COMET Computer-based Module: **Anticipating Convective Storm Structure and Evolution** Summary Page--Key Points to Remember

Buoyancy Processes

- When vertical wind shear is weak, buoyancy processes are the dominant control on convective updrafts and downdrafts
- Positive contributions to buoyant energy come from potential temperature perturbations and water vapor
- Updrafts dominate during the early portion of an ordinary cell's life cycle; downdrafts dominate in the later stages
- Thermodynamic diagrams are essential tools for estimating vertical buoyancy distribution, which has important implications for both updraft and downdraft strength, including entrainment effects
- CAPE provides a quantitative estimate of buoyant energy, especially when calculated using an appropriate low-level average of both moisture and temperature
- CAPE can be used to estimate updraft strength (Wmax)
- CIN can either prevent convective storm development entirely or delay initiation until maximum heating is reached
- Downdraft and near-surface outflow strength depend on both precipitation loading and evaporation processes
- In general, drier mid-levels are associated with stronger downdrafts

Cold Pool/Shear Interactions

- Vertical wind shear is necessary in the creation of organized long-lived convection
- The propagation speed of a cold pool depends on its magnitude and depth
- Buoyancy gradients generate horizontal vorticity
- The lifting created by cold pool circulation alone may be insufficient to allow a surface parcel to reach the LFC (unless the LFC is quite low)
- When low-level wind shear is weak, environmental inhomogeneities determine where new cells will be triggered along a spreading cold pool
- When low-level wind shear is strong, new cell development is favored downshear of the low-level shear vector
- The deepest lifting occurs when the horizontal vorticity generated along the cold pool's leading edge is nearly equal in magnitude to and has the opposite sense rotation as the horizontal vorticity associated with the low-level vertical wind shear

• In midlatitudes, 0 to 2.5 km shear values of 10-20 m/s are generally sufficient to promote lifting deep enough to favor new cell development along the downshear portion of a gust front (5 m/s can be sufficient in tropical environments). Additional shear above this layer can also enhance lifting

Updraft Tilt

- Vertical wind shear acts to tilt an updraft
- When the vertical wind shear is strong, it initially has a detrimental effect on a developing updraft, especially when the updraft is weak (it can tear the cloud apart)
- The magnitude of the storm tilt depends on both the updraft strength and the strength of the vertical wind shear
- Buoyancy gradients on the sides of a towering cumulus create horizontal vorticity on both sides of the rising updraft
- When there is not wind shear, the horizontal vorticity on either side is in balance and the updraft rises vertically
- When the shear is stronger, the updraft will tilt toward the side of the storm that is generating the same sign of vorticity as that associated with the environmental wind shear (i.e., it tilts downshear)
- Precipitation in a sheared storm is distributed downshear of the updraft and has a characteristic tight reflectivity gradient near the updraft
- Storm tilt alone does not appreciably extend the storm's lifetime

Straight Hodograph Dynamic Processes

- Tilting changes horizontal vorticity into vertical vorticity where ever there are horizontal gradients in vertical velocity (across and updraft or downdraft)
- Stretching processes increase or decrease existing vertical vorticity in regions where there are vertical accelerations (in an updraft or downdraft)
- An updraft growing in a sheared environment changes low-level horizontal vorticity into vertical vorticity within the storm, creating a mid-level vortex couplet (visualize tilting a vortex line)
- As the downdraft develops, the up-tilted vortex line can be tipped downward in the center, creating another vortex couplet with each new rotation center having an opposite sense rotation as the pair created by the initial updraft
- The above series of events occurs in all storms growing in vertically sheared environments, creating transient mid-level rotation centers when the wind shear is weak and significant mid-level rotation when the wind shear is strong
- These small-scale rotation centers are associated with lower pressure regardless of the direction in which they rotate
- Given significant unidirectional shear (a primarily straight hodograph), the pressure perturbation field associated with the initial mid-level vortex couplet contributes equally to the development of cyclonically and anticyclonically rotating updrafts on the right and left flanks of the storm, respectively

- This process leads to symmetric storm splitting with new supercells propagating to the left and right of the mean shear vector
- With at least 20-25 m/s of shear over 6 km AGL, and with sufficient CAPE, storms may evolve into supercells in approximately 1 hour
- Given a straight hodograph, both left- and right-moving supercells can be anticipated by plotting points 3-8 m/s off the mean wind perpendicular to the 0-6 km mean shear vector
- The ground-relative motion of both the left- and right-movers can vary substantially depending on the orientation and location of the wind profile on the hodograph plot

Curved Hodograph Dynamic Processes

- In a sheared environment, relative low pressure is created downshear of an updraft
- When the hodograph is curved, this contribution to the pressure perturbation field may have an additive affect on the pressure pattern created by the mid-level vorticies, ultimately favoring one storm flank for new updraft growth
- If the hodograph has clockwise curvature, these pressure forces combine to create enhanced upward vertical motion on the right flank of the storm (with respect to the mean wind shear vector) and to inhibit the updraft on the left flank, leading to a predominate right-moving, cyclonically rotating supercell storm
- Although climatologically less likely, when the hodograph has counterclockwise curvature, the pressure forces combine to create enhanced upward vertical motion on the left flank of the storm and inhibit the updraft on the right flank leading to predominate left-moving, anticyclonically rotating supercell storms
- When a convective cell exhibits deviate motion compared with nearby cells, it is a good indicator that supercell processes are occurring within that cell, independent of whether the hodograph is straight or curved
- Supercell storm motion can be estimated by a point 3-8 m/s off the mean wind perpendicular to the 0-6 km AGL mean shear vector. It will be to the right given a clockwise-curved hodograph and to the left given a counterclockwise-curved hodograph
- Environmental factors other than the shear profile may also play a role in determining which supercells survive, such as proximity to a frontal boundary or interaction with nearby storms

Note 28 July 1997: Italicized bullet above was originally in error in both the module and the first version of this page.

Helicity

- Storm-relative environmental helicity (SREH) provides another way to examine a storm's rotational properties once a realistic supercell storm motion has been either anticipated or observed
- When the storm-relative inflow is perpendicular to the environmental horizontal vorticity vector, the vorticity in the inflow is termed crosswise

- When the storm-relative inflow is parallel to the environmental horizontal vorticity vector, the vorticity in the inflow is termed streamwise and is characterized by helical flow
- Purely crosswise vorticity results in the updraft and vertical vorticity maxima being uncorrelated along the same flank of a steady-state storm, leading to a rotating updraft
- SREH is a measure of the streamwise vorticity in the storm's inflow layer (often taken as 0-3 km AGL), so if the value is high (usually > 150), it is likely that the storm will exhibit a rotating updraft
- When depicted on a hodograph, it is obvious that the storm motion chosen greatly affects the SREH value
- SREH values may increase dramatically once the storm has developed significant off-hodograph propagation. The values will be positive for a right-mover and negative for a left-mover
- Care must be taken when using automated SREH values which make a fixed assumption about storm motion, frequently 75% of the mean wind speed and 30 degrees to the right, regardless of the hodograph length or shape

Near-Surface Rotation

- Supercell storms have strong mid-level rotation due to the tilting and stretching of horizontal vorticity associated with the environmental vertical wind shear
- Recent research has shown that an important contributor to the generation of the near-surface rotation is the tilting and stretching of horizontal vorticity that is generated baroclinically by the storm itself
- A mature supercell can generate significant buoyancy gradients across both its FFD and RFD cold pools and thus create a near-surface source of horizontal vorticity
- This baroclinically generated horizontal vorticity can be much stronger than the vorticity associated with the environmental vertical wind shear
- Some of the low-level vorticity generated baroclinically and ingested into the updraft is streamwise. It plays an important role in near-surface rotation leading to possible tornadogenesis, especially when the vorticity is subjected to stretching within the low-level updraft
- If the low-level rotation becomes stronger that the rotation in mid levels, a downward-directed vertical pressure gradient can locally enhance the RFD outflow. This is referred to as the occlusion downdraft
- This process may continually repeat itself leading to a series of tornadoes from a single supercell storm

Forecast Parameters

• Parameters and indices that measure buoyancy and vertical wind shear can be valuable forecast tools when trying to anticipate storm type

- It is important to use forecast indices as a means to anticipate the processes that may occur in an environment rather than just as threshold values for determining the likelihood of one storm type or another
- CAPE provides the best estimate of updraft strength and buoyancy processes since it is an integrated measure of an environment's convective instability
- CAPE is most useful when examined for not only its value, but also for its vertical distribution
- The lifted index (LI) is another means of quickly assessing instability. Larger negative values indicate the mid-levels of the atmosphere are more unstable. LI does not provide an integrated measure of instability and can be misleading
- Hodograph length and shape over a given depth are the best means for determining an environment's vertical wind shear characteristics and the implications for anticipating convective storm structure and evolution
- Given a steady state storm and a realistic storm motion, SREH provides a measure of the streamwise vorticity in that storm's environment, and thus a tendency for that storm to have a rotating updraft
- BRN is a measure of the buoyancy/shear ratio
- The EHI parameter is based on the product of CAPE and shear
- SREH values > 150, BRN values between 10 and 50, and EHIs >1 are all indicators of environments that are conducive to supercell processes