020 KORTRAPPORT/BRIEF REPORT SERIES
NORSK POLARINSTITUTT 2010

Terrestrial Ecosystems – a flagship programme for Ny-Ålesund

Concluding document from workshop 6–8 May 2009

Editors

Stephen Coulson, Geir Wing Gabrielsen, Christiane Hübner, Maarten Loonen

Svalbard Science Forum

Kortrapport/Brief Report Series no. 020

Terrestrial Ecosystems – a flagship programme for Ny-Ålesund

Concluding document from workshop 6–8 May 2009

Editors

Stephen Coulson, Geir Wing Gabrielsen, Christiane Hübner, Maarten Loonen

Norsk Polarinstitutt er Norges sentrale statsinstitusjon for kartlegging, miljøovervåking og forvaltningsrettet forskning i Arktis og Antarktis. Instituttet er faglig og strategisk rådgiver i miljøvernsaker i disse områdene og har forvaltningsmyndighet i norsk del av Antarktis.

The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in the Norwegian polar regions. The institute also advises Norwegian authorities on matters concerning polar environmental management.

Address
Svalbard Science Forum
P.O.Box 506
N-9170 Longyearbyen
ssf@npolar.no

Participating institutions
Czech Republic: Univ. of South Bohemia; Denmark: NERI; France: CNRS; Germany: AWI; Norway: DNMI, NPI, NVE, RCN, UNIS, Univ. of Bergen, Univ. of Oslo, Univ. of Tromsø; Italy: CNR; Japan: Osaka Prefecture Univ.; Poland: Univ. of Gdansk; Russia: MMBI; The Netherlands: Univ. of Groningen; UK: BAS, Stirling Univ.; Univ. of Aberdeen, Univ. of Newcastle; Univ. of Sheffield

Cover photos: Stephen Coulson – Aphids (*Acyrthosiphon svalbardicum*) feeding on *Dryas octopetala*, Blomstrandhalvøya.
Cover design: Jan Roald, Norwegian Polar Institute
Printed: August 2010
ISBN: 978-82-7666-279-5
ISSN: 1504-3215

Summary

A Svalbard Science Forum workshop concerning terrestrial research in Ny-Ålesund was held in Oslo, 6-8 May 2009. The aim was to discuss focal areas for future research and to initiate the **Terrestrial Ecosystem Flagship programme** as part of a NySMAC science plan.

Overviews of previous terrestrial science activities, current work and future plans of the individual research groups in Ny-Ålesund were presented. The **uniqueness of Ny-Ålesund**, the international and interdisciplinary research environment and potential for collaboration and integrative education, as well as the logistical advantages, accessibility and high-standard infrastructure were highlighted. The northern location, the coastal setting, the great heterogeneity of the area, and the long record of research combine to make Ny-Ålesund to a key location for terrestrial research in the High-Arctic.

Current gaps and infrastructure improvements were discussed. The implementation of **long-term data collection** requires improved organization, standardization and access to the research community. It was proposed to install permanent monitoring instrumentation at several locations in the Kongsfjorden area to record spatially explicit baseline data and to improve replication. Reference areas should be designated but also experimental manipulations need recognition as research tool to understand ecological processes and should be maintained over longer time periods. A prime requirement is for a central **Terrestrial Laboratory Facility** with key equipment and facilities. The laboratory should be operated by a permanent staff that can record scientific activity. Moreover, the need for a mobile field laboratory was recognised. The existing greenhouse and the facilities to maintain animals require renovation

Future research priorities were identified, with a focus on a watershed approach, integrated multi-thematic studies and improved interactions with marine and atmospheric research. **Four integrative projects** were proposed: The project '*Polar terrestrial ecosystems resilience to variability and change*' will exploit the natural variability in the Kongsfjord region, together with complimentary experimentation, to quantify the response of ecosystems to environmental variation and to provide baseline information on genetic diversity and ecosystem processes. The project '*Dynamic interactions of the cryosphere and biosphere*' will quantify and understand the coupling between cryosphere and biosphere across multiple spatial and temporal scales. Key objectives will be to close the carbon cycle and to link permafrost/snow dynamics and geology with biological processes. The project '*Marine-terrestrial links including pollutant fluxes*' will investigate the fluxes of matter, energy and pollutants between marine and terrestrial ecosystems. Flux processes, and their inter-annual variation, will be quantified and diverse webs compared. Understanding biodiversity is a baseline requirement for any programme addressing ecosystem structure, function and response to variability and change. Therefore, the project '*Biodiversity and the history of the Svalbard terrestrial biota*' will combine classical and molecular approaches to the study of biodiversity, in conjunction with dispersal and colonisation processes at various spatial scales. The importance of human impact on biodiversity will also be quantified.

The establishment of a **High-Arctic Land Observatory (HALO)** as part of SIOS was proposed to further integrate and coordinate terrestrial research within Ny-Ålesund and with other polar research bases.

Contents

1. Main features of the Terrestrial Ecosystem Flagship

1.1 Ny-Ålesund Terrestrial Integrated Research

- Ny-Ålesund is a key location for terrestrial research in the High-Arctic offering unique collaborative opportunities due to the outstanding international and multidisciplinary research community.

- Ny-Ålesund as a site for high-quality terrestrial research and monitoring has to focus on the international multidisciplinary synergies within Ny-Ålesund as well as collaborative efforts with other terrestrial stations in the Arctic and sub-Arctic.

- Abiotic measurements relevant to the terrestrial ecosystem need to be intensified and supplemented and their long-term perspective secured. This will provide background data for all research projects.

- Winter studies on the terrestrial ecosystem need to be strengthened to understand the overwintering strategies of the flora and fauna and their adaptations to the short summer.

- Ossian Sarsfjellet is an important plant protection area and requires careful managent. Removal of the reindeer or construction of exclusion fences should be considered.

- Monitoring programmes should document the impact of research and non-research activities, such as infrastructure and tourism, in Ny-Ålesund and in the surroundings.

1.2 Flagship innovations

- The establishment of a High-Arctic Land Observatory (HALO) will enable further integration and coordination of terrestrial research under the flagship programme within Ny-Ålesund and with other polar stations. HALO will be part of the European initiative SIOS.

- HALO will maintain existing and establish new biotic and abiotic data series over meaningful timescales. Ny-Ålesund will be an important long-term reference site providing open access baseline data for detecting future changes in the terrestrial system.

- Reference sites will be designated for monitoring natural changes and will be fully instrumented to record relevant parameters. In combination with long-term manipulative experiments unique possibilities will be provided for studies on the mechanisms of arctic ecosystems.

- A dedicated Terrestrial Laboratory Facility, comparable to The Kings Bay Marine Laboratory, will complement and extend fieldwork. A mobile field laboratory unit will complement the Ny-Ålesund terrestrial laboratory facilities. The existing greenhouse will be refurbished and will comprise an important unit in the infrastructure for terrestrial research in Ny-Ålesund.

2. Introduction

The Kongsfjorden International Research Base (KIRB) is a focal point for arctic research with investment from many institutions and many countries. The base excels in combining procedures to protect the environment and providing an infrastructure which guarantees easy access and a productive visit. There is an ever increasing demand from organisations to join, contribute and use KIRB. To optimize cooperation, and to minimize conflicts, KIRB has established the Ny-Ålesund Science Managers Committee (NySMAC), which is developing a science plan to strengthen cooperation, focus and future planning. This document is a contribution to this science plan for the terrestrial part, called the terrestrial ecosystems flagship.

The aim of this document is two fold. Firstly to describe the wide variety of international research which has contributed to the current success of KIRB and secondly to outline the way forward detailing future infrastructure requirements and improvements in international and interdisciplinary integration.

2.1 Importance of arctic terrestrial research

The arctic terrestrial and marine ecosystem will, in the years to come, experience large transformations due to climate change, increased human activity (tourism, shipping, fishing and oil exploration) and pollution. In order to document the influence on the terrestrial ecosystems it is important to establish research and monitoring programmes that enable us to detect these changes at different scales. Trends in large scale climatic monitoring programmes may differ considerably to trends in smaller microscale programmes. Up to now, only few a studies attempt to monitor at the microscale for longer than the duration of a short summer project. The data monitoring should be directed toward parameters which are key parameters in terrestrial models. The terrestrial data collected in Ny-Ålesund/Kongsfjorden should also be harmonized with monitoring activity in other parts of the Arctic/sub-Arctic. Moreover, integrated research which is directed toward linking the terrestrial ecosystem with the input from the atmosphere, as well as studies which show the influence of the marine ecosystem on the terrestrial systems, will be important for making future predictions. The models of today are mainly based on geophysical parameters in which ecological consequences are not taken into account. Data collection needs to be structured and it is important to secure the continuity of the data gathered from this area. Previous projects have demonstrated strongly the importance of long time series and experiments in order to document changes and influences on terrestrial and marine ecosystems in the Arctic. It will, in the years to come, be important to follow up some of these monitoring and research activities.

2.2 Uniqueness of Ny-Ålesund

The terrestrial research at KIRB makes use of the area in and around Ny-Ålesund, including entire Brøggerhalvøya, the land and glaciers surrounding Krossfjorden and Kongsfjorden, and the islands in Kongsfjorden. Within this area, a large variety of different geological features (for example reactive carbonates, recumbent fold, iron, red

sandstone, basement rocks, schists), soil types (incl. periglacial features), glacier types (cold based, temperate, surging) and habitats (eg. wet moss tundra, polar semi-desert and ornithogenic soils) can be found. Also, chronosequences across recently deglaciated land are more clearly expressed as compared to, for example, in Adventdalen close to Longyearbyen. This high heterogeneity enables researchers to conduct comparative studies in a variety of settings within a relatively small area.

Ny-Ålesund represents a coastal terrestrial environment and it is hypothesized that such an environment will be especially sensitive to changes in sea ice, changes which are occurring rapidly. In addition, the marine system can only be properly understood when the links with the terrestrial ecosystem are acknowledged, and vice versa. Ny-Ålesund with its intensive research focus on marine and terrestrial research represents an excellent showcase to study the interactions of the marine and terrestrial environments in the light of climate change.

From a logistical point of view, Ny-Ålesund is unique due to its location at 78^{o} N with easy accessibility year round and a high standard of scientific logistics and working conditions. All of these are exceptional and cost effective compared to other arctic locations.
The existing Research in Svalbard (RiS) database[1] for projects and data sets functions as an archive for research activities and is an important tool to avoid duplication of research and enhance cooperation.

Ny-Ålesund is furthermore an international and highly interdisciplinary research base, with stations from ten countries that conduct high quality research in a broad range of research themes. Thus, unique long-term data series of abiotic parameters are available and can be set in direct context with the terrestrial ecosystems. In addition, a range of long time series of terrestrial parameters already exist and forms a good foundation for a comprehensive monitoring programme of the terrestrial ecosystem and its changes.

Ny-Ålesund is clearly a potential ‘hub’ for training young scientists in an international and interdisciplinary environment, as recently practiced in most IPY projects conducted in Ny-Ålesund, but also, for example in the current NSINK project.

The Norwegian government presented the new white paper for Svalbard in spring 2009 and highlights the Norwegian intention to promote Svalbard as a reference point for climate change. Svalbard in general is a well protected wilderness that still is relatively pristine. In addition, Ny-Ålesund has been dedicated for research with special regulations, for example hunting restrictions and a ban on trawling in Kongsfjord. Thus, it is possible to compare developments in Ny-Ålesund with other areas in Svalbard and the Arctic.

[1] http://www.svalbardscienceforum.no/pages/database.htm

2.3 The Ny-Ålesund Science Plan & the Terrestrial Ecosystem Flagship workshop

The science community in Ny-Ålesund, under the auspices of NySMAC, is currently developing a revised science plan with the goal to further develop Ny-Ålesund as a premier international arctic research and monitoring facility. The science plan states that 'Ny-Ålesund strives for acting as one well coordinated international research facility, while at the same time maintaining the scientific quality and integrity of individual stations and research groups. Research within Kongsfjorden International Research Base (KIRB) is comprised of activities at all the stations. Substantial portions of these activities are related and complementary. To release the full potential of these complementarities and simultaneously increase the influence of KIRB in the scientific debate, the stations have agreed to build and implement flagship programs during the plan period.'

In order to initiate such a flagship program for terrestrial research, Svalbard Science Forum (SSF) invited leading researchers from 11 nations to a workshop in Oslo, 6-8 May 2009. The present document is the result of this workshop and defines core elements of the Terrestrial Ecosystem Flagship for Ny-Ålesund.

3. Present research structure and future needs

3.1 Data-series

Data collected over a series of years are highly valuable for providing background information to research projects and for documenting (climate) change. At present, some data series are collected for monitoring or management purposes. Specifically the census data on birds, seals, reindeer and arctic foxes fall in this category. However, most data series are gathered within specific periods and projects and are not always intended as long lasting monitoring. In addition, there are data sets which describe a point in time with no prior focus on repetition (for example the vegetation map of Brøggerhalvøya).

Many of the datasets have no detailed protocol recorded on how the data were collected. There is also often a limited availability with a substantial time lag in processing the data. An informative comparison can be made with the Danish arctic base at Zackenberg, where the main focus is to monitor the environment of which terrestrial datasets form the major part.

Registration of datasets and projects is improving. The RiS database of the Svalbard Science Forum registers metadata of projects and data sets. The initiative Svalbard Integrated Arctic Earth Observing System (SIOS), a European Community FP7 program for large scale research infrastructures, will in addition develop extra structures for holding, presenting and processing the actual data. A detailed register of all data sets into the RiS database gathered in the direct vicinity of KIRB, which span at least more than three years will be a direct follow-up of this document.

In general there is no commitment of the science community in KIRB to maintain a dataset for longer than the duration of a science project. The coordinating group

established under this flagship initiative needs to discuss and prioritize a minimum commitment of collecting data. Special attention needs to be paid to the quality of the data and the geographical distribution of the sampling points.

3.2 Facilities

3.2.1 Laboratory facilities with instrumentation

At present, there is no specific laboratory facility for terrestrial research in Ny-Ålesund. Several stations have some general multidisciplinary laboratory space with benches, but instrumentation is either basic or duplicated. Access to these basic facilities can be obtained by incidental agreements, but there is no general vision. This document supports the establishment of multi-user instrumented laboratories for terrestrial research.

The prime requirement is for a dedicated Terrestrial Laboratory Facility. The Kings Bay Marine Laboratory has demonstrated that there is a requirement for laboratory facilities at Ny-Ålesund to complement and extend fieldwork. This laboratory should include both dry and wet labs. In addition to standard laboratory apparatus, the equipment provided should include temperature controlled cabinets and freezers. Moreover, the laboratory should be fully instrumented with, for example specialised microbiological and molecular equipment, ability to handle radio-isotopes, analytical rooms with gas and high performance liquid chromatography systems, as well as additional chemistry apparatus. Reliable access to liquid nitrogen is required. Wet sample preparation laboratories should provide adequate space for handling soil, animals and plants. The dry facilities should also include computer laboratory provision with GIS, digital elevation models, aerial photographs and access to remote sensing data. The laboratory should be operated by a permanent staff responsible for booking procedures and maintenance of the instrumentation. These staff can also be charged with overall responsibility of mapping scientific activities and recording, for example, details of any field manipulations undertaken.

As a temporary solution, a specific laboratory for microbial studies was discussed during the workshop meeting as a first initiative where various countries would invest into equipment and where the laboratory space would be made available by one of the stations (CNR, Italy). This concept needs further evaluation, especially as far as responsibility, maintenance and safety are concerned. Alternative laboratories could include facilities for cleaning, washing, sorting and drying plant and soil samples or facilities to maintain a constant environment.

In addition to a permanent terrestrial laboratory in Ny-Ålesund, the need for a mobile laboratory capable of being placed out in the field has been recognized. This resource would provide onsite bench space, power (wind/solar/petrol) and internet connection for both the laboratory and also for exterior equipment, for example warming cables. Use of Kings Bay huts, or construction of new field bases, within the Kongsfjord area for scientific purposes should be initiated.

As a result of previous research, there are some unique facilities, which need renovation for future use: the greenhouse and the facilities to keep animals in captivity. The green house is divided in three compartments with independent heating. The heating should be replaced by a computer controlled climate control unit to allow a stable temperature regime. The facilities to keep birds and arctic foxes in captivity are attached to respectively the old mine workshop and the old mine bath, southwest of the village. These facilities need renovation before they can be reused or could be replaced at other localities. They can only operate under a license for keeping experimental animals and a remote camera system should keep the animals under surveillance. Both facilities should be managed as joint facilities for the community and a long-term solution for running costs and repair has to be put in place. In addition, these facilities should be extended to accommodate cultures of invertebrates as important contributor to terrestrial animal diversity studies.

3.2.2 Relevant permanent equipment in the field

Terrestrial research relies heavily on background data of weather and snow cover, especially at small and micro scales. At the moment, there are few locations were detailed information on the weather is collected permanently. The main weather station is in the instrument area south of the village. Other locations are linked to specific instrumentation or projects, but there is no integrated plan on measuring local variation. Snow cover is measured locally as albedo or over a wider area with time lapse camera's situated in the Zeppelin station. To date, these measurement have not been interpreted. Snow depth is not yet measured.

There are a several locations which can be considered for permanent equipment to measure parameters relevant for terrestrial research. These locations are already developed with electricity and/or data cables. The instrument area south of the village is the general designated area. The Zeppelin station provides a high view point for time lapse cameras. Moreover, the Amundsen-Nobile-Tower allows installation of instruments at any height up to 30 m. The tower is connected to electricity as well as broadband connection. In addition, the energy-self-sustaining French Corbel station east of Ny-Ålesund is a potential location for instruments.

3.3 Gaps of knowledge

A range of gaps in our current knowledge or understanding of the terrestrial and freshwater system were identified. These fall into two main groups. The first group includes data that is beyond the range of most projects to adequately collect and analyze but which forms essential background information describing the terrestrial and freshwater systems. The second group includes areas that require more detailed studies in order to better understand the processes and links in the terrestrial and freshwater systems.

3.3.1 Long-term time series environmental observations

The lack of long-term time series of environmental parameters are a particular issue. Interannual stochasticity often precludes meaningful extrapolation from environmental data collected within the time frame of a particular project. Seasonal cycles are also difficult, if not impossible, for the majority of projects to effectively describe. In particular it is important to initiate enhanced and coordinated meteorological monitoring including down scaling of climatic/environmental variables from macro to micro scales.

In addition to meteorology there are a range of other parameters that require coordinated monitoring, for example methane fluxes, pollutants, biological phenology and population variability.

3.3.2 Areas of study

There is a need for greater understanding, and detailed records of a range of physical parameters influencing the terrestrial system. Most climate change scenarios project large changes in annual temperatures and precipitation which will be accompanied by significant changes in vegetation communities. However, many plant communities are severely nutrient limited. Nutrient dynamic studies should include allochthonous inputs from the marine environment as well as fluxes from ice and snow. Linked to the soil nutrient cycling is a large gap in our understanding of soil geochemistry, microbiology and methane production, especially in newly deglaciated regions. Finally, a better appreciation of groundwater and permafrost interactions is needed.

The biodiversity of the Arctic is poorly understood. Species lists and the taxonomy of the Svalbard flora and fauna are often confused, especially with regard to the invertebrate fauna. Nonetheless, while knowledge of the invertebrate fauna is poor there is as yet no reliable estimate of the microbial biodiversity. Projects at Ny-Ålesund need to describe the biodiversity by traditional morphometric taxonomy but also by employing molecular techniques to bar-code the flora and fauna. In addition the appearance of new arrivals should be logged.

Few studies of overwintering ecology have been undertaken on Svalbard. A more complete knowledge is needed not only of how the fauna and flora overwinter but also how lifecycles have adapted to maximize the short cool summer period.

Freshwater forms an important element of the arctic terrestrial environment. Many pools, ponds and lakes can be considered isolated entities and ecosystems; islands set within the tundra landscape. Nonetheless, there are key nutrient exchanges with the surrounding environment influencing community dynamics within the freshwater body and the surrounding terrestrial system. Studies on these topics have only been conducted infrequently in Ny-Ålesund and should be strengthened.

There is currently only scant information on the palaeoenvironmental history of Svalbard, for example lake sediments, glacier variations and vegetation cover. Such information is essential to fully understand the history of the current flora and fauna communities and

how they were assembled. In addition, projects studying the periglacial landform activity occurring around Ny-Ålesund are scarce.

3.3.3 Overall themes

Three overarching weaknesses in current terrestrial research are highlighted:

- Replication is often poor in terrestrial research with small sample sites and insufficient sampling, spatial and temporal, to draw meaningful conclusions.
- A watershed approach is required to better describe the system. Such an approach would enable inputs and outputs to be quantified and enhance the predictive value of numerical modeling projects.
- Integrated multi-thematic projects are necessary. Current research often focuses on particular mono-thematic problems or questions. To more fully understand the terrestrial system more multi-thematic projects bringing together workers from diverse specialisms are required.

4. Integrative projects

In order to understand the complexity of terrestrial ecosystems it is crucial to conduct integrated system studies. Several proposals for international and interdisciplinary research projects were developed for this purpose, all emphasizing the importance of winter studies:

1. Resilience of polar terrestrial ecosystems to variability and change
2. Dynamic interactions of the cryosphere and biosphere
3. Marine-terrestrial links including pollutant fluxes
4. Biodiversity and the history of the Svalbard terrestrial biota

4.1 Polar terrestrial ecosystem resilience to variability and change

Understanding and predicting how global ecosystems will respond to current environmental change is arguably the most pressing challenge facing biologists today. Polar terrestrial ecosystems are predicted to experience some of the most rapid changes in climate over the coming decades and they can also be hypothesised to be especially sensitive to change due to their position towards the climatic extremes. Although these ecosystems are often described as ‘simple’, in reality they include examples across a wide range of complexity, providing an unparalleled research tool with which to address fundamental questions relating to ecosystem structure, function and stability, particularly in bipolar or changing environmental contexts. The simplest ecosystems allow probing of ecosystem assembly rules, and may also be particularly strong sentinels of change through their low functional diversity and redundancy. Studying the consequences of change in these ecosystems is a tractable challenge that will generate scientific insight applicable to ecosystems globally.

While some areas of terrestrial biodiversity are relatively well known, either in the context of particular taxonomic groupings or locations, other areas are currently much

less known. This is particularly the case for microbial diversity, although clearly much higher than that of macroscopic animals and plants, and for descriptions of patterns of biodiversity across spatial scales. Thus, robust baseline description of terrestrial biodiversity is both a prerequisite and a foundation of this project.

This project will utilize the marked natural variability (e.g. environmental gradients, microclimate, surface age, underlying geology) in the Kongsfjord region, together with targeted environmental manipulation experiments, to quantify how ecosystem structure and function respond to environmental variation, and to provide baseline information on genetic diversity and ecosystem processes. We will test resilience to variability and change by conducting manipulative experiments both in the field and in controlled environments. Factors under study will include snow depth and density (including ice layer formation), thaw season temperature, water availability, nutrient availability, impacts of grazers (invertebrate and vertebrate), life history factors (including physiology, genomics), and the decomposition process. Many of these areas involve clear linkage with other project level elements of the flagship programme.

4.2 Dynamic interactions of the cryosphere and biosphere

The terrestrial biosphere of the Arctic is strongly coupled to the cryosphere, the structural properties of communities and ecosystems (particularly plant architecture, surface roughness and albedo), is largely influenced by active layer dynamics (thaw progression and thickness), top permafrost thermal state and the distribution of snow in the landscape. This integrative project aims to quantify and understand the coupling between the cryosphere and the biosphere across multiple spatial and temporal scales, and thus contribute to Earth System Modelling.

A key objective will be to close the carbon cycle for this high-arctic system, so that land-atmosphere fluxes of the greenhouse gases CO_2 and CH_4, and land-freshwater fluxes of particulate and dissolved organic and inorganic carbon, can be quantified, predicted and the processes controlling their releases understood. Furthermore, the project will aim to link permafrost/snow dynamics (which are coupled to atmospheric processes and properties), geology, and biological processes across the full hierarchy of levels of organisation from individuals, to species, populations and communities. Biological feedbacks to physical environment, as for example exchange of greenhouse gases, changes in albedo and insulation, will be addressed explicitly. In this respect the biosphere is considered an integral component of the broader Earth System rather than a passive ‘recipient’ of change.

Quantifying and understanding the dynamic interactions of the cryosphere and terrestrial biosphere will require a whole-system approach which cuts across traditional disciplines in the natural sciences. Development of this integrated project will bring together atmospheric scientists and modellers, micrometeorologists, soil and sediment physicists and chemists, hydrologists and hydrogeologists, glacial and periglacial geomorphologists, terrestrial ecologists, biogeochemists, molecular geneticists and microbiologists, ecological and physical modellers. It will also interface directly with issues focused on by the atmosphere, ice and marine flagship programmes in Ny-Ålesund.

Snow-cover, active layer and permafrost dynamics and geomorphological processes: Snow depth, duration, and physical properties tend to vary systematically across the arctic landscape as a result of topography, meteorology, and ecological community characteristics. Superimposed on this spatial variability is substantial interannual variation in snow cover, timing and duration, reflecting climatic stochasticity. Permafrost thermal state affects the active layer thickness and summer water content in the active layer, particularly where ice-rich transient layers exist. In Svalbard the permafrost seems to be not very cold despite the high-arctic location and is clearly affected by the overall maritime setting. Thus increases in the permafrost temperature can cause increases in the active layer thickness, which might release greenhouse gases such as CO_2, CH_4, NO_2 and H_2O directly from the permafrost via the active layer to the atmosphere. However, the parts of the landscape where such releases are most likely to occur have not been identified. To address this possibility, intensive thaw progression data collection is needed through the summer season in addition to permafrost borehole temperature measurements. Sediment coring of the top permafrost is essential to assess the amount of ice in the top permafrost, and for more detailed studies of the greenhouse gas content in this part of the permafrost.

The effects of changing snow cover, active layer expansion and top permafrost thawing on the arctic terrestrial biota are potentially profound, since these aspects of the cryosphere play such a key role in the structure and function of ecosystems. The mosaic of vegetation communities and soil types are largely controlled by snow distribution in the landscape, thaw depth, periglacial processes and landforms. Changes in the active layer thickness, its water/ice content and the top permafrost thermal state, controlled by either overall meteorology or local site specific conditions, affect the rate of periglacial slope processes such as solifluction (gelifluction), active layer detachment failure, debris flow activity, rock glacier speed of movement and in lowlands also ice-wedge dynamics, cryoturbation and generally the overall size of the frost lifting and thaw settlement of the terrain surface annually.

The way in which consumers (both invertebrate and vertebrate) utilize the landscape is related both to vegetation type, phenology, and forage availability, all of which are influenced by snow-cover and thaw depth. The timing of the spring melt also has an important effect on the freshwater systems, for example in the opening of the rivers and streams, of particular importance to migratory populations of the arctic char. Furthermore, the carbon cycle in the High-Arctic is also intimately linked with the cryosphere. Snow cover effectively places a limit on photosynthesis, and much of the photosynthetically active radiation (PAR) in the High-Arctic is unavailable for photosynthesis because many parts of the landscape do not become snow free until mid-summer or later. A snow layer on lake ice cover has a decisive influence on light penetration. While lake ice may be translucent, snow cover will reduce PAR transmission affecting the response of the lake primary producer community early in the season. Another component of the carbon budget that has received considerable research emphasis in sub- and low-arctic ecosystems, but less attention in the High-Arctic, is CH_4. CH_4 formation (methanogenesis) occurs where organic material is available for bacterial decomposition in anaerobic conditions (in soils and sediments).

Different age landscapes for ecological research: Shrinking glaciers and snow patches are exposing new landscapes for colonisation by organisms, as well as they change the dominating geomorphological processes and resulting landforms. These changes provide opportunities to study dispersal and colonisation processes, ecosystem dynamics, community assembly, and the interplay between the biota and the physical environment. The Kongsfjord region specifically provides chronosequences of new surfaces and water bodies, both in the context of the offshore islands (Lovénøyane) and the valley glacier systems (Lovénbreane and Brøggerbreane).

Research infrastructure and techniques: Environmental manipulation experiments (e.g. snow fences) will be implemented to test specific hypotheses regarding the dynamics of contrasting system components in response to environmental change. Already existing experiments (e.g. fertiliser; herbivore exclosure) will also be re-visited, repaired and augmented where appropriate. A watershed ecosystem approach will be deployed as a tool for integrating system components and linking atmosphere, land surface, freshwater and near-shore environments. The proposed project will incorporate the full spectrum of relevant biological communities (e.g. soil microbial, invertebrate, vertebrate, plant, glacial/subglacial, freshwater/terrestrial), and functional type approaches (RNA, 'omics' approaches) will be deployed. Trophic interactions and their role in energy flows and nutrient recycling will be quantified. The project will provide new knowledge of high-arctic carbon cycling that will contribute to the next generation of General Circulation Models (GCMs) of the Earth's climate. Soil and vegetation carbon and other nutrient stocks will be quantified across the landscape to predict likely responses to change, and the lability of soil organic matter stocks to climate change scenarios assessed. Fluxes of greenhouse gases will be measured using both headspace chambers and eddy covariance techniques, and measurements will extend through late winter, the thaw period, summer, and autumn freeze-up in order to capture full seasonal greenhouse gas budgets. Winter CO_2 emissions will be determined to augment these flux measurements and to produce an annual budget for CO_2. For CH_4 both chambers and tuneable diode laser (TDL) technology will be deployed. The interaction between carbon cycling, nitrogen (N) and phosphorus (P) will be investigated both by utilizing natural variability at the landscape scale (i.e. contrasting ornithogenic communities beneath bird cliffs with communities not receiving significant inputs of guano) and by experimental nutrient additions.

Ny-Ålesund and SIOS provide an unprecedented opportunity for the parallel and integrated development of (a) observatory, (b) experimental, and (c) modelling initiatives aimed at quantifying and understanding the interplay between the terrestrial biosphere and the cryosphere, and contributing to a robust mechanistic and predictive model of dynamics in response to global change drivers. There is a real opportunity here to shape an international and multidisciplinary research team that will produce a step-change in understanding of combined biological and geological processes, as well as building research capacity for the future.

4.3 Marine-terrestrial links including pollutant fluxes

The importance of allochthonous nutrient input to the nutrient deficient terrestrial Arctic ecosystems is well recognized yet poorly understood. In the Kongsfjorden region there is a substantial flux of nutrients (C, N and P) from marine to terrestrial ecosystems via avian vectors. Furthermore, both nutrients and pollutants are transferred from the terrestrial to marine systems, mainly during the spring melt-out. This movement can be regarded as a two-way process, although the mechanisms of transfer to land are predominantly avian, while those to sea are mainly fluvial. Transfer of terrigenous particles and terrestrial organic carbon should be receive special attention.

Arctic regions act as a sink for pollutants originating at lower latitudes. Transport of pollutants into arctic regions occurs through four main physical pathways; atmosphere, rivers, sea-ice and ocean currents. The principle pathway is via atmospheric transport. Significant quantities of pollutants are deposited annually in the Arctic, especially in spring. Dry deposition and precipitation scavenging of gaseous and particulate phases are also important pathways of pollutant input into the ecosystem. The Arctic is not isolated from industrialised regions and the marine and terrestrial realms are strongly linked, both locally and regionally. Pollutants of concern include heavy metals (including mercury), radionuclides, POPs, NOx and black carbon which generally originate 1,000s of km further south.

An additional important vector for transport of industrial and agricultural pollutants to the terrestrial ecosystem are seabirds. Seabirds are the link between the sea and terrestrial ecosystem and carry pollutants such as DDT, PCB, radionuclides and mercury in their faeces. Nutrients and pollutants are deposited close to seabird colonies and high levels are found in these areas where many terrestrial animals feed. This process may be adding to the high levels of industrial chemicals found in some arctic regions. PCBs are one example of POPs - chemicals which are broken down very slowly by biodegradation, and which accumulate in living organisms, including humans; other examples are pesticides, including DDT, and multi-purpose substances such as hexachlorobenzene (HCB). How these substances are accumulated and biomagnified in arctic organisms is not entirely clear - the presumption has been that they are transported by several transport routes, as particles in the air, in the sea currents and also in the bodies of migratory species.

During the past two decades, steady progress has been made in the research of contaminants cycling in the Polar Regions. For example, in 1991, the international organization AMAP was established to implement components of the Arctic Environmental Protection Strategy (AEPS). Such programs, which also have introduced in Kongsfjorden, are important for a better understanding of the fate of contaminants in the Arctic region. Moreover, some recent evidence has been accumulated during the past decade that indicates that global change may alter the exposure risks to contaminants delivered in the Arctic. The IPY project COPOL has provided new data from Kongsfjorden on this topic.

To study the fluxes of nutrients between the marine and terrestrial ecosystem it is proposed to establish a research site in one of the main seabird colonies in Kongsfjorden. An interdisciplinary project including, for example, microbiology, botany, soil ecology,

toxicology and seabird ecology would enable the quantification of nutrient and pollutant fluxes from the marine to the terrestrial ecosystem and the response of the terrestrial system to these inputs. Moreover, the terrestrial deposition of nutrients and pollutants over a wider scale than in the spatially restricted areas beneath seabird colonies will be assessed to more fully appreciate the overall effect of such inputs. This project will be coordinated with ongoing pollutant studies including those at the Zeppelin atmospheric monitoring station.

4.4 Biodiversity and history of the Svalbard terrestrial biota

For its latitude, the 'traditional' biodiversity (i.e. species richness) of the Svalbard archipelago is remarkable, in part because in a relatively small and accessible geographical area are found examples of many of the different types of terrestrial ecosystem and biological community found over much wider spatial scales in the continental regions of the Arctic. However, biodiversity is a far more complex concept than a simple count of species numbers, and as defined in the Rio biodiversity convention, includes elements of biological variability at all levels from the genomic to the ecosystem. Thus, understanding biodiversity is a fundamental and baseline requirement for any programme addressing ecosystem structure, function and response to variability and change.

Understanding contemporary biodiversity implicitly requires inclusion of a historical element – the question includes not only 'what is there?', but 'how did it get there, when, and what linkages with other locations?'. Here, forefront molecular phylogeographical techniques can be applied to identify timescales and patterns of colonisation and evolutionary divergence, and to provide insight into levels of population isolation or linkage. The outputs of such studies, as well as providing fundamental advances in biological understanding, can also provide novel constraints and confirmations of glacial reconstruction modelling hypotheses generated by the physical sciences community and central to understanding the regional ice evolutionary history of Svalbard**.** To study the effect of climate change on biodiversity, especially on lower animals and plants, it is essential to document the existing biodiversity. A new method, DNA barcoding, can be used to discriminate and identify species and facilitates the study of patterns of variability as well as species boundaries. It is suggested to establish a reference bar code library of the terrestrial flora and fauna in the Kongsfjorden area as baseline for future changes.

This project will combine classical approaches to the study of biodiversity with these molecular approaches, along with study of contemporary dispersal and colonisation processes at various spatial scales. The latter will involve both small-scale experimental and observational study of dispersal (e.g. through the use of air-traps) and underlying ecophysiological tolerances, as well as the creation of novel inter-disciplinary linkages with climate (meteorological, modelling), air sampling and glaciological (ice coring) communities to study colonisation processes, patterns and opportunities at larger physical scales (and in the case of linkage with ice coring, historical timescales). The importance of direct human impacts on biodiversity, particularly in the context of 'alien' species transport and introduction (including disease pathogens), will also be quantified. Core monitoring sites will be established encompassing a range of terrestrial communities, in

order to permit the description of change in biodiversity over time, and its linkage with environmental and human variables.

5. High Arctic Land Observatory (HALO)

Current terrestrial research at Ny-Ålesund is often fragmented and undertaken over short time periods. This is in sharp contrast to the upper atmosphere and meteorological measurements. During the workshop there was a strong consensus to improve integration of terrestrial research of the various NySMAC members, to join forces in collecting baseline data and to share laboratory facilities. This will be a major improvement for the local science community in Ny-Ålesund and will be soundly anchored within the SIOS process, which covers the whole of Svalbard. We therefore describe a High Arctic Land Observatory (HALO) as management framework for terrestrial research at Ny-Ålesund.

The role of HALO is multifaceted. The primary functions are to manage and oversee the long-term monitoring programmes, the operation of the terrestrial laboratory, the organization of reference and experimental plots and to facilitate visiting researchers. In addition HALO should assist in coordinating, developing and extending the terrestrial research programmes. Central core funding is required for HALO to ensure focus and longevity.

The goals of HALO are:

- link research fields, projects and different scales
- ensure continuity in essential datasets
- ensure coordinated efforts
- provide baseline data for new research projects
- initiate new research projects
- minimize potential conflicts
- integrate the flagships
- link KIRB with other arctic research bases

5.1 Features within HALO

HALO will make an administration available to terrestrial researchers providing access to datasets, including satellite remote sensing and aerial photograph, as well as supervising experimental and reference sites. It will be of utmost importance to make funding available to assist researchers to follow up established projects.

There are few long-term data sets from high-arctic regions and the year round operation of Ny-Ålesund enables the initiation of such monitoring programmes and reference sites through HALO. This will ensure the collection of data over meaningful timescales and will enable Ny-Ålesund to become a valued long-term reference site providing a solid baseline data series for detecting future changes in the terrestrial system. This initiative will be coordinated with existing stations in Svalbard, Greenland, Canada, USA and northern Russia and provide open access to a diverse range of monitoring datasets. This approach will enable data collected at Ny-Ålesund to be seen in a broader perspective and

provide an improved pan-arctic understanding of terrestrial environments. Moreover, the gathering of such datasets will be available to new and established scientists working at Ny-Ålesund providing exceptional background information.

Highlighted parameters that require monitoring are meteorological data at a variety of scales including microscales, population dynamics including marked individuals (animals and plants), genetic fingerprinting, interaction between, foxes, reindeer and birds, microbial community, biotics (NVDI, phenology, taxonomic census), arrival of new species of plant and animal, photosynthetically active radiation (PAR), methane fluxes, permafrost boreholes (active layer depth) and periglacial landforms, species reference collections, pollutants (local and long distance) and coastal dynamics observations (including erosion and deposition as well as fluvial sediment transport).

Reference sites can have different attributes and several approaches are planned. Hunting and trapping within the Kongsfjord catchment area should be suspended and the reindeer removed from Ossian Sarsfjellet. The existing reindeer exclosures should be renovated, replicated and built into the monitoring regime. Selected areas should be protected from major human impact and intensively instrumented to record local events, for example, timing of snow melt and green-up (NVDI). In addition, impact of research activities, tourism on land and cruise ships within Kongsfjord needs to be scrutinized.

Long-term manipulative experiments in zones within the Kongsfjord watershed will be established under the auspices of HALO, manipulating for example snow melt, grazing exposure, nutrient input and carbon flux. Such areas would then provide unique possibilities for studies and experiments on the mechanisms of arctic ecosystems. In addition, the establishment of fox free areas as well as experimental tern and kittiwake colonies will be considered. All manipulations need careful registration to minimize undesired effects on baseline measurements.

Finally, through the establishment of the terrestrial laboratory facilities HALO will promote complimentary laboratory and field studies and hence activities currently restricted by infrastructure limitations.

5.2 Integration with other Ny-Ålesund flagship programmes

So far three flagship programmes have been developed according to the goals of the Ny-Ålesund Science Plan. These flagships include the terrestrial programme, the Kongsfjorden system (marine ecosystem) and the atmosphere programme (troposphere including pollution, abiotic parameters and climate; upper atmosphere). A fourth programme related to the snow and ice system is planned for the near future. The four programmes have close links and will be further harmonized in order to establish an integrated research and monitoring programme for Ny-Ålesund/Kongsfjorden.

These Ny-Ålesund flagship programmes are first steps in combining forces to engage with global environmental issues in manners that the individual projects and stations cannot on their own. This will pave the path towards a comprehensive Earth System science approach for research and monitoring in Svalbard.

5.3 Ny-Ålesund in a broader perspective

There are several research bases in the High-Arctic with long-term terrestrial data series similar to KIRB. Examples are the Polish base at Hornsund, Svalbard, the Danish bases Zackenberg and Nuuk on Greenland and the Canadian field station on Bylot Island. These bases are usually run by one group or nation which has also the responsibility for the science plan. KIRB is unique as an international consortium. It is manned all year and has by far the widest range of disciplines and topics under study. It is important to ensure the integration of KIRB within this network of international research facilities.

5.3.1 Links with other research bases in Svalbard

The four main research bases, Ny-Ålesund, Longyearbyen, Barentsburg and Hornsund are spread out along the west coast of Spitsbergen and are influenced by quite distinguished biotic and abiotic parameters. Cooperation between the bases increases the synergy and, thus, the relevance of results obtained in Svalbard as research hub in the Arctic. There are several initiatives, such as SSF and SIOS, to increase and better coordinate ongoing cooperation between the research bases in Svalbard. Focus points are common protocols and comparative studies, as well as complementarities in the research. Furthermore, researcher and student mobility between the bases should be promoted to further stimulate cooperative efforts.

5.3.2 Links to Greenland

From the terrestrial point of view, Zackenberg station in western Greenland is an important partner. It is situated at the opposite site of the Fram strait. Most of the research at Zackenberg is focused on the terrestrial and freshwater ecosystem. At the base, over a thousand abiotic and biotic parameters are monitored annually following detailed protocols and results are presented in annual reports. From a scientific point of view, there is an interesting comparison where sea currents form a contrast in direction, temperature and e.g. pollutant loading. For KIRB we envisage similar measurements and comparative research that will be strongly coordinated with protocols and target species in Zackenberg. In addition, KIRB needs to develop its own strong characteristics in terrestrial research by creating an opportunity for manipulative field studies.

5.3.3 Pan-Arctic and global perspective

As the largest research base in the European Arctic, with a strong international background, KIRB should together with NySMAC develop its own strategy to participate in circumpolar initiatives like those initiated by the Arctic Council or the working groups AMAP and CAFF. By building an Earth system science capability in Svalbard, KIRB shows the way for the implementation of SIOS. The development of SIOS will provide a cornerstone for SAON which seeks to build a circum-arctic observational system.

Contributions to international networks which are not specifically designed to cover the Arctic would further improve a world perspective on scientific methods and monitoring.

Potential networks are LTER and GLORIA. LTER is a US network with 26 selected sites ranging from Alaska to Florida and the Antarctic. GLORIA is a initiative in Alpine environments, which tries to maintain a global observation network. KIRB, through HALO, should play an active role in data exchange and formulating common research interests with these networks.

6. Funding needs

Traditionally, most investment and data gathering are financed as part of specific research projects. Monitoring of some key environmental parameters has been discussed within NySMAC during various meetings and some of the stations have expressed their commitment to some of the measurements. A financial structure for these measurements has not been established yet.

Though the majority of the data gathering will continue through short term projects, it is essential to commit to some core monitoring activity with proper investment and a sound financial basis. Potential sources for funding are dependent on the key users of the data which include specific institutes (NySMAC), Norwegian authorities, national research funding organisations, the European Community and private parties or sponsors.

The Research Council of Norway (RCN) states in its policy document for Norwegian Polar Research 2010-2013, that it intends to develop a strategy to fund existing and new long-term data series concerning climate and environment. Additionally, Ny-Ålesund as international research station should attract international investment into long-term data series as solid base for future cutting edge research.

The initiative SIOS will develop a legal structure where international investors can contribute to a common research infrastructure. SIOS will thus also facilitate the legal issues concerning this flagship and offer a stable structure of funding common interests. SIOS will thus, secure the running of initiatives such as HALO.

NySMAC should also develop a plan and prioritise options for investment and data gathering. This could be used as a master plan of all future funding opportunities.

European funding for training and mobility (through LSF and ARCFAC) has been instrumental for allowing first time researchers to Ny-Ålesund and to initiate new projects. The funding of small travel grants for established researchers has proven more difficult and hampers continuity in the datasets. In order to secure continuation in the research, it is imperative that additional funding sources for established researchers are created as long as they contribute to baseline datasets.

Appendix 1: Summary of presentations during the workshop

A. Setting the scene - presentations about the history of terrestrial research in Ny-Ålesund

Elisabeth J. Cooper: History of botanical research on Svalbard, especially in Ny-Ålesund

History of Botanical Research on Svalbard and in Ny-Ålesund

There are 174 vascular plant species recorded for Svalbard, 373 species of bryophytes and 630 lichen species. These are greater values than other arctic areas, e.g. Devon Island, Canada (75ºN 84ºW) which has 96 vascular, 70 bryophytes and 120 lichen species, and also Barrow Alaska (71ºN 56ºW) which has 139 vascular, 122 bryophytes and 162 lichen species. The higher plant diversity on Svalbard has been in part contributed to the milder climate due to the Gulf Stream, and the influx of seeds and propagules from the European Arctic and Greenland.

Descriptions of plants seen on Svalbard in the1820s-1930s were first made as part of expeditions which were either focused on mineral prospecting or general scientific interest. Plant samples were in some case collected and contributed to herbaria (e.g. Keilhau - Spitsbergen (Herbaria, Oslo, 1827); Torell and Nordenskiöld - Spitsbergen (1858, 1861); Göes - 1st observations recorded from Ny-Ålesund (1861); Nathorst - Kapp Thordsen (1870); Kjellmann, -Advent Bay (Herbaria, Tromsø, 1872); Andersen - West coast Spitsbergen (Herbaria, Trondheim, 1890); Bruce - Spitsbergen (1906, 1907, 1909); Resvoll-Holmsen - Spitsbergen (1907 onwards). Resvoll-Holmsen was one of the first scientists who came to Svalbard on a purely botanical excursion. She was also a pioneer in nature conservancy issues, and her botanical studies were used as important background material for the establishment of plant protection areas and hunting ban on reindeer in Svalbard in the 1920s and 1930s.

Plant descriptions and lists

Several plant lists have been assembled: Resvoll-Holmsen, 1927: *Svalbards flora*; Rønning, 1961: *Svalbards flora*; Lid, 1967: *Twenty vascular plants from Svalbard*; Löve & Löve, 1975: *Cytotaxonomical atlas of the Arctic flora* ; Elvebakk & Prestrud, 1996: *A catalogue of Svalbard plants, fungi, algae and cyanobacteria.*

From the mid 70s, plant science focused on plant distribution and ecology, rather than just lists of plant species:

1975-85 ‘Man and the Biosphere’ program was ongoing on Svalbard. It gathered ecological information including plant biomass, grazing offtake, reindeer growth rates, soil properties.

1976-78 Vegetation map of Brøggerhalvøya, Brattbakk,1984.

1978: 15 Svalbard reindeer were released for a population growth study in Brøggerhalvøya. 12 survived the first winter and the population increased dramatically thereafter. 3 reindeer exclosures were erected.

1980-90-2000 The response of vegetation to reindeer grazing in Brøggerhalvøya was studied by Hans Staaland from the Norwegian agricultural post-graduate college in

Ås (with masters students Øystein Holland, Jon Øve Schie and Tor Punsvik), and Elisabeth J. Cooper (NPI).

1980-90 Elven, Elvebakk, Engelskjøn, Spjelkavik carried out vegetation mapping throughout central Svalbard, often commissioned e.g. by Store Norske, Statoil.

2005 Vegetation map of Svalbard: Elvebakk

2009 Satellite based vegetation map of Svalbard, including seasonal NDVI: Bernt Johansen NORUT, Hans Tømmervik NINA, Stein Rune Karlsen NORUT

2009 Growing Degree Days Map of Svalbard: Daniel Joly (Université de Franche-Comté), Geir Arnesen & Lennart Nilsen (University of Tromsø).

Process based studies, experiments and monitoring

1990-99 Project TERRØK. Its aim was to study the fundamental ecological processes to increase understanding of dynamics and stability of terrestrial ecosystems in arctic ecosystems Svalbard, using basal ecological research necessary for management to reach the overall goals of the environmental policies. Ann Marie Odasz (Tromsø University) was one of the key plant scientists involved. She set up experiments, including more reindeer exclosures on Brøggerhalvøya, and also monitoring plots set up on Dyrevika.

1990- Netherlands started a research station in Ny-Ålesund: M. Loonen- worked on geese and plants and their interactions, from c 2004- J. Rozema erected OTCs near Ny-Ålesund as part of a climate change effect study on different plant communities.

1991- NERC Arctic Special Topic (ecology) 1991-94 Themes within ecological research were climate effects on plants and invertebrates, carbon balance of various plant species and enhanced N input on tundra vegetation.

1992- Japanese station started up research in the foreground of Brøggerbreen, especially studying plant establishment and carbon balance.

1995 – French station, Midreløvenbreen. Themes included plants as thermophilic indices.

1999-2002 NPI vegetation-reindeer interaction study on Brøggerhalvøya.

2009 NPI sets up vegetation monitoring program in Svalbard (NINA commissioned to set up permanent reference plots at Endalen near Longyearbyen and near Ny-Ålesund)

Other centres for vegetation research in Svalbard

Around most settlements and research bases in Svalbard, vegetation research has been and still is being conducted:

- Longyearbyen and surrounding areas, e.g. Adventdalen, Endalen and around Isfjørd including Sassendalen (UNIS, UoT, VU Univ. Amsterdam) have been studied since1970s.
- Svea (UNIS, UoT) 1985 onwards
- Kinnvika (Swedish IPY base), Nordaustlandet 2007 onwards
- Petuniabukta near Pyramiden, Czech Station 2008 onwards
- In Barentsburg and Hornsund, Russian (e.g. the Polar-Alpine Botanical Garden – Institute, Kola Science Centre) and Polish botanists, respectively, conduct vegetation research

Since the vegetation in Brøggerhalvøya is not representative for whole Svalbard, it is extremely important to seek cooperation with these research bases, as well as to carry out research in other areas.

Stephen Coulson: *Terrestrial invertebrate research at Ny-Ålesund*

There are over 1,100 species of terrestrial and freshwater invertebrate known from Svalbard. However, this list is comprised largely of studies from only two localities, that is Isfjorden and Kongsfjorden. Very little information is still available from the central regions or the east coast of the archipelago.

The first detailed descriptions of the invertebrate fauna of Svalbard began in the middle of the 19th century with the monographs of Boheman and Holmgren. Subsequent reports consisted primarily of taxonomic works or community descriptions. In 1921 Summerhayes and Elton travelled to Svalbard as part of the 1921 Oxford University Spitsbergen Expedition and in 1923 produced one of the first ecological studies of the island. This was followed by a later publication in 1928 developing their ideas on the ecology including dispersal to and colonization of the islands. In 1930 Sig Thor produced a monograph on the Svalbard terrestrial invertebrate fauna including a species list. Until as late as the early 1990s still one of the principle reference works reflecting the relatively few workers studying the Svalbard invertebrate fauna during this period. However, from the 1980s the number of publications concerning the invertebrate fauna began to increase at a rapid rate. Between 1950 and 1959 only 12 terrestrial invertebrate articles were published, however, this had risen to 69 in the period 1980-1989 and in the 8 year period 2000-2008 there have been so far 148 manuscripts. In addition the range of subjects has also increased. While taxonomy and community composition still form an important proportion of the total, the number of circumpolar studies incorporating Svalbard as a sampling location has risen. There are also experimental studies employing Svalbard as a site for manipulative field projects. The rapid expansion of Ny-Ålesund as a research village has contributed greatly to this development.

Future areas of invertebrate research include dispersal and molecular barcoding, lifecycle and adaptations, effects of environmental change including snow depth and lie, freeze-thaw events, synergistic stressors for example simultaneous exposure to low temperature and pollutants, and also the effects of immigrant species on the ecosystem.

In conclusion, studies of the invertebrate fauna of Svalbard commenced fairly recently with considerable development, expressed both as manuscript number or diversity of research theme, during the second half of the 20th century. As such our knowledge is limited but expanding rapidly. This is a trend that shows no sign of decreasing. However, it is striking how few cross theme, integrated studies have been undertaken. How to address this is perhaps the greatest challenge for the future.

Maarten J.J.E. Loonen: *Plant-animal interactions*

The main herbivores in the area around Ny-Ålesund are reindeer (*Rangifer tarandus platyrhynchus*) and barnacle geese (*Branta leucopsis*). In 1978, 15 reindeer were introduced on Brøgerhalvøya after a long period of absence. The population increased steadily until a maximum of almost 300 individuals in 1993. In the following winter there was a population crash due to ice conditions on the tundra and the population decrecreased to less than 100 individuals. Since that period, there have been around 150 individuals on Brøgerhalvøya but reindeer have also dispersed from Brøgerhalvøya to

other areas in the surroundings. Most of the tundra around Kongsfjorden, including the islands are nowadays grazed by reindeer.

Barnacle Geese were very rare in Kongsfjorden in the first half of the twentieth century. Ocassional breeding has been documented from the bird cliffs in Krossfjorden. First breeding on the islands in Kongsfjorden was observed in 1982, after sightings of small moulting flocks. The barnacle goose population in Kongsfjorden increased to a maximum of almost 900 moulting adult geese in 1999. The increase of the local barnacle goose population coincided with a worldwide increase in goose populations together with a general range expansion. Since 1991, predation pressure on geese has increased. An active arctic fox (*Vulpes lagopus*) den within the village of Ny-Ålesund reduced the goose numbers in the most dense moulting area, but also on the breeding islands great skuas (*Stercorarius skua*) have been starting to breed and have been observed to depredate goslings and moulting adult geese. The estimated size of the barnacle goose population during the moulting period is now 400 adults.

The introduction of the herbivores has changed the vegetation composition. Reindeer have removed most of the lichen from the dry tundra and within the village of Ny-Ålesund, tussocks of *Deschampsia alpina* have been disappearing. The direct vicinity of the village is after the bird cliffs the area with the highest vegetation biomass. It holds the densest concentration of barnacle goose, which is probably related to the nutrient input from the historic mining period: geese graze intensively in areas close to the former cattle stables and greenhouses.

A comparison of goose diets from 1990 to 2004 showed disappearance of *Equisetum variagatum* from the diet and decreasing proportions of grass species, replaced by mosses in the wet habitat and *Bistorta vivipara* in the mesic habitat. These trends are similar from experimental grazing trials started on ungrazed vegetation (Kuijper et al. 2009 Polar Biology 32: 1789) .

The effect of herbivores on the vegetation can be studied making exclosures: small areas fenced off from grazing. Within the goose exclosures plants like *Equisetum variagatum, Saxifraga cernua, Cerastium arcticum, Cardamine nymmanii* and *Pedicularis hirsuta* re-appear. These specieas are very rare or absent outside the exclosures. In the grazed areas *Saxifraga cespitosa* and *Saxifraga oppositifolia* are typical vascular plants which can withstand grazing by geese and reindeer. In recent years, in the area around the fox den the vegetation starts to resemble the vegetation inside the exclosures because the foxes keep the geese away.

The exclosures have also been used for studies on plant productivity, seed bank, carbon sequistering, nitrogen dynamics, microbial nitrogen fixation and microbial communities. In al these studies, there was a prominent difference between grazed and ungrazed vegetation. Sofar the data suggest that the effect of grazing is reversible. However in exclosures, the vegetation kept changing over more than 10 years. In general, the vegetation shifted from nearly 100% moss cover to a transitional stage with a dense grass cover. After 6 to 8 years, the grass cover decreased and dicots became more prominent.

There are complex interactions within and between trophic levels. Nitrogen fixing cyanobacteria show different levels of nitrogen fixation dependent on the removal of vegetation and the addition of faeces. Reindeer feed on goose faeces but specifically select droppings from a grass diet and reject droppings from a moss diet. Arctic fox presence varies between years depending on winter survival The presence of ice is in

general beneficial for their access to food. In years without foxes, the grazed plants are overgrazed, but in years when foxes reduce grazing pressure, these plants can recuperate, resulting in cyclic population patterns of plants and herbivores.

Geir Wing Gabrielsen: *The input from seabirds to the terrestrial ecosystem in Kongsfjorden*

A total of 203 bird species are recorded in the Svalbard area. Of these 28 species are breeding in the Svalbard area. There are few terrestrial bird species and only 6 species are terrestrial feeder. The seabird species constitute more than 70 % of the bird species on Svalbard. They are important components of the terrestrial ecosystem as well as the marine environment because they supply nutrients to the environment through their excrements. The seabirds are also an important prey base for their terrestrial predators. Birds excrete nearly insoluble uric acid which forms nitrogen-rich guano that fertilizes the nitrogen-starved soils that enhance plant growth, including mosses and lichens in the coastal ecosystem. The deposition of excrements, by different seabird species, is quite significant. In this presentation the seabird community in Kongsfjorden was used to exemplify the deposition of excrement to the terrestrial and marine ecosystem. At the end of the presentation species specific responses are presented to show how climate change may influence different seabird populations in the Kongsfjorden area.

It is estimated that ca. 15 000 pairs of nine species of seabirds breed in Kongsfjorden. The common eider (*Somateria mollissima*) is the largest contributor to the total bird biomass, followed by black-legged kittiwake (*Rissa tridactyla*) and Brünnich's guillemot (*Uria lomvia*). Virtually all of the birds are migratory, leaving Kongsfjorden during the winter months. Their arrival time in the spring and departure in autumn varies among species. Thus, the peak in total biomass by adult birds inhabiting the area is reached during a 3-month period, ca. 15 May to 15 August. The largest food consumption rate by the seabird community is reached during the chick rearing period, when the adults provision chicks in addition to themselves. The energy expenditure and food consumption calculation for various seabird species was based on a combination of species-specific doubly labelled water experiments, applying an assimilation coefficient of 75 % and using an average energy density of the prey of 5 kJ g-1 wet mass. In Kongsfjorden the seabird community (including non-breeders) consumes 2 850 tons of food per year. Compared to the marine mammals (with a biomass of 107 500 kg) the different seabird species (with a biomass of 36 400 kg) consume 4 times as much food as marine mammals (625 tons per year). Of the total food consumption by birds in the Kongsfjorden area it is estimated that seabirds consume 96 % of the total food intake. In Kongsfjorden the seabird community releases 285 tons of dry guano per year. The annual nitrogen and phosphorus production by the seabird community is estimated to be 10.4 and 4.2 tonnes, respectively. The total annual carbon flux from prey taken in Kongsfjorden through the seabirds was estimated to be 0.21 g C/m*y. Most of the nutrients produced by the seabird community are recirculated into the marine ecosystem, but significant quantities are also exported to the terrestrial ecosystem adjacent to Kongsfjorden. The estimates of the annual carbon flux through the seabird community in Kongsfjorden is similar to the flux obtained in a similar calculation for the seabird community around Bjørnøya (0.18 g C/m*y) and are comparable to the fluxes in seabird communities in productive shelf regions elsewhere.

The Norwegian Polar Institute has been monitoring several seabird species (common eider, kittiwake, fulmar (*Fulmarus glacialis*), and Brünnichs guillemot) in the Kongsfjorden area since the beginning of the 80s. These time series are of great importance today in order to study impact of climate change and pollution on these seabird populations. The number of breeding common eiders in Kongs-fjorden has varied between 1 000 and 4 500 birds since 1981. The number of breeding common eiders is mainly dependent on the sea-ice condition in the fjord. In years with heavy ice conditions in the fjord there are few birds breeding while in years with little or no ice the number of breeding bird are high. During the winters of 2005/2006, 2006/2007 and 2007/2008 Kongsfjorden has not frozen. The average ambient temperature in this area has increased with 2-3 degrees since the 80s and the winter sea water temperature has also been 2-4 degree higher than normal. Despite improved weather condition and less ice in Kongsfjorden the common eider population has not increased during the last 5-10 years (around 2 500 breeding common eiders). Heavy predations and increase in the number of other seabird species (great skua (*Stercorarius skua*), arctic skua (*Stercoraris parasiticus*) and the glaucous gulls (*Larus hyperboreus*)) are probably the main reason for a stable eider population in Kongsfjorden during the last 5 years. While the kittiwake population on the mainland is decreasing in number the overall pattern at Svalbard is a slightly decrease in number during the past 10 years. With regard to the productivity of kittiwake chicks in Kongsfjorden the success of breeding has mainly been related to the amount of polar cod as food during chick rearing. The observed changes in ambient and seawater temperatures in Kongsfjorden have resulted in changed of the diet of kittiwakes. Polar cod have been substituted by capelin as the main diet during the chick rearing period during the last two years. Since capelin has similar energy content as polar cod this has not affected the growth and survival of chicks in Kongsfjorden. For little auks (*Alle alle*) breeding in Kongsfjorden the influence of warm water has changed the food basis for this species from eating energy rich *Calanus hyperboreus/Calanus glacialis* to low energy food as *Calanus finmarcicus*. The consequence for little auk has been less time in the colony and increased time for foraging at sea with a consequence of reduced growth of the chicks in the colony in Kongsfjorden. These examples clearly show species specific responses to climate change and clearly show the importance of doing monitoring in combination of seabird research.

B. Presentation by workshop participants – current research activities

L. Øvreås, C. Quince, A. Lanzèn, J. Green, S.J. Coulson, W.E. Sloan & T.:
Microorganisms and their fundamental role to the functioning of arctic ecosystems
The microbial diversity of the European Arctic is, we believe, the most diverse, most threatened and most poorly documented terrestrial community in Europe today. Diversity of soil microbes on Svalbard is similar to at lower latitudes and there is a potential that we will loose these cold adapted microbes due the rapid warming of the Arctic. Yet there is no strategy to help decision makers manage this risk. Therefore studies to establish the true extent of the microbial diversity of arctic soils, document the potential application of the biodiversity in environmental biotechnology and establish a strategy to manage the impact of climate change on arctic microbial communities i.e. establishment of a long

term ecological research site (LTER) generation of a microbial ark, culture collection and documentation, are in progress

T. Curtis: *Microbial diversity: a rationale*
Microbial diversity represents a unique resource of not only profound practical importance but also providing vital local and global ecosystem services, for example, local carbon cycling, pollutant degradation and low temperature microbiology.

Studies of microbial diversity may have significant economic consequences. Approximately 3% of the energy consumption of Europe is involved win waste water treatment. Digestion to produce methane, hydrogen and electricity is possible but has a lower temperature of 12ºC. It is therefore distinctly possible that the characteristic low temperature anaerobic community in Svalbard sediment could revolutionise a global industry by reducing energy costs.

Furthermore there is the potential for bioprospecting implications for, amongst others, the pharmaceutical industry.

Set in a wider perspective microbial diversity is also intrinsically interesting, for example, holding many clues about immigration, evolution and extinction and should be couple with "proper" ecology. Furthermore, given the rapid development in gene sequencing techniques and equipment there is also an urgent need to monitor and archive.

S. Ventura: *Microbial colonization of terrestrial habitats in Svalbard*
Current studies focus on the terrestrial microbial ecology of Svalbard. Multiple localities are involved for example, the foreland of the Midtre Lovén glacier, Kongsfjord, where a chronosequence approach is being used to examine microbial diversity, primary colonisation, metal mediated interactions between lithoautotrophs and phototrophs in a polar desert and development, structure and functions of (semi-) permanent soil microbial crusts. Complimentary studies are in progress in Sassendalen, Bjørndalen and at the Bockfjord warm springs. Various molecular fingerprinting techniques are being employed to characterise the microbial communities at each site.

P. Wookey: *Soil organic matter dynamics and interacting biogeochemical cycles in the high Arctic*
It is an axiom that increasing temperature in the Arctic will increase plant growth with vegetation zones moving northwards. However, the biogeochemical cycles interact to regulate carbon and mineral nutrients and hence control plant growth. The overall carbon balance of the system is determined by gains associated with nitrogen uptake and losses associated with nitrogen release. Nutrients are needed to underpin this. Rates of change in nitrogen and phosphorous availability might be fundamentally different and soil organic matter dynamics may function as a 'gear', affecting the rate and magnitude of responses to change, especially after initial phenological responses are observed. Ny-Ålesund provides a unique location at which to study these responses for example, broad spectrum of expertise (across biotic and abiotic components), suitability for long-term environmental manipulation studies / monitoring should be established (missed opportunities so far, e.g. ITEX), a natural heterogeneity and gradient in the system (geology, climate, surface age, 'ornithogenic' inputs) and the possibility to link traditional disciplines.

S. Woodin: *Research activities of the University of Aberdeen in Ny-Ålesund*
The University of Aberdeen started in Ny-Ålesund in 1991 and since then has worked with diverse projects studying the effects of nitrogen deposition, mycorrhizal ecology, ecosystem carbon dynamics, functional role of moss and herbivory and ecosystem processes.
Some key results include a strong interaction between the effect of elevated nitrogen and availability of phosprorous on three heath types. Effects were observed in moss and shrub physiology, mycorrhizal infection and community composition. Results were used in setting the UNECE critical load for nitrogen in arctic heaths. Mycorrhizal ecology studied the diversity of mycorrhizas and fruiting bodies and mycorrhizal nitrogen use by way of stable isotopes. Results indicate that there is very high diversity, much higher on roots than in fruiting bodies. The ecosystem carbon studies demonstrated that dry heaths are source of CO_2 but that moisture and moss increase CO_2 sequestration. Warming decreases efflux from dry heath and grazing reduces CO_2 sequestration while grubbing reduces carbon stocks by erosion. Moss plays a pivitol role in the tundra ecosystem, controlling such parameters as soil environment, vascular plant community - species specific positive and negative effects and nitrogen cycle by sequestering nitrogen - from acid deposition and faeces as well as carbon dynamics by sequestering carbon in recalcitrant forms. Current research focuses on reindeer – moss – grass – soil interactions and goose grubbing – vegetation community utilisation and resilience.

M. Tojo: *Population changes of moss inhabiting fungi at the north side cliff of Japanese Ny-Ålesund observatory, Spitsbergen Island, Norway from 2003 to 2008*
During summer 2008 terrestrial scientists working at the Japanese station worked on a variety of projects including; 1) diversity, distribution and eco-physiology of lichens, 2) distribution, eco-physiological characteristics of soil crusts, 3) soil microbial activity and community, 4) eco-physiological characteristics of soil crusts, 5) soil microbial biomass and community structure, interaction among vegetation, soil and microorganisms, 6) plant succession in the deglaciated area of the Austre Brøgger glacier with special attention to the colonizing speed of *Salix polaris*, studies of the diversity and the impact of ectomycorrhizal fungi on *S. polaris* in the ecological succession, and 7) identification of genus *Pythium* inhabiting, a filamentous plant parasitic organs.

Pythium spp., which are plant pathogenic fungi, are believed to be one of the causal agents of leaf discoloration of mosses in Svalbard. A project was commenced to identify the moss parasitic *Pythium* spp. at the north side cliff of the Japanese station. The primary objectives were to clarify population changes of the moss parasitic *Pythium* spp. at the north side cliff of the Japanese station from 2003 to 2008 and to evaluate the potential impact of climate change on population changes of the moss parasitic *Pythium* spp. Results indicate that there are several species of moss parasitic *Pythium* inhabiting in the north facing slope of Japanese Station in Ny-Ålesund. One of the major species appears to have increased in occurrence, perhaps due to heavy rainfall.

E. J. Cooper: *Research activities of the University of Tromsø*
The University of Tromsø is involved a range of medium to longterm terrestrial biology projects on Svalbard, several based in Ny-Ålesund. Themes include biodiversity and activity of methane oxidising bacteria in northern ecosystems, microbial genomes and community gene expression in high-arctic terrestrial ecosystems, landscape

ecology/vegetation ecology, plant species, habitat and community distribution modeling, vegetation mapping and monitoring, biodiversity of mountain ecosystems, biodiversity of northern Svalbard and dispersal and establishment of vascular plants on Svalbard. One particular project is investigating the effect of changes in snow depth and lie on the vegetation. Climate change models forecast increased winter precipitation. This will have implications for depth of snow and period of snow lie. A snow fence project has been established in Adventdalen and measurements include the responses of higher plants and lichen, winter injury in plants, soils and leaching responses and gas exchange, both winter and subsequent summer. This field project is supported by complimentary laboratory studies focusing on plant freeze and anoxia tolerance and temperature effects on gas flux.

The following have been identified as important in developing terrestrial research in Ny-Ålesund. Wet laboratory and equipment, repair and updating of greenhouse, maintenance of good boat access, photographic monitoring via stationary cameras and UAVs, reindeer exclosures to be repaired and maintained, long term monitoring of vegetation established and mapping of previous studies and manipulations.

S.J. Coulson & M.L. Ávila Jiménez: *Invertebrate biodiversity on Svalbard: studies from Ny-Ålesund*

Current research at Ny-Ålesund focuses on biogeography, both geographic and local, and overwintering survival. Circumpolar studies using genetic techniques aim to identify dispersal routes for the arctic soil invertebrate fauna enabling the story of recolonisation following the retreat of the ice to be better understood. Methods of dispersal of this fauna, in particular phoresy with migrating birds, are being examined. Studies of the invertebrate fauna of the seabird nests in Ny-Ålesund are on-going. A project examining local biogeography and constraints on species distribution is underway in Kongsfjord using the aphid *Acyrthosiphon svalbardicum* as a model. The host of this species is *Dryas octopetela* yet the aphid is not found on every patch. It is believed that snow depth is the controlling factor and the relationship between snow depth and presence of the aphid is being investigated as part of a potential long term monitoring project. Overwintering projects include the effect of temperature cycles on overwintering success. Target species have been selected so as to represent examples freeze-tolerance and freeze-desiccations strategies. The studies consist of complimentary field and laboratory studies at UNIS in Longyearbyen.

A. Zwolicki: *The influence of plankton- and fish-eating seabird colonies on the arctic tundra ecosystem of Spitsbergen*

Seabirds may play an inportant role in the transport of nutrients from the marine to the terrestrial environment. The terrestrial environment is typically nutrient poor and via deposition the faeces seabirds may enrich the terrestrial system. The nutrients deposited will depend on the diet of the seabirds, i.e. plankton feeders versus fish feeders, and will hence have different impacts on tundra ecosystem.

Experiments undertaken in the vicinity of Hornsund demonstrate clear vegetation differences between under seabird colonies and areas away from the colony. For example; greater guano deposition and soil ion content (NO_3^-, NH_4^+, PO_4^{3-}, K^+ and lower pH), gradual decrease of soil nutrient contents along the colony-sea axis, higher heterogeneity of tundra plant communities, *Cerastium arcticum* discriminating ornithogenic tundra plant communities and a greater biomass of plants. In addition clear differences were

observed between colonies with a predominate fish diet (kittiwake and Brünnich's guillimot) and plankton feeding colonies (little auk). Under the kittiwake and Brünnich's guillimot colony there was a greater deposition of guano, higher content of phosphates and a dominance of *Cochlearia groenlandica.* Under the little auk colony there was a greater biomass of vascular plants, particularly grasses and a dominance of *Cerastium arcticum.*

P. Convey: *Terrestrial ecology, ecophysiology and genomics in the British Antarctic Survey research programme*
Several groups of lower animals and plants have been collected in the Antarctic to study large scale biodiversity patterns. The patterns don't support the view of recent (post Pleistocene) dispersal. There is more regionalization, endemism and cryptic speciation than previously thought, with evidence for an ancient divide along the Antarctic "Wallace Line". Biotic persistence is studied at different time scales. Nunatak refugia are only part of the answer and reconstruction of ice sheet extent and thickness is important. For this, biogeographic molecular phylogenetic and fossil evidence are important tools. Molecular techniques reveal ecophysiological strategies and new genes. A bipolar comparison using gene chips is an important next step to study universal mechanisms.

F. Mehlum: *DNA Barcoding as a Tool for Biodiversity Assessment and Monitoring -A proposal for Ny-Ålesund*
In polar regions, the effect of climate change on biodiversity needs further studies especially among lower animals and plants. DNA bar coding is a new technique which can be used to discriminate and to identify species. It is a relative easy tool to study patterns of variability and species boundaries in a wide range of species. Advantages are the pooling of morphological different life stages from the same species and a potential reconstruction of past ecosystems by barcoding DNA preserved in permafrost. Samples can be analysed quickly and web-based databases facilitate global comparisons. In the Arctic several barcoding projects (e.g. in Churchill Canada) have been initiated. In Norway the program is called Polar barcode of life (PolarBOLI). A reference library of species from Ny-Ålesund is a short-term goal which will facilitate future studies on ecosystem structure and change.

N. Lebedeva: *Spread of soil biota by birds to Svalbard archipelagos: main directions of study*
Birds can be an important vector for soil micro arthropods and oribatid mites into remote polar areas like Svalbard. These insects are not parasitic and typical soil invertebrates but are found on various species of birds in low numbers. The migration routes of birds might explain the distribution of soil insects along the flyway and into polar regions.

M.J.J.E. Loonen: *Adaptation of Barnacle Geese to a changing World*
Fertilization by farmers and improved protection together with decreased hunting pressure has made goose numbers increase steeply since 1960. This has resulted in range expansions and increased densities on the breeding grounds and made breeding in the former wintering or spring staging areas possible. These shifts make the barnacle goose a model species to study constraints and adaptations to climate change. Changes in the timing of migration, breeding and wing moult are studied on the individual level and

related to changes in the environment . Pathogen pressure is studied as an evolutionary force to explain distribution patterns and differences in survival and growth of juvenile geese.

O. Chastel: *Climate and arctic birds: the need for a multidisciplinary approach*
To understand how birds respond to large-scale changes it is essential to integrate physiological mechanisms, foraging ecology and long term demographic surveys. In the black-legged kittiwake, studies of oceanic conditions are combined with studies on foraging behavior, endocrine mechanisms and ringing programs. Corticosteron is a stress-hormone, reflecting forage conditions within years and over years. Studies using GPS tracking revealed variation in foraging trips over the breeding season and between sexes. These data can be combined with marine measurements outside and inside the fjord.

H. Steen: *Seabirds, reindeer and arctic foxes - research activities of the Norwegian Polar Institute*
The Norwegian Polar Institute has monitoring programs on population estimates of arctic foxes (Eva Fuglei), reindeer (Ronny Aanes) and sea birds (Harald Steen). All these populations have data series since early 1990's and act for many studies as base line data describing the area. The monitoring data are used in various research projects, where also more detailed information on the species is gathered. For the arctic fox the effect of organ chlorine contaminants is studied in relation to the lipid cycle change and stable isotope data are used to unravel food web structure. The reindeer study focus on bottom-up or top-down control of the populations. The sea bird study focuses on timing of breeding and winter distribution. A study on the little auk specifically targets the nutrients from sea to land. All these studies need an integration of research fields e.g. marine and terrestrial research.

J. Elster: *Czech Research in the Arctic (Petuniabukta, Billefjorden, Svalbard)*
The University of South Bohemia manages a small research camp in Petuniabukta, Billefjorden, Svalbard. Here the study focuses on biological and climate diversity. A vegetation map with vascular plants, mosses and cyanobacteria is made of the area. Microclimatic data are measured and animals are dissected to determine the number of parasites. This study links with geo-biodiversity studies at Abisko, Sweden and the Giant Mountains, Czech Republic.

K. Melvold: *Activities of the Norwegian Water Resources and Energy Directorate (NVE) in Ny-Ålesund*
The Norwegian water resources and energy directorate (NVE) has been conducted systematic hydrological measurements in Ny-Ålesund since 1989. Two discharge stations are operational on Svalbard; Bayelva (since 1989) and De Geerdalen (since 1990). Several temporary measurements have been conducted in association with other projects (not comprised in current monitoring network of NVE). The hydrological monitoring in Ny-Ålesund includes: surface runoff, water balance (ex. evaporation), erosion and sediment transport, frost depth and water temperature. It is generally very difficult to do hydrological monitoring at Svalbard, i.e.very hard to find good stable cross-sections for discharge measurements at Svalbard. NVE is, trough the international research programme Arctic Hycos, obligated to report hydrological data from Svalbard and arctic

Norway. The maximum discharge/runoff at both stations is recorded at the end of June-beginning of July. Groundwater and soilwater is measured at one station in Ny-Ålesund. Sediment transport is measured at two stations (in addition to gravel transport at river bottom in Bayelva). Snow is measured at an installation of a snowpillow in Ny-Ålesund (started in 2009). Water temperature is measured by 5 loggers (Bayelva, Londonelva, De Geer, Endalselva, and in Tvillingvatnet). NVE has also established a new water database for Svalbard. The Norwegian national catchment database (REGINE) is now extended to include Svalbard. A lake database, which include lakes, lagoon, glacier dammed lakes and moraine dammed lakes has also been established by NVE. NVE also runs the river network database – ELVIS. NVE has also made models for the impacts of climate change on hydrological processes and snow conditions in the Norwegian Arctic. Measurements and modeling of the runoff from Bayelva show a steady increase from 1980 toward 2050.

K. Isaksen: *The importance of improved snow and precipitation measurements on Svalbard*
The Norwegian Metrological Institute, Oslo, Norway, have been conducting measurement of air temperature and precipitation at Svalbard airport since 1915, Hopen 1920, Ny-Ålesund 1937 and Hopen 1947. The annual air temperature has increased by 0.2, 0.1, 0.5 and 0.2 degree Celcius per decade, respectively. During the same period precipitation has increased with 2.1, 3.1, 3.2 and 3.1 % per decade, respectively. In Longyearbyen, during a period of 35 years, the solid part (snow) of precipitation has decreased while the liquid part (rain) have been stable. In this time period there has been an increase in the mixed type (snow and rain) of precipitation. In Ny-Ålesund the true annual precipitation is more than 50 % higher than the measured amount. This is mainly due to aerodynamic effects leading to precipitation undercatch that are dependent on precipitation type and temperature. Therefore the observed and projected increase in the air temperature in the Arctic would also affect the measured precipitation, even if the true precipitation was unchanged. There is a need for improved snow and precipitation measurements on Svalbard. Ny-Ålesund should be a super-site for climate research (SIOS). There is a need for a DFIR precipitation gauge for measuring “true precipitation”. Also, Present Weather Sensor (PWS) at 2 m level for measuring precipitation duration, type (rain/snow/sleet etc) and intensity should be installed as well as elevated PWS at 6 m level for assessing blowing/drifting snow. There is also a need for more weather stations for long-term monitoring at higher elevations –at present the official stations are located at 0-30 m a.s.l. One should also establish a new AWS at the east coast of Spitsbergen.

J. Boike: *Past and future research on the sensitivity of permafrost*
The Alfred-Wegener-Institute for Polar and Marine Research, Potsdam, Germany, has been conducting permafrost studies in the Bayelva area (near Ny-Ålesund). A persistent and progressive increase in winter soil temperatures at this site has been observed since 1998. The hourly air temperature data from Ny-Ålesund southeast of the Bayelva site shows a long term warming trend of 0.12 °C/ a-1 for the period Jan. 1, 1990 – Dec. 31, 2006, mostly due to recent warming during the spring months (April – May) and despite a cooling trend in the fall months (September – November). The main factors determining the permafrost’s heat transfer are: (i) phase composition of soil (specifically available pore space) which enables vapor diffusion and/or water advection during all periods (ii) the temperature gradient between atmosphere and soil which is largely affected by the

snow cover. The heat transfer into the ground is largely transmitted via conduction with the exception of snow melt and freeze back. The insulating capacity of snow dampens the effect of cold winter air temperatures on the soil. Winter warming events, rain-on-snow events, early-onset snow packs and warm end-of-summer soil conditions can contribute to warmer soil conditions throughout the winter. Warmer soils contain more liquid water and respond more slowly to increased heat loss to the atmosphere. The warming in permafrost temperature is not due to changes in snowpack, but due to warmer soil at the onset of winter, warmer air temperatures throughout the winter and the gain of due to rain-on-snow events. In the future it will be important to extend the permafrost data series from Kongsfjorden. It will be important to identify the parameters, which determine permafrost temperatures as well as to give assessment of the scales, over which these parameters vary, and the magnitude of the variation.

H. Christiansen: *Permafrost research at the University Centre in Svalbard*
The Geology Department at UNIS focuses its research on permafrost/periglacial geomorphology and how climate and meteorology affect the ground thermal regime and landform activity today and for palaeoenvironmental reconstructions. In the IPY project 'Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost in Norway and Svalbard' (TSP Norway) so far the Nordenskiöldland Permafrost Observatory has been established. It consists of 12 new boreholes (4 to 38.8 m deep) in which ground thermal monitoring is conducted to study regional and local ground thermal conditions and their climate control in different permafrost landforms. Permafrost thermal data are already available in the Norwegian Permafrost database, NORPERM as requested by the IPY data policy and ground temperatures from two boreholes in the Longyearbyen area are online. Preliminary data analyses show large inter-site variation between different landforms located close together, reflecting the relative large influence of local conditions. Prior to IPY only one deep borehole down to 102 m existed at Janssonhaugen in Svalbard, with continuous ground thermal monitoring since 1998. In Ny-Ålesund, a 10 m borehole was drilled by Kings Bay in late spring 2008 and instrumented in summer 2008 in collaboration with AWI. Circumpolar Active Layer Monitoring (CALM) has been going on in Adventdalen close to Longyearbyen since 2000. Results show significant interannual variations and that there is no obvious single meteorological control on active layer thickness, but that rather several factors, mainly insulation, affect the active layer thickness.

P. Aastrup: *Terrestrial ecosystem monitoring in Greenland - Zackenberg and Nuuk*
The National Environmental Research Institute, Aarhus University, Denmark, has established a terrestrial monitoring system at Zackenberg and Nuuk in order to answer two fundamental questions; How does climatic variability influence the dynamics of high arctic ecosystems? How do high arctic ecosystems affect the global climate?

While the Zackenberg station has been running from 1995 the Nuuk station has been doing monitoring since 2007. These two sites therefore cover the high-arctic- and the low-arctic/subarctic ecosystem. The science programs at these two stations are build around 5 subprograms; Marinbasis, geobasis, climatebasis, biobasis and glacibasis. Several different institutes are involved in the monitoring programmes; The National Environmental Research Institute, Aarhus University, Greenland Institute of Natural Resources, University of Copenhagen and Asiaq, Greenland Survey Institute. Information

about the two stations can be found at www.zackenberg.dk. In the biological subprograms the following parameters are measured; plant phenology, breeding phenology of birds, CO_2- andCH_4-flux, effects of UVB on plant stress, arthropods and micro-arthropods, lake ecology and population parameters for musk ox. In the geophysical sub- programs the following parameters are measured; snow deposition and snow cover, hydrology, temperature, methane and CO_2 flux. Snow monitoring is done by cameras covering a large area at the two sites. Carbon fluxes are measured using different systems for measurement of carbon dioxide and water. Methane flux is measured by automatic chambers. Long term manipulation experiments as well as studies of plant and arthropod phenology, plant flowering, emergence phenology of arthropods, bird monitoring, lemming census, fox and musk ox monitoring are done on a daily or weekly basis. Results from the monitoring programs are published in annual reports.

Appendix 2: List of abbreviations and definitions

a.s.l. – Above sea level
AEPS – Arctic Environmental Protection Strategy
AMAP – Arctic Monitoring and Assessment Programme (www.amap.no), a working group of the Arctic Council
ARCFAC – The European Centre for Arctic Environmental Research in Ny-Ålesund (www.npolar.no/arcfac/), a group of international stations in Ny-Ålesund providing research infrastructure under a framework programme of the EU
AWI – Alfred-Wegener Institute, Germany
AWS – Automatic weather station
BAS – British Antarctic Survey, UK
C/m*y – Carbon per meter and year
CAFF – Conservation of Arctic Flora and Fauna (http://caff.arcticportal.org/), a working group of the Arctic Council
CALM – Circumpolar Active Layer Monitoring
CH_4 – Methane
CNR – National Research Council, Italy (Consiglio Nazionale delle Ricerche)
CNRS – National Centre for Scientific Research, France (Centre national de la recherche scientifique)
CO_2 – Carbon dioxide
COPOL project – Contaminants in Polar Regions: Dynamic range of contaminants in polar marine ecosystems (www.copol.net/)
DDT – Dichlorodiphenyltrichloroethane
DFIR – Double fence intercomparison reference
DNA – Deoxyribonucleic acid
DNMI – The Norwegian Meteorological Institute, Norway (Det norske meteorologiske institutt)
ELVIS – The Norwegian river network database (http://arcus.nve.no)
EU – European Union
Flagship – A research programme contributing to a recognizable future vision in the Ny-Ålesund Science Plan
FP7 – Seventh Framework Programme in which funding of research by the European Union is organised (http://cordis.europa.eu/fp7/dc/index.cfm)
GCMs – General Circulation Models
GIS – Geographic Information Systems
GLORIA – Global Observation Research Initiative in Alpine environments (www.gloria.ac.at/)
H_2O – Water
HALO – High-Arctic Land Observatory, a level of organization in which all terrestrial research in Ny-Ålesund will be integrated
HCB – Hexachlorobenzene
IPY 2007-2009 – International Polar Year 2007 - 2009 (www.ipy.org/)
ITEX – International Tundra Experiment (www.geog.ubc.ca/itex/)
K^+ – Potassium

KIRB – The Kongsfjorden International Research Base, a term with which all stations and nationalities working in Ny-Ålesund present themselves as one entity
LSF – Large Scale Facility, a group of international stations in Ny-Ålesund that has been providing research infrastructure under a previous framework programme of the EU (until 1998)
LTER – US Long Term Ecological Research Network (www.lternet.edu/)
MMBI – Murmansk Marine Biological Institute, Russian Academy of Sciences
N – Nitrogen
NDVI – Normalized Difference Vegetation Index, , a measure to estimate plant biomass based on differential reflection of red and near infrared, used in remote sensing
NERC – National Environment Research Council, UK
NERI – National Environmental Research Institute, Denmark (Danmarks miljøundersøkelser)
NERO – Nuuk Ecological Research Operations (www.nuuk-basic.dk/), an ecological monitoring program in southwest Greenland
NH_4^+ – Ammonium
NINA – Norwegian Institute for Nature Research (Norsk institutt for naturforskning)
NO_2 – Nitrogen dioxide
NO_3^- – Nitrate
NORUT – Northern Research Institute
NOx – Generic term for the mono-nitrogen oxides NO and NO_2
NPI – The Norwegian Polar Institute (Norsk polarinstitutt)
NSINK project – Sources, sinks and impacts of atmospheric nitrogen deposition in the Arctic (http://nsinkproject.group.shef.ac.uk/NSINK/Home.html)
NVE – Norwegian Water Resources and Energy Directorate (Norges vassdrags- og energidirektorat)
NySMAC – Ny-Ålesund Science Managers Committee (www.npolar.no/nysmac/) with representatives of all research organisations with permanent infrastructure in Ny-Ålesund
Ny-Ålesund Science Plan – a science plan under the auspices of NySMAC with the goal to further develop Ny-Ålesund as a premier international arctic research and monitoring facility
Omics – fields of research in biology ending in –omics, such as genomics or proteomics
OTC – Open top chamber, a wind shelter to increase temperature on vegetation plots
P – Phosphorus
PAR – Photosynthetically active radiation
PCB – Polychlorinated biphenyl
PO_4^{3-} – Phosphate
PolarBOLI – Polar barcode of life (www.ibolproject.org/polar/index.htm), determining species recognition based on DNA
POPs – Persistent Organic Pollutants
PWS – Present Weather Sensor
RCN – Research Council of Norway (Norges forskningsråd)
REGINE – The Norwegian national catchment database (http://arcus.nve.no)
RiS – Research in Svalbard database (www.svalbardscienceforum.no/pages/database.htm)
RNA – Ribonucleic acid

SAON – Sustaining Arctic Observing Networks (www.arcticobserving.org/), a process to support and strengthen the development of multinational engagement for sustained and coordinated pan-Arctic observing and data sharing systems.

SIOS – Svalbard Integrated Arctic Earth Observing System (www.forskningsradet.no/sios) An international initiative to integrate research investments with support from the European Union FP7

SSF – Svalbard Science Forum (www.svalbardscienceforum.no), an organisation to facilitate research in Svalbard

TDL – Tuneable diode laser

TERRØK – Terrestrial ecological processes, environmental management. A Norwegian program for terrestrial research running from 1991 to 1999

TSP Norway – Thermal State of Permafrost in Norway and Svalbard

UAV – Unmanned aerial vehicles

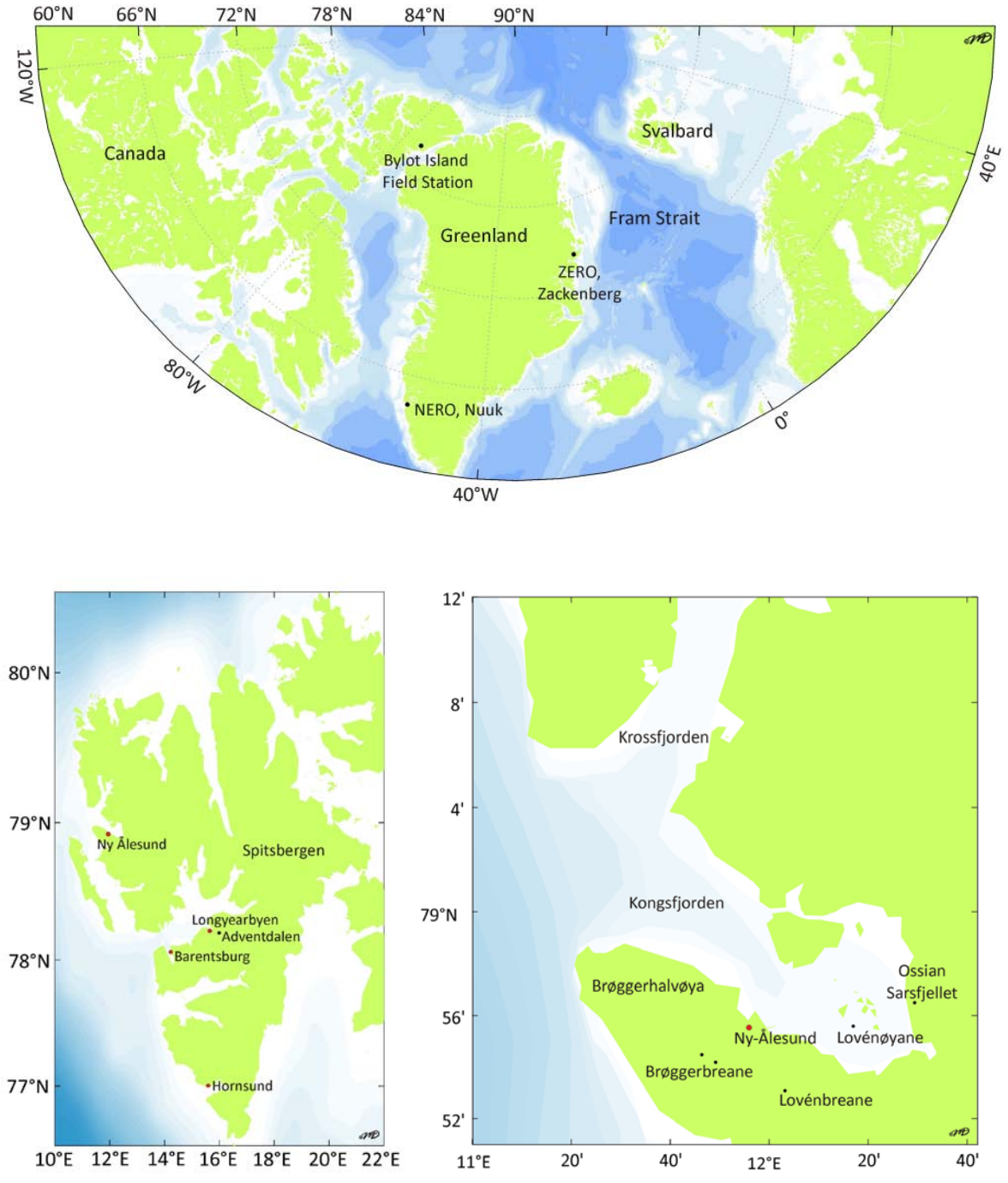
UNECE – United Nations Economic Commission for Europe

UNIS – The University Centre in Svalbard, Norway

UVB – Ultraviolet B

ZERO – Zackenberg Ecological Research Operations (www.zackenberg.dk/), a ecological monitoring program of the Danish arctic research base Zackenberg in western Greenland

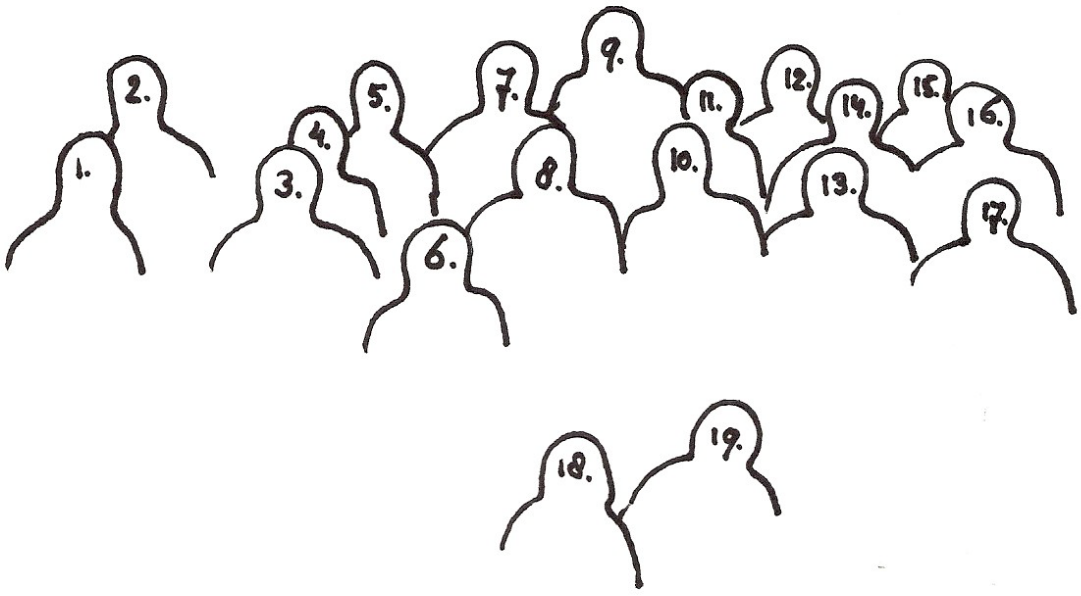
Appendix 3: Maps of locations mentioned in the document



Maps: Malin Daase, NPI

Appendix 4: List of participants

Aastrup, Peter - National Environmental Research Institute (NERI), pja@dmu.dk
Boike, Julia - Alfred Wegener Institute for Polar Research (AWI), Julia.Boike@awi.de
Chastel, Olivier - Centre d'Etudes Biologiques de Chizé, CNRS, chastel@cebc.cnrs.fr
Christiansen, Hanne - University Centre in Svalbard, Norway (UNIS), hanne.christiansen@unis.no
Convey, Pete - British Antarctic Survey (BAS), Natural Environment Research Council (NERC), pcon@bas.ac.uk
Cooper, Elisabeth J. - Biology Department, Tromsø University, Elisabeth.Cooper@uit.no
Coulson, Stephen - University Centre in Svalbard, Norway (UNIS) , steve.coulson@unis.no
Curtis, Tom - University of Newcastle, School of Civil Engineering and Geosciences, tom.curtis@newcastle.ac.uk
Elster, Josef - South Bohemian University in Ceske Budejovice, jelster@butbn.cas.cz
Gabrielsen, Geir Wing - Norwegian Polar Institute (NPI), geir.wing.gabrielsen@npolar.no
Hansen, Georg - The Research Council of Norway (RCN), geha@forskningsradet.no
Hodson, Andy - Department of Geography, The University of Sheffield, A.J.Hodson@Sheffield.ac.uk
Hübner, Christiane - Svalbard Science Forum (SSF), ssf@npolar.no
Isaksen, Ketil - Norwegian Meteorological Institute (DMNI), ketil.isaksen@met.no
Lebedeva, Natalia - Azov Branch, Murmansk Marine Biological Institute, Dept. Terrestrial Ecology, Southern Scientific Center, Russian Academy of Sciences, lebedeva@mmbi.krinc.ru; bird_happy@mail.ru
Loonen, Maarten - University of Groningen, Arctic Centre (AC RuG), m.j.j.e.loonen@rug.nl
Mehlum, Fridtjof - Natural History Museum, University of Oslo, fmehlum@nhm.uio.no
Melvold, Kjetil - Norwegian Water Resources and Energy Directorate (NVE), kjme@nve.no
Steen, Harald - Norwegian Polar Institute (NPI), harald.steen@npolar.no
Tojo, Motoaki - Graduate School of Life and Environmental Sciences, Osaka Prefecture University, tojo@plant.osakafu-u.ac.jp
Ventura, Stefano - National Research Council of Italy (CNR), Institute of Ecosystem Study (ISE), Firenze Unit, stefano.ventura@ise.cnr.it
Woodin, Sarah - University of Aberdeen, s.woodin@abdn.ac.uk
Wookey, Phil - University of Stirling, School of Biological and Environmental Sciences, philip.wookey@stir.ac.uk
Zwolicki, Adrian - Ethology and Vertebrate Ecology Unit, Department of Vertebrate Ecology and Zoology, University of Gdansk, prosoche@poczta.onet.pl
Øvreås, Lise - Centre for Geobiology & Department of Biology, University of Bergen, lise.ovreas@bio.uib.no



Participants: 1. Pete Convey 2. Adrian Zwolicki 3. Stephen Coulson 4. Josef Elster 5. Georg Hansen 6. Natalia Lebedeva 7. Harald Steen 8. Stefano Ventura 9. Phil Wookey 10. Peter Aastrup 11. Lise Øverås 12. Julia Boike 13. Tom Curtis 14. Geir Wing Gabrielsen 15. Elisabeth J. Cooper 16. Fridtjof Mehlum 17. Olivier Chastel 18. Sarah Woodin 19. Maarten Loonen 20 (behind the camera) Christiaane Hübner 21. (not in picture) Hanne Christiansen 22. Tojo Motoaki 23. Thomas Skaugen 24. Ketil Isaksen. Photo: Christiane Hübner

020 KORTRAPPORT/BRIEF REPORT SERIES
NORSK POLARINSTITUTT/NORWEGIAN POLAR INSTITUTE 2010