Dynamics of Exchange in the Beaufort Sea Boundary Current System: Implications for Interior Ventilation

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LONG-TERM GOALS

To understand more clearly the dynamics of high-latitude shelfbreak jets in the presence of strong forcing. This includes the response to external forcing (e.g. winds, air-sea buoyancy flux) and internal forcing (e.g. baroclinic instability).

OBJECTIVES

(1) To quantify the mean and seasonally-varying transport, structure and kinematics of the western Arctic shelfbreak current. (2) To determine the nature and cause of the mesoscale variability of the current, and assess the impact of the variability on the cross-stream exchange of mass and properties. (3) To diagnose the dynamics of the different exchange mechanisms.

APPROACH

From summer 2002 to summer 2004 a high-resolution moored array was maintained across the shelfbreak of the Beaufort Sea in the southern Canada Basin (western Arctic). The array consisted of vertically profiling conductivity/temperature/depth instruments (CTD Moored Profilers), combined with acoustic Doppler current profilers (ADCPs) and profiling acoustic current meters (ACMs). The moorings were spaced approximately 5 km apart, and so this represented the first time that the boundary current system in the Arctic was measured at the scale of the Rossby radius of deformation using moorings. Hydrographic surveys were also carried out during each of the mooring cruises.

WORK COMPLETED

All of the mooring data for both years of the experiment have now been processed. This included calibration of the moored profiler conductivity data and removal of significant density inversions, as well as de-tiding of the ADCP velocity data. A data report describing the moored profiler processing procedures has been completed. Regarding the scientific analysis, a study of the seasonal and synoptic variability of the shelfbreak current was carried out using the mooring velocity data from year 1. Two other studies investigating aspects of eddies spawned from the boundary current have been completed using the shipboard hydrographic data, and an investigation of the response of the boundary current to

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upwelling storms is ongoing using the mooring data in conjunction with weather station timeseries and meteorological fields.

RESULTS

The mooring array has provided the first-ever timeseries of the western Arctic shelfbreak jet, which varies both seasonally and on a synoptic basis. In the mean the jet is bottom-trapped and centered on the shelfbreak (Figure 1a), transporting approximately 0.2 Sv eastward. However, depending on the season, the jet can have a vastly different structure. For example, in late-summer and early-fall the current is surface intensified (Figure 1b) and advects buoyant Alaskan coastal water, whereas in late-fall through late-winter the current is bottom-trapped (more like the mean of Figure 1a) and advects dense winter-transformed Pacific water. During the latter period, Aleutian low pressure systems frequently cause easterly winds to blow in this region of the Arctic (there were 29 such storms the first year alone). These storms usually reverse the jet and cause a strong westward flow for a period of a few days. Interestingly, between storms the eastward-flowing jet often extends to greater depths (Figure 1c), impacting the deep layer of Atlantic water. These results are presented in Nikolopoulos and Pickart (2006), who investigate the nature of the jet's variability throughout the year via empirical orthogonal function analysis.

In addition to the response to wind-forcing, another mode of variability in the boundary current is that due to hydrodynamic instability. The potential vorticity structure of the current satisfies the necessary condition for baroclinic instability, and the mooring data reveal the presence of eddy features (dipole pairs). We now believe that the shelfbreak jet is a major source of the large number of eddies present in the interior Canada Basin. To investigate this further we did a detailed 3-D shipboard survey of one such anti-cyclonic eddy located offshore of the boundary current in summer 2004 (after recovering the mooring array). A lateral view of the feature is presented in Figure 2, which shows the layer thickness of the bounding isopycnals of the eddy. The eddy was centered at a depth of 150 m and was more than 90 m thick. Hydrographic analyses indicate that the eddy contained shelf-origin water that was anomalously cold, turbid, and high in fluorescence, nutrients, and dissolved organic carbon (Mathis et al., 2006). Radioisotopes indicate that the eddy had been spawned several months earlier (Kadko et al., 2006). We believe that the formation of these features represents a significant shelf-basin exchange mechanism. The dynamics associated with their formation and subsequent evolution will be investigated using the mooring and hydrographic data.

IMPACT/APPLICATIONS

The work to date has revealed the existence of the western Arctic shelfbreak jet and its different modes of variability. Baroclinic instability of the current appears to result in the formation of eddies that populate the interior western Arctic. This may, therefore, be an important means by which the cold halocline of the Arctic Ocean is ventilated, which in turn is crucial for the maintenance of the Arctic ice cover.

RELATED PROJECTS

This experiment is part of the western Arctic Shelf-Basin Interactions program (SBI), which is a multi-investigator, interdisciplinary program studying the manner in which the shelves interact with the open Arctic. See http://www.sbi.utk.edu/.

PUBLICATIONS

Pickart, R. S., T. J. Weingartner, S. Zimmermann, D. J. Torres, and L. J. Pratt, 2005. Flow of winter-transformed Pacific water into the western Arctic. *Deep-Sea Research II,* **52**, 3175-3198.

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Nikolopoulos, A. and R.S. Pickart, 2006. The western Arctic boundary current at 152oW: Transport, structure, and variability. *Deep-Sea Research II*, submitted.

Kadko, D., R.S. Pickart, and J.T. Mathis, 2006. Age characteristics of a shelfbreak eddy in the western Arctic and implications for shelf-basin exchange. *Journal of Geophysical Research*, submitted.

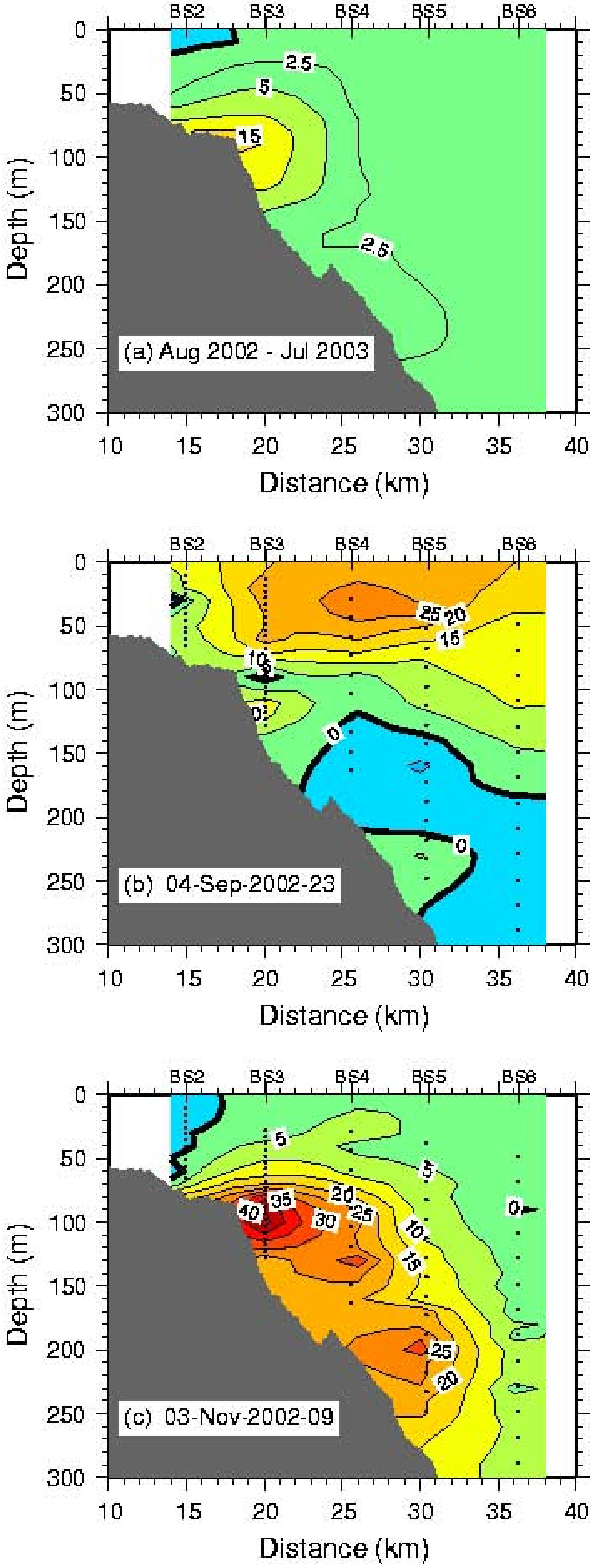

Figure 1: Different states of the western Arctic boundary current, showing the along-slope velocity in cms-1(positive values are eastward). (a) Mean over the time period August 2002 to July 2003. (b) Synoptic snapshot showing the surface-intensified state of the current in late-summer. (c) Snapshot showing the bottom-intensified state of the current in fall (extending into the deep Atlantic layer).

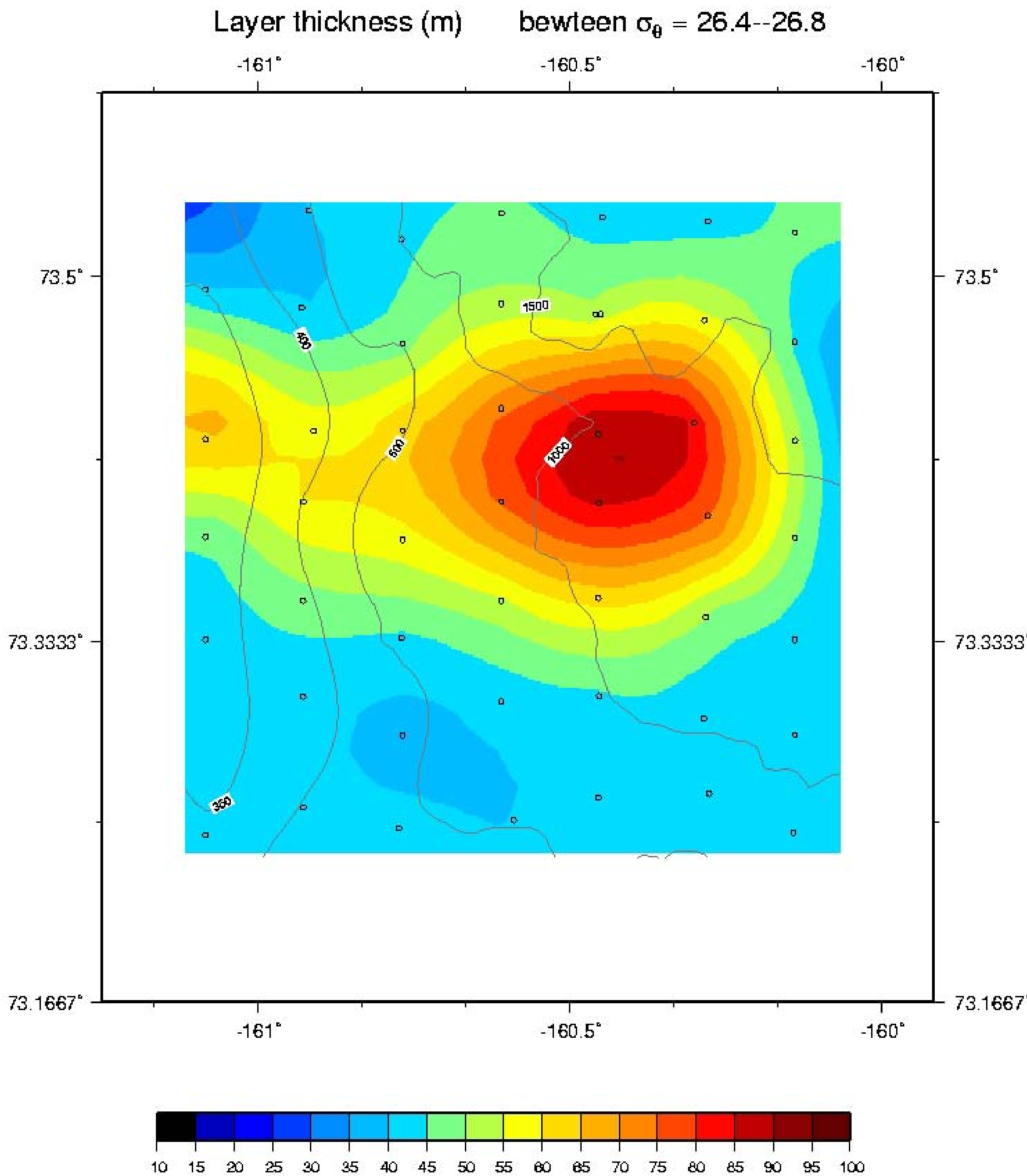

Figure 2: Layer thickness in meters (color) of the anti-cyclonic, cold-core eddy sampled in summer 2004 along the continental slope west of the array site. The bounding isopycnals of the layer are 26.4 kgm-3 and 26.8 kgm-3. The eddy has a thickness of >90 m at its center. The isobaths (in meters) are contoured in grey, and the locations of the expendable CTD stations are indicated by the open circles. The eddy survey took 15 hours to complete.