1) A hurricane at 30^{o} N has wind speeds of 50 m/s that extend 30 km from the eye.

   a) Draw a schematic of the winds and the resultant surface currents associated with the upper ocean's Ekman response.

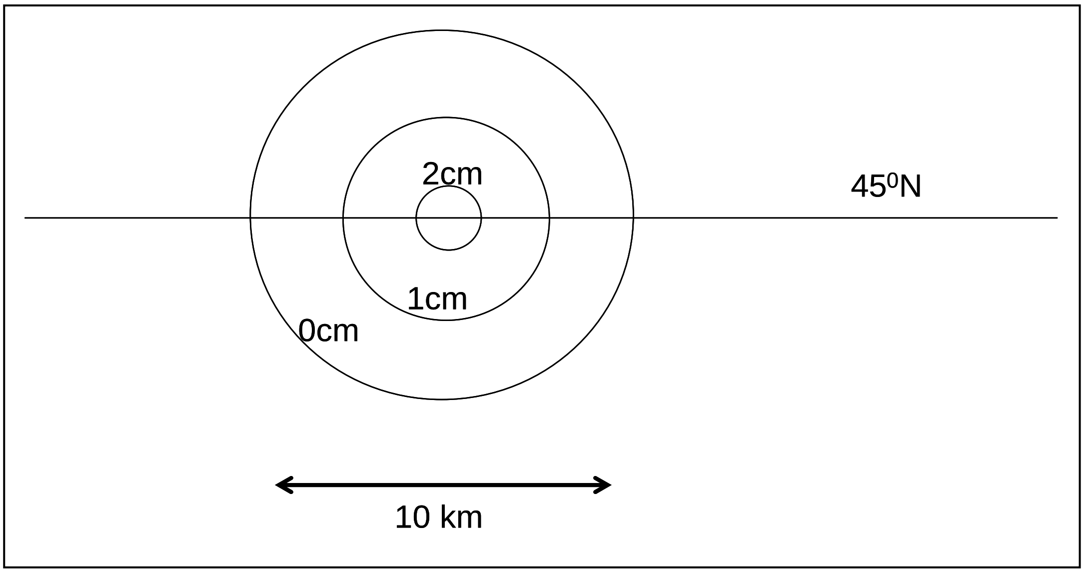
   b) Estimate the Ekman transport in the surface ocean associated with this storm

   c) Draw an x-z (vertical slice) section of the ocean across the storm showing both the Ekman transport (no need to try to draw spiral) and associated vertical velocities required to satisfy continuity.

   d) Assuming that the surface shear stress varies linearly from the maximum values on either side of the storm over a distance of 60 km, derive an expression for the vertical velocity (using the continuity equation) at the base of the Ekman Layer. What is the speed of the vertical velocity (express you answer in both m/s and m/day)

2) A column of fluid at 40^{o}N possesses a relative vorticity of -0.1 f (note that relative vorticity can be expressed as f since they have the same units). The column is 1000 meters thick and moves southward at mean speed of 0.5 m/s to 30^{o}N . During this transit the relative vorticity remains constant. Using the conservation of potential vorticity calculate the vertical velocity at the base of this column during this transit.

3) The sea-surface of a 2-layer ocean is elevated as shown in the plane view below. The center of the bump in sea-level is 2 cm higher than in the surrounding (ambient) ocean. The upper layer has a density of 1022 kg/m^3 and an ambient thickness (away from the eddy) of 100 meters. The



lower layer has a density of 1023 kg/m^3.

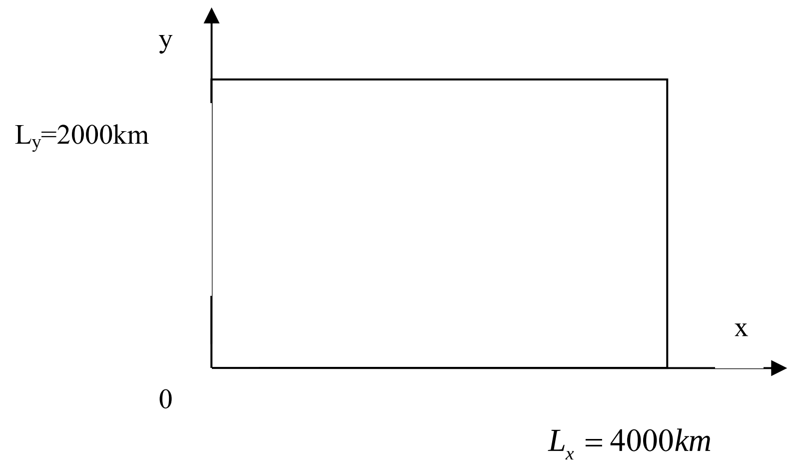
a) Assuming that the flow is geostrophic calculate the flow speed in the upper layer. Draw vectors on the diagram to indicate the direction of the flow.

b) What is the relative vorticity of this eddy?

c) In the lower layer the flow is zero because the thickness of the upper layer has changed in such a way to exactly cancel the pressure gradient associated with the surface slope. Draw an accompanying diagram showing how the depth of the upper layer varies underneath the eddy and estimate the thickness of the upper layer in the center of the eddy.

d) Using the principle of conservation of potential vorticity discuss what would happen to eddy's thickness and/or relative vorcitiy if this eddy moved to latitude 30^{o}N.

4) Consider the steady-state, wind-driven flow in a rectangular ocean:



Where: $f = f_0 + \beta y$

$f_0 = 10^{-4} s^{-1}$

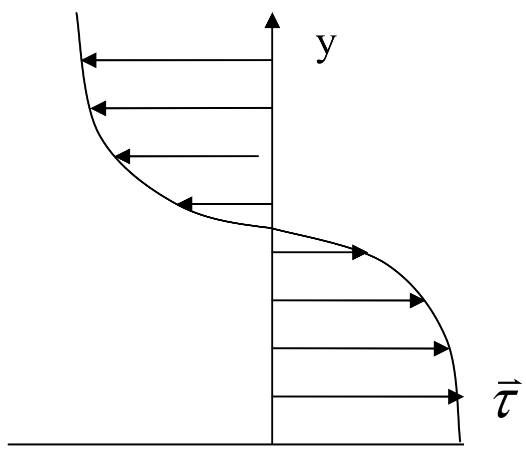
$\beta = 2\times 10^{-11}\ (ms)^{-1}$

$\rho =$ constant=1000kg/m^3

$H =$ constant $= 4000m$

Suppose further that the ocean is forced by an east-west wind stress of the form:

$$\vec{\tau} = (\tau^x, \tau^y) = \left\{ +0.2\cos\left(\frac{\pi y}{L_y}\right), 0 \right\} \ N/m^2$$



(a) According to Sverdrup's theory, the north-south component of velocity in the oceanic interior can be related to the curl of the wind stress. Using this Sverdrup balance, determine the meridional flow in the basin.

(b) Potential vorticity $\{Q = (\zeta + f)/H\}$ is conserved following the fluid motion; that is, it can change only due to inputs from the wind curl field and/or bottom friction. Ignoring bottom friction, describe how the meridional flow in part (a) is consistent with a change in Q due to the wind forcing.

(c) Mass (and therefore volume) must also be conserved. Since the basin is enclosed by solid walls, the net transport across any section (y = constant) must vanish. Therefore, there must be a return flow (a boundary layer) along either the eastern or western wall to balance the interior flow in (a). Using conservation of mass, estimate the volume transport in this boundary layer at $y = (L_y/2)$.

(d) With a linear bottom drag (i.e., Stommel's theory) is this boundary layer on the eastern ($x = L_x$) or western ($x = 0$) wall? Explain your dynamical reasoning.