1. **(20% Total) Squall Lines.**

   According to the study of Bluestein and Jain, what are the different ways by which squall lines typically form?

2. **(30% Total) Multicell Storms**

   a) (15%) What factor(s) determine the period of cell regeneration in 2-D multicell storms and how?

   b) (15%) Illustrate the ways by which the cell motion and cell regeneration affect the propagation of a cluster of multicell storms.

3. **(30% Total) Supercell Storm Dynamics.**

   a) (15%) For a supercell storm developing in an environment with strong unidirectional vertical shear (i.e., the one with straight hodograph), explain why the storm tends to split.

   b) (15%) How does sideward propagation of split cells in this case affect the dynamics of these cells?

4. **(40% Total) Helicity Dynamics.**

   Recall that the storm-relative environment helicity is defined as the storm-relative helicity in the storm environmental integrated over the lowest 3 km of atmosphere. It is given by

   \[
   SREH = -\int_{0km}^{3km} \hat{k} \cdot \left[ \vec{V}_r \times d\vec{V} \right],
   \]

   where \(\vec{V}_r \equiv (\vec{V} - \vec{C})\) is the storm-relative velocity.

   a). (10%) Using the above information and your knowledge of analytic geometry, show that the SREH is equal to minus twice the signed (i.e., positive or negative) area swept out by
the storm-relative wind vector between 0 and 3 km on a hodograph. Note that, by convention, an area is positive (negative) if it is swept out counterclockwise (clockwise). Hint: The area of a triangle is equal to the base length times height divided by 2.

To make the problem simpler for you, let's only consider the case where wind observations are available at the 0 and 3 km levels therefore the hodograph is a straight line between the 0 and 3 km levels.

b). (10%) If the storm-relative velocity at 0 and 3 km levels are \( \vec{V}_{r1} = (u_{r1}, v_{r1}) \) and \( \vec{V}_{r2} = (u_{r2}, v_{r2}) \), respectively, show that SREH can be calculated from

\[
SERH = u_{r2}v_{r1} - u_{r1}v_{r2}.
\]

c). (10%) For the following hodograph and a zero storm-motion vector, calculate SERH using both methods given in question a) and b).

d) (10%) Why does larger SERH tend to promote stronger rotation in thunderstorms?

5. (40% Total) Tornado Dynamics

Briefly summarize our current understanding on the origin and intensification of low-level rotation that lead to the genesis of supercell tornadoes.

6. (40% Total) Hurricanes

a). (20%) What usually happen when a hurricane makes landfall?

b). (20%) Briefly discuss the CISK and Air-sea interaction theories of hurricane formation and maintenance.

Good Luck!

Feel free to ask if you have problem understand the questions.