A Coupled Ice-Ocean Model of the Labrador Sea and Baffin Bay

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The Labrador Sea is a region of deep convection and formation of N. Atlantic Deep Water. Cold, fresh water flows from the Arctic through the Canadian Arctic Archipelago into Baffin Bay. Baffin Bay is ice-covered for about 10 months of the year and the Labrador shelf is seasonally ice-covered. To study this system and the potential interactions between these processes, we have implemented a coupled sea ice, ocean model.

INTRODUCTION

The ocean component of the model is the Princeton Ocean Model. The ice component is a multicategory Hibler model. The model resolution is 1/6° latitude, 1/3° longitude, and 16 vertical levels. The model bathymetry is shown in Figure 1.

To investigate the annual cycle, the model is driven by monthly, climatological atmospheric forcing from the NCEP/NCAR reanalysis.

Figure 1 The model domain and bathymetry. The flow is specified at open boundaries in the N. Atlantic and in channels entering northern Baffin Bay.

Figure 2 The temperature and salinity at 100 m in October at the start of the integration.

A realistic initial ocean temperature and salinity state are critical to the integration. The initial temperature and salinity (Figure 2) are derived from an objective analysis of archived data. Figure 2 shows the cold, fresh water in western Baffin Bay extending along the Labrador Shelf.

RESULTS: OCEAN

Results from integrating the model for one year are shown in Figure 3. The annual average of sea surface elevation and depth-averaged current vectors are drawn in the figure. The predominant feature is the W. Greenland Current following the bathymetry in the northern Labrador Sea and transforming into the southward flowing Labrador current. A fraction of the W. Greenland Current enters Baffin Bay along the east. Arctic water flowing through the Canadian Arctic Archipelago augments this current and forms the southward Baffin current exiting Baffin Bay along the west.

In Figure 4 the model currents are compared with annual averaged currents measured from a set of deployments by the Bedford Institute of Oceanography. Although the model simulates many of the large-scale features there are important differences between the model and observation that are the subject of ongoing study.

Figure 3 Annual averaged sea surface elevation and depth-averaged currents (with bottom contours at 1000 m intervals).

Figure 4 Annual averaged currents in Baffin Bay at 250 m depth (black) with measured currents from a BIO current measurement program (red). Bottom contours at 500 m intervals are drawn. The measured currents are between 100 m and 1000 m depth.

RESULTS: DAVIS STRAIT

Baffin Bay adjoins the Labrador Sea at Davis Strait. Cross-sections of annually averaged temperature, salinity, and the northward component of current are drawn in Figure 5. The temperature and salinity cross-sections show the relatively warm, salty, W. Greenland water in the east and the cold, fresh Baffin current outflow in the west. BIO has deployed a set of current meter moorings in Davis Strait. The transport (annually averaged) measured from this deployment is also shown in Figure 5 and compared with the model transport.

Figure 5 Cross-sections of annually averaged temperature (contour interval 1°C), salinity (contour interval 0.5), north component of velocity (contour interval 0.1 m/s), and transport at Davis Strait. The annually averaged measured transport from a BIO current meter array is also drawn.

RESULTS: SEA ICE

The annual cycle of sea ice concentration from the model is shown in Figure 6. Baffin Bay is largely ice-covered 10 months of the year. Ice forms in October, advances south, and reaches the Grand Banks southeast of Newfoundland in March. Ice then recedes northward. In Baffin Bay there is an east-west asymmetry related to the W. Greenland Current. The break-up of ice in summer in Baffin Bay starts from the north.

Ice thickness is a difficult quantity to measure directly or through remote sensing. The model mean ice thickness and ice velocity at the end of March are drawn in Figure 7. The variation in ice thickness over Baffin Bay is related to ice drift and heat flux from the ocean.

Figure 6 The annual cycle of model sea ice concentration.

Figure 7 Mean ice thickness and ice velocity at the end of March.

RESULTS: NORTH WATER

The North Water is a *polynya* (a region of recurring thin ice and open water in winter) in northern Baffin Bay. The North Water is an important habitat for wildlife and supports significant ocean productivity. The model shows relatively thin ice in the North Water (Figure 8). It suggests that the cyclonic wind and cyclonic ice drift cause thinning off northwest Greenland. The model also shows that the North Water is a region of enhanced ice formation and enhanced ocean heat flux arising from convective mixing from salt rejected during ice formation.

Figure 8 Mean ice thickness (contour interval 0.4 m) and ice velocity at the end of January in the North Water.

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