

MONITORING THE ARCTIC OCEAN

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LONG TERM GOALS

The past few years have demonstrated extraordinarily large and rapid changes in the arctic marine environment, including basin-wide shifts in nutrient distributions, large subsurface warming, and widespread fine structure extending into the interior from the thermally perturbed boundary currents. We seek a quantitative understanding of the processes responsible for these changes, looking toward a physically realistic and mechanistically based predictive capability.

OBJECTIVES

Our immediate objective has been to determine the rates and mechanisms of temporal variability in a part of the Arctic that has been considered effectively isolated both from local surface forcing and from major changes imposed by exchange with the North Atlantic. Essentially we have sought to isolate the mechanisms of change and thereby make the problem tractable in piecemeal fashion. The region selected is the deep Beaufort Sea, adjacent to northern Alaska and northwestern Canada. There the upper ocean stratification is large and the Bering Strait/Chukchi Sea inflow is close at hand, so that regional shelf processes are a major forcing for the interior ocean. The focus has been on the upper few hundred meters of the Beaufort Sea, where the eddy field is known to be energetic and the effects of shelf processes and boundary current advection are large. For comparison, we have worked sites over both the abyssal plain and the continental slope.

APPROACH

Working jointly with the Institute of Ocean Sciences in Canada, we have maintained instrumented moored arrays to measure primarily upper ocean structure and velocity, along with ice thickness, over a period long enough to resolve time scales up to the interannual. The moored measurements are supplemented by full-column hydrography and tracer measurements in sections passing through the mooring locations during each recovery/deployment cycle. This effort is providing statistics on the natural variability of this part of the Arctic Ocean, measurements of processes important to maintaining or altering ocean conditions in the region, and information on the extent of the recent dramatic large-scale changes in temperature and frontal structure in the Arctic Ocean. Ice breaker support has been provided by the Canadian Coast Guard. The moorings carry upward-looking sonar for ice thickness measurements, current meters with temperature sensors, high-precision temperature/salinity recorders, and sediment traps as opportunity permits.

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ACCOMPLISHMENTS

During this past summer we recovered the last mooring on the continental slope from the CCGS *Sir Wilfred Laurier*, and we made supporting hydrographic measurements. We have also submitted our earlier time series to the National Oceanographic Data Center.

SCIENTIFIC/TECHNICAL RESULTS

In addition to our earlier results illuminating the complex eddy field, upper-ocean frontal structures, and regional modification of the Pacific waters, the temporal data base is now sufficient to provide good statistics on the very low frequency variability of the ocean. For example, the weekly average currents, temperature, and salinity over the slope from 1991-1996 show that even at these longer time scales the flow is highly variable, but suggest a fall/winter intensification. At higher frequencies Kelvin waves appear important. Somewhat surprisingly, the long-term mean flow is weakly offshore (1.4 cm s⁻¹ toward 010°T), so that for geostrophic balance a westward pressure gradient is required, opposite to what has been suggested in earlier work. The highly coherent low-frequency temperature and salinity variability reflects the vertical movement of isopycnal surfaces, and the observations therefore cover the halocline from the Pacific mode (with a salinity near 33.1) through the Barents/Kara shelf mode (about 34.3 in salinity). A very large excursion in temperature and salinity early in 1994, for example, represents an elevation of the isopycnals of over 100 m. The long time scales for many of these density-structure adjustments, e.g., over three months for the nearly 100 m lowering of the isopycnals the following summer and fall, suggests changes in the large-scale circulation. As a practical matter, the thermal (and acoustic) environment can therefore remain anomalous for months.

IMPACT FOR SCIENCE APPLICATIONS

- Through definition of the mean fields and their spatial and temporal variability these measurements provide important constraints and checks on the growing array of ocean models of the Arctic.
- Through long time series of temperature and salinity, and thereby sound speed, this work defines the frequency and magnitude of meso- and sub-mesoscale under-ice variability in the operating environment of submarines.
- Through the combination of moored and ship-borne measurements this research illuminates the exchange of materials between the arctic shelves and the adjacent deeper offshore waters.
- Through linkages with moored measurements off the Siberian shelf this work provides a basis for assessing and predicting the transport and dispersal of Russian military and industrial contaminants in the Arctic.

TRANSITIONS

These data are well suited to mapping a variety of parameters in operational products, e.g., current and sound velocity statistics in the upper ocean.

RELATED PROJECTS

In its concern with the structure of the interior ocean and the connections with shelf processes in the western Arctic, this work is complemented by the ONR-sponsored study "Radionuclide Risk Assessment in the Western Arctic: Physical Transport Mechanisms" and by

the two NSF-sponsored studies "Investigations of the Western Arctic: Transport and water properties in Bering Strait and Over the Chukchi Shelf" and "A CTD/Hydrographic Section Across the Arctic Ocean." The work is conducted in close partnership with E. C. Carmack of the Institute of Ocean Sciences, Canada and with R. Moritz of the University of Washington.

PUBLICATIONS

Weingartner, T.J., D.J. Cavalieri, K. Aagaard, and Y. Sasaki, Circulation, dense water formation, and outflow on the northeast Chukchi shelf, *J. Geophys. Res.*, accepted for publication.

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