The Influence of Coriolis on Instability Wavelengths

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The Navy Coastal Ocean Model, a three-dimensional, hydrostatic, primitive equation model developed at the U.S. Naval Research Laboratory (Martin, 2000), is used to study the formation of instabilities on a density front over a shallow, sloping bottom. By applying a uniform and constant surface heat loss to the domain, density increases more rapidly along the coast, and an alongshore thermal wind current develops. Offshore undulations in this current will cause vertical stretching of the water column, and because potential vorticity must be conserved, relative vorticity must compensate by generating cyclonic motions.

The length scale of these instabilities is approximately three times the deformation radius, indicating that the current is baroclinically unstable (Gawarkiewicz & Chapman, 1995). The deformation radius is defined as $R_D = \frac{Nh}{f}$, where N is the buoyancy frequency, h is the local depth and f is the Coriolis parameter. As part of this project, we wish to study the influence of latitude on the instability wavelength by varying the Coriolis parameter. Three experiments are performed, at 60°N, 30°N and at the equator. The surface heat loss is set to 60 Wm^{-2} in all runs, and the topography (Figure 1) depicts an idealized shelf. The planetary beta effect is neglected, because the topographic beta (owing to the sloping bottom) is two orders of magnitude larger.

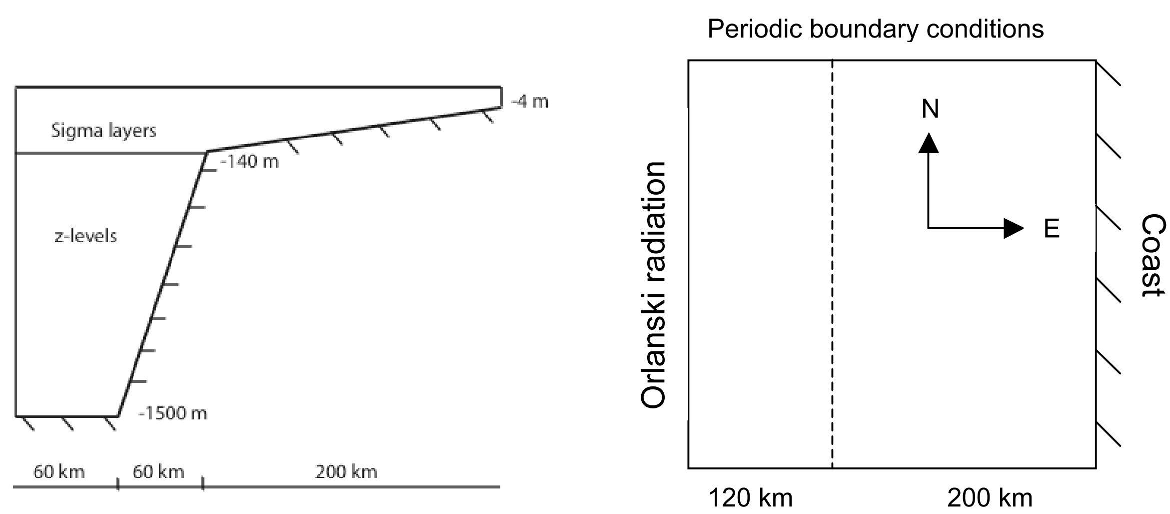

Figure 1. Topography (left) and domain (right) used in the numerical experiments.

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From the expression for the deformation radius, it is expected that the instability length scale decreases with increasing latitude. At the equator then, the scale should tend to infinity and no instabilities be present. Presented below (Figure 2) are sea surface density fields after 60 days of cooling for each latitude. Clearly, latitude plays an important role in determining the instability scale, but it also seems to affect the amount of cross shelf mixing, which is important for biology and chemistry.

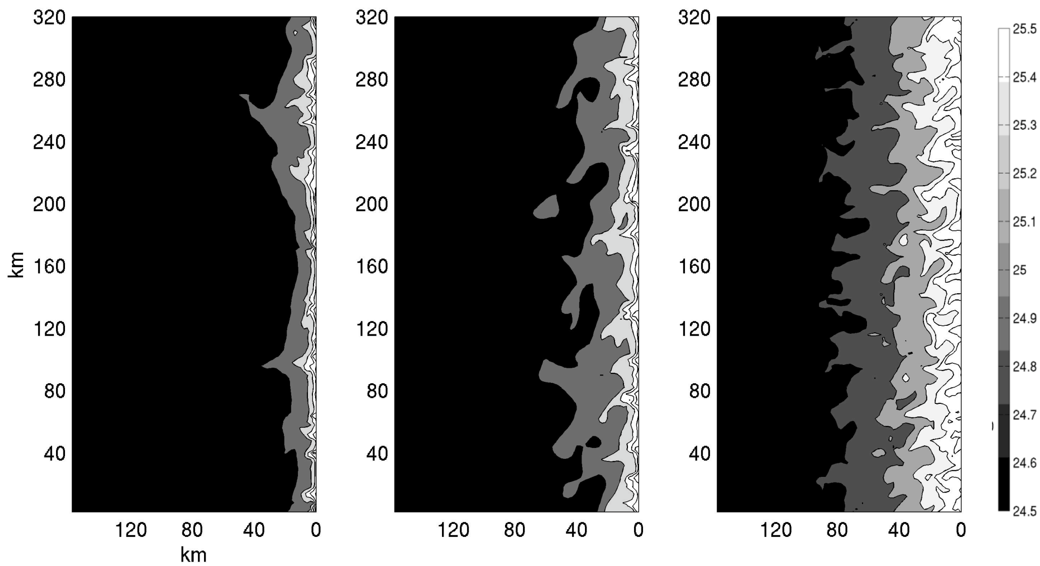

Figure 2. Sea surface density (in $kg\,m^{-3} - 1000$) after 60 days of cooling at the equator (left), 30°N (middle) and 60°N (right).

It is probably difficult to observe this in nature as clearly as it is shown here, since the presence of wind and variable topography will modify the instabilities, however satellite images of sea surface temperature may prove useful in this respect.

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References:

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