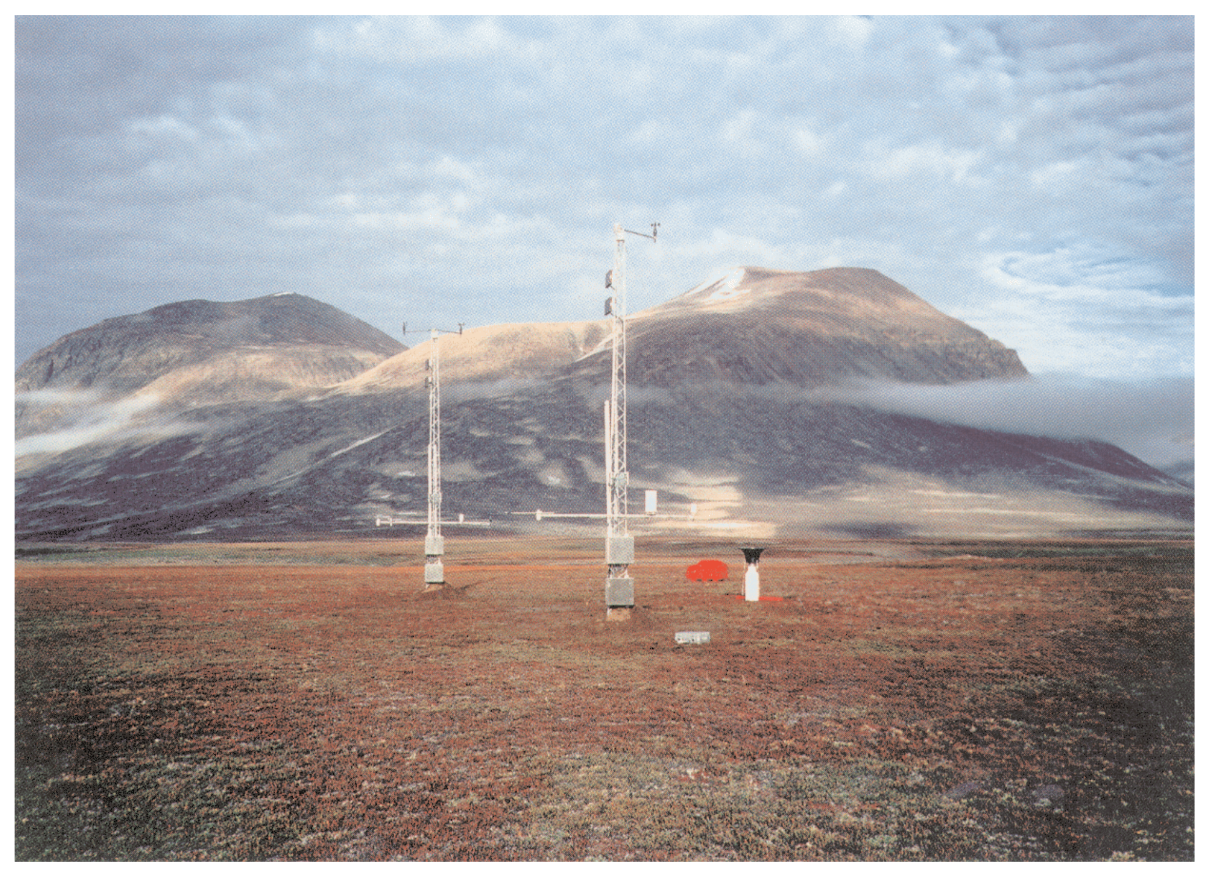
ZERO

ZACKENBERG ECOLOGICAL RESEARCH OPERATIONS

1st Annual Report 1995



Danish Polar Center
Ministry of Research & Technology
1996

Zackenberg Ecological Research Operations

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The permanent climate station in Zackenbergdalen with the Zackenberg mountain as background. August 1995. Photo: Hanne H. Christiansen.

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Executive summary

Following a reconnaissance in 1991, and further surveys and preliminary studies in 1992 and 1994, the establishment of the Zackenberg Ecological Research Station was initiated in 1995 at 74°28'12''N, 20°34'23''W.

During the field season 13 July – 30 August a total of 14 scientists, logisticians and construction personnel worked in the area. A 450 m runway was established, while the construction of five permanent houses will be implemented in 1996.

The general objective of the station is to facilitate research on the dynamics of a High Arctic ecosystem, under the framework of the ZERO (Zackenberg Ecological Research Operations) programme. This objective is met by providing facilities (logistic and scientific) for specific research projects, and by running a long-term monitoring programme Zackenberg Basic. With a time frame of at least 50 years, the programme seeks to sample data on a wide variety of abiotic as well as biotic parameters in the 600 km^2 Zackenberg study area.

A comprehensive digital terrain model is under development, and conditions and processes are monitored. This includes monitoring of air, soil, permafrost and water temperature at different levels and sites, other climatic parameters such as humidity and net radiation, water and sediment discharge in the main river, snow melt, an array of geomorphic processes in the landscape, as well as plant, arthropod and vertebrate population composition, dynamics and phenology.

Hence, the biotic part of Zackenberg Basic includes standardised sampling of quantitative as well as phenological data on flowering in six vascular plant species in 18 study plots, plant community composition and distribution along an 8.8 km transect line from sea level to 1,040 m a.s.l., cryptogamic plant growth and condition, arthropod occurrence and phenology, population size, reproductive phenology and success in bird species, winter nests of collared lemming and occurrence of their predators as well as muskox population dynamics.

Among the specific research projects already initiated are a comprehensive analysis of past and present physical geographical processes, interactions and feedbacks, trace gas exchange between soil and atmosphere, nitrogen mineralization in estuarine waters and collared lemming biology and population dynamics.

The Zackenberg station is owned and run by the Danish Polar Center on grants primarily from the Commission for Scientific Research in Greenland and the Ministry of the Environment and Energy, and the work is carried out in close collaboration with the Greenland Home Rule Government. The ZERO programme is considered a significant part of the official Greenland environmental policy.

A committee composed of Frank Jensen, the Danish Minister for Research & Technology, Marianne Jensen, the Greenland Minister for Health, Environment & Research and senior executives has been formed in order to facilitate the implementation of ZERO.

Zackenbergdalen with the core study area. This locality is home of the long-term high Arctic ecosystem monitoring and research. The mountain to the left is Zackenberg proper.

Photo: Henning Thing

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1. Introduction

Hans Meltofte

In contrast to climatological research having time series of more than a century from many sites to work with, other natural science disciplines most often have been restricted to work with short time series of data. This particularly applies to the Arctic, where logistic constraints have made long term studies even more difficult.

On this background, scientists from the University of Copenhagen together with the Greenland National Park Board initiated discussions in 1986 on the possibilities of establishing a permanent research facility in the National Park in North and East Greenland. The idea gained momentum during the late 1980s in connection with the creation of the Danish Polar Center, and when the Center was established in 1989, a field station in North-east Greenland was high on the agenda.

The Daneborg-Zackenberg region (Fig. 1) was selected as an appropriate locality, as it is situated in a transition zone between the relatively lush and snow rich southern part of the High Arctic and the more barren and arid northern parts. A reconnaissance by six scientists from the University of Copenhagen and the logistician of the Danish Polar Center in 1991 confirmed the exceedingly promising conditions of the area (see section 2.1). Zackenberg was recommended as the site for a field station for terrestrial studies and monitoring, while Daneborg, with the headquarters of the Danish military sledge patrol, Sirius, about 20 km to the SSE along Young Sund was recommended as the site for logistic facilities and as a base for marine research.

Following official evaluation and approval of the scientific as well as the logistic plans by the Danish Natural Science Council, the Greenland Home Rule and the Danish Ministry of Research and Technology, the establishment of a permanent field station in Zackenberg and its framework programme, ZERO (Zackenberg Ecological Research Operations), was initiated in 1995.

This is done by providing year-round logistic facilities and accommodation in Zackenberg and Daneborg, by offering logistic support for transport to and from as well as within the area, and by providing access to a wide range of both biotic and abiotic data from the long-term terrestrial monitoring programme, Zackenberg Basic.

Access to the station and the study area is granted by the Steering Group on the basis of a written application describing aims and practicalities of the project.

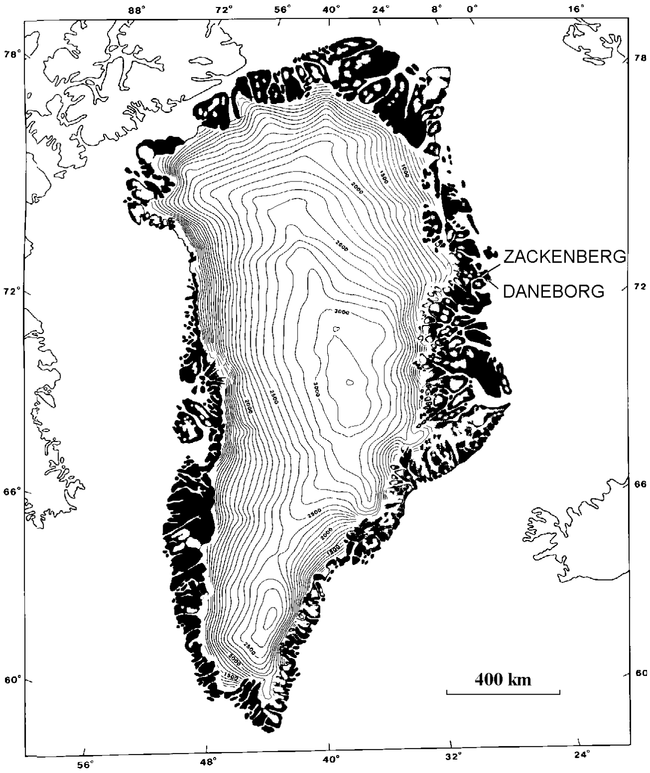


Fig. 1. Map of Greenland with the location of Zackenberg and Daneborg.

1.1. The aim of ZERO

The objective of the station is to facilitate scientific research of High Arctic ecosystems, which according to the ZERO framework programme includes:

* basic quantitative documentation of ecosystem structure and processes,
* baseline studies of intrinsic short-term and long-term variations in ecosystem functions,
* retrospective analyses of organic and inorganic material to detect past ecosystem changes, and
* experimental studies enabling predictions of ecosystem responses to Global Change.

1.2. Organisation of ZERO

Henning Thing

The framework that ZERO supplies to researchers includes all transportation, logistics at Zackenberg and at Daneborg, as well as data from the monitoring programme ‘Zackenberg Basic’. The planning, financing, structuring and implementation of this multifaceted service to Arctic ecosystem science are provided by the Danish Polar Center in close co-operation with a ‘Working Group on Daneborg - Zackenberg’. This group is composed of Danish – Greenlandic key persons and involves both scientists and research administrators.

The members are:

Morten Meldgaard, Director, Danish Polar Center (chairman)

Hauge Andersson, Chief Logistician, Danish Polar Center

J.P. Hart Hansen, Chairman, Commission for Scientific Research in Greenland

Bjarne Holm Jakobsen, Associate Professor, Institute of Geography, Univ. of Copenhagen

Gunnar Martens, Chairman of the Danish Polar Center Board

Hans Meltofte, Special Consultant, Danish Polar Center

Bent Muus, Professor, Zoological Museum, Univ. of Copenhagen

Klaus Nygaard, Director, Greenland Institute of Natural Resources

Hanne Petersen, State Biologist, Danish National Environmental Research Institute

Poul Henrik Sørensen, Special Consultant, Danish Polar Center

Henning Thing, Special Consultant, Danish Polar Center

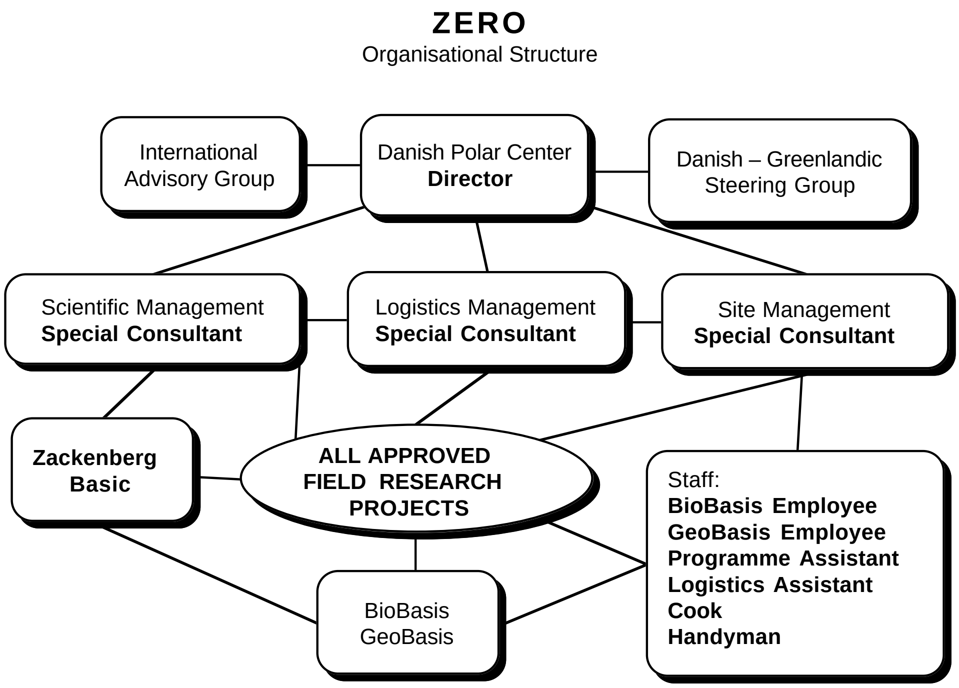
The permits to erect the buildings of the Zackenberg station as well as establishing the runways and transportation corridors have been granted to the Danish Polar Center by the Greenland Home Rule, Directorate of Finances, Dept. of Physical Planning.

An International Advisory Board is proposed as liaisoning body to the national SteeringGroup. This proposed advisory body should have 4-5 members who are all internationally recognised senior scientists within disciplines pertinent to ZERO. Furthermore, these scientists should facilitate vital international links and input to ZERO.

The Royal Geographical Society, London, initiated, in 1993, a global ecological monitoring programme called 'Geographical Observatories Programme' (GOP). In 1994 the board of GOP selected Zackenberg as the Arctic GOP site among the 6-8 'observatories' to be established in all major ecozones on Earth. RGS/GOP is presently preparing to launch their financial and logistics support for Zackenberg, and as a future co-funding body GOP is expected to contribute with individual research projects under the framework of ZERO.

The logistics are obviously the most expensive and complex part of performing modern science in an area as remote as Zackenberg. Therefore, the Danish Polar Center is putting a lot of effort into providing customised but co-ordinated package solutions to optimise the conditions for researchers to do research. These packages include scheduled charter flights, food and lodging as well as basic lab and field equipment. The daily fee for staying at and using the Zackenberg station is set at 250 DKK (including 100 DKK for food).

Efforts are taken to secure that the Zackenberg station setup will match the concept for ZERO. Equipment, incl. power supply systems, will therefore be selected on the basis of maximum 'environment friendliness' to demonstrate that it is of highest priority to maintain the study area in an undisturbed condition and to minimise short-term as well as long-term human impact.



1.3. Presentation of the Zackenberg study area

Hanne H. Christiansen

The Zackenberg study area is located around 74°30'N and 21°00'W within the southern part of the National Park of North and East Greenland. The study area comprises the entire water catchment area of the river Zackenbergelven, totalling about 600 km², whith the core study area situated in the valley Zackenbergdalen at the lower reach of the river (Figs. 1.3.1 and 1.3.2).

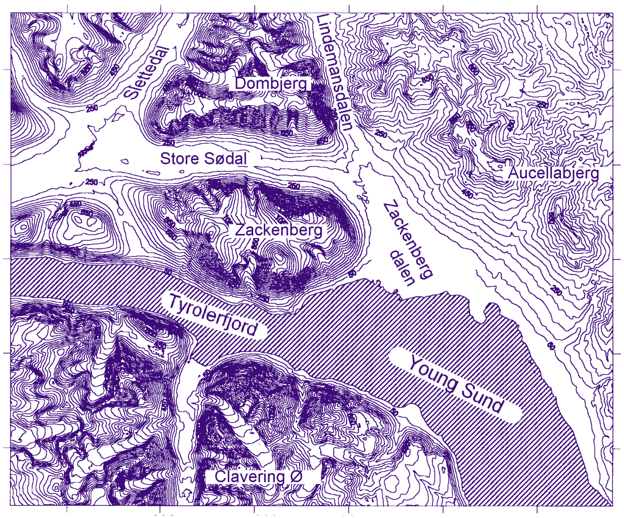


Fig. 1.3.1. Map of part of the study area with names of major localities. Scale: 4 km between marks on axes.

The topography at Zackenberg is dominated by a major valley system comprising Zackenbergdalen, Store Sødal, Lindemansdalen and Slettedal, surrounded by mountains rising to 1,450 m a.s.l. and delimited towards the south by Tyrolerfjord and the sound Young Sund (Fig. 1.3.1).

The Zackenberg area is located in the zone of continuous permafrost with an active layer thickness varying from 20 cm to 80 cm, depending on material. June, July and August have positive mean air temperatures. At Daneborg, 20 km SSE of the Zackenberg station, the warmest month is July with a mean air temperature of 3.8°C, while February is the coldest month with a mean of -17.6°C. The mean annual amount of precipitation is 214 mm water equivalent. As much as 87% of the annual precipitation falls as snow. The prevailing wind direction is from N and NNE. Heavy snowdrift from the N and NNE is frequent during winter (Danish Meteorological Institute 1967, 1968 & 1978, mean values 1961-1990).

A major geological flexure and thrust zone is running nearly N-S through Zackenbergdalen-Lindemansdalen, separating Caledonian gneiss bedrock in the west (Zackenberg area) from Cretaceous sandstone capped by Tertiary basalts in the eastern part (Aucellabjerg area) (Koch & Haller 1971). This distribution of different sorts of rocks makes a varied landscape, with both steep bedrock cliffs and slightly sloping sedimentary landscapes.

At present, the margin of the Greenland ice cap is situated about 60 km west of Zackenberg, and only a few small, local glaciers exist within the area. Relatively flat surfaces found on the top of Zackenberg and at the surrounding mountain tops reveal this part of the landscape to be most probably relatively old, developed during a warmer tropical climate as etchplains.

The youngest parts of the landscape, the glacial landscape, is found at the valley bottom, being deglaciated presumably at about 10,000 years ago. Different glacial landforms such as meltwater plains / sandurs and terminal moraine systems dominate in the study area. Old coastlines can be seen up to 50 to 70 m above the recent sea level. Several periglacial landforms are found in the area such as *e.g.* ice-wedges, solifluction lobes, snowpatches and associated nivation niches.

One major lake, Store Sø in Store Sødal, and a large number of small lakes, ponds and tarns are found in the area. In particular, the valley, Zackenbergdalen, with the core study area, holds a great variety of biotopes like ponds, fens, heaths, fellfield plateaus and grasslands.

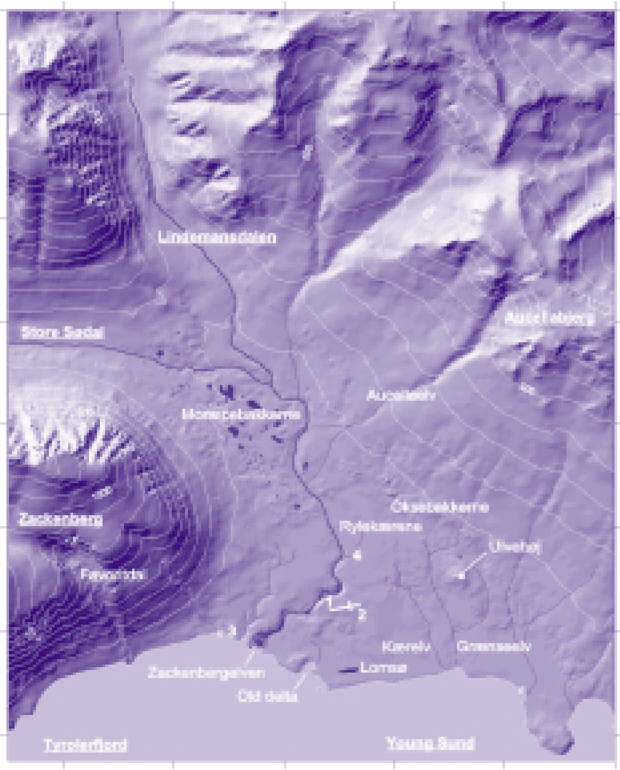


Fig. 1.3.2. Map of Zackenbergdalen with localities mentioned in the report. Officially approved names are underlined. Unofficial names are listed in Appendix 1. Scale: 2 km between marks on axes.

The 1991 reconnaissance team in front of the old Zackenberg trapping station. From left to right: Hauge Andersson, Bent Muus, Hans Meltofte, Bjarne Holm Jakobsen, Jens Böcher, Bent Fredskild and Gert Steen Mogensen.
Photo: Gert Steen Mogensen

2. Preparatory activities on site 1991-1994

Hans Meltofte

2.1. Reconnaissance 1991

A preparatory committee under the Danish Polar Center appointed Zackenbergdalen as an appropriate site for the establishment of a permanent research facility in High Arctic Greenland. On this background, the Danish Natural Science Council granted the financial fundament for a reconnaissance on site in 1991 (see section 6).

The logistics officer of the Danish Polar Center together with one physical geographer, two botanists and three zoologists, all from the University of Copenhagen, visited Zackenberg during 20 July - 4 August (see section 8.1).

The group examined the structure and diversity of the physical and biological scenario of Zackenbergdalen together with the adjacent valleys and fjords, and also visited a number of other sites closer to the outer coast as well as continental areas near the Inland ice.

The group concluded: a) that the Zackenberg area provides a high diversity of physical structures, biotopes and species, 2) that the logistic settings are optimal, and 3) that the scientific prospects for research projects and long-term monitoring appear to be excellent (Andersson *et al.* 1991).

In connection with the reconnaissance, a preliminary runway (220 m) was prepared on the eastern end of the gravel plateau, close to the proposed site of the research station.

Aerial view of the proposed site of the research station. The extend of the preliminary runway is indicated.
Photo: Hauge Andersson

2.2. Logistics and scientific work in 1992

Seven researchers and one logistic officer stayed at Zackenberg during 16 July - 15 August (see section 8.2.). The main tasks were 1) to establish a preliminary runway, 2) to continue the genereal preliminary survey of the Zackenberg study area and 3) to initiate the establishment of an 8.8 km botanical reference line from sea level to the 1,040 m peak of Aucellabjerg, the socalled 'ZERO-line'.

2.2.1. Logistics

The preliminary runway established in 1991 was extended to 300 m, and its surface was levelled to a reasonable smoothness. Furthermore, a preliminary survey of possible sites for the buildings of the research station was carried out.

2.2.2. Physical geography

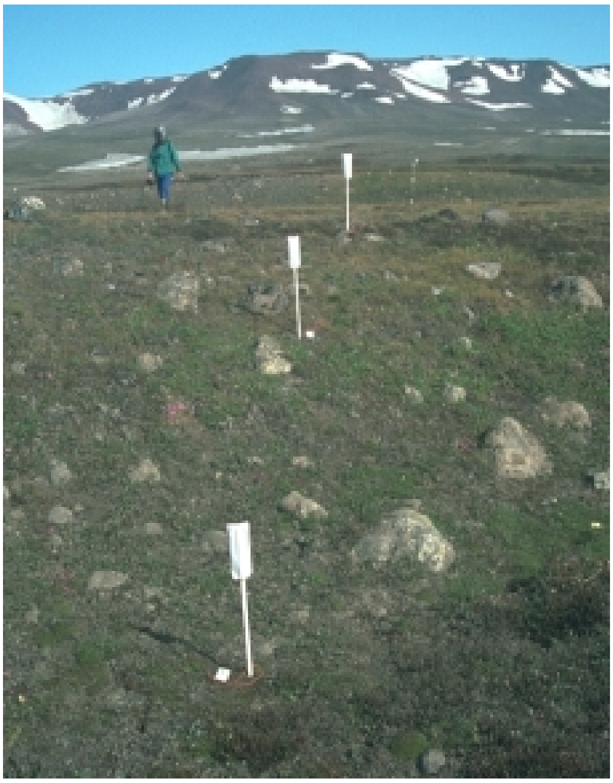
Hanne H. Christiansen & Ole Humlum

During the 1992 field season, Birger Hansen and Anne Jacobsen performed climatological studies registering short-term variations in radiation, energy and water balance combined with studies using remote sensing analyses of satellite data and spectrometer field measurements (Jacobsen 1995).

Also in 1992, the geomorphology of the Zackenberg area was mapped (on a large scale) during a one month field period. This was done in order to produce a geomorphological map of the area. Likewise some of the permanent long-term monitoring plots were established.

Preliminary results of the field investigations combined with studies of aerial photographs have resulted in the establishment of the overall glacial history of the Zackenberg region, as well as a presentation of the characteristic periglacial landforms (Christiansen & Humlum 1993). In that article some dates of different landforms have also been published.

Furthermore, a detailed study of luminescence dating of nival sediments, based on fieldwork in 1992, has been published (Christiansen 1994). Finally, nivation processes and forms were investigated, as a part of a Ph.D. study (Christiansen 1995).



Part of the ZERO - line during the initial phase in the summer of 1992. Aucellabjerg in the background.
Photo: Gert Steen Mogensen.

2.2.3. Botany

Bent Fredskild & Gert Steen Mogensen

2.2.3.1. The ZERO-line

In order to make it possible to monitor future changes in distribution and composition of plant communities along a horizontal as well as vertical gradient, a permanent reference line has been established from sea level to the peak of Aucellabjerg at 1,040 m a.s.l. (Fig. 2.2.3.1).

This transect is called the 'ZERO-line'. It was initiated in 1992 by Fredskild and Mogensen who registered the vegetation along the line from sea-shore to 610 m a.s.l.

All borders between major changes in the vegetation were marked by a total of 106 pegs. The altitude and distance between any two pegs were double checked by theodolite by Birger Hansen and Anne Jacobsen. Accuracy level is 0.1 m.

2.2.3.2. 400 m^2 study sites

In contrast to monitoring changes at geographic positions af major vegetation types a number of 20x20 m study sites was established in order to monitor infrastructures of plant communities. In 1992 four sites were established by Mogensen and of these only one was left undamaged in 1994. This site was analysed in 1992 at an accuracy of 0.1x0.1 m, *i.e.* 40,000 units.

This level of accuracy ollowed for identification of individual plants of *Dryas* when growing on windswept gravel but otherwise left most of the vascular and cryptogamic plant vegetation at a population level. In Fredskild & bay (1993) a detailed map shows the effect of the dominant wind direction on the vegetation.

Plots 2, 3, and 4 were placed in an *Eriophorum scheuchzeri* fen, a *Cassiope tetragona* heath, and in an extremely wet *Eriophorum scheuchzeri*/*Dupontia psilosantha*/*Polytrichum swartzii* -fen.

2.2.3.3. General botanical survey

In Zackenbergdalen, including the slopes of Aucellabjerg along the ZERO-line below 610 m a.s.l, the plant cover was grouped into eight main vegetation types: dwarf-shrub heath, fellfield/abrasion plateau, snow-patch heath, true snowpatch vegetation, herb slope, fen, grassland and fen-like, species rich community on solifluction soil.

These types are described by Fredskild *et al.* (1992) and Fredskild & Bay (1993) which also presents lists of 63 analyses along the ZERO-line and 40 analyses from elsewhere in the valley. A total of 149 species of vascular plants was found making this locality the most diverse in Greenland north of 74°N.

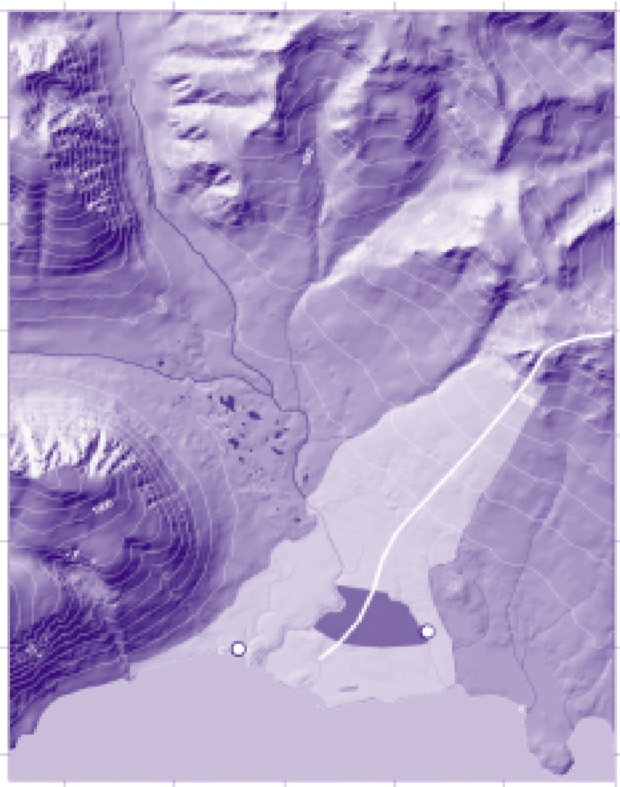


Fig. 2.2.3.1. Map of Zackenbergdalen indicating the ZERO-line, the bird monitoring area (light grey), the lemming monitoring area (dark grey) and two Arctic fox dens. Scale: 2 km between marks on axes.

2.3. Scientific work in 1994

Five researchers stayed at Zackenberg during 20 July to 23 August (see section 8.3). The main tasks were to finish the description of the botanical ZERO-line and other permanent study plots and to continue the survey of the Zackenberg study area.

2.3.1. Botany

2.3.1.1. The ZERO-line

Gert Steen Mogensen

In 1994, the main tasks were to extend the ZERO-line from 610 m to 1,040 m a.s.l. (see section 2.2.3.1), and to replace the pegs marking vegetation changes along the line with a new type that will not be destroyed by foxes. Both tasks were implemented to the effect that the ZERO-line is now marked and described from sea level to the top of Aucellabjerg (Fredskild *et al.* 1995). The line is approximately 8.8 km long. Significant plant community changes are marked with a total of 129 pegs allowing detailed monitoring of changes in vegetational borderlines. Twenty of the 106 pegs placed in 1992 had been destroyed by foxes. These pegs were re-established in 1994 by means of photo-documentation from 1992. In 1994, a few pegs from 1992 were covered by snow throughout the stay; spare pegs of the new type are deposited for later placement.

The upper part of the ZERO-line is quite different from the lower part as it involves manily High Arctic plant communities based on bryophytes and lichens and all on a substrate of basaltic subsoils. Distances, altitudes and major vegetation characteristics were recorded as well as a detailed registration in bryophyte and lichen variation. Re-analyses of this part of the ZERO-line is required at intervals of five years. Further details on the ZERO-line can be obtained from Bent Fredskild or Gert Steen Mogensen, Botanical Museum, University of Copenhagen.

2.3.1.3. Lichen studies

Eric Steen Hansen

Six hundred collections of lichens were made in the Zackenberg area and on a reference locality on Theodolith Plateau, Clavering Ø. Totally, 203 species of lichens and lichen parasites were recorded at these localities. About 50 range extensions were found. Twenty numbers were collected particularly for '*Lichenes Groenlandici Exsiccati*' fasc. XII. Four stands of *Cladonia mitis* were studied with special reference to 'damages' caused by UV-B in relation to the thinning of the ozone layer over the Arctic. Most of the individuals showed brown tips of branches and brown spots scattered on the main stems of the lichen.

Fifty-four vegetation analyses were made along the ZERO-line (see section 2.2.3.1) using the Böcher-modified Raunkjær method and the following method, by which the presence of the lichens in a plant community is recorded: a 4 m long string is placed perpendicular to the ZERO-line in homogenous vegetation.

The distance and the direction to the nearest peg and the direction to the following peg were measured. All lichen species growing within a distance of 10 cm on each side of the line string were noted. In addition, 50 lists of lichens were compiled along the ZERO-line. The vertical distribution of 98 species of lichens was investigated on Aucellabjerg along or near the ZERO-line. Five altitudinal zones are defined by their communities with particular emphasis on the lichens (Hansen in press).

With the intention to monitor vegetation changes *e.g.* caused by climatic changes, 14 permanent plots were established in different types of vegetation more or less rich in lichens and at different elevations on the Zackenberg mountain and Aucellabjerg.

Alpine bearberry Arctostaphylos alpina *in red autumn colour and the evergreen crowberry* Empetrum nigrum. *Both species with berries. Zackenberg is the northernmost locality for Alpine bearberry.*

Photo: Henning Thing

Nine plots are squares (0.2 x 0.2 m), marked with yellow dots at the corners. The slope and exposure of the squares were registered, and the number of plants were counted. Their position within the square was recorded in drawing and photographed. One plot measuring 2.0 x 5.8 m was marked with aluminium pegs at the corners. Besides, four permanent plots measuring 1 x 1 m were placed in different soil living plant communities in the area around Zackenberg. The degree of covering of the individual species was estimated using the Hult-Sernander scale. The corners of these plots were also marked with aluminium pegs. Most of the permanent lichen plots were situated far from the field station with the intention to avoid mechanical and human influence (Fredskild *et al.* 1995).

2.3.2. Nitrogen mineralisation in estuarine water and sediment

Søren Rysgaard

This research project is the first integrated study of primary production, nutrient dynamics and mineralisation in Young Sund. The project is using the Danish Polar Center's logistic facility at Daneborg, 20 km to the SSE from Zackenberg. The data given here represent conditions and activities in the early summer thaw (two first weeks of July). Primary production (5.3 mmol C m^{-2} d^{-1}) and chlorophyll a (4.1 µg l^{-1}) values were found to be comparable with measurements from other Arctic regions.

Water column N-fixation rates were low (<0.02 µmol N m^{-2} d^{-1}), but comparable to other estuarine systems. Despite a constant low temperature in the bottom waters (-1.0°C to -1.8°C) a high sedimentary O_2 uptake (740 µmol m^{-2} h^{-1}) was observed and was primarily caused by the presence of benthic infauna. Bioturbation by benthic infauna was reflected in both homogeneous ^{210}Pb and ^{137}Cs profiles in the upper 4 cm of the sediment.

Permanent accumulation within Young Sund was measured to 0.12 cm yr^{-1} corresponding to 153 mmol C m^{-2} yr^{-1} and 15 mmol N m^{-2} yr^{-1}. Rates of nitrification (22 µmol m^{-2} h^{-1}) and denitrification (9 µmol m^{-2} h^{-1}) were comparable to rates reported for other sediments with much higher environmental temperatures. Sulphate reduction rates integrated over the upper 12 cm of the sediment were calculated to 44 µmol m^{-2} h^{-1}. These finding are presented by Rysgaard *et al.* (in press).

A mathematical dynamic diffusion model describing the mineralisation processes within sediments has been developed. The model is based on the degradation of organic matter stoichiometrically coupled to the consumption of O_2 in the oxic layers and to NO_3^- and SO_4^{2-} in the anoxic layers of the sediment, and all transport of solutes is assumed to take place by diffusion. The model was validated on Young Sund sediments and gave accurate simulations of the measured concentration profiles.

Furthermore, the mineralisation processes, *e.g.* nitrification, denitrification, ammonium mineralisation etc. were predicted with great accuracy in this Arctic sediment. Since the model is based on fundamentally accepted reactions, diffusional transport mechanisms and Michaelis-Menten regulation kinetics, the predictions made by the model is of general use, thereby providing an important tool for a detailed insight in the regulation of the biogeochemical cycle in sediments. These findings are presented by Rysgaard & Berg (submitted).

The annual supply ship anchored off Daneborg. This part of Young Sund is the site for the nitrogen mineralisation study, initiated in 1994 and to be completed in 1997.

Photo: Hauge Andersson

3. Logistic facilities established in 1995

Hans Meltofte

During 13 July - 30 August, a total of 14 researchers, logistics and construction personnel worked at Zackenberg (see section 8.4). Accommodation was based on tents and shelters, including mess and lab facilities.

3.1. Buildings

Shortage of funds prevented the planned shipment of five pre-fabricated houses to Zackenberg and the erection of the buildings during August 1995. However, the foundation material for the houses and small-seized construction equipment were deposited on site, so that the foundations can be installed and ready when the pre-fabricated units are scheduled to arrive in August 1996.

Three Canadian 'Weatherhaven' shelters (each 15 m^2) - were erected for mess, radio communication and housing purposes, respectively. At the end of the season two of the shelters were taken down and one was left as over-winter storage space for equipment. Sensitive equipment and foods were flown to Daneborg for 'polar bear safe' deposition.

Furthermore, one 18 m^2 cabin was built immediately adjacent to the station site by the military Sledge Patrol Sirius as their local inspection facility.

Three sturdy shelters provided good ad hoc facilities for mess, housing and radio communication during the summer season. In the future, customised shelters will be used as accommodation for researchers.

Photo: Jens Böcher

3.2. Runway

During 3-8 August, the existing natural runway on the gravel plateau adjacent to the station site was extended to 450 m and its surface material was levelled and compacted. Additionally, perpendicular to the main runway, a 145 m emergency runway parallel to the direction of local gale force winds, was constructed.

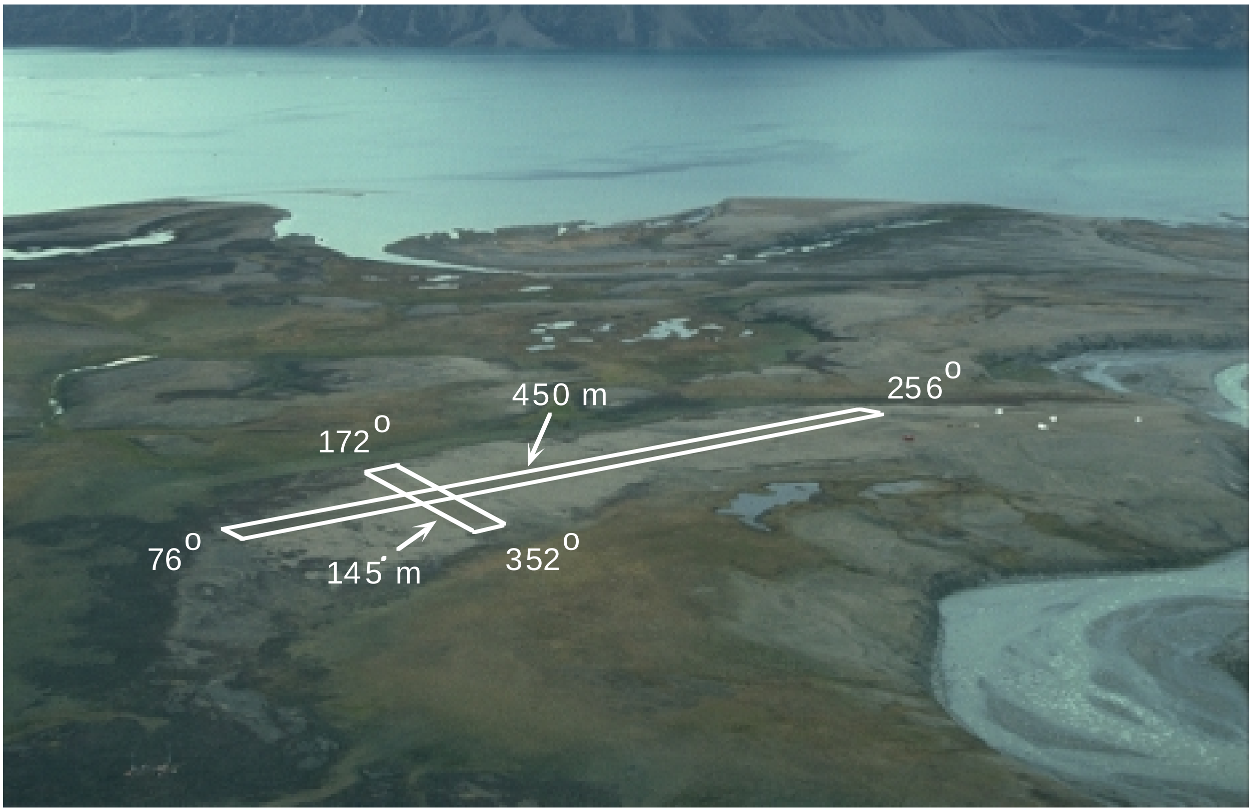
The mid section of the primary runway is situated at 74°28'09"N, 20°33'48"W at 32m (105 feet) altitude. The compass headings for the primary and secondary runway are 76° – 256° and 172° – 352° (true North), respectively. The magnetic declination from true North at the Zackenberg site is at present 27°W.

The Icelandic entrepreneur levelling the surface of the primary runway.

Photo: Henning Thing

3.3. River passage

Zackenbergelven, the main river running through the central part of Zackenbergdalen, is difficult to ford from spring break up and until mid August. Therefore, a boat passage, based on a small rubber dingy fastened on a tight steel wire by a pulley, was installed. This arrangement had a preliminary character, but most passages succeeded without people getting too soaked.



Aerial view towards the south with the location of the two runways and the adjacent Zackenberg station site. Headings (true North) and runway lengths are indicated. Photo: Hauge Andersson

Fording Zackenbergelven by means of the preliminary dinghy-and-wire system required a determined mind. Photo: Hanne H. Christiansen

4. Initiation in 1995 of the monitoring programme ‘Zackenberg Basic’

Hans Meltofte

One of the prominent features of the ZERO programme is the long-term monitoring of abiotic as well as biotic ecosystem processes in the Zackenberg study area. In principle, this monitoring programme, Zackenberg Basic, has a time perspective of at least 50 years. The programme intends to monitor a wide range of parameters that are relatively easy to record in a standardised, concise and reproducible way, and that are manageable by a limited number of personnel. Zackenberg Basic has two components: GeoBasis (the abiotic monitoring) and BioBasis (the biotic monitoring).

Zackenberg Basic is structured to provide basic insight into the dynamics of a High Arctic ecosystem both concerning year-to-year variation and long-term changes, *e.g.* in relation to climatic fluctuations and changes. All procedures and sampling standards of the programme are described in detail in a manual under preparation.

4.1. Topography as the basis for GIS analysis and a GIS related database

Hanne H. Christiansen & Ole Humlum

Since 1992, a digital terrain model (8.5 Mb data) of the Zackenberg area has been prepared as a basis for a GIS database (Fig. 4.1). At the same time a topographical map at a scale of 1:50,000 covering about 300 km^2 has been prepared, but is not yet printed. The mapping was based on aerial photographs from 1985 (scale 1:150,000).

It is presently the plan to produce an orthophoto map covering the entire area of the digital terrain model of Zackenberg, in co-operation with the National Survey and Cadastre (Kort- og Matrikelstyrelsen).

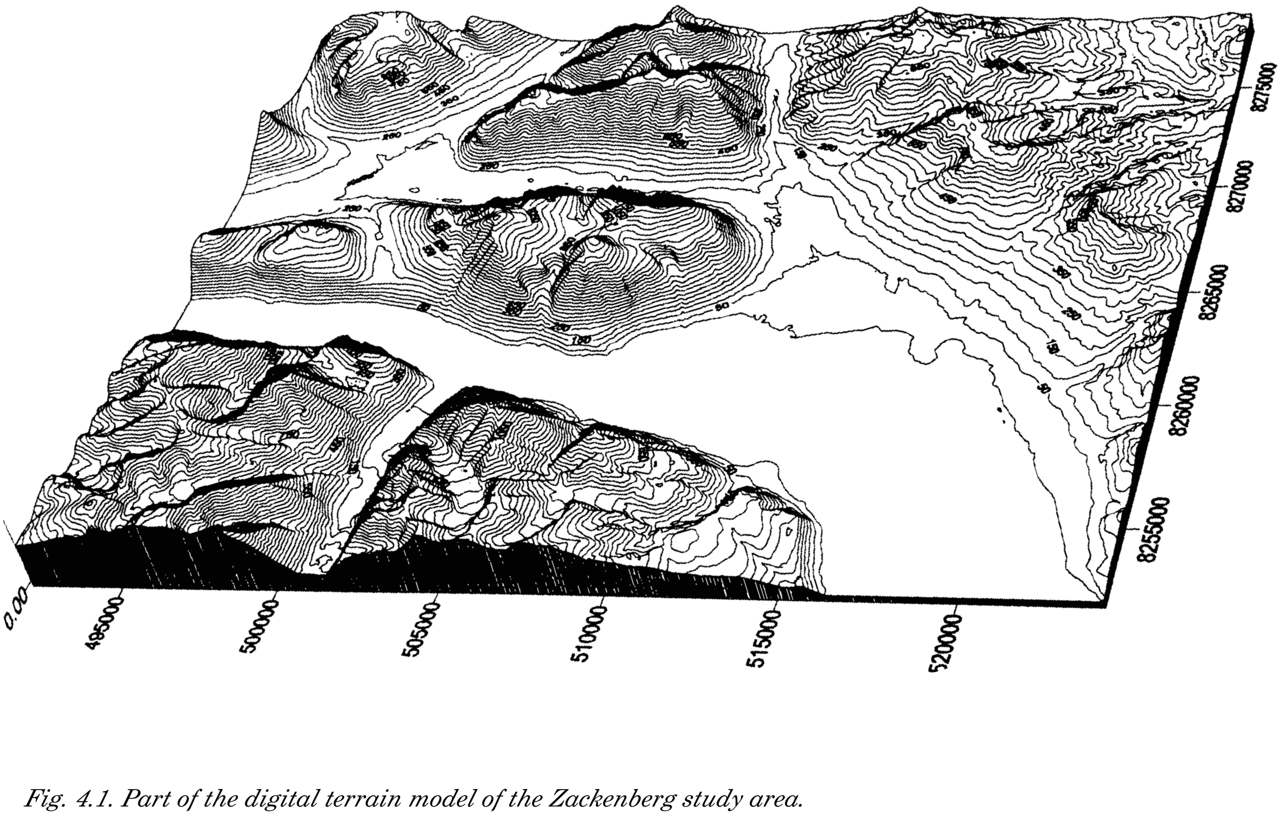


Fig. 4.1. Part of the digital terrain model of the Zackenberg study area.

4.2. The 'GeoBasis' Programme

Hanne H. Christiansen & Ole Humlum

The primary purpose of the GeoBasis monitoring at Zackenberg is to establish knowledge on the dynamics of the physical environment, by investigating *(i.e.* measuring, analysing and mapping) forms, processes and sediments and by sampling meteorological and hydrometrical data series. This information is a prerequisite for understanding edaphic and climatic factors governing plant communities and terrestrial and limnitic animal life. In this way the physical and biotic environments are closely connected, with the collection of physical information forming a basis for large parts of the research project at Zackenberg.

In 1995, large parts of the GeoBasis programme were established, monitoring plots established in 1992 were re-measured, and research on glacial and periglacial geomorphology was continued, as described in section 5.1.

In the following sections the permanent installations established in Zackenberg during the field season 1995 (Fig. 4.2) is presented together with some preliminary data from the field period. The monitoring of different geomorphological landforms is also presented.

4.2.1. The climate station

In order to monitor the High Arctic climate at Zackenberg a climate station is now running permanently (Fig. 4.2.1). Data from the climate station will be used to describe variation of radiation balance components and the variation in energy and mass fluxes. On a longer timescale the data will contribute to documenting changes in the climatological parameters measured.

4.2.1.1. Position, construction, data logging and storing

The design and technical construction of the climate station have been performed in co-operation between Mississueqqaarnerit, Nuuk (Grønlands Forundersøgelse / Greenland Field Investigation) and the Institute of Geography, University of Copenhagen.

The climate station was established in the middle of Zackenbergdalen during 6-17 August 1995 by technicians from Mississueqqaarnerit, Nuuk. The station is located on a remnant of a meltwater plain covered by a homogeneous Cassiope vegetation (Fig. 4.2 and cover photo). This location was chosen because it is representative for large parts of the landscape and vegetation of Zackenbergdalen, and because it is in central part of the core study area.

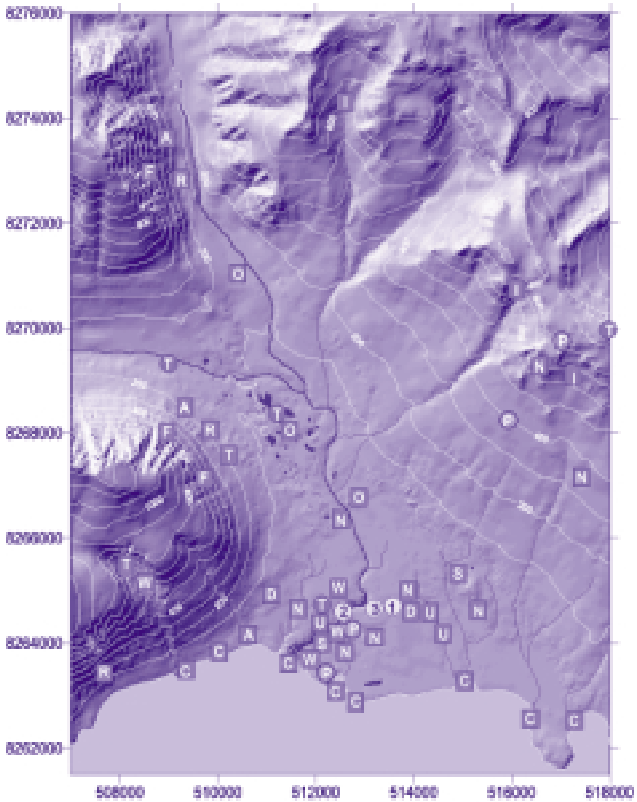


Fig. 4.2. Map showing location of permanent installations and geomorphological monitoring plots in the core study area in Zackenbergdalen. Scale: 2 km between marks on axes.

1 = climate station, 2 = hydrometric station, 3 = temperature measurements in pond , P (in circle) = permafrost / active layer temperature monitoring pro-files, T (in circle) = air temperatur at terrain surface, A = avalanche monitoring, C = coastal monitoring plots, D = monitoring of debris islands, F = free rock face monitoring, I = monitoring of snow / ice accumulations, N = nivation monitoring plots, O = windpolish monitoring, R = rock glacier monitoring, S = solifluction monitoring plots, T (in square) = talus monitoring, U = fluvial monitoring, W = ice-wedge monitoring.

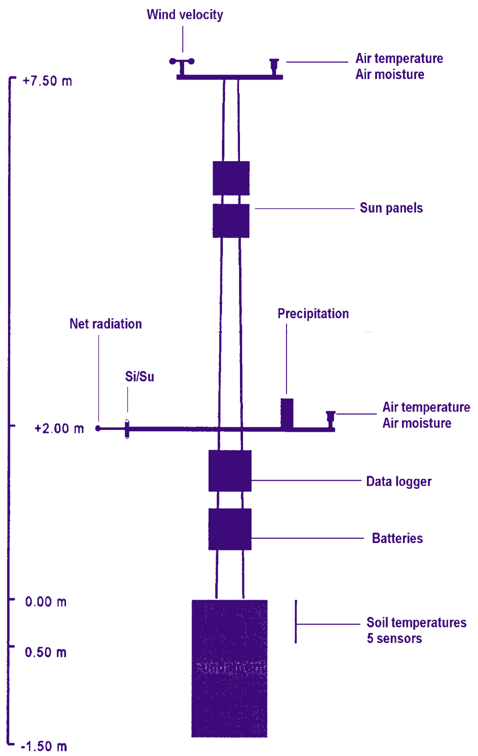
In order to achieve and secure the best and most complete set of meteorological data from the climate station in Zackenberg, the station consists of two nearly identical masts (Fig. 4.2.1). Each has separate sensors and current supply. On each mast, two 9 W solar panels are charging on eight 28 Ah lead-acid accumulators.

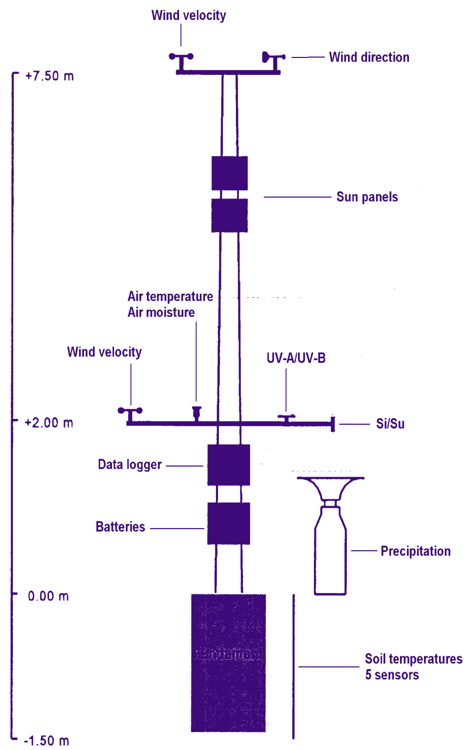
The masts are electroplated lattice-work masts, each 7.5 m high. They consist of a bottom section of 2.5 m and a top section of 5 m. The top of the mast can be raised and lowered by the use of a waist, so that it is possible to replace sensors. The masts have

The automatic climate station was established during August 1995. The masts are 7.5 m high. The black and white equipment to the right of the masts is logging precipitation. The red Sirius cabin and the white shelters of the station are c. 0.5 km away. In the background are Tyrolerfjord and the mountains of Clavering Ø.

Photo: Hanne H. Christiansen

Fig. 4.2.1.





been constructed to resist a wind velocity of more than 100 m s^{-1}. They are anchored in a concrete foundation of 60 x 60 x 140 cm dug down into the permafrost.

Data from the different sensors are logged by a CR10 Campbell datalogger on each mast and stored on a 1M locations memory cards that can contain about 21 months of data, using the present instrumentation and datalogging programs.

4.2.1.2. Instrumentation

The two masts are positioned with a distance of about 25 m between them. The one positioned towards the west is called Zackenberg West while the one to the east is called Zackenberg East. The instrumentation of the two masts is shown on Fig. 4.2.1. Generally, all sensors are scanned once every hour. The wind sensors are, however, scanned every 10 minutes.

A detailed description of the two masts, containing *e.g.* the sort of sensors used, the accuracy of the different sensors and the programs for the different masts can be found in the technical description of the Climate Station Zackenberg (Misissueqqaarnerit 1995). In the following sections some of the meteorological parameters from the field period in August 1995 primarily from the Zackenberg East mast are preliminarily presented. The data are not yet validated which is why only preliminary graphs are shown. All graphs cover data from a 12 day period.

4.2.1.3. Air temperature

In Fig. 4.2.1.3 the air temperature at 2 and 7.5 m above terrain surface at the east mast is shown. A diurnal variation with maximum temperatures during day, and minimum temperatures during the night is clearly seen. The daily air temperature variation was about 5-6ºC in the measuring period, slightly lower at the top of the mast at 7.5 m, and a little higher at 2 m. From 22 to 25 August a colder period with temperatures below zero during large parts of the nights is seen.

4.2.1.4. Soil temperature

Soil temperatures as they are measured at five different depths at the east mast are presented in Fig. 4.2.1.4. The largest daily temperature variations are measured close to the terrain surface, while there is no variation below -80 cm. The lowermost thermistor is positioned in the permafrost layer. The surface of the permafrost layer is moving towards the thermistor positioned at -80 cm during the end of the period, while the temperature of the lower part of the active layer is reduced too. At -40 cm the temperature is colder than at -80 cm during the second half of the period, showing the process of cold penetration from the terrain surface.

Generally the temperature is falling during the period, showing that the autumn is beginning, but it is also due to re-establishment of equilibrium state

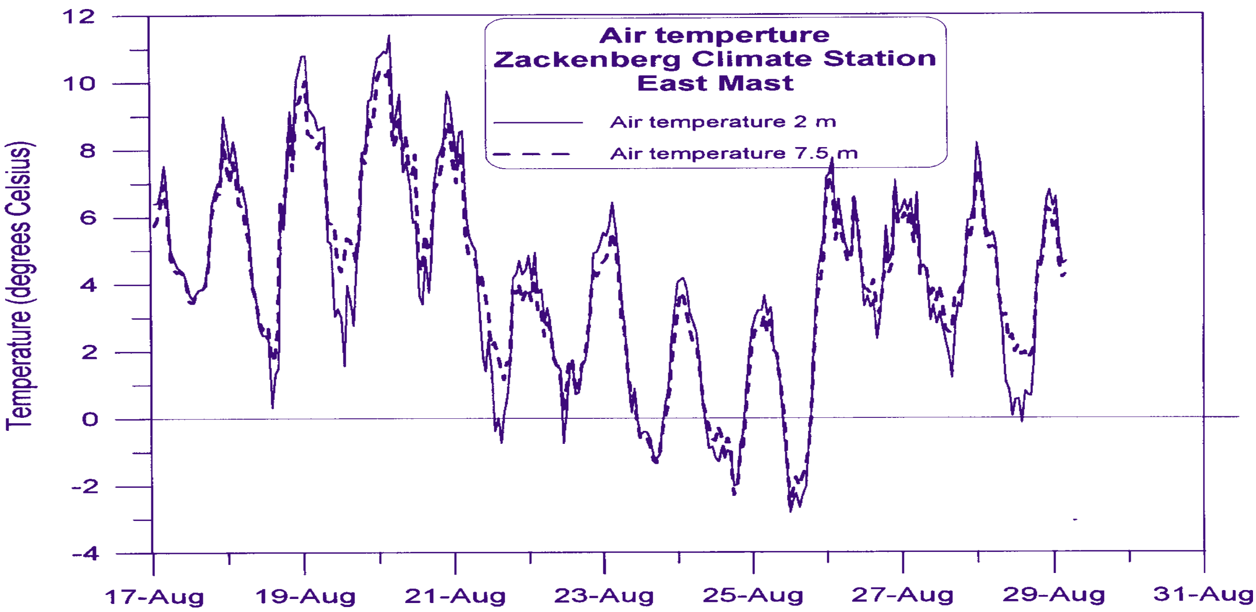


Fig. 4.2.1.3.

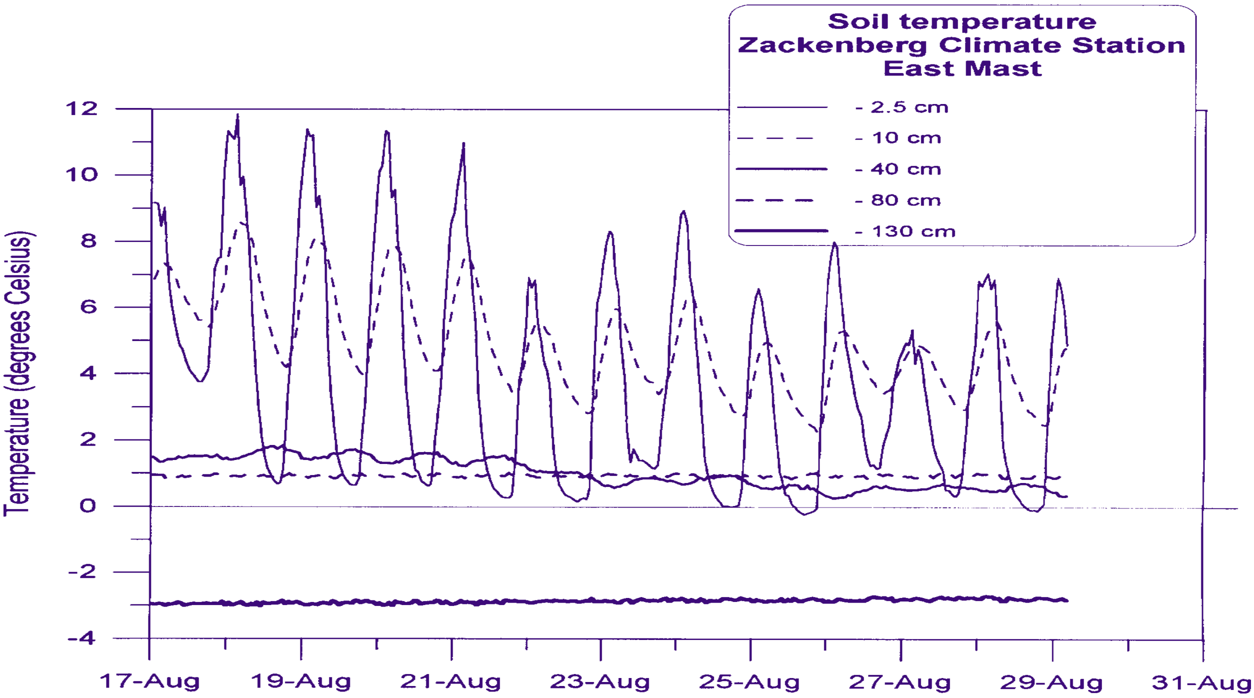


Fig. 4.2.1.4.

after the installation of the thermistors. At the west mast soil temperatures are measured in depths from 0 to 150 cm. All soil temperature sensors are placed in a common profile located between the two masts.

4.2.1.5. Humidity

The humidity data sampled at the east mast at 2 m and at 7.5 m above the terrain surface, are illustrated in Fig. 4.2.1.5.

The humidity varied between 35% and 98%, both at 2 m and at 7.5 m, with a clear daily variation. Highest values were reached during the nights because of lower temperatures, while the lowest humidity values were measured during daytime, when the air temperature was higher.

Particularly in the cold period, described in section 4.2.1.3, the humidity was high, still with a strong diurnal variation.

4.2.1.6. Air pressure

The air pressure measured at 1.6 m above terrain at the east mast is shown in Fig. 4.2.1.6. The air pressure values ranged between 996 and 1019.5 hPa (millibar). Generally the air pressure was low during the cold period, described in section 4.2.1.3.

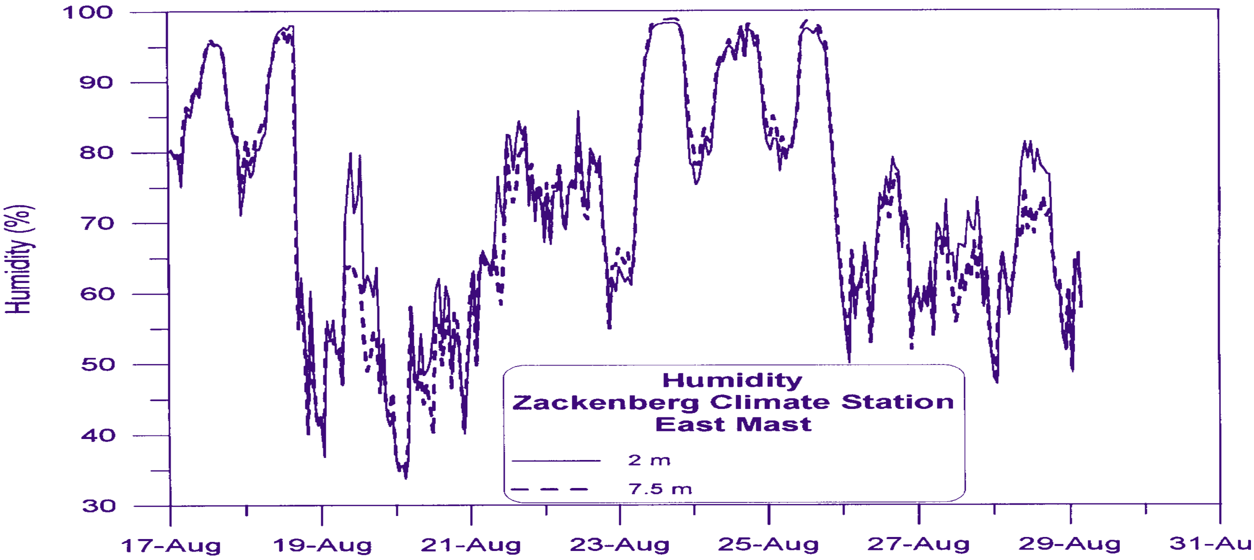


Fig. 4.2.1.5.

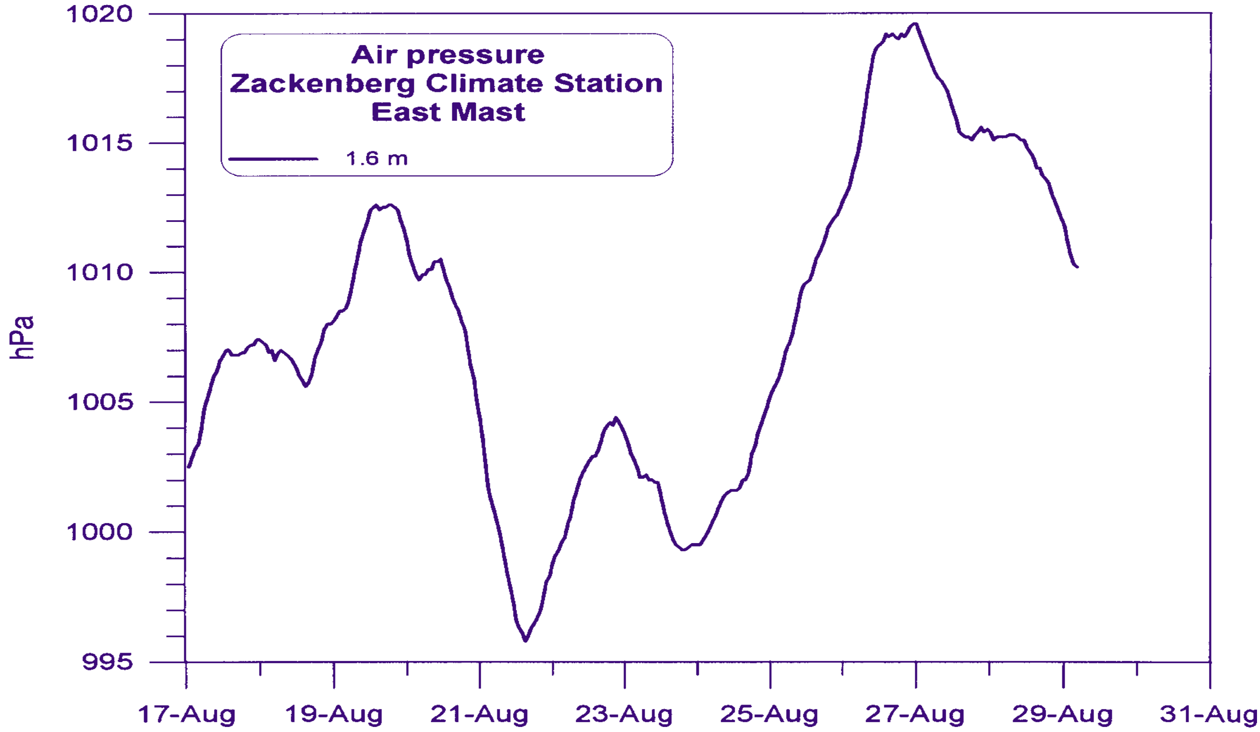


Fig. 4.2.1.6.

4.2.1.7. Wind velocity and direction

Wind velocity at the east mast and wind direction at the west mast, both sampled at 7.5 m above terrain, are shown in Figs. 4.2.1.7.1 and 4.2.1.7.2, respectively. Generally, velocity was low, about 2-3 m s^{-1}, increasing during the cold period.

The wind direction has been changing during the relatively short measuring period. A diurnal variation is evident, particularly in the beginning of the period. The dominating wind direction was from the north during nights and early mornings. It slowly changed from north to south during most of the daytime, and then finally back to north in the evenings.

This shows a typical situation, with a sea breeze during the day, due to a quicker warming of the land surface than of the sea surface, and land breeze during the nights, when cold air flows from land towards the coast and over Young Sund.

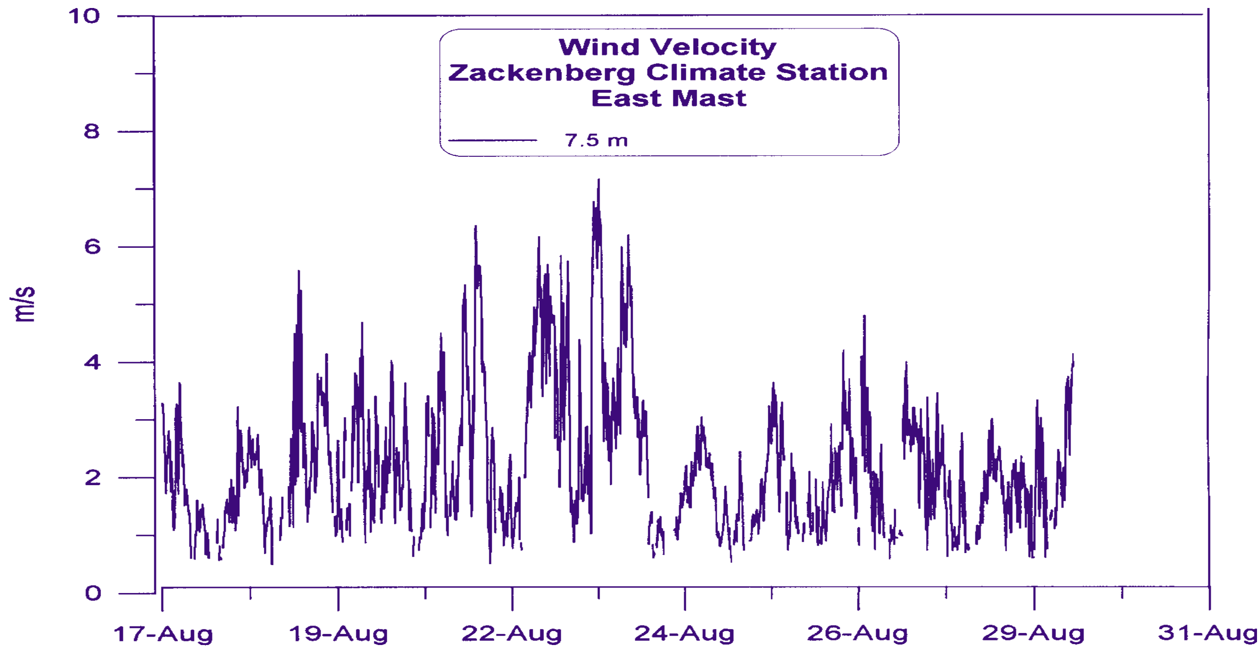


Fig. 4.2.1.7.1.

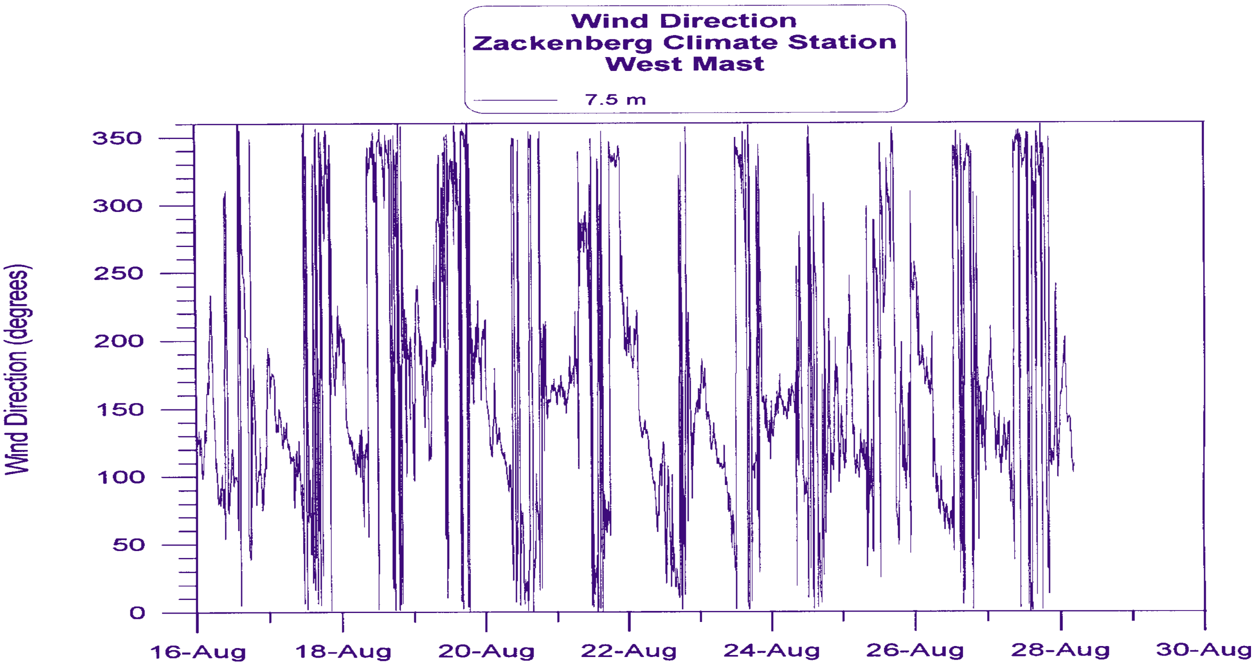


Fig. 4.2.1.7.2.

4.2.1.8. Net radiation

Fig. 4.2.1.8 shows net radiation data from the east mast. Again, strong diurnal variations are seen. On days with a cloud cover, the positive values during the days are reduced as e.g. 27 August. Every day there is a net flow of energy from the ground, illustrated by the high values measured during nights.

4.2.1.9. Precipitation

During the 12 day measuring period in late August no precipitation was measured in either of the two rain gauges, as it did not rain. Only fog was present during periods with high humidity, particularly in nights.. The two rain gauges only measure precipitation falling as water during the summer. In order to

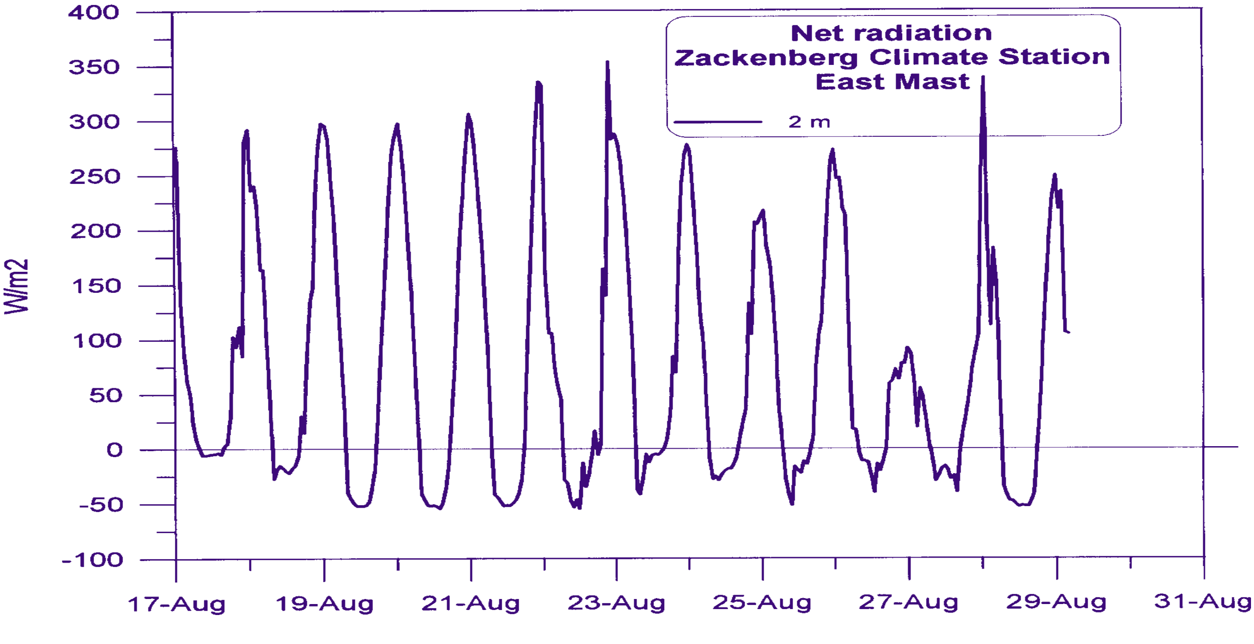


Fig. 4.2.1.8.

measure the precipitation falling as snow in winter, it is planned to equip the climate station with a sonic sensor measuring the distance from the sensor *e.g.* at 2 m above the terrain surface to the surface of the snow. In this way, variations in snow depth can be collected, also showing when snowdrift takes place.

4.2.2. The hydrometric station at Zackenbergelven

At the lower part of Zackenbergelven a permanent hydrometric station is positioned on the west side of the river, as shown on Fig. 4.2. Here the river is about 36 m wide and the water depth varies from 0.5 to 1 m in summer. The current of the river is strong along the sides (current velocities up to 1.4 m s^{-1} were measured).

The hydrometric station was established 8 and 9 August 1995 and data sampling started 9 August. Water depth, air temperature and water temperature are all logged throughout the year at 15 minutes intervals. The hydrometric station is seen on Fig. 4.2.2.The equipment used is a SR 50 Sonic Ranging Sensor that measures the distance to the surface of the river from a fixed point, a 107 Temperature Probe for air temperature (used for calibration of the SR 50 Sonic Ranging Sensor), and a TinyTalk temperature sensor for water temperature. During the summer, a PDCR830 Pressure Transducer for Depth Measurement has been used in order to calibrate the SR 50 sonic signal. Data are stored by a Campbell 21 X datalogger in a SM716 Storage Module which gives more than one year of storage capacity using the present instrumentation and program. The datalogger and storage module are located in a weather shielded PVC plastic box. Power supply for the station is photovoltaic panels charging on accumulators.

During the 1996 field season the first all year data set will be collected from the hydrometric station at Zackenbergelven. These data will reveal when the river freezes (stable distance from SR 50 to water surface) and it will also be possible to follow the thickness of snow above the frozen water surface during the autumn, winter and spring seasons.

4.2.2.1. Water discharge

During the summer, when the river is not frozen, water discharge measurements have been performed in the river cross-profile at the hydrometric station (Fig 4.2.2.1.1), in order to establish a relationship between water depth and discharge. Using this relationship together with the water depth data obtained by logging of data from the SR 50 sensor, it will be possible to calculate the discharge during the entire season with water running in the river.

Fig. 4.2.2. The hydrometric station at the west side of Zackenbergelven. The SR 50 sonic distance sensor is positioned above the water table at the end of the painted bar. To the left, the solar (photovoltaic) panel can be seen. Close to the panel the datalogger is hidden in a white box.

Photo: Henning Thing

In Figs. 4.2.2.1.2 and 4.2.2.1.3 data and some preliminary calculations from the short field season in August 1995 are presented.

Figure 4.2.2.1.2 shows the results of the SR 50 Sonic distance measurements. The sonic distance is the distance from the SR 50 sensor positioned at a fixed point above the water to the changing water surface of the river. In the beginning of the measuring period a diurnal variation is seen, with a low water level during the nights and high water level during the days in Zackenbergelven. A rainstorm dramatically raised the water level by about 20 cm during one day. When the water level was highest it was nearly impossible to wade across the river. Only by clinging to a wire spanning the river, it could be attempted. During this period, a propeller, used for measuring the current velocity of the water, was torn of the instrument in the water by the violent current. After the rainstorm, the water level in Zackenbergelven decreased for the rest of the field period in August, showing the general reduction in the amount of water draining to the river, as autumn starts and melting of snow and permafrost stops in the catchment area.

Fig. 4.2.2.1.1. Water discharge measurement performed in Zackenbergelven. A propeller is mounted at the pole, measuring water velocity.

Photo: Hanne H. Christiansen

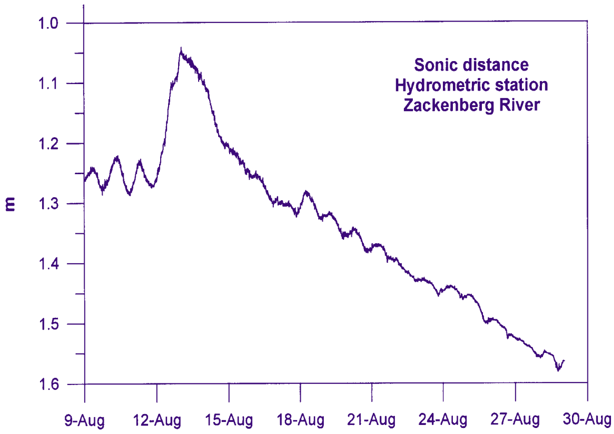


Fig. 4.2.2.1.2.

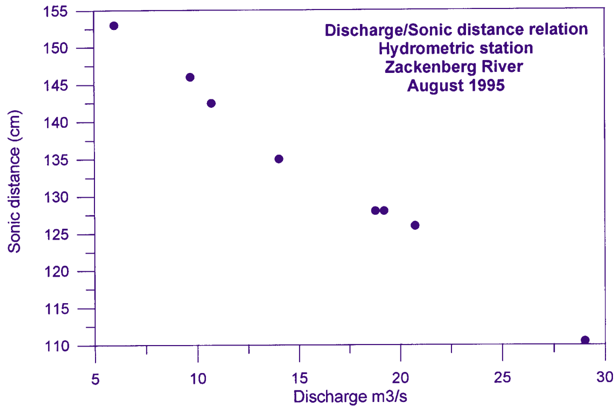


Fig. 4.2.2.1.3.

A preliminary relation of the discharge/sonic distance (water depth) relation is presented in Fig. 4.2.2.1.3, based on the discharge measurements performed in Zackenbergelven in August 1995.

In the period from 12 to 16 August, a rainstorm dramatically reduced the daily temperature variation in the water, because rain and snow falling in the catchment area yielded a general cold drainage.

4.2.2.2. Water temperature

Water temperature data from Zackenbergelven, measured at the hydrometric station during August 1995 show a decreasing trend, as expected for the early autumn (Fig. 4.2.2.2). The water temperature in the river displays a diurnal variation at about 3°C. This reveals a warming of surface water in the many streams leading to Zackenbergelven during the day.

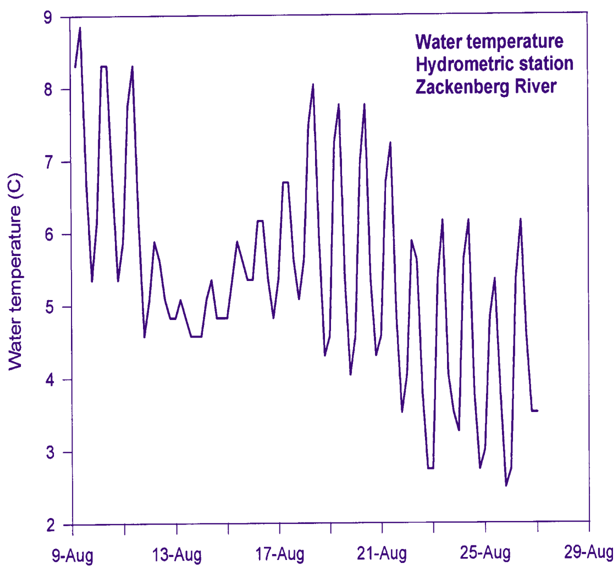


Fig. 4.2.2.2.

4.2.2.3. Suspended sediment and chemical analyses

During the summer field season water samples were taken from Zackenbergelven at the hydrometric station, in order to calculate the amount of suspended sediment in the water. Generally the amount of suspended sediment in the water samples varied from 322 mg l^{-1} to 22 mg l^{-1} during August 1995. The highest concentration was reached during the rainstorm period, when the discharge was also highest. After the rainstorm mid August the amount of suspended sediment was slowly falling towards the end of the month.

Chemical analyses on water samples taken through August 1995 have also been performed, ranging measurements of the content of Na, K, Ca, Mg, Fe, Al, Mn, Cl^- , NO^- , SO_4^{--} and pH, alkalinity and conductivity.

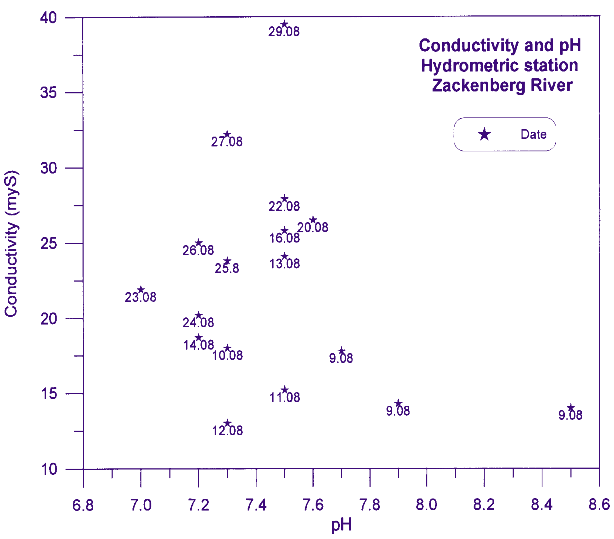


Fig. 4.2.2.4.

4.2.2.4. Conductivity and pH

Conductivity and pH have been measured directly in Zackenbergelven at the hydrometric station, see Fig. 4.2.2.4. It can be seen that conductivity is higher in the end of August and there is a tendency for the pH values to decline at the same time. Obviously this development shows a change in the source of water dominating in the river.

In the early season snow meltwater dominate having a low conductivity, while after snow melt has ceased, interflow water coming from the annual establishment of the active layer dominates, having a higher conductivity. Measurements of conductivity and pH during the entire summer season seem promising for obtaining more information on the sources of water dominating in the river.

4.2.3. Fluvial geomorphology

The fluvial geomorphological activity in Zackenbergelven is monitored by means of recurrent photography from the Zackenberg station, in close connection with data sampling at the hydrometric station, see section 4.2.2. The monitoring was initiated in August 1995 on a weekly basis and only few observations from this month exist. It will be of special interest in the future to obtain data on the formation of river icing covering the river bed during the autumn, and the consequence of this for fluvial runoff pattern during the spring as monitored at the hydrometric station.

4.2.4. Active layer and permafrost temperature monitoring

Along a transect from sea level to the top of Aucellabjerg (Fig. 4.2) dataloggers with thermistors were installed during August 1995 in four profiles, within the active layer and in the permafrost below. Temperatures are scanned five times a day, and the loggers will operate continuously until the summer 1996, when data will be collected and the loggers restarted.

The four temperature profiles are all located in unconsolidated sediments, till, glacio-fluvial and deltaic sands, and were established with consideration to sediment type, surface type, exposure (both sun and wind), distance to the sea and altitude. Supplementary temperature profiles are planned to be established during the summer of 1996.

At all profiles thermistors were installed at the terrain surface and within the active layer (thickness 50-100 cm), ending with a thermistor installed shortly within the upper part of the summer permafrost layer. Installations were carried out in August, when surface thawing reaches maximum depth. In one profile, is was possible to install a further thermistor deeper (about 85 cm) within the permafrost layer. This thermistor was installed within an ice-wedge.

The dataloggers used in this monitoring experiment are rather inexpensive TinyTalk loggers with external thermistors. They are small (about 5x5x4 cm) and contained in a strong and waterproof (max. 15 m water) housing. They operate over a temperature range from – 40°C to 75°C, with a precision of at least 0.2°C. This kind of low-cost dataloggers are successfully operating on a year-round basis in the maritime Low Arctic climate of the Ammassalik area, SE Greenland, in a project that our research group is running there.

Two examples of temperature recordings from two profiles during August 1995 are shown in figures 4.2.4.1 and 4.2.4.2. The installations of thermistors were implemented by digging into the active layer, and except for the surface temperature, the general temperature levels should therefore not be considered as representative of an equilibrium situation.

Re-establishing a valid temperature pattern will probably take considerable time (more than one month), following the disturbance of the sediments within the active layer. The thermistors were, however, injected into undisturbed sediments in the vertical sides of the excavations.

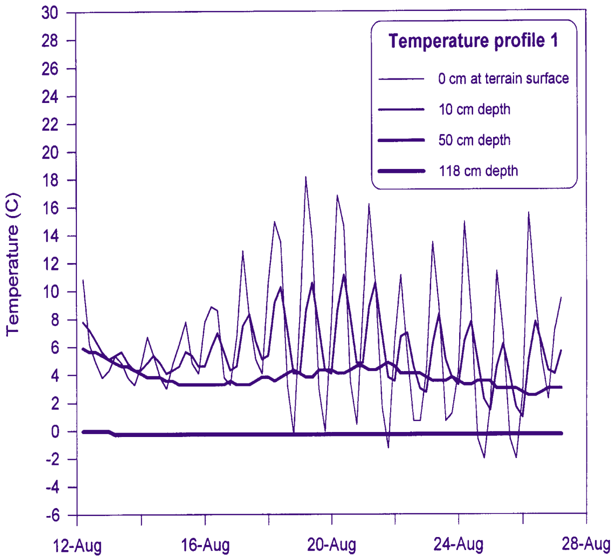


Fig. 4.2.4.1. Temperature monitoring in the active layer and in the top of the permafrost.

4.2.5. Snow cover

Annual variations in snow cover is registered by combining satellite image analyses with repeated photographing of the monitoring area. In practise, photo series covering the entire investigation area will be taken every 10 days, starting from 10 June, during the summer field season from a fixed point at the Zackenberg Station. A satellite image taken in spring presumably in June representing the beginning disintegration of the winter snow cover, and one from late summer or early autumn with a minimum snow cover, should constitute the basis for an area registering of the timing of the snowmelt in the monitoring area.

The scale of the satellite images used should preferably be as large as possible. LANDSAT images have a pixel size of 30 x 30 m, and they would yield the most detailed information. Based on this remote sensing registering and the percentage of snow cover on the photo series, the general course of the snow cover disintegration can be determined.

In areas where a more detailed registration of snow thickness, snow cover duration and water equivalent is needed, detailed measurements of snow depth and density is performed on a plot level scale.

4.2.6. Nivation

Several nivation hollows containing either seasonal or perennial snowpatches are being photographically monitored in order to detect changes in form, vegetational zonation and the annual summer minimum size of the snowpatches (Christiansen 1992). For location of the monitored nivation hollows and snowpatches, see Fig. 4.2.

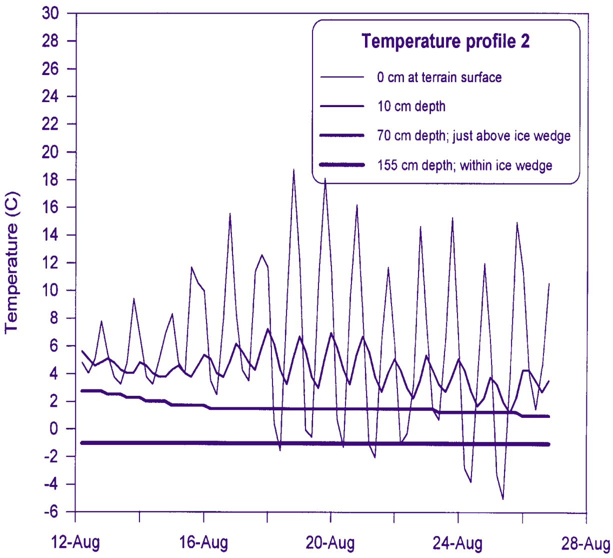


Fig. 4.2.4.2. Temperature monitoring in the active layer and in the top of the permafrost.

The photo monitoring programme was partly initiated already in 1992, but enlarged during the 1995 field season to contain several nivation hollows. Some of the nivation hollows are being stereographically photo-monitored, allowing terrain models to be established on the basis of a photo stereo model.

Fig. 4.2.6. Snowpatch in nivation hollow used for BTS temperature monitoring.

Photo: Hanne H. Christiansen

At one nivation hollow containing a perennial snowpatch the temperature at the terrain surface is being monitored, allowing BTS (winter basis temperature of the snow cover) data to be collected. Here five dataloggers (TinyTalk) with external thermistors were installed at the terrain surface along a transect across a large nivation hollow, containing a perennial snowpatch (Fig. 4.2.6). This nivation hollow contains a well developed vegetational and geomorphological zonation, and the temperature measurements will be used as a means of indirect monitoring of the establishment and duration of snow cover within the nivation hollow. Temperatures are scanned five times a day and the loggers will operate continuously until the summer 1996, when data will be collected and the loggers restarted. The site is located shortly west of Zackenbergelven (Fig. 4.2). Therefore supplementary visual observation and photo documentation is easily obtained by the staff at the Zackenberg station.

4.2.7. Ice-wedges

At one active ice-wedge a profile measuring the temperature at the terrain surface, at 10 cm and at 70 cm below surface was established. The lowermost thermistor was installed within the ice-wedge at 155 cm below terrain surface, while the others were all installed in the active layer. This temperature monitoring profile is one of the four profiles mentioned in section 4.2.4.

Fig. 4.2.7. Active ice-wedge with six pegs installed for measuring growth-rate of the ice-wedge.

Photo: Hanne H. Christiansen

At three active ice-wedges a rate-of-growth measuring net has been installed, in order to follow the growth of the ice-wedges. The location of the three measuring nets is shown on Fig. 4.2. At each of the three ice-wedges 6 fixed pegs were positioned as shown on Fig. 4.2.7, enabling the distance across the ice-wedge to be measured accurately at three positions at each ice-wedge. Stereographic photo monitoring of one of the measured distances (from one peg across the ice-wedge to the corresponding peg on the other side) was also initiated in 1995. Each year the distance will be measured and the rate of growth calculated.

Particularly on the fluvial terraces of the Zackenbergelven delta several dry valleys initiate on one terrace and lead to a lower. The initiation of these dry valleys is caused by ice-wedges degrading due to horizontal thermal erosion, as snowmelt water uses the lowering of the surface of the ice-wedges as drainage channels. In such an ice-wedge initiated valley the backwards erosion is being monitored, by measuring the change in distance from the upper edge of the valley to several painted stones positioned on the undisturbed terrain surface. This is done along the entire head of the valley.

4.2.8. Solifluction

At two solifluction lobes in Zackenbergdalen the rate of movement is monitored at the lobe fronts. by establishing cross-profiles of pegs with a short individual distance, arranged at one lobe parallel to the direction of flow and at the other lobe perpendicular to the direction of flow (Fig. 4.2.8), allowing a study of the differential movement of the lobe. The two solifluction lobes being monitoring are positioned as shown on Fig. 4.2.

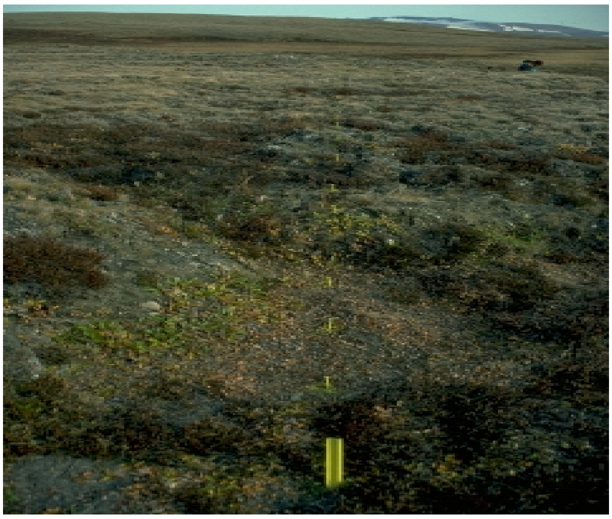


Fig. 4.2.8. Line of pegs perpendicular to a solifluction lobe used in monitoring the rate of solifluction movement.

Photo: Hanne H. Christiansen

The cross-profile parallel to the direction of the solifluction movement was established already in 1992 and the re-measuring between each peg in the cross-profile in 1995 (exactly 3 years later) showed an average reduction in distance at about 0.5 cm. This proves that the monitored solifluction lobe is actively moving with an average of 0.17 cm yr^{-1}. The movement is quicker in the front of the solifluction lobe. At both profiles photo monitoring is performed, and at one site the photo monitoring is of the entire front of the lobe using stereo photogrammetry (Christiansen 1992).

4.2.9. Wind abrasion

In order to monitor the rate of wind abrasion a monitoring plot consisting of eight non-polished small boulders was established just south of Lindemansdalen (Fig. 4.2). This locality is clearly influenced by the northerly winds dominating the area, as seen on the large number of stones having windpolished surfaces.

Fig. 4.2.9. Line of non-polished, partly painted stones to the south of Lindemansdalen, used for windpolish monitoring.

Photo: Hanne H. Christiansen

Eight non-polished stones were positioned on a line extending east-west (see Fig. 4.2.9). On the side of the stones facing towards north, towards the dominating wind direction, an area of 10 x 10 cm has been completely covered by yellow painting.

Wind abrasion will remove the painting in areas and afterwards the surfaces of the stones will eventually become windpolished. In this way it will be possible to monitor how fast wind-abrasion and wind-abraded surfaces will develop on stones of different lithology.

Areas dominated by aeolian activity can be found where the sediment supply is large as is the case *e.g.* at the west end of Store Sø in Store Sødal, where a large delta is acting as a source area for a shallow dune area, accumulating to the south of the delta. Both the delta and the dunes are being monitored photographically.

4.2.10. Debris islands

Debris islands exist in different parts of Zackenbergdalen. In two places photo monitoring of a single and of several debris islands, respectively, was initiated in order to determine the rate of movement (Fig. 4.2).

4.2.11. Rock glaciers

Several rock glaciers are found in the greater Zackenberg research area lining the foot of talus slopes (Fig. 4.2.11.1) or originating within cirques (Fig. 4.2.11.2). Three rock glaciers are monitored by means of recurrent photography (Fig. 4.2), but the monitoring procedure will in the future be extended to include proper surveying techniques as well.

Fig. 4.2.11.1. A talus-derived rock glacier at the NE foot of Zackenberg. The rock glacier front is about 25 m high. View towards SW.

Photo: Ole Humlum

Fig. 4.2.11.2. Glacier-derived rock glacier originating from an E-exposed cirque in the northern part of Lindemansdalen. View towards S.

Photo: Ole Humlum

Two of the rock glaciers are talus-derived, and they are envisaged as being ice-cemented by interstitial ice. One rock glacier, situated in the northern part of the research area, appears to be glacier derived and probably contains a solid core of glacier ice. The rock glaciers appear to represent active features, as their termini are partly covered by an apron of fresh, unvegetated rock fragments, which have recently rolled down from the upper part of the rock glacier front.

Rock glaciers are usually considered as geomorphological features associated to permafrost areas with only little precipitation. The presence of active rock glaciers within the Zackenberg research area, where high-quality meteorological data will be obtained, is therefore of considerable interest in this respect.

4.2.12. Avalanche features

Several talus slopes within the research area are influenced by snow avalanches (Fig. 4.2.12). Three avalanche boulder tongues are currently being monitored (Fig. 4.2) by means of photography whereby changes caused by renewed avalanche events can be studied.

Fig. 4.2.12. Snow avalanche track across talus cone in the southern part of Lindemansdalen. View towards W.
Photo: Ole Humlum

Modern snow avalanche activity within the study area is closely related to the strong and persistent northerly winds, accumulating snow on lee-side localities. The present day distribution of snow avalanche features within the area and the avalanche frequency is therefore an integrated expression of meteorological parameters such as wind and precipitation during the winter.

Lichenometry and weathering studies have been initiated at the monitoring localities in order to gain information on the avalanche frequency in the past.

4.2.13. Talus slopes

Talus slopes are widespread within the research area, especially along north-west, north and north-east facing slopes, west of the Zackenbergdalen – Lindemansdalen axis. Two localities with active talus slopes have been selected for photo monitoring (Fig. 4.2). The potential of the photographic method is exemplified in Figs. 4.2.13.1 and 4.2.13.2.

The weathering of bedrock is usually controlled by both moisture and temperature, and is promoted by low winter temperatures and presence of water along cracks and within pores in the solid bedrock. Modern rock fall activity is thus probably an integrated result of current meteorological parameters such as temperature, precipitation and wind.

Fig. 4.2.13.1. Talus monitoring plot in Favoritdal, SE of the Zackenberg summit. August 1992.
Photo: Hanne H. Christiansen

Fig. 4.2.13.2. Talus monitoring plot in Favoritdal, SE of the Zackenberg summit. August 1995. Note large boulders accumulated in lower left corner since 1992.
Photo: Hanne H. Christiansen

4.2.14. Free rock faces

Free rock faces occur frequently in the greater Zackenberg research area, especially on slopes with north-west, north or north-east aspect. The occurrence is, however, limited to the bedrock area west of the Zackenbergdalen - Lindemansdalen axis. East of this line sedimentary rocks such as shales and sandstones dominate.

The overall appearance of two sections of large free faces along the northern part of the Zackenberg mountain is monitored by means of recurrent photography (Fig. 4.2). Changes regarding surface form and colour, indicating a recent rock fall, will be registered in this way.

4.2.15. Coastal geomorphology

Two photographic monitoring areas at the coast south of the Zackenberg station have been established in August 1992 (Fig. 4.2). One area represents an aggrading coastal plain with beach ridges, while the other represents a curved spit (Fig. 4.2.15.1).

In both areas detailed terrain profiles have been measured since 1991, in 1992 and in 1995 using a modern theodolite instrument, Topcon GTS-6, in order to follow the rate of coastal sediment transport in the monitoring areas.

Fig. 4.2.15.1. Monitoring area at the coast adjacent to the east side of the old Zackenberg river delta.

Photo: Ole Humlum

Further photographic monitoring areas were established along the coast to the east and west of the Zackenbergelven delta during the summers of 1992 and 1995, representing coastal landforms sensitive to changes in sea level, such as beach ridges and spits (Fig. 4.2). In these areas there are several signs of an ongoing relative transgression (Fig. 4.2.15.2) as found by Christiansen & Humlum (1993).

4.2.16. Air temperature at terrain surface

Air temperatures 5 cm above the terrain surface are monitored at three places in the upper part of Zackenbergdalen, in Store Sødal and at the top of Aucellabjerg (Fig. 4.2). This is done by TinyTalk dataloggers with external thermistors. The air temperature is scanned five times a day and the loggers will operate continuously until the summer 1996, when data will be collected and the loggers restarted.

These temperature measurements will provide initial information on regional variations within the greater Zackenberg research area. It will also be possible to derive some information on the establishment and duration of snow cover by this monitoring.

Fig. 4.2.15.2. Monitoring area at the coast west of the mouth of Zackenbergelven.

Photo: Ole Humlum

4.2.17. Pond temperature

One TinyTalk datalogger with external thermistor was installed 1 cm above the bottom of a small freshwater pond, shortly north of the runway at the Zackenberg station (Fig. 4.2). The water temperature is scanned five times a day and the logger will operate continuously until the summer 1996, when data will be collected and the logger restarted. Besides monitoring of water temperature, the datalogger will record the timing of freezing and melting in the pond.

In August 1995, the pond was about 20 cm deep but the terrestrial vegetation indicates water depth to be somewhat larger during the snowmelt season. However, due to the surrounding topography, the water depth will probably not exceed 40 cm. It is not known, if the pond may dry out completely during warm and dry summers, but observations during the summer of 1995 (where ablation of snow was extraordinary) indicate this to be a rare event.

Fig. 4.2.17 presents bottom water temperature recordings during August 1995, using a sampling rate of 20 min. The daily variation is evident, with maximum water temperatures of about 16°C during sunny days.

During nights, the bottom water temperature decreases to about 4°C, representing the non-saline water density maximum, at which point further density induced circulation is brought to a halt and colder surface water stays at the surface. The night of 23 August, however, represents a deviation from this rule. This is due to strong winds during this night, with a resulting wind induced water circulation of cold surface water towards the pond bottom.

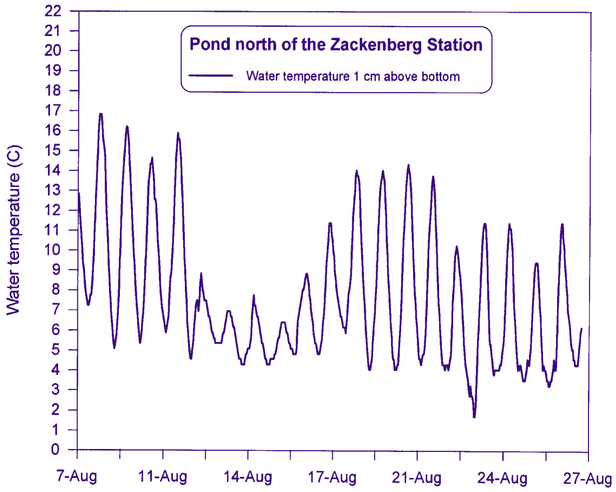


Fig. 4.2.17.

4.2.18. General observations

Hanne H. Christiansen, Ole Humlum & Hans Meltofte

1995 was a year of early snow and ice melt in the Zackenberg area, as it seems to have been in the rest of Greenland and in Iceland. According to the journal in the old Zackenberg trapping station, Zackenbergelven was running already in late May, stressing that snowmelt must have started early this year. Snowpatches were clearly smaller in size than in 1992, which also shows snowmelt to have been quicker and larger than in 1992. These conditions presumably also influenced the thickness of the active layer. It was thicker in 1995 than was found in 1992, must surely as a consequence of either an early snowmelt or that the snow cover in general had been thinner than normal at least during the late spring season.

The fjord ice in Young Sund broke up on 11-12 July, which is quite early. At this time (during our flight on 13 July) all the outer parts of the fjords between Scoresby Sund and Young Sund were covered with unbroken ice. During the rest of the summer, very little ice were present in Young Sund most of the time. The central parts of Store Sø were largely ice covered on 18 July, but only 10% remained on 23 July, and on 29 July it was totally ice free. Some of the ponds just north and south of the airstrip were totally or partly dried up by 12 August, when a period of rainy days started.

View towards the north of the core study area with the present delta of Zackenbergelven in the center. The white shelters are visible at the station site adjacent to the easternmost river bend.
Photo: Hauge Andersson

4.3. 'BioBasis', the biotic programme

Hans Meltofte

The biotic parameters of the monitoring programme, called BioBasis, have been selected to represent a wide range of trophic levels in the local High Arctic ecosystem. At the same time it has been necessary to restrict the monitoring to parameters relatively simple to record allowing the programme to be conducted by 1-2 scientific staff members during the summer season.

4.3.1. Vegetation

The general floristics of Zackenbergdalen and a number of other sites in the region was examined in 1991, 1992 and 1994 (Andersson *et al.* 1991, Fredskild *et al.* 1992, 1995, Fredskild & Bay 1993).

Six main plant communities and a total of 149 vascular plant species were recorded at Zackenberg. This total is significantly more than at any other site studied in High Arctic Greenland north of 74°N.

4.3.1.1. ITEX reproductive phenology

Eighteen study plots were established during late July and August (see also next section). The plots range from early to late snow free environments, and the ratio of flower buds : flowers : senescent flowers : flower heads with exposed seeds (in some species) are now being recorded for *Dryas octopetala* (6 plots), *Salix arctica* (4), *Cassiope tetragona* (4), *Papaver radicatum* (4) and *Silene acaulis* (1) on a weekly basis during the summer season (1 June - 31 August) following the ITEX protocols and standards.

Furthermore, a number of *Saxifraga oppositifolia* plots will be established in 1996. After establishing the plots, the monitoring procedure was tested during the remaining part of the 1995 season.

4.3.1.2. ITEX quantitative flowering

For each plot (see section 4.3.1.1.), the total number of flower buds, flowers, senescent flowers and seed stands was recorded shortly after the establishment of the plot. In Table 4.3.1.2. the totals are presented together with the dimension of each plot.

Table 4.3.1.2. Dimensions and total number of flower buds, flowers, senescent flowers and seed stands of Dryas integrifolia, Salix arctica, Cassiope tetragona, Papaver radicatum *and* Silene acaulis *in 18 ITEX plots in 1995.*

Plot no.	Area (m^2)	# flowers etc. (date)
Dryas 1	3 (1x3)	631 (28.07)
Dryas 2	60 (6x10)	554 (28.07)
Dryas 3	2 (1x2)	603 (16.08)
Dryas 4	4 (2x2)	281 (27.07)
Dryas 5	3 (1x3)	335 (22.07)
Dryas 6 [1]	91 (7x13)	809 (27.07)
Salix 1	60 (6x10)	no ♂♂, too late in season
		520 ♀♀ (28.07)
Salix 2	300 (15x20)	no ♂♂, too late in season
		617 ♀♀ (14.08)
Salix 3	36 (6x6)	239 ♂♂ (23.07)
		253 ♀♀ (23.07)
Salix 4	150 (10x15)	no ♂♂, too late in season
		1073 ♀♀ (16.08)
Cassiope 1	2 (1x2)	1321 (23.07)
Cassiope 2	3 (1x3)	no records, too late in season
Cassiope 3	2 (1x2)	256 (22.07)
Cassiope 4	3 (1x3)	456 (27.07)
Papaver 1	105 (7x15)	302 (23.07)
Papaver 2	150 (10x15)	814 (20.08)
Papaver 3	90 (9x10)	334 (27.07)
Papaver 4 [1]	91 (7x13)	196 (27.07)
Silene 1	1 (1x1)	466 (23.07)

[1)] plots *Dryas* 1 and *Papaver* 4 are identical

Arctic poppy Papaver radicatum *in full bloom*

Photo: Henning Thing

4.3.1.3. The ZERO-line

The botanical ZERO-line (see sections 2.2.3.1 and 2.3.1.1) was not checked in 1995. It is planned to be checked at about five years intervals, *i.e.* first check in 1998. Unfortunately, peg # -37 had to be removed due to the intercept of the line by the expanded runway.

4.3.1.4. 400 m² vegetational study plots

The 400 m² vegetational study plots (see sections 2.2.3.2 and 2.3.1.2) were not checked in 1995. They are planned to be checked at about five years intervals, *i.e.* first check in 1998.

4.3.1.5. Snow melt in 4.3.1.4. plots

At the start of the 1995 field season, on 13 July, all snow had disappeared from the study plots.

4.3.1.6. Selected regional vegetation parameters

The monitoring of selected regional vegetation parameters awaits an aerial photo mapping and ground truthing of vegetation types in the study area. More large scale parameters are planned to be monitored by help of satellite images.

4.3.1.7. Cryptogam study plots

The cryptogam study plots (see section 2.3.1.3) were not checked in 1995. They are planned to be checked at about five years intervals, *i.e.* first check in 1998.

Arthropods are located by hand searching a dry, south-exposed biotope dominated by sedges.

Photo: Henning Thing

4.3.2. Arthropods

Jens Böcher

In general, Greenland's terrestrial arthropod fauna is insufficiently known, and the arthropod fauna of the Zackenberg area is only in the initial stage of exploration. Basic faunistic studies took place in 1991 (Andersson *et al.* 1991) and 1995.

This year, the arthropod monitoring procedure was tested during late July and August, and appropriate sampling sites were selected. The arthropod monitoring is based on a simple methodology, so that it can be performed by persons without an entomological background.

Pitfall traps are emptied at frequent intervals. Most of the arthropods collected with this methods are adapted to a life in the vegetation. Note the dug-down plastic cup in front of the plastic bottle.

Photo: Henning Thing

4.3.2.1. Pitfall traps

Pitfall traps collect mainly arthropods that are active on the ground surface. This year we used plastic cups (diameter 9 cm, height 6 cm) dug into the soil so that the upper rim was level with the soil surface.

In the bottom they had water containing a little detergent and formaldehyde as a killing agent / preservative.

Pitfall trap collections were carried out on a preliminary basis in 1995, in heath, fen and snowbed communities. This involved stratified pitfall collection in five typical plant communities: *Arctagrostis / Eriophorum* fen, *Salix arctica* snow bed, *Cassiope* heath, mixed heath and *Dryas* heath (see section 5.3 for results).

4.3.2.2. Water trays

Water trays sample flying insects. We used yellow trays placed on the soil surface, and like the pitfall traps they held water, detergent and formaldehyde. Insects are attracted by the yellow colour in combination with the glittering water surface.

In 1995, water trays were tested in two places (fen and mixed heath). As expected, they caught large quantities of *Diptera* (flies), which have not yet been identified to species.

4.3.2.3. Window traps

In addition to water traps, flying insects are also planned to be caught by window traps in which the insects hit a transparent wall of perspex and fall down to be killed and preserved in water containing detergent and formaldehyde. This kind of trap was not included in the 1995 preliminary programme, but has been used successfully in other Arctic areas.

A type of window trap floating on the water surface of ponds and lakes and therefore especially catching insects emerging from the water seems to be especially suited for the purposes at Zackenberg and will probably be chosen.

4.3.2.4. Line transect

In order to obtain phenological data on the insects in a simple way, a line transect registration is planned. During optimal weather conditions (*i.e.* clear sun, weak wind) in the middle of the day (10 a.m. - 4 p.m.) the observer walks slowly along a pre-selected route about 2 km in length through the study area west of Zackenbergelven.

All observations of certain given categories of arthropods are recorded within a sector measuring c. 5 m on each side of the observer. The transect was staked out in 1995 so that it traverses a number of different and, for the area, characteristic plant communities. The line transect should be walked once a week during the period 1 June to 15 August.

4.3.2.5. Predation on *Dryas* spp. by *Sympistris zetterstedtii*

In connection with ITEX routine observations of flowers (see sections 4.3.1.1 & 4.3.1.2), predation by caterpillars of the noctuid moth *Sympistris zetterstedtii* on the reproductive organs of *Dryas* flowers will be recorded. In some years, the attacks of the caterpillars result in a high percentage of totally destroyed flowers, whereas in other years almost no flowers are affected. In 1995, no such predation was recorded.

The lowland area on the west side of Zackenbergelven. This is where the arthropod line transect is located.
Photo: Jens Böcher

4.3.2.6. General phenological observations

Large quantities of mosquitoes were active during July, but they had largely disappeared by 1 August. The latest bumble -bee *Bombus polaris* was observed on 24 August, and the latest butterfly *Colias hecla* on 27 August.

Researcher harassed by mosquitoes.
Photo: Hanne H. Christiansen

4.3.3. Birds

Hans Meltofte

Ornithological observations were made during the entire field season from 13 July until 30 August. During the first ten days, Zackenbergdalen was surveyed especially for breeding birds while data on breeding phenology were gathered during all of July and early August. From 1 August and during the remainder of the field season, systematic waterbird counts were performed every third day in the Zackenbergelven delta; the main objective was to monitor wader breeding success (see section 4.3.3.3). A reconnaissance to the upper part of the Store Sødal valley was made during 29-31 July (see section 4.3.3.6).

A comprehensive account of the avifauna of Wollaston Forland is given by Rosenberg *et al.* (1970) and a few supplementary notes by Marris & Webbe (1969) and Meltofte (1972).

Based on the experiences from this summer, a permanent breeding bird census area of 20 km2 was delineated in Zackenbergdalen. It includes the major part of the valley floor together with the adjacent slopes of Aucellabjerg up to the 600 m contour (Fig. 2.2.3.1). A list of bird species breeding or holding territories within this area together with rough estimates on abundance are presented in Table 4.3.3.1.

4.3.3.2. Reproductive phenology in waders

As the field team arrived at the time when most wader eggs hatch (see Meltofte 1985) data on breeding phenology derive mainly from measurements of *pulli* and observations of newly fledged juveniles, *i.e.* with downy head and neck and still accompanied by an adult. The data are presented in Table 4.3.3.2. and they are in good accordance with other data from High Arctic Greenland (Meltofte 1985).

Adult male sanderling Calidris alba *brooding its chicks.* *Photo: Ko de Korte*

4.3.3.1. Breeding populations

The arrival by the field team on 13 July was too late for a proper breeding bird census. By that date most failed breeders and territorial non-breeders have left their territories, and early hatched broods have started to roam the area. Surveys revealed that good populations of several wader species breed in Zackenbergdalen and that a number of other bird species breed there as well.

4.3.3.3. Breeding success in waders

This summer was a good breeding season for waders Charadrii at Zackenberg. We arrived too late to record hatching success, and fledging success was experimentally recorded by counting juvenile waders in the Zackenbergelven delta every third day during August. By repeating such counts every year, an index of wader reproduction can possibly be produced. Cumulative numbers of juveniles recorded during these counts are presented in Table 4.3.3.3. As it appears, red knots did not utilise this habitat to any noticeable extent.

Table 4.3.3.1. List of birds breeding or holding territories in the Zackenberg bird census area together with crude estimates of abundance.

Species	**Abundance**
Red-throated diver *Gavia stellata*	1 pair
Kong eider *Somateria spectabilis*	? (1 ♀)
Long-tailed duck *Clangula hyemalis*	> 2 pairs
Rock ptarmigan *Lagopus mutus*	? (a few seen)
Great ringed plover *Charadrius hiaticula*	> 30 pairs
Red knot *Calidris canutus*	> 10 pairs
Sanderling *Calidris alba*	> 15 pairs
Dunlin *Calidris alpina*	> 25 pairs
Ruddy turnstone *Arenaria interpres*	> 20 pairs
Red-necked phalarope *Phalaropus lobatus*	? (not seen)
Red phalarope *Phalaropus fulicarius*	? (not seen)
Long-tailed skua *Stercorarius longicaudus*	> 5 pairs
Northern wheatear *Oenanthe oenanthe*	> 1 pair ?
Snow bunting *Plectrophenax nivalis*	few in lowland

Table 4.3.3.2. Hatching dates of wader broods in Zackenbergdalen, 1995. For scientific names, see Table 4.3.3.1.

Species	**Mean date**	**Range**	**N**
Great ringed plover	18.0 July	–	1
Red knot	10.0 July	7-13 July	2
Sanderling	12.3 July	6-19 July	4
Dunlin	14.4 July	9-25 July	7
Ruddy turnstone	9.1 July	4-14 July	7

Table 4.3.3.3. Cumulative numbers of juvenile waders recorded during counts at three days intervals during 1 - 28 August in the combined former and present Zackenberg river deltas. All ten counts were performed at low tide. 'Minimum' numbers denote positively identified juveniles while 'maximum' numbers include non-aged individuals distributed to age classes proportionately to the identified sample of the respective counts. A further 78 sanderlings / dunlins are not included. For scientific names, see Table 4.3.3.1.

Species	**N**
Great ringed plover	87 - 90
Red knot	3
Sanderling	192 - 225
Dunlin	226 - 256
Ruddy turnstone	57 - 58

4.3.3.4. Reproductive phenology and success in long-tailed skuas

In agreement with the scarcity of collared lemmings (see section 5.4.1), 1995 appeared largely to be a non-breeding year of long-tailed skuas, *Stercorarius longicaudus*, at Zackenberg. One apparently lonely half grown *pullus* was encountered on 18 July, and on 5 August a newly fledged juvenile appeared.

A dunlin pull., caught by hand, has its beak and tarsal lengths measured in order to age the bird and subsequently calculate the approximate hatching date.

Photo: Henrik Lassen

4.3.3.5. Breeding barnacle geese

At least seven pairs of barnacle geese *Branta leucopsis* brought their broods to Zackenbergdalen. The broods numbered 1, 1, 2, 2, 2, 3 and 3 goslings, respectively, when they were recorded at different stages of their fledging period. Initially, the broods were observed at the ponds and at the river in the upper part of the valley, but eventually all of them ended up on Lomsø near the coast (see map Fig.1.3.2).

These movements within the study area may to a high extent have been provoked by our traffic in the area, as the geese were exceedingly shy. At several occasions family parties were seen to flee out on the river and escape downstream. The actual breeding site for the colony is unknown. Rosenberg *et al.* (1970) found no breeding barnacle geese near Zackenberg in 1964.

4.3.3.6. Line transect

A proper transect route through the valleys north and west of Zackenberg has not yet been established. However, on 29-31 July a 50 km survey trip was made by Henrik Lassen and Hans Meltofte along the southern slopes of Store Sødal almost to the easternmost lake in the upper part of the valley. At least partly due to the late time of the trip, only few 'breeding' birds were encountered: great ringed plover *Charadrius hiaticula* 10, sanderling *Calidris alba* 2, dunlin *Calidris alpina* 2, ruddy turnstone *Arenaria interpres* 1, Arctic tern *Sterna paradisaea* >3 in the delta in the western end of Store Sø, glaucous gull *Larus hyperboreus* 2 pairs along the river east of Store Sø and one at the western delta, Arctic redpoll *Carduelis hornemanni* one family group of 7, snow bunting *Plectrophenax nivalis* about 15, mainly juveniles, in 3-4 family groups.

During surveys north and west of Zackenberg the field team has to be self-contained.
Photo: Hanne H. Christiansen

4.3.3.7. Other observations

This section presents a condensed account of avifaunistic observations in 1995 in the study area other than those given in the previous sections, but including references to diverging information in earlier reports from the same area.

Red-throated diver *Gavia stellata*

A pair breeding in Lomsø (see section 4.3.3.1) had one newly hatched *pullus* on 18 August! Up to three pairs were present on lakes and ponds in Morænebakkerne in July. Up to six individuals were feeding on the fjord outside the Zackenbergelven delta in July and up to five in August. These birds were often seen passing north or south over the valley. Up to four divers were feeding on Store Sø 29-31 July.

Pink-footed Goose *Anser brachyrhynchus*

About 230 non-breeding (immature) pink-feet moulted around the Zackenbergelven delta, 70 at the outlet of Grænseelv and about 250 around the peninsula to the east. Twenty moulted at Store Sø, and another 20 at the easternmost lake in the upper part of Store Sødal. The last (5) flying birds with old primaries were seen on 13 July and the first (3) with new primaries were flying again on 29 July. Still, on 10 August, 25 birds were apparently not yet able to fly. On 31 July, a wolf took a flightless pink-footed goose at Grænseelv. From 3 August more and more flying birds moved inland to feed in the fens. Southward migration was noted from 22 August, and during the following days up to 800-900 pink-feet were feeding in the fens in Zackenbergdalen. The geese were extremely shy and they were easily disturbed by aeroplanes, helicopters and our traffic in the valley both during their moulting period in July and during August. No indication of breeding in the study area was found. In 1964, 8-10 pairs were found in the Zackenberg area, and six broods were observed (Rosenberg *et al.* 1970).

Barnacle goose *Branta leucopsis*

Besides breeding birds (see section 4.3.3.5), flocks of moulting non-breeders (immatures) were found along the coast and at the lakes in Morænebakkerne. In total, these flocks numbered between 150 and 200 individuals. The first (20) flying birds with new primaries were seen on 26 July. A total of 114 moulting barnacle geese were encountered at the river and at Store Sø in eastern Store Sødal as well as 20 birds in the eastern part of upper Store Sødal. In the latter area, 232 barnacle geese including 6 pairs with goslings were counted during an aerial survey in 1988 (Bay & Boertmann 1988).

Common eider *Somateria mollissima*

A colony of more than 1,000 pairs of eiders has since many years been established around the tethered huskies at Daneborg (Meltofte 1978). Besides these, smaller numbers breed on the nearby Sandøen. Some of the females from these colonies apparently bring their newly hatched young to the shallow coastal waters off Zackenbergdalen. A few (*i.e.* about 10) non-breeding females were already present in mid July, and on 19 July the first two females with small young were seen at the Zackenbergelven delta. At least 11 females with at least 34 *pulli* were recorded around the eastern peninsula on 24 July, and a maximum of 12 females with about 65 *pulli* besides four 'lone' females were counted at the Zackenbergelven delta in August. No males were seen.

King eider *Somateria spectabilis*

One female was seen a few times in July and August on the fjord off the Zackenbergelven delta, and one male in eclipse plumage was found at the same place on 28 August.

Long-tailed duck *Clangula hyemalis*

One fox-predated nest was found on 16 July, and one female had 6-8 small *pulli* on Lomsø 30 July (see section 4.3.3.1). Furthermore, single females or a few birds together were seen a few times in July and August on ponds and lakes in Zackenbergdalen. 12-14 males moulted on the fjord off the Zackenbergelven delta and a further c. 25 around the peninsula to the east.

Gyr falcon *Falco rusticolus*

An adult gyr falcon was recorded five times in Zackenbergdalen between 27 July and 16 August, three of the times carrying a prey to a roost on the east slope of the Zackenberg mountain. On 16 August, a calling gyr falcon was heard from the east facing cliff of Dombjerg in Lindemansdalen.

Rock ptarmigan *Lagopus mutus*

A pair was seen on Ulvehøj on 24 July, a female at the same place on 7 August and furthermore a female with 5 large *pulli* here on 9 August.

Great ringed plover *Charadrius hiaticula*

Post-breeding adults were observed inland from 28 July and during the waterbird counts in the Zackenbergelven delta up to 51 adults were recorded (on 4 August). The peak counts of juveniles were 27 on 16 August and 28 on 26 August.

Red knot *Calidris canutus*

The knots disappeared from the Zackenberg area immediately upon fledging of the young. The last family group was seen on 24 July whereupon only one juvenile was seen in the Zackenbergelven delta on 22 August and two on 28 August.

Sanderling *Calidris alba*

Post-breeding flocks of up to 28 adults were recorded in the Zackenbergelven delta in mid July. During the waterbird counts here, up to at least 24 adults were recorded in early August while the peak count of juveniles was 69 on 28 August.

Dunlin *Calidris alpina*

Post-breeding flocks of adult dunlins built up in the Zackenbergelven delta during late July and a peak of about 220 was recorded here on 1 August. Peak counts of juveniles were 54 on 10 and 28 August and 64 on 16 August.

Ruddy turnstone *Arenaria interpres*

Flocks of up to 10 post-breeding adults were seen in mid July and independent juveniles occurred from 27 July. Few adults were recorded in the Zackenbergelven delta, and the peak count of juveniles here was 22 on 28 August.

Long-tailed skua *Stercorarius longicaudus*

During July and early August groups of up to eight adults were displaying in Zackenbergdalen. On 15 July, one at least two years old immature was recorded. Departure of the adult long-tailed skuas started in the last days of July, and from 11 August apparently only one successful pair remained with their single young until last seen on 21 August (see section 4.3.3.4).

Sanderling in a wet sedge habitat.
Photo: Henrik Lassen

Glaucous gull *Larus hyperboreus*

Four to eight adults (mostly in pairs) were recorded in the Zackenbergelven delta during all of August, and single individuals or pairs flew up and down the river daily during our entire stay. The first and only juveniles recorded were two on 28 August.

Arctic tern *Sterna paradisaea*

Up to 200 were seen feeding and roosting on ice floes on the fjord off Zackenberg during August. The nearest breeding colony is on Sandøen, 25 km to the SSE (*e.g.* Meltofte 1972).

Northern wheatear O*enanthe oenanthe*

Single juveniles were seen in Zackenbergdalen four times during 11-28 August. According to the literature, one or a few pairs breed regularly at Zackenberg.

Common raven *Corvus corax*

A family group of two adults and two juveniles were present in Zackenbergdalen already when the field team arrived on 13 July, and they were seen almost daily during our entire stay.

Arctic redpoll *Carduelis hornemanni*

Single individuals flew over the station on 25 and 29 August, and on 25 August a group of five were seen on Aucellabjerg, 600 m a.s.l.

Snow bunting *Plectrophenax nivalis*

In July, family groups and post-breeding adults were seen several times, and from 26 July they dispersed into the lowland of Zackenbergdalen. On 25 August, 300 were encountered on Aucellabjerg, 400-600 m a.s.l.

Moulting barnacle geese concentrate at habitats adjacent to lakes. The bird droppings and lost feathers fertilise the vegetation significantly.

Photo: Hans Meltofte

4.3.4. Mammals

Thomas Bjørneboe Berg

Observations of mammals were made by Thomas B. Berg and Bo Bendix during 13 July - 18 August and by Hans Meltofte during the entire field season 13 July - 30 August. Most attention was given to establishment of the monitoring of the collared lemming population. Two monitoring areas were established and all winter nests from previous seasons were removed. Furthermore, trapping of lemmings, registration of muskox carcasses, fox dens and daily observations of mammalian wildlife were made.

Winter nest of collared lemming. This nest was built and used during the 1994-95 winter.

Photo: Thomas B. Berg

4.3.4.1. Winter nests of collared lemming

Lemmings are common rodents in Arctic ecosystems and characterised by extensive, regular population cycles of 4-5 years duration. The collared lemming *Dicrostonyx groenlandicus* is the only true rodent in Greenland. The species' distribution in Greenland is restricted to the High Arctic part where it is a key organism in the relatively simple terrestrial ecosystem.

Population cycles occur simultaneously over extensive areas but may be asynchronous between geographically separated subpopulations. The most common mammalian and avian predators, *i.e.* ermine *Mustela erminea*, Arctic fox *Alopex lagopus*, long-tailed skua *Stercorarius longicaudus* and snowy owl *Nyctea scandiaca*, fluctuate with the lemming cycle.

Only one main area within Zackenbergdalen appears to be relevant for lemming monitoring (Fig. 2.2.3.1). This area covers about 250 ha with a variety of habitats ranging from *Dryas*, *Cassiope* or *Salix* dominated plant communities over wet fens to snow beds.

During the 1995 field season the monitoring areas were surveyed in detail with the primary objective of mapping every single winter nest. The 250 ha was covered by walking along transects with 10 m intervals. The following parameters were sampled from each nest: diameter of the nest (indexed by 5 cm intervals), sign of predation by fox or ermine, and UTM co-ordinates.

Foxes and ermines will often defecate in the nest or next to it. In addition, the ermine will often use lemming fur to insulate the nest before using it for its own purpose. (See also section 5.4 for preliminary results.)

A two month old collared lemming in the greyish-brown summer coat.

Photo: Thomas B. Berg

1,109 winter nests were found. They obviously differed in age and were consequently divided into two age classes: age class I < 2 years old, and age class II > 2 years old. Age class I was characterised by a light yellow to light grey colour, a fresh smell of hey and a fluffy appearance, while age class II could be anything from a light grey to a dark rotten brown, clearly more suppressed or flat and without fresh smell. 279 nests were of age class I and 830 were age class II nests. Only 5 and 11 age class I nests showed sign of predation by ermine and fox, respectively (see Table 5.4.1.).

Nests showed a lumpy dispersion although nests were found in all habitats. As lemmings prefer areas with a stable and long lasting snow cover for winter nests, the main nest concentrations were seen in two core areas. In years with a high lemming population these areas are probably fully occupied and lemmings will have to disperse into adjacent areas.

Following examination, the nests were discarded to prevent double count. Hence, nests recorded within this study area in future summers will be from the previous winter and will therefore be indicative of the winter population.

A muskox family group feeding in the core study area of Zackenbergdalen.

Photo: Hans Meltofte

4.3.4.2. Muskox occurrence

During the first part of the field season, muskoxen *Ovibos moschatus* in Zackenbergdalen were censused only occasionally but during 11-30 August they were monitored from a fixed point (*i.e.* the roof of the Sirius hut) by scanning the whole valley and the adjacent mountain slopes with a spotting scope once daily. The maximum count in one scan was 136 individuals on 25 August. The lower south-west facing slopes of Aucellabjerg (*i.e.* Oksebakkerne) and the fens just below (*i.e.* Rylekærene) were use most intensively by the muskoxen.

Sodium-dominated salt encrustation on the soil surface.

Photo: Henning Thing

Only in the late part of the season, herds were feeding around the Zackenberg station. It is reasonable to assume that the limited use of the area around the station was caused, at least partly, by the human activities associated with the station. In other parts of Zackenbergdalen muskoxen seemed largely undisturbed by our presence. Air traffic by helicopter and Twin Otters had only a short term impact.

In several places along the river banks the soil surface was rich in mineral encrustations (*e.g.* sodium salts) and numerous muskox tracks at these sites revealed a significant use as salt licks.

An unscavenged carcass of a stillborn muskox calf. Photo: Henning Thing

4.3.4.3. Muskox reproduction

The age composition of muskox groups was recorded whenever possible. In total, 721 individuals were aged in the field (Table 4.3.4.3). It appears that the ratio of 1st calendar year calves (*i.e.* the 1995 cohort) to the other age classes was considerably higher than the ratio of 2nd calendar year calves (i.e. the 1994 cohort surviving until 1995) to the other age classes. Considering the lower than average snow cover in the 1994-95 winter (Sirius pers. comm.) the calf production of 1994 seems to have also been initially lower than the 1995 production.

Table 4.3.4.3. Age distribution of 721 muskoxen recorded in Zackenbergdalen and Store Sødal during July-August 1995. 'Adults' are at least two years old, '2C' denotes second calendar year individuals while '1C' denotes calves of the year.

Adults	2 C	1 C
458	57	206
63%	8%	29%

4.3.4.4. Muskox carcasses

The carcass of a stillborn calf from 1995 was found on 16 August at Aucellaelv. The carcass appeared to be untouched by scavengers (see photo). Apparently, the only other fresh carcass was that of a mature bull below the east slope of Zackenberg.

A registration of muskox carcasses in the entire study area was initiated and 10 skulls were measured. One molar, one incisor and one femur were collected for individual age and size determination.

An Arctic fox den complex with a total of 33 entrances. Photo: Hans Meltofte

4.3.4.5. Arctic fox dens

Two Arctic fox *Alopex lagopus* den complexes were found within the monitoring area (Fig. 2.2.3.1): one at the west side of Zackenbergelven with 33 entrances and one at Kærelv with 44 entrances. At the one at Zackenbergelven at least four entrances were in use. There was no sign of reproduction at either den site. It is likely that additional fox dens will be found in the future, as the area contains several suitable places.

4.3.4.6. Line transect

A 75 km line transect for bird and mammal monitoring going from the field station north through Lindemansdalen, south through Slettedalen, west to the head of upper Store Sødal and eastwards through Store Sødal back to the field station has been planned.

This year, a survey was made during 29-31 July through most of Store Sødal (see section 4.3.3.6). Muskox groups of 24 and 10 besides one lone individual were recorded in the valley. Tracks of Arctic wolf and Arctic fox were seen and only four lemming winter nests were found.

View towards the west through the 13 km long Store Sødal. The local ice cap of A. P. Olsen Land is visible as the white skyline some 40 km away.

Photo: Henning Thing

4.3.4.7. Other observations

Arctic wolf *Canis lupus arcticus*

Wolf tracks were present along Zackenbergelven already when the field team arrived on 13 July. On 21 July a single adult male appeared at the station. On 31 July the wolf (presumably the same individual) came trotting along Kærelv toward its outlet. A visit was made to an old muskox carcass where the wolf urinated and defecated. It continued toward the coast hidden by the river banks. When reaching the small estuary, the wolf attacked a flock of 40 moulting (*i.e.* flightless) pink-footed geese. The attack ended successfully for the wolf as it grabbed a goose and stood exhausted with sea water reaching up to the belly. Apparently, the whole of the goose was eaten leaving only scattered feathers on the ground. Fresh wolf tracks in the sand around tents and shelters at the station and in the mud along the riverbed were found several times during the remainder of the summer.

Arctic fox *Alopex lagopus*

Probably, only two adult foxes were seen during our stay, one blue phase (five observations) and one white phase (two observations), both hunting and foraging mainly near the coast. Several lemming summer burrows had been dug out and some winter nests had been emptied by foxes, as showed by faeces placed within or beside the nests (see section 5.4).

Arctic hare *Lepus arcticus*

Three separate observations of two individuals were made on the east facing slopes of the Zackenberg mountain at about 900 m a.s.l. on 26 July (one subadult in white fur and one adult), at 400 m a.s.l. on 21 August and at 80 m a.s.l. on 22 August.

Arctic fox (white colour phase) feeding on part of a muskox carcass.

Photo: Henning Thing

Ermine *Mustela erminea*

No ermines were observed during the field season but some old and recent lemming winter nests had been taken over by ermine. (See also section 5.4.)

The Arctic hare is often easily approached.

Photo: Henning Thing

5. Research projects in 1995

5.1. Physical geography: past and present processes, interactions and feedbacks

Ole Humlum & Hanne H. Christiansen

5.1.1. Context of research

An important task in environmental research is to understand processes in the physical and biological systems and how processes are coupled through interactions within and between the four main 'spheres' of the systems: the geo-, hydro-, bio- and atmosphere.

The modern concept of systems downplays the statistical notion of their components as stable units; instead it stresses the entirely different notion of dynamic physical systems. This implies that the state of the system considered tends to always be in motion, in the sense that it is always trying to adjust itself toward an equilibrium state that it may never fully achieve before the equilibrium state itself moves on to a new state.

The very conditions that give the Arctic regions their distinctive character, geomorphological or biological, are controlled by climate, and are subject to change when the climate changes. Due to albedo-induced feedback effects, the variability of climate is greater in polar areas than elsewhere. It is therefore the Arctic regions that will likely experience the greatest environmental change from future climatic variations, and it is the Arctic which is itself most vulnerable to any climate change.

The task facing scientists trying to account for environmental variability, past and present, or to predict future natural or man-induced changes, must begin with the formulation of a suitable, quantitative and comprehensive 'model' of the behaviour of the overall environmental system.

From a physical geographical point-of-view, climate-induced variations in snow cover and temperature generate significant changes in the Arctic landscapes. These landscapes should be considered as consisting of a number of terrain elements currently adjusting to present climate, and a number of

The east bank of the early Holocene Zackenbergelven delta. This 20 m high cliff is a natural archive holding a wealth of information on local climate and landscape changes over the past 10,000 years.

Photo: Henning Thing

fossil features, produced under past climatic conditions. Thereby they represent archives on environmental variations, past and present.

Urgent interest is now being directed towards an improved understanding of global climate variations, past and present, and the North Atlantic area is emerging as a key area in this context. Attempts have been made to correlate atmospheric (*e.g.* Greenland ice core data) and North Atlantic marine records. The overall interpretation of these records is, however, still incomplete as long as they cannot be compared to terrestrial records around the North Atlantic.

5.1.2. Structure and goals of research

The physical geography research at Zackenberg is pursued mainly by researchers from the Institute of Geography, University of Copenhagen, funded by a grant from the Danish Natural Science Council and shared with scientists from the Department of Plant Ecology, University of Copenhagen.

The main research by the Institute of Geography focuses on both small scale physical and chemical processes and their consequences at the meso-scale landscape and large scale regional level. Special emphasis will be on past and present climatic variations and landscape evolution.

The project will study quantitatively the relationship between climate, sea level and landscape dynamics, concerning coastal-, lacustrine-, eolian-, fluvial-, slope-, permafrost-, nival- and glacier-phenomena, both past and present.

The approach will be both historical and 'real time' using different palaeo-environmental archives and dating techniques for the historical part as well as extensive field instrumentation and sampling, remote sensing and other field survey techniques.

Field instrumentation, general methodology and data analysis will be standardised to the greatest possible extent. This is given highest priority as a drawback of many former process orientated landscape studies appears to be the adoption of different approaches and techniques.

This to some extent precludes or complicates detailed cross comparisons and future replication for comparative studies. Data storage, data analysis and documentation will exploit the potentials of Geographical Information Systems.

The project will:

– Map gross morphology, topography, soil type and specific landforms in the respective study areas in order to investigate Late Weichselian and Holocene geomorphic activity.

– Investigate current meteorological parameters within the study sites, such as temperature, precipitation, humidity and wind.

– Investigate specific current meteorological fluxes such as ground temperatures and the flux of CO_2.

– Determine current sediment flux, sediment budgets and dynamics for defined catchment areas.

– Relate current geomorphic process rate and frequencies to present climate conditions logged at the study sites.

– Compare current process activity with estimates for the same processes during different parts of the Late Weichselian and Holocene period using palaeo-environmental records.

– From knowledge on past process activity attempt reconstructions of past climate characteristics such as temperature, wind direction and precipitation.

– Establish project databases, geographical information systems (GIS), for the storage, retrieval and analysis of project data, such as elevation, slope angle, vegetative cover, etc. - and in order to facilitate potential future utilisation of the data material.

Fig.5.1.3. Avalanche track and cone at the southeast side of Zackenberg mountain. An Inuit sod house ruin visible in the foreground.

Photo: Ole Humlum

5.1.3. Current status of research

Preliminary investigations were carried out in August 1995, primarily on the overall geomorphology and landscape evolution. More specific investigations were, however, also undertaken such as mapping of an avalanche cone at the south-east corner of the Zackenberg mountain (Fig. 5.1.3). This terrain feature will be briefly described below.

The central part of this cone is clearly affected by frequent snow avalanche activity, as shown by the lack of vegetation and numerous stones and boulders delicately balanced on top of each other. Outside this area with modern avalanche activity, an inactive part of the cone is found. Vegetation is prominent and balanced boulders are sparse. At the coast, but still on the inactive part of the avalanche cone, the remnants of an Inuit sod house are found.

The magnificent view of a High Arctic landscape from the summit of the 1,372 m high Zackenberg mountain. Below is the valley Store Sødal. In the background are glaciers extending from the local ice cap of A. P. Olsen Land. Photo: Henrik Lassen

The upper section of the avalanche track has the form of a large, open depression, cut into the shoulder of the Zacken-berg mountain and exposed towards the south-east. Snow tends to accumulate within this depression with northerly winds.

Lichenometric observations from boulders lying on the now inactive part of the cone indicate that it may be at least 200 years since these boulders were deposited by avalanche activity, and lichens on stones used in the Inuit building indicate that this was constructed about 150 years ago. Also at this time, the outer part of the greater avalanche cone must have been a safe place to live, considering snow avalanches.

The outer zone of the avalanche cone was probably influenced by snow avalanche activity during the Little Ice Age, and the preliminary results indicate this activity to have decreased around 1800 A.D. The greater avalanche activity may have been brought about by increased precipitation (snow), stronger winter winds, or by a change of the dominant wind direction.

Detailed study of nival sediments, nivation forms and the rate of evolution of nivation forms were also performed this summer.

5.2. Trace gas exchange study

Torben Røjle Christensen

Growing evidence from climate and global biogeochemical studies indicates that the water and carbon cycles in the Arctic region strongly influence the global climate. In particular, the exchange of greenhouse gases (CO_2 and CH_4) are important, both for the dynamics of the natural climate and for feedback effects following possible man-induced ‘greenhouse warming’. It is therefore vital to investigate the scale and sensitivity of the tundra ecosystem–atmosphere exchange of these gases in relation to climate.

With the objective of studying these processes a group of geographers and biologists from the University of Copenhagen has started an interdisciplinary gas flux study in the Zackenberg area involving ground-based chambers and micro-meteorological measurements. The ground-based gas flux work will be closely linked to a remote sensing effort in order to up-scale the soil–atmosphere gas exchange to landscape level. The project is funded under the Danish Research Councils’ Polar Programme.

The aim of the preliminary studies in 1995 at Zackenberg was to get a first impression of the scale of gas fluxes in the valley and subsequently to identify a suitable area for a major gas flux study in 1996-1997. Along with gas flux measurements, a number of soil samples were taken for analyses of carbon and nutrient contents etc. At the time of writing (*i.e.* November 1995) only the gas flux data are available.

About 80 independent gas flux measurements were carried out with emphasis on the wet tundra habitats. The mean fluxes from different habitats in the area are presented in Fig. 5.2.1. The fluxes found in Rylekærene are comparable to data from many other northern wetlands as well as those obtained in a recent study of Siberian wet tundra habitats. Consistent consumption rates were found on the *Cassiope* heath and those are also similar to rates found in mesic tundra habitats in Siberia. The large global expanse of this vegetation type makes the consumption rates important to study.

Given the facts that Zackenbergdalen is a High Arctic habitat and that the tundra methane fluxes found here are comparable to 'equivalent' ecosystems significantly further south, the Zackenberg region offers an interesting setting for studying trace gas fluxes in relation to climate.

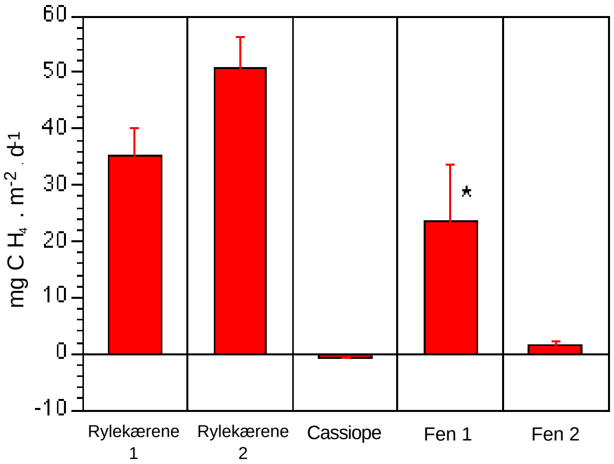


*Fig. 5.2.1. Summary of methane fluxes measured in Zackenbergdalen 12-17 August 1995. Error bars indicate standard error of mean in the observations (N = 6-10). * indicates exclusion of measurements disturbed heavily by ebullition (true diffusive emission is probably somewhat higher).*

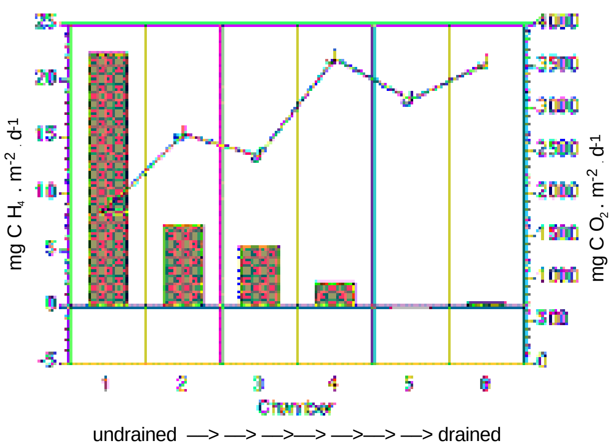


Fig. 5.2.2. The effect of thermokarst draining on wet tundra trace gas fluxes. The bars show methane (left ordinate) and the line carbon dioxide (right ordinate) fluxes along a transect from the undrained (chamber 1) to the drained part (chamber 6) of the fen.

The area also provides a possibility for studying how natural climatic changes may dramatically alter the trace gas emission patterns in a permafrost environment. An isolated fen, Tørvekæret, in the valley has been drained following a thermokarst erosion. Thermokarst erosion can have many different causes but here it seems most likely to be a climatically controlled process.

Fig. 5.2.2 shows how the methane emission drops along a gradient towards the drained parts of the fen. The total respiration (*i.e.* CO_2 production) of the soil increases correspondingly along the same gradient as one would expect when a larger part of an organic soil becomes aerated. This thermokarst erosion area therefore offers an excellent setting for studying the effect of water table position on trace gas fluxes in a High Arctic fen system.

Rylekærene appeared to be the most suitable area for the next two years of gas flux studies. With its relatively homogeneous fen vegetation and topography covering an area of about 15 ha, combined with the scale of gas fluxes shown in the preliminary work, it forms an interesting study object for micro-meteorological tower measurements in 1996-1997.

5.3. Arthropod faunistics

Jens Böcher

In addition to the preparations for the BioBasis monitoring activities (see section 4.3.2) two approaches to the arthropod faunistics of the Zackenberg area were tested in August 1995. Pitfall trap sampling was conducted in the highly diverse habitats around the old delta of Zackenbergelven and along an altitudinal gradient on the south-west slope of Aucellabjerg.

5.3.1. The old delta area

The old Zackenberg river delta at the coast about 1 km south of the station must be regarded a high priority area for biological research. This is due to the intricate mosaic of living conditions giving rise to a high diversity of plant communities created by the old river beds, shore ridges and small interjacent plateaus found from the present seashore up to an altitude of only a couple of metres.

In order to get an impression of whether the arthropod diversity is reflecting the diversity of vegetation, series of pitfall traps were placed in nine of the vegetation zones. The results show marked differences in the fauna composition concurrent with the floristic zonation (Table 5.3.1). Micro-arthropods (*i.e.* Collembola and Acarina = mites) make up a large fraction of the catch in all zones, highly variable, however, from site to site (please note, that flies and midges are not included in the tables). One large red species of mite, *Neomolgus littoralis*, and another species from the genus, *N. mutabilis*, belonging to the Bdellidae ('snout mites'), are especially abundant closest to the seashore. Surprising is the large number of the ichneumonid wasp, *Stenomacrus sp.*, probably a parasitoid on some moths (Lepidoptera), because it is difficult to understand what kind of prey it is hunting for in these biotopes and so late in the season. An association between the aphid *Myzus polaris* and *Dryas octopetala* appears to be evident from this study in spite of the fact that the aphid is generally regarded as associated with *Cerastium alpinum* (Ole Heie pers. comm.).

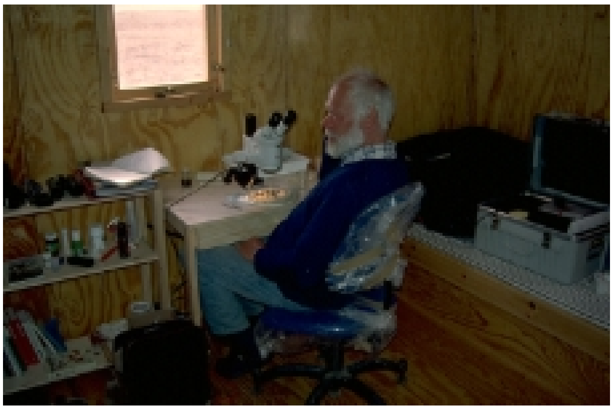
Table 5.3.1. The catch of selected taxa per 10 pitfall traps in six plant communities (decreasing altitude from 1 to 6) of the old Zackenberg river delta 15-22 August. Legend for number of specimens is: x = 11-20; xx = 21-50; xxx = 51-100. The plant communities are given below (some series from similar communities have been combined).

Plant community	1	2	3	4	5	6
# pitfalls	**10**	**10**	**10**	**23**	**16**	**10**
Gnypeta cavicollis[1]						1
Stenomacrus sp.[2]	xx	xx	xxx	7.4	8.8	5
Nysius groenl.[3]	10			0.4		6
Myzus polaris[4]	xxx	1	1	0.4	4.4	5
Pardosa sp.[5]	x	6		1.7	1.3	
Xysticus sp.[6]		8				
Dictyna sp.[7]	xx					
Erigone sp., *etc.*[8]	x		x	1.3	xx	xxx

1) rove beetle (Staphylinidae), 2) ichneumon fly (Hymenoptera: Ichneumonidae), 3) true bug (Heteroptera: Lygaeidae), 4) aphid (Homoptera: Aphididae), 5) - 8) spiders identified to genus (Lycosidae, Thomisidae, Dictynidae, Erigonidae and other families).

Plant communities: (progressively lower altitude from c. 2 m to sea level. ! denotes dominating taxa)
1) *Dryas octopetala*!, lichens plus 'organic crust'!, *Kobresia myosuroides*!, *Saxifraga oppositifolia*, *S. nivalis*, *Minuartia* sp., *Cerastium alpinum*, *Salix arctica*, *Festuca hyperborea*, grass.
2) *Saxifraga hirculus*!, *Salix arctica*!, *Luzula* sp.!, mosses!, 'organic crust', *Dryas octopetala*, *Potentilla hyparctica*, *Saxifraga oppositifolia*, *S. nivalis*, *S. platysepala*, *Silene acaulis*, *Melandrium triflorum*, *Stellaria longipes*, *Cerastium alpinum*, *Polygonum viviparum*, *Koenigia islandica*, *Carex* sp., *Pedicularis* sp., *Poa arctica*, *P. glauca*.
3) *Saxifraga platysepala*!, *Salix arctica*!, *Polygonum viviparum*!, lichens plus 'organic crust'!, *Dryas octopetala*, *Saxifraga hirculus*, *S. caespitosa*, *S. oppositifolia*, *S. nivalis*, *S. cernua*, *Silene acaulis*, *Pedicularis flammea*, *Luzula* sp., *Festuca hyperborea*, *Trisetum* sp., *Poa arctica*.
4) *Saxifraga hyperborea*!, *Stellaria humifusa*!, *Luzula multiflora* ssp. *frigida*!, *Colpodium vahlianum*!, *Puccinellia phryganodes*!, mosses!, lichens plus 'organic crust'!, *Saxifraga cernua*, *S. hyperborea*, *S. nivalis*, *Sagina intermedia*, *Stellaria humifusa*, *Oxyria digyna*, *Cochelearia groenlandica*, *Salix arctica*, *Poa arctica*.
5) *Stellaria humifusa*!, *Puccinellia phryganodes*!.
6) *Stellaria humifusa*!, *Puccinellia phryganodes*!, *Carex subspathacea*!

Another objective of this study was to locate the exact habitat of the rare High Arctic rove beetle *Gnypeta cavicollis* which was found in the delta in 1991. Only one specimen was caught in 1995, in one of the salt marsh series.



Collected arthropods are sorted by family already at Zackenberg. Photo: Henning Thing

Table 5.3.2. Pitfall collections of selected arthropod taxa in mixed heath communities from different altitude on the southwest facing slope of Aucellabjerg 18-25 August 1995. Sixteen pitfalls were placed in each series. Legend to # specimens is: x = 11-20; xx = 21-50; xxx = 51-100; xxxx = > 100.

Altitude (m)	70	270	580
Stenomacrus sp.	xxx	8	
Other Ichneumonidae	2	2	2
Nysius groenlandicus			1
Myzus polaris	1		1
Pardosa sp.	xx	xxx	xxx
Xysticus sp.	3	xx	2
Erigone sp., *etc.*	x	xxx	xxxx

Systematic relationship of arthropods: see Table 5.3.1.

Plant communities: (! denotes dominating taxa)
70 m a.s.l.: *Dryas octopetala*-dominated heath also with *Vaccinium uliginosum* and *Salix arctica* together with open areas with mosses and bare ground. *Stellaria longipes*, *Silene acaulis*, *Pedicularis hirsuta*, *Polygonum viviparum*, *Luzula* sp., *Kobresia myosuroides*, *Carex* sp., *Poa pratensis*, grasses.
270 m a.s.l.: Open heath with *Dryas octopetala*!, *Vaccinium uliginosum*!, *Salix arctica*!, *Silene acaulis*!, *Stellaria longipes*, *Polygonum viviparum*, *Luzula humifusa*, *Carex* sp., *Poa glauca*, *Alopecurus alpinus*, *Poa pratensis*, mosses and lichens.
580 m a.s.l.: Scattered fell-field vegetation with *Dryas octopetala*!, *Salix arctica*!, mosses!, *Ranunculus sulphureus*, *Potentilla hyparctica*, *Saxifraga cernua*, *S. hirculus*, *S. platysepala*, *S. oppositifolia*, *Cerastium alpinum*, *Stellaria longipes*, *Silene acaulis*, *Melandrium apetalum*, *Arenaria pseudofrigida*, *Minuartia rubella*, *Papaver radicatum*, *Polygonum viviparum*, *Campanula uniflora*, *Juncus biglumis*, *Luzula humifusa*, *Kobresia myosuroides*, *Carex rariflora*, *Poa arctica*, *Festuca baffinensis*, *Trisetum* sp., *Poa pratensis*.

5.3.2. Altitudinal difference

A preliminary survey of possible altitudinal differences in the arthropod fauna was made along an altitudinal gradient on the south-west facing slope of Aucellabjerg. This was performed by placing series of pitfall traps at three levels close to the botanical ZERO-line (see sections 2.2.3.1 and 2.3.1.1).

In order to be able to compare the results, it was necessary to select plant associations with an approximately comparable composition, a task that turned out to be difficult. Fen communities are found all the way up the slope but these are not well suited for pitfall collections. It was, however, possible to find areas with a fairly homogeneous, dry heath vegetation dominated by *Dryas octopetala* at three levels: 70 m, 270 m, and 580 m above sea level where one series of 16 pitfalls was placed in each locality.

The preliminary results appear in Table 5.3.2. Contrary to expectations, the diversity and numbers of individuals caught did not simply decrease from lowest to highest position. The highest lying locality gave the impression of a poor fell-field but the flora was, nevertheless, most diverse here, and the catch of some of the arthropod taxa was highest here.

5.3.3. Pitfall trapping through the season

In order to test the procedures a small number of pitfall traps (4-6) was operated throughout the 1995 season in different, well defined plant communities in the vicinity of the Zackenberg station. The traps were put out on 17 and 19 July and emptied on four occasions, 25 July, 1, 14 and 27 August, respectively. Only the total catch is presented here (Table 5.3.3).

Table 5.3.3. Total catch from 4-6 pitfall traps operated continually from 17 July to 27 August in different plant communities in the vicinity of the Zackenberg station.

Taxa	# specimen
Muscidae & Anthomyidae	27
Phoridae[1]	40
Chironomidae[2]	37
Diptera larvae	1
Lepidoptera sp.[3]	1
Stenomacrus sp.	41
Other Hymenoptera Parasitica[4]	13
Tenthredinidae sp. (larva)[5]	1
Nysius groenlandicus	2
Myzus polaris	3
Pardosa sp.	314
Xysticus sp.	4
Dictyna sp.	6
Erigone sp., *etc.*	287
Collembola plus Acarina[6]	>500

1) fly families; 2) midges; 3) moth; 4) parasitic wasps; 5) saw fly; 6) springtails and mites. For other systematic relationships, see Table 5.3.1.

5.4. Collared Lemming Project - Zackenberg

Thomas Berg

The 'Collared Lemming Project - Zackenberg' was initiated as a scientific study this year as an extension of the lemming monitoring programme (see section 4.3.4.1). The main objectives are to test a hypothesis on the regulation of collared lemming populations and to collect basic information on population biology that will allow comparison with similar data from other populations of sibling species in Fennoscandia, Russia and the Canadian Arctic.

A cluster of 'Ugglan-Lemming' traps around a summer burrow occupied by collared lemmings. The traps were baited Salix *and* Dryas *stems plus raisins and müesli and checked four times daily.*

Photo: Henning Thing

5.4.1. Collared lemming biology and population dynamics

The main hypothesis to be tested is that plants through their chemical defence and abundance affect the quality and quantity of food available to lemmings during different stages of the population cycle. This in turn will affect lemming phenotypes which may be differentially affected by predation from the four predator species mentioned in 4.3.4.1. In laboratory experiments, the effect of food quality on the offspring phenotype will be measured by means of offspring size and various measures of developmental stability.

Chemical plant defence reducing the protein assimilation by the herbivore will be added to the food to test the effect on nutritional content of the faeces. The results will be compared with the protein content of winter faeces collected in the field. Furthermore, skeletal parts from lemmings are collected from nests of snowy owl and from sites where long-tailed skuas and snowy owls cast their regurgitated casts.

The second part of the project concerns collection of basic information on lemming population biology at the individual and population levels during different stages of the lemming cycle. In addition to the standard data collected on winter nests (see section 4.3.4.1), information is obtained on: presence of grey and white fur in the nest, indications of breeding in the nest, amount of faeces (index), the kind of nest material, and finally the composition of the dominating plant species within a 5 m radius from nests where faeces samples are taken to determine forage selection in relation to food availability.

Estimates of population density and composition (*i.e.* sex and age classes, morphology and gene type composition) will be obtained from capture–recapture samples at the start and the end of the field season. This will permit estimation of the population size and composition before and after the summer. The overall habitat use will be analysed by location of winter and summer nests determined by UTM co-ordinates.

Some preliminary results are presented in Table 5.4. Data on habitat use, nest distribution and faeces analysis from two selected nests are still being analysed.

Table 5.4. Records of winter nests of collared lemming Dicrostonyx groenlandicus *in a 250 ha study area in Zackenbergdalen in 1995 (see Fig. 2.2.3.1.). Age class I and II denote relatively fresh and older nests, respectively (see section 4.3.4.1.). The columns 'Ermine' and 'Fox' present the amounts of nests showing sign of predation by these predators. 'GF' and 'WF' stand for presence of grey fur and white fur, respectively, while 'BN' denotes signs of breeding in the nest. Presence of fur in the nest indicates moulting from summer to winter (GF) and winter to summer (WF).*

Age class	Nests	%	Ermine	Fox	GF	WF	BN
I	279	25	5	11	20	14	16
II	830	75	0	4	3	1	16

A parallel winter nest survey is carried out on Traill Ø, 220 km south of Zackenberg. Here, 1990 and 1994 were lemming peak years (Benoît Sittler pers. comm.1995). At Zackenberg, the lemming population appeared to be quite small in 1995 but it might have been high in 1994.

The fact that long-tailed skuas were present with very few breeding pairs (see sections 4.3.3.1 and 4.3.3.4) was indicative of the low population. Furthermore, the snowy owl that breed only in lemming peak years was absent.

5.4.2. Fluctuating asymmetry and the collared lemming

Bo Bendix

A graduate student project was initiated within the ‘Collared Lemming Project - Zackenberg’ by M.Sc. student Bo Bendix, entitled ‘Fluctuating asymmetry and the Collared Lemming, *Dicrostonyx groenlandicus*, in relation to its feeding biology’. Fluctuating asymmetry has often been used as a tool to indicate disruption of development homeostasis. The ability of an organism to produce an exact ‘copy’, both geno- and phenotypic, under any kind of genetic or environmental stress is a way of describing the developmental stability.

At regurgitation sites of snowy owl and long-tailed skua researchers sampled a total of 300 casts holding a large number of lemming bones.
Photo: Henning Thing

Deviation from perfect bilateral symmetry is often used as a measure of the sensitivity of development. Fluctuating asymmetry occurs as a random deviation in the development of bilateral symmetric traits, and appears to correlate with fitness differences, particularly where traits directly effect performance. The absolute asymmetry (left minus right) of a character, can be used to describe the individual inability to undergo identical development on both sides of the plane of symmetry and is defined as fluctuating asymmetry (FA).

The project focuses on two problems:
(i) Does low quality food result in increased fluctuating asymmetry?
(ii) Are asymmetric individuals more likely to be taken by predators?

The collared lemming was selected for study under the assumption that, *e.g.* low quality food affects the functional trait processing the food, *i.e.* maxilla - mandible (i). Similarly, the mandible is often found in casts from snowy owl and long-tailed skua which are the two main avian predators on lemmings (ii).

During the study, a total of 100 'Ugglan-Lemming' traps was placed for nine days in two separate areas each about 2-3 ha. The areas were selected by means of positive lemming indicators such as newly dug holes, possible feeding habitats, lemming tracks *etc*. The traps were checked three to four times a day. Location was changed every second day. Bait used was Salix and Dryas stems and leaves together with raisins and muesli. Trap hours totalled about 21,000 h per 100 traps. Five lemmings were caught, of which one unfortunately escaped.

Beside this, casts from snowy owl and long-tailed skua were collected in the field. Especially, the 250 ha research area was thoroughly examined, resulting in about 300 casts. Both snowy owl and long-tailed skua have regurgitation sites where often considerably amounts of casts are accumulated. Twenty-two sites, each with more than 10 casts, were marked with fluorescence paint and UTM co-ordinates were obtained. These marked cast sites will be used for future cast sampling.

Four lemmings (three males and one female) were brought back to Copenhagen where routines and experiences on keeping lemmings in captivity are obtained. Laboratory experiments on varying food quality and its effects on fluctuating asymmetry are planned. Bones from collected casts will be described and analysed for comparison with other Greenland lemming populations. This study will be accomplished in the spring of 1996.

A trapped lemming is sexed, measured and weighed.
Photo: Bo Bendix

Lemming faeces are collected by means of a battery-powered vacuum cleaner. Fecal samples are used for research on seasonal changes in food selection.
Photo: Thomas B. Berg

An opened lemming winter nest that has been taken over by an ermine. Note the greyish lemming fur used by the ermine as insolation.
Photo: Thomas B. Berg

Two adult lemmings at the entrance to their summer burrow dug out in an elevated, sandy and dry habitat.
Photo: Thomas B. Berg

6. Economic investments in ZERO 1991-1995

Henning Thing

Listed below are all Danish and Greenlandic grants allo-cated to planning, co-ordination, logistics, monitoring and research in relation to ZERO.

1991
Source: M.A.B. via the Danish Natural Science Research Council.
Recipients: **B. Fredskild**, H. Andersson, B. Holm Jakobsen, H. Meltofte, G. S. Mogensen, B. Muus.
Project/Activity: Evaluation of locating a natural science research station.
Amount in DKK: 266,000.

Source: M.A.B. via the Danish Natural Science Research Council.
Recipient: J. Böcher.
Project/Activity: Arctic insects as indicator of the Greenhouse Effect.
Amount in DKK: 71,000.

Total in 1991: 337,000 DKK.

1992
Source: Danish Polar Center.
Recipient: B. U. Hansen.
Project/Activity: Participation in „Second Circumpolar Symposium of Remote Sensing of Arctic Environments" presenting a paper on Zackenberg.
Amount in DKK: 8,000.

Source: Greenland Home Rule.
Recipient: P. Møller Lund.
Project/Activity: Remote sensing of High Arctic vegetation at Zackenberg,Northeast Greenland.
Amount in DKK: 16,000.

Source: M.A.B. via the Danish Science Research Council.
Recipients: B. U. Hansen, H. Andersson, H. H. Christiansen, B. Fredskild, O. Humlum, A. Jacobsen, G. S. Mogensen, J. McMurray.
Project/Activity: Establishment of a digital database for „Global Change" studies in a High Arctic Ecosystem.
Amount in DKK: 1,300,000.

Source: Nordic Institute, Nuuk, Greenland.
Recipient: P. Møller Lund.
Project/Activity: Remote sensing of High Arctic vegetation at Zackenberg, Nordøstgrønland.
Amount in DKK: 30,000.

Source: Nordic Institute, Nuuk, Greenland.
Recipient: Danish Polar Center
Project/Activity: Printing and lay-out of a PR prospect on Zackenberg.
Amount in DKK: 25,000.

Source: Ole Lindahl's Design Office, Copenhagen.
Recipient: Danish Polar Center
Project/Activity: Graphics and concept development of a PR prospect on Zackenberg.
Amount in DKK: 15,000.

Total in 1992: 1,394,000 DKK.

1993
Source: Danish Polar Center.
Recipient: H. Thing.
Project/Activity: Planning and secretarial functions.
Amount in DKK: 90,000.

Total in 1993: 90,000 DKK.

1994
Source: Danish Polar Center
Recipient: H. Andersson.
Project/Activity: Planning of logistics and a visit on site.
Amount in DKK: 150,000.

Source: Danish Polar Center.
Recipient: H. Thing.
Project/Activity: Planning, secretarial functions and study tour.
Amount in DKK: 110,000.

Source: Danish Ministry of the Environment & Energy, MIKA
Recipient: Danish Polar Center.
Project/Activity: Zackenberg Basic.
Amount in DKK: 1,500,000.

Source: Danish Natural Science Research Council.
Recipients: G. S. Mogensen, E. S. Hansen, K. Ramskov Petersen, M. Dalsgaard, M. Andersen.
Project/Activity: The susceptibility of Arctic deserts to climate changes: Measurements of changes in mosses and lichens.
Amount in DKK: 275,000.

Total in 1994 : 2,035,000 DKK.

1995
Source: Danish Polar Center.
Recipient: Danish Polar Center.
Project/Activity: Establishment of Zackenberg station.
Amount in DKK: 1,000,000.

Source: Danish Polar Center.
Recipient: H. Andersson.
Project/Activity: Planning and coordination of logistics.
Amount in DKK: 150,000.

Source: Danish Polar Center.
Recipient: H. Thing.
Project/Activity: General planning, coordinating and secretarial functions.
Amount in DKK: 330,000.

Source: Danish Polar Center.
Recipient: various office clerks.
Project/Activity: Administrative assistance to Andersson, Lassen and Thing.
Amount in DKK: 50,000.

Source: Danish Polar Center.
Recipient: H. Meltofte.
Project/Activity: Salary to Zackenberg Basic.
Amount in DKK: 60,000.

Source: Danish Polar Center.
Recipients: H. Andersson, H. Lassen, H. Meltofte, H. Thing.
Project/Activity: Zackenberg related travels as well as 'overhead expenses'.
Amount in DKK: 224,000

Source: Faculty of Natural Science, University of Copenhagen.
Recipients: S. Jonasson, C. Bay, T. R. Christensen, B. Fredskild, B. H. Jakobsen, B. U. Hansen, B. Hasholt, O. Humlum, A. Michelsen, N. Nielsen, H. Søgaard.
Project/Activity: 1 Ph.D. stipend for a physical geographer associated with the Zackenberg activities of the project 'The Arctic Landscape...'.
Amount in DKK: 270,000.

Source: Faculty of Natural Science, University of Copenhagen.
Recipients: S. Jonasson, C. Bay, T. R. Christensen, B. Fredskild, B. H. Jakobsen, B. U. Hansen, B. Hasholt, O. Humlum, A. Michelsen, N. Nielsen, H. Søgaard.
Project/Activity: Laboratory equipment for the Zackenberg activities of the project 'The Arctic Landscape...'.
Amount in DKK: 550,000.

Source: Faculty of Natural Science, University of Copenhagen.
Recipient: H. H. Christiansen.
Project/Activity: Salary to Zackenberg Basic.
Amount in DKK: 111,000.

Source: Commission for Scientific Research in Greenland.
Recipient: T. B. Berg.
Project/Activity: 'Collared Lemming Project - Zackenberg'
Amount in DKK: 37,000.

Source: Commission for Scientific Research in Greenland.
Recipient: Danish Polar Center.
Project/Activity: Sum guaranteed to implement the establishing of parts of Zackenberg Basic.
Amount in DKK: 400,000.

Source: Commission for Scientific Research in Greenland.
Recipient: Danish Polar Center.
Project/Activity: Establishing and running the Zackenberg station.
Amount in DKK: 1,500,000.

Source: Commission for Scientific Research in Greenland.
Recipient: Danish Polar Center.
Project/Activity: Planning of logistics and implementing.
Amount in DKK: 200,000.

Source: Commission for Scientific Research in Greenland.
Recipient: H. Lassen.
Project/Activity: Coverage of expenses concerning logistics assistent.
Amount in DKK: 400,000.

Source: Danish Ministry of the Environment & Energy, MIKA.
Recipient: Danish Polar Center.
Project/Activity: Zackenberg Basic.
Amount in DKK: 720,000.

Source: Danish Research Councils' Polar Programme.
Recipients: S. Jonasson, C. Bay, T. R. Christensen, B. Fredskild, B. H. Jakobsen, B. U. Hansen, B. Hasholt, O. Humlum, A. Michelsen, N. Nielsen, H. Søgaard.
Project/Activity: The Arctic landscape: Interactions and feedbacks among physical and biological processes. A biological and geo-environmental Arctic system research project 1995-1997.
Amount in DKK: 2,800,000.

Source:Danish Research Councils' Polar Programme
Recipients: P. B. Christensen, P. Berg, H. Dahlgaard, K. T. Jensen, N. P. Revsbech, S. Rysgaard.
Project/Activity: Nutrient dynamics in North East Greenland waters and sediment.
Amount in DKK: 2,500,000.

Total in 1995 : 11,232,000 DKK.

For the period 1991 - 1995 the grants amount to 15,088,000 DKK.

The grants have been distributed as follows:
7,887,000 DKK for research,
2,820,000 DKK for monitoring and
4,381,000 DKK for planning and logistics.

The old Zackenberg trapping station located at the coast c. 2 km south-west of the research station. This 50 years old building is a protected historic site with a well kept authentic atmosphere from the days 'before Global Change'.

7. Publications

The references relevant to Zackenberg have been separated into three groups: 7.1 gives papers and reports that present natural science data from the Daneborg-Zackenberg region, 7.2 gives papers and reports that present principal information on natural science of Northeast Greenland, while 7.3 is a list of papers and reports that contain results from the ZERO programme. References given in the text are distributed accordingly.

7.1. Natural science accounts on the Zackenberg region

Backlund, H.G. & Malmqvist, D. 1932
Zur Geologie und Petrographie der nordost-grönländischen Basaltformation. Teil I.
Meddelelser om Grønland 87, 5. 61 pp.

Bay, C. & Boertmann, D. 1988
Biologisk-arkæologisk kortlægning af Grønlands østkyst mellem 75° og 79°30' N. br. Del 1: Flyrekognoscering mellem Mesters Vig (72°12N) og Nordmarken (78°N)
Grønlands Hjemmestyre. Miljø- og Naturforvaltning. Teknisk Rapport nr. 4 - januar 1989. 63 pp. (with English abstract).

Brændegaard, J. 1940
I. Spiders (Araneina) from Northeast Greenland between Lats. 70°25' and 76°50' N.
II. On the Possibility of a reliable Determination of Species of the Females of the Genus Erigone.
Meddelelser om Grønland 125, 8. 31 pp.

Christensen, N.H. 1967
Moult Migration of Pinkfooted Goose (*Anser fabalis brachyrhynchus* BAILLON) from Iceland to Greenland.
Dansk Orn. Foren. Tidsskr. 61: 56-66.

Christensen, N.H. Gensbøl, B. & Rosenberg, T. 1965
Moult Migration of Pink-footed Geese, *Anser Arvensis Brachyrhynchus.*
Ibis 107: 542-543.

Conradsen, F.R. 1957
Ornithologiske iagttagelser ved Daneborg, N.Ø. Grønland.
Dansk Orn. Foren. Tidsskr. 51: 12-18.

Gelting, P. 1934
Studies on the Vascular Plants of East Greenland between Franz Joseph Fjord and Dove Bay (Lat. 73°15'-76°20'N).
Meddelelser om Grønland 101, 2. 337 pp.

Gelting, P. 1937
Studies on the Food of the East Greenland Ptarmigan especially in its Relation to Vegetation and Snow-Cover.
Meddelelser om Grønland 116, 3. 196 pp.

Hansen, B.U. & Søgaard, H. 1989
Vegetations- og sne/is-kortlægning af den grønlandske nationalpark 1988.
Report from Institute of Geography, University of Copenhagen. 28 pp.

Johnsen, P. 1953
Birds and Mammals of Peary Land in North Greenland. Including notes from Northeast Greenland.
Meddelelser om Grønland 128, 6. 135 pp.

Koch, L. & Haller, J. 1971
Geological Map of East Greenland 72° – 76° N. Lat.
Meddelelser om Grønland 183. 26 pp. +13 maps.

Kruuse, C. 1905
List of the phanerogams and vascular cryptogams found on the coast 75°-66°20' lat. N. of East Greenland.
Meddelelser om Grønland 30, 5: 143-208.

Marris, R. & Webbe, A.H.F. 1969
Observations of Birds in East Greenland, 1966.
Dansk Orn. Foren. Tidsskr. 63: 161-170.

Meltofte, H. 1972
Ornithological Observations in the Norwegian Sea, the Greenland Sea, and NE Greenland, July-August 1972.
Dansk Orn. Foren. Tidsskr. 66: 108-112.

Meltofte, H. 1978
A breeding association between Eiders and tethered huskies in North-east Greenland.
Wildfowl 29: 45-54.

Meltofte, H. 1983
Arrival and pre-nesting period of the Snow Bunting *Plectrophenax nivalis* in East Greenland.
Polar Research,1 n.s.: 185-198.

Møhl-Hansen, U. 1949
The Bird-Life in Pearyland, North-Greenland. Observations on the "Dansk Pearyland Ekspedition" in the summer 1947.
Dansk Orn. Foren. Tidsskr. 43: 109-129 (in Danish with English summary).

Rosenberg, N.T., Christensen, N.H. & Gensbøl, B. 1970
Bird Observations in Northeast Greenland.
Meddelelser om Grønland 191, 1. 87 pp.

Seidenfaden, G. 1930
Botanical Investigations during the Danish East Greenland Expedition 1929.
Meddelelser om Grønland 74 (15): 366-382.

Seidenfaden, G. 1931
Moving Soil and Vegetation in East Greenland.
Meddelelser om Grønland, vol. 87, 2. 21 pp.

Seidenfaden, G. & Sørensen, T., 1933
On *Eriophorum caolitrix* Cham. in Greenland.
Meddelelser om Grønland 101, 1. 27 pp.

Seidenfaden, G. & Sørensen, T. 1933
The Vascular Plants of Northeast Greenland from 74°30' to 79°00' N. Lat. and a summary of all species found in East Greenland.
Meddelelser om Grønland 101, 4. 215 pp.

Sørensen, T. 1941
Temperature Relations and Phenology of the Northeast Greenland Flowering Plants.
Meddelelser om Grønland 125, 9. 305 pp.

Sørensen, T. 1945
Summary of the Botanical Investigations in N.E. Greenland.
Meddelelser om Grønland 144, 3. 48 pp.

Trans, P. 1955
Dansk Pearyland Ekspedition 1947-50. Report from the Weather Service.
Meddelelser om Grønland 127, 6. 41 pp.

Vaage, J., 1932
Vascular Plants from Eirik Raude's Land (East Greenland 71°30'-75°40' lat. N).
Skrifter om Svalbard og Island 48. 87 pp.

7.2. Selected natural science accounts on Northeast Greenland

Bay, C. 1992
A phytogeographical study of the vascular plants of northern Greenland – north of 74° northern latitude.
Meddelelser om Grønland, Bioscience 36. 102 pp.

Boertmann, D. 1994
An annotated checklist to the birds of Greenland.
Meddelelser om Grønland, Bioscience 38. 63 pp.

Böcher, J. 1988
The Coleoptera of Greenland.
Meddelelser om Grønland, Bioscience 26. 100 pp.

Funder, S. & Hjort, C. 1973
Aspects of the Weichselian chronology in central East Greenland.
Boreas 2: 69-84.

Hartz, N. & Kruuse, C. 1911
The vegetation of Northeast Greenland 69°25' lat. n. - 75° lat. n.
Meddelelser om Grønland 30 (10): 333-431.

Hjort, C. 1979
Glaciation in northern East Greenland during the Late Weichselian and Early Flandrian.
Boreas 8: 281-296.

Hjort, C. 1981
Present and Middle Flandrian coastal morphology in Northeast Greenland.
Norsk Geogr. Tidsskr. 35: 197-207.

Hjort, C. 1981
Studies of the Quaternary in Northeast Greenland.
Thesis 9. University of Lund. 29 pp.

Hjort, C. 1981
A glacial chronology for northern East Greenland.
Boreas 10: 259-274.

Hjort, C. & Björck, S. 1984
A re-evaluated glacial chronology for northern East Greenland.
Geologiska Föreningens i Stockholm Förhandlingar 105, pt. 3: 235-243.

Jennov, J.G. 1945
Moskusoksebestanden i Nordøstgrønland og Nogle Spredte Iagttagelser og Betragtninger Vedrørende Dyrelivet i Nordøstgrønland.
Østgrønlands Fangstkompagni Nanok A/S. 128 pp.

Meldgaard, M. 1990
Op- og nedgangstider i den arktiske dyreverden. Om mål og midler til langsigtet overvågning af arktiske dyrs bestandssvingninger.
Tidsskriftet Grønland 6-7: 169-180.

Meltofte, H. 1985
Populations and breeding schedules of waders, Charadrii, in high arctic Greenland.
Meddelelser om Grønland, Bioscience 16: 1-43.

Molau, U. (ed.) 1993
International Tundra Experiment. ITEX Manual. Danish Polar Center. 30 pp + Appendices.

Sittler, B. 1995
Response of stoats (*Mustela erminea*) to a fluctuating lemming (*Dicrostonyx groenlandicus*) population in North East Greenland: preliminary results from a long-term study.
Ann. Zool. Fennici 32: 79-92.

Surlyk, F. 1978
Mesozoic geology and palaeogeography of Hochstetter Forland, East Greenland.
Bull. geol. Soc. Denmark 27: 73-87.

Sørensen, T. 1937
The Vascular Plants of East Greenland from 71°00' to 73°30' N. Lat.
Meddelelser om Grønland 101, 3. 177 pp.

Sørensen, T., 1935
Bodenformen and Pflanzendecke in Nordostgrönland. (Beiträge zur Theorie der polaren Bodenversetzungen auf Grund von Beobachtungen über den Einfluss auf die Vegetation in Nordostgrönland).
Meddelelser om Grønland 93, 4. 69 pp.

Vibe, C. 1967
Arctic Animals in Relation to Climatic Fluctuations.
Meddelelser om Grønland 170, 5. 227 pp.

Wolff, N.L. 1964
The Lepidoptera of Greenland.
Meddelelser om Grønland 159, 11. 74 pp. +21 plates.

7.3. Outcome of ZERO (1991 - 1995)

Andersson, T.I.H. 1992
En forskningsstation i Nordøstgrønland.
Naturens Verden 1992 (8): 314-320.

Andersson, T.I.H., Böcher, J., Fredskild, B., Jakobsen, B.H., Meltofte, H., Mogensen, G.S. & Muus, B. 1991
Rapport om muligheden for placering af en naturvidenskabelig forskningsstation ved Zackenberg, Nationalparken i Nord- og Østgrønland.
University of Copenhagen & Danish Polar Center. 48 pp.

Arctic Consultant Group 1991
Zackenberg – en forskningsstation i Grønlands Nationalpark, Nordøstgrønland. Bygherreoplæg.
ACG. 18 pp.

Böcher, J. 1992
Insekter og andre smådyr.
Naturens Verden 1992 (8): 296-300.

Böcher, J. 1992
Rapport over pilotprojektet "Arktiske insekter som indikatorer af drivhuseffekten".
Zoological Museum, Univ. of Copenhagen. 22 pp.

Christiansen, H.H. 1992
Geomorfologisk moniteringsmanual. Zackenberg 1992.
Institute of Geography. 12 pp.

Christiansen, H.H. 1994
Thermoluminescence dating of nival sediments from Zackenberg, Northeast Greenland.
Quaternary Geochronology (Quaternary Science Reviews) 13: 491-496.

Christiansen, H.H. 1994
Landskabsudvikling i tid og rum - fra Zackenberg området i Nordøstgrønland.
Naturligvis, Københavns Universitet - 1994: 12-16.

Christiansen, H.H. 1995
Nivation forms, processes and sediments in recent and former arctic areas.
Ph.D. thesis. Institute of Geography, University of Copenhagen. 185 pp.

Christiansen, H.H. & Humlum, O. 1993
Geomorphology of the Zackenberg Area.
ZERO News # 3: 6-7.

Christiansen, H.H. & Humlum, O. 1993
Glacial history and periglacial landforms of the Zackenberg area, Northeast Greenland: Preliminary results.
Geografisk Tidsskrift 93: 19-29.

Christiansen, H.H. & Humlum, O. 1994
Zackenberg – Geografi oppe og nede.
Hovedområdet 23, 4: 17.

Dalsgaard, M. 1995
Spalchnacéere ved Zackenberg i Nord-Østgrønland.
Unpublished biology project report. 41 pp.

Danish Polar Center 1991
Zackenberg – en forskningsstation i Grønlands Nationalpark, Nordøstgrønland. Fra idé til virkelighed i det højarktiske.
Danish Polar Center. 12 pp.

Danish Polar Center, 1992
Orientering til Nationalparkrådet 21. februar 1992. Forskningsstation & Forskningsprogram i Nationalparken.
Danish Polar Center. 7 pp.

Danish Polar Center 1992
ZERO News.
ZERO News #1, January 1992. 4 pp.

Danish Polar Center 1992
ZERO News.
ZERO News #2, August 1992. 4 pp.

Danish Polar Center 1993
ZERO News.
ZERO News #3, Jan. 1993. 8pp.

Danish Polar Center 1994
ZERO News.
ZERO News #4, August 1994. 4pp.

Danish Polar Center 1995
ZERO News.
ZERO News #5, September 1995. 4 pp.

Danish Polar Center 1993
Analytical Studies of High Arctic Ecosystems. A Multidisciplinary Programme at Zackenberg, NE Greenland. A Letter of Intent.
University of Copenhagen & Danish Polar Center. 26 pp.

Danish Polar Center 1993
Zackenberg – en forskningsstation i Nordøst-grønland. Zackenberg – a research station in North East Greenland.
Danish Polar Center. 8 pp.

Fredskild, B. 1992
Vegetationen ved Zackenberg
Naturens Verden 1992 (8): 282-290.

Fredskild, B. & Bay, C. (eds) 1993
Grønlands Botaniske Undersøgelse 1992. Rapport.
Botanisk Museum, København. 51 pp. (in Danish with English summary).

Fredskild, B., Bay, C., Feilberg, J. & Mogensen, G.S. 1992
Grønlands Botaniske Undersøgelse 1991.
Botanisk Museum, København. 38 pp. (in Danish with English summary)

Fredskild, B., Mogensen, G.S., & Hansen, E.S. 1995
Grønlands Botaniske Undersøgelse 1994. Rapport.
Botanisk Museum, København Universitet. 20 pp. (in Danish with English summary).

Hansen, E.S. in press
Vertical distribution of Lichens on the Mountain, Aucellabjerg, Northeastern Greenland.
Arctic and Alpine Research 28.

Humlum, O. 1995
Naturgeografisk forskning i Grønland.
Almanak. Skrive- & Rejsekalender 1996.
Københavns Universitet.:159-173.

Jacobsen, A. 1995
Overvågning af Climate Change variable i et vegetationsdækket arktisk miljø. Zackenberg, Nordøstgrønland. Under anvendelse af klimatiske feltdata & remote sensing.
(M.Sc. thesis), Geographica Hafniensia C3. Publications, Institute of Geography, University of Copenhagen. 105 pp. (in Danish with English abstract).

Jacobsen, B.H. 1992
Zackenbergområdets naturgeografi.
Naturens Verden: 1992, 8: 306-313.

Jakobsen, B.H. 1995
Tværfaglig arktisk forskning.
Scientia1: 5.

Lund, P.M. 1993
Fjernanalyse af højarktisk vegetation ved Zackenberg, Nordøstgrønland.
Unpublished graduate student report. Telemark Distrikthøgskole, Norway. 63 pp.

Meltofte, H. & Muus, B. 1992
Fra snespurve til moskusokser.
Naturens Verden 1992 (8): 301-305.

Mısissueqqaarnerit 1995
Klimastation Zackenberg. Teknisk beskrivelse. A 1782
Misissueqqaarnerit. 8 pp. +16 enclosures.

Mogensen, G.S. 1992
Mosserne i det højarktiske miljø.
Naturens Verden 1992 (8): 291-295.

Mogensen, G.S. 1994
Zackenberg – Botanik på kryds og tværs
Hovedområdet 23, 4: 16.

Odgaard, J. 1995
År 0 før klimaændringerne.
MiljøDanmark 9, 5: 14-17.

Odgaard, J. 1995
Year 0 before the Climate Change.
Danish Environment 4: 4-7.

Royal Geographical Society 1994
Geographical Observatories Programme. Consultation Paper: Introduction & Scientific Framework. Royal Geographical Society. 13 pp.

Rysgaard, S. & Berg, P. submitted
Mineralization in a northeastern Greenland sediment: Mathematical modelling, measured sediment pore water profiles and actual activety. Limnology and Oceanography.

Rysgaard, S. *et al.* in press
Primary production, nutrient dynamics and mineralization in a northeastern Greenland fjord during the summer thaw.
Polar Biology.

Thing, H. 1992
En forskningsstation i Jordens største nationalpark.
Naturens Verden1992, 8: 281.

Wenink, P.W., Baker, A.J., Rösner, H.-U. & Tilanus, M.G.J. 1995
Global mitochondrial DNA phylogeography of Holarctic breeding Dunlins (*Calidris alpina*).
P. 67-96.
in: Wenink, P.W.: Mitochondrial DNA sequence evolution in shorebird populations. Proefschrift Wageningen. 136 pp.

The 1,444 m high Dombjerg mirrored in a pond in the core study area of Zackenbergdalen.
Photo: Henning Thing

8. Personnel

8.1. 1991 Reconnaissance, 20 July - 4 August

T.I. Hauge Andersson, Danish Polar Center (logistics)

Jens Böcher, M.Sc., Zoological Museum, University of Copenhagen (arthropods)

Bent Fredskild, Ph.D., Botanical Museum, University of Copenhagen (vascular plants)

Bjarne Holm Jakobsen, Ph.D., Institute of Geography, University of Copenhagen (physical geography)

Hans Meltofte, Zoological Museum, University of Copenhagen (birds and mammals)

Gert Steen Mogensen, Ph.D., Botanical Museum, University of Copenhagen (mosses)

Bent Muus, Professor, Ph.D., Zoological Museum, University of Copenhagen (zoology)

8.2. 1992 Logistics and research

T.I. Hauge Andersson, Danish Polar Center (logistics, c. 23 July - c. 2 August)

Hanne Hvidtfeldt Christiansen, M.Sc., Institute of Geography, University of Copenhagen (physical geography, 16 July - 15 August)

Ole Humlum, Ph.D., Institute of Geography, University of Copenhagen (physical geography, 16 July - 15 August)

Bent Fredskild, Ph.D., Botanical Museum, University of Copenhagen (ZERO-line and vascular plants, 16 July - 15 August)

Birger Ulf Hansen, Ph.D., Institute of Geography, University of Copenhagen (physical geography, 16 July - 15 August)

Anne Jacobsen, graduate student, Institute of Geography, University of Copenhagen (physical geography, 16 July - 15 August)

Pipaluk Møller Lund, graduate student, Telemark Distriktshøjskole, Norway (remote sensing and vegetation mapping, 16 July - 15 August)

John McMurray, Ph.D., Duke University, U.S.A. (ZERO-line and mosses, 16 July - 15 August)

Gert Steen Mogensen, Ph.D., Botanical Museum, University of Copenhagen (ZERO-line and mosses, 16 July - 15 August)

8.3. 1994 Logistics and research

Michael Richardt Andersen, M.Sc., Botanical Museum, University of Copenhagen (ZERO-line and lichens, 20 July - 23 August)

Mads Dalsgaard, undergraduate student, Botanical Museum, University of Copenhagen (ZERO-line and mosses, 20 July - 23 August)

Preben Gran Sørensen, technician, Institute of Biological Sciences, University of Aarhus (marine biochemistry, 2-22 July)

Eric Steen Hansen, Ph.D., Botanical Museum, University of Copenhagen (ZERO-line and lichens, 20 July - 23 August)

Gert Steen Mogensen, Ph.D., Botanical Museum, University of Copenhagen (ZERO-line and mosses, 20 July - 23 August)

Kirsten Ramskov Petersen , undergraduate student, Botanical Museum, University of Copenhagen (Zero-line and mosses, 20 July - 23 August)

Søren Rysgaard, Ph.D., National Environmental Research Institute (marine biochemistry, 2-22 July)

8.4. 1995

8.4.1. Scientific

Hans Meltofte, D.Sc., Danish Polar Center (Station manager and Zackenberg Basic, 13 July - 30 August)

Bo Bendix, graduate student, Zoological Institute, University of Copenhagen (Zackenberg Basic and lemming research, 13 July - 18 August)

Thomas Bjørneboe Berg, M.Sc., Danish Polar Center (Zackenberg Basic and lemming research, 13 July - 18 August)

Jens Böcher, M.Sc., Zoological Museum, University of Copenhagen (Zackenberg Basic and arthropod research, 6-30 August)

Torben Røjle Christensen, Ph.D., Botanical Institute, University of Copenhagen (trace gas exchange study, 6-18 August)

Hanne Hvidtfeldt Christiansen, Ph.D., Institute of Geography, University of Copenhagen (Zackenberg Basic and physical geographical research, 6-30 August)

Ole Humlum, Ph.D., Institute of Geography, University of Copenhagen (Zackenberg Basic and physical geographical research, 6-30 August)

8.4.2. Logistics and construction

T.I. Hauge Andersson, Danish Polar Center (logistic officer, 26 July - 18 August)

Henrik Lassen, Danish Polar Center (logistic assistant, 13 July - 30 August)

Bent Sørensen, Misissueqqaarnerit, Nuuk (Greenland Field Investigation) (climate station, 6-18 August)

Kaspar Mortensen, Misissueqqaarnerit, Nuuk (Greenland Field Investigation) (climate station, 6-18 August)

Alda & Johan Gislason, Iceland (runway construction, 3-8 August)

8.4.3. Other

Henning Thing, Ph.D., Danish Polar Center (supervision of ZERO, 6-18 August)

The 1995 team at Zackenberg. Standing next to shelter (from left to right): Kaspar Mortensen, Jens Böcher, Hans Meltofte. Middle row (from left to right): Henning Thing, Hanne Hvidtfeldt Christiansen, Bent Sørensen. Front row (from left to right): Ole Humlum, Thomas Bjørneboe Berg, Hauge Andersson, Bo Bendix, Henrik Lassen and Torben Røjle Christensen. Alda and Johan Gislason were absent. 15 August 1995.

Photo: Henning Thing

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The versatile Twin Otter from Akureyri-based Flugfelag Norðurlands is indispensable to cargo and personnel transportation to and from Zackenberg.

Photo: Jens Böcher

Appendix 1: Unofficial locality names

List of unofficial locality names used in this report (see also Fig. 1.3.2)

Aucellaelv (Aucella river)

Favoritdal (favorite valley)

Grænseelv (border river)

Kærelv (fen river)

Lomsø (loon lake)

Morænebakkerne (the moraine hills)

Oksebakkerne (the muskox hills)

Rylekærene (the dunlin fens)

Tørvekæret (the turf fen)

Ulvehøj (wolf hill)

Zackenbergdalen (the Zackenberg valley)

Zackenbergelven (the Zackenberg river)