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Thermodynamic Parameters

1. Thermodynamic Parameters

1.1 Operational Severe Weather Diagnostic Parameters:

Thermodynamic Parameters

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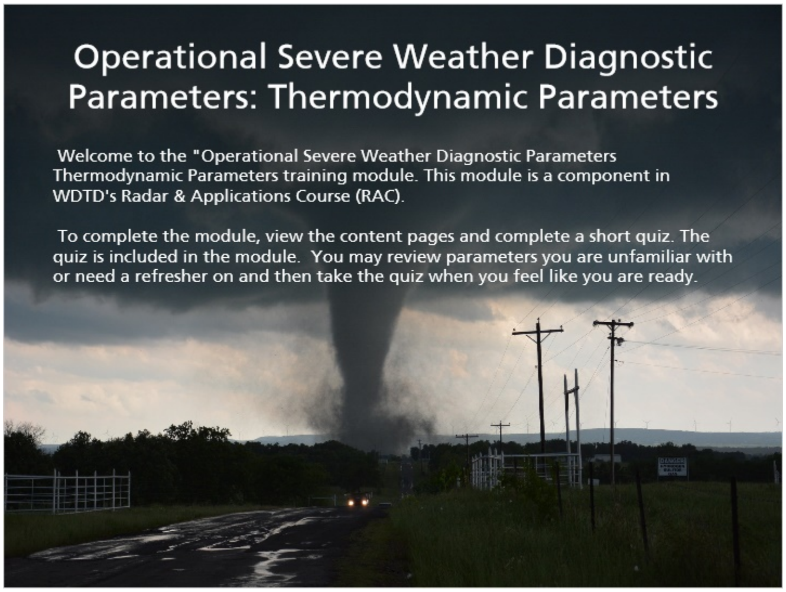
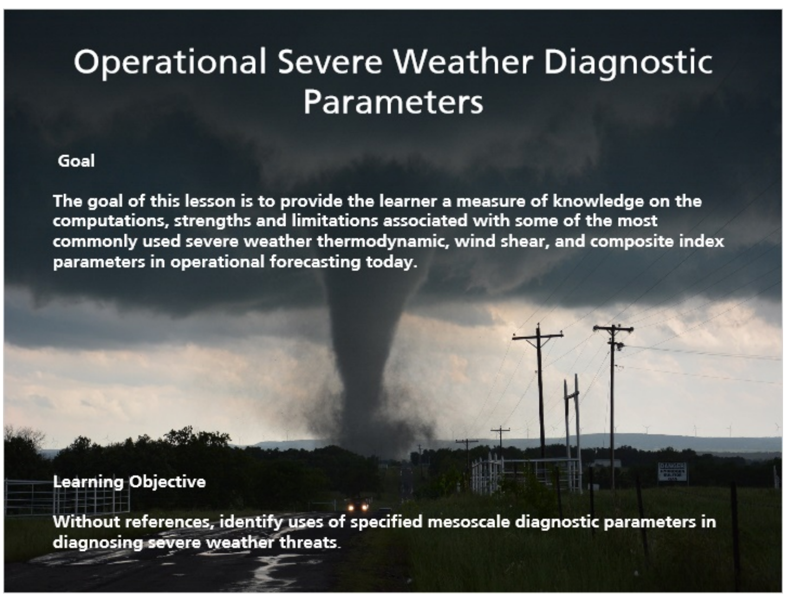
1.2 Operational Severe Weather Diagnostic Parameters: Thermodynamic Parameters



1.3 Operational Severe Weather Diagnostic Parameters



1.4 Thermodynamic Parameters

Thermodynamic Parameters

1.5 CAPE Limitations

CAPE Limitations

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- Sensitive to both magnitude of buoyancy and the depth of integration.
- In AWIPS2, there is no easy way to quantify layered CAPE, such as from the surface to 3 km.
- As in all parcel theory indices, CAPE assumes no mixing with the surrounding environment, and ignores effects of freezing and water loading. If ambient temperature is used instead of virtual temperature to calculate CAPE, lower CAPE values will result.
- Surface based computations will grossly underestimate buoyancy in situations where parcels are experiencing elevated ascent.
- The estimates of maximum updraft strength (Wmax) based on CAPE are usually twice as high as in observed updrafts because of water loading and mixing effects. In well-organized convective storms, vertical velocity in updrafts are much closer to Wmax.
- Supercells can have strong updrafts even when the static instability, as measured by CAPE, is modest (See McCaul and Weisman, 2001). This is due to vertical shear effects.
- The virtual temperature correction can increase low-level CAPE calculations by 20-50 J/kg (see graph from Davies, 2002).

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1.6 About Surface Based CAPE (SBCAPE)

About Surface Based CAPE (SBCAPE)

SBCAPE

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SBCAPE is a measure of instability in the troposphere. This value represents the total amount of potential energy available to a parcel of air originating at the surface and being lifted to its level of free convection (LFC). No parcel entrainment is considered.

A graphical depiction of the positive and negative areas on a sounding resulting from a rising parcel originating at ground level can be found here. Note that Parcel Characteristics shown in NSHARP are derived in different ways depending on the time of the sounding. The parcel parameters of T and Td are computed one of two ways:

In NSHARP, the current surface calculation uses surface station pressure, temperature, and mixing ratio. The Forecast Surface calculation uses an estimate of the afternoon maximum temperature combined with the mean mixing ratio in the lowest 100mb of the sounding. The afternoon temperature is derived from taking the parcel at 850mb dry adiabatically to the ground, and then adding a 2 C superadiabatic "contact" layer.

1.7 About Mixed Layer CAPE (MLCAPE)

About Mixed Layer CAPE (MLCAPE)

MLCAPE

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MLCAPE is a measure of instability in the troposphere. This value represents the mean potential energy conditions available to parcels of air located in the lowest 100-mb when lifted to the level of free convection (LFC). No parcel entrainment is considered.

On the SPC Hourly Mesoscale Analysis web page, this is the CAPE calculated using the lowest 100 mb AGL mean layer temperature and moisture values. (Note: this is the same parcel characteristic used in BUFKIT's default CAPE calculations.)

In NSHARP, a similar computation is the "Mean Temp Lift" parcel lifting option. However this uses the lowest 50 mb mean potential temperature layer above the surface, so these values will differ slightly from BUFKIT.

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1.8 Introduction to CAPE

Introduction to CAPE

Intro to CAPE

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CAPE is calculated by vertically integrating the positive buoyancy of a parcel experiencing moist adiabatic ascent. The formula for CAPE is shown below, where T_{vp} is the virtual temperature of the parcel and T_{ve} is the virtual temperature of the environment, Z_{EL} is the height of the equilibrium level, Z_{LFC} is the Level of Free Convection (LFC), and g is gravity. The units for CAPE are expressed in joules per kilogram.

Alternate forms of the CAPE equation **do not use virtual temperature**, but use environmental and parcel temperatures in degrees Celsius.

$$CAPE = g\int_{Z_{LFC}}^{Z_{EL}} \left(\frac{T_{vp} - T_{ve}}{T_{ve}}\right) dz$$

Untitled Layer 1 (Slide Layer)

Introduction to CAPE

Intro to CAPE

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CAPE is calculated by vertically integrating the positive buoyancy of a parcel experiencing moist adiabatic ascent. The formula for CAPE is shown below, where T_{vp} is the virtual temperature of the parcel and T_{ve} is the virtual temperature of the environment, Z_{EL} is the height of the equilibrium level, Z_{LFC} is the Level of Free Convection (LFC), and g is gravity. The units for CAPE are expressed in joules per kilogram.

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$$CAPE = g\int_{Z_{LFC}}^{Z_{EL}} \left(\frac{T_{vp} - T_{ve}}{T_{ve}}\right) dz$$

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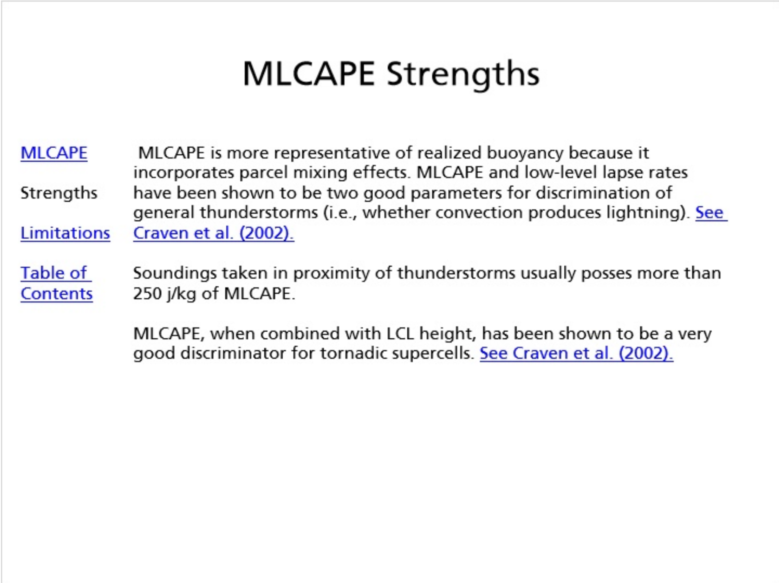
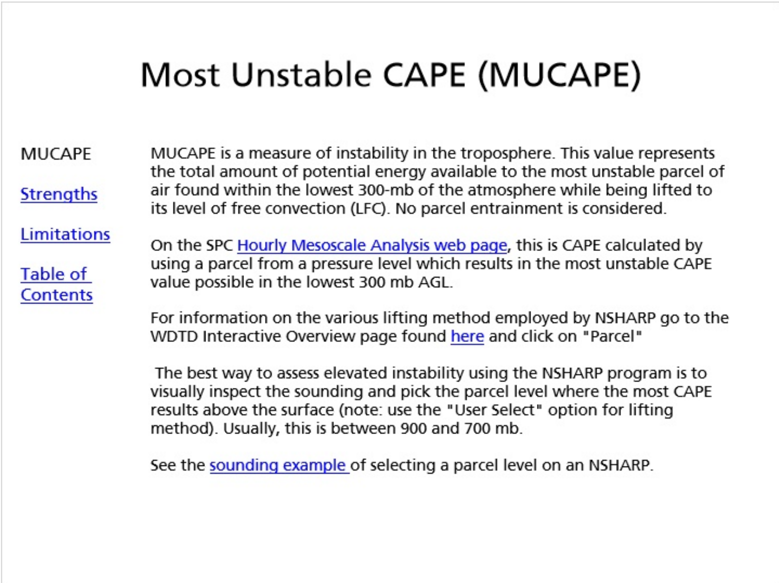
1.9 MLCAPE Strengths



1.10 Most Unstable CAPE (MUCAPE)



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1.11 Most Unstable CAPE (MUCAPE) Strengths

Most Unstable CAPE (MUCAPE) Strengths

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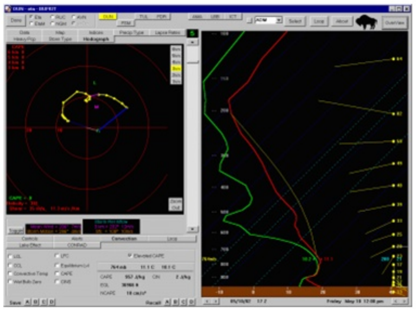
- MUCAPE is the best sounding measure for elevated buoyancy and assessing potential for elevated convection.
- In BUFKIT, one can easily compute CAPE from any level. See the BUFKIT sounding below (or click on the link for an enlarged version) showing a parcel lifted from 764 mb and the resulting CAPE of 957 J/kg.



1.12 CAPE Strengths

CAPE Strengths

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CAPE integrates a substantial portion of the thermodynamic information contained in a sounding. It is proportional to energy available for a rising parcel. CAPE provides an estimate of maximum updraft strength,**(W_{max})**, in convective storms by the relationship:

$$W_{max} = (2CAPE)^{1/2}$$

- CAPE has a significant effect on convective storm intensity.
- CAPE is a fundamental indicator of the potential intensity of deep, moist convection. Operationally, CAPE is more popular than indices such as Lifted Index or K Index which use temperature and dew point data from only a few mandatory levels in a sounding.
- Substantial CAPE (> 400 J/kg) in the hail growth zone (-10 °C to -30 °C) often is a good indicator of large hail.
- Research has shown that low-level CAPE may have relevance to tornado production. More CAPE in the lowest levels above the ground suggests stronger potential for large low-level accelerations and enhanced low-level mesocyclone intensification.

1.13 Most Unstable CAPE (MUCAPE) Limitations

Most Unstable CAPE (MUCAPE) Limitations

- Compared to SBCAPE, PMAX-based CAPE will occasionally result in slightly lower CAPE values when the most unstable parcels originate near ground level (surface).
- "Tall-thin" CAPE is more susceptible to water loading than "short and fat" CAPE. For example, tropical storms, which develop in soundings characterized by high ELs, and tall-thin CAPEs, are not as likely to be as deep (in terms of convective growth) as shallow-topped cool season supercell storms , where representative soundings indicate short-fat CAPE.

1.14 NCAPE

NCAPE

- The NCAPE (Normalized CAPE) is CAPE that is divided by the depth of the buoyancy layer (units of m/s^2)
- Values near or less than .1 suggest a "tall, skinny" CAPE profile with relatively weak parcel accelerations, while values closer to 0.3 to 0.4 suggest a "fat" CAPE profile with large parcel accelerations possible.
- Normalized CAPE and lifted indices are similar measures of instability.
- Recent work on mini-supercells have shown that these environments typically have low values of CAPE. Yet the NCAPE for these environments is similar to that in the more classical severe weather environments. Therefore NCAPE can provide a better indicator of buoyancy in environments in which the depth of free convection is shallow.

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1.15 Downdraft CAPE (DCAPE)

Downdraft CAPE (DCAPE)

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- DCAPE is a parameter designed to try and measure the downdraft strength in convective storms. DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.
- DCAPE is an integrated quantity, to compute DCAPE graphically (see figure at right), one must:

1.Determine the average wet-bulb potential temperature (θ_w) of the layer in which the downdraft is initiated. This is done by lifting a parcel from the downdraft initiation level (for example, assumed around 700 mb in the figure) to a point where it becomes saturated and then following that parcel down a saturated adiabat all the way to the surface.

2. You can then compute the area between the average θ_w and the environmental temperature (green shaded region in the figure).

1.16 Downdraft CAPE (DCAPE)

Downdraft CAPE (DCAPE)

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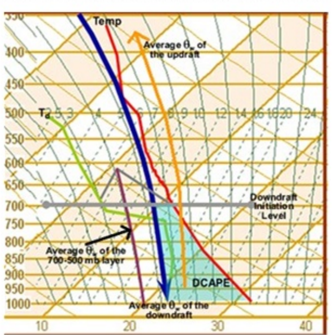
- In the figure below, the dark blue curve represents the downdraft that is completely saturated as it follows the average (mixed) θ_w down to the ground, the thick grey line is the downdraft initiation level at the bottom of the dry layer, and the thick orange line is the θ_w of the updraft.



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1.17 Downdraft CAPE (DCAPE) Strengths

Downdraft CAPE (DCAPE) Strengths

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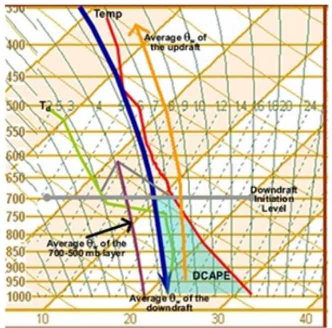
- DCAPE estimates downdraft potential strength better than just measuring relative humidity or T-T_d at some level. It considers diluted updrafts mixing with environmental air.
- Can be used to assess microburst potential for some pulse storms.



1.18 Downdraft CAPE (DCAPE) Limitations

Downdraft CAPE (DCAPE) Limitations

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- DCAPE should be used with caution because it starts the analytical process at some estimated downdraft initiation level, which is not well known. One could just as easily start the integration at a different level than 700 mb. Picking a higher (lower) level most likely creates larger (smaller) DCAPE.
- A second caution of using DCAPE is that the downdraft will most likely be unsaturated as evaporation is never efficient enough to compensate for adiabatic compressional heating of dry air. The downdraft consequently never follows the theoretical qw curve and instead warms more quickly in reality. Most likely the realized DCAPE is much less than the theoretical leading to a weaker than expected downdraft.
- As a third caution, DCAPE does not account for negative buoyancy due to precipitation loading. A reflectivity core of 60 dBZ or greater may create enough precipitation loading comparable to negative thermal buoyancy and therefore lead to a stronger downdraft than the DCAPE suggests.
- Finally, DCAPE does not account for nonhydrostatic downward directed pressure deficits that result from strong mesocyclogenesis or divergence beneath the level of interest. Thus, DCAPE will not accuartely estimate the downdrafts in supercells.

1.19 MLCAPE Limitations

MLCAPE Limitations

MLCAPE

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MLCAPE is unrepresentative of elevated unstable layers higher than 100-mb AGL, such as with a front. MLCAPE has more difficulty in discriminating between general thunderstorms and severe thunderstorms (lots of overlap). See Craven et al. (2002).

1.20 Convective Inhibition (CIN)

Convective Inhibition (CIN)

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$$\mathrm{CIN} = g \int_{Z_{SFC}}^{Z_{LFC}} \left(\frac{T_{vp} - T_{ve}}{T_{ve}} \right) dz,$$

- Convective Inhibition (CIN) is defined as the energy needed to lift an air parcel vertically and pseudoadiabatically from its originating level to its level of free convection (LFC). For an air parcel possessing positive CAPE, the CIN represents the negative area on a thermodynamic diagram and is measured in Joules per kilogram.
- Assessing Convective Inhibition (CIN) is important to diagnosing the potential for deep, moist convection. Generally speaking, the larger the value of CIN, the more difficult it will be for a parcel of air to reach the LFC. This statement is most applicable for a surface based parcel.
- For parcels that are not surface based (e.g., elevated convection), an appreciable amount of low-level CIN can be present, but parcels can still become positively buoyant if forced ascent occurs above the stable layer and some CAPE is present above the stable layer (in many of these elevated convection cases, the level above which lifting occurs is from 850 to 700 mb). In these cases, CIN above the LFC is usually minimal.
- See this link for a graphical depiction of CIN on a Skew-T diagram.

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1.21 Convective Inhibition (CIN) Continued

Convective Inhibition (CIN) Continued

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- In cases where CIN is large, supercells are less likely to produce tornadoes (Grant 1995). Large values of CIN below the LFC is an indication that environment is capped and external mesoscale lifting would be necessary to break the cap.
- Most models depict CIN as a convective forecast parameter, displayable via the AWIPS Volume Browser. There are differences in both individual model forecast CIN computations and CIN values derived from the AWIPS interactive Skew-T.
- The differences in CIN calculations are a result of what parcel level is lifted. (See section on CAPE)
- One can relate CIN to a vertical velocity, Wlift , or the estimated amount of lifting required to overcome the negative area by the following expression:

$$W_{lift} = (2 * CIN)^{1/2}$$

1.22 Convective Inhibition (CIN) Limitations

Convective Inhibition (CIN) Limitations

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- It is often quite difficult to assess how much lifting will overcome the negative energy (CIN). Normally a parcel will need to be lifted by some external process in order to reach its LFC. Mesoscale sources such as boundaries are the usual mechanisms which supply sufficient lifting.
- CIN is sensitive to changes in boundary layer values. A change in the surface dew point or the mean mixing ratio in the boundary layer will change the value of CIN. When selecting the start point for lifting a parcel, be sure to accurately reflect the boundary layer conditions at the time when you expect convection to begin.
- As in all parcel theory indices, CIN assumes no mixing with the surrounding environment, and ignores water loading. The value of CIN will vary depending on the parcel chosen to lift. In cases of elevated instability surface based CIN may be quite misleading. As a result the operational use of CIN is far from easy. However, for surface-based convection, given an adequate forcing mechanism, the probability of deep convection increases when CIN decreases below 50 to 70 J/kg, but it is quite difficult to determine an exact threshold value below which convection will (or will not) occur.

1.23 Surface Based CIN (SBCIN)

Surface Based CIN (SBCIN)

SBCIN

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$$\mathrm{CIN} = g \int_{Z_{SFC}}^{Z_{LFC}} \left(\frac{T_{vp} - T_{ve}}{T_{ve}} \right) dz,$$

- Defined as Surface Based Convective Inhibition (SBCIN) energy, this parameter is a measure of the "negative area" on a sounding between the surface and the LFC and is measured in Joules per kilogram.
- SBCIN is the amount of work required to lift a parcel through a layer that is warmer than the parcel. The parcel must be forced upward sufficiently to overcome the negative buoyancy. This negative area is often referred to as a "lid" or "cap". The formula for SBCIN is very similar to CAPE where Z_{SFC} is the height of the surface and all other variables are the same as in the CAPE calculation. Other computations use temperature (or potential temperature) instead of virtual temperature. The larger the SBCIN value, the more stable the layer of air is between the surface and LFC, the more difficult it will be to lift a parcel of air to its level of free convection.
- This figure depicts positive and negative areas on a sounding.

1.24 Mixed Layer CIN (MLCIN)

Mixed Layer CIN (MLCIN)

MLCIN

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- Mixed Layer Convective Inhibition (MLCIN) represents the "negative area" on a sounding for a parcel of air consisting of mean layer values of temperature and moisture from the lowest 100-mb AGL lifted to its LFC and is measured in Joules per kilogram. No parcel entrainment is considered.
- **Strength:**
  - MLCIN is more representative of realized negative buoyancy than SBCIN because it incorporates parcel mixing effects.
- **Limitation:**
  - MLCIN is unrepresentative of the convective inhibition of elevated unstable layers higher than 100-mb AGL, such as with a front.

1.25 Lifted Index (LI)

Lifted Index (LI)

LI

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- The lifted index is the temperature difference between the 500 mb temperature and the temperature of a parcel lifted to 500 mb. Negative values denote unstable conditions. LI uses a mean 100mb layer parcel.
- The Computation Procedure is as follows:

1. Determine the mean mixing ratio for the lower 100 mb (approximately 3000 ft.) and a forecast maximum temperature. (1200Z sounding only) The lower 100 mb layer or 3000 feet are used as they approximate the surface-based boundary layer.

2. Determine the LCL using the mean mixing ratio and forecast maximum temperature. From the LCL follow the saturation adiabats to the 500 mb level. Let the temperature at this intersection point at 500 mb called TL. The temperature of the parcel at 500 mb is assumed to be the updraft temperature within the cloud.

3. Algebraically subtract TL from the 500 mb temperature. The value of the remainder (including its algebraic sign) is the value of the Lifted Index.

1.26 Lifted Index (LI) Strengths

Lifted Index (LI) Strengths

LI

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- LI is a quick expression of the overall stability/instability of a sounding. Ease of computation, flexible choice of layer to lift (lifting an parcel at 850 mb is the old Showalter Index), pertinent to a particular problem area for ready use in synoptic forecasting.
- Can alert forecasters to those soundings which should be examined more closely.
- LI is more of a measure of actual "instability" than CAPE because it represents the potential buoyancy of a parcel at a level, whereas CAPE is integrated through the depth of the troposphere. the remainder (including its algebraic sign) is the value of the Lifted Index.

1.27 Temperature Lapse Rates (TLR)

Temperature Lapse Rates (TLR)

TLR

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Adiabatic Lapse Rate (ALR_d) = -(dt/dz) = g/C_p

- ALR_d is defined by the equation above where g = 9.8 x 102 cm s-2 and C_p = 1.00 J gm-1 K-1 , LR_d = 9.8 °K km-1 or 9.8 °C km-1 .
- Lapse rates are shown in terms of temperature change (in degrees Celsius) per kilometer in height. Values less than 5.5 - 6.0 degrees C/km (moist adiabatic) represent stable conditions, while values near 9.5 degrees C/km (dry adiabatic) are considered absolutely unstable. In between these two values, lapse rates are considered conditionally unstable. Conditional instability means that if enough moisture is present, lifted air parcels could have a negative LI (lifted index) and/or positive CAPE.
- The saturated Adiabatic Lapse Rate (ALR_s) is always less than ALR_d, but approaches ALR_s as pressure increases or temperature decreases. ALR_s ranges from 3.3 °C km-1 at 500 mb and +20°C to 9.2 C km-1 at 1000 mb and -30 C. (Note: In order to take into account the effect of water vapor on the density of air, one may think of LR_d and LR_s as lapse rates of virtual temperature.)
- Lapse rates are used to assess convective instability and are sometimes displayed (as in BUFKIT example) in tabular format (note ALR_s greater than 8.0 °C/km are highlighted in red in the BUFKIT table).
- Moist adiabatic lapse rates approach the dry adiabatic lapse rate for lower temperatures or higher pressures **at a given temperature.**

1.28 Temperature Lapse Rates (TLR) Strengths

Temperature Lapse Rates (TLR) Strengths

- Determination of parcel static stability , and associated stability criteria (using the parcel method), can be found by comparing the observed or forecast temperature lapse rate with ALR_d (see page 13 of RTM-230).
- Diagnosis of steep mid-tropospheric lapse rates (such as the layer between 700 to 500 mb) have been shown to be a precurser signal to severe storm development (see Doswell et al., 1985).
- Several stability indices have been developed over the years which estimate low-level lapse rates (such as the layer between 850 to 500 mb). The Total Totals (TT) Index (see RTM-230 pg. 18) uses the temperature difference between 850 and 500 mb temps (Vertical Totals) in its computation. Steep lapse rates facilitate the vertical transfer of momentum better.

1.29 Lifted Index (LI) Limitations

Lifted Index (LI) Limitations

LI

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- Important details of the lapse-rate structure may be smoothed out or completely missed even when the index is carefully chosen and evaluated.
- Used alone, a stability index can be quite misleading, and at times, is apt to be almost worthless.

1.30 Temperature Lapse Rates Limitations

Temperature Lapse Rates Limitations

TLR

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- Assessment of the environmental lapse rate by itself is insufficient to determine parcel buoyancies. Actual parcel instability leading to deep, moist convection is primarily associated with vertical parcel displacements. Thus, the key to the possibility for growth of convective storms is the presence of CAPE, not the environmental lapse rates alone (Doswell, 2001).
- Steep lapse rates may signify very dry air aloft which may actually inhibit the development of deep, moist convection in some situations.

1.31 Lifting Condensation Level (LCL)

Lifting Condensation Level (LCL)

LCL

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- The Lifting Condensation Level (**LCL**) is the height at which a parcel becomes saturated when lifted dry adiabatically (see Figure). The **LCL** is commonly used to estimate the level of a cloud base from surface based convection. The computed **LCL** using a Mean **100** mb Layer (**MLLCL**) from the surface has been shown to have the highest correlation to measured cloud base (Craven et al. **2002**). Representative parcels for determining the **LCL** and associated stability are dependent on temperature and dew point mixing proportions in the boundary layer.
- The **SPC** uses a mean **100** mb layer parcel to compute **LCL** height.

1.32 Lifting Condensation Level (LCL) Strengths

Lifting Condensation Level (LCL) Strengths

LCL

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- Research has related the LCL to the amount of low-level relative humidity which can affect cooling through evaporation of rain in the downdraft portion of supercell storms (See Markowski et al. 2002) . The higher the LCL is in the near-storm environment, the drier the boundary layer will be. Lower LCL heights and thus, lower cloud bases, are associated with greater amounts of boundary layer moisture and appear to indicate a higher frequency of significant tornado events (See Craven et al. 2002).
- Relatively low LCLs suggest greater low-level relative humidity near the ground and thus, more unstable air originating in the Rear Flank Downdraft (RFD), which researchers have claimed is critical to tornadogenesis (Markowski et al. 2002). Lesser values of boundary layer relative humidity (from high LCLs) might increase stability in Rear-Flank Downdrafts (RFDs) and decrease tornado potential.
- Rasmussen and Blanchard (1998) showed that LCLs in tornadic supercell soundings were significantly lower (Median value was approximately 800 meters AGL with no occurrences above 1500 meters AGL) than LCLs in nontornadic supercell soundings.

1.33 Lifting Condensation Level (LCL) Strengths

- METAR temperature dew point depressions (Tdd)are a decent proxy to the local LCL height in a well-mixed boundary layer, so this parameter can be analyzed hourly on the mesoscale. T - Td spreads at the surface ranging from 0 to 22° F correspond to LCL heights less than 1500 m AGL in a well-mixed boundary layer and 12° F spreads correspond to 800 m.
- A combination of LCL height (using mean 100 mb layer parcel) and 0 to 1 km shear has been shown to be highly correlated to significant tornado occurrence. See this figure from Craven et al.(2002). The graphed data from Craven et al. (2002) show a strong signal between significant tornadoes (F2 or greater) and significant hail/wind. Significant tornadoes tend to occur with relatively high 0-1 km shear and relatively low LCL height (e.g. less than 1500 m AGL). On the other hand, storms that produce big hail (greater than 2") and/or wind gusts 65 knots or greater, but no strong or violent tornadoes, tend to possess weaker low-level shear and higher cloud bases.
- LCL height is **NOT** affected by the virtual temperature correction.

1.34 Lifting Condensation Level (LCL) Limitations

- Major variations can occur in small time and space scales with LCL. Actual LCL heights in tornadic storms may be considerably lower, so RFD approximations by surface or model data are quite crude at times. LCL computations suffer the same limitations as that of CAPE and CIN calculations in terms of parcel origination levels. Be aware of the level where the saturated parcel originated. The Mean Layer LCL may be the best approximation to actual cloud base.

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1.35 Level-of-Free-Convection (LFC)

Level-of-Free-Convection (LFC)

LFC

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- The LFC, or Level of Free Convection, is the height at which a parcel lifted dry adiabatically to saturation at the LCL and moist adiabatically above the LCL would first become warmer (less dense) than the surrounding air. At the LFC, the parcel experiences positive buoyancy and starts to accelerate upward without further need for forced lifting (See [this figure] for the graphical procedure for determining the LFC).

1.36 Level-of-Free-Convection (LFC) Strengths

Level-of-Free-Convection (LFC) Strengths

[LFC]

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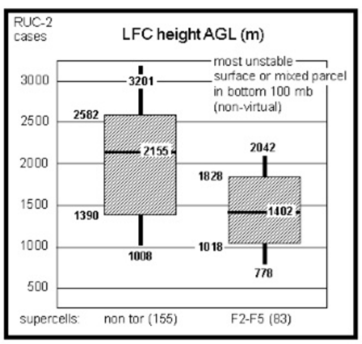
- Low-level CAPE and CIN are related to the height of the LFC (see figure on LFC). Lower LFC heights imply more low-level CAPE and thus, can be correlated to increasing tornadic likelihood in supercells because of the associated potential for stronger low-level vertical accelerations (see figure to the right of LFC height from Davies' 2002 study of supercell storms, Rasmussen, 2001 and more cases from Davies, 2002).

- Higher LFCs tend to imply more CIN, and lower tornado probability.



1.37 Wet-Bulb Zero Height (WBZ)

Wet-Bulb Zero Height (WBZ)

WBZ

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- Usually labeled as WBZ, the wet-bulb zero is the height at which the wet-bulb temperature is 0°C. This approximates both the height at which falling hail begins to melt and the height at which the downdraft begins (OSF/OTB, 1993).
- As seen to the right, on BUFKIT, the WBZ height is shown on the Indices screen (in ft AGL) and is also plotted (optionally) on the Skew-T display in red.
- In AWIPS Skew-T , the WBZ height is displayed on the parameter output in feet Above Sounding Level (ASL).

1.38 Wet-Bulb Zero Height (WBZ) Strengths

Wet-Bulb Zero Height (WBZ) Strengths

WBZ

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- In general, WBZ heights between 7000 ft and 10,500 ft AGL are associated with a potential for large hail at the surface. Higher WBZ heights imply mid- and upper-level stability and imply a large melting zone for falling hail. On the other hand, lower WBZ heights suggest that the lower levels of the atmosphere are too cool and stable to support intense convection.

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1.39 Level-of-Free-Convection (LFC) Limitations

Level-of-Free-Convection (LFC) Limitations

LFC

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- A relatively low LFC height, by itself, does not say anything about the depth of CAPE or total CAPE. Total CAPE and of course, shear, must also be assessed for severe potential. CIN may be a better indicator of whether a storm is surface based and thus, have a higher tornado potential.
- The virtual temperature correction can lower the effective LFC by 200-500m (see this figure from Davies, 2002).

1.40 Wet-Bulb Zero Height (WBZ) Limitations

Wet-Bulb Zero Height (WBZ) Limitations

WBZ

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- WBZ values are only general guidelines for considering hail size potential. WBZ only partially predicts severe hail potential because it doesn't consider updraft strength, persistence, and hail trajectories. Since the ultimate size of a hailstone is most related to the time it resides in a growth region, a forecaster should assess the width and persistence of updrafts above the freezing level. Those storms that exhibit wide and persistent updrafts produce the largest hail that can easily be of extreme size upon reaching the ground. The importance of the WBZ height, in determining whether or not hail or severe hail reaches the ground, is the greatest when the maximum hail size in a storm is marginally severe.
- Supercells greatly dominate all storm types in providing hail stones with the necessary potential residence time in the growth layer to produce significantly severe hail (>2" diameter). However, some supercells are especially prolific at producing large quantities of significantly severe hail. Some of these supercells exhibit broad updrafts where the storm-relative flow reaches a minimum in the hail stone growth layer and allows the hail stone trajectories to remain in the updraft.

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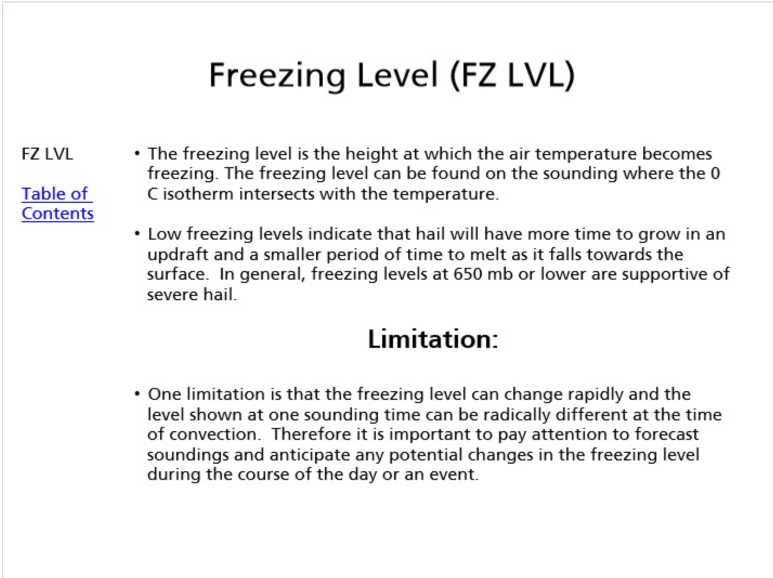
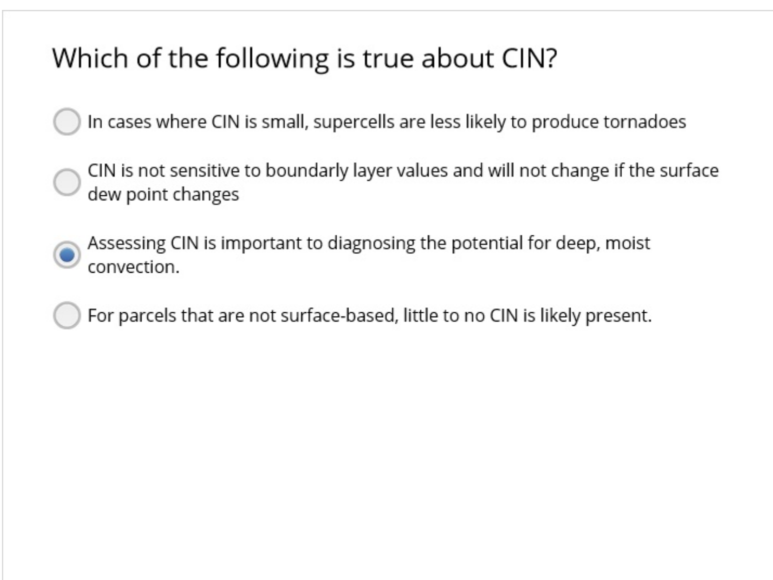
1.41 Freezing Level (FZ LVL)



2. Thermo

2.1 Which of the following is true about CIN?

(Multiple Choice, 10 points, 1 attempt permitted)



Wind Shear Parameters

1. Wind Shear Parameters

1.1 Operational Severe Weather Diagnostic Parameters:

Wind Shear Parameters

Notes:

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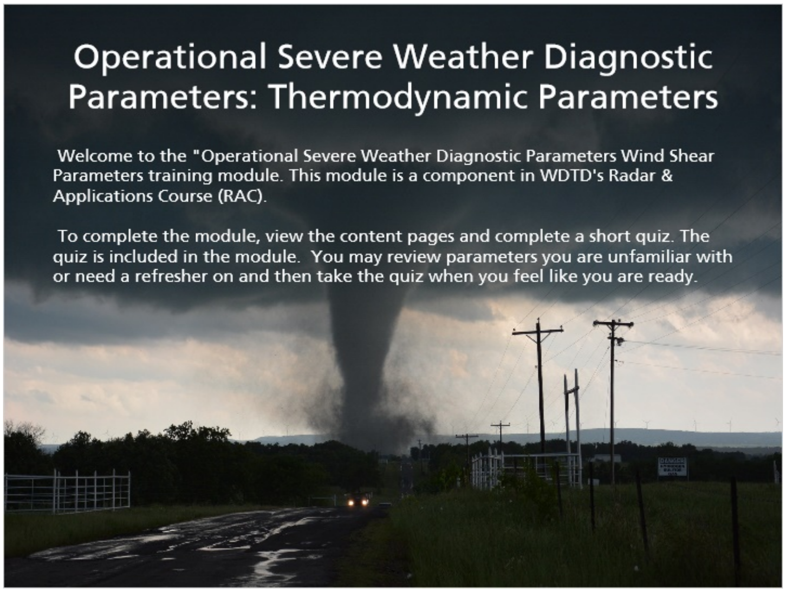
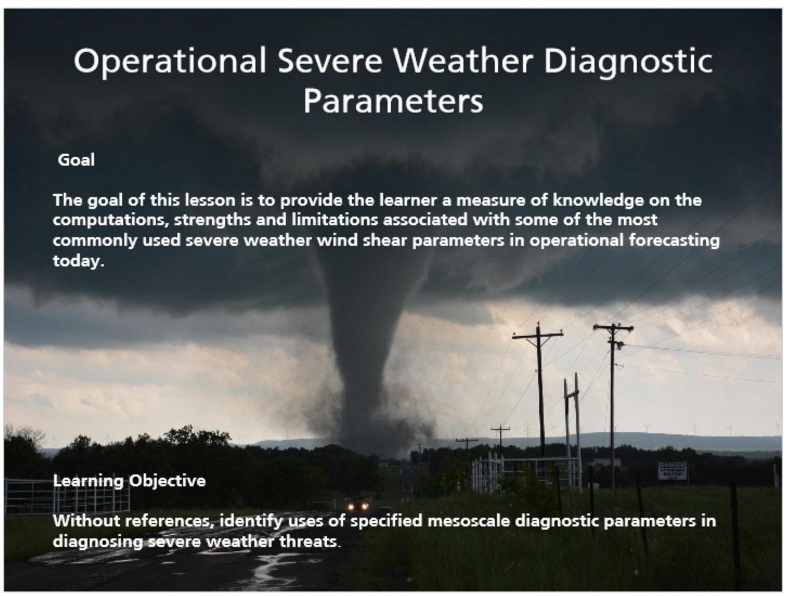
1.2 Operational Severe Weather Diagnostic Parameters: Thermodynamic Parameters



1.3 Operational Severe Weather Diagnostic Parameters



1.4 Wind Shear Parameters

Wind Shear Parameters

Notes:

1.5 Bulk Shear

Bulk Shear

This is actually the bulk wind vector difference and is calculated by subtracting the wind between two layers, such as the surface or boundary layer (ex. 0 - 500 m AGL mean wind) and a representative middle layer (such as 6 km AGL). Dividing by the depth of the layers gives the true bulk shear.

In BUFKIT, the bulk shear is labeled "Shear layer difference" and can be plotted on the overview screen (See BUFKIT overview example).

Mean Shear

Mean shear is defined as the length of the hodograph divided by the depth over which the hodograph was measured. This quantity is computable in the BUFKIT overview screen by selecting the button labeled "Shear (length of hodo)" and clicking on units of (m/s) / km.

The value of shear shown in the lower left of the hodograph graphic in BUFKIT is actually hodograph length (in m/s and in (m/s)/km) as computed from summing around all the points of the hodograph. The ending point that determines the length of the hodograph computations are selectable in kilometer increments from 1 to 6 km. The default is 4 km. (Note: CAPE values are also displayable in layer integral amounts as well).

1.6 Bulk Shear Strengths Part 1

Bulk Shear Strengths Part 1

Bulk Shear

Strengths Part 1

Strengths Part 2

Limitations

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- Shear is the most important parameter for convective storm organization and persistence. Increasing vertical shear (for a given amount of thermodynamic instability) often results in greater convective storm organization, and longevity.
- From observations and numerical modeling simulations, bulk shear, mean shear, and/or hodograph length have all been used to help quantify the amount of vertical wind shear capable of producing the dynamic pressure perturbations and resulting midlevel rotation in supercells.
- The interaction of the updraft with an environment characterized by strong vertical shear of the horizontal wind permits some storms to develop nonhydrostatic vertical pressure gradients that can be as influential in developing updrafts as the buoyancy effects (Weisman and Klemp 1984).

1.7 Bulk Shear Limitations

Bulk Shear Limitations

Bulk Shear

Strengths Part 1

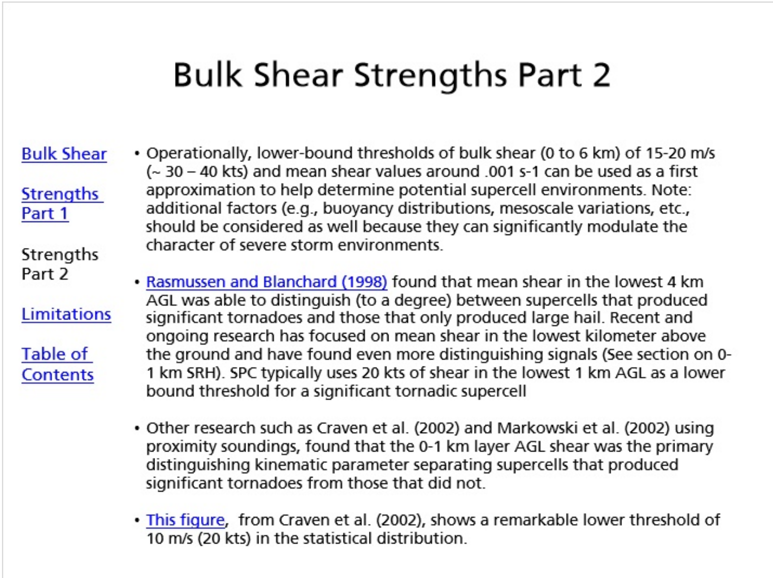
Strengths Part 2

Limitations

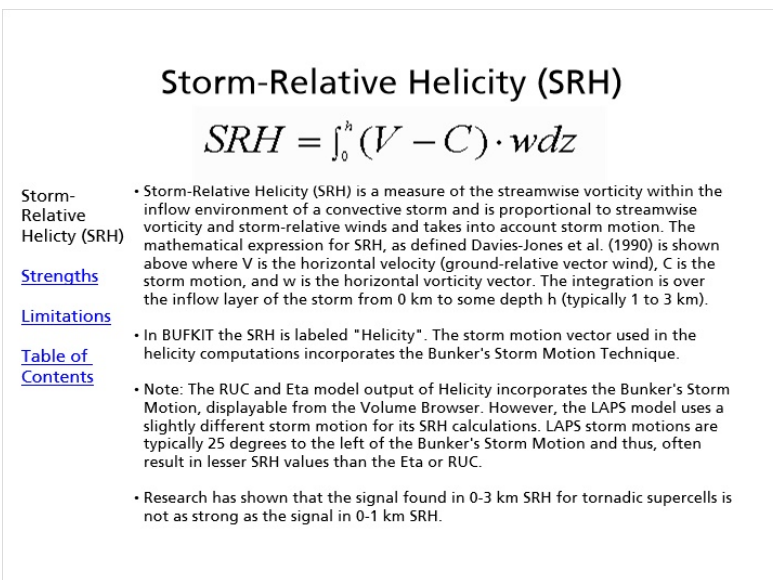
Table of Contents

- Bulk shear (surface to 6 km) has limited utility in distinguishing between supercells that produce significant tornadoes and those that do not (see Rasmussen and Blanchard, 1998).
- Hodograph length is more sensitive to vertical resolution and noise in the observations. Computations using numerous model sounding layers often yield unrealistically high values of shear and should be
- The bulk wind difference can hide important aspects regarding hodograph shape.
- It is also important to note that an appropriate layer depth should be used for the expected storm environment (Using a 0-6km layer in an environment for shallow supercells would yield unrealistic expectations).

1.8 Bulk Shear Strengths Part 2



1.9 Storm-Relative Helicity (SRH)



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1.10 Storm-Relative Helicity (SRH) Strengths

Storm-Relative Helicity (SRH) Strengths

Storm-Relative Helicty (SRH)

Strengths

Limitations

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- Research and operations have found some correlations between increasing SRH values (from the surface to the lowest 3 kilometers) and tornado intensity (Johns et al. (1990), Davies-Jones et al. (1990), and Kerr and Darkow (1996).
- Observed 0-3 km mean SRH using Kerr and Darkow's proximity sounding study showed the following SRH values for various intervals of F scale: Mean 0-3 km SRH was 66 m2/s2 for FO, 140 m2/s2 for F1 tornadoes, 196 m2/s2 for F2 , 226 m2/s2 for F3 tornadoes, and 249 m2/2 for F4 tornadoes. (note: No F5 tornadoes were in their study).
- However, operational experience has shown that current or projected 0-3 km SRH values exceeding 100 m2/s2 often reflect a potential for supercells. The higher the SRH, the greater the potential for supercells.
- Rasmussen, 2001 found that there is a relationship between 0-1 km SRH and supercells that produce significant tornadoes (F2 or greater). See this graphic which shows a box and whiskers graph of 0-1 km SRH for soundings associated with supercells with significant (F2 or greater) tornadoes labeled "TOR", supercells without significant tornadoes (only large hail), labeled "SUP", and nonsupercell thunderstorms (only lightning was reported near the sounding), labeled "ORD". The gray boxes denote the 25th to 75th percentiles of the data set, with the heavy horizontal bar at the median value. Vertical lines (whiskers) extend to the 10th and 90th percentiles (as in Rasmussen and Blanchard, 1998).

1.11 Effective Storm-Relative Helicity (ESRH)

Effective Storm-Relative Helicity (ESRH)

Effective Storm-Relative Helicty (ESRH)

Strengths

Limitations

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- Is a method of calculating SRH based on threshold values of CAPE (100J/kg) and CIN (-250 J/kg).
- Confines the SRH calculation to the part of a sounding where lifted parcels are buoyant, but not strongly capped.
- This is determined by starting with a surface parcel level and going upward until a lifted parcel's CAPE increases to 100J/kg or more with an associated CIN > than -250J/kg. From this level (the "effective inflow base") one continues to look upward in the sounding until a lifted parcel reaches a CAPE of < 100 J/kg or a CIN < -250 J/kg.

1.12 Effective Storm-Relative Helicity (ESRH) Strengths

Effective Storm-Relative Helicity (ESRH) Strengths

Effective Storm-Relative Helicty (ESRH)

Strengths

Limitations

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- Provides a more reasonable estimate of SRH in elevated supercell environments.
- More clearly discriminates between tornadic and non-tornadic storms than the standard, fixed layer versions of SRH. (see this figure)

1.13 Effective Storm-Relative Helicity (ESRH) Limitations

Effective Storm-Relative Helicity (ESRH) Limitations

Effective Storm-Relative Helicty (ESRH)

Strengths

Limitations

Table of Contents

- The ESRH can be missing from a sounding due to:
  1. Insufficient buoyancy
  2. Excessive CIN
  3. The effective inflow layer is a single level within a sounding
- Not a good distinguisher between supercells and non-supercells.

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1.14 Storm-Relative Wind (SR-Wind)

Storm-Relative Wind (SR-Wind)

Storm-Relative Wind (SR-Wind)

Strengths

Limitations

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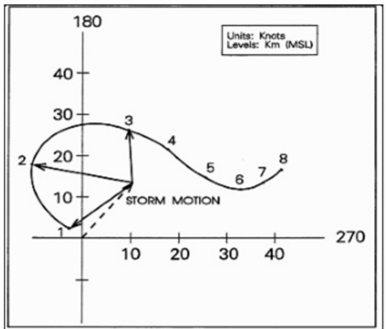

Figure 2. A hodograph showing storm relative wind "inflow" vectors and storm motion. (from NWSTC RTM-230).

- SR-wind is determined by subtracting the parent storm motion vector from the environmental wind vector. Vectors on a hodograph represent wind flow that the storm experiences at various levels as the storm moves through the environment (see figure at left).
- SR-wind affects the precipitation distribution of a storm with respect to the main updraft.
- Higher values of of mid and upper-level SR-wind carry precipitation away from the updraft summits of well-organized storms (such as supercells) thereby diminishing the potential for significant water-loading (OTB, 1993).

1.15 Storm-Relative Wind (SR-Wind) Strengths

Storm-Relative Wind (SR-Wind) Strengths

Storm-Relative Wind (SR-Wind)

Strengths

Limitations

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- SR-wind is more physically significant in producing a particular storm structure than ground relative winds. Strong SR-wind at midlevels mitigates precipitation loading in updrafts, while strong low-level SR-wind is often associated with strong storm-relative helicity and low-level mesocyclones. One can qualitatively assess the amount of SRH by looking at the amount of area swept out on hodograph by the storm-relative wind vectors.
- Thompson (1998) found that supercells were more likely to produce tornadoes when midlevel (~ 500 mb) storm-relative winds were greater than 8-10 m s-1.
- Evans and Doswell (2001) found 0-2 km system-relative winds stronger in derecho events than in non-derecho events. This was likely due to faster forward speed and low-level convergence in derecho events.
- Near-ground (0-1 km) storm-relative wind (speed) may also be crucial to tornadogenesis (Markowski et al. 2002).
- SR-wind significantly influences hail growth because it determines hail trajectories across the updraft.

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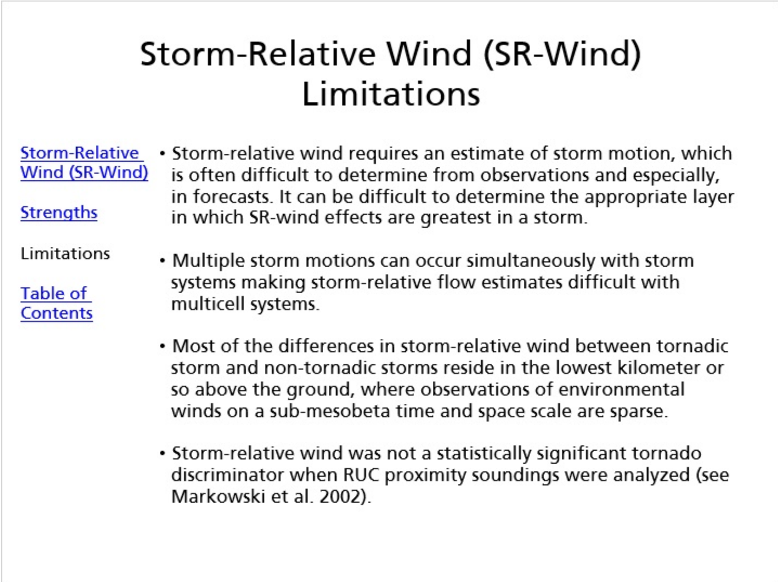
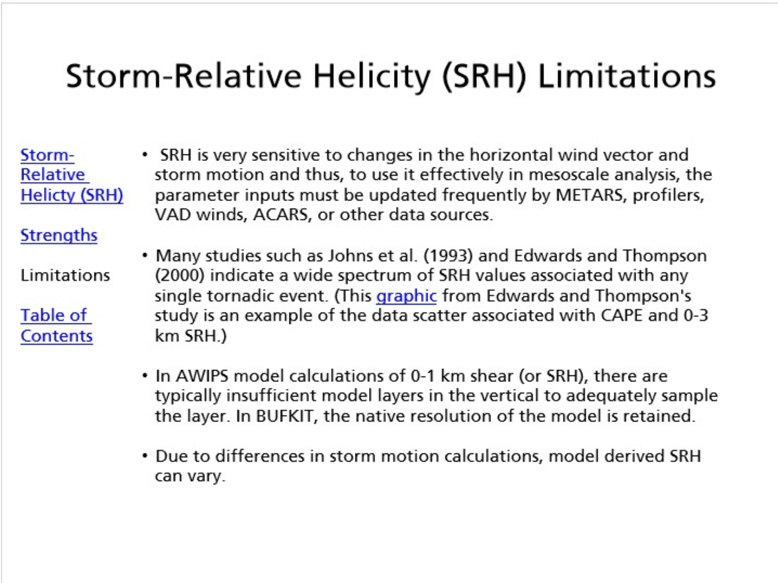
1.16 Storm-Relative Wind (SR-Wind) Limitations



1.17 Storm-Relative Helicity (SRH) Limitations



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1.18 Effective Bulk Shear (EBS)

Effective Bulk Shear (EBS)

EBS

Strengths and Limitations

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- This is the bulk vector difference from the effective inflow base upward to 50% of the equilibrium level height for the most unstable parcel in the lowest 300 mb.
- This parameter is similar to the 0-6 km bulk shear, though it accounts for storm depth (effective inflow base to EL) and is designed to identify both surface based and elevated supercell environments.
- Supercells become more probable as the effective bulk shear vector increases in magnitude from 25-40 kt and greater.

1.19 Effective Bulk Shear (EBS) Strengths/Limitations

Effective Bulk Shear (EBS) Strengths/ Limitations

EBS

Strengths and Limitations

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Strengths:

- Normalizes the shear values for shallow and tall storms, allowing for more realisitc assessments of these storm profiles.
- Allows for elevated and surface-based storm environments to be treated similarly.
- Does a good job of discriminating between supercell and non-supercell storms

Limitations:

- Effective Bulk Shear does not perform well in distinguishing between tornadic and non-tornadic storms.

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Composite Parameters

1. Composite Indices

1.1 Untitled Slide

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1.2 Operational Severe Weather Diagnostic Parameters:

Composite Indices

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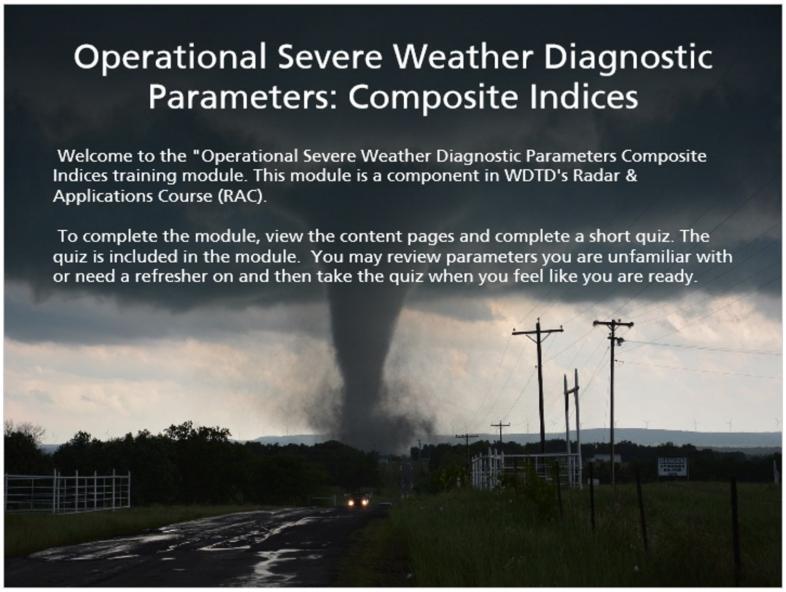
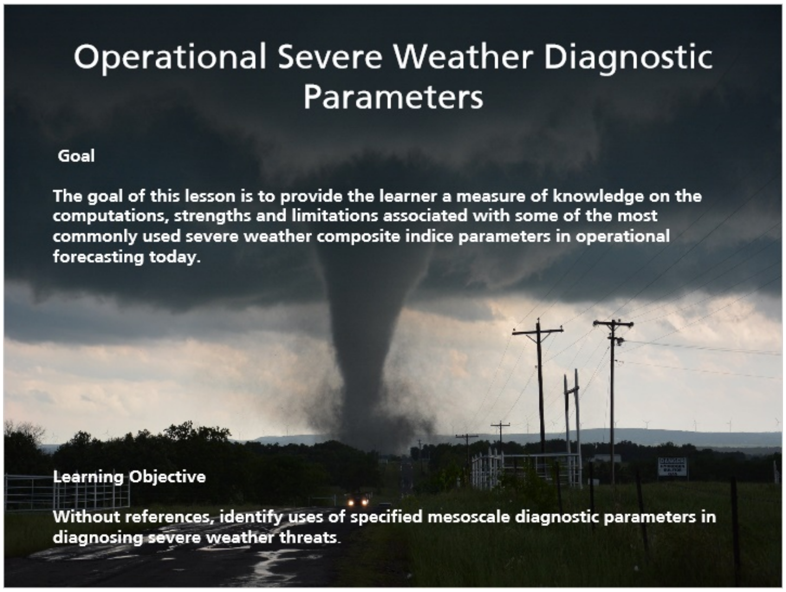
1.3 Operational Severe Weather Diagnostic Parameters: Composite Indices



1.4 Operational Severe Weather Diagnostic Parameters



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1.5 Composite Indices

Composite Indices

Supercell Composite

1.6 Right-Moving Supercell Composite (SCP)

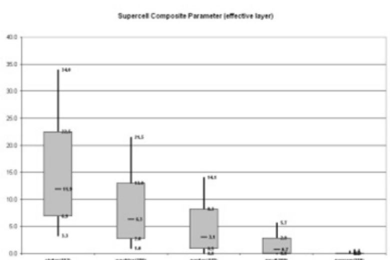
Right-Moving Supercell Composite (SCP)

Right-Moving Supercell Composite (SCP)

Strengths / Limitations

Table of Contents

SCP = (muCAPE / 1000 J kg^{-1}) * (ESRH / 50 m^2 s^{-2}) * (EBWD / 20 m s^{-1})



- SCP is a multiple ingredient, composite index, each ingredient is normalized to supercell threshold values, and larger values of SCP denote greater overlap in the three supercell ingredients. Only positive values of SCP are displayed, which correspond to environments favoring right-moving (cyclonic) supercells.
- The formula for SCP is shown to the upper left, where: ESHEAR = the effective bulk wind difference, ESRH = the effective SRH and MUCAPE = the CAPE value based on the "most unstable" parcel in the lowest 300 mb.
- Values greater than 1 strongly favor supercells, see the figure to the left for a distribution of values for proximity soundings derived from RUC model hourly analyses. For a larger version of this image click here.

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1.7 Right-Moving Supercell Composite (SCP) Strengths / Limitations

Right-Moving Supercell Composite (SCP) Strengths / Limitations

Strengths:
- Is useful for a quick look at the combination of CAPE and shear.
- Is a good discriminator in determining supercell and non-supercell environments.

Limitation:
- CAPE, which is a part of the SCP calculation, is not a strong indicator of storm type. There is a large parameter space with SCP.

1.8 Left-Moving Supercell Composite (LSCP)

Left-Moving Supercell Composite (LSCP)

LSCP = (MUCAPE / 1000 J kg^{-1}) * (ESRH / 50 m^2 s^{-2}) * (EBWD / 20 m s^{-1})

- Similar to the Supercell Composite (SCP), the LSCP can help identify environments favorable to the development of left-moving supercells.
- In the formula to the right, EBWD is divided by 20 m s^{-1} in the range of 10-20 m s^{-1}. EBWD less than 10 m s^{-1} is set to zero, and EBWD greater than 20 m s^{-1} is set to one.
- Only negative values of LSCP are displayed, which correspond to environments favoring left-moving (anticyclonic) supercells. The more negative the LSCP, the more favorable the environment for left-moving supercells.
- Additional information can be found here.

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1.9 Significant Tornado Parameter (STP)

Significant Tornado Parameter (STP)

Significant Tornado Parameter (STP)

[Strengths]

[Limitations]

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STP = [(MLCAPE/1500 J kg^{-1}) * ((2000-MLLCL)/1500 m) * (ESRH/150 m^2 s^{-2})* (ESHEAR/20 m s^{-1}) * ((200+MLCIN)]/150 J kg^{-1})

- STP is a multi-parameter index developed by the SPC that incorporates bulk shear, SRH, CAPE, CIN, and LCL height where MLCAPE is the 100 mb mean parcel CAPE, MLLCL is the 100 mb mean parcel LCL height, MLCIN is the 100 mb mean parcel CIN, ESRH is the effective storm-relative helicity (SRH area confined to lifted parcels that are buoyant with at least 100 J/kg of CAPE and not strongly capped with more than -250 J/kg of CIN), and ESHEAR (maximum bulk shear from the most unstable parcel level upward to 40-60% of the equilibrium height). See [SPC mesoanalysis] web site for more details.
- When the MLLCL is less than 1000 m AGL, the MLLCL term is set to one, and when the MLCIN is greater than -50 J kg^{-1}, the MLCIN term is set to one. The ESHEAR term is capped at a value of 1.5, and set to zero when ESHEAR is less than 12.5 m s^{-1}.

1.10 Significant Tornado Parameter (STP)

Strengths

Significant Tornado Parameter (STP) Strengths

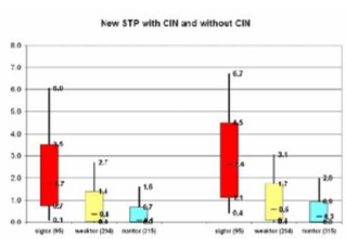
[Significant Tornado Parameter (STP)]

Strengths

[Limitations]

[Table of Contents]

- The STP has been shown operationally to discriminate between significantly tornadic and nontornadic supercells. A majority of significant tornadoes (F2 or greater damage) have been associated with STP values greater than 1, while most non-tornadic supercells have been associated with values less than 1 in a large sample of RUC analysis proximity soundings (See Thompson et. al., 2004).
- The newest version of STP that incorporates CIN can reduce areal false alarms (see [figure] right).



From Thompson et al (2004), this graph shows box and whiskers plots of the new versions of STP with CIN on the left, and without CIN on the right. The 3 classes of surface-based supercells are : significantly tornadic (sigtor), weakly tornadic (F0-F1), and nontornadic. Top and bottom of the shaded boxes denote the 75th and 25th percentile values respectively, with the median marked in each box.

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1.11 Significant Tornado Parameter (STP)

Limitations

Significant Tornado Parameter (STP)
Limitations

Significant Tornado Parameter (STP)

Strengths

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- This multi-parameter index inherits all the other limitations of its constituents. It is used primarily for supercell forecasts of significant tornadoes. There is considerable overlap in the sigtor (F2 and larger) and weaktor (F0 -F1) classes of storms.
- STP, like many other parameters, is dependent on the quality of the storm data.

1.12 Significant Hail Parameter (SHIP)

Significant Hail Parameter (SHIP)

Significant Hail Parameter (SHIP)

Limitations

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SHIP = [(MUCAPE j/kg) * (Mixing Ratio of MU PARCEL g/kg) * (700-500mb LAPSE RATE c/km) *(-500mb TEMP C) * (0-6km Effective Shear m/s)] / 44,000,000

- The Significant Hail Parameter (SHIP) was developed using a large database of surface-modified, observed severe hail proximity soundings. It is based on 5 parameters, and is meant to delineate between significant (>=2" diameter) and non-significant (<2" diameter) hail environments.
- Developed in the same vein as the STP and SCP parameters, values of SHIP greater than 1.00 indicate a favorable environment for SIG hail. Values greater than 4 are considered very high. In practice, maximum contour values of 1.5-2.0 or higher will typically be present when SIG hail is going to be reported. See this box and whiskers diagram for a graph showing ranges of SHIP.

>1 Significant Hail Possible
1.5-2 Significant Hail Likely
2-4 Significant Hail Probable
>4 Significant Hail Extremely Likely

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1.13 Large Hail Parameter (LHP)

Large Hail Parameter (LHP)

Large Hail Parameter (LHP)

LHP Page 2

Strengths

Limitations

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• The LHP is a multiple ingredient composite index meant to discriminate between significant hail (>= 2 inch diameter) and smaller hail.

•The LHP includes three thermodynamic components [MUCAPE, 700-500 mb lapse rates, the depth of the hail growth zone (-10 to -30 C)], as well as three vertical shear components [surface to EL bulk shear, the direction difference between the ground-relative winds at the EL and in the 3-6 km layer, and the direction difference between the storm-relative winds in the 3-6 km and 0-1 km layers] and is formulated as follows:

LHP = (TERM A * TERM B) + 5
Where:

$$\text{TERM A} = (((\text{MUCAPE}-2000)/1000) + ((3200-\text{THK}_{\text{HGZ}})/500) + ((\text{LR}_{75}-6.5)/2))$$

where THK_{HGZ} is the depth of the hail growth zone (the -10 to -30° C layer), and LR_{75} is the 700-500 mb temperature lapse rate.

$$\text{TERM B} = (((\text{Shear}_{\text{EL}}-25)/5) + ((\text{GRW}_{\text{dirEL}}+5)/20) + ((\text{SRW}_{\text{dirMID}}-80)/10))$$

where Shear_{EL} is the magnitude of the vector wind difference between the surface wind and the mean wind in the 1.5 km layer immediately below the EL height for the MU parcel, $\text{GRW}_{\text{dirEL}}$ is the directional difference between the ground-relative mean wind in the 1.5 km layer below the EL and the mean wind in the 3-6 km layer AGL, and $\text{SRW}_{\text{dirMID}}$ is the directional difference betweem the mean storm-relative winds in the 3-6 km and 0-1 km layers.

1.14 Large Hail Parameter Page 2 (LHP)

Large Hail Parameter Page 2 (LHP)

Large Hail Parameter (LHP)

LHP Page 2

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If 0-6 km BWD < 14 m s -1 OR MUCAPE < 400 J kg-1, LHP = 0.

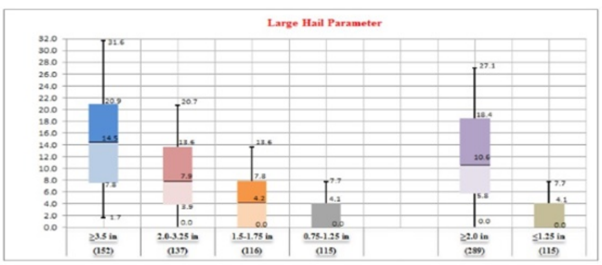
• LHP > 4 = Maximum hail size of at least 1.5-1.75" highly probable*

• LHP > 8 = Maximum hail size of at least 2-3.25" highly probable*

• LHP > 14 = Maximum hail size of 3.5" or greater highly probable*

*given a storm

Click here for a larger version of the figure below.



1.15 Large Hail Parameter (LHP) Strengths

Large Hail Parameter (LHP) Strengths

Large Hail Parameter (LHP)
LHP Page 2
Strengths
Limitations
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- Discriminates between large, very large, and giant hail sizes better than other composite parameters
- Uses hail-growth-zone thickness which differentiates between large hail sizes better than hail CAPE
- Uses shear above 6km (and 0-10km), which differentiates between large hail sizes better than the traditional 0-6km layer.

1.16 Large Hail Parameter (LHP)

Limitations

Large Hail Parameter (LHP) Limitations

Large Hail Parameter (LHP)
LHP Page 2
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- Does not differentiate between severe and non-severe hail
- Only valid if convection occurs
- Does not take into account duration of supercell mode or negative impacts on maximum hail size caused by anvil seeding from upstream convection.

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1.17 Derecho Composite Parameter (DCP)

Derecho Composite Parameter (DCP)

Derecho Composite Parameter (DCP)

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DCP = (DCAPE/980)*(MUCAPE/2000)*(0-6 km shear/20 kt)*(0-6 km mean wind/16 kt)

This parameter is based on a data set of 113 derecho events compiled by Evans and Doswell (2001). The DCP was developed to identify environments considered favorable for cold pool "driven" wind events through four primary mechanisms:

1. Cold pool production [DCAPE]

2. Ability to sustain strong storms along the leading edge of a gust front [MUCAPE]

3. Organization potential for any ensuing convection [0-6 km shear]

4. Sufficient flow within the ambient environment to favor development along downstream portion of the gust front [0-6 km mean wind].

1.18 Derecho Composite Parameter (DCP) Page 2

Derecho Composite Parameter (DCP) Page 2

Derecho Composite Parameter (DCP)

DCP Page 2

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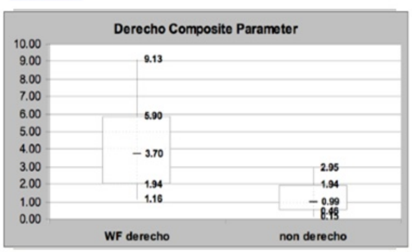

- Normalized values were developed for each parameter using 51 observed proximity soundings near "Weak Forcing" derechos, which were compared to values from 31 proxy soundings from weakly forced non-derecho MCSs. It was found that DCAPE > 980 J/Kg and MUCAPE > 2000 K/kg were common (25th percentile), while sfc-6 km shear > 20 kt and sfc-6 km mean wind > 16 kt were uncommon (75th percentile) in the non-derecho dataset. For more information see this paper by Evans and Doswell in Weather and Forecasting from 2001.
- The ability of the DCP to discriminate between non-derecho and derecho MCSs can be inferred from this figure (also shown at left), which shows complete separation of the interquartile ranges (25th – 75th percentiles) of the DCP between the non-derecho and derecho MCS data sets.

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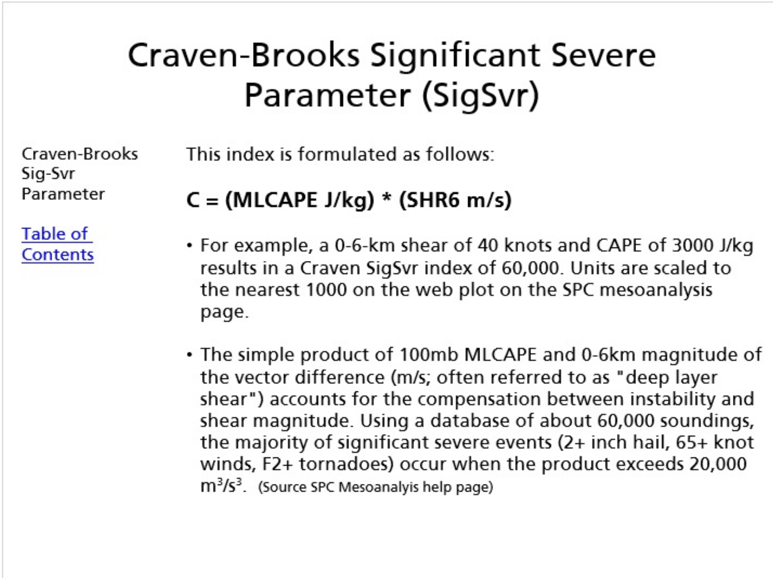
1.19 Craven-Brooks Significant Severe Parameter (SigSvr)



Craven-Brooks Significant Severe Parameter (SigSvr)

Craven-Brooks Sig-Svr Parameter

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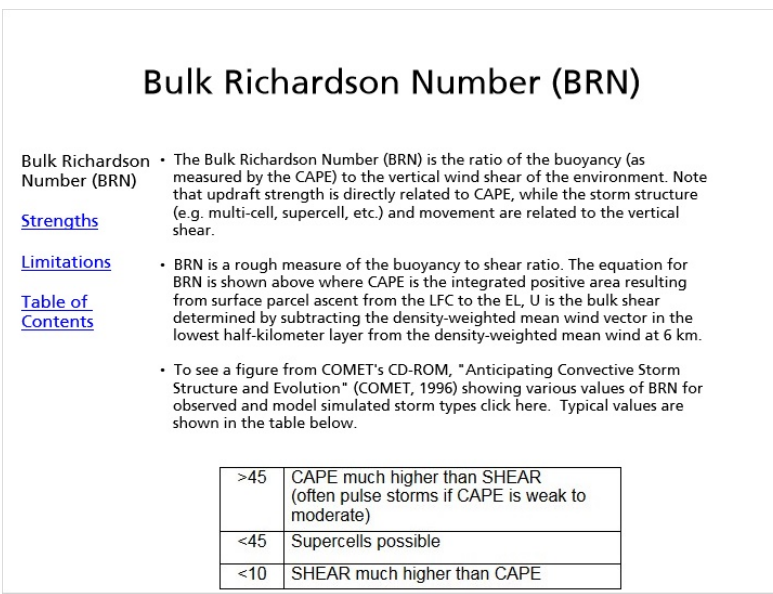
This index is formulated as follows:

C = (MLCAPE J/kg) * (SHR6 m/s)

- For example, a 0-6-km shear of 40 knots and CAPE of 3000 J/kg results in a Craven SigSvr index of 60,000. Units are scaled to the nearest 1000 on the web plot on the SPC mesoanalysis page.
- The simple product of 100mb MLCAPE and 0-6km magnitude of the vector difference (m/s; often referred to as "deep layer shear") accounts for the compensation between instability and shear magnitude. Using a database of about 60,000 soundings, the majority of significant severe events (2+ inch hail, 65+ knot winds, F2+ tornadoes) occur when the product exceeds 20,000 m^3/s^3. (Source SPC Mesoanalyis help page)

1.20 Bulk Richardson Number (BRN)



Bulk Richardson Number (BRN)

Bulk Richardson Number (BRN)

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- The Bulk Richardson Number (BRN) is the ratio of the buoyancy (as measured by the CAPE) to the vertical wind shear of the environment. Note that updraft strength is directly related to CAPE, while the storm structure (e.g. multi-cell, supercell, etc.) and movement are related to the vertical shear.
- BRN is a rough measure of the buoyancy to shear ratio. The equation for BRN is shown above where CAPE is the integrated positive area resulting from surface parcel ascent from the LFC to the EL, U is the bulk shear determined by subtracting the density-weighted mean wind vector in the lowest half-kilometer layer from the density-weighted mean wind at 6 km.
- To see a figure from COMET's CD-ROM, "Anticipating Convective Storm Structure and Evolution" (COMET, 1996) showing various values of BRN for observed and model simulated storm types click here. Typical values are shown in the table below.

>45	CAPE much higher than SHEAR (often pulse storms if CAPE is weak to moderate)
<45	Supercells possible
<10	SHEAR much higher than CAPE

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1.21 Bulk Richardson Number (BRN) Strengths

Bulk Richardson Number (BRN) Strengths

Bulk Richardson Number (BRN)

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- BRN can be used to provide an estimate of rotation potential in storms without considering storm motion. BRN indicates a higher likelihood of supercells when value is between 10 and 50.
- The BRN value is operationally displayable on both AWIPS observed and model skew-t soundings and on BUFKIT model sounding programs.
- The denominator of the BRN equation, known as BRN shear, has been shown in some studies to have the ability to indicate the likelihood of a convective storm to develop low-level mesocyclones (see Stensrud et al. (1997)).
- Based on mesoscale model data , Stensrud et al. (1997) found that BRN shears of 40 - 100 m2/s2 indicated a likelihood for storms to develop low-level mesos.

1.22 Bulk Richardson Number (BRN) Limitations

Bulk Richardson Number (BRN) Limitations

Bulk Richardson Number (BRN)

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- Operational day to day utility is limited due to sensitivity of CAPE value in the numerator of the BRN equation. For large values of CAPE greater than 4000 j/kg , Stensrud et al. (1997) and Thompson et al. (2003) found that BRN was large regardless of the value of the denominator, which is known as BRN shear.
- Another limitation of BRN is that it does not take into account the detailed aspects of the low-level curvature, which has been shown to be significant in supercell dynamics (Weisman and Rotunno 1999). In low buoyancy environments, shear-induced pressure forces, which are related in part to the shear from low-level curvature, can be the dominant factor in controlling updraft strength. Conversely, when bulk shear is weak, the verticle profile of buoyancy can be just as important as the total CAPE value in determining updraft intensity.low-level buoyancy (and lapse rates) can dominate updraft rotation

1.23 MCS Maintenance Probability (MMP)

MCS Maintenance Probability (MMP)

MCS Maintenance Probability (MMP)

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- 348 warm-season MCS proximity soundings from a variety of MCS types were used to develop this parameter. Through hypothesis testing and discriminant analysis on hundreds of sounding parameters, the following four parameters were selected to develop the probabilities:

1. Maximum bulk shear (m/s) in the 0-1 and 6-10 km layer
2. 3-8 km lapse rate (degrees C/km)
3. Most unstable CAPE
4. 3-12 km mean wind speed (m/s)

- It has been found that it can provide useful guidance on the transition of an organized MCS with a solid line of 50+ dbZ echoes to a more disorganized system with unsteady changes in structure and propagation. In particular, the MMP showed a noticeable decline for all MCS cases from the genesis to dissipation stages in the Northern and Southern Plains region.
- Although the MMP was designed to discriminate between mature and dissipating MCSs, the parameter may also be used on longer time scales with NAM output to give a general idea of where mature MCSs may be favored on longer timescales (assuming convection in the model doesn't erroneously remove instability).
- MMP performance in the Eastern Region was markedly poorer, however, likely because of the climatologically lower lapse rates during the summer months.
- More information can be found here.

1.24 Energy Helicity Index (EHI)

Energy Helicity Index (EHI)

Energy Helicity Index (EHI)

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EHI = (CAPE)(SRH)/1.65 x 10^5

- The EHI is a composite index designed to assess the rotational intensity potential of supercells and is defined above where SRH is Storm-Relative Helicity from 0 to 3 km, and CAPE is integrated from the LFC to the Equilibrium Level (EL).
- The EHI (Hart and Korotky, 1991), (Davies, 1993) is used operationally for supercell and tornado forecasting.
- Increasing values of EHI from 1.0 to 3.0 (and higher) indicate an increasing probability of tornadic supercells.
- EHI has also been computed using a 0-1 km SRH in response to results that show 0-1 km SRH is a better tornadic discriminator than its deeper version.
- Click here to see an example of EHI displayed in AWIPS

1.25 Energy Helicity Index (EHI) Strengths

Energy Helicity Index (EHI) Strengths

- EHI has some value in discriminating between supercells that produce tornadoes and those that do not.
- This figure from Rasmussen and Blanchard (1998), suggests that values of EHI around 3.0 or greater indicate a higher likelihood for significant tornadoes.
- Mean 0-1 km EHI values derived from mixed-layer (ML) parcels (MLEHI) were found by Davies (2004) to be consistently large (near 2.0 and greater) for F1-F4 tornado cases compared non-tornadic and F0 cases.
- For an example showing the effective use of EHI, refer to the tornado outbreak case of 09 Oct. 2001 in west central OK. The AWIPS graphic shows a 12-hr forecast of EHI from the ETA valid 00 UTC 10 Oct. 2001. In this event, the EHI accurately "bullseyed" the area of where tornadic thunderstorms subsequently developed over west central Oklahoma and eastern Nebraska.
- Note, the EHI forecasted fields for this event which also indicated a high probability of tornadoes over portions of KS (EHI values were predicted from 1.0 to 3.0) but no tornadoes occurred in this region. Thus, forecasters can expect a relatively high false alarm rate with this single parameter.

1.26 Energy Helicity Index (EHI) Limitations

Energy Helicity Index (EHI) Limitations

- There is some overlap in observed values of EHI between storm "classes", making standard EHI not always a good parameter for discriminating between storms that produce tornadoes and those that do not.
- Also, as was observed in the representative example from 10 Oct. 2001 , EHI values greater than 3.0 (as was forecast in KS) do not always correlate to tornadic supercells. High CAPE can over inflate EHI and render it not as effective. The CIN (or lack of surface-based CAPE) can also wreck the EHI forecast.
- In low CAPE environments and high shear, EHI might underestimate tornado potential. Since EHI is derived from CAPE and shear, it inherits the same limitations and uncertainties from computations of those parameters.

1.27 Vorticity Generation Parameter (VGP)

Vorticity Generation Parameter (VGP)

Vorticity Generation Parameter (VGP)

[Strengths]

[Limitations]

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VGP = [S(CAPE)]$^{1/2}$

- VGP is meant to estimate the rate of tilting and stretching of horizontal vorticity by a thunderstorm updraft.. The equation used by Rasmussen and Blanchard (1998) is shown above.
- S is the mean shear (hodograph length divided by depth over which the hodo was measured - 4 km in their study). Mean shear is assumed to be proportional to the horizontal vorticity vector and CAPE 1/2 proportional to the vertical component of velocity. In Rasmussen and Blanchard's study (1998), the CAPE in VGP used a parcel with the virtual temperature correction and a uniformly mixed theta-E in the lowest 100 m AGL.

1.28 Vorticity Generation Parameter (VGP)

Strengths

Vorticity Generation Parameter (VGP) Strengths

[Vorticity Generation Parameter (VGP)]

Strengths

[Limitations]

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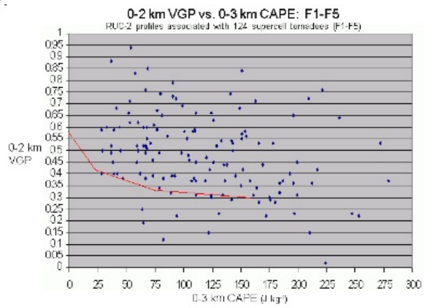
- VGP has been shown to have discriminating ability between supercells and nonsupercells (See figure 14 of Rasmussen and Blanchard, 1998).
- [This] figure, also shown below, from Davies (2002) suggests some usable thresholds in the parameter space of 0-3 km CAPE and VGP.



1.29 Vorticity Generation Parameter (VGP)

Limitations

Vorticity Generation Parameter (VGP)
Limitations

Vorticity Generation Parameter (VGP)

Strengths

Limitations

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- VGP is not as good by itself at discriminating between storms with significant tornadoes. See Rasmussen and Blanchard's (1998) figure 13.
- VGP may underestimate tornado potential in low CAPE environments.
- As with EHI, since VGP is derived from CAPE and shear, it inherits the same limitations and uncertainties from computations of those parameters.

1.30 Microburst Composite

Microburst Composite

Microburst Composite

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- **The Microburst Composite is a weighted sum of the following individual parameters: SBCAPE, SBLI, lapse rates, vertical totals (850-500 mb temperature difference), DCAPE, and precipitable water. The specific terms and weights are listed below:**

- **SBCAPE term : < 3100 set to 0; 3100-3999 set to 1; >= 4000 set to 2;**
- **SBLI term: > -8 set to 0; <= -8 set to 1; <= -9 set to 2; <= -10 set to 3;**
- **0-3 km lapse rate term: <= 8.4 set to 0; > 8.4 set to 1;**
- **vertical totals term: < 27 set to 0; >= 27 set to 1; >= 28 set to 2; >= 29 set to 3;**
- **DCAPE term: < 900 set to 0; >= 900 set to 1; >= 1100 set to 2; >= 1300 set to 3;**
- **precipitable water term: <= 1.5 set to -5; > 1.5 set to 0.**
- All six of the terms are summed to arrive at the final microburst composite value. This value should be viewed as conditional upon the existence of a storm.

MC Value	Chance of microburst
3-4	"Slight chance"
5-8	"Chance"
>= 9	"Likely"

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1.31 Wind Damage Parameter (WNDG)

Wind Damage Parameter (WNDG)

Wind Damage Parameter (WNDG)

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- **WNDG = (MLCAPE / 2000 J kg^{-1}) * (0-3 km lapse rate / 9 C km^{-1}) * (1000-3500 m AGL mean wind / 15 m s^{-1}) * ((50 + MLCIN) / 40 J kg^{-1})**
- The Wind Damage Parameter (WNDG) is a non-dimensional composite parameter that identifies areas where large CAPE, steep low-level lapse rates, enhanced flow in the low-mid levels, and minimal convective inhibition are co-located. The parameter is formulated as shown above where 0-3 km lapse rate < 7 is set to zero, and MLCIN < -50 J kg-1 is set to -50.
- WNDG values > 1 favor an enhanced risk for scattered damaging outflow gusts with multicell thunderstorm clusters, primarily during the afternoon in the summer

1.32 Modified SHERBE

Modified SHERBE

The Modified SHERBE is a composite parameter designed to highlight "low CAPE/high shear" environments capable of producing significant severe storms. MOSHE is formulated as follows:

$$\mathrm{MOSHE} = \frac{(\mathrm{LLLR} - 4\,\mathrm{K\,km^{-1}})^2}{4\,\mathrm{K^2\,km^{-2}}} \times \frac{(\mathrm{S15MG} - 8\,\mathrm{m\,s^{-1}})}{10\,\mathrm{m\,s^{-1}}} \times \frac{(\mathrm{ESHR} - 8\,\mathrm{m\,s^{-1}})}{10\,\mathrm{m\,s^{-1}}} \times \frac{(\mathrm{MAXTEVV} + 10\,\mathrm{K\,Pa\,km^{-1}\,s^{-1}})}{9\,\mathrm{K\,Pa\,km^{-1}\,s^{-1}}},$$

Modified SHERBE

Wet Microburst Severity Index Page 2 (WMSI)

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upward motion at the top of each 2 km deep layer from the surface to 6 km, incremented every 0.5 km. LLLR is the 0-3 km lapse rate, S15MG is the 0-1.5 km shear vector magnitude, ESHR is the effective bulk shear vector magnitude.

This composite parameter indirectly includes some influence of buoyancy through the effective bulk shear term, which requires at least 100 J kg-1 of CAPE and no more than 250 J kg-1 of CIN

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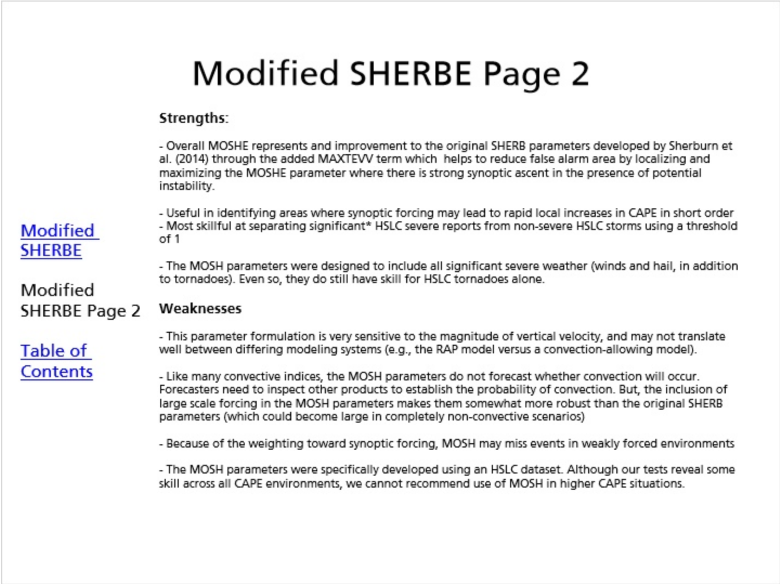
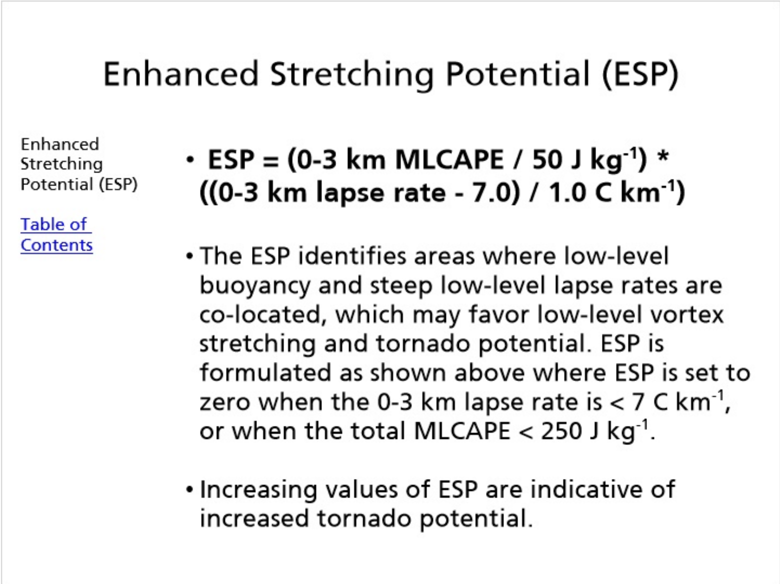
1.33 Modified SHERBE Page 2



1.34 Enhanced Stretching Potential (ESP)



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1.35 Theta-E Index (TEI)

Theta-E Index (TEI)

Theta-E Index (TEI)

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- TEI is the difference between the surface theta-e and the minimum theta-e value in the lowest 400 mb AGL.
- A high TEI will be associated with rapid cooling and drying with height which allows rising parcels to remain warmer and more moist than their surrounding environment. The result is elevated convection when lifting occurs at the base of the layer.
- TEI values of less than 5 are not favorable for elevated convection.
- Values of 5-9 indicate the potential for elevated convection.
- Values of 9 or more indicate significant potential for elevated convection.

1.36 Critical Angle

Critical Angle

Critical Angle

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- Critical Angle is the angle between the storm-relative wind at the surface and the 0-500m AGL shear vector (in knots). Critical angles near 90° infer streamwise vorticity near the ground, favoring stronger cyclonic rotation closer to the ground in a right-moving supercell.
- For more information click here (PDF, opens in a new window)
- **Strength:** Clear delineation between the critical angles of tornadic (near 90°) vs. non-tornadic (generally near 110°) storms
- **Limitations:** While available on the SPC meso-analysis page, the knowledge of variations in low-level wind field is paramount in determining the critical area. This is information that requires better sampling via observational networks and not well forecast by operational models.
- Users should be extremely cautious in using critical angle in environments where the direction of shear changes rapidly in the lowest 1 km of the atmosphere.

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1.37 Non-Supercell Tornado Parameter (NSTP)

Non-Supercell Tornado Parameter (NSTP)

Non-Supercell Tornado Parameter (NSTP)

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•The non-supercell tornado parameter (NSTP) is the normalized product of the following terms:

$$\left(\frac{LR_{0-1}}{9}\right)\left(\frac{MLCAPE_3}{100}\right)\left(\frac{(225-MLCIN)}{200}\right)\left(\frac{18-Shear_6}{5}\right)\left(\frac{\zeta_r}{8}\right)$$

where $LR_{0\text{-}1}$ is the 0-1 km temperature lapse rate in °C km-1, $MLCAPE_3$ is the convective available potential energy for a 0-1 km mixed-layer parcel lifted to 3 km in J Kg^{-1}, MLCIN is the convective inhibition for a 0-1 km mixed-layer parcel (positive for increasing CIN; J Kg^{-1}), $Shear_6$ is the 0-6 km Bulk Shear (ms^{-1}) and ζ_r is the surface relative vorticity ($1e^{-5}s^{-1}$).

•This normalized parameter is meant to highlight areas where steep low-level lapse rates correspond with low-level instability, little convective inhibition, weak deep-layer vertical shear, and large cyclonic surface vorticity.

•Values > 1 suggest an enhanced potential for non-mesocyclone tornadoes. For more information on this parameter see this paper by Baumgardt and Cook.

1.38 Non-Supercell Tornado Parameter (NSTP) Strengths

Non-Supercell Tornado Parameter (NSTP) Strengths

Non-Supercell Tornado Parameter (NSTP)

Strengths

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- It appears the NSTP has higher success rates with boundaries that are somewhat more significant in their thermodynamics and wind fields and also larger in scale. This favors stationary or slow-moving synoptic frontal boundaries that are better resolved in model data.

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1.39 Non-Supercell Tornado Parameter (NSTP)

Limitations

Non-Supercell Tornado Parameter (NSTP) Limitations

Non-Supercell Tornado Parameter (NSTP)

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- The parameter is only a reflection of how well the model represents, or forecasts, the true atmospheric conditions. Correct boundary location and thermodynamic knowledge in the modeling system is key to a representative NSTP forecast. Operational use of the NSTP without considering the model's accuracy in representing the atmosphere correctly is ill-advised.
- With a more noticeable presence in the summer season (when more widespread 0-3 km CAPE is present) the NSTP does have a false alarm component. The false alarms appear mainly in maxima of surface relative vorticity located both along, and away, from the boundary presenting a threat for tornadogenesis.
- False alarms in LAPS are prevalent owing to differences in model resolution. Those false alarm areas where the NSTP>1 away from the true threatening boundary do pose a limitation to the parameter's operational use. Some of these maxima are weak-moderate, isolated cyclonic shear areas not associated with boundaries and only weakly convergent with a lower probability of convective initiation.
- NSTP skill appears to decrease toward lower mesoscale boundaries such as outflow boundaries associated with single-cell or pulse-type convective storms. Mainly, these boundaries are not resolved well by 10 km horizontal resolution models and larger, and thus the NSTP skill suffers.

1.40 Significant Hail Parameter (SHIP)

Limitations

Significant Hail Parameter (SHIP) Limitations

Significant Hail Parameter (SHIP)

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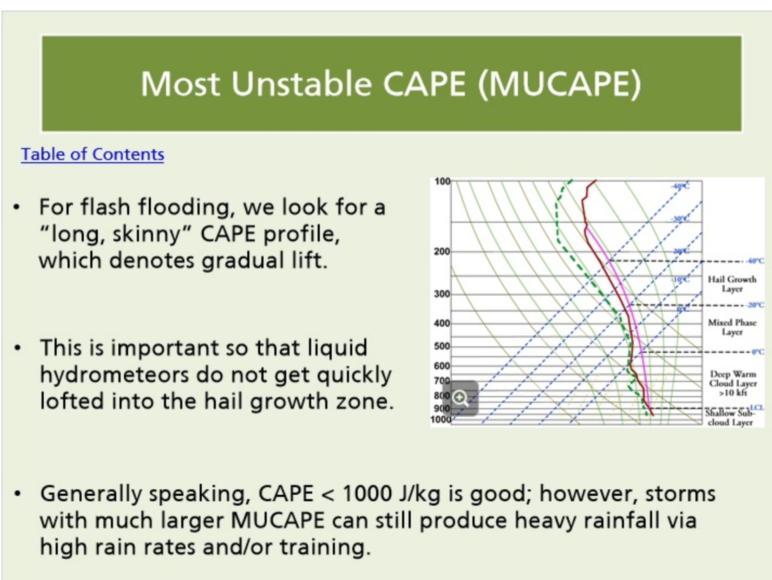
- Since SHIP is based on the RAP depiction of MUCAPE, unrepresentative MUCAPE "bullseyes" may cause a similar increase in SHIP values. This typically occurs when bad surface observations get into the RAP model.

Heavy Rain Parameters

1. Heavy Rain Parameters

1.1 Table of Contents

1.2 Most Unstable CAPE (MUCAPE)



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1.3 Precipitable Water (PW)

Precipitable Water (PW)

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- Precipitable water is a measure of the depth of liquid water at the surface that would result after precipitating all of the water vapor in a vertical column of the atmosphere over a given location.
- PW is usually maximized when the atmosphere is saturated over a large depth.
- To determine the significance of current PW values, they should be compared with climatology for the area. An excellent place to find PW climatologies is the Storm Prediction Center page here.
- Generally, heavy rain events occur with PW values that are above the 75th percentile and usually approach the 99th percentile.

1.4 Relative Humidity (RH)

Relative Humidity (RH)

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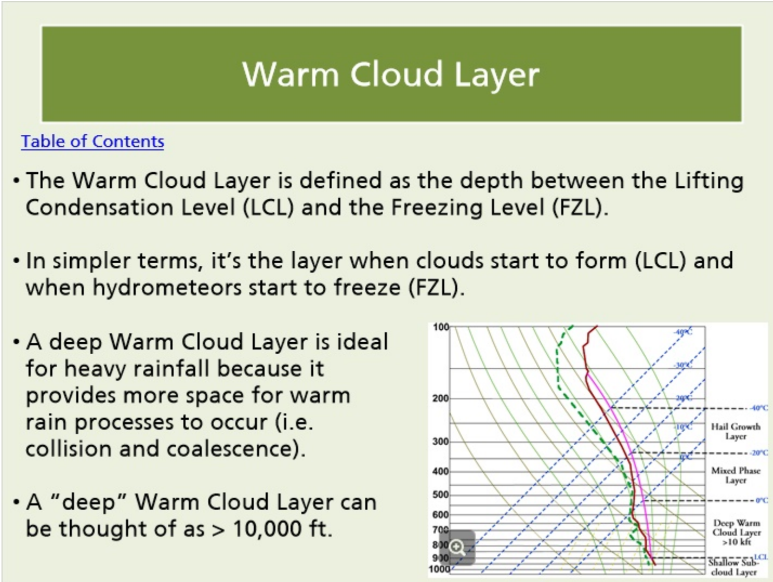
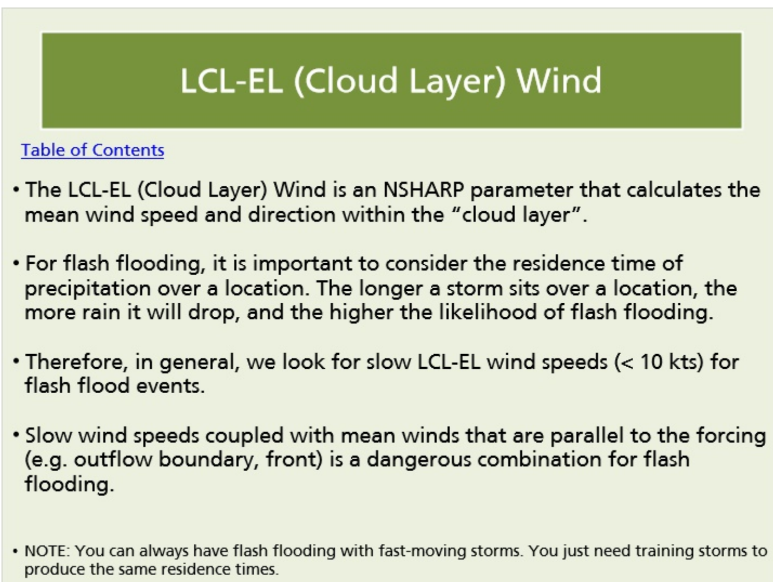
- Generally, Relative Humidity (RH) is the amount of water vapor present in the air expressed as a percentage of the amount needed for saturation at the same temperature.
- Similar to Precipitable Water, it is a proxy for moisture through the vertical profile.
- In NSHARP, RH is given for low- and mid-levels.
- For heavy rainfall, we look for values > 70%. Ideally, this is for both low- and mid-levels.

1.5 Warm Cloud Layer



1.6 LCL-EL (Cloud Layer) Wind



1.7 Upwind Propagation Vector

Upwind Propagation Vector

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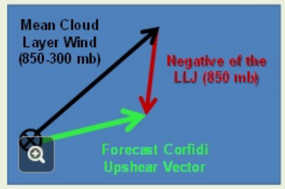

- The upwind propagation vector (aka "Corfidi Upshear" vector) is an estimate of storm motion for a "backbuilding" MCS, where the low-level jet is subtracted from the mean wind.

- For flash flooding, slow Corfidi Upshear winds (< 15 kts) denote the potential for a slow-moving, backbuilding MCS.

- For flash flooding, the downshear component is not as important since it denotes a "forward-propagating" MCS. This type of MCS will not have the same residence times as a backbuilding MCS.

Note: The "Corfidi Downshear" vector is an estimate of net storm motion for a "forward propagating" MCS where the low-level storm inflow is added to the mean wind. Please refer to Corfidi, 2003 and the RAC Lesson on Multicell Motion in the Convective Storm Structure and Evolution section for more information.

1.8 Precipitation Potential Placement Parameter

Precipitation Potential Placement Parameter

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$$RH_{(1000\text{-}700mb)} \times PW$$

where RH (1000-700mb) = lower tropospheric relative humidity and PW = Precipitable Water

- Precipitation Potential Placement is a SPC-derived parameter combining precipitable water and low-level mean RH to help better place where rainfall will occur.

- Rainfall is usually maximized where the best low level convergence and instability overlap with the highest values for this parameter.

- The risk for heavy rainfall increases as values go up. Additionally, thresholds for precipitation also change based on temperatures.
  - Onset of rainfall: ranges from ~0.3 inches with temps < 30F to 1.0 inches above 80F.
  - Increased risk for heavy rainfall: values above 1.0-1.4 inches with temps below 60F and values above 1.6-2.0 inches with temps above 60F.