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Executive summary

Charlotte Sigsgaard, Hans Meltofte, Søren Rysgaard and Morten Rasch

In 2004, Zackenberg Research Station was open for 97 days, from 26 May to 31 August. During this period, 32 scientists and seven staff members worked at the station. 10 research projects were carried out. Her Majesty the Queen Margrethe and His Royal Highness the Prince Consort Henrik visited the station on 3 July 2005 accompanied by 23 guests. A delegation of six guests from the Greenland Home Rule visited the station from 6 to 8 August. At the end of the season the total number of bed nights at Zackeenberg counted 1287.

In 2004, Aage V. Jensen's Charity Foundation funded the establishment of a new VHF repeater to be installed high on the mountain Dombjerg to provide better VHF radio coverage in Zackenbergdalen, Store Sødal, Young Sund, the inner part of Tyrolerfjord and the sea outside Daneborg.

In Daneborg, members of Nordøstgrønlands Kompagni Nanok made significant restorations on the building 'Kystens Perle' to improve the accommodation facilities. The restoration of 'Kystens Perle' was funded by generous grants from Aage V. Jensen's Charity Foundation.

A Zackenberg Basic Workshop was held in Copenhagen in April 2004 to discuss the preparation of a report of the first ten years of research and monitoring at Zackenberg. A draft framework for the book was prepared, a time schedule was agreed upon, and an editorial group with five editors was appointed.

At Zackenberg, the summer of 2004 was among the warmest and driest since 1995, when the meteorological monitoring began. Only the summer of 2003 was slightly warmer. Mean air temperatures for June, July and August 2004 were 2.5°C, 7.5°C and 5.6°C, respectively. The maximum temperature of the summer was 19.1°C, measured on 20 June. This is by far the highest maximum temperature observed in June up to now. The second warmest maximum temperature in June was 14.9°C, measured in 2002.

Rain events occurred primarily in late July and early August, whereas June was very dry, and in total, the summer precipitation of 17 mm was among the lowest measured. At several occasions, new snow was observed down to about 400-500 m a.s.l.

The sum of positive degree-days together with the sum of positive degree hours during the winter months (September until May 1995-2004) show an increase in positive temperatures during the last years and also more frequent episodes of temperatures above the freezing point during winter. Data from the new snow and micrometeorological stations established in 2003 show that both during the coldest winter months and the warmest summer months the mean monthly temperature is higher 420 m a.s.l. than 17 m a.s.l. This reflects the effect of fog and low clouds coming into the valley from the fiord and the different climatic conditions above and below this inversion layer.

The maximum amount of snow measured at the climate station was 0.7 m, which is in the low end of the range (0.5 m in 2000 to 1.3 m in 1999). On 10 June, snow cover in several sub-zones in Zackenbergdalen was even less extensive than in the otherwise snow poor year of 2000. In accordance with the little extent of the spring snow cover and the high spring temperatures (only 2002 was warmer during 21 May – 10 June) snowmelt was extremely early, and also ice melt on the ponds was earlier than recorded before during our nine years of observations. Already in early June, all ponds in Gadekæret and Sydkærene were free of ice.

The river Zackenbergelven broke up early and violently, when a snowmelt-generated slush flow passed the research station on 1 June. Deposits of large amounts of mud and sediment upon the snow on the banks indicated that the size was almost similar to the spring surge in 1999. Total runoff from the Zackenberg drainage basin in 2004 was c. 210 million m^3. This amount is only preliminary, as some water was still running in the river, when we left Zackenberg on 30 August. The discharge in August was high and was only exceeded in 1998, when a rain storm caused a major flood. In 2004, the high discharge in August is assumed to be the result of a combination of a rainy period in late July and early August followed by a very warm period in the first part of August. During June, July and August, Zackenbergelven transported an amount of 21,860 tons of suspended sediment from the drainage basin and into Young Sund. Of this, c.1,388 tons were organic matter.

The fiord ice between Zackenbergdalen and Clavering Ø broke up on 1 July, and from 8 July the fiord was open all the way to the sea. Compared to previous years, this is an early break up, very similar to observations from the last two years.

In late August, the active layer had reached an average depth of 76 cm in ZEROCALM-1 and 65 cm in ZEROCALM-2. This is the deepest records so far and slightly more than the depths measured in 2003. The seasonal snow patch that influences the melt rate in ZEROCALM-2 disappeared already on 17 July, which is about a week earlier than recorded before. Measurements from the snow and micrometeorological station on the slope of Aucellabjerg indicate that the active layer becomes deeper 420 m a.s.l., than in the valley.

At the micrometeorological station, where CO_2 exchange rates between the heath ecosystem and the atmosphere have been measured since 2000, a total of 22.4 g C/m^2 was accumulated during the period 3 June – 28 August 2004. This is very similar to the total accumulation in 2003 and reveals that the Cassiope heath acts as a sink for carbon during the three summer months. The daily net carbon accumulation period (the period when the assimilation exceeds respiration) lasted from 23 June to 24 August and was the longest period of net carbon accumulation during five years. The maximum daily net uptake of CO_2 was measured on 11 July, when an amount of 1.3 g C/m^2 accumulated.

Together with relatively high spring temperatures, the reduced snow cover resulted in many of the flower plots located on ridges and other sun and wind exposed sites being snow free at the start of the season, and that flowering was the earliest ever recorded in the majority of the plots. Even the opening of seed capsules was earlier or among the earliest recorded so far. Numbers of flowers were high – in almost one third of the plots the highest recorded – which must be related to a long growing season in 2003.

A total of 56,686 specimens of insects and arachnids were collected in 2004. This number is in the middle of the range of specimens collected annually 1996-2003, but less than the numbers of the two most recent years. The peak occurrence of midges in the window traps was relatively early, probably as a result of the early ice and snowmelt. Also the Muscidae flies had their peak two weeks earlier in the pitfall traps than the average for the years 1996-2003, but the peak period lasted only three weeks, whereas the average is four weeks.

Numbers of breeding birds in the census area in Zackenbergdalen were much like previous years, the few discrepancies being applicable to differences in census effort and evaluations. Breeding in waders was very early. For three out of four species with more than five aged egg-clutches or broods, 2004 was the earliest breeding season recorded since records began in 1996. Wader nest success was exceptionally high in 2004. Only 3 or 4 out of 55 nests found were depredated, probably by birds. Waders experienced a high breeding success irrespective of a record high number of foxes. This is the first observation in Zackenberg (and Greenland) of a simultaneous occurrence of high numbers of lemmings and foxes and good nesting success, a pattern that is almost a rule in arctic Siberia. Also long-tailed skuas had an early breeding year and a record high breeding success, while barnacle geese showed up at Zackenberg with relatively many broods of close to average size. On Sandøen in outer Young Sund, arctic terns bred in large numbers with good success, while Sabine's gulls were little successful.

The number of collared lemming nests from the previous winter was the second highest recorded so far, following the record low winter population density in 2002-03. Not a single nest was depredated by stoat. In 2004, a new pattern of musk ox occurrence was recorded, with high numbers in June, quite low numbers in July, and very high numbers in August. The 2004 figures were also very much higher than hitherto recorded. Twelve counts exceeded the previous record number of 167 from 1996, with a maximum of 236 in late August. The ratio of calves was also record high, with 21% calves. At least 18 arctic fox pups were found within the 50 km^2 study area including a den holding a litter of nine pups. This is the highest number recorded so far. Numbers of seals hauled out on the fjord ice in June were again modest.

Despite the early ice melt on our study lakes, there were no indications of changes in the average values recorded for conductivity, total nitrogen and total phosphorus, which remained within the usual year-to-year fluctuations. Also, the phytoplankton biomass in terms of chlorophyll *a* was similar to those of previous years, and so were the zoo-plankton communities.

The period with sea ice cover in Young Sund during 2003-04 was much shorter than the norm from 1950 to 1985 supporting recent year observations of a dramatic decrease of sea ice. The temperature in the surface water of the fjord (0-5 m) reached 5.52°C during August. As a mean for the upper 0-45 m during August the temperature reached 0.7°C and a salinity of 31.16‰. At deeper water masses (45-150 m) a mean temperature and salinity of –1.66°C and 33.09 were recorded, respectively. Warmer (>1°C) and saltier (34.77‰) water was observed at 200-300 m water depth outside the fjord. Mean chlorophyll *a* values in the upper 0-45 m water column was 0.41 µg/l and very low pCO_2 values (197 µatm) was recorded in surface waters (0-1 m) this year. The light attenuation coefficient (PAR) was 0.136 and that of UV-B 1.43. Diatoms in general and *Chaetocerous* species in particular dominated the phytoplankton. The dominating copepod species throughout August 2004 were *Pseudocalanus spp*., *Oithona spp*. and *Calanus hyperboreus*. Of the organic matter reaching the sediment microbes and benthic animals mineralized 3.4 mmol m^{-2} d^{-1}. Sulphate reduction accounted for 48% of the carbon mineralization. Presence of fauna creates higher O_2 uptake than the diffusive O_2 uptake. In 2004 the ratio of the total to diffusive O_2 uptake was 1.52 indicating an active role of the fauna. Brittle stars showed a strong increase in abundance with depth. Sea urchins were most abundant in the outer part of the fjord. Bivalve abundance peaked at 20 to 40 m. The sea cucumber *Cucumaria sp*. was highly patchy and no clear trend found. In general, abundance of all benthic species was slightly higher in 2004 compared with 2003. The growth of the bivalve *Mya truncata,* based on growth ring analysis, was reconstructed and peak growth rates of shells were found at regular 10-year intervals around 1965, 1975, 1985 and 1995. Below-average growth occurred around 1970, 1980 and 2000. The annual growth of the underwater plant *Laminaria saccharina* was 105.7 cm ± 6.2 corresponding to 5.8 ± 0.8 g C yr^{-1}. A large group of walruses comprising a maximum of 59 individuals was observed on Sandøen this year.

Ten research projects were carried out at Zackenberg Research Station in 2004.

1 Introduction

Morten Rasch

In 2004, Zackenberg Research Station was open for 97 days, from 26 May to 31 August. During this period 32 scientists and seven staff members worked at the station. 10 research projects were carried out. Her Majesty the Queen Margrethe and His Royal Highness the Prince Consort Henrik visited the station on 3 July 2004 accompanied by 23 guests. A delegation of six guests from the Greenland Home Rule visited the station from 6 to 8 August. At the end of the season the total number of bed nights at Zackenberg counted 1287. This is a bit lower than in 2003, when 39 scientists representing 14 research projects stayed at the station and when the total number of bed nights counted 1597.

A royal visit

It was a special pleasure for Zackenberg Research Station that Her Majesty the Queen Margrethe II and His Royal Highness the Prince Consort Henrik decided to visit Zackenberg Research Station during their official visit to Greenland in the summer of 2004. The honorable guests arrived together with their Greenlandic hosts on the morning of 3 July. Within ten minutes, 23 persons arrived at Zackenberg. During their stay at Zackenberg, our guests had time for a short introduction to the work at Zackenberg by Director Hanne Petersen, Danish Polar Center, an excursion in the surroundings of the station, and lunch. Her Majesty the Queen and His Royal Highness the Prince Consort shall be most welcome to visit Zackenberg Research Station again.

New equipment

A new 38 kW generator was installed in 2004, replacing a 15 kW generator that broke down early in the field season. The generator was flown to the station from Daneborg underneath a Bell 222 helicopter on 16 August 2004.

Aage V. Jensen's Charity Foundation funded a new VHF repeater, which was installed on the mountain Dombjerg to secure a better VHF radio coverage in Zackenbergdalen, Store Sødal, Young Sund, the inner part of Tyrolerfjord and at the sea outside Daneborg. The VHF repeater was flown to Dombjerg with a helicopter on 15 August 2004 and installed during the night between 15 and 16 August 2004. The VHF repeater has been working well and the VHF radio communication in the area has improved considerably.

International cooperation

Zackenberg Research Station is still a member of the networks ENVINET (European Network of Arctic-Alpine Environmental Research) and SCANNET (Scandinavian / North European Network of Terrestrial Field Bases) and is still involved in the establishment of CEON (Circum-Arctic Environmental Observatories Network).

It has been a major objective to secure that the very extensive data material collected by Zackenberg Basic shall be available to anyone interested immediately after the quality control, which normally takes less than one year. The baseline data collected by Zackenberg Basic has been provided to any scientists or monitoring programme asking for the data. Zackenberg Basic has further been involved in or contributed to a large number of international organisations, programmes and networks including Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Arctic Climate Impact Assessment (ACIA), International Tundra Experiment (ITEX), The Global Observation research Initiative in Alpine Environments (GLORIA), Global Runoff Data Center (GRDC), Global Terrestrial Observing System (GTOS), Circumpolar Active Layer Monitoring Programme (CALM), Arctic Coastal Dynamics (ACD), Arctic Birds Breeding Conditions Survey (ABBCS) and Pan-Arctic Shorebird Researcher Network (PASRN).

Extension and restoration of the facilities

The existing shed housing the generators was extended a bit in 2004 to give room for a new generator.

Members of *Nordøstgrønlands Kompagni Nanok* made significant restorations in Daneborg to the house *Kystens Perle* to improve the overall condition of the building and the accommodation facilities. The restoration of *Kystens Perle* was made possible through generous grants from Aage V. Jensen's Charity Foundation.

A new accommodation facility, a power station and a boat house at Zackenberg Research Station have been wanted for several years. Hopefully they may soon be build, as the conditions set by Aage V. Jensen's Charity Foundations for funding the building of the houses were agreed upon by the Greenland Home Rule, Asiaq (Greenland Survey), the Ministry of Science, Technology and Innovation and Danish Polar Center late in 2004. Accordingly it is now the plan to build the houses in 2006 and to have them ready for the expectedly increasing research activity at Zackenberg Research Station during the International Polar Year (2007-8).

Zackenberg Basic workshop

A Zackenberg Basic Workshop was held in April 2004 to discuss the preparation of a report of the first ten years of research and monitoring at Zackenberg. The workshop was held outside Copenhagen, and 42 scientists participated. A draft framework for the book was prepared, a time schedule was agreed upon, and an editorial group with five editors was appointed. A total of more than 50 authors will be involved in the preparation of the book which is planned to be published by an international publishing company in 2007. The Zackenberg Basic Workshop was funded partly by Danish Environmental Protection Agency and partly by the participants.

Plans for the 2005 field season

In 2005, we expect that the activity level at Zackenberg measured in bed nights spent at the station during late May – early September will be approximately the same as in 2004.

We plan to open the station a bit earlier than in the preceding years due to the early snow melt during the recent years. Especially for the GeoBasic programme it is important to be at the station before the snow melt really accelerate and large snow free areas start to appear.

We plan to ship another new 38 kW generator to Zackenberg in the late part of the 2005 field season.

Further information

Details about Zackenberg Research Station and the study area at Zackenberg have been given in previous annual reports (Meltofte and Thing 1996, 1997; Meltofte and Rasch, 1998; Rasch 1999; Caning and Rasch 2000, 2001, 2003; Rasch and Caning 2003, 2004) and the information is also available on the Zackenberg website (www.zackenberg.dk). The ZERO Site Manual has information for scientists planning to use Zackenberg Research Station and is found together with an application form at the Zackenberg website. The address of the secretariat is: The Zackenberg Research Station Secretariat, Danish Polar Center, Strandgade 100H, DK-1401 Copenhagen K, Denmark, phone (+45) 32880100, fax (+45) 32880101, e-mail mr@dpc.dk.

2 Zackenberg Basic: The ClimateBasis and GeoBasis programmes

Charlotte Sigsgaard, Dorthe Petersen, Louise Grøndahl, Kisser Thorsøe, Hans Meltofte, Jørgen Hinkler, Thomas Friborg, Birger Ulf Hansen and Mikkel Tamstorf

The objective of GeoBasis and ClimateBasis is to provide long term data of climatic, hydrological and terrestrial variables describing the dynamics of the physical and geomorphological environment at Zackenberg. GeoBasis is operated by the National Environmental Research Institute, Department for Arctic Environment, in co-operation with Institute of Geography, University of Copenhagen. Since 2003, GeoBasis has been funded by the Danish Environmental Protection Agency as part of the environmental support programme Dancea – Danish Cooperation for Environment in the Arctic. ClimateBasis is funded by the Greenland home rule and operated by ASIAQ, Greenland Survey, who operates and maintains the climate station and the hydrometric station.

The monitoring includes meteorological measurements, seasonal and spatial variations in snow cover and local microclimate in the Zackenberg area, the water balance of Zackenbergelven drainage basin, the sediment, solute and organic matter yield of Zackenbergelven, the seasonal development of the active layer, temperature conditions and soil water chemistry of the active layer, and the dynamics of selected coastal and periglacial landscape elements.

More details about the GeoBasis programme, sampling procedures, instrumentation, locations and installations are given in the GeoBasis Manual, which is available from the Zackenberg homepage: www.zackenberg.dk. Through this homepage all validated data from the Zackenberg Basic monitoring will become accessible when the ZERO Database (see below) is implemented. Until then, data collected by ClimateBasis and GeoBasis are available and may be ordered free of charge from ASIAQ (dop@asiaq.gl) and Institute of Geography (cs@geogr.ku.dk), respectively.

In the following section ClimateBasis and GeoBasis monitoring data are summarised and the season 2004 presented. Location of most GeoBasis and ClimateBasis stations and plots referred to in the text, are given in Fig. 2.1.

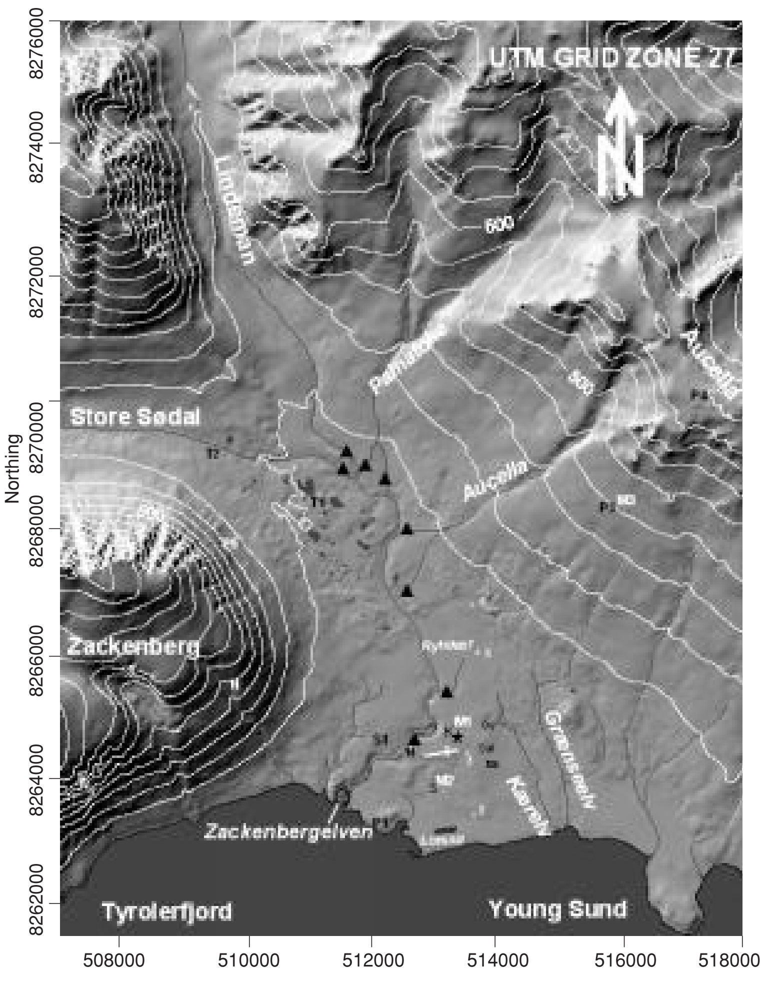

Figure 2.1. Location of GeoBasis and ClimateBasis stations and plots. The climate station is marked by an asterix. H= Hydrometric station. M1= Micrometeorological station. M2 and M3= Snow and micrometeorological stations. Triangles = Water sampling sites from tributaries to Zackenbergelven. N = Nansenblokken. K, S, Dry, Sal, and Mix = Soil water sites. P1, P3, P4, P5, S1, T1 and T2 = TinyTag temperature sites. Small crosses (x) = Snow stakes 2, 3, 5 and 6.

2.1 Meteorological data

The meteorological station at Zackenberg was constructed in the summer of 1995. Technical specifications of the station are described in Meltofte and Thing (1996). In 1997, the radiation sensors from the eastern mast were moved to a separate mast (Meltofte and Rasch 1998). Once a year the

	1996	1997	1998	1999	2000	2001	2002	2003
Yearly mean values								
Air temperature, 2 m above terrain (°C)	–9.2	–10.1	–10	–9.5	–10.0	–9.7	–8.6	–9.2
Air temperature, 7.5 m above terrain (°C)	–8.5	–9.3	–9.4	–8.9	–9.4	–9.2	–	–8.7
Relative air humidity 2 m above terrain (%)	66	69	73	70	70	71	72	74
Air Pressure (hPa)	1008.8	1007	1010	1006.3	1007.6	1008.8	1008.7	1007.8
Incoming shortwave radiation (W/m^2)	85	162	171	100	107	112	105	104
Outgoing shortwave radiation (W/m^2)	36	74	70	56	52	56	54	49
Net Radiation (W/m^2)	9	9	12	4	14	13	18	8
Wind Velocity, 2 m above terrain (m/s)	2.6	3	2.6	3.0	2.4	2.7	2.6	2.6
Wind Velocity, 7.5 m above terrain (m/s)	3	3.4	3.2	3.7	3.1	3.2	3	3.1
Precipitation (mm w.eq.), total	223	148	181	161	176	236	174	263
Yearly maximum values								
Air temperature, 2 m above terrain (°C)	16.6	21.3	13.8	15.2	19.1	12.6	14.9	16.7
Air temperature, 7.5 m above terrain (°C)	15.9	21.1	13.6	14.6	18.8	12.4	–	16.7
Relative air humidity 2 m above terrain (%)	99	99	99	99	100	100	100	100
Air Pressure (hPa)	1041.5	1035.4	1035.6	1035.3	1035.9	1042.5	1037.9	1037.9
Incoming shortwave radiation (W/m^2)	803	832	833	889	810	818	920	802
Outgoing shortwave radiation (W/m^2)	593	566	632	603	581	620	741	549
Net Radiation (W/m^2)	577	634	557	471	627	602	540	580
Wind Velocity, 2 m above terrain (m/s)	17.6	22.5	25.6	19.3	20.7	20.6	21.6	20.6
Wind Velocity, 7.5 m above terrain (m/s)	22.2	26.2	29.5	22.0	23.5	25.0	25.4	23.3
Yearly minimum values								
Air temperature, 2 m above terrain (°C)	–33.7	–36.2	–38.9	–36.3	–36.7	–35.1	–37.7	–34
Air temperature, 7.5 m above terrain (°C)	–31.9	–34.6	–37.1	–34.4	–34.1	–33.0	–	–32.4
Relative air humidity 2 m above terrain (%)	20	18	31	30	19	22	23	17
Air Pressure (hPa)	956.2	953	974.7	960.6	968.5	972.2	954.5	967.4
Incoming shortwave radiation (W/m^2)	0	0	0	0	0	0	0	0
Outgoing shortwave radiation (W/m^2)	0	0	0	0	0	0	0	0
Net Radiation (W/m^2)	–86	–165	–118	–100	–129	–124	–148	–98
Wind Velocity, 2 m above terrain (m/s)	0	0	0	0	0	0	0	0
Wind Velocity, 7.5 m above terrain (m/s)	0	0	0	0	0	0	0	0

Table 2.1. Annual mean, maximum and minimum values of climate parameters for 1996 to 2003.

sensors are calibrated and checked by ASIAQ, Greenland Survey.

Meteorological data from 2003

In 2003, the mean air temperature measured 2 m above terrain was –9.2°C, the maximum temperature of 16.7°C was measured 17 July (21:00) and the minimum temperature of –34.0°C was measured 27 January (01:00) (Table 2.1). The period with frequent temperatures above 0°C started in late May and ended in late September (Fig. 2.2). The annual mean air temperature was high, though not as high as in the very warm year of 2002 (Table 2.2). January 2003 had the coldest monthly mean temperature measured in the years 1996-2003. February, July and August were warmer than usually with monthly mean temperatures in July and August being the warmest in the period 1996-2003.

The total amount of measured precipitation in 2003 was 263 mm. Only 16 mm of the total precipitation fell during the summer period and the rain events occurred primarily in June and July (Table 2.2).

The mean air pressure was 1007.8 hPa and the air pressure was generally more stable during summer than winter (Fig. 2.2).

Relative humidity ranged from 21% (9 November) to 100% with a mean of 74%. The very low relative humidities are observed both summer and winter during *Föhn* situations.

Net radiation ranges from –98 to 573 W/m^2 with a mean of 8 W/m^2. As observed in the previous years, monthly mean net radiation was positive in June, July, August and September and negative in the remaining months.

Mean wind speed 2 m and 7.5 m above the ground was 2.6 m/s and 3.1 m/s, respectively. The highest 10 minutes mean value was 20.6 m/s at 2 m above ground

		Shortwave Rad. W/m² mean in	W/m² mean out	Net Rad. W/m² mean	PAR μmol/m²/s mean	Air temperature °C mean 2 m	°C minimum 2 m	°C max 2 m	Precipitation mm total	Wind velocity m/s mean 7.5 m	m/s max 7.5 m	Wind direction dominant 7.5 m
	Jun	291	106	107	–	1.9	–3.7	13.6	4	1.8	9.9	SE
1996	Jul	208	20	137	–	5.8	–1.5	16.6	7	2.7	12.1	SE
	Aug	142	19	69	–	4.4	–4	14.1	2	2.9	12.5	S
	Jun	216	107	88	–	2.2	–4.4	12.0	23	2.4	14.1	ESE
1997	Jul	225	23	130	–	3.7	–1.0	15.3	28	2.7	13.8	SE
	Aug	174	21	74	–	5.0	–3.0	21.3	16	2.8	13.3	SE
	Jun	269	172	51	–	0.9	–3.0	9.6	5	1.6	8.1	SE
1998	Jul	204	20	126	–	4.7	–2.6	13.8	33	2.2	12.1	SE
	Aug	123	12	64	–	4.6	–1.8	11.5	55	2.4	12.2	ESE
	Jun	294	206	33	–	1.5	–4.5	10.4	2	2.3	15.0	–
1999	Jul	212	32	123	–	6.2	–0.7	15.1	21	2.6	14.8	–
	Aug	143	16	73	–	2.9	–2.7	15.2	11	2.5	14.9	SE
	Jun	294	103	126	–	1.9	–6.2	11.7	10	2.1	15.1	SE
2000	Jul	228	27	141	–	5.3	–1.2	19.1	13	2.9	15.9	SE
	Aug	153	19	82	–	4.0	–3.5	11.6	0	2.3	13.4	SE
	Jun	293	168	67	–	2.1	–4.9	11.9	25	2.1	13.3	–
2001	Jul	231	27	146	–	4.9	–1.5	11.8	7	2.9	13.1	–
	Aug	180	20	84	–	5.8	–0.8	12.6	21	2.8	14.4	–
	Jun	344	151	113	–	2.6	–2.8	14.9	1	1.6	6.8	SE
2002	Jul	205	23	105	424	5.7	–0.9	13.8	3	2.6	9.9	SE
	Aug	128	15	51	272	5.0	–3.1	11.6	21	2.8	12.9	SE
	Jun	294	108	106	612	2.2	–4.8	14.7	7	1.6	5.4	SE
2003	Jul	211	26	96	431	7.7	1.8	16.7	6	2.8	14.2	SE
	Aug	151	20	56	299	6.6	–0.5	15.4	3	2.5	10.1	SE
	Jun	279	73	111	571	2.5	–3.4	19.1	3	2.3	13.6	SE
2004	Jul	225	30	95	464	7.2	–0.7	19.0	10	2.8	10.5	SE
	Aug	150	20	62	300	5.6	–1.4	17.2	4	2.4	12.6	SE

Table 2.2. Climate parameters for June, July and August, 1996 to 2004. Wind velocity max is the maximum of 10 minutes mean values.

and 23.3 m/s at 7.5 m above ground – both measured during a storm 9 November. Wind speeds are generally higher in winter than in summer (Fig. 2.2). In 2003, winds came from N and NNW 40% of the time, mainly in the winter period, and from ESE to SSE c. 22% of the time, mainly in the summer period (Table 2.3 and 2.4). The annual wind statistic for 2003 is in good agreement with the years 1997, 1998, 2000 and 2002. Wind statistics for the remaining years are not given due to significant periods with missing data.

Meteorological data from 2004

Mean values of the climatic parameters, from June, July and August, show the same trend as in previous years (Table 2.2). In 2004, the monthly mean temperatures became positive in June (Table 2.3). The maximum temperature in June (19.1°C measured 20 June 14:00) was the highest measured since monitoring began in 1996, and maximum temperatures in July and August were among the highest measured (Table 2.2).

At the climate station the last snow disappeared 14 June, resulting in a large positive net radiation in the following period.

Dominant wind direction was NNW from January until April and SE from May until August (Fig. 2.2 and Table 2.3). The change in dominating wind direction took place a bit earlier than in previous years. High wind speeds (10 minutes averages of up to 20 m/s) were recorded during several events; 1 January, 16 February and 13 April. During the storm 1 January, wind gusts of up to 40 m/s were recorded. At the beginning of the field season there were several signs reflecting high wind speeds during winter. The toilet house was moved from its base and large containers were lifted and turned by the wind. Also the snow distribution was influenced by heavy wind events. Areas exposed to wind were blown free of snow and accumulations were observed in lee areas.

The precipitation during summer (June, July and August) was 17 mm, which is among the lowest measured and quite similar to the amount of summer precipitation in 2003 (Table 2.2). The last part of July and early part of August were most wet. At several occasions, new snow was observed in the mountains and down to about 4-500 m a.s.l., but during June, July and August no new snow accumulated on the ground in the valley.

ASIAQ's technicians visited Zackenberg in the period from 3 August to 16 August 2004. During their inspection, the climate station received a thorough renovation including replacement of several sensors and cables.

Positive degree days calculated on a monthly basis as the sum of days with daily mean air temperatures above 0°C are shown in Table 2.5. Since 1998, a steady increase in the annual sum of positive degree days has been observed and especially since 2000, the increase has been significant. So far, 2003 has been the year with the highest sum of positive degree days out of the nine years recorded. Positive degree days have been observed from May to September every year, but in the last two years they were also observed in April. In October positive degree days has only been observed in 1997, 2001 and 2002.

If all episodes of positive degrees, also short ones, are included (Table 2.6), February is the only month where temperatures above the freezing point have not occurred. In all other months, small fluctuations above the freezing point have been measured.

If these warm episodes happen when there is snow on the ground, melt water may seep through the snow and create ice crusts at different depths in the snow pack which may cause difficulties for animals seeking for food below the snow.

2.2 Snow, ice and permafrost

New micrometeorological stations

Monthly mean values of selected parameters from the new snow and micrometeorological stations M2 and M3 (see section 2.2 in Rasch and Caning 2004) are reported in Table 2.7 and Figs 2.3 and 2.4. Unfortunately, data are missing from periods in January and February as both stations were running low in battery and stopped logging during the darkest period. The problem will be solved by reducing the logging frequency for the most power consuming sensors during the dark months or by increasing the battery capacity. Due to the missing data, it has not been possible to calculate monthly mean values for February, and monthly mean values for January are based on data from 27 days instead of 31 days.

During the coldest winter months as well as the warmest summer months the mean monthly temperature is higher at M3 (420 m a.s.l.) than at M2 (17 m a.s.l.). Only in September, November, April and May the monthly mean air temperature is lower at M3 (Table 2.7). This reflects frequent periods of temperature inversions in the valley. In Fig. 2.5 periods of temperature inversion have a negative value, whereas periods without have a positive value. The largest increase in temperature with altitude was measured 6 and 7 March, where the mean daily air tempera-

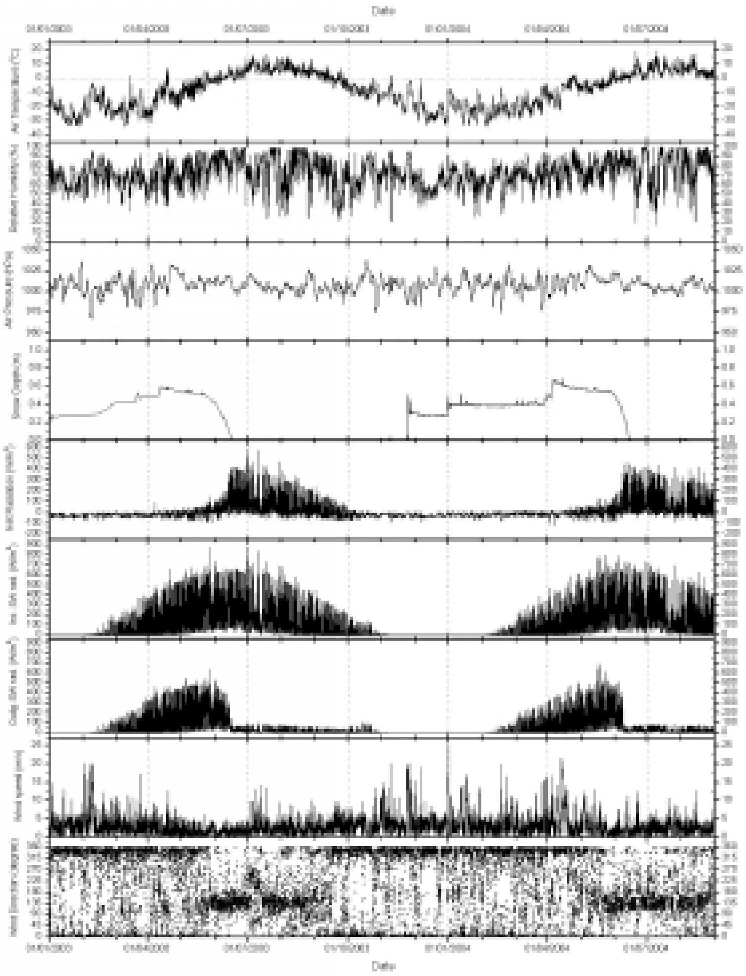

Figure 2.2. Variation of selected climate parameters during 2003 and part of 2004. From above: Air temperature, relative humidity, air pressure, snow depth, net radiation, incoming short wave radiation, outgoing short wave radiation, wind speed and wind direction. Wind speed and direction are measured 7.5 m above terrain; the remaining parameters are measured 2 m above terrain.

	Air Temperature °C 2.0 m	°C 7.5 m	Relative Humidity %	Air Press. hPa	Net Rad. W/m²	Shortwave Rad. W/m² In	W/m² Out	Wind Velocity m/s 2.0 m	m/s 7.5 m	Dominant Wind Dir. 7.5 m
2003										
Jan	–24.4	–23.0	65	1009.6	–26	0	0	2.3	3.1	NNW
Feb	–17.0	–16.1	73	999.0	–20	8	6	3.1	4.6	NNW
Mar	–21.5	–20.6	65	1005.6	–22	61	51	2.8	3.3	NNW
Apr	–13.7	–13.0	69	1015.2	–19	165	140	2.2	2.5	NNW
May	–5.6	–5.3	77	1010.9	–5	266	213	1.5	1.8	N
Jun	2.2	1.8	86	1009.6	106	294	108	1.5	1.6	SE
Jul	7.7	7.3	76	1007.6	96	211	26	2.5	2.8	SE
Aug	6.6	6.5	77	1007.0	56	151	20	2.2	2.5	SE
Sept	0.6	0.8	66	1003.1	0	75	11	2.5	3.0	N
Oct	–8.9	–8.2	69	1010.6	–26	17	8	2.8	3.5	N
Nov	–12.8	–12.3	73	1005.4	–21	0	0	4.2	5.0	NNW
Dec	–23.7	–22.2	59	1008.9	–29	0	0	3.1	3.7	NNW
2004										
Jan	–20.1	–19.4	66	1009.1	–20	0	0	4.0	4.6	NNW
Feb	–22.9	–21.5	65	1008.8	–23	6	6	2.9	3.4	NNW
Mar	–17.1	–16.5	72	1005.7	–14	54	46	3.1	3.6	NNW
Apr	–7.9	–7.5	75	1009.9	–10	136	114	4.0	4.7	NNW
May	–4.5	–4.6	76	1016.5	3	259	202	2.7	3.1	SE
Jun	2.5	2.1	82	1011.4	111	279	73	2.1	2.3	SE
Jul	7.2	6.8	75	1002.8	95	225	30	2.4	2.8	SE
Aug	5.6	5.6	79	1008.6	62	150	20	2.0	2.4	SE

Table 2.3. Monthly mean values of climate parameters, January 2003-August 2004.

ture measured at M3 was 13.3°C higher than at M2 (Fig. 2.5). The longest period of continuous inversion was measured from 11-22 December and the longest period without inversion was measured from 13 September to 9 October (Fig. 2.5).

There is a high negative correlation between differences in relative humidity and differences in temperatures between M2 and M3. When the temperature is higher at M3 than at M2, the relative humidity is lower at M3 than at M2 (Fig. 2.5). During summer, these episodes of inversion are characterised by low clouds or fog coming into the valley from the sea. Station M3 is located above the clouds where the sky is clear, whereas station M2 is located in the valley and influenced by the cooling and shading effects from the clouds. Low wind speeds also characterise these episodes. Fig. 2.6 illustrates the phenomenon with a photo from Nansenblokken taken on 27 June, where low clouds covered the valley while the weather above was fine.

Highest temperature at M3 was 17.9°C measured 11 August (17:30), and at M2 19.0°C measured 20 June (11:30).

Snow depth

In 1997, automatic point measurements of snow depth began in Zackenbergdalen near the meteorological station (Meltofte and Rasch 1998). Snow depth during all seven winters are summarised in Table 2.8, and the accumulation is shown for all years in Fig. 2.7. In the winter 2003/2004 the snow depth reached 0.1 m on 24 November. The maximum measured snow depth, reached in early April, was 0.7 m, which is in the low end of the range recorded (0.5 m in 1999/2000 and 1.3 m in 1998/1999) and about the same level as in the winters 2000/2001 and 2002/2003.

In Table 2.8, the snow depth at the time when the ground temperature reaches 0°C is given as "snow depth at spring". Assuming a density for this compact snow of 400 kg/m^3 an approximate value for the winter precipitation can be calculated (see next section). These values are in reasonable accordance (0-40% difference) with the precipitation measured at the climate station during winter in five out of seven years. For the two years with the largest amount of snow during winter, the values based on "snow depth at spring" are more than twice the measured precipitation.

	1997			1998			2000			2002			2003		
	Fre-quency %	Velocity, m/s mean	max	Fre-quency %	Velocity m/s mean	max	Fre-quency %	Velocity m/s mean	max	Fre-quency %	Velocity m/s mean	max	Fre-quency %	Velocity m/s mean	max
N	10.1	3.9	26.2	7.9	4.2	29.5	10.8	3.8	20.5	19.9	4.7	23.5	19.5	4.2	22.0
NNE	3.9	3.5	19.5	2.5	2.3	14.4	2.9	1.8	14.2	4.3	3.1	25.4	3.9	2.6	18.5
NE	2.9	2.8	19.4	2	2.9	17.9	2.5	2.7	15.3	2.5	2.1	10.9	2.4	2.0	15.8
ENE	3	2.2	12.9	2.4	1.9	12.1	2.8	2.2	10.4	2.7	2.7	15.6	2.9	2.7	17.4
E	5.1	2.2	8.3	4.3	1.9	8.0	4.7	2.2	8.1	3.7	2.1	10.4	3.6	2.1	10.0
ESE	7.3	2.3	10.3	7.9	2.1	6.7	8.0	2.3	9.8	6.7	2.2	9.9	5.9	2.2	10.1
SE	7.2	2.5	18.1	8.2	2.1	7.9	9.5	2.7	7.5	8.4	2.4	8.3	9.1	2.5	9.5
SSE	4.1	2.3	16.2	4.5	2.1	8.3	4.7	2.5	8.4	6.7	2.5	8.4	6.8	2.5	7.9
S	3.3	2.5	9.9	4.2	2.2	7.8	3.3	2.4	6.5	4.2	2.6	8.6	3.8	2.4	7.6
SSW	2.2	2.3	11.5	3.3	2.1	7.0	2.2	2.1	7.8	3.3	2.5	13.4	3.2	2.3	8.1
SW	2	2.2	12.2	3.1	2.1	8.5	2.2	2.1	7.8	2.6	2.1	8.2	2.7	2.1	8.0
WSW	2.5	2.5	15.9	3.3	2.4	7.5	2.4	2.5	10.5	2.6	2.3	8.0	3.0	2.4	8.2
W	2.7	2.6	16.9	3.1	2.1	9.8	2.4	2.5	23.5	2.7	2.4	16.9	3.4	3.0	23.3
WNW	3.7	2.9	15.9	3.8	2.5	14.2	3.6	2.7	19.0	2.6	2.7	16.2	3.0	2.8	19.3
NW	8	3.9	25.1	7.7	3.8	21.1	7.1	3.7	18.3	4.7	3.2	15.2	5.9	3.4	21.8
NNW	27.9	5.1	25.8	26.8	5.1	23.5	26.7	5.0	20.1	18.1	5.0	24.5	20.8	4.4	20.9
Calm	4.1			5.0			4.3			4.2			5.0		

Table 2.4. Wind statistics for 1997, 1998, 2000, 2002 and 2003 based on wind velocity and direction measured 7.5 m above terrain. Calm is defined as wind speed lower than 0.5 m/s. Max speed is maximum of 10 minutes mean values. The frequency for each direction is given as percent of the time for which data exist. Missing data amount to less than 8% of data for the entire year and less than 20 days within the same month.

This clearly demonstrates the challenges in measuring solid precipitation which constitutes the main part of the precipitation in this environment. If snow falls during windy conditions, which is often the case, catchments at the precipitation gauge may be significantly inadequate. Likewise, blocking snow may prevent precipitation to flow into the container and thereby lead to overflow – or a frozen gauge may cause a delay in data registration. At the sonic sensor where the snow depth is measured, redistribution of the snow by the wind may be a problem. In order to overcome these problems more effort will be made in combining different methods. Now, measurement of snow density and snow depth at the end of winter has been implemented in the GeoBasis snow monitoring programme and data will be used to calculate the snow water equivalent (SWE) which is an important tool to evaluate the precipitation measurements from the climate station.

To obtain a better description of the spatial distribution of snow in the drainage basin, manual snow depth measurements will be performed in a larger area. Preferably, these measurements should be performed prior to spring melt for a calculation of the end of winter accumulation.

Maximum snow depths at the snow- and micrometeorological stations M2 and M3 were 175 cm and 25 cm, respectively. Only very sparse snowfall was observed before 24 November, where suddenly during one snow storm 0.4 m of snow fell in the valley (Figs 2.2 and 2.7), and 1.75 m accumulated in the snow patch where M2 is located (Fig. 2.3). No continuous snow pack was located at M3. A maximum of 0.25 m of snow was reached at M3, but several times the frozen ground was blown free of snow, which can also be recognised from the soil temperatures (Fig. 2.4 and Table 2.7). Due to the insulating effect of the snow, soil temperatures rise as soon as snow accumulates on the ground (Fig. 2.3). From 27 May, there was no snow at M3, whereas snow persisted until 24 June at M2. In the valley, snowmelt was complete under the snow mast 14 June.

In Table 2.9 snow depth at the end of May are given as highest daily average in the period 21-31 May. Snow depth is measured at fixed positions representing a transect through the main study area in the valley (location of snow stakes are given in Fig. 2.1). At M2, the snow depth in early June was influenced by a depression in the snow underneath the sensor. This is probably caused by reflections from the cross arm combined with wind being canalised under the solar panel. Compared to the surroundings the depression was c. 25 cm deep.

The major part of the winter precipita-

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
April									0.2	1.1
May		1.1	1.3	0.1	3.6	0.5	0.5	18.2	3.3	4.1
June		63.7	63.7	32.5	52.9	71.8	68.2	99.2	74.2	73.9
July		181.0	115.4	138.4	192.7	164.4	152.0	175.6	237.2	222.2
August		112.9	154.2	143.6	89.2	126.0	181.2	152.5	203.2	168.1
September	11.7	15.3	4.5	11.3	19.7	5.7	31.1	41.2	42.5	
October			1.5				0.3	1.8		
Sum	**11.7**	**374.1**	**340.6**	**325.8**	**358.0**	**368.4**	**433.2**	**488.4**	**560.6**	**469.4**

Table 2.5. Positive degree days calculated on a monthly basis as the sum of daily mean air temperatures above 0°C. Calculations are based on air temperatures from the climate station (2 m above ground).

tion 2003/2004 fell during three main events, 24 November, 1 January and in early April (Figs 2.2-4).

Snow water equivalent

When the research station opened 1 June 2004, the snow had already started melting. Temperatures from the soil surface show that the snow in the valley had already become isothermal (0°C throughout the snowpack).

Snow densities were measured 2 June at all the stations given in Table 2.9 and based on these data the snow water equivalent (SWE) was calculated. Results from actual bulk densities of the snow throughout the valley ranged from 230 kg/m^3 to 540 kg/m^3, which is quite a large variation. Results from the snow pack around the climate station reveal that the assumed density for the snow of 400 kg/m^3 used to calculate SWE in Table 2.8 is a good approximation.

At the climate station, the snow density was measured on a regular basis throughout the ablation period. Results show an increasing density as the snow becomes more and more saturated with melt water. Likewise, snow density was measured at different altitudes, showing an increasing density with altitude.

Within the first days of the field season, snow depths were measured in the valley using the new snow depth probe (Magnaprobe), which automatically logs the position (GPS) and the depth of snow. The system made it possible to cover a larger area and extend the number of point measurements, thereby obtaining a better understanding of the spatial distribution of the snow.

Snow cover

Snow cover in 2004 was relatively limited in extent. The snow cover was less extensive than in other years with similar amounts of snow, indicating significant relocation of snow by the wind during winter. Large accumulations of snow were found in and along the riverbed/channel, whereas the snow cover was sparse in the exposed areas. Spring snow cover on 10

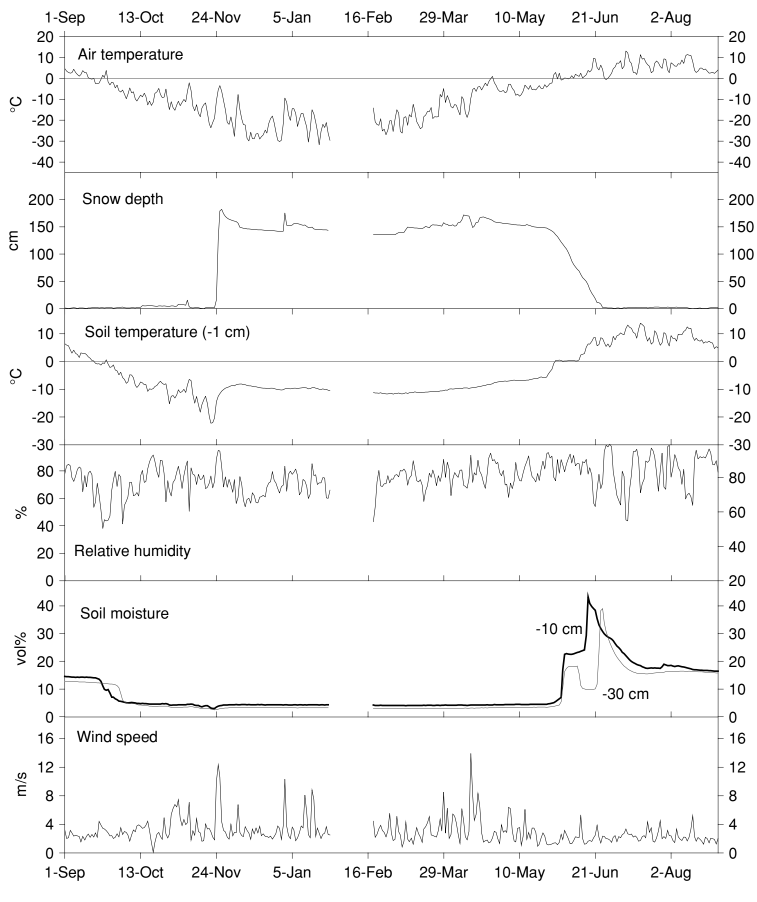

Figure 2.3. Daily mean values of selected parameters from snow- and micrometeorological station M2 (17 m a.s.l.) in the period September 2003 to August 2004. From above: Air temperature, snow depth, soil temperature 1 cm below surface, soil moisture 10 cm and 30 cm below surface, wind speed.

	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
September	452.8	507.0	213.7	366.0	567.1	262.8	870.8	1106.0	1141.1
October		4.7	36.4	1.7	5.9	13.1	23.5	85.2	0.6
November	10.4	0.3		2.6	14.5				5.6
December	1.8	4.3	25.7		14.4		64.0	28.0	
January	1.8	4.3			14.4				
February									
March	22.1		18.0					2.0	
April	12.6		2.4	27.5				62.4	44.2
May	158.6	72.5	46.6	192.9	52.2	32.2	536.1	126.8	148.3
Sum	660.0	593.1	342.9	590.7	668.5	308.1	1494.4	1410.4	1339.8

Table 2.6. Positive degree hours calculated for each winter on a monthly basis as the sum of hours with temperatures above 0°C. Calculations are based on air temperatures from the climate station (2 m above ground).

June, which has been chosen as a good early season indicator for biological conditions, was even less extensive than in the otherwise snow poor year of 2000 (Table 2.10). This was particularly so in the subzones of Zackenbergdalen located below 50 m a.s.l. and above 300 m a.s.l.

Rate of melt and snow cover depletion curves for the central part of Zackenbergdalen (1998-2004) are shown in Fig. 2.8. When the 2004 melting season is compared to other seasons, particular attention should be paid to the 2003 season. The seasons 2003 and 2004 both had limited snow cover and rather similar snow cover depletion. However, the beginning of the 2004 season turned out differently, with the most intense snowmelt during the first weeks of melt-off. This is due to the fact that even though 2003 was the warmest season recorded so far at Zackenberg, the early part of the season was among the coldest – meaning that continuous positive daily mean temperatures (more than three successive days) did not start before 8 June in 2003, whereas in 2004 it started already 29 May.

The snow depletion curves are based on the digital photos captured at the photo monitoring station at Nansenblokken (477 m a.s.l.) on the East facing slope of Zackenbergfjeldet. In June 2004, the digital camera covering the most southern part of the valley and Young Sund (Camera 1) was replaced due to operational failures. The new digital camera is a KODAK model RDC 365.

Ice melting on ponds and lakes

In accordance with the little extent of the spring snow cover and the high spring temperatures (only 2002 was warmer during 21 May – 10 June), ice melt on the ponds north and south of the research station took place earlier than recorded before in our nine years of observations (Table 2.15). Already in early June, all ponds in Gadekæret and Sydkærene were free of ice. Also Lomsø became ice free earlier than before (Table 2.15), i.e. by 3 July all ice had gone. Even the two moni-

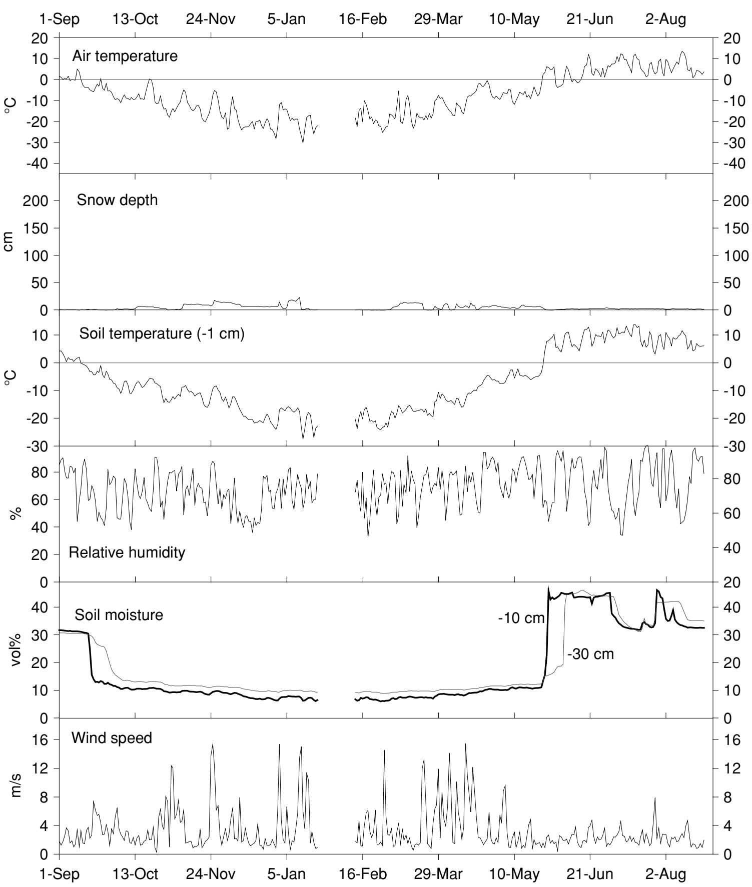

Figure 2.4. Daily mean values of selected parameters from snow and micrometeorological station M3 (420 m a.s.l.) in the period September 2003 to August 2004. From above: Air temperature, snow depth, soil temperature 1 cm below surface, soil moisture 10 cm and 30 cm below surface, wind speed.

M2	Month	Wind speed 2.5 m m/s	Rel. hum 2.5 m %	Air temp 2.5 m °C	Soil temp –1 cm °C	Soil temp –10 cm °C	Soil temp –30 cm °C	Soil temp –60 cm °C	Soil moist –10 cm %	Soil moist –30 cm %
	2003									
	Sep	2.6	68.2	0.6	1.1	1.6	1.4	0.4	12.4	12.3
	Oct	3.0	72.1	–8.7	–8.3	–6.8	–4.3	–1.8	4.8	4.6
	Nov	4.5	76.1	–12.9	–13.1	–12.1	–10.2	–6.9	4.0	3.2
	Dec	2.9	65.2	–23.9	–9.2	–8.9	–8.2	–7.2	4.4	3.3
	2004									
	Jan	(3.8)	(-65)	(-20.7)	(-9.8)	(-9.4)	(-8.7)	(-7.5)	(4.3)	(3.3)
	Feb									
	Mar	3.0	75.8	–17.3	–11.1	–10.7	–10.1	–9.0	4.1	3.1
	Apr	3.8	78.4	–7.9	–8.9	–8.9	–8.7	–8.3	4.3	3.2
	May	2.6	79.0	–4.3	–5.6	–5.9	–6.4	–6.8	4.6	3.5
	Jun	2.1	82.7	2.2	3.7	2.5	0.6	–1.6	27.1	17.5
	Jul	2.5	77.0	6.8	9.8	8.4	5.6	0.7	20.0	17.1
	Aug	2.1	81.6	5.7	8.1	7.3	5.2	1.6	17.3	16.2

M3	Month	Wind speed 2.5 m m/s	Rel. hum 2.5 m %	Air temp 2.5 m °C	Soil temp –1 cm °C	Soil temp –10 cm °C	Soil temp –30 cm °C	Soil temp –60 cm °C	Soil moist –10 cm %	Soil moist –30 cm %
	2003									
	Sep	3.0	69.2	–1.8	–1.1	0.4	0.9	0.6	23.7	28.2
	Oct	3.1	63.6	–8.7	–8.7	–6.0	–4.0	–1.9	10.6	13.4
	Nov	4.7	70.0	–13.0	–11.6	–10.3	–9.1	–7.5	9.4	11.5
	Dec	2.5	55.2	–20.6	–18.7	–16.9	–15.2	–12.7	7.7	10.2
	2004									
	Jan	(5.2)	(62.1)	(-19.3)	(-19.6)	(-18.3)	(-17.3)	(-15.6)	(7.2)	(9.8)
	Feb									
	Mar	3.7	69.3	–15.6	–16.9	–17.0	–16.9	–16.4	7.4	9.6
	Apr	5.3	73.1	–9.0	–10.5	–11.3	–11.9	–12.6	9.1	10.7
	May	2.6	72.7	–4.9	–2.9	–4.8	–6.0	–7.4	14.5	12.6
	Jun	2.2	78.0	2.4	8.3	6.1	2.5	–0.9	43.9	39.3
	Jul	2.5	67.5	7.3	9.8	8.6	6.4	3.2	35.4	36.2
	Aug	2.1	75.1	5.9	7.6	6.9	5.5	3.3	34.4	38.5

Table 2.7. Monthly mean values of selected meteorological parameters from M2 (17 m a.s.l.) and M3 (420 m a.s.l.) from September 2003 to August 2004. Values from January are in brackets as they are based on data from 1-27 January for M2 and 1-23 January for M3.

tored lakes in Morænebakkerne, Langemandssø and Sommerfuglesø, melted earlier than recorded before (see chapter 3.5).

Teltdammen was dry already on 13 June, and in mid July the ponds in Gadekæret and Sydkærene began to dry out. Such dry conditions have only been recorded in similar early snowmelt and dry years like 2000 and 2003; see also section 2.1 and Table 2.2 on precipitation.

The first new ice on the ponds was recorded on 30 August.

Active layer depth

Development of the active layer (the layer above the permafrost that annually experiences freeze and thaw) starts as soon as snow disappears from the ground. The thaw rate was monitored throughout the season at two grid-plots; the homogenous, almost horizontal ZEROCALM-1 grid and the heteorogeneous ZEROCALM-2 grid, situated on a southernly exposed slope. A detailed description of the two sites was given in section 5.1.12 in Meltofte and Thing (1997). In ZEROCALM-1 the first

	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
Max. snow depth, meter	0.9	1.3	0.5	0.7	1.3	0.6	0.7
Max. snow depth reached	29 Apr	11 Mar	19 May	25 Mar	15 Apr	13 Apr	13 Apr
Snow depth exceeds 0.1m from	19 Nov	27 Oct	1 Jan	16 Nov	19 Nov	6 Dec	24 Nov
Snow depth is below 0.1m from	25 Jun	3 Jul	14 Jun	24 Jun	20 Jun	14 Jun	13 Jun
Snowdepth at spring, meter	0.58	0.91	0.38	0.50	0.70	0.28	0.48
Snowdepth at spring, mm w.e.	232	364	152	200	280	112	192
Winter precipitation, mm w.e.	182	176	149	177	130	175	238

Table 2.8. Key figures describing the amount of snow in seven winters; the maximum snow depth during the winter and the date at which it is reached, the date when the snow depth reaches 0.1 m in the beginning of the winter, and the date in spring when the depth gets below 0.1 m due to the melting snow. The snow depth, when the melting snow becomes saturated with water, is given as "snow depth at spring", see text. The equivalent amount of water is calculated assuming a density of 400 kg/m^3. Furthermore, the precipitation measured in the period when snow has been present on the ground is given as "winter precipitation".

grid point was free of snow 7 June and snowmelt was complete 19 June. One third of the gridpoints in ZEROCALM-2 were free of snow when we arrived 1 June and at several gridpoints the active layer had reached a depth of 60 cm. The seasonal snow patch, that affects the melt rate in ZEROCALM-2, disappeared 17 July, which is about one week earlier than observed before. Figs 2.9 and 2.10 show the seasonal development of the active layer in ZEROCALM-1 and ZEROCALM-2, respectively. At the end of the season, on 29 August 2004, the active layer in ZEROCALM-1 reached an average depth of 76 cm and in ZEROCALM-2 an average depth of 65 cm. For both sites, this is the deepest ever measured since 1997 where the grids were established (Table 2.11).

Data from the CALM-sites are reported to the circumpolar monitoring programme CALM (Circumpolar Active Layer Monitoring-Network-II (2004-2008) that is maintained by University of Delaware, Center for International Studies (www.udel.edu/Geography/calm).

The active layer measured at M3 (420 m a.s.l.) was deeper than at any other measured point in the valley. At M3 the active layer reached 108 cm on15 August whereas the deepest gridpoint in ZEROCALM-1 and ZEROCALM-2 was 90 cm and 97 cm. This is mainly ascribed to the facts, that snow disappeared earlier at M3 than in the valley and the daily mean temperatures measured at M3 was higher than at M2, especially during July (Fig. 2.5 and Table 2.7).

Soil temperature

At the climate station, soil and permafrost temperatures are recorded in a profile where sensors are placed in 10 levels below ground (Meltofte and Thing 1996). In 1998, the site was sealed with bentonit pellets in order to prevent seeping of water down the profile.

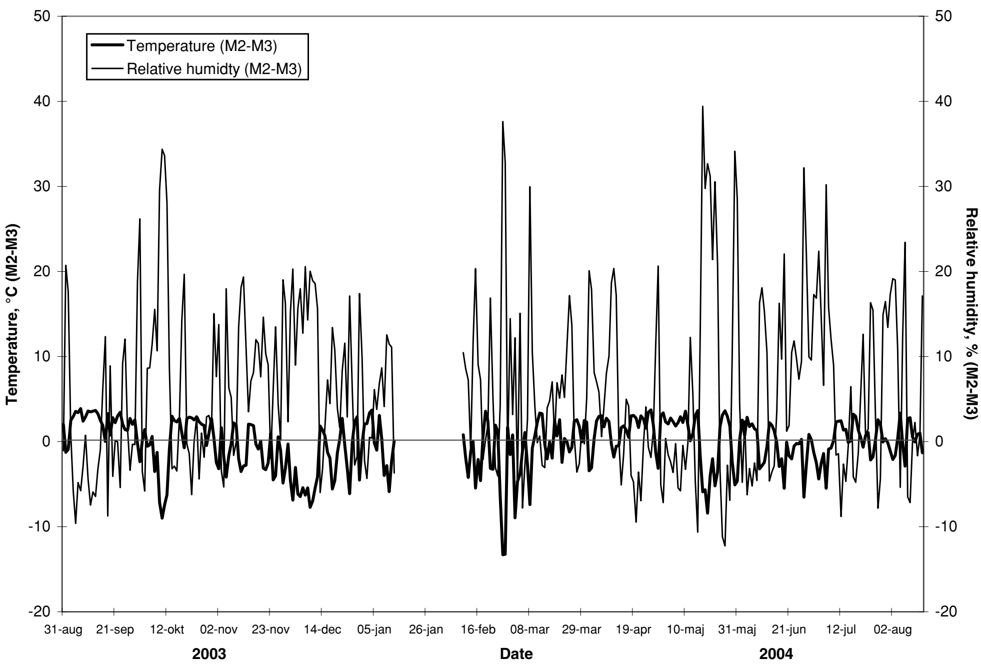

Figure 2.5. The difference in mean daily air temperature and mean daily relative humidity between M2 and M3. Positive values indicate lower values at M3 than at M2, whereas negative values indicate higher values at M3 than at M2.

	1998	1999	2000	2001	2002	2003	2004
0	–	>101	44	79	131	–	–
1	–	–	–	–	–	–	172
2	–	–	–	177	265	197	188
3	–	–	–	–	205	91	155
4	81	118	48	61	110	50	55
5	–	–	–	–	–	50	61
6	–	–	–	–	90	33	32
7	–	–	–	–	–	–	6

Table 2.9. Snow depth at eight permanent stations in Zackenbergdalen in late May 1998-2004 given as the highest daily average during 21-31 May. Stations 0, 1, 4 and 7 are registered with the sonic sensors at the hydrometric station, M2, the climate station snow mast and M3, respectively. Data from station 1 (M2) has been enhanced by 25 cm to compensate for the wind-created hollow under the sensor (see text).

The annual minimum, mean and maximum temperature for each depth is given in Table 2.12 for the years 1996-2003. The minimum and maximum temperatures in the different depths do not occur at the same time for the whole profile, as the temperature deeper in the profile has a delayed response to the changes in air temperature above the ground. Changes in the minimum temperatures from year to year are remarkably higher, than the changes in maximum temperatures (Table 2.12), reflecting the larger difference in mean air temperature during winter than during summer. Monthly mean temperatures for 2003 and first half of 2004 are given in Table 2.13. So far, the warmest mean annual temperatures at all soil depths have been measured in 2002, which was also the year with the highest mean annual temperature. Besides, the soil was isolated by a thick layer of snow during the winter 2001/2002.

Monthly mean soil temperatures from the snow and micrometeorological stations (M2 and M3) are given in Table 2.7. At these stations soil temperatures are measured continuously at 1 cm, 10 cm, 30 cm and 60 cm below the soil surface. Mean daily soil temperatures near the soil surface are shown in Figs 2.3 and 2.4. The warmer soil at M2 is a result of the insulating effect of the large seasonal snow patch.

Figure 2.6. Photo from Nansenblokken (477 m a.s.l.) taken 27 June 2004. Low clouds cover the valley resulting in an inversion in temperature between M2 and M3.

Temperature in different settings and altitudes

GeoBasis operates a total of 35 TinyTag dataloggers for temperature monitoring in different altitudes and different geomorphological settings in the periglacial landscape of Zackenberg. Positions of sites are given in Table 3.1 in Caning and Rasch (2001) and in Fig. 2.1.

In August 2004, a TinyTag temperature logger was installed at the top of Dombjerg c. 1400 m a.s.l. (UTM: 8273009 mN, 507408 mE). Here it measures the temperature 2 m above terrain.

All dataloggers were offloaded in 2004. Annual mean temperatures in the period 1996-2003 are given in Table 2.14. Due to periodic failures, it has not been possible to calculate annual statistic for all loggers. However, data exist during a greater part of the year for several of these loggers.

Break up of the fjord ice on Young Sund

On 1 June the ice edge off Young Sund was several kilometres east of the fjord mouth, and no open water was present around Sandøen. On 17 June, a large open water area covered about half the width of the fjord between Sandøen and Clavering Ø. In mid June, open water began to form in the fjord ice off the rivers, and already on 1 July, the fjord ice between Zackenbergdalen and Clavering Ø broke up. This is the earliest recorded ice break up (Table 2.15). On 4 July, the ice had also broken up around Sandøen, but fast ice still persisted further to the east. On 8 July, the ice broke up in the remaining part of the fiord.

In late July and most of August, drift ice was present in the outermost part of the fiord, and on 8 August, it went all the way to Zackenberg

2.3 River water discharge and chemistry

Spring break up of Zackenbergelven and secondary streams

In 2004, Zackenbergelven broke up on 1 June, and a large surge of meltwater, slush ice and mud passed the hydrometric sta-

	Area (km²)	Area hidden (%)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean
1 (0-50 m)	3.52	3.5	78	74	65	77	91	60	73	77	68	48	71
2 (0-50 m)	7.97	1.2	89	88	90	85	91	57	87	87	92	49	82
3 (50-150 m)	3.52	0.0	88	81	83	83	94	51	89	82	83	51	78
4 (150-300 m)	2.62	0.0	73	74	68	66	86	33	79	56	73	39	65
5 (300-600 m)	2.17	0.0	16	54	73	43	85	31	56	36	49	16	46
6 (50-150 m)	2.15	75.3	86	86	84	87	98	55	84	78	74	56	79
7 (150-300 m)	3.36	69.3	90	81	76	90	97	54	84	74	90	56	79
8 (300-600 m)	4.56	27.5	49	55	66	64	84	37	45	52	66	30	55
9 (0-50 m)	5.01	6.2	92	87	96	91	97	54	96	96	100	58	87
10 (50-150 m)	3.84	2.9	94	85	95	97	98	60	97	93	100	56	87
11 (150-300 m)	3.18	0.2	91	72	86	92	96	77*	97	88	100	66	87
12 (300-600 m)	3.82	0.0	40	66	89	68	89	65	73	65	98	53	71
13 (Lemmings)	2.05	1.0	89	80	76	80	87	58	83	83	89	46	77
Total area	45.70	12.9	76	77	81	80	92	54	82	77	83	49	75

*Table 2.10. Area size and snow cover on 10 June in 13 bird and mammal study sections in Zackenbergdalen and on the slopes of Aucellabjerg 1995-2003 (see Fig. 4.1 in Caning and Rasch 2003 for map of sections). Photos were taken from a fixed point 477 m a.s.l. on the East facing slope of Zackenberg mountain within +/- 3 days of 10 June and extrapolated according to the methods described by Pedersen and Hinkler (2000). Furthermore, the proportions of the areas not visible from the photo point are given. Data from 1995 and 1996 are from satellite images taken on 9 and 11 June, respectively. * Partly cloud covered, giving too high snow cover.*

tion. The surge/flood came from Lindemansdalen and resulted in one of the earliest dates for river break up so far. Also the rivulets from Aucella started to run earlier than recorded before (Table 2.15).

Three hours after the surge, the water level at Zackenberg had dropped, but from dark deposits of mud/sediment on the snow it was estimated, that the surge had been almost similar in size to the violent surge 20 June 1999 (Fig. 2.11).

Due to the heavy pressure from wet snow, the hydrometric station was damaged and no data were obtained during the surge. The steel construction was bent, bolts ripped out and large stones around the foundation were flushed away. Fortunately, it was possible to restore the hydrometric station and readjust the sonic sensor.

The surge was probably initiated by a collapse of a large snow drift that dammed Lindemansdalen. Furthermore, large amounts of snow had accumulated in and along the lee sides in the riverbed/channel due to redistribution of the snow by the wind (section 2.1) – and as this snow was close to saturation with meltwater after the high temperatures in late May, the surge could increase dramatically in size along the way.

The discharge in Zackenbergelven increased again on 7 June, when water started running from Store Sødal, the main contributor to Zackenbergelven.

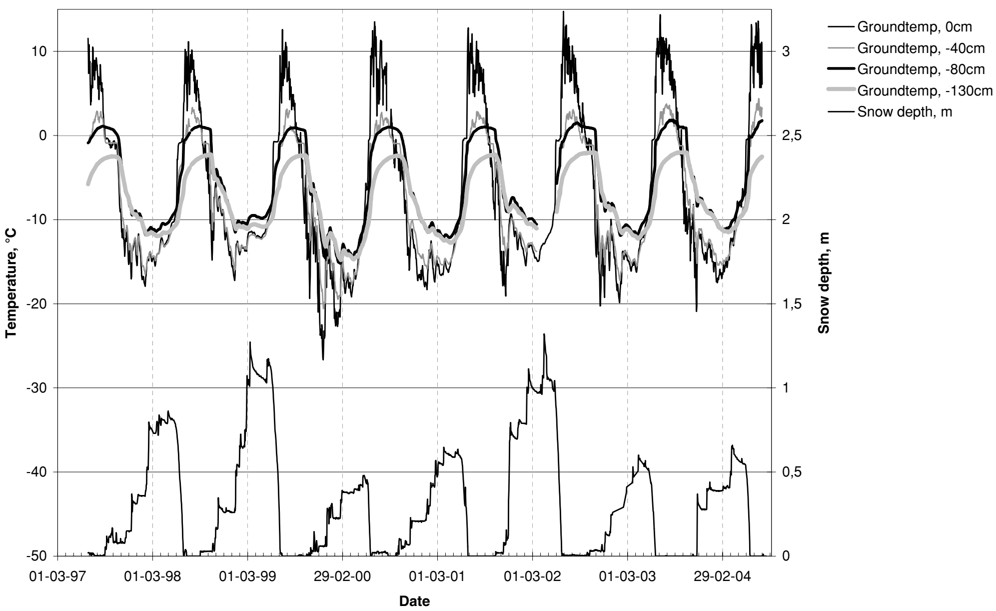

Figure 2.7. Daily mean temperatures at the surface of the ground and 40 cm, 80 cm and 130 cm below the surface. In the lower half of the figure the snow depth is shown.

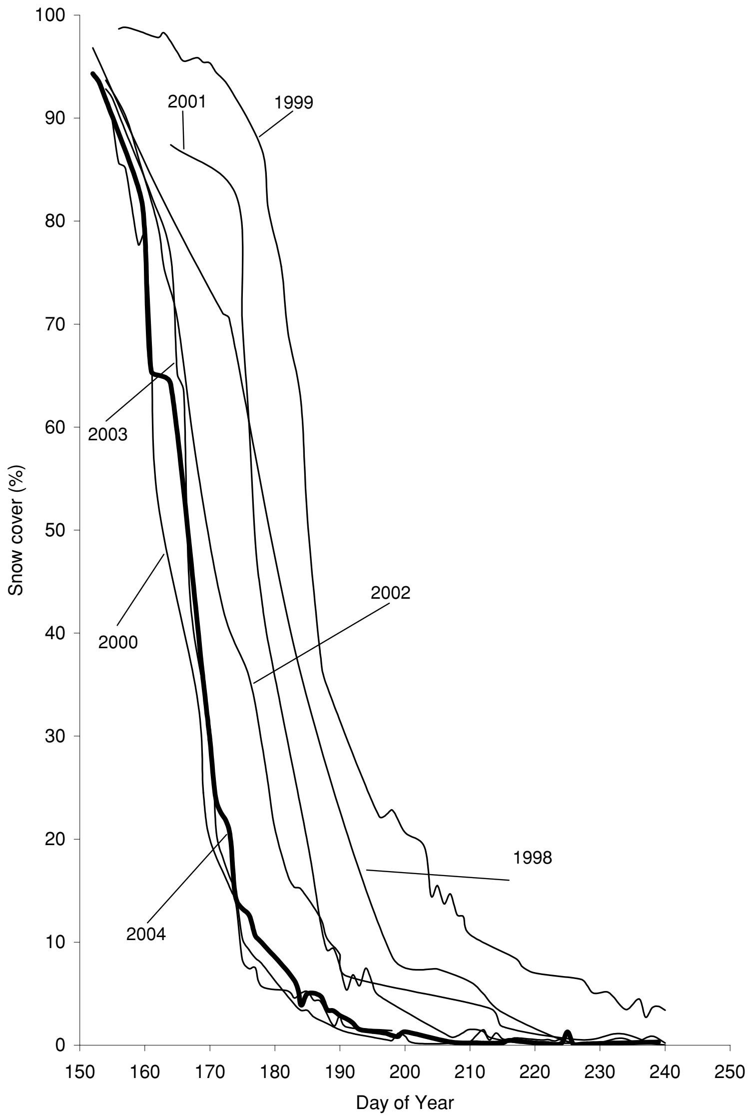

Figure 2.8. Snow cover depletion curves for the central part of Zackenbergdalen 1998- 2004 based on digital photos from Nansenblokken. The 2004-curve is bold, previous years are shown in thin lines.

Zackenbergelven

The drainage basin for Zackenbergelven includes Zackenbergdalen, Store Sødal, Lindemansdalen and Slettedalen. The basin covers an area of 514 km^2, of which 106 km^2 are covered by glaciers.

The hydrometric station was established in 1995 at the lower part of the river, at the west side (Meltofte & Thing 1996). In 1998, the hydrometric station was moved to the eastern bank of the river, due to problems with the station being buried beneath a thick snowdrift each winter.

At the hydrometric station (Fig. 2.1), the water level, water temperature, and air temperature are logged automatically every 15 minutes. The water level is both measured by use of a sonic range sensor and by a pressure sensor. The discharge data for 2004 is primarily based on data from the sonic range sensor. The measured water level is – regardless of the measuring method – recalculated to m a.s.l., which can be transformed to a discharge using an established relation between discharge and water level (Q/h-relation).

Table 2.11. Maximum active layer depth in ZEROCALM-1 and ZEROCALM-2 measured late August, 1997-2004

	1997	1998	1999	2000	2001	2002	2003	2004
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
ZEROCALM-1	61.7	65.6	60.3	63.4	63.3	70.5	72.5	76.3
ZEROCALM-2	57.4	59.5	43.6	59.8	59.7	59.6	63.4	65.0

Q/h-relation

Discharges and corresponding water levels have been manually measured by use of a current meter in the field seasons from 1995 to 2004. The function that describes the relation between water level and discharge is shown in Fig. 2.12. The Q/h-relation is based on discharge measurements performed in the years 1995 to 1998, at discharges ranging from 5.98 to 70 m^3/s. The high correlation of the data and the Q/h-relation indicates that the cross profile at the hydrometric station was stable in the period 1995 to 1998. Manual discharge measurements in 1999 to 2004 indicate that the cross profile has been stable in the last years as well. The Q/h-relation is only valid when the riverbed and banks are free of snow and ice, as snow covering the banks will change the cross profile of the river, and ice layers at the bottom of the river give a false water level.

River water discharge

Total discharge from 2003 has now been updated and data show, that the last measurement of running water in Zackenbergelven was 16 September 2003.

The water discharge in Zackenbergelven in 2004 is shown in Fig. 2.13. In the first period – from the river started flowing on 1 June and until 5 June – the riverbed and banks were covered in ice/snow and the Q/h-relations therefore not valid. Instead, the discharge in these five days is approximated by letting the discharge increase gradually from zero to the discharge found at the first manual measurement on 5 June. As described above, no data were measured during the surge on 1 June and it was not possible to estimate the discharge during this episode. In the period from 5 June until 18 June, the river cross section was altered by a snow wall on the western side. As the manually measured discharges in the period (3 measurements) fit very well with the discharge calculated by use of the Q/h-relation, the Q/h-relation is assumed to be valid for this period also.

Except from the surge, the highest discharge during the 2004 season was 62.6 m^3/s measured 12 July after a period of high diurnal temperatures causing enhanced melting from the perennial snowpatches and glaciers on the plateaus. The total amount of water drained from the catchment in 2004 was c. 210 million m^3. As the river was still running when the station was left the total discharge of 2004 is only preliminary. The total runoff is a bit over the average level for Zackenbergelven, see Table 2.16. With a drainage basin of 514 km^2 this corresponds to a total water loss of 408 mm from the area.

The precipitation in the hydrological year 2004, 1 October 2003 to 30 September 2004, was 271 mm at the climate station in Zackenberg.

Regarding the large difference between the measured precipitation and the water loss, it should be noted that changes in the amount of precipitation with altitude, possible accumulation or ablation on the glaciers in the catchment area and evaporation/sublimation are not taken into account.

In Table 2.16 the runoff is given on a monthly basis. At Zackenberg, July normally renders the highest runoff. The runoff is first dominated by melting of snow in the valley, and later in the season melting of perennial snow patches and glaciers. Summer precipitation is normally very limited (Table 2.2) but may change this pattern. The discharge in August 2004 was only exceeded in 1998, where a rain event caused a flood. In 2004, the high discharge was due to a combination of a rainy period in late July and early August followed by a very warm period in the first part of August (Fig. 2.13).

A clear diurnal variation in the river discharge is observed in periods with no rain. Maximum discharge is at midnight and minimum discharge at midday. Furthermore, the diurnal amplitude is larger early in the season, when the discharge is mainly controlled by snowmelt whereas later in the season the discharge is mainly controlled by melting of ice and snow on the plateaus.

Daily discharge data from Zackenberg are reported to the Global Runoff Data Centre (GRDC) which maintains a global database on river discharge (www.grdc.bafg.de).

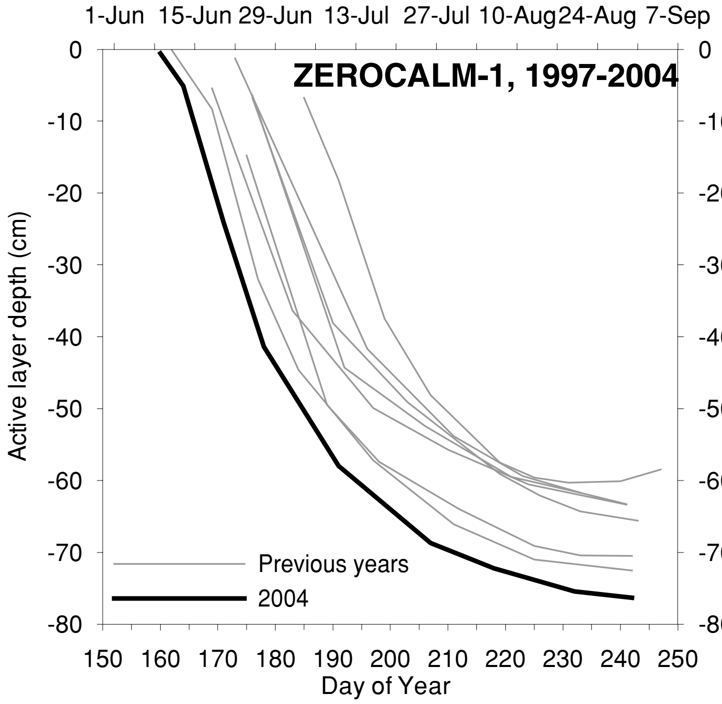

Figure 2.9. Active layer development in ZEROCALM-1, 1997-2004. Only 2004 is shown in bold, other years are thin lines. To distinguish between years compare with Table 2.11.

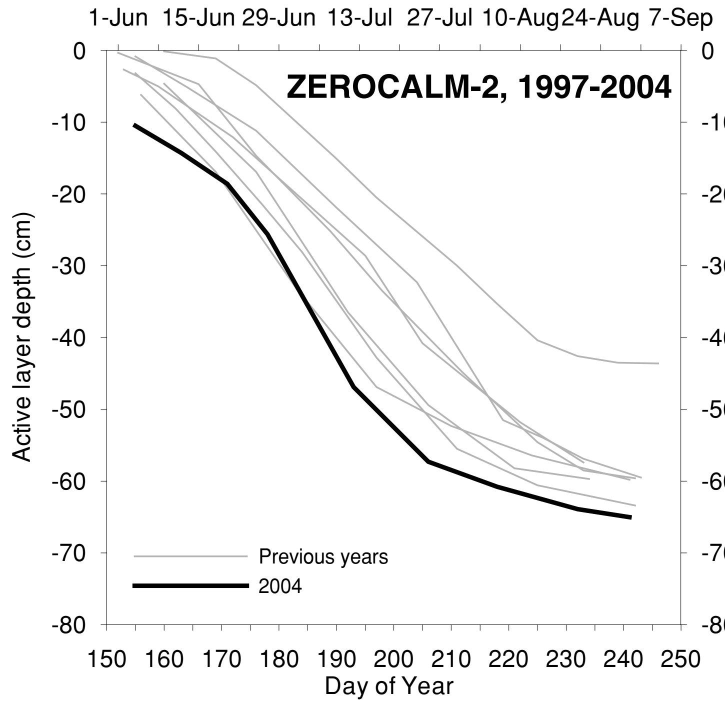

Figure 2.10. Active layer development in ZEROCALM-2, 1997-2004. Only 2004 is shown in bold, other years are thin lines. To distinguish between years compare with Table 2.11.

	1996	1997	1998	1999	2000	2001	2002	2003
Yearly mean temperature, degree Celsius								
0 cm below surface	–8.4	–8.2	–7.3	–8.2	–8.7	–7.6	–6.4	–7.0
2.5 cm below surface	–8.3	–8.2	–7.7	–8.0	–8.4	–7.7	–5.2	–7.3
5 cm below surface	–7.7	–7.6	–6.7	–7.3	–8.2	–7.1	–6.0	–6.6
10 cm below surface	–7.0	–7.0	–6.2	–6.6	–7.0	–6.3	–3.9	–5.9
20 cm below surface	–8.2	–8.4	–7.4	–8.0	–8.8	–7.7	–6.6	–7.2
40 cm below surface	–8.6	–9.0	–8.2	–8.4	–9.0	–8.3	–6.1	–8.0
60 cm below surface	–6.5	–7.1	–6.3	–6.6	–7.5	–6.5	–5.4	–6.0
80 cm below surface	–6.1	–6.8	–6.1	–6.3	–6.9	–6.2	–3.9	–5.6
100 cm below surface	–7.4	–8.2	–7.3	–7.6	–8.6	–7.6	–6.6	–7.1
130 cm below surface	–7.6	–8.6	–7.7	–7.8	–8.6	–7.9	–5.8	–7.2
Maximum yearly temperature, degree Celsius								
0 cm below surface	18.7	16.6	16.5	18.3	23.1	21.0	22.6	21.5
2.5 cm below surface	19.6	24	19.9	21.2	13.9	13.0	14.9	14.1
5 cm below surface	16.3	16.4	17	18.4	12.5	11.6	13.3	13.3
10 cm below surface	12.9	13.6	13	15.2	11.7	11.4	12.4	12.8
20 cm below surface	–	7.5	8	8.7	7.6	7.6	8.2	8.8
40 cm below surface	3.7	3.1	3.5	6.2	2.9	3.1	3.2	4.0
60 cm below surface	2.6	2.7	2.8	8.2	2.4	2.6	3.4	3.9
80 cm below surface	1.2	1.2	1.2	0.9	1.1	1.1	1.6	1.9
100 cm below surface	–0.7	–0.7	–0.6	0.0	–0.7	–0.6	–0.5	–0.4
130 cm below surface	–2.6	–2.4	–2.2	2.3	–2.4	–2.2	–2.0	–2.1
Minimum yearly temperature, degree Celsius								
0 cm below surface	–23.7	–26.2	–18.1	–26.9	–23.0	–19.5	–20.6	–21.8
2.5 cm below surface	–22.6	–25.5	–18.1	–25.2	–21.9	–18.0	–20.1	–20.3
5 cm below surface	–21.9	–24.8	–17.3	–24.1	–20.9	–17.0	–19.0	–19.1
10 cm below surface	–20.9	–23.8	–16.4	–23.1	–20.2	–16.3	–18.0	–18.2
20 cm below surface	–	–24.2	–17.3	–22.9	–20.6	–16.9	–18.0	–18.3
40 cm below surface	–20	–22.3	–16.6	–20.7	–19.5	–16.0	–15.6	–17.3
60 cm below surface	–15.4	–17.3	–13.2	–16.1	–16.2	–13.0	–11.9	–13.8
80 cm below surface	–12.9	–15.4	–11.9	–14.6	–15.2	–12.2	–10.6	–11.9
100 cm below surface	–14.2	–16.1	–12.9	–15.3	–16.1	–13.3	–12.1	–13.1
130 cm below surface	–12.6	–14.5	–12	–13.2	–14.8	–12.8	–11.1	–12.3

Table 2.12. Annual mean, maximum and minimum temperatures in different depths for the years 1996 to 2003.

Suspended sediment

Estimated total annual transport of suspended sediment and organic matter from Zackenbergelven 1997-2004 are given in Table 2.16. In the period from 1 June to 29 August an amount of 21,860 ton suspended sediment was transported from the Zackenberg drainage basin and into Young Sund. Of this, organic matter constituted 1,388 ton (Fig. 2.13). The total transport is based on concentrations measured in water sampled at 08:00 assuming this value can be used as a diurnal mean value. A significant amount of sediment, which has not been included in Table 2.16 is the sediment transported along with the spring surge. This event, of very short duration may have transported large amounts of material in a slurry of slush, mud, ice and snow (Fig. 2.11). Due to our arrival after the spring break up, the first sample of water was collected 5 hours after the flood, and at that time the water level and sediment concentration had already dropped significantly.

During 2004, the amount of suspended sediment in Zackenbergelven varied from 22-234 mg/l with a mean of 123 mg/l (Fig. 2.14). Maximum suspended sediment concentration occurred on 7 June in relation to an increasing water discharge and suspension of the sediment deposited throughout the spring surge. Another peak in sediment concentration that corresponds to a rising water discharge was observed 21 June. The largest variations are observed early in the season, whereas later in the season the concentrations level out. The very high discharges are not necessarily followed by significant sediment peaks (Fig. 2.14). This probably relates to the facts that high discharges mainly come from melting ice caps in the drainage basin, and that material deposited from the spring flood along the river bed has already been flushed away. Finally, Store Sødal acts like a reservoir, where some sedimentation takes place.

Four times during the season, sediment concentration was obtained every second hour in order to describe the diurnal variation (Fig. 2.15). These data show a complex variation, where the sediment concentration seems to be influenced by fluctuations in discharge, which again is highly related to parameters like temperature, precipitation, cloudiness and wind. Also, the time of the season and the time lag through the system play a major role. The four samples cover very different conditions. From fine warm weather early in the season (18-19 June) to a warm sultry day with thin mist (8-9 July), to a cloudy calm day with light rain (19-20 July) and finally to a calm cloudy day (20 August). Data from the first two diurnal measurements indicate, that the assumption of a mean sediment concentration at 8:00 is not always valid and due to this, the total sediment transport estimated in Table 2.16 is probably somehow underestimated. A more detailed analysis will be given when results from the prospected optical backscatter sensor (OBS) exist.

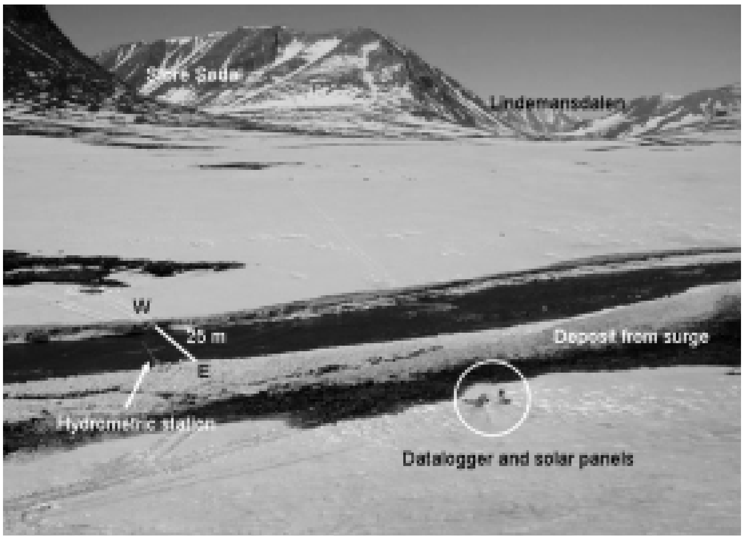

Figure 2.11. Looking northwest at Zackenbergelven four hours after the surge 1 June. The water level has dropped and snow walls of up to a meter bound the river. The dark deposits of sediment almost reach the datalogger station marked by a circle and indicate the size of the surge/flood. The river is c. 25 m wide at the river crossing.

River water chemistry

Water was sampled from Zackenbergelven near the hydrometric station every morning at 08:00. Conductivity, water temperature, pH and alkalinity were measured at Zackenberg and solute concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Mn^{3+}, Cl^-, NO_3^{2-}, SO_4^{2-}) were determined at Institute of Geography, University of Copenhagen. In addition, dissolved organic carbon (DOC) was analysed in 14 of the samples picked on a regular basis throughout the season. DOC analyses were carried out at Botanical Institute, University of Copenhagen.

Daily variations in conductivity and water temperature in Zackenbergelven are shown in Fig. 2.14. High conductivity dur-

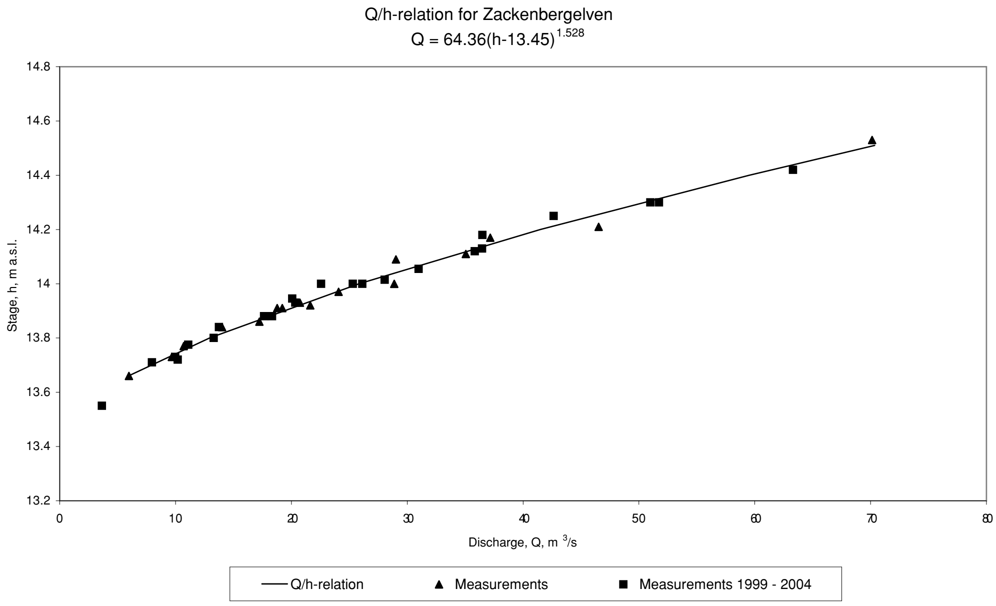

Figure 2.12. Water level – discharge relation curve (Q/h-relation) for Zackenbergelven at the hydrometric station, 1995-1998. The coefficient of correlation (R^2) for the curve is 0.99. Measurements from the period 1999-2004 indicate that no major changes have occurred to the river profile since 1998.

Table 2.13. Monthly mean temperatures for different depths in 2003 and first half of 2004.

	0 cm	–2.5 cm	–5 cm	–10 cm	–20 cm	–40 cm	–60 cm	–80 cm	–100 cm	–130 cm
2003										
Jan	–16.2	–15.9	–15.0	–14.2	–14.9	–14.2	–11.2	–9.6	–10.7	–9.6
Feb	–15.1	–15.1	–14.3	–13.6	–14.7	–14.7	–12.2	–11.1	–12.3	–11.3
Mar	–15.3	–15.3	–14.6	–13.8	–14.8	–14.7	–12.2	–11.2	–12.4	–11.6
Apr	–13.8	–13.9	–13.2	–12.5	–13.7	–14.1	–11.9	–11.2	–12.5	–12.0
May	–9.5	–9.7	–8.9	–8.3	–9.7	–10.8	–9.3	–9.2	–10.7	–10.9
Jun	4.2	2.6	2.8	3.0	0.4	–2.5	–1.8	–2.9	–4.9	–6.8
Jul	10.2	8.7	9.0	9.4	6.7	2.7	2.6	0.8	–1.3	–3.4
Aug	7.5	6.3	6.8	7.4	5.3	2.6	3.2	1.7	–0.6	–2.4
Sept	0.2	–0.2	0.7	1.6	0.4	–0.5	1.2	1.2	–0.6	–2.0
Oct	–9.7	–9.2	–8.1	–7.2	–7.5	–6.1	–2.7	–1.2	–2.5	–2.6
Nov	–13.5	–13.0	–12.0	–11.3	–11.8	–11.1	–8.0	–6.3	–7.2	–6.1
Dec	–13.4	–13.1	–12.3	–11.5	–12.3	–12.1	–9.3	–8.1	–9.1	–8.2
2004										
Jan	–14.2	–13.9	–13.1	–12.3	–13.2	–13.1	–10.3	–9.2	–10.2	–9.4
Feb	–16.6	–16.2	–15.4	–14.6	–15.3	–15.0	–12.1	–10.7	–11.7	–10.7
Mar	–15.1	–15.0	–14.2	–13.5	–14.5	–14.6	–12.1	–11.1	–12.2	–11.4
Apr	–10.9	–11.1	–10.3	–9.6	–11.0	–11.9	–10.0	–9.7	–11.0	–10.9
May	–6.8	–7.2	–6.4	–5.8	–7.4	–8.8	–7.3	–7.4	–9.0	–9.4
Jun	5.2	3.9	4.2	4.4	1.9	–1.2	–0.3	–1.4	–3.5	–5.5
Jul	10.0	8.7	9.1	9.5	6.9	3.0	3.3	1.2	–1.0	–3.0

ing the first days of discharge indicates high dissolved load concentrations in the first melt water. This phenomenon has earlier been ascribed to solutes being washed out of the snow package during the first snowmelt (section 3.3 in Rasch and Caning 2003). Another reason for this pattern seems to be the diluting effect of water from Store Sødal. During the first week, water in Zackenbergelven is dominated by water from the streams Lindemanselven, Aucellaelv and Palnatokeelv, which all have a higher conductivity than water from Store Sødal (Table 2.17). And then 7 June, when water from Store Sødal starts dominating Zackenbergelven, the conductivity drops significantly. Except from the high levels during the first week, concentrations of solutes are fairly constant over the season and the conductivity in the river water ranges between 12 and 30 µS/cm. A rise in conductivity was observed in late July after a period of rain. The rain increases the input of soil water to the river, and the soil water has a higher content of dissolved nutrients than melt water from snow and glaciers.

In Zackenbergelven, DOC decreases through the first month and then more or less levels out during the rest of the season (Fig. 2.14).

Suspended sediment and solutes in tributaries to Zackenbergelven

In 2004, water was sampled six times from the main tributaries to Zackenbergelven. Locations of sampling sites are given in Fig. 2.1. Please notice that the number of sampled streams has increased compared to 2003 (compare Table 2.17 in this section to Table 2.15 in Rasch and Caning 2004). Water is now being sampled in two streams coming from Palnatokebjerg and two streams coming from Aucellabjerg. In 2003, water from Palnatokebjerg corresponds to PalnatokeNW and water from Aucellabjerg corresponds to AucellaS in Table 2.17.

Water temperature and conductivity were measured on location, whereas water chemistry, suspended sediment and organic matter concentration were determined from collected samples. When the first samples were collected 9 June, it was not possible to cross the stream from PalnatokeNW and therefore, water from Store Sødal and Lindemansdalen could not be collected. Table 2.17 show variations in suspended sediment, organic matter, specific conductivity, and dissolved organic carbon (DOC) from the different streams throughout the season. The streams PalnatokeE and AucellaN, included in 2004, are

	TinyTag Site	Eleva- tion m a.s.l.	1996 Mean °C	1997 Mean °C	1998 Mean °C	1999 Mean °C	2000 Mean °C	2001 Mean °C	2002 Mean °C	2003 Mean °C
Ground temperature profile	P1									
	0 cm	20	–7.7	–9.8	–9.1	–9.3	–	–	–8.3	–9.3
	10 cm	20	–	–9.6	–8.8	–8.7	–9.4	–8.7	–7.5	–8.7
	50 cm	20	–6.7	–9.0	–8.3	–8.3	–9.0	–8.7	–7.8	–8.4
	118 cm	20	–5.9	–8.1	–7.8	–8.0	–8.1	–8.3	–7.5	–7.4
Ground temperature profile	P3									
	0 cm	420	–6.2	–9.6	–7.6	–10.5	–8.3	–9.6	–7.6	–7.7
	10 cm	420	–5.9	–8.6	–	–9.0	–7.5	–9.0	–	NV
	66 cm	420	–5.5	–8.7	–	–	–7.4	–8.5	–6.9	–6.5
Ground temperature profile	P4									
	0 cm	820	–8.5	–10.7	–8.2	–10.9	–	–9.5	–5.7	–8.2
	10 cm	820	–8.0	–10.5	–8.0	–10.4	–9.2	–9.4	–8.4	–9.2
	85 cm	820	–7.6	–10.4	–8.6	–9.7	–9.4	–9.5	–8.6	–8.9
Ground temperature profile	P5									
	0 cm	260	–	–9.2	–	–9.9	–	–9.4	–8.2	–8.6
	75 cm	260	–	–8.9	–	–9.2	–	–	–7.8	–8.2
	140 cm	260	–	–8.6	–	–14.8	–	–	–	NV
Ground temperature profile	P6									
	0 cm ny	11	–	–10.1	–9.5	–8.2	–	–9.1	–7.4	–8.7
	10 cm	11	–	–9.9	–	–	–	–8.7	–7.2	–7.8
	30 cm	11	–	–	–	–	–	–9.1	–7.7	–7.8
	50 cm	11	–	–	–	–	–	–9.1	–7.9	–7.3
Temperature in snow patch	S1									
	Plateau above	29	–8.1	–	–12.5	–10.0	–10.0	–9.3	–8.5	–8.4
	Slope high	25	–	–	–5.8	–6.5	–5.3	–5.4	–4.3	–4.5
	Slope low	23	–5.9	–	–	–	–	–5.5	–4.5	–5.4
	Plateau below	16	–	–	–8.0	–13.0	–11.7	–9.9	–8.2	–9.4
Air temperature in Morænebakkerne	T1									
	air, 5 cm	85	–7.3	–9.8	–9.2	–9.8	–10.2	–10.0	–8.9	–9.9
Air temperature in Store Sødal	T2									
	air, 5 cm	129	–7.9	–10.3	–9.8	–11.1	–10.0	–10.5	–9.3	–9.8
Air temperature on Aucellabjerg	T3									
	air, 5 cm	965	–9.2	–	–10.2	–	–	–	–	–10.7
Water temperature in Gadekæret	V2									
	water	35	–10.8	–8.0	–	–	–	–	–6.0	–8.1
Air temperature on Nansenblokken	N1									–6.7
	air	480								
	Dry2									–5.4
Ground temperature	0 cm	45								–5.7
	15 cm									
	Sal1									–7.3
Ground temperature	0 cm	36								–7.9
	15 cm									

Table 2.14. Annual mean temperatures from TinyTags, operated by GeoBasis. TinyTags installed in 2003 are operating without problems but is not a part of this table as data from a calendar year has still not been obtained.

characterised by low concentrations of suspended sediment and high percentages of organic matter in the suspended sediment.

Low conductivity and low suspended sediment concentrations characterise water from Store Sødal, whereas water from the AucellaS and PalnatokeNW are characterised by high suspended sediment concentrations (Table 2.17). The highest conductivity is measured in the streams from Aucellabjerg. Apart from Store Sødal, the streams all show a seasonal increase in conductivity. Water from the fen area (Rylekær in Table 2.17) has the highest content of DOC.

The chemistry and amount of suspended matter reflect the different geology of

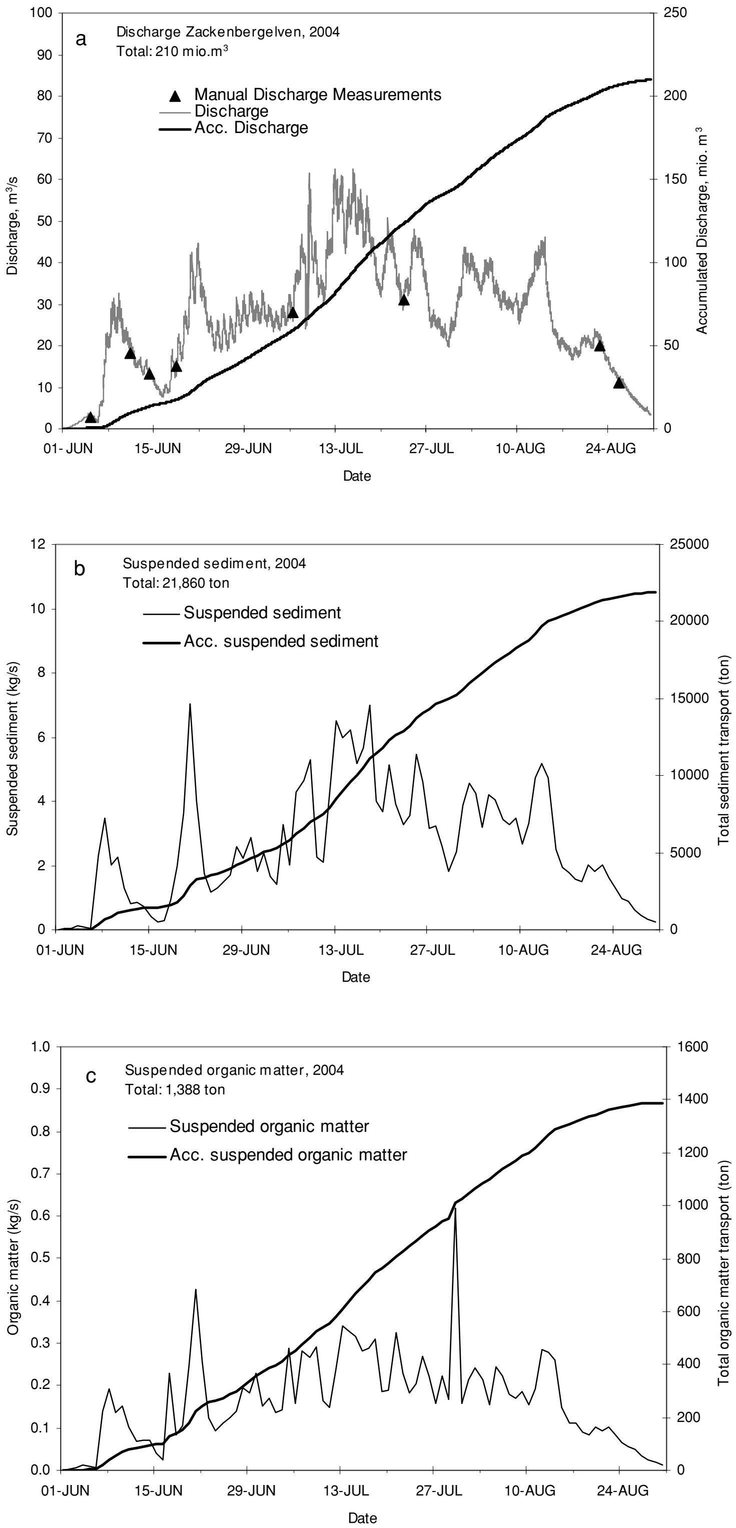

Figure 2.13. Discharge in Zackenbergelven during summer 2004. a) River water discharge. b) Suspended sediment concentration and total annual transport of suspended sediment. c) Suspended organic matter and total annual transport of suspended sediment based on sediment concentration at 08:00 and discharge at 15 minutes interval.

the drainage basins. Store Sødal is fed mainly by glaciers and melt water from snow that passes bedrock dominated by gneissic parent material, whereas the Palnatokebjerg and Aucellabjerg tributaries are fed by snow melt water that pass easily erodable sediments. Due to the relative contribution of water from the different tributaries: Store Sødal, Lindemansdalen, Palnatokebjerg, Aucellabjerg, and Rylekærene, the pattern from Store Sødal dominates in Zackenbergelven.

3.4 Precipitation and soil water chemistry

Precipitation

During the 2004 season, water from the precipitation collector were sampled on 12 June, 20 July, 23 July and 10 August after rain events of varying duration. Conductivity and pH were measured at Zackenberg and filtered subsamples were analysed for total concentration of Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Mn^{3+}, Cl^-, NO_3^{2-}, SO_4^{2-} at Institute of Geography, University of Copenhagen. Rainwater had pH around 4.5 and conductivity of 10-40 µS/cm.

Soil Moisture

Soil moisture at 10 cm and 30 cm below soil surface are measured on an annual basis at the snow and micrometeorological stations M2 and M3. Figs 2.3 and 2.4 show how the soil moisture content decreases significantly when the soil freeze and how it keeps decreasing at a slow rate until February where a minimum is reached. Then, it very slowly increases until the day where the soil thaws and soil moisture reaches saturation.

At M2, the soil dries at a much faster rate than at M3, where soil moisture stays close to saturation for almost a month. This difference is explained by the fact, that overland flow was observed at M3 in this period, whereas at M2, the surface conditions were dry after snowmelt.

A pronounced increase in soil moisture is observed as soon as the air temperature turns positive and meltwater starts to seep through the snow. This reveals that water may penetrate into the frozen soil. The soil moisture content at M3 shows a clear response to the rain events 19 July and 29 July, whereas only a little response is observed at M2 to the rain event 29 July (Figs 2.3 and 2.4).

Table 2.15. Visually estimated dates of 50% ice cover on selected ponds and lakes around the research station, together with start of running water in rivers and break up of the fjord ice in Young Sund during 1995-2003. "West pond" and "East pond" are the two ponds in Gadekæret north of the runway, "South pond" is the major pond in Sydkærene south of the runway. "Rivulets" are the streams draining the slopes of Aucellabjerg through Rylekærene. Zackenbergelven gives the initial date of genuine flow in the river. Young Sund break up is divided between break up of the fiord ice off Zackenbergdalen and in the fiord in general. The 50% ice cover date for Lomsø is tentative, as it is estimated from the research station.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
West pond		4.6	Dry	5.6	10.6	30.5	8.6	2.6	9.6	<26.5
East pond		3.6	Dry	6.6	16.6	1.6	6.6	3.6	12.6	28.5
South pond		<3.6	30.5	7.6	12.6	1.6	8.6	3.6	8.6	<26.5
Lomsø		4.7	2.7	8.7	10.7	1.7	4.7	30.6	29.6	22.6
Rivulets		<6.6	11.6	11.6	15.6	4.6	10.6	4.6	3.6	31.5
Zackenbergelven	<26.5	<3.6	4.6	10.6	20.6	8.6	8.6	4.6	30.5	1.6
Young Sund (Zac.)		13.7	19.7	14.7	14.7	8.7	13.7	1.7	5.7	1.7
Young Sund (all)	12.7	13.7	22.7	22.7	24.7	17.7	23.7	8.7	8.7	8.7

In addition to the continuous measurements, soil moisture is also being monitored manually twice a week throughout the summer season in soil water plots covered by different vegetation communities (see next section).

Soil water

Soil water is collected from various depths at five characteristic soil water regimes covered by the dominating plant communities in the valley. A well drained *Cassiope* heath (K-site); a wet fen area (S-site); a dry heath site covered by Dryas (Dry2-site); a snowbed site covered mainly by *Salix* (Sal1-site) and finally a site covered by mixed heath vegetation (Mix1-site). A more detailed description of the sites is given in Caning and Rasch (2000) and Rasch and Caning (2004).

In 2004, soil water was collected four times during the season and the chemical composition of the soil water determined. Alkalinity, pH and conductivity were measured at Zackenberg and analysis of dissolved major cations and anions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Mn^{3+}, Cl^-, NO_3^{2-}, and SO_4^{2-}) were carried out at Institute of Geography, University of Copenhagen. Furthermore, water was analysed for NH_4^+, DOC and DON at Botanical Institute, University of Copenhagen. Unfortunately, water was not sampled from the Dry2-site and it might be necessary to re-install the suction probes at this site, as the hydraulic contact may be too bad.

Chemical composition of soil water from the sites show a distinct variation with depth and between sites. The total concentration of solutes is reflected in the specific conductivity of the soil water in which an increase is observed in the order: K-site (40-80 μS/cm) < Mix-site (60-100 μS/cm) < Sal-site (50-200 μS/cm) < S-site (100-400μS/cm). The large ranges include the seasonal variations and variations with depth, from each site.

The variations between sites in total solute concentrations correspond to the release of nutrients expected from the decomposability of different plant material. *Cassiope* with evergreen leaves and woody stems has the lowest substrate quality and a slower decomposition rate than *Salix* and the wetland vegetation at the S-site.

3.5 Carbon dioxide flux

During the summer 2004 monitoring of the CO_2 exchange between the heath ecosystem and the atmosphere was continued. Measurements were initiated on 3 June and continued until 28 August giving a total of 86 days of measurements with

Table 2.16. Total and monthly discharge in Zackenbergelven in the years 1996-2004, corresponding water loss for the drainage area (514 km²), and precipitation measured at the climate station. Data are based on a re-evaluation of raw data and may therefore differ from earlier publications. The re-evaluation includes for example use of the same Q/h-relation (described above) for all discharge data. The hydrological year is set to 1 October previous year to 30 September present year. At present, data for 2004 is only available until 30 August 2004. The total annual transport of suspended sediment and suspended organic matter are based on the concentrations measured at 8 am and the daily mean discharge.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
June	43	45	50	41	41	53	143	71	46
July	67	80	98	123	61	47	150	71	100
August	21	61	78	17	47	34	46	43	64
September	1	2	4	0	0	3	0	4	
Total Discharge. mill. m^3	132	188	232	181	150	137	338	189	210
Water loss. mm	257	366	451	352	292	267	658	368	409
Precipitation. mm	239	263	255	227	171	240	156	184	271
Total annual transport									
Suspended sediment (ton)		29,444	130,133	18,716	16,129	16,883	60,079	18,229	21,860
Suspended organic matter (ton)		1,643	11,510	2,297	1,247	1,098	3,267	1,351	1,388

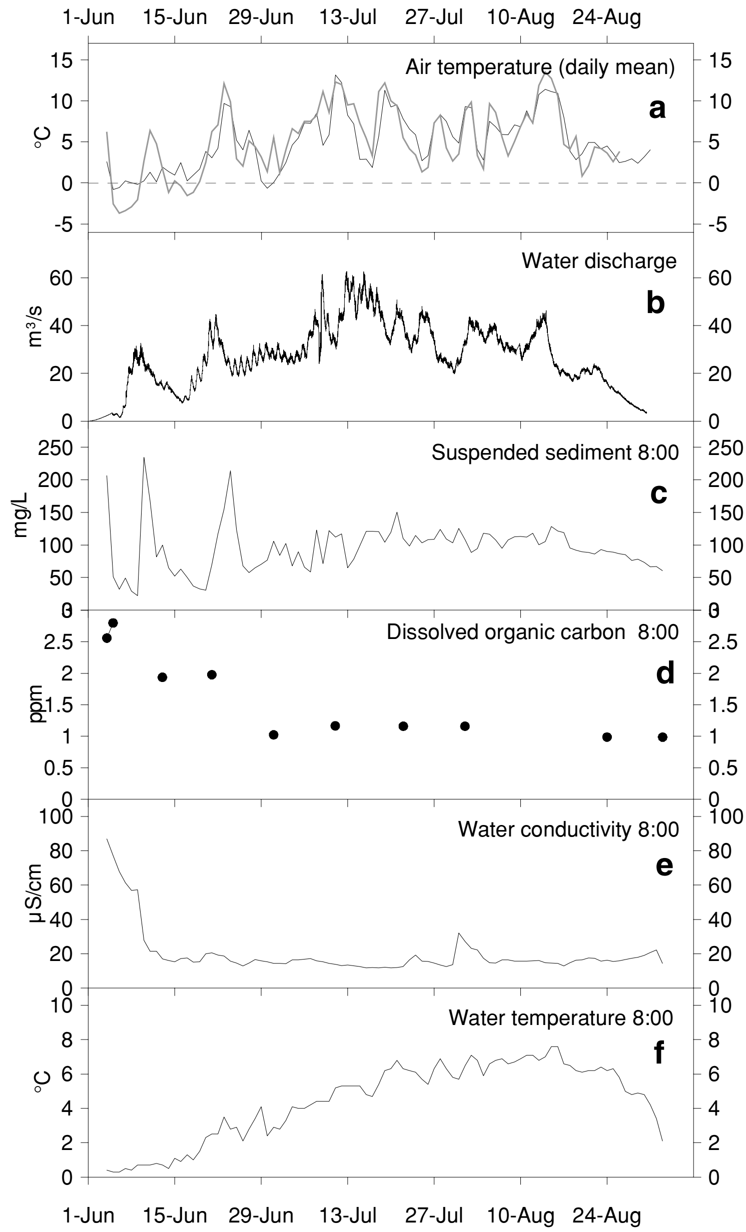

Figure 2.14. Zackenbergelven 2004. a) Daily mean air temperatures at M3 420 m a.s.l. (dotted line) and at M2 17 m a.s.l. b) water discharge, c) concentration of suspended sediment, d) dissolved organic carbon e) conductivity and f) water temperature. Discharge is measured every 15 minutes, whereas all other curves are based on daily measurements performed at 08:00.

only a few interruptions due to maintenance of the equipment.

Vertical fluxes of water vapour and carbon dioxide are measured with a three-dimensional sonic anemometer and an infrared gasanalyser (IRGA). For further details on the instrumentation see section 4.2 in Rasch and Caning (2003).

Fig. 2.16 shows the variation in daily net exchange of carbon dioxide and temperature, during the approximately 3 months of continuous measurements. The sign convention used is the standard for micrometeorological measurements, i.e. fluxes directed from the surface to the atmosphere are positive, whereas fluxes directed from the atmosphere to the surface are negative. The measured flux is the sum of the uptake of CO_2 by plants from the photosynthesis and the loss of CO_2 due to microbial decomposition in the soil, i.e. respiration. Assimilation of CO_2 is dependent of climatic conditions, mainly solar radiation, and the type and amount of vegetation. The vegetation at the heath is mainly dwarf shrubs dominated by *Cassiope tetragona*, *Dryas sp.* and *Vaccinium uliginosum*. The soil respiration process is governed by the microbial activity in the topmost organic matter in the soil and increases exponentially with the soil temperature. The sum of the above mentioned processes is also denoted Net Ecosystem Exchange (NEE). The variation in NEE during the season 2004 is more thoroughly described below.

When measurements started in June, snow had started to melt. From 13 June (DOY 165) a large part of the fetch area was free of snow and the soil surface and soil temperatures rose with increasing respiration as a result. The period had daily air temperatures slightly above zero and daily average NEE above zero, reaching a maximum of 0.7 g C m^{-2} d^{-1} on 12 June (DOY 164). During this period the heath ecosystem was a source of CO_2, meaning that the respiration exceeded the photosynthesis. The loss of CO_2 continued until 22 June (DOY 174). The daily average net CO_2 exchange was 0.3 g C m^{-2} d^{-1}.

The second period was characterised by assimilation exceeding respiration resulting in a net accumulation of CO_2 in the ecosystem. The onset of CO_2 accumulation started when relatively high air temperatures around mid-summer increased the photosynthetic uptake of CO_2. From 23 June (DOY 175) net CO_2 accumulation turned the heath surface from a source to a sink. This was the earliest beginning of the growing season recorded during the five years of measurements (Table 2.18). The maximum net daily accumulation of -1.3 g C m^{-2} d^{-1} was found on 11 July (DOY193). It is in the same order of magnitude as found in 2003. Like 2003, the ecosystem had a strong uptake of CO_2, with a daily average of 0.5 g C m^{-2} d^{-1}. Daily average NEE increased until 17 July (DOY 199) and then NEE gradually decreased as temperatures decreased. July was characterised by periods of very warm weather, and on 8 July a maximum temperature of 18.9°C was recorded. A few occasions of poor weather in mid-July and mid-August caused the respiration to exceed the pho-

Suspended sediment (mg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
9 Jun	nd	nd	720	nd	920	1,720	<2
23 Jun	34	21	70	17	nd	489	<2
13 Jul	71	860	2,399	3	298	2,883	<2
22 Jul	100	201	3,107	dry	5	3,687	<2
12 Aug	96	395	4,450	dry	9	526	<2
25 Aug	81	4	255	dry	3	2,394	<2

Organic matter as part of total suspended sediment (%)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
9 Jun	nd	nd	5	nd	6	5	nd
23 Jun	8	16	10	22	nd	7	nd
13 Jul	6	5	7	75	10	7	nd
22 Jul	5	6	8	dry	73	7	nd
12 Aug	5	5	5	dry	50	5	nd
25 Aug	7	54	9	dry	72	7	nd

Conductivity (µS/cm)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
9 Jun	nd	nd	27	24	52	26	25
23 Jun	7	48	22	28	nd	57	34
13 Jul	8	33	31	98	112	74	65
22 Jul	8	47	34	dry	165	100	45
12 Aug	9	54	35	dry	289	137	dry
25 Aug	8	186	59	dry	282	177	dry

DOC (ppm)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
9 Jun							
23 Jun	1.318	1.305	1.149	2.732	nd	2.196	4.364
13 Jul							
22 Jul	1.414	1.856	1.424	dry	1.988	1.631	3.146
12 Aug							
25 Aug	1.094	1.087	1.167	dry	1.752	1.441	dry

Table 2.17. Suspended sediment, organic matter in percent suspended sediment, conductivity and DOC in water sampled from main tributaries to Zackenbergelven (Store Sødal, Lindemanselven, PalnatokeNW, PalnatokeE, AucellaN, AucellaS and Rylekærene. PalnatokeE and Rylekærene were dry 22 July and 12 August, respectively. PalnatokeNW and AucellaS correspond to Palnatoke and Aucella in Table 2.15 Rasch and Caning 2004. nd = not determined

tosynthesis and reversed the CO_2 flux, and for a few days the ecosystem was a source of CO_2.

From 21 August, the flux reversed and turned the ecosystem into a net source of CO_2. Air temperature decreased but the soil was still warm and respiration exceeded the photosynthesis. The daily average loss was approximately one third of the loss measured during the beginning of the season.

The season 2004 was the fifth season of monitoring at the heath. Compared to the other seasons, the summer 2004 had a high uptake of CO_2, which is very similar to the uptake in 2003 (Table 2.18). The season of carbon accumulation, characterised by high air temperatures providing favourable conditions for assimilation of CO_2 lasted 59 days (23 June to 24 August), which is the longest recorded so far. The uptake of CO_2 during the period of growth was –29.6 g C m^{-2}, which is the same order of magnitude as found in 2003. In total, –22.4 g C m^{-2} was accumulated during the period from 3 June until the end of the measurements 28 August, resembling the accumulation in 2003.

A comparison between the five years seems to indicate a good correlation between accumulated NEE during the growing season and the length of the growing season (Table 2.18). The length of the growing season during the five years has increased from 43 days in 2001 to 59 days in 2004, mainly due to variations in timing of snowmelt. Also air temperature has an impact on the accumulated NEE;

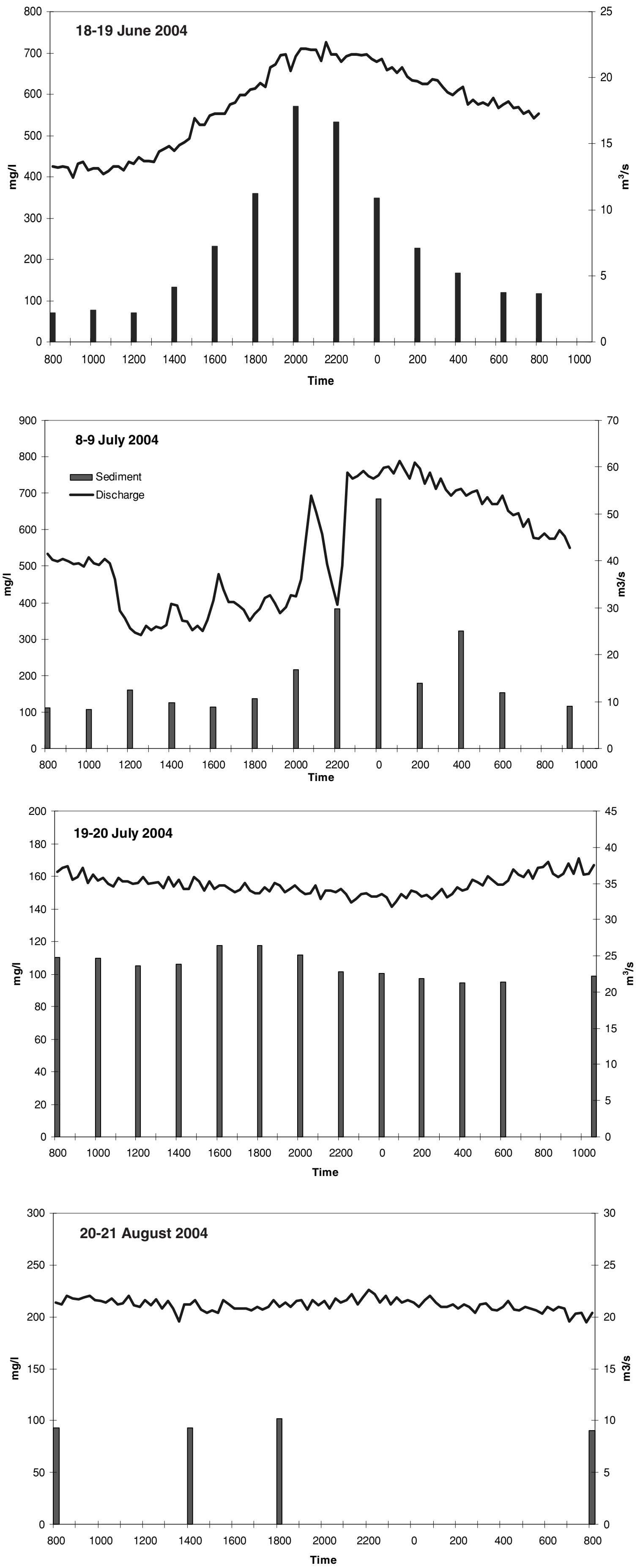

Figure 2.15. Corresponding sediment concentration (mg/l, shown as bars) and water discharge (m^3/s, shown as line) in Zackenbergelven during four diurnal measurements throughout the season. From top: 18-19 June, 8-9 July, 19-20 July, 20-21 August. The variation in patterns reflect different weather situations and different parts of the season (see text). Notice different values on Y- axes.

higher air temperatures favour the accumulation of carbon.

3.6 Geomorphology

Landscape monitoring based on photos of different dynamic landforms such as talus slopes, rock glaciers, mud slides, frost boils, gullies, thermokarsts, beach ridges, coastal cliffs, snow patches and ice wedges are part of the GeoBasis monitoring. In 2004, all photos were taken by digital camera and the digital images will become available from the Zackenberg database. A short description of each photo site and a GPS position are given in the GeoBasis Manual (www.zackenberg.dk).

Coastal geomorphology

Coastal monitoring in Zackenberg comprises measurements of morphological changes at two cross shore profiles, recurrent photography of dynamic coastal landscape features, measurements of coastal cliff retreat rates and measurements of vertical accretion of salt marsh. Locations of the coastal monitoring sites are given in (Fig. 2.17 in Rasch and Caning 2004).

Results of the cliff recession along the southern coast of Zackenbergdalen from 1996-2004 are given in Table 2.19. Between 2003 and 2004 only minor recession was observed at two out of four sites along the coastal cliff.

Four profile lines at the coastal cliff west of the Zackenbergelven river delta were established in August 2000 (D1-D4 in Fig. 2.17 in Rasch and Caning 2004). Extensive erosion rates have been observed at this cliff due to massive block slumping as described in section 3.4 in Caning and Rasch (2001). Only two of the original pegs (D1 and D2) are still left, while the others (D3 and D4) have been lost due to erosion of the cliff. In the period from 2003 to 2004, no changes happened at D1 but additional 2.3 m were eroded at D2. The orientation peg at D3 was encountered 80 cm from the

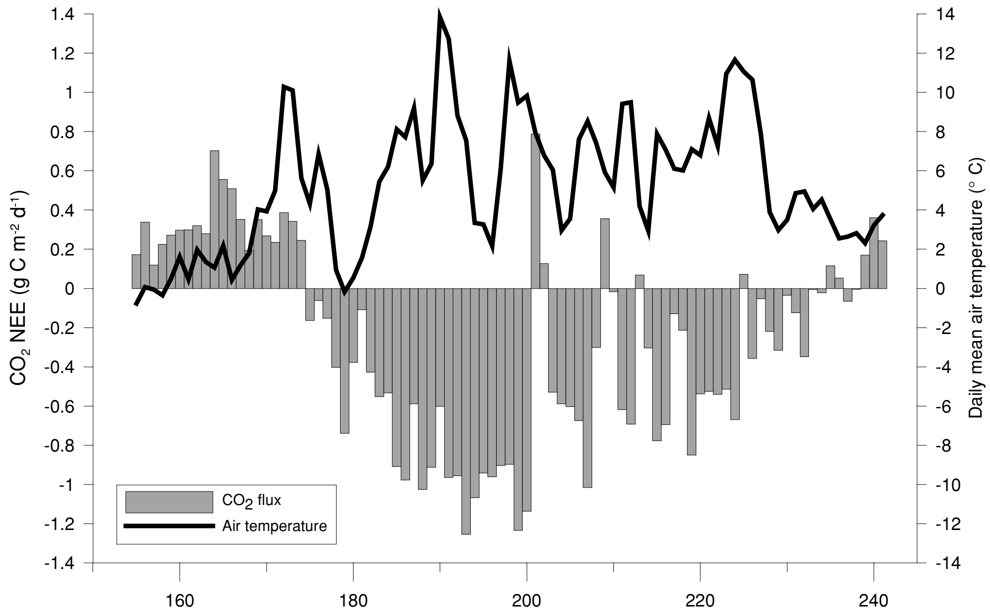

Figure 2.16. Temporal variation in Net Ecosystem Exchange (NEE) and daily mean air temperature at the heath in 2004.

cliff face, which means that the cliff has recessed 24.2 m since 2000. Finally, at D4 the cliff has recessed in the order of 40 m since 2000 (based on the GPS position of the lost peg).

Cross shore profiles

In 2004, the topographic cross shore profiles near the old delta (Profile 1 and Profile 2) were re-surveyed 13 August. Only minor topographic changes have happened since 2003.

	2000	2001	2002	2003	2004
Beginning of growing season	25 June	6 July	2 July	28 June	23 June
End of growing season	11 August	18 august	16 August	20 August	21 August
Length of growing season	47 days	43 days	45 days	53 days	59 days
Beginning of measuring season	6 June	8 June	3 June	5 June	3 June
End of measuring season	25 August	27 August	27 August	30 August	28 August
Length of measuring season	80 days	81 days	86 days	86 days	86 days
NEE for growing season (g C m-2)	(–) 22.7	(–) 19.1	(–) 18.2	(–) 30.4	(–) 29.7
NEE for measuring season (g C m2)	(–) 19.1	(–) 8.7	(–) 9.5	(–) 23	(–) 22.4
Maximum daily accumulation (g C m-2 d-1)	(–) 0.92	(–) 0.94	(–) 1.00	(–) 1.4	(–) 1.3

Table 2.18. Summary of summer season environmental variables and CO_2 exchange, 2000-2004.

	Recession (m)			
	Site 1	Site 2	Site 3	Site 4
1996-1997	0	0	0.3	1
1996-1998	0	0	0.3	1.3
1996-1999	0	0	0.3	1.3
1996-2000	0	0	0.5	1.4
1996-2001	0	0	0.5	1.4
1996-2002	0	0	0.7	2.8
1996-2003	0	0.4	1.6	3.2
1996-2004	0	0.5	1.7	3.2

Table 2.19. Cumulated coastal cliff recession at the southern coast of Zackenbergdalen, 1996-2004.

3 Zackenberg Basic: The BioBasis programme

Hans Meltofte (ed.)

The BioBasis programme at Zackenberg is carried out by the National Environmental Research Institute (NERI). It is funded by the Danish Environmental Protection Agency as part of the environmental support program Dancea – Danish Cooperation for the Environment in the Arctic. The authors are solely responsible for all results and conclusions presented in the report, which does not necessarily reflect the position of the Danish Environmental Protection Agency.

Details on BioBasis methods and sampling procedures are presented in a manual (Meltofte and Berg 2004), which is available from the Zackenberg home page (www.zackenberg.dk). A map with locality names used in this chapter is found at the same home page. Also, a synopsis of the entire BioBasis programme and primary data are presented on the website.

3.1 Vegetation

Susanne M. König and Mikkel P. Tamstorf

The weekly records of snow cover, flowering and reproduction were made by Susanne M. König during the entire season.

As a new development this year, the relative vegetation index (RVI) sensor used for hand-held determination of vegetation greenness was mounted on a 1 m stick in order to avoid possible influence of shading, colour of boots etc. caused by the observer. Unfortunately, the sensor was damaged during the summer, and data from the peak of greening was lost.

Reproductive phenology, amounts of flowering and berry production

2004 was an extremely early year with respect to snowmelt (see section 2.2). Together with relatively high spring temperatures, this resulted in many flower plots, located on ridges and other sites exposed to sun and wind, being snow free, when the observations began in early June. From Table 3.1 it is evident that this was the case for most of the *Dryas integrifolia/octopetala*, *Saxifraga oppositifolia* and *Silene acaulis* plots, but also for the rest of the flower plots, 2004 was among the earliest snow free recorded. Furthermore, the 2004 growing season was dry compared to previous years. Precipitation in June was only one third compared to the 1996-2003 mean, and in August it was only one fourth.

The very early snowmelt and high temperatures meant that in 64% of all flower plots, the dates for 50% open flowers were the earliest ever recorded (excluding the Salix plots, which were recorded for the first time in 2004). Within these 64%, the 50% flowering date was 1-4 days earlier than previously recorded. The remaining 36% of the plots also flowered early (Table 3.2).

The early flowering recorded in the study plots is supported by more random records of first observations of flowers in about 20 plant species recorded since 1996. Here again, flowers were recorded earlier than before or on the same date as the earliest previous record in app. half the species.

The effect of early snow melt was less pronounced with respect to open seed capsules, where only 43% of the plots were the earliest recorded (Table 3.3). However, in general, all recordings of open seed capsules were among the earliest recorded with one to three days – Saxifraga 3 even 17 days earlier than previously observed.

Most of the monitored species form buds one year prior to flowering (Sørensen 1941). 2003 was a year with very thin snow cover and early snowmelt, thus resulting in a long 2003 growing season (Rasch and Caning 2004). It was therefore not surprising to find large numbers of flowers in most plots, although numbers only exceeded previous findings in 29% of the plots. *Papaver radicatum* seems to be the least responsive of the species, but this

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cassiope 1	14.6	9.6	13.6	27.6	2.6	7.6	13.6	6.6	<3.6
Cassiope 2	19.6	21.6	27.6	4.7	<4.6	21.6	20.6	13.6	16.6
Cassiope 3	15.6	21.6	20.6	3.7	13.6	20.6	20.6	7.6	7.6
Cassiope 4	20.6	15.6	20.6	4.7	13.6	21.6	17.6	7.6	7.6
Dryas 1	<3.6	<27.5	(23.5)	6.6	<4.6	<31.5	<30.5	4.6	<2.6
Dryas 2	26.6	27.6	4.7	12.7	21.6	3.7	28.6	22.6	21.6
Dryas 3	6.6	<27.5	7.6	19.6	<4.6	6.6	6.6	6.6	<3.6
Dryas 4	1.6	3.6	13.6	21.6	<4.6	7.6	6.6	(31.5)	<1.6
Dryas 5	6.6	31.5	4.6	14.6	<4.6	5.6	6.6	6.6	<1.6
Dryas 6	21.6	4.7	5.7	11.7	20.6	28.6	30.6	19.6	21.6
Papaver 1	20.6	18.6	21.6	3.7	1.6	20.6	18.6	12.6	14.6
Papaver 2	20.6	20.6	21.6	4.7	14.6	21.6	20.6	21.6	11.6
Papaver 3	21.6	15.6	20.6	3.7	13.6	21.6	19.6	14.6	8.6
Papaver 4	21.6	4.7	5.7	11.7	20.6	27.6	30.6	19.6	21.6
Salix 1	<3.6	<27.5	<27.5	<1.6	<3.6	<31.5	<30.5	(31.5)	<3.6
Salix 2	14.6	20.6	23.6	1.7	13.6	21.6	14.6	14.6	9.6
Salix 3	7.6	8.6	12.6	24.6	<3.6	7.6	7.6	(2.6)	<3.6
Salix 4	20.6	5.6	21.6	22.6	7.6	11.6	10.6	13.6	5.6
Salix 5	–	–	–	–	–	–	–	21.6	11.6
Salix 6	–	–	–	–	–	–	–	–	21.6
Salix 7	–	–	–	–	–	–	–	–	21.6
Saxifraga 1	<3.6	<27.5	<27.5	<1.6	<3.6	<31.5	<30.5	(1.6)	<2.6
Saxifraga 2	<3.6	<27.5	<27.5	(27.5)	<3.6	<31.5	<30.5	(31.5)	<2.6
Saxifraga 3	–	<27.5	27.5	6.6	<3.6	(27.5)	<30.5	(1.6)	<2.6
Silene 1	<3.6	<27.5	<27.5	<1.6	<3.6	<31.5	<30.5	(1.6)	<2.6
Silene 2	<3.6	<27.5	<27.5	(27.5)	<3.6	<31.5	<30.5	(31.5)	<2.6
Silene 3	–	<27.5	27.5	6.6	<3.6	(27.5)	<30.5	(1.6)	<2.6
Silene 4	24.6	28.6	20.6	6.7	21.6	28.6	25.6	19.6	18.6

Table 3.1. Inter- and extrapolated dates of 50% snow cover for white arctic bell-heather Cassiope tetragona, mountain avens Dryas integrifolia/octopetala, arctic poppy Papaver radicatum, arctic willow Salix arctica, purple saxifrage Saxifraga oppositifolia and moss campion Silene acaulis plots 1996-2004. Brackets denote extrapolated dates.

remains to be explored in detail (Table 3.4).

In accordance with previous observations, only a small percentage of female *Salix* catkins were infected by fungi (Table 3.5).

In agreement with the findings of 2003 (Rasch and Caning 2004), large numbers of flowers were produced in the plot with arctic blueberry *Vaccinium uliginosum*, but only very few of these seemed to develop into berries. 6067 flowers were counted, but only three berries were observed (Table 3.6). This does not seem to be in accordance with the fairly large numbers of *Vaccinium* berries observed in the rest of the valley (pers. obs.). It is speculated that a nesting pair of skuas in close proximity to the plot fed on this particular patch of berries. Unfortunately, the count of bearberry *Arctostaphylos alpina* flowers was too late in two of the four plots, rendering it impossible to determine the percentage of flowers that developed into berries. However, the two other plots had an average berry development of 28%.

Vegetation greening in mammal, bird and flower study plots

Greening index data (NDVI) from a Landsat-7 ETM+ satellite image from 29 July 2004 are presented in Table 3.7, and in Table 3.8 they are compared with previous years after extrapolation to simulate 31 July each year (see Figure 4.1 in Caning and Rasch 2003 for location of sections in Zackenbergdalen). Due to a technical problem with the Landsat-7 ETM+ sensor, the 2004 data contain striping of no-data values. Therefore, NDVI for each region is based on areas with valid data, assuming

Table 3.2. Inter- and extrapolated dates of 50% open flowers (50/50 ratio of buds/open flowers) for white arctic bell-heather Cassiope tetragona, mountain avens Dryas integrifolia/octopetala, arctic poppy Papaver radicatum, arctic willow Salix arctica, purple saxifrage Saxifraga oppositifolia and moss campion Silene acaulis 1996-2004. Brackets denote interpolated dates based on less than 50 buds + flowers.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cassiope 1	2.7	6.7	6.7	13.7	(28.6)	4.7	3.7	27.6	23.6
Cassiope 2	6.7	20.7	(21.7)	(26.7)	–	12.7	7.7	3.7	5.7
Cassiope 3	9.7	18.7	(19.7)	(26.7)	–	11.7	9.7	2.7	30.6
Cassiope 4	15.7	15.7	(21.7)	(26.7)	–	19.7	7.7	5.7	3.7
Dryas 1	19.6	22.6	26.6	3.7	26.6	22.6	25.6	30.6	21.6
Dryas 2	13.7	4.8	8.8	–	24.7	1.8	29.7	19.7	18.7
Dryas 3	2.7	26.6	6.7	13.7	27.6	6.7	28.6	29.6	23.6
Dryas 4	27.6	6.7	(9.7)	14.7	26.6	6.7	28.6	23.6	22.6
Dryas 5	30.6	5.7	1.7	7.7	22.6	5.7	28.6	28.6	20.6
Dryas 6	19.7	9.8	(7.8)	19.8	21.7	29.7	1.8	17.7	17.7
Papaver 1	14.7	20.7	24.7	2.8	4.7	12.7	12.7	5.7	11.7
Papaver 2	14.7	23.7	26.7	30.7	15.7	14.7	13.7	8.7	8.7
Papaver 3	14.7	19.7	26.7	1.8	10.7	17.7	13.7	11.7	5.7
Papaver 4	15.7	7.8	11.8	15.8	(20.7)	(27.7)	2.8	17.7	12.7
Salix 1	6.6	6.6	12.6	14.6	11.6	8.6	9.6	17.6	4.6
Salix 2	21.6	29.6	10.7	17.7	28.6	29.6	28.6	28.6	21.6
Salix 3	20.6	25.6	(28.6)	5.7	11.6	24.6	16.6	15.6	7.6
Salix 4	29.6	23.6	2.7	3.7	17.6	28.6	26.6	23.6	21.6
Salix 5	–	–	–	–	–	–	–	5.7	23.6
Salix 6	–	–	–	–	–	–	–	–	15.7
Salix 7	–	–	–	–	–	–	–	–	5.7
Saxifraga 1	–	31.5	5.6	7.6	6.6	8.6	3.6	14.6	5.6
Saxifraga 2	–	2.6	7.6	14.6	9.6	8.6	6.6	14.6	5.6
Saxifraga 3	5.6	1.6	9.6	16.6	7.6	9.6	7.6	14.6	<2.6
Silene 1	20.6	24.6	21.6	28.6	26.6	28.6	23.6	1.7	21.6
Silene 2	23.6	29.6	1.7	30.6	2.7	30.6	27.6	4.7	29.6
Silene 3	30.6	26.6	23.6	6.7	28.6	4.7	28.6	4.7	20.6
Silene 4	26.7	10.8	20.8	–	28.7	29.7	28.7	20.7	19.7

Table 3.3. Inter- and extrapolated dates of 50% open seed capsules for arctic poppy Papaver radicatum, arctic willow Salix arctica and purple saxifrage Saxifraga oppositifolia 1995-2004. Brackets denote interpolated dates based on less than 50 flowers + open capsules.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Papaver 1	5.8	15.8	–	30.8	>26.8	9.8	16.8	20.8	1.8	6.8
Papaver 2	15.8	15.8	24.8	–	>26.8	(17.8)	16.8	17.8	3.8	6.8
Papaver 3	6.8	13.8	19.8	–	29.8	14.8	18.8	20.8	6.8	3.8
Papaver 4	20.8	–	>27.8	–	(>26.8)	(16.8)	24.8	(26.8)	10.8	14.8
Salix 1	8.8	8.8	8.8	5.8	13.8	12.8	2.8	29.7	2.8	26.7
Salix 2	12.8	9.8	19.8	30.8	25.8	20.8	18.8	11.8	3.8	5.8
Salix 3	2.8	8.8	16.8	(19.8)	16.8	12.8	14.8	5.8	28.7	27.7
Salix 4	12.8	17.8	14.8	21.8	16.8	13.8	13.8	12.8	3.8	6.8
Salix 5	–	–	–	–	–	–	–	–	4.8	7.8
Salix 6	–	–	–	–	–	–	–	–	11.8	10.8
Salix 7	–	–	–	–	–	–	–	–	13.8	10.8
Saxifraga 1	–	20.7	10.8	11.8	13.8	9.8	8.8	4.8	7.8	23.7
Saxifraga 2	–	23.7	16.8	24.8	15.8	15.8	14.8	1.8	11.8	27.7
Saxifraga 3	–	7.8	9.8	23.8	16.8	7.8	13.8	12.8	9.8	23.7

	Area	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cassiope 1	2	1321	1386	1855	322	312	28	1711	1510	851	2080
Cassiope 2	3		1759	550	19	16	8	1353	952	1001	1745
Cassiope 3	2	256	844	789	35	18	0	771	449	817	791
Cassiope 4	3	456	1789	391	24	6	3	578	164	1189	1274
Cassiope 5	2.5	–	–	1224	455	474	50	3214	3208	2708	2006
Cassiope 6	2	–	–	>350	16	3	1	544	736	134	2796
Dryas 1	4	(936)	(797)	138	223	852	607	1016	627	744	444
Dryas 2	60	534	1073	230	42	49	46	172	290	552	1174
Dryas 3	2	603	522	123	255	437	266	577	235	294	273
Dryas 4	6	(325)	(164)	155	69	356	55	301	187	224	218
Dryas 5	6	(654)	(504)	123	191	655	312	506	268	589	351
Dryas 6	91	809	1406	691	10	25	140	550	430	627	1854
Dryas 7	12	–	–	787	581	1355	574	1340	1483	1543	1026
Dryas 8	12	–	–	391	240	798	170	403	486	545	229
Papaver 1	105	302	337	265	190	220	197	237	277	278	286
Papaver 2	150	814	545	848	316	315	236	466	456	564	402
Papaver 3	90	334	238	289	266	183	240	259	301	351	221
Papaver 4	91	196	169	192	80	30	35	65	59	56	37
Salix 1 mm.	60	–	807	959	63	954	681	536	1454	1931	1127
Salix 1 ff.	–	520	1096	1349	149	1207	900	1047	1498	2159	1606
Salix 2 mm.	300	–	790	1082	132	416	55	803	1206	967	1276
Salix 2 ff.	–	617	1376	1909	455	418	95	1304	1816	1638	1862
Salix 3 mm.	36	239	479	412	32	52	330	1196	344	621	693
Salix 3 ff.	–	253	268	237	38	68	137	1009	315	333	476
Salix 4 mm.	150	–	1314	831	509	718	965	680	1589	1751	1984
Salix 4 ff.		1073	1145	642	709	880	796	858	1308	1418	1755
Salix 5 mm.	–	–	–	–	–	–	–	–	–	494	844
Salix 5 ff.	–	–	–	–	–	–	–	–	–	371	1314
Salix 6 mm.	–	–	–	–	–	–	–	–	–	–	2162
Salix 6 ff.	–	–	–	–	–	–	–	–	–	1145	2736
Salix 7 mm.	–	–	–	–	–	–	–	–	–	612	621
Salix 7 ff.	–	–	–	–	–	–	–	–	–	839	512
Saxifraga 1	7	–	(1010)	141	163	584	1552	558	542	1213	463
Saxifraga 2	6	–	513	387	432	158	387	515	617	561	584
Saxifraga 3	10	–	529	322	288	707	403	558	318	509	609
Silene 1	7	–	(251)	403	437	993	1327	674	766	1191	1187
Silene 2	6	–	493	524	440	400	692	568	1094	917	1406
Silene 3	10	–	348	211	127	313	274	348	480	1000	719
Silene 4	1	466	270	493	312	275	358	462	470	794	509
E. scheuz. 1	10	–	395	423	257	309	229	111	582	843	780
E. scheuz. 2	6	–	537	344	172	184	201	358	581	339	956
E. scheuz. 3	10	–	392	545	482	587	38	367	260	237	359
E. scheuz. 4	8	–	260	755	179	515	117	121	590	445	176
E. triste 1	10	–	0	3	1	1	1	0	3	11	12
E. triste 2	6	–	98	59	21	16	43	56	67	39	117
E. triste 3	10	–	0	0	0	0	0	0	0	0	0
E. triste 4	8	–	0	0	0	0	0	0	0	0	0
Arctostaphylos 1	–	–	–	–	–	–	–	–	1865	3035	285
Arctostaphylos 2	–	–	–	–	–	–	–	–	215	272	>10
Arctostaphylos 3	–	–	–	–	–	–	–	–	387	375	>68
Arctostaphylos 4	–	–	–	–	–	–	–	–	996	1216	563
Vaccinium 1	–	–	–	–	–	–	–	–	2521	9271	6067

Table 3.4. Area size (m^2) and pooled numbers of flower buds, flowers and senescent flowers of white arctic bell-heather Cassiope tetragona, mountain avens Dryas integrifolia/octopetala, arctic poppy Papaver radicatum, arctic willow Salix arctica, purple saxifrage Saxifraga oppositifolia, moss campion Silene acaulis, arctic cotton-grass Eriophorum scheuzerii and 'dark cotton-grass' Eriophorum triste in flower plots in 1995-2004. Numbers in brackets have been extrapolated from 1995 and 1996 data to compensate for enlargements of plots after 1996 (see Meltofte and Rasch 1998).

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Salix 1	5	4	0	22	4	1	3	+	2
Salix 2	0	1	2	2	0	0	1	0	0
Salix 3	0	0	0	6	0	0	2	0	0
Salix 4	16	3	0	6	0	0	0	0	3
Salix 5	–	–	–	–	–	–	–	–	3
Salix 6	–	–	–	–	–	–	–	–	0
Salix 7	–	–	–	–	–	–	–	–	0

Table 3.5. Peak ratio (per cent) of female Salix pods infested by fungi in Salix plots in 1996-2004.

	Area	1998	1999	2000	2001	2002	2003	2004
Arctostaphylos 1	1.5	148	240	30	99	33	122	22
Arctostaphylos 2	1.5	50	17	2	36	18	55	1
Arctostaphylos 3	1.5	28	91	4	100	32	21	16
Arctostaphylos 4	1.5	139	107	0	14	44	106	201
Vaccinium 1	4	240	532	9	0	1	14	3
Empetrum 1	4	27	1	17	3081	1034	4568	1084

Table 3.6. Area size (m^2) and numbers of berries recorded in alpine bearberry Arctostaphylos alpina, arctic blueberry Vaccinium uliginosum and crowberry Empetrum nigrum plots in 1998-2004.

that the valid data are representative for the entire region. Areas with no data covered in average 20% of each region. Hence, the 2004 data should be interpreted with great care. In general, the values are higher than average for the 1995-2004 period, but still lower than the values from 1997 and 1998. 2004 was very dry during the growing season, which may have had a negative impact on plant growth.

Due to problems with RVI sensors and meters during the vegetational peak season, it is not possible to report the season's results on maximum NDVI records. Attempts are currently made to correct data. If successful, these will be reported together with data for 2005 in the 11th annual report.

	Area	Min.	Max.	Mean	Std.Dev.
1 (0-50 m)	3.52	0.00	0.75	0.41	0.19
2 (0-50 m)	7.97	0.00	0.85	0.49	0.19
3 (50-150 m)	3.52	0.00	0.79	0.53	0.14
4 (150-300 m)	2.62	0.00	0.73	0.40	0.15
5 (300-600 m)	2.17	0.00	0.72	0.30	0.16
6 (50-150 m)	2.15	0.00	0.73	0.45	0.17
7 (150-300 m)	3.36	0.00	0.71	0.44	0.16
8 (300-600 m)	4.56	0.00	0.74	0.32	0.19
9 (0-50 m)	5.01	0.00	0.80	0.51	0.16
10 (50-150 m)	3.84	0.00	0.92	0.54	0.13
11 (150-300 m)	3.18	0.00	0.75	0.44	0.16
12 (300-600 m)	3.82	0.00	0.80	0.40	0.19
13 (Lemmings)	2.05	0.00	0.77	0.47	0.16
Total Area	45.72	0.00	0.77	0.44	0.17

Table 3.7. Area size (km^2) and Normalised Difference Vegetation Index (NDVI) values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen along with the lemming monitoring area (part of Section 2) based on Landsat-7 ETM+ satellite image from 29 July 2004 (see Fig. 4.1 in Caning and Rasch 2003 for position of sections). The image has been corrected for atmospheric and terrain influence (humidity, aerosols, solar angle and terrain effects). All negative NDVI values have been changed to 0. Water and snow covered areas therefore have similar values from year to year. Note that the 2004 data set is incomplete (see the text).

3.2 Arthropods

Jesper Birkedal Schmidt, Susanne M. König and Ole Thorup

Methods and procedures of arthropod sampling during the 2004 season followed those of previous years. The sampling employed five pitfall trap stations, each with eight pitfall traps, together with one window trap station with two traps. The fieldwork was conducted by Susanne M. König and Toke T. Höye. Jesper B. Schmidt carried out the sorting of the specimens. The material is stored in 70% ethanol at the Zoological Museum, University of Copenhagen.

This year, the ice and snow melted earlier than recorded in all previous years (Table 3.9 and section 3.1). 56,686 specimens of insects and arachnids were collected in 2004. This number is in the middle of the range of specimens collected annually 1996-2003. However, it is less than the numbers of the two most recent years, even though the number of trapping days was a bit higher (Tables 3.10 and 3.11).

Window traps

On 1 June, the window traps in Gadekæret were opened. This day, the ice cover on the surrounding pond was 7% (Table 3.9). The traps worked continuously until 26 August, when they were closed. Because of damage by a musk ox, one of the traps was replaced on 19 August.

The total number of specimens caught in the window traps this year was 7751, which is the lowest number in five years (Table 3.10). The main reason was a decline in the numbers of chironomids, which constitute the bulk of specimens

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1 (0-50 m)	0.37	0.43	0.44	0.44	0.30	0.41	0.34	0.34	–	0.42
2 (0-50 m)	0.43	0.50	0.50	0.51	0.41	0.48	0.43	0.44	–	0.50
3 (50-150 m)	0.54	0.53	0.54	0.53	0.41	0.51	0.47	0.49	–	0.54
4 (150-300 m)	0.46	0.45	0.46	0.44	0.31	0.43	0.36	0.38	–	0.41
5 (300-600 m)	0.36	0.35	0.38	0.38	0.22	0.37	0.26	0.26	–	0.31
6 (50-150 m)	0.48	0.48	0.47	0.46	0.33	0.44	0.39	0.41	–	0.46
7 (150-300 m)	0.48	0.46	0.48	0.45	0.32	0.43	0.38	0.39	–	0.45
8 (300-600 m)	0.42	0.38	0.41	0.42	0.25	0.35	0.28	0.29	–	0.33
9 (0-50 m)	0.42	0.50	0.52	0.51	0.39	0.50	0.44	0.45	–	0.52
10 (50-150 m)	0.52	0.53	0.54	0.52	0.40	0.52	0.48	0.48	–	0.55
11 (150-300 m)	0.47	0.45	0.46	0.42	0.26	0.41	0.35	0.36	–	0.45
12 (300-600 m)	0.42	0.42	0.44	0.45	0.28	0.32	0.34	0.33	–	0.41
13 (Lemmings)	0.42	0.49	0.50	0.49	0.40	0.47	0.41	0.43	–	0.48
Total	0.45	0.46	0.48	0.47	0.32	0.43	0.38	0.38	–	0.45

Table 3.8. Mean NDVI values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area (part of section 2) based on Landsat TM, ETM+ and SPOT 4 HRV satellite images 1998-2004 (see Fig. 4.1 in Caning and Rasch 2003 for position of sections). The data have been corrected for differences in date of image between years to simulate the 31 July value. When comparing values, it should be noted that optimum of the plant communities varies between years with 31 July close to optimum of most years. Note that the 2004 data set is incomplete and should be interpreted with great care (see the text).

collected (Table 3.10). On the other hand, the peak occurrence of chironomids was relatively early (Figure 3.1), probably a result of the early ice and snowmelt.

As in 2003, a lower number of ceratopogonids compared to the previous years was recorded (Table 3.10). However, for a few taxa, the numbers were higher than before. 38 specimens of aromyzids were collected versus three or less in other years. The number of muscids was 1440 as compared to 866 in 2003 and 554 in 2002. 11 specimens of Thysanoptera and 10 specimens of *Nysius granlandicus* were caught. In the former years, only a few specimens of these two taxa were found in the window traps. Likewise, the butterfly *Colias hecla* was caught in a higher number than before, and collembolans returned to the high level of the years 2000-2002 (Table 3.10).

Furthermore, three specimens of the cycclorrhaph dipteran family Piophilidae were recorded for the first time this year.

Pitfall traps

The first pitfall traps were established on 1 June and the last on 17 June. During the season, some of the traps were replaced because the water in the traps turned opaque, because of damage by foxes, fox urine and occurrence of a dead lemming.

The number of trapping days amounts to 3437, which is higher than in all previous years (Table 3.11). Weekly totals are pooled for all five plots and presented in Table 4.11 with totals from 1996-2003 for comparison.

The most numerous taxa caught in the pitfall traps were Collembola and Acari. Although the number of Collembola was somewhat lower than in the last five years, the order of magnitude for both taxa was the same. Among the other numerous

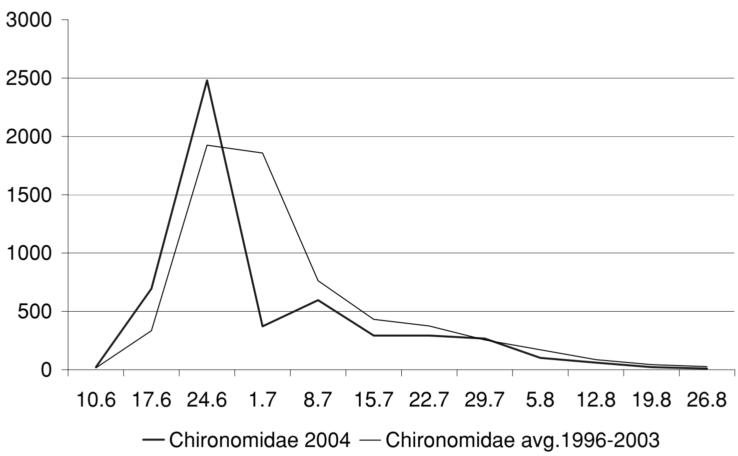

Figure 3.1. Numbers of chironomid midges Chironomidae caught per week in window traps 2004, compared with mean numbers 1996-2003.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Art. 1	3.6	Dry	6.6	16,6	1.6	6,6	3.6	12.6	<1.6**
Art. 2	<3.6*	28.5	29.5	8.6	<4.6*	<31.5*	<31.5*	1.6	<1.6*
Art. 3	14.6	19.6	18.6	27.6	9.6	19.6	14.6	20.6	4.6
Art. 4	14.6	22.6	26.6	2.7	7.6	21.6	20.6	11.6	6.6
Art. 5	4.6	<29.5*	1.6	12.6	<4.6*	8.6	3.6	5.6	<1.6*
Art. 7	–	–	–	<3.6	<4.6*	<30.5	<31.5*	2.6	<1.6*

* 0% snow
** 7% ice cover

Table 3.9. Date of snow-cover (ice-cover on pond at Station 1) in the arthropod plot 1996-2004.

Date	3.6	10.6	17.6	24.6	1.7	8.7	15.7	22.7	29.7	5.8	12.8	19.8	26.8	2004	2003	2002	2001	2000	1999	1998	1997	1996
No. of trap days	4	14	14	14	14	14	14	14	14	14	14	14	14	**172**	168	168	168	166	153	174	184	182
COLLEMBOLA			1	9	17	12	5	62	32	17	14	6		**175**	31	191	119	102	61	5	15	65
COLEOPTERA																						
Latridius minutus														**0**	0	0	0	0	2	0	0	0
HEMIPTERA																						
Nysius groenlandicus		1				6	2	1						**10**	0	1	0	0	0	0	0	4
Aphidoidea						1					2			**3**	1	0	2	0	0	0	0	0
Coccoidea														**0**	0	0	0	3	0	0	0	14
THYSANOPTERA				1	1				2		4	3		**11**	0	3	1	0	0	0	0	8
LEPIDOPTERA																						
Colias hecla				1		1	4	2	1					**9**	2	6	0	2	0	0	0	1
Clossiana sp.							1			2	2			**5**	4	1	1	2	1	1	1	6
Geometridae														**0**	0	2	3	0	0	0	1	3
Noctuidae										1				**1**	1	0	0	0	0	0	2	2
DIPTERA																						
Nematocera larvae														**0**	0	2	0	0	1	0	0	0
Nematocera undet.														**0**	0	0	1418	0	0	0	0	0
Tipulidae														**0**	1	0	0	0	1	0	0	0
Trichoceridae						1			1					**2**	0	0	0	0	0	1	1	0
Culicidae					3	21	31	20	13	6	8	2		**104**	96	232	209	111	322	138	142	98
Chironomidae		22	695	2481	372	596	293	293	267	101	61	22	10	**5213**	7792	6378	3876	8522	5787	3743	7725	6477
Ceratopogonidae				2	1	6	1	3	4	3	1			**21**	66	1598	168	*	1799	*	*	*
Mycetophiliidae						3	3	3	6	4	2			**21**	2	6	23	22	16	624	240	64
Sciaridae			7	30	1	7	5	2				1		**53**	12	56	33	2	171	*	*	*
Cecidomyiidae														**0**	0	3	4	32	6	0	0	1
Empididae			1			1	2		2		1			**7**	8	1	8	10	9	9	1	77
Phoridae														**0**	0	1	1	2	3	0	0	0
Syrphidae					1	1	1	3	2		1	3		**12**	6	10	4	5	1	8	16	4
Heleomyzidae														**0**	0	1	2	0	1	0	0	0
Piophilidae											2	1		**3**	0	0	0	0	0	0	0	0
Agromyzidae	1	13	10	3		2		1			3	1	4	**38**	2	3	0	0	0	0	4	0
Tachinidae					1	2	1	1	2		2	1		**10**	7	0	2	6	1	0	0	0
Calliphoridae				1		1				1		1		**4**	1	1	1	4	5	7	6	2
Scatophagidae						1		1	2	2	4	1	1	**12**	3	7	0	2	10	0	30	11
Anthomyiidae				1	2		1		2	2	2	2		**12**	10	8	2	*	3	26	11	*
Muscidae	1	3	7	165	258	355	101	135	101	97	101	99	17	**1440**	866	554	1312	1455	754	745	809	1355
HYMENOPTERA																						
Bombus sp.					1	1		1		1	1			**5**	3	1	0	0	1	2	6	5
Ichneumonidae					2	14	14	7	6	3	1		1	**48**	70	24	34	48	24	18	44	43
Braconidae		1												**1**	0	0	0	0	0	1	1	0
Chalcidoidea						1								**1**	1	2	14	0	0	0	2	0
Ceraphronoidea														**0**	2	0	0	0	0	0	0	0
ARANEA																						
Lycosidae								1					1	**2**	1	1	0	2	0	0	1	0
Linyphiidae								1			3			**4**	8	8	15	10	6	1	1	8
ACARINA	1		12	76	291	34	24	27	19	16	19	5		**524**	54	347	358	246	191	826	189	299
Total	3	40	733	2770	951	1067	489	564	462	256	234	148	34	**7751**	9050	9448	7610	10588	9177	6155	9248	8547

Table 3.10. Weekly totals of arthropods etc. caught at the window trap station in 2004. The station holds two window traps situated perpendicular to each other. Each window measures 20 x 20 cm. Values from each date represents catches from the previous week. Totals from 1996-2003 are given for comparison. An asterisk marks that the group was not separated from a related group in that year.

taxa, numbers of chironomids were the lowest so far, while coccoids were much higher (Table 3.11).

The Muscidae peaked two weeks earlier than the average for the years 1996-2003, and the peak lasted only three weeks, whereas the average is four weeks (Figure 3.2).

The butterflies (Lepidoptera) had fewer adult specimens caught compared to the two previous years. However, the number of *Clossiana* larvae was higher. Both species of *Clossiana* present in Greenland were caught; arctic fritillary *C. chariclea* being more dominant in numbers than polar fritillary *C. polaris*.

Date	3.6	10.6	17.6	24.6	1.7	8.7	15.7	22.7	29.7	5.8	12.8	19.8	26.8	2004	2003	2002	2001	2000	1999	1998	1997	1996
No. of active stations	3	5	5	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5
No. of trap days	168	196	273	280	280	280	280	280	280	280	280	280	280	**3437**	3101	3059	2954	3155	2706	2702	2797	(1512)
COLLEMBOLA	32	293	1207	571	661	617	298	5518	1704	1494	432	315	135	**13277**	17510	20312	17970	21726	23443	8957	10830	4636
HETEROPTERA																						
Nysius groenlandicus				1		6	6	1	2	7	17	9	47	**96**	3	0	2	0	1	0	5	40
Aphidoidea		3	5	21	8	34	36	74	27	22	13	23	11	**277**	1624	157	359	3	11	185	10	6
Coccoidea		3	23	52	59	364	290	188	50	78	76	78	27	**1288**	42	634	9	781	431	3	548	254
THYSANOPTERA			1					1	2					**4**	0	5	0	0	2	0	0	2
LEPIDOPTERA																						
Lepidoptera larvae		2		24	21	81	72	23	8	20	18	9	2	**280**	37	63	16	18	21	106	168	354
Tortricidae														**0**	1	0	1	0	0	0	0	0
Colias hecla						4	13	9	6	4	1	1		**38**	156	29	0	77	42	12	19	88
Clossiana sp.			1	1		11	46	65	39	44	28	4	1	**240**	468	381	49	329	82	56	180	1052
Lycaenidae														**0**	0	0	0	4	1	0	0	0
Plebeius franklinii									1					**1**	0	7	19	0	0	1	1	2
Geometridae				1			1							**2**	0	6	0	0	0	0	0	0
Noctuidae					1	3	5	4			1			**14**	110	1	15	4	6	2	45	68
DIPTERA																						
Nematocera larvae			2	6	1		1	2	5				1	**18**	29	46	15	279	105	58	39	52
Tipulidae larvae			2				1	1		2				**6**	3	3	3	4	1	0	0	0
Tipulidae							1							**1**	7	4	14	2	4	1	4	14
Trichoceridae				1										**1**	1	1	7	0	3	0	1	0
Culicidae					3	2	8	4	1	1				**19**	23	86	34	61	83	22	16	2
Chironomidae		41	76	441	244	419	204	77	39	24	17	9	5	**1596**	4768	5982	1958	3666	8542	2402	3337	3292
Ceratopogonidae				3	2	2	5	2	2					**16**	107	102	7	0	68	*	*	*
Mycetophiliidae		4	3	2	5	9	5	8	8	17	2			**63**	70	48	181	820	205	1764	1194	526
Sciaridae		3	55	124	215	344	92	35	23	16	5			**912**	1101	762	573	4	796	*	*	*
Cecidomyiidae	2	1	5	1	2	1	1							**13**	8	6	8	24	0	1	0	0
Brachycera larvae														**0**	3	0	0	4	3	0	0	0
Empididae			1		1					2	1			**5**	8	24	28	14	21	10	6	8
Cyclorrhapha larvae							2	8	22	10	5	9	4	**60**	23	22	0	7	7	19	75	16
Phoridae			1	3		12	100	44	72	133	85	3	8	**461**	665	489	445	1316	435	344	214	118
Syrphidae		4	4	1	2	1		4	6	14	7	2		**45**	35	30	18	43	50	28	81	72
Heleomyzidae													1	**1**	1	5	6	1	7	0	0	0
Agromyzidae	1	5	3	1	3	2		1	1	4	10	6	23	**60**	10	6	4	2	0	0	1	0
Tachinidae					1	14	6	5	4	4	6	1	1	**42**	60	23	29	37	37	0	19	0
Calliphoridae	3	6	2	1	1	2			1	6	2	1	6	**31**	17	44	5	218	26	49	48	48
Scatophagidae				2		2					2		1	**7**	42	24	0	1	41	0	385	26
Fannidae														**0**	0	0	0	0	0	0	1	0
Anthomyiidae	3	4	18	15	2	2	2		10	15	30	15	8	**124**	108	238	57	*	88	416	573	*
Muscidae	0	13	225	1178	1022	1351	461	257	260	381	347	83	45	**5623**	8385	7499	6766	12805	10005	5463	6217	8114
SIPHONAPTERA														**0**	0	0	0	0	3	0	0	0
HYMENOPTERA																						
Hymenoptera larvae					1			1	1			1		**4**	8	0	0	4	0	2	0	0
Bombus sp.	1		10	8	4	2		1		2	11	1		**40**	15	7	3	10	2	6	12	2
Ichneumonidae		1	1	24	39	76	71	90	102	99	108	50	59	**720**	974	436	442	710	386	297	567	954
Braconidae			1	1		4	4	5	3	5	6	18	14	**61**	52	11	11	15	10	105	59	44
Chalcidoidea			4	6	4	24	29	61	67	216	208	83	44	**746**	120	190	106	21	9	2	123	48
Scelionidae														**0**	310	5	3	0	101	0	0	0
Ceraphronoidea			1	2	2	1	2			1	2	2		**13**	3	8	3	15	5	0	0	0
Cynipoidae												1	2	**3**	0	0	1	0	0	0	1	0
ARANEA																						
Thomisidae	4	12	8	20	5	7	4	1	3	8	13	2	3	**90**	164	219	177	134	144	89	245	198
Lycosidae	25	199	204	390	403	521	361	221	236	184	551	79	54	**3428**	3438	1760	2618	3254	2118	2123	3806	4548
Lycosidae egg sac				1	4	26	20		1		10	4	3	**69**	85	12	85	101	160	160	138	82
Dictynidae	3	5	8	6	2	5	3	1		2		3	2	**40**	18	107	0	0	79	0	53	0
Linyphiidae	40	214	161	164	108	118	70	92	85	94	119	81	137	**1483**	2526	1438	1833	3523	2243	1108	1644	1436
ACARINA	22	450	4338	3699	1451	1609	1221	1063	505	663	1551	636	408	**17616**	18602	21282	9929	15256	8263	6304	19781	8182
OSTRACODA														**0**	12	9	0	46	84	0	0	0
NEMATODA								1						**1**	4	0	0	3	0	0	0	0
ENCHYTRAEIDAE														**0**	0	1	0	0	0	0	0	0
Unidentified														**0**	0	0	0	2	0	0	0	120
Total	136	1263	6370	6771	4277	5676	3441	7868	3296	3572	3684	1529	1052	**48935**	61756	62523	43811	65344	58174	30095	50446	34404

Table 3.11. Weekly totals of arthropods etc. caught at the five pitfall trap stations in 2003. Each station holds eight yellow pitfall traps measuring 10 cm in diameter. Values from each date represent catches from the previous week. Totals from 1997-2003 are given for comparison. Asterisks mark groups that were not separated from closely related groups in that year.

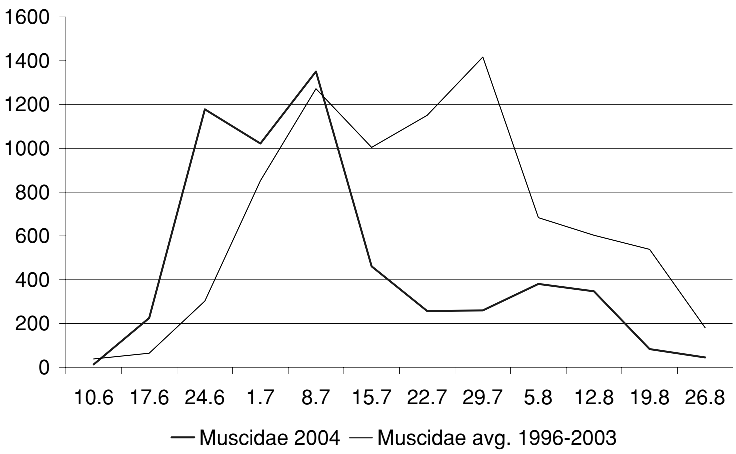

Figure 3.2. Numbers of houseflies Muscidae caught per week in pitfall traps in 2003, compared with means 1996-2003.

Notable in this year's material are the very high numbers of Chalcidoidea (746), *Bombus* (40) and the heteropteran species *Nysius groenlandicus* (96). In none of the previous years the chalcidoids were collected in numbers exceeding 200 specimens, and regarding *Bombus*, the number has doubled since 2003 (see chapter below on *Bombus*).

For *N. groenlandicus* the highest number was 40 in 1996, while five specimens have been the maximum from 1997 to 2003 (Table 4.11).

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004
Salix 1	+	0	0	43	2	0	0	0	0
Salix 2	3	0	0	6	0	0	0	0	0
Salix 3	9	0	0	3	5	0	0	2	0
Salix 4	0	0	0	1	7	0	0	0	0
Salix 5								0	0
Salix 6								0	0
Salix 7								0	0

Table 3.12. Peak ratio (per cent) of female arctic willow Salix arctica pods infested by sawfly larvae in 1996-2004. + indicates that numbers were not quantified.

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004
Dryas 1	2	6	3	0	0	0	15	2	15
Dryas 2	0	5	0	0	0	0	1	0	4
Dryas 3	11	18	3	0	0	0	7	1	33
Dryas 4	17	1	7	0	0	0	11	5	39
Dryas 5	2	8	2	0	0	0	9	2	3
Dryas 6	0	0	0	0	0	0	0	0	1
Dryas 7	–	–	0	26	0	0	2	3	0
Dryas 8	–	–	0	27	0	0	0	11	0

Table 3.13. Peak ratio (per cent) of mountain avens Dryas integrifolia/octopetala flowers depredated by larvae of "black moth" Sympistis zetterstedtii in mountain avens plots in 1996-2004.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
June	1	2	7	7	10	2	4	25	20
July	0	1	4	17	2	2	3	2	5
Total	1	3	11	24	12	4	7	27	25

Table 3.14. Number of wolly-bear Gynaephora groenlandica caterpillars recorded by one observer in study area 1A (the bird monitoring area) in June and July 1996-2004. In 2004, the number of caterpillars recorded was divided by two to compensate for the double effort by two observers (see table 3.16).

Insect predation on *Dryas* flowers and *Salix arctica*

No predation by larvae on *Salix* catkins was observed in 2004 (Table 3.12).

The percentage of *Dryas* flowers predated by larvae was higher than recorded previously (Table 3.13). In addition, a large number of flower buds was predated before they had a chance to develop into flowers. It is speculated that this was a result of the very early snowmelt and relatively warm summer, since the highest percentages of predated flowers were observed in the plots, which are situated on early snow-free ridges (Dryas 3 and 4).

The number of woolly-bear *Gynaephora groenlandica* caterpillars recorded during bird census by Ole Thorup and Hans Meltofte was the highest ever. This is related to the 'double' field effort by two observers. Therefore the numbers presented in Table 3.14 have been divided by two.

Bumblebees

The first bumblebees *Bombus polaris/hyperboreus* were recorded at the day of arrival of the bird observers on 1 June, and the last was seen on 23 August. High activity was recorded on sunny days between 12 June and 13 August, with the highest number (42) recorded on 13 August.

Numbers recorded this year were much higher than before (Table 3.15), but the number of records is highly observer related. On a joint bird survey 12-19 June OT recorded 100 bumblebees, HM only 54.

3.3 Birds

Ole Thorup and Hans Meltofte

Bird observations were recorded by Ole Thorup 1 June – 31 August and by Hans Meltofte 1 June – 28 July. This double manning gave the opportunity to double the effort during the breeding surveys compared to previous years. Valuable information was provided by other researchers and staff during the entire season.

For scientific names in this chapter, see section on Other observations. Most local site names can be found in Meltofte and Berg (2004).

Breeding populations

A complete breeding census was performed between 12 and 19 June, under which two observers mapped birds in the snow free areas in the entire bird census area. The census took 84 man-hours to complete which is far above average due to the 'double-manning'. Each observer spent 41 and 43 hours, respectively, during the census. Most of the 19 km² census area was without snow, and most waders and almost all long-tailed skuas had eggs at the time of mapping. The weather was fine or acceptable during most of the census days. However, some census work had to be performed in fairly strong wind and light sleet.

In addition, large parts of the census area were covered regularly during June and July, exceptions being the closed goose moulting area along the coast and the Aucellabjerg slopes above 350 m a.s.l. The total effort in June and July (Table 3.16) was similar to recent years west of the river, but more than double the usual effort east of the river. Also the fairly substantial amount of time devoted in late July and August for recording breeding success in waders and long-tailed skuas was much above the usual effort. Extensive glacier snowmelt in July practically prevented access to the census area west of the river between 8 and 22 July.

Based on records made during the initial census, supplemented by records during the rest of the season (see Meltofte and Berg 2004), population estimates for five sections of the census area are presented in

	1999	2000	2001	2002	2003	2004	2004
June	–	59	12	48	95	19	243
July	35	34	15	31	16	3	107
Total	–	93	27	79	111	22	350

Table 3.15. Number of bumblebees Bombus polaris/hyperboreus recorded by one bird observer (OT) in June and July.

	West of river	East of river	Total
June	8; 42	36; 177	44; 219
July	10; 25	33; 119	43; 144
August	1; 2	25; 79	26; 81
Total	19; 69	94; 375	113; 444

Table 3.16. Number of trips and hours (trips; hours) allocated to bird census, breeding phenology and hatching success sampling west and east of Zackenbergelven during June, July and August, respectively.

	West of river <50 m.a.s.l. 3.47 km²	East of river <50 m.a.s.l. 7.77 km²	East of river 50-150 m.a.s.l. 3.33 km²	East of river 150-300 m.a.s.l. 2.51 km²	East of river 300-600 m.a.s.l. 2.24 km²
Red-throated diver	1	2	0	0	0
Pink-footed goose	0	0	0	0	0
Common eider	0	1	0	0	0
King eider	0-1	1	0	0	0
Long-tailed duck	0	6	0	0	0
Rock ptarmigan	0	0	0	0	0
Common ringed plover	10	12	1	12	11
Red knot	1	4	7	7	1
Sanderling	8	33	1	14	6
Dunlin	31	70	17	3	1
Ruddy turnstone	3	22	22	3	0
Red-necked phalarope	0	1	0	0	0
Long-tailed skua	5	6	8	2	0
Glaucous gull	1	0	0	0	0
Arctic redpoll	2	0	0	0	1
Snow bunting	34-38	25-30	15-18	10-11	6

Table 3.17. Estimated numbers of pairs/territories in five sectors of the 19.3 km² census area in Zackenbergdalen, 2004.

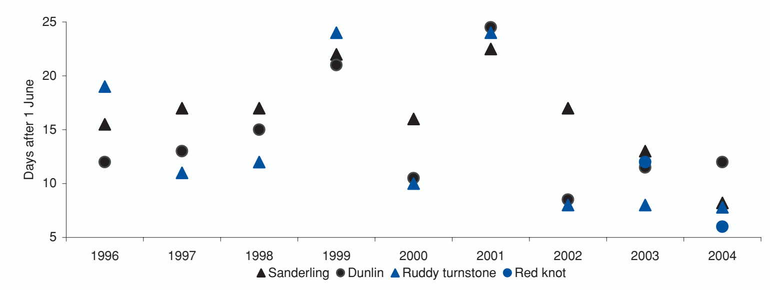

Figure 3.3. Median first egg dates for waders at Zackenberg 1996-2004 for years and species in which the age of at least 5 nests/broods is known.

Table 3.17, and in Table 3.18 they are compared with estimates from previous years. In Table 3.17 two population estimates for red knot are presented: estimates as they appeared in Rasch and Caning (2004) based on the method given in the manual, and a revised estimate based on a more stringent evaluation of the same records founded on improved knowledge of breeding behaviour obtained in nine breeding seasons at Zackenberg. With the revised evaluation the apparent decline seems to be questionable. However, using actual records of individuals during the initial total census in mid-late June, a significant decrease appears. This will be dealt with in a research paper.

The number of mapped snow buntings is much higher than in previous years. Possible explanations might be the large extent of snow free land at the time of mapping, but also that the coverage was better in 2004 due to the observations made by two observers instead of one and thereby increased mapping effort. For the remaining species the 2004 breeding estimates are within the fluctuations of the previous breeding seasons. However, glaucous gull bred for the first time within the bird census area, and more arctic redpolls were territorial within the census area than seen before.

Reproductive phenology in waders

2004 was another early nesting season in Zackenbergdalen. Egg laying was initiated in most wader nests before 20 June and medians of the first egg dates were before 10 June in three out of five species (Table 3.19). For three out of four species with more than five aged egg-clutches or broods, 2004 was the earliest breeding season recorded since records began in 1996 (Figure 3.3). Dunlin bred a little later, probably reflecting that the only areas with extensive snow cover in early June were in the fens, where the majority of dunlins are breeding as the only wader species.

In most years there is a close relationship between the median 1st egg dates in waders and the snow cover in early June. This relationship was pronounced also in 2004 having both the lowest snow coverage and the earliest mean nest initiation date recorded.

Table 3.18. Estimated numbers of pairs/territories from the 19.3 km² census area in Zackenbergdalen, 1996-2004.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Red-throated diver	1-2	2	3	2-3	2-3	2	3	2	3
Pink-footed goose	0	1	0-1	2	1	1	1	0	0
Common eider	0	0	0	0	1	1	1	0	1
King eider	2-3	2	1	2-3	2-4	3-4	4-6	1	1-2
Long-tailed duck	5-8	4-6	6-8	7-8	5-8	5-7	6-7	7-9	6
Rock ptarmigan	3	11-15	4-6	7-8	1-3	2-4	3	0-1	0
Common ringed plover	54-56	40-48	38-45	51-65	41-43	51-54	37-41	29	46
European golden plover	0	0	0	0	0	1	0	0	0
Red knot revised estimate	21-23	22-23	22-24	20	19-21	20	22	18-19	20
Red knot previous estimate	33-43	35-44	27-32	25-33	24-27	27-30	24-27	24-25	19
Sanderling	50-63	55-70	62-70	60-67	58-66	58-72	49-55	67-74	62
Dunlin	69-81	75-91	75-94	80-94	98-103	104-111	120-132	105-114	122
Ruddy turnstone	41-51	49-58	56-63	43-49	48-50	45-51	31-37	33-34	50
Red-necked phalarope	0-1	0-2	1-2	1-2	1-2	1-2	1-2	1-2	1
Red phalarope	0	0	0-1	0	0	1	0	0	0
Long-tailed skua	25-29	22-25	21-24	19-24	21-28	22-25	23-26	25-29	21
Glaucous gull	0	0	0	0	0	0	0	0	1
Snowy owl	0	0	0	0	0	1	0	0	0
Northern wheatear	0	0	1	0	0	0	0	0	0
Arctic redpoll	0	0	0	0	0	0	0	1	3
Snow bunting	45-55	45-56	41-46	52-64	42-47	48-58	58-61	59-61	90-103

Reproductive success in waders

Nest success was exceptionally high in 2004 (Table 3.20). With 1997 as the only exception showing a somewhat higher nest success, the nest predation in all wader nests combined was around 55-65% in 1996-2003, while the predation level in 2004 was less than a quarter of that. Only 3 or 4 out of 55 nests found were depredated. At three nests, shell fragments were found that indicated predation by a bird, most likely a skua or glaucous gull. One nest was deserted, while the remaining nests hatched. In all previous breeding seasons, the nest success has been substantially higher in dunlin than in the other two species with a fair number of data, sanderling and ruddy turnstone, and this pattern was retained in 2004, although at a much higher level.

Waders experienced a high breeding success irrespective of a record high number of fox dens with pups and a high number of fox encounters within the bird census area (Table 3.20). This is the first observation in Zackenberg (and Greenland) of a simultaneous occurrence of high numbers of lemmings (see section 3.4) and foxes and good nesting success, a pattern that is almost a rule in high arctic Siberia.

In general, waders produce four-egg clutches, and 51 out of 54 clutches found in 2004 held four eggs at the finding. Only two nests of dunlin and one of ruddy turnstone were found with three eggs (Table 3.21). One additional ruddy turnstone nest experienced partial predation of one egg and hatched three chicks.

During July and early August a high number of alarming parents and later of juveniles were found of dunlins in fens and marshes, and of common ringed plovers, red knots, sanderlings, dunlins and ruddy turnstones on the slopes of Aucellabjerg and in the dry lowlands. Usually, no data on breeding success of the red knot are collected, but in 2004 unsystematic surveys detected nine successful families out of 23 pairs mapped in the bird census area and immediate adjacent areas of the lower Aucellabjerg slopes. This is a high figure in a species with a very high nest failure rate (Table 3.20), and in which a substantial fraction of territorial birds is suspected not to initiate breeding (Piersma *et al.* in press). In the first half of August an estimated 50-100 juvenile ruddy turnstones were feeding in small groups on the Aucellabjerg slopes, in particular in a zone between 90 and 180 m a.s.l.

In mid July, several individuals of long-tailed skuas apparently specialised at hunting dunlin chicks, walking along the quite few remaining wet gullies in the marshlands that abounded in dunlin chicks. The success rate of this hunting is not known.

The high number of juveniles in the bird census area was not reflected in the number of juvenile waders counted in the deltas of Zackenbergelven (Table 3.22). This discrepancy was especially pronounced in ruddy turnstone, of which the 2004 total was the lowest ever recorded in

	Median date	Range	N
Common ringed plover	14 June	12-17 June	3
Red knot	6 June	4-10 June	7
Sanderling	8 June	4-26 June	23
Dunlin	12 June	3 June-3 July	28
Ruddy turnstone	8 June	31 May-22 June	19

Table 3.19. Median first egg dates for waders at Zackenberg 2004 as estimated from incomplete clutches, egg floating, hatching dates, and weights and observed sizes of pulli.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	1996-2004
Common ringed plover				(40)		(62)				42-48
Red knot	–	–			–		–			(79)
Sanderling	(28)	(0-67)	(22)	60	(54)	81	(77)	55	15-29	47-52
Dunlin			(53-72)	35	32	(25)		37	7	27-33
Ruddy turnstone	(32-79)	0-33	84	72-77	71	(40)	(48)	73-79	17	57-64
Red-necked phalarope	–	–	–		–	–	–	–	–	
All waders	**37-67**	**0-48**	**63-68**	**56-58**	**56**	**57**	**57**	**56-58**	**10-13**	**46-51**
N nests	17	27	44	44	47	32	21	47	54	343
N nest days	163	274	334	521	375	328	179	552	700	3426
Fox encounters	14	5	7	13	11	14	21	11	16	
Fox dens with pups	2	0	1	0	2	2	0-1	2	3	

Table 3.20. Mean nest predation (%) 1996-2004 according to the Mayfield method (Mayfield 1975, Johnson 1979). Poor data (below 125 nest days and 5 predations) are given in brackets. Data from years and species with below 50 nest days are omitted ('-' means no nests). Nests with at least one pipped egg or one hatched young are treated as successful. Also given are total numbers of observations of full grown foxes by the bird observer in the bird census area away from the research station, during June and July, and the number of fox dens holding pups.

Table 3.21. Mean clutch sizes in waders at Zackenberg 1995-2004. Samples of less than five clutches are given in brackets.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Common ringed plover	(4.00)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(4.00)	(4.00)
Red knot				(4.00)	(4.00)		(4.00)		(4.00)	(4.00)
Sanderling	(4.00)	4.00	3.86	4.00	3.67	4.00	3.43	3.83	4.00	4.00
Dunlin		(4.00)	(3.75)	3.90	3.70	3.93	3.63	(4.00)	4.00	3.92
Ruddy turnstone		3.71	3.79	3.81	3.58	3.75	3.75	4.00	3.77	3.92

Table 3.22. Total numbers of juvenile waders recorded at low tide in the former and the present deltas of Zackenbergelven during 15 counts performed every third day in the period 20 July – 31 August 1995-2004. Data from missing counts have been substituted by medians from previous and following counts.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Common ringed plover	96	126	249	42	44	142	320	140	170	253
Sanderling	304	726	149	333	445	366	540	156	242	346
Dunlin	325	360	323	232	509	273	326	554	309	308
Ruddy turnstone	80	108	82	109	23	73	162	183	75	19
Waders total	810	1342	803	722	1021	854	1351	1040	803	928

the delta. Only the common ringed plover occurred in the deltas in numbers well above average. It is uncertain whether the number of juvenile waders recorded on the intertidal delta flats reflects the breeding success in Northern Greenland on a wider scale or if numbers rather reflect, e.g., local feeding or perhaps migration conditions.

Reproductive phenology and success in long-tailed skuas

Long-tailed skuas had an early breeding year (Table 3.23). The first eggs were laid 5 June (3 clutches) and the latest clutch was initiated 21 June.

In total, 23 lemmings were seen by "one observer" inside the bird census area during June and July, and also the number of winter nests within the 2 km^2 lemming census area was the second highest recorded so far (Table 3.23 and section 3.4). Despite a high number of foxes (Table 3.20) the skuas had a record high breeding success (Table 3.23).

Usually, little systematic bird registrations have been performed after late July, but in 2004 time was devoted in late July and early August at checking systematically, whether the youngest skua chick in a brood survived until fledging. In eight broods two fledged juveniles were seen while a further six pairs fledged one juvenile. There were up to eight days between the fledging of the oldest and the youngest chick. This means that a second fledged young may have been missed in other years, when only one fledged young was recorded with a pair of long-tailed skuas.

Breeding barnacle geese

Barnacle geese do not breed in the bird census area, but breeders from the surroundings bring their goslings to the coastal lagunes, lakes, fens and river deltas of Zackenbergdalen. The first families were seen on 30 June. On 7 July, the maximum of the year – 22 families with a total of 57 pulli were seen, and on 15 July 22 families with 48 pulli were present. On 22 July, an additional four families were encountered inland at Sommerfuglesø.

Table 3.23. Egg laying phenology and breeding effort and success in long-tailed skuas at Zackenberg 1996-2004. Median egg laying date is the date, when half the supposed first clutches were laid. Number of clutches found includes replacement clutches. Also given are numbers of lemming winter nests within the 2 km^2 lemming census area (see section 3.4).

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Median 1st egg date	–	7.6	12.6	17.6	18.6	15.6	9.6	15.6	8.6
No. of clutches found	8	17	23	7	5	21	14	7	21
No. of young hatched	1	25	16	1	2	18	14	5	36
Estimated no. of young fledged	0	5	6	1	0	5	4	2	22
Lemming winter nests	161	366	721	331	192	326	282	96	431

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Primo July		(3.0)	3.1	(2.9)	1.9	(3.2)	(1.8)	2.4	(1.8)	2.6
Medio July		(2.3)	2.7	2.3	1.8	(3.1)	(1.7)	2.4	(1.2)	2.3
Ultimo July	(2.0)	(3.0)	2.6	2.2	1.7	3.1		2.3	(1.1)	2.3
Primo August	(2.3)	(2.3)	2.4		1.8		(2.0)	2.2	(1.2)	(1.9)
No. of broods	≥7	6-7	19-21	≥18	29	11	4	32	8	26
Scotland	2.00	2.30	1.95	2.28	1.92	2.20	1.94	2.23	1.59	2.35
Per cent juv.	7.2	10.3	6.1	10.5	8.1	10.8	7.1	12.5	6.4	15.9

Table 3.24. Average brood sizes of barnacle geese in Zackenbergdalen during July and early August, 1995-2004, together with the total number of broods brought to the valley. Samples of less than 10 broods are given in brackets. Data from autumn on the Isle of Islay in Scotland are given for comparison, including per cent juveniles in the population (Ogilvie 2005 and pers. comm.).

At the line transect from Daneborg to Zackenberg 13-14 July, three families with six pulli were seen, while no families were seen at the Store Sødal line transect 25-27 July (see next chapter).

The mean brood size in 2004 was around average, while the number of broods was relatively high (Table 3.24). On Isle of Islay, the main wintering haunt of Greenland barnacle geese in Scotland, on the other hand, the highest average brood size in the last ten years together with the highest juvenile ratio for 14 years was found in 2004 (Table 3.24; Ogilvie 2005)

Line transects

Due to the incomplete coverage of the line transects this year, relevant data are only dealt with under the individual species.

Sandøen

No systematic monitoring is performed on Sandøen, and in 2004 bird observations were collected on three rather brief visits in August, very late in the breeding season. A few additional observations were made by Mads Frost Bertelsen and Mario Acquarone, who performed walrus studies on the island, and by Kaj Kampp visiting the island in late August (Gilg 2005).

In mid June, open water had formed near Sandøen, and in early July, the fjord ice around the island had broken up (see section on Break up of the fjord ice in Young Sund in section 2.2).

Apparently, there were at least 100 breeding pairs of Sabine's gulls *Xema sabini* on the island, but with very poor breeding success. On 9 August, 150 adults and one sub-adult were seen, mostly feeding and roosting on the calm sea west of the island. On 21 August, only three alarming pairs and one large chick alive were seen. Several long dead very small chicks were found, and also one large eaten chick. In total, 19 adults were present in the colony in addition to 35 adults at sea. Eight chicks were banded by Mads Frost Bertelsen and Mario Acquarone. All had gone by 30 August (Gilg 2005).

About 1000 adult arctic terns were seen on 9 August and 1100 on 21 August equivalent to some 700-800 breeding pairs. On 21 August, there were an estimated 500 chicks, of which some 100 were just able to fly. 254 chicks were banded during August by Mads Frost Bertelsen and Mario Acquarone. Peak hatching apparently took place during early August.

A breeding pair of lesser black-backed gull was observed on Sandøen on 9 August, and on 30 August, one alarm calling pair plus one adult were still present. In 2003, the first breeding record in East Greenland was made here (Rasch and Caning 2004).

Other observations

This section deals with bird observations not reported in the previous chapters. When nothing else is stated, observations refer to the bird census area in Zackenbergdalen.

Red-throated diver *Gavia stellata*

Three pairs attempted to breed in 2004, and six nests with eggs were recorded in total, but none of them hatched chicks. The three first clutches were all started 12-18 June, and the three supposed relays were all initiated within a week after the loss of the first clutch. At least one nest, but most probably all six nests, were depredated by arctic fox.

In adjacent areas two pairs were found: one with one chick in Østersøen (east of Okseelv) and one with one or two chicks in Lindemanssø.

Table 3.25. Numbers of moulting pink-footed geese and barnacle geese in Zackenbergdalen and adjacent areas 1995-2004. Brackets denote an incomplete count, '–' a missing count.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Pink-footed geese										
Closed goose moulting area	310	246	247	5	127	35	0	30	41	11
Coastal area west of closed area	230	40	0-60	0	29	0	0	0	0	10
Daneborg transect east of closed area	–	–	0	0	0	0	0	0	0	20
Outer Store Sødal transect	20	12	36	0	5	0	16	8	11	0
Inner Store Sødal transect	20	55	144	123	21	56	69	28	27	–
Barnacle geese total	<315	<342	287	449	<387	369	502	304	328	–

Great Northern Diver *Gavia immer*
One pair was seen on the westernmost lakes (west of the watershed) in Store Sødal on 23 July (Christian Hjort pers. comm.).

Fulmar *Fulmarus glacialis*
A 'single dark' morph fulmar was seen in the mouth of Yong Sund on 9 August.

Pink-footed goose *Anser brachyrhynchus*
Two pairs were present in early June, but apparently none of them stayed and made attempts to breed.

Immature Icelandic pink-footed geese migrating north to moult were observed between 10 June and 1 July with a peak on 16-17 June, when 1084 birds were seen passing in 11 hours. Unsystematic records revealed a total of 1953 migrating geese. In the migration period, small flocks of pink-footed geese were regularly seen feeding in wet grassy areas throughout Zackenbergdalen.

Each year the number of moulting pink-footed geese and barnacle geese is censused along the coast of Zackenbergdalen in mid July and along the coast Daneborg-Zackenberg and in Store Sødal during line transects in mid or late July (Table 3.25). Very few moulting pink-footed geese were observed in the area in 2004, which was also the case the previous four seasons. However, inner Store Sødal was not fully covered this year. At the establishment of the Zackenberg Research Station, the coast of Zackenbergdalen functioned as a moulting site for more than 500 pink-footed geese, but this is not the case any longer, irrespective of the closure of an extensive area along the coast with no entry in the goose moulting period. A similar decrease has not occurred in barnacle geese, which are far less sensitive to disturbance (see section 6 in Meltofte and Rasch 1998).

The first flock on southward migration was seen on 12 August, the next on 21 August. The migration probably peaked at the time of the closing of the station, when 540 pink-footed geese passed in the morning of 31 August. A total of 1018 migrating birds were seen in this period with limited field activity.

Barnacle goose *Branta leucopsis*
In addition to breeders (see section above) unsuccessful adults and immatures gathered at Lomsø and along the coast during June and July with maximum counts of 81 on 5 July and 80 on 7 July. This is well below the observed numbers in the last years.

Away from the coast, 81 barnacle geese were seen in Store Sødal 25-27 July.

A small southward migration was recorded in late August with a maximum of 179 on 28 August.

Common eider *Somateria mollissima*
The first common eiders were seen on 11 June, and a local pair was first recorded at the breeding site, Gadekæret, on 26 June. Chicks hatched in the nest on 24 July, and a clutch of seven small chicks seen nearby five days later was probably the local family.

In late July and early August several families and unsuccessful females arrived at the coast of Zackenbergdalen, probably from the breeding colony at Daneborg, c. 25 km away. The first female with ducklings was seen on 17 July, and maximum was 26 pulli in 6-7 broods and 40 females on 26 July.

King eider *Somateria spectabilis*
One pair was seen regularly in Kystkærene and Lomsø 14 June – 8 July. No chicks were

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Red-throated diver	–	30.5	3.6	4.6	6.6	3.6	–	–	–
King eider	12.6	4.6	15.6	16.6	22.6	9.6	11.6	13.6	14.6
Long-tailed duck	–	30.5	2.6	6.6	6.6	7.6	3.6	7.6	–
Red-necked phalarope	5.6	30.5	5.6	10.6	7.6	4.6	5.6	11.6	–
Arrival bird census observer(s)	3.6	27.5	26.5	1.6	3.6	31.5	31.5	3.6	1.6
First full observation day	4.6	28.5	27.5	2.6	4.6	1.6	1.6	4.6	2.6

Table 3.26. Dates of first observation of selected species at Zackenberg 1996-2004. '-' means species present at the day of arrival of the bird observer(s).' –' means species present at the first full day of observations.

seen, and the birds were probably unsuccessful. In addition, a female was seen west of the river on 16 June; it was scared away by the local pair of red-throated divers, and was never recorded again.

Long-tailed duck *Clangula hyemalis*

Several long-tailed ducks had arrived by the arrival of the bird observers (Table 3.26). In total, five broods were recorded within the bird census area, and the nest of one of these was found in Sydkærene. In addition, one brood was encountered on Sommerfuglesø north of the census area. The broods were recorded between 16 July and 19 August, and all had small chicks when first encountered. Some of the broods most likely were replacements, and in June eggshells depredated by avian predators were found twice.

In July and August, long-tailed ducks gathered along the coast with a maximum of 16 on 25 August.

Gyr falcon *Falco rusticolus*

No birds were seen during the breeding season. During migration in August, four individuals stayed for short periods: on 17 August a dark or intermediate morph adult passed over, on 21 August a white morph bird stayed west of the river, on 24 August a dark morph juvenile stayed for an hour at the station, and on 29 August another dark morph juvenile stayed south of the station.

On 9 August, an adult white morph hunted in the Sabine's gull and arctic tern colony on Sandøen.

Rock ptarmigan *Lagopus mutus*

No rock ptarmigans were observed in the bird census area in 2004.

In the surroundings, three families were recorded: one 200 m a.s.l. on the south slope of Zackenberg on 24 July, one at the foot of the north slope of Zackenberg on 25 July and one north of Djævlekløften on Clavering Ø on 21 August.

Common ringed plover *Charadrius hiaticula*

No pre-breeding flocks were seen in June. After breeding, flocks of adults were observed between 26 July and 7 August with maxima of 26 in the deltas and 24 inland both on 4 August. Peak number of juveniles in the deltas was 67 on 10 August.

Eurasian golden plover *Pluvialis apricaria*

Four observations between 2 June and 11 June of one individual, perhaps the same bird.

Red knot *Calidris canutus*

On 1 June, a flock of 10 birds migrated north. In early June, red knots were regularly recorded feeding in lowland fens, but after 21 June they did not utilise this habitat any further.

In 2003, seven adult red knots were colour marked as breeders in the bird census area and its immediate surroundings, five males and two females. Three of the males were resighted in 2004: two with large chicks and one unsuccessful that was observed claiming territory three times during 24 June – 4 July.

No post-breeding flocks were recorded. The species was only observed three times during 17 counts in the deltas: 3 juveniles on 27 July, 1 juvenile on 29 July and 1 juvenile on 2 August.

Sanderling *Calidris alba*

No pre-breeding flocks were observed. In 2003, 39 breeding adults were ringed, and several ringed breeders were observed in the area in 2004. Only one was identified, a female that hatched chicks about 2500 m from the 2003 nest site.

From 14 July, small post-breeding flocks of adults occurred widespread in drier areas, in one-species flocks or mixed with common ringed plovers. At the waterbird counts in the deltas, adult sanderlings peaked at the first count on 21 July, when

17 were seen. 10 August was the last date with more than one observed adult. Two juvenile peaks were observed in the deltas, the first with 55 on 4 August and 52 on 7 August and the second with 69 on 15 August and 67 on 16 August.

Outside Zackenberg, juveniles abounded on 21 August with 60 on Sandøen, 16 at the beach at Djævlekløften on Clavering Ø and six at Kap Berghaus.

Dunlin *Calidris alpina*

During 1-7 June, a maximum of 13 dunlins fed in Gadekæret on 4 June.

In 2003, 17 adult dunlins were ringed at Zackenberg. In 2004, ringed breeders were observed regularly, and once it was possible to identify two alarming parents. They were ringed nearby also as a pair in 2003.

Post-breeding flocks of adult dunlins were primarily seen in the deltas of Zackenbergelven. The first flock was recorded on 7 July, and maximum was 111 on 29 July. Small flocks and single juvenile birds were observed regularly in most inland pools in late July and the first half of August. During the standardised waterbird counts in the deltas, a juvenile maximum of 70 was recorded on 2 August.

Whimbrel *Numenius phaeopus*

Two observations of this accidental visitor at Zackenberg were made on 8 June and 18 July, respectively.

Ruddy turnstone Arenaria interpres

In 2003, 21 adult breeders were ringed at their nests. Two of these were identified as breeders in 2004, both near their 2003 nest sites.

Only one post-breeding flock of adults was recorded, *i.e.* at the first waterbird count in the deltas on 21 July, when nine were seen. Many juveniles stayed at the slopes of the Aucellabjerg in late July and the first half of August. On 28 August, all had left. Few visited the deltas with 11 on 16 August as maximum.

Red-necked phalarope *Phalaropus lobatus*

A female had already arrived when the bird observers arrived 1 June (Table 3.26). This bird never paired and was seen for the last time on 26 June. On 13 June, a pair arrived. During the first two weeks, they shifted between ponds in Gadekæret and Sydkærene, whereupon they remained in Gadekæret. The female left in the days after 1 July, while the male was flushed repeatedly during July, but nest or chicks were never found. The last record is from 30 July. Red phalarope *Phalaropus fulicarius* was not observed in 2004.

Arctic skua *Stercorarius parasiticus*

On 23 July, a pair consisting of one light and one dark morph bird passed over Sydkærene. The dark morph bird remained in the area for some hours.

Three light morph arctic skuas were observed on the line transect northwest of Daneborg on 13 July, of which one was showing breeding (distraction) behaviour near the mouth of Lille Sødal. Here, a supposed breeding pair was also recorded in 2002 (Rasch and Caning 2003).

Long-tailed skua *Stercorarius longicaudus*

The very large extent of breeding in 2004 meant that few non-breeders were seen during June and July, and no flocking was recorded in Zackenbergdalen. However, 3-4 immature birds were seen regularly in the area often joining alarming breeding pairs.

Perhaps, breeding conditions were less favourable east of Zackenbergdalen. On the line transect, flocks of eight and three long-tailed skuas were recorded 3-5 km east of Kuhnelv on 14 July.

The last juvenile of the year was seen on 18 August and the last adults on 23 August.

Lesser black-backed gull *Larus fuscus*

A second calendar-year bird was flying over the ice in Young Sund on 17 June, while one pale adult belonging to the *graellsii* subspecies passed Zackenbergdalen both on 10 and 15 July. See further in the chapter on Sandøen above.

Glaucous gull *Larus hyperboreus*

A pair bred on a stony islet in Zackenbergelven just inside the bird census area constituting the first breeding record here. On 25 July, a few days old chick was seen, and on 18 August an adult was alarming around a strongly flying juvenile. On 21 August, two juveniles were seen nearby, very likely both from the local breeding pair.

Non-breeders were regularly seen, in particular at Zackenbergelven. Maxima were 44 adults on 11 July and three immatures on 25 June.

Kittiwake *Rissa tridactyla*
On 30 August, about 75 kittiwakes were seen in the mouth of Young Sund (Gilg 2005).

Arctic tern *Sterna paradisaea*
Three records from the deltas of Zackenbergelven. 25 June: 3 above a small hole in the ice, 21 July: 2, 23 July: 12. On the line transect in Store Sødal, three birds were seen at Store Sø on 25 July. See further in the section on Sandøen above.

Snowy owl *Nyctea scandiaca*
No observations from the breeding season. On 28 August, two birds had arrived: an old male hunted between 250 and 350 m a.s.l. near Okseelv, and a female was encountered near Ugleelv at 225 m a.s.l. No owl casts from the previous winter were found in the bird census area, while quite fresh snowy owl casts were found west of Store Sø on 25 July.

Northern wheatear *Oenanthe oenanthe*
Wheatear was not observed at Zackenberg this year. However, some 30 km west of Zackenberg, in westernmost Store Sødal, four families were found on 23 July (Christian Hjort pers. comm.), and in Daneborg three birds, probably juveniles, were seen on 9 August.

Common raven *Corvus corax*
Up to seven birds were seen regularly during June to August, most probably breeders and their offspring from adjacent mountains.

Arctic redpoll *Carduelis hornemanni*
Single arctic redpolls were regularly observed singing over the valley in June and early July. Three pairs/birds behaved as if they were connected to a territory inside the bird census area. They were seen at Pyramiden, 550 m a.s.l. on Aucellabjerg on 17 June, near Nordvestkæret on 23 June, and just east of Vestkæret on 16 and 23 June. The last birds were seen on 10 July.

Snow bunting *Plectrophenax nivalis*
The first juvenile snow bunting was seen on 4 July, and until late July there were very many juveniles all over Zackenbergdalen. In the moulting period during the first half of August, the species was almost absent, but from 23 August flocks of freshly moulted birds were back in the area. As a maximum, 435 birds were found on 28 August, in particular on the slopes of Aucellabjerg between 315 and 670 m a.s.l. The largest flocks were of 186 and 115 individuals, respectively.

3.4 Mammals

Ole Thorup and Trine Theut

The monitoring programme was performed by Ole Thorup (1 June – 31 August) and Trine Theut (21 July – 17 August). Additionally, mammal observations were systematically recorded by Toke Høye (1-28 June) and Hans Meltofte (1 June – 28 July). The station personnel and visiting researchers supplied random observations during the entire field season.

The census area for collared lemming was surveyed for winter nests during 21 July – 17 August. During the entire season, when weather permitted a sufficient coverage, daily counts of musk oxen were made in the evening (between 18 and 24 hrs) from the roof of a house on the research station, by scanning the coastland and mountain slopes from Zackenbergdalen in the west to Lille Sødal near Daneborg in the east. In addition, the total numbers of musk oxen, including age and sex data from as many individuals as possible, were censused almost weekly within the 40 km^2 musk ox census area during 12 June – 28 August.

12 known fox dens within the 50 km^2 fox study area and one just across the eastern border (Kuhnelv) were checked regularly for occupation and breeding, and the only den known between Daneborg and Kuhnelv was checked on 14 July.

Observations of other than lemmings, foxes and musk oxen are presented in the section on "Other observations", where scientific names are also given.

Systematically, numbers of seals on the fjord ice in Young Sund were recorded until 2 July after which date the ice started to brake up. During 29 June – 27 August the south-east and east facing slopes of the Zackenberg mountain were regularly scanned for arctic hares. A line transect Daneborg – Zackenberg was walked by Susanne M. König and Ole Thorup 13-14 July, partly in rather poor weather, while the transect Zackenberg – Store Sødal was walked 25-27 July by the same persons and Trine Theut. The latter transect was

Table 3.27. Annual numbers of collared lemming winter nests recorded within the 2.05 km^2 census area in Zackenbergdalen 1995-2004 together with the numbers of animals encountered by one person (2004: H. Meltofte 1-10 June, O. Thorup 11 June – 31 July) with comparable effort each year within the 19 km^2 bird census area during June-July. Category 1 denotes nests from the previous winter. Category 2 are nests from earlier winters that were not recorded previously.

Year	Winter nests category 1	Winter nests category 2	Animals seen
1995	285	821	–
1996	161	262	0
1997	366	113	1
1998	721	114	43
1999	331	57	9
2000	192	69	1
2001	326	21	11
2002	287	29	4
2003	95	32	1
2004	431	24	23

	Distance	Winter nests	
	km	No.	No./km
Store Sødal			
1996	150	2	0.01
1997	300	11	0.07
1998	150	21	0.14
1999	130	3	0.02
2000	130	1	0.01
2001	130	13	0.10
2002	130	9	0.07
2003	130	12	0.09
2004	108	2	0.02
Daneborg-Zackenberg			
1997	50	22	0.44
1998	50	17	0.34
1999	40	1	0.03
2000	40	0	0.00
2001	40	24	0.60
2002	40	5	0.13
2003	40	1	0.03
2004	40	16	0.40

Table 3.28. Lemming winter nests recorded along the transects Zackenberg – Store Sødal and Daneborg – Zackenberg 1996-2004. Nests were recorded within 3 m on each side of the two observers.

Table 3.29. Numbers of casts and scats from predators collected from 29 permanent sites within the 2.05 km^2 lemming census area in Zackenbergdalen. The samples represent the period from mid/late August the previous year to August in the year denoted.

	Skua casts	Owl casts	Fox scats	Stoat scats
1997	44	0	10	1
1998	69	9	46	3
1999	31	3	22	6
2000	33	2	31	0
2001	39	2	38	3
2002	32	6	67	16
2003	16	0	20	1
2004	27	0	16	3

performed in fine weather 25 July but was not completed due to very harsh weather with sleet and rainstorm on 26 and 27 July.

Collared lemming *Dicrostonyx groenlandicus* population

A total of 431 nests from the previous winter was recorded within the 2.05 km^2 census area (Table 3.27). This is the second highest number recorded so far, following the record low winter population density in 2002-03. Very few winter nests were found at the Store Sødal transect, while the winter population level at the transect Daneborg – Zackenberg was, like in Zackenbergdalen, relatively high (Table 3.28).

In the years 1995-2003, between 0.3% and 5% of the lemming winter nests were depredated by stoat, corresponding to 0.5-13 depredated nests per km^2 (Fig. 3.4). In the winter 2003-2004, not a single nest was depredated by stoat.

The 29 fixed sampling sites for predator casts and scats were checked on 23 August (Table 3.29). In general, the numbers of scats and casts were very low.

Musk ox *Ovibos moschatus* population biology

Two different patterns in musk ox occurrence have been observed in Zackenbergdalen and on adjacent slopes during 1996-2003 (Rasch & Caning 2004: Figure 3.5): 1) Low numbers during June and early July, and increasing numbers throughout July and August, or 2) relatively high and quite stable numbers during June and July, and increasing numbers in August. In 2004 a new pattern was recorded, with high numbers in June, quite low numbers in July, and very high numbers in August (Fig. 3.5, Table 3.30). The low extent of snow cover in June may be an immediate explanation of the high June numbers. However, the only other year with little snow in June, 2000, did not have particularly high numbers of musk oxen in June (Table 3.30).

The 2004 figures are very much higher than hitherto recorded, both within the 40 km^2 census area (Table 3.30) and in the entire visible area of 135 km^2 (Figure 3.6). The highest number of musk oxen counted previously was 167 on 27 August 1996. In 2004 twelve counts exceeded this number, with maxima of 236 on a total count 20 August and 231 on a roof count 27 August.

	June	July	August	Total
1996	445	445	2412	3302
1997	290	1086	1432	2807
1998	522	635	1121	2278
1999	361	392	1292	2045
2000	478	898	1543	2919
2001	922	1257	1689	3868
2002	418	448	1819	2684
2003	287	638	2247	3172
2004	1297	787	3220	5304

Table 3.30. Total numbers of 'musk ox days' per month counted as one musk ox in one day within the 40 km² census area in Zackenbergdalen based on the daily counts from a fixed elevated point at the research station 1996-2004. Data from days without counts are substituted with the median of the previous and the following count.

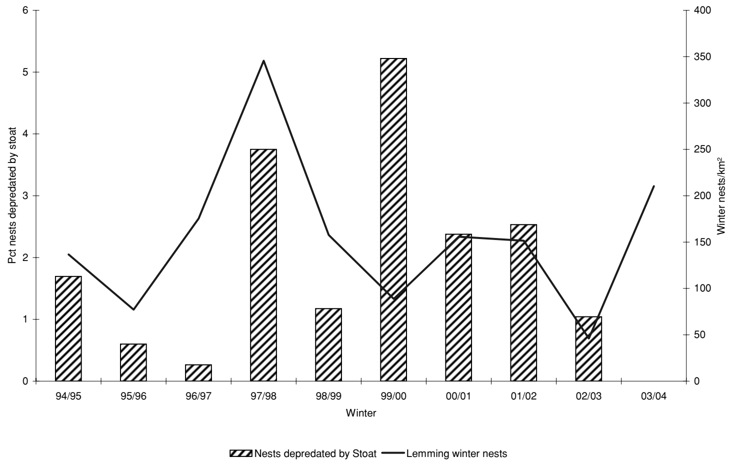

Figure 3.4. Lemming winter nest density (right axis) and stoat predation on lemming nests (left axis) within the census area in Zackenbergdalen (2.05 km²). Data include nests built from October until May. Nest predation by stoat is given as percentage of total number of nests.

The two transects Daneborg – Zackenberg and Zackenberg – Store Sødal were walked mid and late July at a time when very few musk oxen were in the area, and the total from the transects plus the animals in the census area at the contemporary weekly census on 16 July was only at 66 (excluding the uncovered innermost part of Store Sødal). The age of 59 musk oxen was determined, and 11 were calves (19%; Table 3.31), a high figure compared to a range of 9-17% in 1997-2003. The average and median of calves was even larger in four other samples (17 June:184 musk oxen, 11 August: 172 musk oxen, 20 August: 236 musk oxen, and 28 August: 185 musk oxen, ranging between 19-24%).

Although small numbers of musk oxen were present at the time of the transects, a record high density of piles of summer faeces (Table 3.32) indicated that high numbers of musk oxen had been present in June also in Store Sødal as was the case in Zackenbergdalen and along the coast towards Daneborg.

Two fresh musk ox carcasses were found, both inside the 40 km² census area (Table 3.33). Both were at least four-year-old oxen, one male and one female.

Arctic fox *Alopex lagopus* dens

In 2004, a minimum of 18 arctic fox pups (all white colour phase) were found within the 50 km² study area including a den holding a litter of nine pups (den no. 10). This is the highest number recorded so far (Table 3.34). Also the total number of fox records is high, very much higher than recorded previously (Table 3.35).

Pups were recorded in five dens within the study area. It is estimated, however, that this represents only four families, since one family most likely moved from one den to another (from no. 1 to no. 8). Six dens within the study area were used regularly during the summer (nos 1, 2, 3, 4, 5 and 10), and additionally six dens were visited irregularly (nos 6, 7, 8, 9, 13 and 14 (formerly 5.2)). At least four of the six dens that were used regularly, were used for breeding (nos 1, 2, 3 and 10).

Other observations

Polar bear *Ursus maritimus*

One animal was seen east of Daneborg in late July

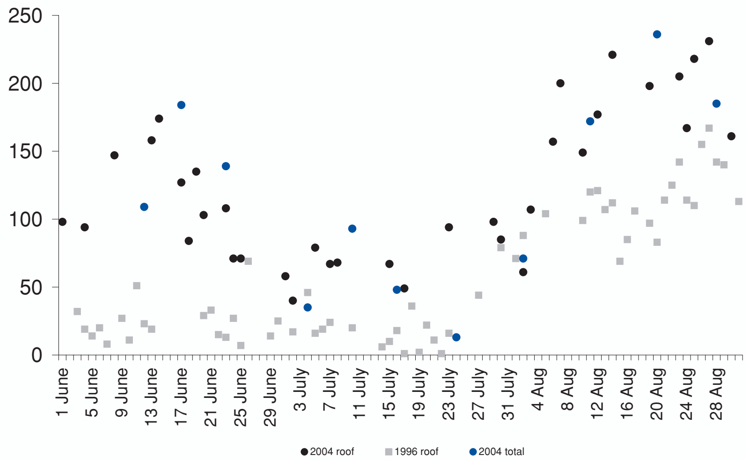

Figure 3.5. Numbers of musk oxen recorded from the roof of the research station in 2004 and in 1996 (the year with the highest numbers hitherto recorded). In addition, the numbers on the total counts 2004 are given.

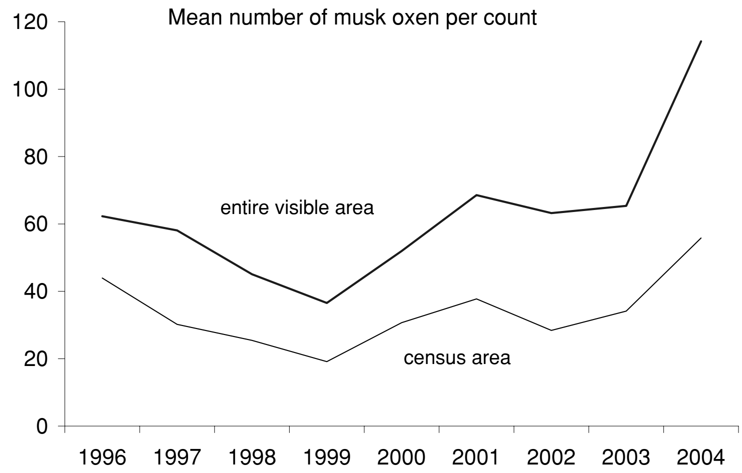

Figure 3.6. Annual average numbers of musk oxen counted from a roof of the research station 1996-2004 in the 40 km² census area and in the entire visible area (approximately 135 km²).

Arctic wolf *Canis lupus*

Neither animals, tracks nor faeces were found in 2004. 2004 is the first season since the ZERO programme started in 1995 without records of wolf or tracks of wolf.

Arctic hare *Lepus arcticus*

The south-east and east facing slopes of the Zackenberg mountain were scanned by a 30x spotting scope daily during the period 29 June – 27 August whenever weather permitted, and the number of visible arctic hares was recorded. A maximum of nine and a mean of 2.3 hares were

Table 3.31. Sex and age distribution (actual numbers) of musk oxen based on total counts along the two line transects and the related total census in Zackenbergdalen 1997-2004. All counts were made within 16-30 July and covered an area of approximately 200 km². Possible double counts have been omitted.

	Calf	F1	M1	F2	M2	F3	M3	F4+	M4+	Total
1997	13	5	6	13	14	8	2	32	10	103
1998	11	6	7	8	8	8	7	44	23	122
1999	24	0	0	9	8	13	7	58	52	171
2000	25	6	7	4	1	7	6	47	44	147
2001	27	10	7	6	7	6	1	58	38	160
2002	21	10	9	12	10	10	4	57	40	173
2003	18	6	7	3	5	3	4	34	29	109
2004	11	4		2	2	8	7	6	19	59

Table 3.32. Musk ox densities (animals/km²) in Store Sødal (92 km² in 1996-1998 and 125 km² in 1999 and onwards), the census area in Zackenbergdalen (40 km²) and in the coastal region between Daneborg and Zackenberg (37 km²) in mid/late July 1996-2004. Also densities of faeces piles (no. of piles/km walked) in Store Sødal (150 km in 1997-1998, 130 km in 1999-2003 and 54 km in 2004) and from Daneborg to Zackenberg (40 km) are given.

	Store Sødal	Zackenberg-dalen	Daneborg-Zackenberg	Snow cover (%) Zackenberg 10 June
Musk oxen/km²				
1996	0.37	0.33	–	77
1997	0.39	1.58	0.13	81
1998	0.62	1.18	0.86	80
1999	0.78	1.20	0.70	92
2000	0.25	2.10	0.22	54
2001	0.31	3.38	0.92	82
2002	0.69	1.68	0.30	77
2003	0.26	1.70	0.22	83
2004	0.28	0.10	0.73	49
Faeces piles/km				
1997 winter/summer	1.91 / 0.59	–	6.13 / 1.03	81
1998 winter/summer	1.86 / 0.47	–	1.43 / 0.85	80
1999 winter/summer	7.42 / 1.93	–	4.58 / 3.08	92
2000 winter/summer	2.76 / 0.45	–	1.13 / 0.28	54
2001 winter/summer	6.57 / 1.32	–	2.63 / 0.45	82
2002 winter/summer	4.93 / 1.81	–	4.73 / 0.60	77
2003 winter/summer	9.58 / 3.08	–	3.70 / 0.68	83
2004 winter/summer	2.33 / 4.13	–	4.03 / 3.45	49

	Snow cover 10 June (%)	Thaw hours	Total carcasses	4+ yrs F / M	3 yrs F / M	2 yrs F / M	1 yr F / M	Calf
1994-1995	76	?	2	0 / 1				1
1995-1996	77	47	13	7 / 1	0 / 1	0 / 2	1 / 1	
1996-1997	81	9	5	0 / 2		1 / 0	1 / 0	1
1997-1998	80	83	2	0 / 2				
1998-1999	92	32	1	0 / 1				
1999-2000	54	35	8	0 / 6	1 / 0			1
2000-2001	82	13	4	0 / 4				
2001-2002	77	88	5	1 / 2	1 / 0			1
2002-2003	83	178	3	0 / 2				1
2003-2004	49	50	2	1 / 1				

Table 3.33. Fresh musk ox carcasses found during the field seasons of 1995-2004. F = female, M = male. 'Thaw hours' are numbers of hours during October-April with positive temperatures, which may have caused ice crust on the snow.

	No. of known dens inside/outside	No. of dens in use inside/outside	No. of breed. dens inside/outside	Total no. of pups recorded	No of muskox carcasses	Lemming winter population
1995	2/0	0/0	0/0	0	2	decrease
1996	5/0	4/0	2/0	5W + 4D	13	low
1997	5/0	1/0	0/0	0	5	increase
1998	5/0	2/0	1/0	8W	2	peak
1999	7/0	3/0	0/0	0	1	decrease
2000	8/0	4/0	3/0	7W	8	low
2001	10/2	6/1	3/1	12W + 1D	4	increase
2002	10/2	5/1	0-1/0	0	4	intermediate
2003	11/2	8/1	3/0	17W	2	low
2004	12/2	12/2	4/1	18+W	2	increase

Table 3.34. Numbers of known fox dens in use, numbers with pups and the total number of pups recorded at their maternal dens within the 50 km^2 fox census area in Zackenbergdalen. 'W' and 'D' denote white and dark colour phase, respectively.

recorded on these counts (n=23). Observation conditions improved after the first half of July due to lower midnight sun, and a mean of 3.0 hares was seen on counts after 15 July (n=17).

Observations from climbing trips to the slopes revealed that only a small fraction of the real number of hares in the area is seen during such scans.

Stoat *Mustela erminea*

Neither animals nor tracks were seen, and stoats depredated none of the 431 winter nests of lemmings found in the census area. The only signs of stoat occurrence in the past were the findings of three stoat faeces from the previous winter during the standardised collection of casts and scats (Table 3.29).

Walrus *Odobenus rosmarus*

Between 50 and 100 walruses use Sandøen as haul out site and feed in Young Sund, where a maximum of 59 was seen in 2004 (Acquarone 2004 and pers. comm.). However, they are only rarely seen in the relatively shallow waters along the coast of Zackenbergdalen, and the only observation in 2004 was of two animals on a sandbank outside Zackenberg Trapping Station on 31 July.

On the transects, two were seen in Young Sund near Lille Sødal on 13 July, and two were seen in front of Pashytten

	Total number of records	Total number colour phase	Number of fox carcasses
1996	34	31W + 3D	
1997	22	17W + 5D	1W + 1D
1998	24	21W + 3D	1W
1999	19	18W + 1D	2W
2000	28	28W	2W
2001	55	54W +1D	1W
2002	23	23W	0
2003	50	50W	0
2004	90	90W	0

Table 3.35. 'Total number of records' gives the number of records of all adults and those of juveniles encountered in the field away from their maternal den. Foxes visiting the research station are included. See further in Table 3.20 for observations in June-July.

Table 3.36. Numbers of seals counted daily from a fixed point at the research station from 1 June until the fjord ice became too fragmented in early/mid July 1997-2004. Only counts performed with good visibility are included.

	Average±SD	Range	Counts
1997	8.52±4.98	3 - 21	23
1998	7.42±4.50	0 - 18	18
1999	25.05±12,32	2 - 61	22
2000	14.38±7.00	2 - 28	16
2001	22.06±14.22	3 - 57	16
2002	28.68±3.82	9 - 48	13
2003	63.58±32.09	14 -126	12
2004	19.00±6.40	9 - 30	13

	SS	SS	SS	LS	LS	LS
Date	22.7	6.8	18.8	22.7	7.8	18.8
Ice cover (%)	0	0	0	0	0	0
Temperature (°C)	7.3	10.4	8.4	8.8	10.3	8.2
pH	6.48	5.95	6.49	6.27	5.83	6.07
Conductivity (µS/cm)	9	18	19	6	9	8
Chlorophyll a (µg/l)	1.26	1.74	1.85	0.80	0.70	1.43
Total nitrogen (µg/l)	200	440	160	130	400	160
Total phosphorous (µg/l)	8	8	6	5	15	14

Table 3.37. Physico-chemical variables and chlorophyll a concentrations in Sommerfuglesø (SS) and Langemandssø (LS) during July and August 2004.

on 14 July. One was seen on a boat trip at the coast of Tyrolerfjorden on 22 July.

Seals *Phocidae* sp.

Seals on the fjord ice were recorded in connection with the daily musk ox counts from 1 June until 2 July, after which date the fjord ice became too fragmented. 13 counts with good visibility were made with an average of 19 seals per census and a maximum of 30 on 8 June (Table 3.36). The day-to-day variation was much smaller, and the maximum and average were much below the 2003 figures.

Narwhal *Monomon monoceros*

On 12 August, 25 narwhals – perhaps many more – moved east through Young Sund.

3.5 Lakes

Kirsten Christoffersen and Erik Jeppesen

The ice cover of both Sommerfuglesø and Langemandssø, the two lakes included in the BioBasis monitoring programme, decreased rapidly during June and was 50% on 24 and 26 June, respectively. This is the third time of early ice-out since 1997.

The usual standard sampling programme was conducted between 22 July and 18 August with about two week's intervals. Water temperatures varied between 7.3°C and 10.4°C, with mean temperatures of 8.7°C and 9.1°C in Sommerfuglesø and Langemandssø, respectively (Tables 3.37 and 3.38). Despite the early ice-out there were no indications of changes in the average values recorded for conductivity, total nitrogen and total phosphorus, which remained within the usual year-to-year fluctuations (Table 3.38).

Unfortunately, the phytoplankton samples were damaged during homeward transport. However, the phytoplankton biomass in terms of chlorophyll *a* was similar to those of previous years, since average concentrations were 1.62 and 0.98 µg/l in Sommerfuglesø and Langemandssø, respectively (Tables 3.37 and 3.38).

The zooplankton community was sampled once in mid August, and the sampling revealed that the cladoceran *Daphnia pulex* was still present in Sommerfuglesø, although in low numbers, and that it appeared together with the copepod *Cyclops abyssorum alpinus* as well as the rotifer *Polyarthra* sp. (Table 3.39). The presence of *D. pulex* clearly indicates that there are no fish present in the lake. This is in contrast to Langemandssø with presence of Arctic char, where *C. abyssorum alpinus* dominates the zooplankton community togeth-

Table 3.38. Average physico-chemical variables in Sommerfuglesø (SS) and Langemandssø (LS) in 1999-2004 (July-August) compared to single values from mid-August 1997 and 1998. ND = no data.

	SS 1997	SS 1998	SS 1999	SS 2000	SS 2001	SS 2002	SS 2003	SS 2004	LS 1997	LS 1998	LS 1999	LS 2000	LS 2001	LS 2002	LS 2003	LS 2004
Date of 50% ice cover	ND	11.7	18.7	25.6	2.7	3.7	24.6	24.6	ND	23.7	21.7	30.6	8.7	6.7	2.7	26.6
Temperature (°C)	6.3	6.5	6.1	10.1	8.4	8.3	11.0	8.7	6.8	6.4	4.0	9.5	8.4	8.1	11.1	9.1
pH	6.5	7.4	6.7	5.8	6.6	6.0	6.5	6.3	6.5	7.0	6.3	5.5	6.4	5.5	6.1	6.1
Conductivity (µS/cm)	15	13	10	18	18	8	12	15	8	9	7	9	8	6	6	8
Chlorophyll a (µg/l)	0.84	0.24	0.41	0.76	0.67	1.27	1.84	1.62	1.04	0.32	0.38	0.90	1.46	2.72	3.14	0.98
Total nitrogen (µg/l)	ND	130	210	510	350	338	277	267	ND	80	120	290	340	387	237	230
Total phosphorous (µg/l)	4	9	11	10	19	11	11	7	8	7	7	11	20	13	10	11

	SS 1997	SS 1998	SS 1999	SS 2000	SS 2001	SS 2002	SS 2003	SS 2004	LS 1997	LS 1998	LS 1999	LS 2000	LS 2001	LS 2002	LS 2003	LS 2004
Cladocera																
Daphnia pulex	0.3	10.5	0.3	6.7	8.2	6.8	7.7	0.7	0	0	0	0	0	0	0.1	0.0
Macrothrix hirsuiticornis	0.1	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0.0	0.0
Chydorus sphaericus	0.05	0	0	0	0.06	0	0	0	0	0.1	0	0.5	0.1	0.07	0.00	0.00
Copepoda																
Cyclops abyssorum alpinus (adult+copepodites)	0.8	0.5	0.5	0.3	0.5	0.2	0.9	0.3	3.3	2.9	4.1	22.0	13.4	6.8	8.6	4.9
Nauplii	5.7	1.3	6.5	1.1	1.4	2.3	0.3	0.3	5.2	3.8	6.4	3.1	4.5	4.5	4.2	0.0
Rotifera																
Polyarthra dolicopthera	171	90	185	97	74	11	0.5	1.87	316	330	274	168	248	22	78	71
Keratella quadrata group	4.5	3	17	0	0	0.4	0.1	0	4.5	28	34	0	0	0.3	0.0	1.3
Conochilus sp.	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0

Table 3.39. Density (no/l) of zooplankton in Sommerfuglesø (SS) and Langemandssø (LS) in mid August 1997-2004.

er with several rotifer species (*Polyarthra* sp. and *Keratella* sp.).

An attempt to sample arctic char in both lakes failed, but will be attempted again in 2005.

4 Zackenberg Basic: The MarineBasis Programme

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This is the report from the second year of the MarineBasis monitoring programme in the Young Sund-Tyrolerfjord system. The aim of the programme is to detect possible changes in a high-arctic marine ecosystem due to climate variability and change. This is accomplished by combining an intense summer field campaign with deployment of automated moorings supplying recordings throughout the year. Physical, chemical and biological parameters are measured in the main research area, Young Sund, but also in Tyrolerfjord and the Greenland Sea when weather conditions allow it.

The overall design of the sampling programme is a combination of stations sampled once every summer, a station sampled frequently every summer and a mooring system deployed in August and retrieved one year later. Density and diversity of benthic fauna were analysed from digital images recorded along 3 transects perpendicular to the coast from 20-60 m water depth. The dominant species were identified and counted. Hydrographic measurements (depth, salinity, temperature, Chlorophyll *a*) were performed along a longitudinal transect from the innermost part of Tyrolerfjord to about 40 km offshore in the Greenland Sea at intervals of 5-10 km between CTD casts (Fig. 4.1). The same measurements were performed along two transects across Young Sund at intervals of 1-2 km (Fig. 4.2).

At the frequently visited station the following parameters were measured roughly every second day: light attenuation (PAR), vertical profiles of salinity, temperature and fluorescence, and water was sampled from 9 depths and filtered for Chlorophyll *a* (Chl. *a*) determination. In addition, samples were taken three times during the 3-week sampling period for vertical profiles of UV-B absorption, NO_3^- + NO_2^-, PO_4^{3-}, NH_4^+, SiO_4, dissolved inorganic carbon (DIC) and total alkalinity (TA) and vertical hauls were made from bottom to top with plankton nets for zooplankton and phytoplankton determination. At the seafloor the sediment-water fluxes of O_2, DIC and nutrients were measured once at a water depth of 60 m. In addition, the vertical concentration profile of O_2 in the sediment was recorded.

The mooring system launched in 2003 was retrieved and replaced with a new system this year. The mooring system was deployed at a depth of ~80 m (74°18.93′N, 20°16.70′W) and consisted of one automatic sediment trap at a depth of 60 m and 2 CTD probes at 65 m and 50 m depth.

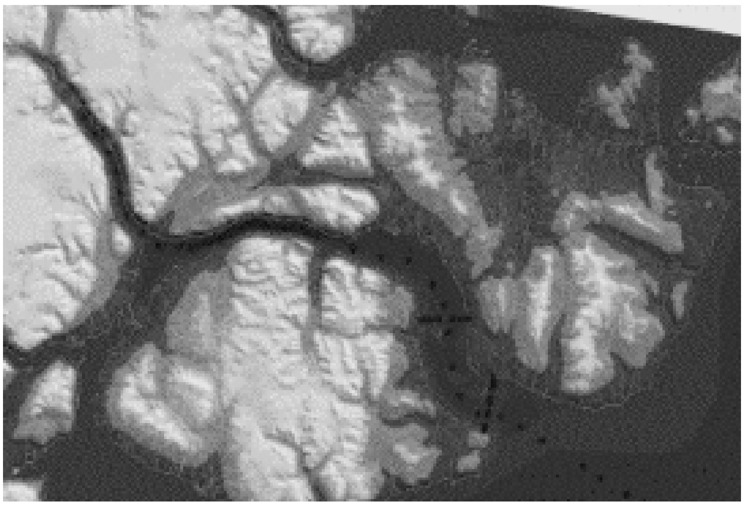


Figure 4.1. Map of the sampling area. The dots represent the hydrographic sampling stations from the innermost Tyrolerfjord on the left to the Greenland Sea on the right.

4.1. Sea ice

Data from the camera systems established during August 2003 in the outer region of

Young Sund shows that a uniform sea ice cover was established 8 November 2003 (Fig. 4.3). Sea ice cover remained intact throughout the winter until 1 June 2004 when the first melt ponds were visible on the surface. Melt ponds developed and grew in size until 7 July and sea ice cover broke up 8 July and drifted out to the Greenland Sea. Very little sea ice was observed during the summer within Young Sund. A little sea ice entered the fjord during 4 August but was exported again the same day.

The military patrol SIRIUS continued their measurements of sea ice and snow thickness at 74°18.59'N, 20°15.04'W during 2003-2004 (Fig. 4.4). Maximum sea ice thickness was 150 cm in April 2004 and mean snow cover thickness was 32 cm during 2003-04.

The annual ice-free periods in the outer part of Young Sund during 2003 and 2004 of 122 and 140 days, respectively, were derived from the camera systems (Fig. 4.3, Table 4.1) and compared well with the observations reported by SIRIUS. Based on historic military reports, in which sea ice thickness was noted for safe dogsledge transport (15 cm thick ice) along with day of sea ice break-up, we constructed the past 54 years of ice-free conditions in the outer part of Young Sund (Fig. 4.5). As is evident from the figure, an ice-free period of approximately 80 days was the norm from 1950 to 1985. After two very unusual years with little sea ice, the ice-free period dramatically increased from the mid-1990s until today, when an ice-free period of 122-140 days is observed (Table 4.1).

4.2. Water column

Continuous data

On 7 April 2004 the buoyancy system failed (due to a fabrication error) with the result that the sediment trap fell to the sea floor. However, we succeeded in retrieving the sediment trap. The sediment trap collected material throughout winter until 7 April, but as sedimentation is very low during that period (see Rasch and Caning 2004), less than 10% of the annual sedimentation was captured. Data from the sediment trap retrieved in 2003 showed that 90 % of the annual sedimentation occurred within the two summer months of July and August. Furthermore, isotopic ($\delta^{13}C$ & $\delta^{15}N$) analysis of particulate organic material (POM) in the sediment trap, of POM of marine origin and in Zackenbergelven indicates that ~50% of the POM material originates from land. This is supported by the high C:N ratio in the sediment trap material of up to 22 during the summer thaw compared with 7-9 during winter and spring when no discharge from land occurs.

An example of continuous data on temperature, salinity, density and pressure collected by the mooring CTDs is presented in Fig. 4.6. Continuous data (1h) is recorded and thus captures the variability in the measured parameters on an annual basis. Mean monthly data at 63 m water depth (74°18.93'N, 20°16.70'W) is presented in Fig. 4.7 and in Table 4.2. Sub-zero temperatures were recorded throughout

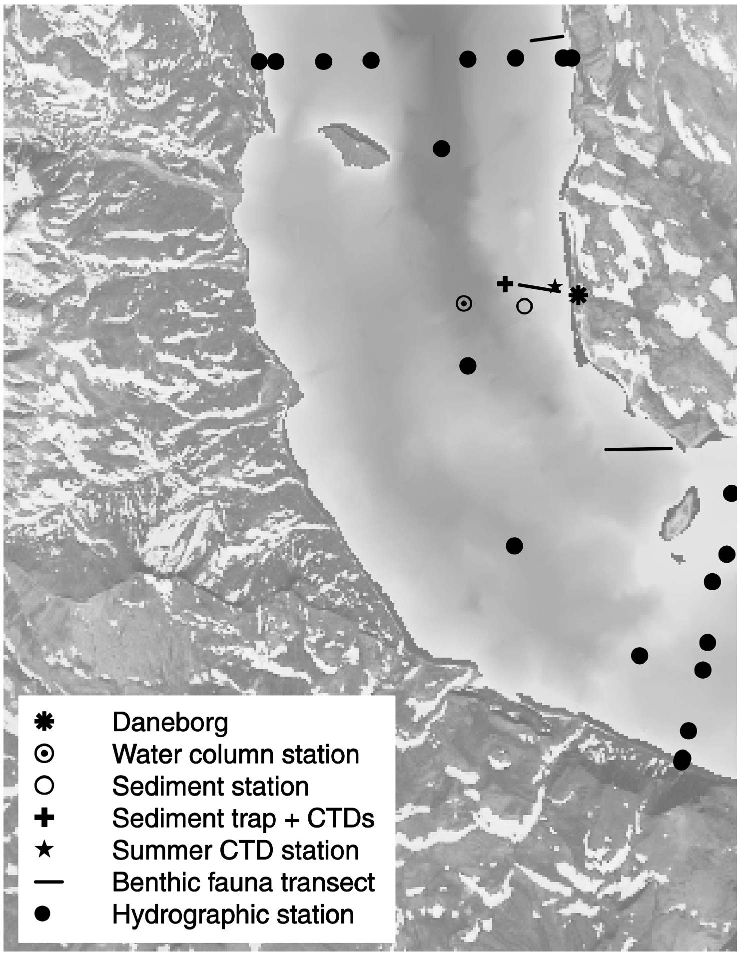


Figure 4.2. Map showing the sampling stations in the outer part of the Young Sund in more detail.

	2003	2004
Ice thickness (cm)	120	150
Snow thicknes (cm)	20	32
Days with ice cover	225	244
Days with open water	140	122

Table 4.1. Sea ice conditions in the outer part of Young Sund.

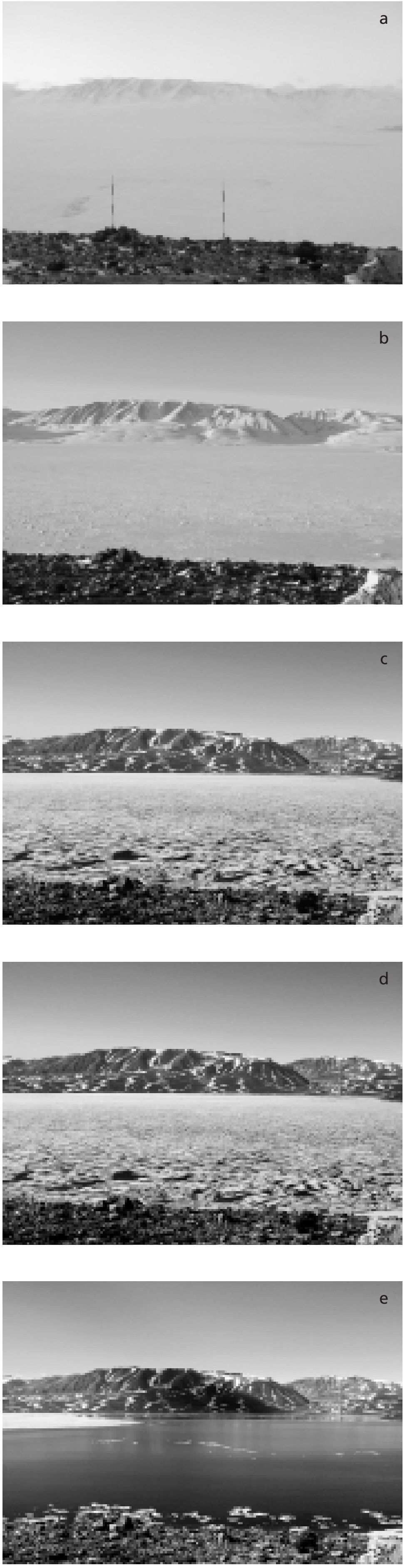


Figure 4.3. Sea ice conditions during 2003-2004. (a) Sea ice cover is uniformly established on 8 November 2003 (b) Sea ice continues to grow – image from 26 February 2004. (c) On 1 June 2004 the first melt ponds at the surface observed. (d) Melt ponds continue to grow until 7 July 2004. e) Sea ice breaks up 8 July 2004.

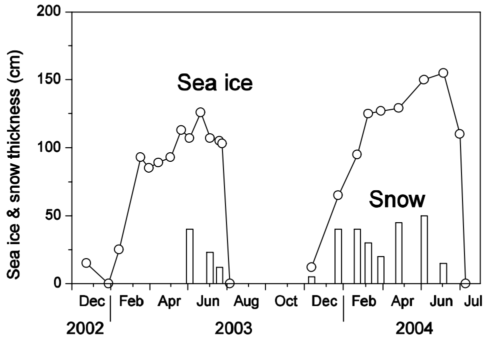


Figure 4.4. Sea ice and snow thickness in the outer part of Young Sund.

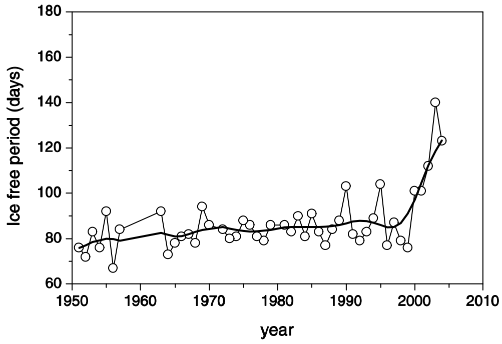


Figure 4.5. Ice-free period in the outer part of Young Sund since 1950. Thick line represents 5-year running mean.

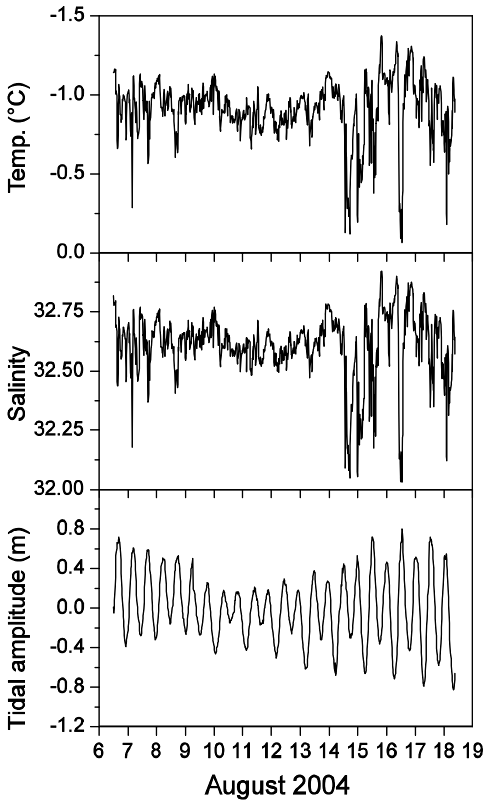


Figure 4.6. Data from the mooring system during the intensive study period.

the year with a mean monthly value of –1.469°C during October 2003 and –1.781°C during April 2004. Mean monthly salinity values of 32.671 were observed during January 2004 and the highest value of 32.971 was observed during May 2004. A clear seasonal variation was observed, possibly relating to sea ice conditions and freshwater discharge from land.

Vertical profiles of temperature, salinity, density and Chlorophyll a across and along Young Sund

Temperature, salinity and Chlorophyll *a* profiles were measured along and across Young Sund. This year very little sea ice and calm conditions enabled us to complete a full-length investigation from the bottom of the fjord to 40 km outside the fjord (Fig. 4.8). Temperatures above 0°C were recorded only in the upper water layers and it is clear that Young Sund is a deep-sill fjord with cold bottom water. The highest salinity of 33.15 recorded within the fjord was found in the deeper part of the Tyrolerfjord. Warmer (>1°C) and saltier (34.77) water was observed at 200-300 m water depth outside the fjord, due to Upper Arctic Intermediate Water. Chlorophyll *a* values were slightly higher outside the sill than inside the fjord. Due to the input of freshwater from melting snow and ice in the catchment area, the surface water was less saline in the inner parts of the fjord where salinity values of 28 and temperatures of 0°C were observed at 36 m water depth. The layer of low-salinity surface water gradually decreased in thickness toward the mouth of the fjord. Little difference in temperature, salinity and Chl. *a* values were seen across the fjord at the two transects investigated (data not shown).

The variability of temperature, salinity and Chl. *a* in the upper 150 m of the water column (74°18.58'N, 20°18.00'W) during August was investigated through measurements made every second day (Fig. 4.9). Temperature and salinity values were fairly stable throughout the period whereas Chlorophyll a values decreased with time. Low Chlorophyll a was present in the surface layer due to nutrient limitation (see below). The disappearance of Chlorophyll a was most likely due to grazing (se below).

	Pot. temp °C	SE	sal	SE	n
2003					
Aug	–1.573	5.3E-05	32.930	2.3E-05	744
Sep	–1.595	7.8E-05	32.910	3.3E-05	720
Oct	–1.469	7.4E-05	32.859	7.4E-05	744
Nov	–1.550	6.0E-05	32.777	9.9E-05	720
Dec	–1.674	2.1E-05	32.678	5.9E-05	745
2004					
Jan	–1.687	2.8E-05	32.671	5.8E-05	744
Feb	–1.754	4.4E-05	32.798	1.1E-04	696
Mar	–1.776	1.1E-05	32.914	2.2E-05	744
Apr	–1.781	1.5E-05	32.970	1.4E-05	720
May	–1.748	2.3E-05	32.971	1.9E-06	743
Jun	–1.743	1.7E-05	32.959	8.9E-06	720
Jul	–1.666	3.6E-05	32.947	4.3E-06	744

Table 4.2. Data from 63 m water depth as measured by mooring in the outer part of Young Sund. Average of hourly values. Pot. Temp. refers to potential temperature. SE refers to standard error of the mean.

Nutrients, dissolved inorganic carbon (DIC) and total alkalinity (TA)

Nutrients, DIC and TA concentrations in the water column of the location 74°18.58'N, 20°18.00'W were measured on three occasions (4, 12 and 19 August). The nitrate concentration was very low in the surface water due to phytoplankton uptake and dilution by melt water, and increased with depth to 4-5 µM (Fig. 4.10). Phosphate concentrations were detectable in the surface water and increased to 0.6-1.2 µM in the bottom water. Silicate concentrations followed the same vertical concentration profile as nitrate and phosphate except that increased concentrations were observed in the upper 10 m freshwater layer. Ammonium was not detected.

Dissolved inorganic carbon ranged from

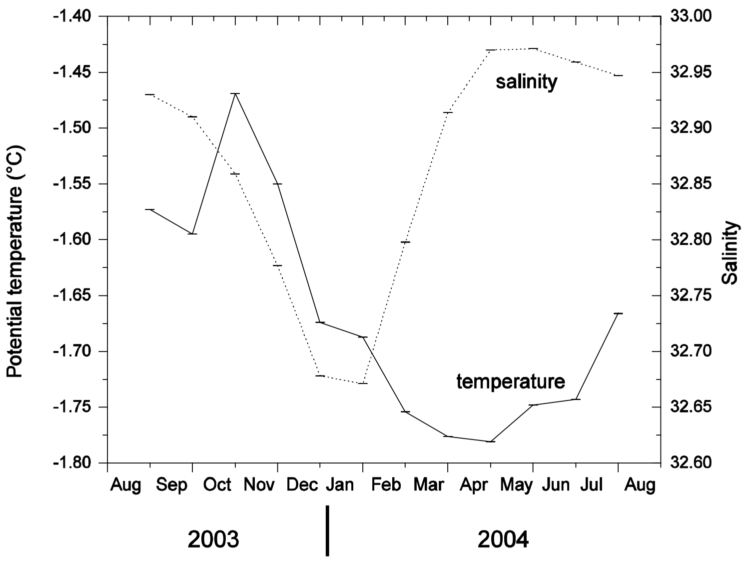


Figure 4.7. Mean monthly data of temperature and salinity at 63 m water depth in the outer part of Young Sund. Based on hourly data from mooring.

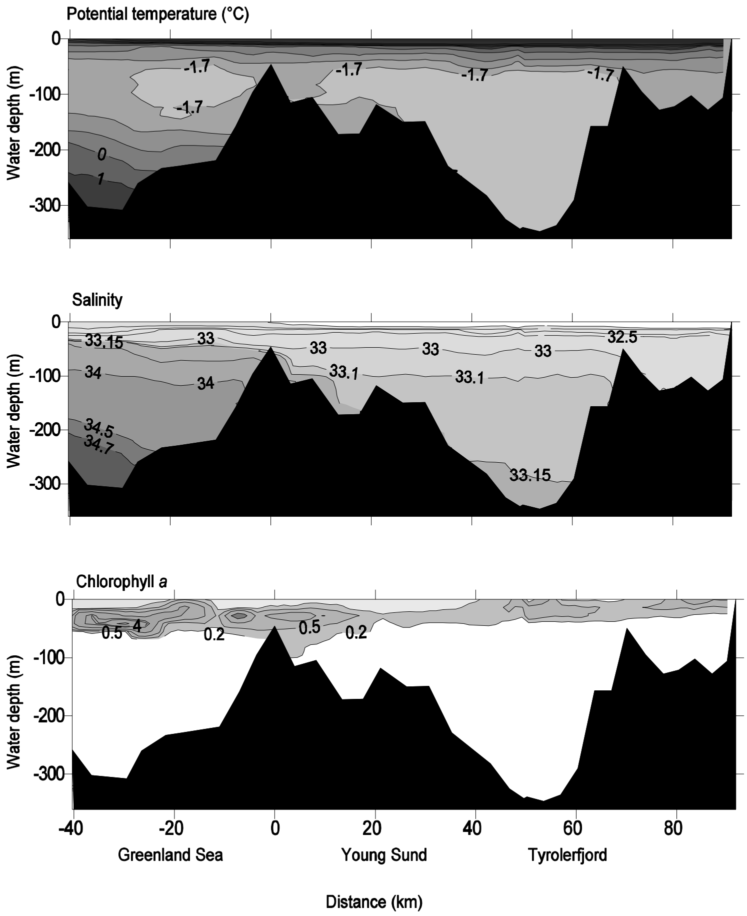


Figure 4.8. Potential temperature (°C), salinity, and Chlorophyll a (µg L⁻¹) in the Young Sund-Tyrolerfjord system and in the Greenland Sea, August 2004.

1769 µM in the upper 0-5 m of the water column to 2172 µM in the bottom water of Young Sund (Fig. 4.11, Table 4.3). TA followed the same vertical trend as DIC and ranged from 1867 to 2347 µM in the water column. Atmospheric pCO_2 levels were significantly higher than pCO_2 levels in the surface water on all sampling dates showing that the CO_2 flux was directed from the atmosphere into the water column of Young Sund. In Table 4.3 the mean hydrographic conditions at the locality in the outer part of Young Sund are given for the first two years of the MarineBasis program.

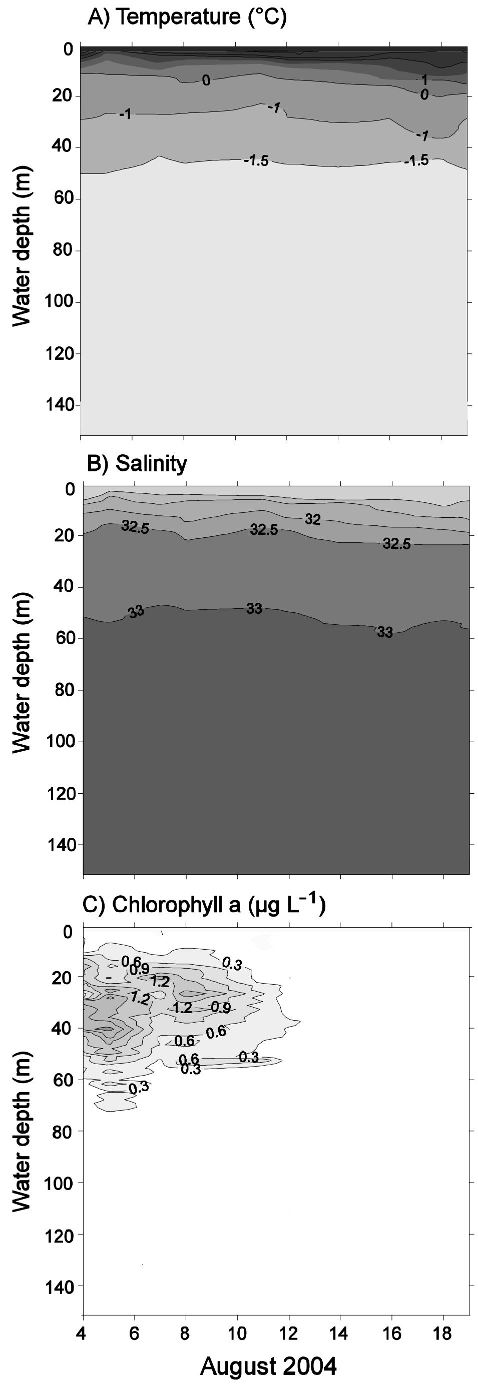


Figure 4.9. Potential temperature (°C), salinity and Chlorophyll ? in Young Sund, August 2004.

Light and optical properties of dissolved organic matter (DOM)

Every second day during August we measured the attenuation of light (PAR) in the water column of Young Sund at the location 74°18.58'N, 20°18.00'W. Furthermore, we collected water from 1 m, 5 m, 30 m and 150 m for determination of the optical properties of DOM in the laboratory. Light attenuation coefficients were calculated for PAR based on the vertical PAR profiles.

The attenuation coefficient varied from 0.13 to 0.15 during August with a mean value of 0.136 ± 0.004 m^{-1} (Table 4.4). In response to the concern raised regarding increased UV levels in the Polar Regions we investigated the absorption characteristics of UV-B in the water column of Young Sund during 4, 12 and 19 August. The absorption coefficient of UV-B in the wavelength range of 280-315 nm was 1.43 ± 0.23 m^{-1} for the upper 5 meters and increased with water depth (Table 4.4). Thus, <1% of incoming UV-B will reach a depth of 3.2 m in the water column.

Phytoplankton and zooplankton

On 4, 12 and 19 August, triplicate vertical net hauls for phytoplankton and zooplankton were performed at 74°18.58'N, 20°18.00'W, at a water depth of 160 m. The phytoplankton cell abundance, species number and diversity was found to decrease over time (Table 4.5) indicating post-bloom conditions. The general composition of phytoplankton, as exemplified by the 10 dominant species, changed little during August. On all three sampling dates diatoms constituted the majority of cells found. Diatoms in general and *Chaetoceros* species in particular were also found to be dominant during August 2003. The abundance of zooplankton showed a decreasing trend during August (Table 4.6) similar to that of the phytoplankton. The dominating copepod species throughout the period were *Pseudocalanus spp.*, *Oithona spp.* and *Calanus hyperboreus*, and overall abundance and composition are similar to results from 2003. A notable difference between 2003 and 2004 was found in the relative abundance the two *Calanus* species *C. finmarchicus* and *C. hyperboreus*. *Calanus finmarchicus* is generally described as belonging to the warmer Atlantic water whereas *C. hyperboreus* is a typical arctic species. In 2003 the ratio of *C. hyperboreus* to *C. finmarchicus* was 56:1 but decreased to 11:1 in 2004. The increased abundance of *C. finmarchicus* in 2004 was partly due to large numbers of copepodite stages IV and V which were not present during August 2003. The abundance of non-copepod plankton was similar to that found in 2003. Dominant taxa throughout the period were *Fritellaria sp.* and *Radiolaria*. In 2003 significant shifts in abundance of single groups were found during the three sampling dates in August, larvae of gastropods and bivalves being dominant, together with *Radiolaria* and *Chaetognatha*.

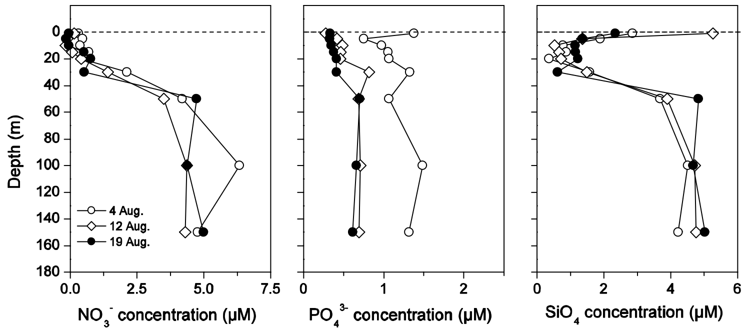


Figure 4.10. Nitrate, phosphate and silicate concentrations in the water column of Young Sund, August 2004.

Table 4.3. Hydrographic conditions in Young Sund. Mean values of depth profiles sampled throughout August. ± represents Standard Error (SE) of the mean.

0-5 m water depth	2003	2004
Potential temperature (°C)	5.570 ± 0.175	5.515 ± 0.158
Salinity	28.103 ± 0.230	26.029 ± 0.247
Chlorophyll a (µg L^{-1})	0.727 ± 0.069	0.060 ± 0.004
DIC (µM)	1806.2 ± 60.4	1769.0 ± 46.5
TA (µM)	1929.5 ± 65.8	1867.5 ± 52.5
pCO_2 (µatm)*	302.2 ± 32.6	197.1 ± 10.1
NO_3^- (µM)	0.00 ± 0.04	0.16 ± 0.05
PO_4^{3-} (µM)	0.25 ± 0.01	0.58 ± 0.17
SiO4 (µM)	2.41 ± 0.30	2.51 ± 0.59
0-45 m water depth	**2003**	**2004**
Potential temperature (°C)	2.564 ± 0.203	0.708 ± 0.095
Salinity	30.449 ± 0.168	31.166 ± 0.104
Chlorophyll a (µg L-1)	0.498 ± 0.032	0.407 ± 0.021
DIC (µM)	2000.6 ± 40.4	1986.3 ± 3.6
TA (µM)	2146.0 ± 44.9	2175.5 ± 31.2
NO_3^- (µM)	0.83 ± 0.27	0.46 ± 0.15
PO_4^{3-} (µM)	0.34 ± 0.03	0.62 ± 0.08
SiO_4 (µM)	2.20 ± 0.2	1.45 ± 0.27
45-150 m water depth	**2003**	**2004**
Potential temperature (°C)	−1.653 ± 0.004	−1.659 ± 0.001
Salinity	32.933 ± 0.002	33.093 ± 0.001
Chlorophyll a (µg L^{-1})	0.257 ± 0.011	0.117 ± 0.004
DIC (µM)	2181.1 ± 7.9	2172.4 ± 0.40
TA (µM)	2318.8 ± 1.7	2347.6 ± 5.0
NO_3^- (µM)	3.95 ± 0.15	4.64 ± 0.14
PO_4^{3-} (µM)	0.58 ± 0.01	0.88 ± 0.11
SiO^4 (µM)	4.22 ± 0.27	4.48 ± 0.11

*mean of surface layer (0-1 m)

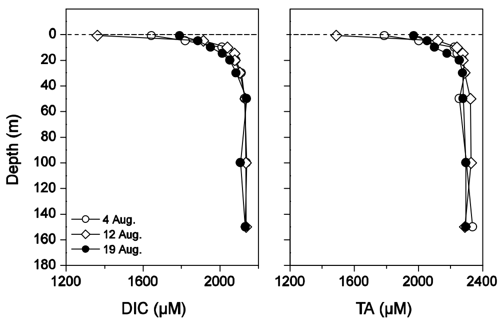


Figure 4.11. Dissolved inorganic carbon (DIC) and total alkalinity (TA) concentrations in the water column of Young Sund, August 2004.

	2003	2004
PAR attenuation coefficient (m^{-1})	0.117 ± 0.007	0.136 ± 0.004
UV-B attenuation coefficient (m^{-1})	1.27 ± 0.05	1.43 ± 0.23

Table 4.4. Attenuation cofficients in water column of Young Sund. SE represents Standard Error of the mean (n = 8).

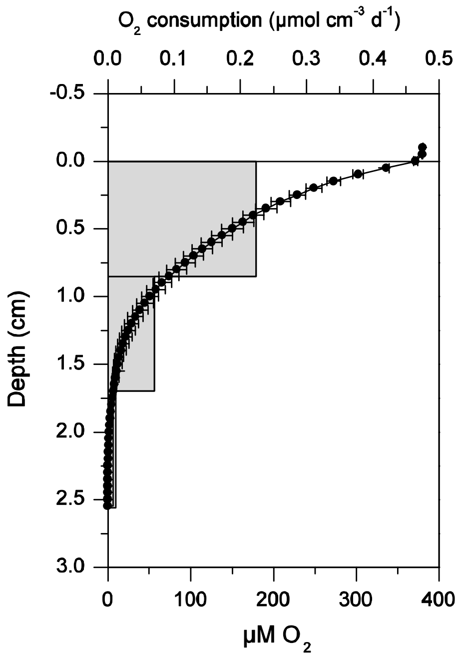


Figure 4.12. Vertical concentration profiles of oxygen (dots) and modeled consumption rates (bars) in the sediment at 60 m water depth in outer Young Sund, August 2004.

4.3. Sediment

Sediment-water exchange rates of oxygen, DIC and nutrients, oxygen conditions and sulphate reduction

The organic matter reaching the sediment from the water column undergoes degradation within the sediment, a process also known as mineralization. This occurs via a number of steps involving several different electron acceptors, or oxidants. In the surface layer, O_2 serves as electron acceptor and below the oxic zone, SO_4^{2-} is the dominant electron acceptor. In the anoxic zone, oxidised Fe and Mn and NO_3^- may act as electron acceptors as well. When either oxidised metals or SO_4^{2-} oxidise the organic matter, reduced species are formed, and subsequent re-oxidation of these species leads to oxygen consumption. The nutrients incorporated in the organic matter undergoing degradation are released and may bind to the sediment particles, participate in reactions in the sediment or be released to the overlying water. The sediment processes were measured in intact sediment cores sampled at a water depth of 60 m (74°18.58′N, 20°15.74′W) on 11 August 2004.

Of the organic carbon reaching the sediment surface 3.372 mmol C m^{-2} d^{-1} was returned to the water column as dissolved inorganic carbon (DIC) in 2004 (Table 4.7). The O_2 consumption by the sediment of 4.429 mmol m^{-2} d^{-1} was higher than the DIC efflux. This indicates that O_2 is not only channelled into oxidation of organic matter, but part of it must be used for reoxidation of reduced metals or sulphide. The specific O_2 consumption was highest in the upper part of the sediment (Fig. 4.12) showing that the main O_2 consumption is created by the fresh organic matter deposited on the surface of sediment.

Sulphate reduction was responsible for almost half of the mineralization of organic matter this year (Table 4.7). It was four times more important in 2004 than in 2003 because the total mineralization was lower and SRR was higher in 2004 than in 2003. Sulphate reduction was low in the upper layers of the sediment, where other miner-

Table 4.5. Phytoplankton diversity (mean ± SE, n=3) during August 2004. The ten most abundant species are given together with their relative accumulated proportion of the total cell count.

	4 August 2004		12 August 2004		19 August 2004	
Number of species	25		19 ± 1.5		14.3 ± 0.9	
Diversity	2.45		1.94 ± 0.07		1.83 ± 0.10	
Equitability	0.76		0.66 ± 0.04		0.69 ± 0.03	
Dominant species	*Fragilariopsis cylindrus*	12%	*Fragilariopsis sp.*	26%	*Chaetoceros decipiens*	22%
	Thalasiossira antarctica	25%	*Pseudonitzschia sp.*	46%	*Fragilariopsis sp.*	45%
	Chaetoceros decipiens	38%	*Amphora sp.*	54%	*Dinobrion sp.*	64%
	Dinobrion baltica	49%	*Dinobrion sp.*	58%	*Chaetoceros eibenii*	76%
	Eucampia sp.	60%	*Thalasiossira sp.*	61%	*Navicula sp.*	81%
	Protoperidinium sp.	68%	*Chaetoceros decipiens*	64%	*Thalasiossira sp.*	85%
	Pseudonitzschia sp.	76%	*Licmophora sp.*	66%	*Licmophora sp.*	88%
	Chaetoceros eibenii	83%	*Atteya cf spetentrionalis*	68%	*Synedra sp.*	89%
	Nitzschia frygida	88%	*Navicula sp.*	69%	*Cryptomonas sp.*	90%
	Navicula sp.	92%	*Chaetoceros eibenii*	70%	*Ceratium sp.*	91%

	4 August 2004			12 August 2004			12 August 2004		
	Mean No m^{-2}	SE n=3	% of total	Mean No m^{-2}	SE n=3	% of total	Mean No m^{-2}	SE n=3	% of total
Copepods									
Pseudocalanus spp.	5248	617	11.1	6667	571	15.1	6315	1232	20.4
Pseudocalanus spp. Nauplii	12288	1263	26.0	5333	1626	12.1	2923	331	9.5
Oithona spp.	11093	1104	23.5	13451	3062	30.5	7797	1742	25.2
Oithona spp. Nauplii	3200	1048	6.8	3840	462	8.7	4437	755	14.4
Calanus hyperboreus	4928	786	10.4	5525	1251	12.5	3413	492	11.0
Calanus glacialis	107	56	0.2	43	28	0.1	203	93	0.7
Calanus finmarchicus	640	98	1.4	757	65	1.7	192	55	0.6
Onchaea	3179	296	6.7	6549	674	14.9	4139	395	13.4
Microcalanus	5803	272	12.3	1261	266	2.9	1088	218	3.5
Harpacticoida	85	21	0.2	128	37	0.3	203	70	0.7
Metridia longa	661	154	1.4	501	11	1.1	203	46	0.7
Sum	47232			44056			30912		
Other Groups									
Cirripedia	192	98	0.8	75	59	0.4	11	11	0.2
Bivalvia, larvae	1003	182	4.2	459	59	2.6	107	65	2.4
Gastropoda, larvae	21	21	0.1	181	105	1.0	75	11	1.7
Fritellaria, bor.	16725	1038	70.1	13141	4218	75.4	2699	1041	61.4
Oikopleura	1237	789	5.2	864	297	5.0	53	11	1.2
Polychaeta, larvae	1472	279	6.2	288	85	1.7	427	65	9.7
Echinodermata, pluteus	85	21	0.4	11	11	0.1	224	115	5.1
Ctenophora, larvae	0	0	0.0	0	0	0.0	0	0	0.0
Amphipoda	21	21	0.1	11	11	0.1	32	18	0.7
Chaetognatha	64	64	0.3	53	38	0.3	11	11	0.2
Radiolaria	2944	1048	12.3	2251	1404	12.9	693	453	15.8
Isopoda	0	0	0.0	32	18	0.2	43	28	1.0
Hydromedusae	85	21	0.4	64	18	0.4	21	21	0.5
Sum	23850			17429			4394		

Table 4.6. Composition of zooplankton in the upper 160 m of Young Sund at three sampling dates in August 2004.

alization processes dominated, and increased significantly with depth (Fig. 4.13). The presence of fauna in the sediment creates a higher O_2 uptake than that measured as diffusive uptake. In 2004 the ratio of total to diffusive O_2 uptake was 1.52, which was approximately the same as the year before, indicating that the role of the fauna was the same in both years at this position.

Benthic animals

The abundance of dominant epibenthic animals was determined by photographs of the sea floor during 2004 (Fig. 4.14) at the same positions as those visited in 2003. Clear distributional patterns between depths and transects where observed in both years. Brittle stars showed a strong increase in abundance with depth except for transect H1 were the maximum was found at 50 m. Sea urchins were almost

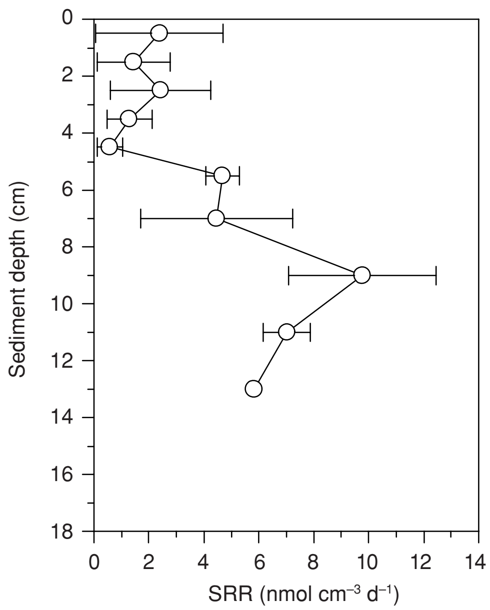
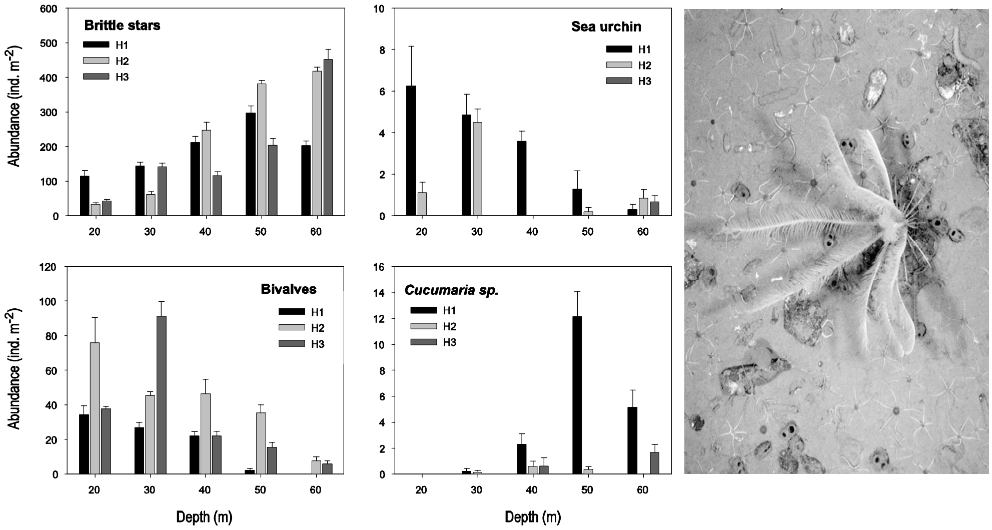


Figure 4.13. Sulfate reduction rates in the sediment at 60 m water depth in outer Young Sund, August 2004.

Figure 4.14. Abundance of dominant benthic species in Young Sund (mean ± SE, n=10) estimated from analysis of 150 photographs from Young Sund in August 2004. Example of photos of benthic animals from transect H1 40 m depth.



absent at the outer transect H3 and showed decreasing abundance with depth at H1 and H2. Bivalve abundance peaks at 20 to 40 m, the highest abundance being generally found at H2 and H3. In the case of the sea cucumber *Cucumaria sp*. distribution was highly patchy and no clear trend was found, although it did seem to prefer depths from 40 to 60 m. In general, abundances of all species were slightly higher in 2004 compared with 2003 (Table 4.8).

Growth of bivalves

In a manner similar to the formation of growth rings in trees, bivalves form increments in their shells when they grow. By measuring the width of individual increments in 30 individuals of age 4 to 53 years an index of the relative population growth can be constructed by a method similar to those used in dendrochronology. This index can be used to identify long-term trends in growth rates of a population. The three-year running mean of the index for *Mya truncata* is presented in Fig. 4.15. Below-average growth occurred around 1970, 1980 and 2000. Peak growth rates of shells were found at regular 10-year intervals around 1965, 1975, 1985 and 1995.

Underwater plants

The annual growth of the algae *Laminaria saccharina* can be quantified by measuring the length of the new leaf produced. The measured growth of individuals collected in August 2004 is thus a result of the physical and biological conditions experienced from the summer 2003 until collection in August 2004 (Table 4.9). In MarineBasis the collected leaf blades are also analysed for the carbon content, which reveals that although growth in cm was similar in 2003 and 2004 the carbon content was lower in 2004. This difference may be due to differences in the techniques used. Traditionally, sub-samples of plant material are analysed for carbon content on an elemental analyser. However, we discovered great variability in carbon contents in different parts of the blade. Therefore we decided to freeze-dry the entire plant (blade) and analyse homogenised sub-samples for carbon content. This procedure will be applied in future.

	2003			2004		
	Average	±SE	n	Average	±SE	n
TOU	–5.191	0.523	10	–4.429	0.925	10
DIC	6.955	2.298	10	3.372	0.457	10
$NO_3^- + NO_2^-$	0.221	0.087	10	0.135	0.045	10
NH_4^+	–0.002	0.064	10	0.041	0.026	10
PO_4^{3-}	–0.017	0.013	10	0.249	0.076	10
SiO_4	0.543	0.090	10	0.474	0.118	10
SRR	0.430	0.084	3	0.816	0.216	3
DOU	–3.026			–2.909		
TOU/DOU	1.72			1.52		
SRR/DIC flux	0.124			0.484		

Table 4.7. Sediment-water exchange rates of O_2 (TOU), DIC (dissolved inorganic carbon), NO_3^- + NO_2^-, NH_4^+, SiO_4 and PO_4^{3-} measured in intact sediment cores, sulphate reduction rates (SRR) in the sediment integrated to a depth of 12 cm, diffusive oxygen uptake by the sediment (DOU) and the ratios of DOU to TOU and SRR to DIC flux. n denotes the number of sediment cores. Positive values indicate a release from the sediment to the water column. All rates are in mmol m^{-2} d^{-1}. SE denotes the Standard Error of the mean.

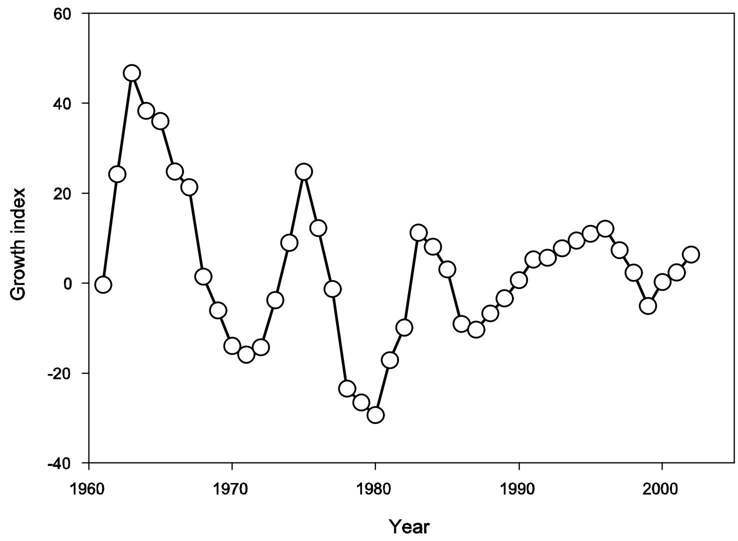


Figure 4.15. Relative growth index for the bivalve Mya truncata in Young Sund. The index shows long-term variation in growth rate estimated from measurements of individual growth increments in the shells of 30 individuals. Negative values indicate periods where growth was less than the overall mean for 1960-2002.

4.4. Other activities

Walrus, seal and arctic char

MarineBasis will report on the number of walruses at the haul-out location at Sandøen. This year, a research project on walruses was carried out by Mario Acquarone et al., who will cover this aspect **(see section ???)**. In short, however, a large group of walruses comprising a maximum of 59 individuals, was observed 4 August on Sandøen this year.

MarineBasis also collected material from ringed seal and Arctic char in connection with the catch made by SIRIUS. The material was frozen and may be used in the future as a data bank of contaminants etc.

	H1		H2		H3	
	2003	**2004**	**2003**	**2004**	**2003**	**2004**
	Mean ± SE (n = 10)	Mean ± SE (n = 10)	Mean ± SE (n = 10)	Mean ± SE (n = 10)	Mean ± SE (n = 10)	Mean ± SE (n = 10)
Brittle stars						
20.0	122 ± 12	115 ± 16	28 ± 4	34 ± 4	4.2 ± 2.6	43 ± 5
30.0	126 ± 8	145 ± 10	242 ± 22	62 ± 7	70 ± 8	142 ± 11
40.0	245 ± 13	212 ± 18	317 ± 23	247 ± 24	118 ± 11	116 ± 11
50.0	206 ± 10	298 ± 20	376 ± 29	382 ± 10	97 ± 8	205 ± 19
60.0	98 ± 13	203 ± 14	267 ± 17	417 ± 13	362 ± 26	452 ± 28
Sea urchins						
20.0	5.7 ± 1.4	6.2 ± 1.9	0	1.1 ± 0.5	0	0
30.0	2.0 ± 0.8	4.9 ± 1.0	2.5	4.5 ± 0.6	0	0
40.0	1.7 ± 0.7	3.6 ± 0.5	0	0	0	0
50.0	0.3 ± 0.3	1.3 ± 0.9	0.8 ± 0.7	0.2 ± 0.2	0	0
60.0	0.1 ± 0.1	0.3 ± 0.3	0.7 ± 0.5	0.8 ± 0.4	0	0.7 ± 0.3
Bivalves						
20.0	30.3 ± 3.4	34.5 ± 5.0	43.3 ± 5.1	76 ± 14.5	11.5 ± 3.9	37.6 ± 1.6
30.0	21.7 ± 3.1	27.1 ± 2.9	20.6 ± 3.7	45.5 ± 2.4	55.1 ± 6.2	91.4 ± 8.4
40.0	19.0 ± 3.4	22.1 ± 2.5	69 ± 10.8	46.6 ± 8.1	9.4 ± 2.7	22.3 ± 2.3
50.0	1.0 ± 0.7	2.2 ± 1.1	19.9 ± 4.1	35.7 ± 4.4	6.4 ± 1.4	15.7 ± 2.8
60.0	0	0	2.0 ± 0.7	7.7 ± 2.3	2.1 ± 1.0	6.0 ± 1.9
Sea cucumbers						
20.0	0	0	0	0	0	0
30.0	0	0.2 ± 0.2	0	0.2 ± 0.2	0	0
40.0	4.1 ± 1.0	2.3 ± 0.8	0	0.6 ± 0.4	0	0.6 ± 0.6
50.0	4.9 ± 1.5	12.1 ± 2.0	2.0 ± 0.7	0.4 ± 0.2	0	0
60.0	3.7 ± 1.1	5.2 ± 1.3	1.0 ± 0.5	0	5.1 ± 2.7	1.7 ± 0.6

Table 4.8. Composition of dominant groups of epifauna along three transects (H1, H2, H3) in Young Sund.

	2003	**2004**
	Mean ± SE (N)	**Mean ± SE (N)**
Length of new leaf blades (cm yr-1)	108.6 ± 7.6 (14)	105.7 ± 6.2 (16)
Production of new leaf blades (g C yr-1)	15.1 ± 1.3 (14)	5.8 ± 0.8 (16)

Table 4.9. Annual growth of Laminaria saccharina in Young Sund.

5 Research projects

5.1. Monitoring effects of ambient UV-radiation on high arctic vegetation

Kristian R. Albert, Helge Ro-Poulsen, Teis N. Mikkelsen, Kirsten B. Håkansson, Linda Bredahl and Riikka Rinnan

UV-exclusion experiments on the vegetation were conducted during 2001-2003 in Zackenberg to investigate possible effects of plant stress induced by ambient UV- radiation (see details in previous ZERO reports). The project aimed at developing a robust monitoring program using parameters sensitive to UV-radiation. Preferentially such a program should be non-invasive and the parameters having biological relevance supplementing to the UV-B irradiance recordings performed at the station. Implementation of such a program might be relevant according to the current increase in UV-radiation, which is hypothesised to affect plants negatively, particular in the high arctic regions. If so, such a monitoring program would provide the basis for continued evaluation of the importance of this global change related stressor in respect to plant responses. The following is a very brief synthesis on different scales of the emerging pattern of plant responses and a discussion of parameters sensitive to UV-B.

The main studied species were *Salix arctica* and *Vaccinium uliginosum*. In general it was found that the plants were more stressed in ambient UV as opposed to treatments excluding a large proportion of UV-radiation. In all experiments, plants exposed to high UV-level were found to synthesise higher amounts of UV-B absorbing compounds to screen off damaging UV-radiation. Despite this screening response, decreases in a range of parameters related to energy processing through the photosynthetic apparatus were detected across sites in both species in the 3-year exclusion experiment. Such a decreased flow of energy equivalents through Photosystem II (PSII) may potentially decrease carbon assimilation in the Calvin Cycle. In practice, this is detectable by gas exchange measures as a decreased net photosynthesis rate. This was indeed found in canopies of *Vaccinium uliginosum*, where a decreased rate of net photosynthesis throughout almost the whole growth season was observed (Fig. 5.2). The rate of respiration was unaffected. Moreover, *Vaccinium* plants showed a clear UV-B avoidance response by changes in biomass allocation and higher content of UV-B absorbing compounds in ambient UV-B. In *Salix arctica* the response to ambient UV-B was different. Here net photosynthesis was unaffected despite higher values of stomatal conductance and intercellular CO2 concentrations. Thus, ambient UV-B seems to reduce the capability to optimise the assimilation processes. Although not observed, the combination of changes in stomata conductance and potential limitation of optimising assimilation processes may result in decreased net photosynthesis, i.e. at higher UV-B doses.

Due to the variation in leaf angle a large variation was seen in energy processing parameters on *Salix*. Therefore it was diffi-

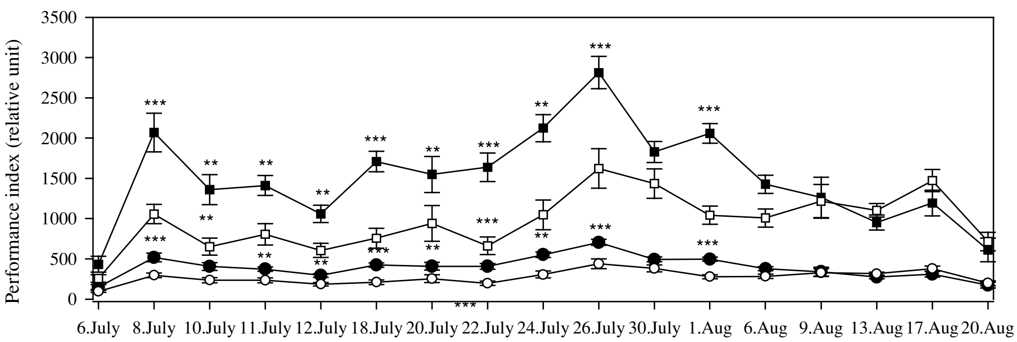


Figure 5.1. Performance indexes from maximum irradiance experiment on Salix arctica *in ambient UV-B (closed symbols) and reduced UV-B (open symbols). Performance indexes integrate the various energy fluxes through Photosystem II into one 'effectivity parameter'. See also Figure 5.3. Data From Albert et al. 2005a.*

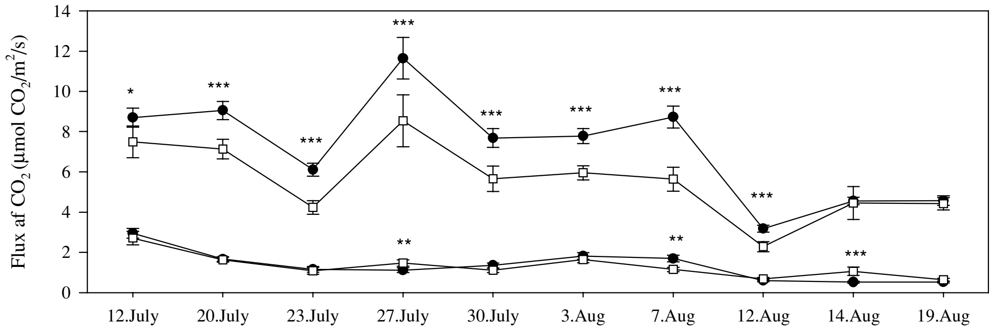


Figure 5.2. Net photosyntehsis (upper curves) and dark respiration (lower curves) on Vaccinium uliginosum *canopies in ambient (closed symbols) and reduced UV-B (open symbols). Data from Albert et al. 2005b.*

cult to interpret the link between energy processing through PSII and carbon assimilation on *Salix*. This was solved by a new experimental design, which allowed for uniformity of the light doses received by the leaves by controlling the leaf angle on *Salix*. This "maximum irradiance experiment" demonstrated a range of energy processing parameters, relating the stepwise flow of energy through PSII on various levels (i.e. probabilities of electron transfer processes and the potential energy fluxes per PSII reaction center and per leaf cross-section) were very sensitive to ambient UV. Further, the derivation of the so-called performance indexes nicely integrated and summed up the decrease in the overall PSII processing efficiency (Figs 5.1 and 5.3). The observed decrease in potential electron transport in ambient UV-B in *Salix* is hypothesised to decrease the Calvin Cycle activity and thereby lead to down-regulation of photosynthesis in ambient UV-B. This will be investigated in more detail during the summer 2005. More work focusing on energy processing through the photosynthetic apparatus (i.e. electron transport and handling of excess light) in plant leaves will be performed.

Analysis of soil samples from the 3-year UV-excluded plots revealed that other trophical levels also were affected of ambient UV-B. Differences in i.e. microbial communities between treatments were observed. Also the plant root biomass was reduced in treatments screening of most UV-radiation.

The naturally occurring UV-radiation doses (ambient UV) vary from year to year as a result of varying cloudiness, and significant plant responses are not necessarily to be expected every year. The manipulative UV-reduction by means of filters only changes the relative doses received by the plants. Therefore, the observed effects until now are believed to be related to plant acclimation in short term. Thus, accumulated effects of continued UV-screening by filters are deduced to a higher degree to be related to acclimation in long term. Bearing this in mind, it is concluded, that the investigated plants are not fully acclimatised to the current level of UV-B and in this perspective ambient UV-B are an important stressor for high arctic plants.

Continued monitoring of plant stress in response to the predicted changes in UV-radiation could provide the basis for eval-

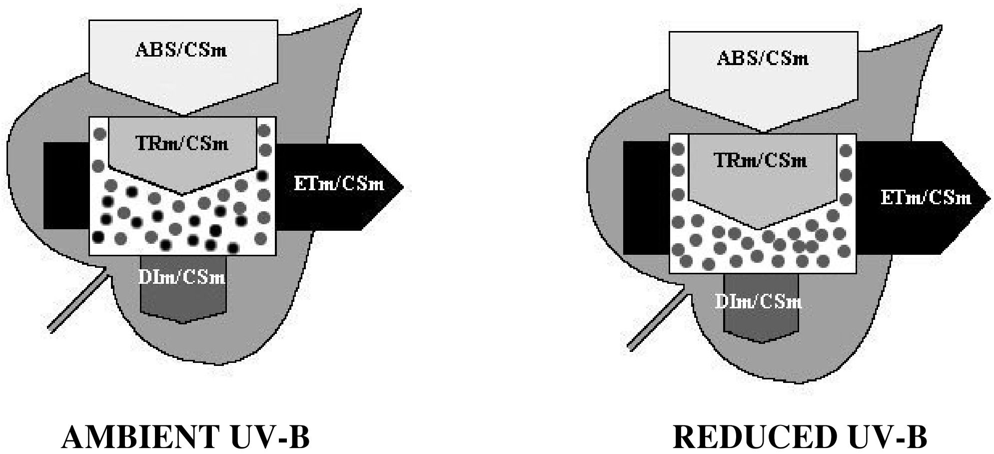


Figure 5.3. Pipeline models from the Maximum irradiance experiment showing the stepwise flow of energy fluxes in PSII. Left ambient UV-B and right reduced UV-B. UV-B stress was detected by calculation of potential maximal energy fluxes per leaf cross-section from chlorophyll-a flourescence transients. Parameter indexing revealed that – Ambient UV-B reduced electron transport (ETm/CSm) by a high dissipation (DIm/CSm) and reduced trapping of electrons (TRm/CSm). Also the number of active PSII reaction centre (black dots) was lower in ambient UV-B. Integration of all these processes resulted in lower performance indexes in ambient UV-B (See Figure 5.1.) and moreover demonstrates that ambient UV-B is a stress factor. Data from Albert et al. 2005a.

Figure 5.4. Vaccinium Canopy Experiment. Field manipulation of ambient UV-B by means of filter screening close to the Zackenberg Research Station.

uation of this important stressor on a larger time scale. The findings within this project points to parameters derived from chlorophyll-a fluorescence measurements as sensitive to UV-B. Moreover such measurements are non-invasive and very fast, providing screening capabilities of a large number of leaves per working hour. The measured and derived parameters are related to the stress level of the plants on different levels: Probabilities of various electron transfer processes, the energy fluxes per PSII reaction centers and per leaf cross-section and integration of these parameters on each level into so-called performance indexes. Since these fluxes are expressing the energy input to energy consumption in primarily the Calvin Cycle, they relate to photosynthesis rate and potentially to primary production. More work will be done on linking energy input to energy consumption by simultaneous measurements of gas exchange and fluorescence to strengthen this point. On one hand, the time consuming measurements of net photosynthesis by traditional gas exchange is recognised as a validated tool for evaluating the accumulation of effects originating from many levels into one parameter. On the other hand, the same can be claimed for electron transport parameters derived from chlorophyll-a fluorescence measurements, where the response may be interpreted as either a result of direct (i.e. the UV-target is photosynthetic apparatus processes) or indirect (i.e. the UV-target is Calvin Cycle activity and which mediates negative feedback on electron transport etc.). The monitoring program carried out until now clearly demonstrates that UV-B induced plant stress is detectable by chlorophyll fluorescence. In conclusion, UV-radiation manipulation by filters combined with detecting plant effects by measurements of chlorophyll-a fluorescence may be a good candidate setup for future monitoring of UV-radiation impact on vegetation.

5.2 Activity, abundance and phenology of flying insects

Toke Thomas Høye and Mads C. Forchhammer

Impacts of climate change have been investigated in a number of phenological traits across a wide range of taxa. The rationale of these studies is based on the assumptions that timing of life history events is advantageous and that climate plays an ultimate role in timing. Thus, any interannual variation in a life history event arise either directly due to interannual variation in climate cues or indirectly because interacting organisms use climatic cues to time their life history (Stenseth and Mysterud 2002).

In High Arctic flying insects, the most conspicuous phenological trait is the emergence pattern following winter dormancy. It is preceding a period of dispersal and/or reproduction and rarely associated with food intake, although pollinators constitute an exception . The short arctic summer poses constraints on both the activity level and the time available to complete the life cycle. Hence, the emergence patterns of most High Arctic flying insects are highly synchronous with rapidly declining densities after a peak emergence period although the exact shape of the density curve may vary among species and taxa (Corbet and Danks 1973; Hodkinson *et al*. 1996).

Emergence phenology and abundance can be estimated by window traps (Meltofte and Berg 2004). However, the probability of capture of a given species in this kind of passive trap is a function of both activity and abundance. The extent to which activity varies with weather parameters is poorly understood, although this relation is important not only to separate activity and abundance in captures from passive traps, but also to understand which conditions are most favorable for insects in ecosystem processes.

To approach this problem we sampled flying insects from two window traps with two catching containers, both of the same kind as used in the BioBasis monitoring program, on a daily basis in the period 3-29 June 2004. These samples contained the following groups: Agromyzidae, Antho-

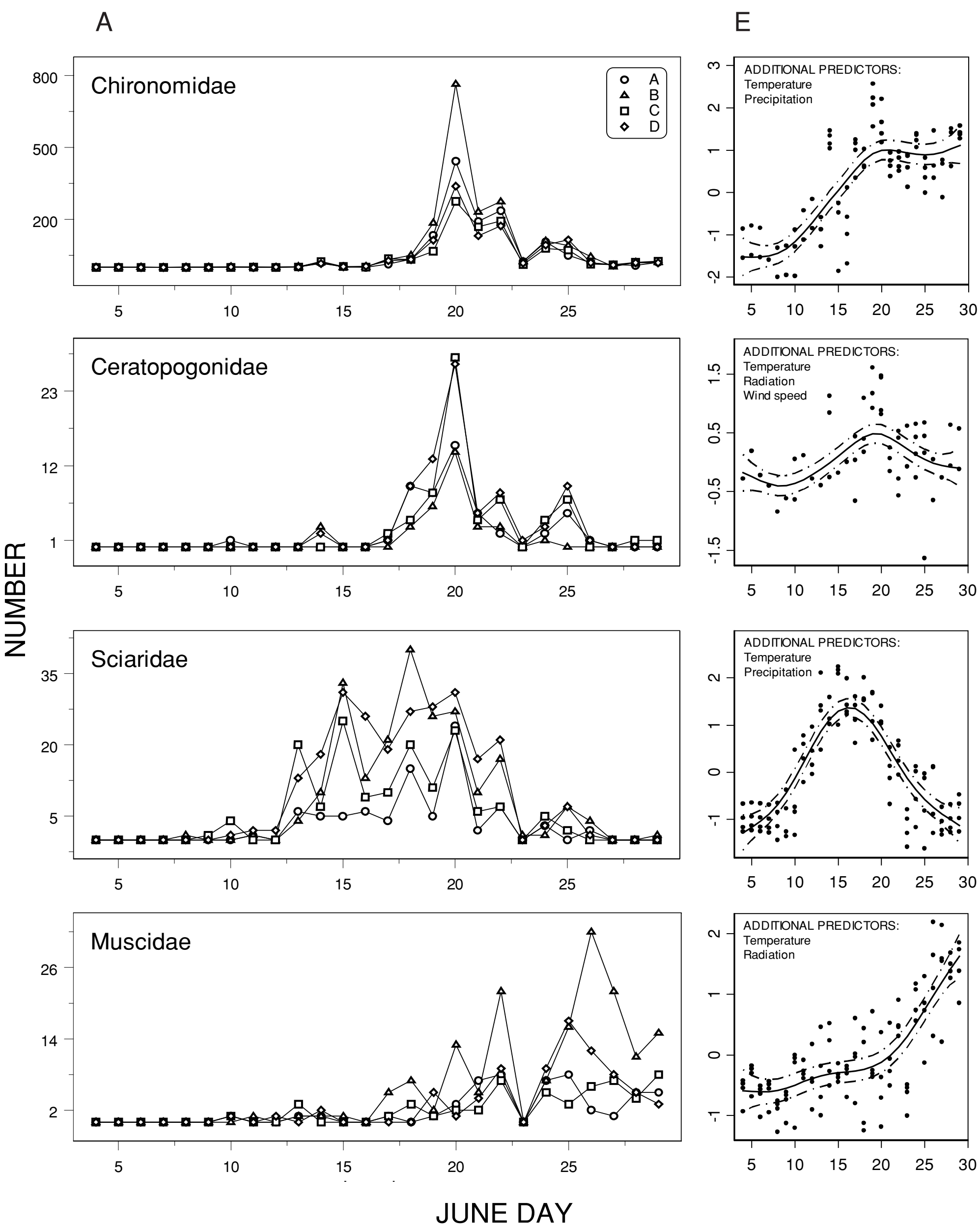


Figure 5.5. A) Number of individuals of the four most abundant groups of flying insects caught in the window traps on each trapping day. Letters denote the different trapping containers. B) Partial smoothing splines (full line) on date from the best reduced generalised additive models of log-transformed catches. Model reduction was based on Bayesian Information Criterion (Quinn and Kough 2002) and full models included trap id, temperature, precipitation, wind speed, solar radiation and date. The values predicted by the smoothing splines estimate the abundance of individuals corrected for the local weather conditions during each catch. The y-axis represents standardised abundance adjusted for the additional predictors given for each species, the dots are standardised residuals and the hatched line is the standard error of the partial smoothing spline.

myiidae, Calliphoridae, Cecidomyiidae, Ceratopogonidae, Chalcidoidea, Chironomidae, Culicidae, Empididae, Ichneumonidae, Muscidae, Scatophagidae, Sciaridae, Symphyta, lepidopteran larvae as well as mites and collembola. A total of 6820 individuals were caught during the sampling period with four families of Diptera being the most numerous: Ceratopogonidae, Chironomidae, Muscidae, and Sciaridae (Fig. 5.5).

Nonlinear models such as generalised additive models (GAM) using smoothing splines (Venables and Ripley 2002) are appropriate descriptors of the seasonal nonlinear variation in insect abundance in relation to short-term weather parameters. The partial smoothing splines on date from the models that best describe variation in catch size corrected for local weather parameters provide an estimate of abundance and the additional predictors estimate the activity level (Fig. 5.5). The predictions from the GAMs integrating effects of local weather agree with overall phenological patterns of the four major groups monitored in the BioBasis program from previous years. Temperature is a significant additional positive predictor in all four groups. For the smaller organisms Ceratopogonidae, Sciaridae and Chironomidae, precipitation and wind speed plays an additional negative role whereas only solar radiation is important for the larger Muscidae. The latter is probably related to their important role as pollinators as local

Table 5.1. Biophysical variables obtained from each of the 135 plots.

- CO_2-flux (ER, GEP, NEP)
- Chlorophyll (a and b)
- Carotenoids
- Leaf area index
- Biomass (wet and dry)
- Water content
- Cover fraction (total and individual plant type)

conditions in flowers are positively influenced by sunlight.

In summary, we managed to separate the daily variation in catch size of flying insects in activity and abundance to better identify the phenological patterns in the emergence of flying insects.

5.3 Spectral Calibration for High Arctic Primary Production Estimation (SCHAPPE)

Mikkel P. Tamstorf, Lotte Illeris, Marie Arndal, Maria Rask Pedersen, Anders Michelsen, Birger Ulf Hansen, Louise Grøndahl, Kristian Albert and Susanne M. König

The SCHAPPE project was developed on the basis of conclusions from an informal workshop with participants involved in the use of BioBasis data. The purpose of the project is to establish a method that will enable non-destructive monitoring of the terrestrial primary production in the Zackenberg valley. The method is based on spectral measurements using vegetation indices for the estimation of primary production. An offspring of the project is a thorough knowledge on the biophysical variables (chlorophyll, leaf area index, biomass, CO_2-emission, etc.) of the vegetation at Zackenberg.

A pilot project was funded by the Danish Ministry of the Environment and carried out during the last two weeks of august 2002. The pilot project successfully established field sites covering the phenological gradients of the five major vegetation types in the valley area (*Cassiope tetragona* heath, *Dryas* heath, *Salix arctica* snowbed, grassland and fen). The project was financed through the Danish Ministry of the Environment, Aage V. Jensen's Foundation and the Danish Research Council, and carried out during the 2004 field season.

The five major vegetation types were analysed (15 locations with three in each vegetation type) and harvested during 9 weeks from late June to mid-August in order to describe the seasonal changes in primary production and to establish a relationship between spectral measurements and primary production for future non-destructive monitoring. Positions of final field locations are shown in Fig. 5.6.

The obtained biophysical parameters are

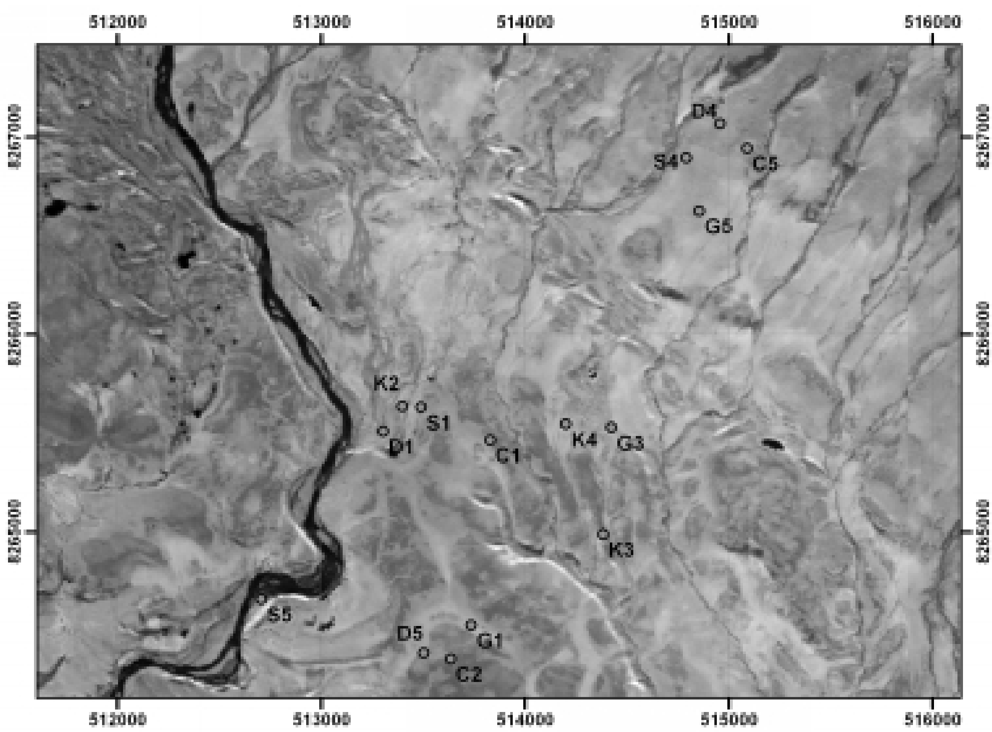


Figure 5.6. Position and id of the 15 harvesting locations with three of each being in the five major vegetation types (Cassiope(C), Dryas(D), Grassland(G), Fen(K), Salix Snowbed(S)).

listed in Table 5.1. Spectral measurements consisted of measurements before and after harvesting with a SKYE two-channel RVI sensor (730/660nm) and with an ASDI Handheld spectroradiometer (350-1150 nm). Additional measurements were done on the h-plot (the one being harvested in week 8) to obtain the seasonal change in reflectance from 15 specific plots.

Additionally, 6 Landsat ETM+ images were acquired during the field season to enable scaling of the primary production measures to the entire valley. As of spring 2005 all data have been preprocessed and validated for analysis but analysis is only started and results will therefore be published later.

5.4 ITACA² – Dayside aurora joint observations in the Greenland-Svalbard sector

Stefano Massetti and Marco Candidi

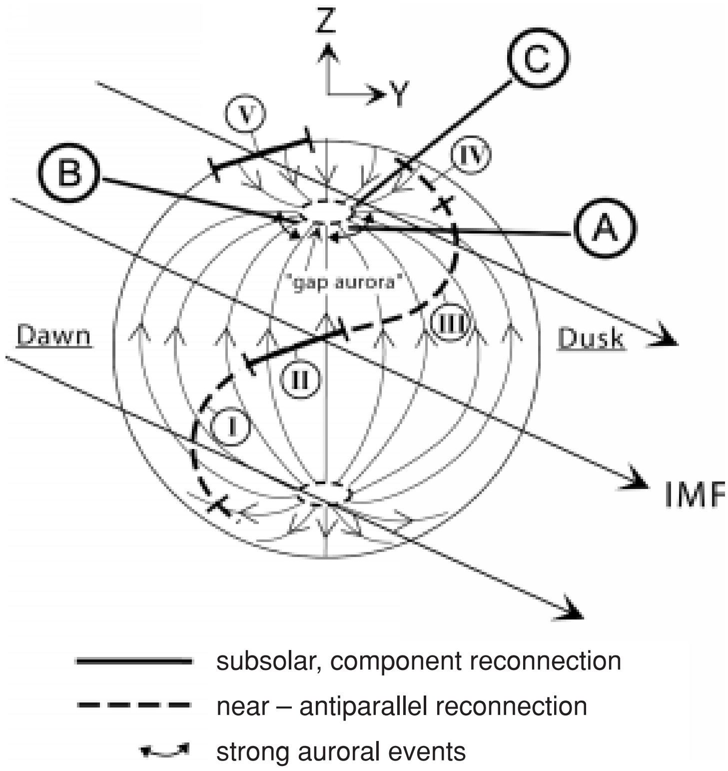


Figure 5.7. Sketch of the magnetic reconnection geometry on the Earth's dayside magnetosphere, during IMF B_y-dominated periods (Sandholt et al. 2004). The labels mark the aurora features that are illustrated in Figure 2.

During 18-20 July 2004, the auroral observatory ITACA-DNB in Daneborg was tested and prepared for the next winter season. We found that, due to the failure of the mechanical shutter, the instrument was not able to collect images during the whole working period (Nov 2003 – Mar 2004). The shutter was replaced with a new one, and several upgrades were applied to the software devoted to drive the instrumentation. The system was left ready for the 2004/2005 season.

Interesting results are obtained from the analysis of the 2002/2003 data, which is still in progress. Our current research is focused on the response of the dayside magnetosphere during periods that are dominated by a horizontal component of the interplanetary magnetic field (IMF), referred as IMF B_y. Even if its vertical component (IMF B_z) is well known to be the key parameter in the solar wind – Earth's magnetosphere interaction by triggering geomagnetic storms and substorms (when IMF $B_z < 0$), recent studies stress the importance of the IMF B_y component in the magnetic reconnection activity on the dayside magnetosphere. In particular, a dominating IMF B_y component (that is, IMF $|B_y| >> B_z$) was found to produce significant magnetosphere-ionosphere coupling and a peculiar magnetosheath plasma precipitation pattern. A noticeable signature of the IMF B_y-dominated coupling is the so-called cusp bifurcation, which was observed to occur both in latitude and in longitude. These patterns arise from the presence of simultaneous magnetic merging in different places of the dayside magnetopause, and can be modelled by the antiparallel magnetic reconnection theory (e.g. Moore et al., JGR, 107, 10.1029/2002JA009381, 2002), see Fig. 5.7. Evidences of magnetic merging events can be obtained by in-situ spacecraft measurements and/or by the monitoring of the auroral activity, which is the signature of the plasma precipitation induced by the reconnection itself. The observation of the auroral activity, both space- and ground-based, has the important feature to allow the analysis of the large-scale magnetic reconnection geometry.

From our joint observations in Greenland and Svalbard, we were able to detect a simultaneous latitudinal and longitudinal cusp bifurcation, which confirms the antiparallel reconnection theory. Fig. 5.8 illustrates the red aurora emission (630.0 nm) derived by combining the map projection of the ITACA-DNB and ITACA-NAL all-sky images. The longitudinal cusp bifurcation constituted by footprint of the northern cusp (A) and the magnetically conjugated counterpart of the southern

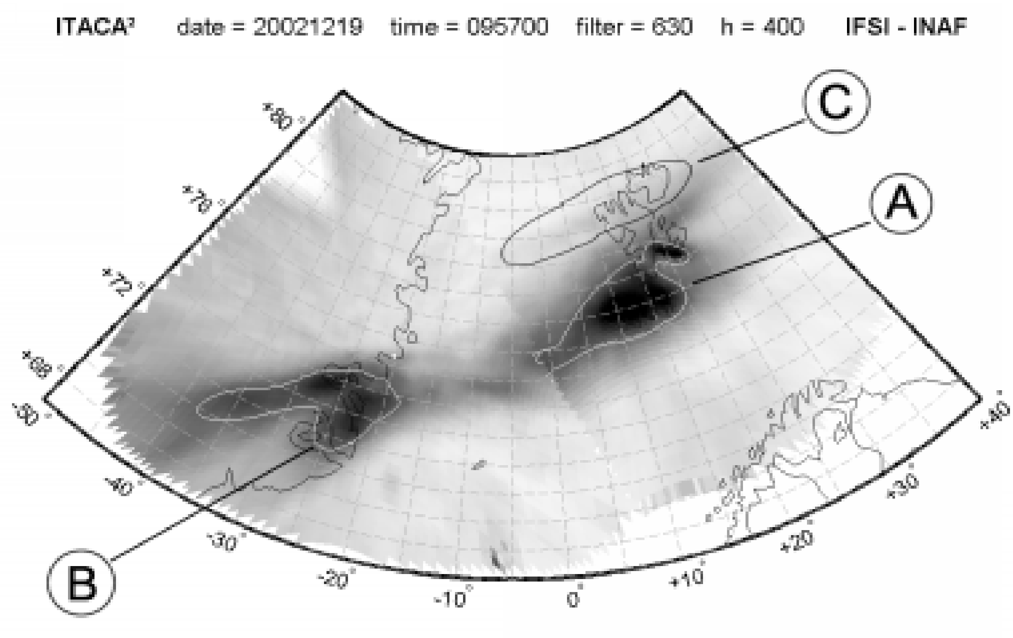


Figure 5.8. ITACA2 combined images projected over a map. The longitudinal bifurcation of the cusp red aurora is clearly visible: the aurora spot over the Svalbard (A) is linked to the local northern cusp, while the aurora spot over the east coast of Greenland (B) is expected to be magnetically conjugated with the southern cusp. The elongated high-latitude auroral signature (C) is due to magnetic reconnection occurring at the northern lobe.

cusp (B) is clearly visible. Poleward of the northern cusp is also present a faint red emission due to electron precipitation induced by the reconnection at the northern magnetic lobe (C), which has been usually reported to take place during IMF $B_z > 0$ periods. In Fig. 5.9 the red and green (630.0, 557.7 nm) ITACA-NAL all-sky images show more clearly the latitudinal cusp bifurcation: the equatorward red-dominated aurora emission (A) due to low energy electron precipitating into the northern cusp, and the poleward green-dominated aurora (C) that marks the lobe precipitation.

5.5 Glaciation history in the East Greenland fiord zone – approached by cosmogenic radionuclides and geomorphological mapping

Lena Håkansson, Christian Hjort and Helena Alexandersson

Earlier on-shore work on the glaciation history of Northeast Greenland have indicated that considerable parts of today's ice free coastal areas were ice free also during the last glacial maximum (LGM) (e.g. Hjort 1981; Funder et al. 1998). The concept of a limited LGM-glaciation has, how-

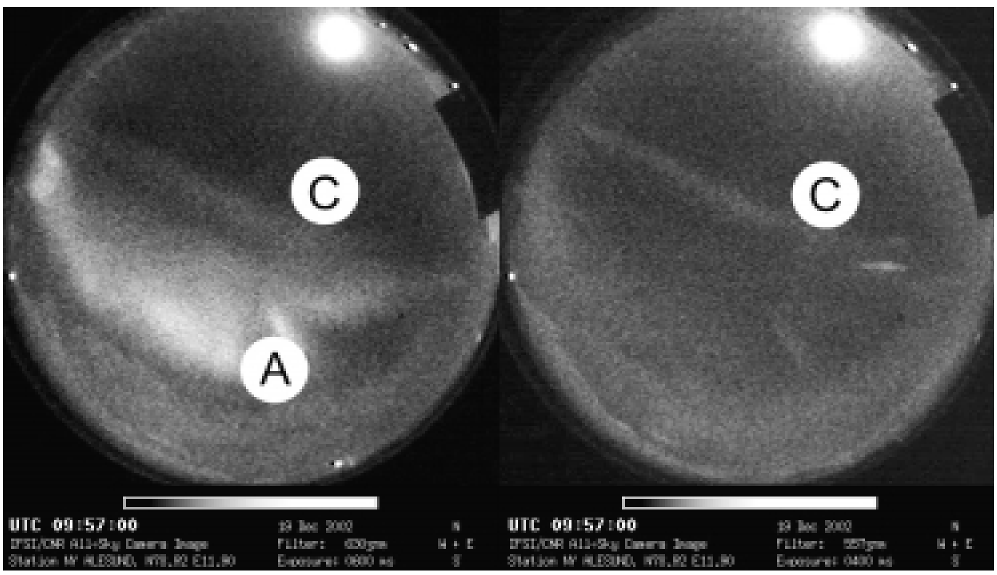


Figure 5.9. ITACA-NAL red (left) and green (right) all-sky images. They show the diffuse low-energy electron precipitation linked to the local northern cusp (A), and the narrow high-latitude aurora dominated by green emission which is linked to the reconnection at the lobe (C). The presence of green emission indicates that the energy of the electrons hitting the ionosphere is higher than in the equatorward cusp signature.

ever, recently been challenged by both marine geological studies (Ó Cofaigh et al. 2004) and by new land-based field data (Bennike and Weidick 2001), interpreted as indicating an extensive LGM-ice reaching towards the shelf-break.

In the East Greenland fjord zone upland plateaus and coastal lowlands are often strongly weathered while the fiord and valley troughs are characterised by fresh glacial erosion. On the strongly weathered plateaus, considerable amounts of glacially transported boulders occur, revealing that the ice has indeed been there at some time. There are two different ways to explain the high degree of weathering, having fundamentally different implications for the reconstructions of the thickness and extent of the Greenland Ice Sheet during the LGM. Either the high degree of weathering is attributed to these surfaces having been ice free for a very long time, indicating a limited LGM glaciation or it is attributed to preservation beneath cold-based non-erosive ice suggesting an extensive LGM ice.

With the present project we would like to test the contrasting hypotheses regarding the glacial history of Northeast Greenland (limited versus extensive LGM ice) by employing the analyses of cosmogenic radionuclides (CRs). CRs are produced within rocks through cosmic radiation hitting the Earth's surface. The accumulated amounts of these nuclides give an estimate of the time a rock surface has been exposed to cosmic radiation, potentially indicating the timing of the last deglaciation. This analysis, applied on the NE Greenland high altitude boulders, can be a valuable tool for testing if the strongly weathered high plateaux have been ice-free or not during the LGM.

During six weeks in July/August 2004, fieldwork was carried out by the authors in five different areas: Jameson Land, Mestersvig, Zackenbergdalen, Tyrolerfjord/western Store Sødal and Wollaston Forland. The last two areas were accessed from Zackenberg with rubber-boat transport. The work focused on sampling glacially transported boulders and glacially eroded bedrock for CR analyses.

The working areas along the Tyrolerfjord – Young Sound area made up a W-E transect from the inner fjords, c. 30 km from today's edge of the Greenland Ice Sheet, to the outer coast. In Tyrolerfjord the valleys are mainly covered by ground moraine, in Zackenberg partly by more hummocky moraines and at Kap Herschell on the outer coast the glacial input is mostly scattered erratics. However, in the latter area there is also a prominent moraine ridge, the Herschellhus Moraine, described by Houmark Nielsen et al. (1994), which can be followed for c. 5 km along the coast. Continuous glacial "trimlines" are observed on the fiord- and valley sides around 500 m a.s.l., near Zackenberg and west thereof. Sampling for the analyses of CRs was carried out above and below the "trimlines" along a transect from central Tyrolerfjord eastwards via Zackenberg to the outer coast, and in the latter area both on top of the Herschellhus Moraine and on the high plateaus above Kap Herschell.

5.6 Plant phenology and ecosystem C budget in Zackenberg

Susanne M. König

Plant monitoring data from the BioBasis programme provide an opportunity to study interactions between plant phenological development and variations in climate in Zackenbergdalen across growing seasons, and from year to year. To provide experimental validation of findings expected from the BioBasis data, an experiment was set up in 2004 in two common plant communities dominated by *Cassiope tetragona* and *Salix arctica* respectively. The experiment contains 5 x 4 manipulations representing possible effects of alterations in growth conditions as a consequence of climatic change, being increased shading, increased growing season temperature and longer or shorter growing season. The experiment was set up as part of a PhD-project, and is therefore planned to last at least until the end of the 2007-growing season.

Several studies have related plant phenology and reproductive ability to species ability to survive in a changing climate, but few studies couple phenology and reproductive effort to overall ecosystem C budget. However, while climatic conditions directly or indirectly influence phenology and reproductive effort, these factors also potentially influence climatic conditions through alterations in ecosystem C budget. A better knowledge of the interdependence between climate and plant de-

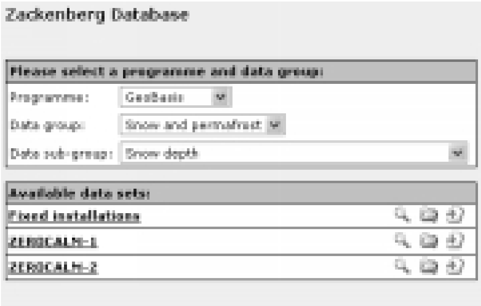


Figure 5.10. Example of database search for snow depth measurement.

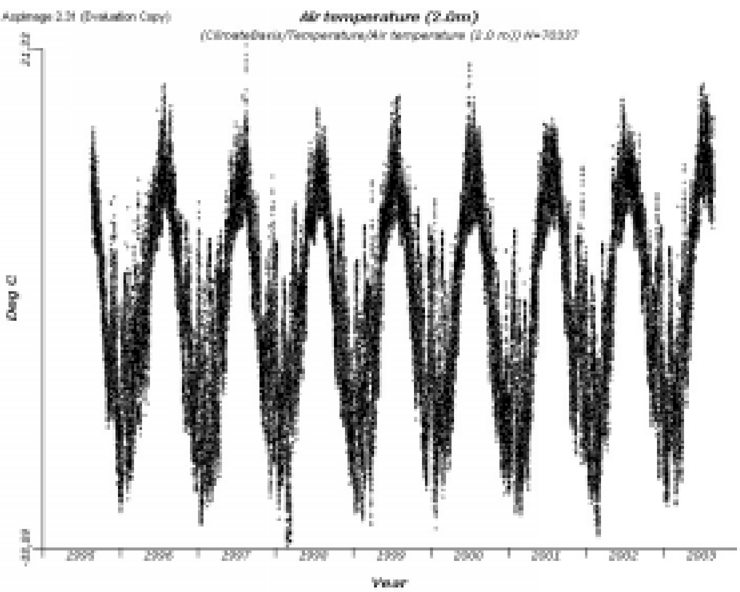
velopment will therefore offer better possibilities for modelling future ecosystem-climate interactions and responses.

Across the season, phenological development was followed both through registrations of bud development, flowering and senescence and with measures of RVI and NDVI as often as possible.

In the beginning of the season, 20 x 20 cm metal frames were inserted in each of the *Cassiope tetragona* plots, to provide permanent bases for measuring ecosystem CO_2-exchange. This was carried out twice a week using a 13.8 l transparent plexiglass chamber attached to a LI-COR 6200 portable infrared gas analyzer (LI-COR, Lincoln, Nebraska).

Data from the 2004-growing season is still being analysed. In 2005, CO_2-exchange measures will be made both in the *Cassiope tetragona* and the *Salix arctica* experimental plots.

Figure 5.11. Measurements of air temperature 2 m above terrain obtained by the ClimateBasis programme. These graphs are available before downloads for all numerical data sets.



5.7 ZERO-database – an easy way to access data from the monitoring programmes

Mikkel P. Tamstorf

Until recently, accessing data from the monitoring programmes at Zackenberg has been a very tedious process. Only BioBasis data were available on the Internet, but in a format which was hard to use for interdisciplinary analyses. A scientist in need of data from the other programmes would have to contact the specific Basis-programme and obtain a set of data in an e-mail or ftp. Often data would circulate between scientists in several formats arising doubt about the level of validation of the individual data. Therefore, an initiative was taken in 2004 to gather all validated results from the monitoring programmes in a single database with web access. This would ensure easy access and that only one valid data set for each parameter would be in circulation.

In 2005 a web-based access to a database with all the data from the four monitoring programmes, Climate-, Geo-, Bio- and MarinBasis will be available on the internet. The database gives easy access to all validated data obtained by the monitoring programmes from 1995 to 2004 (MarinBasis only 2002-2004) and access is gained through a web-interface accessible from all standard web browsers.

Access to the database is gained through www.zackenberg.dk. The original structure of the monitoring programmes is maintained in the database structure so that one chooses first the monitoring programme and then the data group of interest. Subgroups exist for some data group as shown in Fig. 5.10.

The database interface has three options: to view a short description of the dataset, to see a detailed description of the data (range, type etc.) and finally to download the data set as a semi-colon separated ascii text file.

In order to download the data, registration is mandatory with information of name, institution, e-mail, phone number and purpose for download.

The database will be maintained and updated every year and it is the intention that last year's validated data should be available in the database at the beginning of the following field season (around 1 June).

6 Disturbance in the study area

Hans Meltofte

Surface activities in the study area

The number of 'person-days' (one person in the field one day) spent in the terrain in the main research zone 1 (Table 6.1) was normal. The number of visits in zone 1b and 1c, the 'low impact study area' and 'the goose protection area', was also back to normal.

All trips with the Argo all terrain vehicle were along the 'roads' to the climate station or down to the coast in the delta of Zackenbergelven, except for a trip on snow to the innermost end of Store Sø on 27 May.

Aircraft activities in the study area

The number of fixed-wing aircraft take-off and landings in 2004 (Table 6.2) was again relatively high, and so was the number of helicopter visits and passages.

Discharges

As in previous years, combustible waste (paper etc.) was burned at the station, while plastics, cans, bottles etc. were flown out of the area. Solid but biologically degradable kitchen waste together with toilet waste was poured through a grinding mill into Zackenbergelven**.**

During storage of the waste in June, July and August, a total amount of about 50 g 'Vera-flue-safe' was added as a killing agent against fly maggots. The active chemical is cyromazine (N-cyclopropyl-1,3,5-treazine-2,4,6-triamine) in a concentration of 2%.

The total amount of untreated wastewater and solid waste let into Zackenbergelven from the toilets, kitchen, showers, sinks and laundry machines equalled about 825 'person-days'.

Manipulative research projects

No manipulative research projects took place this year.

Take of organisms and other samples

During the SCHAPPE project, harvesting of plant material was done at 15 locations in the valley and on the lower Aucellabjerg slopes covering the five major vegetation types (fen, grassland, *Cassiope* heath, *Dryas* heath and *Salix* snowbed. At each location harvesting was done at nine 19.5 x 19.5cm^2 plots. All above ground material was harvested and removed for later analyses.

UTM (zone 27) co-ordinates of the 15 locations were: 513828N, 8265466E; 513635N, 8264358E; 515089N, 8266943E; 513305N, 8265510E; 514954N, 8267066E; 513502N, 8264389E; 513736N, 8264529E; 514423N, 8265529E; 514854N, 8266626E; 513398N, 8265636E; 514381N, 8264988E; 514199N, 8265546E; 513489N, 8265632E; 514790N, 8266893E; 512708N, 8264660E. Harvesting took place within 20 m from these locations.

As usual, a few hundred adult arctic char were caught off the old trapping station. As part of the BioBasis programme, a total of 56,686 land arthropods were collected during the season (see chapter 3.2).

Research zone	May	June	July	Aug.	Total
1		204	243	206	653
1b		5	14	10	29
1c (20.6-10.8)			1		1
2			18		18
ATV-trips	1				1

Table 6.1. 'Person-days' and trips in the terrain with an ATV (all terrain vehicle) allocated to the research zones in the Zackenberg study area 26 May – 31 August 2004. ATV trips on the roads to the climate station and to the delta of Zackenbergelven are not included.

Type of aircraft	May	June	July	Aug.	Total
Fixed-wing	4	10	14	32	60
Helicopter	2	2		12	16

Table 6.2. Number of flights with fixed-winged aircraft and helicopters, respectively, over the study area in Zackenbergdalen 26 May – 31 August 2004. Each ground visit of an aircraft is considered two flights.

7 Logistics

7.1 General logistics

Henrik Philipsen

In 2004, Research Station Zackenberg was open for 97 days from 26 May to 31 August. During this period, 32 scientist and 7 staff members from the Danish Polar Center worked from the station. The activity in 2004 equals 1287 person days. Zackenberg's branch facility in Daneborg was used by 10 scientists and one logistician from 22 July to 27 July.

In August the station received a visit from Her Majesty Queen Margrethe II, His Royal Highness Prince Henrik and 23 other guests.

Transportation

Two logisticians from Danish Polar Center arrived at Zackenberg on 26 May, finding that snow-storms had caused severe damage to the station. On 1 June, six researchers and a cook arrived.

The number of fixed wing landings and take-offs was 60. Eigtheen landings were with personel, three with visitors and nine with cargo.

The number of helicopter landings and take-offs was sixteen, of which one was for slingtransport of a new generator between Daneborg and Zackenberg.

Local transportation was carried out by ATV on the marked road. On one trip field equipment was carried to the bottom of Store Sødal, on eight trips supplies were carried from Daneborg to the beach, and three trips were to the climate station. The ATV is in good condition and is regularly maintained.

Houses

The Weatherhaven shelters for accommodating guests will still be usable for a few years. The condition of the houses at Zackenberg is good, and they are continuously being maintained.

The generator hut has been extended to double size with a high rising roof.

Electric power supply

One 15 kW generator and a new 38 kW generator supply the station, while five smaller generators are available for field work. The large generators are placed in the generator hut, and thus maintenance is easier and less dependent on weather conditions.

Water supply

In 2004 the Zackenberg waterplant and two water closets with an electrical shredder worked well.

Telecommunication

Communication with the world out-side Zackenberg is done by Iridium and Inmarsat satelitetelephones, fax and e-mail. 786 e-mails were sent and received through a server at Institute of Geography, University of Copenhagen. Telephone communication totaled 1,180 minutes.

To communicate with other stations in Northeast Greenland HF-radio is used. VHF-radios are used for local communication. This year a VHF-repeater station was placed on top of the mountain Dombjerg, giving VHF coverage to the area between Revet and the outer coast of Sandøen.

Boats

A new 5 m rubber boat with a 30 HP two stroke engine was purchased. Due to a failure, the new engine was returned to Denmark for repair. The Zackenberg fleet now counts four boats for local transportation in Young Sund / Tyrolerfjord.

Medicals

Tooth ache, back pain, one abdominal disease, common-cold disease, a sprain ankle and blisters were treated, and a metal fragment was removed from an eye. One person was evacuated with helicopter for medical reasons.

Daneborg

Zackenberg supplied the branch facility in Daneborg with a generator, water pipes, fuel, technical equipment, food and one logistician.

Expeditions

Zackenberg supplied a minor expedition with provision, field equipment, boat transportation, a rifle, a flare gun and a HF-radio.

Garbage

Glass, metal, used engine oil and empty fuel barrels (120) from three years' consumption were transported to Denmark by aircraft and ship. Other non-burnable waste was send to Constable Point for further processing.

7.2 Renovation and development of marine facilities in Daneborg

Niels Lindegaard, Jannik Berntsen, Søren Andersen, Teit Kjeldersgaard and Søren Rysgaard

This year members of *Nordøstgrønlandsk Kompagni Nanok* and Svendborg Yacht Service helped renovate the marine research facility in Daneborg with financial support from Aage V. Jensen's Charity Fondation.

The building served as weather station from 1945 to 1975 and accommodated 7-8 persons. When the marine studies started in 1994, scientists found the building in a very bad condition. The place was cleaned up and used for marine studies for three years. In 1998, marine researchers, together with DPC logistics, further renovated the building with financial support from the Danish Polar Center and the Danish National Environmental Research Institute to house up to 20 researchers during 1999-2001. During these three years the facility was used by a large group of researchers in the marine research project CAMP (Changes in Arctic Marine Production) working off the coast in Daneborg.

In 2004 the facility was further renovated to make it function for scientists in the marine monitoring and research programs. Half of the roof was repaired and received new sealing, several new windows were mounted, and the buildings were painted. An office was established with satellite communication and data processing facilities. Electric wires were supplied to different rooms. A new water supply system was made and a new shower established. The research vessel 'Aage V Jensen' got a new trailer and a new winch system. The renovation took place at the same time as the marine monitoring program was undertaken. Scientist helped with the renovations and members of *Nanok* and *Svendborg Yacht Service* helped with sampling.

8 Personnel and visitors

Compiled by Henrik Philipsen and Morten Rasch

Research

Zackenberg

Kristian Rost Albert, Institute of Biology, University of Copenhagen (SCHAPPE, 22 June–13 July)

Helena Alexanderson, Department. of Geology, Lund University, Sweden (Quaternary Science, 21 July–3 August)

Marie Arndal, Institute of Biology, University of Copenhagen (SCHAPPE, 22 June–24 August)

Louise Grøndahl, National Environmental Research Institute (SCHAPPE, 13–28 July)

Birger Ulf Hansen, Institute of Geography, University of Copenhagen (GeoBasis, 28 July–10 August)

Christian Hjort, Department of Geology, Lund University, Sweden (Quaternary Science, 21–28 July)

Toke Thomas Høye, Institute of Biology, University of Copenhagen (Population Biology, 1–30 June)

Lena Håkansson, Department of Geology, Lund University, Sweden (Quaternary Science, 21 July–17 August)

Susanne M. König, National Environmental Research Institute (BioBasis, 1 June–31 August)

Hans Meltofte, National Environmental Research Institute (BioBasis, 1 June–28 July)

Anders Michelsen, Biological Institute, University of Copenhagen (SCHAPPE, 22–30 June)

Bent Olsen, ASIAQ, Greenland Survey (ClimateBasis, 3–17 August)

Maria Rask Pedersen, Institute of Geography, University of Copenhagen (SCHAPPE, GeoBasis, 30 June–24 August)

Jonathan N.K. Petersen, ASIAQ, Greenland Survey (ClimateBasis, 3–17 August)

Charlotte Sigsgaard, Institute of Geography, University of Copenhagen (GeoBasis, 1 June–28 July and 10–31 August)

Jens Søndergaard, Institute of Geography, University of Copenhagen (SCHAPPE, GeoBasis, 1 June–30 June)

Trine Theut, National Environmental Research Institute (BioBasis, 21 July-17 August)

Ole Thorup, National Environmental Research Institute (BioBasis, 1 June–31 August)

Daneborg

Mario Aquarone, Greenland Institute of Natural Resources (Walruses, 28 July–24 August)

Mads Berthelsen, Greenland Institute of Natural Resources (Walruses, 28 July–24 August)

Martin Blicher, National Environmental Research Institute (MarinBasis, 3-24 August)

Peter Bondo Christensen, National Environmental Research Institute (MarinBasis, 3–24 August)

Tage Dalsgaard, National Environmental Research Institute (MarinBasis, 3–24 August)

Egon R. Frandsen, National Environmental Research Institute (MarinBasis, 3 August–24 August)

Teit Kjeldersgaard, National Environmental Research Institute (MarinBasis, 3–24 August)

Stefano Massetti, IFSI/CNR, Italy (Aurora, 21–28 July)

Søren Rysgaard, National Environmental Research Institute (MarinBasis, 3–24 August)

Mikael Sejer, National Environmental Research Institute (MarinBasis, 10–24 August).

Logistics

Zackenberg

Malene Friis, Cook, Danish Polar Center (14 July–10 August)

Marc Overgaard Hansen, Logistician, Cook, Danish Polar Center (1 June–31 August)

Martin Jens Nielsen, Logistician, Danish Polar Center (21 July–10 August)

Henrik Philipsen, Logistics Manager, Danish Polar Center (26 May–31 August)

Morten Rasch, Station Manager, Danish Polar Center (22 June–4 July and 3–17 August)

Bjarne Schmidt, Logistician, Danish Polar Center (26 May–28 June)
Jørgen Skafte, Logistics Coordinator, Danish Polar Center (13 July–21 July and 5–31 August)

Daneborg

Marc Overgaard Hansen, Logistician, Danish Polar Center (21–28 July)

Others

Zackenberg

Her Majesty the Queen Margrethe II (3 July)
His Royal Highness the Prince Consort Henrik (3 July)
Camilla Castenskiold, Maid of Honour (3 July)
Christian Eugen Olsen, Master of Ceremonies (3 July)
Niels Eilschou Holm, Cabinet Secretary (3 July)
Jens Vester, Navy Commander, Aide-de-camp to the Queen (3 July)
Uffe Haagen Olsen, Rear-admiral, Chief of Greenland Command (3 July)
Peter Lauritzen, Chief Administrative Officer of Greenland (3 July)
Josef Motzfeldt, Vicepresident of Greenland (3 July)
Kaj Kleist, Director, Greenland Homerule (3 July)
Poul Krarup, Chief Editor, AG (3 July)
Asbjørn Date, Journalist, DR (3 July)
Apollo Jeremiassen, Journalist, Greenland's Radio (3 July)
Ida Kaj Sørensen, Police Officer (3 July)
Allan Christiansen, Police Officer (3 July)
Gerth Jacobsen, Constable Officer, Greenland Police (3 July)
Poul Henrik Sørensen, Coordinator, Danish Polar Center (3 July)
Tom Greiffenberg, Greenland Homerule (3–10 August)
Mette Astrid Jessen, Department of Environment and Nature, Greenland Homerule (6–8 August)
Jakob Mathisen, Department of Environment and Nature, Greenland Homerule (6–8 August)
Martin Munch, Nonni Travel Illoqqortoomiut (6-8 August)
Hanne Katrine Petersen, Director, Danish Polar Center (30 June – 4 July)
Hideo Sawahata, Greenland Tourism (6–8 August)
Klaus Søgård, Nonni Travel Illoqqortoomiut (6–8 August)
Jørgen Søholm, Department of Environment and Nature, Greenland Homerule (6–8 August)
Henning Thing, Danish Polar Center (3–10 August)

Daneborg

Søren Andersen, NANOK (Craftsman 10–17 August)
Jannik Berntsen, NANOK (Craftsman, 3–24 August)
Niels Lindegaard, NANOK (Craftsman, 3–24 August)

Further contributors to the annual report

Kirsten Christoffersen, Ph.D., Freshwater Biological Laboratory, University of Copenhagen (BioBasis)
Thomas Friborg, Institute of Geography, University of Copenhagen
Louise Grøndahl, National Environmental Research Institute.
Erik Jeppesen, D.Sc., National Environmental Research Institute, Denmark (BioBasis)
Dorthe Petersen, ASIAQ, Greenland Survey.
Jesper Birkedal Schmidt, M.Sc. student, National Environmental Research Institute, Denmark (BioBasis)
Kisser Thorsøe, ASIAQ, Greenland Survey.

9 Publications

Compiled by Vibeke Sloth Jakobsen

Scientific papers

Allbert K.R. 2004: Effects of reducing the ambient UV-B radiation on the photosynthetic performance of Salix arctica and Vaccinium uliginosum in high arctic Greenland. – M.Sc. Thesis, Biological Institute, University of Copenhagen.

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