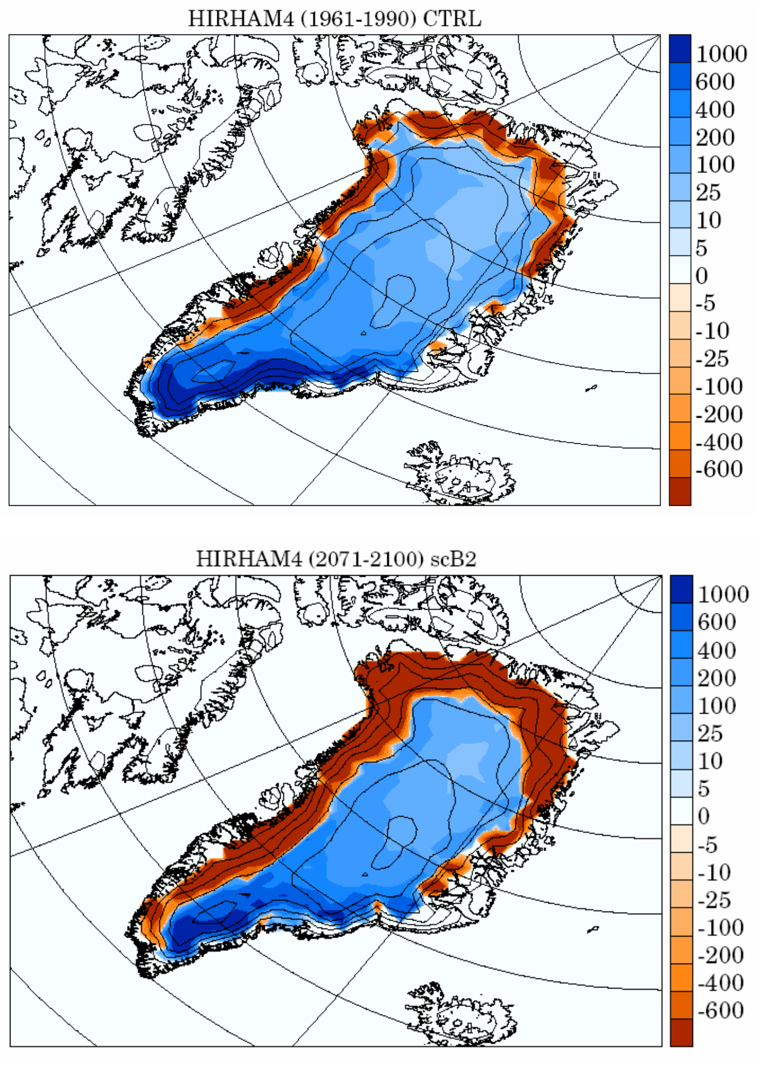
Danmarks Klimacenter

DMI, Trafikministeriet

Grønlands klima

Temadag
mandag den 16. december 2002, DMI



Jens Hesselbjerg Christensen
Rapport 03-01

Grønlands klima. Temadag, mandag den 16. december 2002, DMI

Redigeret af Jens Hesselbjerg Christensen

Danmarks Klimacenter, Rapport nr. 03-01.

ISBN: 87-7478-477-3
ISSN: 1398-490-x (Print)
ISSN: 1399-1957 (Online)

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www.dmi.dk

Omslag:

Akkumulations- og ablationsområder for nuværende klima samt efter perioden 2070-2100 i IPCC's B2 scenario.
Baseret på simuleringer med HIRHAM modellen.

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1. INDLEDNING

Det moderne samfund bliver stadig mere komplekst, og grundlaget for at træffe beslutninger som regulering af aktiviteter, der har betydning for klimaudviklingen, bliver i stigende grad afhængige af avancerede modeller af meget komplekse systemer. Det er afgørende for troværdigheden af de scenarier for fremtiden, som beslutningstagerne får stillet til rådighed, at metoder og usikkerheder er veldokumenterede lige fra beskrivelsen af emissionsscenarier over klimamodeller og konsekvensstudier, til beregninger af samfunds-mæssige og økonomiske konsekvenser af de mulige ændringer. Der er imidlertid stadig mange uafklarede forhold omkring kommende regionale klimaforandringer og deres betydning for miljøet såvel som for det omgivende samfund – et forhold som er helt tydeligt når fokus sættes på Grønland. Grønland og dets indbyggere er til stadighed påvirket af et meget omskifteligt klima, hvor variationerne fra år til år og fra årti til årti altid har været betydelige. Dette vanskeliggør selvfølgelig processen med at identificere og studere klimaforandringer.

DMI's Klimadag 2002 satte fokus på Grønland, som både rummer data om fortiden i iskerner og instrumentelle dataserier, og hvor fremtidige klimaændringer forventes at kunne blive relativt store. Samtidig er de Arktiske økosystemer særligt sårbare over for klimaændringer og -variationer.

Der var inviteret bidrag inden for en bred vifte af faglige discipliner:

- meteorologi
- oceanografi og havis
- permafrost
- glaciologi

Videre var der åbnet for at aspekter af det hydrologiske kredsløb, stofkredsløbet, ozonens rolle i klimasystemet, samt biologiske samt samfundsmæssige aspekter heraf kunne inddrages, afhængigt af hvor stor forhåndsinteressen for mødet vil være. Som det fremgår af denne rapport var der en bred vifte af foredrag indenfor næsten alle tænkelige klimarelaterede områder, som bidrog til at gøre dagen yderst vellykket..

2. PROGRAM

9:00 – 9:30	**Ankomst + registrering**	
9:30	Velkomst	*v. Anne Mette Jørgensen, DMI*
9:35	Klimaet i det sydlige Grønland i de sidste 40 år	*v. John Cappelen, DMI*
9:55	Kvalitet af DMIs serier af temperatur- og nedbørs-observationsdata fra Grønland, 1873-2001.	*v. Ellen V. Laursen, DMI*
10:15	Digital snow monitoring in a high arctic ecosystem in Northeast Greenland	*v. Jørgen Hinkler, KU*
10:35	The near surface circulation in the northern North Atlantic as inferred from Lagrangian drifters: seasonal and interannual variability.	*v. Phillip K. Jakobsen, DMI*
10:55	**Kaffepause**	
11:15	Ecosystem Variability and Regime Shift in West Greenland waters	*v. Erik Buch et al., DMI*
11:35	Synchronization of animal population dynamics by large-scale dynamics	*v. Mads C. Forchhammer, KU*
11:55	Lake-climate interactions in West Greenland: past and present.	*v. John Anderson et al., GEUS*
12:15	Reconstruction of the Fram Strait Ice Export During the 19th and 20th Centuries	*v. Torben Schmith, DMI*
12:35	**Frokost**	
13:30	Deep convection east of Greenland: Atmospheric forcing and oceanic response	*v. Mads H. Ribergaard, DMI*
13:50	Climate change scenarios for Greenland	*v. J. H. Christensen, DMI*
13:10	Permafrost zonation in a future climate	*v. Martin Stendel, DMI*
14:30	Potential biological consequences of climate change in sea around Greenland	*v. Torkel Gissel Nielsen et al., DMU*
14:50	**Kaffepause**	
15:05	Climate responses on Arctic ecosystems. An example from NE Greenland	*v. Søren Rysgaard, DMU*
15:25	Ozonnedbrydning i Arktis	*v. Bjørn Knudsen, DMI*
15:45	Biologiske effekter af UVB stråling i arktiske havområder	*v. Kim Gustavson et al., DHI*
16:05	Afrunding	*v. J. H. Christensen, DMI*

3. ABSTRACTS

3.1 John Cappelen, Danish Meteorological Institute, Copenhagen, Denmark Edward Hanna, Institute of Marine Studies, University of Plymouth, UK

Recent cooling in coastal southern Greenland

Analysis of new data for eight stations in coastal southern Greenland, 1958-2001, shows a significant cooling (trend-line change -1.29 degC), as do sea-surface temperatures in the adjacent part of the Labrador Sea, in contrast to global warming (+0.53 degC over the same period). The land and sea temperature series follow similar patterns and are strongly correlated but with no obvious lead/lag either way. This cooling is significantly inversely correlated with an increased phase of the North Atlantic Oscillation over the past few decades (r = -0.76), and will probably have significantly affected the mass balance of the Greenland Ice Sheet.

Greenland, the world's largest island, is important climatically and glaciologically. The Greenland Ice Sheet, if it were to melt in its entirety, could contribute 6-7 m to global sea-level rise (Hvidberg 2000). The Ice Sheet is either approximately currently in balance or losing mass (Abdalati 2001) but with a large uncertainty. It experiences large interannual variations in snow accumulation and ablation (McConnell et al. 2001, Hanna et al. 2002). Mean annual temperatures around the southern edge of the Ice Sheet are only a few degrees below freezing, -5°C being typical (Ohmura 1987), and summer temperatures rise several degrees above freezing. The marginal zones of the Ice Sheet, from which most of the surface meltwater runoff occurs, are therefore critically sensitive to climatic change (especially a summer warming). Here we explore recent climatic change in southern Greenland, its relation to the North Atlantic Oscillation (NAO) and possible effects on the Ice Sheet mass balance.

Annual temperature series from six Danish Meteorological Institute stations in coastal and near-coastal southern Greenland, were analysed in terms of trends and eight sations were averaged to produce a "Composite Greenland Temperature" (CGT) (Fig. 1). Most of the stations are in SW Greenland. CGT is based on recently published data (Cappelen et al. 2001), with an update to 2001, and the presence of data from at least seven out of the eight stations in any year. The Greenland station temperature records were closely examined and compared with records for related climatic elements from the same stations. Station data were also inter-compared to search for systematic offsets which (where they could not be accounted for by local conditions) were also corrected. A new series was calculated using a Gaussian filter with a standard deviation of three years (G3, equivalent to a 10-year running mean). This series shows a least-squares linear regression trend-line decrease of 1.29degC (σ=0.63degC) from 1961-2001, compared with a simultaneous trend-line increase of 0.53degC (σ=0.16degC) for similarly filtered global mean temperature (GMT). GMT is from the Hadley Centre and Climatic Research Unit (Jones et al. 1999, Parker et al. 1995). In other words while conditions warmed significantly globally, they cooled significantly in coastal southern Greenland.

Sea-surface temperatures off SW Greenland also seem to have cooled over a similar time period. G3 series of HadSST1 (Parker et al. 1995, Rayner et al. 1996) decreased 0.44degC (σ=0.20degC) and

NOAA SST blended to the NCEP Reanalysis skin temperature (Kalnay et al. 1996) decreased 0.80degC (σ=0.29degC) during 1961-99 and 1961-2001 respectively (data from HadSST1 were available only to 1999). There are common patterns to the observed land and sea coolings and no obvious lag: perhaps changes in air temperature/atmospheric circulation in southern Greenland predominantly influence SST in the Labrador Sea rather than vice versa, although establishing the exact cause and effect is challenging. Correlation coefficients between 5-year running means of the series are: 0.69 between the two SST series, 0.71 between CGT and HadSST1, and 0.92 between CGT and NCEP SST. These 'r' values are all statistically significant at the 5% level, and the latter at the 1% level (see Dr. David Stephenson's Web site at http://www.met.rdg.ac.uk/cag/).

The stronger/increasing phase of the NAO during the last ~35 years (see Dr. James Hurrell's Web site "North Atlantic Oscillation (NAO) Indices Information" at http://www.cgd.ucar.edu/~jhurrell/nao.html) links in with the observed cooling (Fig. 2). The 5-yr. RM of NAO was significantly negatively correlated with 5-yr. RM CGT (r = -0.76) during 1961-2000. This is to be expected as southern Greenland is near Iceland, one of the 'ends of the seasaw' of the NAO. Recent milder conditions over north-west Europe were accompanied by stronger cold northerly winds over Greenland. It is unknown whether this is a long-term trend, possibly forced by anthropogenic greenhouse warming, or simply natural/random climatic variation. The NAO-temperature link doesn't explain what caused the observed cooling in coastal southern Greenland (what 'drives' the NAO?) but it does lend it credibility.

The observed cooling in coastal southern Greenland means that the southern part of the Ice Sheet most likely also cooled overall over the past few decades. Although interior (ice sheet) and coastal climates are different, the most relevant part of the Ice Sheet is that around the edges (i.e. nearest the coast) where summer melt rates and variability are highest. Ablation-temperature modelling indicates that an annual or summer temperature rise of 1 degC increases ablation by ~20-50% (Oerlemans 1991, Braithwaite and Olesen 1993, Ohmura et al. 1996, Janssens and Huybrechts 2000). So recent cooling may have significantly added to the mass balance of (at least the southern half of) the Ice Sheet. However, this may have been partially offset by a small temperature rise and thinning of the ice in the mid-late 1990s (Krabill et al. 2000).

Continued systematic observations from Greenland met. stations are of greatest importance for studies of polar and global climate change. We leave it to future investigators to explore the reasons behind this important regional exception to recent 'global warming'.

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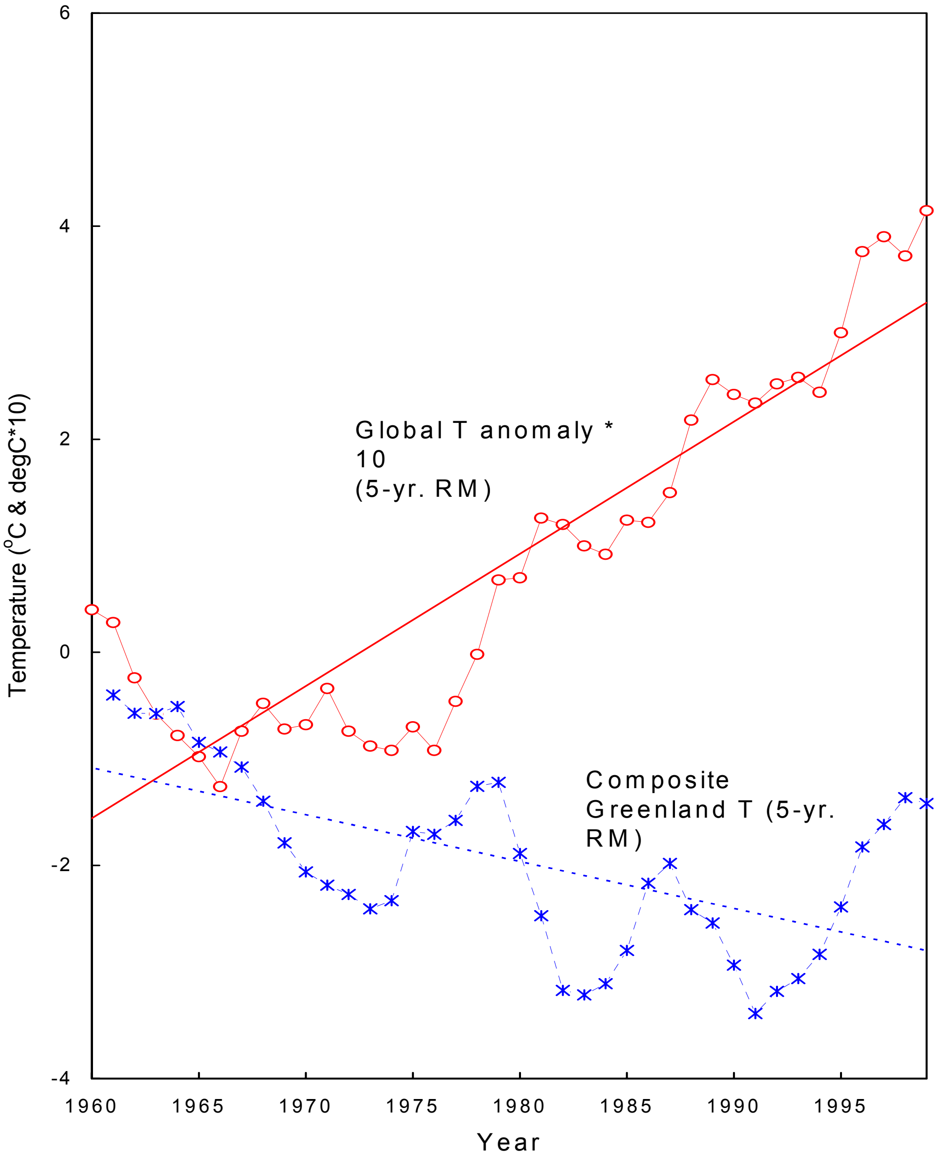

Figure 1. Composite Greenland temperature (CGT) and sea-surface temperatures (Hadley Centre & NCEP) off SW Greenland, all 5-yr. RMs, with trend lines.

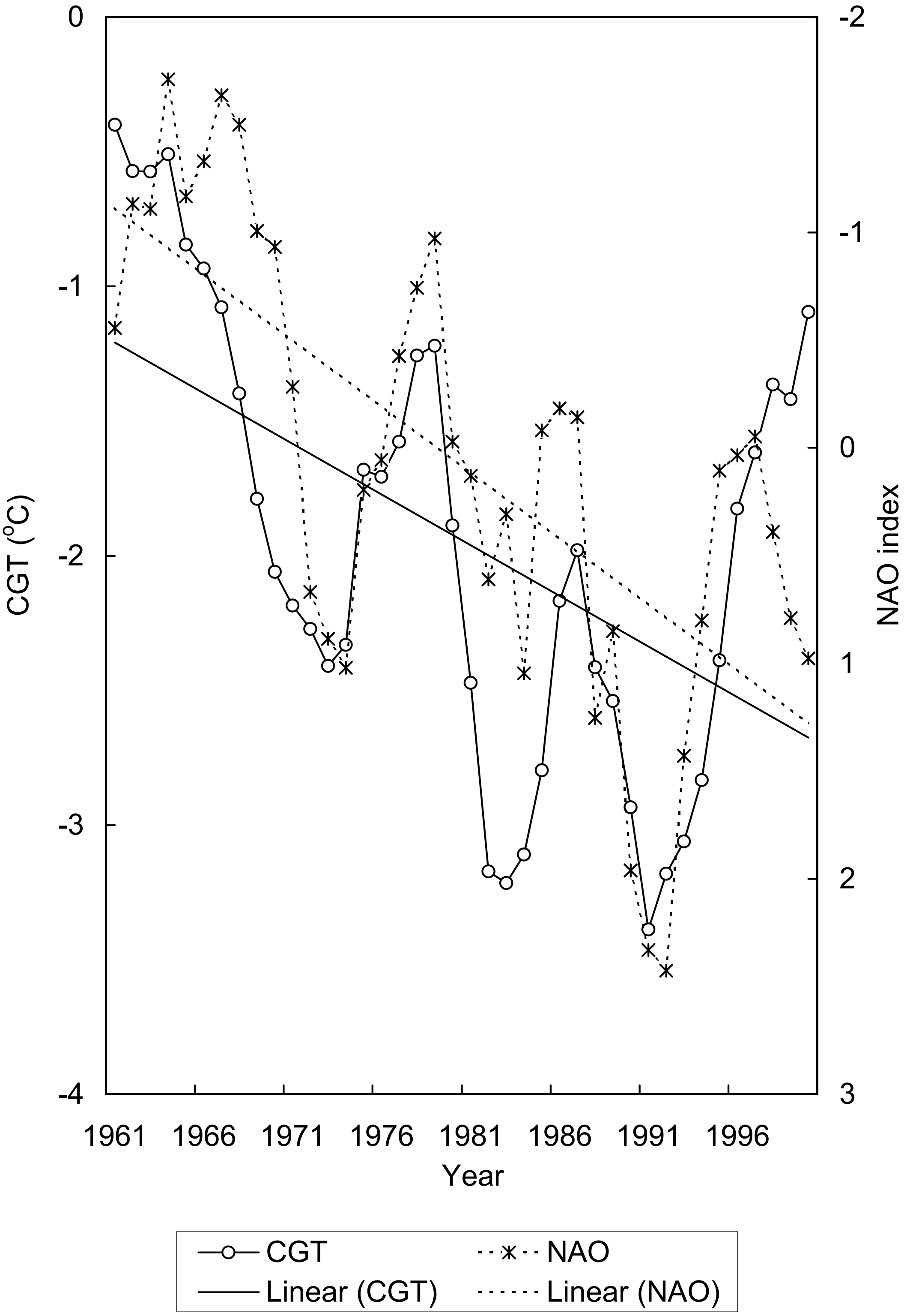

Figure 2. Comparison of CGT and NAO.

3.2 Ellen Vaarby Laursen, DMI, Sektion for Vejr- og Klimainformation

Kvalitet af DMIs serier af temperatur- og nedbørsobservationsdata fra Grønland, 1873-2001.

Efterhånden er en del lange DMI serier af observationsdata fra Grønland nu til rådighed fra DMIs Internet hjemmeside[1]. Observationerne er blevet digitaliseret og/eller gennemgået for fejl i forbindelse med diverse projekter: NARP[2], lange daglige serier[3], klimanormaler for Grønland[4], WASA[5] og NACD[6]. Ved hver gennemgang er der sket en forbedring af data gennem retning af fejl og tilføjelse af metadata. Her gives en status for den nuværende kvalitet af de vigtigste serier. Endvidere vises netop publicerede eksempler på manglen på en signifikant gennemgående trend i seriernes observerede temperatur fra Grønland gennem det 20. århundrede[7].

[1] http://www.dmi.dk/f+u/ vælg 'Publikationer', vælg 'Tekniske rapporter' eller 'Videnskabelige rapporter'.
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[3] Laursen. 2002. Observed Daily Precipitation, Maximum Temperature and Minimum Temperature from Ilulissat and Tasiilaq, 1873-2000. DMI Technical Report 02-15.
[4] Cappelen et al. 2001. The Observed Climate of Greenland, 1958-99 –with Climatological Standard Normals, 1961-90. DMI Technical report 00-18.
[5] WASA: 'The impact of storms on waves and surges: Changing climate in the past 100 years and perpectives for the future'. Data fås fra Schmith et al. 1997. DMI Technical report 97-3.
[6] NACD: 'North Atlantic Climatological Dataset'. Data fås fra Frich et al. 1996. DMI Scientific Report 96-1.
[7] Førland et al. 2002. Twentieth-century variations in temperature and precipitation in the Nordic Artic. Polar Record 38 (206): 203-210.

3.3 Jørgen Hinkler, University of Copenhagen, Institute of Geography

Digital snow monitoring in a high arctic ecosystem in Northeast Greenland

The inter- and intra annual snow cover distribution in the valley Zackenbergdalen, Northeast Greenland, was monitored, using images from a digital camera. The Digital Camera Images (DCI) provides - in contrast to satellite images - data with a high temporal and spatial resolution at a low cost. The digital camera, positioned on a rock 500 m above sea level, automatically takes oblique photographs of the valley. To obtain the necessary "areal consistency" for mapping purposes, the DCIs are transformed into digital orthophotos. Snow cover mapping is performed using these orthophotos. In order to suppress errors due to illumination effects, a normalized index based on RGB values was developed. The index can be used as analog to the Normalized Difference Snow Index (NDSI), commonly used in combination with Landsat TM images. During the melt-off season, a maximum of 10-15 Landsat TM passes occur over the Zackenberg area. E.g. in the 1999 melt-off season only three cloud free TM images were usable for snow-mapping, while 46 DCIs were suitable for this purpose.

Using the DCIs in combination with satellite data (Landsat TM/ETM+, SPOT HRV), obtained in years prior to the setup of the digital camera system, has made it possible to create a model, which describes the inter- and intra annual snow cover distribution in the valley at high detail.

The model was derived using Kriging interpolation to find a relationship between the initial snow accumulations in the beginning of the melt-off season, the accumulated degree days, and snow cover extents calculated from the orthophotos.

Because of dominating northerly winds during winter, the snow generally accumulates on south facing slopes, and the decrease of the snow cover extent therefore is prolonged in these areas. Furthermore, the snow cover depletion rate decreases with altitude. Due to different initial snow accumulations, and different temperature regimes during the different melt-off seasons, the course of the snow cover depletion curves varies from year to year. Thus, it was found that the mean date with 50 % snow cover extent in Zackenbergdalen is June 24th, deviating approximately +/- 2 weeks. A comparison between snow cover extents derived from various remote sensing data and the modeled snow cover extents shows that the model generally produces accurate results. A spectacular periodicity of around 5-6 years with increasing snow cover and then a sudden abrupt decrease was found for the Zackenberg area. Whether or not this periodicity is related to local sea ice accumulations is going to be further investigated.

Currently a multispectral digital camera system is under development at the Institute of Geography. Thus, in the future, multispectral DCI's will make us able also to monitor and model parameters such biomass production and length of growing season in local scale areas like Zackenbergdalen.

3.4 Philip Kruse Jakobsen, Danish Meteorological Institute

The near surface circulation in the northern North Atlantic as inferred from Lagrangian drifters: variability from the meso-scale to interannual

The Greenland, Iceland and Norwegian Sea, i.e. the Nordic Seas, play a key role in ocean-climate through deep water production. This includes mixing both vertically through convection and horizontally due to the local circulation. In this talk we investigate the local circulation from surface drifters and altimetry data and discuss its possible effect on driving the exchanges across the Greenland-Scotland Ridge.

The near surface circulation of the Nordic Seas is basically cyclonic and consists of jets and re-circulation cells, which are tightly linked to the bottom topography. Variable forcing by the largescale rotation of the wind leads to a modulation in the strength of the gyres and their interconnecting jets. This is seen in drifter and altimeter data. Currents are stronger during winter and during phases of high North Atlantic Oscillation Index. The exchanges between the North Atlantic and the Nordic Seas do not seem to be directly affected by this variable forcing. The narrow boundary currents and the inter-gyre jets are subject to instability, causing meso-scale current fluctuations, which contribute to the stirring and mixing of Polar and Atlantic water masses.

3.5 Erik Buch[1], Søren Anker Pedersen[2], and Mads Hvid Ribergaard[3]

Authors in alphabetic order
[1] Danish Meteorological Institute
[2] Greenland Institute of Natural Resources
[3] Danish Meteorological Institute and Greenland Institute of Natural Resources

Ecosystem Variability and Regime Shift in West Greenland waters

A review of the past 50 years climate conditions off West Greenland is given. We find large variability in the atmospheric, oceanographic and sea-ice conditions as well as in the fish stocks. A positive relationship is found between the hydrographic conditions expressed by the water temperature and the fish recruitment of cod and redfish whereas the recruitment of shrimps and halibuts seems to react positive to lower temperatures. Observed shifts in the hydrographic conditions during the second half of the 1990s indicate, that a change in the fish stock environment may be expected in the coming years.

Relationships between the past variations in fisheries resources, hydrographic conditions, and the large-scale climatic conditions, expressed by the North Atlantic Oscillation (NAO), strongly supports the incorporation of environmental variability in prediction models for fish stock recruitment and thereby in the assessment of the fisheries resources.

3.6 Mads C. Forchhammer, University of Copenhagen, Zoological Institute

Synchronization of animal population dynamics by large-scale climate

The hypothesis of synchronization of animal population dynamics by climate is highly relevant in the context of climate change because it suggests that multiple populations might respond simultaneously to climatic trends if their dynamics are entrained by environmental correlation. The dynamics of many species throughout the Northern Hemisphere are, for example, influenced by a single large-scale climate system, the North Atlantic Oscillation (NAO), which exerts highly correlated regional effects on local weather. Yet, efforts to attribute synchronous fluctuations of contiguous populations to large-scale climate are invariably confounded by the synchronizing influences of dispersal or trophic interactions. Here, spatio-temporally extensive data on the dynamics of caribou and muskoxen on opposite coasts of Greenland reveal spatial synchrony among populations of both species that correlates with the NAO index. Moreover, the analysis reveals an influence of the NAO in the high degree of cross-species synchrony between pairs of caribou and muskox populations separated by a minimum of 1000 km of inland ice. The vast distances, and complete physical and ecological separation of these species, rule out spatial coupling by dispersal or interaction. Hence, the combined effect of the NAO and the continued Northern Hemisphere warming has the potential to increase extinction risk of multiple populations across species.

3.7 N. John Anderson[1], Klaus P. Brodersen[2] and Helen Kettle[3]

[1] GEUS
[2] Freshwater Biological Laboratory, Hillerød
[3] Department of Geophysics, University of Edinburgh.

Lake-climate interactions in West Greenland: past and present.

Lakes respond to climate as a variety of timescales. Most obvious is the annual cycle of surface water temperature, which broadly follows the ambient air temperature. In deeper lakes this annual increase in surface temperatures is associated with the development of thermal stratification with associated effects on lake biology. At shorter timescales (hours to days), the passage of fronts and increased wind speeds will cause cooling in surface waters and mixing which may lead to the breakdown of stratification. At intermediate timescales, e.g. decades, lake biota will respond to quasi-cyclical trends in synoptic patterns such as the North Atlantic Oscillation. Over millenial timescales (i.e. during the Holocene), lakes will respond to changes in radiative forcing and changes in regional. As well as direct temperature effects, climate may affect lakes by altering the hydrological mass balance – increased evaporation may lower lake levels, retention time will increase and in closed-basin systems, chemical concentration will occur.

In general, the Arctic is warming and continued change may have substantial effects on lakes. Continued warming may lead to enhanced thermal stratification, stronger hypolimnetic anoxia and hence nutrient reycling with associated implications for species abundance and composition. Equally, cooling – as in parts of SW Greenland – may also lead to longer periods of ice cover and again, increased anoxia. However, it is difficult to estimate what future effects might be without any baseline data to compare future changes. For the thousands of lakes in West Greenland, very little is known about the interaction of lakes with climate. Moreover, it is important that we understand how lakes respond to climate (and weather) today as this strengthens our ability to interpret past, as well as future changes. With this aim, we have been monitoring lake water temperatures along the climate gradient from the ice sheet margin to the coast, south of Sisimiut together with studies of Holocene climate variability based on lake sediment cores.

Present-day lake-climate interactions

We will illustrate the response of lakes to present-day climate forcing by examples of:

- spatial coherence of lake summer temperatures along the ice margin-coast climatic gradient
- spatial variability in ice out
- effect of weather on thermal stratification

Using these data, we have also developed a simple empirical model to predict surface water temperatures for lakes in and around Kangerlussuaq.

Long-term changes in effective precipitation around Kangerlussuaq.

Dramatic changes in the hydrological balance of lakes around the head of Søndre Strømfjord are clear from the many lakes with fossil shorelines, metres above present-day lake level. Sediment cores from these saline lakes provides unambiguous evidence for a more dynamic early Holocene, particularly variable effective precipitation.

Direct climate forcing and the response of lake biota

In contrast to changes observed in closed-basin, saline lakes, freshwater systems respond largely indirectly to climate, with much of the climate forcing being mediated through the biogeochemical processes within the catchment. However, more extreme events, such as the 8.200 yr. BP event do provide evidence for unambiguous climate forcing of lake ecosystems.

3.8 Naja Mikkelsen and Antoon Kuijpers, GEUS

The Norse in Greenland

Only the narrow coastal areas in Greenland are ice-free today, and during glacial times the Greenland ice cap reached out and covered the marine shelf. Greenland has therefore only been inhabited for 4500 years after retreat of the ice from the coastal areas. The first Inuits came to Greenland from Canada by crossing the narrow strait between Canada and Greenland. They were hunters who spread in several pulses along the east and west coast of Greenland following the climatically controlled distribution of their prey.

The Inuits were living in the northern part of Greenland when Norse settlers 1000 years ago arrived in south Greenland. The Norse settlers came from Iceland and were headed by Eric the Red. They established around 985 AD a thriving farming community called 'Eastern settlement' in the Julianhåb Fjord region in southern Greenland during the favourable climatic conditions of the Medieval warm period. More settlers were soon to follow, and they founded the 'Western Settlement' further to the north in the present day Godthåb Fjord region. The Norse settlements survived on a mixed herding and hunting economy in the inner part of the fjord regions.

The Norse settlers survived in Greenland for almost 500 years. The Icelandic Sagas, however, report that the Western Settlement was found abandoned around 1350 AD reportedly due to hostile Inuit attacks. The decline of the Western Settlement also coincides with the onset of the climatic deterioration that followed the medieval warm period. The Eastern Settlement reportedly survived another 100 years. The last written source of information is an Icelandic anal from 1408, and recently a C-14 date has proven that a Norse burial took place in 1460 in the Eastern settlement (Arneborg et al. 2000). But when the Norse culture finally foundered is still an unsolved question.

The Western Settlement was less densely populated than the Eastern Settlement. According to the Icelandic Annals the Western Settlement housed 4 churches and 90 farms of which 'Sandnes' in the inner part of the Ameralik Fjord was the largest and most important. It has even been debated if Sandnes at an early date even was a bishop see just like Gardar in the Eastern Settlement.

Many archaeological investigations have taken place in the southern settlement where as these investigations has been sparser in the Western Settlement.

These archaeological investigations have proven many interesting aspects of the daily day life of the Norse farms in the Ameralik region. Even small changes in the climate and environment had at the time of the Norse era great impact on the life of these settlers. However, no detailed and continuos record of regional changes in these parameters are available from the terrestrial record of the Western Settlement. The aim of the A.v.Humboldt cruise in 2002 was therefore to retrieve a number of marine cores from the two main fjord of the Western Settlement area, which could provide a continuos record of climatic and environmental changes during the Norse era.

3.9 Jens Hesselbjerg Christensen and Sissi Kiilsholm, Danish Meteorological Institute

Climate change scenarios for Greenland

An improved understanding of the Artic climate system is necessary to provide quantitative assessments of the magnitude of global change and to clarify the role of the Arctic regions in the global climate system. Several intercomparison studies analyzed the performance of general circulation models (GCMs) in the Arctic. These results all indicate wide discrepancies in the simulated Arctic climate; large variations were found in simulated sea level pressure, precipitation, cloud cover and many other variables. The deficiencies of the GCMs in describing the Arctic climate are partly due to inadequate parameterizations of physical processes. Typical Artic phenomena like summertime stratus, ice crystal clouds and, during winter, very shallow boundary layer with strong inversions are not captured by current parameterizations. Moreover, current GCMs are characterized by a rather coarse horizontal resolution, which fails to capture mesoscale features caused by coastlines, ice sheets, sea ice margins, and mountains.

An approach to overcome the latter in climate modeling is limited area modeling wherein the horizontal resolution typical for mesoscale developments is applied to a particular region of interest. Forcing at the lateral boundaries using observation-based analysis avoids the import of large-scale errors from the GCMs. Such models are often referred to as regional climate models (RCMs). Here we present results from high-resolution (50 km) climate change simulations for an area covering the entire Arctic have been conducted with the RCM HIRHAM. The experiments were forced at the lateral boundary by large-scale atmospheric conditions from transient climate change scenario simulations performed with the Max Planck Institute for Meteorology coupled ocean atmosphere general circulation model (OAGCM) ECHAM4/OPYC3 with a resolution of ~300 km. The emission scenarios used were the IPCC SRES marker scenarios A2 and B2. We find that due to a much better representation of the surface topography in the RCM, the geographical distribution of present-day accumulation rates simulated by the RCM represents a substantial improvement compared to the driving OAGCM. Estimates of the regional net balance are also better represented by the RCM.

3.10 Martin Stendel, Danish Meteorological Institute

Permafrost zonation in a future climate

A climate change scenario experiment conducted with the state-of-the-art coupled atmosphere-ocean general circulation model ECHAM4/OPYC3 is analysed with the objective to quantify changes in present-day Arctic permafrost conditions. We use modelled deep soil temperatures to estimate the extent of present-day permafrost and the thickness of the 'active layer' of thawed upper soil and their evolution under climate change conditions. The active layer will deepen between 30 and 40%, with the largest increase concentrated in the northernmost Arctic locations. Further south, permafrost will recede further below the surface than the lowest model level.

3.11 Kim Gustavson, Kristine Garde, Torkel G. Nielsen and Anja Skjoldborg-Hansen.

Potential biological consequences of climate change in sea around Greenland

As a part of a larger project about climate changes in Greenland the biological consequences are evaluated. Such a evaluation are difficult and uncertain because most relevant physical and ecological investigations are conducted on local and short-term scale, i.e. less than three decades. Furthermore the present knowledge within this issue is attained from single studies, what means that only extrapolations from these to a larger context can help us determine the consequences of climate change for the ecology of aquatic ecosystems. The possibly effects of climate changes on primary production, food web structure and the balance between autotrophic and heterotrophic processes.

Currently, it is believed that the environmental factors, which exert the greatest control on the polar phytoplankton growth, are the low and relative invariant temperature, the presence or absence of sea ice and the extreme seasonal variations in the high-latitude light regimes. A global increase in temperature is expected to cause dramatic reduction and thinning of Arctic sea ice in summer which also have been confirmed by satellite observations. Based on the linear relationship between annual pelagic primary production and open water period it is expect that an increase in temperature to which increase the annual primary production. Relative to ice algae phytoplankton will get an increased importance and it is expected to prolong the growth season of zooplankton and thereby increase the production and abundance of secondary producers in Arctic waters.

The consequence of changing ice cover on the food web structure and production in western Greenland (Disko Bay) is analysed through application of a dynamic model for the planktonic food web (Skjoldborg-Hansen et al. 2002). A key element in these model are the migrations of Calanus spp. to surface layer from over-wintering depths. In the present study it is assume that Calanus spp. not are able to changes the behaviour as a consequence of rising temperatures and match the changes in the ice break. The study illustrated how a change in the ice cover in Arctic areas can potentially create a mismatch between spring primary production and copepode grazers. In the scenarios without ice-cover the planktonic food web is dominated by protozooplankton, resulting in lower export of organic material out of the photic zone despite increase primary productivity.

Based on the Q_{10} values (temperature coefficients) it appears that the Q_{10} values of the heterotrophic organisms, i.e. bacteria and zooplankton, is higher, that the autotrophic. This indicates that the process of the heterotrophic organisms, such as growth rate and bacteria production will be stimulated to a higher degree than the autotrophic ice-algae and phytoplankton. Studies have revealed higher relative bacterial activity compared to primary production upon temperature increase, which support this hypothesis.

Subject for further attention is finally discussed.

Project supported by DANCEA-Arctic Programme

3.12 Søren Rysgaard, Department of Marine Ecology. National Environmental Research Institute, Denmark

Climate responses on Arctic ecosystems. An example from NE Greenland.

Since the late 1970'ies an overall decrease in sea ice distribution has been observed in the Arctic. Prolonged ice-free periods have been documented on the east coast of Greenland. An ecosystem study from the high-arctic fjord, Young Sound, will be presented. The aim of this study is to link biological production to sea ice and hydrographic conditions in order to predict how expected changes in ice conditions and water column structure will affect high-arctic ecosystems in the future. The presentation will include a short description of Young Sound with respect to surrounding land, bathymetry, sea ice conditions, freshwater input and hydrography. Furthermore, primary production by phytoplankton, sea ice algae and underwater plants are discussed in relation to sea ice cover and hydrographic conditions. A tight coupling between primary producers and grazers in the water column of Young Sound is observed. Grazing in the water column, primarily by copepods, leads to a pulsed vertical export of organic matter to the sea floor where benthic animals and microbes are responsible for further degradation of the organic matter and regeneration of nutrients. The distribution and growth of the dominant bivalves in the fjord will be coupled to the walrus population in the area and discussed in relation to different sea ice conditions.

The regional atmosphere-ocean model (HIRHAM) predicts a temperature increase of 8°C at the end of this century that will lead to increase in freshwater runoff, thinning of the sea ice as well as an increase in ice-free conditions from 2.5 months to 4.7-5.3 months in Young Sound. Expected changes in carbon and nutrient cycling in the fjord, as a response to these future alterations will be discussed.

3.13 Bjørn Knudsen, Danish Meteorological Institute

Ozone depletion in the Arctic

Measurements indicate that stratospheric H_2O has increased by a factor of 2 since the 1950'ies. For 2/3 of the trend there is no scientific explanation. Radiative calculations suggest that this trend – if real - has a substantial effect on global warming and ozone depletion. The calculated radiative forcing 1960-2000 is about 75% of the CO_2 forcing. The H_2O trend results in cooling of more than 2 K in the Arctic lower stratosphere from 1960 – 2000. The cooling again leads to more widespread formation of polar stratospheric clouds (PSC), which enhance ozone depletion. The average PSC area correlates well with calculated total vortex ozone depletions. To estimate the future ozone losses highly significant trends in the average PSC areas 1958-2001 have been extrapolated to 2030. Even though a reduction in the ozone depleting substances is foreseen in the future, the ozone depletion increases in the next 10-20 years, if the trends in PSC areas continue.

3.14 *Kim Gustavson[1], Kristine Garde[1], Jørgen Bille-Hansen[2] og Paul Eriksen[3]*

[1] DHI – Institut for Vand og Miljø
[2] ASIAQ/Grønlands forundersøgelser
[3] Danmarks Meteorologiske Institut

Biologiske effekter af UVB stråling i arktiske havområder

UV-B-indstrålingen i arktiske miljøer er ikke ubetydelig til trods for de lave niveauer af UV-B- stråling. Dette skyldes bl.a., at en stor del af UV-B- strålingen er diffus pga. den lave solhøjde, refleksionen fra is- og sneklædte overflader samt dagens længde. Lægges dertil de kraftige UV-B-impulser, der kan opnås ved store udtyndinger af ozonlaget (huller) samt en større UV-B-følsomhed hos arktiske organismer, anslås det, at den biologiske effekt i Arktis er betydelig.

I projekter støttet af DANCEA/Arktisk Miljøstøtte er mulige effekter af UVB på planktonalger og bakterier i havområder ved Disko og Nuuk undersøgt. Undersøgelser viser effekter af UV-B ned til 6 meters dybde og en sammenhæng mellem UVB-dosis og effekter er fastlagt. Til sammenligning er der målt effekter af UVB på planktonalger ned til 10 meters dybde i farvande ved Thromsø (Helbling et al. 1999).

ASIAQ og DMI driver i dag en række landbaseret målestationer, som tilsammen dækker store geografiske områder af Grønland. I projektet er grundlaget for kalibrering og sammenligning af disse måledata foretaget. Grundlaget for en risikovurdeing for UVB i Arktiske områder er forbedret.

4. TILMELDTE DELTAGERE

NAVN	INSTITUTION / VIRKSOMHED
Uffe J. Andersen	Danmarks Meteorologiske Institut
John Anderson	GEUS
Peter Bondo	Danmarks Miljøundersøgelser
Erik Buch	Danmarks Meteorologiske Institut
John Cappelen	Danmarks Meteorologiske Institut
Jens H. Christensen	Danmarks Meteorologiske Institut
Bettina Christiansen	Danmarks Meteorologiske Institut
Paul Eriksen	Danmarks Meteorologiske Institut
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Mads C. Forchhammer	Københavns Universitet
Lars From	Jyllandsposten
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Kim Gustavson	DHI – Institut for Vand og Miljø
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Søren Rysgaard	Danmarks Miljøundersøgelser
Torben Schmith	Danmarks Meteorologiske Institut
Martin Stendel	Danmarks Meteorologiske Institut
Gabrielle Stockmann	Dansk Polarcenter

DANMARKS KLIMACENTER

Danmarks Klimacenter blev oprettet ved Danmarks Meteorologiske Institut i 1998. Centrets hovedformål er at kortlægge den sandsynlige klimaudvikling i det 21. århundrede - globalt og i Danmark - herunder fremtidige klimaændringers indflydelse på de danske, grønlandske og færøske samfund.

Klimacentrets aktiviteter omfatter udvikling af nye og forbedrede metoder til satellitbaseret klimaovervågning, studier af klimaprocesser (inklusive sol-klima relationer, drivhuseffekt, ozonens rolle og luft/hav/havis vekselvirkning), udvikling af globale og regionale klimamodeller, sæsonprognoser samt udarbejdelse af globale og regionale klimascenarier til effektstudier.

Klimacentret er organiseret med et sekretariat i DMI's Forsknings- og udviklingsafdeling og koordineres af forskningschefen.

Klimacentret har etableret Dansk Klimaforum, som er et forum til udveksling af resultater og viden og til drøftelse af klimaspørgsmål. I Klimaforum afholdes temadage og workshops med deltagelse af klimaforskere og andre, der har interesse i centrets aktiviteter. I 2000 blev Klimaforum udvidet i overensstemmelse med den danske handlingsplan "Klima 2012", og arrangementerne omfatter nu også policyemner. Der er etableret en styregruppe med deltagere fra Energistyrelsen (sekretariat), DMI, Dansk Industri og 92-gruppen.

Centret udgiver et populært nyhedsbrev, KlimaNyt, som udkommer 2 gange årligt. KlimaNyt kan også ses på www.dmi.dk.

DMI har udført klimaovervågning og -forskning siden oprettelsen i 1872 - og oprettelsen af Danmarks Klimacenter har styrket både klimaforskningen på DMI og samarbejdet med forskningsinstitutioner i Danmark og det øvrige Europa.

Tidligere publikationer fra Danmarks Klimacenter:

Rapport 98-1 Dansk Klimaforum 29. - 30. april 1998. (Åbning af Danmarks Klimacenter, Referater fra workshop, Resumé af præsentationer).

Rapport 99-1 Danish Climate Day 1999.

Rapport 99-2 Dansk Klimaforum 12. april 1999. Workshop: Klimatisk variabilitet i Nordatlanten på tidsskalaer fra årtier til århundreder.

Rapport 99-3 Luftfart og den globale atmosfære, Danmarks Meteorologiske Instituts oversættelse af IPCC's særrapport "Aviation and the Global Atmosphere, Summary for Policymakers".

Rapport 00-1 Forskning og Samarbejde 1998-1999.

Rapport 00-2 Drivhuseffekten og regionale klimaændringer.

Rapport 00-3 Emissionsscenarier, Danmarks Meteorologiske Instituts oversættelse af IPCC's særrapport "Emission Scenarios, Summary for Policymakers".

Rapport 00-4 Metoder mødes: Geofysik og emner af samfundsmæssig interesse, Dansk Klimaforums Workshop 15.-16. maj 2000.

Rapport 00-5 A time-slice experiment with the ECHAM4 A-GCM at high resolution: The simulation of tropical storms for the present-day and of their change in the future climate. Wilhelm May.

Rapport 00-6 The climate of the 21st century: Transient simulations with coupled atmosphere-ocean general circulation model. Martin Stendel, Torben Schmith, Erich Roeckner and Ulrich Cubasch. (revideret version; se rapport nr. 02-1).

Bog Climate Change Research – Danish Contributions. Redigeret af Anne Mette K. Jørgensen, Jes Fenger og Kirsten Halsnæs. DMI/Danmarks Klimacenter, 2001. 408 sider. Distribueres af Gads Forlag.

Rapport 01-1 Changes in the storm climate in the North Atlantic/European region as simulated by GCM time-slice experiments at high resolution. Uffe J. Andersen, Eigil Kaas and Wilhelm May.

Rapport 01-2 Klimadag den 26. april 2001; Klimaændringer og deres virkninger - Præsentation af tværfaglig bog om danske bidrag til klimaforskningen.

Rapport 01-3 Synthesis of the STOWASUS-2100 project: Regional storm, wave and surge scenarios for the 2100 century. Eigil Kaas, et.al.

Rapport 01-4 Danmark, Færøernes og Grønlands Klima. DMI's afrapportering til FN's Klimakonvention UNFCCC.

Rapport 01-5 Danmarks vejr og klima i det 20. århundrede. John Cappelen og Niels Woetmann Nielsen.

Rapport 01-6 Using the nudging technique to estimate climate model forcing residuals. A contribution to the ACE Scientific Support Study. Eigil Kaas and Annette Guldberg.

Rapport 01-7 Detection of the Pinatubo volcanic heating signal in the lower stratosphere based on nudging assimilation and analysis increments. A contribution to the ACE Scientific Support Study. Eigil Kaas, Annette Guldberg and Ingo Kirchner.

Rapport 01-8 PRUDENCE kick-off meeting, Snekkersten, December 3-5, 2001. Jens Hesselbjerg Christensen.

Rapport 01-9 Klimaændringer 2001, Den videnskabelige baggrund. En rapport fra IPCC's arbejdsgruppe I, Resume for beslutningstagere: Danmarks Meteorologiske Instituts oversættelse af: Climate Change 2001 – The Scientific Basis, A report from Working Group I of the International Panel on Climate Change, Summary for Policymakers.

Rapport 02-1 The climate of the 21st century: Transient simulations with coupled atmosphere-ocean general circulation model. Revised version. Martin Stendel, Torben Schmith, Erich Roeckner and Ulrich Cubasch.