Climate Dynamics Class Assignment
Undercurrent Model

Due: April 5 2011.
Matlab file and directory: undergui.m /home/students/models/under/udergui

Instructions: Students are expected to provide significant supporting evidence for their assertions in the assignment below.

1. In the upper layers of the equatorial ocean, vertical mixing of horizontal momentum is particularly strong. A fair model of the steady shear (Ekman) flow \((u, v)\) in these layers is given by

\[
\begin{align*}
\epsilon u - \beta y v &= \frac{X}{\rho_0 H} \\
\epsilon v + \beta y u &= \frac{Y}{\rho_0 H} \\
w &= H(u_x + v_y)
\end{align*}
\]

where frictional dissipation is modeled with a linear “Rayleigh” term and where the layer is assumed to be of depth \(H\). The pressure terms in the first two equations are neglected because of the dominance of friction while the third equation is an approximation to the continuity equation. Derive a formula for the upwelling (vertical) velocity as a function of latitude and calculate the latitude for which it vanishes. Assuming for simplicity that only zonal windstress is important and is approximately constant discuss the variation of the extent of the overturning cell implied by these equations as the friction changes.

2. Consider the steady state linear solutions for the undercurrent model and take the dissipation to be 1.0. Which baroclinic modes are primarily responsible for the existence of the undercurrent? Which modes are responsible for the dynamic height pattern? Which component of the flow is mainly responsible for the equatorial upwelling? Provide clear evidence for all your observations.

3. As the linear (and non-linear) model adjusts to equilibrium one can see clear evidence of Rossby wave propagation. Which modes (horizontal and vertical) are apparently primarily responsible for this? Provide evidence from a range of different baroclinic mode truncations and dissipations. How does this transient behavior depend on mode truncation and on dissipation?

4. Consider the surface equatorial zonal flow. By exploring various truncations assess the importance of the various parts of the flow (the various baroclinic modes, the non-linear contribution and the Ekman component) to both the transient and steady state solutions.

5. What is the effect on the undercurrent strength and equatorial upwelling of varying the dissipation? Is the response linear? How do your conclusions regarding the upwelling compare with the analytical solutions derived in question 1 above?