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This ASSERT grant was used to support James Pringle, a physical oceanography student in the MIT/WHOI Joint Program in Oceanography, through the successful completion of his Ph.D. thesis work and the publication of several papers from his thesis. Jamie completed his thesis in 1 June 1998 and took a postdoctoral position with Peter Franks (SIO), where he has developed a coupled 3-D physical-biological numerical circulation model to study biological processes on Georges Bank.

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Physical/Biological Coupling over the Continental Shelf

Robert Beardsley N00014-95-10746

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Presented next is the abstract of Jamie's thesis which is entitled "Cooling and Internal Waves on the Continental Shelf":

Part I

In order to begin to understand the behavior of an ice-free coastal ocean exposed to winter time cooling, the evolution of an initially homogeneous body of water undergoing uniform surface heat loss and wind forcing is examined. The dynamics of this model ocean are modulated by the intense vertical mixing driven by the surface cooling, which in the initially homogeneous ocean is sufficient to mix the entire water column in less than an inertial period. This strong vertical mixing prevents the formation of geostrophic flows and so flows are nearly down pressure gradient and downwind. Cross-shelf temperature gradients are formed by uniform cooling over water of differing depths, and these temperature gradients lead to cross-shelf density gradients. The cross-shelf density gradients and flows can prevent the cooling-driven vertical mixing from reaching the bottom when the cross-shelf bottom velocity becomes sufficiently large.

Once the surface cooling is prevented from mixing the entire water column, alongshore geostrophic flows form, and these flows can be baroclinically unstable. The unstable flow quickly can achieve a steady state in which the length scale of the eddies is governed by either the Rhines arrest scale or a frictional arrest scale, and the surface heat flux is balanced by a cross-shelf heat flux driven by the eddies. Scales are found for the cross-shelf density

gradient which results from this balance, and these scales are tested successfully in a numerical model. It is found with the numerical model that the balance between surface cooling and the cross-shelf heat flux can be attained in less than a winter with conditions typical of the Mid-Atlantic Bight.

Part II:

Linear internal waves shoal and are dissipated as they cross the continental shelf, and, in order to understand how this affects the internal wave climate on the shelf, internal wave solutions are found for a wedge-shaped bathymetry. These solutions for linear internal waves in the presence of linear bottom friction and barotropic alongshore mean flows are approximate; they are based on flat-bottom vertical modes, and the horizontal propagation is found by ray-tracing. It is found that bottom friction is capable of entirely dissipating the waves before they reach the coast, that waves traveling obliquely offshore are reflected back to the coast from an offshore caustic, and that without a mean current, the maximum distance an internal wave ray can travel along the coast is twice the distance from the shore to the offshore caustic.

The solutions for internal waves propagating over a wedge-shaped bathymetry are used to predict the evolution of an ensemble of internal waves whose properties match those of a Garrett and Munk internal wave spectrum at a point offshore. This is meant to be a simple model of the evolution of an oceanic internal wave spectrum across a continental shelf. The shape of the current ellipse caused by this ensemble of internal waves at a given frequency is found to be largely independent of frequency. It is also found that the orientation of the current ellipse is controlled by the alongshore mean currents and the "redness" of the oceanic internal wave spectrum. Because of friction, it is found that internal waves generated in the deep ocean are more likely to be important to the internal wave climate of narrow shelves than wide shelves.

The internal wave climate near two moorings of the Coastal Ocean Dynamics Experiment observation program is analyzed. It is found that the high frequency internal wave energy levels are elevated above the Garrett and Munk spectrum, and the spectrum becomes less red as one moves towards shore. The shape of the current ellipses is largely independent of frequency in the internal wave band, and the major axis is approximately perpendicular to the isobaths. The wave field is dominated by vertical-mode one waves. It is concluded that the internal wave energy is predominantly moving towards the shore from the shelf break, but that a significant portion of the internal wave energy over the continental shelf is generated over the continental shelf.