Problem Set 5
ATM 316: Dynamic Meteorology I
October 21, 2014
DUE Tuesday October 28 at beginning of class

1. Suppose we have a cylindrical tank of water on a turntable. The radius of the tank is r_0 and the depth of water is z_0 initially. We switch on the turntable motor and the tank starts rotating at a fixed rate. As we have seen, if we wait for a few minutes the tank will come into equilibrium in solid body rotation with a parabolic slope of the free surface.

a) Derive an expression for the height of the water surface as a function of radial distance $h(r)$ in terms of z_0. [Hint: consider the total volume of water in the tank]
b) If $r_0 = 1$ m and $z_0 = 30$ cm, calculate the rotation rate necessary to raise the water at the outer edge of the tank to $h = 2\ z_0$.
c) Express that rotation rate in terms of a rotational period, i.e. the length of time required for a single rotation.

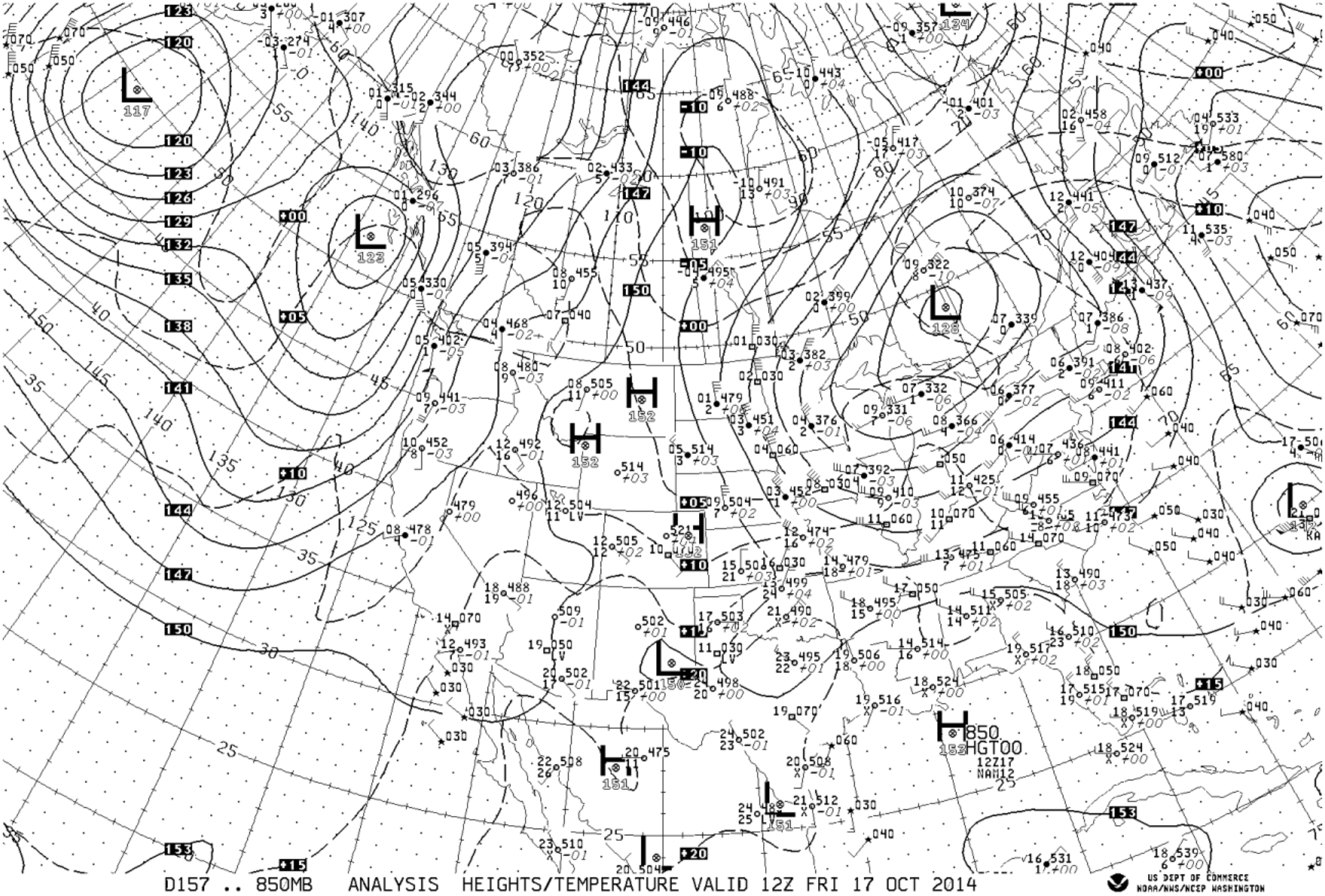
2. Read sections 1.3 – 1.3.2 in your Holton and Hakim book. Then comment on the following:

a) Suppose that the Earth suddenly stopped rotating one day but didn't change shape. If we then placed a ball on the surface of the Earth somewhere in the mid-latitudes (e.g. here in Albany), which way would it start rolling? Why? To answer this question, suppose that the entire surface is covered by a smooth plain with no mountains and valleys.
b) Now imagine that the Earth rotates at twice its usual rate (i.e. each day is 12 hours long). What would happen to the ball in this case, and why?
c) Thinking about your answers in (a) and (b), would you describe the center of our rotating water tank (where we found the free surface to be lowest) as analogous to the equator or the pole of a rotating planet? Why?

3. Consider an air parcel sitting at the equator, and at rest with respect to the rotating Earth.

a) Calculate the absolute velocity of the air parcel as seen from outer space. The radius of the Earth is approximately 6.4×10^6 m.
b) Calculate the centrifugal acceleration of the air parcel. Is it large or small relative to acceleration due to gravity?
c) If the air parcel were located in the mid-latitudes rather than the equator, would its centrifugal acceleration be larger or smaller than what you just calculated? Why?
d) What would the Earth's rotational period have to be (in hours) in order for the magnitude of the centrifugal acceleration at the equator to be equal to the magnitude of the gravitational acceleration?

4. See the attached 850 hPa analysis, which shows the geopotential height field (highs and lows are equivalent to high and low pressure) along with wind barbs. Choose four different places on this map that look interesting to you, and at those locations, sketch the direction of (a) the horizontal pressure gradient force, and (b) the coriolis force. (You might want to use pencils for your sketches in case you change your mind).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