EAS 422
Atmospheric Dynamics

The 2nd one-hour examination April 18, 2003

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Total 135 points

1 (60 pts) Let v be the tangential wind of a circular vortex with $v > 0$ ($v < 0$) denotes the counterclockwise (clockwise) flow. The centrifugal force in the circular vortex is v^2/r, the Coriolis force fv, and the pressure gradient force in the radial direction is $-1/\rho\partial p/\partial r$. The balanced flow equation for the circular vortex is

$$\frac{v^2}{r} + fv = \frac{1}{\rho}\frac{\partial p}{\partial r}. \tag{1}$$

Discuss the following balanced flows; include your answer the balance of forces in mathematical form, force balance diagram, sign of flow (clockwise or counterclockwise or both), and a brief description of the flow.
(a) Geostrophic flow
(b) Cyclostrophic flow
(c) Inertial flow; what is the period of the inertial flow?
(d) Gredient flow (normal high)
(e) Gredient flow (normal low)
(f) In what fundamental way does gredient flow differ from (and similar to) geostrophic flow.

2 (15 pts)
(a) Discuss and sketch a diagram for thermal wind balance.
(b) Discuss the relationship between the turning of the geostrophic wind with height and horizontal temperature advection.
(c) Why the upper level westerly becomes more intense during the winter time?

3 (10 pts) Explain the trajectories and streamlines.

4 (15 pts) The vector vorticity equation can be written as

$$\frac{\partial \zeta}{\partial t} = -\mathbf{V}\cdot\nabla\zeta - \zeta(\nabla\cdot\mathbf{V}) - \zeta\cdot\nabla\mathbf{V} + \nabla\times(-\frac{1}{\rho}\nabla p), \tag{2}$$

where ζ is the absolute vorticity.
(a) What is the difference between the relative vorticity and the absolute vorticity.
(b) Discuss the meaning of each term in equation (2).
(c) Give 3 meteorological examples for the terms in equation (2).

5 (35 pts) A rough approximation to the tangential wind distribution in a tropical cyclone is the Rankine vortex

$$v(r) = \begin{cases} v_{max}\left(\frac{r}{r_{max}}\right), & \text{for } 0 \leq r \leq r_{max}; \\ v_{max}\left(\frac{r_{max}}{r}\right), & \text{for } r_{max} \leq r \leq \infty \end{cases}, \tag{3}$$

where r is the radius, v_{max} the maximum tangential wind, and r_{max} the radius of maximum tangential wind. The vorticity is given by

$$\zeta = \frac{\partial r v}{r \partial r} = \frac{v}{r} + \frac{\partial v}{\partial r}. \tag{4}$$

(a) Calculate the following as function of radius.
 (i) relative vorticity
 (ii) shear vorticity
 (iii) curvature vorticity
 (iv) circulation about a circle of radius r

(b) Sketch as a function of radius
 (i) tangential wind
 (ii) relative vorticity
 (iii) circulation