

**Second Exam  
Mesoscale Meteorology (METR 4433)  
April 19, 2005**

**Total 100 Points  
Time to complete the test: 75 minutes**

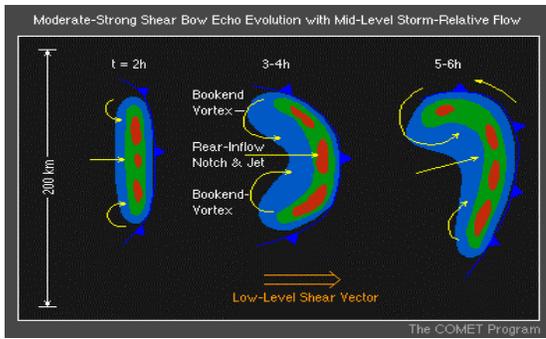
**Please Read the Questions Carefully and Be Sure to Answer All Parts!  
Use sketches to illustrate your points when necessary.**

**Brief answers**

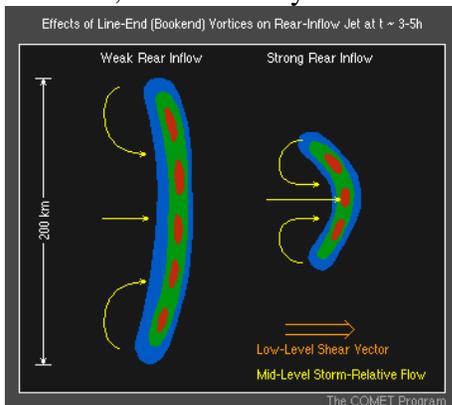
**1. (Total 20%) Bow Echoes**

- (a) (15%) Describe the typical life cycle of a severe bow echo in the Northern Hemisphere. Describe the morphology of the system as it might appear on a radar display during three different stages of its life cycle: developing, symmetric phase, and asymmetric phase. Draw a diagram to illustrate each of these stages. What happens to the relative magnitudes of the cyclonic and anticyclonic bookend vortices as the bow echo becomes more asymmetric, and why? What controls the direction and speed of propagation of the bow echo?

Answer: Here is basically what I was looking for as far as diagrams are concerned. In the developing stages, a bow echo can start as a line of storms or a discrete cell, perhaps a supercell, that grows upscale with time. As the system becomes more mature, a rear-inflow jet and cyclonic and anticyclonic bookend vortices develop on either end of the line. The storm takes on a characteristic bow shape in this phase. On radar, a low reflectivity notch may develop on the rear of the system behind the apex of the bow, indicating the descent of the drier rear-inflow jet into the stratiform region and evaporation of hydrometeors. As the system enters into the asymmetric stage, the cyclonic bookend vortex becomes dominant, due to the concentration of planetary vorticity (the Coriolis forcing), which is of the same sign as the northern cyclonic vortex. (The anticyclonic southern vortex weakens for the same reason, since the planetary vorticity is of the opposite sign. ) The speed of the bow echo is controlled by the strength of the cold pool, which is very strong in bow echoes, thus causing a faster propagation relative to other storms. The bow echo tends to propagate in the direction of the low-level shear vector.



(b) (5%) All other things being equal (i.e. shear, instability, updraft intensity), which would you expect to have stronger surface winds at the apex of the bow, a relatively large bow echo, or a relatively small one? Why? Draw a diagram to illustrate your answer.



The main reason here is that in a smaller bow echo, the bookend vortices are closer together, so their combined circulations additively enhance the rear inflow jet, which can cause stronger surface winds if the rear-inflow jet extends to the surface. In a larger bow echo, the vortices are further apart, so their combined effect is much less on the rear inflow jet.

## 2. (Total 20%) Squall line Dynamics

According to the RKW theory, what is the most favorable environmental condition for long-lasting squall lines and why?

Answer: The RKW theory says that the optimal condition for long-lasting squall lines exists when the environmental wind profile has its **sheared confined to the lowest 2-3 km** layer, and the **circulation induced by the vorticity in the low-level inflow is balanced by the circulation of the opposite sign** that is generated by the horizontal buoyancy gradient at gust front. Under such a condition, an updraft with zero net vorticity would form above the gust frontal lifting hence resulting in a **deep upright updraft**, creating a favorable situation for long-lasting squall line. A vorticity budget analysis provides an optimal condition for long-lasting squall line:  $C = \Delta U$ , where C and U are ....., respectively. Key words of the answer are highlighted in bold.

### 3. (Total 30%) Supercell Storm

- (a) (10%) Explain why the late spring is the favorable season for supercell storms over the central great plains. You need to discuss the synoptic scale weather pattern and the environmental conditions that are favorable for such storms.

**High pressure system** located off the coast of SE US, **southeasterly low-level flow** brings into the central great plains **warm moist air from the Gulf of Mexico**.

Mid-latitude **short wave disturbances** propagating out of the Rockies, and **strong upper level westerly flow**.

**Strong vertical shear** with cyclonically curved hodographs.

- (c) (10%) Why does bounded weak echo region (BWER) form in intense supercell storms?

Because of **very strong updraft** – resulting **suspension of hydrometeors at the upper level**.

**Mid-level rotation** causes hydrometeors wrapping around the updraft.

How does it affect the reflectivity patterns in the horizontal cross section at the low-level, and the vertical cross-section through the weak echo region? Illustrate your points using sketches.

**Hook echo pattern** at low levels. **Weak echo region surrounded by stronger echo** in the vertical cross-section.

- (d) (10%) Draw the conceptual models for LP and HP supercell storms, in terms of low-level flow pattern and key features, and annotate the features.

See powerpoint presentation. Low-level flow features and echo patterns are expected.

### 4. (Total 30%) Supercell Storm Dynamics

The equation for the vertical vorticity  $\zeta$  is

$$\frac{\partial \zeta}{\partial t} = -\vec{V} \cdot \nabla \zeta + \zeta \frac{\partial w}{\partial z} + \left[ \xi \frac{\partial w}{\partial x} + \eta \frac{\partial w}{\partial y} \right],$$

where  $\xi$ ,  $\eta$  are the  $x$  and  $y$  components of vorticity, respectively.

- (a) Assume a convective storm develops in an environmental with constant east-west unidirectional wind shear, with the low-level winds being easterly and upper-level winds being westerly. Before storm splitting occurs, at the middle levels, what kind of

vertical velocity and vertical vorticity pattern do you expect? Why? Use equations and/or sketches to explain.

One updraft or  $w$  maximum center. Positive (negative) vorticity maximum on its south (north) side. Due to tilting of environmental vortex tube which is in N-S direction.

(b) When storm splitting occurs, how does the sideward propagation of the split cells affect the storm dynamics? Give your reason.

Creates storm-relative streamwise vorticity in the low-level inflow as storm-relative low-level flow that is a component parallel to the low-level vortex tube is created by the sideward propagation - this increases potential of vertical rotation - increased rotation creates additional upward PGF  $\rightarrow$  stronger updraft.