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Svalbard, Arctic**

and

**the 40th Anniversary of the Arctowski Polish Antarctic Station,  
South Shetland Islands**

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**IPY STATIONS IN THE NORWEGIAN ARCTIC – THEIR HISTORY AND CURRENT MANAGEMENT**

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The first three International Polar Years – 1882-83, 1932-33 and the International Geophysical Year 1957-58 – resulted in a large number of national scientific stations being established around the circum-arctic region. Most of the stations were only used in this connection and were then on the whole abandoned as they were. In other words they became in time historical material that is now considered worthy of documentation and research and perhaps also conservation and protection. With the steady increase in polar tourism they also become sites for visitation. Several of these stations were established in what is now Norwegian arctic territory: the island of Jan Mayen and the archipelago of Svalbard. Not least among the IGY stations in Svalbard from the 1950s is of course the Polish station in Hornsund. This presentation will introduce the IPY/IGY stations established on Jan Mayen and in Svalbard, outline their history both during and after use, and explain the management of the remains today. The IGY station in Hornsund will not, however, be treated in detail since other presentations cover that.

**PRESENT AND FUTURE ANTARCTIC RESEARCH, IMPORTANCE OF INTERNATIONAL COOPERATION**

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Antarctica offers extraordinary opportunities for scientific research in many fields, and provides critical knowledge about global processes. Antarctic research also offers significant opportunities for international cooperation. Since 1958 the Scientific Committee on Antarctic Research (SCAR) is the leading organization for coordinate and promote international scientific research in Antarctica. SCAR also provides scientific advice to the Antarctic Treaty System, the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC).

SCAR has adapted its structure over the years to fulfill its mission, having currently a series of subsidiary bodies and six Scientific Research Programmes (SRP). A new generation of SRPs is starting to be discussed, which will be a framework and guidance for Antarctic research in the coming decade. In order to achieve its mission, SCAR has published its Strategic Plan for the period 2017-2022 (<https://www.scar.org/horizon/strategic-plans/774-2017-strategic-plan/file/>). The plan takes in consideration the results of the first Antarctic and Southern Ocean Science Horizon Scan. This initiative assembled world leading Antarctic scientists, policy makers, leaders, and visionaries to identify the most important scientific questions that will or should be addressed by research over the next two decades and beyond. This was the first time that the international Antarctic community has formulated a collective vision, through discussions, debate and voting. The outcome was an agreement on 80 of the most important Antarctic research questions, laying out an ambitious scientific “roadmap” for the next 20 years and beyond (<https://www.scar.org/about-us/horizon-scan/overview/>

Answering these many questions will require sustained and stable funding; access to all of Antarctica throughout the year; application of emerging technologies; strengthened protection of the region; growth in international cooperation; and improved communication among all interested parties. At the same time, many Antarctic programmes are suffering budget pressures and uncertainties. The Council of Managers of National Antarctic Programs (COMNAP) led a second stage of the process, with the

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Antarctic Roadmap Challenges (ARC) project, focused on delivering Antarctic science identified in the Horizon Scan.

This presentation will describe the current and future perspectives of SCAR, the process of the Science Horizon Scan, its results and how actions will be implemented to explore and achieve future scientific priorities and discuss the associated challenges. The need of international cooperation and partnership in Antarctic research, and the role of SCAR will be emphasized, highlighting the importance of the contribution from the SCAR nations and their research communities, in which Poland has a long tradition of participation.

**MASS BALANCE OF SVALBARD GLACIERS 1957-2015, IN A GLOBAL CONTEXT**

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Glaciers and ice caps in the Arctic currently experience severe mass loss. They are vulnerable to small temperature changes and contribute significant to global sea-level rise.

The most recent inventory of Svalbard glaciers show reduced ice masses and gives an area of 33 775 km<sup>2</sup> of glaciers covering 57% of the total land area of the archipelago. The glacierized area over the entire archipelago has decreased by an average of 80 km<sup>2</sup> /yr over the past ~30 yrs, representing a reduction of 7 %.

Mass balance monitoring was started by the Norwegian Polar Institute in 1967 at two small glaciers in Kongsfjorden, North-West Spitsbergen. These have been extended to larger glaciers in the same region since 1986 and since 1988 Hansbreen in South Spitsbergen has been monitored by Polish researchers. The mass balance time series are among the longest continuous data series from the Arctic. However, they cover only a small fraction (~2%) of the total glaciated area. The time-series show no clear trend and no recent increased melt-rate can be detected. The larger glaciers are in general more positive, since their accumulation areas are both higher and larger than the smaller glaciers. On all glaciers, summer ablation is more variable than winter accumulation, thus summer temperatures provide most of the control on the net balance.

Geodetic mass balance over entire Svalbard has been obtained by analyzing the Ice, Cloud, and land Elevation Satellite (ICESat) data from 2003-2009. This shows that most glacier regions in Svalbard have experienced low-elevation thinning combined with high-elevation balance or thickening.

Mass balance modelling has been run for the period 1957-2014, forced by ERA-40 and ERAInterim reanalysis data, downscaled to 1 km resolution. The modelling shows a general positive surface mass balance in the period from 1957 to early 1980ies and negative since then with a linear mass balance trend of  $-14 \pm 4.1$  cm w:eq/yr/decade.

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The calving loss is an important part of the overall mass budget and estimates varies from 4 to 8 Gt/yr (12-24 cm w. eq./yr.) Many glaciers are of surge-type and surges may alter the are/altitude distribution and for calving glaciers give a temporary increased mass loss

The current total mass loss estimates of Svalbard glaciers thus vary from -5 to -12 Gt/yr or - 14 to – 36 cm w. eq. /yr.

**BRAZILIANS IN ANTARCTICA: OPPORTUNITIES FOR INTERNATIONAL COOPERATION**

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This presentation aims to review the present objectives and structure of the Brazilian scientific investigations in Antarctica, its insertion in the international community, envisaging topics for joint investigations. The PROANTAR, until 2008, had its investigations restricted to the South Shetlands (mainly in the Comandante Ferraz station, only 10 km away from the Polish Arctowski station), the northern most part of the Antarctic Peninsula and the surrounding water masses. Since then, the programme went through great modifications, as the action plan elaborated for the scientific activity from 2013 to 2022, and the beginning of the construction of a new station with 16 laboratories (at the same site of the old station burnt to the ground in 2012).

The scientific programme seeks to develop a research programme of excellence concerning the Antarctic region and its connections with the Atlantic Ocean and South America. Five research programmes have been implemented: (1) The role of the cryosphere in the Earth system and interactions with South America; (2) Biocomplexity of the Antarctic ecosystems, their connections with South America and climate change; (3) Climate Change and the Southern Ocean; (4) Geodynamics and geological history of Antarctica and its relations with South America; (5) Dynamics of the Antarctic upper atmosphere, geospace interactions, and connections with South America. These scientific aims are broader, including studies on the Arctic environmental changes and implications for the Tropics. Further, two decentralized and virtual institutes were implemented for Antarctic research (one specific for cryospheric sciences and other for environmental research and monitoring). This presentation will also discuss briefly the two main Brazilian platforms for scientific research at this moment: - the Polar Ship Maximiano (Brazilian Navy), and the automatic and sustainable remote scientific module Criosfera 1 for atmospheric, geophysical and glaciological investigation in the West Antarctic Sheet (84°S, 79,5°W).

**LANDSCAPE CHANGE AND THE EMISSION OF GREENHOUSE GASES IN CENTRAL SPITSBERGEN**

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This talk demonstrates how landscape change since the Last Glacial Maximum (LGM) exerts a crucial, long-term control upon greenhouse gas emissions to the atmosphere. The work reported formed the basis of the JPI-funded project: “More than methane: quantifying melt-driven biogas production and nutrient export from Eurasian Arctic lowland permafrost (LowPerm)”. The influences of sea level change, permafrost aggradation, ground thaw and deglaciation will be shown to strongly influence the emission of methane and CO<sub>2</sub> from both the active layer and the sub-permafrost environment. This talk will therefore describe how sedimentary habitats which have formed within Svalbard’s major valley systems over the last 10 k.a. are conducive to biogas emissions from their active layer, but have lower than expected methane generating potential due to a lack of organic matter and a dominant microbial community associated with iron cycling. Rates of organic matter accumulation in Svalbard are therefore crucial for understanding future methane emissions from the expansive wetlands that are found in its coastal lowlands. However, there also exists vast resources of methane in sub-permafrost aquifers, whose rapid escape has been recently connected to the earlier stages of ice sheet retreat through the analysis of pockmark features on the fjord floor. This talk will therefore describe our recent research on the rapid ventilation of such methane directly to the atmosphere via groundwater seeps and open system pingos that are analogous to the pockmarks, but are now found above sea level following sea level change. The role of permafrost aggradation following emergence from the sea is crucial for understanding these hotspots of methane and CO<sub>2</sub> escape. How these fluid escape pathways will respond to contemporary climate change is unclear though, and will remain so until the water and gas source dynamics are better understood. However, what is clear is that the emission of methane and CO<sub>2</sub> from both the active layer and the sub-permafrost environment are intricately linked to landscape change since the LGM.

**OBSERVED IMPACTS ON THE CRYOSPHERE OF THE RECENT COOLING IN THE NORTHERN  
ANTARCTIC PENINSULA**

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The Antarctic Peninsula (AP) is often described in the literature as a region with one of the largest warming trends on Earth since the 1950s, above 0.54°C/decade in Faraday/Vernadsky station. Accordingly, most works describing the evolution of the natural systems in the AP region cite this extreme trend as the underlying cause of the observed changes, often neglecting that the AP warming has been highly variable in space and time, and that most climate studies do not consider instrumental data collected beyond 2006. Recently, Turner et al. (2016) presented a study of the change in the regional temperature trends, showing that a change in trend, from warming to cooling, happened around 1998-1999. Turner's study spans the period 1979- 2014 and makes use of a stacked temperature record for the entire AP, using data from 6 stations. We have analysed climate data from ten stations distributed across the AP, spanning the period 1950-2015, to update and re-assess the spatially-distributed temperature trends and the inter-decadal variability (Oliva et al, 2017). We show that Faraday/Vernadsky warming trend is an extreme case, circa twice those of the long-term records from the northern AP. We also show that most stations data reveal a noticeable cooling for the decade 2006-2015, largest in the northern AP in autumn and winter (up to 1.8°C colder than the previous decade), which has decreased the warming trends, by 10-23% for the longest records and 31-71% for those started in the 1970s. This recent cooling has already impacted the cryosphere in the northern AP, including a certain slow-down of glacier recession, a shift from typically negative to predominantly positive surface mass balances of the peripheral glaciers in this region with data in the World Glacier Monitoring System database, and a shift from thickening to thinning of the active layer of permafrost in islands in the northern AP and the South Shetland Islands archipelago.

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**OCEAN GLACIER INTERACTION IN NORTHEAST GREENLAND**

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The mass loss of the Greenland ice sheet contributes considerably to the global sea level rise of the last decades, and it has been increasing recently. There are indications that since the 1990s, besides surface melt, also ocean warming, causing increased melt at the fronts or under the ice tongues of ocean terminating glaciers, was responsible for this trend. This basal or frontal melt would increase the destabilisation of the glaciers and the upstream ice streams. Predominantly at the southeastern and western coast of Greenland, glacier acceleration in the recent years has been found to coincide with inflow of the warming waters from the North Atlantic into the fjords.

For glaciers at the northeastern coast, however, remote sensing observations showed less reduction but now these glaciers start to destabilize as well. This is probably driven by warming of Atlantic Water that spreads also in the Northern Nordic Seas. However, because the shelf sea off East Greenland is difficult to access due to the permanent sea ice presence, the circulation of of the warming water is particularly poorly investigated through direct observations.

To study the complex, multi-scale interaction between ocean and glaciers in the Northeast of Greenland, the project GROCE (Greenland Ice Sheet Ocean Interaction) was initiated and started in 2017. The focus of GROCE lies on the 79.5N glacier in North East Greenland which, together with its neighbour glacier, drains 16% of Greenlands ice sheet. GROCE combines field measurements, remote sensing and modelling of both the glacier and the ocean from local to regional scale. To understand the ability of warm ocean waters to interact with glaciers information of the pathways that the warm water takes to reach the glacier, the bathymetry below and in front of the glacier and the dynamics of the water exchange at the glacier front was addressed in two recent cruises. Here, we report on first results from an investigation of the circulation of the warm ocean water towards the 79.5N glacier.

**IN SITU WARMING EXPERIMENTS NEAR HENRYK ARCTOWSKI ANTARCTIC STATION:  
UNRAVELING THE IMPACT OF REGIONAL WARMING ON ANTARCTIC VASCULAR PLANTS**

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The Antarctic Peninsula has experienced the second faster warming on Earth in the last century. Concomitantly with warming, vascular plant populations (*Deschampsia antarctica* and *Colobanthus quitensis*) have expanded in the Maritime Antarctica. Several hypotheses have been raised trying to explain the biological bases of these plant expansion, such as those suggesting direct effects of temperature on carbon gain and hence increases of growth and reproduction of these species and also hypothesis related to indirect effects of the increase in temperature on soil nutrient cycling and availability for plant growth. Additionally, negative impacts of warming have been hypothesized, such as loss of freezing tolerance by long term warming exposure in these species. These hypotheses have been contrasted by a combination of field and laboratory studies of plant responses to temperature and *in situ* warming experiments using open top chambers (OTC) in King George Island, near Henryk Arctowski Station. Plant photosynthetic activity, growth, soil nutrient availability and microenvironmental characterization of OTC and open areas (OA) have been monitored during four consecutive seasons in the field. Our results showed that OTC had significant effect on plant growth. However, the response to temperature depends on site nutrient availability (mainly N) and species. Soil respiratory activity increased under OTC concomitantly with the availability of organic matter and nitrogen. Consistently, laboratory studies indicated that growth of both vascular species respond to nitrogen fertilization. The increase in photosynthetic activity at leaf level observed in OTC is not enough to explain plant growth. An integrated photosynthetic canopy activity of the whole growing season is currently performed to fill this gap. Our results suggest that expansion of vascular species is associated to direct and indirect effects of warming. Freezing tolerance of these two plant species has been slightly reduced in the OTC, however they exhibit so far enough resilience to cope with frost

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experienced during the Antarctic growing season. The relative importance of the implicated factors will be discussed.

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**THE POLITICAL CONTEXTS OF THE POLISH POLAR RESEARCH**

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Polish quite long and well-established presence in both polar regions is usually described and considered in the purely scientific categories. However, like the other states, Poland - supporting and organizing polar research and since the very beginning engaging in the international collaboration (just to mention the national expeditions during the International Polar Years) - acts also a political actor on the polar stages and beyond them. Although this political dimension of the development of the Polish presence in the Arctic and the Antarctic remains understudied, it is an interesting case for exploring how domestic and international political developments can support or reduce the interests of mid-latitude states in such special undertakings like polar research. The aim of the presentation is to offer for a discussion an overview of this issue, arguing that while a non-political character of the Polish polar research is a myth, it is still difficult to say that Poland fully takes political advantage of its engagement in the polar research.

**RECENT AIR TEMPERATURE CHANGES IN THE ARCTIC IN THE LIGHT OF OBSERVATIONAL AND REANALYSIS DATA**

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Recent air temperature changes in the Arctic, defined according to Atlas Arktiki (1985), have been investigated based on mean seasonal and annual data calculated for the period 1951-2015 and for the two sub-periods 1979-2015 (the second phase of global warming) and 1996-2015 (the recent rapid Arctic warming). Two kinds of air temperature data (observational and reanalysis) have been used in the research. For the entire study period the observational data were compared with data taken from 20CRv2c and CERA-20C, while for the two sub-periods they were compared with data from six reanalysis products (20CRv2c, CERA-20C, ERA-Int., MERRA-2, NCEP-CFSRR, JRA-55). Anomalies of air temperature for the chosen sub-periods have been calculated and their spatial distributions have been analysed. In addition, spatial distributions of air temperature trends for all three periods are presented and their statistical significance for particular stations or grids have been estimated. Time and spatial differences are shown between statistical characteristics, having been calculated using observational and reanalysed air temperature data. Areas with the greatest discrepancies in air temperature characteristics between data taken from observations and those from reanalysis products have been identified, and an attempt was made to assess their causes. The main aim of the present paper is to present the recent tendencies in air temperature in the Arctic, as well as to indicate the reanalysis products which are most reliable and accord most closely with observations. Atlas Arktiki, 1985. Glavnoye Upravlenye Geodeziy i Kartografiy Moskva: 204 pp.

**MODELLING LAND SURFACE TEMPERATURE (LST) ON THE SVALBARD ARCHIPELAGO**

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The LST reflects the combined effect of surface and weather conditions that together regulate energy flows between the atmosphere and the ground. For this reason, LST is a key parameter both for the monitoring of the surface energy balance and for its modelling. In the polar regions, LST is one of the most important factors affecting the location and character of long-term permafrost, glacial mass balance and ecosystem dynamics. Satellite thermal sensors enable synchronous area evaluation of regional and global LSTs. This is particularly valuable for the vast and hard-to-reach Arctic landscapes where direct LST measurements are very rare and their spatial representativeness is severely limited. In this analysis, LST timely data from MODIS satellites Terra and Aqua (4 measurements per day) from 2000-2016 were aggregated to monthly periods. It covers the Svalbard archipelago area of approximately 58 850 km<sup>2</sup>. Spatial databases provided by the Norwegian Polar Institute (<https://data.npolar.no/home/>) including DEM and land cover maps were also used. The aim of the study was to identify and quantify the significance of geographical factors influencing the seasonal variability of LST in the archipelago. Geographic coordinates (latitude and longitude, height above sea level), terrain slope, direct and diffuse solar radiation, distance from water and open sea, land cover type were potentially significant. For each MODIS pixel a number of statistics are calculated for the variables listed above. The machine learning methods were used to model the relationship between the monthly and annual LSTs in the Svalbard area and independent variables. Preliminary tests have shown that the best result was the Boosted Tree Regression" (BTR) procedure. The obtained BTR models were unbiased and their mean absolute errors ranged from 0.41°C for September to 0.83°C for February (average error of LST annual model was 0.49°C). The scale of average model errors is comparable to the uncertainty of determining LST from a satellite orbit (0.5 - 1K). The spatial distribution of errors shows autocorrelation, which indicates the existence of local factors modifying regional regularities. Location coordinates have had the greatest impact on LST spatial distribution. Composition and order of the secondary factors included in the models changed significantly in the seasons. From January to April, the distance to the water and the sea was the most important. The role of radiation start to be important in February after end of the polar night. From

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May to August, relief, land cover and radiation were of the highest importance. For the entire year LST in Svalbard is determined in 36% by geographic location, evenly 18% by land cover of the site and its relief, 16% - distance from water, and 12% - potential radiation.

**ASSESSING THE CLIMATE IMPACT OF AVIATION EMISSIONS ON THE ARCTIC ENVIRONMENT**

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The continuing decrease of ice cover over the Arctic allows for the increase in shipping and industrial activities in the region. These activities lead to the increase of anthropogenic emissions from shipping, prospecting, exploration, and smelting. Emissions from shipping are dominant, and their magnitude and impact on the Arctic environment have been addressed in recent publications. The objective of this study is to investigate the impact of the increased demand for commercial aviation transport to the Arctic on the air quality near the ground. Also, we will assess the impact of aviation emissions injected at cruise altitudes (9-11 km) from the intercontinental air traffic that over the Arctic quite often will be above the tropopause in the lower stratosphere. We will present results from the GEM-AC model simulations for several aviation emissions scenarios for current and future climate. GEM-AC (Global Environmental Multiscale model for Atmospheric Chemistry) is a chemical weather model where air quality, free tropospheric, and stratospheric chemistry processes are on-line and interactive. In the vertical, the model domain is defined on hybrid levels from the surface to ~60km. The modelling results for current and future climate (2050) in the context of changing atmospheric composition and climate in the Arctic will be presented. The analysis will include changes in atmospheric composition that impact the radiative balance in the atmosphere.



**AIR TEMPERATURE AS A CRITERION FOR SNOW AND RAIN SEPARATION FOR SVALBARD****Katarzyna Cielecka<sup>1,2</sup>, Ewa Łupikasza<sup>2</sup>**<sup>1</sup>*Faculty of Earth Sciences, University of Silesia - Centre for Polar Studies (KNOW), Sosnowiec, Poland*<sup>2</sup>*Faculty of Earth Sciences, Department of Climatology, University of Silesia, Sosnowiec, Poland**e-mail: [katarzyna.cielecka1@gmail.com](mailto:katarzyna.cielecka1@gmail.com)*

The phase of precipitation occurrence is crucial for many environmental processes and model glaciological and hydrological studies. In cold climates the separation of precipitation into snow and rain is necessary for water balance calculations because it determines how much water is available for runoff and soil infiltration, or is stored as snow (Kienzle 2008). In this study we analyse the dependence of precipitation phase on daily, maximum and minimum air temperatures in Svalbard Archipelago to assess the geographical and seasonal variation in temperature thresholds for rain and snow occurrence. We use the data from 5 meteorological stations from the the Svalbard Archipelago and one station – Jan Mayen – located at lower latitudes for comparison studies. The research period was established as a period with data available at every stations and it covers the years between 1978 and 2016. We used the daily precipitation totals, information on precipitation phase, average, maximum and minimum daily air temperature and notation of weather phenomenon (current and past weather). The data come from the eKlima data base that is no longer available for public use and from OGIMET synoptic database. The data for Hornsund station were taken from the archives of Institute of Geophysics Polish Academy of Sciences. We analysed the frequency and conditional probability of liquid, mixed and solid precipitation within daily air temperature ranges, and we build liquid, mixed and solid precipitation curves of cumulative frequency for daily air temperature intervals. Our preliminary results indicate geographical variability in air temperature ranges and thresholds for various precipitation phases. The highest probability of precipitation phases was found in the air temperature from +4°C to +9°C in case of liquid precipitation, from 0°C to +3°C mixed precipitation and from -16°C to -5°C in case of solid precipitation. We found that all precipitation phases are almost equally probable on days with air temperature between -3°C to +4°C depending on the station.

**COMPARISON OF BIOCLIMATIC CONDITIONS ON FRANZ JOSEF LAND (THE ARCTIC) BETWEEN THE TURN OF THE 19<sup>TH</sup> AND 20<sup>TH</sup> CENTURIES AND MODERN TIMES**

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Knowledge of the climatic conditions of Franz Josef Land over recent decades has been well recorded. Meanwhile, information on the meteorological conditions from earlier periods – and biometeorological conditions in particular – is missing. Some of the oldest and most complete historical weather data from the Franz Josef Land were collected during polar expeditions led by Luigi Amedeo di Savoia (wintering in Teplitz Bay in 1889/1900), Anthony Fiala (Teplitz Bay, 1903/1904), Georgiy Yakovlevich Sedov (Calm Bay, 1913/1914) and by the Section for Polar and High Altitude Observations of the Central Geophysical Observatory in St. Petersburg (Calm Bay, 1930/1931). The study describes the weather and biometeorological conditions at the turn of the 19th and 20th centuries during the aforementioned trips, and then compares them with the contemporary period. For this purpose, meteorological data is used from the Ostrov Heisa weather station from the period 1981–2010. The weather conditions were described in terms of air temperature, relative humidity and wind speed. To assess meteorological conditions in terms of their potential as a physiological stimulus a few additional indicators were used. Biothermal conditions were evaluated on the basis of, daily thermal contrasts, which shows the daily temperature amplitude value. In contrast, moisture and wind conditions are presented in typical value ranges. Perceived conditions are presented using three biometeorological indicators: wind chill factor, insulation predicted of clothing and acceptable level of physical activity.

**STUDIES OF AEROSOL OPTICAL PROPERTIES DURING LONG-RANGE TRANSPORT OF BIOMASS BURNING FROM CANADA AND GREENLAND TO SVALBARD IN JULY AND AUGUST 2017**

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The preliminary results of studies of aerosols properties during long-range transport of biomass burning (BB) from Canada and Greenland to Svalbard in July and August 2017 are presented. The subject of these studies is the use of passive and active remote sensing observations, as well as numerical simulations to describe the temporal variability of aerosol properties such as aerosol optical depth (AOD), single scattering albedo (SSA), and aerosol direct short wave forcing at the Earth's surface. BB aerosols have an impact on Earth's climate due to altering the radiation budget and hydrological cycle. Their activity is mainly manifested in absorbing and scattering of solar radiation as well as providing condensation nuclei for cloud droplets. The impact of BB aerosols on the global radiation balance is still not fully understood and requires further research. Transport of BB aerosols posed also a risk to ice sheet, because falling soot turns the surface of the sheet black, and thus speeds up the melting process. Observations of aerosol long range transport was possible due to modernization of atmospheric physics monitoring in Polish Polar Station Hornsund, where in July 2017 ceilometer Luft CHM 15k was placed. Ceilometer enabled detection of aerosol layers up to 10 km. The event of the BB aerosol transport was observed between 28 July and 26 August 2017 in Hornsund and the area around Svalbard. Observations of aerosol optical thickness made in Hornsund and on r/v Oceania shows small values (~0.05 at 500 nm) until 20 August 2017 when values of AOD reached 0.35. Ceilometer plots from 20 and 21 August 2017 show multiple aerosol layers. It is assumed that it is BB aerosol. Sources of BB aerosol were determined using data from MODVOLC, an algorithm that uses low spatial resolution (1-km pixel-size) infrared satellite data acquired by the satellite instrument MODIS to map the global distribution of thermal anomalies in near-real-time. Air mass back trajectory analyses (using Hysplit model) confirm that the wildfires in Greenland and

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Canada were the sources of BB aerosols measured in the region. Simulations from the NAAPS aerosol transport model also confirm the source of detected aerosols.

Wildfires in British Columbia have become common in summer due to rising temperatures, however, year 2017 was the third worst year in the region. The wildfire in Greenland was first spotted by satellites on 31 July. It was burning about 40 miles from the ice sheet in the western part of Greenland. Higher temperatures combined with summer melting which reveals tundra, facilitate outbreaks of wildfires.

**EVOLUTION OF SOUTH SPITSBERGEN COAST DUE TO GLACIER DYNAMICS – PAST AND FUTURE**

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Coasts of glacierized areas undergo faster changes than glacier-free ones due to the displacements of the glacier fronts. Svalbard shoreline changes dynamically as it comprises ~860 km of tidewater glacier fronts. Observations of variations in glaciers' extent suggest that southern Spitsbergen is very sensitive to the contemporary climate change, which manifests as a marked decrease of glaciers' area since the Little Ice Age (LIA). General retreat of glaciers is periodically interrupted by glacier surges and readvance. Both processes (surge and retreat) contribute to the dynamic coastal changes, which are particularly pronounced in Hornsund–Hambergbukta area (S. Spitsbergen).

This work aims to identify and quantify shoreline changes in the area defined above and to analyze the driving forces of the coast evolution and its rate. Based on 21st century glacier retreat rate and measured subglacial topography of Hornbreen-Hambergbreen glacier system we predict the potential evolution of the coastline in subsequent decades.

Maximum Holocene extent of glaciers in southern Spitsbergen occurred at the end of the LIA. Since that time Hornbreen in Hornsund Fjord has retreated ~14.2 km with the only advance period in the mid-1930s. The glacier recession contributed to the development of the inner part of the fjord – Brepollen, and successive separation of former lateral glaciers (Samarinbreen, Hyrnebreen, Chomjakovbreen, Storbreen, Svalisbreen, Mendeleevbreen). Hambergbreen maximum extent at the end of the LIA resulted from a surge that occurred later in the 1960s and 1970s, with lower intensity. Due to predominant recession of glaciers in South Spitsbergen the glacier bridge between Sørkappland and the rest of Spitsbergen has shrunk to ~5.8 km in 2015. We estimate that, if the present retreat rate continues, the icefield will disappear in this area sometime between 2055 and 2065. The potential shoreline after glacier decay depends on present-day subglacial topography of the Hornbreen-Hambergbreen glacier system. The shape of the glacier bed in this area has been debated since the 1960s without reaching firm conclusions. Based on radio-echo soundings conducted in 2013 and 2014, the majority of the glacier bed rests below sea level. No continuous subglacial obstacle rising above

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sea level that could divide the Greenland Sea from the Barents Sea basins was found. The Hornbreen valley floor is ~40 m below sea level, while more powerful erosion took place under Hornbreen and Flatbreen, creating a depression extending below sea level along more than 15 km from the current glacier front and reaching ~70 m depth. Our studies suggest that, after the recession of the Hornbreen-Hambergbreen glacier system, it is very likely the appearance of a new island, which would be the fourth largest of the Svalbard Archipelago.

**TALUS SLOPE EVOLUTION UNDER THE INFLUENCE OF GLACIERS WITH THE EXAMPLE OF SLOPES NEAR THE HANS GLACIER, SW SPITSBERGEN, SVALBARD**

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We present the results of geophysical surveys (electrical resistivity tomography – ERT and ground-penetrating radar – GPR) of the talus slopes near the Hans Glacier, SW Spitsbergen. The studied forms develop in interaction with glacier, which has an influence on the evolution of their internal structure. The aim of our study was to compare the talus slopes in two different parts of the glacierized valley: 1) in marginal zone of glacier (western part), and 2) in the zone without contact with the glacier (eastern part). On the first slope the maximum thickness of sediments reaches up to 20 m and buried glacial ice is present in large part of the form. In the case of second slope, the max. sediments thickness reaches a depth of 35 m, but the ice was diagnosed only in a lower part of the talus. The sediment of the slopes is affected by permafrost from a depth of 2-3 m. Finally, the development of forms depends on the paraglacial processes (non glacial processes, but conditioned by glacier), the intense of which is changeable in time since the deglaciation. One of them is the melting of buried glacial ice, what was observed in the talus slopes near the Hans Glacier. Differences in their structure allowed to determine the different stages of the evolution of both talus slopes. Based on the geophysical and geomorphological data, generalized models were proposed for the early stages of talus slope evolution in valleys under deglaciation. Extensive background of presented problems were published by Senderak et al. (2017).

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**THERMAL PROPERTIES OF SNOW COVER OVER DIFFERENT GROUND TYPES DURING SPRING SEASONS 2016, 2017 IN HORNSUND REGION**

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Snow cover properties play important role in surface energy balance and heat exchange with the ground. Changes of the snowpack physical properties determine thermal behaviour of superficial ground layers as well as lower atmosphere. Hence, depending on the underlying ground type the snow cover may influence hydrothermal state of glaciers, permafrost depth and its active layer thickness, lake ice formation conditions and thickness, ecological activities and others.

This paper aims to define relationships between snow cover structure, its thermal properties and the ground type in the Arctic environment of southern Spitsbergen. Temporal variability of snow properties and its potential influence on energy balance of ground were also investigated.

In the spring 2016 and 2017 numerous observations were performed in snow-pits on selected glaciers (Werenskiolbreen and Hansbreen) and in vicinity of the Polish Polar Station in Hornsund on different ground types: tundra, moraine and Revvatnet lake ice. The snow-pit analysis were repeated every few days and included specifying the snow structure, measurements of snow density and thickness in subsequent layers. Thermal properties were investigated by a needle thermometer and thermal camera in every snow-pit. Additionally, a thermistor string (probes placed every 20/40 cm) were installed in different sites (ablation and ELA zone of glacier, tundra, hill and lake ice). All observations were referred to actual weather conditions recorded by 3 automatic weather stations on Hansbreen and at the Polish Polar Station in Hornsund.

The heat exchange with ground depends on numerous factors such as snow thickness, snow density, surrounding topography and weather conditions. Obtained results confirm the relationship between the snow density and its insulating properties. Ice formations appearing within the snowpack significantly increase the average snow cover density and influence on rise of the thermal conductivity. In consequence, cooling down of snow cover is more efficient.



**GLACIAL AND PERIGLACIAL ENVIRONMENT IN GEOPHYSICAL VIEW**

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Glacial and periglacial environments are explored from the beginning of scientific research independently and separately, although ice is the common subject of their research. Glaciologists, declare research interest in all types of ice, but they deal primarily with glaciers. The subject matter of the periglacialists is much broader: it covers at least 20 types of ice present in the active periglacial zone, and various forms and processes occurring in the ground, also on the glacier forefield, especially including freezing. Although glacial ice may be present in a periglacial environment (ie. dead ice blocks), like ice of periglacial origin - in a glacial environment (ie. ice of so called “internal accumulation”). The second after ice, key element which plays important role in both environments, is freezing. It covers in a similar way both the glacial and the periglacial one. It can be observed, also that in the polythermal glacier one can distinguish similar geophysical boundaries that exist in the perennially frozen ground, namely the surfaces of the temperature close to 0° C. The surface of the permafrost base (PB) may be found on the glacier forefield occupied in favourable climatic conditions by permafrost. Its analog in the glacier body can be the cold-temperate transition surface (CTS) which discriminate between “cold” and “temperate” ice in the polythermal glacier. Similarly, the permafrost table (PT) on the forefield in periglacial area corresponds to the glacier surface (GS), because the existence of an "active layer" in positive temperatures is impossible due to the specificity of glacial ice, which changes phase state and flows from the glacier. This lower environmental axis can be called CTS-PB, while the glacier surface together with the permafrost table constitute the GS-PT axis. A very specific precondition that allows such axes to integrate the glacial and periglacial environments is to classify glacier, and any other type of ice, as components of the lithosphere. Otherwise the distinction of permafrost in glacial environment is impossible. This is in fact the key to the integration of glacial and periglacial research.

**TERRESTRIAL LiDAR REFLECTION INTENSITY AS A PROXY FOR RECENT CALVING OF A TIDEWATER GLACIER**

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Knowledge about calving of tidewater glaciers is crucial for many glaciological studies. In this work we propose a method for estimating the age of calving events based on 3D point clouds. Terrestrial LiDAR scans of the calving front of Fuerza Aerea Glacier (Greenwich Island, South Shetland Islands, Antarctica) were analyzed to determine the timing of the ice face exposure after a calving event. We used the mean reflection intensity of a laser beam within a calving event footprint (Int) as a proxy for the ice exposure time (tLC). Point clouds were used together with information about calving location to create a mathematical model of the intensity-time relationship. An exponential function in the form of  $Int = a \cdot \exp(b/tLC) + c$  describes the relationship between the mean reflection intensity and the time elapsed since the last calving event in a given part of the glacier. The model explains over 70% of the variability in reflection intensity between calving events. Despite the good correspondence between modeled and observed data, the application of the model to predict independent observations has shown to be ineffective. It not possible to infer about the calving time with the available data, due to the shape of the model curve and the high deviation of reflection intensity.

**IMPORTANCE OF DISCRETE RECHARGE AND SUPRAGLACIAL DRAINAGE SYSTEM EVOLUTION  
IN SUBGLACIAL DRAINAGE SYSTEM MODELLING OF SVALBARD POLYTHERMAL GLACIERS**

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In the context of global climate change and, in particular, the fast melting of glaciers around the world, it is important to characterize the evolution of the meltwater drainage systems and their consequences for the behavior of glaciers. Due to its direct impact on englacial and subglacial drainage, studies of supraglacial drainage are crucial to locate where a supraglacial system may switch into an internal drainage system. Such switching can be triggered by moulins, shear fractures and crevasses. Our study focuses on the land-terminating glacier Werenskioldbreen and the tidewater glacier Hansbreen. These glaciers are located in the southern part of the Svalbard archipelago. They have a polythermal regime with most surfaces composed by cold ice. This regime implies an impermeable layer that forms a well-channelized dendritic supraglacial drainage system.

The supraglacial drainage system of both glaciers was mapped using high resolution satellite images (taken during 2010 and 2015), orthophotomaps based upon Norwegian Polar Institute aerial photos (taken during 1990 and 2011) and field observations. This information has allowed us to compare the evolution of the system on a decadal and inter-annual timescale. Additionally, the behavior of the subglacial drainage in 2015 has been modelled, based on the hydraulic potential, the ice thickness, the topography of the bed and the surface morphology of the glaciers.

Non-linear thinning (unequal in the same elevation zone) causes changes in the hydraulic potential and the consequent temporal modification of the subglacial and supraglacial drainage systems (and their connection). Considering the lack of studies measuring directly the water behavior inside the body of a glacier, the actual subglacial drainage system modelled for both glaciers involves substantial assumptions that can lead to inaccurate prediction for the subglacial channels locations. Our knowledge regarding the location of discrete water recharge nodes inside both glaciers mapped during the year 2015, enabled us to critically evaluate the classical approach of Shreve's hydraulic potential model and to discuss the importance of parameter characterizing discrete recharge.

**DISTINGUISHING GLACIER FACIES IN SVALBARD GLACIERS BASED ON REMOTE SENSING AND IN SITU DATA**

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Changes in glaciers facies extents are one of the indicators of Arctic ice masses response to the climatic warming. Their spatial distribution can facilitate estimations of glaciers mass balance and assessment of their drainage systems. For distinguishing glacier facies over large or inaccessible areas in the Polar Regions, Synthetic Aperture Radar (SAR) microwave data are recommended because they are independent on daylight and bad weather conditions, providing information on the surface characteristics. However, it is recommended to validate remote sensing analysis by in situ measurements. Ground Penetrating Radar (GPR) and shallow ice cores are very valuable sources of terrestrial information on the distribution and extension of glacier facies. GPR records reflect signals from subsurface structures in a glacier's profile, whereas shallow ice cores allow to unambiguously identifying glacier zones. This work presents results of surveys to distinguish glacier facies in the western part of Vestfonna (Nordaustlandet) in 2009 and Hansbreen (Spitsbergen) in 2017. Our remote sensing analysis includes both simple single-polarimetric and advanced fully-polarimetric data processing. In addition, we extracted and classified SAR backscatter coefficient ( $\sigma_0$ ) values along the GPR profile. For GPR data, both visual interpretation of the profile and classification of Internal Reflection Energy (IRE) coefficient were applied. Finally, this work compares the results of remote sensing analysis, GPR visual interpretation, IRE classification and information from shallow ice cores drilling.

**FRESH WATER INPUT TO THE HORNSUND WITH THE EMPHASIS ON GLACIER CALVING**

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Tidewater glaciers respond to climate warming more distinctly than land based ones, what is reflected by their significant retreat. Glaciers ending down into the Hornsund (Southern Spitsbergen, Svalbard) drain c. 65% of hydro-glaciological basin of the fjord. Thus, calving of tidewater glaciers influence considerably the fresh water discharge to the fjord, and further, water physical properties, circulation and marine ecosystems.

This study presents the estimation of the total supply of fresh water from land to the Hornsund, basing on glaciological and meteorological data from the period 2006-2015. Calculations include calving intensity of tidewater glaciers, surface ablation over the entire glaciated area, water input from liquid precipitation and from melted snow cover over land.

For estimation of long-term calving intensity we used termini positions and glacier velocity derived from radar satellite images. Bathymetry was collected from Norwegian and Polish datasets. Superficial melting of glaciers has been modeled basing upon mass balance measurements on Hansbreen, Storebreen and Flatbreen/Hornbreen. Fresh water input from precipitation and snow cover over the land was estimated upon meteorological data and snowpack properties surveyed at the Polish Polar Station.

Total average input of fresh water to the Hornsund has been calculated as 2.2 Gt a<sup>-1</sup>. Results show that the leading sources of the freshwater supply are superficial melting of glaciers (c. 45%) and calving (c. 29%). Liquid precipitation and melting of snow on unglaciated area have the contribution of 17% and 9% respectively. More detailed results of Hansbreen show that the contribution of calving on the total mass loss depends on dynamics of glacier front (advance – retreat). Thus, during extremely warm years, the total input of fresh water to the fjord from calving could be larger than estimated 30%.

**SOURCES AND DISTRIBUTION OF ICEBERGS IN THE AMUNDSEN SEA, ANTARCTICA**

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The glaciers that drain the West Antarctic Ice Sheet into the Amundsen Sea presently have the highest glacial mass loss comparing to other glaciers in Antarctica. The estimated ice mass loss induced by basal melt in the basin is about 480 Gt yr<sup>-1</sup> and the calving flux is around 190 Gt yr<sup>-1</sup>, which is 18.5% and 31.6% of the total Antarctic ice mass loss driven by basal melting and iceberg calving, respectively. Although icebergs are an important source of freshwater, and one of the largest terms in the mass balance, focus has historically been on the basal melt induced by ocean currents circulating below the ice shelves. Icebergs themselves are still a poorly quantified component. In this study satellite Advanced Synthetic Aperture Radar Wide Swath Mode (ASAR WSM) images acquired on ENVISAT between 1 January 2010 and 31 December 2011 were analyzed in order to detect, classify and study icebergs in the Amundsen Sea, Antarctica. There is a clear seasonal variability in icebergs number and surface area in the Amundsen Sea. The highest values of both parameters are observed during austral winter; the lowest, during austral summer. The changes concern mostly the icebergs smaller than 1 km<sup>2</sup> and pertain to the area north of the Pine Island Bay. This is a new result not previously studied in the literature. There appears to be two main sources of icebergs in the Amundsen Sea: allochthonous and autochthonous. The monthly distributions and example trajectories in 2010 and 2011 indicate that the small icebergs dominating the northern part of the shelf region are imported from the Bellingshausen Sea and they represent about 25-35% of the total surface area of mobile icebergs in the Amundsen Sea. A general westward drift was observed in the Amundsen Sea shelf area. The drift patterns and the seasonal variation of the distribution indicates that while the large icebergs are drifting westwards and get stranded on topographic ridges, the drift of smaller icebergs is instead strongly modulated by sea ice. In summer there is little sea ice and the small bergs drift freely westward. In autumn icebergs which presumably were calved in the Bellingshausen Sea are drifting into the Amundsen shelf region and get frozen into the sea ice during winter. When the sea ice breaks up in spring they start moving westwards again. The average stay-time of the mobile icebergs in the Amundsen Sea is about one year.

**THE IMPACT OF DEEP OCEAN WATER TEMPERATURES ON ICE FLOW VELOCITIES FOR TWO GREENLANDIC OUTLET GLACIERS**

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The loss of mass in the Greenland and Antarctica Ice Sheets has been linked to increase ocean heat supply to the glaciers grounding lines. Particularly the speed up of marine terminating glaciers in Greenland has been widely attributed to increasing ocean temperatures. In order to increase understanding of this link we have investigated the relationship between surface velocities for two glaciers in Greenland: Helheim on the east coast and Kangiata Nunaata Sermia (KNS) on the west coast and ocean temperatures in the corresponding fiords. Our results cover the period 2009-2013 and show both seasonal and inter-annual variability. Ice flow velocity was measured using feature tracking method (in ImGRAFT: <http://imgraft.glaciology.net/>) and satellite images from Landsat 7 ETM+ mission. We find that the velocity of Helheim glacier is likely influenced by the deep ocean water temperatures (depth > 500 m), namely the influx of warm Atlantic water, whereas water temperature at shallower depths do not appear to have a significant influence on glacier speed. Due to a more complex fjord system, the agreement between the presence of deep ocean water and the speed of the glacier is less clear for KNS. Our study demonstrates the need for multiple-year ocean datasets at different depths in the fiords, if we are to disentangle the complex interactions between glaciers and ocean.

**QUANTIFICATION OF PROGLACIAL DYNAMICS USING UNMANNED AERIAL VEHICLE (UAV) SURVEYS AND ARCHIVAL AERIAL PHOTOGRAPHS**

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Proglacial areas are one of the most dynamic landscapes in the Arctic. They are transformed by various geomorphological processes related to the glacial retreat and meltwater activity, as well as paraglacial adjustment of topography. This study deals with landscape transformation over annual time-scales in the foreland of Ayerbreen, Hørbyebreen and Rieperbreen (Svalbard) and Fjallsjökull and Kviárjökull (Iceland) to assess landscape changes in the period 2014-2017. The main aim of this study is to map and quantify landforms development in detailed spatial scale to provide an insight into geomorphological processes which occurred shortly after the retreat of the ice margin. Low-altitude aerial photographs were taken using small UAV flying at an elevation between 40 and 60 m above the ground level. The images were subsequently processed using structure-from-motion approach to produce orthomosaics (~3 cm cell size) and digital elevation models (DEMs) with 5-10 cm cell size. Subtracting DEMs from subsequent time periods created DEMs of Differences - which enabled us to calculate the amount of material loss or deposition. Accuracy of the orthophotos and DEMs was improved using ground control points measured with dGPS. Over the 2014-2017 period repetitive UAV-based surveys revealed and quantify changes in landscape including: (1) glacier thinning; (2) ice-cored moraines degradation; (3) development of terminoglacial and supraglacial lakes; (4) debris flow activity. Short-time dynamics of different components showed very high variability over time and space illustrating relative importance of ice backwasting and downwasting as well as glaciofluvial processes for studied forelands.

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**GROUND PENETRATING RADAR DATA AS A SOURCE OF INFORMATION ABOUT SUBGLACIAL  
GEOLOGICAL STRUCTURES – SOUTHERN SPITSBERGEN**

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Polar areas of the Southern Spitsbergen are immensely intractable to geological analyses, because of the ice cover. Valuable, indirect source of information are geophysical data, e.g. achieved from ground penetrating (GPR) surveys. Available GPR data for 13 glaciers of Southern Spitsbergen (Recherchebreen, Renardbreen, Scottbreen, Amundsenisen, Torellbreen, Vrangpeisbreen, Hansbreen, Werenskioldbreen, Ariebreen, Storbreen, Hornbreen, Flatbreen and Nornebreen) have been analyzed. GPR profiles have been inspected for occurrence of lineaments under the glaciers such as different types of faults, unconformities, fold axis and rock boundaries. Positions of the geological features derived from geophysical surveys were compared with geological maps of the research area. Obtained results allowed to verify the location of mentioned structures imposed on geological maps, and to conclude on positions of selected lineaments in areas of where those data were not available yet. Finally, the zones of potential existence of studied geological features were designated for future radio echo-soundings. Obtained results are valuable source data in 3D geological modeling of geological structures of Southern Spitsbergen.

**CHANGES OF TRIBUTORY GLACIERS AFTER RECESSION PAIERLBREEN - S. SPITSBERGEN**

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Paierlbreen, a tidewater glacier in South Spitsbergen, has retreated c. 4600 m during the last six decades. It caused separation of six tributary glaciers of its lower reach. They are now unnamed cirque or hanging glaciers on relatively steep slopes of Sofiekammen and Luciakammen mountain ridges located on the western and eastern side of the Vestre Burgerbukta fjord. While size and morphological type of the new independent glaciers are similar, their response to climate warming is different. Large lateral dead glacier ice bodies located near the sea level have also been recognized.

Analysis of archive topographic maps, aerial photos and satellite images permitted to quantify retreat rate and recession style of those small glaciers showing similarities and differences. Glaciers located on the Luciakammen slope and exposed to the west seem to be more sensitive to climate warming than those on the eastern Sofiekammen slope. Different “style” and rate of diminishing of the entire set of new glaciers is discussed taking into consideration local topographic conditions as well.

Despite recognized differences, decrease of small glaciers is less spectacular than the former main glacier Paierlbreen and other large tidewater glaciers in the area. Response of small cirque glaciers to climate warming seems to be more “conservative” than large glacier systems with low slopes and located at lower elevations.

**RETREAT OF THE TIDEWATER GLACIER HANSBREEN, HORNSUND FJORD (SPITSBERGEN)  
FROM THE LITTLE ICE AGE TO THE PRESENT**

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The Little Ice Age (LIA) was the coldest period of the Holocene and its culmination was at the transition from the 19th to the 20th century. Since then, the glaciers started to retreat due to climate warming. Since many of the glaciers on Svalbard are of surge-type, glacier surges interrupt the general retreat. Hansbreen is an example of a well-studied retreating tidewater glacier. During its maximum extent at the end of the LIA, it extended up to the mouth of Hansbukta, as well as into Isbjørnhamna, two neighbouring bays in the Hornsund Fjord on Spitsbergen. At present, the glacier front is located in the inner part of Hansbukta. It has been speculated whether or not Hansbreen is a surging glacier. However, observational evidences from either the terrestrial or marine domains, indicative of any surge event, are still pending. We have used geophysical, geomorphological and sedimentological data from Isbjørnhamna and Hansbukta to study the retreat history of Hansbreen from the end of the LIA until the present. We reconstructed its past evolution on the basis of the modified submarine relief at the forefield of Hansbreen. The relief consists of different landforms with surfaces composed of silt, sand and sandy silt. The identified landforms consist of moraine ridges, iceberg pits, iceberg ploughmarks, ripplemarks, depressions filled with glaciomarine sediments and pockmarks. The lack of landforms characteristic of glacier surges suggests that Hansbreen had a non-surge behaviour during the past ca. 120 years.

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**COMPARISON OF HYDROCHEMISTRY AND ORGANIC COMPOUND TRANSPORT IN TWO NON-GLACIATED HIGH ARCTIC CATCHMENTS WITH A PERMAFROST REGIME (BELLSUND FJORD, SPITSBERGEN)**

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An increase in air temperature over the second half of the 20th century has resulted in widespread permafrost degradation. The occurrence, thickness, and thermal state of permafrost depend on many local factors, e.g.: topography, lithology, geothermal heat flow, vegetation cover, distance to ocean, wind, and snow cover. Permafrost thawing and an increase in its active layer thickness have also been observed in Svalbard. Its degradation influences the hydrochemistry of streams and rivers fed by glaciers and thawing permafrost. We examine eighty-two water samples from two non-glaciated catchments with snow-permafrost regime: the Tyvjobekken Creek and the Reindeer Creek (NW Wedel-Jarlsberg Land, Spitsbergen). We cover hydrometeorological measurements, fluctuations of physicochemical parameters (pH, specific electrolytic conductivity (SEC)), and the presence of selected organic compounds (dissolved organic carbon (DOC), formaldehyde (HCHO),  $\Sigma$ phenols). The results obtained for the chemical analyses of these two, high Arctic creeks confirm the role of the melting permafrost as a rich source of terrestrial organic carbon and organic pollutants, as well as the impact of rainfall on surface water chemistry. It was found that fluctuations of physico-chemical indices (pH, SEC, DOC) were related to changes in mean daily discharge of Reindeer Creek (0.012-0.034 m<sup>3</sup> s<sup>-1</sup>) and Tyvjobekken Creek (0.011-0.015 m<sup>3</sup> s<sup>-1</sup>) ( $r > 0.40$ ). By contrast, no such relationships between the physico-chemical indices and meteorological conditions ( $r < 0.10$ ) or surface runoff were found at Tyvjobekken Creek. In conclusion, next to atmospheric deposition and rock-water interaction, crucial influences on surface-water hydrochemistry of non-glaciated Arctic catchments in Svalbard include the rate of permafrost degradation, the geomorphology of the catchment, soil type, the presence of vegetation and animal activity.

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*Spitsbergen) at their modifications under the influence of rainwater” No. 2015/17/N/ST10/03177. The authors are grateful for the technical support and meteorological equipment given by Prof. Krzysztof Migala and MSc. Eng. Piotr Modzel, and for the field and technical assistance of Dr. Grzegorz Gajek.*

**NEW PALAEOMAGNETIC AND DETAILED PETRO-MAGNETIC DATA FROM METABASITES OF OSCAR II LAND, WESTERN SPITSBERGEN**

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More than 300 oriented cores representing sixteen metabasic sites located in metamorphic Proterozoic – Lower Palaeozoic complex of Oscar II Land (Western Spitsbergen) were selected for palaeomagnetic investigation in a course of a PALMAG project (2012-2016). The results and interpretations were supported by comprehensive set of petrographic, structural and rock- magnetic data. To obtain higher resolution of the petro-magnetic results, standard “whole rock” analyses were enhanced by detailed experiments conducting on Fe-containing separates. Moreover, the palaeomagnetic results were combined with new in situ isotopic age determinations using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS)  $^{40}\text{Ar}/^{39}\text{Ar}$  which allowed to recognized tectono-thermal events recorded in the studied rocks. The results confirmed that the pre-Caledonian ferromagnetic carriers of the metabasic rocks has been completely replaced by metamorphic remineralization. The main ferromagnetic minerals are representing by a low/medium coercivity fraction such as pyrrhotite and Ti-magnetite/maghemite. The method of separation allowed to precisely indicate position of particular ferromagnetic carriers and connect the carriers with the stages of the Western Spitsbergen tectono-thermal history. In the course of isotopic age determinations three resetting events has been distinguished: 426 – 380 Ma (Caledonian sensu lato), 377 – 326 Ma and c. 300 Ma. Complicated tectono-thermal history of the region is reflected in the complex pattern of the natural remanent magnetization (NRM) of metabasites. Received palaeomagnetic directions has shown no convergence with reference path of Laurussia. Four models were proposed to explain this lack of correspondence. A significant contribution of conducted palaeomagnetic investigation was to emphasize the important role of listric faults in modification of the geometry of the Western Spitsbergen tectonic structures.

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**PALAEOMAGNETIC INVESTIGATIONS OF SVALBARD ARCHIPELAGO CONDUCTED BY THE  
INSTITUTE OF GEOPHYSICS POLISH ACADEMY OF SCIENCES IN THE 21<sup>ST</sup> CENTURY**

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Palaeomagnetic investigations conducted by the Laboratory of Palaeomagnetism in the Institute of Geophysics, Polish Academy of Sciences in years 2001-2017 comprised rock formations representing all three Caledonian Terranes of Svalbard postulated by Harland and Wright (1979) as well as the post-Caledonian/pre-Eurekan sedimentary cover of Spitsbergen and Edgeøya. Material for investigations was collected during the following expeditions to different parts of Svalbard Archipelago: (a) XXII PAS Polar Wintering Expedition to Hornsund (1999-2000; Wedel Jarlsberg Land and Torell Land), (b) IGF PAS palaeomagnetic field investigations of Torell Land (2002), (c) IGF PAS palaeomagnetic field investigations of Wedel Jarlsberg Land, Torell Land and Sørkapp (2004), (d) Joined expedition of IGF PAS/University of Greenwich (UK) along western and northern coasts of Spitsbergen (2006; Kongsfiord, Ny Friesland), (e) Palaeomagnetic field investigations of Caledonian Terranes of Svalbard organized in the course of the PALMAG project (NCN, 2012-2013; Oscar II Land, Kongsfiord, Ny Friesland, Nordaustlandet), (f) “Trias North” project joined expedition of UNIS and Statoil to Edgeøya (2016). The whole collection comprised more than 950 independently oriented palaeomagnetic samples representing 156 palaeomagnetic sites.

The results of these investigations are crucial for understanding tectonic structure and paleogeographic and geotectonic history of the Barents Shelf – Greenland sector of the Arctic: 1. Palaeomagnetic studies of the Lower Paleozoic metacarbonates from Hornsund combined with <sup>40</sup>Ar-<sup>39</sup>Ar age determinations of Billefjorden Fault Zone mylonites confirm that Svalbard constituted part of Baltica already from Late Silurian (Michalski et al. 2012)

2. Multidisciplinary palaeomagnetic – structural – geochemical – petrological investigations prove intensive Caledonian remagnetisation of Spitsbergen basement and point to important role of listric faults related to opening of North Atlantic system in modifying geometry of the central – western part of Spitsbergen (Michalski et. al. 2014, 2017; Burzyński et al. 2017)

3. New multidisciplinary palaeomagnetic – structural – petrological studies of the Neoproterozoic – the Lower Paleozoic Murchisonfiord succession suggest that a part of Nordaustlandet could constitute a foreland of the Caledonian orogenic front, and the e pre-Caledonian (primary?) palaeomagnetic

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record could survive. Preliminary palaeomagnetic results from Murchisonfiord suggest that in the Neoproterozoic, the Eastern Svalbard occupied a different palaeogeographic position with respect to the NW Barents Shelf/NE Greenland to that it occupied prior to the opening of North Atlantic/Arctic Ocean basins (the article in revision).



**A NEW INSIGHT ON THE FIRST POLISH MULTI-CHANNEL SEISMIC PROFILES IN THE PACIFIC MARGIN OF ANTARCTIC PENINSULA, WEST ANTARCTICA**Jan Okoń, Jerzy Giżejowski, [Tomasz Janik](#)*Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland**e-mail: [janik@igf.edu.pl](mailto:janik@igf.edu.pl)*

Extensive seismic crustal studies in West Antarctica have been made by the Polish Geophysical Expedition organized by the Institute of Geophysics of the Polish Academy of Sciences in the summer of 1979-1980. The experiment consisted of both deep seismic soundings and multi-channel seismic profiles conducted around the South Shetland Islands and the Bransfield Strait. Deep soundings results have been published numerous times during past 30 years, but MCS data were fully processed in 2014-2015 and published (Okoń et al. 2015). Collected data consisted of 10 linear seismic profiles recorded with 50 meters shot interval. Streamer was 1150 meters long with 24 channels, providing nominal fold of 12 traces per CDP. Two profiles went through South Shetland Trench (SST) while the rest of them were focused around the South Shetland Islands' shelf and the Bransfield Strait. Air gun array used was of about 34 litres capacity. The area of investigations was placed on the active edge of the Antarctic Plate: subduction zone of the South Shetland Trench, island arch of the South Shetlands and in the Bransfield Strait where few of the profiles crossed the young rift system. Data have been processed with modern processing flow including various demultiple attempts and time migration although outdated acquisition scheme limitations could not be overcome. This expedition used one of the strongest airgun which provided more information of a deep structure of the subduction zone than similar expeditions from other countries. Geological structure visible on our data collaborate well with other profiles going through the SST and could help understand structure of the area. Previous interpretation (Maldonado et al. 1994) assumed high accretionary prism (up to 5 km of thickness). Our profiles revealed a distinct reflector below the continental slope. In our interpretation whole continental slope is covered in a glacial-marine sediments while the accretionary prism is restricted to the layer below the reflector. The authors discuss different possible scenarios for the formation of accretionary prism. In the area of Bransfield Strait, very good sediment series of glaciations and deglaciations periods have been recorded. Near the Antarctic Peninsula expedition has registered series of glacial valleys, where one of them is cut through by a volcanic intrusion, leading to the assumption that recent volcanic activities is using post glacial valleys for easier penetration of intrusions.

**POLISH ARCTIC ACTIVE SEISMIC STUDIES**

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Several Polish and international expeditions were performed to Arctic (North Atlantic) in 1976-2017. The net of 14 deep seismic sounding profiles covered the region between 72°N on the south (near Bear Island), and ca. 81°N (near Spitsbergen) on the North, which mainly crosses the continent-ocean transition zone of the western Svalbard and Barents Sea margin. Seismic energy generated by airgun or/and TNT shots was recorded along several profiles by onshore seismic stations, ocean bottom seismometers (OBS), and hydrophone systems (OBH). Good quality reflected and refracted P waves provided an excellent data base for a seismic modelling along the profiles. TNT sources were recorded even up to 300 km distances. A minimal depth of about 6 km of the Moho interface was found east of the Molloy Deep. The Moho discontinuity dips down to 28 km beneath the continental part of the northernmost profile and down to maximum 32 km beneath other profiles. The evolution of the region is considered to be within a shear-rift tectonic setting. The continent–ocean transition zone along the northernmost profile is mostly dominated by extension, therefore the last stage of the development of the margin can be classified as rifting. The margin of the southern Spitsbergen is rather of sheared character while the western Barents Sea margin is of slow to ultraslow spreading type. The research in the region is continued. This year field works of the passive German-Polish OBS project KNIPAS is finished. Next year an active profile is planned.

**THE IMPACT OF THE RECESSION OF GLACIERS ON THE RELIEF AND HYDROLOGICAL CONDITIONS ON THE WESTERN SHORE OF ADMIRALTY BAY (KING GEORGE ISLAND, W ANTARCTICA)**

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Recession of glaciers taking place on the western shore of Admiralty Bay is a geographic marker from the point of view of climatic fluctuations. It is triggered by the increase of the mean annual air temperature which is a main determinant for mass loss of glaciers. Despite the decrease in the mean temperature in the Antarctic Peninsula region in the last few years, previous years of warming resulted in fronts position changes of the glacier uncovering a shallow lagoon which appears to be generally expanding over time. New landforms created by ablation of the glaciers diversify forefields. At the front of Ecology Glacier, Suszczewski Cove has been formed. Its bathymetry is strongly correlated with stages of the front position of the glacier and corresponds with accumulation of the glacier deposits creating pinning points. The impact of the recession of land-terminating glaciers on the relief is also confirmed. Baranowski Glacier has divided into 2 tongues. At the front of the Northern tongue a shallow lagoon has formed and is separated from Staszek Cove with a narrow spit during low tides. On the other hand Southern tongue is terminating around 240 m from the shoreline with forefield diversified by a variety of troughs of the creeks and lakes basins. In most of the creeks, water flows only after intense rainfalls in the ablation period. Only 2 of them: Fosa and Siodło creeks are active over whole summer season. In the presentation, all of the above mention issues will be discussed. Specifically, the results of changes in the front positions of glaciers as well as frontal elevation that lowering reflect evolution of the relief and hydrological conditions of the forefields will be presented.

**NEW KARST SPRING IN HORNSUND, SPITSBERGEN FEEDED BY SUBGLACIAL WATERS**

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New large spring flowing from a pipe karst system has been discovered in the Hornsund area in summer 2015 by J.M. Węśławski (personal communication). The spring is located on the steep rocky wall of the eastern shore of Vestre Burgerbukta at an elevation of 10 m. Water flows directly to the fiord forming small waterfall. Geologically, the rock face drained by the spring belongs to the Gnålberget Marble Formation, from Sofiekammen group, of middle to upper Cambrian age. The outflow has been exposed from underneath of the lateral part of retreating Paierlbreen glacier tongue. Samples from the falling water have suspended mineral matter indicating its source from subglacial drainage system. Nonetheless, water temperature is higher than 0°C suggesting admixture of thermal waters from a deep karst-type circulation.

Preliminary observations of the spring have been done in fall 2015, 2016 and shortly in early September 2017. They are very sparse due to difficult accessibility of the location. In the light of such observation, water temperature measurements and data on chemical composition of water samples together with analysis of mountain and glacier topography of surrounding area, functioning of the karst spring drainage system are discussed in the presentation. Three hypotheses are considered: (a) water supply from underneath of small (0.36 km<sup>2</sup>) cirque/hanging glacier located directly above of the spring but some 300 m higher, (2) long distance circulation from a feeding zone underneath of Kvitungissen, located c. 8 km upstream of Paierlbreen as modification of an idea of M. Pulina (1977) and (c) combination of both.

Authors propose to name this new spring after Professor Marian Pulina (1936-2005), pioneer of the speleological exploration and studies of glacier caves and glacier karst systems in Spitsbergen taking into account their interaction. He was Professor of the University of Silesia, initiator of polar expeditions from this university and the Leader of the 1979/80 Wintering Team in the Polish Polar Station, Hornsund (Institute of Geophysics, Polish Academy of Sciences). The curious nature of this water outflow would be a perfect way to commemorate the ingenious geomorphologist.

**FAN-SHAPED LANDFORMS IN THE PERIGLACIAL HIGH-ARCTIC ENVIRONMENT OF CENTRAL SPITSBERGEN, SVALBARD: SPATIAL DISTRIBUTION, SURFACE MORPHOLOGY AND DYNAMICS**

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Landscape of Svalbard is characterised by occurrence of numerous landforms which shape reassembled fans and cones. In this study, we concentrate on small fans (including alluvial fans, debris-flow fans, talus cones, and different mixed types) that developed along mountain sides on Svalbard and which varied greatly in geomorphology and processes. The study was carried out in the central part of the Spitsbergen Island: in the vicinity of Petuniabukta and Adventdalen. Colluvial fans were the most common within the studied area, followed by debris-flow-dominated fans, and a much smaller number of fluvial-flow-dominated fans. Colluvial fans were the smallest and steepest, whereas debris-flow-dominated and alluvial-flow-dominated fans were significantly larger and characterized by a gentler slope. Moreover, the catchments of colluvial fans were much smaller in comparison to the large catchments of fluvial-flow-dominated fans. Other morphometric properties of both fans and catchments also differed according to type. In the vicinity of Petuniabukta fan-shaped landforms developed along the valley sides and fiord margins. They were unevenly distributed over the study area, with the highest concentration to the east and north of Petuniabukta. In total, 297 fans were mapped and classified according to the dominant processes shaping their surface: 1) Colluvial fans (n=229) with surfaces modified by rockfalls and snow avalanches; 2) Alluvial fans dominated by debris flows (n=49), with traces of recent levees and lobes visible on their surfaces. 3) Alluvial fans dominated by fluvial flows (n=19), with morphology characterized by streams and braided channel networks. The character of the surfaces was assessed based on various remote sensing data and verified during the fieldworks. The uneven spatial distribution of fans was probably to some extent influenced by the topography of the area. A larger number of fans, which were located in the eastern and northern part of the studied region, is potentially related to the existence of a larger number of post-glacial valleys, which were also longer and wider than valleys along the western coast of Petuniabukta. Therefore, the topographic conditions for fan development (i.e. space for their growth) were more favourable there. Surface dynamics of fans were assessed based on multi-temporal surveys with unmanned aerial vehicle (UAV). The presented data will be used for a further in-depth analysis

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of the relationship between the surface morphology of fans, dominant processes, and morphometric variables.

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**THE FIRST DENDROGEOMORPHOLOGICAL RESEARCH IN SVALBARD – FROM THE CONCEPT TO THE METHOD CALIBRATION**

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The modern climatic change affects geomorphic systems in the High Arctic. Recent field observations confirm, that increase of temperature and amount of liquid precipitation can influence the dynamic and activity of geomorphic processes. The development and application of new research techniques, in addition to those traditionally used in geomorphology, is necessary for accurate recognition and dating of the morphogenetic processes in these areas. P. Owczarek (2009) first drew attention to the potential of the arctic dwarf shrubs in the analysis of contemporary morphogenetic processes in the Hornsund area. The next studies (Owczarek et al., 2013; 2014, 2016) presented assumptions and methodological base of the "dendrogeomorphology of the arctic dwarf shrubs". The following research objectives were put forward: 1) verifying whether the dwarf shrubs in this area have annual growth rings, which would allow their use in the geomorphological research, 2) assessing possibilities of precise dating of the age of the dwarf shrubs, 4) evaluating contemporary dynamics of the selected morphogenetic processes based on the age and change of the anatomical characteristics of the dwarf shrubs' wood.

Dwarf shrubs (e.g. *Salix polaris*) are the only wood material, which can be used for dendrogeomorphological studies in this area. These wooden small plants produce clearly visible annual rings. Other wood characteristics as abrupt cell shape changes, scars and reaction wood helped to date geomorphic forms and to analyse their dynamics. The study were conducted on talus cones, solifluction lobes, debris flow tracks and glacialfluvial terraces. The first research was aimed at determining the age of the dwarf shrubs, which could represent the minimum age of the geomorphic forms. Later studies have shown the necessity to calibrate the method depending on the substrate (time of colonization). There are still problems with dating, related to presence of missing rings and proper chronology construction.

Dendrochronological research indicate that activity of debris flows has increased rapidly during last 30 years. These geomorphic episodes were connected with the heavy rainfall events especially in the 1990s and 2002, 2006, 2007. Dendrochronological data have shown the increased lateral erosion and rate of stream downcutting, which occurred in the 1980s and 1990s. This process was intensified,

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especially in the 1990s, under flood conditions generated by extreme rainfall events. The influence of climate change on paraglacial landscape in the light of dendrogeomorphological research is evident and very rapid. Dendrogeomorphology in the High Arctic is a new technique which should be considered in the analysis of contemporary dynamics of the geomorphic processes.



**THE INTERACTION BETWEEN SELECTED POLLUTANTS CONCENTRATION LEVELS AND BACTERIAL PRESENCE IN REVELVA CATCHMENT (SOUTHWEST SPITSBERGEN, SVALBARD)**

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Environmental pollution by organic and inorganic compounds became extensive as mining and industrial activities increased. Environmental pollutants originating from diverse anthropogenic sources have been known to possess values capable of degrading the ecological integrity of all environmental habitats. The Arctic has undergone dramatic change during the past two decades. The phenomenon of Arctic pollution (besides local sources) arises from a combination of long-range transport of pollutants and the Arctic haze phenomenon-locking contaminated air in the area for months. The most common group of contaminants in Arctic are persistent organic pollutants (POPs), characterized by durability and resistance to degradation. The residence time of those pollutants is long enough for them to be transported thousands of kilometers by the air and finally to be deposited in the Arctic.

The freshwater samples were collected from the Revelva catchment located in the Wedel-Jarlsberg Land, in southwestern part of Spitsbergen in summer 2016. The main river (Revelva) is fed both directly by atmospheric precipitation, snow melt water streams and a river originating from the Arie glacier. Revelva drains into the bay of Ariebukta in the south, forming an estuary. In the upper part of the catchment, the main streams originate from the slopes of Eimfjellet and Skålfjellet. The catchment is characterised by an asymmetry, with a dominance of left tributaries, of which the proglacial Ariebekken is the largest. The Revelva catchment has only one small glacierised part but past glacial activity has left traces in its upper part. The bottom part of the Revelva valley is an elevated marine terrace, with abrasion stacks. The diversity of the catchment landscape provides an ideal setting for a comprehensive study of processes of pollutant deposition in different parts of the abiotic environment. The main purpose of the research was to determine selected xenobiotics (e.g. phenolic compounds, formaldehyde). Additionally, the total number of bacteria, size and biomass were quantified. Average concentrations of sum of phenols and formaldehyde were 0.13 mg/L and 0.12 mg/L, respectively. Furthermore, parameters such as dissolved organic carbon, electrical conductivity and pH were

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measured. Microbiological analyses have been conducted using epifluorescence microscope to estimate the impact of chemical compounds presence on the microbiological abundance.

The results obtained show that the bacterial abundance indices depended on nutrient levels to a small extent, showing the environment of the Revelva catchment not to be nutrient limited, which is in accordance with its rich biological life also in macroscale. These indices were equally uncorrelated with the chemical threats (pollutant concentrations), which indicates the microorganisms of the Revelva catchment cope well with the experienced levels of pollution. Moreover, the results obtained serve as early warning signal of expected environmental changes because even low pollutants concentration levels in polar regions may suggest a significant contamination of studied area.

**MARKERS OF ANTHROPOGENIC ACTIVITIES IN FRESH WATERS AT PERIGLACIAL ENVIRONMENTS (WESTERN SHORE OF ADMIRALTY BAY, KING GEORGE ISLAND, ANTARCTICA)**

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Polycyclic aromatic hydrocarbons (PAHs) concentration has been determined in the water samples taken from ice-free environments in the King George Island, Maritime Antarctica. For this purpose, water samples from five different sites distributed along a linear transect running from the Arctowski station to the Baranowski Glacier were collected. Gas chromatography-mass spectrometry was applied to determine PAHs in dichloromethane extracts. PAH indices enabled hydrocarbon fuels and the products of their refining to be identified as likely sources. Nevertheless, we cannot exclude impact of long range atmospheric transport of this group of compounds (forest fires and volcano eruptions, as well as anthropogenic emission). Based on this study we can conclude that organic contaminants present in the hydrosphere constitute a threat for the Antarctic ecosystem (the highest determined  $\Sigma\text{PAHs} > 1300 \text{ ngL}^{-1}$ ). This selected group of contaminants cause special threat because of their toxic, mutagenic and (in some cases) cancerogenic properties. For which reason the long term monitoring of this group of compounds should be continued. Moreover, as a next step of research, interdisciplinary approach should be applied to check the effect of contamination on living organisms. Furthermore, diesel generators usage should be reduced. This could be achieved by renewable energy usage and would lead to a better preservation of the polar ecosystem. This work was carried out as part of an agreement between the Institute of Biochemistry and Biophysics, Polish Academy of Science (IBB PAS), and Gdansk University of Technology. The data used in the paper were collected at the Henryk Arctowski Polish Antarctic Station.

**DIFFERENTIATION AND VARIABILITY OF FLUVIAL TRANSPORT IN POLISH POLAR CATCHMENTS IN THE AGE OF CHANGING CLIMATE**

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Presently we observe climate change in the world, especially in the Polar Regions. It causes rapid ablation of glaciers, which results in increased outflow of waters from the glacierized areas as well as from unglacierized areas. Increased outflow of water is associated with a more dynamic transport of solutes and solids. Among Polish polar research, an important part of them includes, among others: study of fluvial transport in proglacial rivers and streams, and streams fed by permafrost runoff. Three types of fluvial transport will be presented: dissolved (Ld), suspended (Ls) and bedload (Lb). Results from all possible Polish surveys and monitored catchments will be shown, including Antarctic (Petrified Forest, Bezimienna, Ornithologists, Ecology, Baranowski, Czech, Vanishing) and Arctic (Ebbaelva, Dynamiskbekken, Waldemar Stream, Wydrzyca, Scott Stream, Fuglebekken, Ariebekken, Bayelva, Werenskioldelva) stations. The main focus will be on the spatial differentiation of fluvial transport dynamics in Spitsbergen and King George Island, as well as temporal variability from the early 1970s through 2016. The quantitative assessment of relations between different types of fluvial transport, (i.e. Ld:Ls:Lb and Ld:Ls) for selected catchments is presented. For instance for Werenskioldelva the Ld:Ls ratio for different years are as follows: 0.04 (1970); 0.07 (1986); 0.10 (2011); 0.06 (2012) showing no significant temporal changes over 1970-2012, while for Ebba normally the value of this ratio is between 0.3-0.6 but a noticeable difference has been observed

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between 2009 and 2010 for which the values are 0.16 and 0.84, respectively. Much less has been done for analysis of bed load in the Arctic and only complex data are available for Scott River Ld: Ls: Lb = 0,9:1:0,01. On the other hand, for Antarctic catchments mostly localized at Western Shore of Admiralty Bay, the main focus has been paid on suspended and bed load transport. However, the Ld: Ls: Lb has not been investigated yet. Moreover, the results of chemical and mechanical denudation are presented for several catchments. The calculated values are associated with the relationships between dissolved and suspended transport. It is obvious that the rich achievements in hydrology of the Polish Researchers may be only partially outlined in one presentation but this summary provides valuable material for well-established researchers and especially for students who are the future of Polar Hydrology as a discipline and our Polar Society.

**SPRING SNOWMELT IN COASTAL TUNDRA ENVIRONMENT – CASE STUDY FROM THE FUGLEBEKKEN CATCHMENT (SW SPITSBERGEN)**

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Snow covers have strong influence on Arctic environment, as they persist during majority of the year deciding inter alia about vegetation growth and permafrost thawing. Heterogeneous tundra terrain with complex micro-topography leads to great disproportions in snow cover spatial distribution. This is manifested during spring melt period in unequal disappearance of snow from tundra. This in turn can largely differentiate living conditions for plants. Here we present the spatio-temporal distribution of snow in small unglaciated Fuglebekken catchment from three spring periods 2014-2016. Data were collected with automatic time-lapse camera set installed at the summit of Fugleberget (560 m asl). Processing of images (orthorectification, georectification and classification) allowed to assess snow cover extent in the catchment with high spatial (~1 m) and temporal (nearly every day) resolution that is nowadays unavailable from freely available satellite products. Maps of snow spatial distribution were superimposed on the set of GIS sources such as land cover and soil maps supported with set of topographic indices (calculated upon 1m resolution DEM derived from terrestrial laser scanning). The results allowed to designate areas with longest and shortest snow cover duration and link them to information from other spatial data sets. Strongest correlations were found between snow persistence and the terrain exposition to wind. Exposed places melt-out even 50 days earlier than the sheltered ones. Time of complete snow disappearance differed also between variable land cover types, where longest persistence occurred on rock debris without any plants. On the other hand snow melted every year approximately two-weeks earlier in places covered by lichen herb-heath vegetation. Multiyear time-lapse snow monitoring proved general repetitiveness of snowmelt pattern despite different meteorological conditions between successive years. Additionally, combination of the spatial dataset with manual snow depth measurements proved that longer snow occurrence on the ground was highly related to the snow thickness recorded during the winter period.

**LIFE LESSONS FROM ANTARCTIC PLANT SPECIES: HOW TO LIVE IN AN EXTREME ENVIRONMENT AND WHY PLANT SCIENTISTS ARE SO INTERESTED**

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Wild plant species have been domesticated since the beginning of the agriculture 12,000 years ago. During this long process the productive traits have been mostly promoted to reach the current highly productive crop varieties, at the expense of an indirect reduction of stress tolerance. Unfortunately, climate change is imposing several environmental stresses that constraint agriculture worldwide. How to meet the requirements of global food demand considering as well the increase of human population? How to improve stress tolerance in our crops maintaining their productivity? A trade-off between plant productivity and stress tolerance is hypothesized: crops show highest productivity but reduced stress tolerance, while other wild species with impressive stress tolerance capacities have reduced productivity. In the last two years we have been looking for outliers for this relationship, i.e., species that show an important productive capacity and at the same time high tolerance to stressful environmental conditions. For this purpose, we have developed several scientific campaigns looking for plant species that live in the most extreme environments on Earth. From Antarctica to the High Arctic (Svalbard islands) and from Atacama desert (Chile) to the Australian outback more than 300 species have been studied worldwide. There are just 2 vascular plant species native to Antarctica: the hairgrass *Deschampsia antarctica* Desv. and the pearlwort *Colobanthus quitensis* (Kunth) Bartl, with important populations in the surroundings of the Polish Antarctic research station Henryk Arctowski in King George Island (South Shetland, Maritime Antarctica). Both species obtained elevated stress tolerance values in our tests compared with hundreds of species worldwide. Interestingly, their photosynthetic rates (measured as a proxy for productivity) under optimal conditions show higher values than the mean values for their group from worldwide datasets. We will discuss here how these species can

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help us to understand environmental stress tolerance mechanisms and to design new strategies required for increasing crop productivity under the current climate change scenario



**DENDROCLIMATOLOGICAL SIGNAL DERIVED FROM BETULA NANA GROWTH RINGS  
CHRONOLOGY IN NORTHERN ALASKA - FROM LOCAL TO PAN-REGIONAL SCALE**

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The polar regions have been identified as a global hotspot where climate change is inducing the most visible and significant ecosystem impacts. Among vast arctic region the tundra biome has been recongnized as a key study area were both abiotic (i.e., climate) and biotic (for e.g., plant growth) components are strongly coupled. Thanks to growth rings of tundra shrubs, the interaction between those two can be traced in i) high annual resolution and ii) in long time-scales, i.e., longer than on-going experimental and/or monitoring studies. In our study we presented over a century-long growth rings chronology of *Betula nana* from Northern Alaska. Growth of dwarf birch was positively related to June temperature ( $p < 0.001$ ) both at local (intra-site) and regional scale. Additionally, strong negative relationships were revealed between dwarf birch annual growth and i) Pacific Decadal Oscillation (PDO) and ii) sea surface temperature (SST) of the Beaufort Sea. In synthesis *Betula nana* growth ring chronology from Northern Alaska was compared with author's shrub growth chronologies constructed for Western Greenland (*Betula nana*) and central Spitsbergen (*Salix polaris*). The comparisson highlighted well-established dendroclimatological potential of tundra shrubs' studies in a High-Low Arctic transect.

**TRACE ELEMENT CONCENTRATION IN NON-LETHALLY COLLECTED TISSUES FROM  
SVALBARD REINDEER – PRELIMINARY STUDIES**

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Arctic region is specifically prone to climate changes and currently is undergoing the fastest changes. Contaminant transport from more urbanized areas consist a significant thread for polar wildlife. Nevertheless, our knowledge about contaminants distribution and their effect on living organisms is still far from being complete. Reindeers are a characteristic key component of the Arctic terrestrial ecosystem. As a local herbivore they are exposed to xenobiotics mainly by diet composed of different types of vegetation (including lichen and moss). Svalbard reindeer *Rangifer tarandus platyrhynchus* is the smallest reindeer subspecies that can be used for monitor changes in a local terrestrial trophic network. We investigate concentration of multiple trace metals in molten fur and feaces collected from Svalbard reindeer. Non-destructively collected samples give the possibility for studying population for many years, without direct contact with an individual. Mercury did not constitute a significant thread for studied populations, levels in both fur and feaces were low. However, our preliminary studies clearly indicate the need for further monitoring especially in case of lead.

**RHIZOSPHERE MICROBIOTA OF INVASIVE AND NATIVE FLOWERING PLANTS IN ANTARCTICA**

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Rhizosphere of Antarctic plants is the objective of this project. It is the layer of soil, which is directly adjacent to the roots of plants. Polar zone is one of the few places on Earth where it is possible to study the rhizosphere in one species context due to very low complexity of Antarctic terrestrial communities. Only two species of flowering plants, among hundreds occurring in Tierra del Fuego (South America), cross the Drake Passage and inhabited maritime Antarctic *Deschampsia antarctica* Desv. and *Colobanthus quitensis* Bartl. Global anthropogenic activities along with local human influence weakened the barriers that isolate Antarctica from the rest of the World. This could play a relevant role in the abundance of invasive species but an increasing number of reports have shown the presence and spread of non-native plants in Antarctica. Number of plant species in this region has increased lately about a third species of flowering plant, *Poa annua* L., which initially inhabited the anthropogenic habitat, and now spread on natural habitats, where it enters the tundra communities. One of the major contributions of this project is an increase in the knowledge about the peculiar microbial diversity of the rhizospheres of Antarctic vascular plants, especially new data about the great abundance of anaerobes. It is clear that our understanding of root-mediated processes has moved beyond the classical belief that the sole functions of roots are anchorage and uptake of water and nutrients. It is now understood that roots are rhizosphere ambassadors, facilitating communication between the plant and other organisms in the soil. The question is, what adaptive mechanisms help flowering plants to survive in such extreme conditions. One of such mechanisms may be specific communities of microbes surrounding roots and promoting plant growth.

**CAN BIOMECHANICAL PROPERTIES AFFECT PLANT ADAPTATION FOR EXPANSION AND SURVIVAL IN POLAR AREAS?**

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In recent years, interest involving the study of polar plants is increasing concerning plant adaptation skills as well as capability of survival and expansion under difficult conditions such as Polar Regions. Organisms that are able to grow in this environment are flexible in physiology, morphology and anatomy. In the Spitsbergen (Svalbard, Arctic), *Salix polaris* Wahlenb., is the widely distributed Arctic plant, and its habitats are often exposed to solifluction and landslides processes. On the other hand, King George Island (South Shetlands, Antarctica) has two native angiosperms (*Deschampsia antarctica* Desv. and *Colobanthus quitensis* (Kunth) Bartl.), as well as the alien cosmopolitan species, *Poa annua* L., which has successfully adapted to survive the maritime Antarctic. The changing abiotic factors, e.g. climate, contributed to the spread of these individuals on the ice-free areas of the Antarctic islands. The increased habitat of *Poa annua* L. is the result of such phenomena as: melting of ice and perennial snow covers, glacier recession, and the increase of ground surface temperature. Plant adaptation is connected to physiological aspects, i.e. temperature, light, rainfall, snowfall or ice sheet. These factors generate environmental stresses, with which the vegetation has to cope in order to survive or adapt to the new conditions. Moreover, polar plants are exposed to flowing water forces and sediment transport, as they occur in river channels and in overbank flow conditions during floods. In this case, their biomechanical traits play a significant role. For example, *Poa annua* L., as one of the most widely distributed species in the world, has high colonising ability however the biomechanical details regarding its ability to adapt to the mechanical forces acting on it in Antarctic regions have not been studied. Knowledge of the biomechanical properties may be an important component in understanding the adaptation of plants to their unique growth environment. The mechanical traits will provide information regarding the phenotypic plasticity of the plant, which allows adjustment to different habitats. Nevertheless, this area is still unknown and determining whether the biomechanical characteristics are adaptive or not is a challenge. Methodology, which should help to answer the question how biomechanical properties affect plant adaptation, will be presented.

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**MONICA PROJECT 2014-2016 – UAV MONITORING MISSIONS IN ANTARCTICA**

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The main goal of this project was to study the impact of climate change on the Antarctic ecosystem and biodiversity. The study area included King George Island (South Shetlands) which is located in the Western Antarctic Peninsula region. This project utilized Unmanned Aerial Vehicles (UAV) to collect baseline geospatial environmental data, which was used to monitor climate change effects. In particular, we study selected impacts of key element of Antarctic ecosystems by quantifications of seal and penguin populations, as well as flora distribution. During the three Antarctic expeditions (2014-2016) four UAV types: two with piston engines (CryoWingMk1, PW-ZOOM) and two with electric, equipped with digital cameras were used. All seasons of UAVs photogrammetric missions over the investigated areas were completed successfully and flights covered the area of 34.51 km<sup>2</sup>. Penguin and pinniped populations' size and distribution mapping were performed. Analysis included a comparison of digital data with the data acquired from ground based censuses. On the basis of obtained photogrammetry data and historical data, an analysis of changes in bird and pinniped populations in the research area were done. Next step is to develop high resolution vegetation maps and study changes in vegetation cover, on previously investigated areas as well as on new one where glaciers have retreated. High-resolution aerial images allow detailed analyses of periglacial landforms. The study results demonstrate successful application of fixed-wing Unmanned Aerial Vehicles, which allowed us to obtain geospatial environmental data from the investigated areas as a base for long-term monitoring program.

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**INSIGHTS INTO BIOGEOGRAPHICAL PATTERNS OF THE ANTARCTIC MOSS FLORA INFERRED FROM DNA-BASED PHYLOGENY OF SOUTHERN PAN-TEMPERATE *DREPANOCLADUS LONGIFOLIUS*, AND PAN-ANTARCTIC ENDEMIC *SYNTRICHIA SARCONEURUM***

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Historical biogeography of Antarctica, while being one of most exciting subjects in biogeography, is still poorly understood. This deeply contrasts with a wealth of phylogeographical data dedicated to Arctic ecosystems. Due to different geographic characteristics of these two opposite polar regions, distinct biogeographical patterns are expected. The main aim of the presented study is to contribute to our understanding of the evolutionary history and range dynamics of Antarctic mosses. Since mosses constitute the fundamental component of the vegetation cover in the Antarctic, focusing on this group is of the paramount importance to understand processes that shaped the terrestrial biota in this biome. Many moss species are proposed to be postglacial colonists. By contrast, some data support Pleistocene persistence of isolated lineages in Victoria Land refugia (Hills et al. 2010; Pisa et al. 2014). In our research, we focus on several Antarctic moss species representing different phylogeographical elements and apply molecular tools to explore genetic diversity and divergence of their extant populations range-wide. Specimens for DNA analyses are derived from taxonomically revised moss collection from the austral polar regions preserved in the herbarium of the Institute of Botany PAS (KRAM). Until now, two species have been analysed: a Pan-Temperate *Drepanocladus longifolius* (Mitt.) Paris, and a Pan-Antarctic endemic *Syntrichia sarconeurum* (Hook. f. & Wilson) Ochyra & R.H. Zander. Based on the DNA-based phylogenies we suggest that *D. longifolius* populations in the Antarctic region originated fairly recently, with re-colonization following the retreat of glaciers and ice-sheets from their Pleistocene maxima. In the case of *S. sarconeurum*, we have identified the main genetic break within the Antarctic that separates the most northern samples (Antarctic Peninsula, Dronning Maud Land) from those at higher latitudes (MacRobertson, Victoria Lands), with further differentiation within each group. Therefore, we suggest long-term isolation of populations from the south, and that *S. sarconeurum* may have persisted in continental Antarctica throughout previous glaciations. So far, our case study indicates that the species assembly forming the present-day Antarctic moss flora is a result of two distinct processes, namely recent (postglacial)

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colonisation, and range expansions from glacial refugia distributed within Antarctica. Several further species will be analysed to gain a larger overview of the Antarctic phylogeography.

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***POA ANNUA* L. - MOST SUCCESSFUL POLAR INVADER, NEW LOCALITY IN SVALBARD (ARCTIC)**

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Humans activities have been most effective vectors of unintentional species transfer, providing carriage for alien propagules even in such remote regions like Arctic and Antarctic. Ships and planes can transport alien species between locations relatively rapidly what allowed the organisms retain viability during transit. In remote polar region the main introduction routes seems to be associated with the supply of polar stations by cargo and personnel. Probable vectors may include packing materials, vehicles, imported fresh foodstuffs, adhered soil, scientific equipment, building materials, clothing and footwear. Human activity in the Arctic has rapidly increased over the last 40 years. While the tourism sector is increasing rapidly, there are other travel sectors such as that associated with science. Polar scientists often visit and work in several alpine or high latitude environments, and may move frequently between them, increasing the chances of introducing organisms pre-adapted to Arctic environmental conditions.

Here we reported new site of alien species *Poa annua* in Svalbard. This introduction is associated with scientific activity in the region. *Poa annua* is one of the cosmopolitan species of Eurasian origin widely distributed in the world. The species is very interesting because it's only alien flowering plant which successfully has established a breeding population in the maritime Antarctic.

**PRIMARY SUCCESSION PROCESS OF VEGETATION IN THE SELECTED FORELANDS OF SVALBARD GLACIERS**

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Among all taxa forming Arctic vegetation, lichens and bryophytes are its main components. Their participation in the formation of plant communities as a result of the primary succession process in freshly deglaciated areas of glacier forelands is also significant. The aim of the study was to investigate and compare species diversity of lichens, bryophytes and vascular plants in the forelands of selected glaciers in Svalbard Archipelago: Irenebreen (NW Spitsbergen) and Rieperbreen (central Spitsbergen). The localisations of study areas were chosen in term of different climate and microhabitat conditions. Fieldwork was carried out in the summers of 2012 and 2015, in the moraines of Irenebreen and Rieperbreen, respectively. One linear transect consisted of 1 m<sup>2</sup> plots was designated across each of the studied forelands from the front of glacier to the end of foreland. In every plot percentage cover of each species was recorded. Furthermore, additional 200 plots were made in the studied moraines to compare species composition of forelands: 100 plots in Irenebreen moraine and 100 plots in Rieperbreen foreland. Based on the collected data, non-metric multidimensional scaling (NMDS) and species indicator analysis measured with Pearson's phi coefficient were performed to determine similarities in species composition between the studied glacier moraines. Within all recorded taxa, lichens were the dominant group: 88 species were recorded in Rieperbreen moraines and 60 species were recorded in Irenebreen foreland. Concerning bryophytes 37 species were noted in Rieperbreen moraines and 19 species were recorded in Irenebreen moraine. Vascular plants were the least numerous group: 21 species were recorded in Rieperbreen foreland and 20 species were recorded in Irenebreen foreland. Despite the fact that both of the studied glaciers lie in Spitsbergen's warm region, the species composition of studied forelands differs. This may be explained by the fact that Kaffiøyra Plain, where Irenebreen is located, is characterized by higher levels of humidity due to the direct neighbourhood of the sea. In contrast, Rieperbreen is located in a deep Bolterndalen valley at a greater distance from the seashore.

**Keywords:** *colonisation, lichens, bryophytes, vascular plants, moraine, Rieperbreen, Irenebreen*

**EVALUATION OF RADIOACTIVE CONTAMINATION IN TUNDRA OF WESTERN GREENLAND AND NEW FUNLAND AND LABRADOR, CANADA**

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An important group of environmental pollution are radioactive elements. Their presence is related to both the natural processes and human activity. Resulting radioactive contaminants have been spread globally and locally through the atmo- and hydrosphere, reaching even polar environment of the Northern Hemisphere. Arctic region is extremely sensitive to contamination. It is a result of relatively short food chains, efficient transfer of contaminants between different organisms and close relationship with the terrestrial and marine ecosystems. Moreover, observed warming temperature, changes in precipitation type and amount, may contribute to the increase mobility of radioactive substances in the Arctic. Important tool to conducting research in radioecology comprise lichens and mosses - the dominant representatives of Arctic tundra. Because of lichens and mosses do not have wax cuticle and root systems they have to uptake of nutrients from the atmosphere and surface water together with inherent contaminants. Furthermore a relatively slow growth rates and long lifespan result in the incorporation of large amounts of impurities in their intracellular structure with time. This is a potential threat for local ecosystems that are exposed to penetration of toxic radioactive elements through the food chain. The main objectives of this study are estimation of activity concentration of wide spectrum of radionuclides  $^{137}\text{Cs}$ ,  $^{238,239+240}\text{Pu}$ ,  $^{241}\text{Am}$  and identification of potential sources of accumulated contaminants in lichens and mosses from Arctic territory. The research focuses on the vast coastal zone of Western Greenland and Northern Canada. Samples of lichens and mosses were collected during scientific expedition in 2013. Different methods of nuclear spectrometry (alpha, gamma) and radiochemistry were used for this study. First, each sample was measured at high resolution, low-background gamma-ray spectrometers. Next, using appropriate radiochemical procedures, different alpha emitters were separated followed by measurements on alpha radiation spectrometers. There are several sources of anthropogenic radionuclides in the Arctic: global fallout as a result of nuclear weapon tests, satellite Kosmos 954 crash over the Great Slave Lake in Northern Canada (1978), the Chernobyl fallout (1986) and nuclear power plant disaster in Fukushima, Japan

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(2011). The global fallout is dominant source of contamination. On the basis of obtained results and analysis we can conclude that the global fallout is a dominant source of contamination.

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**CRYCONITES AS A SENSITIVE INDICATORS FOR RADIOACTIVE CONTAMINATION IN ARCTIC GLACIERS**

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Cryoconites are aggregates of mineral and organic substances on surfaces of glaciers, which are able to accumulate large amounts of airborne pollutants by binding them to extracellular polymeric substances secreted by microorganisms. The cryoconites are common in the ablation zones of glaciers, particularly those located at high latitudes and high altitudes. They accumulate dust eluted from the atmosphere by dry or/and wet precipitation. The research carried out in five areas of Spitsbergen (Kongsfiord, Kaffiøyra, Bellsund, Hornsund, Sorkapland). The cryoconites were collected from Austre Brogger, Vestre Brogger, Waldemar, Blomli, Recherche, Tjørndals, Renard, Scott, Hans and Stor Glaciers in the western Spitsbergen coast, as soon as from Sykorabreen, Coryellbreen and Kanebreen in the southeastern Spitsbergen coast. Measurements conducted in such a variety of localizations influenced by different environmental conditions provides an opportunity to study the impact of glaciological characteristics on contaminant accumulation in cryoconites. In this study contents of airborne radionuclides (<sup>137</sup>Cs, Pu isotopes, <sup>210</sup>Pb) in cryoconites were determined. The cryoconites collected from the Werenskiold and Waldemar Glaciers reveal the highest activity concentrations of the anthropogenic (<sup>137</sup>Cs, <sup>238</sup>Pu, <sup>239</sup>Pu, <sup>240</sup>Pu) and natural (<sup>210</sup>Pb) radionuclides. Activity concentrations of fallout radionuclides reaching 4500 Bq/kg, 14 Bq/kg, 179 Bq/kg for <sup>137</sup>Cs, <sup>238</sup>Pu and <sup>239</sup>+<sup>240</sup>Pu, respectively. Activity ratios of <sup>238</sup>Pu/<sup>239</sup>+<sup>240</sup>Pu, <sup>239</sup>+<sup>240</sup>Pu/<sup>137</sup>Cs are commonly used to identify and distinguish between global and regional sources of these radionuclides. The average activity ratios for <sup>238</sup>Pu/<sup>239</sup>+<sup>240</sup>Pu are 0.056 suggesting contributions from other than the global fallout sources of plutonium. Global fallout of radionuclides from the atmospheric nuclear weapons testing was characterized by the <sup>238</sup>Pu/<sup>239</sup>+<sup>240</sup>Pu activity ratios (for year 1973) of 0.025. The <sup>239</sup>+<sup>240</sup>Pu/<sup>137</sup>Cs activity ratios are 0.023 and are much lower than the decay-corrected value of

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~0.05 expected for the year 2015, point to possible other sources of  $^{137}\text{Cs}$  in these area. Activity concentrations of airborne radionuclides ( $^{137}\text{Cs}$ , Pu isotopes,  $^{210}\text{Pb}$ ) in cryoconite samples from Spitsbergen were higher than in the soils and lakes of Spitsbergen. The main source of anthropogenic radionuclides in the Arctic is global fallout from atmospheric nuclear weapon tests and local fallout from tests conducted at Novaya Zemlya.  $^{210}\text{Pb}$  in cryoconites is derived mainly from the atmospheric deposition and its activity concentrations reach high values up to 13000 Bq/kg. Transfer of cryoconite material from glacier surface constitutes an additional pathway for the atmospheric contaminants to downstream ecosystems.

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**40 YEARS OF MICROBIOLOGICAL INVESTIGATIONS AT THE ARCTOWSKI POLISH ANTARCTIC STATION**

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Microbiological investigations were initiated on the Polish Antarctic Station H. Arctowski by M.K. Zdanowski at the beginnings of the station activity in the South Shetland region in 1978. Then several Polish researchers, among them microbiologists, were engaged in international abundance dynamics observations of marine organisms during four BIOMASS project expeditions in years 1981-89, which proved pivotal for the estimation of marine life resources of the Southern Ocean. Arctowski station was the support for these expeditions. Later projects dealt with the terrestrial microbial communities of King George Island, Antarctica. The following topics were investigated: penguin guano decomposition and macroalgae decay (2000-2003), microbial community development on recently deglaciated areas (2007-2011), microbial diversity and functions on glacial surfaces (2011-15). Current projects regard rhizosphere communities of Antarctic plants and stress survival of psychrophilic bacteria. Years of investigations employing a multitude of classic and molecular microbiology techniques led to recognition of several Antarctic sites as almost exclusively microbially-maintained ecosystems and provided valuable data for the scientific community.

**OCEAN-GLACIERS INTERACTIONS IN THE FJORD HORNSUND**

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The Arctic fjords constitute a link between the ocean and land, therefore they are highly vulnerable to warming and are expected to exhibit the earliest environmental changes resulting from anthropogenic impacts on climate. In the Arctic, the inshore boundary of a fjord system is usually dominated by tidewater glaciers while its offshore boundary is strongly influenced by warm oceanic waters. Improved understanding of the fjord-ocean exchange and processes within Arctic fjords is of a highest importance because their response to atmospheric, oceanic and glacial variability provides a key to understand the past and to forecast the future of the high latitude glaciers and Arctic climate. The results of oceanographic measurements in the Hornsund fjord, collected under the Polish-Norwegian projects GLAERE and AWAKE-2, will be presented. Interannual variability of warm Atlantic water entering the fjord, seasonal changes of ocean properties in the glacier bays and the structure of the water column in the vicinity of the glacier termination will be addressed. Direct contact of warm oceanic water with a glacier's wall causes submarine melting, undercutting and glacier calving. Turbulent plumes of subglacial meltwater constitute an important mechanism of heat transfer and also influence a glacier retreat. However our understanding of these processes is limited due to problems with obtaining in situ data close to the glacier wall. Therefore special attention will be paid to observations of the underwater parts of Hornsund glaciers and new measurements of water column fine structure and mixing in the turbulent meltwater plumes. Oceanographic data were collected from board or R/V Oceania and from small boats. Field expeditions used also logistical support of the Stanislaw Siedlecki Polish Polar Station in Hornsund.



**BURIAL RATES OF SEDIMENTARY ORGANIC AND INORGANIC CARBON IN TWO HIGH ARCTIC FJORDS**

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Quantifying carbon burial in marine sediments and distinguishing between the sources of buried carbon (marine vs. terrestrial) are key problems of the global carbon cycle, though not well investigated yet. The problems are especially important in the Arctic, where large loads of carbon are buried in sediments and the marine ecosystems are sensitive to effects of climate warming. The aim of this study was to quantify burial of organic carbon (OC) and inorganic carbon (IC) in the sub-surface sediments of two high latitude fjords: Hornsund and Kongsfjorden (Spitsbergen). To achieve this goal, carbon accumulation in sediments was determined together with the share of labile organic carbon in the bulk sedimentary organic matter. The latter, after mineralization or/and hydrolysis, diffuses back to the water column. Additionally, we estimated contributions of glacial and biogenic carbonates to the IC pool in Kongsfjorden. The results showed substantial differences in both quality and quantity of carbon loads to the sediments of the both investigated fjords. The OC burial rates differ significantly between the fjords- in Hornsund OC burial is up to four times higher than in Kongsfjorden (19.3-30.3 g OC m<sup>-2</sup> y<sup>-1</sup> and 5.7-10.0 g OC m<sup>-2</sup> y<sup>-1</sup>, respectively). Higher OC burial efficiency in Hornsund suggests higher contribution of stable, land-delivered OM and/or less effective mineralization processes. Interestingly, the IC burial rate, often marginalized in carbon budget investigations, exceeds in some locations of Kongsfjorden burial of OC, as up to 45.1 g IC m<sup>-2</sup> y<sup>-1</sup> is buried there. This is closely linked with high abundance of carbonates in the geological structures of the Kongsfjorden catchment. Overall, our study demonstrates that OC burial dominates in Hornsund, while IC in Kongsfjorden. Acknowledgement.

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**THE ADAPTATION OF ROMS MODEL TO THE PORSANGER FJORD, NORWAY**

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The understanding of mechanisms responsible for interactions between large-scale oceanic conditions in high-latitude fjords is the main long-term goal of this project. In this presentation we have focused on modeling of the hydrodynamic conditions in the Porsanger fjord using Regional Ocean Modeling System (ROMS) with high spatial resolution. The fjord is located in the coastal waters of the Barents Sea and based on the bathymetry, can be divided into three zones: inner (0-30 km), middle (30-70 km) and outer (70-100 km). The environment in the inner part differs significantly from the other zones. This happens because the exchange of water between the inner and the middle zone is limited by islands and bathymetry. To assess the performance of the model we have used in situ data provided by the Nordflux project. We have compared modeled surface currents with data from high frequency (HF) WERA radar system collected from 10th June to 11th October 2014 and from 28th May to 17th August 2015. Modeled subsurface currents and water temperatures have been compared with experimental data from Nortek Continental 190 kHz ADCP deployed on a mooring (8th June – 24th June 2014). Thanks to in situ hydrographic surveys taking place from 6th to 29th June 2014 and from 29th May to 18th June 2015 we could also compare model results with vertical profiles of salinity and water temperature.

***Acknowledgements:***

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**OCEAN CHANGES IN THE WARMING ARCTIC - THE MAIN RESULTS FROM THE IOPAN LONG-TERM MONITORING PROGRAM AREX**

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Understanding how climate processes impact variable oceanic fluxes of heat and salt, carried by Atlantic inflows into the Arctic Ocean and how they in turn influence ocean-atmosphere-ice interactions, ocean heat content, sea ice cover and propagation of anomalies are key challenges to understand the new, warmer regime of the Arctic Ocean. The Institute of Oceanology PAS (IOPAN) contributes to this challenge with its strategic research initiative, the long-term monitoring program AREX. Multidisciplinary in situ observations in areas such as physical oceanography, air-ocean interactions, ocean biogeochemistry and ecology allow studying the long-term changes of abiotic and biotic Arctic environment. Every summer since 1987 the large-scale field surveys have been carried out in the Nordic Seas and European Arctic from the board of the IOPAN RV Oceania. Annually repeated measurements are collected on a regular grid of more than 200 stations and cover the Atlantic water inflow through the eastern Norwegian and Greenland seas, Fram Strait up to the southern Nansen Basin in the Arctic Ocean. In addition to the open ocean measurements, an extensive observational campaign takes place every year in the western Svalbard fjords. One of the AREX main goals is to recognize and describe processes responsible for changing ocean climate in the Nordic Seas and European Arctic with a special focus on dynamics and variability of the warm Atlantic inflow through Fram Strait. Long-term observations revealed many new details on origin, spatial structure and temporal evolution of warm anomalies, carried by Atlantic water into the Arctic Ocean in the last two decades. A special attention is also paid to processes governing distribution of Atlantic inflow between Fram Strait and the Barents Sea and its impact on oceanic heat advection to the Arctic Ocean. Other topics of interest include Arctic fjord-ocean exchanges and a role of warm Atlantic inflows in the accelerated retreat of tidal glaciers on Svalbard and shrinking sea ice cover in the Nansen Basin of the Arctic Ocean. Ship-borne hydrographic measurements collected every summer during the AREX cruises of RV Oceania are complemented by year-round observations with deep ocean moorings measuring temperature, salinity and sea currents in the entire water column, regular deployments of profiling Argo floats and measurements carried out from small boats in Arctic fjords and glacial bays. Time series of key ocean variables, gathered during 30 years of observations under the AREX

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program bring new knowledge on changing physical and biological environment of the warming Arctic and help to improve numerical predictions of ocean, sea ice and climate in the Arctic region.

**OBSERVED DECREASE OF SNOW DENSITY IN RESPONSE TO RECENT COOLING IN NORTHERN ANTARCTIC PENINSULA. COULD IT HAVE AN INFLUENCE ON THE ESTIMATED SURFACE MASS BALANCE?**

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The Antarctic Peninsula (AP) region has experienced a cooling since the early 21<sup>st</sup> century. This cooling has not been homogeneous, being particularly relevant in the northern AP, including the South Shetland Islands (SSI). Here, decadal summer and winter temperatures measured in Bellingshausen station have changed by  $-0.5^{\circ}\text{C}$  and  $-1.1^{\circ}\text{C}$ , respectively, between the last two decades. Moreover, on-glacier summer average temperatures are typically close to  $0^{\circ}\text{C}$ , so any temperature change is expected to have a significant influence on melting.

The glaciers under study, Hurd (land terminating) and Johnsons (tidewater), are located on Livingston Island, the second largest of the SSI. In 2000 we deployed in these glaciers a net of stakes for surface mass balance (SMB) measurements. Density measurements in snow pits were initiated in 2004 and meteorological data are available in the neighbouring Juan Carlos I station since 1995. SMB has shifted from values typically negative in the late 1990s and early 2000s to predominantly positive values in recent years. This has resulted from both increased accumulation and decreased ablation.

We wonder whether the recent cooling has had a noticeable impact on the density of the snow layer, and, if the answer is positive, whether these snow density changes are significant in terms of SMB estimates. More specifically, we wonder whether, assuming that we have detailed studies of snow density (versus depth) for these glaciers collected during a slightly warmer period than present, the use of such snow density profile for SMB calculations at the current slightly colder period would imply a noticeable bias on the estimated SMB.

The first step of the above analysis is checking whether density changes are indeed observed and whether these are statistically significant. Our preliminary analysis shows an average density of  $518 \pm 3 \text{ kg/m}^3$  (the quoted error is the standard error; the associated standard deviation is  $11 \text{ kg/m}^3$ ) and a density change of  $-16 \text{ kg/m}^3$  during the period 2004-2016, measured from the least-square fit of the yearly average temperatures to a straight line. This density change exceeds the average of the standard errors of the yearly-averaged temperatures during that period, of  $12 \text{ kg/m}^3$ . It is also larger than the

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RMSE of the least-square fit, of  $9 \text{ kg/m}^3$ . We therefore conclude that the observed density decrease is statistically significant and the detailed studies described above are of interest.

**TOWARD A BETTER UNDERSTANDING OF MACROALGAE INTERACTION WITH A CHANGING ARCTIC ENVIRONMENT. ISFJORDEN: A MULTIDISCIPLINARY CASE STUDY**

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Macroalgal beds are an important component of coastal zones in Arctic regions. They provide habitats for a vast number of associated invertebrates and fishes and release a high amount of fresh organic carbon. The distribution of macroalgae is essential for estimating the overall productivity of the Arctic area and for understanding processes occurring at the sea-shore interface. Moreover, macroalgae are sensitive to environmental changes (temperature, salinity, turbidity, current velocity), which may limit or influence their spatial distribution and health. In July 2016 and 2017, we carried out a multidisciplinary expedition to investigate the spatial distribution of macroalgae in Isfjorden (Svalbard). The acoustic detection of macroalgae in 8 designated areas distributed around the fjord was combined with biological and environmental studies. Along with acoustic data from single- and multi-beam echosounders, we collected numerous underwater video recordings across all the depths in the euphotic zone. ADCP measurements in each sampling zone were carried out and CTD profiles were collected (with additional turbidity and oxygen sensors). We found considerable differences in kelp species abundance and distribution on the bottom between the northern and the southern parts of the fjord, where environmental conditions are significantly different. The southern part is influenced by salty, transparent shelf waters, while the northern part is under the influence of glaciers that bring fresh water with dense sediment suspension. Although the results that we would like to present here are at the early stages of processing, they already offer interesting insights into the benefits of multidisciplinary studies in polar regions and into possible interactions between climate change and the Arctic environment.

**VARIABILITY IN THE BENTHIC BIOMASS SIZE SPECTRA ALONG LATITUDINAL GRADIENT (60-80°N)**

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Decline in body-size has recently been predicted as a consequence of global warming in both aquatic and terrestrial systems. However, patterns of spatial variability and drivers of size structures at the community level are still rarely studied, particularly for marine benthic communities. Here we present the first study of benthic biomass size spectra along the latitudinal/thermal regimes gradient spanning the continental Norway and Arctic fjords. The “space for time analogue” approach was applied to determine possible future effects on Arctic benthic ecosystems’ structure (size spectra) and functionality (secondary production) in response to global warming. The study was conducted in six fjords representing a wide geographical (60 to 80°N) and temperature regimes range (-1 to 8°C bottom water temperature). At each location we collected meiobenthic and macrobenthic samples, acquired hydrographic settings and collected sediments for geochemical analyses. Organisms were identified and measured using microscope-based Image Analyses System to assess biovolume and individual biomass needed to construct biomass size spectra. Secondary production was estimated with use of Artificial Neural Network modelling. The shape of size spectra was very conservative across all localities, despite prominent differences in total biomass and abundance among them. The locations of a pronounced gap between meiofauna and macrofauna as well as meiofaunal and macrofaunal peaks were stable across the studied fjords. An increment of the fauna in the highest size classes was observed in Arctic localities. Fresh organic matter availability (as indicated by chlorophyll a content in sediments) defined the levels of the total benthic biomass and secondary production, but had no impact on the partitioning of the standing stocks among direct size classes. We conclude that climate warming and related enhancement of primary production may alter the composition and functioning of benthic communities, but most probably will not alter their size structure.



## HOW GREENLAND SEA OSTRACODA DISTRIBUTION AND DIVERSITY IS REFLECTED IN NANSSEN BASIN?

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Zooplankton species play an important role in marine food-web since they are not only consumers of primary and secondary productions, but also the principle food source for higher trophic levels. They respond rapidly to changes in environmental conditions and so can be good indicators of even the subtlest discontinuities in the hydrographic structure within the water column. Although detritivores pelagic Ostracoda are globally an important component of open ocean ecosystems, they still remain poorly known both taxonomically and ecologically, especially in the deepest zones of the Arctic Ocean. Until now only few attempts towards full inventory of planktonic ostracods in the Nansen Basin and the Greenland Sea had been done, so their potential value as indicators remains unrealised. The Fram Strait is only deep connector of the Greenland Sea in the north and the Nansen Basin in the south, which allows distribution and mixing of ostracods between these water bodies, mainly by advection. As the result of this process the large portion of Arctic zooplankton species are shared with the North Atlantic. The main purpose of this study was to compare variability in the distribution and composition structure of ostracods in the Greenland Sea and the Nansen Basin. The great majority of ostracods from the Greenland Sea, which was a part of the significant historical German study dealing with general zooplankton description, were misidentified as *Boroecia borealis* (an endemic to the boreal Atlantic species), while 86% of them were in fact *Boroecia maxima* (a high Arctic species). In addition to these two *Boroecia* species, three more planktonic ostracods (*Obtusoecia obtusata*, *Discoconchoecia elegans* and new undescribed species *Boroecia hopcrofti*) were found in this Greenland Sea material. Having at our disposal also unique zooplankton samples from several deep water stations from the Nansen Basin, collected during few German and American expeditions, we are aiming to describe planktonic ostracods species diversity and spatial distribution in the Atlantic influenced part of the Arctic Ocean. Preliminary results together with previously published records suggest considerable underestimation concerning both species diversity (approximately only 9 species) and ostracods abundances in the Arctic Ocean. Since the Greenland Sea is connected with the Arctic

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Ocean through Fram Strait, this research is useful evaluation regarding zooplankton diversity and dispersion of planktonic species between the North Atlantic and the Arctic Ocean.

**MACROFAUNA OF KELP FORESTS OF CAPE FAREWELL (SOUTH GREENLAND)**

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Dense canopies of benthic brown algae in temperate zones called kelp forests are very important for functioning of coastal, shallow water systems. They facilitate grow of smaller algae and make habitable conditions for a lot of fauna species thus increasing ecosystem complexity. Being attached to the bottom those formations are very hard to observe and study. When direct sampling is required the only way is to manually take one while diving. This limits feasibility of those studies in polar areas. The area of Cape Farewell was sampled previously over 40 years ago and that survey was focused on shallow water macroalgae. This region, on the other hand, are known to host high standing crops of kelps, which composition and variability together with fauna associated with them are nearly unknown. Goals of presented study is to check whether fauna linked to kelp diversity or standing stock, or those both groups are separated realms and, futhermore, how macroalgae beds with associated fauna respond to environmental gradient. In six places, selected in order to cover exposure gradient in the area (as a proxy of bottom disturbance), divers collected a set of 9 samples: 3 replicates at 3 depth levels (5 m, 10 m and 15 m). Each sample consisted of both flora and fauna collected from the bottom enclosed by 35 cm ring (0.1 m<sup>2</sup>). In total number of 53 samples 8 species of macrophytobenthos and 91 species of associated fauna were identified. Kelp species richness varied from 1 to 4 in individual samples, while their biomass ranged from 2 kg to 40 kg m<sup>-2</sup> (median = 12 kg m<sup>-2</sup>). Fauna species richness varied from 0 to 25 (median = 16 species). Their abundances ranged from 0 to 2189 ind. m<sup>-2</sup> (median = 1370 ind. m<sup>-2</sup>), while their biomass ranged from 0 to 214 g m<sup>-2</sup> (median = 5.568 g m<sup>-2</sup>). Hierarchical clustering of kelps indicated four major groups of vegetation in samples: ones dominated by *Agarum clathratum*, by *Alaria esculenta*, by *Saccharina latissimi* and one with mixed composition devoid of big kelps. Nor abundances of fauna neither their species richness did not vary significantly between communities observed in 3 groups dominated by big kelps. On the other hand biomass of fauna was significantly bigger in samples dominated by *A. clathratum*. Diversity of fauna was not connected to diversity of algae, nor to their standing stock. Mantel test between algal and faunal communities was significant ( $p < 0.05$ ), yet the effect was very weak.

**INTRASPECIFIC VARIATION OF MERCURY CONTAMINATION IN FEATHERS OF ADÉLIE PENGUIN**

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Mercury is naturally present on the planet, although anthropogenic activities can enhance their availability in the environment. Once in the environment, these contaminants can enter the body of the birds, through the feed being incorporated or excreted in various ways. In birds, feathers are an important pathway of excretion of contaminants, including Hg, which can vary its levels according to age, diet and physiological status. The Adélie penguin (*Pygoscelis adeliae*) have a circumpolar distribution, restricted to regions close to the Antarctic continent. This study aimed to determine the Hg excreted by feathers from adult and chicks of *Pygoscelis adeliae*. Fieldwork was carried out during austral summer of 2013/2014 at King George Island, South Shetlands Archipelago, Antarctica. The animals were captured, breast feathers samples were collected and morphometric measurements were recorded, additionally, was collected blood for DNA sexing. Total Hg concentrations were determined by cold vapor atomic absorption spectrometry (FIMS-400, Perking-Elmer) at the Laboratório de Radioisótopos Eduardo Penna Franca at Federal University of Rio de Janeiro and the molecular identification of sex was performed with the amplification of the CHD gene by polymerase chain reaction at the Laboratory of Bird Ecology of the University of the State of Rio de Janeiro, Brazil. Adults ( $602.6 \pm 349.6$  ng/g; n=12) had higher mercury concentrations than chicks ( $102.8 \pm 14.48$  ng/g; n=9;  $t=4.258$  df=19;  $P<0.05$ ), but there were no significant differences between males (adults  $681.8 \pm 460.6$  ng/g; n=6; chicks  $94,25 \pm 14,1$  ng/g; n=5) and females (adults  $523.4 \pm 204.2$ , n=6; chicks  $109.7 \pm 11.8$  ng/g; n=5;  $P>0.05$ ). Furthermore, we did not find any significant interaction between Hg and body size. As expected, older individuals presented higher concentrations of Hg probably because they are bioaccumulating this element longer. Females can eliminate Hg by egg laying, therefore, it was expected that they would have lower concentrations than males. Few studies also address this difference in Hg accumulation with body size, but in this study, males and females of the same age present similar body size (flipper, weight, abdominal circumference and total length). Previous studies have not found a relationship between gender and mercury concentrations in other seabirds.

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Apparently, this relationship is not clear and the majority of studies have not been examined sexual differences in Hg accumulation. Other factors may be influencing the exposure of these animals to mercury accumulation, such as living area and type of food consumed. Studies are ongoing to understand accumulation and excretion of Hg in the individuals of this species.

**FORAMINIFERAL FROM PALEO SUB-ICE-SHELF AND GROUNDING ZONE PROXIMAL SETTINGS  
IN THE WHALES DEEP BASIN, EASTERN ROSS SEA, ANTARCTICA**

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Paleoenvironmental reconstructions of Ross Sea environments based on foraminifera are hindered by the dearth of actualistic data, especially from below the Ross Ice Shelf. To fill this gap, we used a recently developed well-resolved deglaciation record from Whales Deep of the eastern Ross Sea to understand the ecological affinities of different foraminiferal assemblages. During the present-like open-water conditions, two benthic foraminiferal assemblages, strongly dominated by agglutinated species, were present, however in older sediments, we identified five different assemblages of calcareous foraminifera. By Antarctic margin standards, these calcareous assemblages are periodically truly abundant. Along with assemblages dominated by benthic calcareous species that are well known from many *Antarctic settings*, *Trifarina earlandi* and *Astrononion echolsi*, two important assemblages are dominated by a heretofore undescribed spinose morphotype of *G. biora* and poorly known spinose morphotype of *T. earlandi*. Based on our correlations to deglacial record, these two assemblages inhabited near the grounding line or in environments with especially intense bottom water currents. Improved understanding of foraminiferal assemblages from a variety of environments within the eastern Ross Sea may contribute to better use of foraminiferal data to investigate the evolution of environmental changes in grounding-line proximal environments.

**FORAMINIFERAL eDNA FROM SEDIMENTS PROXIMAL TO THE ANTARCTIC ICE SHEET**

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The Ross Sea is the key area to understand past dynamics and future changes of the Antarctic ice sheet. The sea-floor morphology of the Ross Sea embayment has been shaped by glacial and post-glacial process, including sub-glacial deposition, erosion of paleo-ice streams and ice bergs scouring. Advanced multibeam bathymetry system helps to localize various geomorphic structures like megascale glacial lineations, glacial furrows, topsets and foresets of grounding zone wedges. Mixing and reworking of sediments is a common phenomenon which affects also biogenic component, including microfossils.

Next-generation sequencing of environmental DNA (eDNA) isolated from sediments is an innovative method in geology that can enrich paleontological data. In this study, we analyzed foraminiferal eDNA from recent and ancient environments. We isolated 20 samples from four kasten cores, which were taken during NBP1502A cruise in 2015 from different geomorphologic structures in the western Ross Sea. The samples were chosen based on micropaleontological and sedimentological interpretations. During PCR (polymerase chain reaction), we multiplied hypervariable region 37F, that is specific for foraminifera. To minimize risk of passing over more degraded, shorter DNA fragments, we applied two primer pairs, which created two types of amplicons with different lengths. We gained PCR products in 11 samples, which were subsequently analyzed at MiSeq platform (Illumina).

First results show high DNA concentrations at all surface samples. There is no DNA at greater depths, except in one core, where DNA was found throughout the core length. Our results suggest foraminiferal paucity at settings proximal to grounding zone at locations from middle continental shelf (KC4). In contrast, continuous presence of eDNA throughout KC30, suggest occurrence of rich foraminiferal communities at roughly similar setting in outer shelf, i.e. closer to the continental shelf break. Further data processing will help to resolve how closely micropaleontological record parallels molecular data, providing information on DNA leaching and preservation. It will also help to reconstruct complete foraminiferal communities, including less robust species that are not preserved in fossil record.

**FORTY YEARS OF THE ADMIRALTY BAY BENTHIC RESEARCH**

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Admiralty Bay (King George Island) is one of the most comprehensively studied small scale basins in the Southern Ocean. Over 1300 benthic species (e.g. 172 species of amphipods, 162 of polychaetes, 80 species of echinoderms, 48 species of gastropods and 39 species of bivalves) were recorded in this bay for almost 40 years of Polish, Belgian, Brazilian and German research. In 1996 it was designated an Antarctic Specially Managed Area (ASMA No. 1) by the Scientific Committee on Antarctic Research and can be considered a special legacy site. There are about 100 papers focusing on the various aspects of marine life in this basin. Some of them constitute a unique background information for the future studies prepared under the umbrella of various international programs like Antarctic Thresholds – Ecosystem Resilience and Adaptation as well as planning of Marine Protected Areas. This semi-closed, glacially affected ecosystem is also a perfect model system for studies of influence of warming on marine benthic fauna.

The team of the Laboratory of Polar Biology and Oceanobiology (University of Lodz) was involved in the benthic studies of this basin since the establishment of the Polish Antarctic Station Henryk Arctowski in 1977. Our research interests covered several aspects including studies of shallow sublittoral zone, faunal distribution along depth gradient, fauna associated with macroalgae, disturbance processes, comparisons of Arctic and Antarctic fiords and taxonomy of Antarctic invertebrates, mostly of polychaetes, crustaceans, mollusks and echinoderms and diatoms. Extensive datasets collected for almost 40 years of studies were recently gathered in the Admiralty Bay Benthos Database (ABBED) and deposited in the SCAR Mar-BIN portal. This data can be treated as a benchmark against which the future changes associated with climate warming can be assessed. The knowledge about Admiralty Bay benthic ecosystem was also recently summarized as one of the Census of the Antarctic Marine Life (CAML) contributions and published in the Deep-Sea Research II special volume dedicated to marine fauna of the Southern Ocean.

Some selected, vital effects of our benthic studies will be presented.



**FEEDING AND ABUNDANCE OF DOMINANT ANTARCTIC HERBIVOROUS COPEPODS IN RESPONSE TO CHANGE IN PHYTOPLANKTON COMPOSITION (ADMIRALTY BAY, SOUTH SHETLAND ISLANDS)**

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In Antarctic waters diatoms form a main food source for free living copepods, such as *Calanoides acutus* and *Calanus propinquus* which are dominants among the herbivorous copepods. Diatoms are also considered to be an important part of diet of omnivorous copepods, e.g. *Metridia gerlachei*. Recent results of phytoplankton monitoring in the Admiralty Bay revealed a diminished percentage contribution of diatoms in the phytoplankton assemblages in comparison to the earliest studies. Also the lowering contribution of the larger diatoms ( $> 20 \mu\text{m}$ ), such as *Fragilariopsis kerguelensis*, *F. obliquecostata* or *Chaetoceros* spp. has been shown. These phenomena may be related to wider shift in phytoplankton community structure documented in coastal waters along the Antarctic Peninsula. Intense glacial melt-water runoff reduce surface water salinity and cause an increase in water turbidity resulting in more favorable conditions for flagellates and cryptophytes to dominate the phytoplankton assemblages. This marked shift in size distribution of the phytoplankton community are potentially of great importance for the pelagic filter-feeders of the Admiralty Bay. It could presumably impact the feeding of herbivorous copepods, as copepods grazing efficiency is highly dependent on food density and size of its particles.

The aim of the study is to examine and compare feeding behavior of four copepod species – *Calanoides acutus*, *Calanus propinquus*, *Rhincalanus gigas* and *Metridia gerlachei* from three different periods in the Admiralty Bay. A results of the studies on feeding activity (estimated as a percentage of copepods with food in gut) of four mentioned copepod species will be shown. Also the lowering abundance of these species in subsequent years will be presented. This findings are a part of the major research which purpose will be to determine whether the documented shift in size distribution of the phytoplankton community affect the populations and feeding behavior of phytoplankton grazers.

**IMPACT OF TREATED WASTEWATER FROM POLISH POLAR STATION (HORNSUND, SPITSBERGEN) ON THE BACTERIOPLANKTON COMMUNITY STRUCTURE OF THE ARCTIC LAKE**

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Wastewater and its treatment processes represent an unique niches for microorganisms, which are, however, subjected there to a strong selective pressure. Adaptive response of microorganisms is usually associated with the accumulation of the adequate resistance determinants. In respect to the above, the occurrence of resistance to antibiotics become a new and important issue, especially in anthropogenically impacted environments. Little is known, however, about development of such phenomenon in polar regions, which are considered to be subjected to low anthropogenic pressure. In order to compare the anthropogenic and natural impact on the Arctic lakes, water and wastewater samples were collected in the neighborhood of Polish Polar Station (PPS), Hornsund, West Spitsbergen. One lake, serving as a freshwater source for PPS, was sampled at two points: L-MR (mountain river, impacted by the inflows from bird colony) and L-WS (water supply). Second lake was a wastewater receiver (WW-R) and the treated wastewater from the wastewater treatment plant (WWTP) was collected as well. Epifluorescent microscopic techniques were used for evaluation of bacterial cells activity (Live/Dead test), as well as the determination of total cell number, average cell volume, bacterial biomass, and bacterial morphological structure using DAPI direct counting method. The bacterial cell abundance in L-WS ( $1.2 \times 10^6$  cells/ml) was on comparable level as in L-MR ( $1.16 \times 10^6$  cells/ml), and lower than in WW-E and WW-R ( $4.6 \times 10^6$  and  $2.5 \times 10^6$  cells/ml, respectively). Similar trend was observed in case of bacterial cell activity, where the highest share of active cells was observed in case of treated wastewater sample (15,3% of active cells), followed by lower activities in the wastewater receiver (10,2%) and the water supply lake (6,16-8,04% of active cells). Enterococcus spp. bacteria, representing the fecal indicators, were isolated using the cultivation method. Their identification and antibiotic resistance profile was confirmed biochemically (Phoenix™ Automated Microbiology System). All together 78 strains of enterococci were isolated, identified mainly as *E.faecalis* (45%), *E.faecium* (38%) with occasional presence of *E.avium*, *E.hirae* and *E.durans*.

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Among them the highest resistance was reported to the macrolides (43%), tetracyclines (3%), and to the synthetic nitrofurantoin (8%). Community structure was assessed using metagenomic approach (16S rRNA analysis, NGS Illumina). The metagenomic approach showed that in each sample *Proteobacteria* (18-53%), *Bacteroidetes* (7-38%) and *Actinobacteria* (7-17%) were predominant, however in L-MR and L-WS the bacterial diversity was lower than in WW-E and WW-R. In the wastewater receiving lake, the bacteria typical for activated sludge were found: *Planctomycetes* (5,7%) and *Chloroflexi* (5,2%). Therefore the impact of the wastewater treatment processes on the microbial community is visible. We should carefully consider whether biofilm and activated sludge based methods are the most proper ones to be used when planning the investment regarding wastewater treatment in areas as vulnerable as polar regions.

**DYNAMICS OF ICE BREAKING - DEM SIMULATIONS**

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Two classes of solid materials are of special interest for geophysicist, namely lithospheric/mantle rocks and the ice of glaciers. Physical, especially mechanical properties of those materials differ from each other, so their responses to external loading are, without any surprise, not the same. While natural (earthquakes) or anthropogenic (mines, quarry blasts, etc.) breaking and fragmentation of rocks has attracted attention and is well described, similar analysis concerning glaciers and other ice-type materials is still missing. In this presentation, results of the advanced numerical technique used to simulate breaking of ice-type materials under a shock loading leading, are shown. This type of dynamic loading is known to create strong acoustic waves, which can trigger creation of cracks in the material and finally cause its fragmentation. To analyze this process a very simple numerical experiment with an ice-ball self-falling and hitting a rigid floor have been set up. Two different fragmentation mods, which activate at different kinetic energy levels when ball hits the floor, have been noticed. Comparison with a real laboratory experiment carried out with a high speed camera is also presented.

**3D MODELLING OF ICE CRACKING WITH THE DISCRETE ELEMENT METHOD**

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Computer simulations are becoming more and more important research tool in many scientific areas. So-called numerical modelling can be a useful and relatively cheap tool to investigate different phenomena without necessity of conducting difficult and expensive laboratory experiments. The Discrete Element Method (DEM) is one of numerical methods for simulating materials consisting of a large number of particles. The basic idea behind DEM is to represent the material as an assemblage of discrete particles interacting with each other. With advances in computer power and numerical algorithms for nearest neighbor sorting, it has become possible to numerically simulate millions of particles on a single computer processor. Several DEM codes take advantage of parallel processing capabilities to scale up the number of particles or length of the simulation. One of them is an open source software ESyS-Particle, and, due to its advantages it was utilized in this research.

In this study, DEM was used to simulate ice cracking process. Ice was treated as a brittle material consisting of large number of bonded particles interacting with each other. The mechanical properties of ice were studied on the basis of Brazilian Test - a popular procedure of estimating the tensile strength of materials. In this paper were shown efforts of describing the fracturing process of ice during the Brazilian Test from microscopic point of view. The following issues was considered: crack propagation velocities and tip locations, microscopic precursors of the moment of cracking, analysis of relations between macroscopic parameters of the sample (Young's modulus, Poisson's ratio) and microscopic (parameters of bonds and particles).

**CHARACTERIZATION OF THE COMPLETE CHLOROPLAST GENOME OF COLOBANTHUS APETALUS (LABILL.) DRUCE AND COMPARISONS WITH RELATED SPECIES**

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*Colobanthus apetalus* represents genus *Colobanthus* one of the 86 genera of a large family *Caryophyllaceae*, which gather annual or perennial herbs (rarely shrubs) distributed across the globe, predominantly in the Holarctic. The genus *Colobanthus* consist of 25 species with *Colobanthus quitensis*, extremophile plant native to maritime Antarctic among them. Complete chloroplast (cp) genomes have been useful for phylogenetic studies and species identification and therefore highly required. In this study the next generation sequencing (NGS) have been used to identify the cp genome of *C. apetalus*. The complete cp genome of *C. apetalus* is 151 228 bp long with 36.65% GC content, having quadripartite structure with LSC (large single copy) of 83 380 bp and SSC (small single copy) of 17 206 bp separated by IRs (inverted repeats) of 25 321 bp. The cp genome contain 130 genes, including 111 unique genes and 19 genes which are duplicated in the IRs. Among 111 unique genes there are 72 protein coding genes, 30 tRNA genes, four rRNA genes and 5 conserved hypothetical chloroplast ORF of currently unknown functions. A total of 12 forward repeats, 10 palindromic repeats, 5 reverse repeats and 3 complementary repeats were detected. In addition simple sequence repeat (SSR) analysis revealed 41 (mono-, di-, tri-, tetra-, penta- and hexanucleotide) SSRs, most of them were AT-rich. The detailed comparison of *C. apetalus* and *C. quitensis* cp genomes revealed that the gene content and order were identical. A phylogenetic tree constructed based on whole cp genomes of all eleven sequenced representatives of *Caryophyllaceae* and *C. apetalus* showed that *C. apetalus* and *C. quitensis* form clade closely related to group of *Silene* species and *Agrostemma githago*. Moreover genus *Silene* appeared as a polymorphic taxon. This study will contribute to better understanding of the evolution and molecular biology of *Caryophyllaceae*.

**EDU-ARCTIC: ENGAGING STUDENTS IN STEM EDUCATION THROUGH POLAR RESEARCH**

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Polar Regions represent one of the most interesting natural environments that can engage pupils in topics related to global changes. EDU-ARCTIC is a Pan-European initiative available for secondary schools, which uses the Arctic and polar research as a vehicle to encourage pupils aged 13 to 20 to pursue further education in science, technology, engineering and mathematics (STEM), setting them on a path to careers in one of these sectors, or even to become a scientist. Pupils participating in the project have a unique possibility to get to know what scientific careers are like and to learn more about different research disciplines while learning how to apply the scientific methods. It aims to establish strong links between the research and education communities by connecting schools to scientists working in various places of the world. The project focuses mainly on natural sciences and research conducted in the European part of the Arctic. The big interest of the society, policymakers and media in the polar regions builds opportunity to use polar issues as a mechanism to attract youth to science and research. Moreover, by choosing one geographical region, we give pupils access to the wide scale of natural sciences research. Additionally, cooperation with stations in various Arctic countries creates the opportunity to present not only natural determinants, but also sociological, demographical and cultural diversity according to the principle that the larger diversity in presented issues, the bigger benefits pupils gain. The EDU-ARCTIC project uses a mix of different tools for teaching STEM, including online lessons with scientists dealing with polar research, environmental monitoring program, teacher trainings and workshops, an online “Polarpedia” portal explaining scientific terminology, and a chance for students to win a trip to an Arctic research station.

**ENVIRONMENTAL MONITORING PROGRAMME AT POLISH ANTARCTIC STATION  
„ARCTOWSKI”, KING GEORGE ISLAND, SOUTH SHETLAND, ANTARCTICA**

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The year round Arctowski Polish Antarctic Station gives a special opportunity to measure various components of the environment. One of the main roles is to carry out environmental monitoring through standardized measurements or observations conducted repeatedly in the same place, their statistical evaluation and reporting on the state of the environment in order to define quality and trends. The South Shetland area landscape has changed significantly during the last 50 years, through climate change, hence long-term data provides researchers with direct knowledge about the pace of changes. Nationally Polish researchers will utilize the information to play an active part in decision-making in this field. Collected data are also used in particular research projects. In the presentation several different types of environmental monitoring, conducted at “Arctowski” station will be presented. One of the most important, which has been conducted since 1977 is ecological monitoring which consists of observations and census of Antarctic birds (especially penguins), pinipeds and whales. Another type of monitoring involves abiotic components including: hydrological monitoring of streams located at the western shore of Admiralty bay; monitoring of calving of the Lange Glacier; meteorological monitoring; monitoring of stream water chemistry and possible contaminations; monitoring of sea water chemistry and suspension and sea sediments; monitoring of the Earth’s electric field. Some exemplary results associated with every kind of research done at the Arctowski Station will be discussed briefly. Most of the measurements have been realized in collaboration with other national and international scientific institutions. This year three new monitoring programs will start: two will consider precipitation’s chemistry, while the other involves water chemistry and bathymetry of Ginger Lake. The environmental monitoring programme at Arctowski Station will be extended and a guideline of the new work procedures is presented in this poster.



**MACROPLASTIC LITTER ON SVALBARD COAST - NEW VECTOR FOR SPECIES DISPERSAL**

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The 100 km long west coast of Prins Karl Forlandet (westernmost island of Svalbard archipelago) was assessed for the density of macroplastic litter. Most numerous were fragments of fishing gear (buoys, ropes, nets) followed by various containers, sheets of foil and plastic textiles. Average density was estimated as several items per ha (100 x 100 m coast unit) and the range of weight of 15 tons of plastic debris on the inspected coast. Few largest items (fishing boxes, containers) were overgrown with barnacles, *Lepas* sp., bryozoans, *Mytilus edulis*, and marine macro- algae. Possibility to transport groups of adult organisms gives an advantage for dispersal compared to larval transport, and is regarded here as the main reason for reappearance of *M. edulis* on Svalbard.

**CURRENT STATE OF WERENSKIOLD ENVIRONMENT: MAGNETIC STUDY**

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Magnetic minerals are present all over the world and are sensitive to natural processes, what make magnetic methods highly useful to investigate a wide range of environmental processes. In this investigation, we demonstrated the utility of magnetic techniques to study the current state of glacier environment. Surface sediment specimens were sampled from the Nottingham Bay and four streams located in the vicinity of Werenskiold Glacier on Spitsbergen, Svalbard. Short sediment cores (about 40 cm) were taken only from the bay. Magnetic analyses have been supported by granulometric and mineralogical studies. We selected two distinct groups of deposits based on their magnetic properties. The first group, consisting of magnetite and pyrrhotite, has mainly single-domain structure in comparison to the second one, including only magnetite. In the second group, multi-domain grains dominate. The obtained results allowed to recognize different source rock of studied material and changes in the source of delivery to Nottingham Bay.

**FIRST MEASUREMENTS OF THE EARTH'S ELECTRIC FIELD AT THE ARCTOWSKI ANTARCTIC STATION, KING GEORGE ISLAND, BY THE NEW POLISH ATMOSPHERIC ELECTRICITY OBSERVATION NETWORK**

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Atmospheric electricity measurements are performed all over the globe for getting a better understanding of the processes and phenomena operating in the Earth's electric atmosphere, ionosphere and magnetosphere. Over recent years, we have established coordinated observations of atmospheric electricity, mainly of the vertical component of the Earth's atmospheric electric field, from Polish observation stations: Stanisław Kalinowski Geophysical Observatory in Świder, Poland, (21.25°E, 52.12°N, geomagnetic latitude ~50.5°N), Stanisław Siedlecki Polar Station in Hornsund, Svalbard, Norway, (15.50°E, 77.00°N, geomagnetic latitude ~73.9°N) and, for the first time, the Henryk Arctowski Antarctic Station in King George Island (58.47°W, 62.16°S, geomagnetic latitude ~51°S). The organization of this network is presented here as well as a preliminary summary of geophysical conditions at Arctowski, important from the point of view of atmospheric electricity observations. In particular, we refer to the geomagnetic observations made at Arctowski station in 1978-1995. We also present the average fair-weather diurnal variation of the atmospheric electric field based on observations made so far between 2013 and 2015. The variations of the atmospheric electric field at Arctowski during fair-weather is a valuable addition to the monitoring of diurnal variations in the atmospheric electric circuit. The location of Arctowski station is usually away from the Southern Hemisphere ionospheric convection and therefore it can be assumed that the effects of magnetospheric generators can be neglected.

**Aknowledgements:**

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**MAGNETIC PROPERTIES OF TRIASSIC ROCKS OF SVALBARD ARCHIPELAGO**

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The research of para- and ferromagnetic minerals as well as paleomagnetic study were undertaken on Early Triassic sediments from the West Spitsbergen Fold and Thrust Belt (WSFTB; Hornsund, Bellsund) and from the foreland of this orogen (Sassendalen) in order to study how thermal and deformational events affected their magnetic mineralogy. The low- and high-field anisotropy (AMS) were measured in order to assess the degree of deformation and to isolate the ferro- and paramagnetic subfabrics whereas standard paleomagnetic procedures were conducted to determine the magnetic remanence components. Magnetic mineralogy varies and only in partly it depends on the lithology. The magnetic fabric at all sampling sites is controlled by paramagnetic minerals (phyllosilicates and Fe-carbonates). In the fold belt, it reflects relatively a low degree of deformation in a compressional setting with the directions of magnetic lineation following the general NNW–SSE trend of the WSFTB. In the foreland, magnetic lineation is perpendicular to the WSFTB, and reflects the Triassic paleocurrent direction (NE-SW). The dominant ferrimagnetic carriers are magnetite and titanomagnetite. The NRM pattern is complicated with partially overlapping components. However, it is dominated by secondary components characterized by steep inclination (ca. 70-80°). At least some of the secondary, paleomagnetic directions are possibly of pre-Eurekan folding (ca. 150-100Ma) origin and might be related to heating of these rocks by the dolerite intrusions, resulting in remagnetization.

**FLUID PERCOLATION IN FRACTURED SYSTEMS – A 2D DEM SIMULATION**

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In glaciers, which can be described as fractured bodies of ice, a percolation of water can be observed. A water flow can either create or extend already existing fractures. An attempt of 2D simulation of such fracturing process using the Discrete Element Method (DEM) approach implemented in ESyS-Particle Software is presented in this research using simplified model of a glacier.

The body of the glacier is represented as a cuboid assembly of discrete elements (particles). Water is also represented as particles, but with much smaller radii. Those particles are bonded together and undergo different interactions. A broken bond is considered as a new fracture. During this simulation, water is being pushed into the glacier with pre-existing cracks in order to investigate what is happening within the sample, how bonds are breaking thus cracks and fractures are creating and evolving.

**FRESH WATER CHEMISTRY IN THE NEWLY-FORMED PERIGLACIAL ENVIRONMENT AT THE WESTERN SHORE OF ADMIRALTY BAY (KING GEORGE ISLAND, MARITIME ANTARCTICA)**

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This study provides a description of inorganic chemistry of the eight streams flowing in one of the largest ice-free areas on the western shore of Admiralty Bay. In the water samples, collected twice in the summer of 2016, ions and trace metals (and B) were detected and quantified. Additionally, the parameters of pH, specific electrolytic conductivity (SEC) and total organic carbon (TOC) were determined. Moreover, multivariate data set was created and Principal Component Analysis (PCA) was performed. Generally, the water has low total content of the measured mineral constituents < 100mgL. On the basis of PCA analysis we distinguished two groups of chemical variables shaping water chemistry in the investigated creeks: I – components of marine aerosol origin (presence of Na, Cl and B) and II – those associated with chemical weathering processes (presence of Al and Fe). Furthermore, the results showed that the flowing water in the newly-formed periglacial areas (formed over the last 30 years) are rich in easily soluble Al and Fe and have lower total measured contents of mineral constituents during the summer period than creeks in non-glacial catchments. Moreover, local biological factors (lichens and mosses) and those limited to the sea-shore vicinity (seabirds and mammals activity) are significant sources of PO<sub>4</sub>, NO<sub>3</sub> and NH<sub>4</sub>. Despite the described geological and biological features influencing water chemistry, the impact of anthropogenic activity still needs to be verified, especially in terms of heavy metal concentrations.

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**EFFECT OF SODIUM FLUORIDE ON SEEDS GERMINATION AND SEEDLINGS GROWTH OF  
COLOBANTHUS APETALUS (LABILL.) DRUCE AND COLOBANTHUS QUITENSIS (KUNTH)  
BARTL**

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Plants growing in polar regions of the world are subjected not only to cold or water stress, but also to chemical stresses of diverse nature. Although fluorine is the most abundant halogen on the Earth, fluorinated secondary metabolites are rare in nature. Fluorine and its compounds are the most phytotoxic of the common air and soil pollutants in plants. In this study we examined the ability of seeds germination, chlorophyll fluorescence in cotyledons and proline content of seedlings *Colobanthus apetalus* and *Colobanthus quitensis* under sodium fluoride stress. Seeds of *C. apetalus* were harvested in greenhouse of Department of Physiology, Genetics and Biotechnology in Olsztyn. Seeds of *C. quitensis* were harvested in Antarctica (King George Island, South Shetland Island) and from greenhouse cultivation (Olsztyn, Poland). Seeds collected in the above places were used to seeds germination tests under experimental conditions at 20/100C and photoperiod 12/12h, using three different concentrations of sodium fluoride (9 mM, 19 mM, 29 mM). Sodium fluoride, in the applied concentrations, did not inhibit the germination of seeds of *C. apetalus*. Germination of seeds of *C. quitensis* harvested in greenhouse, were significantly inhibited at 9 mM and 29 mM NaF. While, only at 29 mM NaF germination of seeds of *C. quitensis* harvested in Antarctica were inhibited. We noted at 19 mM and 29 mM NaF a significant decrease in chlorophyll fluorescence intensity in cotyledons of seedlings *C. quitensis* originated from greenhouse. A significant decrease in chlorophyll fluorescence intensity was observed also at 9 mM NaF in cotyledons of seedlings *C. apetalus*. However, sodium fluoride did not affect chlorophyll fluorescence intensity in cotyledons of seedlings *C. quitensis* originated from Antarctica. Proline accumulated gradually in young plant tissues of both examined species in response to the increase in NaF concentration in the medium. Seeds and seedlings of *C. apetalus* and *C. quitensis* are characterized by a high degree of tolerance to chemical stress caused by sodium fluoride. However, *C. quitensis* originating from Antarctica seems to be the best adapted to the reproduction and growth under unfavorable environmental conditions.

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