EAS 475/587: Atmospheric and Ocean Dynamics

Assignment 2: Due in class Thursday, Oct. 26 at 2pm.

1. For each of the following, find the characteristic scales for the speed $\mathcal{U}$, length $\mathcal{L}$ and depth $\mathcal{H}$ describing the described fluid motion. From these scales, construct the appropriate Reynolds, Froude and Rossby number and so state the importance of viscosity, total hydrostatic balance and rotation upon the wave motion. In all cases you may assume the fluid's density is uniform and you may refer to the internet to estimate values that are not necessarily intuitive.

   (a) the lateral spread of a tablespoon of honey poured onto a countertop

   (b) a wave sloshing back and forth in your bathtub

   (c) the flow of the Mississippi entering the Gulf of Mexico

   (d) a hurricane approaching Florida

2. The 200 km wide and 1000 m deep Gulf Stream is 10^oC warmer than the surrounding Atlantic Ocean. Using thermal wind balance, derive an order-of-magnitude estimate for the difference in northward speed (in m/s) from the top to bottom of the Gulf Stream.

3. The Antarctic Circumpolar Current has an average eastward speed that changes from 20 cm/s to 0 cm/s going from 50°S to 40°S.

   (a) What is the (vertical component of) vorticity, ζ, associated with the current?

   (b) Taking f_0 to be the Coriolis parameter at 45°S, find the Ekman layer depth at the ocean bottom that would occur if the fluid acted like a uniform-density laminar flow but with an effective (turbulent) viscosity of $\nu = 10^{-2}\,\mathrm{m}^2/\mathrm{s}$,

   (c) Taking the current depth to be 4 km, what is its corresponding spin-down time (in years)?

4. The wind stress acting on the ocean surface is given by $\vec{\tau} = C_D \rho_a |\vec{u}| \vec{u}$ with ρ_a the density of air and $C_D = 10^{-3}$ the drag coefficient. Eastward winds decrease linearly in speed from 10 m/s to 0 m/s going from 40^oN to 60^oN.

   (a) Estimate the Ekman velocity, w_E (in m/s). Is this upward or downward?

   (b) Estimate the average vertically integrated meridional flow $\mathcal{V}_E$ (in m^2/s) resulting from Sverdrup balance. Is this flow northward or southward?

5. Near the equator, geostrophic balance as formulated for mid-latitudes does not apply because $f_0 \simeq 0$. Instead, there is a balance between zonal winds and pressure through the beta-effect.

   (a) Assuming winds about the equatorial Pacific Ocean blow westward with uniform speed U_0, find an expression for the meridional variation of pressure with northward distance y as it depends upon U_0, β, the air density ρ_0 and the pressure P_0 at the equator itself.

   (b) What is the direction of the consequent ageostrophic winds that result from the bottom stress of the ocean acting upon the winds? Are they equatorward or poleward?

   (c) The westward winds drive westward surface currents on the equatorial ocean. What is the direction of the ageostrophic currents that result from the surface stress of the winds acting on the ocean? Are they equatorward or poleward?