Norwegian Research Council
Environment and Development
Changes in Climate and the
Ozone Layer

Bjerknes Centre for Climate Research

Contract No:139815/720

NOClim

Norwegian Ocean Climate Project

Progress Report

Reporting Period: July 2000- December 2001

Project leader: Peter M. Haugan, Geophysical Institute, University of Bergen

Partners:
- Bjerknes Centre for Climate Research (Bjerknes)
- The Norwegian Meteorological Institute (DNMI)
- Institute of Marine Research (IMR)
- Nansen Environmental Remote Sensing Center (NERSC)
- Norwegian Polar Institute (NP)
- University of Bergen (UiB)
- University of Tromsø (UiT)
- University Courses on Svalbard (UNIS)

NOClim

Norwegian Ocean Climate Project

Progress report

Reporting Period: July 2000- December 2001

by

Solfrid Sætre Hjøllo (Bjerknes/UiB)

with contributions from:

Trond Dokken
Peter M. Haugan
Helge Drange
Bjørn Ådlandsvik
Arne Melsom
Martin Miles
Ole Anders Nøst
NOClim participants

CONTENTS

Part A Progress and results from project

Project summary

Progress

The overall objectives of the project are to *contribute to understanding of rapid changes in the thermohaline circulation, ocean and ice processes related to climate, and mechanisms causing significant variability in the hydrography, circulation and ice cover, as well as to maintaining time series for early detection of climate change in the Northern seas*. Furthermore, this shall be done *in a coherent and rational way with Norwegian resources and expertise*. It is too early to attempt any serious synthesis of the scientific progress after just over a year of work. Of the key findings from the initial phase of NOClim are the convergence of proxy and instrumental time series, and the convergence of process and basin scale numerical modeling to observed hydrography and current fields. Scientific break through related to the combination and integration of (instrumental and proxy) observations and numerical modeling is evident, and this illustrates the unique potential for an integrated project like NOClim. On a specific level, an example of progress is the reinvestigation of salinity anomalies in the Subarctic Gyre.

The vision to unify the observation oriented, model oriented and paleo community cannot be realized in such a short time period. However, we feel that the project is utilizing Norwegian resources and expertise in a coherent and rational way, and that we are making significant progress towards the vision.

Deviation from project description

There are some deviations described in the individual task reports, including delays with data sets and analyses, and some reorganization of internal work, but on the overall project level, all major milestones have been reached.

Results

Understanding of rapid changes in the thermohaline circulation

Rapid and dramatic changes mean essential changes in ocean circulation and ice-sheet on time scale 100 years or less, and we have focused on two episodes, Younger Dryas and Heinrich 4 about 13.000 and 40.000 years ago.

The cooling period at start of Younger Dryas is identified by the Vedde Ash Bed, and efforts have been put on constructing time slice maps based on various palaeoclimatic proxies from 38 sediment cores in the northern North Atlantic. The preliminary maps show low SST for most of the area from percentage of *N. pachyderma*, but marked gradients with depleted values along continental margins and north-east of Iceland for $\delta^{18}O$ *N. pachyderma* (s). During the Younger Dryas, strong brine formation took place, and major changes in deep ocean circulation are found. It is unclear whether open ocean convection still was present or considerable reduced. Core analysis from the Northern Iceland Shelf and Hinlopenstredet north of Svalbard shows seasonally open waters and that the marginal ice zone was not far from the Hinlopenstredet. Data from the tropical North Atlantic strongly indicate a build up of heat in the tropics and in the Southern Atlantic during the Younger Dryas. At the end of the Younger Dryas SST increased by about 5°C within less than a decade, consistent with earlier ice core studies.

For the Heinrich 4 episode, $\delta^{13}C$ and $\delta^{18}O$ measurements from benthic and planktonic foraminifera show surface water conditions to be strongly linked to changes observed in the tropics prior to and during Heinrich events. The structure of deepwater formation seems to be instantly responding to changes in surface water properties.

Understanding of ocean and ice processes related to climate

We consider deepwater formation and mixing in the central Greenland Sea, brine formation and dense bottom water production in Storfjorden at Svalbard, and formation of intermediate water along fronts as processes related to climate. Observations in the Greenland Sea have shown deepwater ventilation in anti-cyclonic eddies, with lifetime of 1 year and with a cold core. They reach down to 2000m depth and have a radius of a few kilometres. A simple conceptual model is being put forward for their generation. The rim current of the Greenland Sea gyre separates the stratified exterior waters from the more homogeneous interior. This flow should continuously be prone to baroclinic instabilities generating weakly stratified anomalies of a suitable horizontal scale. When the gyre region is exposed to buoyancy loss, these anomalies act as ”convective guides" whose interior mix and stretch. This model concept is supported by the results from a non-hydrostatic ocean model. Mixing is studied by large scale modelling, and control integrations shows basin scale dipole pattern in the mixing depths, in agreement with observations. The detailed characteristics of the mixing are degraded due to the instantaneous convective adjustment scheme currently used in the model.

A conceptual model of Storfjorden at Svalbard includes brine formation in icefree areas (polynyas). The brine-enriched water sinks to the bottom, and leaves Storfjorden as a deep outflow over the sill. Atmospheric conditions are connected to brine production through polynya location in relation to bottom topography. The hypothesis formulated will be further explored when sea ice time series and the amount and properties of the accumulated brine enriched shelf water are measured.

The sinking of cold, fresh Arctic water over the Polar front, separating Atlantic and Arctic Water, is important for intermediate water formation, which is involved in deep water formation and thus the thermohaline circulation. Observations of the Polar front at the Svinøy section shows that it appears as a sub-surface front with cross-frontal mixing and local downstream weakening and flattening of the frontal signal. In an idealized test case, two different numerical models generate intense mesoscale eddy activities by horizontal and vertical water mass exchange. Sinking of Arctic water is found within cyclonic eddies and in areas exhibiting elongated bands of cyclonic vorticity along advancing fronts pushed by outbreaks of relatively warm and saline Atlantic water, in accordance with observations.

Understanding of mechanisms causing significant variability in the hydrography

Northern seas hydrographical variability is studied by examining connections with both hydrography in adjacent oceans, especially the North Atlantic, and the steric height and thus sea surface height within the northern seas. Furthermore, hydrographic variability has been found to influence atmospheric conditions over land. From a statistical analysis of 100 years data record, it is shown that strong positive SST anomalies in the north-western Atlantic Ocean is connected to rainfall in south-eastern Scandinavia. Rain spells in Oslo coincide with warm pools in the western and cold pools in the eastern Atlantic basin.

The Færøy area is a key region for the Atlantic inflow, and data from the last 40 years show that warm Atlantic water SST in this area is connected to SST in the North Atlantic Drift across the North Atlantic Ocean. In addition, a decadal oscillation in north/south-distribution of SST is found. From SST and modelled mixed layer thickness (MLT), no well defined propagating pathway from the Færøy Islands into the Nordic Seas are found, but for the time lagged MLT winter anomaly a propagating signal across the North Atlantic Ocean is seen. Search for propagating signals in sea surface height data from the Topex/Poseidon satellite, mirroring hydrographical changes are in preparation. Hydrographic time series from the Subarctic Gyre of the North Atlantic throughout the 20th century show both high and low salinity anomalies, found in anti-phase in Northwest and Northeast Atlantic. Low salinity anomalies started out with a high propagation speed in the Greenland-Labrador region and slowed down considerably as they reached the Nordic Seas, while high salinity anomalies accelerates when entering the Nordic Seas. The varying speeds are correlated across the North Atlantic: high propagation speed of high salinity anomaly in the Northeast Atlantic corresponds in time with a high propagation speed of a low salinity anomaly in the Northwest Atlantic. High propagation speeds are found during periods of high NAO index.

Sea surface heigh data from TOPEX/ERS1-2 satellites mirror steric height and thus hydrography, and tools are developed to perform lagged correlation analysis and complex EOF-analysis to search for propagating signals.

<u>Understanding of circulation and ice cover</u>

To understand circulation and ice cover on timescales from 1 to 1000 years and connect to atmospheric variability, instrumental and historic observations have been collected as a coordinated dataset, paleo observations are systematized into three sets of data and ice cover has been studied for the last century .

The coordinated dataset comprises multi-decadal to century-scale time series from around the Nordic Seas and adjacent areas. The sea ice data range from the Labrador Sea to the Barents Sea, with a mean record length of 140 years. Long meteorological time series from around the Icelandic Low region show that, in addition to the annual cycle, the seasonal march of SLP has an appreciable semi-annual cycle as well as anomalies occurring at distinct times in spring and winter. A shift in intraseasonal variability is observed in recent decades, including an extension of the winter Icelandic Low enhancement period into March. Increasing failure or delay of the "usual" abrupt pressure rise in Iceland in late February has contributed to the unusually positive winter NAO index values since the 1960s. However, even in the recent pronounced NAO period, other distinct modes of regional atmospheric circulation may be prominently linked to interannual variability of climate and sea ice around the Nordic Seas region. From the oceanographic data analysis correlations all along the Norwegian coast are unlagged, indicating that large-scale atmospheric forcing is important. Our results further indicate an anti-phase relation between NE and NW Atlantic sea temperature fluctuations. The NAO is generally positively correlated with sea temperature off Newfoundland. While the Barents and Labrador Sea temperatures appear to have been closely linked to the NAO only during the last 3-4 decades, the correlations between the NAO and coastal SST on the west and south coast of Norway are strong and persistent through our observation record.

From the paleo data, SST from the Vøring Platau is found to be strongly linked to Cariaco Basin off Venezuela, indicating that northward movements of the intertropical convergence zone inflicts higher SST in the Nordic Seas. SST for the last 2000 years show that the intensity of the Norwegian Atlantic Current (NAC) temperature variability is 1-2°C, while the Irminger Current(IC) variability is larger, 3-4°C. Both areas display decadal-scale

SST variability. The last 300 years are characterized by SSTs warmer than the mean for the last 2000 years over the Vöring Plateau, and SSTs colder than the mean over the Northern Iceland Shelf. The development of SSTs, at least over the last 600 years, exhibits an anti-phase relation between the Vøring Plateau and the N-Icelandic Shelf (strengthening of IC as the NAC weakens). An NAO type of atmospheric pattern might explain the observed anti-phase relation of SSTs between the eastern and the western Nordic Seas – if so, then during the little ice age (1400-1750 AD) an NAO- state dominated, and during the last 300 years, an NAO+ state dominated the atmospheric circulation. From a proxy record from Malangen, northern Norway, a gradual warming of the bottom water is found after AD 1900 (0.5°C). The record correlates well with other coastal bottom temperature measurements for the last century.

From an ensemble of multi-decadal to century-scale temperature and ice datasets in combination with global atmosphere-ocean climate model, the patterns of variability in Arctic temperature and sea ice in the last two decades are found to be distinct from an early 20th-century warm period and indicate that the recent changes are a response to greenhouse warming. Models are used to project changes in the sea ice cover in the 21st century, with greatest reductions expected in the summer ice extent.

Maintaining time series for early detection of climate change in the Northern seas

The monitoring has been concentrated on the inflow of Atlantic Water, the flow through central straits and the deepwater characteristics. In the Svinøy section in the south, long-term current observations show that in the eastern branch the Atlantic Water flux is estimated to 4.4 Sv, and about 80% of the variability is captured by an instrument in the core of the current at 300m depth, situated above the 720m bottom contour. For the western branch, the mean baroclinic transport westward of a single CTD-profile is estimated to 3.4Sv, with indication of winter maximum and summer minimum.

Further north, an extended measurement programme with ADCP current meter observations in the Fugløya-Bear Island section show that during 2001 it has been a generally lower inflow to the Barents Seas. This measurement programme also confirms that the resolution of an earlier programme (1997-2001) should be sufficient. Long term observations in Fram Strait, monthly means averaged over two years, have shown net transport of 1,6±1.7 Sv to the south (northward flow in West Spitsbergen Current, WSC: 9.5±0.9Sv, southward flow in East Greenland Current, EGC : 11.1±1.1 Sv). The measurements do not cover the East Greenland shelf and thus probably underestimate the southward flow. Transport maximum is found in spring, minimum in summer.

The Greenland Basin type deepwater has retreated southwards during the last 20 years in the Fram Strait, and is replaced by Eurasian Basin type water, perhaps reflecting the decreased deep water formation in the Greenland Sea. In the central Greenland Sea, the deepwater temperature is increased, perhaps due to mixing with Polar Ocean Deep Water in the boundary currents along East Greenland slope. In the WSC for the period 1950-1980, mean decadal summer sea temperature is decreased, while mean winter temperature is increasing. The internal variability is tightly connected to atmospheric circulation. In the 1990s, the maximum temperature increased in the Fram Strait and between Svalbard and Norway due to intensified inflow of Atlantic Water.

Popular science summary

The Nordic Seas are found between the warm Atlantic Ocean and the cold, icy Polar Ocean with strong Arctic winds and dark polar night. Warm, saline Atlantic water enters the area mainly through the Færøy-Shetland Channel and across the Færøy-Iceland Ridge, and begins a round trip where it is thinned, cooled, transformed and sinks down, influenced by a changing atmosphere and surrounding watermasses. In volume, the Nordic Seas occupies 0.3% of the world ocean, but because of its heat content and nutrient-rich water it is important for the mild climate of Scandinavia and the rich fishery resources. Deepwater renewal in the Nordic Seas is believed to influence the world oceans due to the thermohaline circulation.

The first task in NOClim has the title Rapid and Dramatic Changes. Rapid and dramatic changes mean essential changes in ocean circulation and ice-sheet on time scale 100 years or less. Especially two episodes, Younger Dryas and Heinrich 4 about 13.000 and 40.000 years ago, are studied. In connection with the Younger Dryas, the sea surface temperature (SST) change was more than 5°C within less than a decade in certain regions in the Nordic Seas. During the Younger Dryas, strong brine formation (I.e. salinification of sea water due to ice freezing) took place, and major changes in deep ocean circulation are found. It is unclear whether open ocean deep mixing still was present. Core analysis from the Northern Iceland Shelf and Hinlopenstredet north of Svalbard shows seasonally open waters and that the marginal ice zone was not far from the Hinlopenstredet. Data from the tropical North Atlantic strongly indicate a build up of heat in the tropics and in the Southern Atlantic during the Younger Dryas. For the Heinrich 4 episode, a major climatic cold reversal identified in the North Atlantic region, the structure of deepwater formation seems to be instantly responding to changes in surface water properties.

To describe seasonal and year-to-year variations in the inflow and internal circulation in the Nordic Seas is an important part of NOClim. The Færøy area is a key region for the warm inflow, and data from the last 40 years show that warm Atlantic water sea surface temperature in this area is connected to SST in the North Atlantic Drift across the North Atlantic Ocean. In addition, a decadal oscillation in north/south-distribution of SST is found. From SST and modelled mixed layer thickness (MLT), no well defined propagating pathway from the Færøy Islands into the Nordic Seas are found, but for the time lagged MLT winter anomaly a propagating signal across the North Atlantic Ocean is seen. From a statistical analysis of 100 years data record, it is shown that strong positive SST anomalies in the north-western Atlantic Ocean is connected to rainfall in south-eastern Scandinavia. Rain spells in Oslo coincide with warm pools in the western and cold pools in the eastern Atlantic basin.

The Norwegian Atlantic current transports the warm water along the Norwegian Coast. The current is divided into one branch flowing along the continental slope, while the other branch is found offshore, to the west. The transport of Atlantic Water in the eastern branch is estimated to 4.4 Sv (1 Sv $=10^6$ m^3/s), and about 80% of the variability is captured by only one instrument in the core of the current. In the western branch, the mean transport westward of a single CTD-profile is estimated to 3.4 Sv, with indications of winter maxima and summer minima. The western branch is closely connected to the Polar front, separating warm, saline Atlantic water from cold, fresher Polar water. Along the front, Arctic water sinks and contributes to intermediate and deepwater formation, important in the thermohaline circulation. Observations of the Polar front show that it appears as a subsurface front with cross-frontal mixing, explaining local downstream weakening and flattening of the frontal signature. Two different numerical models generate intense mesoscale eddy activities with horizontal and vertical water mass exchange. Sinking of Arctic water is found within eddies and elongated bands along the front.

Following the Norwegian Atlantic Current northwards along the Norwegian continental slope, we may note that the water mass exchange with coastal regions is noticeable, and analysis of bottom sediments in fjords in Malangen, Troms, shows a temperature variability of 2.5°C during the last 230 years, the temperature slightly increasing during the last century. There is a strong link to the North Atlantic Oscillation on annual to interannual timescales, which corresponds well to results from other oceanographic data analysis. Correlations all along the Norwegian coast are instantaneous, indicating that large-scale atmospheric forcing is important. Paleo data indicate possible high-low-latitude teleconnections, thus linking Nordic Seas SST to the Cariaco Basin off Venezuela.

Decadal SST variations in central part of the Nordic Seas for the last 2000 years are reconstructed from cores, and oscillations of 14 and 7.7 years period is found. These periods may reflect atmospheric variability, as also found from shorter timeseries from Svinøy section off Stadt, Norway, where the outer current branch seems to be somewhat colder and fresher in years with strong western wind forcing (high NAO-phase). From core analysis, decadal scale SST variability and a dipole pattern across the Nordic Seas are found. During the little ice age, higher SST is found at the North-Iceland shelf and lower SST at the Vøringplatå. The dipole pattern suggest a negative NAO state. From a coordinated dataset of meteorological, sea ice and oceanographic data, covering 50-400 years back, data for sea level pressure shows decadal and interdecadal variations, and the Icelandic winter low enhancement period is expanded into March. Increasing failure or delay of the usual abrupt pressure rise in Iceland in late February has contributed to the unusually positive winter NAO index values since the 1960s.

Observations in the Greenland Sea have shown deepwater ventilation in anti-cyclonic eddies. The eddies have lifetime of 1 year with a cold core, and they reach down to 2000m depth and have a radius of a few kilometres. A simple conceptual model suggests that instabilities of the gyre rim current generates anomalies amiable to convection. These weakly stratified eddies will mix and stretch when subject to cooling. The accompanying numerical model experiments are consistent with such a scenario. For large scale modelling of deepwater ventilation, control integrations shows a basin scale dipole pattern in mixing depths in agreement with the observations, while the characteristics is degraded due to instantaneous convective adjustment scheme currently used in the model.

Perhaps deepwater production is shifted between open ocean convection, especially in the Greenland Sea, and shelf convection. In Storfjorden at Svalbard brine is formed, producing dense bottom water and outflow. Sea ice time series from Storfjorden are extended allowing interannual variability to be properly addressed, the amount and properties of the accumulated brine enriched shelf water are measured, and the mechanisms of out-flow and advection are addressed by a combination of measurements and modeling.

Publications

Due to the short operating time of the project, only a few of the publications are directly connected to NOClim as the main project. The numbers in parenthesis indicate under which task the publication is carried out. CPO means Project Office. Publications marked by * are the most relevant ones, and can be found attached to the progress report.

Peer-reviewed journals

*Alekseev, G., Johannessen,O.M., Korablev,A, Ivanov, V. and Kovalevsky, D.V., 2001: Interannual variability in the Greenland Sea from 1950-2000. *Polar Research*, Sverdrup Special Issue, Norwegian Polar Institute (in print). **(5)**

*Benestad, R. E., and A. Melsom, 2001: Are the wet autumns in southeastern Norway due to unusual SST anomalies? *Tellus* (subm). **(5)**

*Björck, S., Muscheler, R., Kromer, B., Andresen, C.S., Heinemeier, J., Johnsen, S.J., Conley, D., Koç, N., Spurk, M., Veski, S. (in press). High-resolution analyses of an early Holocene cooling event may imply decreased solar forcing as an important climate trigger. *Geology.* 29 (12) pp1107-1110. **(1)**

Calvo, E., Grimalt, J., and Jansen, E. (In press). High resolution UK37 sea surface temperature reconstruction in the Norwegian Sea during the Holocene. *Quaternary Science Reviews* **(6)**

Cape Project Members (2001). Holocene Paleoclimate Data from the Arctic: Testing Models of Global Climate Change. *Quaternary Science Reviews*., 20, 1275-1287 **(1)**

*Eldevik, T. and K. B. Dysthe (2002): Spiral eddies. *J. Phys. Oceanogr.* (accepted) **(3)**

Elliot, M., Labeyrie, L., Dokken, T., and Manthe, S. (in press): Linking millennial scale climatic events within the Nordic regions and in the North Atlantic Ocean. Earth and Planetary Science Letter. **(1)**

Fahrbach, E. Meincke, J., Østerhus, S., Rohardt, G., Schauer, U., Tverberg,V. and Verduin, J. Direct measurements of volume transports through Fram Strait, Polar Res., The Sverdrup Volume,In Press **(7)**

Furevik, T., M. Bentsen, H. Drange, J. Johannessen and A. Korablev, 2001: Temporal and spatial variability of the sea surface salinity in the Nordic Seas. *J. Geophys. Res*. (submitted). **(3)**

Fimreite, S., Vorren, K.-D. and Vorren, T. 2001: Vegetation, climate and ice-front oscillation in the Tromsø area, northern Norway, during the Allerød and Younger Dryas. *Boreas 30,* 89-100. **(1)**

*Haarpaintner, J. , J.-C. Gascard and P.M. Haugan 2001a. Ice production and brine formation in Storfjorden. *J. Geoph. Res.* 106 (C7), pp. 14001-14013. **(2)**

Haarpaintner, J., J. O'Dwyer, J.-C. Gascard, P.M. Haugan, U. Schauer and S. Østerhus 2001b. Seasonal transformation of water masses, circulation and brine formation observed in Storfjorden. *Ann. Glaciol.* in press. **(2)**

Haarpaintner, J., P.M. Haugan and J.-C. Gascard 2001c. Interannual variability of the Storfjorden ice cover and ice production observed by ERS-2 SAR. *Ann. Glaciol.* 33, in press. **(2)**

Hald, M., Dahlgren, T., Olsen,T.-E. og Lebesbye, E. (2001). Late Holocene paleoceanography in Van Mijenfjorden, Svalbard. *Polar Research* 20, 23-35 **(6)**

Hald, M., Dokken, T. and Mikalsen, G. (2001) Abrupt climatic change during the last interglacial-glacial cycle in the polar North Atlantic. *Marine Geology* 176, 121-137 **(1)**

Jennings A. E., Knudsen K.L., Hald, M. Hansen, C.V. and Andrews, J. T. A mid-Holocene Shift in Arctic Sea Ice Variability on the East Greenland Shelf (in press). *The Holocene.* **(1)**

Johannessen, O. M., L. Bengtsson, S. I. Kuzmina, M. W. Miles, V. A. Semenov, G. V. Akseev, L. P. Bobylev, L. H. Pettersson and A. P. Nagurnyi (2001): Arctic Climate Change – Will the Ice Disappear in this Century? *Science*, submitted **(5)**

*Jónsson, T., and Miles, M. W. (2001). Anomalies in the seasonal cycle of sea level pressure in Iceland and the North Atlantic Oscillation. *Geophysical Research Letters* 28, 4231-34.**(6)**

Marchal, O., Cacho, I., Stocker, T. F., Grimalt, J.O., Calvo, E., Martrat, B., Shackleton, N., Vautravers, M., Cortijo, E., van Kreveld, S., Andersson, C., Koç, N., Chapman, M., Sbaffi, L., Duplessy, J.-C., Sarnthein, M., Turon, J.-L., Duprat, J. and Jansen, E. (In press). Apparent long-term cooling of the sea surface in the Northeast Atlantic and Mediterranean during the Holocene. *Quaternary Science Reviews*. **(6)**

*Meredith, M., K. Heywood, P. Dennis, L. Goldson, R. White, E. Fahrbach, U. Schauer, S, Østerhus, Freshwater fluxes through the western Fram Strait, Geophysical Research Letters, Vol. 28, 1615-1618, 2001 **(7)**

Mork, K.A., and J. Blindheim, 2001: Heat loss of the Norwegian Atlantic Current toward the Arctic. ICES Edinburgh Symposium, *ICES Journal of Marine Science* (submitted). **(5)**

Nagurni, A. P., O. M. Johannessen *et al*., 2001: Arctic ice thickness variation during the period 1970-1990. *J. Geophys. Res*. (subm). **(5)**

Nagurny, A. P., V. G. Korostelev, O. M. Johannessen and P: Wadhams (2001): Multiyear variability of sea ice thickness in the Arctic Basin measured by elastic-gravity waves on the ice surface. *J. Geophys. Res*., submitted. **(5)**

*Orvik, K.A, Skagseth, Ø. and Mork, M. Atlantic inflow to the Nordic Seas: current structure and volume fluxes from moored current meters, VM-ADCP and SeaSoar-CTD observation, 1995-1999, Deep Sea Res. I, 48, 937-957, 2001. **(4,7)**

*Ottersen, G., Ådlandsvik, B., Loeng, H. and Ingvaldsen, R. (Accepted). Temperature variability in the northeast Atlantic. *ICES Marine Science Symposium***.(6)**

Plassen, L. And Vorren, T.O. (in press) Late Weichselian and Holocene sediment flux and sedimentation rates in the Andfjord-Vågsfjord area, North Norway. *Journal of Quaternary Science* **(1)**

Saloranta,T. and Haugan, P.M. 2000: Interannual variability in the hydrography of Atlantic Water northwest of Svalbard. *J. Geoph.Res* 106 (C7), 13931-13943. **(7)**

*Shi, X. B., L. P. Røed, and B. Hackett, 2001: Variability of the Denmark Strait overflow: A numerical study, J. Geophys. Res., 106(C10), 22,277-22,294. **(2)**

Siegert, M. J., Dowdeswell, J. A., Hald, M. and Svendsen, J.-I. (in press) Modelling the Eurasian Ice Sheet through a full (Weichselian) glacial cycle. *Global and Planetary Change* **(1)**

*Skagseth, Ø., 2001*a*: Seasonal to inter-annual variability of the Norwegian Atlantic Current: Connection between the northern North Atlantic and the Norwegian Sea. *Deep-Sea Res*. (subm). **(5)**

*Skagseth, Ø and K.A. Orvik, Identifying fluctuations in the Norwegian Atlantic Slope Current by means of Empirical Orthogonal Functions, Cont. Shelf. Res., In Press, 2001. **(4)**

Vorren, T. O. (in press): Subaquatic Landsystems – continental margins. In: Evans, D.J.A.(ed*.).: Glacial Landsystems.* Edward Arnold Publ. **(1)**

Vorren, T.O. and Plassen, L. (in press): Deglaciation and paleoclimate of the Andfjord-Vågsfjord area, North Norway. *Boreas*. **(1)**

Books

Hald, M. (2001). Climatic change and Paleoceanography. In: R. Schäfer, W. Ritzrau, M. Schlüter and J. Thiede, The Northern North Atlantic: A changing environment, pp 281-290. Springer, Berlin 2001. **(1|)**

Huntley, B., Baillie, M., Grove, J. M., Hammer, U., Harrison, S. P., Jacomet, S., Jansen, E., Karlén, W., Koç, N., Luterbacher, J., Negendank, J. and Schibler, J. (In press). Holocene palaeoenvironmental changes in north-west Europe: Climatic implications and the human dimension. In Wefer, G. and Berger, W. H. (Eds.) *Climate and History in the North Atlantic Realm*. Springer-Verlag, Berlin Heidelberg**.(6)**

Koç, N., and Jansen, E. (In press). Holocene climate evolution of the North Atlantic Ocean and the Nordic Seas – a synthesis of new results. In Wefer, G. and Berger, W. H. (Eds.) Climate and *History in the North Atlantic Realm*. Springer-Verlag, Berlin Heidelberg**.(6)**

Published Conference Presentations and Posters

Andersson, C., Jansen, E., and Risebrobakken, B. (2001). Paleoceanographic variability in the southeastern Norwegian Sea over the past 1000 Years, EGS XXVI General Assembly, Nice, France, 26-30 March 2001. **(6)**

Andersen, C., Koç, N., Jennings, A., Jansen, E. and C.Birks, C. (2001). Holocene SST reconstructions from the Vøring Plateau and the Denmark Strait. International Conference on Changes in Climate and Environment at High-Latitudes, Tromsø, Norway, 31 October - 2 November 2001 **(6)**

Dokken, T. (2001): High resolution deglacial records in the Nordic Seas. Changes in climate and environment at high latitudes. International Conference in Tromsø. **(1)**

Dokken,T. and Jansen.E. 2001. General overview NOClim task 1. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 107-110 **(1)**

Dokken, T., Jansen, E. and Risebrobakken, B.: (2001): High resolution records in the Nordic Seas: Phase relationship between different oceanic proxies during rapid transitions. 7th International Conference on Paleoceanography – Sapporo**.(1)**

Eldevik,T. and Drange,D. 2001. Deep water ventilation in the open sea. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 83-98 **(3)**

Eldevik, T., H. Drange, J. C. Gascard, P. Testor, and G. Alendal (2001): Deep convection and submesoscale coherent vortices in the Greenland Sea. *Meeting abstract for the IAPSO Mar del Plata, Argentina Oct 21-26, 2001*.**(3)**

Eldevik, T., H. Drange, T. Johannessen, J. C. Gascard, and G. Alendal (2002): Convective Submesoscale Coherent Vortices in the Greenland Sea. *Meeting abstract for the AGU 2002 Ocean Sciences Meeting* **(3)**

Forwick, M. and Vorren, T. O. 2001: Deglaciation history and postglacial sedimentation in Balsfjord (North Norway). In: Vorren,T. O., Corner, G., Hald, M., Koc, N. and Mienert, J. (eds.): Changes in climate and environment at high latitudes. *NGF Abstract and Proceedings of the Norwegian Geological Society 2*, 31.

Hald, M., Husum, K., Grøsfjeld, K., Jensen, H., Sharapova, A. and Vorren, T. O. 2001: Sedimentary environment and climate during the Holocene in the subarctic fjord, Malangen, Northern Norway: A multi proxy study. In: Vorren,T. O., Corner, G., Hald, M., Koc, N. and Mienert, J. (eds.): Changes in climate and environment at high latitudes. *NGF Abstract and Proceedings of the Norwegian Geological Society 2*, 35.

Hald, M., Jennings, A., Hagen, S., Lie-Andreassen, T., Smith, M. and Andrews,J.T. 2001. Reconstructing younger dryas surface water masses from high resolution sediment cores from s.e. Greenland margin and w. Barents Sea. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 111-118 **(1)**

Hasle, K., Koç, N. & Hald,M.: The last deglaciation and Early Holocene paleoceanography in Hinlopen, Svalbard, reflected by diatoms. International Conference at the University of Tromsø on Changes in Climate and Environment at High-Latitudes, 31 Oct.-2 Nov., 2001. **(1)**

Haugan,P.M. 2001. Interannual variability of ice and brine formation in Storfjorden. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 99-106 **(2)**

Haugan,P.M. 2001. The Norwegian Ocean Climate Project. Presented at NFR's *Climate and Ozone Conference*, Bergen, Nov. 27-29, 2001 (Invited talk, abstract) **(PO)**

Hjøllo, S.S. 2001a NOClim Technical Report No 1. June 2001 (ed) **(PO)**

Hjøllo, S.S. 2001b. Norwegian Ocean Climate Project. In *Climate and Ozone Conference*, Bergen, Nov. 27-29, 2001 (Poster, abstract) ed.: I. Fløisand, Norw. Inst. for Air Research, 137-138. **(PO)**

Hjøllo, S.S. 2002. NOClim Technical Report No 2. January 2002 (ed) (In preparation) **(PO)**

Hald, M. (2001). Climate change during the recent past. In *Climate and Ozone Conference*, Bergen, Nov. 27-29, 2001 (Poster, abstract) ed.: I. Fløisand, Norw. Inst. for Air Research **(1)**

Hald, M., Andrews, J. T., Austin,W.E.N., Dokken,T, Eiriksson, J., Haflidason, H., Hagen, S., Helgadottir,G. Jansen, E., Jennings, A., Jiang, H. Keigwin, L.D., Klitgaard-Kristensen, D., Knudsen, K.L, , T.H.,., Koc, N. Lie-Andreassen, Rasmussen, T., Rørvik, K.L. & Sejrup, H.P.

(2001).Vedde Ash time slice maps for the northern North Atlantic: preliminary results. Abstract from "Changes in Climate and Environment at high latitudes"an International Conference at the University of Tromsø, Oct 31-Nov. 2, 2001. *NGF Abstracts and Proceeding of the Norwegian Geological Society 2,* 2001. **(1)**

Hald, M, Husum, K., Grøsfjeld, K., Jensen, H., Sharapova, A. and Vorren, T.O. Sedimentary environment and climate during the Holocene in the subarctic fjord, Malangen, Northern Norway: a multi proxy study. (2001a). Abstract from "Changes in Climate and Environment at high latitudes"an International Conference at the University of Tromsø, Oct 31-Nov. 2, 2001. *NGF Abstracts and Proceeding of the Norwegian Geological Society 2,* 2001. **(1)**

Hald, M, Husum, K., Grøsfjeld, K., Jensen, H., Sharapova, A. and Vorren, T.O. Sedimentary environment and climate during the Holocene in the subarctic fjord, Malangen, Northern Norway: a multi proxy study. (2001b). In *Climate and Ozone Conference*, Bergen, Nov. 27-29, 2001 (Poster, abstract) ed.: I. Fløisand, Norw. Inst. for Air Research **(1)**

Hald, M., Husum,K., Vorren, T.O., Grøsfjeld, K. Jensen, H., Mikalsen, G.& Sharapova,Holocene sedimentary environment and climatic shifts reconstructed from sediment cores in the fjord Malangen, Northern Norway. *Abstract Vinterkonferansen 2001, Oslo 8-10 januar 2001.* **(1)**

Hald, M., Jennings,A., Hagen,S., Lie.Andreassen, T-H., Smith,M. and Andrews,J.T. (2001). Reconstructing younger dryas surface water masses from high resolution sediment cores from SE Greenland margin and w. Barents sea. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp. 111-119. **(1)**

Hasle, K., Koc, N. and Hald, M. The last deglaciation and Eary Holocene paleoceanography in Andfjorden, Troms and Hinlopen, Svalbard, reflected by diatoms - preliminary results. International Conference at the University of Tromsø, Oct 31-Nov. 2, 2001. *NGF Abstracts and Proceeding of the Norwegian Geological Society 2,* 2001. **(1)**

Jansen, E., Andersson, C., Nesje, A., Furevik, T., Koç, N., Risebrobakken, B., and Østerhus, S. (2000). Decadal to century scale climate variability in the Nordic Seas during the Holocene – links to instrumental and land records. Invited talk, AGU Fall meeting, San Francisco, USA, 13-17 December 2000. **(6)**

Jansen, E., Andersson, C., Nesje, A., Østerhus, S., Furevik, T., and Koc, N. (2001). Decadal scale records of oceanic variability in the Eastern Nordic Seas over the past 1000 years. EGS XXVI General Assembly, Nice, France, 26-30 March 2001. **(6)**

Jansen, E., Andersson, C., Nesje, A., Birks, C., Chapman, M., Dahl, S. O., Furevik, T., Koc, N. and Risebrobakken, B. (2001). Decadal to century scale climate variability in the North Atlantic and the Nordic Seas during the Holocene: Ocean-land and low-to-high latitude linkages. International Conference on Changes in Climate and Environment at High-Latitudes, Tromsø, Norway, 31 October - 2 November 2001. **(6)**

Jansen,E., Andersson,C. Senneset,L. and Meland,M. 2001.Palaeoclimatic reconstructions for the past 2000 years in the Eastern Norwegian Sea - Status, Results and Plans. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 27-28 **(6)**

Jensen, H., Hald, M., Husum, K. and K, Grøsfjeld, K. Temporal geochemical variations in Holocene subarctic fjord sedments - an example from Malangen, Northern Norway. International Conference at the University of Tromsø, Oct 31-Nov. 2, 2001. *NGF Abstracts and Proceeding of the Norwegian Geological Society 2,* 2001. **(1)**

Jónsson, T. and Miles, M. W. (2001). Anomalies in the seasonal cycle of sea level pressure in Iceland and the North Atlantic Oscillation. EGS XXVI General Assembly, Nice, France, 26-30 March 2001. **(6)**

Koc,N. and Andersen,C. 2001 Century to Decadal Scale Records of North Atlantic Sea Surface Temperature Variations During the Last 2000 years. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 23-26 **(6)**

Koç, N. and Andersen, C. (2001). Sea-surface temperature variability in the eastern vs western Nordic Seas during the last 2000 years. International Conference at the University of Tromsø on Changes in Climate and Environment at High-Latitudes, Tromsø, Norway, 31 October - 2 November 2001. **(6)**

Koc,N. and Hasle,K. 2001. Rapid climate transitions. A case study: younger dryas. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 119-120 **(1)**

Lisæter, K. A., 2001: Arctic variability and trends. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, 43-48. **(5)**

Loeng,H. and Ingvaldsen,R. 2001. Water transport through the western entrance of the Barents Sea. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 73-76 **(7)**

Meland, M., Jansen, E. and Nielsen, A. (2001). Sea surface temperatures in the Nordic Seas and the North Atlantic during the Last Glacial Maximum: a stable isotope approach. EUG XI, Strasbourg, France, 8-12 April 2001. **(6)**

Melsom, A. and Benestad, R.E. 2001. North Atlantic SST patterns and their effect on rainfall in Norway. In *Climate and Ozone Conference*, Bergen, Nov. 27-29, 2001 ed.: I. Fløisand, Norw. Inst. for Air Research, 137-138. (poster, abstract). **(5)**

Melsom, A., H. Drange and R. E. Benestad, 2001. Propagating SST anomalies in COADS and MICOM-NERSC. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 29-36. **(5)**

Mikalsen, G. and Hald, M. (2001). An annual to biannual oceanic temperature record from Malangen fjord, Northern Norway; reflecting regional temperature changes since AD 1770. International Conference on Changes in Climate and Environment at High-Latitudes, Tromsø, Norway, 31 October - 2 November 2001. **(6)**

Mikalsen,G. and Hald,M. 2001Benthonic stable oxygen isotope record from Malangen, Northern Norway, reflecting changing bottom water temperatures and regional climate changes since AD 1770. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 19-22 **(6)**

Mikalsen, G. and Hald, M. (2001). A marine proxy record for the last 160 years from the fjord Malangen northern Norway, compared to instrumental records. Norwegian Geological Winter Meeting, Oslo, January 2001. **(6)**

Mikalsen, G., Hald, M. and Husum, K. (2001). Benthonic stable oxygen isotope records from Northern Norwegian fjords, showing temperature variations and regional climate changes. 7th International Conference on Paleoceanography, Sapporo, Japan, 16-21 September 2001. **(6)**

Mikalsen, G., Hald, M. and Husum, K. (2001). Benthonic stable oxygen isotope records from Northern Norwegian fjords, showing temperature variations and regional climate changes. International Conference on Changes in Climate and Environment at High-Latitudes, Tromsø, Norway, 31 October - 2 November 2001. **(6)**

Mikalsen, G., Hald, M. & Husum, K. Benthonic stable oxygen isotope records from Northern Norwegian fjords, showing temperature variations and regional climate changes. In *Climate and Ozone Conference*, Bergen, Nov. 27-29, 2001 ed.: I. Fløisand, Norw. Inst. for Air Research, 137-138. (poster, abstract). **(6)**

Miles, M. W. and Dretvik, L. (2000). Analysis of the time scales of climate and sea ice variability in the Atlantic Arctic. AGU Fall meeting, San Francisco, USA, 13-17 December 2000. **(6)**

Miles, M. W. and Jónsson, T. (2001). Anomalies in the seasonal cycle of sea level pressure in Iceland and the North Atlantic and Barents oscillations. AGU Fall Meeting, San Francisco, USA, 13-17 December 2001. **(6)**

Miles, M., Løyning, T., Loeng,H. , Ottersen, G. and Ingvaldsen,R. 2001 Climate, ocean and sea ice time series from the northern North Atlantic for the last 50-400 years – dataset, analyses and future plans. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 13-18. **(6)**

Orvik,K.A. and Niiler,P.P. Circulation of Atlantic Water in the northern North Atlantic and Nordic Seas, . ICES. CM 2001/W:19, 2001. **(7)**

Ottersen, G., Ådlandsvik, B., Loeng, H. and Ingvaldsen, R. (2001). Temperature variability in the northeast Atlantic. ICES Symposium on Hydrobiological Variability in the ICES Area 1990-1999, Edinburgh, Scotland, 8-10 August 2001. **(6)**

Pavlov, V. Modern trends in the long-term variability of thermohaline structure in the main gates to the Arctic Ocean., EGS meeting, Nice, April 2000. **(7)**

Plassen, L. And Vorren, T. O. 2001: Sedimentary processes and environment during deglaciation of a fjord basin in Ullsfjord, North Norway. In: Vorren,T. O., Corner, G., Hald, M., Koc, N. and Mienert, J. (eds.): Changes in climate and environment at high latitudes. *NGF Abstract and Proceedings of the Norwegian Geological Society 2*, 82. **(1)**

Risebrobakken, B., Jansen E., Mjelde, E., Andersson, C. and Hevrøy, K. (2001). Paleoclimatic and paleoceanographic changes in the Norwegian Sea through the Holocene, EUG XI, Strasbourg, France, 8-12 April 2001. **(6)**

Senneset, L., Jansen, E. and Backman, J. (2001). A record of high resolution ocean variability from the Skagerrak over the past 500 Years. EUG XI, Strasbourg, France, 8-12 April 2001. **(6)**

Skagseth,Ø. 2001a. Observational Study of the Norwegian Sea Polar Front. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 67-71. **(4)**

Skagseth, Ø., 2001*b*. On the coupling between the northern North Atlantic and the Nordic Seas. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 37-42. **(5)**

Skagseth, Ø. Mork,K.A. and Orvik,K.A. 2001. Atlantic Water in the Svinøy section. In S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 77-82 **(7)**

Tverberg ,V., Pavlov, V., Hansen, E. & O'Dwyer, J. Decadal trends in exchange of heat, salt and deep water between the Arctic Ocean and the Nordic Seas. ICES. CM 2001/W:19, 2001. **(7)**

Vorren, T.O. and Plassen, L. 2001: Deglaciasjon og paleoklima i Andfjord-Vågsfjord regionen, Nord-Norge. In: Vorren,T. O., Corner, G., Hald, M., Koc, N. and Mienert, J. (eds.): Changes in climate and environment at high latitudes. *NGF Abstract and Proceedings of the Norwegian Geological Society 2*, 98. **(1)**

Vorren, T.O. and Plassen, L. 2001: Deglaciation and Palaeoclimate of the Andfjord-Vågsfjord area, North Norway. Abstract. EUG XI, Strasbourg, France. **(1)**

Ådlandsvik, B. Shi, X.B., Røed, L.P. and Budgell, W.P. 2001, Modelling the Arctic Front in the Nordic Seas, Preliminary Results from an Idealized Test Case, in S.S. Hjøllo (ed) NOClim Technical Report No. 1, pp 49-65. **(4)**

Other reports and presentations

Drange,H. 2001. Small and large scale simulations of the SF_6-experiment in the Greenland Sea. Presentation at NOClim Spring meeting May 9-10 2001. **(3)**

Forwick, M. and Vorren, T. O. Deglaciasjonshistorie og utvikling av sedimentasjonsmiljøet i Balsfjord, belyst ved litologiske analyser av kjernemateriale – foreløpige resultater. Norsk geologisk forenings Landsmøte, Oslo, 8-10 januar. Geonytt 2001, p. 50. **(1)**

Hald, M. Reconstructing Younger Dryas surface water masses from high resolution sediment cores from SE Greenland margin and W Barents Sea. *Norpast-Noclim møte, Bergen, Februar 2001*.**(1)**

Haugan, Peter M. Overview of mechanisms. Presentation at Thermobaricity workshop. Monterey, USA, 4-6 October 2000. **(2)**

Haugan, Peter M. 2001b. Invited talk at the Conference "Progress in Arctic Ocean Research over the Past Decades" at the Royal Swedish Academy of Sciences, Stockholm 5-7 November 2001. **(2)**

Haugan, Peter M. Ice edge variability and deep convection. Presentation at Workshop on climate processes related to sea ice. Bergen, 14-15 November 2000. **(3)**

Haugan, Peter M. NOClim. Foredrag på Norsk Geofysisk forenings årsmøte.Geilo, 13. - 15. sep. 2000. **(PO)**

Haugan, Peter M. The new Norwegian project NOClim. Presentation at H.U.Sverdrup Symposium. Tromsø, 22-24 September 2000. **(PO)**

Haugan, Peter M. Climate change and the oceanography of the polar ocean. Presentation at MIZ meeting. Tverminne, Finland, 7-10 October 2000. **(PO)**

Haugan, Peter M. Betydningen av prosessene i havet for klimaet. Foredrag på Temamøte i Bergens Geofysikeres forening. Bergen, 9. nov 2000. **(PO)**

Haugan, Peter M. NOClim. Presentation at RegClim fall meeting. Geilo, 20-21 November 2000. **(PO)**

Haugan, Peter M. NOClim. Foredrag på Klima-fisk møte. Voss, 23. - 24. nov. 2000. **(PO)**

Haugan, Peter M. Drivkrefter for global termohalin sirkulasjon. Foredrag på Norsk Geofysisk forenings årsmøte. Geilo, 12. - 14. sep. 2001. **(PO)**

Haugan, Peter M. Thermohaline circulation. Lecture at Nordic Ph.D course, Nuuk, Greenland, 17-21 September 2001. **(PO)**

Haugan, Peter M. A brief introduction to the Norwegian Ocean Climate Project (NOClim). Presentation at RAPID Steering Committee meeting. Swindon, UK, 8-9 October 2001. **(PO)**

Jansen, E., Andersson, C., Birks, C., Dokken, D., Miles, M., Nesje, A., Risebrobakken, B., Senneset, L., Furuvik, T., Østerhus, S., Dahl, S. O., Koc, N., Chapman, M., Labeyrie, L., Cortijo, E. and Duplessy, J.C. (2001). Decadal to century scale climate variability in the North Atlantic and Nordic Seas during the late Glacial and Holocene - IMAGES results. PAGES-PEPII-ESF-HOLIVAR Climate Variability Through Europe Africa, Aix-en-Provence, France, 27-31 August 2001. **(6)**

Jansen, E., Andersson, C., Nesje, A., Andersen, C., Birks, C., Chapman, M., Dahl, S. O., Furevik, T., Koc, N., Risebrobakken, B. and Østerhus, S. (2001). Decadal to century scale ocean-land linkage in the Nordic Seas and low/high latitude teleconnections during the Holocene. 7th International Conference on Paleoceanography, Sapporo, Japan, 16-21 September 2001. **(6)**

Jennings, A. E., Andrews, J. T., Anderson, D. M. and Koç, N. (2001). High resolution records of ice-ocean-atmosphere interactions on the East Greenland Margin, last 14 ka. 31st Arctic Workshop, Amherst, USA, 22-24 March 2001. **(6)**

Jansen, E. and Meland, M. (2001): Stratigraphy of IMAGES core s in the Faeroe-Shetland area. Report Bjerknes Centre of Climate Research. **(1)**

Johannessen, O. M., E. V. Shalina and M. W. Miles, 2000: NORSEX sea ice concentration in the Arctic, 1978-1999, including MY ice concentration during winter months. *CD-ROM* available on request from Nansen Environmental and Remote Sensing Center, Edv. Griegsv. 3A, N-5059 Bergen, Norway. **(5)**

Johannesen, T. 2001a. Orientation of the tracer experiment in the Greenland Sea. Presentation at NOClim Spring meeting May 9-10 2001.**(3)**

Johannesen, T. 2001b. About isotope measurements. Presentation at NOClim Spring meeting May 9-10 2001.**(7)**

Koç, N. (2001). Nordic Seas and North Atlantic Holocene and last millenium climate development based on diatom transfer functions. ESF conference on Achieving Climate Predictability using Paleoclimate Data, Castelvecchio Pacoli, Italy, 10-15 November, 2001. **(6)**

Mikalsen, G. and Hald, M. Bentisk oksygen isotop serie fra Malangen; korrelasjoner til instrumentelle oseanografiske og atmosfæriske temperatur serier. *Norpast-Noclim møte, Bergen, Februar 2001*.**(6)**

Miles, M. W. (2001). Arctic climate and environment change. Lecture at the Russian Hydrometeological University, St. Petersburg, Russia, April 2001. **(6)**

Miles, M. W., Dretvik, L., Jakobsson, T. and Simonsen, K. (2001). Time scales of climate and sea ice variability in the Atlantic Arctic. Invited Keynote Talk, The Arctic on Thinner Ice: Nordic Arctic Research Program Symposium, Oulu, Finland, 9-11 May 2001. **(6)**

Mork, K. A., 2001: Results from NoClim Task 5.2. Presented at the annual meeting in "*Program Havklima fisk*", Bergen, Oct. 10-11 2001. **(5)**

Nøst,O.A. and Pavlov,V. 2001. Variability in salinity and temperature in the Fram strait. Presentation at NOClim Spring meeting May 9-10 2001.**(7)**

Omar,A. 2001. Does CO_2-uptake increase during brine formation? Presentation at NOClim Spring meeting May 9-10 2001.**(2)**

Skogseth,R. 2000. General circulation in Storfjorden at Svalbard modelled with the Bergen Ocean Model (BOM). Semester exercise in M282, University of Bergen**.(2)**

Skogseth,R. 2001a. Time series analysis of RCM-9 data in Storfjorden. Semester exercise in GFO 270, University of Bergen. **(2)**

Skogseth,R. 2001a. CTD and ice core data report from NOClim Helicopter cruise April 6 and April 23 2001 to Storfjorden, East Spitsbergen, Svalbard. UNIS report 13 pp**. (2)**

Skogseth,R. 2001b. CTD and ADP data report from NOClim cruise LA0105 May 28 - June 3 2001 to Storfjordrenna, Svalbard Barents Sea with R/V Lance. UNIS report 39 pp. **(2)**

Skogseth,R. Presentation at Nordic Ph.D. course in Nuuk, 10-21 September 2001. **(2)**

Skogseth,R. Presentation at workshop in Bergen 23 October 2001. **(2)**

Stuart,G.A. 2001. The Northwestern Barents Sea: A source for water mass fluctuations in Storfjorden, Svalbard? Fulbright report. **(2)**

Sundby, S. 2001: On the mechanisms behind the salinity anomaly signals of the northern North Atlantic. *ICES Annual Science Conference,* Doc. W:18. **(5)**

Vorren, T.O. and Plassen, L. 2001: Deglaciasjon og paleoklima i Andfjord-Vågsfjord regionen, Nord-Norge. Norsk geologisk forenings Landsmøte, Oslo, 8-10 januar. Geonytt 2001, p. 110. **(1)**

Østerhus,S. and Skogseth,R. in prep. Cruise report M/S Håkon Mosby Storfjorden and Northwestern Barents Sea 22 September to 5 October 2000. **(2)**

Ådlandsvik, B. 2001. Modellering av frontal subduksjon med havmodellen ROMS. Seminar Matematisk institutt, Univ. i Bergen, 14 juni 2001. **(4)**

Ådlandsvik,B. and Budgell, P.W. 2001. Modelling Frontal Subduction with ROMS, Second Joint Biannual Terrain-Following Coordinates Ocean Modeling Communities Workshop, Boulder, Colorado, 20 august 2001. **(4)**

Popular science articles and presentations

Drange, H. (2001): Golfstrømmen stopper neppe. Kronikk i *Aftenposten*, 9. juli 2001 **(3)**

Drange, H. (2001), Golfstrømmen stopper neppe, *Cicerone*, **2**, 22-24 **(3)**

Drange, H. (2001), Kan klimasystemet forutsis? Lørdagsuniversitetet, Den Nationale Scene, Bergen **(3)**

Dokken,T. (2001): Variasjoner i havklima. Lørdagsuniversitetet, Den Nationale Scene, Bergen **(1)**

Hald, M., Husum, K. and Mikalsen, G. (2001) Fjordavsetninger som klima arkiv. Cicerone No 5, 19-22 **(6)**

Hjøllo, S.S (2001) Nytt forskningsprosjekt om nordlige havområder og klima. Cicerone No 5 **(PO)**

Hjøllo, S.S: (2001) Hvor raskt stiger havet egentlig? Cicerone No 6 **(PO)**

Jansen,E. (2001): Da Golfstrømmen forsvant – hva vet vi om årsakene? Lørdagsuniversitetet, Den Nationale Scene, Bergen**.(1,6)**

Jansen, E. (2001). Klimaendringer – drivkrefter og årsaker. Senter for Etter og Videreutdanning, University of Bergen – kurs for lærere. December 2001. **(6)**

Koc,N. (2001). Kan betydelige klimaendringer skje raskt?. Lecture at Husbankens Fagdager i Nord – Klimatilpassing av bygninger og bygningsmiljøer, Tromsø. 25.04.2001. **(1)**

Koc, N. (2001). Dekadisk temperaturvariasjoner i Norskehavet gjennom de siste 10,000 år. Lecture at Miljøverndepartmentet, Oslo, April 2001. **(6)**

Koc, N. (2001). Har temperaturen i havet steget de siste 2000 åra? Lecture at the Norwegian Geological Union (NGF), Univ. of Tromsø, September 2001. **(6)**

Skagseth, Ø. and Hjøllo, S.S.(2001): Polarfronten og den vestlige grenen av Den nordatlantiske strømmen. Cicerone No 6 **(4,PO)**

Ådlandsvik, B. and Hjøllo, S.S.(2001): Datasimulering av nedsynking i havet. Cicerone No 6 **(4,PO)**

Outreach towards ministry, trade and industry and organizations

A representative from the EU commission was informed about the scientific activities and the context of the project during a visit in Bergen and subsequently participated in the August 2001 Håkon Mosby cruise to Storfjorden, Svalbard.

Media

Official NOClim web-site: www.noclim.org **(PO)**
NOClim's PT 5 has its own web pages at http://projects.dnmi.no/~noclim/ **(5)**

International cooperation and recruitment

A major and potentially very important link is with the UK NERC RAPID programme which has now been funded at a level of 20 million GBP. The science and implementation plans for this programme are being written at this time, so no details can be given. However, it seems that the structure and approach of NOClim has been well received in the UK planning process and that there will be a good match between the scientific profiles of RAPID and NOClim. The realization of the UK programme will be a major opportunity for Norway to strengthen its capabilities in this area of research. Other international coordination on the project level is described in the section on Coordination/P.O.

Task 1

Following international colleagues are directly involved in subtasks in the workplan for task 1: C. Kissel and Laurent Labeyrie: Laboratoire des Sciences du Climat et de l'Environnement, CEA/CNRS, Gif-sur-Yvette, France. W. Curry, Jerry McManus: Woods Hole Oceanographic Institution, USA. J. Andrews, A. Jennings: INSTAAR, Colorado, USA. M. Sarnthein: University of Kiel, Germany. N. McCave, University of Cambridge, UK.J. Eiriksson, University of Iceland. K.L. Knudsen, University of Aarhus, Denmark.

Task2

International cooperation with French scientists led by Dr. Jean-Claude Gascard was essential in starting the field work in Storfjorden. This has continued in work with joint publications in the NOClim period, and a short visit by Peter M. Haugan to LODYC, Paris, in January 2001. The German scientist Sønke Maus has contributed to several cruises as well as preparation of historical data. Dr. Ursula Schauer, AWI, Germany, with prior experience from Storfjorden and relevant expertise, has been consulted through a visit by Svein Østerhus and Ragnheid Skogseth to AWI in August 2000, and a visit by Ursula Schauer to Bergen in October 2001. Grant A. Stuart, a student from the Middlebury college in Vermont, USA, was a Fulbright Scholar in Bergen from August 2000 to May 2001. He participated in the 2000 fall cruise with Håkon Mosby and subsequent data analysis. Dr. Emmanuel de Lipkowski from EU, Brussels, participated in the August 2001 cruise.

Task 3.

Tor Eldevik, NERSC, visited prof. John Marshall and his group at the Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology (MIT) between May 2-16, 2001. The aim of the visit was to become acquainted with the non-hydrostatic ocean model MITGCM developed at MIT. MITGCM has since been established as the NERSC ocean model for high resolution numerical experiments on open ocean convection in NOClim.

The activity greatly benefits from the established connection with the MIT group, and the already existing collaboration with Prof. J.-C. Gascard, Laboratorie d'Oceanographie Dynamique et de Climatologie, Universite Pierre and Marie Curie, Paris, and Prof. A. J. Watson, School of Environmental Sciences, University of East Anglia, UK;

Task 4.

Xiabing Shi,DNMI is presently visiting Prof. T. Schlössel at Texas A&M University for an extended period.

Task 5.

Work performed at the Institute of Marine Research has in part been conducted in the context of the cooperative effort “International Council for the Exploration of the Sea” (ICES). Work performed at the Nansen Environmental and Remote Sensing Center in subtask 5.3 has been carried out in cooperation with a sister organization (Nansen International Environmental and Remote Sensing Center) in St. Petersburg, Russia. Further, the Naval Research Laboratory (Ms., USA)has provided daily fields at a horizontal resolution of 1/8 degree for sea surface temperature and sea surface height, based on remote sensing data, for the period 1993-2000.
The sea ice work is carried out in close collaboration with colleagues at Max-Planck-Institute for Meteorology (Germany), the Nansen International Environmental and Remote Sensing Center (Russia), the Arctic and Antarctic Research Institute (Russia), and the Bjerknes Center for Climate Research (Norway). In connection with the EU project MAIA ("Monitoring the Arctic Inflow toward the Arctic") which has close scientific relevans for task 5, IMR collaborates with colleagues at SINTEF (Norway), Proudman Oceanograph Laboratory (UK), Laboratorie d'Oceanographie Dynamique et de Climatologie (France), the Fisheries Research Services Marine Laboratory (UK), the Faroese Fisheries Research Insititute (the Faroes) and others.

Task 6

There has been international cooperation in connection with both the modern and paleo components in NOClim Task 6. The instrumental and historical dataset and analysis has been in cooperation with colleagues from Iceland (Drs. T. Jónsson, H. Valdimarsson and T. Jakobsson, Icelandic Meteorological Office), the Faroe Islands (Drs. B. Hansen and K. Simonsen, Faroese Fisheries Research Institute) and the United Kingdom (Dr. W. Turrell, Scotland's Marine Laboratory in Aberdeen) and Bedford Inst. of oceanography, Canada (K. Drinkwater,). During this reporting period, the Task Leader has taken four research stays at the Icelandic Meteorological Office in Reykjavik, 100% externally financed as a NOClim "in kind" contribution by UiB through a Nordic research cooperation activity. The Task Leader has also taken two project-related research stays at the University of Colorado, Boulder, USA, financed partially by NOClim. The paleo data and its analyses have involved international cooperation, in particular with E. Jansen's (UiB) and N. Koç's (NP) network of contacts in the marine core research community (Drs. J. Andrews and A. Jennings, INSTAAR,USA). Most prominently, W.Austin at University of St.Andrews, UK. Regarding recruitment, there are presently three Ph.D. students working in connection with NOClim Task 6, although not supported by any NOClim project stipend.

Task 7

All the measurements in Task 7 is parts of international projects such as VEINS, ASOF and MAIA. We have cooperation with the following institutes: Alfred Wegener Institute, Bremerhaven, Germany, Institute of Oceanography, University of Hamburg, Germany and MISU, Department of Meteorology, Stockholm University

PhD- and Postdoctoral fellows connected to NOClim

Name of fellow	Task No	Institution	Start date	End date	Date of dissertation (if PhD)	% financed by project
Andersen, Cathrine	6	NP/UiB	07/ 2000	06/2002		0% (VISTA)
Fer, Ilker	2	UIB	01.01.02	31.12.03		0%
Ingvaldsen, Randi	6	IMR	1999	2002	Fall 2002	7%
Meland, Marius	1	UIB	2001	2004	2004	0% (VISTA)
Mikalsen, Gaute	6	UiTø	9/2000	8/2001		0% (NORPAST)
Risbrobakken, Bjørg	1	UIB	1999	2002	2002	0%
Skogseth, Ragnheid	2	UIB/UNIS	01.07.00	30.06.03	June 2003	0%

Scientific relations to other coordinated projects

As described in the section on Coordination/P.O., the project has formal connections to RegClim via joint representation in the steering groups and has had a series of joint meetings and exchange of information. On the task level, the following links to NorPast and RegClim have been noted:

Task 1 Both the NORPAST and NOClim projects contain a marine paleodata component and some of the same persons are involved in both projects. Part of the paleodata may be shared between the projects. However, in NOClim, Task 1 and Task 6, the application of these data are strictly linked to oceanographic scientific questions, including relation to ocean instrumental time series, oceanic modelling. In NORPAST (Task 5.4. Marine Archives) the data are primarily linked to land ocean correlation. We see no conflict in this, but rather think that the mulidisiplinary approach is beneficial. We believe that taking the marine paleocomponent e.g. out of NOClim and into NORPAST or visa versa, would be a loss for that project being reduced.

Task 3. The basin scale ocean-sea ice model used in NOClim has been developed in RegClims Task 2. The ocean modelling part in RegClim is primarily devoted to assessing the natural climate variability of the Atlantic-Arctic region, whereas the NOClim activities are related to process understanding and improving parameterisations of, for instance, open ocean convection. The results of the NOClim modelling will be fed back into the RegClim climate modelling by providing an improved parameterisation of (in this case) open ocean convection. There is therefore a tight synergy between the ocean modelling activities in RegClim's Task 2 and NOClim's Task 3.

Task 4. The work in this task may in a later phase relate to RegClim Principal Task 2 and 5 in that it may help in the parameterization of sub-grid scale processes in the coarser mesh RegClim ocean model.

Task 5. Work in this Principal Task is connected to work in Reg Clim's Principal Tasks 2 and 9. The obvious advantage is that both projects have been able to attain a more comprehensive understanding of climate processes, since aspects that have been studied in one coordinated project have shed light on work performed in the other. An example of such synergies is the work that has been carried out in relation to the Nansen Center's MICOM simulations and propagating SST anomalies in the latter half of the 20th century. In the present phase, NOClim has not had the resources to set up and conduct a multi-decadal simulation of the ocean circulation for this purpose. In Reg Clim, such simulations have been executed, however, studies of oceanic processes in the recent past have been outside the scope of the Reg Clim project. Another example of such synergies is the study of links between the North Atlantic SSTs and rainfall patterns. This has mainly been carried out as a Reg Clim study, but experience gained in NOClim with respect to the use of SST data, and the quality of these data, turned out to be of substantial value in this study. No drawbacks in respect to these relations have been noted, and we don't have any desires for changes. However, this experience has made us aware that significant reductions in the funding of any of the coordinated projects' next phases may well harm work in both projects.

Task 6 is connected to NORPAST in the same sense as Task 1. The one main difference is that task 6 is focused on shorter time scales, using high-resolution paleorecords for temporal detailed studies of the past 1000 years.

Coordinated vs. separate projects

The Norwegian Research Council has requested comments on what has been gained by organizing the efforts in a coordinated project as opposed to running separate projects. It is very challenging for the research community to be asked to construct an integrated project proposal. On the other hand, NOClims vision of integrating the modelling, observations and paleocommunity calls for tight coordination. Much cross-communication between disciplines and groups that have not interacted so much before, ample time at project meetings etc. is necessary in order to pave the way for scientific progress. Perhaps a thematic bundle of individual projects grouped together by a programme board (on the level of the present SSG), could have been tried instead of having just one project, but it could not be done via traditional separate projects. "Forced marriages" between individual proposals to a programme board are seldom successful, and it would have been very difficult to set up the cross-institution collaboration in each task as we have done in NOClim, if the structure was to grow out of individual proposals.

The experience from the first year or so of NOClim, is that the Norwegian research community in this area is sufficiently limited that a scientific steering group can have the required overview, and that we were actually quite successful in creating a balanced project. A coordinated national project is better placed to link up internationally to activities such as RAPID, ASOF and possible future EU integrated projects which will be a major mechanism for EU from framework programme 6. Initiatives have already been taken to inform the EU about potential benefits of building upon the RAPID-NOClim as a basis for such an integrated project. Our experience further shows that a full time scientific secretary or science coordinator (the title used in RAPID) is an absolute necessity for a project such as NOClim. The tasks in the project office are not only to run meetings, produce public outreach material and reports, but above all to actively stimulate and integrate the scientific work and synthesis at the cross-task and project level.

The main problem for the project is the extremely limited amount of money allocated relative to the scientific challenges that are posed. This has the consequence that most of the project scientists have to obtain most of the funding elsewhere for their basic research activities, while NOClim funding is used primarily to "top up" other sources and to allow integration and interaction. This has worked satisfactorily so far, but several groups are participating at absolute minimum funding level.

Further plans

When NOClim started, we responded to a request for proposal on "a coordinated research project on ocean climate processes, ocean-atmosphere coupling and Arctic climate processes. The project should emphasize process studies of importance to climate development and interpretation of past and present observations. The project should have a close and formalized collaboration with the project RegClim and with corresponding activities in the UK." In the proposal we stressed that we were to contribute in a coherent and rational way with Norwegian resources and expertise to the overall objectives that we formulated. This led to a geographical and thematic focus of the work in NOClim phase 1, relative to the request for proposal. In essence, within the strong budget limitations, we stressed efforts that would unite already strong disciplinary groups in providing unique contributions from our main area of work, i.e. the Northern Seas. On the other hand, lack of infrastructure prevented field work beyond the ice edge in the Arctic, lack of research traditions and resources prevented low latitude efforts, and lack of coupled climate dynamics expertise prevented dynamical studies of coupled ocean-atmosphere phenomena in phase 1.

Now that the UK RAPID programme (20 M GBP = 250 M NOK over 5-6 years) is coming on stream, and the KlimaProg funding has a longer time perspective, we have a unique opportunity to build upon the consortium that we have successfully established in NOClim. The RAPID Science Plan is expected to be finalized at the next meeting of the RAPID Steering Committee (where Peter M. Haugan is a member) on 18 December 2001, and research activities are expected to be starting late fall 2002. It has been repeatedly stated from the UK side that the initiation of NOClim has been very important for the development of RAPID. The RAPID science and implementation plans which will be available shortly will be important planning documents for the preparation of NOClim phase 2. In particular, we may build upon UK strengths in coupled modelling and climate dynamics to educate a new generation of climate dynamicists, we may integrate the present day and palaeo observations we are making largely in Norwegian waters, in a larger geographical perspective, and we may explore UK under-ice capabilities as well as lower latitude activities.

The oceans are generally extremely undersampled and the challenges of obtaining a sufficient observational data base for detecting and attributing possible rapid climate change and variability calls for considerable efforts. Making these measurements is costly and the presently available funding is far from adequate. Separate funding should be found for development of monitoring capabilities, so that resources in the project can be spent on scientific analyses and studies. In particular there is a big and largely unexplored potential for joint analyses of the long term monitoring data that are brought together for the first time in a single project.

Paleo data generation and analysis is in rapid progress and is now much better integrated with instrumental time series. For paleo modelling the differences between present and past will present large challenges to the model systems. To develop an in-depth understanding of rapid climate changes, we should also aim to strengthen the theoretical basis. A range of models from high-resolution models to coarse resolution large scale models can be used for studies of processes on different scales. In a long perspective, process studies could benefit from the use of coupled ocean-atmosphere-ice models.

With approximately a doubling of the present annual budget, we would be able to maintain a credible scientific profile exploiting the opportunities offered by RAPID, and building higher competence in Norway. We now have about the right size of the project in terms of scientists (approximately 30) to make interaction effective, but too few resources to be able to exploit the material that we bring together in in-depth scientific studies. With the great international interest in Norwegian data sets and expertise of the kind that we have in NOClim (not only from the UK), a low level of funding would mean that our focus will be on the delivery of data rather than on exploiting the scientific potential of the project. It would also mean that the considerable and demanding coordination efforts become much less attractive so that a dissolution of the project is a real danger. In order to serve the needs for knowledge-based advice to the Norwegian government and society on profound climate issues of crucial importance to the country, we need a higher level of funding. We are inspired by the achievements that have been made in the present spin-up phase and are ready to proceed.

Part B Progress and results from individual tasks

Task 1: Rapid and dramatic changes

Task leader: Trond Dokken, The University Courses on Svalbard, UNIS.
Current address: Bjerknes Centre for Climate Research, University of Bergen.

Progress

As specified in the milestones given for task 1, the first one and a half year of operation have had major focus on sampling, different kind of proxy measurements, and compilation of existing datasets. Different working groups involved in task 1 have produced datasets as specified in the work plan. How well we are achieving the major objectives and deliverables described for task 1 will be proven during the next year of operation when all the datasets will be compiled. We already have results that are documenting well that task 1 is producing results in agreement with the project description.

Deviation from project description

The work performed in task 1 is very much in agreement with specified plan given in the milestones. Although task 1 planned to finish all measurements at the end of year 2001, we have to continue some of the measurements and preparations also into year 2002. This can be done within the budget given for 2002. One reason that we have to extend our measurements into year 2002 is that results from external laboratories have not yet been delivered. Some of these measurements have been paid in advance during 2001, and we will expect the results during the early part of 2002. There will still be need for more counting and classification of foraminifera, diatoms, IRD (Ice rafted Debris) and isotope measurements to better be quantifying the rapidity and variability of the climate change in the selected time intervals. This is an ongoing work that has to continue into the year 2002. High resolution studies on decadal scale involves thousands of samples of every proxy. Based on the limited number of people, we basically need time to achieve the high number of samples. In general, task 1 is reporting new and promising results of high quality.

Results

One objective in task 1 is to describe surface water properties and deep water flow across two major phases of abrupt change. One interval selected is the transition in and out of Heinrich layer 4 (H4) which took place about 40,000 yrs before present. H4 belongs to a set of major climatic cold reversals identified in the North Atlantic region during the last glacial. These cold reversals appear to be organised into quasiperiodic cycles following a gradual cooling from a moderately warm climate. The cooling cycle into a final H-event is disturbed by frequent perturbations of less dramatic cooling periods, which is culminating into so-called Heinrich events lasting for about 1,000 years. H-events, representing extreme cooling events with high flux of fresh water added to the surface ocean, and a dramatic drop in temperature, are followed by a rapid transit to a new phase of relatively warm climate. During the first year in NOClim we have compiled a huge dataset of cores containing $\delta^{13}C$ and $\delta^{18}O$ measurements both from benthic and planctonic foraminifera to study changes in surface and deep water properties during this specific interval. Preliminary results indicate a major reorganisation of the formation of deep water during H4 compared to the deep water formation before and after H4. The structure of deep water formation seems to be instantaneously responding to changes

in surface water properties. Surface water conditions seem to be strongly linked to changes observed in the tropics prior to and during Heinrich events. A pre-warming in the tropics seem to trigger changes in the dynamics of the ice sheets, reflected in the amount of ice rafted debris (IRD) and meltwater plumes observed in the surface water.
Mapping of these variables involves close co-operation with international collaborators.

The second interval studied is the Younger Dryas (Y.D) cold period. The Y.D. separates from Heinrich layers as the warming prior to Y.D., called Bølling/Allerød, is much warmer compared to the interval before Heinrich events, at least for large parts of the Atlantic Ocean and the Nordic Seas. The warming in front of Y.D. is almost representing interglacial condition. The return to cold condition of the Y.D. from the incipient interglacial warming, about 13,000 years ago took place within decades, where SST temperatures dropped by 6-8^{o}C. Also the transit out of Y.D., into the Preboreal (c. 11,500 years ago), was very rapid and took place within a decade.

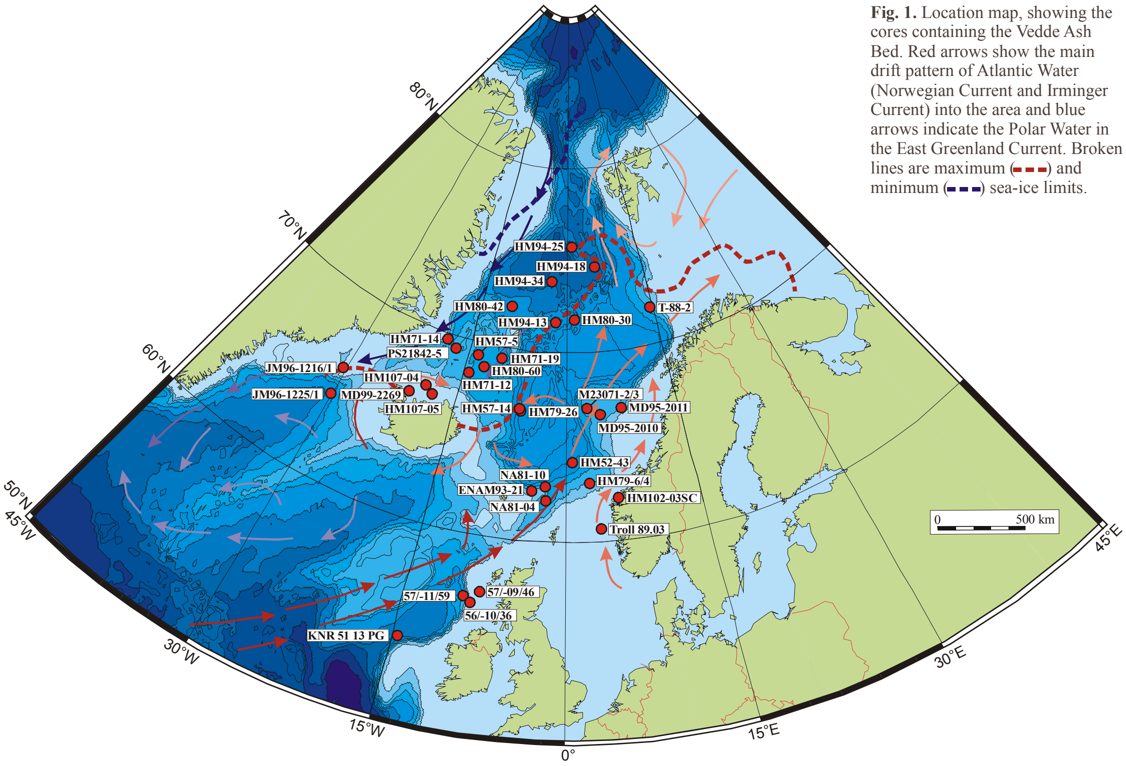


Fig. 1. Location map, showing the cores containing the Vedde Ash Bed. Red arrows show the main drift pattern of Atlantic Water (Norwegian Current and Irminger Current) into the area and blue arrows indicate the Polar Water in the East Greenland Current. Broken lines are maximum (▬ ▬ ▬) and minimum (▬ ▬ ▬) sea-ice limits.

The Younger Dryas time slice work involves most of the people working within task 1. Data from a great variety of environments around the Nordic Seas have been produced during the NOClim project in addition to other available core data that have been included for the purpose of our study. Figure 1 shows the areas that clearly contain potential good Y.D. stratigraphy, and in table 1 we have listed cores and proxies that have been investigated during the first year in task 1.

CORE IDENT.	Depth (m)	Location	LONG	LAT	$\delta^{18}O$	SST proxy		14C	IRD
						Forams	Diatoms		
JM96-1213/2-GC		Denmark Strait	67°17.3' N	30°57.6' W	X	X		X	
JM96-1214/2-GC	1555	Inner shelf, Kang. Trough, shelfward of inner sill	67°18' N	30°58' W	X	X		X	
JM96-1215/1-GC	2030	Kang Trough "Site 7" Basin seaward of inner sill	67°02.8' N	30°51.6' W	X	X		X	X
JM96-1215/2-GC	2030	Kang Trough "Site 7" Basin seaward of inner sill	67°02.8' N	30°51.6' W	X	X		X	
JM96-1216/1-GC	0530	Outer Shelf, Kang. Trough	65°57.77' N	30°38' W	X	X		X	X
JM96-1225/1-GC	1915	Outer Shelf, Kang. Trough	64°54.3' N	29°17.4' W	X	X		X	X
T-88-2	1490	W. Barents Sea	71 °59 29 N	14° 21 52 E	X	X		X	
JM98 820	133	Bellsund Svalbard	77 °35 79N	14 °35 33 E	X	X		X	
MD99-2206	508m	Andfjorden	69 °0822 N	16° 19 31 E				X	X
JM99-1200		Andfjorden	69° 15 95 N	16° 25 09 E				X	
NP94-51		Hinlopen	80°21..35N	16° 17.97 E			X		
MD99-2269		Iceland margin	66° 37.53 N	20° 51.16 W	X	X	X	X	X
MD95-2010	1230m	Voering Plateau	66° 41 N	04° 33 E	X	X		X	X
MD95-2011	1048m	Voering plateau	66° 58 N	07° 38 E	X	X		X	X
MD99-2284	1500m	Fareo-Shetland	62° 22 N	0° 58 W	X	X		X	X

The Vedde Ash Bed (Mangerud et al. 1984) has been identified in several marine sediment cores and represents an important time-marker for the mid/upper Younger Dryas cooling. The age of the Vedde Ash Bed is dated to 10,310±50 ^{14}C years (Birks et al. 1996) and 11,980 ice core years (Grönvold et al. 1995). One goal within the NOClim project is to present Vedde Ash time slice maps based on published and unpublished data from 38 sediment cores in the northern North Atlantic (Fig. 2). Identification of the Vedde Ash Bed in the cores is based on peak abundance of glass shards estimated by quantitative or semi-quantitative grain counts of basaltic and rhyolitic grains and geochemical characterisation at most of the sites. The maps represent various palaeoclimatic proxies including, $\delta^{18}O$ and $\delta^{13}C$ of *Neogloboquadrina pachyderma*, and distribution of planktic and benthic foraminifera. Percentage of *N. pachyderma* sinistral reveals cold sea-surface conditions more or less throughout the whole area. δ ^{18}O *N. pachyderma* (s) however, shows marked gradients with depleted values along the continental margins and an area of higher values north-east of Iceland. The results are preliminary and additional data will be added to these maps.

The Younger Dryas – Preboreal warming is one key target for our study in NOClim. The abrupt warming is well documented in ice core studies, but less documented from the marine environment. We may already conclude that the warming out of Y.D. is as rapid as it is documented from ice core studies. The Vedde ash layer mentioned above represents an important time slice from where we can intercorrelate all available core material included in our study. So far we have put a strong effort in dating the transition from Y.D. to Preboreal, as well as documenting the temperature change during the transition. The sea surface temperature change in certain regions in the Nordic Seas is more than 5^{o}C, and the time span of this transition is almost too rapid to be resolved by AMS C^{14} datings, indicating that the warming took place within less than a decade. We are still expecting a large number of AMS dates from the transition.

Compiling deep sea proxy data indicative for changes in the formation of deep water during the Younger Dryas is an important aspect of our study. Deep sea $\delta^{13}C$ data are conflicting, but clearly indicates that major changes in the deep ocean circulation took place. In the Nordic Seas we see strong evidence that brine formation was more rigorous during the Younger Dryas than before and after. Whether brine formation was totally replacing open ocean convection is unclear. Data from the North Atlantic may indicate that open ocean convection was still present during major parts of the Younger Dryas, but other data suggest that open ocean convection/thermohaline circulation within the Nordic Seas was considerably reduced.

$\delta^{18}O$ analysis on planktic foraminifera in high resolution sediment cores from the SE Greenland margin and Faraoe-Shetland channel indicate a salt anomaly during the onset and middle part of the Younger Dryas cooling. This lends support to the theory of a freshwater forcing of this abrupt cooling event due to reduced thermohaline turnover.

Data from the tropical North Atlantic strongly indicate a build up of heat in the tropics and in the Southern Atlantic during the Younger Dryas. This may imply less northward heat transport during the Younger Dryas, which again imply that the northward surface water current from the tropics into the Nordic Seas was reduced.

Based on our new results we have also updated the previous (Koc et al. 1993) Younger Dryas sea ice cover map. Analysis of core MD99-2269 from the Northern Iceland Shelf shows that the surface waters were at least seasonally open during the Younger Dryas and a moderate influx of Irminger current north of Iceland took place during this time,

Analysis of core NP94-51 from Hinlopenstredet, north of Svalbard shows that the surface waters were open for a limited part of the season and the marginal sea ice zone was not far from the locality during the Younger Dryas.

Task 2: Deep water ventilation from shelves

Task leader: Peter M. Haugan, Geophysical Institute, University of Bergen.

Progress

The work towards stated objectives and deliverables is proceeding according to plan with the exceptions noted below. This implies a strong emphasis on data collection and basic data analysis in 2000-2001 while synthesis and process modelling will be focussed in 2002.

Deviation from project description

The single mooring which was deployed in the outflow plume in fall 2000, was unfortunately never recovered in 2001. The probable cause is the sudden increase in trawling activity in the area and unexpected failure of the Argos transmitter. Since we could only afford one mooring, we have no backup. This loss is severe since it was planned as an essential time series. We now face the more difficult task of reconstructing seasonal evolution from only snapshots obtained in various seasons during cruises. There have also been continuous problems with the weather station at Kapp Dufferin due to polar bears. We only have a short time series so far, but extend the monitoring into 2001-2002 with the aim to get a sufficient period of overlap with other weather stations and data sources in order to construct representative wind and temperature fields for the polynya area. Other planned field activities have been successful. We will get additional satellite and weather station data for 2001-2002 (not in the original project plan) as well as hydrographic data from a whales equipped with CTD during a late fall 2001 NP cruise with Lance.

Results

Completion of the three referee papers by Haarpaintner et al. served to clarify and quantify the mechanisms of polynya formation, ice growth and salt release (upper part of Figure). During NOClim the sea ice time series are extended allowing interannual variability to be properly addressed, the amount and properties of the accumulated brine enriched shelf water are measured, and the mechanisms of out-flow and advection are addressed by a combination of measurements and modelling. Thus, by the expanded oceanographic program, it is the aim to obtain an understanding of all the components in the figure and how their variability is interrelated.

In accordance with the planned timing of activities, most results related to new data and model studies so far are of technical character (data reports) while scientific analysis and interpretation is deferred to 2002. It can be mentioned that during fall 2000 a record high brine water salinity of 35.45 was measured in the Storfjorden basin water, nurturing various already formulated (Haarpaintner et al) and new hypotheses of the relationship between atmospheric forcing and brine production. High resolution hydrography close to the sill show clear mesoscale structures which will be very useful for testing models of exchange mechanisms. Vertical profiles of hydrography and velocity have been obtained in the outflowing plume but remain to be analysed. For further discussion of context, perspectives and scientific ideas, it is referred to Haugan (2001).

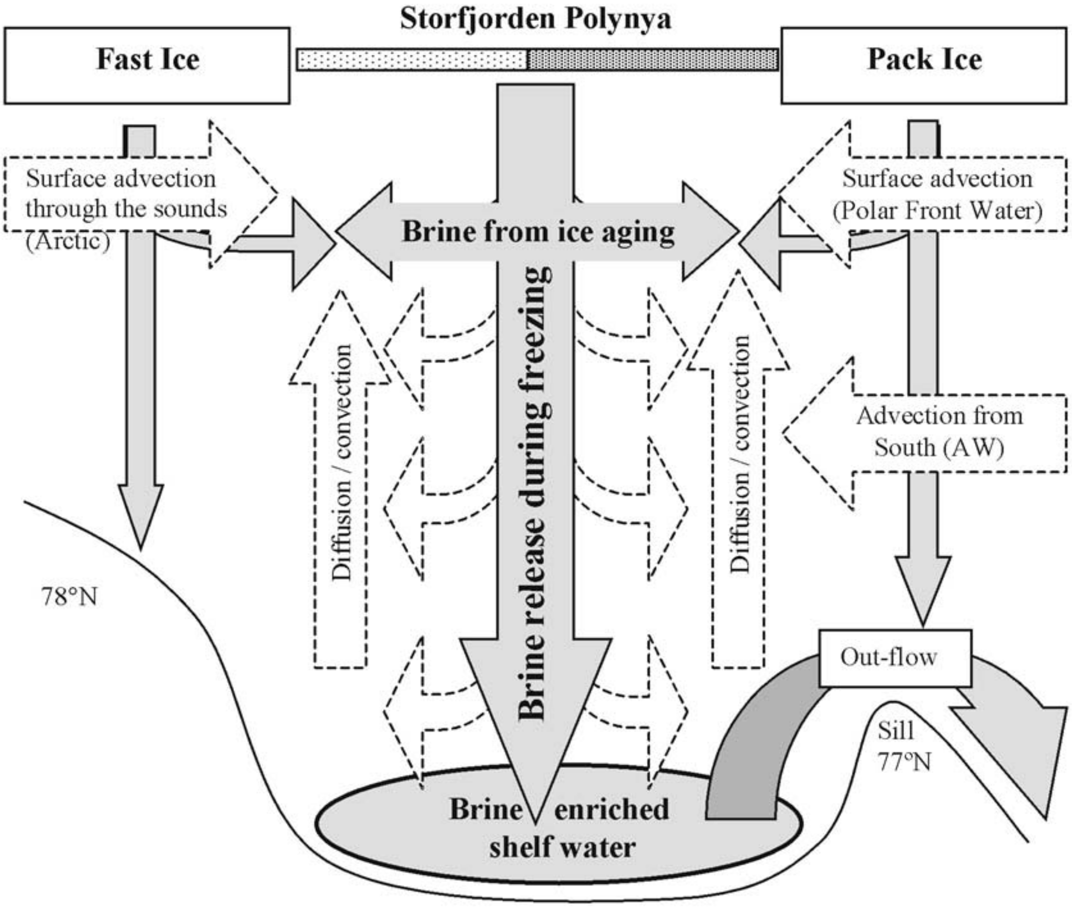


Figure x. From Haarpaintner, Gascard & Haugan, *J.Geoph.Res*. 2001

Task 3: Deep water ventilation in the deep sea

Task leader: Helge Drange, Nansen Environmental and Remote Sensing Center

Progress

The main objective of Task 3 is to investigate the processes which are candidates for effectuating direct deep water renewal in the Greenland Sea, including convective plumes, vertical advection, breaking internal waves and bottom boundary layer transport. Based on the hydrographic, floater and tracer observations from the Greenland Sea SF_6 experiment, a conceptual model has been put forward for describing Greenland Sea deep convection by *Submesoscale Coherent Vortices* (SCVs). The results of the numerical experiments performed are consistent with the suggested model. Based on the high resolution modelling, parameterizations of open water convection will be implemented and examined in three versions of the Nansen Center version of the Miami Isopycnic Coordinate Ocean Model MICOM. The tracer SF_6 were during the James Clark Ross cruise in 1996 released in the Greenland Sea in the central gyre area at isopycnal 28.0472, and its extension is followed within NOCLim/TRACTOR project.

Deviation from project description

The milestones have been reached.

Results

<u>Process modelling</u>

Deep convection in the Greenland Sea area is traditionally associated with the erosion of the gyre dome by strong wintertime buoyancy loss, leaving the weakly stratified interior exposed. Convection will thus ventilate the waters within the gyre to great depths. During the last decade, however, such deep convection has only been observed in very localized areas. Maps of float trajectories and hydrographic measurements from the European Subpolar Ocean Programme (ESOP) in the Greenland Sea during the winter 1996-1997, unambiguously associate thick homogeneous anomalies in that period with submesoscale coherent vortices (SCVs). These long lived (1 year or more) anti-cyclones populate the gyre. Their homogeneous cold core reaches a depth of about 2000 m, has a relative vorticity of $-f/2$, and a radius of a few kilometers (aspect ratio 0.1 to 0.2).

A simple conceptual model for the generation and evolution of Greenland Sea SCVs are suggested based on a gyre jet separating a stratified exterior from a more homogeneous interior. This configuration should continuously be prone to ageostrophic baroclinic instabilities (cf. Eldevik and Dysthe, 2002). A result is (sub-)mesoscale anomalies with weakly stratified cores, amiable to both stretching and mixing. When subject to buoyancy loss, homogenization and stretching of the core may take place, and an SCV is the result.

The non-hydrostatic ocean model MITGCM (Marshall et al., 1997) has been set up to validate the above conceptual model of SCVs and deep convection. The preliminary results are consistent with respect to the suggested SCV generation mechanism. An example is shown in Figure 1. Further experiments (with increased resolution, realistic buoyancy forcing, realistic geometry, etc.) are nevertheless required prior to concluding on the ventilation by SCVs and its implications for the larger system.

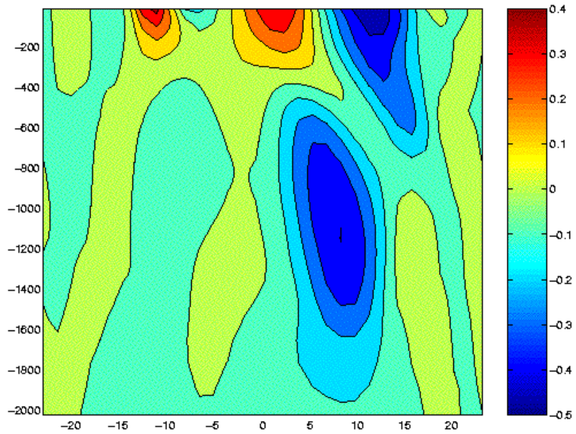


Figure 1: A vertical cross section through a model SCV as displayed in relative vorticity (in unit of f). The units of the horizontal and vertical axes are km and m, respectively.

Large scale modelling

A central goal in Task 3 is to develop improved open ocean parameterization schemes that can be applied in rather coarse resolution (global) climate models. Based on the results of the fine scale modelling described above, parameterization schemes will be developed, implemented and tested in the Nansen Center version of the Miami Isopycnic Coordinate Ocean Model MICOM. Two global versions of the model will be used with horizontal grid spacing in the central Nordic Seas of about 80 and 20 km. Control integrations are finalized in which the models, after an initial spin-up period of ~100 years, are forced with daily NCAR/NCEP forcing fields for the period 1948 to present. Figure 2 shows the simulated mixed layer anomalies for a composite of high and low NAO winters with the default version of the model. The obtained mixing depths are in agreement with the observed, basin scale dipole pattern. The detailed characteristics of the mixing is, however, degraded due to the instantaneous convective adjustment scheme currently used in the model.

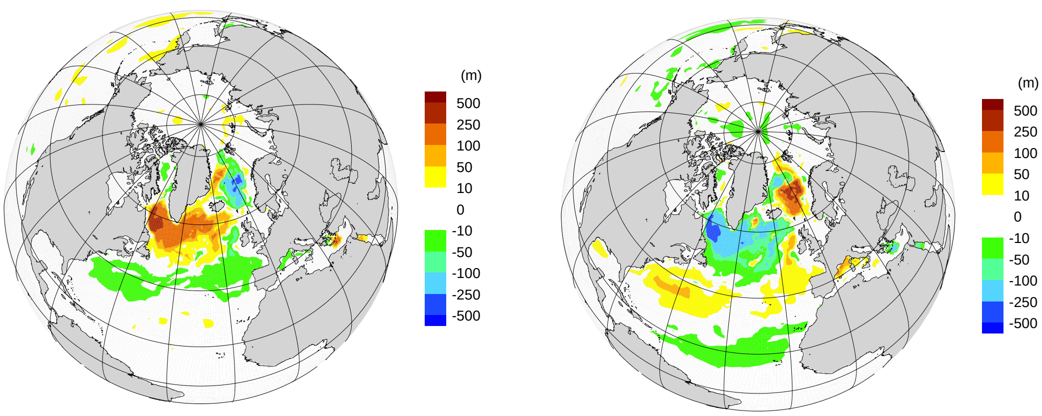


Figure 2: Simulated upper mixed layer thickness anomalies for a composite of high (left panel) and low (right panel) NAO winters.

The SF_6-experiment

The tracer SF_6 were released during the James Clark Ross cruise in 1996 in the Greenland Sea in the central gyre area at a depth of about 300 m (Watson et al, 1999). The objective of the experiment was to tag water masses that are active in the vertical mixing in the Greenland Basin, and consequently follow these water masses as they spread vertically and horizontally. In February 2001, a positive identification of SF_6 were recorded in the Faeroe-Shetland Strait, yielding a transport time from the Greenland Sea into the strait of slightly more than four years. In May 2001, a cruise with MS *Håkon Mosby* traced the SF_6 distribution within the Greenland Basin and the surrounding waters. The samples are presently being analyzed. On this cruise, the new SF_6 instrumentation built at the University of East Anglia from funds from the Norwegian Research Council (including NOClim) and the European Commission (from the TRACTOR project) were successfully tested. The obtained time evolution of the vertical and horizontal distributions of the tracer, together with the results from the fine-scale numerical modelling, will be used to test and modify the mixing schemes in the basin scale OGCM described above.

References

Marshall, J., A. Adcroft, C. Hill, L. Perelman and C. Heisey (1997): A finite volume, incompressible Navier Stokes model for studies of the ocean on parallell computers. *J. Geophys. Res*., **102**, 5753-5766

Watson, A.J., Messias, M.-J., Fogelqvist, E. , Van Scoy, K.A., Johannessen, T. , Oliver K.I.C., Stevens, D.P. Rey, F., Tanhua, T., Carse, F. , Simonsen, K., Ledwell, J., Jansen, E., Cooper, D.,J. Kruepke, J.A. and Guilyardi, E., 1999. Mixing and convection in the Greenland Sea from a tracer-release experiment. *Nature* 401, 902-904.

Task 4: Cross front exchange and formation of intermediate water

Task leader: Bjørn Ådlandsvik Institute of Marine Research

Progress

Subtasks 4.1-4.2

Two different model concepts are used. At IMR the effort has concentrated on the regional ocean model system (ROMS) developed jointly at Rutgers University and the University of California Los Angeles. This model, based on the earlier SCRUM model uses a terrain following vertical coordinate. DNMI has applied the Miami Isopycnal Coordinate Ocean Model (MICOM) developed at the University of Miami.

A flexible setup for idealized model experiments on frontal processes has been designed. This design has been adapted to the frontal regime over the Mohn Ridge separating the Norwegian and Greenland Seas northeast of Jan Mayen. The main purpose has been to reproduce the sinking of cold fresh Arctic Water over the front.

The setup consists of a periodic channel, with an along-channel ridge representing the Mohn Ridge. The initial hydrography is given by analytical formulae providing water masses typical for the area and separated by a smooth front. The internal Rossby deformation radii of deformation are 5 km in the Arctic Water and 7 km in the Atlantic Water. A grid resolution of 1 km is used.

In addition to a common base case experiment with both models, several sensitivity studies has been performed, where the conditions of the experiment has been changed. The model results are presently being analyzed. The analysis has focussed on vertical and horizontal exchange and energy transfer.

Subtask 4.3

The R/V Håkon Mosby instrumented with a SeaSoar CTD and Vessel Mounted - Acoustic Current Doppler Profiler (VM-ADCP) was used to survey the Polar Front region from 18-23 March 2001. The ship speed was about 8 kts speed resulting in one hydrographic profile down to about 420m every 4 km . The vertical range for the ADCP was about 450m at 8 m vertical resolution. Basically seven parallel tracks separated by 10 nm (about 18 km). To retrieve information on the temporal variability one section (Svinøy section) was performed twice.

The hydrographic data are processed, whereas the ADCP data needs to be post processed while merged with high quality ship navigation data to retrieve accurate current velocities. IR satellite images are obtained obtained to compare with the in-situ ship data.

Idealized numerical simulations using idealized set up to based on the observations are underway. This work will be done in collaboration with the IMR.

GFI plans an extended survey of the Polar Front upstream (toward the Faroes /Iceland) in summer 2002.

The analysis will be extended to identify the characteristic scales, mixing rates, and instability mechanisms. The formation of water masses and frontal subduction in the frontal region will also be addressed.

Deviation from project description

The distinction between the two subtask 4.1 and 4.2 has been downplayed. The original plan was that 4.1 should be done at IMR and 4.2 at DNMI. As the two model systems have complementary strengths and weaknesses, we have considered it more fruitful to apply them both on both horizontal and vertical front processes. This change also strengthens the collaboration within the task. The subgoals, milestones and deliverables are not influenced by the change. With the above remark, the work in the task proceeds according to the plan.

Results

<u>Subtasks 4.1-4.2</u>

The results so far are promising. Both models generate intense mesoscale eddy activity accompanied by both horizontal and vertical exchange of water masses. The subduction of Arctic Water is evident in both model results, but is particularly seen in the ROMS results. Sinking of Arctic Water is found within cyclonic eddies and in areas exhibiting elongated bands of cyclonic vorticity found along advancing fronts pushed by outbreaks of relatively warm and saline Atlantic Water. When performing observations along cross-front hydrographic sections, the probability of hitting an along-front band is higher than hitting an eddy. It is noted that the sinking process was observed as often as two out of four sections in the area. This suggests that the observed subduction takes place along elongated bands of cyclonic vorticity created by the eddy activity in the Polar Front area.

The sensitivity studies show that the subduction is a robust process, occurring under different circumstances. The presence of the Mohn ridge seems to influence the process by limiting the area of mesoscale activity. The effect of cabelling is detectable in the simulations, but seems to play a minor role in the subduction process.

<u>Subtask 4.3</u>

In general the Polar Front in this region appear as a sub-surface front with the AW ($S > 35.0$ psu) in the surface layer, and extending in the vertical from about 100 to 400m. General characteristics of the Polar Front in downstream direction is that: 1) the front becomes weaker, 2) the depth of the Atlantic water on the warm side of the front decreases and 3) the depth of the Atlantic water on the cold side of the front increases. These results are in accordance with cross front mixing.

The horizontal fields of temperature, salinity and density at 100 m depth indicate oscillations as a frontal wave that grows and eventually breaks in downstream direction.

The main results are that the Polar Front ;

- appears as a sub-surface front,
- exhibit downstream variation in the frontal structure, and
- exhibit temporal variability.

There are indications of rather large cross-front mixing due to unstable waves.

Comments:

The interplay between modelling and field activity in the task is not optimal. This is mainly due to different focus areas, with modelling northeast of Jan Mayen and observational program further south in the Norwegian Sea. The field program is coordinated with other activities such as current measurements in the Svinøy section. It is much less expensive to move some of the modelling activity. A model experiment is therefore planned in 2002 to study fronts in a shelf edge area in the southern Norwegian Sea.

Task 5: Variability and signal propagation from high resolution information

Task leader: Arne Melsom Norwegian Meteorological Institute

Progress

The project description for Principal Task 5 lists 4 key questions. Below is a brief account of how these questions have been addressed so far. Further details on the outcome of the investigations can be found in the "Results" section below.

1. *Does teleconnections by oceanic pathways give rise to significant interannual variability in the AW inflow, or is the local wind forcing always the controlling mechanism for such variability?* This question has been addressed by *Melsom, Drange and Benestad* [2001] who examined data for the sea surface temperature, and model results for the mixed layer temperature. Recently, the investigation has been extended by including model results for the mixed layer thickness (not yet documented). A complementary study on propagation of salinity anomalies has also been conducted, by *Sundby* [2001]. The latter investigation has primarily been based on hydrographic time series.
2. By quantitative amounts, what is the seasonal and interannual variability in the AW inflow along its eastern and western branches? This question has been addressed by Skagseth [2001a, 2001b] who examined traditional hydrographic time series in conjunction with satellite altimeter data. Another relevant study, by Mork and Blindheim [2001], presents results for the heat loss of Atlantic Water in the Nordic Seas.
3. By quantitative amounts, what are the seasonal and interannual variability, and trends, in the ice and ocean variables and fluxes of the Arctic Ocean? This question has been addressed by examining observations form a variety of sources, by Johannessen et al. [2001] and Lisæther [2001]. Model simulations of projected changes in the Arctic ice cover provide additional information.
4. *What is the seasonal and interannual variability of the position and strength of the front between Atlantic Water and Arctic Water in the Nordic Seas?* This question has not been addressed yet, as it was not scheduled to be examined until 2002 (see the "Schedule" section under the Task description for PT 5 in the NOClim project description).

Moreover, ice data has been collected and organized on a dedicated CD-ROM by *Johannessen, Shalina and Miles* [2000]. Also, observational data and results from numerical ocean circulation simulations have been collected, processed and transformed to facilitate access in the NOClim Project, and from the NoSerC data base.

Deviation from project description

There are no significant deviations from the project description. A minor deviation from the original plan is that there has been a delay in transfer of results and data to the NoSerC data base. This delay is primarily due to delays in the NoSerC project.

Results

A study of lagged (and leading) correlations in the North Atlantic and the southern part of the Nordic Seas of observed (COADS) sea surface temperature (SST), modeled (MICOM) mixed layer temperature (MLT), and modeled mixed layer height has been conducted. Using the time series at a site near the Faroe Islands, the lagged SST winter anomalies do not exhibit any well-defined propagation pathway. The SSTs seemed to exhibit a multipole behavior at no lag, and this topic will be pursued to see if more information can be deduced from the data with respect to the pathway of propagating anomalies. The lagged MLT winter anomalies exhibits a propagation signal similar to that reported by Sutton and Allen [*Science*, 1997]. Nevertheless, additional work with the MLTs are also required, e.g., there is a significant trend that needs to be removed. For both the SST and MLTs, we did not find a well-defined propagation pathway from the Faroe Islands into the Nordic Seas.

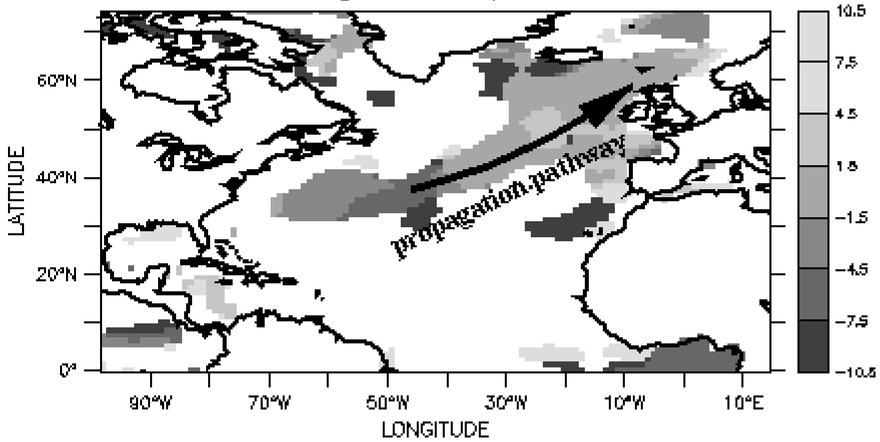
The Great Salinity Anomalies during the 1970s and the 1980s have particularly large amplitudes, and both of them were described as low salinity anomalies. In the present investigation, propagation of negative and positive anomalies, and links between them, are examined. It is shown that the Great Salinity Anomalies are artefacts and not caused by one single mechanism, but is the result of two separate events following each other in time on each side of the North Atlantic. The anomalies have varying speeds of propagation, and the varying speeds are correlated across the North Atlantic. A high propagation speed of high salinity anomaly in the Northeast Atlantic corresponds in time with a high propagation speed of a low salinity anomaly in the Northwest Atlantic. Conversely, a low speed of a low salinity anomaly in the Northeast Atlantic corresponds in time with a low speed of a high salinity anomaly in the Northwest. The varying volume fluxes of the Subarctic Gyre are proposed to be the causal mechanism behind the anomaly signals, and the North Atlantic Oscillation (NAO) might partly explain the flux variations described. High propagation speeds between the North Atlantic and the Arctic tend to dominate during periods of high NAO Indices while low propagation speeds tend to dominate during periods of low NAO Indices.

Further, a study on the hydrographic variability and anomalies in the Norwegian Sea has been performed, with the goal of investigating anomalies in the Nordic Seas by utilizing complementary sets. Hydrography changes are mirrored in the steric height and thus sea surface height (SSH) data from the TOPEX/ERS-1,2 satellites can be used to improve our spatial understanding of the anomalies. Tools that have been developed for analyses of the SSH data include lagged correlation analysis and complex EOF analysis to search for propagating signals. A two-way approach is planned; 1) anomalies identified in SSH data will be compared with hydrography, and 2) hydrographic variability will be related to variability in SSH. The study can be extended to include other data sets such as atmospheric forcing and air-sea fluxes to estimate the effect of the anomalies and how e.g. Ekman transports affect the SSH.

The Arctic is considered to be especially sensitive to greenhouse global warming, Recent changes evident in the arctic climate system may reflect anthropogenic forcing or simply natural multi-decadal variability. To study this, a new ensemble of multi-decadal to century-scale datasets in combination with global atmosphere-ocean climate model simulations have been examined to better quantify and assess the variability. The patterns of variability in arctic temperature and sea ice in the last two decades are found to be distinct from an early 20th-century warm period and further indicate that the recent changes are a response to greenhouse warming. Models are used to project changes in the sea ice cover in the 21st century, with greatest reductions expected in the summer ice extent.

A study of the relationship between the North Atlantic SST (NA-SST) anomaly patterns and rainfall in southeastern Scandinavia has been performed. We found evidence that strongly suggests that the record rainfalls of November 2000 was connected to simultaneous strong, positive SST anomalies in the northwestern Atlantic. Moreover, we found that the east/west distribution of NA-SST anomalies affect the Oslo rainfall in November. Warm pools in the western basin in November, and cold pools in the eastern basin, frequently coincide with wet spells in Oslo. When the distribution of anomalies is reversed, there are frequently dry spells in Oslo. This study will be extended to rainfall records at other locations, and we will include a number of other SST records to evaluate the robustness of the results.

Lags of mixed layer thickness, in years, for regions where the max. lagged correlations with results near the Faroe Islands exceed 0.6 (based on results from a MICOM simulation by NERSC)



Task 6: Coordinated analysis of long time series

Task leader: Martin Miles, Geological Institute, University of Bergen

Progress

The work performed in Task 6 has been primarily within Subtasks 6.1 and 6.2, which respectively: (1) Develop a standardised dataset of instrumental and historical observations, and (2) Develop a well-dated and calibrated dataset of paleo observations. Secondarily, a number of the time series have already been analysed along the lines of Subtasks 6.3 and 6.4, which respectively determine the significant time scales of variability and the relationships between the time series, as well as Subtask 6.6, which is a synthesis and explanation of the observed variability. The work has progressed essentially in accordance with the timetable and milestones.

Instrumental and historical data and analysis. The work performed under Subtask 6.1 has been led by the University of Bergen (UiB) in cooperation with the Institute for Marine Research (IMR) and the Norwegian Polar Research Institute (NP). The statistical analyses of these data have been carried out primarily by UiB and IMR. The purpose of Subtask 6.1 is to assemble and systematise a dataset of pertinent long instrumental and historical time series of meteorological, oceanographic and sea ice parameters from around the Nordic Seas region. This serves as a fundamental dataset for paleodata comparison and calibration (Subtask 6.2) and the Subtask 6.3 and 6.4 statistical analyses. The time series input to the dataset are derived from public domain databases and datasets, governmental organisations, as well as other research groups and individual researchers. These data have now been acquired, documented, evaluated, processed statistically, systematised and placed in user-frendly format. Included in this subtask has been an analysis of some of the less straightforward data (e.g., an index of the so-called Barents Oscillation, coastal and ocean temperatures from SE Iceland and around the Faroe Islands and sea ice indices from SW Greenland) for their reliability and/or representiveness for ocean–climate studies such as NOClim Task 6. New versions of the dataset will be made through at least the first phase of NOClim.

The meterological data analysis thus far has been centred on a new homogenised time series of daily mean sea level pressure (SLP) from Reykjavík and Stykkishólmur, Iceland from 1823-1999. It is therefore uniquely suited to reflect variations in the North Atlantic Oscillation (NAO) on a range of time scales. Time series statistical techniques including harmonic analysis are used to identify the seasonal march of pressure and its variability and changes through the record. The results are assessed regarding the local and regional dynamical mechanisms, as well as NAO. In addition, we have done time and frequency domain analyses of surface air temperature (SAT) and sea ice indices from around the Iceland Low and the Nordic Seas region (e.g., Greenland Sea), thus far focused on the winter season. The results of this latter aspect are still preliminary and will be available during the next reporting period.

The oceanographic data analysis has thus far been focused on the Norwegian coast and Barents Sea, with supporting data from the waters off eastern Canada and the Faroe Islands. The longest series analysed are from the Norwegian coastal lighthouses starting in the 1860s. These data along with the Hurrell NAO index have been analysed in the time and frequency domains. The correspondence between the various variables and locations and the changes over time have been identified and interpreted. In the next reporting period, this approach will be applied to the comprehensive meteorological-ocean-sea ice dataset from Subtask 6.1.

Paleo data and analysis. The work performed during this reporting period falls primarily under Subtask 6.2, which thus far has gone towards obtaining high-quality, high-resolution

paleoceanographic time series. This work has been carried out by UiB, NP and the University of Tromsø (UiTø).
The UiB-led contribution thus far has been an investigation of three cores, from the Vøring Plateau, the Skagerrak and the eastern Norwegian Sea off Storegga. Detailed time scales have been obtained by Pb-210 dating and 14C-AMS dates. The resolution of the records which cover the past 1000 years varies between 3 and 20 years. In the cores SST-estimates are made based on oxygen isotope records, foraminifer transfer functions and the new Mg/Ca-palaeo-thermometry method. The latter is in collaboration with Prof. H. Elderfield, Cambridge Univ., Uinted Kingdom, who is a leading geochemist in the field. Some very interesting preliminary results have come out of work on the Vøring Plateau core, which is still under analysis. The next core to study with this method is a core from the Faroe region, collected during a cruise with R/V Håkon Mosby in May 2001. Concurrently, we have continued efforts to compare the high resolution records with paleoclimatic land data, with good success, and with long instrumental records, compiled in Task 6.1.
The NP-led contribution has been the reconstruction of SSTs at decadal resolution from two cores based on diatom transfer functions. The cores were collected during the IMAGES cruises of the R/V Marion Dufresne. Core MD 95-2011 is located on the Vøring Plateau (66°58N; 07°38E, 1050 m water depth) along the main axis of the northward flowing warm Atlantic water. It is, therefore, in an ideal position to monitor changes in the northward heat flux to northwestern Europe. Core MD 99-2269 is located in the deep Hunafloi trough, off N Iceland (66°37N; 20°51W, 365 m water depth). Today the core lies under the influence of the Irminger current, but it also may be influenced by the cold East Greenland current as the Polar front migrates eastward. Core MD 95-2011 is dated by AMS C-14 and Pb 210 isotope profiles, and core MD 99-2269 by AMS C-14. Core MD 95-2011 has been studied at about 10-20 years resolution through the last 2000 years. Core MD 99-2269 is studied at about 5 years resolution through the last 600 years and about 50 years resolution through the rest of the record. SST variations are estimated by means of three different diatom transfer function methods.
The UiTø contribution, financed primarily by NORPAST and secondarily by NOClim, has included the collection of five new cores for investigation, where tow is dated and shows promising results regarding resolution and bioturbation. Here, focus has been on a high-resolution, 380mm-long sediment core from Malangen fjord in northern Norway. The core has about 2-year resolution from AD 1770 to 1900 and annual-to-biennial resolution after 1900. From this, a 230-year temperature record has been developed in conjunction with the core's benthonic stable isotope record and measured ocean temperature time series compiled in Subtask 6.1. The results of the analysis are summarised in the Results section below, and a paper has been submitted for review.

Deviation from project description

The work has progressed according to plan and the milestones thus far have been reached. The only deviation to mention is that we have gone ahead and "completely" analysed parts of the instrumental dataset, rather than first partially analysing the complete dataset, as the original timetable proposed. The reasons for going ahead with this were to take timely advantage of: (1) unique opportunities for research with Icelandic colleagues in the framework of the Nordic Arctic Research Cooperation Program (1999-2001) and (2) ongoing progress towards the research of G. Ottersen at IMR/UiO. This strategy has already resulted in two peer-refereed journal publications – Jonsson and Miles [2001] and Ottersen *et al.* [Accepted], respectively – and another in preparation for a peer-refereed journal.

Results

Instrumental and historical data and analysis. The coordinated dataset (Subtask 6.1) of meteorological, sea ice and oceanographic data is an important result and in itself represents cooperation within NOClim Task 6 and with Task 5. The dataset now comprises multi-decadal to century-scale time series from 29 meteorological stations or indices (24 air temperature and 5 atmospheric circulation indices), 14 oceanographic stations or transects and 8 sea ice indices from around the Nordic Seas and adjacent areas. The sea ice data range from the Labrador Sea to the Barents Sea, with a mean record length of 140 years. The dataset is at least as comprehensive as any assembled by other research group for this region.

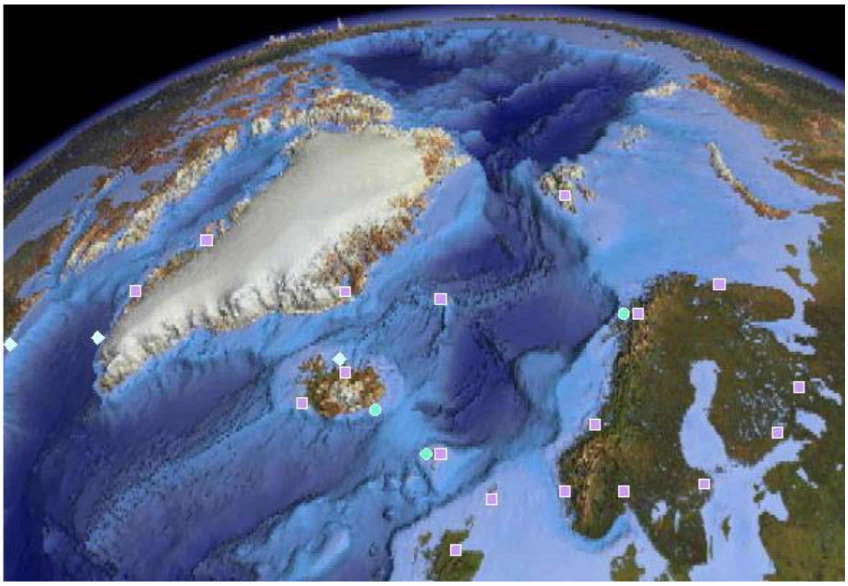


Figure 1. *Location map*

The systematic analysis of the whole dataset in the time and frequency domains remains a work in progress (Subtasks 6.3 and 6.4) Nonetheless, we have obtained results and published from two sets of analyses of a number of the meteorological and oceanographic time series. An analysis of long meteorological time series from around the Icelandic Low region shows that, in addition to the annual cycle, the seasonal march of SLP has an appreciable semi-annual cycle, as well as anomalies (abrupt rises and falls) occurring at remarkably distinct times in spring and winter. Multidecadal variability is apparent in the seasonal cycle and the anomalies. A shift in intraseasonal variability is observed in recent decades, including an extension of the winter Icelandic Low enhancement period into March. Increasing failure or delay of the "usual" abrupt pressure rise in Iceland in late February has contributed to the unusually positive winter NAO index values since the 1960s. From a frequency domain analysis of pertinent SAT and historical sea ice time series from Subask 6.1, it was also found that even in the recent pronounced NAO period, other distinct modes of regional atmospheric circulation may be prominently linked to interannual variability of climate and sea ice around the Nordic Seas region.
These results from the oceanographic data analysis show that correlations all along the Norwegian coast are unlagged, indicating that large-scale atmospheric forcing is important. Our results further indicate an anti-phase relation between NE and NW Atlantic sea temperature fluctuations.The NAO is generally positively correlated with sea temperature off Newfoundland. While the Barents and Labrador Sea temperatures appear to have been closely

linked to the NAO only during the last 3-4 decades, the correlations between the NAO and coastal SST on the west and south coast of Norway are strong and persistent through our observation record. The results from both the meteorological and oceanographic data analyses indicate that the mid-1960s to present should be one focus of Subtask 6.5, which analyses anomalous sub-periods in the time series.

Paleo data and analysis. The results achieved thus far in Task 6.2 are from three sets of analyses. The results thus far are very encouraging, and we foresee a breakthrough in the near future, being the first to show open ocean paleo-proxy records correlated with the instrumental record. Preliminary results from the UiB-led analyses [Senneset *et al*., 2001] also indicate that the Skagerrak record appears to document long-term changes in the NAO index. The high-resolution datasets show very encouraging results with respect to possible low-high latitude teleconnections. The datasets from the Cariaco Basin off Venezuela and the high-resolution Vøring Plateau SSTs document strong links between, indicating that northward movements of the ITCZ inflicts higher SSTs in the Nordic Seas (Fig. 2).

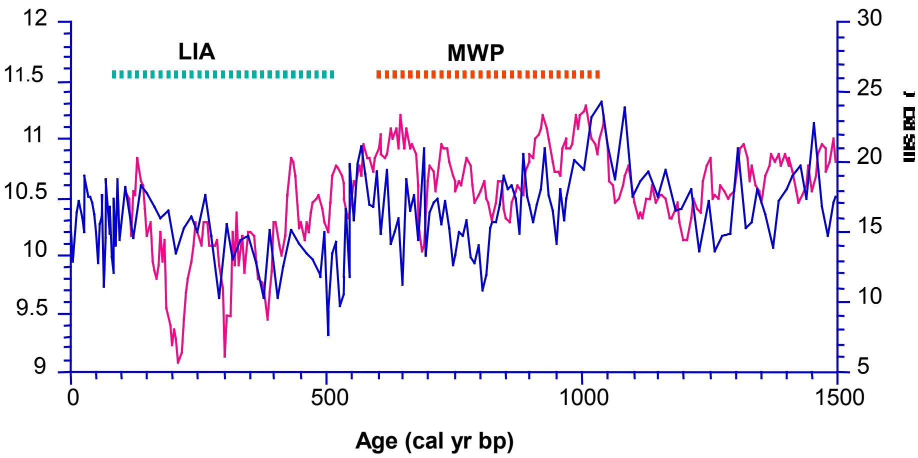


Figure 2. *Correspondence between proxy-derived SSTs in the Nordic Seas and the northern position of the ITCZ, showing strong coviarance. The SSTs (left axis) are from the Vøring Plateau core and the ITCZ proxy is based on Ti in the Cariaco Basin. Higher Ti (right axis) reflects a northward ITCZ [Haug et al., 2001]. Note the LIA and the Medieval Warm Period (MWP).*

The results from the NP-led diatom-based SST reconstructions show that: (1) The intensity of the Norwegian Atlantic Current (NAC) varied around a mean with amplitude of variations of 1-2°C, (2) The intensity of the IC varied around a mean with amplitude of variations of 3-4°C, (3) Both areas display decadal-scale SST variability, (4) The "Little Ice Age" (LIA) starts in core MD 95-2011 with a SST fall of 1.5°C within a decade around 1400 AD and lasts until about 1750 AD, (5) The corresponding interval in core MD 99-2269 is characterized by warm SSTs, (6) The last 300 years are characterized by SSTs warmer than the mean for the last 2000 years over the Vöring Plateau, and SSTs colder than the mean over the N-Iceland Shelf, and (7) Reconstructed SSTs from core MD 99-2269 correlate well with reconstructed sea ice severity around Icelandic coasts since 1600 AD. The conclusions are: (1) Core MD99-2269 shows higher amplitude of SST variability than Core MD99-2011, possibly due to the former's proximity to the oceanic fronts, (2) The development of SSTs, at least over the last

600 years, exhibits an anti-phase relation between the Vøring Plateau and the N-Icelandic Shelf, (3) The anti-phase relation of SSTs during the LIA indicates strengthening of IC as the NAC weakens, (4) An NAO type of atmospheric pattern might explain the observed anti-phase relation of SSTs between the eastern and the western Nordic Seas – if so, then during the LIA an NAO- state and during the last 300 years, an NAO+ state dominated the atmospheric circulation.

The Malangen proxy record developed and analysed by UiT shows a good correlation to measured bottom water temperatures ($r \sim 0.83$) at core location the last 20 years (November). The record also follows the changes in bottom water temperature at Skrova and Sognesjøen (two coastal Norwegian stations) for the last 70 years and the surface waters temperatures at Station M the last 50 years and the Kola profile the last 100 years. The main forcing on the annual to interannual scales changes in water temperature is the NAO. The longer trend shows lower temperatures than present prior to AD 1900 and a gradual warming after AD 1900 (0.5°C). The warming trend correlates to the solar irradience after 1900; however, this correlation is absent prior to AD 1900. From this we conclude the changes in solar irradience has a minor effect on the Malangen record.

Task 7: Long term observations

Task leader: Ole Anders Nøst, Norwegian Polar Institute

Progress

7.1 Continue the long-term current observations at Svinøy.
The Svinøy monitoring program of Atlantic Water fluxes has been performed according to plan and extends 6 1/2 years starting in April 1995. Cruises have been performed in October 2000, March 2001 and finally in October 2001. Observations using combined VM-ADCP/SeasSoar instrumentation have been performed during the cruises reveiling details in the structure of the Norwegian Atlantic Current.

7.2 Current observations in the Fugløya-Bear Island section.
An Aanderaa DCM12 ADCP current meter is purchased and is currently deployed in the Barents Sea. The running costs has, together with the fundings from MAIA, made it possible to continue the regular long-term observations of the inflow by current meters as has been carried out since August 1997 funded by VEINS and IMR.

7.3 Long term observations in Fram Strait

1. Collection of in situ data in Fram Strait.
   Cruises has been performed in September 2000 and September 2001. In 2000 4 moorings on the Greenland Continental slope along 79 °N was deployd. These moorings will be recovered in September 2002. Collection of CTD data and water samples for oxygen isotope data has been performed in 2000 and 2001.

2. Analysis of current meter data, sea ice and hydrography
   - Analysis of current meter data from the Fram Strait in the period from 1997 to 2000 has been done (Fahrbach et al., 2001).
   - Studies of the hydrography and variability of the thermohaline structure in the Fram Strait is done (Pavlov, 2000; Tverberg et al., 2001). Pavlov (2000) has studied trends in long term variability in the gates to the Arctic Ocean, and Tverberg (2001) has investigated the deep water in the Fram Strait.
   - The work to quantify the influence of atmospheric and oceanic driving forces on the flux of water through Fram Strait is ongoing. O.A, Nøst and P.E.Isachsen is studying simple theories for flow along f/H contours in the Arctic Mediterranean. The goal for this is to understand what the observations in the Fram Strait can tell us about the circulation in the Arctic Ocean. Svein Østerhus and Karolina Widell is analysing data from DCM12's and upward looking sonars (ULS) in the Fram Strait in order to quantify the sea ice flux through the Fram Strait and understand its forcing.
   - At NP Ana Carrasco was hired from the 1. December 2001 to analyse current meter records from the western part of Fram Strait. NP has continous current meter records from within the East Greenland Current in the period from 1989 to 2000.
   - We are in cooperation with the Alfred Wegener Institute involved in ongoing work where the goal is to quantify the heat transport through Fram Strait.

3. Analysis of oxygen isotope data
   Measurements of oxygen isotop data ($\delta^{18}O$) to identify and quantify different sources of freshwater in the Fram Strait, were delayed and received in November 2001. The analysis

is measured this year and results and conclusions will be presented in the NOClim spring neeting 2002.

Deviation from project description

Analysis of the oxygen isotope data will be performed and fullfilled during December 2001, and results will be presented on the NOClim spring meeting. All milestones have then been reached.

Results

7.1 Continue the long-term current observations at Svinøy.
This study deals with the inflow of warm and saline Atlantic water to the Nordic Seas. The investigations are carried out along the Svinøy standard hydrographic section, which cuts through the Atlantic inflow to the Norwegian Sea, just to the north of the Faroe-Shetland Channel.

Transport estimates in the Svinøy section, eastern branch
The eastern branch of the Norwegian Atlantic Current is captured by four current meter moorings at the steepest part of the slope at bottom depths of about 500m, 720m, 880m, and 990m. Flux estimates of Atlantic water in this branch is estimated to 4.4 Sv. Linear regression analysis between AW transport based on all current meters and the single current meters show that about 80% of the variance in the AW flux is captured by current meters located in the core of the inflow (at e.g. instrument of 300 m and bottom depth 720m, see figure). This allow us to make simple estimates of the AW flux in the eastern branch by single current meters.

Transport estimates in the Svinøy section, western branch
The western branch of the Atlantic inflow appear as a meandering unstable frontal jet and can therefore not be captured by neither current meters nor standard hydrography. But for the baroclinic part of the Atlantic inflow in a presumed geostrophic balance, transport estimates can be inferred by assuming that a certain reference density interface outcrops the surface somewhere and corresponds to a zero velocity reference interface. Based on this method the baroclinic transports westvard of single CTD profile can be estimated. Somewhat different approach to this method have been made. Orvik et al. (2001) used the density profile at the 990 m isobath (to the west of the eastern branch) and considering the vertical density profile. Their transport estimates ranging from 1.3 Sv to 5.6 Sv with an overall mean of 3.4 Sv and standard deviation of 1.0 Sv, and with an indication of a winter maxima and summer minima.

7.2 Current observations in the Fugløya-Bear Island section.
The current measurements between Norway and Bear Island has revealed that the current into the Barents Sea is highly variable and much more complex than expected. It has been questioned if the measurement programme which has taken place during 1997-2000 has been sufficient to resolve all the dynamics in the area. The last year an extended measurement programme has been performed, and the results show the doubt has been groundless considering the time series of volume transport on monthly time scales. The measurements show that during 2001 there has been generally lower inflow to the Barents Sea. This is probably partly caused by the low NAO during the winter of 2000-2001, but also during the summer of 2001 there has been a somewhat weaker inflow.

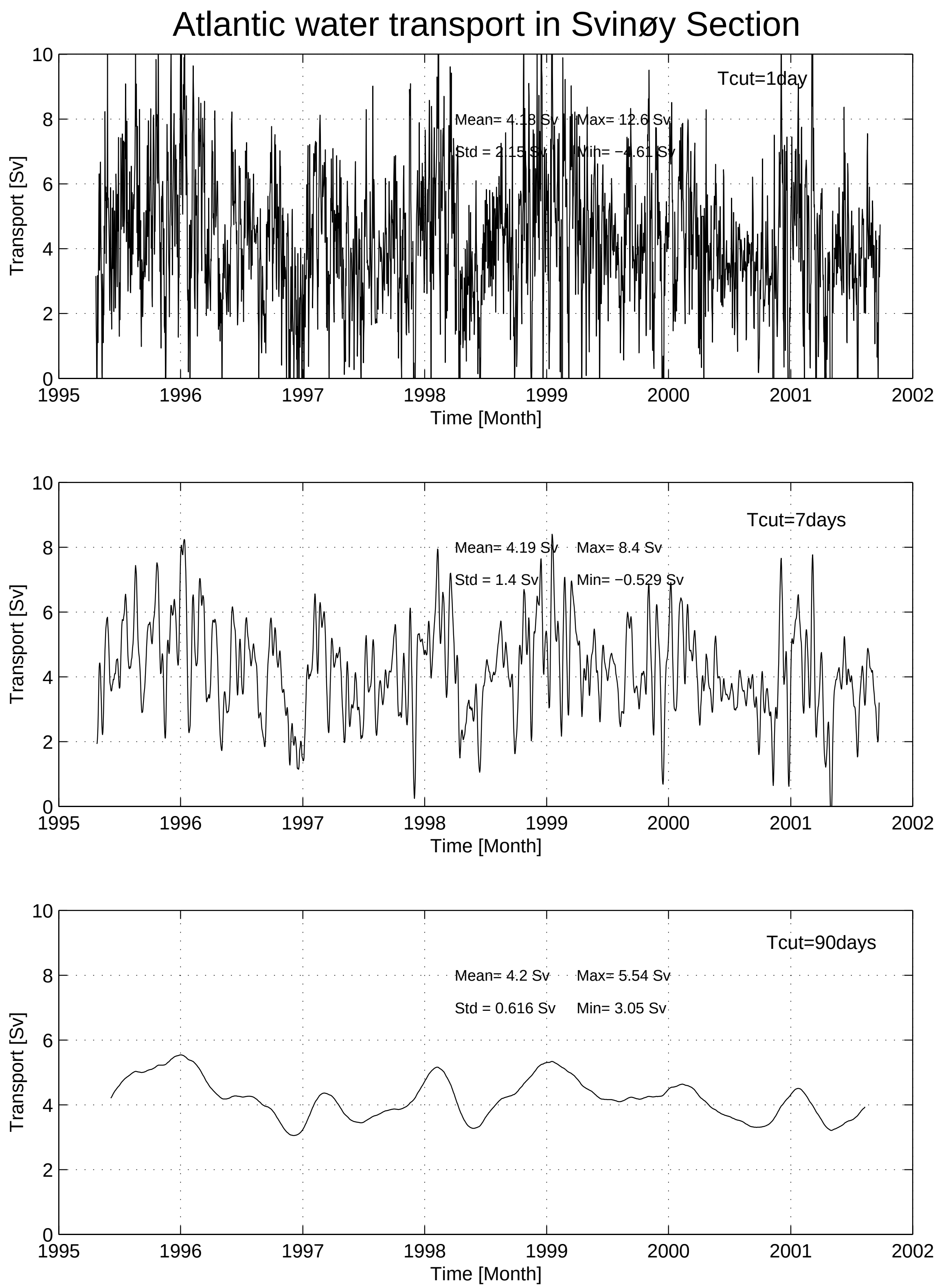


Figure: Time series of transport from a regression model based on one current meter at mooring S1 in Svinøy section in terms of moving average filter of 1, 7 and 90 days in the period from April 1995 to October 2001.

7.3 Long term observations in Fram Strait

There is a lot of activity in analysing data from the Fram Strait. Here follows results from the different initiatives.

Volume transports through Fram Strait 1997-2000 (Fahrbach et al., 2001)

The monthly mean velocity fields reveal intensive variations over seasonal and annual time scales of the velocities and the spatial structure of the northward flowing West Spitsbergen Current and the southward East Greenland Current with a maximum in spring and a minimum in summer. The volume transport obtained by averaging the monthly means over two years amounts to 9.5±0.9 Sv to the north and 11.1±1.1 Sv to the south. The West Spitsbergen Current has a strong barotropic and a weaker baroclinic component, whereas in the East Greenland Current barotropic and baroclinic components are of similar magnitude. The net transport through the strait of 1.6±1.7 Sv to the south is most likely an underestimate, because the measurements do not cover the East Greenland shelf where southward net flow is expected. The obtained northward and southward transports are significantly larger than earlier estimates given in the literature, however the balance obtained from a two years average is within its uncertainty consistent with earlier estimates.

A study on the deep water in the Fram Strait 1980-2000

CTD-data from the period 1980-2000 in the Fram Strait has been investigated in search for temporal changes in the θS-characteristics of the deep water in the region, and linking this to the changes observed in the deep water in the Greenland basin during the same period (Tverberg et.al., 2001).

The Fram Strait, about 2500m deep with some deeper trenches, allows deep water exchange between the Greenland Basin and the Eurasian Basin. Most of the exchange occurs in the slope currents on either side, but there seem to also be some exchange in the central part of the strait. Especially the water between 1700-2500m in the central Fram Strait seem to be mixed between water from the Eurasian Basin, Greenland Basin and the slope currents. Below this layer the salinity of the water in the Eurasian Basin is increasing with depth, while both temperature and salinity of the deepest water in the Greenland Basin is decreasing with depth, so these water types are easily distinguishable. Generally it seems like the Greenland Basin type deep water has retreated southwards during the 20 years period of investigation. The water type could be found further north in the Fram Strait during the 1980's than the last few years, and the deepest water in the Fram Strait has gradually changed from being dominantly of Greenland Basin type to dominantly of Eurasian Basin type. This reflects the decrease taken place during the period in deep water formation in the Greenland Sea. Simultaneously the temperature increase observed in the Greenland Basin deep water the last twenty years is also clear in the central part of the Fram Strait, and of almost the same magnitude. This change can be partly an effect of increased temperature of the Greenland Basin deep water, and partly of a decreased amount of this water type in the Fram Strait.

Freshwater fluxes through Fram Strait

Two hydrographic and delta O-18 transects across Fram Strait (Aug-Sept 1997, 1998) has been used to examine freshwater contributions to the East Greenland Current (Meredith et. Al. 2001). The EGC featured up to similar to 16% meteoric water in both years, but was made comparatively more saline through the formation of up to similar to 11 m of sea ice. The 1997 and 1998 data show a long-term mean sea ice flux through Fram Strait around half the long-term mean meteoric water flux. The 1998 section reveals fresh, low-delta O-18 Water

On the East Greenland shelf whose comparatively large volume constitutes a potentially significant contribution to the total freshwater flux through Fram Strait.

In addition to the work by Meredith et al. (2001) Svein Østerhus and Karolina Widell is analysing data from DCM12's and ULS's from the Fram Strait. The DCM12 measures the current velocity profile in the upper 50 meters in addition to the sea ice velocity. The ULS (Upward Looking Sonar) measures the sea ice draft. There is a good correlation between the sea ice velocity and the atmospheric pressure in the area. They are currently working towards obtaining new estimates on the sea ice flux through Fram Strait, based on data from 1994 to present.

Trends in long term variability of thermohaline structure in the main gates to the Arctic Ocean

This work by Vladimir Pavlov is based on data from the Joint US-Russian hydrographic atlas of the Arctic Ocean.

During 1950s – 1980s there was a decrease of mean-decadal water temperature in summer time and an increase of mean-decadal water temperature in winter time in the West Spitsbergen current. The interannual variability of water temperature in the Fram Strait is tightly connected to the atmospheric circulation. The maximum values of water temperature were observed in the years with maximum values of the NAO index. In the 1990s there was a basic reorganisation of thermohaline conditions of water masses in the main straits of the Arctic Ocean. In the Fram Strait and the strait between Svalbard and Norway the maximum temperature has significantly increased in connection with an intensification of the inflow of Atlantic water.

Circulation along f/H contours.

When moorings are collected in September 2002, we have a 5 year time series from 14 moorings across the Fram Strait. The time series from the western part of Fram Strait is about seven years longer. The question we ask is: What can be said about the circulation within the Arctic Ocean and the Nordic Seas, based on the results from these measurements? In an attempt to answer this question we have looked at simple models for the circulation along f/H contours. On closed f/H contours a simple expression for the bottom pressure gradient may be found assuming we know the wind stress and the hydrography. We are now comparing this results with current meter data and output from numerical models.

Coordination and public outreach

Responsible: Peter M. Haugan GFI UiB /Solfrid Sætre Hjøllo GFI UiB

Progress

- Structures for internal communication and data exchange have been implemented.
- Arrangement of 1 kick-off meeting, 2 all-staff project meetings including invited guests, 3 SSG-meetings have been held.
- Presentations have been given by Peter M. Haugan on a range of national and international meetings in the project start phase.
- Mutual RegClim/NOClim representative in SSG. (H.Loeng and E.A.Martinsen) have been established. Peter M. Haugan is in the Steering Committee in UK „Rapid Climate Change“, a representative from "Rapid Climate Change" took part in the NOClim all-staff fall meeting 2001.
- External information is available on web-site, in media and as Technical Reports from All-staff meeting.

Deviation from project description

The milestones have been reached.

Results

<u>Internal Communication and structures for data exchange</u>

An internal web-site at www.siu.no/noclim.nsf is established and serves as a project data base, accessible for all project participants. Storage capabilities at Norwegian Service Center for Climate Modelling (NoSerC) available. NOClim is represented in NoSerC Steering Group by Peter M . Haugan, who has also been chairing the NoSerC steering group during the first year.

<u>Project meetings and workshops</u>

Kick-off meeting. A kickoff meeting was held in Bergen September 6-8 2000. During two days at Villa Skjoldnes, the participants presented themselves and their projects, detailed plans were set up and interdisciplinary ideas were exchanged.

Spring meeting 2001. A two day meeting was held May 9-10 2001 in Bergen. There were 31 participants, including 5 from RegClim. 26 talks were given, 4 of them about RegClim-activities, the rest about ongoing activity and preliminary results of NOClim. The meeting report is available as NOClim Technical Report no 1.

Fall meeting 2001. A three day meeting was held December 5-7 2001 in Bergen. There were 30 participants. 20 talks were given reporting ongoing activity and preliminary results. The UK-programme "Rapid Climate Change" was presented by its science coordinator Meric Srokosz, and an invited talk was given by Andrew Watson. The meeting report will be available as NOClim Technical Report no 2 in February 2002.

SSG-meetings. Three meetings in the Scientific Steering Group (SSG) have been held.
30/11-00 Bergen: Constitution, meeting plan and internal/external information.
13/04-01 Tromsø: Orientation task 1 and 7, spring meeting
04/09-01 Oslo: Orientation task 5 and 6, fall meeting
SSG participants: Eystein Jansen, Harald Loeng, Eivind A. Martinsen, Lars Petter Røed.

Other meetings. The project leader was invited to the RegClim 2000 spring meeting, and several NOClim PIs were invited to present NOClim at a RegClim meeting in fall 2000. There has also been a joint NorPast-NoClim workshop in winter 2001, and several internal task meetings in various NOClim tasks.

<u>International relations</u>
Already in May 2000, three members of the SSG were invited to a town meeting in London in preparation for the upcoming UK programme. After NOClim was funded, information about it has been communicated to the UK planning process. When RAPID was funded, Peter M. Haugan was invited to serve on its steering committee and has so far participated in its first steering committee meeting in October 2001. Additional international coordination and collaboration occurs through EU projects and through the Arctic and Subarctic Ocean Flux Array (ASOF) where Harald Loeng, Edmond Hansen and Peter M. Haugan are in the steering group.

<u>External information</u>
A web page is made available at www.noclim.org. The site has both Norwegian and English text, and includes project overview, background material, list of participants, activities and so on. The site is hosted at Geophysical Institute, University of Bergen.
An agreement between NOClim and "Cicerone" of NOClim info pages to appear regularly is fulfilled. Four articles were published fall 2001, and six articles, presenting various aspects of the project, are planned for spring 2002.
Technical Report No 1 (report from spring meeting 2001) published June 2001. Technical Report No 2 (report from fall meeting 2001) to be published January 2002
NOClim has been presented at various RegClim and UK meetings (see above) and at the Research Council Programme Conference November 27-29 2001 (presentation and poster).

<u>Other</u>
NOClim receives computer hours at Notur/NTNU. For the reporting period 40.600 cpu-hours were applied for, 32.300 granted.

Part C Economy table

<u>Comments:</u>

- Task 1:In addition to mention personnel Prof. T.Vorren (UIT) has contributed with running cost and data to NOClim.
- Task 2: Running costs in 2000 includes purchase of equipment. The contribution from Dr. Ilker Fer starting in 2002 is subject to confirmation of funding to a separate Post Doc project.
- NERSC numbers for 2000 and 2001 include both Personnel and Running cost-expenses.
- Task 6*:* Own/other financing: UiB: Nordic Arctic Research Program (NARP), partial salary and running costs (travel) [MM] 9/2000-12/2001. NP: VISTA, full salary and running costs [CA] 2000-6/2002. UiT: Nfr NORPAST, partial salary and running costs [GM].
- CPO: Running costs at GFI in 2001 and 2002 include invoices of 10 kNOK per year from each of DNMI, IMR and GEOL-UiB for personell expenses for SSG work in addition to travel and other running costs