Proceedings: Students in Polar and Alpine Research Conference 2021

Conference Paper · May 2021

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SPARC

3–4 MAY 2021 BRNO, CZECH REPUBLIC

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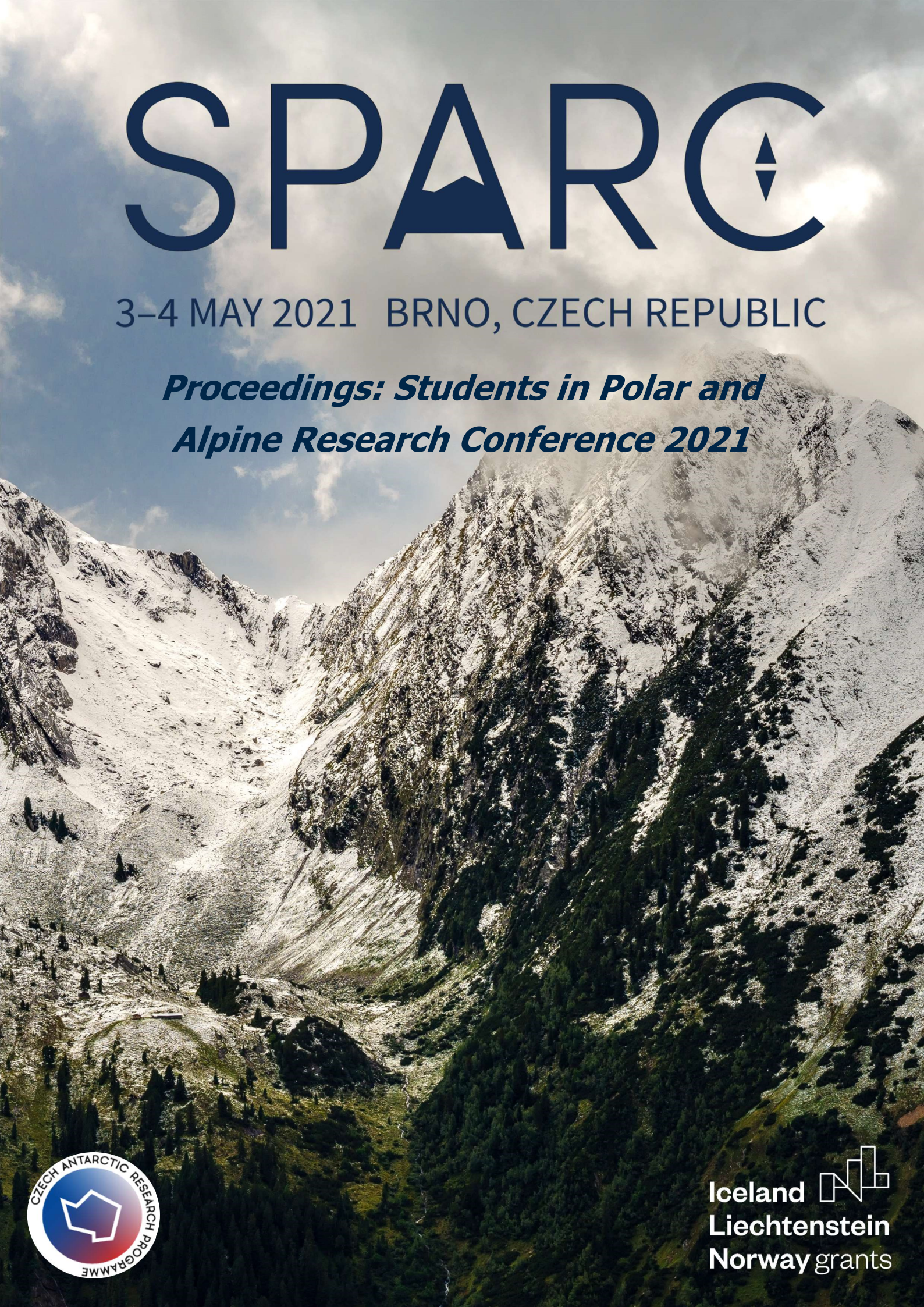

CZECH ANTARCTIC RESEARCH PROGRAMME

Iceland Liechtenstein Norway grants

Students in Polar and Alpine Research Conference 2021 - Preface

Dear colleagues from the polar and alpine research community,

We are honoured to welcome you, albeit only virtually, at the international Students in Polar and Alpine Research Conference that is held for the seventh time under the patronage of the Department of Geography, Masaryk University, Brno, Czechia. This conference provides a platform for students and scientists at the beginning of their career to share their research in the icy-cold regions of the world, in the disciplines of geosciences and biosciences. We hope that networking, perhaps more important than ever, and sharing the knowledge and ideas will bring many new collaborations and interesting results in the foreseeable future.

In total, 75 participants from 16 countries registered for the conference, with scheduled contributions of 28 oral presentations, including 5 keynote lectures, and 12 posters. We would like to thank all the participants, both the young scientists who have presented their interesting research and the keynote speakers for sharing their knowledge and experience with us. We are happy to see old friends as well as colleagues participating for the first time, yet who will hopefully return in the following years.

There is a website dedicated to Students in Polar and Alpine Research Conference, which you can find on https://sparc-brno.webnode.cz. We sincerely hope that we will meet in Brno (hopefully in person) next year.

In Brno, on 3rd May 2021

Jan Kavan, Matěj Roman

Proceedings
Students in Polar and Alpine Research Conference 2021

Place • Date
Brno (Czech Republic) • 3–4 May 2021

Editors:
Jan Kavan, Matěj Roman

Acknowledgements:
The organizing committee of Students in Polar and Alpine Research Conference 2021 gratefully thanks the Department of Geography, Masaryk University for providing us with the conference-related equipment. The conference is organized with financial support from EEA grants via the project „Cool Science – training course in polar research“ (EHP-CZ-ICP-1-003). The funding support for the conference was provided by the project MUNI/A/1570/2020, the projects LM2015078 and CZ.02.1.01/0.0/0.0/16_013/0001708 funded by the Ministry of Education, Youth and Sports of the Czech Republic. We acknowledge the keynote speakers who had the will to contribute to the conference.

ISBN 978-80-210-9859-6

Published by Masaryk University, Žerotínovo náměstí, 617/9, 601 77 Brno, Czech Republic, 1st edition.

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Nature, degradation and collapse of sub-arctic ecosystems in Iceland

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Located right below the Arctic Circle, Iceland is an example of a landmass that includes areas above the tree-line, areas of discontinuous permafrost, as well as lowlands that can be placed within the boreal zone. The effect of frequent freeze-thaw cycles is pronounced due to the cold maritime climate. The nature is characterized by a peculiar mixture of volcanic and Arctic soil systems, which are extremely vulnerable to disturbance. Volcanic eruptions and redistribution of loose sediments as dust have a large influence on the ecosystems. Icelandic ecosystems evolved without large herbivores, which made them still more vulnerable to disturbances from livestock grazing. Birch and willow forests and shrubs dominated the landscapes prior to the Settlement but have limited distribution today. The 1200 years of land-use has caused massive collapse of Icelandic ecosystems, with degraded vegetated systems and fully desertified barren areas, even in places where woodlands once dominated. Land use far exceeds negative influences by climate fluctuations and volcanic eruptions on Icelandic ecosystems. Yet the interaction between land use (reducing resilience), landscape elements such as elevation, drainage and slope, and natural events such as cold spells and volcanic eruptions are important. A large part of the unique Icelandic wetlands, an odd mixture of volcanic and Arctic peatlands, have been drained and they now constitute the largest national source of man-induced greenhouse gas emissions by far. The general public and the foreign visitor usually do not have a meaningful perception of the dramatic changes that Icelandic ecosystems have underwent. Efforts of government institutions and environmental group pressures have in part failed to date – yet efforts to improve the situation still continue. There is a growing pressure for large scale ecological restoration efforts, with some successful projects and developments leading the way.

What do we know about Svalbard hydrology after 50 years of research?

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The Arctic is rapidly changing and Svalbard is at the forefront of that change. Here, the warming is two to six times as fast as the rest of the world, and there is no doubt that we can expect even further increase in air temperature (by 4 – 7°C) and precipitation (by 45 – 65%), with increased occurrence of heavy rainfall and flood events. As a result, glaciers in Svalbard continue to retreat.

We know that increased ice thaw influences freshwater discharge, yet in the environment occupied by a variety of glaciers, the direction of that shift is yet to be uncovered. In addition, while any change in glacier coverage is followed by modification of the capacity for water storage on the surface, thawing of the permafrost and deepening of the active layer have the capacity to alter groundwater budgets.

While the consequences of shrinking cryosphere impact both terrestrial and marine ecosystems, a debate is open whether climate driven changes in the High Arctic have yet to reach the point of no return.

However, it is safe to assume that Polar Regions of the future will be very different to what we can see

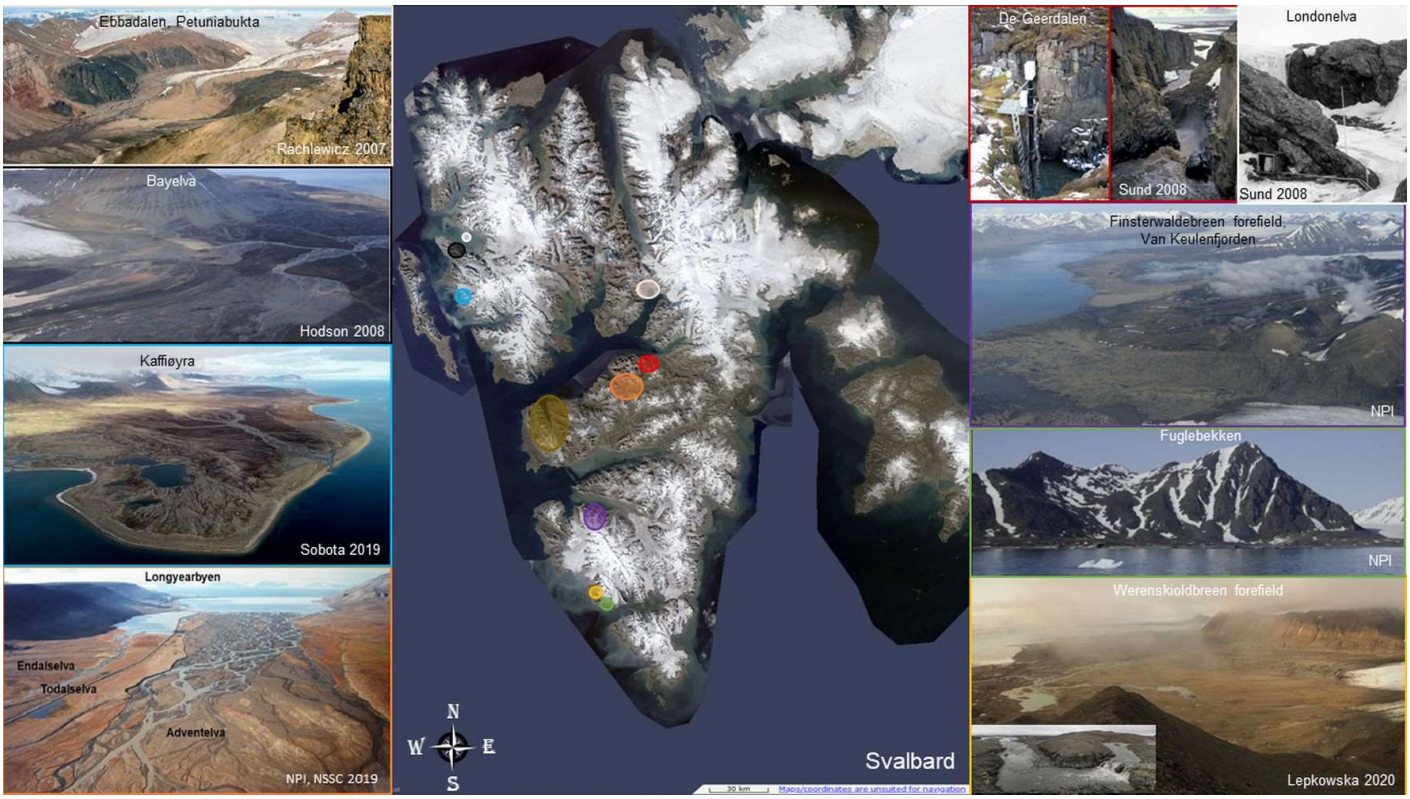

Figure 1 Locations of catchments with long-term hydrological monitoring. From South to Norh: (green) Hornsund – 423 Fuglebekken, (yellow) Nottinghambukta – Werenskioldbreen, (purple) Van Keulenfjorden – 424 Finsterwalderbreen, (brown) Grønfjorden - Grøndalen, Grønfjordbreen, Aldegondabreen, Kongresdalen; 425 (orange) Adventfjorden – Adventdalen; (red) Sassenfjorden – DeGeerdalen, (pink) Petuniabukta – 426 Bartilelva, Ferdinandelva, Ebbaelva, Elsaelva; (blue) Kaffiøyra - Waldemarbreen, Kongsfjorden – (black) 427 Bayelva and (white) Londonelva. Source: Nowak et al. 2021 (SESS Report, Chapter 7)

today. Though, the level of that change will depend on variables intrinsically linked to the water balance. Precipitation (whether solid or liquid), the intensity of glacier melt, surface water discharge as well as elusive groundwater's contribution to total discharge, are therefore of core interest to the scientific community. It is also not surprising that hydrological response to undergoing environmental revolution has been named one of the most important research needs in the High Arctic.

To respond to that need, understand the state of the current hydrological conditions in Svalbard, as well as to understand the direction of their change, a SvalHydro initiative was established. Furthermore, in January 2021, our group consisting of scientists and institutions performing long-term hydrological monitoring produced a comprehensive review of all available datasets linked to the water balance and collected in the last 50 years.

The collaboration also resulted in a report highlighting the current state of knowledge on the water budget components, the direction of hydrological changes, and the knowledge gaps that are yet to be filled. In addition, the report identified key problematic areas that preclude us from completing the water budget for Svalbard and suggested possible solutions.

This talk will therefore present surprising results of the SvalHydro report, highlight the knowledge gaps, and discuss possible improvements to water balance research that need to be implemented if we ever want to further our understanding of the future hydrological changes in the High Arctic.

Poles apart: biogeography and evolutionary history of Polar diatom communities

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Despite increasing evidence for significant levels of endemism among various microbial groups, a comprehensive understanding of the evolution of regional microbiota and how they are shaped by tectonic and paleoclimate events remains virtually lacking. Here, we combine evidence of contemporary and fossil data on morphology, molecular phylogenies and next generation environmental amplicon sequencing to provide insights into the biogeographical and evolutionary history of Antarctic freshwater and terrestrial diatom biomes. We undertook detailed taxonomic inventories of fossil Antarctic diatom assemblages dating back to the Mid Miocene and dovetailed this dataset with a comprehensive assessment of the diversity and biogeography of the contemporary Antarctic flora. In addition, using cultures and eDNA, we complemented the fossil dataset with a detailed Antarctic and global inventory of the molecular diversity and phylogeny of the common cosmopolitan diatom complex *Pinnularia borealis* as a case study for extant diatom lineages. Taken together, our data support the hypothesis of widespread but selective extinction among an ancient diatom flora, characterized by distinct Gondwana elements, in response to the Mid Miocene cooling (ca. 14 Ma) and the subsequent expansion of ice sheets, followed by the evolution of a species-poor yet highly adapted and largely endemic modern diatom flora. Climatic sorting of regional floras resulted in the current bioregionalization patterns in the Antarctic diatom biome, which shares striking similarities with that of macroscopic organisms. In parallel, our molecular data suggest multiple colonizations of Antarctica by the *P. borealis* species complex during the past 25 Ma. Since the majority of the *P. borealis* lineages currently inhabiting Antarctica are presumed to be endemic for the region, isolation and genetic drift following colonization are hypothesised to drive in situ (allopatric) speciation. Altogether, our data suggest that historical processes, i.e., geology and climate, have been crucial in shaping the history of Antarctic microbial lineages, in similar ways as these processes affected macroorganisms.

Growing faster or for longer? Climate-change effects on cambial phenology and kinetics in cold and dry environments

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Woody plants are responding to climate change by alteration of wood formation dynamics (xylogenesis) on various temporal scales. The response on an annual scale can be analyzed using chronologies of tree-ring widths, which are readily available with sufficient density and long temporal span across the globe. However, the direct observations of intra-annual (daily) growth dynamics are scarce and usually do not span more than 5 years. Indeed, the assessment of climate-change effects on intra-annual growth dynamics of woody plants for multidecadal periods can recently be achieved only by employing indirect approaches. For instance, process-based models of wood formation might be used to numerically simulate past patterns and trends of cambial kinetics (speed of cell differentiation during the year) and cambial phenology (duration of the growing season). Process-based models represent algorithms with the mechanistic representation of the current understanding of the growth dynamics.

Here I summarize the main findings of three case studies using the Vaganov-Shashkin process-based model to determine trends in (i) speed of wood formation and (ii) duration of the growing season for ecologically contrasting sites. Vaganov-Shashkin model is a purely climate-driven process-based model which determines the progress of wood formation from the daily temperature, soil moisture, and daylength. We simulated intra-annual growth dynamics for northern cold environments (Arctics), mountain treelines (Alps, Urals, Krkonose Mts.), and dry regions (Mediterranean). We considered species of three widespread coniferous genera – *Pinus*, *Picea*, and *Juniperus*. In total, we performed simulations for 21 sites.

In mountain environments, we observed significant positive trends towards higher growth rates and longer duration of the growing season during the second half of the 20th century. Higher growth rates were stimulated mainly by the temperature increase during spring and summer, while the contribution of growth intensification in autumn was marginal. By contrast, the simulations in the Arctics suggested increasing growth rates with, however, non-significant trends in growing season duration. We suggest that weak trends in growth phenology are jointly due to weak spring temperature increases and higher winter snow depths delaying the spring onset of cambial activity at our Arctic sites. Finally, the Mediterranean dry sites experience declining growth kinetics due to increasing summer drought stress. However, the extension of the growing season duration tends to be stronger in dry localities compared to cold environments. This suggests that the prolongation of the growing season represents a mechanism employed by woody plants to mitigate the effect of increasing summer drought stress.

Our results show that intra-annual growth dynamics of woody species represent a plastic trait, capable to adjust to the local course of climatic conditions. This permits woody species to tightly couple their growth dynamics to site-specific

climate and to sensitively respond to climate change.

Acknowledgments

My research stay at the University of Greifswald was enabled by the post-doctoral project by Alexander von Humboldt Foundation. I credit all coauthors of three case studies which represent a base of my presentation (J. Kašpar, H. Kuželová, V. Shishov, I. Tychkov, M. Popkova, E. Vaganov, V. Treml, V. Ilyin, A. Buras, J.J. Camarero, M. Carrer, R. Shetti, M. Wilmking, J. Altman, G. Sangüesa-Barreda, J. Lehejček).

Evidence and ecological implications of subglacial discharge under sea-ice at a shallow tidewater glacier on Svalbard

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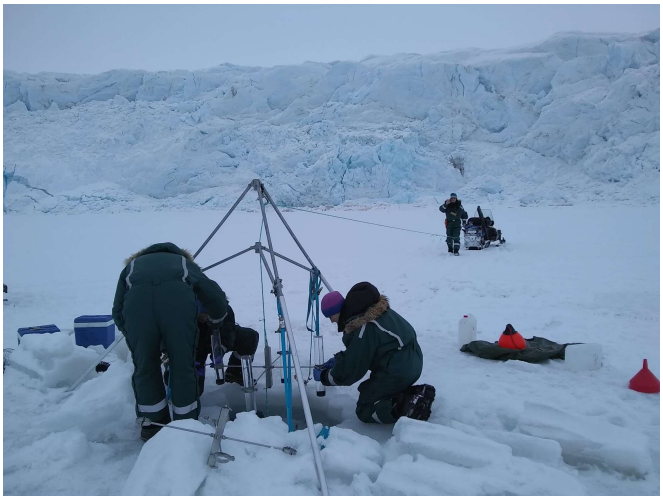
Submarine discharge of meltwater at tidewater glaciers has been recognized as important drivers of Arctic fjord circulation, facilitating high primary production via subglacial upwelling in summer. The presence of subglacial discharge in early spring has been described for both land- and marine terminating glaciers. However, its magnitude and importance on the microbial carbon cycle and diversity in sea ice-covered fjords has not been considered. We hypothesized that subglacial discharge and upwelling is also happening in spring with pronounced impacts on the microbial food web. At a shallow tidewater glacier on Svalbard, we found evidence for submarine discharge in CTD, Nutrients, and turbidity profiles, which was absent from a land-terminating and a marine reference site. The meltwater input lead to a strongly stratified 2 to 4 m deep brackish surface layer and sea ice with very low salinity. Nutrient concentrations were enriched in this brackish surface layer and sea ice with high concentrations at low sea ice brine salinities indicating a direct or indirect freshwater origin. In the brackish surface layer, we found three orders of magnitude higher primary production (5.3 mg C m^{-3} d^{-1}) leading to higher phytoplankton biomass, compared to the marine reference site. We attributed higher nutrient concentrations (subglacial upwelling and direct silicate inputs with glacial meltwater), the shallow mixed layer depth, and 2 times more light penetration (less snow cover, less ice algae biomass) to allow the formation of this moderate under ice phytoplankton bloom. In sea ice at the tidewater glacier, algae biomass was three orders of magnitude lower and algal communities significantly different, which we attribute to the very low brine volume fraction leading to limited nutrient exchange with the underlying water column and limited inhabitable space. With retreating tidewater glaciers in a warming climate this submarine discharge may disappear which leading to lower under ice phytoplankton production and higher sea ice algae biomass. However, sea ice is also disappearing, which may have the opposite effect.

Figure 1 Sediment trap in front of a glacier



Distribution of dissolved organic matter in west Svalbard fjord waters by *in-situ* measurements

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This study was aimed to investigate organic matter components in water structure. One of the important indicators of marine ecosystems such as dissolved organic carbon (DOC) and total nitrogen (TN) were considered. Vertical seawater sampling for further measurement of organic matter components was conducted during oceanographic surveys in Temple Fjord, Advent Fjord, Isfjord, Billefjord, Grønfjord in summer 2017. Total organic carbon and total nitrogen were analyzed in the Laboratory of Russian Arctic Expedition on Spitsbergen, Arctic and Antarctic Research Institute in Barentsburg. Surface-layer DOC concentration ranged from 0.17 to 1.42 mg/L in all studied fjords. Deep-layer DOC concentration ranged from 0.26 to 1.0 mg/L. Vertical distribution TN concentration slightly varied from 0.05 mg/L to 0.4 mg/L. Distribution of TOC DOC and TN is homogeneous regardless of prevailing water masses. Thus, the fjords waters can be described as low-productive in studied summer period (July), that is typical for arctic water oligotrophic ecosystems.

A new record of lichenized fungus species for Antarctica, James Ross Island: *Placopsis antarctica* and *Xanthocarpia tominiii*

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The Antarctic Peninsula has been one of the regions of the world experiencing relatively fast regional climate warming over recent decades and, due to its relatively simple ecosystems, serves as an early warning system in understanding species and ecosystem responses to climate change. Terrestrial ecosystems in the Antarctic are dominated by mosses and lichens. In recent years, researchers have focused lichen biodiversity of Antarctica in their studies.

James Ross Island is one of the richest lichen-rich islands in Antarctica, with more than 140 lichen species reported. Lichen samples were collected from James Ross Island and Galindez Island in Antarctica. The specimens detailed below are deposited in Erciyes University Herbarium Kayseri, Turkey (ERCH).

Lichen samples were separated from different plant or lichen species under the microscope with the aid of a razor. The external morphology has invariably been studied under stereo microscope. The anatomy of the thallus and apothecia were studied under camera light microscope. The colour of medulla, epithecium, hypothecium, ascus and ascospores were recorded both before and after spot tests. Total DNA was extracted using the Dneasy Plant Mini Kit (Qiagen) following the manufacturer's protocol. DNA extractions were used as template in the PCR. The complete nrITS fragment of the nuclear ribosomal DNA repeat was amplified by PCR using primers ITS1F and ITS4. Sequence analyses of the lichen samples obtained from the PCR products were performed by the BM Labosis laboratory. Sequence results of the lichen samples were compared using BLAST program in NCBI website. Then, the results were edited in BioEdit program. The selection of lichen samples from genbank was chosen by taking into consideration the morphological relationships as well as the molecular results with the studied samples. For phylogenetic tree, MEGA 7 (Molecular Evolutionary Genetics Analysis) program was used. The out-groups used in the phylogenetic trees were chosen to be associated with the in-groups.

As a result of our studies aiming to determine the lichen mycota of James Ross Island (Antarctic Peninsula), we report *Placopsis antarctica* and *Xanthrocarpia tominii* from Antarctica, James Ross Island for the first time. Future studies on Antarctic lichenized fungi biodiversity will benefit the results of this study.

Acknowledgements: We like to thank to the support by The Scientific and Technological Research Council of Turkey (TUBITAK) ARDEB 1001 [Project number: 118Z587] program..

Lessons learned from lemmings – and why we should support long term monitoring in ecology

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The reasons for cyclic fluctuations of small rodent populations have been - and still are - intensely discussed among ecologists. The questions relating to the driving factors behind these remarkable fluctuations have been addressed in the scope of the Karupelv Valley Project since 1988 in a long-term study of lemming cycles. The approaches adopted here include the assessment of lemming population dynamics as well as those of its predators. The high Arctic tundra in the Karupelv Valley in North East Greenland serves as study area for our investigations and features one of the most simplified terrestrial animal communities offering ideal conditions to explore basic ecological interactions.

Lemming populations have been monitored through systematic recordings of winter nests in an area of 1500 ha. As winter nests are easy to detect, the study of uncovered lemming nests in summer also allows tracking back predation by stoats in winter. Nests eliminated by stoats are characterized by the remainders of a typical, 'sleeping bag like' fur lining. Besides stoats, other predators such as snowy owls, long tailed skuas and arctic foxes are recorded. Especially avian predators and foxes are easy to monitor by annual assessments of their breeding success or occupation of dens respectively. The sampling of pellets and scats provides detailed information on predators' diets. Other aspects that are repeatedly addressed within the scope of the Karupelv Valley Project are radiotelemetry of foxes, satellite telemetry of snowy owls as well as color ringing and the use of geolocators on waders and skuas.

Lemming populations first displayed the typical pronounced cycling patterns with recurrent and quite severe irruptions every 4 to 5 years. Based on modeling approaches, these fluctuations could be attributed to the delayed density response of stoats, supporting the hypothesis of specialized predation being the driving factor behind the distinctive population cycles in lemmings. The changes that became apparent within the past decade suggest a fading or even levelling of these cycles and may be related to effects of global change (Gilg et al. 2009). Simulations of lemming population development which take into account changes in snow cover seem to support this theory. The missing cyclical outbreaks of lemming populations also affect the reproduction rates of its predators, e.g. the breeding success of snowy owls and long-tailed skuas during the past decade. Our observations suggest a dramatic decrease of the reproductive output in the area. The year 2020 was the first in over 20 years to show a peak in lemming population.

The results within this project show that long term observations are absolutely indispensable for detection and correct interpretation of fundamental changes within this fragile ecosystem. Climate

change has become a main research objective within the project during the past couple of years. In this regard, special attention has been drawn to the assessment of snow cover changes as well as the patterns displayed by sea-ice cover in coastal areas. The latter constitute severe habitat changes for polar bears that become increasingly dependent on foraging ashore during summer.

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Role of permafrost-affected soils in sustainable development of the Russian Arctic

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Permafrost-affected soils are considered to be one of the important cryosphere elements within the climate system. Polar terrestrial ecosystems and permafrost-affected soils are unique indicators of climate change. The aim of our study was to assess the functional diversity of permafrost-affected soils along the bioclimatic and permafrost transect from the northern taiga to the southern tundra of Western Siberia from such parameters as the soil temperature regime, the composition of soil organic matter and the soil biological activity.

Despite the wide array of changes in both physical (soil temperature and moisture) and biological conditions (vegetation composition, content of labile and microbial soil carbon), our results showed that soil CO_2 flux did not vary significantly throughout transect (northern taiga – forest tundra – southern tundra). But the active layer thickness varies significantly. It explains the necessity of adequate assessment of the spatial variability of the active layer thickness as a significant factor influencing regional CO_2 emission.

The factor that has the greatest impact on the diversity of ecosystems and the biological activity of soils in the northern taiga, forest-tundra and southern tundra (zones of continuous, discontinuous and sporadic permafrost) is presence and depth of permafrost. Permafrost determines the type of ecosystems, temperature regime and the activity of the organic matter transformation processes in polar region. In the southern and middle taiga the influence of seasonal permafrost on soil functioning is less pronounced.

The lack of easily available carbon for microorganisms is detected in all investigated soils by the Cmic: Corg ratio. The CO_2 flux and the Cmic: Corg ratios are “site-specific” for the research regions and may be used as indicators of environmental changes. Soils represent a unique natural object and ensure the functional diversity and integrity of polar ecosystems.

Our results show the important role of permafrost-affected soils in the sustainable development of the terrestrial ecosystems along the polar transect from taiga to tundra in Western Siberia.

Long-range transport of Icelandic dust towards Europe

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Iceland is recognised as the largest desert in Europe and in the Arctic. The desert covering approximately 44,000 km^2, including hyperactive dust hot spots of an area smaller than 1,000 km^2, annually produces 135 dust days according to the SYNOP code observations (Arnalds et al., 2016). This, with other High Latitude Dust sources, significantly contributes to the global dust budget and creates a potential risk to the climate and biodiversity in the Arctic regions.

High latitude dust can be transported long distances. Recent studies showed that dust from Icelandic sources travelled about 3,500 km to Balkan Peninsula (Djordjevic et al., 2019), about 2,000 km to Svalbard (Moroni et al., 2018) and a study on Icelandic dust travelling about 1,300 km to Ireland (Ovadnevaite et al., 2009) serves as a case study to identify additional dust events arriving to Mace Head, Ireland.

During January 2020 - February 2021 about 304 dust days were recorded in Iceland by using atmospheric-dust model DREAM (Dust REgional Atmospheric Model, https://sds-was.aemet.es/forecast-products/dust-

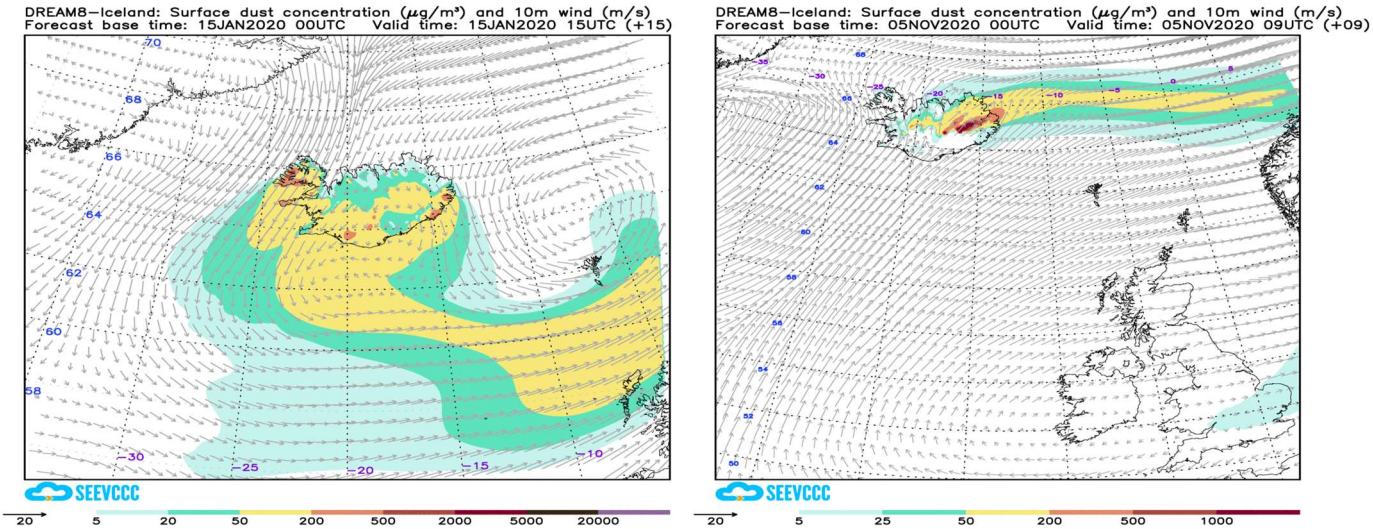

Figure 1. DREAM forecast showing surface concentartion from dust events in Iceland reaching Faroe Islands, the UK and Scandinavia on the 15th January 2020 and 5th November 2020.

Table 1 Overview of long-range dust transport events

	Jan2020	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan2021	Total
Number of dusty day Iceland	31	29	31	30	31	30	26	17	21	15	20	14	9	304
Number of days when the dust reached **Faroe islands**	6	7	8	7	7	2	8	0	0	0	3	0	1	49
Number of days when the dust reached **UK/Ireland**	4	5	8	3	3	0	5	0	2	0	1	0	0	31 (-21 also in Faroe)
Number of days when the dust possibly reached **Scandinavia**	5	1	3	2	2	0	0	1	2	0	2	0	0	18 (-6 also in Faroe)
														Total events 71

forecasts/icelandic-dust-forecast, Cvetkovic et al., submitted). A dust day was recognised as a day when the DREAM model showed surface dust concentrations higher than 50 µg/m^3 in any part of Iceland. Out of these active days 71 were identified to be a long-range transport dust events directed towards Europe, specifically towards Faroe Islands, Great Britain and Ireland, and Scandinavia (Figure 1, Table 1). The poster presents this under investigation study about long-range transport dust events towards Europe.

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Clear-cut timing of Neoglacial episode on the Antarctic Peninsula

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Though austral summers in Antarctic Peninsula have been exceeding upper-ocean temperature records since the 1950s CE, a few rather cold-climate reversals have been evidenced over the Holocene. Precise timing and spatial extent of these episodes, however, remain difficult to estimate as the extensive network of reliable proxies is still missing. Here, we apply biological, physical-chemical, and geochemical techniques to calibrated ^{14}C lake sediment record from the eastern Antarctic Peninsula to extract the multi-proxy evidence for the mid-late Holocene Hypsithermal–Neoglacial transition, the last significant regional climate event of the Late Holocene. Distinctive by slower siliciclastic supply, suppressed diatom activity/productivity and poor organics, our record estimates the abruptly deteriorating climate conditions associated with the onset of Neoglacial period at ~2050 cal. years BP (2σ: 1990–2130). Revealing as statistically indifferent, we show that near-distant Mt. Haddington ice core record and Beak Island lake chronology are temporally consistent with our results, allowing to estimate the weighted area-average for neoglacial onset to ~2070 ± 50 years BP. Moreover, our findings not only place the current warming rates in a Holocene-long context, but also appear timely for the utilization and calibration of glacier-land-atmosphere feedbacks under predicted climate change.

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Preliminary results of spectral UV radiation modeling using Artificial Neural Networks

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Artificial Neural Networks (ANNs) are computing tools applied in a wide variety of fields to model non-linear, complex, or cross-correlated relationships. The greatest advantage of ANNs is that they learn the data patterns in the training process, so there is no need for a-priori knowledge of underlying physical laws, parametrization, or empirical relationships. In the past two decades, ANNs have been often used in many tasks of climatology, such as to estimate evapotranspiration, interpolate surface temperature, or predict precipitation. They have also been successfully employed in the modeling and reconstructing solar radiation, commonly the erythemally-weighted UV doses (e.g., Feister et al., 2008). However, the possibility to use ANNs for the prediction of spectral radiation intensity has not been frequently investigated.

In this study, data obtained at Marambio Base, Antarctic Peninsula Region, have been used to build an ANN model of spectral solar UV radiation. Over the period 2010–2020, the Czech Hydrometeorological Institute and the National Meteorological Service of Argentina were operating the double-monochromator B199 Brewer spectrophotometer there. This instrument was used to measure spectral solar UV radiation and total ozone column (TOC), providing a high-quality time series (Čížková et al., 2019).

The analyzed solar UV spectra consisted of radiation intensities at 127 wavelengths (300.0–363.0 nm with a 0.5 nm step). In order to build the ANN model, four input parameters were selected through a sensitivity analysis: solar zenith angle (SZA), TOC, cloudiness represented by cloud modification factor (CMF), and albedo. Then, ten different randomly initialized multilayer perceptron neural networks were trained. For each of them, the dataset, consisting of 23 260 solar UV spectra paired with the input parameters, was randomly divided to training subset (70 %), testing subset (15 %), and validation subset (15 %). A validation showed that all the ten models performed very well ($R^2 > 0.97$ and RMSE < 0.001 $mW \cdot m^{-2}$ for all models and wavelengths), and the best model was selected.

The study showed that it is possible to use ANNs to estimate solar UV spectra based on more commonly observed parameters (TOC, SZA, cloudiness, and albedo). It would be therefore possible to fill in missing observations or model solar UV spectra in various atmospheric conditions.

Acknowledgments: This study was performed under the financial support of the Project of the Czech Hydrometeorological Institute No. 03461022 'Monitoring of the ozone layer and UV radiation in Antarctica', funded by the State Environmental Fund of the Czech Republic and the projects LM2015078 and CZ.02.1.01/0.0/0.0/16_013/0001708 funded by the Ministry of Education, Youth and Sports of the Czech

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Long range transport of atmospheric dust from Iceland and in the Arctic

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The Arctic and Antarctic regions include large areas of High Latitude Dust (HLD) sources, from where dust is transported long distances. The first estimates are that all high latitude dust sources cover > 500,000 km^2 and contribute to at least 5 % of global dust budget. Iceland is the largest Arctic as well as European desert with high dust event frequency (~135 dust days annually according to the SYNOP code observations).

Remote sensing observations have revealed dust plumes from dust sources in Iceland to be visible at > 1,000 km distances and > 700 km long dust plumes from small dust source of area about 10 km^2. Previous studies confirmed that Icelandic dust travelled distances > 3,500 km towards Europe (Ireland, Serbia) and towards the Arctic (Svalbard). Models have estimated that about 7% of Icelandic dust can reach the high Arctic (N>80°). Svalbard is one of the active HLD sources, but HLD from the North Eurasia, Greenland, Alaska, and Iceland, has been identified to travel to Svalbard based on the aerosol geochemical properties by potential source contribution function (PSCF) analysis (Crocchianti et al., 2021).

Long-range transport dust events from Iceland towards Europe in 2020–2021 were identified using atmospheric-dust model DREAM (Dust REgional Atmospheric Model, https://sds-was.aemet.es/forecast-products/dust-forecasts/icelandic-dust-forecast, Cvetkovic et al., submitted). A total of 71 long-range dust events were identified reaching mainly Faroe Islands, Great Britain and Ireland, and Scandinavia during January 2020 - February 2021 (Figure 1). The DREAM has also captured dust storms in Icelandic territory and dust events with concentrations > 50 µgm^3 resulted in total number of 304 dust days. This is considerably higher than dust events observed at the Icelandic weather stations (135 dust days annually) showing the importance and need for better dust observation network in Iceland.

HLD and HLD sources affect the atmosphere, cryosphere, marine and land ecosystems not only in the Polar Regions, but also in the Europe. New HLD sources are being identified. This study provides an evidence that HLD events have impacts not only on local, but also regional scale.

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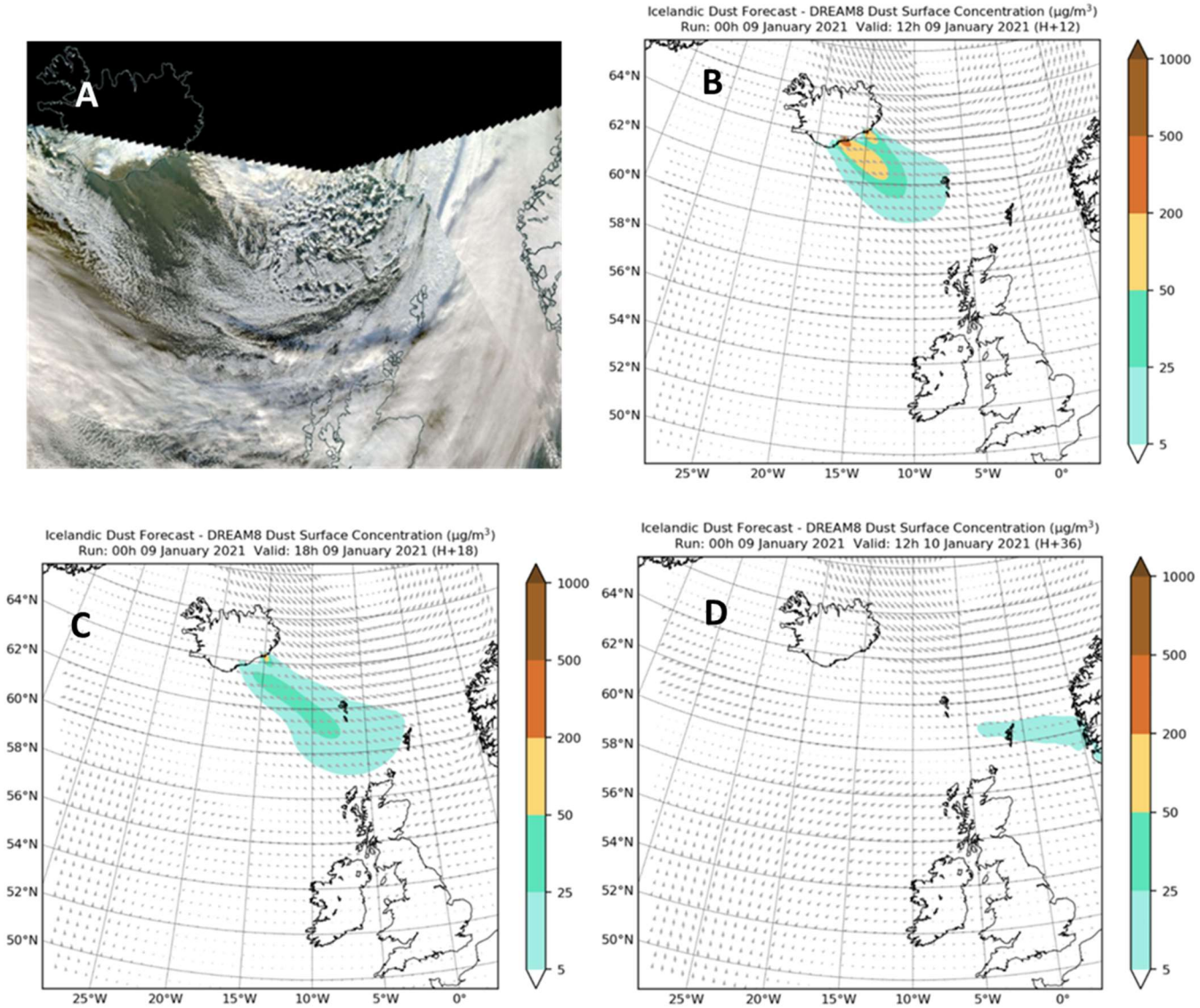

Figure 1 Dust storm in South Iceland on 9th January 2021. A. MODIS true colour image. Notice the dust plumes south of Iceland, B.-D. DREAM forecast showing the plume reaching Faroe Islands and Scandinavia.

Glacier related geological hazards in Caucasus Mountains, Georgia

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The surroundings of Mount Kazbek are infamous for frequent catastrophic debris flows jeopardizing strategically important infrastructure. These geodynamic phenomena occur more frequently in some valleys and are triggered often by activity of glaciers (collapse of a hanging glacier, a glacier surge or the GLOF event). Based on historically recorded debris flow ranges and geomorphological conditions, individual valleys can be categorized in terms of hazard. The type of impending geodynamic phenomenon as well as the trigger can be determined very accurately and the approximate maximum range can be estimated (i.e. the endangered area can be defined). This can be used in urban planning to prevent inappropriate urbanization of vulnerable areas. For example, the infamous case of the Larsi hydroelectric power plant, which was damaged by debris flow in 2014. HPP Larsi was built in the Dariali Gorge that was hit by debris flow several times in the past (Dostalík et al., 2020a). Risk categorization of individual valleys based on geological and geomorphological criteria is one of the goals of a new development project by the Czech Geological Survey in the Kazbegi area. We are also preparing a new direction and territories to continue our cooperation with NEA in Georgia.

We used Google Earth and Sentinel Hub tolls to investigate also other areas of the Georgian Caucasus, where similar geological risks could be expected. The Sentinel Hub application offers various satellite data, especially Sentinel 2 multispectral images, with high spatial resolution (up to 10 m per pixel) and high frequency of scanning (5–20 days). By analysis of this data we identified several recent slope deformations in the Upper Svaneti region. This dynamic landscape has huge economic potential not only for tourist attraction, but also as a source of hydropower. Georgia government plans to build up to 70 hydropower plants in Georgia, half of them in the Upper Svaneti. One of them is the 280 MW Nenskra HPP with its 135m high rockfill dam. It will be constructed in relatively dangerous conditions in the Nenskra river valley.

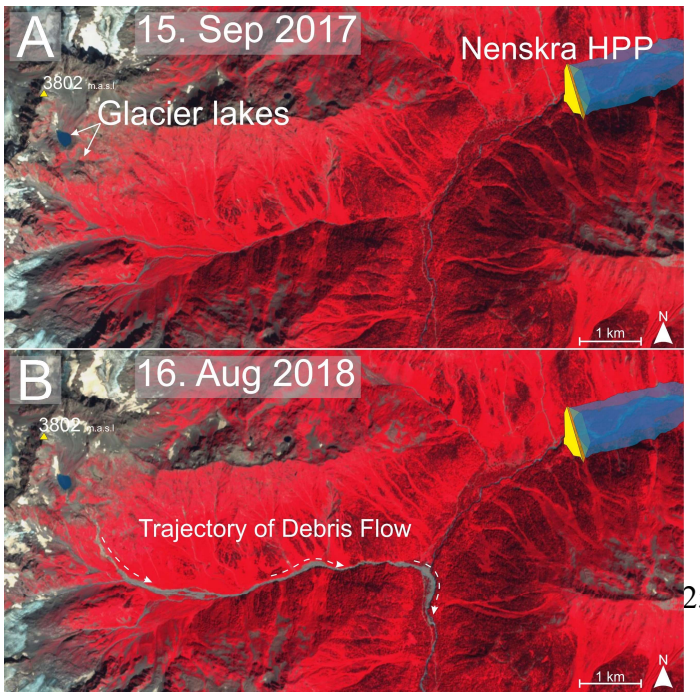
In the Kodori range, moraine dams of two glacial lakes breached and produced catastrophic GLOFs. This catastrophe occurred on July 5th, 2018 in the Okrila river valley, which is a right tributary of the Nenskra river. The active debris flow is entering from the left slope upstream just above of the maximum water level of Nenskra HPP reservoir. According to the report (SLR, 2017) the initial upstream slope instability was activated after the winter of 1986/1987. This slope instability is still superficially active and produces regular debris flows. The last activation was recorded in the period between 4–14 July, 2019.

Satellite images of slope deformations in the Mestia District are also presented: examples of two large rock avalanches and one landslide as a result of rock relaxation after deglaciation. Interesting geodynamic processes have been identified in the valley of the Tsaneri Glacier. Due to the retreat of the glacier, landslides on the sides of the valley were activated. And the series of proglacial and

Moraine-dammed lakes (up to 0.09 km^2) was also created in the valley of the Tsaneri Glacier.

One of the future topics of our further cooperation in Georgia could be inventory database of glacial lakes throughout the Georgian Caucasus. Size and numbers of moraine-dammed supraglacial and proglacial lake systems have increased dramatically during recent times as documented for example by the new proglacial lakes in the Tsaneri Glacier Valley. It would be very beneficial to use the debris flow hazard area assessment methodology in the area of Upper Svanetia. The key elements of the methodology comprise digital terrain model analysis and satellite and field mapping of geological hazards of all major river basins in the area (Dostalík et al., 2020b). In this way, potentially dangerous source areas of landslides within a certain radius around potentially endangered infrastructure can be identified and subsequently monitored. This is the most cost-effective way to pin-point areas with high risk of debris-flow, rock avalanche and/or landslide damage and to prevent any property damage or live loss by incorporating this data into urbanization planning.

Figure 1 Catastrophic GLOFs in the Okrila and Nenskra river valley. Comparison of Sentinel 2 satellite images.



Acknowledgements: This research contributes to the Project "Methodology for the area assessment in terms of debris flow hazard using innovative technology" funded by the Czech-UNDP Partnership for SDGs – Challenge Fund - the Czech Solution for SDGs Ref. UNDPIRH-202005-CFP04-CZECH INNOVATION CHALLENGE. The project is a part of the Strategic Research Plan of the Czech Geological Survey (DKRVO/ČGS 2018-2022) Topic: Geological risk research.

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Potential response of ancient permafrost microorganisms to possible warming processes

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Permafrost is one of the most vulnerable parts of our planet. Interest in the study of permafrost sediments and the paleobiota preserved in them is largely associated with an increase in permafrost temperature recorded as a result of long-term observations. The objectives of our study are to study the microbial communities of marine and lacustrine permafrost sediments, their taxonomic and genetic diversity, and to assess the potential activity of their intra- and extracellular enzymes in response to the permafrost thawing process. For this work four permafrost samples (Kolyma lowland, Northeastern Siberia) with different age and genesis were used: epicryogenic marine (borehole 14/99; 100,000-150,000 y.o.), lake-alluvial (borehole 2/94; 600,000-1,000,000 y.o.), freshwater lake-alluvial (borehole 5/94; 100,000-150,000 y.o.) sediments and the sincryogenic Yedoma Ice Complex deposits (borehole 1/19; ~30,000 y.o.).

To study the response of permafrost microorganisms to thawing processes and their viability level, the permafrost samples were spitted on two subsamples, where one stayed frozen but second one were pre-incubated under 4°C – 3 days and under 15°C – 4 days. Pre-incubation was needed to enable microorganisms to get out of the frozen state, to activate metabolic processes and, if necessary, to restore macromolecular damage accumulated over a long stay in natural cryopreservation conditions. Viable cell count on ½ TSA and R2A (3 to 4 weeks at 15°C) was in range from 2.4×10^4 to 1.5×10^7 CFU g^{-1} of sediment. The character of the cells number distribution calculated by the amount of DNA isolated from pre-incubated permafrost samples, retains the character of the distribution of that in frozen samples, despite the increase in values by 4-5 times. Most of the colonies grown on agar media were colored which support opinion that cell pigments may have a positive effect on survival, and increase resistance to environmental stresses. To study the genetic diversity of permafrost microbial communities, metagenomic sequencing of amplicons of the V4 hypervariable region of the 16S rRNA gene was done. The results showed that *Acidobacteria*, *Actinobacteria*, *Bacteroidetes*, *Firmicutes*, and *Proteobacteria* are the dominant phyla in all samples. Permafrost deposits from boreholes 1/19 and 5/94 are characterized by the greatest microbial diversity.

To reveal enzymatic activity by microorganisms the MicroResp™ method (carbon substrates), and Assay for extracellular enzyme activity (EEA) were used. Analysis of the microbial response to groups of carbon substrates showed that, regardless of the permafrost genesis a significant contribution is made by the reaction to a group of carboxylic acids (66 to 88%) and amino acids (7 to 15%). Analysis of EEA data showed that maximum contribution to the functional microbial profiles introduces a leucine aminopeptidase (35 to 56%), then sulfatase (19 to 28%) and phosphatase (13 to 26%). We assume that such a significant response

may reflect not the reaction of microorganisms to the introduced substrate, but indicate the ongoing processes of cell regeneration after leaving the frozen state.

Acknowledgements: This research was supported by the governmental task AAAA-A18-118013190182-3 and by the RFBR project № 19-04-01240.

Pan-Alpine glacier albedo variability from MODIS data

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Seasonal variability of glacier albedo is an important driver of surface melting. Albedo changes as a function of meteorology (snowfalls, temperature) and the presence of light-absorbing impurities (such as fine debris, cryoconite, dust, black carbon, and biogenic particles). In this study, we evaluate spatial-temporal patterns of glacier albedo on glaciers in the European Alps using data from the MODIS MOD10A1 product from 2000 to 2019. As MODIS data contain gaps and noise, we filter them using a fast Fourier transform (FFT) with varying kernel size. We then evaluate different metrics such as minimum yearly albedo, mean of the summer season and phenological metrics (start, duration and end of the ablation season). Our goal is to investigate how these metrics vary over time and to study their relationship with meteorological fields (from ERA5 reanalysis) and the glacier mass balance (from the World Glacier Monitoring Service database). We find that a larger kernel for the FFT produces the best results for all metrics, and that the filtered minimum albedo and mean summer albedo show the highest correlations with meteorological data and glacier mass balance, with up to 88% explained variance in glacier mass balance for selected glaciers with mass balance measurements. We also identify trends in glacier albedo over time, showing that 67% of the glaciers considered have significant (mostly negative) trends in minimum albedo over the period of investigation. Areas around the glacier equilibrium line altitude are more sensitive to changes, with values up to -0.05 $year^{-1}$.

The lichenized fungi genus *Tetramelas* Norman. from James Ross and Galindez Island, Antarctica

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Tetramelas is a genus that generally lives on mosses and has large brown, single or three-septate ascospores. According to Indexfungorum.org, the last update of which was made in 2018, there are 28 species of *Tetramelas* available in the world. 11 of these species present Antarctica. There is no single source that gives the *Tetramelas* genus in Antarctica. Ovstedal and Lewis Smith (2001) gave 9 of these species under the genus *Buellia* in their books. Elix (2019) gave the *Tetramelas filsonii* and *Tetramelas lokeensis* species in addition to these species in his study on the *Tetramelas* genus in Antarctica.

James Ross Island is a large island off the southeast side and near the northeastern extremity of the Antarctic Peninsula, from which it is separated by Prince Gustav Channel. Galindez Island is an 800 m long island located at 65°15' S, 64°15' W coordinates and on the Graham Land coast of the Antarctic Peninsula. Studies on lichenized fungi in Galindez Island are quite limited. In this study here we report three *Tetramelas* species from James Ross and Galindez Island. In this study, *Tetramelas anisomerus, Tetramelas darbishirei, Tetramelas granulosus* and *Tetramelas pulverulentus* (Antarctic Peninsula, Antarctica), was identified with anatomically, morphologically and/or molecularly.

Acknowledgements: We like to thank to the support by The Scientific and Technological Research Council of Turkey (TUBITAK) ARDEB 1001 [Project number: 118Z587] program.

Seasonal dynamics of snow ablation on selected glaciers in central Spitsbergen derived from Sentinel-2 satellite images

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The dynamics of seasonal snow ablation on 6 glaciers in central Spitsbergen (Dicksonland) were assessed by examining a set of Sentinel-2 satellite images covering the summer ablation season for the period 2016-2019. All glaciers lost 80% or more of their surface snow cover during the studied ablation seasons. This bolsters the recently observed trend of local glacier thinning, even in the high-altitude zones. Snow ablation dynamics are highly dependent on the glaciers altitudes, their position relative to the prevailing wind direction and the exposure to insolation. The accumulation areas of the studied glaciers were delimited based on the overlap of the minimal extent of snow-covered areas in the 4 consecutive studied summer seasons. The high temporal and spatial resolution of available images enabled a detailed description of the seasonal snow ablation dynamics. Moreover, an estimate of the average number of days with below threshold glacier snow cover was made. This study contributes to our understanding of recent processes and might further support the modelling of glacier melt and subsequent runoff.

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The potential of using ERA5 reanalysis data to force snow models in the Arctic

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Reliable and detailed data on snow depth and physical snow properties such as snow density and specific surface area (SSA) are limited in time and space in the Arctic. However, snow plays a major role as it covers the ground in the Arctic for most of the year altering, for example, energy and mass exchange, as well as influencing the growing season and the life of humans, flora and fauna (Callaghan et al. 2011; Liston et al. 2016).

We investigate the potential of using atmospheric data from ERA5 reanalysis (Hersbach et al. 2020) to drive snow models where in situ measurements are rare. Using atmospheric measurements from Villum Research Station in northeast Greenland, we investigate the performance of ERA5 and evaluate strengths and weaknesses of the reanalysis. We use both datasets, atmospheric ERA5 reanalysis and atmospheric *in situ* measurements, to force the alpine snow model Crocus (Vionnet et al. 2012) and evaluate the simulated snow depth evolution from 2014 to 2018 as well as a vertical snow density and specific surface area profile from spring 2018 with field

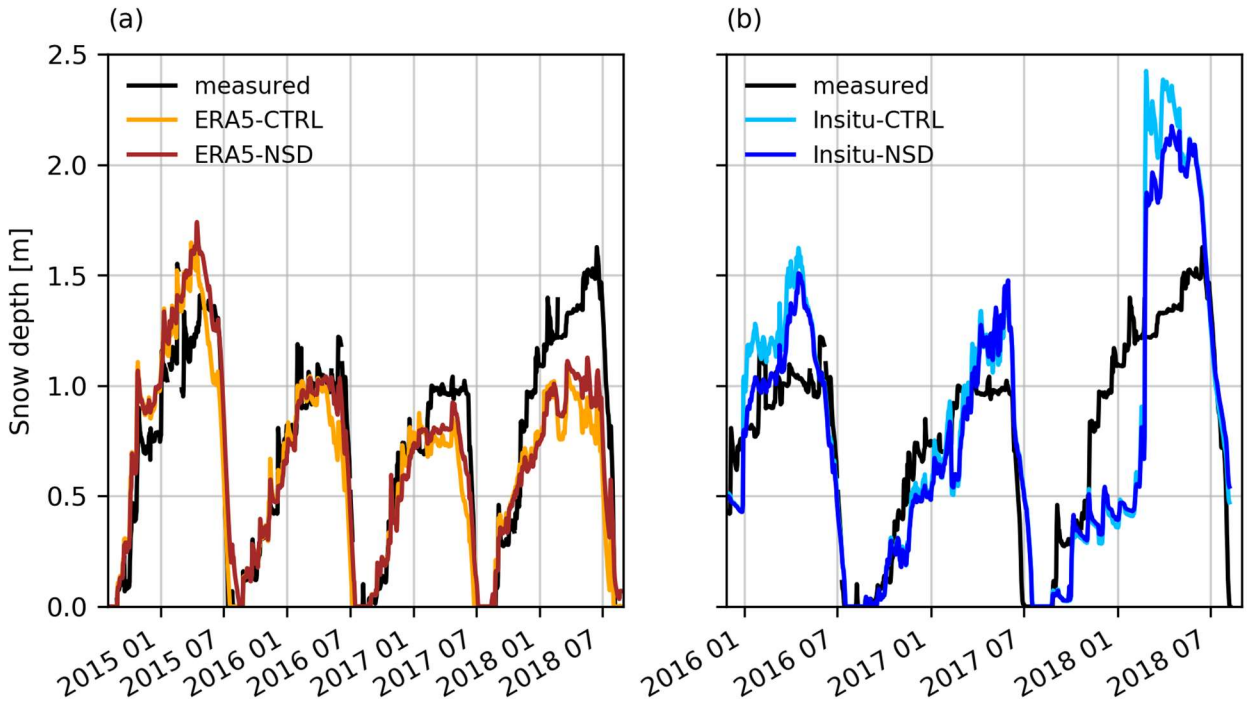

Figure 1 Comparison of measured and simulated snow depth. CTRL: Original snow density parametrisation of freshly fallen snow (Vionnet et al. 2012). NSD: Newly introduced snow density parametrisation of freshly fallen snow

measurements. We find an underestimation of newly fallen snow density in the Arctic using the original version of Crocus. To take differences between alpine and arctic snow into account, we adapt the parametrisation of the density of newly fallen snow to the cold conditions of the Arctic.

Overall, our results show a great potential of ERA5 data for snow modelling. Atmospheric variables needed to force the snow model agree well between reanalysis and measurements. However, due to the relative coarse resolution of ERA5, topography cannot be resolved in detail, causing weaknesses in precipitation, wind speed and wind direction. Nevertheless, unexpectedly for us, simulated snow depth forced with ERA5 agree better with snow depth measurements than simulations forced with in situ measurements. While the original version of Crocus provides reasonably good simulations of snow depth evolution, the simulated vertical profiles of density and SSA for both forcings exhibit biases compared to field measurements. Finally, we highlight that the adjustment of the new snow density parametrisation leads to further improvements of the simulated snow depth and the vertical density and SSA profiles but deviations still exist. We relate this to model limitations such as missing vertical water vapour transport as well as snow redistribution and compaction for strong wind events (Domine et al. 2019).

Acknowledgments: The PAMARCMiP campaign was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – project ID 268020496 – TRR 172, within the Transregional Collaboration Research Center 'ArctiC Amplification: Climate Relative Atmospheric and SurfaCe Processes, and Feedback Mechanisms (AC)3. We thank Marco Zanatta for the snow sampling during the campaign and Villum Research Station for general support. Special thanks go to Keld Mortensen and Andreas Massling for providing observational meteorological data. The authors acknowledge the cooperation and the productive scientific discussion with Christian Haas, Stefanie Arndt, Marco Zanatta and Olaf Eisen. CNRM/CEN is part of Labex OSUG@2020 (ANR-10-LABX-0056). M.D. has received funding from the European Research Council (ERC) under 20 the European Union's Horizon 2020 research and innovation programme (grant agreement No 949516, IVORI).

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Recent development of a windy glacier glacial marginal zone and maritime periglaciation (South Shetland Islands, the Antarctic)

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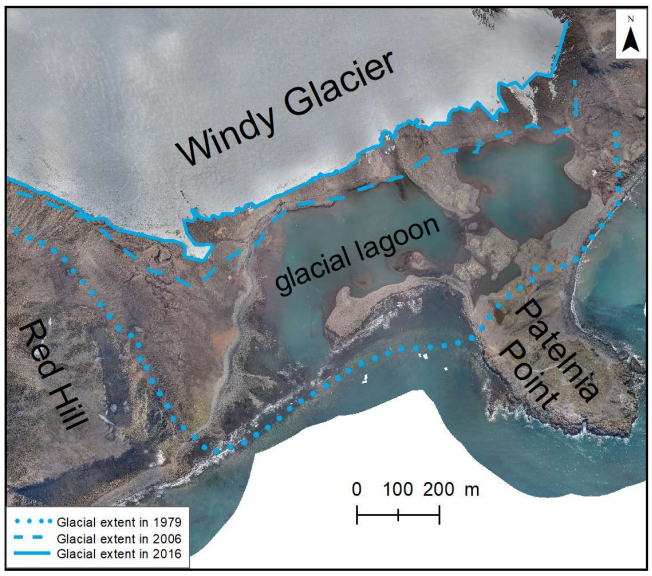
Contemporary retreat of glaciers is well visible in the West Antarctic region. The aim of this study is to identify, map and quantify terrestrial glacial and periglacial landforms developed in front of Windy Glacier (Warszawa Icefield, King George Island, South Shetlands), which recently turned from being tidewater to land-terminating, and on near-by Red Hill. The study is based on an orthophoto map and a DEM elaborated with a use of images obtained during a UAV BVLOS photogrammetric survey in 2016, Google Earth Pro images from 2006 and an orthophoto map from 1978/1979. The geomorphological map obtained includes 31 types of landforms and water bodies. Most area is occupied by glacial lagoon, fluvial and fluvioglacial landforms, not recognized surfaces and littoral landforms. Between 2006 and 2016 the glacier deposited a well-developed patch of fluted moraine with small drumlins. We recognize the glacial-periglacial transition zone between 41 and 47 m GPS height above which solifluction landforms and sorted patterned ground dominate. Advantages of UAV and BVLOS missions are highlighted and problems with vectorization of landforms are discussed. Distinction between flutes and small drumlins is shown on length-to-elongation and length-to-width diagrams and critical reference to previous geomorphological mappings on King George Island is presented.



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Application of remote sensing data to assess the condition of high mountain vegetation

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In the high mountain environment, the main stress factors for plants include too much light, restrictions on access to water, changing weather conditions, or trampling caused by increased tourist traffic. Too high intensity of the stress factor causes irreversible cell changes sometimes leading to the death of a plant cell. Studies in a non-invasive way can be carried out using remote sensing and fluorescence methods. Field studies conducted so far in the area of Kasprowy Wierch, Beskid and Czerwone Wierchy in Tatra National Park (Kycko et al., 2014, 2017, 2018, 2019) allowed to select significant spectral ranges statistically differentiating the state of the studied species caused by trampling and also differences between species. The methodology was developed using remote sensing vegetation indices and fluorescence parameters, which illustrate the state of the photosynthetic apparatus and the dynamics of photosynthetic processes. The applied statistical methods allowed to relate the conclusions and methodology developed on field data to the ceiling of remote sensing information acquisition - aerial and satellite. For this purpose, HySpex hyperspectral imaging acquired on September 15, 2019 and Sentinel-2 multispectral data acquired on the same day were used. The processing and analysis of the two satellite images allowed us to assess the vegetation status of alpine grasslands at a given time period on data with a resolution of 2 and 10 meters, respectively. The analysis of the condition of alpine grasslands was performed in buffers from the tourist trail. The following remote sensing indices describing: (a) general condition, (b) chlorophyll content and condition, (c) amount of light used in photosynthesis, (d) amount of nitrogen, (e) amount of dry matter in the plant, (f) water content in the vegetation, as well as important spectral ranges selected during field studies illustrating the content of chlorophyll in the plant and other photosynthetically active pigments (446-506, 511-519, 569573, 623-695, 706-707 nm), describing cell structures (857-996 nm) and the amount of water and building elements (1360-1364, 1388-1557, 18012500 nm). The study showed statistically significant differences in indicator values depending on the buffers used in distance from the trail. The condition of vegetation up to 5 meters from the trails was assessed as good, but the stress factor of trampling significantly decreases the condition of vegetation and the compactness of its cover. Analysis using publicly available Sentinel-2 data allows for continuous, multi-temporal monitoring of alpine grassland cover.

Acknowledgements: The authors would like to thank MGGP Aero for acquiring, pre-processing and sharing the HySpex data and Tatra National Park (TPN) for sharing vector data and consultation.

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Antarstick: Visual Guidance for Revising Automatically Extracted Snow Height from Time-lapse Photography

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The evolution and accumulation of snow cover are among the most important characteristics that influence Antarctica's climate and biotopes.

The changes in Antarctica are also substantially impacting global climate change. Therefore, detailed monitoring of snow evolution is key to understanding such changes. One way to conduct this monitoring is by installing trail cameras to a particular region and then processing the captured information. This affordable option has many advantages but also drawbacks: the fully automatic solution for the extraction of snow height from these images is not feasible. Therefore, it still requires a human in the loop, manually correcting the wrongly extracted information. In this presentation, we focus on the visual guidance of the user to such potentially wrong values extracted from poor quality images and support for their interactive correction. In this way, obtaining valuable information from the set of images is much faster and more intuitive. This was confirmed within the qualitative study performed with the experts conducting their research at the Mendel Polar Station in Antarctica.

Our proposed web-based tool, called Antarstick, is available at https://antarstick.herokuapp.com.

Although it is primarily tailored to snow height extraction from the images, we believe its central concept can be successfully applied to other domains.

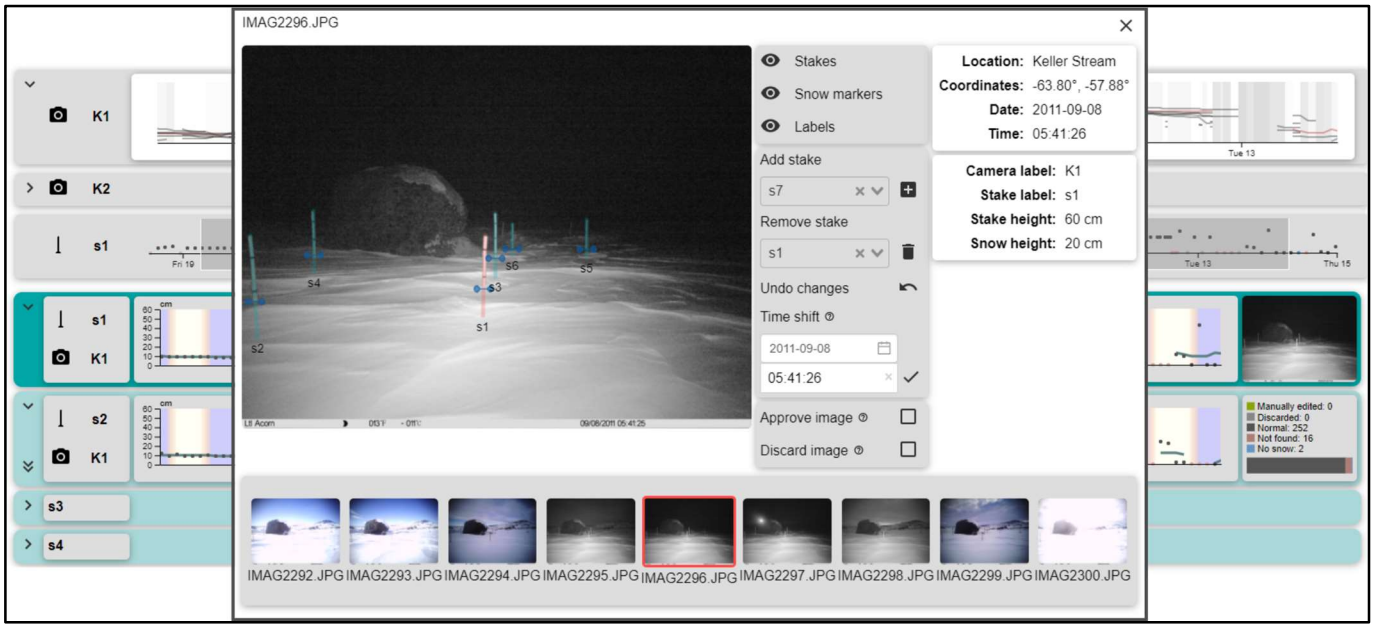

Figure 1 An example of snow-height image processing from the Monolith Lake area on James Ross Island

Changes in hydrological regime in High Arctic non-glaciated catchment in the period 1979-2019

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The behaviour of river catchments, in conjunction with glaciers, permafrost, and biotic elements, is undoubtedly one of the most important indicators of climate and environmental change in the Arctic. The study aims at presenting an updated water-balance study based on both meteorological and hydrological observations conducted at Hornsund (Southern Spitsbergen, Svalbard), since 1978 and 2014, respectively. The Fuglebekken catchment (1.27 km^2) is non-glaciated, and such catchments are becoming common in this area as a consequence of shrinking glaciers and bare ground exposure. The flow of water in Fuglebekken has a seasonal character. The stream is hydrologically active from late spring to early autumn, with varying discharges and remains frozen throughout the cold season. This study focuses on the changes in hydrological regime using available data and by development and testing of the multiple conceptual hydrological models. Observed *in-situ* data comprising air temperature, precipitation, PET, and flow from the six summer seasons (1st of July - 17th of September in years 2014-2019) were used as input for models' workflow. All models were calibrated using available observations from 2014-2019 and validated on the basis of old observations (1980-1981, 2001) and proxy data from time-lapse cameras. As the objective function, the Kling-Gupta efficiency (KGE) was implemented. Two different methods of calibration (fminsearch and SPS-L-SHADE-EIG) and the influence of initial conditions were tested. Based on calculated KGE values, six models with the best performance were selected at calibration and validation stages. These models were applied for reconstruction of past hydrological conditions in Fuglebekken river and analyses of changes in flow regime in the period 1979-2019.

Gelatinous zooplankton and water mass distribution in the Fram Strait (Arctic Ocean): a climate change perspective

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Gelatinous zooplankton, here as pelagic cnidarians and ctenophores, are key players in marine ecosystems. They efficiently prey upon different organisms ranging in size from protists to fish, simultaneously constituting a prey of choice for various vertebrate taxa. Aside from their multiple ecological roles, many authors appraise gelatinous zooplankton as a well-suited biotic indicator for studying the impact of the climate change on the World's Ocean. The Arctic Ocean is often recognized as the most susceptible to the global warming area of the world, presumably due to the increasing inflow of the warm Atlantic waters *via* Fram Strait through a process referred to as Atlantification. In order to disentangle the effects of water mass distribution on gelatinous zooplankton's diversity, and hence to forecast the future of the local planktonic community we conducted a thorough investigation bridging physical oceanography and marine biology.

Gelatinous zooplankton distribution data was obtained from vertically stratified zooplankton samples (down to 1000 m) collected in the Fram Strait along two latitudinal parallel transects (76°30'N and 79°N) of varying influence of Atlantic waters, what allowed us to better understand the effects of climate change on gelatinous zooplankton in the Arctic. Overall, we identified 17 gelatinous zooplankton taxa, of which *Aglantha digitale* was the most abundant. By contrasting gelatinous zooplankton distribution with meticulously collected environmental ecosystem characteristics, we were able to prove, that the more abundant gelatinous zooplankton community is associated with the Atlantic waters, with the maximum at the core of West Spitsbergen Current and that the extent of this current shapes vertical demography of gelatinous zooplankton. Our results indicate that the progression of Atlantification may promote expansion of boreal species to the Arctic, affect gelatinous zooplankton's reproductive success and consequently result in major biodiversity changes.

Can we accurately simulate near-surface air temperature and wind field in a complex Antarctic topography?

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Recent significant temperature changes in the northern Antarctic Peninsula are clearly reflected in the state of local glaciers and other components of the cryosphere. Interactions of atmospheric processes and the cryosphere could be investigated with numerical atmospheric models. A validation of the Weather Research and Forecasting (WRF) model was carried out on James Ross Island, northeastern Antarctic Peninsula. Model output at horizontal resolution of 700 m was compared with air temperature, wind speed and wind direction observations from a net of automatic weather stations on both glacier and ice-free sites covering an altitudinal range of 10–514 m a.s.l. The verification was done in a winter period in 2019 and a summer period in 2019/2020, to capture possible seasonal variability in model performance. The WRF model simulated air temperature well, with a bias less than 2 °C in 47–72 % of the winter period and 66–79 % of the summer period. However, the model failed to accurately reproduce low-level air temperature inversion occurring in two winter days. Further analysis of the model output showed a good quality of the wind speed

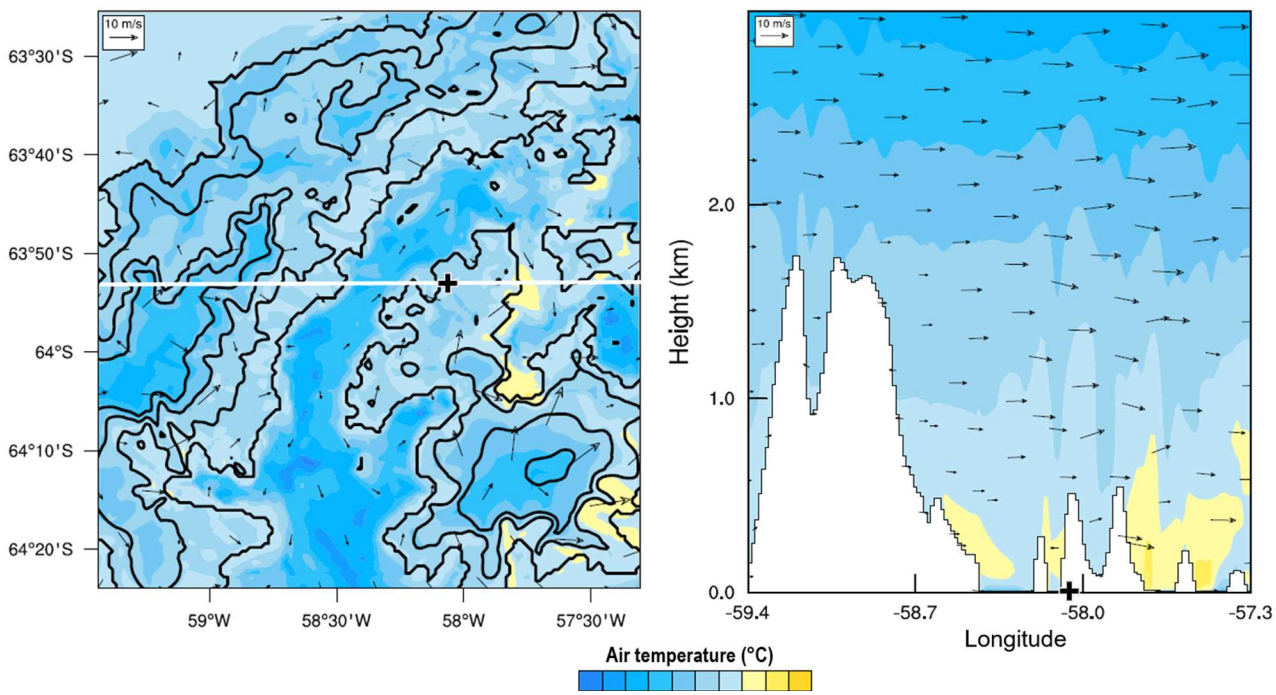

Figure 1 Surface air temperature and wind field (left) and vertical cross-section (right) simulated by the WRF model with the QNSE boundary layer scheme on 02 June 2019 at 00 UTC. Cross-section is led via Davies Dome automatic weather station location (black cross) and shown in the map by the white line. Contour lines at 500 m intervals are given in black.

and direction simulation. All significant high-wind-speed events were correctly simulated, but a slight positive bias was often present. Three boundary layer schemes in the WRF model (MYJ, MYNN, QNSE) were evaluated and the most suitable choices for different seasons and sites were identified. Finally, the impact of strength of synoptic-scale circulation on model accuracy was investigated and discussed.

Acknowledgements: This research was supported by the project of the Czech Science Foundation (GA20-20240S), the project CZ.02.1.01/0.0/0.0/16_013/0001708 funded by the Ministry of Education, Youth and Sports of the Czech Republic and the project of Masaryk University "MUNI/A/1570/2020. Access to the CERIT-SC computing and storage facilities provided by the CERIT-SC Center, under the programme "Projects of Large Research, Development, and Innovations Infrastructures" (CERIT Scientific Cloud LM2015085), is greatly appreciated.

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First evidence of POPs bioaccumulation in Antarctic sponges from the Ross Sea and the South Shetland Islands

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Antarctica represents one of the least contaminated places on Earth due to its geographical isolation and the smaller pressure from anthropogenic activities. Nevertheless, anthropogenic Persistent Organic Pollutants (POPs) may reach this region, mainly through the atmosphere. Their presence was first documented in the 1970s, being now found in every environmental compartment.

A few studies are available on the bioaccumulation of POPs in Antarctic benthos and none is focused on the Phylum Porifera. Sponges have a wide distribution, a high biomass and an important functional role within benthic communities worldwide. They are suspension-feeders and can filter thousands of litres of water per day, being thus able to potentially accumulate large amounts of POPs. The aim of this study was to identify and quantify the POPs found in different sponge species collected at Adèlie Cove and Tethys Bay (Ross Sea) and at Whalers Bay (Deception Island, South Shetland Islands). Sponge specimens were identified to species level. Species were identified through observation of spicules and skeletons taken from a small generic portion of wet and dry sponge respectively. The extraction of the analytes was carried out with matrix solid phase dispersion (MSPD) technique and the clean-up procedure was performed through separation on a multi-layer silica gel column. Residual analyses were performed with gas chromatography coupled with mass spectrometry (GC-MS) technique.

We identified 11 congeners of polychlorobiphenyls (PCBs), hexachlorobenzene (HCB) and the *o,p'*- and *p,p'*- isomers of dichlorodiphenyl-trichloroethane (DDT) and its metabolites (DDE and DDD) in 35 sponge specimens belonging to 17 species. The concentrations of ΣPCBs, ΣDDTs and HCB ranged between 1.61 and 3.15 ng/g dry weight (dw), 0.45 and 2.43 ng/g dw, and 0.18 - 0.55 ng/g dw, respectively. Percentage abundances of the pollutant classes were similar in the three areas and followed the pattern ΣPCB > ΣDDT > HCB. The contamination levels were similar to those found in other Antarctic organisms belonging to the Phyla Mollusca and Echinodermata. The three areas showed some significant differences in contamination levels, being Whalers Bay the most polluted site. The long-range atmospheric transport seemed to be the major driver of contamination in the three areas; however, the presence of scientific stations also appeared to have an influence on the bioaccumulation pattern.

The leaf and root cell wall functional activity of halophytes on the White Sea littoral zone

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The author analyzes the role of the cell wall in the adaptation of halophytes (*Triglochin maritima* L. and *Plantago maritima* L.) growing in the littoral of the White Sea to unfavorable environmental factors – high salinity and heavy metals pollution (Terebova et al., 2020).

Plant cell wall contains four types of ion-exchange groups. Polygalacturonic acid determines the negative charge of the cell wall. This acid is a component of pectins. Pectins as natural ion exchangers can create a mobile system of local changes in pH and charge, to regulate the enzymes activity. Phenolic OH groups are part of the components of the secondary cell wall - lignin and suberin. Most phenolic compounds have powerful antioxidant properties. They can also chelate heavy metal ions (Kulbat 2016).

This research was carried out for three years on the western coast of the White Sea in the village Rastnavolok (64°32′16″ N, 34°46′48″ E) (Republic of Karelia) in July 2017, and in the the village Keret (66°16′45″ N, 33°33′54″ E) (Loukhsky district, Republic of Karelia) in July 2016 and in July 2018.

Determination of the composition and number of ionogenic groups in the cell walls was carried out using the method of potentiometric titration (Meychik 2007). The total number of groups was evaluated by the total ion exchange capacity of the leaf and root cell wall. In the root of *P. maritima*, the total number of groups was 1300–2350 μM per g of the dry weight of the cell wall, and in the root of *T. maritima* – 1250–2770 μM per g of the dry weight of the cell wall.

In the leaves of *P. maritima*, the total number of groups was 1850–3700 μM per g of the dry weight of the cell wall, and in the leaves of *T. maritima* – 1885–3070 μM per g of the dry weight of the cell wall.

The high content of carboxyl groups of polygalacturonic acid in the cell wall of the leaf and root of both species is notable. In *Plantago maritima*, their content was up to 35% of the total number of ion-exchange groups, and in *Triglochin maritima*, their content was up to 70%. The increased content of phenolic hydroxyl groups in the leaf and root cell wall of *Plantago maritima* is 25% and 35%, respectively.

The high ion-exchange capacity of the leaf cell wall is also due to the high content of carboxyl groups of hydroxycinnamic acids (up to 54% of the total content in *Plantago maritima* and up to 66% in *Triglochin maritima*).

Thus, phenolic and pectin substances of the cell wall of the organs of halophytes *Triglochin maritima* and *Plantago maritima* are involved in the mechanisms of binding salts and metals; phenolic substances, providing tissue lignification, protect plants from the negative effect of salts in the littoral of the White Sea. By increasing the content of ion-exchange groups in the cell wall, the plant adapts not only to heavy metals pollution, but also to salinity.

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Table 1 Number of ion-exchange groups.

Type of groups	Number of groups, ΔS±50 µM per g of dry cell wall							
	Plantago maritima							
	Root					Leaf		
	1	**2**	**3**	**4**	**5**	**6,7**	**4**	**5**
Amino groups	300 (18%)	300 (23%)	500 (25%)	250 (11%)	250 (11%)	200 (11%)	250 (6%)	450 (13%)
COOH PGUA	600 (35%)	300 (23%)	400 (20%)	820 (36%)	810 (34%)	350 (19%)	650 (18%)	720 (20%)
COOH HCA	300 (18%)	200 (15%)	500 (25%)	400 (17%)	290 (12%)	1000 (54%)	1650 (45%)	1430 (40%)
OH-groups	500 (29%)	500 (38%)	600 (30%)	840 (36%)	1000 (43%)	300 (16%)	1150 (31%)	970 (27%)
Total number of groups	**1700**	**1300**	**2000**	**2310**	**2350**	**1850**	**3700**	**3570**

Type of groups	Number of groups, ΔS±50 µM per g of dry cell wall							
	Triglochin maritima							
	Root					Leaf		
	1	**2**	**3**	**4**	**5**	**6,7**	**4**	**5**
Amino groups	310 (12%)	350 (13%)	200 (8%)	350 (30%)	450 (36%)	250 (13%)	170 (5%)	450 (17%)
COOH PGUA	1900 (70%)	1400 (51%)	1800 (68%)	90 (8%)	100 (8%)	150 (8%)	1800 (59%)	1000 (37%)
COOH HCA	300 (11%)	620 (22%)	300 (11%)	450 (39%)	470 (38%)	1235 (66%)	850 (28%)	1100 (40%)
OH-groups	200 (7%)	400 (14%)	350 (13%)	270 (23%)	230 (18%)	250 (13%)	250 (8%)	160 (6%)
Total number of groups	**2710**	**2770**	**2650**	**1160**	**1250**	**1885**	**3070**	**2710**

1 - 3 - the sample plots in Rastnavolok (2017)
4 - 5 - the sample plots in Keret (2018)
6 - 7 - the sample plots in Keret (2016)

COOH PGUA - carboxyl groups of ά-D-polygalacturonic acid
COOH HCA - carboxyl groups of hydroxycinnamic acids

Glacial algae in the European Alps: ecophysiology and phylogeny of two species causing blooms on ice

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Glacial algae are extremophilic microorganisms thriving in mountainous and polar regions. The two most common species are streptophytic green algae, filamentous *Ancylonema nordenskiöldii* and unicellular *Mesotaenium berggrenii*. During summer season, they cause macroscopically visible greyish or pinkish blooms on bare ice surfaces, which significantly reduce surface albedo of glaciers and glacier ice sheets, thus accelerating the rate of melting and rising of sea level.

The aim of this study was to explore differences and similarities between these two algae, sampled from European Alps. Since laboratory strains are not available to our knowledge, populations in the field in which one or the other alga dominated were investigated. We inferred phylogeny using 18S rDNA and *rbc*L markers. Furthermore, photosynthetic performance (using PAM), the profile of the fatty acids (GC-MS) and phenolic pigments (HPLC) were compared.

In our phylogenetic analysis of conjugating algae (Zygnematophyceae), the two glacial algae formed one independent clade, together with environmental sequences from an Alaskan glacier. Their closest non-cryophilic relative was *Mesotaenium* sp. sampled from an aero-terrestrial habitat in Germany. Fluorometric measurements showed that the photosystems II of the two studied species were adapted to high light, reflecting light conditions in their natural environment. Nevertheless, *M. berggrenii* got saturated by light sooner and at lower light levels performed better when compared to *A. nordenskiöldii*. Both algae accumulated high level of polyunsaturated fatty acids. Increased desaturation of fatty acids is an advantageous strategy at low temperatures to maintain membrane fluidity. Abundant, water-soluble polyphenolic pigments were present in vacuoles, which work as a sun-screen to protect the chloroplast from excessive light levels and protect the nucleus from ultraviolet radiation.

Acknowledgements: This research was supported by the Czech Science Foundation (GACR) project 18-02634S granted to L.N. and L.P. and by the Austrian Science Fund (FWF) P34073 granted to D.R.

Changes in the Himalayan Cryosphere

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Snowfall variability is linked to the changes in the atmosphere; it was observed that the minimum and maximum temperature shows increasing trends over the Himalayan region, which is consistent with the decrease in the snowfall. There is a decrease in snowfall, about 24.16% ±9.86% per degree increase in minimum temperature (Mishra and Rafiq 2017). These changes in the atmospheric conditions have impacted the glaciers in the Himalayan region and have changed the snowfall patterns as well. Jammu and Kashmir`s largest glacier (Kolahoi) has shrunk from 35 km^2 to 9.88 km^2 from 1857 to 2015.

There are also reports of extreme snowfall events over the Himalayan region which results in avalanches. In 2017 Kashmir valley witnessed multiple heavy snowfall spells in January 2017 that triggered an avalanche, killing 24 people. In the winter season of 2019-2020, heavy snowfall events occurred for months breaking previous records of the highest snowfall (Rafiq and Mishra 2018). Which triggered avalanches and several such avalanches occurred on 4th December 2019. A low-pressure system developed around the Kashmir valley from 6 to 8 November 2019, and Western Disturbances (WDs) were also active during this time. Enough moisture was supplied to this system to result in the formation of dense clouds over the Kashmir Himalayan region, and due to the continuous supply of moisture, this system was active for a long period in January 2020. In this case, the moisture originated over the Mediterranean Sea and the Atlantic Ocean as the WDs migrated eastwards; these wave disturbances also pick up moisture from Caspian and the Arabian Sea. Western disturbances bought a convective system over the Himalayan region of the Kashmir valley, resulting in very heavy snowfall for almost 24hrs. Heavy snowfall in the early winter season destroyed horticulture plantations also.

These extreme snowfall events also pose a high risk of flooding. In the year 2013 Uttarakhand witnessed such a type of disaster in the form of Glacier Lake Outburst Flood (GLOF). Due to heavy rainfall and snowmelt, a runoff of about 22.7 m^3 was produced during 16-17, June 2013 over Chorabari Lake. The lake got filled to its maximum capacity (3822.7 m^3) due to excess discharge and produced a peak discharge of about 1699 m^3/s during an intense water flow episode that lasted for 10-15 minutes on 17th June 2013 killing more than sixty thousand people and destroying properties worth millions. Recent studies have pointed out an increase in temperature and precipitation over the Himalayan region (Rafiq et al., 2012, 2016, 2018). Changing characteristics of snowfall in the context of anthropogenic warming presents major challenges to the socio-economic aspects of the Himalayan region. Planner and decision-makers are recommended to pay attention to these facts and take appropriate adaptation and mitigation measures against such disasters.

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The importance of joining climatic and biotic factors in modelling present and future Antarctic vegetation distribution

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Antarctica is one of the harshest environments for terrestrial vegetation and is thought to be one of the most vulnerable regions to climate change. Antarctic vegetation is mostly composed by lichens, bryophytes and plants (macro components), which are restricted to the ice-free areas along Maritime and Continental Antarctica. Studies have shown changes in these macro components in response to recent climate shifts, like increased temperature. Adding these changes to the fact that Antarctica vegetation is protected under the Antarctic Treaty, it's fundamental to develop standard, non-invasive and easy-to-use tools to diagnose, monitor and predict climate change effects, and the effectiveness of the actions taken for its protection. Developing such indicators for Antarctica has several challenges. The majority of studies regarding climate change effects on Antarctic vegetation tends to focus on the effects of climatic variables on single vegetation components. However, these three components interact with each other, and have different competitiveness strengths. If environmental conditions are suitable for plants, bryophytes and lichens, plants are expected to outgrow lichens and bryophytes, and bryophytes to outgrow lichens. Therefore, better predictions of present and future vegetation patterns should also integrate biotic interactions. The lack of long-term observational records and high spatial resolution environmental data also add extra difficulties to the development of tools to diagnose, monitor and predict climate change effects, highlighting the need to search for innovative approaches capable of overcoming these limitations.

Our objective was to model vegetation abundance under present and future conditions integrating climate direct and indirect effects, via biotic interactions. We used an image-based analysis, adapted from arid ecosystems, to sample along a spatial gradient of climate. The abundance of lichens, bryophytes and plants was determined in 150 photos from 30 sampling sites, distributed in the South Shetland Islands Archipelago. For that, we retrieved topographic and climatic data, at the highest resolution available (8m and 1km, respectively), and distance to natural pollution sources (mammal and penguin colonies). We hypothesized that shifts in the abundance of vegetation components are related to shifts in climatic conditions along altitudinal and distance to the coast spatial gradients, and that incorporating

biotic interactions between vegetation components would allow for better predictions.

Overall, the vegetation was dominated by lichens, followed by bryophytes and plants. Altitude, mean diurnal temperature range and annual temperature evenness (isothermality) were the most important environmental drivers. As we hypothesized, these drivers were related to vegetation patterns directly, and, indirectly, via biotic interaction. The models were successfully used to predict present and future (2100 based on SSP5-8.5 PPC scenario) abundance of lichens, bryophytes and plants for the archipelago region.

These results have a big potential for the future. They show that it is possible to model present and future abundance patterns of the main vegetation components using a simple, non-invasive image-based methodology and the currently available climate data, and that biotic interactions should be considered. Future works should focus on enlarging the spatial climatic gradients and on upscaling results to wider regions using very high to high-resolution UAV and satellite imagery.

Acknowledgements: LICHEN EARLY METER 1 and 2, funded by PROPOLAR/FCT. We are grateful to the Comité Polar Español, the Czech Antarctic Programme and the Bulgarian Antarctic Institute for their help and hospitality.

Comparison of multiple radiometric dating methods for establishing timing of deglaciation

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The Polar Regions are considered the key components of the Earth climate system for its influence and feedbacks have played a paramount role in the past and current environmental changes. The ongoing climatic changes are also most pronounced in the high latitudes due to the amplifying positive feedback processes, which could further accentuate the changes in lower latitudes and on global level. At the peak of the Last Ice Age (~20 ka BP, i.e. thousand years before present), extensive continental ice sheets covered both hemispheres and stored the amount of water that caused sea level lowering of at least 130 metres. The pattern and chronology of the past ice retreat is currently subject of concentrated research for representing an analogue of the ongoing climatic changes and the observed negative mass balance of ice sheets and glaciers in the Polar Regions (Slater et al. 2021). These changes may bear important future implications in the form of contribution to sea-level rise or disruption of global atmospheric and oceanic circulation. Given these concerns, understanding the deglaciation since the Ice Ages until present will improve predictions of the long-term behaviour of the ice sheets and glaciers in the warming world.

Here, the timing and pattern of ice retreat in the James Ross Archipelago, on the eastern side of the Antarctic Peninsula, is discussed. This region is fairly well covered by ages constraining the deglaciation, and having been inferred by various dating methods they provide an opportunity to assess the suitability of individual geochronological techniques in this high-latitude setting. Until now, most absolute radiometric dating methods employed the terrestrial *in-situ* radionuclides, namely ^{10}Be and ^{26}Al, from glacially eroded bedrock or glacially transported erratic boulders. Lacustrine and marine sediments were also used to date the ice retreat, by methods of radiocarbon (^{14}C) and optically stimulated luminescence dating (OSL) dating, with varying results based on the type of material measured and the quality of the natural archive. For example, ^{14}C dating of bulk sediment samples or even aqueous macrofossils seems to yield ages too high due to contamination by old, recycled carbon, and hardwater or reservoir effects. In this case, use terrestrial macrofossils is preferred to obviate these problems. The potential of other methods, such as short-lived radioisotope dating (^{137}Cs and ^{210}Pb), varve counting or relative Schmidt hammer dating, has not yet been fully tapped. Finally, the novel advances of TCN dating, including ^{36}Cl measurements in basaltic rocks, will provide possibilities to date locally-sourced erratics (as opposed to granites originating from the Antarctic Peninsula batholith) and increase the spatial coverage. Recently, new preliminary cosmogenic nuclide ages from hyaloclastite boulders near Monolith Lake provide an additional clue on the age of ice retreat in this part of James Ross Island.

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Variability and changes in ice conditions in the Western Arctic region in the context of the Arctic Amplification

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One of the important features of the current global climate system is Arctic Amplification. The main point of this process is that the changes in the surface temperature in the Arctic region happen faster than changes in the global surface temperature (Latonin et al., 2020).

The mechanism defining the Arctic Amplification connects with a number of the various climate feedbacks. Nowadays, when the sea ice extent in the Arctic is sharply decreasing, the surface albedo feedback is mainly important. Climate warming causes strengthened melting of sea ice leading to exposure of new areas of open water with much lower albedo resulting in the increase of absorption of solar shortwave radiation. It, in turn, causes further sea ice melting. These processes form the positive feedback loop which amplifies warming (Pithan et al., 2014).

The decline in the sea ice extent of nearly 12% per decade for September and about 3% per decade for March in the Arctic region is observed according to systematic data collected from passive microwave data since 1979. Moreover, the most pronounced winter reduction inside the Arctic Ocean is observed in the Svalbard and Barents Sea area (Hanssen-Bauer et al., 2019).

The analysis of the features of the interannual and seasonal variability of the sea ice extent was carried out on the basis of calculated information obtained in the World Sea Ice Data Center of the Arctic and Antarctic Research Institute (Smolanitsky, 2021). To analyze the sea ice thicknesses, the data obtained with the ESA CryoSat-2 Synthetic Aperture Radar Altimeter (SIRAL) were used. The data were processed using an algorithm developed at the Institute of Polar and Marine Research. Alfred Wegener (Hendricks et al., 2019). We also used data from high-latitude air expeditions "Sever", conducted from the 20s to the 80s of the last century (Webster et al, 2004).

In the Kara Sea as well as in the water of the north part of the Barents Sea and in the central part of the Arctic Basin since 2006, the amplitudes of interannual fluctuations in ice extent, in the winter season, significantly increased. It, in turn, could be said about large-scale changes in the ice regime and atmospheric or oceanic circulation in the Western Arctic region (Shapkin et al., 2021).

A comparative analysis of current satellite data and data from the «Sever» expeditions on ice thickness was carried out. According to the results of which we can confidently speak of a decrease in the thickness of the ice cover in the Western Arctic region.

The 5–6-year cycles of fluctuations in ice extent were identified which, in our opinion, are caused by short-term changes in the structure North Atlantic Current. The factors associated with the interaction in the "ocean – sea ice – atmosphere" system are largely responsible for oscillations with periods of 20 years or less. For the ice extent and ice thickness in the seas of the Western Arctic (the

Greenland Sea, Barents and Kara sea), fluctuations with periods of about 60 and 5-7 years are statistically significant (Shapkin et al., 2021).

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Migration of wild reindeer on the territory of Eastern Taimyr (Russia): dynamics of features and factors of influence

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S Seasonal migrations and herd instinct are traditionally recognized as wild reindeer (*Rangifer tarandus* L.) species-specific ecological structure behavioral signs. These animals are forced to overcome great territories during the migrations. Behaviour peculiarities and space and temporal characteristics are considered as the result of the selection process, which has chosen among the sets of strategies, as the only evolutionarily stable one, determining the reproduction and biological survival of wild reindeer as a species in a changing world. Natural processes in the Taimyr population wild reindeer are currently occurring against the background of an increase in the influence of negative factors due to the escalation of the industrial development of the Arctic. That is why the need to identify the ethological and ecological features of these animals during migration time completely arose. Our material presents the results of applying the classical methods of nature observations: Traditional Knowledge (TK), Earth Observations (EO) and initial phase of Remote Sensing (RS), the theory of optimal control and differential games to the wild reindeer study of the migration patterns in migration is overcoming water barriers (initial stage), including major rivers. Statistical analysis of some geographical point reaching by the migration herds results gave a smooth long-term average data, excluding some years of the strong temperature deviations. The agreed quantitative estimates and reasonably chosen parameters are practically the same in determining the specificity of spatial distribution, where chrono-chorological differentiation is

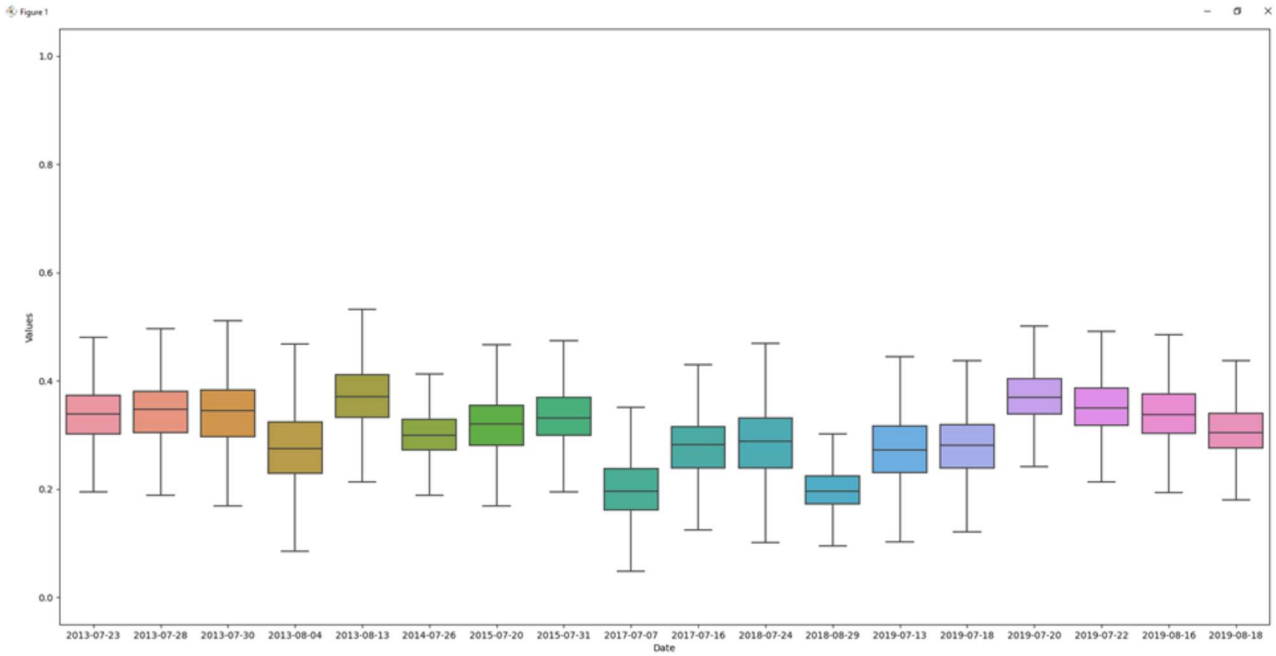

Fig 1 Distribution of the NDVI index by year.

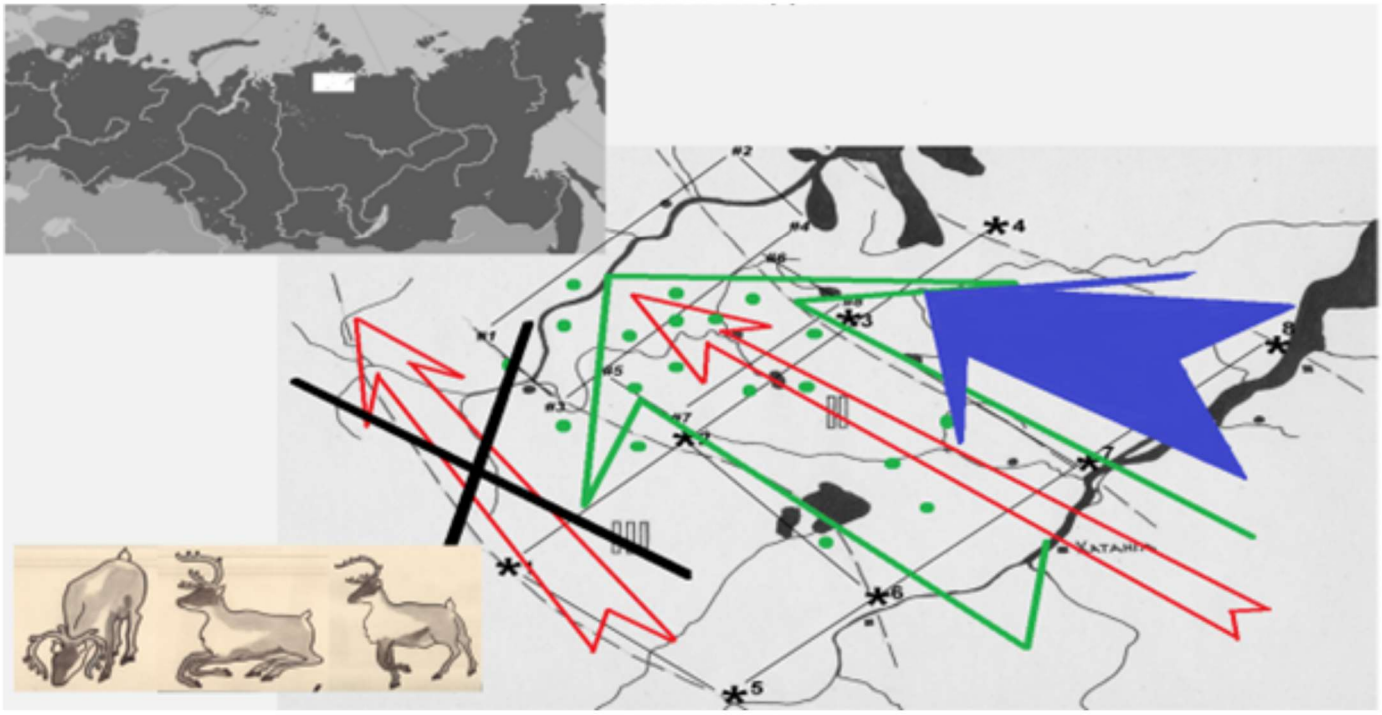

Fig 2 The nature of the reindeer spatial distribution of the „arms“ in different years: blue – intensive; red – middle; green – rare.

clearly traced. The migratory course of reindeer in Eastern Taimyr is carried out not by a continuous stream, but by conventionally distinguished "arms" — western, central, eastern, and is carried out in certain areas (reindeer trails). This migration strategy prevents over pasturing. We suppose the dynamics of wild reindeer pastures monitoring with some RS data. The pulsating timing of the beginning and end of the migratory course, the presence or absence of a reverse course are determined by climatic factors. The timing and intensity of the course, the size of the grouping of each "arm" and inside it, as well as at the sections of the crossing over the Werchnyaya Taimyr River, the largest waterway on the migration route, are different, in different years and even in one season.

Based on these animals' ethological and ecological features and behavior forms, we consider a population as a controlled dynamic system, which also presents two classes of individuals: the leader and the rest of the herd, for which their models, describing the trajectories of their movement, are constructed. Approbation of the obtained results, which can be used in the formation of a common “platform” for the adaptive behavior models systematic construction and as a reserve for the cognitive evolution models fundamental development, is numerically carried out using a model example with observational data on the Werchnyaya Taimyra River (Russia, Taimyr Peninsula)..

A remote view: how Google Earth Engine can provide an insight into Antarctica's dynamic ice-free areas

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Antarctica's ice-free regions cover 0.32% of its landmass but are disproportionally important sediment sources. These ice-free regions contain vast quantities of poorly-consolidated sediments and are characterised by paraglacial and periglacial processes that make this sediment available for transport. These ice-free proglacial landscapes are projected to increase in extent in coming decades as a consequence of rising air temperatures and the resultant loss of glacier mass. However, there has been relatively little research conducted into the landcover and dynamics of Antarctic proglacial environments, particularly outside of the Dry Valleys of McMurdo Sound. This lack of data is largely a consequence of the difficulties associated with accessing the Antarctic continent and the computational challenges of remote-sensing on such a large spatial scale. With the use of Google Earth Engine's cloud-computing platform, this study aims to quantify changes to Antarctica's major ice-free areas and two 30m resolution land classifications of the James Ross Island Group will be presented. The first of these classifications was produced for February 2000 using the Landsat-7 Enhanced Thematic Mapper Plus (ETM+) sensor. The second was produced for February 2016-17 using the Landsat-8 Operational Land Imager (OLI) sensor and has shown an agreement of 75.4% when compared to a classification of an ESA Sentinel-2 mosaic from February 2016. Change detection has been conducted at a 2km resolution and has identified potential increases in the size of rivers on James Ross Island and the extent of supraglacial water on Snow Hill Island**.** This presentation will discuss the techniques used to classify the James Ross Island Group, its merits, challenges and pitfalls and the importance of analysing changes to Antarctica's ice-free regions in the context of a warming climate.

Acknowledgements: This project is funded by a Panorama NERC DTP PhD studentship (start date: October 2020). Thanks are given to my supervisors: Jonathan Carrivick, Duncan Quincey (University of Leeds) and Daniel Nývlt (Masaryk University) and also to Michael Grimes and Elizabeth Mroz of the University of Leeds for their technical support and useful discussions.

Natural versus anthropogenic influence on trace elemental concentrations in precipitation at Dokriani Glacier, Central Himalaya, India

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Atmospheric pollutants transport and deposition to the Himalayas could affect the climate, cryosphere, and monsoon patterns and impose an adverse impact on the Himalayan ecosystem. The data on trace elements (TEs) concentrations and dynamics over the high altitude Himalayan region is scarce and have received less attention. Therefore, in the present work, we investigated the TEs concentration and depositional pattern at Dokriani glacier, the central Himalayas to understand its levels, dynamics, and potential effects. A total of 39 samples were collected from two snow pit stratigraphies, deposited during non-monsoon period and monsoonal precipitation between 4530 to 4630 m.a.s.l altitudes in the year 2017. The results of analysed trace metals (Al, Cr, Mn, Fe, Sr, Co, Ni, Cu, Zn, Cd, As and Pb), showed high enrichment values for Zn, Cr, Co, Ni and Mn compared to other parts of the Himalayan region, suggesting the influence of anthropogenic emissions (e.g., fossil fuel, metal production, and industrial processes) from urbanized areas of South Asia. Our results also revealed the possible health effects related to the enrichment of Zn and Cd, which may be responsible for the skin-related diseases in the Uttarakhand region. We attribute increasing anthropogenic activities in the environment could have a significant impact on the ecosystem health in the central Himalayan region. This study provides the baseline information on TEs concentration and sources in the Himalayas, which needs wide dissemination to scientific as well as policymakers. Therefore, systematic observations, management, and preparing action plan to overcome the health effects from TEs pollution are urgently needed over the remote, pristine Himalayan region.

Satellite broadband albedo validation on the ice sheets through *in-situ* validation

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The albedo (also called bi-hemispherical reflectance, that is the amount of solar radiation that can be reflected by a surface) has a relevant role in the energy budget above all at the Poles, where it is generally high owing to the presence of snow and ice. Variations from these high values could have profound effect on the Surface Mass Balance, leading to severe consequences, considering that the Antarctic and Greenland ice-sheets have a key role on sea level control. However, a satellite-based high-resolution albedo product which can be applied on the ice-sheets during the summer seasons is lacking. In this research, we calculate satellite-based broadband albedo from Landsat 8 OLI and validate it against broadband albedo measurements from different field data sources, located on the Antarctic and Greenland ice sheets. In detail, the compared in-situ datasets include 7 Automatic Weather Stations owned by the *Institute for Marine and Atmospheric Research Utrecht* (IMAU) and 3 stations from the *World Radiation Monitoring Center – Baseline Surface Radiation Network* (WRMC-BSRN), i.e., Concordia, Neumayer and Syowa stations as regards the Antarctic continent and 4 AWSs of the *Program for Monitoring of the Greenland Ice-Sheet* (PROMICE) for Greenland. The model to derive the albedo from raw satellite data includes: a radiometric calibration with solar zenith angle correction, atmospheric and topographic corrections and conversion from narrow-band to broadband albedo. At each step different options were taken into account, in order to provide the best combination of corrections. Results, after being cleaned from anomalous data, show a good agreement with in-situ albedo measurements, above all if compared to previous studies which used mainly lower spatial resolution satellite imagery. In detail, based on a 75-scene comparison, a correlation coefficient of 99.5% was found, and a mean absolute error, standard deviation and a root-mean-square error respectively equal to 0.021, 0.015 and 0.026 were obtained. Considering the structure of the model, it could be applied to data from previous sensors of the Landsat family and help construct a record to analyze albedo variations in the Polar Regions.

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The possibility of using astrogeophysical parameters as predictors for statistical equations for interannual variability of sea ice extent in the Greenland Sea

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The study of the mechanisms of interannual variability of the ice extent in the North European basin as one of the climate change indicators becomes more relevant with each year. Climatic changes are poorly reproduced by hydrodynamic models at the moment. So, a description of the long-term variability ice extent is particularly relevant. One of the ways to solve this is the development of statistical models. The monograph of Frolov et al. (2007) was the basis for inclusion in our study of Astrogeophysical factors as predictors. It describes the Influence of are «Pole Tide» on a ocean level and ice extent Arctic Seas, the nineteen-year-old tide and the rate of rotation Earth. Many years of oscillations of the Astrogeophysical characteristics were analyzed for the period 1900-2020 (IER). The gravitational forces of the moon and the sun and the oscillation of the speed of the Earth's rotation are affected on the ocean level and water circulation. A spectral analysis was carried out. A cycle of 6.3 years was isolated to change the coordinates of the Pole X, Y. It is formed by the imposition of forced twelve-month fluctuations of the axis of rotation Earth and the free fourteen-month-old oscillation Chandlers. The main cyclicity is noted in the nutation Earths in the period of 20 years. This is close to the period of decline waves. Among the significant periods, cyclicity was allocated at 13 and 11 years for the geomagnetic activity index. It is assumed that these parameters are thermal influence (change in solar radiation due to oscillations of solar activity and due to changes between the Earth and the Sun). As well as through atmospheric circulation. Perennial oscillations of the Ice extent Greenland Sea for the period 1929-2020 (AARI) were analyzed. The presence of negative linear trends was confirmed. The cycle of the Greenland Sea ice extent has been distinguished with a period of 22, 17, 13, 11 and 6 years. The coordination of the cycles of Ice extent and Astroogeophysical characteristics were confirmed. The equations used these climatic indexes: AO, NAO, AMO, PNA, AD (NOAA). Statistical equations of the inter-annual variability of the Greenland Sea ice extent are designed with the help of Multiple regression apparatus for winter and summer periods. The parameters of the quality estimates of equations are given. The contribution of the Astrogeophysical characteristics to the general dispersion of the row was more than 50%. The information content of Astrogeophysical factors was investigated. The contribution of each predictor to the overall dispersion of variability Ice extent was estimated. The suggestion was put forward: use of the orientation parameters of the Earth and solar activity as the main predictors in the construction of the descriptive equations of the inter-annual variability of the Greenland Sea ice extent. The obtained statistical equations can serve as a base for the development of methods of the long-term forecast of the ice extent Greenland Sea (in perspective).

Acknowledgements: This work was carried out as a part of the AARI planned scientific topic under the project 5.1 SRTW Roshydromet.

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Modern classification of glacial lakes systems on Svalbard

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Recent studies dealing with glacial lakes have shown not only a rapid and worldwide increase in number and volume of lakes but also emphasized the pronounced impact on polar and high mountains landscape associated with lakes evolution and seasonal changes (Shugar et al. 2020). Good example of events which also increase in numbers are glacial lakes outburst floods (GLOFs), which became one of the most dangerous geohazards in several glaciated regions of the world (Petrov 2017, Veh et al. 2019, Emmer 2020). Main aim of studies was to show potential impact of those rapid changes on environment and stability of described lakes based on their classification.

In my study I have focused on the state of glacial lakes in Svalbard – key area of environmental and climate change research sites in the European Arctic. Using archival maps, collections of aerial imagery from Norwegian Polar Institute and available satellite image I have created the first inventory of modern glacial lakes in Svalbard and classified them using Emmer et al.'s (2016) and Yao et al.'s (2018) classifications. Here I present the results of the classification and discuss the difference in spatial distribution of lakes across the Archipelago. I have distinguished regions characterized by high seasonal variability of glacial lake levels, which are prone to GLOF events. Finally, I have investigated the links between bedrock geology and stability of glacial lake basins. From 566 proglacial lakes I have differentiated four main groups of basins formed in: *unconsolidated material* – 229 (40%), *metamorphic rocks* – 147 (26%), *sedimentary rocks* – 99 (17%) and 21 (4%) *igneous rocks*. There is also one semi-group: *metamorphic, sedimentary* – 70 (12%). In the future I plan to use that information to test if bedrock geology determines the susceptibility of glacial lakes to GLOFs.

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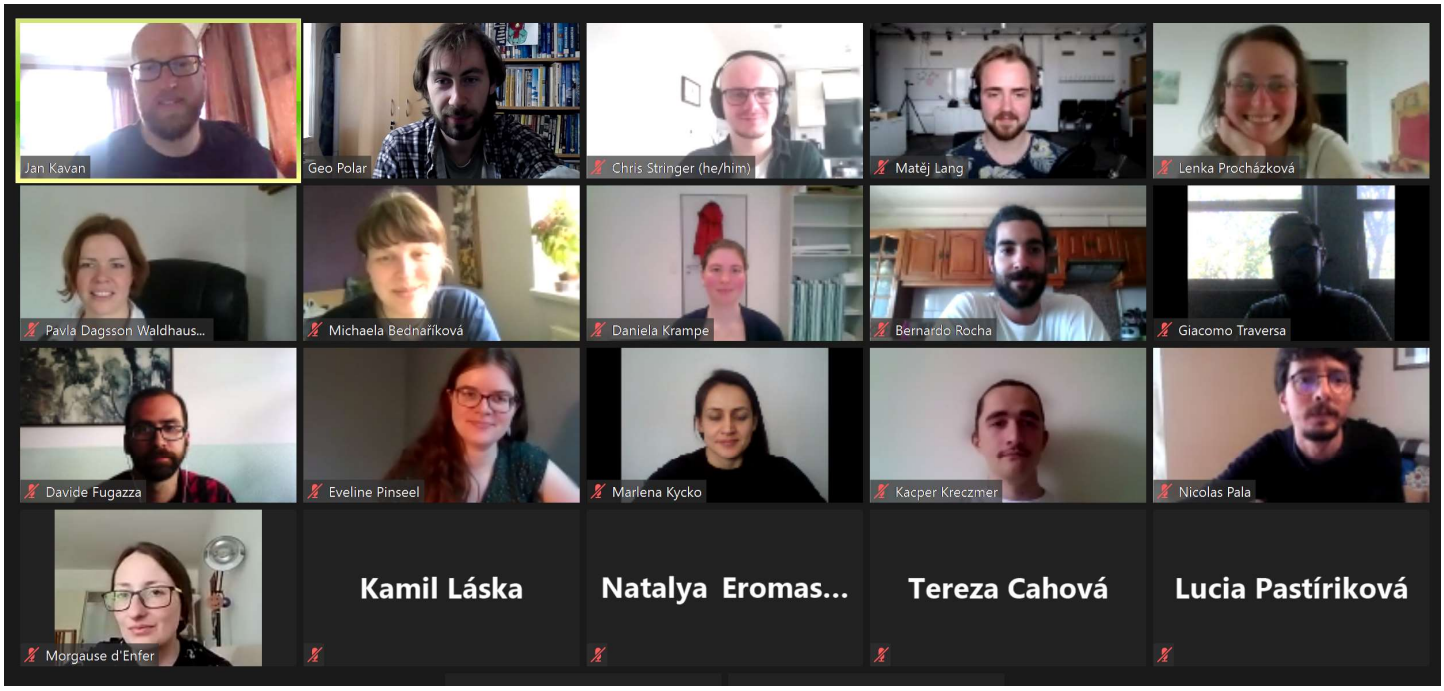

Looking forward to our next meeting!