Problem Set #8  
OCEAN 210: Ocean Circulation  
Assigned: Friday, November 20, 2009  
Due: Wednesday, November 25, 2009  

Regional Wind Stress, Ekman Transport, Pumping, and Suction

1. Consider a box of surface coastal ocean in the northern hemisphere as illustrated in Figure 1 below. The bottom of the box corresponds to the bottom of the Ekman layer, and the box is bounded on the East by a North-South running coastline.
   
   a) Sketch the wind direction and the direction of the resulting Ekman transport in the case of a sustained northerly wind (left two panels) and southerly wind (right two panels).
   
   b) Let’s say our ocean box is part of an infinitely long coast, so that there is no net north/south transport and no change in the dimensions of the box due to wind stress. In each case, what additional flow must enter or leave the box to balance the volume budget? Add these flows to frames c. and d. of Figure 1.
   
   c) Which vertical flow from part b) will result in more nutrients being available in the coastal photic zone? Consider the normal vertical gradient of nutrient concentration in the world ocean.

2. Now imagine the coastal box in Figure 1 is located at approximately 40° N, is 100 km wide (East-West) and has a 13 m s⁻¹ northerly wind blowing across it. What is the magnitude and direction of vertical velocity that will this produce? For this problem, take the density of air (ρ_air) to be 1.3 kg m⁻³, the density of the coastal water (ρ_water) to be 1027 kg m⁻³, and the kinematic viscosity (ν – pronounced “nu,” not to be confused with velocity V) to be 0.06 m² s⁻¹. Additionally, the drag coefficient of the surface ocean (c) is 1*10⁻³, and the Coriolis parameter at this latitude (f) is 9.4*10⁻⁵ radians per second.
   
   a) Calculate the wind stress, \( \tau = c \rho_{\text{air}} U^2 \).
   
   b) Calculate the depth of the Ekman layer, \( D_E = \sqrt{\frac{2 \nu}{f}} \).
   
   c) Now find the resulting average horizontal transport velocity (V_E) of the Ekman layer, given by \( V_E = \frac{\tau \sqrt{2 \pi}}{D_E \rho_{\text{water}} f} \).
   
   d) Using a volume balance (as you did conceptually in problem 1), calculate the vertical velocity produced by this northerly wind. Hint: draw out a three-dimensional box version of Figure 1, and keep in mind that the volume of the box is at steady state (Δvolume/Δt = 0) and that there is no net North/South volume flux.
Figure 1. Plan views (frames a. and b.) and vertical cross-sections (frames c. and d.) of our coastal ocean box for the Northerly (left) and Southerly (right) wind cases.