Single Cell/Pulse Thunderstorm Structure and Evolution

WFO Louisville, KY

Types/Modes of Thunderstorms

Single Cell | Multicell/MCS/ QLCS | Supercell

- Lasts (30-60 min)
- Brief updraft/downdraft
- Brief severe weather if any

- Lasts longer
- Line of storms
- Severe weather more likely

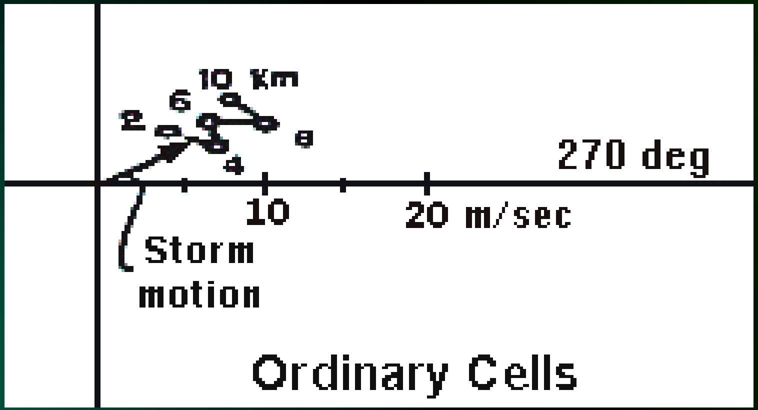
- Lasts for hours
- Most dangerous
- Severe weather most likely!

Amount of environmental vertical wind shear greatly influences storm type, organization, and longevity

Types/Modes of Thunderstorms

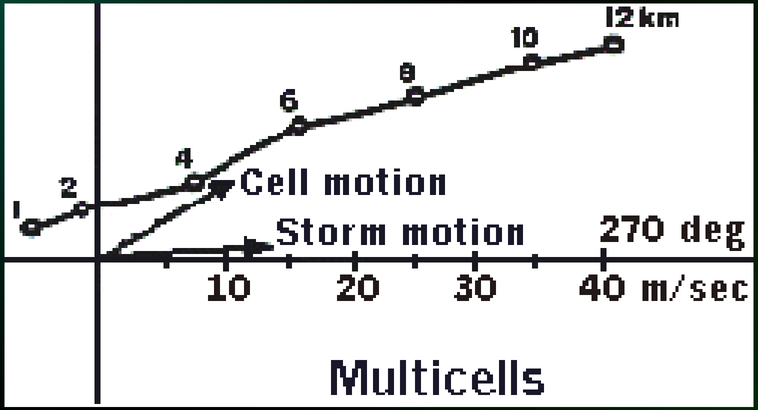
Single Cell/Ordinary/Pulse

- Short-lived (30-60 min)
- Usually non-severe but pulse severe possible; common in summer
- Limited/weak vertical wind shear/weak winds aloft; chaotic hodograph
- *Buoyancy process* important to create new cells



Multicell

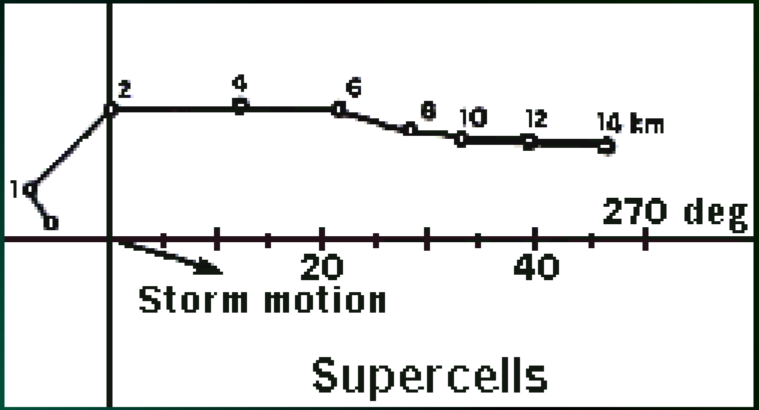
- Group of severe or non-severe cells in different stages of development
- Weak-to-strong vertical wind shear; stronger shear favors severe storms
- Hodograph shape can vary significantly; straight line hodograph indicates speed and/or directional shear
- Include MCSs, squall lines, and bow echoes (QLCSs)
- *Gust front process* important to trigger new cells on gust front (unstable inflow flank of system)



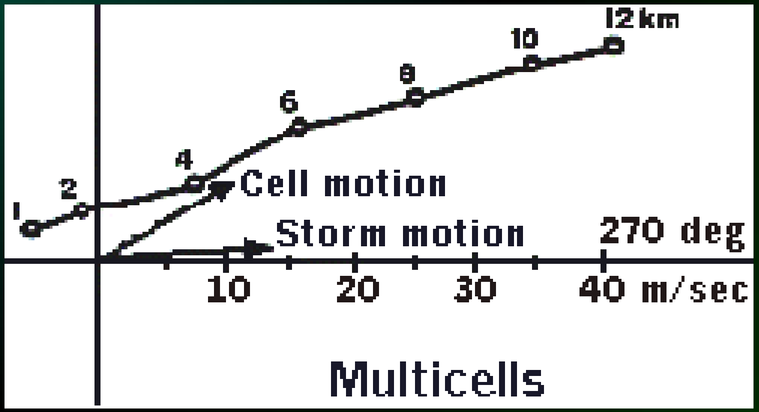
Types/Modes of Thunderstorms

Supercell

- Large severe storm in a strongly vertical sheared environment; > 40 kts total shear in 0-6 km layer
- Quasi-steady, rotating updraft (mesocyclone)
- Usually moves to right of mean wind
- Can produce damaging winds, hail (any size), and tornadoes (EF0 – EF5)
- Can be a straight or curved hodograph
- Types: *classic* (common in Plains), *high-precipitation* (HP) (east of Rockies), *low-precipitation* (LP) (western U.S./High Plains), and *mini supercells* (low top)
- Dynamic process important to storm severity, longevity, and movement



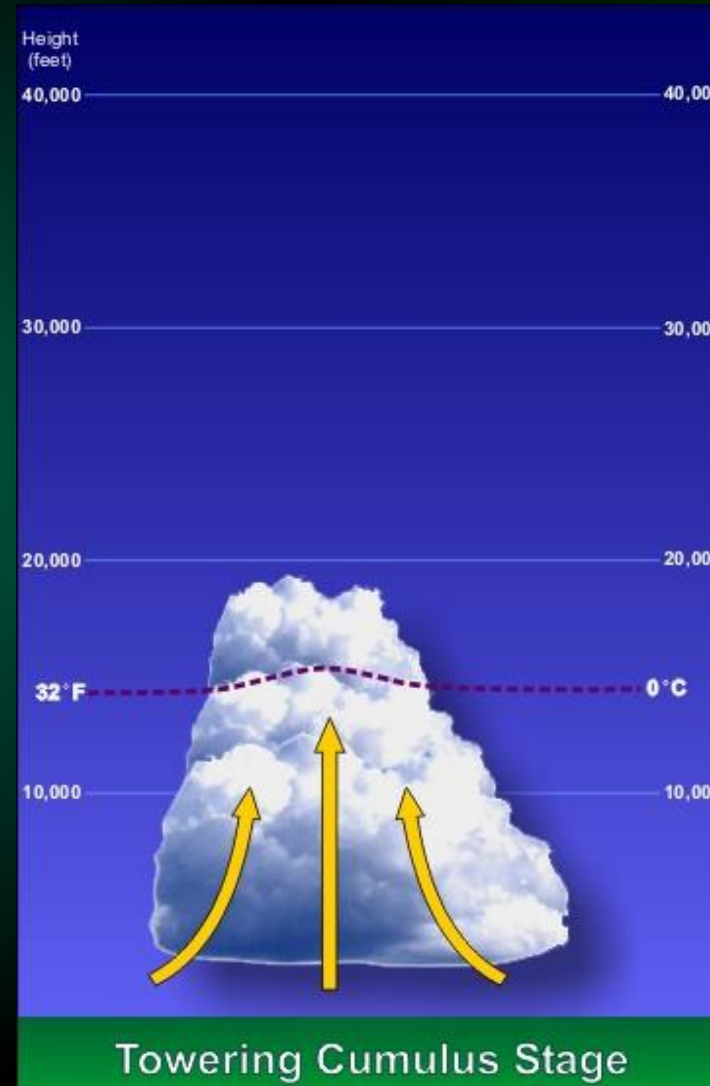
Clockwise curvature (above) due to presence of low-level jet (LLJ), which enhances storm-relative inflow and storm intensity. Straight hodograph (below) can still support a supercell, but no LLJ present so tornado less likely but can still occur



Single Cell Life Cycle

Developing Stage

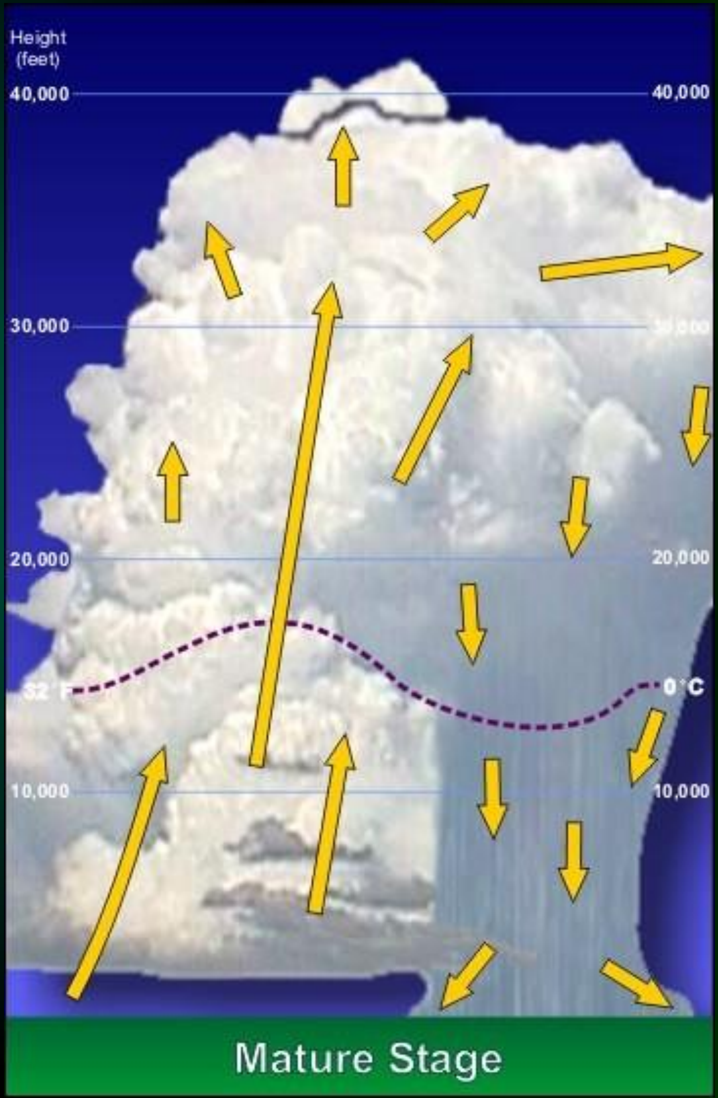
- Warm, moist air sent upward beyond LFC (updraft)
- Vertical development results in a towering cumulus (TCU) cloud
- All updraft, no downdraft
- No rain at surface at this time
- As storm begins to mature, weight of precip (loading) in cloud causes downdraft to form and precip to begin falling out of storm



Single Cell Life Cycle

Mature Stage

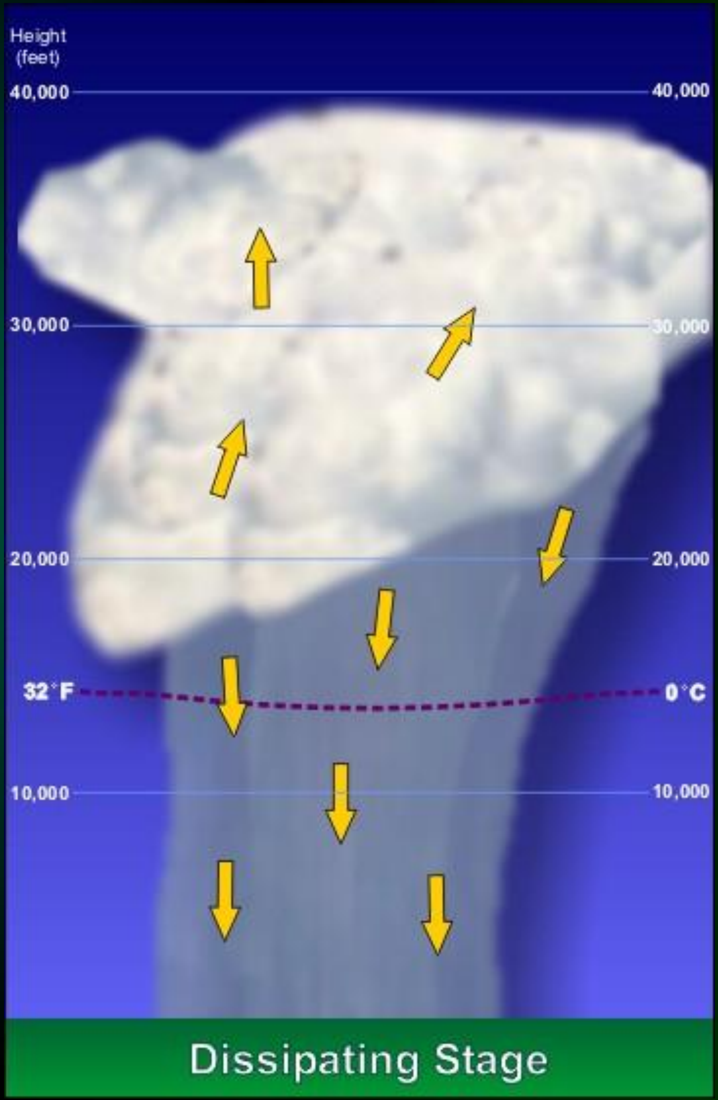
- Updraft and downdraft occur at same time within storm/cumulonimbus cloud (Cb)
- Cooler, denser air aloft is dragged down in downdraft forming surface "*convective cold pool*" whose leading edge is called a "*gust front*" or "*outflow boundary*"
- Heavy rain, thunder, lightning, and possibly hail and gusty winds occur in this stage at surface
- Brief severe weather is possible in the form of a *microburst* from a *pulse severe* storm, but extent and longevity of any severe is quite limited



Single Cell Life Cycle

Weakening Stage

- Storm contains mostly downdrafts, which move away from storm and cut off its inflow and updraft
- Rain becomes lighter and eventually ends as storm loses its source of moisture and lift
- Lower clouds dissipate with mid/upper clouds left over
- Downdraft may cause new cells to form nearby as downdraft spreads out and meets additional warm, moist, unstable air



Flow Chart to Evaluate Severe Pulse or Small Multicell Storms

FLOW CHART TO EVALUATE WET MICROBURST AND LARGE HAIL POTENTIAL FROM PULSE OR MULTICELLULAR THUNDERSTORMS

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Consider these parameters to make informed warning decisions for wet microburst/hail producing pulse or multicell storms. Understand the pre–storm and near–storm environment, and its effects on convection, then enter the flow chart at any point to assess pertinent variables. Given values are approximate and may vary geographically and from case to case. SPS = Severe Pulse Storm. UNK = Unknown.

ENVIRONMENTAL PARAMETERS

▼

Instability
- Are LIs ≤ -4 and CAPE ≥ 2000 (approx)?
- Does theta-e decrease w/ height ≥ 15 K?
- Are low-level (0-2 km) lapse rates steep, i.e., nearly dry adiabatic (≥ 6 K per km)?

YES ►►►

Low-Level Moisture
- Are high values of low-level moisture present (e.g., PW > 1.3; 850 T_d ≥ 12 °C; approx)?

YES ►►►

Evaporative Cooling
- Is unsaturated/low theta-e air present aloft (~750-500 mb, i.e., T_d depression values ≥ 8 °C; approx)? If so, then dry air entrainment will cause evap. cooling which could significantly enhance downdraft and hail potential.

►YES ▼ ▼ ▼ Higher SPS potnl. ▼ ▼ ▼ ▼ **◄◄◄**

▼ **NO ►►** *Limits updraft strength & hail potnl; weak low-level lapse rates limit downward momentum transfer to surface; gusty winds still possible.*

▼ **NO ►►** *Lower SPS potnl but still possible.* **◄◄ NO** ▼

Vertical Wind Shear
- Does vertical wind shear exist in the environment? If so, then updraft rotation, S-R flow aloft, and deviant storm motion are more likely to enhance large hail potential. Stronger/deeper shear is best.

YES ◄◄◄

Height of Freezing Level / Wet Bulb Zero
- Is freezing level (0 °C line) < 13000 ft?
- Is 7000 < WBZ < 12000 ft (approx)? If so, then hail more likely due to a shallower warm cloud layer than outside this range.

YES ◄◄◄

*All **YES** answers:*
Environment very conducive to severe pulse or multicell storms with wet microbursts and/or large hail.
▼ ▼ ▼

▼ **NO ►►** *Large hail less likely unless significant dry air aloft; wet microburst still possible, especially if YES answers to environmental parameters.* **◄◄ NO** ▼

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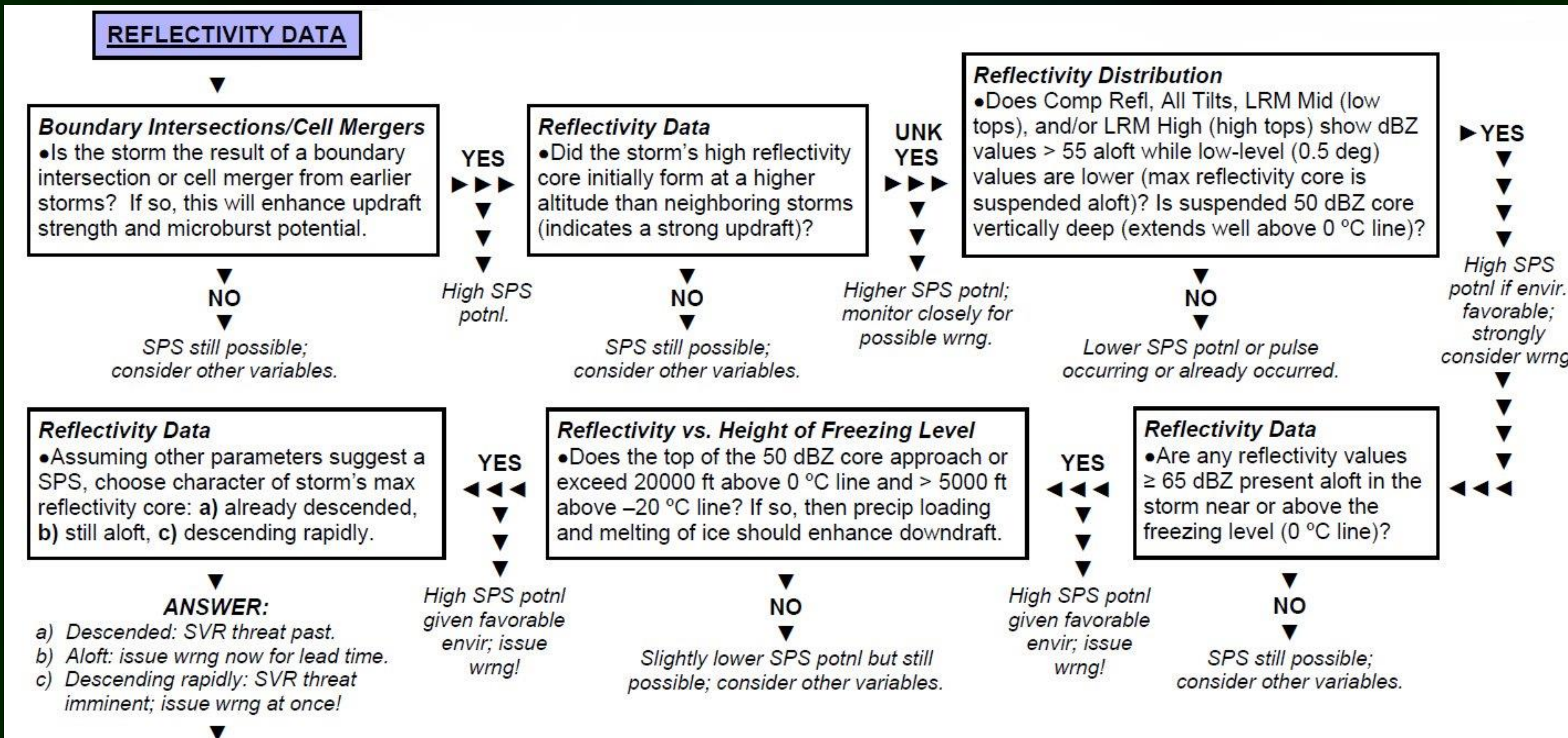

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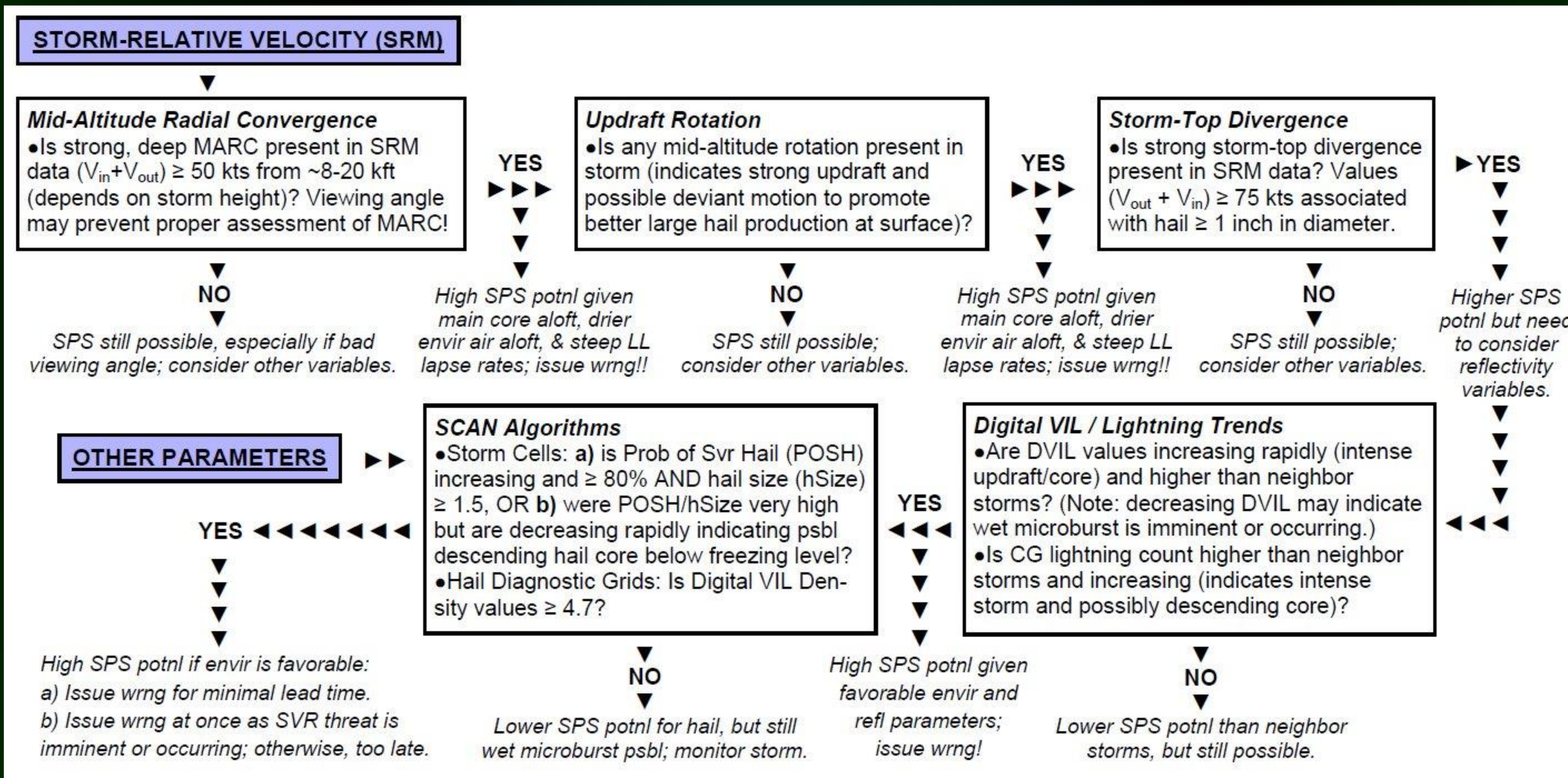

Environmental Factors Associated with Severe Pulse Storms

- *High instability/convective instability*: LI values < -5; CAPE > 2000 J/kg (approx); θe decreasing significantly with height (moist-below, dry-above); layer lifting destabilizes atmosphere even more

- *High low-level moisture content*: High surface to 850 mb dewpoints, which results in less CIN and more CAPE; better precip production to enhance water loading and downdraft

- *Unsaturated/dry air in mid levels*: High dewpoint depressions (T-Td) at 700-500 mb; enhances evaporative cooling of entrained environmental air to enhance downdraft and hail potential

- *Steep low-level lapse rates (ELR)*: Nearly dry-adiabatic in boundary layer; enhances ability of downdraft (momentum) to mix down to surface causing a downburst/microburst

- *Vertical wind shear*: If some shear is present, better chance for storm organization/severity; also favors updraft-downdraft separation to keep hail from falling within heavy rain core, which causes faster melting than if hail fell within light rain or no rain

- *Preferred heights of freezing level (T=0 ℃) and wet bulb zero (Tw=0 ℃)*: <12,000 ft AGL (freezing level); 7000-11000 ft AGL (WBZ). This WBZ range correlates with large hail at surface. Higher WBZ values infer more mid level stability and large melting area for falling hail. Lower WBZ heights indicate low levels may be too cool/stable to support large hail

Radar Signatures Associated with Severe Pulse Storms

- *High reflectivity aloft above 0 ℃ and -20 ℃*: High reflectivity values suspended well up in storm indicates a strong updraft; values > 50 dBZ extending ~20,000 ft above freezing level and ~5000 ft above -20 °C level have a good chance at producing severe microburst due to water loading (drags cold air downward), evaporative cooling, and significant melting of ice which cools the air

- *Reflectivity values ≥ 65 dBZ*: Usually indicates large hail in storm (reflectivity directed related to particle size), although it could be a lot of smaller hail (high density of particles); must consider amount of melting as hail falls to ground; dual pol helps differentiate large from small hail

- *Cell mergers and boundary interactions*: Convective cell and outflow boundary mergers often enhance low-level convergence and updraft intensity to produce a strong or severe storm

- *Updraft rotation*: Indicates a more organized storm and presence of wind shear to separate updraft and downdraft

- *Mid-altitude radial convergence (MARC)*: Inbound and outbound winds converging along same radial in SRM data; deep-layered MARC > 50 kts (V_{in} + V_{out}) within storm often a precursor to severe microburst (assuming favorable environment); can precede bow echo development

- *Strong storm-top divergence*: Inbound and outbound winds diverging along same radial near storm top; indicates intense storm updraft that is diverging out top of storm (anvil)