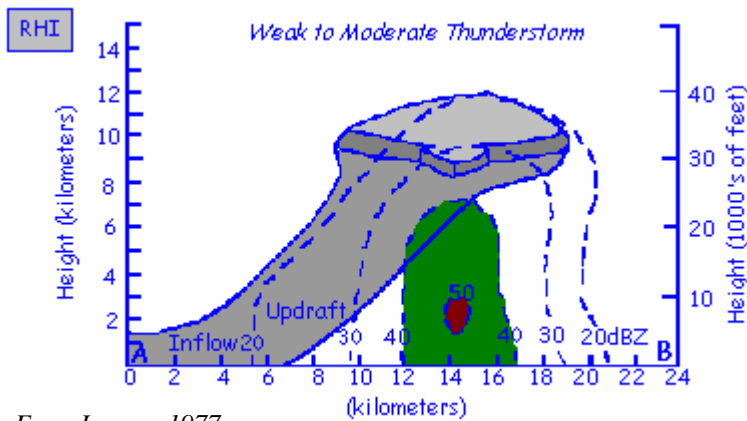


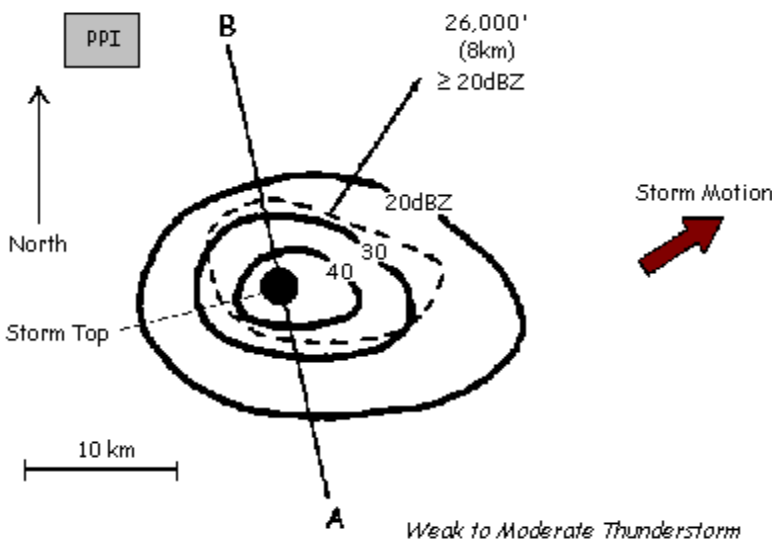
The Lemon Technique

- The Lemon technique is a way for radar operators to determine the severity a storm in a moderate to strong vertically-sheared environment. One can infer updraft strength (at least to a first approximation) with echo top height, location and peak reflectivity along with observing thunderstorm trends.



From Lemon, 1977

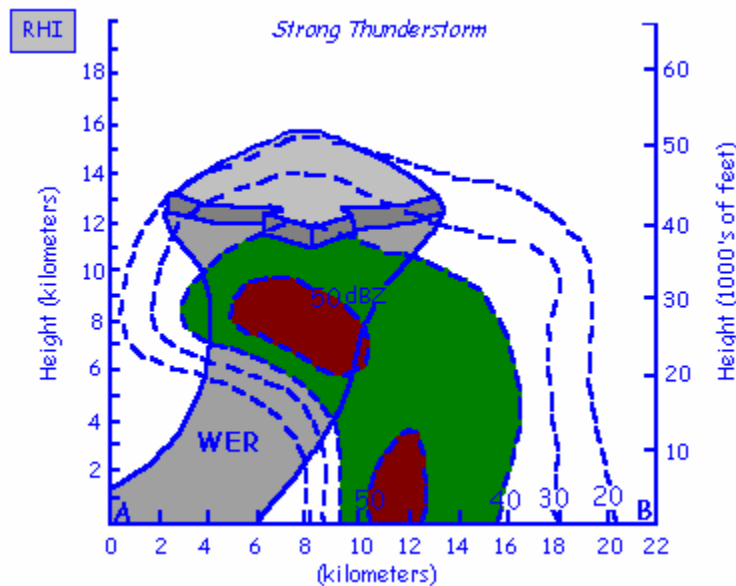
vertically aligned when the shear is relatively weak. As shear increases, the alignment will be less noticeable with the storm top shifting downshear. As the updraft increases, a shift upshear may be observed.



- Updraft tilt is caused by a change in the environmental winds with height but is also a function of updraft strength. Precipitation particles form in the updraft and subsequently fall out down shear. The precipitation echoes at low, mid and upper levels tend to be

- On a PPI, there are no strong reflectivity gradients and no mid-level overhang. The storm top will be downshear of the updraft with strong upper winds, but still over the strongest low-level echoes. The storm motion is determined by the mean wind in the cloud-baring layer, usually approximated by using the 700 mb flow.

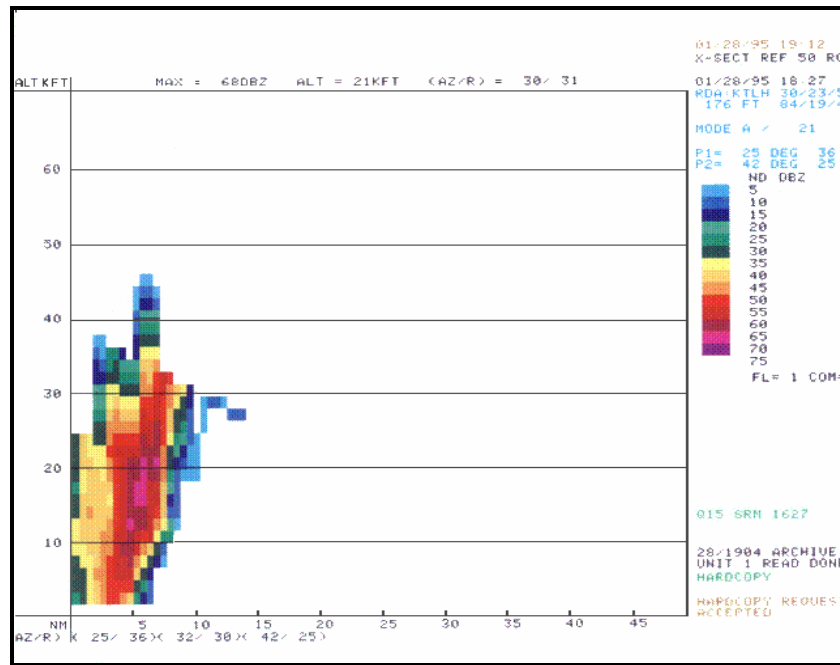
- At this point the thunderstorm needs to be watched carefully for signs of intensification: an increase in echo area and intensity in mid- or upper mid-storm levels, an upwind or upshear shift in echo top, an increase in the near-surface reflectivity gradients on the updraft-flank, a shift in the echo core toward that flank, and the echo becoming more concave inward in the same area. These are also typical indications within mature storms of a strong or intense updraft, as well.
- As updraft increases in strength, it rises with less of a slope and ascends to greater heights. The strong updraft is able to penetrate higher resisting the lateral forces of the wind shear. Precipitation forms in the mid-levels of the storm and is carried downwind of the updraft.



The Weak Echo Region (WER) is shown on the RHI, marked by precipitation above weak returns. The echoes above the WER make up the mid-level echo overhang.

- The WER development results from intensifying divergence which transports large amounts of precipitation upshear into

the SR wind. The precipitation is contained initially within the anvil, but it falls out of the anvil into the storm relative winds and descends forming the "sloping echo overhang" or the precipitation cascade. This region of descending precipitation can often be seen by the field observer as virga, or a white or gray amorphous mass sometimes obscuring the upper- and mid-level portions of the cumulonimbus tower. Thus, there is a sustained WER extending outward over the updraft flank. However, note that the WER is not one and the same with updraft. It owes its origin to an intense or intensifying updraft but only a relatively small portion is often the location of actual updraft.

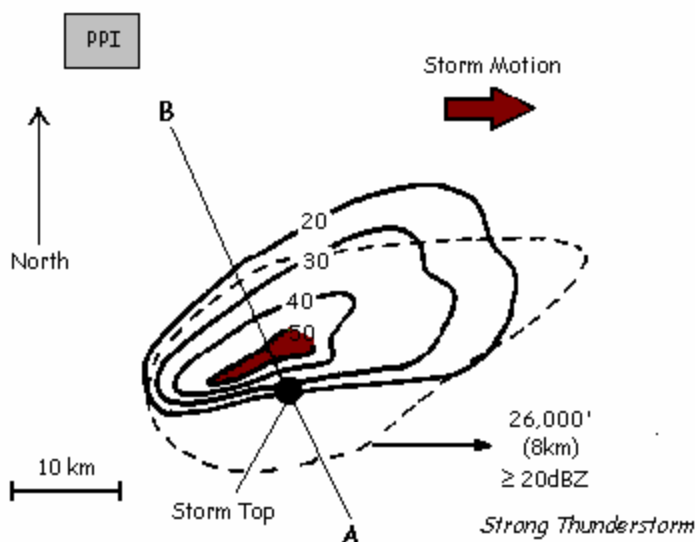


RHI Indicating WER

Notice the mid-level echo overhang at 9 nmi over the WER.

Also, note that +50dBZ returns extend over 30,000 ft

- On the PPI display, the echo elongates in the direction of the mean winds, while the storm top shifts over the greatest precipitation echo gradient on the right, or updraft edge of the storm, perhaps even over the WER.

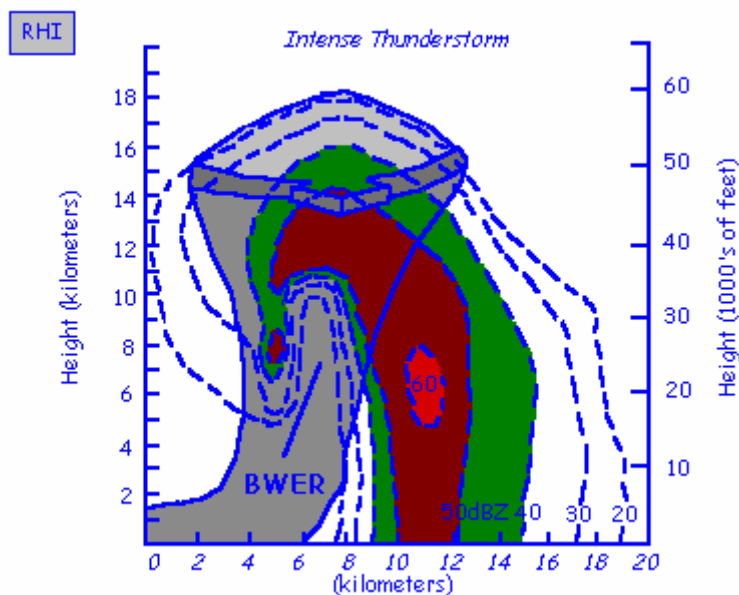


- In a multicell, other tops will exist. This top will now be above a strong low level reflectivity gradient on the updraft storm flank indicating either new cell development, or a sustained single updraft, as in a supercell. The mid-level echo overhang extends outward beyond the low-level reflectivity gradient by 6 to 25

km. A storm with these characteristics often moves slower and veers to the right of other non-severe echoes (approximately 70% of the mean wind and 30° to the right). As rotation

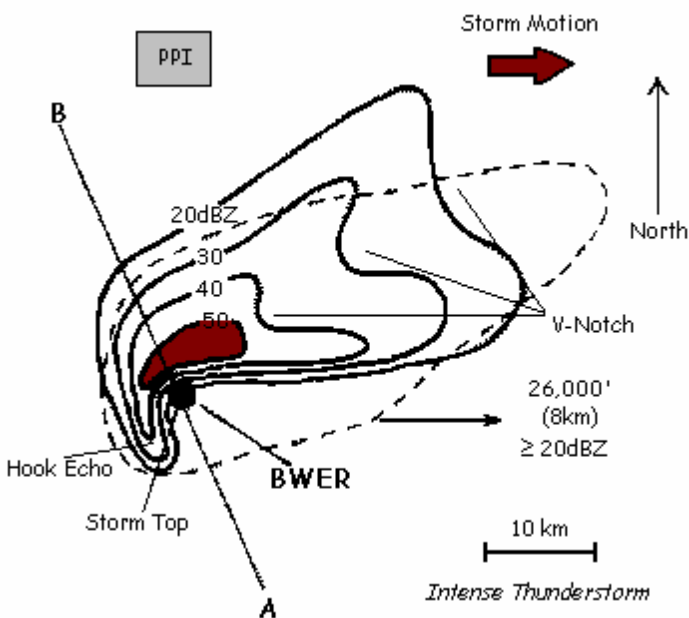
develops in the storm, deviant motion with respect to the mean wind will be determined by hodograph characteristics. However, storm motion is determined additionally by actual propagation and new updraft redevelopment. This echo identifies a hailstorm often with large hail ($>3/4$ " diameter) and gusty surface winds.

- At this point there are strong indications that the storm is severe and hence a warning is likely to be issued. These include the existence of a substantial WER, the displaced echo top, strong reflectivity gradients in low-levels, and high or increasing reflectivities in the low-level echo core which is also often displaced toward the updraft flank. The deviant motion is the result of either discrete episodic propagation or continuous updraft propagation and not necessarily that caused by a mesocyclone. One must consider both the internal and external reasons for updraft propagation. Storms in the vicinity of a boundary that are rooted in the boundary layer tend to "ride" those discontinuities and can deviate from other storms simply because the updraft is rooted in the associated moisture convergence that likely characterizes the discontinuity. Second, the interaction of the environmental shear vectors with the updraft itself can strongly augment updraft propagation. This is especially true of storms in a rightward turning environmental hodograph. Third, the storm's associated gust front often plays a part in updraft propagation. And finally, the existence of a mesocyclone does dynamically induce effects that lower mid-level pressures on its flanks and, thus, induce new updraft growth and propagation. Further determination of the existence of persistent storm-scale rotation can be accomplished by examining Doppler products.



- A more intense updraft will rise almost vertically reaching heights of near 60,000 ft. There are strong reflectivity gradients above the Bonded Weak Echo Region (BWER) and the storm top is over this as well. This configuration is indicative of potential tornadic activity. A BWER does not *necessarily*

indicate strong rotation about a vertical axis, although that might be true. The BWER is the result of an intense updraft which prevents hydrometeors (ice or liquid particles) from falling back into it. The air is rising with such velocity that hydrometeors do not have sufficient time to develop within an air parcel before it reaches high levels. Rotation within the updraft allows for a significant increase in updraft strength, more than can be accounted for by the conversion of potential into kinetic energy through buoyancy. A horizontal cut through the storm will show the BWER as a “hole” in the reflectivity.



- If there is rotation (although rotation is not always necessary) within this storm, the rear flank downdraft will wrap around the rear of the storm, carrying with it precipitation and helping to form the radar detected “hook” or “pendant” echo. However, the development of a second downdraft (the RFD) is apparently responsible for the occlusion process. This reflectivity may be the result of large precipitation

drops and appear to the visual observer as a precipitation-free region.

- The mean flow is influenced by pressure deviations associated with the updraft. Heavier precipitation is carried downwind helping form the V-notch.
- Precursor to the supercell storm is often a non-severe multicell. As each new cell becomes larger than the previous, one eventually dominates and the supercell structure results.
- A storm will not be severe unless 60-65 dBZ reflectivities extend above 26,000 feet (8km), the mid-level echo is strong, and a WER exists. This criterion helps delineate the difference between severe multicell storms forming in a sheared environment and pulse storms. This criterion is not strictly deterministic as height is a poorly measured quantity owing to large beam widths.

- Typically, during the most pronounced BWER, the surface hail is largest. The storm maximum reflectivity and height of that maximum is often at its peak during that time. The collapse phase is often the most dangerous storm phase and the one most easily forgotten. During the "collapse" the BWER is seen to shrink, its summit falls, and it will eventually disappear; the WER lessens and may disappear completely owing to the rapid descent of the sloping echo overhang, reflectivities will decrease and the height of the maximum will often greatly subside. The storm top is also seen to decline. Strangely enough it is not uncommon for tornado formation to commence or if it did so earlier, it will often reach its greatest size and intensity. Strong damaging RFD or so called "straight line" winds will often reach their maximum extent and intensity. The tornado often signals the end of the severe stage, the storm resuming a non-severe configuration again. In certain conditions, the BWER can once again develop.
- A supercell will deviate from the mean wind due in large extent to dynamic perturbations. The storm that moves to the right of the shear vector has a high potential for significant severe weather and possible tornado development. Strong storms are capable of changing the local environment, enhancing the vertical wind shear. Low-level (usually 0-1km) helicity, is a helpful parameter for forecasting tornado potential. Helicity is a measure of streamwise vorticity.
- If a storm splits, each new storm has developed a mesocyclone and thus must be watched for significant severe weather events. Observationally, the right member poses the most significant threat. Notice how the right splitting storms slows down and intensifies while the left splitting storm accelerates and weakens as it moves into a less favorable environment.

