Circulation and Thermohaline Structure Along the Chukchi-Beaufort Continental Slope

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LONG TERM GOALS

My long-term goal is to understand the mean and time-varying density structure and circulation dynamics of the continental slope of the Arctic Ocean and how the slope interacts with the adjacent shelves and basin. The circumpolar boundary currents of the Arctic Ocean are important in the distribution and exchange of mass, heat, and material around the basin and between the shelves and the interior ocean. However, this province of the Arctic Ocean is the least understood and sampled portion of the Arctic.

OBJECTIVES

The field effort and data analyses are addressing the following questions and objectives:

1. What is the decorrelation length scale of the alongslope density field? Does this length scale differ between the Chukchi and Beaufort slopes?
2. How does the magnitude of the alongshore pressure gradient vary along the Chukchi-Beaufort continental slope? Are these changes associated with distinctly different water masses?
3. How does the cross-slope pressure gradient vary along the Beaufort-Chukchi continental slope?
4. Is the flow in the upper halocline consistent with the thermal wind balance?
5. Combine the temperature-salinity data with biogeochemical measurements to better define the water masses encountered along the slope.

APPROACH

To address these objectives, I took advantage of the unique sampling capabilities of a nuclear submarine (SSN *Hawkbill*) operating beneath the ice pack along the Chukchi-Beaufort continental slope in April 1999. My portion of this program sampled the ocean using the sail-mounted CTD and twenty-five (25) submarine-launched expendable CTDs (SSXCTD) probes. The former sampled at 2-second intervals (subsequently averaged into 6-minute segments) at a constant depth while the

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14. ABSTRACT
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submarine was in transit along a grid track that zigzagged across and along the continental slope. The SSXCTDs were deployed at pre-selected locations along the cruise track and sample between the surface (~10m depth) and 750 m depth. This project also supported Dr. Stephen Okkonen who was a rider on the SSN *Hawkbill* during the science mission. Dr. Okkonen was involved in all phases of the oceanographic data collection and is continuing with the analyses of the CTD (sail-mounted and SSXCTD) data sets. Some of these data are being analyzed in collaboration with Robin Muench (ADCP), Terry Whitledge and Dean Stockwell, (nutrients and chlorophyll), and Margo Edwards (high resolution bathymetry from the swath mapper SCAMP [Seafloor Characterization and Mapping Pods]).

WORK COMPLETED

The data have been collected and we are presently analyzing them in conjunction with the aforementioned colleagues. We have computed the geostrophic transports and the along and cross-slope dynamic height fields. We have estimated the heat loss from the Atlantic Layer of the boundary flow. We have also estimated that the decorrelation length scale along the slope is about 20 km, which is the typical diameter of eddies found in the Canada Basin. These decorrelation length scales appear to be similar to the along-slope length scales of bathymetric variability on the Beaufort continental slope.

RESULTS

SSXCTD and continuous, underway sail-mounted CTD data were collected along the NE Chukchi and Beaufort continental slopes in April 1999 from the USN Hawkbill along the transects and at the stations (numbered) in Figure 1.

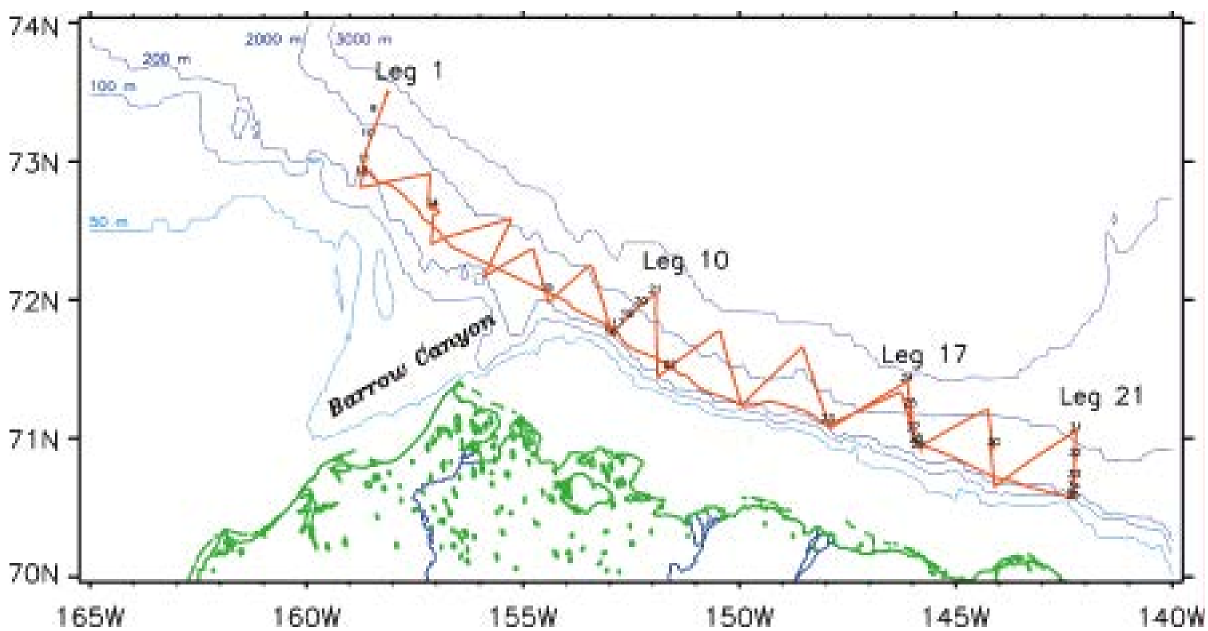

Figure 1. Map showing the transects (orange) along which sail mounted CTD data were collected from the USN Hawkbill in April 1999. The numbers refer to locations where SSXCTD launches were made.

Our results are showing that the Chukchi slope between the Northwind Ridge and Barrow is incised by a rugged topography that includes deep submarine canyons with vertical scales of hundreds of meters while east of Barrow the topography is gentler. The alongslope scale lengths of halocline temperature and salinity appear correlated with the seafloor topography and the dominant alongslope scale of variability is about 20 km. An example of the alongslope variability as obtained from the T/C recorder in the sail of the submarine is shown in Figure 2. This correlation suggests that the halocline displacements result from interactions between the flow field and the slope topography.

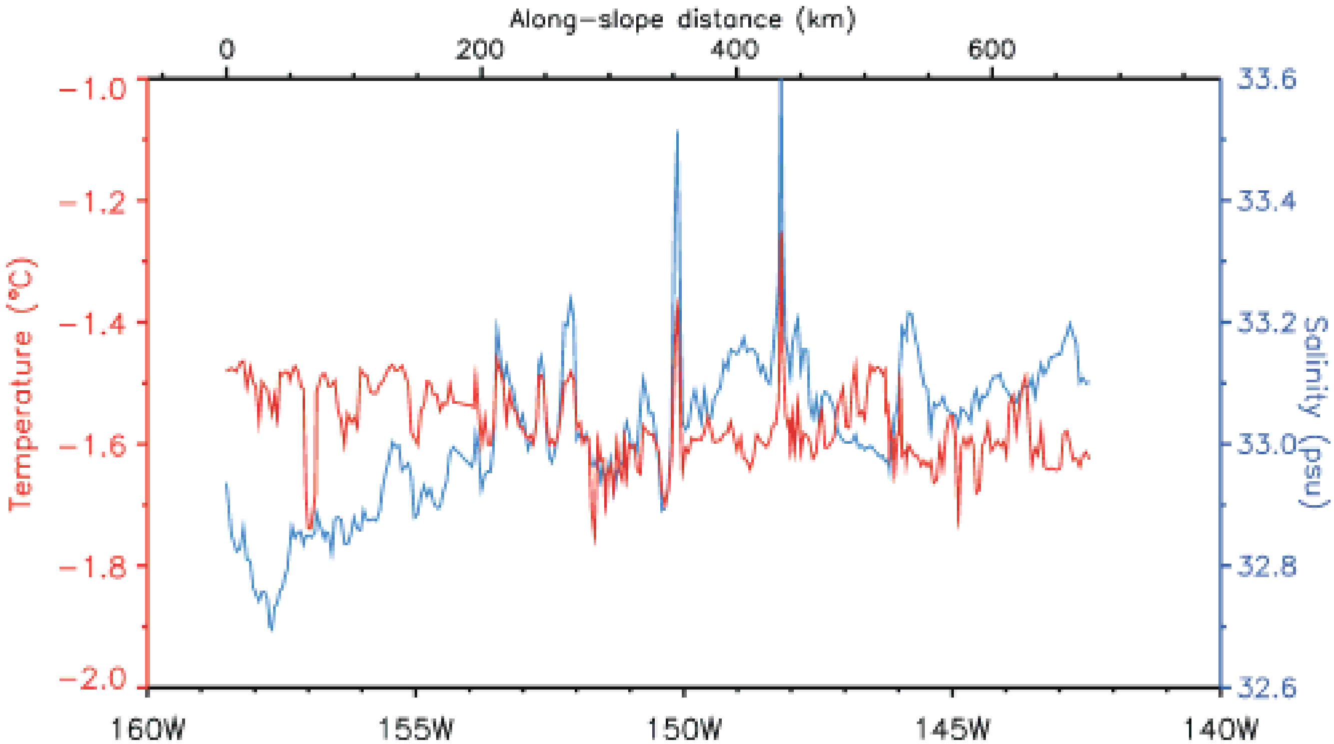

Figure 2. Temperature (red) and salinity (blue) from the sail-mounted CTD at a depth of 117 ± 2m (from west to east along the Beaufort Sea slope. The data are from within the upper halocline of the Arctic Ocean. Each point represents an average over a 6-minute sampling interval). The broad sclae pattern consists of: 1) increasing salinity (~32.75 – 33.05 psu) from the west end of the transect (159 °W) to about (152 °W), and 2) relatively constant salinities (~33.1 psu) east of this longitude. Temperatures range between –1.7 and –1.3°C and are generally greater by about 0.1°C west of 152°W. The two warm and salty peaks at about 150 and 148°W are associated with small-scale upwelling events and imply vertical displacements within the halocline of about 40 m..

We are also finding that the alongslope dynamic topography in April 1999 consisted of a trough in the dynamic height field centered midway along the Alaskan Beaufort slope (Figure 3). This trough, which suggests alongslope convergence in the alongslope flow field, is related to deep upwelling within the Atlantic Layer and halocline. This finding is consistent with the cross-slope dynamic height sections that suggest that the magnitude of the eastward transport in the halocline and Atlantic Water layers decreases moving eastward along the Beaufort slope. As the boundary current flows eastward along the Beaufort Sea slope, waters at depths between 300 and 600 m (within the Atlantic Layer) cool substantially. Concurrent velocity data from moorings (described below) suggest that the observed

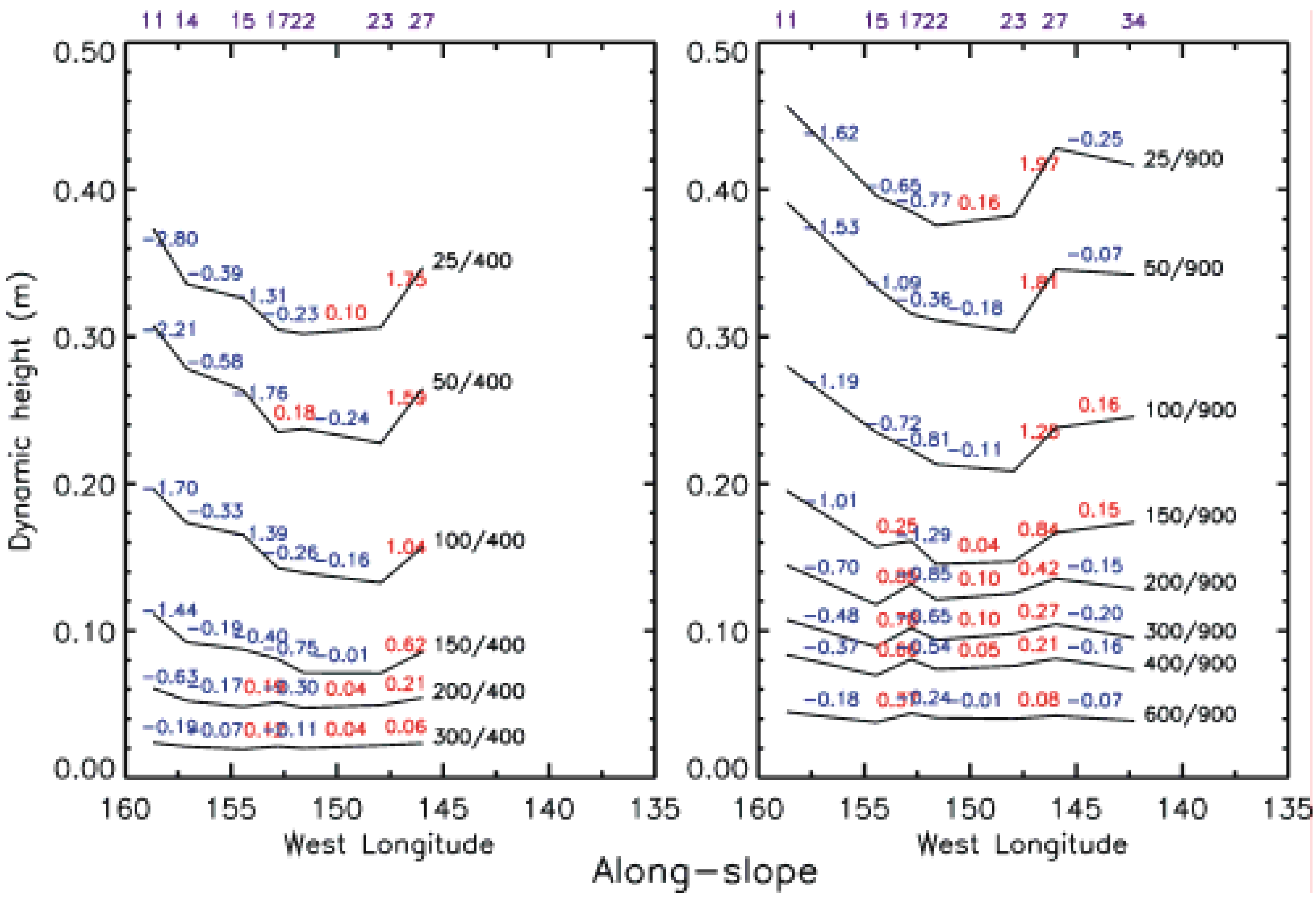

Figure 3. Dynamic height along the Beaufort Sea continental slope referenced to 400 (right) and 900 dbars (left). The dynamic height slopes downward toward the east between 159 and 147°W and upward thereafter. These transitions were accompanied by a decrease in the eastward geostrophic transport of the slope flow along the Beaufort continental slope. Note that beneath 200 dbars the dynamic height field is relatively flat, implying that most of the dynamic relief is associated by displacements within the halocline.

dynamic height field is not permanent feature of the slope circulation field but instead reflects a response to (probably seasonal) wind forcing. We have recently obtained the ECMWF surface pressure fields for 1999 so that we can compute the regional wind field. With these data we will be better able to interpret the CTD and current meter data.

IMPACT/APPLICATIONS

The submarine is the only platform capable of collecting the unique set of measurements being used herein from ice-covered portions of the Arctic Ocean. We were able to sample more than 1000 km of trackline during April in the Arctic Ocean collecting data at a spatial resolution of order tens of meters.

The data set is among the most detailed ever collected in this region. The measurements are shedding new light on the dynamics of flow along the continental slope of the Arctic Ocean and along other slopes not under the influence of western boundary-type currents.

TRANSITIONS

These results, in conjunction with those described below, will provide an unusually valuable data set for guiding model development and for comparison with results from an Arctic Ocean general circulation model. D. Martinson (LDEO) and W. Maslowski (NPGS) have indicated an interest in undertaking such a comparison independent of this project.

RELATED PROJECTS

This SCICEX project complements a set of current meter measurements collected by this PI (and K. Aagaard, E. Carmack, and K. Shimada) under sponsorship by the U.S. Minerals Management Service and the Japan Marine Science and Technology Center. The current measurements were obtained from yearlong moorings deployed along the Beaufort continental slope between September 1998 and 1999.

PUBLICATIONS

We have presented a poster at the AGU/ASLO Ocean Sciences Meeting that was held in San Antonio in January, 2000. The citation is:

Okkonen, S., M. Edwards, T. Weingartner, and R. Muench, Associations between water properties and bottom topography on the Chukchi-Beaufort shelf and slope. *Eos*, *Transaction, AGU*, **80**, 1999.