Comments "On the Effect of Bottom Friction on Continental Shelf Waves"

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21 May 1982

In current literature on continental shelf waves, frequent reference is made to the paper by Brink and Allen (1978) which invokes the mechanism of bottom friction to explain observed phase lags between offshore and nearshore currents. While there is little doubt that bottom friction tends to produce the desired effect in many, if not most, circumstances, it appears that the model of Brink and Allen may lead to erroneous results and, in fact, their numerical example illustrates this shortcoming of the model.

For the simplest model of wind-driven currents with accelerations balanced by wind and bottom stress, the current will lag behind the wind by a quarter of a period in deep water where frictional damping is small, while the current will tend to be in phase with the wind in shallow water where the wind stress is balanced primarily by bottom friction. One, therefore, would expect friction to cause offshore currents to lag behind nearshore currents in agreement with frequent observations. However, it is well known that the response to wind of nearshore currents including topographic wave effects is essentially similar to the familiar damped harmonic oscillator. Thus, for small damping corresponding to deep water, the phase will shift by half a period whenever the forcing frequency passes through one of the normal mode frequencies. In shallow water, the current will tend to remain in phase with the wind and hence offshore currents may lead nearshore currents for certain frequencies.

To illustrate this we may consider a variant of the exponential shelf model of Brink and Allen. For the sake of realism, the nearshore depth is modified to increase linearly from zero at the shore to a point offshore where it matches the depth and the slope of the exponential profile. Furthermore, the deep-water approximation for Ekman-type bottom friction is replaced by the more appropriate Ekman solution for water of finite depth. By straightforward numerical methods we may compute the periodic response of alongshore currents to winds of different frequencies. Fig. 1 shows results for the same shelf width and the same boundary conditions used by Brink and Allen, a wavelength of 3000 km, and an equivalent Ekman depth of 5 m.

The behavior of the solution is readily explained with reference to the inviscid solution. For periods shorter than the first normal mode period (~9 days),

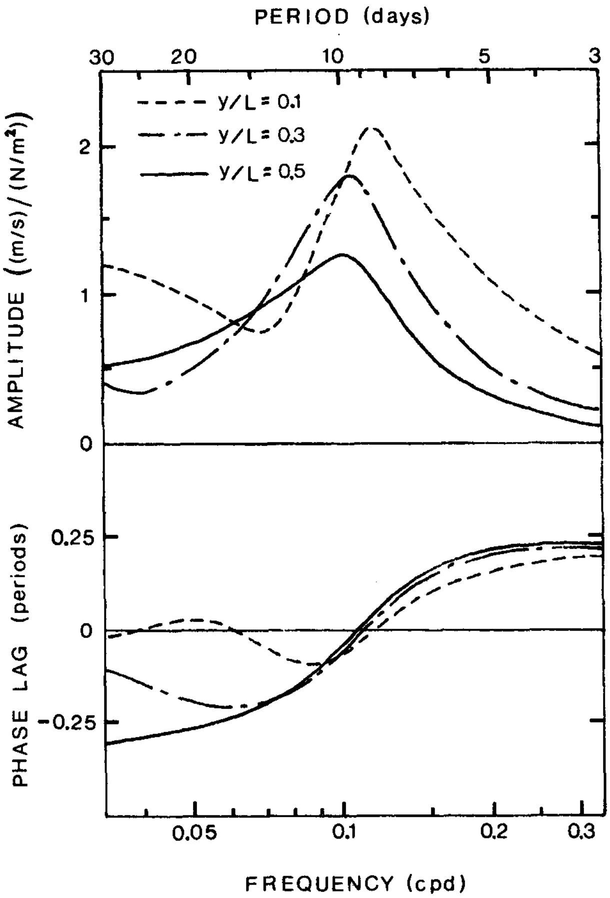

FIG. 1. Response of alongshore current to periodic wind forcing for the exponential shelf of Brink and Allen (1978) with linear depth variation nearshore, finite-depth Ekman friction with an equivalent Ekman depth of 5 m, and a wave length of 3000 km. The ratio y/L measures the offshore distance in terms of the shelf width.

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the inviscid current lags behind the forcing by a quarter of a period. When the forcing period becomes equal to the first mode period, resonance occurs and the phase shifts by half a period. As the forcing period is increased further, the second normal mode with its longer period (~33 days) but narrower width (about one-third of the shelf), will shift the phase of the nearshore current back again. In the presence of bottom friction, the phase shifts are basically similar but phase variations are strongly reduced for shallow water and low frequencies, and only the first mode resonance is able to overcome the damping effects of realistic values of bottom friction.

Comparing these results with the numerical example of Brink and Allen, we note that their choice of a 13-day forcing period for comparable model parameters is rather unfortunate. At this frequency, the nearshore current lags behind the offshore current, just the opposite of their result. Their model also allows for free waves but such waves cannot overcome the large friction used in their example. It must be realized, however, that atmospheric energy spectra are dominated by long planetary and cyclone waves. The frequencies of the corresponding shelf wave modes are so low that the phase lags would be expected to be of the type simulated by Brink and Allen's model.

REFERENCE

Brink, K. H., and J. S. Allen, 1978: On the effect of bottom friction on barotropic motion over the continental shelf. *J. Phys. Oceanogr.*, **8**, 919–922.