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Executive Summary

Summary

2008 was a busy year at Zackenberg with a field season from 13 March to 2 November, 81 scientists visiting the station and the number of bed nights totalling 1712.

In May 2008, the book '*High-Arctic Ecosystem Dynamics in a Changing Climate. Ten years of monitoring and research at Zackenberg Research Station, Northeast Greenland.*' was published as Volume 40 in Advances in Ecological Research (Elsevier, Academic Press). The book was released at the conference 'After the Melt' at Aarhus University, Denmark, on 5 May.

In December 2008, a story about late autumn methane emission from the tundra at Zackenberg (Mastepanov et al. 2008) was published in Nature (see section 10). This was the second publication of Zackenberg research in 'Nature', and it gave plenty of public attention, including press coverage in a large number of Danish and International news media.

ClimateBasis and GeoBasis

Compared to earlier seasons, the field season in 2008 was warm and wet and characterized by a record high amount of snow during winter and also a record high amount of rain during summer. All the summer months (June, July and August) and September had the highest mean monthly temperatures since registration began in 1996. Hence, the mean monthly temperature of June beat the record of 2007 by 1.9 °C, whereas July and August had mean monthly temperatures that were respectively 1.0 °C and 0.3 °C higher than previously seen. For the first time, no freezing degree days were registered during the summer. The maximum temperature of the summer was 18.4 °C (28 July), and the minimum temperature was –35.3°C (6 March).

The total amount of precipitation during summer 2008 was 60 mm which was only exceeded in 1997 and 1998. Most of the rain (49 mm) fell in August during the largest rain event that has been measured so far. Also in September a large rain/snow event took place and all together the amount of rain in 2008 resembled the amount in 1998 which is twice the average amount (1996-2008) and almost five times as much as what have been observed during the last five years.

The winter 2007/2008 was extraordinary in amounts of snow, with an early first occurrence of a continuous layer of snow and with a the long duration of a snow cover above 1.2 m. Snow depth was above 0.1 m from 26 October, and the maximum snow depth measured was 1.3 m, which is similar to 1998/1999 and 2001/2002. However, while the maximum snow depth in the preceding years only lasted for a few days, the maximum snow depth in 2008 lasted for a long period. Snow melt started around 24 May and was complete below the snow depth sensor mast on 25 June, resembling the very fast snow melt in 2002. 2008 had, despite the large amounts of snow at the end of winter, a snow cover by 10 June of 72 %, which is very close to the mean for the entire 1995-2008 period.

The thaw rate of the soil at the two active layer plot ZEROCALM-1 and ZEROCALM-2 showed a very fast thaw progression in July which levelled out after the first week of August. The average active layer depth at the end of the season for both sites were among the deepest ever measured.

In 2008, Zackenbergelven broke up on 7 June and water was running until 10 October. From late September, the river started to freeze, and at the hydrometric station there was ice below the sensor from 24 September. The total amount of water drained from the catchment from 8 6 14th Annual Report, 2008 June until 20 October was approximately 185 million m3 which is close to the average observed since 1996. During the 2008 summer season no floods were observed. However, a large flood event took place during the winter in Zackenbergelven on 26 November 2008 (long after the river stopped running) and a fan of water reached several km

out on the fiord ice. The large amount of water originated from an outburst of a glacier-dammed lake in the north-western part of the Zackenberg drainage basin.

Two major peaks in sediment concentration were observed during the season. The first in early July during a period of increased discharge, and the second and highest peak with concentrations of up to 7,713 mg l-1 was measured during the rain induced flood in late August. Unfortunately, the final discharge data were available at a very late stage this year. The total transport of suspended sediment from Zackenbergelven drainage basin to Young Sund will therefore not be reported before the next edition of the annual report.

The fjord ice off Zackenbergdalen broke up 9 July and a few days later Young Sund was ice free. New ice started to form in early October covering most of Young Sund by mid October.

In 2008, the flux measurements at the heath-site were initiated 12 April and lasted until the 27 October. In the early season only very small CO2 fluxes were measured. As the vegetation developed the photosynthetic uptake of CO2 started and by 6 July, the ecosystem switched from a net source of CO2 to a net sink of CO2. The period with a net uptake lasted 48 days which is in line with other snow rich years. The maximum uptake of CO2 (1.45 g C m-2 d-1) was measured 21 July and is the highest daily uptake ever measured at this site. Despite the relatively short period, the total uptake of CO2 in this period was 36.4 g C m-2 which is the highest assimilation measured since monitoring began in 2000. The net emission in autumn was measured to be 6.6 g C m-2. This is not enough to balance the uptake during summer, and for the entire measuring season we end up with a total accumulation of 30.4 g C m-2.

In 2008, the flux measurements in the fen began 13 April and lasted until the 30 August. The net uptake period started 7 July - just one day later than at the heath site - and lasted until 21 August. Maximum emission was measured 5 July (1.29 g C m-2 d-1). When measurements stopped 30 August emission rates were still relatively high. Both daily emissions and daily uptake rates are much larger in the fen than at the heath. The total CO2 uptake during the net uptake period is measured to be 100.2 g C m-2 which is about three times the amount at the heath site. Both sites are net sinks of CO2.

After the normal summer monitoring of methane in 2007, the run of the methane station was continued for two more months, September and October 2007. After a gradual decrease in CH4 fluxes during August an unexpected burst was registered, peaking in the first quarter of October, when the soil was freezing in. Freeze-in emissions were much more variable than summer emissions. Peak emissions during the freeze-in period in individual chambers reached levels of 112.5 mg CH4 m-2 h-1. The integral of CH4 emissions during the freeze-in period in 2007 amounts to approximately the same as the methane emitted during the entire summer season.

The 2008 monitoring season started as soon as the snow melted enough to start the chambers, i.e. 23 June. A very slow increase of the fluxes progressed until the end of July, when the emission level finally met the values of previous years. One of the possible explanations for such low mid-seasonal fluxes may be a thinning of a subsurface gas pool as a consequence of the previous autumn squeezing burst; suggesting that during 2009 a major part of the CH4 production was used to regenerate this in-soil pool. The system was successfully operated until a storm 25 August, when the site was flooded and the instrument was damaged by sucked water.

GlacioBasis

The primary aim of the GlacioBasis monitoring programme at Zackenberg Research Station is to produce a record of high quality glaciological observations from the A.P. Olsen ice cap and its outlet glacier in the Zackenbergelven drainage basin. This is of great scientific interest given the scarceness of glacier mass balance measurements from glaciers and local ice caps in East Greenland, and given the strong impact that local glaciers and ice caps outside the ice sheet are expected to exert on sea level rise in the present century. The first field campaign was carried out in March-April 2008. Therefore, most results, including the first glacier mass balance, will not be available before the next field campaign, which is planned to take place in May 2009.

During 2008, a network of ablation stakes was setup on the glacier, and the stake positions were determined by GPS methods to allow estimation of the glacier surface velocity field from repeated GPS surveys. Snow depth has been measured by ground penetrating radar (GPR), and snow density profiles have been obtained from snow pits. The winter balance gradient with elevation, for 2008 was 0.3 mm (water equivalent m-1). To quantitatively analyse and model the physical processes governing surface melt, two automatic weather stations (AWS) have been setup. Satellite data telemetry from the main AWS is producing an uninterrupted time series, which shows that the station itself is still fully functional. Remote sensing imagery from the Terra/ASTER sensor has been acquired on demand through the GLIMS project throughout the 2008 summer season, but most scenes are affected by severe cloud cover. Further acquisitions have been scheduled for 2009.

BioBasis

Compared to previous years, the snow melted a little later than average in the permanent monitoring plots in 2008, and this was reflected in a generally late flowering. However, some plots were earlier than average for the previous seasons. The dates of open seed capsules exhibited no clear pattern, with some species being later than average, while others were earlier than average. The total number of flowers produced in 2008 was low, and with new minima for several plots.

Vegetation greening (NDVI) inferred from satellite images revealed that landscape NDVI was a little higher than average for the previous years. In the permanent plant plots (NDVI) culminated relatively late in the season as compared to previous years. The NDVI transects showed that the vegetation peaked around DOY 230 along the ZERO line, and on the lowland transect the vegetation peaked around DOY 208.

The CO2 flux measurements showed that the ecosystem respiration in the *Salix* dominated heath tended to be higher in warmed than control plots, but warming also lead to a stronger increase in Gross Ecosystem Respiration, and the net carbon balance was therefore generally affected by warming. In *Cassiope* dominated heath the pattern was less clear, and warming seemingly did not affect the CO2 fluxes here. CO2 fluxes in the UV-B exclusion and filter controls showed that removal of UV-B may promote Gross Ecosystem Production.
Leaf fluorescence in the UV plots showed only limited and non-significant response to the exclusion of UV-B on the performance of *Salix arctica* and *Vaccinium uliginosum* leaves.

In July 2008, the international monitoring programme *Global Observation Research Initiative in Alpine Environments* (GLORIA) was implemented at Zackenberg as an integrated part of the BioBasis programme. In 2008, high numbers of arthropods were caught in the window traps and the pitfall traps. Numbers varied markedly between arthropod species/groups, and especially the Chironomids constituted the bulk of the arthropods caught. Depredation on *Dryas* flowers by *Sympistris zetterstedtii* larvae was higher than usual in 2008, and four of six plots had record high depredation percentages.

The breeding bird census revealed relatively high numbers of Sanderling and Dunlin territories, whereas territories of Ruddy turnstone were found in average numbers. The number of Red knot territories was around the average for the previous seasons. Despite the relatively late snow-melt, wader nest initiation in 2008 was around average or a little later, and median first egg dates were also around average in all four species. Wader nest success, however, was extremely low, and most nests were depredated. The number of long-tailed skua territories was found in near-average numbers, and with a median nest initiation date around the average, but with a nest success well below average. Average numbers of barnacle goose broods were observed, and with a relatively high mean brood size early in the season and low late in the season.

Collared lemming winter nest density in 2008 was the third lowest recorded so far. As in the last years, no nests were found depredated by stoats. The pattern of musk oxen occurrence in June through August within the musk ox census area resembled that of the previous years, but the extended season showed that musk oxen utilise the valley heavily far into the autumn and also in the late winter. More bulls than usual were observed in 2008, whereas only very few calves were observed. Breeding by arctic foxes was verified in five dens. A minimum of 24

arctic fox pups were registered in 2008. This is the highest monitored number recorded so far. Arctic hares were observed in intermediate numbers.

The two lakes monitored melted free around the average for the previous seasons. The lake samples are still being processed, and the results will be reported in the 2009 annual report.

MarineBasis

In Young Sund, the 2008 field season was characterised by a long ice free season. The ice in the fjord disappeared in early July compared to late July in 2006 and 2007. Reports from the Sirius Patrol indicate that fast ice did not form until November, and the ice-free period could thus approach the record of 131 days from 2002. This will be confirmed when data from the ice camera is retrieved in August, 2009.

The oceanographic mooring deployed in 2007 was checked in 2008. All instruments had been working as planned providing information on annual variability of temperature and salinity and the vertical fl x of particles. Temperature and salinity at two depths showed the typical annual pattern with most variability during the summer and very constant conditions during the winter. From 2007 to 2008 a small increase in salinity was observed. The annual vertical flux of particles was 207 g m-2 y-1 of which 3.2 g were organic carbon. The distribution of salinity, temperature and fluorescence in the fjord during the field campaign reflected the calm conditions. The surface water was well stratified and the surface water was warm compared to previous years with an average at the main station of 4.1 °C (0-5 m depth) and a maximum of 9.1 °C. Nutrient conditions also reflected the calm conditions with very low concentrations in the photic zone due to uptake by phytoplankton.

In the water column the zooplankton community has showed a trend of increasing relative abundance of the Atlantic copepod *Calanus finmarchicus* compared to the Arctic species *C. hyperboreus*. This trend continued in 2008 with a ratio of 1.6 *C. hyperboreus* to every *C. finmarchicus*.

In 2003 this ratio was 56:1. In the benthic community an increase in abundance of the bivalve *Propeamussium groenlandicus* has occurred since 2003 with maximum abundance observed in 2008 (total of 182 specimens). Since 2006, the spatial variation in the surface water content of CO2 (partial pressure, *p*CO2) has been conducted. The data show significant variation within the fjord but also between years. However, the general trend is that the surface water is under saturated with CO2 and therefore takes up atmospheric CO2. This under-saturation tends to be most pronounced at the glacial input in Tyrolerfjord. In March 2008 it was possible to supplement with measurements of CO2 during the winter campaign of the ISICaB project. Results from the winter showed a small flux of CO2 from the sea ice to the atmosphere. The flux to the atmosphere increased during the production of new ice during field experiments. But, the major flux during ice formation is through brine rejection into the water column resulting in sea ice that - when melting - is highly under saturated with CO2. Thus formation and melting of sea ice seem to play an important role for the air-sea flux of CO2 in addition to the biological processes. Although based on very poor seasonal data, the best available estimate is an annual uptake of 1.5 to 2 mol CO2 m-2 in Young Sund. This is high compared to global estimated suggesting the influence of the sea ice to be significant.

Research projects

A total of 14 research projects were carried out at Zackenberg Research Station in 2008. Of these, five projects were part of the Zackenberg Basic monitoring. Nine projects used Zackenberg Research Station as a base and five projects used Daneborg as a base.