REPORTS FROM THE ADHERING BODIES OF THE INTERNATIONAL PERMAFROST ASSOCIATION

Country Reports 2020

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ARGENTINA with South American Partners and Mexico

BY DARIO TROMBOTTO LIAUDAT (IANIGLA-CRICYT-CONICET, ARGENTINA)

2020 has been a year influenced by the global COVID-19 pandemic. The meeting of the Argentine National Sub-Committee of the International Association of Cryospheric Sciences Meeting 2020 at the National Geological Congress in Puerto Madryn, Patagonia, was canceled. However, several scientific contributions were published in well-known magazines. With Canadian colleagues the chapter "The Future? Big Questions about Feedbacks between Anthropogenic Change in the Cryosphere and Atmospheric Chemistry" was finished.

- Miller, L.A., Domine, F., Frey, M.M. and Trombotto Liaudat D., (in press). 'The Future? Big Questions about Feedbacks between Anthropogenic Change in the Cryosphere and Atmospheric Chemistry'. In Shepson, P. and Domine, F. (eds.)*, Chemistry in the Cryosphere: Snow and Ice Chemical Processes in the Context of Climate Change,* (Vol. 3, Advances in Atmospheric Chemistry), World Scientific, 700 p. DOI: 10.1142/12095.

We published two papers with Dr. Noelia Sileo about the hydrogeochemical behavior of water related to rock glaciers.

- Trombotto Liaudat, D., Sileo, N. and Dapeña, C. (2020). Periglacial water paths within a rock glacier dominated catchment in the Stepanek area, Central Andes, Mendoza, Argentina. *Permafrost and Periglacial Processes*, 31(2), 311-323. DOI: 10.1002/ppp.2044.
- Sileo, N., Dapeña, C. and Trombotto Liaudat, D. (2020). Isotopic Composition and Hydrogeochemistry of a Periglacial Andean Catchment and its Relevance in the Knowledge of Water Resources in Mountainous Areas. *Isotopes in Environmental and Health Studies*, 56(5-6), 480-494. DOI: 10.1080/10256016.2020.1814278.

Ana Lía Ahumada (Fundación Miguel Lillo, Tucumán) and her team also published two research chapters about regions with Andean permafrost and applications. While a paper in Acta Geológica Lilloana describes the increases in current degradation processes in Andean permafrost environments in the Cordillera Oriental, another applied research focuses on the sustainability of regional development projects in the Northwest of Argentina related to water management, water works and roads.

- Willink, H., Ahumada, A.L., and Ibáñez Palacios, G.P. (2020). Geomorfología de cuencas criogénicas de altura en la Sierra de Santa Victoria, provincia de Salta. *Acta Geológica Lilloana*, 32(1-2), 47-73. DOI: 10.30550/j.agl/2020.32.1-2/3.
- Toledo, M.A., Ahumada, A.L., and Ibáñez Palacios, G.P. (2020). Alteraciones en el cauce del río Seco y pérdidas de tierras agrícolas, provincia de Tucumán, Argentina. *Boletín de la Sociedad Geológica Mexicana*, 72(2), 35 p. DOI: 10.18268/BSGM2020v72n2a290719.

The Argentine Permafrost Group (SAAP) is validating inventories of active and inactive rock glaciers in the mountains of San Juan. Silvio Pastore (University of San Juan) and his team are continuing with

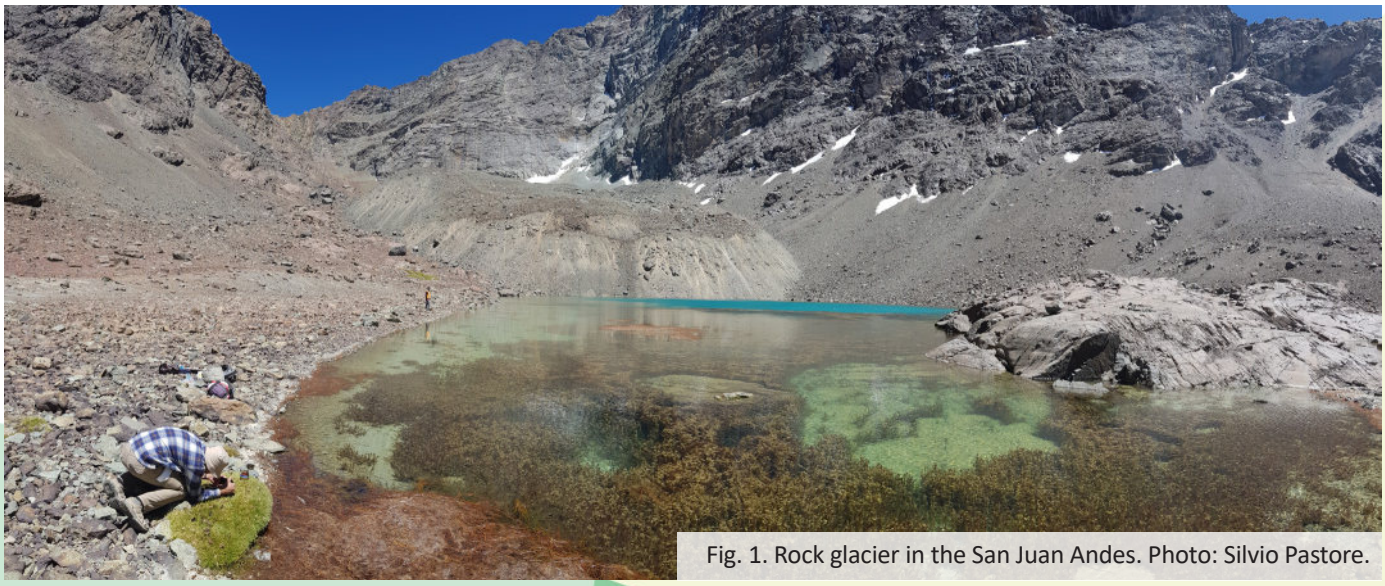

Fig. 1. Rock glacier in the San Juan Andes. Photo: Silvio Pastore.

the project "*Determining the eco-hydrogeologic response of tropical glacierized watersheds to climate change*" which the University of Minnesota (USA) are developing in Ecuador. This research group is also working in collaboration with the IANIGLA Institute (National Research Council).

Cristian Villarroel and Ana Forte together with another group from the University of San Juan have published in Geomorphology in 2020 an article which describes the internal structure and processes involved in the development of rock glaciers in a scarcely studied region. This team is working with different topics related to mountain permafrost in the Andes of San Juan.

- Villarroel, C.D., Forte, A.P., Ortiz, D.A., Beliveau, G.T., and Güell, A. (2020). Active layer and permafrost thickness in rock glaciers derived from geophysical methods in the semiarid Andes of Argentina. *Geomorphology*, 365, 9 p. DOI: 10.1016/j.geomorph.2020.107249.

In Chile, permafrost science still focuses mostly on rock glacier research in the North-Central Andes. Local cooperations with international groups from Argentina (IANIGLA) and Hungary (Eötvös Loránd University) are expanding their research areas (permachile.com/) from Ojos del Salado (27°S), Central Andes and Southern Patagonia (51°S).

PYRN member (Sebastián Ruiz Pereda, Pontifical Catholic University and University of Atacama) are improving permafrost mapping resolution (27-33°S) while research at 33°S assesses mountain hydrogeology combining geophysical and genetic proxies to understand hydrological connectivity. As an Andean region with very scarce water supplies, the integration of permafrost science in both analytical and normative approaches in the water security perspective is vital.

AUSTRIA

BY ANDREAS KELLERER-PIRKLBAUER (UNIVERSITY OF GRAZ)

GRAZ

In 2020, Viktor Kaufmann (Institute of Geodesy, Graz University of Technology) collected the annual geodetic measurements at the four rock glaciers in the Hohe Tauern Range (Dösen, Hinteres Langtalkar, Leibnitzkopf, and Tschadinhorn rock glaciers). In addition, UAV-based aerial surveys were carried out jointly with Gernot Seier and Matthias Wecht (Institute of Geography and Regional Science, University of Graz) at the Tschadinhorn and Leibnitzkopf rock glaciers. The long-term movement behaviour of the Tschadinhorn Rock Glacier was published in 2019.

- Kaufmann, V., Sulzer, W., Seier, G., and Wecht, M. (2019). Panta Rhei: Movement Change of Tschadinhorn Rock Glacier (Hohe Tauern Range, Austria), 1954–2017. Kartografija i Geoinformacije, 18(31), 21 p. DOI: 10.32909/kg.18.31.1.

Permafrost-related research by Andreas Kellerer-Pirklbauer, Gerhard Karl Lieb, Wolfgang Sulzer, Gernot Seier, Matthias Wecht (Institute of Geography and Regional Science, University of Graz) was carried out at twelve mountain regions in the Central Alps and the Northern Calcareous Alps of Austria. In some study areas, research activities were accomplished in close collaboration with the Institute of Geodesy at the Graz University of Technology, the Institute of Earth Sciences at the University of Graz, and the Zentralanstalt für Meteorologie und Geodynamik (ZAMG).

Permafrost monitoring in the Hohe Tauern Range was carried out in 2020 within the framework of two long-term project initiatives supported by national park authorities ("*Permafrost monitoring in the Hohe Tauern National Park Carinthia 2019-2021*" and "*Long-term monitoring of ecosystem processes in the Hohe Tauern National Park – Modul 07*"). Both projects aim to gather long-term data on permafrost (temperature data series) and periglacial processes (rock glacier displacement data series, rock fall activities). In total, some 100 ground temperature data loggers measuring surface and deeper ground temperatures are operated by the Institute of Geography and Regional Science.

Field work and maintenance of the monitoring devices was accomplished at five active rock glacier sites (Dösen, Hinteres Langtalkar/Kögelekar, Leibnitzkopf, Weissenkar, and Tschadinhorn), one active rock fall site (Mittlerer and Hoher Burgstall, near Pasterze Glacier), four marginally permafrost sites (Hochtor area, Fallbichl area, Hintereggen valley, Hochreichart area), and two bedrock permafrost sites (Innerer Knorrkogel, Dachstein Massif). In 2019, a summary was published about the long-term monitoring (since 2004) of sporadic permafrost at the eastern margin of the European Alps. Furthermore, results on permafrost distribution and conditions at the headwalls of two receding glaciers (the Schladming and Hallstatt glaciers) in the Dachstein Massif were published in 2020.

- Kellerer-Pirklbauer, A. (2019). Long-term monitoring of sporadic permafrost at the eastern margin of the European Alps (Hochreichart, Seckauer Tauern range, Austria). *Permafrost and Periglacial Processes*, 30(4), 260-277. DOI: 10.1002/ppp.2021.
- Rode, M., Sass, O., Kellerer-Pirklbauer, A., Schnepfleitner, H., and Gitschthaler, C. (2020). Permafrost distribution and conditions at the headwalls of two receding glaciers (Schladming and Hallstatt glaciers) in the Dachstein Massif, Northern Calcareous Alps, Austria. *The Cryosphere*, 14, 1173-1186. DOI: 10.5194/tc-14-1173-2020.

Angelika Halbwirth and Andreas Kellerer-Pirklbauer (University of Graz) measured the relative age of several rock glaciers and moraine ridges were in the Ankogel and Schober Mountains. Andreas Kellerer-Pirklbauer, Stefan Presslaber, Christian Ziesler (University of Graz) applied electrical resistivity tomography (ERT) to a mountain plateau (Mit-

Fig. 2. ERT measurements at Mittlerer Burgstall (2933 m asl) to detect and quantify the distribution of permafrost.

tlerer Burgstall, Fig. 2), a proglacial area (Pasterze; dead-ice detection), and a proglacial-lateral moraine transition zone (Frossnitz; permafrost detection) in the Glockner and Venediger Mountains. In 2020, a project about proglacial dead-ice characteristics and changes at Pasterze Glacier was concluded. Results about the ice-contact lake evolution and buoyant calving processes were published in 2021.

- Kellerer-Pirklbauer, A., Avian, M., Benn, D.I., Bernsteiner, F., Krisch, P., and Ziesler, C. (2021). Buoyant calving and ice-contact lake evolution at Pasterze Glacier (Austria) in the period 1998-2019. *The Cryosphere*, 15, 1237-1258. DOI: 10.5194/tc-2020-227.

The Alpine Hydrogeology working group of the Institute of Earth Sciences, University of Graz (Gerfried Winkler, Thomas Wagner, Jennifer Brandstätter, Simon Kainz) and its partners at the University of Innsbruck (Karl Krainer, Markus Ribis), University of Freiburg (Stefan Hergarten), and Institute of Geography and Regional Science, University of Graz (Andreas Kellerer-Pirklbauer) completed their research project "*RGHeavyMetal - Water resources management issues of rock glaciers in alpine catchments of the Eastern Alps - storage capacity, flow dynamics and hydrochemistry in particular heavy metal pollution*" (DaFNE-research project 101093). The final report can be accessed at: www.bmnt.gv.at/wasser/wasserqualitaet/RG-HeavyMetal.html.

The first consistent nation-wide rock glacier and rock glacier catchment inventories of the Austrian Alps were published in 2020. The microclimatic effects on the thermal regime of rock glaciers producing interesting results for rock glacier resilience to climate warming was published in 2019. Further knowledge on the storage-discharge behaviour of relict and intact rock glaciers was published after applying recession analysis, natural and artificial tracer analyses and rainfall-runoff modelling.

- Wagner, T., Pleschberger, R., Kainz, S., Ribis, M., Kellerer-Pirklbauer, A., Krainer, K., Phillipitsch, R., and Winkler, G. (2020). The first consistent inventory of rock glaciers and their hydrological catchments of the Austrian Alps. *Austrian Journal of Earth Sciences*, 113(1), 1-23. DOI: 10.17738/ajes.2020.0001.
- Wagner, T., Ribis, M., Kellerer-Pirklbauer, A., Krainer, K., and Winkler, G. (2020). The Austrian rock glacier inventory RGI_1 and the related rock glacier catchment inventory RGCI_1 in ArcGis (shapefile) format. *PANGAEA*. DOI: 10.1594/PANGAEA.921629.
- Wagner, T., Pauritsch, M., Mayaud, C., Kellerer-Pirklbauer, A., Thalheim, F., and Winkler, G. (2019). Controlling factors of microclimate in blocky surface layers of two nearby relict rock glaciers (Niedere Tauern Range, Austria). *Geografiska Annaler: Series A, Physical Geography*, 101(4), 310-333. DOI: 10.1080/04353676.2019.1670950.
- Wagner, T., Brodacz, A., Krainer, K., and Winkler, G. (2020). Active rock glaciers as shallow groundwater reservoirs, Austrian Alps. *Grundwasser*, 25, 215-230. DOI: 10.1007/s00767-020-00455-x.
- Wagner, T., Kainz, S., Krainer, K., and Winkler, G. (2020). Storage-discharge characteristics of an alpine active rock glacier catchment – a multidisciplinary approach applied to the Innere Ölgrube, Austrian Alps. *Authorea*. DOI: 10.22541/au.160872491.12614869/v1.

Fig. 3. Maintenance of a gauging station, Arzkar, Glockturmkamm (2500 m asl). Photo: Gerfried Winkler.

A new project was initiated in 2020, "*RG-AlpCatch – Rock glaciers as groundwater storages in alpine catchments and their impact on downstream river systems with regard to climate change*" (DaFNE-research project 101561). In five regions in the Austrian Alps with considerable rock glacier abundance but different meteorological conditions, test sites with various gauging stations have been installed to capture storage-discharge dynamics of individual rock glacier springs and their influence on downstream river systems within the next two years (Fig. 3). Within his PhD, Simon Kainz will focus on deciphering the impact of rock glaciers as shallow groundwater stores in runoff of alpine catchments and its potential change over time due to climate change.

INNSBRUCK

Karin Koinig, Boris Ilyashuk, Elena Ilyashuk, Roland Psenner, and Ruben Sommaruga (Department of Ecology, University of Innsbruck) continued long-term monitoring on the impact of rock glacier melt-water at different lakes in the valley of Matsch, Ötztal Alps, Italy. The monitoring also includes lakes and ponds without rock glacier inflow as reference sites and is linked to the LTER site Matscher Tal (lter.eurac.edu). Research activities by Karl Krainer and Markus Ribis (Institute of Geology, University of Innsbruck) related to permafrost are mentioned in the Graz-section.

Martin Stocker-Waldhuber and Lea Hartl (Institute for Interdisciplinary Mountain Research, Austrian Academy of Sciences) and Andrea Fischer (Verein Gletscher Klima) continued their long-term monitoring program of surface displacement at Äußeres Hochebenkar rock glacier. The annual flow velocities at the lower part of the rock glacier increased further, so that the terminus is now located just above the road.

- Hartl, L., Stocker-Waldhuber, M., and Abermann, J. (2021). Flow velocity records at Rock Glacier Outer Hochebenkar (Äußeres Hochebenkar), Ötztal, Tyrolian Alps, Austria, since 2016. *PANGAEA*. DOI: 10.1594/PANGAEA.928244.

SALZBURG

Long-term permafrost monitoring was continued in 2020 at the Open Air Lab Kitzsteinhorn (OpAL), Hohe Tauern Range. The monitoring is operated by Ingo Hartmeyer and Markus Keuschnig (Georesearch) and includes deep and shallow borehole measurements, UAV and LiDAR surveys, geophysical measurements, crackmeter recordings, and load monitoring at rock anchor heads. Measurements in 30 m deep boreholes at the Kitzsteinhorn northface revealed a maximum active layer depth of 3.7 m in 2020 (4.2 m in 2019). Bedrock temperature at 30 m depth was -1.7 °C (-1.8 °C in 2019). To expand the observations of fracture dynamics, four additional crackmeters were added to the existing monitoring (Fig. 4).

At several cirques (Sattelkar, Ofenkar, Mitterkar and Steinkar) in the Venediger Mountains, west of Kitzsteinhorn, the disintegration of rock glacier sediments influencing debris flow activity is monitored by Georesearch supported by the Federal Province of Salzburg and the Hohe Tauern National Park authority. At these cirques multitemporal remote sensing monitoring is accomplished. Furthermore, some thirty ground-surface temperature sensors are installed.

Fig. 4. Installation of a crack meter near the cable car top station, Kitzsteinhorn, Hohe Tauern Range (3000 m asl). Photo: Andreas Ewald.

The Zentralanstalt für Meteorologie und Geodynamik (ZAMG) regional office Salzburg focusses on permafrost-related research around the Hoher Sonnblick mountain, Hohe Tauern Range.

VIENNA & KORNEUBURG NEAR VIENNA

Permafrost research activities by Michael Avian, Daniel Binder, Adrian Flores-Orozco, Martina Frießenbichler, Anton Neureiter, Stefan Reisenhofer, Gernot Weyss, and Claudia Riedl (Zentralanstalt für Meteorologie und Geodynamik, ZAMG) are concentrated in the Hohe Tauern Range at the Hoher Sonnblick area (including the meteorological observatory), the Pasterze Glacier area (rock fall monitoring) and the Schober Mountains (rock glacier monitoring).

Permafrost long-term monitoring at Hoher Sonnblick investigates the spatial distribution of permafrost within the project GCW-Permafrost. The following parameters are measured:

- Basal temperature of the snow cover (BTS, since 2012)
- Rock temperature of the Sonnblick north face (since 2016) which was continuously expanded with six more shallow boreholes (temperature sensors 0, 20, 40, 60, 80 and 100 cm depth, every hour, automatically transmitted by a stand-alone GSM transmitter).

Activities within the project SeisRockHT covered rockfall monitoring by means of a local seismological monitoring, annual unmanned aerial vehicle

(UAV) and terrestrial laserscanning surveys. The project ended in 2020 (collaboration with Mertl Research and Georesearch). Currently, the continuation of the SeisRockHT is assured by GCW-Permafrost and the ZAMG-internal ASBO project.

- Binder, D., Mertl, S., Hartmeyer, I., Keuschnig, M., and Lenhardt, W. (2021). SeisRockHT - Seismic Rockfall Monitoring in the Hohe Tauern region by means of Open-Design Products. Austrian Academy of Sciences (OeAW), ESS - Final Report. 288 p. DOI: 10.1553/ESS-SeisRockHT.

At the southern slope of Hoher Sonnblick maintenance work at the 20 m deep boreholes was conducted in 2020. Due to lightning strokes the borehole equipment had to be changed. Permafrost degradation is also monitored at the summit area of Hoher Sonnblick. At least two geophysical measurements per year are carried out at this site using electrical and seismic imaging methods, which are sensitive to variations in the ice and water content. These activities are accompanied by the development of a new algorithm for the joint inversion of geophysical data that directly solve for petrophysical parameters (air, ice, and water content in the subsurface).

Rockfall monitoring in the Burgstall area (Großglockner Mountains) has been carried out using TLS (since 2010) and UAV (since 2019). At Mittlerer Burgstall rock fall events still continued in an active detachment zone. The consolidation of the rockslide mass is detectable at the upper part. Furthermore, substantial glacier ice melting below the lowest part of the rock mass accumulation area was observed. At Hoher Burgstall no significant rock falls could be detected in the area of the alpine track area to Oberwalder Hütte (training center of Austrian alpine club) in the period 2019-2020 (Fig. 5). Monitoring of the frontal area of the rock glacier Hinteres Langtalkar has been carried out using TLS since 2001. Massive advance of the left part of the rock glacier tongue continued in 2020 with maximum rates of 10 m. Both activities (Burgstall, Langtalkar) are funded by a project of the Hohe Tauern National Park authority led by the University of Graz.

Sabine Kraushaar (University of Vienna) and Jan Blöthe (University of Freiburg, Germany) continued with hydrological investigations on the Kaiserberg rock glacier in the Kaunertal valley, Tyrol. The aim of the project is to analyse the geomorphic and hydrologic implications of permafrost degradation in the Alps (GeoHype). With a combination of hydro-chemical analyses, geoelectrical measurements and geomorphic investigations, the detection and relative contribution of the thawing passive layer to the daily summer discharge could be estimated. A short video (www.youtube.com/watch?v=r5M-41ABBZik) was produced for the public by Sabrina Walker (Bonn University). The project GeoHype was selected for a permanent exhibition in the village of Feichten (Kaunertal), opening in summer 2021.

Annett Bartsch (B.geos) contributes to the new HORIZON2020 project CHARTER with experience in remote sensing. The project began in August 2020. Arctic biodiversity issues are addressed, including permafrost-related phenomena. A feasibility study based in radar satellite observations for the quantification of coastal erosion in permafrost regions has been published. It contributes to the HORIZON2020 project Nunataryuk (nunataryuk.org).

- Bartsch, A. Ley, S., Nitze, I., Pointner, G., and Vieira, G. (2020). Feasibility Study for the

Fig. 5. Long- and near-range laser scanning, and UAV-based optical sensing at Burgstall (2803 m asl). Mittlerer Burgstall rock slide area (red), HBUG: Hoher Burgstall rock fall area (orange, violet) with indicated alpine track (white dotted line). Photo: Michael Avian.

Application of Synthetic Aperture Radar for Coastal Erosion Rate Quantification Across the Arctic. Frontiers in Environmental Science, 8(143), 20 p. DOI: 10.3389/fenvs.2020.00143.

Within a PhD project at the University of Salzburg (Helena Bergstedt), several technical developments have been made to advance the utility of surface status information, derived from microwave satellite data, for permafrost related applications. Algorithms which address landscape heterogeneity and subsequent quality issues of derived products have been published

- Bergstedt, H., Bartsch, A., Neureiter, A., Höfler, Widhalm, B., Pepin, N., and Hjort, J. (2020). Deriving a Frozen Area Fraction From Metop ASCAT Backscatter Based on Sentinel-1. *IEEE Transactions on Geoscience and Remote Sensing*, 58(9), 6009-6019. DOI: 10.1109/TGRS.2020.2967364.
- Bergestedt, H., Bartsch, A., Duguay, C.R., and Jones, B.M. (2020). Influence of surface water on coarse resolution C-band backscatter: Implications for freeze/thaw retrieval from scatterometer data. Remote Sensing of Environment, 247, 14 p. DOI: 10.1016/j.rse.2020.111911.

These developments contribute to the ESA Climate Change Initiative project on Permafrost (climate.esa.int/en/projects/permafrost/), where freeze and thaw records are used by the b.geos team to assess consistency between the modelled ground temperature (by University Oslo) and other climate data records. B.geos recently became a member of the Austrian Polar Research Institute (APRI) with which several Austrian permafrost researchers are affiliated. A new webpage was released in 2020 to better disseminate achievements by APRI members (www.polarresearch.at/news/).

For more information contact Andreas Kellerer-Pirklbauer (andreas.kellerer@uni-graz.at).

BELGIUM

BY HANNE HENDRICKX (GHENT UNIVERSITY) AND SOPHIE OPFERGELT (UNIVERSITÉ CATHOLIQUE DE LOUVAIN)

In 2020, Belgium became a country member of the International Permafrost Association as a collective initiative of Hanne Hendrickx (Ghent University), Elie Verleyen (Ghent University), and Sophie Opfergelt (Université catholique de Louvain). Belgium was previously an IPA member between 1998-2008.

The goal of the Belgian Branch of the IPA is to foster collaboration and exchange between Belgian based permafrost scientists in the broad sense (e.g. knowledge and data sharing, collective fieldwork, sample sharing, and job opportunities). For this purpose, the email list ipa_belgium@lists.ugent.be can be used by anyone who is a member. Please contact Hanne Hendrickx if you want to added to this list. Since permafrost news IS increasingly finding its way into the media, the Belgian ranch of the IPA is a good point of contact for journalists who want to get in touch with Belgian-based permafrost scientists.

LAUNCH MEETING OF THE IPA BELGIAN BRANCH

On January 23 we had our first meeting at Ghent University. At this event, everyone briefly introduced their work with topics dealing with:

- Arctic and Antarctic microbial activity and functioning in permafrost soils;
- Mineral weathering response in permafrost regions subject to thawing (WeThaw project: sites.uclouvain.be/wethaw/research/);
- Modelling subsea permafrost and potential methane production;
- Periglacial mountain geomorphology;
- Permafrost traces of the Weichsel Glaciation in Belgium.

Fig. 6. Launch meeting at Ghent University, Belgium.

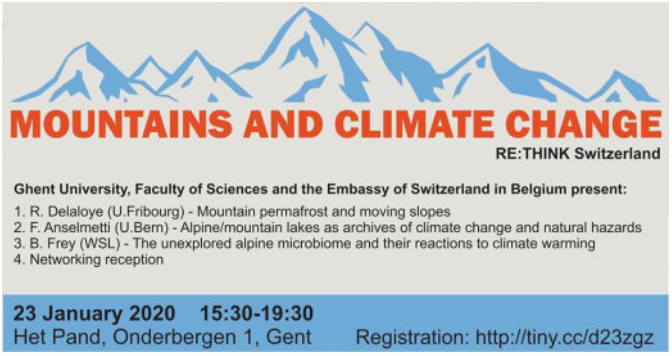

Fig. 7. Programme of the Mountains and Climate Change Workshop at Ghent University.

Participants from four different universities (Ghent University, Université catholique de Louvain, Université Libre de Bruxelles, and University of Liege) attended the meeting (Fig. 6).

WORKSHOP ON MOUNTAINS & CLIMATE CHANGE

The first meeting of the Belgian Branch of the IPA was followed by a workshop on *Mountains and Climate Change*, organized by the Departments of Geography, Geology and Biology at Ghent University in cooperation with the Swiss embassy. The three speakers could count on an interested audience (over 100 registrations) from all over the country (Fig. 7).

LECTURE BY DR JENS STRAUSS

On March 2, Dr Jens Strauss (Alfred Wegener Institute (AWI), Potsdam, Germany) was invited to UCLouvain to present his work about "*Deep permafrost carbon pools and their vulnerability to mobilization*", discussing the role of ice-rich Yedoma permafrost to the carbon-climate feedback mechanism. This event was attended by 50 participants (Fig. 8).

BELGIAN REPRESENTATION AT INTERNATIONAL CONFERENCES

Belgium was very well represented at the 10th Annual Meeting of the Permafrost Carbon Network, held virtually on November 10, 2020 and engaged more than 200 participants from across the world (Fig. 9). There was also an active participation of Belgian members of the IPA at the AGU Online Fall Meeting from December 1-17, 2020.

- Opfergelt, S., Hirst, C., Monhonval, A., Mauclet, E., Thomas, M. (2020). *Why do we need*

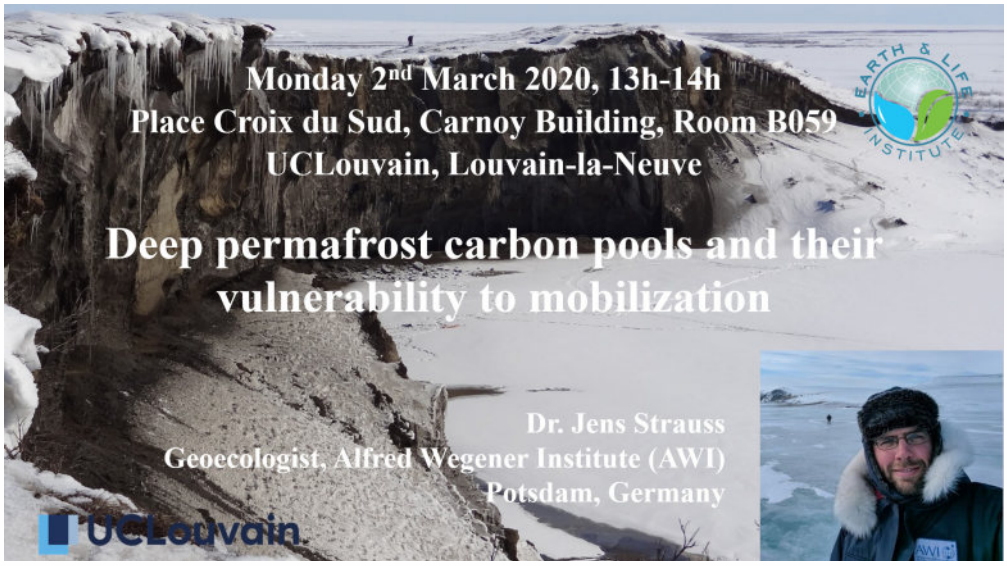

Fig. 8. Announcement for the lecture by Dr Jens Strauss (AAlfred Wegener Institute (AWI), Potsdam, Germany).

to care about the evolution of mineral-organic carbon interactions in permafrost upon thawing? [Conference presentation abstract]. AGU Fall Meeting Online, December 1-17, 2020.

- Thomas, M., Opfergelt, S., Monhonval, A., Broder, L., Jorien, V., Scott, Z., Tank, S., and Kokelj, S. (2020). *Impact of abrupt permafrost thaw on mineral elements release: case study in Peel Plateau, west Canadian Arctic* [Conference presentation abstract]. AGU Fall Meeting Online, December 1-17, 2020.
- Hirst, C., Opfergelt, S., Mauclet, E., Monhonval, A., and Schuur, A.G. (2020). *Mineral element and organic carbon transport from permafrost soils to a headwater stream under contrasting flow regimes and permafrost degradation* [Conference presentation abstract]. AGU Fall Meeting Online, December 1-17, 2020.
- Mauclet, E., Opfergelt, S., Hirst, C., Monhonval, A., Debruxelles, L., Ledman, J., Taylor, M., and Schuur, A.G. (2020). *Influence of Thawing Permafrost on Soil-Plant Mineral Element Transfer: Case Study in Interior Alaska* [Conference presentation abstract]. AGU Fall Meeting Online, December 1-17, 2020.
- Monhonval, A., Opfergelt, S., Mauclet, E., Hirst, C., Pereira, B., Vandeuren, A., Bemelmans, N., Grosse, G., Schirmmeister, L., and Fuchs, M. (2020). *Iron Dynamics during Thermokarst Processes in the Yedoma Domain and Implications for Interactions between Iron and Organic Carbon* [Conference presentation abstract]. AGU Fall Meeting Online, December 1-17, 2020.

Fig. 9. Belgium is well represented in the word cloud presenting the country of origin of the participants of the 10th Annual Meeting of the Permafrost Carbon Network.

FUTURE ACTIVITIES

There will be a permafrost session organized at the Geologica Belgica Congress 2021, "Geology Made in Belgium", hosted by the Royal Museum of Central Africa (Tervuren), September 2021, Wednesday 15 to Friday 17. This congress is held every two years to present the work carried out by scientists based at Belgian universities. The permafrost session will offer an opportunity to contact all members of the Belgian IPA to submit a contribution.

For more information contact Hanne Hendrickx (hanne.hendrickx@ugent.be) or Sophie Opfergelt (sophie.opfergelt@uclouvain.be).

CANADA

BY SHARON SMITH (GEOLOGICAL SURVEY OF CANADA)

Things were certainly different in 2020 for the Canadian permafrost community. Travel to Canada's northern territories was limited due to travel restrictions and this meant it was not possible to conduct some fieldwork as planned. However, fieldwork by northern scientists was conducted and collaborations between scientists in southern Canada and northern partners allowed some fieldwork to go forward. Despite the challenges, the permafrost community was active in many projects.

CANADA AWARDED 13TH INTERNATIONAL CONFERENCE ON PERMAFROST (ICOP)

At the IPA Council Meeting in June 2020, Canada was awarded the 13th ICOP. The conference will be held in June 2024 in Whitehorse, Yukon, and will be organized by Yukon University and the Canadian Permafrost Association (CPA). Yukon College became Yukon University in 2020 (the first Canadian university north of 60°N) and will serve as the main conference venue. The impacts of climate change and economic development have significantly changed the Arctic in recent decades resulting in a wealth of research initiatives and unparalleled engineering projects. The City of Whitehorse, is the ideal place to showcase these recent developments and the current challenges first hand, and its location in Canada's North offers the perfect environment to learn and exchange ideas. The organizing committee has been established and is working hard to plan an interesting conference including a number of field trips in the region. Yukon University and the City of Whitehorse looks forward to welcoming everyone in 2024.

CANADIAN PERMAFROST ASSOCIATION (CPA)

Despite the pandemic, the CPA had a busy year. Although no in-person meetings could be held, the CPA provided the opportunity for the permafrost community to meet by initiating a virtual speaker series in July 2020 with monthly presentations. The CPA also held a very successful virtual Annual General Meeting in November 2020 which included a business meeting and also three technical sessions held in partnership with NSERC PermafrostNet. The CPA produced a book of abstracts from the AGM. For more information on the CPA visit: canadianpermafrostassociation.ca/.

- Arenson, L.U., Rudy, A., and Morse, P. (eds.) 2020. Abstracts: Virtual Annual General Meeting, November 16 & 17, 2020. *Canadian Permafrost Association (CPA)*.

MEETINGS

Permafrost related sessions were also included in other symposiums. Although the NWT/Nunavut Geoscience Forum could not hold its annual in person meeting in Yellowknife, a virtual Geoscience Symposium was held in November 2020. This included a permafrost science session consisting of fourteen oral and poster presentations and also included a discussion session. Presentations are available for viewing until May 2021 (geosympos.ca/?page_id=141). In December 2020, ArcticNet held its annual science meeting virtually with the international Arctic Change 2020 symposium, and included several permafrost related oral and poster presentations as well as breakout group discussions. Presentations are available for viewing by creating an ArcticNet account (arcticnetmeetings.ca/ac2020).

GEOLOGICAL SURVEY OF CANADA PRODUCTS

Scientists at the Geological Survey of Canada (GSC) have developed a new Canadian ground ice map depicting a first-order estimate of volumetric percentage of excess in the upper 5 m of permafrost. The map is also being incorporated into the Permafrost Information Network (PIN) which is being developed to increase the accessibility to permafrost related information (pin.geosciences.ca/en/).

- O'Neill, H.B., Wolfe, S.A., and Duchesne, C. (2020). Ground ice map of Canada. Geological Survey of Canada, Open File 8713, 7 p. (1 sheet), DOI: 10.4095/326885.

ADVANCING HAZARD MAPPING FOR NORTHERN COMMUNITIES IN CANADA

The rapidity and severity of responses of permafrost environments to climate change have spurred the need for reliable and accessible hazard mapping for communities in northern Canada. Roughly half of the communities in the Yukon have hazard maps, while only a small proportion of communities in the Northwest Territories and Nunavut have access to

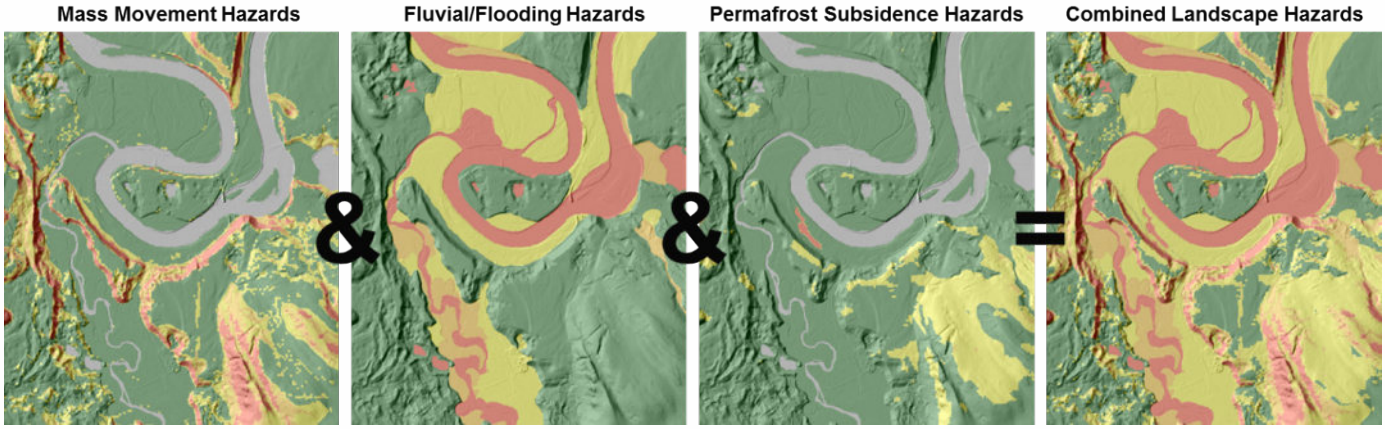

Fig. 10. Excerpt of the multi-hazard mapping outputs derived from Palmer's community-scale (1:15,000) surficial geology mapping of the Carmacks area, central Yukon (Cronmiller *et al.*, 2020).

such information. Community hazard maps inform planning-level decisions regarding existing and proposed land use and infrastructure, and help prioritize and focus associated geotechnical investigations.

Palmer has been working in collaboration with the governments of Yukon and Northwest Territories to develop and test new approaches for community hazard mapping and, in doing so, expand coverage in both territories. Multi-hazard classifications, considering processes related to permafrost, mass movement, flooding and erosion, are derived from detailed (1:10,000 to 1:20,000) surficial geology mapping and high-resolution topographic data (e.g. LiDAR). Interpretations are largely based on observed and inferred (based on landform association) occurrences of key surface indicators of hazard processes. Maps were produced and published for Carmacks, situated alongside Yukon River in a region of discontinuous permafrost in central Yukon (Cronmiller *et al.*, 2020; Fig. 10), and preliminarily drafted for Tuktoyaktuk, a community located along an eroding and subsiding (thermokarst) section of the Beaufort Sea coastline in mainland Northwest Territories.

- Cronmiller, D.C., McParland, D.J., Goguen, K.M., and McKillop, R.J. (2020). Carmacks surficial geology and community harzard susceptibility mapping. *Yukon Geological Survey*, Miscellaneous Report 20, 16 p. plus appendices.

The completion of these mapping projects also served as a catalyst for preparing a presentation for the 2020 NWT & Nunavut Geoscience Symposium, which highlights the importance of community engagement and specification of the implications of hazard classes for community interests.

- McKillop, R.J., Cronmiller, D.C., and Sacco, D. (2020). *Community Hazard Mapping: One Step Short of What Is Actually Needed* [Conference presentation]. 2020 NWT & Nunavut Geoscience Symposium, Online, November 23, 2020.

For more information contact Sharon Smith (Sharon.Smith@nrcan-rncan.gc.ca) or Robin McKillop (robin.mckillop@pecg.ca) at Palmer Environmental Consulting Group regarding community hazard mapping.

CHINA

BY FUJUN NIU, WU TONGHUA, CHENG JI, LI GUOYU (CHINESE ACADEMY OF SCIENCES), AND YUANHONG DONG (CCCC FIRST HIGHWAY CONSULTANTS CO. LTD.)

MAIN ENGINEERING ACTIVITIES

Besides the maintenance and repairing works along the Qinghai-Tibet Railway, the Qinghai-Tibet Highway, the Russia-China Crude Oil pipeline in permafrost regions in China, a newly constructed express highway, the Gonghe-Yushu Expressway (GYE) in the east edge of the Qinghai-Tibet Plateau (QTP) was passed the project acceptance check from the Qinghai Province, after running for more than 5 years. This was the first express highway in the permafrost regions of the QTP (Fig. 11). Considering the high altitude permafrost along the GYE was very warm and unstable, the design of the embankment followed the engineering permafrost energy balanced design principle that was proposed by the design and research team lead by Dr. Shuangjie Wang, the general director of the CCCC First Highway Consultants Co. Ltd. Correspondingly, numbers of innovative heat balance adjusting technologies, such as combined ventilation slab and crushed-rock layer, and combined L-shaped thermosyphon and XPS thermal insulation, were employed to maintain the stability of the embankments.

A field survey after 3 years of operation showed that the distress rate of the GYE was only 6.2%. In early September 2020, the GYE passed the acceptance check form the local government. In late 2020, the research achievements on the highway won the Global Road Achievement Award of the International Road Federation. However, under the background of the global climate warming, along with the influence of the engineering activities, the GYE is also threatened by permafrost degradation. Eventhough the highway was designed with active cooling methods, the heat absorption from the black asphalt surface pavement would lead to permafrost degradation. This process has occurred and is demonstrated by engineering problems, such a thaw settlement, surface cracks and lateral displacement. These phenomena gave us some enlightenment that, if the permafrost degradation cannot be prevented by embankment methods, land bridges might be the final solution. However, the designing methods for pile foundation in degenerative permafrost are still needed for improvement.

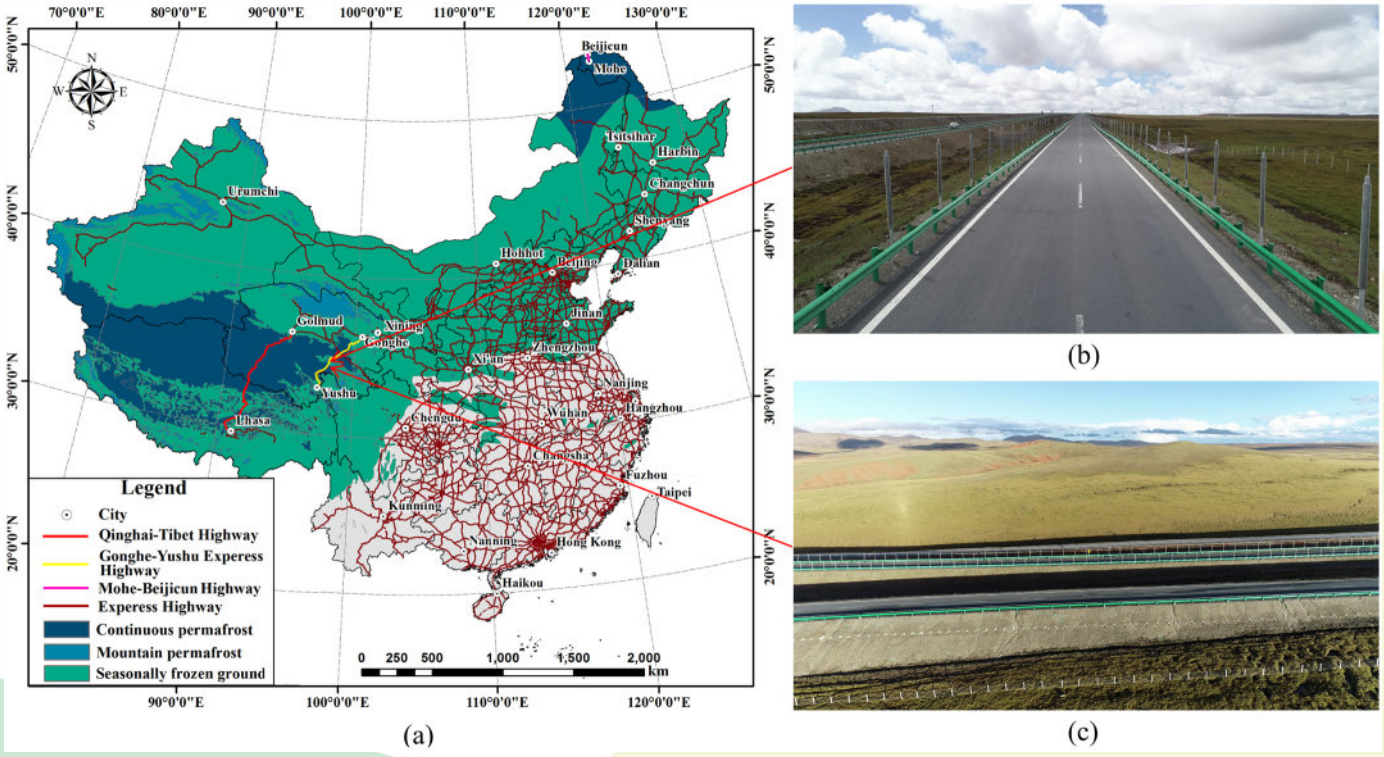

Fig. 11. Permafrost in China and position of the GYE. (a) Permafrost distribution in China and the location of the GYE; (b) the embankment with combined L-shaped thermosyphon and XPS thermal insulation; (c) duct-ventilation embankment.

Another express highway, named the Qinghai-Tibet Express Highway from Golmud to Lhasa, will be constructed in the near future. International cooperation related to construction and the environment in permafrost regions are welcomed.

DEVELOPMENT OF NUMERICAL SIMULATIONS FOR PERMAFROST ENGINEERING

Numerical simulations have been widely used in cold region engineering in China, such as embankments, foundations, tunnels, bridges, pipelines, airports, coal mining, dams, canals, waste disposals, and retaining walls. Some heat transfer models with ice-water phase transition have been proposed to analyze the thermal stability of engineering in cold regions. Then, based on the heat transfer models, some combined methods are developed, for example, the coupled models to describe the process of air-TPCT (two-phase closed thermosyphon) soil system for the embankments, tunnels, bridges, pipelines and foundations. The coupled models used to analyze the temperature distribution characteristics of typical construction methods including crushed-rock embankments, duct-ventilated embankments, and some combined TPCT embankments (i.e., embankment combined with TPCT, insulation and crushed-rock revetment) for the Qinghai-Tibet Highway, Qinghai-Tibet Railway and the GYE in China, and to obtain that the reasonable embankment structure and geometrical parameters have significant influence on cooling the underlying permafrost.

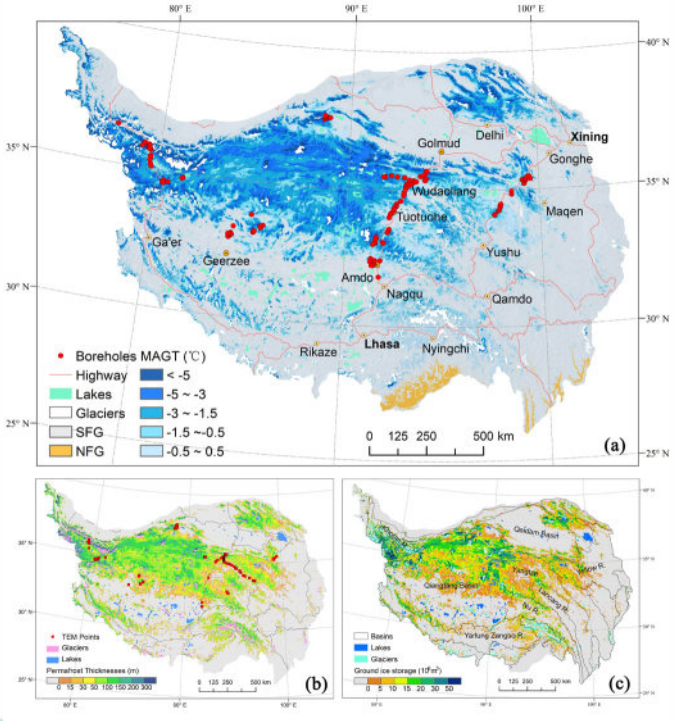

Fig. 12. Current state of permafrost on the Qinghai-Tibet Plateau. (a) Permafrost distribution and mean annual ground temperature (MAGT); (b) thickness of permafrost; (c) ground ice of permafrost.

To explore the freeze-thaw interaction process and predict the long-term stability of engineering in permafrost regions, some thermo-mechanics models, thermo-hydro models and thermo-hydro-mechanics coupling models are established. These models help us better understand the complicated interaction processes among moisture, heat and mechanics during freeze-thaw cycles, i.e., exploring the moisture, heat and deformation behaviors for embankments, determining the optimal thermal insulation layer for tunnels, investigating the hydro-thermal behavior and deformation characteristics for foundations, analyzing the frost damage mechanism and deformation sources for canals, evaluating the thermal stability and pore water redistribution for airports, and predicting the deformation variation for pipelines and coal mining. Some climate models (i.e., GCMs, MLRM, WRF, RCM), have been applied to determine the hydro-thermal boundary conditions for engineering in cold regions under different climate changes.

PERMAFROST DISTRIBUTION, TEMPERATURE, THICKNESS & GROUND ICE IN THE QTP

The research group from the Cryosphere Research Station in the QTP, Chinese Academy of Sciences, has conducted extensive investigations and monitoring on the distribution and characteristics of permafrost on the QTP, and used a model for the temperature at the top of permafrost (TTOP model) with full consideration of vegetation, geomorphological and geological background based on a large number of investigations and monitoring data. The modeled permafrost distribution has been well verified. The results showed that the permafrost and seasonally frozen ground on the QTP are 1.06×106 km² and 1.45×106 km², respectively, accounting for 40.2% and 56.0% of the entire QTP (Fig. 12).

The permafrost on the QTP can be classified into five types: very stable (MAGT < -5 °C), stable (-5 °C < MAGT < -3 °C), sub-stable (-3 °C < MAGT < -1.5), transition (-1.5 °C < MAGT < -0.5 °C) and unstable (-0.5 °C < MAGT < 0.5 °C), with the areas of 0.059×106 km², 0.195×106 km², 0.308 ×106 km², 0.224×106 km² and 0.229×106 km², respectively (Fig. 12a). Sub-stable (30.4%), transitional (22.1%) and unstable permafrost (22.6%) compose the majority of permafrost region on the QTP.

Using MAGT (Fig. 12a) and an inverse relationship, the spatial distribution of permafrost thickness on the QTP is obtained (Fig. 12b). Results reveal that permafrost thickness ranges from several meters to about 350 m on QTP. Permafrost thickness is more than 200 m near the mountain ridges with very high elevation (generally higher than 5500 m asl), 60-130 m under hilly landscape and less than 60 m in the valley bottom of high plateau. Permafrost is 13-17 m thick on the eastern QTP, and about 20 m in the hinterland of QTP along the QTH. Results show that the total ground ice storage in the permafrost regions on the QTP is about 12.7×103 km³ water equivalent (Fig. 12c). Ground ice content increases from south to north and from east to west on the QTP, and is higher in the HohXil area and West Kunlun Mountains than the other regions.

Fig. 13. Palaeoglacial geomorphology in the eastern edge of the QTP. (a) Sorted nets near the Kangding Airport on the Zheduo Mountain; (b) Solifluction terrace near the Garze County; (c) Pattered ground on the Bangda Hill; (d) Rock glacier on the Zheduo Mountain.

THE SECOND TIBETAN PLATEAU SCIENTIFIC EXPEDITION & RESEARCH (STEP)

The First Tibetan Plateau Scientific Expedition and Research was carried out 50 years ago. The climate warming on the plateau is twice the global average during this period which has lead to great changes in the pattern of the ecological environment and water cycle in the plateau, such as glacier retreat, permafrost degradation, ice lake break-up, ice avalanche, grassland degradation, frequent debris flow. The Second Tibetan Plateau Scientific Expedition (STEP) was planned and started in 2017, focusing on the changes of the Earth system on the Tibet Plateau and its key scientific issues. Dr. Niu Fujun's team of the State Key Laboratory of Frozen Soil Engineering undertook the "*Scientific Investigation on Frozen and Thawing Disasters and Major Diseases of Permafrost Engineering*" in 2019. They mainly carried out the investigation of frozen and thawing phenomena (Fig. 13) along the Sichuan-Tibet Railway, which is under construction, and the paleo-permafrost environment. They also investigated

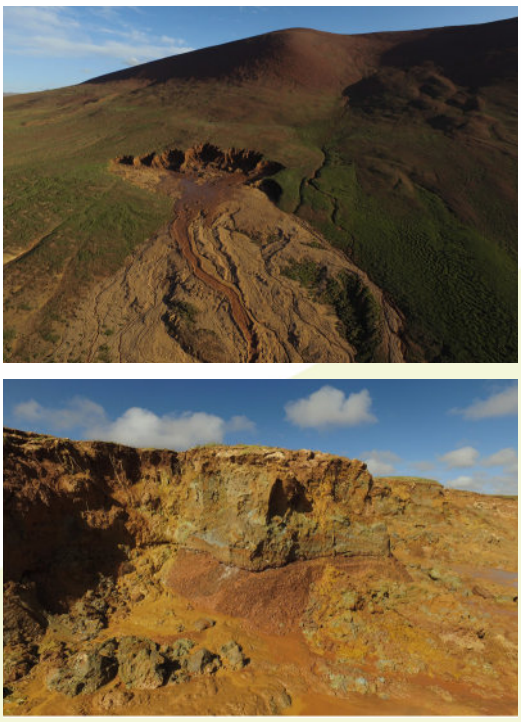

Fig. 14. Retrogressive thaw-slumping on the Gushan Hill near the Beiluhe Basin in the QTP.

Fig. 15. Thaw settlement in the highway embankments in permafrost regions of the QTP. (a) Serious thaw settlement in the old Qinghai-Tibet Highway embankment; (b) Thaw settlement in the new constructed GYE.

regional thawing disasters in Hoh Xil (Fig. 14), and investigation on engineering diseases in permafrost regions of the Qinghai-Tibet Highway, the Qinghai-Tibet Railway and the GYE (Fig. 15).

2020 OPENING OF NEW FIELD MONITORING & RESEARCH FOUNDATIONS

The Beiluhe Observation and Research Station on Frozen Soil Engineering and Environment in the QTP (Fig. 16a), was founded in August 2002 under the strong supports of the Chinese Academy of Sciences and the Ministry of Railways. The station is located in the QTP (34°51'14" N, 92°56'24" E, 4628m asl), and is 320 km from the Golmud City in the south. In 2020, the Beiluhe Station qualified as National Sci-Tech Innovation Bases by the Ministry of Science and Technology, China.

Fig. 16. New qualified national field observational stations for permafrost and permafrost engineering research. (a) Beiluhe Observation and Research Station; (b) Field Observational Station for the Roadway Permafrost Engineering

The Field Observational Station for the Roadway Permafrost Engineering in the QTP (the FOS, Fig. 16b) was built jointly by the CCCC First Highway Consultants Co. Ltd and the Qinghai Province Transportation Institute, and also listed as one of the preferentially built National Sci-Tech Innovation Bases by the Ministry of Science and Technology, China. This station is located on the eastern edge of the QTP, along the GYE.

In 2020, the Da Xing'anling Observation and Research Station of Frozen-Ground Engineering and Environment (50°22'30'' N, 124°6'26'' E) was founded, to improve the study of permafrost in northeast China. Through collecting and monitoring of ground temperature and meteorological data, it aims to understand permafrost degradation and environmental change in middle- and high-latitude cold regions, and the relationship among permafrost, climate change and engineering construction. The monitoring sites have been established along the oil pipeline, highway, railway and airport, and at different environmental sites, such as different vegetation and ground surface types, different latitudes and elevations. The database has been established to serve researchers studying the change and driving mechanism of permafrost, climate and environment. Meanwhile, the engineering measures have been developed to mitigate the frost hazards in the middle- and high-latitudes cold regions.

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FINLAND

BY JAN HORT (UNIVERSITY OF OULU)

FINNISH METEOROLOGICAL INSTITUTE (FMI)

Jouni Pulliainen, Kari Luojus, Kimmo Rautiainen, Hannakaisa Lindqvist, and Tuula Aalto at FMI have developed Earth Observation satellite data-based methods to monitor circumpolar snow cover and soil frost (Fig. 17), including their relation to methane emission from wetlands. The results of the MethEO project funded by the European Space Agency (ESA) provided new insight concerning the relation of autumn methane emissions and the freezing of the permafrost active layer. Additionally, the GlobSnow approach was refined to provide the first reliable assessment on the spatial distribution and trend of the circumpolar seasonal snow mass.

- Pulliainen, J., Luojus, K., Derksen, C., Mudryk, L., Lemmetyinen, J., Salminen, M., Ikonen, J., Takala, M., Cohen, J., Smolander, T., and Norberg, J. (2020). Patterns and trends of Northern Hemisphere snow mass from 1980 to 2018. *Nature* 581, 294–298. DOI: 10.1038/s41586-020-2258-0.

Tuomas Laurila, Mika Aurela, and Juha-Pekka Tuovinen also at FMI continued measurements related to GHG fluxes and GHG and aerosol concentrations in Tiksi, northeastern Russia which began in 2011. The Tiksi station is run in collaboration with Roshydromet (AARI: Vasilii Kustov, Alexander Makshtas, and MGO units). The flux station is located at 71.5943° N, 128.8878° E, 7 m asl, ca. 500 m from the shoreline of the Laptev Sea and ca. 50 km from the Lena River delta.

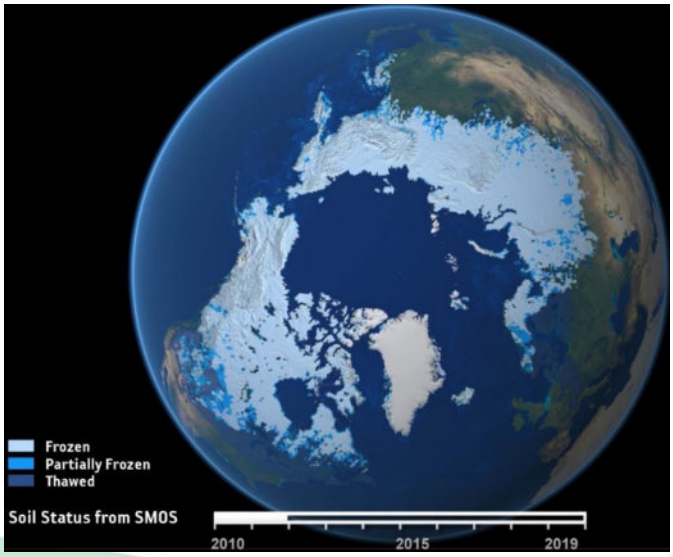

Fig. 17. The status of soil (frozen–partly frozen–thawed) is monitored utilizing Soil Moisture and Ocean Salinity (SMOS) satellite data (ww.esa.int/ESA_Multimedia/Videos/2020/03/Soil_status_from_SMOS).

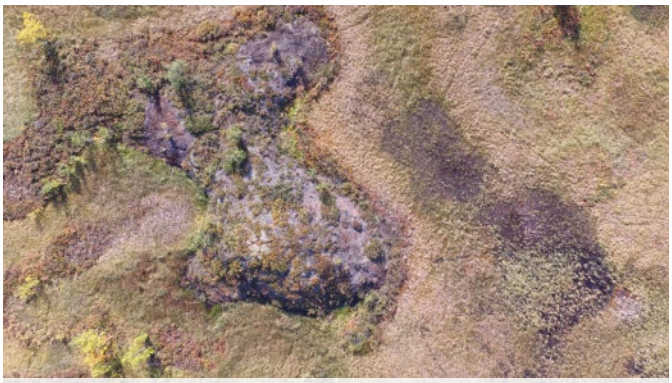

Fig. 18. Palsa in litto, 408 m asl.

UNIVERSITY OF EASTERN FINLAND

Timo Kumpula, Pasi Korpelainen, and Mariana Verdonen in the Department of Geographical and Historical Studies, University of Eastern Finland, have conducted annual high accuracy RTK GPS measurements in two palsas in Laassaniemi and Peera since 2007 (Kilpisjärvi area). Both palsas have about 150 plots from which XYZ and active layer depth are measured annually at the end of August and beginning of September. In the Peera palsa mire, temperature and soil moisture monitoring with loggers has been going on since 2011. Unmanned Aircraft Vehicles (UAV) have been used in monitoring of palsa mires between Markkina and Kilpisjärvi since 2015. At the moment, fifteen different palsa mires are monitored annually with UAV drones in June and August (Fig. 18). In summer 2020, the drone flight campaign was conducted and as a result about 10 km of palsa mire orthophotomosaics and DEM with 3 cm resolution was created.

UNIVERSITY OF HELSINKI

New collaborative projects were established with the '*Arctic Avenue*' funding (a new spearhead research project between the University of Helsinki and Stockholm University). Minna Väliranta, Atte Korhola, and Teemu Juselius from the University of Helsinki are working on the '*Permafrost peatlands under climate warming pressure*' project which aims to increase our knowledge of ground thermal conditions in Fennoscandian permafrost peatlands along a climatic and topographic gradient, in order to bet-

ter project how these environments will be affected by future climate change.

Minna Väliranta is also working on the '*Spatially variable greenhouse gas fluxes from the Arctic permafrost peatlands: the role of biogeochemistry*' project, which intends to test the working hypothesis that microbial activity, which is a function of the active layer depths, contributes to the variable greenhouse gases fluxes in permafrost-associated peatlands in the Arctic. We expect that more organic carbon is available in areas with relatively thick active layers that result in a more persistent anoxic condition as compared to areas with only thin active layers. Such a condition thus favors production of methane over CO_2. In this case, nitrous oxide is expected to be produced by denitrification rather than nitrification due to the low dissolved oxygen content in the soil porewater. As the thickness of active layers is largely a function of the degree of warming, our hypothesis will provide a mechanical explanation on why warming in permafrost facilitates the production of GHGs. To verify this working hypothesis, we will correlate soil fluxes of GHGs with the composition and isotopic signatures of pore solution in the soil, which will be used to infer the microbial reactions that are active.

The third project, led by Minna Väliranta, Hao Li, and Federico Bianchi from the University of Helsinki, concerns '*Volatile organic compound emissions from thawing permafrost*'. Volatile organic compounds (VOCs) play a central role in atmospheric chemistry and climate change by contributing to the formation of secondary organic aerosol (SOA). However, an incomplete understanding of VOCs remains, which yields large uncertainties in quantitative estimates of the climate effects of atmospheric aerosols. A great challenge in understanding VOCs resides in quantification of VOCs emissions, which serves as the basis to model VOCs impacts. Despite being an important group of reactive gases influencing climate change, little is known about VOC emissions from thawing permafrost as related to ongoing climate warming. This project investigates VOC emissions from thawing permafrost.

Minna Väliranta also coordinated a project entitled '*Response of high-latitude peatlands to past and recent warming – predictions for future climate feedbacks*' (2016–2020). It was funded by the University of Helsinki, Academy of Finland, and Chinese Scholarship Council (CSC). To contribute to the development of past and predictive carbon models this project provided vegetation, microbial, hydrology and peat growth rates data derived from a series of high-latitude study sites, which form a circum-Arctic transect. Peatlands play a key role in global carbon cycle and they are sensitive to environmental changes. Briefly, dry peatlands are effective C sinks, but wet peatlands also release C to the atmosphere in a form of methane. We do not yet fully understand how direct the relationship between climate and carbon dynamics is. There is growing interest to model C budgets back in time to facilitate creation of predictive models. Study areas have experienced several notable temperature changes during the last centuries. These changes provided a valuable setting to investigate peatland-climate relationship. First results suggest there is no single environmental factor that alone drives permafrost peatland carbon accumulation. This is manifested by the pattern where in some of the studied permafrost peatlands, warming since 1850 AD has increased carbon accumulation rates while elsewhere there is a slight decrease in carbon accumulation over the same period. These divergent trends suggest that there are alternative response directions to warming in the future and that also an overall decrease in the C sequestration ability may occur for permafrost peatlands. Moreover, preliminary modelling results, carried out in collaboration with scientists from Finnish Meteorological Institute and University of Eastern Finland highlight importance of Arctic peatlands in atmospheric greenhouse gas forcing in long-time scales.

UNIVERSITY OF OULU

Hybrid modelling for improved permafrost risk assessments (HYPERISK) project (2021–2024) was funded by the Kvantum Institute, University of Oulu, and is coordinated by Jan Hjort and Olli Karjalainen. The HYPERISK project continues the work of the INFRAHAZARD (Geomorphic sensitivity of the Arctic region: geohazards and infrastructure) and ArcticSHOC (Spatial ensemble prediction of permafrost thaw, soil carbon and ground-ice in the Arctic) projects. The aim is to produce improved high-resolution permafrost projections, identify critical permafrost hazards, and quantify infrastructure risks across the circumpolar permafrost area. The project has the potential to provide benchmark results for the effects of global warming on the permafrost systems, natural hazards, and infrastructure risks.

Jan Hort continued to monitor temperatures at a palsa in northwest Finland (Kilpisjärvi, Peera).

For more information contact Jan Hort (Jan.Hjort@oulu.fi).

FRANCE

BY ANTOINE SÉJOURNÉ (UNIVERSITÉ PARIS-SACLAY)

GÉOSCIENCES ENVIRONNEMENT TOULOUSE, UNIVERSITÉ PAUL SABATIER TOULOUSE

In 2020, the four year ANR project HiPerBorea started with a kick-off meeting in Toulouse in late February. This project is dedicated to the development of a High Performance Computing simulator for permafrost dynamics, the so-called permaFoam OpenFOAM® solver, and its use for studying the impact of climate change on the permafrost of four environmental monitoring stations in Boreal Eurasia.

The first 3D computations of permafrost dynamics in the Kulingdakan watershed (Central Siberia) have been performed on national French supercomputing infrastructures (OCCIGEN, IRENE-ROME). The associated preliminary results have been presented at the 12th International Conference On Porous Media. They show a good agreement with the available observations, and pave the way to the assessment of 3D effects on the thermo-hydrological transfers in this forested catchment of the continuous permafrost area.

- Orgogozo, L., Pokrovsky, O.S., Grenier, C., Mouche, E., Marcoux, M., and Quintard, M. (2020). *Numerical modeling of coupled heat and water transport for the study of permafrost dynamics: High Performance Computing simulations for watershed scale analysis* [Conference Presentation]. 12th International Conference on Porous Media, 31 August - 4 September 2020.
- Orgogozo, L., Pokrovsky, O.S., Grenier, C., Mouche, E., Marcoux, M., and Quintard, M. (2020). Numerical modeling of coupled heat and water transport for the study of permafrost dynamics: High Performance Computing simulations for watershed scale analysis. In *Interpore2020: Book of Abstracts*, 12th International Conference on Porous Media, 31 August - 4 September 2020, 299-300.

GÉOSCIENCES PARIS-SACLAY, UNIVERSITÉ PARIS-SACLAY

Unfortunately, the team from GEOPS (Geosciences Paris Saclay) could not conduct any field work in Central Yakutia (Eastern Siberia) during 2020 due to the pandemic. However, the team published several papers and were able to launch or continue new international projects. One paper reports on dissolved greenhouse gas (GHG; CO_2 and CH_4) concentrations and fluxes at different seasons in thermokarst lakes of Central Yakutia. The results showed striking differences in dissolved GHGs (up to two orders of magnitude) between lake types and seasons, especially during the winter, a rarely assessed season. Moreover, fluxes measured from lakes of this typical taiga alas landscape were among the highest presented across Arctic and subarctic regions.

- Hughes-Allen, L., Bouchard, F., Laurion, I., Séjourné, A., Marlin, C., Hatté, F., Fedorov, A., and Desyatkin, A. (2020). Seasonal patterns in greenhouse gas emissions from thermokarst lakes in Central Yakutia (Eastern Siberia). *Limnology and Oceanography*, 66(S1), S98-S116. DOI: 10.1002/lno.11665.

Another paper focused on the full-scale physical modelling of Retrogressive Thaw Slumps (RTS) in a cold room. The objectives were to better understand the effect of ice content and permafrost heterogeneities on the dynamics of these erosional features. RTS have significant geomorphological, hydrological and biogeochemical impacts on the landscape. The experimental setup was designed to simulate the thawing of ice-rich permafrost with various ice-rich heterogeneities (ice wedges, icy layers). The results showed that the melting of icy layers induces significant decohesion of the overlapping frozen soil, but the heterogeneous frozen soil with ice wedges undergoes a stronger and faster decohesion of its structure (Fig. 19).

- Costard, F., Dupeyrat, L., Séjourné A., Bouchard, F., Fedorov, A., and Saint-Bézar, B. (2020). Retrogressive Thaw Slumps on Ice-Rich Permafrost Under Degradation: Results From a Large-Scale Laboratory Simulation. *Geophysical Research Letters*, 48(1), 7 p. DOI: 10.1029/2020GL091070.

Finally, an 'Op-Ed article', presenting the IPA-funded Action Group "*Standardized methods across Permafrost Landscapes: from Arctic Soils to Hydrosystems (SPLASH)*", was published in Advances in Polar Science.

- Bouchard, F., Agnan, Y., Bröder, L., Fouché, J., Hirst, C., Sjöberg, Y., the SPLASH team (2020).

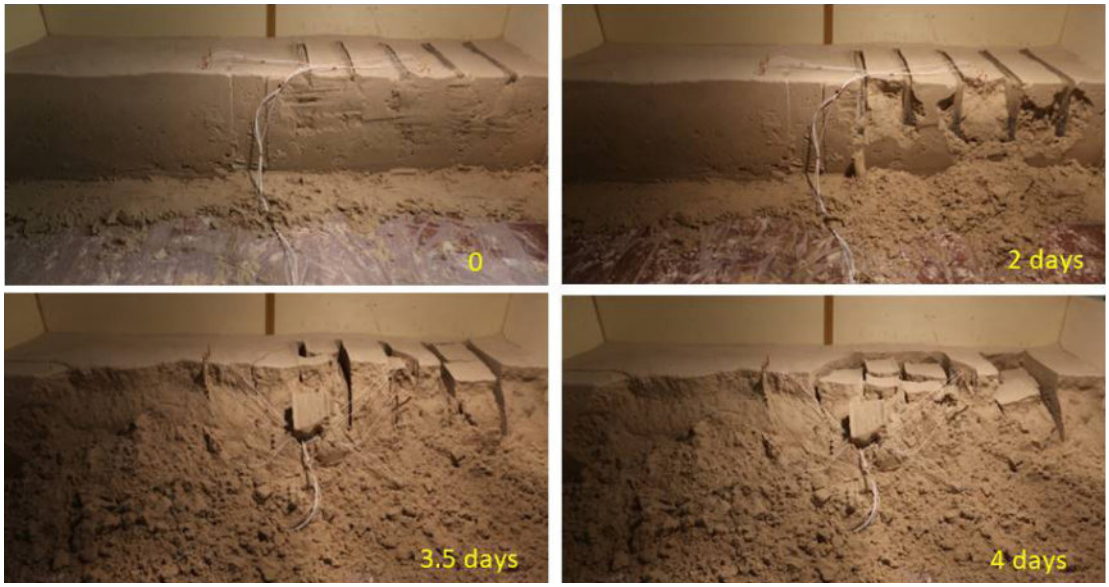

Fig. 19. Retrogressive thaw slumps experiment with ice wedges. The left side of the image shows a homogeneous frozen soil. The right side shows the same frozen soil (saturated fine sand) with additional artificial ice wedge (Costard *et al.*, 2020).

The SPLASH Action Group - Towards standardized sampling strategies in permafrost science. Advances in Polar Science, 31(3), 153-155. DOI: 10.13679/j.advps.2020.0009.

A new project has been successfully funded by the Belmont Forum organization with the call "*Permafrost degradation impacts on soils, human societies, water resources and carbon cycle*". The PRISMARCTYC project (2021-2024) aims to understand the hydrological, geochemical, geomorphological, and microbiological, as well as socio-economic impacts of current permafrost thaw dynamics to soils and surface/groundwaters in the Arctic and sub-Arctic. Our study will focus on the near-surface permafrost-hydrosystem continuum in small Arctic watersheds where localized and rapid thermokarst occurrences remain under-studied. Our team includes scientists from France (Université Paris-Saclay, Université de Toulouse, Institut de Recherche pour le Développement), Russia (Melnikov Permafrost Institute, University of Moscow, Institute of Physico-Chemical and Biological Problems in Soil Science), USA (University of Alaska Fairbanks) and Japan (University of Hokkaido). The outcome is to provide a better understanding of the evolution of small Arctic permafrost watersheds and raise awareness of local communities.

An outreach project "*Describe me the country where you live*" is funded (2020-2021) by the Diagonale Paris-Saclay for promoting the cultural, linguistic and scientific exchange between a school in Central Yakutia (Syrdakh settlement) and two schools near Paris (Chatenay Malabry). The aim here is to develop activities about climate change and exchanges between French and Sakha children.

LABORATOIRE DES SCIENCES DU CLIMAT ET DE L'ENVIRONNEMENT, UNIVERSITÉ PARIS-SACLAY

LSCE activities were strongly altered from the 2020 confinements leading to the canceling of the experimental work in the cold room at GEOPS facility for the second phase of InterFrost, the associated communication at the European Geophysical Union (EGU) and the field trip to Yakutia in September. Nevertheless, the InterFrost website has been improved by providing access to all results from Phase 1 for future modelers to use them.

A climate data analysis study carried out on the Lena catchment focuses on the evolution of the important climatic driver precipitation and temperature in the permafrost region regarding the time of emergence of climate change (ToE). Meteorological station data as well as reanalysis and CMIP5 simulations were combined for the 1920-2100 period and a robust statistical method for the calculation of ToE was developed (Fig. 20).

- Pohl, E., Grenier, C., Vrac, M., and Kageyama, M. (2020). Emerging climate signals in the Lena River catchment: a non-parametric statistical approach. *Hydrology and Earth System Sciences*, 24(5), 2817-2839. DOI: 10.5194/hess-24-2817-2020.

LABORATOIRE DE PLANÉTOLOGIE ET GÉODYNAMIQUE, UNIVERSITÉ DE NANTES

The French National Research Agency (ANR) funded the four-year PERMOLARDS project in 2019 which is investigating the role of degrading permafrost in triggering landslides through the study of "molards". Molards are cones of debris formed

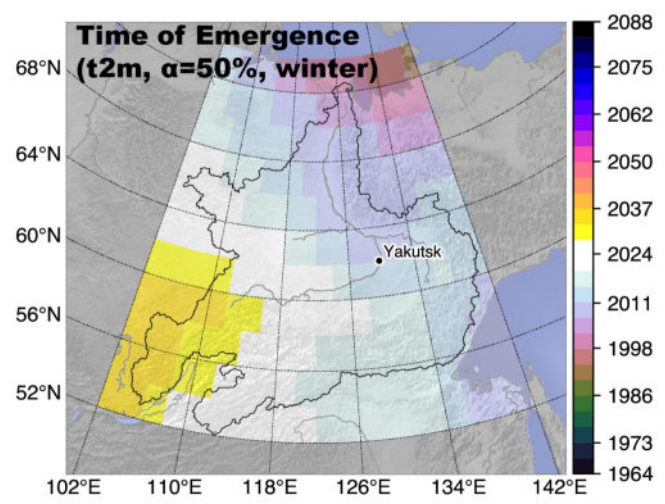

Fig. 20. Time of emergence of climate change in the Lena water catchment (Pohl *et al.*, 2020).

when ice-cemented sediment blocks transported downslope during landslides disaggregate via melting of the cementing ice. They have received scant prior attention but recent work showed they are important markers of degrading permafrost and indicators of landslide dynamics informing hazard assessments (Fig. 21).

- Morino, C., Conway, S.J., Sæmundsson, Þ., Helgason, J.K., Hillier, J., Butcher, F.E.G., Balme, M.R., Jordan, C., and Argles, T. (2019). Molards as an indicator of permafrost degradation and landslide processes. *Earth and Planetary Science Letters*, 516, 136-147. DOI: 10.1016/j.epsl.2019.03.040.

The project includes partners and collaborators from six institutes in France (LPG, EDYTEM, M2C, LMV, IPGP, and GEOPS), and in Denmark, Iceland, Italy, Norway, and UK. The fieldwork planned for Greenland and Iceland in 2020 has been postponed, and the coldroom experiments to form analogue molards are just beginning. In our remote sensing study, we have catalogued candidate molards on nearly all major continents in steepland discontinuous permafrost regions and we are currently analysing the stereo-image-derived digital terrain models at 2 m/pix obtained via the support of the French Space Agency CNES using the Pléiades constellation.

LITTORAL, ENVIRONNEMENT, TÉLÉDÉTECTION, GÉOMATIQUE, UNIVERSITÉ DE NANTES

The scientific actions carried out by the French CNRS lab LETG UMR6554 (Brest and Nantes) for the understanding of arctic and subarctic environments deal with (i) storminess and erosive dynamics of the rocky and sedimentary coasts in Iceland, (ii) coastal sedimentary construction dynamics (coastal plains and deltas) in Svalbard, and (iii) slope dynamics in Nunavik (northern Quebec). These researches are supported by LabEx DRIIHM (Nunavik), and the French polar Institute Paul-Emile Victor (IPEV – all projects).

The pandemic situation over 2020 has impeded field campaigns; however, research has focused on data acquired during previous field campaigns, highlighting:

- Topo-morphological changes of the rocky and accumulation coasts in specific spots of Reykjanes peninsula, Iceland: project EXTREMEVENT IPEV (Serge Suanez, Université de Bretagne Occidentale & LETG-Brest; Pierre Stéphan, CNRS, LETG-Brest; in collaboration with Jérôme Ammann, CNRS LGO UMR6538, Brest, Guillaume Marie, David Didier, Ronan Autret, UQAR, Sigurður Sigurðarson, Vegargerðin Íslands).

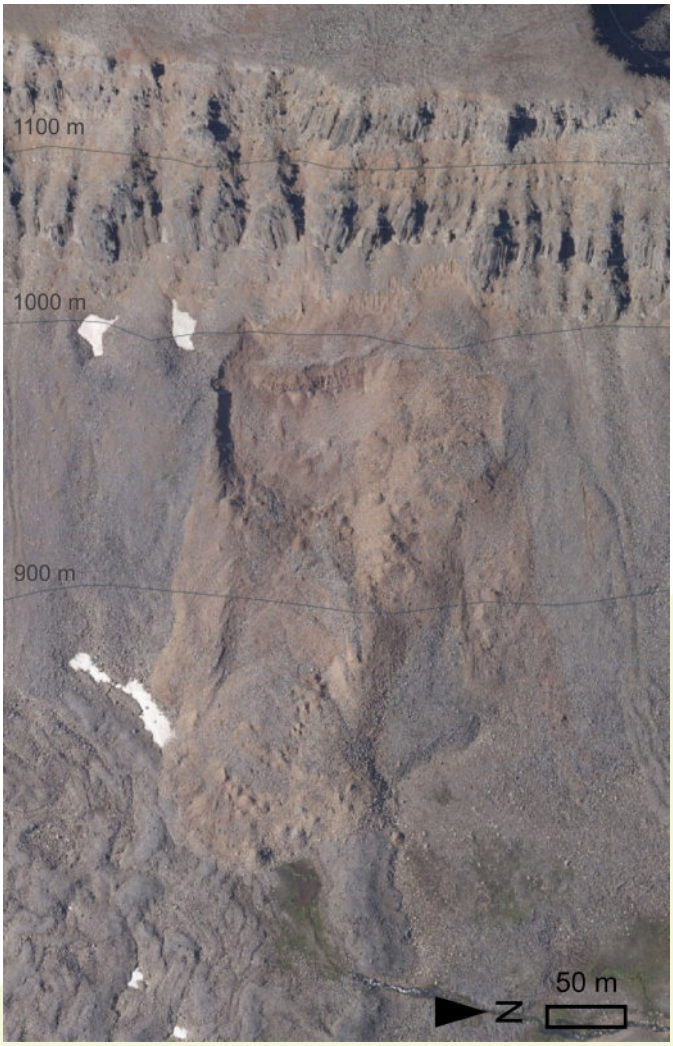

Fig. 21. Aerial image of a recent landslide in northern Iceland near Holar which has molards in the deposits. Photo: Susan Conway (LPGN).

- The development of submarine prodeltas linked with the accelerating discharge of proglacial rivers in Kongsfjorden, Svalbard, revealing a notable development of fauna and flora in the prodeltas: project KONBHAS IPEV (Agnès Baltzer, Université de Nantes & LETG-Nantes, in collaboration with Hélène Howa, Université d'Angers, lab LGP-BIAF).
- The snow-avalanche regime over the last winters nearby Umiujaq, in Nunavik and the conducive meteorological conditions: project MOVE – OHMi NUNAVIK/LabEx DRIIHM & DeSiGN IPEV (Armelle Decaulne, CNRS, LETG-Nantes, in collaboration with Najat Bhiry, Centre d'études Nordiques & université Laval, Québec).

LABORATOIRE ENVIRONNEMENTS, DYNAMIQUES ET TERRITOIRES DE MONTAGNE, UNIVERSITÉ SAVOIE MONT BLANC - LABORATOIRE DE SCIENCES SOCIALES, UNIVERSITÉ GRENOBLE ALPES

We present here the activities of a research group composed of members of different institutions/laboratories, notably EDYTEM (CNRS / USMB, Le Bourget-du-Lac) and PACTE (CNRS / IEP / UGA, Grenoble) labs. The research group has pursued investigations on mountain permafrost and is mainly focused on two main geomorphological objects that are rock faces and rock glaciers.

Rock faces

We drilled and equipped a new 20 m deep borehole in the Vanoise massif in the frame of the EU POIA PermaRisk project, at about 3350 m asl in a north-exposed face , in a c. 60° slope, in the Tignes ski resort. This borehole will allow a long-term monitoring of the active layer thickness and permafrost evolution. Its settings and data will be uploaded in the GTN-P data base.

In the Mont Blanc massif, 10 years of data are now available for the three 10 m deep boreholes of the Aiguille du Midi (3842 m asl). In 2020, a fourth 10 m deep borehole was equipped in a north face of this site. The 17 m deep borehole at the Grands Montets site (3290 m asl), equipped in 2017 has been maintained, and data were collected in 2019.

Investigations on rockwall permafrost processes are enhanced through the starting of the ANR WISPER project that will focus on water- and ice-related processes in rockwall permafrost fractures. A geoelectrical monitoring system has been partly installed at the Aiguille du Midi, with three 160 m long cables. Regular data acquisitions have been performed through Summer and early Fall 2020 and automatic acquisitions will be performed within the coming years to assess permafrost dynamics using petrophysical models such as recently developed for the Cosmiques ridge (3613 m asl).

- Duvillard, P.-A., Magnin, F., Revil, A., Legay, A., Ravanel, L., Abdulsamad, F., Coperey, A. (2020). Temperature distribution in a permafrost-affected rock ridge from conductivity and induced polarization tomography. *Geophysical Journal International*, 225(2), 1207-1221. DOI: 10.1093/gji/ggaa597.

Rockfall inventory has been carried out over 2020 providing 13 years of continuous records and a data base of ~1300 events. This data base will be used to map areas most susceptible to rockfall detachment in the frame of Maeva Cathala's PhD, funded by the Alpes-Ingé company and the French ANRT.

Rock glaciers

Within the PhD and post-doc of Marco Marcer (funded by the POIA PermaRisk project), a complete inventory of destabilized rock glaciers and their evidences (fractures, crevasses, sliding) has been created and published, as well as a specific study of the Lou rock glacier site explained the role of destabilization in the occurrence of debris flow.

- Mercer, M., Serrano, C., Brenning, A., Bodin, X., and Goetz, J. (2019). Evaluating the destabilization susceptibility of active rock glaciers in the French Alps. *The Cryosphere*, 13, 141-155. DOI: 10.5194/tc-13-141-2019.
- Mercer, M., Nielsen, S.R., Ribeyre, C., Kummert, M., Duvillard, P.-A., Schoeneich, P., Bodin, X., and Genuite, K. (2020). Investigating the slope failures at the Lou rock glacier front, French Alps. *Permafrost and Periglacial Processes*, 31(1), 15-30. DOI: 10.1002/ppp.2035.

On this aspect of rock glacier mechanics, a collaboration with ISTerre Lab (Grenoble) demonstrated the potential of passive seismic signal for characterizing mechanical variations in space and time. In parallel, a finite-element model using Lagrangian integration point is under development with 3SR lab. On the same site (Laurichard rock glacier), we set up and evaluated a time-lapse stereo-photogrammetric device that allows measuring spatial fields of surface displacement at a temporal resolution of a few days.

- Guillemot, A., Baillet, L., Garambois, S., Bodin, X., Helmstetter, A., Mayoraz, R., and Larose,

E. (2021). Modal sensitivity of rock glaciers to elastic changes from spectral seismic noise monitoring and modeling. The Cryosphere, 15(2), 501-529. DOI: 10.5194/tc-15-501-2021.
- Melki, S., Daudon, D., Bodin, X., and Thibert, E. (2021). Analysis of the Mechanical Behavior of the Laurichard Rock Glacier (French Alps) in the Recent Climatic Changes. In: Barla M., Di Donna A., Sterpi D. (eds) *Challenges and Innovations in Geomechanics*. IACMAG 2021. Lecture Notes in Civil Engineering, vol 126. Springer, Cham. DOI: 10.1007/978-3-030-64518-2_109.
- Marsy, G., Vernier, f., Bodin, X., Castaings, W., and Trouvé, E. (2020). Temporal Consolidation Strategy for Ground Based Image Displacement Time Series. *IGARSS 2020 - 2020 IEEE International Geoscience and Remote Sensing Symposium*, Waikoloa, HI, USA, 132-135. DOI: 10.1109/IGARSS39084.2020.9324394.

The work of postdoc Mario Kummert (2019-2021) allowed significant advances on the evaluation of the rock glacier / torrent connectivity in the French Alps. Since September 2020, post-doc Benjamin Lehmann has focussed on the long-term development of the rock glaciers coupling cosmonuclides with dynamic modelling of rock glacier mass balances.

A joint effort of EDYTEM, PACTE and IGE labs was devoted in 2019 and 2020 to the investigation of the role of glacier and permafrost in thermokarst evolution (funded by the POIA PermaRisk project) on two sites (Tignes and Chauvet).

Bio-geomorphological investigations were initiated on the Grande Cayolle catchment (Southern French Alps) in collaboration with CBNA (Conservatoire Botanique National Alpin) and the Mercantour National Park (Fig. 22).

For more information see: Cicoira, A., Marcer, M., Gärtner-Roer, I., Bodin, X., Arenson, L.U., and Vieli, A. (2020). A general theory of rock glacier creep based on in-situ and remote sensing observations. *Permafrost and Periglacial Processes*, 32(1), 139-153. DOI: 10.1002/ppp.2090.

OTHER INFORMATION

Thomas Echelard (funded through the PermaRisk project) worked on organizing, securing and ultimately distributing the data collected on rock glaciers in the French Alps since the early 2000s. The group members are involved in the IPA Action Group on rock glaciers, especially in the workshop held in February 2020 in Fribourg (Switzerland). Philippe Schoeneich continues with the GTN-P steering committee as the permafrost representative for GCOS-TOPC.

For more information contact Antoine Séjourné (antoine.sejourne@universite-paris-saclay.fr).

Fig. 22. The upper area of the Grande Cayolle catchment, with a typical Alpine periglacial landscape and, a strongly destabilized rock glacier on the right on which the plant ecology is investigated. Photo: Florence Magnin.

GERMANY

BY MICHAEL FRITZ (ALFRED WEGENER INSTITUTE, POTSDAM)

UNIVERSITY OF BAYREUTH

Our university started work in the new German esearch Foundation (DFG) project ClimRock ("*Characterizing Rockwall Weathering from Microclimate, Rock Moisture and Rockfall Activity*", 2020-2023). The aim of the project is to quantify rock moisture regimes and their role for weathering and to quantify the thermal regime and their role for frost and thermal weathering in alpine rockwalls. For this purpose, our research team installed rock moisture, temperature and kinematic loggers in rockwalls at the Dachstein (Austria) and the Dammkar Valley (Germany; Fig. 23). We conducted a rockwall laserscanning campaign to quantify weathering-induced rockfall. The research team consists of Oliver Sass, Daniel Draebing, Andrew Mitchell, and Till Mayer. We collaborate with Michael Krautblatter (TU Munich), Martha-Cary Eppes (University of North Carolina, USA), Heather Viles (Oxford University, UK) and Sam McColl (Massey University, NZ).

Fig. 23. View from the upper north-facing rockwall in the Dammkar Valley, German Alps. Photo: Andrew Mitchell.

A research team consisting of Jana Eichel (Utrecht University) and Daniel Draebing monitored the movement of turf-banked solifluction lobes along an altitudinal gradient in the Turtmann Valley using UAV and Structure-for-motion techniques. The team authored a paper on UAV-monitoring on solifluction lobes and linked the movement pattern to material properties, freeze-thaw activity and vegetation patterns.

- Eichel, J., Draebing, D., Kattenborn, T., Senn, J.A., Klingbeil, L., Wieland, M., and Erik Heinz. (2020). *Permafrost and Periglacial Processes*, 31(1), 97-109. DOI: 10.1002/ppp.2036.

For more information contact Oliver Sass (oliver.sass@uni-bayreuth.de) and Daniel Draebing (d.draebing@uni-bayreuth.de).

UNIVERSITY OF BONN

The Geomorphology and Environmental Systems Group at the Department of Geography, headed by Lothar Schrott, have successfully completed studies on the regional distribution, ice content, and hydrological significance of rock glacier permafrost in the Central Andes of Argentina (DFG funded project PermArg) with two recently accepted articles. One paper highlights surface velocity fields of active rock glaciers and ice-debris complexes in the Central Andes of Argentina. The other paper focuses on the ice content and interannual water storage changes of the active Dos Lenguas rock glacier in the dry Andes of Argentina.

- Blöthe, J.H., Halla, C., Schwalbe, E., Bottegal, E., Trombotto Liaudat, D., and Schrott, L. (2020). Surface velocity fields of active rock glaciers and ice-debris complexes in the Central Andes of Argentina. *Earth Surface Processes and Lanforms*, 46(2), 504-522. DOI: 10.1002/esp.5042.
- Halla, C., Blöthe, J.H., Baldis, C.T., Trombotto Liaudat, D., Hilbich, C., Hauck, C., and Schrott, L. (2020). Ice content and interannual water storage changes of an active rock glacier in the dry Andes of Argentina. *The Cryosphere*, 15, 1187-1213. DOI: 10.5194/tc-15-1187-2021.

Volumetric ice and water contents were quantified using a petrophysical four-phase model (4PM) based on complementary electrical resistivities (ERT) and seismic refraction tomographies (SRT) in different positions of the respective rock glacier. Vertical and horizontal surface changes were derived for the periods 2016–2017 and 2017–2018 using drone-derived DEM's. The study underpins quantitatively the hydrological significance of active rock glaciers as water stores, regulators and runoff contributors in

dry mountain catchments. Ice-rich permafrost plays a key role in terms of water storage and water releases. The findings will be integrated and extended in upcoming projects focusing on the distribution, ice content, and hydrologic significance of so far overlooked blockslopes and talus slopes in the semiarid Andes.

For more information contact Lothar Schrott (lothar.schrott@uni-bonn.de), Christian Halla (christian.halla@uni-bonn.de), and Jan Blöthe (jan.bloethe@geographie.uni-freiburg.de).

TECHNICAL UNIVERSITY OF MUNICH

The Landslide Research Group of Michael Krautblatter investigated permafrost affected slopes in the European Alps as well as in Norway, Canada and Ecuador. The recently started AlpSenseRely project, financed by the Bavarian State Ministery, aims at developing benchmark in-situ and remote sensing techniques for investigation of climate-change affected permafrost phenomena in the European Alps. These techniques are applied to active sites for real time monitoring and early warning of hazards.

Philipp Mamot completed his PhD research with a stability assessment of degrading permafrost rock slopes based on a coupled thermo-mechanical model.

- Mamot, P., Weber, S., Eppinger, S., Krautblatter, M. (in review, 2020). Stability assessment of degrading permafrost rock slopes based on a coupled thermo-mechanical model. *Earth Surface Dynamics* [preprint]. DOI: 10.5194/esurf-2020-70.

Theresa Raab aim at deciphering the role of permafrost as trigger mechanism of secondary lahars at Cotopaxi volcano in Ecuador. She conducted resistivity calibration of field rock samples in the TUM freezing laboratory to improve the interpretation of ERT profiles in proglacial areas with regard to the structure and condition of the subsurface. This work is part of the recently extended RIESGOS project funded by the German Federal Ministry of Education and Research.

Saskia Eppinger worked on the data collected on Herschel Island (Canada) comparing past and present ERTs with laboratory calibrations, to detect decennial changes and gain a better understanding of the internal thermal behavior.

As conclusion of the CryoWall Project funded by the Norwegian Research Council, a paper was published on monitoring permafrost and understanding its role in unstable rock slopes in Norway.

- Etzelmüller, B., Czekirda, J., Magnin, F., Duvillard, P.-A., Malet, E., Ravanel, L., Aspaas, A., Kristensen, L., Skrede, I., Majala, G. D., Jacobs, B., Leinauer, J., Hauck, C., Hilbich, C., Böhme, M., Hermanns, R., Eriksen, H. Ø., Krautblatter, M., and Westermann, S. (in review, 2021). Permafrost in monitored unstable rock slopes in Norway – New insights from rock wall temperature monitoring, geophysical surveying and numerical modelling. *Earth Surface Dynamics* [preprint]. DOI: 10.5194/esurf-2021-10.

IGSSE founded by Riccardo Scandroglio worked on 4D quantification of permafrost changes in alpine bedrock. With the help of ERT monitoring, he could detect and quantify for the first time a reduction up to 50% of the frozen volume in 13 years. Results will be soon available in Near Surface Geophysics. He also worked on developing new methods for monitoring the hydrothemal state of permafrost, e.g. with relative gravimetry and induced polarization, in cooperation with the University of Bonn (Andreas Kemna).

Regina Pläsken continued her PhD research on a mechanical model of the Kitzsteinhorn considering the mechanical interaction of permafrost rock and alpine infrastructure.

Funded by the Elite Network of Bavaria, Tanja Schröder improved and prepared for publication her thermal model of the Zugspitze summit crest showing permafrost distribution and evolution during the last decade.

For more information contact Michael Krautblatter (m.krautblatter@tum.de).

UNIVERSITY OF HAMBURG

Within the framework of the DFG Cluster of Excellence *Climate, Climate Change, and Society (CLICCS)*, the project *CLICCS-A1 'Carbon Dynamics in the Arctic'* studies carbon cycle processes in permafrost landscapes by combining observations obtained in field research with process-based modeling on pedon-, landscape- and ESM-scales. Currently, two PhD students are working in CLICCS-A1: Leonardo de Aro Galera (group of Eva-Maria Pfeiffer) and Lutz Beckebanze (group of Lars Kutzbach).

Leonardo de Aro Galera isinvestigating the regulation of CO_2 and CH_4 production in soils affected

by thawing permafrost. He found in water-saturated soils of the Lena Delta, a clear negative correlation between active layer depth and CO_2:CH_4 ratio, which may be highly variable. Furthermore, multi-annual measurements of small scale CO_2 and CH_4 fluxes from thawing permafrost soils of an active thaw slump indicate that labile organic matter is rapidly depleted, causing gaseous carbon fluxes from thawing permafrost to decline as long as no fresh vegetation is established.

Lutz Beckebanze is investigating the net ecosystem C balance of the heterogenous polygonal tundra on the landscape scale. He is analyzing the dynamics of lateral carbon fluxes by dissolved organic and inorganic C in discharge water and their contribution to the net ecosystem C balance. Another focus of his work is on the quantification of CO_2 and CH_4 fluxes from shallow water bodies, which are widespread in polygonal tundra due to thermokarst processes. *For more information contact Christian Knoblauch (Christian.Knoblauch@uni-hamburg.de).*

In a new DFG project Melanie Kern started to work on a process-oriented model of frost heave which is one important process explaining cryoturbation besides gelifluction. *For more information contact Melanie Kern (Melanie.Kern@uni-hamburg.de) and Christian Beer (Christian.Beer@uni-hamburg.de).*

In two new PhD projects supervised by Christian Beer and Christian Knoblauch, Lara Kaiser and Cosima Schröer try to explain aerobic and anaerobic organic matter decomposition observed in soil incubation studies by a process-oriented model. *For more information contact Cosima Schröer (cosima.schroeer@uni-hamburg.de), Lara Kaiser (Lara.Kaiser@uni-hamburg.de), and Christian Beer (Christian.Beer@uni-hamburg.de).*

ALFRED WEGENER INSTITUTE (AWI)

AWI & Helmholtz Centre Geesthacht (HZG)

As a cooperation project between AWI, Permafrost Research Section (Hugues Lantuit), and HZG, Institute of Carbon Cycles (Helmuth Thomas), a three-week fieldwork campaign at the mountainside of Iškorasfjellet in Northern Norway from mid-September to beginning of October 2020 was conducted (Fig. 24). The main aim of this project is to investigate the impact of permafrost thaw on erosion rate and alkalinity production in Arctic catchments. It is funded by the DAAD from funds of the BMBF. Nele Lehmann (AWI/HZG), Mascha Treblin (University of Hamburg) and Lukas Detjen carried out the fieldwork. *For more information contact Nele Lehmann (nele.lehmann@awi.de).*

Fig. 24. View to Northeast at Iškorasfjellet during fall 2020 Photo: Lukas Detjen.

FluxWin (ERC starting grant)

Siikaneva, Finland fieldwork October 2020 (Fig. 25) for the new FluxWIN project to investigate annual greenhouse gas flux (including CO_2, CH_4 and N_2O) dynamics in high frequency with special emphasis on the non-growing season biogeochemical drivers. This new project focuses on how C and N cycling and resulting greenhouse gas emissions are affected by soil freezing and thawing to understand how now-frozen permafrost soils will respond to permafrost thaw as soils that are always frozen shift to becoming seasonally or perennially thawed with increased plant activity.

The FluxWIN field site includes three ecosystems along a moisture gradient from wetland bog to upland forest. A new meteorological station was installed at the upland forest site to complement an existing weather station in the wetland 'SMEAR II Siikaneva 2 wetland' publicly available at Fairdata.fi to monitor differences in the microclimate between the sites. Plant Root Simulators were installed to remain in the field over the winter season to monitor nutrient availability rates for all soil ions (NO_3-, NH_4+, $H2PO_4$-, SO_4^{2-}, K+, Ca_{2+}, Mg_{2+}) with ion exchange resin membranes. Initial pore water and soil samples were taken for site descriptive analysis such as C & N stocks, SOM, particle size analysis, particle density, dissolved organic C & N, nitrate, nitrite, ammonium. Lipid biomarkers will be analyzed to elucidate the origin and distribution of organic matter for future decomposition assumptions. $\delta^{13}C$

of dissolved CH_4 and CO_2 in porewater shall indicate different emission pathways. Finally, soil samples were taken until 1 m soil depth for incubation studies back at AWI Potsdam.

For more information contact Lona van Delden (lona.van.delden@awi.de) and Claire Treat (claire.treat@awi.de).

Fig. 25. Siikaneva wetland bog with upland forest in the background, Finland, October 2020.

MOSAiC Permafrost

AWI Permafrost scientists Michael Angelopoulos, Josefine Lenz, and Anne Morgenstern took part in the MOSAiC expedition. Remote sensing observations traced the origin of the MOSAiC central ice floe to the New Siberian Islands where the ice started to form during a polynya event in December 2018. The presence of sediment in multiple sea ice cores from autumn 2019 also demonstrated that the floe was once in contact with shallow shelf waters. Methane that is produced or released by shelf sediments can be up-taken by sea ice and transported into the Central Arctic Ocean by the Transpolar Drift Stream. The biogeochemistry team traced the evolution of sea ice permeability, as well as the pathways of climate-relevant gases (CRG) like methane from autumn to spring for first-year ice, second-year ice, as well as ridged and rafted ice. Through an improved understanding the processes affecting gas fluxes, we can better quantify the Arctic CRG budget.

For more information contact Michael Anfelopoulos (michael.angelopoulos@awi.de).

Lena Expedition 2020

The yearly Russian-German Expedition LENA usually works from April to September in the Lena River Delta region and uses the Research Station Samoylov Island as its scientific and logistical base. Due to the pandemic-related travel restrictions only 12 participants from Russian institutions could visit the Lena Delta in August and September 2020 (compared to 90 Russian and German participants in April to September 2019).

However, thanks to the longstanding and trustful partnership between Russian and German scientists and the support of the Samoylov station staff, all major joint long-term observations and measurements could be continued, e.g. the Samoylov long-term permafrost observatory and the Lena River water monitoring program. This is especially important in light of the extraordinary heat wave over Siberia this summer and its effect on the permafrost ecosystems and their feedbacks with the climate system. The high frequency monitoring of Lena River water biogeochemistry close to the river mouth at the Research Station Samoylov Island now comprises a dataset over two hydrological years. Parameters such as dissolved organic carbon, colored dissolved organic matter, electrical conductivity, temperature and stable water oxygen isotopes are measured every few days and provide improved flux measurements for mass and energy carried by the Lena River to the Arctic Ocean.

For more information contact Anne Morgenstern (Anne.Morgenstern@awi.de).

Finland 2020

In a joined project with the University of Potsdam, a field campaign in Northern Finland was carried out in September 2020. Torben Windirsch (AWI, University of Potsdam) and Matthias Fuchs (AWI) sampled peatlands with different intensities of reindeer influence (Fig. 26) on the premises of the Kutuharju Field Research Station, run by the Reindeer Herder's Association of Finland, and in the surrounding wilderness. The aim of this field campaign was to collect samples to determine the reindeer's influence on soil carbon storage. To achieve this, the station's premises with controlled reindeer population and variable grazing intensities were selected as the main study area, with additional samples taken from the non-managed surroundings. This field campaign was part of the "Permafrost Carbon Stabilization by Recreating a Herbivore-Driven Ecosystem (PeCHEc)" PhD project.

For more information contact Torben Windirsch (torben.windirsch@awi.de).

Fig. 26. Reindeer passing by a sampling site on the Kutuharju Field Research Station premises; the vegetation pictured shows signs of intense reindeer influence. Photo: Torben Windirsch.

German-British CACOON

Organized by the German Federal Ministry of Education and Research (BMBF) and hosted by AWI and the NERC-BMBF project 'Changing Arctic Carbon Cycle in the Coastal Ocean Near-Shore (CACOON)' the "Arktis im Wandel – Changing Arctic Ocean Annual Science Meeting" took place in Potsdam, Germany. Moreover, CACOON was able to get all samples taken in during the Siberian field seasons in 2019 shipped to Germany, start lab work and published a key paper on fast and accelerating eroding permafrost cliff.

- Fuchs, M., Ntize, I., Strauss, J., Günther, F., Wtterich, S., Kizyakov, A., Fritz, M., Opel, T., Grigoriev, M.N., Maksimov, G.T., and Grosse, G. (2020). Rapid Fluvio-Thermal Erosion of a Yedoma Permafrost Cliff in the Lena River Delta. *Frontiers in Earth Science*, 8:336. DOI: 10.3389/feart.2020.00336.

For more information contact Jens Strauss (Jens.Strauss@awi.de).

PermaRisk

The BMBF young investigator group PermaRisk of Moritz Langer aims to investigate the impact of permafrost degradation in infrastructure and ecosystem functions. In 2020, several studies, model developments, and field data were published. Our regular workshop (hackathon) together with the University of Oslo on modeling permafrost with CryoGrid has attracted a growing community of model developers and users. A novel Citizen Science Project UnderCoverEisAgenten in collaboration with DLR-Jena and the Heidelberg Institute for Geoinformation Technology (HeiGIT) funded by the BMBF was granted. Scientific outreach was provided in the frame of digital stories on the impacts of permafrost thaw on local communities including insights into our research goals.

For more information contact Moritz Langer (moritz.langer@awi.de).

Spring expedition to Lake Khamra

From 1-20 March 2020, AWI and the Northeastern Federal University Yakutsk (NEFU) conducted fieldwork at Lake Khamra (Central Siberia). We chartered a MI-8 helicopter and a track vehicle in the village Lensk to bring drilling equipment and people to the study area. We applied an UWITEC (tripod) piston coring system from the ice cover to retrieve long sediment cores. Water depths measurements were performed through ice-holes using a calibrated rope. Trees with fire scars were searched and felled in the catchment. Drone flights were performed on site to catch 150 m long and 20 m wide transects at a flight altitude of 50 m to gain vegetation cover imagery. Accumulation rates of short sediment cores from Lake Khamra retrieved in 2018 showed high mean values of ca. 0.14 cm y^{-1} in the last Centuries. Sampling and analyses of the new sediment cores of up to ca. 12 m length will enable high resolution analyses of charcoal and fire history in the surrounding permafrost area.

For moreinformation contact Boris Biskaborn (Boris.Biskaborn@awi.de).

Outreach proposal "Changing Permafrost"

The outreach project led by Josefine Lenz aims at making the phenomenon of permafrost and implications of a warming climate understandable to a wider audience. With the help of 3D printed thermokarst landscapes, VR glasses and flip images we enable the (almost) full Arctic landscape experience. This is combined by features to comparing the carbon pool (Fig. 27) and area of permafrost, and experiments to see ground settling by perma-

frost thaw. While we are focused on virtual presentations and an image film in 2020, we are eager to test our mobile exhibits in 2021. The project started in January 2020 and is enabled by the Ralf Dahrendorf Award given to the ERC PETA-CARB project (Guido Grosse).

For more information contact Josefine Lenz (Josefine.Lenz@awi.de).

Siberian fire regime shifts

The DFG project led by Elisabeth Dietze (Polar Terrestrial Environmental Systems, AWI) in collaboration with GFZ Potsdam's Organic Geochemistry (Kai Mangelsdorf), aims to understand long-term fire-vegetation interactions during warmer-than-present interglacials. Analysis of the sedimentary anhydrosugar composition (i.e. molecules that form during low-temperature surface fires from the combustion of cellulose and hemicellulose) over the last 430,000 years using Lake El'gygytgyn sediments has revealed that more fire occurred during interglacials compared to late glacials suggesting biomass availability and temperature as dominant drivers on orbital time scales.

Fig. 27. How large is the carbon pool in the northern permafrost region compared to fossil fuels or global soils? The audience can play around with wooden cubes and find the solution inside.

However, on shorter, centennial-millennial time scales the biome composition and overall water availability drives changing fire regimes. A close relationship between the summergreen larch taiga and a surface fire regime was found – a relationship that seems important also to preserve the permafrost, as observed in modern field and dendrochonological studies. With the project, long-term responses to the currently-observed fire regime intensification (more frequent, larger, hotter fires during a longer fire season) can be better understood.

- Dietze, E., Mangelsdorf, K., Andreev, A., Karger, C., Schreuder, L.T., Hopmans, E.C., Rach, O., Sachse, D., Wennrich, V., and Herzschuh, U. (2020). Relationships between low-temperature fires, climate and vegetation during three late glacials and interglacials of the last 430 kyr in northeastern Siberia reconstructed from monosaccharide anhydrides in Lake El'gygytgyn sediments. *Climate of the Past,* 16(2), 799-818. DOI: 10.5194/cp-16-799-2020.

For more information contact Elisabeth Dietze (edietze@awi.de).

ITALY

BY RENATO R. COLUCCI & ANGELINA LO GIUDICE (NATIONAL RESEARCH COUNCIL), MICHELA GIUSTINIANI & UMBERTA TINIVELLA (NATIONAL INSTITUTE OF OCEANOGRAPHY AND APPLIED GEOPHYSICS), MAURO GUGLIELMIN & RICCARDO RIGON (UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA), KATHRIN LANG (TECHNICAL UNIVERSITY OF MUNICH), HÉCTOR MARÍN-MORENO (NORWEGIAN GEOTECHNICAL INSTITUTE), UMBERTO MORRA DI CELLA (ENVIRONMENTAL PROTECTION AGENCY OF AOSTA VALLEY), LUCA PARO (REGIONAL ENVIRONMENTAL PROTECTION AGENCY), DAVID TONIDANDEL & VOLKMAR MAIR (AUTONOMOUS PROVINCE OF BOLZANO).

POLAR REGIONS

In 2020, under the umbrella of the PNRA (Italian National Antarctic Research Program) and within research projects coordinated by Mauro Guglielmin (Università degli Studi dell'Insubria), the Institute of Polar Sciences of the National Research Council (CNR-ISP) in Messina (Italy) carried out microbiological investigations in brine pockets from perennially frozen Antarctic lakes, lying in the Boulder Clay (BC) and Tarn Flat (TF) areas (Northern Victoria Land, Antarctica). The genomic diversity of prokaryotes was explored together with their abundance and metabolic activities. Although similar bacterial and archaeal assemblages were observed at phylum level, differences were encountered when considering the distribution in species.

Overall, the total bacterial communities were dominated by Bacteroidetes. The lakes also hosted sequences of the most thermally tolerant Archaea, also related to well-known hyperthermophiles. RNA sequences of the hyperthermophilic genus Ferroglobus were retrieved in BC brines. A high abundance of the strictly anaerobic methanogens within the active community suggests that anoxic conditions might occur in the lake brines. Diversification of the prokaryotic assemblages between the examined brines were also highlighted in terms of abundance, metabolic potentials and enzymatic activities. In TF brines previous the presence of proteolytic activity, as well as a comparatively lower alkaline phosphatase activity, was observed. Enzymes able to degrade polysaccharides were also detected, whose hydrolytic activity rates were quantitatively different between the studied samples. These peculiar features were ascribed to a lot of factors including brines' historical origin, depth horizon, time of segregation.

Finally, results obtained on the physiological and enzymatic features of cold-adapted bacterial isolates from Antarctic lake brines provided interesting prospects for possible applications in the biotechnological field through future targeted surveys. Our findings indicate perennially ice-covered Antarctic lakes as plausible terrestrial candidates for the study of the potential for extant life on different bodies of our solar system.

In the same framework, the Insubria research group produced a paper in cooperation with ENEA on the dynamic of frost mounds or pingo-like features through UAV and SfM remote sensing techniques. As well as a paper pn remote sensing techniques and ERT on the dynamics of an Antarctic beach at Edmonson Point not so far from the Italian Station Mario Zucchelli (MZS). Moreover the study of granite weathering landforms in cryotic Antarctic conditions was also improved thanks to the analysis and the quantification of weathering rates of tafoni close to MZS.

- Ponti S., Scipinotti R.;Pierattini S., and Guglielmin M. (2021). The Spatio-Temporal Variability of Frost Blisters in a Perennial Frozen Lake along the Antarctic Coast as Indicator of the Groundwater Supply. *Remote Sensing*, 13(3), 435, 17 p. DOI: 10.3390/rs13030435.
- Ponti S., and Guglielmin M. (2021). Shore Evidences of a High Antarctic Ocean Wave Event: Geomorphology, Event Reconstruction and Coast Dynamics through a Remote Sensing Approach. *Remote Sensing*, 13(3), 518, 19 p. DOI: 10.3390/rs13030518.
- Ponti S., Pezza M., and Guglielmin M. (2021). The development of Antarctic tafoni: Relations between differential weathering rates and spatial distribution of thermal events, salts concentration and mineralogy. *Geomorphology*, 373, 12 p. DOI: 10.1016/j.geomorph.2020.107475.

The National Institute of Oceanography and Applied Geophysics (OGS) is working on Gas Hydrate Stability below Subaqueous Permafrost. Many studies demonstrated the coexistence of subaqueous permafrost and gas hydrate. Subaqueous permafrost could be a factor affecting the formation/dissociation of gas hydrate (Fig. 28). They have proposed

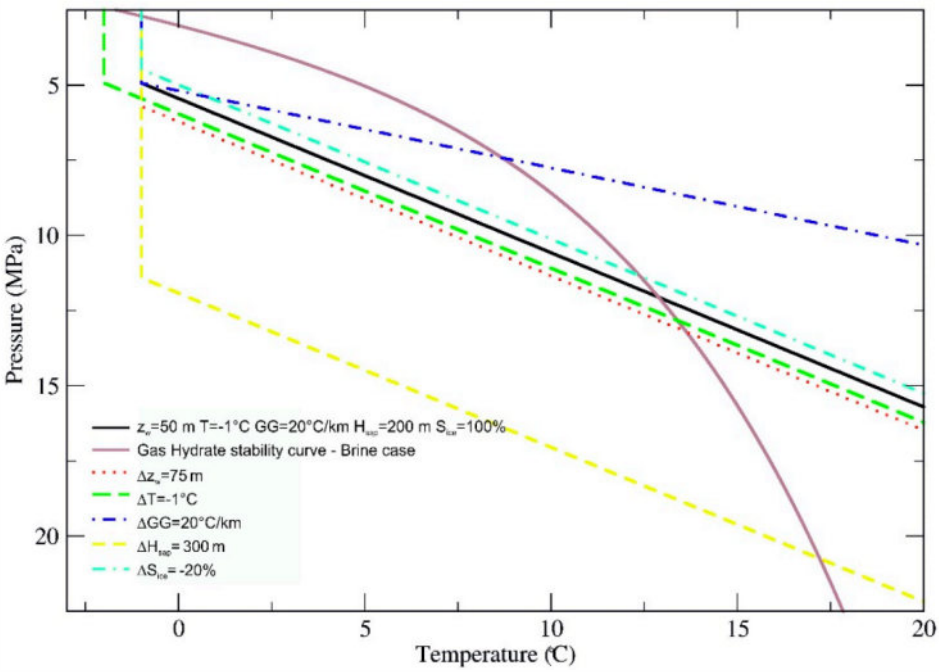

Fig. 28. Thickness of the gas hydrate stability zone (GHSZ) for different combinations of controlling parameters in marine environments (brine with 3.5 wt.% salinity). The black solid line represents the reference case. The other curves are variations of one parameter with respect to the reference. For more information see:

- Tinivella, U., Giustiniani, M., and Marín-Moreno, H. (2019). A Quick-Look Method for Initial Evaluation of Gas Hydrate Stability below Subaqueous Permafrost. *Geosciences*, 9(8), 329, 13 p. DOI: 10.3390/geosciences9080329.

a simple empirical approach that allows estimating the steadystate conditions for gas hydrate stability in the presence of subaqueous permafrost.

This approach was derived for pressure, temperature, and salinity conditions typical of subaqueous permafrost in marine (brine) and lacustrine (freshwater) environments. To their knowledge, this is the first empirical method that allows a quick look and easy initial estimation of the conditions sufficient to have the stability of hydrate below subaqueous permafrost in absence of direct geological or geophysical data. The simple method can be easily and reliably applied to assess if the sufficient conditions to have hydrate stability below subaqueous permafrost are satisfied. Because of the growing interest in subaqueous permafrost environments, this approach is particularly useful in subaqueous permafrost areas with environmental conditions that hinder the acquisition of data, to allow an initial and quick estimation of the thickness of the gas hydrate stability zone.

ALPINE ENVIRONMENT

Western & Central Alps

The long-term permafrost monitoring network of Valle d'Aosta, managed by ARPA VdA (Umberto Morra di Cella, Paolo Pogliotti), turned 14. The core sites are located in the Cervinia basin (Cime Bianche, Matterhorn, Carrel Hut and summit, and Gran Sometta rock glacier) and in the Mont Blanc area (Grandes Jorasses north face and Petit Grapillon glacier fore-field). In 2020, all sites showed extremely warm winter conditions and the maximum thickness of the active layer since the beginning of the measurements, both on flat (Cime Bianche, 6.7m) and on the steep (Carrel Hut, 2.9m) sites.

The Gran Sometta is an active rock glacier monitored since 2012 with a multi-disciplinary approach: UAV/GNSS surface velocities, boreholes temperatures and geophysics. In late 2020 a new GNSS dual frequency antenna has been installed for a continuous tracking of RG movements. Within the Interreg V-A Italy-Switzerland project ReservAqua (2019-2022) ARPA VdA started the hydrological study of the rock glacier: the main objective is to lay the foundation for a quantification of the water outflow (direct observations and modeling) to relate with the surface volume variations (UAV) and hydro-chemical footprint (collab. with DISAFA-UniTO, Nicola Colombo and Michele Freppaz).

At Gran Sometta ARPA VdA collaborates with several research groups, currently: the Geoscience Department of Uni. Fribourg (Christian Hauck and Reynald Delaloye) and TU-Wien (Adrián Flores-Orozco and Theresa Maierhofer) for the geophysical and geomorphological aspects; the GlacierLab of Politecnico di Torino (Alberto Godio, Chiara Colombero) for a pilot-study on rock glacier behavior with passive seismic survey.

The activities on periglacial and permafrost studies and monitoring in Piemonte region are in charge to the Department of Natural and Environmental Risks of ARPA Piemonte (Luca Paro), within the specific institutional topic named "*B3.19 – Monitoraggio del permafrost*" (permafrost monitoring).

These activities started in 2006 and developed significantly thanks to the partnership in EU Interreg projects: in 2008÷2011 Alpine Space project "*PermaNET - Permafrost long-term monitoring Network*", in 2016-2017 ALCOTRA (ItalyFrance) project "*PrévRiskHauteMontagne*" and in 2019-2022 Italy-Switzerland project "*ReservAqua*".

The main 2020 activities were:

- Management of the permafrost monitoring regional network consisting in 6 stations (boreholes 5 to 100 m deep, 2500 to 3020 m asl) and of the geotechnical-thermal station of M. Rocciamelone (borehole 30 m deep at 3150 m asl), and updating analysis of monitoring data related to climate conditions (Fig. 29).
- In situ sensor calibration at the Sommeiller (2980 m asl) and at the La Colletta (2870 m asl) permafrost stations, in collaboration with INRiM (Istituto Nazionale di Ricerca Metrologica, Andrea Merlone's team).
- Management and development of GST monitoring network (12 sites) and of temperature monitoring in ice caves (5 sites, in collaboration with Bartolomeo Vigna, Polytechnic of Torino). Maintenance, data download and analysis of a total 140 sensors placed in rock, debris, soil and ice.
- Management of cold springs monitoring (2 main sites) finalized to develop a hydrogeological model in periglacial and permafrost environment. Installed multiparametric sensors and sampled water for chemical analysis (in collaboration with Michela Rogora and Gianna Tartari, CNR-IRSA, and Polytechnic of Torino).
- Rockglacier surveys (3 sites): GPR, ERT and HVSR surveys have been carried out in collaboration with University of Pisa (Adriano Ribolini and Stefania Sartini); GNSS and UAV photogrammetry surveys have been made in collaboration with ARPA Valle d'Aosta.
- Communication: some data and results are published in scientific papers, technical reports and on the web: 1) Environmental Regional Report; and 2) permafrost index as indicator of climate change effect in National CC Portal.

Within the PRIN RESACC (Response of sensitive alpine ecosystems to climate change) a new model to predict the surface movements in periglacial environment was defined and applied to the Stelvio Pass area (Lombardy region) checking also the effects of the movements on the vegetation.

- Ponti, S., Nicoletta, C., and Guglielmin, M. (2021). A new simple topo-climatic model to predict surface displacement in paraglacial and periglacial mountains of the European Alps: The importance of ground heating index and floristic components as ecological indicators. *Ecological Indicators*, 120, 10 p. DOI: 10.1016/j.ecolind.2020.106889.

In the same area we continue the monitoring of the oldest Italian permafrost borehole series (since 1998) that contribute to the paper on the trend of the 20 years of PACE boreholes monitoring.

- Etzelmuller, B., Guglielmin, M., Hauck, C., Hilbich, C., Hoelzle, M., Isaksen, K., Noetzli, J., Oliva, M., and Ramos, M. (2021). Twenty years of European mountain permafrost dynamics-the PACE legacy. *Environmental Research Letters*, 15(10), 14 p. DOI: 10.1088/1748-9326/abae9d.

Moreover always in the Stelvio area also the monitoring of impacts of climate change on permafrost distribution is going on and gave first documentation of thermokarst depressions started since less than 20 years ago close to the Stelvio Pass.

- Guglielmin, M., Ponti, S., Forte E. Cannone, N.

Fig. 29. Mt. Moro Pass permafrost monitoring station, 2870 m a.s.l., Municipality of Macugnaga, VB. In this site, new calibrated datalogger and thermistor chain have been installed in borehole 30 m deep since 2018, in order to evaluate the climate change effect on permafrost in Monte Rosa area. Photo: Luca Paro.

(2021). Recent thermokarst evolution in the Italian Central Alps. Permafrost and Periglacial Processes [Early view]. DOI: 10.1002/ppp.2099.

The main activities in South Tyrol have been carried out by Volkmar Mair, Kathrin Lang*, and David Tonidandel (Provincial Office for Geology and Building materials testing, Autonomous Province of Bolzano). **Now at the Technical University of Munich.* All the permafrost monitoring stations, which were installed during the Alpine Space project PermaNET, the Interreg IV Italy-Austria project Permaqua are operant and are still collecting data of internal temperatures of three rock glaciers.

In this context, the Office for Geology and Building Materials Testing was strongly collaborating with the two main academic institutions of South Tyrol, Eurac Research and the Free University of Bozen-Bolzano. Within the frame of a PhD project, a regional-scaled and data-driven assessment on the likelihood of ice presence in rock glaciers was carried out and a paper was published in 2020. Additionally, by back-analyzing two recent periglacial debris flow events, destabilizing factors of rock glacier front slopes were studied.

- Kofler, C., Steger, S., Mair, V., Zebisch, M., Comiti, F., and Schneiderbauer, S. (2020). An inventory-driven rock glacier status model (intact vs. relict) for South Tyrol, Eastern Italian Alps. *Geomorphology*, 350, 16 p. DOI: 10.1016/j.geomorph.2019.106887.
- Kofler, C., Mair, V., Gruber, S., Todisco, M.C., Nettleton, I., Steger, S., Zebisch, M., Schneiderbauer, S., Comiti, F. (2021). When do rock glacier fronts fail? Insights from two case studies in South Tyrol (Italian Alps). *Earth Surface Processes and Landforms* [Early view]. DOI: 10.1002/esp.5099.

During 2020, within a collaboration with Stephan Gruber (Carleton University) and Niccolo Tubini and Riccardo Rigon (Trento University) implemented a new model called FreeThaw for the estimation freezing soil dynamics over long periods. This work was peformed in the framework of PhD student Niccolo Tubini. The code is based on a new algorithm, the Newton-Casulli-Zanolli algorithm that overcomes the difficulties in the convergence of the integration of the energy budget which affect the current model. FreeThaw is an open source product.

- Tubini, N., Gruber, S., and Rigon, R. (2020). A Method for Solving Heat Transfer with Phase Change in Ice or Soil That Allows for Large Time Steps While Guaranteeing Energy Conservation. *The Cryosphere* [preprint]. DOI: 10.5194/tc-2020-293.

Dr. Tubini's dissertation is going to be released in the first half of this year and will be a step towards a new integrator of the Richards/groundwater and energy equations with freezing soil in 3D. This task will be accomplished possibly in this year and will be include in the set of WHETGEO (1D,2D,3D) components. WHETGEO stands for Water HEat and Transport in GEOframe and they are a set of components that can be used inside the modelling system GEOframe. Various papers in these topics will be written and submitted to the main journals along 2021.

Eastern Alps

In the Eastern Alps research is mainly focused on ground ice both in relict rock glaciers and high altitude karstic caves. The distribution of rock glaciers is often used to investigate the occurrence of permafrost in mountain areas and to understand their climate and paleoclimate evolution. This requires the creation of regional and global inventories capable of discriminating active and relict landforms in order to forecast the presence or absence of ice in the ground. Through geophysical, climatological and geomorphological surveys, results from a rock glacier located at about 1700 m asl in the Carnic Alps and considered as relict by using common definitions, indicate instead that internal ice were widespread in large portions of it. This research demonstrates that the current altitudinal limit of alpine permafrost can be locally several hundreds of meters lower than forecasted by empirical modeling based only on the rock glacier distribution and classification. Therefore, rock glacier classifications based only on remote sensing and geomorphological evidence as the main sources for extracting regional climate and paleoclimate signals should be treated with caution.

Among the different elements of the mountain cryosphere, ground ice in karstic caves of the eastern Alps represent a peculiar case of sporadic permafrost. A recent work demonstrates how the presence of permanent ice in cave is not only related to the net cooling effect of the air circulation, as it is well known, but also to relict permafrost occurrence. Data support the important role of cryotic conditions in the rock in preserving a permanent ice cave deposit in the present climate, even once the possible relict permafrost inherited from the past disappears. This was done through a detailed rep-

resentation of air and rock temperature patterns inside the cave, showing how ongoing anthropogenic climate warming is responsible for permafrost degradation despite the cooling effect of the air circulation in the cave. Continuous temperature monitoring in selected ice caves is in effect since 2011 and in the Mount Canin area (Julian Alps) new monitoring sites are going to be installed (Fig. 30).

- Colucci R.R., and Guglielmin M. (2019). Climate change and rapid ice melt; suggestions from abrupt permafrost degradation and ice melting in an alpine ice cave. *Progress in Physical Geography*, 43(4), 561-573. DOI: 10.1177/0309133319846056.

For more information contact Renato Colucci (renato.colucci@isp.cnr.it) and see:

- Azzaro, M., Maimone, G., La Ferla, R., Cosenza, A., Rappazzo, A.C., Caruso, G., Paranhos, R., Cabral, A.S., Forte, E., and Guglielmin, M. (2021). The prokaryotic community in an extreme Antarctic environment: the brines of Boulder Clay lakes (Northern Victoria Land). *Hydrobiologia*, 848, 1837-1857. DOI: 10.1007/s10750-021-04557-2.
- Cavallo, F. (2020). *Permafrost nelle Alpi piemontesi: applicazione modellistica e stime per il 2030 e 2050*. MSc Thesis, Politecnico di Torino, 118 p.
- Colombo, N., Ferronato, C., Vittori, Antisari L., Marziali, L., Salerno, F., Fratianni, S., D'amico, M., Ribolini, A., Godone, D., Sartini, S., Paro, L., Morra Di Cella, U., and Freppaz, M. (2020). A rock glacier - pond system (NW Italian Alps): Soil And Sediment Properties, Geochemistry, And Trace-Metal Bioavailability. *Catena*, 194, p. 12. DOI: 10.1016/j.catena.2020.104700.
- Colucci, R.R., Forte E., Žebre M., Maset E., Zanettini C., Guglielmin M. (2019). Is that a relict rock glacier? *Geomorphology*, 330, 177-189. DOI: 10.1016/j.geomorph.2019.02.002.
- Lo Giudice, A., Conte, A., Paple, M., Rizzo, C., Azzaro, M., and Guglielmin, M. (2021). Prokaryotic diversity and metabolically active communities in brines from two perennially ice-covered Antarctic lakes. *Astrobiology*, 21(9), 15 p. DOI: 10.1089/ast.2020.2238.

Fig. 30. Ground ice inside the Leupa ice cave (Julian Alps). Degradation of permafrost and positive feedbacks through buoyuancy ventilation are triggering a fast ice melting. The recent opening of a large hole in this cave brought to a change in the air circulation. Photo Renato R. Colucci.

- Papale, M., Lo Giudice, A., Conte, A., Rizzo, C., Rappazzo, C., Maimone, G., Caruso, G., La Ferla, R., Azzaro, M., Gugliandolo, C., Paranhos, R., Cabral, A.S., Romano Spica, V., and Guglielmin, M. (2019). Microbial assemblages in pressurized Antarctic brine pockets (Tarn Flat, Northern Victoria Land): a hotspot of biodiversity and activity. *Microorganisms*, 7(9), 333, 25 p. DOI: 10.3390/microorganisms7090333.
- Pantaldi, E., D'Amico, M.E., Colombo, N., Colombero, C., Sambuelli, L., De Regibus, C., Franco, D., Perotti, L., Paro, L., and Freppaz, M. (2021). Hidden soils and their carbon stocks at high-elevation in the European Alps. *Catena*, 198, 13 p. DOI: 10.1016/j.catena.2020.105044.
- Rizzo, C., Conte, A., Azzaro, M., Papale, M., Rappazzo, A.C., and Battistel, B. (2020). Cultivable Bacterial Communities in Brines from Perennially Ice-Covered and Pristine Antarctic Lakes: Ecological and Biotechnological Implications. *Microorganisms*, 8(6), 819, 26 p. DOI: 10.3390/microorganisms8060819.
- Rogora, M., Somaschini, L., Marchetto, A., Mosello, R., Tartari, G.A., and Paro, L. (2020). Decadal trends in water chemistry of Alpine lakes in calcareous catchments driven by climate change. Science of the Total Environment, 708, p. 14. DOI: 10.1016/j.scitotenv.2019.135180.

JAPAN

BY KAZUYUKI SAITO (JAMSTEC)

The Japanese Permafrost Association (JPA) membership in 2020 included 1 student and 30 regular members with the president, Kazuyuki Saito (JAMSTEC), and Secretary, Atsushi Ikeda (University of Tsukuba).

ACOP2017 ABSTRACT PUBLISHED

In 2020, the local organizing committee of the 2nd Asian Conference on Permafrost 2017 held in Sapporo, published the "Book of Abstracts, ACOP 2017" presented at the conference.

ARCTIC CHALLENGE FOR SUSTAINABILITY II (ARCS II) PROJECT

Japan started a new five-year national Arctic research project, ArCS II (the Arctic Challenge for Sustainability II) in June 2020. This is a comprehensive and interdisciplinary project attended by more than 200 researchers nationwide. The project aims to promote research on the present and future status of climate and environmental change in the Arctic, and assess the impact of rapid changes on society. A large number of members from the permafrost research community are actively engaged in ArCS II.

Biogeochemical Cycling in the Terrestrial Arctic

"*Biogeochemical Cycling in the Arctic Terrestrial Ecosystem and Periglacial Regions*", one of the 11 research programs, aims to improve the understanding of the ecosystem processes in the tundra and taiga affected by permafrost degradation. It includes a study on physico-geochemical processes at the front of retreating glaciers such as CH_4 flux in the glacier terminus and mercury concentration in thermokarst soil/water. Another study deals with the interaction between the GHG fluxes of the boreal forest ecosystem and permafrost changes, based on the long-term observations being conducted in east Siberia and Alaska.

Data publication is a top priority; obtained data are to be made open to the international observing initiatives. Tightening the linkage between observational and numerical studies is also highlighted, namely for improving land ecosystem and carbon cycle processes in the domestic earth system model. The outcome in 2020 is limited due to the covid-19 pandemic and consequent cancellation of all the planned field activities. Analysis using the existing samples was carried out to confirm a high concentration of mercury in the permafrost soil particles. Modeling studies quantified the impacts of river heat on the Arctic sea ice and ocean heat budget.

- Park, H., Watanabe, E., Kim, Y., Polyakov, I., Oshima, K., Zhang, X., Kimball, J.S., and Yang, D. (2020). Increasing riverine heat influx triggers Arctic sea ice decline and oceanic and atmospheric warming. *Science Advances*, 6(25), 7p. DOI: 10.1126/sciadv.abc4699.

Stability & sustainability under permafrost degradation

The "*Permafrost degradation impact assessments and ecological and water environment changes*" program aims to develop an assessment tool for determining the impact of permafrost degradation on local communities. Integration of field observations, satellite remote sensing, and social methodologies will be implemented to create new knowledge for an assessment to measure stability and sustainability. As for an outcome in 2020, the inter-disciplinary collaboration, initially motivated by participation in the action group "*Permafrost and Culture (PaC)*" of IPA, worked for editing an educational textbook (Fig. 31) with particular attention to the Sakha (Yakut) people in eastern Siberia.

OVERSEAS RESEARCH ACTIVITIES

International collaborations on periglacial monitoring and experiments

After a long-term annual field cooperation between University of Tsukuba (Norikazu Matsuoka, Atsushi Ikeda, et al.) and European universities, fieldwork in the Swiss Alps (since 1994) and Svalbard (since 2004) was finally interrupted in 2020 due to COVID-19. This caused missing data on ground movements and thermal regimes, although data were partly secured by the research partners. Instead, laboratory simulations on sorted patterned ground have intensively progressed in the geomorphological laboratory at University of Tsukuba (Li Anyuan and Norikazu Matsuoka), and the outcome has been combined with phase-separation models (Norikazu Matsuoka).

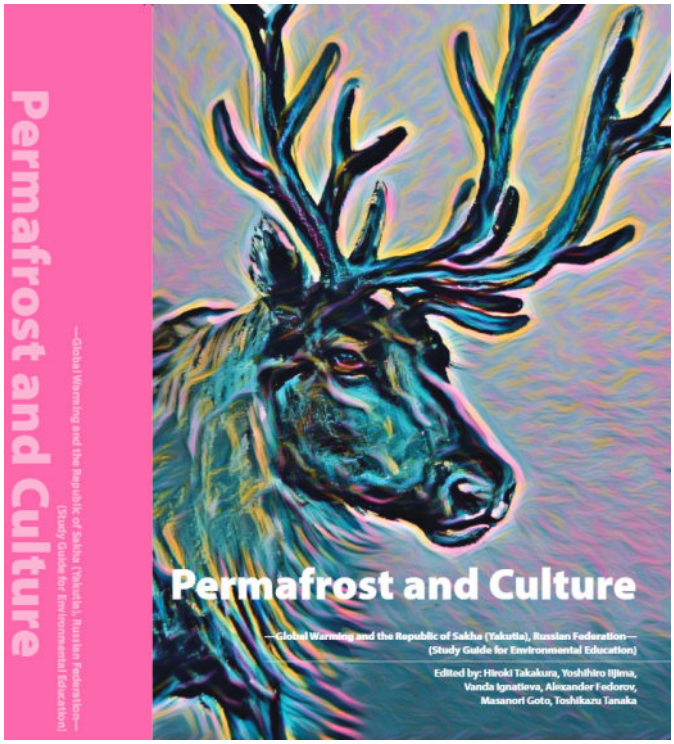

Fig. 31. Takakura, H., Lijima, Y., Ignatyeva, V., Fedorov, A., Goto, M., and Tanaka, T. (2021). *Permafrost and Culture: Global Warming and Sakha Republic (Yakutia), Russian Federation*. Center for Northeast Asian Studies, Tohoku University, Japan, 94 p.

Field observation & SAR image analysis of forest fire sites around Batagay

At the forest fire sites around Batagay, Sakha Republic, Eastern Siberia, Kazuki Yanagiya, Masato Furuya (Hokkaido University), Go Iwahana (University of Alaska Fairbanks), Petr Danilov (North-Eastern Federal University), and Alexander Fedorov (Melnikov Permafrost Institute) conducted SAR imagery analysis and field observation in 2019-20. The main contents of the survey were:

- Observation of ground temperature and soil moisture content;
- Thaw depth measurement with a frost probe;
- Leveling survey.

In 2020, however, we decided not to travel to the site due to COVID-19. Therefore, our local counterparts carried out the work on our behalf. One year time series were obtained from a ground thermometer installed at the 2019 fire site. We verified it with the ground deformation data detected by satellite images. Kazuki Yanagiya plans an extended study around Batagay.

Campaign with Argentina on Antarctica

A joint research team from Argentina and Japan "*El Grupo Criología*" has been studying rock glaciers on the Antarctic Peninsula since the 1990s. The research team recently published a paper in the Journal of Geography (Chigaku Zasshi). Though the text is written in Japanese, the abstract is given in English.

- Fukui, K., Sone, T., Strelin, J.A., and Mori, J. (2021). Surface Elevation Variations on Lachman II Debris-covered Glacier (Ice-cored Rock Glacier), James Ross Island, Antarctic Peninsula, and Its Responses to Recent Climate Change. *Journal of Geography (Chigaku Zasshi)*, 130(1), 27-41. DOI: 10.5026/jgeography.130.27.

International Workshop on "Food Life History of the North"

In November 2020, the 1st international open workshop on "*Food Life History of the North*" focusing on the life, culture and foods related to the underground cache practices under the frozen environment was held online and in person at the RIHN conference room, Kyoto, Japan. Fifty-one people attended from Siberia, Alaska, and Japan (Kazuyuki Saito, Go Iwahana, Alexander Fedorov, Kenji Yoshikawa, and Yuki Sawada). It showcased the diversity and variety in underground cache practices in different regions, such as Siġluaq (Iñupiak), Siqlugqaq (Siberian Yupik), and Elagyaq (Yupik) in Alaska, Buluus (Sakha) or Lednik (Russia) in Siberia, and Himuro (ice house) and Fuketsu (wind holes or natural cold storages) in Japan.

DOMESTIC RESEARCH ACTIVITIES

The Daisetsu Mountains

Ground temperature monitoring has continued on the windblown bear ground. Permafrost temperatures are between -0.3 °C and -0.1 °C, and the active layer ranges from 3 to 5 m thick around the lower limit of permafrost from 1,700 to 1,800 m asl. On the other hand, the seasonal freezing depth was 6 m at 1,740 m asl. The thermal condition of permafrost around the lower limit seems very unstable. The total area of palsas is still decreasing (Toshio Sone, Hokkaido University).

Outreach program measuring frost depth in Japan

Since November 2011, the '*Frost tube in Japan*' project has been conducted in collaboration with the '*Permafrost Outreach Program*' operated by Kenji Yoshikawa (WERC, INE, UAF). As an outreach program, frost tubes were set at 38 schools until the 2020-21 winter season in Hokkaido area, northern Japan, and frost depths have been measured by school children and teachers (Koihiro Harada, Miyagi University).

Field test of the new method to monitor ice formation within blocky material

Yuki Sawada (Fukuyama City University), Toshio Sone and Suguru Mori (ILTS, Hokkaido University) made a temperature monitoring system with chip sensors mounted with a short interval (2 cm) and installed it in the lower part of the block slope, where ice formation and abrasion had been monitored manually in the previous study. The study site is in the summit area of Mt. Nishi-Nupukaushinupuri (1254 m) in Hokkaido, northern Japan. Sawada and Ishikawa (2003) monitored changes of the depth of ice surface in the same site and found snow-melt water flows to the lower part of the slopes and refreezes, adding new ice onto the perennial ice. Sensors were installed between 60 cm and 210 cm depth in the lower-most part of the block slope. Preliminary results (2019) show an abrupt increase in ground temperatures up to 0 °C between 60 cm and 184 cm depth in April, when the air temperature rose to positive and snow-melt started. The 0 °C isotherm gradually moved up to 175 cm depth until May (Fig. 32). The isotherm also showed the lower boundary of daily fluctuation, indicating the border of air and ice existed on this depth. Further monitoring has been conducted.

- Sawada, Y., Ishikawa, M., and Ono, Y. (2003). Thermal regime of sporadic permafrost in a block slope on Mt. Nishi-Nupukaushinupuri, Hokkaido Island, Northern Japan. *Geomorphology*, 52(1-2), 121-130. DOI: 10.1016/S0169-555X(02)00252-0.

Shiretoko Mountain Range, northeastern Hokkaido

Year-round air and ground-surface temperatures have been monitored in the Shiretoko Mountain Range, northeastern Hokkaido by Shota Nakamura, Hiroshi Ohno, Tatsuya Watanabe (Kyoto Institute of Technology) and Toshio Sone (Hokkaido University). The monitoring data indicate the possible occurrence of mountain permafrost near peaks of the mountain range. Measurement of ground temperature will be conducted at sites where the presence of permafrost is expected.

Monitoring on Mt. Fuji

The monitoring system on the summit of Mt. Fuji, which was severely damaged in 2018, could not be recovered during the summer of 2019. In 2020, all the routes to the summit had been closed due to COVID-19 countermeasures (Atsushi Ikeda, Univ ersity of Tsukuba).

For more information contact Kazuyuki Saito (ksaito@jamstec.go.jp).

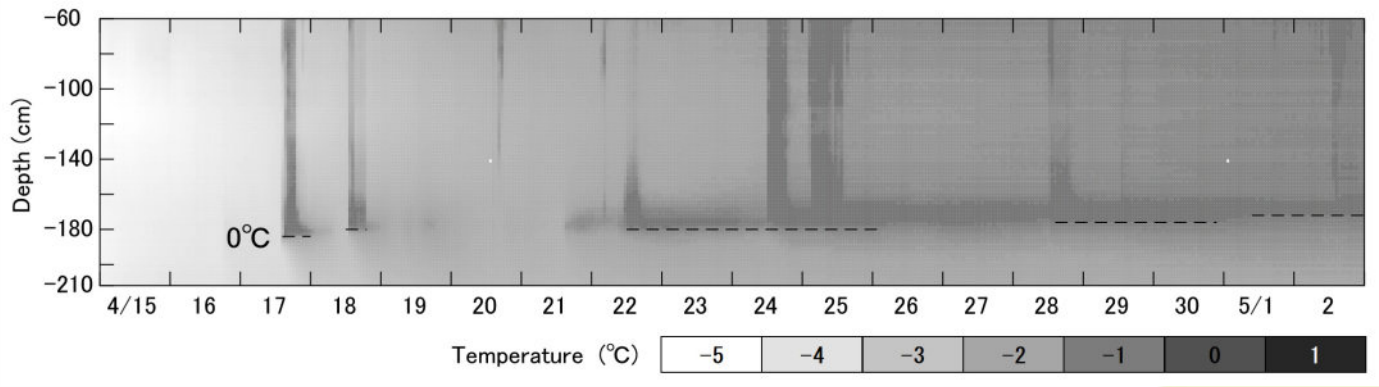

Fig. 32. Changes in ground temperature of the lower-most part of the block slope.

MONGOLIA

BY YAMKHIN JAMBALJAV (MONGOLIAN ACADEMY OF SCIENCES)

PERMAFROST & PERIGLACIAL STUDIES

Permafrost degrades unevenly across the permafrost regions throughout Mongolia, manifesting itself as the detachment of the active layer and the disappearance of shallow permafrost. The lower or southern limits of permafrost have shifted upward or northward by different distances when comparing previous data with current measurements. The southern limit of permafrost has shifted northward by 178 km in the Hentii mountain range, 94 km in the Hangai mountain range, 900 m in the Gobi-Altay mountain range, and 240 m near the Altay mountain range.

Since 2017, Drs. Natsagdorj Sharkhuu (Mongolian Academy of Sciences) and Anarmaa Sharkhuu (National University of Mongolia) have been experimenting with open-top passive chambers at two sites (with and without permafrost) in the Khurkh Valley, Hentei mountains. The project aims to study and estimate the thermal effect of climate warming and grazing livestock on permafrost. Each site has four treatments (warmed and grazed, warmed-only, grazed-only, and a control) with 10 m deep borehole. The Khurkh-Khuiten Valleys are in the isolated permafrost zone. Some areas of the Khurkh-Khuiten Valleys are underlain by permafrost developed under thick peat and have some periglacial landforms such as small pingos or degraded palsas. Permafrost was well delineated in areas of peatlands and under pingos using Electric Resistivity Tomography (ERT) (Fig. 33).

Recently, the wetland area in these valleys is drying and permafrost is degrading. This is very alarming due to the suspected close relationship between peat and permafrost. Degradation of permafrost can induce the degradation of peat, and this area can become a carbon source. Ground temperatures below the peat bog are -1.3 °C at a depth of 10 m (Fig. 34).

This area is very significant for biodiversity and conservation biology. For instance, this is an important breeding area for the White-naped Crane (*Grus vipio*), a threatened species with about 6,000 individuals remaining in the wild. Increasing active layer depth, caused by permafrost degradation, can trigger various ecosystem changes such as a decrease in the water table, change in water biochemistry, and drying wetlands. Thus, changes can potentially limit the size of breeding grounds for the White-naped cranes and other waterbirds in the region.

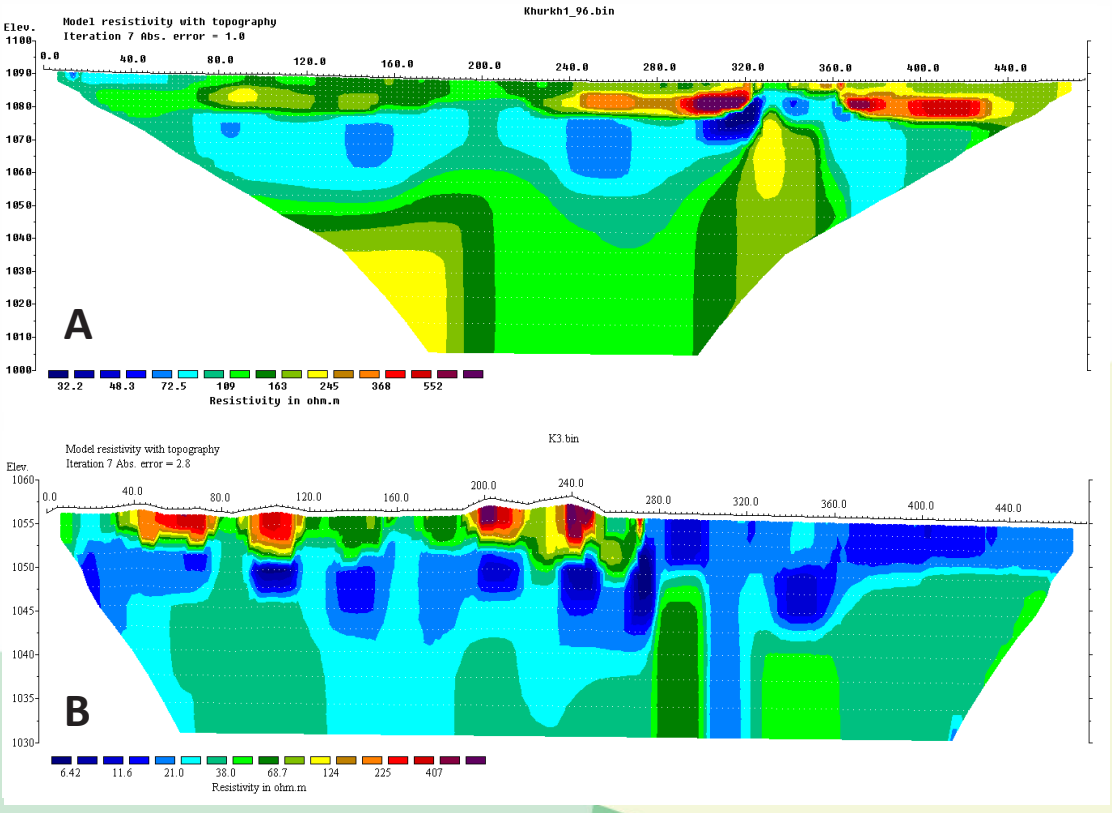

Fig. 33. (A) Southern limit of permafrost distribution at a peatland valley in Eastern Mongolia. Two boreholes are located in sites with and without permafrost. (B) Isolated permafrost zone in eastern Mongolia, where permafrost is confined to pingos. Red indicates ice-rich frozen ground.

The results of the study will help to develop a protection management plan.

Fig 34. Climate observation site, Wildlife Science and Conservation Centre of Mongolia with 10 m deep borehole in the centre of the peatland.

Avirmed Dashtseren (Mongolian Academy of Sciences) leads the "*Climate change effects on water resources (glaciers, permafrost) in mountainous regions of Mongolia*" project. The project is funded by the Swiss Cooperation Office, Embassy of Switzerland in Mongolia, in collaboration with the Mongolian Academy of Sciences. In August 2020, the project team installed four automatic weather stations in the Altay, Hangai, Hovsgol mountains with altitudes above 3300 m asl. This study is one of the first time attempts to create a climate monitoring network in high mountainous areas in Mongolia.

ENGINEERING PERMAFROST

About 20 villages are located on permafrost, and 1,200 km of paved roads across Mongolia's permafrost zones. Most buildings (schools, hospitals and local government offices) are damaged, and some undulations have formed on asphalt surfaces. The buildings were constructed according to the first principle of construction on permafrost. However, thawing of permafrost under buildings and under asphalt roads is common in the permafrost regions of Mongolia (Fig. 35).

In addition, visits to Mongolia by international project teams (from Norway and China) have been postponed due to COVID-19. We hope they will be able to come in 2020 and start a successful international cooperation.

For more information contact Yamkhin Jambaljav (jambaljav@gmail.com).

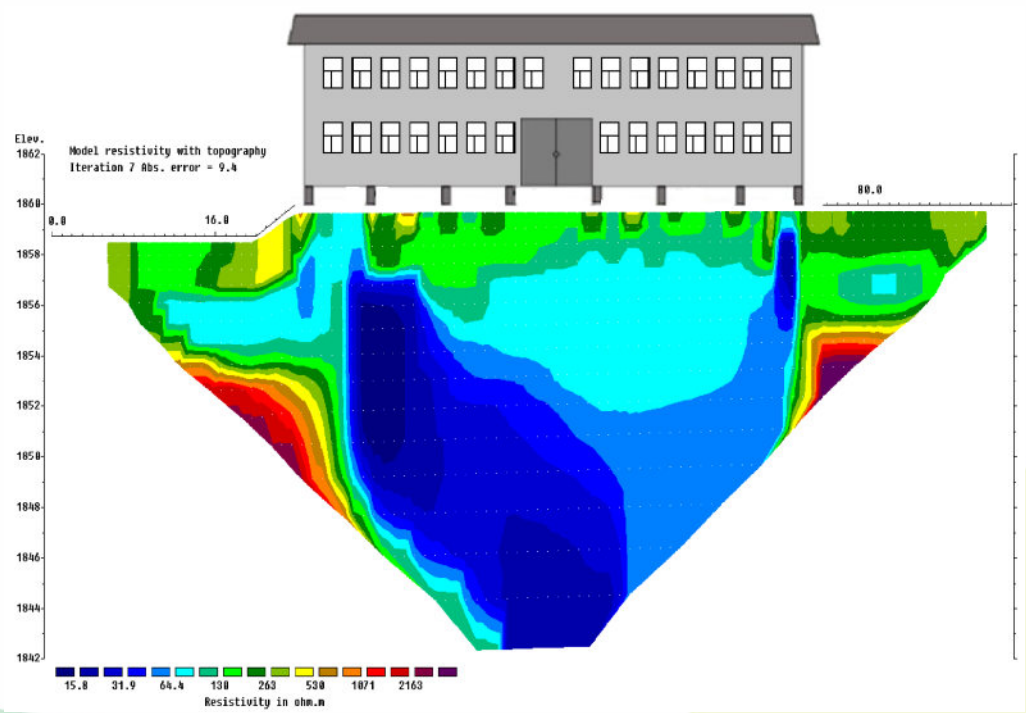

Fig. 35. Permafrost thawing under a school building, Hangai mountain region.

NEW ZEALAND

BY TANYA O'NEILL (UNIVERSITY OF WAIKATO), MARJOLAINE VERRET (VICTORIA UNIVERSITY OF WELLINGTON), AND JACOB ANDERSON (UNIVERSITY OF OTAGO)

ANTARCTIC RESEARCH CENTRE, VICTORIA UNIVERSITY OF WELLINGTON

At the Antarctic Research Centre, the Friis Hills Drilling Project team continued to investigate the ~50 m thick sequence of ice-cemented permafrost recovered in 2016-17 (Fig. 36). This permafrost sequence not only consists of a terrestrial archive of Antarctic environmental changes from approximately 14–15 Ma, but also records the paleoenvironmental changes of the Neogene and provides insight on the modern hyper-arid environment of the McMurdo Dry Valleys. PhD student Hannah Chorley submitted her thesis entitled "*Antarctic ice sheet and climate evolution during the mid-Miocene*", which reveals the sedimentologic and paleoenvironmental significance of this terrestrial record. This thesis provides rigorous chronologic constraints of the permafrost cores allowing correlation with existing marine global climate records for the mid-Miocene period.

PhD student Marjolaine Verret also submitted her thesis entitled "*Reconstructing 15 Myr of environmental change in the McMurdo Dry Valleys through permafrost geochemistry*", which uses geochemical environmental proxies that have rarely been applied to Antarctic terrestrial records to characterize the sediments, organics, and ground ice of the Friis Hills cores. A paper was published discussing the cryostratigraphy and ground ice geochemistry of the Friis Hills permafrost cores.

Fig. 36. The 2016-17 Friis Hills Drilling Project in the high elevation of the McMurdo Dry Valleys of Antarctica. Photo: Richard Levy.

- Verret, M., Dickinson, W., Lacelle, D., Fisher, D., Norton, K., Chorley, H., Levy, R., and Naish, T. (2020). Cryostratigraphy of mid-Miocene permafrost at Friis Hills, McMurdo Dry Valleys of Antarctica. Antartic Science, 1-15. DOI: 10.1017/S0954102020000619.

GEOSCIENCE SOCIETY OF NEW ZEALAND ANNUAL CONFERENCE

In New Zealand, we were fortunate enough to hold the annual Geoscience Society of New Zealand conference in-person. Marjolaine Verret presented the results of her work using ground ice in mid-Miocene permafrost as paleo-temperature proxy for the McMurdo Dry Valleys of Antarctica. Jacob Anderson (University of Otago) presented on his PhD work using cosmogenic nuclides to constrain the age and depositional processes of permafrost in Pearse Valley, Antarctica (Fig. 37).

Fig. 37. Permafrost drilling at Pearse Valley.

GEOLOGICAL & NUCLEAR SCIENCES, UNIVERSITY OF OTAGO & SAPIENZA UNIVERSITA DI ROMA

Gary Wilson (GNS Science and University of Otago) and Livio Ruggiero (National Institute of Geophysics and Volcanology) and their teams are leading a joint research programme funded by the Italian Antarctic Research Programme, PNRA (Programma Nazionale di Ricerche in Antartide), and supported by Antarctica New Zealand. They are working in the McMurdo Dry Valleys to measure greenhouse

gas concentrations and emissions (primarily CO_2 and CH_4) from permafrost and/or thawing shallow strata. The second field season took place during 2020/21, with Gary Wilson and Bob Dagg (University of Otago) travelling to Antarctica. The team completed a reduced field campaign, and conducted two day-trips to the Taylor and Wright Valleys, where they recovered gas probes installed last season, downloaded data collected over the previous year, and installed three new gas probes. The present project aims to provide first evaluations of the gas concentrations and emissions from permafrost and/or thaw of shallow strata. The results will be used to derive a first total emission estimate for CO_2 and CH_4 from the Southern Polar Hemisphere and will enable estimates of rates of permafrost gas release in response to specific warming scenarios.

UNIVERSITY OF WAIKATO & MANAAKI WHENUA-LANDCARE RESEARCH

Soil permafrost temperature monitoring

Manaaki Whenua-Landcare Research, the University of Waikato, and the Natural Resource Conservation Service of the United States Department of Agriculture maintain a network of soil-permafrost climate stations in the Ross Sea region of Antarctica. Tanya O'Neill (University of Waikato) travelled to Antarctica in late January 2021 to undertake the annual maintenance and data download (Fig. 38). COVID-19 flight restrictions greatly reduced our capacity to visit all nine soil climate stations, with only five visited and only two 30 m temperature strings downloaded which were run in collaboration with Mauro Guglielmin (Università degli Studi dell'Insubria). The data contributes to the CALM (circum-polar active layer monitoring) programme and the GTNP (Global Temperature Network-Permafrost).

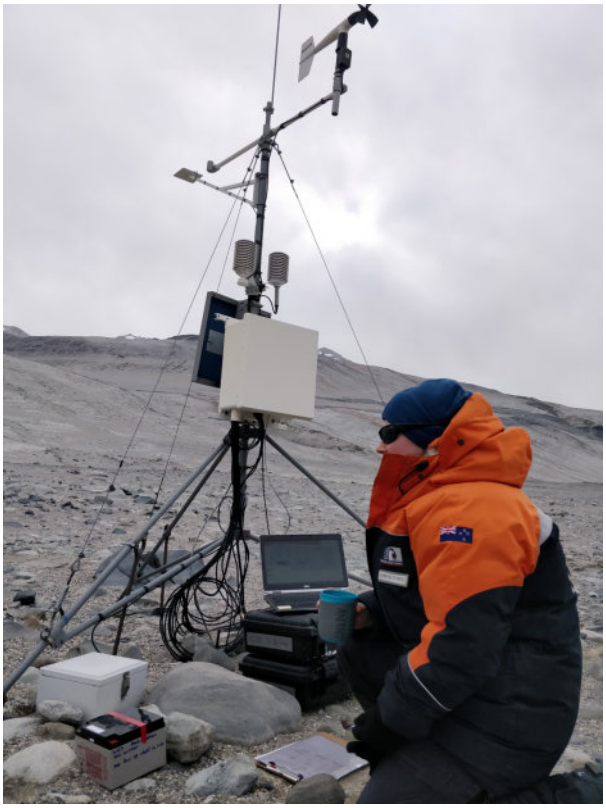

Fig. 38. Tanya O'Neill at the Bull Pass soil climate station in the Wright Valley of the McMurdo Dry Valleys. Photo: W. Dobson.

Scott Base redevelopment

Antarctica New Zealand continue work towards a major redevelopment of Scott Base. Preliminary work to gather baseline data for environmental impact reporting has been completed as well as understanding potential issues with undertaking the construction on permafrost. While in Antarctica, Tanya O'Neill and Pete Wilson (University of Canterbury) installed a new soil-permafrost climate station at Scott Base (Fig. 39), because the existing site (since 1999) will be impacted by the station rebuild. The new installation will allow a two year overlap of data before earthworks for the new station begin.

Fig. 39. The new Scott Base soil climate station, Crater Hill and the wind farm in the background.

For more information contact Tanya O'Neill (toneill@waikato.ac.nz).

NORWAY

BY ARNE INSTANES (UNIVERSITY CENTRE IN SVALBARD, UNIS) & BERND ETZELMÜLLER (UNIVERSITY OF OSLO)

NORWEGIAN GEOTECHNICAL INSTITUTE (NGI)

Risk assessment methodology for disposal of waste from mining activities

Disposal of waste from mining activities and local settlements in the Arctic has often relied on permafrost as a natural geological barrier that prevented leaching of contaminants to the environment. The impact of climate change on arctic permafrost challenges this practice. A risk assessment methodology has been developed to assess the consequences of changes in climate, natural hazards and hydrological regime on the performance of permafrost as a natural barrier. The activity was funded by NGI and the Svalbard Environmental Protection Fund.

Geophysical brine pocket characterization & depth-to-bedrock mapping

In autumn 2020, research activities were continued at sites within and around the town of Longyearbyen. The objective of these activities was to conduct geophysical measurements in the form of Electrical Resistivity Tomography (ERT) and Induced Polarization (IP) at several locations. Several surveys were performed within Longyearbyen, targeting different aspects of the soil and permafrost stratigraphy. In many cases, these profiles were at survey sites measured in previous years, during other projects. The comparison of the new 2020-profiles with those conducted previously will provide some insight into recent changes in soil conditions in Longyearbyen in response to warming.

At a site in the Adventdalen valley, a gridded survey consisting of six, ca. 200 m long profiles, was carried out, in order to provide a 3D understanding of soil geometry (Fig. 40). The site was established as part of the multi-institutional Norwegian Geo-Test Sites (NGTS) project in 2016. Saline soils are widespread in the lower parts of the valleys in central Svalbard (e.g. under the early Holocene marine limit) and underlie large portions of the town of Longyearbyen. Because of the salt content, residual from the time of deposition, the soils are partially unfrozen. ERT and IP are excellent methods for imaging the permafrost soils and distinguishing between frozen and unfrozen zones in the stratigraphy. The results of these studies will be published in the coming period. Activities in 2020 were funded by the Svalbard Science Forum (Norwegian Research Council).

Fig. 40. Geophysical measurements in the Adventdalen valley, September 2020. Photo: Markus Schütz.

UNIVERSITY OF OSLO, DEPARTMENT OF GEOSCIENCES

Most planned fieldwork was suspended due to the COVID-19 pandemic. Juditha Schmidt and Sebastian Westermann conducted a one-week campaign to Ny-Ålesund on Svalbard with the goal to investigate the thermal regime of rockwalls at and close to the sea. We installed iButton temperature loggers in cliffs from the inner parts of Kongsfjorden to the tip of Bøgger peninsula, at elevations from sea level to about 250 m asl. The project was funded by Research Council of Norway.

In addition, Nora Nedkvitne, Sigrid Trier Kjær, Peter Dörsch, and Sebastian Westermann conducted a one week campaign in Northern Norway, with the goal to take samples from peat plateaus for laboratory analysis. The campaign was jointly conducted with the Norwegian University of Life Sciences, Ås, Norway. Finally, Bernd Etzelmüller, Juditha Schmidt, and John Hult were able to download logger data in our permafrost observatories both in southern and northern Norway, including most rock wall loggers.

GEOLOGICAL SURVEY OF NORWAY (NGU)

Ivanna Penna, Martina Bøhme, Reginald Hermanns, Pierrick Nicolet, Marie Bredal, François Noél, and Jose Pullaruello carried out mapping of unstable rock slopes for hazard and risk assessment over en-

tire Norway as part of the Norwegian landslide hazard mapping program supervised by the Norwegian Water and Energy Directorate. Within this activity, mapping of unstable rock slopes was carried out in 2020 in permafrost environments as well as in areas not affected by permafrost. In 2020, NGU compared the database for unstable rock slopes that contain more than 500 unstable slopes distributed over Norway against existing permafrost and permafrost in rock wall maps.

Results indicate that in northern Norway (north of the polar circle) most of the known rock slope instabilities lie in sporadic to discontinuous permafrost environments, while this number is much lower in the south. Both in northern and southern Norway lie the most active rock slope instabilities (highest deformation rates) in sporadic or discontinuous permafrost while the number of rock slope instabilities that do not show deformation today lie on slopes not affected by permafrost.

UNIVERSITY CENTRE IN SVALBARD (UNIS)

Research and educational field activities have been reduced at UNIS during 2020 due to the COVID-19 pandemic. During the start of the pandemic all winter field activities were fully stopped. During late spring, some key activities were resumed, and during summer most of the basic research fieldwork was running, but with strict infection control measures. All course activity was fully cancelled at the outbreak of COVID-19 at UNIS, so no field education has been done in courses in the 2020 autumn semester. UNIS education was hit rather hard by the pandemic because it is not possible to train students in the field, which is a key component in all UNIS courses. However, individual bachelor, master and PhD thesis fieldwork studies continued as soon as fieldwork was possible again.

The permafrost group at UNIS lost a major winter drilling season to establish new boreholes as part of the SIOS InfraNOR project, and we have now replanned for this activity to happen in winter 2021.

During 2020, the IPA Secretariat moved from the Arctic Geology Department at UNIS to Canada. This happened during the COVID-19 pandemic situation, with no possibilities for any physical meetings to assist this transition.

The INTPART project *'Landscape & infrastructure dynamics of frozen environments undergoing climate change in Canada, Norway and Svalbard*', FROZEN CANOES started in 2018 and was planned to end in 2021. It is funded by the Norwegian Research Council (NRC). FROZEN CANOES was also hit hard by the pandemic. The second master course *'Geohazards and geotechnics in high Arctic permafrost environments'*, which was developed by the FROZEN CANOES project and meant to have run over five weeks period in June-July 2020, was cancelled together with the other courses at UNIS.

All intensive master courses have also been cancelled at UNIS until midsummer 2021. The project was put on hold due to the pandemic, preventing any of the planned exchange, meeting or teaching activities. However, the session '*Integrating Science and Engineering, Education for Challenges to Northern Infrastructure Under a Changing Climate*' was held at the virtual Arctic Change conference in December 2020, with presentations from both FROZEN CANOES project members and others working on applied permafrost challenges in the Arctic. The session ended with a good online discussion. We have been allowed to expand the project period at first to the end of 2022 for the major project educational and research collaboration activities to become possible.

ROCK GLACIER KINEMATICS IN NORTHERN NORWAY & SVALBARD

The Technology Department of the NORCE Norwegian Research Centre collaborated with the University of Oslo and UNIS within the '*Climate Change Initiative (CCI) Permafrost CCN2*' project from the European Space Agency. CCI Permafrost, in synergy with the IPA Action Group '*Rock glacier inventories and kinematics*', promotes the development of products to document and exploit rock glacier kinematics as climate change indicator. The Norwegian team applied satellite remote sensing techniques, such as Synthetic Aperture Radar Interferometry (InSAR), to map and monitor rock glacier creep rate in three study areas of Northern Norway and Svalbard. Entirely new or updated rock glaciers inventories were generated (Fig. 41) and velocity time series extracted at selected landforms.

NORWEGIAN METEOROLOGICAL INSTITUTE (MET NORWAY)

New operational permafrost monitoring site at 80°N established on Svalbard

A 31 m deep borehole for long-term permafrost monitoring was established and fully instrumented at Verlegenhuken, the northernmost point at Spits-

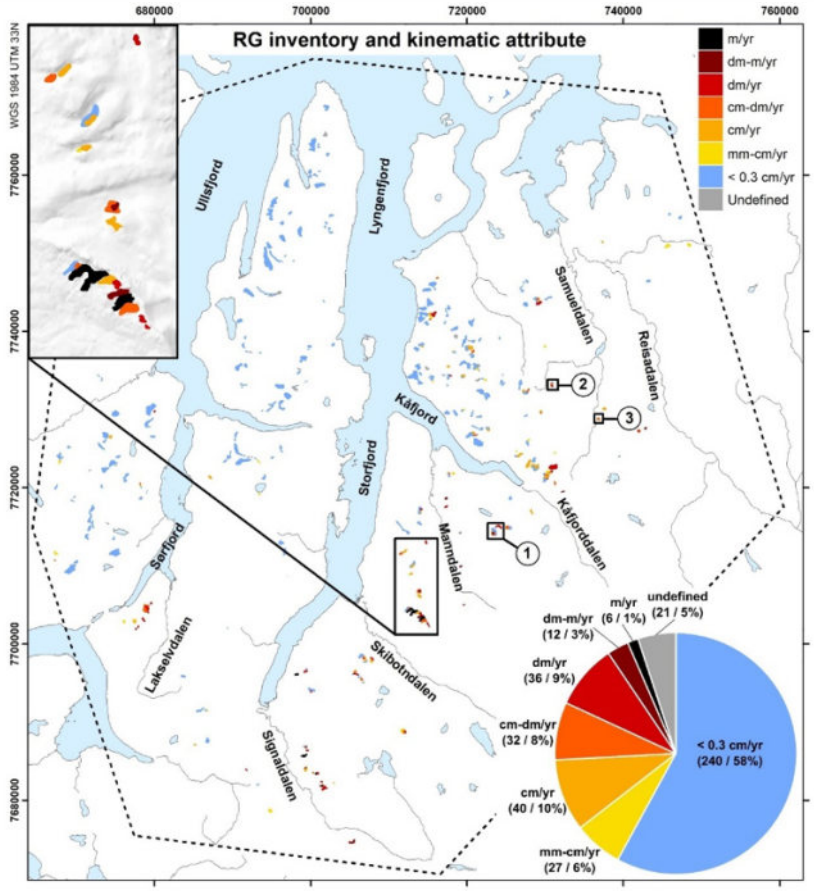

Fig. 41. Updated rock glacier (RG) inventory in Kåfjord-Lyngen, Northern Norway, based on the initial work of Lilleøren and Etzelmüller (2011); updated with integration of Sentinel-1 InSAR-based kinematic attribute (Rouyet et al., submitted). Work funded by the Research Council of Norway (FrostInSAR project 263005) and ESA CCI Permafrost (CCN2 project 4000123681/18/I-NB).

- Lilleøren, K.S., and Etzelmüller, B. (2011). A regional inventory of rock glaciers and ice-cored moraines in Norway. *Geografiska Annaler: Series A, Physical Geography*, 93, 175-191. DOI: 10.1111/j.1468-0459.2011.00430.x

bergen, Svalbard (80°N). The new permafrost monitoring site is a part of the Svalbard Integrated Arctic Earth Observing System (SIOS) and was funded by the SIOS initiated InfraNOR Norwegian Research Council infrastructure project. The establishment and installations at Verlegenhuken was led by MET Norway in collaboration with UNIS. The borehole was drilled by Ullrich Neumann (Kolibri Geo Services) and his drill crew in July 2019.

In August 2020, a digital temperature cable with 27 sensors down to a depth of 30 m was installed and connected to the automatic weather station (AWS) at the site (Fig. 42). The AWS at Verlegenhuken has been in operation by MET Norway since the 1990s and was upgraded in 2020 with radiation and snow depth measurements as part of the SIOS InfraNOR project. The new permafrost station provides real-time data, and data transfer and storage takes place through MET Norway operational systems. The drilling operation and installations were part of the annual service of weather stations around Svalbard with the Norwegian Coast Guard.

Svalbard Global Seed Vault

The Svalbard Global Seed Vault has been upgraded due to challenges related to meltwater in the access tunnel (Fig. 43). The construction work was completed in 2020. The objective of the upgrade was to construct a storage facility for seeds, that will remain cold, dry, and dark for the next centuries, even under the most extreme climate warming scenarios. This design was achieved by a combination

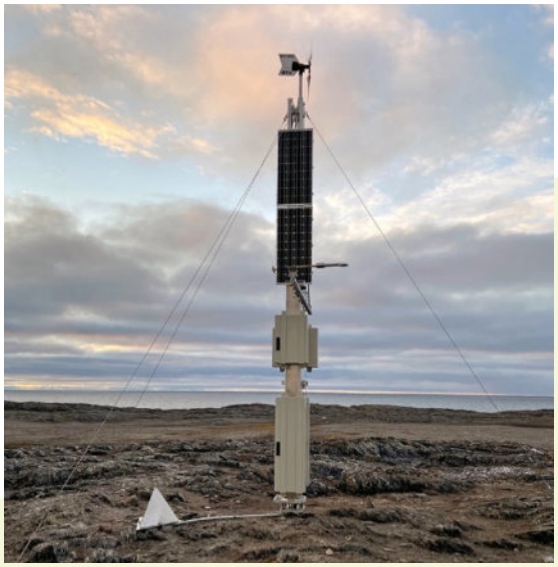

Fig. 42. The new weather station and permafrost borehole next to the station installed August 2020. The weather station, borehole and cables were protected against polar bears. Photo: Bernt Enge Larsen.

of construction procedures including watertight concrete, low permeability backfill material and artificial cooling of the permafrost soils and rock. The engineering design shows that construction work in permafrost regions is challenging, especially in an extreme climate warming scenario.

The engineering design was developed by Dr.techn. Olav Olsen AS (concrete and structural engineering) in cooperation with Instanes AS Consulting Engineers (geotechnical and permafrost engineering).

For more information contact Arne Instanes (arne.instanes@unis.no) and Bernd Etzelmüller (bernd.etzelmueller@geo.uio.no).

Fig. 43. Svalbard Global Seed Vault, June 2019.

POLAND

BY RAJMUND PRZYBYLAK (UNIWERSYTET MIKOŁAJA KOPERNIKA)

ADAM MICKIEWICZ UNIVERSITY IN POZNAŃ

Due to the COVID-19 pandemic, Adam Mickiewicz (University in Poznan) organized only a two-week expedition to the station in Petuniabukta (central Spitsbergen) at the beginning of September 2020, with the participation of two members. The main aim was to maintain the functionality of meteorological and ground-temperature registration devices, download data from loggers and record thickness of the active-layer at end of season. All measurement systems were set up to operate until the next summer season.

INSTITUTE OF GEOPHYSICS, POLISH ACADEMY OF SCIENCES

Permafrost monitoring in Hornsund, Spitsbergen is carried out by the Institute of Geophysics PAS. The results from the period 2016–19 were presented in the latest State of Environmental Science in Svalbard reports. Comparison of data against other monitoring sites in Svalbard indicated that the highest permafrost temperature observations at the Depth of Zero Annual Amplitude are from Hornsund, where temperatures are only -1.2 °C at 12 m depth. This value has been fairly stable over the analyzed period (2017–19).

Regarding the active-layer thickness, the deepest thaw depth in 2020 was recorded at the Meteo borehole in Hornsund – approx. 5 m. The active-layer thickness increased by 0.75 m from 2018 to 2019. The observations at Hornsund are quite exceptional and might reflect a more complicated situation at the site than simple heat conduction. The very thick active layer may be influenced by groundwater flow during summer, but it is also possible that the quartzite bedrock, with its high thermal conductivity, has caused this. Active seismic profiling in Hornsund imaged the permafrost internal structure in two seasons to show an unusually thick active layer at the mountain slope, reaching 20 m, with a deep influence of underground water flow observed down to 30 m as seismic velocity changed, and a complicated state of cryotic coastal permafrost due to the influence of sea water reaching 300 m from the sea shore.

- Marciniak, A., Owoc, B., Wawrzyniak, T., Nawrot, A., Glazer, M., Osuch, M., Dobiński, W., and Majdański, M. (2019). Near-Surface Geophysical Imaging of the Permafrost – Initial Result of Two High Arctic Expeditions to Spitsbergen. *25th European Meeting of Environmental and Engineering Geophysics,* 1-5. DOI: 10.3997/2214-4609.201902454.

GDAŃSK UNIVERSITY OF TECHNOLOGY

In 2020, we analyzed samples taken in various locations in Svalbard (Arctic) and on the western shore of Admiralty Bay (Maritime Antarctica). The water and sediment from the Antarctic location was tested for ions, metals, non-metals, and Total Organic Carbon (TOC) concentrations, showing the importance of rock weathering on the elemental fluxes in river waters impacted by increased snowmelt. However, increases in Pb and Cd concentrations near the Antarctic station facilities indicate their anthropogenic origin.

In the Arctic, we studied three locations in Svalbard: Bellsund, Hornsund and Longyearbyen area. In Bellsund, lakes in glacier-free terrain were investigated, and the highest organic pollution levels were found in those close to the sea shore and exposed to wind. Pyrogenic PAHs were pollutants of special environmental concern in that location. In surface waters of the Hornsund area (streams, rivers and lakes), too, PAHs occurred, some of which may come from local sources in the activity around the Polish Polar Station (as suggested by the inverse correlation of naphthalene with distance from station). There, similar to the Antarctic samples, local rock weathering was a strong driver of elemental concentrations in waters. However, a mixture of processes has influenced the composition of these samples, including long-range atmospheric transport of chemicals.

A study on local environmental impact was conducted in Longyearbyen. It focused on untreated wastewater emissions of contaminants into the fjord. Through the determination of trace elements (V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Hg, As, Cd, Pb, U), total suspended solids and TOC, we established the impact to be low but of potential concern due to the increasing trend in the number of local inhabitants and tourists.

This work were carried out in the cooperation with the Kazimierz Wielki University in Bydgoszcz, the Institute of Biochemistry and Biophysics, the Polish Academy of Science (Warsaw), and Maria Skłodowska-Curie University in Lublin.

NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

In 2020, monitoring of active-layer thickness continued at a few fixed measurement points on the Kaffiøyra Plain around the Nicolaus Copernicus University Polar Station. These research points are part of the CALM program network and are among the few points located in the High Arctic region. The measurement points represent typical Kaffiøyra sites: sandy beach, tundra plain and moraine embankment. Size of ground thawing and thickness of active layer have been measured every 7–10 days since 1996.

Active layer (ground) temperatures were measured. For this purpose, automatic temperature loggers were installed various depths (max. 1.5 m) at measurement points. Temperature have been recorded continuously, year-round at the measurement points on the moraine (since 2006), the beach (since 2012) and the tundra (since 2006).

In 2020, investigations of factors controlling permafrost table degradation in the area of the Waldemar River outwash fan (NW Spitsbergen, Svalbard) continued. Moreover, lateral erosion rated was measured in streams at two sites in middle and distal zones of the Waldemar River outwash fan. Thermoabrasive niches were also investigated (developed due to the progradation of the thawing zone within the frozen river bank). The morphometry of these niches (length, height and depth) were measured in the middle zone of the Waldemar River outwash fan.

UNIVERSITY OF SILESIA

Recently, achievements in Polish permafrost research have widely recognized the need to revise the definition of "active layer" (AL) in the light of the latest discoveries. The geophysical and thermal variability of the entire AL thickness in the Hornsund area was first documented by Kasprzak et al. However, the need to redefine AL also results from the impossibility of applying the existing definition to cryotic permafrost, which is common especially in coastal high-latitude areas, where mineralization prevents freezing.

Cryotic permafrost up to approx. 300 m inland was found by Glazer et al. (2020). The results of these studies are confirmed by temperature monitoring in three recently drilled wells in the vicinity of geophysical surveys in Hornsund in Spitsbergen. A proposal to solve the difficulties with determining the AL thickness by more precisely defined criteria was published by Wojciech Dobiński. It is a synthetic work on the permafrost active layer. The findings and proposals contained therein may become the subject of a broader discussion in the international permafrost society, as they allow for an attempt to broadly systematize the issue of the active layer in relation to both periglacial and glacial environments.

- Glazer, M., Dobiński, W., Marciniak, A., Majdański, M., and Błaszczyk, M. (2020). Spatial distribution and controls of permafrost development in non-glacial Arctic catchment over the Holocene, Fuglebekken, SW Spitsbergen. *Geomorphology*, 358, 1-17. DOI: 10.1016/j.geomorph.2020.107128.
- Dobiński, W, (2020). Permafrost active layer. *Earth-Science Reviews*, 208, 1-20. DOI: 10.1016/j.earscirev.2020.103301.

Another issue developed in an original way by the community of Polish researchers of permafrost and the periglacial environment is the integrally perceived glacier–permafrost relation. A special achievement in the studies undertaken is the recognition of the key role of the environmental axis of the cold-temperate transition surface (CTS) transforming into the permafrost base (PB) surface (CTS-PB), which somehow integrates the glacial and periglacial environment at the glacier front. On the other hand, deglaciation in the upper, accumulative part of glaciers opens up space for permafrost aggradation in areas above glaciers (nunataks). The glacier-permafrost relation is elaborated in a special volume of Geosciences (MDPI).

- Szafraniec, J.E., and Dobiński, W. (2020). Deglaciation Rate of Selected Nunataks in Spitsbergen, Svalbard—Potential for Permafrost Expansion above the Glacial Environment. *Geosciences*, 10(5), 18 p. DOI: 10.3390/geosciences10050202.
- Dobiński, W. and Kneisel, C. (eds.) 2020. Permafrost and Glaciers: Perspectives for the Earth and Planetary Sciences. *Geosciences*.

A third important issue of broad importance is to propose a solution to the problem of permafrost extent in Greenland, and of glaciers and their substrate in general. This is an important issue because it covers an area of almost 2 million km². It is obvious that there is subglacial permafrost in each case,

because the temperature under a glacier cannot be higher than 0 °C.

- Dobiński, W. (2020). Northern Hemisphere permafrost extent: Drylands, glaciers and sea floor. Comment on the paper: Obu, J. *et al.* (2019). Northern Hemisphere permafrost map based on TTOP modeling for 2000–2016 at 1 km² scale, *Earth Science Reviews*, 193, 299-316, DOI: 10.1016/j.earscirev.2019.04.023. *Earth-Science Reviews*, 203, 1-7. DOI: 10.1016/j.earscirev.2019.103037.

Based on recently published works, it is possible to raise the level of master's and doctoral studies at Polish universities, which have a chance to overtake other centers of international importance.

UNIVERSITY OF WROCŁAW

In 2020, due to COVID-19, no field investigations were conducted. Nevertheless, two articles on permafrost in the Arctic coastal zone were published. The research present results of a geophysical survey on the Greenland Sea shore in SW Spitsbergen (Svalbard), indicating a strong thermal influence of sea water on the land and the shape of the permafrost base. These theorize the existence of a specific permafrost wedge at the land surface, decreasing in thickness seawards due to the existence of marine intrusions inland.

- Kasprzak, M. (2020). Seawater Intrusion on the Arctic Coast (Svalbard): The Concept of Onshore-Permafrost Wedge. *Geosciences*, 10(9), 1-11. DOI: 10.3390/geosciences10090349.
- Kasprzak, M., Łopuch, M., Głowacki, T., and Milczarek, W. (2020). Evolution of Near-Shore Outwash Fans and Permafrost Spreading Under Their Surface: A Case Study from Svalbard. *Remote Sensing*, 12(3), 27 p. DOI: 10.3390/rs1203048.

For more information contact Rajmund Przybylak (rp11@umk.pl) and see:

- Christiansen, H.H., Gilbert, G.L., Neumann, U., Demidov, N., Guglielmin, M., Isaksen, K., Osuch, M., and Boike, J. (2021). Ground ice content, drilling methods and equipment and permafrost dynamics in Svalbard 2016-2019 (PermaSval). In: Moreno-Ibáñez *et al* (eds), *State of Environmental Science in Svalbard (SESS) Report 2020*. Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 258-282. DOI: 10.5281/zenodo.4294095.
- Christiansen, H.H., Gilbert, G.L., Neumann, U., Demidov, N., Guglielmin, M., Isaksen, K., Osuch, M., and Boike, J. (2020). Permafrost temperatures and active layer thickness in Svalbard during 2017/2018 (PermaSval). In: Van den Heuvel *et al.* (eds), *State of Environmental Science in Svalbard (SESS) Report 2019*. Svalbard Integrated Arctic Earth Observing System, Longyearbyen, 236–249.
- Kalinowska, A., Szopińska, M., Chmiel, S., Kończak, M., Polkowska, Ż., Artichowicz, W., Jankowska, K., Nowak, A., and Łuczkiewicz, A. (2020). Heavy Metals in a High Arctic Fiord and Their Introduction with the Wastewater: A Case Study of Adventfjorden-Longyearbyen System, Svalbard. *Water*, 12(3), 16 p. DOI: 10.3390/w12030794.
- Kozioł, K., Marek, R., Pawlak, F., Chmiel, S., and Polkowska, Ż. (2020). Spatial Differences in the Chemical Composition of Surface Water in the Hornsund Fjord Area: A Statistical Analysis with A Focus on Local Pollution Sources. *Water*, 12(2), 21 p. DOI: 10.3390/w12020496.
- Lehmann-Konera, S., Marek, R., Franczak, ł., and Polkowska, Ż. (2020). Contamination of Arctic Lakes with Persistent Toxic PAH Substances in the NW Part of Wedel Jarlsberg Land (Bellsund, Svalbard). *Water*, 12(2), 15 p. DOI: 10.3390/w12020411.
- Potapowicz, J., Lambropoulou, D., Nannou, C., Kozioł, K., and Polkowska, Ż. (2020). Occurrences, sources,and transport of organochlorine pesticides in the aquatic environment of Antarctica. *Science of the Total Environment*, 735, 13 p. DOI: 10.1016/j.scitotenv.2020.139475.
- Potapowicz, J., Szumińska, D., Szopińska, M., Bialik, R., Machowiak, K., Chmiel, S., and Polkowska, Ż. (2020). Seashore sediment and water chemistry at the Admiralty Bay (King George Island, Maritime Antarctica) – geochemical analysis and correlations between the concentrations of chemical species. *Marine Pollution Bulletin,* 152, 12 p. DOI: 10.1016/j.marpolbul.2020.110888.
- Potapowicz, J., Szumińska, D., Szopińska, M., Sebastian, C., and Polkowska, Ż. (2020). Electrical conductivity and ph in surface water as tool for identification of chemical diversity. *Ecological Chemistry and Engineering*, 27(1), 95–111. DOI: 10.2478/eces-2020-0006.

PORTUGAL

BY GONÇALO VIEIRA (UNIVERSIDADE DE LISBOA)

INTRODUCTION

The Portuguese permafrost research community currently includes teams from four research centres of the University of Lisbon and one from the University of Évora. Due to COVID-19 restrictions that affected the boreal summer of 2020 field activities, the Portuguese field research in the Arctic was limited to February 2020. The field season was regular in the Antarctic Peninsula with several active projects. The summer field season in the Western Canadian Arctic and Northern Quebec has been cancelled, with the research focussing on remote sensing data analysis and laboratorial procedures.

One relevant new project concerning permafrost is the foundation of the College on Polar and Extreme Environments at the University of Lisbon, an interdisciplinary program joining four faculties and several research centres. Polar2E conducts several permafrost-related projects in the Arctic and Antarctic and research on mountain paleoenvironments in Portugal and Spain.

Gonçalo Vieira (CEG/IGOT, University of Lisbon) was elected member of the Executive Committee of the IPA in 2020 and is currently one of its two Vice-Presidents.

ANTARCTIC PENINSULA

University of Évora, Institute of Earth Sciences (PI: António Correia)

Under the framework of the project "*Study of electrical resistivities in the permafrost and Machu Picchu aquifer, Punta Crepín, Admiralty Bay, King George Island, Antarctica*", funded by the government of Peru and the Peruvian Antarctic Institute, several electrical resistivity tomography profiles were carried out to study the geometry of the aquifer that supplies water to the Machu Picchu Antarctic Station and the existence of permafrost near some of its facilities. The field work started on January 25 and ended March 5 and had the collaboration of students and researchers of INGEMMET (Geological, Mining and Metallurgical Institute of Peru). Preliminary results of the fieldwork carried out during 2020, together with results from fieldwork in previous years, indicate that permafrost degradation is probably taking place in the area where the Peruvian Machu Picchu Antarctic Station is located.

University of Lisbon, CEG/IGOT (PI: Gonçalo Vieira)

The project PERMANTAR aims at monitoring and modelling the thermal state of permafrost and associated dynamics in the western Antarctic Peninsula. Field activities in 2020 took place mainly in Barton Peninsula (King George Island), where data from the 13 m permafrost monitoring borehole, drilled in 2019, was collected for the first time (Fig. 44). Data was also collected from a network of ground surface temperature loggers enabling the identification of microclimate controls on permafrost. The results have been presented in a masters thesis by Joanna Baptista.

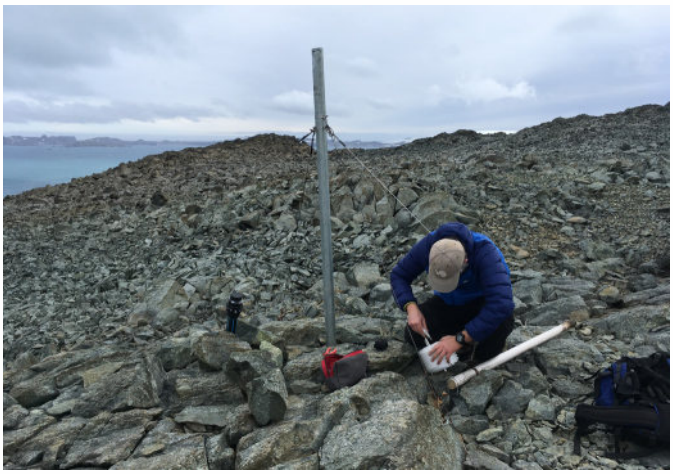

Fig. 44. Maintaining the King Sejong Station permafrost borehole in Barton Peninsula (King George Island).

PERMANTAR members have also conducted the maintenance of boreholes in Livingston Island, Deception Island and Cierva Cove, while in Amsler Island, support was provided by USAP Palmer Station. The GNSS annual surveys of Hurd rock glacier deformation have been repeated, and the site was resurveyed using UAV photography. PERMANTAR in 2020 involved international collaboration with the Argentinean Antarctic Institute (Claudio Matko), ETH-Zurich (Daniel Vonder Mühll), University of Alcalá (Miguel Ángel de Pablo, Miguel Ramos), the Korean Polar Research Institute (Hyoungseok Lee). National partners are CERENA/IST-ULISBOA (Pedro Pina, Gabriel Alejandro Goyanes) and IDL-ULIS-

BOA (Mohammad Farzamian). The project benefited from the logistical support of the Argentinean Antarctic Institute, Bulgarian Antarctic Institute, Chilean Antarctic Institute, Korean Polar Research Institute, Spanish Polar Committee and of the Portuguese Polar Program (PROPOLAR/FCT), who funds the project.

University of Lisbon, CERENA/IST (PI: Pedro Pina)

The research developed by CERENA/IST/ULisboa team in 2020 is mainly related to projects on the mapping and monitoring of terrestrial areas in Antarctica through multiscale remote sensing. The main focus of interest has been in vegetation and patterned ground. The typical small and sparse patches of *Usnea spp.* and mosses are being discriminated in satellite imagery with more robust classification models calibrated with the very detailed data acquired after Unmanned Aerial Vehicle (UAV) surveys. The analysed patterned ground consists of large fields of sorted stone circles. These were extensively characterized using image mosaics and digital elevation models of ultra-high resolution, built after UAV surveys. Its key features have been assessed along altitudinal gradients and compared with the occurrence of vegetation (*Usnea* and mosses). The field sites are located in the South Shetlands, namely in King George and Livingston islands. This research frames the PhD of Vasco Miranda. This research is part of the project VEGETANTAR, funded by PROPOLAR/FCT.

University of Lisbon, IDL (PI: Mohammad Farzamian)

The activities were framed within the project ANTERMON (Antarctic Electrical Resistivity Monitoring Network). During the 2019-20 Antarctic season the activities took place in two areas. At Livingston Island a new A-ERT monitoring system was installed at the GTN-P site of Mount Reina Sofia, to monitor the active layer and upper permafrost dynamics at 6h intervals (Fig. 45). Geophysical surveys using a DualEM-21 equipment were conducted, allowing a fast and non-invasive mapping of soil electrical conductivity to delineate the active layer and permafrost distribution. ERT profiles that had been measured in 2006 were resurveyed to study the permafrost changes. At Deception Island, the existing A-ERT system at the Crater Lake CALM site was upgraded and maintained, as well as repeating ERT profiles that had been measured in 2006. ANTERMON is funded by PROPOLAR/FCT. ANTERMON is a collaboration with the CEG/IGOT – University of Lisbon (Gonçalo Vieira), University of Alcalá (Miguel Ángel de Pablo) and the University of New South Wales, Sydney (John Triantafilis).

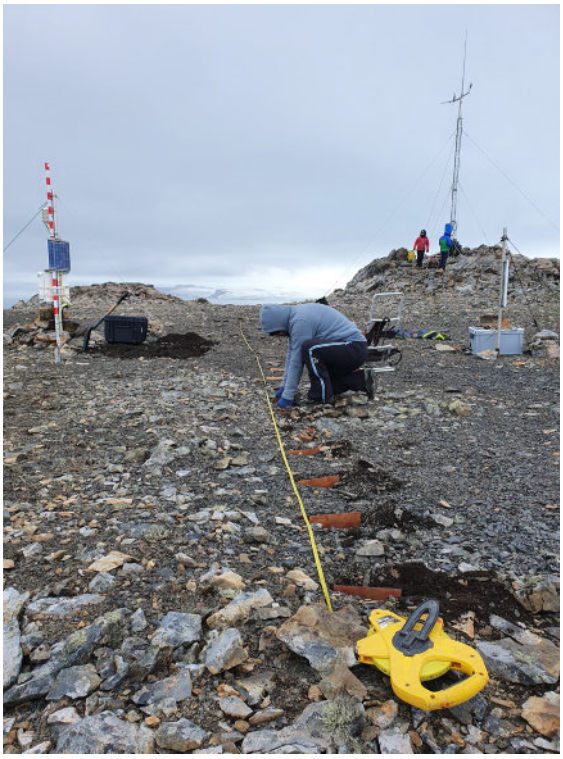

Fig. 45. Setting up the A-ERT monitoring system in Mount Reina Sofia (Livingston Island).

NORTHERN QUEBEC, CANADA

University of Lisbon, CEG/IGOT (PI: Carla Mora)

The activities in project THAWPOND - Remote sensing analysis of vegetation and thaw pond colour dynamics at the tundra-forest zone: from local to regional scale (Whapmagoostui – Kuujjuarapik, Hudson Bay, sub-Arctic Canada) focussed on the analysis of UAV optical and multispectral data collected in 2019, as well as on the processing of very high resolution satellite imagery. The main aim of the project is the detailed characterization of the vegetation and geomorphic characteristics of several thaw lake and pond areas, and evaluate their impacts on the biogeochemical characteristics of lake water. Using remote sensing imagery, we are analysing the interannual and intra-annual changes in lake water colour at the study sites and will use these areas as the basis for extending the analysis to a regional transect across Northern Quebec. This research frames the PhD of Pedro Freitas. THAWPOND is a collaboration with CEN/Ulaval (Warwick F. Vincent) and CQE/IST-ULISBOA (João Canário) and is funded by PROPOLAR/FCT.

University of Lisbon, CQE/IST (PI: João Canário)

The permafrost research at the Centro de Química Estrutural from the University of Lisbon focussed on the biogeochemistry studies of permafrost thaw lakes in the Canadian subarctic. These studies relate with the chemical characterization of natural organic matter (NOM). The aim is assessing its lability and the consequent potential for GHG gas release, and the remobilization of priority pollutants, namely mercury (Hg), during permafrost degradation. NOM characterization has been done using structural techniques (e.g., 2D 1H 13C NMR) and results showed that lability of NOM is particularly related with the degree of permafrost degradation. On the other hand, mercury studies have been pointing to the existence of extremely favourable conditions in thaw lakes in organic-rich areas for Hg methylation, therefore increasing the potential toxicity in these systems. This research frames the PhD of Diogo Folhas Ferreira and is integrated in PERMAMERC funded by PROPOLAR/FCT.

BEAUFORT SEA COAST (WESTERN CANADA)

University of Lisbon, CEG/IGOT (PI: Gonçalo Vieira)

Research in the coast of the Beaufort Sea is being conducted by the University of Lisbon in the framework of the EC H2020 project Nuntaryuk. The aim is monitoring coastline changes and quantifying retreat rates using multiple remote sensing platforms. The data will feed into the permafrost modelling components of Nunataryuk. UAV surveys conducted in Tuktoyatkuk and Paulatuk are being used for modelling flooding, and assessing coastal erosion and ice-wedge degradation, respectively. The field season of 2020 has been cancelled and work has focussed on the analysis of newly remote sensing imagery acquired specifically for the project for the Tuktoyaktuk Peninsula and western Darnley Bay. The activities are a collaboration with the Geological Survey of Canada (Dustin Whalen), AWI (Hugues Lantuit) and bGeos (Annett Bartsch) and in Portugal, with CERENA/IST (Pedro Pina) and CQE/IST (João Canário).

SERRA DA ESTRELA (PORTUGAL)

University of Lisbon, CEG/IGOT

The research in the Serra da Estrela has been focussing on the reconstruction of the paleoenvironmental evolution of the mountain. Field activities in the summer of 2020 have been framed within the project TERRA NOVA - Tor exhumation rates and soil erosion: relation between non-glaciated and formerly vastly glaciated areas (Fig. 46). The project is lead by the University of Zurich (Gerald Raab, Markus Egli), with the CEG/IGOT – University of Lisbon (Gonçalo Vieira), University of Wroclaw (Piotr Migoń), Boku (Christopher Luthgens) and University of Calabria (Fabio Scarciglia). The team has been surveying and sampling tors and glacial landforms and deposits in the Estrela UNESCO Global Geopark plateaus, to unravel their chronology and better understand the landscape evolution in this granite mountain. The Serra da Estrela shows extensive evidence of Quaternary glaciation and periglaciation, but their chronology is still poorly constrained. TERRA NOVA counts with the collaboration of the Estrela UNESCO Global Geopark and is funded by the University of Zurich.

Fig. 46. Sampling tors for determining exhumation rates (Serra da Estrela, Central Portugal).

For more information contact Gonçalo Vieira (vieira@campus.ul.pt).

RUSSIA

BY DMITRY S. DROZDOV (RUSSIAN ACADEMY OF SCIENCES)

EARTH CRYOSPHERE INSTITUTE, TYUMEN SCIENTIFIC CENTRE, SIBERIAN BRANCH, RUSSIAN ACADEMY OF SCIENCE (ECI TYUMEN SCIENTIFIC CENTRE SB RAS)

Results of the most fundamental and advanced investigations from the Earth Cryosphere Institute (ECI SB RAS) and other Institutes and organizations specializing in permafrost/cryosphere research are presented in the journal "*Earth's Cryosphere*" ("*Kriosfera Zemli*"), such as:

- Galanin, A.A. (2020). Stable isotopes ^{18}O and D in cave ice of the Lena Pillars National Nature Reserve (Eastern Siberia). *Earth's Cryosphere*, 24(1), 3-19. DOI: 10.21782/EC2541-9994-2020-1(3-19).
- Pankova, D.S., Olenchenko, V.V., Tsibizov, L.V., Kamnev, Y.K., Shein, A.N., and Sinitskiy, A.I. (2020). The structure of permafrost within Parisento Station (Gydan Peninsula) from geophysical data. *Earth's Cryosphere*, 24(2), 52-67. DOI: 10.21782/KZ1560-7496-2020-2(52-67).
- Fotiev, S.M. (2020). Debateable problems of geocryology: review of achievements. *Earth's Cryosphere*, 24(3), 3-15. DOI: 10.21782/EC2541-9994-2020-3(3-15).
- Melnikov, V.P., Anikin, G.V., Ishkov, A.A., Andrianov, I.E., and Gurtovoy, V.A. (2020). Modes of two-phase carbon dioxide flow is soil temperature stabilization systems depending on heat load: an experimental study. *Earth's Cryosphere*, 24(3), 52-59. DOI: 10.21782/EC2541-9994-2020-3(52-59).
- Chernov, R.A., and Muraviev, A. Ya. (2020). Catastrophic outburst-flood of the Spartakovskoye glacier-dammed lake on the Bolshevik Island (Servernaya Zemlya). *Earth's Cryosphere*, 24(4), 50-59. DOI: 10.21782/EC2541-9994-2020-4(50-59).
- Kopylov, D.V., and Sadurtdinov, M.R. (2020). The study of talik under small watercourse by the capacitive resistivity method. *Earth's Cryosphere*, 24)6), 38-46. DOI: 10.21782/EC2541-9994-2020-6(38-46).

MELNIKOV PERMAFROST INSTITUTE, SIBERIAN BRANCH, RUSSIAN ACADEMY OF SCIENCE (MPI SB RAS, YAKUTSK)

Selected Research Results

2020 marked a very special triple anniversary for the Melnikov Permafrost Institute (MPI). In 1960, the Permafrost Institute was founded in Yakutsk as a successor to the Obruchev Institute of Permafrost Studies in Moscow. To celebrate the anniversary, MPI held a national conference "*Environmental and Infrastructure Integrity in Permafrost Regions*" on 28-30 September 2020 (Fig. 47). About 70 talks were presented, including:

- Permafrost science issues: climate change and anthropogenic impacts on environmental integrity;
- Surface and ground water interaction,

Fig. 47. A group of conference participants, 30 September 2020, Yakutsk.

hydrology and geochemistry of periglacial landscapes;
- Permafrost engineering issues: climate change and anthropogenic impacts on infrastructure integrity.

MPI continued extensive field studies in Siberian permafrost regions. Several surveys were undertaken throughout the year for detailed permafrost and terrain characterization in problem areas.

Investigations of cover sands in Central Yakutia (the D'olkuma Formation) continued in 2020 to reconstruct climate, vegetation and environments during the last 40,000 years (Fig. 48). Pollen spectra from the sand deposits were found to be dominated by steppe and semi-desert herbaceous communities (*Poaceae, Chenopodiaceae, Artemisia, Caryophyllaceae* and *Cyperaceae*) and dry shrub tundra (*Betula sect. Nanae*). The data obtained from this study will improve our knowledge of the Late Neopleistocene and Holocene climates and landscapes in Central Yakutia.

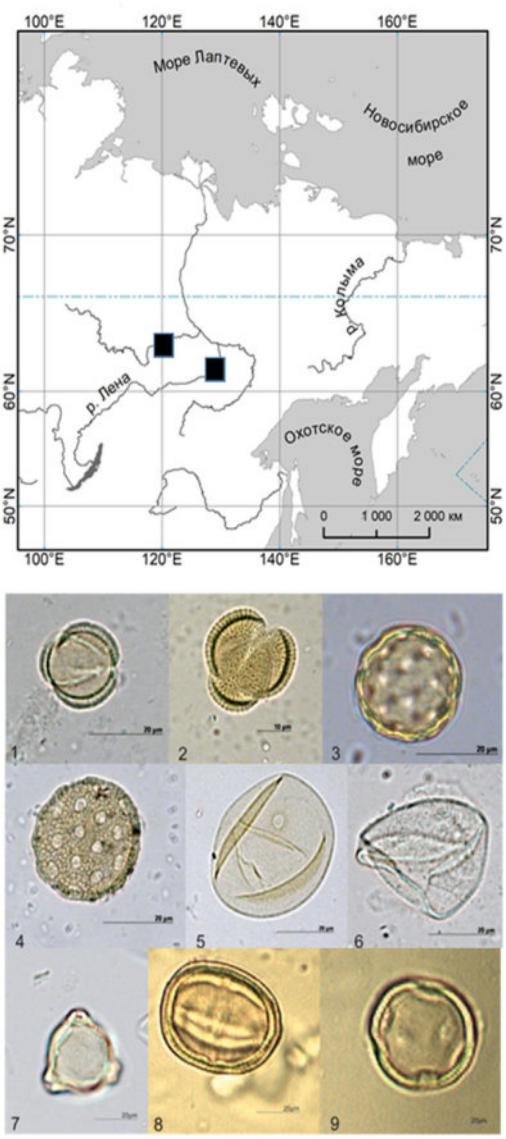

Fig. 48. Location of the D'olkuma Formation study sites (top) and key pollen taxa in dune deposits (bottom): 1 - Artemisia; 2 - Brassicaceae; 3 - Chenopodiaceae; 4 - Caryophyllaceae; 5 - Poaceae; 6 - Cyperaceae; 7 - Betula sect. Nanae; 8 - Polygonaceae; 9 - Thalictrum.

The geophysical group implemented a multi-technique approach to subsurface mapping and characterization of unfrozen aquifers in alluvial sands. Field surveys were conducted on the Bestyakh terrace of the Lena River, Central Yakutia, from 2018-2020 using electrical resistivity tomography (ERT), ground penetrating radar (GPR), seismic refraction (SR), capacitively coupled resistivity (CCR) and radio magnetotellurics (RMT). A combination of ERT and GPR was found to be optimal, providing more reliable information on taliks occurring above and within permafrost and can be effectively used for three-dimensional mapping of unfrozen aquifers.

Arctic permafrost programs are continuing in the Lena Delta and the Laptev Sea coastal region, including the Russian-German Lena Expedition. During 2020, new data were collected on coastal dynamics at key monitoring sites, as well as on degradational processes in the Lena Delta and in the Pleistocene Ice Complex along the Laptev Sea (Fig. 49). Studies were undertaken to locate permafrost beneath the Lena River distributary channels using a bottom probe.

In 2020, a 123-paged monograph "*The Subsurface Temperature Field and Permafrost in the Vilyui Basin*" by Mikhail N. Zhelezniak and Valery P. Semenov was published in Novosibirsk by the RAS Siberian Branch Press (in Russian). It presents an overall summary of geothermal research conducted in the region by MPI since the 1950s.

SERGEEV INSTITUTE OF ENVIRONMENTAL GEOSCIENCE RAS (IGE RAS, MOSCOW)

The field studies were carried out by the Institute of the Earth's Crust SB RAS in conjunction with the Institute of Environmental Geoscience of the Russian Academy of Sciences. The current position and internal structure of the southern geocryological zone's borders near the Lake Baikal were estimated. It helped to identify the coastal segments with marks of active, passive and relict geocryological phenomena that linked with permafrost southern border dynamics. It is including the polygonal structures, solifluction steps and terraces, nivation niches and rock glaciers. The long-focus photographing of the shores from the "Geolog" research vessel, and the perspec-

Fig. 49. Eroding ice-rich coastline, Bykovsky Peninsula, Laptev Sea.

tive and orthogonal aerial photographing from a radio-controlled quadcopter were used (Fig. 50).

INSTITUTE OF PHYSICOCHEMICAL & BIOLOGICAL PROBLEMS IN SOIL SCIENCE, RAS (SOIL CRYOLOGY LABORATORY) (PUSHCHINO, RUSSIA)

The presence of photosynthetic microorganisms in permafrost is a well-known phenomenon. For the first time, this issue has been studied by metagenomic approach and was recently published.

- Vishnivetskaya, T.A., Almatari, A.L., Wu, X., Spirina, E.V., Williams, D.E., Pfiffner, S.M., Rivkina, E.M. Insights into Community of Photosynthetic Microorganisms from Permafrost. *FEMS Microbiology Ecology*, 96(12), 17 p. DOI: 10.1093/femsec/fiaa229.

Data about methane concentration in the permafrost sediments from the Antarctic boreholes have been recently summarized. The maximum (up to 330 mol/kg) was obtained for marine sediments from the KGI area. The methanogenic activity has been proved by experiments with isotopically marked substrates.

- Rivkina, E.M., and Abramov, A.A. (2020). Methane as an indicator of permafrost formation conditions in Antartica. *Earth's Cryosphere*, 24(3), 46-51. DOI: 10.21782/EC2541-9994-2020-3(46-51).

The viable Protista from permafrost were studied with genetic approach in mind and recently published.

- Malavin, S., Shmakova, L., Claverie, J.M., and Rivkina, E. (2020). Frozen Zoo: a collection of permafrost samples containing viable protists and their viruses. *Biodiversity Data Journal*, 8, 23 p. DOI: 10.3897/BDJ.8.e51586.

CRYOLITHOLOGY & GLACIOLOGY DEPARTMENT, GEOGRAPHICAL FACULTY, LOMONOSOV MOSCOW STATE UNIVERSITY

Cryolithological research

Victor V. Rogov and Irina D. Streletskaya continue to study the cryogenesis role in the formation of loess sediments in the Lower Volga River region. Four stages of the development of permafrost processes during the Late Pleistocene were newly recognized for the region through the example of the Srednyaya Akhtuba reference section.

- Taratunina, B. Rogov, V. Streletskaya, Thompson, W. Kurchatova, A., Yanina, T., and Kurbanov, R. (2020). Late Pleistocene cryogenesis features of a loess-paleosol sequence in the Srednyaya Akhtuba reference section, Lower Volga river valley, Russia. *Quaternary International*, 590, 56-72. DOI: 10.1016/j.quaint.2020.12.015.
- Rogov, V.V., Streletskaya, I.D., Taratunina, N.A., Kurchatova, A.N., Kurbanov, R.N., and Yanina, T.A. (2020). Late Pleistocene cryogenesis in the lower Volga River region. Vestn. Mosk. un-ta, Series 5, *Geografiya*, 6, 73-85 (in Russian).

Irina D. Streletskaya obtained new data in the course of studying the organic matter and the gas component in permafrost in the north of Western Siberia. Based on our studies in the Marre-Sale area, new reliable data was obtained on the methane content in the active layer, underlying frozen soils of the transition zone of the upper permafrost, and data on the methane emission into the atmosphere for the dominant landscapes of the typical tundra region of Western Yamal.

- Oblogov, G.E., Vasiliev, A.A., Streletskaya, I.D., Zadorozhnaya, N.A., Kuznetsova, A.O., Kanevskiy, M.Z., and Semenov, P.B. (2020). Methane content and emission in the per-

Fig. 50. Inspection of proluvial fan on the western coast of Lake Baikal.

mafrost landscapes of Western Yamal, Russian Arctic. *Geosciences*, 10(10), 21 p. DOI: 10.3390/geosciences10100412.

Irina D. Streletskaya and colleagues from VNIIOkeangeologiya have developed a geochemical model of changes in geosystems of the coastal shelf zone under the conditions of current climate warming in the Arctic. Together with terrigenous material, organic matter, gases, occluded in ice and sediments, and low-valent metal ions (mainly Fe_2) enter the water, thus causing a change in physicochemical parameters of the coastal zone environment. The research performed geochemical studies of ground ice and host sediments on three sections of the Kara Sea coast (Spindler area; Marre-Sale subsoil; Sopochnaya Karga subsoil). The results allowed developing a geochemical model of changes in the geosystems of the coastal-shelf zone under current climate warming conditions in the Arctic.

- Vanstein, B.G., Streletskaya, I.D., and Pismeniuk, A.A. (2020). Coastal geosystems of the Kara Sea in a changing climate. *Arctic Ecology and Economy*, 3(39), 73-86. DOI: 10.25283/2223-4594-2020-3-73-86.

Yuri B. Badu published the results of the analysis of the spread of frost-heaving mounds (pingos) in the north of West Siberia. The density of the spread of pingos on the Yamal, Gydan and Tazovsky peninsulas is naturally concentrated above the neotectonically heterogeneous part of the sedimentary cover incision, which concentrates gas deposits of gas-bearing structures at depths of no more than 700-900 m from the daily surface; the highs of the area distribution of pingos are timed to the coastal areas of the sea and lagoon-sea terraces of the western and eastern Yamal, the north and south of the Gydan Peninsula, the north and central part of the Taz Peninsula.

- Badu, Yu. B., Nikitin, K.A. (2020). Frost mounds within the gas-bearing structures, northern part of West Siberia. *Earth's Cryosphere*, 24(6), 17-26. DOI: 10.21782/EC2541-9994-2020-6(17-26).

Detailed analysis of five gas emission craters (GEC) found in the north of West Siberia was undertaken by Alexander I. Kizyakov with co-authors. GECs are found in various environmental (shrublands or moss-grass tundra) and geomorphic (river valley, terrace, slopes) conditions. The mechanism of GEC formation is most likely similar for all the GEC and is controlled rather by internal geologic and cryolithologic structure than by any surface properties.

- Kizyakov, A.I., Leibman, M., Zimin, M., Sonyushkin, A., Dvornikov, Y., Khomutov, A., Dhont, D., Cauquil, E., Pushkarev, V., and Stanilovskaya, Y. (2020). Gas emission craters and mound-predecessors in the north of West Siberia, similarities and differences. *Remote Sensing*, 12(14), 23 p. DOI: 10.3390/rs12142182.

Valery I. Grebenets, Fedor D. Yurov, Vasiliy A. Tolmanov and Vladimir A. Fedin continued to analyze the regional aspects of the interaction of cryogenic processes and economic infrastructure in the Arctic settlements.

Larisa I. Zotova summarized the experience of estimated permafrost maps on a landscape basis for environmental purposes. Main permafrost and biotic factors and anthropogenic pressure, calculating the integral coefficients for clustering landscapes, evaluation mapping. The principles of drawing up multiscale maps are considered all assesed. To create these maps, methods of landscape indication, interpretation of satellite images, expert assessments, statistical calculations, and GIS analysis are used.

- Zotova, L.I. (2020). The experience of estimated permafrost maps creation on a landscape basis for environmental purposes/Landscape Science and Landscape Ecology: Considering Responses to Global Challenges. *Book of Abstracts of the 1st International IALERussia online conference*, Moscow, 14-18 September 2020. Eds. A.V. Khoroshev, T.I. Kharitonova. Moscow: Faculty of Geography, Lomonosov Moscow State University. 249 p.

Alexey A. Maslakov has conducted landscape and permafrost studies within key area of Eastern Chukotka coastal plains. The influence of climate variations and human activity to thermal regime of communal ice cellars of Eastern Chukotka settlements has been assessed. Coastal erosion within Lorino settlement was studied.

- Maslakov, A.A., Nyland, K.E., Komova, N.N., Yurov, F.D., Yoshikawa, K., and Kraev, G.N. (2020). Community Ice Cellars In Eastern Chukotka: Climatic And Anthropogenic Influences On Structural Stability. *Geography, Environment, Sustainability*, 3(13), 49-56. DOI: 10.24057/2071-9388-2020-71.

Glaciological research

Under the leadership of Viktora V. Popovnina, in the summer of 2020, a set of field work was carried out in the basin of the representative mountain glacier

Dzhankuat in the Central Caucasus. The long-term series of mass-balance observations is continued.

Mikhail N. Ivanov studied modern changes in the glaciers of the Polar Urals and the climate. A numerical estimate of the reduction in their area was given. The complete disappearance of 44 glaciers has been established (Nosenko et al., 2020, Cherkasova, Ivanov, 2020). In the Polar Urals, field glaciological, geophysical and geodetic works were carried out.

- Nosenko, G.A., Muraviev, A.Ya., Ivanov, M.N., Sinitskiy, A.I., Kobelev, V.O., and Nikitin, S.A. (2020). Response of glaciers of the Polar Urals to modern climate change. *Ice and Snow*, 60(1), 42-57. DOI: 10.31857/S2076673420010022.

Marina A. Vikulina continued collecting data of the Khibiny mountains. Winter 2019-2020 characterized by maximum snow cover thickness of 1.68 m. An increase in avalanche activity in the territory of the Khibiny mountains range was established, associated with an increase in the amount of solid precipitation and the duration of the avalanche active period.

- Vikulina, M.A., and Marchenko, E.S. (2020). The current state of avalanche danger in the Khibiny / Materials of the XVII glaciological symposium "*The role of the cryosphere in the past, present and future of the Earth*", Abstracts, St. Petersburg. 30 p.

Dmitry A. Petrakov continued glaciological research in Central Asia jointly with research group from Switzerland. An important role of the cryosphere in water security has been emphasized. We analyzed reasons of the most catastrophic glacial debris flow in Central Asia during recent decades, claimed about 100 people. Recommendations on regional risk mitigation were provided. During research in the Central Caucasus jointly with scientists from IG RAS a technology how to assess growth potential of glacier lakes has been developed.

- Barandum, M., Fiddes, J., Scherler, M., Mathys, T., Saks, T., Petrakov, D.A., and Hoelzle, M. (2020). The state and future of the cryosphere in Central Asia. *Water Security*, 11. DOI: 10.1016/j.wasec.2020.100072.
- Petrakov, D.A., Chernomorets, S.S., Viskhadzhieva, K.S., Dokukin, M.D., Savernyuk, E.A., Petrov, M.A., Erokhind, S.A., Tutubalina, O.V., Glazyrin, G.E., Shpuntova, A.M., and Stoffel, M. (2020). Putting the poorly documented 1998 GLOF disaster in Shakhimardan River valley (Alay Range, Kyrgyzstan/Uzbekistan) into perspective. *Science of the Total Environment*, 724. DOI: 10.1016/j.scitotenv.2020.138287.
- Lavrentiev, I., Petrakov, D.A., Kutuzvov, S., and Smirnov, A. Assessment of lgacier lakes development in Central Caucasus. *EGU General Assembly 2020*, Online, 4-8 May 2020. DOI: 10.5194/egusphere-egu2020-6471.

Snow-avalanche studies to detect changes in snowfall and avalanche activity were continued at the Elbrus educational and scientific base of MSU. A decrease in the degree of avalanche activity has been established due to predominance of snowy, warm winters in the last decade with a peak in snow accumulation and avalanches in the spring.

- Oleinikov, A.D., and Volodicheva, N.A. (2020). Winters of avalanche maximum in the Greater Caucasus for the period of instrumental observations (1968–2016). *Ice and Snow*, 60(4), 521-532. (In Russian). DOI: 10.31857/S2076673420040057.

A catalogue of catastrophic avalanches in the Elbrus region (upper reaches of the Baksan river valley) was compiled based on the results of a 50-year record (1968-2018). The generalization of the information about fluctuations of the southern slope glacier Big Azau and addition to the dating of moraines of the last stages of glaciation, from the Little Ice Age to the end of the 20th century are made.

The scientists of our department, the scientists of ECI and many others took a part in The European Geosciences Union (EGU) General Assembly 2020, American Geophysical Union (AGU) 2020 Fall Meeting, The XVII Glaciological Symposium "*The role of the cryosphere in the past, present and future of the Earth*" (St. Petersburg, AARI, November 17-20, 2020) and made many presentations. During the symposium Dmitry A. Petrakov was elected as one of Vice-Presidents for the Glaciological Assosiation.

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SPAIN

BY MARC OLIVA (UNIVERSITAT DE BARCELONA), MIGUEL ÁNGEL DE PABLO (UNIVERSIDAD DE ALCALÁ), ENRIQUE SERRANO (UNIVERSIDAD DE VALLADOLID), AMELIA GÓMEZ-VILLAR (UNIVERSIDAD DE LEÓN), JAVIER SANTOS (UNIVERSIDAD DE LEÓN)

ACTIVITIES OF THE IPA-SPAIN GROUP

The COVID-19 pandemic has impacted the research activities conducted by the different research groups working on permafrost and periglacial processes in Spain during 2020. In contrast to previous years, field seasons were mostly focused in Iberian mountains (Pyrenees, Cantabrian Mountains, Sierra Nevada, Iberian Range, Central Iberian Range), although some researchers carried out research also in Antarctica from January to February 2020. Despite the pandemic situation, there has been an intense collaboration between the different groups. Researchers from the universities of Barcelona, Valladolid, Complutense and Autónoma of Madrid, Alcalá, Extremadura, León, the Pyrenean Institute of Ecology and the Basque Centre for Climate Change have collaborated in different projects, along with other international centres.

6TH EUROPEAN CONFERENCE ON PERMAFROST

During the last European Conference in Chamonix, the Spanish permafrost community made an official proposal to organise the next on Permafrost in Puigcerdà (Fig. 51), in the heart of the eastern Pyrenees, from June 20-23, 2022. In July 2019, this proposal was accepted by the Executive Committee of the International Permafrost Association. However, due to pandemic situation, several permafrost conferences were postponed and the 6th European Conference on Permafrost (EUCOP6) will now be held from June 19-22, 2023.

Fig. 51. Puigcerdà, in the valley floor of the Cerdanya, will host the next EUCOP conference.

This event promoted by the IPA council is celebrated every four years with the main objective of providing interdisciplinary collaboration and joint initiatives between the different research groups working on periglacial and permafrost subjects.

RESEARCH BY SPANISH GROUPS

Researchers from the Department of Geography of the Universitat de Barcelona of the Antarctic, Arctic and Alpine environments (ANTALP) Research Group have conducted research activities in the Central Pyrenees and León Mountains. The Arctic season that was supposed to take place in July on northern Ellesmere Island (Canada) was cancelled because of COVID-19.

ANTALP research included a field season in the Aran Valley with the purpose of reconstructing the glacial and postglacial landscape evolution. The team collected tens of samples for cosmogenic dating purposes from glacial records (moraines, erratic boulders and polished surfaces) as well as from rock glaciers in order to better understand the origin, evolution, and stabilization of these permafrost-related features. This work was complemented with an accurate geomorphological surveying and mapping using UAVs. In addition, Ferran Salvador (Universitat de Barcelona) also continued with his long-term monitoring of soil and air temperatures in high mountain environments in the Eastern Pyrenees, namely in Cerdanya area.

Despite the difficulties derived from the COVID-19 pandemic, Enrique Serrano, Universidad de Valladolid (Pangea) and José Juan Sanjosé, University of Cáceres, continued with their research activities focused on mountain permafrost and periglacial geomorphology in the Cantabrian Mountains and the Pyrenees. In addition, the team has collaborated with the Pyrenean Institute of Ecology (IPE-CSIC) coordinated by Nacho López-Moreno on the glaciological research at the Aneto and La Paúl glaciers, as well as with the Alfa Underground Explorations Club (Madrid) led by Javier Sánchez, Universidad de León.

Fig. 52. Top: the Áliva area in the Picos de Europa at 1750-1850 m asl, under the Peña Vieja peak (2573 m asl). Bottom: fieldwork in the K-5 Ice Cave at 120 m depth.

Research activities have been developed in the same sites where both research groups have worked for 20 years, namely the Cantabrian Mountains (Fig. 52; Picos de Europa, Aliva, León Mountain and Campoo area) and the Pyrenees (Posets and Maladeta massifs). Field activities centred on monitoring periglacial processes and landforms (solifluction, slides, debris slopes, rock glacier, ice caves and permafrost distribution in the high mountain). The objectives and methodological approach have been the same in annual surveys conducted in previous years, including geomatic techniques; terrestrial laser scanner, GPS-RTK and photogrammetry applied to glaciers, rock glaciers and mass movements (and UAV for second year).

The summer fieldwork carried out in the Picos de Europa and Campoo area focused on ice caves, solifluction and slides, obtaining news ground thermal data (Fig. 52). In the ice caves of Picos de Europa, we equipped fives ice caves with dataloggers reinstalling some of the loggers in the Verónica, Altaiz and Castil ice caves. In S5 ice cave, that has not been explored since 1980s, we also installed dataloggers to monitor environmental parameters. This work will be expanded and complemented during the following years. The summer field work season in the Pyrenees developed on the same places where the research group has been working for the last nine years, namely on the monitoring of rock glacier and glaciers as well as periglacial processes and permafrost in the Posets and Maladeta massifs (Fig. 53). Systematic surveys of rock glaciers and glaciers, and two field surveys were made in September. As a result of this work, four research articles were published in 2020 centred on periglacial processes and mountain permafrost both in the Cantabrian Mountains and the Pyrenees.

Fig. 53. La Maladeta, Pyrenees. Top: view of La Maladeta rock glacier. Bottom: GPS-RTK measurements.

- Serrano, E., López-Moreno, J.I., Gómez-Lende, M., Pisabarro, A., Martín-Moreno, R., Rico, I., and González, E. (2020). Frozen ground and periglacial processes relationship in temperate high mountains: a case study at Monte Perdido-Tucarroya area (The Pyrenees, Spain). *Journal of Mountain Science*, 17, 1013-1031. DOI: 10.1007/s11629-019-5614-5.
- De Sanjosé-Blasco, J.J., López-González, M., Alonso-Pérez, E., and Serrano, E. (2020). Modelling and terrestrial laser scanning methodology (2009-2018) on debris cones in temperate high mountains. *Remote Sensing*, 12(4), 21 p. DOI: 10.3390/rs12040632.
- Serrano, E., Pisabarro, A., López-Moreno, J.I., Gómez-Lende, M., Martín-Moreno, R., and Rico, I. (2020). Mapping the potential distribution of frozen ground in Tucarroya (Monte Perdido Massif, the Pyrenees). *Cuadernos de Investigación Geográfica*, 46(2), 395-411. DOI: 10.18172/cig.4414.
- Pisabarro, A., and Serrano, E. (2020). Chronolgy of geomorphological changes in a valley of Cantabrian Mountains over the last 20,000 years. *Cuaternario y Geomorfología*, 34(3-4), 61-78. DOI: 10.17735/cyg.v34i3-4.86012.

The permafrost research team of Universidad de Alcalá, once the PERMASNOW project finished last year, has focused on the maintenance of the TSP and CALM stations in Livingston and Deception Islands, Antarctica thanks to the resources provided by the Spanish Polar Committee for the Antarctic temporal series. Members of the team participated in the Spanish Antarctic Season 2020 to download data from the dataloggers and to measure the active layer thickness in their monitoring sites (Fig. 54). Due to the COVID-19 pandemic, they reduced the scientific activity to the data processing after 15 years of the oldest stations. The group continues the study of environmental conditions on Mars as part of NASA's Curiosity mission scientific team, and they are contributing to the develop of Mars2020 (NASA) and ExoMars (ESA), the next missions to Mars.

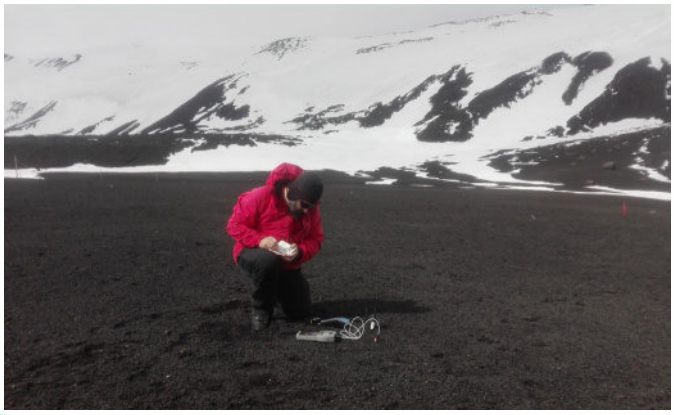

Fig. 54. Miguel Ángel de Pablo measuring different ground surface thermal properties at the Crater Lake CALM site on Deception Island, Antarctica in early January 2020.

The research group at Universidad de León, GEOPAT (Geomorphology, Landscape and Territory) is working on rock glaciers of the Cantabrian Mountains. This year the fieldwork includes relative chronology using the Schmidt hammer on several rock glaciers of this range. In collaboration with Universidad Complutense de Madrid, Universitat de Barcelona and Universidade de Lisboa, cosmogenic dating of rock glaciers has also been carried out (Fig. 55).

Fig. 55. Sampling a relict rock glacier, Cantabrian Mountains.

The objective is to reconstruct glacial and periglacial evolution of some massifs, as scarce data about this range still exists. During the fall, fieldwork was conducted to perform an electrical resistivity tomography on a rock glacier in order to complete analysis of the internal structure of relict rock glaciers. The group is also monitoring the ground thermal regime in periglacial environments in the same range. Two young researchers (Sergio Alberto Peña and Adrián Melón) have joined the group and are going to prepare their PhD theses on periglacial and snow processes in the Cantabrian Mountains. This year the first has focused on the sedimentological analysis of talus slopes in the Peña Ubiña massif.

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SWITZERLAND

BY CÉCILE PELLET (UNIVERSITÉ DE FRIBOURG)

SWISS PERMAFROST MONITORING NETWORK

The Swiss Permafrost Monitoring Network (PERMOS) celebrated its 20th anniversary in 2020, which was therefore characterized by reporting on the key results from the two decades of operation. PERMOS started in 2000 as an unconsolidated network of sites from research projects and now coordinates observations from six partner institutions: ETH Zurich (ETHZ, Daniel Farinotti, Luisa Pruessner), the Universities of Fribourg (UNIFR, Reynald Delaloye, Christian Hauck, Christin Hilbich, Martin Hölzle, Cécile Pellet), Lausanne (UNIL, Christophe Lambiel), Zurich (UZH, Isabelle Gärtner-Roer, Andreas Vieli), the WSL Institute for Snow and Avalanche Research (SLF, Marcia Phillips, Jeanette Nötzli) and the University of Applied Sciences and Arts of Southern Switzerland (SUPSI, Cristian Scapozza).

It is the first national long-term observation network for permafrost and an early component of GTN-P. After 20 years of operation, development and evaluation, PERMOS holds today the largest (28 sites) and most diverse (3 observation elements) collection of mountain permafrost data worldwide and can be considered a role model regarding its structure and organization (Fig. 56). The monitoring strategy is based on ground-surface and subsurface temperatures, changes in subsurface ice content, and permafrost creep velocities. All observation elements consistently indicate significant changes of mountain permafrost in the Swiss Alps over the past 20 years. A clear warming trend is underlined by the consistent decrease of subsurface ice and an increase in rock glacier velocities.

Fig. 56. Borehole and meteorological station at Stockhorn (3400 m asl). Photo: Andreas Hasler.

Due to the restrictions related to the COVID-19 pandemic, meetings and excursions had to be postponed, held virtually or cancelled. Fortunately, the field work could take place as usual by respecting additional safety regulations related to the pandemic. Problems for the data acquisition were only caused by the exceptionally early snowfall in October 2020, which buried several of the GST loggers and complicated a small number of terrestrial geodetic surveys on rock glaciers. However, the borehole stations with their continuous measurements and recordings were not affected.

NEWS FROM RESEARCH PROJECTS & ACTIVITIES

In parallel to its long-term monitoring of borehole temperatures in cooperation with PERMOS and GTN-P (Jeanette Nötzli), the WSL Institute for Snow and Avalanche Research SLF continues to investigate permafrost slope deformation and the processes controlling them (Robert Kenner). The role of permafrost in deep-seated rock slope failures is investigated at selected sites in Switzerland and rock avalanche data are collected in a permafrost rockfall data base. Mountain infrastructure stability and temperatures around structures are monitored (Marcia Phillips) in collaboration with practitioners. Non-conductive processes in ice-rock mixtures and within the active layer are modelled using SNOWPACK and GERM (Luisa Pruessner, Daniel Farinotti, Matthias Huss, Martin Hölzle). A new permafrost and ground ice map of Switzerland was published at the end of 2019.

- Kenner, R., Nötzli, J., Hölzle, M., Raetzo, H., and Phillips, M., (2019). Distinguishing ice-rich and ice-poor permafrost to map ground temperatures and ground ice occurrence in the Swiss Alps. *Cryosphere*, 13(7), 1925-1941. DOI: 10.5194/tc-13-1925-2019.

Three boreholes were drilled in the Schafberg rock glacier in 2020 (Pontresina, Engadine) and instrumented with piezometers, temperature sensors and cross-borehole electrical resistivity tomography to investigate the influence of water on rock glacier

Fig. 57. Borehole drilling in August 2020 on the ice-rich Schafberg rock glacier. Photo: Nora Bühler.

creep rates (Fig. 57). The drilling site was chosen after taliks were discerned on the basis of borehole temperature data and frequency domain electro-magnetometry measurements (Jacopo Boaga).

In addition to its monitoring activities about mountain permafrost related parameters, the High Mountain Geomorphology group of the Institute of Earth Surface Dynamics, University of Lausanne (lead by Christophe Lambiel), has continued its research on permafrost distribution and rock glacier dynamics. A new shallow borehole was drilled at the top of the Mont Fort (3300 m asl) in order to investigate the thermal state of a high elevation permafrost site. A new project was started in collaboration with Université de Savoie, France (Ludovic Ravanel) about permafrost distribution in steep rock walls and thermal regime of hanging glaciers in the Valais Alps. We also initiated a new project on the hydrology of rock glaciers in collaboration with Daniel Hunkeler (CHYN, Neuchâtel) and Cristian Scapozza (SUPSI, Lugano). Sebastián Vivero continued his PhD thesis on rock glacier dynamics, using mainly UAV for the quantification of surface changes at very high resolution, with the objective of increasing our knowledge on rock glacier motion. Finally, in the framework of the ESA CCI+ project, we are investigating the rock glacier kinematics in the Southern Alps of New Zealand using Sentinel-1 InSAR (Fig. 58).

At ETH Zurich, WSL Birmensdorf and SLF Davos (Luisa Pruessner, Matthias Huss, Marcia Phillips, and Daniel Farinotti) a research project is being conducted to extend the Glacier Evolution and Runoff Model's capabilities to allow the modelling of ground temperatures of permafrost and rock glaciers. The aim of this project, conducted in the frame of WSL's Climate Change Impacts on Alpine Mass Movements (CCAMM) programme, is to predict the long-term development of the thermal regime and possible runoff from high mountain permafrost. To this end, the newly developed model will be driven by recently released future climate scenarios, spanning time frames up to the end of the 21st century.

Permafrost research in the Cryosphere & Geophysics research group at the University of Fribourg focused on developing new geophysical measuring and modelling techniques to quantify ground ice content and its temporal evolution. New modelling techniques were developed through the so-called petrophysical joint inversion (PJI) scheme using electric and seismic data to quantify ground ice content, water content and porosity (Coline Mollaret in collaboration with Florian Wagner, Aachen University). New measuring techniques (spectral induced polarisation, SIP) to quantify ground ice are explored within the Swiss-German-Austrian collaboration project SPICE by combining laboratory measurements (University of Bonn, Germany) with field-based SIP surveys and monitoring (Vienna University of Technology, Austria & University of Fribourg, Theresa Maierhofer, Adrian Flores-Orozco, and Christin Hilbich) in the Swiss and Italian Alps. Within the GCOS Switzerland funded project REP-ERT a community-based effort was initiated to create an international data-

Fig. 58. UAV survey at Morenas Coloradas rock glacier (Central Andes).

base of geoelectrical surveys on permafrost (Christian Hauck, Christin Hilbich, Coline Mollaret, and Cécile Pellet). This pilot project was recently extended to an IPA Action Group starting in 2021.

Regarding permafrost modelling, Jonas Wicky developed a 2D convective heat flow model within the SNSF project MODAIRCAP, which is capable of simulating the thermal effects of convective heat flow on coarse blocky permafrost terrain (i.e., rock glaciers and talus slopes). In a second modelling project, Cassandra Koenig developed a 2D hydro-thermal model aiming at simulating the future runoff characteristics of high altitude sites in the Chilean Andes in the context of climate induced thawing of permafrost (in collaboration with BGC Engineering, Canada).

A new project aiming to understand the heat exchange through the coarse debris mantle to better predict the thermal evolution of the underlying permafrost in response to climate change started in 2020 (Dominik Amschwand, Martin Scherler, Martin Hölzle). A detailed energy balance and heat flux measurement station was installed in summer 2020 on Murtèl rock glacier and will be coupled with numerical modelling.

The Alpine Cryosphere and Geomorphology research group is part of the ESA (European Space Agency) Permafrost CCI (Climate Change Initiative) project, promoting the integration of mountain permafrost in worldwide overviews of permafrost state and evolution (Chloé Barboux, Cécile Pellet, and Reynald Delaloye). The IPA Action Group on rock glacier inventories and kinematics (Reynald Delaloye, Chloé Barboux, Cécile Pellet, and Thomas Echelard) launched in 2018 is in its second phase. It currently counts more than 130 members from 22 countries. Baseline concepts for inventorying rock glaciers and including kinematics as an attribute within rock glacier inventories have been compiled and reviewed in the course of two international workshops (in Evolène, 2019 and in Fribourg, 2020). Based on the recommendation of the action group, GTN-P submitted a proposal to the Global Climate Observing System (GCOS) to include Rock Glacier Kinematics as a new associated product of the Essential Climate Variable (ECV) for permafrost. Julie Wee started her PhD thesis on the topic of Glacier forefields in mountain permafrost environments. She characterizes and analyses the changes within these systems using a combination of photogrammetry techniques, in-situ geophysics and geodetic surveys.

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UNITED KINGDOM

BY JULIAN MURTON (UNIVERSITY OF SUSSEX)

PERMAFROST DRILLING AT BATAGAY MEGASLUMP, SIBERIA

Drilling of permafrost deposits at the Batagay megaslump in the Yana Uplands of northern Yakutia, Russia, was carried out in March 2020 as part of a Russian–UK research project to reconstruct ancient permafrost environments of western Beringia. Two boreholes, each about 70 m deep, were drilled by a team from the North-Eastern Federal University (NEFU), Yakutsk, in the Sakha Republic (Yakutia) (Fig. 59). The boreholes penetrated through two major cryostratigraphic units (upper sand unit and upper ice complex; Fig. 60) and into underlying bedrock. The research project was collaborative between the Institute of Applied Ecology of the North, NEFU (led by Grigoriy Savvinov); the Melnikov Permafrost Institute, NEFU (led by Alexander Fedorov); and the University of Sussex, UK (led by Julian Murton). Geological and geocryological analyses of the permafrost cores is being planned, to investigate sedimentological, ground ice, age and other properties. The cores, it is hoped, will provide good cryostratigraphic control for testing and developing the preliminary age model for Batagay, which suggests that the oldest deposits there date from the early Middle Pleistocene, at least 650,000 years ago.

- Murton, J.B., Opel, T., Toms, P., Blinov, A., Fuchs, M., Wood, J., Gärtner, A., Merchel, S., Rugel, G., Savvinov, G., and Wetterich, S. (in review). A multi-method pilot dating study of ancient permafrost in Batagay megaslump, East Siberia. Submitted to *Quaternary Research*.

Fig. 59. Permafrost core from the Batagay megaslump, drilled by staff from the North-Eastern Federal University, Yakutsk, March 2020. Photo: Peter Danilov.

MIDDLE PLEISTOCENE PALAEOKARSTIC ACTIVITY IN A PERIGLACIAL CONTEXT

A re-evaluation of stratigraphy in north Essex contributes to our knowledge of the Middle Pleistocene periglacial record within East Anglia. In north Essex, deep cryogenic brecciation, loess and coversand attest to the extreme conditions that preceded arrival of Anglian ice (Marine Isotope Stage [MIS] 12, 480-420 ka BP).

- Baker, C.A., (2018). Middle Pleistocene palaeokarst in the buried chalk landscape of northwest Essex. *Mercian Geologist,* 19(3), 169-180.
- Baker, C.A., (2019). The Widdington Sands: high-level Kesgrave Sands and Gravels near the Cam-Stort interfluve, northwest Essex, UK. *Proceedings of the Geologists' Association*, 130(5), 559-581. DOI: 10.1016/j.pgeola.2019.02.006.

Also recognised is the presence of palaeokarstic activity within this periglacial context, including dolines and sinkhole pipes (Fig. 61). Chalk karst processes (more typically associated with temperate conditions) such as dissolution, fissure enlargement, basal support removal, and upward migration of cavities leading to roof collapse, are invoked to account for the stratigraphy, and these must have occurred within the early Anglian periglacial phase. Downfolding of ductile sediment and fracturing of brittle sediments by reversed ring faults are also identified. The most likely trigger mechanism for such ground failure was differential thermokarst, stimulated by short warm spells punctuating early Anglian cooling. Perhaps discontinuous (warm) permafrost, or taliks within continuous (cold) permafrost, contributed to this combination of brittle and ductile behaviour.

In principle permafrost should be unfavourable for karst development, near-surface chalk karstification being more active during warmer, non-periglacial conditions. Groundwater percolation throughout the British Pleistocene record occurred readily during interglacials and interstadials, but karstic systems would have shut off when limestone was frozen in glacial and stadial stages.

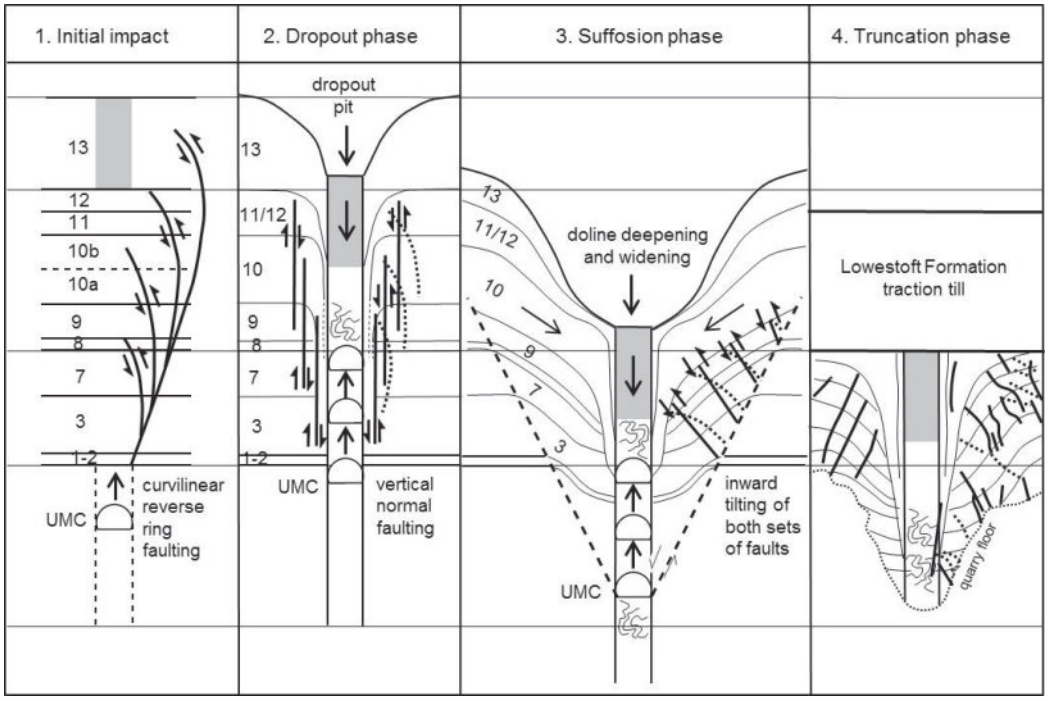

Fig. 60. Upper ice complex (containing large syngenetic ice wedges) overlain by upper sand unit (containing thin syngenetic ice wedges and composite wedges), Batagay megaslump. The boreholes were drilled near this exposure.

- Murton, J.B., and Ballantyne, C.K., (2017). Periglacial and permafrost ground models for Great Britain. In: Griffiths, J.S., Martin, C.J., (Eds.), Engineering Geology and Geomorphology of Glaciated and Periglaciated Terrains – Engineering Group Working Party Report. *Engineering Geology Special Publication 28*, Geological Society of London, 59-368. DOI: 10.1144/EGSP28.5.

Fig. 61. Four-stage model for sinkhole development in the Early Anglian periglacial phase (after Baker, 2019, Fig 18).

Some workers, however, have speculated that karstic processes are possible under cold conditions. For example, Spektor and Spektor (2009) have identified widespread present-day karstification in the Lena valley, where infiltration of summer rainfall actively promotes dissolution within the Siberian continuous permafrost zone.

- Spektor, V.B., and Spektor, V.V., (2009). Karst processes and phenomena in the perennially frozen carbonate rocks of the middle Lena river basin. *Permafrost and Periglacial Processes,* 20, 71–78. DOI: 10.1002/ppp.639.

In East Anglia, perhaps fissure enlargement was initiated during the temperate Cromerian interglacial, but subsequently a considerable thickness of hard-frozen Early Pleistocene sands maintained coherent bridges across these growing cavities. With short-lived warm spells, snowmelt and ground-ice meltwater could have been released abruptly into the system, causing sand bridges to fail. The Cromerian/Anglian transition (MIS13/12) was not a simple downturn; two or three cold-temperate cycles are recognised in the polygenetic Valley Farm Soil, and at least three cycles of dry polar desert can be inferred from the Barham Coversand. Thus multiple periods of palaeokarstic activity could have been switched on and off in climatic perturbations.

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UNITED STATES OF AMERICA

BY U.S. PERMAFROST ASSOCIATION (USPA)

The U.S. Permafrost Association (USPA) is a membership organization consisting of more than 200 individual scientists, engineers and students, agencies, university departments and institutes, and corporate members. The Association was officially established in 2001 to better enable U.S. scientists to contribute to the IPA and to promote permafrost science and engineering in the United States. Stated briefly, the mission continues to encourage scientific and engineering investigations in permafrost and related topics and to disseminate results related to permafrost research. The USPA has a 13-member Board of Directors and committees related to communications, membership, and education. The following is a summary of the more detailed 10,000-word Annual Report posted on the USPA web site:

- Brown, J., Wilson, S., and Lilly, M.R. (Eds.) 2021. *US Permafrost Association 2020 Annual Report*. Fairbanks, Alaska, US Permafrost Association. 24 pp.

THE YEAR IN REVIEW

Due to COVID-19 restrictions, the Annual Meeting of the USPA was held virtually on December 15, 2020, to coincide with the Fall Meeting of the American Geophysical Union (AGU) in San Francisco, CA. Participating in the meeting were approximately 50 members, including Board and Committee members. Results of the annual Board of Directors elections and appointments were announced.

Newly elected and appointed members:

- John Thornley, President-Elect, Golder Associates, Anchorage, AK
- Susan Wilson, Secretary, 3rdRock Consulting Ak, Wasilla, AK
- Jessica Ernakovich, Members-at-Large, University of New Hampshire, NH
- Michelle Walvoord; Members-at-Large, U.S. Geological Survey, Denver, CO
- Anna Wagner, Members-at-Large, USA CRREL Fairbanks
- Helena Bergstedt, PYRN Representative, University of Alaska Fairbanks, AK

Continuing on the Board are:

- Cathy Wilson, President, Los Alamos National Laboratory, NM
- John Zarling, Past-President; Zarling Aero and Engineering, Hailey, ID
- Peppi Croft, Treasurer, Shannon and Wilson, Fairbanks, AK
- Torsten Mayrberger, Member-at-Large, PND Engineering, Anchorage, AK
- Kevin Schaefer, U.S. Representatives to the IPA Council, University of Colorado, Boulder
- Edward Yarmak, U.S. Representatives to the IPA Council, Arctic Foundations, Anchorage, AK
- Fritz Nelson, Member IPA Executive Committee, Michigan State University, East Lansing, MI

The USPA continued to develop plans for the IPA Regional Conference on Permafrost (RCOP) and the American Society of Civil Engineers' (ASCE) International Conference on Cold Regions Engineering (ICCRE) under the leadership of Tom Douglas. Due in large part to COVID-19, the conference has been delayed to October 24-29, 2021 as an all-virtual meeting with some potential in-person events in Boulder, Colorado, and elsewhere. The ASCE's Cold Regions Engineering Division, reviewed approximately 35 papers under the leadership of Jon Zufelt. Those papers will be published in an ASCE proceedings volume.

The USPA-PYRN Education Fund (UPEF), chaired by Kelsey Nyland (George Washington University), provided four grants to cover registration costs associated with the AGU Fall Meeting (Fig. 62).

The Membership Committee, chaired by Jerry Brown, reported an updated 2020 membership of 205 mem-

Fig. 62. Recipients of USPA-PYRN Education Fund (UPEF).

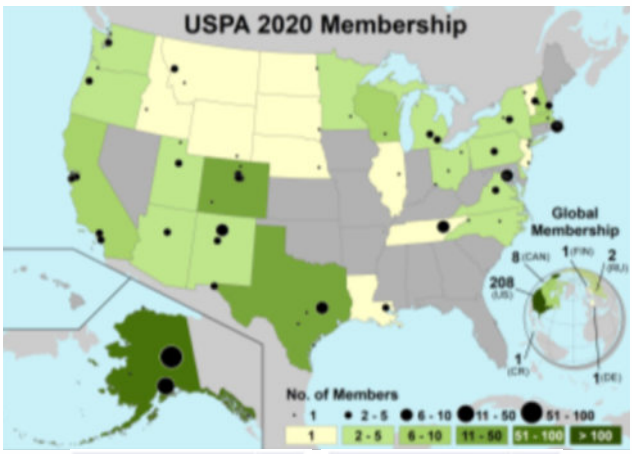
bers, an increase from last year's 171 (Fig. 63). Peppi Croft was appointed as the chair of the Permafrost Engineering Education Program (PEEP). The Diversity, Equity, and Inclusion Advisory (DEI) Committee, chaired by Cathy Wilson, was organized during the year. The Communications Committee, chaired by Michael Lilly, reported that American Geosciences Institute (AGI) continued to provide the Permafrost Monthly Alert (PMA) program and added 294 serial accessions and 545 conference abstracts. For 2020, PMA content inquiries (views by individual readers) exceeded 12,900. For the third consecutive year, a compilation of AGU Fall Meeting permafrost-related presentations was produced. These totaled 300, presented as virtual papers, including 49 from USPA members. Student presentations totaled 14.

The following highlights the institutions and corporate members contributing to the detailed Annual Report, arranged by membership type and contribution level.

Institutional Members

USPA currently has 10 University/Institutional members, arranged below by contribution level:

1. Massive Ice (membership fee $1000 per year)
   - Geophysical Institute Permafrost Laboratory, University of Alaska
   - Institute of Northern Engineering, Water and Environmental Research Center, University of Alaska
   - National Snow and Ice Data Center, University of Colorado



States	30
Universities	47
Federal agenices	7
State agencies-AK	2

Demographics	
Female	86
Male	134
Scientists	174
Engineers	46

Fig. 63. USPA Membership, by state and demographic. Map prepared by Kelsey Nyland.

2. Ice Wedge ($300 per year)
   - International Arctic Research Center, University of Alaska, Fairbanks
   - Department of Environmental Sciences, University of Virginia
   - Woodwell Climate Research Center, Woods Hole, MA

3. Ice Vein ($100 per year)
   - American Geosciences Institute
   - Center for Snow and Avalanche Studies, Silverton, CO
   - Systems Ecology Laboratory, University of Texas at El Paso
   - U.S. Arctic Research Commission, Washington DC

Corporate Members

1. Lifetime (one time $1000)
   - Arctic Foundations, Anchorage, AK

2. Ice Wedge ($300 per year)
   - ABR Inc., Fairbanks and Anchorage, AK
   - Alaska Ecoscience, Fairbanks, AK
   - Geo-Watersheds Scientific, Fairbanks, AK

3. Non Member Agencies/Organization
   - Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys
   - American Society of Civil Engineers
   - Oak Ridge National Laboratory
   - U.S. Army Cold Regions Research and Engineering Laboratory
   - U.S. Geological Survey

4. Non Member Universities
   - George Washington University, Washington, DC
   - Michigan State University
   - Pennsylvania State University
   - University of Alaska, Anchorage
   - Alaska Geobotany Center, University of Alaska Fairbanks
   - University of New Hampshire

Network Reports

- Permafrost Carbon Network
- Permafrost Young Researchers Network (PYRN)
- Permafrost Collaboration Team

IN MEMORIAM

- Oscar Ferrians, USGS, December 19, 2019
- Wayne Tobiasson, USA CRREL, August 14, 2020