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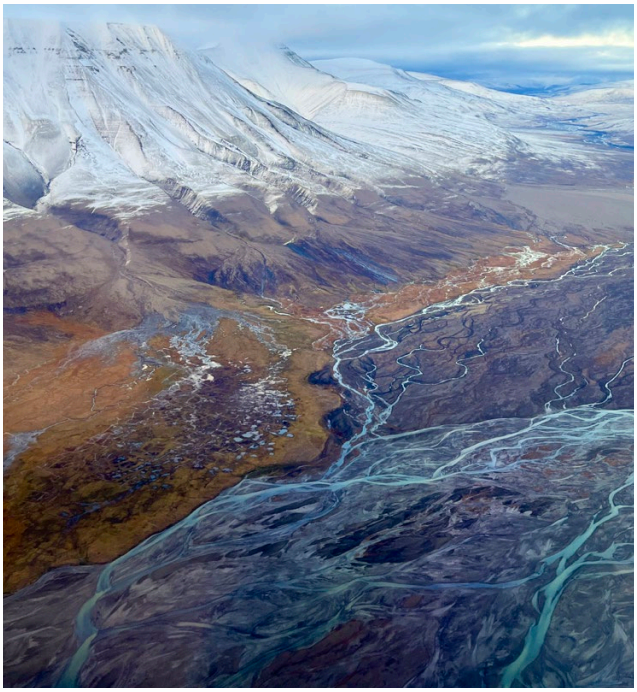
Frozen Ground

THE ANNUAL NEWS BULLETIN OF THE
INTERNATIONAL PERMAFROST ASSOCIATION
WWW.PERMAFROST.ORG

Words from the President

BY CHRIS BURN,
CARLETON UNIVERSITY, CANADA



Ice wedge polygons wearing their fall colors. The Adventdalen valley in Svalbard taking from the air. September 2023. **IPA Photography Contest Winner: Marjolaine Verret** (UNIS, Svalbard, Norway).

First, I hope you enjoy the winning submissions to the IPA's 2024 Photography Contest (p. 46), especially the overall best photo by Marjolaine Verret on this page.

This letter is being composed a month before the 12th International Conference on Permafrost (ICOP2024) begins in Whitehorse, Yukon. The conference will round off a year since the successful 6th European Conference (EUCOP6) organized in Puigcerdà, Spain, by Marc Oliva and his team. A more normal pace of IPA activities has been re-established after the hiatus of the pandemic. We are all grateful to the Canadian organizing committee, especially Lukas Arenson, Kumari Karunaratne, Ryley Beddoe, Fabrice Calmels, and Brian Horton for their work towards ICOP2024.

We congratulate Antoni Lewkowicz (Canada) and Hans-Wolfgang Hubberten (Germany), presidents of the IPA in 2012-2016 and 2008-2012, respectively, on receiving Lifetime Achievement Awards for 2024. We are delighted to honour two dedicated and distinguished scientists not only for their scientific contributions, but also their extensive efforts in organizing conferences and working groups to fulfill the IPA's mandate. Their far-reaching impacts include Toni's role as editor of *Permafrost and Periglacial Processes* and Hans's contribution in establishing the permafrost group at the Alfred Wegener Institute (AWI). There are two awards in 2024 because we did not make one in 2022 due to the pandemic.

Each ICOP marks a transition in the IPA Executive Committee (EC) and 2024 will be a year of considerable innovation in our arrangements. We expect Isabelle Gärtner-Roer (Switzerland) and Gonçalo Vieira (Portugal) to assume a joint

CONTINUED FROM PAGE 1

Presidency for 2024-2028. We also expect to welcome Joe Young (Canada) as the inaugural PYRN representative to the EC for a two-year term (2024-2026). Finally, we will formally create a Past-President position to help the new Presidency in the first two years of every cycle. Among the more normal transitions, we will welcome Lukas Arenson (Canada) to the EC and Kjersti Gisnås (Norway) for a second term.

In the next few years, the IPA will look forward to a series of conferences that will enable us to understand better the challenges faced in a wide range of environments in the permafrost realm due to climate heating – a term I have learned is preferable to climate warming because it explicitly implies engagement with the hydrologic dimensions of the atmospheric regime (i.e., Q_e and Q_h). Mongolia proposes to host the 3rd Asian Conference on Permafrost in 2026, an exciting prospect indeed for those of us without personal experience of central Asia. The 13th ICOP will be held in Florence in 2028, hosted by Italy and supported by Austria, Spain, and Portugal. Poland and the Czech Republic propose to organize the 7th European Conference in 2030. At ICOP2024, I hope that we will have welcomed the Czech Republic to the IPA.

In preparation for ICOP2024, the IPA has assembled a comprehensive review of progress in geocryology during 2020-2024. It is being reviewed by *Permafrost and Periglacial Processes* for open-access publication as I write. The review touches on 17 subfields of permafrost science and engineering and two technical areas. It demonstrates the near-universal influence of climate heating on our discipline and takes stock of the expansion in areas of interest. For example, in the recent engagement of geochemical aspects of sediments released by thawing permafrost and in pure and applied studies of contaminants. It is a collaboration of 29 experts from 12 countries. I expect you will find much of interest in your own subdisciplines and in areas that are new or unfamiliar. One such topic concerns the increasing detection of mercury in the permafrost realm. This is, in fact, the subject of a new Action Group for 2024-2026.

Thank you all for your commitment to managing the effects of climate heating on the cryosphere and for persevering under trying circumstances in the last four years. In a few short weeks, the Presidency will have moved on and, more importantly, the Secretariat that maintains the regular pulse of the IPA. Emma Stockton will finish her term as the Executive Director and we will look forward to welcoming Dr Lin Chen to the position. I thank Emma for all she has done for us over the past four years.

IPA EXECUTIVE COMMITTEE, 2023-2024

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Carleton University,
Canada

CONFERENCES

6th European Conference on Permafrost (EUCOP6)

BY MARC OLIVA (UNIVERSITY OF BARCELONA, CATALONIA, SPAIN)

The 6th European Conference on Permafrost (EUCOP6) was held from **18-22 June 2023** and coordinated by the University of Barcelona with several other institutions in Spain. 450 researchers from 33 countries gathered in the capital of Cerdanya to enjoy lectures, meetings, workshops, and excursions. EUCOP6 was the largest scientific meeting held in the Pyrenees and a logistical challenge for Puigcerdà with no congress hall for large events. The conference was an excellent opportunity to showcase permafrost science in the Pyrenees and the landscape and culture of Catalonia. International experts presented their findings in 24 scientific sessions held at the Casino Ceretà, Cinema Avinguda, Museu Cerdà, and Municipal Library. A dozen specific seminars throughout the conference and a public event on 20 June were held at the Casino Ceretà with a round table on *"The future of permafrost research"*. Five excursions were organised to glacial and periglacial landforms in the Malniu, Carlit, Vall de Núria, and Andorra valleys, and historical and archaeological sites in Cerdanya.

Official photograph of the scientific meeting in Puigcerdá. See p. 48 for more photos.

CONFERENCES

12th International Conference on Permafrost (ICOP2024)

BY LUKAS ARENSON (BGC ENGINEERING INC., CANADA), CONFERENCE CHAIR

The 12th International Conference on Permafrost (ICOP2024) will be held in Whitehorse, YT, Canada from **16-20 June 2024**. Whitehorse is the capital of the Yukon and is situated on the banks of the Yukon River, in the Traditional Territory of the Ta'an Kwäch'än Council and the Kwanlin Dün First Nation. The conference has garnered an overwhelming response, with the call for papers and extended abstracts leading to a rapid in-person sell-out. Sessions and poster presentations will be streamed for virtual registrants. The conference theme, *"Permafrost Thaw, Change and Adaptation: Integrating Perspectives"*, will showcase the latest advancements and foster rich dialogue between indigenous, academics, industry, practitioners, governments, and students. Pre- and post-conference field trips are organised for the Whitehorse area and the Alaska Highway, Dempster Highway, and Inuvik to Tuktoyaktuk Highway. The local organising committee encourage you to engage in this pivotal event that will shape the global conversation on permafrost science and engineering.

CONFERENCES

13th International Conference on Permafrost (ICOP2028)

BY MAURO GUGLIELMIN (UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA, ITALY)

The 13th International Conference on Permafrost (ICOP2028) will be held in Florence, Italy, from **25-30 June 2028**. The conference will be hosted at the Congress & Exhibition Center near the main railway station of Santa Maria Novella, reachable by high speed train from Milan and Rome. An event will also take place in the Palazzo Vecchio, Salone dei Cinquecento, one of the city's most famous monuments. The venue can host up to 1040 attendees.

ICOP2028 will be organized by Italy, Spain, Portugal, and Austria.

A pre-conference trip to Liguria and Sardinia to see relict block streams and weathering features such as fantastic tafoni will be led by Prof. Nicoletta Cannone and Prof. Mauro Guglielmin. Three post-conference trips will offer a variety of permafrost and periglacial landforms (e.g., rock glaciers, protalus rampart, and thermokarst) and large permafrost-related landslides (i.e., Val Pola). The trips will be lead by Prof. Marc Oliva and Prof. Enrique Serrano (Eastern-Central Pyrnees), Prof. Mauro Guglielmin and Prof. Nicoletta Cannone (Central Italian Alps), and Prof. Andreas Kellerer-Pirklbauer and Dr. Renato Colucci (Eastern Alps in Austria and Italy).

A local geomorphological excursion and tour of the city will also be available mid week (Wednesday).

The conference logo is designed to show the occurrence of relict and current mountain permafrost close to the capital of the Renaissance.

ACTION GROUPS

ABCflux v2

BY ANNA-MARIA VIRKKALA (WOODWELL CLIMATE RESEARCH CENTRE, USA)

In 2023, the Arctic-Boreal Carbon Flux Data Compilation and Synthesis (ABCflux v2) created a database of monthly CO_2 and CH_4 flux data measured with various techniques from terrestrial and aquatic ecosystems across Arctic and boreal regions. The group received data from >150 researchers, ~10 repositories, and ~50 flux studies. It is the largest database of Arctic-boreal carbon fluxes, with ~50,000 unique monthly carbon flux estimates from >500 sites. It will help us understand the magnitudes and drivers of permafrost region carbon fluxes, and estimate permafrost region carbon budgets in changing climate and disturbance regimes.

In 2023, the group presented at the European Geophysical Union (EGU), American Geophysical Union (AGU), and International Boreal Forest Association (IBFRA), and held two online mini-workshops to inform researchers about their work and share data. The group organized the *Arctic-boreal carbon flux upscaling workshop* in Sweden to discuss future uses of the database, which led to a review study summarizing the discussions and key literature. At the Woodwell Climate Research Center, Christina Shintani visualized part of the database on a flux network poster, and Isabel Wargowsky was interviewed for an ICOS blog to share insights about the strengths and challenges associated with large flux data compilation efforts.

In 2024, the group plans to (i) advertise activities at key events, (ii) finalize the database and write a subsequent synthesis publication, (iii) draft the workshop publication, and (iv) prepare the final maps and plain-language summaries of the Arctic-boreal flux database.

Participants of the *Arctic-boreal carbon flux upscaling workshop* in Sweden.

ACTION GROUPS

Rock glacier inventories and kinematics (RGIK)

BY REYNALD DELALOYE & SEBASTIÀN VIVERO (UNIVERSITY OF FRIBOURG, SWITZERLAND)

In June 2023, the Rock Glacier Inventories and Kinematics (RGIK) completed its official status as an IPA Action Group. Launched at EUCOP5 in Chamonix (2018), the objectives of the Action Group were to (i) coordinate the definition of standard guidelines for rock glacier inventories worldwide, and (ii) promote rock glacier velocity as a new associated parameter of the GCOS ECV Permafrost, representative of the evolution of mountain permafrost.

The last workshop of the Action Group (Workshop III) was held on 17 June 2023 at EUCOP6. Participants worked on the final development of the Action Group activities and established the Puigcerdà Commitment, which defines the goals and lays the foundation for the transition from an IPA Action Group to a Standing Committee.

Transitional rock glacier (above Grau Roig, Andorra) during a local excursion at EUCOP6.

In 2023, the Rock Glacier Inventory (RoGI) Baseline and Practical Concepts were merged into a single document (RoGI_BPCv1.0). RoGI exercises were developed with ESA CCI+ Permafrost (see p. 28), and cross-validation and consolidation are being carried out globally. Refined versions of the Rock Glacier Velocity baseline (RGV_BC) and practical concepts (RGV_PC) were also developed.

In 2022-2023, monthly online seminars allowed members to share their research and foster informal exchanges. The successful seminar series will continue in 2024.

To participate in the RGIK initiative, join their mailing list, which comprises 235 subscribers from 25 countries in Asia, Oceania, North and South America, and Europe.

Participants of the RGIK Workshop III at EUCOP6 (17 June 2023).

ACTION GROUPS

Himalayan PERmafrost Consortium

BY MILAP SHARMA, SOUMIK DAS, & ELORA CHAKRABORTY (JAWAHARLAL NEHRU UNIVERSITY, INDIA)

The Himalayan PERmafrost Consortium (HiPERC), initiated in May 2023, is embarking on its second phase to (1) install instrumentation and collect samples in the Himachal Himalaya region; (2) explore the evolution of permafrost using absolute and relative dating methods to chronologically constrain ages; and (3) advance permafrost research in India through workshops and presentations.

HiPERC has collected 24 AMS Radio Carbon (14C) samples from peat bogs at different elevations in the

CONTINUED FROM PAGE 5

Spiti Valley. Buried sedimentary deformation structures were also identified and collected for luminescence dating. These samples are being analysed at the AMS lab (Inter University Accelerator Centre) and OSL lab (Jawaharlal Nehru University).

In 2023, HiPERC organized four events to disseminate knowledge on Himalayan permafrost, hosted a special session on *Himalayan Periglacial Geomorphology and Permafrost* at the 35th National Conference of the Indian Institute of Geomorphologists (IGI), and presented at EUCOP6.

- Das, S., Chakraborty, E., and Sharma, M.C. (2023). Evolving Permafrost-groundwater interactions in arid Trans-Himalayan landscapes of Spiti region, NW India. *EUCOP6: Book of Abstracts*, p. 119.
- Das, S., *et al.* (2024). Report on the 35th National Conference of the Indian Institute of Geomorphologists (IGI). *Journal of Geological Society of India*. DOI: 10.17491/jgsi/2024/173881.

In June 2024, 10 Geoprecision temperature loggers will be installed in the study area. The consortium aims to develop a high-resolution model for the distribution of permafrost in the study area with particular emphasis on the Spiti Valley. The framework for this research initiative is nearing finalization. A comprehensive summary will be produced by November 2024. In conjunction with the distribution model, an extensive inventory of Rock Glaciers is in progress across the Lahaul and Spiti district. Following the Rock Glacier Inventory and Kinematics (RGIK) guidelines, an analysis of rock glacier characteristics is underway. Over 770 rock glaciers have been documented, with ongoing efforts dedicated to detailing their respective attributes.

Collecting peat samples in dry (left) and wet (middle) hummock trenches in Spiti Valley, NW Himalayas (right).

ACTION GROUPS

Permafrost Agroecosystems

BY MELISSA WARD JONES (UNIVERSITY OF ALASKA FAIRBANKS) & MATHIAS ULRICH (GERMAN ENVIRONMENTAL AGENCY)

Permafrost Agroecosystems focuses on agricultural activities, including crop cultivation and animal husbandry practices (livestock and herding) in permafrost areas.

The final year of the action group provided a venue for international scientists within the physical and social sciences to exchange ideas and network. The Permafrost and Society session at EUCOP6, led by Melissa Ward Jones and J. Otto Habeck, included six oral and 11 poster presentations on permafrost, land use, and human interactions.

Melissa Ward Jones also led a collaborative manuscript for a special issue on Arctic and Alpine Social-Ecological Systems: Sustainability and Resilience with *Arctic, Antarctic and Alpine Research*. Melissa and 28 co-authors from nine countries provide the first global comprehensive study (to their knowledge) of permafrost-agroecosystems. Currently we do not know the locations of agricultural activities in permafrost areas but this is needed to accurately study them and help in policy development. In the paper they show countries with permafrost accounting for ≥10 % of the countries' surface area and highlight the complexities of permafrost-agroecosystems in light of changing climate, permafrost thaw, livelihoods, regional economies, and policies through seven case studies:

CONTINUED FROM PAGE 6

Left: attendees at the EUCOP6 Permafrost and Society oral presentations. Right: sinkhole development in a hay field during the 2023 growing season (Fairbanks).

(1) crop cultivation in Alaska, USA, (2) indigenous food systems and crop cultivation in NWT, Canada, (3) horse and cattle husbandry and Indigenous hay production in the Sakha Republic, Russia, (4) mobile pastoralism and husbandry in Mongolia, (5) yak pastoralism in the central Himalaya, Nepal, (6) berry picking and reindeer herding in northern Fennoscandia, and (7) reindeer herding in northwest Russia.

- Ward Jones, M. *et al.* (in press). Socio-ecological dynamics of diverse global permafrost-agroecosystems under environmental change. *Arctic, Antarctic, and Alpine Research*.

NEW ACTION GROUPS

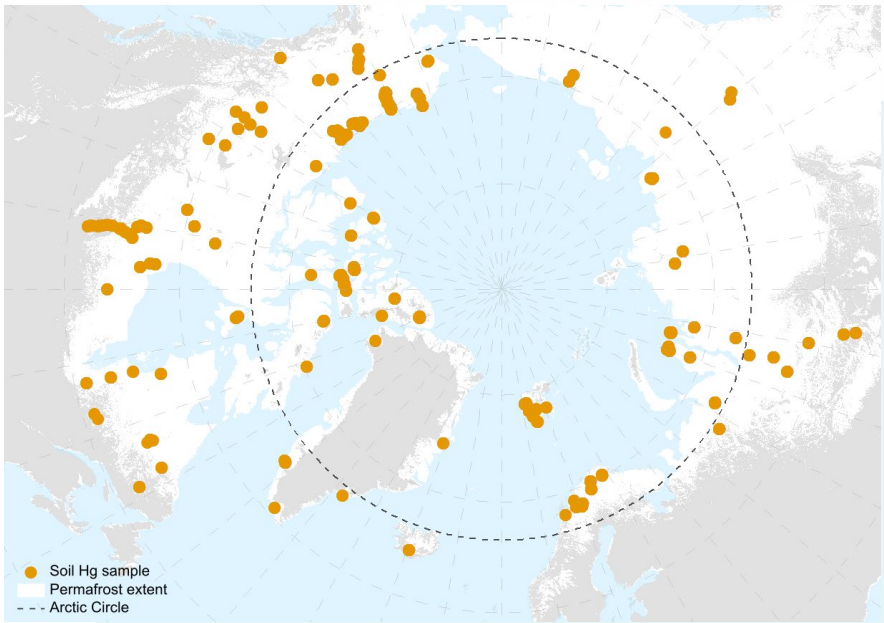
PermHg: A global database of mercury concentrations in permafrost dominated regions

BY CHRISTINE OLSON (UNIVERSITY OF COLORADO BOULDER, USA) & ALYSSA AZAROFF (STOCKHOLM UNIVERSITY, SWEDEN)

Mercury is a global pollutant of concern due to its toxicity to humans and wildlife. Mercury has an atmospheric lifetime of about six months, allowing it to be transported and deposited in far removed ecosystems. High levels have been found in permafrost regions despite their remoteness from known natural and anthropogenic sources.

PermHg aims to synthesize mercury data in soils, plants, and water from permafrost regions in a publicly available database. To date, PermaHg has compiled all known mercury and geospatial data in permafrost soils and discussed data analysis and a revised global estimate of mercury stored in permafrost soils. This work is important to understand how climate change and permafrost thaw will impact the cycling and storage of mercury.

In May 2024, researchers from eight organizations and three countries met to discuss data collection and formatting, and support for geospatial software in the database. In 2025, their goal is to disseminate findings at the American and European Geophysical Unions and in a peer-reviewed journal article. This will contribute to the ongoing effort aimed at improving mercury data accessibility and predictions of future ecological impacts.



Permafrost soil mercury samples included in the PermHg database (Obu et al. 2019).

NEW ACTION GROUPS

International Database of Geoelectrical Surveys on Permafrost (IDGSP): Phase 2

BY CHRISTIAN HAUCK & COLINE MOLLARET (UNIVERSITY OF FRIBOURG, SWITZERLAND)

The first phase (2021-2023) of IDGSP addressed the lack of publically available geoelectric data on permafrost. It has >100 subscribers from 18 countries, ~40 members, and a steering committee of 10 researchers. The main accomplishments were the development of the database, python scripts for automatic data filtering and inversion, a call for geoelectrical data, and a best practices publication:

- Herring, T., *et al.* (2023). Best practices for using electrical resistivity tomography to investigate permafrost. *Permafrost and Periglacial Processes*, 34(4). DOI: 10.1002/ppp.2207.

IDGSP's second phase (2024-2026) intends to sustain a network of geoelectrical data on permafrost, which currently includes 450 profiles from 15 countries. The main objectives for 2024 will be to continue populating the database and organize a workshop for the Action Group members.

STANDING COMMITTEES

Permafrost Young Researchers Network (PYRN)

BY EMMA LATHROP (NORTHERN ARIZONA UNIVERSITY, USA), NATALIE ARPIN (QUEEN'S UNIVERSITY, CANADA), KAYTAN KELKAR (UNIVERSITY OF ALASKA FAIRBANKS, USA), SASKIA EPPINGER (TECHNICAL UNIVERSITY OF MUNICH, GERMANY), XIANGLONG LI & JINGBANG ZHAI (NORTHEAST FORESTRY UNIVERSITY, CHINA)

The Permafrost Young Researchers Network (PYRN) supports and fosters collaboration of early-career researchers (ECR) in permafrost science and engineering.

PERMAFROST YOUNG SCHOLARS ONLINE ACADEMIC EXCHANGE FORUM

In July, Xianglong Li and Jingbang Zhai (Northeast Forestry University) with the *Journal of Glaciology and Geothermics* Editorial Board launched the Permafrost Young Scholars Online Academic Exchange Forum. So far, >400 participants have attended two sessions.

14TH DACH PERMAFROST CONFERENCE, OBERELSBACK, GERMANY

PYRN-DACH hosted a workshop for ECRs from German (D), Austrian (A) and Switzerland (CH). Prof. Krautblatter and Prof. Müller talked about their careers and how ECRs can benefit from their experiences and struggles on their way to professorship. It also included discussions and networking with other young researchers and senior scientists. PYRN-DACH awarded Best Presentation to Maike Offer and Best Poster to Madina Dolle.

Participants of the PYRN-DACH workshop in Oberelsbach, Germany.

EUCOP6 ECR WORKSHOP

Adam Kirkwood, Costanza Morino, Charlotte Haugk, and Judith Aga organized a workshop with talks, networking, and a dinner party. Dr. Lantuit, Dr. Treat, Dr. Kuhn, Dr. Draebing, Dr. Boike, Dr. Wild, and Adam Kirkword presented a range of topics (permafrost carbon feedback, fieldwork challenges, and science communication. PYRN awarded the Best Presentation to Natalie

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Arpin (1st) and Samuel Gagnon (2nd), and Best Poster to Pia Petzold (1st) and Norman Steiner (2nd).

SEMINAR SERIES: USA & VIRTUAL
In October, PYRN hosted a virtual seminar with >100 participants. Dr. Vladimir Romanovsky presented permafrost research history and highlighted the need for high-resolution maps to track permafrost thaw in the coming century.

AGU23
USPA and PYRN travel grants supported the attendance of five ECRs to the American Geophysical Union (AGU23) in San Francisco (p. 40). Finally, in 2024, PYRN will organise a workshop at ICOP2024 and welcome the next executive committee.

STANDING COMMITTEES

The Global Terrestrial Network for Permafrost (GTN-P)

BY DMITRY STRELETSKIY & EMMA HAGGERTY (GEORGE WASHINGTON UNIVERSITY, USA)

GTN-P organised a workshop at EUCOP6 where breakout groups gathered ideas and discussed the GTN-P database, joint publications, and future actions. Members also shared insight on data usage, user-friendly database interfacing, and gaps in current analyses based on their data collection. GTN-P is organising a session at ICOP2024 on *Permafrost Temperature, Active Layer Thickness, and Rock Glacier Velocity*. At GTN-P's Annual Virtual General Assembly (16 November 2023), members discussed permafrost activities and welcomed new national correspondents from 13 countries. The GTN-P database continued to provide valuable service to the broader scientific community. Members contributed to the latest State of the Climate report chapters on global climate and the Arctic. GTN-P worked with GCOS and GCW on WMO's Permafrost Best Practice guide that will be formally approved before becoming publicly available. Philippe Schoeneich represented GTN-P as an Ex-Officio member for TOPC, and is now looking for a replacement.

Participants of the GTN-P workshop at EUCOP6.

STANDING COMMITTEES

Antarctic Permafrost, Periglacial Environments and Soils (ANTPAS)

BY MAURO GUGLIELMIN (UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA, ITALY)

ANTPAS continues to monitor permafrost, the active layer, and related ecosystems in maritime Antarctic (Signy Island, Livingstone Island, Deception Island, King George Island, James Ross Island, and Antarctica Peninsula), continental Antarctica (McMurdo Dry Valley and Northern Victoria Land), and eastern Antarctica. In 2023, a review paper summarizing recent active layer regimes was published:

- Hrbáček, F., *et al.* (2023). Active layer and permafrost thermal regimes in the ice-free areas of Antarctica. *Earth Science Reviews*, 242. DOI: 10.1016/j.earscirev.2023.104458.

ANTPAS hosted a session and meeting at EUCOP6. Sessions are also planned at ICOP2024 and SCAR2024 with 24 presentations combined. In 2023, co-deputy, Marc Oliva, stepped down. A vote for the substitute will be held after SCAR2024. ANTPAS thanks Marc for his work in developing permafrost and periglacial research in Antarctica.

Education & Outreach

BY ANNA KLENE (UNIVERSITY OF MONTANA, USA) & YLVA SJÖBERG (UMEÅ UNIVERSITY, SWEDEN)

The Education and Outreach Standing Committe (SC) coordinates and promotes permafrost education and outreach to all generations across the globe. The SC also coordinates with the University of the Arctic Thematic Network for Permafrost (TNP).

Several education and outreach activities were organised in 2023, indicating an increase in activities since the COVID-19 pandemic. A session on *Education & Outreach: Cartoons, Communities, and Cooperation* at EUCOP6 included four oral presentations and eight posters that attracted many people.

OUTREACH ACTIVITIES

Led by Adiya Saruulzaya (Mongolian Academy of Sciences), Frozen-Ground Cartoons (FGC) was published and printed in Mongolian and included activities with local schools. SC members also wrote:

- Bouchard, F. and Sjöberg Y. (2024). Frozen-Ground Cartoons—Revealing the Invisible Ice. In: A., Hemkendreis, and A.S., Jürgens (eds). *Communicating Ice through Popular Art and Aesthetics*. PSMEC. DOI: 10.1007/978-3-031-39787-5_12.

The *UndercoverEisAgenten* project engages with young citizen scientists in Canada and Germany. Students from Moose Kerr School in Aklavik, NT, flew drones over permafrost landscapes to collect images for mapping and analysis in a web application to identify polygonal structures and permafrost thaw. In 2023, team members from AWI, DLR, and HeiGIT visited schools in Germany to teach kids about permafrost, geoinformation, and citizen science.

A pilot of the permafrost VR experience, *Sunny Smog digs permafrost*, was launched and demonstrated by creator Deanna Ewers at the EUCOP6 poster session.

Left: Dronne training in Aklavik, NT, Canada for *UndercoverEisAgenten*. Photo: Marlin Mueller. Bottom: Field school in Salekhard with Moscow State University. Photo: Nikita Samokhvalov.

EDUCATIONAL ACTIVITIES

The UArctic *PermaIntern* project hosted a workshop about permafrost internships at EUCOP6. Since then, a pilot website was launched, and the first supervisors and hosts have been certified in the program.

In 2023, Moscow State University organized summer field schools to central Caucasus and Salekhard. Students studied active layer thickness and permafrost landscape features in alpine and Arctic environments.

In March 2023, students from Germany, France, Brazil, Czech Republic, Luxembourg, and Argentina visited rock glaciers and others cryogeoforms of the Cordón del Plata, Andes of Mendoza (Argentina). The trip was organized by the University of Bonn and the Geocryology group of Mendoza for the *Spatial occurrence and hydrological significance of Andean permafrost, Agua Negra, Argentina (HyPerm)* project.

Comments and suggestions can be sent to co-chairs Anna (anna.klene@gmail.com) and Ylva (ylva.sjoberg@umu.se).

NSERC PermafrostNet

Canada's strategic partnership for permafrost knowledge

2019-2025

www.permafrostnet.ca

Front cover:
Galina Jonat and Hannah Macdonell
Ekati region, Lac de Gras, NT
September 2022

Edited by Tristan MacLean, Emma Stockton, and Stephan Gruber

NSERC CRSNG

NSERC PermafrostNet

By Janet King (Chair of the Board) and Stephan Gruber (Scientific Director)

Canada is a permafrost country and already today, permafrost thaw affects all Canadians directly or indirectly. For example, through effects on community infrastructure, ecosystems that support traditional livelihoods and cultural practices, national and regional infrastructure, and through thawing carbon that further amplifies global climate change. Currently, our permafrost knowledge is not sufficient to address and prepare for thaw-related issues.

Canadians concerned about permafrost have joined forces to provide leadership on understanding, predicting, and adapting to permafrost thaw. This is important because connecting and advancing permafrost knowledge for action requires new types of research, new expertise, new modes of collaboration, new services, and greater capacity. As part of our strategic mandate, we also work to broaden and sustain the conversation about a forward-looking vision and strategy about permafrost knowledge in Canada.

The collaborative focus of projects in NSERC PermafrostNet has nurtured stronger, more sustainable, and strategic partnerships across Canada, bringing together northern communities, government, industry, and academia. NSERC PermafrostNet has also enhanced the training of graduate students, northern research assistants and post-doctoral fellows, who will bring new knowledge and practice into their professional lives, along with the experience of considering multiple perspectives.

As funding for NSERC PermafrostNet concludes in 2025, it will leave a legacy of a knowledge community better connected and better equipped to support adaptation to permafrost change across the North.

This compendium of 11 completed projects serves as a snapshot of the 42 projects that the network is undertaking.

On behalf of all network participants, we extend our sincere gratitude to the organizations and individuals that support NSERC PermafrostNet. We hope the collaborations and connections made through this network will continue to grow.

The network

NSERC PermafrostNet is a strategic partnership network connecting over 40 partner organizations, 50 students and postdocs, and 12 universities with the common goal of boosting Canada's ability to adapt to permafrost thaw. Partners include Federal, Indigenous, Provincial, and Territorial government as well industry, not-for-profit, and other research networks in Canada and internationally.

The network operates from 2019 to 2025, with core funding from the Natural Sciences and Engineering Research Council of Canada (NSERC) and major contributions from partner organizations. NSERC PermafrostNet is hosted by Carleton University and follows a shared governance model with partner organizations and northerners making decisions at the highest level.

The network is structured in five themes. The network investigators include the theme leads as well as Dr. Stephan Gruber, Dr. Shawn Kenny, Dr. Melissa Lafrenière, Dr. Brian Moorman, Dr. Bernhard Rabus, and Dr. Oliver Sonnentag.

PermafrostNet
NSERC | CRSNG

Theme 1: Characterization of permafrost, led by Dr. Daniel Fortier and Dr. Duane Froese, is advancing the quantitative understanding of ground-ice in the field and laboratory.

Theme 2: Monitoring permafrost change, led by Dr. Trevor Lantz and Dr. Antoni Lewkowicz, develops and integrates diverse methods to detect and quantify permafrost change.

Theme 3: Prediction of permafrost characteristics and change, led by Dr. Claude Duguay and Dr. Joe Melton, works to improve the accuracy and delivery of permafrost simulation to support partner needs across scales.

Theme 4: Hazards and impacts of permafrost thaw, led by Dr. Jocelyn Hayley and Dr. Pascale Roy-Léveillée, works to understand the relevance and controls of impacts and hazards driven by permafrost thaw and improve their prediction.

Theme 5: Adaptation to permafrost thaw, led by Dr. Ryley Beddoe and Dr. Christopher Burn, supports northerners in adapting to permafrost in transition, e.g., sump failure, embankment stabilization, and infrastructure maintenance costs.

Research and training

The network's research has the goal of boosting Canada's ability to monitor, predict, and adapt to large-scale permafrost thaw and its consequences. It takes a collaborative approach, integrating expertise across disciplines, sectors, and regions. Training in NSERC PermafrostNet connects students and post-doctoral fellows through theme and network meetings as well as joint supervision and field campaigns with northern research assistants and collaborators in partner organizations. The network investigators, students, and post-doctoral fellows are also building capacity, sharing knowledge, and learning about permafrost through their collaborative activities with Northern communities. Data is an important element in NSERC PermafrostNet research. The network has developed protoypes of reliable and useful data and knowledge products for stakeholders, some of which integrate field data with simulation.

Building and sustaining a permafrost knowledge partnership

Nearly 60 people with an interest in permafrost and from diverse backgrounds – government, researchers, industry, northerners – gathered for a workshop "Toward a Canadian Permafrost Network" at Carleton University in 2017. Results identified focus areas for research, community needs such as a secretariat and increased capacity, and important principles for collaboration: shared governance and inclusion of northerners, open data, and communication that makes knowledge available for action. The workshop led to the formation of NSERC PermafrostNet and the Canadian Permafrost Association (CPA).

Subsequent meetings have shaped the network application and informed its evolution. Since 2019, NSERC PermafrostNet has been fostering new relationships and collaboration across Canada's diverse permafrost community and internationally via coordinated research, open data, and meetings. In the second half of the funded network duration, the importance of strategically building permafrost knowledge in Canada has been acknowledged as vital. As an Arctic nation, Canada has a responsibility and opportunity to be a global leader in understanding, predicting, and adapting to permafrost thaw. To catalyze this vision, the network is engaging with other initiatives such as ArcticNet, the Canadian Permafrost Association, Permafrost Pathways, and raising the agenda in the policy world, e.g., through micro-engagements, publications (Gruber et al., 2023), and sessions at the Canadian Science Policy Conference.

The value created

A survey to NSERC PermafrostNet members in January 2024 asked what value they get from participating in the network. The responses have been summarized in a word cloud. Reading the responses in detail, data sharing and strengthened community ranked highest. These were supported by strong relationships and trust, as well as new and complementary people, connections, and capabilities. This enabled exposure to and integration of diverse perspectives, shared field opportunities, relevant research questions, and new standardized methods. Making the network research valuable for others is a strong desire of the participants. Translating, mobilizing, and applying the research results over time leads to new practice for a sustainable future. The connections formed will continue to build and strengthen the depth and impact of permafrost knowledge in Canada.

Establishing a Canadian database of geoelectrical surveys of permafrost

By Teddi Herring and Antoni G. Lewkowicz (University of Ottawa)

This project addresses the need for a comprehensive database of electrical resistivity tomography (ERT) surveys of permafrost in Canada. The Canadian Permafrost Electrical Resistivity (CPERS) database was created to facilitate data sharing to enable researchers, practitioners, and communities to collaboratively enhance their understanding of permafrost conditions and dynamics.

Methodology and key findings

Teddi Herring developed the CPERS database to archive ERT surveys in a standardized manner, promoting easy data sharing and access. The database currently includes data from 280 ERT surveys conducted between 2008 and 2022 across Canada and Alaska. Teddi used this data to make large-scale interpretations of permafrost conditions in relation to climate, landform type, surface cover, and surface disturbance, which would not have been possible without the amalgamation of a large, standardized dataset. Best practices for ERT surveying of permafrost have also been published as a part of the CPERS project, offering guidance to optimize data acquisition, processing, and interpretation (Herring *et al.*, 2023).

Taking action

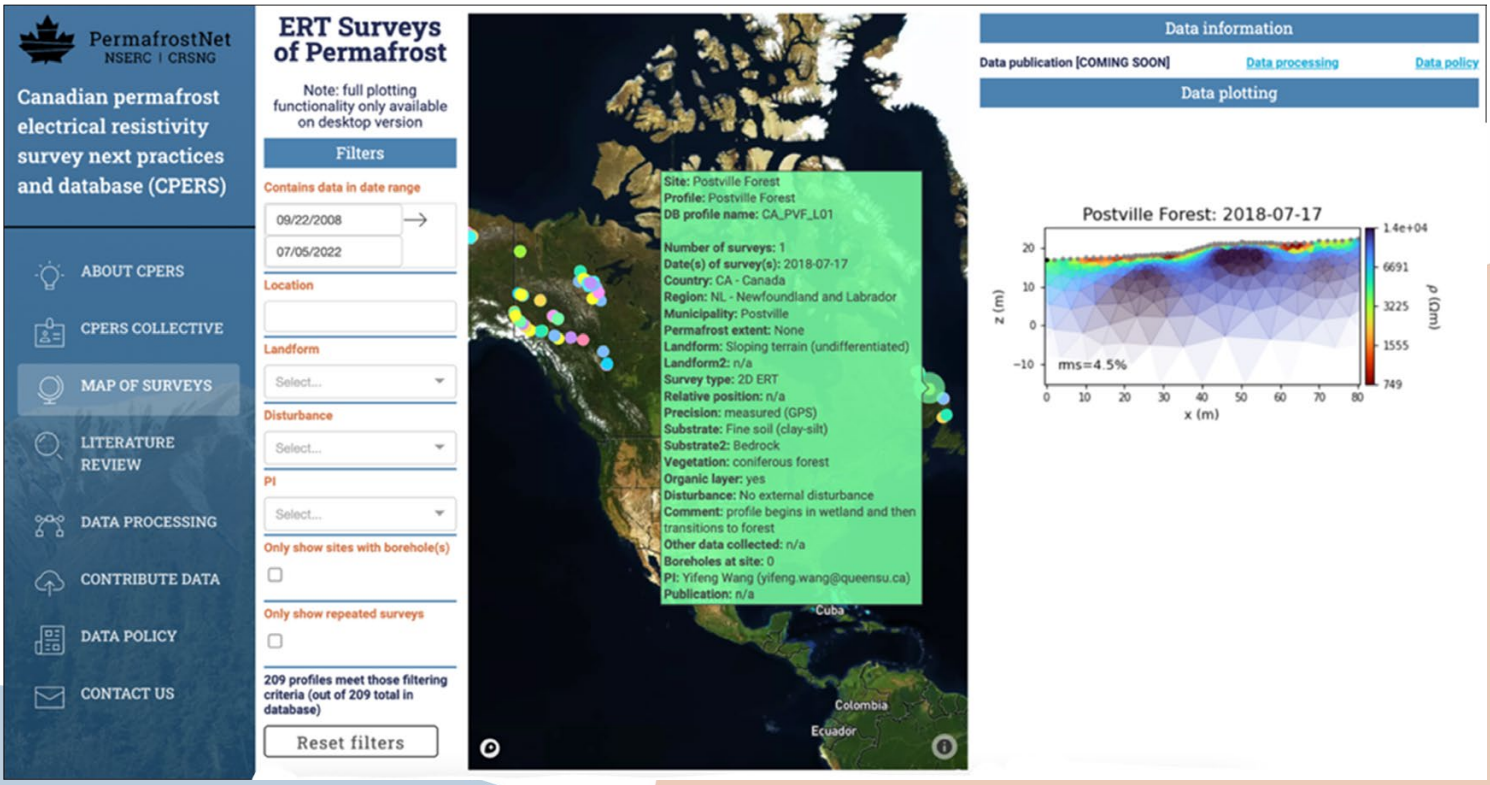
Recognizing the importance of data in characterizing permafrost environments and making informed decisions, the project encourages contributions to the CPERS database.

Partnerships and support

The project was based at the University of Ottawa and had numerous contributors, including data providers (Antoni Lewkowicz, Alexandre Chiasson, Yifeng Wang, Robert Way, Joseph Young, and Duane Froese), technical support personnel (Nick Brown and Etienne Godin), and field assistants. This project ran in parallel with the IPA Action Group "Towards an International Database of Geoelectrical Surveys on Permafrost (IDGSP)", enabling collaboration on several aspects. Metadata fields and database structure were developed with IDGSP, and Teddi wrote the data processing and website code used by CPERS and IDGSP.

Acknowledgments

Thanks to the Inuit of Nunatsiavut, Labrador, the Sahtu Dene and Métis of the Central Mackenzie valley, Teslin Tlingit Council, Kluane First Nation, White River First Nation, Nacho Nyak Dun First Nation, Kaska Dena First Nation, Tr'ondek Hwëch'in First Nation, Vuntut Gwitchin First Nation, the Nunatsiavut Government, Nunatsiavut Research Centre, NunatuKavut Community Council, and communities of Fort Good Hope, Norman Wells, and Tulita. Digital resources were provided by the Digital Research Alliance of Canada.



Interactive Canadian permafrost electrical resistivity survey (CPERS) web map.

Non-destructive characterization of permafrost cores using industrial computed tomography and multi-sensor core logging

By Mahya Roustaei, Joel Pumple, Jordan Harvey, and Duane Froese (University of Alberta)

This study develops the non-destructive methods of Industrial Computed Tomography (CT) and Multi-Sensor Core Logging (MSCL), to characterize permafrost materials. The focus is on visualizing cryostructures, measuring bulk frozen density, and estimating excess ice and volumetric ice content. These approaches address limitations of traditional methods, and in the case of MSCL, provide a rapid and standardized tool for permafrost characterization.

Methodology

The study uses a recently installed Nikon XTH 225 ST Industrial CT scanner and Geotek Multi-Sensor Core Logger in the Permafrost Archives (PACS) Lab at the University of Alberta. We developed a new approach to maintain frozen samples for several hours through scans, allowing high resolution micro-CT data to be collected at high spatial resolution. MSCL benefited from a new calibration approach to frozen bulk density using a 137Cs gamma source, high resolution imaging and magnetic susceptibility. Dragonfly (ORS 2021) was used to process the 3D scans of the frozen cores. Segmentation was completed through multiple image processing steps using an automatic image segmentation algorithm called "Otsu".

Key findings and taking action

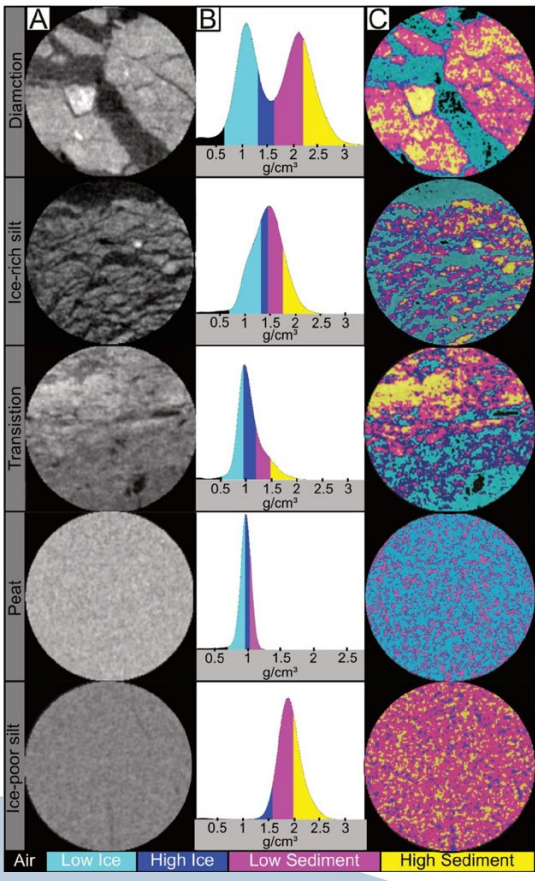
Results demonstrate strong agreement with destructive analyses at similar spatial scales, highlighting the accuracy of these non-destructive methods. These techniques can be integrated into standard core processing, but also provide legacy digital archives of permafrost physical properties to support future studies, along with preservation of sampled materials for future investigations.

Partnerships and support

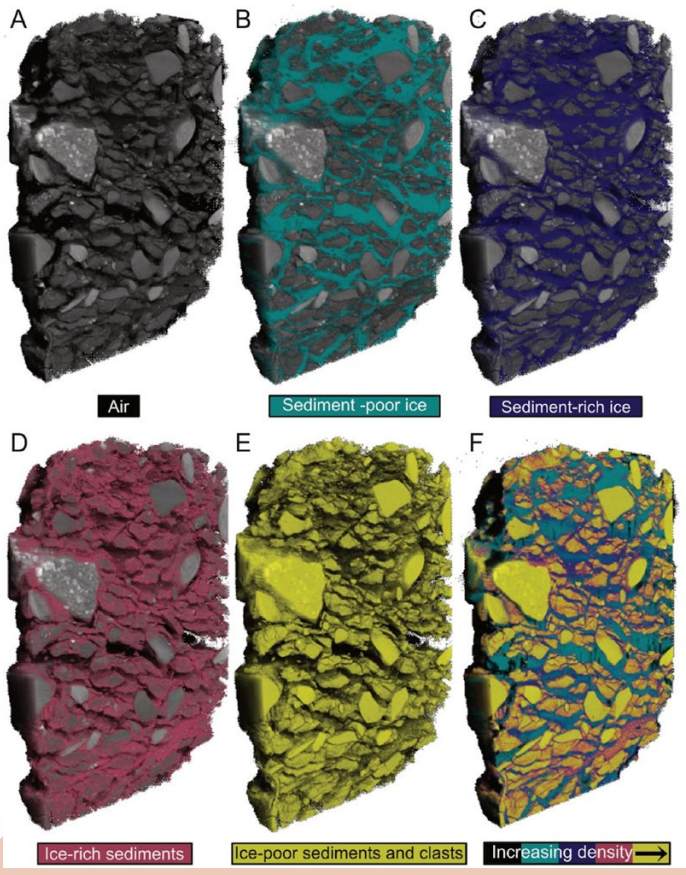
The project involved collaboration with researchers from the University of Alberta, PACS Lab, Northwest territories Geological Survey, Sahtu Communities, and research assistants.

Acknowledgments

Laboratory infrastructure for the PACS Lab was funded by Canadian Foundation for Innovation, Government of Alberta, and University of Alberta. We also thank Geotek and Nikon Metrology for their support and constructive feedback.



(A) Slices of the cores before image processing, (B) histograms, and (C) image segmentation results.

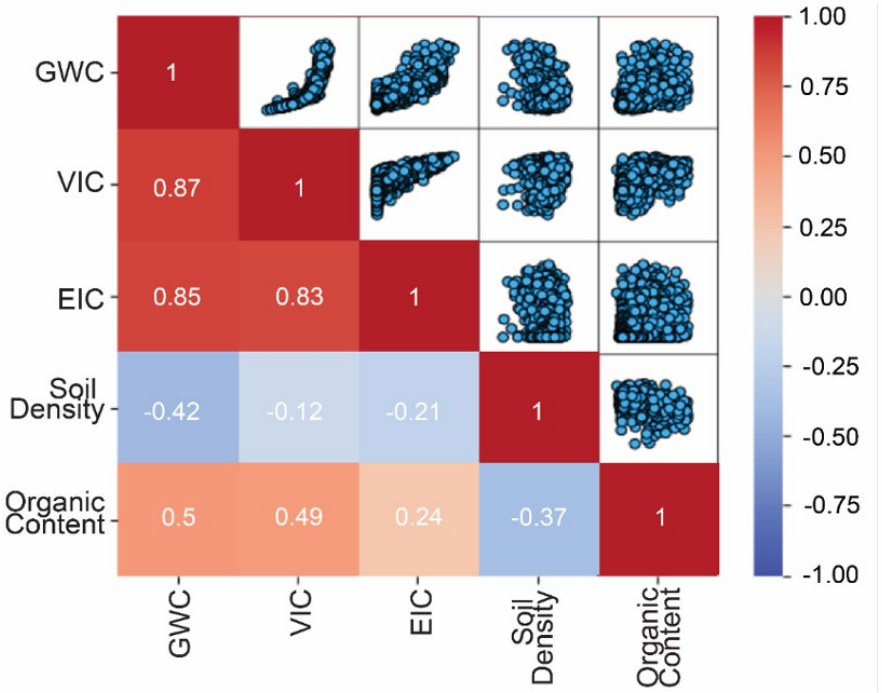


Segmentation of an ice-rich diamict with with the distribution of sediment and ice from industrial CT scanning.

Permafrost index properties database

By Omid Asghari, Mahya Roustaei, Joel Pumple, Alexandre Chiasson, Duane Froese (University of Alberta), and Steve Kokelj (Northwest Territories Geological Survey)

Index properties of soils are commonly used in site investigations and to estimate geotechnical behaviour. In this study we develop a Permafrost Index Properties database of over 2,500 permafrost samples from northern Canada covering a range of depositional environments. The goal of the research is to establish relations between gravimetric water content (GWC) and excess-ice content in permafrost to ultimately build ground ice models from geotechnical databases (>100,000 measurements). This aligns with the goals of Theme 1 to develop a Ground Ice Potential database and contribute to the Ground Ice Map of Canada Network Data Product.



Correlation coefficients of cuboid permafrost index properties. The blue dots represent ~2000 samples from various depositional environments.

Methodology

We sampled over 150 permafrost cores from diverse depositional environments (till, lacustrine, eolian, peat, glaciofluvial and colluvial), primarily from northwestern Canada. These cores were cut into 3 cm³ at two-centimeter intervals. For each cuboid we directly measured GWC, volumetric and excess-ice content (VIC, EIC), organic content (OC), and soil density.

Key findings and taking action

We see a high positive linear correlation (~0.85) between EIC, GWC, and VIC. Database cleaning and filtering were crucial for evaluating relations between variables. Peat and samples with high organic content (≥17%) pose a challenge due to water absorption properties of peat which complicated EIC estimates. We use this database and these relations to convert the large geotechnical databases from northern Canada. The principal component indicates (1) GWC is the main predictor of EIC; (2) higher latitudes correlated more positively with EIC than longitude; and (3) EIC decreased with depth. A Beta regression model was developed to estimate EIC from a large database of geotechnical data (~60,000 measurements) based on the Permafrost Archives (PACS) Index Properties data. Subsequently these data have been used to develop vertical ground ice profiles.

Partnerships and support

We worked with the Northwest Territories Geological Survey, Northern Engineering, and Geological Survey of Canada.

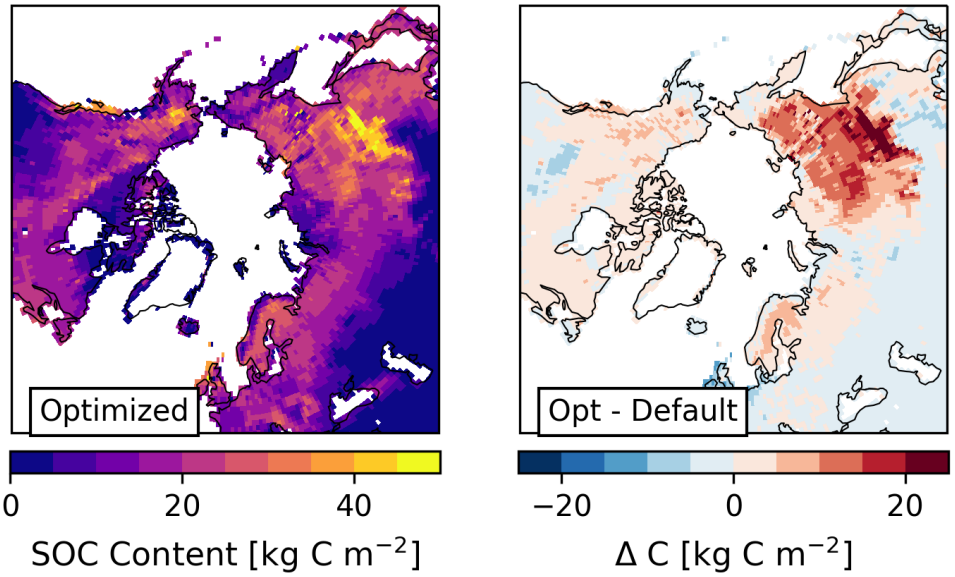
Acknowledgments

Funding was provided by NSERC PermafrostNet, University of Alberta, Canadian Foundation for Innovation, and Government of Alberta.

Fate of carbon in Canadian permafrost-affected soils

By Charles Gauthier, Oliver Sonnentag (Université de Montréal), and Joe Melton (University of Victoria)

This study, conducted at Université de Montréal in collaboration with Environment and Climate Change Canada (ECCC), addresses the critical challenge of understanding the response of soil organic carbon to climate change in permafrost-affected soils. Soil carbon dynamics are simulated in numerical models through simplifications ('parameterizations') of the complex microbially mediated processes that occur in nature. This study improves accuracy of these simulated processes by incorporating observations of both the quantity of carbon and carbon fluxes when determining the form of the parameterization used. Improving the accuracy of simulated soil carbon will enhance the accuracy of climate models and better quantify the amount of carbon that can be emitted while keeping below a certain warming threshold.



Left: average 1950-2000 soil organic carbon content of the top 100 cm of soil simulated using the optimized parameter set from the Bayesian optimization. Right: difference in simulated soil organic carbon between the optimized and the CLASSIC default parameter sets.

Methodology

Charles Gauthier optimized the CLASSIC soil carbon parameterization through first determining the most important parameters via a global sensitivity analysis. Secondly, he developed a Bayesian optimization framework that utilized observations of bulk soil carbon from a global compendium of soil cores and soil respiration data from a database of continual chamber measurements to determine optimal parameter values.

Key findings

The optimized parameters demonstrated a difference in simulated soil carbon at the end of the century compared to default parameters. CLASSIC, with the new parameterization, predicted a global increase in soil carbon, particularly in high latitudes, challenging previous predictions based on default parameters.

Implications and taking action

The study underscores the pivotal role of models like CLASSIC in projecting future permafrost thaw and its associated challenges. To address issues arising from thawing permafrost, the findings of this project underscore the importance of appropriate parameterization of soil carbon schemes to ensure the projected response to future change is accurate. Additionally, it demonstrates the importance of a more extensive data collection effort around soil carbon (e.g., radiocarbon) in the many permafrost regions that are under sampled. The refined soil carbon scheme in CLASSIC is a valuable contribution to the broader modeling community, which will facilitate more accurate projections of soil carbon dynamics under future climate change and permafrost thaw.

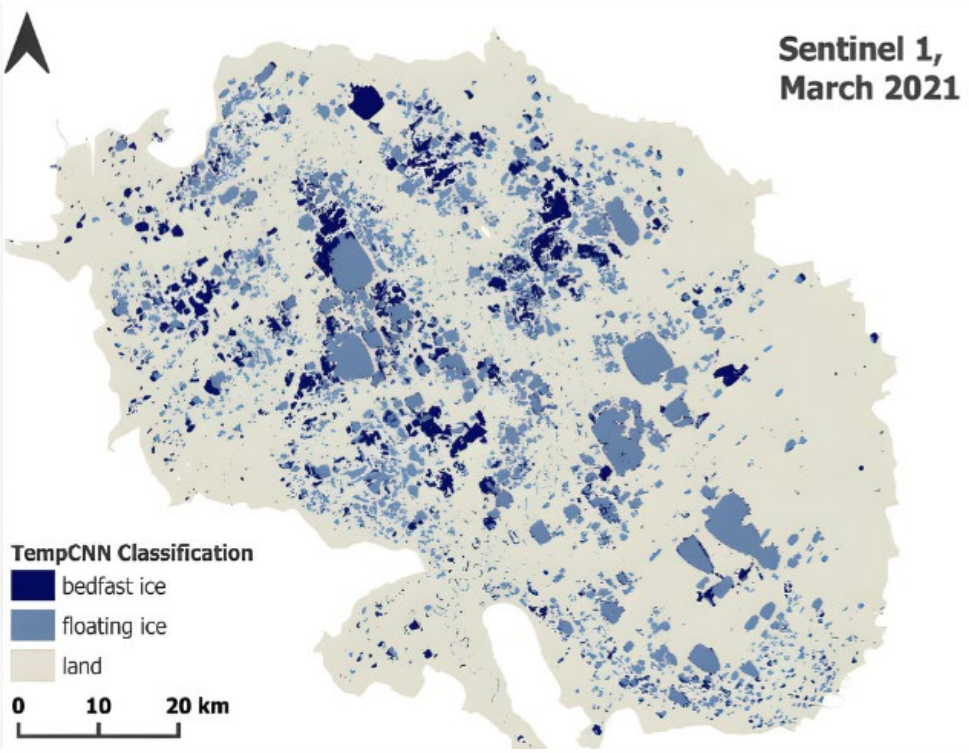
Acknowledgments

The project benefited from advice and feedback from other network members. This interdisciplinary approach enhances the robustness of the research and contributes to a comprehensive understanding of permafrost-related processes. Special thanks to Dr. Gesa Meyer (ECCC) for supporting the simulations with CLASSIC.

Mapping and understanding thermokarst lake ice dynamics over decades

By Maria Shaposhnikova, Claude Duguay (University of Waterloo), and Pascale Roy-Léveillée (Université Laval)

This study focused on mapping and characterizing the changing ice conditions in shallow lakes, particularly in thermokarst lakes. The team produced maps spanning 30 years using machine learning and satellite imagery. Results help understand the critical relation between lake ice conditions and permafrost stability.



TempCNN classification output for Sentinel 1 at Old Crow Flats, YT.

Methodology and key findings

Maria Shaposhnikova employed a temporal convoluted neural network algorithm to generate maps distinguishing bedfast ice (frozen to the lakebed) from floating ice. This distinction is crucial for understanding permafrost stability. Maps over a 29-year period (1993-2021) for Old Crow Flats (OCF) in Yukon revealed an increase in bedfast ice coverage. As permafrost may be sustained or aggrade in a bedfast-ice regime, this transition may affect permafrost sustainability and talik development beneath OCF lakes. This change is tentatively attributed to factors such as catastrophic lake drainage, lower water levels, and reduced snowfall. The accuracy of these maps was tested against field measurements and the Canadian Lake Ice Model.

Implications and taking action

Covering about 20% of northern permafrost regions, thermokarst lowlands are significant reservoirs of soil organic carbon. Documenting transitions between bedfast and floating ice is essential for understanding permafrost dynamics and their impacts on methane ebullition and the regional carbon balance. These maps can aid in tracking lake drainages, identifying catastrophic events, and predicting future changes by simulating lowland thermokarst based on observed bedfast ice and lake extent.

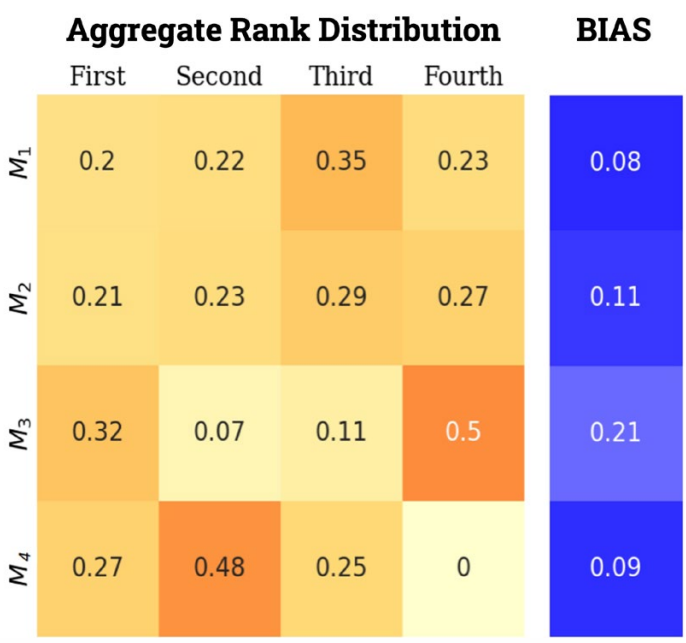
Acknowledgments

The project was conducted at the University of Waterloo, in collaboration with Université Laval. We acknowledge the traditional territory of the Vuntut Gwitchin First Nation. Collaborative efforts with Yukon University and technical support from various contributors enhanced the project's scope and depth. Additional support was available through the NSERC Alexander Graham Bell Canada Graduate Scholarship.

Guiding model selection to support adaptation decision making: a statistical evaluation framework for transient permafrost simulations

By Hannah Macdonell and Stephan Gruber (Carleton University)

This research developed a statistical framework for evaluating and ranking daily ground temperature simulations from different models. This is important because the value of permafrost simulation for informing adaptation depends on our ability to measure and communicate simulation quality. We identified and addressed five key obstacles in evaluating simulations, (1) limited spatial coverage of observations, (2) variables of interest that differ from observed variables, (3) lack of consensus on evaluation statistics, (4) intangible statistical values, and (5) incomplete observational datasets. We frame the testing of permafrost simulations as a ranking problem. Which model or parameter set performs best? Did the new model code result in an improvement, as expected?



Ranking of four models (M_1-M_4). Values represent the proportion bootstrap samples in which a model occupied a specific rank. Values close to 1 denote high confidence in the model's rank. Bias shows the proportion of a model having a warm bias.

Methodology

To address limited spatial coverage, model performance is evaluated separately for different terrain types to mitigate potential observation bias. To address differing variables of interest, we explore in a test case how model performance differs between the surface and deeper observations. Three complementary statistical measures are selected: bias, mean absolute error, and Pearson correlation coefficient. To increase the number of useable observations, a bootstrap procedure works on month-long blocks of the time series. Model ranking with uncertainty is calculated by aggregating model performance using each statistic.

Key findings

Ranking with uncertainty produces summary information that is intuitive to interpret and compare, while reflecting the number and variability of observations available. The 'pyramid of results' produced, allows experts to interrogate simulation performance in more detail as needed. For example, one can view performance by terrain type or by month, and see the distribution of values for the underlying statistical measures.

Taking action

The methods developed are made available in the Python package Accomatic. It will mature with adoption and adaptation, especially in optimising how users can understand results to contextualize their application of permafrost simulations.

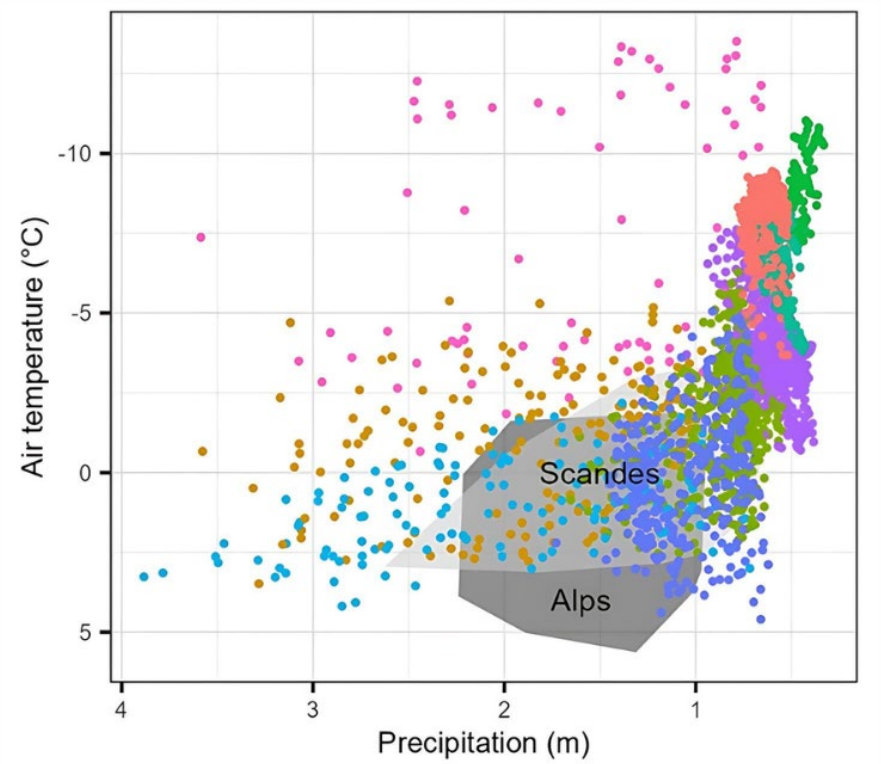
Acknowledgments

The project received support from the Digital Research Alliance of Canada and the Government of the Northwest Territories, with technical support from Nick Brown.

Transferring cryosphere knowledge between mountains: a case study of the western Canadian mountains, the European Alps, and the Scandes

By Emilie Stewart-Jones and Stephan Gruber (Carleton University)

This project originates from a need to quantify permafrost characteristics in western Canadian mountains to better understand permafrost change and related landslides and other hazards. The goal is to determine where knowledge from permafrost research in European mountains can be applied to western Canada directly and where new local research is needed.



Comparison of mountain areas with permafrost in western Canada (coloured) and European areas (grey) for mean annual air temperature and total annual precipitation at a resolution of 30 km x 30 km.

Methodology

The project quantified the similarity in regional climates between well-studied European mountain areas (the Alps and Scandes) and western Canadian mountain regions with permafrost. Using the ERA5 climate reanalysis, the study calculates and compares relevant permafrost-related variables at a grid resolution of about 30 km x 30 km, including mean annual air temperature, incoming solar radiation, precipitation, continentality, latitude, and elevation.

Key findings

The project found that direct transfer of knowledge about ground temperature regimes and their spatial patterns from the Scandes and Alps to western Canada is inappropriate. Overlap in climatic variables that drive ground temperature is concentrated in small areas only. The areas in western Canada receive more radiation than those in the Scandes, and less than in the Alps. The areas in western Canada are more continental than the European areas and extend into much colder conditions.

Implications and taking action

Further localized research is needed in western Canada to understand its mountain permafrost. The comparison method developed here can equally help inform the transfer of knowledge to other understudied permafrost areas globally by highlighting climatic similarities and differences with well-studied regions. Although imperfect, reanalysis climate data enables such analysis in remote cryosphere areas with sparse in situ data.

Acknowledgments

Thanks to Marten Geertsema (BC Ministry of Forests) for his continuing support and advice.

Compacting snowbanks along highway embankments to lower ground temperatures and preserve permafrost

By Patrick Jardine and Christopher Burn (Carleton University)

Snow accumulation beside highway embankments insulates the ground from cold winter conditions, traps heat below the surface, and causes permafrost to thaw. Permafrost degradation may lead to infrastructure damage, such as cracking and subsidence of the driving surface. Compacting the snow increases its thermal conductivity, allows heat to escape from the ground more easily, and prevents permafrost beside the road from thawing. The technique is relatively inexpensive and easy to implement compared to traditional engineering solutions such as installing cooling systems beneath the road.

Using skidoos to compact snowbanks along the South McQuesten Road; an offshoot road of the Silver Trail used to access Eagle Gold Mine north of Mayo, YT.

Methodology

Patrick Jardine conducted field experiments along the Dempster Highway and Silver Trail in Yukon to investigate the effectiveness of snow compaction using skidoos. The snowbanks were compacted over 50 m sections. Patrick measured the difference in ground surface temperature between compacted sites and locations nearby that were undisturbed.

Key findings

Compaction was effective at reducing mean daily ground surface temperatures by about 2-3 °C. The greatest temperature differences were observed in February, with a maximum difference of 12.1 °C. Increases in snow density were limited to the basal depth-hoar layer of the snowpack at tundra sites but were recorded throughout the snowpack at sites in the boreal forest.

Implications and taking action

The results suggest that compaction may be a viable method for preserving permafrost and protecting infrastructure in cold regions. The effectiveness of compaction depends on the snow conditions and the timing of compaction. Further testing is needed to optimize compaction techniques and scheduling, and to determine the feasibility of using the technique on a large scale. Further study should examine the potential environmental impacts of compaction and forecast the long-term effects of compaction on permafrost.

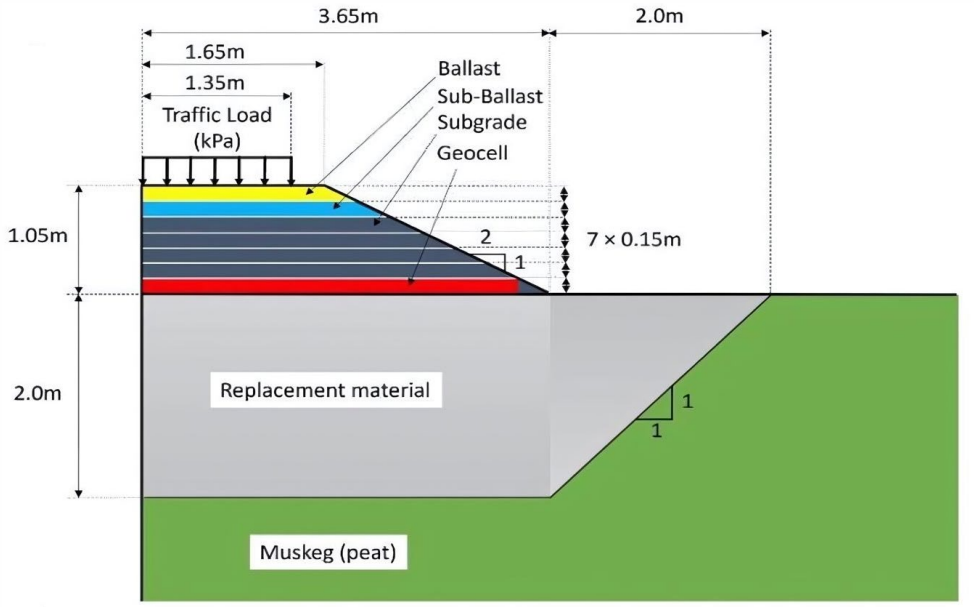
Acknowledgments

The project was based at Carleton University with support from the First Nation of Na-Cho Nyäk Dun and collaboration with the Government of Yukon.

Geocells as effective supports for permafrost thaw under railway embankments

By Payam Sharifi and Ryley Beddoe (Royal Military College)

The Hudson Bay Railway (HBR) in northern Manitoba faces significant deformations and instabilities annually due to permafrost degradation. To address this, geocells, commonly used in non-permafrost soils, have been employed to enhance railway support. This project assessed the effectiveness of geocells in reducing thaw-induced deformations and settlements, employing numerical scenario analyses and field monitoring.



Schematic view of a Hudson Bay Railway geocell embankment with details of the embankment layer.

Methodology

Modeling experiments focused on rail deformation and embankment stability under degrading permafrost conditions. A series of numerical models were conducted to simulate and quantify the performance of a typical geocell reinforced embankment founded on peat with underlying permafrost. Thermo, hydro, and mechanical processes were considered using the finite element software package, GeoStudio (including TEMP/W, SEEP/W, and SIGMA/W). In the field, digital image correlation monitored track displacement and deformations at geocell-reinforced locations. The project evaluates geocell effectiveness under varying permafrost conditions and analyzes long-term stability.

Key findings

The study reveals that geocell reinforcement strongly reduces lateral deformation, especially when the active layer is between 1-2 m below the rail. Optimal geocell height improves embankment stability by up to 50%. However, the study notes a gradual performance decline over the long term due to the increasing effect of permafrost degradation. Overall, geocells can offer substantial improvements to embankment design life when applied judiciously.

Implications and taking action

Integrating geocell-supported designs into standard practices for future linear infrastructure, particularly in permafrost regions, is promising. This research highlights the potential for extended design life and improved resilience, encouraging further exploration of geocell applications in similar contexts and exploration of geocell applications in other linear infrastructure designs. The project's findings emphasize the use of geocells on the HBR, demonstrating improvements in stability and resilience.

Acknowledgements

The project was conducted at the Royal Military College, with strong support from industry partners, Brett Young and Nathan Gullacher from Arctic Gateway Group.

Increasing climate-related highway maintenance costs in permafrost environments of Yukon

By Astrid Schetselaar and Christopher Burn (Carleton University)

Yukon's highway network spans about 4,800 km across varied terrain divided into seven physiographic regions. Climate-related maintenance costs have risen substantially since 1994 throughout the network. The effects requiring attention from maintenance staff are primarily caused by hydrologic processes above permafrost.

Dempster Highway north of Eagle River bridge (top) and in the Ogilvie River Valley (bottom).

Methodology

Historical Operation and Maintenance (O&M) expenditures were examined for 20 maintenance camps within Yukon's highway network. The data spans over 28 fiscal years from April 1994 to March 2022. Five activities in the record were identified as climate-related: snow management, icing control, culvert activities, and clearing of landslides, and repair after washouts. Expenditure profiles for seven distinct physiographic regions were investigated based on specific landscape characteristics, climate variables, and permafrost conditions.

Key findings

Mean annual climate-related O&M expenditures (constant 2021 dollars) increased from $7.1M in 1994-1999 to $10.9M in 2017-2022 for the network. The costs rose from 25% to 47% of the total maintenance budget. Hazardous events, such as landslides and washouts, increased in frequency and magnitude, particularly for highways within permafrost zones. Expenditure profiles for each region varied depending on landscape characteristics and climate conditions. On a per-kilometer basis, O&M expenditures have been twice as costly for highway sections in terrain with more than half of the area underlain by permafrost than for sections with less permafrost.

Implications and taking action

The variability of costs across the network indicates the range of responses to climate change in terms of required maintenance activities throughout Yukon. Hazard assessment and management may need an approach at the scale of maintenance sections that are 100-150 km long. At this scale, landscape factors that differ between sections may be recognized. This information will help to inform targeted, cost-effective efforts and create a highway network more resilient to the effects of climate change.

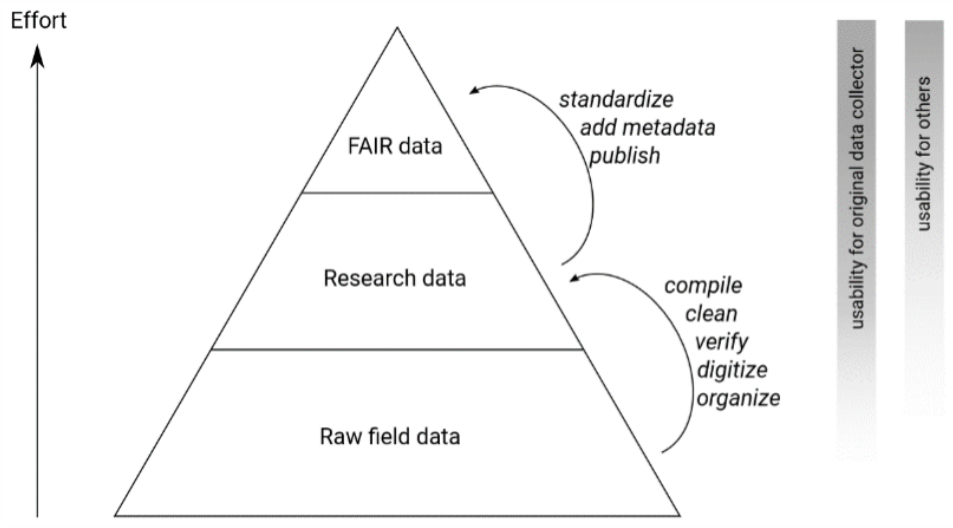
Acknowledgments

The project received support from Highways and Public Works Yukon, Transport Canada's NTAI program, and Polar Knowledge Canada's Northern Scientific Training Program.

Making permafrost data FAIR (Findable, Accessible, Interoperable, and Reuseable)

By Nicholas Brown, Stephan Gruber, Peter Pulsifer, and Amos Hayes (Carleton University)

Data are a unifying element in the network that links themes, stakeholders, and projects. Despite their importance, permafrost data are difficult to obtain due to the expense of measurements and a lack of standardized tools. A number of initiatives and projects demonstrate next practice for managing and distributing interoperable permafrost data and offer a framework for efficient data handling from field to publication.



Only a fraction of collected permafrost data are made available.

Methodology

Five essential challenges were identified in permafrost data management, focusing on ground temperature, site characterization, and borehole profile data. These challenges are framed as a set of requirements and a comprehensive permafrost data system has been designed to meet them. Data publication is conceptualized as a two-phase process, emphasizing the importance of reducing effort at each stage to enhance the overall publication rate for permafrost data. By utilizing established standards for interoperability, the system facilitates the development of visualizations and services to make permafrost data more accessible to diverse stakeholders.

Key outputs

The prototype data system provides a practical solution for researchers collecting permafrost data to streamline, centralize and publish observations. The system, supported by a custom database and existing software (ERDDAP), aligns with international data standards. Additionally, an open-source python library (TSP) was developed to handle ground temperature data heterogeneity by reading from diverse sources and models. The software incorporates functions for common visualizations, analyses, and data output in a variety of widely used formats.

Taking action

The prototype data system can be used to enable researchers and organizations to efficiently manage and distribute their observations. The project encourages further action through the development of visualizations, workflows, and services for-technical stakeholders using the standardized ERDDAP endpoint (data.permafrostnet.ca). The TSP software library can also be collaboratively developed within the permafrost community. Researchers are encouraged to contribute to TSP by adding new modules to support their specific data loggers or model outputs.

Acknowledgments

This project benefited from collaboration with the Canadian Consortium for Arctic Data Interoperability (CCADI) and support from Compute Ontario and the Digital Research Alliance of Canada.

Publications

The following are a selection of network publications. For a full list visit www.permfrostnet.ca/ resources/publications/.

Ahmed, U.I., Rabus, B., and Kubanski, M. (2021). Off-nadir photogrammetry for airborne SAR motion compensation: a first step. 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, Brussels, Belgium. DOI: 10.1109/IGARSS47720.2021.9553861.

Brown, N., *et al.* (2024). A prototype field-to-publication data system for a multi-variable permafrost observation network. *Environmental Modelling & Software*, 175. DOI: 10.1016/j.envsoft.2024.106006.

Brown, N. (2022). tsp ("Teaspoon"): A library for ground temperature data. *Journal of Open Source Software*, 7(77). DOI: 10.21105/joss.04704.

Cao, B., *et al.* (2020). The ERA5-Land soil temperature bias in permafrost regions. *The Cryosphere*, 14(8). DOI: 10.5194/tc-14-2581-2020.

Clark, A., Moorman, B.J., and Whalen, D. (2023). UAV-SfM and geographic object-based image analysis for measuring multi-temporal planimetric and volumetric erosion of Arctic coasts. Canadian Journal of Remote Sensing, 49(1). DOI: 10.1080/07038992.2023.2211679.

Clark, A., *et al.* (2022). Multiscale object-based classification and feature extraction along Arctic Coasts. *Remote Sensing*, 14(13). DOI: 10.3390/rs14132982.

Gruber, S. (2020). Ground subsidence and heave over permafrost: hourly time series reveal interannual, seasonal and shorter-term movement caused by freezing, thawing and water movement, *The Cryosphere*, 14(4). DOI: 10.5194/tc-14-1437-2020.

Gruber, S., *et al.* (2023). Considerations toward a vision and strategy for permafrost knowledge in Canada. *Arctic Science*, 9(4). DOI: 10.1139/as-2023-0016.

Herring, T., and Lewkowicz, A.G., (2022). A systematic evaluation of electrical resistivity tomography for permafrost interface detection using forward modeling. *Permafrost and Periglacial Processes*, 33(2). DOI: 10.1002/ppp.2141.

Herring, T., *et al.* (2023). Best practices for using electrical resistivity tomography to investigate permafrost. *Permafrost and Periglacial Processes*, 34(4). DOI: 10.1002/ppp.2207.

Hille, E. (2022). Using river geochemistry to monitor the hydrology of Arctic watersheds. *Nature Reviews Earth & Environment*, 3(1). DOI: 10.1038/s43017-021-00257-6.

Huang, L., *et al.* (2023). Identifying active retrogressive thaw slumps from ArcticDEM. *ISPRS Journal of Photogrammetry and Remote Sensing*, 205. DOI: 10.1016/j.isprsjprs.2023.10.008.

Kokelj, S.V., *et al.* (2023). The Northwest Territories Thermokarst Mapping Collective: a northern-driven mapping collaborative toward understanding the effects of permafrost thaw. *Arctic Science*, 9(4). DOI: 10.1139/as-2023-0009.

Mohammadi, Z. and Hayley, J.L. (2023). Qualitative evaluation of thaw settlement potential in permafrost regions of Canada. *Cold Regions Science and Technology*, 216. DOI: 10.1016/j.coldregions.2023.104005.

Pumple, J., *et al.* (2023). Non-destructive multi-sensor core logging allows rapid imaging, measurement of bulk density and estimation of ice content in permafrost cores. *EGUsphere*, [preprint]. DOI: 10.5194/egusphere-2023-571.

Roghangar, K. and Hayley, J.L. (2024). A study of thermal modeling parameters and their impact on modelled permafrost responses to climate warming. *Cold Regions Science and Technology*, 221. DOI: 10.1016/j.coldregions.2024.104155.

Roghangar, K. and Hayley, J.L. (2024). Prediction of permafrost extent along the Hudson Bay Railway corridor using freezing and thawing Indices. *Geo-Congress 2024 Proceedings*. DOI: 10.1061/9780784485330.077.

Schetselaar, A.B., Andersen, T.S., and Burn, C.R. (2023). Performance of climate projections for Yukon and adjacent Northwest Territories, 1991-2020. *Arctic*, 76(3). DOI: 10.14430/arctic77263.

Shaposhnikova, M., Duguay, C., and Roy-Léveillée, P. (2023). Bedfast and floating-ice dynamics of thermokarst lakes using a temporal deep-learning mapping approach: case study of the Old Crow Flats, Yukon, Canada. *The Cryosphere*, 17(4). DOI: 10.5194/tc-17-1697-2023.

Stewart-Jones, E. and Gruber, S. (2023). Transferring cryosphere knowledge between mountains globally: a case study of western Canadian mountains, the European Alps and the Scandes. *Journal of Alpine Research*, 111-2. DOI: 10.4000/rga.12203.

Young, J.M., *et al.* (2022). Recent intensification (2004–2020) of permafrost mass-wasting in the central Mackenzie Valley foothills is a legacy of past forest fire disturbances. *Geophysical Research Letters*, 49(24). DOI: 10.1029/2022GL100559.

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PROJECTS

Permafrost Discovery Gateway

BY ANNA LILJEDAHL (WOODWELL CLIMATE RESEARCH CENTER, USA)

The Permafrost Discovery Gateway (PDG) is an online resource to enable big data creation and discovery for the permafrost science community, school teachers, and public. In 2023, major datasets were published, including the pan-Arctic ice-wedge polygon dataset. The pan-Arctic lake change dataset will be available soon. The visualization portal is constantly evolving based on user feedback and new datasets are frequently added. In 2023, PDG was awarded $5M from the *google.org Impact Challenge*. Scientists and engineers from USA and Germany with Google staff (fellows) will use the funds for geospatial artificial intelligence (geoAI) to track changes in permafrost and its impacts. AI will also be used to improve user interaction in the Local Environmental Observer (LEO) network.

2024 will feature new datasets, such as regional to pan-Arctic datasets of retrogressive thaw slumps based on AI detection algorithms. Further ongoing efforts are focused on the extraction of building and infrastructure footprints, and AI-based analysis of permafrost landscape change processes and pan-Arctic projections of permafrost thaw impacts on infrastructure. Availability and access to important tools and datasets will provide a better understanding of permafrost-related processes and challenges.

PROJECTS

Permafrost Carbon Network

BY TED SCHUUR AND EMMA LATHROP (NORTHERN ARIZONA UNIVERSITY, USA)

The Permafrost Carbon Network (PCN) is an international community of researchers producing new knowledge through data synthesis. PCN focuses on the global impacts of changing permafrost, targeting the issue of permafrost carbon feedback to climate change.

In May 2023, PCN hosted a workshop in Flagstaff, AZ, for 38 participants. Day one focused on carbon flux synthesis and permafrost carbon modeling, which form the key focal science syntheses of current PCN funding. Day two focused on science communication and emerging syntheses, such as abrupt thaw, methane fluxes, microbial dynamics, and geospatial data. Day three focused on permafrost carbon in the policy world and included a draft congressional resolution and review of EPA Greenhouse Gas reporting.

Participants of the PCN workshop in Flagstaff, AZ (May 2023).

PCN organized oral and poster sessions at AGU23 in San Francisco, CA. The Vulnerability of Permafrost Carbon to Climate Change session featured a range of topics and demographic speakers.

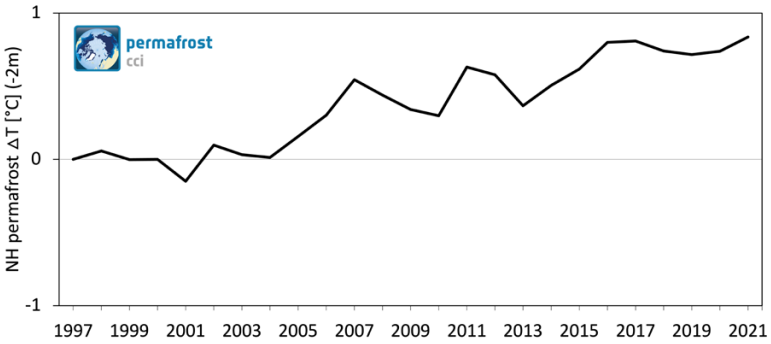
In 2024, PCN activities will focus on (i) hosting another meeting at AGU24, and (ii) co-sponsor smaller, targeted workshops for active emerging syntheses.

PROJECTS

ESA CCI+ Permafrost

BY ANNETT BARTSCH (B.GEOS, AUSTRIA) & TAZIO STROZZI (GAMMA REMOTE SENSING, SWITZERLAND)

The project is now in Phase 2 (2022-2025). In 2023, the fourth version of the climate data records of mean annual ground temperature and active layer thickness for the northern hemisphere extending to 2021 was completed (University Oslo, CryoGrid model). A circumarctic 10 m landcover map based on data from the Copernicus Sentinel-1 and Sentinel-2 missions was developed to support model parameterization. In 2023, a beta version for areas north of the treeline was released. Coverage is extended under the ESA-funded *AMPAC-Net* project, which focuses on wetlands and flux measurements across the Arctic.



Deviation of Northern Hemisphere average ground temperature (2 m depth) from 1997. From v4 Permafrost_cci.

The procedure for rock glacier inventories (RoGI) was consolidated and 12 regional inventories were completed in a multi-operator exercise with the IPA action group, *Rockglacier inventories and kinematics (RGIK)* (p. 5).

At EUCOP6, two tutorials focused on access and use of open source tools with climate data records generated in Phase 1. A workshop was also co-organized with RGIK to discuss the background, current status, challenges, and future needs of RoGI and Rock Glacier velocity (RGV).

PROJECTS

Can-Peat

BY NANCY GOUCHER & KIM KLEINKE (UNIVERSITY OF WATERLOO, CANADA), DAVID OLEFELDT (UNIVERSITY OF ALBERTA, CANADA), & OLIVER SONNENTAG (UNIVERSITÉ DE MONTRÉAL, CANADA)

A group of Canadian researchers, led by Maria Strack (University of Waterloo), are working together through *Can-Peat* to improve estimates of greenhouse gas emission reductions from peatland management actions. By evaluating policy instruments, they are also supporting solutions development. The project is undertaken with the financial support of the Government of Canada.

So far, *Can-Peat* has hired 14 graduate students and postdoctoral fellows to lead research activities, and established a network of >150 experts who share information about peatlands as nature-based solutions, responsible use, and peatland restoration. Two research activities are led by Drs. David Olefeldt and Oliver Sonnentag.

Dr. Olefeldt and PhD student, Christopher Schulze, have measured greenhouse gas emissions from burned peatlands in northernmost Alberta, including sites that burned recently and up to 15 years ago. Their findings will inform models of the current and future greenhouse gas balance of Canadian peatlands, and decisions of peatland conservation and management.

Dr. Sonnentag aims to understand changes in land surface-atmosphere interactions in response to increasing natural and anthropogenic pressures. He has established micrometeorological measurement towers (e.g., eddy covariance) along a 2000 km permafrost and climate gradient across the boreal forest of northwestern Canada. He uses remote sensing and modeling to study changes in Arctic-boreal ecosystem composition, structure, and function and leads a training network to build local Indigenous capacity in NWT for community-based monitoring of ecosystem changes.

Permafrost Pathways

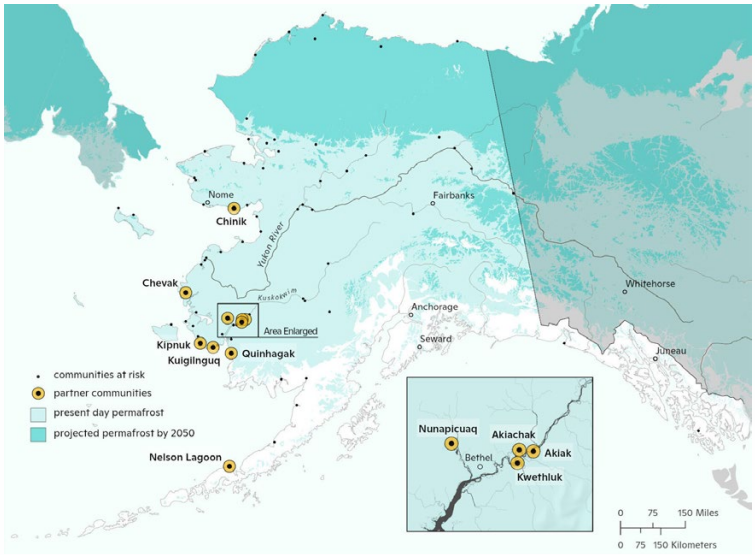
BY SUE NATALI & KATE PETERSEN (WOODWELL CLIMATE RESEARCH CENTRE, USA)

In 2023, Permafrost Pathways made important discoveries about carbon cycling in the permafrost region, supported community-led information-gathering and capacity-building with Alaska Native partner communities, and extended their policy impact and reach by developing new collaborations in Alaska, Canada, and across the Arctic.

MONITORING & MODELING

Findings from flux synthesis efforts suggest the global permafrost region may be a net source of CO_2 and CH_4 to the atmosphere when accounting for terrestrial, fire, and aquatic sources. The team also found that carbon emissions from permafrost thaw and northern wildfire could reduce global carbon budgets to remain <1.5 or 2 °C by up to 20%. Both findings underscore the importance of a core project goal to urge decision-makers to cut fossil fuel emissions more rapidly to mitigate catastrophic climate impacts in the Arctic-boreal zone and globally.

A northern sunrise over the rebuilt flux tower at Scotty Creek Research Station (March 2023). Photo: Marco Montemayor.



Map of Permafrost Pathways partner communities and permafrost extent in Alaska (Greg Fiske).

ADAPTATION STRATEGIES

The team supported community-led relocation and planning with 10 Alaska Native partner communities, and shared environmental monitoring practices and tools to inform community-led assessment and decision-making. The team also provides input to federal climate adaptation strategies through an appointment to the federal Advisory Council on Climate Adaptation Science by the U.S. Dept. of the Interior.

POLICY REACH & SOCIAL IMPACT

The team elevated awareness of permafrost thaw and its impacts on Arctic communities and global climate in USA, international, and pan-Arctic arenas. They were recognized as a key federal collaborator in the Implementation Plan for the U.S. National Strategy for the Arctic Region and were invited to agenda-setting climate policy events in USA and internationally. Recognition as a trusted source on permafrost science grew with the team mentioned in media outlets (e.g., The New York Times and CNN). They also developed a high-engagement quarterly newsletter to share research updates and amplify Indigenous voices and stories about the impacts of permafrost thaw in the North. The team was named winner in three Anthem Award categories: Special Projects, Collaboration, and Community Outreach.

For more information see:

- Ramage, J., *et al.* (2024). The net GHG balance and budget of the permafrost region (2000–2020) from ecosystem flux upscaling. *Global Biogeochemical Cycles*, 38(4). DOI: 10.1029/2023GB007953.
- Virkkala, A.-M., *et al.* (2024). An increasing Arctic-Boreal CO_2 sink despite strong regional sources. *BioRxiv*. DOI: 10.1101/2024.02.09.579581.
- Treharne, R., *et al.* (2024). Comprehensive assessment of permafrost carbon emissions indicates need for urgent action to keep Paris Agreement temperature goals within reach. *Research Square*. DOI: 10.21203/rs.3.rs-3909244/v1.

PROJECTS

Permafrost Coastal Systems Network (PerCS-Net)

BY BENJAMIN M. JONES (UNIVERSITY OF ALASKA FAIRBANKS, USA), SASHA V. PETERSON (UNIVERSITY OF TEXAS AT EL PASO, USA), CANSU DEMIR (UNIVERSITY OF TEXAS AT AUSTIN, USA)

The Permafrost Coastal Systems Network (PerCS-Net) is an international "network of networks" funded by the U.S. National Science Foundation aimed at bridging knowledge gaps and fostering collaboration to address the transformation of permafrost coasts in the Arctic. PerCS-Net has ~250 members from 22 countries.

In 2023, PerCS-Net launched the Arctic Coastal Observations, Research, and Networking (ACORN) monthly webinar series. Several early career researchers lead and presented the series, which provided feedback on their studies.

In August 2023, PerCS-Net co-convened the Permafrost and Infrastructure Symposium in northern Alaska with ~50 national and international Arctic science and engineering experts, and local and regional planners. Participants saw coastal permafrost issues firsthand and learned from those who design, build, repair, and live with infrastructure on thaw-susceptible soils.

In October 2023, PerCS-Net co-organized the Arctic Coasts Workshop at the University of Colorado Boulder for 68 experts and knowledgeholders to (i) exchange observations and insight on coastal hazards and impacts; (ii) strengthen and expand partnerships; and (iii) develop actionable and immediate recommendations for Arctic research and community resilience.

Left: Participants of the Arctic Coasts Workshop in Boulder, CO (photo: Jenna Vater). Right: Participants of the Permafrost and Infrastructure Symposium in Utqiagvik, AK, experience Iñupiaq culture and environmental worldview through traditional dance (photo: Lloyd Pikok).

PROJECTS

PRISMARCTYC

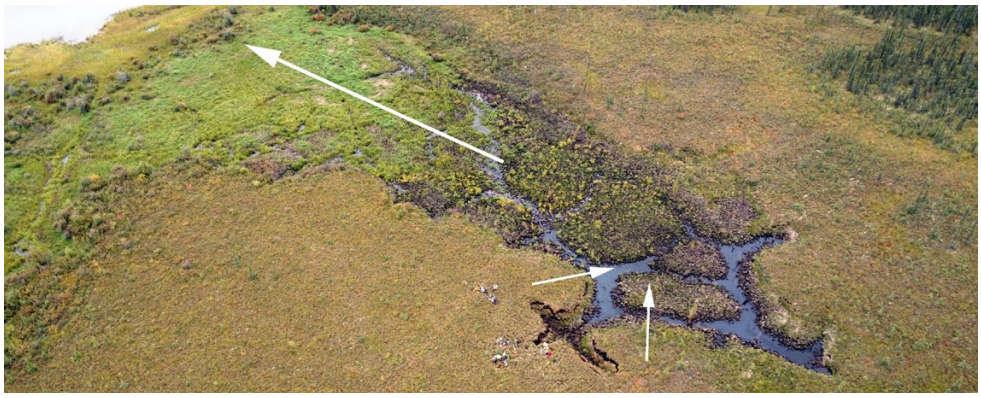
BY ANTOINE SÉJOURNÉ (UNIVERSITÉ PARIS-SACLAY, FRANCE)

Researchers from the Belmont Forum-ANR project, PRISMARCTYC, went to western Yukon, Canada for the 2nd year to collect data on the impacts of thawing permafrost on Arctic watersheds. The project aims to understand the impacts of permafrost thaw on soils, surface/groundwater fluxes, the carbon cycle, and their controlling factors. The study focuses on small inland Arctic watersheds where localized and rapid thermokarst occurrences remain understudied. French, Canadian, American, and Japanese researchers visited Beaver Creek, where numerous lakes are actively developing as permafrost thaws. The aim was to study the permafrost-soil-lake continuum, focusing on key lakes from last year. The team collected drone images and samples (water, gas, soil, permafrost), and conducted geophysical surveys and drilling.

Interactions with the local community was important to learn about the evolution of the region through indigenous knowledge. The team are in the process of creating an educational guide on climate change and permafrost with classes in France

CONTINUED FROM PAGE 30

and Nunavik. The team will include a section on indigenous knowledge and culture, and some exchange activities on these aspects. The guide is being piloted by their partner, the Office for Climate Education, which has pedagogical expertise.



Active thawing of permafrost along polygons on the bank of a lake. White arrows indicate the input of water to the lake along the continuum. Photo: Antoine Séjourné.

PROJECTS

SuPerTip

BY BIRGIT WILD (STOCKHOLM UNIVERSITY, SWEDEN)

Methane (CH_4) emissions related to subsea permafrost thaw are one of the large uncertainties regarding the future greenhouse balance of Earth. Subsea permafrost extends over large areas under the Arctic Ocean, is thawing faster than land permafrost, and high CH_4 concentrations have been observed in the water above. Possible mechanisms include: (i) CH_4 could be produced by microbial decomposition of thawing subsea permafrost organic matter, (ii) CH_4 could be stored in or underneath subsea permafrost (e.g., as hydrates or thermogenic deposits) and could be released to the surface with subsea permafrost thaw, and (iii) CH_4 could be consumed by microorganisms in subsea permafrost, filtering CH_4 before it reaches the water and atmosphere.

Current understanding of subsea permafrost and its potential as a source, conduit, or sink of CH_4 is scarce and limits projections of possible future emissions from this system. The *SuPerTip project (Quantifying methane emissions from the subsea permafrost tipping system)* is funded by the Swedish Knut and Alice Wallenberg Foundation. It will shed light on the connection between subsea permafrost and CH_4 in the Arctic Ocean, and how the interplay between physical, chemical, and biological properties shapes the magnitude of CH_4 fluxes from this system. The project will start in summer 2024 and integrate experimental and modelling components to target this goal.

PROJECTS

THAWIMPACT

BY GONÇALO VIEIRA (UNIVERSIDADE DE LISBOA)

THAWIMPACT is a new 3-year project funded by FCT-Portugal, aiming to understand climatic sensitivity, fate, and potential impacts of permafrost changes in the Antarctic Peninsula in the 21st century.

The project is coordinated by CEG/IGOT (PI: Gonçalo Vieira) with CQE/IST (Co-PI: João Canário) at University of Lisbon), University of Coimbra (Pedro Pina), and IPMA (Sofia Ermida). THAWIMPACT also collaborates with the universities of Alcalá (M.A. de Pablo), Barcelona (M. Oliva), Mazaryk (F. Hrbacek), Oslo (S. Westermann), Viçosa (C. Schaefer), the Korean Polar Research Institute (H. Lee), and bGeos (A. Bartsch).

Participants of the THAWIMPACT kick-off meeting in Lisbon, Portugal (31 May 2023).

The project started in April 2023 with a kick-off meeting at IGOT in May 2023. It will use the PERMANTAR network observatories, remote sensing, and reanalysis data to improve permafrost temperature modelling for the Antarctic Peninsula at the local and regional scales. The project plans to (i) improve the Antarctic Peninsula geospatial database, (ii) evaluate reanalysis and remote sensing data, (iii) improve cold-spots data, (iv) model permafrost, and (v) assess the impacts of changing permafrost.

PROJECTS

The Great Thaw

BY MICHAELA GRILL & KARL LEMIEUX

The Great Thaw is a essayistic documentary on ecosystems (e.g., boreal forest, tundra, and Arctic coastline) that documents the consequences of permafrost thaw. It focusses on microscopic to large-scale effects, radical landscape transformations, and the beauty of permafrost. With Dr. Jennifer Watts (Woodwell Climate Research Centre) the filmmakers and sound artist visited several scientists and research sites from Fairbanks to Toolik Field Station and travelled further north to engage with the Iñupiat community in Utqiaġvik. The film is a loosely woven narrative of images and sounds. The work creates an emotionally dense atmosphere to make the invisible visible. The result is a poetic questioning of the relation between nature and climate change, and an effort to think non-human ways of agency. They hope to raise awareness and reach a broad audience to give them the chance to fall in love with the beauty of permafrost.

PROJECTS

Arctic Permafrost Atlas

BY TIINA KURVITS, TINA SCHOOLMEESTER, & ODA MULELID (GRID-ARENDAL)

The impacts of climate change on permafrost are less conspicuous and understood by people not living or working in the Arctic. Yet, as the new *Arctic Permafrost Atlas* shows, its importance to Arctic ecosystems and the global climate cannot be overstated. Through maps, graphics, storytelling, and art, the atlas presents the state of knowledge on the "country of permafrost" to the world.

From planning to publication, the *Atlas* was almost six years in the making, involving >100 researchers, Arctic residents, cartographers, and writers from 14 countries. It contains 82 original maps, graphics, and supporting text. It was previewed at the Nunataryuk General Assembly in May 2023 and officially launched at the Arctic Circle in Reykjavik in October 2023. The *Atlas* and accompanying exhibition have been presented at UNFCCC COP28 and One Planet-Polar Summit in Paris, and will be showcased at Arctic Circle Berlin and ICOP2024. Although the first print run of the *Atlas* is almost exhausted, GRID-Arendal will reprint soon for purchase.

This illustration resembles an inuksuk (a traditional Inuit stone monument, used as a landmark for travellers and installed in sacred places and burial sites). Permafrost is represented as a block of ice: a fragile basis for the life of local residents. The moon and stars against the background of the polar sky silently observe the changes that have already begun.

This first atlas on permafrost stressed the need for an integrated and participatory approach to the complex issues at the nexus between climate change, permafrost thaw, infrastructure damage, contaminants, and health. In response, the newly launched ILLUQ project takes a holistic approach to permafrost thaw, pollution, One Health, and well-being in the Arctic, marking another pioneering effort for permafrost.

PROJECTS

Warming Permafrost Model Intercomparison Project (WrPMIP)

BY CHRISTINA SCHAEDEL (WOODWELL CLIMATE RESEARCH CENTER, USA)

Permafrost is a critical component of Earth's climate system and yet many Earth System models do not adequately represent permafrost processes. The complexity of Earth System Models and the pressing need to reduce model spread requires innovative approaches to evaluate and analyze model results.

The *Warming in Permafrost Model Intercomparison (WrPMIP)* project, uses manipulative field-based experiments to inform long-term projections about the magnitude and underlying mechanisms of permafrost carbon dynamics in a changing Arctic. Specifically, they (i) perform and analyze multi-model simulations at the pan-Arctic scale and site-level that align with experimental perturbation approaches; and (ii) assess implications of benchmarking for pan-Arctic upscaling and forecasts. Using multi-model simulations from international land modeling groups, they are assessing coherence among models, evaluating model performance against experimental benchmarks, and using the outcomes to inform future measurements.

In 2023, 28 permafrost scientists and modelling experts from 15 international organizations met at Woodwell Climate Research Center for a 3-day workshop. They explored initial results from gridded pan-Arctic model simulations and discussed the most efficient approaches for conducting site-level simulations to represent warming experiments in permafrost regions.

In early 2024, the WrPMIP team published a commentary in *Nature Climate Change* on the challenges associated with accurate representation of permafrost processes in Earth System Models, such as the importance of (i) including disturbance processes (e.g., abrupt thaw and wildfire-soil interactions); (ii) improving hydrology and snow representation; and (iii) improving decomposition and Arctic vegetation distribution in Earth System Models.

- Schädel, C. *et al.* (2024). Earth system models must include permafrost carbon processes. *Nature Climate Change*, 14.

Participants of the WrPMIP model workshop at the Woodwell Climate Research Center, Falmouth, MA (September 2023).

PROJECTS

Social Sciences & Humanities Initiative on Permafrost (SHIP)

BY SUSANNA GARTLER (UNIVERSITY OF VIENNA) & ANASTASIYA HALAUNIOVA (SCIENCES PO PARIS)

Today, permafrost is no longer an object for natural scientific inquiry only as it attracts increasing attention from social scientists and interdisciplinary researchers. To explore the social dimensions of permafrost's life, a collaborative platform *"Social Sciences and Humanities Initiative on Permafrost (SHIP)"* was recently created and is looking for new members to join. *SHIP* is an informal network of scholars who understand permafrost as central to socio-environmental processes in the Arctic and beyond, and are interested in developing new questions concerning permafrost, new methodologies of studying its social and material lives, and new interventions regarding its potential futures. By digging into the meanings and livelihoods that emerge around frozen ground, *SHIP* wants to develop a more critical understanding of this subject.

Permafrost Grown

BY MELISSA WARD JONES (UNIVERSITY OF ALASKA FAIRBANKS, USA)

Permafrost Grown, a $3M 5-year (2022-2027) project funded by the US National Science Foundation's Navigating the New Arctic Initiative, is co-producing knowledge with farmers in Alaska to better understand permafrost and agriculture interactions. Research sites are in the Tanana Valley and Bethel. They are also collaborating with Gardens in the Arctic in Anaktuvuk Pass.

The team drilled in farm fields and adjacent uncleared areas to understand rates of permafrost thaw after land clearing. Electric drills with an auger attachment were used in the upper 5 m while a rig drilled through the entire permafrost (up to 55 m). They excavated 12 soil pits to describe the soil morphological characteristics at active and legacy farm sites. The pits provided information on the depth to top of permafrost prior to thaw (likely due to land clearing) based on certain physical characteristics, such as soil color changes and presence of lenticular cryostructures. Former depths ranged from 43-57 cm for fields cleared between 1908-2001. Finally, they continued monitoring rates of subsidence through repeat UAV surveys using a LiDAR camera.

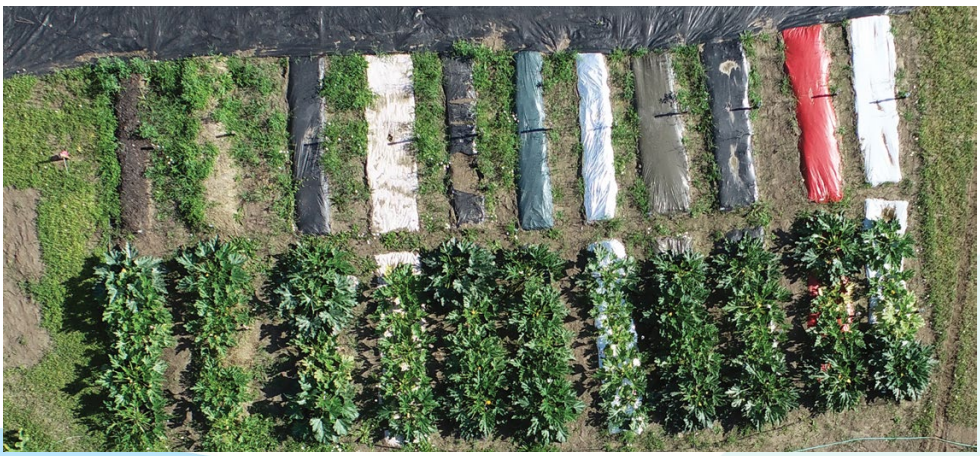
In 2023, five automatic weather stations were established (four in Fairbanks, one in Anaktuvuk Pass) that upload and provide near-real time data on the project website. Sensors were also installed in cleared and uncleared areas to measure the thermal impact of land clearing.

The *Great Mulch Study* is measuring the thermal and moisture impact to permafrost, as well as yield, and weed suppression of 11 different mulch types. They evaluated mulch with zucchini crops and without any crops and evaluated the biodegradability of 5 mulches. Preliminary results show that mulch choice may either enhance or limit permafrost thaw. Due to long photo periods at this latitude, wave-selected mulches are particularly effective at artificially heating the soil with solar radiation. For example, red mulch recorded a maximum surface temperature of 53 °C and 43 °C with and without crops, respectively, during a clear sunny day near the solstice. Straw and compost were identified as potentially permafrost thaw limiting mulches as their recorded maximum surface temperatures were between 22-25 °C for mulch applications with and without crops.

Drill rig being used to drill deep boreholes at farm sites in Fairbanks, AK.

An asparagus variety trial showed promise as a potentially profitable perennial crop on permafrost-affected soils. It takes about 3 years to establish asparagus before cultivation. The trial on permafrost has performed better than asparagus crops of the same age established in areas without permafrost.

Permafrost Grown is working towards developing best practice guides for cultivation on permafrost-affected soils. These resources and knowledge will support sustainable high-latitude agriculture and will contribute to economic resilience and food security.



Aerial UAV image of the *Great Mulch Study* at University of Alaska Fairbanks Experimental Farm. Left to right: deep compost (~15 cm), straw, classic black plastic, paper, BioRadical plastic, InfraRed Transmitting (IRT) green plastic, silver, IRT olive plastic, Bio 360 plastic, selective reflective red plastic, and white-on-black plastic. The study included a soil-only control.

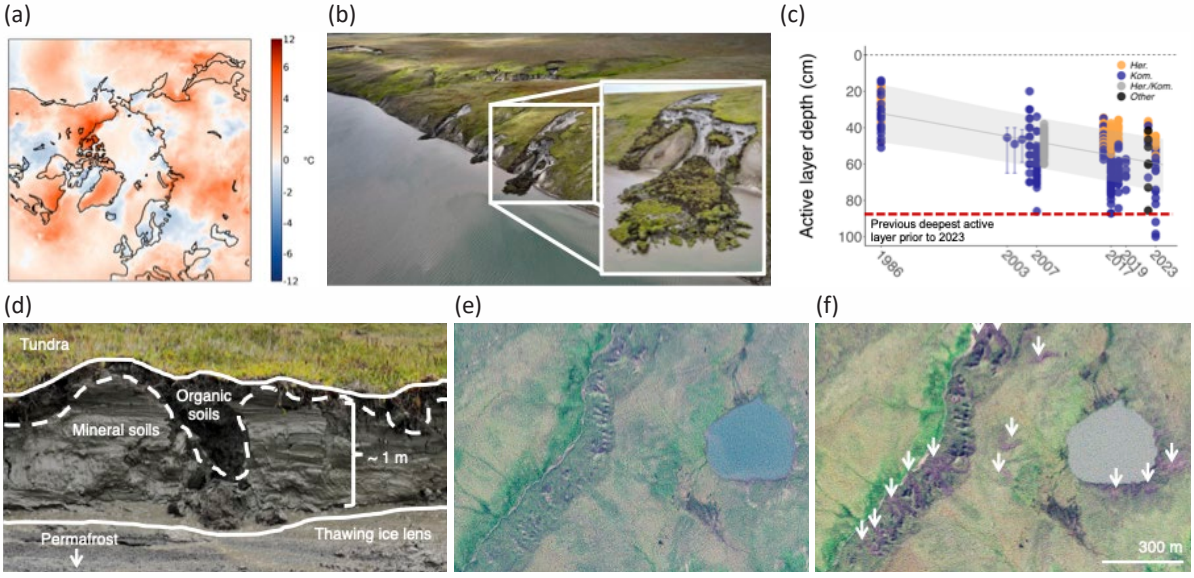
PROJECTS

Team Shrub

BY MADELAINE ANDERSON (UNIVERSITÉ DE SHERBROOKE, CANADA), ISLA MYERS-SMITH (UNIVERSITY OF BRITISH COLUMBIA CANADA), CAMERON ECKERT & RICHARD GORDON (YUKON PARKS, CANADA)

During the exceptionally warm summer of 2023 a dramatic thaw event occurred in the ice-rich permafrost landscapes of Qikiqtaruk – Herschel Island, YT. July temperatures were 5 °C warmer than average in late July and thaw depths reached >1 m, exceeding the previous maximum of 89.6 cm in 2017. Active layer depths have been increasing from ~40 cm in the 1980s to up to ~80 cm in 2023 at the same locations. Substantial permafrost thaw led to the formation of active layer detachments (ALDs). From 1 August 2023, disturbed tundra slid down slopes, removing the vegetation layer. ALDs formed ribbon-like patterns over hillsides with soils accumulating in valley bottoms, thus changing local hydrology by blocking streams and shifting flow paths. Coastal ALDs deposited soils into the ocean increasing sedimentation and altering the coastline of the island. ALDs occurred during an exceptionally warm and dry summer without July precipitation on a range of slopes, aspects, inclination, encompassing varied topography. Preliminary analysis from satellite imagery reveals >50 ALDs by September 2023.

Future research will (i) monitor ALDs to track growth or stabilization, (ii) observe changes to local hydrology, and (iii) quantify sediment and carbon loss from disturbed landscapes. The team will return to Qikiqtaruk in 2024 to quantify the extent of the disturbances and document any further thaw. This event illustrates how summer Arctic heat waves can push systems beyond thaw tipping points with cascading impacts across landscapes.



(a) July heatwave in the western Arctic (modified from European Space Agency); (b) active layer detachments; (c) active layer depth increases over time; (d) profile of the active layer after detachment; and satellite imagery (e) before and (f) after active layer detachments.

PROJECTS

T-MOSAiC

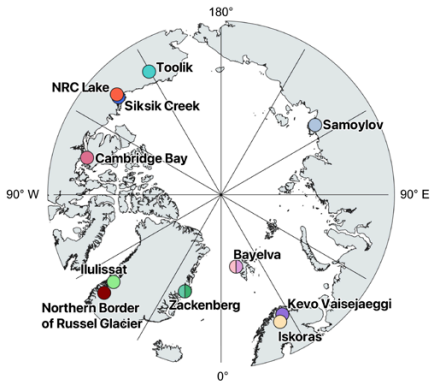
BY JULIA BOIKE, MAYBRIT GOLDAU, & JENNIKA HAMMAR (AWI, GERMANY)

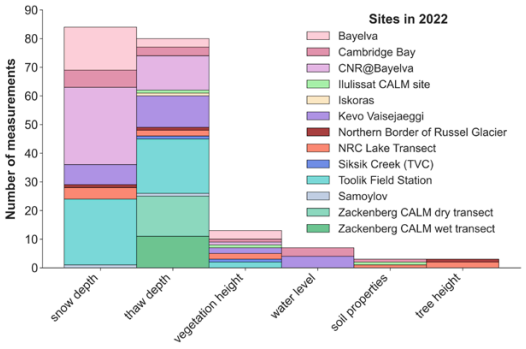
Permafrost Thaw AG

The Permafrost Thaw Action Group (AG) is dedicated to standardized field data collection to quantify permafrost thaw dynamics. The free myThaw app can be used for entering and uploading measurement data and photos. It is instrumental in enhancing data collection, with annual quality checks ensuring the reliability of information uploaded to PANGAEA. In 2023-2024, the AG improved the app with bug fixes, updated measurement protocols, and user-requested features. Their website offers open access to all raw data, project details, and metadata, including 12 pan-Arctic sites collecting snow depth, thaw depth, vegetation height, water level, soil properties, and tree height. The 2021 datasets are accessible on PANGAEA and 2022 is under review. The 2023 data is also being prepared for publication. The AG anticipates further contributions

CONTINUED FROM PAGE 35

and aims to extend their understanding of permafrost thaw processes.





Sites and measured parameters collected following a user-friendly protocol and uploaded with the myThaw app (2022).

PROJECTS

Controls on high-latitude mountain permafrost distribution & sensitivity to climate change

BY PHILIP BONNAVENTURE (UNIVERSITY OF LETHBRIDGE, CANADA)

The Bonnaventure Lab for Permafrost Science continued their work in mountain valleys of Yukon along the North Canol and Dempster Highways and in Whatì, NT.

The impact of surface-based temperature inversions (SBIs) on surface air temperatures was quantified using historical radiosonde data across northwestern Canada. SBI breakup were examined to extend previous work on quantifying the impact of SBIs on elevational air temperature patterns, and the ground thermal regime in mountain valleys of Yukon.

- Noad, N.C., and Bonnaventure, P.P. (2022). Surface temperature inversion characteristics in dissimilar valleys, Yukon Canada. *Arctic Science*, 8(4). DOI: 10.1139/as-2021-0048.
- Noad, N.C., and Bonnaventure, P.P. (2023). Examining the influence of microclimate conditions on the breakup of surface-based temperature inversions in two proximal but dissimilar Yukon valleys. *Canadian Geographies/ Géographies canadiennes*. DOI: 10.1111/cag.12886.
- Noad, N.C., *et al.* (2023). Surface-based temperature inversion characteristics and impact on surface air temperatures in northwestern Canada from radiosonde data between 1990 and 2016. *Arctic Science*, 9(3). DOI: 10.1139/AS-2022-0031.

The aim was to develop an understanding of processes driving SBI breakup and form hypotheses for changes to future SBI patterns. The current and future impact of SBIs on the ground thermal regime in the valleys was modelled using TTOP. The ground thermal regime is most susceptible to climate warming at mid to high elevations where air temperature is the warmest due to SBIs. Coupling between the air and ground temperature is greatest owing to lack of vegetation cover and soil development. Work also continued in the community of Whatì to compare the TTOP model to permafrost probability predicted in a multiple regression model, to identify strengths and limitations of each model for predicting permafrost presence in and surrounding the community. Finally, the distribution of rock glaciers in western NWT mountains were examined to generate a predictive model.

- Vegter, S., *et al.* (2024). Modelling permafrost distribution using the temperature at top of permafrost model in the boreal forest environment of Whatì, NT. *Arctic Science*. DOI: 10.1139/AS-2023-0010.
- Daly, S.V., Bonnaventure, P.P., and Kochtitzky, W. (2022). Influence of ecosystem and disturbance on near-surface permafrost distribution, Whatì, Northwest Territories, Canada. *Permafrost and Periglacial Processes*, 33(4). DOI: 10.1002/ppp.2160.

Members of the Bonnaventure Lab for Permafrost Science along the Demoster Highway, YT.

PROJECTS

Permafrost Archives Laboratory

BY DUANE FROESE, JOEL PUMPLE, SUZANNE TANK, BRIAN LANOIL, & DAVID OLEFELDT (UNIVERSITY OF ALBERTA, CANADA)

In 2021, the Permafrost ArChives Science Laboratory (PACS Lab) was established at the University of Alberta. It is an integrated permafrost core archive and research facility, modeled after ice and lake sediment core laboratories (e.g. Canadian Ice Core Laboratory and the LacCORE facility at University of Minnesota). It merges archives of difficult-to-collect materials with preparation and analytical facilities that go beyond the support of a single investigator.

The PACS Lab has a large collection of permafrost cores (~750 m with capacity for ~2.5 km) from across northern Canada, and laboratories for diverse permafrost research needs. The facility includes walk-in freezers, core-cutting facilities, an industrial CT scanner, Geotek multi-sensor core logger, water and gas isotope analyzers, and clean lab facilities for ancient DNA extractions from permafrost materials. It supports about a dozen graduate and post-doctoral students, and government and industry partners.

PACS Lab equipment: (a) archive freezer, (b) cutting/core processing room, (c) Nikon XTH 225 Industrial CT Scanner, and (d) Geotek multi-sensor core logger.

The lab supported Theme 1 of PermafrostNet to develop non-destructive and standardized approaches to ground ice characterization, including a large curated laboratory dataset of permafrost index properties (>2500 samples) and community mapping projects with the Northwest Territories Geological Survey. The lab supports a collaboration with the K'asho Got'ine (Fort Good Hope, NT) to map permafrost carbon in the Tuyeta Indigenous and Territorial Protected Area, permafrost microbiology, ancient environmental DNA, and permafrost thaw impacts on aquatic systems. The PACS Lab is open to external projects and operates on cost-recovery basis.

PROJECTS

Permafrost and Periglacial Processes

BY MAURO GUGLIELMIN (UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA, ITALY)

Permafrost and Periglacial Processes (PPP) improved for the third consecutive year. It is ranked 2nd out of 48 journals for Geology and in the first quartile for Physical Geography.

The new Virtual Issues are published with their own webpage without waiting for the full compilation. N. Jelinskj and A. Lupachev edited several papers for *"Cryopedology across scales:Integrating experiments,observations and models"*. H. Jin, D. Goering, F. Dramis, N. Jelinski, and M. Guglielmin edited 5 papers for *"Formation and melting of ground-ice and sustainable permafrost engineering under a warming climate: A Chinese contribution devoted to Academician Guodong Cheng's 80th birthday"*. Several more are under review. The recently closed call for *"Land-Ocean Interactions in Polar Regions: Landforming Processes, and Fluxes of Energy and Matter"* was proposed following a session at EUCOP6 and will be edited by M. Strzelecki, M. Fritz, F. Miesner, and M. Angelopoulos.

10 invited papers from ICOP2024 will be published in a Virtual Issue entitled "*Transactions of the IPA No 4"* and edited by D. Froese, A.-M. Leblanc, C. Treat, and J. Boike.

In 2023, 29 regular papers (>500 pages) were published on various topics with the majority authored in China and Canada.

ASSOCIATED ORGANIZATIONS

Yukon University (YukonU)

BY FABRICE CALMELS, LOUIS-PHILIPPE ROY, CYRIELLE LAURENT, CASEY BUCHANAN, PHILIP SEDORE, & CATHY KOOT (YUKONU RESEARCH CENTRE, CANADA)

In 2023, the Permafrost and Geoscience Research (PGR) team, led by Dr. Fabrice Calmels, conducted applied research across Yukon. The team continued a 4.2-year National Trade Corridors Fund project on enhancing Yukon highway resilience to northern geohazards. Addressing permafrost and surficial hydrology, it supports the efforts of the territory's department of Highways and Public Works to better prepare for current and future impacts of changing climate on road infrastructure. Field work occurred along the Dempster and Alaska Highways. After finalizing modernization and enhancement of PGR's ground temperature monitoring network with high-performing monitoring stations, new sites were studied using geotechnical investigation, permafrost sampling and thermal monitoring, and 2D electrical resistivity tomography (ERT) profiling. Drone surveys were conducted at many geohazard-sensitive sites to monitor annual evolution. The team implemented a new surveying approach using drone-based radiometric thermal imagery and LiDAR surveys to assess critical sites such as the Alaska Highway retrogressive thaw slump (km 1456). The partnership between Champagne and Aishihik First Nations continued for a final year, evaluating the impact of a thawing landscape on traditional territory land-use and way of living, while creating new permafrost monitoring capacities. YukonU students gained research skills with new drones acquired for training.

Transport Canada, Crown-Indigenous Relations and Northern Affairs Canada, ArcticNet (NorthxNorth), and BMO Foundation contributed to the research program.

Left: Fabrice looking at permafrost degradation, Dempster Highway. Middle: Tristan (YukonU student) installing a permafrost and weather monitoring station, Alaska Highway. Right: Louis-Philippe holding a permafrost core sampled in Champagne and Aishihik First Nation's lands.

ASSOCIATED ORGANIZATIONS

International Centre for Integrated Mountain Development (ICIMOD)

BY PRASHANT BARAL & MIRIAM JACKSON (ICIMOD, NEPAL)

In 2014, ICIMOD initiated permafrost monitoring activities in the Hindu Kush Himalaya (HKH) following a permafrost research meeting. Ground temperature sensors were deployed at high elevations in Langtang in central Himalayas of Nepal, and the network has gradually expanded. ICIMOD recently expanded permafrost monitoring to Mustang and Humla in central and western Himalayas of Nepal. They have conducted regular fieldwork to collect data from the deployed sensors.

Workshops and meetings have continued since then, including the Cryosphere Forum 2021, a workshop in 2022, and regional training. In 2023, ICIMOD organised workshops and fieldwork with academic institutions and government agencies in Nepal to build their capacity on permafrost research. In 2024, fieldwork will include participants from several HKH countries. ICIMOD also includes communities living near areas of permafrost.

Data since 2014 is publicly accessible on the Regional Database System. To increase institutional capacity related to permafrost research, ICIMOD expanded permafrost expertise to upscale knowl-

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edge and support capacity building programs.

In 2023, a review paper was published on the impacts and adaptation strategies related to permafrost change in High Mountain Asia, and advocates for more research.

- Brashant, P., *et al.* (2023). Climate change impacts and adaptation to permafrost change in High Mountain Asia: a comprehensive review. *Environmental Research Letters*, 18. DOI: 10.1088/1748-9326/acf1b4.

A regional capacity building workshop on permafrost monitoring is planned for September 2024 with participants from Nepal, Bhutan, India, and Pakistan. Some participants will be invited to join a working group to generate a synthesis of current permafrost knowledge in the HKH. A document on the current state of permafrost knowledge targeting policymakers and stakeholders is also being prepared.

Top: ground temperature data readout near a rock glacier in Humla. Photo: Prashant Baral. Bottom: participants from ICIMOD and Tribhuvan University at Tungling, Humla.

ASSOCIATED ORGANIZATIONS

Chinese Academy of Sciences (CAS)

BY MU YANHU & NIU FUJUN (CAS, CHINA)

The Qinghai-Tibet Highway (QTH) from Golmud, Qinghai Province in the north, to Lhasa, Xizang Autonomous Region in the south, traverses the largest expanse of high-altitude permafrost on the Earth. It is a very important link between Xizang Autonomous Region and central China.

The QTH was constructed in 1954 with a gravel road surface, and paved with an asphalt surface in 1970s. In the past 50 years, the QTH has been rehabilitated four times. However, due to rapid climate warming and wetting of the Plateau, damage related to permafrost warming and thawing are still serious along the QTH. Traffic jams caused by poor road conditions are becoming increasingly frequent and protracted.

To meet the rapid growing demand for transportation, a new rehabilitation project is underway. Four experimental test sections across 28 km will be constructed under the guidance of permafrost scientists. Many new construction methods, embankment configurations, and active cooling measures will be used. Monitoring sensors will be installed during the construction process to evaluate performance. This project provides an opportunity to test new highway construction techniques on permafrost, after the milestone project of the Qinghai-Tibet Railway.

Thaw settlement along the QTH.

ASSOCIATED ORGANIZATIONS

United States Permafrost Association (USPA)

BY MING XIAO (PENN STATE UNIVERSITY, USA), USPA PRESIDENT

In 2024, Dr. Ming Xiao assumed the presidency. Dr. Anna Wagner, completed their 2023 presidency with dedication and accomplishments. New board members are Dr. Victoria Herrmann and Dr. Vladimir Romanovsky. Mr. Michael Lilly and Dr. Fritz Nelson completed their terms, and their efforts are gratefully acknowledged.

The Diversity, Equity and Inclusion (DEI) Committee started 2023 with workshops on field safety and working with Indigenous communities, led by co-chairs Julian Dann and Shannon Dillard. The group welcomes everyone to permafrost science. In October 2023, Permafrost Engineering Education Program (PEEP) and USPA-PYRN developed the USPA Technical Training Webinar Series, which has drawn substantial national and international interest. Six seminars are planned for 2024.

Recipients of the 2023 USPA travel grants and Andrew Slater Memorial Award. Top (L-R): Hailey Webb (University of Colorado Boulder), Vasily Tolmanov (Michigan State University), Kaytan Kelkar (University of Alaska Fairbanks). Bottom (L-R): Katie Braun (University of Wisconsin-Madison), Leah Clayton (Yale University), Jon Wells (Northern Arizona University).

In 2024, board member, Dr. Melissa Ward Jones and the DEI Committee co-developed the Family Care Program (FCP) which provides resources, events, and financial awards to help alleviate the logistical burdens and financial costs of work-related travel (e.g., fieldwork, conferences, child and elder care).

In 2023, USPA awarded five student travel grants to attend and present at AGU23. The Andrew Slater Memorial Award was given to Jon Wells for outstanding work on permafrost modelling.

ASSOCIATED ORGANIZATIONS

Canadian Permafrost Association (CPA)

BY GUY DORÉ (UNIVERSITÉ LAVAL), CPA PRESIDENT

The Canadian Permafrost Association (CPA) has led several upcoming conferences, including ICOP2024 (see p. 3). In 2025, the 9th Canadian Permafrost Conference will be held in conjunction with GeoManitoba in Winnipeg, MB. The association is also involved in developing a bid to host the 2028 International Geological Congress in Calgary, AB.

In 2023, the CPA proudly issued the Hugh French Award to Antoni Lewkowicz and the Don Hayley Award to Ed Hoeve. The Membership Committee launched a mentorship program to help early career researchers with personal professional development. The Dissemination Committee launched several social media initiatives (e.g., monthly CPA member spotlight and photo contest), published online resources on permafrost courses and field gear, and organised six webinars.

In 2024, the Permafrost Terminology Action Group will finalize an updated glossary of permafrost science and engineering terms; the Thermal Modelling Action Group will produce guidelines for the development and use of reliable thermal models in permafrost conditions; and the new Perma-

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frost Engineering Resources Action Group will develop a web compendium of resources to support permafrost engineering activities. Specific Interest Groups (SIGs) are under development and will foster collaboration and disseminate information around specific topics, such as drilling or sampling in permafrost. In November 2023, Kumari Karunaratne passed the CPA to Guy Doré. The CPA thanks Kumari for her exemplary and imaginative leadership, which included overseeing and guiding the North Yukon Permafrost Conference in August 2022, the first research conference organized by a national association and three First Nations. We wish her great success as Director of the Northwest Territories Geological Survey.

ASSOCIATED ORGANIZATIONS

Aurora Research Institute (ARI)

BY JEN HUMPHRIES (ARI, CANADA)

The Aurora Research Institute (ARI) continued to support permafrost research in the western Arctic and expand its own programs. During a Northwest Territories State of Emergency in summer 2023, ARI ensured visiting researchers were safely evacuated and fieldwork for territorial and federal science programs were completed in the wake of the evacuation. Logistics, equipment, field assistance, and opportunities were provided to national and international academic institutions, Parks Canada, Geological Survey of Canada, Government of the Northwest Territories (GNWT), Department of Fisheries and Oceans, Joint Secretariat, and others. Ongoing ARI contributions include (i) monthly thaw depth, snow depth, and vegetation data for T-MOSAiC, (ii) two long-term permafrost monitoring sites near Inuvik with Carleton University, and (iii) mapping for the Northwest Territories Thermokarst Mapping Collective.

In Inuvik, the permafrost research group is leading a multidisciplinary program to understand the relations between permafrost and the performance of transportation infrastructure, and permafrost degradation and water quality. The program examines (i) the thermal evolution of the Inuvik-Tuktoyaktuk Highway embankment five years after construction, (ii) water geochemistry to study the effects of permafrost degradation on the hydrology of Arctic watersheds, and (iii) multidecadal trends in retrogressive thaw slumping and coastal erosion along Kugmallit Bay, focusing on key sites identified by the Tuktoyaktuk Hunters and Trappers Committee.

ARI continued to co-manage the ground temperature monitoring network in the Beaufort Delta Region with GNWT departments, including the Dempster Highway and Inuvik-Tuktoyaktuk Highway. ARI also delivered dozens of presentations and >200 hands-on science events.

For more information see:

- Humphries, J.K., *et al.* (2024). Embankment evolution of a gravel road on permafrost terrain five years after construction: the Inuvik-Tuktoyaktuk Highway. *In:* Proceedings of the International Conference on Permafrost (ICOP2024).
- Humphries, J.K., and Wilson, A. (2023). *"The Personality of Permafrost in the Western Arctic"*. Aurora Research Institute Speaker Series, 28 June 2023.

Kelly Kamo McHugh and Celtie Ferguson at a school for ARI's outreach program. The program fosters interest and education in STEM by visiting schools, creating resources for educators, and holding community events in the NWT.

INDUSTRY

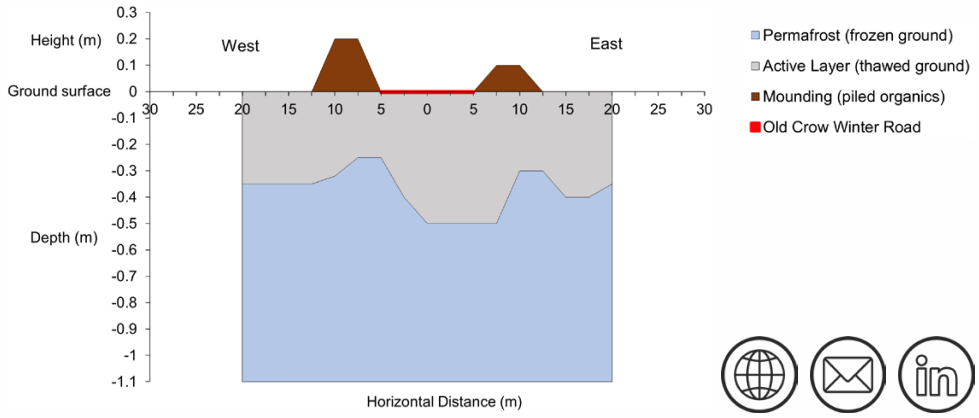
Palmer

BY ROBIN MCKILLOP & JENNA WHITNEY

Old Crow, situated on the Porcupine River, YT, Canada, is only accessible by air for most of the year. Since the 1950s, a 269 km-long winter road (OCWR) from the Dempster Highway has transported heavy equipment to Old Crow.

Palmer was retained to assess the OCWR's effect on underlying ice-rich permafrost and recommend protection measures. An initial desktop-based analysis was completed to assess broad differences in the thaw sensitivity of permafrost, largely based on interpretation of surficial materials and indicators of ground ice in high-resolution imagery and topographic data. In July 2023, interpretations were field-checked by documenting permafrost features, excavating and examining shallow pits, and measuring thaw depths along road-spanning transects at 20 sites.

Cross-sections revealed varying thaw depths and helped quantify apparent impacts of road disturbances on underlying permafrost. The OCWR has depressed the permafrost table directly beneath the road, where surface organics have been compacted or inadvertently bladed during road maintenance, and raised the permafrost table beneath accumulated mounds of organics alongside the road. Recommended measures to minimize further impact on permafrost included redistribution of organics during road decommissioning, dispersal of plowed snow piles, and compaction of snow during winters when the road is not re-established.



Cross-section of thaw depths beneath and adjacent to the OCWR.

INDUSTRY

Beadedstream Inc.

BY HAYLEY CROTEAU

Specializing in digital temperature monitoring solutions, beadedstream proudly manufactures digital temperature cables, data loggers, and beadedcloud software, producing real-time actionable data. Leveraging data telemetry from pole to pole, the company provides real-time data for a wide range of environmental, civil engineering, and geotechnical monitoring applications on permafrost.

In 2023, beadedstream piloted a Temperature Forecasting Tool (TFT), a revolutionary predictive analytics tool developed and trialed with an ice road operator in the North Slope of Alaska. This tool, based on machine learning algorithms, generated a 30-day ground temperature forecast crucial for ice road planning and safety. Beadedstream attended EUCOP6 and the Yellowknife and Yukon Geoscience Forums, and eagerly anticipates ICOP2024 and ICCRE2024.

Beaded celebrates its 20th anniversary in May 2024. With a firm foothold in the industry, the organization looks forward to continuing its journey of innovation and collaboration, shaping the future of environmental monitoring with passion and expertise.

Beadedstream's D605 remote data loggers being installed for ice road monitoring.

INDUSTRY

Arctic Foundations, Inc. (AFI)

BY ED YARMAK, AUSTEN WHITNEY, & TERESA SANTOFERRARA

In 2023, Arctic Foundations, Inc. (AFI) manufactured 73 Thermo Helix-Piles (THPs) equipped with hybrid heat exchangers to support a new general store in Kotzebue, AK. The THPs were built during winter and barged to Kotzebue in June. Piling installation using the conventional drill and slurry technique occurred from late July to late August. Unbonded soil was encountered up to 7.3 m, which required casing. The internal heat exchangers in the THPs were used to actively stimulate the thermosyphon piling and freeze the slurry material in the bearing zone of the piling to accommodate an expedited construction schedule required by the owner. The heat exchangers were located just above the bearing zone of the THPs to conserve energy and provide direct freezing to the required zone. Active refrigeration work began in late August, once electrical power was available at the site. By early October, all THPs were frozen at the base with the capacity to sustain building construction loads in winter. As seasonal air temperatures dropped below soil temperatures, the THPs began to passively cool the subgrade, and the capacities of the piles increased. By April 2024, THP temperatures ranged from -3.6 to -10 °C. Temperature variability was due to initial site conditions and wind-drifted snow accumulations. In the future, the owner can deploy active cooling capabilities of the THPs to respond to climate warming.

Hybrid Thermo Helix-Piles at the new general store, Kotzebue, AK.

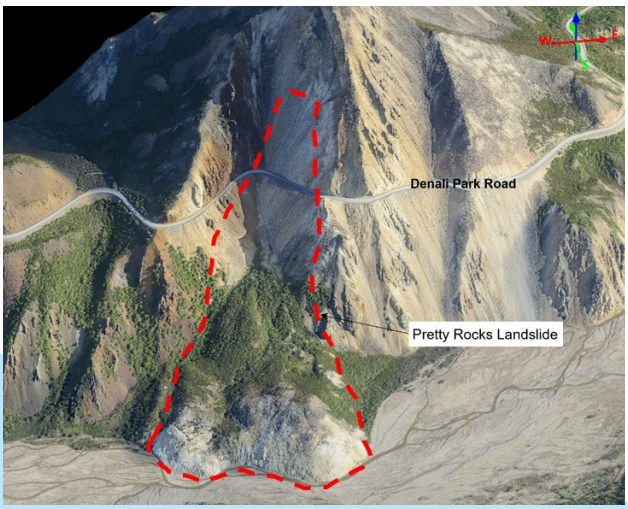
INDUSTRY

BGC Engineering Inc.

BY HEATHER BROOKS & LUKAS ARENSON

The 92 mile-long Denali Park Road is the only access road into the National Park. The roadway was closed in 2021 due to the accelerated movement of Pretty Rocks Landslide. Since 2021, the design team has developed a bridge to reopen the road. It consists of a 145 m, single-span steel truss bridge founded in rock. The east abutment consists of a clay-like, ash tuff, overlain by 0.3 m of ice and ~27 m of rhyolite with ice joints. Ground temperatures are ~-0.5 °C.

A 3D geological model was developed in Seequent's Leapfrog Geo software using borehole, geophysics, LiDAR, and structural geological maps. The geometry was imported into GeoStudio's Build3D software to apply the model mesh, boundary conditions, and material properties; followed by Temp3D for geothermal modelling. Once calibrated and the scarp material removed (due to deformation of the slide), projected air temperatures were cycled for five years for each climatic timestep (2020-2040, 2040-2060, 2060-2080, 2080-2100). 3D geothermal modelling was completed to determine if the ice will degrade during the ex-



Composite photo (2015) of the Pretty Rocks Landslide across the Denali Park Road.

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pected service life of the structure. Results showed permafrost degradation is likely at the depth of the ice without mitigation measures. Additional modelling with 22 thermosyphons installed to 33.5 m depth in a trapezoidal prism around the east abutment cooled the subsurface to the extent needed, and provided stable conditions for the foundation.

IN MEMORIAM

Samuel I. Outcalt

(1936-2023)

BY FREDERICK "FRITZ" NELSON (MICHIGAN STATE UNIVERSITY) & KEN HINKEL (UNIVERSITY OF CINCINNATI)

Sam Outcalt was raised in Indianapolis, IN. He received a BA in Geology from the University of Cincinnati (1959) and an MA in Geography from the University of Colorado Boulder (1964). Sam's masters thesis, a photogrammetric evaluation of the mass balance of small cirque glaciers in the Colorado Front Range, was published as a monograph in the prestigious University of Colorado Studies in the Earth Sciences series. In 1965, Sam moved to the University of British Columbia to pursue a PhD with J.R. Mackay. His dissertation was an innovative simulation study of needle-ice events.

Sam spent most of his teaching career at the University of Michigan's, supervising many graduate students. He taught thousands of undergraduates in his large introductory and upper-division courses. Sam's eclectic interests are reflected in publications addressing a range of scientific topics: physical climatology, permafrost, periglacial geomorphology, glaciology, soil physics, geomorphometry, urban climate, and physical limnology. His work is recognized for pioneering applications in physics-based computer simulation to geographical problems. His later work applied innovative rescaling and fractal analysis to problems involving physiographic regions, soil temperature and chemical time series, and stream discharge. In retirement, Sam continued to contribute insights to the research projects of his former students and to the education of his many "grand-students".

Outcalt, S.I., Nelson, F.E., and Hinkel, K.M. (1990). The zero-curtain effect: heat and mass transfer across an isothermal region in freezing soil. *Water Resources Research*, 26(7). DOI: 10.1029/WR026i007p01509.

IN MEMORIAM

Thomas G. Krzewinski

(1949-2023)

BY JOHN THORNLEY (WSP)

Tom Krzewinski passed away unexpectedly on 12 April 2023 while in Toronto, Canada, pursuing his passion for solving ground engineering problems related to cold regions and permafrost engineering. Tom was an internationally recognized expert in cold regions geotechnical engineering, with experience across North America on large infrastructure and industrial development projects such as the Trans Alaska Pipeline System (TAPS), the Red Dog Mine in NW Alaska, and a new railway to the Ring of Fire mining area in Ontario, Canada. He is survived by his wife Carol, three children and many grandchildren.

Tom started his long and prestigious career on the design of TAPS almost immediately after graduating from the University of Minnesota, Duluth (BSCE 1972), before being whisked away to Alaska for final design and construction. Throughout his distinguished career he contributed to cold regions engineering through the ASCE, USPA, IPA, IACORDS, Arctic Technology Conference, and many more. Tom was an associate editor for the ASCE *Journal of Cold Regions Engineering*, editor of multiple monographs by the ASCE Cold Regions Engineering Division, and frequent contributor to international conferences.

Krzewinski, T.G. and Tart, R.G. Jr (1985). *Thermal design considerations in frozen ground engineering*. ASCE Publications, 285 p.

IN MEMORIAM

Robert “Bob” Lewellen

(1936-2024)

BY JERRY BROWN (PAST PRESIDENT, IPA)

Robert "Bob" Lewellen began his Arctic career while enlisted at the US Army's Cold Regions Research and Engineering Laboratory (CRREL). He was instrumental in providing support to CRREL’s frozen ground investigations in Barrow, AK, such as (i) establishing a series of active layer plots; (ii) re-establishing the 1940s USGS coastal erosion sites; (iii) developing a multi-year, hydrology site; and (iv) georeferencing a series of boreholes for stratigraphic and geochemical studies.

After CRREL he continued to investigate coastal processes and subsea permafrost near Barrow. The results were presented at the 2nd ICOP and were the basis for his PhD at Denver University. He also prepared a two-volume monograph on the fluvial environment of Alaska’s Arctic Coastal Plain. Bob attended the first four ICOPs before starting his sea ice career, providing expert advice for the North Slope oil exploration and related drilling in the Beaufort Sea; and thus acquiring the life-long nickname *“Iceman”*.

His early career activities at Barrow contributed to the subsequent initiation of international programs including, the Circumarctic Active Layer Program (CALM), Arctic Coastal Dynamics (ACD), and Global Terrestrial Network (GTN-P).

His colleagues will remember his jovial and easy-going manner and generosity in time and efforts.

Lewellen, R. (1973). The occurrence and characteristics of nearshore permafrost, Northern Alaska. In: North American Contribution Permafrost Second International Conference, p. 131-136.

IN MEMORIAM

Ronald "Ronnie" P. Daanen

(1972-2023)

BY INA TIMLING

Ronald P. "Ronnie" Daanen died on 20 July 2023 in a helicopter crash near Wainwright, AK, while doing research for Alaska’s Department of Natural Resources, Division of Geological & Geophysical Surveys.

Originally from the Netherlands, Ronnie achieved his Environmental and Agricultural Engineering degrees there. After receiving a PhD in Water Resource Science from the University of Minnesota (2004) he became a post-doctoral fellow and professor at the University of Alaska Fairbanks.

Ronnie was a brilliant hydrologist and modeler, with a deep understanding of ecosystems. He modeled vegetation-permafrost interactions and snow distribution in ice-wedge polygon landscapes. In 2008, he recognized frozen debris lobes in the Brooks Range. Until his death he advanced our understanding of permafrost distribution and projected change across a warming Alaska, as well as slow-moving landslides. Ronnie was a wholehearted educator; starring in educational “music videos” and created ice sculptures to explain permafrost and hydrology concepts to the public.

His tremendous knowledge across disciplines, endless curiosity, and down-to-earth and welcoming attitude made him a go-to person for cold climate hydrology and ecosystem sciences. Informally, he often could be found chatting with tourists and locals alike while working in the field, explaining permafrost features, evidence of groundwater, or even his favorite orchids.

Ronnie will be remembered as a tremendous credit to the permafrost and groundwater hydrology field and as a wonderful, caring person with incredible patience and an excellent sense of humor.

Daanen, R.P., *et al.* (2012). Rapid movement of frozen debris-lobes: implications for permafrost degradation and slope instability in the south-central Brooks Range, Alaska. *Natural Hazards and Earth System Sciences*, 12(5). DOI: 10.5194/nhess-12-1521-2012.

The International Permafrost Association's

PHOTOGRAPHY Contest

Theme:

Permafrost in Colour

This year's Photography Contest was captured in many spectacular and inspiring photos. We thank all the contestants for sharing their memories and research activities with the international permafrost community.

Visit **permafrost.org** to see all the 2024 entries.

**Antoni Lewkowicz kindly donated his award to the other winners.*

Winner (€125)

Marjolaine Verret
University Centre in Svalbard,
UNIS, Norway

Runner-up (€75)

Josefine Lenz
UndercoverEisAgenten,
AWI, Germany

Runner-up*

Antoni Lewkowicz
University of Ottawa,
Canada

THE INTERNATIONAL PERMAFROST ASSOCIATION

The mission of the International Permafrost Association is to promote research in permafrost and permafrost-related fields within the global scientific and engineering communities, to support the activities of researchers in these disciplines, and to disseminate findings concerning permafrost to decision-makers, the general public, and educators.

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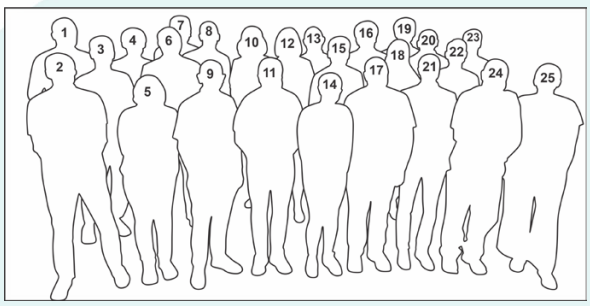
Participants of the IPA Council meeting at EUCOP6 in Puigcerdà, Spain (Sunday 18 June 2023).

1. Olli Karjalainen (Finland), 2. Reynald Delaloye (Switzerland), 3. Helena Bergstedt (Austria), 4. Tetsuo Sueyoshi (Japan), 5. Carla Mora (Portugal), 6. Rajmund Przybylak (Poland) 7. Petru Urdea (Romania), 8. Michael Krautblatter (Germany). 9. Antoni Lewkowicz (Canada), 10. Britta Sannel (Sweden) 11. Christopher Burn (Canada), 12. Kjersti Gisnås (Norway), 13. Mauro Guglielmin (Italy), 14. Sophie Opfergelt (Belgium), 15. Fujun Niu (China), 16. Gonçalo Vieira (Portugal), 17. Edward Yarmak (USA), 18. Isabelle Gärtner-Roer (Switzerland), 19. John Thornley (USA), 20. Bernd Etzelmüller (Norway), 21. Michael Fritz (Germany), 22. Antoine Séjourné (France), 23. Geert Hensgens (The Netherlands), 24. Frederick "Fritz" Nelson (USA), and 25. Emma Stockton (Canada). Photo: Marc Oliva (Spain).



Photos from the 6th European Conference on Permafrost (EUCOP6)

SENT BY MARC OLIVA (UNIVERSITY OF BARCELONA, CATALONIA, SPAIN)