GENERATION OF INTENSE MESO-SCALE FLOWS OVER THE CONTINENTAL SHELF BY SHELF WAVE SCATTERING IN THE PRESENCE OF A MEAN ALONGSLOPE CURRENT

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In both the Black and Mediterranean seas, persistent narrow currents flow along the upper continental slope, roughly parallel to the local isobaths, in the direction of Kelvin wave propagation. These slope currents are accompanied by highly variable, mesoscale flow features with time scales of one to two weeks and spatial scales of O (10-100 km) which may persist in certain locations or propagate along the current, varying in both intensity and location. Particularly good examples may be found along the northwest Black sea shelf edge, where the Rim Current flows along the slope through a region of highly variable topography and coastline, and the Gulf of Lions in the northwestern Mediterranean. These mesoscale features are most often attributed to instabilities (barotropic and/or baroclinic) of the mean current as it encounters variable bottom topography or coastline. While instability processes undoubtedly play an important role in many cases, they may not be the only mechanisms which contribute to the development of these meso-scale features associated with slope currents. Sometimes meso-scale features are present along currents which appear too weak to be unstable. Furthermore, it is not always clear that the observed temporal and spatial patterns are consistent with the proposed instabilities. As an alternative mechanism, we have developed a linear, barotropic model which shows that the scattering of shelf waves in the presence of a narrow slope current may generate intense mesoscale currents in regions of strong alongshore topographic irregularities when the slope current is entirely stable. In the absence of a mean current, barotropic shelf waves may exhibit forward (long waves) or backward (short waves) energy flux propagation relative to the direction of phase propagation. The addition of the mean current enhances the shelf wave phase speeds due to the Doppler shift. This effect is small for long, low modes which travel much faster then typical mean current speeds. However, the Doppler effect is enormous for the shorter and/or higher mode waves which propagate slowly. In addition, only waves which travel faster than the maximum velocity of the mean current can exist as propagating modes. As a result, the backward propagating modes may be entirely eliminated, and the number of forward propa-gating modes can be severely limited. Figure 1 shows the effect that increasing the Rossby number has on wave frequency and the number of propagating modes. The Rossby number is defined as $\mathcal{R}o=\mathcal{U}_{max}/fL$ where $\mathcal{U}_{max}$ is the maximum velocity of the mean current, f is the Coriolis parameter and L is the width of the channel. The wave frequency of the lowest three modes is not altered appreciably over this range of Rossby numbers. However, the higher modes are consecutively eliminated as $\mathcal{R}o$ increases, until only the lowest three modes can propagate when $\mathcal{R}o > 0.05$. Changes in the mean current shear also alter the shelf wave dispersion properties and structure. This effect becomes especially notable for waves whose phase speed is close to $\mathcal{R}o$. In this case, the wave structure tends to concentrate in the vicinity of the mean current and contains small-scale features near the current axis.

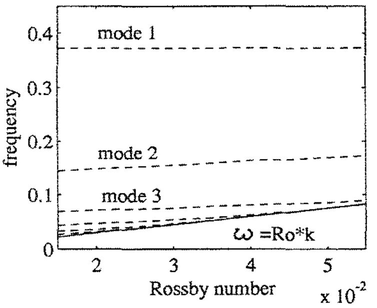

Figure 1 : Frequency ω versus the Rossby number $\mathcal{R}o$ for propagating modes at a fixed wavenumber k=1.5 (normalized by the channel width).

As the shelf wave encounters a region of varying topography/ coastline, the wave structure adjusts to satisfy the condition of no flow through the solid boundaries. This adjustment excites additional modes available at the incident wave frequency. If the mean current is absent, then a limited number of propagating modes exist at the incident wave frequency, with both forward and backward propagating waves possible. With the mean current present, only a few propagating modes may exist downstream of the scattering region, and reflection of the incident wave energy may not be possible. The regime can easily be reached in which the propagating modes which exist downstream of the scattering region are insufficient to provide the incident mode adjustment. In this case adjustment occurs through the generation of evanescent modes (e.g. NARAYANAN and WEBSTER, 1987) which do not propagate energy alongshore, but instead decay exponentially outside the scattering region, thereby introducing new spatial scales of the order of the topographic irregularities or even smaller. When the scattering is strong, the evanescent modes may be quite large, dominating the velocity field over the shelf and appearing as intense, isolated mesoscale flows. Figure 2 shows the increase in amplitude of these modes as the scattering becomes stronger. Evanescent modes can also produce a signal upstream of the scattering region, even when backward propagating modes do not exist, in agreement with the results of WILKIN and CHAPMAN (1990). In the present study the amplitudes of the evanescent modes are much larger relative to the incident and transmitted wave fields. We suspect that this mechanism may contribute to the generation of observed mesoscale flows over the shelf and slope in the presence of a mean alongslope current.

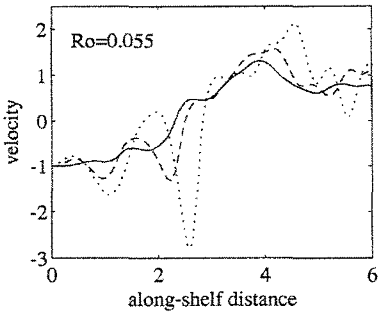

Figure 2: Along-shelf velocity component at the coast for cases of a shelf narrowing by a factor of (solid line) 1.25, (dashed line) 1.5, and (dotted line) 1.75. The velocity is normalized by the amplitude of the incident wave. The alongshelf extent of the scattering region is 1.3 to 2.5 for the two weaker scattering cases, and 1.6 to 2.8 for the strongest scattering case. Evanescent modes with wavelengths 1.3-1.5 are evident upstream and within the scattering region.

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