




BOOK OF ABSTRACTS

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16th DACH
Permafrost Conference

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Seddiner See, Germany

Cover photos top down:

1. Rockwall inspection and data retrieval at Kitzsteinhorn, Austria. Photo: R. Delleske.
2. Borehole maintenance at Kitzsteinhorn, Austria. Photo: R. Delleske.
3. Vadret da Morteratsch glacier with Piz Palü and Bellavista in the back, Bündner Alps, Switzerland. Photo: S. Weber.
4. Permafrost and ice wedges exposed by lake drainage, Kotzebue, Alaska. Photo: J. Strauss.
5. Winter fieldwork team in the Alaskan Arctic. Photo: F. Seemann.
6. Permafrost lagoon in the outer Mackenzie Delta, Canada. Photo: M. Jenrich.

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Preface

The DACH Permafrost Union (http://dach-permafrost-union.org/), a permanent working group of the German Society for Polar Research (DGP), provides a forum for scientists from the DACH region (Germany, Austria, and Switzerland) and neighbouring countries who work in polar and mountainous permafrost environments. Its main objective is to strengthen the network within the permafrost research community and to jointly develop and advance methodological approaches. The DACH Permafrost Conference, held annually, represents the Union's most important platform for promoting direct scientific exchange and develop new synergies between polar and alpine permafrost researchers and engineers.

The Permafrost Research Section at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, in cooperation with the University of Potsdam, the GFZ Helmholtz Centre for Geosciences, Technische Universität Berlin, and Universität Hamburg, is delighted to host the 16th DACH Permafrost Conference in Seddiner See in January 2026. With this meeting, we aim to support collaboration across the broad interdisciplinary spectrum of permafrost research and to foster exchange between scientists, engineers, and practitioners from different countries and across all career stages, including students, PhD candidates, postdoctoral researchers, senior scientists, and professors.

In total, we recorded 94 registrations from eight countries (Germany, Austria, Switzerland, Sweden, France, the Czech Republic, Finland and Belgium) and received 80 abstract submissions, underlining the strong interest in the conference and the vitality of the international permafrost research community.

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Potsdam, January 2026

Jens Strauss
for the organising committee

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Using Electrical Resistivity Tomography (ERT) to Evaluate Permafrost Containment of Legacy Contaminants in the Mackenzie River Delta

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Oil and gas exploration activities of the past century have left the Mackenzie River delta of the Canadian Northwest Territories dotted with more than 200 drilling mud sumps. These sumps are mounds created by excavating the ground, placing drilling fluid wastes and drilled cuttings inside and backfilling with excavated material. Permafrost was intrinsic to sump design, as, once frozen, the cap would contain and prevent the escape of contaminated material to the environment. However, as the ground warms due to climate change, it is uncertain whether these sumps will continue to function as containment or for how long. In this work, we monitor the apparent electrical resistivity of the shallow subsurface using repeat Electrical Resistivity Tomography (ERT) measurements in order to understand the freezing and thawing of the sumps. We focus on several drilling mud sumps, some featuring opportunistically repeated measurements and one fitted with a monitoring setup measuring in 4-day intervals across freezing and thawing seasons between August 2024 and 2025. This allows us to observe changes in the temperature and ice content of permafrost beneath the sumps and the surrounding tundra. Our measurements reflect a clear footprint of the sumps on the subsurface resistivity distribution, with lower resistivities found beneath the sump compared to the surrounding undisturbed tundra. We find potentially perennially unfrozen zones along the sumps' rims that may serve as pathways for contaminant transport which correlate with vegetation height, snow depth and other environmental factors. With our results we aim to shed light on the thermal effect these legacy contaminated sites have on the permafrost and describe potential factors that can affect its stability and therefore the ability to provide long-term containment to drilling fluids.

Post-glacial emergent permafrost processes in coastal and paleo-lagoon landscapes on Svalbard

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Saline permafrost exists beneath shallow shelf seas, coastal plains shaped by past marine transgressions, and post-glacially uplifted landscapes that were once submerged. Salinity influences the freezing point and mechanical strength of permafrost and is therefore a critical parameter for assessing its stability. On Svalbard, the Kvadehuksletta region northwest of Ny-Ålesund features a diverse landscape comprising raised beach terraces, lagoons, paleo-lagoons (now lakes), and surface seeps. Our research aims to decipher how marine sediments transform after emergence. We hypothesize that ice formation during permafrost aggradation produces a porewater salinity gradient that triggers the downwards migration of salt in slowly uplifting sediments that are weakly susceptible to groundwater flushing. Sufficient salt build-up may lead to the formation of cryopegs – unfrozen layers or pockets within permafrost that persist at subzero temperatures to their elevated salt content. In summer 2024 and 2025, we carried out several electrical resistivity tomography (ERT) profiles, including three profiles (ranging from 800-2300 m in length) perpendicular to the coastline. The westernmost profile (collected in 2025) intersected a dynamic lagoon that was connected to the sea in 2024 but became completely cut off in 2025 by storm-surge deposits. To help delineate frozen and unfrozen permafrost conditions, electrical resistivity-temperature experiments on field samples collected from shallow cores (down to 250 cm) are currently underway. Laboratory tests indicate that the near-surface marine clays adjacent to the lagoon exhibit low resistivity values (< 10 Ωm) when thawed and freezing point temperatures down to -1.6 °C. The field samples are also being analysed for porewater chemistry (electrical conductivity, cations & anions, pH, stable water isotopes) and basic sedimentological properties like grain size. At two coring sites (1 paleo-lagoon, 1 beach setting), an annual ground temperature time series was also collected between field seasons. While the physical and electrical properties of the marine sediments are important to establish, so is their thickness. To determine depth to bedrock along selected ERT profile segments, we conducted multiple seismic refraction tomography (SRT) surveys (115 m length) in 2025 using a sledgehammer as an energy source. The synthesis of all datasets to describe uplifted permafrost is a work

in progress, but preliminary conclusions suggest that cryopeg occurrence is most likely in low-lying coastal areas characterized by warm permafrost, occasional seawater submergence, and saline marine clays with low hydraulic conductivity.

10 years of land surface deformation monitoring across Arctic lowland permafrost regions with Sentinel-1

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Land surface deformation derived from SAR interferometry can serve as an indication for potential permafrost degradation and as a tool to describe wet/dry gradients. Progress has been made specifically with the launch of the Copernicus Sentinel-1 mission in 2015. Challenges remain including data gaps due to acquisition strategies, and ionospheric and atmospheric effects. Data availability and processing constrains have been investigated across Arctic permafrost lowlands. On average data from half of the years could be utilized. Results were compared to other parameters including land cover and permafrost properties (Permafrost CCI records). Differences were found due to region specific disturbances, but in general linkages were similar across the Arctic.

A novel laboratory approach to study the formation of cryoturbation features in permafrost soils

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In the Arctic, the thickness of the active layer in permafrost soils is increasing due to ongoing climate change trends. Some former or present-day permafrost soils preserve their climatic history in the form of mechanically perturbed soils in the active layer known as cryoturbation features. These visually distinct features are proposed to form by freeze–thaw cycles inducing solidification and liquefaction fronts resulting in the vertical displacement and mixing of grains. However, the physical processes, environmental conditions, and timescales that control the formation of different types of cryoturbation features remain poorly constrained. The potential physical processes include frost heave, thaw settlement, moisture gradients, pore-pressure build-up, and water migration toward the freezing front.

As the physical processes are difficult to disentangle, we present a novel approach to study the formation and evolution of cryoturbation features under controlled laboratory conditions to isolate controlling parameters and infer their formation processes. At the GEOPS cold chamber facility, we force 60-hour freeze-thaw cycles on the surface of an 80 × 80 × 50 cm box composed of fully saturated sand and loess layers. The sidewalls of the box are thermally insulated to minimize horizontal heat exchange, and the bottom boundary is maintained below the freezing point. Differential surface heating and cooling are applied to force a curvature of the isotherms within the soils, mimicking natural surface inhomogeneities. In the field, differential surface covers (e.g., vegetation, ponds, snow) can generate such subsurface thermal imbalances, which can trigger feedback loops that enhance surface heterogeneity.

The experiment is monitored with an array of temperature sensors and by photographic observations through transparent sidewalls of the experimental container. Due to the experimental design, the transparent sidewalls can cause side effects that would not occur in continuous soils. Therefore, at the end of the experiment, after 30 cycles, we perform vertical transects into the unfrozen soil at 5 cm intervals. From the transects, we generate a photogrammetry-based interpolated spatial model of the cryoturbation features to assess their distribution within the experimental volume.

Initial results show a curvature pattern in the soils that follows the induced curvature of the isotherms, representing the most basic cryoturbation pattern. The aim is to expand the experimental protocol to force more complex cryoturbation types. Determining under what environmental conditions different types of cryoturbation features can form will help improve understanding of the response of these permafrost soils to climatic variations.

Drilling waste buried in permafrost environments – Tracing organic contaminants in surrounding soils and water bodies

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From the 1960s to the early 2000s, subarctic Canada was subject to extensive onshore and offshore gas exploration activities. For onshore drilling, it was common practice to bury the generated drilling waste in open pits at the drill site. Once the drilling waste was frozen, these constructed drilling mud sumps were covered with a dense cap of fine-grained substrate, leaving the waste encapsulated solely in the perennially frozen permafrost soil. Although the drilling fluids used were primarily freshwater-based, the sump cap material often contains elevated levels of organic contaminants. These likely originate from petroleum hydrocarbons present in recovered formation water, oil and grease, as well as technical additives in spent drilling fluids. The inherent salinity of both formation water and drilling fluids buried in drilling mud sumps may cause the surrounding permafrost to thaw, leading to the risk of contaminant mobilization and their discharge into surface soils and waters.

In this study, we analyzed soils and water bodies surrounding six drilling mud sumps for organic contaminants in a non-targeted screening. Soil samples were extracted using acetone and n-hexane, enhanced by ultrasonication and dispersion. The extract was separated into six fractions by column chromatography through subsequent elution with solvents of increasing polarity. Water samples were extracted sequentially with pentane, pH-neutral and pH-modified dichloromethane, generating three extract fractions. All soil and water extract fractions were analyzed using a TRACE 1610 gas chromatograph coupled with an ISQ 7610 single-quadrupole mass spectrometer (Thermo Scientific). Comprehensive non-target screening was performed using the XcaliburTM Software linked to the NIST library.

This investigation is part of a multidisciplinary study with the overarching goal of understanding the impact of drilling mud sumps on permafrost ecosystems. Tracing organic contaminants in surrounding soils and water bodies will support the evaluation of individual sump stability and potential risks posed by sump failure. The results will further contribute to assessments of the effects on soil microbial communities, vegetation and hydrology.

Improving permafrost wetland mapping

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Incomplete knowledge of wetland extent and types contributes to the notoriously high uncertainty range that still affects estimates of arctic carbon stocks and fluxes. In my PhD project, I approach this challenge from several angles.

First results of efforts to improve wetland type distinction in the permafrost zone will be presented. This includes a prediction of organic layer depths with machine learning, which indicates peat presence and depth. A second part of the project started with field spectrometry of vegetation in northern Canada, with the goal to support hyperspectral remote sensing for mapping common northern ecosystem types including wetlands.

Delayed Active-Layer Freeze-Back and Prolonged Thawed Periods in Polygonal Tundra on Samoylov Island, Siberia

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Rapid Arctic warming is reshaping snow regimes and the thermal–hydrological state of permafrost, yet multi-year, co-located observations remain scarce in Northeast Siberia. We present a ten-year dataset from Samoylov Island in the central Lena River Delta, Siberia (72.3742° N, 126.4959° E), characterizing an ice-wedge polygon under a cold, dry climate with a mean annual air temperature of −11.7 °C and typically shallow snow. Three instrumented soil profiles capture the microtopographic gradient between an elevated, relatively dry rim and a lower, seasonally inundated center. Complementary soil sampling in August 2012 of the active layer and near-surface permafrost provides physical and geochemical properties: bulk density, ice content, pH, electrical conductivity, ammonium, nitrite, and pore-water chemistry. Soils are highly porous and sand-dominated with some silt and little clay. Total organic carbon and nitrogen are greatest in the shallow active layer and decrease with depth. Methane concentrations peak just above the permafrost table, then decline to moderate levels at mid-depth and to low levels near the base of the sampled profile. Across all years, the onset of freeze-back was relatively similar between depths but shifted later over the study period by roughly seven to eleven days, while the duration varied strongly with depth and year. Shallow layers refroze first and most quickly, deeper layers took much longer, and the polygon center consistently froze later and over a longer period than the drier, elevated rim, reflecting higher water content and stronger snow insulation in the center. Years 2015, 2016, and 2020 stood out with particularly long zero-curtain periods, coinciding with deeper snowpacks and higher snow water equivalent, and toward the end of the period the active layer thickened so that deeper sensors (e.g. at 52 cm) shifted from perennially frozen to seasonally freezing. Overall, the combination of delayed onset and sometimes very long freeze-back duration implies a longer annual thawed period, especially in the wetter polygon centers. This dataset provides a valuable benchmark for calibration and validation of permafrost and land-surface models.

Toward a comprehensive satellite-based inventory of aufeis across cold-arid high mountain environments

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Aufeis describes seasonal, layered ice masses that form in winter through successive freezing of water seeping through the ground, from springs of from below river or lake ice. It represents a distinct cryospheric feature in many cold and permafrost-dominated environments. Most existing studies focus on North America and Siberia, where *aufeis* is considered as an important hydrological feature and a potential engineering problem. In contrast, research in high mountain areas remains in an early phase, where our first systematic studies showed widespread distribution and in the case of Ladakh, India, active integration of *aufeis* in to the local irrigation systems in the form of ice reservoirs ("artificial glaciers"). As these studies have shown it to be a prevalent phenomenon in the cold-arid Trans-Himalaya, the question arises how it is distributed across similar environments.

This early work-in-progress presented extends *aufeis* detection to the remaining parts of High Mountain Asia and to the Andes, where its occurrence could already be observed on satellite and trail-camera imagery. Utilizing remote sensing imagery from the Landsat and Sentinel-2 missions (2000–2025) in combination with a machine-learning approach, a comprehensive *aufeis* inventory for these environments will be developed. The analysis will integrate digital elevation models to derive elevational ranges and topographic conditions, permafrost distribution to study the relationship between *aufeis* and permafrost occurrence, as well as gridded precipitation and temperature datasets to explore regional climatic controls on *aufeis* formation.

First preliminary results indicate widespread existence across High Mountain Asia, presumably in regions of localized groundwater discharge, while in the Dry Andes distribution is more localized and concentrated in Northwestern Argentina. Their size however does not reach the same as in most parts of Asia. Minor occurrences were also detected along the western side of the Andes in Chile.

By establishing a comprehensive inventory across these mountain systems, the study contributes to the ongoing scientific efforts to map and understand *aufeis* formation patterns and dynamics across the globe. Furthermore, it can serve as a starting point for an advanced understanding of hydrological interactions in some of the world's driest high-elevation landscapes.

Short-Term Temperature Effects on Methanotrophic Activity and Microbial Community Structure in Soils of Western Greenland

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Permafrost regions play a major role in the global carbon cycle and are expected to increase atmospheric methane concentrations due to large-scale thawing processes. However, small-scale microbial processes within the active layer can create local methane sinks, as observed in multiple regions. To better understand how environmental conditions shape methane-oxidizing microbial communities, we conducted a multifactorial incubation experiment using soils from Qeqertarsuaq (Western Greenland). Active layer samples from below different vegetation covers were incubated for one week under two different temperatures and four moisture levels. The microbial activity was subsequently assessed by combining gas flux chamber measurements with genetic analyses, including metabarcoding and quantitative PCR (qPCR) of both genomic DNA (gDNA) and RNA (analysed as complementary or cDNA). Targeting both DNA and RNA, we were able to compare microbial community composition and abundance with gene expression as a possible proxy for microbial activity. We used the 16S rRNA gene to assess general prokaryotic abundance (bacterial and archaeal) and the *pmoA* gene as a marker for methanotrophs (microorganisms that feed on methane).

The overall prokaryotic diversity in the soils was very diverse with Shannon indices above 6. Methanotrophic gene expression, general prokaryotic gene expression and alpha diversity were positively correlated with temperature. Warmer conditions reduced the relative dominance of the most-abundant taxa, indicating a temperature-driven shift in community composition. Moisture only influenced general prokaryotic abundance and not much the community composition. Neither gene expression nor alpha diversity showed a significant moisture dependence. Beta diversity analyses revealed that methanotrophic community composition was similar between the three sites investigated while the overall prokaryotic community was separated by sites, suggesting functional convergence for methanotrophs across the investigated locations.

The bacterial genus *Methylocapsa* emerged as the dominant and potentially most relevant methanotroph across all treatments. Further, facultative (not obligatory) methanotrophic taxa dominated the samples. Methane fluxes correlated with the DNA-based abundance of prokaryotes and - more specifically - methanotrophs but not with RNA-based gene copy numbers. This could indicate that community abundance rather than gene expression approximates ecosystem processes.

Overall, the findings highlight temperature as a major driver of short term (methanotrophic) community dynamics in Arctic active layer soils of Western Greenland, while moisture seems to be less important.

Systematic links between DinSAR surface kinematics and ERT-derived permafrost characteristics in alpine periglacial landforms – Consequences for RGV monitoring

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Rock glaciers are debris landforms shaped by permafrost creep and, as such, key indicators for the occurrence of mountain permafrost. Their annualized surface velocity, described by the term rock glacier velocity (RGV), was recently added as a quantity of the essential climate variable (ECV) permafrost. Therefore, identifying representative monitoring sites has become increasingly important but selecting suitable areas remains challenging as systematic, high-resolution investigations are required to distinguish long-term creep from other processes such as seasonal subsidence. Differential SAR Interferometry (DinSAR) has been successfully applied for rock glacier inventories but never tested for its suitability to identify representative sites for RGV monitoring. Therefore, we analyze five years of Sentinel-1 DInSAR time series data from five sites in the Central European Alps to assess this potential. Horizontal and vertical displacement components are derived as well as seasonal acceleration during snow-free months to characterize movement dynamics. These data are combined with electrical resistivity tomography (ERT) data from 24 profiles of more than 4500 m length, enabling detailed comparison between surface kinematics and subsurface characteristics for those five study sites. Our results clearly indicate systematic links between subsurface resistivity and surface kinematics: unfrozen zones (<10 kΩm) exhibit low velocities unless affected by nearby active areas or other non-permafrost related processes. Ice-poor permafrost (10 - 100 kΩm) shows predominantly horizontal creep with low seasonality, while ice-rich permafrost (100 kΩm - 1 MΩm) and sedimentary ice (>1 MΩm) are rather affected by enhanced subsidence and high seasonal variability. However, movement patterns are linked more strongly with geomorphological context than ice content alone. The spatial and seasonal patterns differ particularly strong between areas, where interaction between glaciers and permafrost has occurred in the past and purely periglacial areas. As such, areas of former glacier-permafrost interaction are dominated by high resistivities (high ice content) and subsidence due to meltout of predominantly sedimentary ice, whereas talus-derived rock glaciers are dominated by permafrost creep. We therefore recommend excluding glacially influenced or glacier forefield-connected landforms from RGV monitoring and focusing instead on middle to lower parts of stable talus-connected rock glaciers. Our results show that DInSAR-derived seasonality proves to be a robust and scalable metric for identifying representative monitoring sites and excluding zones affected mainly by subsidence and permafrost degradation. Besides, interannual displacement trends in thaw-affected

areas could help to better understand permafrost degradation and its role in alpine landscape evolution under ongoing climate change.

Thermal evidence for degradation of ice-cored moraines on Svalbard: Preliminary analysis of airborne MACS data

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In the course of Earth analogue studies for Mars on Svalbard, several flight campaigns have been conducted with the MACS-Polar (Modular Aerial Camera System) in 2020 and 2024. MACS-Polar, a camera system developed by DLR in Berlin, consists of two high-resolution RGB and infrared (IR) cameras as well as a cooled bolometer to take thermal images. One of our target areas is an ice-cored lateral moraine of Kongsvegen glacier on the Brøgger peninsula in western Spitsbergen. The moraine is a highly dynamic environment, with intense sediment re-mobilisation due to slumping of a debris layer along the debris-ice contact. Thermal contrast, which involves both temperature and material specific emissivity differences, is fairly small in this natural polar environment with dominating glacial till material; solar radiation and exposition-induced effects are dominating the main thermal dynamics in the scene. While in the IR-RGB data the sparse vegetation and morphological features can be clearly depicted and mapped, the thermal channel highlights active melt zones on the ice-cored lateral moraine, which cannot be clearly differentiated form older inactive melt and slumping features by just using the high resolution RGB and IR data.

We exemplarily present data of degrading permafrost on Svalbard depicting active melt- and slump-zones and the connected hydrological system, and highlight the science potential and the challenges of thermal imaging systems in polar environments.

Evidence of incomplete talik refreezing reveals enhanced organic carbon mobilization potential in the continuous permafrost zone

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Thermokarst processes strongly reshape permafrost landscapes in the Arctic, mobilizing permafrost carbon. In this study, we investigated a coastal lowland transect on the Baldwin Peninsula (northwestern Alaska) spanning a sequence of five landscape units representing different stages of thermokarst, from rather intact Yedoma upland (UL) to thermokarst lake (L), semi-drained (SDL) and completely drained lake basins (DLB), and a coastal retrogressive thaw slump (RTS) connecting to the marine environment.

Combining high-resolution aerial imagery (1952–2022) with geochemical and biomarker analyses, we reconstructed spatiotemporal landscape evolution over decadal time scales. Based on organic matter (OM) quality (molecular composition and pre-thaw alteration) and near-surface organic carbon inventories (0–1 m), we found that OM degradation and its potential mobilization are strongly controlled by landscape context: persistent talik conditions in the SDL for ~60 years after drainage likely sustained OM degradation, whereas rapid permafrost aggradation in the DLB stabilized existing OM and new sequestration (peat). Accelerating RTS retreat (8 m yr^{-1}, 2020-2022) may drain the thermokarst lake within the next years, releasing labile OM from lacustrine and OC-rich Yedoma deposits.

This case study illustrates how thermokarst evolution governs the distribution and potential fate of OM in the continuous permafrost zone, providing empirical evidence of incomplete talik refreezing even after ~60 years of post-drainage exposure (in SDL) and sustained carbon loss. Here, at the southern margin of the continuous permafrost zone and a setting of rather warm ground temperatures, this may indicate a systemic shift of freshly drained DLB systems from temporary carbon sinks (due to refreezing taliks) to persistent sources (due to not refreezing taliks anymore) under ongoing warming.

IPA Action Group (Permafrost-Associated Gas Hydrates): Update for a geospatial directory of relevant gas hydrate and subsea permafrost metadata

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The IPA action group on permafrost-associated gas hydrates (kick-off in April 2025) has been working towards building a geospatial directory of relevant gas hydrate and subsea permafrost metadata by establishing a list of key parameters and linking it with peer-reviewed articles, data repositories, as well as government and industry reports. Important parameters include, but are not limited to, water depth, sediment temperature, porewater salinity, permafrost characteristics, and the depth (top and bottom) of subsurface regions such as ice-bearing and ice-bonded permafrost, and the gas hydrate stability zone (GHSZ). The directory, which will be available in user-friendly GIS and Google Earth formats, will help plan future land-to-sea drilling transects and refine regional interpretations of the GHSZ. Our efforts also constitute preliminary work for an International Continental Drilling Project (ICDP) workshop proposal. Over the coming months, we also aim to integrate existing and previously published geospatial products into our directory, to maximize metadata availability for the user. Our plan is to produce a first draft of our deliverable by December 2025 and then work towards a funding renewal application in the new year.

Quantifying electrical resistivity in arctic permafrost soils: the influence of ice content, cryostructure and pore water chemistry on temperature vs. resistivity laboratory experiments

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Due to its robust and simple operability, as well as its non-invasiveness, electrical resistivity tomography (ERT) is becoming increasingly popular for investigating Arctic permafrost, its features and its ground thermal regime. As the electrical resistivity depends on many factors like ice, water-, and salt content, as well as sedimentological properties, it is necessary to quantify the influence of these factors to be able to interpret field resistivity data correctly. This is especially important when deciphering the ground thermal regime from ERT data.

We performed laboratory tests on artificial samples to delineate the influence of sample sizes, array orientation, electrode spacing, electrode type and anisotropy on the apparent resistivity. Therefore, we conducted small-scale electrical resistivity measurements along six quadrupoles per sample orientated in three different orientations compared to internal layering. To evaluate hysteresis effects, the tests were conducted by warming up the samples close to the freezing point and then refreezing them to approximately -10°C. To further quantify the temperature-resistivity behaviour of warming permafrost, some samples were completely thawed before refreezing them again.

As the complexity of natural permafrost is hardly represented by artificial samples, we then conducted electrical resistivity vs. temperature experiments on permafrost samples from Canada, Greenland, and Svalbard. We combined these results with porewater, grain size and ice content analyses. The strong dependency of resistivity on salinity and iron content, as well as the anisotropy factor induced by the thickness of ice lenses, clearly highlight the need for an improved understanding of these relationships for interpreting field ERT data. Consequently, our research enables a more accurate assessment of permafrost characteristics across time and space.

How snow, vegetation and soil properties determine soil temperatures in a permafrost environment (Trail Valley Creek, Western Canadian Arctic)

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Warming ground temperatures in the Arctic raise the need to forecast permafrost thaw. Seasonal snow cover is a crucial factor for ground temperatures as it can have a warming or cooling effect on the underlying soil, depending on snow cover timing and its physical properties. Vegetation and topography modulate snow distribution and affect the snow thermal insulation.

However, the formation processes and resulting properties of Arctic snowpacks are difficult to represent in snow models and in-situ data is sparse. Further understanding of the interactions between snow, vegetation and permafrost and the deduction of empirical relationships could support the parametrization of snow in permafrost modeling.

We study how the ground thermal regime is influenced by the interplay of snow, vegetation, topography and climatic conditions. In particular, we evaluate the effect of snow density variation on the ground thermal regime. We present a novel dataset that combines air, surface and soil temperature, as well as soil moisture time series recorded from September 2024 to August 2025 with end-of-season snow depth distribution and high-resolution vertical snow density profiles. Temperatures and soil moisture were monitored using 60 TOMST TMS-4 loggers, distributed across different vegetation types and topographic features in the taiga-tundra ecotone (Trail Valley Creek, Northwest Territories, Canada). Snow density profiles were measured in March 2025 next to the TOMST loggers using a SnowMicroPen.

Our data show several characteristic snowpack types which do not only differ in depth but also have a different layering structure. Low density snowpacks with high depth hoar fractions are most prominent in forested areas that are shielded from the wind, whereas leeward slopes can accumulate thick, high-density wind slab, regardless of vegetation. While snow depth is clearly one of the major drivers of soil temperature, the role of snow density is more complex.

Categorization of different tundra vegetation types with characteristic snow conditions and specific impact on permafrost vulnerability helps to refine permafrost models and constrain predictions of permafrost thaw.

Spatial patterns of rockfalls in the eastern European Alps and their relationships with permafrost and glacial retreat

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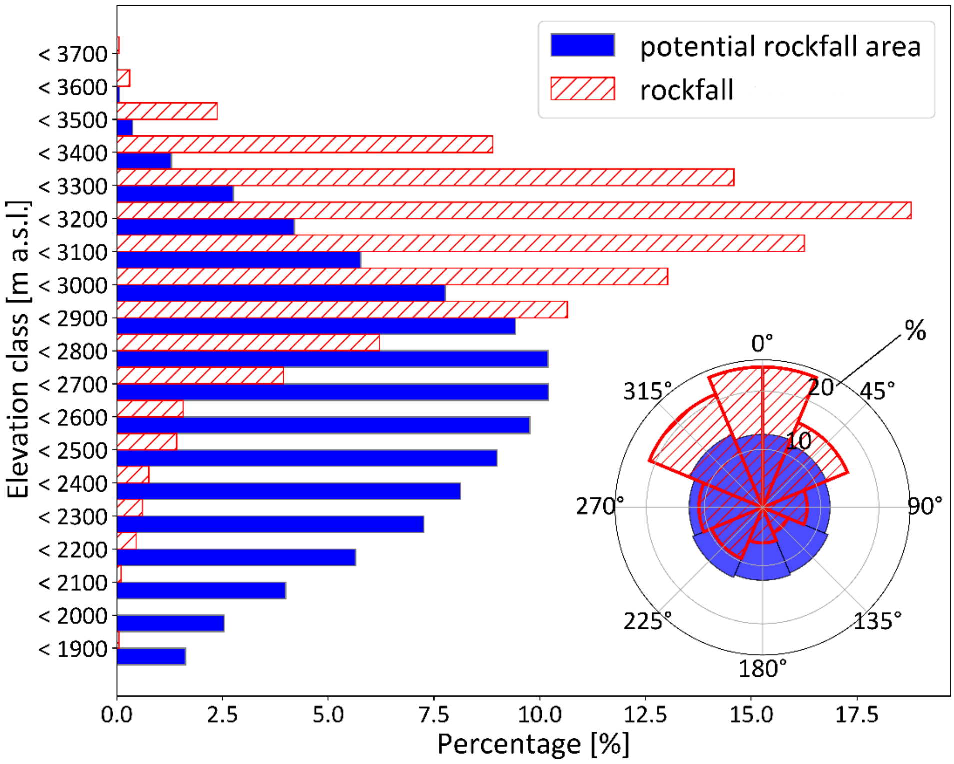
High mountain environments are among the regions most affected by global warming, with significant implications for slope stability due to glacier retreat and permafrost degradation. This study investigates the spatial distribution of rockfalls above the timberline in the Stubaier and Ötztaler Alps, located in the Eastern European Alps. Rockfalls were identified using an automated pre-classification approach and manual verification

of detected rockfalls based on digital surface models (DSMs) derived from 2006 and 2017 airborne laser scanning (ALS) datasets and orthoimages. To assess the influence of permafrost degradation, the mean annual ground surface temperature (MAGST) was modelled using a simplified surface energy balance approach, incorporating altitude and solar radiation. Glacier retreat was analysed using glacier inventories from 1969, 1998, and 2006 to identify areas of ice loss and their impact on slope stability.

A total of 1,989 rockfalls were identified, with volumes ranging from 200 m^3 to 200,000 m^3. The results reveal a strong spatial correlation between rockfall occurrence and areas affected by permafrost degradation and glacier retreat. Notably, 76% of the rockfalls occurred in areas with a MAGST below 0°C, which represents only 22% of the potential rockfall area. Furthermore, 40% of the rockfalls were located in areas that have been deglaciated since 1969, accounting for just 4.7% of the potential rockfall area. Rock faces located in northern sectors and at altitudes above 3,000 meters are particularly prone to rockfall. Although these areas constitute only 22% of the total rock surface area, they account for 75% of all rockfalls occurring at this elevation (see Figure below).

The findings align with previously published local rockfall inventories that focus on specific rock faces or glacial cirques, while expanding the scope to encompass a broader region ranging from 1,800 to 3,770 m a.s.l. and covering an area of 1,350 km^2. This study represents the first extensive regional inventory of recent rock-falls across a larger area in the Eastern Alps, demonstrating a significant spatial correlation between rockfall occurrences, permafrost degradation, and glacier retreat zones.


potential rockfall area
rockfall
Elevation class [m a.s.l.]
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< 3600
< 3500
< 3400
< 3300
< 3200
< 3100
< 3000
< 2900
< 2800
< 2700
< 2600
< 2500
< 2400
< 2300
< 2200
< 2100
< 2000
< 1900
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Percentage [%]
%
0°
45°
90°
135°
180°
225°
270°
315°
10
20

Depth-dependent, opposing trends of N_2O and CH_4 turnover processes in upland tundra soils of West-Greenland

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Tundra soils are sources or sinks of the non-carbon greenhouse gases (GHG) nitrous oxide (N_2O) and methane (CH_4), which mainly depend on small-scale differences in topography along with varying soil moisture and vegetation communities. However, little is known about how soil properties such as organic O-layer characteristics or O-layer depth influence GHG emissions, and there are only few studies of upland tundra soils in which the fluxes of the two GHG are examined together. In this study, we measured summer land-atmosphere exchange fluxes of N_2O, CH_4 and CO_2 of upland tundra soils with varying O-layer thickness and properties, moisture and vegetation cover using a closed chamber method with portable high frequency gas analysers on Disko-Island. We found that soils with similar O layer thickness and moisture exhibit similar in-situ land-atmosphere GHG fluxes and show opposing trends of N_2O and CH_4 fluxes. To uncover what is happening beneath the surface in the soil, we also analysed the uptake and production GHG in soil horizons with different physicochemical properties in aerobic microcosm experiments with vegetation directly in the field. In the upland tundra soils, the GHG fluxes were depth-dependent, with highest production of CO_2 and N_2O in the uppermost O-layers, the Oi and Oe layers, whereas CH_4 was mainly taken up from the lower O-layers, the Oe and Oa layers. Soils with the thickest O layers and lowest volumetric water content (VWC) showed the highest CH_4 uptake and N_2O emission while wettest soils showed the opposite. N_2O and CO_2 production mainly depended on carbon (C)-and nitrogen (N)-compounds (TOC, DOC, TN, DON, C/N) whereas CH_4 uptake depended on N availability (TN, ammonium).

The land–ocean Arctic carbon cycle: A review of sinks and sources including the permafrost domain

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The integrated Arctic system (terrestrial and marine combined) is presently an overall carbon sink, largely driven by oceanic uptake of CO_2 from the atmosphere and OC accumulation into shelf sediments. The magnitude of this overall sink is expected to weaken.

This presentation relates to our review article in Nature Reviews Earth and Environment on The land–ocean Arctic carbon cycle. Here, we synthesize the most recent quantitative data on carbon cycle components along the Arctic land–ocean continuum (see Figure below). We present carbon stocks and fluxes in the pan-Arctic domain that include terrestrial and marine stocks, lateral fluxes from rivers and coastal erosion, as well as vertical fluxes on land and in the ocean (see Figure below).

Numerous research initiatives and databases have recently improved the quantification of carbon reservoirs and fluxes between different components of the Arctic — such as the Circum-Arctic Sediment CArbon DatabasE (CASCADE), the pan-ARctic Catchment DatabasE (ARCADE), the REgional Carbon Cycle Assessment and Processes 2 (RECCAP2), the Arctic Great Rivers Observatory (ArcticGRO), the Northern Circumpolar Soil Carbon Database (NCSCD), the Global Terrestrial Network for Permafrost (GTN-P) and the Arctic Monitoring and Assessment Programme (AMAP) of the Arctic Council. They have also improved process understanding of the impact of climate change on carbon cycling over the land–ocean continuum. However, most comprehensive overviews of the Arctic carbon cycle were more than 15–20 years old and precede the last decade of amplified Arctic warming. Thus, our updated overview of the current state of the Arctic carbon cycle is timely to assess responses to ongoing environmental change.

We conclude our review by discussing the implications of anthropogenic climate change on the Arctic carbon cycle and suggest that future research should focus on under-represented areas, such as small catchments, and the impact of non-linear processes, including extreme events.

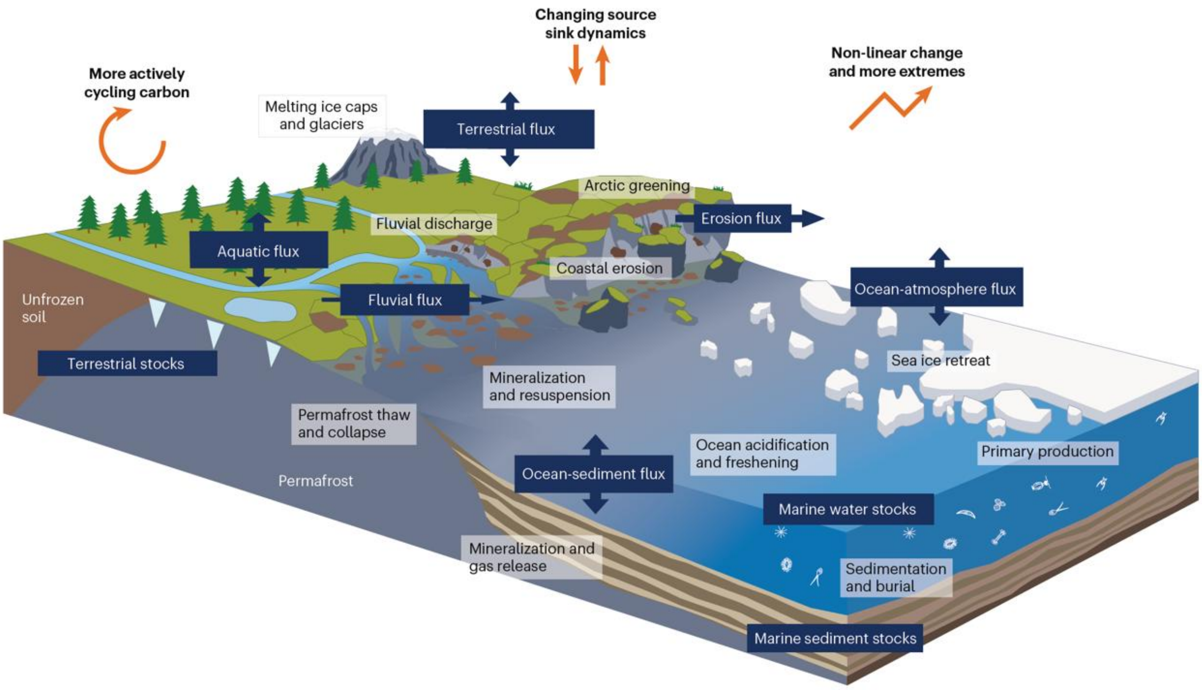

Figure: Carbon cycling across the integrated Arctic system. Adapted from Vonk, Fritz et al. (2025)

Remotely sensed spatial and temporal variability of dissolved organic carbon within and across river channels of the Mackenzie Delta, Canada

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Arctic rivers transport large amounts of organic carbon from land to ocean, with dissolved organic carbon (DOC) accounting for up to 83% of this flux. Thawing permafrost mobilizes previously frozen terrestrial organic carbon into the aquatic environment, where it undergoes alteration, influencing DOC export to the sea and eventually carbon cycling in Arctic shelf seas. However, DOC dynamics within Arctic river deltas, the transition zone between terrestrial and marine systems, are poorly constrained due to limited field accessibility. Remote sensing can potentially overcome this with frequent and synoptic observations, yet its application in Arctic river deltas remains rare so far.

This study aims to combine in situ data with optical satellite imagery to investigate the spatial and temporal variability of DOC concentrations across various channels in the Mackenzie Delta, Canada. The best performing atmospheric correction and DOC retrieval algorithm for the region was identified, allowing mapping of DOC concentrations across seasons. These synoptic observations also aim to detect local DOC sources and contribute to the quantification of land-ocean fluxes for carbon budgets.

In our study, we retrieved DOC concentrations from Sentinel-2 MSI (Multi-Spectral Instrument) imagery and tested multiple atmospheric correction algorithms and existing algorithms for the retrieval of coloured dissolved organic matter (CDOM) absorption. Retrieved satellite CDOM absorption was translated into DOC concentrations using in situ data from the high-frequency Mackenzie River monitoring program in Inuvik (https://mackenzie-monitoring.awi.de/) and applied to multiple Sentinel-2 scenes of the river delta during different seasons in 2024.

The combination of the Case 2 Regional CoastColour (C2RCC) atmospheric correction and the CDOM retrieval algorithm of El Kassar et al. (2023) provided the best DOC estimates ($R2 = 0.85$, $RMSE = 1.25$ mg/L). The satellite-retrieved DOC values captured the full range of seasonal variation and revealed pronounced variability within and between river channels. These spatial and temporal patterns would have remained undetected by limited stationary in-situ sampling. High DOC concentrations were observed particularly after spring freshet with marked seasonal shifts in the spatial distribution of DOC across the channels (see Figure below).

The results demonstrate the capability of high-resolution remote sensing to complement in situ monitoring in space and time and to detect DOC variability in Arctic deltas. This approach contributes to closing the knowledge gap in DOC fluxes and dynamics within the land-ocean continuum in Arctic regions.

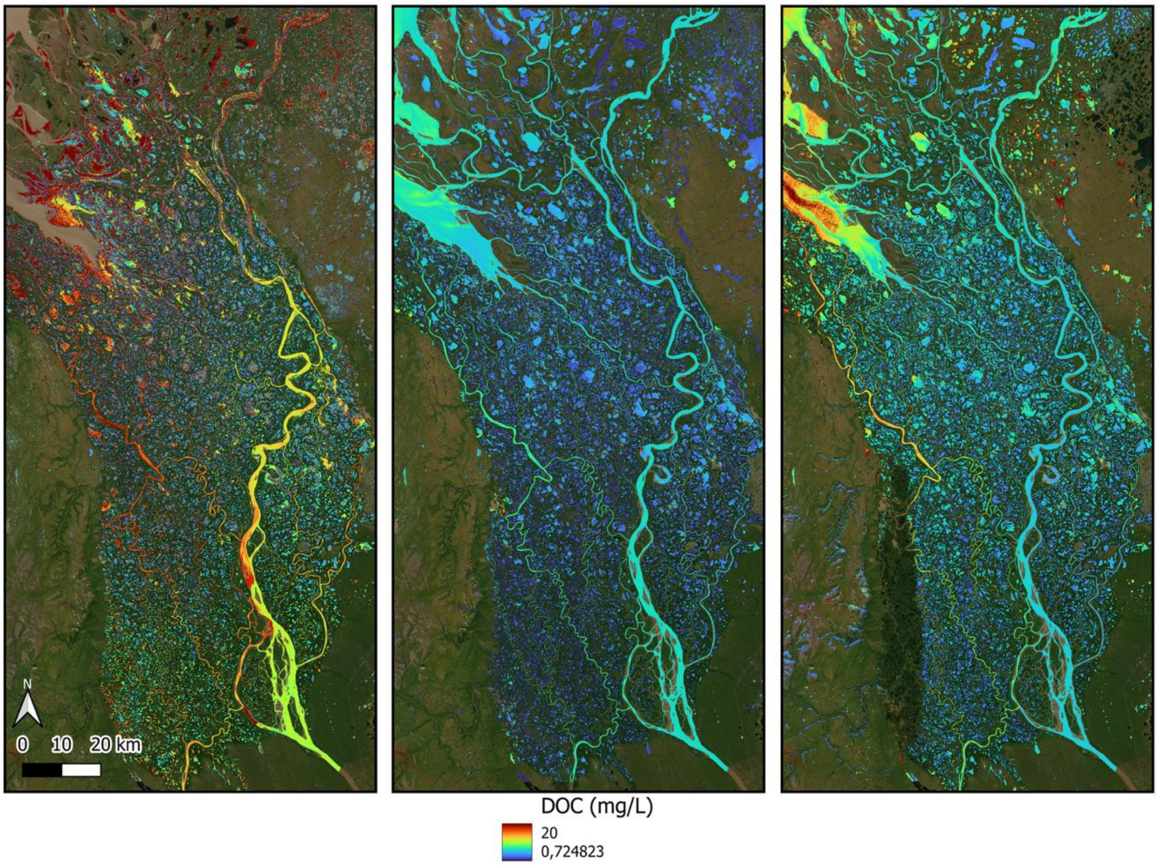

Figure: Satellite retrieved DOC concentrations (mg/L) in the Mackenzie Delta, Canada, from 01.06.2024 (left), 05.08.2024 (middle) and 04.10.2024 (right).

The future of the Arctic land-ocean carbon cycle: projections, priorities, and policy needs

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The Arctic region stores vast amounts of organic carbon in permafrost soils and sediments and has acted as a sink of anthropogenic carbon to date. However, steadily increasing atmospheric greenhouse gas concentrations and rapid Arctic warming – currently occurring three to four times faster than the global average – are intensifying carbon cycling across the region. Carbon dioxide (CO_2) and methane (CH_4) emissions from thawing permafrost and other natural sources are rising, while the buffering capacity of terrestrial and marine carbon sinks may be approaching its limits. Recent studies indicate that the Arctic may be shifting from a net sink to a net source of CO_2 and CH_4, but substantial uncertainties remain in quantifying current fluxes and projecting their future evolution.

In a research project between the University of Hamburg and the German Environment Agency, we aim to (1) synthesize current knowledge and quantitative data on the Arctic land and ocean carbon cycle, (2) provide model-based assessments of the future evolution of Arctic carbon fluxes under different climate scenarios, and (3) communicate these findings to political decision-makers through various targeted formats. Here, we present future projections of Arctic permafrost extent as well as terrestrial and marine CO_2 fluxes based on a multi-model ensemble of CMIP6 Earth system models. We find, for example, that the permafrost area would roughly halve at 2.7 °C of global warming relative to pre-industrial conditions. In addition, we outline key research priorities and policy recommendations that emerged from an interdisciplinary workshop held in September 2025, which brought together experts from terrestrial and marine Arctic carbon research along with representatives from policy and the science–policy interface. These insights are currently being consolidated into a collaborative white paper.

High spatial and seasonal heterogeneity in methane emissions linked to unique hydrology in alpine peatlands

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Alpine peatlands share certain characteristics with northern peatlands: they have a short growing season, strong seasonality, and are snow-covered for 6-9 months/year. Whether they have the same greenhouse gas emission characteristics as northern peatlands, and whether these are driven by the same mechanisms, is however largely unknown. We investigated an alpine peatland in Voralberg, Austria during the summer, winter, and snowmelt seasons. The selected field site is located at 1670 m.a.s.l. altitude on a slight slope of a plain surrounded by mountains up to 2416 m.a.s.l.

Methane flux measurements with static chambers showed that this peatland is a strong emitter of CH4 in summer, although emissions depended strongly on the weather in the days before/during the measurements, showing a large impact of temperature and moisture (CH4 emission of 49 mg m2 h-1 on average on a warm summer day, 13 mg m2 h-1 on a cold summer day after a rainy period), with local rates of over 150 mg m2 h-1. Although the observed summer CH4 emissions were consistently high, we observed a very large spatial variation, even within the 1 m2 scale, and large temporal variations between day and night (see Figure below). The large variation in GHG emissions is supported by a large variation in soil carbon and nitrogen content between locations within the peatland site.

Besides the temporal variation on the diurnal scale, we also observed a large variation on the seasonal scale. We detected a surprising switch from methane emissions in summer, to methane uptake in certain locations in spring, potentially indicating a large variation in redox conditions with the seasons.

In winter, when the area is covered in >1m of snow, the sampled alpine peatland remains partly uncovered due to the continuous input of 5'C spring water. This creates a unique environment in which microbial carbon cycling continues at a higher rate than at nearby sites and leads to methane emissions throughout winter.

In addition to presenting these results, I will also present the upcoming multidisciplinary research at this field site that will combine geohydrology, geophysics, plant science and biogeochemistry.

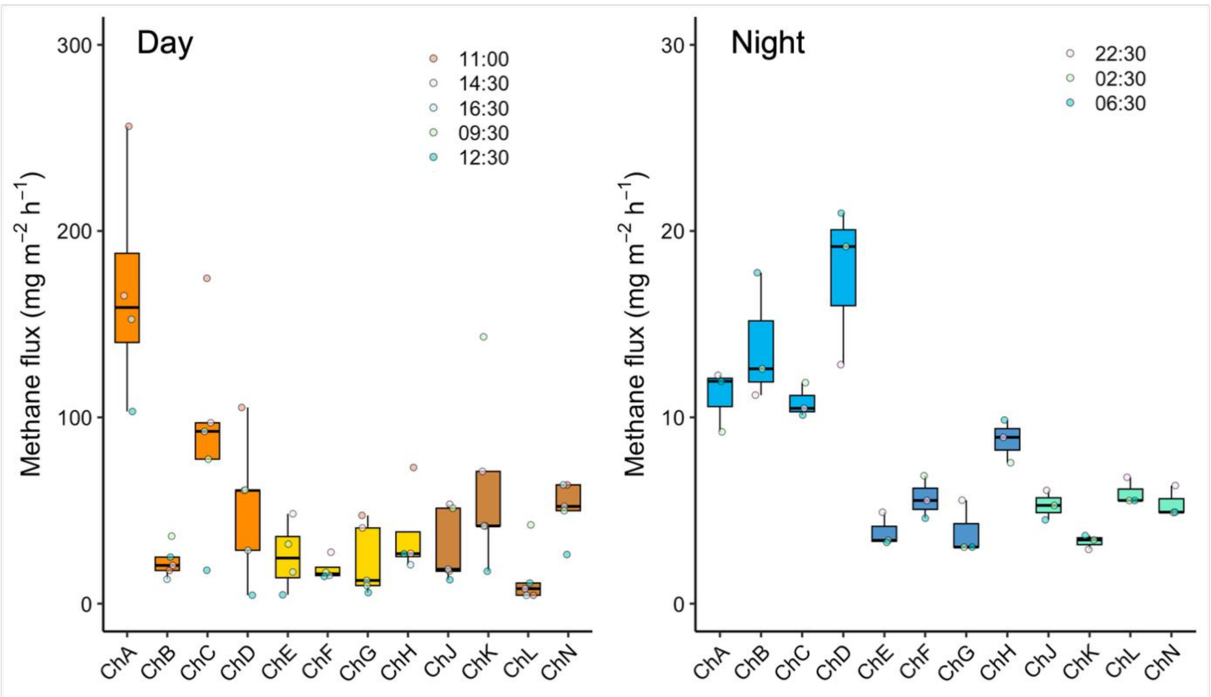

Figure: Spatial variability of methane fluxes in the sampled peatland in summer. Each box represents one chamber, which was measured at different times during the day or night. Boxes of the same colour indicate that those chambers were located within 1 m2, with 5 m distance between each group of 4 chambers.

Rapid Permafrost Thaw Carbon Trajectories (PeTCaT) – A new large international permafrost research endeavour

Guido Grosse[1], Katey Walter Anthony[2], Suzanne Tank[3], Christian Beer[4], Gustaf Hugelius[5], Moritz Langer[1,6], Duane Froese[3], Erika Hille[7], Christian Knoblauch[4], Steve Kokelj[8], Sebastian Laboor[1], Josefine Lenz[1], Tillmann Lübker[1], Dmitry Nicolsky[2], Jan Nitzbon[1], Ingmar Nitze[1], David Olefeldt[3], Mike Palmer[9], Vladimir E. Romanovsky[2], Friedrich Roeseler[1], Jens Strauss[1], Carolina Voigt[1,4]

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Arctic permafrost soils contain the largest terrestrial pool of organic carbon (C). Even partial mobilization of permafrost C may propel our current atmospheric greenhouse gas (GHG) concentrations into heights unknown in recent Earth history. Rapid thaw of ice-rich permafrost causes ground subsidence, thermokarst lake growth, talik formation, or thaw slumping. While the major effects of rapid permafrost thaw on heterotrophic respiration, methane release, and the potential for climate feedbacks have been recognized, they are not yet considered by Earth System Models (ESM). This creates large uncertainty in projections of C release from permafrost thaw and climate feedback estimates. Key challenges include (1) assessing permafrost thaw rates under diverse and changing environmental conditions on a panarctic scale; (2) analysing impacts of varied thaw processes on the heterogeneous permafrost C stock; and (3) integrating and scaling such dynamics using process models, and implementing these in ESM to project permafrost C trajectories and climate feedbacks.

PeTCaT, a new international research endeavour funded by Schmidt Sciences within their Virtual Institute of Carbon Cycle (VICC) program, will tackle these challenges with a team combining expertise on permafrost, soil C and GHG biogeochemistry, remote sensing, process modeling, and global climate modeling. In the 5-yr project we will address Rapid Thaw Processes, i.e., where, how fast, and how deep rapid thaw takes place and how atmospheric changes will influence these dynamics in the future, as well as what the distribution of ground ice is; the Reactivity of Rapidly Thawing Organic C, i.e., where, how much, and what type of organic matter is thawed, how fast it decomposes under which conditions, and what the consequences for GHG fluxes are; and the Emission Contribution and Global Consequences, i.e., whether the strength of the permafrost carbon-climate feedback is currently underestimated, causing an overestimation of the remaining C budget.

Our Work Packages include remote sensing and deep learning of rapid thaw features (WP1), ground temperature, talik formation, and thaw subsidence observations (WP2), and process-based modeling of rapid thaw processes and ground ice dynamics (WP3). We will carry out field observations (Alaska/Canada) and lab experiments for understanding the fate of permafrost C in terrestrial and aquatic systems under various rapid thaw settings (WP4). We will conduct novel panarctic mapping of C stocks and ground ice (WP5) and drive ESM advancements and applications (WP6). A coordination and data management work package (WP7) will lead the GTN-P database development and coordinated data.

Spatial soil temperature variability as a result of the snow depth distribution at Trail Valley Creek, NWT, Canada

Inge Grünberg[1], Ephraim Erkens[1], Jennika Hammar[1], Nick Rutter[2], Julia Boike[1,3]

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Snow is one of the most important drivers of permafrost temperature and changes in snow depth, snow cover timing, and snow properties can potentially amplify or mitigate permafrost thaw. While changes in snow cover spatial extent have already been observed at both local and global scales, snow depth and snow thermal properties are more difficult to observe. Furthermore, the effect of varying Arctic snow properties on soil temperature is still not well quantified. We study snow depth distribution and snow properties at Trail Valley Creek, NWT, Canada, a low Arctic site in the tundra-taiga transition zone. We derive end of season snow depth at 1m^2 resolution over 150km^2 using airborne laser scanning once per year in late March/early April in 2023, 2024, and 2025. This data is validated with extensive field surveys. The spatial snow distribution is combined with 3 years of air/snow, surface, and soil temperature data from 34 sensors distributed at 9 different vegetation types covering a range of topographical locations. Snow depth is strongly related with snow melt timing and with the spatial distribution of soil temperature, both for the specific time of the snow depth observation and for the whole winter and even the mean annual temperature. However, we observe interesting differences among the three years. While the relationship between spring snow depth and mean annual temperature is very strong in 2022/2023, it is much less pronounced in the 2023/2024 season, likely due to the exceptionally deep snow cover the latter season. While air temperature warming rates are well understood in most parts of the Arctic, changes in snow depth and snow properties are hard to quantify and less consistent in space. Further work is needed to quantify changes and to understand the manifold effects of snow on active layer and permafrost temperature. This is critical to understand the response of soil temperature and freeze/thaw state under future climate conditions.

ESA CCI Permafrost time series maps as Essential Climate Variable (ECV) products primarily derived from satellite measurement

Antonie Haas[1], Annett Bartsch[2], Birgit Heim[3], Andreas Walter[3], Mareike Wieczorek[3], Guido Grosse[3], Tazio Strozzi[4], Sebastian Westermann[5], Frank Martin Seifert[6], Sonja Hänzelmann[1]

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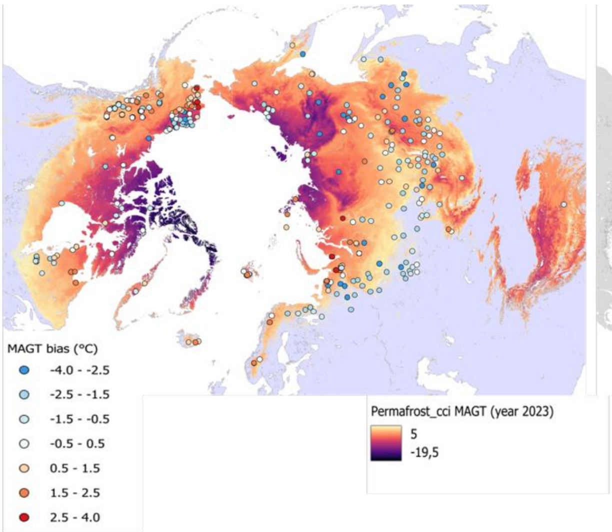
We present an update on the visualisation of permafrost-related map products within the framework of ESA DUE GlobPermafrost (2016–2018) and the follow-up programs ESA CCI+ Permafrost Phases I and II (2018–2021 and 2023–2026).

In ESA DUE GlobPermafrost, the project committee processed a comprehensive range of map products: These included N-South transects in the Northern Hemisphere with trends in Landsat multispectral indices, Arctic land cover, lake ice grounding, InSAR-based land surface deformation and rock glacier velocities. The main products were global permafrost essential climate variables (ECVs) from a spatially distributed permafrost model forced by land surface temperature and snow water equivalent. These ECVs include permafrost extent and probability (PEX), mean annual ground temperature (MAGT) and active layer thickness (ALT) per pixel.

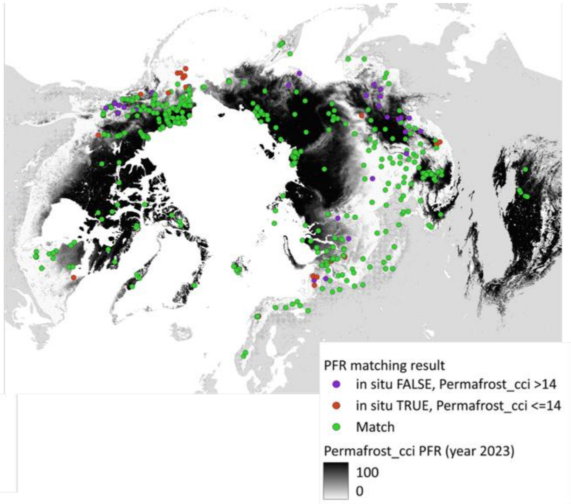
ESA CCI+ Permafrost extended the ECV products to time series spanning a period from 1997 to 2023, exceeding twenty years, comprising the CCI+ Permafrost circum-Arctic model output for MAGT, PEX and ALT from the surface down to a depth of 10 m. All data products are available at yearly resolution, as well as the calculated averages of MAGT, PEX and ALT over the time series.

To enhance the user interaction, we visualised all products in WebGIS projects using WebGIS technology within the O2A (Observation to Analyses and Archive) data workflow framework at AWI. This modular, scalable and highly automated Spatial Data Infrastructure (SDI) has been developed and operated at AWI for over a decade and has undergone continuous improvement, providing map services for GIS clients and portals. We implemented the FAIR principles to meet the growing demand for discoverable and accessible research data and metadata. The ESA Permafrost WebGIS products were designed using GIS software and published as a Web Map Service (WMS) in the internationally standardised Open Geospatial Consortium (OGC) format, using GIS server technology. Additionally, we have developed project-specific visualisations of raster and vector data products adapted to their specific spatial scales and resolutions.

Alongside the ESA CCI+ Permafrost data products, we incorporated the locations of WMO GCOS ground-monitoring networks belonging to the permafrost community. These networks are managed by the International Permafrost Association (IPA) and form part of the Global Terrestrial Network for Permafrost (GTN-P). We updated this feature layer on an ongoing basis. All data products have been registered with the Digital Object Identifier (DOI) system and archived in the PANGAEA or ESA CEDA data archives.



Permafrost_cci v4 Ground Temperature per Depth (GTD) median bias across all depths over mapped Permafrost_cci GTD 2023 (2 m depth) in the Northern hemisphere.



Permafrost_cci v4 Permafrost Fraction (PFR) match-up sites (color-coded point symbols grouped by matching characteristics with color-coded green points representing 'Match') over mapped Permafrost_cci PFR 2023 in the Northern hemisphere.

Spatial and Temporal Variability of Water Temperature, EC, and Isotopic Composition for Two Periglacial Catchments in the Upper Engadine

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The hydrology of alpine catchments is shaped by the variable contributions from diverse landforms, such as glaciers, rock glaciers, moraines, talus slopes, and meadows. These landforms influence both the water storage capacity and the timing and magnitude of water release. However, the internal hydrological processes of rock glaciers and other periglacial landforms, as well as their interactions with groundwater, remain poorly studied. Therefore, this study investigates the influence of different periglacial landforms on the hydrology of two neighbouring small alpine catchments in the Engadine region of Switzerland: Val Muragl and Val Champagna. The main objectives are to (1) characterize the physical and chemical water quality characteristics of water coming from the different periglacial landforms in the two catchments, (2) assess the diurnal and seasonal (between July and October) variations in the flow coming from these landforms, and (3) estimate the relative contribution of the different landforms to streamflow further downstream. To reach these objectives, we measured the water temperature, electrical conductivity (EC), and the abundance of the stable isotopes of hydrogen and oxygen for water coming from the different landforms, including two active rock glaciers and a moraine complex associated with the former Muragl glacier, as well as the main river, at a bi-weekly interval (25 sites). In addition, we continuously measured the temperature at seven sites, and the water level and EC at four sites.

The preliminary results show that the discharge from the rock glaciers and the end moraine was constantly cold, while the temperature of the water from the other sources in the catchment varied much more. This suggests that the end moraine still has an ice-core. The EC was higher for water coming from the rock glacier and the adjacent scree slopes than for the other sources, indicating older water and/or more intense water-rock interaction for water coming from these landforms. The EC increased over the summer and decreased after rainfall events, indicating dilution during rainfall events, but the diurnal patterns differed. For the end moraine, the EC was lowest when the discharge was highest, while for the two rock glaciers, the EC peaked simultaneously with the discharge.

These findings enable a clear differentiation of the water coming from the different landforms, especially the permafrost-related landforms, and highlight the role of periglacial landforms in controlling both the timing and chemical signature of downstream river discharge.

Extreme rainfall amplifies near-surface soil warming in discontinuous permafrost

Jennika Hammar[1], Simone Maria Stünzi[1,2], Inge Grünberg[1], Smit Doshi[1], Julia Boike[1,2]

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Extreme precipitation events are expected to increase in Arctic and subarctic regions, but their potential to alter near-surface soil thermal conditions in discontinuous permafrost remains poorly understood. Permafrost responses to increased rainfall vary across environmental settings and are shaped by complex local interactions. Controlled field experiments and numerical model analyses indicate that extreme rainfall during warm summer periods will have the strongest effect on soil temperatures and consequent permafrost thaw. However, spatially distributed observations are required to assess permafrost sensitivity to rainfall at a pan-Arctic scale. We investigated how extreme precipitation influences short-term warming of surface and subsurface temperatures in a discontinuous permafrost environment on Qeqertarsuaq (Disko Island), Kalaallit Nunaat (Greenland). We combined data from 46 stand-alone sensors that record temperatures at 15-minute intervals at three distinct depths (16 cm above the ground surface, directly at the surface, and 6 cm below it) and concurrent soil moisture measurements. The sensors were installed and running between September 2022 to September 2025 along three uphill-oriented transects and complemented with information on vegetation height, plant functional types, and organic layer thickness. We focused on two extreme rainfall events: one in September 2022, which delivered over 130 mm of precipitation within two days, and another in July 2023, driven by an atmospheric river that triggered hundreds of slush and debris flows, to identify the conditions that maximize soil warming. Our study improves understanding of seasonal, event-driven permafrost thaw and inform regional and pan-Arctic modeling of future rainfall impacts.

Svalbard Permafrost Landforms as Analogues for Mars (SPLAM): Scientific outcomes and outlook

Ernst Hauber[1], Harald Hiesinger[2], Nico Schmedemann[2], Andreas Johnsson[3], Michael Zanetti[4], Tilman Bucher[5], Cynthia Sassenroth[3], Michael Angelopoulos[6], Bernard Hallet[7]

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Fieldwork on terrestrial analogues is essential for understanding planetary landforms and their evolution, as the Earth is still our "reference" to understand geologic processes. The knowledge gained from fieldwork helps to establish multiple working hypotheses and test them.

The Arctic archipelago of Svalbard constitutes a unique terrestrial analogue environment for comparison to latitude-dependent cold climate landforms on Mars. Svalbard contains abundant and diverse (peri)glacial features in close proximity, allowing for an integrated landscape analysis approach.

The main questions driving our fieldwork on Svalbard are:

- Does the formation of cold-climate landforms on Mars require freeze-thaw processes and the presence of snow/ice & liquid water?
- What are the rates of cold-climate processes on Mars?
- How do analogous landforms on Mars respond to changing climates, which on Earth has some of its most dramatic consequences in the Arctic? What controls the recent environmental evolution of Mars?

Since 2008, we have been conducting Earth-analogue studies for Mars on Svalbard, including qualitative and quantitative studies of individual landforms, mapping efforts, and short- and long-term monitoring activities. We acquired high-resolution (cm-scale) aerial datasets of selected key regions on Svalbard in the years 2008, 2020, and 2024. Derived data sets include visual, near-infrared and thermal image mosaics as well as high-resolution DEMs. Their interpretations have been complemented by ground truth observations to characterize near-surface materials and conditions, and to produce detailed geomorphological maps. Fieldwork involves the acquisition of pole and kite imagery for structure-from-motion analysis, and measuring several weather and soil parameters during the active thawing season. Moreover, using the KNaCK ultra-high resolution mobile LiDAR scanning system, we are able to measure local topography with very high resolution, with repeatable control for change detection. All data are geodetically controlled, with dGPS precision of <2 cm.

Comparing LiDAR data from 2024 and 2025, we aim to identify cm-scale changes in patterned ground over timescales of days to years. We can compare these data with older data acquired since the 1980's to extend our monitoring timeline to decades during which environmental conditions have changed significantly and changes in microrelief and clast positions are sufficiently large to be clearly measured. Scarp retreat rates on debris flows over an ice-cored moraine are quantified over both day-to-day and decade-long timescales with unprecedented accuracy. We also closely cooperate with the Technical University of Munich (TUM) which uses Electrical Resistivity Tomography (ERT) measurements to characterize permafrost conditions in post-glacially uplifted deposits.

ESA CCI+ Permafrost - Validation using international and national permafrost monitoring networks

Birgit Heim[1], Mareike Wieczorek[1], Heidrun Matthes[1], Guido Grosse[1], Antonie Haas[2], Kirsten Elger[3], Sebastian Westermann[4], Cécile Pellet[5], Reynald Delaloye[5], Tazio Strozzi[6], Annett Bartsch[7], Frederieke Miesner[1], Anna Irrgang[1]

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Special emphasis in the ESA Climate Change Initiative (CCI) program is placed on validation of the CCI Essential Climate Variable (ECV) products using in situ data from international and national monitoring networks in cooperation with the involved communities. Permafrost_cci produces ECV time series from 1997 to 2023 of yearly circum-Arctic permafrost maps on mean annual ground temperature at different depths down to 10 m, Active Layer Thickness and Permafrost Probability. We describe the data compilation and standardisation effort deriving the validation data set for Permafrost_cci MAGT products.

We compiled a circum-Arctic collection on ground temperature temporal records from the main communities' (permafrost, meteorology) pre-existing in situ ground temperature records. We assembled ground temperature within a wide range of depths from shallow measurements down to 20 m depth mainly from the Global Terrestrial Network for Permafrost (GTN-P) managed by the International Permafrost Association (IPA) and also from associated communities. They do not represent easy-to use time-series depth data suitable for validation. We optimised the ground temperature data collections by error-checking, and depth and metadata standardization.

This newly compiled, harmonised data collection of ground temperature depth-time series from 1997 to 2023 is published in the PANGAEA data repository providing the first consistent circum-Arctic data collection with standardized measurement depths. It covers all permafrost zones of the Northern hemisphere. Especially the shallow ground temperature time series represent a very interesting validation and parametrization dataset for climate and land surface models.

Future Methane Dynamics of Arctic Coastal Lakes Upon Oceanic Intrusion

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About one-third of the world's coastline is classified as permafrost coastline. As this permafrost thaws, it can form thermokarst landscapes, where previously stored organic matter becomes available for microbial degradation. With rising sea levels, coastal thermokarst landscapes may be inundated by seawater, causing lakes to gradually transform into marine-influenced lagoons (Jenrich et al., 2025a). Depending on the connectivity of the lagoon to the open sea, (sedimentary) methanogenic communities are exposed to high concentrations of ions, especially sulfate, which promotes the establishment of competitive anaerobic methanotrophic archaea and sulfate-reducing bacteria consortia and thus leads to shifts in the composition and activity of the microbial community (e.g., Yang et al., 2023; Jenrich et al., 2025b). While previous research has focused on surface sediments from lagoon systems and on surface soil samples from the intertidal zone, vertical sediment profile incubations have not yet been examined.

The aim of this study is to get a deeper understanding of the effects of oceanic inundation on the microbial community and the associated carbon dynamics of erosion-affected coastal environments in the Canadian Arctic. We used subsamples of sediment cores from lakes, coastal ocean, and soils from an intertidal zone from the Tuktoyaktuk area (NWT, Canada). We realized anoxic long-term incubation experiments under in situ and marine conditions to simulate saltwater intrusion. Corresponding methane and carbon dioxide productions were monitored by monthly measurements. In addition, sedimentary pore water and bulk organic matter characteristics were analysed to examine potential relationships between biogeochemical parameters and greenhouse gas production. Additionally, we investigate potential shifts in the microbial community during the incubation by 16S rRNA sequencing. Preliminary results of the first months of incubation indicate that more distanced freshwater lakes showed higher initial methane concentrations and production rates, whereas negligible amounts and rates were found for marine-influenced coastal water bodies. This pattern suggests a significant shift in the methane dynamics of coastal lakes under increasing marine influence and will further constrain the effects of anthropogenic pressure on the carbon source-sink dynamics of Arctic coastlines.

Investigation of palsa mires in northern Norway with electrical resistivity tomography

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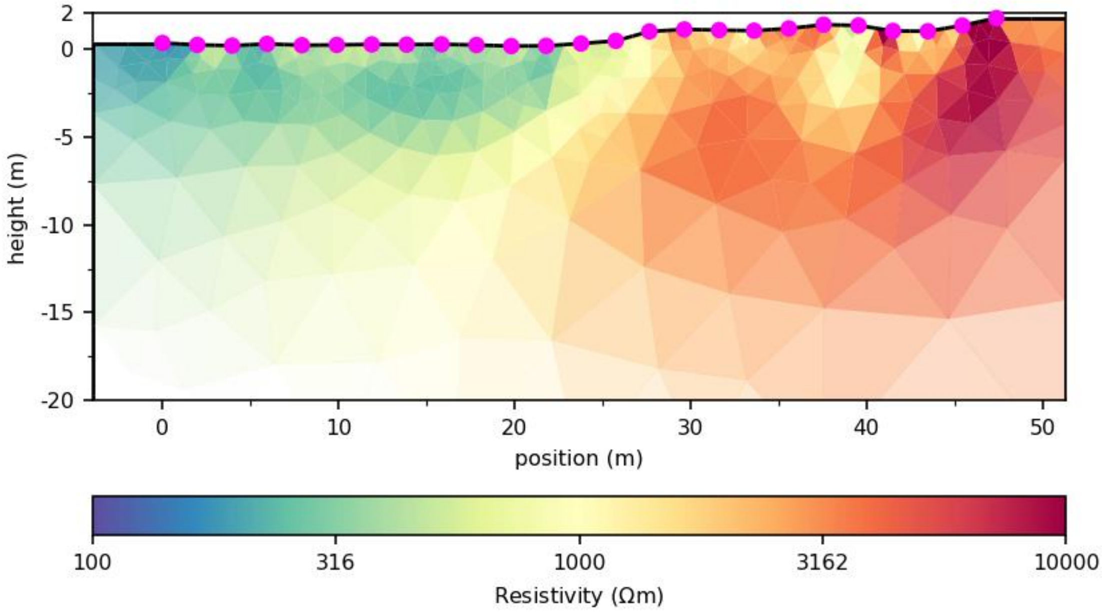
In northern Norway, palsa mires shape the landscape. Palsas are hillocks up to 1.5m high covering an area of up to one square kilometre and rising from the otherwise flat mire. They have a permanently frozen core of peat or silt along with small ice crystals or lenses. In summer a dry upper layer of peat prevents the frozen core from thawing. However, in autumn the moist upper layer of peat allows cold air to penetrate the hillock. Therefore, palsas are characteristics of permafrost regions. Because of their sensitive reaction to environmental changes, they are of great interest in studying the effect of climate change in permafrost regions.

The aim of this study is to demonstrate that hillocks in a palsa mire near Áidejávri (Norway) are frozen, in contrast to the ground under the depressions between them. Another goal is to show that the inversion of electrical resistivity tomography (ERT) data is robust to parameter variations and different error models.

During a measurement campaign in May 2025 eleven profiles covering a total area of approximately 1000m^2 of palsa mire were examined using ERT. The profiles run parallel 2m apart from southwest to northeast and are each 48m long. The Wenner configuration was chosen as the measurement setup. A two-dimensional inversion method is used in the evaluation to calculate a spatial distribution of the electrical resistivity from the measured data.

The inversion results show that topographically elevated areas exhibit higher electrical resistivity than topographically lower areas. Since ice has a higher electrical resistivity than water, the elevated resistivity of the hillocks likely indicates that they contain frozen cores as characteristics of palsas. The Figure below illustrates this relationship exhibiting the first of the eleven measured profiles as an example. Modifying the smoothing parameter used in the inversion does not fundamentally change the spatial resistivity distribution but merely results in different error values for the inversion result. The same applies to the assumption of different error models and errors of varying magnitudes.

The ERT results are consistent with field observations based on the topography and are robust against changes in the inversion settings. ERT is a reliable and efficient method for investigating palsa mires in permafrost regions.


2
0
-5
-10
-15
-20
height (m)
0
10
20
30
40
50
position (m)
100
316
1000
3162
10000
Resistivity (Ωm)

Sedimentological and biogeochemical analysis of sediment cores from the world's largest thermokarst lake: Teshekpuk Lake, Alaska

Maximilian Simon Hipp[1], Maren Jenrich[2], Benjamin Jones[3], Guido Grosse[2], Jens Strauss[2]

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Teshekpuk Lake stands out on the Alaskan North Slope as the largest thermokarst lake in the world. To our knowledge, no comprehensive sediment core datasets directly from the lake have been published to date, unlike to most of the neighbouring smaller lakes. During a pilot study, one sediment core taken on an expedition in 2022 on the northern coast of Teshekpuk Lake, was analysed for basic sedimentological and geochemical parameters, including magnetic susceptibility, total (organic) carbon, nitrogen and mercury.

Further analysis for grain size, $\delta^{13}C$ and dating is in progress, as well as an expansion of the study area to one neighbouring lake (Peatball lake).

First results of the Teshekpuk Lake core showed a thick sandy sediment layer with very low total organic carbon (TOC), total nitrogen (TN) and total mercury (THg) contents. The typical peat layer lies further down in contrast to most other local thermokarst lakes. This opens a discussion about the origin of these sandy sediments to which there are multiple theories.

On mapping Permafrost Landscapes at Pan-Arctic Scale: Datasets, Challenges, and Deep Learning Approaches

Tobias Holzer[1], Ingmar Nitze[1]

[1]*Alfred Wegener Institute, Potsdam (tobias.hoelzer@awi.de)*

We will discuss the challenges and approaches for mapping permafrost landscapes across the pan-arctic region. We will present an overview of available datasets and the problems that arise when scaling a method to cover such a vast area. Furthermore, we will introduce different deep learning strategies used to create accurate permafrost maps at a pan-arctic scale. Attendees will gain insights into the latest advancements in permafrost mapping and the potential applications of these methods for environmental monitoring and climate change research.

Soil Moisture Variability in the Antarctic Peninsula Region

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Soil moisture is one of the key parameters affecting the thermal regime, freeze–thaw dynamics, and thermal properties of the ground. In permafrost-affected regions, shifts in soil moisture can be particularly important. In high polar environments such as Antarctica, water availability during summer is also essential for vegetation abundance and overall state of the environment. Yet, research on soil moisture in Antarctica remains scarce and is limited to only a few areas. The aim of this contribution is to present the soil moisture monitoring network established in the Antarctic Peninsula region and to discuss the use of its results for further research activities.

The monitoring network was initiated in 2017 on James Ross Island. Since then, installations have been expanded to six areas of the Antarctic Peninsula, comprising 19 profiles in total. Most installations (12) are located on bare ground in close proximity to long-term measurements of active layer thickness and permafrost, or at sites equipped with autonomous electrical resistivity tomography systems (A-ERT). The sites are instrumented with CS655 TDR probes (Campbell Scientific) and SMT100 probes (Truebner). Typically, 3–4 sensors are installed in each profile: one in the surficial layer, one to two in the middle part, and one near the base of the active layer. At several sites, seasonal mapping of surficial soil moisture is also carried out to assess the influence of lithology or vegetation patches.

Initial data from the network reveal clear differences in soil moisture patterns between the relatively arid James Ross Island (JRI) and sites within the oceanic climate zone of the South Shetland Islands (SSI). On JRI, the seasonal regime during summer is relatively stable, with a distinct peak associated with snowmelt during early thaw. On the SSI, soil moisture is affected by snowmelt at the beginning of summer and typically exhibits several additional peaks likely related to rainfall or secondary snowmelt events. Furthermore, analysis of freeze-thaw curves highlights differences among soil types across the Antarctic Peninsula. In some cases, such as fine-grained soils or soils close to the coastline, we observed a depression of the freezing point and changes in the temperature corresponding to residual water content. These observations may be particularly valuable for studies of active layer thaw depth and its relationship to the ground thermal regime.

Tracking a Thawing World: The Global Terrestrial's Network for Permafrost new Data Platform is now online

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Permafrost covers nearly one quarter of the Northern Hemisphere's land surface, storing vast amounts of carbon. As the climate warms, permafrost temperatures are rising globally, destabilizing landscapes and infrastructure and releasing greenhouse gases such as methane and carbon dioxide. Long-term observations are essential to understand permafrost responses to warming and to estimate its future role in global carbon emissions. The Global Terrestrial Network for Permafrost (GTN-P) is the main international program for sustained permafrost monitoring. Researchers from over 30 countries collect permafrost temperature (PT) and active layer thickness (ALT) data, shared through the GTN-P platform. The original system, launched in 2015, has become outdated, prompting the development of a modernized database. Developed at the Alfred Wegener Institute's Permafrost Research Section under the GTN-P Steering Committee and within the Arctic PASSION Horizon2020 project, the new GTN-P data platform is going to be the central platform for sharing and accessing permafrost data. It supports the Permafrost ECV products PT and ALT and will soon include Rock Glacier Velocity.

The new GTN-P platform features an intuitive interface, flexible data downloads, and time-series visualization tools. An annual global data compilation includes co-authorship for contributors, and additional synthesized products will be provided. Collaboration with the WMO ensures adherence to international data standards, enhancing interoperability and compliance with FAIR Data Principles. For data providers, the streamlined upload process includes automated quality checks with real-time feedback. Supported by AWI's IT infrastructure, the new GTN-P platform strengthens accessibility, reliability, and sustainability for the global permafrost research community.

Mackenzie River Water Biogeochemistry at Inuvik, NWT Canada

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The Mackenzie Monitoring-Program at Inuvik investigates the influence of climate-driven environmental changes, particularly permafrost thaw, on the biogeochemistry of one of the Arctic's largest river systems. Conducted in collaboration with the Western Arctic Research Center (WARC) in Inuvik, this program established high-frequency and long-term river sampling at the East Channel of the Mackenzie River. The sampling began in May 2023 and continues as a multi-year effort to capture short-term variability and long-term trends in carbon and nutrient dynamics under changing hydrological and climatic regimes.

The main objective of the Mackenzie Monitoring Program is to directly observe seasonal and event-driven variations in biogeochemistry by taking frequent measurements. Year-round weekly to bi-weekly sampling covers all major hydrological phases of the river (winter under-ice flow, spring break-up, summer discharge, and autumn freeze-up). These high-frequency observations and derived biogeochemical fluxes from the Mackenzie watershed to the Arctic Ocean may help to identify shifts in watershed processes linked to permafrost degradation, hydrological reorganization, and climate-induced mobilization of terrestrial carbon.

Year-round, fieldwork is conducted by WARC personnel with support by AWI researchers during at least yearly visits. Water samples along-side measurements of temperature and electrical conductivity are collected either from shore or through ice-holes, depending on the season, and analysed for bulk dissolved and particulate organic carbon concentrations, chromophoric dissolved organic matter (CDOM), carbon isotopes ($\delta^{13}C$), suspended sediment loads, dissolved nutrients, stable oxygen isotopes and elemental concentrations. Opportunistic discharge measurements using a SonTek RiverSurveyor M9 Acoustic Doppler Current Profiler (ADCP) are carried out at the sampling location. The sampling and processing protocol was designed for non-specialists, ensuring long-term data continuity and accessibility through remote collaboration with local partners.

Since May 2023, around 100 samples have been collected (approximately 30 per year), and the corresponding parameters have already been analysed.

All processed data are made publicly available through the project's interactive data dashboard (https://mackenzie-monitoring.awi.de/), promoting open science and transparent environmental monitoring.

The expanding high-resolution dataset enables assessments of change in this northern river system and its role in Arctic carbon-climate feedbacks. In addition, these observations connect watershed processes to coastal variability, offering a vital baseline for predicting permafrost-driven and hydrological impacts on river biogeochemistry and cascading downstream impacts.

Mobilization and methylation: coastal erosion sets mercury in motion along the Yukon coast, Canada

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Permafrost thaw and coastal erosion are key drivers of mercury (Hg) release from Arctic coastal regions. This mobilization eventually poses risks to marine ecosystems, as Hg can be transformed into methylmercury (MeHg), a potent and bioaccumulating neurotoxin. Understanding the Hg dynamics in coastal zones is essential to assess their role in the pan-Arctic Hg cycle under the One Health approach. In this study, we quantified terrestrial Hg stocks of the Yukon coast in northwestern Canada, estimated the annual Hg release through coastal erosion, and investigated the fate of Hg in the marine environment of the Beaufort Sea.

We measured total Hg and MeHg concentrations in terrestrial and marine sediment samples and filled data gaps using a random forest model. We quantified Hg stocks and fluxes by considering cliff height, ground ice content and regional erosion rates. The total Hg stock of the Yukon coast (approximately 300 km long, extending 2 km inland) is estimated at 381,080 (271,540–501,930) kg, of which 113 (87–163) kg are released annually through coastal erosion. MeHg concentrations, measured here for the first time, were higher in terrestrial sediments (0.29 ± 0.25 µg kg^{-1}) compared to marine sediments (0.21 ± 0.08 µg kg^{-1}). The same pattern was observed for Hg concentrations in the nearshore zone (up to 2000 m distance from shore). This suggests that some Hg released from coastal erosion is not directly buried in marine sediments but remains in the water column, probably settling in sediments beyond the shelf break of the Beaufort Sea, where higher Hg concentrations have been observed before. Other pathways include exchange with the atmosphere, transformations within the water column (including methylation), and uptake of MeHg by phytoplankton, thereby entering the food web.

Our results indicate no immediate risks to local communities or ecosystems. However, as permafrost thaw and coastal erosion intensify with ongoing Arctic warming, monitoring of fish and marine mammals might become increasingly important to detect potential long-term bioaccumulation and ecosystem impacts.

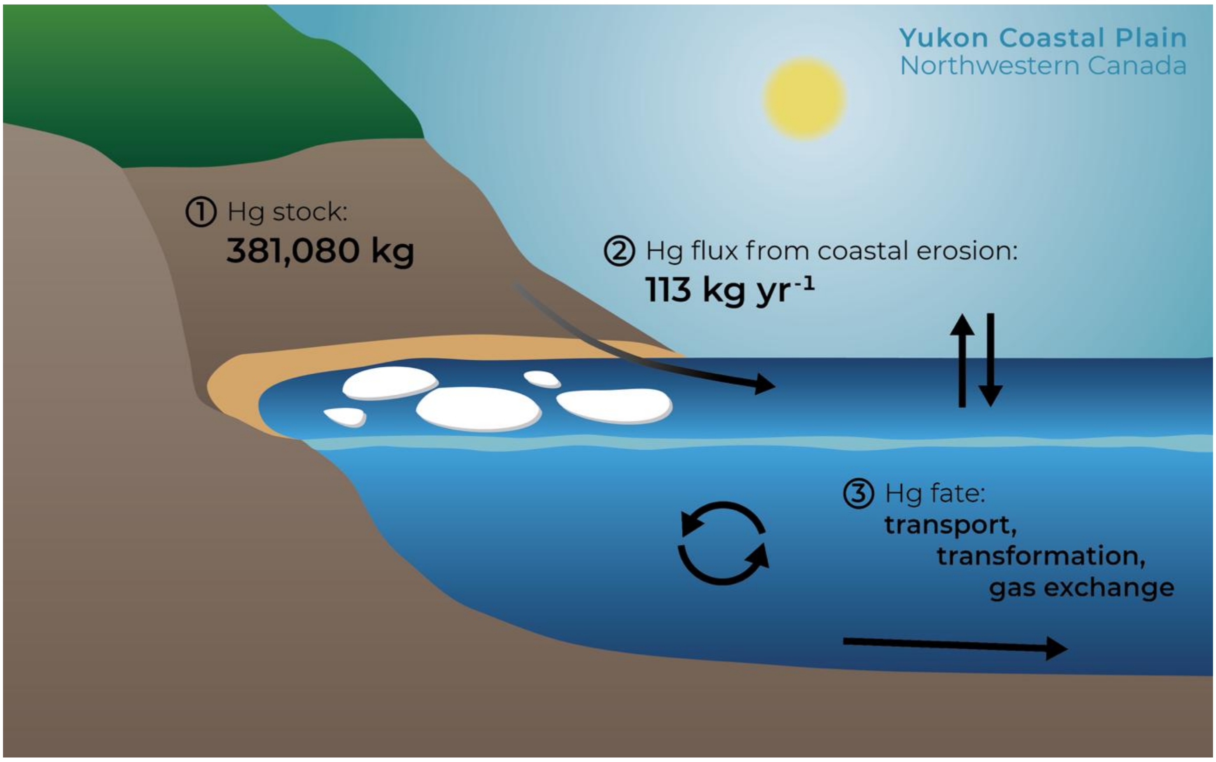

Figure: Illustration of mercury stocks and fluxes from coastal erosion at the Yukon coast, Canada, and the potential pathways of mercury in the marine environment.

Arctic greenhouse gas sinks: exploring coldspots of methane in the permafrost domain

Maren Jenrich[1], Christian Beer[2], Bo Elberling[3], Christian Knoblauch[2], Susanne Liebner[4], Friederike Neiske[1,2], Aimée Pellisier-Tanon[1,2], Henri Siljanen[5], Oliver Sonnentag[6], Anna-Maria Virkkala[7], Carolina Voigt[1,2]

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The Arctic, known for its vast carbon and nitrogen reservoirs, is warming faster than the global average and is a significant source of greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O). However, research has disproportionately focused on high-emission “hotspot” areas, overlooking the potential for arctic soils to act as net sinks for these gases. Such “coldspots” may partially offset emissions and could alter prevailing assumptions, with impacts on arctic greenhouse gas budgets and model estimates of arctic climate feedbacks.

The ERC-funded COLDSPOT project addresses this gap by investigating when, where, and why Arctic soils take up CH_4 and N_2O by aiming at identifying the biogeochemical and microbial mechanisms driving this uptake in arctic plant-soil systems. We apply a multi-scale approach, combining high-resolution, laser-based measurements at field sites in Canada, Greenland, and Finland with machine learning and experimental manipulations. At two key sites in Canada and Finland, automated chamber systems continuously record greenhouse gas fluxes from contrasting upland tundra ecosystems, established CH_4 sinks, during the growing season. These measurements will be combined with manual, campaign-based measurements to cover a larger spatial variability of CH_4 and also N_2O uptake, and extensive laboratory studies such as soil incubation experiments.

In summer 2025, initial field campaigns were conducted in Finland and Canada focusing on greenhouse gas flux measurements, as well as on soil and pore water sampling for biogeochemical and microbial investigations, and data processing is underway. Preliminary results from manual greenhouse gas flux measurements (CO_2, CH_4) across upland tundra, permafrost peatland, and forest sites will be presented, together with data on in situ soil nutrient dynamics. These early findings will provide insight into the temporal and spatial variability of greenhouse gas fluxes, and particularly greenhouse gas uptake, during peak biological activity.

From Permafrost to Plume: Tracing Organic Carbon Across the Arctic Land–Ocean Continuum by Satellite Remote Sensing

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Rapid Arctic warming and widespread permafrost thaw are mobilizing large pools of terrestrial organic carbon (OC) into rivers, deltas, and coastal seas. These fluxes are critical for Arctic coastal ecosystems, influencing water quality, light conditions, and biogeochemical cycling, with consequences for biodiversity and food security. They also affect carbon budgets by determining whether terrestrial carbon is buried, respired, or released back to the atmosphere. Yet major uncertainties remain due to the remoteness, harsh conditions, and logistical challenges that limit observations across Arctic land-ocean transition zones. This lack of large-scale, continuous monitoring limits our ability to quantify how mobilized terrestrial material moves, transforms, and influences coastal ecosystems.

Satellite remote sensing offers a powerful means to overcome these gaps by providing synoptic, repeatable coverage across riverine, coastal, and offshore compartments. Drawing on recent multi-platform field campaigns in the Mackenzie Delta-Beaufort Sea region and high-frequency river monitoring, our results show how Sentinel-2 and Sentinel-3 observations extend and strengthen traditional in situ sampling. We evaluated satellite atmospheric-correction approaches, developed robust bio-optical relationships from in situ data, which are then used to calibrate constituent-retrieval algorithms across a range of water types. Our results show that satellites can reliably resolve spatial and temporal variability in OC and suspended sediment and capture transport dynamics along the entire Mackenzie River and catchment-scale drainage network, through its delta and distributary channels, and into nearshore and offshore shelf waters.

These observations uncover seasonal and interannual patterns in terrestrial carbon transport and transformation, offering a more complete view of how mobilized terrestrial material moves from land to sea, beyond what field measurements alone can resolve. Satellite-based monitoring thus delivers the synoptic perspective needed to link riverine carbon fluxes with coastal ecosystem responses, advancing scientific understanding and supporting adaptation strategies for Arctic communities facing rapid environmental change.

Integrating numerical and empirical modelling to assess near-surface permafrost in the 21st century at 1-km spatial resolution

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The need for accurate information on the current and future permafrost conditions is essential for better predictions of permafrost thaw related processes and the release of greenhouse gases from thawing soils. Permafrost simulations and modelling studies show substantial variation both in current and future conditions regardless of the technique used. Numerical solutions provide physically based estimates of permafrost properties and their change. However, they are limited to coarse spatial resolutions owing to strict data requirements (i.e., physical parameterization of soil, vegetation and snow layers). Empirically based models can be applied with high spatial resolutions but are limited in addressing the transient effects involved in the heat transfer in surface and soil layers.

We apply a hybrid modelling approach with the aim of combining numerical and empirical model (random forest) outputs and algorithms to produce improved predictions of near-surface permafrost temperature and active-layer thickness (ALT) in the Northern Hemisphere during the 21st century. We further rigorously evaluate the modelling with distance-constrained cross validation and area-of-applicability analysis to quantify the spatial applicability of the models and the limitations posed by relatively sparse monitoring network in permafrost regions.

Compared to ‘traditional’ machine learning modelling, a lowered reduction in permafrost extent and ALT increase by mid- and late-century was predicted when process-based estimates were considered. The hybrid modelling yielded improved evaluation metrics compared to similar circumpolar modelling efforts. Moreover, owing to machine learning-based downscaling of process-based data we were able to retain a relatively high 1-km spatial resolution of ALT predictions in the current and future conditions.

The hybrid modelling results suggest that incorporating process-based model outputs can help address the transient effects in near-surface permafrost degradation. The transferability of the permafrost temperature–ALT relationship in time is a key issue when assessing model performance and is affected by the environmental coverage of the model training data and the thematic quality of geospatial data. This study highlights the possibilities and uncertainties related to producing theoretically-sound permafrost predictions in high resolution.

A treasury squirreled away till now: Diet and habitat of Pleistocene Arctic ground squirrels revealed by plant remains gathered in their nest

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Duvanny Yar is type locality for the Late Pleistocene Ice Complex in Western Beringia and known for spectacular finds of remains of now-extinct large mammals as well as for the revitalization of ancient plant material preserved in Pleistocene arctic ground squirrel nests. During fieldwork in 2015, such a fossil nest was recovered, containing large numbers of extremely well-preserved seeds and fruits gathered presumably by an Arctic ground squirrel (Urocitellus parryi) according to size and shape of recovered droppings. AMS radiocarbon dating of Carex myosuroides fruits from the nest resulted in an infinite age of >49.000 years BP, which together with stratigraphical context, places the find into the early or middle Weichselian cold stage (MIS 3 or 4). The aim of the presentation is to shed light on the dietary preferences of Pleistocene Arctic ground squirrels and to draw conclusions about the vegetation and palaeoecological conditions existing in Western Beringia during the ground squirrels' lifetime. The plant material was dried in the field and then dry-sieved in the lab using standard test sieves with mesh sizes between 2 and 0.25mm, screened with an Olympus SZX 16 stereomicroscope and hand-picked for macrofossil identification. Differing from the standard protocol, wet-sieving was not necessary as the studied material consisted nearly exclusively of well-preserved seeds and fruits almost without proportions of mineral material. Altogether 24 plant taxa could be identified mainly comprising species with large or putatively nutritious seeds and fruits such as grasses (Festuca, Poa, Puccinellia), sedges (Carex myosuroides), legumes (Hedysarum hedysaroides) and other forbs like Eritrichium, Cerastium maximum, Silene samojedorum, Potentilla arenosa, and Polemonium boreale. All detected plant species are characteristic of Arctic grassland vegetation and mainly occur in tundra-steppes (Kobresietea communities), which are restricted in modern tundra to open, dry and exposed extrazonal sites like pingos or rocky elevations. Neither such habitats nor tundra steppes nor Arctic ground squirrels themselves can be found locally at Duvanny Yar today. Their Late Pleistocene occurrence is therefore an indication for distinctly drier than today, more continental climate conditions.

Moisture as a moderator: How water content controls thermal dynamics in Antarctic permafrost soils

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Thermal properties of permafrost-affected soils largely dictate their response to ongoing climate warming, affecting the rate of acceleration of active layer thickening and either the amplification or inhibition of permafrost degradation. Thermal properties of soils vary in close connection with a number of parameters, of which the one frequently cited as most prominent is soil moisture. While future projections point toward an increase in precipitation rates overall, long-term drying of the surficial level of soil is also predicted due to increased infiltration of moisture into deeper soil layers; a trend we have confirmed at one of our sites in James Ross Island.

In the first step of this study, we have conducted a laboratory experiment on four different samples of soils from James Ross Island, Antarctica, with varying texture and lithological origin, encompassing Cretaceous marine sediments, glacigenic deposits, and volcanic rocks. The experiment was carried out using a thermal properties analyser (ISOMET 2114), measuring soil thermal conductivity and volumetric heat capacity across a range of soil moisture from totally dry soil up to full water saturation. The results of this experiment closely correspond with the published theoretical curves, showing low thermal conductivity in very dry soil, which progressively increases as water is introduced, with the most rapid increase situated within a relatively narrow window that is unique to each soil. This indicates that there is a threshold below or above which the wetting or drying of climate can have a dramatic impact on thermal properties. In the subsequent step, we employ the widely used Stefan model to calculate active layer thickness for differing amounts of thawing degree days and soil moisture levels, to predict the evolution of ALT under various climate scenarios; and overlay these predictions with our instrumental data.

The results suggest that while atmospheric warming leads to a thicker active layer in general, the effect is less pronounced with higher moisture levels within the soil. Enhanced permafrost degradation might thus be expected in areas experiencing atmospheric drying. This underlines the role of soil moisture as a significant moderator of the climate change effect on the active layer. These changes will also very likely negatively influence the well-being of the local biota.

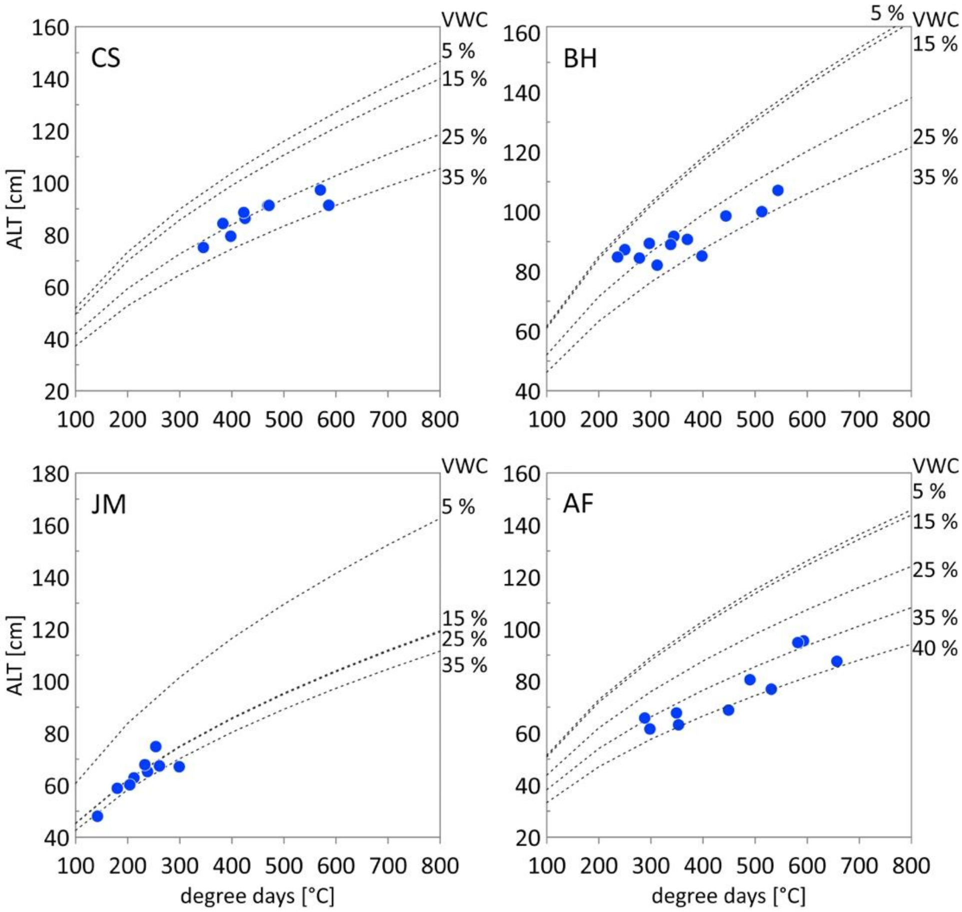

Figure: Active layer thickness (ALT) predicted by the Stefan model for the different soil moisture/thermal conductivity scenarios; blue dots represent instrumental data.

Thawing permafrost stabilises organic carbon from recent plant litter inputs

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One of the deep uncertainties in climate change research is the response of greenhouse gas fluxes from the circum-Arctic tundra to rapidly rising temperatures. Numerous studies have substantially increased our understanding of the production of greenhouse gases from thawing permafrost. However, we do not know how fast fresh organic matter (OM) from decaying plant litter — which is increasing in warming permafrost landscapes — may be stabilised in thawing permafrost, nor to what extent this may occur.

To investigate this process, we incubated permafrost samples from two Siberian islands for nine years, using 13C-labelled plant litter under both oxic and anoxic conditions. In this experiment, we quantified the formation of CO_2 and CH_4 from two carbon sources: permafrost organic carbon (permafrost-C) and litter carbon (litter-C). We used these data to calibrate a two-pool carbon decomposition model to determine the mean residence times (MRTs) of the labile and stable carbon pools of permafrost-C and litter-C. At the end of the incubation period, we fractionated the remaining OM into dissolved, particulate, and mineral-associated permafrost-C and litter-C.

Approximately half of the added litter-C was mineralised to CO_2 and CH_4 after nine years. Most of the permafrost-C and litter-C were bound to the mineral fraction. However, the final mineralisation rates of litter-C were 10-fold higher than those of permafrost-C, indicating that the mineral-associated carbon fraction contains OM of different decomposability. The median MRT of the stable litter-C pool was 18 years (oxic) and 52 years (anoxic), indicating substantial stabilisation of litter-C in thawing permafrost. Nevertheless, the MRT of the stable permafrost-C pool was an order of magnitude higher, demonstrating that permafrost OM is dominated by relatively stable OM.

Our data shows that carbon from fresh plant litter is preferentially bound to pre-existing organic matter on the mineral fraction, and that this carbon remains relatively decomposable. Furthermore, we found no evidence that particulate OM is more labile than mineral-associated OM, or that particulate OM can be used as a proxy for a more decomposable carbon pool in thawing permafrost.

Understanding the mechanical destabilization of large permafrost rock slope failures using data, samples and models from the Bliggspitze 2007, Fluchthorn 2023 and Kleines Nesthorn/Blatten 2025 failures

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Warming in the last two decades has caused massive rockfall activity with limited mobility in the range of 101^{-6} m^3. However, only a few highly destructive and mobile rock avalanches above 1 Mio. m^3 have been documented. Rock-ice mechanical models explaining high-magnitude rock slope failure in permafrost have been postulated but not validated on real failures.

This study combines complementary expert knowledge to decipher the 1 Mio. m^3 Fluchthorn rock slope failure that detached on June 12, 2023, from the before 3399 m high summit causing a rock avalanche that additionally eroded ca. 120.000 m^3 of ice. InSAR data shows deformation rates in the range 4.1 – 7.1 ± 0.13 cm/a from April 2021 to March 2023. Mountain guides have observed singular failures before the event. IR drone flights immediately after the event indicate rock temperatures at the failure planes in the range of 0 to -2°C and ice-filled fractures. Solid, scarcely fractured pseudotachilitic sequences in the summit regions may have contributed to the massive oversteepening of the Fluchthorn Westface without significant pre-failures. In a seismic analysis we can for the first time exactly reconstruct the temporal and spatial trajectory of a rock-ice avalanche, velocities and energy release during the 120-second rock-ice-avalanche propagation consistent with fragmentation and deposits. High-resolution photogrammetry highlights massive ice erosion and accumulation patterns during the rock avalanche propagation. In addition, we analyse all precursors in the last two years before the failure in detail in UltraCam & LiDAR surveys.

In an IRAZU model, capable of nucleation and growth of fractures based on nonlinear fracture mechanics applied stresses produce progressive fracturing that closely resembles the real failure. In a discontinuum model (UDEC), we can show the stabilizing effect of permafrost on developing fracturing patterns in a combined rock-ice mechanical approach.

We currently start to analyse rock samples from the Kleines Nesthorn and compare them to similar lithologies we have tested before. We find similarities in the geological and tectonic preconditioning and warming history to the Fluchthorn and also discuss similarities with the glacier-permafrost interaction observed during the Bliggspitze 2007 failure (Pfluger et al. 2025).

In summary, we show a unique combination of datasets deciphering pre-failure tectonic and geological controls and forcing, syn-failure permafrost-related mechanics, and second-resolution data on rock-ice avalanche evolution in a cryospheric settings with massive ice uptake for the Fluchthorn and compare them to analogue data sets/samples/models from the Bliggspitze and the Kleines Nesthorn.

Deep Learning Supported Permafrost Disturbance Segmentation from Satellite Imagery - Challenges and Outlook

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The impact of rapid permafrost disturbances on the Earth system is still uncertain. Consequently, the production of reliable, long-term observational data of disturbance dynamics are an important research focus to better quantify and understand the interconnections and feedbacks between permafrost and other ecosystem components. Specifically, Retrogressive Thaw Slumps (RTS), a major mass-wasting phenomenon and a rapid disturbance in ground-ice rich permafrost landscapes, erode large volumes of formerly frozen ground, leading to substantial sediment, carbon, and nutrient mobilization. Once initiated, they can grow and develop into broader erosion disturbances. Over time they may exhibit polycyclic behaviour of initialization, growth, stabilization, and re-activation. The spatial distribution and temporal dynamics of RTS are generally poorly quantified so far on a pan-arctic scale with the exception of regions that have been the focus of more intensive research.

Multiple methods and data are used to map permafrost disturbances like RTS on local to regional scales, including in-situ mapping. However, due to the remoteness and reduced accessibility, earth observation data serves as the primary source of large RTS inventories. While RTS mapping is also done manually utilizing expert knowledge from high-resolution remote sensing imagery, machine learning and AI techniques are increasingly used to segment permafrost features from satellite images. Recent advances in deep learning based inference methods make feature segmentation with modern data science techniques now much more feasible and efficient, opening the opportunity to evaluate different architectures and source data to create large pan-arctic inventories.

Our current work aims at detecting RTS on a pan-arctic scale using a multi-sensor and multi-resolution approach with data originating from different satellite platforms. This includes multispectral imagery from European Space Agency's Sentinel-2 platform or downstream data products like digital elevation models (DEM, for example ArcticDEM), as well as cutting datasets like foundation model embeddings. We present our recent work and result datasets. We will also give an outlook on the identified knowledge gaps and planned work over the forthcoming months and years, including the development of downstream tasks like data dissemination, the engagement with the permafrost and

modelling community, as well as a vision for enhancing and refining our methods and products.

An investigation of organic carbon reactivity in subsea permafrost

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Subsea permafrost (SSPF) extends under ~2.5 million km^2 of the Arctic Shelf and stores and estimated >2800 Pg organic carbon. Under climate change, Arctic Ocean bottom waters are expected to become warmer and more saline, accelerating the thawing rate of SSPF and exposing long-preserved organic matter to microbial decomposition. A key uncertainty in quantifying the resulting carbon release (CH_4, CO_2) from SSPF lies in the reactivity of the thawed organic matter.

Here, we used a combined experimental and modeling approach to determine the reactivity of SSPF organic matter. We measured the production of CH_4 and CO_2 throughout year-long, 4°C and 10°C, anaerobic laboratory incubations of SSPF sediment from the Laptev Sea. No initial lag phase was observed as production of CO_2 and CH_4 began immediately after the initial abrupt temperature variation, revealing that the SSPF microbial communities react rapidly to the transition from a frozen to a thawed environment. The reactivity of the incubated organic matter was inversely determined by fitting a reactivity model to the incubation gas production rates. We found the reactivity of SSPF organic matter to be similar to that of organic matter from terrestrial permafrost decomposing under anoxic conditions. Within the incubation year, gas production peaked in the first few weeks after thaw, then declined over time. Long-term model projections of thawed SSPF organic matter decomposition indicated slow but persistent decomposition under anoxic conditions.

Thawing SSPF thus represents a chronic, and potentially important source of greenhouse gases. Our study provides new quantitative constraints on SSPF reactivity that will help reduce key uncertainties in SSPF biogeochemical models and ultimately improve estimates of SSPF's contribution to global greenhouse gas emissions.

Youth-powered Permafrost Mapping: Participatory Research with the UndercoverEisAgenten

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Permafrost thaw in the Arctic remains a poorly resolved but globally consequential process, affecting carbon release, hydrology, and landscape stability. The UndercoverEisAgenten Citizen Science project, funded 2021-2024 by the BMBF (now BMFTR) and led by AWI, DLR, and HeiGIT, bridged this knowledge gap by combining high-resolution drone surveys and, local expertise and educational outreach to monitor permafrost in Northwestern Canada.

The project's goals were threefold: (1) To generate fine-scale permafrost observations via student-operated UAV flights; (2) To harness volunteered geographic information (VGI) through micro-mapping by German school students and (3) to engage youth in climate science while co-producing scientific data with local communities in Canada.

UndercoverEisAgenten succeeded in crowd-sourced mapping of ice-wedge polygon centre points using a Voronoi-based spatial framework. The validation of this method showed that volunteered data from students reliably approximated expert-derived spatial structures and ice-wedge network topology. Results demonstrated that non-expert participants, when properly guided, can produce scientifically valid geospatial datasets. In addition to the mapping outcomes, the project reported strong educational impacts: Students and teachers reported enhanced understanding of permafrost geomorphology, thermokarst dynamics, and the role of permafrost in the carbon cycle.

UndercoverEisAgenten presents a novel, scalable model that unites permafrost research and participatory education. By validating that citizen-generated VGI can reproduce complex geomorphological features (e.g., ice-wedge polygons) with high accuracy, the project paves the way for broader engagement in cryosphere monitoring. This approach not only augments scientific datasets but also empowers young participants through climate science literacy and cross-cultural knowledge exchange.

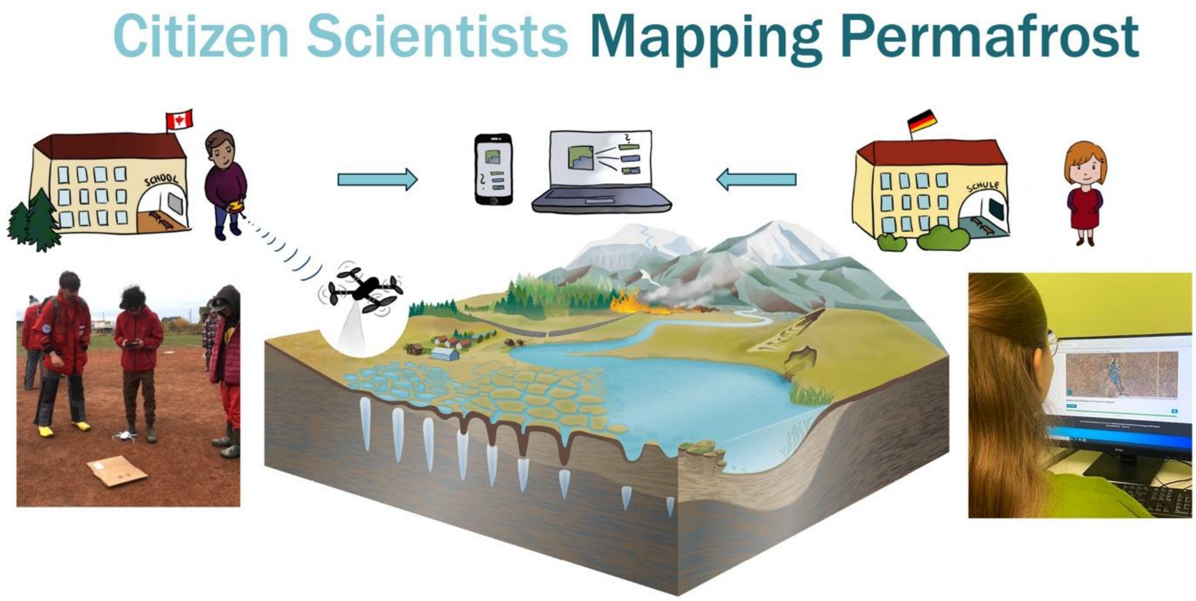

Figure: The concept of citizen scientists mapping permafrost polygons with drones (Canada) and digital mapping application (Germany).

Pathways and Fluxes of Organic Carbon Across the Fluvial-Marine Transition of the Mackenzie River Delta-Beaufort Sea and Implications on Ocean Colour Remote Sensing

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Increasingly warmer temperatures in the Arctic have led to accelerated permafrost thaw and re-mobilization of previously sequestered terrestrial organic carbon (Frey and Smith, 2005). Coupled with steadily increasing riverine discharge (McClelland et al., 2006), the transport of terrestrial organic matter into coastal waters is intensifying across major Arctic watersheds (Clark et al., 2022). Yet these transport pathways and the ultimate fate of organic carbon and sediments remain poorly quantified due to constrained in situ data as a result of limited accessibility. Ocean-colour satellite products offer a promising means to address critical data gaps and assess how land-to-sea carbon fluxes influence the broader pan-Arctic carbon budget. While remote sensing holds great promise, the accuracy of dissolved organic carbon (DOC), particulate organic carbon (POC) and sediment particulate matter (SPM) retrievals depends on transferable relationships between optical and biogeochemical properties (Doxaran et al., 2012; Juhls et al., 2022). These relationships are still poorly constrained across the entire river, delta, coastal to offshore continuum (Lizotte et al., 2023). Without improved observations in these transition zones, monitoring and modelling carbon fluxes at relevant spatial and temporal scales remains limited.

This study focuses on the Mackenzie River Delta–southern Beaufort Sea system, a large, permafrost-dominated watershed that represents a major Arctic source of land-derived carbon to the ocean (Holmes et al., 2012). Using a compartmentalized framework and a synthesized dataset spanning 2009–2024, we quantify DOC, POC, and SPM variability across four key aquatic compartments along the complete salinity gradient from river to ocean. We refine empirical relationships between optical properties and organic carbon concentrations, and we demonstrate the potential of an optical-water-type-based classification algorithm to improve ocean-colour retrievals in optically complex Arctic waters. Our results reveal distinct patterns of organic carbon transformation across compartments that correspond to consistent optical regimes, directly linking biogeochemical processes to observable spectral signatures. This study presents the first integrated assessment of DOC, POC, SPM, and inherent optical properties across all major components of the Mackenzie River Delta–Beaufort Sea continuum, providing essential information for improving remote sensing algorithms and for constraining Arctic land–ocean carbon fluxes.

Holocene Development of a Thermo-Erosional Valley on Kurungnakh Island, Lena River Delta

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As arctic regions experience climate warming, degradation processes such as thermal erosion increasingly affect the geomorphology, hydrology, and ecology of vast permafrost landscapes. These processes involve the formation of distinct landforms, such as thermo-erosional valleys (TEVs). Especially in the ice-rich Yedoma permafrost of Siberia, thermal erosion has created widespread TEV networks during the Holocene, but our understanding of their impact on affected deposits remains very limited.

Here, we investigated the Holocene development of a thermo-erosional valley in late Pleistocene Yedoma deposits on Kurungnakh Island (Lena River Delta, Siberia), based on near-surface stratigraphy and surface characteristics. We analysed four permafrost cores up to 184 cm long, taken on the floor, slope, and adjacent Yedoma upland of a thermo-erosional valley. The stratigraphic analysis included computed tomography (CT) scans, cryostratigraphic classification, radiocarbon dating, volumetric ice content (VIC), grain size distribution (GSD), total organic carbon (TOC) content, TOC/TN (total nitrogen) ratio, stable water isotopes ($\delta^{18}O$, $\delta^{2}H$, d-excess), pH, electrical conductivity, and robust endmember (rEM) analysis. Additionally, we account distributed measurements of active layer thickness (ALT) and water table depth (WTD) within the study area.

The deposits were mainly of Holocene age, reaching 11399 cal yr BP on the Yedoma upland and about 834 cal yr BP in the valley floor. For a sediment lens within the wedge ice contained in one slope core we specified an age of up to 22220 cal yr BP. All samples exhibited high VIC (> 52 vol%) and contained massive wedge ice. Stable isotope data showed more depleted values in wedge ice and a negative relationship between $\delta^{18}O$ and d-excess at specific depths of the valley floor, suggesting freezing fractionation. Polymodal grain size distributions and five rEMs indicated multiple sediment transport processes. Fluctuating GSD, TOC, and TOC/TN ratios in the valley floor core reflected alternating depositional and erosional phases. Together with ALT and WTD measurements, these findings suggest a stable, well-drained Yedoma upland, in contrast to the slopes, which show evidence of erosion and re-deposition throughout the Holocene. The young valley-floor deposits, along with high ALT and low WTD, indicate ongoing TEV development in a variable energy environment with alternating phases of erosion and sediment accumulation during the Holocene.

Overall, the valley, particularly its slopes with shallow sediment covers above relic wedge ice, remains highly vulnerable to continued warming and extreme climatic events. Multi-year data could provide further valuable insights into the temporal evolution of this fragile permafrost landscape.

Surface Water Biogeochemistry Across Thawing Permafrost in Northwestern Alaska

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Thawing of ice-rich permafrost deposits in the Arctic mobilizes carbon, nitrogen, and trace metals into surface waters. As a consequence, the biogeochemical characteristics of ponds, lakes, streams, and coastal waters are changing in ways that can influence aquatic productivity, greenhouse-gas emissions, and water quality. These shifts affect aquatic ecosystems and also have implications for local communities that depend on aquatic resources. As permafrost thaw is accelerating under rapid Arctic warming, understanding spatial differences in surface water chemistry across the landscape, along with their relation to geomorphological setting and their spatio-temporal dynamics, can provide important insights into the hydrological and biogeochemical processes related to permafrost degradation within the contributing catchments.

As part of interdisciplinary fieldwork focused on permafrost-ecosystem interactions in northwestern Alaska from 2022 through 2025, we conducted extensive water sampling campaigns on the Baldwin and Seward peninsulas. Sampling locations included sites visibly impacted by recent, rapid permafrost thaw, such as thermokarst features, thaw slumps, and thermo-erosional gullies as well as sites that appear undisturbed based on their current surface expression or that have no ice-rich permafrost. The multi-year sampling design across environmental, permafrost, and surface geology gradients and disturbance types enables comparisons across varying disturbance intensities and landscape settings. The collected water samples were analysed for pH, electrical conductivity (EC), dissolved organic carbon (DOC), total dissolved nitrogen (TDN), the absorption of coloured dissolved organic matter (CDOM), stable water isotopes ($\delta^{18}O$, δD), and major ions, providing a valuable baseline dataset to characterize hydrochemical variability.

Our analyses aim to identify patterns that distinguish thaw-impacted from undisturbed sites, to explore potential linkages between catchment features and water chemistry, and to evaluate how different types of permafrost disturbance manifest in aquatic systems. The presentation will provide a first overview of spatial variability and spatio-temporal development and offer a preliminary interpretation of the results in the context of ongoing permafrost thaw, with emphasis on its implications for hydrological connectivity, material fluxes, and Arctic freshwater ecosystems and future trajectories.

How Warming and External Loading Can Alter Frictional Processes in Permafrost Rock and at Glacier Bases

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Studies have shown that the mechanical adhesive strength of rock-ice interfaces is highly dependent on temperature and normal stress. In addition, deformation measurements prior to permafrost rock slope failures have indicated that movement rates increase significantly shortly before failure. This may be due to the ductile material behaviour of the ice. Yet, another explanation for this is that rock is sliding over the ice surface after exceeding shear strength. This rock-on-ice friction is a component that has not yet been considered in rock-ice mechanical models. In addition, studying this process offers the opportunity to better understand the sliding of glaciers over a hard bed.

In this work, we aim to analyse the residual shear strength of rock-ice mechanical laboratory tests. We aim to assess the influence of temperature and normal stress variations in an already destabilised system state and to integrate this into existing approaches for rock-ice mechanical modelling.

Investigating the rock-ice mechanics, is based on more than 250 shear experiments conducted at normal stresses between 100 kPa and 1600 kPa. Temperatures ranged from -0.5 °C to -8 °C and shear velocity consistently was maintained at 0.75 mm/min. We monitored the mechanical strength parameters for total deformations of 12 to 14 mm.

Our data show that the dynamic coefficient of friction between rock and ice can decrease from a maximum of 0.74 to 0.09 due to simultaneous warming and loading. These results significantly change the modelling of permafrost rockslides by integrating an additional strength-enhancing component. This enables a more realistic representation of fracture processes, as previous models underestimated the overall strength of the system. In addition, we propose a novel approach to dynamically adjust the friction coefficient of hard-bedded glaciers. Integrating the modulation of normal stress due to external loading or general thermal warming of the glacier bed might be crucial to simulate glacier destabilization.

This study provides new data to improve the rock-ice mechanical model in terms of post fracture total system strength and proposes a novel approach to dynamically adjust basal glacier friction due to external loading or thermal warming.

Biota-mediated greenhouse gas dynamics in Arctic ecosystems: Exploring plant and microbial controls on methane and nitrous oxide uptake

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Arctic soils are often reported as sources of methane (CH_4) and nitrous oxide (N_2O), particularly in the context of climate warming. However, growing evidence indicates that arctic soils can also function as sinks for these greenhouse gases (GHGs) under specific environmental conditions. While abiotic variables like temperature, moisture, and soil structure play a role in regulating GHG uptake, the biological mechanisms remain poorly understood. Plants influence soil biogeochemical processes both directly, and indirectly by releasing organic substrates via rhizodeposition and by shaping microbial communities that mediate denitrification and methane oxidation. Therefore, plants likely play a central role in determining whether soils act as sources or sinks of these potent gases.

This research aims to elucidate the drivers of GHG dynamics in Arctic ecosystems, with a particular emphasis on the contribution of biota to GHG uptake. Specifically, we seek to identify how interactions among plants, microbial communities, and soil conditions regulate GHG fluxes.

A combination of field and laboratory approaches is applied, spanning scales from the rhizosphere to the landscape level. In situ GHG flux measurements have been and will be conducted across contrasting vegetation types representing key plant functional groups (e.g., sedges, shrubs, mosses, and bare soil) in the Finnish and western Canadian Arctic, using both manual and automated chamber techniques. A plant-exclusion experiment, established in summer 2025, will help to disentangle plant- and fungal-mediated controls on GHG fluxes. Complementary soil incubations and mesocosm studies will trace carbon and nitrogen fluxes associated with rhizosphere activity, providing mechanistic insights into how plants and microbes regulate GHG uptake.

By integrating biogeochemical, microbial, and plant ecological perspectives, this work contributes to the overarching goal of the COLDSPOT project — to better understand the conditions under which Arctic soils act as GHG sinks.

How seasonality drives interglacial permafrost thaw: Insights from speleothems and climate modelling

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Various proxy records have suggested widespread permafrost degradation in northern high latitudes during interglacial warm climates, including the mid Holocene (MH, 6000 years before present) and the last interglacial (LIG, 127 ka BP), and linked it to substantially warmer high-latitude climates compared to the pre-industrial period (PI). However, most Earth system models suggest only modest warming or even slight cooling in terms of annual mean surface temperatures during these interglacials. Here, we combine paleo permafrost reconstructions derived from speleothem and pollen records with paleoclimate simulations of the AWI-ESM-2.5 climate model and the CryoGridLite permafrost model to investigate the ground thermal regime and freeze-thaw dynamics in northern high-latitude land areas during the MH and the LIG. The simulated paleo permafrost extents are broadly in agreement with proxy constraints from speleothems. The simulations further revealed that not only changes in mean temperatures, but also the enhanced seasonal temperature amplitude due to a different orbital forcing have driven permafrost and ground ice dynamics during past interglacial climates. Our results provide an additional explanation of reconstructed periods of marked permafrost degradation in the past, which was driven by deep surficial thaw during summer, while colder winters allowed for permafrost persistence in greater depths. Our findings suggest that past interglacial climates have limited suitability as analogues for future permafrost thaw trajectories, as rising mean temperatures paralleled by decreasing seasonal amplitudes expose the northern permafrost region to magnitudes of thaw that are likely unprecedented since at least Marine Isotope Stage 11c (about 400 ka BP).

Towards Near Real-Time Tracking of Lake Drainage in Arctic Permafrost Regions

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Lakes are an abundant landscape feature in permafrost regions, with many of them being highly dynamic thermokarst lakes particularly in ice-rich permafrost settings. They are formed through permafrost thaw, thaw subsidence, ponding, pond coalescence and shoreline erosion, leading to self-reinforcing feedbacks between water bodies and further permafrost degradation. Their expansion typically results in greenhouse gas emissions such as CO_2 and CH_4. However, once they reach a topographic drainage gradient, they often drain catastrophically within hours to days or even years. Drained lakes then often become carbon sinks due to permafrost aggradation and peat accumulation, while at the same time new wetlands may also emit CH_4. Overall, carbon emissions from lake expansion outweighs the carbon uptake of drained lakes. Accelerated thermokarst lake cycling, including widespread drainage, indicate ongoing permafrost degradation and hydroclimatic changes at high latitudes.

In this study, we developed a satellite image processing pipeline to monitor the dynamics of approximately 4 million circum-arctic lakes to allow detection of lake drainage events in near real-time (NRT). We extracted a baseline layer of polygons for lakes larger than 1 ha. We then created monthly datasets from the recent period (2017-2024) using Dynamic World land cover data to extract areas of surface water. For longer time scales, we also explore annual surface water information from the JRC Global Surface Water dataset. We extract time-series information from these datasets for each of individually tracked lakes across the Arctic permafrost region and automatically identify sudden and sustained water surface loss as lake drainage.

Preliminary results reveal distinct spatial and temporal patterns of lake drainage events consistent with previous regional analyses. Lake drainage also follows distinct seasonal patterns peaking in early summer. These results indicate both spatial and temporal clustering of drainage events. The temporal frequency offers a more precise understanding of significant short-term events that have been anticipated in regional analyses but not at a pan-Arctic level.

This work lays the foundation for NRT analysis and an early warning system for lake drainage events in the northern permafrost zone. First results showed that several lake drainage events were detected less than a month after they happened. Within the framework of the Permafrost Discovery Gateway (PDG), we will further utilize this novel dataset to explore spatio-temporal influencing factors on lake drainage and permafrost hydrology using geoAI methods and enable a NRT monitoring of permafrost thaw with preliminary products made publicly available through the automated workflows.

Deciphering the Thermo-Hydro-Mechanical Rhythms of Permafrost Rockwalls: A Year of A-ERT Monitoring at the Kitzsteinhorn

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The dynamics of water and ice within fractures are increasingly recognised as key mechanical drivers in the weakening of permafrost rockwalls. However, monitoring these hydrostatic and cryostatic processes remains challenging due to their transient nature and spatial heterogeneity. In this study, we evaluate the potential of automated electrical resistivity tomography (A-ERT) monitoring to constrain seasonal time windows of increased predisposition to destabilisation in permafrost rock slopes. A-ERT measurements were conducted on the steep north face of the Kitzsteinhorn (3203 m a.s.l., Hohe Tauern, Austria) between April 2024 and April 2025. Quantitative interpretations were supported by resistivity-temperature relations derived from borehole temperature and laboratory experiments.

Five characteristic seasonal phases, defined by environmental forcing parameters (rock temperature, snow cover, and meltwater infiltration), were distinguished and are likely representative of many alpine permafrost rockwalls: stable freezing from April-May (phase I), snow melt and subsurface warming from May-July (phase II), maximum active layer thickness from July-September (phase III), superficial cooling from September-November (phase IV), and deep freezing from November-April (phase V). The A-ERT dataset for each seasonal phase was combined with mechanical observations from load cells installed on two heads of 25 m-long anchors and hydrostatic pressure levels derived from deep piezometric measurements.

Two phases were found to coincide with increased hydrostatic or cryostatic pressures and could be temporally constrained using A-ERT data: late spring to early summer (phase II), when snowmelt-driven infiltration caused sharp decreases in resistivity and a significant reduction in anchor load; and early winter (phase IV), when subsurface freezing induced increasing resistivity and rising anchor loads, consistent with ice segregation and stress redistribution within the jointed rock mass. Although monitoring techniques in alpine permafrost settings remain operationally demanding, our results demonstrate that A-ERT monitoring effectively captures the linked thermal, hydraulic, and mechanical responses of rockwalls, offering a valuable tool for identifying time periods of increased predisposition to slope instability under ongoing permafrost warming.

Water down the gully – using multi-source derived DSMs to monitor thermo-erosional gully evolution

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Thermo-erosional gullies are characteristic features of ice-rich permafrost landscapes. With the Arctic rapidly warming, thermo-erosional gullies are expected to develop more often and expand more rapidly. This has far-reaching consequences, influencing not only the local hydrology through changed drainage pathways, but also leading to ground ice loss, release of greenhouse gases, and changed nutrient and sediment fluxes. The underlying dynamics and processes at gully scales are complex, involving mass-wasting on slopes, erosion, and thaw-related subsidence. They are expected to be influenced by factors such as gully morphology, snow cover, and vegetation. To gain a better understanding of these processes, we used multi-temporal digital surface model (DSM) data. These data were derived photogrammetrically from both unmanned aerial vehicle (UAV) and airborne images from the modular aerial camera system (MACS), as well as ground-based and airborne lidar data.

Our data was acquired at three thermo-erosional gully sites in Northwestern Alaska: two on the Baldwin Peninsula (BAP-B: 2022, 2023, 2024, and 2025; BAP-S: 2022, 2023, and 2024) and one on the central Seward Peninsula (CSP-F: 2021, 2022, 2023, and 2024). The BAP-B site is a coastal gully exceeding 10 m incision into the surrounding hillslope terrain. The gullies at BAP-S and CSP-F were formed following lake drainage, recently for BAP-S in 2022 and around 20 years ago for CSP-F. We derived DSMs from the densely overlapping visible-spectrum imagery acquired during drone flights over multiple years using photogrammetric software for structure-from-motion (SfM) image processing, and finely co-registered them. We compared the final DSMs with differential GPS (dGPS) data collected along transects at the two gully sites to evaluate the vertical accuracy of the UAV-derived DSMs. Furthermore, we complemented the time steps with additional DSMs derived from lidar and airborne MACS data by co-registering them to the UAV data.

Our results show that UAV-derived DSMs provide reliable elevation data even in difficult tundra settings. They also highlight that ground control points and careful co-registration are vital, particularly for comparisons across multiple time steps. The repeated measurements, including the additional time steps derived from airborne and lidar data, allowed us to detect and monitor the development of a slumping area within the BAP-B gully, and the gully at BAP-S widening. In addition to the gully morphology, we were able to extract the height of early summer snow bank remnants. These datasets provide crucial input for analysing thermo-erosional gully development.

A History of Submerged Permafrost Mapping

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Permafrost is defined by temperature: it is any Earth material, regardless of composition or ice content, that remains perennially below 0°C (cryotic). This simple principle leads to confusion in studies of subsea permafrost, where marine sediment beneath the Arctic shelves may be perennially cryotic, but never frozen. The cartographic representation of permafrost requires a common and inclusive frame of reference. We describe the development of cartographic representations of subsea permafrost since the early 20th century, with the aim of developing suggestions for such a frame of reference.

Permafrost on Earth has been classified and represented cartographically in various ways: by distribution (continuous, discontinuous, sparse and sporadic, probability), by temperature (cold, warm) or by location (terrestrial, alpine, submarine, planetary). Subsea permafrost was first mapped in the 1930s, using cryotic bottom water extent on the Eurasian shelf to delineate cryotic sediments. Later maps in the early 1970s made the conceptual leap to areal extent of frozen, or icy, sediment. By the late 1970s, interaction between North American and Soviet researchers led to circumpolar maps delineating subsea permafrost extent. In general, mapping of subsea permafrost has been limited by the lack of observational data. Industry survey and borehole geophysical data made public in the 21st century have begun to provide an observational basis for permafrost areal and depth extent, especially on the Beaufort Sea shelf, and more recently in the Kara and East Siberian seas as well.

Observational evidence for permafrost presence, absence or state in a saline and inaccessible environment such as the sub-seafloor is nearly always determined via some indirect measure of ice content, rather than temperature. In addition to detection, the functions of subsea permafrost – groundwater aquaclude, gas migration barrier, organic material and gas hydrate stabilizer – all depend on primarily ice content (phase state) rather than temperature (thermal state). For terrestrial permafrost, the differences in permafrost area and volume as defined by thermal or phase states are often negligible at larger than regional scales. In the subsea realm, these differences are substantial and comparable in scale to the total area (or volume) mapped. Ice content is more relevant to the study of permafrost as it freezes and thaws in response to transgressions and regressions. We argue that ice content should be the basis for a frame of reference common to marine and terrestrial permafrost, providing a wholistic understanding of permafrost development independent of the current coastline position.

Spatial controls of methane uptake and nitrous oxide fluxes in upland soils in Finnish Lapland and the western Canadian Arctic

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The Arctic and sub-arctic regions are highly sensitive to climate change and are warming faster than the global average. Permafrost-affected soils have historically been recognized as a net sink in the global carbon cycle, but their biogeochemical cycling is affected by rapid environmental change and thaw processes. Although the Arctic greenhouse gas (GHG) budget is dominated by CO_2 (per mass units), the Arctic region is also considered as a net source of methane (CH_4), and potentially nitrous oxide (N_2O) - two critical GHGs.

Recent studies have documented that the actual role of the Arctic as a net carbon sink or a source remains ambiguous, highlighting the potentially important switch from sink to source at local scales. Furthermore, the focus on high-emitting sites – referred to as “hotspots” – induces an observational bias that leads to a poor understanding of microbial processes, particularly high-affinity CH_4 oxidation.

By capturing low fluxes with portable gas analysers, we highlight the potential of Arctic soils to act as a sinks (“coldspots”) for CH_4 and potentially N_2O in different uplands ecosystems. We conducted dark chamber-based measurements during the peak summer period (July to August) at two contrasting Arctic locations: Finnish Lapland and the Western Canadian Arctic, across different ecosystems (upland tundra, palsa and forest ecosystems). By integrating measurements of well-defined flux drivers (e.g. soil moisture, temperature), other environmental variables (e.g. thaw depth, soil properties), microbial sampling, and soil nutrient concentration measurements, we collected a dataset of intricate variables documenting the spatial variability and small-scale heterogeneity of CH_4 and N_2O fluxes and their drivers. To further explore the patterns of CH_4 uptake and its environmental controls, we plan to conduct controlled incubations experiments to investigate how nutrient availability (Cu, C, N) and soil pH might shape the high-affinity methanotrophic community.

Preliminary results show that all well-drained upland locations displayed net CH_4 uptake, with mean rates of 2.98 mg CH_4 m^{-2} d^{-1} (Kilpisjärvi region) and 1.17 mg CH_4 m^{-2} d^{-1} (Western Canadian Arctic). The CH_4 uptake rate showed spatial variability linked to land cover type (e.g., dwarf shrub, herbaceous shrub, lichen/barren). Our study highlights the critical importance of (sub) arctic upland soils to act as “coldspots” in the Arctic CH_4 budget and provides new data on the spatial variability of N_2O fluxes, an understudied GHG, in two Arctic regions.

From what is and what could be: Arctic Coastal Ecosystem Services and their Changes on Qikiqtaruk, Canada

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Global climate change is affecting Arctic coasts in a variety of ways. In Northern Canada, for instance, permafrost coastlines are increasingly exposed to coastal erosion, more frequent and severe flooding, and stronger waves and winds. These processes affect not only vast uninhabited coastal areas but also the livelihoods of people who often have established campsites directly along the shore.

Our study area encompasses the Herschel Island Territorial Park on Qikiqtaruk, where a campsite is situated on a low-lying sand spit. This site is used only during the summer months, making it ideal for investigating the influence of climate change on local campsites during the open-water season.

We applied the concept of ecosystem services (ES) to assess how the coast of Qikiqtaruk is being used and valued. In July 2025, we conducted participatory mapping surveys with individuals on the island, including Yukon Territorial Park Rangers, a Yukon Parks Conservation Biologist and scientific groups from Canada and Europe. These surveys were carried out through interviews and group exercises. The collected data was analysed both quantitatively and qualitatively, focusing on ecosystem services such as fishing, tourism, and scientific activities, as well as the environmental factors influencing them. To contextualize our findings, we also recorded various physical parameters near the fishing grounds and linked survey responses to existing environmental datasets from the island.

Together, these measurements and analyses will help characterize the ecosystem services present on Qikiqtaruk, illustrating how they are changing - and are likely to continue changing - in the context of ongoing climate change. Our evaluation also considers the island's dual role as a Territorial Park and a site of traditional land use and education. Ultimately, the results of this study will support future land-use planning and management for Herschel Island–Qikiqtaruk Territorial Park.

myThaw 2021-2023 — 3 years of successful Circum-Arctic permafrost thaw data collection

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The myThaw data sets provide standardized measurements for permafrost thaw and the linked parameters snow depth, vegetation height, water level and soil texture. These data sets were collected using the myThaw app, which follows the standardized, multi-parameter protocol for monitoring permafrost thaw developed by the Terrestrial Multidisciplinary distributed Observatories for the Study of the Arctic Connections (T-MOSAiC) International Arctic Science Committee (IASC) initiative. The data sets contain detailed metadata for each site including data on the timing of data collection, geographical coordinates, and land surface characteristics (vegetation, ground surface and water features). The myThaw data collection was started in 2021, collecting data yearly since then. The thaw depth measurements were conducted from the end of the snow melt period, throughout the summer and represent the thaw depth evolution per site until it reaches its maximum extent by the end of the summer. Other parameters such as snow depth, vegetation height, water level and soil properties (organic layer thickness, soil texture), were measured at the same transect as the thaw depth. All measurements were uploaded by the contributors to the myThaw database. We performed a quality check of the data sets and removed erroneous data including wrong units, sign errors (coordinates) and incorrect days of measurement. Raw data sets remain accessible on our database, while the quality-checked data sets are published on PANGAEA. Overall, the data sets present a valuable addition of permafrost thaw data sets. We show site specific dynamics in freeze-back processes, as well as variations in thaw depths. Snow depths variations are high, even at sites with close proximity, which can be attributed to topographic conditions. However, we face some incoherencies that need to be addressed in future data collection and data set publishing, whether it is within the myThaw project or comparable projects.

Permafrost monitoring in Sweden's largest coherent palsa mire, Vissátvuopmi

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Palsas are a permafrost landform found in northern peatlands, characterized by peat mounds with a frozen core. Widespread degradation of palsas affects biodiversity, hydrology, carbon fluxes, and local infrastructure. Therefore, palsa mires are considered a priority habitat under the EU Species and Habitat Directive and are integrated into Sweden's environmental goals. Despite their threatened status, the largest coherent palsa mire in Sweden, Vissatvuopmi (N 68°47', E 21°11'), has no protective status. At this site, we study several palsas and peat plateaus, using a wide range of methods to understand both exterior and interior dynamics. A UAV with LiDAR scanner is used to obtain high-resolution terrain models and track topographical changes. These data are supported by UAV orthophotos, active layer thickness grids and several boreholes (2–6 m deep). Regarding the palsas' interior, we conducted large pseudo-3D surveys of Electrical Resistivity Tomography (ERT). The results indicate that the shape of the frozen core in palsas is heterogeneous and strongly controlled by the presence or absence of shallow boulders that affect frost heave. This multi-method approach provides a comprehensive view of palsas' structure and will help advance our understanding of how peatland permafrost responds to a rapidly changing climate.

Circum-Arctic Soil Permafrost Region database (CASPeR)

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Considerable uncertainties persist in accurately mapping Arctic permafrost carbon on a circumpolar scale, increasing at greater soil depth. Quantifying the permafrost soil carbon pool has shown to be particularly challenging, due to the large spatial and vertical variability of soil properties in the Arctic environment and the scarce availability of soil reference data. We aim to provide updated circumpolar soil carbon maps using geospatial modelling. However, calibrating and evaluating our model requires detailed and accurate soil reference data. Most existing permafrost carbon datasets do not serve that purpose, as they lack in structure, resolution and additional metadata. In particular, inaccuracy of geographic coordinates and lack of vertical resolution of the data are major issues.

We developed a new harmonized, standardized, structured, extensive, analysis ready and FAIR soil profile reference database for the northern circumpolar permafrost region, called the Circum-Arctic Soil Permafrost Region database (CASPeR). This database contains geochemical and physical soil properties from soil profile measurements, harmonized from published data (Open data repositories, journal publications) and yet unpublished data (institute archives). While our primary focus was on gathering soil carbon observations, we developed CASPeR as a general purpose permafrost soil database, including information on nitrogen, isotopes, soil texture and extensive metadata, from mineral and organic soils.

Once published, CASPeR will be the largest structured soil carbon database for the Arctic permafrost region. CASPeR already incorporates most of the data from the NCSCDv2 database, the current standard for Arctic soil carbon data, and will replace it in the future. We are committed to deliver a high-quality and metadata-rich soil reference database for the Arctic research community. It is planned to distribute CASPeR v1.0 under an Open Source license after final quality checks and reviews, together with an interactive dashboard, a Python API for easier access and a data paper giving an overview on the data and harmonization methods. CASPeR can be used for circumpolar-scale mapping of carbon and nitrogen stocks, maximum soil depth and ground ice distribution. Furthermore, it supports the development of process-based models to improve the representation of permafrost in Earth system models, allows in-depth uncertainty analysis using the quality attributes, and allows investigation of soil properties with respect to their relation to permafrost landscape characteristics and landforms.

Following the water: The thawing and erosion of permafrost increase input of reactive nitrogen to the coastal water at the Baldwin Peninsula, Alaska.

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Permafrost affected soils and especially Yedoma deposits contain a huge amount of carbon and nitrogen, which can be released and become available after thawing. Coastal and thermal erosion, e.g. in drain lake basins, are important processes for the release and transport of reactive nitrogen and carbon from soils to the aquatic environment and consequently to the coastal waters and the Ocean. The faster warming of the Arctic in relation to the rest of the world will amplify the rate of release of nitrogen and carbon.

To understand the hydrological conditions and release pathways of the thawing nitrogen and carbon, we investigated a drained lake basin (Schaeffer Lake) and a Yedoma cliff (Cape Blossom) at the Baldwin Peninsula, Alaska. Samples from rain, snow, ice wedges, outflow water, basin water, pore water and soil were taken. By measuring biogeochemical properties (dissolved inorganic (DIN)and organic nitrogen (DON) plus ^{15}N stable isotopes, ^{18}O-H_2O, dissolved gases (Methane and N_2O) et al.), we want to unravel the path of the water and how carbon and nitrogen are enriched and transported.

First results show that the out-flowing water contained a considerable amount of DIN and DON, the ^{15}N stable isotopes of nitrate were significantly enriched and the water was oversaturated with methane and N_2O. This indicates that not only reactive nitrogen is released by the thawing and erosion, but also quickly processed by microbial activity that is stimulated by the nutrient input.

Late Pleistocene (MIS 3/MIS 2) and Holocene (MIS 1) climate reconstruction in the Laptev Sea region (Northeast Siberia) using palaeoecological and modeling data.

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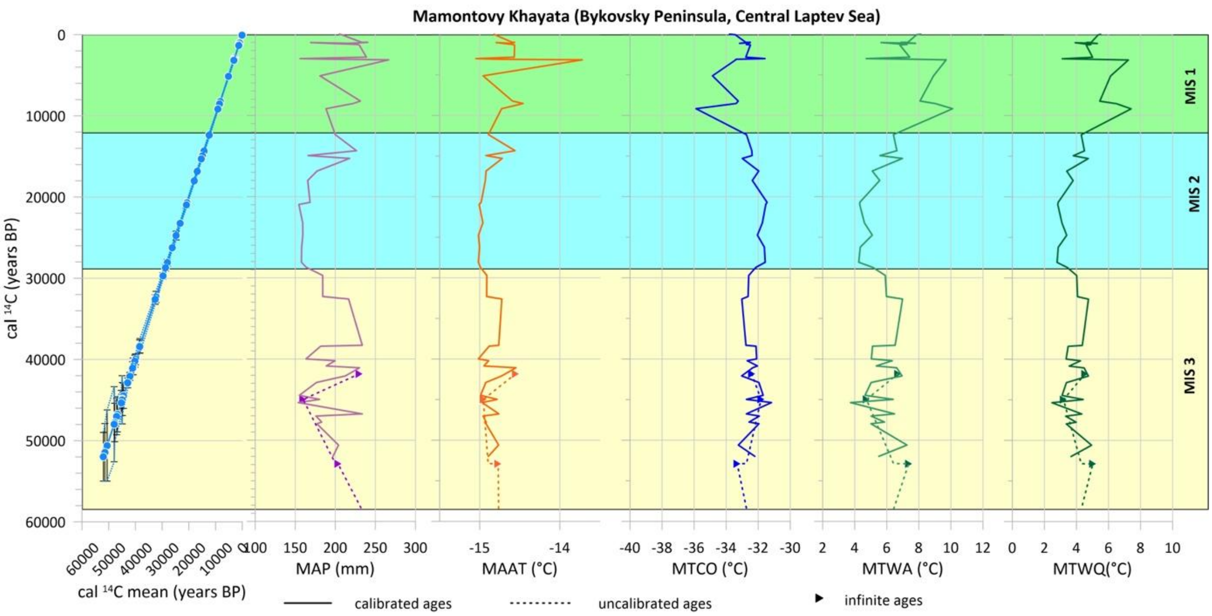
We integrate geochronological, palaeoecological, and modeling data to reconstruct the climate in the Laptev Sea region from MIS 3 to MIS 1. Analysis of floral and faunal records from these deposits suggests temperature shifts between different periods, as well as within individual periods. Previously published palaeoecological data from several sites along the Laptev Sea coast were used to reconstruct climate parameters.

The geochronology is based on numerous ^{14}C dates obtained during the last 25 years. Pollen-based climate reconstructions were based on a northern hemispheric modern pollen training dataset. Climate reconstructions were performed using the modern analogue technique (MAT) by applying the MAT function to the pollen percentages of the selected pollen taxa.



Climate reconstruction using the insect fauna shows differences between stages. The warmest period is correlated with the Early Holocene, while the coldest interval occurred during early MIS 2. The insect fauna indicated a sharp increase in the Arctic tundra during the LGM and a subsequent warming. The distribution of the steppe weevil

Stephanocleonus eruditus enables the reconstruction of a warmer and drier climate along the modern south coast of the Laptev Sea, as well as a more humid and colder climate in the north.

Comparison of climate data retrieved from different proxy records with paleoclimate modeling will utilize CMIP6 PMIP experiment simulations, which provide data from 15 models spanning 8 kyr BP (PMIP MidHolocene) and data from 4 models spanning 21 kyr BP (PMIP4 LGM). For MIS 3, model simulations from AWI's paleoclimate modeling efforts will be utilized, spanning the time period from 38 kyr BP to the LGM time slice as defined in PMIP.

Morphological and kinematic analysis of landslides in mountain permafrost: a regional analysis in the Mattertal, Valais, Swiss Alps

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The Alpine periglacial environment, where mountain permafrost is likely to occur, is shaped by diverse slope movements. These include landslides, which result from long-term preparatory phases and sometimes culminate in failures. Another process is permafrost creep, internal deformation of the frozen ground taking place at the shear horizon. Rock glaciers are examples of landforms resulting of permafrost creep. This contribution focuses on landslides in mountain permafrost in the Mattertal (Valais Alps, Switzerland) and the role of frozen ground on their dynamics.

Synthetic Aperture Radar Interferometry (InSAR) dating from the 1990s has permitted to detect several periglacial slope movements (Delaloye et al. 2007). We have monitored half a dozen landslides for the past 15-20 years using geodetic surveys. Situated above 2600 m a.s.l. under (discontinuous) permafrost conditions, initial velocities ranged from dm/month to multiple dm/month. Current measurements show that the landslides have accelerated by factors of 2 to >10, following similar development as rock glaciers in the area. Despite the strong acceleration, no catastrophic failure has occurred. Seasonal patterns are characterized by velocity maxima at the end of summer and minima in spring, typical for permafrost creep.

Meanwhile, new geospatial data such as high-resolution DEMs, InSAR and orthoimages has become available, allowing better characterization of landslides. We conduct a multimethod analysis combining remote sensing and morphological analysis to complement the existing kinematic datasets. For this contribution, we have chosen the sector around the already monitored landslides, with the aim to later upscale to a larger area. Various SAR sensors and temporal baselines capture a wide range of velocities. Photogrammetry aids to detect motion in areas unsuitable to be analysed with InSAR, or areas moving several meters per year, which is above the InSAR detection limit. Each landslide is characterized by material, movement type, current velocity and complexity of the motion to establish a typology. Velocity measurements are validated using in-situ geodetic data.

Preliminary results identify over 20 landslides distributed across elevations ranging from 2300 to 3300m a.s.l. Several connect to gully systems, supplying debris to the valley floor. Velocities range from <10 cm/year to several m/year. Spatial analysis indicates heterogeneous movement patterns, with some landslides exhibiting different velocity compartments.

Assessing Water Input from Permafrost Thaw in Tibetan Catchments Using Cryo-Hydrological Modeling

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Rapid warming on the Qinghai–Tibet Plateau is causing pronounced thaw of the region's widespread permafrost and substantial deepening of the active layer. These transitions are tightly linked to shifts in both surface and subsurface hydrological processes, yet the quantitative role of ground-ice melt within regional catchment water budgets remains insufficiently understood. The overarching research question addresses whether meltwater generated from the warmest and most vulnerable permafrost zones represents a significant water input relative to other sources, such as rainfall, snowmelt, and glacier melt.

To address this, a cryo-hydrological modeling framework targeting different catchments will be developed, centring on the application of the CryoGrid Community Model. Catchment selection is guided by indicators of strong thaw susceptibility and high ground-ice content. Model parameterization employs recent geospatial datasets for land surface and subsurface characteristics, alongside remote sensing and reanalysis products for climate forcing.

Due to the limited availability of in situ measurements, the workflow emphasizes the use of thermal and soil-moisture observations for both model input and validation. Sensitivity analyses systematically vary key parameters, including those related to soil properties, ground-ice fraction, and surface energy balance, to generate conservative upper estimates of meltwater production within each catchment.

Results from these simulations will then be benchmarked against contributions from rainfall, snowmelt, and glacier melt, grounding the analysis in a comparative, process-based perspective. This approach is expected to yield robust, quantitative insights into the volume and hydrological significance of water generated by permafrost thaw across high-mountain catchments. Through prioritizing conservative scenario assumptions and rigorous benchmarking, the analysis aims to clarify the potential impact of ground-ice meltwater within catchment water budgets and to enhance process-based understanding of cryospheric change and hydrological dynamics in High Mountain Asia.

Soil moisture and temperature controls on belowground methane dynamics and in a warming Arctic: insights from a soil column experiment

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Rising temperatures in Arctic permafrost regions may accelerate microbial breakdown of soil organic matter (SOM), increasing greenhouse gas emissions. High uncertainties remain about the timing, magnitude, and distribution of the two gaseous carbon species CO_2 and CH_4. Especially net CH_4 fluxes are highly variable and difficult to predict, because two opposing governing processes, CH_4 production and CH_4 oxidation, may respond differently to permafrost-thaw induced shifts in soil hydrology and temperature.

With this study, we aim to explore the effects of changes in soil redox conditions and temperature on belowground CH_4 production and vertical transport under near-nature conditions. Undisturbed soil columns from a wet Arctic field site on Disko Island, Greenland, are incubated in a climate chamber under different soil moisture and soil temperature scenarios. We keep the vertical temperature gradient intact, and the bottom of the soil column stays frozen, simulating permafrost. We monitor CO_2 and CH_4 concentration and porewater chemistry along the soil profile and gas release to the atmosphere.

Preliminary results from a pre-experimental test phase show that under saturated conditions, CO_2 accumulated in deeper soil layers, indicating limited gas diffusion at depth. No clear vertical pattern was observed in CH_4 concentrations. Dissolved organic carbon (DOC) followed a vertical gradient, with highest values at depth, hinting at a release of DOC to the soil porewater under saturated conditions. A drop of the water table by 40 cm led to an increase in redox potential, switching to positive values after two days. This was followed by a pulse of both CO_2 and CH_4 efflux, probably caused by diffusion of gases trapped under water-logged conditions.

We expect to gain further insights from the main experiment about microbial CH_4 production and consumption along the soil column under transient soil conditions, contributing to improved understanding of the greenhouse gas response to a warming Arctic.

The ice content of palsas and peat plateaus in Finnmark estimated with High-Frequency Induced Polarization

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Permafrost represents one of the largest carbon reservoirs on Earth, and its thawing due to global warming constitutes a critical tipping point within the Earth's climate system. In northern Fennoscandia, permafrost occurs discontinuously and is usually confined to peatland environments where ice-rich features like palsas and peat plateaus may form. Because their temperature is close to zero degrees, these landforms are particularly sensitive to even minor temperature increases. Degradation of the permafrost results in the release of previously frozen carbon to the atmosphere. Understanding the current state and spatial variability of permafrost in such areas is crucial for assessing ongoing landscape and climate feedbacks.

This study investigates the permafrost landscape of the Aidejavri peat mire in northern Norway using High-Frequency Induced Polarization (HFIP) and Electrical Resistivity Tomography (ERT). HFIP is a relatively new approach that measures the frequency-dependent electrical conductivity ranging from 100 Hz up to 100 kHz. Within this frequency range, the dielectric permittivity of water ice shows a steep decrease, which allows the estimation of the ice content from polarization behaviour. The HFIP data were first processed and inverted with a layered model to separate polarization effects from electromagnetic induction and then interpreted in 2D using a two-component dielectric mixture model in order to resolve spatial variations in the distribution of ice.

ERT profiles were gathered along the same transects for validation and comparison. ERT can only delineate resistivity contrasts that distinguish frozen from unfrozen ground, while HFIP gives additional, frequency-dependent information which allows quantification of the ice content. The results demonstrate that HFIP yields a more detailed and quantitative representation of ice-rich permafrost than ERT. Though ERT is highly efficient in defining large-scale resistivity contrasts and very well adapted for fast mappings over large areas, HFIP allows for an ice content estimation. However, their measurement and processing are more time-consuming and require more cautious data handling.

The comparison between both methods reveals consistent spatial patterns with high ice contents beneath elevated, intact parts of the mire and low ice fractions in degraded or ponded areas, indicating ongoing permafrost thaw. These results demonstrate that the Aidejavri mire is characterized by pronounced spatial variability in permafrost conditions and ongoing degradation processes. Preliminary repeat measurements have already been conducted and will be extended further this coming year in order to study time-dependent variations in the internal structure and ice contents of the Aidejavri permafrost.

Organic Carbon Degradation and Mineralization Across Saline Thermokarst Landforms on the Barrow Peninsula, Alaska

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Saline thermokarst landscapes occur along the Alaskan coastline, where late-Pleistocene marine sediments were deposited when sea levels were higher compared to today. These deposits are particularly prone to thaw because salinity lowers the freezing point of porewater. This is critical in thermokarst lowlands as these landscapes store disproportionately large amounts of organic carbon and the presence of saline permafrost could lead to earlier and more extensive thaw than previously anticipated.

In this study, we investigate representative thermokarst landforms along a land-to-sea transect on the Barrow Peninsula, Alaska. Our objectives are (1) to characterize the degradation state of organic carbon and (2) to assess the potential for greenhouse gas (GHG) production from these sediments. We address these aims through biogeochemical analyses, focusing on n-alkane biomarkers and aerobic incubation experiments.

Our results show that unfrozen brackish and saline sediments beneath thermokarst lakes and a thermokarst lagoon exhibit stronger organic carbon degradation signals than permafrost and active layer sediments from undisturbed tundra, a drained and refrozen lake basin, and an unfrozen non-thermokarst lagoon. Although saline lake sediments produce less carbon dioxide (CO_2) overall due to their lower total organic carbon (TOC) content, CO_2 production normalized to TOC is substantially higher in the saline lake (92.1 mg C g^{-1} TOC) than in undisturbed tundra permafrost (43.6 mg C g^{-1} TOC), and nearly comparable to the active layer of the drained lake basin (99.3 mg C g^{-1} TOC).

These findings highlight the high vulnerability of organic carbon stored in saline permafrost regions. While absolute CO_2 production from saline sediments were measured to be low, their high carbon degradability suggests that potentially TOC-rich saline sediments could become a significant source of greenhouse gases under future thaw scenarios. Our results emphasize the importance of considering salinity as a key factor in permafrost carbon vulnerability assessments.

Investigating the role of groundwater in thawing Swedish palsa peatlands

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Permafrost in Sweden is only found at the highest elevations in the northern Scandinavian mountains and in peatlands where it appears as palsas and peat plateaus in the northernmost part of the country. Recent studies have shown how palsas and peat plateaus are rapidly thawing in the region with consequences for ecosystem services, such as carbon sequestration. While this thawing is primarily driven by increasing air temperatures, groundwater flow can alter thaw rates considerably. Moreover, climate warming can lead to changes in groundwater levels and flow rates which further impact greenhouse gas fluxes from these peatlands. But the current understanding of groundwater dynamics in Scandinavian palsa peatlands is limited by a lack of systematic observations as well as incomplete mechanistic understanding.

We are investigating the seasonality and climate sensitivity of groundwater in five palsa peatlands in northern Sweden. Using a combination of remote sensing methods, field observations, and modeling we aim to better understand what drives seasonal variations in groundwater levels and how changes in groundwater levels and flow may impact permafrost thaw rates. We will present our first modeling results on the sensitivity of permafrost to groundwater flow surrounding palsas, which suggest that palsas underlain by high hydraulic conductivity materials thaw more rapidly from below than those underlain by low conductivity materials. We will also present our strategy for investigating groundwater levels and flow in palsa peatlands underlain by materials covering a range of hydraulic conductivities, using a combination of satellite remote sensing and field observations.

Large driftwood accumulations along arctic coastlines and rivers

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Driftwood deposits along Arctic coastlines play key ecological roles and serve as indicators of past environmental conditions. Yet, there is a lack of knowledge regarding large-scale distribution patterns, which are important to assess its ecological and geomorphic impacts and carbon stocks. Here, we present a systematic mapping of Arctic driftwood in the North American low Arctic using PlanetScope nano-satellite imagery and deep learning. We identify 19,717 driftwood deposits covering 22,960,000 m^2. Driftwood accumulates in clusters near major river deltas, strongly correlating with boreal forest cover within river catchments. Accumulation declines sharply beyond 200 km from river mouths, challenging current narratives of predominantly long-range redistribution. We compare the performance of driftwood-mapping using PlanetScope imagery with sub-metre aerial imagery. Our method underestimates the total driftwood area by 23.18% but captures large deposits with high accuracy (-4.28% bias). Our assessment highlights the abundance of driftwood on Arctic coastlines and forms a baseline for exploring its temporal variability across large regions, its role in coastal erosion mitigation, and its importance as a carbon sink.

Hidden legacy carbon in high-elevation blockfields of the permafrost region

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Mountain permafrost degradation affects hydrological processes and surface kinematics. Yet, the implications for the soil organic carbon (SOC) cycle remain poorly understood, as these mainly unvegetated environments were assumed to be free of SOC. Meanwhile, the upward migration of alpine vegetation into current permafrost areas could reshape future carbon dynamics. To address this gap, we sampled five sites in the high-elevation permafrost region across the European Alps. Hidden beneath up to one metre of stones, a finer soil in vegetation-free blockfields contained surprisingly high SOC. We address two main research questions: Where does the SOC originate from? How will SOC dynamics change under future warming and greening trajectories?

At each site, we used isotopic, thermal, and fractionation methods combined with radiocarbon dating and reactive soil mineral analysis to assess the soil and C characteristic. SOC stocks, in-situ and incubation CO_2 fluxes, as well as radiocarbon signatures of microbially respired CO_2 were measured to gain insights into C dynamics. The soils contained SOC stocks of 0.8 to 1.1 kg C m^{-2}, with surface radiocarbon ages ranging from 800 to 4400 cal yr BP and aligning well with warm Holocene periods. The vast majority of SOC was mineral-associated and had low $\delta^{13}C$ and C:N ratios, typical for C originating from vegetation. Nearly all C was released below 600°C, excluding graphite as a major C source. Although C input by atmospheric deposition cannot be excluded, we interpret the soils in high-elevation blockfields as remnants of past vegetation that colonized these sites during warmer Holocene periods. Flux measurements revealed CO_2 emissions of pre-modern age, while sites with <5% vegetation cover released modern C. In combination with the unchanged SOC stocks between un- and sparsely vegetated sites, our data indicate a shift in C cycling but no accumulation in the soil.

Despite the limited contribution to overall SOC stock inventories, these hidden soils present an overlooked C reservoir in the mountain permafrost region. Their existence provides evidence for past colonization by vegetation, suggesting that this region has functioned as a C sink. Future studies should consider legacy C as well as new C inputs into high-elevation soils.

Earth Hummocks — Overlooked Players in Tundra Methane Cycling?

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Although widespread in tundra landscapes, cryopedogenetic pattern-ground features like earth hummocks are often neglected from arctic biogeochemical modeling, in order to avoid complexity. Consequently, their contribution to biogeochemical cycles and greenhouse gas fluxes are largely unknown. Based in the glacial valley Kuup Ilua in western Greenland, this study investigated the role of earth hummocks soils in methane (CH_4) cycling by comparing them to a tundra cryosol without frost pattern-ground features.

We combined in-situ greenhouse gas land-atmosphere flux measurements with physicochemical and molecular soil analyses. We assessed nutrient availability and water content of soils, and characterized the microbial community using 16S rRNA gene metabarcoding and pmoA-targeted qPCR to quantify key methanotrophs.

Flux measurements revealed that earth hummocks consistently acted as methane sinks, demonstrating significantly higher CH_4 uptake rates compared to the area cryosol without patterned-ground formation. The soils of the earth hummock have more favourable conditions for microbial communities, including greater nutrient availability. These findings were strongly supported by molecular data, as the earth hummock showed a significantly higher pmoA gene copy number and a greater relative abundance of known methanotrophic bacteria, confirming a larger and more active methanotrophic community within the hummock structure. We propose that cryogenic earth hummocks function as distinct biogeochemical hotspots rather than passive landscape features. Their special cryoturbated soil properties appear to enhance microbial habitat suitability, specifically favouring the abundance and activity of methanotrophic bacteria. Consequently, these hummocks serve as strong localized CH_4 sinks. We conclude that these cryopedogenetic patterned-ground features, which are widespread in periglacial tundra landscapes are overlooked players in tundra biogeochemistry and essential for accurately modeling the Arctic's role in the global greenhouse gas budget.

Ice-rich Yedoma deposits on Baldwin Peninsula: their degradation and stabilization in the past and present

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Ice-rich Yedoma Ice Complex (IC) deposits are widespread across the Arctic lowlands of northeastern Eurasia, Alaska, and northwestern Canada. An important feature of Yedoma deposits is their high content of the buried well-preserved organic matter (OM). Therefore, the high-resolution mapping of the Yedoma deposits provides a basemap for studying the Yedoma-landscape changes in the past and present, as well as for accurate estimation of OM stock and potential greenhouse gas emissions.

Baldwin Peninsula in northwestern Alaska represents one of the Yedoma distribution areas, formed by a complex sequence of marine, fluvial and glaciogenic mid-Pleistocene deposits overlain by Yedoma IC. During field campaigns in 2024 and 2025, we conducted cryolithological studies of exposed coastal outcrops, drilled boreholes, and conducted geomorphological field surveys and validation of satellite remote sensing (RS) data. Vegetation surveys were carried out to assess the variability of plant communities across the main landforms and to evaluate the stabilization role of vegetation in disturbed areas.

Based on high-resolution satellite RS and DEM data, our field observations, and historical report data, we mapped the distribution of Yedoma uplands across the Baldwin Peninsula (420 km^2) and conducted subsequent geomorphological analyses. Yedoma uplands are preserved in 36% of the Baldwin Peninsula. This indicates that approximately two-thirds of the original late Pleistocene Yedoma plain has been affected by thermokarst during the Holocene. The lake-area percentage within Yedoma uplands and alases is 1.1% and 8.8%, respectively. Lakes in alases represent residual water bodies, whereas lakes on Yedoma uplands mostly correspond to initial thermokarst lakes with potential for further expansion. Preserved Yedoma uplands are characterized by good drainage conditions, and their slopes are often covered by dense willow and alder shrubs, which likely protect Yedoma deposits from further degradation and act as a stabilizing factor.

The thickness of Yedoma IC exposed in coastal outcrops is about 10–15 m, whereas the thickness of Holocene alas deposits is 3–8 m. Radiocarbon dating of the upper part of the Yedoma IC indicates MIS 3 and older ages, while MIS 2 ages are rare. In contrast to other Yedoma regions such as northeastern Siberia, this pattern likely reflects the subsequent degradation of MIS 2 deposits on Baldwin Peninsula.

The current distribution of preserved Yedoma IC may therefore serve as a key to reconstructing the complex late Pleistocene history of the Baldwin Peninsula, highlighting both the formation and degradation dynamics of Yedoma deposits in the past and present.

Exhibition: Permafrost Matters

Leena-Kaisa Viitanen[1], Tina Schoolmeester[2], Anna Sinisalo[2], Björn Alfthan[2], Torjus Eckhoff[2], Michael Fritz[1], Tiina Kurvits[2], Hugues Lantuit[1], Frederieke Miesner[1], Oda Mulelid[2], Paul Overduin[1], Levi Westerveld[2]

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Across the Arctic, people rely on the permanently frozen ground for building their homes and roads on, to store their food in and to take part in traditional practices such as hunting and fishing.

With rising temperatures due to climate change, this permafrost ground is now gradually thawing, and undergoing dramatic transformations. These changes will not only impact the Arctic communities, infrastructure, livelihoods, and landscape processes – but they are also considered a major threat to global climate targets as the release of previously frozen organic carbon may push the global climate warming above the 1.5 °C targeted in the COP21 Paris Agreement.

Based on the Arctic Permafrost Atlas https://nunataryuk.org/news/atlas this exhibition tells the story of Arctic permafrost thaw and its impact on peoples ways of life as well as the ecosystems across the Arctic, and the implications it may have on the global warming. It showcases maps, graphics and illustrations from the Atlas, a key output of the international research project, funded by European Union Horizon 2020 (H2020) called NUNATARYUK (grant no. 773421) and supported by the International Arctic Science Committee (IASC).

The exhibition is composed of 17 posters: 15 with actual content + cover + intro. They can be exhibited all together or in pairs of text + image. Format varies. 4 panels are of A0 landscape, 9 panels of A1 portrait , and 4 panels are an elongated A0 landscape.

You can see the full exhibition online in here:

https://gridarendal-website-live.s3.amazonaws.com/production/documents/:s_document/1042/original/PermafrostMatters_lores.pdf?1697786017

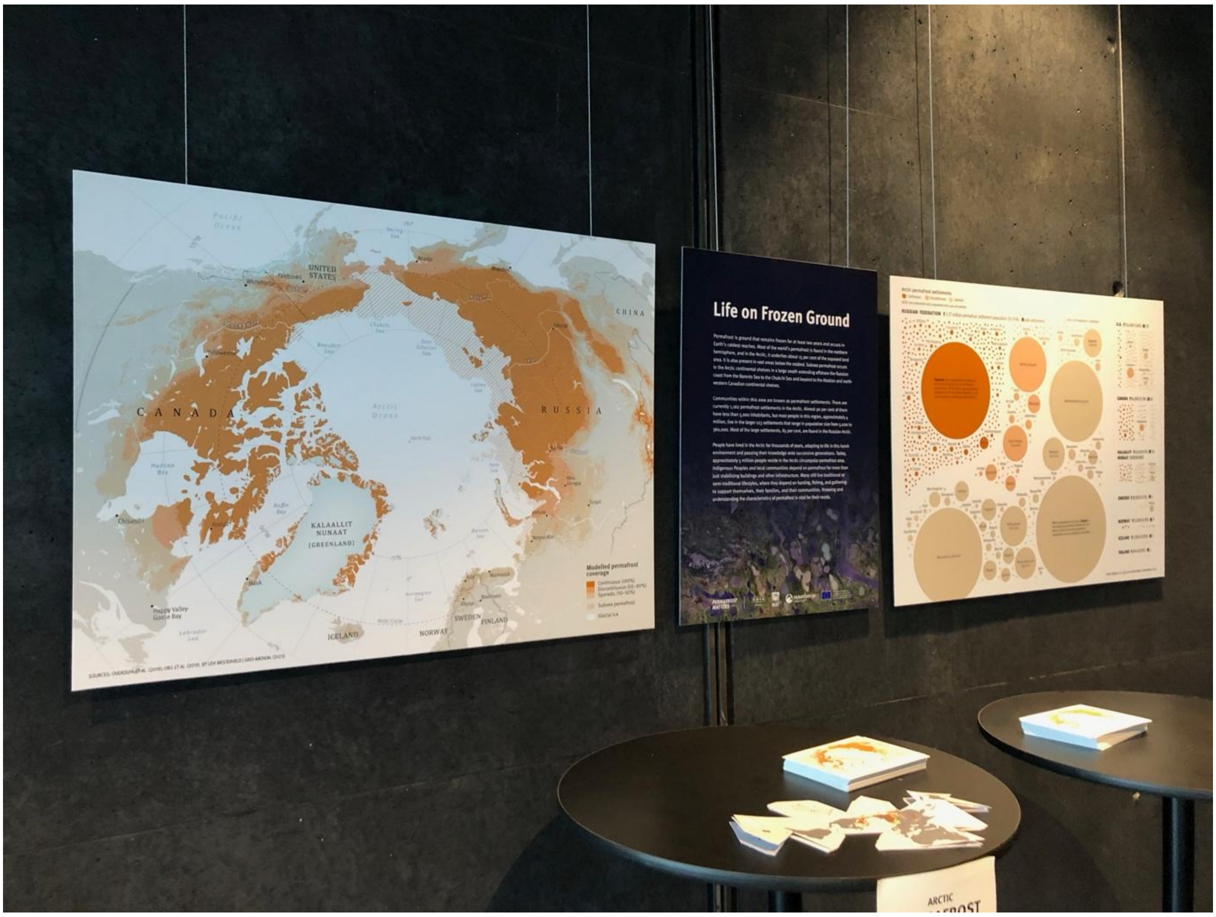

Figure: "Permafrost Matters" Exhibition panels at the launch of the Arctic Permafrost Atlas at the Arctic Circle Assembly in Reykjavik on 23 October 2023.

Effects of temperature and moisture on atmospheric methane oxidation in permafrost peatland and upland soils in the Finnish and Western Greenlandic Arctic

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Arctic wetlands are large sources of methane (CH_4) a strong greenhouse gas. However, the majority of the Arctic land area is covered by well-drained upland soils, which often are relatively small sources of CH_4. Commonly, these drier northern soils are CH_4 neutral or act as CH_4 sinks. A change in moisture conditions or temperature may alter the functioning of such typical upland soil CH_4 sinks, and shift landcover types from a net sink to a source. It is therefore important to understand the abiotic and biotic drivers regulating the magnitude of CH_4 uptake in arctic soils, in order to improve our understanding of arctic C budgets.

Here, we measured in situ CH_4 fluxes from upland soils and a palsa mire (permafrost peatland) near Kilpisjärvi in Finnish Lapland (68° 51' N, 21° 06' E), and from upland tundra on Disko Island, Greenland (69°16' N, 53°27' W). Fluxes were measured from different vegetation (shrub-dominated, lichen-dominated) and landcover types (palsa, upland forest, upland tundra) using manual chambers. Measurements were repeated within the same week with comparable soil moisture conditions but a 10°C difference in air temperature (at ca. 10°C and 20°C) to roughly assess the in situ temperature sensitivity of CH_4 fluxes. Surface soil samples (0–10 cm) were collected from all flux measurement locations, homogenized, and incubated in the laboratory under three temperatures (4°C, 10°C, 20°C) and three moisture treatments (20% water-holding capacity [WHC], field moisture, 60% WHC, 100% WHC).

All sites displayed net CH_4 uptake in situ, and CH_4 oxidation rates under field-moist conditions were largest in upland forest (-7.47 ng CH_4–C (gDW)$^{-1}$ h^{-1}, followed by palsa (-3.05 ng CH_4–C (gDW)$^{-1}$ h^{-1}) and upland tundra soils (-1.25 ng CH_4–C (gDW)$^{-1}$ h^{-1}). CH_4 oxidation was slightly larger when shrubs were absent (-4.43 ng CH_4–C (gDW)$^{-1}$ h^{-1}) than under dwarf shrub cover (-3.42 ng CH_4–C (gDW)$^{-1}$ h^{-1}). At the Finnish sites, oxidation rates did not significantly differ between temperature treatments, but the effect of soil moisture was pronounced, with the highest CH_4 oxidation under the 20% WHC treatment. In contrast, the Greenlandic sites exhibited a pronounced temperature dependency across all moisture treatments.

Our study shows that the response of high-affinity CH_4 oxidation to environmental variables is complex, and that arctic sites may respond differently to changes in temperature and moisture, depending on site conditions such as nutrient availability and soil pH, regulating the microbial community structure and functioning.

Piz Buin Pitschen: A deep-seated slope instability in bedrock permafrost

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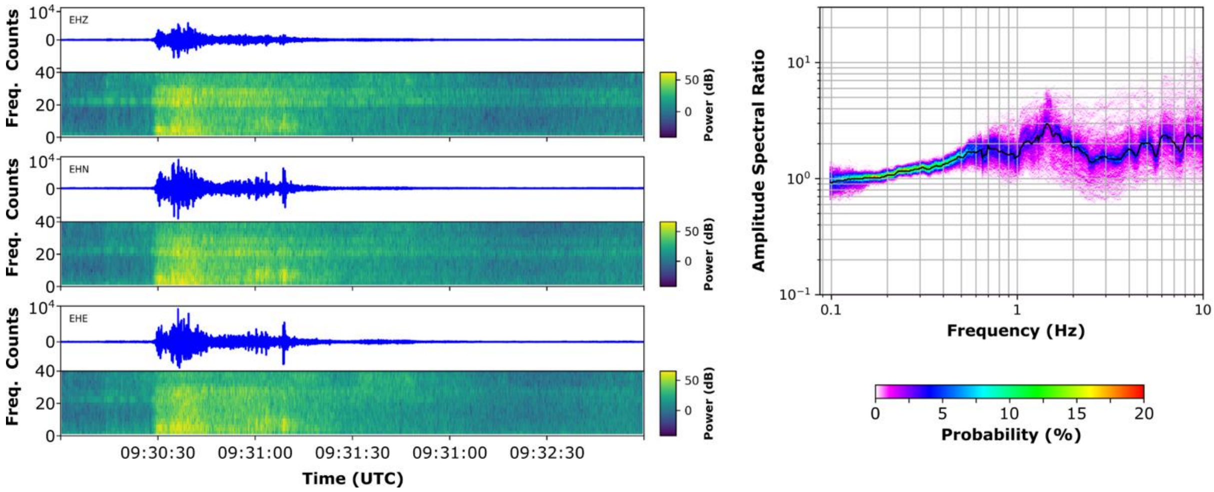
Piz Buin is an iconic peak of the Silvretta Range (Eastern Alps), straddling the Swiss-Austrian border. Its smaller neighbour, Piz Buin Pitschen (3,255 m asl), hosts a deep-seated slope instability within bedrock permafrost, first identified during a field inspection in July 2020. A strongly fractured and deformed rock mass, including an open crown fracture near the summit, indicates progressive destabilization with potential for a large-scale failure. Such an event could pose various hazards, particularly given the proximity of the popular climbing route to the Grossen Piz Buin (3,312 m asl), which passes nearby via the Ochsentaler Glacier.

Destabilization in failure-prone permafrost rock slopes is expected to intensify with ongoing climate change, as warming leads to ice loss and increased water infiltration. Thus, rock slope displacements and failures can become more frequent, especially in the case of water-sensitive predispositions. However, forecasting the timing and magnitude of catastrophic failures remains challenging. Early identification and multi-sensor monitoring are therefore essential for risk assessment and mitigation.

At Piz Buin Pitschen, we apply a multi-scale, multi-sensor approach that integrates (i) historical and crowdsourced image analysis to detect long-term surface changes, (ii) yearly drone-based photogrammetry for high-resolution mapping, displacement and mass loss measurement based on derived DSMs, (iii) periodic ground-based radar interferometry for velocity monitoring, (iv) continuous seismic measurements for rockfall detection and structural characterization, (v) ground temperature time series to assess permafrost conditions, and (vi) geological and numerical modelling to explore potential failure scenarios.

Year-round seismic and temperature monitoring reveal rockfall activity. Seismic events are recorded throughout the year, with a slightly increased rate between July and September. Distinct seismic responses to individual rockfall events confirm the sensitivity of the system to near-surface processes. In parallel, ambient seismic vibration analyses provide complementary insights into the slope's structural integrity and dynamic response. This technique quantifies local seismic amplification from site and topographic effects, and, when combined with further data (temperature, rainfall, snowmelt, or earthquakes), helps to identify critical constellations potentially leading to slope failure.

Ongoing monitoring and modelling at Piz Buin Pitschen enhance understanding of deep-seated permafrost instabilities and evaluate the performance of different observation techniques. The integrated application of geophysical, geodetic, and thermal data represents a methodological advance, offering a comprehensive characterization of subsurface and surface processes. As one of the few sites worldwide with extensive pre-failure datasets, Piz Buin Pitschen provides a unique natural laboratory to advance quantifying and anticipating climate-driven rock slope instabilities.



The hidden potential of Active-layer Detachments? Biogeochemistry of Active-layer Detachment Failures on Qikiqtaruk, Canada

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Permafrost is degrading at an unprecedented speed, especially ice rich permafrost regions. One of those is Qikiqtaruk (Herschel Island), a glacial ice-thrust remnant with an area of approximately 100 km2, mainly composed of shallow-water and marine sediments overlying ice-rich continuous permafrost. These conditions are ideal for numerous active-layer detachment slides and retrogressive thaw slumps on the island, most of which are influenced and triggered by coastal erosion. In recent years, annual mean temperatures have risen due to anthropogenic climate change. Over the past 76 years, Canada's warmest periods were 1949, 2021, and 2024, with the summer of 1949 being the hottest on record. June 2021 saw the country's all-time high of 46.2°C in Kamloops, and July 2024 was the warmest July since 1949. Recent years, including 2024–2025, have also been unusually warm and dry, approaching historical records. This has resulted in frequent active layer detachments, with an increasing number of slides triggered in recent years.

Within the scope of this study, we aim to test the hypothesis that permafrost degradation followed by terrain disturbance causes changes in surface dynamics and conditions, influencing the biodiversity of Qikiqtaruk and carbon cycling. In more detail, we aim to determine the active layer detachment's potential for greenhouse gas emissions and to estimate decomposition rates. Therefore, we analyse the biogeochemistry of active layer detachments. Sediment samples were collected from four different locations on the island at various depths within the active layer. Laboratory analyses include (1) Grain size distribution, (2) elemental composition (C, N, Hg), (3) stable carbon isotopes ($\delta^{13}C$) and lipid biomarker composition (alkanes, fatty acids, alcohols).

This study provides initial insights into the biogeochemistry of active layer detachment-affected soils, allowing a first assessment of changing soil parameters and emissions.

Investigating snowmelt infiltration into tundra soils on Qeqertarsuaq (Disko Island), Greenland

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While snow is the primary source of surface water in the Arctic, few studies have investigated how much snow melt is able to infiltrate into soils during the melt season. To address this knowledge gap, we collected vertical soil cores in two years at Blæsedalen, Qeqertarsuaq (Disko Island), Greenland from 14 sites varying in soil properties, snow depth, and landscape position. Soil cores were collected in 2024 before the onset of snowmelt (mid-April), mid-snowmelt (mid-May), and directly after snowmelt (early June), while soil cores in 2025 were collected before snowmelt (early April) and a few weeks after snowmelt (late June) Soil cores were separated into sections, after which we measured bulk density, gravimetric water content (GWC), organic content, and the water isotope composition of the soil water of each soil core section. Water isotope composition was also measured for vertically-integrated snowpack samples at each sampling location, so that we could attribute any changes in soil moisture to infiltrating snowmelt runoff. Post-snowmelt cores were separated into frozen and unfrozen sections.

The GWC varied from 0.25 – 43 among soil core sections, reflecting differences between dense loamy soils with little organic material and porous, saturated peat. After snowmelt, soil water in the top 0 – 20 cm of the soil column experienced a significant shift towards the isotope composition of snow, regardless of whether the soil was frozen or not. Interestingly, frozen soils from the top 20 cm of the soil column experienced a larger increase in GWC than unfrozen soils, suggesting that frozen soils did not hinder the ability of snowmelt to infiltrate into soil. Below 20 centimetres in the soil column, no significant changes in water isotope composition or GWC were observed. Soils with lower bulk densities also tended to see greater increases in GWC, however denser soils tended to have higher pre-snowmelt GWC. We also observed no clear link between the snow water equivalent of the overlying snowpack and the increase in GWC after snowmelt.

The presence of ice on the soil surface at some pre-snowmelt sampling locations in 2025 and occurrence of mid-winter above-zero air temperatures suggests that mid-winter snowmelt occurs at this location. As the climate continues to warm, more of the Arctic will be exposed to mid-winter snowmelt, which could affect snowmelt runoff dynamics and soil heat fluxes as more saturated frozen soils shift to be more thermally conductive but also increase in their heat capacity.

Meeting Community Needs: Adapting Subarctic Land Use to Climate and Economic Challenges

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Research in remote communities is undoubtedly interwoven with local and regional rightsholders. As in politics, this poses an irrefutable need for participation, especially of indigenous communities, in research implementation, and ideally research design. Research results, which's implementation into active land use practices might intercept or alter traditional land use practices, therefore should not be implemented without communities' participation. A potential pathway for such implementations is outlined here for a project affecting both permafrost and more general environment stability as well as traditional reindeer herding practices. A pilot project was developed with local herders to assess the options for altering reindeer herding strategies to a more climate change-adapted format while simultaneously stabilising local permafrost conditions. This poster reports on the project itself, to install supplementary winter-feeding sites atop of thaw-threatened palsas, as well as on the project design process and the communication pathways behind the project.

Drained lake systems on the Baldwin Peninsula, W Alaska: Sedimentary conditions and organic matter properties

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Drained lake basins dominate large parts of lowland Arctic Alaska, where thaw of ice-rich permafrost is changing surface hydrology patterns and leading to both thermokarst lake formation and lake drainage. The Baldwin Peninsula in western Alaska has abundant thermokarst lakes and drained lake basins, with drained lake area generally dominating over lake area. These lake and drained lake basin systems are highly dynamic, and often create a mosaic of shallow topographic depressions with increased surface water retention and wetland formation. In fact, many basins develop into peat-forming wetlands following lake drainage. In addition, ice-wedge polygon networks frequently develop in these drained lakes. In Arctic lowlands with ice-rich permafrost, cryoturbation, thermokarst-induced sediment disturbances and mass wasting processes in general can make sediment-based palaeoreconstructions challenging. Therefore, the often relatively undisturbed peat sequences from the centres of ice-wedge polygons can be highly valuable palaeo-archives, particularly for Holocene time scales. Similarly, the centres of drained lake basins have less disturbed sediment than their marginal parts. We targeted peat from drained lake basins as archives to infer past environmental and landscape dynamics as well as vegetation composition and organic matter storage and decomposition in this highly dynamic region of the Arctic.

During field work in April 2024, sediment cores were obtained from the upper 2-2.5 m of frozen ground in the centres of fifteen drained lake basins. Coring site selection in the field targeted the centres of ice-wedge polygons, which have been shown to have the least disturbed sedimentation and peat growth within ice-wedge terrain. Here we present the first results of sediment and organic matter composition. For the first eight cores, sediment core logs, elemental contents and composition of carbon, nitrogen and mercury as well as grain size distribution provide an insight into the palaeoenvironment before and after lake drainage. In at least two of the basins, there is initial evidence that the cores capture an entire life cycle of a thermokarst lake from lake inception to drainage followed by wetland initiation. These palaeoarchives provide a unique view into one of the most common and dynamic landforms of permafrost lowlands relevant for past, current, and future carbon cycling and sequestration.

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