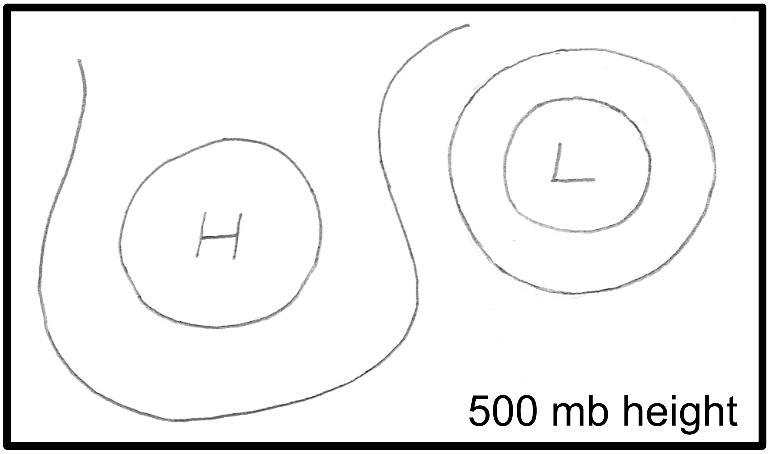
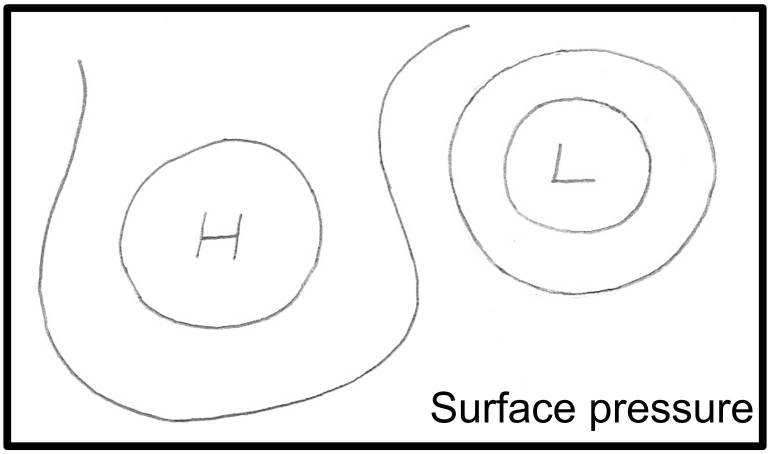
MAE578 Fall 2011 Homework #8

Effect of friction on geostrophic balance

1. The following are two hypothetical maps of 500 mb height (top) and surface pressure (bottom, assuming that the surface is flat), each for a large-scale flow over a region in the *Southern Hemisphere*. Try to draw the anticipated horizontal velocity vectors, in the fashion of Figs. 7.4 and 7.25, given the pressure/height pattern. For the surface map, you should consider the effect of friction. Provide a brief explanation of your drawing (e.g., by sketching the balance of forces for a selected wind vector). **(2 point)**





Conservation of angular momentum and Hadley circulation

2. Solve Prob 1 of Chap 8. **(2 points)**

3. Solve Prob 2 of Chap. 8. Qualitatively sketch the trajectory of an air parcel that starts at the upper troposphere at 10 °S and moves to 20 °N while preserving its absolute angular momentum. **(1 point)**

Heat transport by the eddies

4. Solve Prob 7 of Chap. 8. **(2 points)**

Rotating tank experiment

4.
(a) The *Rossby number*, *Ro*, is defined as the ratio of the "inertial term" ($-\vec{v}\cdot\nabla\vec{v}$ or $\partial\vec{v}/\partial t$) to the Coriolis force in momentum equation. For example, from the analysis in Sec 7.1 (p. 110), large-scale circulation in the atmosphere typically has *Ro* ~ 0.1, indicating the dominance of Coriolis effect (also see Fig. 7.5). Try to estimate the typical value of *Ro* for the flow fields in our rotating tank experiments (the 2nd and 3rd experiments with rotation turned on).
(b) Compare the magnitudes of the centrifugal and Coriolis forces in our rotating tank experiments. Suppose that you have a very delicate rotating tank that allows a precise control of the rotation rate and flow velocity, could you envision a situation when the Rossby number of the flow is small (ideally Ro ~ 0.1) and, at the same time, Coriolis force is significantly greater than centrifugal force? (Try to see what combinations of *U*, Ω, and *R* might lead to such a flow regime. Here, *U* is the velocity scale of the flow, Ω the rotation rate of the tank, and *R* the radius of the tank.)
(c) We have used the rotating tank to mimic the global atmospheric circulation. For example, while the tank is much smaller than the Earth, we dramatically increase its rotation rate such that the Coriolis effect is of first order importance for the flow in the tank. There are, however, some aspects of the real atmosphere that cannot be properly re-scaled to the rotating tank. Provide a few examples of those aspects and explain why it is difficult to re-scale them in the lab.
(2 points)

Note: (1) Since we have included centrifugal and Coriolis forces in our equation, we are considering a fluid system in the rotating frame; The "velocity scale" *U* is for the velocity as measured by an observer rotating with the tank. It should not be confused with the "absolute velocity" of the fluid which would be on the order of Ω*R*. In our experiments, we did not have a direct measurement of *U* but a reasonable number to use would be a few cm/s, based on tracking of colored dye in the water. (2) The length scale of the flow, *L*, needs not be the same as the radius of the tank, *R*. For the last part of the problem, however, we want *L* to be large in order to make *Ro* small. Then, a natural choice would be *L* ~ *R*.