

news from the



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ARCTIC-SUBARCTIC LINKAGES TO FORM A NEW FOCUS OF AOSB ACTIVITY

Over the past decade, we have learned a lot about Arctic Ocean variability. Three main factors were responsible¹. First, an intensified observational program by surface research vessels and by the submarines of the US SCICEX program contributed an improved hydrographic description of the upper Arctic Ocean in most years of the 1990s. Second, the release of a vast military archive of oceanographic data gave us the improved "climatology" we needed to identify what was anomalous about these new data-sets. And third, we now know that the winter climatic forcing over the Arctic Ocean and Nordic Seas was at a century-long extreme state during the 1990s. The upshot was that when data and climatology *were* compared, the changes identified were large and extensive.

The main changes seem to be these¹: that in the late 1980s–early 1990s, a warmer, fresher and probably stronger transport of Norwegian Atlantic Water was carried north to the Fram Strait and Barents Sea. Some of this warm Atlantic water would have recirculated southwards, but a proportion appears to have continued north into the Arctic Ocean. 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 mutual front between waters of Pacific and Atlantic origin shifted from the Lomonosov to the Alpha-Mendeleev Ridge². At shallower depths in the Eurasian Basin, the cold freshwater cap which had acted to insulate the sea-ice from the warm Atlantic layer below weakened significantly³.

Hydrography, tracers and modelling all suggest that this was most likely due to the eastward diversion of Russian river input in response to the altered atmospheric circulation, and this changed windfield also appears to have been responsible for driving an increased volume flux of ice south to Nordic Seas⁴.

While these regional events seem unambiguous, they do beg larger questions. First, *do such changes in the ocean-atmosphere system of the Arctic have global change implications?* This question seems natural in view of the fact that variability in the Arctic has long seemed to have some especial involvement in global change; polar amplification and feedback are recurrent themes in numerical climate modelling. However, we cannot yet answer it effectively. We can identify a range of *potential* effects of course, acting locally through the effect of a changing ocean-stratification³ and ice cover⁵ on surface heat flux or air–sea carbon dioxide flux and remotely through the variable export of fresh waters and heat to the headwaters of the global thermohaline circulation. But we continue to lack knowledge of the mechanisms that are supposed to underpin this link to "global change", and while we may have confidence that our observations have *qualitatively* captured the essence of recent Arctic variability, we are a long way short of being able to quantify these changes.

Thus, en route to answering the global change question, the priority issues would seem to be *"what do we have to do to improve our estimates of*

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the heat flux from lower latitudes to the Arctic Ocean, of the freshwater flux from the Arctic to lower latitudes, and of the feedback in the carbon dioxide cycle?" Having said that, variability itself prompts a third question. That even if we are correct in attributing the recent episode of "Arctic warming" to extreme (positive) behaviour of the North Atlantic Oscillation (NAO), there was a previous and even greater warming episode at high latitudes of the Atlantic sector between the 1920s and 1950s^{6,7} for which the NAO offers little explanation. Certainly, in studies of historic temperature change in the Barents Sea⁸, the 0-200m temperature on the Kola Section appears to bear little relation to either the NAO Index or to the Bear Island-Fugloya atmospheric pressure gradient prior to 1960, despite the robustness of these relationships thereafter. If a warmer inflow to the Arctic is of global significance now, it must have been then. *So what caused the earlier episode(s) of Arctic warming?*

These issues were recently reviewed by the Arctic Ocean Science Board at its 18th meeting (29 March-1 April, 1999) in the National Institute of Polar Research, Tokyo, Japan. In considering its future programme the Board agreed that "Arctic Variability and Global Change; Arctic-Subarctic Linkages" was a subject of sufficient importance to form a focus of its future activities. Though plans are still preliminary, the Project is likely to contain the following elements:

1. Improved estimate of heat and salt fluxes to the Arctic (a) via Fram Strait. The first perceived gap is that we still need to quantify the heat and salt input contributed by the western (warmer, more saline) branch of Atlantic inflow to the Arctic. The EC-VEINS investigation of the Fram Strait throughflow has been very successful, but needs supplementary measurements if we are to identify that part of the flow which will enter the Arctic Ocean from that which will recirculate southwards without ever entering the Arctic. Figure 1, based on hydrography by F/S *Polarstern* in summer 1997, shows the location of a suggested moored array site running northwards across the Continental Slope from the NW tip of Spitzbergen. This array would cross the warm, saline Atlantic inflow at the earliest point after it has actually entered the Arctic Ocean, where the ice cover is likely to be less problematic than further east and where the warm, saline current core is still well

confined against the upper Slope so that the flow can be monitored with a limited array of bottom-mounted gear (well protected against shellfishing activities!). A long term sealevel station nearby at Barentsberg is available to help with the transport estimate.

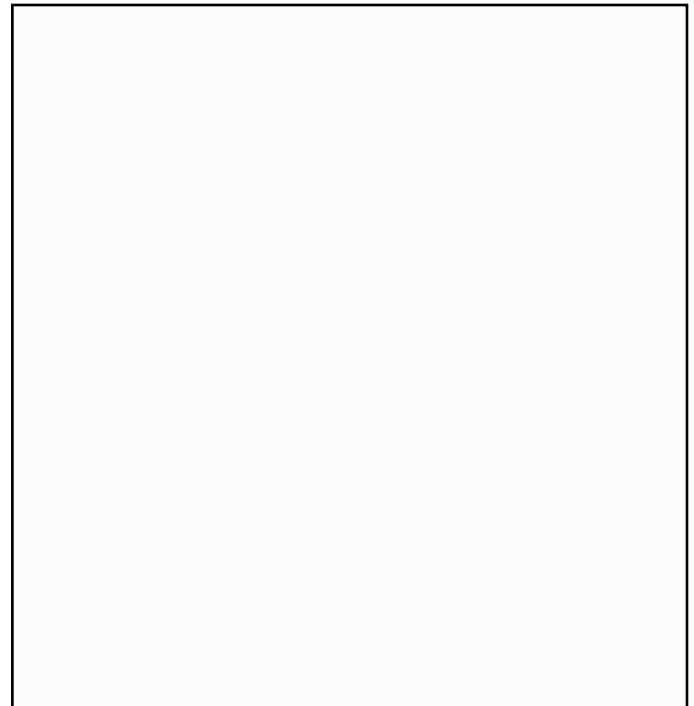


Figure 1. Numbered dots mark the location of the moored instrument array that is proposed to monitor the inflow of Atlantic water from the eastern Fram Strait to the Arctic Ocean. Figure kindly supplied by Dr R Meyer, Alfred-Wegener-Institute, Bremerhavn.

(b) via the Barents Sea. The present successful EC-VEINS effort to monitor the colder, fresher (Barents Sea) branch of inflow to the Arctic is focused on a moored current meter array across the western entrance to the Barents Sea, but as with the Fram Strait array, our knowledge of heat input to the Arctic from this source is likely to be compromised by an unknown component of westward recirculation. A Norwegian/Russian team has already shown that it is possible to monitor this branch close to its point of entry to the Arctic Ocean (St. Anna's Trough) in their successful recovery of a pioneering long-term current meter array from waters between Franz Josef Land and Novaya Zemlya⁹; the location of the inflow core was clearly demonstrated in the

strong, steady flows towards the south side of this passage. Thus the array itself is practicable in technique, location and physical access.

(c) via the Bering Strait. Inflow from the Pacific is a critically important source of low-salinity water and nutrients to the Arctic system. The former is a major component of the Arctic's freshwater budget and halocline, while the latter is key to supporting carbon fixation, particularly on adjacent shelf regions. Modelling efforts suggest that variability in the flow through Bering Strait reflects fluctuations in the balance between the hydraulic head (northward) and an opposing wind stress. Monitoring such flows has been an ongoing effort of oceanographers at the University of Washington since the 1960's, and in recent years this effort has been joined by oceanographers from Canada's Department of Fisheries and Oceans. Recent observations show a remarkable freshening of the Pacific's inflow, a full unit (psu) in salinity during the present decade.

2. Improved measurement of the freshwater flux from the Arctic. Achieving a better measure of freshwater flux from the Arctic is one of the targets of EC-VEINS and is being achieved by an Icelandic team using repeat hydrography and new current measurements east of Iceland. However the important component of freshwater flux under the East Greenland ice-pack has proved elusive and this may be the major component of southward flux. The need to provide a good measure of this flux is underlined by the global importance that coupled models currently assign to relatively minor changes in freshwater distribution at high latitudes¹⁰. Figure 2 shows the component parts of a new array designed to provide such a measure under the ice of the SE Greenland shelf. Basing the sensor deployment on summer and winter salinity transects during the IGY, the suggestion is that this could be achieved using two moorings each equipped with multiple salinity sensors focused on the freshest layers of the upper water-column and with current meters of one type or another to provide the necessary detail on the vertical current structure. Development work would largely consist of attempts to design an ice-proof instrument and buoyancy shell so that impact with pack ice would temporarily deflect rather than destroy the moorings. Since recent transects and moored arrays in Barrow Strait (Canada/US JOIS cruise, 1997) have successfully

shown the way in measuring the freshwater flux through the Canadian Arctic Archipelago, it makes good sense to make coordinated measurements of both these components of the freshwater flux at the same time, particularly since the most advanced Arctic ocean models now anticipate that their time-dependence may be linked.

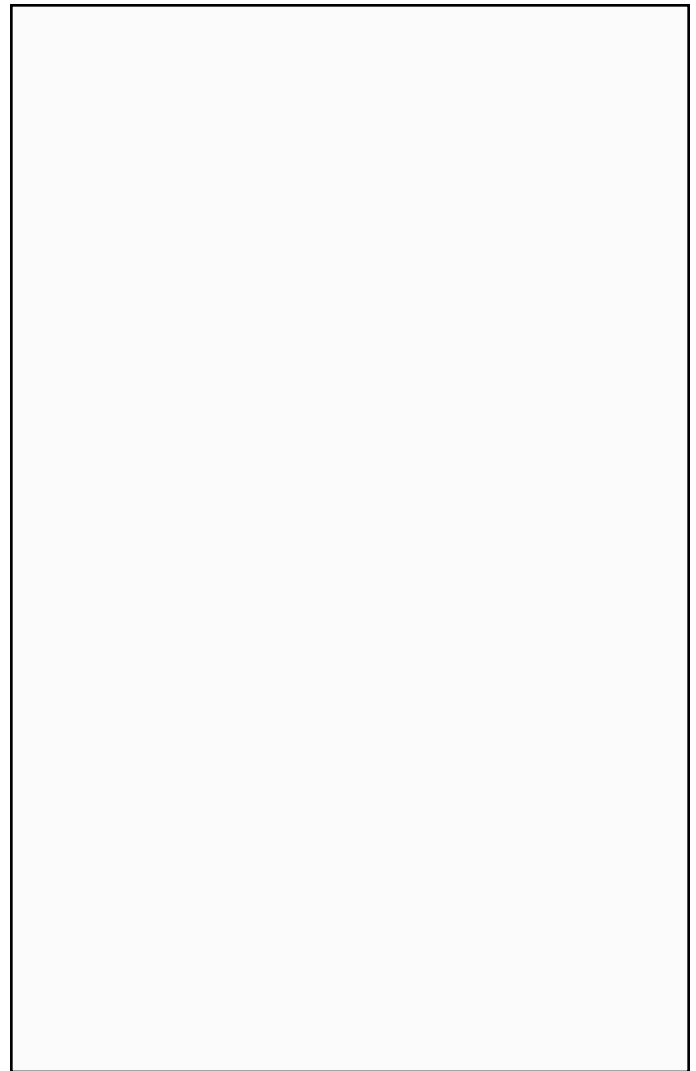


Figure 2. Schematic diagram of an instrumented array designed to monitor the freshwater flux over the East Greenland shelf. Salinity transects are observations from the IGY.

3. What caused the earlier Arctic warming? In many ways, the earlier episode of Arctic warming in the middle decades of this century was more amplified, more protracted (e.g. Figure 3) and more extensive than the relatively restricted spreading

of subsurface warmth that has attracted our attention in the 1990s. This much seems clear from the Report of the ICES Special Scientific Meeting on the subject in 1948 and from its comprehensive bibliography by Arthur Lee¹¹. To revisit and continue these early steps toward understanding these warm decades, our own first step is to reassemble the relevant hydrometeorological record. It is proposed in this project to identify ocean and meteorological data from the maritime Arctic for the period 1922-1958, roughly spanning the period from the Maud Expedition to the IGY, ---- a period of active scientific research throughout the Arctic which included the Second International Polar Year. The geographical region will extend from the Bering Sea, throughout the Arctic Ocean and marginal seas and into the Nordic Seas. The data sets most relevant to our understanding of decadal warming will come from the physical sciences (physical oceanography, meteorology, sea ice and hydrology). However, we recognise that marine biogeochemistry may also provide direct evidence of the sources of the warming, and that such data support the greater objective of understanding the *consequences* of Arctic warming. Many of these data will already reside in various national and international archives, so that their identification and collation should be relatively straightforward, but other records may well be "lost" or inaccessible in institutional or even private archives, requiring a greater and well-directed effort in data rescue. The International Arctic Research Center, University of Alaska, is proposed to take the lead in assembling all these data, promoting data-archaeology and data-rescue activities where necessary, and producing a CD-ROM for general distribution as well as for submission to World Data Centers. Such a data assembly project is timely, following other recent and present efforts to assemble and distribute sets of Arctic data from more recent decades, mainly 1950-90¹². We wish this component of the project to begin at once, costs are expected to be modest (<\$150,000) and we anticipate that the bulk of the useful information will be in the hands of the research community by mid-2001.

4. What is the sensitivity of the carbon cycle to Arctic variability? The preceding paragraph made passing reference to the likely importance of Arctic change on marine biogeochemical processes. The rationale is that much of the water which enters the Arctic Ocean does so across extensive shelves,

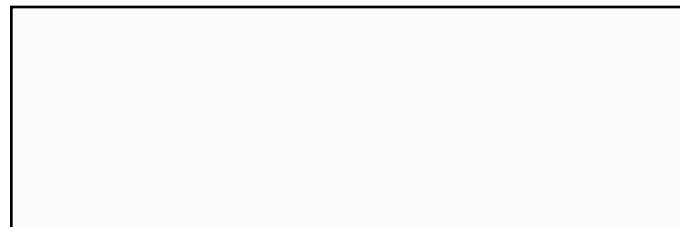


Figure 3. Three-year running averages of yearly temperature along the Kola Section of the Barents Sea, 1900-90 (from Loeng 1991), clearly illustrating the high-latitude warming that took place in this sector during the middle decades of this Century.

---- the Atlantic inflow through the Barents Sea, and the fresher Pacific inflow which enters across both the Bering Sea and Chukchi Sea shelves. An extensive heat loss takes place during both of these inflows which, together with a substantial primary production, drives an air-sea flux of carbon dioxide. In the present context, the question is how sensitive this air-sea flux is to climate variability and hydrographic change. Some elements of this response are known. Warming the inflowing water will decrease the solubility and thus the air-sea flux; changes in the volume flux will affect the air-sea gas exchange by changing both the inventory of dissolved inorganic carbon, and the supply of nutrients; increased melting of sea ice can affect summer primary production by increased stratification and through the effect of stratification changes on light- and nutrient-supply; an increased summer melt-back of ice will increase the heat loss during the winter season and increase brine production, with consequent effects on ventilation and the sequestration of anthropogenic carbon dioxide. The difficulty is to evaluate the relative importance of these processes in order to incorporate their net effect in climate models. As we move towards the period of peak anthropogenic carbon dioxide release¹⁰, the importance of being able to do so becomes a priority for the Arctic.

These four questions seem, for the present, to address the important unknowns in identifying how Arctic variability feeds through to lower latitudes and contributes to global change. The Japanese Frontier Research System for Global Change, the US-NOAA Global Change Research Program, the US-NSF Arctic System Science Study, the WRCP Arctic Climate System Study (and its likely successor study on Climate and Cryosphere), and the specified priority interests of the upcoming

EC Framework-V Key Action on "Global change, Climate and Biodiversity" all express an implicit or explicit need to link Arctic Ocean variability with climate change and its societal impacts in the region, the adjacent subarctic, and the Hemisphere. This unanimity of view would not in itself justify the involvement of the AOSB; however the key role of ocean processes and exchanges in carrying the climate signal to and from the Arctic, the desirability of achieving a pan-Arctic coordination in certain of these studies (e.g. in assessing whether and how the freshwater fluxes of the Canadian Arctic Archipelago and Fram Strait might co-vary, already anticipated in models), and the occasional need to persuade political access to key experimental sites or "buried" data sets all seem well suited to the abilities and interests of the AOSB.

For continuing news of how this programme develops, the reader is referred to the AOSB website : <http://www.aosb.org>

-Bob Dickson, Leif Anderson, Marty Bergmann
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April 1999

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The 18th Arctic Ocean Sciences Board Meeting

The Arctic Ocean Sciences Board held its 18th Meeting on 29 March – 1 April 1999 at the National Institute for Polar Research (NIPR) in Tokyo, Japan. The Board reviewed recent progress in AOSB and related Arctic Ocean science programs; discussed relevant issues; developed plans for its future scientific program and related activities; and elected officers for the next two years.

In conjunction with the International Arctic Polynya Programme (IAPP), the Board approved in concept the convening of a symposium on polynya research in 2001. This symposium will address the physics, chemistry, biology and carbon cycling in polynyas; the mechanisms for polynya formation; and interannual variability in polynya processes. The Board also agreed to explore possible options for a future study of the Lincoln Sea polynya. The membership of the Scientific Coordinating Group (IAPP-SCG) will be broadened to address these wide-ranging responsibilities.

The Board acknowledged with appreciation and will distribute widely the results of the 1998 AOSB/NATO Symposium on the Freshwater Budget of the Arctic and of recent research under the Arctic Paleo-River Discharge Program (APARD) and the Study of Biodiversity and Fluxes of Glaciated Arctic Fjords (BIODAFF).

The Board discussed the scientific planning now underway for the Greenland Arctic Ocean Shelf

Project (GRASP) and for Shelf-Basin Interactions (SBI) and offered to assist in facilitating the international aspects of such planning as appropriate. The Board reviewed recent activities in data management in the Arctic and agreed to encourage inclusion of Arctic Ocean databases in international directories of Arctic data.

The Board decided that “Arctic variability and global change: Arctic Ocean linkages” should be a focus of the AOSB’s future efforts. The concept for such an effort is the primary subject of this Newsletter.

The Board will work closely with the International Arctic Science Committee (IASC) and other interested international bodies concerned with Arctic research to coordinate their meetings and other activities in future to improve efficiency.

The NIPR led a series of presentations to the Board on recent Arctic research in Japan, including at the NIPR, Hokkaido University, JAMSTEC, and the Arctic Environment Research Institute.

The Board elected Dr. Leif Anderson as Chair and Dr. Jean Claude Gascard as Vice Chair. Dr. Dieter Fütterer will serve as Past Chair.

-Lou Brown, Secretary
April 1999

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