Institute of Geophysics
Polish Academy of Sciences

PUBLICATIONS OF THE INSTITUTE OF GEOPHYSICS POLISH ACADEMY OF SCIENCES

Geophysical Data Bases, Processing and Instrumentation

437 (M-35)

Achievements of the Institute of Geophysics, PAS: Annual Report 2020

Warsaw 2021 (Issue 6)

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ISBN 978-83-66254-07-7 eISSN-2299-8020
DOI: 10.25171/InstGeoph_PAS_Publs-2021-043

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C O N T E N T S

Editorial note

This Monograph outlines the recent achievements of the **Institute of Geophysics, Polish Academy of Sciences,** focusing on the main strategic areas: Geosystem Processes, Earth Structure and Georesources, Anthropogenic and Natural Geohazards, Climate Change and Polar Research.

The publication is a reviewed and formatted version of the **Annual Report 2020**, providing information about the research done at the seven departments (Seismology, Atmospheric Physics, Lithospheric Research, Theoretical Geophysics, Hydrology and Hydrodynamics, Magnetism, Geophysical Imaging, and Polar and Marine Research), together with the Institute's infrastructure, instrumentation, projects that have been completed or are under way, as well as editorial, educational and many other activities.

We hope the information contained in this monograph may be useful for a broader audience, in particular those who may find the presented materials applicable in their work, or perhaps arrange a co-operation with the Institute.

The Editors
of the *Publications of the Institute of Geophysics PAS*

1. GENERAL

Beata Orlecka-Sikora, Mariusz Majdański, Beata Fromeliusz, Krzysztof Otto

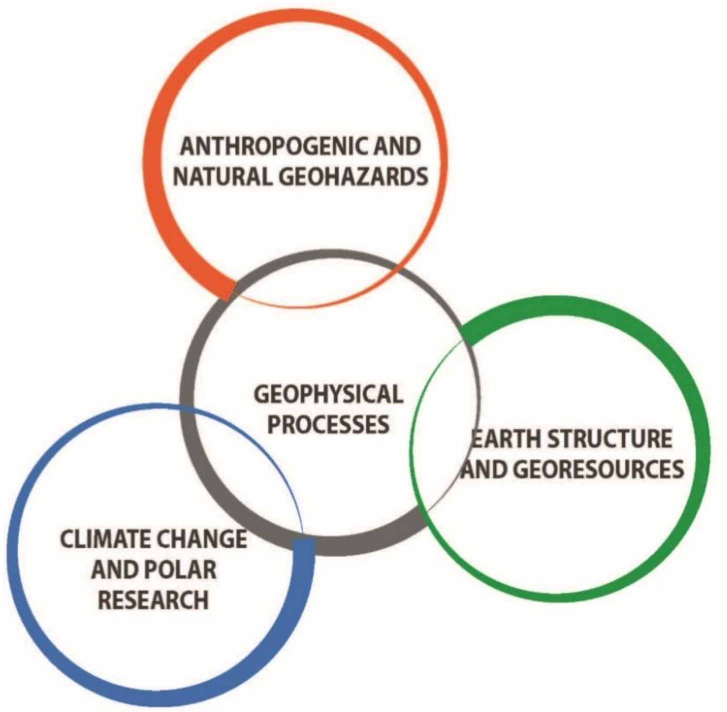
1.1 The mission of the Institute of Geophysics, Polish Academy of Sciences

Studying geophysical processes for better understanding of the mechanisms controlling the Earth's system and risk management

- Working for the benefit of the society and economic development
- Development and maintenance of strategic research infrastructure
- Geophysical monitoring
- Training future leaders of scientific communities

1.2 Research areas

The main research areas and their interrelations, as described below:



Main research areas of the Institute of Geophysics PAS.

1.2.1 Anthropogenic and natural geohazards

The history of mankind and the development of civilizations are full of examples of the subordination and harnessing of nature's forces to serve people. Even though the paradigm of Mankind's mastery over nature has changed somewhat in recent history, being diverted towards sustainable development and living in harmony with the environment, humanity will always struggle with violent and unpredictable natural phenomena. The study of the risks and consequences of sudden and catastrophic processes in the lithosphere, atmosphere, magnetosphere and hydrosphere has for many years been within the scope of scientific research at the Institute of Geophysics, Polish Academy of Sciences (IG PAS). Scientists from the IG PAS are among Poland's and the world's leading specialists in dealing with natural hazards and adverse human impact on the environment. The IG PAS scientific and educational activities in these fields has contributed to finding methods of prediction, analysis and management of geohazards that translate into solutions for the better protection against the destructive forces of nature. Through these methods, practical solutions can be developed to mitigate or eliminate humanitarian and economic losses due to both natural and man-made disasters.

Research in the Institute of Geophysics PAS focuses, *inter alia*, on natural and human-induced geohazards including earthquakes, landslides, floods, torrential rains, local inundations and droughts, water and air pollution, and the negative effects of the UV rays and chemical aerosols on human health. All these natural hazards are thoroughly investigated within the contexts of climate change and evolving societal needs. Research engages the latest analytical methods, specialized equipment and laboratories within the possession of the IG PAS, including two stations located in both polar regions, as components of leading global geophysical research networks. Methodologies developed by specialists from the IG PAS encompass both basic and applied science, and include mathematical and physical modeling of natural phenomena, magnetic analysis of soil, water and air pollution, seismic monitoring of natural and induced earthquakes, geophysical imaging of shallow and deep Earth structure, hydrological measurement of seas, rivers and lakes, and investigations of the cryosphere and polar environment in the Arctic and Antarctica.

1.2.2 Geosystem processes

The Earth is a complex system (hereafter called geosystem) in which many components interact across all space and time scales. To address the complex interactions between the atmosphere, the hydrosphere, the troposphere, the ionosphere and the crust, complementary approaches have to be used, combining observational data with theoretical and mathematical models and numerical computing. The quality of such models is intrinsically correlated with the quality and quantity of data available for their calibration and validation. Therefore, structuring adequate monitoring networks is paramount to keep track of the geosystem dynamics at the various spatio-temporal scales.

The study of the present state of the Earth and its environment cannot be done in isolation from its dynamical history. Knowing the past is essential for understanding the present drivers and links between them, as the past is the key to understand the present and to predict the future. Theoretical and numerical modelling helps in capturing the physics of the Planet's evolution from its origin, but monitoring activities are essential in this case.

Last decades revealed how strongly mankind, just a small fraction of the global biota, can effectively disturb the whole ecosystem, paving a way to the mass extinction. Before we reach the point of no return, we must learn in detail about how we interfere with nature, and determine necessary means and actions that have to be undertaken to prevent passing a turning point after which there will be no place for us on the planet. The Geosystem Processes Working Group is a very inclusive group, which combines expertise spanning from atmospheric sciences to lithospheric research, magnetism and hydrology. Indeed, the complexity of the geosystem dynamics from the deep geological past to the present requires a transdisciplinary approach to be studied. Particular aims of the group for the next few years involve maintenance and further development of the Polish geophysical monitoring system (seismic, magnetic, atmospheric), determination of the influence of ozone layer dynamics on the UV radiation, study of atmospheric electricity and its interactions with aerosols, and investigations of crust structure and dynamics through seismic soundings, including unravelling the earthquake source physics and physics of subduction zones.

1.2.3 Earth structure and georesources

The traditional domain of research in IG PAS in the "Earth structure and georesources" thematic group was the recognition of the structure of the Earth's crust and upper mantle using various seismic (active, passive, refractive and reflective) and (electro) magnetic methods, as well as palaeogeographic research and tracking selected tectonic processes on the basis of palaeomagnetic analyzes. The results of these studies were of great cognitive importance and contributed to the development of regional geology, mainly in Central Europe and the polar regions. The methods developed in the above-mentioned basic research were (and may be in the future) adapted to application research (recent examples are shale gas exploration, tracing the spread of anthropogenic pollutants, studying structures related to mass movements). While basic research in the field of recognizing the structure and restoring tectonic evolution in various areas will still have a leading share in the research profile of most of IG PAS teams, it is also important to expand the "portfolio" of applied research so that it relates to new civilization challenges.

Earth sciences, including geophysics, are important for various areas of the economy. Sustainable economic growth and social welfare will require, *inter alia*, access to clean energy sources, minerals and clean water. It is crucial to strengthen our presence in research related to these three aspects. In the case of the energy sector, our methods can be used in projects related to the production of geothermal energy, underground hydrogen storage, capture and underground storage of CO_2 or underground storage of radioactive waste. In the case of searching for mineral resources, including the so-called critical raw materials, it is important to both reduce the cost of exploration and their impact on the natural environment through a greater share of non-invasive geophysical research. In the case of research related to groundwater resources, cooperation with national regulators (e.g. the National Hydrogeological Service) would be of key importance.

Participation in such projects on a national scale is conditioned by the state policy, but it would be desirable to acquire relevant competences in projects implemented in other EU countries, where, for example, geothermal research is much more developed.

In strictly basic research, their high substantive level should be maintained through the use of the latest methods and the correct selection of research goals. These goals should be clearly defined and relate to possibly large, regional research problems in the field of the structure and evolution of the lithosphere. The results of the research should reach both specialized scientists in this field as well as all others interested in the history of the Earth. Therefore, it is important to popularize the research as much as possible.

1.2.4 Climate change and polar research

The years 2014–2016 were the warmest in the history of meteorological and oceanographic measurements, not only globally, but also in many regions of the world, including Europe. The speed of ongoing changes causes an imbalance in the processes that make up the existing and future state of the climate. Increasing intensity and frequency of extreme phenomena, such as fires, droughts, floods indicates a disruption of the balance and increased risk of extinction for many species, including humans.

Modelling future hydro-climatic conditions at global and local scales is one of the key challenges in earth sciences. Despite the debate over the causes of climate change, the existence of climate change is widely accepted. With the changing observed hydro-climatic conditions the threats to social and economic development increase. Therefore, it becomes particularly important to identify future conditions and develop adaptation to reduce the effects of potential threats.

For example, in the Anthropocene, due to human influence on the functioning of natural processes, drought is no longer just a natural hazard and its management at this stage is not fully effective. Therefore, there is a need to rethink the design of the drought process to account for these interactions. The predicted increase in temperature will affect the hydrologic regime. This is already reflected in the increased frequency and magnitude of droughts, the effects of which are causing increasing losses around the world.

The polar zones are the fastest-changing and most important terrestrial and marine areas for understanding global change, also in relation to other locations, including Poland. This is particularly important for the assessment of, among others, climate change scenarios, rising ocean levels, the evolution of the biosphere, and its adaptation to new conditions. Quoting the strategy of Polish polar research, “Important aspects of our involvement in polar research are not only the development of science, but also the possibility of expert support for public administration and the economy, the impact on increasing its innovation, and – in the long term – on sustainable development of our country”.

The melting and disintegration of glaciers and ice sheets of Antarctica and Greenland are responsible for more than half of the currently observed sea-level rise. It is estimated that with continued high atmospheric greenhouse gas emissions, more than 600 million coastal people may be forced to leave their homes before the end of this century. Current research indicates that the disappearance of glaciers could inhibit the global deep-sea and surface water exchange system, the primary mechanism for heat, salt, and nutrient exchange on Earth. The disappearance of sea-ice itself, in turn, leads to, among other things, greater absorption of solar energy by the ocean, modification of weather conditions, and an increase in the destructive effects of wave action on Arctic coastlines.

The proposed research fits very well with the Horizon Missions and in particular the Starfish missions “Healthy Oceans, Seas, Coastal and Inland Waters” and “Adaptation to Climate Change Including Societal Transformation”.

1.3 Management

The Board of Directors:

Prof. Beata Orlecka-Sikora
Director of the IG PAS

Mariusz Majdański
Deputy Director for Scientific Affairs

Beata Fromeliusz
Deputy Director for Administration and Finance

Krzysztof Otto
Deputy Director for Technical Issues

1.4 Employment structure

The structure of employment is illustrated by tables and graph below:

The number of employees

N = 71.3	Total	Researchers	PhD students
2016	175	69	29 (6 KNOW)
2017	178	67	26 (6 KNOW)
2018	187	74	22 (6 KNOW)
2019	184	78	18 (9 DS)
2020	179	77	15 (12 DS)
Change	+4	+8	–8

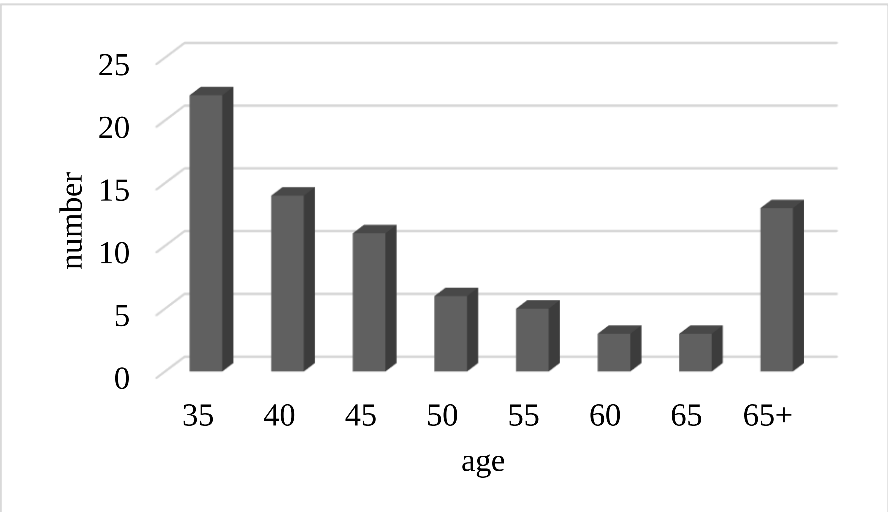
The employees by function

Function	Number
Polar expedition	9
Administration	49
Technicians	44
Researchers	77
Total	179

Researchers	Number
Research Assistant	9
Assistant Professor	30
Associate Professor	25
Professor	13

The employees by sex

	Female	Male
Total	79	100
Researchers	26	51
Other	53	49



Researchers' age structure.

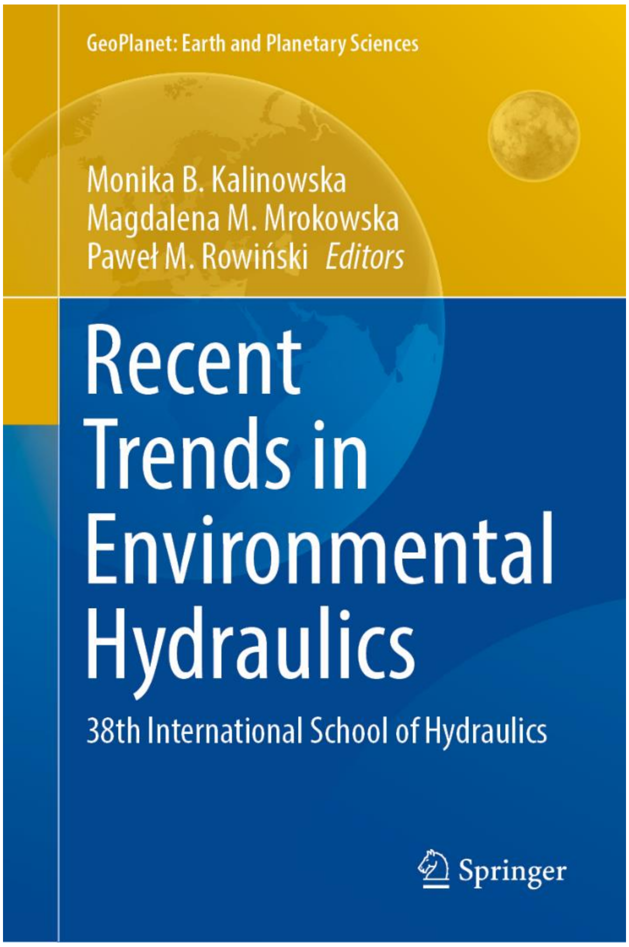
1.5 Activity of Scientific Information and Publishing Department

As in the previous years, in 2020 the activity of the Scientific Information and Publishing Department concentrated on the three titles:

- *GeoPlanet: Earth and Planetary Sciences Book Series,*
- *Publications of the Institute of Geophysics, Polish Academy of Sciences,*
- *Acta Geophysica*.

GeoPlanet: Earth and Planetary Sciences Book Series

The Editor-in-Chief of *GeoPlanet Series* is Prof. Paweł M. Rowiński.
In the year 2020 one book was published within this series:
– "Recent Trends in Environmental Hydraulics" edited by Monika Kalinowska et al.



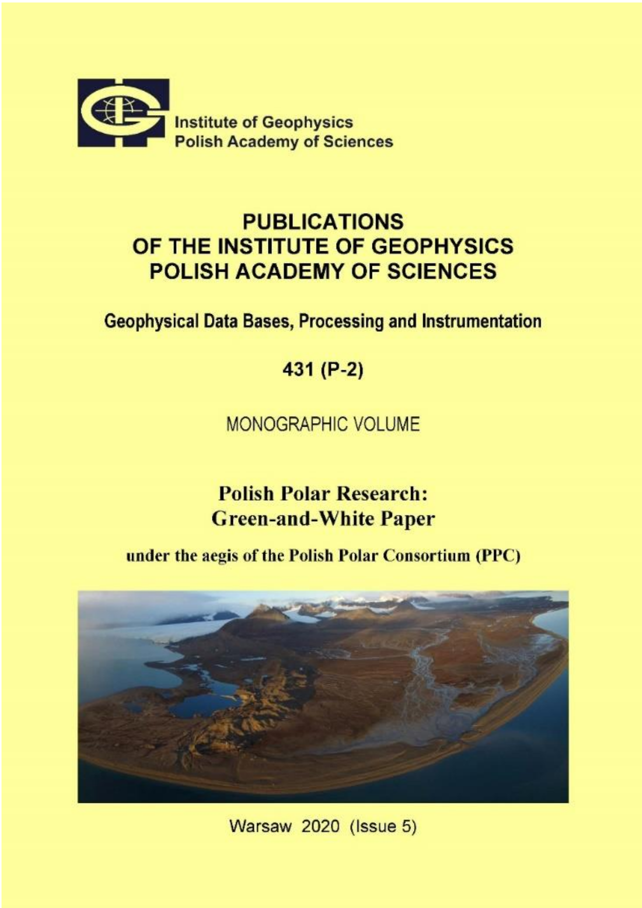
Front cover of *GeoPlanet: Earth and Planetary Sciences*.

Publications of the Institute of Geophysics, Polish Academy of Sciences

It is an electronic journal published by the Institute of Geophysics. It is available at https://pub.igf.edu.pl/.
The Editor-in-Chief is Marek Kubicki. In the year 2020, six issues were published:
– "The Microscopic Insight into Fracturing of Brittle Materials with the Discrete Element Method" by Piotr Klejment;

– "Analysis of Measurements and Modelling of the Biologically Active UV Solar Radiation for Selected Sites in Poland – Assessment of Photo-medical Effects" by Agnieszka E. Czerwińska and Janusz W. Krzyścin;
– "Magnetotellurics Data Application in Medium Enthalpy Geothermal Prospects" by Denis Mutebi et al.;
– "Ozone Content Variability in the Ground-level Atmosphere Layer in the Mazowieckie Voivodeship, Central Poland" by Izabela Pawlak and Janusz Jarosławski;
– "Polish Polar Research: Green-and-White Paper under the aegis of the Polish Polar Consortium (PPC)" by Marek Lewandowski et al.;
– "Zielono-biała Księga Polskich Badań Polarnych pod egidą Polskiego Konsorcjum Polarnego (PKPol)" by Marek Lewandowski i in.

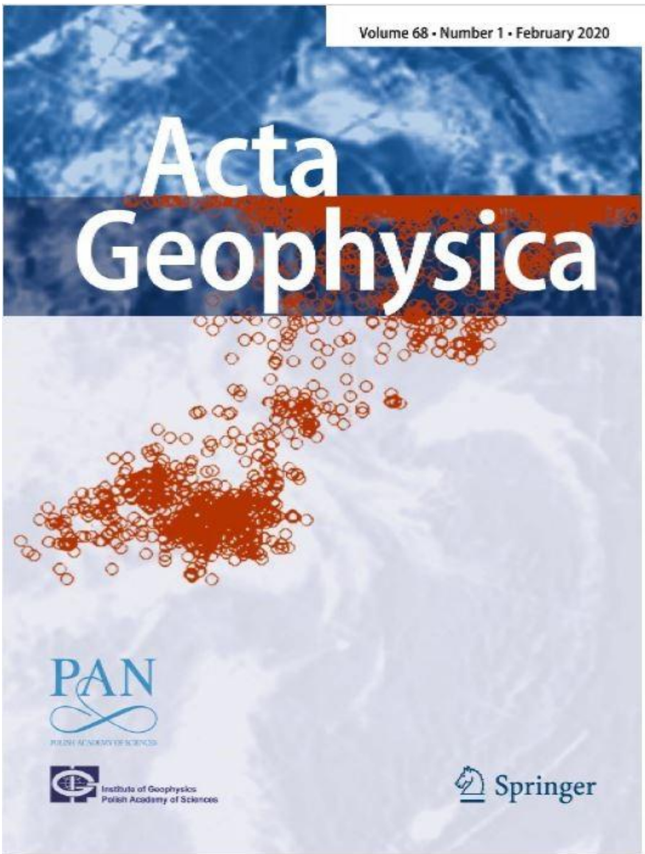
The last two issues were also published in printed version, as hard-cover books.



Front cover of *Publications of the Institute of Geophysics, Polish Academy of Sciences.*

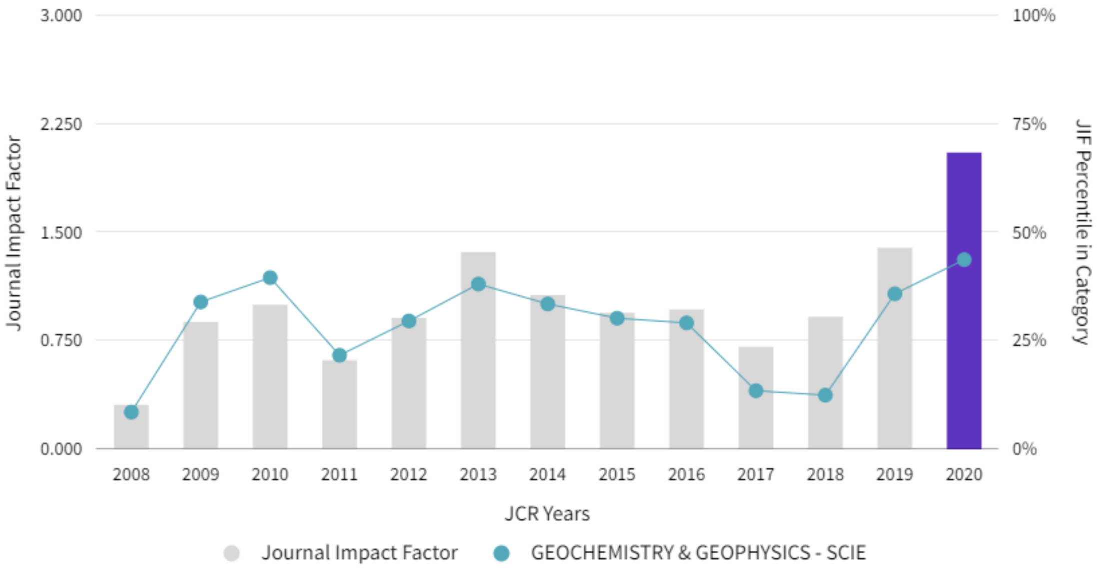
Acta Geophysica

Acta Geophysica is a leading geophysical journal published by the Institute of Geophysics and Committee of Geophysics. The Editor-in-Chief is Prof. Eleftheria Papadimitriou. In the editing of *Acta Geophysica* she is supported by eminent international experts who hold the position of Associate Editors.



Front cover of *Acta Geophysica.*

In the year 2020, six issues of *Acta Geophysica* were published. The total number of pages (B5) was 1898, and the number of articles was 128. **The impact factor is now 2.054, which is the highest value in *Acta*'s history**. In the upcoming years, a further increase of Impact Factor is expected.



Impact Factor of *Acta Geophysica*.

1.6 Educational activity of the Institute in the Academic Year 2019/2020

The GeoPlanet and International Environmental Doctoral Schools made their debut in October 2019 and immediately turned out to be a great success, as evidenced by the great interest of candidates for the first year of studies.

The GeoPlanet PhD School offers interdisciplinary studies in 7 scientific institutions of the Polish Academy of Sciences. The main tasks of the school will include educating doctoral students in climate change, dynamics of geophysical and space processes, natural disasters and extreme phenomena on Earth, in oceans and in space, protection and exploitation of natural resources (including water management), monitoring of processes occurring on Earth, in oceans and in the Solar System and developing new methods for the research and measurement of the Earth and space.

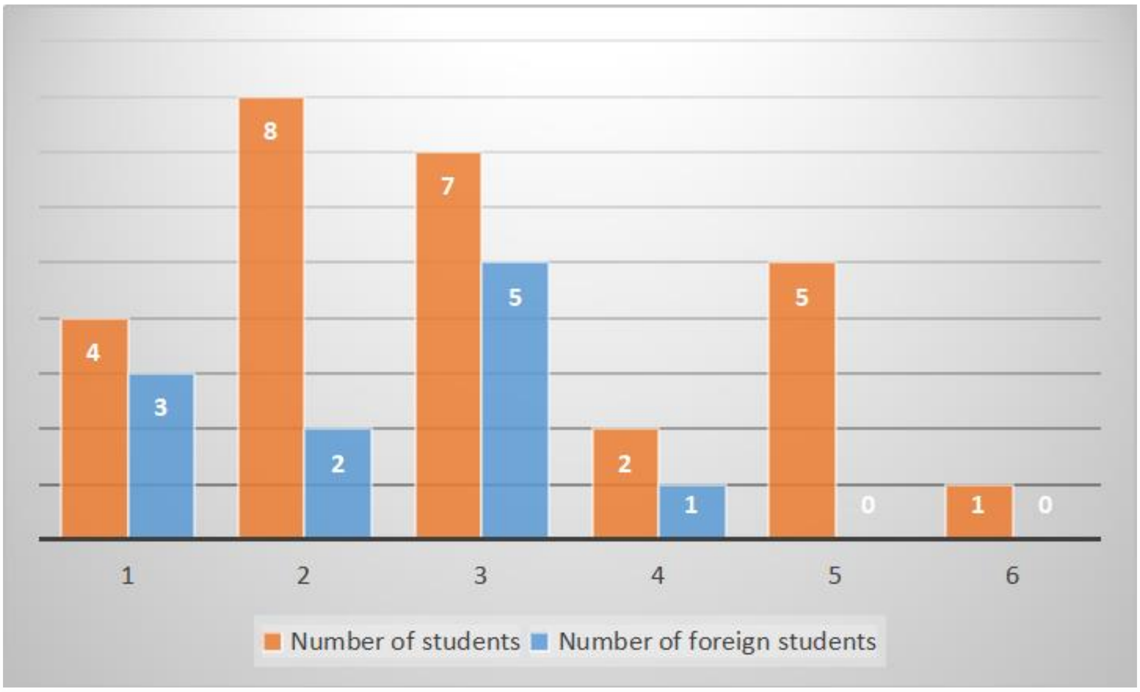
The International Environmental Doctoral School associated with the Centre for Polar Studies at the University of Silesia in Katowice (IEDS) provides the education in the field of Natural Sciences in academic disciplines: Mathematics, Earth and related environmental sciences, and in the field of the Engineering and Technology in academic discipline: Materials engineering. The aim of the IEDS is to provide a new generation of scientists with new opportunities for high-quality contributions to scientific research by offering them theoretical and practical (methodological) training, designed to stimulate their intellectual growth and boost their academic status.

In the previous academic year (2019/2020), the educational activity in the Institute of Geophysics was deeply affected by the pandemic of the Covid-19. Currently, 27 students are studying at our Institute, 4 of whom were recruited to doctoral schools for the first year of study. One person is to submit a doctoral dissertation in the beginning of 2021, while 5 students received an extension of their studies for the 5th year. Eleven doctoral students came from abroad, representing different countries of the world (India – 6 students, Ethiopia – 2, and Italy, Iran and Vietnam – 1), which accounts for the international community in our Institute (see the table and figures below).

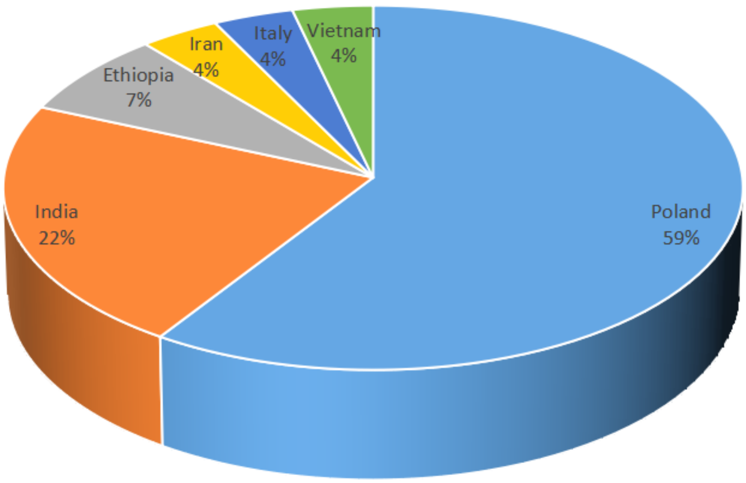
Students in PhD programme in the IG PAS. The beginning of 2021

1st year, recruited in 2020 to Doctoral Schools		2nd year, Doctoral Schools		Regular studies of the IG PAS			
GeoPlanet	IEDS	GeoPlanet	IEDS	3rd year	4th year	“5th year”	“6th year”
2	2	6	2	7	2	5	1

In the 2019/2020 academic year, the scientists from the IG PAS carried out 12 courses for students of the regular PhD Studies (classes in the core block were compulsory) and for the GeoPlanet PhD School (optional classes). Additionally, during the meeting of the International Environmental Doctoral School, lecturers from the IG PAS conducted 4 courses in the form of lectures and seminars (obligatory for PhD students from the International Environmental PhD School). In total, the lecturers from the Institute conducted 272 hours of teaching last year. Additionally, the students from PhD Schools could choose classes from the offer of other partner institutes of the Schools and universities. Due to the Covid-19 virus pandemic, classes in the summer semester were conducted on-line.



Total number of students and foreign students by years of studies.



Students by countries.

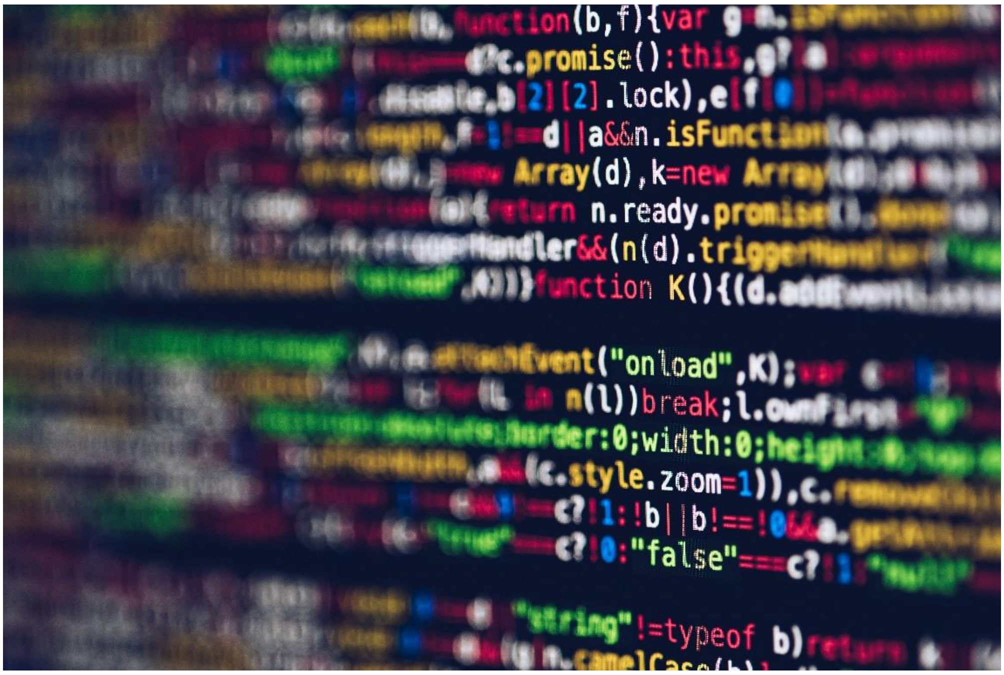
In the next academic year, a reduction in the number of students is expected due to the defenses of doctoral dissertations by people who have extended their studies for the fifth and sixth years. This will be offset by a similar number of new students recruited this year and, as a result, the number of PhD students will remain relatively constant. Note that our studies are of international character and the results of recent recruitment indicate a growing trend of internationalization.

The level of students in both PhD Schools and regular studies of the IG PAS is high, although there is some room for improvement. The activity of doctoral students in the scientific and organizational field, both in Poland and abroad, is more than satisfactory. Students take part in courses beyond the offer of IG PAS and doctoral schools, organize trainings and workshops and research trips by themselves. In the year 2019/2020 every doctoral student received a NAWA scholarship to cover the cost of a scientific trip, unfortunately, the plans were thwarted by the Covid-19 pandemic.

In addition to cooperation with national institutions, in the last academic year an agreement of Doctoral School with Politecnico di Bari, Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica (DICATECh) regarding the exchange of doctoral students and lecturers was signed.

1.7 Data management portal

The data portal of the Institute of Geophysics is a research data management platform, built for storing, sharing, exchanging, and publishing the data related to the Institute's research activities. Since proper data management is crucial for any organization to ensure the authenticity of data, increase its quality and maintain accuracy, rules and procedures for dealing with scientific data in the Institute were introduced, and the data portal officially came into operation in 2020. Following the national and international regulations, such as FAIR principles, the research data and metadata were structured and standardized as a basis for interoperability. The data steward provided researchers with consultation and support in storing and handling their data within the entire data lifecycle as well as utilizing the data management platform. In November 2020, a virtual workshop was conducted on how to properly fill the metadata fields, as well as make scientists familiar with the FAIR and NCN regulations. Obtaining digital object identifier (DOI) for each data was another activity of the data management team since some of the scientific journals only accept articles if the relevant data is published; moreover, the data with an assigned DOI can be cited and accessed more efficiently. The data portal hosted 18 datasets, including 14 public and 4 private ones, and 12 projects at the end of 2020. A ticketing system is allocated for a better communication between the scientists and the data steward, hence, several contacts were made to fix issues, answer questions, and receive suggestions. As the IG data portal was a new platform, it was rigorously monitored to find technical and structural deficiencies. Based on the users and data steward experience, some new features were proposed which will enhance the data management services.



1.8 Projects / commercial agreements

Iceland Liechtenstein Norway grants / Norway grants	1 project
FNP Fundacja na rzecz Nauki Polskiej	2 projects
HORYZONT 2020	7 projects
European Commission	6 projects
Ministry of Science and Higher Education Republic of Poland	20 projects
NAWA NARODOWA AGENCJA WYMIANY AKADEMICKIEJ	5 projects
NATIONAL SCIENCE CENTRE POLAND	32 projects
OŚRODEK PRZETWARZANIA INFORMACJI PAŃSTWOWY INSTYTUT BADAWCZY	2 projects
The Research Council of Norway	5 projects
SIOS SVALBARD INTEGRATED ARCTIC EARTH OBSERVING SYSTEM	3 projects

1.9 Polish polar stations

Polish Polar Station Hornsund

The Polish Polar Station Hornsund, named after prof. Stanisław Siedlecki, is a modern inter-disciplinary research platform located in the southern part of Spitsbergen, the largest island of the Svalbard archipelago. It was established in 1957 and has been in operation year-round since 1978. It is the only year-round Polish research observatory in the Arctic. The main objectives of the monitoring and research programmes carried out at the Station are related to the evolution of the High Arctic environment with respect to Climate Change.

The Station is managed by the Institute of Geophysics, Polish Academy of Sciences based in Warsaw, Poland. Well-equipped scientific laboratories, satellite communication and high standard accommodation and research facilities are available for over 20 visitors, in addition to the permanent staff of about 10 members of IG PAS Polar Expeditions.

Polish Antarctic Station A.B. Dobrowolski

Polish Antarctic Station A.B. Dobrowolski is a scientific station located in East Antarctica (Bunger Hills, Wilkes Land – 66°16′29″S, 100°45′00″E). Handed over to Poland by the Soviet Union in 1959, the station currently belongs to the Polish Academy of Sciences and is managed by the Institute of Geophysics, Polish Academy of Sciences. The station remains in hibernation, but thanks to the recent progress in the development of measuring instruments, scientific data acquisition, and telecommunication networks, IG PAS has undertaken a decision to revitalize the station. The necessary funds have been recently granted by the Ministry of Science and Higher Education.

Signposts at the two Polish Polar Stations.

2. DEPARTMENT OF SEISMOLOGY

Stanisław Lasocki and Łukasz Rudziński

2.1 About the Department

Department of Seismology core research activity is in the field of anthropogenic seismicity. In 2020, IG PAS started to develop new scientific strategy after external expertise of the Institute's resources. Following the accepted approach of main pillars, the Department of Seismology identified three main fields of research involvement: Geohazard, Geosystem and in lesser extend Polar research. Main scientific interest of the Department fits in the Geohazard, which is clearly linked with anthropogenic seismicity. However, the department's research activities extend also on natural seismic processes. The research activities of the Department can be divided into: seismicity induced by exploitation of geo-resources, seismicity triggered by water reservoirs and hazard related with them, statistical properties of anthropogenic and natural seismic processes, engineering seismology and tectonic seismicity leading to large earthquakes. The most interesting scientific works of Department last year were related to rupturing process in the Geysers geothermal field, aftershock prediction in the underground mines, and precursory clustering of seismicity before the Chiapas, M8.2 (Mexico, 2017) earthquake.

The novel discoveries such as proving rate-and-state model useful for evaluating aftershock hazard in an operating mines and clearly linking the local tectonic structures as a main triggering factor of mining seismicity are important not only for the broadening of the knowledge, but also show the potential for the further application of this knowledge to the engineering practice.

On the other hand theoretical earthquake source studies performed in 2020 in the Department reached a high degree of sophistication, which resulted in obtaining rupturing process of fractures and dimension of fault, rupture velocity and particle velocity for seismic events that occurred in The Geysers geothermal field in the USA. The research was done in the framework of S4CE H2020 project.

One of the most fascinating issues, which were in the spotlight of our research was precursory clustering before large earthquakes. The results of faster decrease of the studied clustering parameter until the mainshock seems to be very promising in view of further development of this research.

In addition to research activities, Department of Seismology was also active in EPOS Programme. The consortium EPOS Thematic Core Service Anthropogenic Hazards (TCS AH) is currently led by Prof. S. Lasocki from the Department. The development of the crucial TCS AH infrastructure was performed within EPOS SP H2020 project, EPOS PL, and EPOS PL+ national projects.

2.2 Personnel

Head of the Department
Stanisław Lasocki (until July)
Professor
Łukasz Rudziński (since August)
Associate Professor

Professor
Beata Orlecka-Sikora

Assistant Professors
Maria Kozłowska
Konstantinos Leptokaropoulos (until June)

Grzegorz Lizurek
Janusz Mirek (since October)
Dorota Olszewska
Taghi Shirzad
Monika Sobiesiak (until May)

Research Assistants
Alicja Caputa
Szymon Cielesta (until March)
Beata Plesiewicz
Piotr Sałek (until August)
Monika Staszek

Senior Technical Officer
Jan Wiszniowski

Technical Assistant
Izabela Dobrzycka
Michał Lelonek (since October)
Kaj Michałowski
Dominika Wenc

Administrative Coordinator
Anna Leśnodorska

PhD Students
Alicja Caputa, Poland; Łukasz Rudziński – PhD supervisor
Jakub Kokowski, Poland; Łukasz Rudziński – PhD supervisor
Izabela Nowaczyńska, Poland; Grzegorz Lizurek – PhD supervisor
Anna Tymińska, Poland; Grzegorz Lizurek – PhD supervisor

2.3 Main research projects

- S4CE: Science for Clean Energy, S. Lasocki, H2020, 2017–2020;
- SERA: Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe, S. Lasocki, H2020, 2017–2020;
- EPOS SP, B. Orlecka-Sikora, H2020, 2020–2023;
- EPOS PL, D. Olszewska, POIR, OPI, 2016–2021;
- EPOS PL+, D. Olszewska, POIR, OPI, 2019–2023;
- Analysis of post-blasting seismic sources recorded after rock burst active prevention, A. Caputa, NCN, 2018–2020;
- Comprehensive analysis of the impact of local production conditions, main shock parameters and stress transfer on productivity and distribution of aftershocks in induced seismicity – research for improving the safety of natural resources extraction, M. Kozłowska, Fundacja Nauki Polskiej, 2018–2020;
- Initialization and development of anthropogenic seismic processes induced by artificial surface reservoirs, G. Lizurek, NCN, 2018–2021.

2.4 Instruments and facilities

Equipment

- LUMINEOS – seismic network for monitoring of the mining induced seismicity in Legnica–Głogów Copper District,
- BOIS – seismic network for monitoring of the seismicity induced by mining in Lubelski Węgiel Bogdanka,
- SENTINELS – seismic network for monitoring of the induced seismicity around Czorsztyn – Niedzica artificial lake,
- Lai Chau – seismic network for monitoring of the seismicity in the vicinity of artificial water reservoir in Vietnam,
- Hue – seismic network for monitoring of the seismicity in the vicinity of artificial water reservoir in Vietnam,
- Seismological monitoring of the area of past hydrofracturing operations in Wysin,
- Geodynamic monitoring of Poland – seismic network for monitoring of the natural seismicity in Poland (in cooperation with Technical Support Department).

Department of Seismology in cooperation with Technical Support Department is involved in seismic monitoring of potential nuclear power plant (NPP) site in northern Poland since 2015. During that time, IG PAS has been operating surface seismic stations including broadband and short period devices. The signals are recorded continuously and contain information not only about possible local seismic activity but also influences of regional earthquakes.

INFRASTRUCTURE BUILDING:

Thematic Core Service Anthropogenic Hazards (TCS AH) Consortium. In 2019 Members of the Consortium of Thematic Core Service Anthropogenic Hazards signed the Consortium Agreement. TCS AH members: Instytut Geofizyki Polskiej Akademii Nauk (PL), Akademickie Centrum Komputerowe "Cyfronet" AGH (PL), Instituto Nazionale di Geofisica e Vulcanologia (IT), Centre National de la Recherche Scientifique (FR), Helmholtz Zentrum Potsdam Deutsches Geoforschungszentrum (DE), L'Institut National de l'Environnement et des Risques (FR), Geofyzikalni Ustav AV CR (CZ), Oulun Yliopisto (FIN), Lulea Tekniska Universitet (SE), University of Keele (GB), Główny Instytut Górnictwa (PL), Polska Grupa Górnicza (PL).

The year 2020 was the first of 5 years the Institute of Geophysics acting as a hosting institution. Professor Stanisław Lasocki is the TCS AH Director.

The mission of TCS AH is to integrate research infrastructures within EPOS, for studies on anthropogenic hazards, particularly those related to the exploration and exploitation of georesources. The consortium will therefore maintain and further develop the TCS AH core services on the e-research platform IS-EPOS https://tcs.ah-epos.eu/ by integrating new episodes, tailored software applications, and collaborative functions on the platform with work programs that also address:

- Interoperability between these services and the Integrated Core Service of EPOS;
- Promotion of the services, dissemination and outreach actions;
- Industry collaborations and brokering.

Till now, most of the TCS AH activities have been carried out within national and international projects like: IS-EPOS, SHEER, EPOS PL, EPOS IP, SERA, S4CE etc. It is expected that TCS AH will sign a permanent agreement with EPOS-ERIC in 2020. Another chapter of the EPOS was initiated in 2020. It is the EPOS SP project, in which the development of TCS AH infrastructure is foreseen until 2023.

Laboratory

Department of Seismology is equipped with 78 modern seismic stations: 62 broadband, 6 very broadband seismometers, and 10 strong motion monitoring devices. 48 stations are already installed in seismically active areas: two mining regions in Poland and two regions with seismicity induced by water reservoirs in Poland and Vietnam. With the exception of data embargoed by the principals, all data is on the IS-EPOS Platform (http://tcs.ah-epos.eu/).

2.5 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

AFTERSHOCKS IN MINING SEISMICITY

M. Kozłowska, **B. Orlecka-Sikora**, **D. Olszewska**, **Ł. Rudziński**

In 2020 the analysis focusing on studying the rate-and-state based model for aftershocks prediction post strong mining earthquake was finalized. It was performed together with colleagues from IG PAS, LKAB mining company and Lulea Technical University in Sweden. Data from iron ore Kiruna mine in Swedish Lapland was analyzed. The main goal of this study was to verify whether the model, utilizing Coulomb stress transfer calculations, can be used as a good tool for evaluating aftershock hazard in an operating mine, and, as a result, may be incorporated in creating a re-entry protocol post strong seismic events. The results of the analysis have shown that aftershocks in mining-induced seismicity tend to occur in areas active before, where the so-called background seismicity occurs. The distribution of Coulomb stress changes is a secondary factor influencing the spatial distribution of aftershocks, it rather affects their rate. This study has also shown that there might be some additional process, not included in the applied model, influencing the aftershock activity. We discuss two options: the dynamic triggering and the influence of weaker zones in the host rock. The Fig. 1 below shows the scheme of the modeling shown for one of studied events. The main two inputs are: (a) background seismicity distribution, and (b) Coulomb stress changes distribution. Panel (c) shows the resulting post-main shock seismicity rate. Concluding, our study has shown that rate-and-state model is a good tool for evaluating aftershock hazard in operating mines; however, it requires constant seismic monitoring and fast location, as well as good quality moment tensor analysis of strong earthquakes.

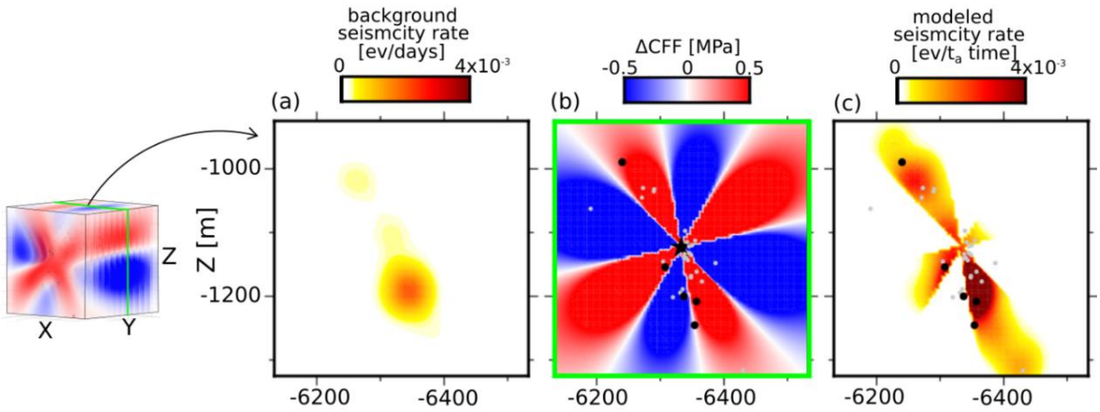


Fig. 1. Scheme of modeling for one of the studied events (explanation in the text). Modified from Kozłowska et al. (2021)[1].

[1]Kozłowska, M., B. Orlecka-Sikora, S. Dineva, Ł. Rudziński, and M. Boskovic (2020), What governs the spatial and temporal distribution of aftershocks in mining-induced seismicity: Insight into the influence of coseismic static stress changes on seismicity in Kiruna mine, Sweden, *Bull. Seismol. Soc. Am.* **111**, 409–423, DOI: 10.1785/0120200111.

RUPTURING PROCESS AND EVENT INTERFEROMETRY IN THE GEYSERS GEOTHERMAL FIELD

T. Shirzad, **S. Lasocki**, **B. Orlecka-Sikora**

Theoretical earthquake source studies, especially dynamic simulations, have reached a high degree of sophistication, which is driven by the rapid development of the computational power and numerical methods. Source imaging by back-tracing of seismic waves recorded by dense arrays allows us to track the areas of strongest high-frequency radiation. We used the rupturing process with an accurate *P*-wave velocity model, which is obtained by the first arrival *P*-wave tomography approach, to obtain rupturing process of fractures and dimension of fault, rupture velocity and particle velocity. An example of using the rupturing approach for an event that occurred in The Geysers geothermal field in the USA can help us to compare the resulted properties with focal mechanism solution information. For this purpose, an earthquake M_w 4.2 with hypocenter ~5 km was selected. After applying back-projection technique, the amplitudes of the stacked signal for 0.30 and 0.35 s at different depths represent rupturing of a fault, as shown in Figs. 1 and 2 below.

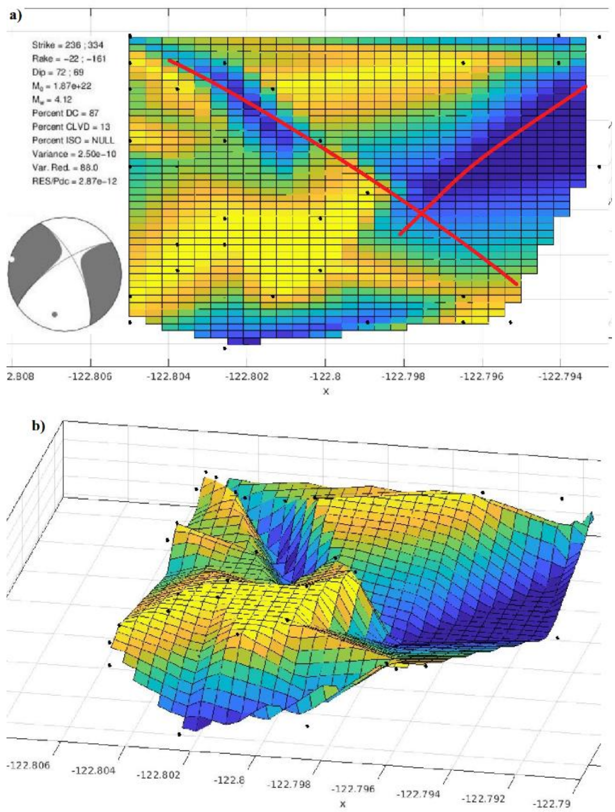


Fig. 1: (a). Horizontal slice of maximum amplitude with 0.1 s time intervals; (b) 3D-view of the maximum amplitude of rupturing procedure. The color just indicates the topography variation. The focal mechanism was reported by https://ncedc.org. The red lines are the suggested fault plane (after Shirzad et al. 2020).

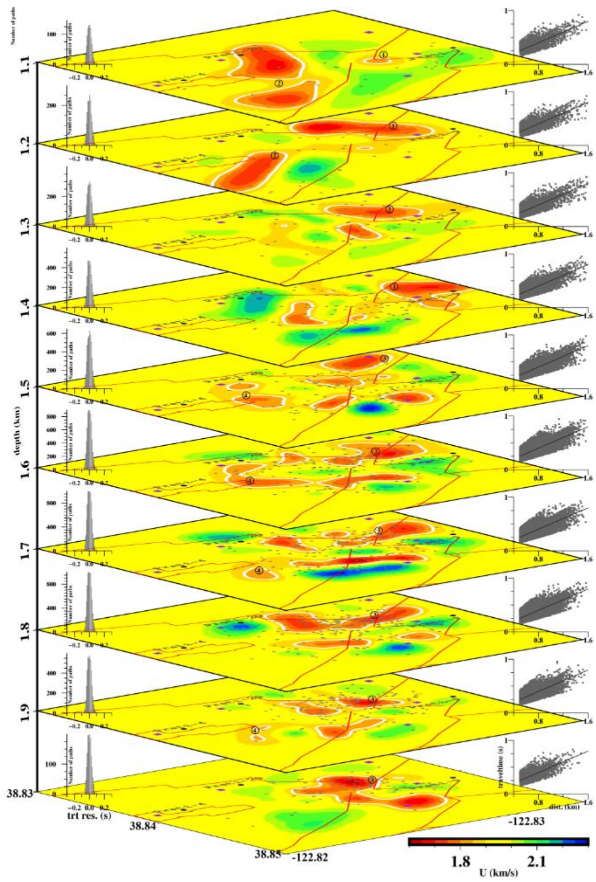


Fig. 2. Rayleigh wave group velocity maps in the depth range from 1.1 to 2.0 km. The small grey circles are vertical projections of micro-earthquakes onto the nearest horizontal layer. The known faults are depicted by red lines. The observed traveltimes as the function of inter-event distance are at the right edge of each map, the traveltime residual (trt res.) histograms are depicted at the left (after Shirzad et al. 2020).

The possibility of retrieving empirical Green's functions (EGFs) using virtual seismometers provides an opportunity to calculate high-resolution velocity models without a set of dense stations. The cross-correlations of earthquakes contain significant information about the EGFs between event pairs. By using a new application of virtual seismometers on a very small scale in superficial layers, the NW part of The Geysers geothermal field was considered. We processed 1276 micro-earthquakes, which occurred in a cuboid with the horizontal side of ~1 × ~2 km and the vertical edge at a depth from 1.1 to 2.0 km, to obtain the high-resolution (100 × 100 m) velocity structure. The group velocity map for each horizontal layer was obtained using FMST tomographic approach. The three-dimensional image created by a set of these maps as a function of depth in Fig. 2 indicated a low-velocity anomaly related to existing inactive faults, and low-velocity anomalies possibly stimulated by fluid injection. The latter anomalies were connected at some depths (e.g., 1.8 km).

PRECURSORY CLUSTERING OF SEISMICITY IN A PARAMETER SPACE BEFORE THE GIANT CHIAPAS, M8.2 (MEXICO, 2017) EARTHQUAKE

S. Lasocki

Following the earlier studies it was suggested that the seismic events preceding M8+ earthquakes might cluster in the space of interevent time, interevent distance, and magnitude. We investigated 1153 M4.5+ seismic events from 1.01.1999 until the Chiapas earthquake on 8.09.2017. In the first step, the ordered in time series of events was re-parameterized in terms of $dt(i)$ – the time lapse between the occurrences of the events $i-1$ and i, $dr(i)$ – the orthodromic epicentral distance between the events $i-1$ and i, $m(i)$ – the magnitude of the event i, $i = 2,..,1153$. Next, dt , dr, m were transformed to equivalent dimensions and then the dt , dr, m values series was divided into 100 element consecutive time-windows being-shifted by 20 events. The degree of clustering of n seismic events in the space $\{dt, dr, m\}$ was quantified by the average distance between these events

$$d_c = \frac{2}{(n-1)n}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\sqrt{[dt(i)-dt(j)]^2 + [dr(i)-dr(j)]^2 + [m(i)-m(j)]^2}$$

Finally, d_c was evaluated in the consecutive data windows.

Figure 1 presents time-variations of the degree of clustering, d_c, during 18 years before the Chiapas earthquake. A distinctly visible strong signal consists of: (i) a decreasing trend of d_c from the beginning of the study period to the middle of 2007, (ii) a steady increase of d_c

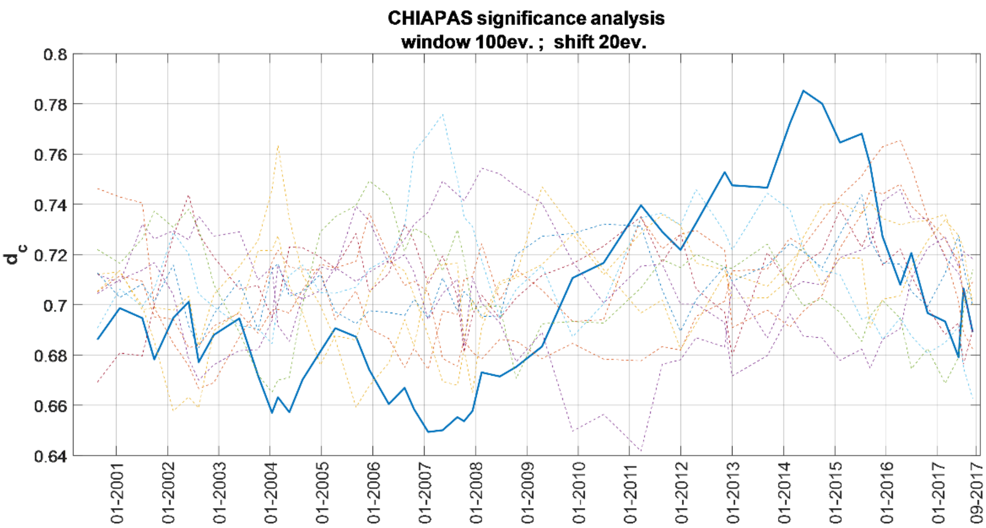


Fig. 1. Chiapas significance analysis (explanation in the text).

between the middle of 2007 and the end of 2014, (iii) a comparatively faster decrease until the mainshock. The same signal appeared when non-overlapping time-windows were analyzed. In the figure, light lines present variations of d_c calculated from random permutations of the *dt*, *dr*, *m* values series. The behavior of d_c evaluated from the actual series (heavy line) is clearly different regarding the systematic trends and extreme amplitudes, which proves the statistical significance of the d_c signal.

The research was carried out in collaboration with E. Papadimitriou, V. Karakostas from the Aristotle University of Thessaloniki and R. Zúñiga from the Universidad Nacional Autónoma de México (UNAM).

2.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- B. Orlecka-Sikora, Athropogenic seismicity; University of Lulea, Lulea, Sweden, 30.01.2020, Invited lecture;
- T. Shirzad, Tracking the development of seismic fracture network by considering the fault rupture method; EGU General Assembly Conference, Austria, 4–8.05.2020, Poster;
- T. Shirzad, Applications of Ambient Seismic Noise Tomography; 19th Iranian Geophysical Conference, Iran, 5–7.11.2020, Oral;
- M. Kozłowska, Aftershock productivity in mining-induced seismicity – the case of Rudna copper ore mine, Poland; AGU Fall Meeting, USA, 1–17.12.2020, Poster;
- T. Shirzad, Velocity Structure of the Mosha Fault, NorthernIran, from Local Earthquake Tomography; AGU Fall Meeting, USA, 1–17.12.2020, Poster.

2.7 Publications

ARTICLES

Caputa, A., and **Ł. Rudziński** (2020), Syntetyczne testy inwersji pełnego pola falowego w warunkach rzeczywistej sieci monitoringu sejsmicznego ZG Rudna, *Prz. Geof*. **45**, 3–4, 123–138, DOI: 10.32045/PG-2020-012.

Lasocki, S., and **B. Orlecka-Sikora** (2020), High injection rates counteract formation of far-reaching fluid migration pathways at the geysers geothermal field, *Geophys. Res. Lett.* **47**, 4, e2019GL086212, DOI: 10.1029/2019GL086212.

Marzec, P., et al., **S. Lasocki** (2020), Seismic imaging of mélanges; Pieniny Klippen Belt case study, *J. Geol. Soc*. **177**, 3, 629–646, DOI: 10.1144/jgs2018-220.

Marzec, P., et al., **S. Lasocki** (2020), Reply to discussion of "Seismic imaging of mélanges; Pieniny Klippen Belt case study", Journal of the Geological Society, London, https://doi.org/10.1144/jgs2018-220, *J. Geol. Soc*. **178**, 2, jgs2020-111, DOI: 10.1144/jgs2020-111.

Tokarski, A.K., et al., **S. Lasocki** (2020), Active faulting and seismic hazard in the Outer Western Carpathians (Polish Galicia): evidence from fractured Quaternary gravels, *J. Struct. Geol.* **141**, 104210, DOI: 10.1016/j.jsg.2020.104210.

Leptokaropoulos, K. (2020), Magnitude distribution complexity and variation at The Geysers geothermal field, *Geophys. J. Int.* **222**, 2, 893–906, DOI: 10.1093/gji/ggaa208.

Leptokaropoulos, K., and **S. Lasocki** (2020), SHAPE: A MATLAB software package for time-dependent seismic hazard analysis, *Seismol. Res. Lett*. **91**, 3, 1867–1877, DOI: 10.1785/0220190319.

Mendecki, J.M., et al., **G. Lizurek** (2020), Mining-triggered seismicity governed by a fold hinge zone: The Upper Silesian Coal Basin, Poland, *Eng. Geol*. **274**, 105728, DOI: 10.1016/j.enggeo.2020.105728.

Orlecka-Sikora, B., and **Sz. Cielesta** (2020), Evidence for subcritical rupture of injection-induced earthquakes, *Sci. Rep.* **10**, 4016, DOI: 10.1038/s41598-020-60928-0.

Orlecka-Sikora, B., **S. Lasocki**, et al., **P. Urban**, **P. Sałek**, **K. Leptokaropoulos**, **G. Lizurek**, **D. Olszewska**, **K. Chodzińska**, **Ł. Rudziński**, **I. Dobrzycka**, **Sz. Cielesta** (2020), An open data infrastructure for the study of anthropogenic hazards linked to georesource exploitation, *Sci. Data* **7**, 89, DOI: 10.1038/s41597-020-0429-3.

Ilieva, M., et al., **Ł. Rudziński**, **G. Lizurek**, **D. Olszewska** (2020), Combined study of a significant mine collapse based on seismological and geodetic data – 29 January 2019, Rudna Mine, Poland, *Remote Sens.* **12**, 10, 1570, DOI: 10.3390/rs12101570.

Shirzad, T., et al. (2020), High resolution upper crustal velocity structure beneath Qeshm Island (SE Zagros) from surface wave, first arrival, and interevent interferometry tomography methods, *Phys. Earth Planet. In*. **308**, 106569, DOI: 10.1016/j.pepi.2020. 106569.

Najafi, M.N., et al., **T. Shirzad** (2020), Avalanches on the complex network of Rigan earthquake, *Europhys. Lett.* **130**, 2, 20001.

CHAPTERS

Lasocki, S., and **B. Orlecka-Sikora** (2020), anthropogenic seismicity related to exploitation of georesources. **In:** H.K. Gupta (ed.), *Encyclopedia of Solid Earth Geophysics*, 2nd ed., Springer.

3. DEPARTMENT OF ATMOSPHERIC PHYSICS

Janusz Krzyścin

3.1 About the Department

The Department activities comprise modelling and monitoring of unique atmospheric parameters (column amount of ozone and its vertical distribution, atmospheric electricity, lightning, aerosols, UV spectra, trace gases, waves in the tropical atmosphere) in different parts of the atmosphere: surface layer, troposphere, stratosphere, and ionosphere. The aim is to determine and predict the variability of atmospheric parameters and to identify the sources of this variability on different time scales (from days up to decades). The Department contains five internal groups: **Atmospheric Aerosols (AA)**, **Atmospheric Electricity (AE)**, **Global Modelling (GM)**, **Ozone and UV (O_3UV)**, and **Tropical Dynamics (TD)**. The groups focus on the following topics in 2020:

- The long-term changes of the Antarctic ozone hole characteristics. The basic finding is that the hole is recovering faster than previously thought based on the decrease in the concentration of ozone-depleting substances in the atmosphere, suggesting the importance of climate changes for the development of the Antarctic ozone hole (O_3UV);
- Estimations of the daily amount of skin-synthesized vitamin D and erythemal doses by adults during the cruise to Spitsbergen (2017) and by pre-school children in Poland (2018) – analyses of the measurement campaigns (O_3UV);
- Examination of the vertical structure of aerosols and impact of absorbing particles on the height of planetary boundary layer (AA);
- Investigation of cloud structure over tropical Atlantic using ultrafast thermometer during EUREC4A campaign in Jan/Feb 2020 (TD);
- Detection of cloud-to-ground flashes by our measuring stations of Local Lightning Detection Network in the Warsaw region to identify their time development and main E-field components (AE);
- Influence of aerosol layering in the free troposphere on surface UV radiation. Identification of layer geometry that results in differences between radiative transfer model calculations and measurements (AA);
- Participation in ACTRIS COVID-19 initiative aimed at the study of continent-wide lockdown on anthropogenic pollution. Data analysis form three participating sites by GRASP software (AA);
- Short campaign at Belsk to close LIDAR derived extinction profile with in-situ size distribution measurements. Preparation of UAV setup for low altitude profiling of particulate matter, filling the gap between in-situ and lowermost part of extinction profile (AA);
- Analysis of main generators on the Global Electric Circuit (GEC) based on the atmospheric electricity, aerosol and air radioactivity measurements in mid-latitudes and polar regions (AE);
- Fair-weather atmospheric electricity and solar effects in ground-level atmospheric electric field at polar and mid-latitude regions (AE);
- Developing a novel method for measuring the vertical ozone profile from ground-based Brewer spectrophotomer measurements (O_3UV).

3.2 Personnel

Head of the Department
Janusz Krzyścin
Professor

Associate Professors
Janusz Jarosławski
Jacek Kamiński
Aleksander Pietruczuk

Assistant Professors
Agnieszka Czerwińska
Daniel Kępski
Magdalena Kossakowska
Michał Posyniak
Artur Szkop

Post-Doctoral Researchers
Dariusz Baranowski
Jakub Guzikowski
Marek Kubicki
Anna Odzimek
Izabela Pawlak
Piotr Sobolewski
Jose Tacza

Research Assistants
Piotr Barański
Magdalena Morawska
Jakub Wink

Observers
Anna Głowacka
Dorota Sawicka

PhD Students
Alnilam Fernandez, India; Aleksander Pietruczuk – PhD supervisor
Beata Latos, Poland; Aleksander Pietruczuk – PhD supervisor
Anahita Sattari, Iran; Jacek Kamiński – PhD supervisor
Wojciech Szkółka, Poland; Krzysztof Mizerski – PhD supervisor

3.3 Main research projects

- Multi-scale interactions over the Maritime Continent and their role in weather extremes over Central and Eastern Europe, Baranowski Dariusz, Foundation for Polish Science, 2018–2020;
- Identification of processes responsible for anomalous total ozone variability in the Northern Hemisphere mid-latitudes, Kamiński Jacek, The National Science Centre (OPUS12), 2018–2020;

- Impact of the aerosols optical properties on the surface UV and photochemical smog, Pietruczuk Aleksander, The National Science Centre, Poland, 2018–2020;
- Monitoring of Total Ozone Amount in the Atmosphere and UV-B Radiation at Belsk Observatory in 2017–2020, Jarosławski Janusz, Chief Inspectorate of Environment Protection, 2017–2020;
- Impact of absorbing aerosols on the planetary boundary layer height, Posyniak Michał, The National Science Centre, Poland, 2016–2020;
- Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems, Odzimek Anna, COST, 2016–2021;
- Recognition of the aerosols vertical structure and its influence on the Earth electric field intensity – pilot studies, Kępski Daniel, The National Science Centre, Poland, 2021;
- Multi-station analysis of solar effects in the ground-level atmospheric electric field, Tacza Jose, National Agency for Academic Exchange, Ulam Program Fellowship, 2020–2022;
- Multifunctional photocatalytic prefabricates made of porous concrete to improve water conditions and air quality, Jarosławski Janusz, The National Centre for Research and Development, Poland, 2021–2023.

3.4 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

INVESTIGATION OF PHOTOCATALYTIC CONCRETE PAVING BLOCKS – VERYFICATION OF EFFECTIVNESS OF NITRIC OXIDES REDUCTION AND A NOVEL EFFICIENCY TEST METHOD

J. Jarosławski

The problem of air quality has become one of the major challenges nowadays. In the urban areas one of the dominant sources of the airborne pollution is traffic. Hence, the air quality has been analyzed in many direct measurements, as well as in numerical simulations. Analysis of air pollution in Europe indicated that among a variety of airborne pollutions, reduction of NOx emissions is one of the most urgent and potentially the most beneficial.

Photocatalytic concrete (Fig. 1) is one of the most promising concrete technologies of the last decades. Application of nanometric titanium dioxide to cement matrix enables reduction of harmful airborne pollutants, mainly nitrogen oxides. Although several implementations of this technology have been described, problems related to test conditions were reported. One of the major issues is the sufficient light irradiation that for higher latitudes can be significantly re-

Fig. 1. Photocatalytic concrete paving block studied in the research. Figure from Witkowski et al. (2020).

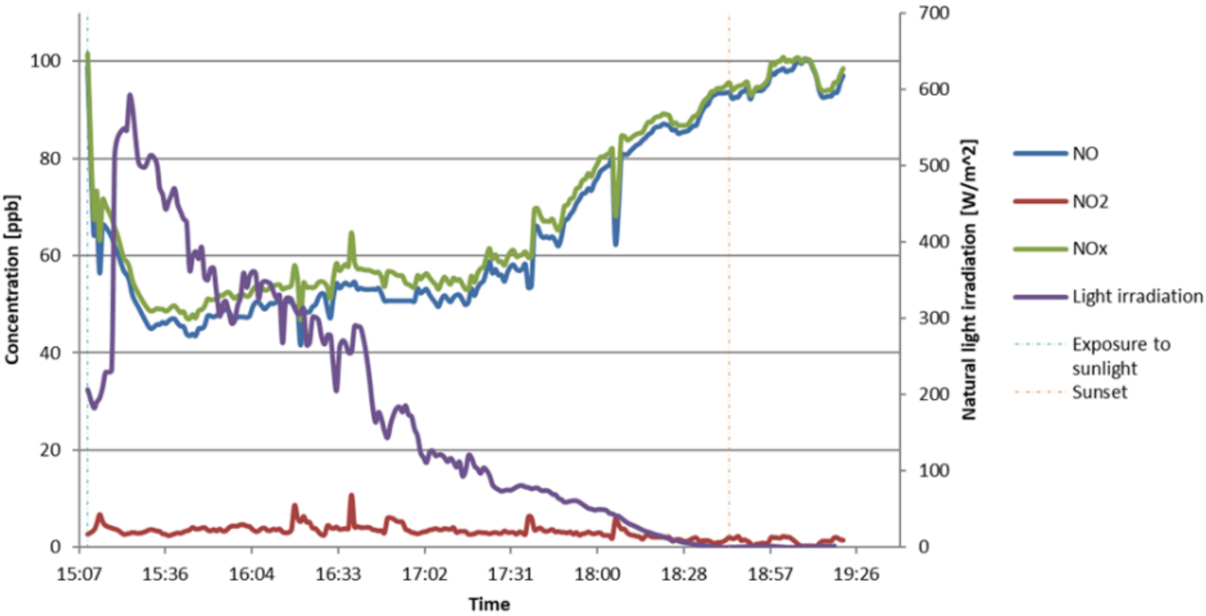


Fig. 2. NO, NO_2 and NOx abatement with natural UV irradiance measured with the novel test method. Figure from Witkowski et al. (2020).

duced. On the basis of experience from the field campaign, a novel test method has been developed. An effectiveness of nitric oxides reduction was verified at natural light irradiation for various dates of solar position at noon in central Poland (51.83°N). The obtained results confirm the rationality of using photocatalytic materials at higher latitude locations. Significant reduction of NOx concentrations (up to 40% of initial values) has been observed at high solar zenith angles, typical for the winter season in Central Poland (Fig. 2). The experimental setup used in the study combines the advantages of controlled measurement conditions typical for laboratory tests with a possibility of including natural sunlight conditions into the investigation process.

IMPACT OF ABSORBING AEROSOLS ON THE PLANETARY BOUNDARY LAYER HEIGHT

M. Posyniak

The objective of the project is to examine the impact of absorbing aerosols on the height of planetary boundary layer (PBL) based on the measurement campaigns carried out in 2018 and 2019 on Szyndzielnia Mountain (the Silesian Beskids) near the town of Bielsko-Biała.

The aerosol optical properties were measured by in-situ and remote techniques. The measuring equipment was placed in several locations nearby the Szyndzielnia cable car. During this campaign, the micro-aethalometer AE-51 and the optical particle counters PMS7003 and OPC-N2 were mounted on the cable car and used to measure profiles of black carbon (BC) concentration and aerosol size distribution. In-situ measurements of optical properties of the aerosol were carried out with the use of AE-31 aethalometer and photo-acoustic devices. For determination of PBL height and presence of aerosol layers, a prototype 3-wavelength lidar was used.

In the middle phase of the study (1st – 6th March 2018), significant temperature inversions were observed, which also persisted during the day. During the inversion period, the extensive parameters describing the amount of aerosol in the air increased significantly. The concentration of elemental carbon exceeded the level of 15 $\mu g/m^3$ several times (the average level was 5.39 ± 4.42 $\mu g/m^3$). On the other hand, the results obtained in the first and third phase of the experiment were at the level of the aerosol background (1.45 ± 0.88 $\mu g/m^3$ and 0.90 ± 0.95 $\mu g/m^3$, respectively). Significant differences were also observed in the vertical profiles of PM10 and the concentration of molecular carbon. In the middle phase of the study, the profiles show a significant reduction in the concentration of pollutants with height, while in the first and third phases the changes are slight with height.

Figure 1 presents mean vertical profiles of PM10 and equivalent black carbon (eBC) mass concentrations obtained in three periods of experiment. The mean PM10 and eBC profiles for the first and third period show small variability with altitude. Both quantities are almost constant with altitude. Significant change has been found for the second stage (Fig. 1b). PM10 decreases from about 90 μg/m^3 to close surface to 50 μg/m^3 (upper station). Reduction of eBC is from about 12 μg/m^3 to 6 μg/m^3. For both PM10 and eBC the reduction is mostly observed in the first 150–200 m. In the upper layer, both quantities change slightly. Significant reduction of aerosol mass concentration with altitude can be explained by surface or lower troposphere temperature inversions, which were observed every night during the second stage of the field campaign.

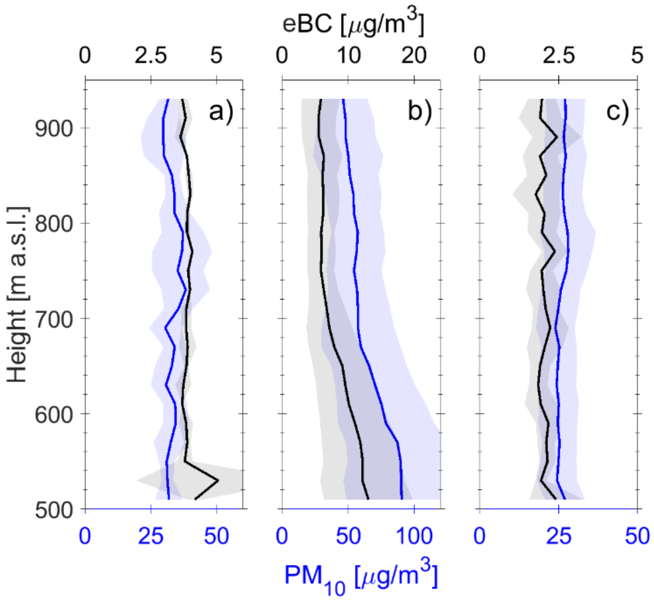


Fig. 1. Mean vertical profiles of PM10 in [μg/m^3] (blue line), eBC concentration in [μg/m^3] (black line) obtained during cable car soundings on 28th February 2018 (a), between 1st and 6th March 2018 (b), and between 7th and 10th March 2018 (c) in morning hours (before 10 UTC). Shading corresponds to standard deviation of profiles (after Posyniak et al. 2021)[2].

NUMERICAL ESTIMATIONS OF THE DAILY AMOUNT OF SKIN-SYNTHESIZED VITAMIN D BY PRE-SCHOOL CHILDREN IN POLAND

A. Czerwińska, **J. Krzyścin**

UV radiation effects on human health can be both positive (vitamin D skin synthesis) and negative (skin cancers). Our research group is working to show scenarios, how to gain the maximum vitamin D_3 dose from sun exposure without negative health effects, such as sunburn. Recently (in 2018) a new guideline for Poland on supplementation of vitamin D were proposed. The guidelines assume that in the period between 10 am and 3 pm from May to September, 15 minutes of sun exposure with uncovered forearms and lower legs is enough to gain the recommended daily dose of vitamin D_3, equivalent to 600–1000 I.U. for children and 800–2000 I.U. for adults. We presented the observation campaign and numerical estimations of the daily amount of skin-synthesized vitamin D by pre-school children in Poland.

[2]Posyniak, M.A., K.M. Markowicz, D. Czyżewska, M.T. Chiliński, P. Makuch, O. Zawadzka-Manko, S. Kucięba, K. Kulesza, K. Kachniarz, K. Mijal, and K. Borek (2021), Experimental study of smog microphysical and optical vertical structure in the Silesian Beskids, Poland, *Atmos. Poll. Res.* **12**, 9, 101171, DOI: 10.1016/j.apr.2021.101171.

The observation campaign was conducted in Warsaw from April to September 2018 during good weather conditions. The sites of observations included a playground at a kindergarten and a nearby park (52.31°N, 21.06°E) (Fig. 1). During the campaign UV Index (UVI) was measured with hand-held Solarmeter 6.5 (by Solar Light Company, Inc.) only a few times around local noon but it was enough to reconstruct the UVI daily course (for each day of the campaign) with an interval of 5 minutes. Furthermore, the way of dressing of kids aged 4–6 years was noted to estimate the daily production of vitamin D_3 from skin exposures using a model approach. The children's clothing was recorded in seven categories (long sleeves, long trousers; t-shirt, long trousers, etc.) together with the number of children in each category and a rough estimation of the percentage of uncovered body area. Further, we estimated doses of skin-synthesized vitamin D by 4- and 6-year children for selected periods: 15 min, 30 min, 45 min, and 1 h, with starting points at 10:45 am, solar noon – 30 min and 1:30 pm. Starting points at 10:45 am and 1:30 pm were selected on the basis of the daily kindergarten schedule. The period around solar noon is a period with the greatest exposure during the day. Sunbathing near the solar noon is possible for non-kindergarten children and for all children during weekends.

We concluded that it is hard to get a sufficient daily amount of vitamin D3 (equivalent to 600–1000 I.U. taken orally) during recommended 15 minutes of outdoor exposure between 10 am and 3 pm in the warm period of the year (May–September). Nevertheless, a schedule of daily activities in the kindergarten includes outdoor playing for at least an hour a day. This is

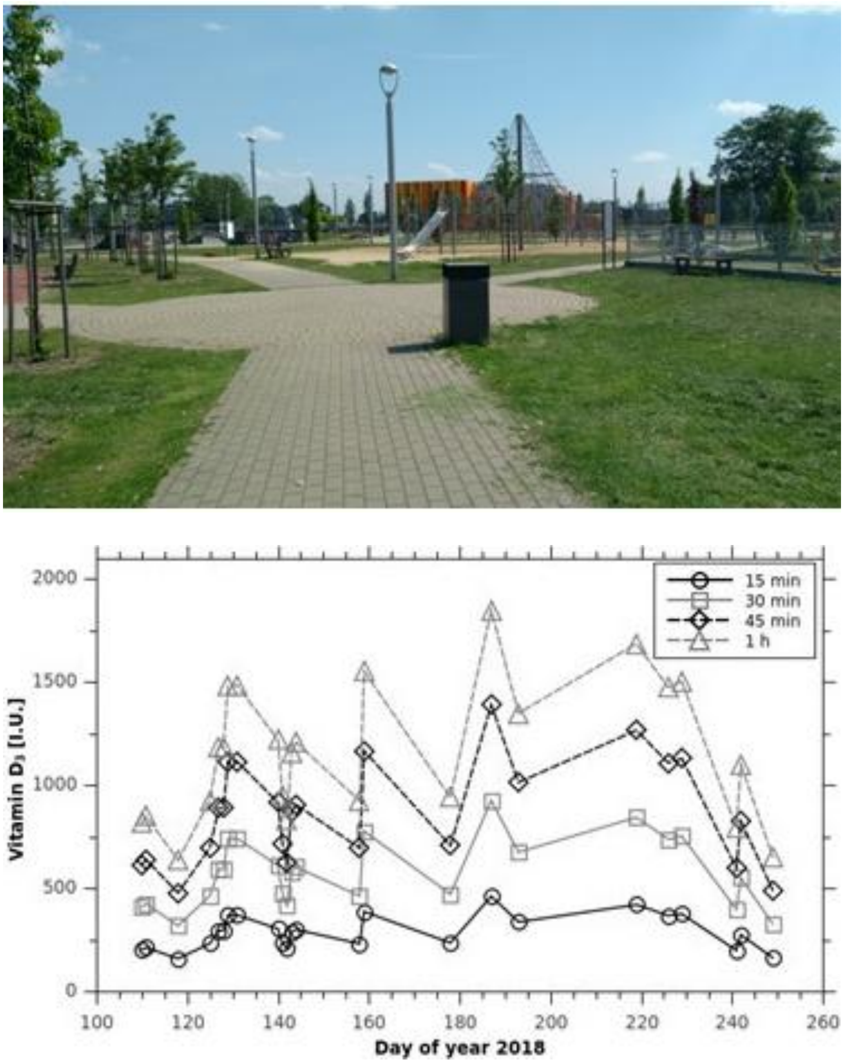


Fig. 1. Site of measurements: nearby park (52.31ºN, 21.06ºE) – top panel (photo A. Czerwińska). The skin-synthesized vitamin D_3 dose by 6-year old children during 15, 30, 45, and 60 min. of typical out-door playing around local noon (noon ±30 minutes) – bottom panel. Figures are from Czerwińska and Krzyścin (2020).

sufficient time to get the adequate vitamin D status for pre-school children. To avoid getting sunburn, the clothing should cover parts of the body, which are horizontally oriented (shoulders and ears) or inclined to the Sun (forehead). More can be found in the article: Numerical estimations of the daily amount of skin-synthesized vitamin D by pre-school children in Poland, *J. Photochem. Photobiol. B Biol*. **208** (2020), 111898, https://doi.org/10.1016/j.jphotobiol.2020.111898.

3.5 Visiting scientists

Jose Tacza, Presbyterian McKenzie University, San Paulo, Brasil, 2020–2022.

3.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- A. Pietruczuk, J. Krzyścin, A. Szkop, A. Fernandes, Aerosol layering in free troposphere, its impact on modification of the UV irradiation over industrial site in southern Poland, EGU General Assembly 2020, Vienna, Austria, 4–8.05.2020, Oral;
- J. Krzyścin, A. Fernandes, A. Szkop, A. Pietruczuk, Wpływ uwarstwienia aerozolu w wolnej troposferze na poziom UV przy powierzchni gruntu w Raciborzu w 2019, The Role of Aerosol in a Climate System, Warsaw, Poland, 3–4.12.2020, Oral;
- M. Posyniak, Research on microphysical and optical vertical structure smog in the area of the Silesian Beskids, The Role of Aerosol in a Climate System, Warsaw, Poland, 3–4.12.2020, Oral;
- J. Tacza, K. Nicoll, E. Macotela, M. Kubicki, A. Odzimek, J. Manninen, Measuring global signals in the atmospheric electric field at high latitude sites, American Geophysical Union Fall Meeting 2020, USA, 1–17.12.2020, Oral.

3.7 Publications

ARTICLES

Baranowski, D.B., et al. (2020), Social-media and newspaper reports reveal large-scale meteorological drivers of floods on Sumatra, *Nature Commun*. **11**, 2503, DOI: 10.1038/s41467-020-16171-2.

Czerwińska, A.E., and **J.W. Krzyścin** (2020), Climatological aspects of the increase of the skin cancer (melanoma) incidence rate in Europe, *Int. J. Climatol*. **40**, 6, 3196–3207, DOI: 10.1002/joc.6391.

Czerwińska, A., and **J. Krzyścin** (2020), Numerical estimations of the daily amount of skin-synthesized vitamin D by pre-school children in Poland, *J. Photochem. Photobiol. B: Biol.* **208**, 111898, DOI: 10.1016/j.jphotobiol.2020.111898.

Witkowski, H., **J. Jarosławski**, et al. (2020), Application of photocatalytic concrete paving blocks in Poland – verification of effectiveness of nitric oxides reduction and novel test method, *Materials* **13**, 22, 5183, DOI: 10.3390/ma13225183.

Ménard, R., et al., **J.W. Kamiński** (2020), Coupled stratospheric chemistry–meteorology data assimilation. Part I: Physical background and coupled modeling aspects, *Atmosphere* **11**, 2, 150, DOI: 10.3390/atmos11020150.

Kossakowska, M., and **J.W. Kamiński** (2020), A note on the potential impact of aviation emissions on jet stream propagation over the northern hemisphere, *Acta Geophys*. **68**, 4, 1187–1199, DOI: 10.1007/s11600-020-00444-x.

Krzyścin, J. (2020), Is the Antarctic ozone hole recovering faster than changing the stratospheric halogen loading?, *J. Meteorol. Soc. Japan* **98**, 5, 1083–1091, DOI: 10.2151/jmsj.2020-055

Krzyścin, J.W., **J. Guzikowski**, **A. Pietruczuk**, and **P.S. Sobolewski** (2020), Improvement of the 24 hr forecast of surface UV radiation using an ensemble approach, *Meteorol. Appl*. **27**, 1, e1865, DOI: 10.1002/met.1865.

Krzyścin, J., **B. Rajewska-Więch**, and **J. Borkowski** (2020), Stan warstwy ozonowej nad Polska w okresie 1979–2018, *Prz. Geof*. **45**, 3–4, 103–121, DOI: 10.32045/PG-2020-011.

Arnone, E., et al., **A. Odzimek** (2020), Climatology of transient luminous events and lightning observed above Europe and the Mediterranean Sea, *Surv. Geophys*. **41**, 167–199, DOI: 10.1007/s10712-019-09573-5.

Zieliński, T., et al., **M. Posyniak**, **P. Sobolewski** (2020), Study of chemical and optical properties of biomass burning aerosols during long-range transport events toward the Arctic in summer 2017, *Atmosphere* **11**, 1, 84, DOI: 10.3390/atmos11010084.

AboEl-Fetouh, Y., et al., **P.S. Sobolewski** (2020), Climatological-scale analysis of intensive and semi-intensive aerosol parameters derived from AERONET retrievals over the Arctic, *J. Geophys. Res. Atmos*. **125**, 10, e2019JD031569, DOI: 10.1029/2019JD031569.

MONOGRAPHS

Czerwińska, A.E., and **J.W. Krzyścin** (2020), Analysis of Measurements and Modelling of the Biologically Active UV Solar Radiation for Selected Sites in Poland – Assessment of Photo-medical Effects, *Publs. Inst. Geoph. PAS* **428** (D-75), 111 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2020-002.

Pawlak, I., and **J. Jarosławski** (2020), Ozone Content Variability in the Ground-level Atmosphere Layer in the Mazowieckie Voivodeship, Central Poland, *Publs. Inst. Geoph. PAS* **429** (D-76), 97 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2020-004.

4. DEPARTMENT OF LITHOSPHERIC RESEARCH

Tomasz Janik and Working Group[3]

4.1 About the Department

NSL1. Structure and evolution of Central Europe's lithosphere with particular emphasis on the area of Poland

The main task of the work carried out under the topic is to identify the structure and evolution of the lithosphere of Central Europe by experimental seismic methods. Large projects of deep seismic soundings are carried out in multiannual cycles, usually in broad international cooperation. In 2020, the Trans-European Suture Zone research projects included: a seismic modeling along the **TTZ-South** profile (Poland-Ukraine) and interpretation was continued; the interpretation of data from the profile of deep seismic soundings of **RomUkrSeis** (Romania-Ukraine) was completed and published (*Tectonophysics*); the interpretation of data along the **BalTec** profile (Baltic Sea) was continued.

In addition, we also dealt with materials from other projects: **KOKKY** (published in *Pure and Applied Geophysics*) and **ESO** (interpretation advanced) in Finland, and **BASIC** (Sweden). Work on the latter will be continued in the following years.

In January 2020, passive seismic research **AniMaLS** (Sudetes) project, which was continued for several years, was finished in its measurement stage, and research in the **PACASE** (Carpathian Mountains, Pannonian Basin) project, planned for several years, was started in broad international cooperation.

Implemented in Central and Southeastern Europe, all the projects allow the structure of the Earth's crust to be determined, and partly also the lower lithosphere along profile lines (two-dimensional models) or spatial (three-dimensional models). The data obtained along new generation of seismic profiles are of fundamental importance for understanding the geodynamics of the European continent. They are the base of reference for other disciplines of Earth sciences. Numerous citations testify to this. Our studies are also relevant for exploration seismic.

NSL2. Structure and evolution of the northern Atlantic lithosphere in the contact zone of the Eurasian and North American plate in the Arctic

The purpose of the work under the **NSL2** theme is geodynamic research in the North Atlantic in the Svalbard Archipelago area in the Arctic using seismic methods. This region, with oblique ultra-slow mid-oceanic Knipovich Ridge, is of fundamental importance in the study of tectonic evolution of the Earth.

We have finished interpretation of data from the active part of the **KNIPAS** experiment realized in collaboration with the Alfred Wegener Institute (AWI) from Bremerhaven from summer 2016. Modeling of 2-D lithosphere structure along six profiles performed in the Logachev Seamount region on Knipovich Ridge was completed. A publication of these results is advanced.

Also as a part of the **KNIPAS** project, the department team cooperated with the German side in studies based on passive data. The results will broaden our understanding of the mechanisms of ocean floor expansion in oceanic ridge regions at the "ultra-slow" rate (Knipovich Ridge). First manuscript based on local events recorded during this project is published.

In collaboration with the University of Bergen and Hokkaido University, deep seismic soundings were performed in 2019 in the North Atlantic, from the Knipovich Ridge (part of the Mid-Atlantic Ridge) to the Barents Sea along the profile KNIPSEIS. Dr. Wojciech Czuba is the

[3]Working Group of the Department of Lithospheric Research: Monika Bociarska, Wojciech Czuba, Tomasz Janik, Weronika Materkowska, Julia Rewers, Piotr Środa, Dariusz Wójcik.

leader of the NCN project (UMO-2017/25/B/ST10/00488). The interpretation of obtained data is ongoing.

4.2 Personnel

Head of the Department
Tomasz Janik
Professor

Professor
Aleksander Guterch

Associate Professor
Piotr Środa

Assistant Professors
Wojciech Czuba
Monika Bociarska

Research Assistants
Kuan-Yu Ke
Weronika Materkowska
Dariusz Wójcik

Technician
Edward Gaczyński

PhD Students
Julia Rewers, Poland; Piotr Środa – PhD supervisor

4.3 Main research projects

- Profile of deep seismic soundings TTZ-South, T. Janik, National Science Centre, 2017–2022;
- Determination of the seismic anisotropy of the lithosphere in the Lower Silesia area, P. Środa, National Science Centre, 2017–2021;
- Structure of the Knipovich Ridge on the basis of seismic surveys – KNIPSEIS, W. Czuba, National Science Centre, 2018–2021;
- Passive seismic studies of the lithosphere and asthenosphere of the Southern Poland (Carpathian area), W. Czuba, National Science Centre, 2020–2024.

4.4 Instruments and facilities

Equipment
- 90 × TEXAN portable seismic recorders with 1C 4.5 Hz geophones,
- 60 × CUBE portable seismic recorders with 40×1C and 20 × 3C 4.5 Hz geophones,
- 100 × CUBE portable seismic recorders with 3C 4.5 Hz geophones (since March 2020),
- 10 × Güralp CMG-DM24S3EAM broadband seismic stations with CMG-6T 30 s seismometers,
- 4 × Ocean Bottom Seismometers, semi-broadband (Güralp),
- 20 × L-4C-3D 1 Hz seismometers,
- 6 × timing system devices (for shot time recording).

4.5 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

ROMUKRSEIS PROJECT

The interpretation of data from the profile of deep seismic soundings of RomUkrSeis (Romania–Ukraine) was completed and published:

V. Starostenko, **T. Janik**, **V. Mocanu**, **R. Stephenson**, **T. Yegorova**, **T. Amashukeli**, **W. Czuba**, **P. Środa**, **A. Murovskaya**, **K. Kolomiyets**, **D. Lysynchuk**, **J. Okon**, **A. Dragut**, **V. Omelchenko**, **O. Legostaieva**, **D. Gryn**, **J. Mechie**, and **A. Tolkunov** (2020), RomUkrSeis: Seismic model of the crust and upper mantle across the Eastern Carpathians – From the Apuseni Mountains to the Ukrainian Shield, *Tectonophysics* **794**, DOI: 10.1016/j.tecto.2020. 228620.

Abstract

RomUkrSeis is a controlled source wide-angle reflection and refraction (WARR) profile acquired in August 2014. It is 675 km long, running roughly SW-NE from the Apuseni Mountains in Romania and the Transylvanian Basin, crossing the arc of the Eastern Carpathian orogen and terminating in the East European Craton (EEC) in SW Ukraine (Fig. 1). Well-constrained 2-D ray-tracing *P*- and partly *S*-wave velocity models have been constructed along the profile from 348 single-component seismic recorders and eleven shot points (Fig. 2). The Eastern Carpathian arc formed in the Cenozoic has obscured the pre-existing Teisseyre–Tornquist Zone (TTZ), which is a transition zone between the Precambrian EEC and continental terranes accreted to it from the southwest in the Palaeozoic. The TTZ is characterised by low-velocity through its entire crust (6.0–6.3 km/s) and a considerable width (~140 km). It is interpreted as EEC crust stretched during rifting and continental margin formation in the Neoproterozoic and early Palaeozoic. The crust of the TTZ has a "trough in trough" structure wherein an upper body of ~40 km width comprising Outer Carpathian (*Vp* 4.9 km/s) and Late Palaeozoic-Mesozoic (*Vp*

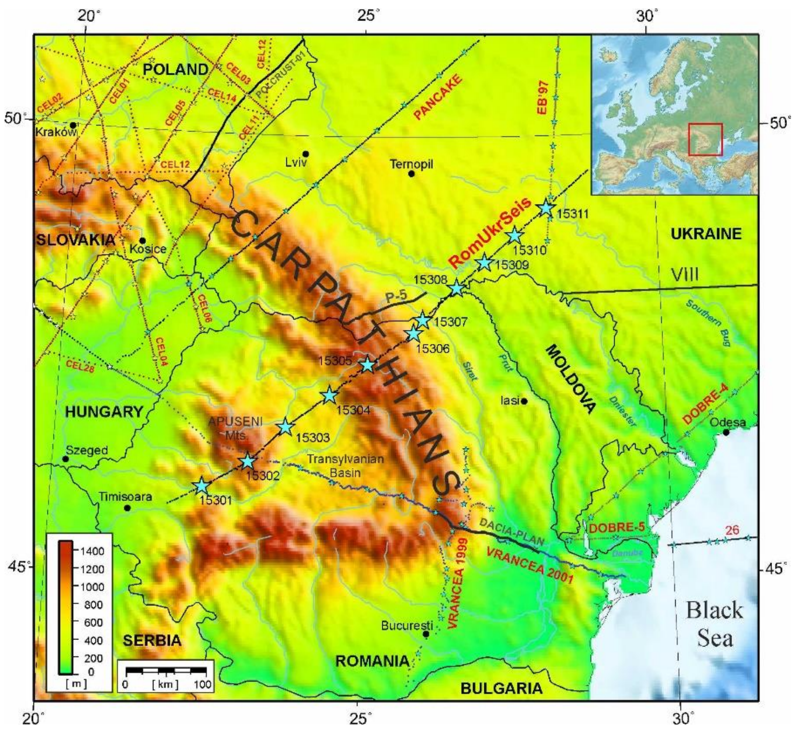


Fig. 1. Location of the RomUkrSeis profile and previous WARR (stars representing shot points and tightly compacted dots recording stations, names in red) and deep reflection (solid blacklines, names in black) seismic profiles in the study area (after Starostenko et al. 2020).

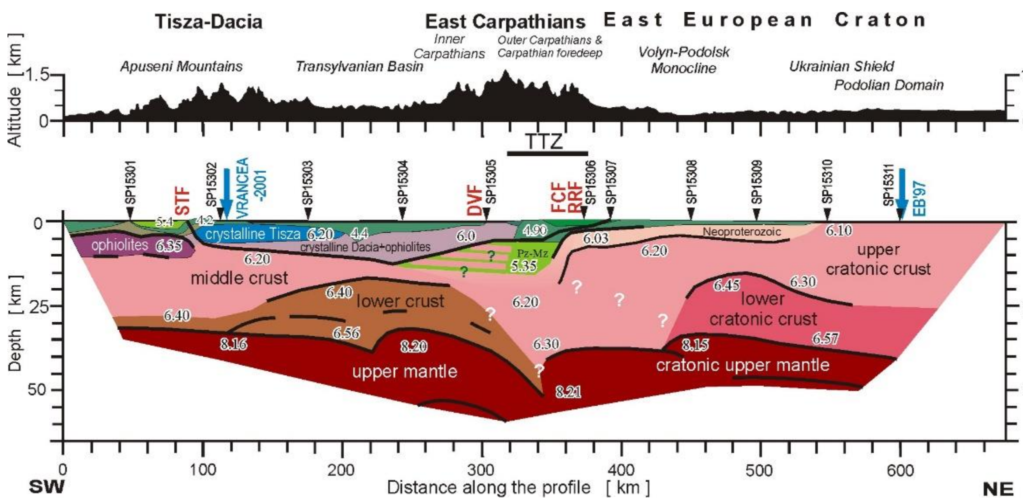


Fig. 2. Interpreted upper lithospheric structure along the RomUkrSeis profile. Shot point locations are shown by inverted triangles above the profile; numbers indicate P-wave velocity in km/s. Solid black lines indicate seismic boundaries (refractions and/or reflections), short black lines in the lower crust below the Transylvanian Basin indicate reflecting boundaries. Label DVF indicates the approximate Surface projection of the inferred Dragos Voda Fault. Blue arrows show intersections with other WARR profiles (labelled EB'97 and VRANCEA-2001) (after Starostenko et al. 2020).

5.4 km/s) units to 15 km depth lies above a wider, deeper one of inferred Neoproterozoic-early Palaeozoic strata. The crust of the Transylvanian Basin and Apuseni Mountains is relatively thin (~32 km). A high-velocity body at 4–12 km depth in this area is interpreted as a rootless fragment of an ophiolite complex exposed at the surface in this area. The lower crust beneath the Transylvanian Basin displays higher velocities than adjacent segments. Moho topography is strongly differentiated along the profile, varying from 32 to 50 km. The Moho shape, especially in the area between the Inner and Outer Carpathians, suggests a NE dip and, hence, thrusting of the Tisza-Dacia lowermost crustal and upper mantle units under the TTZ domain which, in turn, could be thrust under the cratonic (EEC) block.

PASSIVE SEISMIC EXPERIMENTS PACASE

The data acquisition in the frame of the **PACASE** passive seismic experiment (Pannonian-Carpathian Seismic Experiment) started in 2019 and will continue to the end of 2021 (Fig. 1). The

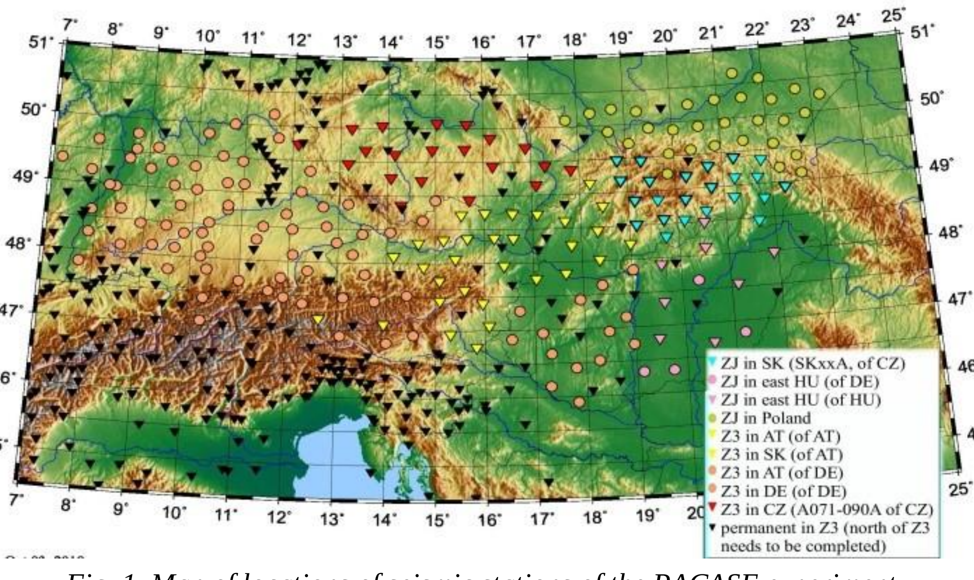


Fig. 1. Map of locations of seismic stations of the PACASE experiment.

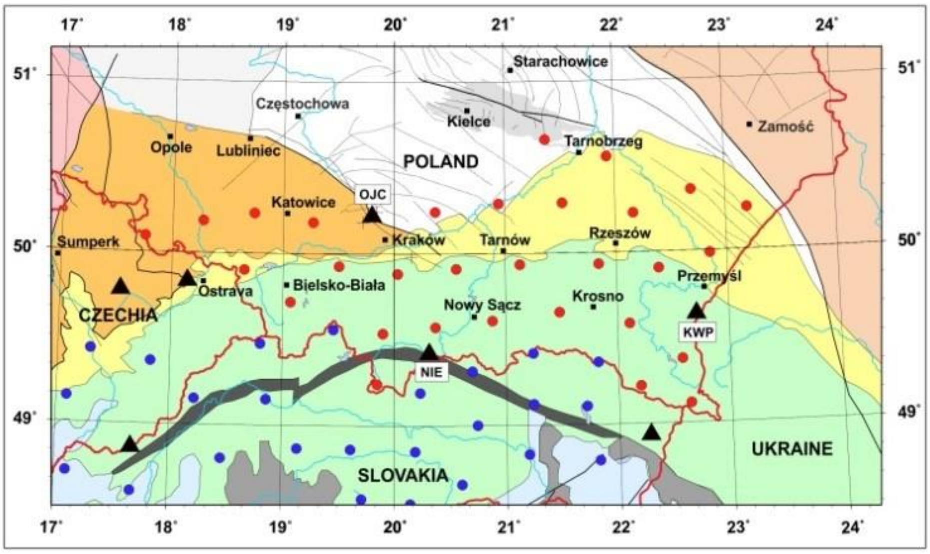


Fig. 2. Map of locations of Polish seismic stations of the PACASE. Red dots – Polish stations, blue dots – other stations used in the experiment, black triangles – permanent stations.

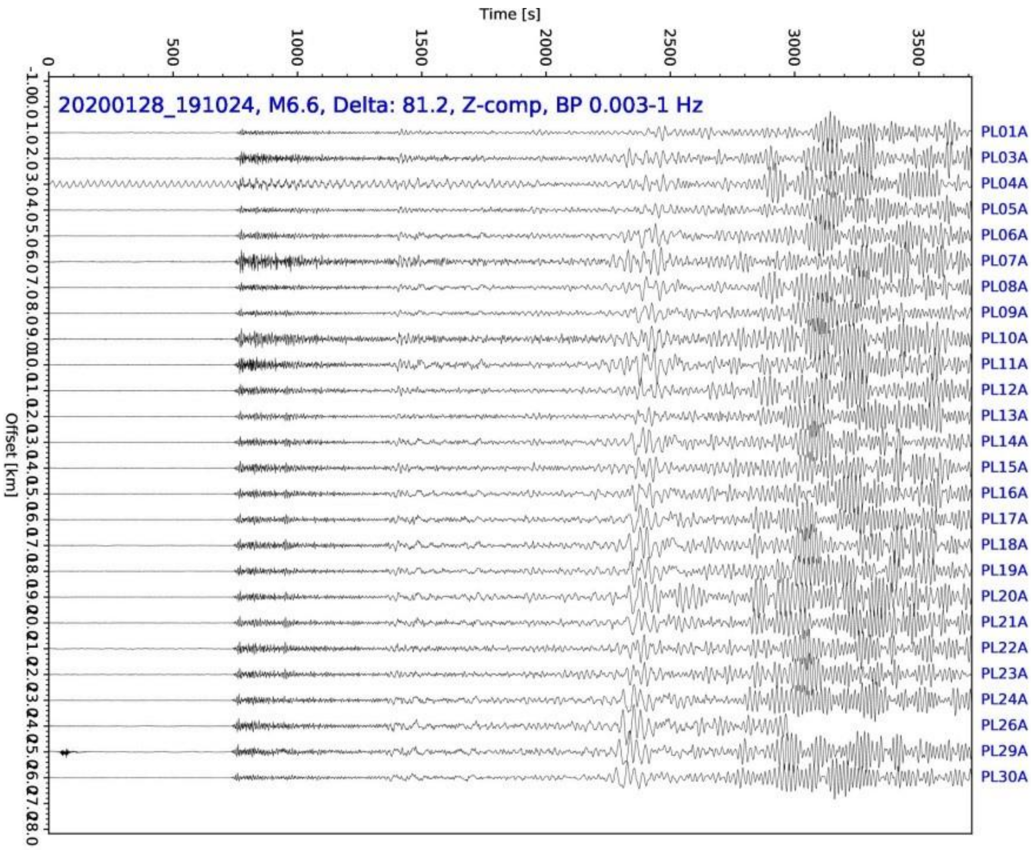


Fig. 3. Example seismograms of a teleseismic event (vertical component) recorded by Polish stations of PACASE experiment.

IG PAS participates in the acquisition with 23 broadband seismic stations deployed in Southern Poland. The area of the experiment is covered with over 210 broadband stations with ~40 km inter-station distance (Fig. 2). The main scientific objectives of the project involve: detailed geophysical study of the lithosphere in the Carpathians – Pannonian Basin – Eastern Alps region; study of seismic anisotropy and its relation to mantle fabrics, petrology and tectonic deformations, study of local seismicity and focal mechanisms, developing a 3D seismo-tectonic model for better understanding of the evolution of the Carpathian orogen. The **PACASE** seismic network forms a connection between the area of the AlpArray experiment and the region of planned **AdriaAr-ray** network. The project is an international cooperation involving 14 scientific institutions from Czech Republic, Slovakia, Austria, Hungary, Germany, and Poland. The data will be used for modelling of the upper mantle properties with seismic interpretation methods as body-wave tomography, *P*- and *S*-receiver functions and their azimuthal harmonics, shear wave splitting, surface wave, and ambient noise techniques. An example of the seismic data acquired during the experiment is presented in Fig. 3. The Polish activity in the experiment is connected with the IG PAS project "Passive Seismic Studies of the Lithosphere and Asthenosphere of the Southern Poland (Carpathian area)" (grant of Polish National Science Centre, agreement: UMO-2019/35/B/ST10/01628).

KNIPOVICH RIDGE STUDIES BASED ON SEISMIC MEASUREMENTS – KNIPAS AND KNIPSEIS

The structure of the oceanic crust generated by the ultraslow-spreading Knipovich Ridge still remains a relatively uninvestigated area compared to the other North Atlantic spreading ridges further south. The complexity of the Knipovich Ridge with its oblique ultraslow-spreading and segmentation makes this end-member of Spreading Ridge Systems an important and interesting ridge to investigate.

An ocean bottom seismic experiment **KNIPAS** has been carried out over the Logachev Seamount at the ultraslow-spreading Knipovich Ridge during Maria S. Merian cruise MSM67. The controlled source experiment covering a net of six intersecting wide-angle reflection and refraction (WARR) profiles was undertaken as German (AWI) – Polish (IG PAS) collaboration.

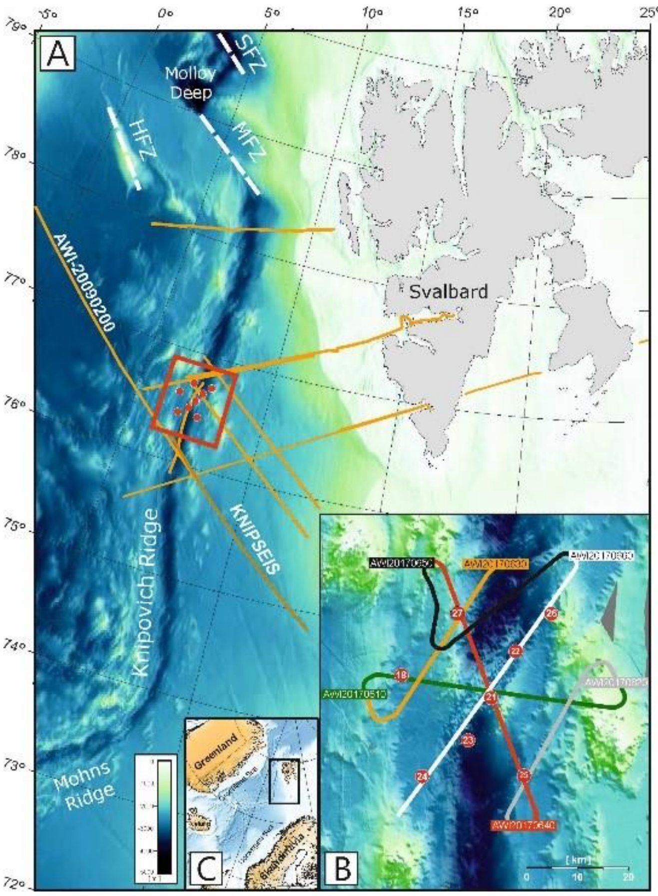


Fig. 1. (A) Location map of the KNIPAS and KNIPSEIS active seismic survey in the Northern Atlantic (Norwegian-Greenland Sea) with previously published seismic profiles in this area. The red dots indicate the locations of Ocean Bottom Seismometers (OBS). Red frame is the area of the inset. Bathymetry data is from GEBCO (2019). SFZ: Spitsbergen Fault Zone, MFZ: Molloy Fault Zone, HFZ: Hovgård Fracture Zone. (B) Map of seismic refraction lines over the Logachev Seamount with OBS locations and their numbers indicated with red dots. Bathymetry is compiled of multibeam echo sounder data acquired during several cruises. (C) General map of the Arctic region. The black rectangle indicates the location of the main map.

The main goals of this experiment were to investigate the crustal structure underneath a prominent volcanic centre of an ultraslow-spreading ridge and the role which volcanic centers play in the crustal accretion process.

Modeling of 2-D seismic structure and interpretation along several profiles is completed this year. A low-velocity anomaly is determined. It may indicate the presence of partial melts under the Logachev Seamount. Pronounced variations in crustal thickness suggest highly focused melt supply from the mantle.

In collaboration with the University of Bergen and Hokkaido University, new deep seismic soundings were performed along the **KNIPSEIS** OBS profile (~280 km), crossing the Knipovich Ridge in the western Barents Sea. The study is connected with the IG PAS project: “Structure of the Knipovich Ridge based on seismic measurements – **KNIPSEIS**” (grant of Polish National Science Centre, agreement: UMO-2017/25/B/ST10/00488). This profile, connected with previously realized German 20090200 profile (Hermann and Jokat 2013), provides information on the seismic crustal structure of the Knipovich Ridge as well as oceanic and continental crust in the transition zone (Fig. 1). The interpretation works (an example in Fig. 2) are ongoing.

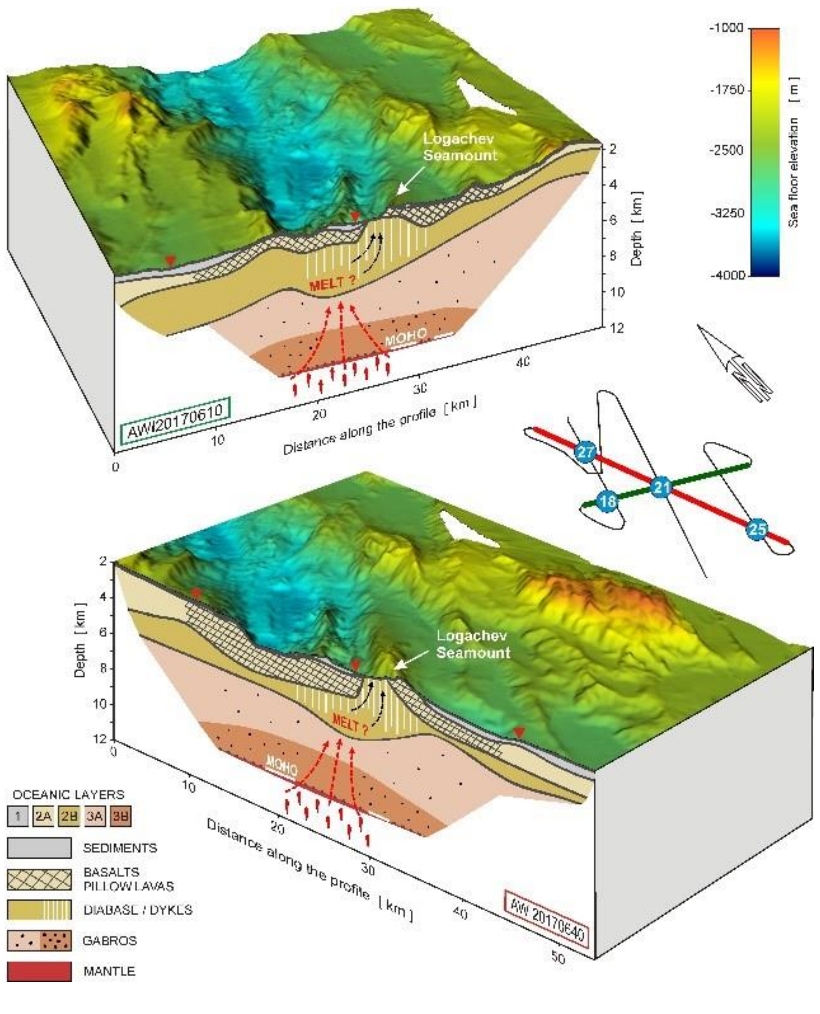


Fig. 2. Examples of interpretation KNIPAS models. OBSs are plotted as red triangles. Schematic map indicate which profiles are presented. Blue dots with a number show location of the OBS on the profiles. The arrows indicate focused melt delivery.

Reference

Hermann, T., and W. Jokat (2013), Crustal structures of the Boreas Basin and the Knipovich Ridge, North Atlantic, *Geophys. J. Int*. **193**, 1399–1414, DOI: 10.1093/gji/ggt048.

4.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- W. Czuba, T. Janik, Ocean Bottom Seismic Survey in the Knipovich Ridge area, SEISMIX 2020, Perth, Australia, 15–19.03.2020, Poster;
- T. Janik, D. Wójcik, Crustal structure in the transition zone from the Precambrian to Palaeozoic platform in the southern Baltic Sea – inferences from newly acquired potential field and seismic data, EGU General Assembly, Wien, Austria, 04–08.05.2020, Poster;
- D. Wójcik, T. Janik, New refraction/wide-angle reflection profile across the Teisseyre–Tornquist Zone offshore Poland, EGU General Assembly, Wien, Austria, 04–08.05.2020, Oral;
- T. Janik, W. Czuba, P. Środa, D. Wójcik, The transition of the East European cratonic lithosphere to that of the Palaeozoic collage of the Trans-European Suture Zone as depicted on the TTZ-South deep seismic profile (SE Poland to NW Ukraine), Wien, Austria, 04–08.05.2020, Poster;
- W. Czuba, PACASE: passive seismic experiment in Poland, ORFEUS/EPOS SP/AdriaArray WORKSHOP 2020, 11.2020, Oral;
- T. Janik, Huge seismic lithospheric experiments in the Central and Eastern Europe from the East European Craton to the Eastern Alps, since 1987, ORFEUS/EPOS SP/AdriaArray WORKSHOP 2020, 11.2020, Oral;
- W. Czuba, T. Janik, Segment-scale seismicity of the ultraslow spreading Knipovich Ridge: Mechanisms of melt focusing and segmentation, AGU Fall Meeting 2020, USA, 1–17.12.2020, Poster.

4.7 Publications

ARTICLES

Guterch, A., and **T. Janik (**2020), In Memoriam Professor Marek Grad (1951–2020) an outstanding Polish geophysicist and polar researcher, *Polish Polar Res*. **41**, 4, 315–316, DOI: 10.24425/ppr.2020.135372.

Janik, T., et al., **W. Czuba**, **P. Środa**, **D. Wójcik** (2020), TTZ-South seismic experiment, *Geofiz. Zhur. – Geophys. J.* **42**, 3, 1–15, DOI: 10.24028/gzh.0203-3100.v42i3.2020.204698.

Starostenko, V., **T. Janik**, et al., **W. Czuba**, **P. Środa** (2020), RomUkrSeis: Seismic model of the crust and upper mantle across the Eastern Carpathians – From the Apuseni Mountains to the Ukrainian Shield, *Tectonophysics* **794**, 228620, DOI: 10.1016/j.tecto.2020.228620.

Tirra, T., **T. Janik**, et al. (2020), Full-scale crustal interpretation of Kokkola–Kymi (KOKKY) seismic profile, Fennoscandian Shield, *Pure Appl. Geophys*. **177**, 3775–3795, DOI: 10.1007/s00024-020-02459-3.

5. DEPARTMENT OF THEORETICAL GEOPHYSICS

Zbigniew Czechowski

5.1 About the Department

Scientific activity of Department of Theoretical Geophysics is concentrated on the following issues: seismic source, seismic forecast, fracture mechanics, fluid flows, stochastic models, time series modeling and monitoring of rotational effects.

Seismic forecasts and hazard estimations can be expressed in terms of the return time of large earthquakes. It is determined by the long term balance between the strain accumulation rate due to tectonic processes and its release by earthquakes and aseismic slip movements along tectonic faults. The return time expression has been derived as a function of geodetic moment rate, maximum earthquake magnitude, earthquake magnitude range, and the Gutenberg–Richter law's *b* value. The *b* value has been related to fault characteristics and discussed within the asperity fault model framework. In particular, the characteristic earthquakes have been defined as the largest earthquakes in a given region, from a narrow magnitude range, subject to *b* close to 1.5 value, that recur more or less regularly. Using available data, the return times of the largest and characteristic earthquakes in Japan Trench subduction zone, San Andreas Fault, and its Parkfield section, have been discussed. This work generalizes and corrects shortcomings of previous solutions for earthquake return time estimations.

The Discrete Element Method was used in numerous studies, ranging from engineering application to simulate the mechanical strength of industrial sandstones from the active quarries in Poland or breaking thin tissues subjected to stretching, through the methodological analysis like an attempt of using the machine learning for analysis of output of DEM simulations, application of the Multiple Linear Regression method for simplifying the DEM calibration tasks or analysis of various microscopic interaction models in simulation of the uni-axial compression tests, up to theoretical analysis of a relation of the DEM method and the fiber bundle model – an advanced model of statistical physics.

The effective Brinkman equations were investigated taking into account the drag force caused by obstacles in the channel. Effective equations with macroscopic coefficients were obtained. Such equations are an appropriate model that will be used in the problems of gravity current flows in channels with obstacles at the bottom. In the first approximation, we assume a linear resistance force with respect to the velocity vector. The primary goal is to adjust the numerical model to the results of the channel experiment.

The time clustering phenomenon in sequences of extremes of long-term correlated time series has been investigated. As a stochastic model the linear Langevin equation with fractional Gaussian noise was chosen. The aim of the work was to find relationships between the Hurst exponent related to the time series generated by the Langevin equation with fractional noise and three measures of time-clustering of the corresponding extremes. The results suggest that for persistent pure fractional noise the sequence of the extremes is clusterized, while extremes obtained by antipersistent or Markovian pure fractional noise seem to behave more regularly or Poissonianly. However, for the Langevin equation with fractional noise, the clustering of extremes is evident even for antipersistent and Markovian cases.

5.2 Personnel

Head of the Department
Zbigniew Czechowski
Professor

Professor
Wojciech Dębski

Associate Professors
Włodzimierz Bielski
Piotr Senatorski

Adiunkt
Piotr Klejment

Specialist
Krzysztof Teisseyre

5.3 Main research project

- Introducing the stochastic Langevin-type model and procedures of its reconstruction from persistent of order p geophysical time series, Zbigniew Czechowski, National Science Centre (NCN) Opus 11, 2017–2020.

5.4 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

EARTHQUAKE PHYSICS, ITS UNDERSTANDING, MODELING AND FORECASTING
P. Senatorski
The activity concerns earthquake physics, its understanding, modeling and forecasting. It is mainly focused on subduction zone seismicity. The following papers have been prepared:

Senatorski, P. (2020), Gutenberg–Richter's *b* value and earthquake asperity models, *Pure Appl. Geophys*. **177**, 1891–1905, DOI: 10.1007/s00024-019-02385-z. In this work, the Gutenberg–Richter relationship is derived from first principles. Its meaning as the most uniform distribution under physical constraints is discussed. Specifically, the Gutenberg–Richter law's *b* value is shown to represent the constraint related to slip stability, rupture propagation conditions, and fault characteristics. Empirical frequency-magnitude for the largest earthquakes is shown to be consistent with the theory: They are subject to the Gutenberg–Richter law with *b* close to 1.5 value, which is explained within the asperity fault model context.

Senatorski, P. (2020), Gutenberg–Richter law's meaning: Asperity fault model context (under review). In this work, three different aspects of seismicity are discussed within the asperity fault model context: the strain accumulation and its release by slow and fast slips processes, the Gutenberg–Richter relationship, and the scaling relations for earthquake parameters. Such an approach leads to a consistent view of subduction zone seismicity that combines earthquake physics and statistics. Specifically, the expression for large earthquake recurrence time, as a function of the Gutenberg–Richter law's *b* value, is derived. Next, dependence of the *b* value on asperity fault characteristics is explained. A new approach towards earthquake modeling and forecasting as sampling with constraints, is proposed.

Senatorski, P. (2020), On the return time of characteristic earthquakes (to be submitted). In this work, the return time of the characteristic earthquakes is considered in the geodetic moment deficit accumulation rate and its release by seismic and aseismic slip context. Respective expressions have been derived and applied to real world seismicity: San Andreas fault and its Parkfield section in California, and Tohoku-Oki earthquake region along Honshu section of the Japan subduction zone. The results have been compared with other author's solutions; their shortcomings are discussed and corrected. Dependence of the return time on the geodetic moment rate, the moment release partition among aseismic slip and different seismic moment ranges, the maximum seismic moment estimation, and the Gutenberg–Richter law's *b* value is discussed. It is shown that characteristic earthquakes can be defined by their narrow magnitude range below maximum magnitude value and the Gutenberg–Richter law's $b \sim 1.5$ value.

These results are expected to contribute to better understanding of seismicity. Since seismic hazard estimations can be expressed in terms of the return time of the largest earthquakes, they can be applied to seismic forecasts.

DEVELOPMENT, THEORETICAL ANALYSIS AND APPLICATION OF THE DEM METHOD

W. Dębski, **P. Klejment**

Before every mining or civil engineering project, rock tests are performed for the purpose of feasibility studies. That is the cause of huge costs, including drilling, sample collection, sample handling and finally laboratory testing. Numerical models showed that they can provide estimates of rock strength values and can complement, or even partially replace, laboratory tests which are time consuming, expensive, and also leading to the destruction of samples.

One of us (PK) contributed to this activity together with Faculty of Geology (Warsaw University) employing the Discrete Element Method to examine (simulate) the mechanical strength of industrial sandstone. The performed numerical simulations considered various loading scenarios. Among them, the fragmentation of rock samples under compression, resistance against failure by impact of an object, vibrations, or abrasion were considered. The Fig. 1 shows an example of a simulated fracture pattern at the surface of the sample under impact resistance test.

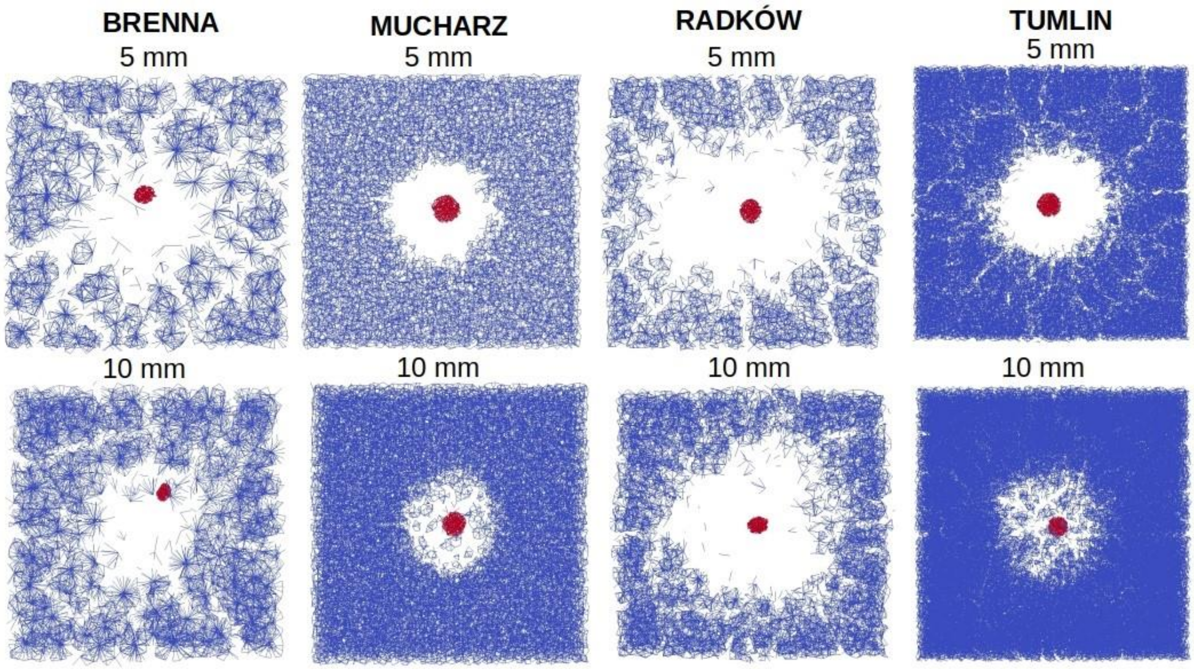


Fig. 1. Network of fractures that appeared in the sample after impact resistance test (after Klejment et al. 2021)[4].

[4]Klejment, P., R. Dziedziczak, and P. Łukaszewski (2021), Strength of industrial sandstones modelled with the Discrete Element Method, *Studia Geotech. Mech.*, DOI: 10.2478/sgem-2021-0020.

Fig. 2. Complex multi-fracture breaking mechanism of a thin tissue.

Another important (mostly for biological uses) application of DEM simulations was an analysis of breaking thin tissues under uniform stretching. Various breaking modes both predicted by the fracture mechanics and new ones have been identified and qualitatively described. The Fig. 2 shows an example of simulated complex breaking mechanism by strongly interacting sub-fracture system developing in an initially homogeneous tissue subjected to a vertical stretching.

Besides the applicable orientated DEM analysis, a more methodological work was also carried out. An attempt to apply the machine learning methods to analyze outputs of DEM simulations, and particularly the Multiple Linear Regression to ease the DEM calibration tasks was undertaken. The top analysis of this sort was based on a series of DEM simulations and supporting the fiber bundle prediction of an existence of the precursor of imminent failure for a class of brittle materials.

References

Dębski, W., and P. Klejment (2021), Earthquake physics beyond the linear fracture mechanics: a discrete approach, *Phil. Trans. R. Soc. A* **379**, 20200132, DOI: 10.1098/rsta.2020.0132.

Klejment, P. (2020), The Microscopic Insight into Fracturing of Brittle Materials with the Discrete Element Method; *Publs. Inst. Geoph. PAS* **427** (A-31), 128 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2020-001.

CLUSTERING OF EXTREME EVENTS IN TIME SERIES GENERATED BY THE FRACTIONAL ORNSTEIN–UHLENBECK EQUATION

Z. Czechowski

The theory of extremes has always raised great attention in the scientific research for its important implications, especially related with natural hazards. Very few studies have been focused on the temporal properties of sequences of extremes, and, in particular, on their possible clustering structures. When the underlying time series displays long memory, the distributional characteristics of the point process of extremes become much more complex than for the case of data with short memory. The intervals between extreme events can be correlated as well and the return interval distribution does not follow the typical exponential form.

Based on the run theory, we analyzed sequences of extremes derived from realizations of linear Langevin equation with fractional Gaussian noise (i.e., the fractional Ornstein–Uhlenbeck model) that represent a large class of natural long-term time correlated processes. We investigated the relationship between the Hurst exponent (a parameter quantifying persistence/antipersistence) related to the fractional Ornstein–Uhlenbeck process and three clustering measures of extremes. We used the percentile-based definition of extremes based on the crossing theory or run theory, where a run is a sequence of L contiguous values above a given percentile. Thus, a sequence of extremes becomes a point process in time, being the time of occurrence of the extreme, the starting time of the run. Several statistical quantities can be employed to quantify the time-clustering in a sequence of extremes: the global coefficient of variation and the local coefficient of variation if the sequence of extremes is represented by the interoccurrence times, and the Allan Factor if the sequence of extremes is represented by the counting process. Behaviours of these quantities are interpreted along with the forms of estimated distribution function for intervals between extreme events. Moreover, the influence of the width of the quadratic Langevin drift potential on the clustering is analysed.

Our results suggest that the extremes are time clusterized for persistent pure fractional Gaussian noise, but regularly or Poissonianly distributed for antiperistent or Markovian pure fractional Gaussian noise. However, the fractional Ornstein–Uhlenbeck equation introduces two additional mechanisms that change the behaviour of the time series: the process is governed by the differential equation (so the next state is dependent on the previous state) and walls of the potential limit lengths of stochastic jumps. Then, we obtain clusterization of extremes even for antipersistent and Markovian cases, but for very large timescales a loss of the clustering is observed. The increase of a slope of the potential walls influences the extremes clustering effect – the clustering is weaker and weaker with increasing slope.

These results are important for the aim of modelling the background processes for which extremes behave like that generated by the fractional Ornstein–Uhlenbeck equation and for prediction of future states in natural time series.

References

Telesca, L., and Z. Czechowski (2020), Clustering of extreme events in time series generated by the fractional Ornstein–Uhlenbeck equation, CHAOS **30**, 093140, DOI: 10.1063/5.0023301.

5.5 Meetings, workshops, conferences, and symposia

Presentation of the Department's member:

- Piotr Klejment, The Influence of Granular Layer on the Stick-Slip Dynamics of Sheared Fault Gouges Modelled with the Discrete Element Method, Supercomputing Frontiers Europe 2020, Warsaw, Poland, March 2020, Oral.

5.6 Publications

ARTICLES

Telesca, L., and **Z. Czechowski** (2020), Clustering of extreme events in time series generated by the fractional Ornstein–Uhlenbeck equation, CHAOS **30**, 093140, DOI: 10.1063/5.0023301.

Senatorski, P. (2020), Gutenberg–Richter's *b* value and earthquake asperity models, *Pure Appl. Geophys*. **177**, 1891–1905, DOI: 10.1007/s00024-019-02385-z.

MONOGRAPH

Klejment, P. (2020), The Microscopic Insight into Fracturing of Brittle Materials with the Discrete Element Method; *Publs. Inst. Geoph. PAS* **427** (A-31), 128 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2020-001.

6. DEPARTMENT OF HYDROLOGY AND HYDRODYNAMICS

Jarosław Napiórkowski

6.1 About the Department

Under the framework of NHH02, the following main objectives have been achieved.

- **Dynamics of solid particles settling in stratified aquatic environment:** A series of experiments performed in Hydrodynamic Micromodels Laboratory, IG PAS, provided new findings on the settling dynamics of non-spherical particles, represented by disks, that may advance the knowledge on sedimentation-related processes in a stratified marine environment. Thanks to visualization methods combined with image analysis, fundamental mechanisms of particles settling dynamics in a density transition were revealed including interactions between a settling disk and a wake formed in the flow behind the particle. The results confirmed that stratification-induced deceleration mechanisms identified at the scale of a single particle affect the residence times of disks in a density transition region.
- **Modelling drought dynamics:** Continuation of research on drought dynamics within Polish–Chinese project HUMDROUGHT (project http:/HUMDROUGHT.igf.edu.pl). This year work was focussed on data collection, processing and statistical analysis. Acquired datasets include hydro-meteorological point data from the River Vistula Basin (water levels/flows temperature and precipitation time series), groundwater data and spatially interpolated EOBS datasets. Research of historical information on human activities influencing hydrological cycle in the basin was also performed. A number of drought indices based on the observations was derived, including standardized drought indices. Statistical analysis of trends and change point detection was applied to separate human and climatic forcing. A number of precipitation-runoff models, including SWAT modelling tool, HBV and TOPMODEL were applied to the River Kamienna catchment.
- **Flood Risk Assessment Methods:** The classical approach to flood frequency analysis (FFA) may result in significant jumps in the estimates of upper quantiles along with the lengthening series of measurements. Our proposal is a multi-model approach, also called the aggregation technique. In 2020 an aggregation by a mixture of probabilities has been proposed as a new variant of multi-model approach in FFA and compared with the previously presented aggregation by a mixture of quantiles. The aggregation of distributions has turned out to be an effective method for the modeling of maximum flows, in large part eliminating the disadvantages of traditional methods.
- **Modelling of stream water temperatures:** A large number of models have been developed for stream temperature simulations. The so-called data driven models do not try to describe physical processes at all, but instead search for mathematical relationships between various variables which are related to stream temperature. In 2020, the use of dropout solely for input neurons of product unit neural networks for the purpose of stream temperature modelling has been proposed. The tests on data collected from six catchments located in temperate climate zones on two continents in various orographic conditions were performed. It was shown that the average performance of product unit neural networks trained with input dropout was better than the average performance of product units without dropout, product units with dropout applied to every layer of the networks, multilayer perceptron neural networks with or without dropout, and the semi-physical air2stream model.

6.2 Personnel

Head of the Department
Jarosław Napiórkowski
Professor

Professors
Renata Romanowicz
Paweł Rowiński

Associate Professors
Ewa Bogdanowicz
Monika Kalinowska
Krzysztof Kochanek
Michael Nones
Marzena Osuch
Adam Piotrowski

Assistant Professors
Emilia Karamuz
Iwona Kuptel-Markiewicz
Anna Łoboda
Magdalena Mrokowska
Łukasz Przyborowski

Assistant
Arianna Varrani

PhD Students
Marta Majerska, Poland; Marzena Osuch – PhD supervisor
Motuma Regasa, Etiopia; Michael Nones – PhD supervisor
Tesfaye Senbeta, Etiopia; Renata Romanowicz – PhD supervisor

6.3 Main research projects

- Comparison of satellite imagery and time-lapse photography to track the riverine morphodynamics of the Po River, Italy, M. Nones, ASI (Italian Space Agency), 2019–2021;
- Assessing Catchment Sediment Yield and Siltation Impacts on Reservoir Capacity under Land Cover/Use Changes: the Case Study of the Fincha Dam, Ethiopia, M. Nones, National Science Center Poland, 2020–2024;
- Tracking riverine morphodynamics from satellite imagery: the case of the Po River, Italy, M. Nones, ESA (European Space Agency), 2019–2021;
- Hindcasting and projections of hydro-climatic conditions of Southern Spitsbergen, M. Osuch, National Science Center Poland, 2018–2021;
- Impact of expected climate change on water temperatures of selected Polish rivers, A. Piotrowski, National Science Center Poland, 2017–2020;
- Polish–Chinese SHENG1; Project HUMDROUGHT Human and climate impacts on drought dynamics and vulnerability, R. Romanowicz, National Science Center Poland, 2019–2022;
- Experimental study on the impact of density gradient on settling dynamics of non-spherical particles, M. Mrokowska, Ministry of Science, 2018–2020;
- Experimental studies on the effects of exopolymers on the settling dynamics and interactions between solid particles in density-stratified aquatic systems, M. Mrokowska, National Science Center Poland, 2020–2023;

- Comprehensive hydrological research of the Świder basin using modern measurement techniques, E. Karamuz, Ministry of Science, 2018–2020.

6.4 instruments and facilities

Equipment

- Model 801 Electromagnetic Open Channel Flow Meter
- Model 10 Field Fluorometer au-005-ce (sn. 6857)
- Fluorometer: (sn. 800606)
- YSI Professional Plus handheld multiparameter meter
- GPS LEICA gx1230gg (sn. 467006)
- ProODO Optical Dissolved Oxygen Instrument
- A wireless weather station Pro2™ Plus including UV and Solar Radiation Sensors
- ADCP – acoustic Doppler current profiler model RiverSurveyor S5 (SonTek)
- Bench Top Testing Machine 5ST (Tinius Olsen)
- ADV – acoustic Doppler velocimeter (Sontek)
- ADV – acoustic Doppler velocimeter (Nortek) (×2)
- Cameras: GoPRO HERO 3 (×1), GoPRO HERO 3+ Silver (×2), GoPRO HERO 3+ Black (×2)
- Microscope model Delta optical Genetic Pro Trino (Delta Optical)
- DJI PHANTOM 4 Drone
- Van Veen grab sampler
- DJI Phantom 4 PRO V2.0

Laboratory

Main equipment in Hydrodynamic Models Laboratory:
– two hydraulic channels
– ultrasonic flowmeters
– high-resolution macro image acquisition system
– refractometer
– precision and analytical balances
– 2 sediment traps with mesh 1.6 mm and 2 mm

6.5 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

QUANTILE MIXTURE AND PROBABILITY MIXTURE MODELS IN A MULTI-MODEL APPROACH TO FLOOD FREQUENCY ANALYSIS

I. Markiewicz, **E. Bogdanowicz**, **K. Kochanek**

An aggregation by a mixture of probabilities of non-exceedance (MF) has been proposed in 2020 as a new variant of multi-model approach in flood frequency analysis. This method was compared with an aggregation by a mixture of quantiles (MM) presented in previous authors' studies. For both aggregation variants, analytical formulas were derived for the asymptotic standard error of the estimate of design quantile and for its root mean square error, which takes into account the bias of the estimates of quantiles from the candidate distributions with respect to the aggregated quantile. The simulation experiment indicates that the latter version is more accurate and allows for reducing the quantile bias with respect to the unknown population quantile. For the case study, the 0.99 quantiles are determined for both variants of aggregation along

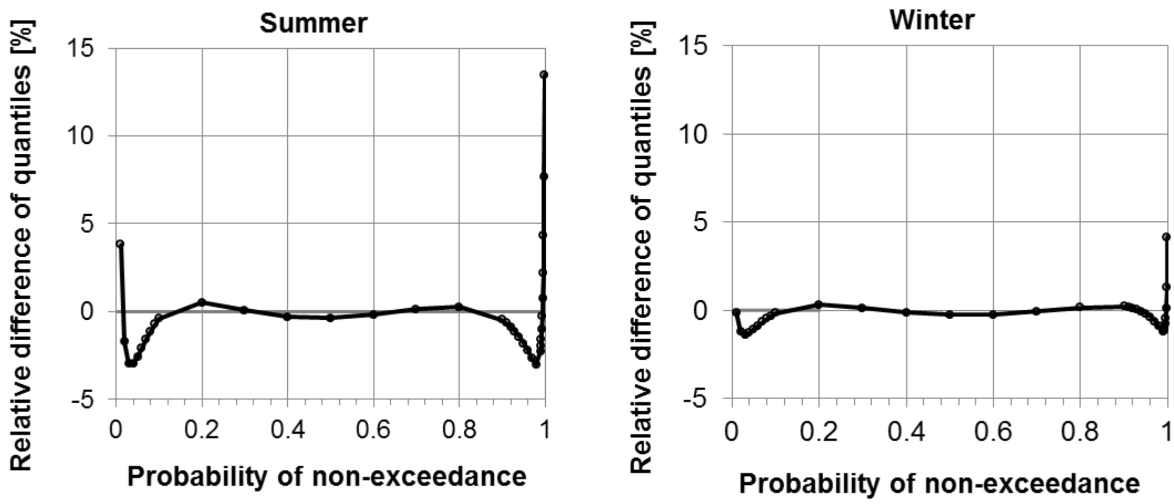


Fig. 1. The difference between quantiles of the same order in MF and MM approach expressed in [%] of MM value: (a) aggregated summer quantile; (b) aggregated winter quantile.

with the assessment of its accuracy. The results differ slightly, with the greatest difference being in the upper tail of model distributions. The relative differences of the quantiles obtained from the MF and MM methods with respect to the quantile value from MM are presented in Fig. 1.

The aggregation methods prove to be a useful and productive approach to flood frequency analysis. Compared with the classic selection of the best-fit distribution, aggregation methods are less sensitive to wrong model selection and give estimates of design quantiles more stable when extending the observation series. Both quantile and probability mixture models provide a promising tool for parameter estimation that may be useful in various (broad) areas, especially in the life sciences – for example, when some parameters of the experiment are out of the control or when the experiment cannot be repeated under the same conditions.

The results were described in the article:

Markiewicz, I., E. Bogdanowicz, and K. Kochanek (2020), Quantile mixture and probability mixture models in a multi-model approach to flood frequency analysis, *Water* **12**, 10, 2851, DOI: 10.3390/w12102851.

DYNAMICS OF SOLID PARTICLES SETTLING IN STRATIFIED AQUATIC ENVIRONMENT

M. Mrokowska

Recent studies on processes in the ocean stress the need for better understanding of marine particles dynamics to facilitate the explanation of particulate organic matter descent through sharp density gradients known as pycnoclines. To address this problem, a series of experiments was performed in Hydrodynamic Micromodels Laboratory, IG PAS. The study provided new findings on the settling dynamics of non-spherical particles, represented by disks, that may advance the knowledge on sedimentation-related processes in stratified marine environment. Thanks to visualization methods combined with image analysis, the fundamental mechanisms of particles settling dynamics in a density transition were revealed including the effects of fluid stratification and particle geometry on the variation of disk settling velocity with depth, disk orientation instability, and the pattern of particle trajectory (Fig. 1). Hydrodynamic conditions for the variation of settling velocity and instabilities in particle orientation were identified. Moreover, the research demonstrated interactions between a settling disk and a wake formed in the flow behind the particle with the focus on a bell-shaped structure observed for the first time in this study in the presence of sharp density gradient (Fig. 2).

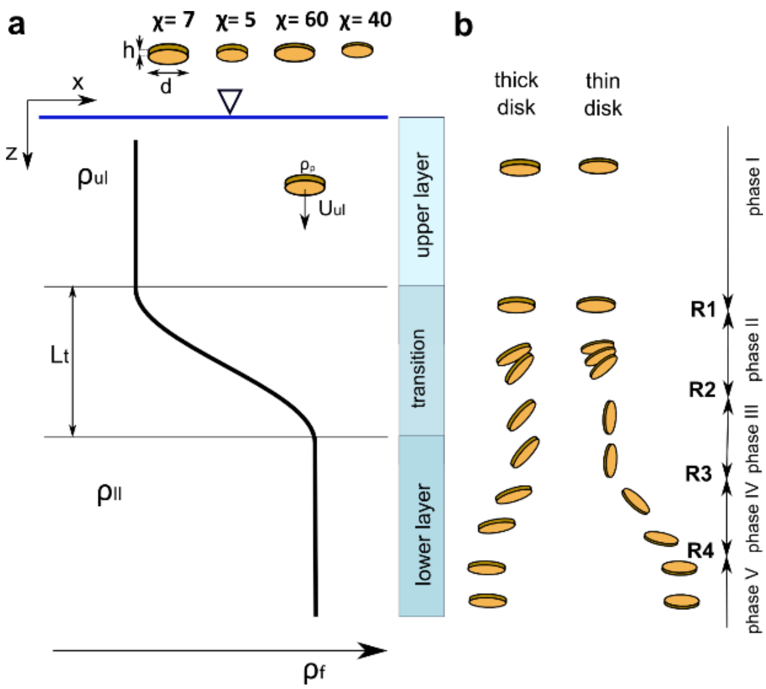


Fig. 1. Schematic of stratification conditions in a two-layered liquid column and disk settling dynamics. (a) Variation of liquid density with depth; ρul, ρll – density of upper and lower layer, Lt – density transition thickness, χ – disk aspect ratio. Particle of density ρp settles in the upper layer with terminal velocity Uul. (b) Settling dynamics of thin and thick disks (adapted from Mrokowska (2020a), licenced under CC BY 4.0).

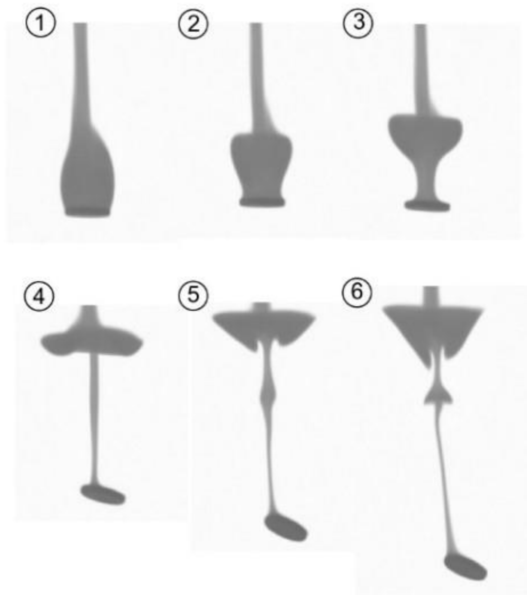


Fig. 2. Evolution of settling dynamics of disk and wake structure during descent through density transition (adapted from Mrokowska (2020a), licenced under CC BY 4.0).

The results confirmed that stratification-induced deceleration mechanisms identified at the scale of a single particle affect residence times of disks in a density transition region, which considerably exceeds the residence times evaluated by methods conventionally used in sedimentation studies. This observation shows that a density gradient plays a significant role in the accumulation of particles at pycnoclines, and the effects of fluid stratification and shape of particles should be considered in estimation methods to improve the reliability of particulate flux assessment in the regions of density transitions. The results may facilitate future research on settling dynamics of phytoplankton, minerals, microplastics, and marine snow crossing pycnoclines in aquatic environment.

The results have been presented in papers:

Mrokowska, M.M. (2020a), Influence of pycnocline on settling behaviour of non-spherical particle and wake evolution, *Sci. Rep*. **10**, 1, 20595, DOI: 10.1038/s41598-020-77682-y;

Mrokowska, M.M. (2020b), Dynamics of thin disk settling in two-layered fluid with density transition, *Acta Geophys*. **68**, 4, 1145–1160, DOI: 10.1007/s11600-020-00455-8.

6.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- V. Blauhut, C. Teutschbein, M.N. Andersen, M. Brunner, C. Cammalleri, K. Kalin, D.C.Finger, M. Huysmans, K. Manevski, M. Osuch, R. Romanowicz, K. Stahl, M. Stoelzle, A.F. Van Loon, M.T.H. Van Vliet, N. Wanders, J. Vogt, J.-P. Vidal, P. Williams, Perceiving and managing the 2018 & 2019 droughts in Europe: is there a need for macro-governance in Europe?, EGU2020, 05.05.2020, Poster;
- E. Karamuz, Drought analysis using the EOBS-based SPI maps, II Workshop of Polish–Chinese HUMDROUGHT project, Warsaw, Poland;
- E. Bogdanowicz, Statistical analysis of low flows along the River Vistula, II Workshop of Polish–Chinese HUMDROUGHT project, Warsaw, Poland;
- J. Napiórkowski, Web page presentation, II Workshop of Polish–Chinese HUMDROUGHT project, Warsaw, Poland;
- E. Karamuz, New possibilities in extreme flow event modelling and evaluation, AGU Fall Meeting, 1–17.12.2020, Poster;
- M. Majerska, T. Wawrzyniak, M. Osuch, Hindcasting and projections of hydro-climatic conditions of Southern Spitsbergen (HyMote), SIOS's Online Conference on "Earth Observation (EO), Remote Sensing (RS) and Geoinformation (GI) applications in Svalbard", 5.06.2020, Oral;
- M. Mrokowska, Effects of stratified water column on settling dynamics of microplastics and implications for interactions between microplastics and marine ecosystem, Micro2020 Fate and Impacts of Microplastics: Knowledge and Responsibilities, Lanzarote, Spain – Virtual conference, 23–27.11.2020, Oral;
- M. Nones, M. Guerrero, GIS and remote sensing for tracking morphological changes and vegetation coverage at the reach scale: the Po River case study, River Flow 2020, 7–10.07.2020, Oral;
- M. Osuch, T. Wawrzyniak, M. Majerska, Hydrological measurements and modelling (Fuglebekken catchment, Hornsund), SESS Report Meeting, SvalHydro, 13.08.2020, Oral;
- M. Papa, M. Nones, C. Cavallo, G. Ruello, M. Gargiulo, Data-fusion of satellite and ground sensors for river hydro-morphodynamics monitoring, EGU General Assembly, 3–8.05.2020, Oral;
- Ł. Przyborowski, A. Łoboda, Bursting phenomena downstream aquatic plants growing in natural conditions, 1st IAHR Young Professional Congress, 11.2020, Poster;
- R. Romanowicz, Present state of the project, II Workshop of Polish–Chinese HUMDROUGHT project, Warsaw, Poland, 16.10.2020, Oral;

- R. Romanowicz, Impact of climate change on flow composition using a model tailored to runoff components, AGU Fall 2020, San Francisco, USA, 16.12.2020, Poster;
- Senbeta, Romanowicz, Evaluating historical drought using different drought indices and data processing schemes, 1st IAHR Young Professional Congress, 17–18.11.2020, Oral;
- M.S. Regasa, M. Nones, Effects of land cover/use changes on the Ethiopian Fincha Dam capacity, 1st YPN IAHR Congress, 17–18.11.2020, Oral;
- T.B. Senbeta, Data acquisition and the development of a SWAT model – Kamienna catchment case study, II Workshop of Polish–Chinese HUMDROUGHT project;
- T.B. Senbeta, The formation and development of hydrological drought – Kamienna River case study, AGU Fall 2020, San Francisco, USA, 15.12.2020, Oral;
- A. Varrani, P. Rowiński, M. Mrokowska, Plastics in streams; transport dynamics and open questions, 1st IAHR Young Professionals Congress, 17–18.11.2020, Poster;
- A. Varrani, A "sediment transport" perspective on microplastics movement: incipient motion, Micro2020 Fate and Impacts of Microplastics: Knowledge and Responsibilities, 23–27.11.2020, Poster;
- T. Wawrzyniak, M. Osuch, State of Revvatnet hydrodynamics in the year 2020 (STAREV), Polar Night Week 2020, Longyearbyen, 13–17.01.2020, Oral;
- K. Kochanek, Statistical modelling of the peak flows based on selected maximal sample elements (censored sample), The IUGG National Committee, 25.11.2020, Lecture;
- K, Kochanek, Engineering Hydrology, Warsaw University of Technology, 09.2020–02.2021, Lectures;
- A. Łoboda, Building your PhD dissertation on papers, online for broad audience by YPN Poland, 04.2020, Oral;
- M. Nones, Flood risk management is not only water management: insights from Europe, Diamond Harbour Women's University, India, 10–11.09.2020, Invited lecture;
- M. Osuch, Geomarketing, Wyższa Szkoła Informatyki Stosowanej i Zarządzania, Warszawa, Polska, Lectures;
- M. Osuch, Przysposobienie sieciowe, Wyższa Szkoła Informatyki Stosowanej i Zarządzania, Warszawa, Polska, Lectures;
- P. Rowiński, Environmental hydrodynamics as the basis of nature based solutions in water management, Warsaw University of Life Sciences SGGW, Warszawa, Polska, 30.09.2020, Invited inaugural plenary lecture;
- A. Varrani, Fundamentals of river engineering, Warsaw University of Technology, Warszawa, Polska, 4.1.2020–31.1.2020, MSc lecture.

6.7 Publications

ARTICLES

Karamuz, E., **R.J. Romanowicz**, and J. Doroszkiewicz (2020), The use of unmanned aerial vehicles in flood hazard assessment, *J. Flood Risk Manage*. **13**, 4, e12622, DOI: 10.1111/jfr3.12622.

Kochanek, K., **W.G. Strupczewski**, **E. Bogdanowicz**, and **I. Markiewicz** (2020), The bias of the maximum likelihood estimates of flood quantiles based solely on the largest historical records, *J. Hydrol*. **584**, 124740, DOI: 10.1016/j.jhydrol.2020.124740

Mirosław-Świątek, D., et al., **K. Kochanek** (2020), The impact of climate change on flow conditions and wetland ecosystems in the Lower Biebrza River (Poland), *Peer J*. **8**, e9778, DOI: 10.7717/peerj.9778.

Markiewicz, I., **E. Bogdanowicz**, and **K. Kochanek** (2020), On the uncertainty and changeability of the estimates of seasonal maximum flows, *Water* **12**, 3, 704, DOI: 10.3390/w12030704.

Markiewicz, I., **E. Bogdanowicz**, and **K. Kochanek** (2020), Quantile mixture and probability mixture models in a multi-model approach to flood frequency analysis, *Water* **12**, 10, 2851, DOI: 10.3390/w12102851.

Mrokowska, M.M. (2020), Dynamics of thin disk settling in two-layered fluid with density transition, *Acta Geophys*. **68**, 4, 1145–1160, DOI: 10.1007/s11600-020-00455-8.

Mrokowska, M.M. (2020), Influence of pycnocline on settling behaviour of non-spherical particle and wake evolution, *Sci. Rep*. **10**, 20595, DOI: 10.1038/s41598-020-77682-y.

Nones, M. (2020), On the main components of landscape evolution modelling of river systems, *Acta Geophys*. **68**, 2, 459–475, DOI: 10.1007/s11600-020-00401-8.

Nones, M. (2020), Remote sensing and GIS techniques to monitor morphological changes along the middle-lower Vistula river, Poland, *Int. J. River Basin Manage*., DOI: 10.1080/15715124.2020.1742137.

Nones, M., et al. (2020), Computational advances and innovations in flood risk mapping, *J. Flood Risk Manage.* **13**, 4, e12666, DOI: 10.1111/jfr3.12666.

Nones, M., et al., **A. Varrani** (2020), Numerical modeling of the hydro-morphodynamics of a distributary channel of the Po River delta (Italy) during the Spring 2009 flood event, *Geosciences* **10**, 6, 209, DOI: 10.3390/geosciences10060209.

Aleixo, R., et al., **M. Nones** (2020), Applying ADCPs for long-term monitoring of SSC in rivers, *Water Resour. Res.* **56**, 1, e2019WR026087, DOI: 10.1029/2019WR026087.

Maselli, V., et al., **M. Nones** (2020), Tidal modulation of river-flood deposits: How low can you go?, *Geology* **48**, 7, 663–667, DOI: 10.1130/G47451.1.

Wawrzyniak, T., and **M. Osuch** (2020), A 40-year High Arctic climatological dataset of the Polish Polar Station Hornsund (SW Spitsbergen, Svalbard), *Earth Syst. Sci. Data* **12**, 805–815, DOI: 10.5194/essd-12-805-2020.

Piotrowski, A.P., **J.J. Napiórkowski**, et al. (2020), Impact of deep learning-based dropout on shallow neural networks applied to stream temperature modelling, *Earth-Sci. Rev.* **201**, 103076, DOI: 10.1016/j.earscirev.2019.103076.

Piotrowski, A.P., **J.J. Napiórkowski**, et al. (2020), Population size in Particle Swarm Optimization, *Swarm and Evolutionary Computation* **58**, 100718, DOI: 10.1016/j.swevo.2020.100718.

Zhu, S., and **A.P. Piotrowski** (2020), River/stream water temperature forecasting using artificial intelligence models: a systematic review, *Acta Geophys* **68**, 5, 1433–1442, DOI: 10.1007/s11600-020-00480-7.

Caroppi, G., et al., **P.M. Rowiński** (2020), Acoustic Doppler velocimetry (ADV) data on flow-vegetation interaction with natural-like and rigid model plants in hydraulic flumes, *Data in Brief* **32**, 106080, DOI: 10.1016/j.dib.2020.106080.

Hamidifar, H., et al., **P.M. Rowiński** (2020), Influence of rigid emerged vegetation in a channel bend on bed topography and flow velocity field: laboratory experiments, *Water* **12**, 1, 118, DOI: 10.3390/w12010118.

Rajwa-Kuligiewicz, A., et al., **P.M. Rowiński** (2020), Hydromorphologically-driven variability of thermal and oxygen conditions at the block ramp hydraulic structure: The Porębianka River, Polish Carpathians, *Sci. Total Environ.* **713**, 136661, DOI: 10.1016/j.scitotenv.2020.136661.

MONOGRAPH

Kalinowska, M.B., **M.M. Mrokowska**, and **P.M. Rowiński** (eds.) (2020), *Recent Trends in Environmental Hydraulics*, GeoPlanet: Earth and Planetary Sciences, Springer, 318 pp.

CHAPTERS

Kalinowska, M.B., et al., **P.M. Rowiński** (2020), Modelling of velocity distribution in a channel partly covered by submerged vegetation. **In:** *Recent Trends in Environmental Hydraulics*, GeoPlanet: Earth and Planetary Sciences, Springer, 91–101.

Nones, M., et al. (2020), Monitoring of riparian vegetation growth on fluvial sandbars. **In:** *Recent Trends in Environmental Hydraulics*, GeoPlanet: Earth and Planetary Sciences, Springer, 197–206.

Christiansen, H.H., et al., **M. Osuch** (2020), Permafrost temperatures and active layer thickness in Svalbard during 2017/2018 (PermaSval). **In:** F. van den Heuvel et al. (eds.), SESS Report 2019, Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 236–249.

Retelle, M., et al., **M. Osuch**, T. Wawrzyniak (2020), Environmental monitoring in the Kapp Linné-Grønnfjorden Region (KLEO). **In:** F. van den Heuvel et al. (eds.), SESS Report 2019, Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 84–107.

7. DEPARTMENT OF MAGNETISM

Waldemar Jóźwiak

7.1 About the Department

The main research directions in the Department of Magnetism include studies of the lithospheric structures using electromagnetic methods, research in the field of magnetohydrodynamics with applications to the dynamics of the Earth's interior, paleomagnetism and research in the field of environmental magnetism.

Paleomagnetic team took part in a wide range of activities in 2020. The environmental magnetism group working within NM1 task, continued the application of combined magnetic and non-magnetic methods to study the environment pollution. In particular, the scientific interests were focused on the study of traffic-related pollution, the quality of outdoor and indoor air, the pollution of river bank and soils. The collaborate efforts with other teams allowed for a multidisciplinary approach to resolve the questions concerning sources of pollution and evaluation of adverse health effects for children and adults related to exposure pathway of heavy metals. The monitoring service of the PM concentration and magnetic susceptibility to study temporary trends for three locations in Warsaw was also continued. The studies carried out within the NM2 task concerned mostly problems of paleogeographic and tectonic reconstructions. In particular, the investigations in the Carpathians (Poland and Slovakia) Africa (eastern Zimbabwe), in the area of Svalbard and in the south-western part of the East European Craton (Poland, Lithuania, Belarus) were continued. The research concerned paleogeographic positions of both large lithospheric plates as well as kinematics of smaller units, such as terranes, individual tectonic blocks or nappes. We investigated also Silurian gas-bearing shales from northern Poland focusing on problems concerning organic matter preservation. We investigated detail composition and the properties of magnetic minerals in shales in relation to variable depositional environment in the sedimentary basin.

The magnetic dynamo team within the NM3 has conducted research on scale selection phenomena in magnetohydrodynamic flows and convective heat transfer. The construction of three-dimensional models of the geoelectric structure for selected regions in Poland was also continued. A combined quantitative interpretation of the GCM and DC-R methods was used to solve the problem of flooding as an application of these methods in engineering geology. In addition, the studies of source effects which constitute a limit in the properties of natural source signals beyond which the magnetotelluric method does ceases work properly were continued. Throughout 2020 the absolute measurements and continuous recording of the Earth's magnetic field in Belsk, Hel and Hornsund (Spitsbergen) observatories were conducted. All three observatories are members of the global INTERMAGNET network. A continuous recording of geomagnetic field changes with real-time data access has been carried out in the five permanent stations. Moreover, Schumann Resonance observations have been continued in Hornsund and Suwałki.

Furthermore, the Department of Magnetism is responsible for the Task 3 and Task 4 of the EPOS-PL project. In 2020, the works on the paleomagnetic and magnetotelluric database were continued. The EPOS+ project has also started, which will allow for the further expansion of our laboratories.

7.2 Personnel

Head of the Department
Waldemar Jóźwiak
Associate Professor

Professors
Magdalena Kądziałko-Hofmokl
Marek Lewandowski
Maria Teisseyre-Jeleńska

Associate Professors
Tomasz Ernst
Beata Górka-Kostrubiec
Rafał Junosza-Szaniawski
Krzysztof Michalski
Krzysztof Mizerski
Anne Neska
Krzysztof Nowożyński

Assistant Professors
Katarzyna Dudzisz
Sylwia Dytłow
Marek Gradzki
Szymon Oryński

Research Assistants
Dominika Niezabitowska
Iga Szczepaniak-Wnuk

Laboratory Technician
Grzegorz Karasiński

Technicians
Paweł Czubak
Krzysztof Kucharski
Mariusz Neska
Anna Wójcik
Stanisław Wójcik

Head of Laboratory for Paleomagnetism and Environmental Studies
Tomasz Werner

Head of Belsk Observatory
Jan Reda

PhD Students
Dominika Niezabitowska, Poland; Rafał Szaniawski – PhD supervisor
Agata Bury, Poland; Anne Neska – PhD supervisor
Dorota Staneczek, Poland; Rafał Szaniawski – PhD supervisor
Wojciech Szkółka, Poland; Krzysztof Mizerski, Dariusz Baranowski – PhD supervisors

7.3 Main research projects

- Diversity of technogenic magnetic particles in the soil environment depending on the emission sources and their role in transport of potentially toxic elements, B. Górka-Kostrubiec, National Science Centre (NCN) OPUS 12, 2017–2020;

- Magnetic properties of sediments applied for assessment of pollution level of heavy metals of Vistula River water within Warsaw, I. Szczepaniak-Wnuk, National Science Centre (NCN) Preludium 13, 2018–2020;
- EPOS – PL European Plate Observing System; Task 4 – CIBAL – Centre of Research Infrastructure of Analytical laboratories, T. Werner, Operational Program Smart Growth 2014–2020, 2017–2021;
- EPOS – PL European Plate Observing System; Task 3 – CIBOGM – Geomagnetic and Magnetotelluric Observations Research Infrastructure Center, W. Jóźwiak, Operational Program Smart Growth 2014–2020, 2017–2021;
- Własności magnetyczne łupków gazonośnych dolnego Paleozoiku z obszaru północnej Polski, D. Niezabitowska, National Science Center, Poland Etiuda 7, 2019–2020;
- Własnosci minerałów magnetycznych jako potencjalny wskaznik zawartosci materii organicznej, D. Niezabitowska, IG PAS Internal Grant for the Young Scientists, 2019–2020;
- Buoyancy driven magnetic dynamo, K. Mizerski, National Science Center, Poland Sonata Bis, 2018–2021;
- The role of lithospheric memory in the spatial and temporal localization of the intraplate deformation – investigating a deep structure of the Grójec Fault Zone based on potential field anomalies and seismic data, W. Jóźwiak, National Science Center, Poland Opus 13, 2018–2021;
- Diagramy FORC jako narzędzie do kompleksowej charakterystyki faz ferromagnetycznych, K. Dudzisz, National Science Center, Poland Miniatura 3, 2019–2020;
- Badania zasięgu zanieczyszczeń poeksploatacyjnych przy użyciu metod magnetycznych i anizotropii podatności magnetycznej na obszarze Sudetów, K. Dudzisz, IG PAS Internal Grant for the Young Scientists, 2019–2020;

7.4 Instruments and facilities

Equipment for magnetic susceptibility measurements in the field

- MS2 susceptibility meter (Bartington, Great Britain) with sensors
- MS3 susceptibility meter (Bartington, Great Britain) with sensors

Equipment for PM dust collection (environmental magnetism studies)

- PNS15C/ PM dust samplers (Atmoservice, Poland) – 3 units
- PNS18T/ PM dust samplers (Atmoservice, Poland and Comde Derenda) – 3 units

Equipment for magnetotelluric survey and magnetic observations

- 2 Magnetotelluric broad-band stations Phoenix
- 8 Magnetotelluric low-frequency stations Geomag
- 6 Low-frequency magnetometers LEMI
- 4 PMP proton magnetometers
- 4 Proton Overhauser magnetometers
- 4 Torsion photoelectric magnetometers PSM
- 4 DIFLUX magnetometers for absolute measurements
- 13 NDL digital recorders
- 18 LB-480 digital recorders

Laboratory for paleomagnetism and environmental studies – list of the laboratory equipment:

Equipment for measurements of magnetic remanence with step-wise AF/TH demagnetization

- 755–1.65 2G Enterprises cryogenic magnetometer DC SQUID with AF degausser
- JR6a automated dual speed spinner magnetometer (Agico, Czech Republic)
- MMTDSC – Nonmagnetic furnace for thermal demagnetization Magnetic Measurements, Great Britain
- MMTD-80 Nonmagnetic furnace for thermal demagnetization by Magnetic Measurements, Great Britain
- MMTD1 Nonmagnetic furnace for thermal demagnetization by Magnetic Measurements, Great Britain

Equipment for acquisition of magnetic remanence

- LDA5/PAM1 Alternating Field Demagnetizer/Anhysteretic and Pulse Magnetizer, Agico, Czech Republic
- LDA3a/AMU1a, Alternating Field Demagnetizer/Anhysteretic Magnetizer, Agico, Czech Republic
- Two MMPM10 pulse magnetisers, Magnetic Measurements, Great Britain
- SI6 – Pulse magnetizer, Sapphire Instruments, Canada
- Two MMLFC low field cages, Magnetic Measurements, Great Britain

Equipment for magnetic susceptibility measurements

- KLY-5A/CS-4/CS-L – Susceptibility bridge Agico, Czech Republic
- MFK1-FA – Susceptibility bridge, Agico, Czech Republic
- KLY-3/CS-3/CS-L – Susceptibility bridge, Agico, Czech Republic
- KLY2 – Susceptibility bridge, Geofyzika Brno, Czechoslovakia
- MS2 – Susceptibility meter (Bartington, Great Britain)
- MS3 – Susceptibility meter (Bartington, Great Britain)

Equipment for studies of magnetic hysteresis and Curie temperatures

- Micromag AGFM 2900-02 Alternating gradient force magnetometer, Princeton Measurements Corp., USA
- VSM Nuvo Vibrating Sample Magnetometer, Molspin Ltd, Great Britain
- AVFTB (Advanced Variable Field Translation Balance) Petersen Instruments, Magnetic Measurements, Great Britain) upgrade of the cooler unit (EPOS-PL)
- STEPS III apparatus for SIRM (T) experiments (TUS Electronics, Poland) – upgrade of the new electronics (EPOS-PL)

Mass balances

- The microbalance MYA 5.4.Y F (RADWAG, Poland) for mass determination of PM collected on filters used in dust samplers (EPOS-PL)

7.5 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

PALEOMAGNETIC AND MAGNETIC FABRIC DATA FROM LOWER TRIASSIC REDBEDS OF THE CENTRAL WESTERN CARPATHIANS: NEW CONSTRAINTS ON THE PALEOGEOGRAPHIC AND TECTONIC EVOLUTION OF THE CARPATHIAN REGION

R. Szaniawski, **M. Ludwiniak (University of Warsaw)**, **S. Mazzoli (University of Camerino)**, **J. Szczygieł (University of Silesia)**, **L. Jankowski (Polish Geological Institute)**

In the Central Western Carpathians (CWC), most of the published paleomagnetic results from Permo-Mesozoic rocks document extensive remagnetizations and come from thin-skinned thrust units that have undergone multistage deformation. We present results from lower Triassic redbeds from the autochthonous cover overlying the basement that carry a primary magnetization. Petromagnetic results indicate that the dominant ferromagnetic carrier is hematite, while magnetic susceptibility and its anisotropy are controlled by both ferromagnetic and paramagnetic minerals. Magnetic fabrics document weak deformation related to Late Cretaceous shortening. The directions of the high unblocking temperature remanence components pass both reversal and fold tests, attesting to their primary nature. Paleomagnetic inclinations are flatter than expected from reference datasets, suggesting small latitudinal separation between the CWC and stable Europe. Paleomagnetic declinations are mostly clustered within individual mountain massifs, implying their tectonic coherence. They show only minor differences between the massifs, indicating a lack of significant vertical-axis tectonic rotations within the

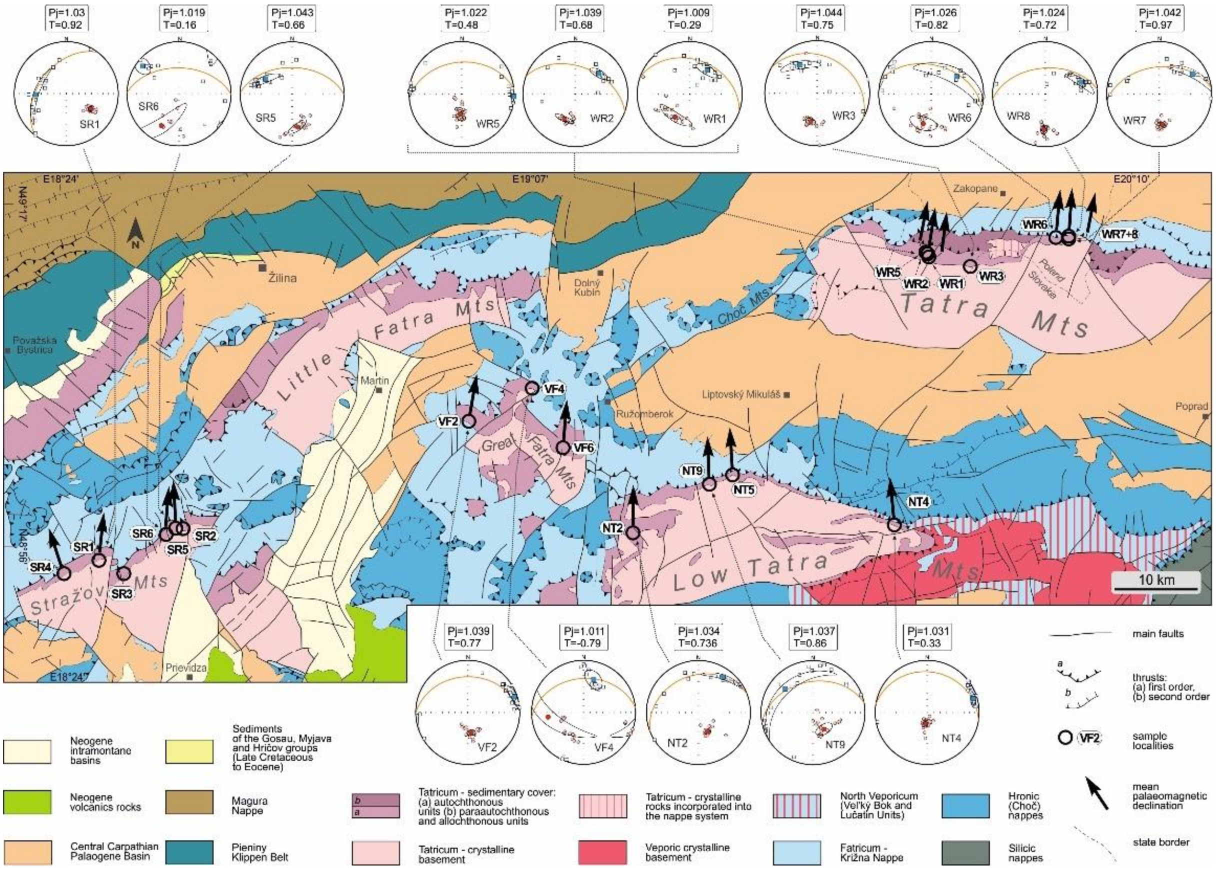


Fig. 1. Simplified geological map of the study area with marked location of sampling sites. Stereographic diagrams show AMS results (only for samples in which the susceptibility is higher than 30×10^{-6} SI volume); AMS principal axes are marked as red circles (K_{min}) and blue squares (K_{max}). Larger symbols representing site-mean principal axes are shown with their 95% confidence ellipses. Orange circles are mean bedding. T – shape parameter; Pj – corrected anisotropy degree (after Szaniawski et al. 2020).

studied central parts of the CWC. The paleomagnetic declinations are therefore representative of the whole of the CWC in terms of regional paleogeographic interpretations, and imply moderate counterclockwise rotations (c. 26°) of the region with respect to stable Europe since the Early Triassic (Fig. 1).

HYDROMAGNETIC DYNAMO IN NON-STATIONARY TURBULENCE

K. Mizerski

The turbulent hydromagnetic dynamo is a process of magnetic field generation by chaotic flow of an electrically conducting fluid (plasma, liquid iron, etc.). It is responsible for generation of large-scale magnetic fields of astrophysical objects such as planets, stars, accretion discs, galaxies, galaxy clusters, etc. In particular, the dynamical process of induction of large-scale fields by highly conducting plasma has been very difficult to understand, as very low resistivity is not capable of creating a phase shift between magnetic and kinetic components of waves, making their interaction ineffective for generation of a large-scale electromotive force (EMF). It has been demonstrated in Mizerski K.A. (2020, Renormalization Group Analysis of the Turbulent Hydromagnetic Dynamo: The Effect of Nonstationarity, *Astroph. J. Suppl. Ser*., 251(2):21) that when the typically invoked statistical stationarity of turbulence is relaxed, large-scale magnetic fields can be very effectively generated by low-resistivity plasma. The renormalization group technique was applied to extract the final expression for the mean EMF from the fully nonlinear dynamical equations (Navier-Stokes, induction equation) and the mean-field equations were solved for a force-free mode. Non-stationarity was shown to strongly enhance the process of large-scale EMF generation via wave interactions and the dynamo effect induced by non-stationarity was proved to be effective. The results were also used to demonstrate the influence of magnetic fields and non-stationarity on energy and helicity Fourier spectra of turbulent flows.

The analysis was focused on derivation of the full set of magnetohydrodynamic equations describing the dynamics of mean velocity and magnetic fields and the large-scale dynamo process in strong, fully nonlinear, non-stationary stirred turbulence. An important feature of the analysis performed was the inclusion of the effect of the Lorentz force on the flow, hitherto scarcely considered in the literature. We have applied the renormalization technique, which allowed to incorporate the effect of the nonlinear terms in the dynamical equations for turbulent fluctuations, in the limit of a small 'Rossby' number $Ro \ll 1$, defined as a relative measure of the fluid’s inertia with respect to the stirring force. The main results are listed below:

- The complete form of the mean EMF was obtained for strong, non-stationary turbulence. Both it’s linear and nonlinear dependence on the large-scale magnetic field, the latter resulting from the action of the Lorentz force, were fully described.
- Of particular astrophysical interest is the limit of low viscosity and resistivity, which was thoroughly examined. In such a limit it was the non-stationarity of turbulence, i.e. the fully nonlinear interactions of waves (Fourier modes) with distinct frequencies, which were predominantly responsible for creation of the large-scale EMF, dominating the diffusively controlled mechanism. The latter, based on resistive phase shift between the kinetic and magnetic components of waves, is the only mechanism of large-scale EMF generation in stationary turbulence.
- Full energy evolution, including amplification and saturation, was found and studied for a force-free mode of the mean magnetic field. The value of the saturational energy was obtained (Fig. 1).
- It was reported, that in the strong MHD turbulence the energy spectra are substantially influenced by the helical component of the stirring force.

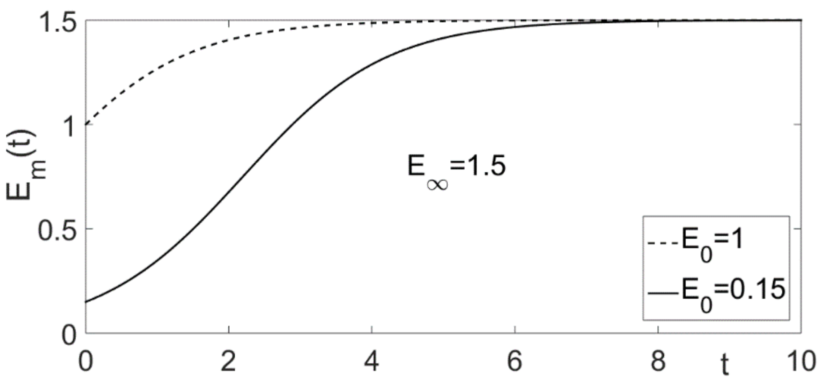


Fig. 1. Saturation of the magnetic energy of a force free mode for two cases: $E_\infty/E_0 = 10$ (solid line) and $E_\infty/E_0 = 1.5$ (dashed line); in both cases the asymptotic energy value is $E_\infty = 1.5$, but the initial energies differ (after Mizerski 2020).

ANISOTROPY OF OUT-OF-PHASE MAGNETIC SUSCEPTIBILITY AS A TOOL FOR TRACKING HEAVY METALS POLLUTION: A NEW APPROACH TO ENVIRONMENTAL MAGNETISM STUDY

K. Dudzisz, **S. Oryński**

The anisotropy of magnetic susceptibility (AMS) was successfully used to track deformation and flow directions in rocks and unconsolidated sediments. However, it has been very rarely applied to soils. In this study, AMS measurements together with in situ mappings of magnetic susceptibility and electromagnetic (EM) methods were employed to study soils around histori-cal mining areas in the Sudetes Mountains (Poland) (Fig. 1). This place was selected in order

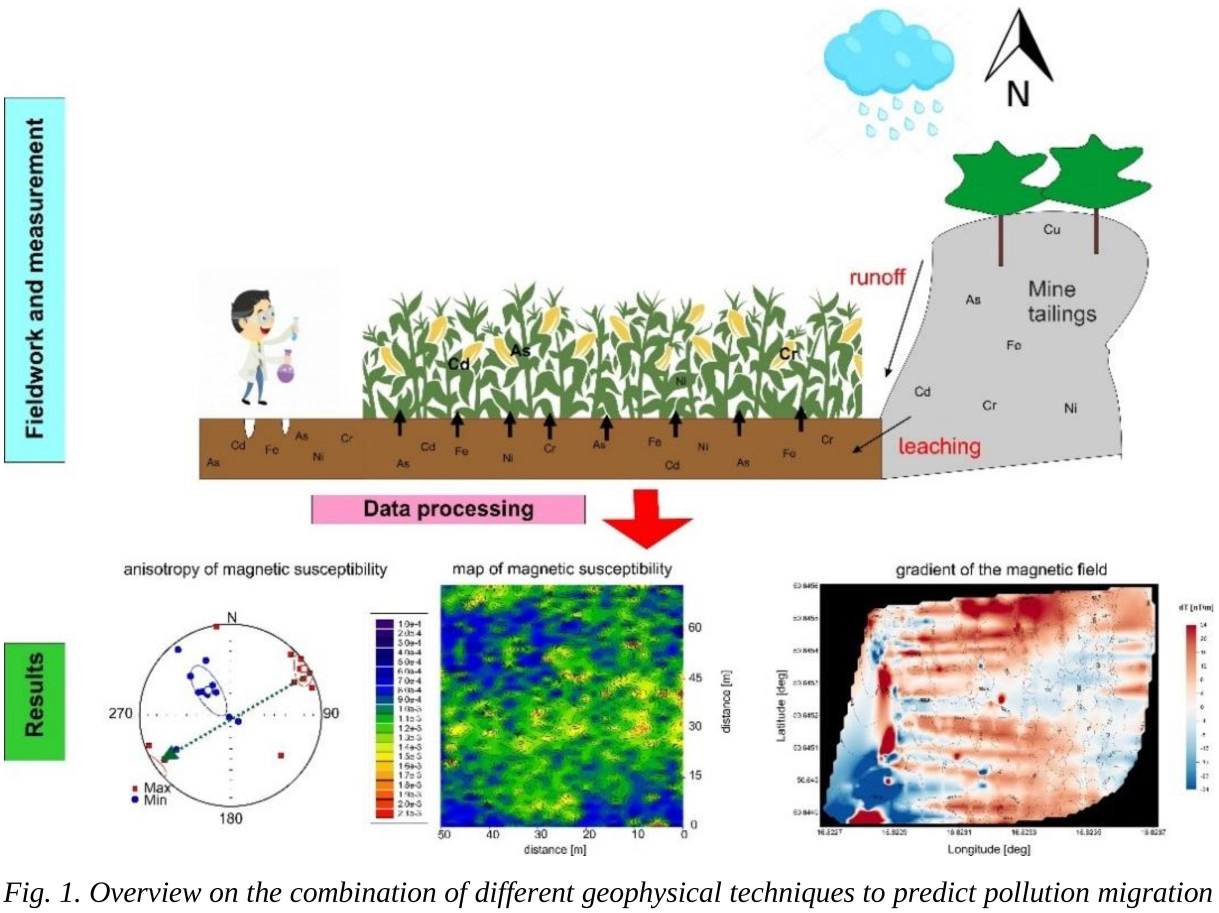


Fig. 1. Overview on the combination of different geophysical techniques to predict pollution migration from mining areas and the expected outcomes.

to examine the spatial spread of contamination from the tailings, their potential sources and to test the potential use of the AMS to study migration pathways. These sites are diversified in terms of exploitation time and type of ore (Zloty Stok – gold and arsenic, Janowa Gora – iron, and Szklary – nickel). They were selected in order to examine the spatial spread of contamination from mine tailings, their potential sources and to test the potential used of the AMS to study migration pathways.

The highest values of magnetic susceptibility ($1–5\times10^{-3}$ SI) are observed around nickel tailings, whereas the lowest values ($60–120\times10^{-6}$ SI) characterize the iron mining area. Preliminary results of GCM and magnetometry indicate the occurrence of overlapping anomalies in the studied area. Mapping of in situ magnetic susceptibility shows variability within particular sites. For Szklary, all methods indicate the presence of an elongated anomaly roughly NE-SW oriented. Although AMS axes of in-phase susceptibility are randomly distributed for all sites, magnetic fabric created by ferromagnetic minerals (out-of-phase, opAMS) indicate well-grouped maximum susceptibility axes mainly oriented NE-SW. There is a clear correlation between the mapped anomaly around nickel tailings (Szklary) and opAMS lineation. Outside the anomaly, opAMS directions are oriented SE-NW. For other sites, opAMS is also in line with results of EM methods. Taking these results, as well as landforms and hydrological conditions into account, it is suggested that magnetic minerals accompanying heavy metals migrate most likely with subsurface runoffs, and opAMS is capable of detecting changes in the direction of the pollution spread.

7.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- M. Lewandowski, M.A. Kusiak, A. Nawrot, B. Barzycka, M. Laska, T. Werner, B. Luks, Dust over Svalbard: evidence for a recent , short distance transport, The 4th Workshop on Effects and Extremes of High Latitude Dust, Islandia, Reykjavik, 13–14.02.2020, Oral;
- J. Reda, Report on definitive data timelines, INTERMAGNET Meeting, 13–15.07.2020, Oral;
- J. Reda, Progress on one-second data collection, INTERMAGNET Meeting, 13–15.07.2020, Oral;
- D. Niezabitowska, J. Roszkowska-Remin, R. Szaniawski, Magnetic Susceptibility Variations in Lower Paleozoic Shales of the Baltic Basin (Northern Poland) – A Helpful Tool for Regional Correlations and Decoding of Paleoenvironment Changes, Goldschmidt Virtual 2020, 21–26.06.2020, Oral;
- K. Dudzisz, S. Oryński, Can anisotropy of out-of-phase magnetic susceptibility be used for tracking heavy metals pollution in soils: insights from mining areas in Sudetes Mountains, Poland, Magnetic Interactions 2020, Southampton, UK, 9–10.01.2020, Poster;
- K. Dudzisz, S. Oryński, B. Górka-Kostrubiec, W. Klityński, Anisotropy of out-of-phase magnetic susceptibility as a tool for tracking heavy metals pollution: a new approach to environmental magnetism study, EGU General Assembly, 4–8.05.2020, Oral;
- K. Mizerski, Equations of hydrodynamics in geophysical problems, Faculty of Mathematics, Informatics and Mechanics, University of Warsaw, Warsaw, Poland, 02.06.2020, Lecture;
- K. Mizerski, Applications of mathematics in astrophysical hydrodynamics, Faculty of Mathematics, Informatics and Mechanics, University of Warsaw, Warsaw, Poland, 12.2020, Seminar;

- D. Niezabitowska, The thermal and chemical evolution of sedimentary basin materials, and the effects on measurable magnetic properties, Institute for Rock Magnetism, University of Minnesota, Minnesota, Minneapolis, USA, 13.02.2020, Lecture;
- K. Dudzisz, Evaluating pollution distributions in soils around abandoned mining areas in the Sudetes Mountains, Poland: insights into the application of magnetic and electromagnetic methods, Institute of Applied Geosciences, Karlsruhe Institute of Technology, Karlsruhe, Germany, 23.01.2020, Invited lecture.

7.7 Publications

ARTICLES

Ernst, T., **K. Nowożyński**, and **W. Jóźwiak** (2020), The reduction of source effect for reliable estimation of geomagnetic transfer functions, *Geophys. J. Int*. **221**, 1, 415–430, DOI: 10.1093/gji/ggaa017.

Górka-Kostrubiec, B., et al., **K. Dudzisz**, **S. Dytłow** (2020), Integrated magnetic analyses for the discrimination of urban and industrial dusts, *Minerals* **10**, 12, 1056, DOI: 10.3390/min10121056.

Gumsley, A., et al., **K. Michalski** (2020), Caught between two continents: First identification of the Ediacaran Central Iapetus Magmatic Province in Western Svalbard with palaeogeographic implications during final Rodinia breakup, *Precambr. Res*. **341**, 105622, DOI: 10.1016/j.precamres.2020.105622.

Lewandowski, M., M.A. Kusiak, **T. Werner**, A. Nawrot, et al., B. Luks (2020), Seeking the sources of dust: Geochemical and magnetic studies on “cryodust” in glacial cores from southern Spitsbergen (Svalbard, Norway), *Atmosphere* **11**, 12, 1325, DOI: 10.3390/atmos11121325.

Mizerski, K.A. (2020), Renormalization group analysis of the turbulent hydromagnetic dynamo: The effect of nonstationarity, *The Astrophys. J. Suppl. Ser*. **251**, 2, 21, DOI: 10.3847/1538-4365/abb8dc.

Caggio, M, et al., **K.A. Mizerski** (2020), Vertical heat transport at infinite Prandtl numer for micropolar fluid, *Arch. Mech.* **72**, 6, 525–553.

Del Corpo, A., et al., **J. Reda** (2020), An empirical model for the dayside magnetospheric plasma mass density derived from EMMA magnetometer network observations, *J. Geophys. Res. (Space Phys.)* **125**, 2, e2019JA027381, DOI: 10.1029/2019JA027381.

Satolli, S., et al., **D. Staneczek** (2020), Magnetic fabric in carbonatic rocks from thrust shear zones: A study from the Northern Apennines (Italy), *Tectonophysics* **791**, 228573, DOI: 10.1016/j.tecto.2020.228573.

Szaniawski, R., et al. (2020), Paleomagnetic and magnetic fabric data from Lower Triassic redbeds of the Central Western Carpathians: new constraints on the paleogeographic and tectonic evolution of the Carpathian region, *J. Geol. Soc*. **177**, 3, 509–522, DOI: 10.1144/jgs2018-232.

Szczepaniak-Wnuk, I., **B. Górka-Kostrubiec**, **S. Dytłow**, et al. (2020), Assessment of heavy metal pollution in Vistula river (Poland) sediments by using magnetic methods, *Environ. Sci. Poll. Res.* **27**, 24129–24144, DOI: 10.1007/s11356-020-08608-4.

8. DEPARTMENT OF GEOPHYSICAL IMAGING

Michał Malinowski

8.1 About the Department

Department activities in 2020 were traditionally focused on the two research topics. The first one deals with geophysical imaging of geological structures at various scales; the second one – with the mathematical analysis of complex system in geophysics and the dynamics of porous media. The scale of applications ranged from near-surface to the deep crust. We have been working towards solving some fundamental research questions like the structure of the crust in SE Poland at the junction of Sarmatia and Fennoscandia from reprocessing of the PolandSPAN regional profiles (highlight 1) or structure of the crust within the Nankai Trough seismogenic zone in Japan, employing innovative methods like full-waveform inversion (FWI) and reverse-time migration (RTM). We finished passive seismic data collection stage in the Rydułtowy mine within the SHENG project (collaboration with H. Zhang group from China) for mapping the production – induced velocity changes in the rock mass from coda-wave interferometry. Multimethod geophysical survey repeated at the Cisiec landslide site was supplemented with passive seismic component (5 BB stations) to derive interferometric time-lapse *Vs* model. New analysis of the seismic data acquired previously in Hornsund revealed that the permafrost layer is affected by the seasonal changes to much greater depth than previously assumed (30 m) (highlight 2). We continued working on the marine reflection seismic data acquired offshore Poland (BalTec project), finalizing the reflection data processing part and starting the interpretation stage. This year, the EU-funded H2020 Research and Innovation Action project called "Smart Exploration" was finished. Within this project, we obtained pioneering results of imaging the iron-ore mineralization at Ludvika (Sweden) by the use of FWI (highlight 3), as well as improved imaging of the bauxite-hosting strata at Gerolekas (Greece) through data reprocessing and pre-stack depth migration. We continue to work on machine learning applications: clustering of the reflectivity patterns from PolandSPAN data using deep-neural network (highlight 1), as well as automatic detection of noise panels containing body-wave energy in continuous seismic records using convolutional neural-network. We also finalized working on the methodology for characterization of the unconventional reservoirs (shale gas bearing) with the direct geostatistical inversion for reservoir properties. The theoretical group was developing universal model in the form of a stochastic cellular automaton integrating fundamental empirical laws describing statistical properties of earthquakes and enabling the study of a relationship between these laws, as well as investigating the impact of the geometry of pore space on the dynamics of dissolution processes in porous media on the level of laboratory experiments and numerical simulations. Thanks to the collaboration of the two groups in the Department, a summer field camp organized by the SEG Student Chapter at IG PAS was performed in Smerdyna quarry, where a multimethod geophysical data were collected to image the dissolution structures.

8.2 Personnel

Head of the Department
Michał Malinowski
Associate Professor

Associate Professors
Mariusz Białecki
Mariusz Majdański

Assistant Professors
Yaser Alashloo
Rafał Czarny
Andrzej Górszczyk

Research Assistants
Marta Cyz
Brij Singh

PhD Students
Lalit Arya, India; Mariusz Białecki – PhD supervisor
Michał Chamarczuk, Poland; Michał Malinowski – PhD supervisor
Wojciech Gajek, Poland; Michał Malinowski – PhD supervisor
Silvana Magni, Italy; Mariusz Białecki – PhD supervisor
Artur Marciniak, Poland; Mariusz Majdański – PhD supervisor
Miłosz Mężyk, Poland; Michał Malinowski – PhD supervisor
Quang Nguyen, Vietnam; Michał Malinowski – PhD supervisor
Bartosz Owoc, Poland; Mariusz Majdański – PhD supervisor
Rishabh Sharma, India; Mariusz Białecki – PhD supervisor
Brij Singh, India; Michał Malinowski – PhD supervisor

8.3 Main research projects

- Active and passive source multiscale subsurface imaging and monitoring based on the full seismic waveform, M. Malinowski, National Science Centre, 2019–2022;
- Linking deep and shallow geological processes in the transition from Precambrian to Palaeozoic platform in the southern Baltic Sea using new geophysical data, M. Malinowski, National Science Centre, 2018–2021;
- Relationship of permafrost with geomorphology, geology and cryospheric components based on geophysical research of the Hans glacier forefield and its surroundings. Hornsund, Spitsbergen, M. Majdański, National Science Centre, 2017–2020;
- Extension of seismic monitoring network in Hornsund, M. Majdański, SIOS, Susp. due to COVID;
- Mechanistic explanation of a generation of (and deviations from) the universal curve of the Earthquake Recurrence Time Distribution by means of constructions of solvable stochastic cellular automata and their analytical description, M. Białecki, National Science Centre, 2018–2021;
- Sustainable mineral resources by utilizing new Exploration technologies (SMART EXPLORATION), M. Malinowski, European Commision, 2017–2020;
- Three-dimensional imaging of subduction zones with full waveform inversion of two-dimensional seismic data, A. Górszczyk, National Science Centre, 2020–2022;

8.4 Instruments and facilities

Equipment

- A pool of seismic recorders (40 × 1C DATA-CUBE, 20 × 3C DATA-CUBE, 20 × 1C SmartSolo) and PEG-40 accelerated weight drop source was supplemented in 2020 by the Source Signature Recorded (Seismic Source Co) for GPS timing.

Laboratory

- Facilities for seismic data processing, imaging, modelling and interpretation including local InfiniBand cluster (expanded in 2020 by 2 new nodes), GPU Workstation and NAS data storage systems; Industry state-of-the art software, such as ProMAX, Reveal, Globe Claritas, TSUNAMI, VISTA, OMNI3D, Petrel, Kingdom Suite, GOCAD, Hampson Russell + in-house and academic software.

8.5 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department's staff:

STRUCTURE OF A DIFFUSE SUTURE BETWEEN FENNOSCANDIA AND SARMATIA IN SE POLAND BASED ON REGIONAL REFLECTION SEISMIC PROFILES AND UNSUPERVISED CLUSTERING

M. Mężyk, **M. Malinowski**

We derived detailed images of the entire crust and Moho discontinuity in SE Poland from re-processing several 2D Vibroseis regional seismic reflection profiles with the use of the extended-correlation technique. We apply this method to a subset of the ION Geophysical PolandSPAN™ dataset, a regional seismic program covering the marginal region of the East European Craton (EEC) and originally aimed at imagining Lower Palaeozoic shale play over the entire country. Given the raw, uncorrelated seismic data, acquired with a 28-s listening time and 16-s long sweep, we were able to extend the nominal record length up to 22 s two-way-time (60 km depth). Our new processing revealed a so-called diffuse cryptic suture zone, where the materials from colliding Fennoscandian and Sarmatian plates are mixed over large distances to form a unified continental crust. We support our interpretation by performing the unsupervised clustering of the observed seismic reflectivity patterns. Application of the *k*-means algorithm coupled with the data reduction through Deep Neural Network to the regional 2D crustal-scale seismic profiles provided a more detailed image of the middle to lower crust when compared to a conventional seismic section plotted in the user-defined amplitude range. Due to better continuity and visibility of reflections (see Fig. 1), the clustered sections can be an asset

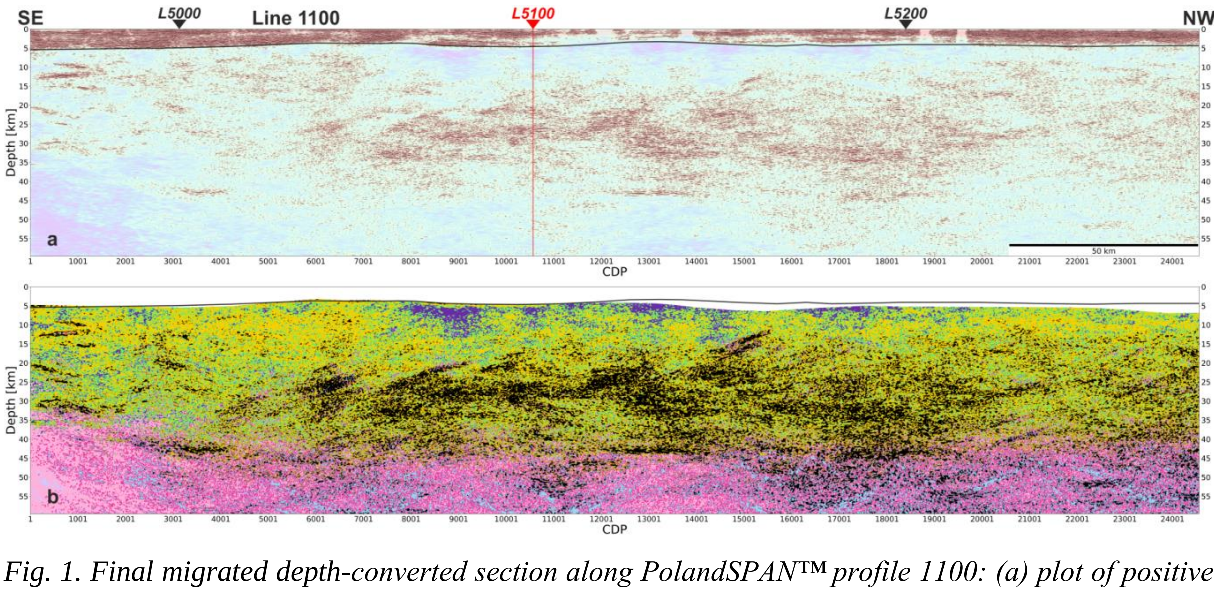


Fig. 1. Final migrated depth-converted section along PolandSPAN™ profile 1100: (a) plot of positive amplitudes with amplitude envelope attribute in the background; (b) plot of clustered reflectivity section, where samples were replaced with the cluster's membership number. Colours represent assignation to different clusters

in presenting or interpreting this kind of seismic data. Moreover, clustering not only enriches the image but also allows to carry out a comparative interpretation of several 2D seismic profiles across the survey by binding the resulting clusters. Technical details about the clustering can be found in Mężyk and Malinowski (2020, EAGE Extended Abstract).

SURPRISINGLY THICK ACTIVE LAYER OF PERMAFROST IN THE MOUNTAIN SLOPE IN THE SW SVALBARD

M. Majdański, **A. Marciniak**, **B. Owoc**

Two high arctic expeditions have been organized to use seismic methods to recognize the shape of the permafrost along inclined profile between the coast and the mountain slope in two seasons: with the unfrozen ground (October 2017) and frozen ground (April 2018). For measurements, stand-alone seismic stations have been used with accelerated weight drop with in-house modifications and timing system. Seismic profiles were acquired in a time-lapse manner and were supported with continuous temperature monitoring in shallow boreholes.

Joint interpretation of seismic data using Multichannel analysis of surface waves, First arrival travel-time tomography and Reflection imaging show clear seasonal changes affecting the permafrost, where apparent *P*-wave velocities are changing from 3500 to 5200 m/s. This confirms the laboratory measurements showing doubling the seismic velocity of water-filled high-porosity rocks when frozen. Independent refraction seismic analysis in two seasons shows in average a 10 m thick sedimentary layer on top of compacted bedrock. In sediments, the *P*-wave velocity is changing from 1500 to 4000 m/s between seasons. Velocities in the bedrock are also changing from 4000 to 5500 m/s. Moreover, tomographic interpretation shows that significant change in *P*-wave velocities is observed down to 30 meters (see Fig. 1).

Such unusual active layer behavior is confirmed in in-situ thermal observations with above 0°C temperatures at a depth of 19 m. Those observations can be explained with strong underground flow during the frozen period confirmed with borehole.

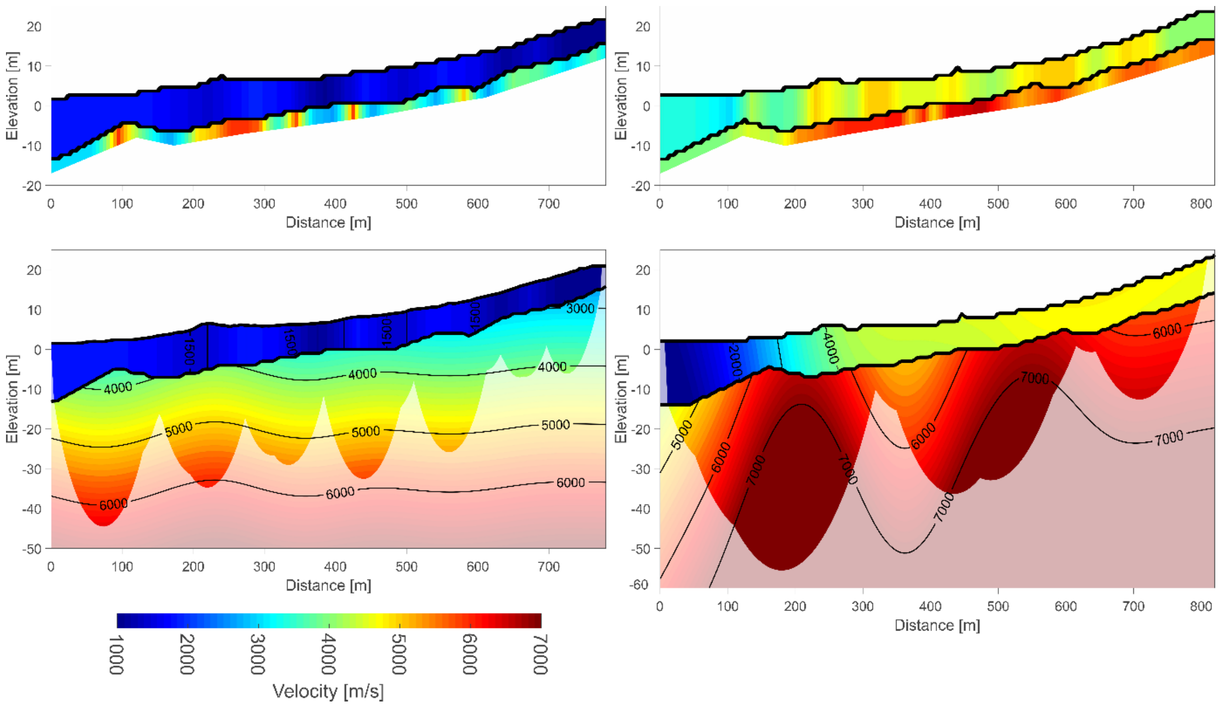
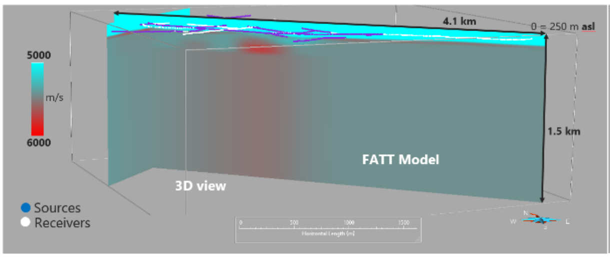


Fig. 1. Significant change of the seismic waveform characteristics observed in two different seasons: unfrozen ground in the Autumn 2017 (left), frozen in the Spring 2018 (right). Results of refraction seismic (top) shows Vp change in sediments and their thickness. Tomography (bottom) shows velocity difference down to 30 m.

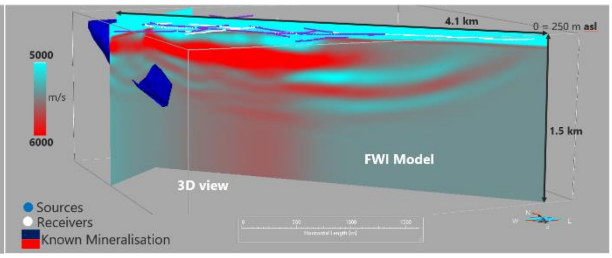
HIGH_RESOLUTION VELOCITY MODEL BUILDING USING FULL_WAVEFORM INVERSION IN HARDROCK ENVIRONMENT

B. Singh, **M. Malinowski**, **A. Górszczyk**

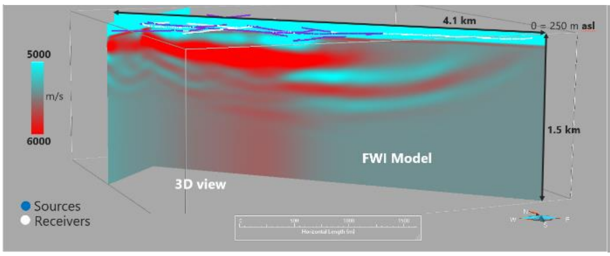
Velocity model building in hardrock environment has been a challenging task due to the associated complex geological setting and restricted use of available information, e.g., first arrival based traveltime tomography (FATT) which produces rather smoother velocity models (low-wavenumber). With the recent exponential growth in computation power, full waveform inversion (FWI) re-emerged and quickly established itself as a preferred choice for building high resolution velocity models by utilising the entire information available within the seismic traces. Here, we use FWI to image iron mineralisation hosting formations in Ludvika (Sweden) based on the 3D seismic data acquired as a part of the H2020 SmartExploration project. Data preprocessing workflow and inversion strategy was developed, aimed at enhancing the first-arrivals, increasing the local coherency and improving signal-to-noise ratio. We built an external mute function to eliminate direct and shear wave energy. Source wavelet was estimated using all the shots, and the velocity model obtained from FATT. We inverted for *P*-wave velocity only, keeping the density constant. We used a steepest descent optimization algorithm with smooth hessian during the inversion. A comparison of velocity models obtained from FATT and FWI is shown in Fig. 1. We can observe velocity details within the FATT model (Fig. 1a) is, which restricted to first few hundred meters from the surface while FWI derived velocity model (Fig. 1b) has much higher details. There are alternating high/low velocity layers dipping downdip in southeast direction and coinciding very well with the know mineralisation (Figs. 1c and 1d) along with some structural features marked by yellow arrow in Fig. 1c. The velocity model further suggests the curved nature of mineralisation in the southeast direction (Fig. 1c). It also provides some hints that mineralisation is extended downdip in southeast direction (Fig. 1d).



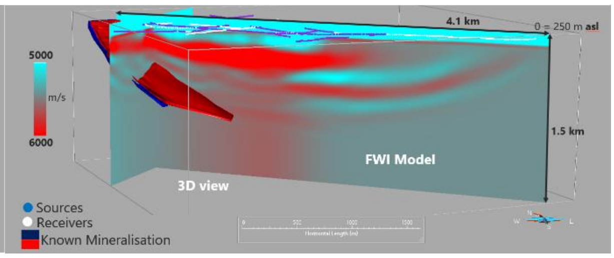
(a)



(c)



(b)



(d)

Fig. 1. Comparison of velocity models obtained from FATT and FWI: (a) A 3D view of FATT derived velocity model. The velocity details are restricted to only first few hundred meters from surface, (b) FWI derived velocity model with much higher resolution compared to FATT in (a), (c), and (d). Blue and red surfaces show the already know mineralisation. A very good fitting is obtained with the alternating high/low velocities obtained in the FWI model along with some structural features marked by yellow arrow. The velocity model also confirms the curved nature of mineralisation in southwest direction and that it further goes downdip in the southeast direction.

8.6 Visiting scientists

Johann Robertson, ETHZ, Zurich, Switzerland, 17.01.2020,
Deyan Draganov, TU Delft, Delft, Netherlands, 23–24.01.2020,
Yohei Tutiya, Kanagawa Institute of Technology, Atsugi, Japan, 4–12.02.2020.

8.7 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- W. Gajek, Extension of seismic monitoring network in Hornsund, Polar Night Week, Longyearbyen, Norway, I.2020, Oral;
- M. Malinowski, High-resolution geophysical imaging of the permafrost – the result of two high arctic expeditions to Spitsbergen, Seismix 2020, Perth, Australia, III.2020, Oral;
- M. Malinowski, Crustal structure along the fossil margin of Baltica: what we learned from the PolandSPAN project?, Seismix 2020, Perth, Australia, III.2020, Oral;
- M. Malinowski, Can we use sparse 3D seismics in mineral exploration? Takeaways from COGITO-MIN project, Seismix 2020, Perth, Australia, III.2020, Oral;
- M. Majdański, Geophysical imaging of permafrost in the SW Sbalbard – the result of two high arctic expeditions to Spitsbergen, EGU 2020, Austria, V.2020, Oral;
- A. Marciniak, Imaging of permafrost in the SW Svalbard by multiple geophysical methods – the result of two high arctic expeditions to Spitsbergen, AGU 2020, San Francisco, XII.2020, Oral;
- Y. Alashloo, Enhanced crustal-scale depth imaging using least-squares RTM of short-streamer seismic data, SEG 2020, Houston, USA, X.2020, Oral;
- B. Singh, Application of full waveform inversion and advanced pre-stack depth migration to hardrock seismic data, Smart Exploration Project-General Assembly Meeting #2, Kraków, Poland, I.2020, Oral;
- B. Singh, Full Waveform Inversion of the 2019 3D dataset, Smart Exploration E-workshop, Uppsala, Sweden, IV.2020, Oral;
- B. Singh, High resolution velocity model using full waveform inversion by utilizing the Ludvika-3D seismic dataset, Smart Exploration Project E-Meeting, Uppsala, Sweden, IX.2020, Oral;
- B. Singh, 3D velocity model building in hardrock environment using FWI: A case study from Blötberget mine, Sweden, EAGE NSG 2020, Amsterdam, Netherlands, XII.2020, Oral;
- R. Czarny, Modeling of seismic wave propagation around coal mine roadway with presence of excavation-damaged zone, EGU 2020, Austria, V.2020, Oral;
- R. Czarny, Characterisation of the tunnel-channel wave around a coal mine roadway based on synthetic and real data, EAGE NSG 2020, Amsterdam, Netherlands, XII.2020, Oral;
- M. Chamarczuk, Impact of drilling-related operations on imaging iron-bearing formations in Pilbara, Western Australia using seismic interferometry, SEG 2020, Houston, USA, X.2020, Oral;
- M. Chamarczuk, Towards retrieval of reflections using ambient-noise recorded during drilling operations: iron ore formation imaging in Pilbara, Western Australia, Seismix 2020, Perth, Australia, III.2020, Oral;
- M. Chamarczuk, Unsupervised learning used in automatic detection and classification of ambient-noise recordings from a large-N array, Seismix 2020, Perth, Australia, III.2020, Poster;

- A. Górszczyk, Multitechnique regional seismic imaging – a case study from the Tokai area, Japan, Seismix 2020, Perth, Australia, III.2020, Oral;
- A. Górszczyk, GO_3D_OBServer – offshore benchmark of subduction environment in realistic visco-elastic representation, Seismix 2020, Perth, Australia, III.2020, Poster;
- A. Górszczyk, Mitigating the nonlinearity of crustal-scale full waveform inversion through the graph space optimal transport misfit function, Seismix 2020, Perth, Australia, III.2020, Poster;
- A. Górszczyk, Relaxing the initial model constraint for crustal-scale full-waveform inversion with graph-space optimal transport misfit function, EAGE, Netherlands, XII.2020, Oral;
- A. Górszczyk, Relaxing the initial model constraint for crustal-scale full-waveform inversion with graph-space optimal transport misfit function, EGU, Austria, V.2020, Oral;
- A. Górszczyk, The influence of subducting seamounts: variations in accretionary prism deformation style along the nankai trough from combined ocean-bottom seismometer and multichannel seismic data, GSA, USA, X.2020, Poster;
- A. Górszczyk, Velocity model building from sparse long-offset node data by slope tomography and extended waveform inversion, SEG (Workshop 11), Houston, USA, X.2020, Oral;
- Q. Nguyen, Seismic processing and imaging of the new 2D marine reflection seismic data in the Polish sector of the Baltic Sea, EGU, Austria, V.2020, Poster.

8.8 Publications

ARTICLES

Chamarczuk, M., et al., **M. Malinowski** (2020), Unsupervised learning used in automatic detection and classification of ambient-noise recordings from a large-N array, *Seismol. Res. Lett*. **91**, 1, 370–389, DOI: 10.1785/0220190063.

Glazer, M., et al., **A. Marciniak**, **M. Majdański** (2020), Spatial distribution and controls of permafrost development in non-glacial Arctic catchment over the Holocene, Fuglebekken, SW Spitsbergen, *Geomorphology* **358**, 107128, DOI: 10.1016/j.geomorph.2020.107128.

Bashir, Y., et al., **S.Y. Moussavi Alashloo** (2020), Inspiration for seismic diffraction modelling, separation, and velocity in depth imaging, *Appl. Sci*. **10**, 12, 4391, DOI: 10.3390/app10124391.

Hermana, M., L.A. Lubis, **S.Y. Moussavi Alashloo**, and Julikah (2020), A novel method in hydrocarbon and reservoir properties prediction based on elastic properties, *J. Earth Sci. Technol*. **1**, 1, 38–43.

CHAPTERS

Köhler, A., **W. Gajek**, **M. Malinowski**, J. Schweitzer, **M. Majdański**, W.H. Geissler, **M. Chamarczuk**, and A. Wuestefeld (2020), Seismological monitoring of Svalbard's cryosphere: current status and knowledge gaps (CRYOSEIS). **In:** F. Van den Heuvel et al. (eds.), SESS Report 2019, Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 136–159.

9. DEPARTMENT OF POLAR AND MARINE RESEARCH

Marek Lewandowski

9.1 About the Department

This was a year of intensive studies on natural processes in the polar system. Our work focused on three main components (litho-, atmo-, and hydrosphere, with a small though important contribution from the biosphere), interacting in the High Arctic and Antarctica. We contributed to an international project, which indicated that the low elevation of Svalbard glaciers drives high mass loss variability (Noël et al. 2000), and that they are on their way to total decay, probably even in this century. Part of the story is the dust that accumulates in the glaciers, which effectively lowers the albedo of the snow and ice (Lewandowski et al. 2020; Kavan et al. 2020). Melting and calving glaciers furnish fresh water and abiotic components to the local fiords (Głowacki and Deane 2020), influencing marine ecosystems with unpredictable consequences for humans. Associated with glacial melt are processes driving heavy metal distribution in the seawater of Arctic fjords (Zaborska et al. 2020). A 40-year High Arctic climatological dataset from the Polish Polar Station Hornsund (SW Spitsbergen, Svalbard) has been compiled and published (Wawrzyniak and Osuch 2020), depicting essential changes experienced by the region. Publications mentioned above are just a fraction of the 24 articles published by our Department in 2020.

Moreover, we were active partners in the Svalbard Integrated Observing System consortium (SIOS), coordinating efforts of international research units in the High Arctic region. We also participated in other international enterprises, including EU PolarNet (Horizon 2020), INTAROS, and Interact II, with important educational components.

Aiming to develop polar research on the other side of the globe, we have been preparing the revitalization of Dobrowolski Station in the Bunger Hills in Wilkes Land of East Antarctica, continuing technical dialogue with our research and logistics partners from Arctic Antarctic Russian Institute and the Okeangeologia Research Institute of St. Petersburg, Russia, about the terms of our participation in the Russian Antarctic Expedition the expedition of 2021/22. Aiming to combine geological research from Arctic (Greenland and Labrador) and Antarctic (Enderby Land), we commenced the PAAN project, financed from the Polish–Norwegian funds in the framework of the GRIEG programme. A major goal of the project is to compare Archean crustal fragments, now dispersed over the two geographic poles, in order to infer the extent and composition of continental crust in the early Earth. A new colleague, geochemist prof. Daniel J. Dunkley and two PhD students, have been employed in the Department from project funds.

Finally, as a result of a three-year effort, we published the "Polish Polar Research: Green-and-White Paper", presenting the Polish potential for polar research and plans of the Polish polar community in the next decade.

9.2 Personnel

Head of the Department
Marek Lewandowski
Professor

Professor
Piotr Głowacki

Professors of the Institute
Daniel J. Dunkley
Monika A. Kusiak

Assistant Professors
Oskar Głowacki
Bartłomiej Luks
Mateusz Moskalik
Adam Nawrot
Tomasz Wawrzyniak

PhD Students
Tanmay Keluskar, Indie; Monika A. Kusiak– PhD supervisor
Piotr Król, Poland; Monika A. Kusiak– PhD supervisor
Marta Majerska, Poland; Tomasz Wawrzyniak– auxiliary PhD supervisor
Marcin Mieszczak, Poland; Monika A. Kusiak– PhD supervisor
Julian Podgórski, Poland; Piotr Glowacki– PhD supervisor
Karol Torzewski, Poland; Adam Nawrot– auxiliary PhD supervisor

9.3 Main research projects

- SIOS – Zintegrowany Arktyczny System Obserwacyjny dla Svalbardu, Głowacki P., Ministry of Science and Higher Education – Polish Road Map of Research Infrastructure, 2018–2023;
- “Poles together – missing links between Arctic and Antarctic early Earth records PAAN UMO-2019/34/H/ST10/00619”, Kusiak M.A., Norway grants GRIEG, 2020–2023;
- Microbial anthropogenic footprint in snow-dominated Karkonosze catchments, Nawrot A., NAWA – PHC Polonium, 2019–2020;
- Badanie procesów wpływajacych na intensywnosc cielenia lodowca Hansa przy pomocy metod teledetekcyjnych, Podgórski J., IG PAS internal project, 2019–2020;
- State of Revvatnet hydrodynamics (StaRev), Wawrzyniak T., SIOS access call research infrastructure, Norway, 2019–2021;
- Measuring the melt rate of glacier ice with underwater noise, Głowacki O., IG PAS internal project, 2017–2021;
- Studying the contribution of submarine calving to the mass loss of tidewater glaciers, Głowacki O., Ministry of Science and Higher Education of Poland – “Mobility Plus”, 2018–2020;
- Connecting science with society, EU-PolarNet no: 652641, Horizon 2020, 2015–2020;
- Integrating and opening research infrastructures of European interest, INTERACT II no. 730938, Horizon 2020, 2016–2020;
- Integrating and opening research infrastructures of European interest, INTERACT III no. 871120, Horizon 2020, 2020–2024;
- Integrated Arctic observation system, INTAROS no. 727890, Horizon 2020, 2016–2021.

9.4 Instruments and facilities

Equipment

- Marine Sedimentology – Hydro-Bios Multi Water Sampler SlimeLine 6 with Sea & Sun CT (PolarPOL); Hydro-Bios Multi Sediment Trap 24 Bottles (PolarPOL); Plastic Water Samplers 1l and 3.5l; Sediment Traps Sets; Sequoia Laser In-Situ Scattering and Transmissometery LISST-100X 2.5–500 μm with Sea-Bird MicroCat CT, BIOBLOCK and 2× Large Battery Pack (PolarPOL); Small Gravitation Sediment Corer Sampler;

- Physical Oceanography – Teledyne RDI ADCP WH300 with float (PolarPOL); Teledyne RDI ADCP Sentinel V20 with Battery Pack; SAIV A/S STD/CTD SD204 with Dissolved Oxygen and Turbidity Sensors (PolarPOL); 6× RBRsolo T (PolarPOL); 2× RBRduet TD (PolarPOL); 2× RBRconcerto CTD (PolarPOL); 2× RBRvirtuoso Tide & Wave; Valeport miniCTD; 3× Sub Sea Sonic AR-50 Acoustic Release (PolarPOL); Russell Technology XIR3000C Marine Radar System with Furuno antenna (PolarPOL); 7× Digisnap Autonomous Photographic Systems;
- Seismoacoustic and Bathymetry – Kongsberg Geoswath 4 Multibeam Echosounder 250 kHz (PolarPOL); EdgeTech Chirp Sub-Bottom 3100-P SB-216S 2–20 kHz (PolarPOL); SEABED Sub-Bottom Profiler 3010-MP 3–14 kHz; Seismoacoustic Sparker and Boomer System; EdgeTech Side Scan Sonar 4125 400/900 kHz with Depressor Wing (PolarPOL); Tritech Side Scan Sonar StarFish 990F; Wesmar Side Scan Sonar SHD700SS; CODA DA 100 Acoustic Acquisition System; Lowrance Echosounder LMS 527C DF GPS 50/200 kHz; Lowrance Echosounder HDS-9 Gen 3 50/200 kHz with Structure Scan;
- Passive Acoustic – 2× Wildlife Acoustic song Meter SM3M Submersible (PolarPOL); 2× Tascam DR-680 registrator with 4× hydrophones with 5 m and 50 m cables;
- Other Equipments for Marine Research – Diving equipments; Buster Cabin E Boat (PolarPOL); SEARIS Multipurpose Unmanned Surface Explorer MUSE with Winch and Camera System (PolarPOL); 2x Hydro-Bios Hand Winch with Motor (PolarPOL); GoPro Hero3+ Silver; GoPro Hero4 Sliver with Underwater Lights and Macro Converter;
- Hydrology/Hydrochemistry – Flow meter Nivus PCM-F with Active Doppler sensor (KDA-KP 10) – runoff ; HOBO U20 – water temperature and water level in streams; NIVUS PCM-F with Active Doppler sensor (KDA-KP 10) (2 sets) – discharge measurements (PolarPOL); Autosampler ISCO 6712 (2 sets; PolarPOL); ISCO rain gauge meters (2 sets; PolarPOL); OnSet Hobo U20 (8 sets) – water level and temperature; OnSet Hobo U24 (4 sets) – water conductivity and temperature; Sontek FlowTracker – Doppler method current meter (PolarPOL); Valeport 802 – Electromagnetic Current Meter;
- Meteorology/Climatology – Vaisala MAWS 301 – automatic weather station – 3 sets (PolarPOL) Geomorphology and cryosphere research, GNSS Leica GR25 (2 sets), GS14, GS10, GNSS Leica GS14 Professional, GNSS Leica GS10 Professional (PolarPOL); Terrestrial Laser Scanner Riegl VZ6000 (PolarPOL); Ice core driller Kovacs Coring System Mark II (PolarPOL); Georadar MALÅ ProEx with antenas (1 set PolarPOL, 1 set ZBPiM); Unmanned aerial vehicle (UAV) Phantom 4 Pro+ (3 sets); MicroMap UAV (PolarPOL); snow density meter (3 sets), TinyTag Plus 2 temperature recorders i Tomst soil humidity and temperature recorders.

Laboratory

- XRF OLYMPUS VANTA M – advanced handheld X-ray fluorescence (XRF) device. Provides rapid, accurate element analysis and alloy identification to demand laboratory-quality results in the field;
- pH and conductivity meters (2 sets) – hydrochemistry analyses;
- Geoprocessing Belsk Laboratory (GeoBeLa).

9.5 Research activity and results

Brief description/abstracts/summaries of some of the achievements of the Department’s staff:

SEEKING THE SOURCES OF DUST: GEOCHEMICAL AND MAGNETIC STUDIES ON ”CRYODUST” IN GLACIAL CORES FROM SOUTHERN SPITSBERGEN (SVALBARD, NORWAY)

M. Lewandowski, **M.A. Kusiak**, **T. Werner**, **A. Nawrot**, **B. Barzycka**, **M. Laska**, and **B. Luks** (published in: *Atmosphere* (2020), **11**, 12, 1325, DOI: 10.3390/atmos11121325)

Natural mineral particulate matter deposited from aerosols and trapped in glaciers – herein defined as “cryodust” – may be an excellent indicator of atmospheric circulation, if terrestrial

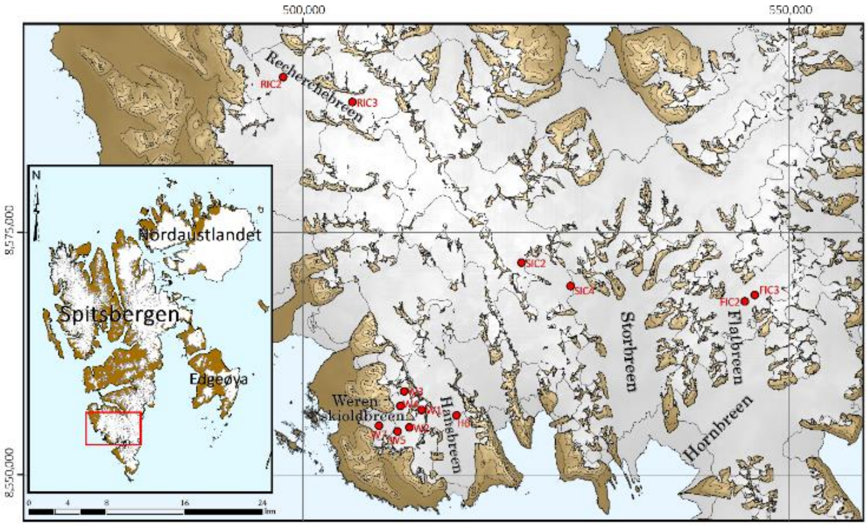


Fig. 1. Map of Southern Spitbergen with drilling sites marked by red dots.

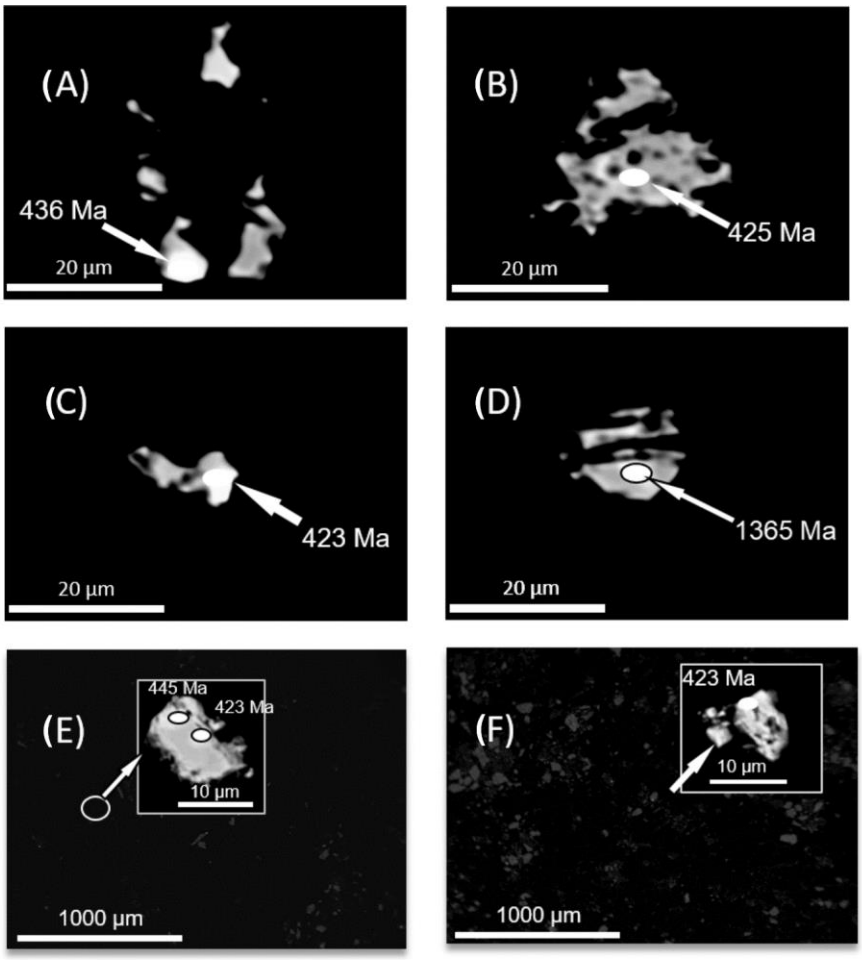


Fig. 2. Monazite grains, analytical points, and grain’s ages in Ma.

sources of dust can be identified. In this study, we analyzed the composition of cryodust in shallow ice cores taken from five glaciers in Southern Spitsbergen (Svalbard, Norway, see Fig. 1). The chemical composition, magnetic properties and radiogenic ages of individual grains were measured, where possible, to provide indicators of source areas. To identify mineral and rock fragments, solid particulates were examined by Scanning Electron Microscope fitted with a backscattered electron and Energy Dispersive Spectroscopic detectors. An Electron Micro-Probe was employed for the U-Th-Pb chemical dating of monazite grains. Magnetic measurements comprised analyses of magnetic susceptibility (κ) vs. temperature (T) variations and determination of magnetic hysteresis parameters. Monazite ages span 445–423 Ma, consistent with mineral growth during the Caledonian orogeny (Fig. 2). Caledonian rocks are exposed in the Nordaustlandet area of North-Eastern Svalbard, and this is the most probable source for monazite grains. Magnetic analyses show a predominance of ferrous (FeII) over ferric (FeIII) phases (Fig. 3), consistent with a lack of input from subtropical sources. The results from both methods are consistent with local sources of dust from exposures in the Svalbard archipelago.

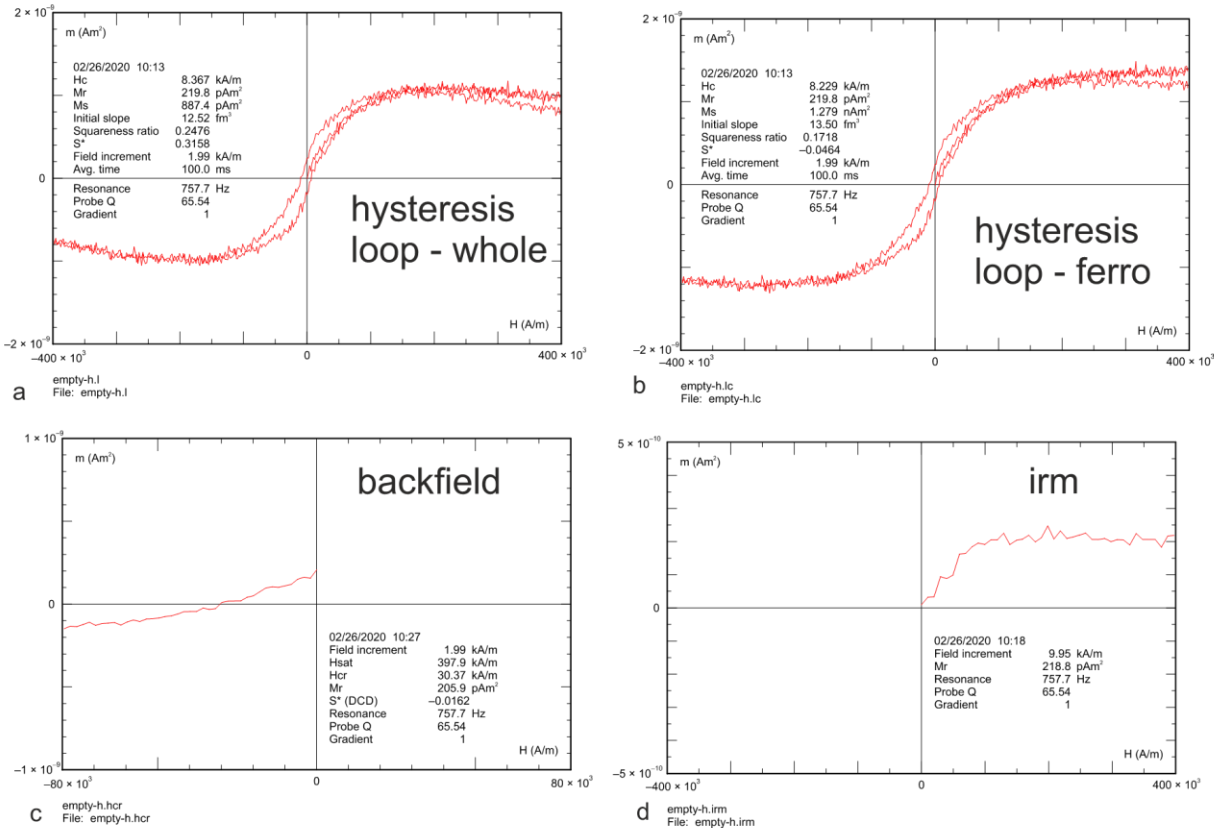


Fig. 3. Hysteresis for cryodus grains assembly, showing sole presensce of low Hcr grains.

QUANTIFYING ICEBERG CALVING FLUXES WITH UNDERWATER NOISE

O. Głowacki, **G.B. Deane** (published in: *The Cryosphere* (2020) **14**, 3, 1025–1042, DOI: 10.5194/tc-14-1025-2020)

Accurate estimates of iceberg calving fluxes are required to understand the dynamics of tide-water glaciers and quantify their contribution to the ocean's freshwater budget and sea level rise. Here we investigate the use of underwater noise produced by iceberg-water impact to measure calving flux at Hans Glacier, Svalbard. A relationship between the acoustic energy and ice mass loss associated with 169 subaerial calving events is explored through the combination of ambient noise cryology and time-lapse photography. The analysis includes an error budget

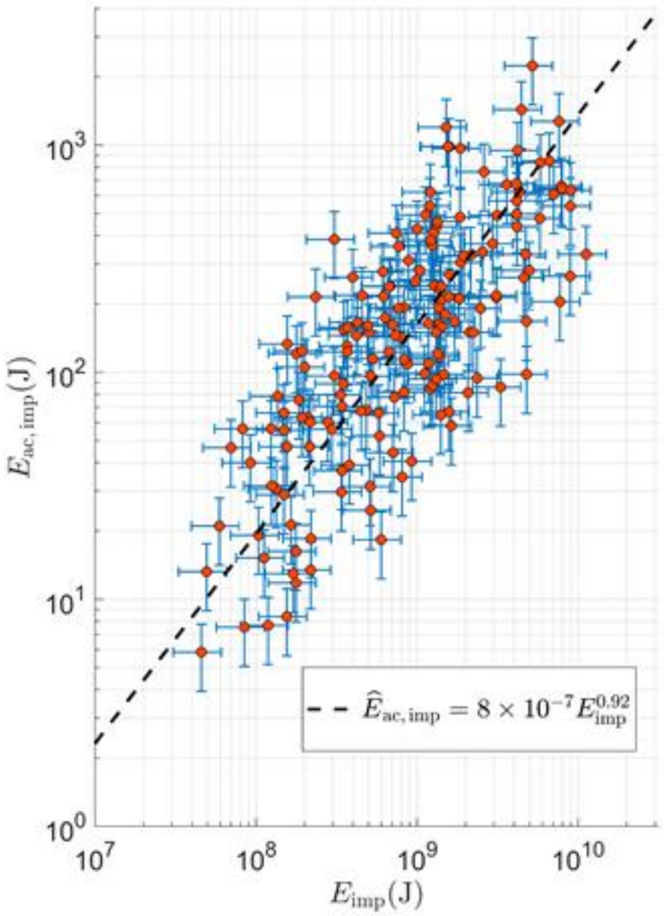


Fig. 1. Relationship between the block-water impact energy and underwater acoustic emission below 100 Hz. Uncertainties are marked with blue whiskers and were estimated to be 33% for both variables.

for all major factors affecting the impact noise: (i) variability of the thermohaline structure in the glacial bay, (ii) varying bathymetry along the propagation path, and (iii) the contribution of underwater sound reflected from the glacier terminus. A robust correlation of 0.75 is found between the (log-transformed) impact noise energy and kinetic energy of the falling ice blocks (Fig. 1). The multiplication factor and exponent of the power law relationship are found to be 8×10^{-7} and 0.92, respectively. A simple model based on this correlation can be used to quantify solid ice discharge, if supplemented by a site-specific average drop height. The accuracy of the acoustic technique improves with number of calving events analyzed: 25% for 25 ice blocks and 10% for 135 impacts. Further improvements to the model will require a better understanding of the source mechanisms of underwater noise generated by calving icebergs.

LOW ELEVATION OF SVALBARD GLACIERS DRIVES HIGH MASS LOSS VARIABILITY

B. Noël, **C.L. Jakobs**, **W.J.J. van Pelt**, **S. Lhermitte**, **B. Wouters**, **J. Kohler**, **J.O. Hagen**, **B. Luks**, **C.H. Reijmer**, **W.J. van de Berg**, and **M.R. van den Broeke** (published in: *Nat. Commun*. (2020), **11**, 4597, DOI: 10.1038/s41467-020-18356-1).

About 60% of Svalbard, the archipelago with Spitsbergen as its largest island, is covered by glaciers. These glaciers can handle yearly temperature fluctuations as long as they are covered by a layer of porous snow, also called firn, which buffers much of the meltwater. Using a high-resolution climate model, we have now shown that Svalbard's firn line has retreated to a critical altitude in the mid-1980s (Fig. 1). Since then, most of Svalbard's glaciers have lost their protective firn layer, which leaves the ice much more vulnerable to summer melt. The results were published in *Nature Communications*.

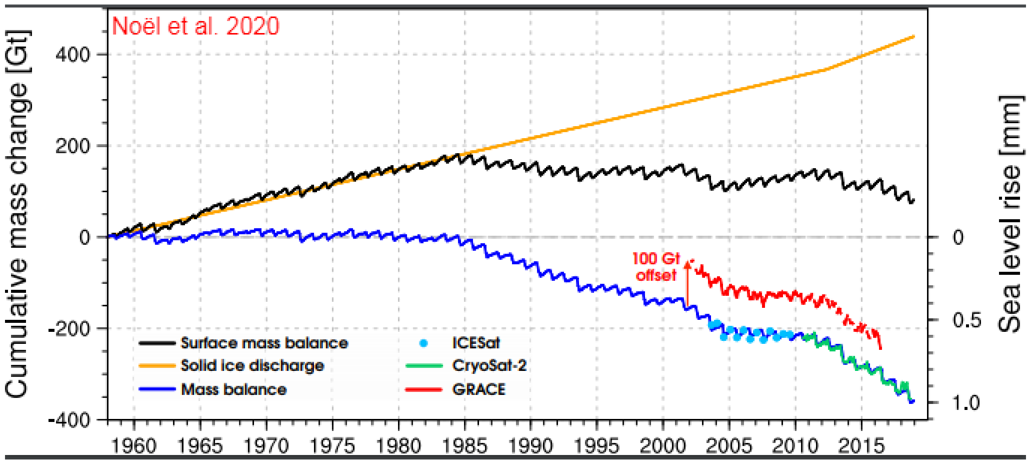


Fig. 1. Until the mid-1980s, the mass balance of the Svalbard glaciers (blue line) is stable around a neutral position, but then starts to fall, with a clear pause between 2005 and 2012. Mass loss since the mid-1980s is translated into global sea level rise.

9.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- M. Moskalik, LONGHORN – Long-term oceanographical monitoring in Hornsund region, Sustainable Svalbard Coasts (Svalcost), Longyerabyean, Svalbard, Norway, 18–20.02.2020, Oral;
- M. Moskalik, LONGHORN – Long-term oceanographical monitoring in Hornsund region, SIOS Core Data Workshop, 5–6.11.2020, Oral;
- M. Moskalik, LONGHORN – Long-term oceanographical monitoring in Hornsund region, SIOS Marine Infrastructure Workshop, 19.11.2020, Oral;
- T. Wawrzyniak, M. Osuch, M. Majerska, M. Retelle, S. Roof, M. Moskalik, State of Revvatnet hydrodynamics in the year 2020, Polar Night Week 2020, Longyearbyen, Svalbard, Norway, 13–17.01.2020, Oral;
- H. Vishnu, M. Chitre, O. Głowacki, M. Moskalik, D.M. Stokes, G.B. Deane, Vertical line array measurements of the sound radiated by melting glaciers in Hornsund Fjord, 179th Meeting of the Acoustical Society of America, 7–11.12.2020, Oral;
- H.A. Johnson, H. Vishnu, G.B. Deane, P. Tuckman, O. Głowacki, M. Moskalik, Depth dependence of acoustic signals produced by bubble release events in melting glacier ice, 179th Meeting of the Acoustical Society of America, 7–11.12.2020, Oral;
- G.B. Deane, O. Głowacki, D.M. Stokes, M. Moskalik, M. Chitre, Measuring tidewater glacier melt rates with underwater noise, Ocean Sciences Meeting, San Diego, USA, 16–21.02.2020, Poster;
- O. Głowacki, G.B. Deane, Quantifying calving flux from underwater noise of iceberg impact, Ocean Sciences Meeting, San Diego, USA, 16–21.02.2020, Oral;
- G.B. Deane, O. Głowacki, D.M. Stokes, Acoustical remote sensing of ice sheets and tidewater glaciers: recent progress and remaining challenges, Ocean Sciences Meeting, San Diego, USA, 16–21.02.2020, Poster;
- O. Głowacki, Measuring iceberg calving fluxes with underwater noise, Workshop of the International Partnership for the Acoustic Monitoring of Glaciers (IPA OMG), La Jolla, USA, 26.02.2020, Oral;

- M. Błaszczyk, B. Barbara, M. Laska, J. Jania, M. Grabiec, D. Ignatiuk, B. Luks, P. Głowacki, Long term monitoring of glacier mass balance in Hornsund (Svalbard) with satellite and in-situ measurements, 2020 EUROPEAN POLAR SCIENCE WEEK, 26–30.10.2020, Oral;
- J. Tuszynska, J. Jania, M. Błaszczyk, B. Luks, The Svalbard glaciers response to the climate change: an investigation into Hansbreen dynamics, SIOS's Online Conference on "Earth Observation (EO), Remote Sensing (RS) and Geoinformation (GI) applications in Svalbard", 4–5.06.2020, Oral;
- R. Salzano, K. Kristoffer Aalstad, E. Boldrini, J.C. Gallet, D. Kępski, B. Luks, L. Nilsen, R. Salvatori, S. Westerman, Terrestrial photography applications for snow cover monitoring: implementation of a shared approach, SIOS's Online Conference on "Earth Observation (EO), Remote Sensing (RS) and Geoinformation (GI) applications in Svalbard", 4–5.06.2020, Oral;
- J. Podgórski, Detailed iceberg inventory from high-resolution satellite imagery, Cooperation in remote sensing of calving glaciers, Hornsund and Ny-Ålesund, Warsaw, Poland, 02.2019–07.2020, Oral;
- T. Wawrzyniak, Hydrogeological measurements in SW Spitsbergen, Fundamental and Advanced Topics in Hydrogeology and Hydrological Simulation, Cagliari, Italy, 10–15.02.2020, Oral;
- T. Wawrzyniak, Climate variability, hydrological processes and ground thermal regime at the Polish Polar Station Hornsund, APECS Polar Career Workshop 2020, 14.10.2020, Oral;
- M. Majerska, M. Osuch, T. Wawrzyniak, A. Nowak, Airborne imagery and in-situ measurements Hornsund campaign 2020, SIOS's Online Conference on Earth Observation, Remote Sensing and Geoinformation applications in Svalbard, 04–05.06.2020, Oral;
- S. Dahlke, N.E. Hughes, P.M. Wagner, S. Gerland, T. Wawrzyniak, B. Ivanov, M. Maturilli, The observed recent surface air temperature development across Svalbard and concurring footprints in local sea ice cover, EGU General Assembly 2020, 04–08.05.2020, Oral;
- T. Wawrzyniak, Meteorological monitoring in Hornsund region, SIOS Core Data Workshop, 5–6.11.2020, Oral.

9.7 Publications

ARTICLES

Dunkley, D.J., et al. (2020), Geological subdivision of the Lützow–Holm Complex in East Antarctica: From the Neoarchean to the Neoproterozoic, *Polar Sci*. **26**, 100606, DOI: 10.1016/j.polar.2020.100606.

Bose, S., et al., **D.J. Dunkley** (2020), Origin of orthopyroxene-bearing felsic gneiss from the perspective of ultrahigh-temperature metamorphism: an example from the Chilka Lake migmatite complex, Eastern Ghats Belt, India, *Mineral. Magaz.* **84**, 5, 712–737, DOI: 10.1180/mgm.2020.71.

Sassi, R., et al., **D.J. Dunkley** (2020), HT–LP crustal syntectonic anatexis as a source of the Permian magmatism in the Eastern Southern Alps: evidence from xenoliths in the Euganean trachytes (NE Italy), *J. Geol. Soc.* **177**, 6, 1211–1230.

Głowacki, O. (2020), Underwater noise from glacier calving: Field observations and pool experiment, *J. Acoustic. Soc. Am*. **148**, 1, EL1–EL7, DOI: 10.1121/10.0001494.

Głowacki, O., and G.B. Deane (2020), Quantifying iceberg calving fluxes with underwater noise, *The Cryosphere* **14**, 1025–1042, DOI: 10.5194/tc-14-1025-2020.

Vishnu, H., et al., **O. Głowacki**, **M. Moskalik** (2020), Vertical directionality and spatial coherence of the sound field in glacial bays in Hornsund Fjord, *J. Acoustic. Soc. Am*. **148**, 6, 3849–3862, DOI: 10.1121/10.0002868.

Jayananda, M., et al., **M.A. Kusiak** (2020), Multi-stage crustal growth and Neoarchean geodynamics in the Eastern Dharwar Craton, southern India, *Gondwana Res*. **78**, 228–260, DOI: 10.1016/j.gr.2019.09.005.

Lewandowski, M., **M.A. Kusiak**, T. Werner, **A. Nawrot**, et al., **B. Luks** (2020), Seeking the sources of dust: Geochemical and magnetic studies on "cryodust" in glacial cores from Southern Spitsbergen (Svalbard, Norway), *Atmosphere* **11**, 12, 1325, DOI: 10.3390/atmos11121325.

Andersen, J.K., et al., **B. Luks** (2020), The Arctic, *Bull. Am. Meteorol. Soc*. **101**, 8, S239–S286, DOI: 10.1175/BAMS-D-20-0086.1.

Błaszczyk, M., et al., **B. Luks**, **M. Moskalik**, **T. Wawrzyniak** (2020), Factors controlling terminus position of Hansbreen, a tidewater glacier in Svalbard, *J. Geophys. Res.: Earth Surf*. **126**, 2, e2020JF005763, DOI: 10.1029/2020JF005763.

Ignacio López-Moreno, J., et al., **B. Luks** (2020), Intercomparison of measurements of bulk snow density and water equivalent of snow cover with snow core samplers: Instrumental bias and variability induced by observers, *Hydrol. Process*. **34**, 14, 3120–3133, DOI: 10.1002/hyp.13785.

Noël, B., et al., **B. Luks** (2020), Low elevation of Svalbard glaciers drives high mass loss variability, *Nat. Commun*. **11**, 4597, DOI: 10.1038/s41467-020-18356-1.

Schuler, T.V., et al., **B. Luks** (2020), Reconciling Svalbard glacier mass balance, *Front. Earth Sci*. **8**, DOI: 10.3389/feart.2020.00156.

Zaborska, A., et al., **M. Moskalik** (2020), Processes driving heavy metal distribution in the seawater of an Arctic fjord (Hornsund, southern Spitsbergen), *Marine Poll. Bull*. **161**, Part A, 111719, DOI: 10.1016/j.marpolbul.2020.111719.

Kavan, J., et al., **A. Nawrot**, **T. Wawrzyniak** (2020), High latitude dust transport altitude pattern revealed from deposition on snow, Svalbard, *Atmosphere* **11**, 12, 1318, DOI: 10.3390/atmos11121318.

Podgórski, J., et al. (2020), Detailed lacustrine calving iceberg inventory from very high resolution optical imagery and object-based image analysis, *Remote Sens*. **12**, 11, 1807, DOI: 10.3390/rs12111807.

Wawrzyniak, T., and M. Osuch (2020), A 40-year High Arctic climatological dataset of the Polish Polar Station Hornsund (SW Spitsbergen, Svalbard), *Earth Syst. Sci. Data* **12**, 2, 805–815, DOI: 10.5194/essd-12-805-2020.

Dahlke, S., et al., **T. Wawrzyniak** (2020), The observed recent surface air temperature development across Svalbard and concurring footprints in local sea ice cover, *Int. J. Climatol*. **40**, 12, 5246–5265, DOI: 10.1002/joc.6517.

MONOGRAPHS

Lewandowski, M. (edit.), et al., **P. Głowacki**, **B. Luks** (2020), Zielono-biała Księga Polskich Badań Polarnych pod egidą Polskiego Konsorcjum Polarnego (PKPol), *Publs. Inst. Geoph. PAS* **430** (P-1), 135 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2020-005.

Lewandowski, M. (edit.), et al., **P. Głowacki**, **B. Luks** (2020), Polish Polar Research: Green-and-White Paper under the aegis of the Polish Polar Consortium (PPC), *Publs. Inst. Geoph. PAS* **431** (P-2), 135 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2020-006.

CHAPTERS

Schuler, T.V., et al., **B. Luks** (2020), New data, new techniques and new challenges for updating the state of Svalbard glaciers (SvalGlac). **In:** F. Van den Heuvel et al. (eds.), *SESS Report 2019*, Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 108–134.

Wolken, G.J., et al., **B. Luks** (2020), Glaciers and ice caps outside Greenland. **In:** *NOAA Arctic Report Card 2020*, 8 pp., DOI: 10.25923/nwqq-8736.

Retelle, M., et al., **M. Osuch**, **T. Wawrzyniak** (2020), Environmental Monitoring in the Kapp Linné-Grønfjorden Region (KLEO). **In:** F. Van den Heuvel et al. (eds.), *SESS Report 2019*, Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 84–107.

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