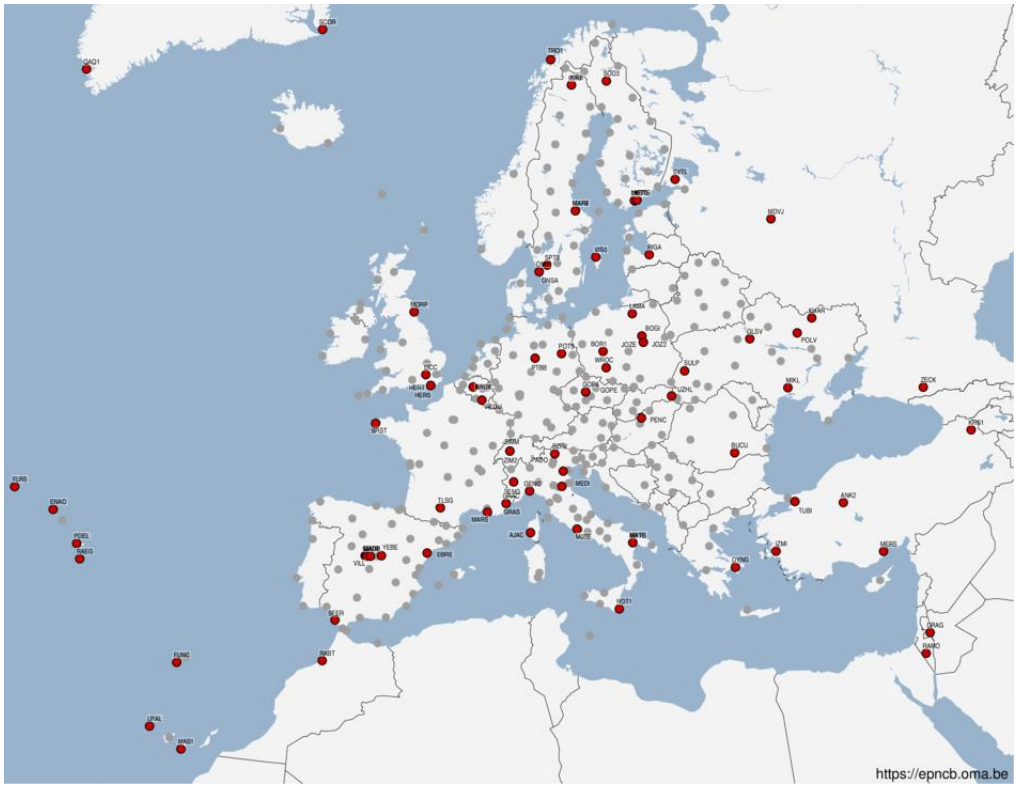

Figure 1.4: IGS stations in Romania (11401-M001 BUCU)

According to the present EPN classification the stations in Romania belong to C1 Class (BACA and BAIA), C6 Class (BUCU and DEVA), C2 Class (COST).
The National Space Geodetic Network (GNSS) was proposed (before the present EPN classification) to be divided into “classes” to be separated from the old triangulation network divided in “orders”. The proposed classes and present status are presented in the next table.
The National Spatial Geodetic Network (NSGN) is formed from the total ground points that have coordinates determined in the ETRS89 Coordinate Reference System and normal heights in Black Sea 1975 reference system, with the possibility to be transformed into the European Vertical Reference System (EVRS).
National Spatial Geodetic Network is structured on classes, using the precision and density criteria, as in the following table.

Table 1.1: Classification of the NSGN components

Network class	**ID**	**MSE (cm)**	**No. points/Density/ Distribution**	**Domain / Observations**
National Spatial Geodetic Network Class A0	A0	1.0	*5 GNSS permanent stations (IGS and EUREF-EPN)* *1 point / 50000 km^2* *Uniform distribution*	- link to the global and European geodetic networks; - regional and local geodynamics measurements, deformation determination real time positioning services, meteorology

Network class	ID	MSE (cm)	No. points/Density/ Distribution	Domain / Observations
National Spatial Geodetic Network Class A	A	1.0	*74 GNSS permanent stations* *1 point / 3250* km^2 *Uniform distribution*	- link to the class A0 network, - regional and local geodynamics measurements, deformation determination real time positioning services, meteorology
National Spatial Geodetic Network Class B	B	2.0	*330 points* *1point ./700km^2* *Uniform Distribution*	- regional and local geodynamics measurements, high precision topographic determinations
National Spatial Geodetic Network Class C	C	3.0	*About 4750 points* *1point/50km^2* *Uniform distribution*	- high precision topographic measurements, cadastre; -partial realized
National Spatial Geodetic Network Class D	D	5.0	*At least 1point/5km^2* *even distribution*	- topographic measurements, densification networks, G.I.S. - partial realized

MSE – Mean Square Error of the 3D position determination

Class B network was observed in 2003 and the results were included into national database in 2005. From the total number of stations about one third have geometric leveling. A number of 86 stations are old triangulation markers observed by GPS with coordinates in national geodetic reference system S42 with Krasovski ellipsoid and Stereographic 1970 projection system). The Class B network was constrained on the Class A network. The precisions for the coordinates of these stations are less than 2cm. Class C network including more than 1000 stations was observed since 2005 till present and it is not yet complete. The precisions for the coordinates of these stations are less than 3cm. Class D network it is realized in general for cadaster with no uniform distribution and the precision of these stations will be less than 5 cm. [http://gnss.rompos.ro]

Figure 1.5: Class B - National Spatial Geodetic Network (NSGN) (green – new monuments; blue – old monuments from triangulation network)

Development of ROMPOS aiming to facilitate users' access to the data provided by the system.

- Improving the quality of ROMPOS services by recalculating the coordinates for 21 permanent GNSS stations to the ITRF2014 datum (as of October 1, 2017) for the epoch of August 1, 2019. This recalculation is necessary due to antenna replacements, repositioning, or antenna shifts over time.
- Installation of 6 new permanent GNSS stations equipped with Leica GR50 receivers and Leica AR20 LEIM antennas. Such equipment has also been installed at a new location in Bârlad, expanding the local network of permanent GNSS stations and contributing to the increased quality of positioning services in that area.
- Providing ROMPOS users with a module for accessing the system's performance indicators, which can be accessed from the main page of app.rompos.ro. This module complements the system's connectivity verification application and offers real-time indicators directly from the ROMPOS central processing software through a monitoring framework.

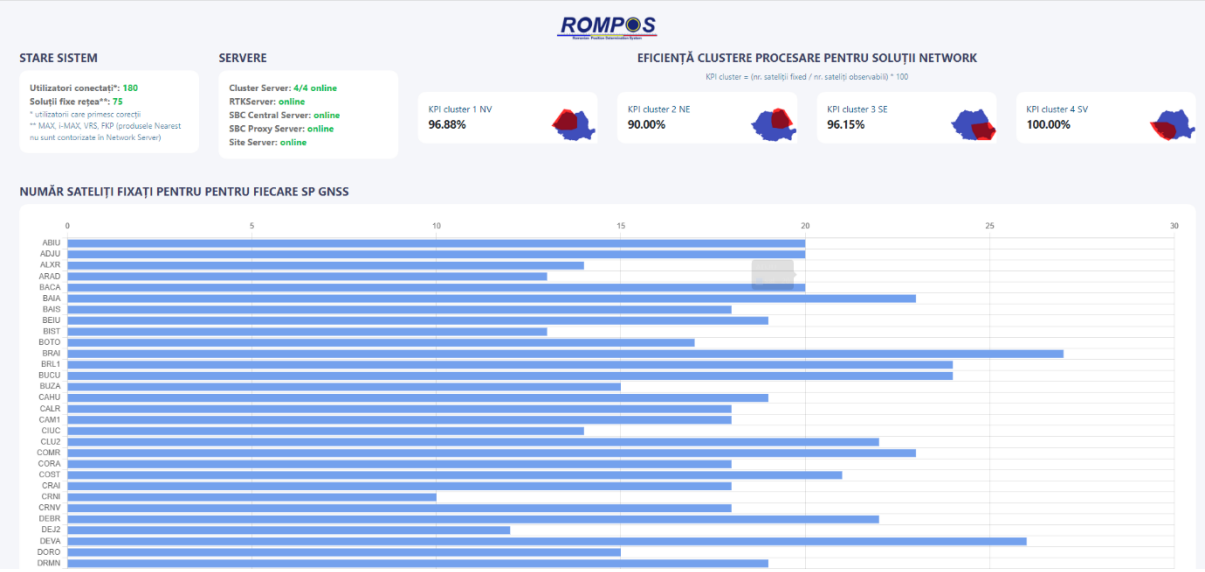

Figure 1.6: Visualization of system performance indicators (KPIs) directly from the address app.rompos.ro.

- Integration of all permanent GNSS stations of ROMPOS, as a member of the EUPOS GNSS network, into the Quality Monitoring Service (http://monitoringeupos.gku.sk/). This service allows for hourly evaluation of RTK determination accuracies. The influence of ionosphere and troposphere, as well as the global RMS value, is available on the NOVA Maps page of the rompos.ro website. The stability of GNSS antennas and the quality of solutions in static determinations are presented in monthly stability reports, which are accessible on rompos.ro.
- Development of the ROMPOS modules "Activity Analysis" and "Journal Download," which provide users with the ability to review all GNSS RTK determination sessions conducted within a specific time period. These modules display only the points with a "fixed" solution and allow for downloading the raw journal that contains all the information about an RTK determination session. The journal is available in both .xml (native) and .html (optimized for printing) formats.
- Development of the "Position Monitoring" and "Real-time" modules, which enable users to quickly check the connection of their GNSS equipment to the ROMPOS server, approximate position, and solution type (fixed or float). These modules also provide the capability to view real-time error messages, if any.

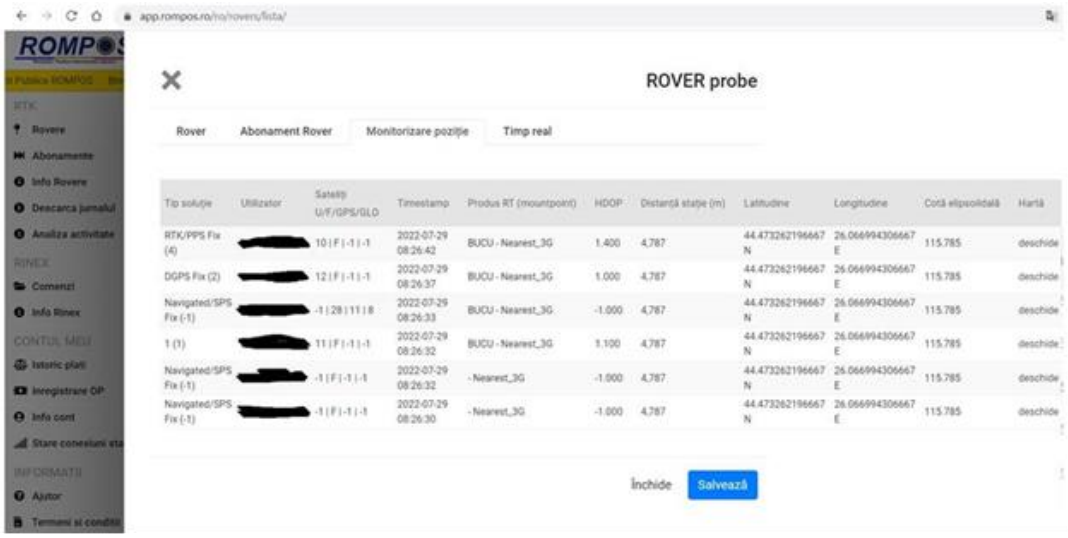

Figure 1.7: "Position Monitoring" Module

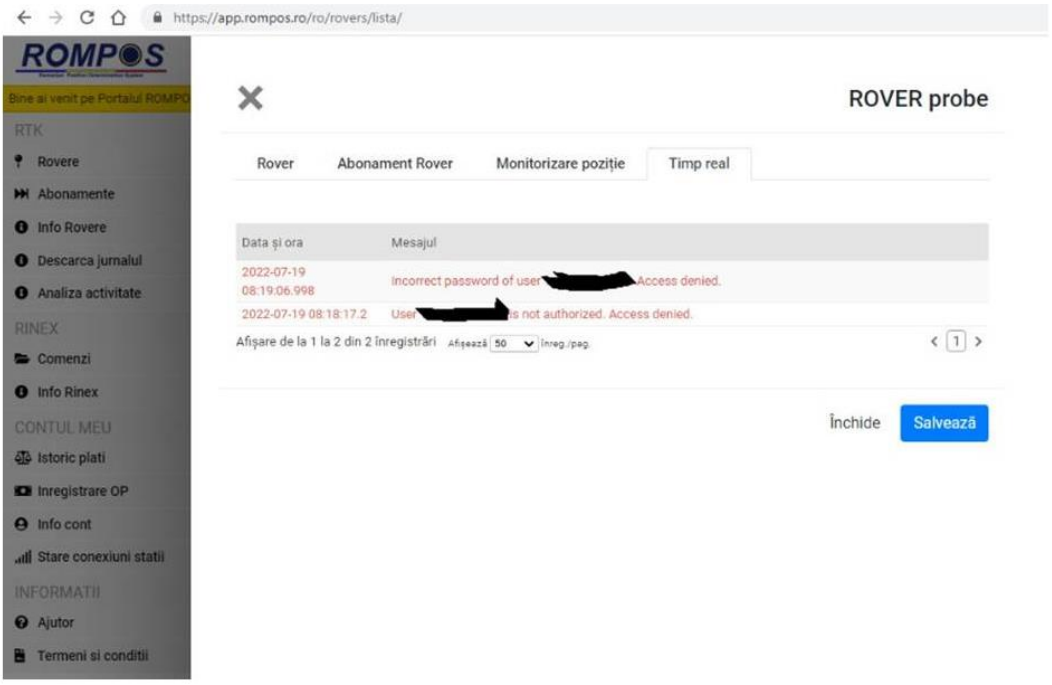

Figure 1.8: "Real-time" Module

Contracting services for the production of orthophoto maps for Bucharest Municipality, county capitals, municipalities, and cities throughout Romania.

1.1.3. Other GNSS permanent networks

GEOPONTICA

GeoPontica is GeoEcoMar's permanent GNSS station network, consisting of 13 permanent GNSS stations and operational since 2013. This network is part of the EUXINUS Black Sea Hazard Monitoring and Warning System (*www.euxinus.eu)* operated by GeoEcoMar and aims to monitor the geodynamics of the Western Black Sea coastal region.

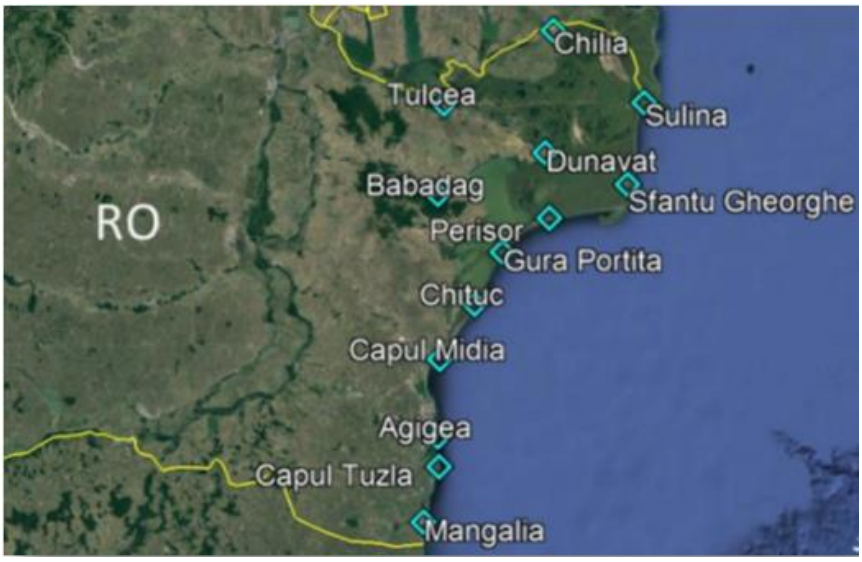

Figure 1.9: GeoPontica, GeoEcoMar's network of permanent GNSS stations

The main components of GeoPontica permanent GNSS stations:

- Monumented geodynamic pillar, drilled or embedded in live rock. The "deep drilled braced monument" construction solution was chosen in accordance with UNAVCO specifications. The height of the geodynamic pillar does not exceed 2 m and its footprint is approximately 2.5 m2.
- Topcon Net-G3A GNSS receivers.
- The laboratory-calibrated assembly by Geo++ GmbH / GeoService GmbH, consisting of the Topcon CR-G5 GNSS antenna, the antenna mast and the antenna dome.
- Auxiliary sensors: inclinometer, Vaisala WXT520 automatic weather station.
- Power system: 220V mains, batteries and photovoltaic panels.
- Communication system: GPS/GPRS, public internet.
- Equipment protection enclosure.

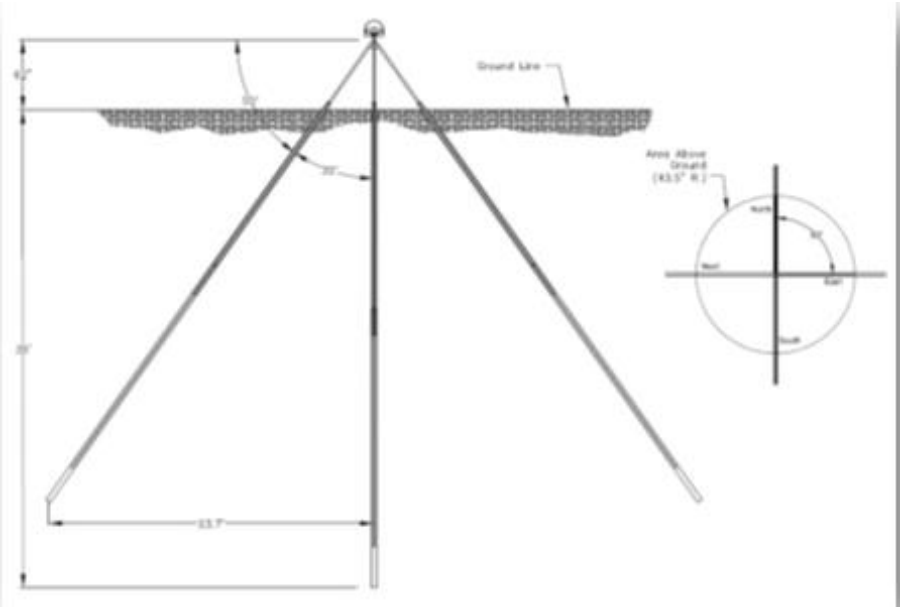

Figure 1.10: Monumented geodynamic pillar of GeoPontica permanent GNSS stations

GeoPontica network of permanent GNSS stations provides continuous (24/7) satellite data at 1s intervals.

Data acquisition is done in real time, the recorded data are in RAW DATA and RINEX v.3 format and are available on a dedicated NAS (Network attached storage) at the Euxinus Centre in Constanta and also on a dedicated server at GeoEcoMar Bucharest.

The GNSS raw data is open access, provided on the basis of an official request, according to internal procedures approved within GeoEcoMar, and made available through an FTP service or a push service, to the requested destination. Access is via a secure VPN (Virtual Private Network) connection, where the end-user will be given a username and password.

Within GeoEcoMar, the GNSS data processing is done using the Topcon Tools software package and recently the Magnet Tools software package.

By courtesy of Dr. Robert W. King (MIT, Department of Earth, Atmospheric, and Planetary Sciences) GeoEcoMar received free of charge, for research purposes, the installation kit and user rights to the GAMIT/GLOBK software package for GNSS data processing which was developed by specialists from the Massachusetts Institute of Technology (MIT) - Department of Earth, Atmospheric, and Planetary Sciences, Scripps Institution of Oceanography and Harvard University.

GeoPontica products:

- Differential solutions for series of 5 days, related to IGS station - BUCU (Bucharest) - internal product;
- Differential daily solutions (24h), related to EUREF - IGEO station (Chișinău, Republic of Moldova / East-European platform) - internal product;

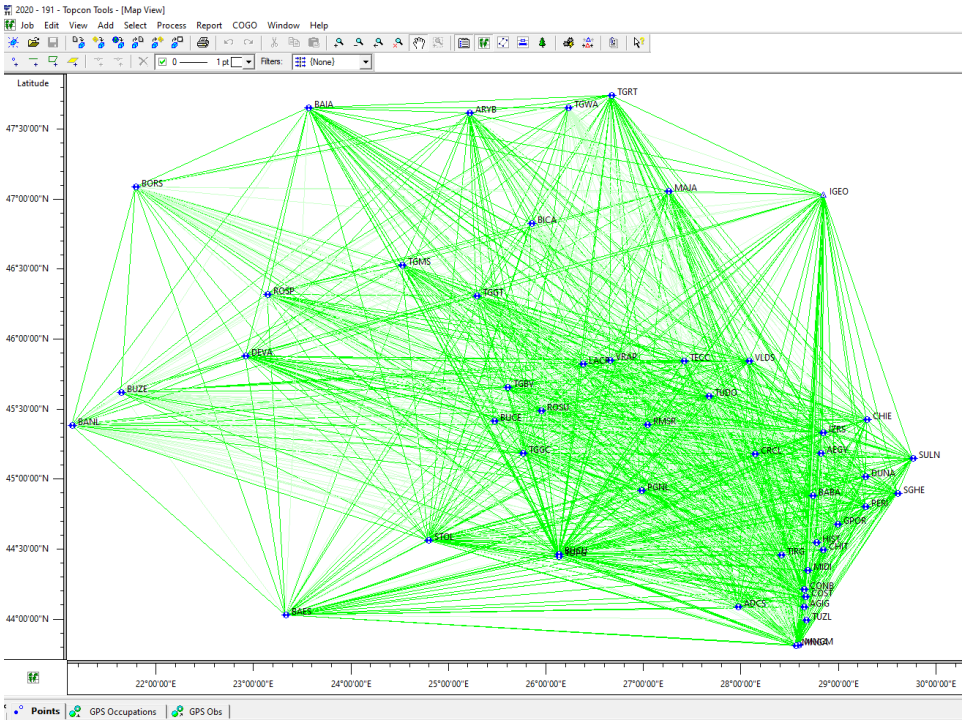

Figure 1.4: Example: Configuration of the GNSS stations (blue dots) and vectors (green lines) of the differential solution of the day 191 of the year 2020 (i.e., 10.07.2020), using Chisinau (acronym IGEO, marked with blue triangle) as reference station. Print-screen from Topcon Tools.

- Crustal deformation maps (vertical and horizontal) - internal product.

GNSS daily solutions were further used for assessing the PSInSAR processing at local and regional scale.

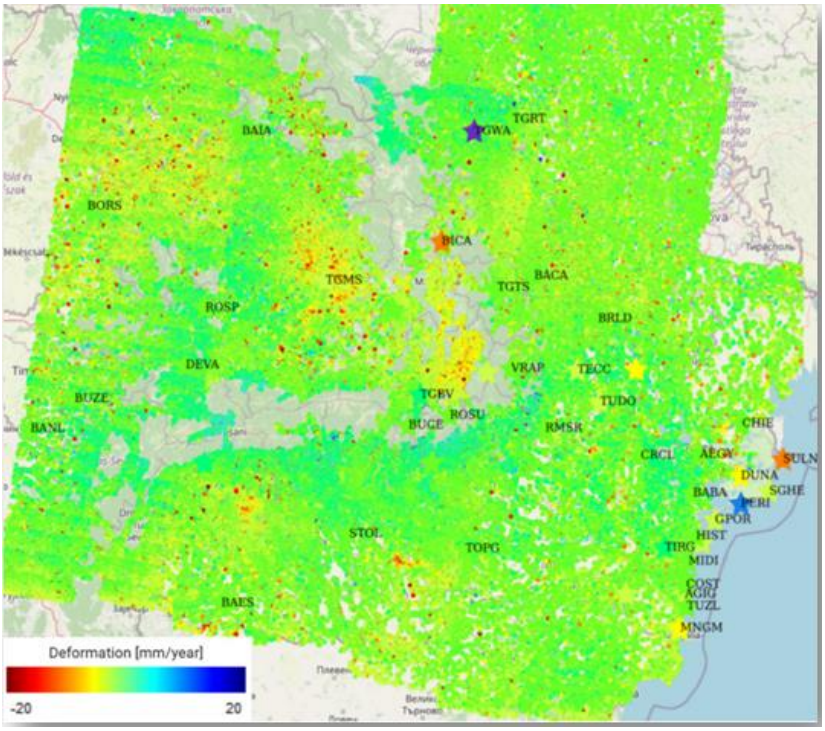

Figure 1.52: Example: GNSS daily solutions used for assessing the PSInSAR processing in Poncoş et al. 2022 (https://doi.org/10.3390/rs14041046)

Currently, the GNSS data provided by GeoPontica is integrated and made available through the SETTING project (https://setting.epos-ro.eu/), the preparatory phase of EPOS-RO (https://epos-ro.eu/). EPOS-RO is facilitating the integration and use of data, products and services from national research infrastructures in the field of Earth Sciences, as Romania's participation to EPOS ERIC (https://www.epos-eu.org/).

TRIMBLE VRS NOW Services

Trimble Company realized in USA and Europe, GNSS services based on GNSS permanent station networks. Trimble services are known under the name „Trimble VRS Now" due to the VRS (Virtual Reference Station) concept implemented for the first time by this company. *Trimble VRS Now* includes real-time services DGNSS and RTK. Starting with 2012, *Trimble VRS Now* services are available in Romania. These services are provided in Romania based on a GNSS permanent network including 9 GNSS permanent stations installed in the area (Figure ***1.6***). There are a various number of GNSS receivers able to work with *Trimble VRS Now* services, able to process CMR and CMR+ data formats. Such equipments are provided mainly by *GISCAD SRL* company in Arad. Access to these services can be realized by *SYSCAD SRL* company in Bucharest. There are available few types of registration (monthly, yearly). There are *first private DGNSS/RTK services* provided in Romania by a private company *with full country coverage*.

Figure 1.63: Trimble VRS Now GNSS permanent stations in Romania

Leica TGREF Services

Leica Geosystems company realized in last few years DGNSS/RTK services based on GNSS permanent networks under the name of „Leica SmartNet" in Europe and other areas [http://www.smartnet-eu.com/]. In Romania, Leica Geosytems represented by TopGeocart SRL company established a GNSS permanent station network named *TGRef* including 8 stations and DGPS, RTK (single base) and post-processing services. RTK service transmits corrections in Leica proprietary format.

Figure 1.74: Leica TGRef permanent stations in Romania

Topo Service (GNSSPos) Services

Topo Service GNSS permanent network includes 44 stations situated in Romania, Bulgaria, Serbia, Macedonia and Moldova.

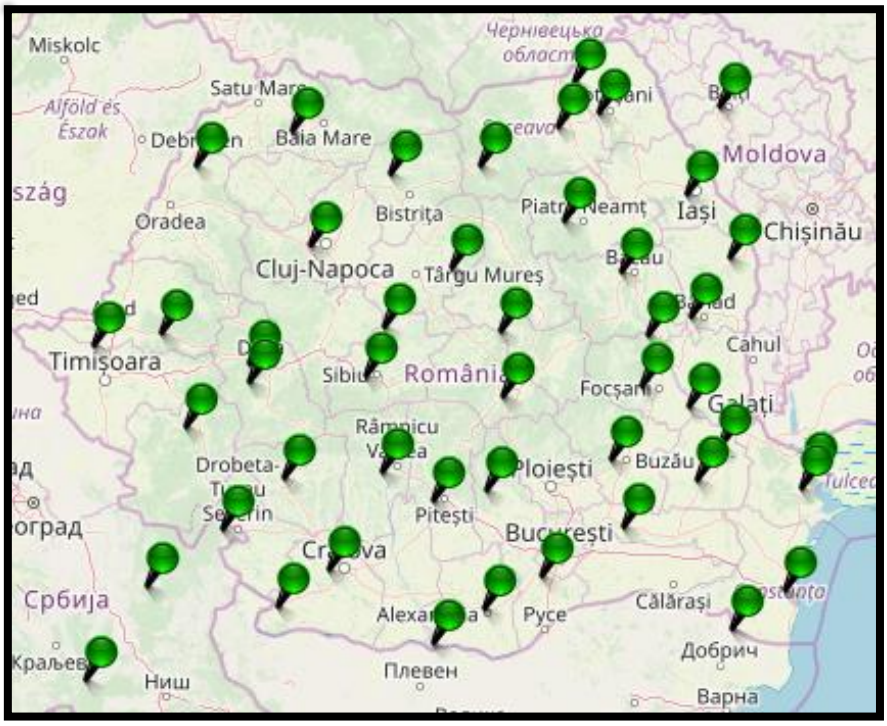

Figure 1.85: Topo Service GNSS permanent stations
[https://webapp.pivot.gnsspos.ro/Map/SensorMap.aspx]

Topo Cad Vest Services

Topo Cad Vest is a private network of 19 permanent GNSS stations across Romania, and 4 additional stations located in Bulgaria near the Romanian border.
At present, it is intended to put into operation another 14 stations (blue ones in Figure 1.15).

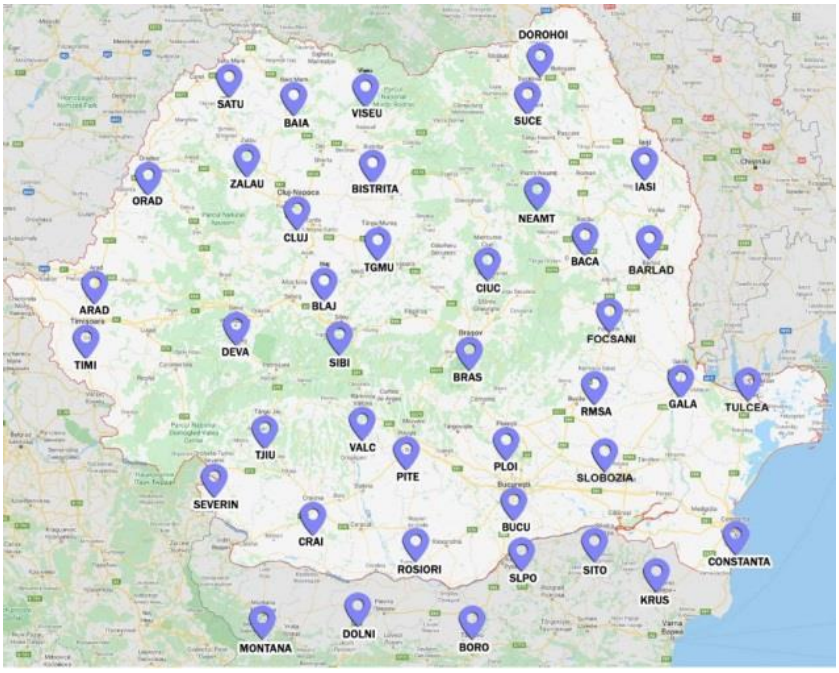

Figure 1.96: Topo Cad Vest permanent stations
[https://www.topocadvest.ro/produs/cont-statii-de-referinta]

INCDFP (National Institute for Earth Physics) GNSS Network

National Institute for Earth Physics developed a regional GNSS/GPS network for monitoring deformations in the Carpathian-Danubian-Pontic space and studying the impact of local earthquakes.

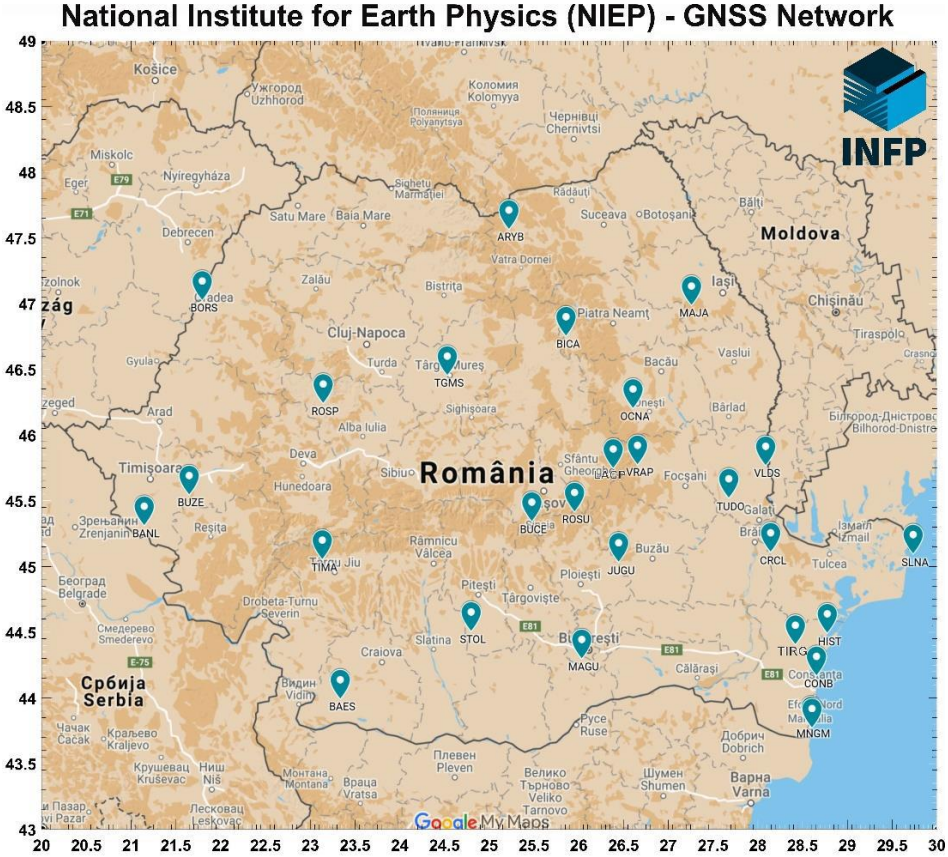

Figure 1.10: INCDFP GNSS Network

The modern GNSS/GPS network (Global Navigation Satellite System, Global Positioning System) was designed and implemented starting from 2001 when the first permanent station was installed on Mount Lăcăuţi, in the curvature zone of the Eastern Carpathians, west of the epicentral area of Vrancea. The network currently consists of 24 operational stations and 3 stations under construction for the year 2017. The main objectives can be highlighted as follows: surface monitoring of crustal movements occurring within and around the Romanian Carpathians, as well as neighboring tectonic units, as a direct result of tectonic processes at a global scale (e.g., the interaction between the Eurasian Plate and the African Plate) and observations regarding crustal movements to better understand the surface-depth interconnection of earthquakes in the Vrancea area.

The GNSS/GPS station network can also provide reliable and highly precise measurements for global weather forecasts, climate monitoring, seismic precursors, ionospheric studies, co-seismic studies, GNSS positioning and navigation, and other complementary research purposes.

SYSCAD RTK GNSS Network

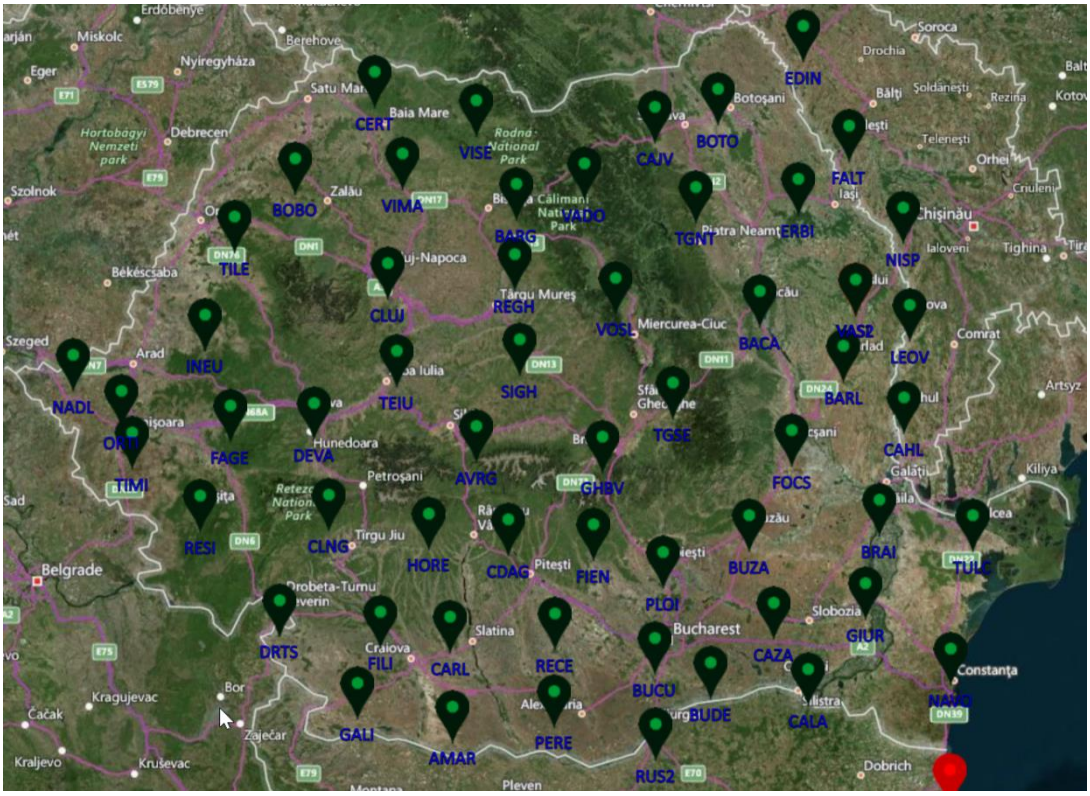

Figure 1.11: SysCAD GNSS Network

This network is developed by SysCAD Solutions company and is validated by the National Agency for Cadastre and Land Registration (ANCPI) and the National Cartography Center (CNC). The network consists of 59 permanent stations, of which 51 are located within the national territory, and 8 are established through partnerships with the Republic of Moldova and Bulgaria. The network utilizes all available constellations (such as GPS, Beidou, GLONASS, and Galileo), including VRS (Virtual Reference Station) and Nearest techniques.

RTK PREMIUM GNSS Network

The RTK Premium network offers highly accurate measurements with a precision of less than 1.5cm. It consists of over 2,000 strategically placed base stations with an average baseline of 60km, ensuring comprehensive coverage for reliable data acquisition.

With an uptime of 99.98% since 2018, users can rely on uninterrupted access to precise positioning services. The network employs the standard RTCM format, making it compatible with all GNSS devices and brands.

The RTK Premium network provides full European coverage, enabling seamless cross-border functionality. It allows users to conduct accurate measurements and surveys across different regions without limitations.

Furthermore, the RTK Premium network utilizes certified ETRF coordinates, ensuring accuracy and consistency with European Terrestrial Reference Frame standards (ETRF) for 2022.

Figure 1.12: RTK Premium GNSS Network European coverage [https://www.rtkpremium.ro/]

1.1.4. SiMonA Project

SiMonA Project was dedicated to the realization of the prototype system based on GNSS in order to provide a low cost System for Monitoring of the Rockfill Dams. The project was realized by a research group from the TU of Civil Engineering Bucharest, Research Centre on Spatial Geodesy, Photogrammetry, Remote Sensing and GIS (GEOS). A GNSS system that is built starting from the U-blox ZED-F9P receiver, integrated on a development board produced by SparkFun was connected to the Raspberry Pi 4 Model B single-board computer. The Raspberry Pi computer and the development board made by SparkFun allows great flexibility in making such a system. Physical and logical connections between all the equipment used and, also, several programs made in the Python programming language for different applications were designed and realized for this custom-built system. These applications may include geodetic monitoring, real-time kinematic measurements, using the system as a permanent station or RTK correction server.

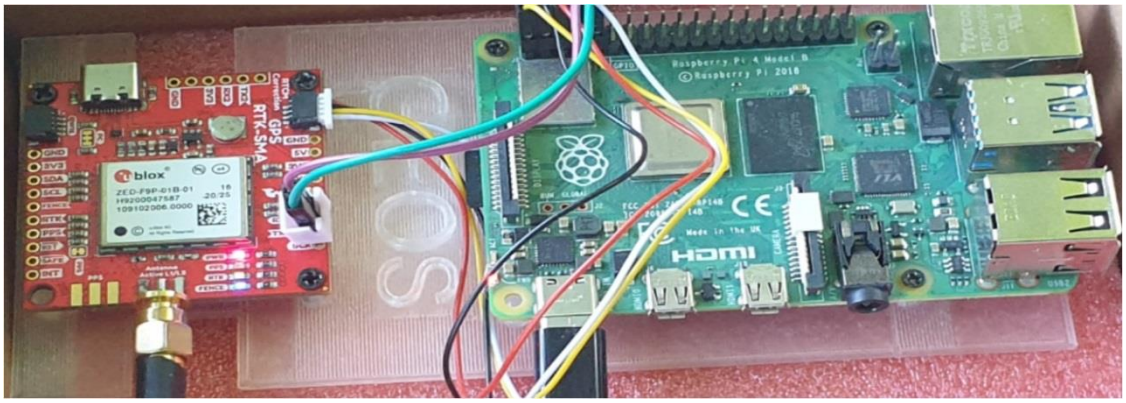

Figure 1.13: GNSS receiver and microcomputer to realize a GNSS permanent station

A set of three such systems including GNSS antenna and UPS (powerbank) were integrated and installed at a rockfill dam in Romania.

Figure 1.14: SiMonA components integrated and tested

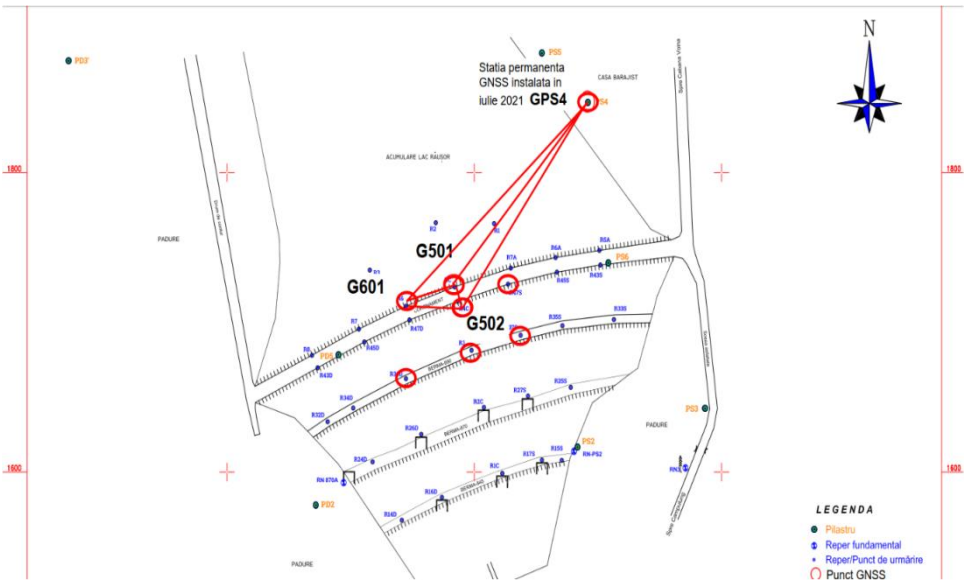

Figure 1.15: SiMonA system installed in the geodetic network of the dam (GPS4 – stable point, G501, G502, G601 – moving points)

A connection between the historical local geodetic reference system and the spatial (satellite) geodetic reference system need to be introduced. The mathematical model required for such a coordinate transformation is simple, but the choice of common points necessary to determine the transformation parameters is of particular importance. These points must belong to the category of stable points, which can be considered as having fixed coordinates. Their choice will be made by using *stability tests.* In many cases, at the rockfill dams, it is found that the number of stable points is minimal (2), reaching a limit situation. It is preferable to have a larger number of such points in the network. In the case of installing a continuous dam monitoring system based on a network of permanent GNSS stations, such stations should be installed and in the stable / fixed points of the network. In some cases this condition is difficult to achieve if the points are located on slopes in areas covered by vegetation and therefore with poorer satellite "visibility". As possible solutions would be the installation and operation only in the seasons with low vegetation (autumn-winter), when however a connection with these points can be made and / or the use of classical terrestrial technologies (total station) for the connection with these points.
It is not possible to install GNSS antennas in all monitoring points, but the representative points for the behavior of the dam will be chosen under the action of specific forces (water level, temperature, precipitation), and to meet the conditions satellite “visibility” conditions.
The pilot project SiMonA demonstrated with a low cost (less than 5000 euros) the possibility to introduce GNSS technology for the dam deformation studies as long as a lot of dams in Romania have old working time (more than 50 years). The four constellation (GPS, GLONASS, GALILEO, BEIDOU) miniaturized receivers and computers have a lot of benefits in data acquisition, data storage and dissemination by wireless communication into a cloud at long distance. The project demonstrated the GNSS performances for continuous dam deformation monitoring. Extended at a large scale, GNSS technology fitted to this objective can be a spatial geodetic solution for the long term evolution of large constructions as dams. Use of the space monitoring infrastructure created in the dam area will *facilitate testing of other systems and technologies*, such as UAV systems combined with laser scanning technology (LIDAR) for large structures monitoring.

1.1.5. Leveling Network - Romanian Contribution to EVRS Realization

The National Leveling Network it is divided in 5 orders (function of precision). The National Precise Leveling Network of I^{st} order consists in a number of 19 polygons with a length of 6600 km and includes 6400 points with a density of 1 point/km^2. 24 leveling lines establish the connections with neighbour countries: 2 with Ukraine, 1 with Republic of Moldova, 6 with Bulgaria, 10 with Serbia/Montenegro and 5 with Hungary.
This network was densified till 32 polygons with levelling networks of II^{nd} -V^{th} order (Figure ***1.16***). Normal heights are available for the National Leveling Network.

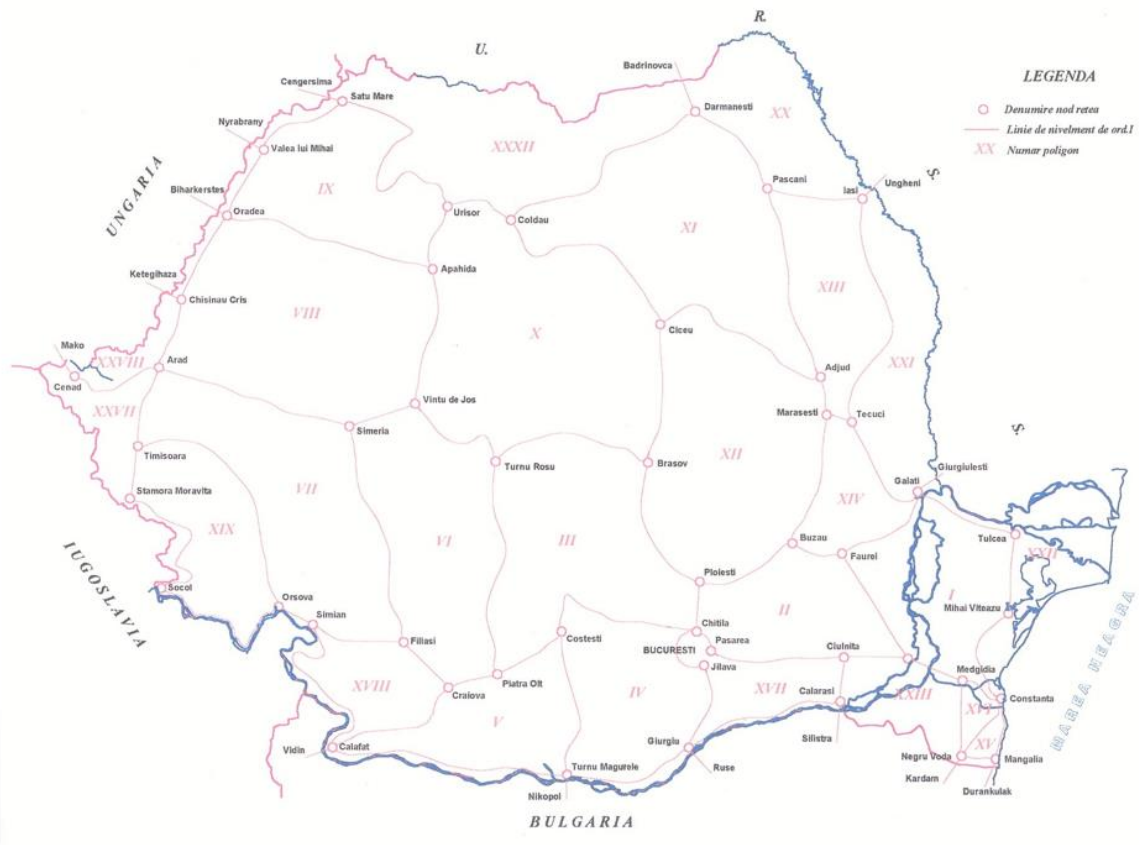

Figure 1.16: Romanian Leveling Network

The Romanian contribution to UELN (2000) contains the nodal points of the polygons of first order (65 points) and 89 levelling observations.

In 2007 the National Agency for Cadastre and Land Registration introduced officially the results of a new adjustment of the leveling network performed by National Center for Geodesy, Cartography, Photogrammetry and Remote Sensing and Technical University of Civil Engineering Bucharest as “Black Sea 1975 datum (Edition 1990)”.

The EUVN97 (European Unified Vertical Network 1997) included 4 points from the Romanian Levelling Network: RO01 (Sirca-Iasi), RO02 (Constanta), RO03 (Timisoara) and RO04 (Tariverde – Height 0) points measured with GPS technology and absolute gravity. For these points the known ETRS89 coordinates and normal heights (precise levelling) in Black Sea 1975 datum were determined together with absolute gravity.

For the ECGN project in September 2004, Austrian Federal Office of Metrology and Surveying (BEV– Bundesamt fuer Eich-und Vermessungswessen) in cooperation with Romanian National Agency for Cadastre and Land Registration (NACLR) and Military Topographic Directorate, performed an absolute gravity observation campaign in Romania. A number of 4 absolute gravity stations were observed by JILAg-6 absolute gravimeter. Romania participated with such information to the EVRS realization - EVRF2000 and EVRF2007.

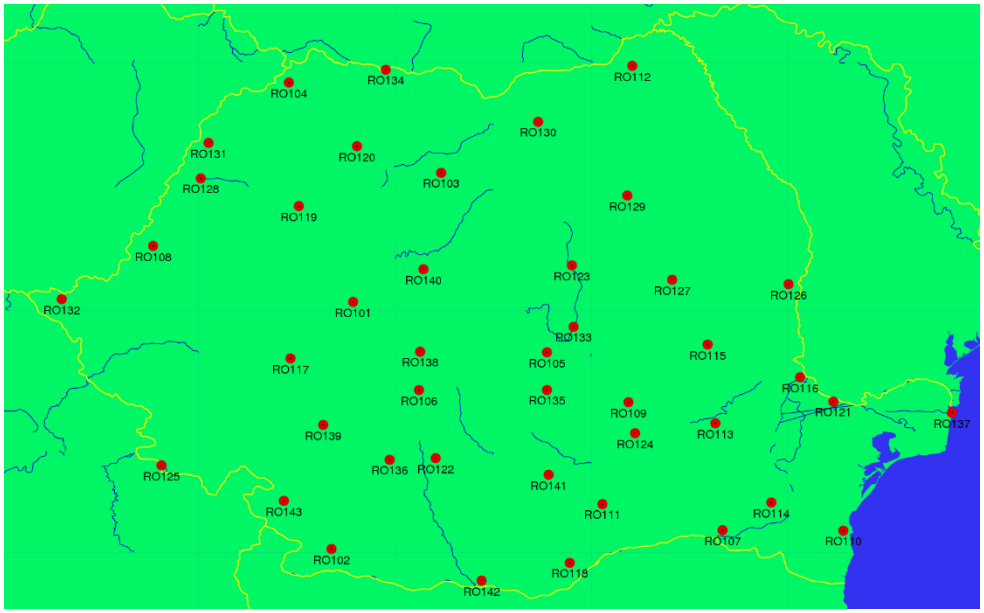

Figure 1.17: Romanian contribution to EUVN_DA project

After 2000 year Romania further contributed by providing new data including 43 stations with ETRS89 ellipsoidal heights and normal heights in national height reference system (Figure ***1.17***). This was the contribution to the EUVN_DA (Densification Action) project with final result the EVRF2007 realization. 25 European countries participated and submitted the data of more than 1500 high quality GPS/leveling benchmarks. The submitted data was validated and converted into uniform reference frames. The final report was discussed at Technical Working Group meeting and presented at the EUREF2009 symposium, held in Florence (Italy). The results were circulated to all contributing National Mapping Agencies including Romanian National Agency for Cadastre and Land Registration.

As a final EVRF2007 realization in Romania, a standard transformation parameters were computed by EVRF computing center from Federal Agency for Cartography and Geodesy (BKG, Germany). These set of parameters realize the transformation of normal heights from Black Sea 1975 System to EVRF2007 (RO_CONST / NH to EVRF2000 and EVRF2007).

Transformation parameters were derived from 48 identical points (UELN nodal points) with a transformation RMS of 0.004 m, and residual deviation between -0.012 m and +0.013 m.

A general view of the EVRF2007 realization in comparison with national height reference systems can be seen on the next picture.

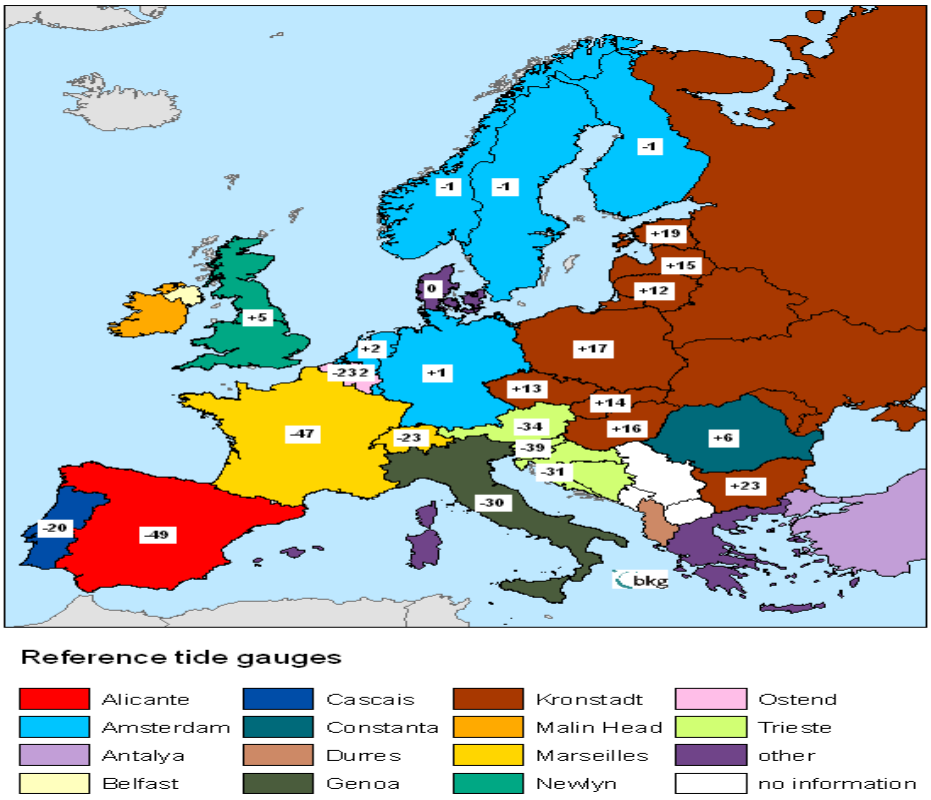

Figure 1.18: Mean differences between EVRF2007 and national height reference systems (+6 cm Romania)

In 2009, NACLR finalized the coordinate transformation including a distorsion model from ETRS89 system to S42 (Krasovski ellipsoid) – Stereographic 1970 projection system and provided *TransDatRo* software and algorithm for the users.

Transformation of normal heights from Black Sea 1975 System to EVRF2007, finalized at the present moment, complete the most recent link between the national coordinate reference systems and pan-European systems. NACLR included this option in the software package for coordinate transformation *TransDatRO* which is published on internet and was implemented on national geoportal for spatial data harmonization and interoperability. The transformation parameters were published on the on-line information system *(http://www.crs-geo.eu/),* which contains the descriptions of the different national Coordinate Reference Systems (CRS) for position in Europe as well as the transformation parameters from the national systems to the ETRS89 according to the ISO standard 19111 Geographic information - Spatial referencing by coordinates.

- The GNSS permanent stations included in the national GNSS reference network, are connected by leveling with the national leveling network (precise leveling close to the building and than precise trigonometric leveling to the antenna).
- A leveling campaign was started by NACLR in 2010 and was continued in 2011 and 2012 in the metropolitan area of Bucharest. The goal of the project was to establish and densify the national leveling datum for this area by

precise (geometric) leveling. The project included gravity observations in this area in order to compute a local quasigeoid (+/- 5 cm rms).

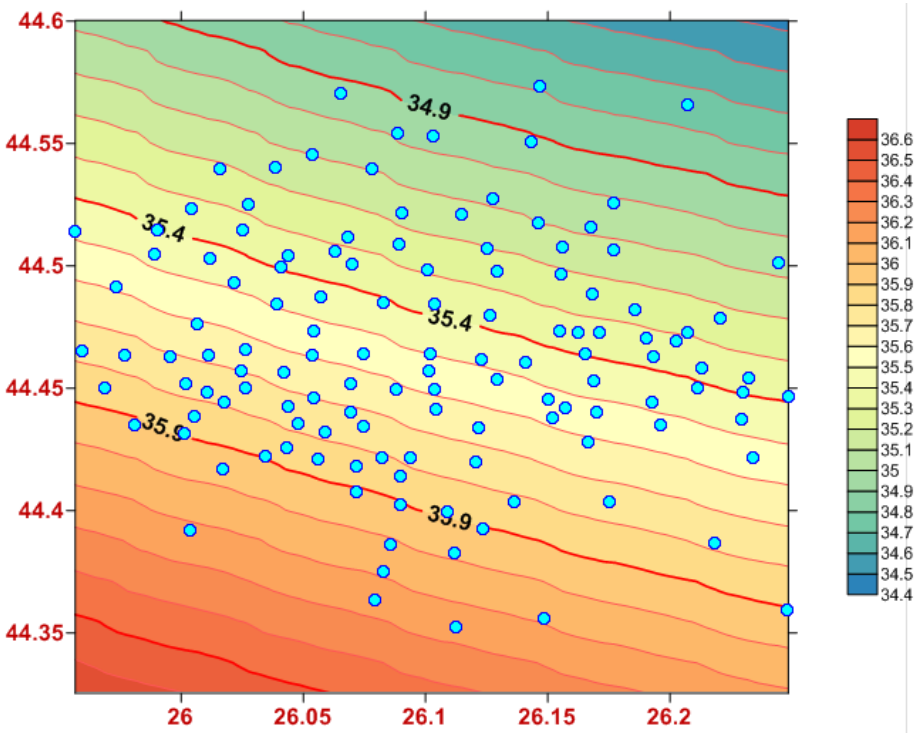

Figure 1.19: Local quasigeoid for Bucharest and Ilfov county (129 points observed)

In the last six years determination of the new gravimetric quasigeoid of Romania was started in parallel with continuation of GNSS/leveling observations in order to contribute to this project. In a number of thirty counties (from 42) the observations were done and the results are included in the new version (4.08) of *TransDatRo* software.

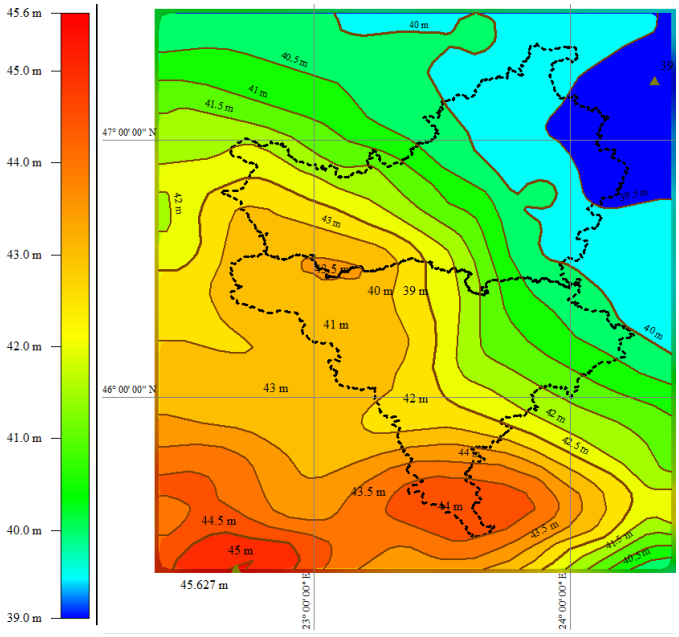

Figure 1.20: Local quasigeoid for Alba and Cluj counties (preliminary results)

Performing relative gravimetric measurements within the territory of Romania and determining a national-level gravimetric quasigeoid model.

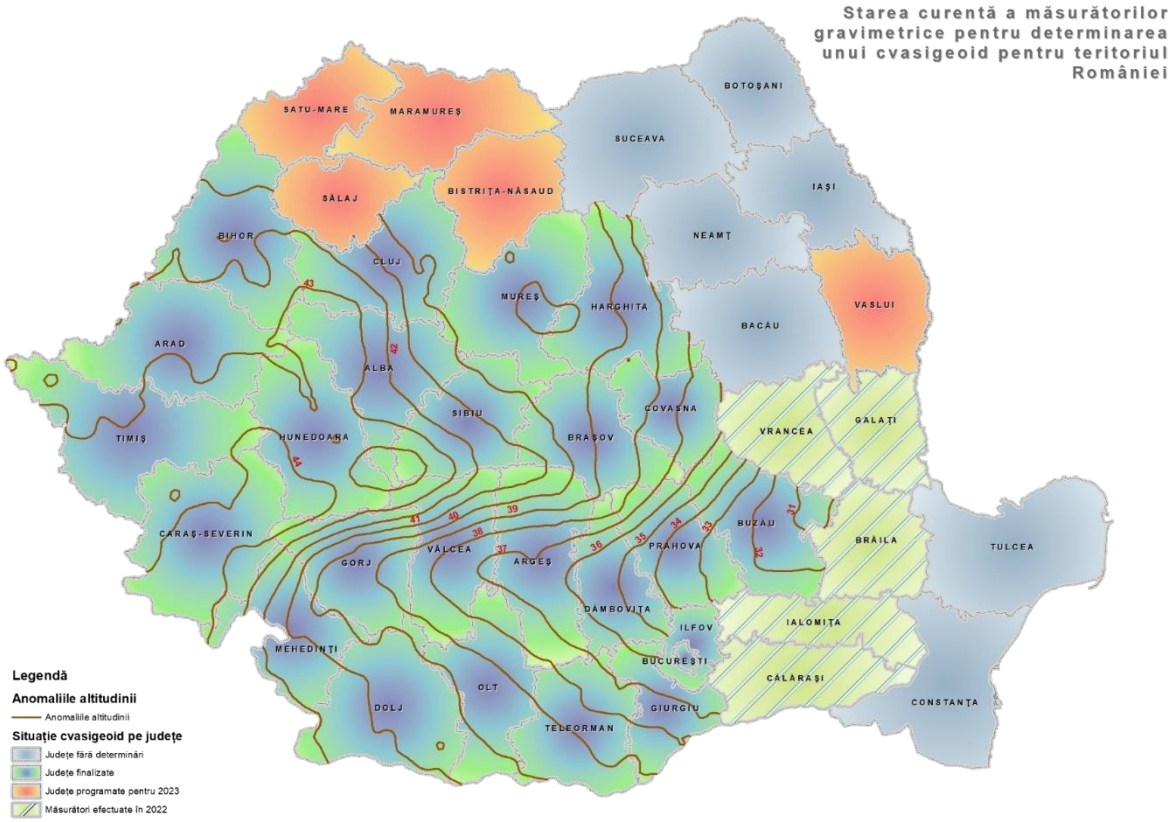

Figure 1.21: Current status of field measurements and development of the national-level gravimetric quasigeoid model.

1.2. Advanced Space Geodesy

1.2.1. EUPOS (European Position Determination System)

Romania participates by National Agency for Cadastre and Land Registration at the EUPOS (European Position Determination System). The EUPOS initiative is an international expert group of public organizations coming from the field of geodesy, geodetic survey and satellite deployment. Partners from CEE (Central and East European) countries have come together with the aim to establish in their countries compatible spatial reference infrastructures by using the Global Navigation Satellite Systems (GNSS) GPS, GLONASS, GALILEO and BEIDOU by building up Differential GNSS *EUPOS* reference station services. The *EUPOS* services *(RTK, DGNSS and Geodetic)* will allow a high accuracy and reliability for positioning and navigation and provide a wide range of geoinformation applications on this basis.

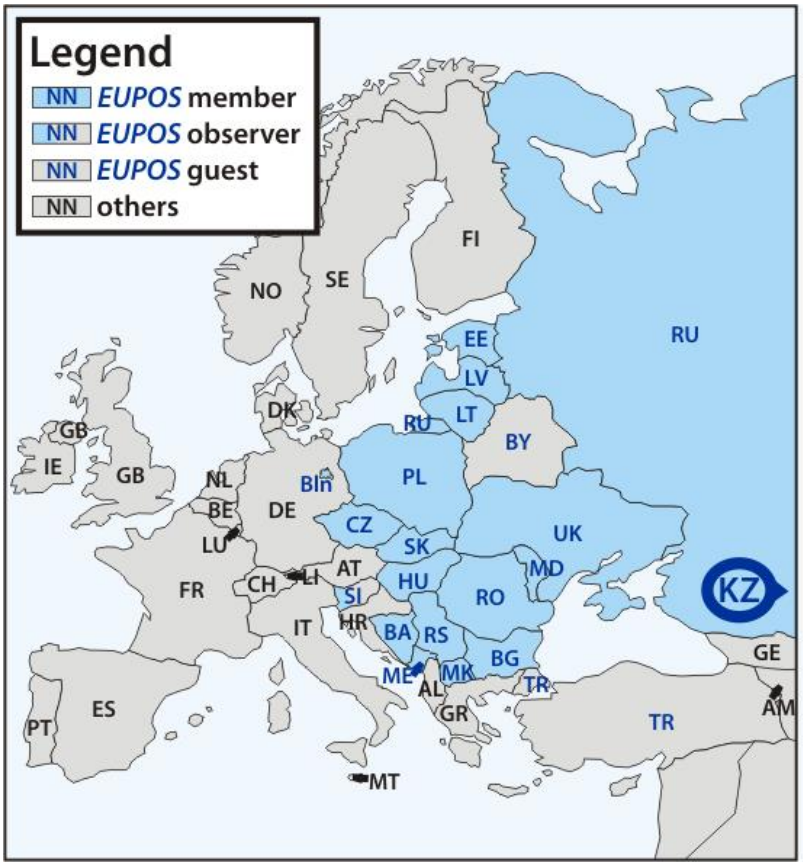

Figure 1.22: Distribution of EUPOS members (www.eupos.org)

Members of the *EUPOS* cooperation (2011) are topically Bosnia and Herzegovina, Bulgaria, Czech Republic, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Ukraine and the German State Berlin. Slovenia has an observer status.

This fundamental infrastructure is based technically on a network of DGNSS reference stations and adequate communication lines. The data products can be used in many different applications requiring accuracy better than 3 m up to the 1 cm level in real-time *(DGNSS and RTK services)* and sub-centimeter precision by post-processing *(Geodetic service)*. This “full scale accuracy” concept aiming all types of users from environmental protection, transport and public security, hydrography, maritime surveying, river and maritime traffic, fishing, machinery and vehicle control, to spatial data infrastructure developers and to geodesy. *EUPOS* is independent of private company solutions and uses only international and unlimited worldwide usable standards. In case international agreed standards do not exist, *EUPOS* is working on the standardization in the corresponding organizations like the Radio Commission on Maritime Services, Special Committee 104 (RTCM SC 104). *EUPOS* provides the GNSS observation data and real-time corrections for high precise positioning and navigation with guaranteed availability and quality.

The responsibility of developing and operating the *EUPOS* reference station network is distributed among participating organizations on national level, which give the characteristic flavor of the organization. The backbones of the developments are the

International *EUPOS* Steering Committee (ISC) and the National Service Center (NSC) concept, that requires the establishment of a NSC in every participating country.

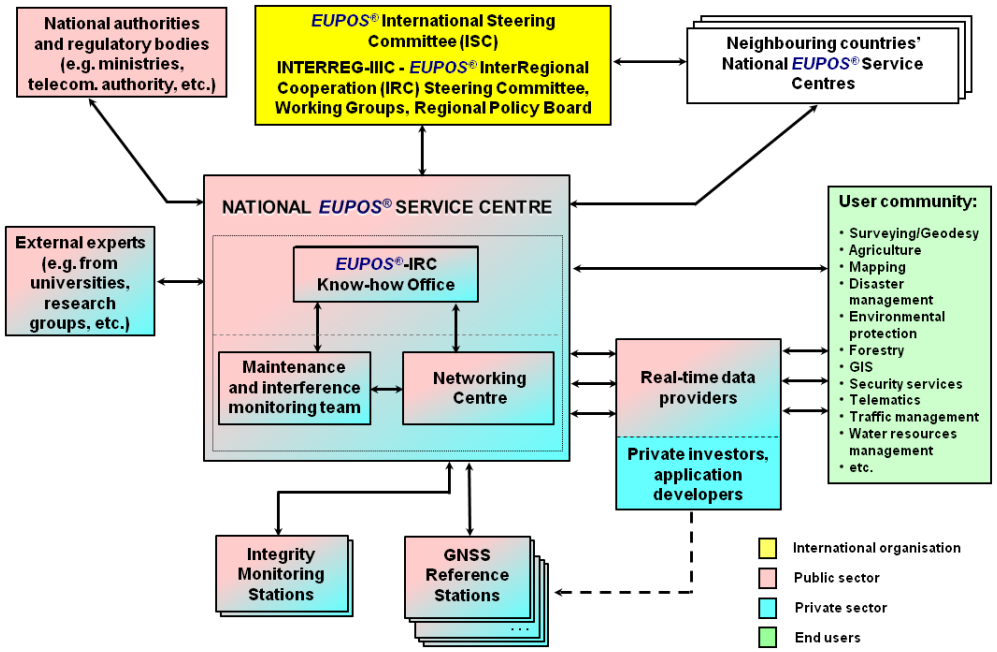

Figure 1.23: EUPOS National Service Centre structure

The NSCs are responsible not only for network developments and operation, but they are the focal points of user information, quality and integrity assurance and international relations with other *EUPOS* countries. The International *EUPOS* Steering Committee decides and agrees the organizational and technical framework of *EUPOS*. The ISC Office (ISCO) at the Senate Department for Urban Development in Berlin/Germany is the central point of contact for interests of international importance.

With the creation of the European Terrestrial Reference System (ETRS 89) in 1989, a three dimensional geodetic reference system became available for the whole Europe for the first time. Its spatial referencing connection is maintained up-to-date, notably through the EUREF Permanent Network (EPN), which contains the European stations of the International GPS Service (IGS). The ETRF base on the worldwide ITRF. *EUPOS* provides DGNSS correction data referred to ETRS.

NACLR has implemented in September 2008 the EUPOS services by Romanian Position Determination System (ROMPOS) according to the EUPOS standards based on the GNSS network with 48 permanent stations. Since 2010 the station number increased to 58 and was finalized in 2012 at 74 stations with station's spacing of about 70km.

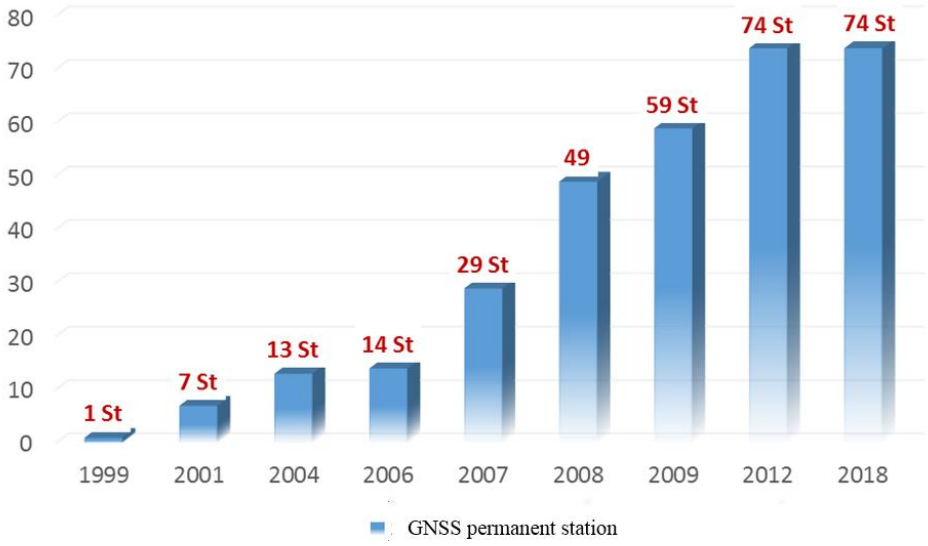

Figure 1.24: ROMPOS GNSS permanent stations evolution

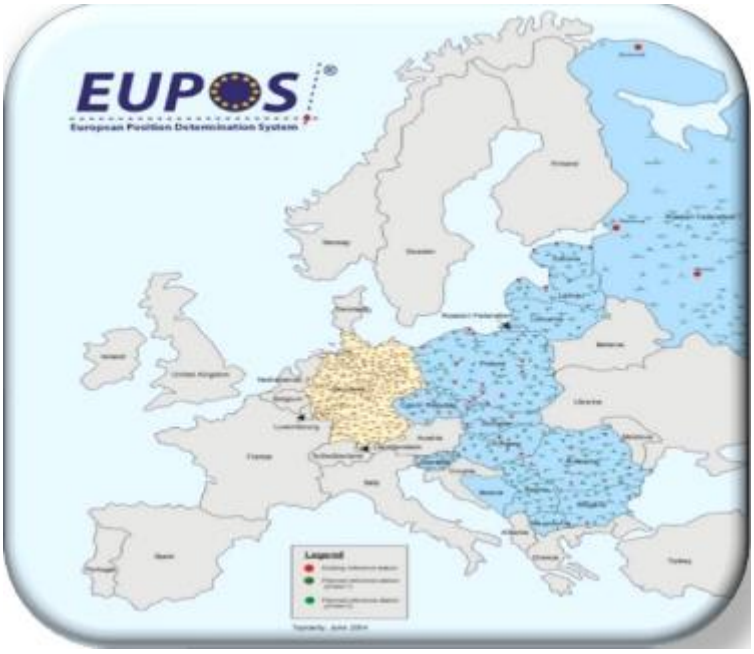

Figure 1.25: EUPOS countries and GNSS permanent stations

ROMPOS services include three services:

- *ROMPOS DGNSS* for real-time DGNSS applications by code and code-phase measurements with meter up to sub-meter accuracy;
- *ROMPOS RTK* for real time DGNSS applications by carrier phase measurements with centimeter accuracy;
- *ROMPOS Geodetic* for post processing applications by code and phase measurements in static or kinematic mode with decimeter up to sub-centimeter accuracy.

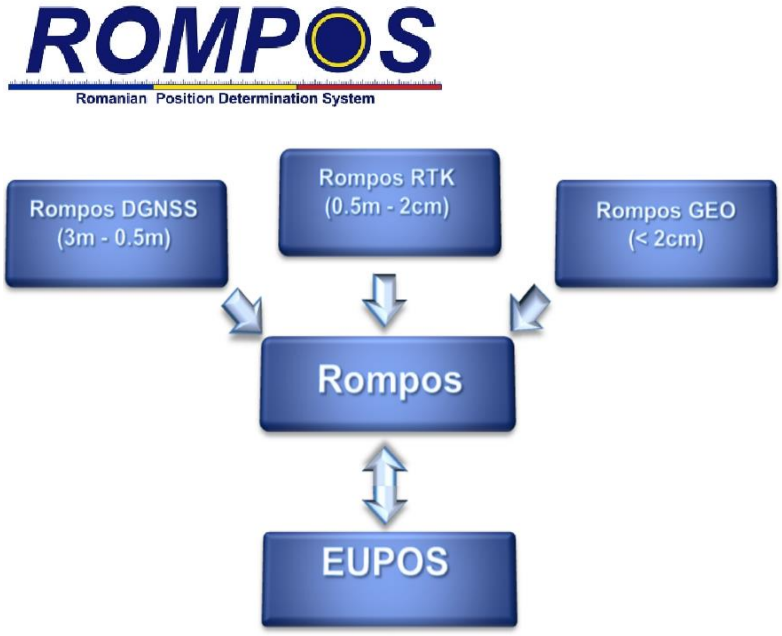

Figure 1.26: ROMPOS (Romanian Position Determination System) Services

In the EUPOS frame, Romania established a very closed cooperation with specialists from EUPOS countries including all neighbor countries (Bulgaria, Serbia, Hungary, Ukraine and Republic of Moldova). GNSS cross-border data exchange was technically already realized between GNSS stations from Romania and agreements are signed with Hungary (updated 2016), Moldova (2010), Ukraine (updated 2015), Bulgaria (2015) and Serbia (2015).

In addition to the standard quality check procedures provided by commercial GNSS permanent network software, a new procedure it is developed under EUPOS umbrella and ROMPOS stations are included in the pilot tests performed.

New applications of the ROMPOS reference stations will be developed in the near future. Research activities are performed at Technical University of Civil Engineering Bucharest (Faculty of Geodesy) for reference frame establishment (ITRF, ETRF) and cross-border studies, geodynamics, engineering surveying based on GNSS (large structures monitoring) et al.

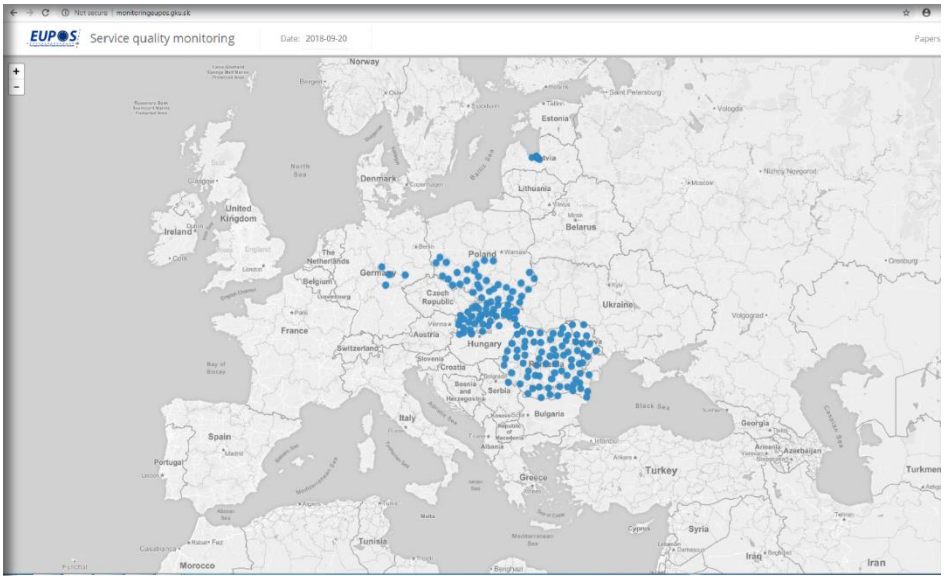

Figure 1.27: EUPOS Service quality monitoring including ROMPOS stations [http://monitoringeupos.gku.sk/]

1.2.2. EGNOS

Known as a satellite-based augmentation system (SBAS), EGNOS provides both correction and integrity information about the GPS system, delivering opportunities for Europeans to use the more accurate positioning data for improving existing services or developing a wide range of new services. EGNOS it is the augmentation system for GALILEO in Europe.

The EGNOS signal is broadcast by three Inmarsat-3 satellites – one positioned east of the Atlantic, and the other above Africa – and by ESA's Artemis satellite, which is also above Africa. These three satellites' orbits are in the equatorial plane, at three different longitudes, with each able to broadcast EGNOS services across Europe. Unlike GPS, EGNOS offers integrity of signal, increased accuracy, coverage and a service level agreement (e.g. alert within specified time). This makes it suitable to provide a number of navigation services. For the most common applications, EGNOS gives a positioning accuracy of one to three meters, compared to the less accurate 10 to 15 m provided by GPS alone. The three services available are:

- Open Service
- Safety-of-Life Service
- EGNOS Data Access Server (EDAS)

The EGNOS *Open Service* has been available since *1 October 2009*. EGNOS positioning data are freely available in Europe through satellite signals to anyone equipped with an EGNOS-enabled GPS receiver. EGNOS Certification is now being managed by the European Commission, who have announced that since *1 March 2011,* EGNOS *Safety-of-Life* signal was formally declared available to aviation. For the first time, space-based navigation signals have become officially usable for the critical task of vertically guiding aircraft during landing approaches. EGNOS provides also a terrestrial commercial data service called the EGNOS Data Access Service

(EDAS). EDAS is the single point of access for the data collected and generated by the EGNOS infrastructure. It supports the multimodal use of EGNOS (and later on Galileo) by disseminating EGNOS' services in real time. In order to understand the market's interest for EDAS data, a beta test was designed and works to allow industry, research institutes, and private and public organizations to free access to EDAS' data. This test provides information to the provider of the EDAS service about potential users and how they use the data.

In Romania EGNOS system it is at present less used and needs a better promotion in order to inform the potential beneficiaries of services. The figure below presents the EGNOS signal acquisition at Faculty of Geodesy in Bucharest (GNSS permanent stations BUCU).

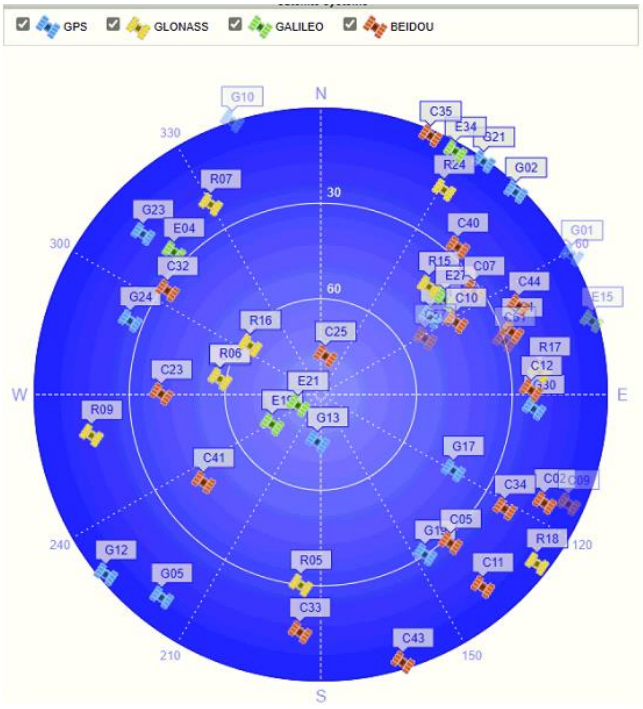

Figure 1.28: GPS, GLONASS, GALILEO, BEIDOU and EGNOS tracking at GNSS/EGNOS permanent station in Bucharest (11401M001 BUCU00ROU)

The tracking data indicate that for this position the elevation angle it is less than 50 degrees for any of the EGNOS satellites.

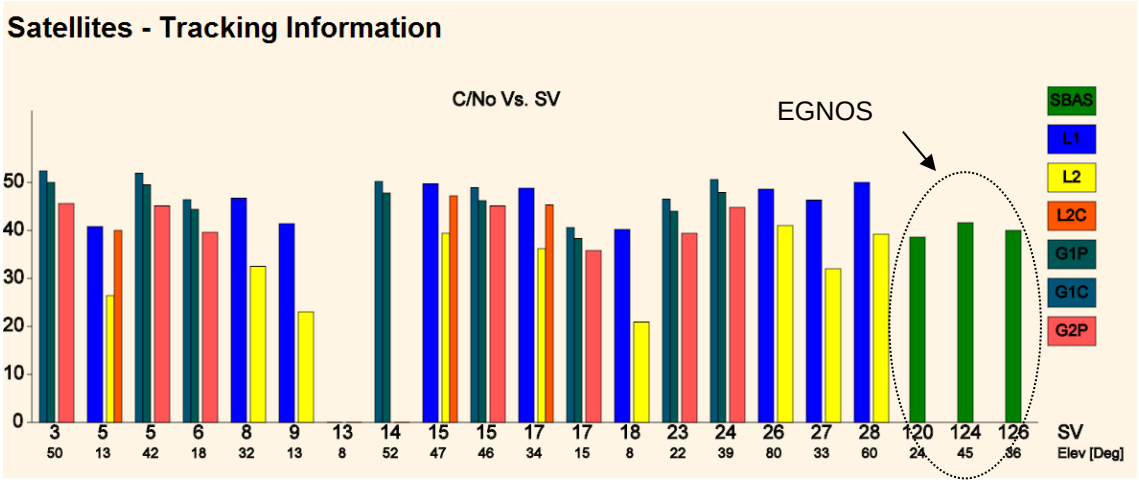

Figure 1.29: GPS, GLONASS and EGNOS signal at GNSS/EGNOS permanent station, Bucharest (BUC1)

A number of about six ROMPOS GNSS permanent stations are capable to provide GALILEO signals in addition to GPS and GLONASS signals.

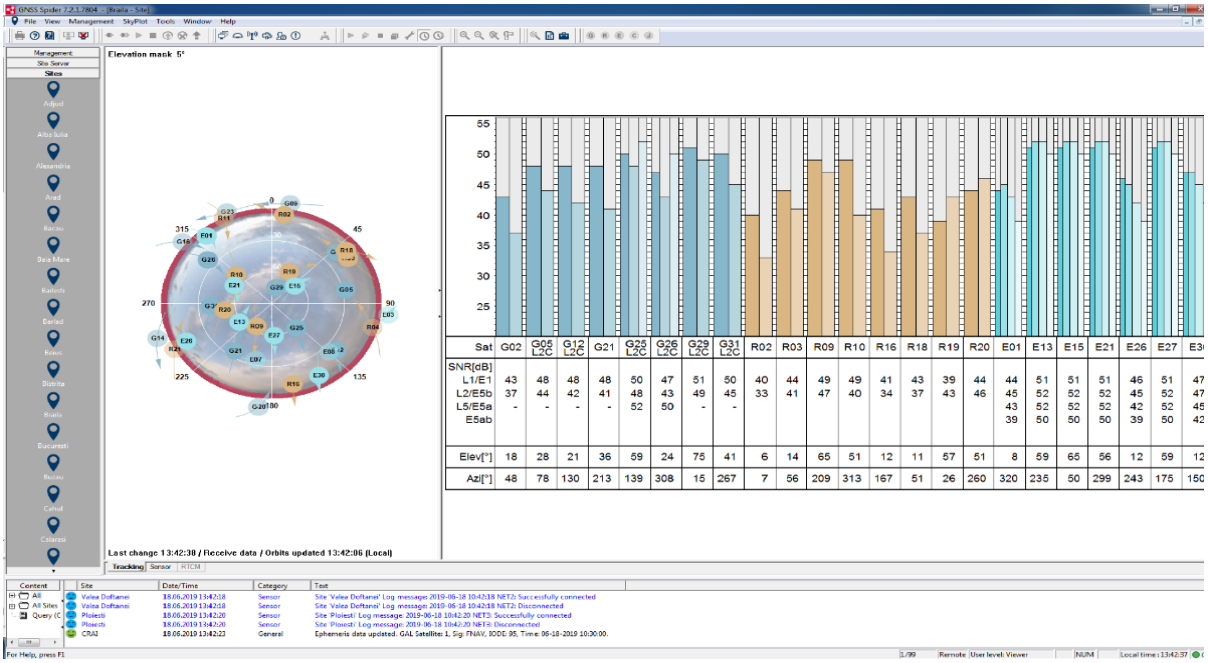

Figure 1.30: GPS, GLONASS and GALILEO signal at ROMPOS stations

GNSS technology evolves at a fast pace and, along with it, the number of applications that are based on this technology increases. An important part of the applicability of GNSS technology is in the field of geodesy. In this article we propose to present a GNSS system that is built starting from the U-blox ZED-F9P receiver, integrated on a development board produced by SparkFun that is connected to the Raspberry Pi 4 Model B single-board computer. The Raspberry Pi computer and the development board made by SparkFun allows great flexibility in making such a system. The article will present physical and logical connections between all the equipment used and, also, there are presented several programs made in the Python

programming language for different applications that can be designed from this custom-built system. These applications may include geodetic monitoring, real-time kinematic measurements, using the system as a permanent station or RTK correction server. We will also present other equipment that can equip this system to make it suitable for different geodetic applications.

1.3. Determination of the Gravity Field

The National Gravity Network of 1st and 2nd order (about 270 points) was observed by the Ministry of Defense – Topography and Cartography Directorate.
Gravity data at the present are not sufficient for the development of an geoid model with an accuracy of 10 cm or better. The EGG97 geoid model available from IAG was purchased by NACLR and tested in order to improve it locally by geometric method (local data and ellipsoidal heights from GPS). A new geometric quasigeoid solution was calculated in 2010 (TUCE Bucharest) based on EGG97 and about 600 ground markers with ETRS89 ellipsoidal heights and normal heights (Black Sea 1975 datum). Further efforts should are going to be done for the modernization of the gravity network. Since 2004 there are no new absolute gravity determinations in Romania.
NACLR started a new project for quasigeoid determination in Romania, based on gravity, GNSS and leveling data. Gravity observations are performed with Scintrex (CG5) equipments.

Figure 1.31: Gravity observations with Scintrex Autograv CG5

1.4. General Theory and Methodology

The theoretical and practical aspects of the Geodesy as geoscience continued the evolution in 2019-2022 time interval. The uniform application of the new standards needed the elaboration of new methodologies for the success of the implementation. At the global level some standards organizations took the responsibility for the geosciences as **ISO (International Standards Organization).** In Romania the counterpart of the ISO it is **ASRO** (Romanian Standardization Association).
The International GNSS Service (IGS), formerly the International GPS Service, is a voluntary federation of more than 200 worldwide agencies that pool resources and

permanent GPS & GLONASS station data to generate precise GPS & GLONASS products. The IGS is committed to providing the highest quality data and products as the standard for Global Navigation Satellite Systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. Currently the IGS includes two GNSS, GPS and the Russian GLONASS, and intends to incorporate GALILEO and BEIDOU. We can think of the IGS as the highest-precision international civilian GNSS community. The IGS global system of satellite tracking stations, Data Centers, and Analysis Centers puts high quality GNSS data and data products on line in near real time to meet the objectives of a wide range of scientific and engineering applications and studies.

The IGS collects, archives, and distributes GNSS observation data sets of sufficient accuracy to satisfy the objectives of a wide range of applications and experimentation. These data sets are used by the IGS to generate the data products mentioned above which are made available to interested users through the Internet. In particular, the accuracies of IGS products are sufficient for the improvement and extension of the International Terrestrial Reference Frame (ITRF), the monitoring of solid Earth deformations, the monitoring of Earth rotation and variations in the liquid Earth (sea level, ice-sheets, etc.), for scientific satellite orbit determinations, ionosphere monitoring, and recovery of precipitable water vapor measurements.

The primary mission of the International GNSS Service, as stated in the organization's 2002-2007 Strategic Plan, “to provide the highest quality data and products as the standard for global navigation satellite systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. These activities aim to advance scientific understanding of the Earth system components and their interactions, as well as to facilitate other applications benefiting society."

The IGS Terms of Reference (comparable to the by-laws of the organization) describes in broad terms the goals and organization of the IGS. To accomplish its mission, the IGS has a number of components: an international network of over 350 continuously operating dual-frequency GPS and GNSS stations, more than a dozen regional and operational data centers, three global data centers, seven analysis centers and a number of associate or regional analysis centers. The Central Bureau for the service is located at the Jet Propulsion Laboratory, which maintains the Central Bureau Information System (CBIS) and ensures access to IGS products and information. An international Governing Board oversees all aspects of the IGS.

The IGS is an approved service of the International Association of Geodesy since 1994 and is recognized as a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) since 1996.

Romania it is contributing to the IGS with postprocessing and NRT (Near Real Time) data from one GNSS permanent station *(BUCU*) and real time data (project *IGS-IP*).

EUREF is the IAG Reference Frame Sub-Commission for Europe, integrated in the Sub-Commission 1.3, Regional Reference Frames, under Commission 1 – Reference Frames, following the implementation of the new IAG structure at the IUGG (International Union of Geodesy and Geophysics) General Assembly held in Sapporo, 2003.

The Sub-Commission EUREF was founded in 1987 at the IUGG General Assembly held in Vancouver.
EUREF deals with the definition, realization and maintenance of the European Reference Frame - the geodetic infrastructure for multinational projects requiring precise geo-referencing (e.g. three-dimensional and time dependent positioning, geodynamics, precise navigation, geo-information) - in close cooperation with the IAG components (Services, Commissions, and Inter-commission projects) and EuroGeographics, the consortium of the National Mapping Agencies (NMA) in Europe. (www.euref-iag.net).
Romania it is contributing to EUREF/EVRF with GNSS permanent stations and epoch stations, leveling and gravity stations included as mentioned in *Section I*.
EuroGeographics as the central-hub for Europe's Geographic Information (GI) developments – a unique and diverse network working of all concerned with European GI; National Mapping and Cadastral Agencies (NMCAs), the European Commission and others. The websites contain information of national European Coordinate Reference Systems (CRS) and pan-European Coordinate Reference Systems for position and height. On the sites the following information can be found:

- Description of national Coordinate Reference Systems;
- Description of pan-European Coordinate Reference Systems (ETRS89 / EVRF2000);
- Description of Transformation parameters from national Coordinate Reference Systems to pan-European Coordinate Reference Systems including:
  - qualitiy of transformation;
  - verification data of transformation;
  - possibility for online conversion and transformation of single points for test;
  - verification purposes (position).
- The Joint **Research Centre of the European Commission** jointly organized with Eurogeographics and EUREF two Workshops (Spatial Reference Workshop 1999 and the Cartographic Project Workshop 2000 in Marne-la-Vallee). These Workshops laid the foundations for the definition of uniform European coordinate reference systems in position and height for the unique georeferencing of data. The Information System contains the description of national and pan-European Coordinate Reference Systems (CRS) for position and height orientates on the international standard 19111. It contains also the descriptions of transformations of national Coordinate Reference Systems of European countries to pan-European CRS. In the future a service module will be enabled for the transformation and conversion of coordinates for test purposes.

CRS-EU is a extension and advancement of the former existing and now in this system integrated information system about European Coordinate Reference Systems CRS (http://crs-geo.eu).
According to the international and European standards and recommendations, Romania has adopted or recommends the use of these standards. ***National Agency for Cadastre and Land Registration (NACLR)*** is the main civil public institution involved in the realization of standards and methodologies for cadastre, geodesy,

cartography and land registration. NACLR implements the recommendations of the ISO, IGS, EUREF, Eurogeographics and EUPOS. Other Romanian institutions involved in the realization and implementation of geosciences standards are ASRO (Romanian Association for Standardization) and INM (National Institute of Metrology).

- One of the most important standard it is related to the Coordinate and Reference System to be used in Europe. Since 2008 in Romania was introduced ***ETRS89*** for GNSS applications and pan-European cartographic products. This reference system on present situation it is used in parallel with the national reference system S42 (Krasovsky ellipsoid) mainly due to the huge cadastre information who need a long time to be converted to the new reference system.
- The ***INSIPIRE Directive*** of the EU was transposed into national legislation in 2009 and National Spatial Information Infrastructure Committee was created by government decision (no.493/19 May 2010). The Committee it is coordinated by National Agency for Cadastre and Land Registration (NACLR) and includes representatives from all ministries;
- Standards adopted by EUPOS (European Position Determination System) were implemented in Romania for GNSS network (Class A);
- New standards for national reference topographic map at scale 1:5000 were released by NACLR in 2009 and updated (TOPRO 5);
- Standards for scanning and georeferencing of old cadastral maps were adopted and updated;
- Technical standards for digital orthophoto realization at 1:5000 scale were realized based on the twinning project RO 2006/IB/OT–01, PHARE 2006 /018-147.02.01.03;
- New rules were realized and adopted and updated by NACLR for authorization of private and state institutions or persons (from Romania or EU) to realize cadastre works in Romania.
- An important step in implementation of the ETRS89 in Romania was the realization of the ***direct and inverse coordinate transformation between ETRS89 CRS and S-42 CRS.*** *The strategy for coordinate transformation from European Coordinate Reference System (CRS) ETRS89 to national CRS S-42 (Krasovsky 1940 – Stereographic 1970 Map Projection) it is based on a knowledge of the pattern of distortion data (due to large errors in the survey control network) and it consists of two main steps:*
  - *Global datum transformation that is accomplished by a conformal transformation;*
  - *Interpolation of residual coordinate corrections from a grid of coordinate shifts*
  - *The grid of coordinate shifts was generated using least squares prediction method for the distortion modelling between ETRS89 and S-42 which ensures a continuous transformation process that does not destroy spatial relationships established on the national local datum.*

In order to provide the compatibility and precise georeferencing of spatial data into the ETRS89 (European Terrestrial Reference System 1989) for the pan-European products, according to the INSPIRE (Infrastructure for Spatial Information in the European Community) directive of the Europe Parliament from 14.03.2007, National Agency for Cadastre and Land Registration (NACLR) provided an Order of the NACLR General Director for adoption of the ETRS89 Coordinate Reference System (CRS) in Romania. The implementation of the ETRS89 in Romania and the actual tendencies of the GNSS satellite technologies applications for the most of the geodetic works required the implementation of an standard algorithm for spatial data transformation from ETRS89 CRS to national CRS (Stereo 1970 projection) and opposite. This situation from Romania, similar with other European or World countries, requires serious problems for spatial data transformation from the old CRS to the new CRS (ETRS89), due to large distortions inside the triangulation networks as effect of the classical datum orientation of the S-42 CRS.
In order to underline the distortions between ETRS89 and S-42 CRS from Romania, there was used an conform orthogonal transformation (2D Helmert), based on a common set of coordinates from both systems. Table 1.2 presents the statistics of coordinate differences (distortions).

Table 1.2:Statistics of coordinate differences for common geodetic points after Helmert 2D transformation (before distortions modeling)

==========

Grid step = 15000 m
No of nodes = 2106

Statistic	East	North
Medium:	0.0000	-0.0000
Standard deviation	0.2648	0.3756
Max.:	0.8466	1.3288
Min.:	-0.8632	-1.1928
Total no. of common points	894	894
No. of points above +/-3*(Std.Dev.):	8	3
% points in +/-3*(Std. Dev.):	99.11	99.66

Statistics situation shows that standard deviation of coordinate differences it is about +/- 0.30 m. The value and the surface disposal can be seen in Figure ***1.32*** (distortions are presented as vectors).
The big distortions observed in Figure ***1.32*** should be modelled by a proper technique according to the reality in order to provide a good transformation of spatial data from old datum to the new datum and opposite.
The transformation technique adopted it is similar to the techniques applied in other countries from Europe or abroad and this technique can be implemented also into the GNSS receivers for RTK applications and into the GIS databases for spatial data representation at big scales.

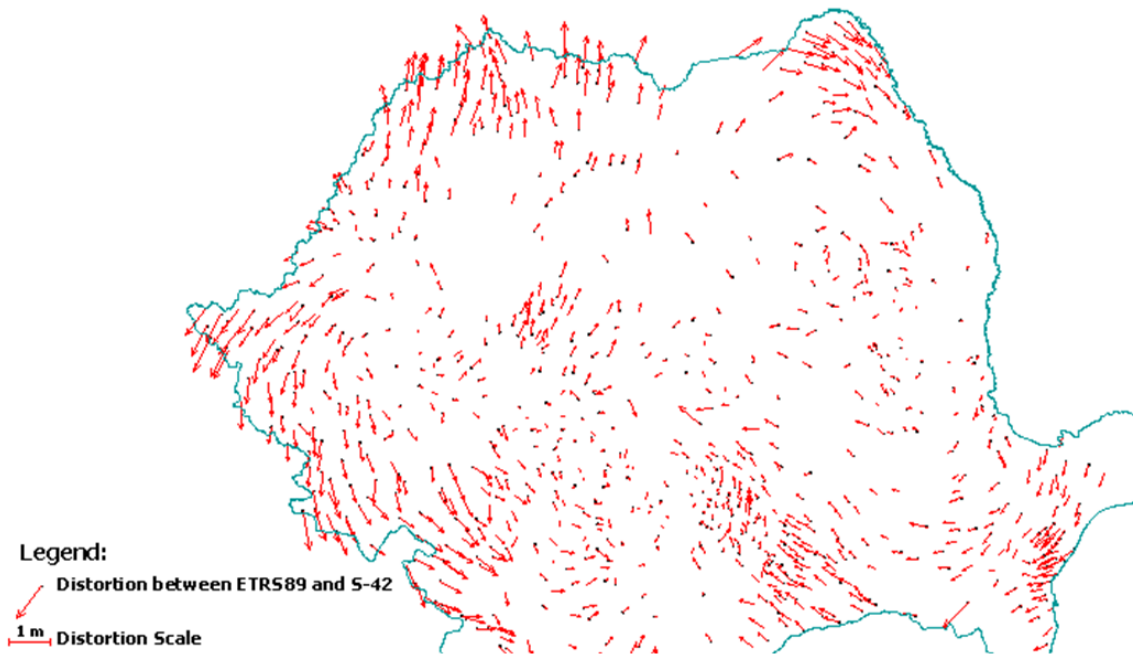

Figure 1.32: Distortions between ETRS89 and S-42

The existence of common points in a big number and well distributed positions on national surface it is a major requirement for the coordinate transformation from national CRS to the European CRS and opposite. Based on this set of data can be generated the distortion grids and can be predicted the distortions for any interest point in our country. NACLR included in his projects for this year the finalization of the necessary common set of coordinates by GNSS observations done in triangulation points and of the transformation grid which will be introduced into the GNSS receivers observing in Romania.

Based on other countries experience in transition from local datums to the new geocentric reference systems (ETRS89, WGS84), we can conclude that the transformation errors and transformation accuracies of points in Romania will be around ±10-15cm, sufficient for the mapping on big scales.

The following table presents the statistic situation of coordinate differences on geodetic common points, available at the present moment, after distortion modelling.

Table 1.3 Statistics of coordinate differences for common geodetic points after Helmert 2D transformation (after distortions modeling)

Grid step = 11000 m		
No of nodes = 3816		
Statistic	East	North
Medium:	0.0001	-0.0000
Standard deviation	0.0415	0.0456

```
Max.:                                0.1750     0.1644
Min.:                               -0.1729    -0.2022
Total no. Of common points             894        894
No. of points above +/-3*(Std.Dev.):15             18
% points in +/-3*(Std. Dev.):     98.32      97.99
-----------------------------------------------------
```

From this statistic situation analysis it can be deduced that the transformation algorithm adopted it is good and can provide precise and fiducial transformation results for all the users.

1.5. Geodynamic studies

1.5.1. Introductory

During the 2019 - 2022 timespan, the Solid Earth Dynamics Department (SEDD) in the Institute of Geodynamics "Sabba S. Stefanescu" (IGSSS) of the Romania Academy has continued its research within two active geodynamic areas of SE Romania: the eastern part of the Moesian Plate and the bending zone of East Carpathians. Both regions are well-known for their intense seismic events (Figure ***1.33***).

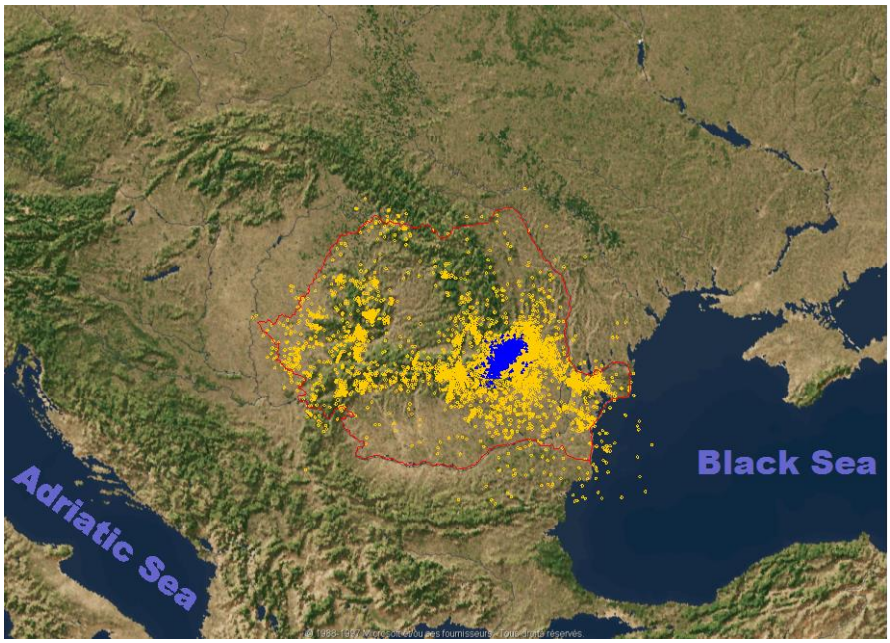

Figure 1.33: Seismicity map of Romania. Yellow dots mark epicenters of crust EQs, while blue ones are epicenters of Vrancea intermediate-depth EQs

The unusual craton seismicity and the intermediate-depth earthquakes within full intra-continental environment of the so-called Vrancea zone have been subject to research for many years.

It seems that lithosphere expelled by the opening of the West Basin of the Black Sea (Figure ***1.34***) split the eastern Moesian Plate into numerous lithospheric compartments by creating or reactivating some of the major faults known in the area (Figure ***1.35***).

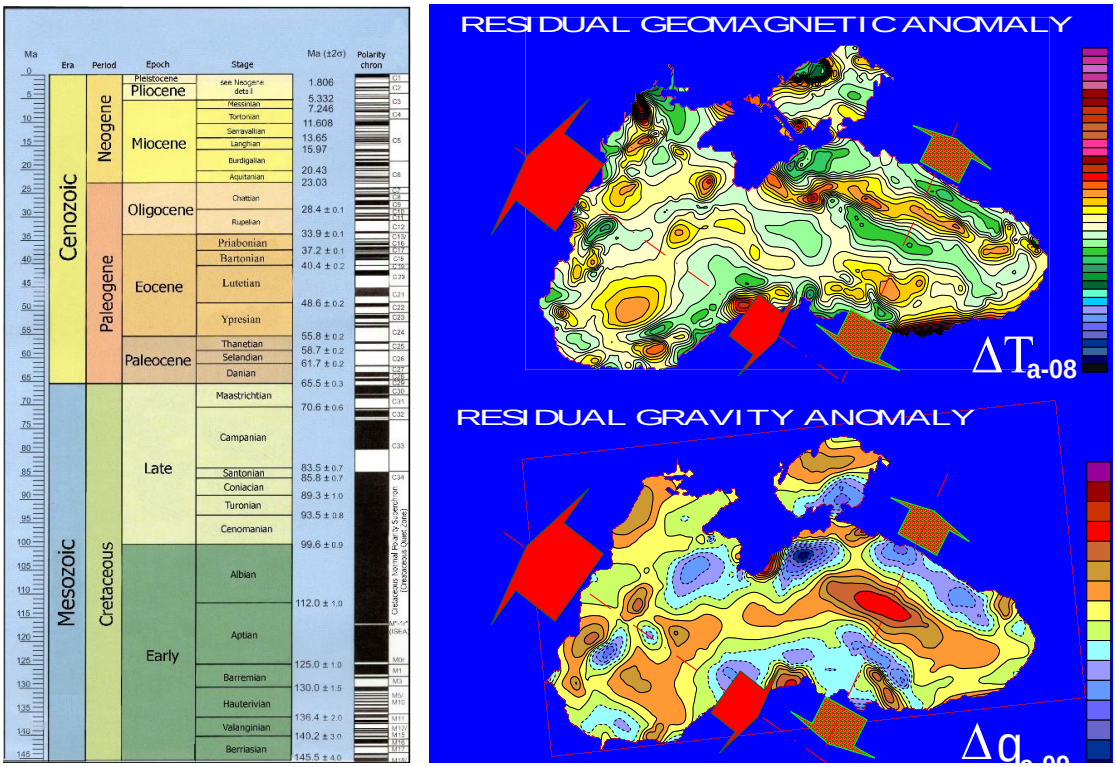

Figure 1.34: Geophysical imprints and timing of the Black Sea opening. Arrows show direction of the sea floor spreading (according to Besutiu & Zugravescu, 2004)

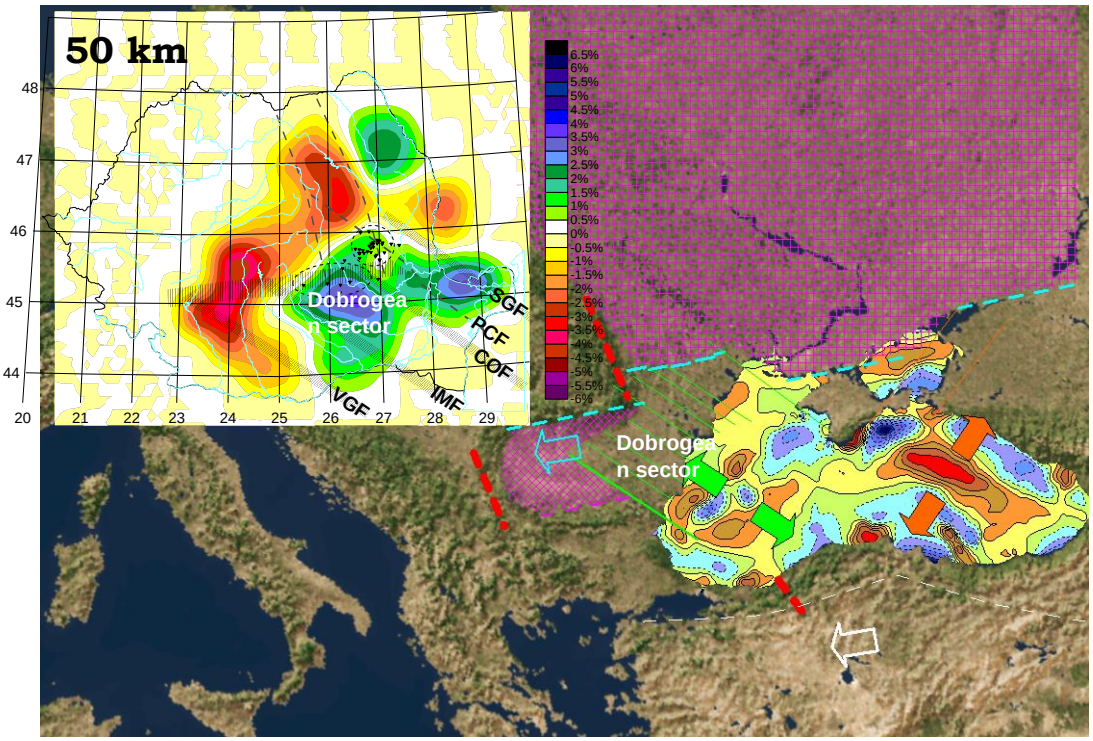

Figure 1.35: Residual geomagnetic and gravity anomalies over the Black Sea with arrows showing the assumed direction of spreading, and tectonic consequences of the west basin opening reflected in the P wave tomography (seismic data according to Martin et al, 2006) *(Besutiu, 2009)* PCF, Peceneaga-Camena Fault; SGF, Sfantu Gheoghe Fault; COF, Capidava-Ovidiu Fault; IMF, Intramoesian Fault; VGF, Varna-Giurgiu Fault

After the end of the Black Sea opening, the compartments move towards NW pushed by the Black Sea micro-plate, which, in turn, is moved by active rifting in the Red Sea and Aden Bay. The two rifts push the Arabian Plate that, in turn, acts on the micro-plates (among which is the Black Sea too) located between Eurasia and Africa Megaplates (Figure ***1.36***).

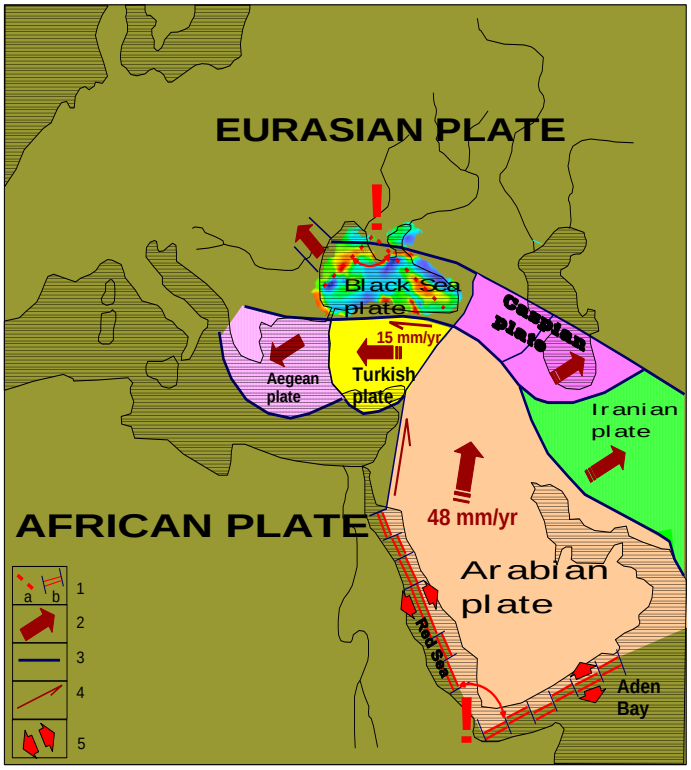

Figure 1.36: The active rifting in SW Arabian Plate and its geodynamic consequences 1, rift (a, past; b, active); 2, direction of movement/tectonic force; 3, plate boundary; 4, strike-slip direction; 5, sea-floor spreading)

Under the tectonic stress generated by the Black Sea micro-plate, the lithospheric compartments of the Eastern Moesian Plate move towards NW kept together by friction. But when tectonic forces overpass the friction threshold they may relatively slip each-other, thus generating earthquakes along their edges. This mechanism may justify the seismicity of the eastern Moesian Plate (Figure ***1.36***).

Concerning the Vrancea intermediate-depth seismic zone the seismo-tectonic frame is a bit different. There are many years of national and international research trying to unveil mechanisms of this unusual seismicity and several models have been proposed (e.g., Tondi et al., 2009; Ismail-Zadeh et al., 2012). Among them, credit should be given to two more recent, and somehow similar models.

Both assume a lithosphere sinking into the upper mantle but driven by different engines. The sinking of colder lithosphere into the hotter upper mantle determines thermo-baric disequilibrium and accommodation phenomena like thermal stress and phase-transforms processes, that generates EQs through implosion and expulsion of fluids.

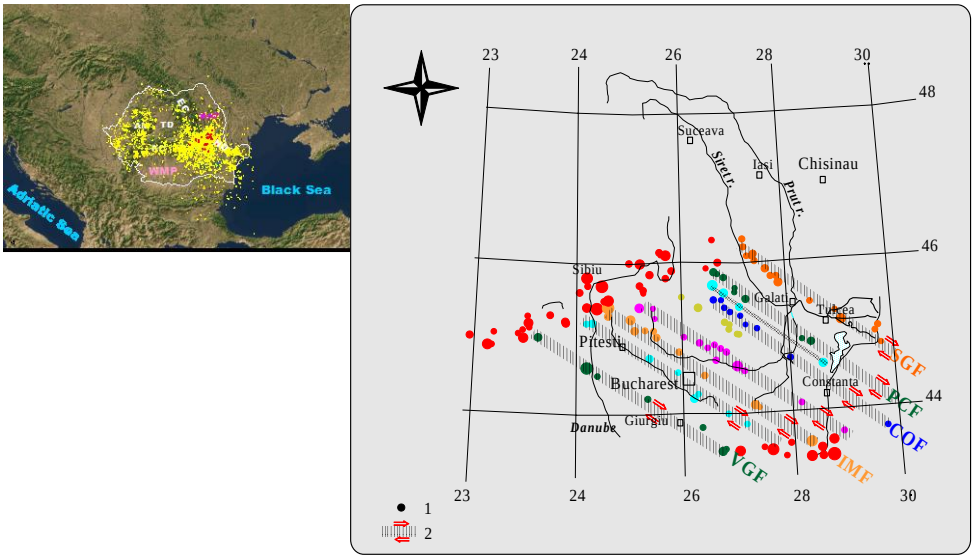

Figure 1.37: Seismicity map of Romania and clustering of crustal EQs epicentres within E Moesian Plate along strike-slip block-bounding faults known in the area (according to Besutiu, 2001) Various colours mark EQs along different faults

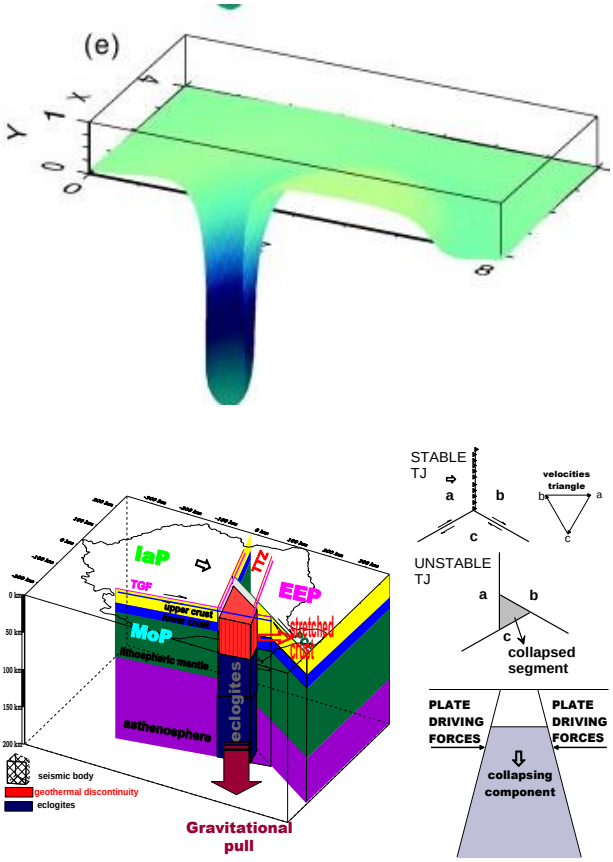

Figure 1.38: Up, Riley-Taylor gravitational instability (Hauseman et al, 2007; Lorinczi & Hauseman, 2008), and below, the unstable triple-junction model (Besutiu, 2001; 2009) for explaining lithosphere sinking within Vrancea region

1.5.2. The infrastructure for research

Basic considerations

Based on the above-mentioned tectonic model for the SE foreland of Carpathians, including the unstable triple-junction for Vrancea zone (Figure ***1.39***), SEDD has developed a specific research infrastructure in the attempt to monitor changes in tectonic forces that might generate both crustal and sub-crustal seismicity.

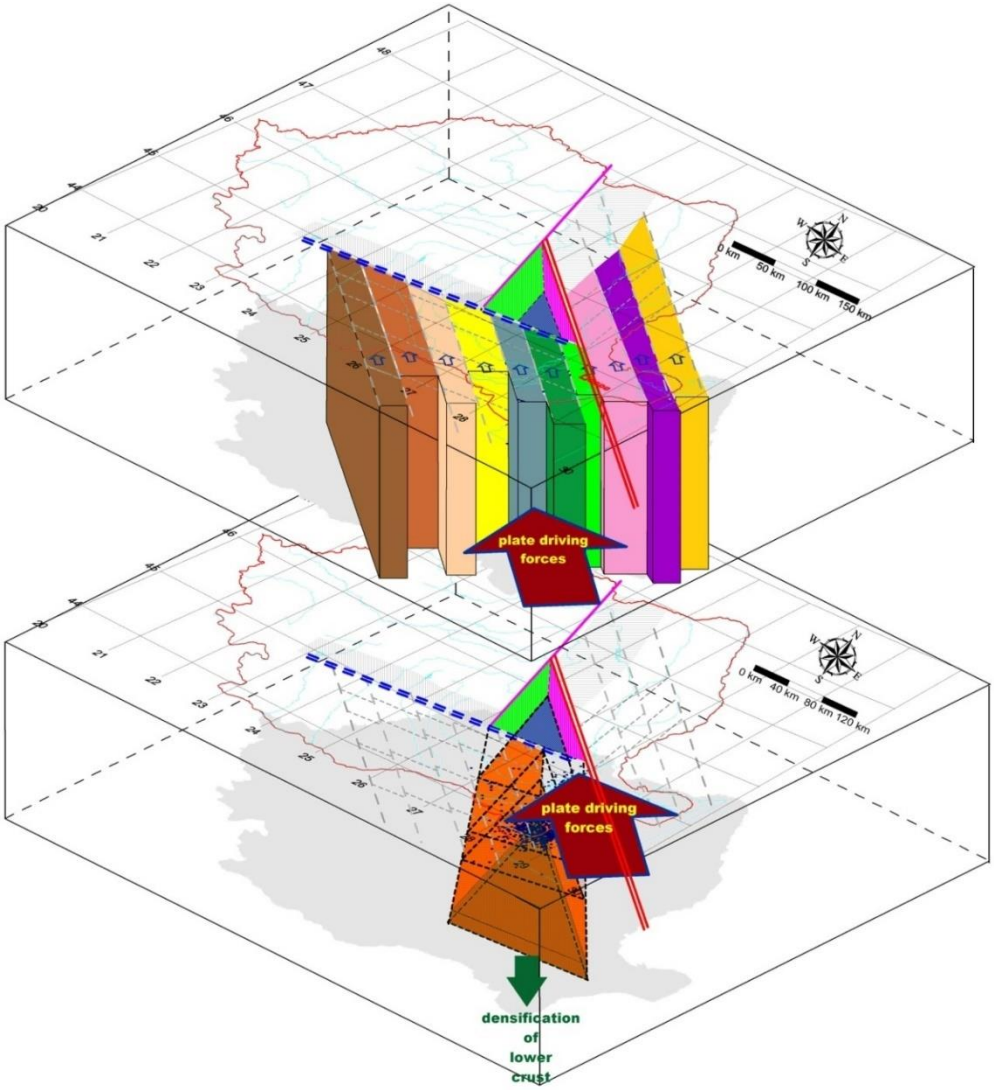

Figure 1.39: Tectonic and geodynamic environment model adopted by SEDD. The red double line represents Peceneaga-Camena Fault

According to this model, the increase of tectonic stress may generate both crust events along the MoP compartments bounding faults, but also intermediate seismicity through the sinking of lithosphere within Vrancea zone due to its reverse-horst geometry.

Near-fault Baspunar Geodynamic Observatory

The permanent geodynamic station located in Fântâna Mare village belonging to Tulcea county, and conventionally designated as Başpunar Geodynamic Observatory (BGO) after the former (Turkish) name of the village represents a **near-fault observatory** aimed at monitoring slip rate along the Peceneaga-Camena Fault (PCF) that represents a lithospherioc contact between the Moesian Plate and SW part of the EEP, represented here by North Dobrogea folded belt.

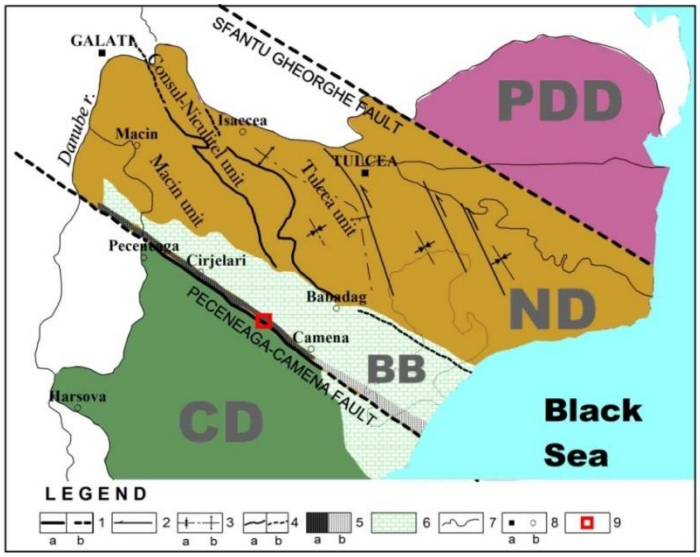

Figure 1.40: Tectonic location of BGO. 1, PCF track (1, cropping out, b, covered by recent sediments); 2, secondary fault; 3, structural axes (a, syncline, b, anticline); 4, secondary faults (a, cropping out, b, covered); 5, Carjelari mylonitic zone (a, cropping out, b, covered by loess); 6, Babadag Basin; 7, river; 8, human settlements (a, major; b, minor); 9, BGO. CD, Central Dobrogea; BB, Babadag Basin; ND, North Dobrogea; PDD, Pre-Dobrogean Depression (compiled after Grădinaru, 1984; 1988; Seghedi & Oaie, 1994)

The seismic tomography clearly shows the lithospheric nature of PCF, separating domains of distinct seismic velocity deeper than 130 km (Figure ***1.41***).

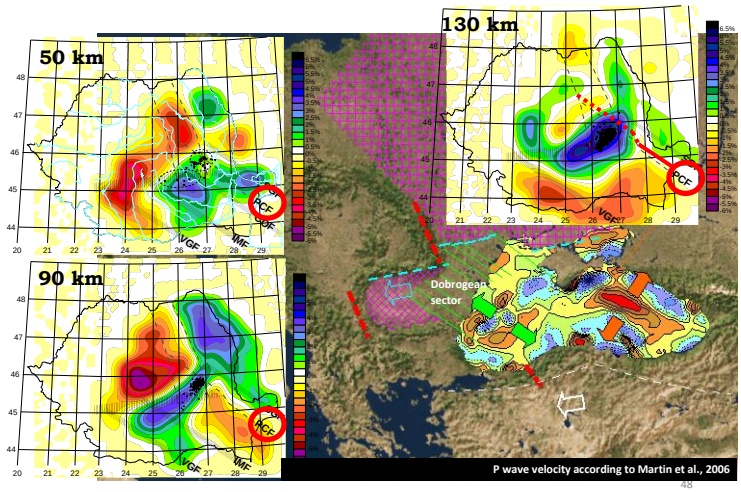

Figure 1.41: In depth development of PCF as unveiled by P wave tomography (compiled after Martin et al, 2006)

The BGO infrastructure (Figure ***1.42***) mainly consists of two total stations placed on the PCF southern flank (MoP green schists) pointing to laser reflectors located on the northern PCF flank, on NDO Jurassic deposits, along with a weather station for allowing the atmospheric corrections applied.

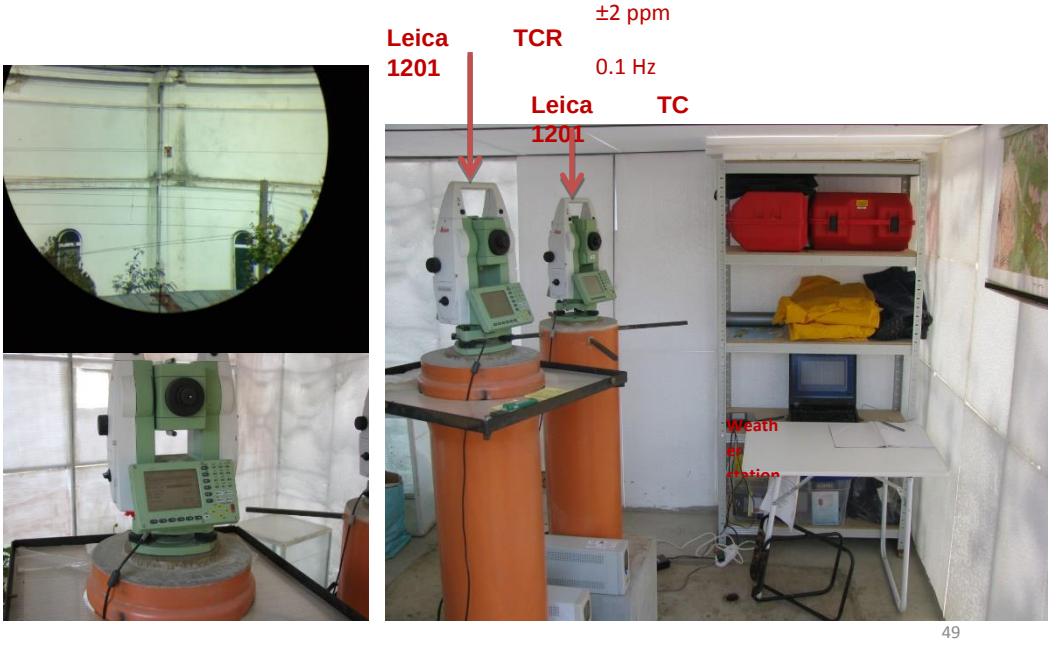

Figure 1.42: BGO technical facilities

Local position of the BGO infrastructure has been carefully chosen, based on geological (e.g., Grădinaru, 1984; 1900) and geophysical investigations (Besutiu et al., 2014; Cosma et al., 2014).
Total stations' observations are corrected for changes in atmospheric factors as follows:

Leica TPS 1200

TC

$$\Delta D_1 = 283,05 - \left[\frac{0,29196.p}{1+\propto.t} - \frac{4,126.10^{-4}.r}{1+\propto.t}.10^{x}\right]$$ **(λ=0,780 μ m)**

Leica TPS 1200+

TCR

$$\Delta D_1 = 286,34 - \left[\frac{0,29525.p}{1+\propto.t} - \frac{4,126.10^{-4}.r}{1+\propto.t}.10^{x}\right]$$ **(λ=0,658 μ m)**

where:

ΔD_1= atmosphere factors correction [ppm]

p= absolute atmosphere pressure [mbar]

t = temperature [°C]

b=237, 3

$$x = \left(7,5.\frac{T}{b+T}\right) + 0,7857$$

Also, cautions have been made to avoid/mitigate distortions due to the temperature deformation of the support of the reflectors due to the direct hit of sun rays. Therefore, records during the night have been considered only and daily averages were used in the assessment of the fault slip rates.
Extensive time series of the BGO records have revealed an overal slight yearly/seasonal change, not necessarily linked to the temperature evolution (Figure ***1.43***).

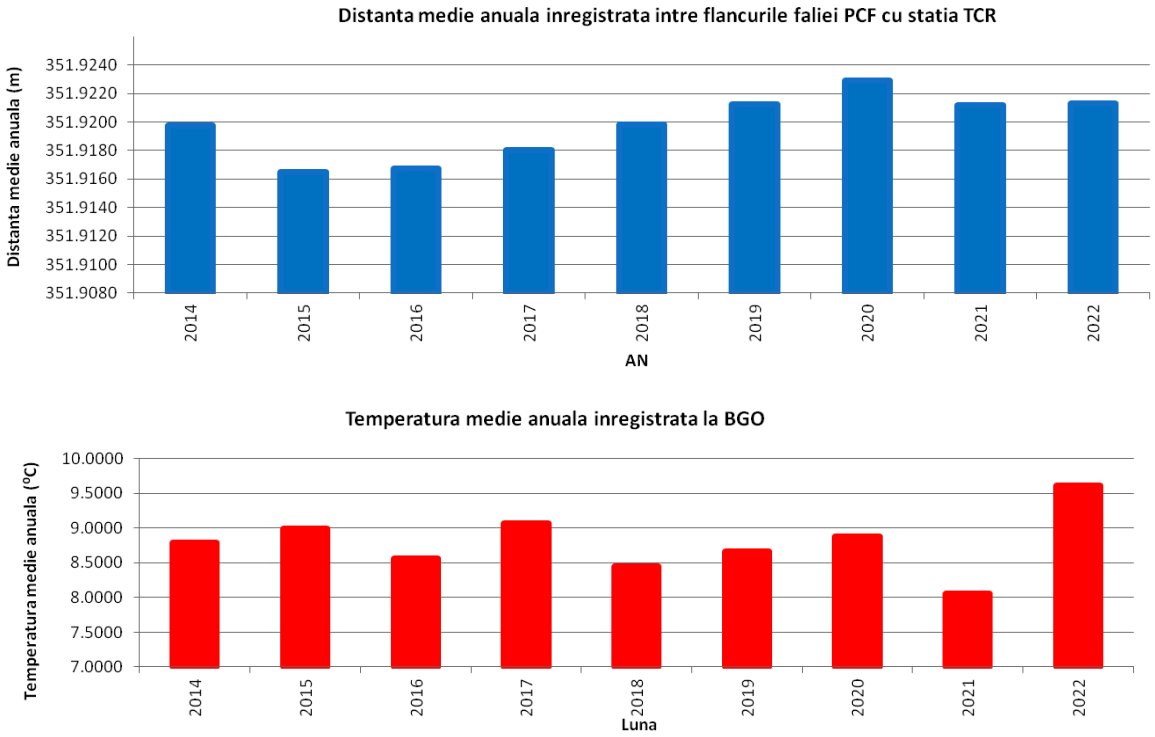

Figure 1.43: Yearly average records of the distance between PCF flanks against average temperature

Overall, the fault slip recorded shows a right-lateral behaviour of 1 - 3 mm/year, with short left-lateral episodes.
It is worth mentioning that ignificant increase of tectonic stress seems to be confirmed by intensifications of the PCF slip rate that precede some crustal seismic episodes within the East Carpathians foreland.
This is the case of the Galati-Izvoarele seismic swarm (Besutiu et al., 2019), when PCF slip rate has increased by approx 14 times. The intensification of tectonic forces also had an echo on the Vrancea zone leading to an acceleration in lithosphere sinking that generated a week later two significant intermediate-depth earthquakes (Figure ***1.44***).
Another major seismic event (Mw 5.4, H=40.9km) took place on 22 November 2014, NW of the precedent Galati-Izvoarele swarm, and according to BGO records it has been also preceded by a right-lateral slip rate increase (Figure ***1.45***).

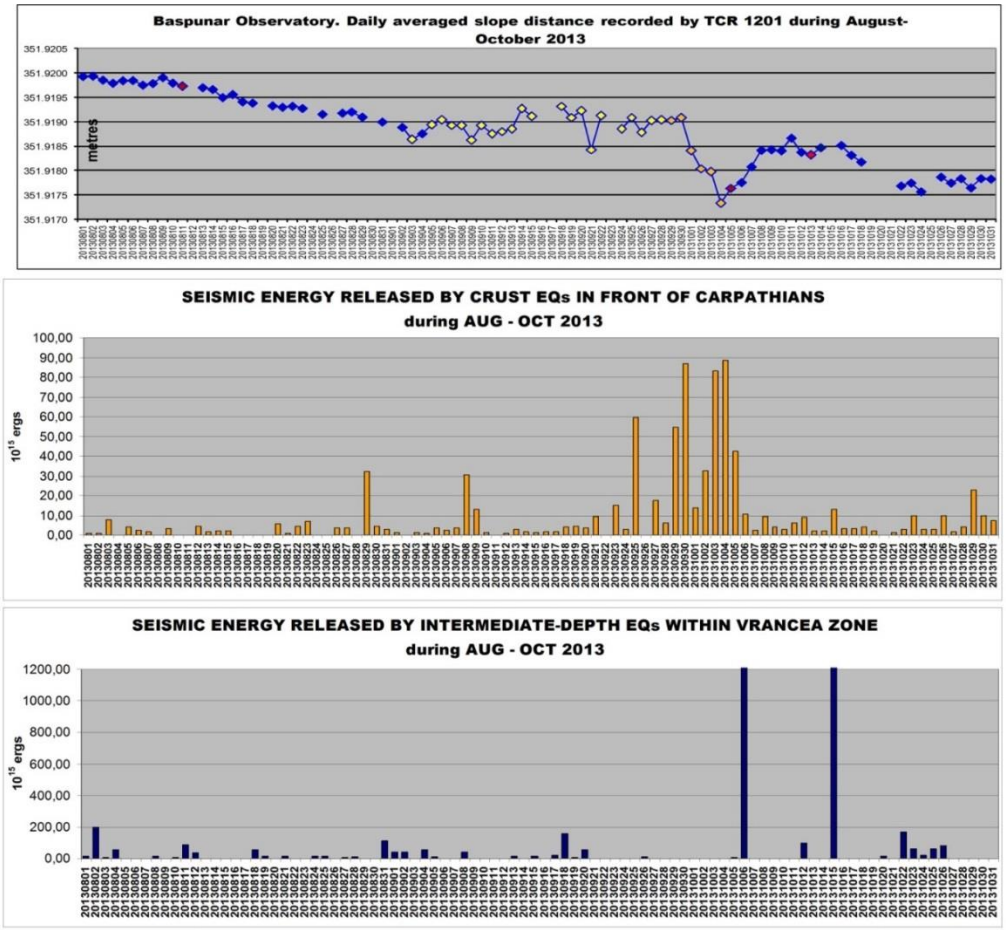

Figure 1.44: Correlation between changes in PCF slip rate, as recorded at BGO, and seismic energy released within Carpathians foreland and Vrancea zone on the occasion of Galati-Izvoarele swarm (after Besutiu et al., 2019)

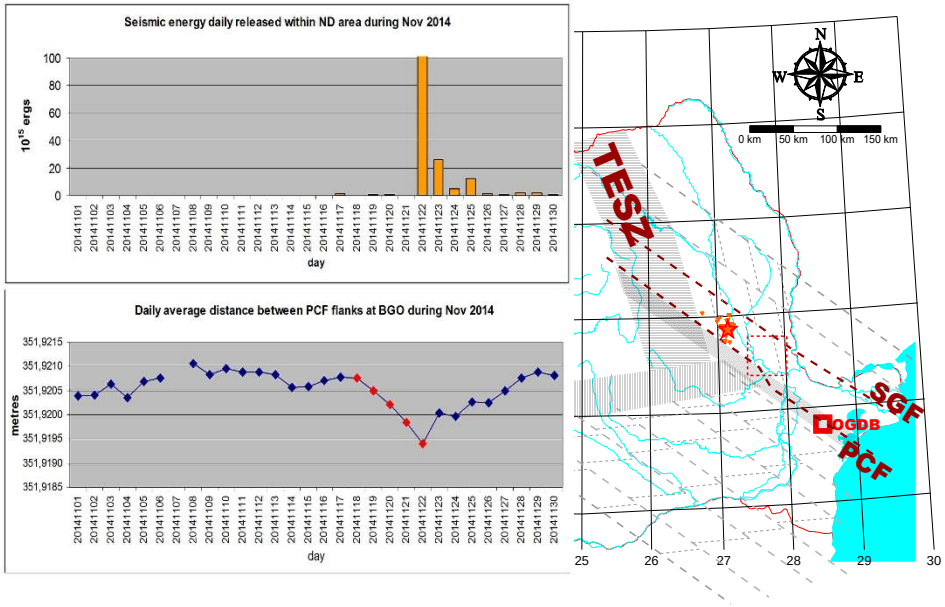

Figure 1.45: Correlation between changes in PCF slip rate as recorded at BGO, and seismic energy released by the seismic event of November 22, 2014 (Mw 5.5) Red star shows EQ epicentre; red dotted line square marks location of the 2013 Galati-Izvoarele swarm; ODGB is BGO location; TESZ, Trans European Suture Zone

Vrancea gravity dedicated network (VGDN)

VGDN represents the second infrastructure developed by SEDD for monitoring Vrancea active geodynamic area where intermediate-depth EQs occur (Figure ***1.46***).

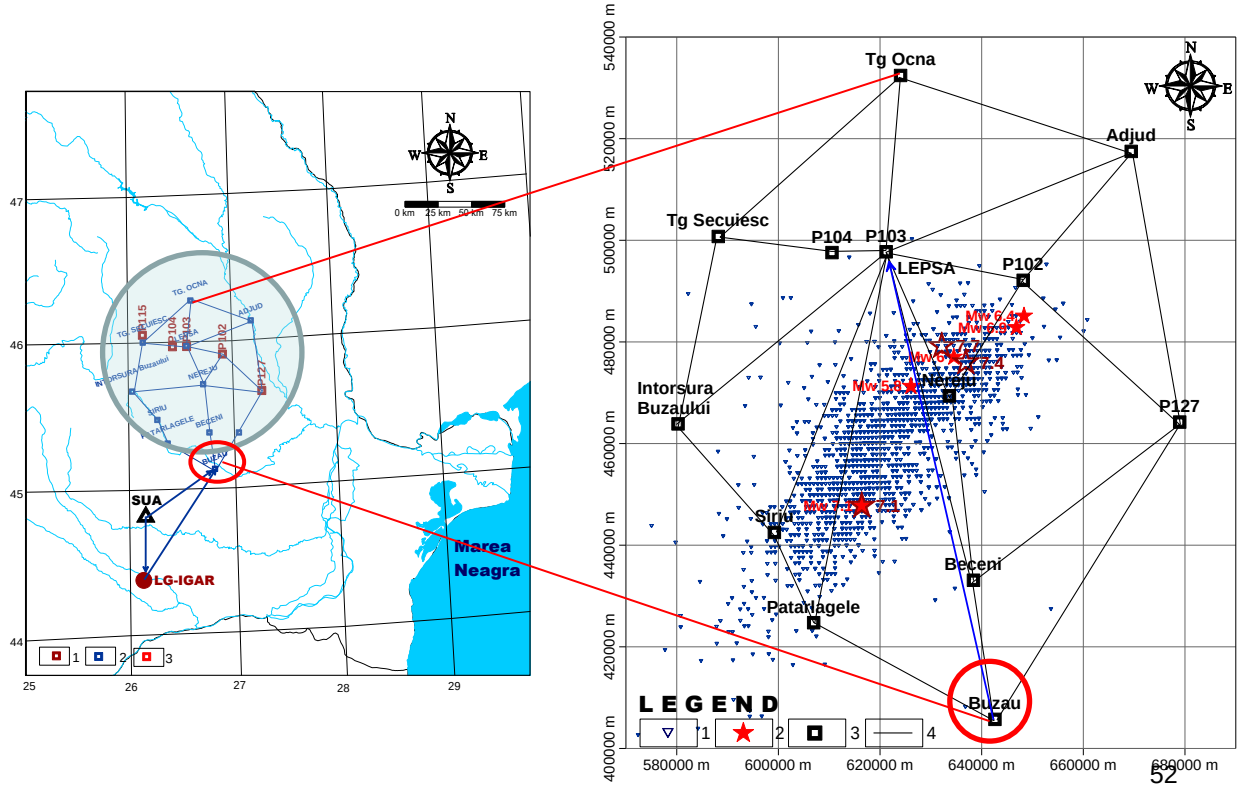

Figure 1.46: Location and design of the VGDN and the scheme for absolute gravity transfer Subcrustal EQs epicentres (1, usual; 2, major); 3, epoch base station; red squares mark Vrancea geotraverse of the National Geodynamic Network Besutiu et al., 2006); 4, gravity tie SUA, fundamental gravity point; LG-IGAR, underground gravity lab of SEDD

It has been aimed at performing repeated high accuracy relative gravity determination for revealing changes in gravity due to underground mass deformation/displacement.

As can be seen in Figure ***1.46*** it has been mainly designed as an independent triangle network with epoch base stations located in the active geodynamic area except for the base station BUZAU, in the southernmost side, located outside the active geodynamic area and employed for the transfer of absolute gravity values within VGDN.

Absolute gravity is transferred during each field campaign from the fundamental/reference point of gravity, located at the Surlari Observatory, run by Geological Institute of Romania (Figure ***1.47***).

Additionally, a back up value is also transferred to the SEDD underground gravity lab (Figure ***1.48***).

Figure 1.47: Scintrex CG5 #40387 meter run on the pillar of the national fundamental gravity point

Figure 1.48: Scintrex CG5 meter on the pillar of the SEDD underground gravity lab

To provide reproducibility to repeated gravity observations, each epoch base station of the network consists of a steel-reinforced concrete pillar weighting more than 1000 kg (Figure ***1.49***). Right on the pillar top a special device for centring GPS antenna (CERGOP2 standard) has been implemented for allowing high accuracy space geodetic determinations too.

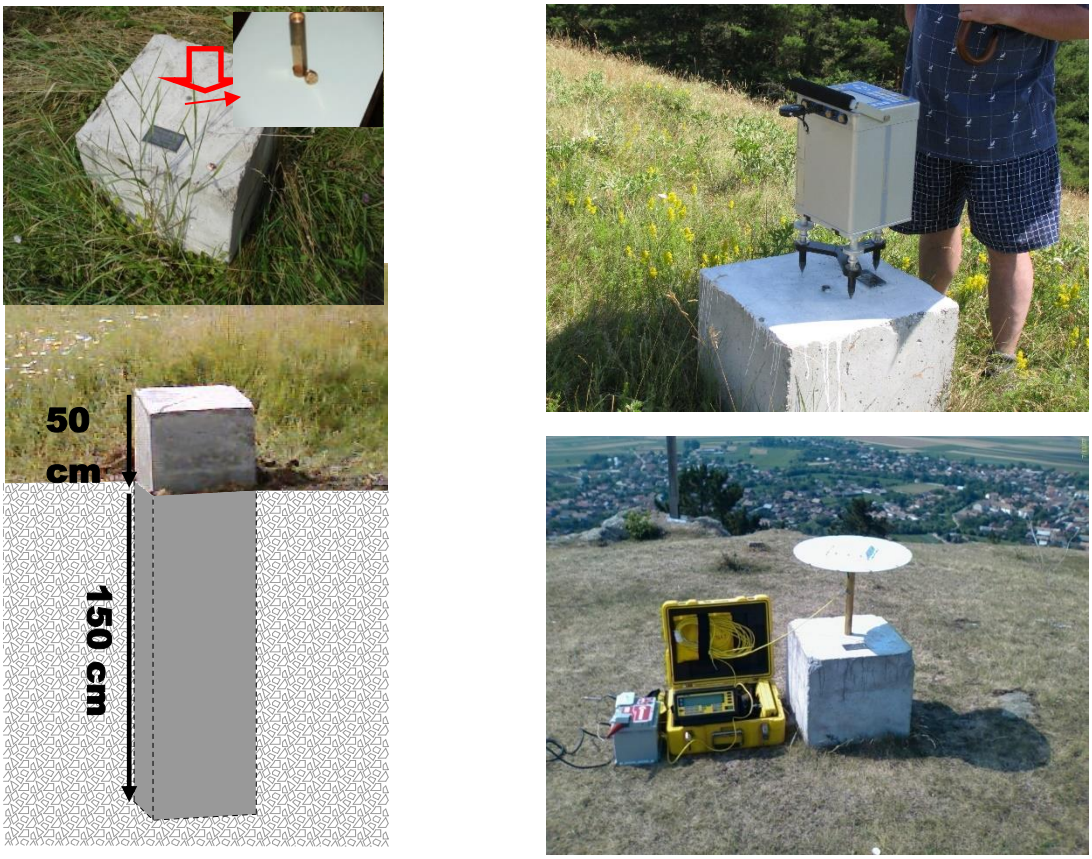

Figure 1.49: Left: Steel-reinforced concrete pillars of the VGDN epoch stations. Red arrows show location and aspect of the device for centring GPS antenna. Right: gravity and GPS observations conducted on VGDN pillars

Yearly campaigns of gravity observations within VGDN have revealed an overall decrease of gravity within intermediate-depth seismicity epicentre area (Figure ***1.50***).

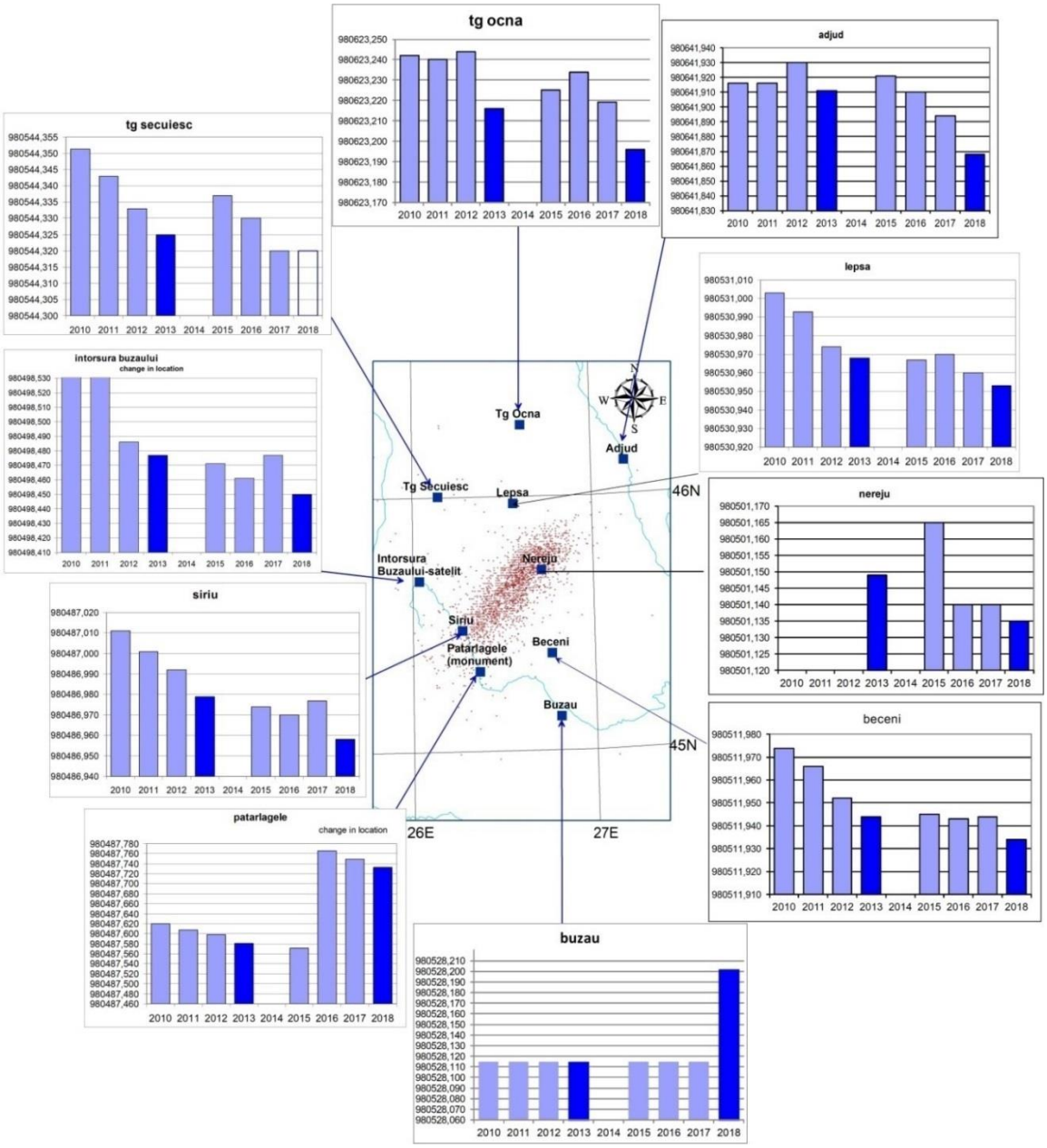

Figure 1.50 Gravity behaviour recorded within VGDN between 2010 and 2018 Please note the stability of gravity within Buzau reference station that confirms its location outside geodynamic active area. Sudden unusual large variations are due to the change of the observation site

Figure ***1.51*** shows the space-time change of the gravity field over a timespan of 20 years (2000 - 2020).

The epicenter area is characterized by both the gravity decrease and topography subsidence raising an intriguing issue. 3D inversion of gravity data has revealed a mass deficit starting bellow about 10 km depth (Figure ***1.52***) that has been explained as a result of the crust vertical stretching due to the eclogitization of the lower crust sunk into the upper mantle.

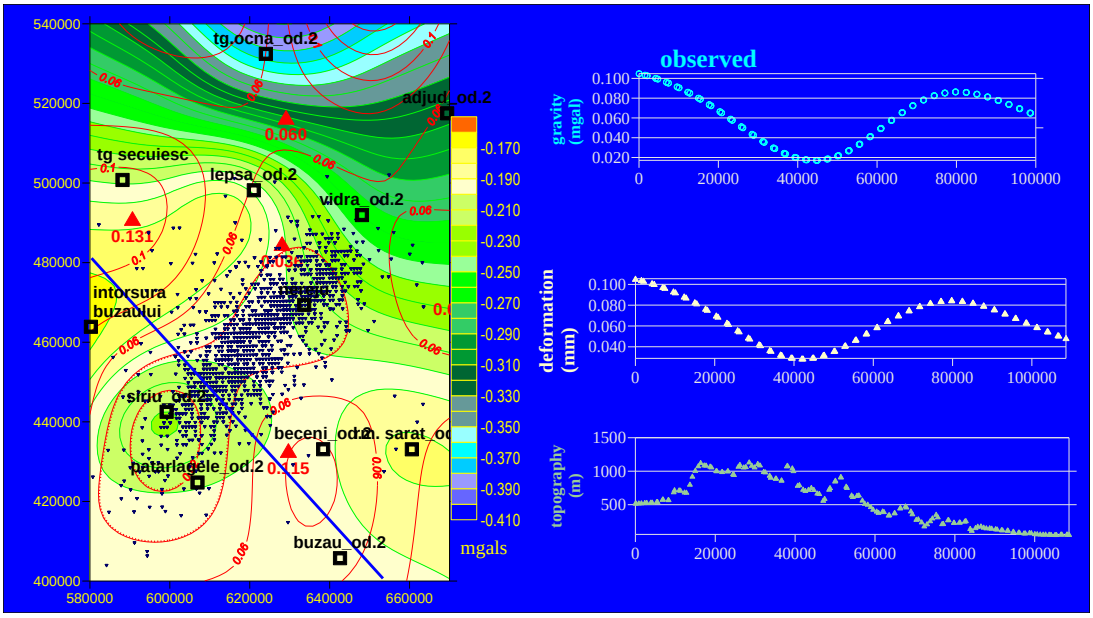

Figure 1.51: Non-tidal gravity change within Vrancea area over a time-span od 20 years against the crust deformation as determined by CERGOP project (Ghitau et al, 2003). Red contours show crust vertical deformation, with red triangles as data points.

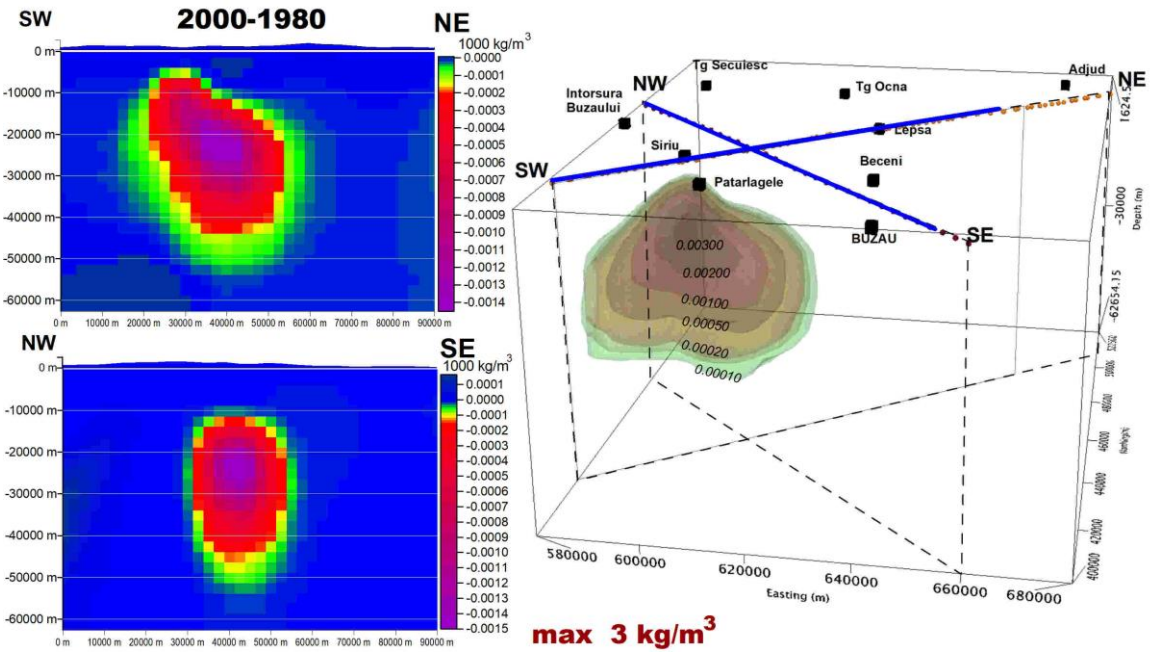

Figure 1.52: Mass deficit bellow the epicentre area due to the vertical stretching crust

Interesting results have been obtained by successive field campaigns conducted prior and after some significant seismic events (Figure ***1.53*** and Figure ***1.54***), always showing a gravity decrease over the epicenter area.

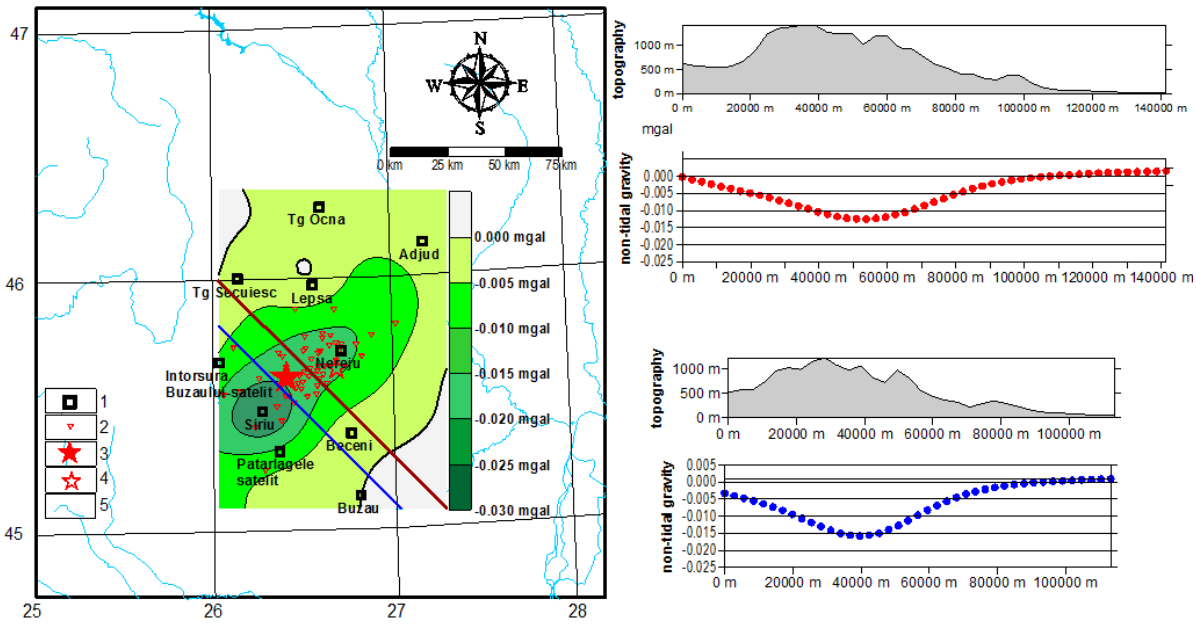

Figure 1.53: Non-tidal gravity change associated to the October 6, 2013 Mw 5.6 earthquake: 1, data points; 2, EQ epicentres occurred between gravity campaigns; 3, M5.6 EQ epicentre

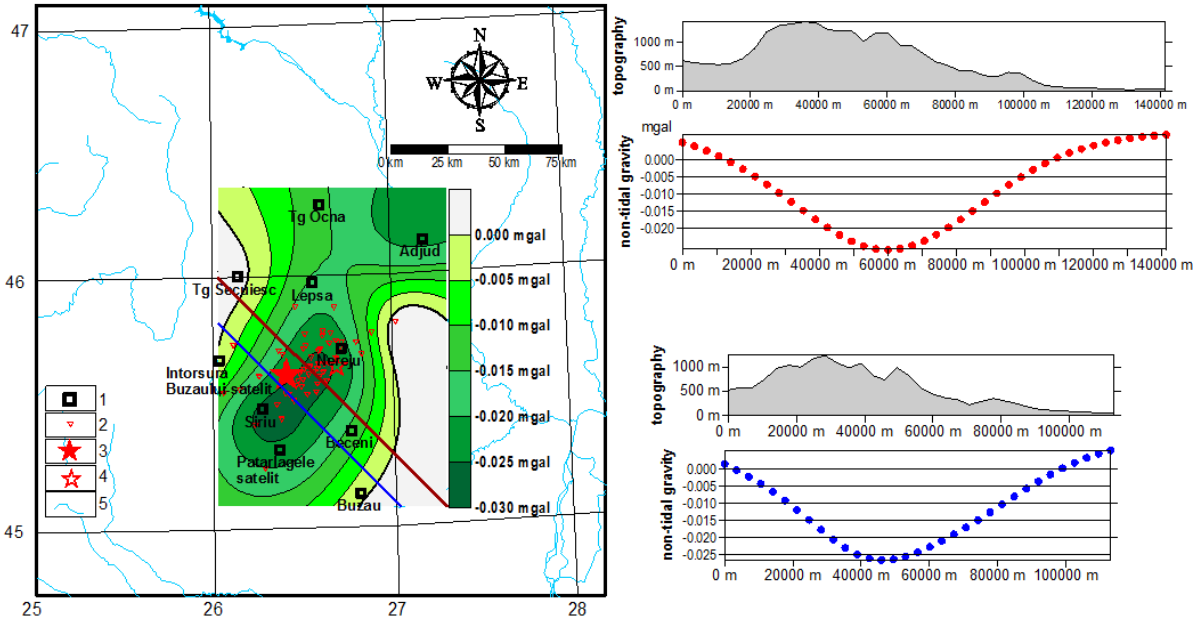

Figure 1.54: Non-tidal gravity change associated to the October 28, 2018 M 5.8 earthquake: 1, data points; 2, EQ epicentres occurred between gravity campaigns; 3, M5.6 EQ epicentre

It is worth stressing that amplitude of the gravity signal seems related to the EQ magnitude, while the top of the mass-deficit depends on the depth of EQ foci (Figure ***1.55***).

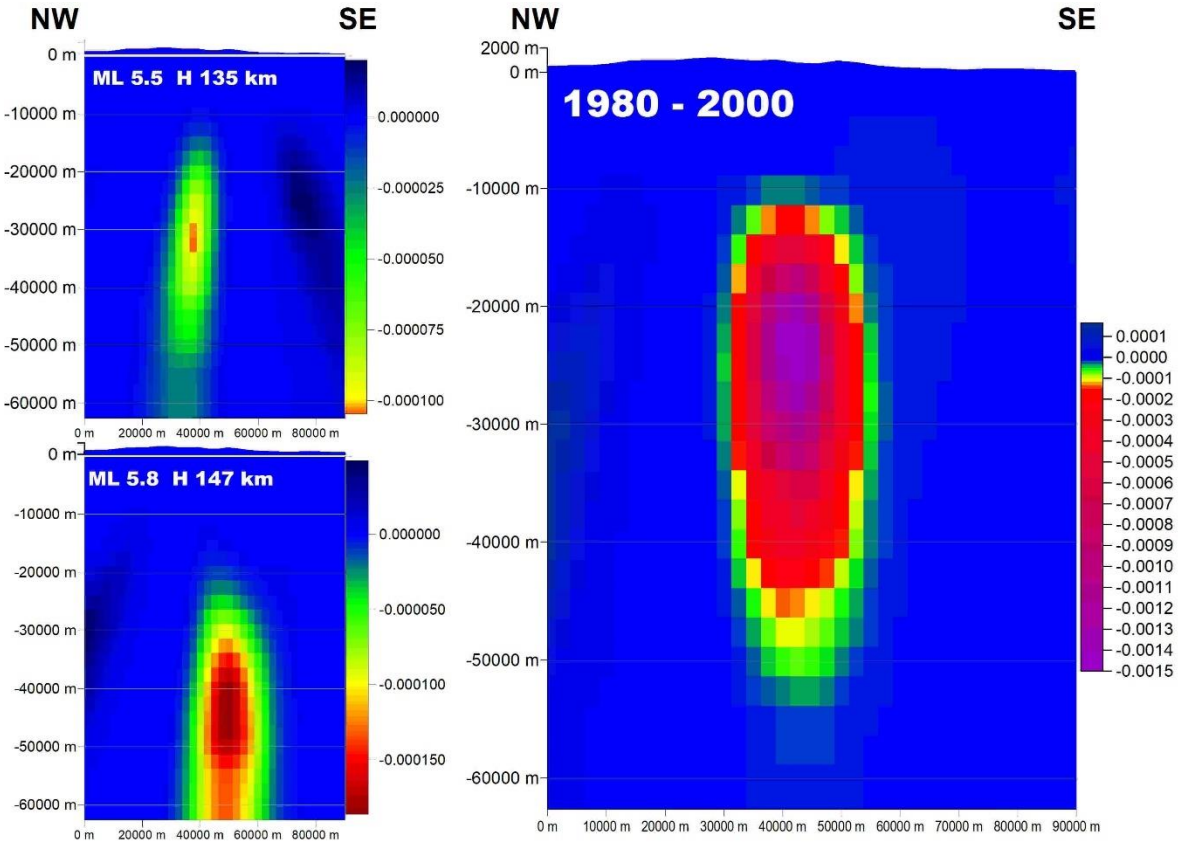

Figure 1.55: Comparative view of the event-related mass deficit for some significant EQs and the overall mass deficit revealed over 20 years timespan

2. Participation of the Romanian specialists in international projects or programs

Romania participates especially by National Agency for Cadastre and Land Registration to the international and national projects. The most important projects are mentioned below.

- Determination of a gravimetric quasigeoid for the Romanian territory.
- Geodetic and oceanographic measurements at tide gauges in the ports of Constanța, Mangalia, and Sulina for long-term monitoring of sea level fluctuations in the Black Sea relative to the reference level, through connection to the leveling network and integration of national geodetic networks into the European reference systems EUREF and EUVN.
- Administration, monitoring, development, and operation of ROMPOS.
- Keeping the information regarding permanent GNSS stations up to date in the EUREF and EUPOS databases and ensuring GNSS data exchange within national and international agreements and protocols.
- MSCA-RISE VOLTA project (innoVation in geOspatial and 3D daTA).
- European Position Determination System (EUPOS) – interregional cooperation

The main objectives of the project are to strengthen the cooperation and cohesion between the participating countries and regions from Central and East Europe and to create awareness for the benefits of satellite-based applications. It can be reported that the goal will be achieved by the operation. The cooperation between the countries and regions was extended from only some higher level persons to the working level by the cooperation of the GNSS National Service Centres or Know-how offices, by the regional workshops and study visits. New standards for the EUPOS components were developed and implemented and a common data centre will be created. Cross border cooperation was improved and GNSS realtime data exchange extended step by step. Cooperation agreements were signed with relevant organizations in Europe (EUREF, EUMETNET).

- **EuroBoundaryMap (EBM) –** The objective of the project it is to realize a geospatial data set for Europe including the administrative limits of Romania, their codes and names for 1:100000 scale. In August 2014 version 9.0 was released, and the limits were updated regularly.
- **EuroGlobalMap (EGM) –** The objective of the project it is to realize a uniform set of geospatial data at 1:1000000 scale for the entire Earth. Version 5.1 of this product was released in 2014 and new updates are available.
- **EuroRegionalMap (ERM) -** The objective of the project it is to realize a uniform set of geospatial data for Europe at 1:250000 scale structured in seven thematic layers: administrative boundaries, hydrographs, transport, localities, vegetation and soil, topographic names, and others (high power lines, tourist buildings, parks, national parks et al.). Update rate for this products it is one year. Version 8.0 for Romania was provided in October 2014 and new updates are available.
- **Euro Digital Elevation Model (EDM)** - The main objective of the project is a digital representation of the ground surface topography of Europe, (not including

'first surface' elevations such as vegetation and man made structures). Geospatial elevation data is used by the scientific and resource management communities for applications relevant for environmental hydrologic cartography such as ortho-rectification of imagery, creation of relief maps, flight simulations, design of mobile telephone networks, geological structure studies. EuroDem data are essential for applications Fast Track Services, which are to be implemented within GMES (Global Monitoring for Environment and Security). The participants have also taken into consideration the financial aspects, aiming at creating a cheap product comparing with the prices of other products from the market. EuroDem is provided from the national data bases by the National Mapping and Cadastral Agencies. According to the Eurogeographics policy, the updating as well as the distribution of the product is regulated by agreements signed by all projects partners, including ANCPI.

- **Cross border cooperation programmes – FAIRWAY Danube project (2015-2020)**

In order to improve navigation on the Lower Danube area, some European projects are underway. The focus of FAIRway Danube project (2015-2020) is to provide current and harmonized information about shallow sections, water levels and water level forecasts. Available depths will be used optimally by adapting the location of the waterway to the current riverbed conditions. In parallel, FAIRway Danube is aiming at preparing the harmonized rehabilitation of the Danube and its navigable tributaries. The bilateral conventions and agreements signed by Romania and Bulgaria, as well as between AFDJ Galati - Low Danube River Administration (Romania) and IAPPD Ruse - Executive Agency "Exploration and Maintenance of the Danube" (Bulgaria), establish the responsibilities for maintaining the appropriate airworthiness conditions from km 845 to km 375. The authorities of both states have agreed to significantly improve airworthiness in the Danube section, their intention being to minimize as much as possible periods of time when commercial navigation is not possible: both during the winter, when ice climbs occur, and in summer when the Danube level is very low. As a support of the FAIRway Danube project, geodetic activities in that area included in last years geodetic observations (GNSS, leveling, bathymetry, Lidar). Previous geodetic studies performed by TU of Civil Engineering Bucharest – Research Centre on Spatial Geodesy, Photogrammetry, Remote Sensing and GIS (GEOS) established connections between CRS (Coordinate Reference Systems). If 2D connections are more easily to be established, the height connection between the old and new CRS on the left and right bank of the Lower Danube are more difficult to be established. GEOS contributed to this project by realizing a local quasigeoid model on the project area with an accuracy of 3-5 cm. The model established the connection between the ellipsoidal heights (ETRS89) and EVRF07 normal heights with the possibility to transform to the Black Sea 1975 (RO) and Baltic Sea 1982 (BG) datums. A user friendly software (DARAT) was realized.

- **CERGOP (Central European Regional Geodynamic Project)/CEGRN (Central European Geodynamic Regional Network)**

The main objective of the project is to monitor the recent crust movements, detecting the borders of the tectonic plates and quantifying their three dimensional rates. The objective is achieved especially by the use of GPS/GNSS technology and other significant data sources. Romania participates at this project since 1995 by Technical University of Civil Engineering and National Centre for Geodesy, Cartography, Photogrammetry and Remote Sensing Bucharest (former Institute for Cadastre, Geodesy, Photogrammetry and Cartography). „Geodynamics of Central Europe“, WP.10.2. *Three Dimensional Plate Kinematics in Romania*.

In the frame of the CERGOP a Central European Regional Geodynamic Network (CEGRN) was designed and realized including permanent and epoch stations observed by GPS technology. CEGRN was designed for geodynamic purposes (tectonic and geological position, markers, repeatability). The coverage includes the Central Europe (CEI countries) and was observed yearly (1994-1997) and every two years after (1999 – present). CEGRN was continuously extended with new stations, especially permanent stations in the last decade. Romania sends at present continuously GNSS data from 7 permanent stations to CEGRN data center in Padova (Italy) excluding the five Romanian EPN stations. Totally, data from 12 permanent stations are available.

3. Organization of national and international scientific conferences

- GeoPreVi Student 2019, Faculty of Geodesy, Technical University of Civil Engineering Bucharest, 13 December 2019;
- The Romanian Surveying Week, first edition, Cluj-Napoca, Romania, 23-27 September 2019;
- The Romanian Surveying Week, second edition, Brașov, Romania, 15 - 18 March 2022;
- The Romanian Surveying Week, third edition, Iași, Romania, 15 - 19 November 2022;
- The Romanian Surveying Week 2023, fourth edition, Oradea, Romania,10 - 13 May 2023;
- GeoCAD 2022, NATIONAL SCIENTIFIC SYMPOSIUM WITH INTERNATIONAL PARTICIPATION, "1 Decembrie 1918" University of Alba Iulia, Romania, 20-21 May 2022,- online -
- GeoCAD 2020, NATIONAL SCIENTIFIC SYMPOSIUM WITH INTERNATIONAL PARTICIPATION, "1 Decembrie 1918" University of Alba Iulia, Romania, 20-23 May 2020
- GEOMAT 2022, International Conference,”Geospatial Data Management for Built Environment”, November 15-22, 2022, Iasi, Romania

4. Participation of the Romanian specialists in the international symposiums and conferences

- 19th International Multidisciplinary Scientific GeoConference SGEM 2019, 30 June - 6 July 2019, Albena, Bulgaria;
- Working Party on the Standardization of Technical and Safety Requirements in Inland Navigation, Fifty-ninth session, Geneva, 23–25 June 2021;
- 21st International Multidisciplinary Scientific GeoConference SGEM 2021, June 26 – July 05, 2022, Albena, Bulgaria
- 22nd International Multidisciplinary Scientific GeoConference SGEM 2022, June 26 – July 05, 2022, Albena, Bulgaria;
- FIG Congress 2022, "Volunteering for the future - Geospatial excellence for a better living", Warsaw, Poland, 11–15 September 2022;
- DISC 2022 – Danube Information System Conference, 14-15 Decembre 2022, Bucharest, Romania;
- EUREF Symposium 2019, 21–24 May 2019,Tallinn, Estonia;
- EUREF Symposium 2021 (online), 26–28 May 2021, Ljubljana, Sloveniaș
- EUREF Symposium 2022, May 31 - June 03, 2022, Zagreb, Croatia
- The XVII th Edition of the Scientific Symposia, "Technological Progress – Result of the Research", General Association of the Romanian Engineers, April 27, 2023

5. Publications: articles and Proceedings papers

2022

Poncoş, V.; Stanciu, I.; D. Teleagă ; L. Maţenco ; I. Bozsó ; A. Szakács; D. Birtas; Ş.-A. Toma,; A. Stănică ; V. Rădulescu, An Integrated Platform for Ground-Motion Mapping, Local to Regional Scale; Examples from SE Europe. Remote Sens. 2022, 14, 1046, 10.3390/rs14041046.

Rus, T., Actual Problems on Geodetic Dam Deformation Studies , DISC 2022 – Danube Information System Conference, 14-15 Decembre 2022, Bucharest, Romania.

Rus, T., Research Grant, UTCB-CDI-2022-003, "System for Spatial Monitoring of the Rockfill Dams".

Spiroiu, I., Crisan, R-D-N., Belinchi, I., Sorta, V., Avramiuc, N., (2022). Determination of a New Gravimetric Quasigeoid for Romania (11305), FIG Congress 2022, Volunteering for the future - Geospatial excellence for a better living, Warsaw, Poland, 11–15 September 2022

2021

Besutiu l., Szakas A., Zlagnean L., Isac A., Romanescu D., 2021. *On the uncertainty of geophysical data interpretation in volcanic areas through a case study: Ciomadul Volcano*. Physics of The Earth and Planetary Interiors 319 (1):106781

Ilie, A.S., T. Rus, V. Danciu,, M. Plopeanu, C.Cristea , CUSTOM-BUILT GNSS SYSTEM FOR GEODETIC APPLICATIONS, 21st International Multidisciplinary Scientific GeoConference SGEM 2021, www.sgem.org, SGEM2021 Conference

Proceedings, 14 - 22 August, 2021, 21, Issue 22, 319-326, DOI:10.5593/sgem2021/2.2/S09.039
Rus, T. "Despre stadiul actual si probleme ale sistemelor de referinta si coordonate in Romania", Revista Constructiilor, nr.182, Iulie 2021, pg.62-65
Rus, T., V. Danciu,, M. Plopeanu, A.S. Ilie, M. Dumitrana, DEVELOPMENT OF A SPATIAL MONITORING SYSTEM FOR ROCKFILL DAMS, 21st International Multidisciplinary Scientific GeoConference SGEM 2021, www.sgem.org, SGEM2021 Conference Proceedings, 14 - 22 August, 2021 21, 22, 319-326, 10.5593/sgem2021/2.2/S09.039
Rus, T., R. Soare R., SATELLITE POSITIONING SYSTEMS ON INLAND WATERWAYS, Working Party on the Standardization of Technical and Safety Requirements in Inland Navigation, Fifty-ninth session, Geneva, 23–25 June 2021

2020

Cuibac Picu I. A., Dragomir P. I., Peters R. (2020). The future of mapping – 3D maps, the comparison of two of the most used methods in photogrammetric field, Journal of Applied Engineering Sciences, Volume 10: Issue 2
Pârvu A., Dogaru M., Pfeifer N. (2020). Lidar Initiatives at the National Center of Cartography Romania 2D–3D data fusion research in the VOLTA project, LIDAR Magazine
Pârvu I. M., Cuibac Picu I. A., Dragomir P. I., & Poli D. (2020). Urban Classification from Aerial and Satellite Images, Journal of Applied Engineering Sciences, 10(2), pp. 163-172
Pârvu I. M., Remondino F., Ozdemir E. (2020). Aerial Point Cloud Classification Using an Alternative Approach for the Dynamic Computation of K-Nearest Neighbors, Journal of Applied Engineering Sciences, 10(2), pp. 155-162

2019

Iliescu, A.I., T. Rus, V. Danciu, C. Moldoveanu, A. Ilie, CURRENT SITUATION OF GNSS NETWORKS IN ROMANIA, Bulletin UASVM Horticulture Volume 76(2) / 2019
Plopeanu, M., A.Ilie, T. Rus, V. Danciu, C.Moldoveanu, SPECIAL GEODETIC MONITORING OF ROCKFILL DAMS-RAUSOR DAM CASE, 19th International Multidisciplinary Scientific GeoConference SGEM 2019, Conference Proceedings, 19, p.99-108, 30 June - 6 July 2019, Albena Co., Bulgaria, doi: 10.5593/sgem2017/22/S09.069
Rus, T. Danciu V., Moldoveanu C., A.S.Ilie, C.Cristea, Developing Conversion And Transformation Parameters To Improve Navigation On Lower Danube, 19th International Multidisciplinary Scientific GeoConference SGEM 2019, Albena, Bulgaria
Seghedi I., Besutiu L., Mirea V., Zlagnean L., Popa R.-G., Szakacs A., Atanasiu L., Pomeran M., Visan M. (2019) Tectono-magmatic characteristics of post-collisional magmatism: Case study East Carpathians, Călimani-Gurghiu-Harghita volcanic range. Physics of the Earth and Planetary Interiors, 293, DOI: 10.1016/j.pepi.2019.106270

IAGA ACTIVITIES IN ROMANIA

2019-2022

NATIONAL REPORT ON GEOMAGNETISM AND AERONOMY

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CONTENT:

PART I: ORGANIZATION

This report is a collection of institutional and individual reports edited by national delegates. In the reference lists the readers find papers papers published in various geophysical journals.

The numbering of sections (I-VI) indicates the number of IAGA divisions.

Romanian IAGA Activities:

- **Internal Magnetic Field –Paleomagnetism and Rock magnetism**
- **Solar Wind and Interplanetary Field**
- **Geomagnetic Observatories, Surveys and Analyses**
- **Electromagnetic Induction in the Earth and Planetary Bodies and Inter-Associations (IAGA-IASPEI-IAVCEI) Working Group: Electromagnetic Studies of Earthquakes and Volcanoes (EMSEV)**

Institutions:

The list of participating institutes is as follows**:**

- **University of Bucharest, Faculty of Physics**, www.fizica.unibuc.ro/Fizica/Main.php
- **Institute of Geodynamics, Bucharest**, http://www.geodin.ro
- **Geological Institute of Romania, Bucharest**, www.igr.ro

Professional Organizations:

- **Romanian Society of Applied Geophysics (SGAR)**
- **Romanian Society of Geophysics (SRG)**

Publications:

- **Romanian Geophysical Journal**

PART II: PROFESSIONAL ACTIVITY

1. Research orientation

1.1. Division I: Internal Magnetic Field – Paleomagnetism and Rock magnetism

The Paleomagnetic Laboratory of the University of Bucharest is part of the Romanian's contribution at The European Plate Observing System (EPOS), a pan-European infrastructure for solid Earth science (ERIC) (https://epos-ro.eu/).
The activity of the petrophysics laboratory within the Surlari Geomagnetic Observatory was represented in the last years by providing rock-magnetism data (bulk magnetic susceptibility and magnetic susceptibility anisotropy) as well as by density determinations of geological samples.
The susceptibility and density measurements made were used within the PN 19 45 03 01 project, for the creation of geological models for certain areas of interest and for the production of works already published or still in progress.
The magnetic susceptibility measurements were carried out both in the laboratory, using a Bartington MS2 susceptiometer connected to an MS2B sensor (Figure 1), with two frequencies, and in the field, using a KT5 susceptiometer, produced by Geophysica Brno.

Figure 1: MS2 Magnetic Susceptibility Meter with MS2B Dual Frequency Sensor

The magnetic susceptibility measurements made in the laboratory were made on compact, cubic rock samples with a side of 20 mm. They aimed to obtain both the global magnetic susceptibility and the magnetic anisotropy of the rocks. The anisotropy measurements assume the existence of oriented samples and the realization of 6 susceptibility measurements for each sample, in order to construct the ellipsoid of the magnetic susceptibility distribution in the rock. In this case, the magnetic susceptibility is no longer a scalar but a tensor.

The density measurements were made with the help of a precision electronic balance KERN EMB 500-1 and a graduated cylinder. The accuracy of determination for this method for compact rocks with low porosity is +-0.1 g/ cm3.

1.2. Division IV: Solar Wind and Interplanetary Field

In the time interval covered by the present report, the research direction, namely space climate/space weather, has been continued at the Institute of Geodynamics of the Romanian Academy, in close relation with the ISWI program (International Space Weather Initiative) and the BBC SWS Regional Network cooperation (Balkan, Black Sea and Caspian Sea Regional Network on Space Weather Studies).
These studies have been focused on the following research lines:

- study of coronal mass ejections (CMEs) and of high speed streams in the solar wind (HSSs);
- analysis of long-term (decadal, inter-decadal and centennial) solar and geomagnetic activities;
- solar/geomagnetic forcing on terrestrial climate.

1.2.1. Study of CMEs and HSSs

Coronal mass ejections represent the principal trigger for geomagnetic storms. The possibility of predicting whether or not a given CME will be associated with a geomagnetic storm is a subject of exhaustive studies in the research community. In respect to this we attempted to predict the geoeffectiveness of a given CME using a logistic regression model, based only on initial CME parameters detected by LASCO during the ascending phase of solar cycle 24. The geoeffectiveness of HSS has also been investigated by a non-linear logistic regression method. It has been outlined that the empirical model could predict the association of a HSS generated by a coronal hole with a geomagnetic storm, but this model might be improved.
In the following of our efforts to update and further to publish a HSS catalogue for the entire solar cycle 24, in this time interval we accomplished a complex catalog of the HSSs produced by coronal holes and their effects in terrestrial magnetosphere as geomagnetic storms. This catalogue was structured in three parts describing the high speed stream characteristics, the interplanetary magnetic field state, and the properties of the associated geomagnetic storms. The catalogue is available online at http://www.geodin.ro/varsiti/.

1.2.2. Analysis of long – term solar and geomagnetic activity

The space climate research direction has been carried on within the frame of the Institute of Geodynamics of the Romanian Academy, being known the fact that the evolution of the system heliosphere – magnetosphere, at the timescales of Hale (22 years) and Gleissberg (60-90 years) solar cycles, was quite similar, pointing to a common pacing source, the solar dynamo. By accumulating new data for time series of parameters describing the space climate, characterizing media such as the Sun, the heliosphere and the magnetosphere, we were able to complete the former results to the present and characterize the space climate in the last 400 years, at the timescales of the Gleissberg and Hale solar cycles. The actual trend in space climate is given by the superposition of the inter-decadal and sub-centennial variations on the long-term inter-centennial trend.

As regards the geomagnetic data, it is well known that (1) the study of geomagnetic phenomena known as geomagnetic activity has long contributed to progress in solar-terrestrial science and (2) the long geomagnetic time series both ones recorded at geomagnetic observatories and ones provided by long-time geomagnetic models (gufm1, Cov-Obs), have provided means to characterize the Sun-Earth interaction at times prior to space era, via geomagnetic indices. As the instrumental space research began only in 1964, we relied also on solar, interplanetary and magnetospheric parameters reconstructions using both space and geomagnetic data.

1.2.3. Solar/geomagnetic forcing on terrestrial climate

In the present report interval 2019-2022, the study of the influence of solar and geomagnetic activity on climate has continued by investigating the nature of the solar-terrestrial relationship, by using appropriate indices that describe solar variability, such as Wolf sunspot number, the radio flux F10.7, aa geomagnetic index, on one side, and climate variability, such as hydro-climatic indices and precipitation in the Danube basin, on the other.

The relationship between terrestrial variables and external indices was established based on the application of (1) information theory elements, namely, synergy, redundancy, total correlation, transfer entropy and (2) wavelet coherence analysis. By using these methodologies we could reveal the linear or non-linear behaviour of the solar-terrestrial link and bring additional information on the signature of solar/geomagnetic variability in terrestrial variables in the Danube basin and in climate indices over the Atlantic-European region. It seemed that significant solar/geomagnetic forcing appeared in the terrestrial variables with a delay of 2–3 years, proving our previous results regarding multi-decadal variability in the Danube Basin associated

both with the Atlantic variability and with solar variability, a result of direct action of large-scale circulation patterns modulated by solar activity.

1.3. Division V – Geomagnetic Observatories, Surveys and Analyses

1.3.1. Secular varation studies

1.3.1.1. National Network of Repeat Station

In the time interval 2019 – 2022, the national network of repeat stations consisting of 26 stations has been reoccupied as much as possible every two years by a systematic survey of the geomagnetic field, supporting the international scientific community efforts in creating and maintaining a repeat station database to be used together with satellite and observatory data in complex geomagnetic field modelling at regional and global scale. Measurements of the horizontal component, H, total intensity, F, magnetic declination, D, and magnetic inclination, I, have been performed at the repeat stations, by means of two DI-Flux theodolytes (LEMI 024, Bartington Mag 01H), one proton magnetometer (Geometrics G-856), and two Quartz Horizontal Magnetometers (QHM). The values obtained for the geomagnetic elements have been reduced to the middle of the year (geomagnetic epoch year.5) in which measurements were taken, by means of records provided by the Surlari geomagnetic observatory (IAGA code SUA) and maps with geographical distribution on the Romanian territory have been developed.
In cooperation with the Geological Institute of Romania (Surlari geomagnetic Observatory), the geomagnetism group from the Institute of Geodynamics of the Romanian Academy has been involved in providing declination maps over Romanian territory necessary to the Romanian Air Traffic Services Administration to compute periodically the magnetic headings used to fly from an airport to another and to deliver updated Romanian aeronautical maps in accordance with the European legislation regarding aeronautical safety requirements.

1.3.1.2. Secular variation. New insights from long time series of observatory data and long – term main field models

The studies regarding long-term evolution of the main geomagnetic field have continued by approaching (1) the short-term constituents of the secular variation, at inter-decadal (20-30 years) and sub-centennial (60-90 years) time scales, present in observatory data and main field models and (2) the relation between length-of-day (LOD) fluctuations to geomagnetic field and flow oscillations in the fluid outer core.
As regards the constituents with internal sources of secular variation, we explored the appearance, structure, and dynamics of the secular variation foci, based on data from long time-span geomagnetic models. By using Time-Longitude/Latitude plots for various longitudes/latitudes respectively, and further applying a Radon transform, we

got information on displacement in time of the constituents and of the SV foci, in the form of Latitude-Azimuthal-Speed and Longitude-Meridional-Speed power plots. Our results showed the tendency of the westward drift of the inter-centennial constituent to the southern hemisphere, the absence of meridional displacement of the inter-centennial constituent and the westward drift of the higher frequency constituents in a ±20º equatorial band. Also, the Earth's surface field variability, in terms of its constituents, for the 400 years time-span was analyzed.
The Earth's rotation rate, expressed by the length of day (LOD), has been decomposed, in the same way as for the evolution of the geomagnetic field, by applying a Hodrick-Prescott filtering and then a Butterworth one, in fluctuations at several timescales, namely: sub-centennial (60-90 years), inter-decadal (20-35 years), decadal (~11 years) and intra-decadal (~6 years). The probable sources for these fluctuations, such as Alfvén torsional oscillations in the outer core, triggered by variations in the magnetospheric ring current, or a direct control of geomagnetic declination by variations in the magnetospheric ring current, have been investigated.
Decomposition of the geomagnetic field from certain main geomagnetic field model, in oscillation modes at various timescales by means of empirical orthogonal functions (EOF), was an innovative issue in the field, approached by our geomagnetism group. The EOF analysis showed that the first three oscillation modes are characterized by periodicities of >100 years, being responsible for more than 90% of the observed features at Earth's surface, while modes 4 and 5 are characterized by dominant periodicities of 60-90 years.

1.3.1.3. The geomagnetic disturbance field: space weather studies

In the time **interval** 2019-2022, covered by this report, according to the international scientific interest, the external geomagnetic field arising from the magnetospheric and ionospheric current systems, has mainly been studied in relation to both sources of it, and its natural induced hazard in the conductive structure of the Earth, known as space weather hazard. Major geomagnetic storms represent a significant space weather hazard through ground and near-Earth impacts.
To identify the sources accountable for the perturbations observed in geomagnetic data for certain major storms of solar cycle 24 (2008-2018) we used data from the SuperMAG database for the northern hemisphere. The geomagnetic data were analyzed using the empirical orthogonal function method (EOF) and the wavelet coherence analysis was used to assess the link between the time series of the EOF modes and various geomagnetic indices (Dst, AE, PC) that describe current systems in the magnetosphere and ionosphere, sources of perturbations. The results show that the main cause (45-68%) for the perturbations observed in data is given by the increase of the ring current during the storms.

The surface electric field (E), the geophysical input in assessing ground space weather impact of geomagnetically induced currents (GICs) hazard, one of the better recognised examples of space weather, was determined by using both the geomagnetic field recordings from European geomagnetic observatories, during intense geomagnetic storms from solar cycle 24, and the information regarding the underground electric conductivity. The geographical distribution of the maximum induced surface geoelectric field over Europe has been mapped showing that the maximum value, Emax, has not been reached at the same moment at all observatories and its orientation has been dependent on that moment of the storm development. These works showed that the geoelectric hazard (GICs) is significant above the 50ºN (S) geomagnetic latitude.

The surface electric field, at the local scale, namely the country scale, induced by the variable magnetic field of certain geomagnetic storms occurred in the solar cycle 23 and 24, was determined based on the geomagnetic field recordings from the Surlari geomagnetic observatory and on information regarding the underground electric conductivity from a recent magnetotelluric model of the Romanian lithosphere, showing that its amplitude depends on the morphology rather than the amplitude of the disturbance and highligthing the different behaviour of certain areas of the country. Therefore, even though the risks produced by the space weather hazard in the countries from middle latitudes might seem small, their are important to be studied.

Also, at a small extent, the response of the Earth interior (core and mantle) to the oscillations in the external currents system, particularly in the ring current, has been investigated and some characterization of electrical properties of the interior were obtained. This kind of work are still in progress.

1.3.2. Geomagnetic Observation and Geomagnetic Data and Indices

Surlari Observatory(SUA) is the unique Romanian geomagnetic observatory and has been functional continuously for over 79 years. Founded by the Geological Institute of Romania on October 16, 1943, it plays a major part as the national reference station for all kinds of magnetic maps and a center for fundamental research in both geomagnetic field and magnetic prospecting applications. Since 1998, Surlari observatory is an INTERMAGNET(www.intermagnet.org) member, and the very first goal of Surlari team is to promote modernization of observatory practice in order to achieve the present and future IAGA standards. The continuous recording main and back up equipments consist of two suspended FGE fluxgate variometers (DTU), two GSM90 Overhauser magnetometers (Gem Systems) and two improved MAGDALOG dataloggers developed at Niemegk observatory, Germany for observatory practice only. For the absolute measurements a DI-Flux single axis magnetometer (Bartington) mounted on a Zeiss 010B theodolite and a G856 proton magnetometer (Geometrics) for scalar measurements are the magnetic reference instruments for variometers

(https://eeris.eu/ERIF-2000-000G-44661). All these new developments – since 2009 - together with the checking and processing routine activities are upgraded - based on the operational methods and standards from data collection to rapid-delivery. At present, a data base adequately structured, as well as a methodological experience in processing phenomena with large enough spatial distribution and spectrum of periods, bring information of high interest not only in warning criteria for the magnetic status evolution, but also in the factors correlating these with some human activities for societal needs.

The geomagnetic team of Surlari National Geomagnetic Observatory from Geological Institute of Romania (IGR) has full expertise to measure, records, models and interprets the dynamic of the Earth's natural magnetic field.

The main objective of the observatory in this period was the use of unique institutional performance, at national level, in the field of metrology and geomagnetic field monitoring, in the context of providing specific and necessary services to align Romania with European standards on risk mitigation with consequences for air and maritime traffic, a national strategic objective. Through the studies performed, specific methodologies are created, improved and standardized by adapting the existing unique equipment and validating them in field conditions, for monitoring, measuring and interpreting the particularities of the geomagnetic field, with specific applications in reducing risks in aero navigation.

On the other hand, advancing space weather nowcasting and forecasting capabilities were carried out in the frame of SAFESPACE project: institutional capacities and services for the research, monitoring and forecasting of risks from extra-atmospheric space. The aim was deciphering the pattern of geomagnetic variations and creating a system for monitoring and forecasting geomagnetic activity.

In figures 2 and 3 are show of geomagnetic data analysed, sampled at 1 minute, from Surlari Observatory, for May 12, 2021, recent geomagnetic storm. In top-down order are: the geomagnetic signal recorded on the North direction, absolute coefficients for the level 5th wavelet transform with the db5 function, spectral analysis of North geomagnetic field and wavelet analyses.

For geomagnetic activity forecast Long Short-Term Memory (LSTM) recurrent neural networks used in discrete signal prediction are a type of recurrent neural networks that are able to record long-term dependencies. Conceptually, a recurrent unit LSTM tries to "remember" all past knowledge the network has seen so far and "forget" irrelevant data. This is done by introducing different layers with activation functions called "gates" for different purposes. Each LSTM recurrent unit also maintains a vector called "internal cell state" that conceptually describes the information that was chosen to be retained by the previous LSTM recurrent unit.

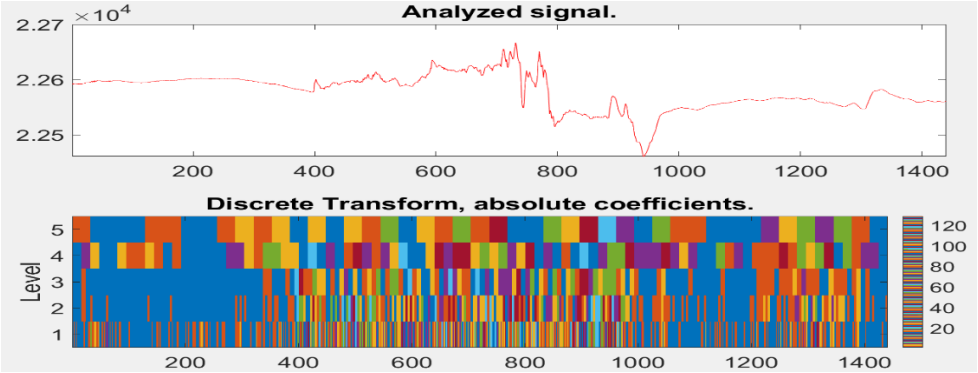

Figure 2: North geomagnetic field from Surlari Observatory and absolute coefficients for the level 5th wavelet transform with the db5, for May 12, 2021

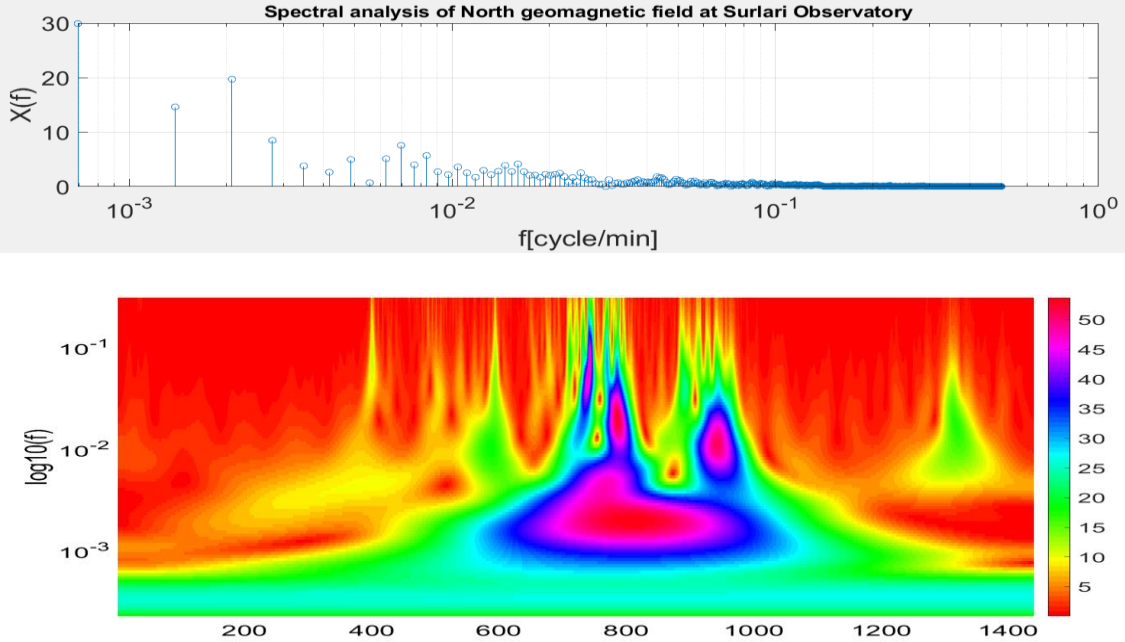

Figure 3: Spectral and wavelet analyses for North geomagnetic field from Surlari Observatory; for May 12, 2021.

An LSTM network comprises four different gates for different purposes as described below:

- Forget gate: determines to what extent previous data can be forgotten.
- Input gate: determines the information to be written in the internal cell state.
- Input modulation gate: it is considered as a part of the input gate and is used to modulate the information that the input gate will write on the internal cell state internally adding non-linearity to the information and normalizing the information. This is done to reduce learning time, ensuring faster convergence. Although the actions of this gate are less important than the others and are often treated as a concept that provides finesse, it is good practice to include this gate in the structure of the LSTM unit.

- Output gate: determines which output (next hidden layer) to generate from the internal state of the LSTM unit.

The implementation of the solution for predicting certain geomagnetic parameters is implemented in the MATLAB language, with the help of the Deep Learning Toolbox. It provides a framework for the design and implementation of deep neural networks (Deep Learning), convolutional neural networks (ConvNets, CNN) and recurrent LSTM networks are available for classification or regression of image, time series and text data. Also, in addition to using the MATLAB environment, the solution can be accessed, modified, or enhanced in the Jupyter Notebook computing environment.

1.4. Division VI: Electromagnetic Induction in the Earth and Planetary Bodies and Inter – Associations (IAGA – IASPEI – IAVCEI) Working Group: Electromagnetic Studies of Earthquakes and Volcanoes (EMSEV)

In the interval 2018–2022 the electromagnetic researches realized in the frame of: (i) IAGA DIVISION VI (Electromagnetic Induction in the Earth and Planetary Bodies); (ii) Inter-Associations (IAGA-IASPEI-IAVCEI) Working Group on “Electromagnetic Studies of Earthquakes and Volcanoes “(EMSEV), have included the following activities:

1.4.1. Electromagnetic studies for better understanding of the relation between the deep geoelectric structure of the Vrancea zone and earthquake generation mechanism.

For long time electromagnetic data supplied a large scale of information regarding the deep structure of the Carpathians’ Arc Bend Zone and surrounding areas, necessary for understanding the correlation between the structure and its geodynamic activity. Therefore, the Plates model (Figure 4) and the lithosphere/upper mantle 1-D conductivity models (Figure 5, Figure 6, Figure 7), which are complementary to other geophysical data and aid at defining constraints to the geological models, such as seismic tomography or reflection seismic models, temperatures or fraction of melt or volatiles. In the class of EM studies, the magnetotelluric sounding method (MTS) can provide information about the electrical properties of the deep crust and upper mantle, by using sufficiently long rage data recordings of the Earth’s electromagnetic components (Ex, Ey, Hx, Hy and Hz), in several sites, placed on the profiles crossing the main geotectonic units from Romania, such as:

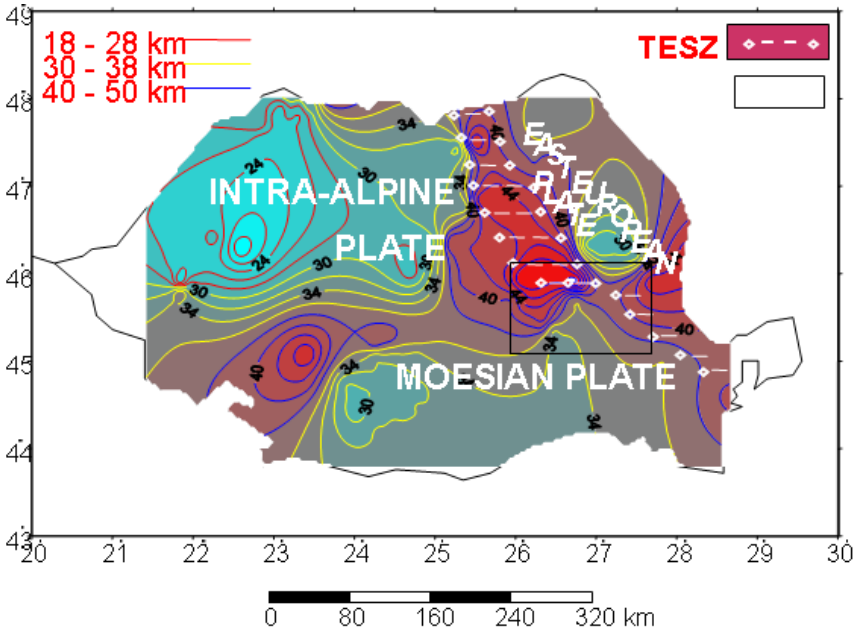

Figure 4: Plates model on the Romanian Territory; 18-28km (I-AP); 30-38km (MP); 40-50km(EEP)

East European Platform

1-D resistivity model (ρ) in lithosphere

Layers	ρ[Ωm]	H [km]	Observations
1	10	10	Sedimentary cover of the platform
2	1000	35	Crystalline basement
3	10	10	Crust-upper mantle transition zone
4	500	120	Upper mantle
5	10		Asthenosphere

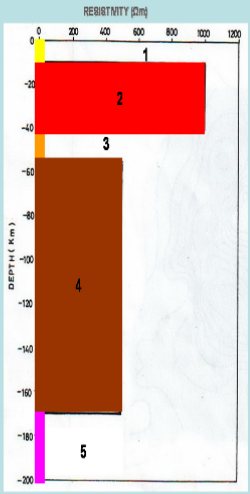

Figure 5: 1-D resistivity model EEP

Transylvanian Depression

1-D lithospheric resistivity (ρ) model

Layers	ρ [Ωm]	H [km]	Observations
1	5	5	Post-teclogenetic sedimentary cover
2	500	2	Central-East Carpathian Nappes Systems
3	700	24	Crystalline basement
4	10	10	Crust-upper mantle transition zone
5	500	40	Upper mantle
6	10		Asthenosphere

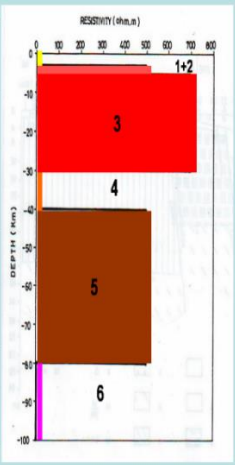

Figure 6: 1-D resistivity model TD

Moesian Platform

1-D resistivity model (ρ) in lithosphere

Layers	ρ [Ωm]	H [km]	Observations
1	10	10	Sedimentary cover of the platform
2	1000	30	Crystalline basement
3	10	10	Crust-upper mantle transition zone
4	500	80	Upper mantle
5	10		Asthenosphere

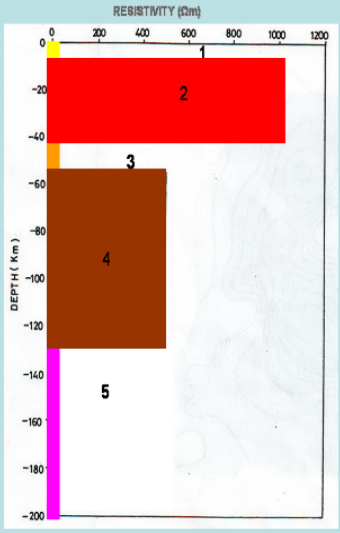

Figure 7: 1-D resistivity model MP

The 1D models emphasizing the resistivity distribution at different depths, gave information regarding:

a) the thickness of the East Carpathians flysch nappes systems and their over-thrust lineament with sedimentary cover of the East European Platform (EEP) (Figure 5);

b) the thicknesses of the volcano-sedimentary formations, Carpathian Foredeep and platforms sedimentary cover;

c) the thicknesses of the crust and upper mantle for (EEP, MP, TD and Pannonian Depression);

d) the major suture alignments (TESZ and Tethyan);

e) the crustal and lithospheric faults (Intra-Moesian, Trotuș and Peceneaga - Camena).

1.4.2. Pre-seismic geomagnetic signature related to Vrancea earthquakes and some other in the ward.

Electromagnetism and Lithosphere Dynamics Department have realized researches in the frame of the Priority Program with the theme: "*Electromagnetic study to emphasize the geodynamic activity of the Vrancea zone with possible implications in seismic events generations".* According to the methodology elaborated, the following parameters have been used to emphasize geomagnetic pre-seismic signatures related to Vrancea intermediate depth earthquakes and some others active areas in the ward:

- the normalized function BPOL which is time invariant in non-geodynamic conditions and it becomes unstable due to the geodynamic processes generated by the intermediate-depth seismicity, being associated with the

resistivity changes along the high conductivity faults in the crust and upper mantle;

- the parameter BPOL* obtained by using a statistical analysis based on standardized random variable equation.

Some example haw this methodology works are presented in papers and abstracts published.

2. Publications

2.1. Peer - reviewed publications

2022

Besliu-Ionescu, D., Maris Muntean, G., Dobrica, V., Complex Catalogue of High Speed Streams Associated with Geomagnetic Storms During Solar Cycle 24, *Solar Physics*, 297:65, 2022

Mares, C., Dobrica, V., Mares, I., Demetrescu, C., 2022, Solar signature in climate indices, *Atmosphere*, 13, 1898, https://doi.org/10.3390/atmos13111898.

Mares, I., Mares, C., Dobrica, V., Demetrescu, C., 2022, Selection of optimal Palmer predictors for increasing the predictability of the Danube discharge: New findings based on information theory and partial wavelet coherence analysis, *Entropy*, 24, 1375, https://doi.org/10.3390/e24101375.

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2021

Besliu-Ionescu, D., Mierla, M., Geoeffectiveness Prediction of CMEs, F*ront. Astron. Space Sci*., 8:672203, 2021, doi: 10.3389/fspas.2021.672203

Dobrica, V., Stefan, C., Demetrescu, C., Planetary scale geomagnetic secular variation foci in the last 400 years, *Global and Planetary Change*, 199, 103430, 2021

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Preoteasa L. Vespremeanu-Stroe A. Dan A. Țuțuianu L., Panaiotu C., Stoica M., Sava T., Iancu L.M., Stănică A-D, Zăinescu F.,2 Mirea D.A., Olteanu D. C.,6 Pupim F. N., Ailincăi S., 2021. Late-Holocene landscape evolution and human presence in the northern Danube delta (Chilia distributary lobes), *The Holocene*, 31(9), 1459–1475.

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Parvulescu, L., Perez-Moreno, JL., Panaiotu, C.,Dragut, L., Schrimpf, A., Popovici, ID., Zaharia, C., Weiperth, A., Gal, B., Schubart, CD., Bracken-Grissom, H., 2019. A journey on plate tectonics sheds light on European crayfish phylogeography, *Ecology and Evolution*, 9 (4), 1957-1971.

Preoteasa, L., Vespremeanu-Stroe, A., Panaiotu, C., Rotaru, S., Tutuianu, L., Sava, T., Birzescu, I., Dimofte, D., Sava, G., Mirea, DA., Ailincai, S., 2019. Neolithic to modern period palaeogeographic transformations in southern Danube delta and their impact on human settlements in the Enisala-Babadag region, *Quaternary International*, 504, 139-152.

Sortan, SA, Panaiotu, CG, Dimofte, D, Roban, RD, Necula, C, 2019. anisotropy of magnetic susceptibility analysis of the Rusca-Tihu volcaniclastic formation (East Carpathians): flow directions recognition, *Rom. Rep. Phys*., 71 (3), Article Number: 715.

2.2. Other journals articles and Proceedings papers

2022

Asimopolos L., Asimopolos N.-S., Asimopolos A.-A., (2022) Procedures for smoothing and filtering geophysical anomalies to evaluate geological sources, Oltenia. Studies and communication Natural Sciences, 38, No. 1, ISSN 1454-6914, p. 25-31;

Asimopolos N-S., Stanciu Alexandru, Asimopolos A-A., Asimopolos L., Balea-Roman B., 2022, Predictive methods for major geomagnetic disturbances, Oltenia. Studies and communication Natural Sciences, 38, No. 1, ISSN 1454-6914, p. 35-40;

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Dobrica, V., Demetrescu, C., Oscillations at sub-centennial timescales in the space climate of the last 150 years, *Rom. Geophys. Journal*, 65, 71-77, 2021

2020

Asimopolos N-S., Asimopolos L., Balea-Roman B., Asimopolos A-A., 2020, Statistical survey of geomagnetic indices in solar cycle 23, Oltenia. Studies and communication Natural Sciences;

Asimopolos L., Asimopolos N-S., Balea-Roman B., Asimopolos A-A., 2020, Numerical experiments about forecast of the strong geomagnetic disturbances, Oltenia. Studies and communication Natural Sciences;

2019

Besliu-Ionescu, D., Maris Muntean, G., An empirical model for geoeffectiveness of high speed streams in solar wind, *Rom. Geophys. Journal*, 63-64, 69-76, 2019-2020

Niculici E. L., Dinu L., Sandulescu A. M., Alexe V. E., Ultrabasic xenoliths from alkaline basalts from Racos and Bogata Olteana. Physical characteristics and their significance for the study of the structure and composition of the upper mantle, Oltenia. Studies and communication Natural Sciences;

Stefan, C., Dobrica, V., Demetrescu, C., Geomagnetic field characteristics revealed by empirical orthogonal functions analysis, *Rom. Geophys. Journal*, 63-64, 63-67, 2019-2020

2.3. Books

Demetrescu, C., Dobrica, V., The geomagnetic dipole evolution in the last 400 years. Sub-centennial oscillations, *Geoscience for Society, Education and Environment*, Chitea F. (Ed.), Romanian Academy Publishing House, doi:10.5281/zenodo.4322617, 2021

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IAHS ACTIVITIES IN ROMANIA

2019-2022

NATIONAL REPORT ON HYDROLOGICAL SCIENCES

Romanian IAHS Committee

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Content:

PART I: ORGANIZATION

The International Association of Hydrological Sciences (IAHS) support the scientific knowledge exchange in hydrology and related sciences for sustainable development in a changing world. The naib objective is to advance and promote hydrological sciences worldwide in order to contribute to interdisciplinary understanding of water-cycle processes, sustainable use of water resources and risk mitigation.

IAHS has 10 commissions, whose mission is to synthesise and accelerate science in various fields of hydrology:

- the Coupled Land-Atmosphere System (ICCLAS)
- Surface Water (ICSW)
- Groundwater (ICGW)
- Continental Erosion (ICCE)
- Snow and Ice Hydrology (ICSIH)
- Water Resources Systems (ICWRS)
- Water Quality (ICWQ)
- Statistical Hydrology (ICSH)
- Remote Sensing (ICRS)
- Tracers (TIC)

Also, within the IAHS, certain working groups are periodically defined according to pressing problems in the field of hydrology, currently there are 3 of them: IAHS Working Group on MOXXI (Measurements and Observations in the 21st Century); IAHS CandHy Working Group (Citizens and Hydrology); IAHS Working Group on the History of Hydrology.

The activities of IAHS organization in Romania took place under the supervision of the members of the Romanian IAHS committee, a Section of the Romanian National International Union of Geodesy and Geophysics (IUGG) Committee. IAHS National Committee is in the responsibility of National Institute of Hydrology and Water Management, the main institute involved in the hydrological activities at national level.

Romanian IAHS activities implied not only different specialists and researchers in hydrology field, but also professional organizations or institutions that develop studies and research projects. The main institutes that contribute to the improvement of hydrological knowledge are:

- National Institute of Hydrology and Water Management;
- National Institute for Research and Development on Marine Geology and Geo-ecology – GeoEcoMar;
- “Danube Delta” National Institute for Research and Development;
- National Institute for Marine Research and Development “Grigore Antipa”;
- National Institute for Research and Development in Environmental Protection;
- Institute of Geography, Romanian Academy.

Other professional organizations are linked to hydrological progresses, like:

- Romanian Association of Hydrological Sciences;

- Romanian Limnogeographical Association;
- Global Water Partnership Romania;
- Romanian Water Association.

One of the most important activities is education and efficiency increasing, which means the implication of some universities, like:

- University of Bucharest – Faculty of Geography;
- Technical University of Civil Engineering Bucharest - Faculty of Hydrotechnical Engineering;
- Babeș-Bolyai University, Cluj-Napoca - Faculty of Geography;
- Politechnical University, Bucharest - Faculty of Hydropower;
- "Alexandru Ioan Cuza" Universitaty, Iaşi - Faculty of Geography and Geology;
- "Gheorghe Asachi" Technical University, Iaşi – Faculty of Hydrotechnical Structures, Geodesy and Environmental Engineering;
- Ovidius University, Constanţa;
- University of Agronomic Science and Veterinary Medicine, Bucharest- Faculty of Land Reclamation and Environment Engineering.

The main institution that manages water resources at the national level should also be mentioned here, respectively "Romanian Waters" National Administration. It administers the waters of the public domain of the state and the infrastructure of the National Water Management System as well as the infrastructure of the national quantity and quality monitoring systems of the water resources.

National Institute of Hydrology and Water Management (NIHWM) is the national authority which carries out research and development activities and provides services in the field of hydrology, hydrogeology and management of surface and ground water resources at national level as technical support for the activities of the "Romanian Waters" National Administration and the Ministry of Environment, Waters and Forests, during extreme events (floods, droughts), as well as in normal conditions.

The institute provide various services in the field of hydrology, hydrogeology and water resources management. Also, it provides short, medium and long-term hydrological warnings and forecasts. Main objectives and responsibilities are:

- coordination of the hydrology and hydrogeology activity at national level from scientific point of view, ensuring the technical and specialized guidance for the hydrological network;
- development of methodologies and regulations in the field of hydrology, hydrogeology and water management;
- assess the water resources;
- carry out the hydrological and water management studies;
- suport the implementation of EU Directives (WFD, Floods, INSPIRE) and related management plans – FRMPs, RBMPs;
- exchange of hydrological data, forecasts, information and methodologies with the Romanian neighboring countries;
- responsible for elaboration of hydrological forecasts and warnings in Romania.

PART II: PROFESSIONAL ACTIVITY

1. Main research orientation in the fields of hydrological sciences

1.1. Surface Water

Ensuring the unitary methodological and operational framework regarding the collection and primary processing of hydrological data obtained from the national hydrological network

In order to know the evolution of water resources over time and the water management, the national hydrological network must ensure continuous series of data, over a long period of time and of appropriate quality. Data quality assurance is carried out through the activities of analysis and validation (expertise) of their processing solutions, guidance and methodological and technical control of hydrological stations and services and verification and validation of activity programs (for establishing and keeping the necessary data at each location).

The methodological and technical guidance of the national hydrological network for the continuous improvement of the current activity and the quality of the hydrometric data

This activity was carried out through trips to the territorial units within the national hydrological network (hydrological and hydrometric stations, hydrological services) and had the purpose of verifying the way of carrying out specific activities, the technical condition of the facilities and equipment provided for carrying out the complex of measurements and to provide scientific, methodological and technical support in their correct performance.

Elaboration and implementation of methodological instructions in the field of hydrometry

The analysis of the technical regulations, of the WMO guidelines and the standards in the field of hydrology and hydrometry, had as main purpose the updating and improvement of the methodological guidelines and instructions used for the hydrological activity and their updating, considering the numerous documents developed by the WMO in the field of hydrology and hydrometry, and the large amount of information that WMO guides, reports and manuals contain.

Annual summaries on the hydrological regime of the representative and experimental basins in the hydrometric network

In order to know the characteristics of the runoff in the small river basins with an up to 150 km^2 surface, in Romania there are 14 representative basins located in all the physic – geographical areas of the country. The location of Representative Basins in Romania offers the possibility to study the characteristics of the liquid and solid runoff for a large variety of conditions, as concerning: soil, geology, relief, vegetation.

The research in small basins was necessary because some of regularities that act in large basins, cease to action for the little ones.

In this case, the important tools at these basins, in the period 2019 – 2022 was:

- to establish the regionalization relation between different type of runoff and the main morphometric parameters;
- determination the values of the runoff coefficient for a diversity of conditions (precipitation, the afforestation coefficient, basin slope, soil texture) and for various agriculture crops;
- solving the relation between the concentration time and various physico-geographical areas;
- the detecting trends and changes in runoff regimes;
- validation the modelling in the large scale.

Data accumulated in the representative basins are systematized in the form of year books including a multitude of hydrological data referring to the characteristics of the liquid and solid flow and the above-mentioned meteorological data in form of tables and graphs.

Experimental hydrological research with experimental plots, in correlation with complex programs of observations and measurements, is conducted at 2 research units (Voinești and Aldeni). The content of these activity concerns the establishment of quantitatively defined relationships of runoff and genetic and conditional factors. These basins are situated in the Curvature Subcarpathians.

Within the Aldeni Experimental Basin and Voineşti Experimental Basin, the micro-scale study of hydrological components of the water budget is conducted with an observation equipment (Figure 1) that allows an estimation of the physiographic influences in the region (geomorphic, climatic, soil) and anthropogenic intervention - land reclamation.

Figure 1: Experimental aspects (rain-runoff) carried out on the slopes (Aldeni Experimental Basin)

In order to study the process of **evaporation and evapotranspiration** during the period 2019 – 2022, a complex program of hydrometerological observations and measurements was carried out daily, at fixed deadlines, about a number of 52 evaporimeter stations.

The influence of water temperature on the evaporation process – case study on Caldăruşani lake

The water temperature of Caldărușani lake varies annually, depending on the air temperature, which determines the recording of maximum values of the water temperature on the surface in the summer season (over 27ºC in July and August) and lower values in the spring (around 20-21ºC) and autumn (drops below 14ºC).

Amounts of precipitation falling on the water surface and high wind intensities can generate a decrease in the water temperature from the surface to a depth of 0.4 m. The day and night analysis of the water temperature indicated that the maximum hourly values of the water temperature are recorded in around 16:00 – 18:00, while the minimum values occur in the morning after 7:00. Thus, the data processing carried out, it can be stated that the water temperature for lakes with relatively small depths in the plain regions, as is the case of Căldăruşani lake, had low values in the early hours of the morning, respectively at 7:00 a.m., these maintaining for about 2 hours, then increasing by about 2.0ºC until 13:00 and reaching a maximum after 17:00. The differences between the maximum and minimum values of the daytime water temperature, naturally (without anthropic interventions or extraordinary situations), cannot exceed 4ºC (for water bodies with morphometric and climatic characteristics similar to those of Căldăruşani lake).

At the same time, through the comparative analysis of the water temperature of Caldărușani lake measured directly (in situ), with the values generated by the MODIS satellite products (free data, at a time step of 8 days), it was observed that they show a normal temporal variation with temperature increases in the spring months, a maximum reached during the day in the summer season (up to 32°C), and with temperature drops in the autumn (up to 11°C values in October). The differences between the values measured directly and those estimated based on MODIS can be attributed to the high resolution of the product of 1 km^2, but also to the different time periods at which the water temperature is measured or recorded.

The analysis of the spatial variation of the temperature of the water of the Căldăruşani lake shows higher values at the extremities, near the greatest width of the lake, the western part, but also in the eastern part, at the tail of the lake, where during the summer the silted process occurs, from cause of abundant vegetation.

Regarding the spatialization of evaporation and evapotranspiration based on water temperature, it was observed that there are very large differences between them, the latter being twice as high as water evaporation. By spatializing the two processes, using water temperature data obtained from MODIS satellite products, no differences can be identified regarding water evaporation and evapotranspiration of the aquatic vegetation developed on the shore, since the 1 km^2 pixel surface covers both water and vegetation.

Thus, we consider that to estimate evaporation and evapotranspiration from the surface of water bodies and for their spatialization, it is necessary to know and use several parameters, both climatic and morpho-hydrological. Water temperature, although directly related to evaporation and evapotranspiration, is in turn conditioned by a number of factors, namely air temperature, precipitation, and even wind speed.

Assessing the role of soil moisture in hydrological processes at different scales

The role of soil moisture in hydrological process has been assessed by: (1) analyzing the soil water content measured in the Voinesti experimental catchment using Delta T profile probe and soil moisture sensors on experimental parcels using Decagon sensors; (2) modelling soil moisture using ModClark semi-distributed hydrological model implemented in HEC HMS software. Investigation of soil water movement on soil profiles revealed that in the hilly area the interaction between soil and atmosphere is developing between 20 and 40 cm depth, while the lateral flow controls the soil water content in the lower soil horizons (40-100 cm). The daily soil moisture measured on soil profiles between 2015 and 2019 in the Voinesti catchment showed that the geological structure represented by synclines and anticlines influences the spatially distribution in this specific subbasin. On the level of experimental parcels soil moisture measurements have been used to estimate soil infiltration coefficients. In addition, measured precipitation and discharge were used to calculate runoff coefficients for numerous hydrological events. Soil hydraulic properties were derived in laboratory using undisturbed soil samples collected from experimental parcels.

Visualization and modeling of 3D sub-surface processes in Ialomita-Buzau catchments

The analysis of subsurface hydrological processes at different spatial scales allowed the following conclusions and recommendations to be identified:

- based on the data from the lithological and hydrogeological monitoring boreholes, analyzed and visualized multidimensionally with the help of the ArcHydro Groundwater extension, a better understanding of the geological and hydrogeological substrate needed for soil moisture modeling could be obtained. This extension is particularly useful for managing, analyzing and visualizing subsurface data. Based on the results obtained, the role of subsurface runoff in basin hydrology was highlighted with applications both in the assessment of flood production potential and in water resource management. In future applications, it is recommended to combine borehole data with geophysical borehole logs in order to improve the description of formation types, sequence and depth of strata as well as their thickness;
- the results obtained in the 3D modeling stage show the need to adapt the modeling methods according to the purpose of the study. If in the case of detailed studies, on a local scale, the finite element method allows the modeling of continuous structures within the stratified soil profile, on a regional scale, rain-runoff models integrate the best response of drainage surfaces to precipitation. The two approaches used at different scales are complementary and allow a better understanding of subsurface hydrological processes.
- the results of the simulation of the rain-runoff process allowed the identification of two types of hydrological behavior, determined by the characteristics of the geological formations: (1) sub-basins in which impermeable formations

predominate, causing a low infiltration rate and a significant runoff on the slope, (Figure 2) favoring the occurrence of floods; (2) sub-basins in which permeable formations predominate, which determine a significant infiltration rate and a reduced runoff on the slope, favoring the basic supply of the rivers in periods of insufficient precipitation.

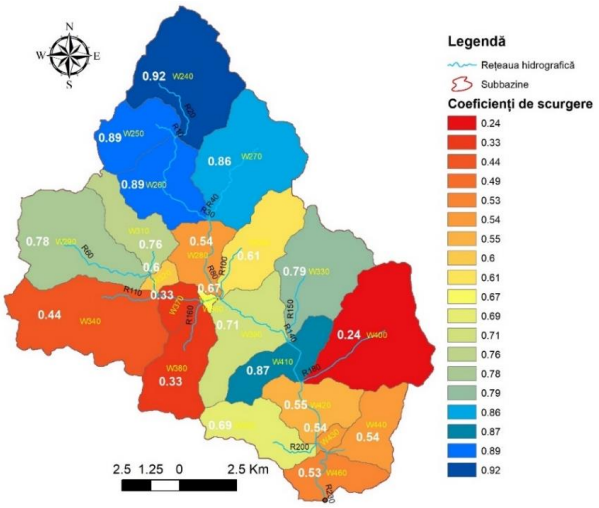

Figure 2: Spatial distribution of the runoff coefficients corresponding to a rain with the exceeding probability of 0.01 (1%)

Comparative study on the methods of estimating runoff coefficients using open-source data at different spatial scales within the Ialomița-Buzău basins

The runoff coefficient is an important tool in hydrological studies of urban and rural engineering projects, being used to estimate maximum flows with different exceedance probabilities. In this context, the estimation of the runoff coefficient must be as rigorous as possible, taking into account the characteristics of precipitation, the previous soil moisture as well as the current physical-geographical characteristics, especially the way of land use.

Estimating runoff coefficients from observational data, under the most varied conditions, has been a continuous activity within INHGA, especially within representative and experimental basins (Miță, 2019). This activity is currently being continued, within the Voinești and Aldeni experimental basins, by exploiting the data base obtained starting from 2019 with the help of automatic sensors that allow the continuous measurement of water level, soil moisture and precipitation at a very fine temporal resolution.

The use of runoff coefficients in any hydrometrically uncontrolled section in Romania requires the spatial extrapolation of observational data. In this study, based on spatial data with free access at European level and the values of runoff coefficients for the most varied conditions regarding the degree of afforestation, soil texture and slopes, determined by Miță (2019), a preliminary map of the coefficients was made. The validation of these coefficients was done by comparing them with the values of the coefficients determined for historical floods in certain hydrometrically controlled sections of the Ialomița-Buzău basins and which have a natural hydrological regime. This comparison highlighted an underestimation of the values in the preliminary map of the runoff coefficients, the explanation could be related to the fact that the values of the runoff coefficients determined by Miță (2019) are determined for floods with

different overflow probabilities, while the historical floods analyzed have probabilities of exceeding between 1 and 5%. Under these conditions, the extrapolation of runoff coefficients on a national scale for the estimation of maximum flows should take into account the highest floods recorded, with an exceedance probability of less than 5%.
Analysis of historical floods analyzed for sub-basins with natural hydrological regime in B.H. Ialomita-Buzău highlighted a wide range of runoff coefficients from one rainfall event to another, which determines the need to use an average flood runoff coefficient. The analysis of runoff coefficients from 2014 using adjusted radar precipitation highlighted the heterogeneous nature of precipitation and the need to use in the future data estimated by meteorological radars covering the entire territory of Romania, for a rigorous determination of runoff coefficients.
Therefore, based on the historical floods analyzed and the spatial data available for the entire territory of Romania, it is necessary in the next period to update the map of the runoff coefficient made in INHGA by the team coordinated by Blidaru and Niţă, 1977.

Updating methodologies for determining maximum flows with different exceeding probabilities in view for publication through normative acts

The general objective was the regulation by a normative act of the methodologies for calculating the maximum flows with different probabilities of exceeding, currently used in our country, both for basins with large areas and for those with small areas, taking into account both flow regimes, respectively the natural one and the influenced by hydrotechnical facilities with the role of mitigating flood waves.
In the work, the methods and models were presented in detail, both direct and indirect methods for calculation of maximum flows with different exceeding probabilities for the natural flow regime.
The requirements for determining the maximum flows with different overflow probabilities of the calculation floods in the hydrotechnical regime are constantly increasing due to the existence in our country of numerous hydrotechnical constructions that must be taken into account in the process of mathematical modeling of the flow in a basin arranged hydrograph. For this reason, in the work, the methods for determining flood waves were also described, modified as a result of the influence of hydrotechnical facilities.

Computing of ecological flows in accordance with the requirements of the Water Framework Directive, for a series of priority dams

The determination of the ecological flows, in accordance with the requirements of the Water Framework Directive, for a series of priority dams is the first step of the complex process that can lead to the fulfillment/maintenance of the environmental objectives provided by the Water Framework Directive for the water bodies of rivers in Romania.
The purpose of the study is to determine the ecological flows for a series of dams located on priority water bodies (more than 120 dams/water intakes) belonging to the National Administration "Romanian Waters", in accordance with the requirements of the Water Framework Directive (2000 /60/EC) and the ecological flow calculation

methodology approved by Decision no. 148 of February 20, 2020. The "Romanian Waters" National Administration has prioritized the dams under the administration of the A.N.A.R. system, depending on: the state/potential of the water body located immediately downstream of the dam, the fish element, the global hydromorphological state and the hydrological regime element.

In order to achieve the purpose of the study, the following main activities were carried out (being structured by Water Basin Administrations and each dam/water outlet separately):

- Computing of the hydrological parameters that are the basis for the calculation of the ecological flows in order to be ensured downstream of the priority dams;
- Computing of the ecological flows corresponding to the hydrological regime of low, medium and high waters correlated with the monthly hydrological forecast classes, in order to ensure downstream priority dams;
- Computing of servitude discharge.

The results of the study consist of ecological flows/servitude flows corresponding to the hydrological regime of small, medium and large waters correlated with the monthly hydrological forecast classes, in order to ensure downstream priority dams (60 dams), in accordance with the requirements of the Water Framework Directive. Taking into account the present study as well as the previous studies carried out within the I.N.H.G.A., ecological/servitude flows were calculated for more than 120 dams/water intakes under the administration of the A.N.A.R. system. The results of the study represent support for the practical implementation of ecological flows for a series of priority dams.

Catalog of measures to mitigate the impact of hydromorphological alterations in accordance with the provisions of the Water Framework Directive (2000/60/EC) and their effectiveness in terms of ecological status

The study represents a support study that can contribute to the implementation of the Water Framework Directive in Romania.

The purpose of this study is to develop the Catalog of measures to mitigate the impact of hydromorphological alterations in accordance with the provisions of the Water Framework Directive (2000/60/EC) and their effectiveness in terms of ecological status.

In order to develop the Catalog and establish the effectiveness of each mitigation measure in terms of the quality elements required by the Water Framework Directive, the following activities were carried out:

- Presentation of the general aspects regarding the Water Framework Directive and the quality elements that define the ecological state.
- Presentation of the types of activities generating pressures/hydromorphological alterations at the level of surface water bodies.
- Detailed analysis of the types of hydromorphological pressures/alterations existing in Romania.
- Presentation/classification of measures to mitigate hydromorphological alterations generated by different drivers for various purposes

- Presentation of the classification system/criteria for evaluating the effectiveness of mitigation measures in terms of ecological status.
- Elaboration of the Catalog of measures to mitigate the impact of hydromorphological alterations

The result of the study is the "Catalog of measures to mitigate the impact of hydromorphological alterations, which contains measures for the following categories of surface waters: rivers, lakes, coastal waters and transitional waters" and includes a theoretical efficiency of these measures in terms of all required quality elements of the Water Framework Directive.

The measures to mitigate the impact of hydromorphological alterations are addressed to some types of factors ("drivers") possibly generating hydromorphological alterations through the hydrotechnical works necessary for energy production, water supply to the population, industry, irrigation, fish farming, flood risk management, agriculture (drainage-drainage systems) and navigation.

Establishing the theoretical effectiveness of the mitigation measures in terms of all the quality elements characteristic of the water categories rivers, lakes, coastal waters and transitional waters, represented a challenge and was based on the consultation of various bibliographic sources but also on the basis of the opinion of the INHGA specialists involved in the elaboration of the study.

The catalog of measures to mitigate the impact of hydromorphological alterations will contribute to the second update of the National Management Plan for the national portion of the International River Basin of the Danube River.

1.2. Coupled Land-Atmosphere System

The estimation of surface water resource evolution in the Someș-Tisa, Crișuri and Argeș-Vedea hydrographic areas in the context of the climate changes for 2021-2050 and 2071-2100 time periods

In order to estimate the impact of climate changes on the hydrological resources of a hydrographic basin, a water balance hydrological model with a monthly time step (Water-Balance, WatBal) was used. The time series of input data to this model include: effective precipitation (which includes corrections for seasonal plant interception, altitude and measurement errors), potential evapotranspiration, and for calibration, mean monthly runoff for a fixed time interval, common for all stations for which the simulations are to be performed.

In order to carry out the simulations of the average monthly runoff with the help of the Watbal balance hydrological model, the climatic data for all the hydrometric stations selected in the area of interest were processed, in a first step. Thus, the average monthly values of air temperature and the monthly values of the amounts of atmospheric precipitation were analyzed and processed for the three proposed analysis intervals: 1981-2010, the reference interval, 2021-2050, the interval of the near future and 2071- 2100, the range of the far future.

Following the simulations carried out with the WatBal balance model, using the climate data corresponding to the RCP 2.6, RCP 4.5 and RCP 8.5 scenarios, the

average monthly flow values at the analyzed hydrometric stations were obtained, values that were averaged and transformed into volumes. For the time horizon 2021-2050, within the climate scenario RCP4.5., at the monthly level, cases of decreasing trends predominate (Figure 3).

In order to identify trends in the variability of the average resource on a monthly and annual scale and to establish the statistical significance of any trends, the Mann-Kendall non-parametric statistical test was applied with the help of the MAKEENSES 1.0 program, on the series of monthly and annual values of the average water stock, resulting in following modeling with the WatBall program, for the three intervals analyzed: 1981-2010, 2021-2050 and 2071-2100 and for the three climate scenarios used.

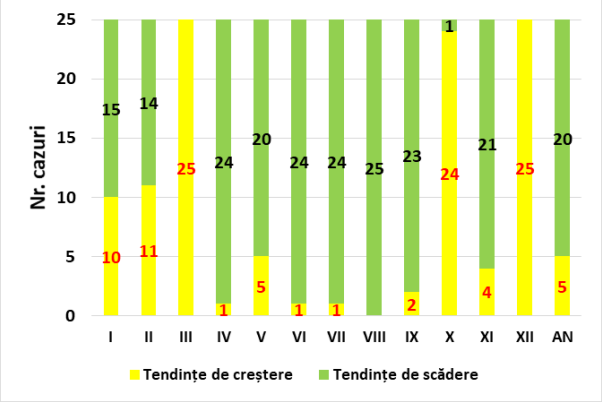

Figure 3: Trends of increase and decrease of the average monthly stock at the 25 hydrometric stations analyzed in Argeș-Vedea hydrographic space for the 2021-2050, RCP 4.5 climate scenario

1.3. Groundwater

Hydrogeological studies support for the implementation in Romania of the groundwater provisions of the Water Framework Directive 2000/60 / EC and the Groundwater Directive 2006/118 / EC, in order to elaborate the Hydrographic Basins Management Plan 2022-2027

Main results consist in:

- Evaluation of the relationship between groundwater bodies, surface waters and associated ecosystems;
- Assessment of the relationship between the habitats related to sites of community importance (SCI) and areas of special avifaunistic protection (SPA), according to the Natura 2000 classification, with Romanian phreatic groundwater bodies;
- Development of conceptual models and groundwater flow models for part of the phreatic groundwater bodies on the territory of Arges-Vedea, Buzau-Ialomita, Olt, Jiu, Banat and Siret Water Administration (Figure 4 and Figure 5);
- The use of mathematical modeling in the analysis of the possibility of using phreatic groundwater as a source for irrigation as well as the effects produced by this activity on the groundwater bodies;
- Evaluation of the data in order to update the values of the natural background and the threshold values for the groundwater bodies of Romania.

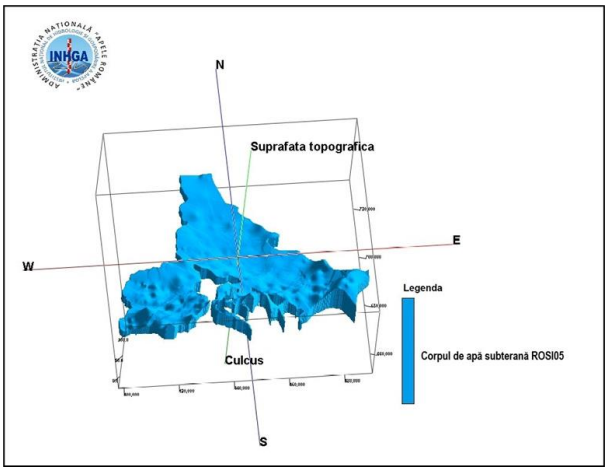

Figure 4: The 3D hydrogeological model for the groundwater body ROSI05– Lower Siret Plain

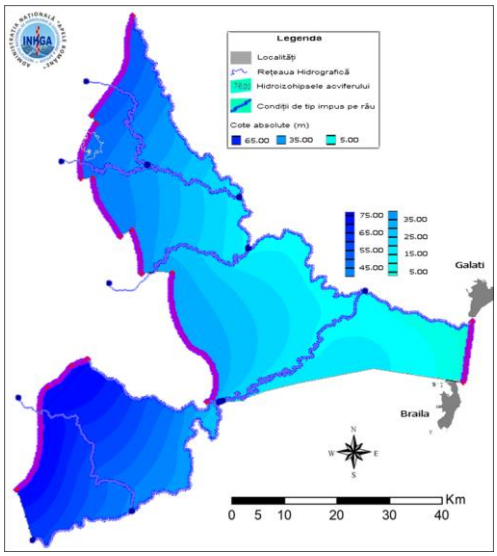

Figure 5: Numerical model of groundwater body ROSI05, natural flow regime

1.4. Statistical Hydrology

Trends in minimum runoff on rivers in Romania

Parameters that were analyzed are BFI - The ratio of annual baseflow in a river to the total annual runoff on a river; Q_{med} - multiannual average flow; Q95, Q90 - 95 and 90 percentiles of the daily average flow duration curve and Flow deficit - hydrological drought event characterized by duration, volume, intensity, minimum flow and duration time

Series of daily average flows from 132 hydrometer stations located on Romanian rivers were used for1970-2015 period. The analysis was done using LFSTAT software (Koffler and Laaha, 2013) - developed in the R program based on the methodology documented in the Manual of Low-Flow Estimation and Prediction (OMM, 2008).

Between 1970 and 2015, years with significant change were identified at 69 hydrometer stations. For 55 hydrometric stations a negative change with high statistical significance (greater than 95%) was identified.

River basins that cannot sustain the runoff during periods of prolonged drought due to poor underground supply (BFI values ranging from 0.13 to 0.30) were identified only at 9 hydrometer stations of the 132 analyzed.

The highest percentages of the annual maximum deficits, calculated for the two cases, of 97.33% and 85.6% respectively, were determined in 2012. The comparative analysis of the runoff deficit frequency over different time intervals reveals the period of the last 10 years (2006-2015) as the most affected by the hydrological drought (Figure 6).

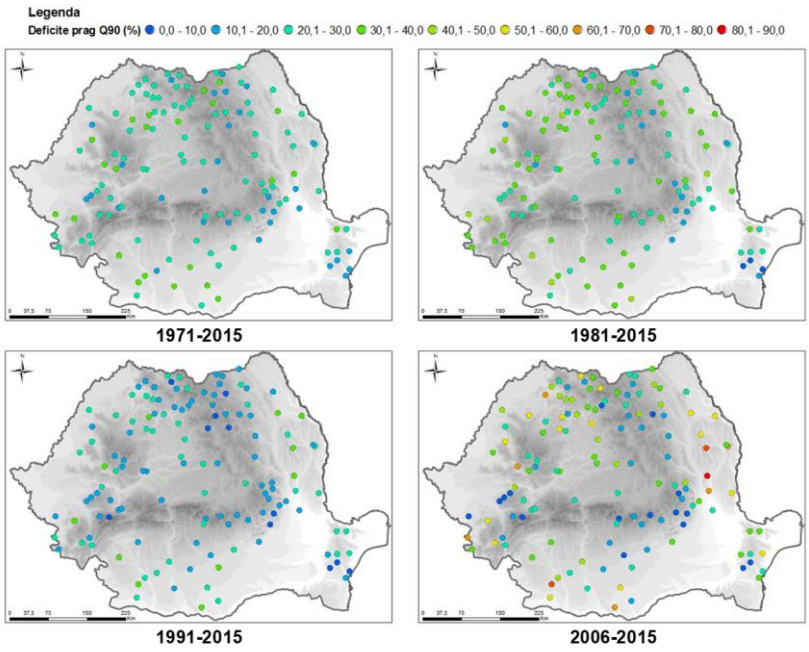

Figure 6: Frequency of the flow deficit

The seasonality of the minimum runoff on rivers in Romania in the last 40 years

The seasonality index high-lighted, both at the level of 40 years and for the last 20 years, a high degree of seasonality of the minimum runoff ($r > 0.5$) for a number of 90 hydrometric stations (82%) and, respectively, of 95 hydrometric stations (86%).

The period of the last 20 years between 1980 and 2019 showed an increase in the percentage of hydrometric stations corresponding to some hydrographic subbasins with a regime of low flow in the warm season and, at the same time, a decrease in the percentage of hydrographic subbasins with the appearance of minimum flows in the cold season (Figure 7).

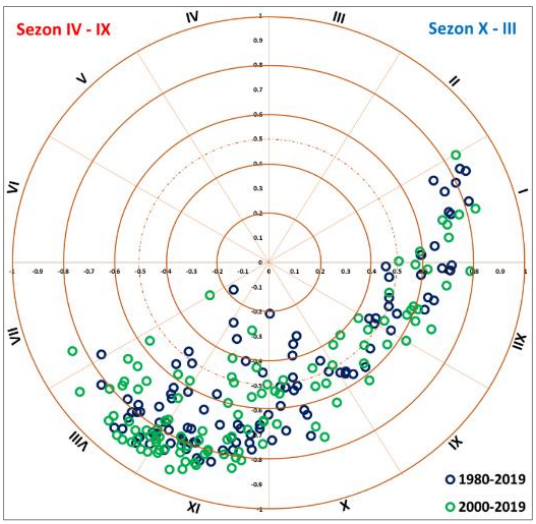

Figure 7: Seasonality index
(1980 – 2019 vs. 2000 – 2019)

The disparity in the date of appearance of the minimum flows in the last 20 years, from 5 to 55 days, occurred at approximately 50% of the total utilized stations;

instead, the delay in the date of appearance of the minimum flows, from 1 to 31 days, was evident at 23 hydrometric stations (21%).

The application of a linear regression model led to the estimation that with the increase in altitude, there is also a lag in the date of appearance of minimum flows in the last 20 years, but this is not predictable, and the power of association of the two variables is moderate; the average altitude of the hydrographic basin explains only 16.5% of the variability of the difference between the minimum runoff occurrence dates, corresponding to the two studied time intervals, and a significant amount of information (the dependent variable) is not explained by the model used; in conclusion, the changes in the date of occurrence of minimum flows can be produced to a lesser extent by some physical-geographical elements but, with certainty, they can be triggered and accentuated by climatic and anthropogenic factors that were not part of the analysis of the study.

2. Participation of the Romanian specialists in international programs or projects

The participation of Romanian specialists in national and international programs and projects is an objective necessity mostly motivated by the requirements of the economy to know the main hydrological and hydrogeological characteristics of water resources. That is why the projects and programs had aimed to establish the most efficient methods and models to determine the status of water resources under various circumstances.

The participation of Romanian specialists in **international programs** and working groups aimed at similar objectives – this time expanded at regional level, using at the same time the experience of specialists coming from different countries, involved in giving solutions to the scientific and technical problems raised by socio-economical requirements.

At **international level** we can mention participation of Romanian specialists in important international programs and workgroups current activities, like WMO, ICPDR, PHI-UNESCO, IGU, COST Actions etc.

Some of Romanian experts holds important positions within organizations, such as Mrs. Liliana ZAHARIA, which is vice-chair of the IGU Commission for Water and Sustainablity (since 2020), Member in the Management committee of the COST Action titled *Process-based models for climate impact attribution across sectors (PROCLIAS*) – COST CA 19139 and leader of the Task group 4.2. within the Working Group 4 (*Communication and dissemination of climate impacts*) of the *PROCLIAS* – COST ACTION

2.1. Participation within the activities of the Hydrological Workgroup "Regional Association VI – Europe" and WMO

- Meeting of the Steering Committee of the Support System for the Development of Flash Flood Warnings for Southeast Europe (SEEFFGS), organized by the WMO Secretariat, on 10-11.11.2022 in Antalya, Turkey
- The Regional Conference of the VI Regional Association (RECO RA VI) of the World Meteorological Organization (WMO), regarding the Role of National Meteorological and Hydrological Services in the future: Leadership and Management, organized by the WMO Secretariat between 2-4.11.2022 in a hybrid system
- 17th Annual EFAS (European Flood Warning System) partners meeting, videoconference, 27-28.09.2022
- 3rd Regional Forum for Region VI - Europe of Hydrology Advisors, online format, 28.06.2022
- 29th Working Meeting of the Regional Hydrological Cooperation of the Danube Countries within the framework of PHI-UNESCO and XXVIIIth Conference of the Danube Countries on Hydrological Forecasting and Hydrological Bases of Water Management, 05-08.11.2019, Kiev, Ukraine

- Global workshop for Flash Floods Guidance System (FFG), 04-08.11.2019, Antalya, Turkey
- International Danube Day 2019 – technical-scientific conference organised by Bulgarian Scientific Academy and Global Water Partnership, 1.07.2019, Sofia, Bulgaria
- First working meeting in order to plan and start the necessary activities for the integration of weather radar data in the South East Europe Flash Flood Guidance System (SEEFFG), organised by WMO, 24-25.10.2019, Split, Croatia
- Fourth conference of the European Central Group of the International Hydrogeological Association, 18-20.06.2019, Donji Milanovac, Serbia
- 3rd Annual Meeting of European and Global Drought Observatories, 21-22.05.2019, Stresa, Italy
- 4th WMO RA VI Hydrology Forum and First meeting of the RA VI Task team on Hydrology, 02-04.04.2019, Bratislava, Slovakia
- Technical Conference for Priorities of Hydrology Activities in the Future and Extraordinary session of the Hydrology Commission, 11-14.02.2019, Geneva, Suisse

2.2. Participation within the activities of the International Hydrological Program (IHP- UNESCO)

- UNESCO International Conference on Water, 13-14.05.2019, Paris, France

2.3. Participations to the current activities of the European Committee:

- 31st Meeting of the CIS Working Group Floods of the European Commission and the WGF Workshop on "Lessons learned following the implementation of Cycle 2 of the Floods Directive, 19-21.10.2022
- 42nd CIS-GROUNDWATER WORKING GROUP MEETING, Praga, Czech Republic, 11-12.10.2022
- The workshop on the theme "Pluvial floods" (18 – 19.05.2022) and at the 30th meeting of the Working Group on Floods (19 – 20.05.2022), organized by the European Commission in hybrid format
- 40th CIS-GROUNDWATER WORKING GROUP (VIRTUAL) MEETING under Slovenian 2021 EU Council Presidency, 13 – 14.10.2021
- 29th Meeting of the Working Group Floods of the European Commission and the WGF Workshop on "Adapting flood risk management for climate change", which took place in a hybrid format between 12-14.10.2021
- 39th CIS-GROUNDWATER WORKING GROUP (VIRTUAL) MEETING under Portugal's 2021 EU Council Presidency, 22 – 23.04.2021
- 26th Meeting of the Working Group on Floods of the European Commission, 15-18.10.2019, Helsinki, Finland
- 37th Meeting of the Working Group on Groundwater within the Joint Strategy for the Implementation of the Water Framework Directive (WFD CIS GW WG) and the joint Workshop "Better integration of drinking water considerations in the River Basin Management Plan", 14-16.10.2019, Helsinki, Finlanda

- 25th Meeting of the Working Group on Floods (25th Meeting of the Working Group on Floods) of the European Commission-Directorate General Environment, the workshop "Awareness of risks and their communication in Flood Risk Management Plans" and the Focus The group on the evaluation of the Flood Directive (Fitness Check), 26-29.03.2019, Lisboa, Portugal

2.4. Participation at the current activities of the International Committee for the Protection of Danube River (ICPDR):

- 32nd Meeting of the ICPDR Groundwater Task Group, Hof, Germany, 15-16.09.2022
- 30th meeting of the Group on water management issues in the Tisa river basin, organized by the International Commission for the Protection of the Danube River (ICPDR) and the meeting on the elaboration of the JOINTISZA 2.0 and LAREDAR project proposals, 6-7.07.2022, in Szolnok
- 31st Meeting of the Groundwater Task Group, On-line ZOOM meeting, 30.03.2022
- 27th meeting of the HYMO Working Group within the ICPDR, organized online, 16.03.2022
- 30th meeting of the Working Group on Groundwater (GW TG) within the International Commission for the Protection of the Danube River (ICPDR), 06-07.10.2021, in online format
- 28th meeting of the Group on water management issues in the Tisa hydrographic basin, organized by the International Commission for the Protection of the Danube River (ICPDR), which took place in videoconference format, 13.05.2021
- 29th Meeting of the Technical Group on Groundwater (GW TG) within the International Commission for the Protection of the Danube River (ICPDR), online 10-11.03.2021
- 22nd meeting of the working group on hydromorphological issues (HYMO TG) within the International Commission for the Protection of the Danube River (ICPDR), 24-25.09.2019, Ljubljana, Slovenia
- 21st meeting of the working group on hydromorphological issues (HYMO TG) within the International Commission for the Protection of the Danube River (ICPDR), 18-19.03.2019, Viena, Austria

2.5. Participation in international projects (2019-2022)

- **MERLIN, 2021-2025** – Mainstreaming Ecological restoration of freshwater-related ecosystems in a landscape context: INovation, upscaling and transformation, https://project-merlin.eu/
- **REXUS, 2021-2024** – Managing Resilient Nexus Systems Through Participatory Systems Dynamics Modelling, https://www.rexusproject.eu/
- **WaterForCe, 2021-2023** – Water Scenarios for Copernicus Exploitation, https://waterforce.eu/
- **PIMEO AI, 2020-2023** - Pollution Identification, Mapping, and Ecosystem Observation with AI-powered water quality USV,

- **CERTO, 2019-2023 -** Copernicus Evolution – Research for harmonized and Transitional water Observation, https://certo-project.org
- **MONOCLE, 2018-2022 -** Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries, https://monocle-h2020.eu/
- **Danube Floodplain, 2018-2021 -** Reducing the flood risk through floodplain restoration along the Danube River and tributaries
- **DARREFORT, 2018-2021 -** Danube River Basin Enhanced Flood Forecasting Cooperation"
- **JOINTISZA, 2017-2019 -** Strengthening cooperation between river basin management planning and flood risk prevention to enhance the stats of waters of the Tisza River Basin
- **DanubeSediment, 2017-2019 -** Danube Sediment Management – restoration of the sediment balance in the Danube River –
- **NAIAD, 2016-2020 –** Nature Insurance value: Assessment and Demonstration, https://naiad2020.eu/

3. Organization of national and international scientific conferences

- **Sustainable Water Management Scientific Session** at the International Geography Congress, 18-22.07.2022, Paris (by Morosanu G. from IGAR, as Chair of IGU YECG-GEOSUS working group).
- **National Conference *Living by the rivers*,** 20-22.05.2022, Cluj – Napoca, Romania, was organized by the Stefan Cel Mare University, Suceava and Institute of Geography of the Romanian Academy.
- **5th International Conference *Water resources and wetlands*,** Tulcea, 8-12.09.2021. Main organizer: ARLG http://www.limnology.ro/wrw2020/wrw2020.html
- Organization of a field application, **"Hydrology Field Experience"**, in Kaunertal National Park, Austria, 26-29.09.2019, together with the Hydrology Group of European Association of Geography Students and Young Researchers (EGEA).
- **Annual Conference *Air and Water Components of the Environment Conference***, Cluj- Napoca – orgainsed by Babeş-Bolyai University, Faculty of Geography, Department of Physical and Technical Geography, March 2019, 2020, 2021, 2022.

4. Participation of the Romanian specialists in the international symposiums and conferences

- International conference "Geographical perspectives on global changes", 18 – 19.11.2022, Bucuresti,
- IAHS International Symposium on River sediment quality and quantity: environmental, geochemical and ecological perspectives, October 2022.

- Geographical research and cross border cooperation**,** Sixth Edition, 6-8.10.2022, Craiova
- International Symposium Environment and Industry, E-SIMI 2021, Online Events, 24.09.2021, Bucharest
- International Geographical Congress, 18-22.07.2022.
- IGU – UGI Congress, Time for Geographers, 18-22.07.2022, Paris
- 35-ème Colloque de l'AIC, Le changement climatique, les risques et l'adaptation, 6- 9 July 2022, Toulouse
- 4th International Conference I.S. Rivers Proceedings – Integrative Sciences and Sustainable Development of Rivers, 4-8.07.2022, Lyon, France.
- Scientific Week of the Marroccon Association for Applied Sciences, 21-31.05.2022, Istanbul, Turkey (online)
- The International Conference Air and Water - Components of the Environment**,** 14th Edition, 18.03.2022, Cluj-Napoca (on-line)
- The 2nd international conference: Geographical sciences and future of Earth, 12.11.2021, Bucharest (on-line)
- 6th Edition of the International Conference on GIS and Applied Computing for Water Resources (WMAD21) – on-line, 24- 25.09.2021, Kenitra Morrocco (on-line)
- 5th International Hybrid Conference Water resources and wetlands, 8-12.09.2021, Tulcea (Romania)
- International Scientific Conference 6th Forum Carpaticum, 21-25.06.2021, Brno (Czech Republic)
- "Deltas and Wetlands" International Jubilee Scientific Symposium, Tulcea, Edition XXVIII, 13-18.09.2021
- The 5th International Conference on Water Resources and Wetlands, 8-12.09.2021, Tulcea, Romania.
- International Geography Union (IGU) Congress, Instanbul, 16-20.08.2021 (Online).
- International Geographical Conference „Dimitrie Cantremir", 40th edition, Iași, 24.10.2020
- Conference *Re-shaping territories, environment and societies: new challenges* (ReTES), Bucharest, 20-21.11.2020
- „Dimitrie Cantemir" International Geography Seminar, Iași, 24.10.2020.
- Goldschmidt International Conference, 21-26.06.2020 (Online)
- Conference *Air and Water Components of the Environment*, Cluj-Napoca, 22-24.03.2019
- EGU General Assembly, Wien, April 2019
- International Conference *Water sustainability in a changing world,* 11-14.06.2019, Bucharest
- Rencontres Internationales du colloque *Géohistoire Des Zones Humides D'ici Et D'ailleurs,* Tulcea, 3-8.06.2019

- ECOSMART – 2019, International Conference – Environment at a CrossrOads: SMART approaches for a sustainable future, Bucharest, 5-8.09.2019
- CEST, 16th International Conference on Environmental Science and Technology Rhodes, 4-7.09.2019
- Seminarul geografic internațional *Dimitrie Cantemir*, 18-20.10.2019, Iași

5. Publications

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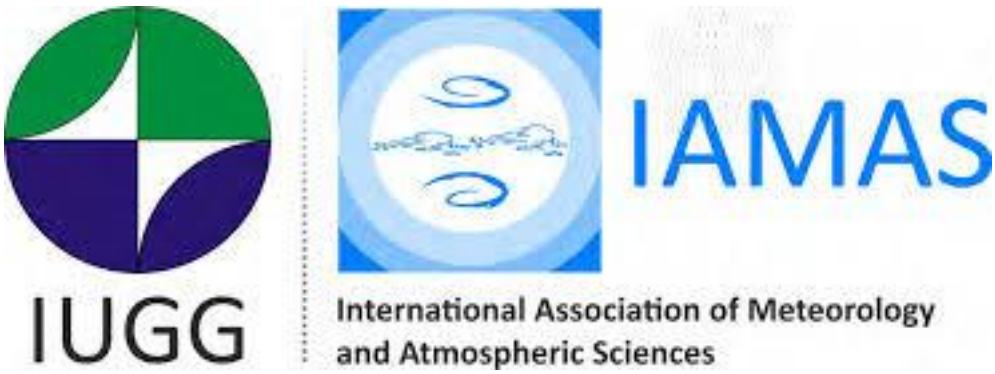

IAMAS ACTIVITIES IN ROMANIA

2019 - 2022

NATIONAL REPORT ON METEOROLOGY AND ATMOSPHERIC SCIENCES

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Content:

PART I: ORGANIZATION

Organization for Romania, a Section of the Romanian National International Union of Geodesy and Geophysics (IUGG) Committee, was constituted at the National Meteorological Administration in cooperation with the Faculty of Physics, Department of Atmosphere Physics of the University of Bucharest, National Institute of Research and Development for Optoelectronics and National Institute for Research and Development of Marine Geology and Geo-ecology.

The Romanian Meteorological Service was set up in July 1884, being one of the oldest scientific institutions in Romania. Romania is a member of the World Meteorological Organization starting with 1948.

The National Meteorological Administration of Romania (MeteoRomania), settled through Law 216/2004 is a Romanian legal entity, of national, public interest, whose main aim is to ensure the meteorological protection of life and property.

MeteoRomania general experience is related to: supplying information on weather, forecasts and warnings to the community, mostly through the media and cooperation with emergency management organizations in preparedness planning; supplying a wide range of operational meteorological services to the important users like: agriculture, maritime and air navigation, national defense and security; supplying meteorological support to the hydrological forecast and the air quality protection; participating to the adjacent activities aimed at preventing the meteorological hazards; providing advice on meteorological, climatological and air quality matters and policy implications, including human impacts on the climate system and ozone layer; planning, implementing, using and maintaining surface and upper air sounding observation networks at the level of the Romanian territory; using and maintaining systems for meteorological observation-data collection, quality control and processing; elaborating climate evolution studies and scenarios; leading Romanian providers of geo-spatial products and services for operational meteorology and environment applications (like monitoring and assessment of meteorological and hydrological extreme events: floods, droughts, accidental pollution); organizing and co-coordinating the national capacity building and training system in the fields of meteorology, climatology and physics of the atmosphere; fulfilling international obligations, including those deriving from the WMO Convention as well as pursuing the national interests, through participating to specific programs and activities at European and world level.

The infrastructure operated by MeteoRomania consists of surface weather stations (including agrometeorological program and actinometrical observations), upper-air station, Doppler radar systems, MSG satellite data reception system.

MeteoRomania represents the country within international forums/organizations: World Meteorological Organization (WMO); The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), as full member state from 2010; The European Centre for Medium-Range Weather Forecasts (ECMWF), as cooperating state; European Consortiums: High Resolution Numerical Weather Prediction Project (ALADIN) and Consortium for Small-scale Modeling (COSMO).

At the **Faculty of Physics**, the Department of Atmosphere Physics, the students and the teachers work in the fields of Dynamic Meteorology, Physics of Climate, Thermodynamic and Radiation of the Atmosphere, Electricity of the Atmosphere and they collaborate with the researchers from NMA.

National Institute of R&D for Optoelectronics (INOE) was established in 1996 as a non-profit, independent research institute, under the coordination of the Romanian Ministry of Education and Research. The Remote Sensing Department focuses on observing and studying the composition of the atmosphere, and has multidisciplinary expertise spanning from laboratory/in-situ chemical analysis to remote sensing Earth Observation (EO) techniques and applications. It contributes to the joint European and global climatological database as part of international networks (EARLINET, AERONET, MWRNET, PGN), and leads the Romanian initiative for ACTRIS (Aerosol, Clouds and Trace gases Research InfraStructure). ACTRIS ERIC has been approved by the European Commission on 25 April 2023.
As part of ACTRIS, INOE hosts a GAW regional station, located in a suburban area, flat terrain, 6 km SW from Bucharest city, operating aerosol remote sensing, aerosol in situ, cloud remote sensing, trace gases remote sensing, meteorological and radiation instrumentation. Through the synergy of measurements and modelling, INOE's main expertise is in studying aerosol microphysics, clear-sky direct aerosol radiative forcing, aerosol-cloud interaction, fog, local and long range transported pollution, satellite sub-pixel variability, a.s.o. The infrastructure operated by INOE is open to the public (scientists, engineers, students), offering access to data, laboratories and expertise for developing specific research projects and experiments, training, scientific and satellite Cal/Val campaigns, testing of prototypes through direct comparisons.

The National Institute of Research and Development for Marine Geology and Geoecology - GeoEcoMar represents the national pole of excellence in geological, geophysical and geoecological research and counselling of marine, coastal and inland waters, as well as a reference center for the Sea and Earth Sciences.
In the Bucharest headquarters of GeoEcoMar, a number of research teams work, their activity being focuses on certain areas of study (the Danube River, the Danube Delta, the coastal area, the Black Sea), but also on certain specialized research methods (bathymetry and seismo-acoustic, gravimetry - magnetometry, stratigraphy - paleontology, environmental geophysics and geo-archeology, geological storage of CO_2). The "GIS, digital cartography and databases" and "Environmental studies" compartments are also carried aut here.
The scientific research carried out here concerns the geological composition and geotectonical evolution of the Black Sea basin and of other areas of interest in the World Ocean, the geological - sedimentary and geophysical mapping of the Black Sea continental platform, the complex study of sediments (granulometry, mineralogy, chemistry, biology, micro-plastics) in the Black Sea, the coastal area, The Danube Delta, the Romanian sector of the Danube and its main Romanian tributaries. There are also studies on greenhouse gas emissions (CH_4, N_2O, CO_2) in wetlands in the

Danube hydro-sedimentary geo-system - Danube Delta - Black Sea, paleoecological and paleo-environmental research, studies on the geological and environmental impact of global climate and the sea level changes in the past and present. There are also carried out the study of the anthropogenic activities effects on the main ecosystems (fluvial, deltaic, seaside and marine), the assessment of the quality of the marine, lake and river aquatic environments and the monitoring of marine natural hazards and the alarm of authorities in case of danger to the Black Sea coastal area.

IAMAS has 10 commissions:

- International Commission on Atmospheric Chemistry and Global Pollution (ICACGP)
- International Commission on Atmospheric Electricity (ICAE);
- International Commission on Climate (ICCL);
- International Commission on Clouds and Precipitation (ICCP);
- International Commission on Dynamical Meteorology (ICDM);
- International Commission on the Middle Atmosphere (ICMA);
- International Ozone Commission (IO_3C);
- International Commission on Planetary Atmospheres and their Evolution (ICPAE);
- International Commission on Polar Meteorology (ICPM);
- International Radiation Commission (IRC).

The general objectives of IAMAS (to promote the study of the science of the atmosphere, to initiate, facilitate and coordinate international cooperation, to stimulate discussion, presentation and publication of scientific results, to promote education and public awareness) are also the objectives of the organization in Romania, although the activities related to these sections are different, some sections, such as: dynamic meteorology, climatology or air pollution enjoying more interest as against upper air or polar meteorology.

The Romanian Meteorological Society also supports the IAMAS activities for Romania.

Romanian IAMAS Activities:

- **Dynamic Meteorology**
- **Nowcasting**
- **Climate**
- **Agrometeorology**
- **Remote sensing and Satellite Meteorology**
- **Atmospheric Physics**

- **Metocean (meteorologic and oceanographic) data and services**

Institutions:

- **National Meteorological Administration (NMA)**
- **University of Bucharest: Faculty of Physics**
- **National Institute of Research and Development for Optoelectronics (INOE)**
- **National Institute for Research and Development of Marine Geology and Geo-ecology (GeoEcoMar)**

Professional Organizations:

- **Romanian Meteorological Society**

National Conferences:

- **Annual Scientific Session of the National Meteorological Administration**
- **Annual Scientific Session of the Faculty of Physics, University of Bucharest**
- **Annual Conference of Physics**

Publications:

- **Romanian Journal of Meteorology**
- **Romanian Reports in Physics**
- **Romanian Journal of Physics**
- **Journal of Optoelectronics and Advanced Materials**
- **GeoEcoMarina**

PART II: PROFESSIONAL ACTIVITY

1. Research orientation

1.1. Dynamic Meteorology

1.1.1. The COSMO numerical weather prediction model

The non-hydrostatic numerical weather prediction model COSMO (Consortium for Small-scale Modelling) is run operationally at the National Meteorological Administration since 2005, the current operational version being 6.00. The COSMO model is integrated at two horizontal resolutions (7 km and 2.8 km respectively), four times a day at 00, 06, 12, 18 UTC, for 78, 48, 174 and 48 hours at the coarser 7 km resolution and for 30, 18, 90 and 30 hours respectively at the higher 2.8 km resolution. Initial and lateral boundary condition come from the ICON (Icosahedral Nonhydrostatic) global model for COSMO-7km. Model output from COSMO-7km is used as initial and lateral and boundary conditions for COSMO-2.8km.
The integration domains (figure 1) cover the entire Romanian territory with 201x177 grid points for COSMO-7km and 361x291 grid points for COSMO-2.8km.

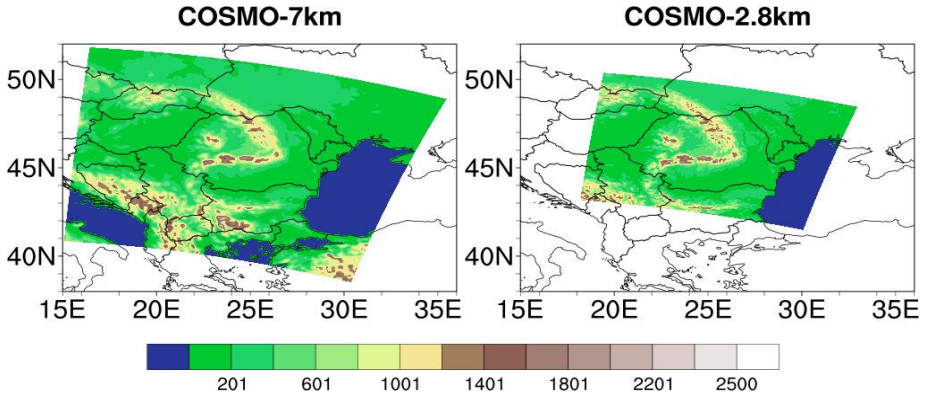


Figure 1: Operational integration domains for COSMO-7km and COSMO-2.8km.

The COSMO model at both orizontal resolutions is run operationally using SYNOP data assimilation. The output of the COSMO model at the 7 km and 2.8 km horizontal resolutions is available both in graphical form and as numerical results and is used by forecasters and other beneficiaries. Direct model output parameters include: radar reflectivity, wind gust, precipitation, snow, pressure, dew point temperature and so on, represented as maps, grid values, vertical profiles (figure 2) and meteograms (figure 3). Post-processed parameters include fog stability index and snowdrift index.

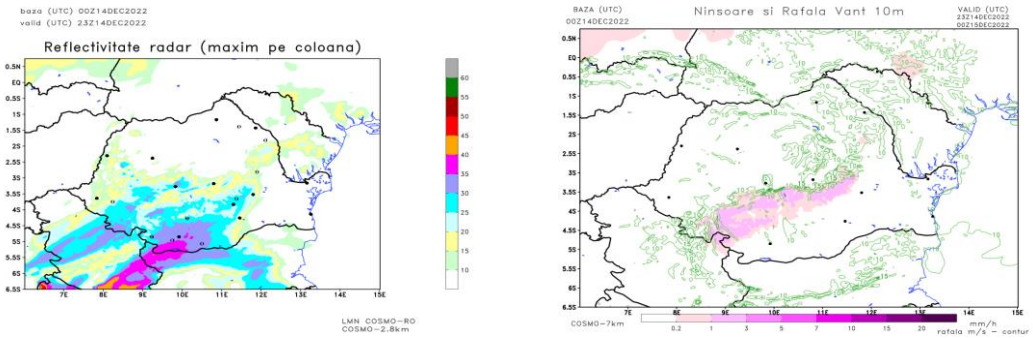


Figure 2: COSMO-2.8km numerical forecast (direct model output): maximum radar reflectivity (left); 1 hour accumulated snow and 10 meter wind gust (right).

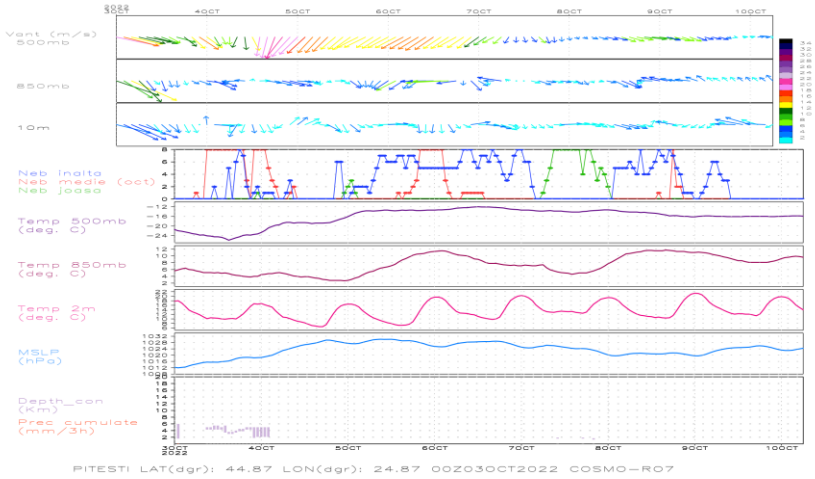


Figure 3: COSMO-7km numerical forecast: meteogram.

1.1.2. The ICON modelling framework (ICON in Limited Area Mode)

The ICON model was designed by Deutscher Wetterdienst (DWD) in collaboration with the Max Planck Institute for Meteorology and starting with 2015 it replaced the previous GME (Global Model) numerical weaher forecast model as the current global model run operationally by DWD. The ICON modelling framework was initially developed as a unified global numerical weather prediction and climate modelling system, but has also ben adapted for use in limited area mode (ICON-LAM).

The ICON model, which is set to replace the COSMO model, has been implemented in NMA and is run operationally since 2020 at 2.8 km horizontal resolution. The current operational version of the ICON model is 2.6.5. Initial and lateral boundary conditions for ICON-2.8km are provided by the ICON global model (same data used for operational COSMO-7km). The ICON model is run with 65 vertical levels and a 24s time step for an integration domain that convers the entire Romanian territory.

The output of ICON-2.8km is available in various formats: netcdf for model, pressure and height levels on a regular lat/lon grid, grib2 for model, pressure and height levels on a regular lat/lon grid, as well as grib2 for model levels using the native, unstructured model grid. The forecasts of the ICON model are available both in

graphical form and as numerical results and are used by forecasters and other beneficiaries.

Direct model output parameters obtained from the ICON model include: lightning stability index (figure 5), weather interpretation, precipitation, wind gust, air temperature, surface temperature, mean sea-level pressure and so on, represented as maps, vertical profiles (figure 4) and meteograms. Post-processed parameters include fog stability index and snowdrift index (figure 5).

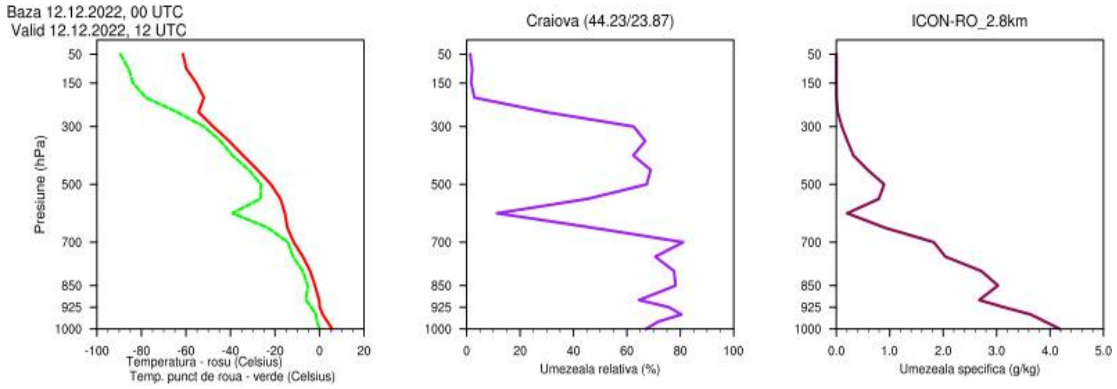


Figure 4: ICON-2.8km numerical forecast: vertical profiles for temperature - red and dew point temperature - green, relative humidity - purple, specific humidity - magenta (left to right).

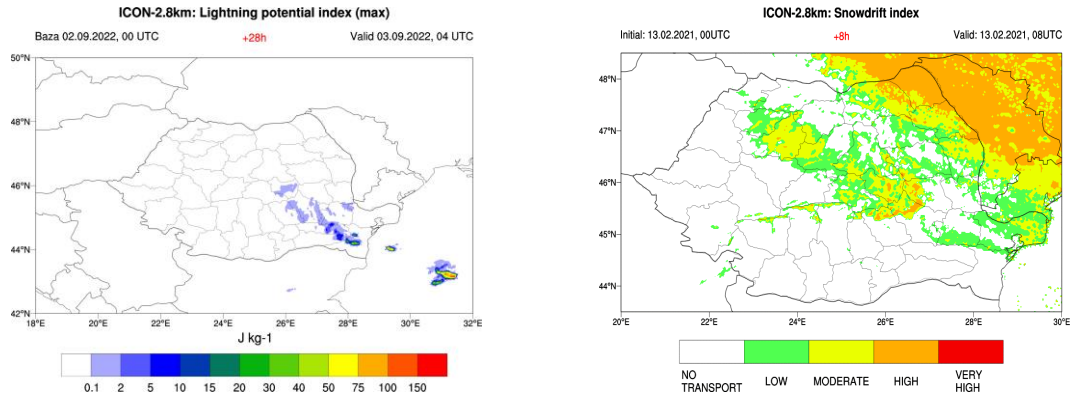


Figure 5: ICON-2.8km numerical forecast: direct model output for lightning potential index (left); post-processed parameter – snowdrift index (right).

1.1.3. The ALARO numerical weather prediction model

The current setup of ALADIN/ALARO model, developed in the frame of ALADIN (Aire Limitée Adaptation Dynamique Développement International) and RC-LACE (Regional Cooperation for Limited Area modeling în Central Europe) consortia, is running operational at the National Meteorological Administration. Romania is member of ALADIN (Aire Limitée Adaptation Dynamique Développement International) consortium since 1991 and starting from 2007 is member of RC-LACE. At the beginning of 2021, the ALADIN, RC-LACE and HIRLAM (High Resolution

Limited Area Model) have joined into the single consortium named ACCORD (A Consortium for COnvection-scale modelling Research and Development).
The operational version of ALARO (ALARO-0 baseline cy43t1) is running since April 2016 at 6.5 km horizontal resolution, 60 vertical levels, 240s timestep, covering Romania with 240x240 gridpoints. The initial and lateral boundary conditions are coming from the global model ARPEGE with 3-hour frequency. The forecast range is up to 78 hours for 00 and 12 UTC, up to 54 hours for 06 and 18 UTC.
Examples of the displayed meteorological parameters are presented in figure 6.

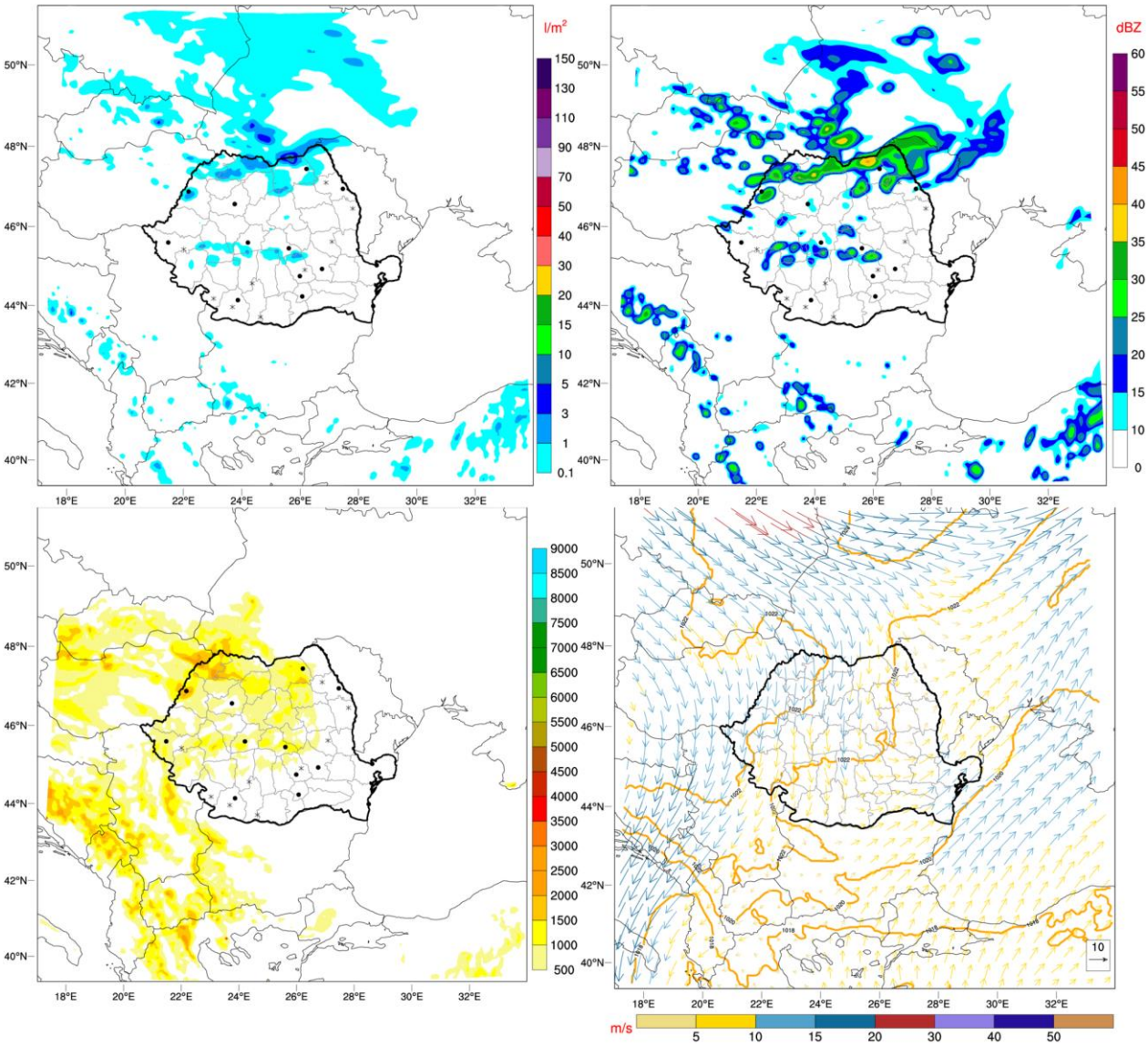


Figure 6: Examples of the displayed meteorological parameters for ALARO model at 6.5 km: hourly precipitation, radar reflectivity, CAPE and wind speed and direction at 500 hPa.

In the last year, a new version of the ALADIN/ALARO model (ALARO1-Vb, cy43t1) is integrated in operational mode at 4 km horizontal resolution (figure 7), keeping the number of the vertical levels with a time step of 180s, covering Romania and the entire Black Sea, having 600 x 432 gridpoints. This version contains a new radiation scheme (ACRANEB2) and turbulence scheme (TOUCANS). Regarding the optimal

setup for running the ALARO1-Vb model, several tuned configurations were run using two different integration domains.

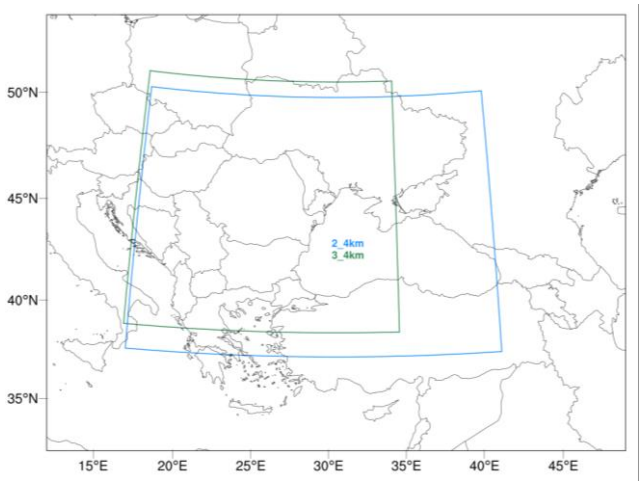


Figure 7: Integration domain of the ALARO model at 4 km for two different domain size.

Examples of the displayed meteorological parameters are presented in figure 8.

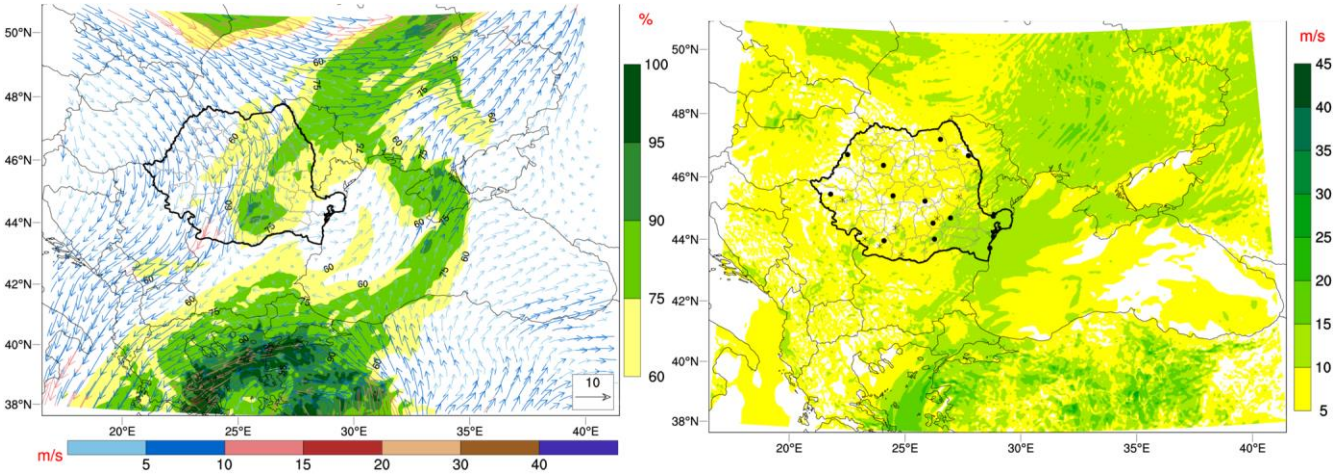


Figure 8: Examples of the displayed meteorological parameters for ALARO model at 4 km: relative humidity and wind speed at 700 hPa and wind gust la 10 m.

1.1.4. The Statistical post-processing

MOS technique is being applied to ARPEGE model since 1998, to ECMWF model since 2004 and to ALARO model since 2016. The MOS techniques are similar, for all models: multiple linear regression (MLR) and logistic regression (LR) are used for MOS models which are updated every two years. Available products: daily maximum and minimum temperature, total cloudiness (in category), 6 hours precipitation (in category), speed and wind direction. The results for all Romanian surface meteorological stations (166) are displayed on maps and in a text format as well. A version of MIXT_MOS using MOS_ECMWF and MOS_ARPEGE is used to forecast extreme temperatures from 166 weather stations, the results of this model are better to individual models.

1.1.5. The Forecast verification

In National Meteorological Administration, the following forecast categories are verified:

- the final forecasts produced by meteorologists
- special forecasts for customers and/or mass media
- the numerical models forecast for surface parameters
- the MOS forecasts.

There are daily procedures (1, 3, 4) and monthly procedures.

Daily procedures: spot daily errors - (direct model nearest point-observation) for all numerical models: ECMWF, ARPEGE, ALARO, COSMO and ICON; maps and graphs are displayed daily (figure 9) on the specialized web-site - *"Statistical post-processing and Verification – AS".*

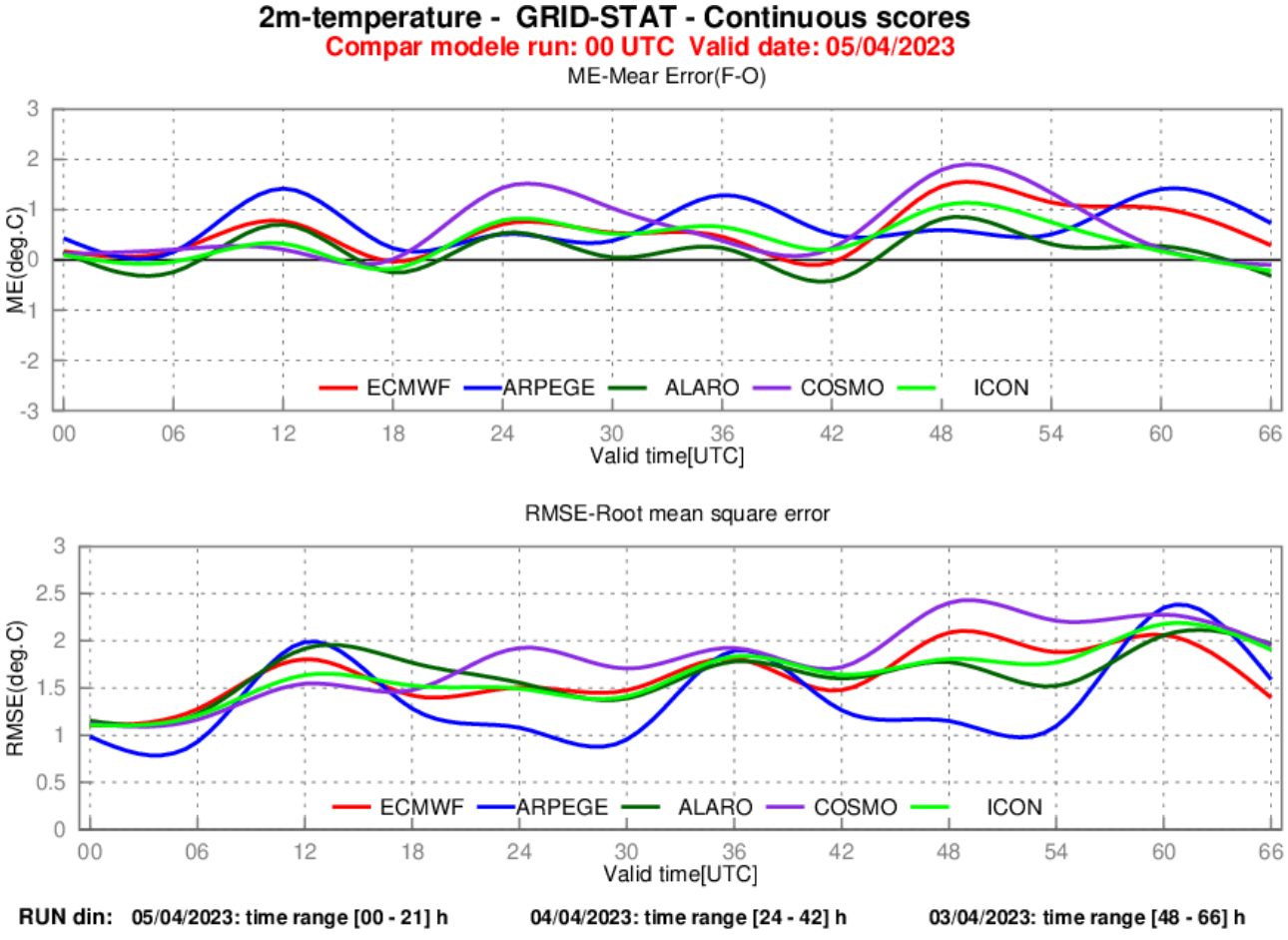


Figure 9: Examples of Direct models output daily verification scores

Monthly procedures: The verification system VERMOD – developed at NMA performs direct model verification against point-observations. This system is in operation since 01 June 2008. The verified models are: ECMWF – (0-180 h), COSMO (0-78 h), ARPEGE (0 – 102h) and ALARO (0 – 78h) and recently ICON. The verified parameters are: 2-m temperature, total cloudiness, 6-hour total precipitation, wind speed, wind direction and components, for 166 meteorological stations.

***Verification scores are**:* mean error, mean absolute error, root mean square error, correlation coefficients for the continuous variables and Percent Correct, HSS, POD, FAR etc. for the categorical ones. For all scores we compute the confidence interval using the bootstrap method. Various graphs are monthly displayed on the web-site, for each model or all model scores are plotted on the same graph in order to compare the performance of the models over Romania.
Since 2014 a new procedure named GRIDSTAT developed in METv from NCAR was implemented to verify the model output form ECMWF (figure 10), ARPEGE, ALARO, COSMO and ICON, against local observation. The procedure runs twice a day for the parameters: 2m temperature, 10m wind speed, total cloudiness and relative humidity.

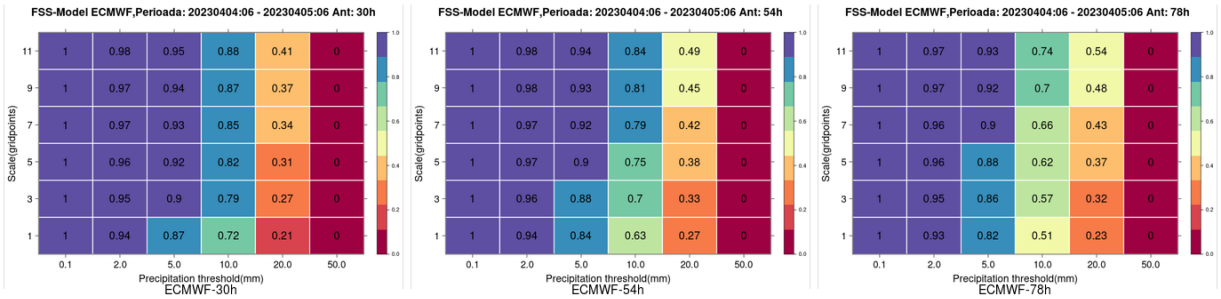


Figure 10: Example of daily ECMWF verification – Fraction Skill Score

Multi-year scores:
For final forecasts, we plot moving average monthly scores (figure 11) for the last 3,5 and 10 years

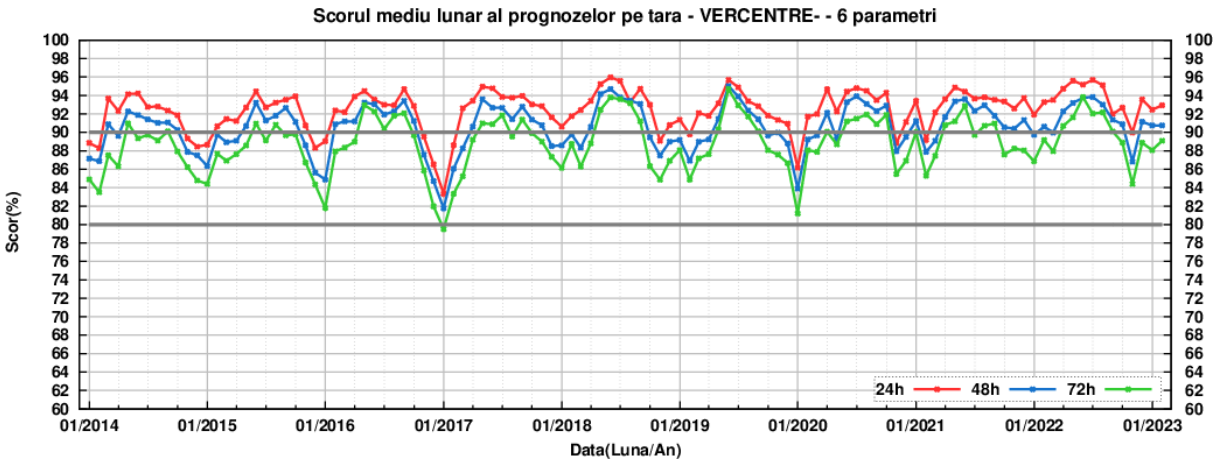


Figure 11: Examples of multi-year monthly scores for final forecasts

1.1.6. Monthly to seasonal time-scale

The research and operational activity on monthly - seasonal prediction has been continued and developed, during the reporting interval. An operational chain delivering products and Bulletins for Monthly prediction (a six weeks prediction now) twice a week: Tuesdays and Fridays in running and continuously developed. On seasonal side also an operational chain of products and monthly Bulletin are delivered, one per month, with many new products relying on operational chains

post-processing but also on research based on these products. There are two sites for delivery of the output of these two chains: one focusing the support of the prediction activity at the National Centre of Prediction Romania (192.168.4.11) and another is in the support of research activity at RC6 Regional Centre for Climate, LRF (Long Range Forecasting Node), Region 6 (193.26.129.171) and (193.16.129.82). Another main direction of research was focused on regional climate change and developing applications oriented towards regional climate-services. These are described next.

The operational products processed for seasonal prediction at NAM are based on multi-model data from: SEAS5-ECMWF, JMA, CSF global models and regional downscaling with RegCMv5 model. Monthly products from global centers are brought to anomalies reported to a same climatology 1980-2010 and 1990-2020 using high resolution gridded observations ROCADA. Forecast from members is delivered as anomaly predictions, also as reconstructed Full-Field (required for some applications), and also as multi-model ensemble means. Predictions are provided (twice a week) together with probabilities of occurrence of extreme events as high amount of weekly accumulated Precipitations and probability of extreme (warm or cold) weekly mean temperatures. Seasonal products are processed monthly as an ensemble of initial conditions and time-lag perturbed ensemble extracted from JMA model and processed for SE Europe. We noticed that inclusion of time-lag perturbations improves the prediction skill for our region. Probabilities are estimated from the ensemble measures (a total of 52 members, 4 time-lag * 13 initial conditions members). Validation of past re-forecasts monthly-seasonal is continuously ongoing.

1.2. Very short range forecasting (Nowcasting)

Complementary to the basic operational activity of the weather radar group, which aims to ensure the functioning of weather radar systems and dissemination of radar information to the National Center for Meteorological Forecasting research activities have also been carried out throughout 2019-2022. The main topics addressed were related to the identification of the anomalous propagation of the radar beam, the study of the quality index of the radar data, to observe the effect of the blocking of the radar beam in areas with complex terrain and the height of the 0°C isotherm on the radar measurements from a given moment in time.

Computing the average radar reflectivity (figure 12) over a 24-hour period, one can capture the maximum spatial extent of the echoes caused by anomalous propagation, as well as their average intensity. Thus, the figure below shows the 24hrs average reflectivity field. One can observe that the average intensity of echoes caused by anomalous propagation is between 15 and 20 dBZ, a value specific to ground targets.

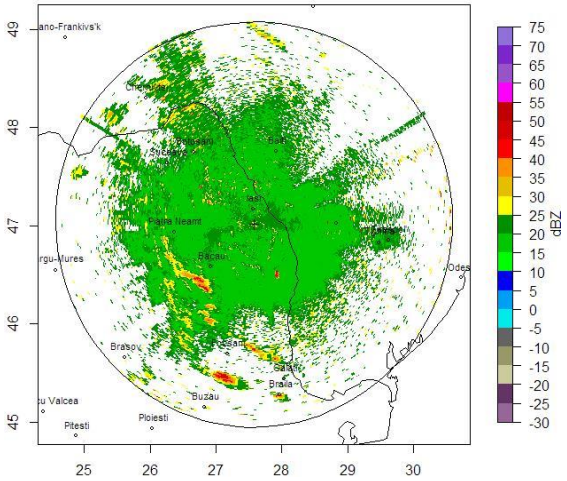


Figure 12: Average reflectivity field, at 0.5° elevation, during 24hrs (26.05.2019 12:02 UTC – 27.05.2019 11:55 UTC).

To investigate how often echoes caused by anomalous propagation are detected, but also how persistent in time these are, radar echo detection frequency maps were generated. This represents the number of detections, in a given radar pixel, of an echo that has a threshold reflectivity value (e.g., 15 dBZ). Detection frequency (%) and detection persistence (hours) are illustrated in the figures below (figure 13), denoting that non-meteorological echoes caused by anomalous radar beam propagation can be detected very frequently and, moreover, they can persist over many consecutive scans. Thus, it is observed that at short and medium distances to the radar, the average percentage of detection is 30–40%, while at great distances to the radar (> 100 km) the percentage is lower (~10%).

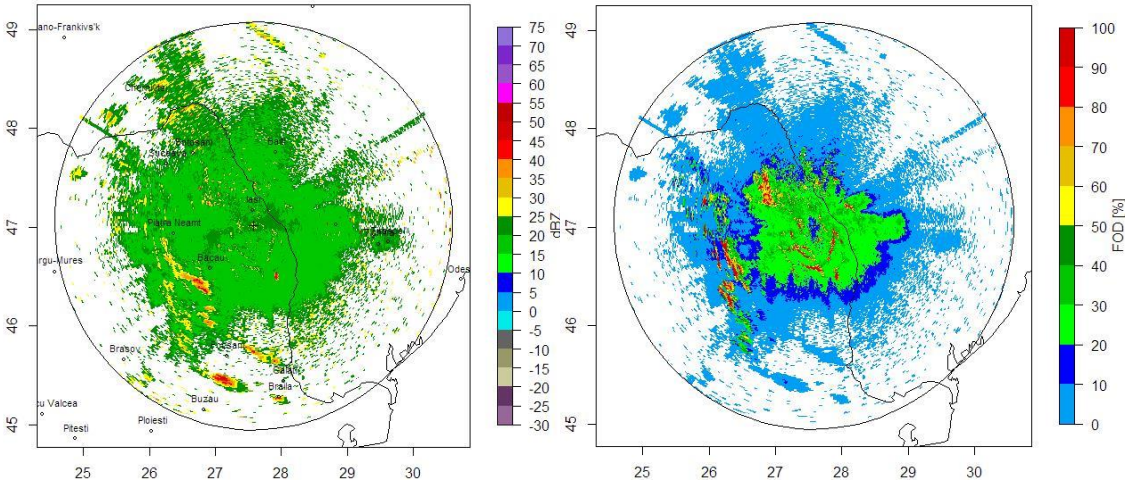


Figure 13: Frequency of detection (left) and temporal persistence (right) of reflectivitty ≥ 15 dBZ, during 24hrs (26.05.2019 12:02 UTC – 27.05.2019 11:55 UTC).

As specified above, echoes caused by anomalous propagation are different from ground noise; the ground noise detection percentage is much higher, reaching a maximum of 100%. This difference is also captured by the spatial distribution of the temporal persistence of echoes with a reflectivity value > 15 dBZ, ground targets being detected almost all the time, during an interval that can reach up to 24 hours.

Such studies can improve the process of interpreting meteorological phenomena in a certain area of the country, based on radar data.
Research on the radar quality index was also performed, to study the effect of complex terrain on radar quantitative precipitation estimations. The method of computing this index considers few variables, such as radar site environmental conditions, beam blockage, etc. The figure below illustrates a radar quality index field, showing that good data quality for QPE is observed in the center, north-west, south-east and south-west of the coverage area up to distances of about 150 km from the radar site (figure 14). The very low values of the quality index correspond to the areas with severe beam blockage.

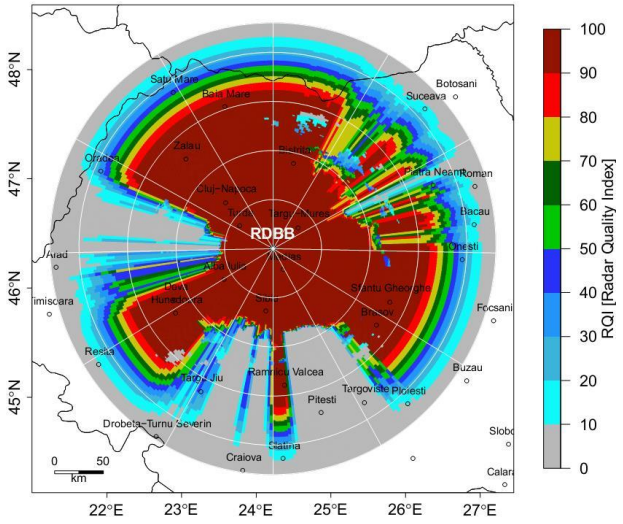


Figure 14: Radar quality index field, Bobohalma, Mureș County

The weather radar group also carried out studies on meteorology and climatology of convective storms. The radar-derived characteristics of convective storms were used to document the spatial and temporal distributions and storm properties in terms of duration, distance travelled, movement direction, and intensity.
Research aimed at enhancing the accuracy, performance, and reliability of national nowcasting warning systems by the use of machine learning (ML) techniques applied on radar, satellite and weather stations' observations was also carried out. The focus was on obtaining higher precision in predicting the occurrence and the areas affected by severe meteorological phenomena, as well as attaining lower decision times (compared to current, exclusively human decision times). The approach was to develop and validate novel machine learning computational models and techniques specially tailored for accurate nowcasting, development and user evaluation of an annotated atlas of meteorological observations, and development of an open-source platform for early forecast of severe weather phenomena.

1.3. Climate

1.3.1. Climate Research

Research in the field of climatology involves the integration of climate monitoring techniques and the analysis of various data sources such as in-situ observations, satellite data, reanalysis data, and regional climate models. The aim of this research is to develop practical applications for different socio-economic sectors by creating climatic products and services that meet the specific needs of users. The findings of this research are disseminated through scientific publications and presentations at dedicated events. Additionally, specific products are created: new sets of climatic indicators with improved spatial and temporal resolution, which provide information on current climate conditions and future projections for areas of interest such as river basins, the Black Sea basin, and agricultural regions. Diagnostic and forecast assessments of climate patterns are also generated at various time scales, ranging from yearly to decade and century intervals, as well as climate hazard risk maps.

Research activities in 2019 focused on investigating the variability and predictability of extreme phenomena such as convective episodes, extreme precipitations episodes and droughts. The project "Improving early warnings, forecasting and mitigating the effects of drought and floods based on hydro-climatic indicators in real time" (IMDROFLOOD) continued the update for a geoportal dedicated to the Prut basin (http://imdroflood.meteoromania.ro/geoportal/), in collaboration with the Remote Sensing Laboratory and SIG, the Laboratory of Numerical Modeling and the National Institute of Hydrology and Water Management.

Also, 2019 continued the research into sources of predictability for winter conditions in Europe. The analysis of retrospective prediction experiments showed that temperature, precipitation and atmospheric pressure anomalies in winter for Europe and Romania, can be prognostically estimated starting from the previous October, using the Arctic ice expansion (ice concentration) in the Barents and Kara Seas area.

The SUSCAP project (Developing resilience and tolerance of crop resource use efficiency to climate change and air pollution - http://suscap.meteoromania.ro/), financed by the SusCrop ERA-Net Cofound program, was developed between June 2019 and May 2022. It was focused on the analysis of complex stress relationships (such as aerosol and ozone pollution, drought, extreme temperatures and soil fertility), which can have negative effects on the efficient use of resources and the increase of agricultural productivity. Temperature and precipitation, results from the models, were adjusted for different climate change scenarios (figure 15).

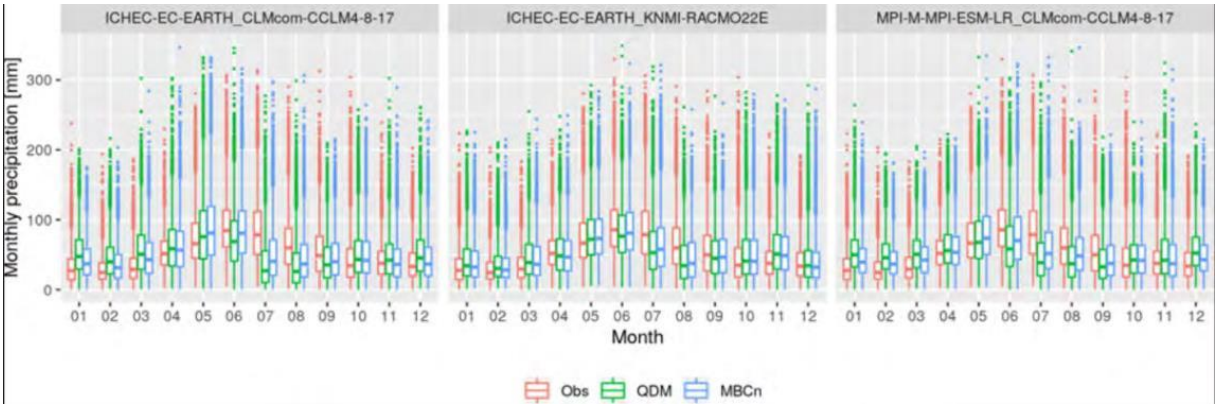


Figure 15: Statistical properties of monthly precipitation in 1971-2005 timeframe for observed data (ROCADA) and for data extracted from three EURO-CORDEX models, adjusted by two statistical methods (QDM – quantile mapping and MBCn - multivariate bias correction)

Moreover, the changes in air temperature were also analysed using the adjusted results, under the conditions of each climate scenario. In 2020, changes in air temperature and atmospheric precipitation were analysed using a set of data adjusted from numerical experiments carried out with regional models (Euro-Cordex). In 2021 there were published the adjusted climate scenario data for the territory of Romania RoCliB - Bias corrected CORDEX RCM dataset over Romania (https://zenodo.org/record/6336837). These data are available in netCDF format and contain daily information on minimum, average and maximum air temperature and precipitation for the period 1975-2100. Climatic products (maps and graphics), obtained from RoCliB data processing, were published in an interactive and easy-to-use environment on the project web page, as a (climate) support service (http://suscap.meteoromania.ro/en /roclib).

In the framework of URCLIM (Advance on Urban Climate Services) project, financed by ERA4CS (September 2017 - June 2021), it was aimed to create urban climate services based on the 3D co-visualization of urban and climate data, and moreover to carry out impact studies in urban areas for the current and future climate. Hazard and risk maps for heat waves were developed with a focus on the effect on health conditions for the population in the City of Bucharest. The spatial distribution of the UTCI index, which illustrates thermal discomfort, was also analysed (figure 16).

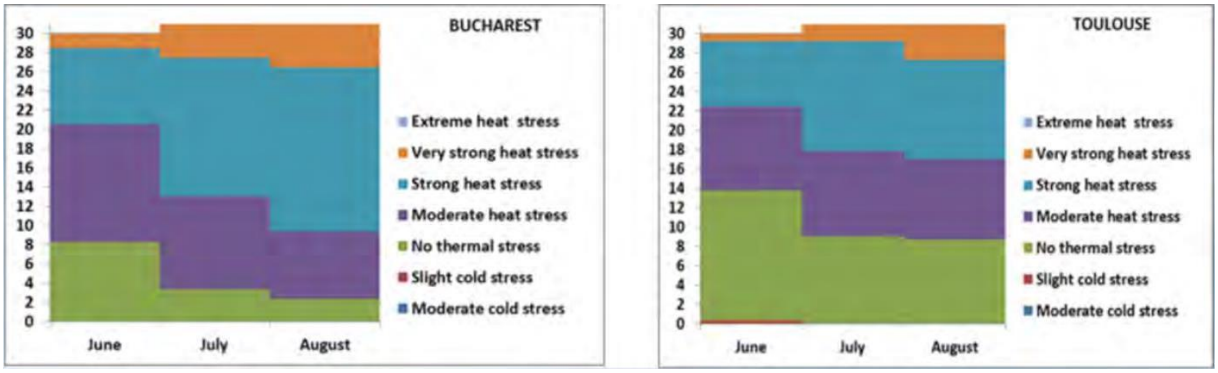


Figure 16: The average monthly number of days with pronounced heat stress, based on ERA5 data in the period June-July-August 2009-2018, for Bucharest (left) and Toulouse (right)

The INDECIS project (Integrated approach for the development across Europe of user oriented climate indicators for GFCS high-priority sectors: agriculture, disaster risk reduction, energy, health, water and tourism), financed by ERA4CS, was carried out from September 2017 to June 2021. The main goal was the investigation of physical impacts of climate change on relevant indices for agriculture and urban environment. The results of this activity are available on the project website (http://www.indecis.eu/wp2.php and http://www.indecis.eu/wp6.php). The main research directions within this project were: (1) identify and tabulate data sources based on observations and measurements in the European area for the essential climate variables (ECV) selected in the project; (2) identify and tabulate alternative data sources (observation-based, regularly gridded datasets, reanalyses, model outputs) for the European area, for ECVs selected in the project; (3) comparative analysis of the performance of alternative datasets compared to observational datasets; (4) sectoral applications of the indices selected or developed in the project.
Results from this last objective showed that the climatic indices defined for the vegetation growing season presented, in general, higher values in the area of Oltenia and especially in the south-west area, as well as an increasing trend during the period 1981- 2010. Conversely, the climatic indices defined for the cold season presented the lowest values in Oltenia area, and the trend of increase/decrease in the analyzed period is not clearly marked in the data series.
WECTOU (Weather and Climate information for Tourism) project was financed under a contract with ECMWF (www.ecmfw.int), under the umbrella of the Copernicus Climate Change program (https://climate.copernicus.eu/). The project has been implemented in the period January 2020 - June 2021. The project focused on designing a web application (http://wectou.meteoromania.ro/) that offers all actors in the field of tourism (tourists, travel agencies, investors, local authorities) a service based on climate and environmental information that contains products specially adapted for this field (e.g. heat stress, number of days with pleasant weather for outdoor activities, snow depth, sea water temperature, risk of frostbite or risk of sunburn, etc.) The information is available free of charge for 162 localities of touristic interest in Romania. This application was developed both in terms of content (e.g. products based on climate, satellite and numerical forecast information) and web platform building. It was promoted to the general public through regularly updated marketing strategies, as well as to the expansion of the range of products offered (e.g. products based on climate projections, adding new localities to the free content, introducing new functionalities that allow the use of promotional tourism information or other types interest data for tourism i.e. the population of a locality, the number of tourist arrivals in the previous year, etc.).
The EXHAUSTION project (Exposure to heat and air pollution in EUrope – cardiopulmonary impacts and benefits of mitigation and adaptation 2020 - 2021), was financed by the Horizon 2020 framework program of the European Union. The research activity consisted of analyzes (at Bucharest level) of the link between daily temperature and daily mortality, in order to proceed in the next stages to develop a downscaling methodology to urban spatial scales. Downscaling climate and air

quality variables to urban scales will allow the estimation of future mortality in European cities based on the results of the climate models obtained for Europe. It aimed to estimate the impact of heat waves, air pollution and climate change on public health in Europe, with an emphasis on the vulnerability analysis to heart and lung disease. During extremely hot and dry periods, the risk of forest fires increases, causing intense air pollution by increasing the concentration in air of fine particles that can reach people's lungs and circulatory system. High ozone levels have also been observed during recent heat waves, and it is estimated that climate change may increase summer ozone levels, which is also a major health risk. Air pollution is today the environmental challenge associated with the highest mortality in Europe. Based on observed and projected future climate and air quality data under climate scenarios, including at city scale, we identify adaptation strategies that will help avoiding premature death and disease among vulnerable groups, including people in age, women, infants, chronically ill and disadvantaged people.

The support project for preparation of DANUBIUS-RI - DANS2 focused on elaborating a vulnerability and risk study necessary in the framework of resilience assessment and adaptation to the impact of climate change for the major project on the Danube Delta Supersite within the International Center for Advanced Studies for Large River Systems DANUBIUS - RI. The main objective of the project was to assess the vulnerability to climate hazards and climate change of the DANUBIUS-RI research infrastructure and its components (including the Murighiol hub, field stations and observation points within the Danube Delta supersite and the Data Center), distributed over the surface of Tulcea, Constanța, Brăila and Galați counties, under current (1971-2013) and future climate conditions (2021-2050, in RCP4.5 and RCP8.5 scenarios). The climate component of the study within this project aimed to analyze current trends in climate evolution and future climate change, as well as the potential climate hazards (exposure) to which the research infrastructure project and its components are vulnerable. The results of this climate study (exposure analysis) shaped the premise for assessing the related climate risk level for each component of the infrastructure project, and also outlined the proposal of a set of adaptation measures to reduce the climate risk to an acceptable level according to the JASPERS methodology, as recommended by the European Commission (The Basics of Climate Change Adaptation Vulnerability and Risk Assessment, 2017). There were analyzed features as the regional profile of hydro-climatic hazards and their potential effects on the elements of the research infrastructure (e.g. heat and cold waves, freeze-thaw phenomena, abundant precipitation in diurnal temporal sequences, drought, phenomena of floes and ice bridge on the Danube, days with maximum gust wind speeds greater than 20 m/s), and likewise, signals of current and future changes in the annual and seasonal regime of average, maximum and minimum temperature, precipitation, average wind speed and maximum gust wind speed. This project took place during the period June-July 2021.

1.3.2. Regional climate predictions for Romania

1.3.2.1. Monthly-seasonal predictions: regional extremes

Two directions were developed in the last 4years. First focus was to bring added value regarding regional and sub-regional climate extremes, events that are not predictable at the actual resolution of seasonal prediction models. The research was conducted for:

- understanding and predicting the larger-scale context favoring occurrence of **late-spring blizzard events** because these may affect a big percent of the whole year production. The results were used to implement predictive indices that are now operationally computed and provided monthly for seasonal forecast (target April month);
- **predicting flood pre-conditioning** environment for Romania was conducted using large sets of data, hydrological extremes data-basis from INHGA and numerical model sensitivity simulations. The results conduced to define flood pre-conditionning indices that are used now (with success) in predicting months in advance potential conditions for flooding events, based on predicted precipitation, MSL pressure, Z500 and identified links with regional flooding conditions. These indices are intended to be extended for decadal predictions for Romania / SE Europe region;
- identifying remote large-scale-regional scale links that might favor climate extremes as increased frequency of storm tracks over Romania; an analysis has been conducted that identified the modes of variability that are linked with time-lag relations to storm-tracks frequency crossing Romania.
- **predictive indices of extreme storm-tracks frequency (high or low)** based on lagged-links (computed as convolutions of correlations) are now used in operational forecast of storm-tracks extremes over Romania and also over Europe.

1.3.2.2. Extended regional predictions: decadal predictions

Decadal predictions were analyzed for Romania to provide estimates for the time horizon 2027, request for agriculture activity planning and management. This direction will be further exploited for derived processing, validation and potential impact analysis support.

1.3.2.3. Regional climate change for Romania

A main research action on **climate change for Romania** was conducted along national projects: “RO-adapt” and “Desertification”. Data from multi-model ensembles of CMIP5, CMIP6 and CORDEX were analyzed to assess main regional changes and hot-sport of high/ accelerated estimated change. Also, **down scaling regional climate-change and land-cover change mixed scenarios** were simulated using

RegCMv5 model at high resolution (5km) coupled with an ensemble of CMIP5 models. These emphasized new features of land-climate change feedbacks and provide a useful information database for mitigation and adaptation at regional level.

1.3.2.4. Oriented applications and projects for Regional climate services in Romania

- **prediction of air quality:** this is based on using Chimere atmospheric chemistry and transport model forced by predictions from ECMWF. At the time we intend to extend the 10 days (actually ongoing) predictions to monthly and seasonal, and to insert main estimated variability of local emissions. The current system is used for 10 days forecast for local point-emissions registered or estimated;
- **prediction of drought:** this implemented computing SPEI forecasted index on seasonal time-scale based on seasonal predictions from SEAS5-ECMW and JMA models. Monthly maps with forecasted areas of drought / wet conditions are provided (192.168.4.11) ([7]);
- **crop seasonal prediction of phenological parameters**: optimal planting date, Nitrogen fertilization level and genotype (this is performed monthly along the year, based on seasonal predictions from SEAS5-ECMWF, the DSSAT model and the operational PREPCLIM system);
- **agro-climate service** on identification of optimal sewing date, Nitrogen fertilization and Ideotype under climate change, horizon 2050: this system was implemented under PREPCLIM project (https://incda-fundulea.ro/cercet/prepclim.html) and is now an open, operational tool, interactive under user-request, providing answer to management options of the user (region of interest, time slice, sewing date, fertilization, irrigation, etc,. The Optimal Genotype identification uses deterministic modeling with DSSAT crop model and a hybrid deterministic-Machine Learning method. The user request receives answer on-line, and the interrogation page has multiple access (linux /windows interfaces). The system-tool is uploaded on EERIS platform: https://eeris.eu).
- **extreme wave modelling for the Black Sea**: POM ocean model was run at very high resolution (5km) coupled with an ensemble of CMI5 models in order to simulate the Black Sea response to projected climate changes for two scenarios: RCP45 and RCP85 ([11, 12]). A wave spectral module is coupled to POM for the research and impact studies of wave parameters projected changes under climate change.

1.4. Agrometeorology

The main purpose of Agrometeorological Network is continuous surveillance of the agrometeorological phenomena (thermal, hydric and mechanic stress/risk) in order to identify in real time the most vulnerable areas and the dissemination of information

towards the users aiming at making the right decision to prevent and mitigate the effects upon the crop efficiency.

Romanian agro-meteorological observations network is formed of 68 weather stations integrating a special program of agrometeorological measurements – soil moisture and phenological data (winter wheat, maize, sunflower, rape, fruit trees and vineyards).

The agro-meteorological stations are considered representative for the entire agricultural land of the country, that information received from all stations was used to map the spatial distribution of precipitation and to delineate the regions affected by different drought and heat wave intensities.

Soil water balance is directly affected by the crop water requirement through evapotranspiration, which is dependent mainly on temperature and stage of vegetation. Crop water requirements depend on local weather conditions, soil and plants' characteristics and plant stage of growth. An agricultural or pedological drought occurs when root-zone soil moisture is insufficient to sustain crops between rainfall events.

NMA Agrometeorology Laboratory developed specialized products, such as:

- ♦ Base Products:
- Weekly agrometeorological prognosis / diagnosis, monthly and seasonal
- Specialized agrometeorological studies
- ♦ Specialized products (e.g., maps, graphs etc.):
- *Parameters and maps of thermal vulnerability* and risks at national/regional/ local level (temperature, cold/frost units, scorching heat intensity and duration etc.)
- *Indicators of water stress at national, regional and local level* (precipitation, precipitation under 1 l/m^2, potential evapotranspiration - ETP, real evapotranspiration – ETR (figure 17), relative air humidity etc.)
- *Aridity indices* (standardized at the entire agrometeorological network level);
- *Agrometeorological forecast and diagnosis* (updated daily) includes specific information (air temperature, precipitation, ETP, soil moisture, crop water requirement) useful for assessing the occurrence of drought;
- *Soil moisture maps*, weekly agrometeorological information and seasonal forecasts which are updated daily according to the operational activity are made available to the public on the *NMA website* (*www.meteoromania.ro*);
- *Phenological maps*, weekly agrometeorological observations made for winter wheat and maize crops, Figure18.

Main beneficiaries of agrometeorology information are: Ministry of Environment, Water and Forests, Ministry of Agriculture and Rural Development, farmers, Agricultural Associations, public media etc.

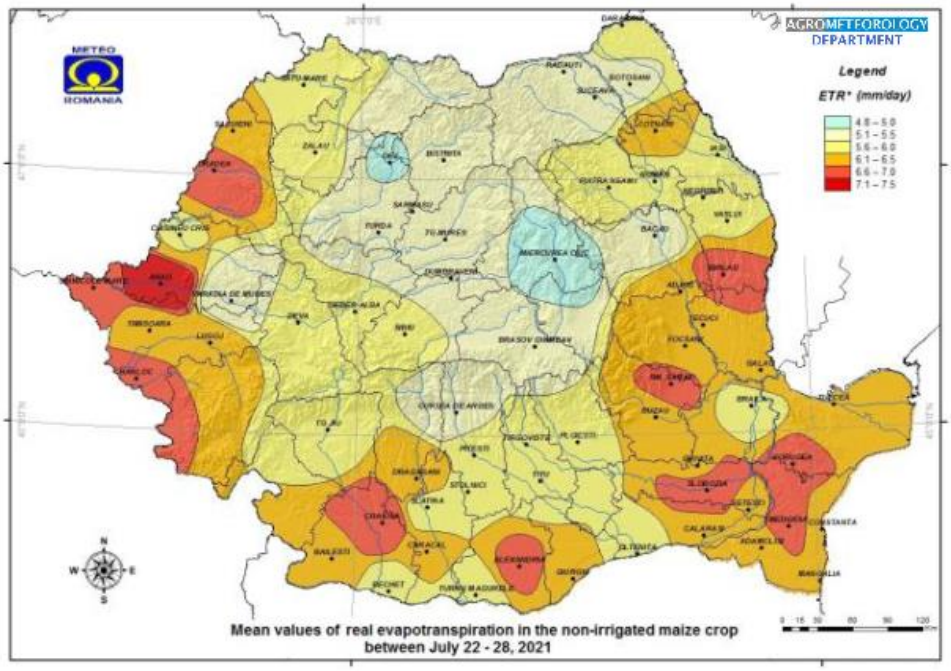


Figure 17: Mean values of real evapotranspiration in the non-irrigated maize crop, 22-28 July 2021

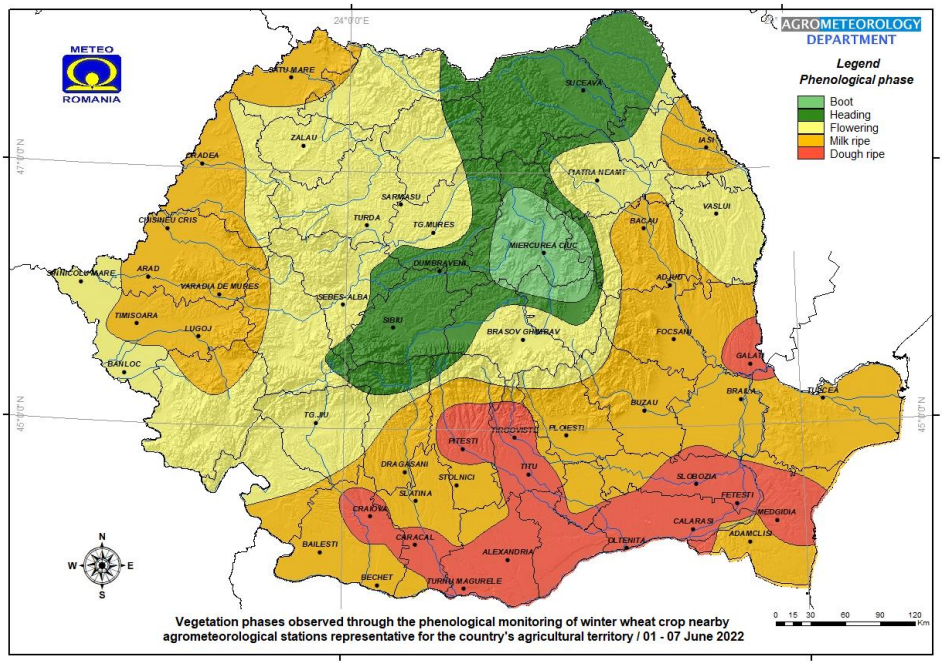


Figure 18: Vegetation phases observed through the phenological monitoring of winter wheat crop nearby agrometeorological stations representative for the country's agricultural territory, 01-07.07.2022

1.5. Remote Sensing and Satellite Meteorology

1.5.1. Operative activity

The operative activity consisted in:

- **Vegetation state and drought monitoring** (using Normalized Difference Vegetation Index – NDVI maps, figure 19), **snow cover monitoring** (using

Normalized Difference Snow Index – NDSI maps, figure 20, **monitoring floods** by creating maps of the areas affected by floods (figure 21), etc. All these products achieved in the Remote Sensing and Satellite Meteorology Laboratory (RSSML) are disseminated to the Agrometeorology Laboratory which includes the NDVI map in the weekly Agrometeorological Bulletin, to other interested departments, as well as to other institutions (the flood map is sent to the National Institute of Hydrology and Water Management);

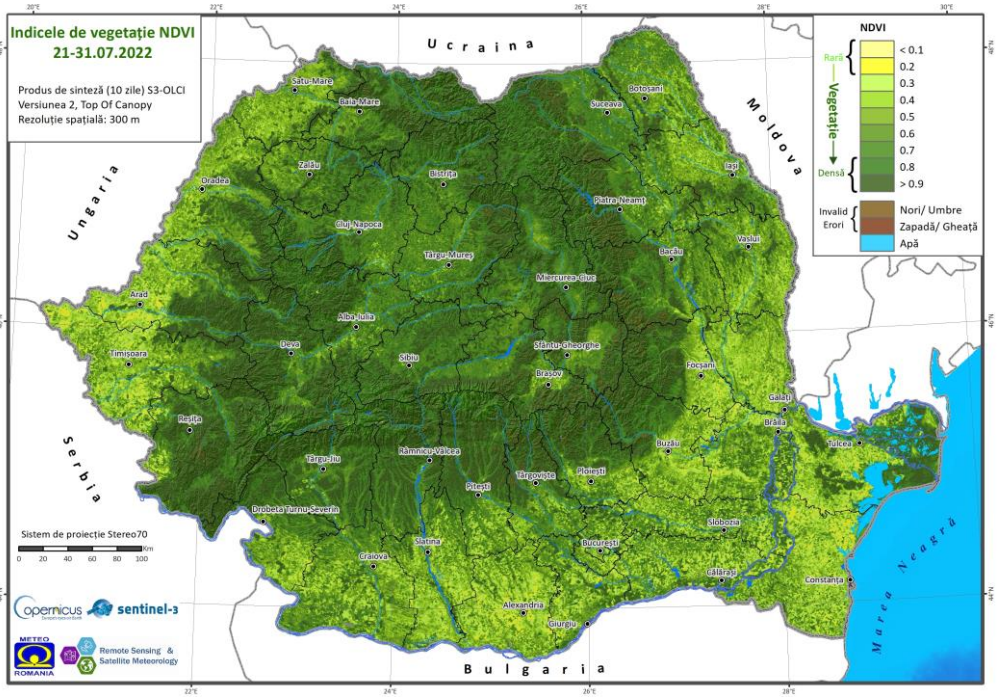


Figure 19: NDVI map for 21-31.07.2022 derived from Sentinel-3 data

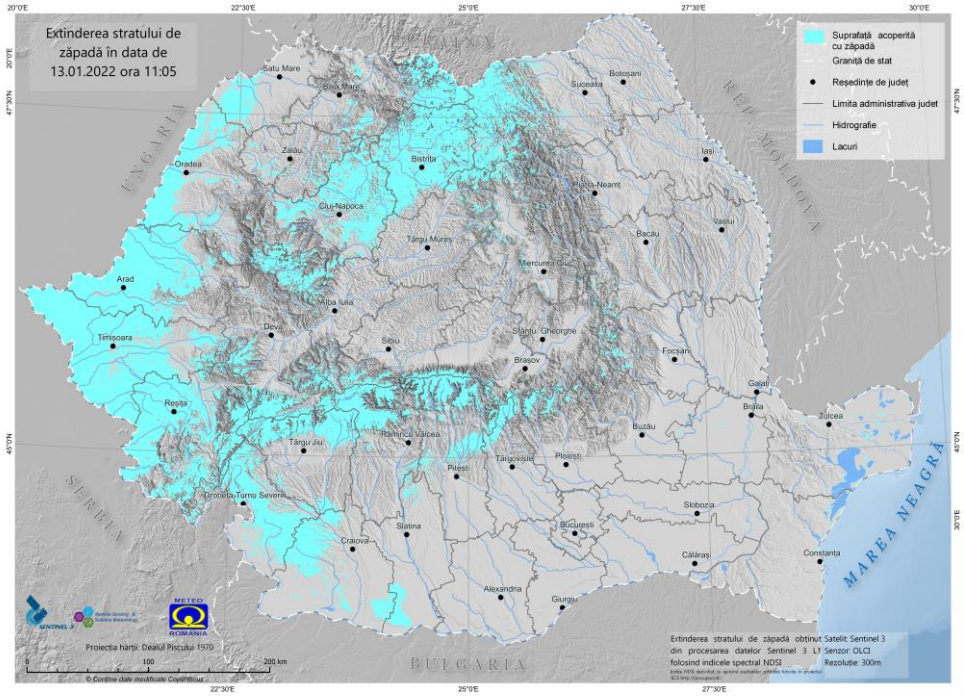


Figure 20: Snow cover extent - 13.01.2022 derived from Sentinel-3 satellite data

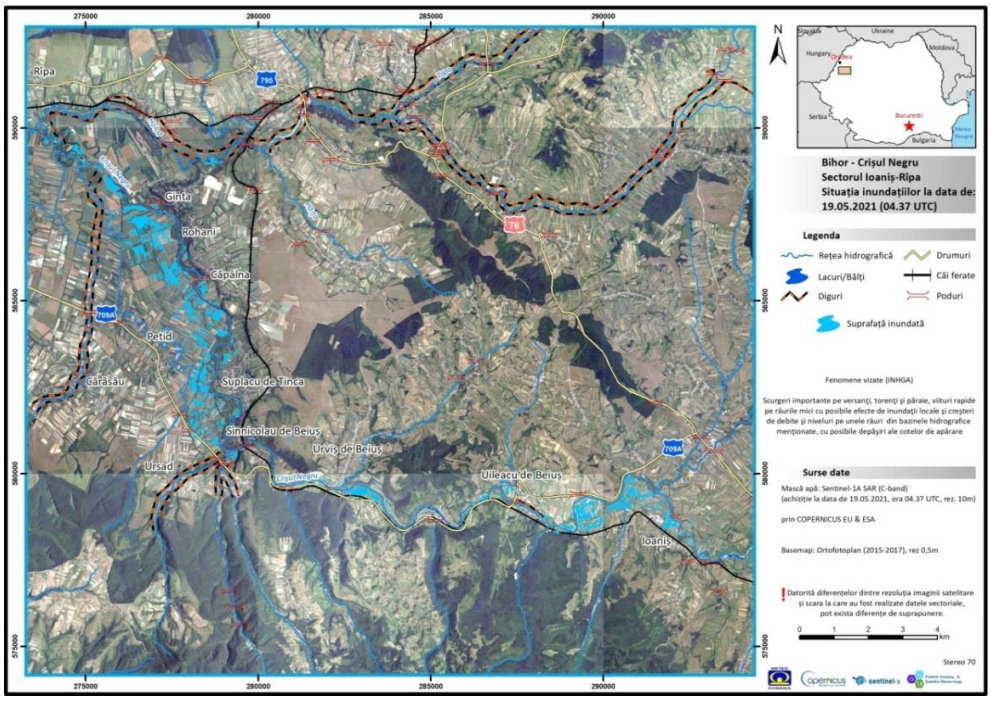


Figure 21: Flood monitoring on Crișul Negru River - 19.05.2021 (product derived from Sentinel-1 data)

♦ **Reception and processing of digital data from geostationary operational meteorological satellites** (0 Degree service mission and RSS - Rapid Scanning Service mission), from polar orbital operational meteorological satellites (MetOp, NOAA) and transmission of the final products to the National Forecast Center;

♦ **Reception and post-processing of satellite products transmitted through the EUMETCast system (LANDSAF, OSISAF, H-SAF):**

- **adapting and testing the following satellite products, created and provided by the EUMETSAT working group LSA SAF** (Satellite Apllication Facility on Land Surface Analysis): *Land Surface Temperature (LSA-001 & LSA-004); Land Surface Temperature - All Sky (LSA-005*, Evapotranspiration (LSA-311); Reference Evapotranspiration (LSA-303), figure 22; *Sensible and Latent Heat Flux (LSA-304 & LSA-305), Downward Surface Longwave Flux (LSA-204); Downward Surface Shortwave Flux (LSA-201); Total and Diffuse Downward Surface Shortwave Flux (LSA-207),* figure 23; *Fire Risk Map (LSA-0504.2)*, figure 24.

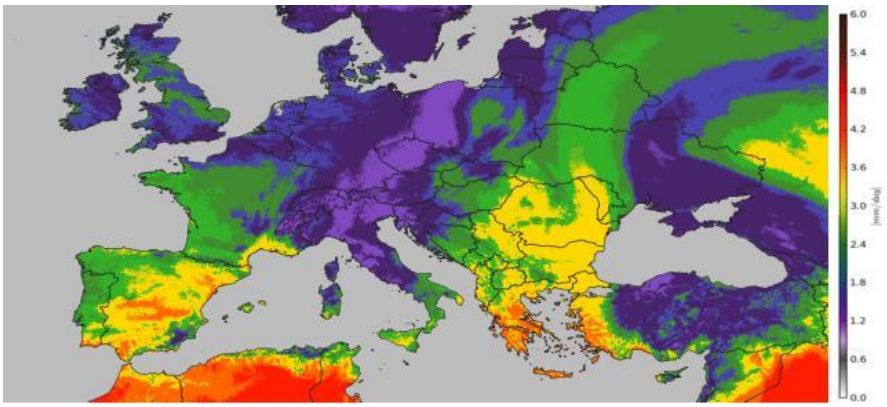


Figure 22: Reference Evapotranspiration (LSA-303) from 12.04.2021, 00:00 UTC

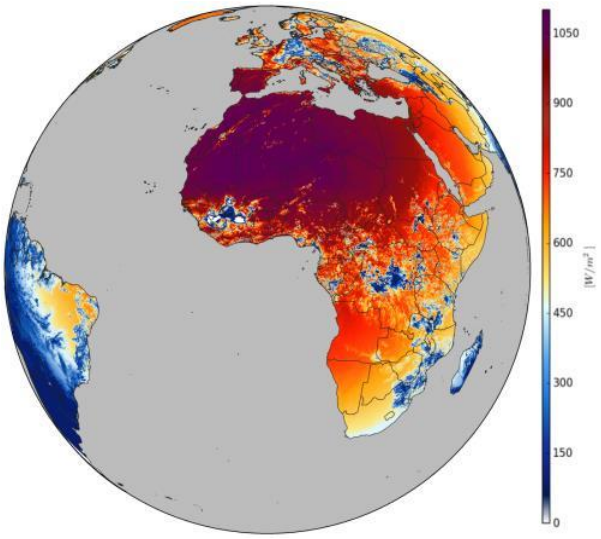


Figure 23: Downward Surface Shortwave Flux (LSA-201) from 06.06.2021, 12:00 UTC

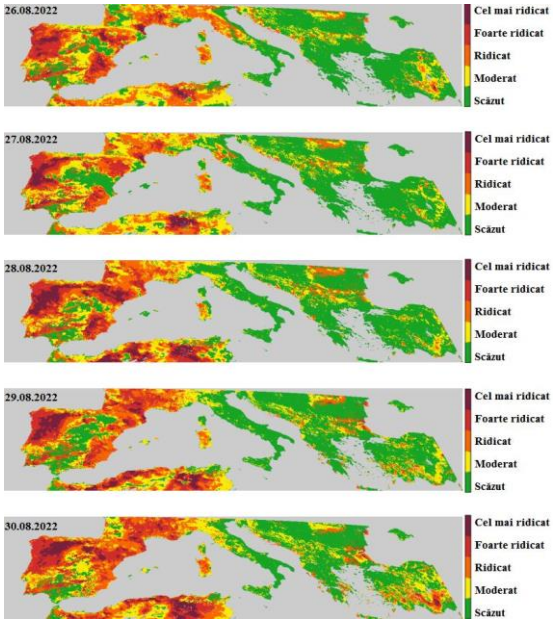


Figure 24: Fire Risk Map (LSA 504.2) from 25.08.2022 (+24h, +48h, +72h, +96h, +120h)

- **adapting and testing of the satellite products created and provided by the EUMETSAT working group H-SAF** (Satellite Application Facility on Support to Operational Hydrology and Water Management): *Precipitation rate at ground by MW conical scanners (H01)* in netCDF4 format, figure 25; *Precipitation rate at ground by MW cross track scanners (H18) & Acumulated precipitation at ground by blended MW and IR (H05B); Disaggregated Metop ASCAT NRT SSM* at 1 km which is the surface soil moisture (0-2 cm) obtained by re-sampling 1 km spatial resolution (for Europe) Soil moisture global product (H16, at 25 km spatial resolution) using spectral information provided by ASCAT radar sensor oboard MetOp satellites (SM-OBS-2, H08); *Snow detection (snow mask) by VIS/IR radiometry covering full MSG Disk (H34)*; *Metop ASCAT NRT Root Zone Soil Moisture Profile Index 10 km resolution* for several soil depth, between 0 to 289 cm, figure 26.

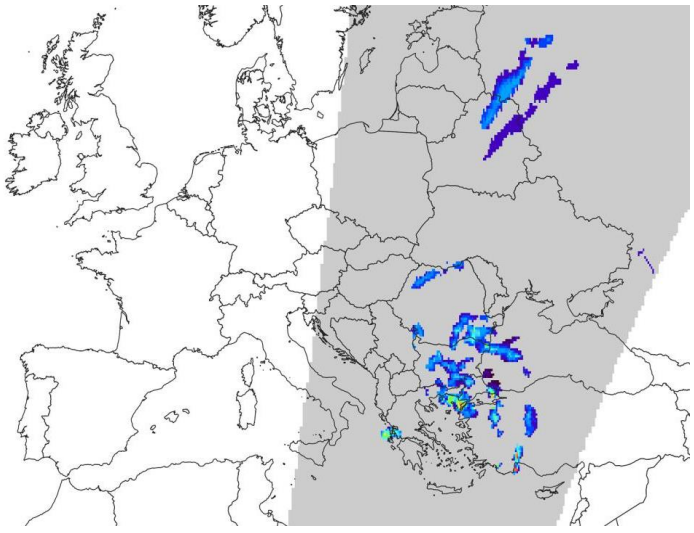


Figure 25: Precipitation rate at ground by MW conical scanners from 16.10.2021, 03:14 UTC

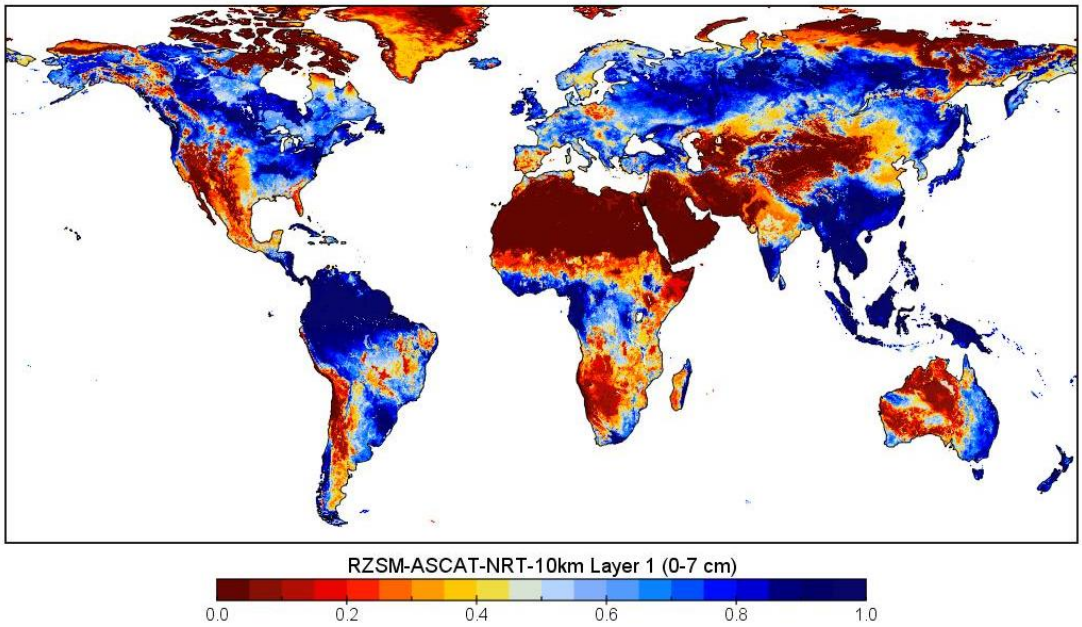


Figure 26: Metop ASCAT NRT Root Zone Soil Moisture Profile Index 10 km resolution (H26), for 0-7 cm depth, from 20.05.2022

- **adapting and testing of the satellite products created and provided by the EUMETSAT working group OSI – SAF** (Satellite Application Facility on Support to Ocean and Sea Ice): Meteosat Downward Longwave Irradiance (OSI-303-a), figure 27; Meteosat Surface Solar Irradiance (OSI–304-a) - *Figure 27:*; Global Metop Sea Surface Temperature (OSI-201-b), figure 28.

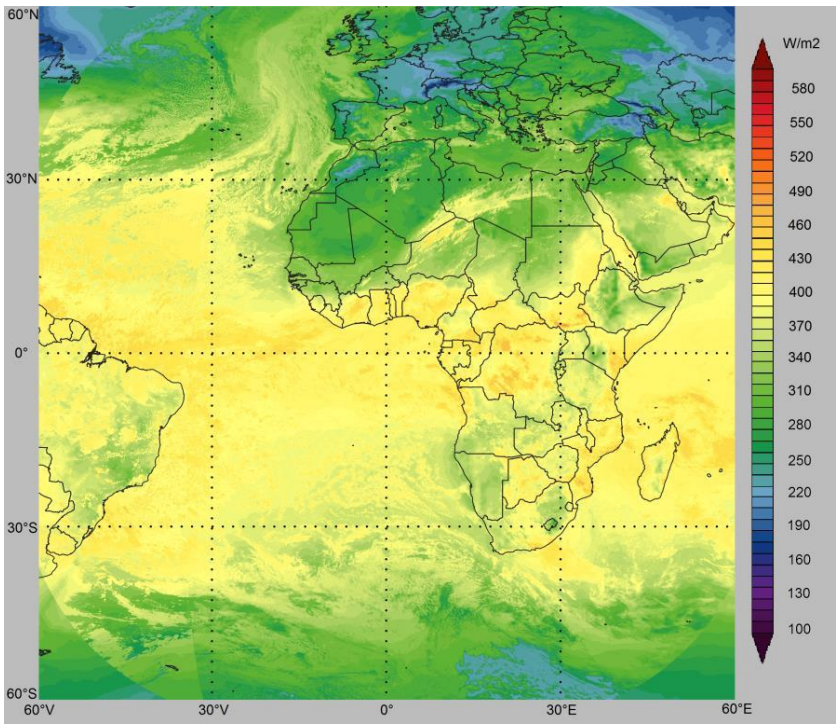


Figure 27: Meteosat Downward Longwave Irradiance (OSI-303-a) from 07.03.20200, 09:00 UTC

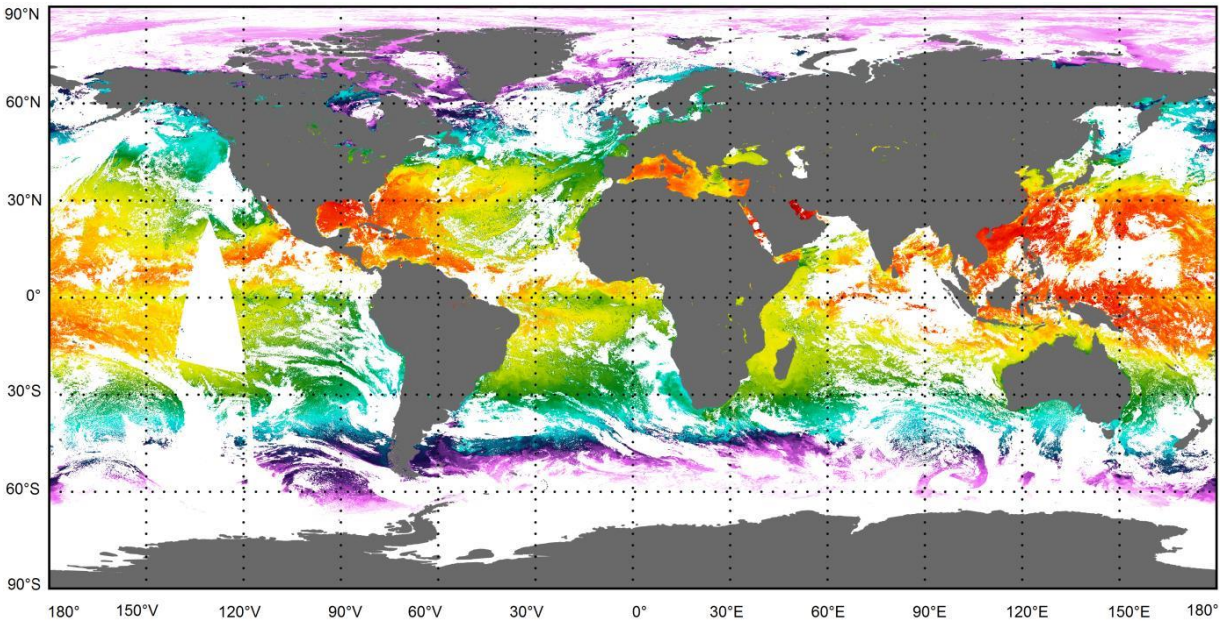


Figure 28: Global Metop Sea Surface Temperature (OSO-201-b), from 25.07.2022

- local generation of nowcasting products created and provided by the EUMETSAT working group NWC SAF (Satellite Application Facility on Support to Nowcasting and Very Short Range Forecasting) using NWC/GEO software: Cloud Mask (CMA), Convective Rainfall Rate (figure 29) from Cloud Physical Properties (CRRPh), Precipitating Clouds (PC), Cloud Microphysics (CMIC).

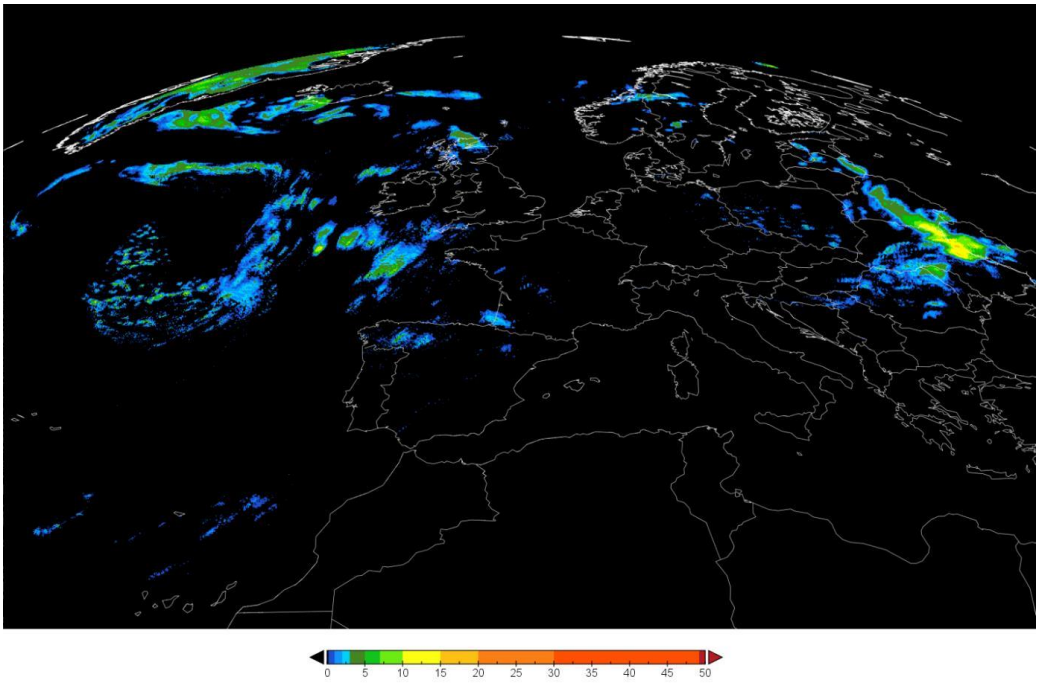


Figure 29: Convective Hourly Rainfall Accumulation from 25.10.2022, 13:15 UTC

1.5.2. Research activity

The research activity at the laboratory level had the main purpose of achieving the following objectives:

♦ improving the methodologies for the application of remote sensing techniques used to study the vegetation cover dynamics, the evaluation of water resources in the snow layer, the prevention and supervision of areas at risk of flooding;

♦ the study of the consequences of extreme meteorological phenomena in Romania using remote sensing and GIS techniques;

♦ IT tools and techniques for the implementation of services facilitated by the network, according to the INSPIRE Directive;

♦ developing methodologies for the spatial representation of meteorological parameters and obtaining maps using remote sensing and GIS techniques.

The laboratory research activity has been accomplished through RSSML implication in several national and international projects.

♦ *Developing resilience and tolerance of crop resource use efficiency to climate change and air pollution – SUSCAP*

The main objective of the project was to develop a new generation of process-based crop models to better understand the mechanisms and hence impacts, of these multiple stresses both for the current day and future 2050 climates. This will allow us to identify the magnitude; frequency and geographical distribution of the combined stresses most likely to limit resource use efficiency and hence crop productivity. This will be important since, in spite of international efforts to reduce emissions, poor air quality in Europe is currently set to continue to substantially impact crop yields until at least 2050 and GHG emissions are still on course to see large changes in climate over the coming decades. Within SusCap Project, RSSML is responsible for processing the products derived from satellite data: Meteosat/Seviri; Terra, Aqua/Modis; SMOS; MetOp/Ascat; Sentinel-1 & Sentinel -2, at the European level, for the interval 2000-2019, depending on the availability of satellite data. The products obtained by processing satellite images are: Leaf Area Index - LAI (Leaf Area Index), Evapotranspiration - ET and Soil moisture - SM. The satellite database for LAI (2000-2019) (figure 30) and ET (2001-2019) (figure 31) and SM was developed.

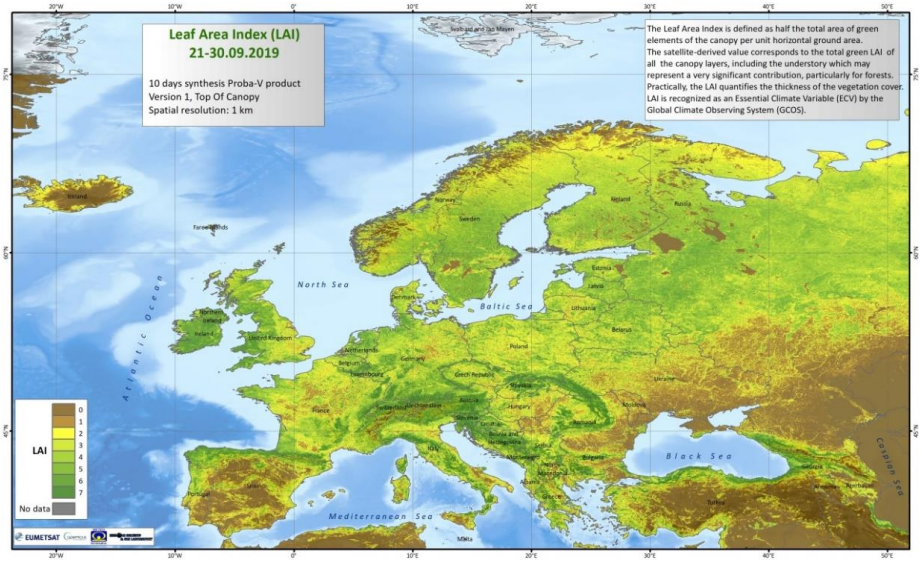


Figure 30: LAI spatial distribution, for 21-30.09.2019

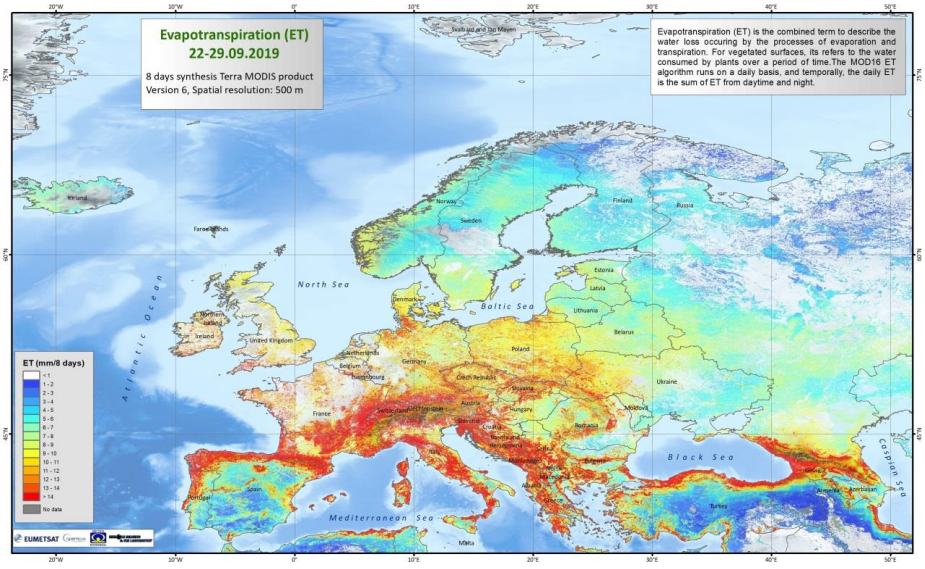


Figure 31: ET spatial distribution for 22-29.09.2019

During 2020 - 2022, RSSML was involved in the following activities:

- obtaining satellite derived from Sentinel-2 data for a better spatial and temporal resolution (needed for agricultural modelling);
- extracting the wheat plots identified from the databases provided by the project partners (Great Britain, Germany, Spain, Italy and Romania);
- calculation and extraction of the biophysical indicator Leaf Area Index (LAI) for previously identified wheat plots, for different agricultural years (2017 - 2018 and 2018 - 2019 for Romania, Germany, United Kingdom of Great Britain; 2017 - 2018 for Italy; 2019 - 2020 for Spain), figure 32.

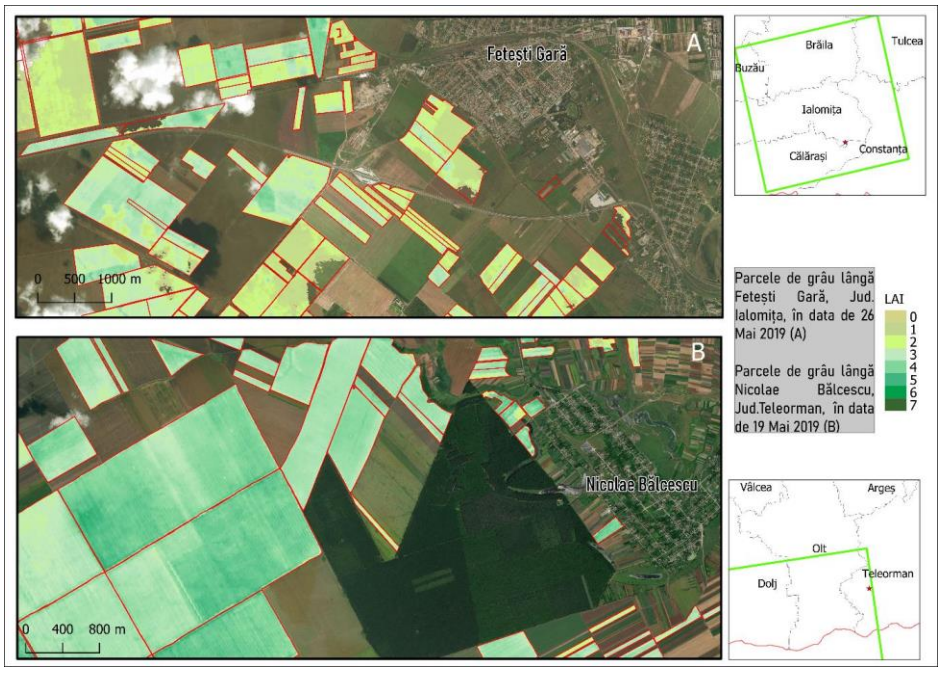


Figure 32: LAI distribution for 2 scenes (Romania), for agricultural year 2018-2019

- the extraction of climate information, at European level, for the analysed

agricultural years, necessary for the agricultural modelling activity;

- aggregation of yield data for the two analysed wheat crops, common wheat and durum wheat, initially for the period 2009-2019, with a subsequent extension for the period 2005-2020. Yield data were downloaded from the Database - Agriculture - Eurostat portal (europa.eu) at the level of territorial units for statistics (NUTS 2). These were spatially aggregated with NUTS 2 geometries for each individual year, the geometries being different for 3 time intervals.
- extraction of SoilWaterContent data for all consortia agreed plots for the period 2017-2019 using laboratory-produced SWC data derived from SWI Sentinel1 data at 1km.

♦ *Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake – FPCUP.*

The main objective of the project is the development and expansion of geospatial services based on Copernicus satellite data among the member countries of the European Union. National Meteorological Administration, through RSSML was involved in:

- increasing the degree of adoption of the Copernicus program data and services at the European and national level by defining public policies at the level of the relevant authorities (eg: the Ministry of the Environment, the Ministry of Water and Forests, the Ministry of Public Works, Development and Administration, etc.);
- building a snow cover extension monitoring service using Copernicus satellite data (figure 33Figure 33:). The most important technical achievement is related to the development of an IT infrastructure capable of processing and distributing products derived from satellite data.

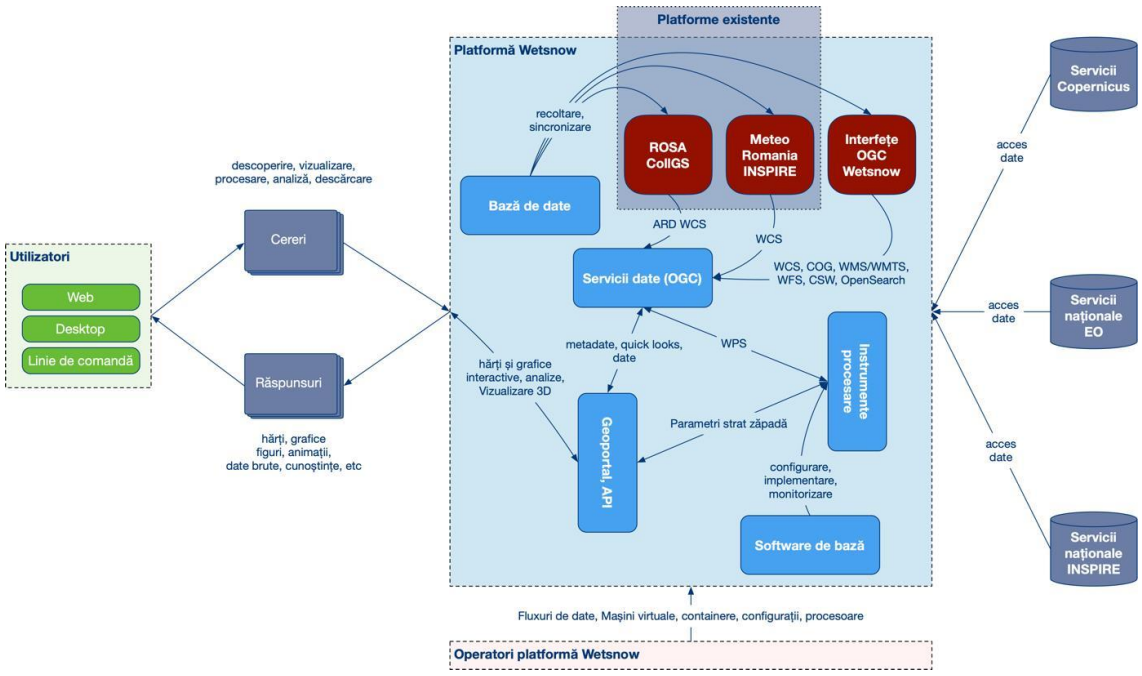


Figure 33: The architecture of the snow cover extension monitoring service

- the use of GEOINT (Geospatial Intelligence) techniques in support of

environmental protection activities and the identification of illegal activities (especially air pollution);

- creation of a snow cover moisture monitoring service using Copernicus satellite data (Wetsnow);
- building the architecture for the data processing platform related to the moisture of the snow cover;
- implementation of data visualization and download components from the WETSNOW platform (figure 34);
- development of a web mapping application for the interactive visualization of WETSNOW products;
- defining the GEOINT4ENV air quality monitoring service using satellite data and Copernicus CAMS products;
- developing the prototype version of the GEOINT4ENV knowledge sharing platform.

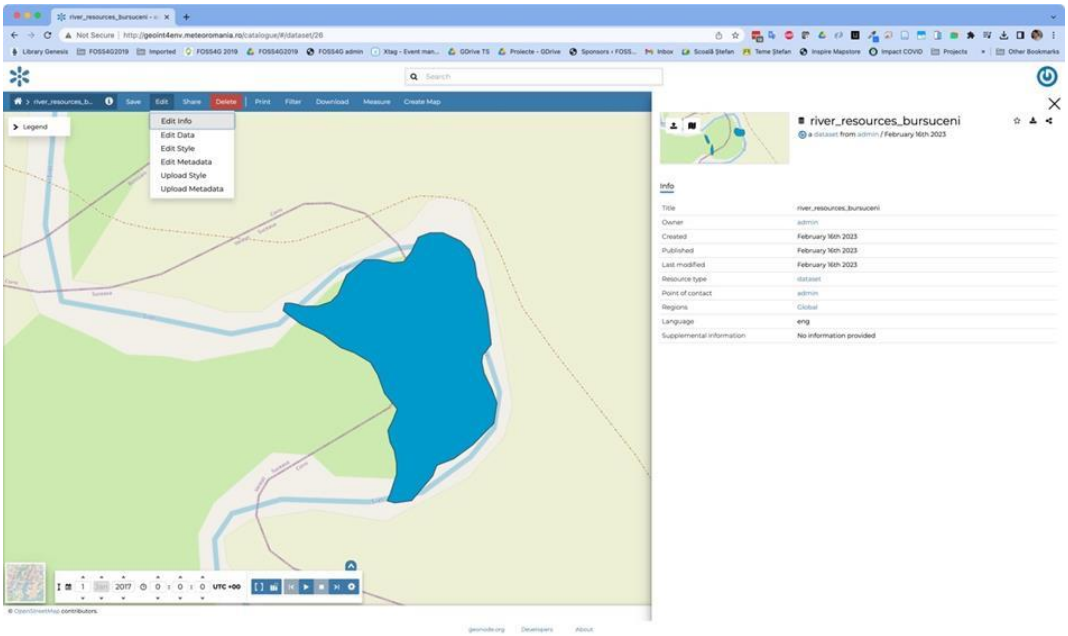


Figure 34: The graphical interface of the GEOINT4ENV knowledge sharing platform prototype

♦ *GNSS-R Retrievals of Soil and Snowpack Parameters for Land Surface Modelling Applications – ESA GRASP*

The overall objective of the project is to demonstrate that GNSS interferometric reflectometry can produce accurate soil moisture observations – comparable to measurements obtained with current soil moisture sensors that could serve agricultural needs.

The activity of the Remote Sensing and Satellite Meteorology Laboratory within the related GRASP project involved:

- algorithm development for soil moisture calculation from GNSS-R data from GPS and Galileo positioning satellites;
- the collection and processing of GNSS-R data from the GRASP reception stations installed in Bucharest, Târgu Secuiesc and Joseni;

- calibration/validation of soil moisture calculated from GNSS-R data with in-situ measured data.

♦ *NWCSAF CDOP-3: The 3rd Operational and Continuous Development Phase of EUMETSAT's Center for Nowcasting and Very Short-Range Weather Forecasting Satellite ApplicationsNational projects*

The main objective of the project is to provide software for the generation of nowcasting products from geostationary and polar-orbital satellites data for Short and Very Short Term Forecasting.

The RSSML activity involved the following:

- studying the impact of GFS and ECMWF model data on Cloud Mask (CMA), Cloud Types (CT) and Cloud Top Height and Temperature (CTTH) products generated using the GEO and PPS software packages (figure 35);
- comparing the CMA, CT and CTTH products generated using the NWCSAF GEO v2018.1 and PPS v2018.4 software packages, in order to identify the differences that may come from: the characteristics of the radiometers, the pixel size and the available channels of the two types of satellites (geostationary and polar - orbitals);
- installation and testing of the latest available NWC/GEO and PSS software packages for product generation: Cloud Mask (CMA), Cloud Type (CT) and Cloud Top Height and Temperature (CTTH), (figure 36);
- collecting and archiving primary data and generating products based on them;
- Python code development required for pixel-level comparison of products;
- development of algorithms for calculating level 3 products from data from the MTG LI space lightning sensor.

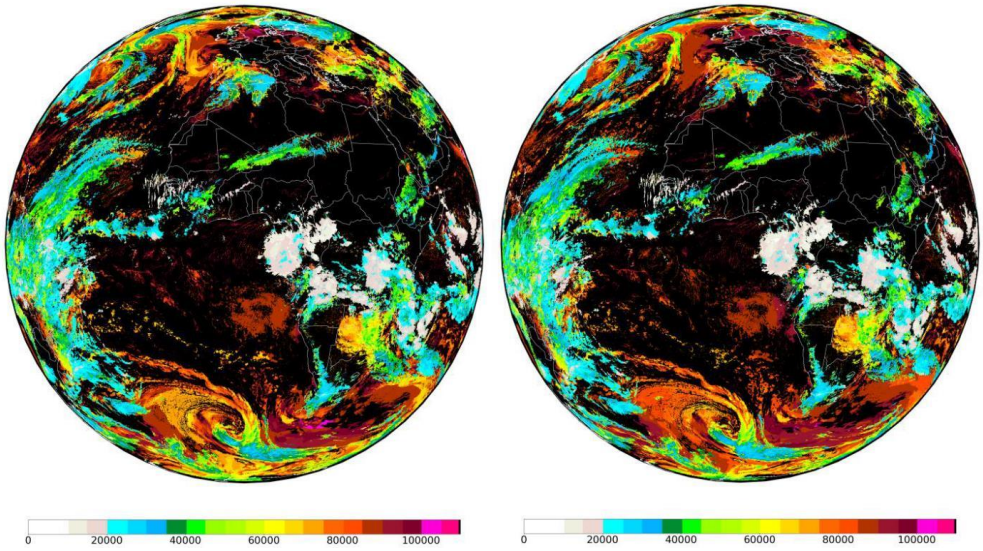


Figure 35: CTTH Pres (în Pa) GEO ECMWF 0.5 (left) and GEO GFS 0.5 (right), from 01.03.2021, 15:00 UTC

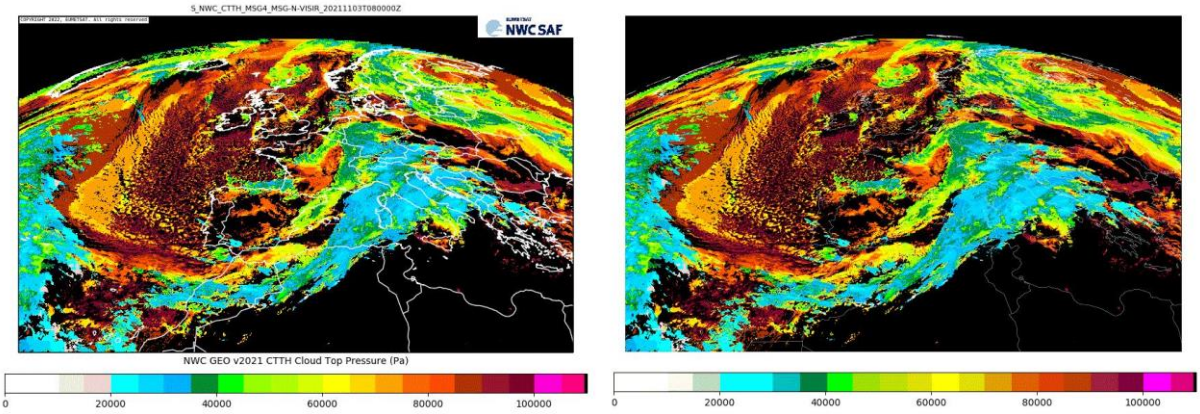


Figure 36: Reference CTTH Pres (Pa) GEO ECMWF 0.5 (left) and generated afte software instalation (right), from 03.11.2021, 08:00 UTC

♦ *Integrated computer system for monitoring and epidemiological modeling to limit the effects of the coronavirus pandemic in the case of community transmission - IASO*

The main objective of the project was to develop a computer solution for monitoring and modelling the SARS-CoV-2 epidemic, a solution applicable on the territory of Romania. The project was financed by Executive Unit for the Financing of Higher Education, Research, Development and Innovation (UEFISCDI) through The National Plan for Research, Development and Innovation for the period 2015 – 2020 (PNCDI III), Program 2 – Increasing the competitiveness of the Romanian economy through research, development and innovation, Sub programme 2.1, Competitiveness through research, development and innovation, Solutions financing instrument – 2020 – 2. The IASO system consists of three main components that achieve: (1) automatic monitoring of congested areas, (2) ensure epidemiological triage and (3) allow the simulation of epidemiological evolution over time based on a mathematical model implemented at the central server level. The database continuously feeds the web interface for quasi-real-time display of congested areas and allows the user to perform time-predictive simulations of epidemiological evolution based on the current situation. The mobile application is used both to feed the database with user positions and to define a score/grade used later for the triage action in the case of users requesting access to hospitals or public institutions.

The IASO GIS module, developed by the National Meteorological Administration, integrates the data collected and generated by the components of the IASO system, offering a clear and objective perspective on the magnitude of the SARS-CoV-2 pandemic and its effects on human agglomerations in Romania. The module is built based on a distributed architecture and uses the latest Web and GIS technologies. It is accessed by users via the Internet, through a web browser. Through this application, users send requests to the web mapping service and also view the results returned by it (figure 37).

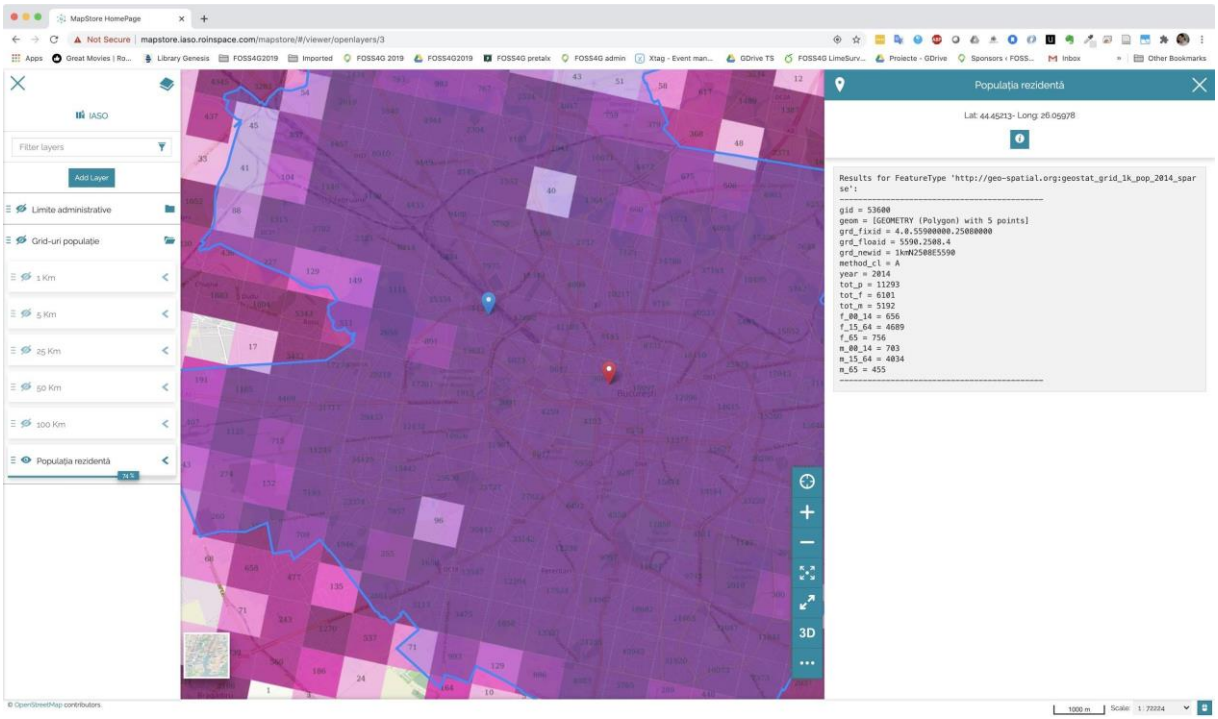


Figure 37: Web cartographic client of the IASO system

♦ *Consulting and expertise services for the development of emergency management studies using airborne sensors - SUASA*

The project SUASA was financed by Ministry of Environment, Waters and Forests and had as a main objective the systematization, improvement and simplification of the national legislation by creating and implementing the regulation for the management of emergency situations generated by the types of risk specific to the Ministry of Environment, Water and Forests, including dangerous meteorological phenomena and the types of risk where the ministry provides the support function, as well as situations regarding the state of the environment.

The RSSML activity involved:

- the analysis regarding the monitoring of emergency situations with the help of airborne sensors and the documentation of their impact in order to reduce the negative consequences and prevent similar cases;
- a study regarding the development of an integrated monitoring system using airborne sensors of accidental air pollution and meteorological conditions in urban areas.

1.6. Atmospheric Physics

1.6.1. Solar radiation – activities and scientific preoccupations

The activity within the Atmospheric Physics Observatory was concerned with the research of the measured solar radiation values over the territory of Romania. For that purpose, several studies were done.

In one of the works, there has been created a distribution of the number of clear sky days at four radiometric stations over a period of 15 years. Amongst the results which we've obtained, we mention the following:

- ♦ the highest number of clear sky days in august;
- ♦ a relatively high number of clear sky days in April;
- ♦ the highest nebulosity in the November to February period;
- ♦ a slightly higher fraction of clear sky days at the sea site (Gura Portitei);
- ♦ a similarity between the four curves constructed by the multiannual monthly averages;
- ♦ a possible increasing trend of the annual fraction of clear sky days.

The above aspects can be observed in the two graphical representations (figure 38 and 39) below.

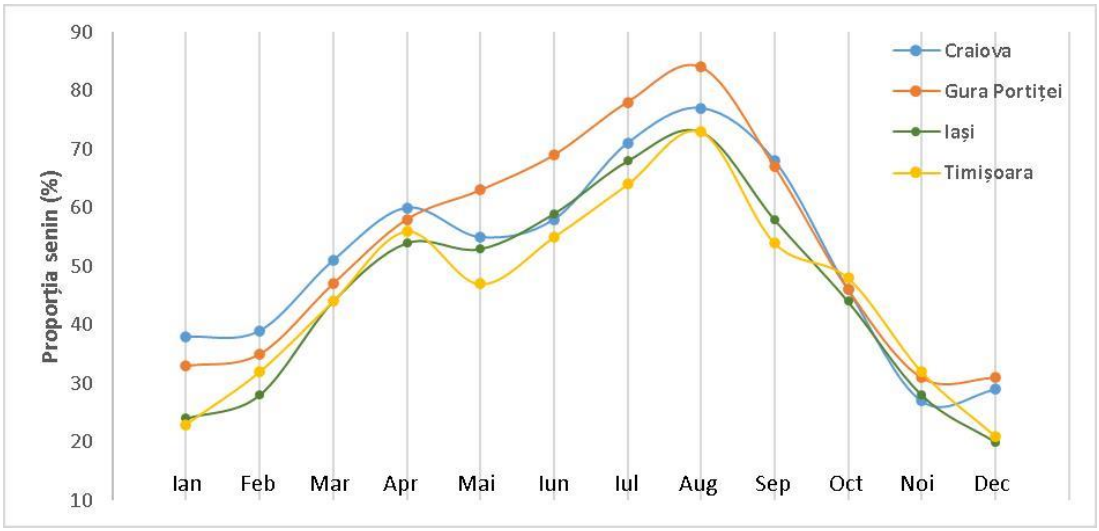


Figure 38: The average monthly fraction of clear sky days

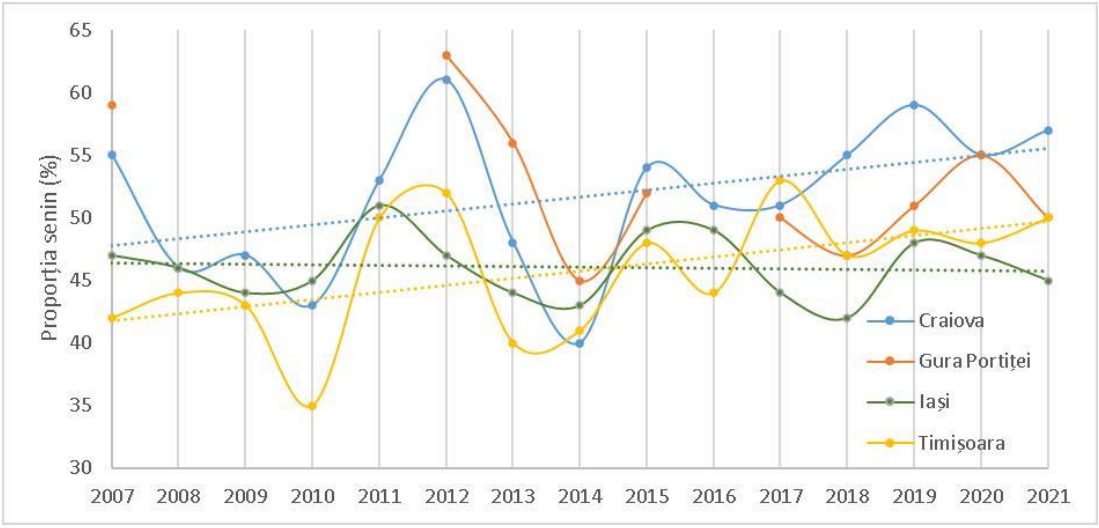


Figure 39: The annual fraction of clear sky days

The performance of the REST2 model (2008, author C.A. Gueymard) was tested by comparing with the measured solar radiation values. The required input of the model which consisted of aerosol data, water and ozone amounts was available on the AeroNet's webpage for four radiometric stations, namely Bucharest, Cluj-Napoca, Iasi and Timisoara. The computations were made for a total of 167 clear sky days that were observed during the 2018 and 2019 years at the four mentioned locations. Based on the results that we've obtained, we found that the REST2 model gives a very good estimation of the global solar radiation. More precisely, the difference between the theoretical and the measured values was, in most of the cases less than 5%, with an average of less than 1%.

Further in another study we've calculated the monthly and annual clarity indexes for over 60 radiometric stations during the year 2020, the values being then used to construct monthly and annual maps. There, we could remark the following:

- July, August and September having the highest clarity indexes;
- the south-east part of the country having the highest clarity indexes;
- in contrast, the center, north and north-west of the country being characterized by a higher nebulosity.

Some of the results can be seen in the graphical representation of the annual clarity indexes which is presented below (Figure 40:figure 40).

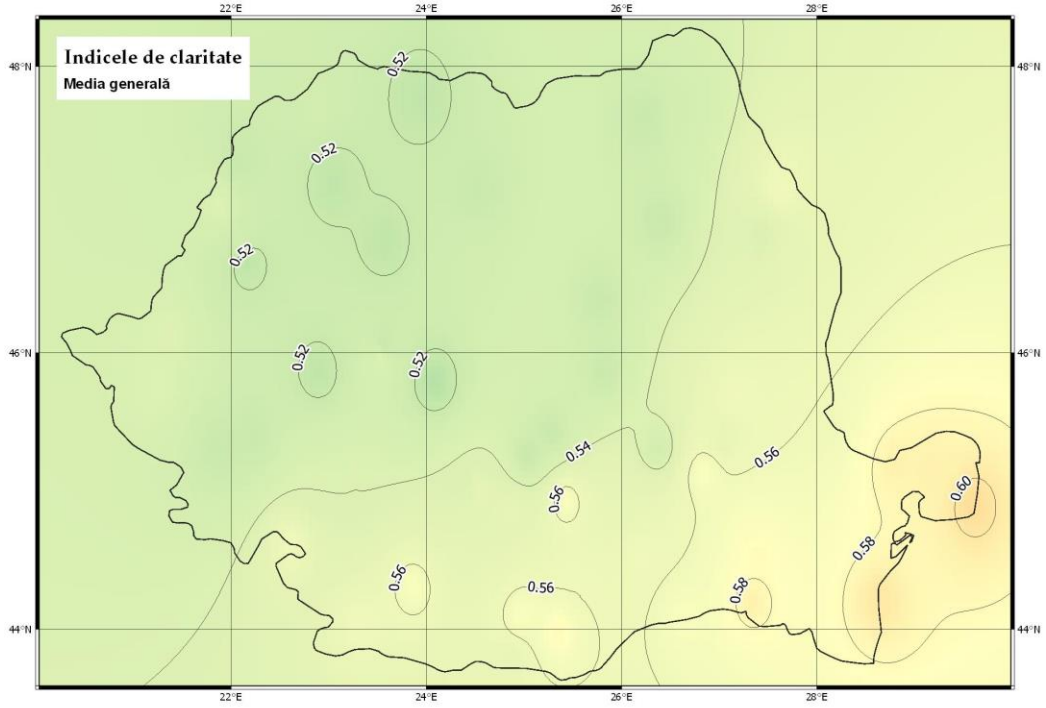


Figure 40: The annual means of the clarity index over the territory of Romania

1.6.2. Study regarding the determination of the pollution potential for the Bucharest urban area

The phenomena of transport and deposition of atmospheric pollutants constitute an extremely vast field of research, in which research methods and techniques are continuously developed and perfected, especially those that result in the estimation of boundary layer parameters, involved in diffusion studies.
Data on mixing height and wind speed provide an opportunity for qualitative assessment of urban pollution potential. A quantitative interpretation can be achieved by using a mathematical model of dispersion over the urban area.
The model used in this study determines the average normalized concentration ($(\overline{X}/\overline{Q})$) ($\overline{X}$- the average concentration on an area and $\overline{Q}$- the average uniform emission rate), depending on the mixing height (H), the wind speed U) and the average diameter (S) of the city. Figure 41Figure 41: shows the estimated pollution potential for March, July and December.

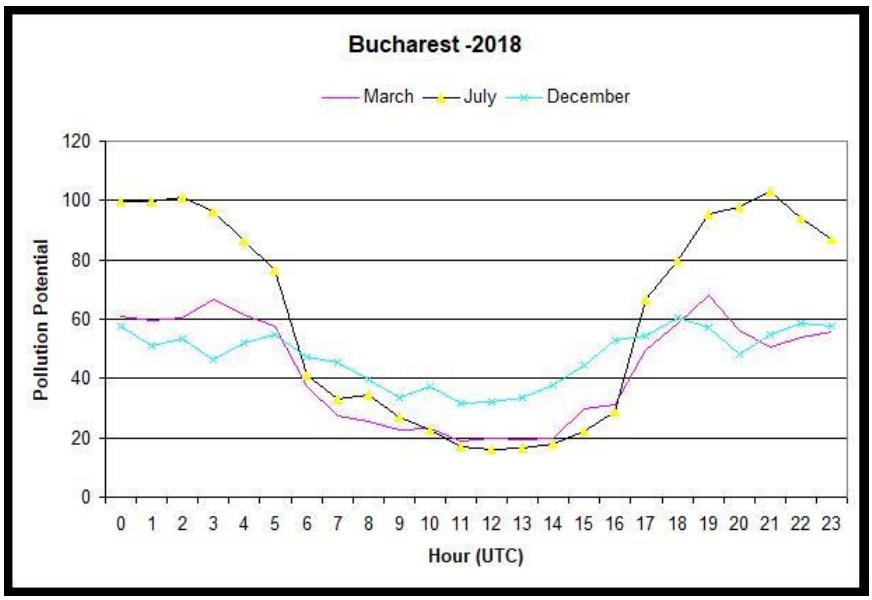


Figure 41: Estimated Pollution Potential for Bucharest 2018

1.6.3. Total Ozone

Main activities in the ozone field consist in monitoring of the ozone layer; long term monitoring is carried out in Bucharest since January 1980 and is performed with Dobson spectrometer No. 121; Data processing and instrument maintenance.
The research activities were focused mainly, as follows:

- ozone climatology related with meteorological condition on locale scale;
- total ozone data analyzed with respect to changes in atmospheric circulation and natural variability;
- annual and seasonal stratospheric temperature trends and tropopause height variations;
- statistical analysis of the total ozone series, measured at the Bucharest station, using an ARIMA (autoregressive integrated moving average) type model;

♦ besides the specialized studies, it has also to be mentioned: various articles for general public aimed at correct explanation of the ozone depletion, mass-media information concerning the ozone layer, courses for students from the meteorological and environmental training system referring to the atmospheric ozone and its depletion.

1.6.4. Interaction with other programs and activities

Bucharest station is part of GAW (Global Atmospheric Watch) Ozone Network as "associated station".

1.7. Metocean research

INCD GeoEcoMar continued the activity in the institute's main research and development directions, metocean study for western Black Sea, complex knowledge of the Danube - Danube Delta - Black Sea macro-geo-system (geological evolution and structure, marine resources, specialized expertise), knowledge of the structure and functioning of the ecosystems in the Danube - Danube Delta - Black Sea macro-geo-system, studies and research for the integrated management of the coastal zone, the study of global changes (sea level, climate) and knowledge of their effects on the environment and the development of strategies, studies, forecasts regarding the development of the field of science and the branch/sector of activity.
GeoEcoMar continue to provide data collection and analysis of offshore Black Sea current velocities (i.e., speed and direction, Table 1), water column characteristics (i.e. conductivity and temperature, Figure 42a and 42.b), and meteorological data (Figure 43) for the period 2013 through 2023 to characterize water column hydrodynamics and meteorological conditions of the Western Black Sea.

Table 1. Examples of tendency statistics – water current amplitude (cm/s) – July 2019 – June 2020 at one offshore location

Year	Month	Mean	Minimum	Maximum	Q1	Q2	Q3	95%	99%	Dominant Direction (°)
2019	July	10.50	0.26	40.61	5.87	9.09	13.85	22.41	30.07	149.0
	August	14.14	0.45	59.04	6.77	11.98	19.78	31.91	44.51	151.3
	September	11.08	0.39	51.23	5.39	9.20	15.02	26.20	33.82	149.3
	October	7.31	0.32	25.73	3.90	6.00	9.66	18.28	22.49	146.7
	November	9.34	0.10	36.08	4.54	7.72	12.74	21.48	28.03	131.5
	December	10.90	0.57	42.33	5.82	9.40	13.97	26.04	35.78	144.5
2019		**10.54**	**0.1**	**59.04**	**5.13**	**8.67**	**13.92**	**25.23**	**34.57**	**146.9**
2020	January	11.52	0.26	47.82	5.59	9.55	15.44	27.10	40.43	163.9
	February	10.00	0.48	36.52	5.10	8.52	13.51	22.18	28.73	114.8
	March	8.88	0.32	34.00	4.61	7.68	11.54	21.21	27.87	172.3
	April	11.09	0.23	48.80	4.77	8.85	14.74	28.96	41.73	167.6
	May	14.21	0.15	51.88	6.46	11.19	20.21	34.66	43.60	148.6
	June	17.06	0.49	59.69	9.72	15.28	22.63	35.05	50.14	167.2
2020		**12.12**	**0.15**	**59.69**	**5.65**	**9.90**	**16.37**	**29.85**	**41.56**	**158.4**

Count of water	Column Labels								
Row Labels	**S**	**E**	**N**	**NE**	**NW**	**SE**	**SW**	**W**	**Grand Total**
<1 or (blank)	0,45%	0,00%	0,75%	0,30%	0,30%	0,45%	0,00%	0,00%	2,26%
1-5	3,61%	4,82%	3,31%	2,71%	3,77%	4,07%	2,26%	2,86%	27,41%
5-9	4,22%	5,72%	3,31%	2,41%	2,11%	7,23%	3,61%	2,26%	30,87%
9-13	3,31%	3,46%	2,26%	1,81%	1,36%	6,02%	1,51%	1,20%	20,93%
13-17	2,86%	1,05%	1,96%	1,05%	0,15%	2,26%	0,75%	0,15%	10,24%
17-21	1,36%	0,15%	0,45%	0,75%	0,00%	2,11%	0,00%	0,00%	4,82%
21-25	1,36%	0,00%	0,00%	0,00%	0,00%	0,30%	0,00%	0,00%	1,66%
25-29	1,05%	0,00%	0,00%	0,00%	0,00%	0,75%	0,00%	0,00%	1,81%
Grand Total	**18,22%**	**15,21%**	**12,05%**	**9,04%**	**7,68%**	**23,19%**	**8,13%**	**6,48%**	**100,00%**

Count of water	Column Labels								
Row Labels	S	E	N	NE	NW	SE	SW	W	Grand Total
<1 or (blank)	0,004518072	0	0,0075	0,003	0,003	0,0045	0	0	0,02259036
1-5	0,036144578	0,0482	0,0331	0,027	0,038	0,0407	0,023	0,029	0,27409639
5-9	0,042168675	0,0572	0,0331	0,024	0,021	0,0723	0,036	0,023	0,30873494
9-13	0,03313253	0,0346	0,0226	0,018	0,014	0,0602	0,015	0,012	0,20933735
13-17	0,028614458	0,0105	0,0196	0,011	0,002	0,0226	0,008	0,002	0,10240964
17-21	0,013554217	0,0015	0,0045	0,008	0	0,0211	0	0	0,04819277
21-25	0,013554217	0	0	0	0	0,003	0	0	0,01656627
25-29	0,010542169	0	0	0	0	0,0075	0	0	0,01807229
Grand Total	0,182228916	0,1521	0,1205	0,09	0,077	0,2319	0,081	0,065	1

Row Labels	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°
1-5 cm/s	0,03313253	0,0271	0,0482	0,041	0,036	0,0226	0,029	0,038
5-9 cm/s	0,06626506	0,0512	0,1054	0,113	0,078	0,0587	0,051	0,059
9-13 cm/s	0,088855422	0,0693	0,1401	0,173	0,111	0,0738	0,063	0,072
13-17 cm/s	0,108433735	0,0798	0,1506	0,196	0,14	0,0813	0,065	0,074
17-21 cm/s	0,112951807	0,0873	0,1521	0,217	0,154	0,0813	0,065	0,074
>21 cm/s	0,112951807	0,0873	0,1521	0,227	0,178	0,0813	0,065	0,074

Figure 42a: Example of water current amplitude [cm/s] - at one offshore location

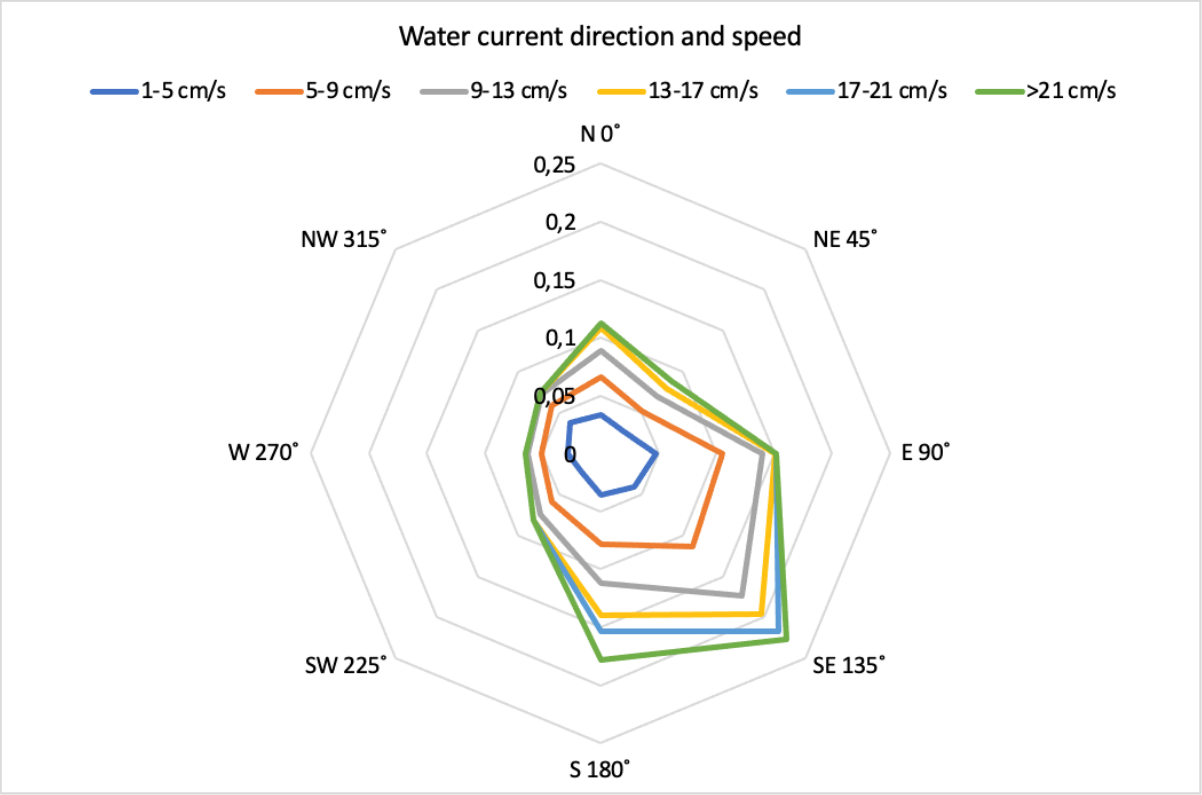
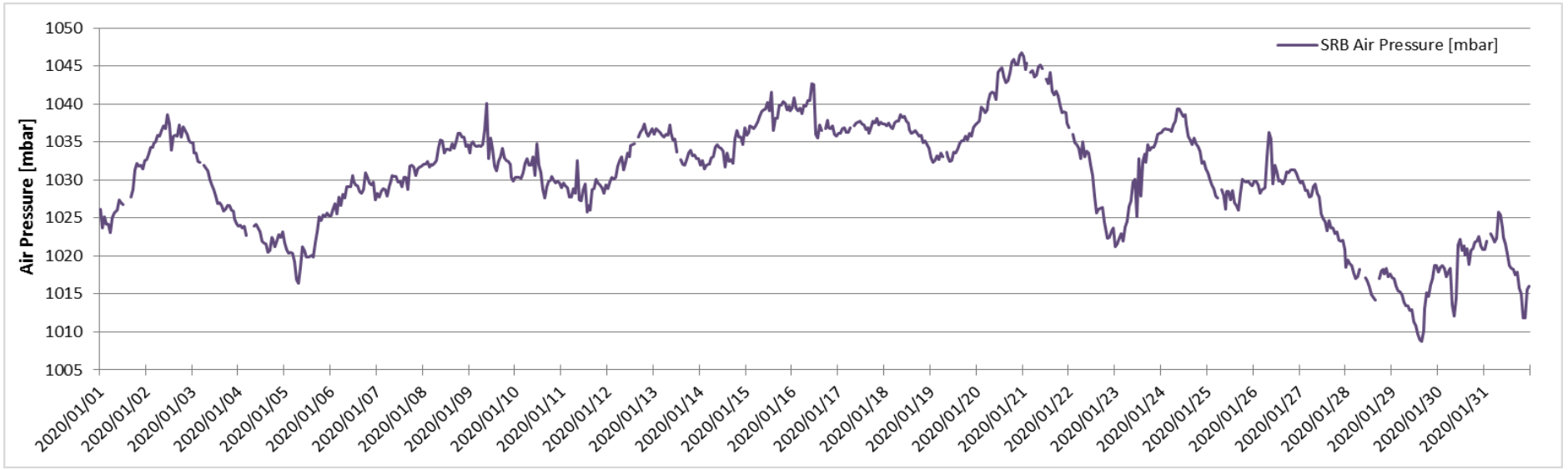


Figure 42b: Example of wind rose for water current amplitude [cm/s] - at one offshore location


Air Pressure [mbar]
SRB Air Pressure [mbar]
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
2020/01/01
2020/01/02
2020/01/03
2020/01/04
2020/01/05
2020/01/06
2020/01/07
2020/01/08
2020/01/09
2020/01/10
2020/01/11
2020/01/12
2020/01/13
2020/01/14
2020/01/15
2020/01/16
2020/01/17
2020/01/18
2020/01/19
2020/01/20
2020/01/21
2020/01/22
2020/01/23
2020/01/24
2020/01/25
2020/01/26
2020/01/27
2020/01/28
2020/01/29
2020/01/30
2020/01/31


Air Temperature [°C]
SRB Air Temperature [°C]
10
9
8
7
6
5
4
3
2
1
0
-1
-2
2020/01/01
2020/01/02
2020/01/03
2020/01/04
2020/01/05
2020/01/06
2020/01/07
2020/01/08
2020/01/09
2020/01/10
2020/01/11
2020/01/12
2020/01/13
2020/01/14
2020/01/15
2020/01/16
2020/01/17
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2020/01/19
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2020/01/21
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2020/01/31

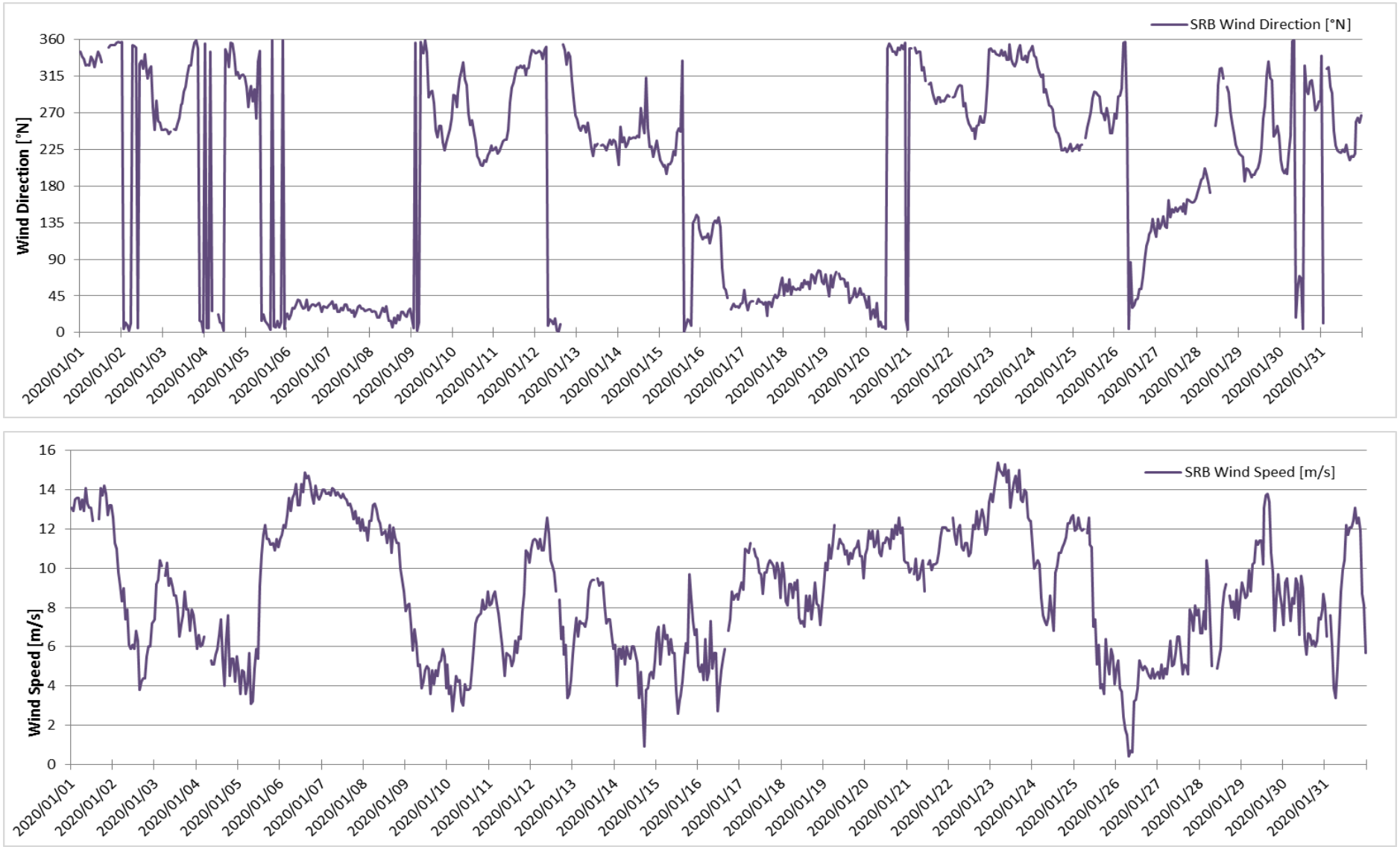

Figure 43: Example of meteorological data (air temperature, air pressure, wind direction and wind speed) at one offshore location

2. Participation of the Romanian specialists in international projects or programs

- ATMO-ACCESS (H2020, GA 101008004, 2021-2025) - Sustainable Access to Atmospheric Research Facilities (https://www.atmo-access.eu/).
- RI URBANS (H2020, GA 101036245, 2021-2025) - Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (https://riurbans.eu/).
- ACTRIS-IMP (H2020, GA 871115, 2020-2023) - EU project on formally implementing ACTRIS as European Research Infrastructure.
- CAMS21b (2019-2021) – Is a pilot project aiming to provide to CAMS (Copernicus Atmospheric Monitoring Service) ACTRIS data related to aerosol vertical profiles within the Framework Agreement ECMWF/COPERNICUS/2019/CAMS21b/CNR
- EMSO-ERIC, The European Multidisciplinary Seafloor and water column Observatory (EMSO) aims to explore the oceans, to gain a better understanding of phenomena happening within and below them, and to explain the critical role that these phenomena play in the broader Earth systems.
- Study for the development of the 2019-2030 National Strategy on the prevention and combating of desertification and land degradation, 2021-2022
- SUASA: Consulting and expertise services for the development of emergency management studies using airborne sensors, financed by Ministry of Environment, Waters and Forests, 2021.
- WeaMyL: Enhancing the performance and reliability of national weather warning systems by use of deep learning techniques applied on radar, satellite and ground meteorological observations, Norway Grants, 2020-2023 (https://weamyl.met.no/)
- WECTOU: Weather and Climate for Tourism, ECMFW, 2020-2021 (http://wectou.meteoromania.ro/)
- EXHAUSTION: Exposure to heat and air pollution in EUrope – cardiopulmonary impacts and benefits of mitigation and adaptation, 2019-2023 (https://cicero.oslo.no/en/projects/exhaustion)
- SusCrop: Developing resilience and tolerance of crop resource use efficiency to climate change and air pollution, 2019-2022 (https://www.suscrop.eu/about-suscrop)
- FPCUP: Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake, 2018-2023, EU project (https://www.copernicus-user-uptake.eu/).

- GRASP: GNSS-R Retrievals of Soil and Snowpack Parameters for Land Surface Modelling Applications, financed by ESA, 2018-2022.
- NWCSAF CDOP-3: The 3rd Operational and Continuous Development Phase of EUMETSAT's Center for Nowcasting and Very Short-Range Weather Forecasting Satellite ApplicationsNational projects, financed by EUMETSAT, 2018-2022.
- DIVA (ESA project no. 4000121773/17/I-EF, 2017-2023) - Demonstration of an Integrated approach for the Validation and exploitation of Atmospheric missions (http://diva.inoe.ro/).
- INDECIS: Integrated approach for the development across Europe of user oriented climate indicators for GFCS high-priority sectors: agriculture, disaster risk reduction, energy, health, water and tourism, EU project, 2017-2021 (http://www.indecis.eu/)
- CAMARO-D project: Cooperating towards Advanced Management Routines for land use impacts on the water regime in the Danube River Basin, 2017-2019 (http://www.interreg-danube.eu/approved-projects/camaro-d)
- DRIDANUBE Project: Drought Risk in the Danube Region (Danube Drought Risk), 2017-2019 (http://www.interreg-danube.eu/approved-projects/dridanube)
- SAMIRA Project: SAtellite based Monitoring Initiative for Regional Air quality, ESA project, 2016 - 2019 (https://samira.nilu.no/)
- IRIDA Project: Innovative methods based on data and satellite techniques used to implement a decision support system on the management of water resources in agriculture, 2016-2019 (http://irida.grupoinnovati.com/)
- COSMO Projects:
  - CARMENs: Cosmo Application of Rfdbk/MEC on ENS (2022-2024)
  - C2I4LC: Establishing COSMO to ICON migration for Licensees' Countries (2022-2023)
  - CITTA: City Induced Temperature change Through A’dvanced modelling (2021-2024)
  - C2I: COSMO transition to ICON-LAM (2018 – 2022)
  - CARMA: Common Area with Rfdbk/MEC Application (2018 – 2020)
  - CDIC: Comparison of the dynamical cores of ICON and COSMO (2015 – 2018)
  - SPRT: Support Activities (2012 – present)
- The international ALADIN project (Aire Limitée Adaptation dynamique Développement InterNational; http://www.cnrm.meteo.fr/aladin/)
- The international RC-LACE project (Regional Cooperation for Limited Area modelling in Central Europe; http://www.rclace.eu/)

- The international ACCORD project (A Consortium for COnvection-scale modelling Research and Development; http://www.umr-cnrm.fr/accord/)

3. Organization of national and international scientific conferences

- Annual National Scientific Conference, Bucharest, Romania, 23-25.11.2022.
- Joint LACE Data Assimilation Working Days and ACCORD Data Assimilation basic kit Working Days, Bucharest, Romania, 19-23.09.2022
- Annual National Scientific Conference, Bucharest, Romania, 10-12.11.2021.
- 23rd COSMO General Meeting, Bucharest, Romania, 14-17.09.2021 (online)
- Virtual training course: Vegetation indexes, in situ phenology observations and remote sensing products for monitoring the cereal crops, forest and pastures Malawi and Tanzania, 06-09.09.2021.
- Annual National Scientific Conference, Bucharest, Romania, 25-27.11.2020.
- Virtual Training Course on the Use of Satellite Products on Drought Monitoring and Applications in Agrometeorology, 23.10-10.12.2020.
- Annual National Scientific Conference, Bucharest, Romania, 19-21.11.2019
- DriDanube Project: National Drought Seminar, Bucharest, Romania, 02.04.2019.
- Camaro-D Project: 4th Meeting, Bucharest, Romania, 28-30.01.2019.

4. Participation of the Romanian specialists in the international symposiums and conferences

- EUMETSAT LI MAG (Lightning Imager Mission Advisory Group) Meeting #14, 06-07.12.2022
- ECMWF–ESA Workshop on Machine Learning for Earth Observation and Prediction, ECMWF workshop, hybrid event 14-17.11.2022
- 75th J-STG-AFG (Scientific & Technical Group - Administrative and Finance Group) Meeting, 13.10.2022
- Data Assimilation Working Days, 19 – 23.09.2022, Bucharest, Romania
- EUMETSAT Meteorological Satellite Conference 2022, Brussels, Belgium, 19-23.09.2022
- International Aerosol Conference, Greece, Athens, 04-09.09.2022
- 30th International Laser Radar Conference - ILRC 30, USA, 26.06-01.07.2022
- 2022 DTC METplus Users' Workshop, NCAR, on-line event , 27-29.06.2022

- Kick-off meeting for the Network of Drought Observatories in the EU, Ispra, Italy, 16-17.06.2022
- Shaping the future EUMETSAT support to Climate Services, Darmstadt, Germany, 08-10.06.2022
- ACTRIS Science Conference, Finland, 11-13.05.2022
- 80th EUMETSAT STG (Scientific & Technical Group) Meeting, 20.04.2022
- EUMETSAT LI MAG (Lightning Imager Mission Advisory Group) Meeting #13, 05-6.04.2022
- MAELSTROM dissemination workshop (28 March) and Machine Learning Workshop, European Centre for Medium- Weather Forecasts, on-line event, 29.03 – 1.04.2022
- First WMO/WWRP Weather and Society Conference, Societal and Economic Research Applications (SERA) si WMO World Weather Research Program (WWRP), on-line event 28.02 – 11.03.2022
- Young Researchers Workshop "Integrated environmental research and sustainable development in the Anthropocene", Bucharest, Romania, 10.12.2021.
- Copernicus Satellite Data in Chile and Latin America, Monitoring Meteorology with Copernicus, 03.12.2021
- European Lidar Conference - ELC 2021, Granada, Spain, 16-18.11.2021
- ESA-ECMWF Workshop 2021, ESA-ESRIN - Hybrid Event, 15-18.11.2021
- European Weather Cloud User Workshop, EUMETSAT, 10-11.11.2021
- EUMETSAT LI MAG (Lightning Imager Mission Advisory Group) Meeting #12, 12-13.10.2021
- Data Assimilation Working Days, 22 – 24.09.2021, remote, Ljubljana, Slovenia
- EUMETSAT Meteorological Satellite Conference 2021, Bucharest, Romania, 20-24.09.2021
- 50th EUMETSAT STG-OWG (STG Operations Working Group) - Meeting, 09-10.09.2021
- 34th International Geographical Congress, Istanbul, Turkey, 16-20.08.2021
- Annual Scientific Conference, Institute of Geography, Bucharest, Romania, 25.06.2021
- MEDIA WORKSHOP - International Communication on Climate Change, on-line event, 17-18.06.2021
- MedRIN and SCERIN Virtual Capacity Building Workshop on Earth System Observations, 15.06.2021

- Workshop on machine learning for numerical weather predictions and climate services for Member and Cooperating States, European Centre for Medium-Range Weather Forecasts, on-line event, 14 -15.06.2021
- Online Computing Training Week - European Centre for Medium-Range Weather Forecasts, on-line event, 17 -21.05.2021
- EGU General Assembly, Wien, Austria, 19-30.04.2021
- Machine Learning for Numerical Weather Predictions and Climate Services Workshop for Member and Co-operating States - European Centre for Medium-Range Weather Forecasts, on-line event, 14 – 16.04.2021
- Multi-Scale Modelling for Urban Environment Studies, American Metetorological Society Webinars, 22.02.2021
- Young Researchers Workshop "Integrated environmental research and sustainable development in the Anthropocene", Bucharest, Romania, 04.12.2020
- 6th Workshop on Geoinformatics in the framework of SYNASC 2020: 22nd International Symposium on Symbolic and Numeric Algorithms for Scientific Computing, Timișoara, Romania, 01-04.09.2020
- Monitoring Soil Moisture using Earth Observation Workshop, JNCC, 14-15.07.2020
- SusCap Project “Virtual” Meeting, Madrid, Spain, 16-23.06.2020
- SusCap Project Meeting, Oslo, Norway, 09-10.01.2020
- "Dimitrie Cantemir" International Geographical Seminar, XXXIX Edition, Iasi, Romania, 18-20.10.2019
- IGU LUCC Thematic Conference, Koper, Slovenia, 24-26.09.2019
- Data Assimilation Working Days, Viena, Austria, on-line, 19 – 21.09.2020
- Transnational learning event, Sibiu, Romania, 11-13.09. 2019
- “Space for a Safe Society and Sustainable Growth” Copernicus International Conference, Bucharest, Romania, 04-05.06.2019
- „Space Solutions for Sustainable Agriculture and Precision Farming” International conference, Cluj Napoca, Romania, 06-10.05.2019
- Numerical Model Training Course, Langen, Germany, 8 – 12.04.2019 (as lecturers for the additional course “How to install ICON - including necessary libraries”)
- EGU General Assembly, Wien, Austria, 07-12.04.2019

5. Publications

5.1. Peer-reviewed ISI publications

2022

Angearu, C-V, Ontel . I., Irimescu, A., Burcea, S., Dodd, E., (2022) Remote sensing methods for detecting and mapping hailstorm damage: a case study from the 20 July 2020 hailstorm, Baragan Plain, Romania. *Nat. Hazards,* 114, 2013–2040, 10.1007/s11069-022-05457-x.

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Busuioc, A., Dumitrescu, A., Iriza-Burca, A., Chitu, Z., Dumitrache, R., Dima, A. (2022). Projection of future changes in summer thermal stress index in Romania using statistical downscaling and associated uncertainties. *Clim. Res.,* 87:39-66, 10.3354/cr01689

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Dima, M., Lohmann, G., Ionită, M., Knorr, G. & Scholz, P. (2022). AMOC modes linked with distinct North Atlantic deep water formation sites. *Clim. Dyn.*, 59, 837–849, 10.1007/s00382-022-06156-w.

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Micu, D.M., Amihăesei, V.A., Milian, N., Cheval S. (2021) Recent changes in temperature and precipitation indices in the Southern Carpathians, Romania (1961-2018), *Theor. Appl. Climatol.*, 144, 691–710, 10.1007/s00704-021-03560-w

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5.2. Other journals articles and Proceedings papers

2022

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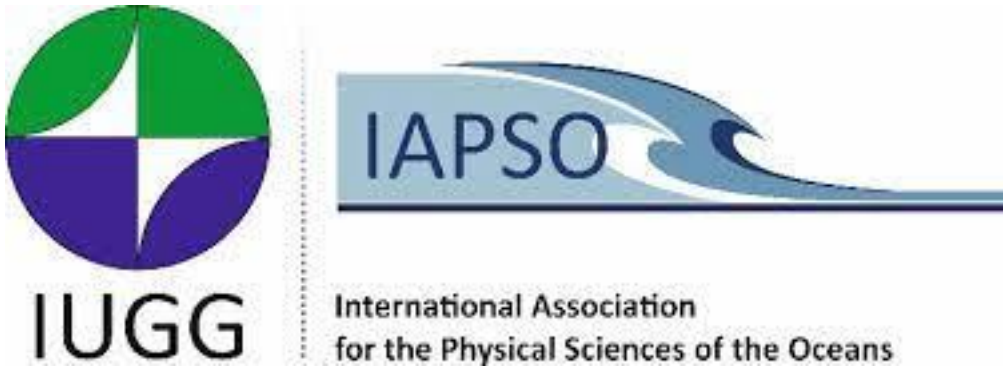

IAPSO ACTIVITIES IN ROMANIA

2019-2022

THE INTERNATIONAL ASSOCIATION FOR THE PHYSICAL SCIENCES OF THE OCEANS

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Contents

PART I: ORGANIZATION

Organization for Romania, a Section of the Romanian National International Union of Geodesy and Geophysics (IUGG) Committee, was constituted at the National Institute for Research and Development of Marine Geology and Geo-ecology (GeoEcoMar) in cooperation with the Maritime Hydrographic Directorate " Commander Alexandru Cătuneanu" (DHM) and The National Institute for Marine Research and Development "Grigore Antipa" (NIMRD)

Romanian marine sciences researches, relative to IAPSO topics, have been carried out between 2019 - 2022 period by several research institutes located both in Bucharest and Constanta.

Most of these studies are focused on the western Black Sea Basin, its coastal zone and on its relationship with the Danube River. The main research have been carried out in the framework of the National Research Programs like Core program (Program Nucleu), PNIII and PNIV founded by the Romanian Ministry of Research, Innovation and Digitization and in the framework of the H2020 European Programs.

International or bilateral programs and projects represented also a very important support and framework of marine sciences development in Romania. These programs are mainly in collaboration with the European Commission. Bilateral co-operation projects between Romanian and French, German, Italian, US, Ukrainian, Bulgarian, Greek, Norwegian and Turkish teams of scientists constituted also a good opportunity to develop the marine sciences in the Black Sea area.

The technical facilities and logistics available for the marine research has grown continuously as a consequence of the participation of Romanian scientists at national and international research projects.

The National Institute for Marine Research and Development "Grigore Antipa" (NIMRD) is operating under the coordination of the Ministry of Education and Research and carries out basic, applied and technological research for the knowledge, protection and management of the coastal zone and marine environment, oceanography, marine and coastal engineering, management of the marine living resources in the Black Sea and World Ocean, developing the Geographic Information System and the remote sensing techniques for marine environment; implementation of the international conventions for the Black Sea, research and specific studies. It is the support for solving the national and international problems regarding the Romanian marine sector and the Black Sea Exclusive Economic Zone, according to Romania's tasks assumed under international conventions. Also, NIMRD insures the national, regional, and European marine strategies/plans implementation. NIMRD has:

- Scientific responsibility for the national program of the physical, chemical and biological national monitoring for marine waters and for coastal erosion surveillance
- National scientific responsibility for the implementation of Marine Strategy Framework Directive (MSFD)
- National scientific responsibility for the collection and management of fisheries data (Data Collection Framework (DCF).

Being the technical operator of the marine monitoring network (physical, chemical, and biological) and for coastal erosion survey, NIMRD hold a comprehensive volume of marine data and information, which are exchanged in the framework of several international projects.

Romanian National Oceanographic and Environmental Data Centre (RoNODC) was established in 2007 and operates within the framework of NIMRD. The Centre is officially recognized by the IOC/IODE and IOC/GOOS) and included in the list of world oceanographic data centers.

In the frame of the NIMRD - GFCM collaboration, in 2017 the Shellfish Aquaculture Demonstrative Center in Constanta (S-ADC) was established at NIMRD's headquarters.

NIMRD scope of activity comprises mainly research-development and basic, applied and technological development research in oceanography and environmental protection. Within the scientific and technological research in marine ecology and environmental protection, oceanography, marine and coastal engineering, as well as marine living resources management in the Black Sea and other ocean areas, complying with the national and international requirements in the Exclusive Economic Zone of the Black Sea.

NIMRD conducts (or participates) in:

- Environmental Impact Assessments for on/offshore oil and gas industry
- Studies for elaboration of national Program of Measures for achieving Good Environmental Status (GES) of the Black Sea in accordance with the MSFD requirements
- Sediments, sea water pollutants, microbiological analyses bulletins for economic sector

The National Institute for Marine Geology and Geoecology – GeoEcoMar is a research-development institute established in 1993, under the coordination of the Romanian Ministry of Education and Research. GeoEcoMar represents the focal point of national excellence in research and consultancy on marine, coastal, river and lacustrine geology, geophysics and geoecology, as well as a reference centre for Marine and Earth Sciences. Due to its technical capabilities and scientific performance achieved in a short period of time, the centre has become since 1996 an "Institute of National Interest", its main research goal being the complex study of

the Danube River-Danube Delta-Black Sea macro-geosystem. The main scientific activities and expert services of GeoEcoMar are: geology, sedimentology, stratigraphy, paleontology, geochemistry, mineralogy, grain size analysis; coastal researches and integrated management, geophysics (seismo-acoustics, 2D marine seismics, magnetometry, gravimetry, electrometry), environmental quality investigations (hydro-chemistry, gas chromatography, eco-toxicology, greenhouse gas emissions), real time monitoring and study of marine geo-hazards, geo-archaeology and geological mapping of the Romanian Black Sea continental shelf.

In recent years, GeoEcoMar has won numerous competitions launched by the Research Ministry (Excellence Research – CEEX, Core Program – PN), NCSRHE and the Romanian Academy (grants), as well as tenders for projects launched by government research authorities, including for projects with international co-financing. GeoEcoMar has a rich international activity through the European Commission's Funding Programs, collaborating with European institutions and universities in France, Italy and Portugal. GeoEcoMar also participates in joint scientific research projects with partners from Switzerland, Ukraine, China and Canada.

The structure of GeoEcoMar corresponds to its main scientific aims. GeoEcoMar has 19 scientific departments, a technical and navigational department and an operational-financial-administrative one. The activity includes:

- environmental and geo-ecological studies on the Danube River - Danube Delta - Black Sea geo-system;
- geological – geophysical investigation of the Black Sea basin: deep and superficial structure, sedimentary processes;
- evaluation of the quality of marine, lacustrine and fluvial environments;
- living and non-living resources in the Black Sea
- study of natural hazards specific to marine, fluvial and lacustrine environments (landslides, gas releases, tsunami waves, erosion, floods, extreme seasonality, etc.), their forecasting and mitigation of their effects using monitoring systems;
- studies on CO2 storage in geological structures;
- paleo-ecological and paleo-environmental studies; past and present environmental and geological impact of the Sea Level Changes;
- coastal integrated management: land-sea and river – sea interaction zones.

GeoEcoMar has provided and continues to provide specialized and consulting services to Romanian and foreign companies, including OMV-PETROM, EXXON Mobil, Sterling, Black Sea Oil and Gas, CNE, MAREXIN Bv, DHV, but also to funding agencies such as JICA (Japan) and the United Nations Development Program – EMBLAS cruises on the Black Sea.

Maritime Hydrographic Directorate " Commander Alexandru Cătuneanu" (DHM) comes with strong expertise in the hydrographic and oceanographic research field at the international and regional level, as the leading expert in the western Black Sea on matters concerning the maritime boundaries as well as maritime geography and hydrography.

Since 1926, MHD has been designated the national authority with an advisory role for government institutions and operators in the maritime field, including specialized structures providing oceanographic support for the Romanian Navy.

One of the MHD main attributes is to implement the IHO procedures for the oceanographic research and hydrographic surveys, to provide the technical support for the oceanographic activities performed by other Romanian or foreign, public or private institutions and organizations, under the Romania Hydrography Law (Law 395 / 2004), and to cooperate with the military and civilian specialized institutions and structures (NATO, IHO, IMO, BASWG, MBSHC, etc.).

The main missions of MHD are: hydrographic and oceanographic surveying to support the Black Sea navigation; execute geodetic and other nature research of the objects from the coastal, sea, land and underwater submarine area studies on the morphology and morphological changes of the Black Sea bottom (https://www.dhmfn.ro/en/activitate_oceano.shtml); periodical hydrographic and oceanographic measurements (https://www.dhmfn.ro/en/activitate_hidro.shtml); the aids to navigation for the Romanian coastline through the Lighthouses and Safety of Navigation Department Activity (https://dhmfn.ro/en/activitate_semn.shtml); research and development activities (fundamental research, applied research, experimental development) in natural sciences and engineering (https://dhmfn.ro/en/cercetare-stiintifica.shtml; https://dhmfn.ro/en/quietseas.shtml); and also supports Government Action at Sea and provides expertise in work related to maritime limits and boundaries.

The Maritime Hydrographic Directorate elaborate, product and update the Romanian official charts and nautical publications. Produces the Electronic Navigation Chart (ENC) for its use onboard merchant and navy vessels within ECDIS (Electronic Chart Display and Information System) equipment. Being produced by the national authority in the field of maritime hydrographic activity, on behalf of the Ministry of Defense of Romania, in respect with the international standards proposed by the International Hydrographic Organization (IHO), the International Centre for Electronic Navigational Charts (IC-ENC), the International Association of Lighthouse Authorities (IALA) and considering the International Maritime Organization (IMO) resolutions, the Electronic Navigation Chart produced by the Maritime Hydrographic Directorate deserves its full title, recognized in the international literature of "ENC" (https://dhmfn.ro/en/harti_electronice.shtml). Therefore, the ENCs produced by DHM are the official Electronic Navigation Charts and fully meet the requirements for the charting of vessels following the obligations of the United Nations Convention for the Safety of Life at Sea (SOLAS) for use within ECDIS equipment. Moreover, the

Hydrographic Note requires information to the mariners when new discover or susceptible navigation hazards occurs following some changes in the aids to navigation or consider the corrections to analogue and electronic charts or nautical publications of the Maritime Hydrographic Directorate.

Furthermore, under Law No. 395/2004 and UNCLOS, the Marine Scientific Research Consent is issued by the Maritime Hydrographic Directorate grants permission to perform the research activities in the area of the national competency of Romania to the Black Sea (https://dhmfn.ro/en/avize_cercetare.shtml).

PART II: PROFESSIONAL ACTIVITIES

1. Research orientation

1.1. Sustainable development at the Black Sea Conference - SUST-BLACK 8th-11th of May 2019 Bucharest, Romania

The Romanian Presidency of the EU Council in the first Semester of 2019 is an excellent opportunity to build, strengthen, promote and disseminate its strategic goals, which are in accordance with the EU policies and objectives. Positioned both in the lower part of the Danube Region and the Western Black Sea, Romania has been strategically interested in strengthening cooperation in both regions.

The “Sustainable Development at the Black Sea” Conference under the auspices of the EU Council Presidency was an excellent opportunity for Romania as well as the whole EU to take major steps towards the development, approval and implementation of a Strategic Agenda in the Black Sea region. This will support and guide the way towards a knowledge-based society, where innovation and smart activities bring the sustainable social and economic growth in the entire Black Sea region.

The “Sustainable Development at the Black Sea” (SUST-BLACK) took place in Bucharest on 8-9 May 2019 at the House of the Romanian Parliament. The conference is a Romanian EU Council Presidency event, supported by the European Commission.

The conference has brought together all major categories of stakeholders with active and potential roles in building a sustainable and innovative society in the Black Sea region. Besides the research and academic communities, the Conference will bring together actors from all the Black Sea countries, supporting a smart connection between Europe and Asia, aiming to bring to life the “Silk Road” of the future. Decision and policy makers, academics, professionals, local communities, environmental NGOs, business persons will work together in five parallel sessions.

The scope was to identify policy options and priorities, as well as plan future actions. Outcomes of the parallel sessions will be used to strengthen and support the “Bucharest Declaration” aimed to build a Sustainable and Innovative Society around the Black Sea. The Conference was a landmark also on a process started by the EC in 2016, which has grouped DG R&I, DG MARE, the Eastern Partnership and a group of researchers in the Black Sea countries to develop a strategic plan to back the smart and sustainable growth in the region.

SUST-BLACK was the event where the ”Bucharest Declaration” of the scientific community will be issued, launching the Strategic Research and Innovation agenda for the Black Sea. Important contributions to this document have already been made by researchers and stakeholders from countries in the Black Sea basin and elsewhere in Europe, providing an excellent example of science diplomacy in this area. The Strategic Research and Innovation Agenda for the Black Sea will play a

major role in better knowing the marine basin itself, its opportunities for Blue Growth and for healthier and wealthier communities along its shores.

The main objectives of the event where:

- Presentation of the Strategic Research and Innovation Agenda for the Black Sea;
- Presentation of major research initiatives funded by the European Union and of the main international organizations that support scientific cooperation in the Black Sea;
- Presentation of experiences concerning basin-wide Strategic Research and Innovation Agendas in other European seas;
- Introduce to the Black Sea marine research community the opportunities given by the major European research and monitoring infrastructures and initiatives;
- Introduction of the main pillars of the Strategic Research and Innovation Agenda for the Black Sea;
- Establishment of concrete short-term steps for the successful implementation of the Strategic Research and Innovation Agenda for the Black Sea;
- Presentation of the Bucharest Declaration regarding the Strategic Research and Innovation Agenda for the Black Sea.

1.2. The Black Sea Strategic research and innovation Agenda: A COMMON VISION FOR THE BLACK SEA - Bucharest - 21 May 2019

This first version of the Strategic Research and Innovation Agenda (SRIA) will guide stakeholders from academia, funding agencies, industry, policy and society to address together the fundamental Black Sea challenges, to promote blue growth and economic prosperity of the Black Sea region, to build critical support systems and innovative research infrastructure and to improve education and capacity building. The Blue Economy has a great potential for the Black Sea countries and for Europe as a whole as it can be considered an instrument to promote cooperation, stability and empower the coastal communities in the region. While the Black Sea is a unique sea basin that is rich in biodiversity, heritage and natural resources, the basin is increasingly under pressure due mainly to the increasing impacts from human-induced factors, such as eutrophication and hypoxia, overfishing, and introduction of alien species, in addition to the effects of climate change. The combination of these stressors is considered to be the main cause for the degradation of the Black Sea marine ecosystem, which has undergone dramatic changes since the early 1970s.

Moreover, the deeper 90% of the Black Sea is the largest oxygen-free and hydrogen sulphide-rich volume of marine waters on Earth, just as the global ocean of the geological past was for a billion years between 1.8 and 0.8 billion years ago. Therefore, the Black Sea, with its marine basin and coastal socioeconomic systems combined, can be considered a natural laboratory of global significance, for fundamental science, sustainability policy and the Blue Economy.

1.3. EUXINUS EMSO - the first complex system of monitoring - real-time alarm at natural marine hazards in the Western Black Sea

Since 2014, the Romanian National Institute for Research and Development of Marine Geology and Geoecology - GeoEcoMar has the first complex system of monitoring - real-time alarm at natural marine hazards in the Western Black Sea called EUXINUS EMSO. The system is of particular importance for the security of Romania's coastal area as it is able to collect real-time data for several environmental key-parameters, data collected from three observatories moored offshore 160 km from the Black Sea coastal area and at a depth of water of about 90 meters. EUXINUS is one of the central elements of Romania's marine research infrastructure, being the only structure of this kind at national level that is part of a European consortium for marine research infrastructures (ERIC) in the marine field - EMSO ERIC. EUXINUS EMSO also promotes multidisciplinary collaborations on marine monitoring systems through cooperation with other European ESFRI initiatives.

The EMSO- EUXINUS Black Sea nodes of EMSO ERIC

The EUXINUS sub-system is composed of:

- *3 complex, fully automatic marine stations (buoys), placed close to the shelf break, with automatic equipment for measuring the characteristics and the dynamics of water and air masses*. *Tsunameters are attached to each station (Figure 1).*
- *A coastal station, placed in front of the coastline at Mangalia (~ 15 m water depth) for measuring the characteristics and the dynamics of water and air masses in the coastal zone.*

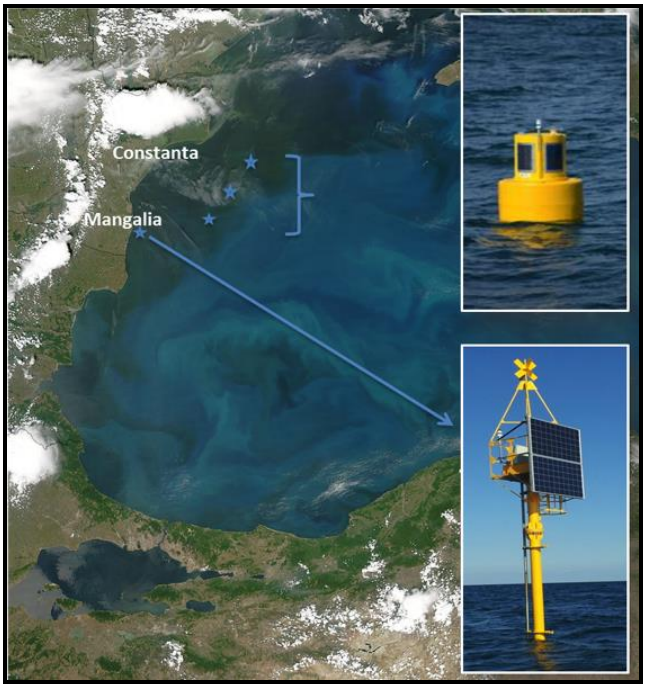

Figure 1: Locations of gauges on the western Black Sea Shelf

The off-shore stations are measuring water characteristics at two water depth levels:

- At 5 m water depth: water temperature; conductivity; Oxygen content; turbidity; chlorophyll; pressure; speed and direction of currents
- At 70 m water depth: temperature; conductivity; chlorophyll; pressure; speed and direction of currents

The measured meteorological characteristics are: air temperature; air pressure, wind direction and speed.
The Mangalia Coastal station is measuring:

- meteorological characteristics: air temperature; air pressure, humidity, wind direction and speed;
- At 5 m water depth: water temperature; conductivity; Oxygen content; turbidity; chlorophyll; pressure; speed and direction of currents
- at 7m water depth and ADCP processing data collected during 30m minutes related to wave characteristics for deducing directional wave spectrum and calculating Hmo (Significant amplitude); Hmax (Maximum Amplitude); Tm (Mean Period); Tp (Peak Period); Dm (Mean waves direction) and Dp (Peak waves direction).

The GeoPontica sub-system (Figure 2): the first on-line geodynamic surveillance network in the entire Black Sea region. The GeoPontica includes 18 on-line geodynamic stations located along the Romanian-Bulgarian coast. Based on EU Terrestrial Reference System and Vertical Reference Network, GeoPontica provides information on:

- Vertical movements of the Earth crust as isostasy, epeirogenetic up-lift, subsidence, sediment compaction;
- Horizontal movements of the Earth crust due to global tectonics (motion of the lithosphere plates) or relative movements of tectonic blocks;
- Changes of the mean sea level position.

Figure 2: Locations of the Geodynamic stations along the shore line

The Black Sea Seismicity sub-system

EMSO-EUXINUS – a Marine Hazards Monitoring and Early Warning System represents the first marine high-tech system installed in the Western Black Sea aiming at protecting coastal zone population, environment and socio-economic objectives.

The Black Sea Seismicity System (Figure 3) is composed of:

- 5 Ocean Bottom Seismometers;
- 1 Marine 2D Seismic Acquisition System installed on-board the R/V “Mare Nigrum”

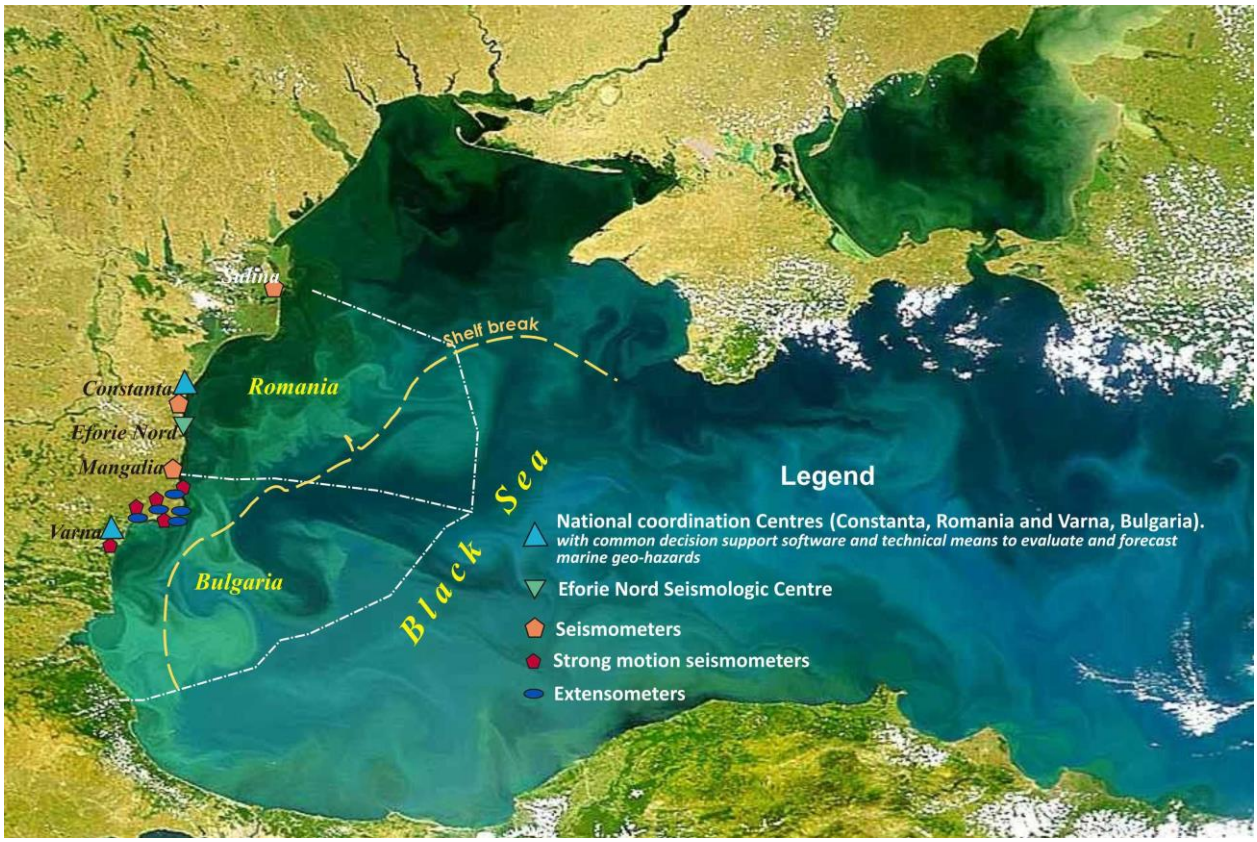

Figure 3: Black Sea Seismicity sub-system

The System allows an immediate detection and evaluation of the magnitude and possible effects of natural and man-made crisis – hazards and an early notification of specialised emergency response authorities. A special Decision Support Tool of the System assesses and predicts the occurrence of hazards and their magnitude.

As the Western Black Sea coast is subject to a high risk of marine hazards occurrence the Black Sea Security System represents an extremely useful tool for a sustainable management and protection of the coastal zone of Bulgaria and Romania.

The system is providing for the first time a continuous year-long flux of data about the quality and dynamics of water and sediments within the offshore zone of the Western Black Sea as well as about the meteorological characteristics of this zone. The data refers not only to the superficial level of the sea but also to the near bottom layer of water.

These data contribute to the permanent environmental monitoring of the western Black Sea that is under direct impact of largest European rivers as Danube, Dnieper and Dniester.

The Black Sea Security System enters from the beginning the major EU Earth and Ocean Observing Systems and ESFRI projects:

- GOOS – Global Ocean Observing System, specifically Black Sea GOOS, and EOS – Earth Observing System
- EMSO ERIC – European multidisciplinary seafloor observation infrastructure - a European network of fixed point, deep sea observatories aiming at a real-

time, long-term monitoring of environmental processes related to the state and interaction between the geosphere, biosphere, and hydrosphere

- EPOS ERIC - European Plate Observing System – Research Infrastructure and e-Science for Data and Observatories on Earthquakes, Volcanoes, Surface Dynamics and Tectonics
- EURO-ARGO – Research infrastructure for ocean science and observations
- LIFE WATCH – Science and technology infrastructure for biodiversity data and observatories

The system is operational from June 2013.

1.4. DANUBIUS RI - The Danube International Centre for Advanced Studies in the River – Delta – Sea systems: a Pan-European Research Infrastructure

The Mission of DANUBIUS-RI is to provide a world-leading research infrastructure (RI) that will enable excellent interdisciplinary research in river – sea (RS) systems that will have high social and economic impact. It will be a pan-European distributed RI supporting excellence in research and innovation and knowledge exchange. RS systems in Europe are among the most impacted globally, after centuries of industrialisation, urbanisation and agricultural intensification. However, progress in understanding and sustainable management is limited by fragmentation of largely discipline-specific research. Current RIs are inadequate for urgently needed interdisciplinary research and innovation.

DANUBIUS-RI will draw on RS systems and existing research excellence across Europe, enhancing the impact of European research while maximizing investment efficiency. It will provide access to a range of European RS systems, facilities and expertise, a platform for interdisciplinary research, access to harmonised data, and a 'one-stop shop' for knowledge exchange in their management. Of particular importance, it will make a major contribution to bridging the gap in research on transitional zones between coastal marine and freshwater areas, such as deltas and estuaries. DANUBIUS-RI will be a platform for innovation, inspiration, education and training.

The physical structure of DANUBIUS-RI, under a single governance structure, will comprise a *Hub* in the Danube Delta and a *Data Centre* also in Romania, together with *Nodes* and designated *Supersites* across Europe and a *Technology Transfer Office* in Ireland. This structure will provide an integrated suite of facilities, services and expertise for research scientists and other stakeholders in Europe and globally.

The *Hub* will provide leadership and governance, the framework for coordination and standardisation of activities, communication with other RIs and major stakeholders, and key scientific, educational and analytical capabilities.

Discussions are taking place to locate the *Data Centre* at the Magurele High Tech Cluster where it would take advantage of existing data and IT expertise. It will serve the whole structure of DANUBIUS-RI.

Supersites will be designated field locations providing the focus for observation, research and modelling at locations of high scientific importance and opportunity, covering the RS systems – from source (upper parts of rivers – mountain lakes) to the transition with coastal seas. Most *Supersites* will be in transition zones such as between freshwater and marine (deltas, estuaries). Each will have a Hosting Laboratory, which will be responsible for managing a coordinated observation programme, providing field facilities, facilitating field access, and capturing data. Wherever possible, there will be a symbiotic relationship between DANUBIUS-RI and other pan-European RIs in the use of *Supersites*. The *Hub* will be the Hosting Laboratory for a Danube Delta *Supersite*.

Nodes will provide facilities and services in areas of infrastructure that are needed to fulfil the DANUBIUS-RI Mission. Initially, *Nodes* will cover Observation, Analysis, Modelling, and Social and Economic Sciences, though other Nodes may be added as the project progresses, in the light of developments and need. Each *Node* will have a Lead Laboratory, selected on the basis of excellence, breadth of capability and expertise, and contribution to DANUBIUS-RI. The Lead Laboratory will evaluate and accredit other laboratories (based in ERIC member countries), that reach a threshold of capability and expertise and undertake to follow DANUBIUS-RI protocols and quality standards, as service providers. *Nodes* will provide facilities and services, data storage and provision, experimental and in situ measurements facilities, state-of-the-art analytical capabilities and implementation of standardised procedures. *Nodes* will provide interfaces with regional and local stakeholders, enhancing knowledge exchange and innovation. Through *Node* accreditation DANUBIUS-RI will grow both the capacity and capability of European infrastructure.

DANUBIUS-RI will have a legal basis as an ERIC. The General Assembly, the decision-making body, will be composed of representatives of Member countries of DANUBIUS-RI. Countries may be Members through making a long-term commitment for Danubius-RI implementation, operation and decommissioning, involving payment of an annual membership fee. Observer status, with a lower annual fee (or free of charge) but no voting rights, will also be available to countries and to international organisations. Only an organisation in a Member Country will be eligible to be the Hosting Laboratory of a *Supersite*, or the Lead Laboratory or accredited service provider of a *Node*, and organisations in these roles will be expected to contribute resources, in kind or through funding, in addition to the country's annual membership fee.

Access to the facilities, services and expertise of DANUBIUS-RI will be open to any research scientist or stakeholder subject to peer review, feasibility and any intellectual property considerations. Access may involve a fee, depending on the service or facility provided or further use of knowledge (e.g. for education purposes it

could be free of charge), which will be lower for scientists in Member country organisations.

Hosting and Lead Laboratories will be selected on a set of criteria including science and infrastructure excellence, and financial and/or in-kind contribution to the cost of constructing and/or operating the *Supersite* or *Node.*

2. Participation of the Romanian specialists in international projects or programs

- MARBEFES: MARine Biodiversity and Ecosystem Functioning leading to Ecosystem Services, HORIZON-CL6-2021-BIODIV-01-03, GA 101060937, 2022-2025.
- MSP4BIO: Improved Science-Based Maritime Spatial Planning to Safeguard and Restore Biodiversity in a coherent European MPA network, HORIZON EU, 2022-2025
- ILIAD Integrated DigitaL Framework for Comprehensive marItime dAta anD information services,H2020, 2022-2025
- HEU project “Euro GO-SHIP”, 2022 – 2025
- EROVMUS: Enhanced Remote Operated Vehicle interface for MUnition Studies, 2022-2024
- DOORS: Developing Optimal and Open Research Support for the Black Sea, H2020: Project Number: 101000518, 2021-2025
- BRIDGE-BS: Advancing Black Sea Research and Innovation to Co-Develop Blue Growth within Resilient Ecosystems, 2021-2025, H2020
- EMODnet: European Marine Observation and Data Network, Lot 3 Seabed Habitats, EASME/2020/OP/0006, 2021-2023.
- ESA / I-DT for Black Sea and Danube Regional Initiative: Black Sea Environmental Protection:Services for Black Sea Protection, 2020-2022
- ESA AO/1-9640/19/I-DT for Black Sea and Danube Regional Initiative: Sea Coastal Zone Management: Services for Black Sea Coastal Zone Management, 2020-2022
- MARSPLAN-BSII: Cross border Maritime Spatial Planning for Black Sea - Bulgaria and Romania, 2019-2021, EMF/EASME project
- Horizon 2020: Black Sea CONNECT: Coordination of Marine and Maritime Research and Innovation in the Black Sea. 2019-2022
- DG MARE/EASME: European Marine Observation and Data Network (EMODNET) – Chemistry 4, 2019-2022
- DG MARE/EASME: High resolution seabed mapping (EMODNET Bathymetry), 2019-2022
- EASME/EMFF/2018/1.3.1.8/Lot2/SI2.810241- EMODnet – Seabed Habitats, 2019 – 2021.

- ♦ CeNoBS: Support MSFD implementation in the Black Sea through establishing a regional monitoring system of cetaceans (D1) and noise monitoring (D11) for achieving GES,DG ENV, 2019-2021
- ♦ EO4SIBS: An Earth Observation Data Exploitation Platform for Science and Innovation in the Black Sea, financed by ESA, 2019-2021
- ♦ COASTAL: COllaborative And Sea inTegrAtion pLatform,H2020, 2018-2021
- ♦ ANEMONE: Assesing the vulnerability of the Black Sea marine ecosystem to human pressures, CBC Black Sea Basin Programme 2014-2020, 2018-2020
- ♦ DANUBIUS-PP: Preparatory Phase For The Paneuropean Research Infrastructure DANUBIUS–RI, Horizon 2020, 2016-2020.

3. Publications

3.1. Peer-reviewed ISI publications

2022

Begun T., Teacă A., Muresan M., Quijon P.A., Menabit S., Surugiu V. (2022). Habitat and macrozoobenthic diversity in marine protected areas of the Southern Romanian Black Sea Coast. *Front. Mar. Sci.* 9:845507. https://doi.org/10.3389/fmars.2022.845507, WOS:000773910800001.

Bosneagu, R.; Scurtu, I. C.; Popa, A.; Matulea, I; Popov, P.; Mihailov, M. E.; Baracu, T.; Lupu, S.; Serban, S.; Lupu, C.; Atodiresei, D. (2022). Assessment for a buoy model 14 the Romanian Black Sea waters, *J. Enviro. Prot. Ecol*., 23 (5), 1884-1893.

Bosneagu, R., Scurtu, I. C., Popa, A., Popov, P., Mihailov, M. E., & Atodiresei, D. (2022). Computational Fluid Dynamics analysis of a wave energy converter. *J. Enviro. Prot. Ecol*, 23(4), 1441-1448.

Bucşe A, Pârvulescu OC, Vasiliu D., Mureșan M. 2022. The Contents of Some Trace Elements (As, Br, Cu, Hg, Se, and Zn) in Mytilus galloprovincialis Mussels From Agigea Port, Romania. *Front. Mar. Sci.* 9:899555. https://doi.10.3389/fmars.2022.899555.

Chirosca, G., Mihailov, M. E., Tomescu-Chivu, M. I., & Chirosca, A. V. (2022). Enhanced machine learning model for meteo-oceanographic time-series prediction. *Rom. J. Phys.,* 67(9-10).

Constantinoiu, L. F., Rusu, E., Mihailov, M.E. (2022). UXO Assessment on the Romanian Black Sea Coast. *J. Mar. Sci.,* 4 (2), 7-17, ISSN 2661-3239, https://ojs.bilpublishing.com/index.php/jms/article/view/4497.

Ion, G., Briceag, A., Vasiliu, D., Lupascu, N., Melinte-Dobrinescu, M. (2022). A multiproxy reconstruction of the Late Pleistocene-Holocene paleoenvironment: New insights from the NW Black Sea. *Mar. Geol.*, 443, 106648.

Marsset, T., Ballas, G., Munteanu, I., Aiken, C., Ion, G., Pitet-Roudaux, M., Dupont, P., 2022. Tectonic-sedimentary architecture of surficial deposits along the continental slope offshore Romania (North of the Viteaz Canyon, Western Black Sea): Impact on sediment instabilities. Global and Planetary Change 208, Article

Number 103708 DOI 10.1016/j.gloplacha.2021.103708. Menabit S., Begun T., Teacă A., Mureșan M., Lavin P., Purcarea C., (2022). DNA Barcoding and Distribution of Gastropods and Malacostracans in the Lower Danube Region. *Diversity,* 14 (7), 533.

Muresan M., Motoc R., Menabit S., Teaca A., Begun T., (2022). A New Species of Free-Living Nematodes (Desmodorida, Desmodoridae) in the Romanian Black Sea Waters. *Diversity*, 14 (11), 933.

Teaca A., Begun T., Menabit S., Muresan M., (2022). The first record of the Marenzelleria neglecta and spread of the Laonome xeprovala in the Danube Delta – Black Sea ecosystem. *Diversity*, 14 (6), 423, 10.3390/d14060423.

D.C., Haliuc, A., Mănăilescu, C., Sava, G., (2022). A detailed chronology of the sedimentation in the Danube abyssal fan records the major episodes of the late-Holocene Black Sea evolution. *Quat. Geochronol.*, 70, 101279

Muresan M., Teaca A., Begun T., (2022). Occurrence of Podocorynoides minima (Trinci, 1903) (Hydrozoa: Rathkeidae): a new species of hydromedusa and historical records of Podocoryna carnea (M. Sars, 1846) (Hydrozoa: Hydractiniidae) in the Black Sea. *Biologia*, 10.1007/s11756-022-01051-5.

Mureşan, M., Teacă, A., Begun, T., (2022). Correction to First record of the hydrozoan Podocorynoides minima in the Romanian Black Sea waters. *Biologia*, 10.1007/s11756-022-01092-w

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Teaca A., Begun T., Muresan M., (2021). Annelid invaders in the Black Sea region: The distribution of Streblospio gynobranchiata and first occurrence of Laonome xeprovala. *Glob. Ecol. Conserv*., 32, 10.1016/j.gecco.2021.e01920.

Pojar, I., Kochleus, C., Dierkes, G., Ehlers, S. M., Reifferscheid, G., Stock, F. (2021). Quantitative and qualitative evaluation of plastic particles in surface waters of the Western Black Sea. *Environ. Pollut*., 268, 115724.

Pojar, I., Stănică, A., Stock, F., Kochleus, C., Schultz, M., Bradley, C. (2021). Sedimentary microplastic concentrations from the Romanian Danube River to the Black Sea. *Sci. Rep.,* 11(1), 1-9.

2020

Giorgetti, A., Lipizer, M., Molina Jack, M.E., Holdsworth, N., Jensen, H.M., Buga, L., Sarbu, G., Iona, A., Gatti, J., Larsen, M. and Fyrberg, L., (2020). Aggregated and Validated Datasets for the European Seas: The Contribution of EMODnet Chemistry, *Front. Mar. Sci.,* 7, p.583657

Mihailov, M.E., (2020). Sound speed characteristics and impulsive noise hotspots assessment in the North-Western Black Sea, *Rom. Rep. Phys*., 72, 703 (http://www.rrp.infim.ro/2020/AN72703.pdf).

Mihailov, M.-E., Coatu, V., Oros, A., Constantinoiu, F.-L., Duțu, L., Boicenco, L., & Lazăr, L. (2020). Romanian Index for Hydrodynamics Assessment in Transitional and Coastal Waters on the North-Western Black Sea Coast. Revista Cercetări Marine - Revue Recherches Marines - Marine Research Journal, 50(1), 6-25.

Moldovan, Z., Covaciu, F.D., Turcu, I., Ion, G. (2020). Determination of the Light Hydrocarbons in Sediment Pore water from the Black Sea by Gas Chromatography (GC). *Anal. Lett.,* 10.1080/00032719.2020.1761826

Vasiliu, D., Bucse, A., Lupascu, N., Ispas, B., Gheablau, C., Stanescu, I. (2020). Assessment of the metal pollution in surface sediments of coastal Tasaul Lake (Romania). *Environ. Monit. Assess.*, 192, 12. 10.1007/s10661-020-08698-0.

Teaca A., Muresan M., Menabit S., Bucse A., Begun T., (2020). Assessment of Romanian circalittoral soft bottom benthic habitats under Danube river influence. *Reg. Stud. Mar. Sci.*, 40, 1-15.

2019

Bosneagu, R., Scurtu, Ionut Cristian; Popov, Petrică; Mateescu, Razvan; Dumitrache, L; Mihailov, Maria Emanuela. (2019). Hydraulics numerical simulation using Computational Fluid Dynamics (CFD) method for the mouth of Sulina channel, *J. Environ. Prot. Ecol.,* 20 (4), 2059–2067

Briceag, A., Yanchilina, A., Ryan, W.B.F., Stoica, M., Melinte-Dobrinescu, M.C., (2019). Late Pleistocene to Holocene paleoenvironmental changes in the NW Black Sea. *J. Quat. Sci.,* 34 (2), 87-100

Mureșan M., Teaca, A., Popa A., Begun T., (2019). Free-living marine nematodes community structural changes within a post-dredging site at the Romanian shelf. *J. Environ. Prot. Ecol.,* 20, No 2, pp. 753-760.

Teaca, A., Mureșan M., Begun T., Popa A., Ion G., (2019). Marine benthic habitats within a physical disturbed site from the Romanian Coast of the Black Sea. *J. Environ. Protect. Ecol.*, 20 (2), 723-732.

Zăinescu, F., Vespremeanu-Stroe, A., Anthony, E., Tătui, F., Preoteasa, L. and Mateescu, R., (2019). Flood deposition and storm removal of sediments in front of a deltaic wave-influenced river mouth, *Mar. Geol*., 417, p.106015.

3.2. Other journals articles and Proceedings papers

2022

Vlasceanu, V., R. Bosneagu, I. C. Scurtu, D. Marin, R. Mateescu, 2022, Investigations on the marine current regime in the maritime port of Constanta and its adjacent areas, Scientific Bulletin of Naval Academy, XXV, pg. 128-135

Ilie, M., Sava, T., Vespremeanu-Stroe, A., Duliu, O., Cristea, G., Ion, G., Olteanu, Constantinoiu, L. F., Rusu, E., Mihailov, M. E., Discovering the WWII Secrets of the Black Sea - Sidescan Sonar for Underwater Object Detection, Hydro International, issue 4, 2022 (https://www.hydro-international.com/content/article/discovering-the-wwii-secrets-of-the-black-sea).

2021

Krutov, A., Golumbeanu, M., Abaza, V., Nicolaev, S., Boicenco, L., Vlas (Culcea), O., Marin, O., Oros, A., Coatu, V., Lazar, L. chapters in: Black Sea, State Of Environment Report, 2009-2014/5BSC, 2019. Publications of the Commission on

the Protection of the Black Sea Against Pollution (BSC) 2019, ISBN 978-605-84837-0-5, Istanbul, Turkey, p. 811.

Mihailov, M. E., Chirosca, A. V., & Chirosca, G., 2021. Sea level prediction in the north-western black sea using autoregressive integrated moving average and machine learning models, GEOLINKS International Conference 2021 Water Resources Section, Book 1, 3, 471-480, 2021. (https://www.geolinks.info/library-bookview/geolinks-international-conference-2021%2C-book-1).

Vlasceanu, E., Mateescu, R. and Rusu, E. 2021, Waves Penetration Inside the Port Acvatories Asociated with The Extreme Storm Regime On The Romanian Coast, 21st International Multidisciplinary Scientific GeoConference SGEM, 21, Book 3.1, 571-578

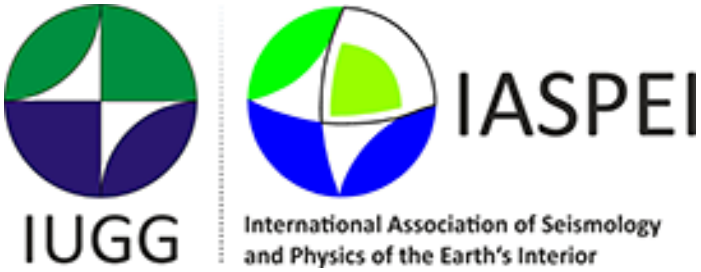
3.3. Books and book chapters

2021

Alexandrov L., Troeva V., Vasiliu D., Ghinea B., Stancheva M., Vintilă D., Tsvetkov M., Georgieva M., Gyorev A., Băilești eanu L., Huzui A., Toth G., Stanchev H., Manova M., Aivaz K., Stan I., Ioniț iu I., Novakova M., Motev S., Nikitov E., Kermekchiev B., Antonova D., Apostolova D., Tzenov P., Kolev M., Nasser J., Hitova V., Toteva D., Popova T., Boicenco L., Niț ă V., Spînu A., Niculescu D., Anton E., Nicolaev S., Abaza V., Lazăr L., Marin O., Filimon A., Vlăsceanu E., Maximov V., Bujini J., Caraivan Gl., Rădulescu V., Begun T., Mureș an M., Țuț uianu R., Bălan S., Kalinov K., Bogdanov B., Gerchev N., Dobrev I., Angelov S., Trayanova A., Hristova R., Kalinov T., Chervenkov Y., Georgiev Y., Kaloyanchev P., Truhchev D., 2021 - Defining and analyzing existing conditions in the maritime space, support for Maritime Spatial Planning: MARSPLAN-BS II Project / Cross Border Maritime Spatial Planning in the BlackSea–Bulgaria and Romania. Editura Celebris. ISBN 978-606-9711-21-7, 174 pp.

Alexandrov L., Stancheva M., Vasiliu D., Stanchev H., Manova M., Vintilă D., Troeva V., Novakova M., Niț ă V., Boicenco L., Spînu A., Abaza V., Lazăr L., Marin O., Filimon A., Mihailov E., Niculescu D., Vlăsceanu E., Țiganov G., Bujini J., Rădulescu V., Begun T., Mureș an M., Țuț uianu R., Bălan S., Georgieva M., Gyorev A., Țenea D., Ghinea B., Băilești eanu L., Huzui A., Milotinovici E., 2021 - Synthesis report on maritime uses, support for Maritime Spatial Planning: MARSPLAN-BS II Project/Cross Border Maritime Spatial Planning in the BlackSea–Bulgaria and Romania. Editura Celebris. ISBN 978-606-9711-22-4, 138 pp.

Ion G., Popa A., Teacă A., Simionescu M., Begun T. (2021). Sea floor habitat mapping - a physical approach. ISBN: 978-606-9658-21-5, 55 pp.



IASPEI ACTIVITIES IN ROMANIA
2019-2022

NATIONAL REPORT IN SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

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Content

PART I: ORGANIZATION

Organization for Romania, a Section of the Romanian National International Union of Geodesy and Geophysics (IUGG) Committee, was constituted at the National Institute for Earth Physics in cooperation with the Faculty of Physics, Department of Atmosphere Physics of the University of Bucharest, Institute of Geodynamics “Sabba S. Ştefănescu” of the Romanian Academy and Faculty of Geology and Geophysics, University of Bucharest.

National Institute for Earth Physics (INFP)

Main research directions related to IASPEI activities:

(1) seismology and seismotectonics
(2) seismic hazard and risk assessment
(3) earthquake prediction
(4) engineering seismology
(5) seismic tomography
(6) real-time seismic monitoring
(7) global monitoring as part of the CTBT (Comprehensive Nuclear Test Ban Treaty)

Research departments which are involved research activities related to IASPEI activities:

(1) Seismology and Lithospheric Structure Department
(2) Romanian Seismic Network Department
(3) National Data Center Department
(4) Engineering Seismology Department
(5) Applied Geophysics, Education and Prevention Department

Main research directions in the department (1):

- advanced seismicity (including historical seismicity) and macroseismic studies
- seismic source physics
- seismic wave propagation
- structure and dynamics of the Earth's interior
- seismic and tsunami hazard assessment
- earthquake forecasting

Main research directions in the department (2):

- Installation, maintenance and upgrading of equipment, transmission, collection and archiving of seismic data, continuous seismic monitoring, tsunami monitoring
- Early warning system
- Data exchange with international seismology centres

Main research directions in the department (3):

- Archives of seismic data
- Ensures Romania's technical participation in global seismological monitoring in compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT) through the seismological station Muntele Roșu (MLR) and the National Data Centre (ROM CND);

- Produces revised seismic bulletins, generates and updates the official catalogue of earthquakes recorded in Romania - ROMPLUS;
- Monitors infrasound sources by processing and analyzing data recorded by Romanian acoustic stations (BURARI 3 and IPLOR).

Main research directions in the department (4):

- Engineering seismology;
- Regional and local seismic hazard assessment (microzonation studies);
- Mechanics and nonlinear dynamics of degraded rocks (soil) during strong earthquakes and experimental studies on resonant columns;
- Local seismic site effects;
- Development and implementation of nonlinear seismology in engineering applications for hazard assessment and seismic risk reduction of densely populated areas;
- Development of seismic studies and site-specific investigations for nuclear power plants and critical infrastructures (dams, military constructions, bridges, hospitals, etc.);
- Seismic risk assessment for urban areas, industrial structures and transport networks.

Main research directions in the department (5):

- Exploration geophysics
- Environmental and Engineering Geophysics
- Underground monitoring and geological and geophysical data modelling
- Earthquake awareness for population

Research infrastructure:

- 160 real-time seismic stations (Romanian Seismic Network)
- 2 seismic arrays (BURAR with 12 elements and PLOR with 7 elements)
- 2 infrasound arrays (BURARI and PLORI)
- GPS/GNSS network
- administration of GLASS node
- administration of EIDA node
- Vrancea Multidisciplinary Observatory (radon monitoring system, meteorological stations, electromagnetic stations and atmospheric ionization monitoring systems)

Faculty of Physics, University of Bucharest

Main research directions related to IASPEI activities:

- paleomagnetism
- paleoclimate
- geodynamics
- coupling of surface processes with natural processes taking place in lithosphere and atmosphere
- interconnection between anthropic and natural processes

- natural and anthropic hazards

Departments involved in IASPEI activities: Department of Physics of the Atmosphere and Earth. Research infrastructure:

- Paleomagnetism Laboratory
- Laboratory of mineralogy and petrography
- Laboratory of geochemistry
- Laboratory of structural and ambient geology
- Platform for Interdisciplinary Studies in Geosciences

Institute of Geodynamics "Sabba S. Ştefănescu "of the Romanian Academy

The departments in the institute which are involved research activities related to IASPEI activities:

(1) Solid Earth Dynamics
(2) Electromagnetism and Dynamics of Lithosphere
(3) Natural Fields
(4) The Role of Fluids in the Dynamics of Lithosphere
(5) Endogene Processes, Natural Hazards and Risk

Main research directions in the department (1):

- Building up consistent national / international geophysical fields models
- Modelling lithosphere structure, especially within active geodynamic zones
- Modelling crust deformation, based on ground and space geodesy
- Modelling deep lithosphere dynamics, based on the space-time gravity evolution
- Studying the geodynamic setting of the Vrancea seismic zone
- Complex research on the intimate mechanisms of the intermediate-depth seismicity

Main research directions in the department (2):

- Elaboration and implementation of the electromagnetic (EM), geo-magnetic and geo-electric methodologies used for:
- Shallow and deep geodynamic structures' investigation (mapping, inversion, modeling and tomographic imaging);
- Monitoring of the specific phenomena/parameters related to the natural hazards (seismicity, landslides) and risk assessment:
- Research by continuous monitoring of some geophysical parameters obtained by EM methodology to improve the pre-seismic and landslides hazard evaluation;
- Studies to integrate multidisciplinary results in the earthquake seismic hazard forecasting;
- Development of software to analyze EM parameters with a seismic precursory character.

Main research directions in the department (3):

- Thermal modeling of tectonic processes that are involved in the lithosphere dynamics beneath Romania;
- Heat flow map of Romania;
- Investigating the lithosphere thermal budget along 2D transects across the Romanian territory;
- Investigating the geomagnetic field characteristics on the territory of Romania;
- Analyzing the distribution across Europe of the eleven-year period fluctuations of the magnetic field;

Main research directions in the department (4):

- Geochemistry, diagenesis and quality assessment of porous rocks reservoirs;
- Hydrochemical fingerprint of geodynamic activities;
- Seismic activity in the context of complex internal dynamics of fluid flow;
- Geoelectrical investigation for environmental problems.
- Research infrastructure:
- network of geodynamic observatories and observation points capable of monitoring tectonic stress in active seismic areas
- gravity laboratory
- ground-based measuring system

Faculty of Geology and Geophysics, University of Bucharest

Main research directions related to IASPEI activities:

- geology
- tectonics
- engineering geology
- geodynamics
- paleomagnetism
- sedimentology

Research infrastructure:

- instruments for near surface geophysical data and geotechnical information
- multi-scale laboratories
- paleomagnetism laboratory

National Conferences:

- Annual Scientific Session of the Faculty of Physics, University of Bucharest
- Annual Scientific Conference in Geophysics of the Faculty of Geology and Geophysics, University of Bucharest

Publications:

- Romanian Report in Physics
- Romanian Journal of Physics

PART II: PROFESSIONAL ACTIVITY

1. RESEARCH ORIENTATION

1.1. MONITORING OF NATURAL AND INDUCED SEISMICITY

The National Institute for Earth Physics (NIEP) manages two Installations and Special Objectives of National Interest: Romanian Seismic Network (RSN) and National Data Center (NDC). NIEP operates a real-time seismic network designed to monitor the seismic activity in Romania, dominated by the Vrancea intermediate-depth (60-200 km) earthquakes. The monitoring of seismic activity takes place within the National Seismic Network Laboratory.

The significant development in the last few years of the seismic network and of an advanced acquisition system is an essential factor to achieve the strategic objective of reducing earthquakes impact on society.

Starting with 2002 the modernization of Romanian Seismic Network was based on the installation of new seismic stations acquired in real time. This network consists of digital seismic stations equipped with acceleration sensors (EpiSensor) and velocity sensors (broadband – STS2, CMG3ESP, KS2000, CMG40-T or short period – MP, SH-1, S13, Mark Product, etc).

The real-time digital seismic network consists of 150 seismic stations with three components and 2 arrays: BURAR with 12 elements and PLOR with 7 elements. All data recorded by this network are transmitted in real time at NIEP for automatic data processing, analysis and dissemination. The seismic station's locations and equipment characteristics for the real-time Romanian Seismic Network are shown in Table 1.

Table 1. Real-time stations existing in Romania
BB-BroadBand, SP-Short Period, Acc-Accelerometer

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
ADCR	44.0882	27.9657	161	Adamclisi CT	Acc
ADJ	46.0952	27.182	100	Adjud VN	Acc
AMRR	44.6102	27.3351	86	Amara IL	BB, Acc
ARCB	44.4667	26.0758	125	Arc Triumf Sector 1	Acc
ARCR	47.0855	24.3537	356	Arcalia BN	BB, Acc
ARR	45.3657	24.6332	924	Vidraru AG	BB, Acc
ASE	44.4445	26.0904	850	ASE Sector 1	Acc
BAC	46.5669	26.9124	169	Bacau BC	Acc
BAIL	44.0201	23.345	100	Bailesti DJ	BB, Acc
BANR	45.3828	21.137	159	Banloc TM	BB, Acc

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
BAPR	44.4059	26.119	103	Parcul Copiilor Sector 4	SP, Acc
BBER	44.3085	26.1899	112	Berceni IF	Acc
BDTR	44.4142	26.0224	67	Gradinita Sector 6	Acc
BFER	44.4049	26.0771	86	Ferentari Sector 5	Acc
BIR	46.2334	27.6436	168	Birlad VS	BB, Acc
BISC	44.4328	26.2135	125	Catelu Sector 3	Acc
BISRR	45.5481	26.7099	866	Bisoca BZ	BB, Acc
BIZ	46.9387	26.1029	549	Bicaz NT	BB, Acc
BMR	47.6728	23.4969	227	Baia Mare MM	BB, Acc
BORR	47.0902	21.7856	190	Bors BH	BB, Acc
BOSR	46.0749	25.6611	595	Bodos CV	BB, Acc
BPLR	44.43	26.05	132	Politehnica Sector 6	Acc
BPO	44.4483	26.1378	143	ISU Pompieri Sector 2	Acc
BSTR	44.4458	26.0984	125	COS Sector 1	SP, Acc
BTMR	44.437	26.1067	142	Geotec Sector 2	SP, Acc
BUC	44.4107	26.0938	95	Cutitul de Argint	Acc
BUC1	44.3479	26.0281	120	Bucuresti Magurele	BB, Acc
BUR01	47.6148	25.2168	1150.6	Bucovina Array SV	BB, Acc
BUR05	47.6326	25.2176	1184.8	Bucovina Array SV	BB, Acc
BUR31	47.644	25.2002	1216.9	Bucovina Array SV	BB
BUR32	47.633	25.1805	1397	Bucovina Array SV	BB, Acc
BURAR	47.644	25.2002	1216.9	Bucovina Array SV	BB
BUZR	45.1503	26.8099	141	Buzau BZ	Acc
BVES	44.3862	26.1069	114	Gradinita Sector 4	Acc
BZS	45.6188	21.6401	260	Buzias TM	BB, Acc
CBBR	46.7683	23.5501	336	Cluj Babes-Bolyai CJ	Acc
CEIR	47.6865	22.496	198	Carei SM	BB, Acc
CFR	45.178	28.1362	57	Carcaliu TL	BB, Acc
CHLR	45.4245	29.289	42	Chilia TL	BB, Acc

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
CICN	44.197	27.0261	18	CICN Ciocanesti CL	BB, Acc
CIOR	44.4489	25.8799	135	Ciorogarla IF	SP, Acc
CJR	46.7133	23.5981	750	Cluj CJ	BB, Acc
CLIR	44.3784	25.9414	84	Clinceni IF	Acc
CLISU	44.1901	27.3557	590	ISU Calarasi CL	Acc
COPA	44.1343	25.2172	114	Copaceanca TR	BB, Acc
COPR	45.8442	26.1687	601	Covasna CV	Acc
COR	44.4656	26.0315	127	Giulesti Sector 6	Acc
CRAR	44.325	23.7999	125	Craiova DJ	BB, Acc
CRBR	45.4108	22.2383	284	Caransebes CS	Acc
CTISU	44.184	28.6491	740	ISU Constanta CT	Acc
CVD1	44.3207	28.0624	50	Cernavoda_1 CT	BB, Acc
CVDA	44.3336	28.0374	43	Cernavoda CT	SP, Acc
CVDP	44.3421	28.033	62	Cernavoda Primarie CT	Acc
CVSR	45.7944	26.1238	550	Covasna_Papauti CV	BB, Acc
DALR	45.3629	26.5966	719	Dalma BZ	SP, Acc
DEV	45.887	22.898	249	Deva HD	BB, Acc
DJISU	44.2971	23.8363	160	ISU Dolj DJ	Acc
DOPR	45.9675	25.3886	544	Dopca BV	BB, Acc
DRBR	48.2073	26.6091	269	Darabani BT	BB, Acc
DRGR	46.7917	22.7111	923	Valea Draganului CJ	BB, Acc
EFOR	44.075	28.6323	103	Eforie CT	BB, Acc
FAGR	45.8361	24.9354	435	Fagaras BV	Acc
FLGR	44.883	26.4438	880	Fulga PH	Acc
FOC	45.7032	27.1906	86	Focsani VN	Acc
GIRR	46.9551	26.5009	334	Girov NT	BB, Acc
GISR	45.4411	28.0541	67	Galati ISU GL	SP, Acc
GIUM	45.485	28.2081	102	Giurgiulesti MD	SP, Acc
GRER	45.3801	26.9747	287	Greabanu BZ	BB, Acc

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
GRISU	43.8898	25.9518	660	ISU Giurgiu GR	Acc
GRLR	45.3809	26.9494	398	Livada BZ	BB, Acc
GSMB	44.4813	26.0273	89	Gradinita Sector 1	Acc
GZR	45.3933	22.7767	850	Gura Zlata HD	BB, Acc
HARR	44.6893	27.9303	123	Harsova	BB, Acc
HERR	44.881	22.416	246	Herculane CS	BB, Acc
HUMR	44.5281	24.9804	247	Humele AG	BB, Acc
IACR	45.1358	27.4802	470	Ianca BR	Acc
IASR	47.1777	27.5748	183	Iasi IS	BB, Acc
IBH1	47.6149	25.2168	1198	Infrasound Bucovina	BDF
IBH2	47.615	25.2199	1169	Infrasound Bucovina	BDF
IBH3	47.6169	25.2112	1211	Infrasound Bucovina	BDF
IBH4	47.6186	25.2132	1119	Infrasound Bucovina	BDF
IBH5	47.6186	25.22	1181	Infrasound Bucovina	BDF
IBH6	47.6202	25.2184	1134	Infrasound Bucovina	BDF
IBZR	45.6681	26.0567	698	Intorsura_Buzaului BZ	BB, Acc
ICOR	44.1168	27.8009	121	Ion Corvin CT	BB, Acc
INCR	44.441	26.1611	145	Incerc Sector 2	SP, Acc
INMR	44.5118	26.0773	104	INMH Sector 1	Acc
INXR	45.4231	23.3771	653	Petrosani HD	SP, Acc
IPH1	45.852	26.6466	706	Infrasound Plostina VN	BDF
IPH2	45.8502	26.6437	701	Infrasound Plostina VN	BDF
IPH3	45.854	26.6455	722	Infrasound Plostina	BDF
IPH4	45.8512	26.6498	672	Infrasound Plostina VN	BDF
ISR	45.1187	26.5432	791	Istrita BZ	BB, Acc
IZVR	45.5442	27.7655	85	Izvoarele GL	BB, Acc
JIMR	45.7818	20.7024	125	Jimbolia TM	Acc
JOSR	46.7059	25.5154	749	Joseni	BB, Acc
JURR	44.7661	28.8769	37	Jurilovca TL	Acc

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
KIS	46.9975	28.8175	255	Chisinau MD	BB, Acc
LEHL	44.4739	26.8194	900	Lehliu	BB, Acc
LEOM	46.4733	28.2467	54	Leova MD	BB, Acc
LOT	45.446	23.7698	1361	Lotru VL	BB, Acc
MANR	43.8168	28.5876	72	Mangalia CT	BB, Acc
MARR	46.676	23.1189	1135	Marisel CJ	BB, Acc
MDB	46.1497	24.3765	423	Medias SB	BB, Acc
MDVR	44.7815	21.7128	720	Moldovita CS	BB, Acc
MESR	47.1499	22.9494	306	Meseseni SJ	BB, Acc
MFTR	44.1779	28.4224	980	Murfatlar CT	BB, Acc
MHISU	44.6227	22.6535	102	ISU Mehedinti	Acc
MILM	46.9186	28.8127	640	Milesti MD	BB, Acc
MLR	45.4909	25.945	1392	Muntele Rosu	BB, Acc
MNCR	45.3135	25.992	597	Maneciu PH	Acc
MTUR	45.2349	25.0739	1083	Matau AG	Acc
NEGRR	45.5373	27.8771	143	Negrea GL	BB, Acc
NEHR	45.4272	26.2952	584	Nehoiu BZ	BB, Acc
NGRR	46.8375	27.4422	126	Negresti VS	BB, Acc
ODSR	46.2969	25.2919	575	Odorheiu Secuiesc HR	BB, Acc
ONER	46.3349	26.394	456	Valea Uzului BC	BB, Acc
OTISU	44.4278	24.3755	210	ISU Olt OT	Acc
PANC	45.8723	27.1477	160	Panciu VN	BB, Acc
PETR	45.723	27.2311	85	Petresti VN	BB, Acc
PGOR	44.9199	26.9768	102	Pogoanele BZ	BB, Acc
PLOR	45.8512	26.6498	680	Plostina Array VN	BB, Acc
PLOR4	45.8512	26.6498	680	Plostina Array VN	BB, Acc
PMBB	44.4345	26.0926	810	Primaria_Buc Sector 5	Acc
PMGR	44.5275	25.9937	98	Mogosoaia IF	Acc
PPC	44.9314	26.0201	154	Ploiesti-Protectia Civila	Acc

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
PRAR	47.3552	26.2337	431	Petru Rares SV	BB, Acc
PUNG	44.2782	22.9325	131	Punghina MH	BB, Acc
PURM	46.5293	29.8723	40	Purcari MD	BB, Acc
RMGR	44.6627	22.6922	119	Halanga MH	BB, Acc
RMSR	45.3906	27.0384	154	Ramnicu Sarat BZ	Acc
RMVG	45.0363	24.2848	264	Ramnicu Valcea VL	SP, Acc
SAHR	45.7266	26.6855	804	Sahastru VN	SP, Acc
SBDR	45.7555	24.1118	503	Sibiu-Dumbrava SB	Acc
SCHL	45.5007	27.8302	52	Schela GL	BB, Acc
SCHLR	45.4702	27.8314	81	Schela GL	BB, Acc
SCTR	45.6741	27.9949	181	Scanteiesti GL	BB, Acc
SECR	45.0355	26.0677	420	Seciu PH	Acc
SGEB	44.3812	26.1369	80	Bucuresti-Scoala	Acc
SGRR	44.2228	25.9743	115	Singureni GR	SP, Acc
SINR	45.355	25.5526	834	Sinaia PH	Acc
SNMR	46.0713	20.6017	133	Sannicolau_Mare TM	BB, Acc
SORM	48.135	28.3513	640	Sorm	BB, Acc
SRE	44.6609	23.2038	386	Strehaia	BB, Acc
STFAR	44.8629	24.9609	495	Stefanesti	BB, Acc
SULR	44.6777	26.2526	129	Surlari IF	BB, Acc
SURR	45.754	22.1246	239	Surduc TM	BB, Acc
SUVR	47.6402	26.2448	354	Suceava SV	Acc
SVMR	44.5003	26.1841	880	Voluntari IF	Acc
TATR	45.5977	28.0498	760	Tatarca GL	BB, Acc
TCAR	45.1178	23.3161	268	Turcinesti GJ	SP, Acc
TECR	45.8416	27.4089	62	Tecuci GL	Acc
TESR	46.5118	26.6489	375	Tescani BC	BB, Acc
TGMR	46.5284	24.5222	321	Tg_Mures MS	BB, Acc
TGSR	45.9929	26.1152	621	Targu_Secuiesc CV	BB, Acc

Station	LAT	LON	ALT (m)	Station Name	Sensor Type
TIM	45.7365	21.2211	134	Timisoara TM	SP, Acc
TIRR	44.4581	28.4128	77	Targusor CT	BB, Acc
TLBR	44.5445	28.0467	115	Topalu CT	BB, Acc
TLCR	45.1861	28.8151	74	Tulcea	BB, Acc
TNR	45.652	24.273	519	Turnu Rosu SB	BB, Acc
TPGR	44.8565	28.4196	449	Topolog TL	BB, Acc
TRGR	44.9361	25.4563	303	Tirgoviste DB	Acc
TRISU	43.9719	25.3296	870	ISU Teleorman TR	Acc
TSCT	44.1608	28.6572	70	Contanta - Port CT	SP, Acc
TSMN	43.8011	28.595	70	Mangalia - Port CT	SP, Acc
TSSL	45.1621	29.7269	68	Sulina TL	BB, Acc
TUDR	45.5939	27.6687	33	Tudor Vladimirescu GL	SP, Acc
TUDR	45.5939	27.6687	33	Tudor Vladimirescu GL	Acc
TURN1	44.35	26.0311	156	Magurele-Turn IF	Acc
TURN2	44.35	26.0311	156	Magurele-Turn IF	Acc
TURN3	44.35	26.0311	156	Magurele-Turn IF	Acc
VARL	45.8996	27.8487	123	Varlezi GL	BB, Acc
VASR	46.6415	27.7911	275	Vaslui VS	BB, Acc
VLAD	43.9986	24.4038	138	Vladila OT	BB, Acc
VLDR	45.8443	28.0808	155	Vladesti GL	BB, Acc
VOIR	45.4371	25.0495	966	Voina AG	BB, Acc
VRI	45.8657	26.7277	475	Vrancioaia VN	BB, Acc
ZIMR	43.6572	25.3652	88	Zimnicea TR	BB, Acc
ZOBR	45.6131	25.6347	634	Brasov BV	Acc

The remote seismological stations have three-component seismometers for weak motions and three-component accelerometers for strong motion. In cooperation with the Institute of Geophysics and Seismology Kishinev, Republic of Moldova, we installed five seismic stations in Republic of Moldova at Leova (LEOM), Giurgiulesti (GIUM), Milestii Mici (MILM), Kishinev (KIS) and Soroca (SORM). All the data from the seismic from the seismic stations installed on the Republic of Moldova territory are received in real time at NIEP Data Centre using seedlink connection.

The primary goal of the real-time seismic network is to provide earthquake parameters from more broadband stations with high dynamic range in order to compute more rapidly and with better accuracy the location and magnitude of the earthquakes. Seedlink and Antelope™ program packages are used for real-time (RT) acquisition and data exchange (Ionescu et al., 2021).
The real-time digital seismic network developed by NIEP is represented in Figure 1. Near-future strategy includes installing additional broadband stations in the central and western part of Romania and other 40 strong motion stations in Bucharest city.

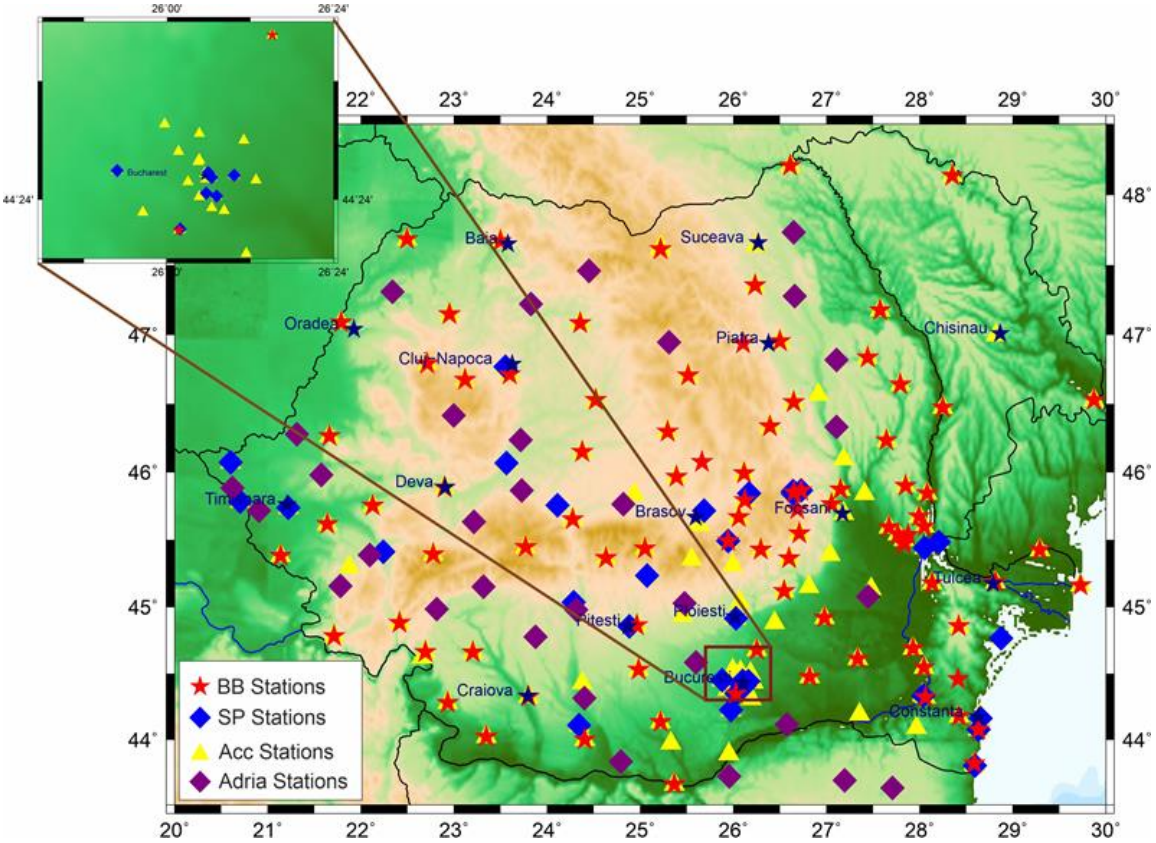

Figure 1: Real Time Seismic Network of Romania

A completely automated seismological system Antelope (developed by BRTT) (Figure 2) runs at the Data Center in Magurele. The Antelope™ data acquisition and processing software is running for real-time and post processing. The Antelope real-time system provides automatic event detection, arrival picking, event location and magnitude calculation. It provides graphical display and automatic location within near real-time after a local, regional or teleseismic event occurred (Ionescu et al., 2021).
SeisComP, another automated system, has been running at NIEP since 2014 providing the following features: data acquisition, data quality control, real-time data exchange, network status monitoring, real-time data processing, issuing event alerts, waveform archiving, waveform data distribution, automatic event detection and location, easy access to relevant information about stations, waveform and recent earthquakes (Figure 3 and 4).

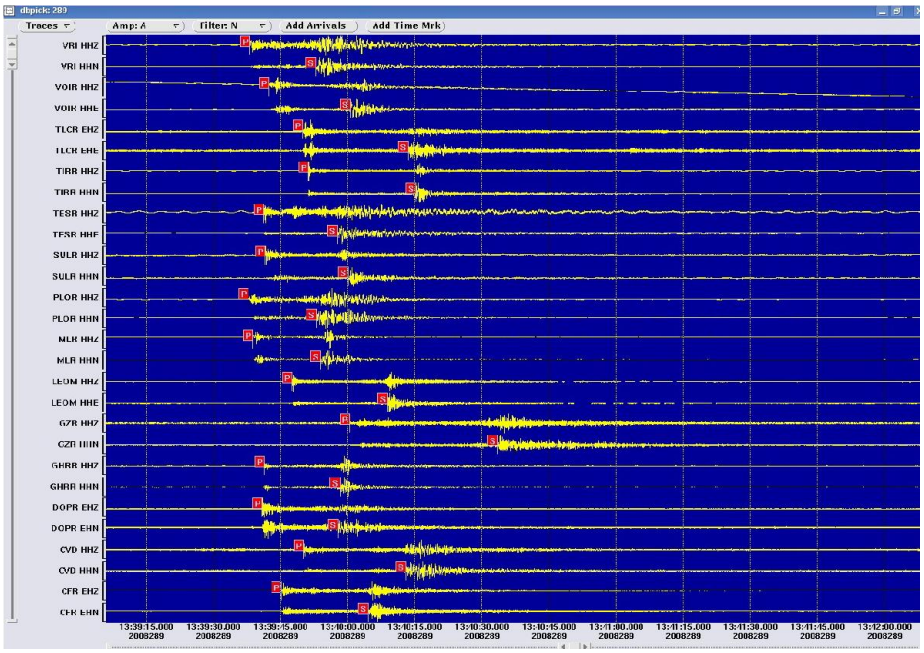

Figure 2: Example of manual data processing with Antelope software

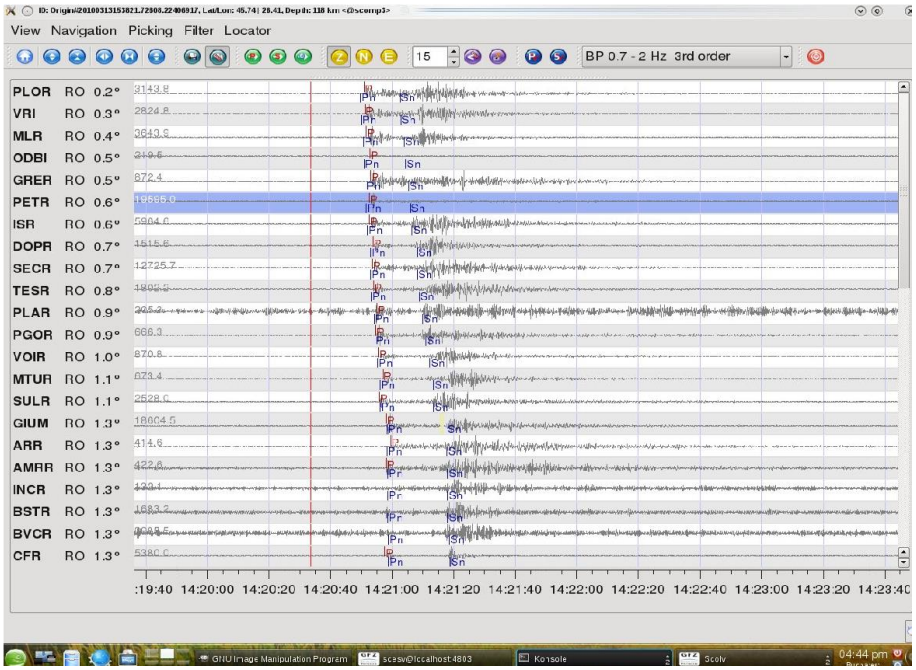

Figure 3: Automatic detection using SeiscomP Software

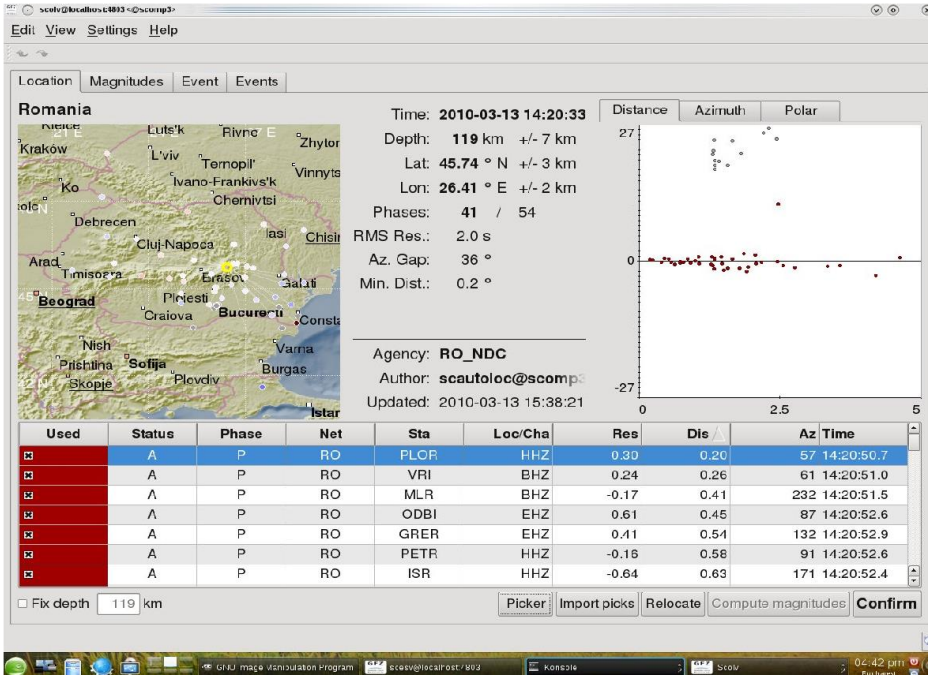

Figure 4: Seismic data processing using SeiscomP Software

The Antelope software (http://www.brtt.com/software.html) is running on three servers for data acquisition as well as automatic and real-time data processing, data distribution and seismic data archiving.

One server works as a principal unit and the other two are working as back-up units. A block diagram describing the data processing flow is shown in Figure 5.

Since 2014 NIEP has become an EIDA (European Integrated Data Archive) node providing services and access tools to all EIDA stations (Figure 6). NIEP is in charge of collecting, archiving and sharing data from Romania and neighbouring countries (Bulgaria, Republic of Moldova, Serbia, Ukraine). This way, NIEP is actively participating to the European strategy of integration and homogenization of data and procedures (Ionescu et al., 2021; Lanzano et al., 2021; Lenhart et al., 2021; Marmureanu et al., 2021; Strollo et al., 2021).

For automated data acquisition from seismic stations at NDC two servers are used, one main server which uses Antelope 5.7 software and the second one with SeiscomP program, considered as back-up.

Both systems produced information about local and global parameters of earthquakes. In addition, Antelope is used for manual processing (association events, magnitude computation, database, sending seismic bulletins, calculation of PGA and PGV, etc.), generating ShakeMap products and interacts with international data centres.

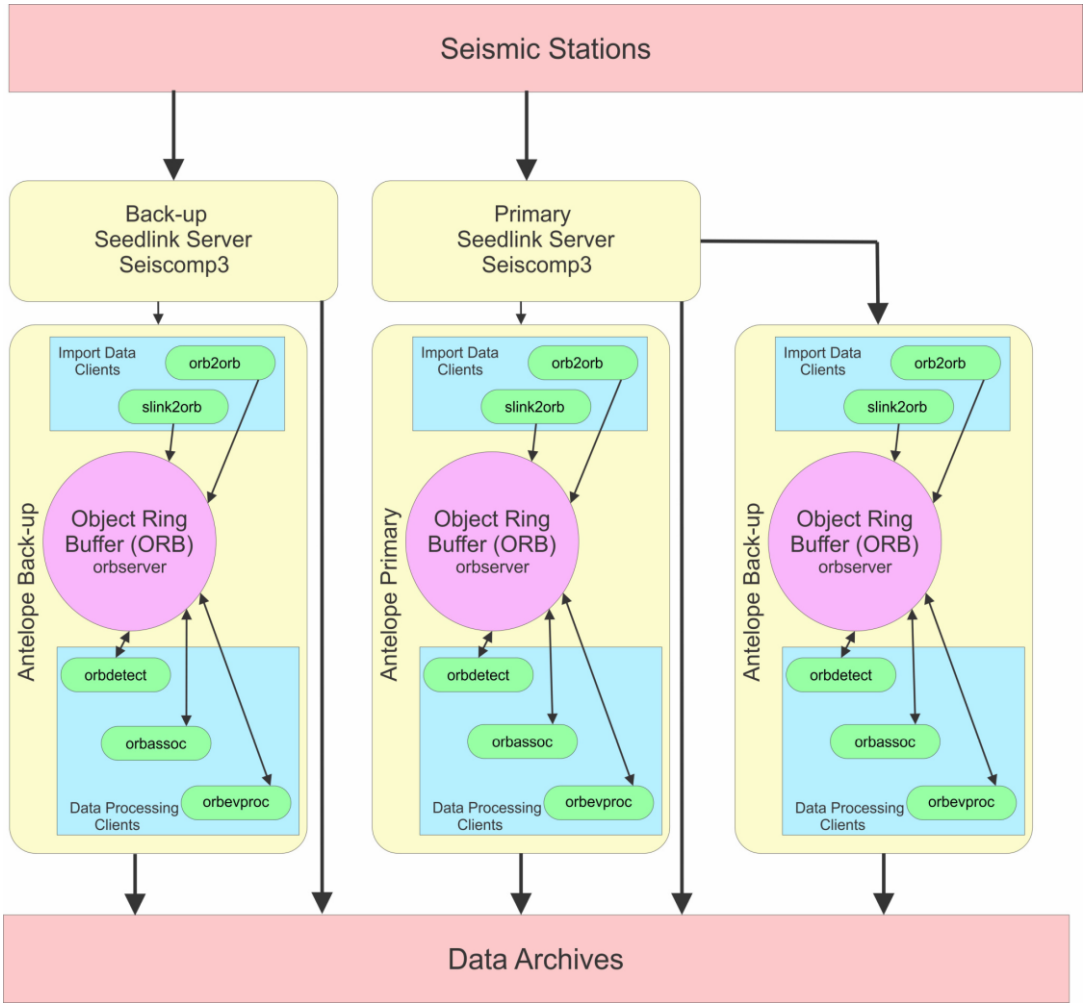

Figure 5: Data Flow at Romania Data Center

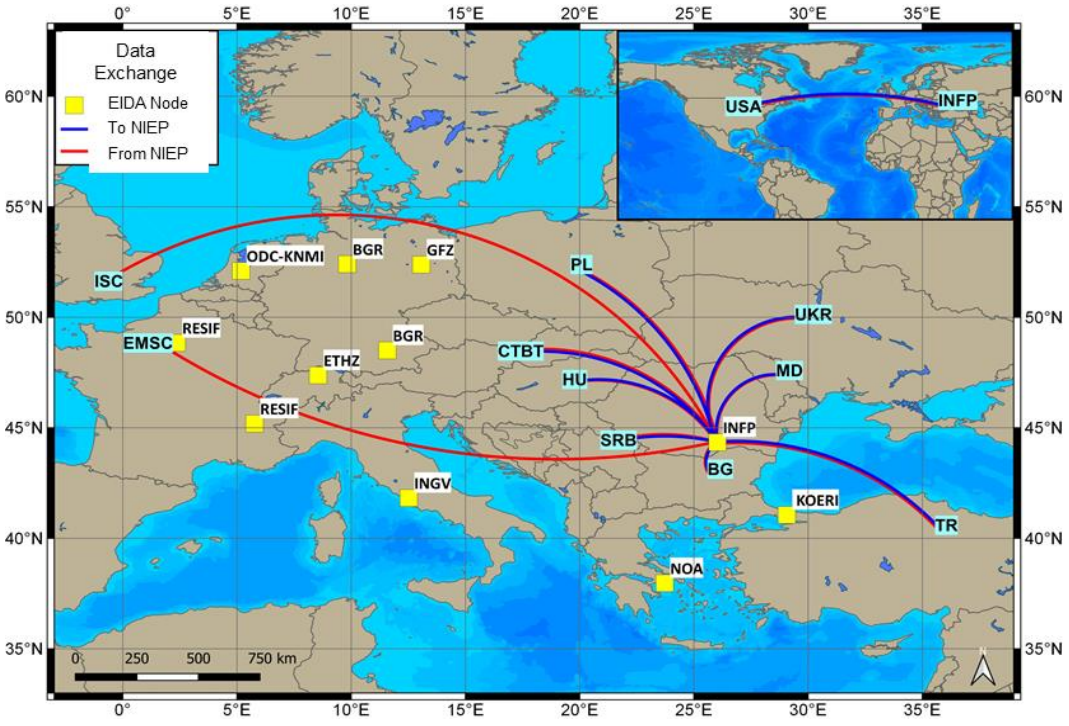

Figure 6: EIDA Nodes

In order to make all this information easily available across the Web and to establish a more modular and flexible development environment, the National Data Center has developed tools to enable centralising of seismological data from software such as Antelope. Because Antelope is using a dedicated database system (Datascope, a database system based on text files) we moved the data to a more general-purpose database, Mysql, which acts like a hub between different acquisition systems used in the data center. Mysql database also provides better connectivity at no expense in security (Figure 7).

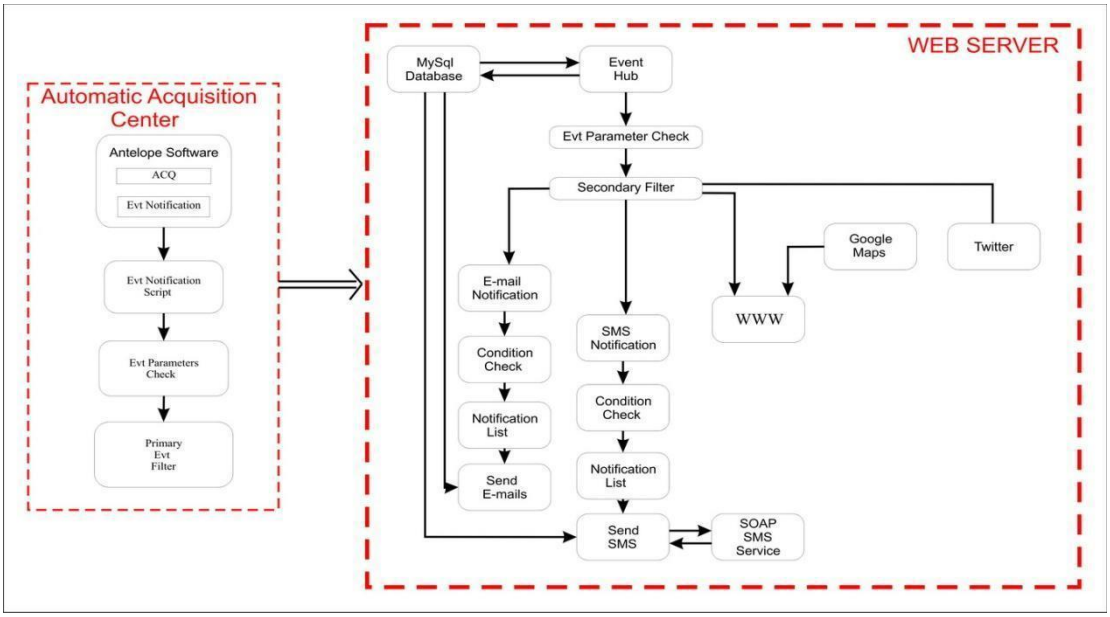

Figure 7: Web Server Configuration

Mirroring certain data to MySQL also allows the National Data Center to easily share information to the public via the new application which is being developed and also mix in data collected from the public (e.g. information about the damage observed after an earthquake which internally is being used to produce macroseismic intensity indices which are then stored in the database and also made available via the web application). For internal usage, there is also a web application which uses data stored in the database and displays earthquake information like location, magnitude and depth in semi-real-time.

Another usage of the data collected is to create and maintain contact lists to which the data centre sends notifications (SMS and emails) based on the earthquake parameters.

Lately, improvements have been made to get rapid evaluation of the source parameters (location, moment tensor) by implementing optimised applications (Apostol et al., 2022a; Plăcintă et al., 2021; 2022a). At present an Early Warning System is operational for earthquakes located in Romania (Marmureanu et al., 2019). Progress was made in developing and implementing advanced algorithms to detect and locate microearthquakes (Kinscher et al., 2020; Lei et al., 2020; Metaxian et al., 2020; Namjescnik et al., 2021; Palgunadi et al., 2020; Poiata et al., 2021a; 2021b).

Impetuous development of the seismic network led to a significant improvement of the monitoring and decrease of the magnitude threshold for detecting seismic events. This is why, the weight of artificial events has tremendously increased in the Romanian routine catalogue (Romplus). Consequently, several discrimination techniques have been proposed to filter the catalogue (Armeanau et al., 2022; Dinescu et al., 2021a; 2021b; Ghica, 2021; Radulian et al., 2019a).

NIEP has more than 25 years of experience in global seismological monitoring in support of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). It is participating in international verification activities with the seismic station Muntele Rosu, which was included in the auxiliary seismic network of the International Monitoring System, and with the operation of Romania's National Data Centre (NDC). In order to ensure Romania’s technical contribution to CTBT at the operational standards required by the Treaty, since 1999 an important upgrade has been under development both at the seismic station Muntele Roşu and at the NDC, involving both technical cooperation with the Government of Japan and technical assistance from the CTBT Organization. Hence, in the fall of 2001 a new seismic monitoring system was installed and is now fully operational, by recording continuous earth motion data at Muntele Rosu site and transmitting these data in real-time to the facilities in Bucharest, in the framework of the Japan International Cooperation Agency project „Technical Cooperation for Seismic Monitoring System in Romania”.

NDC ensures the exchange of data and information (bulletins, seismic phases) with national data centres from other countries, as well as with international seismological centres (Figure 8, Figure 9).

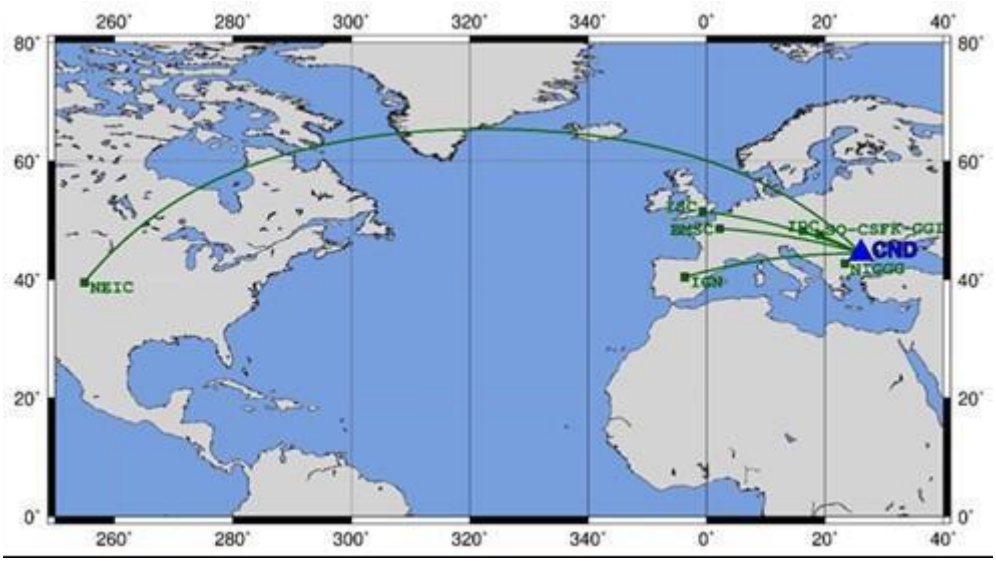

Figure 8: National and international data centres that receive information from ROM NDC

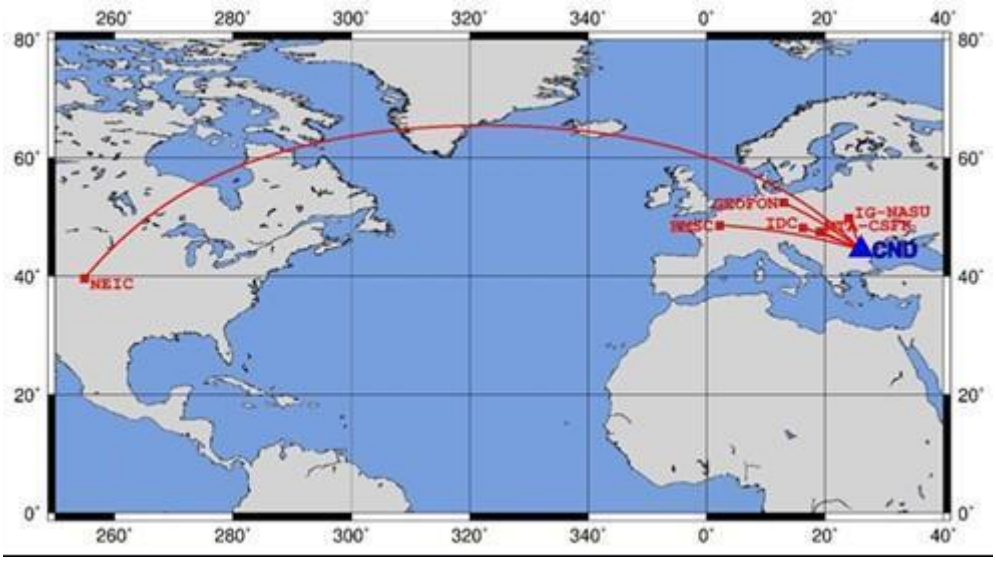

Figure 9: National and international data centres that transmit information to ROM NDC

Plostina seismo-acoustic array is located in the central part of Romania, in Vrancea region, (Figure 10). The array deployment started in 2007, when four seismic elements (PLOR1, PLOR2, PLOR3 and PLOR4) were installed. In 2009, two more seismic sites (PLOR 5 and PLOR6) were added, and the infrasound array deployment was initiated, by placing of three infrasonic instruments (IPH4, IPH5 and IPH6), collocated with the corresponding seismic locations. In 2010, another seismo-acoustic element (PLOR 7 and IPH7) was added and during 2012, sites 2 and 3 were equipped with infrasound sensors. Plostina seismo-acoustic array is currently distributed over an area of 3.5 km^2.

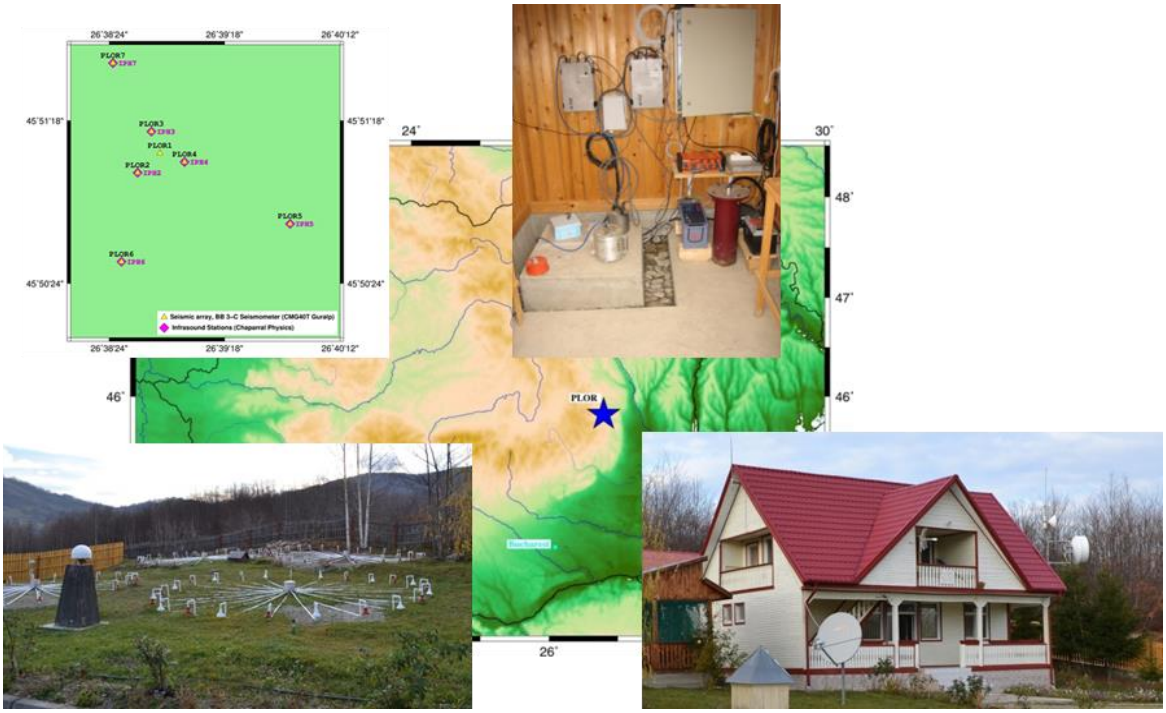

Figure 10: Plostina Observatory and elements of integrated system operating in the area (PLOR* - seismic array, IPH* - infrasonic array)

Presently, at Plostina, NIEP operates an integrated system (Figure 10) which includes advanced technologies such as: seismic and infrasound arrays, strong motion sensors, magnetic field and electric field monitoring, soil temperature measuring, and a weather station. The main applications of this system are:

- monitoring of the local microseismic activity
- acoustic measurement (infrasound monitoring of explosions, mine and quarry blasts, volcanic eruptions, earthquakes, aircraft etc.)
- observation of the magnetic field variation in correlation with solar activity
- observation of the variation of radioactive alpha gases concentration
- observation of the variation of telluric currents.

Since July, 2002, a new seismic monitoring system, **Bucovina Seismic Array (BURAR)**, has been established in the Northern part of the country (Figure 11), in a joint effort of the Air Force Technical Applications Center (AFTAC), USA and NIEP. Data recorded by BURAR array are continuously transmitted in real time to the National Data Center of USA in Florida and to NDC, in Magurele. BURAR seismic array consists of 10 seismic stations located in boreholes and distributed over an area of 5 km^2. Nine stations are equipped with short-period vertical sensors (GS-21) and one station is equipped with broadband three-component sensor (KS 54000).
In 2008 five new elements equipped with 3-C broadband sensors were installed aiming to obtain the most convenient array combination of 3-C elements for the recording and identification of the secondary seismic phases, to optimize the array response, achieving a superior sensitivity and resolution of BURAR in S-type seismic signals identification.

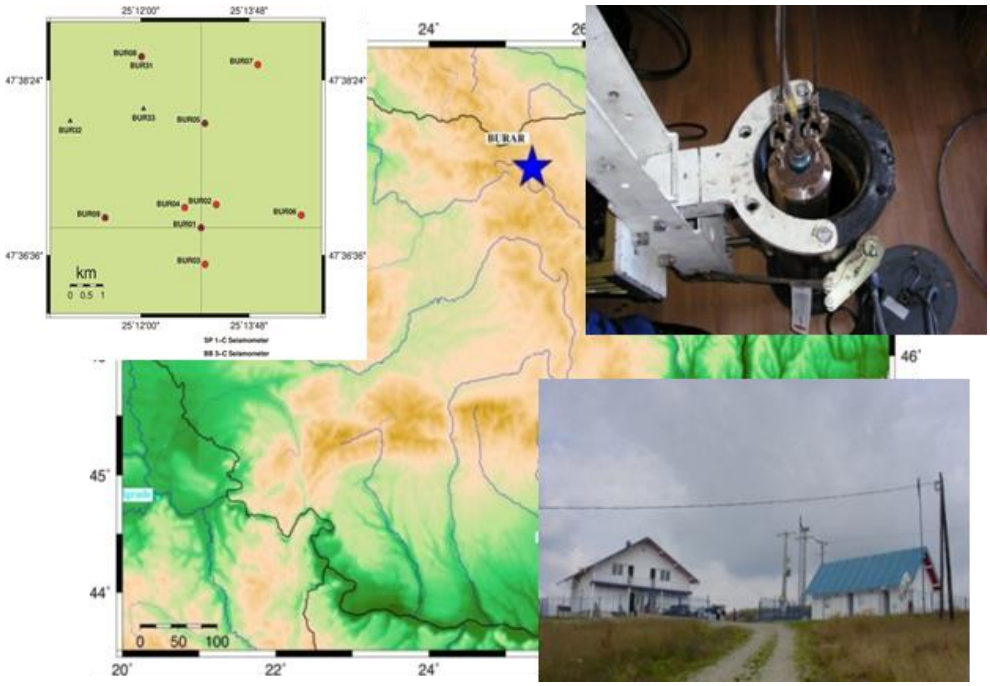

Figure 11: Bucovina Observatory (BURAR) and array elements distribution

NDC is a partner in the Romanian-American collaboration with the Air Force Technical Applications Center (AFTAC). As part of this collaboration, an infrasound

array (BURARI) was installed in July 2016 in parallel with the BURAR seismic array: four elements distributed over an area with an aperture of 1.2 km. In September 2019, the system was modernised by reconfiguring it, the new configuration consisting of six elements installed in an aperture of 0.7 km. The elements were equipped with Hyperion 5113/A broadband microbarometers (Hyperion Technology Group Inc.) and high-performance wind noise reduction systems, consisting of flexible tubes arranged in a star configuration with 32 air capture ports.

The collaboration with AFTAC has as main objectives: processing of the data recorded with the seismo-acoustic array in Bucovina (BURAR) and the analysis of the results, including their integration in reports and studies; design of array type stations (seismic and infrasound); participation in the Joint Scientific Commission (JSC) between AFTAC and NIEP. The seismo-acoustic array is continuously monitoring local to near-regional quarry blasts, volcanic eruptions, atmospheric major phenomena, etc. (Bondar et al., 2022; Ghica et al., 2020; Sindelarova et al., 2021). Examples are given in Figures 12 and 13.

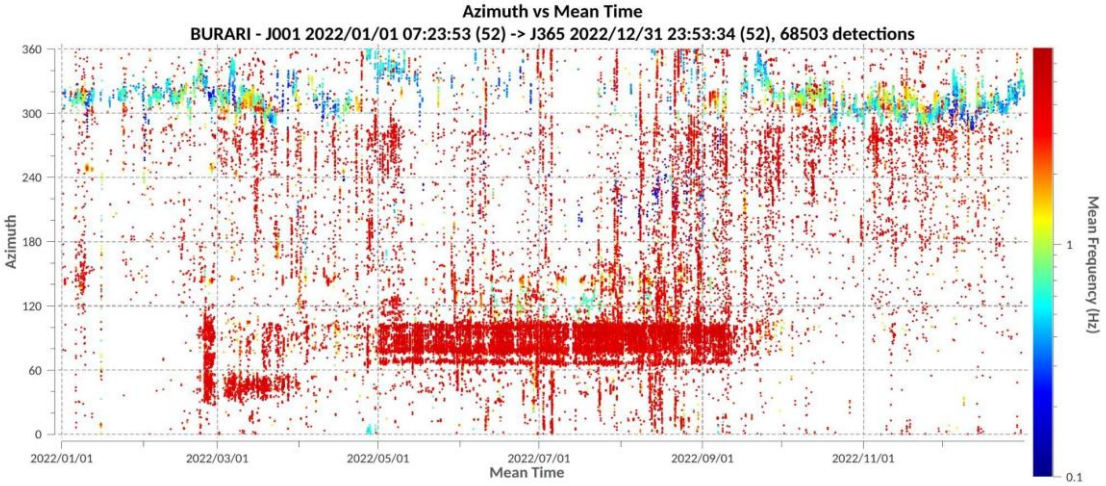

Figure 12: Daily distribution of the frequency content according to the direction of arrival (back azimuth) for the infrasonic signals detected by the BURARI infrasonic array in the year 2022.

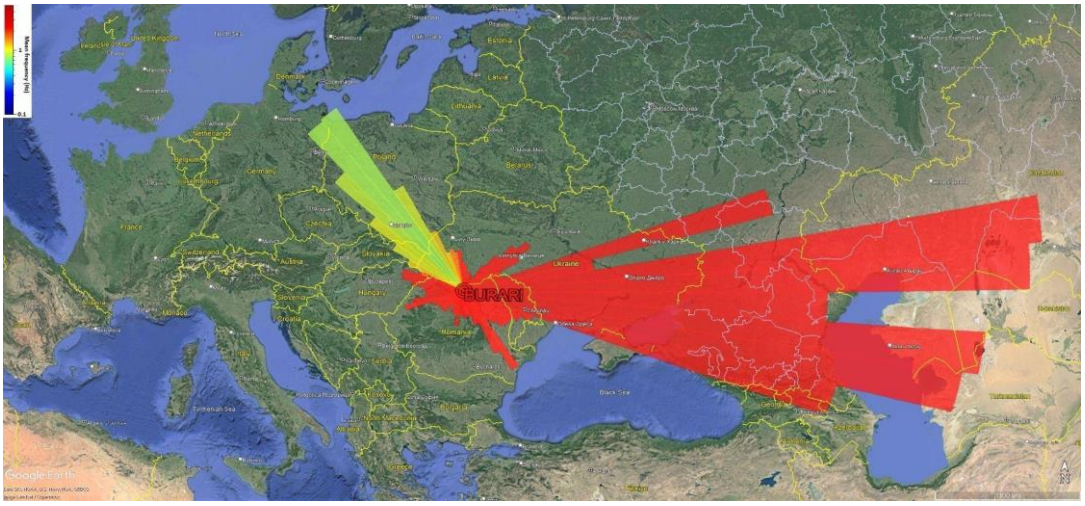

Figure 13: Statistical azimuthal distribution according to the frequency content of the number of infrasonic signals detected by the BURARI array in 2022.

Another important research direction is the discrimination of seismic events of tectonic nature from those caused by man-made activities (Dinescu et al., 2021a; 2021b; Radulian et al., 2019b).

The NIEP GPS Permanent Network

The development of the Romanian GNSS/GPS (Global Navigation Satellite System/Global Positioning System) network started in 2001 when the first permanent station was installed at Lăcăuţi. Since then, the network has grown to 29 active stations and is still expanding (Figure 14). The maintenance and operation of the GNSS/GPS network is done in the National Seismic Network Laboratory.

The main purpose is to monitor the seismically induced movement, to determine the surface velocity in the studied regions and to correlate the surface kinematics with land processes (Mateciuc and Bala, 2019; 2020a; 2020b; Muntean et al., 2019; Nastase et al., 2020; 2021; Nistor et al., 2021a; 2021b; Zoran et al., 2019a; 2019b). GPS observed surface motion, combined with other independent geophysical investigations can support understanding and modelling of the ongoing processes in the study areas (Mateciuc and Bala, 2020b; 2021). The global nature of GPS makes it possible to determine and monitor the surface's vertical and horizontal components of displacements with high accuracy, which is needed for these studies. Repeated measurements over a long time span make the technique suitable for detecting the surface movements. The 20-Hz-sampling displacements for earthquakes that may occur in the Vrancea area represent important recordings for investigating coseismic contributions at frequencies higher than 1Hz.

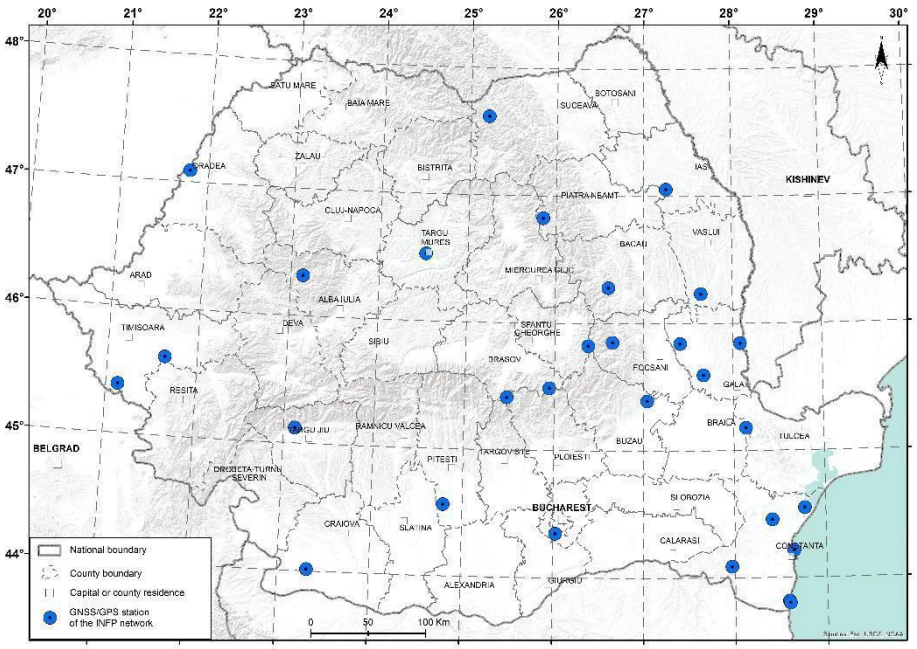

Figure 14: GPS network settlements

The network was established as a result of an international research project based on a strategic partnership between: the National Institute for Earth Physics (NIEP), the Faculty of Geology and Geophysics – University of Bucharest (FGG), Delft University of Technology, the University of Utrecht and the Netherlands Research Center for Integrated Solid Earth Sciences (ISES) and, more recently, with TopGeocart company.

The stations have mixed equipment, a vast majority of it being produced by Leica Company: GRX1200GGPro and the GRX1200 + GNSS receivers type and antenna models LEIAT504, LEIAT504GG, LEIAR10 and LEIAX1202GG. We also operate 3 stations with Septentrio equipment. During 2014, we used our newest Leica GR10 receiver in order to put in real-time our oldest station LACP. In the meantime, replacements of the old CRS 1000 and SR530 receivers took place. Attached below (Figure 15) one can see details about the equipment used, the locations, settlement and other pieces of information. Moreover, NIEP is equipped with Leica GRX 1230 and SR530 campaign receivers.

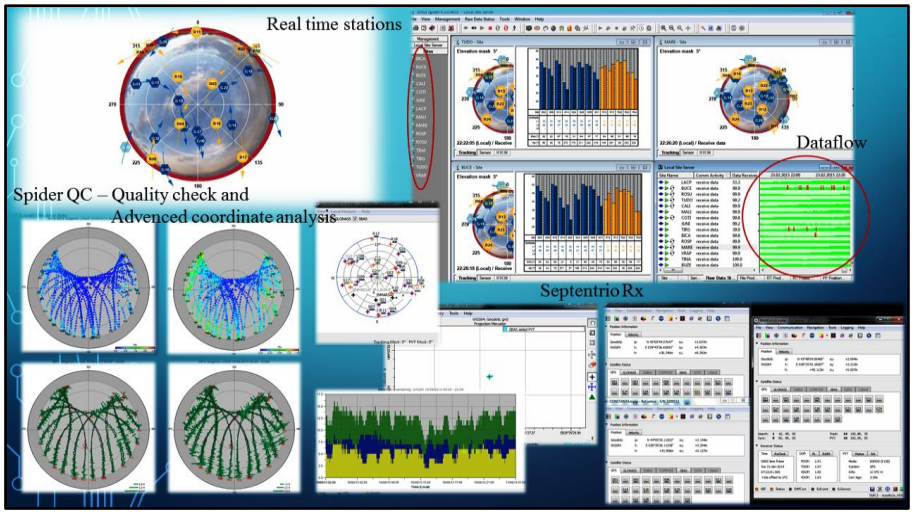

Figure 15: Software applications

Data acquisition is achieved in real time, in RAW DATA format and RINEX format, using Leica GNSS Spider and Septentrio Rx software. Furthermore, 8 of the network's stations simultaneously record Ring Buffer data on receiver's internal memory at a rate of 20 Hz. (0.05s).

Regarding post-processing, an agreement has been reached between NIEP and Jet Propulsion Laboratory ("JPL"), the latter is an operating division of the California Institute of Technology, regarding the following software licence: GIPSY OASIS NPO – GPS Inferred Positioning System Orbit Analysis and Simulation Software. This licence is available and will be used by the National Seismic Network Laboratory, with the purpose of monitoring crustal deformations by using GNSS data on Romanian territory. This is the basic software used to achieve data availability for the entire working period (Figure 5), time series and displacement vectors. More recently, LGO software (Leica Geo Office), GLab (developed by ESA-European Space Agency) and RTKLIB (Open Source Package) have been used for complementary purposes.

Among the most significant achievements in the past years, we mention:

- A fully automated and networked system dedicated to digital acquisition and real-time processing of seismological data, as well as to rapid exchange of earthquake information has been implemented. At present, NIEP participates with 6 BB stations to the Virtual European Broadband Network and is ready to significantly increase its contribution to the objectives of the research infrastructures integrating activity, one of the main domains of the Structuring the European Research Area.
- The Romanian Earthquake catalogue (ROMPLUS) comprises updated, complete, user-friendly and rapidly accessible earthquake information. The catalogue refers to earthquakes that occurred in Romania and at the neighbour boundaries since 984 up to present, including information related to locations and other source parameters, as well as links to waveforms of strong earthquakes. Seismicity analysis is continuously performed implying updating of the earthquake catalogue, spatial-temporal-magnitude patterns in different seismic regions of Romania, earthquake sequences. Interpretation and reconsidering of historical data constitute an important issue for the seismic hazard investigation.
- Field investigations of microearthquakes and earthquake sequences;
- Research on natural and induced seismicity.

Future Developments of the Romanian Monitoring Network

The Romanian Seismic Network will be enlarged by the installation of new stations that will provide seismic data in real-time to the data centre. The upgraded network will provide new data for site effects studies and microzonation purposes and will be used for developing and evaluations of the Shakemaps for all country and in the Bucharest area.

For future development, amongst others, the data centre plans to compare the locations provided by Antelope 5.7 and SeiscomP using the same velocity global model.

1.2. SEISMOLOGY

The National Institute for Earth Physics (NIEP, http://www.infp.ro) is the leading institution for seismology in Romania, responsible for the earthquake monitoring of the territory and basic and applied research in seismology. It was established in 1977 as an organization for research and development in Earth sciences. Now it is coordinated by the Romanian Ministry of Research, Innovation and Digitalization, being mainly financed by contracts from public sources. It has a wide background in Earth sciences research, with focus on seismic source and seismotectonics, hazard assessment and earthquake forecasting.

The seismological research in Romania during 2019-2022 time interval has been focused on the following main directions:

- historical seismology and macroseismology
- seismicity
- seismic source physics
- wave propagation
- seismotectonics
- hazard assessment
- earthquake forecasting

Since Romania is an earthquake prone area, it is of crucial importance to obtain quantitative information needed for seismic risk mitigation and related public policies and seismic safety measures. The most damaging earthquakes in Romania concentrate in Vrancea region, located at the sharp bend of the Eastern Carpathians chain, in a well-confined focal volume at intermediate depths (60 to 200 km). The extremely peculiar seismotectonics and geodynamic processes in this area focused the attention of numerous seismologists. At the same time, taking into consideration the dramatic social and economical implications of the Vrancea earthquakes, major efforts have been made to seismic hazard assessment and seismic microzonation of the large urban areas affected by these earthquakes, and first of all of Bucharest, for long-term protection against earthquakes.

1.2.1. Historical seismology and macroseismology

Contemporary seismology must respond to the necessity for security of modern and critical infrastructures (N.P.P., dams etc.). To come to this goal extensive research on historical earthquakes and their physical characteristics is of primary importance. Recently, significant steps forward have been achieved within the historical seismology field by collecting large amounts of historical records for the earthquakes in Romania (Rogozea et al., 2021). The main attention was focused on the strongest earthquakes which control the maximum observed intensities and therefore largely determine the seismic hazard level and implicitly the anti-seismic design and strategy. Special attention was paid to those earthquakes which are important in defining specific seismogenic areas, but for which we have poor information.

In order to set the basis of some rigorous standards and norms of anti-seismic design, capable of assuring maximum security to buildings, in accordance with the

idea of promoting and developing a national system, compatible with the European standardising systems, a large research activity has been developed during 2019 – 2022 focused on updating the database with historical seismograms and converting them into digital format for future processing (Oros et al., 2019a; 2019b; Vanciu et al., 2021; 2022; two presentations at the The Third European Conference on Earthquake Engineering and Seismology - 3ECEES, 2022, Bucharest). This has involved sustained work to scan analog seismograms and digitise them. This kind of activity represented NIEP's contribution to the objectives of the Working Group of European Seismological Commission on “Legacy seismograms”.

A new research direction was initiated in NIEP related to historical earthquake simulation using ambient seismic noise. Preliminary results obtained for the Vrancea (Romania) source were presented at the European Geosciences Union General Assembly conference in April 2022 (Placinta et al. 2022).

Taking this into consideration, we have obtained important results, in the field of macroseismology, in the framework of the project “Seismic macrozoning of the territory of Romania, based on revalued macroseismic intensities corroborated with complex geological and geophysical data” (2007-2016 National Strategic Plan for Research, Development and Innovation II) with the participation of two partners (GIR and UB-FGG). As concerns this type of information, macroseismic investigations have been carried out in order to define macroseismic field of the recent crustal and subcrustal earthquakes occurred in Romania. This activity is continuous through evaluation of macroseismic effects of recent earthquakes using both types of collected data: online and classical macroseismic questionnaires (Constantin et al., 2022) (Figure 16).

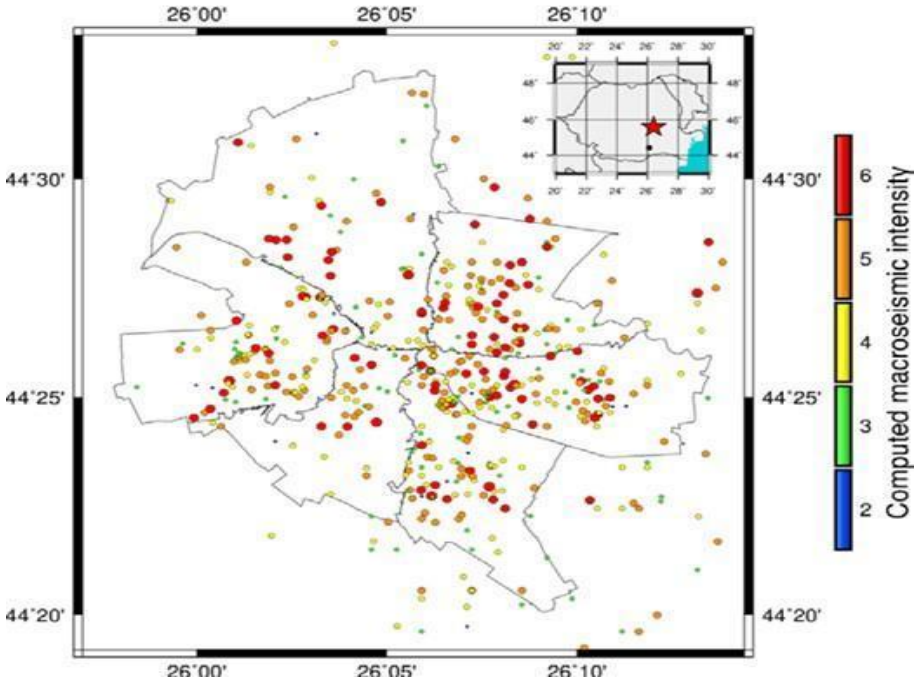

Figure 16: Preliminary map of the intensities obtained following the occurrence of the Vrancea earthquake of 28.10.2018 in Bucharest and adjacent areas (Constantin et al., 2022).

We note in this regard the new perspective open by integrative work carried out on the basis of the results obtained within successive international projects, involving border countries (Bulgaria, Hungary, Republic of Moldova, Serbia, Ukraine) and using integrated databases and processing tools at European level.
Conversion relationships between macroseismic intensity and ground motion parameters (PGV and PGA) for crustal and subcrustal earthquakes were investigated (Figure 17) (Ardeleanu et al., 2020; Constantin et al., 2021a; 2021b; Moldovan et al., 2019a).

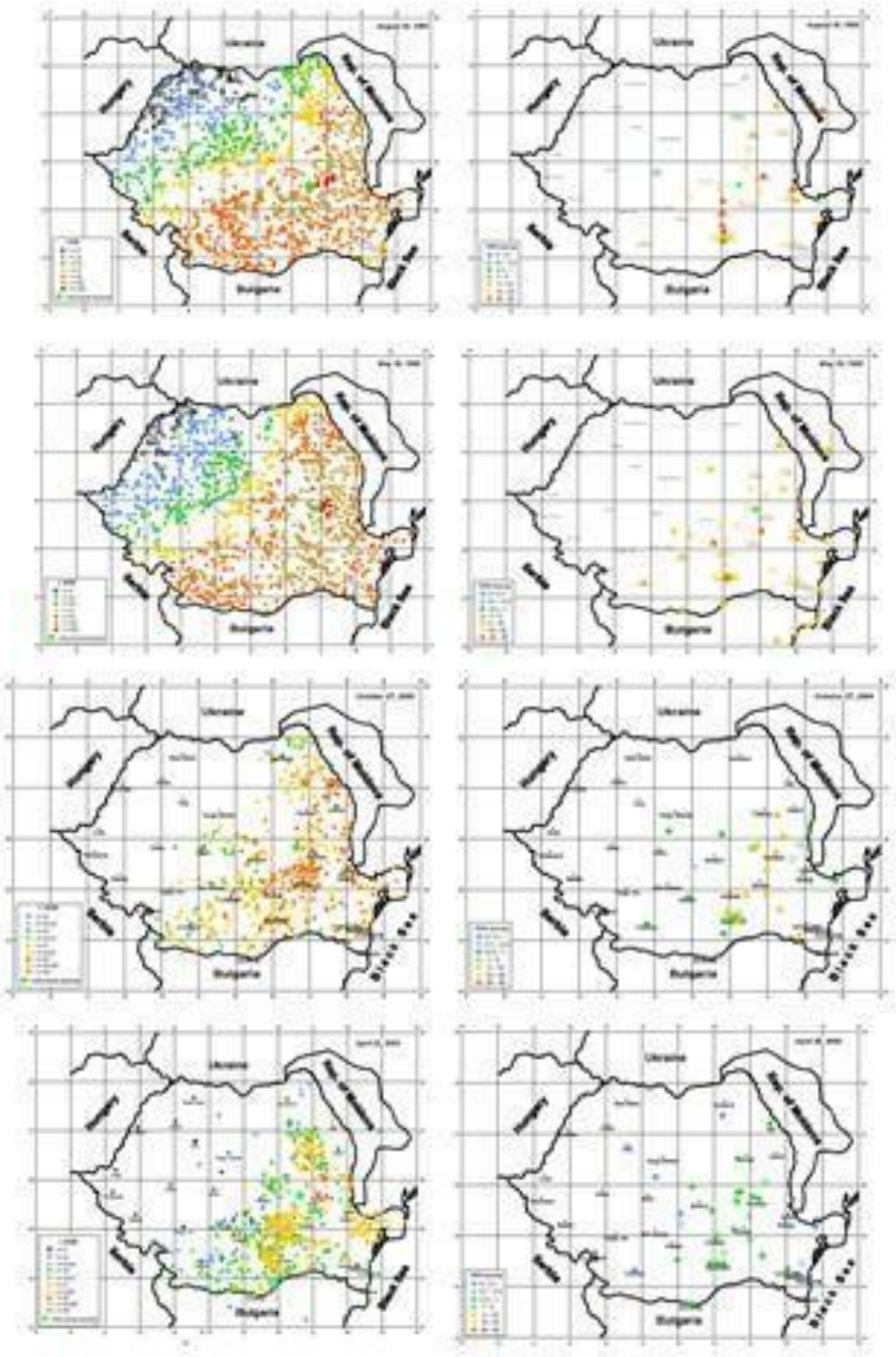

Figure 17: Comparative representation of intensity and PGV distributions for the Vrancea earthquakes of 1986 and 1990 (Constantin et al., 2021a).

1.2.2. Seismicity

The main concern was for seismicity in Romania and for the better determination of the seismogenic sources. Updating and revising the earthquake catalogue is a permanent concern. Various group localization techniques were applied for this purpose, using double differences or cross-correlations. New techniques for discrimination between earthquakes and explosions were investigated. On the basis of revised and updated catalogue data and seismotectonic investigations, revised seismogenic zones are proposed for Romania and border areas and for the Black Sea (Partheniu et al., 2019a), as shown in Figure 18.

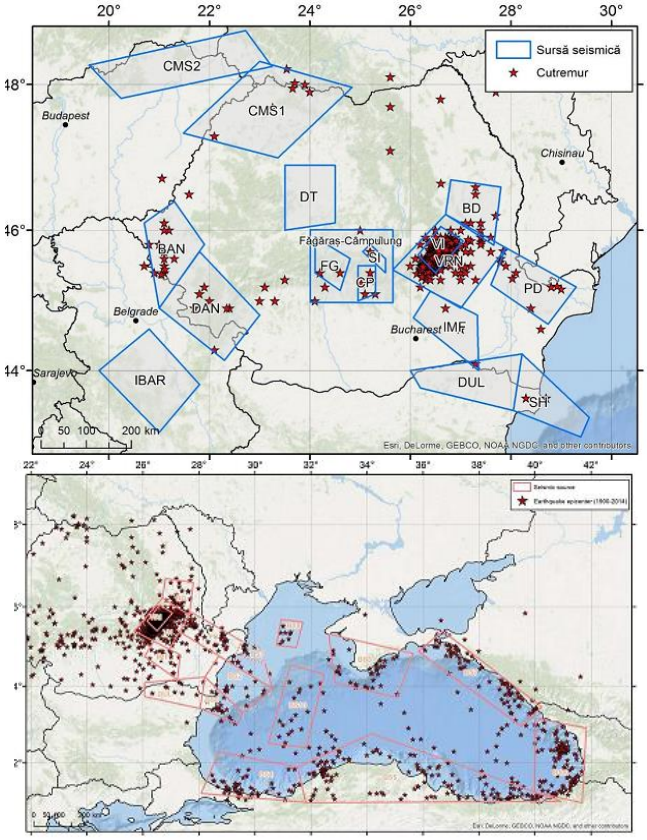

Figure 18: Updated version of the seismogenic zones in Romania and Black Sea area.

An important direction was the analysis of the seismic sequences as well as the investigation of the seismicity patterns (Dinescu et al., 2019; Ghita et al., 2021; Oros et al., 2021a; Popescu et al., 2021). Declustering techniques of the catalogue are investigated (Ghita et al., 2019). The statistical distribution of the size of the earthquakes, which is a general pattern empirically tested, is physically explained by an energy accumulation mechanism (Apostol et al., 2020a; 2021a; 2021b). It was shown that focal geometry and statistical distribution of the seismic events strongly contribute to magnitude distribution. In the same way, Bath's empirical law, reported as an empirical law valid for aftershock sequences, can be derived on physical grounds from the magnitude-difference statistical distribution of earthquake pairs.

One significant parameter is the b slope of the Frequency-Magnitude Distribution whose variation in time and space can provide significant information regarding the evolution of the seismogenic system (Ghita et al., 2020; 2022a; Figure 19).

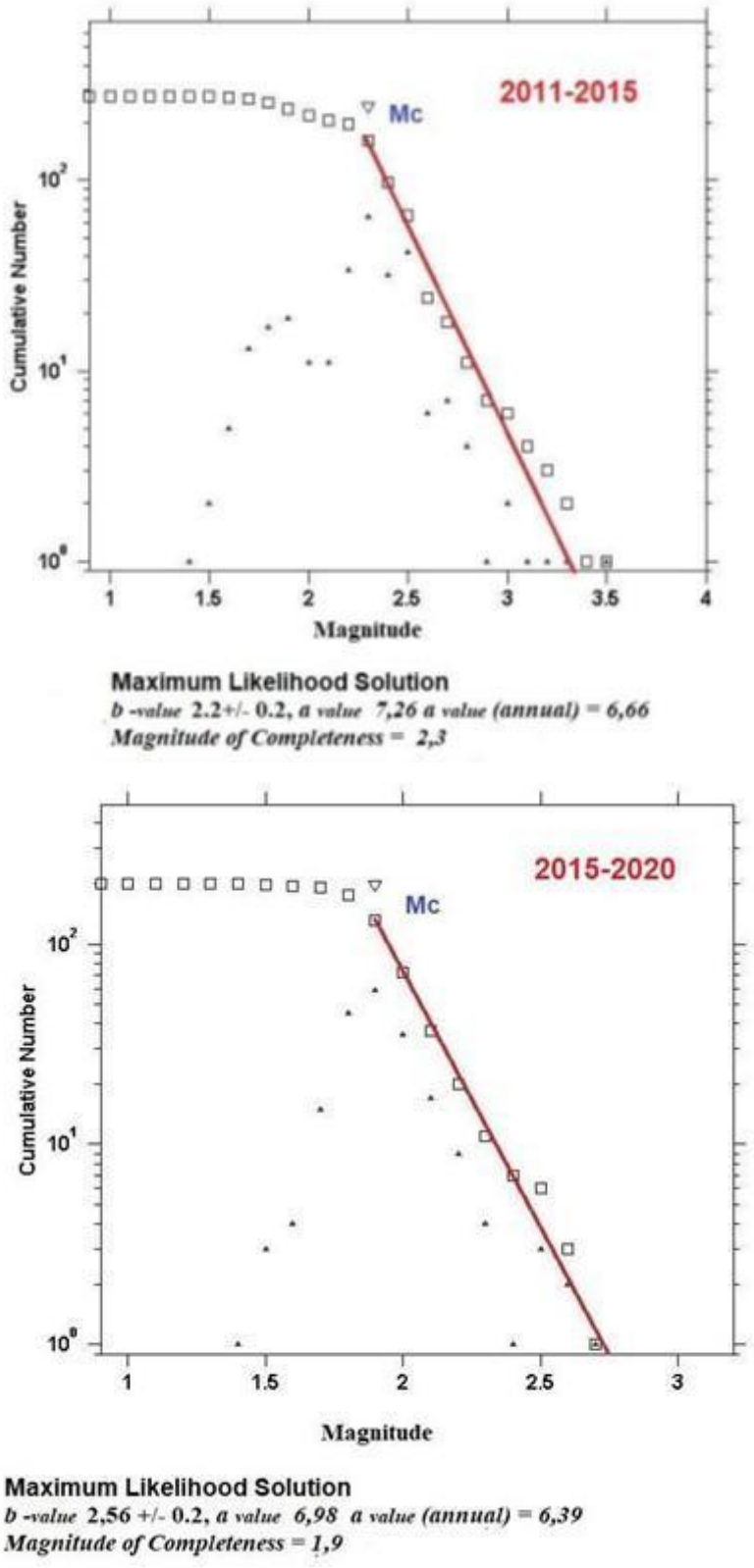

Figure 19: Frequency-magnitude distribution for the north-eastern part of Romania for two separate time intervals (Ghita et al., 2022a).

1.2.3. Seismic source physics

Modelling the earthquake source is one of the main tasks with the long-term goal to construct a quantitative physical model for the entire earthquake process, including tectonic stress accumulation, nucleation of rupture, and the dynamics of the rupture propagation and cessation. Integration of the multiple aspects of the earthquake phenomena, from the small scale (dynamic rupture) to large-scale (plate boundary tectonics) processes is becoming of increasing interest for many researchers.

The increase of the seismic network of the NIEP after 2015 in number and quality of instruments, the integration in the European virtual network have contributed to a better covering of the Romania territory and provided higher-quality database for seismic source studies. Besides the Vrancea intermediate-depth focus, where the most damaging earthquakes of Romania are generated, systematic investigations have been carried out in other seismogenic zones on the territory.

Waveform inversion for small to large earthquakes has been applied using local and teleseismic recordings in order to retrieve source parameters and focal mechanism. The recent advance in both observations and computer simulations has strongly increased our performance in constraining the source parameters over a broad magnitude range.

The source time function and its characteristics are determined using stress tensor inversion or empirical Green's function deconvolution. An analytical solution is proposed for a simple source model by Apostol et al. (2020b) which is discussed in relation to other measurable quantities. The static deformation produced by this force in a half-space is also evaluated. The solution to this problem and its particular cases are presented in a recent paper (Apostol, 2022a, 2022b, 2022c). The practical application of the theory of determining the seismic source and earthquake parameters from local seismic recordings of the P and S seismic waves is presented by Apostol (2019a; 2019b). Through this application the earthquake energy and magnitude can be derived, as well as the volume of the focal region and the focal slip. Also, it is shown how to determine the tensor of the seismic moment, the focal strain and the duration of the seismic activity in the earthquake focus. It was described how to deduce the orientation of the fault and the direction of the focal slip.

Recent investigations pointed out the crucial role played by the presence of fluids at intermediate depth in explaining the mechanism of the Vrancea earthquakes (Ferrand and Manea, 2021; Kovacs et al., 2021).

Another approach to understand the way the seismic cycle in the Vrancea region evolves has been the stress transfer modelling. Apparently, the major Vrancea earthquakes are generated alternatively in two separated segments on depth and this behaviour would be in favour of a stress coupling among these segments. Stress transfer plays a major role also in generating aftershock sequences (Craiu et al., 2022a).

A few studies dealt with the source properties for the earthquake sequences recorded recently in Romania (Oros et al., 2020b; Placinta et al., 2021).

Seismic source scaling properties, seismicity clustering and geometrical alignments have been investigated in correlation with the tectonics, geodynamics and other

geophysical properties (Supino et al., 2020; Petrescu et al., 2021; Czirok et al., 2022). Possible coupling between the Vrancea subcrustal seismic activity and shallow seismicity in the overlying crust has been explored in a few studies. A lot of discussion has been addressed to issues related to the geotectonical models in order to explain the particular seismic activity at the South-Eastern Carpathians arc bend: oceanic slab detachment, continental delamination, deep and unstable gravitational root, etc., and their consequences on crustal movements, orogen features, magmatism, subsidence, heat flow and gravity.

The catalogue of the fault plane solutions has been updated and several investigations have been performed in order to constrain the stress field characteristics in connection with the seismogenic areas (Bala et al., 2019a; 2019b; 2020a; 2020b; 2021a; Craiu et al., 2019, 2022b; Czirok et al., 2022; Oros et al., 2020b; 2021a; 2021b; 2021c; 2022; Radulian et al., 2019b).

One of the main targets of the NIEP is to model the influence of the seismic source on seismic hazard distribution and to simulate the strong ground motion characteristics in dense-populated areas of Romania, and first of all in Bucharest. The relative deconvolution methods, like spectral ratios or empirical Green's function deconvolution were applied to retrieve the source parameters. Implications of the source directivity and focal depth effects upon the strong ground motion distribution have been analysed as well.

1.2.4. Wave propagation and structure modelling

The seismic wave propagation is the main factor which controls the shape and amplitude of the ground motion as recorded at the Earth's surface. Modelling the propagation of seismic waves through complex three-dimensional structures is one of the most difficult challenges in seismology.

The lateral inhomogeneities in the lithosphere and the local geology beneath the site are critical in shaping the ground motion distribution and subsequently in mapping the seismic hazard.

The analysis of travel times for different body wave phases provides the basic information related to the seismic wave path trajectory and velocity of propagation from the earthquake focus to the observation point. Relative techniques are applied as well, using double-differences and waveform cross-correlation for large sets of earthquake recorded data. S to P converted waves, as recorded by the Romanian seismic network, were investigated to determine the crustal thickness in the SE Carpathians arc bend area (Borleanu et al., 2021a).

Seismic tomography using local body wave travel times was carried out to determine three-dimensional velocity structure beneath Romania territory. Of special interest was the tomography imaging of the Vrancea subducting zone and its neighbourhood. P- and S-wave tomography illuminates a well-defined high-velocity body dipping almost vertically, where intermediate-depth earthquakes are generated. However, the extension of investigation to the west and north shows possible deep lithospheric roots in the South-Eastern Carpathians back-arc region as well. They were

tentatively put into correspondence with magmatic activities which are still active there.

Examples of profiles obtained by high-resolution tomography investigations are given in Figure 20.

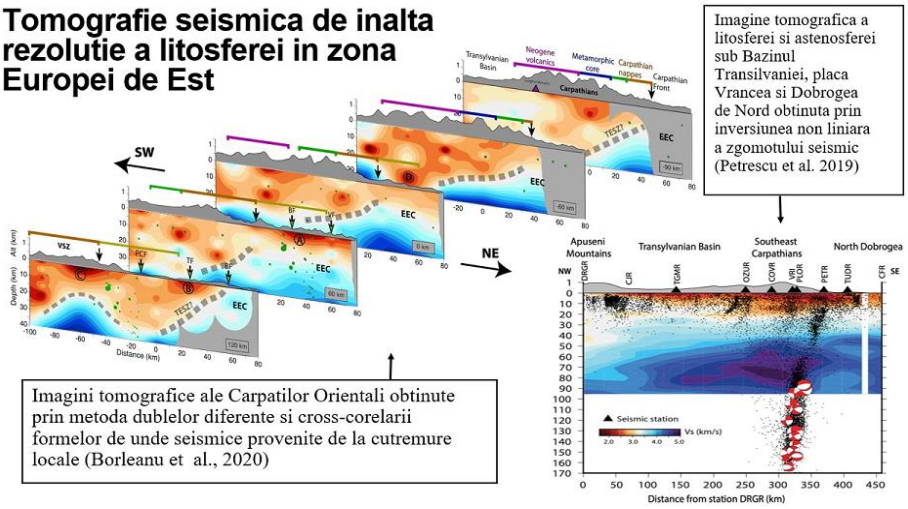

Figure 20: High-resolution tomography profiles in the Eastern Carpathians and crossing Vrancea region.

The seismic wave attenuation has been investigated using modal summation technique to model the complete synthetic waveforms. This technique has been developed within the Department for Earth Sciences of Trieste for one-dimensional and two-dimensional structural models (Ardeleanu et al., 2022). The spectral-ratio method has been applied as well to determine lateral variations in seismic wave attenuation. Scattering and absorption properties of the seismic waves coming from the Vrancea subcrustal source are investigated using coda waves (Borleanu et al., 2021b). Figure 21 shows the results obtained by Ardeleanu et al. (2022) for the attenuation of seismic waves along some crustal profiles that cross the Vrancea region and the adjacent extra-Carpathian area, carried out using local recordings of small crustal earthquakes.

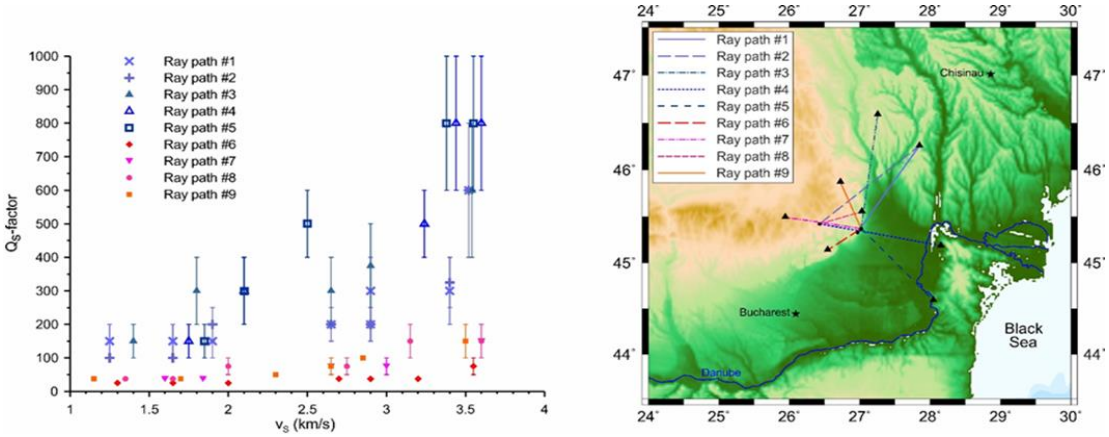

Figure 21: Q factor vs shear wave velocity for the study crustal profiles (Ardeleanu et al., 2022).

The data recorded during long-range seismic experiments in Romania along different refraction profiles or by other temporary networks provide important additional information on specific wave propagation (Mihai et al., 2022). They were designed mostly to investigate the Vrancea region but extended also recently to the west, in the Carpatho-Pannonian region (South Carpathian Project, in cooperation with the University of Leeds).

The receiver functions technique is a tool frequently used to determine the crust and upper mantle structure at regional and global scale. P- and S-wave receiver functions are computed at the broadband stations of the Romania network to estimate vertical structure in the crust and upper mantle (Bala and Toma-Danila, 2019; Besutiu et al., 2019).

A tomography map of the lithosphere in the Black Sea area obtained by Petrescu et al. (2022a) using ambient noise is represented in the Figure 22.

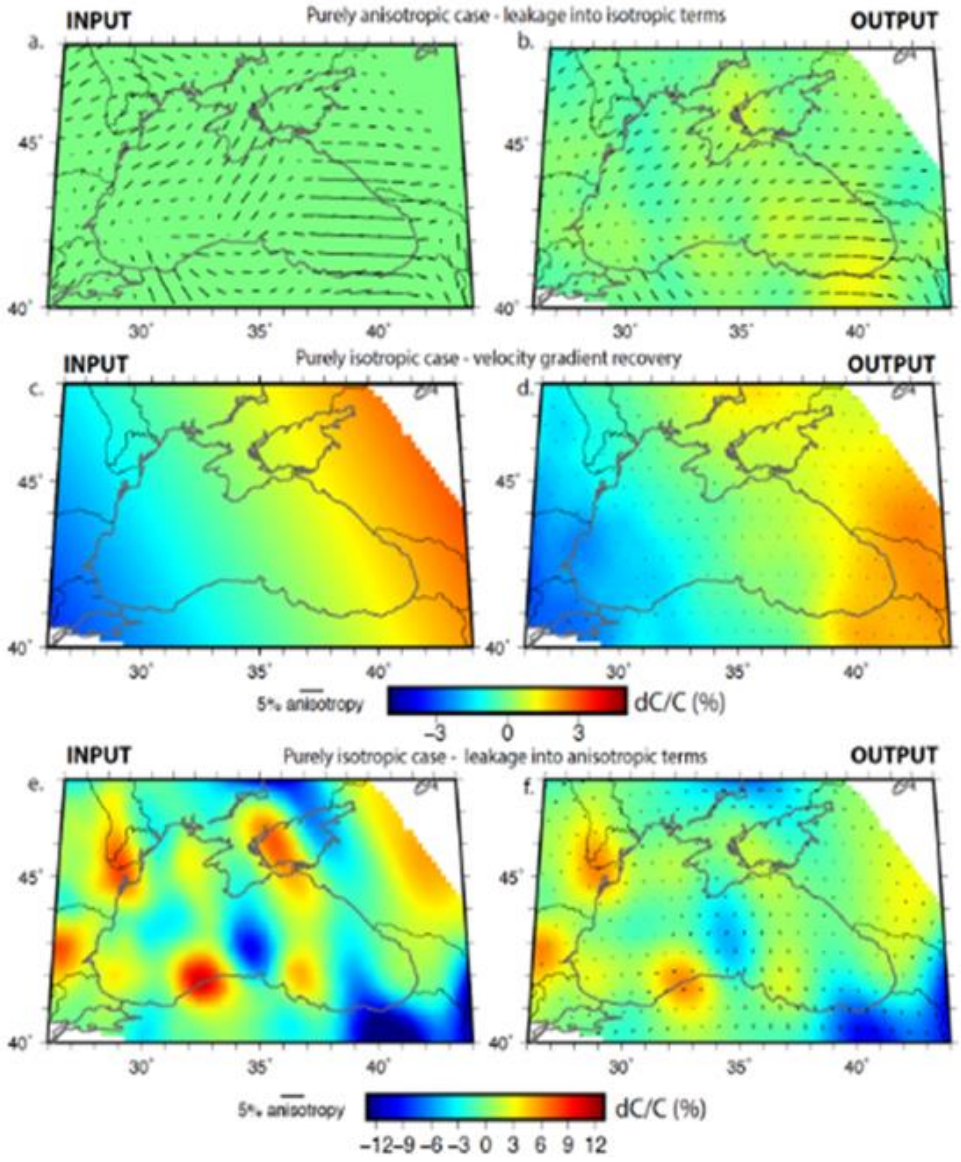

Figure 22: Structural map of the lithosphere in the Black Sea area obtained using transdimensional ambient noise tomography (Petrescu et al., 2022b)

For the study of surface geology, analysis methods based on seismic noise data and data recorded during earthquakes were used. The inversion of H/V curves and the combined inversion of H/V curves and Rayleigh wave dispersion were applied to determine the bedrock topography (Coman et al., 2020; Manea et al., 2019; 2020; 2021 - Figure 23).

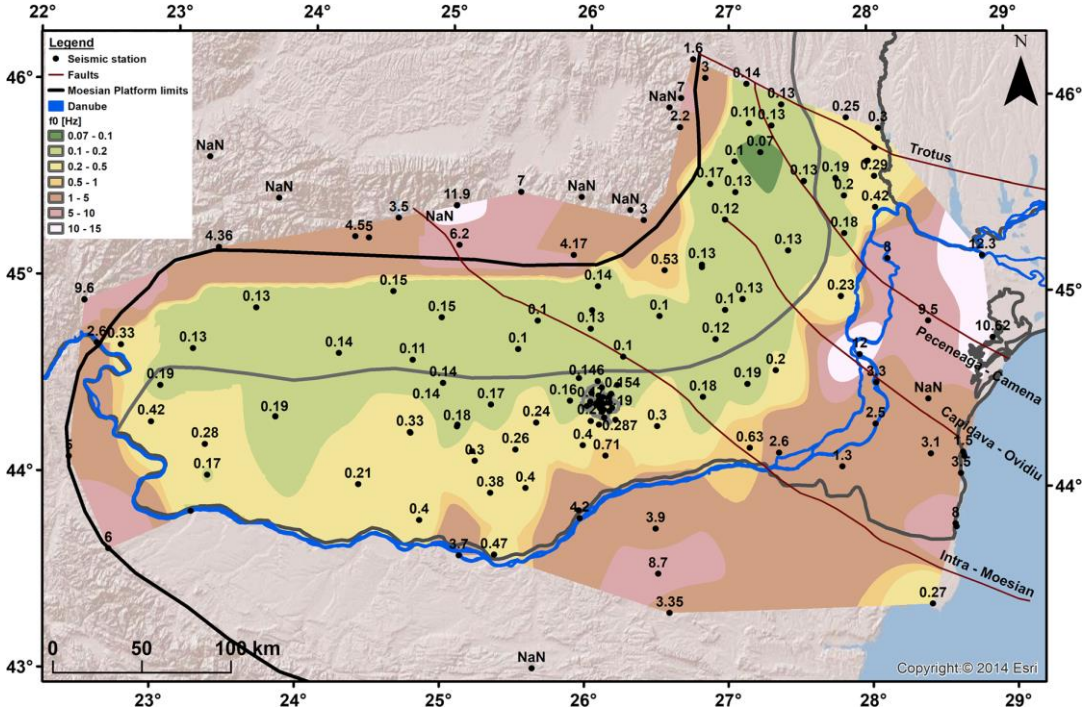

Figure 23: Distribution of fundamental frequencies over the entire Moesian Platform area (Manea et al., 2020).

Anisotropy properties in the seismic wave propagation provides important new information and constraints in the seismotectonic modelling of the Vrancea region (subduction, flow pattern in the upper mantle, slab delamination etc.). Shear-wave splitting is a powerful diagnostic of anisotropy that has been used to detect mantle fabric and flow beneath the Vrancea seismic region. This kind of investigation is fundamental for understanding thermal structure in the upper mantle, slab dehydration, melt generation and transport, and slab dynamics. Both SKS and SKKS broadband teleseismic shear waves were analysed in order to investigate mantle and crust anisotropy properties over country territory (Petrescu et al., 2020a; 2020b). Shear wave splitting led to delay times up to 2 s and is highly variable with a marked change of the fast direction from perpendicular to the Carpathians Arc in the foredeep region to a parallel direction in the Vrancea epicentral area. It was assumed that the anisotropy is caused by specific flows induced by the particular geometry of the lithosphere body descending in the upper mantle.

Another approach to investigate the crustal seismic-velocity structure that has been applied in the last years is the use of surface wave dispersion and the ambient-noise cross-correlation. For pairs of stations the Green's function is computed by cross-correlating long and multiple time series currently recorded by the seismic network. The method takes advantage of avoiding the often highly nonuniform and sporadic

distribution of earthquakes and of the increased density of stations after the recent seismic network improving (Petrescu et al., 2019; 2022b).

1.2.5. Seismotectonics

Several new models of the seismotectonics in the Vrancea seismic region were proposed in the last years. Other studies were focused on the correlation between seismotectonics, earthquake focal mechanism, structure of the deep crust in the seismic active zones of the Carpathians foredeep, Dobrudja and Southern part of the Transylvanian depression (Ducea et al., 2020; Kovacs et al., 2021). Efforts were made to relate crustal seismicity patterns to active faults morphology following the procedure proposed in the SHARE project (Diaconescu et al., 2019a; 2019b; 2019c; 2021a).

Focal mechanism solutions were analysed in order to determine the stress field and to correlate with the seismicity.

Implications of paleomagnetic research on seismotectonics in the Carpathians region were studied.

Main research directions:

- Lithosphere structure at regional and local scale;
  Structure of the lithosphere in Romania; Moho depth in Romania
  New models at the geologic and tectonic scale.
- Dynamics of the lithosphere by complex interpretation of the actual movements of the crust; physical properties of the rocks.
- Studies of the crustal seismicity, seismotectonic models associated and assessment of the dynamic properties of the crust.
  Crustal seismicity
  Seismotectonic models
  Assessment of the dynamic properties of the crust in Romania
  Improvement of seismic hazard assessment;
  Reduction of seismic risk

In the last years, several studies about the natural hazard at a local scale were performed.

- Microzonation studies (local seismic hazard) of densely populated areas
  Site effects analyses;
  Advanced methodologies in processing of seismic refraction data;
  Share wave seismic velocity determination in Bucharest
  Local seismic hazard with special view to the Bucharest area.

Subjects as dynamics of the lithosphere are also followed and study of the movements of the crust using GPS and satellite methods.

1.2.6. Hazard assessment

1.2.6.1. Seismic hazard

The seismic hazard assessment is a crucial step towards mitigation of urban earthquake risk and improvement of disaster prevention management. A permanent threat for urban areas on the Romanian territory and extended areas in Europe

comes from Vrancea intermediate depths destructive earthquakes. Bucharest is among the megacities mostly affected by those large earthquakes. Extensive studies concentrate on the characterisation of the macroseismic field of Romanian earthquakes, such as Vrancea intermediate-depth events and also crustal earthquakes, from Romania. The earthquakes from Romania and adjacent areas are documented for a millennium (since 984 a.c.) and represent very peculiar characteristics. The seismic hazard was evaluated using probabilistic and deterministic approaches for all seismogenic sources from Romania.

To apply the probabilistic approach, attenuation laws corresponding to Vrancea earthquakes were empirically determined in terms of macroseismic intensity and peak ground acceleration and a maximum magnitude value was prescribed (Constantin et al., 2019; Marmureanu et al., 2020; Moldovan et al., 2019b; Oros et al., 2019c; Placinta et al., 2020). The seismic hazard assessment in dense-populated geographical regions and subsequently the design of the strategic objectives (dams, nuclear power plants, etc.) are based on the knowledge of the seismicity parameters of the seismogenic sources which can generate ground motion amplitudes above the minimum level considered risky at the specific site and the way the seismic waves propagate between the focus and the site. Extremely vulnerable objectives, like large cities, hydro-energetic dams (Constantin et al., 2020; Placinta et al., 2020) or nuclear power plants, are present all around Romania, and not only in the Vrancea intermediate earthquakes action zone. The best example is the western part of Romania that is not affected by Vrancea intermediate-depth earthquakes and where the crustal seismicity is high. In this part of the country are cities like Timisoara, Arad and Oradea and the "Portile de fier I and II" hydro-energetic dams.

The complete set of information required for a probabilistic assessment of the seismic hazard in Romania relative to the crustal and intermediate-depth sources have been obtained: (1) geometrical definition of all seismic sources affecting Romania - Figure 24, (2) estimation of the maximum possible magnitude, (3) estimation of the frequency magnitude relationship, (4) estimation of the attenuation law and, finally, (5) computing PSH with the algorithm of McGuire – Figure 25.

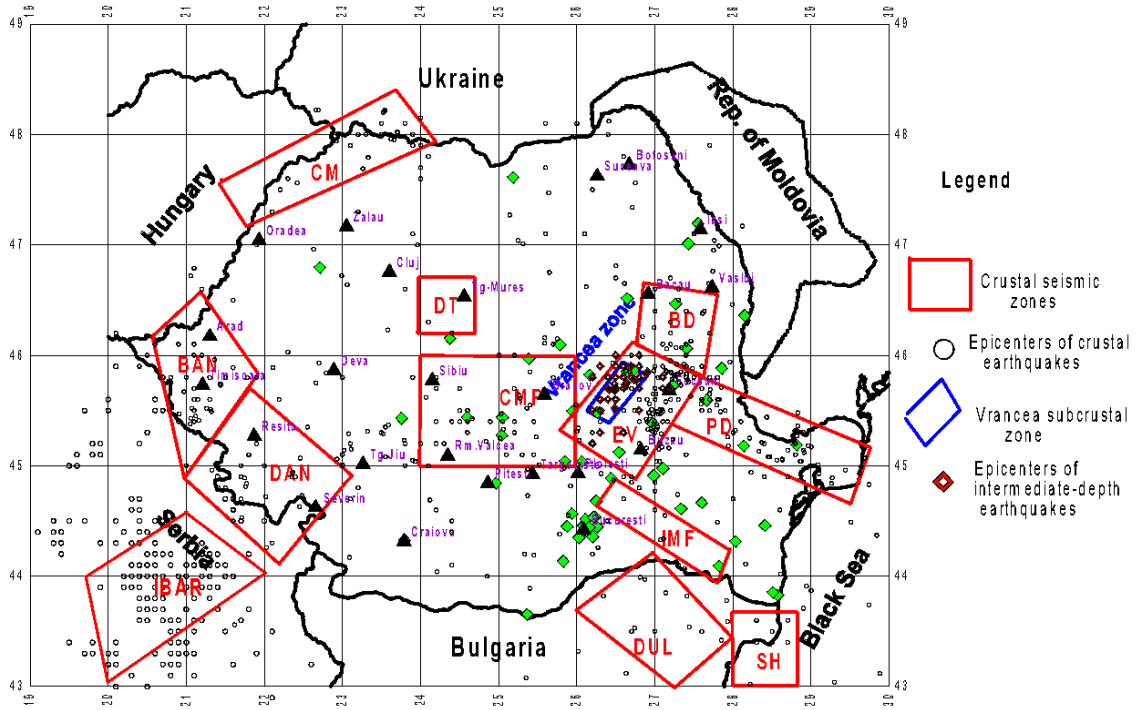

Figure 24: Seismic crustal and intermediate active zones in Romania and adjacent areas and their characteristics

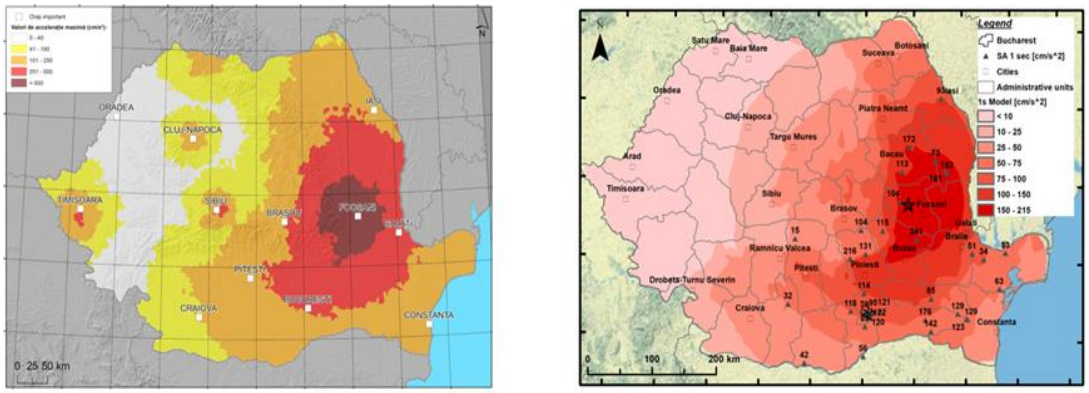

Figure 25: Hazard maps for Romania considering all the seismic sources (left) and for a single Vrancea event of magnitude 6.9 (30 May 1990) (right) (Manea et al., 2021)

Recent advances in computer technology make possible the use of the deterministic numerical synthesis of ground motion for seismic hazard calculations. The deterministic approach is completely different and complementary to the probabilistic approach. It addresses some issues largely overlooked in the probabilistic approach: (a) the effect of crustal properties on attenuation are not neglected; (b) the ground motion parameters are derived from synthetic time histories and not from overly simplified attenuation "functions"; (c) the resulting maps are in terms of design parameters directly, and do not require the adaptation of probabilistic maps to design ground motions; (d) such maps address the issue of the deterministic definition of ground motion in a way which permits the generalization to locations in which there is little seismic history.

A review of up-to-date seismic hazard studies is envisaged with emphasis on the complex physics-based waveform modelling method (Neo-Deterministic Seismic Hazard Analysis), as an application to national and local scales, in order to deliver a powerful input to risk analyses for Romania. Applied on national scale, NDSHA realistically reproduces the macroseismic field of Vrancea intermediate-depth events while on local scale, the observed and the synthetic signals displaying similar features (Cioflan et al., 2020; 2022).

1.2.6.2. Other geohazards

Besides earthquakes, other geohazards or geological hazards are events caused by geological features and processes that present severe threats to humans, property and the natural and built environment (landslides, volcanoes, avalanches, and tsunamis are typical examples of such events). A permanent target of NIEP is to characterise geohazards and their impact in Romania and neighbouring countries and to develop efficient alert systems (Marmureanu et al., 2019).

Recently, NIEP is participating within the FP7 project "Assessment, STrategy And Risk Reduction for Tsunamis in Europe - ASTARTE" (FP7 ENV.2013.6.4-3, Grant agreement no: 603839) and to the JRC program Global Tsunami Informal Monitoring Service (GTIMS). A few related results on tsunami monitoring and modelling scenarios for the Black Sea have been obtained (Diaconescu et al., 2020; 2021b; Partheniu et al., 2019a; 2019b).

1.2.7. Earthquake forecasting

The failure in predicting the strong recent earthquakes (California, Japan, Haiti, Turkey) drew attention to the serious limitations of the standard earthquake prediction methods and at the same time provoked seismologists to look for new approaches to this extremely complex problem.

Vrancea seismogenic zone is a conspicuous active area in terms of its extraordinary seismotectonic features, outstanding persistent and highly recurrent seismicity displaying a remarkable regularity in occurrence of large events and manifestation of a plethora of geophysical precursors and severe socio-economic impact with a huge felt area.

Extensive analyses in order to detect premonitory changes in seismicity patterns as possible precursors of the Vrancea strong shocks were performed for past and future earthquakes. Analysis and discussions of a variety of precursory seismicity patterns belonging to all temporal developmental stages of the preparatory geophysical process leading to the major Vrancea earthquake of August 30, 1986 were performed and documented, clearly proving that the earthquake would not have been unexpected.

Different algorithms, like CN and the geostatistical method were applied to predict the strong Vrancea earthquakes. The CN algorithm has been initially created for the retrospective analysis of the seismicity patterns which precede the strong earthquakes within California-Nevada regions. The algorithm has been modified so that it can be applied, without any parameters adjustment, for all the seismic regions

in the world. The method consists in analysis of a set of precursory phenomena reflected in the temporal evolution of the seismicity recorded in the earthquake catalogue. Although it was firstly conceived for crustal events, the CN algorithm can be also applied for prognosis of the intermediate earthquakes. The results are different depending on the seismic region which is under study. Thus, in case of Vrancea and Sicily regions where the paleosubduction is one of the possible interpretations, the results are positive (in case of Vrancea the strong earthquakes from 1977, 1986 and 1990 have been predicted), while for intermediate earthquakes within the regions where the subduction is still active, the algorithm can not be applied.

It has been recently experimented the electromagnetic and infrasonic methods to predict Vrancea intermediate-depth earthquakes and look for seismo-electromagnetic and infrasonic precursors. NIEP operates a real-time geomagnetic, electric, electromagnetic VLF/LF and infrasonic network (named The Romanian Electromagnetic Field and Infrasound Monitoring Network - MEMFIS) consisting of 6 stations, 4 of them centred in the Vrancea seismic zone and 2 of them outside the seismogenic zone (Figure 26).

The geophysical data (geomagnetic, electric and infrasonic data) are transmitted in an ASCII format, from the stations to the data centre, using the TCP/IP protocol. The time resolution is given by the chosen sampling rate, and the accuracy is of +/- 1µs; the measurement resolution is of 24 bits. The data transfer rate is minimum 0.5 Mbits/s. The Romanian data centre collects geomagnetic data from all stations of the real-time INTERMAGNET network.

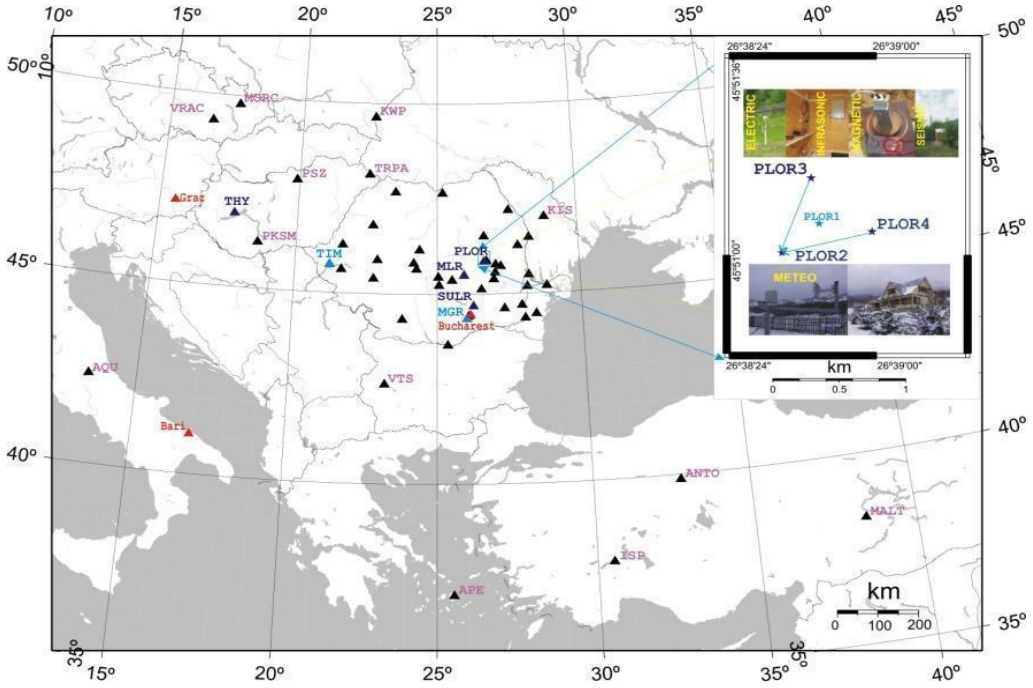

Figure 26: The Romanian seismic (black triangles) and geophysical network (blue and light blue triangles). On the figure are also marked the seismic stations that assure the real time seismic international data exchange and the THY Intermagnet station. In the upper right corner is presented the new Plostina geophysical network comprising seismic, magnetic, electric and infrasonic sensors

The Romanian Electromagnetic Field and Infrasound Monitoring Network (Table 2) is equipped with 4 triaxial fluxgate magnetometers (Bartington – Figure 27), with seismic sensors in each monitoring site, with 3 infrasound stations – MBAZEL2007 (Figure 27) and 1 Chaparral Infrasound sensor (Figure 28), 1 electrometer measuring the vertical atmospheric electric field - Boltek EFM100 (Figure 27) and one meteorological station –La Crosse WS-3600 (Figure 29).

Table 2: The geophysical observatories
from the Romanian Electromagnetic Field and Infrasound Monitoring network

Observatory Code	Equipment	Latitude	Longitude	Altitude (m)
MLR	Seismic/magnetic	45.49N	25.95E	1360
SURL (SRL)	Seismic/magnetic	44.68N	26.25E	97
PLOR2	Seismic/magnetic +/-100uT /infras+/-50PA	45.8502N	26.6438E	694
PLOR3	Seismic/magnetic +/-100uT /infras+/-50PA	45.8539N	26.6455E	708
PLOR4	Seismic/vertical electric +/-20kV/m Boltek/infras MBAZEL2007+/-50PA / infras Chaparal/meteo	45.8512N	26.6499E	656
AZEL	VLF-LF/ meteo/ infras +/-50PA	44.3548N	26.0282E	76
Dobrudja Observatory	VLF-LF/meteo/vertical elctric Boltek	44.0750N	26.6325E	23

Figure 27: An outer image of PLO3 site and some of the equipment that is involved.in the monitoring process: Data Acquisition System, Microbarometer MBAZEL2007, Triaxial Fluxgate Magnetometer MAG-03MS. The Electric Field Monitor EFM-100 is installed at PLO4, in the vicinity of the Weather Station WS-3600.

Figure 28: The Chaparal infrasound sensor located at Plostina main building (PLO4)

Figure 29: A part of the meteorological station installed at PLO4

The monitoring sites are located in the Vrancea seismic zone (Figure1) and one of them is located near Bucharest, outside the epicentral area. The geophysical database consists of more than 10 years of geomagnetic recordings at Muntele Rosu Observatory and in one year of multiple geophysical recordings (magnetic, electric and infrasonic) at Plostina Observatory - PLO2, PLO3 and PLO4.

Starting with March 2009 the **Romanian Electromagnetic Field and Infrasound Monitoring Network** was enhanced with VLF and LF antennas (Figure 30) and one Elettronika receiver (offered by Prof. P.F. Biagi - Department of Physics, University of Bari, http://beta.fisica.uniba.it/infrep/GroupsEU/ROM/Research.aspx) and is operating in the Dobruja Observatory (Table 2). The amplitude and phase data are collected with a 60 s sampling interval.

Figure 30: Magnetic VLF and LF antennas installed on the roof of the Dobrudja Observatory

During the geophysical monitoring of the Vrancea area there have been noticed a number of anomalies that have been identified to be in correspondence with local tectonic, atmospheric and space global phenomena. Some possible anomalous animal behaviour prior to the Vrancea strong earthquakes was investigated as well.
The results of several projects have been integrated into a precursor factor monitoring network with results that can be applied in the field of climate change effects. The multidisciplinary monitoring stations of INFP record the changes of geophysical, geochemical and geo-hydrological parameters as an effect of tectonic stress. The main purpose is to identify seismic precursor specific to tectonic fault zones. The result is the growth of the seismic alert service through: perfecting risk evaluation, seismic forecast, informing the decision factors regarding the impact minimization of natural disasters and the education of the population.
Only a multidisciplinary activity can estimate if a prognosis of a future seismic event is valid. The multidisciplinary monitoring network includes at present monitoring of gas emissions (radon and CO_2), geochemical parameters, geomagnetic, electric, electromagnetic - ULF, VLF and LF -, infrasonic and acoustic, borehole temperature, air ionization, telluric currents) in correlation with tectonic, atmospheric, ionospheric or solar fields (Biagi et. al 2019; Mihai et al., 2019a; 2019b; 2019c; 2021; Toader et al., 2019a; 2019b; 2020; 2021a; 2021b; 2021c; Galiana-Merino et al., 2022) to highlight the correlation of their variation with different natural and artificial, local and global phenomena (e.g. magnetic storms caused by solar activity or anomalies related to tectonic activity) (Biagi et al., 2019; Nicolae et al., 2019). Table 3 presents the structure of stations and the equipment. Each monitoring location is on a fault with a known geological structure (Figure 31). An example of a monitoring station is in Figure 32.

Table 3. Sensor types for station locations

Station	Location	Sensors
BISR	Bisoca	Seismic velocity-acceleration, acoustic, radio ULF, inclinometer, radon, air temperature, pressure and humidity, CO_2/CO
LOPR	Lopatari	Acoustic, inclinometer, radon, air temperature, pressure and humidity
NEHR	Nehoiu	Seismic velocity-acceleration, acoustic, ionization, meteorological station, inclinometer, radon, air temperature, pressure and humidity, CO_2
MLR	Muntele Rosu	Seismic velocity-acceleration, acoustic, inclinometer, radon, air temperature, pressure and humidity, magnetic field, X, Y, Z
COVR	Covasna	Seismic velocity-acceleration, radio ULF
PLOR4	Plostina	Seismic velocity-acceleration, acoustic, infrasound, meteorological station, ionization, telluric field, air electrostatic field, inclinometer, air -ground – borehole temperature, radon, CO_2/CO
PLOR7	Plostina	Seismic velocity-acceleration, radio ULF, video camera for clouds, radiometer for solar direct and reflected monitoring (long and short waves)
VRI	Vrancioaia	Seismic velocity-acceleration, air - ground acoustic, radio ULF, infrasound, ionization, telluric field, solar radiation (pyranometer), ground temperature, meteorological station, air electrostatic field, scalar magnetic field, video for clouds, radon, air temperature, air pressure and humidity, CO_2/CO
ODBI	Odobesti	Seismic velocity-acceleration, acoustic, radio, telluric field, borehole temperature, meteorological station, radon, air temperature, pressure and humidity
PANC	Panciu	Seismic velocity-acceleration, radio ULF

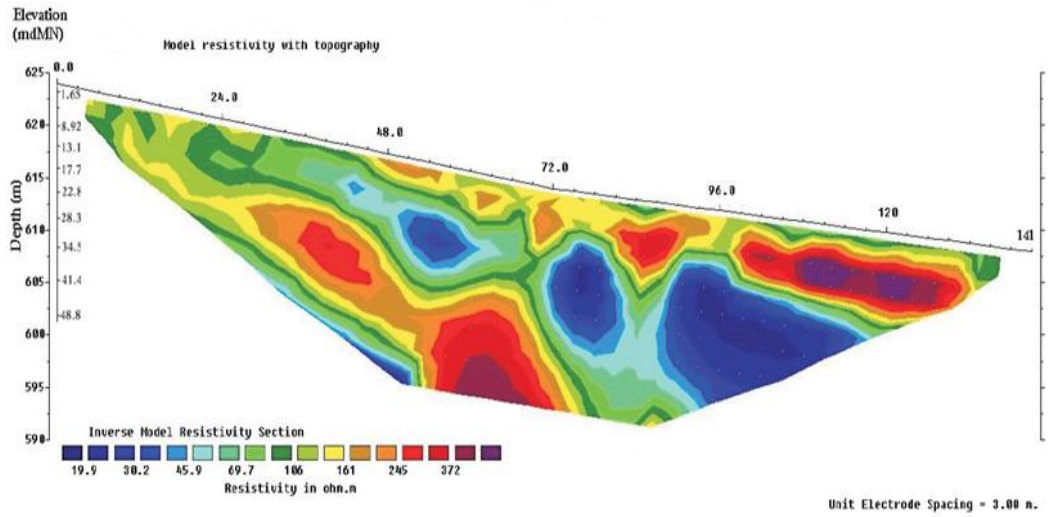

Figure 31: Electrical tomography, Plostina site PLOR4

Figure 32: VRI monitoring station

The multidisciplinary network offers:

- On-line information from ground multidisciplinary monitoring stations installed inside and outside seismogenic zones, equipped with: seismic, geomagnetic – telluric and vertical electric field, acoustic (high frequency and infrasound), radio ULF/VLF/LF;
- Off-line information on Radon, meteorological, air ionization, CO_2, vertical temperature profile of a borehole, radiometer for solar radiation direct and reflected, clouds monitoring with video camera, lighting detection and animal anomaly behaviour from online reports from the country;
- Own designed software for data acquisition, visualization and analysis;
- Possibility to extend the multidisciplinary monitoring stations with more improved and new sensors types (like borehole temperature, radon, CO + CO_2).
- Experience in earthquakes forecast based on precursors factors;
- Experience in providing seismic information to other organizations (e.g. EPOS – ORFEUS), experience that can be used in the project for geophysical data sharing among partners.
- Long term experience in interaction with authorities, intervention and decision factors.

The procedures are based on methods for assessing the time-dependent seismic hazard (Figure 33) and are complemented by seismic data analysis. The cumulative energy method is used, the bits of the Gutenberg-Richter law, the tectonic stress, the breaking area and the correlation with the seismic breaks.

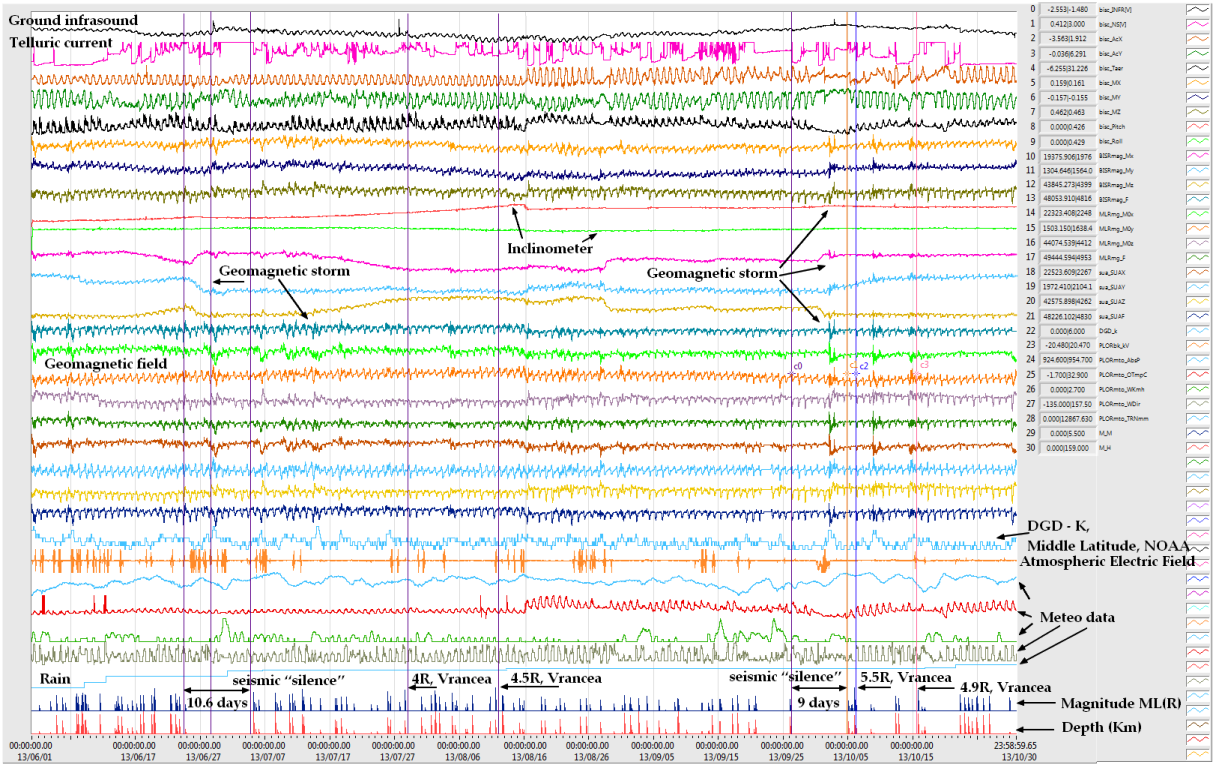

Figure 33: Analysis software for seismotectonic precursor phenomena

A virtual platform has been recently implemented for collecting, processing and disseminating seismic and geophysical parameters time evolution providing real-time information for a large number of potential beneficiaries (https://ph.infp.ro/). Monitoring of possible precursors is published on the GEOBS page (Toader et al., 2022, "geobs", Mendeley Data, V2, doi: 10.17632/28kv3gsgcz.2 - http://geobs.infp.ro/).

1.3. ENGINEERING SEISMOLOGY

The evaluation and mitigation of the seismic risk is one of the permanent and urgent problems facing Romanian society, equally implying work of seismologists, geologists and engineers. Significant efforts were made to predict the peak values and spectral characteristics of the strong motion in large urban areas, like Bucharest. Scientific research directions are oriented toward improving anti-seismic design standards, engineering applications for hazard assessment and seismic risk mitigation, highlighting the nonlinear effects of the behaviour of degraded rocks under strong seismic movement and experimental studies on dynamical devices. Applicative and theoretical studies of engineering seismology are developed, accounting for nonlinear effects in the ground-structure interaction, and the behaviour of the spectral parameters of the soil-structure system during strong earthquakes (Balan et al., 2020a; 2020b; 2021; Apostol et al., 2022a). The aim of these activities is to improve and complete the microzoning studies related to the Bucharest Metropolitan area and other areas of the country, to collaborate in achieving standards in the field of zoning territory and seismic local seismic hazard assessment

of densely populated localities and to highlight the destructive seismic potential of major earthquakes in large urban localities (Bala et al., 2021b; 2021c; Coman et al., 2021; Manea et al., 2022; Marmureanu et al., 2021b; Toma et al., 2022a). The activity is also carried on in characterising the severity of ground movement in a given location and to undertake seismic risk studies for urban areas, industrial structures and transport networks (Toma et al., 2020).

The modal summation method and finite differences technique were applied to calculate the expected ground motion in Bucharest due to large intermediate-depth Vrancea earthquakes. The results outlined that the presence of alluvial sediments and the possible variation of the event scenario require the use of all three components of motion for a reliable determination of the seismic input. The local site amplification was computed for the Bucharest city and provides very useful quantities to study the local effects in the frequency domain. In the context of Vrancea seismicity, the innovative NDSHA has proved to be very efficient and provides a consistent estimate for engineering design and risk assessment (Cioflan et al., 2022).

A special attention was given to the testing of seismic ground motion prediction models (GMPM) for intermediate earthquakes as well as for crustal earthquakes (Solakov et al., 2021). The database required for crustal tests is still under development, but for the Eastern and South-Eastern regions of the country, results obtained together with an international team have already been presented (Manea et al., 2022, 3ECEES-2022).

Study of dynamic parameters of soils by using resonant columns and geophysical methods, realistic modelling of seismic input taking into account source, wave path propagation and local site effects have been permanent tasks for Romanian seismologists and important outcomes for seismological engineers. Laboratory analyses were made also to determine the attenuation effects for surface layers and its dependence on the strain level induced by large earthquakes.

The role of the non-linear effects in the local site response has been the subject of several studies outlining their important contribution to the strong motion in Bucharest area. This will be a challenge for seismological research in the next years.

Activities carried out within the Laboratory of Engineering Seismology of NIEP were focused on:

- assessment of local seismic effects by non-deterministic seismic hazard methods
- determination of ground motion models (GMPE-ground motion prediction equations)
- studies on the seismic vulnerability of structures
- near real time seismology – the PAGER module of SeisDaRO and estimation of direct losses (residential buildings and affected population) immediately after the earthquake
- non-invasive investigations of the local sedimentary structure (evaluations and mapping of fundamental periods, sedimentary velocity models, bedrock depth)
- studies on non-linear behaviour of soils and site response
- studies on base isolation

- risk assessment methodology at national level; estimation of direct damage to the transport infrastructure; classical deterministic hazard scenarios (with mitigation law) as input for the assessment of exposure, vulnerability and risk
- monitoring of the building performance to seismic action
- modernization of design codes

The aim was to achieve fundamental knowledge in the field of Earthquake Physics and pursue practical applications in domains of social and economic interest. The main point of research is specific to engineering seismology and the evaluation of the seismic risk and hazard on the territory of Romania, associated especially to the Vrancea seismic region. The basic method for achieving this objective was the scientific study of the earthquakes, by using both theoretical physical models and the analysis of the data provided by the recordings of the seismic monitoring network of Romania.

The vulnerability studies were carried out essentially in analytical terms. Two main subjects were dealt with:

- Analysis of evolutionary vulnerability, mainly as a consequence of the cumulative effects of successive earthquakes;
- Vulnerability and risk analysis of multi-location systems, like lifelines, railway networks etc.

The studies on modernization of codes were intended mainly to adapt the codes for practice to the outcome of more consistent techniques of control of structural safety.

The buildings performance to seismic action is assessed using data from seismic sensors installed in structures and information regarding design. The rapid estimation of damage generated by a strong earthquake in Romania, in terms of affected buildings and socio-economic losses can be performed within a system that involves representative building typologies and methodology for ground motion estimation (Balan et al., 2019a; 2019b; 2022; Toma et al., 2022b; Țiganescu et al., 2019; 2021a; 2021b; 2021c; 2022a; 2022b; Ozcebe et al., 2022).

Within the TURNkey Project (2019 - 2022), financed by the European Union, NIEP contributes, along with important external partners, to the development of an innovative platform devoted to structural monitoring, using low-cost sensors (Raspberry Shake 4D), which were installed in typologically representative buildings in Bucharest (Figures 34 and 35). This platform was intended to facilitate the connection of other stakeholders. The system is very useful to civil engineers for tracking the structural behaviour over time and recommending consolidation measures. In the case of retrofitted structures, the system can validate the impact of the intervention. In case of structures equipped with seismic protection systems (base isolation, seismic dampers), the system can facilitate the evaluation of their performance (Țiganescu et al. 2020; 2022a; 2022b). An important part of the project results were presented and published in the "3rd European Conference on Earthquake Engineering & Seismology (3ECEES)", Bucharest, 2022, at which NIEP was a co-organizer.

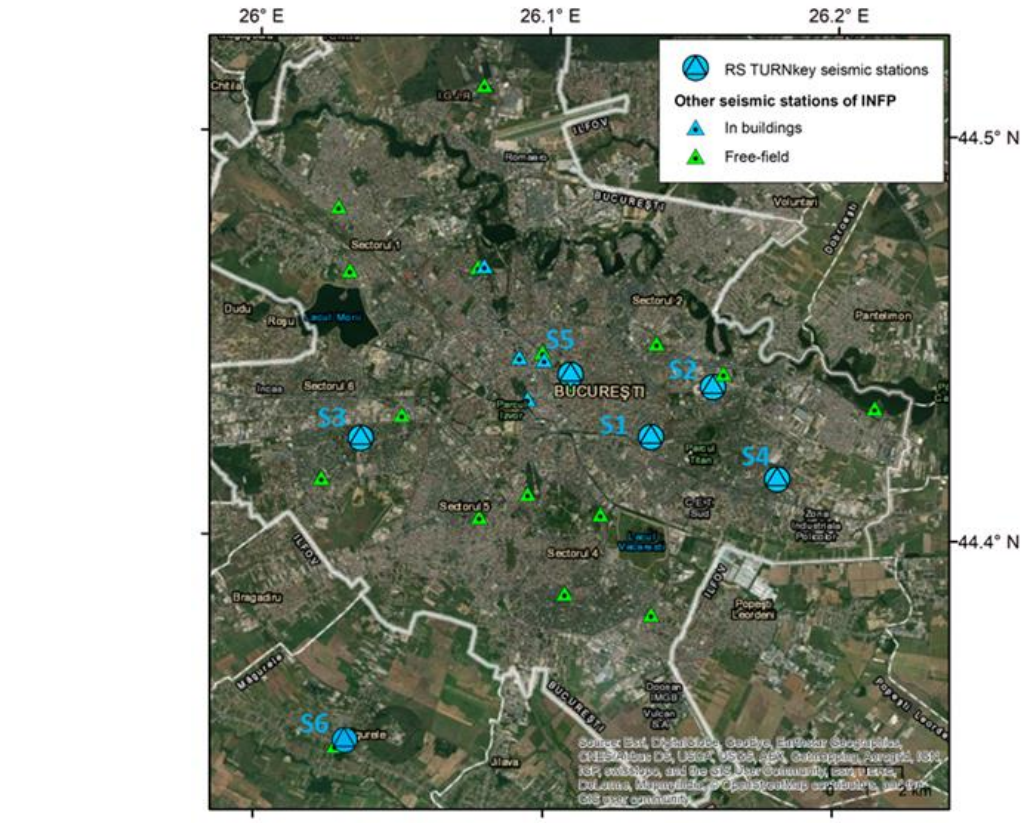

Figure 34: Location of the buildings in Bucharest monitored within TURNkey project.

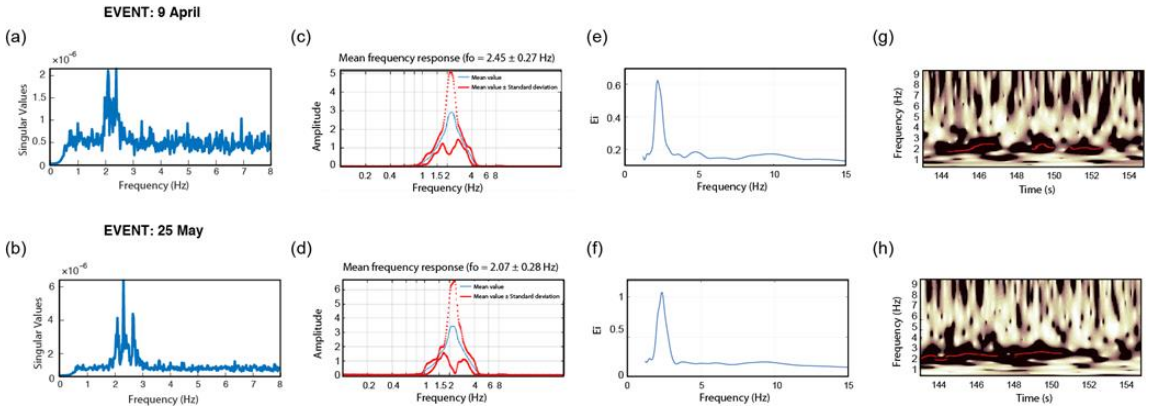

Figure 35: Examples of analysis carried out for recordings of sensors installed in buildings for two Vrancea earthquakes (9 April 2021 and 25 May 2021).

In order to take advantage of the Romanian Seismic Network that nowadays has more than 150 seismic stations in real-time, since 2006 NIEP implemented the ShakeMap software (developed by USGS) that enables the automatic generation of maps and data for instrumental intensity, PGA, SA or PGV. These outputs are highly important for authorities and the large public immediately after an earthquake, since they provide geographically hints regarding the possible distribution of effects and areas that have to be investigated. Currently the 3.5 version of ShakeMap is in use. For the Vrancea Area a special ground motion prediction equation (GMPE), developed by Sokolov et al. (2005), was implemented. The overall computation time

is under 8 minutes for an event, for an area between 20°E - 29°E longitude and 43.5°N - 48°N latitude.

The Near-real time system for estimating the seismic damage in Romania, implemented by NIEP in 2011 and currently at version 3 (from 2017), is capable of estimating seismic damage through a PAGER-like module, based on instrumental intensity values, population distribution and coefficients derived from intensity-casualty historical data, at national level, and also through a SELENA module, based on acceleration values, vulnerability curves for 39 representative building typologies in Romania, the Improved-Displacement Coefficient Method and casualty rates and 2011 national census data for residential buildings and residents, at city/commune level (and more detailed for Bucharest). Due to the characteristics of the intermediate-depth Vrancea earthquakes, each of these systems and modules is customized in order to better reflect local specificity. Risk evaluation has been extended to transportation networks in Romania and in Bucharest city (Toma-Danila et al., 2020).

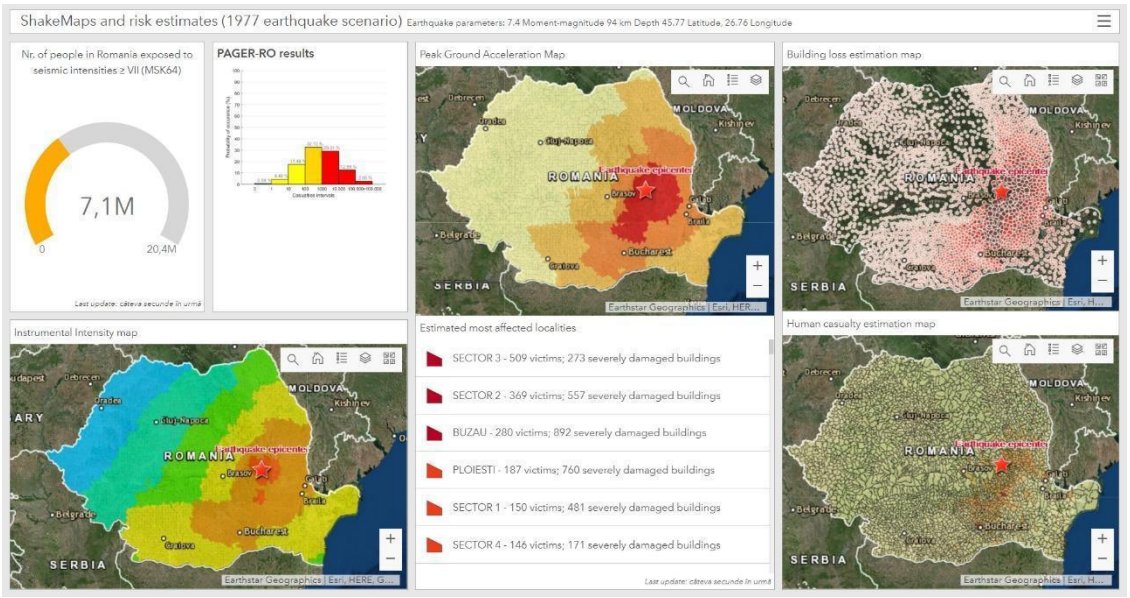

Figure 36: SeisDaRo3 dashboard for an earthquake scenario similar to the 4 March 1977 Vrancea earthquake, revealing the main outputs of this system

Currently, this system uses for building loss estimation the analytical methods (as the Improved-Displacement Capacity Method - I-DCM) implemented within the open-source software SELENA (SEismic Loss EstimatioN using a logic tree Approach), together with HAZUS methods for estimating the human casualties. The building stock is defined through 48 different capacity and fragility curves, depending on construction material, height and age. As hazard data, PGA and SA values obtained through the ShakeMap System and based on real recordings and attenuation relations are used. The area currently analyzed by the system consists of 19 Romanian Counties, capital Bucharest and 9 regions in northern Bulgaria; resolution of the data is at administrative unit (commune or city) level.

This system also enabled the analysis of Bucharest, one of the most vulnerable capitals in Europe due to earthquakes, to an even higher resolution extent, based on

new census data. The recently published results (Crowley et al., 2020; 2021; Toma-Danila et al., 2022a) highlight the need for greater impact mitigation actions, since many casualties are expected to occur during a future major Vrancea earthquake (Figure 36).

In 2021 a new department was established in NIEP: the Laboratory of Applied Geophysics, Prevention and Education. Its purpose is to promote advanced knowledge and modelling of Earth's surface and subsurface processes with applications in exploration, environmental and engineering geophysics. The vision and mission of the laboratory express precisely the desire to approach new directions of applied research, to make use of the latest technologies in the field of monitoring seismic phenomena, data processing and numerical calculation that allow the transfer of research results in specific forms to the beneficiaries. The specific objectives are:

- Development of fundamental and applied geophysical and multidisciplinary research for monitoring processes on the Earth's surface and exploring its subsoil
- Development and modernization of NIEP infrastructure relevant for applied research in the field of geophysics
- Diversification of NIEP's offer of research and development services in the field of Earth Sciences intended for the private environment
- Informing the population about earthquakes and their effects in correlation with the promotion of the field and research results with applicability and impact in minimising the seismic risk

The planned research directions include:

- Geophysical exploration for the shallow structure (down to 5 km). Seismics, electric, electromagnetic and gravimetric techniques are considered. Applications range from microseismicity monitoring, subsurface imaging from seismic noise data, to imaging, modelling and monitoring based on data from natural and controlled sources
- Geophysical investigation at surface (down to 50 m). The objective is to develop tools centred on environmental geophysics studies that aim to understand the natural or anthropogenic processes that take place on the Earth's surface or in its immediate vicinity.
- Monitoring and modelling of the subsoil based on integrated data from geodesy and geophysics. The objective is to establish an integrated continuous iterative optimization procedure, combining geodetic data processing and geophysical modelling.
- Informing the population about earthquakes and their effects in correlation with promoting the field and research results with applicability and impact in minimising seismic risk. The purpose is to increase public awareness of seismic risk and interest in Earth Sciences through specific information, education and training actions tailored to target groups.

Significant results obtained so far within the laboratory refer to:

- ambient noise investigations using low-cost instruments (Raspberry Shake) both for seismic sites characterization and building behaviour (Grecu et al., 2021; Tolea et al., 2021). An example of analysis for recordings of a sensor in a building is given in Figure 37
- development of outreach and educational activities
- site characterization of research infrastructures of national interest through integrated geophysical investigations and optimised methodologies (Figure 38)

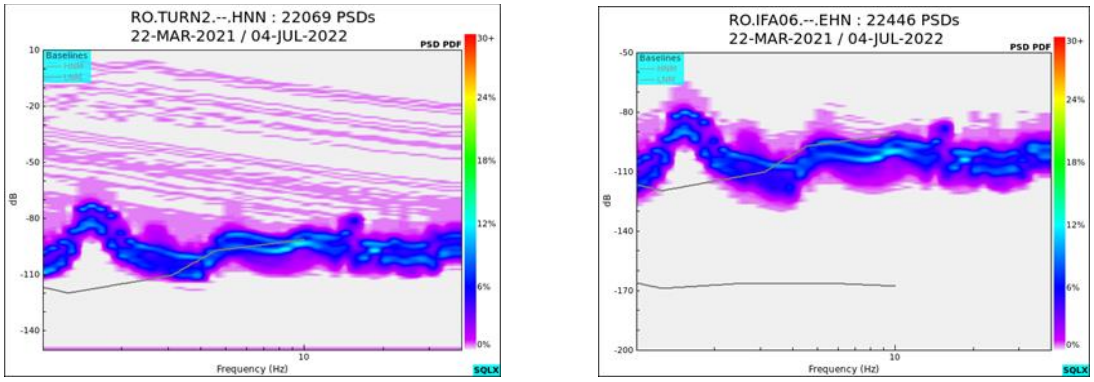

Figure 37: Density probability functions for two sensors, one low-cost (left) and other professional (right), installed on the 6th floor of IFA building (Magurele).

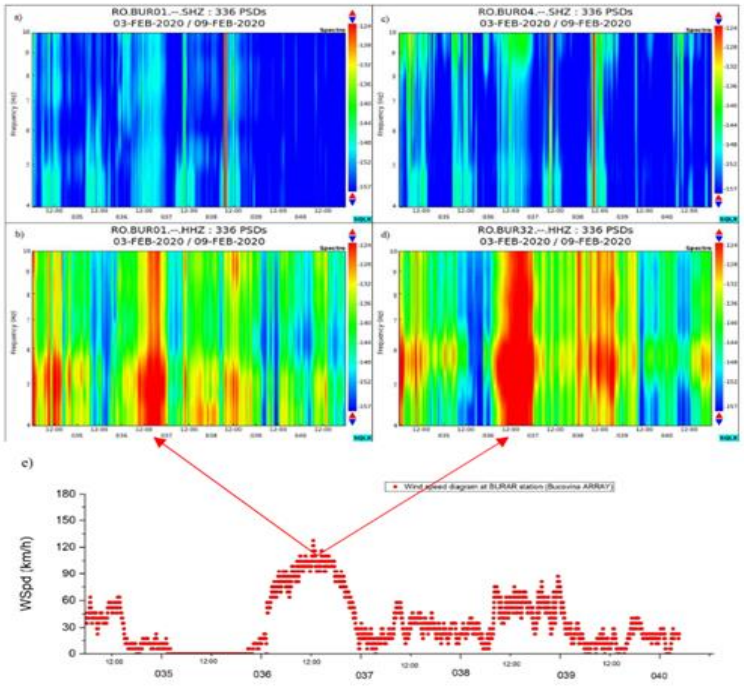

Figure 38: Example of site characterisation for Bucovina array (BURAR), located in the northern part of Romania.

In the last years, a particular emphasis has been put on development of outreach and educational activities (Tataru et al., 2022; Vanciu et al., 2020). For this purpose, significant improvements were carried out to the Romanian Educational Seismic Network (established in 2012 - 2016). This has been continuously developed, reaching by the end of 2022 to contain 10 horizontal SEP seismometers, 7 vertical

Slinky seismometers and 24 Raspberry Shake seismometers in various configurations (1D, 3D or 4D). The introduction of Raspberry Shake seismometers in the network since 2020 has led to a significant increase in the number of recorded earthquakes (Tataru et al., 2022; Zaharia et al., 2022).

2. Participation of the Romanian specialists in international projects or programs

In the past four years the Romanian seismology has been actively contributing to:

(1) *World-wide interdisciplinary international research programs*

- Romania's technical participation in support of the Comprehensive Nuclear-Test-Ban Treaty (CTBT)

The National Institute for Earth Physics hosts the Romania's National Data Centre (NDC), with operates the seismic station Cheia-Muntele Rosu (MLR) for its uninterrupted participation to the global monitoring network of the verification system, and co-operates with national and international organizations for upgrading and maintaining. NDC receives and analyzed the data coming from MLR station and from the International Monitoring System, as well the products of the International Data Centre (IDC) from Vienna, Austria.

- European Plate Observing System (EPOS-IP)**,** ESFRI Program, H2020, 2015-2019, INGV Rome, Sustainability phase (EPOS-SP), 2019-2023, http://www.epos-eu.org/
- Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe (SERA), 2016 – 2020, www.sera-eu.org
- All Risk Integrated System TOwards Trans- boundary hoListic Early-warning ARISTOTLE - Pilot phase, 2015 – 2020, http://pilot.aristotle.ingv.it; ARISTOTLE - European Natural Hazards Scientific Partnership (ENHSP), 2020 - 2023, aristotle.ingv.it;

(2) International cooperation

- ReCoN-nect - The Green Deal: Research communication to CommuNities, 2021 - 2022
- TURNkey - Towards improving the resilience of urban societies against seismic threats through multi-sensor-based Early Warning information systems and Rapid Response actions

(3) Bilateral cooperation

- **The bilateral project on "Seismic microzoning of Bucharest"** with the University of Trieste (Italy) has the goal to estimate the ground motion parameters due to waves coming from complex seismic sources and propagating in highly realistic structural models to mitigate the seismic risk in Bucharest metropolitan area.

During several stays as visiting scientists at ICTP and DES - University of Trieste, a group of researchers from NIEP worked within different NATO and EC projects focused on Vrancea earthquakes and their implications to the seismic hazard using the deterministic method developed at DES – Trieste. Complex research on microzonation, seismic source and earthquake prediction (CN method) was carried out on this occasion.

- **Maintenance operations of the BURAR Seismic Array. Research and development studies of seismic sources using local and regional data**

A bilateral cooperation between the National Institute for Earth Physics (NIEP) and the Air Force Technical Applications Center (AFTAC) of the United States of America started in 1999 aiming at installing and operating a seismic array in the northern part of Romania (Bucovina array). The array consists of 9 short-period stations and 1 broadband station and started to be fully operational in July 2002. Another bilateral cooperation (NIEP and the Geoforschungszentrum Potsdam - GFZ) has been active since 1999 for the operation of the broad-band station Cheia - Muntele Rosu (belonging to the GEOPHON network). An important upgrade of the Cheia – Muntele Rosu station, as well as of the National Data Centre in Bucharest has been done since 1999, involving both technical cooperation with the Government of Japan and technical assistance from the CTBT Organization. Hence, in the fall of 2001 a new seismic monitoring system was installed and is now fully operational, by recording continuous earth motion data at Muntele Rosu site and transmitting these data in real-time to the facilities in Bucharest, in the framework of the Japan International Cooperation Agency project „Technical Cooperation for Seismic Monitoring System in Romania". Also, during 2001-2002, the CTBT Organization has supported the site preparation works at the seismic station Muntele Roşu and supplied equipment for establishing reliable data communications links between the seismic station, the NDC and the International Data Centre from Vienna.

- **STIM - School Tune Into Mars, ERASMUS**

3. Organization of national and international scientific conferences

- **3ECEES** - Third European Conference on Earthquake Engineering and Seismology, onsite, 04 - 09.09.2022, Bucharest, Romania
- **ILP-GEOSCIENCE2023 -** ILP16th & GEOSCIENCE 7th Conference, hybrid, 06 - 07.10.2022, Bucharest, Romania
- **BGS2021** - 11th Congress of the Balkan Geophysical Society, virtual, 10 - 14.10.2021

4. Participation of the Romanian specialists in the international symposiums and conferences

Many of the results obtained by the Romanian seismologists in the past four years have been presented at a series of national and international meetings as follows:

2022

- "45 years after the 1977 earthquake". Session of scientific communications and debates of the Romanian Academy Integrated Assessment of Natural Risks in Romania

- Honorary Symposium, A life dedicated to Earth sciences, the legacy of Professor Corneliu Dinu, 11 April 2022, Vasile Lăzărescu Hall, Faculty of Geology and Geophysics, Bucharest, Romania
- European Geosciences Union General Assembly - EGU2022, 23 -28 April 2023, hybrid, Vienna, Austria
- National Conference of the Geographical Society, Focșani, Vrancea
- Seismological Society of America-Annual Meeting, 19 - 23 April 2022, Bellevue, Washington, USA
- New Zealand Society for Earthquake Engineering - Annual Technical Conference - NZSEE, 27 - 29 April 2022
- National Conference of the Community "Education for Science", 28 - 30 April 2022, Suceava, Romania
- AOSR Spring Conference, Central University Library, 6 - 7 May 2022, Bucharest, Romania
- Japan Geoscience Union Assembly - JPGUA 2022, 22 May - 3 June 2022, hybrid, Chiba, Japan
- European Physical Society Forum 2022, 2 - 4 June 2022, Paris, France
- 2022 Annual Scientific Session of the Physics Faculty, 24 June 2022, Bucharest, Romania
- SGEM Conference, 04 - 10 July 2022, Albena, Bulgaria
- SEDI Study of the Earth's Deep Interior, 11 - 15 July 2022, Zurich, Switzerland
- 20th International Balkan Workshop on Applied Physics and Materials Science, Constanta, Romania 12-15 July 2022
- 20th International Balkan Workshop on Applied Physics and Materials Science, 15 July 2022, Constanța, Romania
- 3ECEES 2022, the Third European Conference on Earthquake Engineering and Seismology, 4 - 9 September 2022, Bucharest, Romania
- British Seismology Meeting - BSM, 12 - 14 September 2022, Cambridge, UK
- 15th Emile Argand Conference on Alpine Geological Studies, 12 - 14 September 2022, Ljubljana, Slovenia
- 28th European Meeting of Environmental and Engineering Geophysics - NSG, 18 - 22 September 2022, Belgrade, Serbia
- vrs-SSP Market Event and Conference 2022, Bucharest, Romania
- The 12th International Conference of the International Society for the Integrated Disaster Risk Management - IDRiM2022, online, 21 - 23 September 2022
- The 16th Workshop of International Lithosphere Program Task Force Sedimentary Basins & 7th Geoscience - ILP & Geoscience, 6 - 7 October 2022, Bucharest, Romania
- Joint General Assembly of Asian and African Seismological Commissions, 10 - 13 October 2022, Read Sea Egypt
- 6th Annual AlpArray Scientific Meeting, 12 - 14 October 2022, Praga, Czech Republic

- 3rd International Conference on Advanced Electrical and Energy Systems (AEES), 22 - 24 October 2022, Lanzhou, China
- SSA Tomography 2022, 28 - 30 October 2022, Toronto, Canada
- 2022 Taiwan-Japan-NZ Seismic Hazard Assessment Meeting, 31 October - 4 November 2022, Luyeh, Taitung County, Taiwan
- "The earthquake from 10th of November 1940"Symposium, Bucharest, Romania
- TIM22 Physics Conference, 23 - 25 November 2022, Timișoara, Romania
- Annual Conference of Geological Society of New Zealand, 29 November - 1 December 2022,
- Advancing Earth and Space Science - AGU, 12 - 16 December 2022, hybrid, Chicago, USA

2021

- NEAMTWS Tsunami Exercise – 'NEAMWave21', 8–10 March 2021
- 1st Croatian Conference on Earthquake Engineering - 1CroCEE, 22-24 March 2021, Zagreb, Croatia
- European Geosciences Union General Assembly - EGU 2021, 19–30 April 2021, online
- International City, Environment and Health Congress (Urban and Hazards), 16 - 20 April 2021, Turcia
- Agriculture for Life Conference, București, 3 - 5 June 2021, online
- Annual Scientifc Session of the Physics Faculty, Bucuresti, 18 June 2021, online
- Symposium at the Centre for Research in Spatial Geodesy, Photogrammetry, Remote Sensing and G.I.S. (GEOS) of the Department of Geodesy and Photogrammetry of the Faculty of Geodesy - Technical University of Construction Bucharest, online
- CTBT Science and Technology Conference 2021 - SnT2021, 28 June - 2 July 2021, Vienna, Austria, online
- 21st International Multidisciplinary Scientific GeoConference, SGEM 2021, 16 - 22 August 2021, Albena
- IAGA-IASPEI, 21-27 August 2021, New Delhi, India
- 6thWorld Multidisciplinary Earth Sciences Symposium - WMESS, 6-11 September 2021, Prague
- General Assembly of Seismological Commission - ESC 2021, 19-24 September 2021, online
- 17th World Conference of Earthquake Engineering, 27 September – 2 October 2021, Sendai, Japonia
- 11th Congress of Balkan Geophysical Society - BGS 2021, online, 10 - 14 October 2021
- ORFEUS Annual Meeting and Workshop, 8-9 November 2021, online
- TIM 20 – 21 Physics Conference, 11 - 13 November 2021, online
- The 2021 International Lithosphere Program (ILP) Sedimentary Basins Task Force (VI), 17 - 19 November 2021, Rueil-Malmaison, France

- PD2 ChEESE Live Demo, 22 November (online)
- 17th Session of the Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS-XVII), UNESCO, 24–26 November 2021 (hybrid mode)
- GEOSCIENCE 2021, 10 December 2021, hybrid, Bucharest, Romania
- AGU21, American Geophysical Union Fall Meeting, 13 - 17 December 2021, hybrid, New Orleans, USA

2020

- Topo Transylvania scientific meeting, 26 February 2020, Sopron
- European Geosciences Union General Assembly (EGU), 4 -8 May 2020, Vienna, Austria
- „43 years from the 1977 earthquake"
- International Congress on Risks, Contribution of the Science for Disaster Risk Management, 18 - 22 May 2020, Portugalia
- 17th World Conference on Earthquake Engineering (17WCEE), 13 - 18 September 2020, hybrid & Sendai, Japan
- 28th Conference Surveying, Civil Engineering, Geoinformation in Sustainable Development, 2 – 4 June 2020, Bydgoszcz, Polonia
- Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 4 - 5 June 2020, Bucharest, Romania
- WMESS 2020, 7 - 11 September 2020, Praga, Cehia
- SEISAN on-line workshop, Japonia
- AFTAC/NIEP Joint Scientific Comission (JSC) Meeting, online
- DSC 2020: 3rd Conference of the UTCB Doctoral School (DSC), Technical University of Civil Engineering of Bucharest, București
- V International Congress on Risks, 12 – 16 October, 2020, Coimbra, Portugal,
- ORFEUS/EPOS-SP/AdriaArray (online), 2 - 6 November 2020, UE
- GEOSCIENCE 2020, 16 - 18 November 2020, Bucharest, Romania
- AGU 2020 - American Geophysical Union, Fall Meeting 2020 (online), 1 - 17 December 2020, New Orleans, SUA

2019

- Romania Academy, Bucharest, Romania
- 3rd Schatzalp Workshop on Induced Seismicity, 5 - 8 March 2018, Davos, Switerzland
- Geolinks 2019, 26 - 29 March 2019, Athenes, Greece
- European Geophysical Union General Assembly, 7-12 April 2019, Vienna, Austria

5. Publications

5.1. Peer-reviewed ISI publications

2022

Apostol B.F., Borleanu F., Cune L.C. *Seismic source and earthquake parameters from local seismic recordings*. Earthquakes of 28.10.2018 and 23.09.2016, Vrancea, Romania; Romanian Reports in Physics, 2022a.

Apostol B.F., Cioflan C.O., Mărmureanu A. Spectral characteristics of the seismic response from local recordings. Application to urban areas; Romanian Reports in Physics, 2022b.

Apostol B.F. Near-Field Seismic Motion: Waves, Deformations and Seismic Moment; Axioms, 2022c.

Ardeleanu L., Neagoe C., Plăcintă A.O., Coman A. On the seismic wave attenuation at the bend of the Southeastern Carpathians; Journal of Seismology, 2022.

Bălan S.F., Apostol B.F., Țigănescu A. The Impact of Turnkey Seismic Monitoring Network in Bucharest; Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 2022.

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Ghiță C., Tuta L., Moldovan I.A., Ionescu C., Nicolaescu M. FastICA algorithm applied on Black Sea water level ultrasound measurements; Atmosphere, 2022c.

Ivan M., Petrescu L., Wang R., An attenuating, isotropic and heterogeneous uppermost inner core: evidence from global PKiKP-PKIKP amplitude ratio tomography, Geophysical Journal International, ggac142, 10.1093/gji/ggac142, 2022.

Manea E.F., Cioflan C.O., Danciu L. Ground-motion models for Vrancea intermediate-depth earthquakes; Earthquake Spectra, 38, 407-431, 2022.
Moldovan I.A., Apostol A., Muntean A., Ghiță C., Toader V.E., Ambrosius B. A possible slow-slip-event in the Vrancea seismic active region of Romania; Romanian Journal of Physics
Năstase E., Muntean A., Nistor S., Dimitriu S., Jecu M.N., Suba N.S. Influences on vertical shallow crust deformations in the shallow crust deformations in the Carpathian-Danubian-Pontic Area, an Earth science integrated thematic service case study; Romanian Journal of Physics
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5.3. Books and book chapters

5.3.1. Books

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5.3.2. Book chapters

2021

Borleanu F., Advanced multidisciplinary research for seismic monitoring and modelling, Chapter 22: Application of waveform correlation to improve the monitoring and localization of seismic events in Romania and adjacent areas, Ed. Romanian Academy, ISBN 978-973-27-3383-7, p. 525-552, 2021a.

Dinescu R., Ghica D., Popa M. Identification of quarry blasts in the Deva region (Romania) using seismo-acoustic analysis, Chitea F. (Ed) Geoscience for Society Education and Environment, Chapter 3: Geoscience for Environment, ISBN: 978-973-27-3336-3, D.O.I. 10.5281/zenodo.4322617, 2021a

Ghica D.V. Advanced multidisciplinary research for seismic monitoring and modelling, Chapter 18: Identification and characterisation of anthropogenic and natural impulsive seismo-acoustic sources: accidental/chemical, industrial (mine and quarry detonations), meteorite explosions, severe storms, using infrasound and seismic sensor measurements, Ed. Romanian Academy, ISBN 978-973-27-3383-7, 447-470, 2021.

Oros E., Popa M., Placinta A. O., Moldovan I-A., Rogozea M., Diaconescu M., Paulescu D. Advanced research on seismic monitoring, modelling and risk reduction, Chapter 4: Considerations on the relationship between crustal stresses, geological structure and seismic activity in the Banloc-Voiteg area, Ed. Romanian Academy, ISBN 978-973-27-3383-7, p. 103-128, 2021b.

Oros E., Popa M., Placinta A. O., Radulian M., Diaconescu M., Ghita C., Neagoe C., Rogozea M. Advanced Multidisciplinary Research for Monitoring and Modeling of Seismic Phenomena, Chapter 6: Active Stress Field and Tectonic Regime in the Intracarpathian Region and Adjacent Areas. Realistic constraints for defining seismogenic sources, Ed. Romanian Academy, ISBN 978-973-27-3383-7, 145-172, 2021c.

Popescu E., Placinta A. O., Borleanu F., Radulian M. Advanced research on seismic monitoring, modelling and risk reduction, Chapter 3: Modelling clustered seismic processes in Romania's seismotectonic zones to parameterise earthquake sources, Ed. Romanian Academy, ISBN 978-973-27-3383-7, p. 65-102, 2021.

Rogozea M., Popa M., Radulian M., Toma-Danila D., Glavceva R., Paulescu D. Advanced multidisciplinary research for seismic monitoring and modelling, Chapter 10: Reassessment of major historical earthquakes in the Vrancea area compared with instrumental data, Ed. Romanian Academy, ISBN 978-973-27-3383-7, p. 247-280, 2021.

2020

Ghica D., Popa M. Chapter 8: New research directions -NDC and seismo-acoustic station from Bucovina. "National Research and Development Institute for Earth Physics at 25 years of activity" (ISBN 978-973-27-3198-7), pp 116-126 (Romanian) and pp 254-264 (English), 2020

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International Association of Volcanology
and Chemistry of the Earth's Interior

IAVCEI ACTIVITIES IN ROMANIA
2019 - 2022

NATIONAL REPORT ON VOLCANOLOGY AND CHEMISTRY OF THE EARTH'S INTERIOR

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Content:

Part I: ORGANIZATION

Organization for Romania, a Section of the Romanian National International Union of Geodesy and Geophysics (IUGG) Committee, was constituted at the Institute of Geodynamic —Sabba S. Ştefănescu in cooperation with the Technical University of Cluj-Napoca—North University Centre of Baia Mare and Babeş-Bolyai University Romania—Faculty of Environmental Science and Engineering.

Institute of Geodynamic —Sabba S. Ştefănescu

The Institute of Geodynamic "Sabba S. tefanescu" of the Romanian Academy focused its interest on fundamental research imposed by the tasks implied by the Priority Program of the Romanian Academy. "Complex geophysical research in geodynamically active areas" in such as areas: earthquakes occurrence; the study of natural internal and external geohazards; the monitoring of gravitational, geomagnetic,geoelectric fields of the Earth, tectonic blocks, evolution of the lithosphere; studies of endogenous processes in the geodynamic evolution, mainly in Romania.

Technical University of Cluj-Napoca - North University Centre of Baia Mare

The main activity of North University Centre of Baia Mare is researching and teaching in the field of green mining. The higher education in the field of mining and metallurgy, organized at North University Center of Baia Mare in the frame of Technical University of Cluj Napoca Romania, has a remarkable tradition in accordance with the rate and prestige of the mining industry has always had in that part of Romania.

Babeş-Bolyai University Romania - Faculty of Environmental Science and Engineering

The Faculty of Environmental Science and Engineering is currently one of the modern and dynamic faculties of Babeș-Bolyai University, providing training in environmental issues for undergraduate, master's and doctoral degrees. Over the years, the Faculty has constantly developed and adapted to the priorities promoted by environmental strategies and research policies. The faculty is focuses on advanced research and technology transfer.

IAVCEI commissions:

- Commission on the Chemistry of Volcanic Gases
- Commission on Volcanic Lakes
- Commission on Volcano Geology
- Commission on Volcanic Clouds
- Commission on Collapse Calderas
- Commission on Large Igneous Provinces
- Commission on Monogenetic Volcanism
- Commission on Submarine Volcanism

- Commission on Volcanogenic Sediments
- Commission on Volcano Geoheritage and Protected Volcanic Landscapes
- Volcanic and Igneous Plumbing Systems
- Commission on Volcanic Hazards and Risk
- Commission on Statistics in Volcanology
- Commission on Tephrochronology
- Commission on Tephra Hazard Modelling
- Commission on Cities and Volcanoes
- and other five IACS/ IAGA/ IASPEI/IAG/IAVCEI Joint Commission

The general objectives of IAVCEI are to encourage, initiate and coordinate research, and promote international cooperation in volcanological studies.

Romanian National Societies

- Geological Society of Romania
- Romanian Society of Geophysics

University centers in Romania where IAVCEI-related topics are being investigated:

- University of Bucharest, Faculty of Geology and Geophysics, Bucharest
- Babeş-Bolyai University, Faculty of Biology and Geology, Cluj-Napoca
- Sapientia University, Faculty of Natural Science and Arts, Dept. of Environmental Sciences, Cluj-Napoca
- Alexandru Ioan Cuza University, Faculty of Geography and Geology, Iaşi
- Technical University of Cluj-Napoca, North University Centre of Baia Mare, Faculty of Engineering, Dept. of Mineral Resources, Materials and Environmental Engineering.

Scientific symposia:

- National Symposium of Geophysics

Publications:

- Revue Roumaine de Géologie
- Revue Roumaine de Géophysique
- Studia Universitatis Babeş-Bolyai, Cluj-Napoca
- Analele Universităţii „Al. I. Cuzaǁ Iaşi, Geologie
- Romanian Journal of Earth Sciences
- Anuarul Institutului Geologic al României
- Carpathian Journal of Earth and Environmental Sciences
- Environmental engineering and management journal

PART II: PROFESSIONAL ACTIVITY

1. Research orientation

During the inter-IUGG General Assembly time period 2019-2022, the small volcanological community in Romania continued to decline. There is less and less interest in Volcanological studies. At University level there are not specific courses targeting volcanological domain, so the students with interest in this topic are rare. Between-2019-2022 only few National Projects included individuals with volcanological knowledge and in the last two years there are missing financed project at the national level. These are the main reasons of the declining trend of Romanian IAVCEI group and as well membership. Still there are few scientists with constant interest and dedication in IAVCEI-related topics, forming an active core of the Romanian National IAVCEI Section. They are getting older, but are still active in research and publication willing to take part in IAVCEI-organized activities and events. They were able to continue their work at decent standards, as being involved in international cooperation with scientists from other countries. In most of the cases this implies also the possibility to use analytical facilities, not available in Romania.

2. Publications

IAVCEI-related scientific domains in our country are: paleovolcanology, petrology of volcanic rocks, igneous rocks-related mineralogy, fluid geochemistry, ore geology in volcanic areas, geophysics of volcanic areas and recently geoheritage:

2.1. **Peer-reviewed Research articles** (the active IAVCEI members are shown in bold)

2022

Dill, H.G., Balaban, S.I., Buzatu, A., Bornemann, A., & Techmer, A. (2022). The Quaternary volcanogenic landscape and volcaniclastic sediments of the Netherlands Antilles: markers for an in-active volcanic arc. *Int. J. Earth Sci.*, 111, 149-172.

Dincă, G., Apopei, A. I., Szabo, R., & Maftei, A. E. (2022). The Effect of Mn Substitution on Natural Sphalerites by Means of Raman Spectroscopy: A Case Study of the Săcărâmb Au–Ag–Te Ore Deposit, Apuseni Mountains, Romania. *Minerals, 12(7)*, 885. DOI: 10.3390/min120708852022

Eskdale, A.E., Smith, D.J., Ene, V.V., Negulici, M., & Onescu, D. (2022). Economic By-Products in copper Porphyries: Silver in the Ascuțita Cu-Porphyry. *Ore Geology Reviews.* https://doi.org/10.1016/j.oregeorev.2022.105135

Hîrtopanu, P., Dumitraş, D.G., Marincea, Ș., & Călin, N. (2022). Inesite, hubeite, ruizite, apophyllite, and manganoan ilvaite from Cavnic, Eastern Carpathians, Romania. *Carpathian J. Earth Environ. Sci.*, 17(2): 387-400. DOI:10.26471/cjees/2022/017/230

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Li Vigni, L., Cardellini, C., Temovski, M., **Ionescu, A**., Molnár, K., Palcsu,L., et al. (2022). Duvalo "volcano" (North Macedonia): A purely tectonic related CO_2 degassing system. *Geochem., Geophys., Geosystems*, 23, e2021GC010198. https://doi.org/10.1029/2021GC010198

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Seghedi, I. & Szakács, **A**. (2022). The evolution of mapping and structural models of the Neogene Călimani-Gurghiu-Harghita volcanic range. *Rev. Roum. Géologie/Rom. J. of Geology*, 64-65 (2020-2021), 21-38, Bucureşti

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Seghedi, I., Ntaflos, T., Pécskay, Z., Panaiotu, C., **Mirea V., &** Downes H., (2022). Miocene extension and magma generation in the Apuseni Mts. (western Romania): a review. *Int. Geol. Rev.*, 64, 13, 1885-1911. DOI: 10.1080/00206814.2021.1962416.

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2.2. Book chapters

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