

APPENDIX A

An Open Letter Describing a Program For A Study of Arctic Change

4/7/97

Dear Colleague,

This open letter is a first step in development of a program to track and understand major changes in the Arctic environment. The program is tentatively called the Study of Arctic Change.

It is becoming increasingly clear that the Arctic is in the midst of a significant change. This appears to involve both the atmosphere and ocean, but we first became aware of it in the hydrography of the Arctic Ocean. The results of several recent expeditions indicate that the influence of Atlantic Water is becoming more widespread and intense than previously found. Data collected during the cruise of the *USS Pargo* in 1993 (Morison et al, 1997), the cruise of the *Henry Larsen* also in 1993 (Carmack et al., 1995; McLaughlin et al., 1996), and the Summer 1994 Arctic Ocean Section of the *Polar Sea* and the *Louis S. St Laurent* (Carmack et al., 1996) all indicate that the boundary between the eastern and western halocline types now lies roughly parallel to the Alpha and Mendeleev Ridges (AMR). In terms of longitudinal coverage, this means the area occupied by the eastern water types is nearly 20% greater than previously observed.

The greater intensity of the Atlantic influence is also manifest in the warm cores observed over the Lomonosov and Mendeleev ridges in the *Pargo* and *St Laurent* data, with temperatures over the Lomonosov Ridge greater than 1.5°C. Carmack et al. (1995) and McLaughlin et al. (1996) also observed an Atlantic Layer temperature increase over the Mendeleev Ridge. Results of the Transarctic Acoustic Propagation (TAP) experiment conducted in April, 1994 also suggest warmer waters in the Atlantic layer (Mikhalevsky, et. al., 1995, and Mikhalevsky, et. al., 1996). The historical data of Gorshkov (1983) and Treshnikov (1977) give no indication of such warm cores and show a temperature over the Lomonosov Ridge nearly 1°C colder. The recently prepared digital atlas of Russian hydrographic data (Environmental Working Group, 1997) confirms that no temperatures greater than 1° were observed during numerous investigations between 1950 and 1989.

The observed differences represent a fundamental change. The start of the change may have been in the late 1980s. The cruise of the *Oden* in 1991 (Anderson et al., 1994, and Rudels et al., 1994) shows a slight warming near the Pole, and Quadfasel (1991) reports warmer than usual temperatures in the Atlantic Water inflow in 1990. The differences from climatology are too large and spatially consistent to be attributed to instrument error or normal seasonal and interannual variability.

According to Morison et al. (1997) there are some indications that the observed shift in frontal positions is associated with a decadal trend in the atmospheric pressure pattern (Walsh et al., 1996). The pressure fields and ice drift data of Colony and Rigor (1993) and Rigor and Colony (1995) show the whole patterns of pressure and ice drift for 1993 were shifted counterclockwise 40°–60° from the 1979–92 pattern, just as the upper ocean circulation pattern derived from the hydrographic data of the 1993 cruise of the *USS Pargo* is shifted relative to climatology. Examination of the yearly average pressure maps in the International Arctic Buoy Program (IABP) data reports indicates the shift in the atmospheric pressure pattern began in about 1988–89. Before that time the Beaufort High was usually centered over 180° longitude. After 1988 the annual average Beaufort High was weaker and usually confined to West longitudes. This change is consistent with the findings of Walsh et al. (1996) that the annual mean atmospheric surface pressure is decreasing

and has been below the 1970–95 mean in every year since 1988. Therefore, the temporal shift in the atmosphere roughly corresponds to our estimate of when the ocean changes began. According to Morison et al. (1997) the atmosphere might drive the observed changes in ocean near surface circulation by Ekman pumping, and the effect of these circulation changes may reach deeper with time.

We feel it is of utmost importance that these changes in the Arctic Ocean be studied in detail. They may represent a decadal-scale change. Some simulations of both wind-forced (Proshutinsky and Johnson, 1996) and thermohaline-forced (Yang and Neelin, 1993; Steele et al., 1996) regimes have suggested decadal-scale variability may occur in the coupled air-ice-ocean system of the high northern latitudes. On the other hand the changes may represent the start of a longer term shift. While we are cognizant of the difficulty in distinguishing between anthropogenic climate change and other natural variability, we are also aware that climate models are nearly unanimous in predicting amplified polar response to greenhouse warming (e.g., Manabe and Stouffer, 1994). The connection between lower atmospheric pressure in the Arctic and incursion of warm Atlantic water into the Makarov Basin may indicate an important link in how the climate system manifests polar amplification.

In either case examining the evolution of the changes over time will likely tell us much about the interplay of the Arctic with the rest of the globe. This study warrants a multifaceted approach of measurements, data analysis, and modeling. However, the urgent need is for repeated hydrographic measurements over the whole basin. We do not want to miss the change as it is taking place. We are therefore formulating a plan for repeated large-scale hydrographic surveys along with buoy, mooring, and remote sensing observations. One experimental plan is patterned after the Russian Sever expeditions from 1950–1987. We would set out two or three small mother camps each spring. These camps would be manned by small crews and serve as refueling stations for survey aircraft that would employ the camps and shore bases to make short (1 hour) CTD-stations at 40 to 100 locations in the Arctic Basin. The survey flights would also provide for deployment of the IABP buoys measuring atmospheric pressure and temperature. In addition to serving as base camps for the survey flights, the mother camps would also be the site of drifting buoy and mooring installations. These unmanned buoy stations and moorings would provide year around time series at a few key points and provide a high temporal resolution perspective.

In addition to the aircraft surveys we hope to take advantage of the SCICEX submarine cruises for CTD measurements. At present no major surface ship cruises are planned for the central basin for the rest of the decade, but our interests fit in with other ship-borne expeditions. Sections in the Canada Basin have been suggested to ARCSS/OAII for 1999 or later. Also, as demonstrated by the cruises of the *Polarstern* in 1993, 1995, and 1996, it is possible to gain important insights into the basin hydrography by completing short sections from the shelves into the deep basins. Such sections would help our effort and could be done as adjuncts to planned work on the arctic shelves (ex. ARCSS-OAII Shelf Basin Interactions).

The survey program will have to be an international program. Russian participation is essential since we need to use Russian airbases to reach many of the most important areas. Their experience and facilities for this type of airborne survey are essential. For similar reasons Canadian, and perhaps Greenland participation is vital. Other nations with long-standing and emerging arctic interests should be involved. These include Norway, Sweden, Germany, and Japan.

Another area where international cooperation will be crucial is in monitoring the variability of the inflows and outflows to the basin. One explanation for the observed changes is that they are forced by changes in the inflows and outflows. In this area we hope to tie in with ongoing programs where possible. For example, Fram Strait will probably be monitored by a Scandinavian-German

consortium. The exchange through the Canadian Archipelago is a major open question that might be addressed in this initiative by a Canadian and American effort. American and Russian scientists have been monitoring Bering Strait.

The logistics and experimental techniques required for such a program are not new. The community knows how to do the surveys. At its full scope it is a large undertaking, but it can be started with a subset of the full program and provide critical information. Indeed, if we do not make some measurements very soon, there will be a tragic gap in the record of Arctic change. Also there are several logistical factors that may provide tremendous logistical advantage at reasonable cost. For example, we can use the SHEBA drift station as one of the mother-stations in 1998. The U.S. Forest Service has two new turbine-powered DC-3 aircraft which they use for fire fighting in the summer months. If the NSF were to take over operation of these aircraft in the Spring and equip them with skis, they would provide ideal long-range survey and supply aircraft for this and other programs. The Alaska Air National Guard (ANG) has provided Blackhawk helicopters with air-air refueling capability and C-130 tankers for long range buoy deployments in the past. The ANG 109th Squadron has similar capabilities and through their relation with NSF might provide unparalleled support for aircraft CTD surveys and buoy deployments.

We have focused here on the need for field observations because we do not want to miss observing the change, and it may take considerable time to get the fieldwork started. However, analysis of existing data and modeling should also play a major part in this study. We must look at historical records of atmospheric parameters in studies like that of Walsh et al. (1996). There is considerable historical hydrographic data collected by the Russians that is now becoming available (Environmental Working Group, 1997). In addition they have other data such as river runoff and sea level that have been routinely collected for many years. These data sets should be analyzed in detail for evidence of past changes. Over the last several years the exchanges through Fram and Bering Straits have been monitored, and these data can be analyzed for their relation to the observed changes. All these should be compared to decadal and longer period changes at lower latitudes in the ocean and atmosphere. A number of Arctic Ocean models (ex. Hakkinen, 1992; Pavlov, 1995; Maslowski et al., 1996; Proshutinsky and Johnson, 1996; Zhang et al., 1996) could be run with atmospheric forcing representative of the last 15-20 years to examine the role of atmosphere in the ocean change. Taken further these models could predict the further ramifications of such change.

There are several existing programs under whose auspices the Study of Arctic Change might be carried out in whole or in part. These include ACSYS and the ARCSS-OAII (ex. SHEBA and Shelf Basin Interaction). The program should be closely coordinated with ongoing international activities. The international coordination would be especially well served through the ACSYS connection.

We are circulating this letter as a first step in exploring the scientific issues and opportunities. We plan to propose to NSF at least a pilot survey in the Spring of 1998 and to ONR/NSF the collection of hydrographic data from future SCICEX cruises. Finally, we would like to propose to NSF to hold an open international meeting on the Arctic change as a spring-board to further work on this urgent issue. We feel now is a very good time to propose a project that is driven by such a strong science question and that is large enough to address various elements of the observed changes in the Arctic. We are very interested to hear of your thoughts on this program and your interest in participating. Would you as an investigator be willing to join us and sign this letter? You may respond by

email or regular mail. Regular mail may be addressed to Study of Arctic Change, c/o Polar Science Center, 1013 NE 40th St, Seattle, WA 98105. Finally, we also ask that you forward this letter to other scientists who you feel would have an interest in this program.

Thank you,

| | | | |
|------------------------------|------------------------------|------------------------------|----------------------------------|
| James Morison ¹ | Knut Aagaard ¹ | Robin Muench ² | Michael Steele ¹ |
| Miles McPhee ³ | N. Untersteiner ¹ | James Swift ⁴ | Kelly Falkner ⁵ |
| Peter Schlosser ⁶ | John Walsh ⁷ | R. Shuchman ⁸ | Andrey Proshutinsky ⁹ |
| Seelye Martin ¹ | Mark Johnson ⁹ | Eric D'Asaro ¹ | Timothy Boyd ⁵ |
| Gary Maykut ¹ | James Maslanik ¹⁰ | Mark Serreze ¹⁰ | William Smethie ⁶ |
| Steve Ackley ¹¹ | Peter Jones ¹² | Greg Holloway ¹³ | Richard Pawlowicz ¹⁴ |
| T. Weingartner ⁹ | R. Lindsay ¹ | John Newton ¹⁵ | Tom Manley ¹⁶ |
| Drew Rothrock ¹ | Jim Overland ¹⁷ | Robert Bourke ¹⁸ | Ernst Augstein ¹⁹ |
| E. Fahrbach ¹⁹ | Torgne Vinje ²⁰ | Jinping Zhao ²¹ | Yas Sasaki ²² |
| Roger Bayles ²³ | F. MacLaughlin ¹³ | Charles Greene ²³ | Peter Wadhams ¹³ |
| P. Mikhalevsky ²⁶ | Doug Martinson ⁶ | Walter Munk ⁴ | Fred Tannis ⁸ |
| V. Pavlov ²⁷ | L. Timokhov ²⁷ | V. Nikiforov ²⁷ | W. Maslowski ¹⁸ |
| J. L. Zhang ¹ | | | |

Affiliations

| | |
|--|--|
| 1 University of Washington | 2 Earth and Space Research, Seattle, WA |
| 3 McPhee Research, Naches, WA | 4 Scripps Institute of Oceanography |
| 5 Oregon State University | 6 Lamont Doherty Earth Observatory |
| 7 University of Illinois, Urbana | 8 Environmental Research Inst. of Mich. |
| 9 University of Alaska | 10 University of Colorado |
| 11 Cold Regions Res. Engr Lab. | 12 Bedford Institute of Oceanography |
| 13 Inst. of Ocean Sci., Syney, B.C. | 14 University of British Columbia |
| 15 San Diego, CA | 16 Middleberry College |
| 17 Pacific Marine Env. Lab, Seattle, WA | 18 Naval Postgraduate School, Monterey, CA |
| 19 Alfred Wegener Institute, Germany | 20 Norske Polar Institute, Oslo, Norway |
| 21 Inst. of Oceanology, Qingdao, China | 22 Earth Sci. & Tech. Org., Japan |
| 23 University of Arizona | 24 Greeneridge Sci Inc., Santa Barbara, CA |
| 25 Scott Polar Research Inst, Cambridge | 26 Science Applications Inc., McLean, VA |
| 27 Arctic and Antarctic Res. Inst., Russia | |