Submarine-Based Acoustic Doppler Current Profiler (ADCP) Measurements of the Upper Arctic Ocean

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LONG-TERM GOALS

The long-term goals of this project are to better understand and quantify the processes that are primarily responsible for redistribution of heat and salt within the Arctic Ocean. The topical focus has been on quantification of the slope-trapped boundary currents and on understanding the roles of small-scale and mesoscale processes in the redistribution of water properties within the central basins. The geographical focus spans the Arctic Basin but emphasizes the Nansen, Amundsen and Makarov basins and the frontal systems that overlie the inter-basin ridges.

OBJECTIVES

Four primary objectives contribute to the above goals.

- Improve the present understanding of mean circulation patterns in the Arctic, with a focus on the topographically controlled boundary currents that redistribute heat and salt.

- Quantify the speeds, heat, salt and mass transports associated with the boundary currents.

- Improve our understanding of the nature, distribution and dynamics of upper ocean mesoscale eddies and frontal systems, and assess their role in the transport of heat and salt.

- Assess the roles of turbulent mixing and double diffusion in redistributing heat and salt, with an emphasis on the impact of these processes on the halocline and their potential effects on the pack ice cover.

APPROACH

We have approached the above goals through the analysis of recent field data. The core data set has been collected from submarine deployments during the SCICEX experiment (1995-1999) and two subsequent post-SCICEX accommodation cruises during 2000 and 2001. The SCICEX data span the entire Arctic Ocean, including repeat transects across the major ocean basin features along approximately co-located lines. The data include temperature, salinity, dissolved oxygen and upper ocean currents. These data have been supplemented with similar data collected during a 1991 *Oden* cruise; 1993, 1995 and 1996 cruises of the German research icebreaker, *Polarstern*; with data from the 1994 US/Canadian trans-

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14. ABSTRACT
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Arctic section; and with time series data from an array of instrumented moorings deployed off the Siberian continental slope from 1995-1996.

WORK COMPLETED

The ADCP upper ocean current data and concurrent navigation data for the SCICEX 1998 and 1999 cruises were reviewed to determine possibilities in recovering current velocities from these data sets. Consultation with Bernie Coakley (Univ. of Alaska) is continuing at this time to evaluate optimal ways to reprocess the navigation data for this goal.

Further analysis of the CTD and XCTD data from various Arctic datasets continued with emphasis on tracing the warming of the Atlantic Water layer during the later half of the decade of the 1990's and into the new millennium. A partial transect across the eastern-most basins in the Arctic Ocean for 2001 was obtained from the Arctic Submarine Laboratory to augment the earlier transects obtained during SCICEX and other historical trans-Arctic expeditions. Results from this analysis were presented at three meetings; the ASLO/AGU Ocean Sciences Meeting in Honolulu, HI in February 2002, at the ACSYS Workshop on Measurements and Modeling of the Arctic Ocean Circulation at Lamont-Doherty Earth Observatory in Palisades, NY in June 2002 and at the ARCUS Arctic Forum in Washington, D.C. during May 2002.

Collaboration continues with Michael Steele (Univ. of Wash.), Timothy Boyd (OSU) and Robin Muench (ESR) on various Arctic Ocean topics. A paper was published on the partial recovery of the Cold Halocline Layer in the Arctic Ocean (Boyd, et al., 2002) and a paper on the warming of the Atlantic Layer between 1995-2001 is in the final stages of preparation in anticipation of submission to the *Journal of Geophysical Research*.

RESULTS

The analysis conducted in previous years examining the evolution of the maximum temperature in the Atlantic Water layer (AW) in the Arctic Ocean (Gunn and Muench, 2001) led to an expansion of this topic to look at the evolution of temperature in the entire AW layer over the period 1995-2001 using the various Arctic data sets acquired by ESR and other institutions, extending the analysis over the breadth of the Arctic Ocean.

Ocean temperature and salinity have been measured annually from 1995 to 2001 along transects across the central Arctic Ocean using submarine-launched expendable CTD probes. Data from these probes have been integrated with data acquired from surface vessels over the same period. These data, which encompass the major trans-ocean ridges and circulation gyres interior to the Arctic Ocean, are used to assess inter-annual variations across the basin.

The overall trend was for continued warming in the AW layer throughout the period. In particular, AW temperatures increased in warm cores in the Amundsen and Makarov basins and over the Chukchi Rise in the Canadian Basin (Figure 1). The temperature patterns were also consistent with lateral spreading of these cores as well. However, the pattern was patchy both spatially and from year to year. For example, some early cooling was evident in the upper 200 m of the AW layer overlying the Lomonosov Ridge and extending slightly into the Makarov Basin, however, the Makarov side of the Lomonosov Ridge showed warming in 2001. Persistent warming in the western Amundsen and

Makarov basins probably reflected preferential input to these regions of warmer water from the warm, eastward slope current north of Siberia (not shown). Other more ephemeral features probably reflect system responses to fluctuations in the regional wind field and, by association, the Arctic Oscillation.

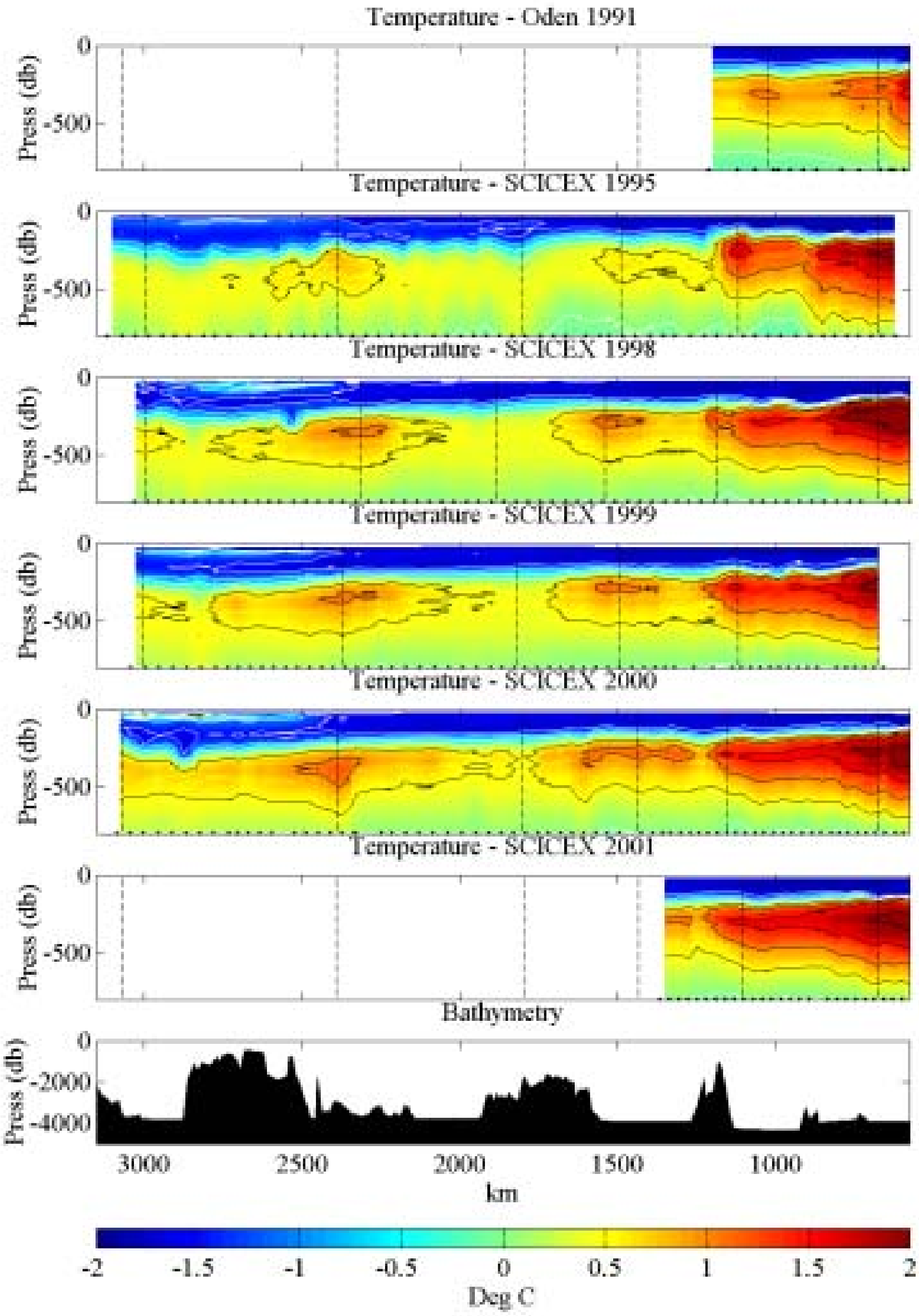

Figure 1. Temperature cross sections from 1991, 1995, 1998, 1999, 2000, and 2001 along the same Arctic Ocean transect showing the increasing temperature in the Atlantic Water layer in the various basins. The bathymetry is plotted in the lowest panel showing the alignment of the warm cores with the various ridges.

The warming has continued pretty much monotonically even though the Arctic Oscillation itself has fluctuated over the past decade. The AW warming trend has also continued through the near loss and partial recovery of the cold halocline layer (Boyd, et al. 2002) so the warming in the AW layer may be forced in some different fashion, more remotely, or perhaps over a larger area than the CHL, which is nearer the surface. Speculatively, it would appear that the response of the upper Arctic Ocean to local winds and freshwater impacts as documented by Boyd, et al. 2002, either doesn't extend to the AW layer or, possibly, other forcing masks their influence.

IMPACT/APPLICATIONS

The results concerning the warming in the Atlantic Layer and the fluctuations of the CHL have implications with respect to the reduction in the thickness and extent of the Arctic Ocean pack ice cover. The role these changes in the water column have, or may have, in the sea ice distribution have yet to be determined and quantified and are subject to results of further research concerning the transfer of heat in the Arctic Ocean and the balance between oceanographic and atmospheric processes. Changes in the sea ice cover, as well as related changes in the upper ocean structure, have potential impact on Naval operations as well as global and large scale climatic change.

TRANSITIONS

Information derived from this research ultimately contributes to parameterization of Arctic Ocean and climate change models that may predict changes in the Arctic sea ice cover with implications concerning Navy operations in the region.

RELATED PROJECTS

Results on upper ocean mixing processes are being directly integrated with results being obtained from the Weddell Sea AnzFlux (Antarctic Zone Fluxes) and international DOVETAIL (Deep Ocean Ventilation Through Antarctic Intermediate Layers) programs. The integrated results will provide information on the relationships among wind-driven surface currents, tidal currents, bottom topography, sea ice cover, upper ocean stratification and mixing processes over a spectrum of parameter values that typify high latitude oceans.

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