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Arctic Land Expeditions in Permafrost Research

The MOMENT project:
Expedition to the Arctic Station, Qeqertarsuaq, Disko Island and Ilulissat, West Greenland in 2022

Edited by

Julia Boike, Simone M. Stuenzi, Jannika Gottuk,
Niko Bornemann, Brian Groenke

HELMHOLTZ

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Titel: Malerischer Blick nach Norden während sich die Wolken über Kuup Ilua (Blaesedalen-Tal) auf Disko zusammenziehen, September 2022 (Foto: Simone M. Stuenzi, AWI)

Cover: Scenic view to the north as the clouds gather over Kuup Ilua (Blæsedalen Valley) on Disko, September 2022 (Photo: Simone M. Stuenzi, AWI)

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19 August - 20 September 2022

Alfred Wegener Institute

Helmholtz Centre for Polar and Marine Research Potsdam

Edited by

Julia Boike, Simone M. Stuenzi, Jannika Gottuk,
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HELMHOLTZ

MOMENT

GEFÖRDERT VOM

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Contents

1 Objective

This report describes the AWI Permafrost MOMENT 2022 expedition to Disko Island and Ilulissat (West Greenland), which took place during August and September 2022. The expedition took place in preparation for the larger project MOMENT (Permafrost Research Towards Integrated Observation and Modelling of the Methane Budget of Ecosystems), which is funded by the German Federal Ministry of Education and Research (BMBF) and runs for three years, from November 2022 to October 2025. The project is led by the University of Hamburg under the coordination of Christian Beer, and partners with researchers at the German Research Centre for Geosciences (GFZ), the Leibniz Universität Hannover, the Max Planck Institute for Biogeochemistry (MPI-BGC), the Max Planck Institute for Meteorology (MPI-M), Universität Hamburg (UHH), the University of Cologne (UzK), the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI). The project aims to close important gaps in the process of understanding the methane cycle in northern latitudes using innovative laboratory studies and multi-scale methane flux observations based on state-of-the-art infrastructure.

The fieldwork described in this report was conducted by the AWI team, consisting of Prof. Dr Julia Boike, Dr Simone M. Stuenzi, Jannika Gottuk, Niko Bornemann, and Brian Groenke (Fig. 1). Our exploratory fieldwork at both sites involved vegetation, soil, and water surveys and sampling, along with mobile albedo measurements.

In the Blæsedalen Valley on Disko Island, we installed automated temperature and soil moisture sensors. In Ilulissat, we anchored "subsidence sticks" deeper into the permafrost for future observations of surface lowering due to permafrost ice melt. Additionally, we learned about infrastructure-related challenges, such as new airport construction and road failures.

Figure 1: Group photo with collaborators near Ilulissat. From left to right, back: Simone M. Stuenzi and Brian Groenke, front: Niko Bornemann, Jannika Gottuk, Torsten Sachs (GFZ), Thomas Ingeman-Nielsen (Technical University of Denmark, DTU).

2 Campaign Overview

2.1 Introduction

The campaign was separated into two parts, one of which took place around Ilulissat and the second one in the Blæsedalen Valley on Disko Island, close to the town of Qeqertarsuaq (Tab.1).

Table 1: Campaign overview.

Name	GL-Land_2022_Moment
Expedition to	Arctic station, Qeqertarsuaq, Disko Island and Ilulissat, West Greenland
Duration	August 19 – September 14, 2022
Field days	15
Field station	Arctic Station
Science	Julia Boike, Simone M. Stuenzi, Jannika Gottuk, Niko Bornemann, Brian Groenke, Lars Kutzbach, Thomas Ingeman-Nielsen, Bo Elberling, Torsten Sachs
Project	BMBF WTZ MOMENT (Permafrost Research Towards Integrated Observation and Modelling of the Methane Budget of Ecosystems)
Primary study sites	Blæsedalen Valley, Disko Island and Ilulissat
Keywords	Expedition report, Greenland, Disko Island, Ilulissat, Permafrost

2.2 Project description

Permafrost regions are a central element in our climate system - the soils of these regions store large amounts of organic carbon, most of which has so far been stored in permanently frozen soil. Due to the currently observed above-average warming, the permafrost soils are thawing deeper, and the previously stored carbon can be broken down by microorganisms into the greenhouse gases methane (CH_4) and carbon dioxide (CO_2). Reliable forecasts of the future development of the permafrost system and its contribution to the global carbon budget are therefore of great importance. For their preparation, a comprehensive qualitative and quantitative understanding of the processes of the CH_4 cycle in permafrost regions is essential. The project MOMENT will close important gaps through innovative laboratory studies and multi-scale methane flux observations based on state-of-the-art infrastructure. For this purpose, investigations of the recent carbon cycle in West Greenland will be carried out. The overall goal is to reduce uncertainties in future greenhouse gas projections.

MOMENT is divided into four sub-projects:

- Sub-project 1: Scientific and technical coordination (Subproject lead: Christian Beer, Universität Hamburg)
- Sub-project 2: Process studies on methane production and oxidation (from micro to pedon scale) (Subproject lead: Susanne Liebner, German Research Centre for Geosciences)
- Sub-project 3: Effects of permafrost degradation and aggradation on CH4 fluxes in heterogeneous tundra landscapes (from pedon to landscape) (Subproject lead: Lars Kutzbach, Universität Hamburg)
- Sub-project 4: Modelling analysis of spatial heterogeneity and temporal variability of permafrost landscapes and their greenhouse gas fluxes (Subproject lead: Victor Brovkin, Max Planck Institute for Meteorology, Hamburg)

Sub-projects 2 and 3 conduct fieldwork in West Greenland. Prof. Dr. Julia Boike is a collaborator within sub-project 3. The goal is (1) the preliminary exploration of the field sites in the Blæsedalen Valley on Disko with soil descriptions and soil sample collection, (2) the determination of the joint investigation sites for CH_4 flux measurements and soil control factors, (3) the initialization of data collection on the spatial variability of snow properties and soil control factors. Furthermore, the group conducted exploratory fieldwork around Ilulissat in collaboration with Prof. Dr. T. Ingeman-Nielsen (DTU).

2.3 Acknowledgement

We acknowledge that we were able to conduct fieldwork on the ancestral land of the People of *Kalaallit Nunaat*, past and present and honour with appreciation the land itself and the *Kalaallit* People.

3 Blæsedalen Valley, Qeqertarsuaq, Disko Island

3.1 Introduction

The main study site during this fieldwork campaign was located in the Blæsedalen Valley on Disko Island (Fig. 2). We installed automated temperature and soil moisture sensors in plots defined by vegetation units along two transects (Fig. 3 and 4), collected soil and water samples, described the vegetation composition and height, conducted drone surveys, measured land surface albedo, and recorded temperature profiles using a so-called thermal lance.

3.2 Study area

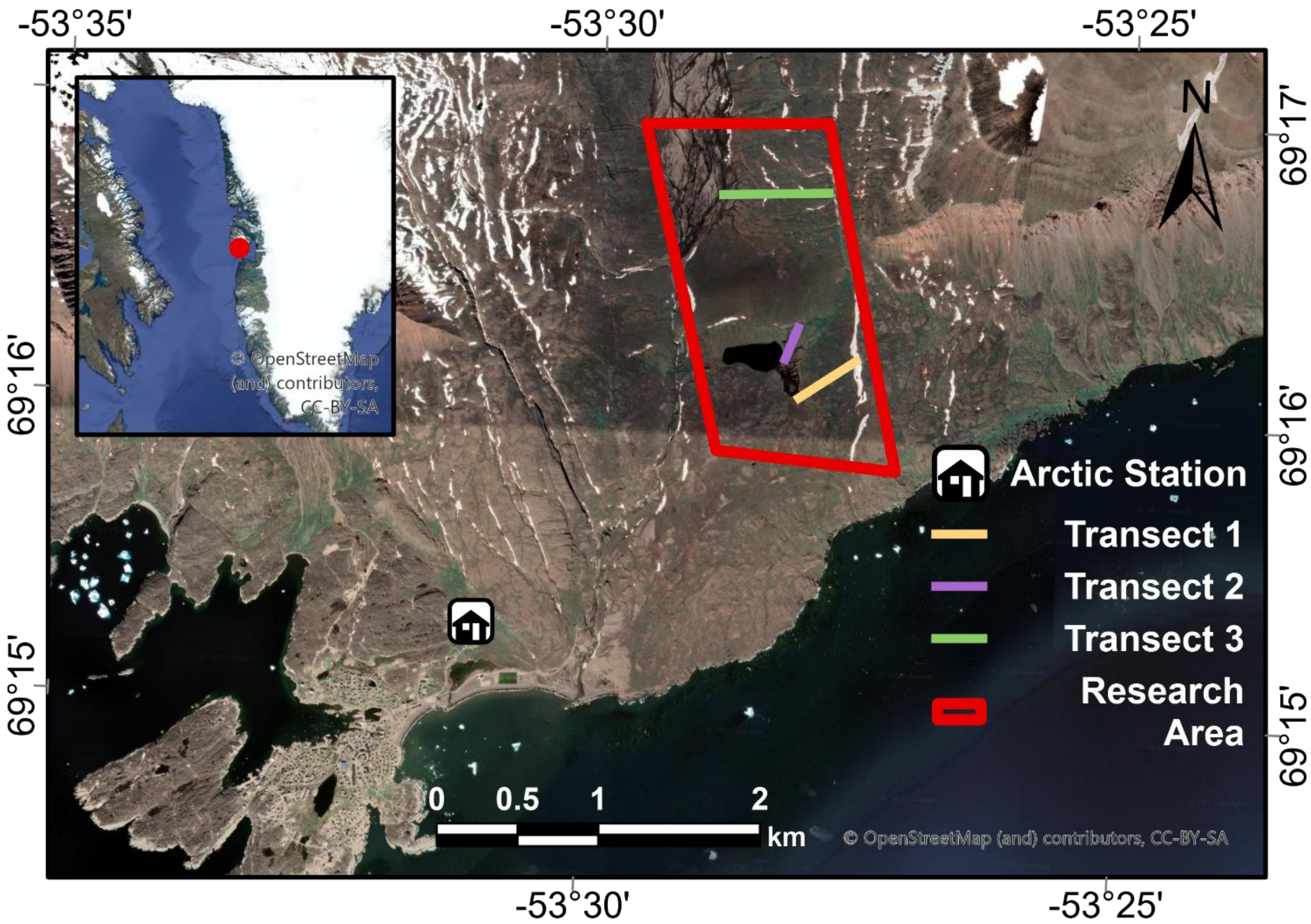

Figure 2: Study site overview of Disko island. The inset map in the top left corner shows the location of Disko Island in Greenland. The satellite image shows the Blaesedalen research area with the three transects which are being sampled and worked on within the framework of the MOMENT project. To the left, the location of the Arctic Station research station (https://arktiskstation.ku.dk/english/) is visible. Map data © Google Earth, OpenStreetMap and contributors (2023).

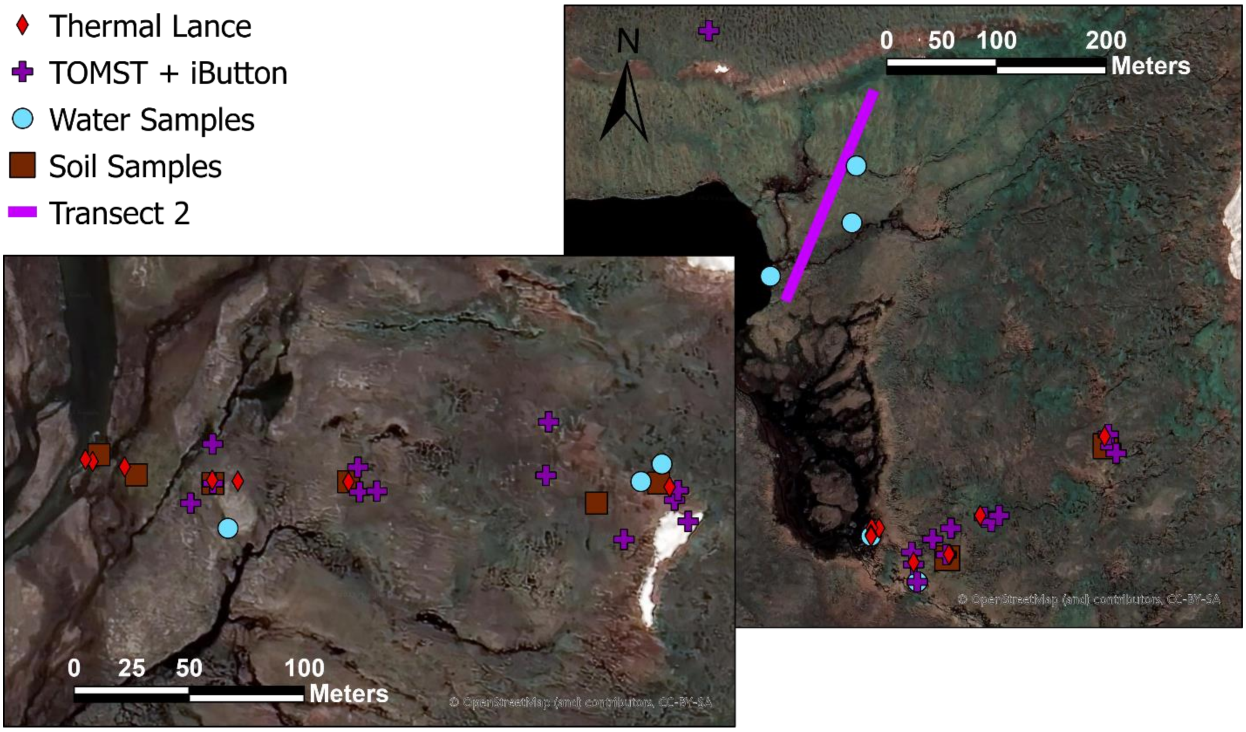

Figure 3: Location of sites where we extracted water and soil samples at transect 3 (left) and at transect 1 and 2 and on the moraine (right) during the September 2022 field campaign. We installed Temperature-Soil-Moisture-Sensor-4 - TMS-4 (TOMST) loggers for continuous automated temperature measurements in the upper soil (at 6 cm depth), at the ground surface (2 cm depth), and air temperature at 15 cm above the ground, and continuous automated soil moisture measurements in the upper soil. Each TOMST was equipped with an iButton, a sensor recording the soil temperature at 2-3 cm depth.). For discrete, and deeper temperature measurements we carried out “Thermal lance” measurements at selected sites. Map data © Google Earth, OpenStreetMap and contributors (2023).

Figure 4: Landscape photographs of two of the transects in the Blaesedalen Valley on Disko Island. Transect 1 on September 8, 2022 (left) and transect 3 on August 25, 2022 (right).

3.3 Soil and snow cover instrumentation

At transects 1, 3, and on the moraine, we installed a total of 28 Temperature-Soil-Moisture-Sensor-4 (hereafter called TOMST) sensors (Wild et al., 2019). TOMST are standalone loggers which record air and soil temperature at three depths (-6, +2 and +15cm) with a resolution of 0.0625 °C and with an accuracy of ±0.5 °C (±0.3 °C after 0°C ice bath calibration) and soil moisture at one depth (Wild et al. 2019) (Fig. 5). At each TOMST profile, we installed an additional iButton sensor (MAXIM integrated), a standalone sensor for soil temperature recordings (accuracy of ±0.35 °C after 0°C ice bath calibration), 2-3 cm below the surface. For sensor installation, we separated the transects into distinct landcover units. The landcover units are based on the vegetation composition and vegetation heights. We installed three senor units per landcover unit. At each plot, soil pits were dug and time-domain reflectometer (TDR, HydroSense II, Campbell Scientific Ltd.) measurements were taken to indirectly assess the soil moisture content based on the travel time of a high-frequency electromagnetic pulse through the soil.

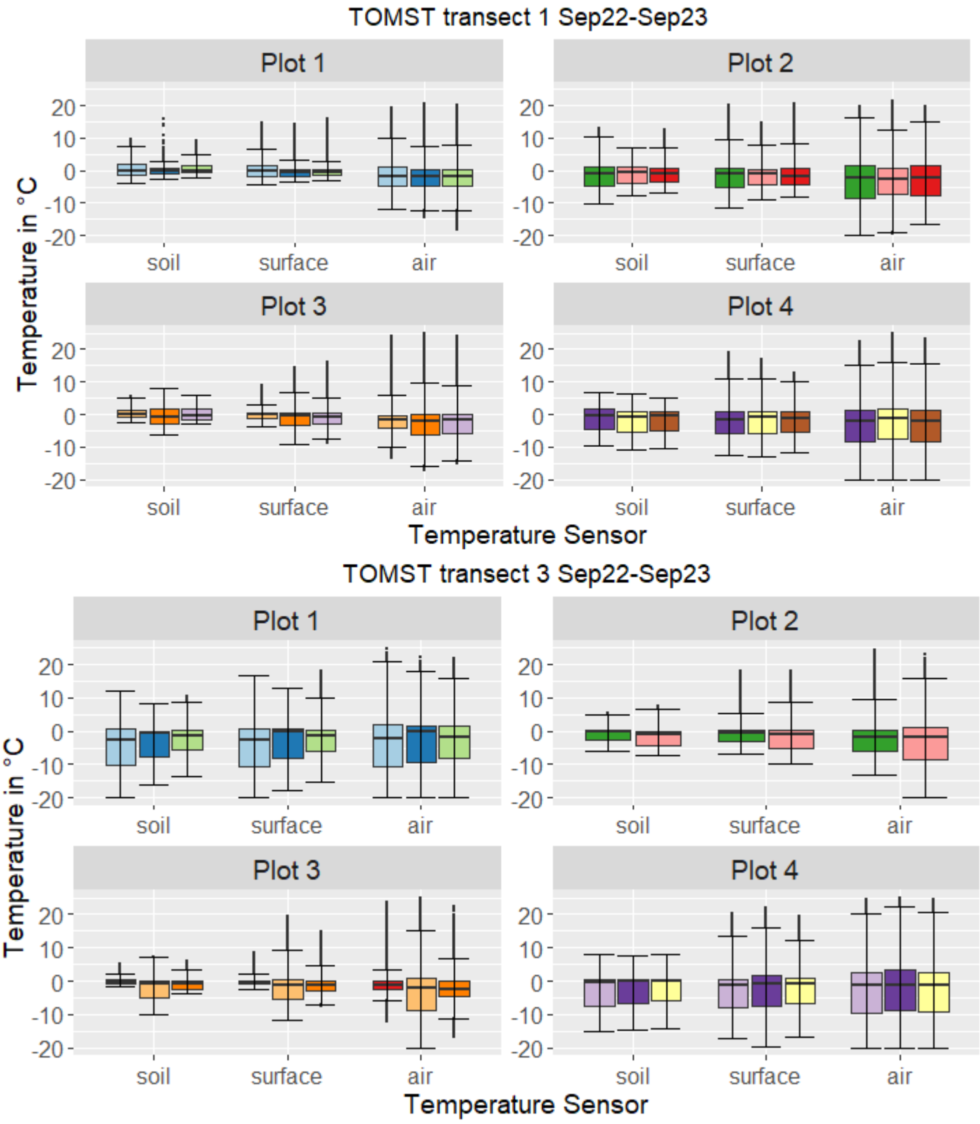

Figure 5: Boxplot of the three measured temperatures (soil, surface, and air) of each TOMST logger at transect 1 (top) and transect 3 (bottom) for the period from September 2022 to September 2023. The same colors within the plots indicate the same TOMST sensor per transect.

In each vegetation unit, 2 soil samples were taken in varying depths between 2 to 7 and 19 to 24 cm depth. The samples were analyzed for grain size, and carbon and nitrogen content.

Additionally, snow depth measurements were planned to be conducted manually by Juliane Mølgaard in March 2023. Three to four snow depth measurements at each TOMST sensor location complement the TOMST data set.

3.3.1 Bulk Soil Sampling

We collected bulk samples at transect 3 and south of the Lyngmarks Glacier and soil tin can samples at transects 1 and 3. All sampled profiles did not show signs of cryoturbation. The samples were analyzed for grain size and carbon and nitrogen in the lab.

3.4 Water sampling

We collected ten water samples from surface streams in the Blæsedalen Valley, the stream (also used for drinking water) next to the Arctic station and the exceptionally high precipitation event (rainfall) on September 11, 2022. The stream samples were taken in the middle of the running stream water in 250 ml sterile bags. Samples were frozen right after sampling and kept frozen until analysis in January 2023. Samples were filtered through 0.22-micrometer sterile filters and water were analysed for major cations and ions, Dissolved Organic Carbon (DOC), and stable water isotope (Table 2 in appendix).

3.5 Albedo measurements

We measured albedo with a portable Albedometer that measured GPS, incoming and outgoing shortwave radiation with a global navigation satellite system (GNSS) module and two SRA01 Hukseflux second-class pyranometers, classified with the third highest accuracy in the ISO 9060 - 1990 standard (Fig. 6). In total, 1434 measurements at 170 data points were collected along and outside the transects 1 and 3 (Table 3 in appendix). The field data showed noticeable differences between surface characteristics, vegetation compositions and cloudiness with albedo ranging from 0.05 to 0.28. Black, bare soil, dark stones, and patches with surface water had albedos < 0.1. Areas dominated by pale vegetation, such as mosses, lichens, *Equisetum* spec., and *Salix glauca* showed the highest albedo values (> 0.2) (Fig. 7). Mean albedo, incoming and outgoing shortwave radiation was higher on the cloudless day.

Figure 6: Albedo measurement at transect 3, August 30, 2022.

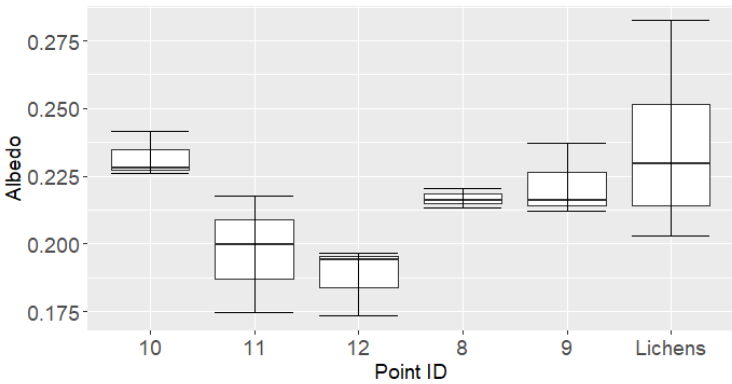

Figure 7: Measured albedo at points close to location in Figure 6, August 30, 2022.

3.6 Vegetation description

We described vegetation cover in a 1x1 m plot around the TOMST and iButton sensors to understand the land cover diversity (see Fig. 8). We recorded vegetation height at 4 points within each plot following the standardized permafrost monitoring protocol (Boike et al. 2021). Additionally, we recorded the cover percentage per common vegetation type. The vegetation in Blæsedalen is dominated by moss, *Salix glauca*, *Betula nana*, *Equisetum*, lichens and sedges with varying species composition (Figure 8). The vegetation height is below 30 cm in most areas, but *Salix* shrubs exceed 50 cm in vegetation unit 3 in transect 1.

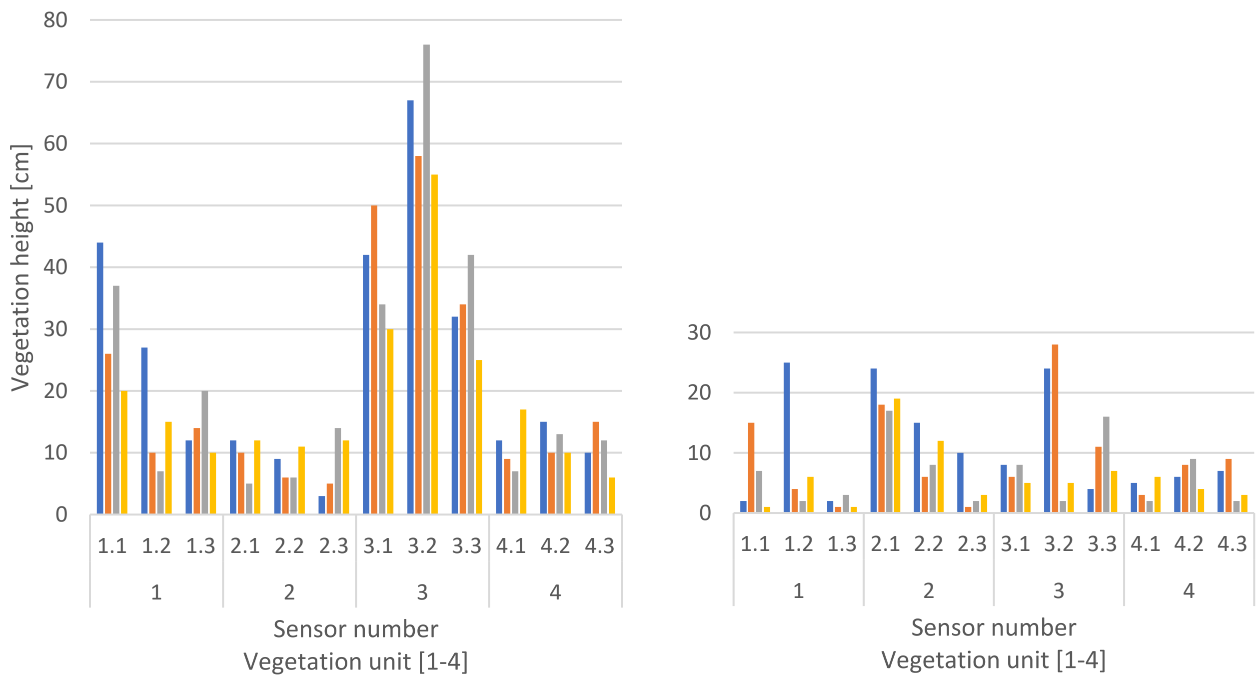

Figure 8: Vegetation height measurements at transect 1 (left) and transect 3 (right). The colors represent the four measurements following the standardized permafrost monitoring protocol (Boike et al. 2021).

3.7 Drone survey

We recorded drone images around transect 1 (September 8, 2022) and 3 (September 7, 2022) using a DJI Mini 2 drone, and collecting a little over 11 MB of imagery (Fig. 9). We further use the imagery to illustrate the area and create a background map and orthoimages (Fig. 10). They allow for comprehensive documentation of the study sites, including topographic features, vegetation, and surface hydrology. Furthermore, the aerial images provide a valuable basis for mapping the study areas. The collected data can help identify patterns, test hypotheses, and gain new insights.

Figure 9: Drone surveying at transect 1, September 8, 2022, with a ground control point (GCP) mat to the right.

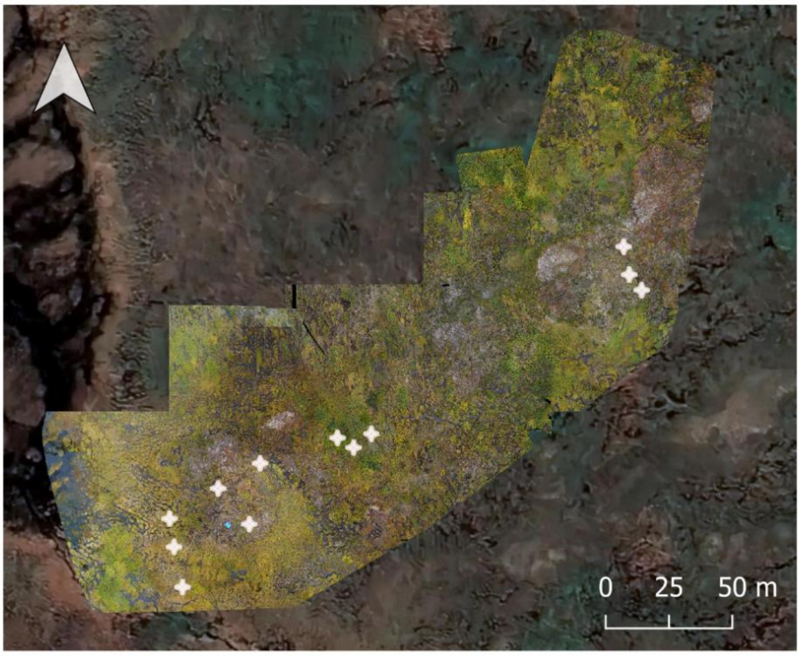

Figure 10: Orthomosaic of transect 1. The location of the TOMST-TMS-4 sensors are marked with white crosses. Map data © 2015 Google and contributors.

3.8 Thermal Lance

See chapter 4.3. for information on the use of the thermal lance.

In total, we conducted 18 measurements, of which nine were located at transect 1, seven at transect 3 and 2 at the Arctic Station.

4 Ilulissat, West Greenland

4.1 Introduction

We additionally worked at a study region in the proximity of Ilulissat on mainland Greenland (Fig. 11 and 12). We conducted active layer thaw depth measurements at the Ilulissat CALM site (by T. Ingeman-Nielsen, DTU, coordinates in table 4 in appendix) and started T-MOSAIC recordings (vegetation cover, soil pit, photographs, active layer measurements). Thanks to collaborator T. Ingeman-Nielsen we were able to visit several permafrost sites around Ilulissat measuring permafrost temperatures in boreholes. We installed a total of 46 "subsidence rods" to record how much the ice-rich permafrost sinks in the following years.

4.2 Study **area**

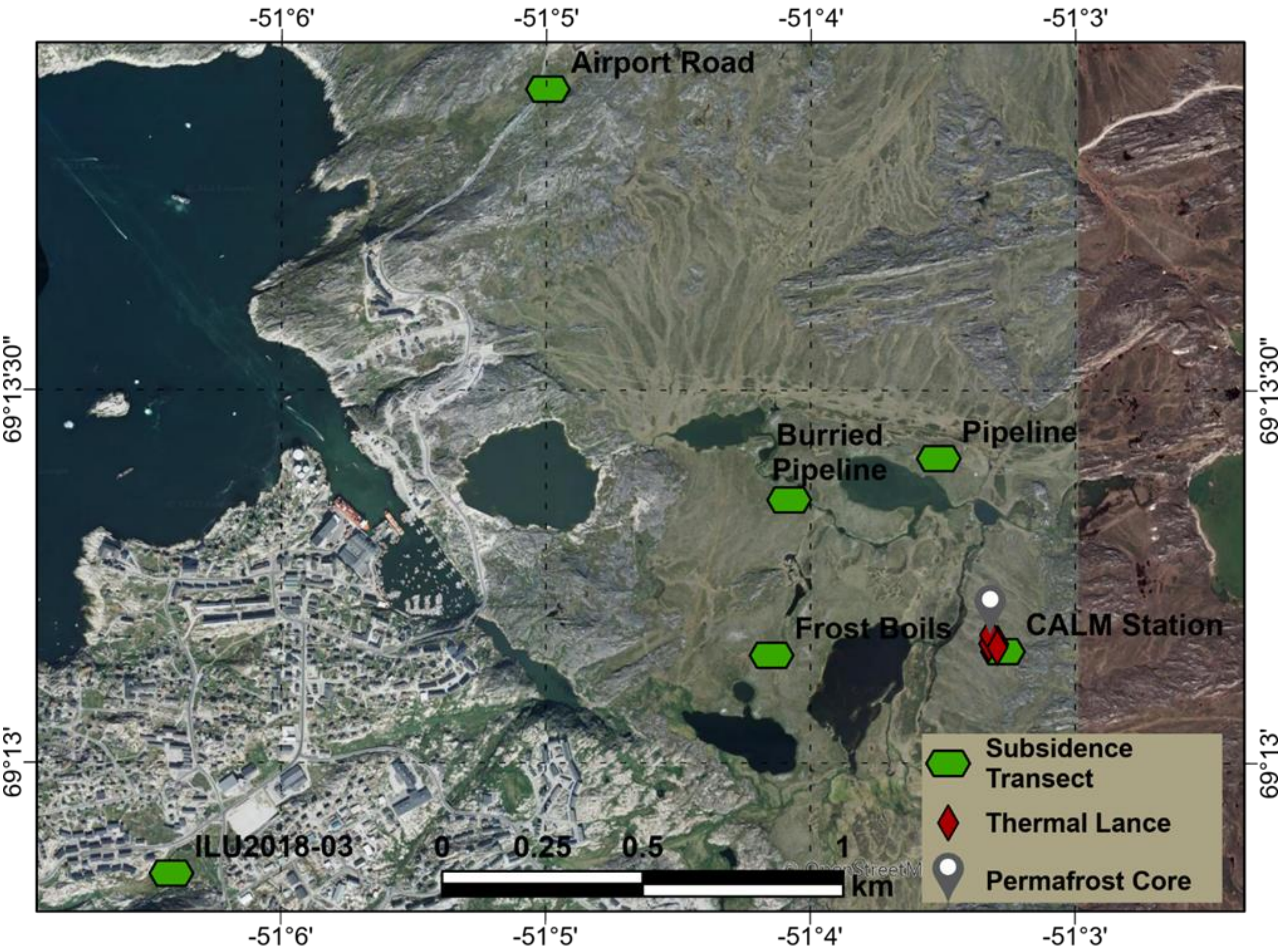

Figure 11: Overview of sampling locations around Ilulissat. We installed subsidence sticks along 6 transects. At the Circumpolar Active Layer Monitoring (CALM) site, we completed 5 temperature measurements using the “thermal lance” and drilled one permafrost core. Map data © Google Earth, OpenStreetMap and contributors (2023).

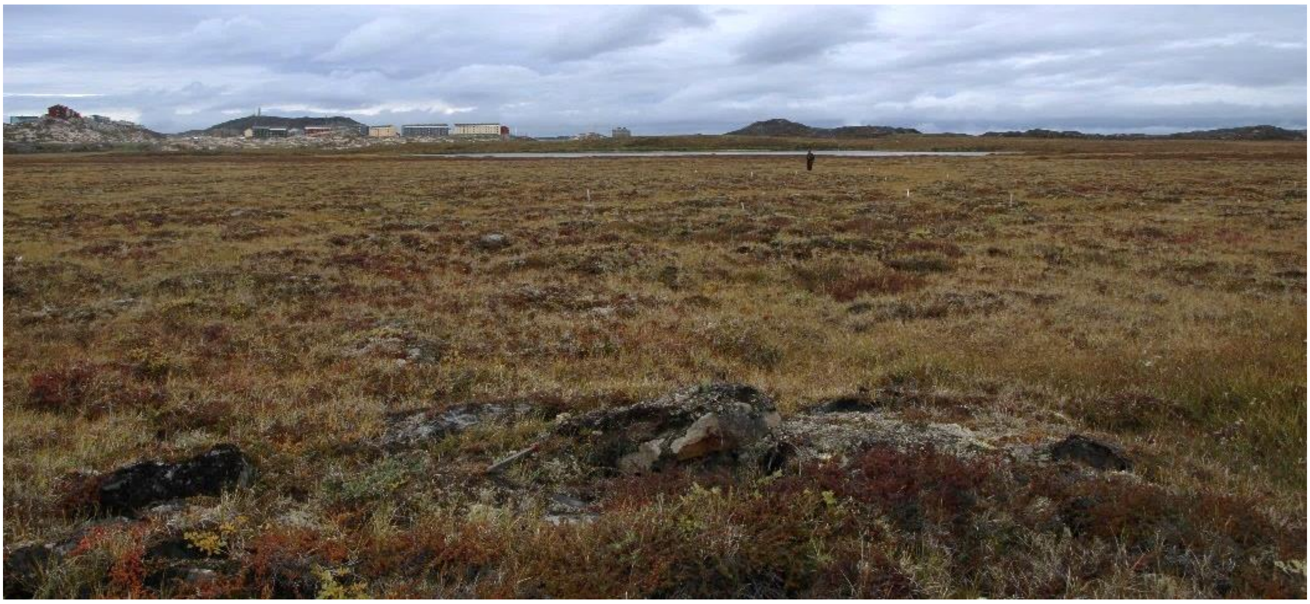

Figure 12: Landscape photograph of the CALM site east of Ilulissat on September 2, 2022. The flat study site with lakes that serve for drinking water is covered by heath vegetation and surrounded by rock outcrops. Ilulissat is visible in the background.

4.3 Thermal lance

We measured ground temperature at depths ranging from 50 to 150 cm at each transect point as well as at other locations of interest using the “thermal lance”. The thermal lance is a 1.5 m stainless steel probe with 30 digital temperature sensors and 2 accelerometers designed by

Figure 13: Thermal lance after being installed near the Ilulissat meteorological station on the CALM site. The battery powered drill can be seen lying behind and to the right of the lance. Here we used an active layer probe to make the lance flush with the side of the side of the drilled hole. The box hanging from the active layer probe is the portable data logger.

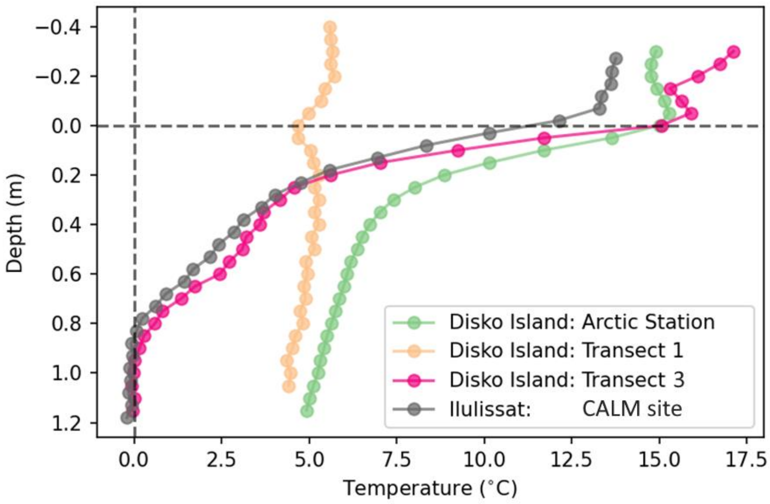

Figure 14: Temperature profiles measured by the thermal lance at selected locations. Note that at both transect 3 and the CALM site, thaw depth is estimated to be around 80-90 cm which is generally consistent with active layer probe measurements. The dotted horizontal lines represent the estimated depth offset, i.e. the first sensor below the surface. Sensors above this point are generally exposed to the air and therefore subject to advective variation.

William Cable (Miesner et al. 2023) (Fig. 13). The depth to which we were able to install the lance varied widely depending on the ground material at each location (Fig. 14). To insert the lance into the ground, we drilled a hole using a battery-powered drill. Areas with large amounts of rock or sticky, clay-like material typically prohibited drilling to depths deeper than 50-70 cm. The equilibration time of the temperature measurements as estimated by the data logger software generally ranged from 15-30 minutes. Ideally, temperature variations between subsequent measurements should be < 0.01 K before removing the lance. At some locations, this equilibrium was not reached and the probe had to be removed. In some cases, we left the probe in the ground for longer (hours or even days) to obtain more accurate temperature profiles.

4.4 Surface subsidence

Fiberglass rods were installed to measure surface subsidence (Fig. 15). The 45 fiberglass rods (length 2.0 m, diameter 1.0 cm) were installed at 6 different locations (Table 4 in appendix).. We drilled holes using a battery-powered drill to the maximum extent of drill rods (1.2-1.3 m) to reach at least 15-20 centimeter below the seasonally thawed ground. Four localities were within the water protection zone east of Ilulissat, while the two others were in the town. A location table is in the appendix.

The collected measurements will complement the continuously collected CALM active layer measurements and climate station data around Ilulissat (by DTU).

With an extended corer, holes were cored to install the rods below the frost table for future quantification of subsidence due to permafrost thaw. According to previous results from DTU, the average seasonal subsidence can amount to about 7 cm/year (Scheer et al. 2023).

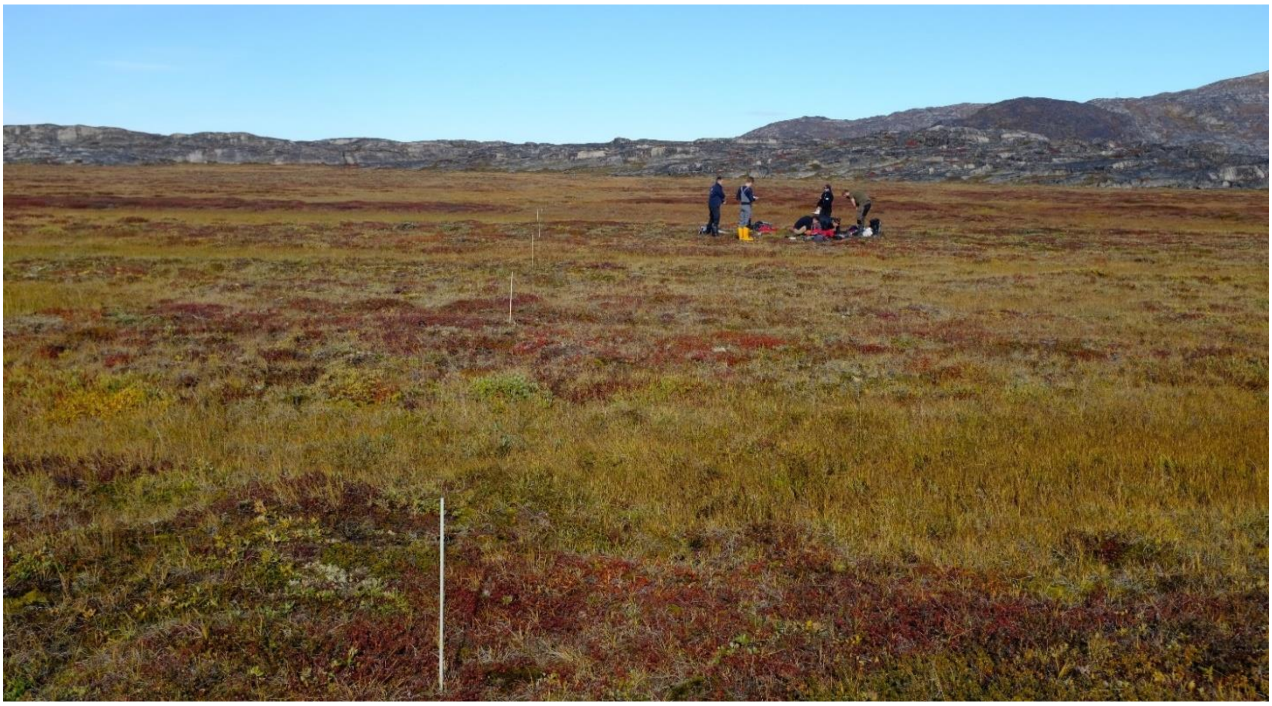

Figure 15: Subsidence transect near pipeline, September 4, 2022.

4.5 CALM and T-MOSAIC protocols

Following the T-MOSAIC protocol for field data inquisition to assess permafrost changes we conducted the following measurements at the CALM site at 69.219137 °N, -51.054799 °E. We conducted active layer measurements along the CALM grid with a total of 121 CALM points, where we each did two measurements (at the CALM point and 1 m to the west). We dug a soil pit, described the soil and sampled the organic and mineral horizons for analysis of soil properties. We described the vegetation cover at 21 points along the CALM transect following the vegetation protocol in Boike et al. 2021. These measurements will be repeated in the coming years.

5 Data management

Expedition data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) or on the open repository ZENODO operated by CERN (zenodo.org) within five years after the end of the expedition at the latest. By default, the CC-BY license will be applied. This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” under Topic 5 and Subtopic 5.3.

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7 Appendix

7.1 Detailed sample overview

Table 2: Overview of water samples.

Site name	Sample name	Latitude (°N)	Longitude (°E)	Water body
Blæsedalen North	GL22_BN_W1	69.2789	-53.4744	Stream
Blæsedalen North	GL22_BN_W2	69.2788	-53.4747	"spring" / stream
Blæsedalen North	GL22_BN_W3	69.2786	-53.4792	Stream
Blæsedalen South	GL22_BS_W1	69.2676	-53.4668	Stream
Blæsedalen South	GL22_BS_W2	69.2690	-53.4859	Stream
Blæsedalen South	GL22_BS_W3	69.2710	-53.4686	Stream
Blæsedalen South	GL22_BS_W4	69.2705	-53.4687	Stream
Blæsedalen South	GL22_BS_W5	69.2700	-53.4705	Lake
Blæsedalen South	GL22_BS_W6	69.2679	-53.4679	Standing Water
Arctic Station	GL22_Arctic_Station	69.2533	-53.5175	Rainfall

Table 3: Date, location and amount of albedo data points collected in 2022.

Date	Site Name	Transect	Data Points	Cloud Coverage
Aug 29	Arctic Station	NA	24	100%
Aug 30	Blæsedalen North	3	3x15	< 5%
Aug 30	Blæsedalen North	NA	34	< 5%
Sep 8	Blæsedalen South	1	3x20	100%
Sep 8	Blæsedalen South	NA	7	100%

Table 4: Location of subsidence transects.

Subsidence Transect	**Number of Sticks**	**Latitude (°N) (Transect Center)**	**Longitude (°E) (Transect Center)**
CALM_station	11	69.2192	-51.0546
Pipeline	7	69.2235	-51.0586
Burried_Pipeline	7	69.2226	-51.0680
Frost_Boils	8	69.2191	-51.0691
ILU2018-03	6	69.2142	-51.1069
Airport_Road	7	69.2317	-51.0833

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