Monitoring DiskoBasis

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ARCTIC STATION

FACULTY OF SCIENCE
UNIVERSITY OF COPENHAGEN

Annual Report 2013

Cover photo:
Gas measurements near newly-established snow fences at sites representing a wet ecosystem (photo: Bo Elberling).

Editors:
Trine Warming Perlt and Kirsten Seestern Christoffersen.

About the report

The Board of the Arctic Station is pleased to inform the public and the many users of the station about the status and activities of the station. The report is compiled by the Board based on contributions from researchers, guests, and the staff at the station.

The "Annual Report of the Arctic Station" contains brief descriptions of research projects, field courses and other educational activities, international meetings, and official visits. Furthermore, the report contains information about the staff, buildings, and other facilities, including the research vessel R/V Porsild. It also contains a summary of the research activities carried out at or in collaboration with the station, plus a list of publications resulting from these activities.

The report is published in a limited printed edition, and as a pdf file, which may be downloaded directly from the website, where it is also possible to find additional information about the work and activities of the Arctic Station (*arktiskstation.ku.dk*).

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The Chairman's report

At the beginning of 2013, the members of the Board were Professor Reinhardt Møbjerg Kristensen, (chairman, zoology), Professor Bo Elberling (vice chairman; geography), and Professor Kirsten Seestern Christoffersen (biology). Associate Professor Gunver Krarup Pedersen (logistics, geology) resigned from the Board on 1 January 2013 after 17 years as a very dedicated member because she was appointed to a new position at GEUS. Several new members were elected for the Board in August 2013. They were Associate Professor Nina Lundholm (marine plankton), Associate Professor Peter Stougaard (microbiology), Professor Anders Michelsen (terrestrial botany), Professor Peter Juel Hansen (marine microbiology), and Associate Professor Aart Kroon (geology).

The year 2013 was a busy year at Arctic Station. A total of 197 guests visited the station and spent a total of 2,137 nights there. Students made up 27% of these nights and scientists 51%. The research vessel R/V Porsild was in use for 89 days. Kjeld Aqaaraq Mølgaard was appointed as temporary chief of logistics in 2012; and, in 2013, the assignment was made permanent. All the Greenlandic staff members, including the Captain Frederik Grønvold of R/V Porsild, have taken good care of the scientists and students visiting the station. Antoinette Mølgaard has been in charge of cleaning the station and has, furthermore, been a fantastic cook for several courses and workshops.

Gitte Henriksen, the secretary for the station and a Board member appointed by the Faculty, has been efficient and dedicated in her work for the station in 2013. All the bookings for courses and specific research programs pass through her hands. In addition, she is responsible for the station's budget and all financial transactions. She visited the station in June 2013.

Several courses took place at the station in 2013. Beside the annual courses and workshops arranged by the University of Copenhagen, there was also an international PhD course (ForBio) organized by Tromsø, Bergen, and Aarhus Universities.

At the same time, the year 2013 marked the beginning of a new era and the end of an old for Arctic Station. The scientific leader Ole Stecher is not only responsible for his own research program, but he also manages the monitoring programs related to the station. A new monitoring program was initiated at Arctic Station in 2012 based on a 2-year funding scheme for Bo Elberling (2013-2014) from the Danish Energy Agency and associated with the Greenland Ecosystem Monitoring (GEM) programme. Most of the programme was not fully operative until 2013, e.g., the new Automatic Climate Station in Østerlien (see elsewhere in this report). The INTERACT programme (EU project) and the new Center for Permafrost (CENPERM) associated with Arctic Station were also fully operative in 2013. Another official event in 2013 was a visit by Ralf Hemmingsen, Rector of the University of Copenhagen, Nils S. Pedersen, Chairman of the Board of the University of Copenhagen, John Renner, Dean of the Faculty of Science, Morten Pejrup, Associate Dean of the Faculty of Science and the former Dean Nils O. Andersen, who visited Arctic Station in late July. Bo Elberling and I acted as hosts for Arctic Station and showed the prominent guests some of the projects being run from Arctic Station, e.g., the Automatic Climate Station in Østerlien, the CENPERM snow fence experimental site in Blæsedalen, and the homothermal springs at Kuuanit.

After ten years as Chairman of the Board, I resigned from my position on 31 December 2013. My association with the station has been long; I first visited the station as a student on the first arctic field course in 1973; and, from 1976 to 1979, I was the Scientific Leader of the station. My first appointment to the Board was in 1988, when I was assigned as Zoological Board Member; and, for several years, I was the vice-chairman for the Board. I wish the station and the Board all the best in the coming years.

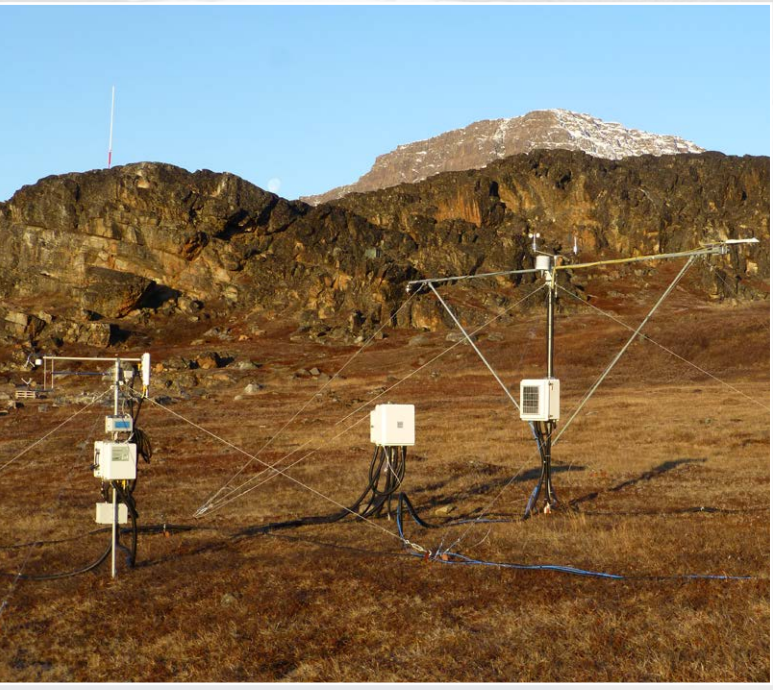
Reinhardt Møbjerg Kristensen

Monitoring

DISKOBASIS

Charlotte Sigsgaard, Ole Stecher, Bo Elberling, and Kirsten S. Christoffersen, University of Copenhagen, Denmark

More and more activities at Arctic Station are being incorporated into the framework of the ecosystem monitoring programme "DiskoBasis", which was initiated in 2013. The programme is associated with the Greenland Ecosystem Monitoring (GEM) programme but is currently not financed by GEM but through project funding from the Danish Energy Agency (2013-2014). DiskoBasis includes some of the ongoing monitoring at Arctic Station and has been expanded with a new automatic weather station, gas flux measurements, fluvial transport, etc. Efforts have been made to standardise methods, instrumentation and sampling frequency in order to allow for comparison with other monitoring projects within GEM. The location, the power availability and the fact that Arctic Station is manned by scientific and technical staff all year around makes it an ideal site for the long-term collection of data.



Automatic weather station in Østerlien (photo: Charlotte Sigsgaard).

A new weather station

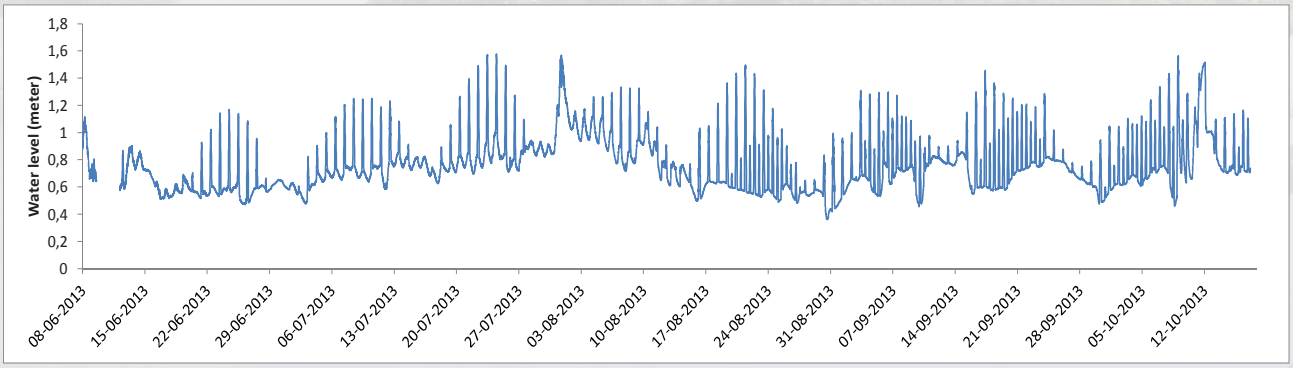
In August 2012, a new automatic weather station was established in Østerlien approximately 100 m east of the garage at Arctic Station in a gently sloping area covered by low vegetation. At the weather station, the following parameters are being measured continually: air temperature, wind speed, wind direction, air pressure, relative humidity, short- and long-wave radiation, red- and near-infrared radiation, snow depth, soil moisture, soil heat flux, and soil temperature (in 2013, an additional borehole was drilled, and ground temperatures are now being measured down to a depth of 350 cm). Gas fluxes or land-atmosphere exchanges of carbon dioxide and water vapour are being measured by the eddy covariance technique on a separate mast. These measurements make it possible to do an energy balance and a carbon balance for the area and to describe the inter-annual variations. The stable power availability allows detailed winter measurements of the gas fluxes as well, and the first annual carbon budget will soon be presented. Inside Arctic Station, a monitor in the hall displays a real time view of air temperature, wind speed, wind direction and air pressure from Østerlien. The weather station is a fundamental part of the monitoring programme, and it is a supplement to and an expansion of the existing weather station located at the scientific leader's house, where meteorological parameters have been logged since 1991. In the years to come, the new and the old station will be running side by side in order to correlate similar parameters and to secure a complete data set of these measurements.

Fluvial monitoring

Fluvial monitoring of the river Røde Elv was also initiated in 2013. Runoff from the Røde Elv drainage basin (ca. 101 km^2) is an important part of the water balance and an essential tool to estimate the total output of freshwater, sediment and nutrients from land to ocean. In May 2013 after the river breakup, a multisonde (YSI 6820) was installed in the river near the bridge.

Hydrological monitoring in Røde Elv. The red circle points out the position of the multisonde (photo: Charlotte Sigsgaard).

The sonde automatically recorded variations in water level, water temperature, salinity, turbidity, nitrate, conductivity and pH until it was removed on 17 October due to ice. Based on data from the first runoff season, it has been decided to move the sonde farther upstream in 2014, as the location near the bridge is too influenced by tidal variations. The tidal pattern with nip and spring tide is recognisable in the figure below: high peaks are present during spring tide with "extra" increases in water level up to one meter, whereas the effect is lower or absent during nip tide. Only on a few occasions did saline water actually come all the way in. The highest "true" peak of the season was observed on the first of August after a rainy and warm period. In addition to the



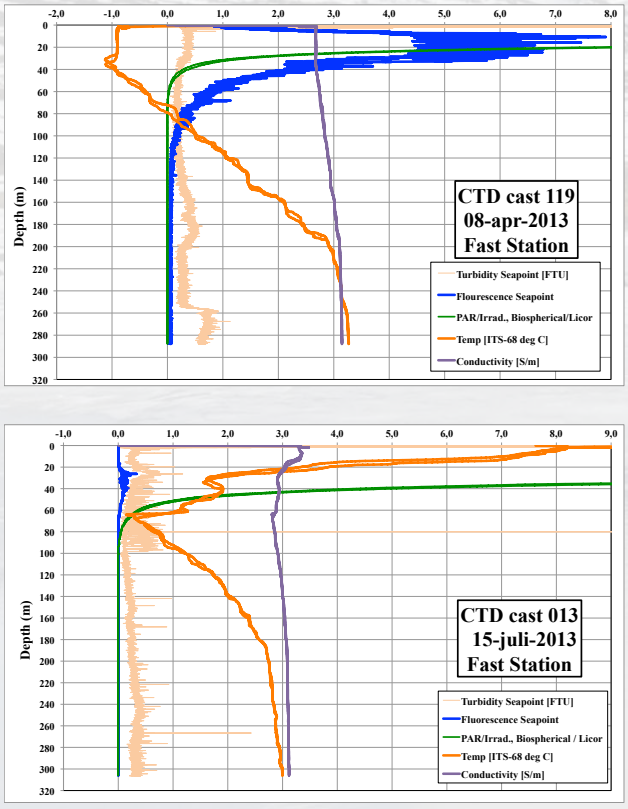
Relative variation in the water level in Røde Elv throughout the 2013 runoff season – measured at the bridge.

automatic measurements, water samples were collected twice a week and will be analysed for suspended sediment, dissolved and particulate organic carbon as well as major anions and cations to provide a measure of the fundamental chemical composition of the water.

Marine monitoring

For a long time, Arctic Station has conducted a basic marine monitoring programme with monthly CTD measurements from a fixed position called 'Fast Station' (69°11N, 53°31W), where temperature, conductivity/salinity, fluorescence, turbidity, PAR/Irradiance, and pressure/depth are measured from the sea surface to a depth of app. 300 m. Examples of CTD data are given in the illustrations below. The duration and extent of sea ice cover as observed from the main research building has likewise been recorded for some time. In addition to these measurements, visiting researchers with interests in the marine environment have collected additional CTD measurements at many different positions throughout the entire Disko Bay area with most positions close to Qeqertarsuaq.

With the new DiskoBasis programme, we have expanded the monthly monitoring programme with two additional CTD positions on a transect from the 'Fast Station' towards Arctic Station and the sediment plume from Røde Elv. At all three positions, water samples will be collected just below the surface (0.5-1 m) and at a depth of 20 m in order to measure the suspended sediment load and the water chemistry. The two new stations will be important additions to the general monitoring programme of the Røde Elv.



CTD profiles measured at the 'Fast Station'. (A) Spring measurement with algae bloom (i.e., high fluorescence values) and (B) Summer measurement with high surface temperature.

Lake monitoring

Basic conditions (temperature, conductivity, oxygen, nutrients, chlorophyll, and diversity of phyto- and zooplankton) have been recorded manually in two lakes, Morænesøen in Blæsedalen and the largest of the lakes at Kangarssuk, once or twice every second year since 2008.

During the last few years, a pilot programme for an automatic monitoring programme of two lakes has been tested. The setup includes a permanent deployment of a multisonde in the two lakes – one in Morænesøen in Blæsedalen and the other in the lake at Kangarssuk. The sondes are equipped with sensors for the daily registration of light, temperature, oxygen, conductivity, and chlorophyll as well as cylinders for collection of sedimented materials. The oxygen and chlorophyll sensors use the new optode technique. The instruments are mounted in an aluminium rig (tripod), which is deployed in the deepest part of the lake from a rubber boat. An underwater buoy and GPS position is used to re-locate the rig. The results are very promising, and data series with one full year of continual measurements have already been obtained. However, a few technical problems still need to be solved.

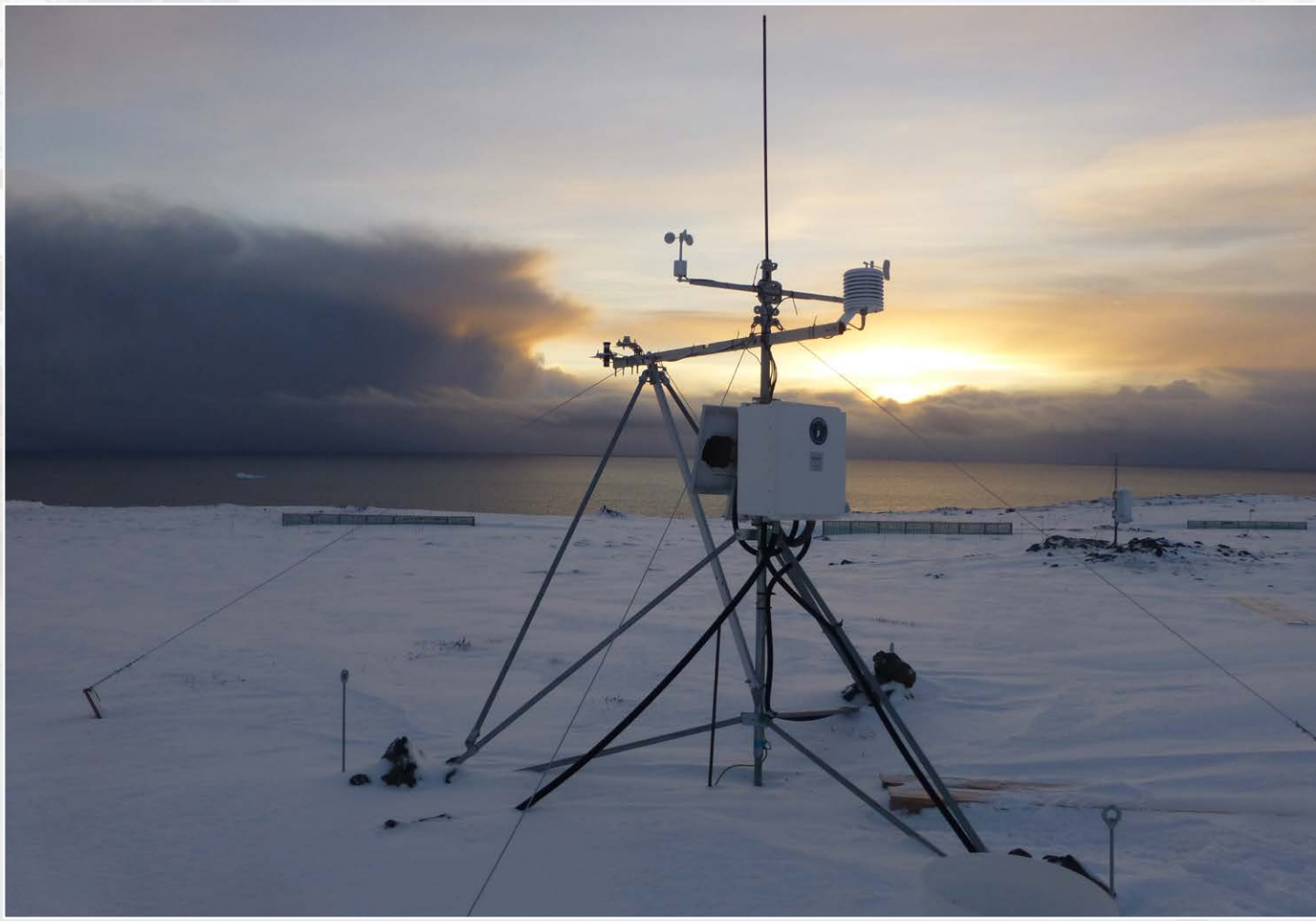
Based on experiences from 2011-14, the setup with multisondes will be adjusted (e.g., increased battery power, better anchorage to avoid drifting, and the development of a better solution for re-locating the rig), and the measuring scheme

will be improved. Thus, from 2015, a new and more extensive programme for lake monitoring will be included in the DiskoBasis programme.

Furthermore, soil water is now being sampled once a week from the upper 40 cm of the soil in Østerlien, and automatic cameras are installed and used to estimate seasonal variation in vegetation greenness and snow cover variations in Østerlien. A detailed description of all parameters included in the DiskoBasis programme as well as the manual will be available on the homepage of Arctic Station during 2014-15.

All DiskoBasis data are public domain and, after internal quality assurance, validated data will be available from the Department of Geosciences and Natural Resource Management, University of Copenhagen. Contact: Gitte Henriksen (*gin@science.ku.dk*).

Multisonde from Morænesøen (photo: Jørgen Skafte).



Automatic weather station at the snow fence site in Blæsedalen (photo: Charlotte Sigsgaard).

Research projects

CENPERM: SNOW FENCE EXPERIMENT AND ELEMENT CYCLES

Bo Elberling (PI), Daan Blok, Anders Michelsen, Riikka Rinnan, Anders Prieme, Carsten Suhr Jacobsen, Karen Elisabeth Bjerre, David Morten Balslev-Clausen, Malte Nordmann Winther, Søren Christensen, Christian Emil Kjærsgaard, Marie Arndal, Katrine Maria Lund Johansen, Lene Seierø, Nanna Baggesen, Paul Christiansen, Per Freiberg, Mathias Madsen, Jens Gammeltoft, Thomas Holst, Thomas Ingeman-Nielsen, Anders Vest, Heidi Sjursen Konestabo, Thor Nygaard Markussen, Frida Lindwall, Michelle Scholler, Ludovica D'Imperio, Cecilie Skov Nielsen, Mette Bendixen, Nynne Marie Rand Larsen, Morten Mikkel Mejlhede Rolsted, Center for Permafrost (CENPERM), University of Copenhagen, Denmark

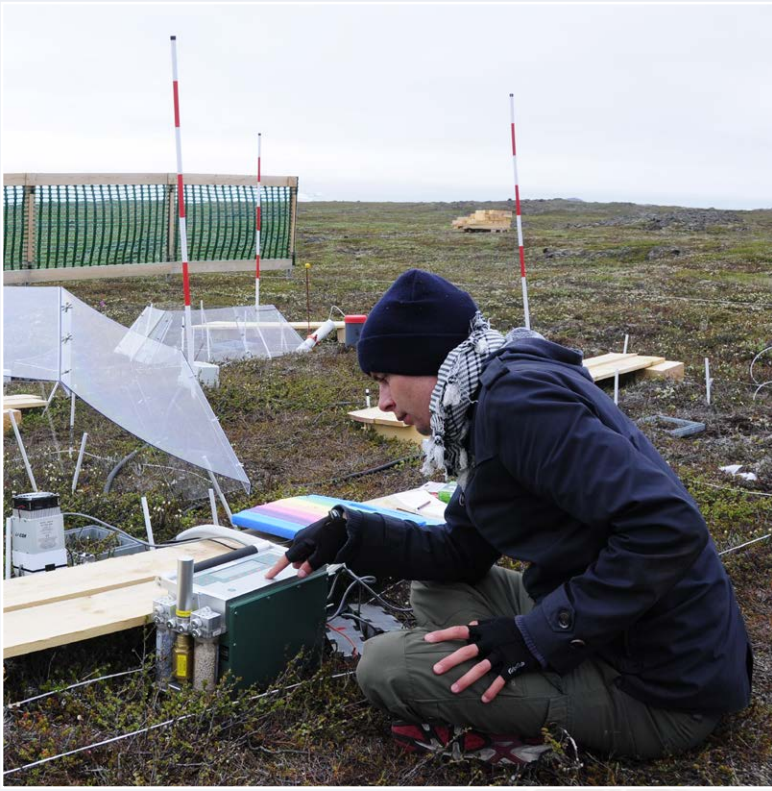
The purpose of the visit was fivefold: 1) to collect new field data from the snow fence experimental site, established in Blæsedalen in 2012, and to build six new fences representing a wet ecosystem, 2) to establish a geophysical monitoring station near the station to obtain active layer characteristics during the freezing period from June until Dec 2013, 3) to establish a BVOC eddy tower for continuous measurements of BVOC gasses during the entire growing season, 4) to establish the photosynthetic responses of *Betula nana* to summer warming and delayed snow melt timing, and 5) to sample litter bags and obtain soil cores for the litter trace project.

Snow fences

The snow fence study aims to assess the effects of seasonal warming on carbon and nitrogen cycling through plants, microorganisms, soil, and permafrost in two contrasting landscapes/ecosystems: a poorly-drained wet ecosystem dominated by graminoids and a coarse-grained, well-drained tundra heath. Most previous research has focused on the effects of summer warming on tundra vegetation and soil microbial processes. However, most of the warming that is predicted for the

Disko snow fence (photo: automatic camera part of the monitoring).

coming century will likely occur during the winter period. By locally elevating the snow height by using snow fences, we mimic predicted increases in winter precipitation and higher winter ground temperatures through the insulating effect of snow compared to control plots. Summer soil temperatures are also manipulated at selected plots by using Plexiglas open-top chambers. Finally, the cooling effect of shrub canopies on summer soil conditions is assessed by clipping the shrub biomass from half of the plots. This further changes the competition between plant species. Shrubs are known to profit from higher air temperatures by growing denser and taller and, thus, potentially providing a negative feedback to permafrost warming by shading the soil surface and lowering soil temperatures. A full factorial design with six replicate snow fences provides an opportunity to test the effects of winter and summer warming as well as summer soil cooling on plant growth and the exchange of carbon and nitrogen through permafrost, plants and microbes. The dry tundra site was established in 2012 and the wet site in 2013. Both sites will be intensively studied during the entire snow-free period in 2014-2016 by a large CENPERM research campaign. We will study the effects of the summer and winter warming treatments on above- and below-ground plant performance, greenhouse gas emissions, root development, soil fauna assemblages, microbial functioning, and nitrogen cycling.



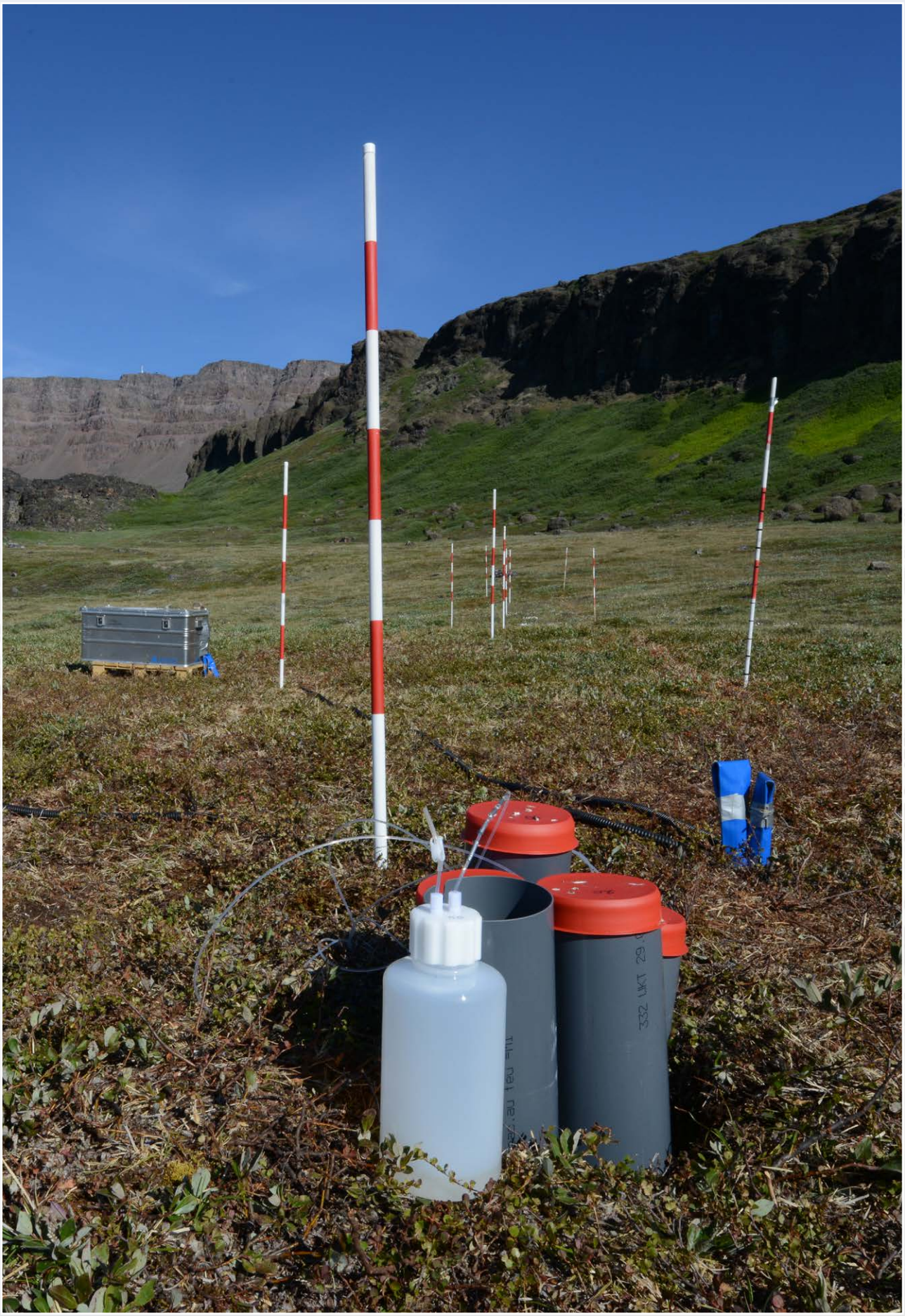
Morten Rolsted at work in the experimental snow fence site in Blæsedalen, Disko Island (photo: Daan Blok).

Geophysics

Linking seasonal freezing and active layer dynamics are lacking from the Arctic although the general pattern of water movement to the freezing front is well-described. This subproject is the first in the Arctic aiming to capture the entire freezing (from June until Dec) and relate redistribution of water to collected soil water characteristics. The main hypothesis is that, depending on snow insulation, the ions (and nutrients) will accumulate in certain depth intervals during winter and will not be available the next year before these layers start to thaw. That means that autumn freezing partly controls the timing of nutrient availability during spring. The monitoring setup has worked well for 150 days and will hopefully continue to acquire data through the winter; intermediate results (in resistivity and IP) clearly show the freezing layer. During the same period, soil water has been collected weekly.

Biogenic Volatile Organic Compounds (BVOC)

Although there have been some studies on boreal and sub-arctic sites published recently, there is still a lack of knowledge about BVOC emissions from a range of northern latitude ecosystems – especially, with respect to seasonality and on the ecosystem level – to compare with emission estimates from model approaches. This subproject is the first to use the eddy-covariance technique to measure BVOC ecosystem exchange directly in Greenland. The aim was to get a continuous set of ecosystem-scale fluxes of the most relevant



Soil water extracted near geophysical monitoring station (photo: Bo Elberling).

BVOCs from an arctic coastal environment, covering most of the growing season. Based on experiences from other sites, the main research hypotheses were that this arctic coastal environment on Disko Island would emit BVOCs (e.g., methanol, isoprene, monoterpenes) at a substantial rate and that the seasonality of emissions would be very pronounced due to the short growing season.

Betula nana

We investigated the photosynthetic functioning of *Betula nana* leaves in response to summer warming and the timing of the snow melt. It is expected that, in the Arctic, summers will be warmer in the future and the amounts of precipitation during winter will be higher. More winter snow may delay the snow melt but also supply more water for plants during the snow-free growing season. By contrast, summer warming may dry soils and decrease plant water availability, decreasing plant performance. However, higher temperatures may also increase plant metabolism and increase soil nitrogen availability due to greater turnover of soil organic matter. In this study, we assess the effects of contrasting winter and summer climatic changes on the performance of a key arctic tundra shrub species with circumpolar distribution, *Betula nana* (dwarf birch). We expect summer warming to increase the photosynthetic capacity of *Betula nana*. Furthermore, we expect winter warming initially to delay leaf phenology and reduce photosynthesis in *Betula nana* early after snowmelt but to increase photosynthesis later in the growing season, compared to control plots, due to greater water availability. Snow fences were constructed to create snowdrifts, resulting in delayed snowmelt compared to control plots with ambient snow. Plexiglas transparent open-top-chambers were used to warm the air passively inside the chambers during summer by approximately 2 degrees Celsius. Branches of *Betula nana* were measured 10 times during the growing season from late June to mid-August in control, snow-manipulated and summer-warmed plots as well as combinations of snow-manipulated and summer-warmed plots. We used a LI-COR 6400XT portable photosynthesis system with attached lighted opaque conifer branch chamber. Using this setup, we could control light levels, carbon dioxide concentrations and temperature. *Betula nana* leaves were removed after measurements and analysed for delta-^{13}C to assess plant drought status. Results are pending.

Litter trace

The aim of this study is to evaluate the effects of summer and/or winter warming on the decomposition of plant leaf litter and the cycling of nitrogen contained in the leaf litter. It is predicted that the arctic region will warm rapidly during the coming decades (especially during winter), which may have a great impact on plant growth and the functioning of the arctic community. One major function that could be altered by changes in climate is decomposition and nitrogen turnover of plant leaf litter. Changes in nitrogen cycling may potentially have tremendous consequences for plant performance and plant community composition through competition for the scarce available nitrogen pool in arctic ecosystems. However, it is unknown how seasonal winter and summer warming affect decomposition rates and nitrogen cycling patterns. The working hypothesis is that warming will enhance decomposition and stimulate the release of 15N from the decomposing litter with either winter or summer warming having a predominant effect on litter decomposition and nitrogen cycling.

During the two fieldwork periods in 2013, we sampled litterbags that were incubated in early October 2012 during three periods: directly after snowmelt (mid-June), peak summer (mid-July) and late summer (early August). Below each litterbag, a soil core was cut to determine soil extractable ^{15}N nitrogen. Soil cores were split into bulk soil, roots, and organic matter after which sorted soils were used in a fumigation extraction assay at the Arctic Station laboratory. Litter mass loss was calculated by deducting stove-dried mass of incubated litter from pre-incubated litter mass. Results are currently being processed and analysed for publication in a scientific journal.

MICROBIAL CONTRIBUTIONS AND RESPONSES TO CLIMATE CHANGE IN GREENLAND

William E. Holben (PI), Frances R. Gilman, Cellular Molecular and Microbial Biology, University of Montana, United States of America
Carsten Suhr Jacobsen, CENPERM, University of Copenhagen, Denmark

Microbial contributions and responses to climate change vastly exceed previous expectations and appear to be substantially impacting both climate change rates and ecosystem responses; yet, they remain poorly understood. This microbial "black box" needs to be exposed and examined to provide more accurate climate models. Specifically, my thesis aims to address the microbial community composition and community function observed in permafrost and the correlation to greenhouse gas emissions measured in two different field sites in Greenland. Permafrost samples were collected in Zackenberg, Greenland in the summer of 2012, and more samples were collected on Disko Island at the CENPERM snow fence field site this past summer. My thesis research will involve deployment of molecular analyses including deep 16S rRNA sequencing, metagenomic analyses, comparative metatranscriptomics and quantitative PCR for key enzymes in controlling methane production and carbon and nitrogen cycles. Using these techniques will help to develop better predictions as to how microbial communities shift in changing environments in the Arctic.

UPERNAVIK ICEFJORD

Camilla Andresen (PI), Niels Nørgaard-Pedersen, Kaarina Weckström, GEUS, Ministry of Climate, Energy and Building, Denmark
Ben Harden, Woods Hole Oceanographic Institution, United States of America
Rasmus Fenger-Nielsen, Amalie Cordua, Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark

At the turn of this century, a marked increase in mass loss of the Greenland Ice Sheet was observed. In particular, marine-terminating glaciers thinned, retreated and increased their discharge, and it was suggested that the glacier destabilization was related to climatic warming. Recent studies indicate that warm ocean currents around Greenland may come into contact with the submerged glaciers by traversing deep cross-shelf troughs and fjords. The purpose of our cruise was to survey Upernavik Icefjord by the Upernavik outlet glacier system. By retrieving sediment cores, undertaking oceanographic measurements of temperature and salinity and mapping the bathymetry, we intend to investigate one as yet largely unsurveyed fjord in northwest Greenland. Analysis of the sediment cores will provide valuable insight on outlet glacier-climate interactions on longer timescales and allow us to put the recent satellite monitored glacier changes into context. The hydrographic measurements will allow us to estimate the amount of heat delivered by the ocean to the glacier and allow us to measure the volume of summertime runoff - both values are vital to understand how the glacier is responding to current changes. These measurements will also provide a modern-day context for interpretations of the sediment cores.

In addition, icebergs were observed and measured during the survey. The purpose was to collect in situ data that would enable the estimation of iceberg dimensions (size and volume) and to compare these with relevant satellite data that was acquired regularly during the field survey. To retrieve sediment cores, a Rumohr lot equipped with 2-metre long plastic core liners was used. Using R/V Porsild's winch with a newly-acquired steel wire, we were able to retrieve sediment cores from >1000 meters water depth. To measure hydrography, an RBR Conductivity-Temperature-Pressure device was lowered at 29 locations throughout the fjord. We took a long transect down the fjord from mouth to 2 km from the glacial tongue as well as from a set of cross-fjord sections. For estimating iceberg dimensions, icebergs were photographed from different angles and, then, 3D-modelled, using advanced image-processing software.

We were successful in retrieving 16 sediment cores situated along the fjord and conducted

Upernavik Ice fjord sediment coring, preparing the corer (photo: Amalie Cordua).

several oceanographic transects. Analyses of sediment cores are underway. Furthermore, we conducted bathymetric surveys in a region for which bathymetry is practically unknown at the present time. It is of crucial importance for (model-) studies of ocean-glacier interactions to know the extent of troughs across the shelf, as these troughs potentially allow warm Atlantic water in the vicinity of the marine-based glacier margins. The detailed hydrographic surveys will allow us to map the progression of waters up the fjord. In addition, the cross-sections will allow us to determine the currents in the fjord that move warm water towards the tongue and glacial melt water toward the open ocean. A total of 30 icebergs were 3D-modelled, and the dataset is now being analysed and related to the 28 satellite images that were acquired during the survey.

EMISSIONS OF NATURAL VOLATILE ORGANOHALOGENS FROM SOIL

Christian Nyrop Albers, GEUS, Ministry of Climate, Energy and Building, Denmark

Volatile organohalogens (VOX) are some of the world's major pollutants, but some may also be produced naturally in both terrestrial and marine environments. It is important to know the natural contribution in order to quantify the anthropogenic contributions and the effect of regulating the use of such substances. The Arctic is viewed as insignificant with regards to natural VOX, but actual measurements are almost non-existent. As part of the project "ArctiVOX" (Natural emissions of volatile organohalogens in arctic and subarctic terrestrial systems – A study of the Arctic's role in the atmospheric organohalogen budget) and in cooperation with Center for Permafrost, a sea-

sonal study of VOX emission was conducted in two areas near Arctic Station: the terrain just east of the station and the recently established heating experiment in Blæsedalen. Emissions of VOX were determined using custom-made flux chambers and the sampling of chamber air on sorption tubes, which were later analysed at GEUS in Copenhagen. Preliminary results show that the site next to Arctic Station produced a small amount of chloroform and no other detectable VOXs. The soil in Blæsedalen produced slightly more chloroform as well as some bromodichloromethane but still in low amounts. There was some seasonal variation with highest emissions in mid-summer, but the seasonal variation seems to be minor. In addition, the effect of warming was apparently minor or non-existent. Compared to measurements we have made at similar latitudes in northern Sweden, chloroform emissions from Disko Island are apparently very low.

FROM MANTLE TO MICROBES: DISKO ISLAND AS A TEST BED OF CARBON PATHWAYS

Claire Cousins (PI), Mark Fox-Powell, Casey Bryce, University of Edinburgh, United Kingdom
Sami Mikhail (Co-PI), Carnegie Institute of Washington, United States of America

The principal aim of our field campaign was to investigate Disko Island as a potential locality for multidisciplinary research into the terrestrial deep carbon cycle, from carbon fluxes and speciation in the mantle to microbial carbon cycling in the subsurface biosphere. Disko Island hosts very unusual basaltic lava flows that contain FeNi alloys and Fe carbides that are extremely rare on the Earth's surface. The petrogenesis of these unusual samples remains enigmatic, and limitations exist in that the geological context of available samples is poorly constrained. Therefore, our aim was to provide a spatial study of FeNi alloy and Fe carbide bearing basalt and neighbouring metal-absent basalts. Disko Island also hosts geographically-isolated deep thermal springs, which permeate through the bedrock. These springs include mud volcanoes, salt springs, and cold to warm springs with temperatures between 0-19°C. These provide an ideal site for the study of subsurface microbiological communities and their carbon pathways within a range of compositional environments. The secondary aim of this field campaign was to engage in a variety of public outreach channels, including a field documentary, online field-blog, and news features, in order to inform the public about deep carbon research. We conducted field surveys of these geological and biological sites and collected samples of basalts and deep homothermic hot spring material in order to acquire a contextualised sample set that is of interest to studies that fall within the remit of the Deep Carbon Observatory, the main funders of our expedition. We also acquired several hours of HD video footage of fieldwork, which has been made into a short documentary

Filming and sampling at Lyngsmark glacier (photo: Claire Cousins).

that can be viewed here: *https://www.youtube.com/watch?v=vMsQ9yice_k*. Additionally, we wrote a regular web blog from the field, which was viewed by > 800 people during the course of the field campaign. The blog can be read here: *http://clairecousins.wordpress.com/category/fieldwork/disko-island/.* This field campaign was a joint initiative between the Carnegie Institute of Washington, University College London, and the United Kingdom Centre for Astrobiology at the University of Edinburgh. Samples collected will be used for ongoing projects based at all three institutions and made available for future collaborative projects internationally via cataloguing of samples on the System for Earth Sample Registration database.

THE SOCIO-ECOLOGICAL DIMENSIONS OF HYDROCARBON DEVELOPMENT IN THE DISKO BAY REGION OF GREENLAND: OPPORTUNITIES, RISKS, AND TRADE-OFFS

Graham McDowell (PI), James Ford, Climate Change Adaptation Research Group, McGill University, United States of America

The goal of our project is to identify and examine the opportunities, risks, and trade-offs that emerge from hydrocarbon development activities in light of existing socio-ecological conditions and changes. We also aim to situate findings in the context of emergent regional, Greenlandic, and circumpolar hydrocarbon development activities and governance arrangements. To obtain these goals, we carried out a total of 45 community-based interviews, as well as 10 key informant interviews, and participant observations in Ilulissat, Aasiaat, and Qeqertarsuaq. Although there is a strong local interest in the economic expansion and diversification that regional hydrocarbon development activities may deliver, concerns about risks and trade-offs are in evidence. Environmental change has been insufficiently analysed in planning processes, which leads stakeholders to endorse hydrocarbon development based on information that may underreport uncertainty and the extent of potential harm. To assess whether and under what conditions hydrocarbon development activities in the Disko Bay region can be considered socially and environmentally tenable, this study reveals that scholarly investigations into the effects of multiple interacting stressors across space and through time, equitable arrangements for risk/benefit sharing within and beyond the Disko Bay region, and moral questions stemming from attempts to improve social conditions in Greenland by way of perpetuating a hydrocarbon-based energy system are urgently needed.

GREENT FIELD WORK AND MAINTENANCE OF QEQERTARSUAQ GEOMAGNETIC OBSERVATORY

Jürgen Matzka (PI), Nynne Louise Berthou Lauritsen, DTU Space, Technical University of Denmark
Alexey Kuvshinow, ETH Zürich, Austria
Wolfgang Nitsch, Vienna, Austria

GreenT is a magnetotellurics project funded by the Danish Research Council to make a geophysical investigation of the Nagssugtoqidian orogeny and to compare the results with same age orogenies in Canada and Scandinavia. The geomagnetic observatory Qeqertarsuaq is a major geophysics and space physics research infrastructure; the geomagnetic field has been recorded since 1926. Magnetotellurics experiments consist of measuring time series of naturally-occurring magnetic and electric field changes. We have undertaken a three-day magnetotellurics experiment next to the Qeqertarsuaq football field and started a long-term experiment at the geomagnetic observatory. Additionally, we have performed maintenance work at the geomagnetic observatory. The data will be analysed in a PhD study. The geomagnetic observatory now works without problem (data transfer reliability from one of the two variometers was improved significantly during the visit).

Dinophilus taeniatus *(Annelida) from Nippisat (photo: Greg Rouse).*

Alexandra Kerbl and Nicolas Bekkouche, University of Copenhagen, sampling beach meiofauna at Flakkerhuk (photo: Kirsten K. Christoffersen).

MEIOFAUNA SAMPLING AROUND DISKO ISLAND

Katrine Worsaae (PI), Alexandra Kerbl, Kirsten Louise Kvindebjerg Christoffersen, Alejandro Martínez García, Nicolas Bekkouche, Department of Biology, University of Copenhagen, Denmark
Maikon Di Domenico, University of Campinas, Brazil & Department of Biology, University of Copenhagen, Denmark
Reinhardt Møbjerg Kristensen, Natural History Museum of Denmark, University of Copenhagen, Denmark

The purpose of our stay at Arctic Station was to sample a range of described and previously reported but as yet undescribed microscopic marine animals along the coast of Disko. The animals concerned are key organisms for building the larger animal tree of life (using transcriptomics) and are to be included in more locally PCR-based phylogenetic studies of separate annelid lineages. Several of the animals collected represent unique morphological features (in, e.g., nervous system) within the animal kingdom to be studied in detail with various advanced microscopy techniques. In order to collect these marine meiofauna animals, living within the sediment, we went out to different marine habitats around Disko Island near Iterdla, Flakkerhuk, Disko Fjord, Nipissat, etc. All trips were done with the R/V Porsild from Arctic Station, using a dredge or mini van Veen to collect sediment. From the beach, we snorkelled and collected the sand by hand. One of the main goals was to collect the freshwater microscopic animal *Limnognathia maerski* (Micrognathozoa), which lives in the cold spring mosses at Isunngua on the southeast coast of the Island. We found several specimens of *L. maerski* that we fixed for future genetic and morphological studies. We also found *Diuronotus aspetos*, a large gastrotrich, and *Draculiciteria tesselata*, another gastrotrich that has hitherto not been reported in Greenland. Detailed immunohistochemical, morphological and genetic studies are now being performed in Denmark. In all samples, freshwater and marine, we found several different tardigrades, collected by the Professor R. M. Kristensen. The rest of the sampling was mainly focused on various interstitial annelids for which the trip was a great success. For instance, several new species of the former "Archiannelid" group, *Protodrilus* sp. and *Protodriloides* sp., were sampled and are currently under description. Other records are *Psammodrilus aedificator*, *Microphthalmus* sp. from Flakkerhuk, *Nerilla* cf. *antennata* from Nipissat algae, *Meganerilla* and

Paranerilla from Iqpik. Finally, we also did intense collecting of *Dinophilus taeniatus*, another minute annelid, which lives among algae in the harbour of Qeqertarsuaq. Some were brought back for culturing, others fixed for ongoing morphological and genetic studies. Dinophilus is of particular interest for studies on miniaturisation and underlying evolutionary mechanisms. One of the conclusions of this extensive sampling of meiofauna is that, at least for interstitial annelids, the diversity is very high at Disko Island, which offers many different suitable habitats for meiofauna despite the cold waters.

TESTING OF ACOUSONDE TAG ON BOWHEAD WHALES

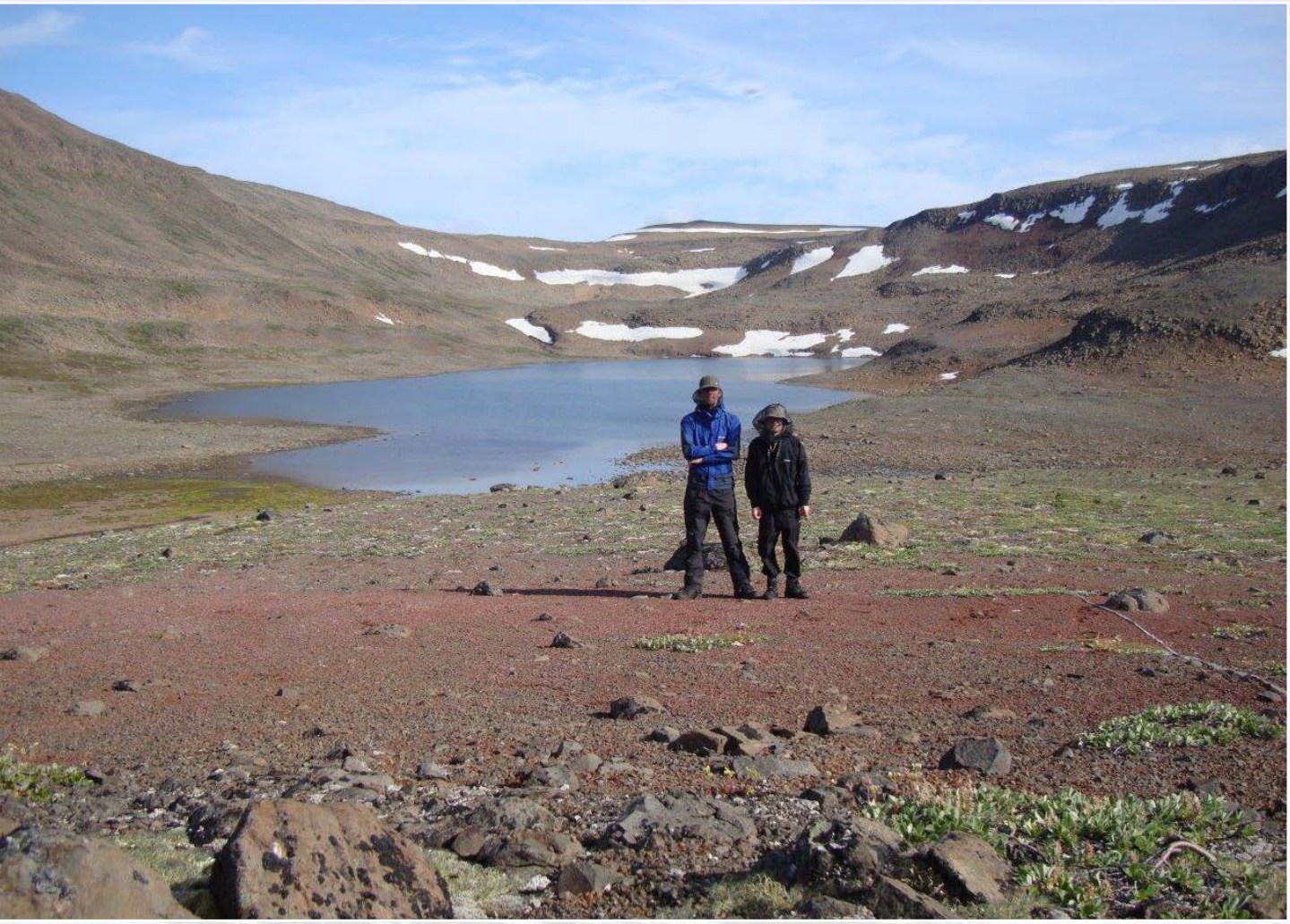
Mads Peter Heide-Jørgensen (PI), Nynne Hjort Nielsen, Greenland Institute of Natural Resources, Greenland
Susanna Blackwell (Co-PI), Greeneridge Ltd, Switzerland
Silje Rekdal, Natural History Museum, Norway

The overall objective was to test deployment, retrieval, and data collection of Acousonde recorders (*http://www.acousonde.com/*) on bowhead whales. The Acousonde is a sophisticated behavioural recorder that records underwater sounds from two hydrophones while also collecting depth, temperature, light, 3D accelerometer and 3D magnetometer data. Of special interest were the recordings of bowhead calls for identification in future automatic filtering of recordings. A secondary objective was to continue the collection of biopsies from bowhead whales in Disko Bay and, in particular, to use biopsies from instrumented whales to determine their sex.
We deployed Acousonde tags on four bowhead whales in Disko Bay, using a previously developed pole system and with assistance from local hunters. Biopsies for genetic sex determination were collected from the same whales. The four deployments lasted between 8 and 25 hours, and they were all retrieved thanks to the satellite tracking system developed for these tags. The main results were the acquisition of high resolution data on bowhead whale behaviour and vocalisations. The data will be used for developing a satellite-linked acoustic recorder together with the Alaska Department of Fish and Game.

ARCTIC LAKE CARBON PROCESSING AND TERRESTRIAL VEGETATION TRANSITIONS (INTERACT LAC-VEG)

Suzanne McGowan, University of Nottingham, United Kingdom

The Arctic is warming rapidly, and vegetation coverage will expand northwards – a process commonly referred to as "greening". Such vegetation shifts influence soil carbon and nutrient cycling, but the extent to which the storage or release of carbon at a landscape scale is influenced and the role that lakes play as carbon-processing focal points is not well understood. However, many lakes today release significant amounts of carbon dioxide and methane into the atmosphere, and a proportion of this carbon comes into the lake from the vegetation and soils of the surrounding landscape. It is, therefore, important to understand how catchment vegetation changes will influence lake carbon processing to induce greater lake productivity, i.e., lake autotrophy and carbon drawdown, or greater dissolved organic carbon (DOC) export from the catchment, leading to heterotrophy and carbon dioxide release. This project focuses on lakes in Disko Island, located in an area and elevation that has likely straddled thresholds of vegetation change throughout the Holocene period (present tundra- Little Ice Age non-vegetated- Holocene Thermal Maximum shrub tundra). We propose to use geochemical analyses of sediment cores to reconstruct catchment vegetation change and link this to past periods of lake autotrophy/heterotrophy. Thus, the aim of our visit was to use Holocene lake sediment core sequences from three lakes in Blæsedalen on Disko Island to: 1) investigate how past climatic changes (e.g., Holocene Thermal Maximum and Little Ice Age) have influenced the flux of terrestrially-derived carbon to lakes using lipid and pigment geochemical markers, 2) evaluate whether changes in terrestrial DOC flux can cause lakes to switch between



Lake 2 in a glacial cirque valley that runs west into the Kaussuaq incised valley, extending to the north of Blæsedalen (photo: Mark A. Stevenson).

net autotrophy or heterotrophy, and 3) quantify changes in lake sediment carbon and nitrogen accumulation rates as catchment vegetation changes. We accessed four lakes in total to collect two replicate sediment sequences using Russian core drives for the deeper part of the record and a kajak corer for the upper sediments. This achieved our objectives fully and also allowed us to core an extra lake (accessible by boat from Lakesbugten) to look at the potential influence of glacial inputs.

The support from Arctic Station in guiding us to the sites by snowmobile was excellent. The final site was rather more difficult to access because of the icy conditions, but we found a safe route to the site.

CATCHMENT VEGETATION CALIBRATION FOR HOLOCENE SEDIMENT CORES (CVC-CORE)

Mark A. Stevenson (PI), Joseph Bailey, University of Nottingham, United Kingdom

The summer fieldwork provided the opportunity to re-visit the lakes that had been sediment-cored in April 2013 as part of the INTERACT, LAC-VEG project (see elsewhere in this report). We successfully collected plant, soil, and water samples from three lakes on Disko Island, which will enable the calibration of lipid and pigment geochemical analyses carried out on sediment cores from the same lakes. The visit also provided the opportunity for hydro-geomorphological and vegetation catchment surveys of the lakes. These surveys and the calibration samples collected during summer fieldwork will prove useful

for interpreting changes in carbon cycling and shifts between autochthonous (in-lake) and allochthonous (terrestrially-derived) algal production over the Holocene. Fieldwork for lakes 1 and 2 was completed by hiking along Blæsedalen, and lake 4 was accessed by boat. Both filtered and unfiltered lake water samples were taken as appropriate for the analysis of ions and anions, phosphorus, nitrogen, silicates, ammonium, alkalinity, chlorophyll and phytoplankton. Vegetation surveys were completed using a 50 cm quadrat placed randomly within 10 x10 meter grids at a minimum of three elevations surrounding each lake. Vegetation and soil samples for calibration of sediment cores will be analysed for lipid biomarkers with gas chromatography-mass spectrometry, pigments with high-performance liquid chromatography and carbon isotopes ($\delta^{13}C$) with mass spectrometry. Results from the lipid, pigment and isotope calibrations of soil and plant samples are pending and form part of Mark Stevenson's PhD research. Results are anticipated towards the end of 2014 with submission of the dissertation in 2015/16.

PARASITES EXPLAIN PARTHENOGENESIS IN EXTREME ENVIRONMENTS

Matthew Tinsley, University of Stirling, United Kingdom

The factors influencing animal population sex ratios have long interested biologists. Many systems in which sex ratios deviate from the normal 50:50 have become important test beds for fundamental evolutionary theories. Related to sex ratio research is the study of factors that encourage animals to reproduce either sexually or asexually, a study field that has generated innumerable hypotheses but few general explanations. The Greenlandic seed bug, *Nysius groenlandicus*, is one of the most common terrestrial arthropods in Greenland, and it is also found elsewhere in northern arctic-alpine habitats. There is considerable variation around Greenland in the population sex ratio of *N. groenlandicus*, and some populations appear to reproduce asexually. In areas where males are common, these insects can be highly promiscuous. One factor that commonly causes biased population sex ratios and switches between sexual and asexual reproduction in insects is infection by parasitic bacteria. This project aimed to investigate the role of parasitic bacteria in causing reproductive variation in *N. groenlandicus*. In addition, I tried to determine factors that influence the frequency with which these insects mate. I collected seed bugs from vegetation and off the tundra surface in the vicinity of Arctic Station using pooters. Collections took place over timed periods to estimate abundance; bugs were classified as to their gender and whether they were mating at the time of capture. Environmental data were collected at the time of collections. Bugs were preserved in ethanol for diagnosis of infection with bacterial parasites upon return to the United Kingdom. Previous authors have extensively mapped the sex ratio variation of

Male and female Nysius groenlandicus *mating on* Saxifraga tricuspidata *close to Arctic Station (photo: Matthew Tinsley).*

N. groenlandicus population at different spatial scales around Greenland. During these field studies, I recorded short-term (hourly) variation in the sex ratio of the population of active bugs. I found that this variation was caused by marked differences in the behaviour of males and females, which were active at different times. I was able to study the impact of diurnal rhythm, temperature and solar intensity on behaviour in the two sexes and discovered strong environmental effects on mating rate. This work revealed environmental conditions under which male activity increases markedly. At these times, females suffer extreme harassment to copulate and population mating rates escalate to a point at which the majority of females in the population are mating at any one time. After leaving Arctic Station, I undertook further studies on mainland Greenland around Ilulissat and Kangerlussuaq and collected comparative samples of *N. groenlandicus* to investigate spatial variation in the incidence of parasitic bacteria.

COMPARISON OF BIODEGRADATION BETWEEN EXPOSED AND UNEXPOSED ENVIRONMENTS – COUPLING OF CHEMICAL FINGERPRINTING AND TOXICITY TESTING

Mette Kristensen, Department of Plant and Environmental Science, University of Copenhagen, Denmark

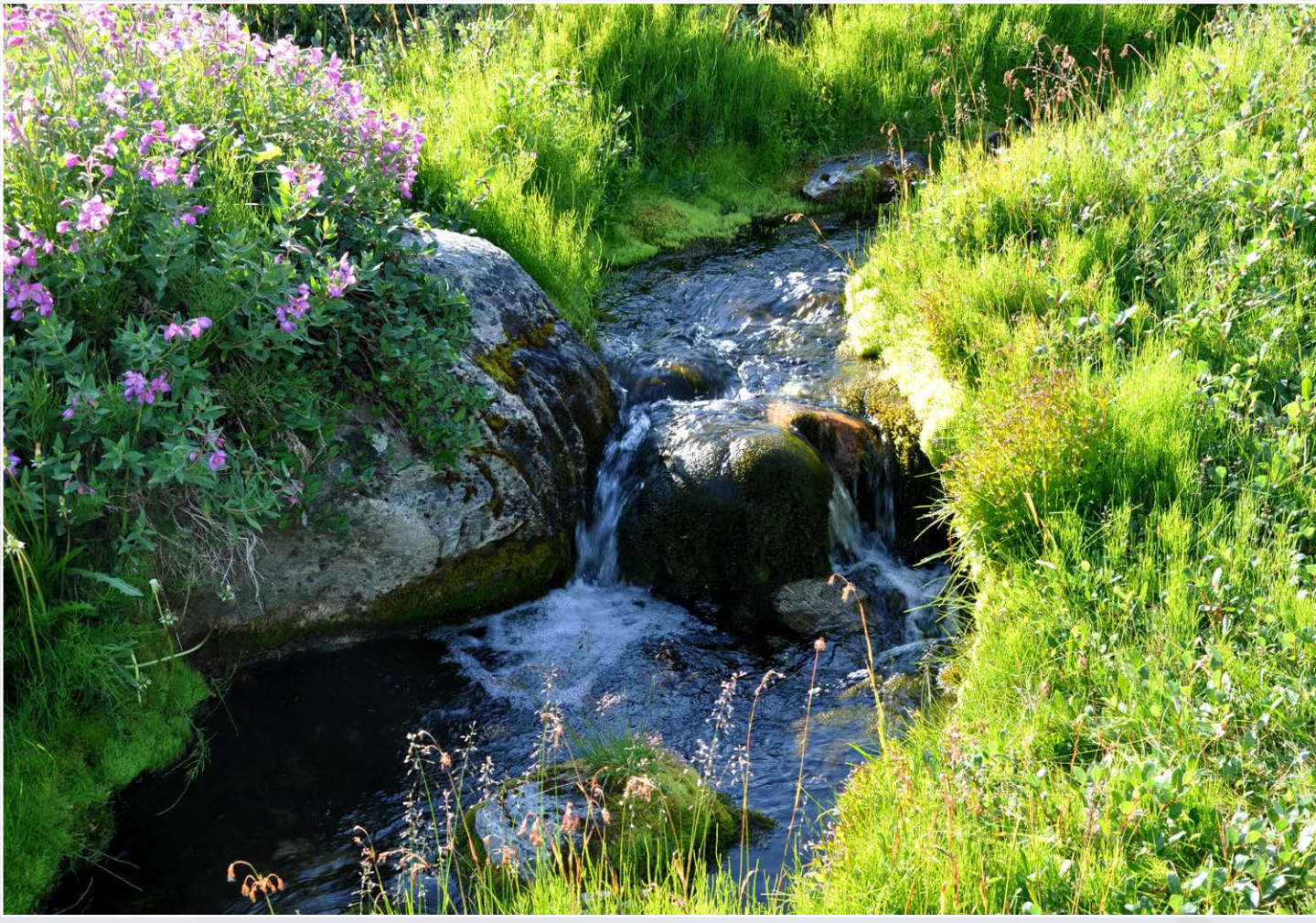
The purpose of my project is to investigate differences in biodegradation of crude oil between previously exposed and unexposed environments. This is achieved by chemical fingerprinting coupled to a variety of toxicity tests on indigenous bacteria, standard bacteria and marine algae. The project is based on two main hypotheses: 1) Biodegradation of oil is faster in marine environments previously exposed to hydrocarbons, due to adaption of the microbial community in the water column. Additionally, bacteria in unexposed environments will only be capable of degrading easily degradable compounds, while adapted bacterial communities will have the potential to degrade more complex compounds. 2) As degradation increases a higher fraction of resin compounds are formed, which leads to increased toxicological effects on marine organisms. To test these hypotheses, water was collected from a depth of 150 meters from R/V Porsild, and a CTD measurement was conducted on sampling location. Water was afterwards transported to University of Copenhagen. For comparison, water was also collected from the North Sea offshore from Hirtshals Harbour, Denmark. Microcosms of the two waters were spiked with crude oil and incubated in 5 and 15 degrees for Greenlandic and North Sea water, respectively. Biodegradation and toxicity of the microcosms were analysed for six sampling days during the 71 days following set-up. Subsampling of the water phase was used for different toxicity tests: MPN enumeration, Microtox Assay, Leucine incorporation Assay, and growth inhibition of the marine green algae *Dunaliella tertiolecta*. Water phase and oil phase were also analysed by gas chromatography - mass spectrometry, which provides the chemical fingerprint of the crude oil. The results are still pending, as the experiments are not yet completed.

EXPLORING HEATED FRESHWATER SYSTEMS IN THE CIRCUMPOLAR AREA (RING OF FIRE)

Nikolaj Friberg, Norwegian Institute for Water Research, Norway

Geothermal systems are ideal natural experimental systems for studying the impact of temperature on stream ecosystems in a global warming context. It is not confounded by dispersal barriers or difference in glacial history and does not have the same shortcomings as experimental set-ups in which the need for replication often compromises realism. In previous work in the geothermal area Hengill in South East Iceland, we have found declines in beta-diversity with temperature, increased response to nutrient additions, increased ecosystem respiration rates (making the streams sources of carbon dioxide), and increase in food chain length with temperature. The Hengill area is unlikely to be the only one of its kind, and there should be heated streams in the circumpolar area that could provide similar avenues

of research to validate and generalize the findings from Iceland. I have previously done limited work in tectonically heated streams in Greenland, which I wanted to explore further during this summer's stay. In addition to Greenland, I have visited Svalbard, Kamchatka and Alaska during the summer 2013. In a global warming context, all these systems are close to the Arctic Circle, where rapid warming (~7.5°C) is predicted for the next century. My idea was to explore these potential sites in search for similar areas as Hengill in which the geothermal activity is not confounding chemistry. My intention was to take a number of spot chemical and biological samples to evaluate their suitability. We undertook *in situ* measurements of oxygen, conductivity, temperature, pH and water velocity using transportable meters. In addition, we measured habitat composition, which involved estimating the coverage of substrates and vascular plants. We took water samples for chemical analysis and collected biological material including algae scrapes from stones, filamentous algae and those vascular plants that cannot be identified in the field, sediment samples and samples for macroinvertebrate composition. The samples were preserved in the field (lugol for algae samples; ethanol for macroinvertebrates) or frozen (water samples) and brought back to Denmark for further analysis. The collected material has not yet been fully processed. Both algae and macroinvertebrate samples have been pre-processed and sorted but not identified. It is anticipated that all samples (including samples taken in Alaska, Kamchatka and Svalbard) will be processed during the course of 2014 with planned submission of at least one paper by the end of the year.



Stream near Arctic Station (photo: Kirsten S. Christoffersen).

Icebergs seen from Kuannit (photo Kirsten S. Christoffersen).

INTERACTIONS BETWEEN DIATOMS IN THE ARCTIC AND THEIR GRAZERS

Nina Lundholm (PI), Sara Hardardottir, Marina Pancic, Natural History Museum of Denmark, University of Copenhagen, Denmark

Microscopic diatoms constitute the basis of the marine artic food web. It was recently realized that one of the common arctic diatoms is producing toxins. In temperate areas around the world, toxic diatoms cause problems for fisheries, ecosystems, and human health. We know from previous experiments that arctic copepods graze on toxic diatoms, but no studies have explored whether the young stages of copepodites graze on the diatoms, whether they accumulate toxins, whether they are affected by the toxin, and whether potential grazing by copepodites affects the diatoms. We initiated the first experiments on this in temperature-controlled conditions at 4°C at Arctic Station, using locally collected grazers and monoclonal diatom cultures that had previously been established based on single cells isolated from Disko Bay. Using 200 µm plankton-net hauls, copepodite stages IV and V were collected, manually sorted using stereo microscopes and kept in "fecatrons" in temperature-controlled conditions at 4°C, while being fed with locally-isolated cells of *Thalassiosira*. Clonal cultures of locally-isolated *Pseudonitzschia seriata* (toxic) and *P. obtusa* (non-toxic) were grown in large volumes at 4°C in suitable light conditions. Some experiments looked into copepodite grazing pressure on the diatoms, while others were performed in specially designed containers in which one part of the container holding diatoms and grazers were separated from another part of the container by a 2 µm pore sized membrane to look at grazer-phytoplankton interactions. The preliminary results showed that the copepodites did graze on both toxic and non-toxic diatoms and that there was no difference in survival for copepodites on the two types of diet. The samples are presently being processed with plans for drafts of a publication ready at the end of 2014.

DIVERSITY OF FLAGELLATES

Nina Lundholm (PI), Natural History Museum of Denmark, University of Copenhagen, Denmark
Øjvind Moestrup, Lis Munk Frederiksen, Department of Biology, University of Copenhagen, Denmark
Helge Thomsen, DTU Aqua, Technical University of Denmark

The diversity of heterotrophic dinoflagellates, choanoflagellates, and coccolithophorids based on, e.g., environmental molecular studies has been shown to be huge in the Arctic, but the morphological identity and taxonomy of these ecologically important organisms is still unknown to a large degree and has never been studied in detail combining molecular and morphological methods. We observed a surprisingly high degree of particularly heterotrophic dinoflagellates. The organisms were studied using light microscopy; cells were fixed for later studies of their ultrastructure and single cells isolated for molecular studies. The samples are being presently being processed.

CONFIRM THE PRESENCE OF *EUROIS OCCULTA* LARVAE ON DISKO

Per Mølgaard (PI), Karen Christensen, Magnus Stjernegaard Vöge, Gustav Bæhr Christensen, Kasper Vöge Ommundsen, University of Copenhagen, Denmark

The ITEX plots have been monitored since 1989. During the observation period, a severe decline in the number and size of *Papaver radicatum* has been observed alongside an increase in ground cover of *Salix arctica*. The change in performance of the two main species in the sample plots started in 1996 – at the same time as a dramatic decrease in winter ice cover duration and ice thickness at the Disko Bay. This influence on plant life and performance may eventually lead to a change in the distribution and behaviour of animal life, as the willow plants are important for food and cover. During fieldwork from Arctic Station on Disko in 2012, we encountered caterpillars of the Great Brocade Moth (*Eurois occulta*) – also known as the Great Gray Dart. The larvae are very greedy; and here in Greenland, they prefer

Caterpillar of Great Brocade Moth (Eurois occulta) *(photo: Per Mølgaard).*

to forage on dwarf shrubs – especially, willows, e.g., *Salix glauca*. This was a new northern border for the moth, whose northern distribution limit used to be around Sisimiut-Kangerlussuaq along the Arctic Circle. In 2004 and 2005, an immense number of larvae were seen in the Sisimiut-Kangerlussuaq area, and it is probably from that outbreak that the newly-encountered larvae at Disko derive. We saw a very large number of larvae in Ilulissat. All roads were covered, and people did not like the slimy creatures getting squashed under their shoes. The caterpillars displayed their usual greedy behaviour – here, also in the grass. At Disko, they were in large numbers in Blæsedalen, where they foraged on *Salix glauca*. We did not have time to stay long enough to see the effect of this herbivory but were told that, later in the season, most of the willow plants had some important regrowth. We visited Kronprinsens Ejlande to look for insect larvae herbivory and saw a few woolly bear caterpillars (Gynaephora).

ROLE OF DISPERSANTS OF OIL ON COPEPODS IN HIGH ARCTIC AREAS

Kim Gustavson, Rasmus Nørregaard, Eva Friis Møller, Jakob Strand, Zhanna Tairova, Department of Bioscience, Aarhus University, Denmark

The purpose of the project is to increase the knowledge on the effects of using dispersants on oil spills in high arctic areas: more precisely, to investigate accumulation in and effects on high arctic copepods. Such knowledge is crucial for performing a robust net environmental benefit analysis prior to making a decision as to whether or not dispersant may be allowed as an operational oil spill response in high arctic sea areas. Dispersants are a response technique with a high potential for removing spilled oil from the sea surface in the remote and icy high arctic areas. Depending on type of oil and dispersant used, organisms in the water column may be exposed directly or indirectly to the components in the oil and the dispersant. Arctic *Calanus* copepods occupy a key role in the food web of the high

Biogenic volatile organic compounds chamber measurements close to Arctic Station (photo: Frida Lindwall).

arctic seas as food for fish, sea birds and marine mammals. *Calanus* spp. in arctic areas spend the winter hibernating in deep waters but ascend before the phytoplankton spring bloom, during which they feed to refuel their energy reserves for next winter's hibernation. *Calanus hyperboreus* produce most of their eggs while still in the deep waters. Oil exposure during winter may, therefore, affect the egg production and the offspring directly while exposure later in the year may affect their food intake. Preliminary results indicate that there is a high risk for the accumulation of oil components in arctic copepods, probably due to i) a unique and high content of lipids and ii) a slow metabolism. There is a high accumulation increase risk for toxic effects on the copepods and offspring as well as a high risk for exposure of the fish, bird and marine mammals feeding on the copepods. Sampling of *Calanus hyperboreus* was done using large plankton nets at a depth of 300 metres from R/V Porsild. Live samples were brought back to the laboratory and kept and sorted in the cooling container. *Calanus hyperboreus* were exposed to oil components and dispersant. During a period of 6 weeks, the accumulation and excretion of oil components and dispersed oil components were investigated with regular sampling of the copepods and the water in which they were kept. The specific quantification of the accumulation and excretion was determined with a high pressure liquid chromatography system at the Department of Bioscience, Aarhus University.

EMISSION OF BIOGENIC VOLATILE ORGANIC COMPOUNDS FROM ARCTIC ECOSYSTEMS

Riikka Rinnan (PI), Frida Lindwall, Michelle Schollert, CENPERM, University of Copenhagen, Denmark

Emissions of biogenic volatile organic compounds (BVOCs) from arctic ecosystems are poorly understood. The purpose of our field work was to increase our understanding on the quantity and quality of BVOCs released from different arctic plant species and vegetation types. Effects of climate change on the emissions were studied in the snow fence experiment. Based on previous knowledge, we expected that warming by open top chambers would clearly increase emissions and alter the blend of compounds emitted. BVOC emissions were measured both from individual plants and at the ecosystem level from vegetation-soil plots. The plant measurements were done enclosing a plant shoot into a polyethylene terephthalate bag through which air was circulated into an adsorbent cartridge that trapped the compounds of interest. Correspondingly, vegetation-soil plots were enclosed in chambers, allowing the collection of the emitted volatiles. The adsorbent cartridges were transported for analysis by thermal desorption and gas chromatography-mass spectrometry to Copenhagen. Furthermore, structural adaptations in plants, such as leaf and cell layer thickness, and the presence of leaf hairs or glands affects BVOC emissions. In order to find out whether the differences in the anatomy of arctic plants and the potential effects of climate change on the anatomy affect BVOC emissions, we took samples of measured plants for microscopy analyses. The field season was successful and devoid of technical problems, so we expect to get a wealth of new information on the topic studied once the data is analysed.

VARG – VOC FLUXES AT THE ARCTIC STATION IN GREENLAND

Thomas Holst, Department of Physical Geography and Ecosystem Science, Lund University, Sweden

This project aimed to measure biogenic volatile organic compound (BVOC) emissions directly, using the eddy-covariance (EC) technique on the ecosystem scale. This technique has never previously been used for BVOCs in Greenland, and the plan was to get a continuous set of ecosystem-scale fluxes of the most relevant BVOCs from an arctic coastal environment, ideally covering most of the growing season.

The main research hypotheses were: 1) that the arctic coastal ecosystem would emit BVOC (e.g., methanol, isoprene, monoterpenes) at a substantial rate, 2) that these emission capacities are thought to be in the range of other ecosys-

Lousewort (photo: Nina Lundholm).

tems with the same climatological background (e.g., Abisko/Sweden), 3) that the emissions were thought to be highly dependent on the variability of weather, and to show a stronger increase with favourable conditions as standard emission algorithms would predict, and 4) that, due to the short growing season, the seasonality of the BVOC emissions was expected to be very pronounced. Furthermore, another aim was to compare the ecosystem-scale measurements with an up-scale of BVOC chamber measurements done within a CENPERM project (R. Rinnan, see elsewhere in this report) at the same site. The VOC fluxes were measured at Arctic Station, which is located in a low artic, coastal climate. The surroundings of the station are dominated by a high number of vegetation species with almost half of Greenland's species present. This project was the first to apply (disjunct) EC techniques to quantify continuously and directly the ecosystem-scale exchange of BVOCs in Greenland. Proton Transfer Reaction-Mass Spectrometry (PTR-MS) was used to measure online VOC concentration and to monitor continuously (24/7 over most of the growing season) a set (5-8 compounds, e.g., isoprene, methanol, monoterpenes, acetaldehyde, acetone) of BVOCs at a very high temporal resolution (2 Hz) with sensitivity down to about 50 pptv. The combination of PTR-MS and a 3D ultrasonic anemometer sampling at 20 Hz by disjunct EC allowed a determination of a time series (e.g., at 30min resolution) of the ecosystem exchange for the natural high-latitude arctic ecosystem. The instruments were set up at the site in the first campaign and run successfully until the end of the growing season. Preliminary analyses have shown that the PTR-MS was able to cover about 8 weeks of the very short growing season with measurements producing continuous ecosystem flux data, plus some days in a chamber system setup. The first results of the ecosystem flux measurements also showed that there was a substantial emission, comparable with the Abisko site in northern Sweden.

DELTA DYNAMICS AND FLUX OF SEDIMENT AND MATTER FROM LAND TO SEA – TOWARDS QUANTIFYING AND BUDGETING CARBON FLUXES IN ARCTIC COASTAL WATERS

Verner Brandbyge Ernstsen (PI), Thor Nygaard Markussen, Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark
Marius Becker, Gabriel Herbst, Zentrum für Marine Umweltwissenschaften, University of Bremen, Germany

The purpose of our investigations was threefold: 1) to investigate the flux of sediment and matter from the fluvial to the coastal marine environment, i.e., land-sea transport mechanisms, in order to improve the understanding of transport processes towards quantifying and budgeting carbon fluxes to arctic coastal waters, 2) to investigate the potential for advective matter transport in sandy permeable sediments in the coastal marine environment with the future aim of budgeting organic matter turnover in permeable sediments in arctic coastal waters, and, finally, 3) a specific case study to investigate the long term impact of a glacier surge on delta morphology and progradation. The investigations were carried out within three projects: "Biogeochemical controls on flocculation and sediment dynamics in an arctic fjord" (CENPERM, Danish National Research Foundation), "Process-based understanding and prediction of morphodynamics in a natural coastal system in response to climate change" (Danish Council for Independent Research / Natural Sciences) and "The role of seabed morphology and sediment mobility in organic matter remineralization and nutrient turnover in permeable sandy sediments" (German Research Foundation).

The study sites were the delta and fjord system in Kuannersuit Sulluat in Disko Fjord and the delta and bay system at Røde Elv in Disko Bay in close proximity to Arctic Station. Surveys were carried out from on board the R/V Porsild and a smaller survey boat. Echo-sounding and sidescan sonar imaging were performed in order to map and describe the overall bathymetry and

the detailed delta morphology. Bed samples were collected to describe the large-scale variations in bed material characteristics at the two sites and the grain size variations in relation to the detailed delta morphology. Samples were also prepared for subsequent microbiological analyses in part, to assess the potential for organic matter remineralization and denitrification. Water column hydroacoustics, e.g., acoustic Doppler current profiling, was applied in order to describe the spatial distribution of hydrodynamics and suspended matter, including vertical gradients. At selected locations, detailed time series measurements of hydrodynamics, physiochemical water properties and suspended matter were carried out to resolve the complex water column transport processes and to assess the temporal variations. As part of this, novel and innovative in situ laser imaging of particles and aggregates in the water column was successfully tested. In relation to the main purposes of the investigations, the preliminary results reveal: 1) flocculation/aggregation of particles in the water column may greatly redistribute the matter and alter fluxes; 2) vast areas of permeable sandy sediments associated with current-induced bedforms in combination with organic matter, including the supply of organic matter from land by the rivers, yield a potential for large advective matter transport and organic matter turnover in the coastal marine environment; and 3) there is a potential for reconstructing volumetric delta progradation in response to the surging glacier event in Kuannersuit Sulluat in the 1990s.

DATECH2: RECONSTRUCTING THE GLACIAL HISTORY OF GREENLAND USING THE SURFACE EXPOSURE DATING TECHNIQUE AND "PLANÈTE GLACE": FRENCH DOCUMENTARY ABOUT GLACIERS AROUND THE WORLD

Vincent Rinterknecht (PI), University of St Andrews, United Kingdom
Vincent Jomelli, The National Center for Scientific Research, France
Vincent Favier, Laboratory of Glaciology and Geophysical Environment, France
Vincent Amouroux, Jean-Pierre Rivalain, Olivier Halin, Julien Berrod, Julie Binetti, Mona Lisa film company, France

The purpose of our stay at Arctic Station encompassed two major goals: 1) collecting rock samples for surface exposure dating using cosmogenic radionuclides to test the hypothesis that, during the Last Glacial Maximum, ice covered the Island of Disko and 2) obtaining footage for a documentary about glaciers in Greenland, "Planète Glace" with the Mona Lisa film company. We collected rock samples from crystalline erratic boulders perched on top of volcanic bedrock using a chisel and a hammer. The samples are being processed at the University of St. Andrews, United Kingdom and at the Laboratoire de Géographie Physique, France. The sample preparation and data processing are ongoing at this time. The documentary is expected to be released in the spring of 2014.

Snow drift building up on the lee side of the snow fence (photo: Charlotte Sigsgaard).

Education / Courses

FORBIO – MARINE FIELD COURSE GREENLAND 2013

TEACHERS

Christiane Todt, University Museum of Bergen, Norway
Anne Helene Tandberg, Institute of Marine Research Tromsø, Norway
Peter Funch, Department of Bioscience, Aarhus University, Denmark

STUDENTS

Andreas Altenburger, University of Copenhagen, Denmark
Jeroen Brijs, Daniela Carvalho de Abreu, Jenny Marie Egardt, Maria Perpétua Scarlet, Josefin Ann-Charlotte Sefbom, Gothenburg University, Sweden
Mari Heggernes Eilertsen, Henning Van Phan Flørenes, University of Bergen, Norway
Sandra Lage, Inga Meyer-Wachsmuth, Stockholm University, Sweden
Arom Mucharin, Mette Nielsen Møller, Jakob Thyrring Christiansen, Aarhus University, Denmark
Peter Kohnert, Ludwig-Maximillians Universität, Germany

This was a PhD-level field course in marine biodiversity and systematics, organised by ForBio, the Research School in Biosystematics at the Natural History Museum, Norway. Participants of this course were students or researchers at universities in four different countries (Norway, Denmark, Sweden, and Germany). The main goal of the course was to investigate the marine fauna and flora close to Arctic Station and in Disko Fjord. We used R/V Porsild for 6 days to collect marine fauna and flora. We took samples with plankton nets, water sampler, Ockelman sledge, large and small triangular dredges, and RP-sled. Locations included Qeqertarsuaq Harbour, Kangerluk, Eqalunguit, outer Disko Fjord, off Skarvefjeld, between Udkiggen and Kødøen (Qeqertarsuaq), Godhavn Rende, and off Hvidfiske Øer. We obtained video footage in Laksebugten. In addition, we did hand collecting in the littoral zone in Qeqertarsuaq and Nippissat. In total, we collected data from 50 stations. Samples were sorted and analysed (identified) in the laboratory. We used microscopic equipment and camera systems present at Arctic Station, as well as equipment brought from the University of Bergen and Aarhus University. We identified 98 taxa of marine invertebrate animals (73 to species level), 29 taxa of macroalgae (25 to species level), and 21 phytoplankton taxa (15 to species level). Individual student projects have differing foci, covering fields such as the gut contents of sculpin, specific chemical compounds in phytoplankton extracts, and genetic or morphological studies. In the material from Kangerluk, we found two species of Solenogastres (Mollusca) new to science. These are currently undergoing description. During the course, we published a course blog with short items on different aspects of the course and the individual projects. The blog was hosted by the blog site of the University Museum of Bergen's invertebrate lab, which can be accessed here: *http://invertebrate.b.uib.no/2013/09/19/forbio-course-marine-biology-greenland-arctic-station-disko-island/*

Participants and teachers in the 2013 ForBio Marine Course Greenland (photo: Kjeld Akaaraq Mølgaard).

NEW YORK UNIVERSITY ABU DHABI (NYUAD) CENTER FOR SEAL-LEVEL CHANGE GREENLAND FIELD SCHOOL

TEACHERS

David M. Holland, Denise Holland, New York University, United States of America

STUDENTS

Beatrice Ionascu, Xiaohua Liu, Tina Skorjanc, Jaen Ocadiz, New York University, United States of America

OTHERS

Brian Rougeux, David McGlennon, Carl Gladish, New York University, United States of America

The purpose of the field work was to build a data set to understand the contribution of Greenland's glaciers to global sea-level change and to introduce students to working with CTD instrumentation and computers in a hands-on manner. The trip also provided a good opportunity for the students to experience the types of research being carried out at Arctic Station and to make scientific connections with the scientists working there. We used two main types of oceanographic equipment, CTD and moorings. For CTD, we deployed a SeaBird 19Vplus, outfitted with oxygen, turbidity, and fluorescence sensors. Surveys were conducted across the width and breadth of the Disko Bay. For mooring, we attempted to recover a mooring at the mid-mouth of Disko Bay that we had deployed the previous summer but were unsuccessful. Likely causes of failure are battery failure, iceberg damage, or fishery trawls. We deployed a new mooring at the end of our cruise, using a new style of acoustic release, and we hope to have better luck when we return next year to attempt recovery. The students gathered data and wrote reports about their trip and presented their experiences to other undergraduate students at their home institutions. The culture and environment of Greenland and Denmark are remarkable, and this event provides a unique opportunity for students to learn about new cultures, as well as the flora and fauna of the region. Our cruise on the R/V Porsild and our visit at Arctic Station were deemed to be a big success by us, the organisers, and our students, judging by the enthusiastic feedback we received from them. The undergraduate students have gained considerable knowledge about synoptic oceanography both through theory, via lectures we held on the ship and at the station, and practically through the data we collected. Our data set will be archived in the National Oceanographic Data Center in the USA and will be made freely available to researchers worldwide. Such data collection and archiving is critical to understanding the long-term evolution of the Greenland Ice Sheet and its contribution to global sea-level change.

GU-AASIAAT GEOGRAPHY FIELD TRIP 2013

TEACHERS

David N. Penney, Allan Christensen, GU-Aasiaat, Greenland

STUDENTS

Andreas Mikkelsen Knudsen, Aqqalu Kunuk Inûsugtok, Arnaq Olrik, Camilla Marie Guldager, Camilla Nina Hansen, Cecilie Regine Jensen, Emil Petersen, Finn Rasmus Brandt, Hans-Kristian Broberg, Jens Peter Isak Nielsen, Johanne Geisler, Kathrine Louise Broberg, Lars Ungaaq Sørensen, Ludvig Jonas Zeeb, Malik Hans Abel Kristensen, Mathias K.J.M. Kaspersen, Navarana Marie Bidstrup, Nukaaraq Aputsiaq Zeeb, Oline Elisabeth Petersen, Pipaluk Jensine Bourup, Pipaluk Karen Kristensen, René Peter Kristiansen, GU-Aasiaat, Greenland

In early September 2013, students from the new natural science study programme from GU-Aasiaat visited Arctic Station as an obligatory part of their courses in geography. The class was about equally divided between those taking ordinary (C) and advanced (B) level courses. This was the first year, probably ever, that the geography department at GU-Aasiaat had a chance to avail itself of the opportunities provided by Arctic Station and its surroundings. It also enabled them to make field observations and measurements for use in reports and to study landscape types that are unavailable on the little island of Aasiaat, just across the bay from Qeqertarsuaq. During the two-day visit, students worked on the following themes:

- Glacial Geomorphology – U-shaped valleys, hanging valleys, moraines, glacial straie, etc.
- Periglacial Geomorphology – stone circles and stripes and other periglacial landforms
- Measuring permafrost levels in Pietresson's Moraine (in collaboration with Ole Stecher of Arctic Station).
- Streamflow project: measuring streamflow on both sides of the pump station beside Arctic Station.
- Volcanic rock types – pillow lava, polygonal lava, basalt, etc.).

GU-Aasiaat's 1st geography class at Arctic Station, 2013 (photo: Kjeld Akaaraq Mølgaard).

Beach Tuapaat (photo: Aart Kroon).

FIELD AND METHODS COURSE IN PHYSICAL GEOGRAPHY

TEACHERS

Aart Kroon, Thorbjørn Joest Andersen, Mette Bendixen, Bo Elberling, Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark

STUDENTS

Mikkel Skovgaard Andersen, Jens Arne Antoft, Karoline Edelvang, Christina Marie Stenvig Jensen, Lise Frydendahl Mølck, Kirsten Prisum, Kerstin Elise Krøier Rasmussen, Gregor Ratzmann, Amanda Josofine Wilke Steenstrup, Mathias Teglbrænder-Bjergkvist, Katrine Wulff

The purpose of the field course was to organise and carry out geographical fieldwork independently in an arctic environment and to be able to analyse, evaluate, document and communicate the results of this study in a scientific way. There were four projects defined. Three of them were executed during a nine-day expedition to the Tuapaat area, approximately 40 km east of Arctic Station, and one of them was executed in the Kuannersuit Sulluat area with the use of R/V Porsild. We also organised a field excursion in the Tuapaat area with a focus on geomorphologic processes and landforms. Before the field expeditions, we stayed at Arctic Station to prepare the field experiments and arrange the logistics. After the field expeditions, we used some of the laboratory facilities, organised our field data and had an excursion around Arctic Station with a focus on the CENPERM field activities. Each student group gathered data in the field and did further work on some samples in the laboratory at Arctic Station and in Copenhagen. They also wrote scientific papers for the course report at the end of 2013.

Findings and conclusions may be found in the report "Field and Methods Course in Physical Geography in 2013 at Disko Island, Greenland", which can be obtained free of charge from Aart Kroon (*ak@ign.ku.dk*).

Official visits

VISIT BY THE RECTOR OF THE UNIVERSITY OF COPENHAGEN

In July 2013, Ralf Hemmingsen, the Rector of the University of Copenhagen, visited Arctic Station along with Nils S. Pedersen, Chairman of the Board of Copenhagen University, John Renner, Dean of the Faculty of Science, Morten Pejrup, Associate Dean of the Faculty of Science and the former Dean Nils O. Andersen. The purpose of the visit was to determine the possibilities for promoting arctic research through an optimised use of the station. Hosting the visit were the old and the new chairmen, Reinhardt Møbjerg Kristensen and Bo Elberling. The guests were shown some of the projects run from Arctic Station, e.g., the Automatic Climate Station in Østerlien, the CENPERM experimental snow fence site in Blæsedalen, and the homothermal springs at Kuuanit. Morten Pejrup stayed a while longer and also visited the famous Isunngua spring in Mudderbugten.

Rector Ralf Hemmingsen (Center, brown coat) with fellow visitors, hosts and staff from Arctic Station.

The visitors from the rectorate at the CENPERM experimental snow fence site in Blæsedalen.

Field trip to see the basalt formations at Kuannit and explore the homothermal springs (photo: Bo Elberling).

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Summer feeling at Arctic Station (photo: Kirsten S. Christoffersen).

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