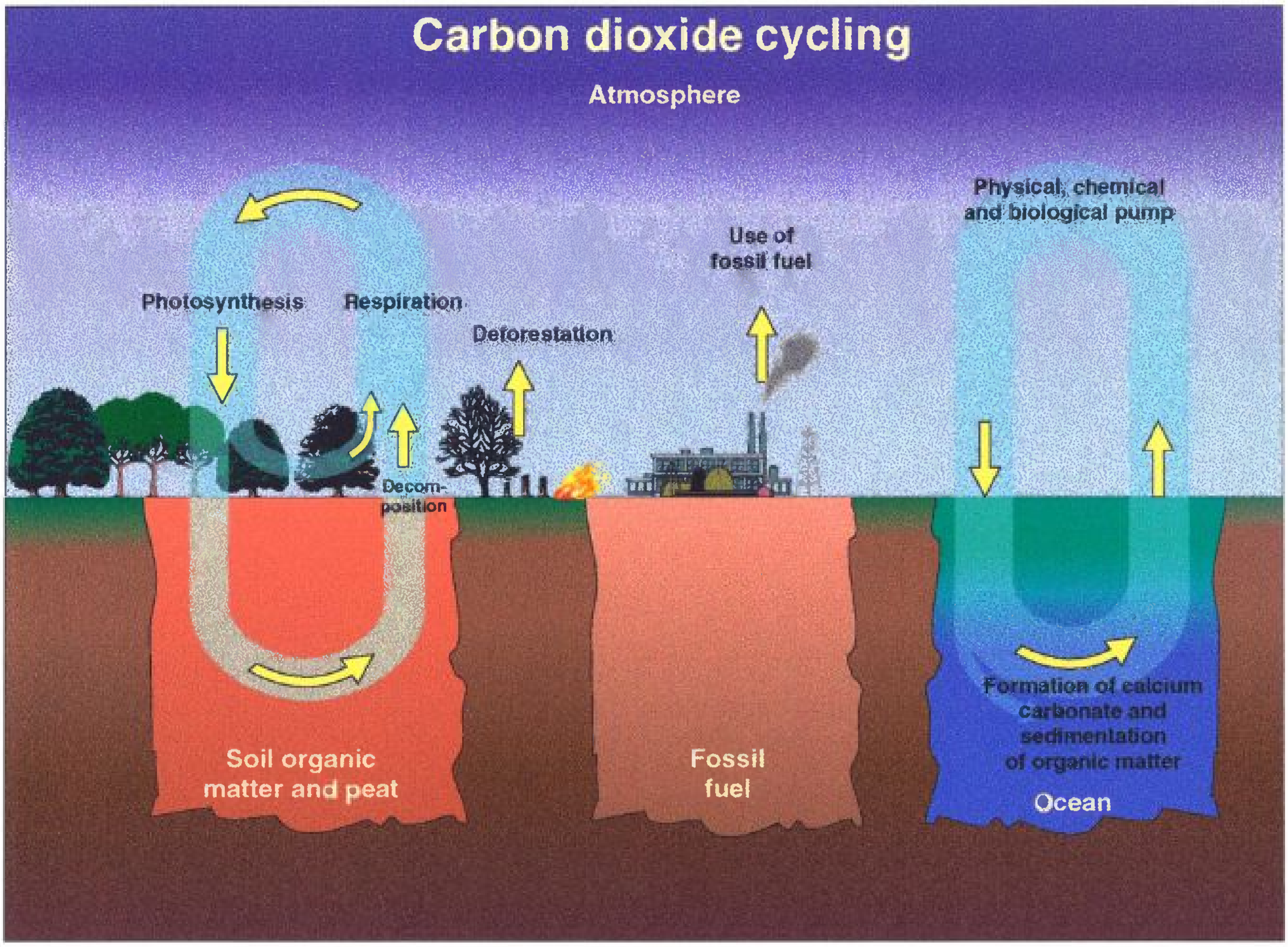
The Norwegian Climate and Ozone Research Programme



Workshop

Solstrand Fjord Hotel, Os

11-12 March, 1996

Norges forskningsråd

NILU

NILU	OR 15/96
REFERENCE	O-95103
DATE	MARCH 1996
ISBN	82-425-0750-3

The Norwegian Climate and Ozone Research Programme

Workshop
11-12 March, 1996
Solstrand Fjord Hotel, Os

Elin Dahlin (ed.)

Preface

The Norwegian Climate and Ozone Research Programme, Norwegian Research Council, started in 1989. Workshops have been organized every second year by the board of the research programme, and many of the participants in the programme have been invited to present their work and to learn about the research that is carried out within the programme as a whole.

The programme for this year's workshop reflects that there is a growing body of information about regional consequences of climate change and even ozone layer depletion. The international climate research effort over the last years has strengthened the scientific basis for the conclusion that there is a global warming taking place and that there is an anthropogenic contribution to that warming. But the discussion about what the regional consequences will be for Scandinavia has widened the prospects rather than narrowed them lately, with doubt being introduced even about the sign of the temperature change that we can expect over the next century or so. Perhaps this workshop can enlighten us about what the prospects are for the climate and ecosystems in Scandinavia in the future.

Øystein Hov
Chairman of the Board
The Norwegian Climate and Ozone Research Programme

Index

Page

Abstracts in order of presentation

Workshop
Solstrand Fjord Hotel, Os
11-12 March, 1996

Programme

Monday 11 March, 1996

1130-1200	Registration
1200-1245	Lunch
1245-1300	Welcome by Øystein Hov, UiB, Chairman of the Board, The Norwegian Climate and Ozone Research Programme

Session 1: Regional Effects of Climate Change with Emphasis on Ecology
Chairman: Audun Rosland, SFT

1300-1330	Richard F. Wright, NIVA: "CLIMEX: Climate Change Experiment".
1330-1350	Ørjan Totland, UiB: "Research on Possible Effects of Global Warming on Alpine and Arctic Plants".
1350-1410	Hilary H. Birks, UiB: "The Kråkenes Project: A Multidisciplinary Study of the Impact of Late-glacial Climatic Changes on Biota and Ecosystems".
1410-1430	John Birks, UiB: "The KILO project - Climatic Change and Forest Ecosystems in Nothern Norway and Sweden over the Last 10,000 Years: A Quantitative Palaeoecological Study".
1430-1450	*Coffee break*
1450-1510	Karl-Dag Vorren, UiTø: "The Effects of Climatic Changes on Forest Lines and Radial Pine Tree Growth During the Last 100-1,000 Years".
1510-1530	*Discussion*

Session 2: Climate Research Related to the North Atlantic
Chairman: Lars Petter Røed, DNMI

1530-1550	Sigbjørn Grønås, UiB (invited speaker): "The Increased Atmospheric Greenhous Effect and Regional Climate Change".
1550-1610	Trond Iversen, UiO: "Climatic Impacts of Anthropogenic Aerosols".
1610-1640	Helge Drange, NERSC: "A Coupled Physical-Biogeochemical Model for the Seasonal Cycling of Carbon and Nitrogen in the Ocean".
	Truls Johannessen, UiB: "The Carbon Cycle in the Nordic Sea".
1640-1650	*Coffee break*
1650-1710	Svein Østerhus, UiB (invited speaker): "Change in the Deep Water Formation in the North Atlantic".
1710-1730	Ingunn Skjelvan, UiB: "Instrumentation and Analytical Methods in Carbon Balance Studies - Inorganic Components in a Marine Environment".
1730-1750	Sigrún Karlsdóttir, UiO: "Methane as a Climate Gas".
1750-1810	Rasmus E. Benestad, Oxford University: "An Introduction to *El Nino Southern Oscillation* (ENSO): Its Causes and its Implications for the Local and Global Climate".
1810-1830	*Discussion*
1830-1840	Presentation of the IPCC Second Assessment Report (UN Climate Panel) Working Group 1, by Ivar Isaksen, UiO.
1840-1935	Video presentation (for those who are interested) - "The Arctic Tundra in a Changing Climate" (ITEX-prosjektet) - "A Short Story of the Ozon Layer"
2000	*Dinner*

Tuesday 12 March, 1996

Session 3: What Lessons can be drawn from Paleoclimatology about Changes in the Current Climate?

Chairman: Naja Mikkelsen, Danmarks Geologiske Undersøgelser

0900-0930	Nalân Koç, UiB: "Rapid Climatic Fluctuations into and out of Interglacials"
0930-0950	Jan Mangerud, UiB: "Interglacial and Glacial Paleoclimates in NW-Russia".
0950-1010	Hans Petter Sejrup, UiB: "Climatic Implications of New (Old?) Views on the Glaciation of Southern Fennoscandia and the North Sea".
1010-1030	*Coffee break*
1030-1050	Morten Hald, UiT: "Rapid Climatic Changes During Early Post-Glacial Time: Evidence from the Euro-Arctic Continental Margin".
1050-1110	Lars Harald Blikra, NGU: "Climatic Change and Avalanche Hazard".
1110-1130	*Discussion*

Session 4: Changes in the Ozone Layer and their effect on UV and Biology

Chairman: Øystein Hov, UiB

1130-1200	Geir O. Braathen, NILU: "Use of Ozonesondes to Identify Stratospheric Ozone Change Caused by Chemical Processes".
1200-1220	Kjersti Karlsen, NILU "UV-VIS Spectroscopy Applied to Stratospheric Chemistry, Methods and Results".
1220-1310	*Lunch*
1310-1330	Berit Kjeldstad, NTNU: "Spectral Ultraviolet-B Radiation Fluxes at the Earth- and Ocean-Surface: Are there Long-term Variations?"

1330-1350	Jan Borgeraas, UiO: "Effects of UV-Radiation on Plankton".
1350-1410	Gunnar Ogner, NISK: "Effects of Increased Temperature and CO_2 on Soil Quality".
1410-1430	*Discussion*
1430-1440	Presentation of the IPCC Second Assessment Report (UN Climate Panel) Working Group 2, by Jon Barikmo, DN.
1440-1450	Kirsten Broch Mathisen, Norwegian Research Council: Information about the Norwegian Climate and Ozone Research Programme.
1450-1500	Concluding remarks Anton Eliassen, DNMI.
1510	*Bus departure for Flesland Airport*

Seminar: Climate and Ozone Research in Norway Solstrand Fjord Hotel, 11-12 March 1996

CLIMEX Climate Change Experiment

Richard F. Wright
Norwegian Institute for Water Research
Box 173 Kjelsås
0411 Oslo

tel: +47 22185204
fax: +47 22185200
E-mail: richard.wright@niva.no

Summary

CLIMEX (Climate change experiment) is an international, interdisciplinary research project in which atmospheric CO_2 levels and temperature are experimentally altered at 2 complete forested headwater catchments. The objective of CLIMEX is to investigate directly the integrated ecosystem-scale response of vegetation, soils and runoff water to future global change. CLIMEX is the only such experiment at which the fluxes of gases, water and chemical components across the atmospheric-terrestrial and terrestrial-aquatic interfaces are measured.

The CLIMEX site is located at Risdalsheia, near Grimstad, southernmost Norway, in upland terrain characteristic of large areas of the northern boreal forest. Vegetation is sparse pine-spruce forest on thin and patchy soils developed from granitic glacial materials. The site was established in 1983 as part of the Norwegian RAIN project (Reversing Acidification In Norway), and was modified in 1993 to accommodate the CLIMEX treatments. CLIMEX comprises 2 separate but related climate change experiments. At KIM catchment (860-m^2) a transparent greenhouse completely encloses the forested catchment. Here CO_2 levels are raised to 560 ppmv during the growing season, and the air temperature is raised 3°C above ambient in the summer and 5°C above ambient in the winter. At EGIL catchment (400-m^2) an open-sided roof structure covers the catchment. Here soil temperatures are raised above ambient by 3-5°C by means of electric heating cables placed on the soil surface. At both KIM and EGIL catchments the uppermost 10-20 % of the catchment is not treated and provides control plots for vegetation and soil investigations. Three adjacent catchments serve as untreated references.

Scientific investigations at CLIMEX encompass vegetation, soils, water and gases. The ecosystem-scale responses are integrated by means of models. Studies include: (1) phenology and photosynthesis in trees, (2) growth, nutrition and nutrient cycling in trees and shrubs, (3) soil fauna and decomposition processes, (4) soil and soil solution chemistry, (5) soil and catchment hydrology, (7) ecosystem fluxes of water and chemical components, and (8) fluxes of trace gases.

CLIMEX began in December 1993 with construction and installation of technical equipment and collection of background data. Increased CO_2 and temperature treatment began April 1994. One year of background data and 1 1/2 years of treatment data are available. In addition there are 10 years of soil and runoff chemistry data from the catchments obtained during the RAIN project.

The ecosystem effects of these climate changes can be viewed as a *cascade of response*. Increased CO2 and temperature at KIM catchment resulted in an immediate response by the above-ground vegetation. The growing season was extended both with earlier bud-burst and leaf-out in the spring and delayed senescense and leaf fall in the autumn. Leaf photosynthetic rate increased. Stomatal density decreased. Shrubs showed increased biomass. These changes are in time expected to affect soil processes such as decomposition and nutrient uptake, but measurements during the first 2 growing seasons indicate that the soil response is not yet manifest. Changes in soil processes are expected to then lead to changes in soil solution and runoff chemistry as well as trace gas fluxes, but here again these have not yet been observed.

At EGIL catchment the soil warming apparently *short-cuts* the cascade of response. Here after 2 growing seasons the above-ground immediate response by the plants is lacking because neither the air temperature nor CO2 level is changed. Increased soil temperature, on the other hand, has apparently resulted in increased release of nitrogen, which appears as significantly higher concentrations of both nitrate and ammonium in runoff.

At both experiments additional years of treatment are necessary to evaluate transient responses, to determine longer-term trends, and to give these ecosystems the time necessary to respond to cascade of changes induced by step-changes in climatic conditions. To date CLIMEX is the only whole-ecosystem experiment with mature trees *in situ* in which the links between the atmosphere, terrestrial and aquatic ecosystems can be followed directly. CLIMEX contributes to the GCTE (Global Change & Terrestrial Ecosystems) Core Project of the IGBP (International Geosphere-Biosphere Programme).

Key CLIMEX Publications

Beerling, D. J. and Woodward, F.I. 1994. The climate change experiment (CLIMEX): Phenology and gas exchange responses of boreal vegetation to global change. Global Ecology and Biogeography Letters 4, 17 - 26.

Dise, N.B. and Jenkins, A. (Eds) 1995. The CLIMEX Project: Whole Catchment Manipulation of CO_2 and Temperature. Climate Change Research Report 3/95, Norwegian Insitute for Water Reaserch, Oslo, 130pp.

Jenkins, A. and Wright, R.F. 1995. The CLIMEX Project: Performance of the Experimental Facility During the First Year of Treatment. p. 323-327, In: Jenkins, A., Ferrier, R.C. and Kirby, C. (Eds) Ecosystem Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystem Research Report 20. Commission of the European Communitites, Brussels, 374 pp.

Lükewille, A., Arp, W., Verburg, P., Jenkins, A. and Wright, R.F. 1995. The CLIMEX soil heating experiment at Risdalsheia, Southern Norway. p. 331- 334. In: Jenkins, A., Ferrier, R.C. and Kirby, C. (Eds) Ecosystem Manipulation Experiments: Scientific

Approaches, Experimental Design, and Relevant Results. Ecosystem Research Report 20. Commission of the European Communitites, Brussels, 374 pp.

Verburg, P., and van Breemen, N. 1995. Effects of climate change on decomposition of soil organic matter in a boreal ecosystem. p. 557-560, In: Zwerver, S., van Rompaey, R.S.A.R., Kok, M.T.J., and Berk, M.M. (Eds.) Climate Change Research: Evaluation and Policy Implications. Studies in Environmental Science 65A, Elsevier Science, Amsterdam, 674 pp.

Jenkins, A. (Ed) 1995. CLIMEX Climate Change Experiment: Final Report on Phase 1 the first year of treatment May 1994 - December 1994. Climate Change Research Report 4/95, Norwegian Institute for Water Research, Oslo, 47 pp.

Research on possible effects of global warming on alpine and arctic plants

Ørjan Totland
Botanical Institute, University of Bergen, Allégaten 41, N-5007 Bergen, Norway

Abstract
Predicted future climate warming may result in large changes in the environmental conditions for the plants that surround us, and these changes are assumed to be greatest for alpine and arctic plants. At present, we know little about the potential consequenses of climate change on these plants, despite extensive research efforts on these topics. The International Tundra Experiment (ITEX) is a co-operative unit of researchers that aims to examine how alpine and arctic plants will respond to future climate change. At present, ITEX-research is done at 26 sites spread around the northern hemisphere. Finse in south Norway is one such site. ITEX has adopted an experimental approach. It uses small open-topped greenhouses that passively increase temperature by ca. 2-4°C immediately around the plants being investigated to examine how changed environmental conditions, and especially increased temperatures affect the plant species under consideration. ITEX has developed a standardized methodology that is used on species common among the sites. This makes it possible to compare responses to the experimental manipulations on different populations of the same species across large parts of the species distributional range. ITEX ask four basic questions in its research; (1) How will the environmental conditions that the plants experience be changed as a result of experimental temperature changes? (2) Are populations of arctic and alpine plant species able to accomodate warmed climate conditions over the long term? (3) Will experimental warming result in a shift in the selective regime experienced by the plants? (4) Are populations of alpine and arctic plants able to change through evolutionary adaptations as a response to the future climate change? To answer these questions phenological-, growth-, and reproductive responses of experimentally warmed plants are compared to those of control plants.

Finse was selected as an ITEX-research site in 1993, and since then, ITEX-studies on seven species have been initiated there. The results so far suggest that plants at Finse will increase their growth rates and reproductive output, and that they will accelerate their growth, flowering, and fruiting phenology in response to experimental warming. These results are in close agreement to those found for others species at other ITEX-sites. Thus, it is now well established that many arctic and alpine plants will actually benefit from temperature increase, at least in the short-term. However, our knowledge on the effects of changes in species interactions, e.g. competition and herbivory, as a result of increased migration rates by low-land species into alpine and arctic areas is largely lacking. Such interactions can be of great importance in influencing the ability of alpine and arctic plant to withstand climate warming. As a consequence, the ITEX-research effort will increasingly be concentrated around such questions in the future.

The Kråkenes Project: a multidisciplinary study of the impact of late-glacial climatic changes on biota and ecosystems

Hilary H. Birks
Botanical Institute, University of Bergen

Kråkenes Lake lies on an exposed peninsula on Vågsøy Island, western Norway (62° 02'N, 5° 00'E). Its deepest sediments were deposited during the late-glacial period, when climate changed irregularly from glacial to interglacial conditions. Around 12,300 ^{14}C yr BP, the ice sheet withdrew and deposition started in Kråkenes Lake. During the return to cold climatic conditions in the Younger Dryas (10,700 - 10,000 ^{14}C yr BP), a cirque glacier developed on the mountain behind Kråkenes, and its outflow entered the lake directly, depositing laminated silts and sand. In response to warming at the opening of the Holocene (10,000 ^{14}C yr BP) the glacier melted rapidly. Large-scale minerogenic sedimentation ceased and organic sediments accumulated in the lake.

These sediments hold a fossil record of the contemporary biota in and around the lake that can be used to reconstruct the terrestrial and aquatic ecosystems and their reactions to the dramatic climatic and environmental changes during the late-glacial and early Holocene periods.

Because of the potential interest of the Kråkenes sequence demonstrated by the original study of Larsen *et al.* (1984), a multi-disciplinary study on new cores was initiated by Hilary H. Birks in 1993. An international group of 24 scientists are studying glacial geomorphology, sedimentology of the Younger Dryas laminations, palaeomagnetism, radiocarbon (AMS) dating, identification and dating of volcanic ash layers, stomatal density and CO_2 reconstruction, and biological indicators including pollen and spores, plant macrofossils, mosses, diatoms, chrysophytes, other algae, fungi, siliceous protozoa, Bryozoa, Oribatid mites, Cladocera, Chironomidae, Coleoptera, and Trichoptera. A major focus of the Kråkenes Project is to reconstruct the past changes in the ecosystems, both terrestrial and aquatic. Because of the high sedimentation rate, decadal or less sampling can be used, especially over periods of rapid climatic changes. The project has been described by Birks *et al.* (1996a).

Leaves of *Salix herbacea* (dwarf willow) are common throughout the sequence. They have been used for 60 AMS radiocarbon dates that, together with whole sediment dates, provide the most detailed radiocarbon chronology for this period (Gulliksen *et al.*, in preparation). The stomatal density of the leaves has been used to reconstruct late-glacial changes in atmospheric CO_2 concentrations (Beerling, Birks & Woodward, 1995). To these results will be added stable carbon isotope ($\delta^{13}C$) measurements (Beerling, 1996). The high-resolution of the Kråkenes CO_2 record is much more detailed than those from ice cores. The mid-Younger Dryas Vedde Ash and the early Holocene Saksunarvatn Ash have been identified and closely dated by AMS (Birks *et al.*, 1996b). These are geographically widespread time markers. The above results have a wide-ranging or global significance in Younger Dryas research.

The presentation at the NFR symposium by Hilary H. Birks will concentrate on the terrestrial and aquatic vegetational responses over the Younger Dryas/Holocene boundary. The rapid climatic amelioration (*ca.* 10-20 yr according to the Greenland ice-core data) at the end of the Younger Dryas had widespread effects throughout the North Atlantic region. The high rate of sedimentation over this period at Kråkenes has allowed fine time-resolution sampling, for radiocarbon dating and for plant macrofossil and pollen analyses. Calibration against the German dendrochronological time-scale has fixed the age of the boundary at 11,300 ± 45 calendar yr BP (Gulliksen *et al.*, 1996), and enabled a calendar year timescale to be applied to the subsequent vegetational changes.

The vegetational changes have been reconstructed from detailed macrofossil (H.H. Birks) and pollen analyses (S.M. Peglar) on the same core, aided by numerical analyses of the data (H.J.B. Birks). The vegetational succession at Kråkenes resembles those found today on recently deglaciated landscapes in Scandinavia, but with some differences in rates of development related perhaps to continuing climatic limitations, or to the relatively long distances from the nearest populations in the early Holocene.

The results from the Kråkenes Project are in the process of being published in international scientific journals, as listed below. The total number may reach 30. Some popular scientific articles are planned, e.g. in 'Naturen', and aspects of the project have been reported in the Norwegian press. Two Masters (Cand. Scient.) projects have been successfully completed on the Kråkenes material, in palaeomagnetism and sedimentology.

References

Beerling, D.J., Birks, H.H. and Woodward, F.I. (1995). Rapid late-glacial atmospheric CO_2 changes reconstructed from the stomatal density record of fossil leaves. Journal of Quaternary Science 10: 379-384.

Beerling, D.J. (1996). $\delta^{13}C$ discrimination by fossil leaves during the late-glacial climate oscillation 12-10 ka BP: measurements and physiological controls. Oecologia in press.

Birks, H.H. + 23 others. (1996a). The Kråkenes late-glacial palaeoenvironmental project. Journal of Paleolimnology in press.

Birks, H.H., Gulliksen, S., Haflidason, H., Mangerud, J. and Possnert, G. (1996b). New radiocarbon dates for the Vedde Ash and the Saksunarvatn Ash from western Norway. Quaternary Research in press.

Brooks, S.J. (1996). The response of Chironomidae (Insecta: Diptera) assemblages to late-glacial climatic change in Kråkenes Lake, western Norway. Submitted.

Gulliksen, S., Possnert, G., Birks, H.H. and Mangerud, J. (1996). The calendar age of the Younger Dryas/Holocene transition at Kråkenes. In preparation.

Hauge, F. (1995). Paleomagnetisk korrelasjon av Yngre Dryas lakustrine sedimenter fra Møre, Nordvest-landet. Thesis, University of Bergen.

Jonsgard, B. and Birks, H.H. (1996). Late-glacial mosses and environmental reconstructions at Kråkenes, western Norway. Lindbergia in press.

Kårevik, M. (1995). Seinglasial sedimentasjon i Kråkenesvatnet, Vågsøy, Sogn og Fjordane. Thesis, University of Tromsø.

Larsen, E., Eide, F., Longva, O. and Mangerud, J. (1984). Allerød - Younger Dryas climatic inferences from cirque glaciers and vegetational development in the Nordfjord area, western Norway. Arctic and Alpine Research 16: 127-160.

van Dinter, M. and Birks, H.H. (1996). Distinguishing *Betula nana* and *B. pubescens* using their wingless fruits: implications for the vegetational history of the west Norwegian late-glacial. Vegetation History and Archaeobotany, submitted.

THE KILO PROJECT - CLIMATIC CHANGE AND FOREST ECOSYSTEMS IN NORTHERN NORWAY AND SWEDEN OVER THE LAST 10,000 YEARS: A QUANTITATIVE PALAEOECOLOGICAL STUDY

H.J.B. Birks and Sylvia M. Peglar
Botanical Institute, University of Bergen, N-5007 Bergen

Quantitative palaeoecology involves the numerical analysis and statistical modelling of palaeoecological data, such as counts of pollen, diatoms, etc. preserved in peats and lake sediments. Scandinavia was the birthplace of modern Quaternary pollen analysis and a very wide range of descriptive and qualitative palynological studies have been produced. Little attention has, however, been paid to quantitative approaches. These can be used to advantage to establish, for example, the numerical relationships between modern pollen and modern climate and to reconstruct quantitatively past climate from fine-resolution pollen sequences.

A regional pollen assemblage at a particular time and place is a function of the regional flora and vegetation. As these are largely influenced by regional climate, there is a relationship, admittedly a complex one, between regional pollen and regional climate. If this relationship can be quantified for the present-day, fossil pollen data from lake sediments can thus be used to reconstruct past regional climates for the last 9-10,000 years. The general theory is as follows. If Y represents the biological responses, in our case pollen assemblages, X the environmental variables causally related to Y (e.g. mean July temperatures), and U the empirical regression coefficients based on the observed patterns of Y in modern surface-muds in relation to X, we need to solve

$$Y=U\,(X)$$

We estimate U_m, the modern coefficients by regression using the modern training set Y_m (modern pollen) and X_m (modern climate),

$$Y_m=U_m\,(X_m)$$

Given Y_f, the fossil pollen data, we can reconstruct X_f, the past climate from

$$X_f=\hat{U}_m\,(Y_f)$$

where $\hat{U}_m \equiv U^{-1}$.

The aims of the KILO (<u>KI</u>runa - <u>LO</u>foten) project are to answer the following questions: (1) how accurately do modern pollen assemblages preserved in surface lake-sediments from Norway reflect modern climate?; (2) using a modern pollen-climate training set, can we use fossil pollen assemblages preserved in lake sediments to reconstruct climatic parameters over the Holocene (last 10,000 years)?; (3) how have vegetation and climate changed along the strong west-east vegetational and climatic gradients in northern Norway and Sweden since deglaciation?

A training set of 191 modern pollen and associated climatic variables has been developed from small, low-lying lakes throughout Norway and northern Sweden. Statistical methods of partial least squares (PLS) and weighted averaging PLS (WA-PLS) have been used to model modern pollen-climate relationships. The predictive power of this training set has been assessed by statistical cross-validation (jack-knifing) to derive root mean square errors of prediction for mean July temperature (0.94°C), mean January temperature (3.06°C), and annual precipitation (353 mm).

The second part of the project concerns the Holocene pollen stratigraphy and vegetational and climatic history along the strong west-east climatic gradient in northern Norway and Sweden. Sediment cores were collected from seven lakes, comparable in size and morphometry with the training-set lakes and critically positioned near present-day ecotonal boundaries, along a west-east transect from Vesterålen to east of Kiruna. So far, detailed pollen analyses have been completed at five of the lakes along the transect - Alanen Laanijärvi near the western range limit of *Picea abies* (spruce) just east of Kiruna; Vuoskojaurasj in the sub-alpine birch forest just east of Abisko near the western limit of pine east of the main mountain ranges in Swedish Lappland; Austerkjosen near Østervik in the zone of mixed birch and pine forest today; Myrvatnet just at the western range limit of pine on Hinnøya, and Litlevatnet in the western birch forest zone on Vesterålen.

The pollen stratigraphy at Vuoskojaurasj (Fig. 1) covers the last 9000 ^{14}C years (10125 calender years). After a pioneer phase of *Salix, Juniperus, Hippophae rhamnoides,* and herbs, *Betula* forest rich in ferns developed at *ca.* 8000 BC (9000 ^{14}C years ago). The forest opened and possibly was less mesic at *ca.* 6400 BC (7500 ^{14}C years ago) with the expansion of *Juniperus. Pinus* became a forest dominant from 5700 (6800 ^{14}C years ago) to 2900 BC (4200 ^{14}C years ago) but persisted locally until 1350 BC (3000 ^{14}C years ago). *Alnus incana* (grey alder) occurred locally between 5700 (6800 ^{14}C years ago) and 2900 BC (4200 ^{14}C years ago). It is absent from the area near the lake today. Sub-alpine birch forest rich in Ericaceae (heaths) developed in the last 3300 years.

Quantitative climatic reconstructions for Vuoskojaurasj using the modern pollen-climate training set suggests that mean July temperatures were *ca.* 0.5-1°C warmer than today (11°C) from *ca.* 8000 to 6400 BC and that annual precipitation (600-700 mm) was considerably higher than today (350 mm). Between 5700 and 2900 BC mean July temperatures were 1.5-2°C warmer than today whereas annual precipitation was only slightly greater (*ca.* 400 mm) than today. Pine became locally extinct when mean July temperature fell to 11.5°C. In the last 3300 years mean July temperature and precipitation were similar to modern values. Superimposed on these general climatic trends, the quantitative reconstructions also suggest short, rapid phases of climatic change, particularly between 2910 and 4200 BC.

The pollen stratigraphy from Alanen Laanijärvi east of Kiruna suggests that little vegetational change has occurred there over much of the Holocene, with dominant *Pinus* throughout. To the west of the mountains, the pollen stratigraphy at Austerkjosen suggests changes in the forest vegetation, in particular of the abundance of *Alnus incana*, ferns, and *Pinus*. At Myrvatnet, right at the western range limit of *Pinus* today in northern Norway the forest composition does not appear to have changed greatly, except that pine may have declined in absolute abundance in the last *ca.* 2000 years. The pollen stratigraphy from Litlevatnet suggests little change in forest composition during much of the Holocene, with a dominance of fern-rich birch woods throughout.

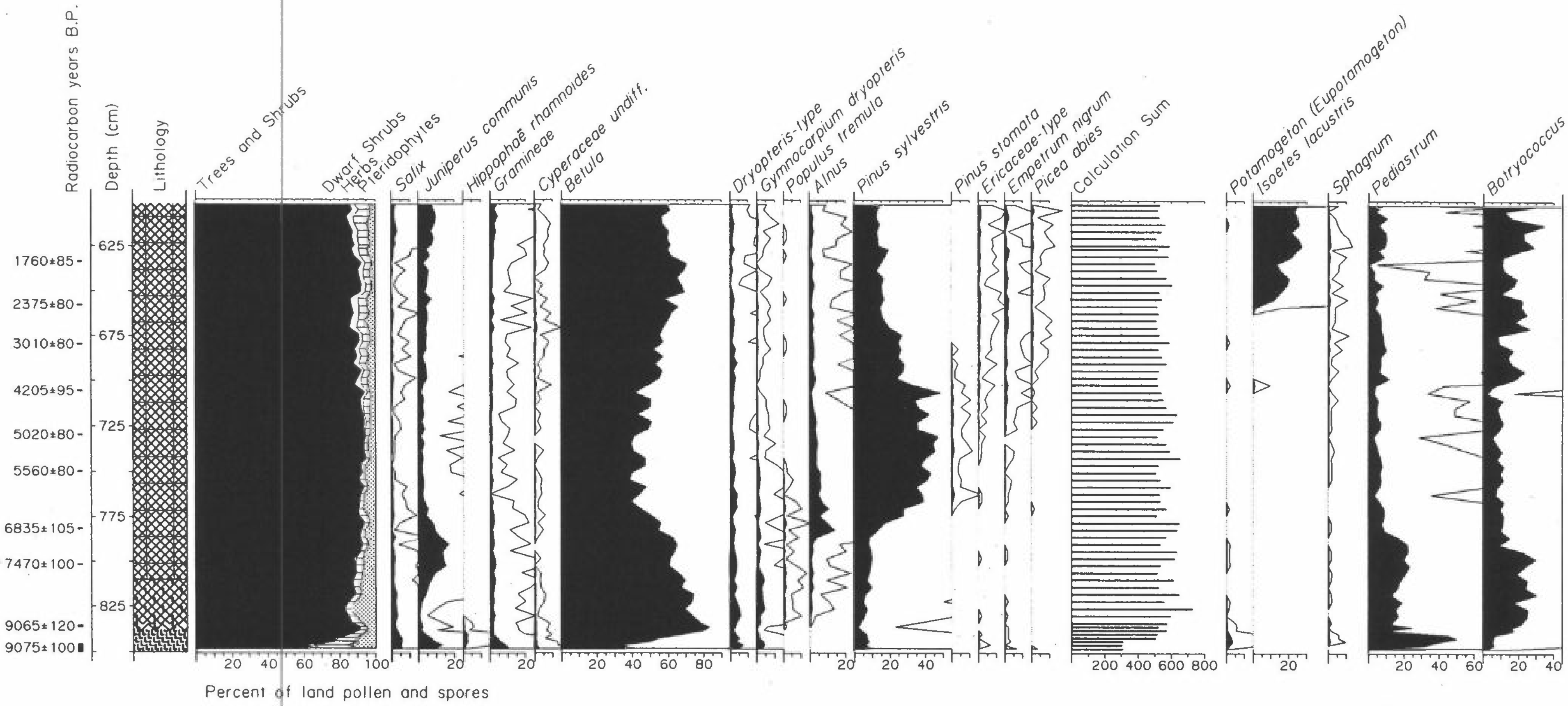
Two sites remain to be studied, one in the mountain *Betula* forest west of the watershed on Haugfjellet and one above tree-line today on Haugfjellet.

The pollen stratigraphies along the east-west KILO transect suggest little vegetational and hence climatic changes in the extreme east near Kiruna or in the extreme west on Vesterålen or on Hinnøya, some vegetational and climatic shifts in the area at the head of Ofotfjorden, and major vegetational and climatic changes just to the east of the main mountatin range in the Abisko - Torneträsk area where *Pinus sylvestris* grows locally today on south-facing slopes, presumably as a relict from the warmer mid-Holocene of 6800-3000 ^{14}C years BP (5700-1350 BC). The KILO project illustrates the differential response of natural forest ecosystems to climatic changes and shows how plant responses to climatic shifts are greatest at or near their range limits. The results provide insights into the magnitude of forest change to future climatic warming in northern Scandinavia.

VUOSKOJAURASJ

Selected pollen & spore percentages

Anal: Sylvia M. Peglar, 1995



The Effects of Climatic Changes on Forest Lines and Radial Pine Tree Growth during the last 100-1000 Years

by

Karl-Dag Vorren & Adreas Kirchhefer

University of Tromsø, N-9037 Tromsø

Stratigraphic investigations indicate that the altitudinal forest lines of northern Norway at 69°N Lat. have oscillated only moderately during the last 2500 years. The oscillations of the pine forest-line during this period probably corresponds to centennial differences in the mean July temperature of about 0.5° C.

A study of the spatial applicability of the seasonal climate signals of pine tree-rings in northern Norway is presented. It includes the establishment of eight tree-ring series in an oceanic-continental (west-east) transect at 69°N Lat. One maritime pine tree-ring chronology (Forfjorddalen) and one continental chronology (Dividalen) are presented.

The maritime tree-ring widths correlate significantly ($p=0.05$) positively with the July mean temperature ($r=0.61$) and the August mean temperature ($r=0.56$) (the summer temperature). The continental tree-ring widths correlate significantly positively with the July temperature ($r=0.76$) and the spring precipitation. Both series show good, stable growth during the 15th and 20th centuries. The period between is characterized by growth cycles with a frequency of c. 25 years in the western tree-ring chronology. There were growth maxima in 1705 and 1800 and poor growth in the early to middle 17th century and from 1820 to 1900. The differences between the maritime and the continental tree-ring series are probably best seen in the light of the precipitation variables.

The increased atmospheric greenhouse effect and regional climate change

Sigbjørn Grønås, Geophysical Institute, University of Bergen, Allégaten 70, 5007 Bergen

1. Methods to predict regional climate change

Consensus has been reached among scientists that increases in greenhouse gas concentrations since pre-industrial times have led to a positive radiative forcing of climate, tending to warm the surface and to produce other changes of climate. In order to predict future changes of climate, integrations of coupled numerical climate models (CCM) of the atmosphere, ocean and cryosphere give the main information. Control runs with such models have been made to simulate present climate during the last 120 years up to present. Integrations into the future are made with a gradual increase in the level of greenhouse gases in accordance with standards, which normally represent a pollution policy called "business as usual" (IPCC, 1990). This modelling activity is limited to a few major meteorological centra in the world, in Europe to the Hadley Centre, England (HC) and Max Planck Institute in Germany (MPI). An example of global temperature results are given in Fig. 1 after Hasselmann et al. (1995).

Regional climate change, for regions like the North Atlantic/European region (NAR), may be studied from the global integrations. Due to lack of computer power, the resolution in the CCM's is course. As a consequence, e.g. extratropical cyclones do not get sufficient intensity, and the regional mountains like the Scandinavian mountains are far from resolved. This means that regional variation is not as detailed as one could wish. Nevertheless, the main information to study regional changes comes from integrations of CCM's.

Attempts are being made to get more regional details out of the global integrations. This activity have been named "downscaling" of the global integrations. Two basically different types of downscaling have been tried. Firstly, limited area numerical models (LAM) with high resolution are applied, driven by the global results as boundary values. Typically, the grid distance in present climate models is 300 km in the atmosphere, while 50 km is often used in the LAM. So far, the LAM activity has been concentrated on developing the method, and few results have been published. Again, HC and MPI play the leading role in this research. Secondly, statistical relationships have been found between observed meteorological parameters, like temperature and precipitation, and analyzed large scale grided fields. The derived relations are then used on similar data from climate runs to give local interpretations. This method has been used by many for our region.

2. Regional climate variations observed recently

As measured by storm tracks during the last century (Rogers, 1995), the area from Iceland into the Norwegian Sea has the greatest natural climate variability. A much used measure of the interannual and decadal variation is the NAO-index (Bjerknes, 1964), which is measured as a seasonal mean pressure difference between a station in Portugal and Iceland. The variation of this index since 1864 is shown in Fig. 2 (Hurrell, 1995). From about 1960 this index has increased from a minimum to the largest maximum ever measured. The pressure and temperature variation in the latest part of this period are shown in Fig. 3 (Hurrell & van Loon, 1995). The westerlies have become stronger. The continents have become significantly warmer, while there is a negative anomaly southwest of Greenland. A positive precipitation anomaly is found in the Norwegian sea (not shown).

The minimum pressure of the extratropical cyclones has decreased and the frequency of strong storms has increased in our area during the latest decades (Pedersen, 1995; Lamb, 1991). However, others authors (e.g von Storch et al., 1993) is not able to identify any change. Despite a debate on the change of strong winds, there seem to be a consensus that the height of the waves has increased significantly during the same period (van Hoof, 1994; Hogbein, 1994).

It is believed that these recent regional changes are fingerprints of the predicted climate change caused by the increased greenhouse effect (Hasselmann, 1995). Wallace et al. (1995) have estimated that 60 % of the change is caused by the increased greenhouse effect.

Of particular interest is the increase of fresh water into the Norwegian Sea, which some scientists think will cause a change in the thermohaline ocean circulation (THC) (Manabe & Stouffer, 1995; Rahmstorf, 1995). There seem to be a close relation between the temperature in our region and the strength of the THC. This has first of all been shown in coupled model simulations (Manabe & Stouffer, 1995). The same relationship has not yet been verified from direct observations. However, scientists have tried to explain climate anomalies, such as the Little Ice Age and the Younger Dryas period, from variation in the THC (Broecker & Denton, 1990).

3. Predicted regional climate change

The GCC runs published in IPCC (1995) show a 25 % decrease in the THC by the time of doubled CO_2. However, increased temperature is still predicted over Scandinavia. New, yet unpublished GCC runs by MPI and HC show a nearly unchanged THC in the near future (Bengtsson, MPI; Mitchell, HC, personal communications). At MPI the resolution of the ocean model has been increased to 1° grid mesh, 0.5° in tropical areas. At HC the resolution is as before, but the physical parametrization has been improved. At both places the surface flux correction schemes are unchanged. The temperature increase over Europe and the precipitation increase over northern Europe are much as before.

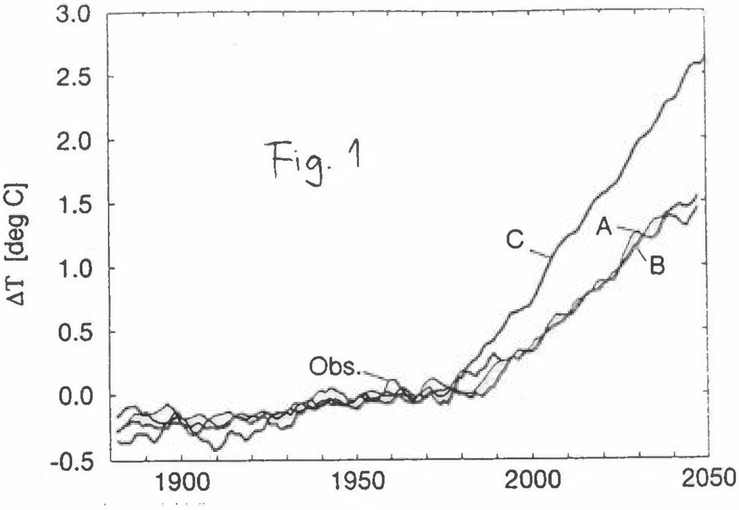
The level of the storminess in the North Atlantic and the Norwegian Sea has particular interest. Future change in the frequency of strong winds has first of all been investigated by HC scientists (Carnell et al., 1996; Hall et al., 1994). The main result is that the cyclones become deeper and stronger, giving an increased frequency of strong winds. This is illustrated in Fig. 4, taken from Carnell et al. (1996). The reasons for the change are 1) the unchanged or increased baroclinicity in the area and 2) an increased effect of released latent heat in the cyclones because of warmer SST in the southern NA ocean. Significant decadal variation can be expected.

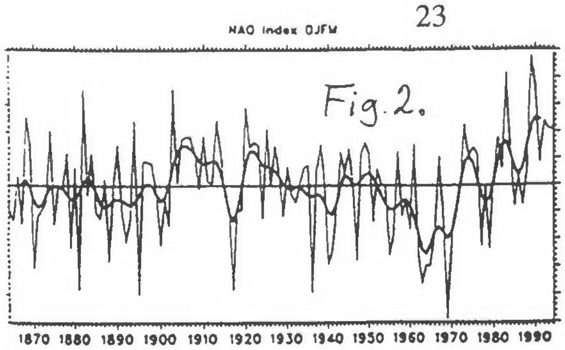
References

Bjerknes, J., 1964. Advances in Geophysics. Academic Press, 1-82.
Broecker, W.S & G.H. Denton, 1990. Sci. Am., 262, 48-56.
Carnell, R.E, C.A. Senior and J.F.B. Mitchell, 1996. The Hadley Centre, Meteorological Office, Bracknell. To apperar in Climate Dynamics.
Hall, N.M.J., B.J. Hoskins, P.J. Valdes, C.A. Senior, 1994. Q J R Meteor Soc, 120, 1209-1230.
Hasselmann K., L. Bengtsson, U. Cubasch, G.C. Hegerl, H.Rodhe, E. Roeckner, H. v. Storch, R. Voss, J. Waszkewitz, 1995. Proceeding of Modern Dynamical Meteorology (in honour of Aksel Wiin Nielsen) . Københavns Universitet.
Hogbein, N., 1994. The Royal Institute of Naval Architects, London, W5.
Hurrell, J. W., 1995. Science, 269, pp 676-679.
Hurrell, J. W. & H. van Loon, 1995. 6th International meeting on statistical climatology, pp 79-82, June Galway, Ireland.
Manabe S, R. Stouffer, 1995. Nature, 378, 9 November 1995.
Pedersen, K. 1995. Department of Geophysics, University of Oslo, Institue Report Series No. 98.
Lamb, H., 1991. Cambridge University press.
Rahmstorf, S., 1995. Nature 378, 145-149.
Rogers, J.C., 1995. 6th International meeting on statistical climatology, pp 79-82, June Galway, Ireland.
van Hooff, R. W., 1994. Underwater Technology 19, 20-23.
von Storch et al., 1993. Max Planck Institut für meteorologie, Hamburg, Report No. 116.
Wallace, J.M. et al., 1995. Science 270, 780-783.

Figure captions.

Figure 1. Observed and computed globally averaged near-surface 5 year mean temperature changes. The two integrations A and B differ only through insertion of a perturbations on run A. In run C the effect of aerosols is absent. (Hasselmann et al., 1995).
Figure 2. Time variation of the normalized winter NAO-index. (Hurrell, 1995).
Figure 3. a) Mean anomalies in sea surface pressure. Positive anomalies hatched negative dotted. b) Mean anomalies in 2 m temperature over land and SST. Positive anomalies hatched, negative dotted. (Hurrell & van Loon 1995).
Figure 4. Histograms of the frequency of wind in winter from 10 years. a) From the control run, data north of 30°N. b) Climate prediction minus control in the eastern North Atlantic. (Carnell et al., 1996).





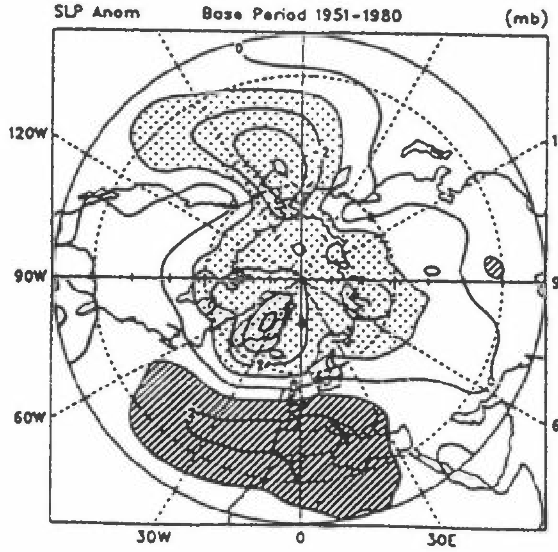


Fig. 3 a

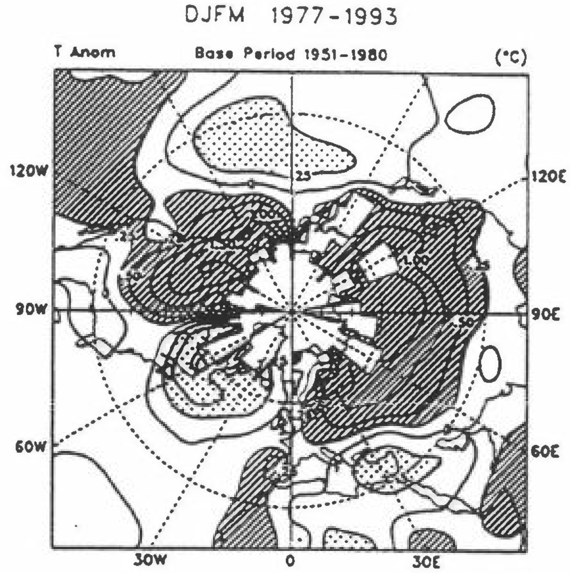


Fig. 3 b

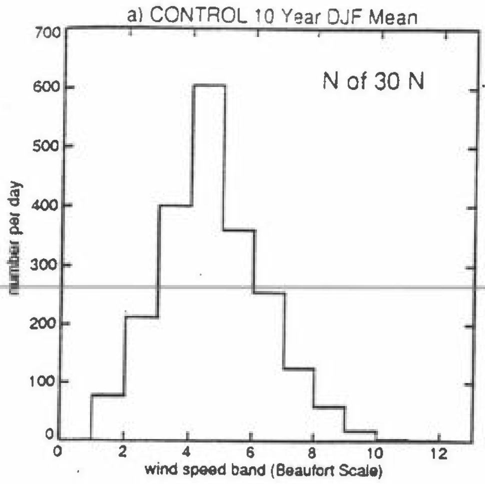


Fig. 4a

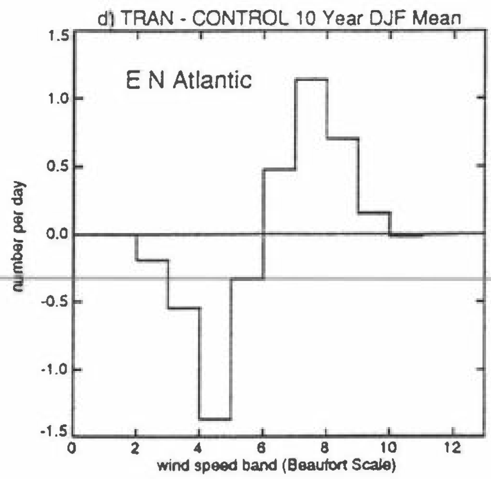


Fig. 4 b

CLIMATIC IMPACTS OF ANTHROPOGENIC AEROSOLS.

Trond Iversen
Department of Geophysics, University of Oslo
P.O.Box 1022 - Blindern, N-0315 OSLO

ABSTRACT

of a presentation in a Seminar on Climate- and Ozone-related research in Norway at Solstrand Fjord Hotel, Os, Norway, 11. - 12. March 1996.

Aerosols play a key role in several important atmospheric processes related to weather and climate. Direct origins of natural hygroscopic aerosols are primarily the sea salts. Hygroscopic particles are also indirectly produced naturally by gas-to-particle conversion, in particular by oxidation of gaseous DMS (dimethylsulphide) produced in considerable amounts biogenically over oceans. Particles which primarily consist of non-soluble species mainly originate from deserts or similar land-areas consisting of loess- and clay-minerals produced by weathering. Carbonaceous and organic particulate matter is also produced naturally by pyrolysis in wildfires, which is a gas-to-particle process.

Anthropogenic production of aerosols is mainly connected with fossil fuel combustion. Coal and oil containing sulphur produce sulphur dioxide in the combustion process which is further oxidized to particulate sulphate in the atmosphere. Measured by particulate mass, the anthropogenic sulphate production is the dominating source of aerosols in the Northern Hemisphere. Particles emitted through mechanical processes, fly ash etc. are less important due to their shorter atmospheric residence time. Carbonaceous particles of anthropogenic origins are mainly released by pyrolysis in incomplete combustion processes. This soot as well as that produced naturally, may partly consist of pure graphitic carbon.

Once emitted into the atmosphere aerosols are in constant evolution. An aerosol originally consisting of a population of particles over a broad size-spectrum ranging from radii smaller than 0.01μm to larger than 10μm, will change as it is transported away from its source region. The smallest particles (the nucleation mode), generally produced by gas-to-particle reactions, will coagulate to larger particles through the action of Brownian motion. This process is of decreasing importance as the particle size grows. Large particles (the coarse mode), generally produced by mechanical disruptions, weathering and evaporating sea-water micro-droplets,

tend to precipitate out through a gravitational settling. Thus after a few days in the air the number density of particles in the population is dominated by a narrow distribution of particle radii about 0.1 - 0.3 μm (the accumulation mode). Eventually particles are removed in precipitation events, however, a considerable part is recycled by evaporation of droplets, so the aerosol mass in the accumulation mode will have a considerable residence time, probably on the order of a week.

Particles in the coarse mode are not considered important globally or regionally due to their efficient removal. Particles in the nucleation mode is believed to be dominated by an external mixture of carbonaceous and other particles such as sulphuric acid droplets. In the accumulation mode of an aged aerosol, the particles of different chemical composition are believed to be dominated by an internal mixture (one particle consists of different constituents), frequently coated by water due to the hygroscopic parts. These two types of particle mixing creates different optical properties for the aerosol.

Possible climatological impacts of anthropogenic aerosols are normally separated into two categories. **Direct effects** are alterations of the radiative heating budget due to the aerosol particles in clear air. Since the diameters of the major part of the particles in the accumulation mode are close to the wavelength of maximum radiance of the solar radiation (visible light), increased amounts of particles may potentially increase the effectiveness of Mie scattering and thus the albedo. This effect of increased atmospheric contents of aerosols should then lead to cooling of the low-level troposphere. Some part of the aerosol mass of anthropogenic origins may include significant amounts of soot which is a very effective absorber of solar radiation. In the Arctic which is dominated by a very large natural ground albedo, the scattering effect is relatively unimportant so that the total net effect of increased aerosol content may be heating and not cooling.

Indirect effects of the aerosol particles on climate are linked to the interactions between particles and cloud processes. Increased amounts of activated CCN in the troposphere may increase the number density and decrease the average size of cloud droplets, and thus both increase total cloudiness and change the microphysics of preexisting clouds. The most probable effect of this on solar radiation is an increase of the albedo and thus cooling. There are still considerable uncertainty connected with the quantification of the indirect effect.

First attempts at estimating effects of sulphate particles on the global climate, yielded a cooling rate of about 1 W/m^2. More comprehensive effect studies in climate models estimate a global cooling of about a half of this. We have tried to estimate the effect of sulphate and soot in the Northern hemisphere by assuming Black Carbon to amount to 15% of a calculated distribution of sulphate. A simplified one-layer radiation model yields up to 7 W/m^2 cooling in the most polluted mid-latitude areas, and a up to 1 W/m^2 heating due to soot absorption in the Arctic. This differential trend in heating rates may have significant effects on atmospheric meridional circulations which is important for the atmosphere as a thermo-dynamic system.

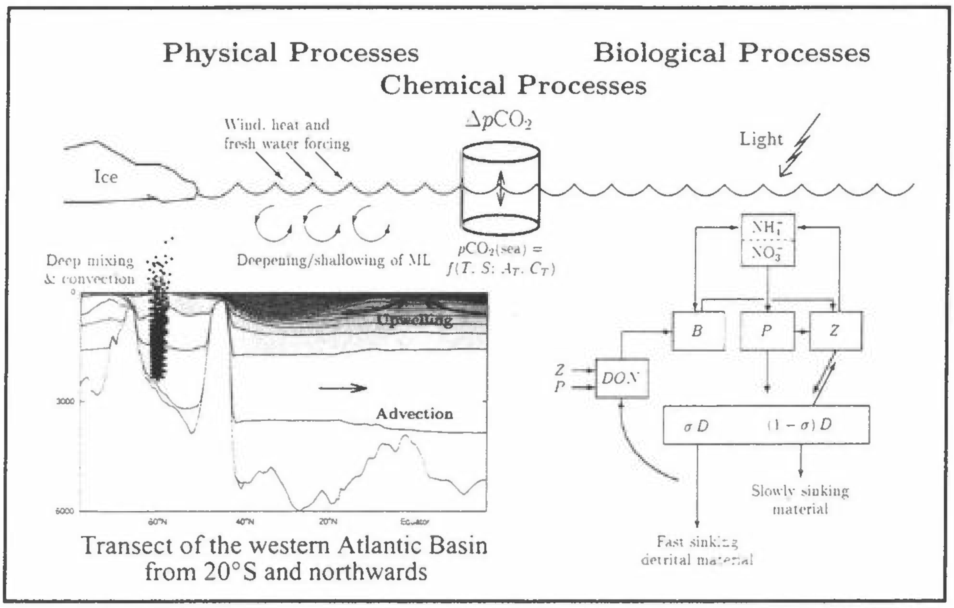
Lately we have introduced better descriptions of the sulphur chemistry in the hemispheric scale dispersion model, along with an inclusion of soot carbon as a separate component. We separate between nucleation mode particles and the accumulation mode. This information will be utilized in a model for Mie scattering and absorption, assuming different ways of mixing beween carbon and sulphate in the two modes. The Mie calculations yield extinction coefficient, single scattering albedo and asymmetry factor for a given size-distribution of particles with a given complex refractive index. With a given spatial distribution of particles, the total radiative forcing can then be estimated by a radiation model of the atmosphere. We have made some preliminary estimates of radiative forcings, but the work is still under development.

We will also try to estimate concentrations of cloud condensation nuclei (CCN) based on the modelled size-distributions and the composition of the particles. This will be done as a step towards the quantification of a possible indirect effect.

A Coupled Pysical-Biogeochemical Model for the Seasonal Cycling of Carbon and Nitrogen in the Ocean

Helge Drange (Nansen Environmental and Remote Sensing Center. Edv. Griegsv. 3A, N - 5037 Solheimsviken, Norway; +47–55–29 72 88; e-mail: helge.drange@nrsc.no)

Ecosystem and chemical modules have been coupled to the Miami Isopycnic Coordinate Ocean Model MICOM (Bleck *et al.*, J. Phys. Oceanogr., **22**, 1992) in order to model the seasonal cycling of plant nutrients and carbon, and the associated carbon fluxes, in the North Atlantic Ocean and the Nordic Seas. On the top of the ocean, there is a bulk parameterization of the mixed layer (Gaspar, J. Phys. Oceanogr., **18**, 1988). The horizontal resolution varies between 0.5-by-0.5 and 1-by-1 degree, and there are 19 isopycnic layers below the upper mixed layer. Algorithms have been developed to ensure conservation of the total model inventory of nutrients and carbon, to advect the biogeochemical compartments with modest numerical diffusion, and to split thick isopycnic layers in the euphotic zone into thinner biogeochemical sublayers. The biogeochemical model can be run fully coupled to the physical model, or in off-line mode. The coupled model is illustrated in the figure below.



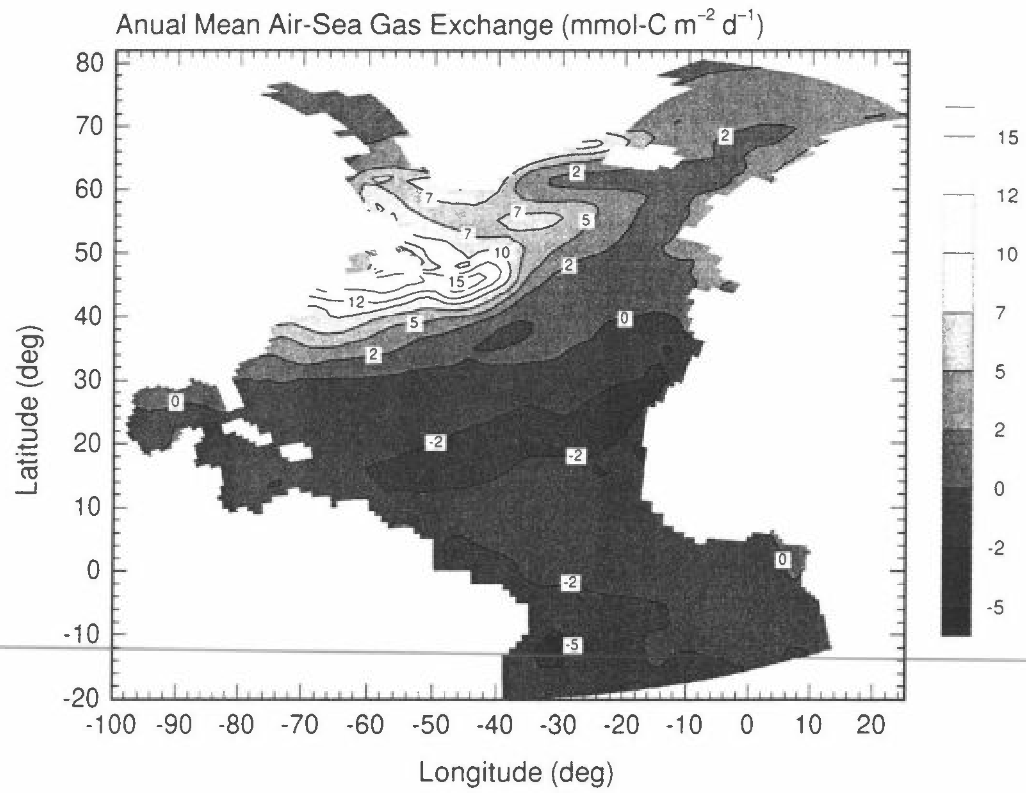
The ecosystem formulation in the euphotic zone is based on the seven-compartment nitrogen-based model by Fasham *et al.* (J. Mar. Res., **48**, 1990). The living biota consist of phytoplankton, zooplankton and bacteria; the nutrients are nitrate and ammonium; and organic matter is split into one dissolved and one particulate pool. Carbon has been added to the ecosystem by assuming constant atomic C/N ratios for phytoplankton (C/N=7), zooplankton (5.5) and bacteria (5); the C/N ratio of dissolved and particulate matter varies according to the sinks and sources for the compartments. The biogenic formation of calcium carbonate has been parameterized by assuming that the production of $CaCO_3$ equals 20% of the organic matter that sinks out of the euphotic zone in temperate waters, whereas the biogenic production of $CaCO_3$ is gradually reduced in cold waters. Below the euphotic zone, the biogenic compartments decay to ammonium, and then to nitrate. There is no accumulation of biogenic matter on the ocean floor.

The local changes in the total dissolved inorganic carbon content (C_T) and the total alkalinity

(A_T) are computed based on biogenic fixation of carbon and nitrate/ammonium, remineralization of organic matter, formation/dissolution of $CaCO_3$, exchange of CO_2 across the air-sea interface, and changes in the fresh water content of the surface layer due to evaporation/precipitation. The partial pressure of CO_2 in the surface water is computed based on the modelled water temperature, salinity, total dissolved inorganic carbon content and total alkalinity. The flux of CO_2 across the air-sea interface is driven by the concentration difference across the interface, and increses in a non-linear way with increased surface wind (Wanninkhof, J. Geophys. Res., **97**, 1992). The atmospheric concentration of CO_2 is prescribed, and is based on observed pCO_2-values from the 1980's.

The initial nitrate field is based on historical data sets analyzed at the NOAA/National Oceanographic Data Center (Levitus *et al.*, Prog. Oceanog., **31**, 1993), and the fields of C_T and A_T are derived from data suppled by T. Takahashi, Lamont-Doherty Earth Observatory of Columbia Univ., NY.

After an initial 20 yrs spin-up integration of the physical model, several multi year simulations have been carried out with the coupled model. Comparison with observations of nitrate, C_T, A_T and pCO_2, and remotely sensed surface chlorophyll, indicate that the model reproduces the main features of the seasonal cycling of plant nutrients and carbon over large parts of the model domain. The model predicts that the Atlantic Ocean acts as a net sink of atmospheric CO_2 north of about 30°N (the uptake amounts to about 0.35 Gt-C per year), whereas there is a weak outgassing of CO_2 at lower latitudes. The computed, annual mean air-sea gas exchange in mmol-C m^{-2} d^{-1} is illustrated below (positive values means oceanic uptake of atmospheric CO_2, and the white mask indicates land).



The coupled physical-biogeochemical model is now being extended to a global model domain, including the entire Arctic Basin, in order to study the cycling of carbon and plant nutrients in the world oceans.

The Carbon Cycle in the Nordic Sea

Truls Johannessen, Eystein Jansen, Lisa Miller, Michel Stoll and Ingunn Skjelvan.
SMR, University of Bergen

A total of 12 cruises were executed in the Nordic Seas as parts of the CARDEEP and the ESOP-1 programs. The aim of these cruises was to study the inorganic carbon cycle on a seasonal to interannual bases. The ultimate goal is to estimate the air/sea fluxes of CO_2 and the carbon transport due to deepwater formation and advection.

During the winter season a considerable drop in fCO_2 (fugasity of CO_2) is observed in the surface water in the Greenland Sea. In general this reflects the low residence time of the surface waters and that the carbon system never reaches equilibrium in the Greenland Sea. A ΔpCO_2 of approximately - 50 µatm during the winter season clearly shows that the Greenland Sea acts as a sink of atmospheric CO_2 even during the winter season. During the spring season a much more complicated picture of ΔpCO_2 is observed. The situation is patchy and a difference across the air/sea interface in terms of ΔpCO_2 is observed as low as 200 µatm. Together with stronger winds this might lead to a considerable episodic uptake of CO_2 during the spring season. But taking into consideration the relative low life time of such a ΔpCO_2 event, since it is probably linked to phytoplankton blooms, and the slow equilibration time for CO_2 between the atmosphere and the ocean surface waters it might be that the net effect is not as large as the ΔpCO_2 should indicate. Demineralisation of organic matter within the thermocline and additional carbon transport from waters below the thermocline along isopychnals might reduce the air/sea differences as well as CO_2 from the atmosphere. Different calculations of the surface waters uptake capacity of CO_2 give a relative consistent answer of approximately 0.1Gt C/year.

A suite of inorganic carbon variables were measured in the water column, such as total carbonate (Ct), alkalinity (Alk) and pH in addition to measurements of the nutrient and oxygen content. These measurements were performed in the whole water column to get a three-dimentional picture of the carbon distribution in the Nordic Seas. Based upon these distributions we estimated the southward transport of CO_2 into the North Atlantic Ocean and the estimate excess CO_2 (anthropogenic CO_2 input) in the Nordic Seas. A tentative estimate of the amount of excess CO_2 in the Nordic Seas will be given at the meeting.

CHANGE IN THE DEEP WATER FORMATION IN THE NORTH ATLANTIC

by
Svein Østerhus
Nordic WOCE Project Office

The increasing concern about the possibility of a global warming being caused by human emissions of greenhouse gases to the atmosphere, has actualized the need of identifying and understanding thermal variability in the ocean. Of particular interest is the deep and bottom-water formation which ventilates the world oceans' abyss, and activates large bodies of water which may act as a flywheel to the climate variability. Most of the deep water formation in the world ocean takes place at a few locations in the Atlantic Ocean; The Weddell Sea, the Labrador Sea and the Greenland/Iceland Sea. This presentation will deal with observed change in deep water formation in the northern North Atlantic.

Though they remain both sparse and sporadic, our longest hydrographic time-series from the North Atlantic confirm the existence of natural variability at all space scales out to those of the ocean basin and on time-scales out to decades and centuries. Even in the upper ocean these changes are not simple reflections of the scales of atmospheric forcing but display at least two modes of ocean-atmosphere interaction. While sea surface temperature [SST] variations on *interannual* time-scales may display a coherent local relationship with the surface wind, *interdecadal* changes in SST appear to be governed by basin-wide dynamical interactions which take effect through changes in the large-scale ocean circulation.

In the deep-convection centres of the North Atlantic, where atmospheric forcing is able to drive hydrographic change at subsurface depths, the ocean's response is likely to be even more protracted. We now know that changes in the intensity of winter convective activity have evolved over decades in the Labrador Sea and Greenland Sea due to slow changes in the forcing, and the evidence is that these changes were semi-synchronous [in phase but of opposite sign] at these two main sites. As the products of this variable convection spread out slowly in the deep circulation, they carry the signal of decadal change throughout their respective basins, complicated by interactions with topography and with resident waterbodies of different climatic history. Evidence of decadal change can therefore be expected to be present in many parts of the North Atlantic and over a considerable depth range.

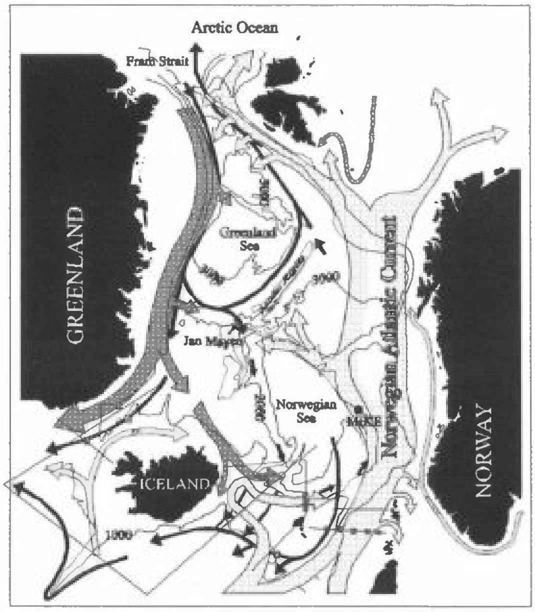


Fig. 1 The main current system (schematic) in the Nordic Seas with the position of the weather ship station MIKE, Nordic WOCE moorings (square) and the hydrographic sections. The open hatched arrows indicate the surface current patterns, and the black arrows indicate the deep/bottom current pattern as reported before the changes indicated in this paper.

The complex interactions between the decadal changes of the Arctic Ocean, Greenland Sea and Norwegian Sea are more important than most, however. The Arctic Ocean and Greenland Sea are the most important sources of intermediate and deep water in the Northern Hemisphere, with the former contributing significantly to North Atlantic Deep Water production and hence to the ventilation of the world ocean via the global thermohaline circulation. The Deep Water of the Norwegian Sea (NSDW) is formed from a mixture of Greenland Sea Deep Water (GSDW) and Arctic Ocean Deep Water (AODW), carrying information on decadal change from both sources. Ocean Weather Station (OWS) MIKE (66°N,2°E) is suitably located to monitor the intermediate and deep water for evidence of such changes, operating above the eastern margin of the Norwegian Sea deep basin (Figure 1) since 1948, the hydrographic record from OWS MIKE is the longest existing homogeneous time series from the deep ocean, with daily oceanographic measurements in the surface layer, and weekly sampling to the bottom using a method (Nansen bottles with reversing thermometers) which has not changed significantly for decades. The Nordic WOCE field program (Figure 1) is well designed for monitoring the exchange between the North Atlantic and the Nordic Seas. The Arctic Ice Thickness Project (AITP) monitoring exchange through the Fram Strait. The Greenland Sea is cover by The Greenland Sea Project and national cruises.

We will use the hydrographic record from OWS MIKE, current meter and hydrographic records from the Nordic WOCE, from AITP and from Greenland Sea to study change in deep and bottom formation in the northern North Atlantic.

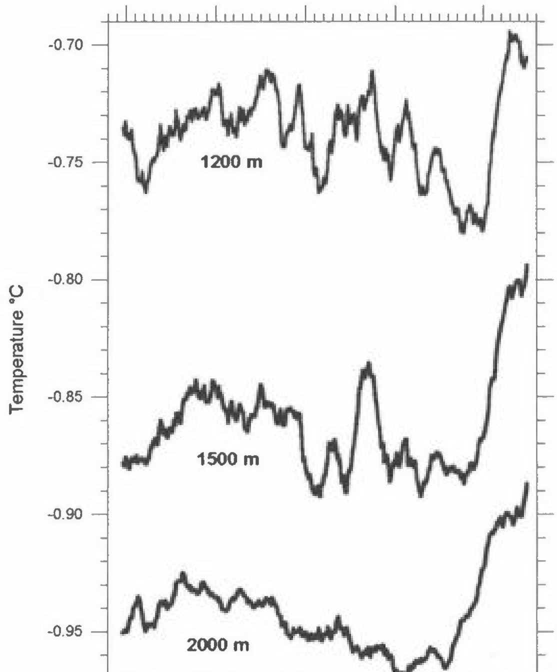


Fig. 2 Time series of smoothed monthly mean temperatures (in degrees Celsius) at the depth of 1200m, 1500m and 2000m from the weather ship station MIKE. Monthly means are computed as the average of weekly readings of two Deep-Sea Reversing (mercury-in-glass) thermometers at each depth. Altogether 2878 at 1200m, 2682 at 1500m and 2450m at 2000m thermometers readings are included. The accuracy is better than ±0.02 °C for the monthly mean temperatures. The monthly mean values are smoothed over 21 months by a running mean filter.

The "diagnostics" we have available for this purpose are introduced in Figure 2. Here, smoothed monthly mean temperatures for the 3 deepest standard sampling-depths at MIKE (1200 m, 1500 m and 2000 m) are compared for the period 1948-1995, and show three notable features. First, it is evident that a rapid warming has occurred in the NSDW over the last decade. Second, it is equally clear that its occurrence is depth-dependent; starting at 2000 m in 1985, the warming gradually penetrates upwards, beginning in 1987 at 1500m and reaching the 1200 m level in 1990. The third significant feature of these records is the fact that the warming then abruptly stops, (the deep layer once again leading), sometime between 1990 and 1993. Overall, the increase in temperature is about 0.07°C, it is nearly constant with depth, and it culminates in absolute maximum values for the entire 47-year record at all three depths. In terms of equivalents, the warming equates to a deepening of isotherms by 400 m at 2000 m depth or 200 m at 1200 m depth, to a 6 mm rise in sea level due to thermal expansion, or to a heat flux of about 1 W m^{-1}, which is close to the estimated radiative forcing due to anthropogenic greenhouse gases. This illustrates how important it is to take the ocean thermal content into account when climatic variability is discussed. In fact, just 2.5m of the ocean has the same heat capacity per unit area as the whole depth of the atmosphere. This means that the heating observed in the 1000-2000 m layer at MIKE, corresponds to a heating of 20°C of the corresponding atmospheric column. We suggest these time-series reflect a mix of local and regional influences which themselves result from global changes in the windfield.

Since the low temperature of the Norwegian Sea Deep Water is maintained by the deep horizontal incursion of cold Greenland Sea Deep Water (GSDW), it is likely that the basic cause of this rapid warming of NSDW would lie in changes within the "parent" waterbody in the Greenland Sea. Figure 3, shows a recent update of the variation in potential temperature for waters deeper than 2000m in the central Greenland Sea. As shown, a period of cooling from the late 50's to the early 70's is followed by a dramatic and sustained warming thereafter, continuing into the 1990's. The GSDW is itself renewed from two sources, either by horizontal exchange with the deep waters of the Arctic Ocean through the Fram Strait (sill depth 2600m) or by vertical exchange as a result of local deep-reaching open-ocean convection. Cooling of GSDW can only be carried out from above, by convection, while warming can only be effected from outside the basin of the Greenland Sea, by lateral exchange with AODW (the warmest and most saline deepwater in the Arctic-Ocean/ Nordic Seas system).

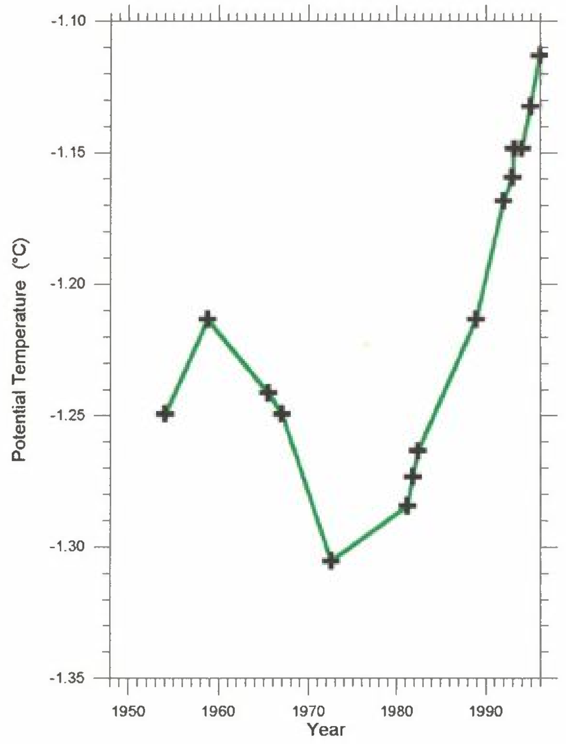


Fig. 3 Time series of the mean temperature below 2000m in the central Greenland Sea

The cooling and warming cycle in Figure 3 has therefore been interpreted as evidence of intensifying Greenland Sea convection with deepening vertical exchange through the 1960's to the early 70's followed by a progressive capping of convection and increased horizontal exchange with the Arctic Ocean since then.

The causes of such radical changes (reduction of local wind stress curl during the 1980's and changes of wintertime pressure over Greenland) are discussed elsewhere. Here, the key point is that these events seem consistent with our observations from the Deep Water of the Norwegian sea, already described. The almost complete cessation of deep-reaching convection in the Greenland Sea, the increased flux of warm AODW through Fram Strait, and latterly the collapse of the Greenland Sea "dome" all contributed to rapid warming of the GSDW by some 0.17°C between the early 1980's and 1995. This warming GSDW, with its increasing admixture of AODW would then have passed through the Mohn Ridge (Figure 1) to renew the Deep Water of the Norwegian Sea. Exchange of water masses between the two deep basins takes place through a channel which has a threshold depth of 2200 m and is situated just north of Jan Mayen. Current meter moorings deployed in this Jan Mayen Channel on several occasions in the 1980's all show a steady flow from the Greenland Sea to the Norwegian Sea, with an average speed of about 7 to 8 cm s^{-1}.

These deep, weak currents are in so-called geostrophic balance, which means that they are steered by the bottom topography. Thus, during the 80's the water flowing through the Jan Mayen Channel would follow the 2000m isobath, circuit the western and southern margins of the Norwegian Sea basin (see arrows, Figure 1) to reach our monitoring point at OWS MIKE with a delay of a few years, and with the warming reduced to about half its original amplitude by mixing along its path. The fact that the maximum temperature change in the Greenland Sea was centered on 2000-2500m depth, and the existence of a sill at 2200m depth in the Jan Mayen Channel together explain why the warming signal in the Norwegian Sea is seen first at 2000m, propagating upwards with time. It also explains why so little warming is found in the Norwegian Sea *below* this depth. Temperature profiles obtained across the Southern Norwegian Sea in 1982/84 and 1994 show that in the central basin the warming was much less (0.02°C), and the salinity is constant below 2200m.

Since the warming of GSDW appears to have continued unchecked to date, (Figure 3) the cessation of warming observed in the NSDW since 1990-93 is certainly unexpected, (Figure 2) suggesting that as GSDW production has (virtually) ceased, the transport through the Jan Mayen Channel may have reduced or even reversed, cutting off the deep Norwegian Sea from the influence of the GSDW and its changes. To check this point, a current meter mooring was deployed there between November 1992 and July 1993. A comparison of these measurements with all pre-existing measurements from 1982-84 shows that the deep water flow between the Greenland Sea and the Norwegian Sea has indeed reversed, now exhibiting an average current of 0.8 cm s^{-1} into the Greenland Sea (Figure 4).

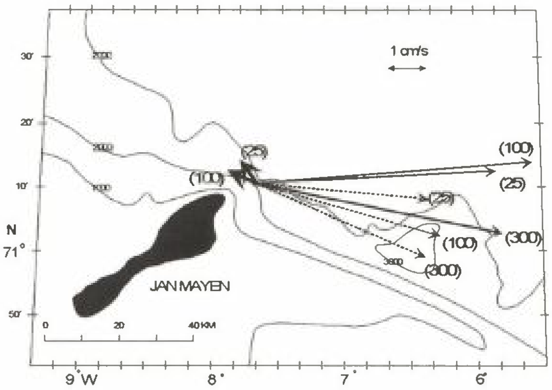


Fig. 4 Results from the current measurements in the Jan Mayen Channel from April to November 1991 (thin doted arrows), September 1983 to July 1984 (thin arrows) and from November 1992 to July 1993 (thick arrows). The numbers in parentheses indicate height of current meter above the bottom. The stability factor (defined as the absolute value of the average current vector divided by the average speed) was 0.91 in 83/84 and 0.18 in 92/93. The mean temperature was -1.01°C in 83/84, increasing to -0.94°C in 92/93.

Although global temperatures have been abnormally high in a succession of recent years, culminating (1995) in the highest mean temperatures since measurements were first properly recorded (1860), the extensive warming in the deep water of the Nordic Seas is not obviously or directly linked to global warming. Instead, the multi-decadal changes in the convective intensity of the Greenland Sea, from which these changes stem, appear to reflect a long-period shift in the North Atlantic Oscillation, though of course the causes of *that* remain obscure. The key importance of the northern seas to the climate system as the expected site of an enhanced global warming signal and as significant contributor of deep water to the global thermohaline circulation is undisputed, however. It is therefore important that we identify, understand and attempt to simulate the causal mechanisms that control the changing inter-basin dynamics of the North Atlantic with the use of regional models.

Fortunately, Ocean Weather Station MIKE continues in operation, well-placed to describe not only the trends of the deep water but also those of the Atlantic current-branch entering the area. Figure 5 shows that the Atlantic water at MIKE has indeed become cooler and fresher since 1991, and at 300-400 m depth down to the levels observed during the late 70's, when the so-called "Great Salinity Anomaly" passed through. Nordic WOCE observations indicate that the inflow of Atlantic Water to the Nordic Seas has been reduced and Arctic Surface Water is accumulating in the Nordic Seas. The relevance and value of new observations from MIKE and a continuation of the Nordic WOCE field program are therefore undiminished.

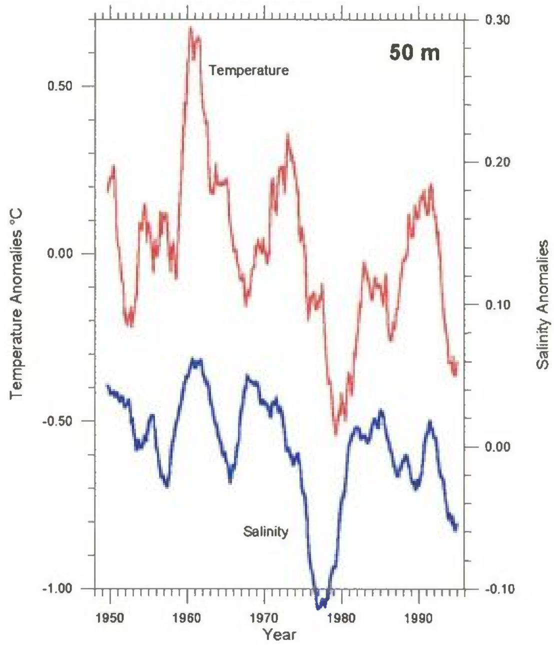


Fig. 5 Time series of temperature and salinity anomalies in the Atlantic Water (50m depth) at the weather ship station MIKE. Monthly means and filtering as in fig 2.

Background papers:

- Østerhus and Gammelsrød. The Abyss of The Nordic Seas is Warming. Submitted (1996)
- Nordic WOCE reports 1993-96.
- Blindheim, Hansen, Malmberg, Turrell and Østerhus. Accumulation of Arctic Water in the Nordic Seas during the last Decade. In prep.
- Dickson, Lazier, Meincke, Rhines, Swift. Long-term Coordinated Changes in the Convective Activity of the North Atlantic. Prog. Ocean. 1996 (in press.).

Svein Østerhus
Nordic WOCE Project Office
Geophysical Institute, University of Bergen
Allegt. 70, N-5007 Bergen, Norway

Phone: +47 55212607, Fax. +47 55 960566

E-mail: svein.osterhus@gfi.uib.no

Instrumentation and analytical methods in carbon balance studies - inorganic components in a marine environment

Ingunn Skjelvan, Truls Johannessen, Lisa Miller, and Michel Stoll.
Centre for Studies of Environment and Resources/Geophysical Institute, University of Bergen.

The emission of greenhouse gasses have increased dramatically as a consequence of human activities. Among others, anthropogenic CO_2 is fed into the atmosphere in huge amounts, and it is removed by different sinks. The land biota acts as a sink for CO_2, and the effect of this is the most uncertain. The ocean absorbs about 30% of the anthropogenic CO_2 added to the atmosphere. The last years a lot of knowledge has been gained in this field, but more investigation is still needed.

How the ocean acts as a sink for CO_2 is central in understanding the carbon cycle. In this project, we are investigating the *inorganic* carbon in the ocean. Important parameters for us are *total dissolved inorganic carbon*, C_T; *alkalinity*, A_T; and *partial pressure of* CO_2 in surface ocean and atmosphere, pCO_2. These parameters tell us about carbon content in sea water, the buffering capacity of the ocean, and the ability of the sea water to absorb CO_2. This information will hopefully contribute to better estimates on the size of ocean sinks for carbon and give more knowledge on the important carbon cycle.

Total, dissolved inorganic carbon - C_T
To determine C_T we use a coulometric analysis, which is the recommended method for these measurements. The system was developed at Brookhaven National Laboratory in USA, and the principle is to acidify an exact amount of sea water and determine the amount of extracted carbon using a coulometer.

Alkalinity - A_T
Alkalinity is determined using a potentiometric titration, which also is a recommended method. There is currently discussion among scientists as to whether the titration should be closed or not, i.e. a fixed volume or not.

Partial pressure of CO2 - pCO_2
The principle of this measurement is to circulate a small amount of air in a large amount of sea water. After a short time delay, we can assume that the amount of CO_2 in the air reflects the CO_2 concentration in the water. We use infra-red detection to determine the pCO_2 in the gas phase. In some groups, detection by gas chromatography is utilized. In addition, we determine pCO_2 in the atmosphere, allowing us to calculate the difference, ΔpCO_2, which gives information about sink or source activities.

For both total carbon and alkalinity measurements discrete samples are collected at all depths in the ocean, but for pCO_2-detection an underway system is used, which determines pCO_2 in the surface ocean continuously.

Methane as a climate gas

by
Sigrún Karlsdóttir

Institute for Geophysics
P.O.Box 1022, Blindern
University of Oslo
Norway

One of the key compounds in the atmosphere is methane. It plays an important role in the oxidation capacity of the atmosphere by affecting the OH concentration. In the troposphere methane is a precursor for the ozone production. In the stratosphere methane contributes to the OH radical concentration, and to HCl, which is a reservoir gas for Chlorine. These species control the ozone concentration in the stratosphere. Methane is also an important greenhouse gas due to its absorption of thermal radiation. There has been a rapid increase in the methane concentration since pre industrial time. Its concentration has increased with more than a factor of two over the last two centuries (IPCC, 1994). About 2/3 of the methane emission is due to human activities. The basic sources of methane have been identified, but there are still many uncertainties about the source strength.

The basic loss process for methane is through its reaction with OH:

$$CH_4 + OH \rightarrow CH_3 + H_2O \qquad (1)$$

As much as 90% of CH_4 is lost through this reaction in the troposphere. About 5% is lost through the soil and 5% is lost in the stratosphere. Since reaction (1) is the basic loss process it provides a possibility for positive feedback (Isaksen, 1988; Berntsen et al. 1992). The relation goes as follows:

Enhanced emissions → enhanced concentrations → increased chemical lifetime → further enhanced concentrations.

Changes in methane will affect the concentrations of other gases, since OH is involved in many of the removal processes of trace gases. A model is a very important tool to study sensitivity due to changes in concentration of gases. To study the effect of changes in methane concentration on other trace gases a 3 dimensional global chemistry transport model is used. The model has a global resolution of 8° × 10° (latitude × longitude) and 9 vertical layers. The mass transport scheme is developed by Prather et al., (1987). Meteorological fields, which approximately reproduce seasonal and daily variation the wind, pressure, temperature and precipitation fields are generated from the NASA-GISS GCM (Hansen et al., 1983). Natural and anthropogenic emissions of NO_x, CO, CH_4 and NMHC's (non methane hydrocarbons) are included in the model. Wet and dry deposition are also included The chemical scheme in the model includes 49 compounds, 101 reactions, and 16 photolytic reactions. The trace gas concentrations are calculated every 30 min., using a modified quasi steady state approximation (QSSA) method (Hesstvedt et al., 1978). The model has been used to look at three cases:

Case 1: A reference run, which include no changes in the CH_4 concentration, and a run with 20% increase in the CH_4 concentration are compared.

Case 2: The same runs as above with CO emission reduced with 50%.

Case 3: The same runs as in case 1, with NO_x emission from the ground and NO_x flux from the stratosphere reduced with 50% and NO_x emission from lightning reduced from 5.7 Tg/yr to 2.0 Tg/yr.

The results show that enhanced methane concentration will have strongest effect in remote regions. In polluted areas local chemistry will have remarked effect. The lifetime of methane will increase in all cases by approximately 7%. The feedback was positive in all the cases, and strongest in case 2. This is because a larger fraction of OH loss is through reaction (1). Average atmospheric lifetime calculated in the model is 7.6 years. This is in agreement with recent estimates based on observations (Prinn et al., 1995), and which are lower than precious estimates.

This work will contribute to the IGBP (GAIM) project. There will also be a co-operation with the Dep. of Earth System Sciences, University of Irvine, California.

References

Berntsen T., Isaksen I.S.A. and Fuglestvedt J.S. Chemical-dynamical modelling of the atmosphere with emphasis on the methane oxidation. *Ber. Bunsenges. Phys. Chem.* 96, No. 3, 1992.

Hansen J., Russel G., Rind D., Stone P., Lacis A., Lebedeff S., Ruedy R and Travis L. Efficient three dimensional global models for climate studies: Models I and II. *Mon. Weather Rew., 111*, pp 609 - 662, 1983.

Hesstvedt E., Hov Ø., Isaksen I.S.A, Quasi steady-state approximation in air pollution modelling: Comparison of two numerical schemes for oxidant prediction. *Int. Journal of Chem. Kinetics, Vol X.* , pp 971 - 994, 1978.

IPCC, 1994 Climate change: Radiative forcing of climate change and an evaluation of the IPCC IS92 emission scenarios. Houghton J.T., Meira Filho L.G., Bruce J., Hoesung Lee, Callander B.A., Haites E., Harris N., Maskell K. (Eds.) *Cambridge University Press, Cambridge, U.K.* **, 1995**

Isaksen I.S.A, Is the oxidizing capacity of the atmosphere changing. *The changing atmosphere, Rowland F.S. and Isaksen I.S.A. (Eds) John Wiley & sons* pp 141 - 159, 1988.

Prather M., McElroy M., Wofsy S., Russel G., Rind D., Chemistry of the global troposphere: fluorocarbons as tracers of air motion. *J. Geoph. Res.*, 92, pp 6579 -6613, 1987.

Prinn R.G., Weiss R.F., Miller B.R., Huang J., Alyea F.N., Cunnold D.M., Fraser P.J., Hartley D.E., Simmonds P.G., Atmospheric trends and lifetime of CH_3CCl_3 and global OH concentrations. *Science, VOL. 269,*. pp 187 - 192, 1995.

An Introduction to *El Nino Southern Oscillation* (ENSO): Its causes and its implications for the local and global climate.

Rasmus E. Benestad, Oxford University.

ENSO causes the most important natural climate change with a time scale of less than 10 years. The most important aspects of ENSO involve an oscillating east-west dipole of high and low pressure regions in the tropical Pacific. This pressure system is characterised by an irregular oscillation, and is known as the *Southern Oscillation.* The Southern Oscillation also represents a change in the *Walker Circulation,* (i.e. the large scale tropical atmospheric circulation) and consists of an eastward shift of the strongest convection in the *Inter Tropical Convection Zone* (ITCZ). At the equator, the winds blow down the pressure gradients, and the Southern Oscillation implies changes in the trade winds in the central Pacific. Changes in the tropical atmosphere also involve changes in the precipitation patterns and air temperatures.

In the oceans, ENSO manifests itself as changes in the Sea Surface Temperatures (SSTs), thermocline, sea level and currents. During a cold phase (La Nina), the sea surface temperatures are colder than normal in the eastern tropical Pacific. This coincides with a shallow thermocline in the east and a deep thermocline to the west. During a warm phase (El Nino), the thermocline deepens in the east and shallows in the west. This coincides with a warming in the ocean surface in the eastern Pacific.

The physical processes in the atmosphere and the ocean interact in such a way as to give rise to various feedback mechanisms. It is believed that these feedback mechanisms are responsible for the highly non-linear and irregular character of ENSO. Anomalously warm seas in the eastern Pacific coincide with low sea level pressure over the same region and sometimes westerly surface winds along the equator. Similarily, cold sea surface temperatures in the east Pacific seem to imply a high pressure region in the east and stronger easterly trades along the equator. The trade winds along the equator force the equatorial currents, and are responsible for a higher sea level in the western Pacific than in the eastern Pacific.

The mechanisms that are responsible for the transition between the cold and warm phases of ENSO are controversial and still not well known. On some occasions, a warm event is initiated by anomalously warm sea surface temperatures in the east that subsequently expand into the central Pacific. Some El Ninos, however, are also known to start with warm sea surface temperatures in the west or central Pacific, which then propagate to the west. It is remarkable that ENSO seems to be strongly synchronised with the annual cycle

The main ENSO mechanism hypothesis can be catogorised by: 1) the *Delayed Oscillator Mechanism*, that involves equatorially trapped oceanic Kelvin waves; 2) the *Slow Coupled Mode*, in which Ekman pumping is an important factor; 3) *Stochastic Atmospheric Forcing*, where atmospheric noise triggers instabilities; 4) *Wyrtki* mechanism, in which a slow accumulation of warm water in the western Pacific is followed by a break down; and 6) the *Ramanathan* thermostat hypothesis.

Computer simulations are important tools in the study of ENSO and the evaluation of the different ENSO hypothesis. Various numerical ENSO models have been constructed, ranging from simple conceptual models to complex coupled *General Circulation Models* (GCMs). The conclusion of model studies seems to be that none of the ENSO hypothesis can be discarded, and there are no hypothesis that stands out as the correct mechanism of ENSO.

ENSO models have also been used in predicting El Nino, and there has been some success of predicting ENSO up to a year in advance. Up till now, no particular ENSO model seems to be better than others. However, ENSO prediction schemes have already been beneficial to countries affected by ENSO. An example is that the ENSO predictions guide some governments in Latin America as to what crops to grow. El Ninos are associated with droughts in part of Africa, Australia and floods in Latin America. The storm tracks in the Pacific are altered during El Nino years, and damages costing billions of US dollars are caused by El Nino due to flooding, collapse of fisheries, and droughts. El Nino is also associated with outbreak of diseases and various ecological devastation.

It is possible that ENSO can give an indication of whatconsequences for instance a global warming can have in terms of economical, social and ecological changes. Despite the dissimilarities between ENSO and the greenhouse effect, one crucial aspect of both phenomena is that they both involve coupling between the atmosphere and the ocean. ENSO ought to be easier to simulate than the global climate response to increased Carbon Dioxide, thus, a minimum criteria for climate change models is the ability to reproduce ENSO.

RAPID CLIMATIC FLUCTUATIONS INTO AND OUT OF INTERGLACIALS

Nalân Koç (Dept. of Geology, Univ. of Bergen, Bergen, Norway)

How the climate is going to evolve and what the consequences of human activities on the natural global climate change will be are of much recent concern. Studies based on diatom assemblages and sea-surface temperature (SST) estimates indicate that the Nordic Seas are already in a "preglacial state" as foreseen by Imbrie et al. (1992). Nordic Seas have been gradually cooling since 5000 yrs BP. and the sea-ice cover has been expanding in step with decreasing summer insolation in the Northern Hemisphere (Koç and Jansen, 1994; Koç et al, 1993). What will be the character of climatic transition from the present warm period to the coming glacial period?

The initial transition from the last glacial period to the present warm period, the Holocene, started with the decay of high-latitude Northern Hemisphere ice sheets between 15,000-13,000 yrs BP. (Koç and Jansen, 1994). Warming of the surface ocean first took place at 13,400 yrs BP. After the initial warming, oceanic conditions during the Bølling/Allerød interstadial complex (13,200-11,200 B.P.) exhibited high variability. This period was punctuated by four progressively more severe SST minima: between 12,900-12,800 B.P. (BCP I); 12,500-12,400 B.P. (BCP II); 12,300-12,000 B.P. (OD I); and 11,800-11,500 B.P. (OD II) (Koç Karpuz and Jansen, 1992; Koç et al., 1996). The Younger Dryas (YD) (11,200-10,200 B.P.) represents the severest and most prolonged cold episode of the Bølling/Allerød series of climatic deteriorations, before the final warming into the Holocene.

Climatic conditions of a transition from an interglacial to stadial period was investigated from DSDP Site 609 in the North Atlantic (Koç, in prep.). For this purpose isotope stage 5 was studied. The transition from the last interglacial to the stadial period (between substages 5e/5d) is represented by a total estimated SST drop of around 4°C at this site. This transition from interglacial conditions to stadial conditions is not a smooth one; it is characterized by rapid SST fluctuations. Substage 5d corresponds in time to the lowest Northern Hemisphere summer insolation values found during stage 5 (and for the last 230 ka). Based on ice-rafted detritus concentrations, the initial growth of Northern hemisphere ice-sheets has been proposed to start then also (McManus et al., 1994). It is possible that this large change from the highest summer insolation values (substage 5e) of the last 200 ka to the lowest values (substage 5d) caused the instability observed in the SST record of mid-North Atlantic during this transition. Ventilation of the deep North Atlantic seems to have varied during this period also (Keigwin et al., 1994), supporting general instability of the whole ocean system as the incoming insolation changed from one extreme to the other.

These results might indicate that climate acts highly variable during both the transition into and out of an interglacial. However, the insolation signal during the last glacial-interglacial cycle and the present cycle are very different. A brief summary of the new NFR project proposal, which is hoped to resolve this complication, will be given.

REFERENCES:

Imbrie, J., and 17 others, 1992. On the structure and origin of major glaciation cycles 1. Linear responses to Milankovitch forcing. *Paleoceanography*, v. 7, p. 701-738.

Keigwin, L. D., Curry, W. B., Lehman, S. J., and Johnsen, S., 1994. The role of the deep ocean in North Atlantic climate change between 70 and 130 kyr ago. *Nature*, v. 371, p. 323-326.

Koç, N. (in prep.). Demise of the Last Interglacial in the North Atlantic: clues for our future?

Koç, N., Jansen, E., and Haflidason, H., 1993. Paleoceanographic reconstructions of surface ocean conditions in the Greenland, Iceland and Norwegian seas through the last 14ka based on diatoms. *Quaternary Science Reviews*, v. 12, p. 115-140.

Koç , N., and Jansen, E., 1994. Response of the high-latitude Northern Hemisphere to orbital climate forcing: Evidence from the Nordic Seas. Geology, v. 22, p. 523-526.

Koç Karpuz, N., and Jansen, E., 1992. A high-resolution diatom record of the last deglaciation from the SE Norwegian Sea: Documentation of rapid climatic changes. *Paleoceanography*, v. 7, p. 499-520.

Koç, N., Jansen, E., Hald, M., and Labeyrie, L. (1996). Lateglacial-Holocene sea-surface temperatures and gradients between the North Atlantic and the Norwegian Sea: Implications for the Nordic heat pump. In: Andrews, J.T., Austin, W.E.N., Bergsten, H.E. (eds.) *The Late Glacial Paleoceanography of the North Atlantic Margins*. Geological Society Special Publication, No. 111, p. 177-185.

McManus, J. F., Bond, G. C., Broecker, W. S., Johnsen, S., Labeyrie, L., and Higgins, S., 1994. High-resolution climate records from the North Atlantic during the last interglacial. *Nature*, v. 371, p. 326-329.

Interglacial and glacial paleoclimates in NW-Russia

Jan Mangerud and John Inge Svendsen
and several other PECHORA project members.
See attached sheet for participants and adresses.

The timing and extension of ice sheets that periodically covered the Barents and Kara seas and adjacent parts of northern Eurasia remains one of the greatest uncertainties in global ice age reconstructions. For example, reconstructions of the last glacial maximum, around 20 000 years ago, range from almost complete coverage of northern Eurasia by a contigious ice sheet centered on the continental shelf to individual ice caps on the Ural mountains and the arctic islands. In the western literature and paleoclimatic modelling, the maximum reconstructions have dominated.

When they existed, the large ice sheets, in addition to being a response to climatic change, strongly influenced the climate system: They were large «white montains» creating an atmospheric high pressure, they blocked ocean currents, and they dammed the large northflowing Russian rivers, diverting fresh water discharge from a considerable part of the Eurasian continent from the Arctic Ocean to the North Sea or the Mediterranean Sea.

What is needed in order to resolve these problems are new and carefully documented field observations, linked with an analytical program. One, although not the only, reason that such major questions are not solved in this region is that it is an enormous vaste and indeed remote area. We therefore started a field based project in the Pechora lowland (between the Ural Mountains and Cape Kanin) in 1993. We think we already are able to document the *extension* of the last glacial maximum for much of this area; it is considerably less than the commonly cited maximum reconstruction. However, we have yet not been able to prove its age. Some observations and dates indicate an age around 20 000 years, similar to the age of the maximum extension of the Scandinavian Ice Sheet, whereas some other observations points to aconsiderably higher age. Dating is a major problem for depostis older than 10 000 years in Arctic areas, because organic matter is absent in cold intervals. We try to apply new techniques of luminescens and U-series dating.

For the first time we have found field evidences indicating that there were two major glacial advances during the last glaciation. This will be further investigated the coming summer. We are also searching for sites that potentially could provide a more or less continuous record of the climatic and environmental development through the last interglacial-glacial cycle, but so far we have not had success.

The southern coast of the Barents Sea had a different configuration during the last interglacial; relative sea level was higher, the coast was some 100 km inland compared to the present coast, and there was a connection between the Baltic and White seas. The shallow water fauna indicates exceptionally warm temperatures; at least as warm as southern Troms today. This is further studied by dr. Svend Funder, Copenhagen University.

Paleo Environment and Climate History of the Russian Arctic

-PECHORA

PECHORA is a Russian-Norwegian interdisciplinary project aiming to reconstruct the history of late Quaternary environment and Early Man in North-Russia.

OBJECTIVES:
The main purpose of this project is to increase our understanding of the climatic changes and influence on the physical and biological environment and human habitation:

1) Geology and geophysics: Timing and extension of the great ice sheets and crustal movements.

2) Paleobotany: Vegetation history.

3) Archaeology: Immigration of Early Man and cultural developement.

4) Paleozoology: Migritatory pathways and changes in the mammalian fauna.

We will especial focus on the last interglacial-glacial cycle, a period of 130,000 years. However, we also consider to study older periods including the Saale ice age.

PRINCIPAL SCIENTISTS:

Prof. Valery Astakhov
Inst. of Remote Sensing Methods for Geology,
St.Petersburg, Russia

Dr. Ljudmila Andreicheva
Inst. of Geology of the Komi Scientific Center
Russian Academy of Sciences, Syktyvkar, Russia

Dr. Pavel Pavlov
Inst. of Language, Literature and History,
Russian Academy of Sciences, Syktyvkar, Russia.

Dr. Nikolai Smirnov, Institute of Plant and
Institute of Plant and Animal Ecology,
Russian Acad. of Sciences, Ekaterinburg, Russia

Research scientist Alexei Matyushkov
All-Russian Geological Institute (VSEGEI)
St.Petersburg, Russa

Prof. Jan Mangerud
Department of Geology, University of Bergen
Bergen, Norway

Ass. prof. Aage Paus
Botanical institute, University of Bergen,
Bergen, Norway

Prof. Svein Indrelid
Inst. of archaeology, University of Bergen
Bergen, Norway

Research scientist Anne Karin Hufthammer
Department of Zoology, University of Bergen
Bergen, Norway

Dr. scient. Jan Tveranger
Department of Geology, University of Bergen
Bergen, Norway

PROJECT CO-ORDINATOR:

Dr. scient. John Inge Svendsen
Centre for Studies of Environment and Resources, University of Bergen,
Høyteknologisenteret, N-5020 Bergen, Norway
Tlf.: +47 55544240, fax: +47 55324801

Climatic implications of new (old?) views on the glaciation of southern Fennoscandia and the North Sea

Hans Petter Sejrup, University of Bergen

The coastal lowlands of Jæren, south-western Norway, have an extensive cover of Quaternary sediments. Lithological, biostratigraphical and geochronological investigations of a series of borholes across Jæren have allowed us to combine earlier and new information on these deposits into a temporal model of Quaternary sedimentation.

The Jæren cores show evidences of at least four ice free episodes with marine deposition, mainly under Arctic conditions. The oldest of these, is considered to be from ca. 200 ka and the youngest is the Sandnes interstadial which is AMS dated to 31 ka BP. Interbedded between these units are 10 - 40 m thick units of till with components of marine material.

These findings, together with reevaluation of distinct morphological features on Jæren and earlier provenance studies, strongly suggest that Jæren has been a boundary zone between a large ice stream following the Norwegian Channel, draining a major part of the southern parts of the Fennoscandian ice sheet, and local ice from south-western Norway. The Norwegian Channel ice stream have through multiple periods of glaciations starting c. 1 my ago, been the main conduit of erosion products from southern Scandinavia to the deep Norwegian Sea.

Comparison with ice stream profiles from Antarctica suggest that the elevated position (c. 200 m a.s.l.) of the relatively young marine deposits on Jæren, are a result of glacial isostasy, rather than regional tectonic movements. The repeated existence of a Norwegian Channel ice stream is a result of climate change, however, an ice stream of this size hasitself a strong impact on climate, especially in periods of rapid disintegration (>200 years) when large amounts of freshwater are delivered to the ocean.

Rapid climatic changes during early post-glacial time: evidence from the Euro-Arctic continental margin.

Morten Hald, Trond Dokken, Sveinung Hagen and Vidar Kolstad
University of Tromsø, Geological Dep. IBG, N-9037 Tromsø

Four locations on the Euro-Arctic continental margin are investigated in order to elucidate paleoclimatic changes over the last 15,000 radio carbon years: 1) northern Norwegian margin (ocean depth 505 m), 2) Barents slope (1500 m), 3) Svalbard margin (1360 m) and the St. Anna Trough (144-633 m). The sediment cores from these sites are of high stratigraphic resolution, allowing for time resolution from 1000 to less that 100 years. Based on lithology, planktic foraminifera sea surface temperatures (SST), benthic foraminifera, stable oxygen and carbon isotopes and radiocarbon chronology, a three step warming of the surface ocean is indicated: The first step appears at c.12, 500 years B.P. and the warming is indicated by increased abundances of planktic foraminifera. The second step occurs at c. 10,200 characterised by a sudden rise in sub polar foraminifera indicating an increase in the sea surface temperatures of 2-3 ^{o}C within < 50 years. The third step shows a more gradual rise in subpolar foraminifera indicative of a rise in SST of 2-3 ^{o}C between 10,000-9,600 years B.P. An early Holocene climate optimum is indicated around 9,000-8,000 years B.P. at the northernmost sites, followed by a colder mid Holocene.

The first SST rise appears to be a time transgressive phenomenon in the eastern North-Atlantic -Norwegian Sea, starting as early as 13,500 in the south (55-60 ^{o}N) and gradually reaching the western Barents Sea continental margin (72 ^{o}N) a thousand years later. On the other hand, the two subsequent warming steps represent regional simultaneous events, reflected both in the marine- terrestrial and ice-core stratigraphy in the Nordic Sea region.

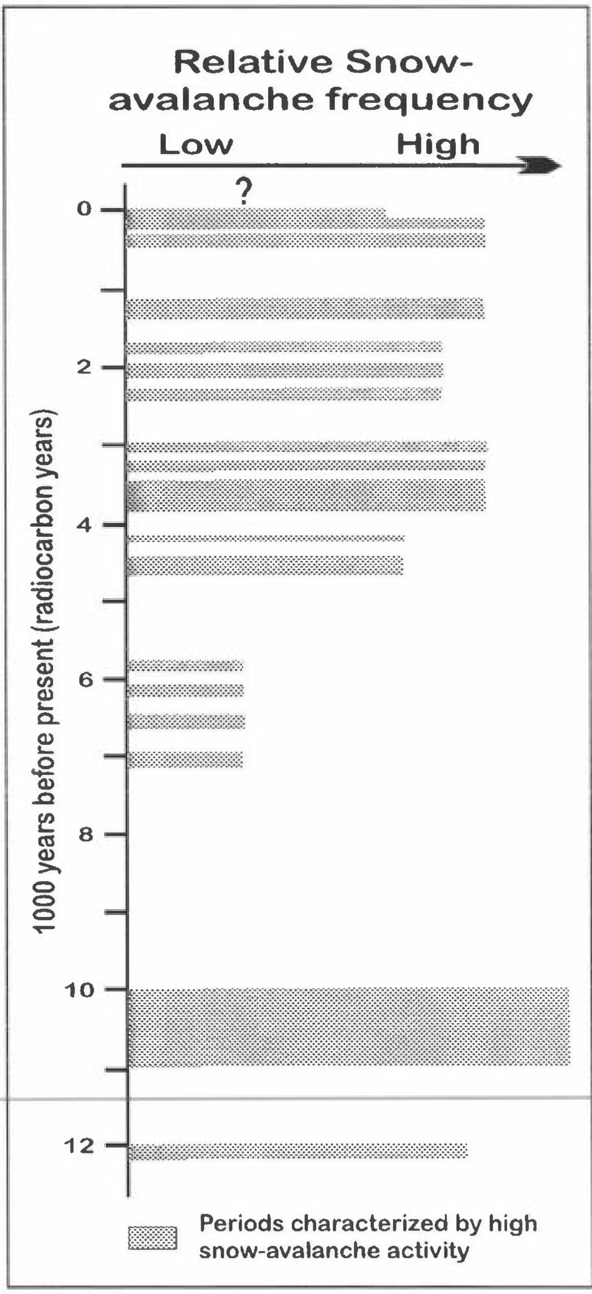
Between 9,000 and 7000 years B.P. there is a reduction in the sediment flux to the ocean at all the sites investigated. The reason for this reduction may be linked to a) final retreat of inner fjord glaciers (northern Norwegian margin); cooling by reduced inflow of Atlantic Water (Svalbard margin and St. Anna Trough); sea level rise and reduced river input (St. Anna Trough) and reduced winnowing of the shallow banks (Barents slope).

CLIMATIC CHANGE AND AVALANCHE HAZARD

Lars Harald Blikra, Geoogical Survey of Norway, P.O.Box 3006, N-7002 Trondheim

The study of avalanche deposits has shown that the occurrence and frequency of avalanches are strongly controlled by the fluctuations in climate. A series of case studies from western Norway demonstrate the close relationship between postglacial and Holocene climatic change and avalanche activity. This research not only shows the link between avalanches and climate, but contribute also with valuable information about past weather conditions. Natural and man-induced changes in the climate has thus direct implications on avalanche-hazard estimation.

The record of snow avalanches are thought to show the fluctuations in the occurrence of major winter storms (see figure), or in general the winter-climatic conditions (air temperature, snowfall intensity, prevalent wind directions and snow-drift accumulation). Snow-avalanche activity were extremely high during the cold Younger Dryas period (11-10.000 years BP). The Holocene record show also a remarkebly good correspondance with the regional record of glacier fluctuations. Snow avalanches were at most localities almost nonexistent during the first half of the Holocene, i.e. during the climatic optimum, but began to increase at about 5000 years before present. The snow-avalanche sedimentation show highly fluctuating winter-climatic conditions, and demonstrates further that episodes characterized by major winter storms with heavy snowfall and high snow avalanching were more frequent in some phases of the Holocene than it is today (see figure). Debris avalanches in the stratigraphic record probably reflect extreme rainfall events, and this record indicate a high incidence in the second half of the Holocene. Particularly high frequency seem to have occurred at about 3000 years before present, 1500 years before present and today. These data thus indicate that some distinct periods in the past were characterized by extreme rainfall events. The record of rock avalanches shows also an increased activity during the second half of the Holocene.



The avalanche deposits indicate that phases charaterized by extreme weather conditions, including both major winter storms and major rainfall events, were common in the past and have varied with time. We have thus to be extremely careful to make conclusions about human-induced changes in the climate based on the occurrence of extreme weather events today. If the climate changes as postulated by the Intergovernmental Panel on Climate Change (IPCC), the occurrence and frequencies of different avalanches will change. An increased precipitation, and in particularly higher frequency of heavy rainfall events, will probably lead to a distinct increase in debris-avalanche activity. A general warmer climate will reduce the snow-avalanche activity in most places, as we can achieve a climate comparable with the first half of the Holocene. However, higher precipitation will also increase the snow-accumulation rates at higher altitudes, and thus be responsible for more snow avalanching at high-altitude mountains.

Since the climate is the single most important factor for the incidence of avalanches, the pattern of climatic change plays an important role in connection with avalanche-hazard evaluation. The society want an estimation of avalanche hazard, which means that we must try to calculate frequency of avalanches during a specific time interval. If we know aproximate the total number of events in an area, we also need to know something about the time interval these avalanches had occurred. The present work show that we should use the last 5000 years as a base when estimating avalanche hazard, but when dealing with debris-avalanche hazard we should use 3000 years as a base. The studies also demonstrete that the climate has changed abruptly (on/off), suggesting that also the present avalanche conditions may change rapidly. Snow-avalanche hazard were for example higher in some phases in the past than it is today, meaning that we must use a relatively long time span (geological record) when evaluating potential hazard. Potential changes in avalanche activity due to the greenhouse effect should also be evaluated. Especial important will be to verify areas of potential debris-avalanche hazard, since we expect this type of hazard to increase due to higher precipitation rates. Furthermore, populated areas situated at the base of very high-altitude mountains can experience increased snow-avalanche risks due to increased snow-fall rates.

Further research on this topic include a NFR project on Holocene climatic variations in western Norway based on avalanche activity and glacier fluctuations. This research project and existing data on avalanche activity and climate are an important base for avalanche-hazard projects at the Geological Survey of Norway.

Use of ozonesondes to identify stratospheric ozone change caused by chemical processes

Geir O. Braathen, Norwegian Institute for Air Research,
P.O. Box 100, N-2007 Kjeller, Norway

Introduction

The ozonesonde is a well suited instrument to detect ozone change in the stratosphere due to its high vertical resolution and the fact that sondes can be launched under almost all weather conditions.

Earlier studies indicate that ozone depletion did take place during the 1988-89 winter (Schoeberl et al., 1990; Kyrö et al., 1992). During the relatively mild EASOE winter in 1991-92, some ozone depletion evidently took place as well (Braathen et al. 1994; von der Gathen et al., 1995a). During the 1992-93 winter, noticeable ozone depletion took place, and loss rates of 1% per day has been reported (Larsen et al., 1994). During the SESAME campaign winter in 1994-95, there were PSCs for such a long period that extensive ozone depletion took place over large areas of the Arctic (Fløisand et al, 1995; Bojkov et al, 1995; von der Gathen et al., 1995b). These studies show that ozone depletion is closely linked to time periods with temperatures lower than the threshold temperature for the formation of PSC type I in the lower stratosphere. Since the most obvious depletion of ozone so far has apparently taken place during the most recent winter, it is of interest to investigate whether ozone depletion has taken place in the Arctic earlier, and to what extent this is correlated with the incidence of temperatures cold enough for PSCs to exist.

Ozonesonde data (approx. 600 profiles) from several Arctic stations (Bear Island, Egedesminde, Gardermoen, Heiss Island, Kiruna, Ny-Ålesund, Polarfront, Scoresbysund, Sodankylä and Thule) for the seven winters 1988-89 through 1994-95 have been combined into a comprehensive analysis of ozone in the Arctic polar vortex. Temporal trends of the ozone mixing ratio, during the individual winters, have been quantified for the Arctic polar vortex, taking into account the position of each measurement relative to the edge of polar vortex. The stations' position relative to the vortex edge has been determined by using wind and temperature data from the European Centre for Medium Range Weather Forecasts (ECMWF). Temperature data from ECMWF has been used to determine the geographical extent of temperatures below the thermodynamic threshold for formation of nitric acid trihydrate polar stratospheric clouds (PSC type I). Comparison of ozone trends with the extent of PSC temperatures shows clearly that ozone decline is concurrent with theoretical PSC condensation conditions.

It is shown that the wintertime loss of ozone is affected by the length of the active loss period and the average loss rate. Interannual meteorological variability causes large variations in these two parameters. The study deals mainly with the 475K isentropic level (approx. 20km). The largest observed loss of ozone at 475K, within this data set, about 39%, occurred during the winter of 1994-95, when the average loss rate was only moderate for the Northern Hemisphere, but when the active loss period lasted about 100 days. In contrast, in 1991-92, the average loss rate was quite higher, but due to the shortness of the active loss period the observed loss was only 9% at the same level. Consideration of the effects of diabatic descent for ozone trends at 475 K indicates that the actual chemical loss has been even larger. At the 435K level (approx. 17km) the accumulated loss of ozone reached 54% during the 1994-95 winter.

Results at the 475K level

Table 1 shows the calculated ozone change for the seven winters at 475K.

Table 1 : Calculated ozone loss at 475K for the winters from 1988-89 through 1994-95.

Winter	Active ozone loss period (days)	Accumulated loss of ozone (%)	Average ozone rate of change (%/day)	Period of most rapid ozone decline (days)	Maximum ozone rate of change (%/day)
1988-89	30-60	21	-1.0 ± 0.2		
1989-90	22-70	26	-0.68 ± 0.21		
1990-91	not	enough	data		
1991-92	10-25	9	-0.80 ± 0.36		
1992-93	15-85	33	-0.72 ± 0.05	35-70	-1.0 ± 0.2
1993-94	40-85	23	-0.45 ± 0.11	55-80	-0.58 ± 0.21
1994-95	1-100	39	-0.50 ± 0.04	18-55	-1.1 ± 0.1

These results will be illustrated by figures for one winter with no or little ozone loss and one winter with severe ozone loss. Figure 1 shows the PSC area and ozone development during the 1991-92 winter. This winter (1991-92) was characterized by PSC activity during late December an most of January. However, a major warming in late January prevented PSC formation after 25 January. The ozone data suggests a small downward trend during January, and no clear trend later in the winter.

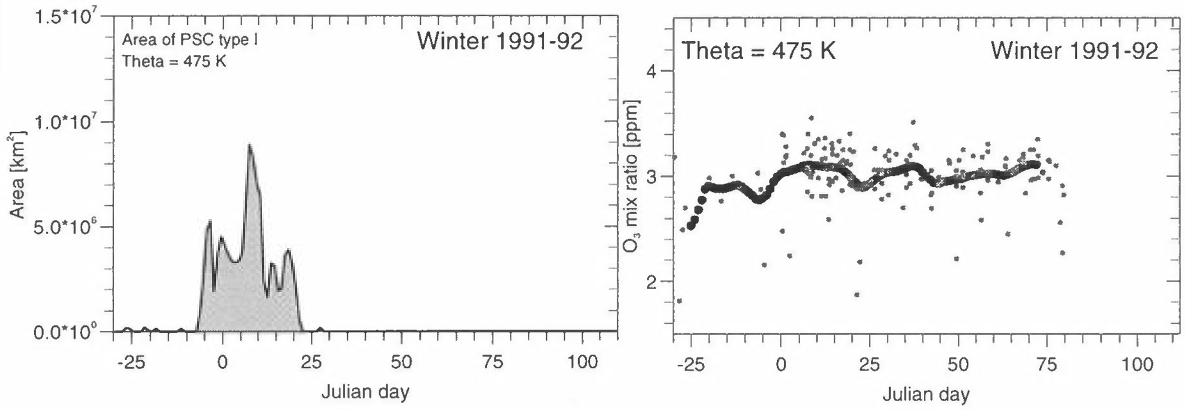


Figure 1. *The leftmost panel (a) shows the combined area of grid cells with temperatures below the PSC type I condensation limit at the 475K isentropic level for the 1991-92 winter (EASOE). The rightmost panel (b) shows the temporal development of ozone at the same level. The solid line represents a Gaussian 15 days running average.*

Figure 2 shows the development during the 1994-95 winter. This winter was very cold during most of December and the whole of January. Conditions for PSCs persisted until day 40 (see Figure 2a). Due to a subsequent rise in temperatures, there were almost no PSC conditions at 475K from day 40 to day 63. Then the cold set in anew, and made PSCs possible until day 75. The variation of ozone (see Figure 2b) shows a steady downward trend, which starts around day 5 and lasts until day 75. However, there is a large scatter in the mixing ratio after day 70. This scatter might have been caused by horizontal exchange with air masses outside the vortex.

Results for the 435K level

Although the emphasis of this study has been on the 475K level, data for the most recent winters indicate that substantial depletion also takes place lower down in the stratosphere. This can be quantified by investigating the 435K level for the two winters with the most pronounced

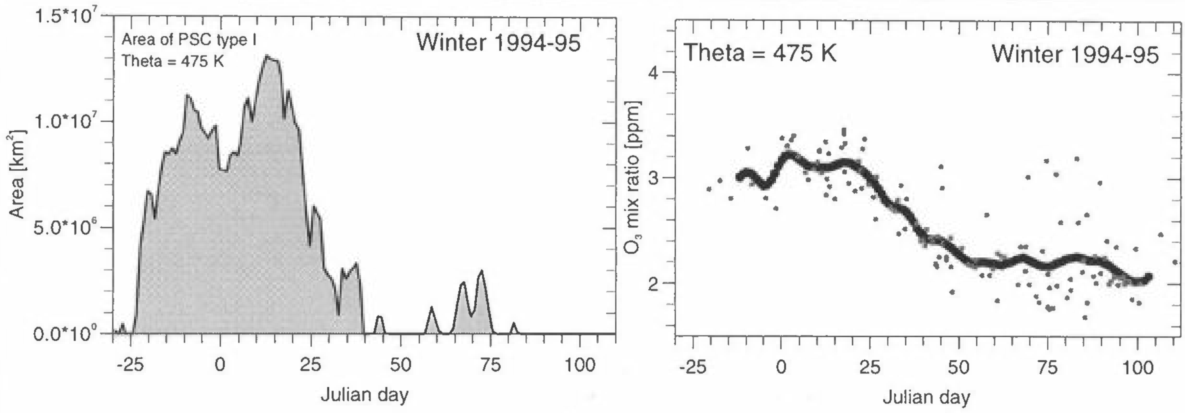


Figure 2. *The leftmost panel (a) shows the combined area of grid cells with temperatures below the PSC type I condensation limit at the 475K isentropic level for the 1994-95 winter (SESAME phase III). The rightmost panel (b) shows the temporal development of ozone at the same level. The solid line is a Gaussian 15 days running mean.*

ozone reduction at 475K, namely 1992-93 and 1994-95. The possible PSC area as calculated earlier for the 475K level is even higher in the late winter at 435K. This can be explained by the subsidence of the cold air mass. Figures 3 and 4 show the temporal development of the ozone mixing ratio at 435K for these two winters together with a Gaussian running mean and

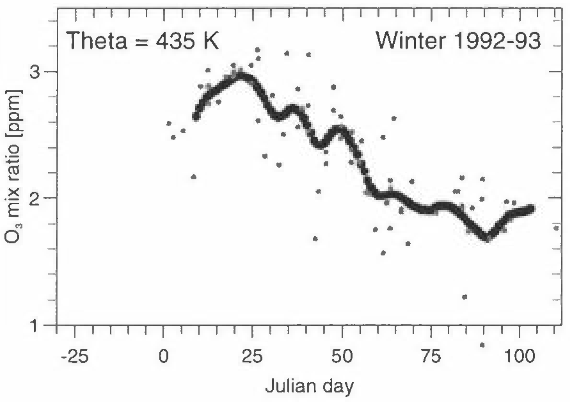


Figure 3. *Temporal development of ozone at 435K during the 1992-93 winter. The small grey spots represent individual soundings, whereas the solid curve is a Gaussian 15 days running average (see main text).*

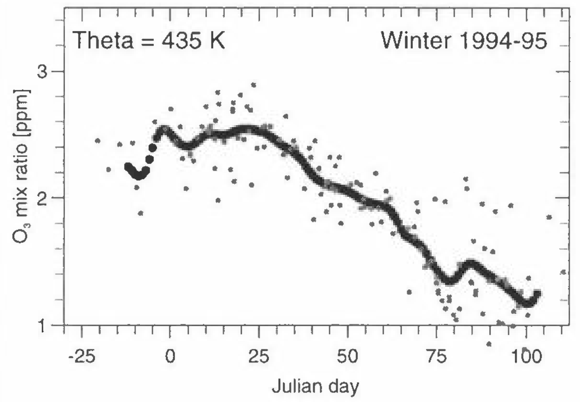


Figure 4. *Same as Figure 3, but for winter 1994-95.*

Table 2 shows the calculated ozone loss rates at this level.

Table 2 : Characteristics of ozone loss at 435K during the winters 1992-93 and 1994-95.

Winter	Active ozone loss period (days)	Accumulated loss of ozone (%)	Average ozone rate of change (%/day)	Period of most rapid ozone decline (days)	Maximum ozone rate of change (%/day)
1992-93	20-90	43	-0.80 ± 0.10	45-60	-1.8 ± 0.5
1994-95	20-100	54	-1.00 ± 0.06	60-80	-2.5 ± 0.6

References

Bojkov, R.D., V.E. Fioletov, D.S. Balis, C.S. Zerefos, T. V. Kadygrova, A.M. Shalamjansky (1995): Record low ozone over Siberia in winter/spring 1994-95. In: Abstracts of the International Conference on Ozone in the Lower Stratosphere, 15-20 May 1995. Halkidiki, 10.

Braathen, G.O., M. Rummukainen, E. Kyrö, U. Schmidt, A. Dahlback, T. Jørgensen, R. Fabian, V. Rudakov, M. Gil, and R. Borchers (1994): Temporal development of ozone within the arctic vortex during the winter of 1991/92. Geophys. Res. Lett., 21, 1407-1410.

Fløisand, I., F. Stordal, G.O. Braathen, S.J. Reid, B.A.K. Høiskar, N. Larsen, V. Dorokhov, B. Rognerud and I.S.A. Isaksen, Evidence of chemical ozone depletion inside the polar vortex in winter and spring 1995. Submitted to J. Atm. Chem.

von der Gathen, P., M. Rex, N.R.P. Harris, D. Lucic, B.M. Knudsen., G.O. Braathen, H. De Backer, R. Fabian, H. Fast, M. Gil, E.Kyrö, I.S. Mikkelsen, M. Rummukainen, J. Stähelin and C. Varotsos (1995a): Observational evidence for chemical ozone depletion over the Arctic in winter 1991-92. Nature, 375, 131-134.

von der Gathen, P., H. Gernandt, R. Neuber and M. Rex (1995b): Ozone deficits in the lower and middle stratosphere of the Arctic polar vortex. In: Abstracts of the International Conference on Ozone in the Lower Stratosphere, 15-20 May 1995. Halkidiki, 32-33.

Hanson, D.R. and K. Mauersberger (1988): Laboratory studies of the nitric acid trihydrate: Implications for the south polar stratosphere. Geophys. Res. Lett. 15, 855-858. Jansco, G. et al. J. Phys. Chem. 74, 2984 (1988).

Kyrö, E., P. Taalas, T.S. Jørgensen, B. Knudsen, F. Stordal, G. Braathen, A. Dahlback, R. Neuber, B.C. Krüger, V. Dorokhov, V.A. Yushkov, V.V. Rudakov, and A. Torres (1992): Analysis of the ozone soundings made during the first quarter of 1989 in the Arctic. J. Geophys. Res., 97, 8083- 8091.

Larsen, N., B. Knudsen, I. S. Mikkelsen, T. S. Jørgensen, and P. Eriksen (1994): Ozone depletion in the arctic stratosphere in early 1993. Geophys. Res. Lett., 21, 1611-1614.

Rummukainen, M., B. Knudsen, and P. von der Gathen (1994): Dynamical Diagnostics of the Edges of the Polar Vortices. Annales Geophysicae, 12, 1114-1118.

Schoeberl, M.R., M.H. Proffitt, K.K. Kelly, L.R. Lait, P.A. Newman, J.E. Rosenfield, M. Loewenstein, J.R. Podolske, S.E. Strahan, and K.R. Chan (1990): Stratospheric constituent trends from ER-2 profile data. Geophys. Res. Lett., 17, 469-472.

UV-VIS Spectroscopy Applied to Stratospheric Chemistry, Methods and Results

Kjersti Karlsen
Norwegian Institute for Air Research, P.O.Box 100, 2007 Kjeller

1 BACKGROUND

The Antarctic ozone hole was discovered in 1985 by British scientists [Farman et al., 1985]. Numerous observations from the ground, from aircraft, balloons and satellites together with modeling have shown, with a very high degree of certainty that the manmade emissions of CFCs and halons are the culprits of the Antarctica ozone hole. It has also become evident that the ozone layer in the Northern Hemisphere has suffered a certain decline over the last 10-15 years [WMO 1994]. Although it is not as clear as in Antarctica, it appears quite plausible that the Northern Hemisphere ozone loss is also caused by CFCs and halones.

Previous work [Andersen et al. 1989, Solomon et al, 1990] indicate that 20-30% of the observed decline of ozone is caused by the coupling of chlorine and bromine chemistry via the catalytic cycle

ClO + BrO ---> ClOO + Br ---> BrCl + O_2 (1)
ClOO + M ---> Cl + O_2 + M (2)
BrCl + hν ---> Br + Cl (3)
Cl + O_3 ---> ClO + O_2 (4)
Br + O_3 ---> BrO + O_2 (5)

----

net result $2O_3$ ---> $3O_2$

Reaction 1 competes with the following reaction

ClO + BrO ---> OClO + Br (6)

The relationship between the chlorine and bromine chemistry is not yet fully understood. Within this project we will assemble a UV-VIS spectrometer for measuring the species OClO and BrO. The amount of both these species provide an independent estimate of the magnitude of the chlorine and bromine activation of the stratosphere. Both chlorine and bromine can catalytically distroy several ozone molecules. It has been suggested [Schiller et al., 1990] that the amount of OClO is linearly dependent of the ClO amount in the stratosphere. A recent model study [Sessler et al, 1995] questions this correlation and claims that OClO for SZA lower than 92° is only a good indicator at low ClO concentrations. However, OClO is a good indicator of BrO due to its linearly concentration dependency.

During this project we plan to compare and discuss measured diurnal variations of OClO and BrO with model calculations.

2 MEASURING AND ANALYSING TECHNIQUE

One measuring technique for detecting OClO and BrO is the Differential Optical Absorption Spectroscopy (DOAS) technique. During this project we have developed a spectrometer for detecting gas compounds as O_3, NO_2, BrO, OClO and IO by this technique. All these compounds absorb electromagnetic radiation in the ultraviolet and visible spectral range (300-600 nm). The instrument consists of a grating spectrometer from ACTON, with a focal length of 270mm and a 1024 pixels photodiode array detector. The light source is scattered sunlight from the zenith sky. The different wavelengths in the incoming light is refracted by the grating in different directions, and therefore reaches different pixels on the detector. With a photodiode array we therefore record the whole spectrum simultaneously, and the spectrometer does not need to contain any moving elements.

The spectrometer measures down to a SZA of 96°, which is 6° under the horizon. We have built a system which is flexible, making it possible to optimize instrument parameters such as spectral range, resolution and sampling ratio, for the specific measuring situation.

The recorded spectra are analyzed with the method known as the DOAS analysis. This is based on the Lambert Beers equation

$$t = \ln(I/I_0) = \exp(-L\ \Sigma(\sigma_i\ c_i))$$

where I_0 is the intensity measured at high sun, I is the intensity measured at low sun, L is the optical path, σ_i is the absorption cross section of gas compound i, c_i is the concentration of the compound i.

The broad band features which include attenuation by molecular Rayleigh and aerosols Mie scattering is removed by fitting a low order polynomial and divide by this. The remaining features are the differential absorption spectra containing only the absorption structure from the absorbing constituents in the atmosphere. The differential spectra are fitted with laboratory spectra (absorption cross section) of the various absorbing compounds by using a multiple linear regression analysis. All known absorbing compounds within the spectral region of interest, are taken into account. The analysing technique gives the slant column which varies with the solar zenith angle. The ratio between the slant and vertical columns is the so called Air Mass Factor (AMF), which can be calculated by a radiative transfer model. Using the AMF factors, the slant column is converted to a vertical column.

3 RESULTS

The instrument was delivered last June and installed at Ny-Ålesund in September -95 after developing software to run the instrument automatically. During the autumn season one does not expect to find compounds as OClO due to meteorological conditions. This period the instrument was therefore set to measure O_3 and NO_2. To decide the reliability of a new instrument, it is important to compare it with data from other instruments. Comparison with the SAOZ spectrometer also run by NILU is shown in figure 1 and figure 2.

The two instruments follow each other very well, but the ACTON spectrometer generally measures higher values than the SAOZ. The observations of ozone and NO_2 are in general agreement with established climatology.

The instrument was again installed at Ny-Ålesund after the polar night (middle of February) this year, to measure OClO, BrO, NO_2 and O_3.

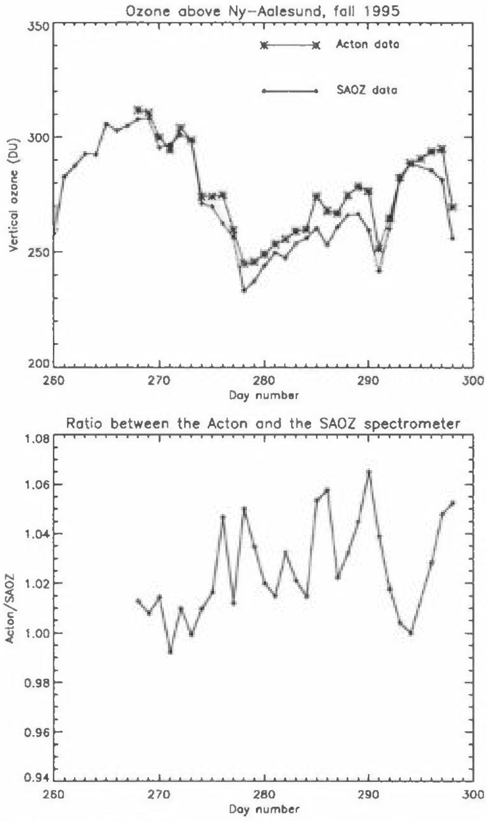


Figure 1a) Total vertical column of ozone measured by the ACTON and the SAOZ spectrometer in Ny-Ålesund, during autumn 1995. b) The ratio between the measured ozone values from the ACTON and the SAOZ spectrometer is given

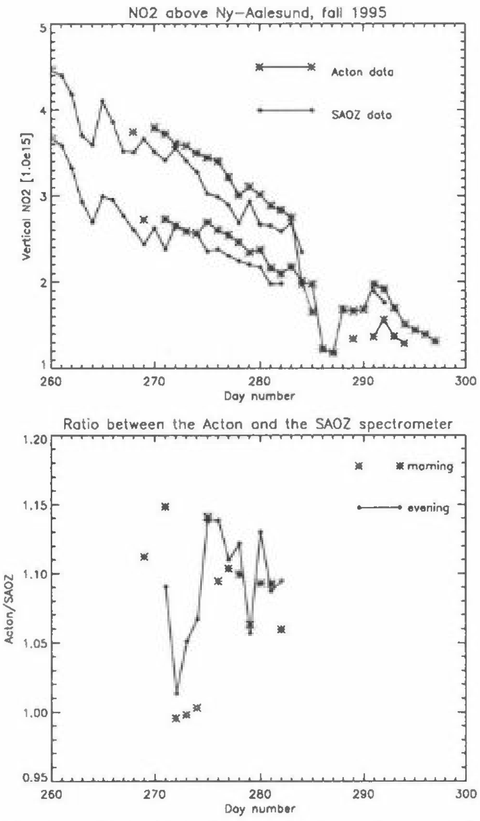


Figure 2a) Total vertical column of morning and evening values of NO_2 measured by the ACTON and the SAOZ spectrometer in Ny-Ålesund, during autumn 1995. b) The ratio between the measured ozone values from the ACTON and the SAOZ spectrometer is given.

4 REFERENCES

Anderson, J.G., W.H. Brune, S.A. Lloyd, D.W. Toohey, S.P. Sander, W.L. Starr, M. Loewwenstein and J.R.Podolske, Kinetict of O3 destruction by ClO and BrO within the Antartic vortex : An analysis based on in situ ER-2 data, *J. Geophys. Res. 94,* **11**, 480-11,520, 1989

Farmann, J.C., B.G. Gardiner and J.D. Shanklin, Large losses of total ozone in Antartica reveal seasonal ClOx/NOx interaction, *Nature*, **315**, 207-210,1985

Schiller, C. A.Wahner, U.Platt, H.Dorn, J.Callies and D.Ehhalt, Near UV Atmospheric Absorption Measurements of Column Abundanced during Airborne Artic Stratospheric Expedition, January-February 1989: 2. OClO Observations, *Geophys. Res. Lett.*,**17**, 501-504, 1990

Sessler, J., M.P.Chipperfield, J.A.Pyle and R.Toumi, Stratospheric OClO measurements as a poor quantitative indicator of chlorine activation, *Geophys. Res. Lett.*, **22**, 687-690, 1995

Solomon, S, R.W. Sanders and H.L. Miller, Jr., Visible and near-ultraviolet spectroscopy at McMurdo station Antartcia, 7, OClO diurnal photochemistry and implications for ozone destruction, *J. Geophys. Res 89,* 11, 633-11,644 1990

WMO, Scientific Assessment of Ozone Depletion : 1994, World Meteorological Organization, Global Ozone Research and Monitoring Project - Report No. 37

Seminar: Klima og ozonforskning i Norge.
Førsteamanuensis Berit Kjeldstad,
Norges Tekniske Naturvitenskapelige Universtitet (NTNU),
Fysisk institutt, Dragvoll.
Abstract:

«Spectral ultraviolet-B radiation fluxes at the earth- and ocean-surface: Are there long-term variations ?»

The spectral ultraviolet-B radiation (UV-B) fluxes at the earth- and ocean-surface change naturally during the day and during the year. The natural fluctuations can be very high, due to meteorological conditions. Solar elevation and clouds are the most important parameter for averaged daily totals of UV and the most important factor for cumulative UV-B expose of the ecosystem. A slightly increase in UV-B has been observed at some places. Correlation to simultaneously long-term decrease in ozone is high. How significant this long-term increase in UV is, for biological effects, is an important question to discuss.

However, changes in ozone influence the spectral distribution of UV-B. Decreased total atmospheric ozone (O) increase the UV irradiance (I), specially for lower wavelengths. The radiation amplification factor (RAF), defined as: $I \propto O^{-RAF}$ changes from approximately 0.7 for higher wavelengths and solar elevation to 2.8 for lower wavelengths and solar elevation. For the erythema weighted UV dose the RAF changes from 1.3 to 0.95. These RAF values are examples of results from measurements made in Switzerland, 3576 m a.s., during 1981 to 1993. The RAF might be different for different latitudes. Data from Antarctica, from a two year period, gave a RAF value for erythemal UV dose of 1.1. Similar results are yet not published for Arctic conditions, which would be of great interest.

Even if Trondheim is located south of the arctic circle (63N10E), it is of interest to calculate RAF from spectral UV data at this latitude. Our spectroradiometer, an Optronic 752 with double monochromator and an integrating sphere, has been measuring spectral UV radiation continuously for shorter periods within the last two years. Much work has been done to evaluate the data quality and the total uncertainty of the measurements. Data processing are under progress. Participation in a Nordic intercomparison in 1993 concluded with the necessity of performing characterisation of different instrumental properties. This work will be published. It is of great importance to perform good UV-measurements. The procedures and techniques to perform quality control of spectral UV data are under development. We are participating in an EU project, SUVDAMA - Scientific UV Data Management (project-nr.; PL 950247) where we will contribute on these problems.

To evaluate effects of increased ultraviolet radiation on different ecosystems at our latitudes, it will be of importance to focus on radiation measurements specially during spring time. The combination of rapid changes in the ozone concentration (with low ozone events) in addition to changes in cloud conditions might give rise to extreme UV levels for short periods. This type of exposure might result in larger biological damage than slowly long-term effects on cumulative UV doses. It will be of interest in future to investigate whether the frequency of single high UV peak doses will increased.

Work to be published:

Thorseth, T.M. and B. Kjeldstad: «Characteristics of a spectroradiometer; Angular Response and Temperature Dependence.» NATO-Advanced Study Institute, Report, Halkidiki, Greece 1995.

Effects of UV-radiation on plankton

Jan Borgeraas, Department of Biology, University of Oslo.

There is a need for more information about effects of the stratospheric ozone depletion and subsequent increased UV-B radiation on foodchains in marine and freshwater communities. However, it is evident that even the present level of UV-radiation act as a powerful ecological parameter, affecting both production, geographical and vertical distribution and competition as well as mutation frequencies and evolution. Distribution of organisms are undoubtedly restricted by detrimental UV. Hence it should be emphasized that most probably UV-radiation is a largely underestimated abiotic factor with major effect on ecosystems even if a potential UV-increase is not taken into consideration.

An important question regarding aquatic systems is the penetration of UV-radiation into the water column. It has been demonstrated that in offshore marine waters, biologically active UV-B may penetrate to depths below 10 m. In lakes rich in organic carbon, like humic compounds, UV penetration is restricted to the top centimeters. On the other hand, oligotrophic lakes, and particularly alpine lakes, may receive high doses of UV-B light at significant depths. For an oligotrophic alpine lake, lake Bessevatn, we found that 10 % of incident surface light remained at 10 m depth, while at 400 nm 40 % of surface light was present, demonstrating that UV-B may also be a potential hazard in fresh waters.

Special attention has been paid to the susceptibility of primary production of marine ecosystems because planktonic algae is an important CO_2-sink in the global carbon cycle and they constitute the base of marine food-webs. The negative effects caused by UV-radiation on phytoplankton are well known and includes impairment of orientation and motility, inhibition of cell division and growth rate, and reduced uptake of ammonia, nitrate and phosphorus. UV-radiation may cause both direct and indirect damage to zooplankton populations. Indirect effects may include reduced primary production and shifts in phytoplankton species composition, increased phytoplankton cell-wall toughness and thus reduced digestability, or toxic effects caused by release of chelated metals. Direct effects include production of reactive oxygen species with subsequent oxidant damage to proteins, membranes and DNA. Direct damage may be prevented by behavioural responses, pigment sun-screens or various antioxidant defence systems.

We focus on the effects of UV-radiation on susceptible key species found in freshwater ecosystems, the crustacean zooplankters, *Daphnia magna*, *D. longispina* and *D. pulex*. These species has a world-wide distribution in localities susceptible to high UV-doses, may show morphological and genetic adaptations and may be easily cultured and cloned. We have adapted this genus as an model organism for the study of behavioural and physiological responses, genetic damage, protective pigments and antioxidant expression of various levels and spectra of UV and near UV-light. In addition to lab experiments we have focused attention on zooplankton communities in alpine and arctic localities. These localities are charcterized by high UV and near-UV exposure because of their elevation, high water transparency, absence of depth refugia, and long day length. In these areas highly light-exposed *Daphnia* populations possess a carapace melanization, a property clearly linked to UV-exposure. Within a region, the melanized clones occur in the clearest ponds and are replaced by non-melanic clones when vegetation increases or water transparency decreases. Laboratory experiments have shown that melanized clones are more tolerant to UV-stress. With the exception of carotenoids and melanin, there are virtually no data available on the role of other antioxidants as UV-protective agents in freshwater zooplankton. We are currently developing screening techniques to assess levels of the antioxidants glutathione and ascorbic acid and the antioxidant enzymes catalase, superoxide dismutase, glutathione peroxidase and glutathione transferase as well as to evaluate DNA-damage and lipid peroxidation effects in *Daphnia* under various light regimes. Low temperatures may result in low repair capacities for UV-induced damages. Thus, special interest is taken to evaluate UV-effects at lower temperatures.

Effects of increased temperature and CO_2 on soil quality

Gunnar Ogner
Norwegian Forest Research Institute,
Høgskoleveien 12, N-14432 Ås, Norway.

ABSTRACT

The Norwegian Forest Research Institute has studied the effects of increased CO_2 and temperature on forest soil, soil leachate and plants in an open top chamber (OTC) experiment. The goal was to analyze the changes in soil parameters and the leaching of elements. Nitrate and aluminium received special attention. The growth of Norway spruce and birch was followed, and its impact on the soil parameters.

The experiment was located in Ås, with a climate close to inland climate. Six OTCs (3 m Ø, 3.5 m high) contained each a lysimeter table with 4 lysimeters (30 cm Ø, 35 cm deep) of a homogenous natural podsolic soil profile. The first lysimeter contained one plant (clone) of birch. The second and third contained six different clones of spruce plants with three clones in each lysimeter. The forth (control) contained no trees at all, only a moss cover. The CO_2 levels were 350, 500 and 700 µmol/mol, with two replicates. Two identical lysimeter table setup were outside the chambers for chamber control. The treatment with CO_2 started May 1993 and ended October 1995. CO_2 was added only during the growth seasons. Lysimeter soil temperature was at the most 4-5 °C higher during the warmest summer days compared to the forest soil where the soil was collected. Air temperature in the OTCs was only slightly higher relative to the chamber control.

Preliminary results indicate that the temperature increase of the soil, and consequently an increased turnover of soil organic matter, clearly had the major effect on the quality of soil leachates. CO_2 was of minor importance. The raw humus layer of moss covered lysimeters was more decomposed than for the other lysimeters. Leaching of NO_3^- was high from control lysimeters with moss cover, up to 750 µM NO_3^-. Lysimeters with birch hardly leached NO_3^- at all. Spruce is in an intermediate position. Increased leaching of Al^{n+} is found for moss lysimeters, up to 200 µM Al^{n+}. Leachates from birch lysimeters have high consentrations of Al^{n+}, up to 300 µM, only at the end of the growth seasons.

Plant growth is to some extent increased by the CO_2 treatments. Birch grew well in all lysimeters and all treatments, spruce developed clearly symptoms on stress. This result do not fit with the increased availability of nutrients in soil solution.

Analytical data of soil parameters will be reported later.

Key words: Climate change, increased CO2, increased temperature, Norway spruce, birch, soil chemistry, leaching, nutrients, nitrate, aluminium.

The IPCC Second Assessment Report Summary of the Contribution of Working Group II

Frøydis Kvaløy
Jon Barikmo

Directorate for Nature Management

The Task of Working Group II

The task of the IPCC Working Group II has been to give an overview of possible effects of climate change on physical and ecological systems, human health and on socio-economic systems. The group has also been responsible for reviewing possible technical and economic feasibility of potential adaptation and mitigation strategies.

Nature of the Issue

Human activities are increasing the atmospheric concentrations of greenhouse gases which tend to warm the atmosphere and, in some regions, aerosols which tend to cool the atmosphere. The climate models, taken into account greenhouse gases and aerosols, project an increase in global mean surface temperature of about 1-3,5°C by year 2100, and an associated increase in sea level of about 15-95 cm. The information indicates that climate-induced environmental changes cannot be reversed quickly, if at all, due to the long time scales associated with climate change. Policymakers are faced with responding to the risks by emissions of greenhouse gases in the face of significant scientific uncertainties.

Vulnerability to Climate Change

The ecological systems contain the Earth's entire reservoir of genetic and species diversity. They also provide many goods and services critical to humans and society. Climate change is expected to change many ecosystem's composition and geographical distribution. Some ecological systems may not reach a new equilibrium for several centuries after the climate achieves a new balance.

For mid-latitude regions , a global warming of 1-3.5°C over the next 100 years would be equivalent to a poleward shift of the present isotherms by approximately 150-550 km or an altitude shift of about 150-550 meters. Entire forest types may disappear, while new assemblages of species and new ecosystems may be established. The largest changes in vegetation types are expected to be on higher latitudes, while tropical areas will be less affected.

According to the Working Group II the deserts are likely to become more extreme in that they will become hotter but not wetter. Furthermore, it is estimated that between one-half and one-third of the mountain glaciers could disappear within the next 100 years. This will, among others factors, affect the seasonal water flow and water supply to hydropower generation and agriculture. Among the expected consequences on oceans of climate change is a change in sea level, altered ocean circulation, vertical mixing, wave climate, and reductions in sea-ice cover. Estimations in the report suggest that 46 million people are currently living in areas that are at risk of flooding due to storm surges. With a 50 cm rise in sea level it is estimated that about 92 million people will be living in the areas potentially affected by ocean flooding, and with a sea level rise on 1 meter the number will increase to 118 million. Vulnerable coastal nations like the Netherlands, Bangladesh and the Majur atoll (Marshal islands) may experience a substantial loss of land. Developing countries are most vulnerable of changes in the sea level because they do not have satisfactory protection systems.

Climate change is expected to have extensive effects on human health with substantial loss of life. Direct health effects include increases in deaths and illness due to the expected increase in the intensity and duration of heat waves. Indirect health effects include increases in potential transmission of vector-borne infectious diseases like malaria, dengue and yellow fever. An increase in temperature on 3-5°C by year 2100 would result in 50-80 million new malaria incidences per year. This number must be seen on the background of today's total of 500 million cases of malaria.

Options to Reduce Emissions and Enhance Sinks of Greenhouse Gases

A number of studies indicate that 10-30% energy efficiency gains above present levels are feasible at little or no costs in many parts of the world. However, the potential of greenhouse gas emission reductions exceeds the potential for energy use efficiency because of the possibility of switching fuels and energy sources.

The Working Group suggests various measures to meet the negative effects of climate change. The measures suggested in the agricultural sector include changing the management of agricultural areas, storage of methane from fertilizer storages and usage of the fertilizers in more effective ways. Among the measures suggested in the forestry sector are to slow down the deforestation, to conserve the current forest cover and to establish forest plantations.

Mitigation of the negative effects of climate change depends on reducing barriers to the diffusion and transfer of technology, mobilizing financial resources, supporting capacity building in developing countries, and other approaches to assist in the implementation of behavioral changes and technological opportunities in all regions of the world.

Research Needs

The future research needs in climate change issues related to effects on ecosystems listed by the IPCC Working Group II coincide to a large extent with the research needs listed in the Norwegian research program on questions related to climate and ozone. The IPCC report says that future research is needed to understand and predict the effects of climate change on different types of ecosystems and that this should represent balance and coordination between field studies, including paleoenvironmental data collection; monitoring, experimental studies; and modeling. The research requirements include:

- Specific regional studies (transects, data acquisition, mapping, observations of different ecosystems and so on)

- Paleo data to establish baselines, to evaluate responses of ecosystems to natural climate variability, and to provide data for model verification

- Monitoring to establish long-term baseline data, in particular in potentially sensitive regions

- Experimental studies to improve fundamental understanding, to test hypotheses, and to provide empirical information for modeling studies

- Modeling to ameliorate climate scenarios using various downscaling approaches, to improve understanding of how topographic and edaphic variability influence ecosystems and natural resources on the regional scale, and to improve mechanistic modeling of physical, biological, and socio-economic systems

Integrated assessment models to address the complex interrelationships of different systems and to provide valuable multidisciplinary information to a range of end-users, including policymakers.

List of participants

Bakken, Lars
Norges Landbrukshøgskole
Inst. for jord- og vannfag
Postboks 5028
1432 ÅS
Tel.: 64 94 82 19
Fax: 64 94 82 11
E-mail: lars.bakken@ijvf.nlh.no

Barikmo, Jon
Direktoratet for naturforvaltning
Tungasletta 2
7005 TRONDHEIM
Tel.: 73 58 05 67
Fax: 73 91 54 33
E-mail: jon.barikmo.
@dnpost.md.dep.telemax.no

Benestad, Rasmus Emil
Atmospheric, Oceanic and Planetary Physics
Oxford University
Parks Road
OXFORD OXI 3PU
U.K.
Tel.: +44 1865 272088
Fax: +44 1865 272923
E-mail: r.benestad1@physics.ox.ac.uk

Birks, H. John B.
Universitetet i Bergen
Botanisk institutt
Alleg. 41
5007 BERGEN
Tel.: 55 21 33 50
Fax: 55 31 22 38
E-mail: john.birks@bot.uib.no

Birks, Hilary H.
Universitetet i Bergen
Botanisk institutt
Alleg. 41
5007 BERGEN
Tel.: 55 21 33 25
Fax: 55 31 22 38
E-mail: birks@bot.uib.no

Blikra, Lars Harald
Norges geologiske undersøgelse
Postboks 3006
7002 TRONDHEIM
Tel.: 73 90 40 11
Fax: 73 92 16 20
E-mail: lars.blikra@ngu.no

Borgeraas, Jan
Universitetet i Oslo
Biologisk institutt
Avd. for limnologi
Postboks 1027 Blindern
0316 OSLO
Tel.: 22 85 45 55
Fax: 22 85 44 38
E-mail: jan.borgeraas@bio.uio.no

Braathen, Geir O.
Norsk institutt for luftforskning
Postboks 100 Kjeller
2007 KJELLER
Tel.: 63 89 81 80
Fax: 63 89 80 50
E-mail: geir.braathen@nilu.no

Broch Mathisen, Kirsten
Norges forskningsråd
Postboks 2700 St. Hanshaugen
0131 OSLO
Tel.: 22 03 70 00
Fax: 22 03 70 01
E-mail: kirsten.broch.mathisen@nfr.no

Dahlin, Elin
Norsk institutt for luftforskning
Postboks 100
2007 KJELLER
Tel.: 63 89 81 61
Fax: 63 89 80 50
E-mail: elin.marie.dahlin@nilu.no

Drange, Helge
Nansen senter for miljø og fjernmåling
Edv. Griegsv. 3A
5037 SOLHEIMSVIKEN
Tel.: 55 29 72 88
Fax: 55 20 00 50
E-mail: helge.drange@nrsc.no

Eliassen, Anton
Det norske meteorologiske institutt
Postboks 43 Blindern
0313 OSLO
Tel.: 22 96 30 00
Fax: 22 96 30 50

Elvebakk, Arve
Universitetet i Tromsø
Inst. for biologi og geologi
Botanisk avdeling
9037 TROMSØ
Tel.: 77 64 44 36
Fax: 77 64 56 00
E-mail: arve@ibg.uit.no

Eriksen, Aud Berglen
Universitetet i Oslo
Fytotronen
Biologisk inst.
Postboks 1066 Blindern
0316 OSLO
Tel.: 22 85 46 88
Fax: 22 85 47 26

Fuglestvedt, Jan S.
CICERO
Universitetet i Oslo
Postboks 1129 Blindern
0317 OSLO
Tel.: 22 85 87 64
Fax: 22 85 87 51
E-mail: j.s.fuglestvedt@cicero.uio.no

Grønås, Sigbjørn
Universitetet i Bergen
Geofysisk institutt
Alléq. 70
5007 BERGEN
Tel.: 55 21 29 74
Fax: 55 96 05 66
E-mail: sigbjorn@gfi.uib.no.

Hald, Morten
Universitetet i Tromsø
Inst. for biologi og geologi IBG
9037 TROMSØ
Tel.: 77 64 44 12
Fax: 77 64 56 00
E-mail: mortenh@ibg.uit.no

Haugan, Peter M.
Universitetet i Bergen
Geofysisk institutt
Alleg. 70
5007 BERGEN
Tel.: 55 21 26 91
Fax: 55 96 05 66
E-mail: peter.haugan@gfi.uib.no

Heimdal, Berit Riddervold
Universitetet i Bergen
Høyteknologisenteret
Institutt for fiskeri- og marinbiologi
Thormøhlensg. 55
5020 BERGEN
Tel.: 55 54 44 82
Fax: 55 54 44 50

Hofgaard, Annika
NINA Trondheim
Tungasletta 2
7005 TRONDHEIM
Tel.: 73 58 07 74
Fax: 73 91 54 33
E-mail: annika.hofgaard@nina.nina.no

Hov, Øystein
Universitetet i Bergen
Geofysisk institutt
Alleg. 70
5007 BERGEN
Tel.: 55 21 26 36
Fax: 55 96 05 66
E-mail: hov@gfi.uib.no

Isaksen, Ivar S.A.
Universitetet i Oslo
Inst. for geofysikk
Postboks 1022 Blindern
0315 OSLO
Tel.: 22 85 58 22
Fax: 22 85 52 69
E-mail: ivar.isaksen@geofysikk.uio.no

Iversen, Trond
Universitetet i Oslo
Inst. for geofysikk
Postboks 1022 Blindern
0315 OSLO
Tel.: 22 85 58 21
Fax: 22 85 52 69
E-mail: trond.iversen.@geofysikk.uio.no

Jansen, Eystein
Universitetet i Bergen
Geologisk inst.
Allég. 41
5007 BERGEN
Tel.: 55 58 34 91
Fax: 55 58 94 17
E-mail: eystein.jansen@geol.uib.no

Johannessen, Truls
Universitetet i Bergen
Høyteknologisenteret
Senter for miljø og ressursstudier
5020 BERGEN
Tel.: 55 54 42 40
Fax: 55 32 48 01
E-mail: truls.johannessen.@smr.uib.no

Karlsdóttir, Sigrún
Universitetet i Oslo
Inst. for geofysikk
Postboks 1022 Blindern
0315 OSLO
Tel.: 22 85 58 31
Fax: 22 85 52 69
E-mail: sigrun.karlsdottir@geofysikk.uio.no

Karlsen, Kjersti
Norsk institutt for luftforskning
Postboks 100 Kjeller
2007 KJELLER
Tel.: 63 89 81 82
Fax: 63 89 80 50
E-mail: kjersti.karlsen@nilu.no

Kjeldstad, Berit
NTNU
Fysisk institutt
7055 DRAGVOLL
Tel.: 73 59 19 95
Fax: 73 59 18 52
E-mail: berkje@alfu.avh.unit.no

Koç, Nalân
Universitetet i Bergen
Geologisk institutt
Alleg. 41
5007 BERGEN
Tel.: 55 58 34 70
Fax: 55 58 94 17
E-mail: nalan.koc@geol.uib.no

Kylling, Arve
NORUT Informasjonsteknologi AS
9005 TROMSØ
Tel.: 77 62 94 00
Fax: 77 62 94 01
E-mail: arve.kylling@itek.norut.no

Lauritzen, Stein-Erik
Universitetet i Bergen
Geologisk institutt
Alleg. 41
5007 BERGEN
Tel.: 55 58 35 08
Fax: 55 58 94 16
E-mail: stein.lauritzen@geol.uib.no

Mangerud, Jan
Universitetet i Bergen
Geologisk institutt
Alleg. 41
5007 BERGEN
Tel.: 55 58 35 04
Fax: 55 58 94 17
E-mail: jan.mangerud@geol.uib.no

Mikkelsen, Naja
Danmarks Geologiske Undersøgelser
Thoravej 8
DK-2400 KØBENHAVN
DANMARK
Tel.: +45 31 10 66 00
Fax: +45 31 19 68 68
E-mail: nm@dgu1.dgu.min.dk

Ogner, Gunnar
Norsk institutt for skogforskning
Høgskolev. 12
1432 ÅS
Tel.: 64 94 90 18
Fax: 64 94 29 80
E-mail: gunnar.ogner@nisk.nlh.no

Rosland, Audun
Statens forurensningstilsyn
Postboks 8100 Dep.
0032 OSLO
Tel.: 22 57 35 47
Fax: 22 67 67 06
E-mail:
audun.rosland@sftospost.md.dep.telemax.no

Røed, Lars Petter
Det norske meteorologiske institutt
Postboks 43 Blindern
0313 OSLO
Tel.: 22 96 30 10
Fax: 22 96 30 50
E-mail: larspetter.roed@dnmi.no

Sejrup, Hans Petter
Universitetet i Bergen
Geologisk inst.
Allég. 41
5007 BERGEN
Tel.: 55 58 35 05
Fax: 55 58 94 16
E-mail: Sejrup@geol.uib.no

Skjelvan, Ingunn
Universitetet i Bergen
Geofysisk inst.
Senter for miljø og ressursstudier
Høyteknologisenteret
5020 BERGEN
Tel.: 55 54 42 68
Fax: 55 32 48 01
E-mail: ingunn.skjelvan@smr.uib.no

Stordal, Frode
Norsk institutt for luftforskning
Postboks 100 Kjeller
2007 KJELLER
Tel.: 63 89 81 75
Fax: 63 89 80 50
E-mail: frode.stordal@nilu.no

Svendsen, John Inge
Universitetet i Bergen
Høyteknologisenteret
Senter for miljø og ressursstudier
5020 BERGEN
Tel.: 55 54 42 40
Fax: 55 32 48 01
E-mail: john.svendsen@smr.uib.no

Thorgeirsson, Halldór
Head of Department
Agricultural Research Institute
Keldnaholti
112 REYKJAVIK
ICELAND
Tel.: -354-577-1010
Fax: 354-577-1020
E-mail: dori@rala.is

Toresen, Håvard
Miljøverndepartementet
Postboks 8013 Dep.
0030 OSLO
Tel.: 22 24 59 73
Fax: 22 24 27 55

Totland, Ørjan
Universitetet i Bergen
Botanisk institutt
Alleg. 41
5007 BERGEN
Tel.: 55 21 33 70
Fax: 55 31 22 38
E-mail: orjan.totland@bot.uib.no

Vorren, Karl-Dag
Universitetet i Tromsø
Inst. for biologi og geologi
Økologisk avdeling - botanikk
9037 TROMSØ
Tel.: 77 64 49 34
Fax: 77 64 56 00

Wright, Richard F.
NIVA
Postboks 173 Kjelsås
0411 OSLO
Tel.: 22 18 52 04
Fax: 22 18 52 00
E-mail: richard.wright@niva.no

Østerhus, Svein
Universitetet i Bergen
Geofysisk institutt
Alleg. 70
5007 BERGEN
Tel.: 55 21 26 07
Fax: 55 96 05 66
E-mail: svein.osterhus@gfi.uib.no

List of projects within the Norwegian Climate and Ozone Research Programme

Ref. no./ Project no.	Name Project title
732.96/002 B 1	**Kjemisk institutt UiO**
110493/720	Nielsen, Claus J. Professor
KLIMA	Lavtemperatur laboratorie-studier av atmosfærens kjemi
Bev.periode	**01/01/96 - 31/12/96**
Stilling bev.:	Loewenschuss, Aharon gjesteforsker
742.93/003 B 1	**Eksogen geologi, Avd. for UiTø**
101542/720	Larsen, Eiliv Førsteamanuensis
KLIMA	Kvartærstratigrafi på Jæren: paleomiljø, klimavariasjoner og tektonikk
Bev.periode	**01/07/93 - 30/06/96**
742.93/012 S 1	**Eksogen geologi, Avd. for UiTø**
101530/720	Larsen, Eiliv Førsteamanuensis
KLIMA	Kvartærstratigrafi på Jæren: paleomiljø, klimavariasjoner og tektonikk
Bev.periode	**01/09/93 - 31/08/96**
Stilling bev.:	Janocko, Juraj doktorgradsstipendiat
742.95/006 B 1	**Norges geologiske undersøkelser**
107251/720	Blikra, Lars H. Forsker
KLIMA	Holocene climatic variations in western Norway with focus on avalanche activity
Bev.periode	**01/01/95 - 31/12/97**
742.95/009 B 1	**Geologisk institutt UiB**
107726/720	Mangerud, Jan Professor
KLIMA	Paleo Environment and Climate History of the Russian Arctic (Pechora)
Bev.periode	**01/01/95 - 31/12/97**
Stilling bev.:	Tveranger, Jan postdoktorstipendiat

Ref. no./ Project no.	Name Project title
742.95/010 B 1	**Miljø og ressursstudier, Senter for**
107727/720	Svendsen, John Inge Forsker
KLIMA	Paleo Environment and Climate History of the Russian Arctic (PECHORA)
Bev.periode	**01/01/95 - 31/12/97**
742.96/004 B 1	**Biologi og geologi, Inst. for UiTø**
110222/720	Lyså, Astrid Stipendiat
KLIMA	Sen Pleistocen geologisk og Paleoklimatisk utvikling i Nordvest Russland
Bev.periode	**01/01/96 - 31/12/96**
742.96/009 B 1	**Geologisk institutt UiB**
110494/720	Lauritzen, Stein-Erik Førsteaman
KLIMA	Ultra-high precision climato-stratigraphy and paleoclimatic gradients through Europe from caves
Bev.periode	**01/01/96 - 31/12/97**
743.96/002 B 1	**Geologisk institutt UiB**
110478/720	Koc, Nalan Post-doktorstipendiat
KLIMA	Paleoceanographic reconstructions of isotope stages 10-11: Implications for the next climatic cycle
Bev.periode	**01/01/96 - 31/12/97**
Stilling bev.:	Koc, Nalan forsker
743.96/004 B 1	**Biologi og geologi, Inst. for UiTø**
110492/720	Hald, Morten Førsteamanuensis
KLIMA	Studies of rapid paleoclimatic and paleoceanographic shifts on Atlantic-Arctic margins
Bev.periode	**01/01/96 - 31/12/98**

Ref. no./ Project no.	Name Project title
746.92/001 B	**Miljø og ressursstudier, Senter for**
1	
101179/720	Miljø og ressursstudier, Senter
KLIMA	Karbonkjemi og fysiske prosesser i GIN-havet (CARDEEP)
Bev.periode	**01/01/92 - 31/01/97**
Stilling bev.:	Miller, Lisa forsker 100 % stilling for
746.93/005 B	**Det norske meteorologiske institutt**
1	
101528/720	Røed, Lars Petter Professor
KLIMA	Mesoskala fenomens betydning for den mellomårlige og sesongmessige variabilitet i de nordiske hav (CARDEEP)
Bev.periode	**01/08/93 - 14/11/96**
Stilling bev.:	Rudberg, Anders doktorgradsstipendiat
746.94/002 B	**Nansen senter for miljø og fjernmåling**
1	
101181/720	Drange, Helge Post-doktorstipend
KLIMA	Modellering av den marine karbon-syklus i Nord Atlanteren
Bev.periode	**01/02/94 - 31/01/96**
Stilling bev.:	Drange, Helge postdoktorstipendiat
746.95/004 B	**Miljø og ressursstudier, Senter for**
1	
107728/720	Jansen, Eystein Professor
KLIMA	Development of new methods, improvement and implementation of chemical measurements on underway pCO2 systems.
Bev.periode	**01/01/95 - 28/02/98**
Stilling bev.:	Skjelvan, Ingunn doktorgradsstipendiat
746.96/004 B	**Nansen senter for miljø og fjernmåling**
1	
110483/720	Drange, Helge Post-doktorstipend
KLIMA	Sensitivity of the General Circulation in the North Atlantic /Nordic Seas to Fresh Water Boundary Conditions
Bev.periode	**01/01/96 - 31/12/97**
746.96/005 B	**Geofysisk institutt UiB**
1	
110479/720	Gade, Herman G. Professor
KLIMA	Varmetransport i Norskehavet-Barentshavet
Bev.periode	**01/01/96 - 31/12/97**
Stilling bev.:	Haugan, Peter Mosby forsker

Ref. no./ Project no.	Name Project title
746.96/012 B	**Storbritannia**
1	
110481/720	Benestad, Rasmus Emil Doktorstip
KLIMA	Simulating and Predicting Seasonal to Interannual Climate Variability
Bev.periode	**01/01/96 - 31/12/97**
Stilling bev.:	Benestad, Rasmus Emil doktorgradsstipendiat denne perioden er i Storbritannia
747.94/001 B	**Geofysikk, Inst. for UiO**
1	
101531/720	Isaksen, Ivar S. A. Professor
KLIMA	Modellstudier av CH4 og ut-veksling mellom atmosfæren og biosfæren
Bev.periode	**01/11/94 - 31/08/98**
Stilling bev.:	Karlsdottir, Sigrun doktorgradsstipendiat
747.95/004 B	**Geofysikk, Inst. for UiO**
1	
107729/720	Isaksen, Ivar S. A. Professor
KLIMA	Analyse av satelittdata for bruk i atmosfæremodeller
Bev.periode	**01/01/95 - 31/12/96**
747.95/007 B	**Norsk inst. for luftforskning**
1	
107730/720	Stordal, Frode Professor
KLIMA	Coupled chemistry-radiation-stratospheric circulation global 2-D model of the stratosphere and troposphere
Bev.periode	**01/01/95 - 31/12/96**
Stilling bev.:	Kraabøl, Anne Gunn doktorgradsstipendiat
747.95/010 B	**Geofysikk, Inst. for UiO**
1	
107731/720	Iversen, Trond Professor
KLIMA	Climatic impacts of Anthro-pogenic Aerosols
Bev.periode	**01/01/95 - 30/06/98**
Stilling bev.:	Det skal ansettes en, doktorgradsstipendiat
747.96/006 B	**Norsk inst. for luftforskning**
1	
110482/720	Stordal, Frode Professor
KLIMA	Pollution from Aircraft Emissions in the North Atlantic Flight Corridor (POLINAT-2): NILU's participation
Bev.periode	**01/01/96 - 31/12/97**

Ref. no./ Project no.	Name Project title

747.96/011 B **Geofysikk, Inst. for UiO**
1
110484/720 Isaksen, Ivar S. A. Professor
KLIMA Ozone as a climate gas
Bev.periode **01/01/96 - 31/12/97**
Stilling bev.: Haugland, Svenn Owe doktorgradsstipend
Sundet, Jostein doktorgradsstipendiat
Sundet, Jostein postdoktorstipendiat

747.96/012 B **CICERO UiO**
1
110501/720 Fuglestvedt, Jan S.
KLIMA Quantification of the impacts of NOx emissions on climate through changes in tropospheric O3 and CH4
Bev.periode **01/01/96 - 31/12/97**

754.93/004 B **Norsk inst. for skogforskning**
1
101509/720 Skogforskning, Norsk institutt f
KLIMA Virkning av økt CO2 og temperatu-r. II Effekt på jordprosesser
Bev.periode **01/01/93 - 31/12/96**

754.95/013 B **Økologisk avdeling - botanikk UiTø**
1
107733/720 Vorren, Karl-Dag Professor
KLIMA Dendroclimateological study on pinus sylvesteris L. in northern Norway
Bev.periode **01/01/95 - 31/12/98**
Stilling bev.: Kirchhefer, Andreas doktorgradsstipendiat

754.96/009 B **Norsk inst. for vannforskning**
1
110485/720 Wright, Richard F. Seniorforsker
KLIMA CLIMEX - Climate change experiment
Bev.periode **01/01/96 - 31/12/96**

755.93/001 B **Botanisk institutt UiB**
1
101414/720 Birks, H. John B. Professor
KLIMA Spatial and temporal patterns of Holocene climatic changes in Norway
Bev.periode **01/08/93 - 31/07/96**
Stilling bev.: Peglar, Sylvia postdoktorstipendiat

755.94/001 B **Botanisk institutt UiB**
1
101535/720 Birks, H. John B. Professor
KLIMA Mulige effekter av global oppvar-ming på reproduksjon i alpine plantepopulasjoner: en eksperi-mentell framgangsmåte
Bev.periode **01/04/94 - 31/03/97**
Stilling bev.: Totland, Ørjan forsker

755.95/012 B **Botanisk institutt UiB**
1
107734/720 Birks, Hilary Helen Forsker
KLIMA Climate change and aspects of the global carbon cycle over the last glacial-interglacial.
Bev.periode **01/01/95 - 31/12/97**
Stilling bev.: Birks, Hilary Helen forsker

755.96/009 B **Botanisk institutt UiB**
1
110486/720 Birks, H. John B. Professor
KLIMA Holocene climatic history and ecological impacts in Setesdal, southern Norway. A quantitative pollen-analytical study
Bev.periode **01/08/96 - 31/07/98**
Stilling bev.: Peglar, Sylvia forsker

758.94/002 B **Biologisk institutt UiO**
1
101536/720 Hessen, Dag O. Professor
KLIMA Effekter av UV-stråling på plankton
Bev.periode **01/05/95 - 30/04/98**
Stilling bev.: Borgeraas, Jan doktorgradsstipendiat

758.95/002 B **NINA-NIKU - Trondheim**
1
107735/720 Jensen, Arne J. Forsker
KLIMA Effekter av klimaendring på vekst og livshistorie hos laks i Repparfjordelva. FORLENGELSE
Bev.periode **01/01/95 - 31/12/96**

Ref. no./ Project no.	Name Project title	Ref. no./ Project no.	Name Project title

761.92/001 B **Norsk inst. for luftforskning**
1
101538/720 Braathen, Geir O. Forsker
KLIMA Tolkning og vurdering av spektroskopiske målinger i stratosfæren
Bev.periode **01/01/92 - 30/06/96**
Stilling bev.: Kåstad, Britt Ann doktorgradsstipendiat

761.94/006 B **Norsk inst. for luftforskning**
1
102945/720 Dahlback, Arne Forsker
KLIMA Effekten av skyer, ozon og albedo på UV-stråling ved jordens overflate
Bev.periode **01/01/94 - 31/12/96**

761.94/007 B **Norsk inst. for luftforskning**
1
101526/720 Braathen, Geir O. Forsker
KLIMA Høyoppløselig spektroskopi anvendt på stratosfærisk kjemi og dynamikk
Bev.periode **01/04/94 - 31/03/97**
Stilling bev.: Karlsen, Kjersti doktorgradsstipendiat

761.95/002 B **Fysisk institutt AVH**
1
107736/720 Kjeldstad, Berit J. Førsteamanue
KLIMA Ultrafiolett stråling i naturen
Bev.periode **01/01/95 - 30/09/98**
Stilling bev.: Thorseth, Trond doktorgradsstipendiat

761.96/001 B **Fysisk institutt UiB**
1
110487/720 Stamnes, Jakob J. Professor
KLIMA Lysspredning og absorbasjon fra ikke-sfæriske partikler i luft og vann
Bev.periode **01/01/96 - 31/12/98**
Stilling bev.: Stamnes, Knut gjesteforsker
Stamnes, Knut gjesteforsker
Stamnes, Knut gjesteforsker

761.96/002 B **Norges Fiskerihøgskole UiTø**
1
110488/720 Eilertsen, Hans C. Førsteamanuen
KLIMA Significance of Solar Ultraviolet Radiation in Artic Waters; Phytoplankton and fish-larvae
Bev.periode **01/01/96 - 31/12/96**
Stilling bev.: Hansen, Geir Arne forsker

761.96/006 B **NORUT Informasjonsteknologi AS**
1
110489/720 Kylling, Arve Forsker
KLIMA Ultraviolet radiation in the Artic, past, present and future (UVRAPPF)
Bev.periode **01/01/96 - 31/12/98**

761.96/008 B **Norsk inst. for luftforskning**
1
110490/720 Braathen, Geir O. Forsker
KLIMA Ozone soundings as a tool for detecting ozone change (OSDOC)
Bev.periode **01/01/96 - 31/12/97**

761.96/012 B **Norsk inst. for luftforskning**
1
110491/720 Stordal, Frode Professor
KLIMA The Contribution of Reactive Halogen Species to the Oxidation Capacity of the Troposphere-Cycles, Mechanisms and Field Observations
Bev.periode **01/01/96 - 31/12/97**

Norsk institutt for luftforskning (NILU)
P.O. Box 100, N-2007 Kjeller - Norway

REPORT SERIES Oppdragsrapport	REPORT NO. OR 15/96	ISBN-82-425-0750-3	
DATE 5.3.1996	SIGN.	NO. OF PAGES 78	PRICE
TITLE The Norwegian Climate and Ozone Research Programme Workshop 11-12 March, 1996 Solstrand Fjord Hotel, Os		PROJECT LEADER	
		NILU PROJECT NO. O-95103	
AUTHOR(S) Elin Dahlin (ed.)		CLASSIFICATION * A	
		CONTRACT REF.	

REPORT PREPARED FOR:

The Norwegian Research Council

ABSTRACT

This report includes abstracts from a workshop arranged by the Norwegian Climate and Ozone Research Programme.

NORWEGIAN TITLE

Forskningsprogram om klima- og ozonspørsmål. Seminar-rapport.

KEYWORDS		
Climate	Ozone	Workshop

ABSTRACT (in Norwegian)

Denne rapporten inneholder sammendrag av presentasjoner fra seminaret Klima- og ozonforskningen i Norge som er arrangert av Forskningsprogram om klima- og ozonspørsmål.

** Classification*	*A*	*Unclassified (can be ordered from NILU)*
	B	*Restricted distribution*
	C	*Classified (not to be distributed)*