ATM 240 – Fall 2008

Problem set #7 — 30 pts — Due: 25 November 2008

1. Jet stream acceleration and maintenance. In this problem the zonal mean eddy momentum flux convergence is compared with the angular momentum conservation in a poleward ageostrophic flow. Consider figure 5.7a. At 30N, from 75E to 135E, the wind at 200 hPa accelerates from 45 to 70m/s.

a. (2 pts) Evaluate the acceleration in the flow over the indicated longitude range by finding the value of $u^{\#}/\{r*\cos(\varphi)\}\ \partial u/\partial\lambda$. Use the average value of u for $u^{\#}$.

b. (1 pt) Estimate the ageostrophic wind V_a from this balance: $f V_a = u/\{r*\cos(\varphi)\}\ \partial u/\partial\lambda$.

c. (4 pts) Use zonal mean observations of [u'v'] to estimate $-\{1/r\}\ \partial\{[u'v']\cos(\varphi)\}/\partial\varphi$ at two latitudes: 30N and 40N. [u'v'] = 28.42 m^2/s^2 at 27.5N, = 39.23 at 32.5N, = 38.94 m^2/s^2 at 37.5N, and = 31.11 at 42.5N. Compare the acceleration found in part a with the accelerations found in part c.

2. Eddy Kinetic Energy Generation. Using the closed system model of Fig 4.21 as a guide, estimate the following energy-related quantities. The "box" is 800 mb deep and is a rectangle with sides: 2000 km in the east-west direction and 1000 km in the north-south direction.
Assume these things about the **eastern half** of the domain:

the surface low exactly covers only the eastern half of the domain.
the volume average virtual temperature is 264 K.
the average surface P = 1000 mb on the eastern side;
the average top pressure is 200 mb on the eastern side
the volume average efficiency factor is $\varepsilon = 0.02$
the horizontal average rain rate is 1.5 cm/day.
the eddy wind components are given by $v' = G(p,t)\sin(\gamma)$ and $u' = -G(p,t)\cos(\gamma)$ where γ is a compass angle measured from true north. If p is in mb, then $G(p,t)=U(t)\ (\{p-600\}/400)$.

a. (3pts) Estimate the total latent heat energy release rate (Q) in the eastern half of the domain. You may use latent heating and density of liquid water at 0^oC. Q has units J/s.

b. (3 pts) Estimate the volume average heating rate (q) in the eastern half of the domain. q has units K/s. The following formula is helpful:

$$Q \text{ (from part 1a)} = \iiint C_p\, q\, dM = C_p\, q \iiint dM$$

c. (1 pt) Using q from part b, estimate the volume average T change over 24 hours.

d. (4 pts) Assume that **half** the diabatic energy conversion from the rainfall is simultaneously converted into kinetic energy. Estimate the volume average vertical velocity (ω) above the surface low. (Your answer should be in Pa/s.) Note that using (4.31), we are assuming that:

$$\varepsilon Q/2 = \{-\varepsilon\omega/g\} \iiint \alpha\, dP\, dx\, dy$$

e. (5 pts) Using (4.34) as a guide, set the local derivative of eddy KE in the eastern half equal to the baroclinic conversion ($=\varepsilon Q/2$, from part d). Assume that the storm is initially weak, with wind magnitude U(0)=3 m/s. What is the wind magnitude $U(\tau)$ after 24 hours? Express your answer in m/s.

f. (3 pts) Assume that the rain continues even as the low reaches maturity (fig 4.22). To simplify matters, assume that the information is the same as above with these three exceptions: $\varepsilon = -0.02$ (since the low now has a cold core); U(0) =23 m/s; and the vertical structure is barotropic: G(p,t)=U(t). What is the wind magnitude (U) after 24 hours in this case?

g. (4 pts) Efficiency factor ε was specified above. Estimate it from the following information at 850hPa. Global mean temperature T_m=273K and temperature averaged over the low is T_8=275K. Static stability $S = -\Delta\theta/\Delta P = 3\times10^{-4}$ K/Pa. Find θ_m, θ_8, and use S to find the pressure P_m of the θ_m surface over the low. Since the reference pressure is P_r=850 hPa, $\varepsilon = 1 - (P_r/P_m)^{\kappa}$ where $\kappa = R/C_p$.

NOTE: all homework is to be done by you as an INDIVIDUAL: no 'group' efforts, please. For written answers, please use a word processor, so that penmanship is not an issue. Equations and derivations can be *neatly* hand-written. Full credit requires proper units be included. Any plot must be completely and unambiguously labeled, including title and axes. Show ALL math steps.