Severe Weather Forecasting Tip Sheet: WFO Louisville

Vertical Wind Shear & SRH

- 0-6 km bulk shear > 40 kts – supercells
- 0-6 km bulk shear 20-35 kts – organized multicells
- 0-6 km bulk shear < 10-20 kts – disorganized multicells
- 0-8 km bulk shear > 52 kts – long-lived supercells
- 0-3 km bulk shear > 30-40 kts – bowing thunderstorms

SRH

- 0-3 km SRH > 150 $m^2 s^{-2}$ = updraft rotation becomes more likely
- 0-3 km SRH > 300-400 $m^2 s^{-2}$ = rotating updrafts and supercell development likely

BOTH

- 0-6 km shear < 35 kts with 0-3 km SRH > 150 $m^2 s^{-2}$ – brief rotation but not persistent
- 0-6 km shear < 35 kts – any storm that acquires rotation will not persist for very long
- 0-6 km shear > 40 kts with 0-3 km SRH < 150 $m^2 s^{-2}$ – a supercell can still develop
- 0-6 km shear > 40 kts with 0-3 km SRH > 150 $m^2 s^{-2}$ – updraft rotation may be strong
- When 0-6 km shear is 30-40 kts (i.e., marginal), but the atmosphere is very unstable
- CAPE > 2500 J kg^{-1}, supercells can still form. This is especially true along low-level boundaries.

BRN Shear

- BRN > 40 – multicell storms are more likely
- BRN 10-50 – supercells possible – higher numbers especially if boundary present
- BRNSHR > 40 $m^2 s^{-2}$ – supercells; BRNSHR > 80-100 $m^2 s^{-2}$ – long-lived supercells

Long Track Tornadoes

- Mean BRNSHR = 275 $m^2 s^{-2}$
- 0-1 km bulk shear ≥ 30 kts/0-1 SRH = 261 $m^2 s^{-2}$
- 0-8 km bulk shear: ≥ 60-70 kts
- 5 km flow: average values around 60 kts
- Supercell motion: average 30-40 kts
- 500 mb height falls: average -90 meters
- 500 mb jets: average speeds 75kts
- Location: 250 miles south and east of surface

Short Track Tornadoes

- If low-level shear is large, but 0-8 km shear, storm motion, and mid-level flow are relatively weaker, then short track tornadoes are more likely.
- Often form along or interact with warm fronts, stationary fronts, or outflow boundaries
- Location is usually within 100-200 miles of surface low

Movement of Supercells

- Long-lived supercells often move parallel to low-level boundary for a long period. Storm longevity is often compromised when it crosses boundary into a colder air mass, although tornado potential can persist into the colder air mass. Storms move to right of mean wind due to dynamical processes.

Hodograph shape:

- Straight: splitting storms; Curved (clockwise): Right moving supercell favored to persist

Discrete versus lines:

- Discrete: deep layer shear vectors cross a boundary at a ≥ 45° angle
- Discrete supercell at southern end of line: deep layer shear vectors cross boundary at 90 degrees
- Discrete right moving supercell at upshear end: deep layer shear vectors parallel to boundary
- Discrete: flow within 2-6 or 2-8 km layer (or 500 mb) is perpendicular to boundary
- Linear: flow within 2-6 or 2-8 km layer (or 500mb) is parallel to boundary
- If shear becomes concentrated in lowest few kilometers, bow echoes are more likely
- If shear is distributed through a deep layer of atmosphere, supercells are more likely

Tornadic Supercells

- Unstable warm sector air mass, with well-defined warm and cold fronts (i.e., strong extratropical cyclone)
- Strong mid and upper-level jet observed to dive southward into upper-level shortwave trough, then rapidly exit the trough and cross into the warm sector air mass.
- Pronounced upper-level divergence occurs on the nose and exit region of the jet.
- A low-level jet forms in response to upper-level jet, which increases northward flux of moisture.
- Intense northwest-southwest upper-level flow/strong southerly low-level flow creates a wind profile which is very conducive for supercell development. Storms often exhibit rapid development along cold front, dryline, or pre-frontal convergence axis, and then move east into warm sector.
- Most intense tornadic supercells often occur in close proximity to where upper-level jet intersects low-level jet, although tornadic supercells can occur north and south of upper jet as well.

Hodograph:

- The 0-1 km hodograph spike is relatively straight (no curvature). Above the spike, the hodograph then displays stronger turning and curvature.
- 0-1 km bulk shear > 20 kts
- 0-1 km SRH > 150-300 $m^2 s^{-2}$
- Boundary layer RH > 65%
- LCL heights ≤ 1000 m (3000 ft)
- Most of the 0-3 km SRH is concentrated in 0-1 km layer
- Low LCL heights (large boundary layer RH) favor warm RFDs and tornadogenesis
- High LCL heights (low boundary layer RH) favor cold RFDs and tornadogenesis-failure

Importance of Boundaries:

- Horizontal vorticity enhancements necessary for low-level mesocyclogenesis as air rapidly accelerates into updraft, which appears to precede tornadogenesis if other key structures develop (e.g., warm RFD).
- Tornadogenesis requires augmentation of the horizontal vorticity associated with the mean shear by the baroclinic vorticity generated by preexisting boundaries.
- Storm-boundary interactions may not be necessary when the environmental shear is very large.

Mergers:

- Watch for cells merging into the inflow flank of supercells. This is often a precursor to tornadogenesis.

Mini-Supercells

- Surface warm sector with dewpoints ≥ mid 50s within roughly 200 miles of a cold core 500 mb low
- Surface boundary intersection or focus area (usually east/northeast/southeast of surface low) is located within about 200 miles of a cold core 500 mb low
- Surface thermal ridge extends north/northeast into boundary intersection area east of surface low
- Equilibrium level is below 300 mb (low top storms)
- Total CAPE in sounding 1000 J kg^{-1} or less; 0-3 km CAPE = average 100-200 J kg^{-1}
- 0-6 km shear, 0-1 km shear, and 0-1 km SRH are usually lower in magnitude when compared to more traditional tornadic supercell environments. But, because instability is located closer to surface, tilting and stretching of available environmental horizontal vorticity can be intense, and may compensate for relatively weaker sheared environment
- Radar attributes are less pronounced than traditional supercells, but large hail, tornadoes, and damaging wind can still occur

Non-Mesocyclone Tornadoes

- Form through low-level vertical stretching of pre-existing vertical vorticity along slow-moving wind shift boundaries via thunderstorm updrafts positioned over the boundary. Non-supercell tornado events often occur in environments associated with higher LCL heights and weak 0-1 km SRH and deep layer shear
- Lapse rates in the lowest 3 km are > 8.0 C km^{-1}
- CIN is < 10 J kg^{-1}
- Level of Free Convection (LFC) height around 1500 m

Wet Microbursts

- Environments characterized by moderate to large CAPE values, steep low-level/sub-cloud lapse rates (generally in 0-3 km layer), large boundary layer moisture values (i.e., high surface dewpoints, mixing ratio, and precipitable water values), and weak vertical wind shear
- Surface theta-e to minimum theta-e aloft: differential of ≥ 20 deg
- 850-500 mb lapse rate ≥ 6.5 C km^{-1}
- Lowest 50-100 mb dewpoint depression ≥ 10 degrees
- Wet bulb lapse rate below 700 mb ≥ 5.8 C km^{-1}

MCS Maintenance

Continue:

- 0-10 km shear vector magnitude > 40 kts
- 3-8 km lapse rates > 6.5 C/km
- MUCAPE in lowest 300 mb > 1700 J kg^{-1}
- 3-12 km mean wind > 35 kts
- Significant trailing rain behind leading line within squall line/QLCS

Dissipation:

- MCS moves away from 850 mb theta-e source, slow weakening

Large Hail

- -10 to -30° C layer is the hail growth zone; look for a large CAPE within -10 to -30° C layer
- Rotating updraft – the longer hail resides within hail growth zone, the greater the potential for large hail

Supercells & Hail

- Large boundary layer moisture
- 700-500 mb lapse rates > 7.0 C km^{-1}
- Moderate to large CAPE, including “fat” CAPE for rapid acceleration
- 0-6 km shear > 40-50 kts (includes speed and directional)
- 0-3 km SRH > 150-200 m^2 s^{-2}

Non-supercell hail events

- Large boundary layer moisture
- 700-500 mb lapse rates > 7.0 C km^{-1}
- Large CAPE, including within hail growth zone
- Freezing level and Wet Bulb Zero level < 10500 ft

Melting issues

- Large depth between LCL and freezing level (i.e., deep warm cloud zone to promote melting)
- Freezing level and wet-bulb zero levels are > 10500 ft
- High RH in the lowest several km’s
- Lapse rates 850-500 mb are moist adiabatic
- Hail falling within heavy rain core; limited vertical wind shear

Flash Flooding

- High moisture content extends through at least 500 mb
- PW values >150 pct of normal; high surface dewpoints
- Weak to moderate vertical wind shear with veering
- Large-scale forcing mechanisms are negligible or weak
- Persistent Low-level jet present into/over a boundary
- 850-300 mb mean flow parallel to low-level boundary
- Most of 50 dBZ echo below 0° C (highly efficient rainfall producers due to low centroid storms)
- 10,000 ft depth between LCL and freezing level (deep warm cloud)
- A tall skinny CAPE profile vs. a fat CAPE profile
- Think about rate versus duration
- Cells propagate downwind with regeneration in same area (training)

Development of Convective Cold Pools

- MCS in small (large) surface Td depressions: organized cold pool development is not likely (likely)
- Mature MCS will create its own cold pool as cells congeal
- Wind gust potential affected by cold pool-ambient temp differential

Bow Echoes & Derechoes

Bow Echoes - warm season pattern

- Quasi-stationary low-level thermal boundary oriented nearly parallel to the mean tropospheric flow
- Mid/upper-level flow is usually west or northwest, at significant angle to low-level flow. Mid-level wind speeds are usually no greater than around 40 kts
- 0-2.5 km bulk wind shear is between 35-50 kts
- 700-500 mb Mean RH between 50-80 pct
- CAPE is very high, averaging around 4500 J kg^{-1} along boundary with moisture pooling

Bow Echoes – dynamic, cool season pattern

- Strong migrating shortwave trough and surface low pressure system
- Low-level jet is more parallel to mid/upper-level jet. Mid-level winds are stronger for dynamic bow echo patterns compared to warm season pattern, and instability can range from low to high. This can result in classic leading line-training stratiform QLCS, with mesovortices embedded along leading line.
- 700-500 mb mean RH between 50-80 pct
- Moderate to strong low-level (0-3 km) shear, with moderate to strong winds aloft, but little additional shear aloft

Derechoes

- Prolonged bow echo/damaging wind events; favored in environments with high to extreme instability; fast low to mid-level unidirectional flow
- 0-3 km bulk shear > 30 kts; 0-6 km bulk shear > 40 kts

Predicting Movement of MCSs & Multicells

- MCS composed of meso-beta scale elements (MBEs), i.e., the heavy rain producing convective cells observed on radar
- Backward Propagation: usually directed opposite to low-level jet; MCS may move downwind but new cells form in upwind end within unstable LLJ inflow
- Forward propagating: MCSs move forward; new cells develop and merge into MCS along downwind/leading end where unstable low-level inflow resides
- MCSs tend to propagate toward highest low-level theta-e air and Most Unstable (MU) CAPE
- Propagation characteristics of MCS associated with whether low-level theta-e axis/unstable inflow will reside ahead of system or to rear of system
- Propagation/movement of MCS can be faster than predicted by mean wind due to effect of cold pool/density current on movement (Corfidi)

Weak vertical wind shear

- Motion of multicells/weak pulse-type storms governed by location of most unstable inflow air, and can be modulated by outflow boundaries
- Motion of multicell and pulse storms is similar to that of MCS (although a low-level jet is usually not present)
- Advection tends to occur with the mean cloud bearing flow, while propagation tends to occur in direction where the strongest moist, unstable low-level flow impinges upon the storm’s cold pool (gust front)

Moderate vertical wind shear (shear in lowest 2- 3 km’s is 20 kts or greater)

- Multicells develop along leading gust front and can last longer than in weakly sheared environments; cells propagate rearward compared to leading line

Mesovortices (MVs)

- Damaging wind events and line tornadoes are associated with mesoscale vortices embedded within leading edge, along and just north of apex of bowing structures. They produce intense, narrow swaths of damaging surface winds from accelerations induced by large horizontal pressure gradient due to vortex rotation. Greatest wind damage along a squall line is associated with mesovortices. Rapid, transient tornado development can occur as well.
- Mesovortices may be difficult to detect on velocity data, esp. distant from radar. Use reflectivity structure (bows, inflow notches) to discern concern area
- Bowing structures which are sub-severe may produce locally severe winds if a mesovortex forms
- Wind gusts are most intense on the side of the vortex in which the rotational wind field is in the same direction as the system’s movement
- Usually develop after the RIJ and trailing stratiform rain forms
- First determine if bow echoes are possible, and evaluate for presence of strong vertical wind shear in lowest 0-4 km
- Strong MVs: Shear in lowest 0-4 km oriented perpendicular to bow echo and > 40 kts; Short-lived mesovortices: Shear in lowest 0-4 km and < 30 kts