Institute of Geophysics
Polish Academy of Sciences

PUBLICATIONS
OF THE INSTITUTE OF GEOPHYSICS
POLISH ACADEMY OF SCIENCES

Geophysical Data Bases, Processing and Instrumentation

445 (M-36)

Achievements of the Institute of Geophysics, PAS: Annual Report 2021

Warsaw 2023 (Issue 2)

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ISBN 978-83-66254-17-6 eISSN-2299-8020
DOI: 10.25171/InstGeoph_PAS_Publs-2023-002

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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 2021**, 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

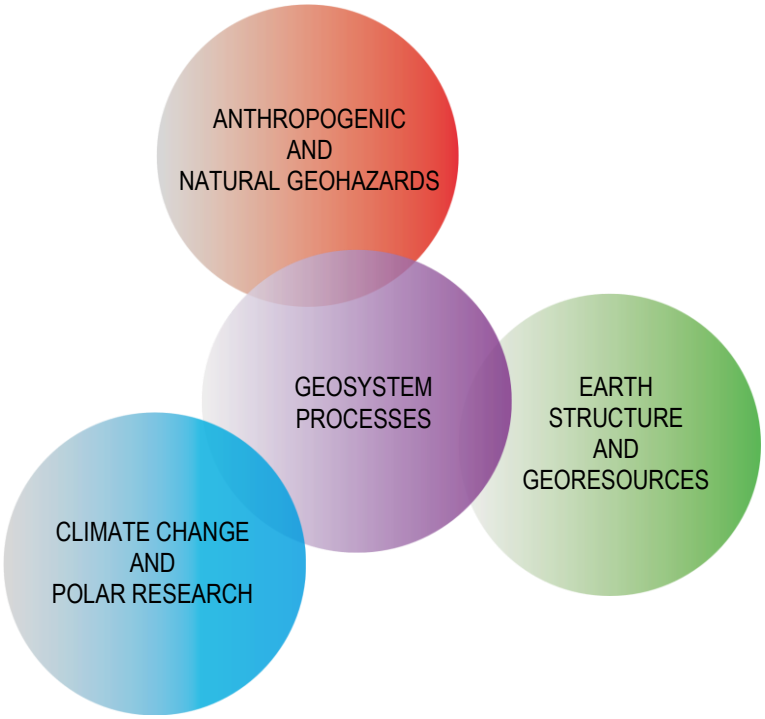
Beata Orlecka-Sikora, Mariusz Majdański, Beata Fromeliusz, Krzysztof Otto

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 community

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 the 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 observed changes in 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".

2. ACHIEVEMENTS

2.1 Anthropogenic and natural geohazards

HIGHLY SIGNIFICANT CORRELATION BETWEEN KINEMATIC AND DYNAMIC PARAMETERS OF THE SEISMIC EVENTS PRECEDING THE CHIAPAS M8.2 EARTHQUAKE

S. Lasocki

A canon of seismology is the independence of earthquake kinematic parameters – occurrence time and location, and a dynamic parameter – magnitude. In probabilistic seismic hazards analysis, this independence allows us to replace the joint probability distributions of occurrence time, location, and magnitude of the earthquake with the marginal distributions of these three random variables. In stochastic models of seismicity, e.g., in the ETAS model and its modifications, stochastic relationships are introduced for the time of occurrence and sometimes also for the earthquake location, while the magnitude is considered a statistical (memoryless) variable of a (usually) exponential distribution. No correlation between the time and location of an earthquake and the magnitude also implies no correlation between any quantity defined solely by time and location and any quantity defined solely by magnitude.

While studying the seismicity preceding the Chiapas earthquake, we obtained results contrary to this "iron rule". Two parameters were calculated in data windows composed of 100 seismic events each, and sliding by 20 phenomena over 17.5 years prior to the Chiapas earthquake. The data consisted of 1048 events which gave rise to 48 sliding windows. The first was the average distance between the events projected on a plane of *dt* and *dr*, transformed to equivalent dimensions. For a seismic event *i*, the value of the *dt* parameter is the difference between its occurrence time, t_i, and the occurrence time of the preceding event, t_{i-1} $dt = t_I - t_I - 1$. *dr* is the orthodromic distance between the epicenters of this event and its predecessor, $dr = f(\lambda_i, \lambda_{i-1}, \phi_i, \phi_{i-1})$, where λ is the latitude and ϕ is the longitude of the epicenter. The average distance on the mentioned plane between the events from a 100 event window is

$$d_c(dt, dr) = \frac{1}{4950}\sum_{i=1}^{99}\sum_{j=i+1}^{100}\sqrt{[dt(i) - dt(j)]^2 + [dr(i) - dr(j)]^2}\ .$$

$d_c(dt, dr)$ is defined solely on the kinematic parameters t_i, λ_i, ϕ_i.

The second calculated parameter was the reciprocal of the Gutenberg–Richter *b*-value in the window, 1/*b*. If M_i, $i = 1, ..100$ are magnitudes of the events from the window,

$$1/b = 0.01\sum_{i=1}^{100}(M_i - M_c) + 0.5\varepsilon\ ,$$

where M_c is the magnitude completeness level, and ε is the accuracy of magnitude determination. 1/*b*(*M*) is defined solely on the dynamic parameters, M_i. Figure 1 presents a time plot of changes of $d_c(dt, dr)$ and 1/*b*(*M*), and a scatterplot of the 1/*b*(*M*) vs. $d_c(dt, dr)$ values. The strong interdependence between these two parameters in clearly visible. It is confirmed by the correlation analysis. The Spearman rank correlation coefficient is $\rho(d_c(dt, dr), 1/b(M)) = 0.5569$, and the respective *p*-value, $p = 4\times10^{-5}$, indicates highly significant correlation between these two parameters. The obtained result is paramount for seismic process modeling and seismic hazards analysis. Further research will study the conditions under which the observed correlation between kinematic and dynamic earthquake parameters arises. This study is a continuation of research 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).

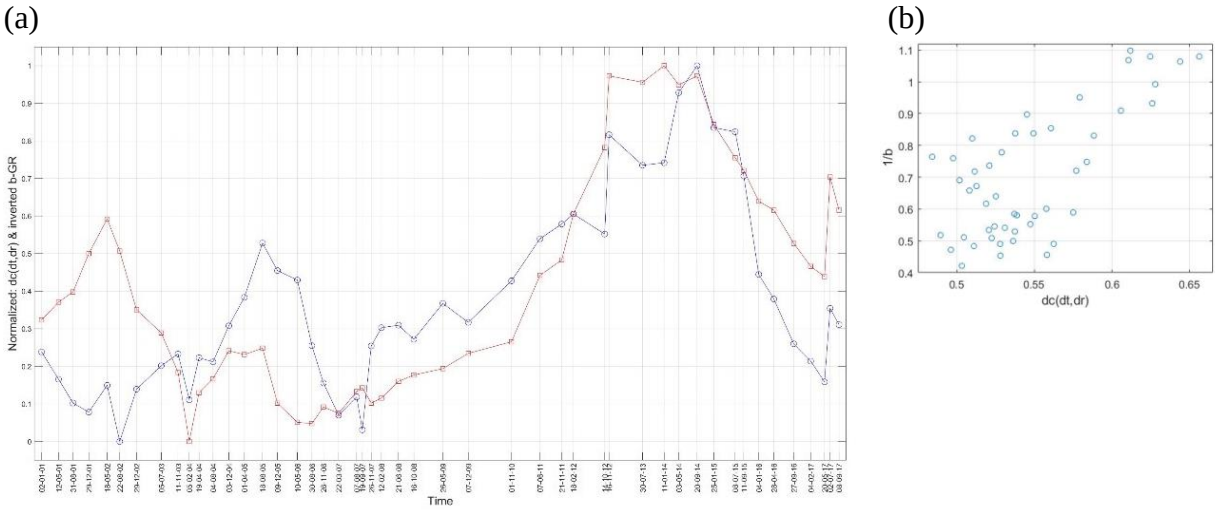


Fig. 1: (a) Changes of $d_c(dt, dr)$ (blue) and 1/b(M) (red) in 100 event windows sliding of 20 events. The last event of the last window is the Chiapas M8.2 mainshock; (b) $d_c(dt, dr)$ vs. 1/b(M) scatterplot.

DEPTH–DURATION–FREQUENCY RELATIONSHIP MODEL OF EXTREME PRECIPITATION IN FLOOD RISK ASSESSMENT IN THE UPPER VISTULA BASIN

I. Markiewicz

The Upper Vistula Basin is a flood-prone region in the summer season (May–October) due to intensive rainfall. From the point of view of water management, it is particularly important to assess the variability in this main factor of flood risk, as well as to establish the depth-duration-frequency (DDF) relationship for maximum precipitation, this having not yet been derived for the region. The research concerns the series of daily precipitation during the summer half-year from the period 1951–2018 collected by 11 meteorological stations (Fig. 1).

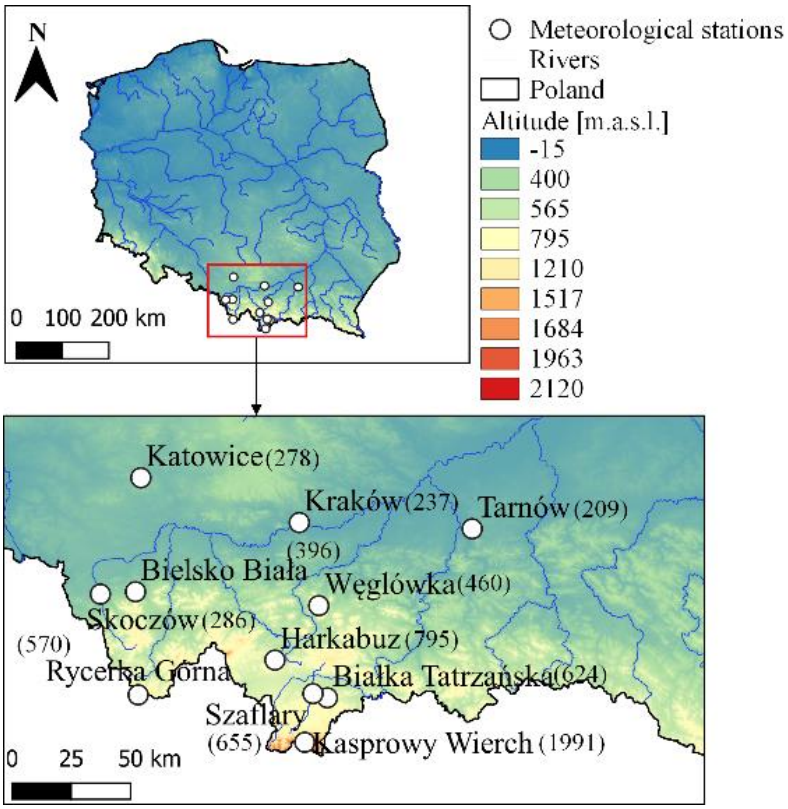


Fig. 1. Location of the 11 analyzed meteorological stations along with their altitudes (after Markiewicz 2021).

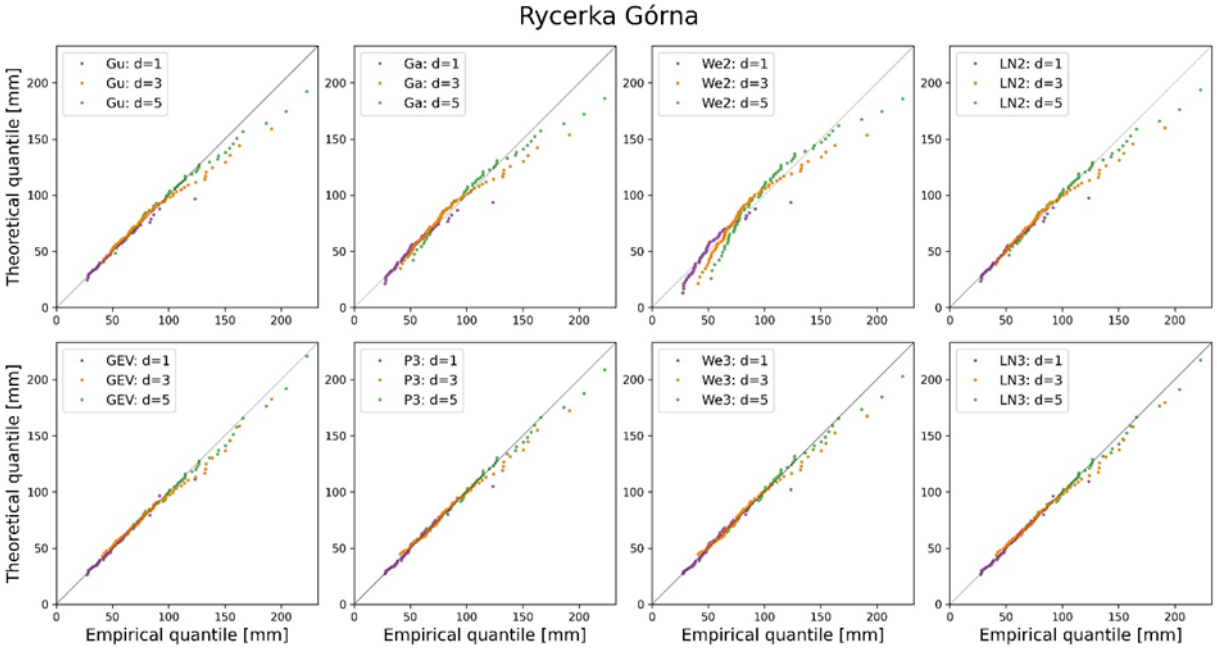


Fig. 2. Q–Q plot of the theoretical and empirical quantiles of the observation series for summer (May–October) maximum precipitation of adequate durations for Rycerka Górna station (after Markiewicz 2021).

An example Q–Q plot of the theoretical and empirical quantiles of maximum precipitation of various durations is shown in Fig. 2 for the Rycerka Górna station. In general, the three-parameter distributions show a better fit to the seasonal (May–October) maximum precipitation in the Upper Vistula Basin than their two-parameter counterparts.

The analysis showed the series' stationarity, which supports the conclusion that there is no increase in the risk of rainfall floods due to the intensification of extreme precipitation. A new approach is proposed for the determination of the DDF relationship, where the best-fitted distribution for each station is selected from among the set of candidate distributions, instead of adopting one fixed distribution for all stations. This approach increases the accuracy of the DDF relationships for individual stations as compared to the commonly used approach. In particular, the traditionally used Gumbel distribution turns out to be not well fitted to the investigated data series, and the advantage of the recently popular GEV distribution is not significant.

EVALUATION OF INDOOR/OUTDOOR URBAN AIR POLLUTION BY MAGNETIC PARAMETERS

M. Teisseyre-Jeleńska, T. Werner, M. Kądziałko-Hofmokl, G. Karasiński

The comparison of outdoor and indoor air pollution was carried out by means of magnetic characteristics of dust gathered outdoors and indoors on air filters. Outdoor dust (particulate matter smaller than 10 μm PM10) was collected by means of PM sampler placed at the yard of the building of the Institute of Geophysics, Polish Academy of Sciences (IG PAS) (Fig. 1a,b). Indoor dust samples were collected with the same type of PM sampler placed inside this building. The magnetic methods were applied for the estimation of concentration and magnetic mineralogy of magnetic particles present in PM. We are especially interested in the evaluation of magnetite content in PM for environmental and health-related purposes. Magnetic measurements such as low and high-temperature dependence of volume magnetic susceptibility $\kappa(T)$, hysteresis parameters, and frequency dependence of mass magnetic susceptibility χfd, showed that

outdoor and indoor PM contained fine-grained magnetite-like minerals with significant contribution of superparamagnetic particles (Fig. 1c,e). This pointed to the common outdoor sources of pollution intruding inside the building through windows, ventilation systems, and partly carried on dresses by people. Mass of PM10 collected outdoors is of the same range as the mass of PM10 from inside the building. The mass susceptibility of indoor filters is about 1/3 of the mass susceptibility of outdoor filters (Fig. 1d). The relationship between volume susceptibility and mass showed a relatively homogenous composition of indoor dust but a varying composition of outdoor dust, with a chaotic significant inflow of nonmagnetic exogenous particles.

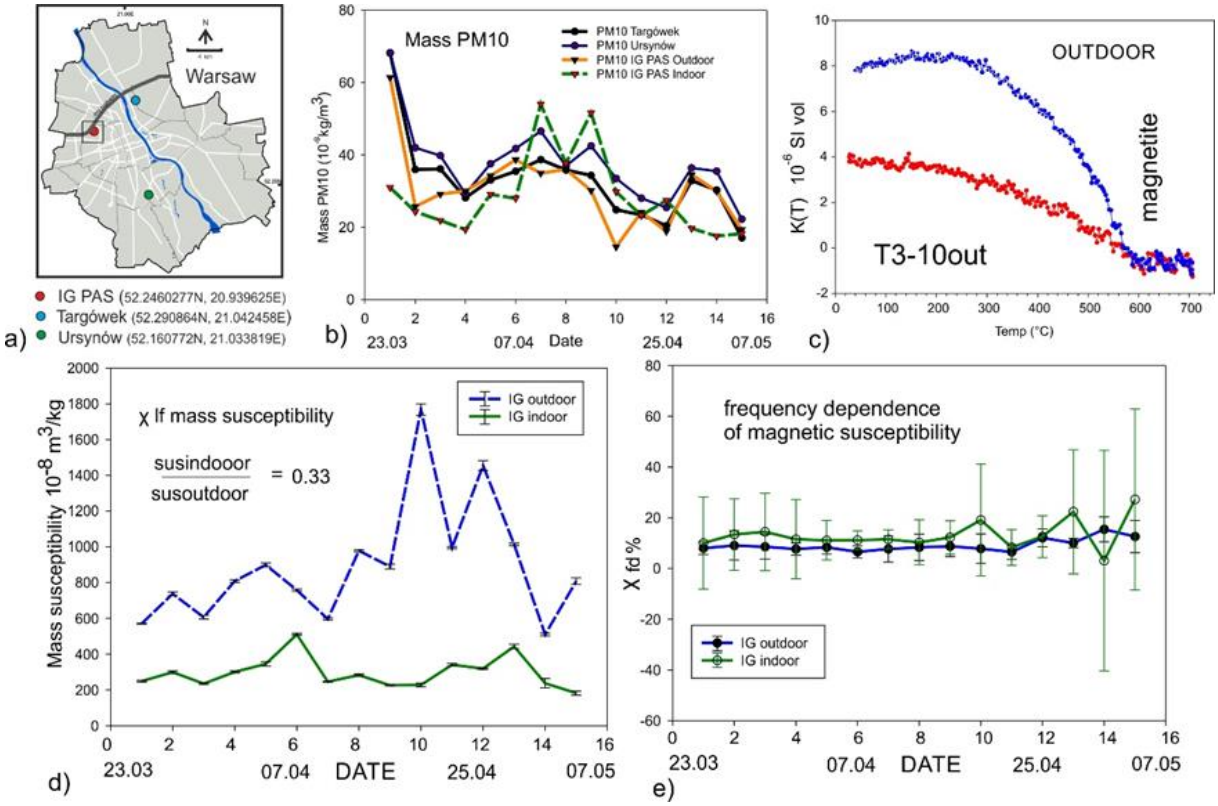


Fig. 1. Results of mass and magnetic susceptibility for PM10 dust at IG PAS location: a) locations, two reference PM stations marked, b) PM mass data compared, c) the changes of magnetic susceptibility upon heating, d) comparison of susceptibility for indoor and outdoor PM, and e) the parameter of frequency dependent susceptibility for both locations (modified from Jeleńska et al. 2022).

References

Jeleńska, M., T. Werner, M. Kądziałko-Hofmokl, and G. Karasiński (2022), Evaluation of indoor/outdoor urban air pollution by magnetic parameters; preliminary study, *J. Appl. Geophys*. **206**, 104804, DOI: 10.1016/j.jappgeo.2022.104804.

INTEGRATED GEOPHYSICAL IMAGING OF A MOUNTAIN LANDSLIDE

A. Marciniak, M. Majdański, A. Górszczyk, W. Gajek, B. Owoc

Landslides are one of the largest geohazards for modern society. They are particularly dangerous in mountainous areas, where progressing urbanization necessitates the transformation of potentially endangered areas for housing and public use. It is also a fact that progressing climate change and global warming manifested by a shortened winter period, increased rainfall, and general hydrogeological changes are not without impact on landslides.

Fig. 1. The deploying of seismic line, with dense 1 m geophone spacing. The three component Omnirecs Stations allowed for gathering high-resolution geophysical data, which in near future deliver information about the evolution of the landslide in the Cisiec study site. The measurements conducted in October 2021, were part of long term research, aimed to investigate anthropogenic as well as climatic factors triggering the high mountain landslides development and evolution. The project is realized in cooperation with the Faculty of the Geology of the University of Warsaw and the Faculty of Natural Sciences of the University of Silesia as well as the Department of Magnetism of IG PAS (photo by Mariusz Majdański).

In the project realized in the Department of Geophysical Imaging and project founded by NCN grant Preludium 19 received by Artur Marciniak, the use of multiple geophysical imaging methods to observe and explain landslide triggering and evolution processes is ongoing. In 2021, the first of two main data acquisition series was conducted with very dense seismic, resistivity, and magnetic data gatherings (Fig. 1). During the three day long fieldworks, 500 m long seismic profile, six 500 m electrical lines, and magnetic measurements were conducted. Such intense studies in a time-lapse manner will provide unique information about the time evolution of the subsurface. Different research methods will be jointly interpreted in a developed in the institute processing scheme using additional uncertainty analysis. This will allow getting more accurate and well-connected results. In 2022, the next series of measurements with additional borehole cored drilling will be conducted to obtain even more precise information about soil movement. The preliminary results from study of field recognition datasets can be found in the publication by Marciniak et al. (2021).

Reference

Marciniak, A., S. Kowalczyk, T. Gontar, B. Owoc, A. Nawrot, B. Luks, J. Cader, and M. Majdański (2021), Integrated geophysical imaging of a mountain landslide – A case study from the Outer Carpathians, Poland, *J. Appl. Geophys*. **191**, 104364, DOI: 10.1016/j.jappgeo.2021.104364.

DISPERSIVE SEISMIC WAVES IN A COAL SEAM AROUND THE ROADWAY IN THE PRESENCE OF EXCAVATION DAMAGED ZONE

R. Czarny, M. Malinowski, M. Chamarczuk

Excavation damaged zone (EDZ) is a fractured rock mass in the vicinity of the roadway. Knowing its elastic properties, such as seismic velocity, is crucial for the safety of underground min-

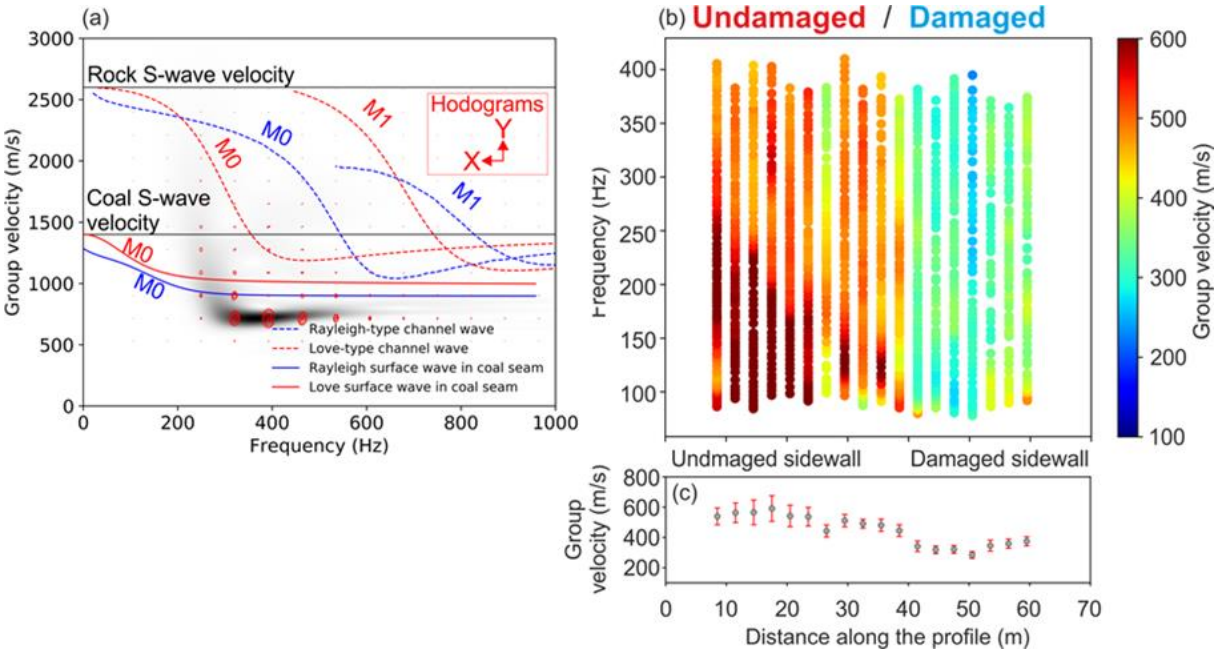


Fig. 1: (a) Modelling results for the model including cylindrically shaped roadway and the EDZ in group velocity-frequency domains. Blue and red dashed lines indicate theoretical dispersion curves of Rayleigh- and Love-type channel waves, respectively. Blue and red solid lines are the theoretical dispersion curve of Rayleigh and Love surface waves. The thin red line is the particle motion (hodogram) in a 2-D plane (X and Y); (b) dispersion curves of a roadway mode through the seismic profile for 21 m offset together with (c) average group velocities and their standard deviations computed for corresponding curves (after Czarny et al. 2021).

ing. However, the seismic wavefield's complexity due to the low-velocity layer (e.g., a coal seam) makes it difficult to obtain reliable velocity estimates.

In 2021 we studied the influence of a roadway and EDZ on the seismic wavefield propagation inside the coal seam along the roadway close to the sidewall based on numerical simulation (Fig. 1a) and in-seam seismic measurements (Fig. 1b). We focused on dispersive waves due to their dominant energetic contribution and, hence, application potential. We observed a strong so-called roadway mode wave. Polarization analysis on synthetic data shows that such a mode in a horizontal plane in the center of the coal seam is the mix of Love-type channel and Rayleigh surface tunnel waves (Fig. 1a). Moreover, the EDZ causes a significant decrease of the group velocity, which turns out to be even lower than the lowest group velocity of the surface tunnel waves which travel solely in a coal seam. We also observe that the roadway mode with the presence of the EDZ is less dispersive, which can be useful with imaging the EDZ by those modes. Those roadway mode features were confirmed by the real seismic data from an underground experiment in the Rydułtowy coal mine in Poland (Fig. 1b). The rock mass deformation in the vicinity of the roadway strongly correlates with the roadway mode dispersion characteristic. Our study shows the great potential of using roadway mode in imaging and monitoring of underground excavations in the presence of a low-velocity layer.

Reference

Czarny, R., M. Malinowski, M. Chamarczuk, M. Ćwiękała, S. Olechowski, Z. Isakow, and P. Sieradzki (2021), Dispersive seismic waves in a coal seam around the roadway in the presence of excavation damaged zone, *Int. J. Rock Mech. Min. Sci*. **148**, 104937, DOI: 10.1016/j.ijrmms.2021.104937.

RESERVOIR TRIGGERED SEISMICITY RESEARCH

G. Lizurek, J. Wiszniowski, I. Nowaczyńska, A. Tymińska, B. Plesiewicz

Description: We investigated the impact of a gap in reservoir filling during maintenance operations and the effect of seasonal water level changes after refilling on seismicity and the associated hazard in Song Tranh 2 reservoir vicinity (Fig. 1). It is a reservoir in central Vietnam with a maximum water level of 35 m. Seismic activity in the area of the reservoir began in 2011, shortly after it was filled. Previously, this part of Vietnam was considered nearly aseismic. We found that the one-year pause in reservoir filling is characterized by nearly twice as much seismic activity and a significantly higher seismic hazard determined during this period for magnitude 3.5 and above compared to the time before the reservoir was emptied and after it was refilled. We have shown a seasonality of seismic activity in the latter period (2013–2016), which is related to water changes during the dry season, when water is released from the reservoir after reaching maximum filling, and the wet season, when water is collected during the period of increased rainfall. Related to this is also a significant difference in the seismic hazard. In the dry season, a tremor of magnitude 3.5 or stronger is almost three times more likely to occur than in the rainy season. We inferred that the main factor influencing seismicity triggering is the change in pore pressure associated with changes in water levels during the year. Another research in this field was related with developing automatic detection algorithm using artificial neural network for weak seismicity observed in the area of a Lai Chau reservoir in the Northern Vietnam. The results of this work show that the artificial neural network can detect both natural and reservoir – induced seismic events and the Single Layer Recurrent Neural Network (SLRNN) can detect new induced seismic events. We also found that retraining improves precision without loss of sensitivity and only a few hundred examples are needed to effectively train the detection. It proves that compared to deep learning algorithms, fewer examples were needed to train the SLRNN.

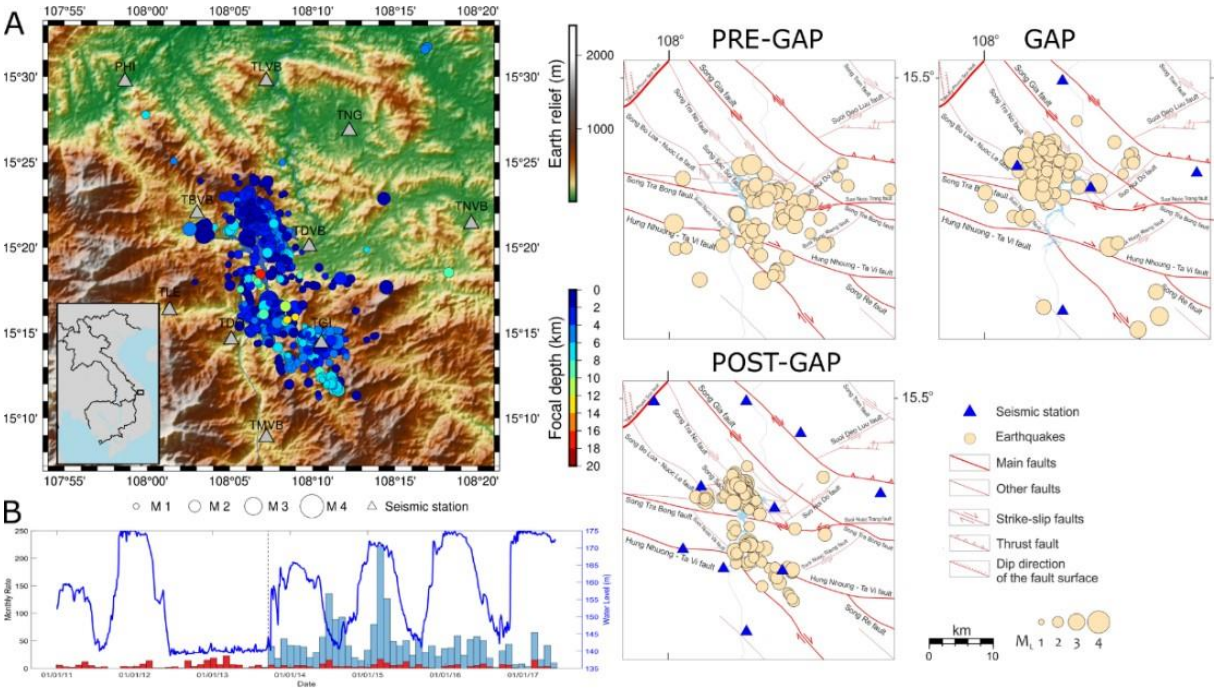


Fig. 1. Seismic activity and its relation to water level and local discontinuities in Song Tranh 2 reservoir vicinity (after Lizurek et al. 2021).

2.2 Geosystem processes

MAGNETIC SUSCEPTIBILITY VARIATIONS IN LOWER PALEOZOIC SHALES OF THE WESTERN BALTIC BASIN (NORTHERN POLAND) – A TOOL FOR REGIONAL STRATIGRAPHIC CORRELATIONS AND THE DECODING OF PALEOENVIRONMENTAL CHANGES

D.K. Niezabitowska, J. Roszkowska-Remin, R. Szaniawski, A. Derkowski

Deciphering lithostratigraphic features or petrophysical parameters of marine sediments requires applying comprehensive logging methods. One of commonly used, magnetic susceptibility (MS) core logging, will be presented in this paper and considered as a tool useful when identifying paleoenvironment and potentially high organic matter content. Combining together magnetic methods, Rock-Eval pyrolysis data, and the results of natural gamma-ray wire-line logging allowed to define the relationship between them. The MS logging was performed on six drill cores from exploration boreholes in lower Paleozoic shales from the Baltic Basin, northern Poland. The examined intervals, approximately 200-m-long each one, constitutes rocks with variable organic matter content. The samples for the laboratory measurements purposes were collected from depths greater than 3,500 m from two drill cores.

The obtained results indicate that throughout the analyzed profiles MS has a positive correlation with bioturbation and oxygen indices (BI and OI), whereas a negative with total organic carbon (TOC). This observation suggests that the redox conditions on the seabed determined MS values during early diagenesis of the examined marine sediments. Other important finding was a strong dependence between MS variations and percentage amount of ferroan chlorite (Fig. 1). Due to thermal history of analyzed rocks, buried above 80°C, it could be assumed that chlorite has likely diagenetic origin. However, as the amount of chlorite does not increase with depth, we suggest that the amount of chlorite precursors (modified during burial to Fe-chlorite) was defined on the early stage of rock formation, during the deposition of sediments.

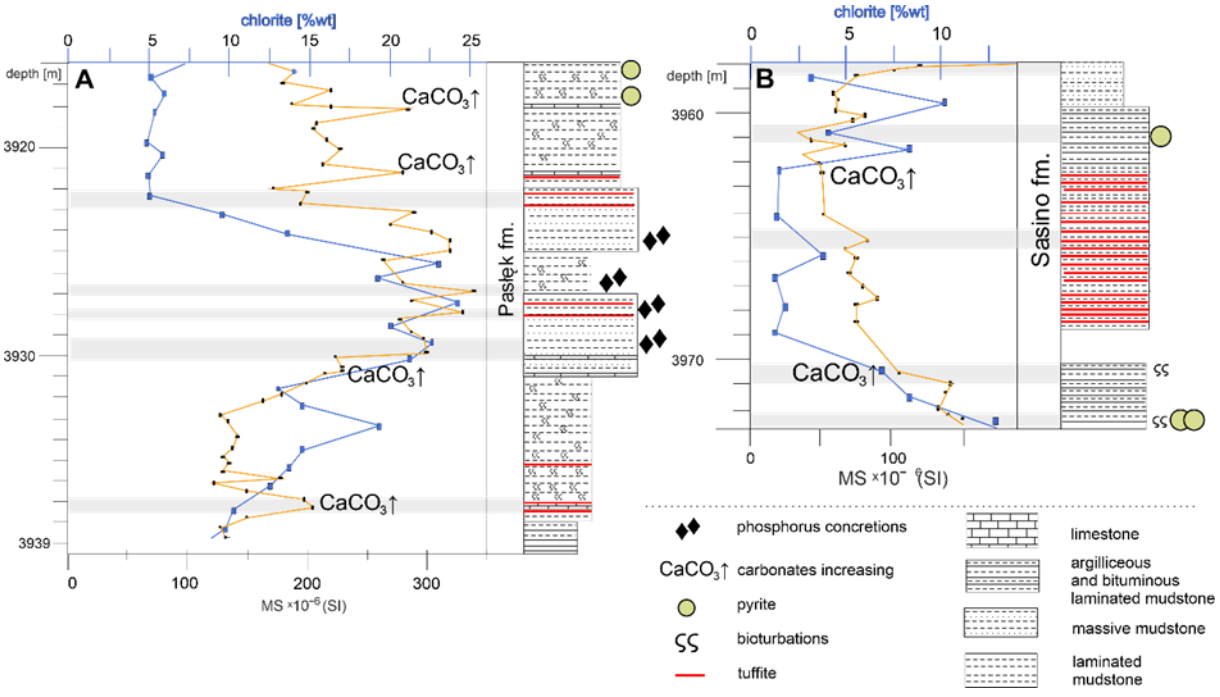


Fig. 1. A comparison between MS (orange line) and the chlorite content (blue line) through a lithological profile of drill core F for selected formations: the Pasłęk (A) and the Sasino (B). In gray, the anomalies of MS are marked (after Niezabitowska et al. 2021).

REEVALUATION OF TOTAL COLUMN OZONE MEASUREMENTS BY THE DOBSON SPECTROPHOTOMETER AT BELSK (POLAND) FOR THE PERIOD 1963–2020

J.W. Krzyścin

Monitoring of total column amount of ozone (TCO3) and its vertical profile started at COG IG PAS at Belsk (51.84°N, 20.78°E) on 23 March 1963. The monitoring has been continuing up to now using the same instrument, a Dobson spectrophotometer No. 84. In Europe, there are only two stations with longer time series, including Arosa (since 1926) and Hradec Kralove (since 1961). TCO3 observations at Belsk were carried out regardless of the weather conditions, excluding only the days with continuous rain or snow fall.

In total, ~120 000 intra-day manual observations have been taken up to 31 December 2020. These observations were made for various combinations of the instrument settings, including double wavelength pairs in UV range (AD, CD) and the observation category, i.e., direct Sun, zenith blue, and zenith cloudy. The optimal setting of the instrument was selected in order to obtain the highest possible accuracy of the TCO3 measurement in given weather conditions Direct Sun & AD observation has the highest accuracy, whereas zenith cloudy & CD observation has the lowest accuracy (which usually occurs in late autumn and winter).

Krzyścin et al. (2021a) proposed the homogenization procedure applied to all intra-day TCO3 observations to account for: less accurate Dobson observations under low solar elevation, presence of clouds, instrument's stray light, and sensitivity of the ozone absorption on temperature. For the first time, a statistical analysis of the short-term TCO3 variability (with the time scales up to 24 h) from the Dobson observations was presented (Krzyścin et al. 2021b). Usually, long-term TCO3 analyses are made based on the monthly TCO3 data. Our results showed that the short-term TCO3 variability changed only slightly (if ever) since the beginning of the ozone observations at Belsk. Expected more intense day-to-day TCO3 variability due to recent climate changes (as it was observed in various weather phenomena) has not been identified. Figure 1a illustrates that the long-term variability of TCO3 at Belsk is consistent with that inferred for this location from the satellite (SBUV) and reanalyzed (MERRA-2, MSR-2) data. The annual means of TCO3 at Belsk performed differently comparing to the corresponding 45–55°N zonal means. TCO3 at Belsk has been steadily declining relative to the mid-latitudinal ozone since around 1980 (Fig. 1b).

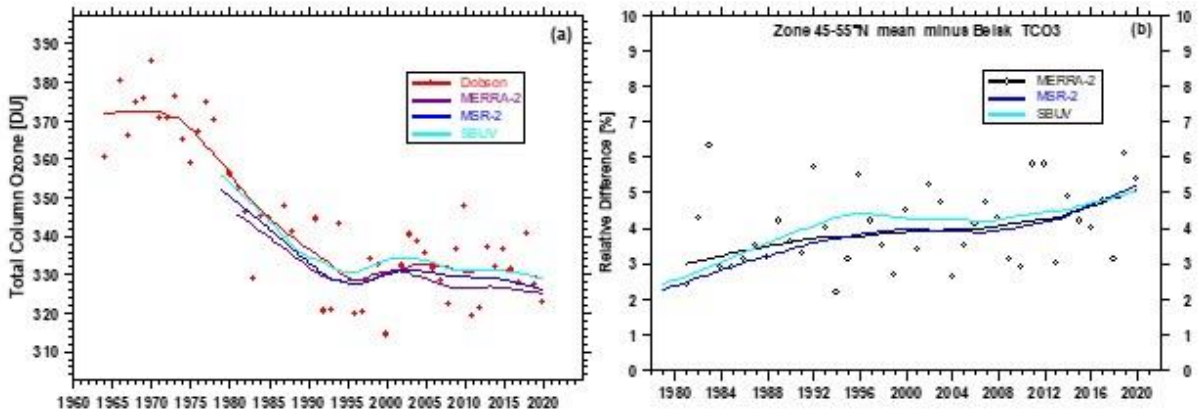


Fig. 1: (a) Yearly means of TCO3 at Belsk (red circles) and their smoothed pattern (red curve) superposed on the smoothed satellite (SBUV) and reanalysis (MSR-2 and MERRA-2) data, (b) smoothed relative differences between annual means of TCO3 for the 45-55°N zone and Belsk (as a percentage of the Belsk's TCO3).

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EFFECTS OF SOLAR WIND CONDITIONS ON GROUND-LEVEL ATMOSPHERIC ELECTRICITY

S. Michnowski, A. Odzimek, N. Kleimenova, O. Kozyreva, M. Kubicki, Z. Klos, S. Israelsson, N. Nikiforova, J. Tacza, E. Tueros, J.-P. Raulin, M. Kubicki, G. Fernandez, A. Marun

Solar wind affects the atmospheric electricity at ground level due to the coupling with the Earth's magnetosphere and ionosphere, which manifests itself the strongest during substorms and geomagnetic storms. Recently we have reviewed results of research at the Institute of Geophysics PAS made in collaboration with the Schmidt Institute of the Physics of the Earth RAS, and revised analyses of individual cases from years 1989–2006 of such effects in fair-weather atmospheric electric field (or the electric potential gradient, PG) continuously measured at Stanisław Siedlecki Polish Polar Station in Hornsund, Spitsbergen (77.00°N, 10 m a.s.l.) and at Stanisław Kalinowski Geophysical Observatory in Świder (52.12°N, 100 m a.s.l.). In the high-latitude Hornsund, the main characteristic disturbances have been identified as resulting from the ionospheric convection having diurnal dependency with irregular enhancements and the activity of field-aligned currents of Region 1, especially during morning substorms, and the Region 0/NBZ currents associated with northward Bz at MLT noon (Fig. 1). The observed decreases of the field at Świder have been only associated with main phases of magnetic storms, but except of the associated effects of Forbush decreases, changes on shorter time scales are still not well explained.

We have also calculated the average diurnal variation of the fair weather electric field in Hornsund and Świder in years 2004–2011 at both quiet and magnetically disturbed periods. The above-mentioned disturbances at Hornsund can be identified in the mean curve corresponding to the disturbed conditions, however, the interpretation of these statistical variations have been possible at present due to the many case studies performed in the past – as there is large variability of solar wind parameters and local atmospheric conditions. The field fluctuations in Hornsund under all conditions are very high. However, the average daily curve of the field changes under quiet conditions has a surprising consistency with the representative curve of global changes of the Earth's electrical activity, the so-called Carnegie curve. Other, local conditions affect the diurnal curve at Świder, and space weather effects are not so evident. The conclusions have been published in *Surveys in Geophysics* (Michnowski et al. 2021).

Latest investigations, made possible due to a fellowship funded by NAWA, and a collaboration with the Mackenzie Presbyterian University in Sao Paulo, Brazil, and Complejo Astronomico El Leoncito in San Juan, Argentina, concern the effects of Solar Proton Events (SPEs) and modulations of cosmic rays, on the ground-level atmospheric electricity at two stations: mountain station CASLEO in Argentina (31.78°S, 2550 m a.s.l.), and at Świder. Statistical analysis of effects of energetic SPEs (>100 MeV) and intense Forbush decreases (FD) or Ground Level Enhancements (GLE) of cosmic rays with superposed epochs technique revealed

potential gradient deviations at Casleo, and no statistically significant effects at Świder. At Casleo an increase of the PG after a strong SPE is similar to those observed in the past at other high-altitude sites, and probably resulting from global effects after modulation of the atmospheric conductivity. A decrease of the PG at Casleo in GLE events was interpreted as resulting from the increase of the conductivity at the ground level. These recent results have been submitted to *Space Weather* (Tacza et al. 2022).

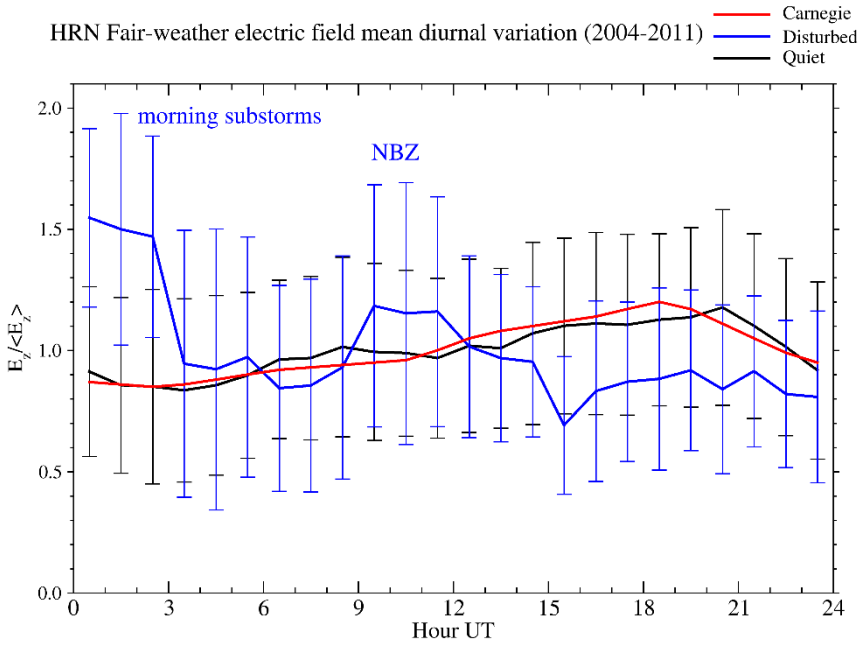

Fig. 1. Mean diurnal variation of the fair weather atmospheric electric field at Hornsund station 2004-2011 at quiet (station's K-index = 0-1) and disturbed conditions (K-index = 4-9), and compared with the Carnegie curve. Points at each hour represent reduced median values divided by the mean median. Error bars indicate the interquartile range. Recognised effects of morning substorms and the NBZ currents present in the disturbed curve are indicated by text labels (after Michnowski et al. 2021).

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COMPLEXITY OF MATERIAL FAILURE DURING STRETCHING REVEALS LIMITATIONS OF THE FIBER BUNDLE MODEL

W. Dębski

It has recently been reported that the equal load sharing Fiber Bundle Model (FBM) predicts that the rate of change of the elastic energy stored in the bundle reaches its maximum before catastrophic failure occurs, making it a possible predictor for imminent collapse. However, the equal load sharing Fiber Bundle Model does not contain central mechanisms that often play an

important role in failure processes such as localization. Thus, there is an obvious question whether a similar phenomenon is observed in more realistic systems. This question has been addressed using the Discrete Element Method (DEM) to simulate breaking of a thin tissue subjected to a stretching load. Our simulations have confirmed (Dębski et al. 2021) that for a class of virtual materials which respond to stretching with a well-pronounced peak in force, its derivative and elastic energy, we always observe an existence of the maximum of the elastic energy change rate prior to maximum loading force. However, some significant discrepancies between FBM and DEM predictions have been observed. The most significant one concerns the change of elastic energy stored in the bundle or DEM sample with stretching of the material. The FBM model always predict fast and monotonic decrease of elastic energy. The DEM simulations also predicts such a behavior, but in particular cases one can observe much more complex evolution pattern of the elastic energy. We have studied this issue in details, performing another set of DEM simulations to answer the question how the loading velocity influences the breaking process. The obtained preliminary results, shown in Fig. 1, are surprising and cast a new light on the dynamics of the fragmentation process. Besides that, the performed simulations have clarified the limitations of the FBM approach – the method applies mostly in case of fast rupturing processes when the localization process does not enter into a game.

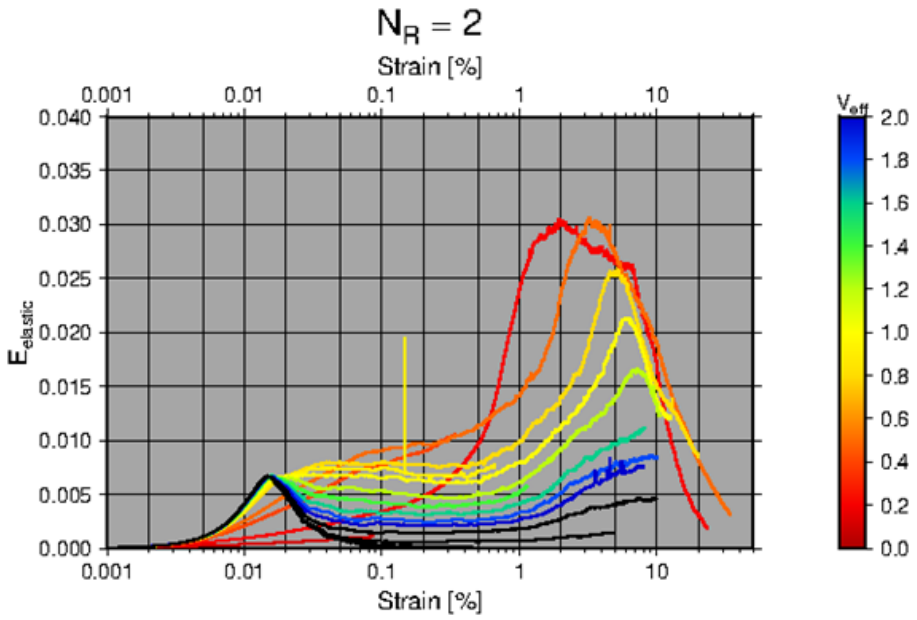

Fig. 1. Variation of elastic energy stored in the DEM sample with samples extension for a range of stretching speed V_{eff}.

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DEM MODELLING AND ITS PRACTICAL APPLICATIONS

P. Klejment

Discrete Element Method (DEM) was employed to examine in a noninvasive manner the mechanical strength of industrial sandstones (Klejment et al. 2021). Modelling of a fragmentation

of the considered sandstones under compressional regime was a source of knowledge about energy storage inside the material and energy release, as well as appearance of fractures inside the matter and final sandstone fragmentation into crumbs (Fig. 1). DEM simulations were also applied to test how sandstones react against various mechanical external factors, such as breaking, compressional and abrasion forces or impact by external objects and vibrations. The impact resistance experiment showed that scaled number of fractures as a function of sample thickness was almost constant and independent of sample thickness, but the number of fractures was inversely dependent on uniaxial compressive strength.

DEM simulations generate huge amounts of data, and involve numerous independent parameters. Supervised machine learning was employed to look for dependencies in DEM huge result datasets (Klejment 2021). Multiple Linear Regression and Random Forest were applied to the results of more than 6000 DEM simulations of uniaxial compression tests. Accuracy of over 99% give good hope for finding a universal relation between input and output parameters (for a specific DEM implementation) and reducing the number of simulations required for the calibration procedure. Lack of effective method for selecting appropriate input parameters so that simulations can accurately reproduce the behaviour of real systems is still a major barrier to the effective use of DEM in a larger scale. It has been also proven that calibration of certain parameters can be done on smaller samples, where the critical threshold is around 30% of the radius of the original model.

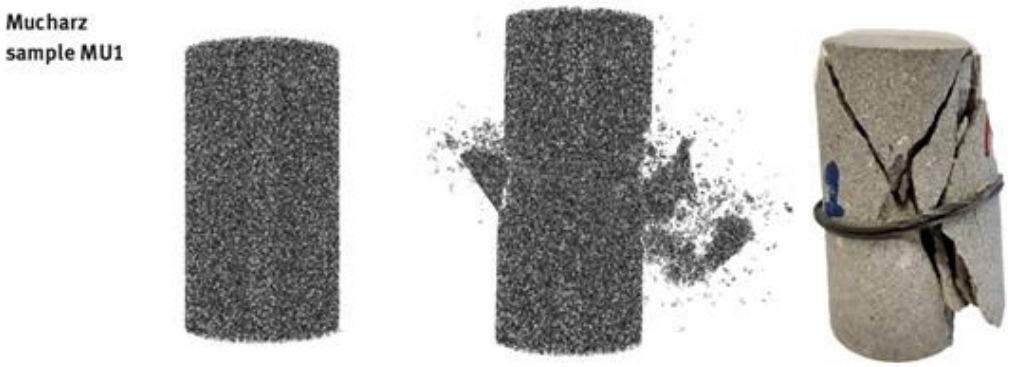

Fig. 1. Comparison of failure patterns in DEM modeling and in laboratory (after Klejment et al. 2021).

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DISCRETE STOCHASTIC MODEL OF P-ORDER PERSISTENT TIME SERIES AND PROCEDURE OF ITS RECONSTRUCTION

Z. Czechowski

Long memory in time series is a still rapidly growing field of theoretical and applied research. In the Langevin equation driven by the fractional Brownian motion, the memory is described by one parameter – the Hurst exponent. This approach works very well for long-range correlated processes which behave regularly. It should be underlined that due to the fractional calculus the whole history of previous states was taken into account in fractional models. However,

in many natural time series this feature may not be proper because their memory can be long but limited to a shorter range. Moreover, it may be dependent on different patterns of previous increments. For these cases we propose the discrete Langevin-type equation that enables modeling *p*-order persistent processes (Czechowski 2021). In general this model requires 2*p* persistence parameters. Our approach corresponds to neural networks, in which the system recognizes a pattern of previous states and proposes the next step. For applications, a good stochastic model of time series should be supplemented with the procedure of reconstruction of the equation from time series. Such a procedure is proposed and successfully tested on artificial (simulated) time series generated by the modified Langevin equation with a few forms of drift and diffusion terms and with different *p*-order persistence. Our method was applied to a natural time series of daily mean river discharge data (Dusseldorf 1900–2016) giving credible stochastic model of the process. Knowledge of the stochastic model is important for physical interpretation of the analyzed phenomenon. The approach can offer a new tool for modeling other geophysical time series in which persistence is the essential feature of interest.

It is worthwhile to recall that stochastic models of the Langevin-type are also commonly used to the description and predictability of financial and economic processes, so our extension of this tool for processes with different forms of persistence will be very useful in that field.

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VEGETATION DYNAMICS IN OPEN CHANNEL FLOWS

M. Nones

The knowledge of the hydro-morphological evolution of lowland rivers is essential to developing integrated river management plans. Satellite data can provide continuous and efficient means to monitor both fluvial geomorphological changes and vegetation dynamics at various spatiotemporal scales. The work was focused on developing automatic classification and extraction methods to analyze the evolution of a 40 km reach of the Italian Po River from 1986 to 2020. Public domain multispectral satellite data acquired by Landsat 4-5-TM, Landsat-8-OLI, and Sentinel-2-MSI were processed to extract the wet-channel and its variations over time, as well as the dynamics of the riparian vegetation (Fig. 1). This was done via open-source software like Google Earth Engine and QGis. Very high-resolution GeoEye-01 and WorldView-02 images were also employed for validating the classification method. The overall accuracy, obtained by multitemporal controls with very high-resolution images, was always greater than 0.90 for all the missions, showing that the classification accuracy remains consistent through time. Combining satellite data with hydrological measurements permitted monitoring the river at the reach scale and investigating the effects of river restoration works.

Downscaling the analysis from the reach scale to the segment and section scale, additional phenomena can be studied. Using the lowland Świder River as a case study, the effect of vegetated patches on local hydrodynamics was evaluated. The conditional quadrant analysis was modified and applied to the data from experiments performed downstream of two patches of submerged aquatic vegetation to study turbulence structures propagating from the mixing layer formed at the interface between the vegetation canopy and flow above. These structures were responsible for the majority of momentum transport and tended to vary in strength, length, and frequency with patch distance, height and plant physical characteristics. Two kinds of organized motions were identified as dominating: strong sweep motions, which carried water flow into

the low-velocity region below the vegetation height; strong ejections, which pushed flow towards the water surface. The study has shown how the observed changes in ejection and sweeps distribution reflect the model where vegetation canopy-induced vortices transform into the dual-head hairpin vortices downstream of the plant.

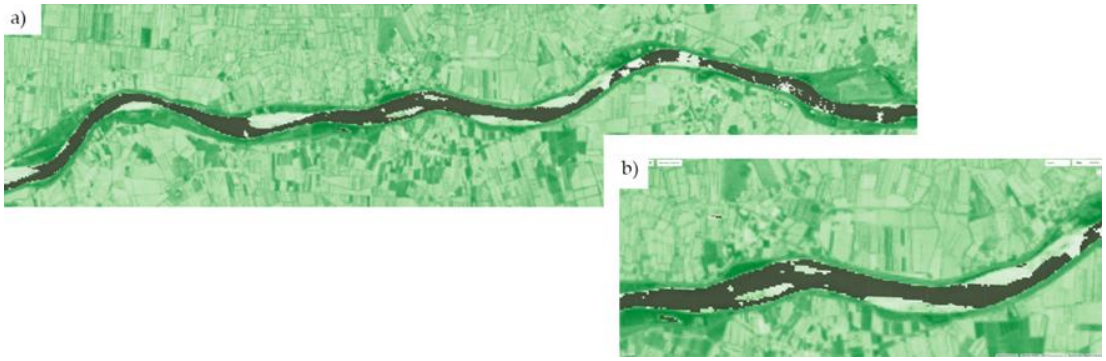

Fig. 1. Median NDVI (Normalized Difference Vegetation Index) for the period 1988–2018, in: a) the whole reach, and b) the central part, computed via Google Earth Engine.

SPATIAL AND TEMPORAL MULTIPLET ANALYSIS FOR IDENTIFICATION OF DOMINANT FLUID MIGRATION PATH AT THE GEYSERS GEOTHERMAL FIELD, CALIFORNIA

M. Staszek, Ł. Rudziński

Description: Multiplet analysis is based on the identification of seismic events with very similar waveforms which are used then to enhance seismological analysis, e.g., by precise relocation

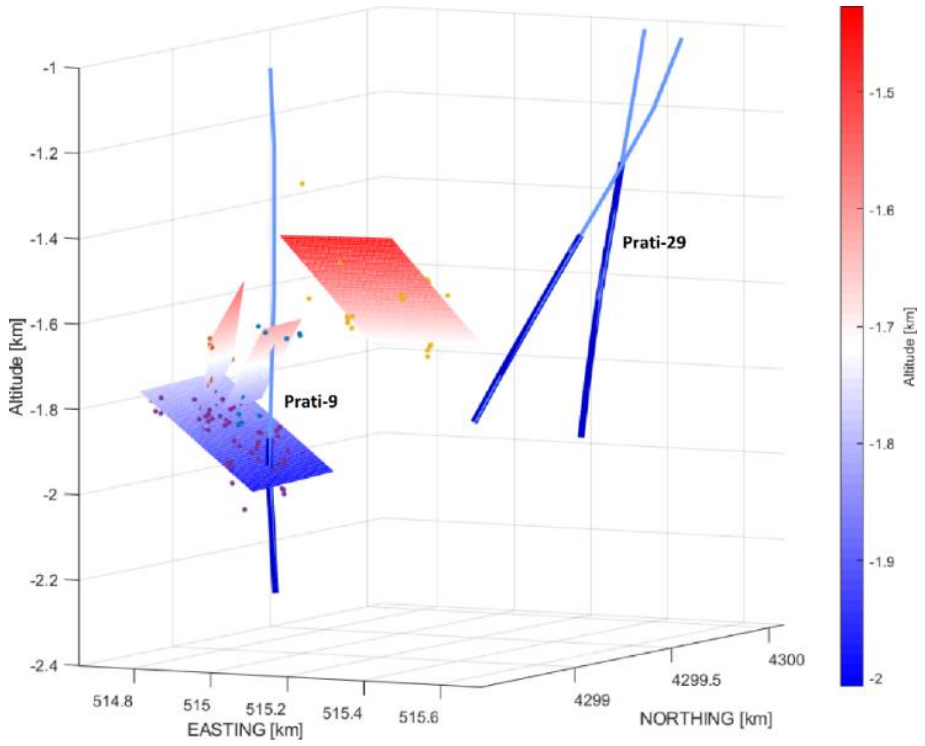

Fig. 1. Orientation of planes best fitted to ME from groups: A (blue dots), B (orange dots), C (yellow dots), and D (violet dots). Trajectories of injection wells are plotted with blue, open-hole sections with dark blue. The coloring of planes reflects the altitude (after Staszek et al. 2021).

of sources. In underground fluid injection conditions, it is a tool frequently used for imaging of subsurface fracture system. We identify over 150 repeatedly activated seismic sources within seismicity cluster induced by fluid injection in NW part of The Geysers geothermal field (California). Majority of multiple events (ME) occur along N-S oriented planar structure which we interpret as a fault plane (ME group D, Fig. 1).

Remaining ME are distributed along structures interpreted as fractures, forming together a system of interconnected cracks enabling fluid migration (ME groups A, B, and C, Fig. 1). Temporal analysis reveals that during periods of relatively low fluid injection the proportion of ME to non-multiple events is higher than during periods of high injection. Moreover, ME which occur within the fault differ in activity rate and source properties from ME designating the fractures and non-multiple events. In this study we utilize observed differences between ME occurring within various structures and non-multiple events to describe hydraulic conditions within the reservoir. We show that spatial and temporal analysis of multiplets can be used for identification and characterization of dominant fluid migration paths.

2.3 Earth structure and georesources

3D IMAGING OF THE ELECTRICAL RESISTIVITY OF THE LITHOSPHERE IN POLAND

W. Jóźwiak, K. Nowożyński, S. Mazur

An exceptionally large and complex three-dimensional model of the resistivity distribution in the lithosphere in Poland has been developed by inverting the data from 593 points collected over the past 50 years (Fig. 1). For the data from the last 30 years (268 points) it was possible to calculate the full impedance tensor (Z) and the geomagnetic vertical transfer function (VTF) for the periods in the range of 5 to 10 000 s. Moreover, older historical data was verified and partially processed. For these data, the VTF for 325 points was calculated over a limited range

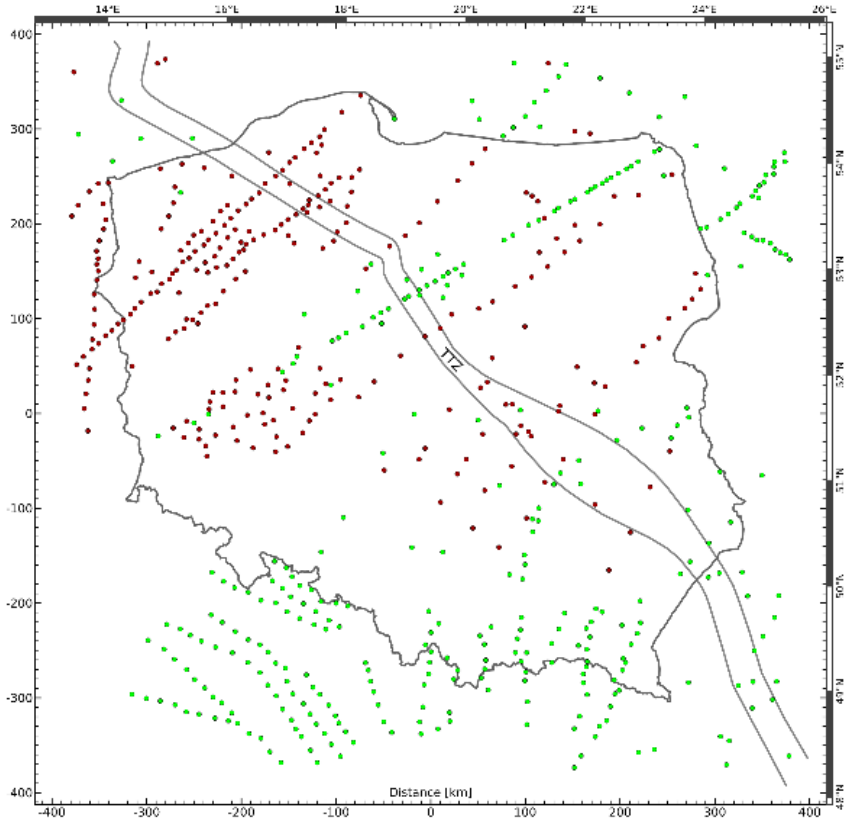

Fig. 1. Locations of measurement points (magnetotelluric – red, magnetovariation – green).

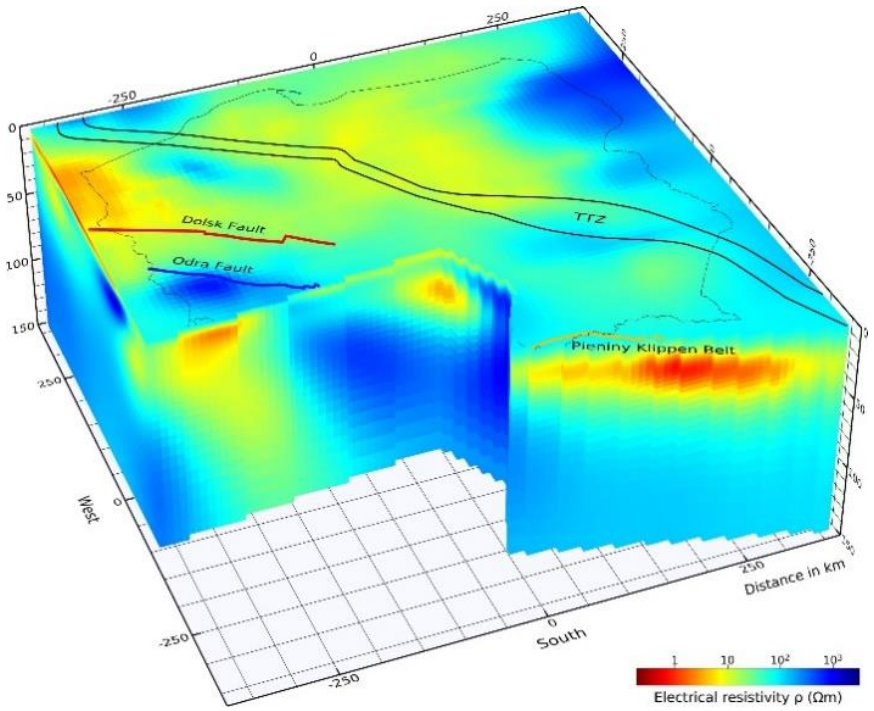

Fig. 2. Model of resistivity distribution in the lithosphere.

of periods. The ModEM code was used to invert the data and obtain a conductivity distribution model. The full size of the grid with edges was 3000 by 3000 kilometers and 600 kilometers in the vertical direction, and the modeling field was digitized with 104×104×52 cells (+10 air) in geographic orientations. Many attempts have been made to select the best parameters for modelling, such as the initial model and the covariance matrix. As a result, a three-dimensional model of resistivity distribution in the crust and upper mantle was developed (Fig. 2).

In shallow layers, the model corresponds to a morphology of the sedimentary cover. In the east, the area of the non-conductive East European Platform is clearly marked. The slope of the platform and the increasing thickness of the sedimentary layer towards the west are visible. In the Paleozoic platform, the depth of the basement is much greater, which is reflected in the conductivity distribution, and high conductivity values are observed there at greater depths. The conductivity image clearly shows the less conductive areas, corresponding to the Central Polish anticlinorium and the Fore-Sudetic monocline. Shallow non-conductive complexes are visible under the Sudetes and Holy Cross Mountains. At slightly greater depths (7–10 km), the conductive Lublin basin is clearly visible. Below, the presence of deep and extensive conductive anomalies in the earth's crust is revealed, the pattern of which reflects past tectonic processes. The distribution of these resistivity anomalies is presumably due to the early Permian continental rifting. The latter resulted in a thinning of the lithosphere in the south-west direction and the subsidence of a wide sedimentary basin in central Poland. The effects of Late Cretaceous-Paleogene accretion of the Western Carpathians and inversion of the Permian-Mesozoic Polish Basin are also clearly visible. This indicates a large role of relatively young tectonic processes in the evolution of the transition zone between the old and stable Eastern Europe and the younger, mobile Western Europe.

ACTIVE DEEP SEISMIC PROFILE, SHIELD'21

T. Janik, D. Wójcik, W. Czuba, P. Środa

Despite many objective adversities, with a one-year delay, it was a great achievement to conduct deep seismic soundings along the SHIELD'21 profile in Ukraine (Fig. 1) at the turn of July and

August 2021. The profile crossed the Ukrainian shield from west to east, stretching from the border with Romania to the border with Russia, about 650 km long in total. Ten sources generating seismic energy (explosives from 300 to 800 kg of TNT) have been placed along the profile. The depth of the boreholes was close to 30 m. The largest shots were located close to the profile ends. Shot times were recorded using GPS devices and, simultaneously, by additional seismic recorders located close to the shot points. Data acquisition was accomplished using 260 mobile single-component seismic recorders (100 Reftek 125-Texan and 160 DSS-CUBE) with 4.5 Hz geophones and 100 Hz sampling rate. Recorders were deployed at spacings of ~2.5 km, 90% of them belonged to the Department of Lithospheric Research. Despite the pandemic, a team from Poland participated in the measurements, setting up the equipment along the most difficult, 200 km long south-western section of the profile, which overlaps with the end of the previously made RomUkrSeis profile, crossing the Carpathians.

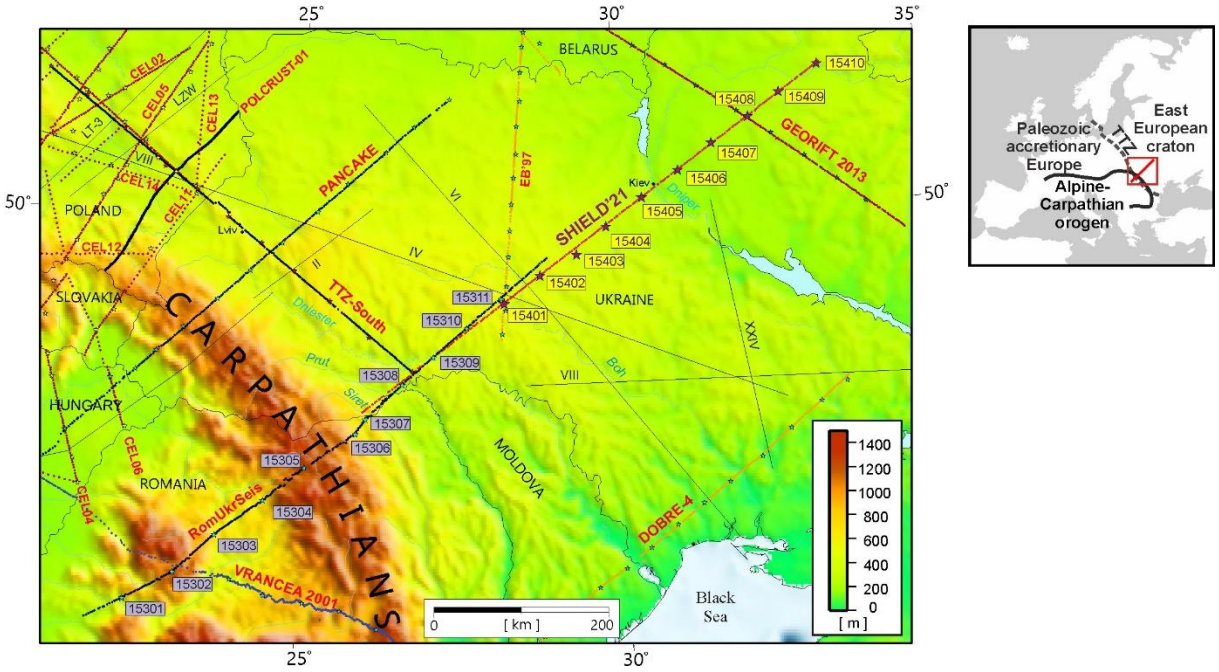

Fig. 1. Location of the deep seismic soundings profile, SHIELD'21.

KNIPOVICH RIDGE STUDIES BASED ON SEISMIC MEASUREMENTS – KNIPAS & KNIPSEIS – NORTH ATLANTIC

D. Wójcik, W. Czuba, T. Janik

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 active part of the ocean bottom seismic experiment KNIPAS (Fig. 1) carried out over the Logachev Seamount at the ultraslow-spreading Knipovich Ridge in German–Polish co-operation allowed to acquire a net of six intersecting wide-angle reflection and refraction (WARR) profiles. The seismic crustal structure underneath a prominent volcanic centre of an ultraslow-spreading ridge was modelled along the profiles. A publication is in preparation after first reviews.

In collaboration with the University of Bergen and Hokkaido University, deep seismic soundings were performed along the KNIPSEIS OBS profile (~280 km), crossing the Knipovich Ridge in the western Barents Sea (Fig. 1). 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). The seismic crus-

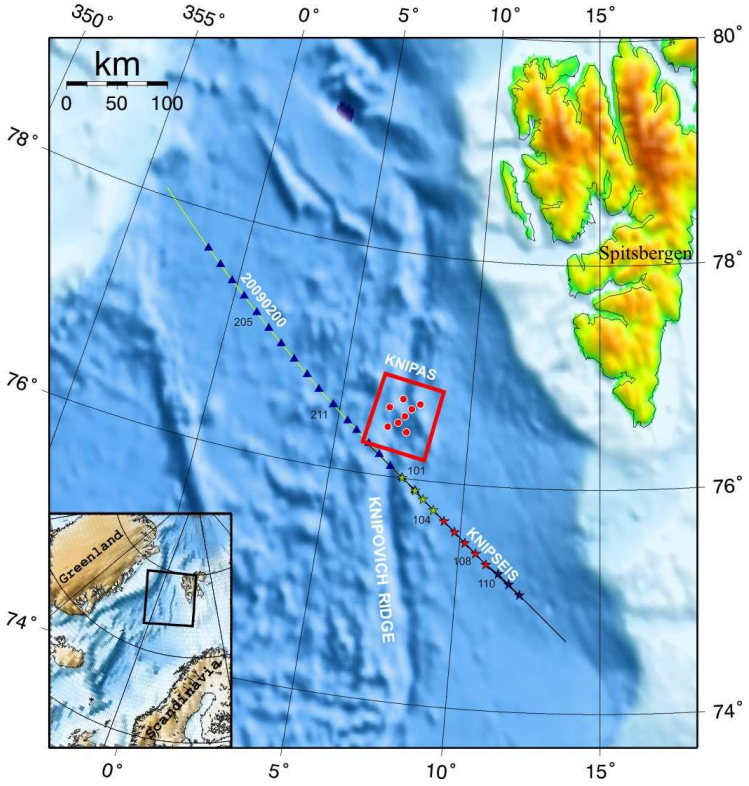

Fig. 1. Location map of the KNIPAS & KNIPSEIS active seismic survey in the Northern Atlantic (Norwegian–Greenland Sea). Dots, stars, and triangles indicate locations of Ocean Bottom Seismometers (OBS). Red frame is the area of the KNIPAS survey. Bathymetry data is from GEBCO (2019). The inset black rectangle indicates the location of the main map.

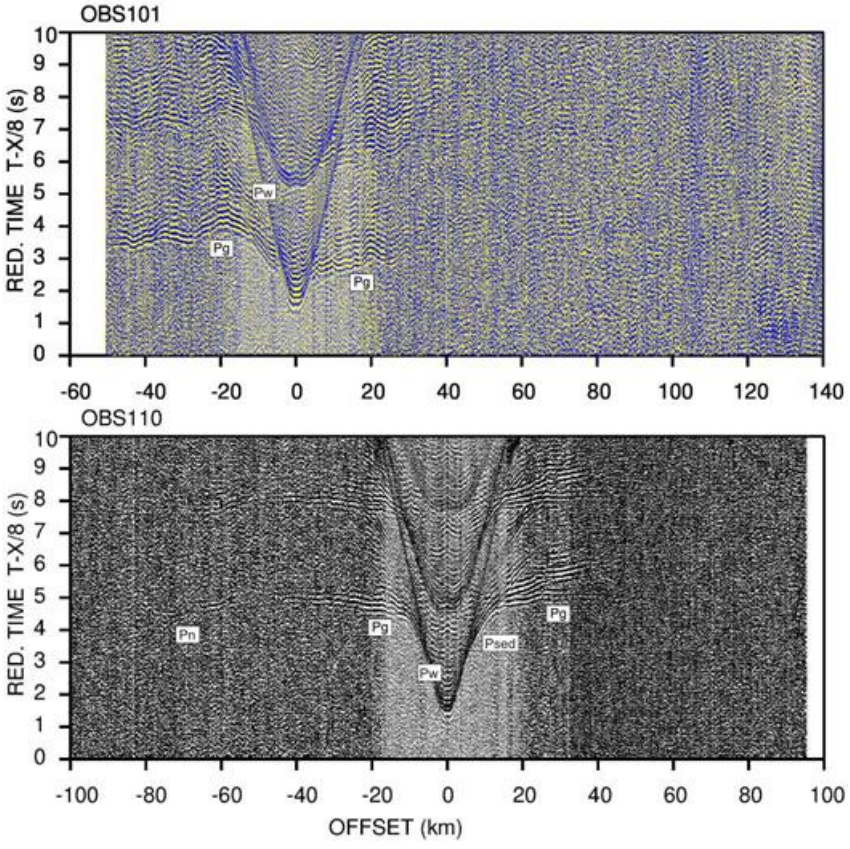

Fig. 2. Examples of normalized seismic record sections along the KNIPSEIS profile, reduction velocity 8 km/s.

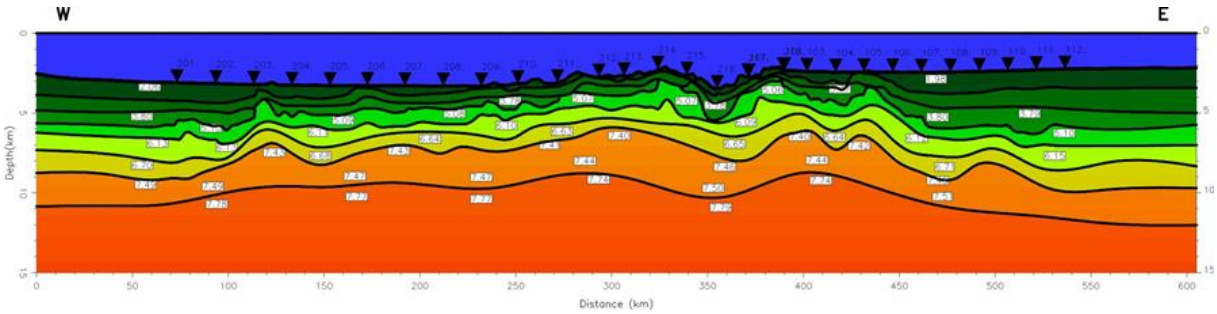

Fig. 3. Very preliminary common seismic model along the profiles 20090200 and KNIPSEIS. Triangles represent OBS locations, colors P-wave velocities. Numbers in rectangles are modelled P-wave velocity values in km/s.

tal structure (Fig. 2) was jointly modelled along the KNIPSEIS profile and along the previously realized German 20090200 profile (Hermann and Jokat 2013). It provides information on the seismic structure of the Knipovich Ridge as well as oceanic and continental crust in the transition zone (Fig. 3). The interpretation works are ongoing.

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PASSIVE SEISMIC EXPERIMENTS IN SOUTHERN POLAND – ANIMALS AND PACASE

P. Środa, M. Bociarska, J. Rewers, W. Materkowska, K.-Y. Ke, S. Abdollahi, W. Czuba, D. Wójcik, T. Janik

The passive seismic experiment AniMaLS started in 2017 in the Polish Sudetes. One of the objectives was to study the anisotropy of the sub-crustal lithosphere and asthenosphere beneath the NE termination of the Bohemian Massif. The Sudetic lithosphere represents a complex mosaic of several Proterozoic to the Quaternary units. Temporary seismic network of 23 broadband stations was operated for ~2 years, providing broadband seismograms of local, regional, and teleseismic events which are currently analysed using shear-wave splitting, receiver function and surface wave dispersion methods. The results of the SK(K)S splitting show time delays between slow and fast *S*-wave largely in the range of ~0.5–1.6 s (Fig. 1). The azimuths of fast velocity axis are mostly consistent and vary from WNW-ESE to NW-SE direction. They correlate well with surface trends of tectonic units and with strikes of major fault zones. The splitting is interpreted as a result of lattice-preferred orientation (LPO) of mantle olivine. Obtained results are compared with previous seismic studies of the mantle anisotropy in other areas by various methods. This work is connected with the IG PAS project "Determination of the seismic anisotropy of the lithosphere in the Lower Silesia area" (grant of Polish National Science Centre, agreement: UMO-2016/23/B/ST10/03204).

The data acquisition for the PACASE passive seismic experiment (Pannonian-Carpathian Seismic Experiment) started in 2019 and will continue to 2022. The Polish team operates 30 broadband seismic stations in Southern Poland (Fig. 2). Examples of data and of noise analysis are shown in Figs. 3 and 4. The whole area of the experiment is covered with over 210 broad-

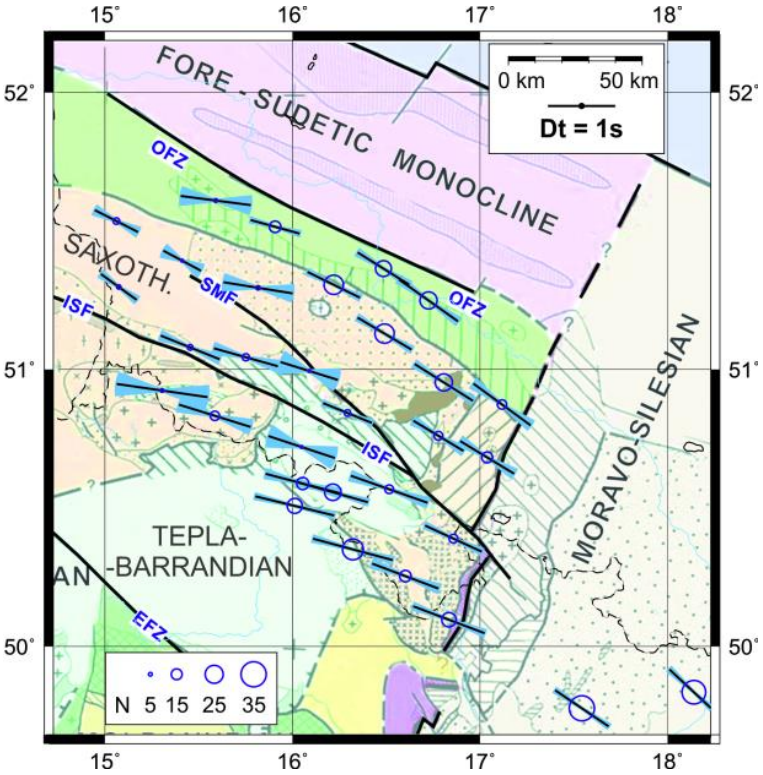

Fig. 1. Results of the SKS splitting study in the Sudetes.

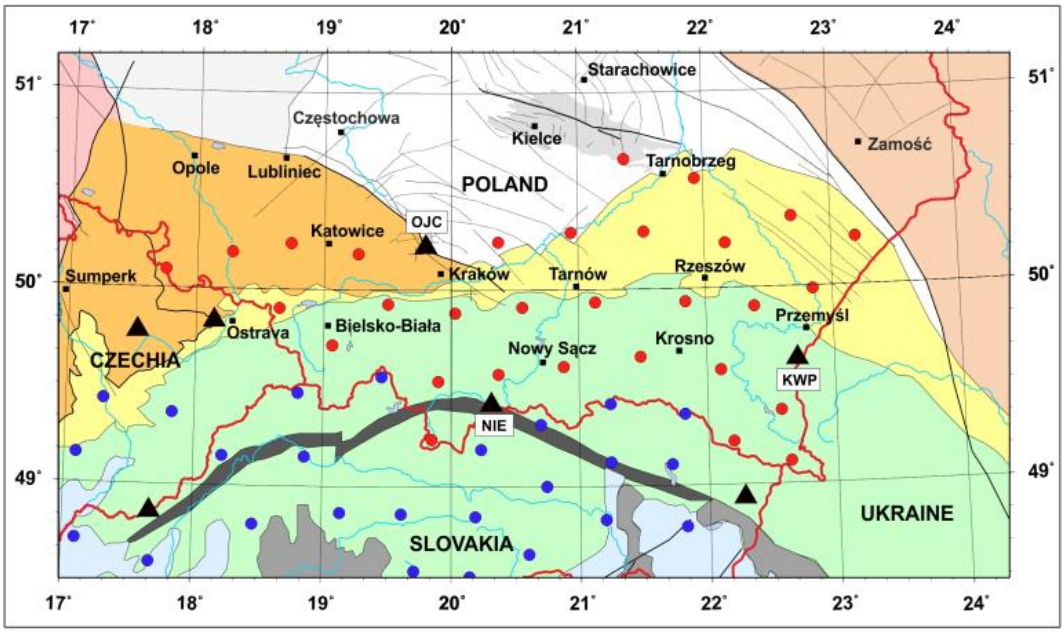

Fig. 2. Locations of Polish seismic stations of the PACASE. Red dots – Polish stations, blue dots – other stations of the experiment, black triangles – permanent stations.

band stations. The main objectives of the project involve: detailed geophysical study of the lithosphere-asthenosphere system of the Carpathian orogen, Pannonian Basin, and Eastern Alps; study of seismic anisotropy in relation to mantle fabrics, petrology and tectonic deformations, analysis of local seismicity, developing a 3D seismo-tectonic model of the region. The PACASE forms a connection between the areas of the AlpArray and planned AdriaArray experiments. The project involves 14 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, receiver functions, shear wave

splitting, ambient noise techniques. Results will be interpreted in terms of the structure and petrological properties of the crust and the upper mantle. The Polish part in the study 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).

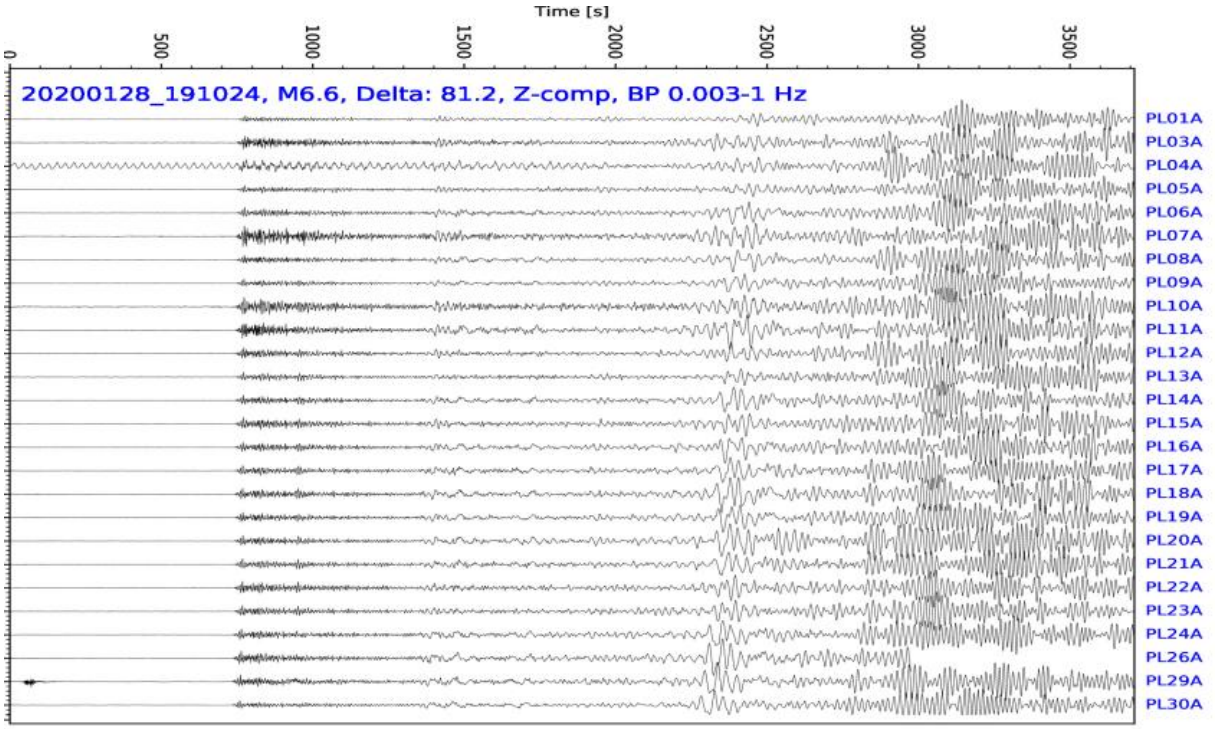

Fig. 3. Example of seismic data recorded by stations in Poland: event in Cuba region, magnitude 6.6, Z-component, band pass filtered (1–33 s).

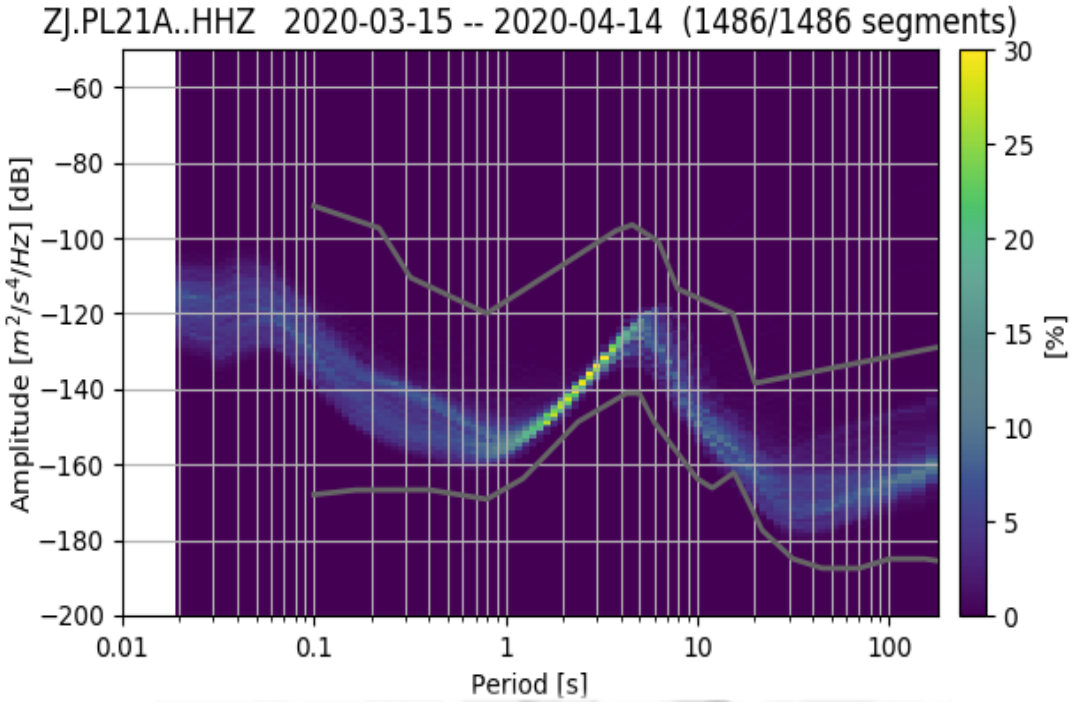

Fig. 4. Noise level analysis for station PL21A – probabilistic power spectrum density (PPSD) on the Z-component.

2.4 Climate change and polar research

EOARCHEAN CRUST IN EAST ANTARCTICA: EXTENSION FROM ENDERBY LAND INTO KEMP LAND

M.A. Kusiak, D.J. Dunkley, S.A. Wilde, M.J. Whitehouse, A.I.S. Kemp

Published in: *Gondwana Res*. (2021), **93**, 227–241, DOI: 10.1016/j.gr.2020.12.031

The main goal of this paper was to verify the presence of Eoarchean (4.0–3.6 Ga) rocks in Kemp Land in East Antarctica. To do so, zircon grains from three samples of orthogneiss from Aker Peaks have been investigated. The methods used in the study included isotopic analyses utilizing Sensitive High-Resolution Ion Microprobe (SHRIMP) for U-Pb dating of single zircon domains and Laser Ablation Multi-collector Inductively Coupled Plasma Mass Spectrometry (LA-MCICPMS) for concurrent analysis of Lu-Hf isotopes. The results were compared to those obtained in other studies from the adjacent Enderby Land to identify a common history across the Napier Complex.

The new zircon isotopic data presented in the study (Fig. 1) confirmed that Eoarchean protoliths are not restricted to the Tula Mountains of Enderby Land, raising a possibility that such ancient crust is widespread across the Napier Complex. Zircon geochronology corroborated that high- to ultrahigh-temperature metamorphism between 2550 and 2540 Ma was widespread, supporting the concept that this event was the one that assembled crustal blocks to form the Napier Complex. There is no evidence in this study for metamorphism at ca 2.8 Ga, although if 3.7 Ga zircon in the mafic orthogneisses and late-stage growth in the trondhjemitic orthogneiss is due to high-temperature metamorphism, this is the first recognition of such an event in the Napier Complex. The coupled Pb and Hf isotopic data demonstrated that some age scatter was due to isotopic disturbance during metamorphism. Regardless, slightly sub-chondritic initial $\varepsilon Hf(t)$ for zircon of the Aker Peaks trondhjemitic orthogneiss suggested some input from older crustal rocks into the sources of the rocks. The study showed that there is no requirement for the melting of Hadean crust, or for contributions from a depleted mantle component into the Aker Peaks gneisses.

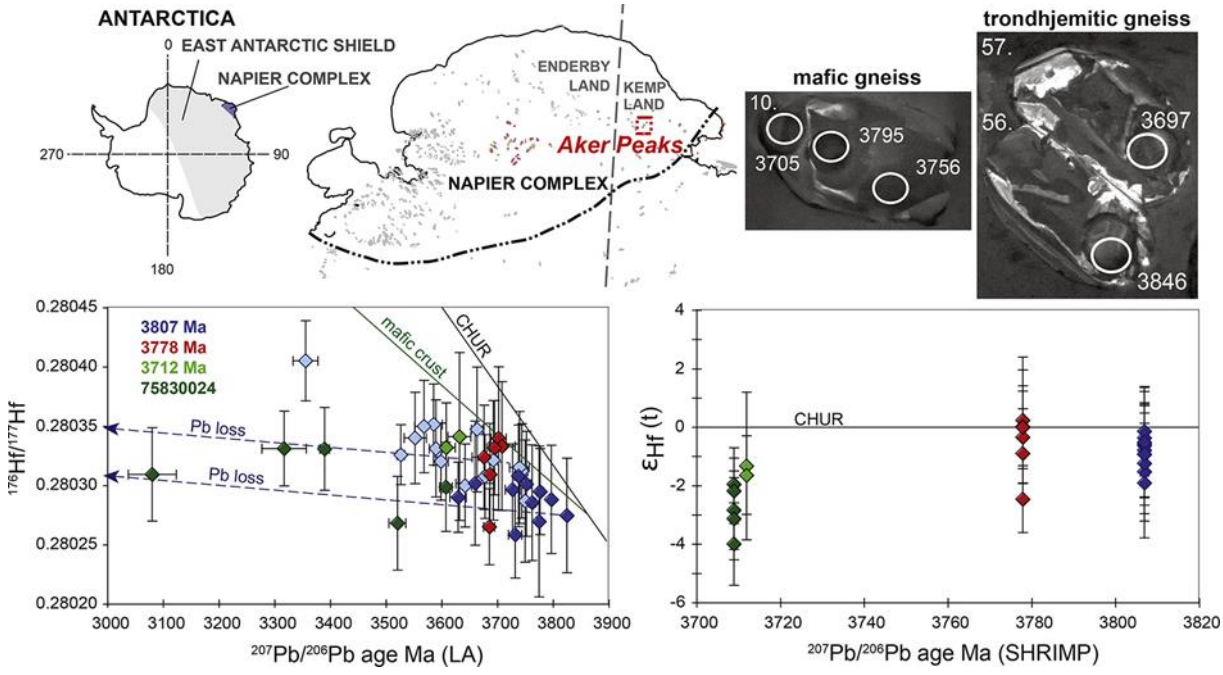

Fig. 1. Top row: Outline of the Antarctica with the Napier Complex indicated and outcrop mapped; examples of zircon grains analysed in this study. Bottom row: Hf isotope vs time systematics of zircon grains from the Aker Peaks.

SEISMOLOGICAL MONITORING OF HANS GLACIER

W. Gajek

Calving of tidewater glaciers is a key driver of glacier mass loss as well as a significant contribution towards sea level rise. However, this dynamic process is still challenging to quantify. In addition, there are very few direct measurements of calving activity in Svalbard at daily to sub-daily resolution due to the requirement of continuous human labour at the calving front for field studies. Seismic instruments in the vicinity of glaciers offer the potential to circumvent this issue since they record ground motion signals, including those generated by calving events, with an unprecedented sub-second resolution.

In the summer of 2021, an 8-day long time series of integrated measurements was acquired at the calving front of Hansbreen, South Spitsbergen, in a joint initiative of scientists from IG PAS, St Andrews University in Scotland and NBMU, Norway. It included remote sensing observations from a millimetre-wave radar (AVTIS2), Terrestrial Laser Scanner and time-lapse cameras correlated with a seismic dataset from two local arrays deployed at direct vicinity of calving front (25 stations) and a closeby regional permanent seismological station in Hornsund (Fig. 1). Integrating these datasets brings an opportunity to correlate visual observations of calvings including volumetric ice loss derived from radar scans with seismic signatures registered at nearby seismic arrays and develop a model linking chosen seismic parameters with volumetric ice loss.

Local arrays were installed for a limited time; however, having nearby permanent seismological station will enable to apply detection algorithm trained using observed calving events to decade long records and, consequently, to revisit over a decade long history of Hansbreen calving.

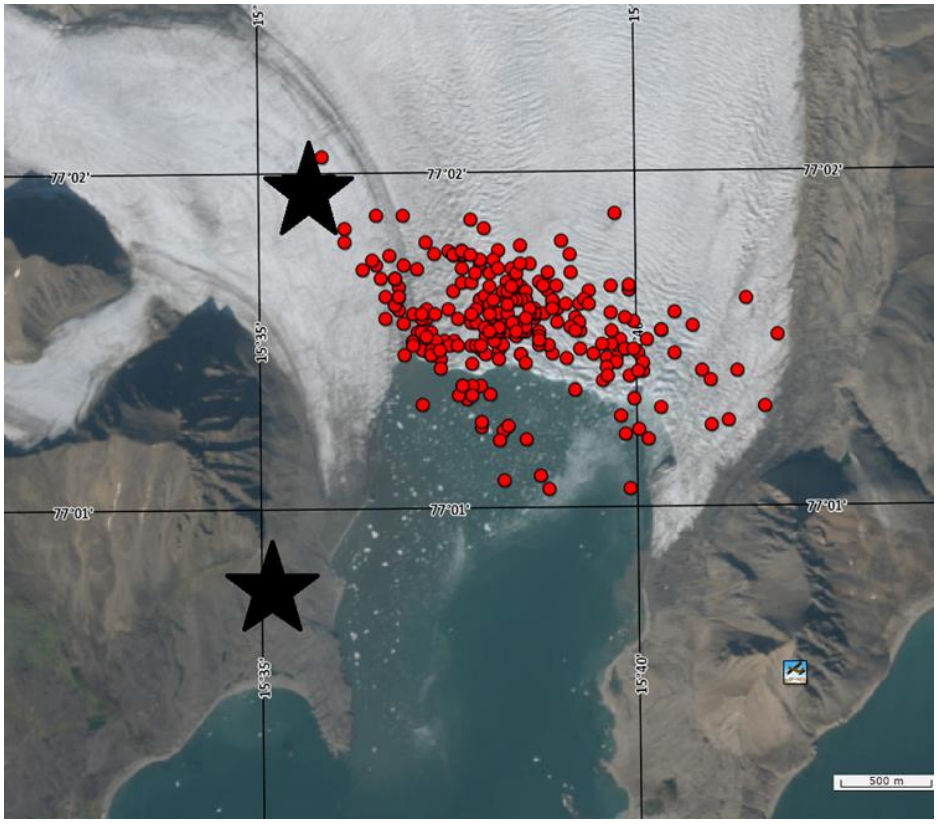

Fig. 1. Locations of 260 calving-style seismic events (red dots) obtained using records from 2 seismic arrays (black stars) within 8 days between 26 July – 2 August 2021. Detection algorithm was tuned based on calving events observed on-site.

IMPACT OF SUBSEASONAL WEATHER VARIABILITY ON LOCAL ENVIRONTMENT OVER THE MARITIME CONTINENT, EXTREME PRECIPITATION GENERATION, AND FLOODS (TD)

Dariusz Baranowski, Beata Latos, Wojciech Szkółka

The Maritime Continent is an archipelago within Indo-Pacific warm pool characterized by the largest precipitation amount, globally. Such environmental conditions combined with complex topography make it favorable for extreme precipitation events and its adverse effects, such as floods and mudslides. Our study focuses on interactions between propagating, subseasonal weather modes (such as the Madden–Julian oscillations – MJO – and convectively coupled equatorial waves – CCEW), local environment and large-scale conditions, and their importance for generation of regional-scale weather hazards.

On the basis of long-term climatology and detailed analysis of multiple case studies we show that CCEWs and their interactions with large-scale and local environments serve as precursors for extreme weather-driven events, such as heavy rainfall, floods, and tropical cyclogenesis in the Maritime Continent. Often, CCEWs are embedded within the larger-scale envelope of the MJO. They can contribute to the onset of a smaller-scale convective system and sudden heavy rainfall, through changes to atmospheric stratification, moisture advection, low lever convergence and upper-level convergence. Although different physical processes can be associated with different CCEW modes, they all enhance local convection and help with convective organization throuth aggregation processes. The Makassar flood of January 2019, which was the largest flood ever observed in this area, is an example of such interactions. The study shows that Kelvin and Rossby Waves activity over Sulawesi nearly doubles the chance of flood and extreme rain event development, while the probability of flood / extreme rain during their joint activity is 8 times bigger. Moreover, in this area tropical waves can trigger weather-driven hazards even when MJO is inactive (Latos et al. 2021).

Another example of multi-scale nature of extreme precipitation and importance of CCEWs and MJO for convection development and organization was the genesis of tropical cyclone Seroja in March/April 2021, which brought historic flooding and landslides to southern Indonesia, East Timor, and Western Australia's Mid-West region. Here, multiple CCEWs contributed to initiation, organization and strengthening of atmospheric convection through interactions between large scale circulation and local vorticity. Pre-Seroja originated from a breakdown of Equatorial Convection which developed on the leading edge of MJO. The interaction between Rossby and two Kelvin waves, provided a supportive environment for aggregation and intensification for this extreme event.

We have also studied impact of MJO and CCEWs on local diurnal cycle processes, including diurnal evolution of precipitation and wind patterns. This research is based on analysis of long-term Equatorial Atmospheric Radar (EAR) data from Sumatra. We show that subseasonal weather modes significantly contribute to day-to-day and diurnal variability in tropospheric winds. In particular, diurnal variability is affected first, before the mean wind profiles alter in response to a given mode.

This indicates the importance of local diurnal cycle processes for an overall subseasonal variability. Such response has been recognized in repsonse to CCEWs, MJO as well as lower frequency variability such as ENSO.

Finally, we have shown that tropospheric moisture properties, derived from GNSS data, provide an opportunity to investigate multi-scale interactions within tropical atmosphere. The data have very high temporal resolution, while long term records are able to well represent variability associated with low frequency modes such as ENSO. Thus, this method provides a consistent framework for investigation of interaction between local high frequency variability

(e.g., diurnal cycle), subseasonal weather modes and low-frequency, climate scale phenomena such as ENSO (Baldysz et al. 2021).

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INVESTIGATION ON THE SOURCES AND IMPACT OF TRACE ELEMENTS IN THE ANNUAL SNOWPACK AND THE FIRN IN THE HANSBREEN (SOUTHWEST SPITSBERGEN)

A. Spolaor, B. Moroni, B. Luks, A. Nawrot, M. Roman, C. Larose, Ł. Stachnik, F. Bruschi, K. Kozioł, F. Pawlak, C. Turetta, E. Barbaro, J.-C. Gallet, D. Cappelletti

Published in: *Front. Earth Sci.* (2021), **8**, 536036, DOI: 10.3389/feart.2020.536036

In this interdisciplinary paper we present a thorough evaluation of the water soluble fraction of the trace element composition (Ca, Sr, Mg, Na, K, Li, B, Rb, U, Ni, Co, As, Cs, Cd, Mo, Se,

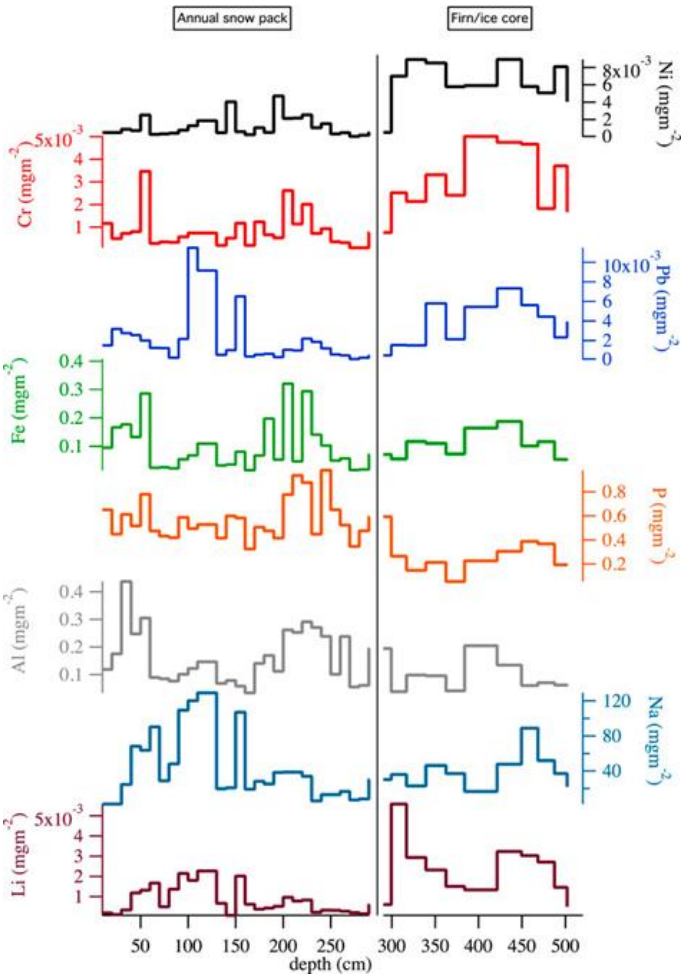

Fig. 1. Snowpack sample flux (left panels) versus firn sample flux (right panels) of selected elements for the three groups. Lithium, Ni, Cr, and Pb are representatives of the third group (Bi, Se, Ca, K, U, Pb, Rb, Tl, Li, Co, In, Cr, Mn, Zn, Ni, and Cd), Fe and Na of the second (B, V, Na, Ti, Fe, and Ce), and Al and P of the third (Mo, P, Mg, Th, Sr, Al, Ba, and As). The left and right axis units are both mg m^{-2}, lower axis represents the depth (in cm) from the annual snowpack surface.

Eu, Ba, V, Ge, Ga, Cr, Cr, P, Ti, Mn, Zr, Ce, Zn, Fe, Gd, Y, Pb, Bi, Yb, Al, Nb, Er, Nd, Dy, Sm, Ho, Th, La, Lu, Tm, Pr, Tb, Fe, In, Tl) and their fluxes in the annual snowpack and the firn of the Hansbreen (a tidewater glacier terminating in the Hornsund fjord, southwest Spitsbergen) (Fig. 1). The trace element samples were obtained from a 3 m deep snow pit dug at the plateau of the glacier (450 m a.s.l.), and from a 2 m deep firn core collected from the bottom of the snow pit. The comparison of elemental fluxes and enrichment factors allowed us to constrain specific summer and wintertime deposition patterns of water-soluble trace elements in the southern part of the Svalbard archipelago.

Our results suggest that the chemical composition of the Hansbreen (and likely other glaciers where the summit is close to the equilibrium line) is mainly affected by summertime deposition of trace elements from local sources and some volatile elements, which may be transported into the Arctic when the polar vortex is weak. The melting of the annual snowpack seems to have a minor influence on the overall chemical signature of the glacier ice.

HYDROMETEOROLOGICAL DATASET (2014–2019) FROM THE HIGH ARCTIC UNGLACIATED CATCHMENT FUGLEBEKKEN (SVALBARD)

T. Wawrzyniak, M. Majerska, M. Osuch

Published in: *Hydrol. Process*. (2021), **35**, 1, e13974, DOI: 10.1002/hyp.13974

Continuous hydrometeorological monitoring in polar environments is crucial for understanding processes controlling the water circulation in the catchments. Inter- and intra- annual variability of the variables gives an insight into river functioning. In this study, a hydrometeorological dataset of unglaciated High Arctic catchment is presented. The provided variables are essential to the recognition of the functioning of Arctic catchments. In particular, this dataset can be used to understand water circulation in the catchment as input data to multiple hydrological models. It can be used in a variety of research topics, including streamflow projections, and more generally in examining Arctic ecosystems and climate change impact studies. The time series en-

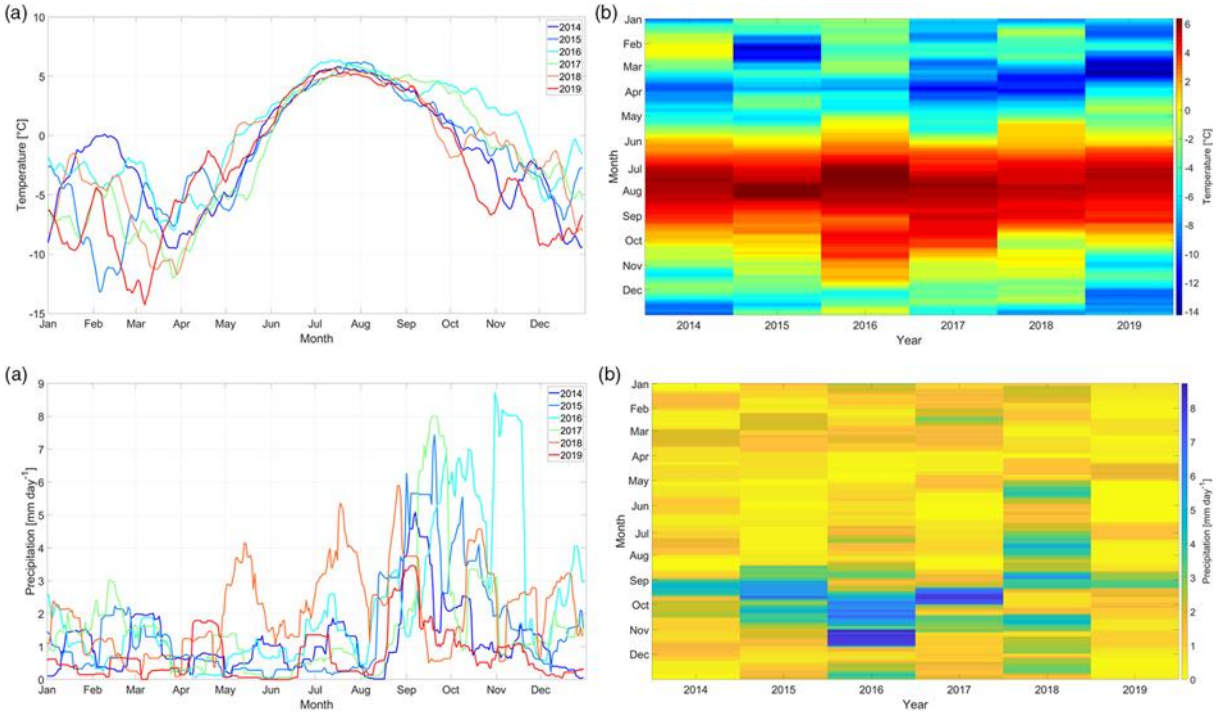

Fig. 1. Visual representation of the MASH results for air temperature (upper panel) and precipitation (lower panel) time series at the Hornsund site in 2014–2019.

compasses air temperature, precipitation, wind speed, relative humidity, and runoff data from 2014 to 2019. Meteorological data come from continuous meteorological monitoring carried out at the Hornsund station located in SW Spitsbergen. Flow in the Fuglebekken stream was measured using a portable flowmeter Nivus PCM-F with an Active Doppler sensor. The variations of air temperature were especially noticeable in the winter months (Fig. 1). Each summer season was characterized by similar conditions, although there were interannual differences in the length of the period with positive air temperatures. The highest air temperatures were noted in 2016, with positive daily air temperatures present from mid-May to the first half of November. In the case of precipitation, there were high inter- and intra-annual differences (Fig. 1). The highest amount of precipitation occurred usually in the warm season from the middle of August until the end of October. An exception is the year 2019 with dry conditions throughout the whole year. The highest annual sum of precipitation was observed in 2016 and 2018.

Fuglebekken was listed in the Research and Observatory Catchments by The Consortium of Universities for the Advancement of Hydrologic Science as one of only a few of the High Arctic sites.

CHANGES IN THE FLOW REGIME OF THE FUGLEBEKKEN CATCHMENT, SW SPITSBERGEN

M. Osuch

The behaviour of river catchments, in conjunction with glaciers, permafrost and biotic elements, is undoubtedly one of the most important indicators of climate and environmental change in the Arctic. The study focuses on the changes in flow regime in the Fuglebekken catchment for the years 1979–2020 that was reconstructed based on archival observations and simulations of six models (FLEX-IS, GSM-SOCONT, PRMS, HBV, Nordic HBV, and GR4J). The analyses were performed using the MASH method.

Figure 1 shows the simulated flow time series. The colour of the lines periods of averaging. The outcomes indicated the following changes: earlier occurrence of snowmelt driven floods, large increases in autumn flows, prolongation of the hydrologically active season and winter flows due to rain on snow events.

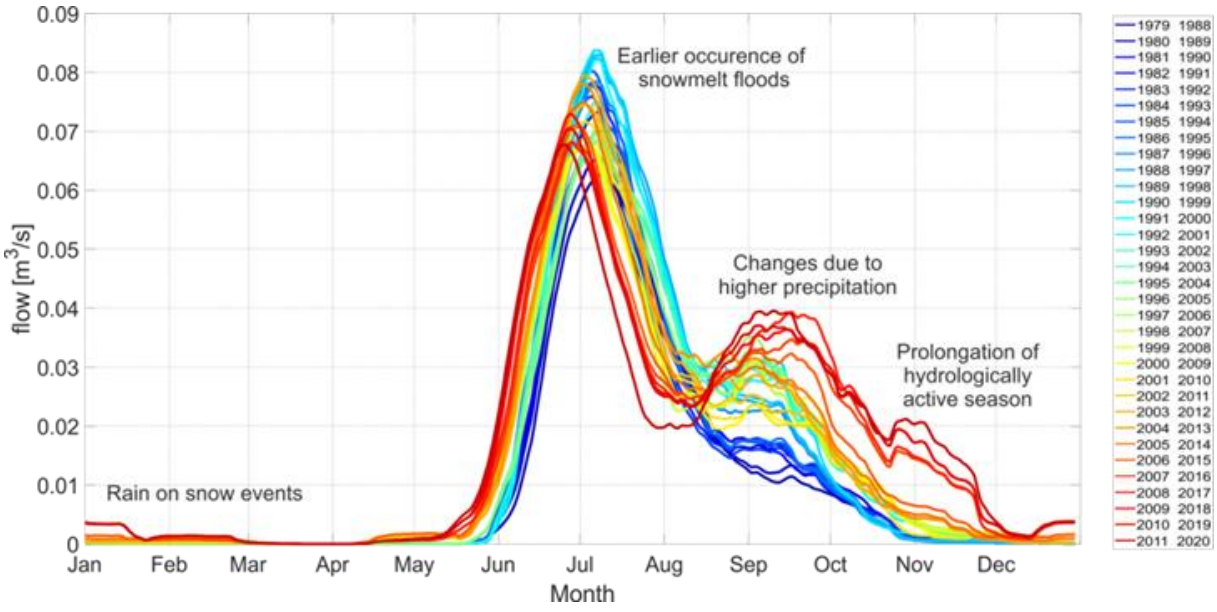

Fig. 1. MASH results for simulated flow time series in the Fuglebekken in years 1979–2020 (w = 15, Y = 10). The colour of lines represents the period of averaging (33 periods as MASH is composed of Nh = 33 patterns) (after Osuch et al. 2022).

Figure 2 presents the results of the Mann–Kendall test for trend detection of smoothed flow time series in Fuglebekken in 1979–2020. A statistically significant increase in runoff was estimated for the two periods: from mid-May till the end of June and from August till mid-November. The changes in the first period result from increases in air temperature and earlier occurrence of snowmelt driven floods. An estimated runoff increase in the second period corresponds to large changes increases in rainfall. A decrease in runoff was estimated in July and the first part of August. Such changes are the consequence of the increases in air temperature, earlier disappearance of snow and decreases in precipitation in this period. The presented results document that the hydrological regime of the Fuglebekken catchment has already changed.

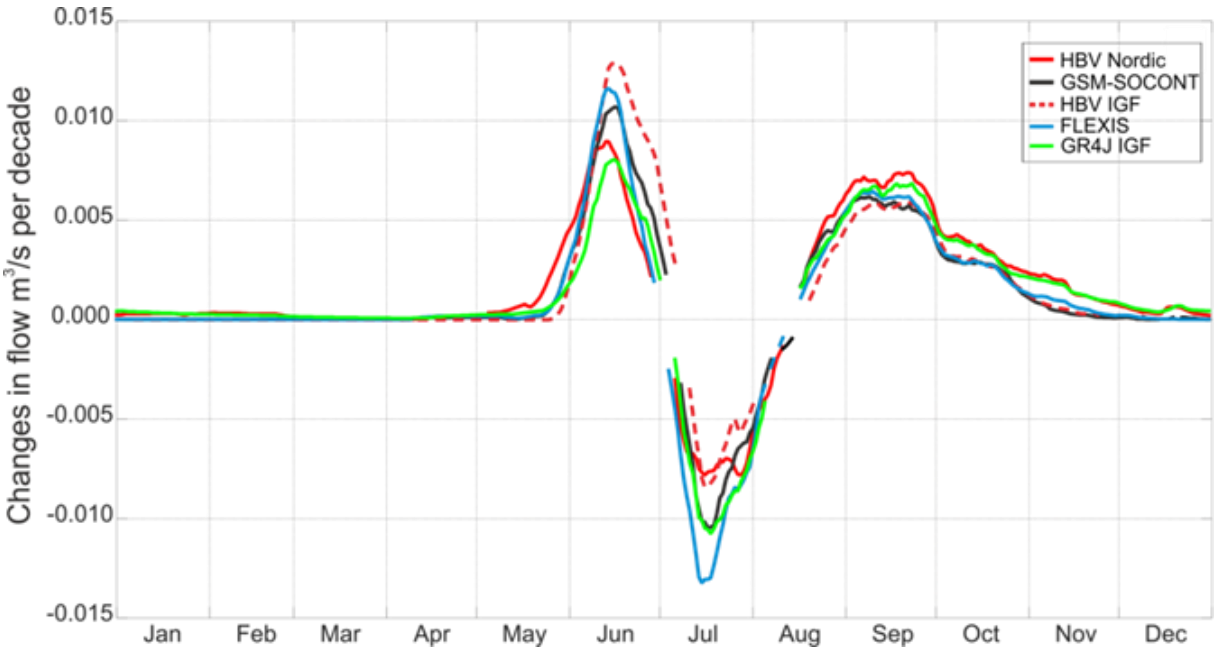

Fig. 2. Results of Mann–Kendall test for trend detection of smoothed flow time series in Fuglebekken in 1979–2020 (w = 15, Y = 10). Statistically significant changes at the 0.05 level are represented by the continuous lines. Colours represent different models (after Osuch et al. 2022).

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3. MANAGEMENT

The Board of Directors:

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Director of the IG PAS

Mariusz Majdański
Deputy Director
for Scientific Affairs

Beata Fromeliusz
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for Technical Issues

3.1 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)
2021	176	75	23
Change	+1	+6	–6

The employees by function

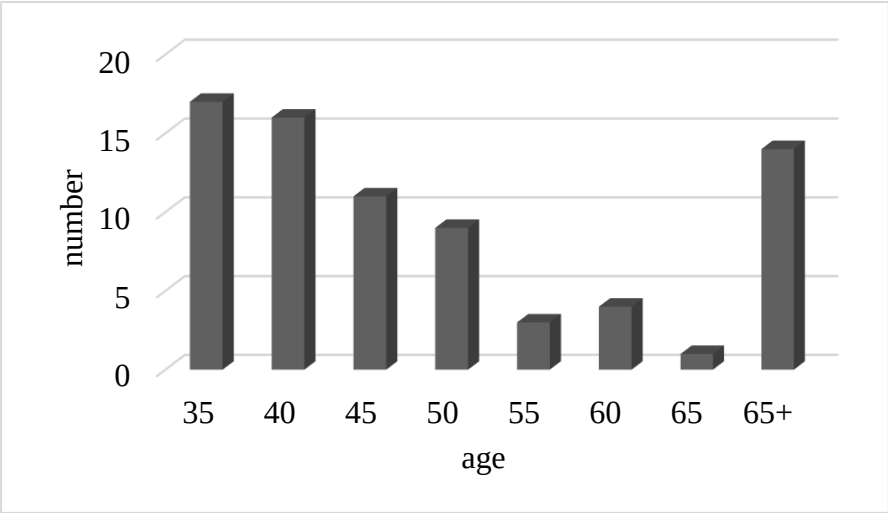
Function	Number
Polar expedition	8
Administration	48
Technicians	45
Researchers	75
Total	176

⇨

Researchers	Number
Research Assistant	8
Assistant Professor	30
Associate Professor	23
Professor	14

The employees by sex

	Female	Male
Total	74	102
Researchers	24	51
Other	50	51



Researchers' age structure

3.2 Activity of Scientific Information and Publishing Department

In the year 2021, like in the previous years, the activity of the Scientific Information and Publishing Department concentrated on the three titles:

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

Acta Geophysica

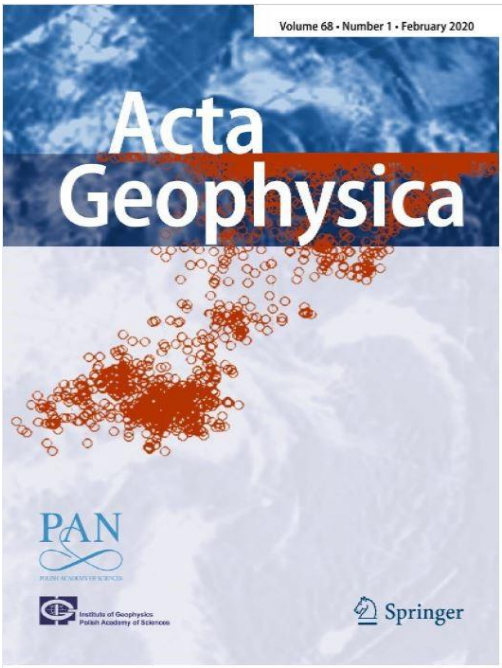
Acta Geophysica is a leading geophysical journal; it is published by the Institute of Geophysics and the Committee of Geophysics, Polish Academy of Sciences. It deals with all aspects of general and applied geophysics. This broad field is divided into five main categories: Solid Earth Sciences, Hydrology, Atmospheric and Space Sciences, Anthropogenic Hazard, and Applied Geophysics.

Acta Geophysica publishes all kinds of high quality contributions: research and review articles, short communications as well as comments to published papers, and letters to the editor.

Proposals for special, topical issues are also welcome, for which careful assistance of the editorial team matches considerable independency granted to their Guest Editors.

The content-related supervision over the quality of *Acta Geophysica* is performed by the Editor-in-Chief (Prof. Eleftheria Papadimitriou from Greece), and her work is supported by the Co-Editors-in-Chief and Associate Editors – specialists in their fields, selected from among outstanding scientists.

Apart from the Editor-in-Chief, Co-Editors-in-Chief and the Associate Editors, there is the Editorial Advisory Board, consisting of prominent specialists from Poland and abroad.



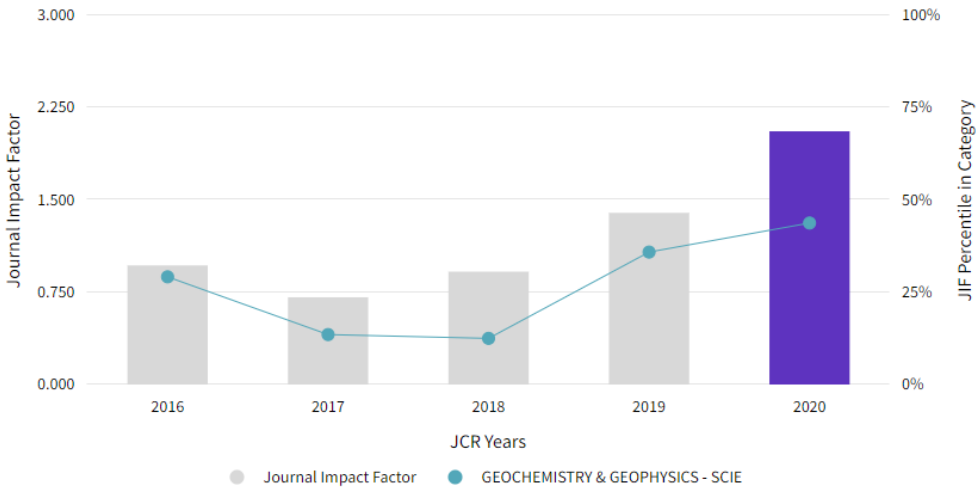
Front cover of *Acta Geophysica*

In the year 2021, six issues of *Acta Geophysica* were published, including two special issues ("Advances in Engineering, Environmental and Mining Geophysics" and "Samos (Greece) Earthquake and Eastern Aegean Seismicity and Seismotectonics"). The total number of pages (B5) was 2498, and the number of articles was 178. The number of all papers submitted to *Acta Geophysica* in 2021 was 839.

Acta Geophysica has significantly increased its Impact Factor in the last three years (IF for 2018: 0.917, for 2019: 1.395, for 2020: 2.054). This is due to a large amount of work by an active international group of Editors and the publisher (Springer Nature). In the upcoming years, a further increase of Impact Factor is expected.

According to the JCR ranking (indicators: JIF – Journal Impact Factor and JCI – Journal Citation Indicator), the journal is currently in the third quartile (Q3) of the most significant journals in the GEOCHEMISTRY & GEOPHYSICS group.

Publication website: https://www.springer.com/journal/11600/.



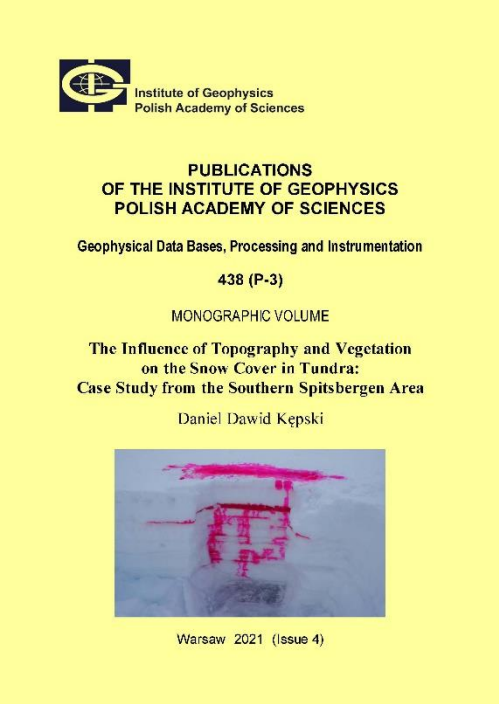
Impact Factor of *Acta Geophysica* (source: https://jcr.clarivate.com/)

Publications of the Institute of Geophysics, Polish Academy of Sciences

It is an electronic journal published by the Institute of Geophysics, Polish Academy of Sciences. It is available in Open Access form at https://pub.igf.edu.pl/. The Editor-in-Chief is Marek Kubicki. In the year 2021, seven issues were published:

– "Anisotropy Estimation of Lower Paleozoic Shales from Northern Poland using Microseismic Data" by W. Gajek,
– "Results of Geomagnetic Observations: Belsk, Hel, Hornsund, 2019" by J. Reda et al.,
– "Book of Extended Abstracts. Webinar on Experimental Methods and Laboratory Instrumentation in Hydraulics, 13–15 April 2021",
– "The Influence of Topography and Vegetation on the Snow Cover in Tundra: Case Study from the Southern Spitsbergen Area" by D. Kępski,
– "Achievements of the Institute of Geophysics, PAS: Annual Report 2018",
– "Achievements of the Institute of Geophysics, PAS: Annual Report 2019",
– "Achievements of the Institute of Geophysics, PAS: Annual Report 2020".

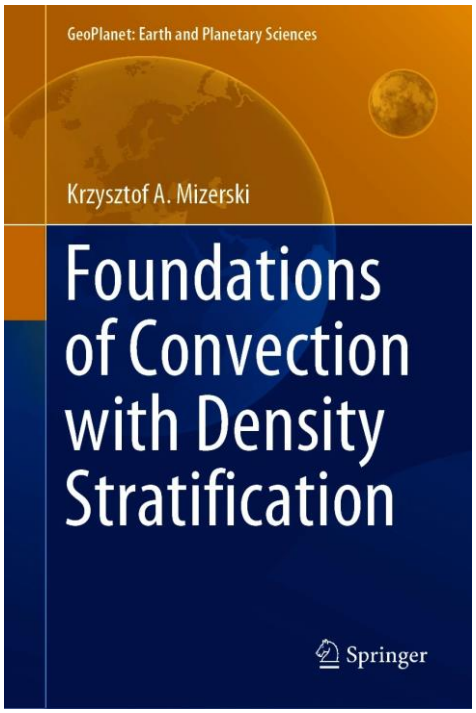
All the above-mentioned issues were published only in electronic form.



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

GeoPlanet: Earth and Planetary Sciences Book Series

The *GeoPlanet* series is in part a continuation of *Monographic Volumes of Publications of the Institute of Geophysics, Polish Academy of Sciences*. Its Editors represent a consortium GeoPlanet (Earth and Planetary Research Centre), formed by five Institutes affiliated with the Polish Academy of Sciences: Institute of Geophysics, Space Research Centre, Institute of Geological Sciences, Nicolaus Copernicus Astronomical Centre, and Institute of Oceanology. The Editor-in-Chief is Paweł Rowiński.



Front cover of *GeoPlanet: Earth and Planetary Sciences*

This series is a forum for presenting the state-of-the-art and newest achievements in the Earth and space sciences. Its main objective is a multidisciplinary approach to link scientific activities in various Earth-related fields (geophysics, geology, oceanology) with the Solar System research.

The publications are produced in close cooperation between the GeoPlanet Series Editors and Springer.

In 2021, two issues were published:

– "Foundations of Convection with Density Stratification" by K. Mizerski,
– "Climate Change, Human Impact and Green Energy Transformation" by J. Kiciński and P. Chaja.

Publication website: https://www.springer.com/series/8821.

3.3 Educational activity of the Institute in the Academic Year 2020/2021

Currently, 23 students are studying at our institute, including 3 people who have been recruited to Doctoral Schools for the first year of studies. Two people obtained an extension of studies for the 5th year. One person from the 6th year defenced the doctoral thesis in January 2022, while 1 person intends to submit a doctoral thesis within the first months of 2022.

Eleven PhD students come from abroad, representing various countries of the world (India, Ethiopia, Iran, and Vietnam), which makes our educational offer relatively well recognizable in other parts of the world and contributes to raising the degree of "internationalization" of studies and the Institute.

Currently, 16 doctoral students receive a scholarship from the Institute's funds, while the others are financed from external project funds. It should be mentioned that 2 people from the 5th year obtained a conditional extension of the period of payment of the scholarship until the end of 2021.

GeoPlanet Doctoral School

At the moment, nine students are studying at the GeoPlanet Doctoral School. Five of them receive a regular scholarship from the Institute's founds, and three from scholarships financed from additional grant funds. All students received promotion for the next year of study. In addition, in July 2021, we admitted two new students for the first year of study, both of which are funded by the Institute's founds. One person dropped out of the school during the first year.

International Environmental Doctoral School

In 2020/2021, five people studied at the International Environmental Doctoral School and two of them receive a scholarship from the Institute's founds. All students from the first and second year of studies received promotion for the next year. Recruitment for the first year was completed in October and no new doctoral students were accepted at that time; it was only in November that a person was accepted for the grant of Prof. M. Osuch.

Mid-term evaluation

According to the Act of 20 July 2018 "Law on Higher Education and Science" and the regulations of the GeoPlanet Doctoral School in the middle of the education period, i.e. 24 months from the start of education (and if the education lasts six semesters during the fourth semester), the doctoral student is subject to mid-term evaluation in accordance with Article 202 of the Act. The basis for this assessment, carried out by a three-member committee appointed by the Director of the Institute, is a written report on the progress in the implementation of the Individual Research Plan (IRP) reviewed by the supervisor(s). The evaluation was carried out by both doctoral schools in September 2021.

In 2021, six second-year students joined the Assessment at the GeoPlanet School, and two doctoral students qualified for the assessment at the International Environmental Doctoral School. At GeoPlanet, all second-year students received a positive grade and thus promotion to the third year of study. In the International Environmental Doctoral School, one person received a positive assessment, and the other refused to take the assessment due to maternity leave. The work of both committees has been documented in the form of:

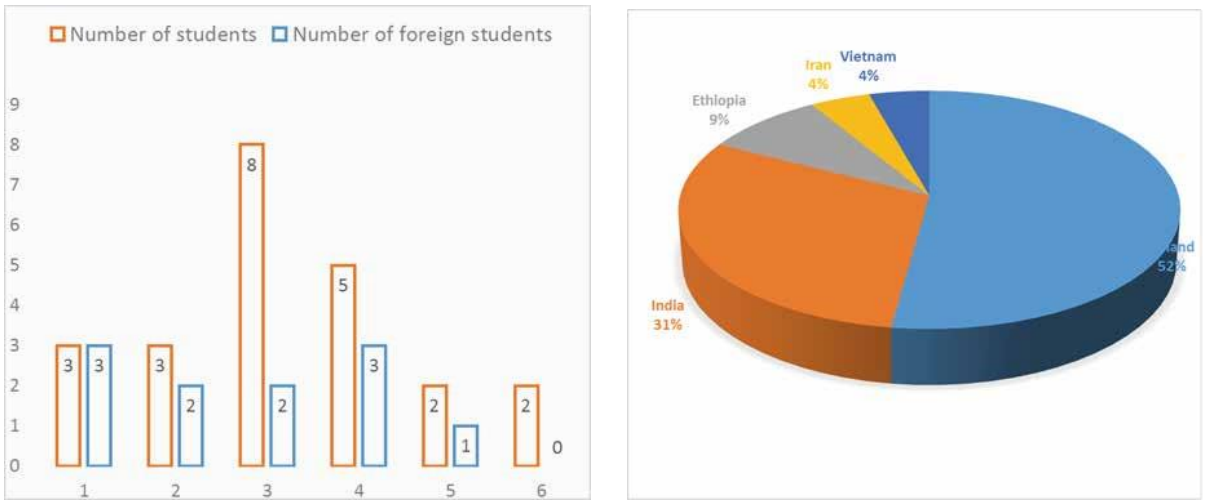
1. Minutes of work (meetings) of the committee, common to all evaluated students. These protocols have been archived and, if necessary, will be made available to the committee carrying out the periodic audit of the doctoral school.
2. Individual assessment of each student, together with justification, drawn up in writing. The assessment and justification are public and have been made available on the Institute's website.

The Institute of Geophysics Doctoral Studies

There are nine doctoral students studying at the IGF doctoral studies. Four doctoral students benefit from the extension of studies for the 5th and 6th year. Students have already obtained the number of ECTS credits required in the Study Regulations and are focusing on research and writing a doctoral theses. The academic year 2021/2022 will be the last official year of activity of Doctoral Studies according to the old formula and regulations.

Classes at Doctoral Studies and Doctoral Schools

In the academic year 2020/2021, lecturers from the Institute no longer conducted courses for the "old-formula" Doctoral Studies. All classes were offered for GeoPlanet Doctoral Schools and the International Environmental Doctoral School. In addition, the GeoPlanet Doctoral School students could choose classes from the offer of other institutes forming the School and online courses organized by recognized universities around the world. Due to the COVID-19 pandemic, classes were conducted online.



Total number of students and foreign students by years of studies (left) and students by countries (right)

Prospects for the development of doctoral students' education at the Institute

In the next academic year, a further reduction in the number of the Doctoral Students is expected due to the defence of doctoral theses by people whose studies have been extended to the fifth and sixth year. This was partially offset by a similar number of new students recruited this year and as a result, the number of PhD students will remain relatively stable. A positive trend is the observed decreasing average duration of studies – the defence of doctorates takes place earlier, at the latest one or a year and a half after the end of formal education. It should also be mentioned that our studies are international and the results of recent recruitment indicate a growing trend of internationalization of studies. Interest in studies among Polish candidates is negligible. Unfortunately, there is also a noticeable decrease in the education level of candidates for our studies.

However, as can be deduced from doctoral seminars, mid-term evaluation and grades in individual subjects, the level of students remains at a constant high level, although some people have not managed to defend their doctoral thesis before the graduation date. The activity of doctoral students in the scientific field (number of published papers) and organizational fields both in Poland and abroad is satisfactory. Students are eager to look for courses outside the offer of the Institute and doctoral schools, organize trainings and workshops and embark on scientific trips themselves. Practically every Doctoral Student received a NAWA scholarship for a trip; unfortunately, the plans were thwarted by the COVID-19 pandemic.

3.4 Data management portal

Proper management of scientific data is a key aspect of any reputable research organisation to ensure the authenticity of the collected data, improve its quality and maintain accuracy. In order to achieve the above-mentioned objectives, the data handling policies and procedures have been incorporated into the Institute's management policy and strategy. In addition, from October 2020, the IG PAS Data Portal was launched.

The IG PAS Data Portal is an open data platform of the Institute of Geophysics, Polish Academy of Sciences. This portal is used to collect, store, publish and share scientific data related to research activities, including access to data from external repositories. In line with national and international regulations and conventions such as FAIR principles, a metadata schema and data standards have been developed as the basis for interoperability. However, this process is still ongoing to follow new requirements, changes in scientific societies and funding

institutions, improve data management and data sharing. For better communication between users, including scientists, with the data steward, all requests are allocated and handled by the ticketing system. Thanks to this approach, many problems were fixed, the questions answered and the suggestions received, making the database more mature and error-free. As the IG PAS Data Portal is still under development, it was rigorously monitored in search of technical and structural deficiencies. Based on the experiences of data steward and users, several new features have been proposed and metadata standards have been provided to enhance data management services and standardise databases.

The data of IG PAS are open and made available free of charge for non-commercial purposes on the basis of the applicable laws on the provision of data financed from public funds. If the data is used by external entities, the data source should be provided in accordance with the guidelines contained in the metadata of the IG PAS Data Portal. The Data Portal stores 51 publicly available datasets and 21 projects (as of March 11, 2022). These numbers are constantly increasing as the process of adding new data is not complete.

The data steward provides researchers with consultations and support in managing, storing, and handling data and metadata throughout the entire data lifecycle. Additionally, he deals with the operation, monitoring, development, control and maintenance of IG PAS databases, including IG PAS Data Portal. The data steward is also involved in defining data management policies and standards in order to create more consistent, uniform and user-friendly databases according to commonly used data conventions and formats. The recent result of this task was the creation of a new database under the OPeNDAP protocol with all its features, including easy access and management of NetCDF files, for polar research datasets. The data in this database is in accordance with ACDD and CF conventions. To facilitate the addition of datasets to the IG PAS Data Portal, a new, more detailed instruction was prepared in one document. The data steward assists with the process of obtaining DOI numbers. This aspect is very important as datasets with these permanently assigned identifiers enable accurate and efficient data localization, easy citation tracking, discovery by other researchers, facilitate multiple reuse, and serve as references. Additionally, the data steward prepared an easy-to-fill template for obtaining a DOI number.

3.5 Projects / commercial agreements

Iceland Liechtenstein Norway grants	3 project
HORYZONT 2020	6 projects
European Commission	5 projects
Ministry of Science and Higher Education, Republic of Poland	23 projects
NAWA Narodowa Agencja Wymiany Akademickiej	5 projects
National Science Centre Poland	37 projects
Ośrodek Przetwarzania Informacji Państwowy Instytut Badawczy	3 projects
The Research Council of Norway	1 projects
SIOS Svalbard Integrated Arctic Earth Observing System	5 projects
PASIFIC	1 project
Narodowe Centrum Badań i Rozwoju	2 projects
Commercial agreements	5 projects

3.6 Polish polar stations

Polish Polar Station Hornsund

The Polish Polar Station Hornsund, named after prof. Stanisław Siedlecki, is a modern interdisciplinary 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. Every year, Polar Expedition to Hornsund Station is organized (photo by M. Moskalik).

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. After 40 years, the 4th Polish Antarctic Research Expedition to Dobrowolski Station started on November 10, 2021, from the port in Bremerhaven, in which Prof. Marek Lewandowski, Prof. Monika A. Kusiak, Dr Adam Nawrot, and Prof. Wojciech Miloch participated (photo by 4th PARE).

4. DEPARTMENT OF SEISMOLOGY

Łukasz Rudziński

4.1 About the Department

Department of Seismology is involved in the three main scientific fields which are focused on Anthropogenic and Natural Geohazard, Geosystem Processes and, to a lesser extent, Polar Regions. 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 (RTS), 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 topics last year concerned the role of water in seismogenic processes of: (i) RTS and (ii) geothermal production. The analysis of tectonic seismic activity in Mexico was also in the spotlight of Departmental scientific activities. RTS main research was dealing with seasonal variations of seismicity and its influence on seismic hazard in the vicinity of Song Tranh2 reservoir in Vietnam. It was found that in the dry season, a tremor of magnitude 3.5 or stronger is almost three times more likely to occur than in the rainy season. It was also proved that during one year gap in the filling of reservoir nearly twice as much seismic activity was observed and a significantly higher seismic hazard was determined during this period compared to the time before the reservoir was emptied and after it was refilled. Another research in RTS field was related with developing automatic detection algorithm using artificial neural network for weak seismicity in the area of a Lai Chau reservoir in the Northern Vietnam.

The role of fluids was also studied in The Geysers geothermal field (USA). Mutliplet identification and localization allowed to determine that the majority of multiple events occur along N-S oriented planar structure interpreted as a fault plane. Other multiplet events are distributed along structures interpreted as fractures, forming together a system of interconnected cracks enabling fluid migration. It was revealed that spatial and temporal analysis of multiplets can be used for identification and characterization of dominant fluid migration paths.

Kinematic and dynamic parameters of the seismic events preceding the Chiapas M8.2 earthquake were studied. Major tectonic seismicity research is based on the rule that no correlation between the time and location of an earthquake, and the magnitude also implies no correlation between any quantity defined solely by time and location and any quantity defined solely by magnitude. While studying the seismicity preceding the Chiapas earthquake results contrary to this "iron rule" were obtained. The obtained result is paramount for seismic process modelling and seismic hazards analysis.

Similarly as in previous years, the Department of Seismology was also active in EPOS Program. The Department is strongly involved in the consortium EPOS Thematic Core Service Anthropogenic Hazards (TCS AH) which is currently led by Prof. S. Lasocki. In 2021, Institute of Geophysics PAS, together with two other Polish institutes involved in TCS AH, by the decision of the Polish Minister of Education and Science, received funding for their activities within the EPOS TCS AH consortium. The development of the TCS AH infrastructure was supported within the following projects: EPOS SP (H2020), EPOS PL, and EPOS PL+.

4.2 Personnel

Head of the Department

Łukasz Rudziński (Associate Professor)

Professors
Stanisław Lasocki (Consortium EPOS TCS AH Director)
Beata Orlecka-Sikora (Director of the IG PAS)

Assistant Professors
Maria Kozłowska
Grzegorz Lizurek
Taghi Shirzad

Research Assistants
Alicja Caputa
Monika Staszek

Geophysicists
Janusz Mirek
Dorota Olszewska
Jan Wiszniowski

Electronics Engineer
Mieczysław Rekowski

Electronics Technician
Mariusz Chmielewski

Technicians
Izabela Dobrzycka
Kaj Michałowski
Beata Plesiewicz
Dominika Wenc

Technical Project Manager
Michał Lelonek (Consortium EPOS TCS AH)

Executive Office Manager
Anna Leśnodorska (Consortium EPOS TCS AH)

PhD Students of the Geoplanet Doctoral School
Jakub Kokowski, Poland; Łukasz Rudziński – PhD supervisor
Izabela Nowaczyńska, Poland; Grzegorz Lizurek – PhD supervisor
Anna Tymińska, Poland; Grzegorz Lizurek – PhD supervisor

4.3 Main research projects

- TCS AH Thematic Core Services Anthropogenic Hazard, S. Lasocki, Minister of Education and Science, 2021–2023;
- EPOS SP, B. Orlecka-Sikora, H2020, 2020–2023;
- EPOS PL, D. Olszewska, POIR, OPI, 2016–2022;
- EPOS PL+ (Task 2), Ł. Rudziński, POIR, OPI, 2019–2023;
- Initialization and development of anthropogenic seismic processes induced by artificial surface reservoirs, G. Lizurek, NCN, 06.2018–05.2022 (extended due the pandemic situation).

4.4 Instruments and facilities

Equipment

SEISMIC NETWORKS:

- Polish Seismological Network PLSN – the main regional seismological network in Poland. The network consists of eight very broad-band Streckeisen STS2 seismometers, seven in Poland and one in Hornsund. The network is a backbone system for seismological observation for both natural and induced seismicity. It also supports the IG PAS cooperation with local and regional authorities as well as governmental agencies and industrial partners. The data are open and available within EPOS seismological services;
- LUMINEOS – local monitoring of the mining – induced seismicity in Legnica–Głogów Copper District: 17 broadband (5s) seismometers and 10 strong motion instruments. Data are open and available within EPOS TCS AH EPISODES platform;
- BOIS – local monitoring of the seismicity induced by mining in Lubelski Węgiel Bogdanka colliery: 12 broadband (5s) seismometers, the network is directly connected with B+R project for Lubelski Węgiel Bogdanka S.A. Part of the data are already available within EPOS TCS AH EPISODES platform;
- SENTINELS – local monitoring of the induced seismicity around Czorsztyn–Niedzica artificial water reservoir: 10 broadband (5s) seismometers. Data are open and available within EPOS TCS AH EPISODES platform;
- Lai Chau –artificial water reservoir in Vietnam network cooperated with Institute of Geophysics Vietnamese Academy of Science and Technology: 5 broadband seismometers (belonging to IG PAS) and 5 broadband seismometers (belonging to IG VAST). Data are available within EPOS TCS AH EPISODES platform;
- Geodynamic monitoring of Poland – the network for monitoring of the natural seismicity in Poland: 23 mobile stations supported by PLSN, the network is directly connected with B+R project for the Polish Geological Institute – National Research Institute (PGI-NRI);
- PGE EJ1 – the interdepartmental project involved in seismic monitoring of potential nuclear power plant (NPP) site in northern Poland in cooperation with Polskie Elektrownie Jądrowe Sp. z o.o. The project deals with local seismic activity as well as regional earthquakes. It is also supported by PLSN network.

INFRASTRUCTURE BUILDING:

Thematic Core Service Anthropogenic Hazards (TCS AH) Consortium.

Since 2019, the Institute of Geophysics PAS and 12[1] European research, industry, and private sector institutions have formed the Consortium of Thematic Core Service Anthropogenic Hazards (EPOS TCS AH). 2021 was the second year of the 5-year period IG PAS acting as a hosting institution and Professor Stanisław Lasocki in the EPOS TCS AH Director role.

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 EPISODES https://tcs.ah-epos.eu/ by integrating new episodes,

[1]University of Science and Technology – Academic Computer Centre "Cyfronet" (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), Central Mining Institute (PL), Polish Mining Group (PL), Drobot Popławski Przybyłowicz Liszka-Gronek Radcowie Prawni Spółka Partnerska (PL).

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.

In the past years since 2013, most of the TCS AH activities have been carried out within national and international projects like: IS EPOS, SHEER, EPOS PL, EPOS PL+, EPOS IP, SERA, S4CE, EPOS SP, etc.

In 2021, the TCS AH Consortium signed a Multi-year Collaboration Agreement (2021–2023) with EPOS ERIC for co-financing TCS AH activities connected with Governance and Coordination, Integration of TCS AH infrastructure with central EPOS ERIC hub ICS, and Promotion & Dissemination.

In 2021, Institute of Geophysics PAS, Academic Computer Centre Cyfronet AGH, and the Central Mining Institute, by the decision of the Polish Minister of Education and Science, received funding for their activities within the EPOS TCS AH international consortium. The decision of the Minister is a response to the application for funding for the project "TCS AH Thematic Core Services Anthropogenic Hazard", submitted within the programme "Support for participation of Polish scientific teams in international research infrastructure projects". The consortium received funding for 2021–2023 for over 4 million PLN. Polish project TCS AH is also led by IG PAS and personally by Professor Stanisław Lasocki.

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 are available on the EPISODES Platform (http://tcs.ah-epos.eu/). Additionally, in cooperation with the Institute of Biochemistry and Biophysics PAS, IG PAS started observation in Arctowski Antarctic base using both very broad-band seismometer and accelerometer.

In 2021, IS EPOS Platform was rebranded to EPISODES Platform. The EPISODES e-platform commonly owned by IG PAS and Academic Computer Center Cyfronet AGH, whose concept was designed in the Department of Seismology, is a gateway for data and research

applications related to anthropogenic hazards. Data is stored in data nodes as metadata, applications, and AAAI, and presented on the platform. There are two data nodes linked to the platform: the first one in IG PAS, managed by the Department of Seismology, and the second managed by EOST located in Strasbourg. Currently, 32 out of 37 datasets called episodes available on the EPISODES platform are stored in the Polish e-Node. The current number of applications is 67. Two new language versions were successfully introduced in 2021 – Polish and French.

4.5 Seminars and teaching

Seminars and lecture

S. Lasocki, Scientist's ABC: How to successfully apply for the financing of research projects as well as present and publish scientific research results, GEOPLANET Doctoral School, Poland, Lecture

B. Orlecka-Sikora, Anthropogenic seismicity, GEOPLANET Doctoral School, Poland, Lecture

B. Orlecka-Sikora, Anthropogenic seismicity, International Environmental Doctoral School, Poland, Lecture

G. Lizurek, Introduction to Seismology, GEOPLANET Doctoral School, Poland, Lecture

G. Lizurek, Introduction to Seismology, International Environmental Doctoral School, Poland, Lecture

Ł. Rudziński, Data processing in Seismology, International Environmental Doctoral School, Poland, Lecture

Ł. Rudziński, Seismological Data, GEOPLANET Doctoral School, Poland, Lecture

A. Leśnodorska, V4 Training, Biuro Promocji Nauki PolSCA PAN, Belgium, Training

Teaching

T. Shirzad, M. Rezaei, Crustal velocity structure study in NE Iran (Khorasan) using Rayleigh wave tomography, Department of Physics, School of Sciences, Ferdowsi University of Mashhad, Mashhad, Iran

Ł. Rudziński (member of Examining Board), Anna Sidiropoulou, Contribution to the better understanding of physical processes associated with microseismicity, Aristotle University of Thessaloniki, School of Geology, Department of Geophysics, Thessaloniki, Greece

S. Lasocki, E. Battimelli, Methodologies for environmental risks assessment related to the exploitation of energy geo-resources, Università degli Studi di Salerno, Salerno, Italy

Visiting scientists

Andrzej Kijko, University of Pretoria, Pretoria, Republic of South Aftrica, 06–17.09.2021

Aderson Farias do Nascimento, Federal University of Rio Grande do Norte, Natal, Brasil, 02–12.11.2021

4.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- S. Lasocki, Thematic Core Service Anthropogenic Hazards (TCS AH) Workshop, TCS AH Research Infrastructures and Use Cases for and by the Induced Seismicity Community, Online, 16–17.06.2021, Oral, Workshop;

- S. Lasocki, Ł. Rudziński, A.K. Tokarski, B. Orlecka-Sikora, Joint Scientific Assembly IAGA-IASPEI 2021, A seismic event three years after hydrofracturing in Wysin, Poland, Online, 21–21.08.2021, Conference;
- S. Lasocki, V. Karakostas, E. Papadimitriou, F. R. Zuniga, Joint Scientific Assembly IAGA-IASPEI 2021, Precursory clustering of seismicity in a parameter space before the M8.2 Chiapas, Mexico, 2017 earthquake, Online, 21–21.08.2021, Conference;
- S. Lasocki, GEODAYS event by Pôle AVENIA, EPOS Thematic Core Service Anthropogenic Hazards: A step-change in tackling challenges of hazards associated with the exploitation of georesources, Online, 22–24.06.2021, Conference;
- G. Lizurek, K. Leptokaropoulos, J. Wiszniowski, I. Nowaczyńska, N.V. Giang, B. Plesiewicz, D.Q. Van, EGU General Assembly 2021, Seasonal trends of reservoir-triggered seismicity in Song Tranh 2 reservoir, Vietnam, Vienna, Austria, 19–30.04.2021, Conference;
- G. Lizurek, K. Leptokaropoulos, J. Wiszniowski, I. Nowaczyńska, N.V. Giang, B. Plesiewicz, D.Q. Van, Joint Scientific Assembly IAGA-IASPEI 2021, Influence of a gap in the filling of reservoir on seismic activity and hazard parameters in Song Tranh2 reservoir vicinity (Vietnam), Online, 21–21.08.2021, Conference;
- G. Lizurek, K. Leptokaropoulos, N.V. Giang, I. Nowaczyńska, B. Plesiewicz, D.Q. Van, A. Tymińska, AGU Fall Meeting 2021 Influence of gap in the filling of reservoir on seismic activity increase and seasonal seismic activity in reservoir triggered seismicity in Song Tranh2 (Vietnam) lake area, New Orleans, USA, Online, 13–17.12.2021, Conference;
- I. Nowaczyńska, G. Lizurek, B. Plesiewicz, J. Wiszniowski, EGU General Assembly 2021, Seasonal stress inversion trends of RTS in Song Tranh2 reservoir, Vietnam, Vienna, Austria, 19–30.04.2021, Conference;
- B. Orlecka-Sikora, Ł. Rudziński, G. Lizurek, D. Olszewska, T. Shirzad, Joint Scientific Assembly IAGA-IASPEI 2021, Slow slip-driven seismicity triggered by the water-reservoir impoundment, Online, 21–21.08.2021, Conference;
- A. Tymińska, G. Lizurek, EGU General Assembly 2021, Reliability tests of moment tensor inversion of anthropogenic seismicity, Vienna, Austria, 19–30.04.2021, Conference;
- T. Shirzad, S. Lasocki, B. Orlecka-Sikora, EGU General Assembly 2021, An application of induced event interferometry approach at The Geysers Geothermal Field, California, USA, Vienna, Austria, 19–30.04.2021, Conference;
- N. Shakeri, T. Shirzad, S. Ashkpour Motlagh, S. Norouzi, EGU General Assembly 2021, Shallow Crustal Structure in the DehDasht Region (SW Iran) from Ambient Seismic Noise Tomography, Vienna, Austria, 19–30.04.2021, Conference;
- M. Rezaei, T. Shirzad, EGU General Assembly 2021 Crustal structure of Khorasan (E-SE Iran) using the Rayleigh wave tomography, Vienna, Austria, 19–30.04.2021, Conference;
- T. Shirzad, B. Orlecka-Sikora, AGU Fall Meeting 2021, Velocity Structure of the Song Trahn 2 reservoir in Vietnam from first arrival P-wave, New Orleans, USA, Online, 13–17.12.2021, Conference;
- M. Rezaei, T. Shirzad, AGU Fall Meeting 2021, Crustal Structure of the Khorasan, NE Iran, Using Rayleigh Wave Inversion, New Orleans, USA, Online, 13–17.12.2021, Conference;
- M. Kazemnia, T. Shirzad, N. Shakeri, S. Norouzi, S. Ashkpour Motlagh, AGU Fall Meeting 2021, Shallow crustal model of the DehDasht in Zagros, Iran, using classical Rayleigh wave tomography, New Orleans, USA, Online, 13–17.12.2021, Conference.

4.7 Publications

ARTICLES

Caputa, A., **Ł. Rudziński**, et al. (2021), How to assess the moment tensor inversion resolution for mining induced seismicity: A case study for the Rudna mine, Poland, *Front. Earth Sci.* **9**, 671207, DOI: 10.3389/feart.2021.671207.

Cielesta, S., **B. Orlecka-Sikora**, et al. (2021), Rotation of the stress tensor in a westerly granite sample during the triaxial compression test, *Geotech. Geol. Eng.* **40**, 2455–2474, DOI: 10.1007/s10706-021-02038-w.

Kozłowska, M., et al., **D. Olszewska** (2021), On the aftershock productivity in mining-induced seismicity—insight into seismicity of Rudna copper ore mine, Poland, *Geophys. J. Int*. **225**, 2, 1258–1270, DOI: 10.1093/gji/ggaa613.

Kozłowska, M., **B. Orlecka-Sikora**, et al., **Ł. Rudziński** (2021), 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**, 1, 409–423, DOI: 10.1785/0120200111.

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Rudziński, Ł., **S. Lasocki**, **B. Orlecka-Sikora**, **J. Wiszniowski**, **D. Olszewska**, **J. Kokowski**, and **J. Mirek** (2021), Integrating data under the European Plate Observing System from the regional and selected local seismic networks in Poland, *Seismol. Res. Lett*. **92**, 3, 1717–1725, DOI: 10.1785/0220200354.

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5. DEPARTMENT OF ATMOSPHERIC PHYSICS

Aleksander Pietruczuk

5.1 About the Department

The Department's activities focus on monitoring and modelling of a wide range of physical atmospheric parameters, including columnar amount of ozone and its vertical distribution, atmospheric electricity and lightning activity, concentration and characteristics of airborne aerosols, UV spectra, trace gases concentrations, as well as dynamics and atmosphere-ocean interaction processes in the tropics. These studies focus on different parts of the atmosphere: surface layer, troposphere, stratosphere, and ionosphere. The common aim of these activities is to determine and predict the variability of atmospheric parameters and to identify the drivers of this variability on various time scales (from days up to decades). The Department contains four internal groups: **Atmospheric Aerosols (AA)**, **Atmospheric Electricity (AE)**, **Ozone** and **UV (O3UV)**, and **Tropical Dynamics (TD)**. These groups focused on the following topics in 2021:

- Examination of the vertical structure of aerosols and impact of absorbing particles on the height of planetary boundary layer (AA);
- Influence of aerosol layering in the free troposphere on surface UV radiation. Identification of layer geometries that correspond to the differences observed 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);
- A short campaign in Belsk to close LIDAR derived extinction profiles 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), and preparation for UAV observation of the diurnal evolution of boundary layer temperature and humidity during planned TerraMaris experiment (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);
- 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);
- Total column ozone measurements by the Dobson spectrophotometer at Central Geophysical Observatory in Belsk (from 1963), the total of ~120,000 intra-day observations, were homogenized. For the first time, the short-term variability (up to 24h) in the long-term ozone data was investigated. Climate changes did not intensify the ozone variability on this timescale. This is also confirmed by satellite observations of ozone over Belsk, which allows for the study of such variability of ozone on a global scale (O3UV);
- Estimations of the daily amount of skin-synthesized vitamin D and erythemal doses in teenagers after the first COVID-19 lockdown in 2020 (May–September) – on the basis on observations gathered in BRITEC project by children aged 12–18 (O3UV);
- Developing a novel method for measuring the vertical ozone profile from ground-based Brewer spectrophotomer measurements (O3UV);

- Investigation of lower tropospheric, upper ocean and cloud structure over tropical Atlantic during EUREC4A campaign in Jan/Feb 2020 (TD);
- Extreme precipitation and floods variability over the Maritime Continent in response to large scale forcing at sub-seasonal time scales (TD);
- Tropospheric and lower-stratospheric winds structure and variability over Sumatra (Indonesia) and feedbacks with local environment and large-scale meteorological conditions (TD);
- Examination of the vertical structure of aerosols and impact of absorbing particles on the height of planetary boundary layer (AA);
- Recognition of the influence of the vertical structure of aerosols on the intensity of the Earth's electric field during field campaign in Polish Polar Station Hornsund (Svalbard).

5.2 Personnel

Head of the Department
Aleksander Pietruczuk
Associate Professor

Professor
Janusz Krzyścin

Associate Professors
Janusz Jarosławski
Jacek Kamiński

Assistant Professors
Dariusz Baranowski
Agnieszka Czerwińska
Jakub Guzikowski
Daniel Kępski
Magdalena Kossakowska
Marek Kubicki
Michał Posyniak
Artur Szkop
Jose Tacza

Research Assistants
Anna Odzimek
Izabela Pawlak

Technical Assistants
Piotr Barański
Anna Głowacka
Magdalena Morawska
Alicja Płacik
Dorota Sawicka
Piotr Sobolewski
Jakub Wink

PhD Students

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

5.3 Main research projects

- Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems, A. Odzimek, COST, 2016–2021;
- Impact of the aerosols optical properties on the surface UV and photochemical smog, A. Pietruczuk – coordinator J. Krzyścin, A. Szkop, J. Wink, W. Wojtak, National Science Centre, Poland, 2018–2021;
- Impact of absorbing aerosols on the planetary boundary layer height, M. Posyniak, National Science Centre, Poland, 2016–2021;
- Recognition of the aerosols vertical structure and its influence on the Earth electric field intensity – pilot studies, D. Kępski, National Science Centre "Miniatura", Poland, 2021;
- Multi-station analysis of solar effects in the ground-level atmospheric electric field, J. Tacza, A. Odzimek, National Agency for Academic Exchange, Ulam Program, Poland, 2020–2022;
- Dopełnienie profili pionowych aerozoli atmosferycznych przy użyciu pomiarów in-situ na powierzchni ziemi, A. Szkop, National Science Centre "Preludium", Poland, 2018–2021;
- Wpływ procesów wieloskalowych na powstawanie ekstremalnych opadów w tropikach, D. Baranowski, B. Latos, W. Szkółka, National Science Centre "Opus", Poland, 2020–2022;
- Ekstrema pogodowe: powodzie i susze. W jaki sposób wielkoskalowa cyrkulacja atmosferyczna oraz para wodna nad Wschodnim Oceanem Indyjskim ze soba oddziałują?, B. Latos, D. Baranowski, National Science Centre "Preludium", Poland, 2021–2024;
- PROM, B. Latos, National Agency for Academic Exchange, Poland, 2021;
- Monitoring of Total Ozone Amount in the Atmosphere and UV-B Radiation at Belsk Observatory in 2021–2022, J. Jarosławski, Chief Inspectorate of Environment Protection, 2021–2022;
- Technologia wytwarzania innowacyjnych samoczyszczacych się prefabrykowanych elementów elewacyjnych i nawierzchniowych poprawiających jakość powietrza, J. Jarosławski, National Centre for Research and Development, Poland, 2021–2023.

5.4 Instruments and facilities

Equipment

- Two medium sized UAVs (drones) equiped with SparvIO dataloggers and a set of lightweight detectors, including dual-redundant pHT sensors, optical particle counters (alphasense N3 OPCs), and Trisonica sonic anemometers;
- Particle counters SPS30 (7 psc.), PM 2.5, PM10 concentration and aerosol size distribution;
- .High frequency ocean temperature data loggers: SBE 57 and RBR Solo T.

Laboratory

- Thunderstorm electricity;
- Three VLF/LF stations for the recordings of the electric field for the purpose of detection and classication of different types of lightning discharges in the Warsaw region – part of Local Lightning Detection Network installed in 2009.

5.5 Seminars and teaching

Seminar and lecture

A. Czerwińska, Biologicznie czynne promieniowanie UV, University of Warsaw, Department of Physics, Warsaw, 19.05.2021, Seminar

B. Latos, Equatorial waves triggering extreme rainfall and floods in southwest Sulawesi, Indonesia Centre National de Recherches Météorologiques, Toulouse, France, Toulouse, 02.09.2021, Invited Lecture

Fellowships and visiting scientists

Jose Tacza (fellowship), NAWA Polish National Agency for Academic Exchange, Peru, 06.07.2020–05.07.2022.

5.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- P. Barański, G. Karnas, G. Maslowski, 35th International Conference on Lightning Protection (ICLP 2021), Preliminary breakdown electricic field signatures of positive ground flash incidents recorded during 2019 thunderstorm season in Warsaw region, online/Colombo Sri Lanka, 20.09.2021, Oral, Conference;
- M. Kubicki, J. Konarski, W. Gajda, XXXVIII International Polar Symposium "Environmental changes in polar regions: New problems – new solutions", Thunderstorm observation in Polish Polar Station in Hornsund (770N, 150E). Present infrastructure and further plans, Toruń, Poland, 19.11.2021, Oral, Symposium;
- A. Odzimek, P. Barański, M. Kubicki, J. Berliński, D. Jasinkiewicz, European Geophysical Union General Assembly 2021, Ground-level atmospheric electricity of mid-latitude Nimbostratus and Stratus cloud at Świder station, Poland, Online, 29.04.2021, Oral, Conference;
- J. Tacza, A. Odzimek, M. Kubicki, J.-P. Raulin, European Geophysical Union General Assembly, Effects of energetic particles on the potential gradient measurements at different latitudes, Online, 29.04.2021, Oral; Conference;
- D. Kępski, M. Kubicki, XXXVIII International Polar Symposium "Environmental changes in polar regions: New problems – new solutions", Thunderstorm activity in high latitudes registered on manned WMO weather stations in years 2000–2019, Toruń, Poland, 19.11.2021, Oral, Symposium;
- A. Czerwińska, J. Krzyścin, Quadrennial Ozone Symposium 2021 (QOS), Climatological aspects of melanoma incidence increase in Europe, Online, 08.10.2021, Oral, Symposium;
- J. Krzyścin, B. Rajewska-Więch, Quadrennial Ozone Symposium 2021 (QOS), Long-term variability (1980–2020) of total column ozone in Northern Hemisphere from Reanalyses (MSR2, MERRA2, and ERa5) and a comparison with the Dobson data taken at Belsk (51.84N, 20.79E), Poland, Online, 04.10.2021, Poster, Symposium;
- B. Rajewska-Więch, J. Krzyścin, J. Jarosławski, Quadrennial Ozone Symposium 2021 (QOS), The reevaluated intraday total column ozone series from the Dobson spectro-photometer No. 84 operating at Belsk (51.84N, 20.79E), Poland, since March 23,1963, Online, 09.10.2021, Poster, Symposium;
- J. Jarosławski, J. Krzyścin, B. Rajewska-Więch, Quadrennial Ozone Symposium 2021 (QOS), Comparison of the Ozone Vertical Profiles based on the Umkehr Observations by Collocated the Dobson and Brewer Spectro-photometers at Belsk, Poland, for the period 2011–2016, Online, 09.10.2021, Poster, Symposium;

- J. Krzyścin, 21 výroční zasedání Polární sekce České geografické společnosti, České Skalici, On the recovery of the Northern Hemisphere total column ozone, Face-to-face, 14.10.2021, Oral, Workshop;
- P. Sobolewski, M. Posyniak, J. Krzyścin, 21 výroční zasedání Polární sekce České geografické společnosti, České Skalici, Long-term UV Observations at the Polish Polar Station Hornsund in the period 2005–2021 (17 years), Face-to-face, 14.10.2021, Oral, Workshop;
- A. Fernandes, A. Szkop, A. Pietruczuk, European Aerosol Conference (EAC) 2021, Characterization and profiling of the anthropogenic aerosols in Europe during the COVID-19 ACTRIS/EARLINET campaign, Online, 30.08.2021, Poster;
- S.P. Malinowski, W. Kumala, J. Nowak, S. Król, R. Grosz, M. Posyniak, T. Lachlan-Cope, A. Blyth, S. Boeing, European Geophysical Union General Assembly 2021, Centimeter-scale-resolution airborne temperature measurements in clouds and in marine surface layer during EUREC4A, Online, 30.04.2021, Oral, Conference;
- B. Latos, T. Lefort, M.K. Flatau, P.J. Flatau, D.B. Baranowski, W. Szkółka, P. Peyrillé, European Geophysical Union General Assembly 2021, Application of SpectralWeather to prediction of flood and extreme rain events in the Maritime Continent, Online, 27.04.2021, Oral, Conference;
- B. Latos, T. Lefort, M.K. Flatau, P.J. Flatau, D.B. Baranowski, P. Peyrillé, 34th Conference on Hurricanes and Tropical Meteorology, On the Role of Tropical Waves in Sulawesi Flood of January 22, 2019: A Multi-Scale Interaction Perspective, Online, 12.05.2021, Oral, Conference;
- D.B. Baranowski, M.K. Flatau, P.J. Flatau, 34th Conference on Hurricanes and Tropical Meteorology, Convectively Coupled Kelvin Waves Contribution to Hazardous Weather in Sumatra, Online, 12.05.2021, Oral, Conference;
- W. Szkółka, D.B. Baranowski, M.K. Flatau, P.J. Flatau, D. Karnawati, K. Barabasz, M. Labuz, J. Schmidt, J.A.I. Paski, Marzuki, 34th Conference on Hurricanes and Tropical Meteorology, Upper Level Forcing of Interaction between Convectively Coupled Kelvin Waves and Local Diurnal Cycle over Sumatra, Online, 12.05.2021, Oral, Conference.

5.7 Publications

ARTICLES

Azaneu, M., et al., **D.B. Baranowski** (2021), Subsurface oceanic structure associated with atmospheric convectively coupled equatorial Kelvin waves in the eastern Indian Ocean, *J. Geophys. Res. – Oceans* **126**, 7, e2021JC017171, DOI: 10.1029/2021JC017171.

Stevens, B., et al., **D. Baranowski**, **M. Posyniak**, **W. Szkółka** (2021), EUREC^{4}A, *Earth Syst. Sci. Data* **13**, 8, 4067–4119, DOI: 10.5194/essd-13-4067-2021.

Czerwińska, A., et al. (2021), Estimations of the erythemal UV doses and the amount of the sun-synthesized vitamin D by adults during the cruise to Spitsbergen – polar measurement campaign (2–21 July 2017), *Atmosphere* **12**, 4, 474, DOI: 10.3390/atmos 12040474.

Fernandes, A., **A. Pietruczuk**, **A. Szkop**, and **J. Krzyścin** (2021), Aerosol layering in the free troposphere over the industrial city of Raciborz in southwest Poland and its influence on surface UV radiation, *Atmosphere* **12**, 7, 812, DOI: 10.3390/atmos12070812.

Kosmopoulos, P.G., et al., **J. Jarosławski** (2021), Real-time UV index retrieval in Europe using Earth observation-based techniques: system description and quality assessment, *Atmos. Meas. Tech*. **14**, 8, 5657–5699, DOI: 10.5194/amt-14-5657-2021.

Barbaro, E., et al., **D. Kępski**, B. Luks (2021), Measurement report: Spatial variations in ionic chemistry and water-stable isotopes in the snowpack on glaciers across Svalbard during the 2015–2016 snow accumulation season, *Atmos. Chem. Phys*. **21**, 4, 3163–3180, DOI: 10.5194/acp-21-3163-2021.

Krzyścin, J.W., **B. Rajewska-Więch**, and **J. Borkowski** (2021), Short-term variability of total column ozone from the Dobson spectrophotometer measurements at Belsk, Poland, in the period 23 March 1963 – 31 December 2019, *Tellus B: Chem. Phys. Meteorol.* **73**, 1, 1912958, DOI: 10.1080/16000889.2021.1912958.

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Narbutt, J., **J. Krzyścin**, **P. Sobolewski**, et al., **B. Rajewska-Więch** (2021), A Priori Estimation of the Narrow-Band UVB Phototherapy Outcome for Moderate-to-Severe Psoriasis Based on the Patients' Questionnaire and Blood Tests Using Random Forest Classifier, *Clin. Cosmet. Investig. Dermatol.* **14**, 253–259, DOI: 10.2147/CCID.S296604.

Kubicki, M., et al., **A. Odzimek** (2021), Nature of relationships between atmospheric electricity parameters at ground surface and air ionization on the basis of nuclear accidents in power plants and weapons tests, *Front. Earth Sci.* **9**, 647913, DOI: 10.3389/feart.2021.647913.

Burakowska, A., **M. Kubicki**, et al. (2021), Concentration of ^{7}Be, ^{210}Pb, ^{40}K, ^{137}Cs, ^{134}Cs radionuclides in the ground layer of the atmosphere in the polar (Hornsund, Spitsbergen) and mid-latitudes (Otwock–Świder, Poland) regions, *J. Environ. Radioactiv*. **240**, 106739, DOI: 10.1016/j.jenvrad.2021.106739.

Latos, B., et al., **D. Baranowski** (2021), Equatorial waves triggering extreme rainfall and floods in southwest Sulawesi, Indonesia, *Mon. Weather Rev*. **149**, 5, 1381–1401, DOI: 10.1175/MWR-D-20-0262.1.

Baldysz, Z., et al., **B. Latos**, **D.B. Baranowski** (2021), Interannual variability of the GNSS precipitable water vapor in the global tropics, *Atmosphere* **12**, 12, 1698, DOI: 10.3390/atmos12121698.

Fdez-Arroyabe, P., et al., **A. Odzimek** (2021), Glossary on atmospheric electricity and its effects on biology, *Int. J. Biometeorol*. **65**, 5–29, DOI: 10.1007/s00484-020-02013-9.

Hunting, E.R., et al., **A. Odzimek** (2021), Challenges in coupling atmospheric electricity with biological systems, *Int. J. Biometeorol*. **65**, 45–58, DOI: 10.1007/s00484-020-01960-7.

Michnowski, S., **A. Odzimek**, et al., **M. Kubicki** (2021), Review of relationships between solar wind and ground-level atmospheric electricity: Case studies from Hornsund, Spitsbergen, and Świder, Poland, *Surv. Geophys*. **42**, 3, 757–801, DOI: 10.1007/s10712-021-09639-3.

Pawlak, I. (2021), Statistical analysis of ozone weekend effect in the largest cities in Poland, *Earth Sci*. **10**, 6, 265–274, DOI: 10.11648/j.earth.20211006.12.

Posyniak, M.A., et al. (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.

Markowicz, K.M., et al., **M. Posyniak**, **J.W. Kamiński**, **A. Szkop**, **A. Pietruczuk** (2021), A decade of Poland-AOD Aerosol Research Network Observations, *Atmosphere* **12**, 12, 1583, DOI: 10.3390/atmos12121583.

Markowicz, K.M., et al., **M. Posyniak** (2021), A large reduction of direct aerosol cooling over Poland in the last decades, *Int. J. Climatol*. **42**, 7, 4129–4146, DOI: 10.1002/joc.7488.

Han, K.M., et al., G. Karasiński, **P. Sobolewski** (2021), Data assimilation of AOD and estimation of surface particulate matters over the Arctic, *Appl. Sci*. **11**, 4, 1959, DOI: 10.3390/app11041959.

Tacza, J., et al., **M. Kubicki**, **A. Odzimek** (2021), Measuring global signals in the potential gradient at high latitude sites, *Front. Earth Sci.* **8**, 614639, DOI: 10.3389/feart.2020.614639.

MONOGRAPHS

Kępski, D. (2021), The Influence of Topography and Vegetation on the Snow Cover in Tundra: Case Study from the Southern Spitsbergen Area, *Publs. Inst. Geoph. PAS* **438 (P-3)**, 131 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2021-041.

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Salzano, R., et al., **D. Kępski**, B. Luks (2021), Terrestrial photography applications on snow cover in Svalbard (PASSES). **In:** SESS Report 2020: The State of Environmental Science in Svalbard – An Annual Report, Svalbard Integrated Arctic Earth Observing System, 236–251, DOI: 10.5281/zenodo.4294084.

Odzimek, A., et al. (2021), Ocena aktywności burzowej w latach 2012–2017 na lotniskach kontrolowanych na terenie Polski na podstawie zobrazowań satelitarnych meteosat w produktach overshooting tops. **In:** M. Grzegorzewski (ed.), *Wykorzystanie Technik Nawigacyjnych w Lotnictwie. Część 1*, Lotnicza Akademia Wojskowa, 187–200 (in Polish).

6. DEPARTMENT OF LITHOSPHERIC RESEARCH

Tomasz Janik and Working Group[2]

6.1 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 2021, the work of the Department of Lithospheric Research focused on the continuation of the interpretation of materials collected in previous seismic experiments, both active and passive, such as **BASIC (UPPLAND)** – Fennoscandia; **AniMaLS** – Sudetes, and the Trans-European Suture Zone research projects included interpretation along the **TTZ-South** profile (Poland–Ukraine) and **BalTec** – South Baltic.

Since January 2021, in broad international cooperation, we have been continuing acquisition of the passive seismic data in the **PACASE** (Carpathian Mountains, Pannonian Basin) project, which will be completed in the middle of next year.

At the turn of July and August, we took part in a large **SHIELD'21** deep seismic sounding project in Ukraine.

Having their place in Central and Southeastern Europe, all these projects allow the structure of the Earth's crust to be investigated, and partly also the lower lithosphere along profile lines (two-dimensional models) or spatial (three-dimensional models). The data obtained along of seismic profiles new generation 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 surveys.

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.

An active part of the ocean bottom seismic experiment **KNIPAS** carried out over the Logachev Seamount at the ultraslow-spreading Knipovich Ridge in German (AWI) – Polish co-operation allowed us to acquire a net of six intersecting wide-angle reflection and refraction (WARR) profiles. The seismic crustal structure underneath a prominent volcanic centre of an ultraslow-spreading ridge was modelled along the profiles. A publication is in preparation after first reviews.

First manuscript based on local events recorded during passive part of the **KNIPAS** project was published in 2021. Results of these studies will broaden our understanding of the ocean-floor spreading mechanisms in the ultra-slow spreading mid-ocean ridges (e.g. Knipovich Ridge).

In collaboration with the University of Bergen and Hokkaido University, a deep seismic soundings were performed along the **KNIPSEIS** OBS profile (~280 km), crossing the Knipo-

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

vich 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). The seismic crustal structure was jointly modelled along the **KNIPSEIS** profile and along the previously realized German (AWI) 20090200 profile. It provides information on the seismic structure of the Knipovich Ridge as well as oceanic and continental crust in the transition zone. The interpretation works are ongoing.

6.2 Personnel

Head of the Department
Tomasz Janik
Professor, NSL1 leader

Professor
Aleksander Guterch

Associate Professor
Piotr Środa

Assistant Professors
Somayeh Abdollahi
Wojciech Czuba, NSL2 leader

Research Assistants
Weronika Materkowska
Dariusz Wójcik

Technical ssistants
Monika Bociarska
Arkadiusz Tokarz

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

6.3 Main research projects

- Structure of the Knipovich Ridge based on seismic investigations – KNIPSEIS, W. Czuba, National Science Centre "Opus", 2018–2022;
- Passive seismic studies of the lithosphere and asthenosphere of the Southern Poland (Carpathian area), W. Czuba, National Science Centre "Opus", 2020–2024;
- Deep Seismic Soundings Profile TTZ-South, T. Janik, National Science Centre "Harmonia", 2017–2022;
- Determination of the seismic anisotropy of the lithosphere in the Lower Silesia area, P. Środa, National Science Centre "Opus", 2017–2022;
- EPOS – European Plate Observing System (EPOS-PL), Task 7, W. Czuba, Operational Programme Smart Growth, 2014–2020, Co-financing from European Regional Development Fund, 2017-2022.

6.4 Instruments and facilities

Equipment

- 80 × 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,
- 11 × Güralp CMG-DM24S3EAM broadband seismic stations with CMG-6T 30 s seismometers,
- 1 × Ocean Bottom Seismometers, semi-broadband (Güralp),
- 20 × L-4C-3D 1 Hz seismometers,
- 6 × timing system devices (for measuring times at shooting points).

6.5 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- D. Wójcik, W. Czuba, T. Janik, AGU Fall Meeting, Structure of the Knipovich Ridge based on seismic investigation. Projects KNIPAS and KNIPSEIS, New Orleans, LA, USA and online everywhere, 13–17.12.2021, Poster, Conference;
- T. Janik, W. Czuba., P. Środa, D. Wójcik, AGU Fall Meeting, TTZ-South deep seismic profile from western Ukraine to southeastern Poland – crustal structure along the Teisseyre–Tornquist Zone at the transition from Sarmatia to Fennoscandia segments of the East European Craton and into the Palaeozoic Platform, New Orleans, LA, USA and online everywhere, 13–17.12.2021, Poster, Conference;
- T. Ninivaggi et al., W. Czuba, AGU Fall Meeting, Nature and origin of an undetected seismic phase in waveforms of southern Tyrrhenian (Italy) deep earthquakes, New Orleans, LA, USA and online everywhere, 13–17.12.2021, Poster, Conference;
- W. Czuba, T. Janik, P. Środa, S. Abdollahi, 5th AlpArray Scientific Meeting, n/a, Prague, Czech Republic and online, 09–12.11.2021, n/a, Meeting;
- W. Czuba, T. Janik, P. Środa, S. Abdollahi, M. Bociarska, W. Materkowska, D. Wójcik, J. Rewers, ORFEUS Annual Observatory, Meeting and Workshop, n/a, Online, 08–09.11.2021, n/a, Meeting and Workshop;
- W. Czuba, T. Janik, P. Środa, AdriaArray Seismic Network Meeting, n/a, Online, 12.05.2021, n/a, Meeting;
- J. Rewers, P. Środa, IASPEI 2021, Upper mantle structure and anisotropy beneath Sudetes based on data from passive seismic experiment AniMaLS, Online, 08.2021, Oral, Conference.

6.6 Publications

ARTICLES

Bociarska, M., **J. Rewers**, **D. Wójcik**, **W. Materkowska**, **P. Środa**, et al., **T. Janik** (2021), Passive seismic experiment "AniMaLS" in the Polish Sudetes (NE Variscides), *Geosci. Instrum. Meth. Data Syst.* **10**, 2, 183–202, DOI: 10.5194/gi-10-183-2021.

Meier, M., et al., **W. Czuba**, **T. Janik** (2021), Segment-scale seismicity of the ultraslow spreading Knipovich Ridge, *Geochem. Geophys. Geosyst.* **22**, 2, e2020GC009375, DOI: 10.1029/2020GC009375.

Guterch, A., and **T. Janik** (2021), Marek Grad (1951–2020), *Prz. Geof.* **66**, 1–2, 85–92.

Janik, T., et al., **W. Czuba**, **P. Środa**, **D. Wójcik** (2021), TTZ-SOUTH seismic experiment, *Geophys. J*. **43**, 2, 28–44, DOI: 10.24028/gzh.v43i2.230189 (in Ukrainian).

Buntin, S., et al., M. Malinowski, **T. Janik** (2021), Long-lived Paleoproterozoic eclogitic lower crust, *Nat. Commun*. **12**, 6553, DOI: 10.1038/s41467-021-26878-5.

7. DEPARTMENT OF THEORETICAL GEOPHYSICS

Zbigniew Czechowski

7.1 About the Department

Scientific activity of Department of Theoretical Geophysics was concentrated on the following issues: seismic models and forecast, fracture processes described by DEM, fluid flows, time series analysis, stochastic models, monitoring of rotational effects.

Stochastic modeling of subduction zone seismicity and earthquake forecasting were studied. Assigning probabilities of earthquake occurrences within given time, space, and magnitude ranges, estimating expected return times of large earthquakes, and searching for large earthquake precursors, belonged to our tasks. To find the relation between plate interface characteristic, such as asperity distributions and structures, earthquake statistics and seismicity patterns, and to indicate large earthquake precursors in real world, we analyzed the long term seismicity in different regions, including Japan and South America subduction zones, as well as the Himalaya-Nepal collision zone. To this end, we combined some novel data science methods, including topological data analysis and stochastic geometry. The developed methods can be used for other complex, spatio-temporal geophysical processes.

Discrete Element Method (DEM) was applied to examine in a noninvasive manner the mechanical strength of industrial sandstones. Supervised machine learning was employed to look for dependencies in DEM huge result datasets aiming in reducing the number of simulations required for the calibration procedure.

On the other hand, DEM was used to study limitations of the fiber bundle model. Observed variation of the elastic energy stored in DEM samples not only clarified the capability of the fiber bundle methods but also shed new light on a complexity of breaking solid materials under mode I of fracturing.

The classic Lagrange long gravitational wave of a homogeneous incompressible fluid in a shallow canal with a corrugated bottom was considered. By using the asymptotic expansion method, the effective depth of a one-dimensional canal and the effective wave velocity was found. A flow in a two-dimensional tank with a corrugated bottom was also studied by this method.

Application of the multivariate Mahalanobis distance method to seismic data (Southern California earthquake catalogue, 1980–2020) enabled a new quantification of changes in the dynamics of the seismic process.

The stochastic discrete Langevin-type equation, which can describe p-order persistent processes, was introduced. The procedure of reconstruction of the equation from time series was proposed and tested on synthetic data. The approach was applied to hydrological data leading to the stochastic model of the phenomenon.

Analysis of intermediate field rotational seismograms obtained during mining works (excavations) allowed for a comparison of three different techniques of measurement: fiber optic gyro seismometers, horizontal pendulum rotational seismometers, and a net of seismometers.

7.2 Personnel

Head of the Department
Zbigniew Czechowski
Professor

Professor
Wojciech Dębski

Associate Professors
Włodzimierz Bielski
Piotr Senatorski

Assistant Professor
Piotr Klejment

Specialist
Krzysztof Teisseyre

PhD Student
Venkata Gangadhara Rao Kambala, India; Piotr Senatorski – PhD supervisor

7.3 Main research project

- DEM numerical modeling of the influence of Young's modulus and Poisson's ratio on the process of geomaterials fragmentation, Piotr Klejment, Computational Research Grant of supercomputer Cray XC40 "Okeanos", 2019–2021.

7.4 Seminars and teaching

Seminars and lectures

P. Klejment, „Introduction to Machine Learning", Lecture for PhD students from: Institute of Geophysics PAS, Institute of Oceanology PAS, Space Research Center, Nicolaus Copernicus, Astronomical Center PAS, Silesian University, Warsaw, Poland, 03–04.2021, Lecture (PhD students)

P. Klejment, „Enhancing datasets management with SQL", Lecture for PhD students from: Institute of Geophysics PAS, Institute of Oceanology PAS, Space Research Center, Nicolaus Copernicus Astronomical Center PAS, Warsaw, Poland, 11–12.2021, Lecture (PhD students)

W. Dębski, Time Reversal an efficient way of data analysis, Faculty of Mathematics, Informatics and Mechanics, Warsaw University, Warsaw, Poland, 14.01.2021, 08.02.2021, Seminar

W. Dębski, How nature speaks about imminent catastrophic failure – the DEM analysis, Institute of Fundamental Technological Research PAS, Warsaw, Poland, 08.03.2021, Seminar

W. Dębski, Inverse theory – a modern method of data analysis IGF PAN, GEOPLANET Center, Warsaw, Poland, 06.2021, Lecture

7.5 Meetings, workshops, conferences, and symposia

Presentation of the Department's member:

- K. Teisseyre, Polish contribution to the ocean science, and the marine environmental education. Conference of the UN Decade of Ocean Science for Sustainable Development (2021–2030); Earth. Is there a place for our grandchildren?, Sopot, Poland, 28.09.2021, Oral, Conference.

7.6 Publications

ARTICLES

Bielski, W., et al. (2021), Long gravity waves in a canal with a corrugated bottom in the asymptotic description, *J. Theor. Appl. Mech*. **59**, 3, 443–454, DOI: 10.15632/jtam-pl/138855.

Czechowski, Z. (2021), Discrete Langevin-type equation for *p*-order persistent time series and procedure of its reconstruction, *Chaos* **31**, 063102, DOI: 10.1063/5.0048598.

Matcharashvili, T., **Z. Czechowski**, et al. (2021), Changes in the dynamics of seismic process observed in the fixed time windows; case study for southern California 1980–2020, *Phys. Earth Planet. In*. **319**, 106783, DOI: 10.1016/j.pepi.2021.106783.

Dębski, W., and **P. Klejment** (2021), Earthquake physics beyond the linear fracture mechanics: a discrete approach, *Philos. Trans. Roy. Soc. A* **379**, 2196, DOI: 10.1098/rsta.2020.0132.

Dębski, W., et al. (2021), Criterion for imminent failure during loading—Discrete Element Method analysis, *Front. Phys*. **9**, 675309, DOI: 10.3389/fphy.2021.675309.

Klejment, P. (2021), Application of supervised machine learning as a method for identifying DEM contact law parameters, *Math. Biosci. Eng*. **18**, 6, 7490–7505, DOI: 10.3934/mbe.2021370.

Klejment, P., et al. (2021), Strength of industrial sandstones modelled with the Discrete Element Method, *Stud. Geotech. Mech*. **43**, 4, 346–365, DOI: 10.2478/sgem-2021-0020.

Teisseyre, K.P., et al. (2021), Study of rotational motions caused by multiple mining blasts recorded by different types of rotational seismometers, *Sensors* **21**, 12, 4120, DOI: 10.3390/s21124120.

Jaroszewicz, L.R., et al., **K.P. Teisseyre** (2021), A test performance of optical fibre sensors for real-time investigations of rotational seismic events: a case study in laboratory and field conditions, *Opto-Electron. Rev*. **29**, 4, 213–219, DOI: 10.24425/opelre.2021.140102.

8. DEPARTMENT OF HYDROLOGY AND HYDRODYNAMICS

Jarosław Napiórkowski

8.1 About the Department

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

- **Experimental studies:** Flume experiments on microplastics incipient motion were carried out in the Hydrodynamic Models Laboratory. Incipient motion conditions for two different types of plastic particles resting on a plastic mobile bed were determined, depending on their size and density. A second set of experiments modelled microplastic onset of transport on a gravel bed, revealing a more complex dependency on the quantity of plastics laying on the bed. Additional laboratory studies were conducted on the rheological properties of polysaccharide hydrocolloids and their effects on particle settling dynamics suggested that exopolymers found locally in the ocean may influence the sinking of marine particles such as minerals and microplastics. The results showed that the inner structure of model salt water with dispersed exopolymer gels affects sinking velocity, drag and orientation of solid particles, revealing that colloidal dispersions are more effective in retarding particle motion than particulate dispersions.
- **Modelling drought dynamics:** Continuation of research on drought dynamics within Polish–Chinese project HUMDROUGHT. This year the interactions between temperature changes and drought conditions were studied by statistical analyses of minimum temperature, consecutive days with temperature exceeding the 0ºC threshold value, the number of melting pulses in the winter season and the Standardized Evaporation Precipitation Index. Additionally, shifts in the onset of days with spring temperature and snow cover occurrence were analysed. A Mann–Kendall test was applied for the trend analysis. Studies have shown significant changes in thermal characteristics in the winter season over the past 70 years, affecting the moisture conditions in the Vistula basin. As a result of those changes, the Vistula Basin is more prone to droughts.
- **Estimating the risk of extreme events in rivers:** New methods of selection and aggregation of the probability distribution models of the maximum seasonal and annual flows estimated by the L-moments method were developed. The aggregation of the statistical models enabled the reduction of the models used for analysis without a decrease in accuracy of the estimation of the upper quantiles. A multi-criteria analysis of extreme rainfall conditions was carried out, covering summer periods without precipitation and periods with very heavy rainfall in the summer half-year in Upper Vistula Basin. This research complemented the hydro-meteorological characteristics of the region, showing a relationship between the longest sequences of days with no precipitation and periods of drought.
- **Vegetation dynamics in open channel flows:** Remote sensing for analysing the dynamics of riparian vegetation and changes of the morphology along the Italian River Po, using Landsat and Sentinel data. This application shown that it is possible to combine data having different spatiotemporal resolution to infer information on large scale changes, but also to evaluate the local effects of training works and river infrastructures. In addition, coherent structures were measured downstream of two patches of submerged vegetation in a lowland river to evaluate the effects of the vegetation on the local turbulence. The observed coherent structures were responsible for the majority of momentum transport and tended to vary in strength, length, and frequency with patch distance, height and plant physical characteristics.
- **Modelling lake surface temperature:** The air2water model is a widely used tool for the forecasting of lake water temperatures and projection of climate change. However, it em-

ployed the 20 years old Particle Swarm Optimization as the calibration method. We implemented 12 advanced optimization algorithms to calibrate and validate the air2water model. Daily observed water temperature in twenty two temperate lakes in Poland were used to evaluate the model performance. Each optimizer was run 30 times with different settings of the maximum number of function calls. We have found that the PSO method performed relatively poor compared with most of the recent algorithms. However, only the HARD-DE (hierarchical archive-based mutation strategy with depth information of differential evolution) algorithm was never outperformed by any competitor.

8.2 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 candidate; Paweł Rowiński, Magdalena Mrokowska – PhD supervisors

Technical Assistant
Andrzej Skrzyński

PhD Students
Geetika Harish Chauhan, India; Krzysztof Kochanek, Iwona Kuptel-Markiewicz – PhD supervisors
Marta Majerska, Poland; Marzena Osuch, Tomasz Wawrzyniak – PhD supervisors
Motuma Regasa, Etiopia; Michael Nones – PhD supervisor
Tesfaye Senbeta, Etiopia; Renata Romanowicz, Krzysztof Kochanek, Emilia Karamuz – PhD supervisors

8.3 Main research projects

- Skutki zmian w łączności ekosystemów na procesy metaboliczne i emisje gazów cieplarnianych z ocieplających się jezior Arktycznych i Alpejskich, M. Moskalik PI, M. Bartosiewicz, M. Osuch, T. Wawrzyniak, National Science Centre, Poland, 2021–2024;
- Visualization of methane fluxes along coastal boundaries of Arctic permafrost and glaciers, M. Bartosiewicz PI, M. Moskalik, M. Osuch, PASIFIC, 2021–2024;
- BRITEC PROJECT, M. Kalinowska, Erasmus Plus, 2019–2021;
- NAWA PROM: Assessment of the feasibility of using remote sensing measurements methods to effectively determine river shoreline and hydrodynamic flow conditions for different floodplain land cover characteristics, E. Karamuz, NAWA, 2020–2021;
- Application of machine learning and cluster identification for insight in the spatio-temporal changes of seismogenic processes triggered by water reservoirs, K. Kochanek, National Science Centre, Poland, 2020–2021;
- FORecasting hydrological response, Carbon balance and Emissions from natural mires in arctic-to-temperate zone transect in abrupt climatic change, K. Kochanek, NORWAY GRANTS, 2020–2021;
- Understanding and modeling compound climate and weather events, I. Kuptel-Markiewicz, University of Lisbon, 2018–2022, COST Action CA17109;
- NAWA PROM: Assessment of the impact of changes in the riverbed as a result of the presence of submerged vegetation on hydrodynamic processes with the use of multibeam echosounder and remote sensing methods, A. Łoboda, NAWA, 2020–2021;
- Variability of arctic river thermal regimes in a changing climate (VariaT), M. Majerska, M. Osuch, T. Wawrzyniak, NCBiR SMALL GRANT SCHEME, 2021–2023;
- 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 Centre, Poland, 2020–2023;
- 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 Centre, Poland, 2020–2024;
- Comparison of satellite imagery and time-lapse photography to track the riverine morphodynamics of the Po River, Italy, M. Nones, ASI, 2019–2021;
- Tracking riverine morphodynamics from satellite imagery: the case of the Po River, Italy, M. Nones, ESA, 2019–2021;
- Hindcasting and projections of hydro-climatic conditions of Southern Spitsbergen, M. Osuch PI, National Science Centre, Poland, 2018–2021;
- Applied remote sensing and geophysical imaging in recognition of the changes of the water balance in High Arctic catchments, M. Osuch PI, National Science Centre, Poland, 2021–2025;
- Particle tracking velocimetry technique in the study of macroplastic transport in vegetated channels – scientific consultation, Ł. Przyborowski, National Science Centre, Poland, 2021–2022;
- Human and climate impacts on drought dynamics and vulnerability Polish-Chinese SHENG1 Project HUMDROUGHT, R. Romanowicz , E. Bogdanowicz, E. Karamuz, J. Napiórkowski, M. Nones, I. Kuptel-Markiewicz, National Science Centre, Poland, 2019–2022;
- Laboratory experiments on microplastics transport in open channel flow, A. Varrani, National Science Centre, Poland, 2021–2024;

- Flume experiments on bed particles movement, A. Varrani PI, Ł. Przyborowski, IG PAS, 2020–2021;
- Preliminary laboratory studies on microplastics' mobilisation in open-channel flows, A. Varrani, Ubertone, 2021;
- State of Revvatnet hydrodynamics in the year 2020/21 (STAREV), T. Wawrzyniak PI, M. Osuch, SIOS, 2020–2021.

8.4 Instruments and facilities

Equipment

- DJI PHANTOM 4 Pro V2.0 Drone
- Parrot SEQUOIA+ (multispectral camera)
- Drone Mavic Air
- Drone DJI Matrice 300 RTK with two cameras DJI Zenmuse H20T and Micasense RedEdge-MX
- GPSMap 66i z PL TOPO 2020.4

Hornsund

- Trail camera NumAxes PIE1035 (×5)
- Thomst datalogger TMS4 (×10)
- Meteorological stations Gill GMX 400 with logger metstream100 (×6)
- Geoprecision thermistor strings
- Nivus PCM F (×2)

Laboratories

Hydraulic Laboratory:

- two tilting flumes with flow recirculation system for open channel flow and gravity currents studies (dimensions: 5 m long × 0.25 m wide; 5 m long × 0.15 m wide)
- two ultrasonic flowmeters (range: 0.6–150 L/min; 1–250 L/min)
- high-precision inclinometer: 2 directional slope measurement
- two cameras GoPro HERO9 BLACK

Laboratoryof Hydrodynamic Micromodels:

- high-resolution macro image acquisition system (two monochrome 60 fps CMOS cameras, macrolenses, computer)
- density meter (range: 0–3 g/cm^3, accuracy: 0.0001 g/cm^3)
- refractometer
- precision balance (readability: 0.01 g, max capacity: 6100 g)
- analytical balance (readability: 0.1 mg, max capacity: 220 g)

8.5 Seminars and teaching

Seminars and lectures

E. Karamuz, Short background and introduction to work (part 2), University of Victoria, Victoria, Canada, 12.2021, Seminar lecture;

K. Kochanek, Engineering Hydrology, Warsaw Univesity of Technology, Poland, Summer semester of the year 2020/2021, Lecture;

K. Kochanek, Statistics in Geophysics, Warsaw Univesity of Technology, Poland, 05.2021, Lecture;

K. Kochanek, Research workshop – statistical methods in geophysics, Warsaw University of Technology, Warsaw, Poland, 05–06.2021, Lectures;

I. Kuptel-Markiewicz, Research workshop – statistical methods in geophysics, Warsaw University of Technology, Warsaw, Poland, 05–06.2021, Lectures;

A. Łoboda, Short background and introduction to work (part 1), University of Victoria, Victoria, Canada, 09.2021, Seminar lecture;

M. Osuch, Geomarketing, WSISiZ, Warsaw, Poland, Winter semester 2021/2022, Lecture;

M. Osuch, Przysposobienie sieciowe, WSISiZ, Warsaw, Poland, Winter semester 2021/2022, Lecture;

M. Osuch, Zajęcia wyrównawcze z Informatyki, WSISiZ, Warsaw, Poland, Winter semester 2021/2022, Lecture;

A. Varrani, Intrduction to river morphodynamics, Warsaw University of Technology-WUT & Brandenburg Technical University Cottbus-Senftenberg – BTU-CS, Warsaw (PL) & Cottbus (DE), Online, 02.2021, Lecture;

A. Varrani, Introduction to river engineering, WUT & BTU-CS, Warsaw (PL) & Cottbus (DE), Online, 12.2021, Lecture.

Teaching

M. Osuch, M. Majerska, A. Laskowski, Analiza stanu wegetacji roślin uprawnych na podstawie zmienności własności spektralnych pozyskanych metodami teledetekcyjnymi na terenie gminy Łochów, WSISiZ, Warsaw, Poland;

M. Osuch, B. Solarz-Niesłuchowski, M. Zych, System do monitorowania danych o stanie obserwowanych komputerów z poziomu telefonu z możliwością rozbudowy aplikacji za pomocą pluginów, WSISiZ, Warsaw, Poland;

A. Krztoń-Maziopa, M. Mrokowska, A. Piskosz, Research on the rheological properties of aqueous exopolymer solutions with the addition of electrolyte mixtures and their impact on the dynamics of solid particles falling, Warsaw University of Technology, Warsaw, Poland.

Visiting scientists

Massimo Guerrero, Università di Bologna, Bologna (IT), 04.08–06.08.2021

8.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- E. Bogdanowicz, R. Romanowicz, E. Karamuz, 6th IAHR Europe Congress, Low flows along the Vistula River (and more) – some preliminary results of the Chinese–Polish HUMDROUGHT project, Warsaw, Online, 15–18.02.2021, Poster, Conference;
- E. Bogdanowicz, R. Romanowicz, E. Karamuz, STAHY 2021, Changes in the hydrological regime along the Vistula river course, Valencia, Spain, Online, 17.09.2021, Oral, Workshop;
- M. Kalinowska, A. Goździk, STEM High Level Event Bringing Research Into the Classroom, Citizen Science Education in the classroom: case study on monitoring of seasonal

changes of riparian vegetation and river microclimate, Online, 20–21.05.2021, Oral, Conference;

- M. Kalinowska, A. Goździk, 6th IAHR Europe Congress, Citizen science initiative of observing seasonal change of river riparian vegetation and microclimate of river valleys, Warsaw, Online, 15–18.02.2021, Congress;
- M. Kalinowska, E. Karamuz, M. Nones, Ł. Przyborowski et al., 6th IAHR Europe Congress, Influence of vegetation maintenance on flow and mixing in an agricultural ditch: preliminary results from field investigations, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- E. Karamuz, R. Romanowicz, 6th IAHR Europe Congress, Temperature changes and their impact on soil moisture in winter and spring, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- K. Kochanek, Water Round Table. Water management – Challenge for Poland., To build levees or not to build, Wrocław, Poland, 08.09.2021, Oral, Symposium;
- K. Kochanek, STAHY 2021, Does the climate change pose the threat to the wetlands ecosystems with fluviogenic type of supply? The Lower River Biebrza (Poland) case study, Valencia, Spain, Online, 16–17 .09.2021, Oral, Workshop;
- K. Kochanek, 6th IAHR Europe Congress, The bias of the maximum likelihood estimates of flood quantiles based solely on the largest historical records, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- I. Kuptel-Markiewicz, 6th IAHR Europe Congress, Introduction to statistical modelling of hydrological extremes, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- A. Łoboda, E. Karamuz, Ł. Przyborowski, 6th IAHR Europe Congress, Application of UAV based images for study bed forms movement at lower Świder River (Poland), Warsaw, Online, 02.2021, Oral, Conference;
- K. Migała, M. Osuch et al., 3rd International Conference Polar Climate and Environmental Change in the last Millenium, A few remarks on the dynamics of contemporary climate conditions in Svalbard, Toruń, Poland, 30.08–01.09.2021, Oral, Conference;
- M. Mrokowska et al., 6th IAHR Europe Congress, Rheological effects of exopolymers in salt aqueous solutions on particle settling dynamics with implications to sedimentation in natural waters, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- M. Mrokowska et al., 6th IAHR Europe Congress, Influence of rough bed on propagation of lock-exchange saline gravity currents, Warsaw, Online, 15–18.02.2021, Poster, Conference;
- M. Mrokowska et al., ASLO 2021 Aquatic Sciences Meeting, Effects of stratification and dissolved exopolymers on settling dynamics of solid particles in relation to mechanisms of marine snow formation, Palma (Spain), 22–27.06.2021, Oral, Conference;
- M. Mrokowska, Ł. Przyborowski, M. Nones et al., Experimental Methods and Laboratory Instrumentations, Application of digital close-range photogrammetry to determine changes in gravel bed surface due to transient flow conditions, Online, 13–15.04.2021, Oral, Webinar;
- M. Nones, 6th IAHR Europe Congress, Flood mapping at the European scale: the actual state of Floods Directive implementation, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- M. Nones et al., 2nd IAHR YPN Congress, Sentinel2-derived hydro-morphological dynamics of a reach of the Vistula River in Poland, Online, 30.11–02.12.2021, Conference;
- M. Nones et al., 6th IAHR Europe Congress, Tidal modulation of a river flood: a numerical analysis, Warsaw, Online, 15–18.02.2021, Poster, Conference;

- M. Nones et al., 6th IAHR Europe Congress, River hydro-morphodynamics monitoring by satellite and ground sensors data-fusion, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- M. Osuch et al., Arctic Science Summit Week 2021, Changes in the flow regime in the four High Arctic catchments with a different stage of catchment glaciation, Online, 19–26.03.2021, Oral, Conference;
- M. Osuch et al., 3rd International Conference Polar Climate and Environmental Change in the last Millenium, Reconstruction of the hydrological processes in four High Arctic catchments (SW Spitsbergen), Toruń, Poland, 30.08–01.09.2021, Oral, Conference;
- M. Osuch et al., XXXVIII Międzynarodowe Sympozjum Polarne, Projections of hydro-climatic conditions in SW Spitsbergen, Toruń, Poland, 18–20.11.2021, Oral, Conference;
- Ł. Przyborowski, A. Łoboda, 6th IAHR Europe Congress, Identification of coherent structures downstream patches of aquatic vegetation in a natural environment, Warsaw, Online, 15–18.02.2021, Oral, Conference;
- Ł. Przyborowski, M. Nones, M. Mrokowska, Experimental Methods and Laboratory Instrumentations, Laboratory investigation of sediment transport under transient flow – preliminary results, Online, 13–15.04.2021, Oral, Webinar;
- M. S. Regasa, M. Nones, 1st IAHR Online Forum, Reservoir sedimentation and sustainable management of the Fincha Fdam, Ethiopia, under land use land cover changes, Online, 05–07.07.2021, Oral, Forum;
- R. Romanowicz, E. Karamuz, J. Napiorkowski, T.B. Senbeta, vEGU21 General Assembly, Effects of climate change and human interactions on water balance dynamics in the River Vistula basin, Vienna, Austria, Online, 30.04.2021, Oral, Conference;
- T.B. Senbeta, R. Romanowicz, STAHY 2021, Influence of uncertainty on the estimates of water balance dynamics and drought indices in the River Vistula basin, Valencia, Spain, Online, 17.09.2021, Oral, Workshop;
- T.B. Senbeta, R. Romanowicz, 2nd IAHR YPN Congress, Catchment baseflow ad streamflow responses to land cover dynamics using the SWAT model, Spain, Online, 02.12.2021, Oral, Conference;
- A.Varrani, 6th IAHR Europe Congress, Incipient motion of plastic particles investigated in experiments with increasing and decreasing flow discharge, Warsaw, Online, 15–18.02.2021, Oral , Conference;
- A. Varrani, M. Mrokowska, Ł. Przyborowski et al., 2nd IAHR YPN Congress, Incipient motion of compact-shape microplastics: experimental design and expected results, Online, 30.11.–02.12.2021, Poster, Conference;
- A. Varrani, A. Łoboda, Ł. Przyborowski et al., 6th IAHR Europe Congress, Side-effects of networking for early-career researchers: A Polish perspective, Warsaw, Online, 15–18.02.2021, Poster, Conference;
- T. Wawrzyniak, M. Osuch, XXXVIII Międzynarodowe Sympozjum Polarne, Recent, past and future climate change impacts on permafrost in SW Spitsbergen (Svalbard), Toruń, Poland, 18–20.11.2021, Oral, Conference;
- T. Wawrzyniak, M. Osuch, Winter Cyberseminar Series: Research and Observatory Catchments: the Legacy and the Future, Flow regime in catchments with different level of glaciation in SW Spitsbergen, Online, 24.02.2021, Oral, Seminar series;
- T. Wawrzyniak, M. Osuch, VI Apecs Brasil Polar Symposium, Climate change impacts on the hydrological processes in Svalbard, Online, 02–04.02.2021, Oral, Symposium.

8.7 Publications

ARTICLES

Bogdanowicz, E., **E. Karamuz**, and **R.J. Romanowicz** (2021), Temporal changes in flow regime along the River Vistula, *Water* **13**, 20, 2840, DOI: 10.3390/w13202840.

Karamuz, E., and **R.J. Romanowicz** (2021), Temperature changes and their impact on drought conditions in winter and spring in the Vistula Basin, *Water* **13**, 14, 1973, DOI: 10.3390/w13141973.

Karamuz, E., **E. Bogdanowicz**, **T.B. Senbeta**, **J.J. Napiórkowski**, and **R.J. Romanowicz** (2021), Is it a drought or only a fluctuation in precipitation patterns? — Drought reconnaissance in Poland, *Water* **13**, 6, 807, DOI: 10.3390/w13060807.

Balcerowicz, M., et al., **K. Kochanek**, **R. Romanowicz** (2021), Gospodarowanie wodą – wyzwania dla Polski [Managing water – challenges for Poland], *Nauka* **1**, 79–102, DOI: 10.24425/nauka.2021.136305 (in Polish).

Grygoruk, M., **K. Kochanek**, et al. (2021), Analysis of long-term changes in inundation characteristics of near-natural temperate riparian habitats in the Lower Basin of the Biebrza Valley, Poland, *J. Hydrol.: Reg. Stud*. **36**, 100844, DOI: 10.1016/j.ejrh.2021.100844.

Wawrzyniak, T., **M. Majerska**, and **M. Osuch** (2021), Hydrometeorological dataset (2014–2019) from the high Arctic unglaciated catchment Fuglebekken (Svalbard), *Hydrol. Process*. **35**, 1, e13974, DOI: 10.1002/hyp.13974.

Markiewicz, I. (2021), Depth–duration–frequency relationship model of extreme precipitation in flood risk assessment in the Upper Vistula Basin, *Water* **13**, 23, 3439, DOI: 10.3390/w13233439.

Markiewicz, I. (2021), Okresy bez opadu oraz z opadem bardzo silnym w półroczu letnim w dorzeczu górnej Wisły [Periods without precipitation and with very heavy precipitation in the summer half-year in the Upper Vistula Basin], *Prz. Geof*. **66**, 3–4, 187–208, DOI: 10.32045/PG-2021-024 (in Polish).

Nones, M. (2021), Remote sensing and GIS techniques to monitor morphological changes along the middle-lower Vistula river, Poland, *Int. J. River Basin Manage*. **19**, 3, 345–357, DOI: 10.1080/15715124.2020.1742137.

Boothroyd, R.J., **M. Nones**, et al. (2021), Deriving planform morphology and vegetation coverage from remote sensing to support river management applications, *Front. Environ. Sci*. **9**, DOI: 10.3389/fenvs.2021.657354.

Cavallo, C., **M. Nones**, et al. (2021), Monitoring the morphological evolution of a reach of the Italian Po River using multispectral satellite imagery and stage data, *Geocarto Int*., DOI: 10.1080/10106049.2021.2002431.

Regasa, M.S., **M. Nones**, et al. (2021), A review on Land Use and Land Cover change in Ethiopian basins, *Land* **10**, 6, 585, DOI: 10.3390/land10060585.

Tramblay, Y., et al., **M. Osuch** (2021), Trends in flow intermittence for European rivers, *Hydrol. Sci. J*. **66**, 1, DOI: 10.1080/02626667.2020.1849708.

Piotrowski, A.P., **J.J. Napiorkowski**, et al. (2021), Input dropout in product unit neural networks for stream water temperature modelling, *J. Hydrol*. **598**, 126253, DOI: 10.1016/j.jhydrol.2021.126253.

Piotrowski, A.P., **M. Osuch**, and **J.J. Napiorkowski** (2021), Influence of the choice of stream temperature model on the projections of water temperature in rivers, *J. Hydrol*. **601**, 126629, DOI: 10.1016/j.jhydrol.2021.126629.

Zhu, S., **A.P. Piotrowski**, et al., **J.J. Napiorkowski** (2021), How does the calibration method impact the performance of the air2water model for the forecasting of lake surface water temperatures?, *J. Hydrol.* **597**, 126219, DOI: 10.1016/j.jhydrol.2021.126219.

Przyborowski, Ł., and **A.M. Łoboda** (2021), Identification of coherent structures downstream of patches of aquatic vegetation in a natural environment, *J. Hydrol*. **596**, 126123, DOI: 10.1016/j.jhydrol.2021.126123.

Kenea, U., et al., **M.S. Regasa**, **M. Nones** (2021), Hydrological responses to land use land cover changes in the Fincha'a watershed, Ethiopia, *Land* **10**, 9, 916, DOI: 10.3390/land10090916.

Wang, W., et al., **R. Romanowicz** (2021), Uncertainty in SPI calculation and its impact on drought assessment in different climate regions over China, *J. Hydrometeorol*. **22**, 6, 1369–1383, DOI: 10.1175/JHM-D-20-0256.1.

Caroppi, G., et al., **P.M. Rowiński** (2021), Comparison of flexible and rigid vegetation induced shear layers in partly vegetated channels, *Water Resour. Res*. **57**, 3, e2020WR028243, DOI: 10.1029/2020WR028243.

Senbeta, T.B., and **R.J. Romanowicz** (2021), The role of climate change and human interventions in affecting watershed runoff responses, *Hydrol. Process*. **35**, 12, e14448, DOI: 10.1002/hyp.14448.

CHAPTERS

Christiansen, H.H., et al., **M. Osuch** (2021), Ground ice content, drilling methods and equipment and permafrost dynamics in Svalbard 2016–2019 (PermaSval). **In:** *SESS Report 2020 – The State of Environmental Science in Svalbard*, 258–275, DOI: 10.5281/zenodo.4294095.

Nowak, A., et al., **M. Osuch**, T. Wawrzyniak, **M. Majerska** (2021), From land to fjords: The review of Svalbard hydrology from 1970 to 2019 (SvalHydro). **In:** *SESS Report 2020 – The State of Environmental Science in Svalbard*, 176–201, DOI: 10.5281/zenodo.4294063.

9. DEPARTMENT OF MAGNETISM

Waldemar Jóźwiak

9.1 About the Department

The activities of the Department of Magnetism include the studies of lithospheric structures and dynamic processes inside the Earth, environmental magnetism, and the study of magnetohydrodynamics with applications to the dynamics of the Earth's interior.

Problems of environmental pollution (outdoor and indoor air, soil and water sediments) and their wide range of impacts on human life are contained within the NM1 task. In 2021, the work was focused on the application of combined magnetic and non-magnetic methods to study quality of outdoor and indoor air, transformations of Fe-bearing magnetic minerals in technogenic soils, pollution around former and active mining areas and to identify which of Fe-bearing phases bind heavy metals in road dust. The multidisciplinary national and international level collaboration allowed to study sources of urban air pollution and to evaluate adverse health effects related to exposure pathway of heavy metals. The monitoring service of the concentration of particulate matter (PM10 and PM2.5) and its magnetic susceptibility to trace the trends in the ground-level air pollution variability was also continued.

The research group working on the NM2 task conducted research on paleogeographic and tectonic issues. In 2021, research work was carried out in the Carpathians (Slovakia and Poland) and Svalbard, as well as in the area of the East European Craton, the latter studied based on rock material from drilling cores. The main subject of these research works was the paleoposition of lithospheric plates and tectonic deformations related to the collision of lithospheric plates and the formation of mountain belts. The problem of stability of the magnetic field in the Proterozoic was also investigated. In addition, organic-rich shales were studied in the context of environmental changes, in particular the variable geochemical conditions on the seabed and related preservation of organic matter in marine sediments.

Within the NM3 task, the construction of regional models of the geoelectric structure as well as research on source effects in the magnetotelluric method was continued. A detailed, three-dimensional model of the resistivity distribution in the lithosphere in Poland has been developed using the magnetotelluric and the magnetovariation data from 593 points collected over the last 50 years. Other activities included the study of large-scale magnetic fields and their generation in the Earth's core and other astrophysical objects, such as the Sun and the Milky Way galaxy. It was shown that turbulent fluctuations of the Lorentz force in the fluid medium (liquid iron or plasma) can lead to creation of negative diffusivity effects and rapid enhancement of the magnetic energy. Throughout 2021, the monitoring tasks included the absolute measurements and continuous recording of the Earth's magnetic field in Belsk, Hel, and Hornsund (Spitsbergen) observatories, a continuous recording of geomagnetic field changes with real-time data access at four permanent stations and Schumann Resonance observations in Hornsund and Suwałki. Our magnetic observatories and permanent stations participated in the INTERMAGNET, IAGA, IMAGE and EMMA networks. We are also continuously providing geomagnetic data for SWARM missions.

Furthermore, in 2021 the works on the paleomagnetic and magnetotelluric databases was completed under the EPOS–PL project.

9.2 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 Grądzki
Dominika Niezabitowska
Szymon Oryński

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
Agata Bury, Poland; Anne Neska – PhD supervisor
Paweł Jujeczko, Poland; Krzysztof Mizerski – PhD supervisor
Sarasija Sanaka, India; Anne Neska – PhD supervisor
Dorota Staneczek, Poland; Rafał Szaniawski – PhD supervisor
Wojciech Szkółka, Poland; Krzysztof Mizerski – PhD supervisor

9.3 Main research projects

- EPOS–PL European Plate Observing System; Task 4 – CIBAL – Centre of Research Infrastructure of Analytical Laboratories, T. Werner, B. Górka-Kostrubiec, European Regional Development Fund, Operational Program Smart Growth 2014–2020, 2017–2022;

- EPOS–PL + European Plate Observing System; Task 4 – CIBAL – Centre of Research Infrastructure of Analytical Laboratories, T. Werner, S. Dytłow, European Union, European Regional Development Fund, Operational Program Smart Growth 2014–2020, 2020–2023;
- Diagramy FORC jako narzędzie do kompleksowej charakterystyki faz ferromagnetycznych, K. Dudzisz, National Science Centre "Miniatura", Poland, 2019–2021;
- Magnetic fatigue: effect of cyclic loading under elevated temperatures on the magnetic and structural behaviour, K. Dudzisz, Deutsche Forschungsgemeinschaft (DFG), 2021;
- EPOS–PL European Plate Observing System; Task 3 – CIBOGM – Geomagnetic and Magnetotelluric Observations Research Infrastructure Center, W. Jóźwiak, European Union, European Regional Development Fund, Operational Program Smart Growth 2014–2020, 2017–2022;
- EPOS–PL + European Plate Observing System; Task 3 – CIBOGM – Geomagnetic and Magnetotelluric Observations Research Infrastructure Center, W. Jóźwiak, European Union, European Regional Development Fund, Operational Program Smart Growth 2014–2020, 2020–2023;
- 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 Centre "Opus 13" Poland, 2018–2021;
- Buoyancy driven magnetic dynamo, K. Mizerski, National Science Centre "Sonata Bis", Poland, 2018–2021;
- Svalbox 2.0 – FAIR geoscientific data from Svalbard, K. Michalski, Research Council of Norway, 2021–2023.

9.4 Instruments and facilities

Equipment

Equipment for field laboratory for paleomagnetism and environmental magnetism

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

financed by EPOS-PL+

- DJI MATRICE 600 PRO drone with AIR DRON/ AD – SH 24 unit for PM measurements
- PM meter/sampler (DustTrak 8533DRX, TSI, USA) – 2 pcs
- Black carbon meter – aethalometr (AE-51, Aeth-Labs, USA)
- MS3 susceptibility meter (Bartington, Great Britain) with new sensors
- Portable rock drills (RSD, Germany) – 2 pcs
- Nonmagnetic sample containers (Magnetic Measurements, Great Britain) – 4 pcs

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
- 2 torsion photoelectric magnetometers PSM
- 4 DIFLUX magnetometers for absolute measurements
- 4 induction coil magnetometers
- 1 GEM GSM-19T Gradiometer
- 1 electromagnetic conductivity meters CMD MiniExplorer 6L (2021)
- 13 NDL digital recorders
- 18 LB-480 digital recorders

Laboratory

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, 2021 – the upgrade of cooling system (financed by EPOS-PL)
- 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

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)

9.5 Seminars nad teaching

Seminars and lecture

K. Dudzisz, Can titanomagnetites from pyroclastic rocks be used to explain the emplacement mechanism and determine the emplacement temperatures?, Institute of Technology, Karlsruhe, Germany, 07.05.2021, Seminar;

K. Dudzisz, How deep and how far can pollution migrate from abandoned mining areas? Insights from the application of magnetic and electromagnetic methods, Institute of Technology, Karlsruhe, Germany, 11.06.2021, Seminar;

K. Mizerski, Negative diffusion effects in magnetohydrodynamic turbulence induced by fluctuations of the Lorentz force, Physics Faculty, University of Warsaw, Warsaw, Poland, 05.11.2021, 13.12.2021, Seminar.

Teaching

K. Dudzisz, A. Kontny, Microstructures course (co-conducting the practical part), Karlsruhe Institute of Technology, Karlsruhe, Germany;

K. Mizerski, M. Grądzki, Hydromagnetic dynamo theory in geo- and astrophysics, Physics Faculty, University of Warsaw, Lecture.

Thesis

R. Szaniawski (supervisor), Dominika Niezabitowska, Rock magnetic properties of lower Paleozoic gas-bearing shale rocks from northern Poland, IG PAS, Warsaw, Poland.

Visiting scientists

Darko Matešic, Faculty of Mining, Geology and Petroleum, Engineering, University of Zagreb, Zagreb, Croatia, 06–23.12.2021;

Yuri Sumaruk, Institute of Geophysics of the National Academy of Sciences of Ukraine, Kiev, Ukraine, 07–17.11.2021;

Dorota Staneczek, University of Silesia, Katowice, Poland, 15–20.03.2021, 21–24.06.2021, 05–16.07.2021, 22–26.11.2021, 06–17.12.2021.

9.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- J. Reda, Report on definitive data timelines, INTERMAGNET Meeting, Online, 27.09–1.10.2021, Oral and Poster;
- J. Reda, Progress on one-second data collection, INTERMAGNET Meeting, Online, 27.09–1.10.2021, Oral and Poster;
- J. Nawrocki, K. Standzikowski, T. Werner, M. Łanczont, J. Gancarski, Z. Gil, EGU General Assembly 2021, Reuse of medieval bricks as important limitation for construction of geomagnetic secular variation curves based on archeomagnetic studies of brick buildings in Poland, Vienna, Austria, 19–30.04. 2021, Oral, Conference;

- M. Lewandowski, M.A. Kusiak, A. Nawrot, T. Werner, B. Barzycka, M. Laska, B. Luks, The 5th High latitude Dust Workshop, Seeking the Sources of Dust: Geochemical and Magnetic Studies on "Cryodust" in Glacial Cores from Southern Spitsbergen (Svalbard, Norway), Reykjavik, Iceland, 10–11.02.2021, Oral, Workshop;
- K. Dudzisz, R. Harrison, Magnetic Interactions 2021, Magnetic signature recorded on soils from mining areas – an indicator of soil transformation?, St. Andrews, UK, 07–08.01.2021, Poster, Conference;
- K. Dudzisz, M. Walter, R. Krumholtz, B. Reznik, A. Kontny, GeoKarlsruhe 2021: Sustainable Earth – from processes to resources, Effect of cyclic loading at elevated temperatures on the magnetic susceptibility of a magnetite-bearing ore, Karlsruhe, Germany, 19–24.09.2021, Oral, Conference;
- G. Karasiński, B. Górka-Kostrubiec, T. Werner, Workshop on Changes of the Polar Ecosystem, Measurements of magnetic susceptibility of PM10 in Warsaw, Česká Skalice, Czechy, 13–15.10.2021, Oral, Workshop;
- K. Mizerski, International Congress on, Theoretical and Applied Mechanics ICTAM2020+1, Large-scale magnetic field generation by wave interactions in highly conducting plasma, Milano, Online, 22–27.08.2021, Oral, Conference;
- K. Mizerski, Konferencja Zastosowań Matematyki 49, Renormalizacja równań magnetohydrodynamiki, Zakopane, 20–25.09.2022, Oral, Conference.

9.7 Publications

ARTICLES

Bury, A., **M. Lewandowski**, and **K. Mizerski** (2021), Possible risk resulting from the recent decay of the dipolar component of the terrestrial magnetic field, *Acta Geophys*. **69**, 1, 47–52, DOI: 10.1007/s11600-021-00536-2.

Dudzisz, K., et al. (2021), Effect of cyclic loading at elevated temperatures on the magnetic susceptibility of a magnetite-bearing ore, *Geophys. J. Int*. **228**, 2, 1346–1360, DOI: 10.1093/gji/ggab400.

Dudzisz, K., **M. Lewandowski**, **T. Werner**, **G. Karasiński**, et al. (2021), Paleolatitude estimation and premises for geomagnetic field instability from the Proterozoic drilling core material of the south-western part of the East European Craton, *Precambrian Res*. **357**, 106135, DOI: 10.1016/j.precamres.2021.106135.

Dytłow, S., and **B. Górka-Kostrubiec** (2021), Concentration of heavy metals in street dust: an implication of using different geochemical background data in estimating the level of heavy metal pollution, *Environ. Geochem. Health* **43**, 1, 521–535, DOI: 10.1007/s10653-020-00726-9.

Magiera, T., **B. Górka-Kostrubiec**, et al. (2021), Technogenic magnetic particles from steel metallurgy and iron mining in topsoil: Indicative characteristic by magnetic parameters and Mössbauer spectra, *Sci. Total Environ*. **775**, 145605, DOI: 10.1016/j.scitotenv.2021.145605.

Uzarowicz, Ł., **B. Górka-Kostrubiec**, **K. Dudzisz**, et al. (2021), Magnetic characterization and iron oxide transformations in Technosols developed from thermal power station ash, *CATENA* **202**, 105292, DOI: 10.1016/j.catena.2021.105292.

Mizerski, K.A. (2021), Nonlinear turbulent dynamo induced by fluctuations of the Lorentz force, *Phys. Rev. E* **104**, L053102, DOI: 10.1103/PhysRevE.104.L053102.

Mizerski, K.A. (2021), Possible role of non-stationarity of magnetohydrodynamic turbulence in understanding of geomagnetic excursions, *Symmetry* **13**, 10, 1881, DOI: 10.3390/sym13101881.

Mizerski, K.A. (2021), Renormalization group analysis of the magnetohydrodynamic turbulence and dynamo, *J. Fluid Mech*. **926**, A13, DOI: 10.1017/jfm.2021.707.

Mizerski, K.A. (2021), Renormalization group analysis of the turbulent hydromagnetic dynamo: Effect of anisotropy, *Appl. Math. Comput*. **405**, 126252, DOI: 10.1016/j.amc.2021.126252.

Jones, Ch.A., **K.A. Mizerski**, et al. (2021), Fully developed anelastic convection with no-slip boundaries, *J. Fluid Mech*. **930**, A13, DOI: 10.1017/jfm.2021.905.

Williams, E., et al., **M. Neska** (2021), Evolution of global lightning in the transition from cold to warm phase preceding two super El Niño events, *J. Geophys. Res.: Atmos*. **126**, 3, e2020JD033526, DOI: 10.1029/2020JD033526.

Niezabitowska, D.K., et al., **R. Szaniawski** (2021), Magnetic susceptibility variations in lower Paleozoic shales of the western Baltic Basin (northern Poland): A tool for regional stratigraphic correlations and the decoding of paleoenvironmental changes, *AAPG Bull*. **105**, 5, 987–1007, DOI: 10.1306/12092019183.

Oryński, Sz., **W. Jóźwiak**, and **K. Nowożyński** (2021), An integrative 3-D model of the deep lithospheric structure beneath Dolsk and Odra fault zones as a result of magnetotelluric data interpretation, *Geophys. J. Int*. **227**, 3, 1917–1936, DOI: 10.1093/gji/ggab322.

Vellante, M., et al., **J. Reda** (2021), Multi-instrument characterization of magnetospheric cold plasma dynamics in the June 22, 2015 geomagnetic Storm, *J. Geophys. Res.: Space Phys*. **126**, 6, e2021JA029292, DOI: 10.1029/2021JA029292.

Narloch, W., **T. Werner**, et al. (2021), Deformation mechanisms and kinematics of a soft sedimentary bed beneath the Scandinavian Ice Sheet, north-central Poland, revealed by magnetic fabrics, *Sediment. Geol*. **416**, 105862, DOI: 10.1016/j.sedgeo.2021.105862.

Nawrocki, J., et al., **T. Werner** (2021), Secular variations of inclination of the geomagnetic field in SE Poland between 1200 and 1800 AD, *Geochronometria* **48**, 1, 95–104, DOI: 10.2478/geochr-2020-0031.

MONOGRAPHS

Mizerski, K.A. (2021), *Foundations of Convection with Density Stratification*, GeoPlanet: Earth and PlanetarySciences Book Series, Springer Cham, DOI: 10.1007/978-3-030-63054-6.

Reda, J., **M. Neska**, **S. Wójcik**, and **P. Czubak** (2021), Results of Geomagnetic Observations: Belsk, Hel, Hornsund, 2019, *Publs. Inst. Geoph. PAS* **433 (C-114)**, DOI: 10.25171/InstGeoph_PAS_Publs-2021-002.

10. DEPARTMENT OF GEOPHYSICAL IMAGING

Michał Malinowski

10.1 About the Department

Department activities in 2021 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. 2021 was also a special year in the Department. It started with the transition of the Department Head (M. Malinowski) to his new position at the Geological Survey of Finland. Four members of the group successfully defended their PhD theses (M. Cyz, B. Owoc, M. Chamarczuk, M. Mężyk). After the pandemic-related downturn, 2021 proved to be a record year in terms of publications (18 papers).

Department activities were mostly related with the research projects (ongoing four NCN grants and the new PRELUDIUM grant awarded to A. Marciniak). We were also finalizing work related to the past projects, e.g., NCN project focused on permafrost structure in Spitsbergen, ERA-MIN COGITO-MIN and H2020 SmartExploration projects (both dealing with seismic methods in mineral exploration). Our research spans both the basic and applied topics. Basic research was represented this year by the continuous work on the Nankai Trough structure using full-waveform inversion (FWI) imaging and FWI developments, interpreting structure of the Fennoscandian crust (UPPLAND profile, Buntin et al. (2021), Nature Communication), interpretation of regional seismic data from the southern Baltic Sea. Regarding the latter, a unique proof of a leaking petroleum system was found west of Trzebiatów Fault in form of a gas chimney rooted in Triassic and producing gas-charged layer below the seafloor (PhD work of Q. Nguyen). A new short-term seismic network was deployed again in the vicinity of the Hans glacier in Hornsund (highlight 2), supplementing our earlier cryoseismological studies. Applied research was represented by the new integrated geophysical measurements campaign at the Cisiec landslide site (highlight 1, PhD work of A. Marciniak). Very promising results were obtained within the NCN SHENG project in the Rydułtowy coal mine (highlight 3) related to possibility of the rock mass monitoring. We continued also work towards unified seismic imaging workflow for mineral exploration in hardrock terrains using data from Ludvika (Sweden) and Kylylahti (Finland) mining areas (PhD work of B. Singh).

The theoretical studies continue developing universal model in the form of a stochastic cellular automaton integrating fundamental empirical laws describing statistical properties of earthquakes, as well as investigating the impact of the geometry of pore space on the dynamics of dissolution processes in porous media by creating specific measures for quantification of the process, microtomography image analysis and numerical simulations. In particular, these methods were applied to limestones collected in Smerdyna quarry.

10.2 Personnel

Head of the Department
Michał Malinowski
Professor

Associate Professors
Mariusz Białecki
Mariusz Majdański

Assistant Professors
Yaser Alashloo

Rafał Czarny
Wojciech Gajek
Andrzej Górszczyk

Research Assistant
Marta Cyz

PhD Students
Michał Chamarczuk, 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 Prakash Sharma, India; Mariusz Białecki – PhD supervisor
Brij Singh, India; Michał Malinowski – PhD supervisor

10.3 Main research projects

- Three-dimensional imaging of subduction zones with full waveform inversion of two-dimensional seismic data, A. Górszczyk (PI), Y. Alashloo, W. Gajek, NCN OPUS, 2020–2022;
- 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 (PI), NCN OPUS, 2018–2022;
- Active and passive source multiscale subsurface imaging and monitoring based on the full seismic waveform, M. Malinowski (PI), R. Czarny, A. Górszczyk, M. Chamarczuk, NCN SHENG, 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 (PI), Q. Nguyen, NCN OPUS, 2018–2022;
- Anthropogenic triggering of landslides in the environment modified due to climate change – geophysical investigation, A. Marciniak (PI), M. Majdański, NCN PRELUDIUM, 2021–2023.

10.4 Instruments and facilities

Equipment
- Department equipment was supplemented in 2021 with 4 seismic recorders (SpiderNano) and 4 accelerometers Sara SA10.

Laboratory
- Geophysical data analysis performed at the Department is supported by the local cluster composed of blade servers. In 2021, cluster was upgraded with a purchase of 3 additional blade servers.

10.5 Seminars and teaching

Seminars and lecture
A. Górszczyk, GO_3D_OBS – The multi-parameter benchmark geomodel for seismic imaging methods assessment and next generation 3D surveys design, Barcelona Marine Science Institute, Barcelona, Spain, 18.02.2021, Invited Seminar;

M. Majdański (lectures) Marciniak A. (classes), Seismology and active seismic, Warsaw University, Warsaw 10.2021–02.2022, Lecture;

A. Marciniak, Geophysics in geology, Warsaw University, Warsaw, 25.05.2021, Invited Lecture.

Thesis

Michał Malinowski, **Miłosz Mężyk**, Imaging the East European Craton margin by reprocessing and interpretation of the PolandSPAN reflection seismic profiles supported by machine learning, IG PAS, Warsaw, Poland;

Michał Malinowski, **Marta Cyz**, Selected rock properties of the Lower Paleozoic shales from Baltic Basin based on the quantitative interpretation of the 3D wide-azimuth seismic data, IG PAS, Warsaw;

Michał Malinowski, **Michał Chamarczuk**, Development of body-wave seismic interferometry imaging for mineral exploration, IG PAS, Warsaw;

Michał Malinowski (co-supervisor), **Sebastian Buntin**, Seismic structure of the central Svecofennian lithosphere, Uppsala University, Uppsala, Sweden;

Mariusz Majdański, **Bartosz Owoc**, Analysis of the uncertainty of traveltime tomography in various scales of seismic experiments, IG PAS, Warsaw.

10.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- W. Gajek, European Seismological Commision – 37th General Assembly, The dynamic component of the alpine glacier drainage system revealed by shear wave splitting, Online, 19–24.09.2021, Oral, Conference;
- A. Górszczyk, SEG/IMAGE 2021, Regional-scale FWI of wide-angle OBN data from a crude initial model using graph-space optimal transport, Denver, USA, Online, 26.09.2021–01.10.2021, Oral, Conference;
- A. Górszczyk, EAGE 2021, GOMCRUST – The crustal-scale extension of the 2004 BP velocity model for long-offset OBN acquisition setting, Amsterdam, Niderlandy, 18–21.10.2021, Poster, Conference;
- A. Górszczyk, DEEP 2021, Nankai Trough velocity structure reconstruction using FWI of wide-angle OBS data with graph-space optimal transport mis t function, Pekin, Chiny; Online, 05.11.2021, Oral, Conference;
- M. Mężyk, EAGE 2021, Deep embedded clustering as a seismic attribute: A case study of 2D crustal-scale interpretation, Amsterdam, Niderlandy, 18–21.10.2021, Oral, Conference;
- M. Białecki, DREAMS21: Dynamics of Random Expanding networks: Analysis, modelling and simulation of Multi-Scale spatial exploration spreading, On distributions out of simple random merging model, Paris, France, 08–09.12.2021, Oral, Conference;
- M. Majdański, EGU 2021, Surprisingly thick active layer of permafrost in the mountain slope in the SW Svalbard, Viena, Austria, Online, 26.04.2021, Oral, Conference;
- A. Marciniak, ESC 2021, European Seismological Commision – 37th General Assembly, Seismic studies of seasonally varying permafrost conditions in the SW Svalbard, Online, Oral, Conference.

10.7 Publications

ARTICLES

Bashir, Y., et al., **S.Y.M. Alashloo** (2021), Seismic wave propagation characteristics using conventional and advance modelling algorithm for d-data imaging, *J. Seism. Explor*. **30**, 1, 21–44.

Chamarczuk, M., **M. Malinowski**, et al. (2021), 2D body-wave seismic interferometry as a tool for reconnaissance studies and optimization of passive reflection seismic surveys in hardrock environments, *J. Appl. Geophys*. **187**, 104288, DOI: 10.1016/j.jappgeo. 2021.104288.

Chamarczuk, M., **M. Malinowski**, et al. (2021), Characterization of drilling-related noise and curvelet-based evaluation of seismic-interferometric reflections for imaging of iron-bearing formations in Pilbara, Western Australia, *Geophys. J. Int.* **226**, 1, 377–404, DOI: 10.1093/gji/ggab059.

Cyz, M., et al. (2021), Direct Geostatistical Seismic Amplitude Versus Angle Inversion for Shale Rock Properties, *IEEE Trans. Geosci. Remote Sens.* **59**, 6, 5335–5344, DOI: 10.1109/TGRS.2020.3017091.

Konon, A., et al., **M. Cyz**, **M. Malinowski** (2021), Using seismic and well data to determine processes of folding in the Pomeranian segment of the Caledonian Foredeep Basin, Poland, *Mar. Petrol. Geol*. **124**, 104804, DOI: 10.1016/j.marpetgeo.2020. 104804.

Czarny, R., **M. Malinowski**, **M. Chamarczuk**, et al. (2021), Dispersive seismic waves in a coal seam around the roadway in the presence of excavation damaged zone, *Int. J. Rock Mech. Min. Sci.* **148**, 104937, DOI: 10.1016/j.ijrmms.2021.104937.

Górszczyk, A., et al. (2021), GO_3D_OBS: the multi-parameter benchmark geomodel for seismic imaging method assessment and next-generation 3D survey design (version 1.0), *Geosci. Model Dev*. **14**, 3, 1773–1799, DOI: 10.5194/gmd-14-1773-2021.

Górszczyk, A., et al. (2021), Graph-space optimal transport concept for time-domain full-waveform inversion of ocean-bottom seismometer data: Nankai Trough velocity structure reconstructed from a 1D model, *J. Geophys. Res.: Solid Earth* **126**, 5, e2020JB021504, DOI: 10.1029/2020JB021504.

Górszczyk, A., et al. (2021), Nankai Trough velocity structure reconstruction using FWI of wide-angle OBS data with graph-space optimal transport misfit function, *Acta Geol. Sin. – Engl*. **95**, S1, 11–14, DOI: 10.1111/1755-6724.14818.

Cao, J., et al., **A. Górszczyk** (2021), 3-D multiparameter full-waveform inversion for ocean-bottom seismic data using an efficient fluid-solid coupled spectral-element solver, *Geophys. J. Int*., DOI: 10.1093/gji/ggab484.

Sambolian, S., **A. Górszczyk**, et al. (2021), Mitigating the ill-posedness of first-arrival traveltime tomography using slopes: application to the eastern Nankai Trough (Japan) OBS data set, *Geophys. J. Int*. **227**, 2, 898–921, DOI: 10.1093/gji/ggab262.

Buntin, S., et al., **M. Malinowski**, T. Janik (2021), Long-lived Paleoproterozoic eclogitic lower crust, *Nat. Commun*. **12**, 6553, DOI: 10.1038/s41467-021-26878-5.

Gajek, W., and **M. Malinowski** (2021), Errors in microseismic events locations introduced by neglecting anisotropy during velocity model calibration in downhole monitoring, *J. Appl. Geophys*. **184**, 104222, DOI: 10.1016/j.jappgeo.2020.104222.

Mazur, S., **M. Malinowski**, et al. (2021), Pre-existing lithospheric weak zone and its impact on continental rifting – The Mid-Polish Trough, Central European Basin System, *Global Planet. Change* **198**, 103417, DOI: 10.1016/j.gloplacha.2021.103417.

Marciniak, A., et al., **B. Owoc**, A. Nawrot, B. Luks, **M. Majdański** (2021), Integrated geophysical imaging of a mountain landslide – A case study from the Outer Carpathians, Poland, *J. Appl. Geophys*. **191**, 104364, DOI: 10.1016/j.jappgeo.2021.104364.

Mężyk, M., **M. Chamarczuk**, and **M. Malinowski** (2021), Automatic image-based event detection for large-N seismic arrays using a convolutional neural network, *Remote Sens*. **13**, 3, 389, DOI: 10.3390/rs13030389.

Mężyk, M., **M. Malinowski**, et al. (2021), Structure of a diffuse suture between Fennoscandia and Sarmatia in SE Poland based on interpretation of regional reflection seismic profiles supported by unsupervised clustering, *Precambrian Res*. **358**, 106176, DOI: 10.1016/j.precamres.2021.106176.

MONOGRAPH

Gajek, W. (2021), Anisotropy Estimation of Lower Paleozoic Shales from Northern Poland using Microseismic Data, *Publs. Inst. Geoph. PAS* **432** (B-43), 94 pp., DOI: 10.25171/InstGeoph_PAS_Publs-2021-001.

11. DEPARTMENT OF POLAR AND MARINE RESEARCH

Marek Lewandowski

11.1 About the Department

This was another year of intense field and conceptual work for scientists studying polar regions. The main efforts in our department focused on questions related to processes in the litho-, atmo-, and hydrosphere, with a small but crucial biological component, that interact to shape functioning of diverse ecosystems throughout the High Arctic. Melting and calving of glaciers, for instance, supplies fresh water and abiotic components to the local fiords, influencing marine ecosystems with important, yet poorly resolved, consequences for geochemical and biological cycles. The accelerating loss of glacial mass drives heavy metal distribution in the seawater of Arctic fjords, impacting marine food webs and fisheries. Processes and interactions between the geological, meteorological and chemical structuring of the High Arctic research sites monitored by our department were carried out at the Polish Polar Station in Hornsund and again contributed to the development of knowledge within the extensive network of the long-term FAIR database. As part of our international polar scientific network, we have actively contributed to the Svalbard Integrated Observing System consortium (SIOS) and coordinated the efforts of several international research units in the High Arctic region. We have also participated in other international enterprises such as INTAROS and Interact III (Horizon 2020), with an important educational component.

One of the major challenges in 2021 was to send out three of our colleagues on an expedition to the Dobrowolski Station in the Bunger Hills of East Antarctica, which has been not in use for the past 42 years. This effort will allow us to better connect Polish polar research between Arctic and Antarctic and strengthen our continuing cooperation with partners from the Arctic and Antarctic Russian Institute (AARI) in St Petersburg and the University in Oslo.

Another major achievement relates to establishment of a new laboratory GeoBeLa (Geoprocessing Belsk Laboratory), financed from the Polish–Norwegian funds, in the framework of the GRIEG program. This innovative facility will further establish functional links between research in the Arctica and Antarctic. A major goal of this new project is to compare Archean crustal fragments now dispersed over both polar regions, to infer the extent and composition of continental crust in the early Earth. Two new PhD students have joined our team with support from the project funds.

This year we also welcomed a new scientist to our team, Dr. Maciej Bartosiewicz. His tenure at our department started with a successful application for a Polish–Swiss Research Grant funded through both NCN and SNF. Through this project, we will develop a novel analytical capacity by establishing a gas chromatography method for gaseous and liquid sample analysis. The Polish–Swiss project also allows us to initiate limnological monitoring on Hornsund and adds yet another "pole" to our research, the so called "third pole" of the Alps. Another project that will be hosted in our department, co-financed by the Marie-Curie EU funds through the PASIFIC program, will strongly depend on this new infrastructure when visualizing CH_4 emissions from glacial and permafrost ecosystems in Hornsund. Adding to this overall success of our proactive team, collaboration with partners from the United States of America and Singapore under the International Partnership for the Acoustic Monitoring of Glaciers (IPA OMG) was extensive and advanced innovations in the development of acoustic methods for the monitoring of iceberg calving and melting. That research enterprise, with IG PAS acting as a founding member of the IPA OMG, is essential for understanding processes contributing to the retreat of marine-terminating glaciers.

The goal of Arctic expeditions conducted in 2021 provided a more comprehensive information on climate change impacts and the hydrodynamic state of rivers, lakes and seas in the

SW Spitsbergen. We again expanded measurement networks into new locations and initiated new monitoring techniques and methodologies. This will interlink with existing datasets from Hornsund station and enable comparison with research conducted at other Arctic sites.

11.2 Personnel

Head of the Department
Marek Lewandowski
Professor

Professors
Piotr Głowacki
Monika A. Kusiak

Associate Professors
Daniel J. Dunkley
Mateusz Moskalik

Assistant Professors
Maciej Bartosiewicz
Oskar Głowacki
Piotr Król
Bartłomiej Luks
Adam Nawrot
Zuzanna Świrad
Tomasz Wawrzyniak

PhD Students
Tanmay Keluskar, Indie; Monika A. Kusiak– PhD supervisor
Piotr Król, Poland; Monika A. Kusiak– PhD supervisor
Marta Majerska, Poland; Marzena Osuch, Tomasz Wawrzyniak– PhD supervisors
Marcin Mieszczak, Poland; Monika A. Kusiak– PhD supervisor
Blanka Pajda, (MŚSD, IO PAN), Poland; Mateusz Moskalik – PhD supervisor
Julian Podgórski, Poland; Piotr Głowacki, Michał Pętlicki (Centro de Estudios Cientificos, Chile) – PhD supervisors
Karol Torzewski, Poland; Adam Nawrot– PhD supervisor

11.3 Main research projects

- INTAROS – Integrated Arctic observation system, P. Głowacki, EU HORIZON 2020, 2016–2022;
- Interact II – International Network for Terrestrial Research and Monitoring in the Arctic, P. Głowacki, EU Horizon, 2016–2021;
- Interact III – International Network for Terrestrial Research and Monitoring in the Arctic, P. Głowacki, EU Horizon, 2020–2024;
- SIOS – Svalbard Integrated Arctic Earth Observing System (Zintegrowany Arktyczny System Obserwacyjny dla Svalbardu), P. Głowacki, Polish Road Map of Research Infrastructure, Ministry of Science and Higher Education, 2018–2023;
- Poles together – missing links between Arctic and Antarctic early Earth records (PAAN), M.A. Kusiak, M. Lewandowski, D.J. Dunkley, P. Król, Norway grants, 2020–2023;

- In-situ snow measurements for distributed modelling of the seasonal melting (SNOWME), B. Luks, SIOS, Access Programme, 2021–2022;
- An Integrated Network to Measure Seasonal Processes in Arctic Habitats via Novel Experiments – IN-SPACE, B. Luks, SIOS Access Programme, Ecole Centrale de Lyon, France, 2020–2021;
- Microbial anthropogenic footprint in snow-dominated Karkonosze catchments, A. Nawrot, B. Luks, NAWA – PHC Polonium, 2019–2021;
- Role of animals in shaping cryoconite hole ecosystems – effects of bioturbation and food choice, A. Nawrot, NCN–OPUS, AMU, Poland, 2019–2022;
- State of Revvatnet hydrodynamics (StaRev), T. Wawrzyniak, SIOS Access Programme, Norway, 2019–2021;
- Hindcasting and projections of hydro-climatic conditions of Southern Spitsbergen, M. Osuch, T. Wawrzyniak, et al., NCN, 2018–2021;
- Applied remote sensing and geophysical imaging in recognition of the changes of the water balance in High Arctic catchments, M. Osuch, T. Wawrzyniak, et al., NCN, 2021–2025;
- Ecosystem connectivity effects on the metabolism and greenhouse gas flux in warming Arctic and Alpine lakes (ConGas), M. Bartosiewicz (PI), T. Wawrzyniak, M. Osuch, NCN, 2021–2025;
- Visualization of methane fluxes along coastal boundaries of Arctic permafrost and glaciers, M. Bartosiewicz, M. Moskalik, PASIFIC, 2021–;
- Variability of arctic river thermal regimes in a changing climate (VariaT), M. Majerska, T. Wawrzyniak, M. Osuch, NCBiR, SMALL GRANT SCHEME, 2021–2023;
- Measuring the melt rate of glacier ice with underwater noise, O. Głowacki, M. Moskalik, IG PAS internal project, 2017–2021;
- "RAW – Retreat And Wither" – What is the influence of glaciers recession from tidewater to land-based on the marine biological production and biogeochemistry in the Arctic?, M. Moskalik, O. Głowacki, Norway grants GRIEG, 2021–2024;
- Quantification of heavy metal discharge with freshwater runoff to an Arctic fjord ecosystem (Hornsund, Spitsbergen), M. Moskalik, O. Głowacki, NCN OPUS, IO PAN, 2021–2024;
- Ecosystem connectivity effects on the metabolism and greenhouse gas flux in warming Arctic and Alpine lakes (ConGas), M. Moskalik, NCN OPUS LAP, 2021–2025;
- Wave energy delivery to the shores of Hornsund fjord, Svalbard, Z. Świrad, M. Moskalik, NCN SONATINA, 2021–2024;
- The evolution of Archean crust: magmatic and metamorphic events in the Napier Mountains, Napier Complex, east Antarctica, P. Król, SYNTHESYS EU project, 2021.

11.4 Instruments and facilities

Equipment

- Zeiss Axioscope 5 petrographic microscope for analysis in transparent and reflected lights and fluorescence;
- TinyTag Plus 2 temperature recorders – 10 pieces; Software for TinyTag recorders with data cable; Soil humidity and temperature recorders Tomst;
- The TMS-4 dataloggers – 10 pieces, measurement of air and soil temperature as well as soil moisture thanks to three temperature sensors and one soil moisture sensor;

- Onset Dissolved Oxygen loggers – 4 pieces, Onset pH loggers – 4 pieces, Onset temperature loggers (TidBit) – 10 pieces.

Laboratories

HyChe 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.

GeoBeLa Laboratory

- EKO-LAB LAB-02-130 Rock crusher with a Vacuum cleaner with HEPA filter;
- EKO-LAB Sieve and shaker set;
- Air compressor and cleaning gun;
- Zeiss Primotech petrographic microscope with PC;
- Zeiss Stemi 508 binocular microscope with PC;
- Geochemical fume cupboard (digestorium) with w carbon filter attachment (Tawo)• WAMED Drying oven.

11.5 Seminars and teaching

Seminars and lectures

B. Luks,Winter fieldwork safety in mountains and polar regions, University of Silesia / International Environmental, Doctoral School, Poland, 10.03.2021, Lecture;

O. Głowacki, Hydroacoustics as a tool in geophysical research, International Environmental Doctoral School, Poland, 22.02.2021, Seminar;

T. Wawrzyniak, Climate change impacts on the hydrological processes in Svalbard, APECS – Brasil the Brazilian Antarctic Program (PROANTAR) and the Oceanographic Institute of the University of São Paulo (IO-USP), Brazil, 02–04.02.2021, Invited lecture, The VI APECS-Brasil Symposium online;

T. Wawrzyniak, Modeling the temperature of perennially frozen ground, International Environmental Doctoral School, Poland, 02.2021, Lecture;

T. Wawrzyniak, Flow regime in catchments with different level of glaciation in SW Spitsbergen, Consortium of Universities for the Advancement of Hydrologic Science, USA, 24.02.2021, Invited Lecture, Winter Cyberseminar Series: Research and Observatory Catchments: the Legacy and the Future;

M.A. Kusiak, How to submit a good application. Personal view, European Regional Science Association (ERSA), Online, 11.05.2021, Invited lecture;

M.A. Kusiak, Poles together – missing link between Arctic and Antarctic early Earth record, NCN / Kraków, 17.06.2021, Invited lecture;

M.A. Kusiak, GeoProcessing Belsk Laboratory, Obserwatorium w Belsku, 18.06.2021, Seminar;

P. Król, How to separate minerals, Obserwatorium w Belsku, 18.06.2021, seminar.

Thesis

Bartłomiej Luks (co-supervisor)/Barbara Woronko, Piotr Widliński, Dynamics of the movement of the Hans Glacier in 2006–2019 (Hornsund, SW Spitsbergen, Svalbard), University of Warsaw, Warszawa, Poland.

Visiting scientists

Prof. Francisco Navaro, Universidad Politécnica de Madrid, Madryt, Spain, 11–13.10.2021.

11.6 Meetings, workshops, conferences, and symposia

Presentations of the Department's members:

- B. Luks, J.I. López Moreno, L. Leppänen, E. Alonso-González, M. Błaszczyk, S. Gascoin, C. Deschamps-Berger, M. Osuch, J.C. Gallet, SIOS Polar Night Week 2021, In-situ snow measurements for distributed modelling of the seasonal melting, Longyearbyen, Norway, Online, 11–15.01.2021, Poster, Conference;
- S. Aaboe, K. Isaksen, W. Van Pelt, A.O. Pedersen, B. Luks, SIOS Online Conference on "Earth Observation (EO) and Remote Sensing (RS) applications in Svalbard", Svalbard: decadal trends in snow cover and sea-ice area, Longyearbyen, Norway, Online, 08–10.06.2021, Oral, Conference;
- R. Salzano, K. Aalstad, E. Boldrini, J.C. Gallet, D. Kępski, B. Luks, L. Nilsen, R. Salvatori, S. Westermann, SIOS Online Conference on "Earth Observation (EO) and Remote Sensing (RS) applications in Svalbard", Towards a Svalbard Time-Lapse Network: the PASSES experience, Longyearbyen, Norway, Online, 08–10.06.2021, Oral, Conference;
- M. Lewandowski, M.A. Kusiak, A. Nawrot, T. Werner, B. Barzycka, M. Laska, B. Luks, The 5th High Latitude Dust Workshop, Seeking the Sources of Dust: Geochemical and Magnetic Studies on "Cryodust" in Glacial Cores from Southern Spitsbergen (Svalbard, Norway), Reykjavik, Iceland, 10–11.02.2021, Oral, Workshop;
- M. Osuch, T. Wawrzyniak, K. Migała, E. Łepkowska, Ł. Stachnik, D. Ignatiuk, Arctic Science Summit Week 2021, Changes in the flow regime in the four High Arctic catchments with a different stage of catchment glaciation, Online, 19–26.03.2021, Oral, Conference;
- S.A. Wilde, M.A. Kusiak, D.J. Dunkley, M.J. Whitehouse, W. Richard, 3rd European Mineralogical Conference, Evaluating nanoscale inclusions and clusters of radiogenic lead in zircon, Kraków, Poland, Online, 29.08–02.09.2021, Oral, Conference;
- P. Król, M.A. Kusiak, D.J. Dunkley, S.A. Wilde, K. Yi, M.J. Whitehouse, 3rd European Mineralogical Conference, A possible mosaic of domains with independent geological histories, Kraków, Poland, Online, 29.08–02.09.2021, Oral, Conference;
- M.A. Kusiak, D.J. Dunkley, M.J. Whitehouse, S.A. Wilde, M.J. Mieszczak, 3rd European Mineralogical Conference, Comparing Eoarchean records of crustal growth in the North Atlantic Craton between the Saglek Block of Labrador, Canada and the Itsaq Gneiss, SW Greenland, Kraków, Poland, Online, 29.08–02.09.21, Oral, Conference;
- M.J. Whitehouse, M.A. Kusiak, D.J. Dunkley, S.A. Wilde, T. Keluskar, 3rd European Mineralogical Conference, Observation and inference in the interpretation of zircon ages obtained from a purported >3.9 Ga gneiss in the Saglek Block, Labrador, Kraków, Poland, Online, 29.08–02.09.2021, Oral, Conference;
- L. Shumlanskyy, A. Gawęda, D. Chew, K. Szopa, A. Bekker, D.J. Dunkley, 3rd European Mineralogical Conference, Fluid-controlled apatite-calcite equilibrium in calc-silicate rocks from Zavallya, Podillya domain of the Ukrainian shield (Ukraine), Kraków, Poland, Online, 29.08–02.09.2021, Poster, Conference;

- D.E. Harlov, D.J. Dunkley, E. Hansen, C. Ishwar-Kumar, V. Samuel, T. Hokada, Goldschmidt 2021, Zircon as a recorder of chemical change during metamorphism of Neoarchean lower crust, Shevaroy Block, Eastern Dharwar Craton, southern India, Online, 04–09.07.2021, Oral, Conference;
- M. Osuch, T. Wawrzyniak, et. al., 3rd International Conference Polar Climate and Environmental Change in the last Millenium, Reconstruction of the hydrological processes in four High Arctic catchments (SW Spitsbergen), Toruń, Poland, 30.08–01.09.2021, Oral, Conference;
- K. Migała, M. Osuch, T. Wawrzyniak, et. al., 3rd International Conference Polar Climate and Environmental Change in the last Millenium, A few remarks on the dynamics of contemporary climate conditions in Svalbard, Toruń, Poland, 30.08–01.09.2021, Oral, Conference;
- T. Wawrzyniak, M. Osuch, XXXVIII Międzynarodowe Sympozjum Polarne, Recent, past and future climate change impacts on permafrost in SW Spitsbergen (Svalbard), Toruń, Poland, 18–20.11.2021, Oral, Conference;
- M. Osuch, T. Wawrzyniak, et al., XXXVIII Międzynarodowe Sympozjum Polarne, Projections of hydro-climatic conditions in SW Spitsbergen, Toruń, Poland, 18–20.11.2021, Oral, Conference;
- M. Majdański, A. Marciniak, B. Owoc, W. Dobiński, T. Wawrzyniak, M. Osuch, A. Nawrot, M. Glazer, EGU General Assembly 2021, Surprisingly thick active layer of permafrost in the mountain slope in the SW Svalbard, Vienna, Austria, 05.2021, Oral, Conference;
- O. Głowacki, 6th Underwater Acoustics Conference & Exhibition (UACE2021), Studying submarine calving with ambient noise oceanography, Online, 21–24.06.2021, Oral (invited), Conference;
- G.B. Deane, O. Głowacki, H. Vishnu, M.D. Stokes, M. Chitre, H.A. Johnson, J. Tęgowski, 6th Underwater Acoustics Conference & Exhibition (UACE2021), Recent Progress in Monitoring Tidewater Glaciers with Passive Cryoacoustics, Online, 21–24.06.2021, Oral (invited), Conference;
- H.A. Johnson, G.B. Deane, M.D. Stokes, O. Głowacki, M. Moskalik, M. Chitre, H. Vishnu, 181st Meeting of the Acoustical Society of America, Predicting the acoustic energy radiated by melting glacier ice Seattle, Washington, USA, 29.11–03.12.2021, Oral, Conference;
- H. Vishnu, G.B. Deane, M. Chitre, O. Głowacki, M.D. Stokes, M. Moskalik, H.A. Johnson, 181st Meeting of the Acoustical Society of America, Spatial variation in acoustic field due to submarine melting in glacial bays Seattle, Washington, USA, 29.11–03.12.2021, Oral, Conference;
- P. Zagórski, K. Jarosz, M. Moskalik, J. Jania, M. Błaszczyk, 38 International Polar Sympozjum, On difference of surge type behavior of three glaciers in southern Svalbard, Toruń, Poland, 18–20.11.2021, Oral, Conference;
- A. Goździk, P. Głowacki, J. Giżejewski, 38 International Polar Sympozjum, Polar Research as a vehicle to raise interest in science and awareness of environmental changes in the Arctic – EDU-Arctic.PL case study, Toruń, Poland, 18–20.11.2021, Oral, Conference.

11.7 Publications

ARTICLES

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