

**Report of the
Seventeenth Meeting of the
Arctic Ocean Sciences Board**

**30 March - 1 April 1998
Oslo, Norway**

Cover photograph “Bad Boys of the Arctic” by Thomas D. Mangelsen

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**ARCTIC OCEAN SCIENCE BOARD (AOSB)
Seventeenth Meeting (AOSB-XVII)**

30 March - 1 April 1998
Norsk Polarinstitutt
Oslo, Norway

OPENING OF THE MEETING

The Chair, Dr. Dieter Fütterer, opened the meeting at 1:00pm at the Norsk Polarinstitutt. He thanked the ACSYS Staff, Dr. Roger Colony and Ms. Tordis Villinger, for their assistance in making arrangements for the Meeting. The list of Meeting participants is attached as Appendix II.

Dr. Olav Orheim, Director of the Norsk Polarinstitutt (NPI), welcomed the participants. He presented a summary of the NPI's research activities and interests in the Arctic Ocean and of other relevant recent developments in Norway.

Dr. Orheim reported that the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR) will sponsor a conference on Polar Aspects of Global Change in late August of 1998 in Tromsø, Norway. The response of scientists has been excellent and more than 150 abstracts have been submitted. A number of Arctic science organizations (such as IASC; AMAP; some IASC Working Groups; and a group of polar operators) will be meeting in conjunction with the conference.

He noted, however, that many such meetings to discuss coordination of Arctic research seem to involve the same scientists. He proposed that the organizational infrastructure for Arctic research be reexamined. If it is determined that all or some of these organizations are needed, then perhaps they can be encouraged to better coordinate their activities to reduce the large number of meetings and at least minimize the travel for participants.

Dr. Orheim suggested that the most important thing AOSB can do is develop a good scientific basis for studies in the Arctic. He cited the AOSB Freshwater Balance study as one in which Norwegian scientists are likely to be very much interested. He encouraged the Board to have a successful meeting.

The Chair suggested that the Board discuss the rationalization of meetings related to Arctic Ocean research and consider ways to optimize the Board's efforts, taking into account the interests and activities of other organizations with related scientific interests. The Chair noted the need for the Board to retain the flexibility to assure the continued success of its programs such as the Greenland Sea Project (GSP) and the study of the North East Water (NEW) -- the first phase of the International Arctic Polynya Programme (IAPP) -- which have been completed recently and the study of the Northwater (NOW) now underway -- the second phase of the IAPP.

AGENDA FOR THE MEETING

The Chair introduced the draft agenda which includes a number of reports on Arctic ocean science which should be considered in the light of identifying needs for future research. The agenda was adopted (as reflected in Appendix I).

THE INTERNATIONAL ARCTIC POLYNYA PROGRAMME (IAPP)

Prof. Louis Legendre, Chair of the Scientific Coordination Group for the IAPP (IAPP-SCG), noted that the concept of an IAPP had been developed in 1987 in Santander, Spain. In 1988 in Bremerhaven, Germany, three polynyas were identified as targets for potential study: NEW, NOW and the St. Lawrence Island Polynya (SLIP). A major objective of the IAPP is to consider the linkages between polynyas and broader-scale ocean circulation. The U.S. and Australia are involved in such a study in the Antarctic.

The NEW field programs and analyses have been completed and the results presented at a very successful Symposium in 1997. Planning for a NOW program began in 1991 and continued into 1994-1995. A detailed proposal for Canadian support of a NOW program was approved by the National Science and Engineering Research Council (NSERC) in February of 1997.

The central hypothesis is that there are two principal mechanisms of polynyas, latent heat (acting through winds) and sensible heat (working through movement of ice). It is thought that in the Northwater, the two co-exist, not always acting at the same time. Many predictions have been developed as to the response of biological systems to these driving forces because such response will vary, depending on the relative importance of the two driving forces. The interaction of sensible and latent heat is predicted to govern not only the biology, but also the carbon cycle in the polynya.

About sixty principal investigators are involved (about thirty from a wide range of Canadian government institutions and universities and thirty from other countries, including Japan, Denmark, Poland, the United States, Belgium and Great Britain) in the field study which was launched in 1997 with deployment of deep moored arrays, including upwards-looking ADCP's, from the CCGS *Louis St. Laurent*.

The 1998 field program is expected to involve about 120 scientists and the primary platform will be the CCGS *Pierre Radisson*. The first three legs will involve 83 stations. Seven of the nine 1997 instrument lines will be re-deployed, but others will be placed at different locations to better study the inflow and outflow of subsurface waters. In addition, the 1998 field program utilizes a trackline that avoids the fixed-ice regions that local populations use as hunting grounds. Surface temperature, salinity and chlorophyll will be monitored continuously; the distribution of birds and mammals will also be monitored. Ice conditions and color will be monitored by remote sensing continuously for the next five years.

For this year, a major objective is to determine whether the sensible heat mechanism is very active along the coast of Greenland, as indicated by the initial preliminary studies in mid-

May of 1991. At that time record levels of chlorophyll had been observed in this region. Connections with the Arctic basin may be considered for future study.

The shore-based program will focus on ice studies around Cape Isabella at the northern end of the study region and on bird studies at Coburg Island in the south. The efforts of Polish scientists will address primarily near-shore processes, but are also expected to contribute to study of water exchange with the Arctic. An initial cross-section of the Jones Strait was conducted in 1997. It is hoped that funding from other participating countries can be found to undertake additional studies in August of 1999 when the moorings will be retrieved, but Canadian funding is presently not expected to be available for such research.

The IAPP-SCG has been informed by U.S. colleagues that an organized study of the SLIP is now very unlikely. It was suggested that, if the IAPP-SCG continues, it should focus on Arctic polynyas on the Russian side of the basin, especially the Laptev Sea polynya. It was also noted that, while sediment traps had been deployed and a few cores had been obtained in the polynya studies to date, sedimentary processes and influences have not been a major component of these studies.

The NEW program resulted in new hypotheses regarding the relationship between biological productivity and physical processes. These hypotheses were then considered in planning for the NOW program. A synthesis paper prepared for NOW planning identified the ice barrier issue as important, but the ice barrier has not reappeared. This year the ice in front of one of the major glaciers disappeared and no icebergs were generated in this region.

It is not clear what role is played by ice bridges in the NOW region, but one of the exciting early conclusions was that there may be a persistent catabatic wind on some glaciers. An array of weather stations will be deployed this year which may provide additional information on this.

It was agreed that the improved understanding of polynyas that has resulted from the IAPP to date should assist scientists to identify future polynya research for study and determine what such studies should involve. The IAPP-SCG will be asked to consider whether the program should be broadened and, if so, how new components should be initiated and which other organizations might best be involved.

It was agreed that the IAPP-SCG be encouraged to meet as soon as possible after the NOW field season to consider future directions for the IAPP. It was agreed that a scientific workshop might be the best way to determine what the next area of research should be relative to the issues which need still to be resolved.

Scientists involved in polynya research should be invited to participate to bring together the results of NEW and NOW and develop lessons for the future. The scientists should be asked to formulate the scientific questions; consider the extent to which the NEW and NOW answered these questions; and then assist the Board to identify the most appropriate directions for future polynya research.

Other questions the IAPP-SCG and/or such a workshop should be asked to consider include:

1. whether Arctic basin polynyas, especially those on the Russian side (the large Laptev Sea polynya, for example), should be included in the program,
2. the role of the carbon cycle and the sediments in polynyas, and
3. comparison of Arctic and Antarctic polynyas.

It was suggested that the IAPP-SCG should meet initially through a teleconference and then at a later date in a regular meeting. The membership of the IAPP-SCG should be strengthened, especially to provide expertise not now available to them.

Action: The Chair of the IAPP-SCG will be asked to convene a meeting of the IAPP-SCG prior to the next AOSB meeting to consider the issues identified above. The agenda and discussion papers for the IAPP-SCG should be organized under the direction of Dr. Legendre and administrative arrangements should be coordinated by the Secretariat. AOSB Members will be invited to nominate scientists for the IAPP-SCG, particularly in the areas of mammals and physical oceanography.

FRESHWATER BALANCE IN THE ARCTIC

Dr. Geoff Holland reported that NATO had agreed to co-sponsor a symposium on The Freshwater Balance in the Arctic with the U.S. National Science Foundation (NSF) which had provided some initial funding through the Scientific Committee on Oceanic Research (SCOR). The symposium will be convened as a NATO "Advanced Research Workshop" in late April in Tallinn, Estonia. Scientists from a wide range of countries are expected to be invited. An advisory committee assisted in the planning. Key speakers include eminent scientists whose presentations will be augmented by comprehensive discussions. AOSB Members will be able to attend. Rapporteurs will assist in preparation of a publication, intended to contribute to a critical assessment of the freshwater balance of the Arctic.

Dr. Lyn Lewis (Canada) will report on the results of the workshop to the meeting on Polar Aspects of Global Change in Tromsø in August. Dr. Holland agreed to prepare a synthesis on the results of the workshop and the role that the AOSB might play in developing cooperative programs in this area. It was agreed to include the synthesis in the report:

Report of the NATO Advanced Research Workshop

Discussions at the NATO Advanced Research Workshop on the Freshwater Budget of the Arctic Ocean (27 April - 1 May, 1998, Tallinn) indicated that in both the atmosphere and ocean, episodic events are important and therefore, the processes involved need to be better understood before the longer-term changes can be appreciated. Important examples of such events/processes are atmospheric cyclones bringing large quantities of moisture into the system and the formation of deep ocean water.

In terms of how the Arctic Ocean and its freshwater budget might be impacted by global change or how the Arctic processes themselves contribute to the global situation, two issues hitherto neglected need to be understood: (1) coupling between seasonal cycles (e.g., run-off

vs. ice formation) and (2) points of bifurcation (e.g., freshwater input from the Laptev entering the Canadian or Eurasian Basin; freshwater leaving the archipelago via Fram Strait).

The Arctic basin is still a data-sparse region. Therefore, it is important to not only maintain existing observation and monitoring systems, but also to establish more extensive and continuous networks. Finally, models which are becoming available with finer resolution can and should be used not only for forecasting longer-term trends, but also to shed light on processes and eventually replace some of the physical data networks through assimilation techniques.

The Workshop recommended the following priorities for future research:

Atmospheric Conditions

There are significant changes in the major atmospheric patterns affecting the distribution and flow of moisture into and out of the Arctic basin. The North Atlantic Oscillation (NAO) and the position of the Aleutian High have significant effects on atmospheric flows over the polar region and consequent changes in ice and ocean flows.

The root causes of these system changes and their downstream impacts need to be studied; coupled ocean/ice/atmosphere processes need to be better understood; and estimates of precipitation and evaporation over the Arctic Ocean need to be improved.

Freshwater Influx

The Arctic Ocean receives its freshwater inflow from the inputs of direct atmospheric precipitation and from run-off from catchment areas draining into the Arctic basin. In addition, as the Arctic warms, there are potential contributions from glacier meltback and permafrost melting. Records on the input from major rivers are relatively good over the past fifty years. However, there is little data on oceanic precipitation and evaporation; on present glacial input; on run-off from smaller rivers; and on permafrost melting.

It is recommended that: (1) data on input from Canadian rivers be added to the present U.S./Russian bilateral database; (2) the rawinsonde data network in the region be improved; (3) information be obtained regarding glacial and permafrost contributions; (4) paleo records of river flows be examined to study their variability and periodicity; and (5) data be obtained on input from small rivers.

Ocean Water and Sea-Ice

The exchange of water at the surface and at depth between the Arctic Ocean and both the Atlantic and Pacific Oceans has been studied extensively in recent years and is increasingly well-understood. However, recirculation of water at the Atlantic entrance to the Arctic complicates exchange of these waters. In addition, coupled hemispheric models at present appear to not give sufficient weight to the Bering Strait and the Canadian Archipelago as sites of freshwater exchange.

The seasonal pulse of freshwater from melting ice can affect the ocean processes which control outflow from the Arctic basin and freshwater budgets can be affected by meltwater and sea-ice transport.

It is therefore important to: (1) study shelf processes in the formation of sea ice and of dense bottom water, paying attention to polynyas and leads; (2) study the outflow of freshwater and ice through the Canadian Archipelago; (3) study the impact of diminution or cut-off of inflow of Pacific water; and (4) continue the present monitoring of the overall exchange with the North Atlantic, including the export of ice.

Action: Board Members are requested to consider the above priorities in the light of the future program of the Board and of possible value-added research programs that the Board might consider undertaking in this area.

CANADIAN ICEBREAKERS AND THEIR ROLE IN ARCTIC OCEAN RESEARCH

Mr. Ray Pierce, Regional Director (Central and Arctic) of Oceans and Fisheries Canada, reported that the Department of Fisheries and Oceans Canada (DFO) and the Canadian Coast Guard (CCG) had merged in 1995. He stressed that there are many challenges involved in vessel operations in the Arctic. For example, management of safety control zones is not a simple matter of mastering ships in the Canadian Arctic, as there are different operational dates for different classes of ships, dealing with safety and protection of wildlife.

There are also significant issues related to land claims. DFO coordinates closely with Canadian northern populations on management issues and recommends that other nations interested in operating in this region work closely with DFO to establish the correct protocols. Dr. John Cooley is the contact for such issues.

The Canadian icebreaking fleet includes six major icebreakers, eleven medium icebreakers/navigational aids/multi-mission ships and eight other ice-strengthened ships. The CCGS *Louis S. St-Laurent* is the most capable of the Canadian icebreakers for science applications, particularly following its recent refit. The CCGS *Terry Fox* is basically a commercial icebreaker design; the Hudson conducts fisheries research, physical oceanography and hydrography. DFO schedules the fleet on a multi-year basis through two committees, one dealing with science and one with operations. The fleet receives 80-90% of its funding from a single source.

Discussions have been held recently with other countries in the Pacific region regarding the potential regular use of the CCGS *Sir Wilfrid Laurier* for scientific applications in the western Arctic. As a result, the ship will be dedicated for such purposes.

The DFO would like to explore ways in which they can plan more effectively for matching scientific needs with ship allocations and scheduling. Both clearly go through peaks and valleys and perhaps there are some new ways to smooth these out through improved interaction between scientists and operators. In outfitting icebreakers for science, the DFO has developed suites of equipment that can be packed and transferred from vessel to vessel. The DFO wants to determine how they might best support science in the Arctic, both operational science and research.

Canadian icebreakers have made substantial contributions to the joint success of the NOW,

SHEBA and JOIS programs, but other opportunities may have been lost along the way. It is important to have all interested nations involved in identifying opportunities and in planning jointly for good science programs. AOSB may be a vehicle to provide for discussions of such future Arctic science opportunities.

POLAR ACTIVITIES OF THE EUROPEAN POLAR BOARD (EPB)

The European Marine and Polar Science (EMaPS) was established in October 1995 with a polar and a marine board being formed. The polar board is expected to focus its program initiatives on land-ocean interactions in the Arctic, especially in conjunction with the Russians. The European Science Foundation (ESF) is promoting interaction between the social and natural sciences in the Arctic through the CLIMPACT Network. EMaPS is undergoing review during 1998. Meanwhile, the polar board is considering how it might interact most effectively with organizations such as the AOSB, IASC, and the Arctic Council.

Dr. Carol Williams summarized the meeting that had been held to discuss the future of Arctic science and stressed the importance of modeling and recognized the importance of problems of scale for Arctic climate models. Scale is also an issue for models that address such issues as human dimensions and decadal to century periods. It was acknowledged that additional emphasis should be placed on natural - as opposed to anthropogenic - changes and on inclusion of paleoclimate data. It was agreed that atmosphere/ice/ocean interactions should also be built into models.

It was noted that the Polar Board is also investigating the possibilities of a European-owned C-130 as a vehicle to use for both Arctic and Antarctic research. Use of such an aircraft would prolong polar operating seasons and enable rotation of scientists without requiring them to spend extensive periods in transit aboard vessels.

POLAR ACTIVITIES OF THE EUROPEAN UNION (EU)

Dr. Jean Boissonnas reported on a conference on Mediterranean oceanography, organized by the Marine Science and Technology Programme (MAST) and held in November 1997 in Rome, Italy. The meeting concluded that both policymakers and scientists should accept that scientists are appropriately part of the policy process, not just providers of facts for this process. He pointed out that the European Commission (EC) adopts its science policy and programs through the "Framework" process. The Fourth Framework period runs through the end of 1998. The Fifth Framework period begins later this year and runs through the year 2002.

The structure of the Framework program has been changed and simplified somewhat for this Fifth period. There are four thematic programmes: the quality of life and management of living resources, the user-friendly information society, competitive and sustainable growth, and energy, environment and sustainable development. Within each area, essential "key actions" were identified. These are expected to be supported by generic technologies and

research infrastructure, the latter being defined as ways to network and coordinate the use of existing European infrastructure. Marine science and technology falls primarily under the fourth area and partially under the third.

The initial proposal was for 16.3 billion ECU. Conciliation, which is an important step in this process, will begin after the European Parliament has given its next reading in June and will take some months. It is expected that marine research activity will receive about the same level of funding as in the Fourth period.

Footnote: Framework program 5 is now officially adopted. The budget is 15 billion EURO (formerly ECU).

It was reported that both the U.S. and Canada have agreed in recent months on cooperative science agreements with the EU. There may be a major "event" to celebrate the new U.S.-EU Agreement sometime in early June.

VARIABILITY OF EXCHANGES IN NORTHERN SEAS (VEINS)

Dr. Bob Dickson reported that the VEINS project has reached the point at which all equipment has been acquired and deployed, and the results of initial efforts are already available. The data return is expected to be high due to the use of large instrumented arrays and to a high equipment recovery rate thus far.

The VEINS Field Phase has taken place during an extreme development of the NAO, the primary recurrent mode of atmospheric forcing in the Atlantic sector. By the late 1980s–early 1990s, the extreme amplification of the NAO had carried a warmer, fresher and probably stronger transport of Norwegian Atlantic Water north to the Fram Strait and Barents Sea. This climatic signal appears to have passed beyond the Nordic seas to affect the Arctic Ocean proper where it has formed the focus of a considerable parallel research effort. [Entering the Arctic, the Atlantic-derived sublayer shoaled and warmed by up to 2°C in the Eurasian Basin and extended in distribution by about 20%, so that the first of the US submarine (SCICEX) surveys in 1993 showed that its "front" had shifted from the Lomonosov to the Alpha-Mendeleev Ridge. At shallower depths, the cold halocline (freshwater cap) which had acted to insulate the sea-ice from the warm Atlantic layer below, dwindled away in the Eurasian Basin, with effects on the surface energy- and mass-balance of sea-ice in that region. Hydrography and tracers backed up by modeling suggest this change may have stemmed from the eastward diversion of Russian river input in response to the altered atmospheric circulation.]

The extreme positive state of the NAO in the 1990s also appears to be responsible for spreading the influence of Arctic change south to Nordic Seas where the main VEINS effort is focused. For example, the anomalous airflow is held responsible for increasing the annual volume flux of ice passing south through the western Fram Strait to a peak of 4687 km³/month in 1994-5, and a part of the VEINS analytical effort has been concerned with establishing the track and fate of this freshwater through the western Greenland, Iceland and Irminger Sea.

VEINS has also been concerned with describing the causes of change in the Denmark Strait overflow, one of which appears to have been the southward recirculation of warmth from the eastern Fram Strait during the warm episode of the 1990s. Data recovered from the Denmark Strait Overflow in August 1997 by R/V *Meteor*, including the first successful year-long measurements of overflow plume thickness by 12 kHz Inverted Echo Sounder (IES), revealed a remarkable and instructive suite of changes in winter 1996-97. Current speeds in January-February 1997 slowed to a few cm s^{-1} in part of the overflow core which has hitherto been characterized by a vigorous and (when time-averaged over weeks to months) rather steady mean flow. At the same time, its monthly average temperature rose to the highest value yet recorded (2.40°C), and its layer-thickness, determined acoustically by IES, dwindled from 300m to 50m. The simplest explanation is that the extreme warmth of the overflow caused it to run higher on the "wall" of the East Greenland Continental Slope where it descends to the deep ocean, so that one current-meter mooring and the IES were temporarily "dropped" from its core. Experiments with a numerical overflow model appear to confirm this. If so, then we may have acquired some ability to predict overflow characteristics from the hydrographic variability upstream. Tests of the hypothesis continue, and the full VEINS array of 6 current meter moorings and three inverted echo sounders are in place for the purpose.

Since the Denmark Straits Overflow is a major contributor to North Atlantic Deep Water (NADW), the question of its variability has implications for our understanding of change in the headwaters of the global thermohaline circulation, and these changes may therefore have a more-than-regional importance.

Quite apart from the recent extreme behavior of the NAO, it is already clear that a substantial post-VEINS effort is both scientifically important and technologically feasible. Variability in the Arctic has long seemed to have some especial involvement with global change. Polar amplification and feedback are recurrent themes in numerical climate modeling. The initial results of VEINS now clearly demonstrate the importance of sub-Arctic seas to the Arctic "system", acting both as a source of Arctic change and as a conduit through which such change may have global effects. A strengthened linkage between VEINS and ACSYS would assist materially to establish monitoring and observations in key regions on a long-term basis. It is also true that a number of key components of the Arctic - sub-Arctic system remain to be quantified, of which the most important are probably the input of heat to the Arctic via both Atlantic "gateways" and obtaining an improved measure of the freshwater flux passing south on the East Greenland shelf.

It was decided, therefore, to ask the VEINS scientists to put together a paper on extending the VEINS program to look at the two-way interactions between the Arctic and the outside oceans, including the deep-water connection.

Action: Dr. Dickson should be asked to prepare a preliminary proposal for discussion at the Tokyo meeting.

ARCTIC PALEO-RIVER DISCHARGE (APARD)

Dr. Ruediger Stein summarized the progress made in planning for research in this area through

two workshops in 1996 and 1997. These resulted in a draft science plan focussing on modern and ancient riverine processes and their importance for the chemistry, biology and sedimentology of the Arctic basin. It is possible to use stable isotopes in the surface layer (as organisms living in this surface layer preserve these isotopes) as a proxy of surface layer salinity. Incidence of specific materials in the sediments can also provide indicators. Ratios of strontium isotopes and their variability can be useful. Mineralogical studies can also characterize the various rivers.

Some hydrologists have correlated the characteristics of river meanders (both length and width) with riverine discharge. Stable isotopes give information regarding overall freshwater input, as opposed to just riverine discharge (e.g., meltwater). The studies of ancient processes are now intended to involve three different time scales, but it is recommended that these studies be extended further back into the Pleistocene.

These planning efforts have resulted in a small book which is intended to go to the publisher in a few weeks. A summary is being published in the "Nansen Icebreaker" for Spring of 1998. APARD also has its own website: www.awi-bremerhaven.de/GEO/APARD/index.html. The APARD Programme will be described in "Reports on Polar Research" in Summer of 1998. It is expected that the first results of the research will be available for an APARD Conference, possibly in 2000.

The Chair concluded that the scientists had addressed all of the key questions that the Board had asked at its last meeting. It was agreed that APARD is now an AOSB Program and that a Steering Group should be established to provide coordination for APARD and an umbrella for its various sub-projects. This Steering Group should be drawn from the "core group" of scientists who are and will be involved in this research.

Action: Dr. Ruediger Stein should be asked to correspond with the Core Group of scientists and develop an appropriate Steering Group. The Steering Group should be encouraged to draw up Terms of Reference for submission to the Board in Tokyo. The group should also consider the schedule of work for APARD, bearing in mind the following points from the Board's debate.

The Steering Group might identify the various rivers by priority and identifies gaps in planned research. A key role for the Steering Group should be to lead in the synthesis of information from the Eurasian and Canadian Arctic, bringing together scientists from both regions. The first results of the research could be made available through an APARD Conference, possibly in 2000. The Steering Group could play a key role in planning for the Conference and in identifying scientific meetings and other activities that might be needed between now and then.

SURFACE HEAT BUDGET OF THE ARCTIC (SHEBA)

Dr. Larry Clark noted that the overall objective of SHEBA is to develop a better understanding of the heat balance of the Arctic. The scientific foci are to study the high sensitivity of Arctic climate to both atmospheric and oceanic variability; the impact of the

Arctic, in turn, on global climate; and key Arctic feedback processes, all over a full year.

Getting the program underway was complex. SHEBA had originally been envisaged as an ice-camp operation that would enable study of the same water mass for the duration of the experiment, but was changed to a ship operation, with the attendant improvements in science capabilities and habitability. Canada's largest icebreaker, CCGS *Louis S. St-Laurent*, led a smaller 90m icebreaker, the CCGS *Des Groseilliers* to the site. This mode of operation proved very effective.

Site selection was based on fifteen years of ice data, taking into account the need to stay within the same water mass and ice system. As it turned out, SHEBA headed for Russia and, more importantly, to open water. In addition, the warm water generated serious ice stability problems. For example, a plane carrying television news crews could not land because of the ice conditions. Crew rotation could also be jeopardized as the site moves to the maximum range of Twin Otter aircraft.

Early results of the field program were presented at a recent meeting in Seattle. A paper on the SHEBA website describes the oceanography at the site and the current structure under the ice. The high productivity of the area was surprising. If ice conditions worsen further, the biologists, chemists, and some physical oceanographers would be willing to continue their work aboard ship and possibly drive the ship into the ice. The meteorologists have a great deal of equipment set up on the ice and might not be willing to disassemble and reassemble it at a new site.

RELATED RESEARCH IN THE UNITED STATES

It appears that the Arctic science program at NSF will receive a 13% increase for 1999. There is a possibility that, as a result, SHEBA could receive additional support and/or other new projects could be started. There are plans for a 1998 and possibly a 1999 SCISECS submarine cruise in the Arctic Ocean. The class of submarines being used is being decommissioned and thus the long-term future of such cruises may be in doubt. These programs will be available for international cooperation which could be set up through the AOSB. There are already some links between SHEBA, JOIS, and NOW.

SHELF-BASIN INTERACTIONS (SBI)

The SBI Program in the Western Arctic is the next project likely to be conducted under the Arctic System Science (ARCSS) program. The Arctic is expected to present a large signal of impacts from climate, physically, chemically and biologically. The focus of the SBI program is on the Chukchi and Beaufort Seas, with intensive field work followed by modeling. The program announcement will probably be issued shortly and integrated proposals are expected to be structured along the lines of the four main project themes. The program is intended to be conducted over a seven-to-ten year period beginning in 1999. The SBI could also be open to links with polynya research.

It was suggested that shelf-basin interaction is the main oceanic question for the Arctic Ocean. There are initiatives underway or being planned in Europe as well as in the U.S., and it is important to increase communications between the American efforts in the Chukchi and Beaufort Seas and the efforts on the east-Atlantic side.

Canadian scientists are looking at the interaction between the Arctic Basin and both the Atlantic and Pacific. A group of scientists from many countries are looking at fjords and their contribution to the oceans across the shelves. Norwegian and Swedish scientists are working in the Barents Sea, studying transformations of water masses. German scientists are also interested in shelf-basin interactions.

It appears that a scientific program in this area which endorses a broad range of cooperation in shelf-basin interactions could assist in opening up a number of opportunities. It was agreed that key questions for studies of shelf-basin interaction are: what is feeding the shelves? which biological, chemical and physical processes are occurring there? what is driving the shelf-basin interactions? what are the associated fluxes? what is the sensitivity of these processes to climate change? Contributors to these issues include runoff, inflow, biology.

It was suggested that the AOSB could bring together the full range of expertise for shelf-basin interactions and could, among other things, serve as a forum for exchange of information; planning for workshops and other interactions; etc.

Action: Scientists involved in the planning of future studies of shelf-basin interactions should be invited to prepare a paper/proposal for the Board's consideration at its next Meeting in Tokyo. The proposal should consider the need for a possible Conference on Shelf-Basin Interactions.

EUROPEAN SUBPOLAR OCEAN PROGRAMME (ESOP) ACTIVITIES

Dr. Leif Anderson reported that the ESOP Steering Committee is meeting simultaneously in Hamburg. The objective of ESOP-2 is to understand the thermohaline circulation in the Greenland Sea, its sensitivity, and its impact on global ocean circulation, building on a unique combination of novel experimental techniques.

ESOP-2 includes a Greenland Sea Gyre Experiment, a key component of which is an SF₆ tracer experiment to capture the start of deepwater formation. Float systems have been deployed and a number of cruises have been made in the Greenland Sea to track this tracer. The tracer was injected as an emulsion at a density surface at about 350m depth. There may have been some sinking, although no more than 20kg of the original 320kg. At one site, deep water was clearly formed, sinking without entraining the tracer.

The carbon cycle group has been looking at all the various exchanges. During the spring season, there is flux from the surface layer to deeper layers. In the fall, there is a net flux in the other direction. The release was injected effectively; was mapped well; and is combined with other tracers. The tracer studies indicate that the Greenland Sea is a year-round sink of

atmospheric carbon. Modeling will be a focus in the near future.

JOINT OCEAN-ICE STUDIES (JOIS) RESEARCH PROGRAMME

Mr. Martin Bergmann (Fisheries and Oceans Canada - Central and Arctic Region) reported information on a joint physical, chemical and biological oceanography program, which was conducted aboard the CCGS *Louis S. St-Laurent* in the late summer and early fall of 1997. The CCGS *Louis S. St-Laurent* completed a transect from east to west through the Arctic Archipelago, which focussed on climate-related processes, contaminant deposition and living resources.

The JOIS research program was developed to take advantage of the joint CCGS operations with the CCGS *Des Groseilliers*. The CCGS *Louis S. St-Laurent* provided ship support to the CCGS *Des Groseilliers* from eastern Arctic Canada to the Arctic Ocean, carrying cargo and scientific equipment on behalf of the project. The CCGS *Des Groseilliers* provided the research platform for the SHEBA Program from October 1997 to October 1998.

JOIS was a complex multi-disciplinary program divided into four legs. It included a transit of the Davis Strait, a preliminary study of the NOW region, Lancaster Sound and the Beaufort Sea. Finally, a transect was conducted from the Prudhoe Bay to the SHEBA Drift Site. Sediment coring studies suggest that sedimentation rates in Lancaster Sound are of the same level as those in the Hudson Bay.

There is a possibility for JOIS work in 1998 which would focus more on the biological and contaminant aspects of the Archipelago west of Resolute. Ship activity would take place as part of the vessel transit from Baffin Bay to pick up the CCGS *Des Groseilliers* on its return from the SHEBA drift site.

THE INTERNATIONAL ARCTIC SCIENCE COMMITTEE (IASC)

IASC is a non-governmental organization. All the Arctic countries with national science organizations are members, as well as 10 non-Arctic countries that conduct Arctic research. The main activity is to develop research projects for which circum-Arctic or international cooperation is required. The IASC Secretariat is hosted by Norway in Oslo.

The IASC has a governing structure with a Council, an Executive Committee operating between Council meetings, and about 15 Project groups mainly charged with research planning and implementation. A Regional Board composed of members from the eight Arctic countries has a special responsibility for looking after Arctic interests in a research context, as well as developing the relationship with the Arctic Council.

IASC has a problem-oriented project selection strategy; i.e. to identify a major-priority problem, develop the project idea with potential users, and thereafter address it with all relevant expertise - often a multidisciplinary approach.

IASC provides support for programs such as the Barents Sea Impacts Study (BASIS); the Bering Sea Impact Study (BESIS); the study of the Mass Balance of Arctic Glaciers and Ice Sheets in relation to Climate and Sea Changes (MAGICS); and the Land-Ocean Interactions in Russian Arctic Program (LOIRA).

IASC activities of special interest to the AOSB at this point include the following:

The Arctic Bathymetric Map Project

The objective of the Arctic Bathymetric Map Project is to promote and oversee development of a coherent data base of all bathymetric observations available and to construct a new, more accurate seafloor map for the region north of 64°N. This project was initiated by IASC, AOSB and the International Oceanographic Commission (IOC). A planning workshop was held in September 1997 in St. Petersburg, Russia and the report is now available. A Joint Project Group has been established. Consensus-building is underway in order to promote release of "sensitive" national data to the project.

LOIRA

Mr. Odd Rogne presented an overview of the LOIRA Program. Scientific planning was based primarily on Russian scientific priorities in the region. The main objective is to understand the fundamental physical, chemical, geological and biological processes under the influence of global change and anthropogenic factors in the Russian Arctic.

Activities in 1998 are focussing on development of science and implementation plans. Proposals will be considered by an international advisory board consisting of representatives of the IASC, EU, EPB, IPA and AMAP. There is a great deal of interest in Russia and there is an opportunity to link European and Russian scientists, as well as scientists from North America and Asia.

International Arctic Environmental Data Directory (ADD)

The ADD is a network cooperation between major Arctic environmental data holders, usually through linking national Arctic data directories and directories established by major circum-Arctic organizations. The added value of the ADD is to provide user groups with access to all of the Arctic directories. A lot of data can be traced through this network already, although it will take years to make it complete.

Arctic Science Summit Week

IASC is encouraging the various international Arctic science organizations to meet together in order to save time and expenses. Dr. Rogne invited the AOSB to consider meeting next in conjunction with IASC and other similar bodies in such an Arctic science summit week.

ARCTIC MONITORING AND ASSESSMENT PROGRAMME (AMAP)

Dr. Lars-Otto Reiersen indicated that a scientific report, prepared by more than 200 scientists, is now available. An executive summary has also been made available for the use of policymakers. More than 70% of the volume of water which reaches the Arctic is from areas south of the Arctic. Much of this water contains significant levels of contaminants.

Indigenous peoples have 100 times the input of contaminants than non-indigenous peoples, due to diet and high ration of consumption of native foods. Contaminant levels are significantly higher in marine mammals than in terrestrial mammals. Freshwater fish have higher levels of radioactivity than marine fish due to the way in which it is taken up (related to salt content).

Mercury continues to be a problem in the Arctic. Coal-firing industry is the highest contributor to world levels. Lead-free petroleum has apparently contributed to reductions in lead levels. There is an expansion of oil exploration activity in the Arctic. AMAP has advised ministers that there is insufficient information available to draw conclusions regarding climate and UV radiation in the Arctic. The situation with regard to persistent organic pollutants (POPs) is not improving; levels of heavy metals may be increasing; radioactivity risks remain high; and the region continues to be impacted by acidification.

The AMAP Program for the period 1998 to 2003 will focus on human health; POPs; heavy metals; TBT; oil and PAH' s; acidification and radioactivity; climate change effects on terrestrial and marine processes; UV; and ozone.

AMAP until recently reported to the ministers of environment and now to the foreign ministers as well. Ministries of natural resources are also involved. Indigenous peoples play an integral role in AMAP, including in the decision-making. A project directorate has been formed. AMAP has established links with other Arctic science organizations. AMAP finds AOSB to be important since it is able to provide a forum for information exchange.

Quality control of data from some countries was difficult. Intercalibration with Russian data was not adequate in some cases. As a result, AMAP needs original data, not just mean or summarized values. Other problems include the coordinates provided for sample collection and the data formats. AMAP data is presently stored at a number of locations: marine data is archived at the International Council for the Exploration of the Seas (ICES) in Copenhagen; atmospheric data in Oslo; FW data at the FWI; radiation data in Oslo; and human health data in Denmark.

REMOTE SENSING ACTIVITIES RELEVANT FOR ARCTIC OCEAN RESEARCH

The European Space Agency (ESA) has led development of the European Remote Sensing Satellites ERS1 and 2, which were launched in 1991 and 1994 and are still operating well. ERS2 is fully operational. Although ERS1 has lost about 38% of its power, it is still serving as a backup for ERS2 and the tandem missions planned for will be advanced timewise to exploit the interferometer capabilities while both satellites are operational. The Synthetic Aperture Radar (SAR) is working very well. More than one million SAR scenes have been produced, including a great number acquired in the Arctic Ocean by the Alaska SAR Facility in Fairbanks. ENVISAT is being manufactured presently for a possible launch in December 1999. The SAR onboard is generally comparable to the RADARSAT, but has two polarizations rather than just one.

The METOP-1 program has recently been funded for a possible launch in 2001 to be

followed by METOP-2 and -3 at about five-year intervals. The METOP program is supported by the U.S. as well as by European countries. They will carry improved Advanced Very High Resolution Radiometer (AVHRR) sensors.

No new earth observation program has yet been approved to follow ENVISAT. However, plans will be presented to a Ministerial Council meeting in June 1998 for a follow-up on an Envelope Programme which includes the Earth Explorer and Earth Watch Missions. Earth Explorer Missions are directed towards new applications covering a wide range of research. European industry is being sought to support Earth Watch Missions jointly with ESA.

Other satellites relevant for Arctic marine research include:

- The National Oceanic and Atmospheric Administration (NOAA) satellites with AVHRR still in operation which are extremely useful for sea-ice monitoring purposes (cloud permitting);
- The DMSP series of satellites with the SSM/I instrument still in operation; together with the NIMBUS-7 Scanning Multichannel Microwave Radiometer (SMMR), these satellites have provided continuous microwave radiometer data since 1978;
- The SPOT satellites, including the recently-launched SPOT-4 with a special vegetation sensor for land observations; and
- SeaWifs which was launched in August 1997, the first images from which were published in March 1998 (the images are now available on the web). It appears to be performing well enough to support studies of plankton, but it remains to be seen whether the necessary calibration can be done.

Relevant activities of the U.S. National Aeronautical and Space Administration (NASA) include planning for the very ambitious Earth Observation System (EOS) program and for putting sensors on the Japanese ADEOS satellites.

Over the next year, Dr. Preben Gudmandsen will be analyzing satellite radar data from the last five-to-six years, acquired at approximately two-week intervals of the ocean from the Fram Strait to the Lincoln Sea west of Cape Morris Jesup in North Greenland.

ARCTIC CLIMATE SYSTEM STUDY (ACSYS) PROJECTS

ACSYS is the only regional program of the World Climate Research Programme (WCRP) and has responsibility for a broad range of high latitude studies including: sea ice dynamics and thermodynamics; ocean circulation and shelf/basin exchange processes; atmospheric dynamics and thermodynamics; land surface and riverine hydrology; and mathematical modeling. ACSYS began in 1994 and is expected to continue for ten years. The key question being addressed is, "what have been the global consequences of change in the Arctic climate system?"

ACSYS activities are evenly split among: recovering historical data sets; field oceanography; regional studies; process studies; analyses and modeling; designing and maintaining monitoring programs; and establishing data bases and information regarding them.

Dr. Christoph Oelke described BARKODE, an ACSYS project to organize a comprehensive data base for the physical oceanography of the Barents and Kara Seas. In the past these data have been held by many separate institutes and departments, both military and civil. Recently, the military data (from Norway, US, and Russia) have been declassified and made generally available to the research community. Furthermore, civil institutes have come to realize the value of integrated data sets. The creation of a uniform, comprehensive data base is the first step to documenting climate and climate change in this transitions zone separating the warm surface Atlantic water from the cold surface waters of the Eurasian Basin.

A second ACSYS project focuses on the circulation of the Arctic Ocean. ACSYS scientists are now intercomparing the simulations from many separate ocean models. The study will try to reconcile the circulation simulations to hydrographic and tracer observations. This information will be made available on the web and ACSYS is considering organizing a workshop next year to review overall present understanding of the circulation.

T. Vinge summarized the ACSYS historical ice-edge archive. He reported that Norwegian archives of ice edge information are comprehensive, with measurements for every two weeks from 1868 onward. It is intended to extend this dataset back to 1730 by including sealing data that exists for this period. There is a high correlation between the ice-edge information and Northern Hemisphere sea surface datasets. Most importantly, recent data indicates there has been a reduction of 500,000 square kilometers in ice cover in the Northern Hemisphere from the 1970's to the 1990's.

A major workshop on "Scientific Use of Ice Charts" will be held in Seattle in late August 1998 and will specifically address data from before 1950. An ice thickness program is also being developed utilizing data from roughly forty upward-looking sonars. The ice thickness dataset from the Southern Beaufort Sea is good, but it is not clear whether information from one such area could be extended to develop ice information for the entire Arctic.

The Levitus Climatology, although it covers the period up to 1994, contains relatively little Arctic data. Hydrographic data from the 1950's to late 1970's includes about 1125 stations from the surface to the bottom. Some work has been done recently on differentiating the implications of removing certain physical forcing factors and determining flow patterns. The retraction of the ice-edge from the mid-50's to the last 20 years appears to be due only in small part to ice-thickness differences, the rest is due to area.

Arctic Ice and Environmental Variability (ARCICE) is a UK initiative to study the relationship between Arctic ice and environmental variability and to enhance understanding and predictability of the dynamics and variability of Arctic ice cover relative to climate change. Substantial new funding is expected for this program.

ARCTIC OCEAN DATA MANAGEMENT

The Board asked the Steering Group to review the overall issue of Arctic data management and to explore ways in which the AOSB might assist in this area. The Steering Group noted that the Board had earlier suggested that the potential value of use of the internet be considered and that the Board had agreed at this meeting that the AOSB website should include national reports based on the reports prepared and submitted annually for Board meetings.

The Steering Group agreed that AOSB Members should be invited, in preparing such national reports, to include information on their national centers which hold Arctic ocean data, including general descriptions of the ocean data holdings of these centers and information as to how scientists interested in obtaining and/or exchanging data with these centers can arrange to do so.

Action: The Secretariat should proceed with design and establishment of an AOSB Website. Future expansion of the site to include an inventory of Arctic ocean data holdings should be a priority agenda item for the next Meeting.

FUTURE PROGRAMS

The Board was originally established to encourage and promote access to facilities; bring together scientists through combined programs; promote access to waters otherwise difficult to study, etc. It was agreed that the AOSB should identify and address scientific needs that are important enough to bring together scientists from Europe, North America and Asia. In looking at these suggestions, the Board will focus on the added value that it brings to the programs it adopts.

The AOSB umbrella should assist to address problems of access and funding. The AOSB should be the group identifying the scientific umbrella and overview and encourage the various groups of scientists to develop proposals for specific projects.

It was suggested that AOSB consider additional activities in the biology of the Arctic and in returning to one of its initial efforts - sharing of major facilities, e.g., making more effective use of the larger and more capable platforms that are becoming available for Arctic Ocean research, perhaps through joint operations. Since the Board is "Arctic", it might be appropriate for the Board to look in the future to high Arctic issues, since most of the Board's efforts to date have focussed in the sub-Arctic.

The Board agreed to invite interested scientists to develop papers on in the following scientific areas which could benefit from attention by the Board and could be planned/developed in the next one to two years: polynya research (the IAPP-SCG); follow-up to the VEINS program (Dr. Bob Dickson); shelf-basin interactions (Dr. Larry Clark and Dr. Leif Anderson); BIODAFF (Dr. Jan Marcin Weslawski); freshwater balance (Dr. Geoff Holland and Dr. Lyn Lewis); and fjord studies (to be determined). These papers will be distributed to Members and then reviewed at the next Meeting. It was suggested that it

might be useful to group together under one umbrella the various programs related to deep-water formation.

Action: AOSB Members should be invited to identify possible additional Arctic Ocean research issues for consideration by the Board at its next meeting.

RATIONALIZATION OF MEETINGS RELATED TO ARCTIC RESEARCH

In response to the proposals tabled by Dr. Orheim and Mr. Rogne to rationalize the structure of international meetings related to Arctic research, the Board agreed to encourage rationalization of its activities with those of other international organizations interested in Arctic research. It was suggested that at a minimum, the Board should work with these organizations to improve coordination of meetings of the various organizations. It was suggested that in some years AOSB could meet with IASC, in other years with the EPB or other Arctic science organizations.

The Board agreed that more focussed meetings are required and meeting preparations should be improved. It was suggested that, although discussion of some Arctic science issues is repeated at various meetings, the foci of these meetings are very different and that some repetition is therefore necessary.

Action: The Board will communicate to IASC, EMaPS, and the Arctic Council the Board's interest and its willingness to work with them in this area.

OTHER CONCLUSIONS/ACTIONS

Cooperation With Russia

It was suggested that an important question for the future might be to identify opportunities for multilateral cooperation with Russia. Increased Western presence in knowledge gathering and formulating knowledge in the Russian Arctic might, among other things, better enable the Russians to make better policy decisions. The Board will be querying its members for suggestions on how it might address this issue.

Other Points

The SG recommended that the Board meet in 1999 in Japan; in 2000 in the United Kingdom; and in 2001 in Canada. It was agreed to invite ACSYS to be represented regularly in AOSB meetings and to keep in communication with them.

A new member has been added to the AOSB staff -- Ms. Cara Sucher -- who is located at the USGCRP Office in Washington. She will complete development of the AOSB website and will collect information for inclusion. This should include information on key national Arctic ocean data centers/repositories. Dr. Geoffrey Holland has developed a draft brochure and Ms. Sucher will prepare this for publication and distribution. It was also agreed to encourage AOSB Members to consider presenting lectures at universities that would include information on AOSB programs and activities.

APPENDIX I**ARCTIC OCEAN SCIENCES BOARD
Seventeenth Meeting (AOSB-XVII)**

30 March - 1 April 1998
Oslo, Norway

AGENDA**MONDAY, 30 March**

- 0900-1200 AOSB Steering Committee Meeting
- 1200-1300 Lunch (NP Canteen)
- 1300- 1315 Opening of Meeting by AOSB Chair (*D. Fütterer*)
- 1315-1345 Welcome to Norsk Polarinstitut (*O. Orheim*)
- 1345-1530 AOSB Programmes
- International Arctic Polynya Programme (*L. Legendre*)
 - Freshwater Balance of the Arctic Symposium (*G. Holland*)
- 1530-1550 Coffee Break
- 1550-1730 Related Arctic Programs
- Canadian Coast Guard Vessels (*R. Pierce*)
 - Polar Climate Research (*J. Boissonnas*)
 - European Union (*J. Boissonnas*)
 - Warming in the Arctic Ocean (*R. Dickson*)
 - Variability and Exchange in the Northern Seas (*R. Dickson*)
- 1900 AOSB Dinner (Petit Bistro, Majorstuveien 34; Tel: 22 69 57 40)

TUESDAY, 31 March

- 0900-1000 AOSB Programmes (continued)
- Arctic Paleo-River Discharge (*R. Stein*)
 - Shelf-Basin Interactions (*L. Clarke*)
 - ESOP (*L. Anderson*)
 - Surface Heat Budget of the Arctic (*L. Clarke*)
- 1030-1050 Coffee Break

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- 1050-1230 Related Arctic Programmes (continued)
•Joint Ocean Ice Studies (*M. Bergmann*)
•NODC Russia (*E. Vyazilov*)
- 1230-1330 Lunch
- 1330-1600 Related Arctic Programmes (continued)
•Land Ocean Interaction in the Russian Arctic (*O. Rogne*)
•Arctic Monitoring and Assessment Program (*L. O. Reiersen*)
•ACSYS presentation (*R. Colony, C. Oelke, T. Vinje*)
- 1600-1620 Coffee Break
- 1620-1800 Reports from other meetings
•Climate Variability (CLIVAR) Activities (*R. Dickson*)
•Atmospheric Circulation in Relation to Oscillations of Sea-Ice and Salinity (ACROSS), (*R. Dickson*)

WEDNESDAY, 1 April

- 0900-1040 Relations to IASC and other Arctic Science Programs
•International Arctic Science Committee (*O. Rogne*)
•European Polar Board (*C. Williams*)
•Arctic Climate System Study (*R. Colony*)
- 1040-1100 Coffee Break
- 1100-1300 Future Program and Schedule of the AOSB and Other Business
- 1300 Close of Meeting

APPENDIX II

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APPENDIX III**Summaries of National Arctic Ocean Science Programs****CANADA****A. Department of Fisheries and Oceans**

The Department of Fisheries and Oceans (DFO) researchers involved in Arctic research in Canada, are located in different regions across the country. In 1997 a number of groups have been active in Arctic research initiatives.

In the Atlantic region at the Bedford Institute of Oceanography (BIO), the Ocean Sciences Division has begun work on a project to measure the transport of mass, heat and salt from the Arctic to the Atlantic Ocean through the Canadian Archipelago. During the past year, they have collaborated with Geological Survey of Canada (GSC) - Atlantic; to compile all the existing bathymetry within the Archipelago as the basis of a finite element circulation model that will be developed. They have purchased the necessary hardware (Acoustic Doppler Current Profilers, 3 component flux gate compasses and Temperature/Salinity sensors) for the first of three planned transport arrays. This array will be set across Lancaster Sound in 1998. They plan to purchase the hardware for each additional array in succeeding years so that by the summer of 2000 they will be able to set three arrays to simultaneously measure the transport through all the major channels of the Archipelago. This project is a major Canadian contribution to ACSYS.

The Laurentian Region, with scientists located primarily at the Maurice Lamontagne Institute Laboratory (MLI) in Quebec performed analyses on metal contaminants (mercury, cadmium and lead) in Arctic Ocean sediment. Data were published on the distribution of cadmium in cores taken from the continental shelf and slope in the Beaufort Sea area. The data were also used to prepare the *Canadian Arctic Contaminant Assessment Report (CACAR)*. In addition, a study was undertaken, along with Pacific Region, to test the hypothesis that whalebone from Arctic bowhead whales could be used to track temporal changes in mercury contamination.

Over the next year, the Laurentian Region will continue to conduct research on contaminants in Canada's northern regions. MLI scientists are currently associated with three projects for which funding applications have been submitted to the Northern Contaminants Program (administered by Dept of Indian and Northern Affairs). These projects concern the long-distance transport and uptake into the food chain of mercury and organochlorine compounds. The work will be done in cooperation with other Canadian government scientists, primarily located in Winnipeg.

During 1997/98, the Laurentian Region also conducted work on the impact of organic matter transported by the Grande Riviere de Ia Baleine on local productivity along the coast. This project will be completed in 1998/99, with the publication of a technical report.

Atlases of coastal habitats and fishery resources have been published for the following areas: eastern shore of James Bay, eastern shore of Hudson Bay, and Ungava Bay. The information in these atlases was taken from the fish habitat management information system. In 1998/99, this database is expected to be made accessible through a Web site.

In 1997, Laurentian Region helped with sampling linked to a study of beluga migration patterns in eastern Hudson Bay. The Region also conducted a study of the beluga population structure in Hudson Bay.

JOIS Project

Canadian coordination for the JOIS program originated in the centre of the country at the Freshwater Institute in Winnipeg, Manitoba (Central and Arctic Region). The JOIS program was borne from the research opportunity provided by the vessel operations requirements associated with the 2-ship transit to the SHEBA site.

The combined SHEBA/JOIS programs constitute the most complex and broadly based ocean study ever undertaken in the Arctic. Work involved three ships, over 50 universities and laboratories and approximately 100 principal investigators; field work spans a full year from October 1997 to October 1998.

As part of the operational considerations of the United States SHEBA program, the joint transit of the 2 Canadian icebreakers from eastern Canada to the western Arctic, provided Canadian researchers with an opportunity to carry out a research program in August and September of 1997. The JOIS science program objectives stem from Canada's ongoing commitment to the improved understanding of Arctic marine ecosystems, including:

- Climate-related processes, contaminants disposition and living resources are central issues driving present day research on the Arctic
- At least one metre long core suitable for dating was collected from the Melville Viscount Sound; this has implications for future work in the area
- The transit of the CCGS *Louis S. St-Laurent* from the eastern to near the western limit of the Canadian Arctic provided the first opportunity to collect, during a single cruise, physical, geochemical, biological, geological and contaminant samples from Lancaster Sound to the Canada Basin in the Arctic Ocean (this work included scientists from the U.S. and other Canadian Federal Departments as well)
- An Arctic website has been produced which includes information on the JOIS program; it is available at: <http://www.arcticexplorer.com>

The Canadian Coast Guard research icebreaker, CCGS *Louis S. St-Laurent* has been chartered for the SWEDARCTIC Tundra Northwest 1999 program. Canadian scientists will be working with Swedish scientists in support of terrestrial and freshwater research. An oceanographic research opportunity may be considered as part of the planning process in 1998.

At the SHEBA site, an extensive year-long marine sampling program of the water column has been ongoing since the beginning of October, 1997 and will continue until October, 1998.

On the west coast (Pacific Region), a number of oceanographers attended an international workshop which was convened and sponsored by JAMSTEC in Tokyo, Japan. Twenty invited experts were included in the discussion at the "International Workshop on Exchange Processes between Arctic Shelves and Basins". An important conclusion emerging from the discussion was that shelf basin research in the Arctic is inherently international because the long-term goal must include circumpolar understanding, and ultimately an extension to global issues. Another overarching issue that emerged was the repeated need for sustained interaction between modeling and observational work.

A number of scientists from DFO were active at the annual ACSYS meeting held in the U.S.. DFO input to ACSYS continues to be of significant importance for Canadian ocean climate research.

B. Geological Survey of Canada

Geological Survey of Canada - Atlantic

In 1997, investigations of coastal processes along the Beaufort Sea were undertaken in order to monitor the rate of coastal changes and potential impacts of climate change. Low level air photography, and beach and near-shore surveys were performed at eight sites, many of which have historical or archaeological significance. Historical changes were evaluated using digitized air photos and satellite data. Databases of environmental parameters (wind, ice, tides) have been compiled.

This program will continue in 1998 with additional ground surveys, satellite imagery and coastal videography. The latter will be used to map the Canadian Beaufort Sea coast into the GSC - Atlantic coastal information system. A proposal has been developed as part of the APARD initiative, the objective of which is to define the input of sediment to the Beaufort Sea as a result of coastal erosion.

The fifth year of a sea floor mapping survey was completed offshore of Resolute Bay in August 1997. The project involved the detection and mapping of ice scours generated by drifting ice keels. Ice scours were investigated using sidescan sonar and SCUBA divers. The integrated biological-geological study of scours was designed to both assess the impact of scouring on the benthic community and to determine re-scouring rates of Arctic coastal waters.

Time series data collected over the past 5 years (1993-1997) will be analyzed over the next 2 years. Project participants include the GSC - Atlantic, the Canadian Museum of Nature and California State University at Monterey Bay.

During the fall cruise of the CCGS *Louis S. St. Laurent* (JOIS transit in August and September), marine sediment cores were obtained from area of high mud deposition at the eastern and western ends of the Northwest Passage through the Canadian Arctic Archipelago. Together with DFO scientists, the cores are being studied to determine recent and past changes in plankton and benthic populations that may be related to climatic change and/or pollution. The cores have been analyzed for changes in physical properties that indicate past differences in sea and glacier ice cover and related changes in freshwater runoff, sediment

provenance, and depositional style. Radiocarbon dates from shells in these cores will be available by April, 1998 for numerical estimates of sedimentation rates and fluxes of biological productivity.

In a joint project with Stockholm University, site survey and cores were collected on the Lomonosov Ridge. This Ridge, located in the central Arctic Ocean, is a high priority target for paleoceanographic studies because it is comprised of a thick (500 m), sediment cover in relatively shallow water (ca. 1000 m). In 1997, GSCA and Stockholm University analyzed (at GSCA) the core samples collected during the summer of 1996.

In January, 1998, a first draft of a drilling proposal was prepared for submission to the Ocean Drilling Program and the Nansen Arctic Drilling Program. Stockholm University has negotiated with the Swedish Polar Secretariat for in-kind support of one of their ice-breakers which will be included in the proposal. A second icebreaker - perhaps DFO Canadian Coast Guard, would significantly enhance the proposal, which was submitted for consideration in mid-March.

As part of an effort to understand the origin and evolution of the Davis Strait region, this project continues a regional study that investigates the conjugate Canada and Greenland margin in the region. Initial efforts are producing thematic geological and geophysical maps of the region.

Geological Survey of Canada - Calgary

In 1997 the GSC in Calgary worked on northern Axel Heiberg and eastern Prince of Wales. Open file maps are in preparation. This year they will begin a major mapping project on northeastern Ellesmere Island and will be mapping the area from Bache Peninsula to the northern tip of Judge Daly Peninsula over the next three field seasons.

C. National Research Council of Canada

The glaciology group of Terrain Sciences Division has drilled three cores in the last three years for climate change research. Two on Penny Ice Cap (S. Baffin) have shown it was connected to the Laurentide Ice Sheet 19,000 years ago. Its Holocene record shows the now familiar (Canadian) one of an early Holocene thermal maximum with temperatures declining until about 150 years ago, followed by a modern warming. The Devon core was drilled in 1997 to 100 m and is preliminary to the present plan of drilling to bedrock in April of this year.

D. North Water Polyna Study

Field work for the International North Water Polyna Study (NOW) began in the summer of 1997 with the successful mooring of nine instrument lines (current meters, ADCPs, CTDs, tide gauges and sediment traps) in the North Water between Canada and Greenland. Hydrographic and biological conditions were also surveyed and Danish and Canadian teams studied birds throughout the North Water region. The moored instruments will allow us to monitor the hydrographic conditions leading to the growth of the polyna in the spring of 1998, as part of the spring to summer transition of the area. On 26 March, 1998, 42

scientists embarked on a 112 day, multidisciplinary study of the North Water polyna onboard the CCGS icebreaker *Pierre Radisson*. Divided in four 28 day legs, the expedition will accommodate more than 100 scientists from all over the world. The expedition will be carried out by the different teams and will make this endeavour one of the most comprehensive studies of an Arctic marine ecosystem in history.

A comprehensive overview of the program can be accessed via the internet at:
<http://www.fsg.ulaval.ca/giroq/now>

DENMARK

Sea Ice in the Greenland Sea

Within ESOP-2, The European Subpolar Ocean Programme - phase 2 under the European Commission's Marine Science and Technology programme (MAST), studies of ice formation and decay in the Arctic at large and in the Greenland Sea in particular have been carried out on a daily basis using active and passive microwave observations from satellite. Large-scale and medium-scale digital ice maps are used as forcing fields in the atmosphere-ice-ocean modelling work of the project.

In the IMSI project (Integrated use of new Microwave Satellite data for Improved sea ice observation) methods for use of new satellite Earth observation data in sea ice monitoring are explored and tested with a view to improved utilisation of these observations in a wider user community. It includes development of new ice products from passive microwave satellite data and the development of an Internet-based data distribution system for ice information, see <http://www.dcrs.dtu.dk/DCRS/latest-ice.html>.

Other studies of microwave signatures of sea ice are directed towards improved algorithms for deriving ice concentrations and ice-type information from microwave satellite observations. In the period 1994-97 a number of field campaigns were conducted with airborne polarimetric synthetic aperture radar, multi-channel microwave radiometers, video equipment, and photographic equipment. The campaigns also served as underflights for microwave remote sensing satellites such as the ERS-1/2 SAR and the SSM/I microwave radiometers.

The work was carried out in co-operation with the Danish Meteorological Institute.

(Leif Toudal, Danish Center for Remote Sensing, Technical University of Denmark, DK-2800 Lyngby, lt@emi.dtu.dk).

Evaluation of RADARSAT data for ice mapping.

About 50 RADARSAT ScanSarWide images from Greenland waters were analysed in 1997. A number of underflights were undertaken almost simultaneously with the satellite data acquisition. Special attention has been made to the waters around Cape Farewell. These waters are often windy, cloud covered and with small floes of thick polar ice. The small floe size and changing winds often render the detection of ice difficult, yet this ice is still extremely dangerous to navigation. Various statistical filtering enabled detection of even

small icebergs. During July melt water on the ice surface sometimes made the ice mapping unreliable. The ultimate goal is to make ice mapping operational to improve safety of navigation. The study is part of the IMSI Project and is supported by European Commission's Centre of Earth Observation.

DMI contributed to the ESOP-2 project with geo-coded images and sea surface temperatures derived from NOAA data. Ice maps were provided for selected periods. Ocean-atmospheric interaction models were further developed and tested.

(Hans H. Valeur and Rasphal S. Gill, Ice and Remote Sensing Division, Danish Meteorological Institute, Lyngbyvej 100, DK-2100 Copenhagen O, hhv@dmi.min.dk).

Marine geological investigations

Marine geological investigations were carried out on the south east Greenland margin in order to study the relation between water exchange ('overflow') between the Greenland Sea and the Irminger Sea and late Quaternary climate change. For this purpose acoustic investigations were carried out and a number of piston cores was taken from R/V *Prof. Logachev* (St. Petersburg) and R/V *Dana* (Hirtshals). The work is carried out as a co-operation between Dutch, Danish, Russian, Canadian, British and Swedish scientists.

(Antoon Kuijpers, Geological Survey of Denmark and Greenland, Thoravej 8, DK-2400 Copenhagen NV, aku@geus.dk).

Narwhal research

In August 1997 five narwhals were instrumented with satellite linked radio transmitters at Tremblay Sound, NWT. All whales stayed in the waters east and south of Bylot Island until mid September. One whale moved south along Baffin Island, visiting several fjords and bays, during September and October, and by November it had moved east towards southern parts of the Baffin Bay mid way between Canada and Greenland. During the monitored period the whales showed a preference for deep water areas including deep fjords and the continental slope where the depths are in the range of 500-1000m. However, deeper areas were also frequented in the winter with maximum daily dives exceeding 1000 m. It was demonstrated that a digital video camera could be deployed to a whale and retrieved within Tremblay Sound. One hour of recording from a tusk revealed information on dive behaviour and use of underwater sound.

(Rune Dietz, Department of Arctic Environment, National Environmental Research Institute, Copenhagen, rdi@dmu.dk, in co-operation with Greenland Institute of Natural Resources and Department of Fisheries and Oceans, Canada).

Seabird Survey

Concentrations of seabirds during spring migration in the eastern Baffin Bay were surveyed from airplane in May. The planning of flight lines was supported by satellite data. Satellite data also serves the purpose of studying the relationship between bird distribution and ice conditions.

(Anders Mosbech & David Boertmann, Department of Arctic Environment, National

Environment Research Institute, Tagensvej 135, DK-2200 Copenhagen N, amo@dmu.dk).

Seabird ecology in the North Water Polynya

As a component of the international North Water Project (NOW), studies of seabird ecology is carried out in relation to the polynya, focusing on three species with different foraging strategies: the Thick-billed Murre (a deep-diving fish predator), the Dovekie (a diving plankton feeder), and the Kittiwake (a surface feeder preying upon fish and zooplankton).

The main issues are:

- breeding phenology and success in the Thick-billed Murre and the Kittiwake
- detailed studies of the Murre foraging ecology (foraging trip duration, dive depth, foraging range)
- adult Murre diet
- population density estimates of Dovekies,
- chick diet in the Dovekie (M.Sc. research by CEP).

All studies of the Murres and Kittiwakes were co-ordinated with a study at the Canadian side of the polynya (by Canadian Wildlife Service), as was sampling for analyses of trophic level of all seabird species to compare conditions at the two sides of the NOW. The research will continue in 1998.

(K. Falk & K. Kampp, Ornis Consult, Vesterbrogade 140A, DK-1620 Copenhagen V, ornis@ainet.uni2.dk; Carsten E. Pedersen, Institute of Population Biology, University of Copenhagen.)

Pelagic food web studies

Since 1992 studies concerning the pelagic food web structure in the Disko Bay have been carried out. Similar studies were carried out in connection with the Northeast Water Polynya Project (1993) and in Young Sound in Northeast Greenland (the CAMP Project). The aim of the latter is to evaluate potential changes in the pelagic food web structure and productivity in response to global warming. These undertakings are supported by the global change research programme under the Danish Natural Sciences Council.

(Torkel Gissel Nielsen, Dept. Marine Ecology and Microbiology, National Environmental Research Institute, Frederiksborgvej 399, DK-4000 Roskilde, tgn@dmu.dk; Benni W. Hansen, Roskilde University; Helge A. Thomsen, Copenhagen University and Peter Munk, Danish Fisheries Research Institute).

FEDERAL REPUBLIC OF GERMANY

R/V *Polarstern* expedition ARK-XIII 1997 (14 May to 29 September) was subdivided into three legs. Original planning for one leg comprised biological and geological sampling across the northern continental margin of the Kara Sea as part of a bilateral German-Russian project. These plans had to be modified at short notice as research permission to work in the Russian Exclusive Economic Zone did not arrive in time.

Activities of **Leg ARK-XIII/1** (14 May - 25 June, 1997) were concentrated on two areas. Biological investigations in the marginal sea-ice zone of the central Barents Sea east of Svalbard were focussed on the coupling of the different compartments sea ice, water column and sea floor in a multidisciplinary approach. Off the east coast of Greenland two sampling transects at 81°N and 75°N respectively crossing the East Greenland continental margin focussed on:

- Investigations on particle production in the sea ice and upper water column, their modification during settling and their final sedimentation.
- Identification of distribution and activity patterns of organisms on and within the seafloor.
- Measurements of nutrients within the water column and sediment and of transport mechanisms of oxygen and carbon into the seafloor.

Leg ARK-X111/2 (25 June - 11 August 1997) carried out a sampling programme at the continental margin of Svalbard, across the Yermak Plateau, and in the Fram Strait. The main components of this multidisciplinary project comprised:

- Oceanographic investigations to understand and quantify both the circulation and water mass transformations;
- Biological investigations on pelago-benthic coupling; sea-ice biology and biogeography;
- Geological investigations including sediment coring, sampling of sea ice for sediment transport, sampling of aerosols, studies of modern particle flux by sediment trap sampling;
- Geochemical studies of early diagenesis, particle transport and chemical turnover in the benthic nepheloid layer;
- Bathymetric swath sonar mapping in the northern Fram Strait.

In addition, the OFOS (Ocean Floor Observation System), which allows a direct observation of the sea floor by means of a video and photo camera, was for the first time employed successfully under extremely heavy ice conditions.

Leg ARK-X111/3 (13 August - 29 September 1997) was originally planned to work in the area of the Morris Jessup Rise in the North of Greenland. However, ice conditions encountered during this leg did not allow us to penetrate the area as originally planned. As a situation like this is not unlikely to occur, alternative projects had been planned in advance to be carried out between Greenland and Svalbard and in Fram Strait.

The major scientific objective was to gather new geophysical information on the North Greenland margin, in the Fram Strait and along the West Svalbard Margin (Van Mijenfjord) to investigate the geodynamic and glacial processes of the region. For this, mainly seismic reflection, seismic refraction and gravimetric methods were used. A number of multichannel seismic lines were performed between the North-Greenland and Svalbard continental margins. In addition, seismic lines were acquired across the East Greenland Shelf between 80°30'N and 78°30'N to investigate glacial sediment deposits while a seismic refraction experiment was performed in the Van Mijen Fjord as planned.

The distribution of water masses of Arctic origin was studied by CTD measurements and nutrient analyses. Finally, the hydrographical and chemical observations on a section at

75°N between Greenland and Bear Island were performed as in previous years to reveal the processes associated with the deep-water renewal in the central Greenland Sea. Part of these investigations belong to the EC program ESOP2. Marine chemical investigations also dealt with dissolved organic compounds (DOM) throughout the cruise.

The cruise report is published in Reports on Polar Research No.262,1998,

The **VEINS-Project** (Coordinator: Jens Meincke, Univ. of Hamburg, Germany) was started during summer 1997 according to schedule: The four major passages between the Arctic Ocean and the North Atlantic are instrumented with moored current meter arrays and repeat hydrography. Large-scale modelling as well as regional-scale + modelling resumed. The present phase is characterised by strong fluctuations in the Denmark Strait overflow characteristics, so that the VEINS-participants are confident to monitor a phase of active exchanges between the Arctic and the Atlantic.

The German contribution to the project is provided by the Alfred-Wegener-Institute for Polar and Marine Research and by the Institute for Marine Research at the University of Hamburg.

As part of the **bilateral German-Russian cooperation** a joint expedition with the RV *Akademik Boris Petrov* into the Ob and Yenisei estuaries of the Kara Sea was carried out from August 14 to October 07, 1997. On a total of 26 stations along gradients from the estuaries to the sea measurements and sediment sampling was carried out for biological, geological and geochemical investigations.

The multidisciplinary research project **System Laptev Sea 2000** was launched by Russia and Germany to study the environment of Siberian Arctic and its present and past role in global climate. The project includes land and marine expeditions to the Laptev Sea and the Lena Delta during different seasons of the year, workshops, as well as the exchange of scientists. The overall objectives to be investigated are follows:

- Seasonal changes in permafrost
- Effects of environmental changes
- Terrestrial-marine interactions in coastal zones
- Reconstruction of climatic trends in the central Siberian Arctic

As part of this project the TRANSDRIFT V Expedition to the Laptev Sea is scheduled for 1998. Main target areas for this expedition are the eastern Laptev Sea, the region north of the Lena delta, and the area NW of the Taymyr Peninsula. This cruise is joined by the LENA 98 expedition to the Lena Delta, aiming to study the sedimentation history of the delta as well as to investigate the seasonal changes of greenhouse gases and microbial communities in permafrost regions.

Polarstern - Expedition ARK-XIV during summer and autumn 1998 will be subdivided into two legs.

Leg 1, ARK-XIV/1 (29 June to 20 August) will head for the area north of Svalbard and Yermak Plateau. It is planned to complete the seismic network in the Fram Strait and along the North Greenland and Svalbard margins. Specific targets are the Yermak Plateau and the continent-ocean transition along the Western Svalbard margin and will be investigated with wide angle seismics in combination with gravity measurements. Bathymetric mapping of the

Lena Trough should be completed to the intersection with the Gakkel Ridge if the ice conditions will allow.

During **Leg 2, ARK-XIV/2** (24 August to 15 October), RV *Polarstern* will fulfill the VEINS and ESOP 2 requirements. The moorings in Fram Strait and the central Greenland Sea will be exchanged. The hydrographic survey in Fram Strait will be repeated on the same track line as in 1997. Afterwards a section across the Greenland Sea will be carried out at 75°N and a series of transects across the East Greenland Current as far south as Denmark Strait are planned.

JAPAN

North Water Polynya program

(Shuki Ushio: the Arctic Environment Research Center, NIPR, ushio@nipr.ac.jp)

As a part of the International Arctic Polynya Program (IAPP), a research expedition went to the North Water on board the CCG icebreaker *Louis S. St. Laurent* from 15 to 28 August 1997. The North Water forms in northern Baffin Bay and is regarded as one of the most productive areas in the Arctic. To reveal the role of the North Water ecosystem in the Arctic biota and its response to global change, biological and physical measurements were made in cooperation with the Canadian team. The main operations on the cruise were to deploy 9 long-term moorings in and outside the polynya and to carry out a preliminary survey of the biological/hydrographic environment. NIPR was in charge of setting two sediment traps and two current meters at the southernmost mooring site. Surface characteristics of chlorophyll, temperature and salinity were monitored with pumped-up water during the cruise. Nutrients, total carbon (TIC/TOC) and CO₂ samples were collected from the surface water. Additionally, phytoplankton were collected to analyse algal taxonomy and how algae acclimate their photosynthetic characteristics. As for the hydrographic measurements, XBT profiles were obtained along the north-south and east-west sections of the polynya. After the cruise, we held a workshop with Canadian scientists to discuss the observational results and to plan the following cruises in 1998 and in 1999.

The North Water Polynya Study (NOW) will be continued in 1998. As a main plan of the program, research cruises (biological sampling, retrieval/re-deployment of moorings) will be carried out on 4 legs from April to July on board the CCG *Pierre Radisson*. A total of 9 Japanese scientists, including graduate students, will participate in the NOW program.

NIPR also intends to seek possibilities for future work in the Greenland Sea, focusing on carbon dioxide exchange between atmosphere and ocean and its relation to biochemical processes.

Oceanographic study on board the T/S *Oshoro Nlaru* in the Bering Sea and its adjacent waters

(Seuchi Saito, Faculty of Fisheries, Hokkaido University, ssaitoh@salmon.fish.hokudai.ac.jp)

The T/S *Oshoro Maru* of FF-UU, Hokkaido University, conducted their annual cruise (cruise

#78) in the northern North Pacific, Bering Sea and Gulf of Alaska, including the SLIP area during July - August, 1997. Hydrographic observations, drift gill net research, salmon surface long-line research, mid-water trawl research, trawl research and plankton sampling were carried out. Salmonid abundance, distribution, stock origins, and various aspect of salmonid age, growth, maturity and ocean ecology were also investigated. A study of the vertical transport of organic particles in the Northern North Pacific and Bering Sea was also carried out with time series sediment traps. Emphasis was concentrated on the Polynya water south of St. Lawrence Island (SLIP), where Arctic cod is assumed to be dominant and important in the biological production process in the region. Research was also carried out on the abundance and distribution of age zero-juvenile pollock on the Bering Sea Shelf and zonal transport of heat and sediments in the North Pacific Sub-Arctic Circulation were estimated. The grazing intensity of microzooplankton was estimated with the aid of the high latitude bio-optical algorithms for satellite ocean color remote sensing (SeaWiFS and OCTS/ADEOS) which were developed in 1996.

All data collected during cruise #78 is published in "Data Record of Oceanographic Observations and Exploratory Fishing, No.15, 1998" (FF-HU).

The *Oshoro Maru* will conduct the annual cruise (#87) in a similar area to cruise #78; however, the SLIP area will not be covered during cruise #87 from June to August 1998. Items of research on cruise #87 is almost similar to the previous year.

JAMSTEC participation in SHEBA

(Takatoshi Takizawa, JAMSTEC, takizawat@jamstec.go.jp)

JAMSTEC participated in the SHEBA field program (Surface Heat Budget of the Arctic Ocean) in 1997 and recovered two oceanographic moorings offshore of Barrow, Alaska; the JAMSTEC-WHOI team deployed the Ice-Ocean Environmental Buoy No.2 (IOEB-2) from the SHEBA drift ship CCG *Des Groseilliers* in the Beaufort Sea, and IOEB-2 is now an element of the SHEBA buoy array; JAMSTEC deployed the Northwind Ridge (NWR) oceanographic mooring and occupied two XCTD sections in the Beaufort Sea from the SHEBA support ship CCG *Louis S. St. Laurent*. During 1998 SHEBA cruise, JAMSTEC plans to recover of the NWR mooring and the IOEB-2, and to conduct XCTD measurements in the vicinity of the SHEBA ice camp. A joint cruise of JAMSTEC, UAF, APL/UW and IOS onboard the CCG *Sir Wilfred Laurier* is planned to carry out the hydrographic survey and recovery/deployment of moorings in the Bering Strait and Beaufort shelf break region in summer. A trial cruise of JAMSTEC's new research vessel *Mirai* is scheduled during August-September in the Bering-Chukchi Seas.

Studies on the biological and biogeochemical processes of the ecosystems in the subarctic Pacific Ocean and Bering Sea carried out on board the *Hakuho Maru*

(Kouichi Kawaguchi, Ocean Research Institute, University of Tokyo, kawaguchi@on.u-tokyo.ac.jp)

The *Hakuho Maru* cruise between 9 July and 8 September 1997 (KH-97-2) was successfully accomplished, and the results are summarized below:

1. Research programs

1. Comparative studies on the community structures and biological production processes in the western and eastern subarctic Pacific Ocean and Bering Sea
2. The interaction between pelagic and benthic ecosystems
3. The structures and functions of communities of primary and higher producers (from bacteria to nekton)
4. The structure of the marine food web in the epi- and mesopelagic zones and related biogeochemical processes
5. The effect of air-sea interactions on the flux of green house-effect gases
6. The vertical transport of sinking, suspended and dissolved organic and inorganic materials
7. The characterization of aerosol and radioactive substances in the air
8. Chemical and paleoenvironmental studies based on deep-sea marine sediment cores

2. Contents of programs

The subarctic Pacific and Bering Seas are known not only as one of the most productive waters in the world, supporting a great amount of fisheries resources, but also as key waters controlling the air-sea flux of green house-effect gasses like CO₂. In this cruise we tried to characterise these productive waters, as ecosystems with the above-mentioned structures and functions, from biological, chemical, physical and geological perspectives. Studies on the biological processes included the primary and lower production process in the epipelagic zone, the interactions among epi-, mesopelagic and benthic animals and their biological production. The chemical process study focused on the characterization and flux of the sinking, suspended and dissolved organic and inorganic materials which are related to biological processes. Furthermore, studies on the air-sea flux of green house-effect gases and the characterization of marine aerosols were also included in the chemical studies. The physical oceanographical work was mostly related to the measurement of environmental factors in the ecosystems such as light and temperature fields and profiles. Sampling by various types of plankton nets and water samplers was made to collect marine organisms ranging from bacteria to nekton. Chemical analysis of sea water samples, culture experiments of bacteria and plankton, measurement of physical oceanographic factors by CTD and vertical flux of sinking particles by sediment trap, core sampling of deep-sea sediment by the multiple-core sampler, and continuous aerosol sampling were also conducted aboard the R/V *Hakuho Maru* by the scientists involved in these various scientific fields. Studies on the ecosystems as biological production fields are being planned in relation to the international cooperative projects GLOBEC (Global Ocean Ecosystem Change) and PICES (North Pacific Marine Science Organization). GLOBEC is under the JGOFS (Joint Global Ocean Flux Study) program. Material, especially carbon, cycling processes in ecosystems will be studied.

3. Expected Results

1. Understanding of the differences in the community structures of marine organisms between the western and eastern subarctic Pacific Ocean (faunal differences, distributional patterns, biomass, diel vertical migration patterns)
2. Depicting the food web structures of the communities based on new technology including the stable isotope and immunological methods
3. Elucidation of the relationships between biological processes and biochemical

- processes such as the production process of organic matters and their sinking processes based on the cooperative works of biologists and chemists
4. Elucidation of the difference in the structures and functions of ecosystems in the western and eastern subarctic Pacific Ocean to establish conservation and management of subarctic fisheries resources
 5. Elucidation of the air-sea exchange processes of materials including green house-effect gases
 6. Understanding the paleoceanographical changes in the subarctic Pacific based on sediment core sample reading

Frontier Research Program

(Motoyoshi Ikeda: Graduate School of Environmental Earth Science, Hokkaido University, miked@ees.hokudai.ac.jp)

Frontier Research Program for Global Change (FRPGC) is establishing its branch at the International Arctic Research Center (IARC), Fairbanks, Alaska. Its activities are briefly explained here. The objectives of the IARC-FRONTIER are to:

- * understand the mechanisms of climate variability particular to the Arctic
- * reveal roles of the Arctic region in global change, and
- * predict impact of global change on the Arctic region.

FRPGC is going to establish, with a hope of providing a critical mass to Arctic research community, interactive research teams focusing on the following topics:

- coupled sea ice-ocean system
- dynamic meteorology and energy balance
- climate variability
- atmospheric compounds
- marine bio-geochemical process

The first three topics are given the highest priority reflecting the overall funding strategy of the FRPGC. Accordingly, our hiring strategy emphasizes these topics, i.e. five positions for those topics are currently being advertised (98/99-year). Tentatively, our hiring would include the last two topics, atmospheric compounds and marine bio-geochemical processes in 99/00-year. Upon establishment of the above mentioned research teams, we shall further include the following topics starting 00/01-year:

- terrestrial ecosystem
- paleoclimate

There may be cases where smaller teams with the last two topics are formed sooner (before 00/01 year) so that they can provide pathways to other national and international research programs and projects.

POLAND

Polish Arctic marine research in 1997 was carried out by a number of institutions and comprised studies on various subjects. Institute of Oceanology Polish Academy of Sciences

in Sopot continued its yearly summer research in the waters of the Norwegian, Barents and Greenland Seas on board the R/V *Oceania*. The investigations included oceanographic measurements, observations of aerosol generation as well as zooplankton sampling. The main research concentrated on two areas, namely the West Spitsbergen Current, where dense coverage by CTD stations aimed at the study of structure, dynamics and interannual variability of the WSC, and on Norway-Spitsbergen opening, Bjørnyøa Trough, Kveitehola Canyon and Storfjordrenna in particular, where sampling focussed on the search for local dense water and the study of interannual variability of water exchange. These research tasks partially accomplished the obligations of the 10 PAS due to the corroboration in the VEINS and ACSYS projects. The third research area was Kongsfjorden (Spitsbergen), where investigations originating from the BIODAFF project (Germany, Norway, Poland and UK initiative to study Biodiversity and Fluxes in Arctic Glaciated Fjords) were performed. The 10 day research was dedicated to the study of occurrence of benthic fauna along sedimentation and salinity gradients, the study of patterns in spatial distribution of pelagic fauna in relation to hydrography as well as the study of necrophagous fauna from the Arctic in comparison to the Antarctic environments. The Centre for Marine Biology Polish Academy of Sciences in Gdynia, together with St. Petersburg University and White Sea Biological Station (Russia), organised an expedition to Kolguev Island and Pechora Sea. The aim of the expedition was to collect samples for the survey of genetic variability of selected crustacean species inhabiting Arctic as well as temperate areas. A research team from Gdansk University, in co-operation with University Studies on Svalbard (UNIS), performed small scale research project on the ecosystem of the tidal flat in Adventfjorden (Spitsbergen) and a team representing Szczecin University, in co-operation with IOPAS, did a survey on the geographical variability of littoral diatom flora along the coast of Spitsbergen

SWEDEN

In 1997, no Swedish marine activities took place in the high Arctic, but concentrated to the Nordic Seas, within the EU programmes ESOP-2 and VEINS and the Nordic WOCE, instead.

Two groups from the Department of Analytical and Marine Chemistry, Göteborg University participated in the ESOP-2 cruise to the Norwegian and Greenland Seas from April - May onboard the R/V *Johan Hjort*. Their responsibility was the determination of tracers (SF₆ and CFCs, PI Professor Elisabet Fogelqvist) and the carbonate system (PI Professor Leif G. Anderson).

Three groups from Sweden were involved in the Nordic WOCE/VEINS cruise to the waters between Scotland and Greenland in August - September on the R/V *Aranda*. Two groups were from Göteborg University: one from the Department of Oceanography and one from the Department of Analytical and Marine Chemistry. The first group was involved in the physical oceanography programme (PI Klas Lindblad) and the latter one determined CFCs (PI Professor Elisabet Fogelqvist). The third group was from the University of Stockholm, Department of Meteorology, and was also involved in the physical oceanography programme (PI Professor Peter Lundberg).

Furthermore, a two week expedition to Svalbard was performed in July, with the aim of

studying the social science research in polar regions. This expedition had some connection to marine research in that it documented archaeological sites of whaling activities and other historic areas of interest to polar research.

UNITED KINGDOM

(1) Peter Wadhams, Sea Ice and Polar Oceanography Research Group, Scott Polar Research Institute, University of Cambridge. (pw11@cam.ac.uk), Dr N R Davis, S Wells, 3 Wilkinson, plus Miss A B Petrangeli (Visiting Researcher), and students named in the text.

The sea ice and polar oceanography group continued its focus on sea ice processes relevant to the global climate system (four EC research projects; one ONR project). Two concurrent field programmes took place during March 1997:- (a) a cruise into the Odden ice tongue by the ice-strengthened R/V *Jan Mayen*, (PW Chief Scientist) on charter from the University of Tromsø on behalf of the Second Phase of the EC-MAST European Subpolar Ocean Programme (ESOP-2; 1996-9), which seeks to understand the nature of the thermohaline circulation in the Greenland Sea and the mechanism for deep winter convection. Apart from SPRI personnel, participants were invited from Dunstaffnage Marine Laboratory, Oban; the University of Paris; CNRS (France); Technical University of Denmark; and the National Aerospace Development Agency (NASDA) (Japan). From March 3-13, the ship worked the area between 72° and 76° N, 0° and 8° W where the cold surface water of the Jan Mayen Polar Current supports the development of a dense cover of pancake ice mixed with multi-year polar floes from the East Greenland Current. The cruise aim was the intensive study of sea ice physics and of ice-ocean interactions within the Odden ice tongue to examine the role of local sea ice growth and its corresponding salt flux on the convection process. In addition, the French group led by J-C Gascard (Paris) deployed sets of neutrally buoyant floats in the area just north of Odden to track mid-depth water movements. Fieldwork included 40 CTD stations to 2000 m; the measurement of wave fields within the ice zone by directional wave buoy; the direct sampling of pancakes aboard ship to determine their temperature, salinity, ¹⁸O content and ice fabric; the sampling of frazil ice between the pancakes using a mesh sampler; and at three sites the deployment of an innovative Argos/GPS ice drifter, the "pancake buoy", designed by J Wilkinson to mimic and track pancake movement. Later analysis of pancake samples at SPRI by Dr Jinro Ukita, (NASDA, Japan) showed that all pancakes were completely formed out of frazil ice crystals, with no evidence of congelation growth. PW and JW attended the ESOP-2 mid-term science workshop in Villefranche on September 28 - October 2 1997. [The final project science report of ESOP-1 will form a special issue of Deep- Sea Research].

The second field operation was an ice mechanics experiment in the Gulf of Bothnia, ("Zooming in Ice Physics" or ZIP-97), with SPRI participants (Aksenov, Wells and Down) and participation from the Helsinki University of Technology and the Universities of Helsinki, Oulu and Iceland. The ZIP-97 experiment was a component of the EC "Ice State" programme (1996-9), co-ordinated by Helsinki University of Technology (Prof. Kaj Riska) which seeks to understand the relationship between sea ice mechanical processes and the resistance offered by an ice sheet to ship passage. The field study, which covered both drifting and fast ice zones, aimed to measure stress and strain in the ice cover at sites where

ridge formation was occurring, and to relate the results to the rate of deformation as observed by larger-scale arrays of drifting buoys and remote sensing (hence "zooming"). Strainmeters, tiltmeters and accelerometers were used to measure ice response to deformation, temperature measurements were made through the ice by thermistor chains and the ice was drilled for thickness measurements, especially across ridges. Further work was carried out during a visit to the site by the R/V *Aranda*. SPRI involvement in ice mechanics also includes the comparison of the statistical properties of ice thickness profiles obtained by PW aboard HM submarine *Trafalgar* in summer 1996 with ERS-2 SAR images from the same time and place to identify parameters in the SAR analysis relevant to ice deformation state. A collaborating theoretician on this project, Dr Bryan Kerman of Atmospheric Environment Service, visited SPRI in June 1997.

PW had previously coordinated an EC research project in the Environment and Climate Programme, shared with IMGA-CNR in Modena (Dr Flavio Parmiggiani), whose purpose was to measure the thickness of frazil and pancake ice in the Greenland Sea by analysing the change in the wavelength and direction of ocean waves as they enter the ice using spectral analysis of SAR imagery from the ERS-1 and ERS-2 satellites. Though the project ended in December 1996, research and exchange visits by Parmiggiani and Wadhams continue as a component of ESOP-2, and Anna Petrangeli (ENEA, Rome) visited SPRI during 1996-7 as an EU exchange scientist to work on this project.

The ONR-supported project, which ended in February 1997, concerned interpretation of data gathered on the SIMI programme (Sea Ice Mechanics Initiative), an ice camp in the Beaufort Sea north of Alaska in which SPRI had measured ice tilt, heave, strain and accelerations in conjunction with other groups measuring stress and ice dynamical parameters. Interpretation includes the role of ridge-building in generating wave activity, and the flexural response of the ice sheet to the tidal cycle. Results are relevant to the aims of the Ice State project above.

New projects include:

- partnership in the experimental programme of the European Ice Tank in Hamburg where a consortium of eight European laboratories (INThRICE) have designed and executed a collaborative experimental programme on physical, biological and sedimentological processes in sea ice. SPRI experimental work, includes work on the development of brine drainage channels in November 1996-April 1997 (F Cottier, assisted by M Reiemann of DAMTP), and on the dispersion relation for wave propagation through frazil ice (R Hall; April 1997). PW has been appointed Co-ordinator for the second phase of these experiments, in spring and autumn 1998.
- an EC "Ice Routes" project, initiated in 1996-7 under the Transport programme, co-ordinated by Earth Observation Sciences Ltd, with the aim of devising improved techniques for real-time classification of ice types from SAR images, for use in a future ice management and forecasting system. SPRI is a partner, with involvement by PW as PI, Richard Hall and Lawson Brigham.
- a range of student projects include (a) PhD thesis submitted by Mark Tadross in February 1997 on microwave remote sensing of young sea ice in the Greenland Sea. MT has remained to work on the Ice State project until November 1997 (b) Richard Hall's NERC CASE studentship on remote sensing and classification of ice

types in the Greenland Sea (c) PhD research by Capt. Lawson Brigham (US Coastguard, retired) on the ice cover of the Kara, Laptev and East Siberian Seas (d) PhD research by Finlo Cottier on the physics of brine drainage channels in sea ice and their influence on thermal properties and salinity distribution, plus work in August 1997 on the physical habitat of sea ice biota at the National Institute of Polar Research, Tokyo, (e) continued PhD research by Yevgeny Aksenov with support from the EU Ice State programme on sea ice mechanics (f) a continuing PhD project by Matt Huddleston on an ice-ocean numerical model for the Arctic Ocean and Greenland Sea (g) continued PhD research by Ingibjorg Jonsdottir on the historical statistics of sea ice distribution around Iceland. All the above students were supervised by PW.

Dr Wadhams spent December 1996 -February 1997 as British Council-Monbuscho Visiting Professor at the Graduate University of Advanced Studies National Institute of Polar Research Tokyo, with ancillary visits and talks. He continued joint work with NIPR on the interpretation of Japanese ERS satellite imagery, as project 38 of the NERC-Japan agreement on collaboration in remote sensing.

(2) Dr Karen J. Heywood, Prof. Andrew J. Watson, Dr. Grant R. Bigg, Dr Mike Meredith, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ. [k.heywood@uea.ac.uk; a.watson@uea.ac.uk; g.bigg@uea.ac.uk; m.meredith@uea.ac.uk] <http://www.uea.ac.uk/~ajw/aiw.htm>, <http://www.uea.ac.uk/~e151/mpm.html>, <http://www.uea.ac.uk/~e930/wwwgrb.html>

The UEA groups' activities continue to be focussed around the EC programmes ESOP-2 and VEINS. Four cruises to document vertical and horizontal mixing processes have followed the fate of the SF₆ tracer released into the centre of the Greenland Sea gyre in summer 1996 under ESOP-2. Partner institutes include U. Bergen, CTH/Göteborg University Sweden, U. Wisconsin, WHOI, and Université Pierre et Marie Curie, Paris. These have allowed measurement of the rates of vertical mixing inside and outside the gyre in both summer and winter, and in particular the effect of the wintertime deep convection. Vertical mixing rates were found to be rapid, even in summer, compared with earlier measurements in more quiescent and more stratified regimes. During winter in the central Greenland Sea rates increased by a further order of magnitude as a result of deep convection. Horizontal mixing rates at the mesoscale have also been measured. Attention is now beginning to focus on the role of larger scale transport of the tracer out of the Greenland Sea. One year into the experiment the tracer had spread to the E.Greenland continental slope to the west, and into the Boreas basin to the North, but not had not yet been observed in the Icelandic Sea or Denmark Strait region. Further cruises are scheduled for 1998 to document the tracer as far north as Fram Strait and South to the Denmark Strait. ESOP-2 is due to finish at the end of 1998, but documentation of the tracer release will continue on selected VEINS cruises.

Under the new NERC ARCICE "thematic programme" (Arctic Ice and Environmental Variability; see report by Kerr), proposals are being prepared to study the influence of ice formation and melting on deep convection and water mass transformation using both the existing tracer release experiment and UEA expertise in delta 18-O measurements. A cruise or cruise programme will begin during 1999. Delta 18-O is an especially powerful tracer in

the Arctic region, since it allows us to discriminate between the freshwater component derived from meteoric waters (which is extremely light isotopically at high latitudes) from the freshwater component derived from sea-ice melt (which has an isotopic composition close to that of the seawater from which it formed). As part of the VEINS study, for example, the cold, fresh bottom plume south of Svalbard has been determined to be of meteoric water origin (rather than sea-ice melt) from its isotopic characteristics. The main effort involving delta 18-O in the VEINS programme is its measurement across each section through which water enters or leaves the Greenland/Iceland/Norwegian Seas. By combining these measurements with hydrographic, current meter and ADCP data, the fluxes of freshwater will be partitioned into fluxes of meteoric waters and fluxes of sea-ice melt. The spatial distribution of these components will then be related to the processes of sea-ice and watermass formation/alteration that occur in the GIN seas and Arctic. In the East Greenland Current near Fram Strait, for example, the delta 18-O measurements show a negative fraction of sea-ice melt present in the water column, i.e. there has been a net formation of sea-ice from these waters. The data also show a large proportion of river-runoff there, implying that a significant proportion of the sea-ice was initially formed from meteoric waters. Integrating the fractions with depth and accounting for the difference in densities between sea-ice and water enables us to estimate the total volume of sea-ice being exported. It is planned to compare these results (which are representative of a long-term mean) with the instantaneous measurements obtained from Upward-Looking Sonars at Fram Strait. The sampling program will repeatedly visit the key locations (such as Denmark Strait and Fram Strait) to provide insight into the nature of interannual variability in the fluxes of meteoric freshwater and sea-ice melt.

On modeling, a proposal by Bigg and Siebert will address the following topics:

(i) *The greenhouse Arctic*. To model the evolution of the coupled climate system over the period 1850-2200 under several IPCC (1995) greenhouse gas emission scenarios, focusing on the critical area of the Arctic. These simulations will enable a better understanding of possible recent and potential future interactions in deep water formation strength and location, sea ice extent and intrusion of North Atlantic and Pacific waters into the Arctic. Recent and future contributions to oceanic freshwater flux and marginal sedimentation in the polar NE Atlantic through iceberg decay will also be investigated. One possible consequence of this latter work will be to determine whether likely changes in iceberg production can cause rapid climatic change.

(ii) *Arctic Holocene variability*. To investigate natural variability over time-scales of 3000-5000 years. The coupled climate model (see next section) will be capable of simulating a time period beyond the overturning timescale of the ocean. Using stochastic forcing (Osborn, 1997) to stimulate the variability contained within the ocean-atmosphere system we would hope to be able to study variation over millennial timescales in such climatic signals affecting the Arctic as the North Atlantic Oscillation. By considering such long timescales currently undiscovered internal feedbacks may be detected which would aid palaeoclimatic studies of the Arctic and European Holocene.

(iii) *The Glacial Arctic*. To examine the IRD production and pattern over the northwestern Eurasian margin during the last glacial maximum (LGM) in order to establish the contribution of iceberg deposition to glacial sedimentation in this region. As part of a current research

project funded by the Leverhulme Trust

with which one of the PIs (GRB) is involved a coupled model simulation of the LGM will be produced by early 2000. The oceanic and atmospheric fields from this will be used to force an iceberg trajectory model based on the output of the icesheet modeling of Dowdeswell and Siegert (1998).

(iv) *Deglaciation in the Arctic.* To examine feedbacks within the climate system during deglaciation and, in particular, the impact of the melting of the Eurasian icesheet on climate and IRD sedimentation along the Eurasian margin. Using forcing from the Dowdeswell and Siegert (1998) icesheet model, a 2000-5000 year coupled model simulation of the climatic effects of the deglaciation of the Eurasian icesheet will be performed. This will identify the role of the Eurasian icesheet in climatic change during deglaciation, and specifically its contribution to the onset of the Younger Dryas. Associated with this will be a simulation of IRD patterns at a number of timeslices during deglaciation which will show the differences in IRD sedimentation between periods of static icesheet development and rapid change.

(3). Dr R.R. Dickson Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Lowestoft NR33 OHT, Suffolk. (r.r.dickson@cefas.co.uk)

CEFAS has the following current interests in Arctic Research:

(i). The 5.4 Mecu VEINS project of MAST-III (running for 42 months from April 1997) is now reaching the end of its 1st year. RRD acts as coordinator of the Denmark Strait component (VEINS-4). CEFAS objectives are (with FRG and Finland), to make long term direct measurements of the speed of the Denmark Strait Overflow using current meter moorings on the Continental Slope off East Greenland; to monitor the thickness of the overflow using Inverted Echo-Sounders (IES) or ADCPs; to determine its characteristic time scales of variation over periods from days to years; thus measuring the variability of overflow transport and determining its cause. All these aims have progressed. The two moorings of the CEFAS pre-VEINS trial current meter array, laid by R/V *Bjarni Saemunsson* in December 1996, were successfully recovered by F/S *Meteor* in August 1997 with two full and four partial records (64% data return). The trial POL-IES mooring laid in August 1996 from R/V *Poseidon* was recovered with a full 1-year record of plume thickness, thus providing the first successful simultaneous measure of flow speed and thickness for the near-bottom overflow current. All 6 moorings of the FIMR/CEFAS/IFMH array were relaid as planned along with 2 IES moorings, and a further RDI 150 kHz. ADCP was later deployed from by R/V *Bjarni Saemunsson* in February 1998, to complete the full planned VEINS array. These will be serviced and replaced in August 1998 by R/V *Valdivia*. In addition, Dr James B Girton and Thomas B Sanford (Applied Physics Laboratory, University of Washington, USA), made direct observations of the ocean velocity profile in the Denmark Strait aboard R/V *Aranda* during August 1997 using expendable current profilers (XCPs), ship-mounted ADCP and multi-antenna GPS. The hydrographic character of the overflow was monitored by seasonally-repeated hydrographic sections worked by Iceland. (see also the UEA report on oxygen isotope sampling in summer 1997).

(ii). A study has begun into the causes of time-dependence in Denmark Strait overflow properties on a decadal time-scale. Initial results suggest the possibility of rapid climate-

signal propagation to the deep Atlantic via Nordic Seas, relevant both to the VEINS objective of understanding the transformation of watermass properties around the circuit of northern seas, and to the study of the NAO response in the Arctic.

(iii) A broadly based study on "*The Arctic Ocean response to the North Atlantic Oscillation*" by R.R. Dickson, T. J. Osborn, J. W. Hurrell, J. Meincke, T. Vinje, G. Alekseev and W. Maslowski was prepared for the ACSYS Symposium on Polar Processes and Global Climate in Seattle, 3-6 November. For the first time this study examines the windfield and storm climate associated with the NAO, and identifies the effect on inputs to the Arctic [moisture flux, precipitation balance, heat and Atlantic Water and associated circulation changes], as well as adjustments and outputs from the Arctic [hydrography, dynamic height, sea level sea-ice extent, Fram Strait ice flux]. A second-phase study is planned for the IARC Conference in Fairbanks, October 1998.

(4) Dr Peter Kershaw, Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Lowestoft NR33 OHT, Suffolk. (p.j.kershaw@cefas.co.uk).

CEFAS has continued to investigate the long distance transport of radionuclides from the Sellafield and La Hague reprocessing plants. Results from a cruise to the Barents Sea in 1994 have been published and were presented at the 3rd mt. Conf. on Environmental Radioactivity in the Arctic, held in Tromsø in 1997. The 10-fold increase in the discharge of ^{99}Tc from Sellafield, from 1994/95 onwards, has been of particular interest. The ^{99}Tc 'plume' has been followed through UK coastal waters and a collaborative project is underway to trace its progress along the Norwegian Coastal Current into Arctic waters. The study will be in collaboration with Institutes in Norway, Denmark and Germany. There is a further proposal under ARCICE (see below) to include the Tc data in a high-resolution model being developed at Southampton University.

(5) Dr Andrew Kerr, ARCICE Programme Manager, Edinburgh University (andrew.kerr@ed.ac.uk)

The NERC Thematic Programme, ARCICE has begun with funding of £3M over 3 years. The Programme aims to enhance the understanding and predictability of the dynamics and variability of Arctic ice cover relevant to climate and sea level change in NW Europe. One of the three elements of the Programme is concerned with Atmosphere/Sea Ice/Ocean Interactions, and twelve groups have been invited by the programme steering group to submit full proposals on this topic. Of these, four propose to study ocean circulation and sea ice fluxes in the Greenland Sea and Fram Strait, using the UK research ship *James Clark Ross*, which will conduct a 40-day cruise in summer 1999. There is the possibility of a further cruise in 2000. The final 1999 cruise plan will depend which of the full proposals are funded (to be decided in August 1998), but to optimise use of the *James Clark Ross*, a second call for small grant proposals is expected to be issued in the late summer 1998.

Of the remaining eight proposals, two involve satellite studies of sea ice dynamics in the Arctic Ocean. A further five groups propose assorted modelling studies of sea ice/ocean dynamics, ocean circulation and ice/ocean/atmosphere interactions focusing both on the Greenland Sea and the entire Arctic Ocean. The remaining proposal concerns a joint

laboratory-modeling experiment of convection beneath ice leads.

The proposals which are selected are expected to dovetail with existing international and national programmes of work in the Arctic, and there is a strong desire for further collaboration with European, particularly Norwegian, partners. Further information can be found at the ARCICE web site:

<http://www.cecs.ed.ac.uk/arcice>

(6) Mr. Alister Skinner, British Geological Survey, Edinburgh, Scotland
(a.skinner@bgs.ac.uk)

The British Geological Survey's interest in the Polar regions continues to be focused through the work of the marine operations group which is now part of the Petroleum and Marine Geology Group of BGS. Due to the restriction on science funding it is unlikely that BGS will participate in the scientific aspects of Polar Science in the near future but this will not affect the operations part co-operating with any group wishing to undertake science where the BGS offshore equipment and personnel could assist.

For the past two years BGS have been discussing ways of rock-coring with the British Antarctic Survey using the BAS Research Vessel the RRS *James Clark Ross*. This has culminated in the vessel being fitted with dynamic positioning for station keeping, a trial in the North Sea with BGS coring equipment and a very successful trip to the Northern Antarctic Peninsula and Weddel Sea where high resolution seismic and sidescan was run and rockdrill and vibrocore samples collected in water depths from 60 - 1600 metres. Dr Richard Dingle at BAS should be contacted for further information on this but it is clear that, with this important new BAS facility the UK now have a capability for powered coring in Polar condifions which does not exist elsewhere.

BGS are talking with the proponents of ARCICE regarding coring work on their project but this has not gone beyond the proposal stage yet. Again the RRS *James Clark Ross* is the preferred vessel for the work but careful attention will have to be given to juxtaposition and complimentarity of equipment during any phase of the work as heavy gear deployments and heavy winches impose restrictions on deck space. BGS (A. Skinner) are likely to be involved as drilling consultants in work offshore Greenland this summer where a drilling project is being conducted by the Danish Lithosphere Centre.

A Skinner continues to have an involvement on the technical side with the revised Nansen Arctic Drilling Committee on behalf of NERC. In preparation for future drilling in the Arctic the previous committees have been reduced and refined into one executive committee and a number of scientific panels dealing with particular areas where drilling is proposed. The panels are not yet filled as the previous committees made proposals for interim chairs which have now to be ratified by the member countries before the process can proceed further. Another meeting is proposed for 29-30th April in Fairbanks, Alaska after the IASC council and regional board meetings.

(7). Professor Julian Dowdeswell, Inst. of Earth Studies, The University of Wales, Aberystwyth. (iud@aber.ac.uk) <http://www.aber.ac.uk/~glawww/>

Work in the Centre for Glaciology, University of Wales, Aberystwyth. J.A. D. has concentrated on the reduction, interpretation and publication of marine geophysical and geological datasets acquired in earlier cruises to Arctic and sub-Arctic waters. Several publications have appeared concerning the GLORIA long-range side-scan sonar imagery, and ancillary acoustic data, collected on the first Arctic cruise of the RRS *James Clark Ross* in 1994. Numerical ice-sheet modeling of the Eurasian Ice Sheet through a glacial cycle has also been used to predict glacier-derived sediment delivery to the eastern margin of the Polar North Atlantic. Research student Justin Taylor has also been working on the reduction of GLORIA data from the northern Faeroes margin, acquired during a 3-week cruise in 1996.

(8) Dr T Murray, School of Geography, University of Leeds (tavi@geog.leeds.ac.uk) and Dr A M. Smith, Ice & Climate Division, British Antarctic Survey. (amsm@bas.ac.uk).

The University of Leeds and the British Antarctic Survey, along with other UK institutes, are currently investigating glaciers with soft beds and the contribution of Svalbard glaciers to sea level changes. The overall aim is improved knowledge of the causes and controls of glacier surges, which are still poorly understood. Basal conditions and, in particular, sediment deformation and basal hydrology are undoubtedly of fundamental importance, but are extremely difficult to investigate; thus although the deformation of clean ice is relatively well understood, the processes that control coupling at the ice-sediment interface, and thus partitioning between sliding and sediment deformation, are a major unsolved problem in glacier dynamics.

This project uses high resolution seismic and ground penetrating radar (GPR) surveys to provide, for the first time, the link between detailed measurements in boreholes and large-scale measurements of the ice dynamics from surface surveys. The results of the fieldwork should therefore feed directly into studies of surging glaciers; of large, fast-flowing ice streams; and improving basal boundary conditions for glacier modelling. A specific object of this study are the "sticky spots" at the glacier bed, defined as localised regions, distributed over the glacier bed, which support a disproportionate amount of the basal shear stress. Till discontinuities, or local sediment stiffness variations are considered likely to provide these sticky-spots.

Bakaninbreen in the Svalbard archipelago is a glacier which is reaching the end of an active surge phase. The seismic and GPR surveys should allow us to identify regions of the bed where sediments are dilated and undilated and thus infer regions of active deformation. The distribution of these regions will be compared with the predictions from basal shear stresses and sediment strengths. Any localised areas where deformation is predicated, but not occurring, are probably the hypothesised sticky-spots. In addition, the GPR will provide 3-D images of basal ice geometry and sediment inclusions at the glacier bed, especially in regions where sticky-spots are identified. We thus aim to link the mechanical properties with their 3-D form and hence, to characterise sticky-spots.

(9) Drs Seymour Laxton and Duncan Wingham, Mullard Space Science Laboratory. (swl@mssl.ucl.ac.uk; djw@mssl.ucl.ac.uk)

(i) *Ice Sheets: (to be supplied; or link with Julian Dowdswell via his collaboration on SAR interferometry)*

(ii) *Sea Ice:* Sea surface height (SSH) variability maps of the Arctic Ocean have been generated from ERS-2 radar altimeter data. Patterns of high and low SSH variability predicted by the OCCAM and POCM models in the Arctic correspond well with the altimeter observations. In the future we plan to compare observed seasonal and interannual SSH anomalies with the predictions of improved resolution models of Arctic circulation. Separation of altimeter returns from water and ice surfaces has allowed the first ever direct estimates of ice freeboard to be obtained from a spaceborne instrument. Ice thickness value, inferred from the altimeter freeboard measurements, compare closely with the known climatology. Future efforts will concentrate on intercomparison of altimeter derived ice freeboard and Upward Looking Sonar derived ice drafts to calibrate and validate the altimeter measurements.

(10). Dr Howard Cattle, Ocean Applications, Meteorological Office (UKMO), Bracknell, Berkshire. (hcattle@meto.gov.uk). Chairman, Scientific Steering Group for the WCRP Arctic Climate System Study (ACSYS).

Development of a new version of the Hadley Centre coupled climate model (HADCM4), which was reported as being underway last year, is now well advanced. The model has a resolution of 1.25 degrees in the ocean and 2.5 x 3.75 degrees in the atmosphere. Multi-decadal timescale integrations of an intermediate version (HADCM3) with the same resolution have been carried out and the simulation in the Nordic Seas examined as part of the EU's ESOP-2 programme. The model shows a slow warming of the Nordic Seas and the Arctic Ocean as the integration progresses. This unrealistic aspect of the simulation is currently being investigated. Despite the oceanic warming, the model shows a stable sea ice simulation which includes decadal timescale variability. Aspects of the model's high latitude performance were described in a poster presentation at the ACSYS Scientific Conference in Rosario, November 1997. The formulation of the sea ice component is being improved, with particular attention to both dynamics and thermodynamics. The model is intended for studies of climate variability and change. One application will be to test the impact of climate variability, particularly that due to the North Atlantic Oscillation, on the circulation of the North Atlantic and Arctic Oceans.

The Meteorological Office's Forecast Ocean Atmosphere Model (FOAM), a global ocean data assimilation and forecast system, is now operational in the Meteorological Office's Numerical Weather Prediction suite at 1-degree resolution. The model includes a sea ice component which is being developed to assimilate observed sea ice concentration fields available in near real time. The system has been used off line in a first assimilation of the historical dataset of ocean observations of Levitus (1994), including those available in the Arctic Ocean. Further experiments with the FOAM system in this mode are planned.

(11). Mrs Angela Morrison, Secretary, Polar Science Expert Group, NERC, Polaris House, Swindon (a.j.morrison@nerc.ac.uk)

NERC continues to maintain a strong interest in Arctic science. A new programme,

ARCICE, started in November 1997, and it is anticipated that awards under this programme will be announced in late summer 1998. The programme is enhanced by the availability of the ice-strengthened research vessel, the RRS *James Clark Ross*, for research cruises in the northern summers of 1999 and 2000. Within ARCICE, there is a strong focus on international collaboration and scientific partnership with Arctic nations. Further information about the ARCICE programme is available on the Internet. (<http://www.cecs.ed.ac.uk/arcice>).

The lease on the NERC Arctic fixed field laboratory has been extended for a further five years from 1997, and with effect from 1 January 1998, the NERC base station is part of the EU Large Scale Environmental Research and Monitoring Facilities at Ny-Alesund in Svalbard. The station is available during the summer months (normally June to early September): exceptionally in 1998, the NERC station is opening for scientific research for the month of April.

A new focus group, the UK Arctic Network (UKAN), is being established by the NERC Centre for Ecology and Hydrology with the aim of bringing together UK ecologists and hydrologists working in the Arctic. The co-ordinator for this group is Professor Steve Albon, head of the CEH Institute of Terrestrial Ecology at Banchory in Scotland.

(12). Polar Regions Section, Foreign and Commonwealth Office, London. (saad.fco@gtnet.gov.uk).

The UK maintains distinct and strong interests in the Arctic, acting as an Observer to the Arctic Environmental Protection Strategy (AEPS) since 1991 and to the Barents Euro-Arctic Council since 1992. The AEPS has now been subsumed into the Arctic Council with its much broader agenda. The UK is actively participating in the Arctic Council process on issues such as the development of an Arctic University. To strengthen the UK's participation in Arctic matters, the FCO is examining means of developing a more collective and coordinated national approach to Arctic / High North issues. Improved co-operation on Arctic matters, both within Government Departments and between Government and non-governmental organisations (scientific and commercial) is seen as essential. Furthermore, the UK Government is also examining ways of strengthening the bilateral relationship with Norway by means of enhanced co-operation in the Arctic / High North. The various mechanisms being considered include greater collaboration on a range of scientific initiatives, including marine programmes.

APPENDIX IV**Arctic Data Contact Points****CANADA**

Savithra Narayanan, Director
Marine Environmental Data Service
Ottawa, Canada
narayanans@dfo-mpo.gc.ca

DENMARK

Preben Gudmandsen, Professor Emeritus
Technical University of Denmark
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Telefax: + 45 45 93 16 34
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GERMANY

Geological and Environmental Data:
Dr. H. Grobe
E-mail: sepan@awi-bremerhaven.de

Physical Oceanography:
Dr. E. Fahrbach
E-mail: efahrbach@awi-bremerhaven.de

NORWAY

National Norwegian data should be stored at the Institute for Marine Research in Bergen but much is still widespread throughout the country. The Norwegian Polar Institute, which is on the move to Tromsø, has data as does the University of Bergen.

RUSSIA

Evgeny Vyazilov
Russian NODC RIHMI-WDC
6, Koroleva, Obninsk, Kaluga region
249020 Russia
Phone: (08439) 74676
Fax: (095) 2552225
Web: RIHMI-WDC <http://www.meteo.ru>
Russian NODC Web: <http://www.meteo.ru/nodc/index.html>

SWEDEN

At present Sweden does not have a person responsible for Swedish Arctic data, but they are building up a marine data base center in Göteborg that will include most of the Swedish data collected in the Arctic Ocean. Until that center is organized contact Leif Anderson (E-mail: leif@amc.chalmers.se). He is one of three scientists in charge of that data center.

UNITED KINGDOM

Lesley Rickards
CCMS-POL British Oceanographic Data Centre
Bidston, Merseyside
E-mail: ljr@ccms.ac.uk
Web: <http://www.pol.ac.uk/bodc/ukmed>.

Arctic Data Contact Points for International Programs**Arctic Monitoring and Assessment Programme (AMAP)**

AMAP has five thematic data centers that store and quality control the environmental data gathered for AMAP assessment work (marine, atmosphere, freshwater, radioactivity and human health). The contact point is:

Simon Wilson, AMAP Secretariat
P.B. 8100 Dep. 0032
Oslo, Norway
Phone: + 31-104662989 (phone and fax) or +47-22573676
Fax: +47-22676706
E-mail: s.wilson@inter.nl.net
Web: <http://www.grida.no/amap>

Arctic Climate System Study (ACSYS)

ACSYS has hydrographic data from the Barents and Kara Seas. The International ACSYS Project Office (IAPO) is in the process of creating a new comprehensive data base for that region.

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International Council for the Exploration of the Seas (ICES)

Harry Dooley
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Web: <http://www.ices.dk/ocean> (from which you can get the link to any specific project such as VEINS)

APPENDIX V

Acronyms

| | |
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| ACSYS | Arctic Climate System Study |
| ADCP | Acoustic Doppler Current Profiler |
| ADD | International Arctic Environmental Data Directory |
| ADEOS | Advanced Earth Observing System (Japan) |
| AEPS | Arctic Environmental Protection Strategy |
| AMAP | Arctic Monitoring and Assessment Programme |
| APARD | Arctic Paleo-River Discharge |
| APL | Applied Physics Laboratory at the University of Washington (USA) |
| ARCICE | Arctic Ice and Environmental Variability |
| ARCSS | Arctic System Science |
| AVHRR | Advanced Very High Resolution Radiometer |
| BAS | British Antarctic Survey |
| BASIS | Barents Sea Impacts Study |
| BESIS | Bering Sea Impact Study |
| BGS | British Geological Survey |
| BIO | Bedford Institute of Oceanography (Canada) |
| BIODAFF | Biodiversity and Fluxes of Glaciated Arctic Fjords |
| CACAR | Canadian Arctic Contaminant Assessment Report |
| CAMP | Coastal Area Management Plan |
| CCG | Canadian Coast Guard |
| CCGS | CCG Ship |
| CEFAS | Centre for Environment, Fisheries and Aquaculture Science (UK) |
| CLIVAR | Climate Variability and Predictability |
| CNRS | Centre National de Recherche Scientifique (France) |
| CTD | Conductivity, Temperature, Depth profiler |
| DFO | Department of Fisheries and Oceans Canada |
| DMI | Danish Meteorological Institute |
| DMSP | Defense Meteorological Satellite Program (USA) |
| DOM | Dissolved Organic Material |
| EC | European Commission |
| EMaPS | European Marine and Polar Science Program |
| ENEA | European Nuclear Energy Agency (Italy) |
| ENVISAT | satellite |
| EOS | Earth Observing System |
| EPB | European Polar Board |
| ERS | European Remote Sensing Satellite |
| ESA | European Space Agency |
| ESF | European Science Foundation |
| ESOP | European Subpolar Ocean Programme |
| EU | European Union |
| FCO | Foreign and Commonwealth Office (UK) |

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| FF-HU | Faculty of Fisheries, Hokkaido University (Japan) |
| FIMR | Finnish Institute of Marine Research |
| FOAM | Forecast Ocean Atmosphere Model |
| FRPGC | Frontier Research Program for Global Change |
| GIN | Greenland-Iceland-Norwegian |
| GLOBEC | Global Ocean Ecosystem Change |
| GPR | Ground Penetrating Radar |
| GPS | Global Positioning System |
| GSC | Geological Survey of Canada |
| GSP | Greenland Sea Project |
| HADCM | Hadley Centre Coupled Climate Model |
| IAPO | International ACSYS Project Office |
| IAPP | International Arctic Polynya Programme |
| IAPP-SCG | IAPP-Scientific Coordination Group |
| IARC | International Arctic Research Center |
| IASC | International Arctic Science Committee |
| ICES | International Council for the Exploration of the Seas |
| IES | Inverted Echo Sounder |
| IFMH | Institut für Meereskunde der Universität Hamburg (Germany) |
| IMSI | Integrated use of new Microwave Satellite data for Improved sea ice observation |
| IOC | International Oceanographic Commission |
| IOEB | Ice-Ocean Environmental Buoy |
| IOPAS | Institute of Oceanology Polish Academy of Sciences |
| IOS | Institute of Ocean Sciences (|
| IPCC | Intergovernmental Panel on Climate Change |
| IRD | Ice Rafted Detritus |
| JAMSTEC | Japanese Marine Science and Technology Center |
| JOIS | Joint Ocean-Ice Studies |
| LGM | Last Glacial Maximum |
| LOIRA | Land-Ocean Interactions in Russian Arctic Program |
| MAGICS | Mass Balance of Arctic Glaciers and Ice Sheets in relation to Climate and Sea Changes |
| MAST | Marine Science and Technology Programme |
| METOP | Meteorological Operational Satellite (EU, USA) |
| MLI | Maurice Lamontagne Institute Laboratory (Canada) |
| NADW | North Atlantic Deep Water |
| NAO | North Atlantic Oscillation |
| NASA | National Aeronautic and Space Administration (USA) |
| NASDA | National Aerospace Development Agency (Japan) |
| NATO | North Atlantic Treaty Organization |
| NERC | National Environmental Research Council (UK) |
| NEW | North East Water |
| NIMBUS-7 | atmospheric research satellite (USA) |
| NIPR | National Institute of Polar Research (Japan) |
| NOAA | National Oceanic and Atmospheric Administration (USA) |
| NOW | Northwater |
| NPI | Norsk Polarinstitutt (Oslo, Norway) |
| NSERC | National Science and Engineering Research Council (Canada) |

| | |
|----------|--|
| NSF | National Science Foundation |
| NWR | Northwind Ridge |
| OFOS | Ocean Floor Observation System |
| ONR | Office of Naval Research (USA) |
| PAH | Polycyclic Aromatic Hydrocarbon |
| PICES | North Pacific Marine Science Organization |
| POPs | Persistent Organic Pollutants |
| RADARSAT | Radar Satellite (Canada) |
| SAR | Synthetic Aperture Radar |
| SBI | Shelf-Basin Interactions |
| SCAR | Scientific Committee on Antarctic Research |
| SCISEX | Submarine Arctic Science Cruise Exercise |
| SCOR | Scientific Committee on Oceanic Research |
| SHEBA | Surface Heat Budget of the Arctic Ocean |
| SIMI | Sea Ice Mechanics Initiative |
| SLIP | St. Lawrence Island Polynya |
| SMMR | Scanning Multichannel Microwave Radiometer |
| SPOT | System Pour l'Observation de la Terre (France) |
| SPRI | Scott Polar Research Institute (UK) |
| SSH | Sea Surface Height |
| SSM/I | Special Sensor Microwave/Imager |
| UAF | University of Alaska, Fairbanks (USA) |
| UEA | University of East Anglia (UK) |
| UKAN | UK Arctic Network |
| UKMO | UK Meteorological Office |
| USGCRP | United States Global Change Research Program |
| UV | Ultraviolet |
| UW | University of Washington (USA) |
| VEINS | Variability of Exchanges in Northern Seas |
| WCRP | World Climate Research Program |
| WHOI | Woods Hole Oceanographic Institute (USA) |
| WOCE | World Ocean Circulation Experiment |
| XBT | Expendable Bathythermographs |
| XCP | Expendable Current Profilers |
| ZIP | Zooming in Ice Physics |