ATM 612 Mid-Term Exam (10/23/17)

For all exam questions, assume the Coriolis force is zero

1) (10 pts) Buoyancy is fundamental to all convection, but is also a scale dependent process, becoming less effective as the scale of convection increases. Using appropriate equations, describe why this is.

2) (15 pts) Multicellular convection tends to be enhanced in environments with strong low-level shear. What process(es) contribute to such enhancement?

3: (30 pts) A supercell can be distinguished from an ordinary buoyant convective cell based on it's development of a quasi-steady, mid-level rotating (cyclonic or anticyclonic) updraft(s) that propagate(s) off the hodograph, to the right or left of the mean environmental vertical wind shear vector.

A) (20 pts) Using the vorticity equation, diagnostic pressure equation and vertical momentum equation, describe the physical processes that contribute to generating such mid-level updraft characteristics for an environment with unidirectional vertical wind shear.

B) (10 pts) How does the inclusion of directional environmental vertical wind shear alter the above described storm evolution.

4: (15 pts) For the three hodographs (A-C) included on the attachment, add the storm motions that might be expected for any mature convective cells that could develop with the given shear profiles. Include the mean motion(M), as would be expected for an "ordinary" convective cell, as well as the motions for a cyclonic, "right-moving" (R) or anticyclonic "left moving" (L) supercell, if the shear magnitude and profile is sufficient to support such convective modes. Also indicate whether the cyclonic or anticyclonic supercell would be expected to be dominant for the given shear profile. Assume thermodynamically favorable conditions for convection for all of the cases.

5: (30 pts) Supercells often produce significant rotation (mesocyclone) near the surface that can evolve through a process that appears similar to an occluding larger-scale cyclone.

A) (8 pts) Draw a schematic of the low-level storm structure associated with such an occluding supercell, including the general reflectivity structure, appropriate streamlines and any storm-generated surface boundaries. Also indicate where a tornado would be most likely to occur.

B) (12 pts) Research has shown that the source of such low-level rotation is quite different than that associated with the mid-level updraft mesocyclone. Using the vorticity equation and circulation theorem, describe the source of this low-level rotation.

C) (10 pts) Less than 20% of supercell storms with significant low-level mesocyclones in nature go on to produce tornadoes. What factors may be limiting the ability of such storms to generate tornadoes?

The following equations may be useful:

$$\frac{\partial v}{\partial t} + v \cdot \nabla v = -C_p \overline{\theta}_v \nabla \pi + Bk \tag{1}$$

$$B \equiv g \left[\frac{\theta'}{\overline{\theta}} + .61(q_v - \overline{q}_v) - q_c - q_r \right] \tag{2}$$

$$\nabla \cdot (C_p \overline{\rho} \overline{\theta}_v \nabla \pi) = -\nabla \cdot (\overline{\rho} v \cdot \nabla v) + \frac{\partial B}{\partial z} \tag{3}$$

$$\begin{aligned} \nabla \cdot (C_p \overline{\rho} \overline{\theta}_v \nabla \pi_{dn}) = & -2\overline{\rho} \left[\frac{\partial v}{\partial x} \frac{\partial u}{\partial y} + \frac{\partial u}{\partial z} \frac{\partial w}{\partial x} + \frac{\partial v}{\partial z} \frac{\partial w}{\partial y} \right] \\ & - \overline{\rho} \left[\left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial y} \right)^2 + \left(\frac{\partial w}{\partial z} \right)^2 - \frac{d^2 ln \overline{\rho}}{dz^2} w^2 \right] \end{aligned} \tag{4}$$

$$\nabla \cdot \left(C_p \overline{\rho} \overline{\theta}_v \nabla \pi_B \right) = \frac{\partial \left(\overline{\rho} B \right)}{\partial z} \tag{5}$$

$$\frac{dw}{dt} = -C_p \overline{\theta}_v \frac{\partial \pi_{dn}}{\partial z} + \left[-C_p \overline{\theta}_v \frac{\partial \pi_b}{\partial z} + B \right] \tag{6}$$

$$\frac{d\zeta}{dt} = \omega_H \cdot \nabla_H w + \zeta \frac{\partial w}{\partial z} \tag{7}$$

$$\frac{d\eta}{dt} = -\frac{\partial B}{\partial x} \tag{8}$$

$$\frac{d}{dt} \left(\frac{\omega \cdot \nabla \theta_e}{\rho} \right) = 0 \tag{9}$$

$$C \equiv \int_C v \cdot dl = \int_S (\nabla \times v) \cdot dA \tag{10}$$

$$\frac{dC}{dt} = \int_C Bk \cdot dl \tag{11}$$