

PROJECT: NANSEN AND AMUNDSEN BASINS OBSERVATIONAL SYSTEM

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Motivation

It is widely recognized that processes in the Arctic have global implications. Arctic ice controls the high-latitude heat balance by moderating the heat exchange between the atmosphere and ocean. Export of arctic ice and fresh water to lower latitudes is an effective regulator of the intensity of the large-scale ocean overturning with consequences for global thermohaline circulation.

There is new evidence that the Arctic environment experienced unprecedented changes in the past decades. Arctic surface air temperature (SAT) for 1979--1990 shows warming [Rigor et al., 2000]. Atmospheric sea level pressure (SLP) has decreased and the cyclonic vorticity of winds has been enhanced in the late 1980s through early 1990s relative to any time in the past several decades [Walsh et al., 1996]. The number of cyclones coming into the Arctic from the North Atlantic and carrying warmth from lower latitudes into the polar region has increased [Serreze et al., 1997].

Many of the recent changes of the Arctic environment may be related to the strong positive phases of the decadal-scale variability associated with the Arctic Oscillation (AO) and interdecadal low-frequency oscillation (LFO) with approximate time scales of 60--80 years [Polyakov and Johnson, 2000]. The SLP fields averaged over the positive and negative phases of the multidecadal and decadal modes of arctic variability show that during negative phases of the LFO and AO, the center of high SLP in the western Arctic is well developed and the Icelandic Low is depressed while during positive phases of the LFO and AO, the SLP high in the western Arctic is weaker and the Icelandic Low is stronger extending farther into the Barents and Kara seas.

Recent anomalous atmospheric conditions drove major changes in the Arctic Ocean. Over this period, the Arctic showed decrease of ice extent. Using submarine-based observations of arctic ice drafts, Rothrock et al. [1999] document a substantial reduction of ice thickness in the central Arctic in the 1990s relative to the 1950--1970s. Polyakov and Johnson [2000] proposed an explanation of anomalously thin arctic ice observed in the 1990s. A combination of century- and half-a-century-long data records and model integrations led Polyakov and Johnson to conclude that two modes of arctic natural variability, AO and LFO, have been in their positive, cyclonic phases resulting in numerous openings in the ice cover, replacement of multiyear ice with first-year ice and overall thinner ice in the central Arctic.

Observations collected during scientific cruises in the 1990s revealed a significant salinification of the surface water in the mid-Eurasian Basin resulting in the retreat of the Arctic cold halocline into the Makarov Basin with possible effects on surface energy balance and ice mass [Steele and Boyd, 1998]. They argued that the salinization of the upper Eurasian Basin in the late 1980s and early 1990s stemmed from the eastward diversion of Russian rivers in response to the anomalous atmospheric circulation. Extreme amplification of polar vortex in the late 1980s and early 1990s carried stronger transport of subsurface water of Atlantic origin along the continental margin of the Eurasian Basin into the Canadian Basin [Quadfasel et al, 1991; Carmack et al., 1995] causing corresponding relocation in the position of the Atlantic/Pacific front [Carmack et al., 1995; McLaughlin et al., 1996].

Despite progress in understanding the recent anomalies in the Arctic and their link with the external climate system, there are still major uncertainties in driving processes and mechanisms at work. The basic constraint is the scarceness of the available observational data. For example, there is evidence that the large-scale Arctic Ocean subsurface circulation consists of several cyclonic loops within each of the major basins [Aagaard, 1989; Rudels et al., 1994]. These large-scale counterclockwise loops are formed by relatively narrow boundary currents. However, this circulation pattern is mostly inferred from indirect, synoptic-scale observations of inversions and chlorofluorocarbon concentrations. Long-term observations of subsurface arctic currents are extremely scarce. Thus, the circulation scheme in the deep Arctic Ocean requires further investigation and quantitative evaluation.

The transformation mechanisms by which the Atlantic Water, ranging from about 200 to 600--800 m, is modified on its pathway along the slope of the Eurasian Basin are far from clear. According to Russian observations [Blinov and Popkov, 1986], the Atlantic Water loses about two thirds of its heat on its way along the slope between Franz Josef Land and Novosibirskiye Islands. A portion of this heat is advected upward, thinning the ice. This process may have a dramatic effect on the fresh water balance in the Eurasian Basin. This conclusion contradicts, however, to findings by Rudels et al. [1994]

who concluded that the heat loss from the Atlantic Water to the upper layer, the ice, and the atmosphere is negligible. These conclusions are based on scarce observations; direct measurements of heat fluxes were impossible.

We need to advance our understanding of the mechanisms responsible for exchange of properties between the arctic shelves and the basin interior owing to the fact that the arctic marginal seas may act as a source of Arctic change [Nikiforov and Shpaikher, 1980]. There is an informational gap in our knowledge of interaction of small- and large-scale processes (for example, tides and general circulation) and many other phenomena.

The fundamental limitation of the most observations in the Arctic is that they are not systematic. The lack of systematic long-term observations in the Arctic explains why it is difficult to conclude definitely whether or not the anomalous situation observed in the Arctic in the 1990s represents an episodic event or a long-term shift in the Arctic environment. Two exceptions are the monitoring system of arctic ice drift derived from drifting buoys and satellites and long-term observations in Fram Strait. Since 1990, the Norwegian Polar Institute (NPI) has monitored the ice thickness and ice transport through Fram Strait. Starting 1997, Alfred-Wegener-Institute (AWI) and NPI have operated fourteen moorings across Fram Strait as a part of the EU project.

The proposed project focuses on establishing the long-term observational system in the Eurasian Basin. Together with a set of moorings across Fram Strait operated under EU programs, twelve moorings grouped in four cross-sections along the continental slope of Nansen and Amundsen Basins are capable of tracking major transports and water mass transformations in vast polar area.

Purpose and objectives

The purpose of the project is to provide a quantitative observationally based assessment of circulation, water mass transformations, and transformation mechanisms in the Eurasian Basin of the Arctic Ocean. The major objectives of this project are 1) to quantify the structure and variability of the circulation in the upper, intermediate, and lower layers of the Eurasian Basin; 2) to evaluate mechanisms by which the Atlantic Water is transformed on its pathway along the slope of the Eurasian Basin; to evaluate the impact of heat transport from the Atlantic Water on ice; to investigate the strength and variability of the Fram Strait and the Barents Sea branches of the Atlantic Water; 3) to estimate the rate of exchange between the arctic shelves and the interior in order to clarify mechanisms of the arctic halocline formation.

Approach

Monitoring the Eurasian Basin using long-term oceanographic moorings meets many of the project's requirements. This method of arctic observation has been widely tested and is well established. Moorings allow continuous long-term measurements of key physical characteristics at selected locations. Time series obtained from these observations will be suitable for separation of synoptic-scale noise from the climatic signal. Located at the basin margins along the major pathways of water, heat, and salt transports, moorings can capture climatically important changes in oceanic conditions. Cross-sections formed by several moorings crossing the continental slope will allow along-slope transports and shelf-interior interactions to be monitored.

Water velocity, temperature, and salinity will be measured at selected depths supplemented by ice thickness observations made by upward-looking sonars. In addition, acoustic Doppler current profilers will measure vertical profiles of velocity in near-bottom and upper ocean layers. The instruments at each mooring will be arranged in three clusters to obtain as much information as possible about three natural oceanic layers - the upper ocean (including the halocline), the Atlantic Water layer, and the near-bottom layer.

Moorings will operate for one year with replacement every one or two years. Moorings will be kept in the same locations from year to year to obtain multiyear records. There will be a gradual increase in the number of moorings from one or two during the first-year field experiment to perhaps twelve moorings after several years.

We plan to deploy twelve moorings grouped in four cross-sections crossing the continental margins of the European Basin. The location of moorings within each cross-section is designed to capture the major near-slope transports within surface, intermediate, and bottom layers. For this purpose, one mooring is planned to be placed at the shelf break, at a depth of approximately 400--500 m. This location of the moorings also allows to measure processes in the upper Atlantic layer. One mooring is planned to be placed at the lower portion of the continental slope, at a depth of approximately 2000--2500 m, and the last, third, mooring will be deployed somewhere at the intermediate position between the first two moorings. The geographical location of the cross-sections S1 and S2 may have a potential importance in understanding the interaction of

the Arctic Ocean with the Atlantic, the cross-section S4 may help in understanding the partition of subsurface water between the two branches following the Lomonosov Ridge and continental slope of the Amundsen Basin, respectively. The estimates of heat fluxes from all moorings may be useful in evaluation of the heat exchange between the Atlantic Water and upper and lower layers. All the measurements may help in understanding major mechanisms of the halocline formation and exchange of properties between the shelves and the basin interior. Contribution of short-term observations from all moorings. After several years of observations the number of moorings within each cross-section may be reduced keeping one-two moorings representative for the specific region of the cross-section. The released moorings will be relocated extending the area of experiment. The decision on this relocation will be made based upon available information obtained during the field program.

The standard mooring includes floatation, anchor, two acoustic releases, beacon, sea level recorder, and upward looking sonar. Within surface and bottom layers we plan to deploy ADCPs measuring vertical profiles of current velocity, and temperature and salinity recorders (TC). The deeper moorings require additional equipment to resolve intermediate Atlantic layer. To accomplish this goal we plan to equip these moorings with the TC recorders and current meters at several oceanographic levels starting from 200 through 700 m. We also plan to equip the central mooring of the cross-section S3 with a turbulimeter which will measure the turbulent heat and momentum fluxes at the upper Atlantic layer boundary (approximately 200–300 m). Processing and preliminary analysis of observational data will follow each annual field program.

Relationship between international institutions

The proposed program is beyond the resources of any single research institute or country and thus the international cooperation is essential. We consider participation of international scientific communities at every stage of the project to be crucial to the success of the program. Cooperation of international researchers will take the following forms: 1) Cooperative field programs; exchange of participating scientists, specialists, and researches; and the exchange and joint publication of their results; 2) Joint scientific workshops; 3) Participation of scientists from both countries in multilateral cooperative activities within the scope of work of the project.

The cooperative efforts of many countries is the key element in achieving the goals of this project. It is worth saying that the vast area of the Nansen Basin is entirely within 200-mile Russian economical zone. We are participating in developing a new Agreement between Governments of the U.S. and Russian Federation on cooperation in oceanographic research which includes NABOS as a specific project.

We consider IARC's mission in NABOS as an initiator of the project, as the key participant in establishment and maintaining the observational system, and as a coordinator the efforts of various international institutions within the scope of the project.

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