Exchange Processes Near Wide Arctic Canyons and Modeling Exchange Processes Near Wide Arctic Canyons

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LONG TERM GOALS

Understanding across-shelf exchange and shelf dynamics due to wind and buoyancy forcing.

OBJECTIVES

The main objective of this project is to describe and physically explain the dominant processes active within the wide Canadian Mackenzie Canyon prior to the onset of winter freezing. More specifically, the project will answer the following questions:

1. Do fresh Mackenzie shelf waters exit preferentially through Mackenzie Canyon?

2. How does the canyon circulation respond to local wind forcing?

3. Does an orographically induced wind-stress curl impact the canyon dynamics?

4. What are the spatial and temporal scales of vortices that populate this canyon?

APPROACH

Hydrographic surveys of the Mackenzie Shelf and Canyon took place in 1986, 1987, 1990, 1991, and 1994. **Figure 1** shows the study area. Prior ONR support enabled me to lead an 8-day experiment in 1994 aboard the *CCGS Arctic Ivik* which surveyed Mackenzie shelf, slope, and canyon. Surface drifters and 2 vessel-mounted acoustic Doppler current profilers (ADCP) measured the quasi-synoptic velocity fields for the duration of the experiment. Ongoing close collaboration with scientists at the Canadian Institute of Ocean Sciences in Sidney, BC (Drs. Carmack and Melling) ensures generous exchange of data, analyses, and ideas. The data analysis motivates a regional model study of the canyon dynamics that is supported by an AASERT grant. The AASERT student will configure and run the S-Coordinate-Rutgers-University-Model (SCRUM) for an Arctic shelf/slope region at the intersection of the narrow Beaufort and the wide Mackenzie shelf. Mackenzie Canyon separates these two regimes. Open boundary conditions will be similar to those used by Signorini et al. (1997) in a regional Barrow Canyon model. Ice dynamics are excluded at this point.

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ACCOMPLISHMENTS

All available historical hydrographic and forcing data from Canadian sources (Dr. Carmack) now resides at Rutgers University. Data from the 1994 experiment such as hydrographic (CTD and XBT), transmissometer, drifter, and 1228 kHz ADCP data are processed, calibrated, and quality controlled. ADCP mooring data (Dr. Melling) was used to estimate tidal variability to aid in the removal of tidal currents from the ADCP survey data (Münchow et al., 1992; Münchow, 1998a). We furthermore acquired forcing fields such as coastal sea level, Mackenzie and Peel river discharge, data on the position of a retreating ice edge, and winds from both Canadian regional data assimilation models and coastal point measurements. A highly qualified student (Hank Statscewich) was recruited for the AASERT modeling component this project.

SCIENTIFIC/TECHNICAL RESULTS

Hydrography from both 1986 and 1994 (**Figure 2**) reveal that fresh and thus buoyant Mackenzie Shelf waters extend almost entirely across the 80-km wide upper Mackenzie Canyon. In 1994 plume waters with densities σ_t<20 kg m^{-3} occupy a 15-m thick stratified surface layer that forms a surface front at km-20. We also measured current shear across this outcropping main pycnocline with a 1228 kHz ADCP. **Figure 3** shows that the rms. vertical current shear exceeds 10^{-1} s^{-1} within the main pycnoclines at 15 m depth. A second, shallower pycnocline at 5 m depth near km-70 also corresponds to a maximum shear layer. The shear is not sufficient, however, to overcome the strong vertical stratification, i.e., bulk Richardson numbers within both pycnoclines are larger than 1 and mixing thus is unlikely. In contrast, we find weaker vertical stratification but substantial shear on both sides of the surface front to vertically mix this body of water. In Figure 2 note the large vertical isopycnal excursions that exceed 50 m at depth. The frontal location thus does not only reflect surface processes even though these probably dominate. Similar vertical excursions occured in 1986 when the 32.0 and 32.2 psu isohalines were separated by more than 60 m within 10 km off the western flank of the canyon while they were separated by less than 5 m over the center of the canyon (not shown).

IMPACT FOR SCIENCE

The results of this and prior ONR projects (Münchow and Carmack, 1997; Münchow et al., 1998b) influenced the Western Arctic Shelf-Basin Interaction initiative that NSF and ONR jointly co-sponsor. The research will benefit both biological and chemical oceanographers that investigate the cycling and transport of bio-chemical compounds from the shallow shelves to the deep basins of the Arctic Ocean. The research may also impact questions related to the recently observed freshening of the surface polar mixed layer (McPhee et al., 1998) which, we hypothesize with Macdonald (pers. comm., 1998) and Weingartner et al. (1998) is caused by large across-shelf movement of buoyant Mackenzie River water through Mackenzie Canyon rather than global warming.

TRANSITIONS

None

RELATED PROJECTS

We closely collaborate with Dr. Signorini who presently conducts ONR funded regional model studies of the Barrow Canyon area to incorporate an ice component to the ice-free simulations reported in Signorini et al. (1997). Canadian and Russian researchers analyze mooring data from the canyon and slope region (Carmack and Kulikov, 1998).

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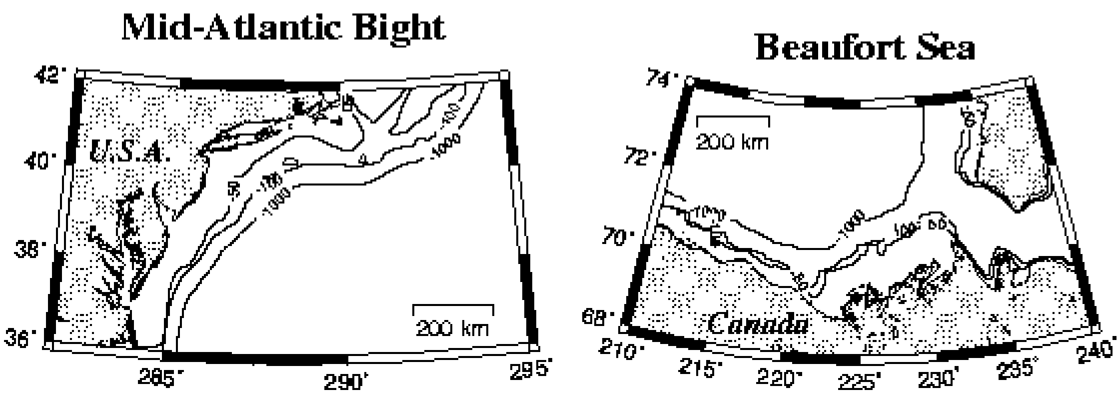

Figure 1: Map of the study area (right panel) along with the Mid-Atlantic Bight (left panel) on the same scale. The 50, 100, and 1000 m isobaths are shown as contours. Mackenzie Canyon is the roughly 100 km wide indentation of 50 and 100 m isobaths above the last letter of "Canada."

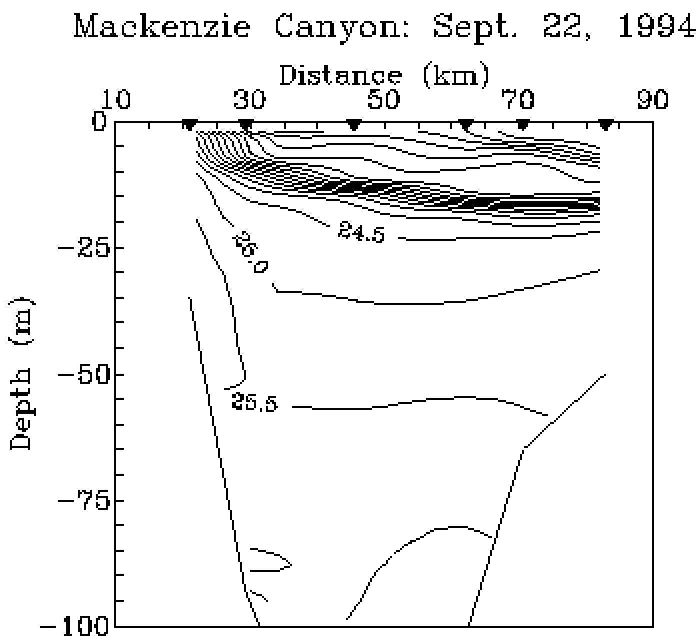

Figure 2: Density section across the upper reaches of Mackenzie Canyon in 1994. The section is roughly west to east, i.e., the wide Mackenzie shelf with its large fresh water discharge is to the right while the narrow Beaufort shelf is to the left. The triangles indicate station locations. The top 25 m of this section is also shown in Figure 3.

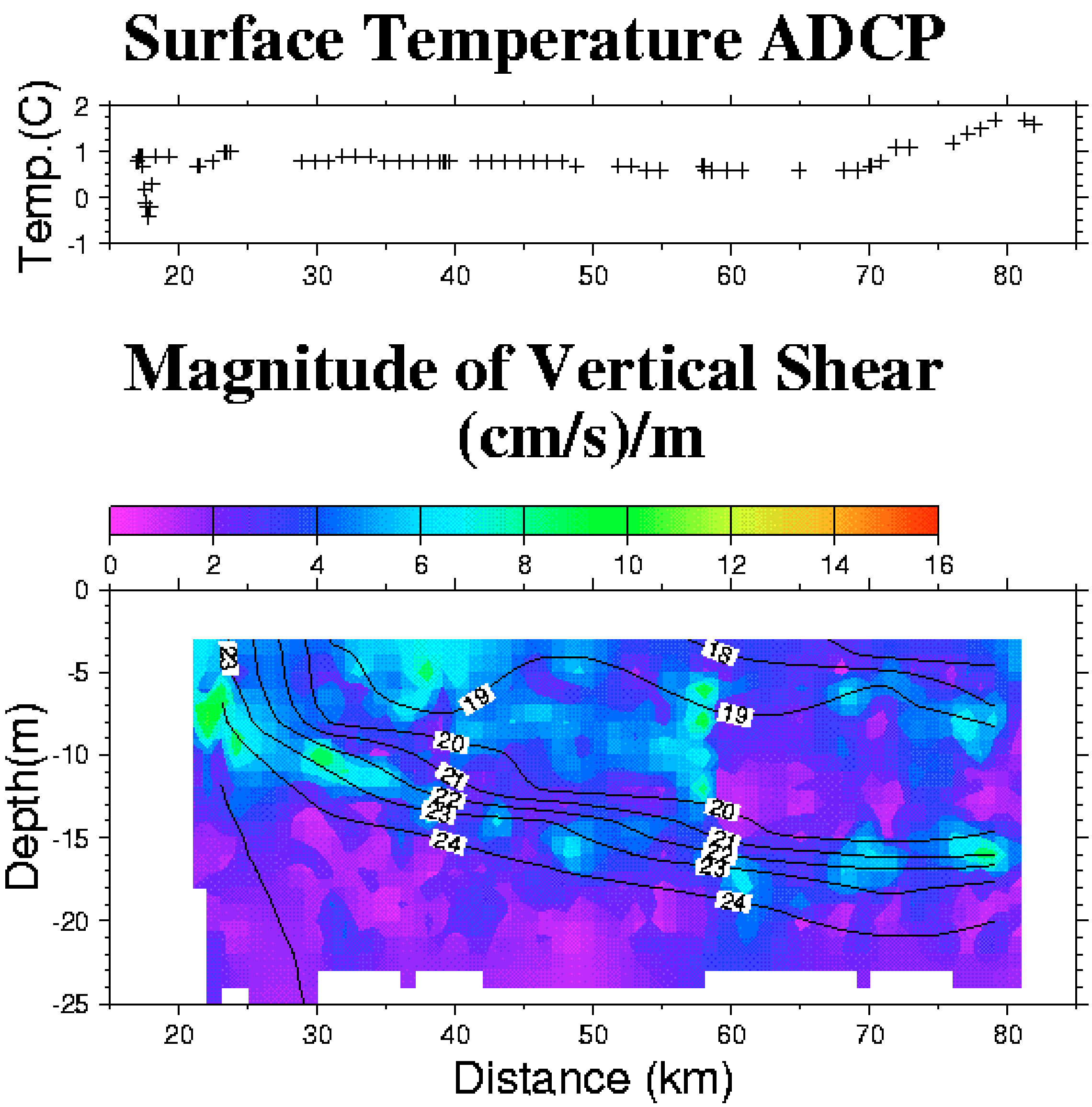

Figure 3: Section of vertical current shear (rms.) from vessel-mounted velocity profiling across the upper reaches of Mackenzie Canyon in 1994. Contours are isopycnals from vertical hydrographic profiles (Figure 2b). Note the close correspondence of enhanced vertical current shear with isopycnals both at about 15 m and, 5 m depth. The surface temperatures shown in the upper panel are taken from the ADCP transducers.