Thermodynamic Parameters

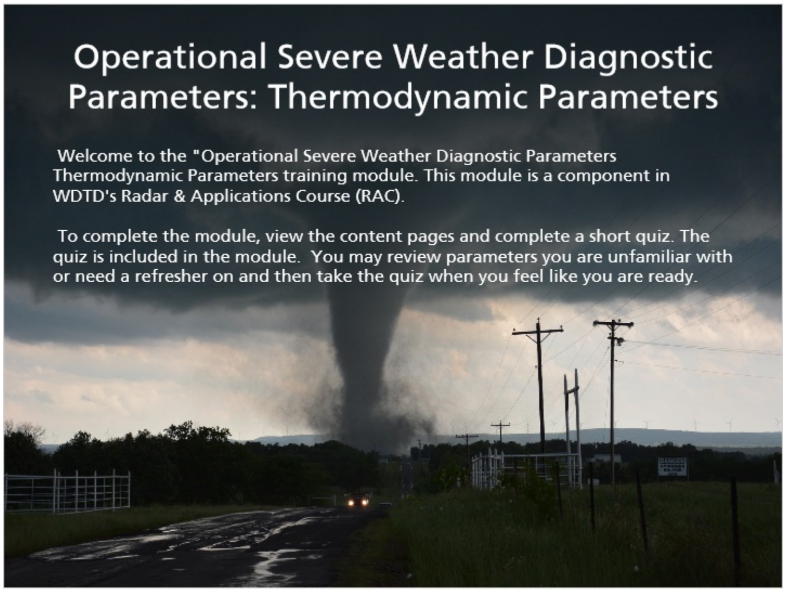
1. Thermodynamic Parameters

1.1 Operational Severe Weather Diagnostic Parameters:

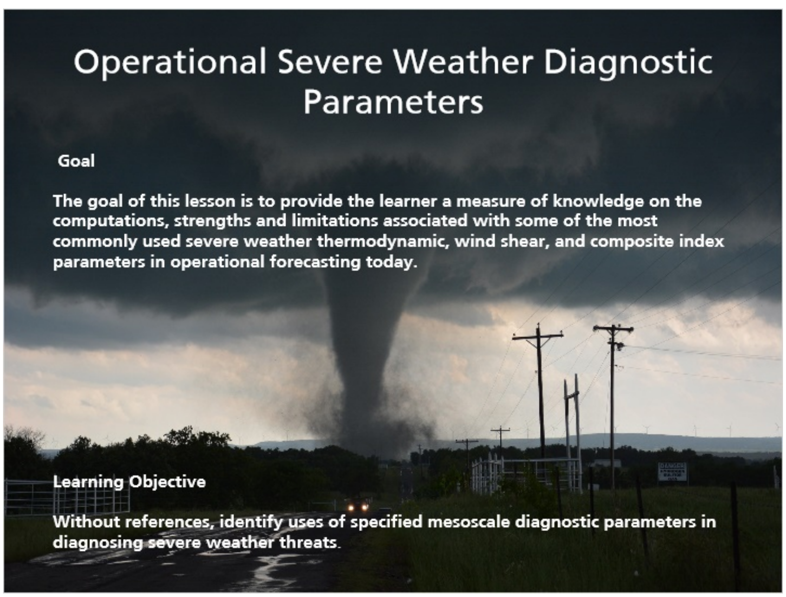
Thermodynamic Parameters

Notes:

1.2 Operational Severe Weather Diagnostic Parameters: Thermodynamic Parameters



1.3 Operational Severe Weather Diagnostic Parameters



1.4 Thermodynamic Parameters

Thermodynamic Parameters

Convective Available Potential Energy (CAPE)
SBCAPE MLCAPE MUCAPE NCAPE DCAPE

Convective Inhibition (CIN)
Surface Based CIN (SBCIN)
Mixed Layer CIN (MLCIN)

Lifted Index (LI)

Temperature Lapse Rates (TLR)

Lifting Condensation Level (LCL)

Level-of-Free Convection (LFC)

Wet-bulb Zero Height (WBZ)

Freezing Level (FZ LVL)

Quiz

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).

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.

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.

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

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

1.9 MLCAPE Strengths

MLCAPE Strengths

MLCAPE
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MLCAPE is more representative of realized buoyancy because it incorporates parcel mixing effects. MLCAPE and low-level lapse rates have been shown to be two good parameters for discrimination of general thunderstorms (i.e., whether convection produces lightning). See Craven et al. (2002).

Soundings taken in proximity of thunderstorms usually posses more than 250 j/kg of MLCAPE.

MLCAPE, when combined with LCL height, has been shown to be a very good discriminator for tornadic supercells. See Craven et al. (2002).

1.10 Most Unstable CAPE (MUCAPE)

Most Unstable CAPE (MUCAPE)

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MUCAPE is a measure of instability in the troposphere. This value represents the total amount of potential energy available to the most unstable parcel of air found within the lowest 300-mb of the atmosphere while being lifted to its level of free convection (LFC). No parcel entrainment is considered.

On the SPC Hourly Mesoscale Analysis web page, this is CAPE calculated by using a parcel from a pressure level which results in the most unstable CAPE value possible in the lowest 300 mb AGL.

For information on the various lifting method employed by NSHARP go to the WDTD Interactive Overview page found here and click on "Parcel"

The best way to assess elevated instability using the NSHARP program is to visually inspect the sounding and pick the parcel level where the most CAPE results above the surface (note: use the "User Select" option for lifting method). Usually, this is between 900 and 700 mb.

See the sounding example of selecting a parcel level on an NSHARP.

1.11 Most Unstable CAPE (MUCAPE) Strengths

Most Unstable CAPE (MUCAPE) Strengths

MUCAPE

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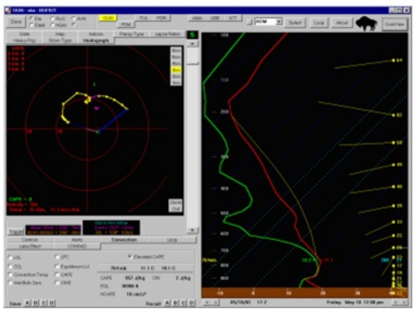
- MUCAPE is the best sounding measure for elevated buoyancy and assessing potential for elevated convection.
- In BUFKIT, one can easily compute CAPE from any level. See the BUFKIT sounding below (or click on the link for an enlarged version) showing a parcel lifted from 764 mb and the resulting CAPE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

MUCAPE

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- 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

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- 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.

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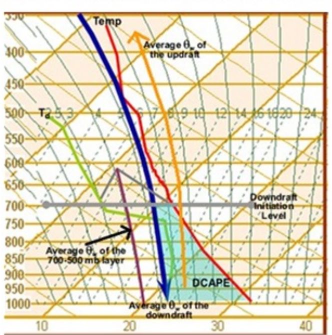
- In the figure below, the dark blue curve represents the downdraft that is completely saturated as it follows the average (mixed) θ_w down to the ground, the thick grey line is the downdraft initiation level at the bottom of the dry layer, and the thick orange line is the θ_w of the updraft.



1.17 Downdraft CAPE (DCAPE) Strengths

Downdraft CAPE (DCAPE) Strengths

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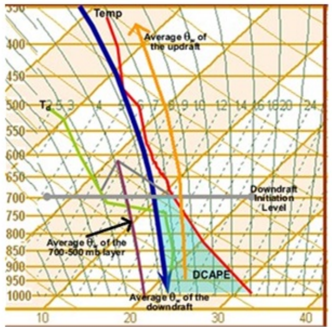
- DCAPE estimates downdraft potential strength better than just measuring relative humidity or $T\text{-}T_d$ at some level. It considers diluted updrafts mixing with environmental air.
- Can be used to assess microburst potential for some pulse storms.



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.

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

- 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

[Strengths]

[Limitations]

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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]

Strengths

[Limitations]

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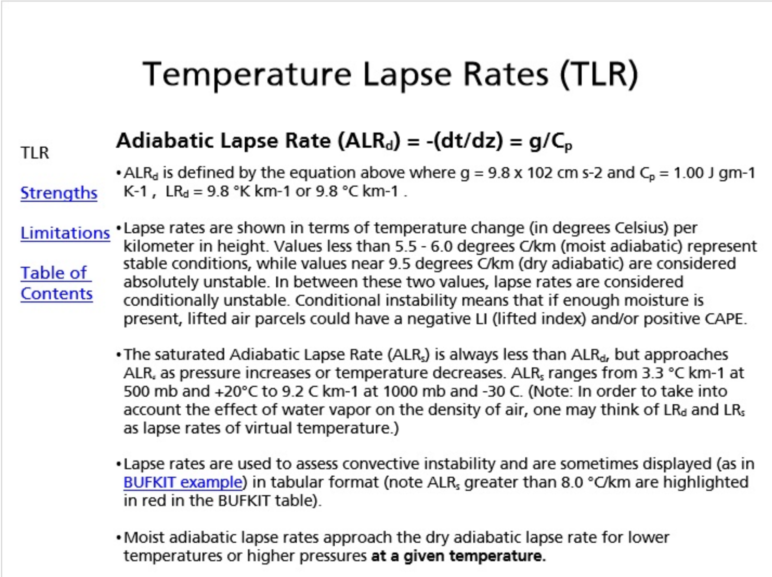
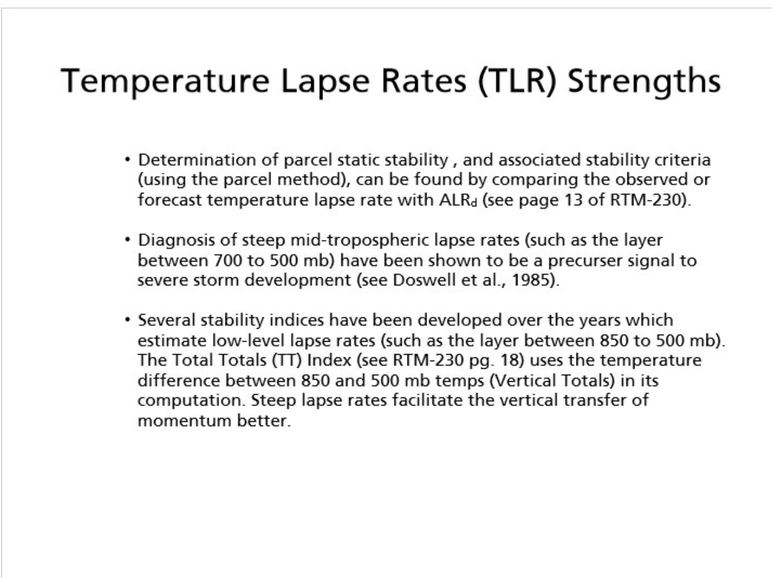
- LI is a quick expression of the overall stability/instability of a sounding. Ease of computation, flexible choice of layer to lift (lifting an parcel at 850 mb is the old Showalter Index), pertinent to a particular problem area for ready use in synoptic forecasting.
- Can alert forecasters to those 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.

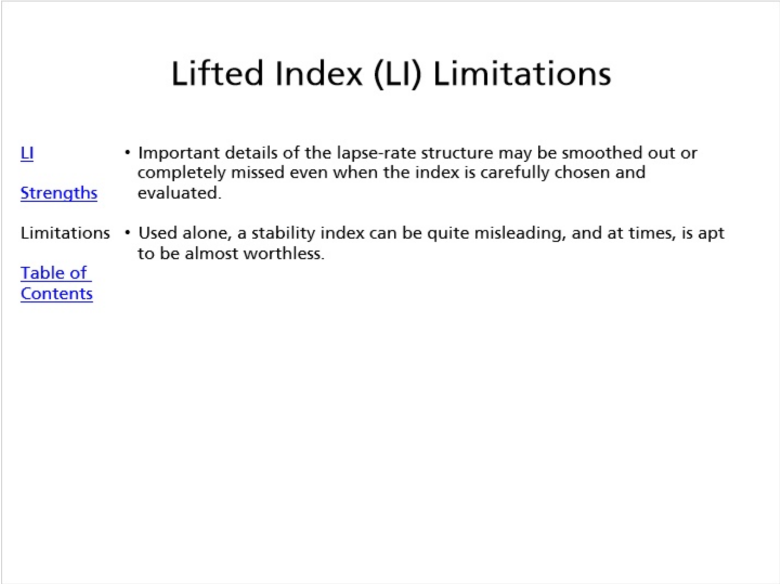
1.27 Temperature Lapse Rates (TLR)



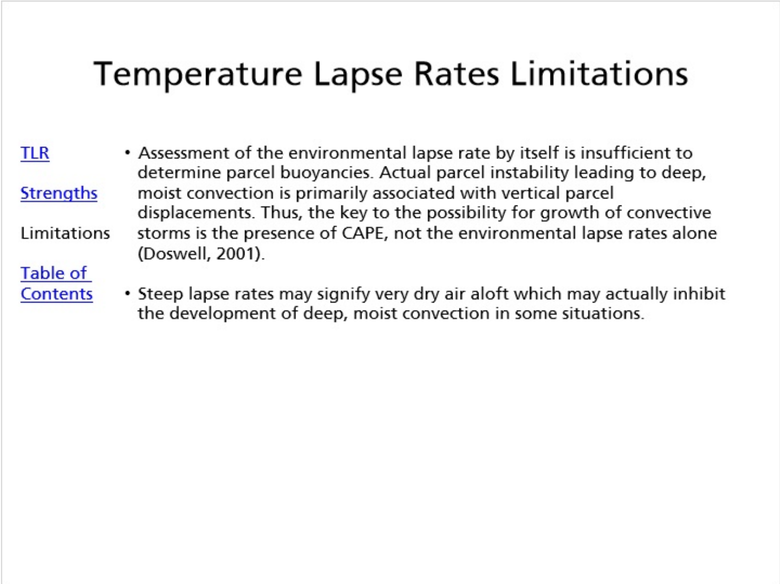
1.28 Temperature Lapse Rates (TLR) Strengths



1.29 Lifted Index (LI) Limitations



1.30 Temperature Lapse Rates Limitations



1.31 Lifting Condensation Level (LCL)

Lifting Condensation Level (LCL)

LCL

Strengths

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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

Lifting Condensation Level (LCL) Strengths

LCL

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- 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

Lifting Condensation Level (LCL) Limitations

LCL

Strengths

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- 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.

1.35 Level-of-Free-Convection (LFC)

Level-of-Free-Convection (LFC)

LFC

Strengths

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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

Strengths

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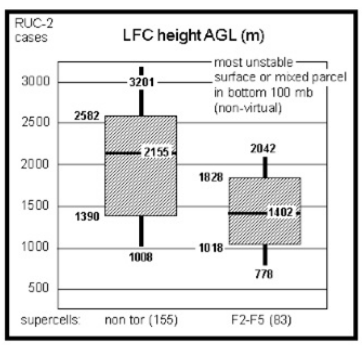
- Low-level CAPE and CIN are related to the height of the LFC (see figure on LFC). Lower LFC heights imply more low-level CAPE and thus, can be correlated to increasing tornadic likelihood in supercells because of the associated potential for stronger low-level vertical accelerations (see figure to the 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

Strengths

Limitations

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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

Strengths

Limitations

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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.

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

Level-of-Free-Convection (LFC) Limitations

LFC

Strengths

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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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Limitations

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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.

1.41 Freezing Level (FZ LVL)

Freezing Level (FZ LVL)

FZ LVL

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- The freezing level is the height at which the air temperature becomes freezing. The freezing level can be found on the sounding where the 0 C isotherm intersects with the temperature.
- Low freezing levels indicate that hail will have more time to grow in an updraft and a smaller period of time to melt as it falls towards the surface. In general, freezing levels at 650 mb or lower are supportive of severe hail.

Limitation:

- One limitation is that the freezing level can change rapidly and the level shown at one sounding time can be radically different at the time of convection. Therefore it is important to pay attention to forecast soundings and anticipate any potential changes in the freezing level during the course of the day or an event.

2. Thermo

2.1 Which of the following is true about CIN?

(Multiple Choice, 10 points, 1 attempt permitted)

Which of the following is true about CIN?

- ( ) In cases where CIN is small, supercells are less likely to produce tornadoes
- ( ) CIN is not sensitive to boundarly layer values and will not change if the surface dew point changes
- (•) Assessing CIN is important to diagnosing the potential for deep, moist convection.
- ( ) For parcels that are not surface-based, little to no CIN is likely present.

Correct	Choice
	In cases where CIN is small, supercells are less likely to produce tornadoes
	CIN is not sensitive to boundarly layer values and will not change if the surface dew point changes
X	Assessing CIN is important to diagnosing the potential for deep, moist convection.
	For parcels that are not surface-based, little to no CIN is likely present.

Feedback when correct:

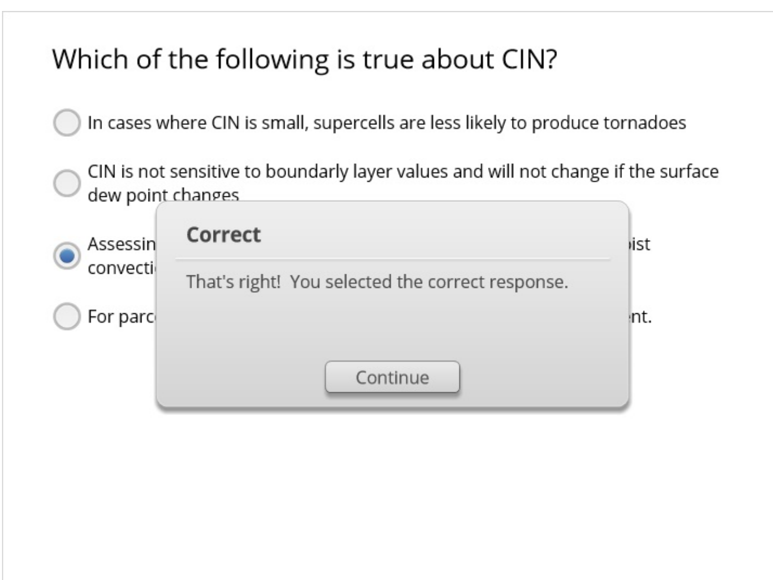
That's right! You selected the correct response.

Feedback when incorrect:

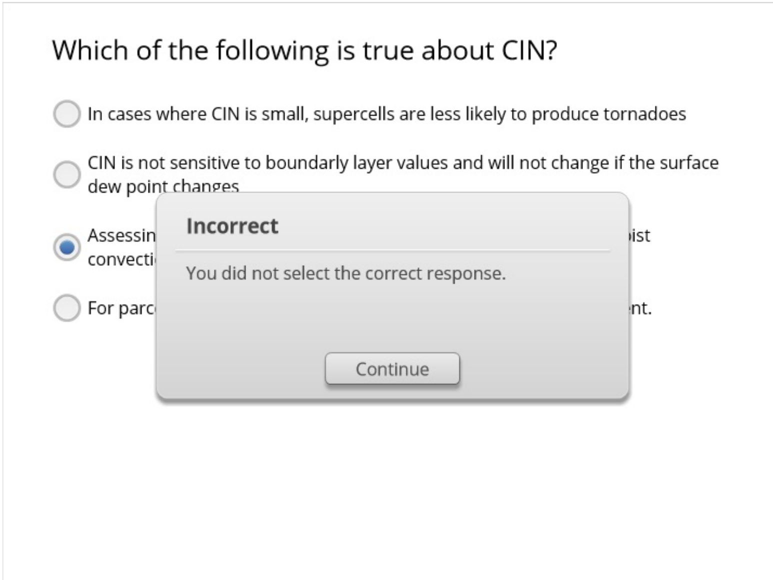
You did not select the correct response.

Notes:

Correct (Slide Layer)

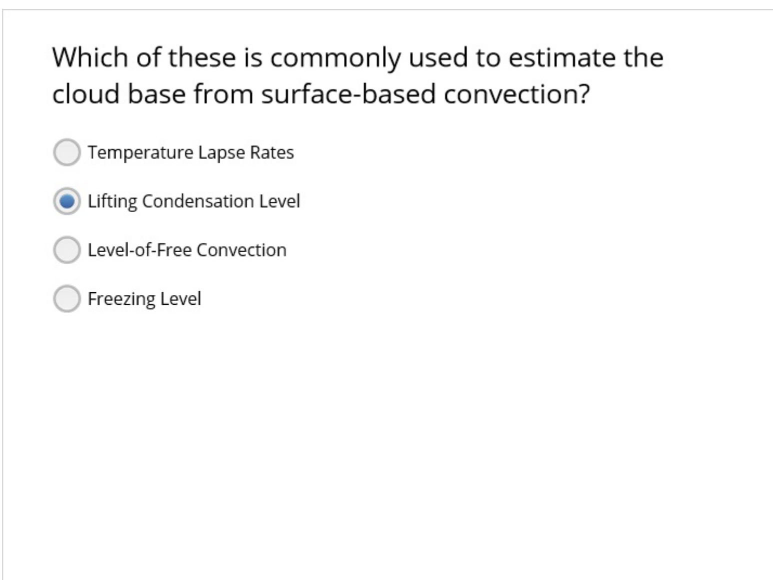


Incorrect (Slide Layer)



2.2 Which of these is commonly used to estimate the cloud base from surface-based convection?

(Multiple Choice, 10 points, 1 attempt permitted)



Correct	Choice
	Temperature Lapse Rates
X	Lifting Condensation Level
	Level-of-Free Convection
	Freezing Level

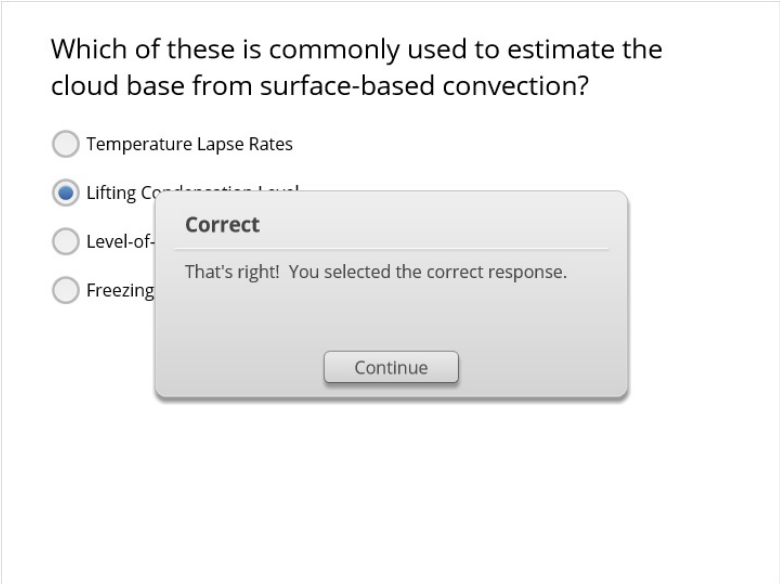
Feedback when correct:

That's right! You selected the correct response.

Feedback when incorrect:

You did not select the correct response.

Correct (Slide Layer)



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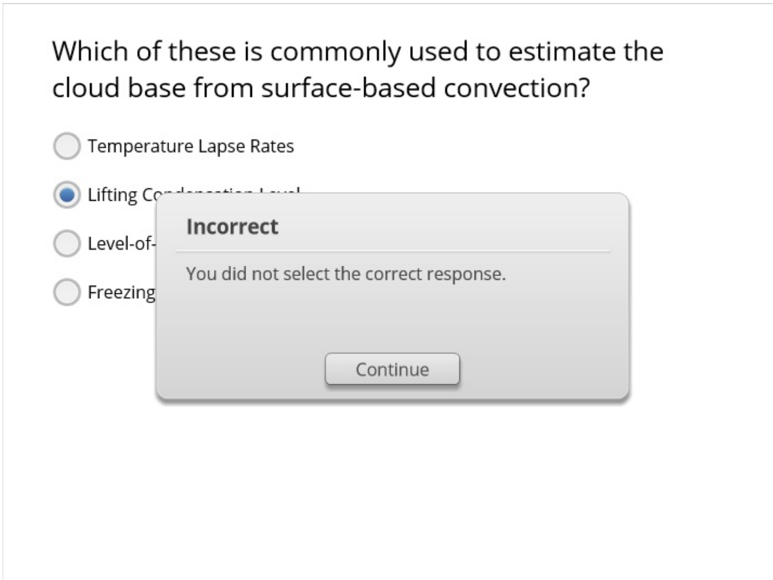
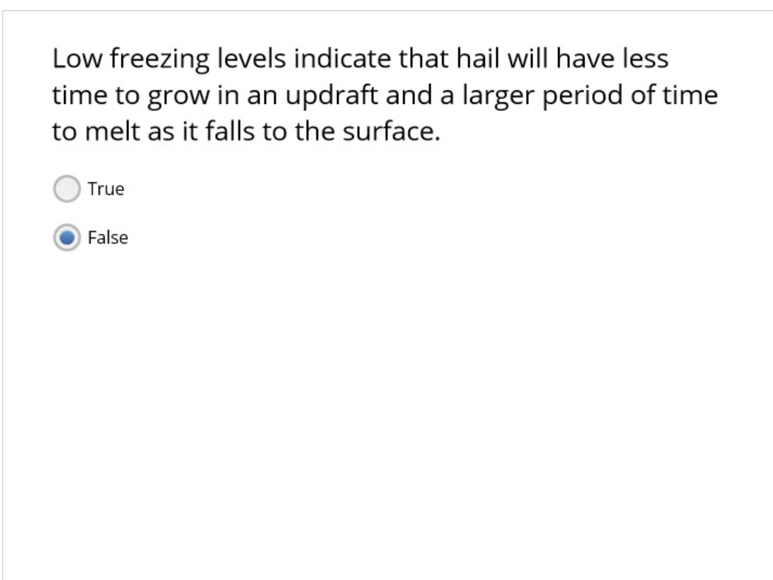


2.3 Low freezing levels indicate that hail will have less time to grow in an updraft and a larger period of time to melt as it falls to the surface.

(True/False, 10 points, 1 attempt permitted)



Correct	Choice
	True
X	False

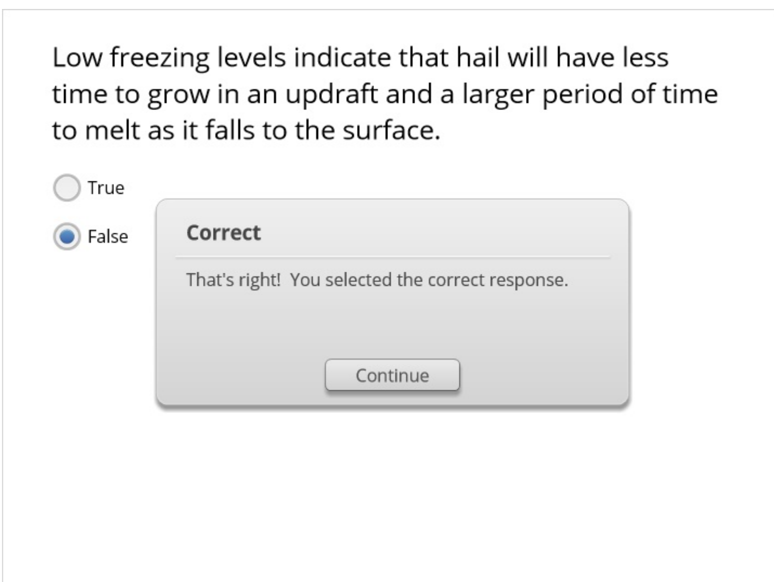
Feedback when correct:

That's right! You selected the correct response.

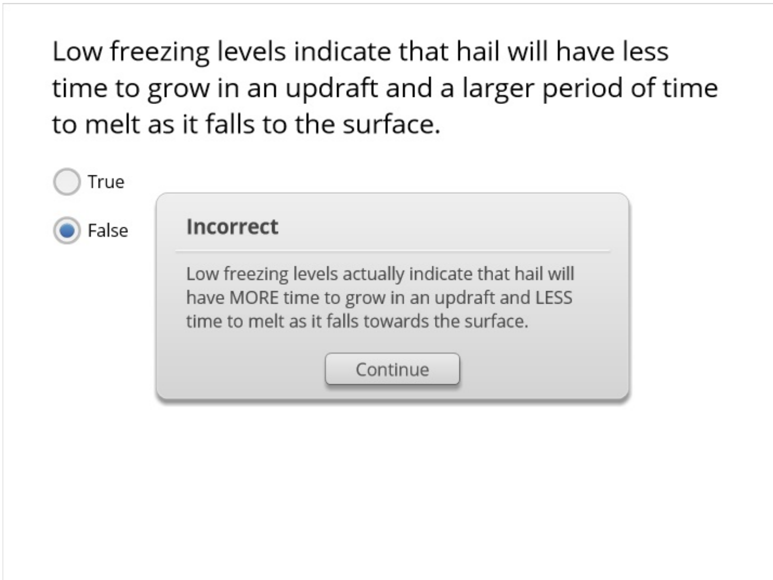
Feedback when incorrect:

Low freezing levels actually indicate that hail will have MORE time to grow in an updraft and LESS time to melt as it falls towards the surface.

Correct (Slide Layer)

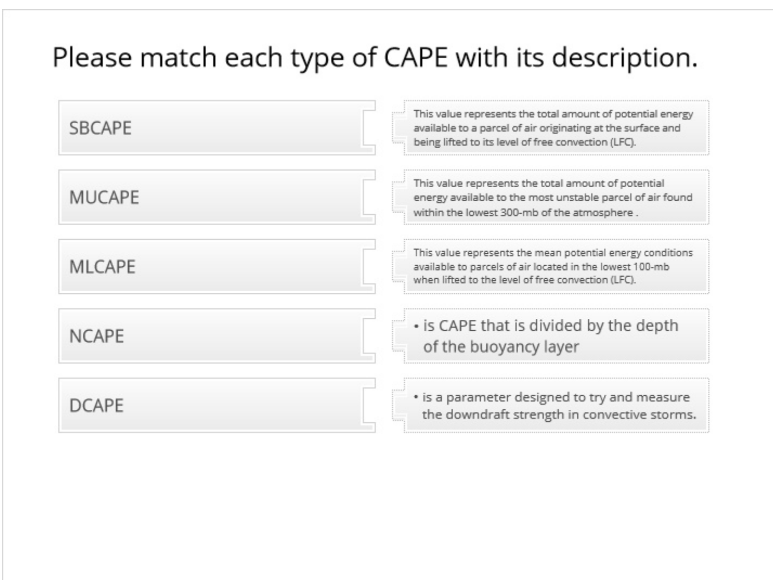


Incorrect (Slide Layer)



2.4 Please match each type of CAPE with its description.

(Matching Drag-and-Drop, 10 points, 1 attempt permitted)



Correct	Choice
SBCAPE	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).
MUCAPE	This value represents the total amount of potential energy available to the most unstable parcel of air found within the lowest 300-mb of the atmosphere .
MLCAPE	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).
NCAPE	is CAPE that is divided by the depth of the buoyancy layer
DCAPE	is a parameter designed to try and measure the downdraft strength in convective storms.

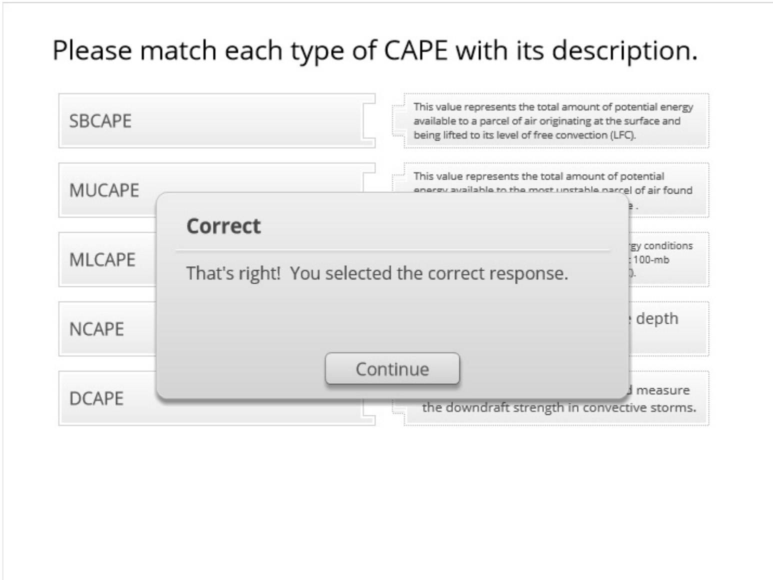
Feedback when correct:

That's right! You selected the correct response.

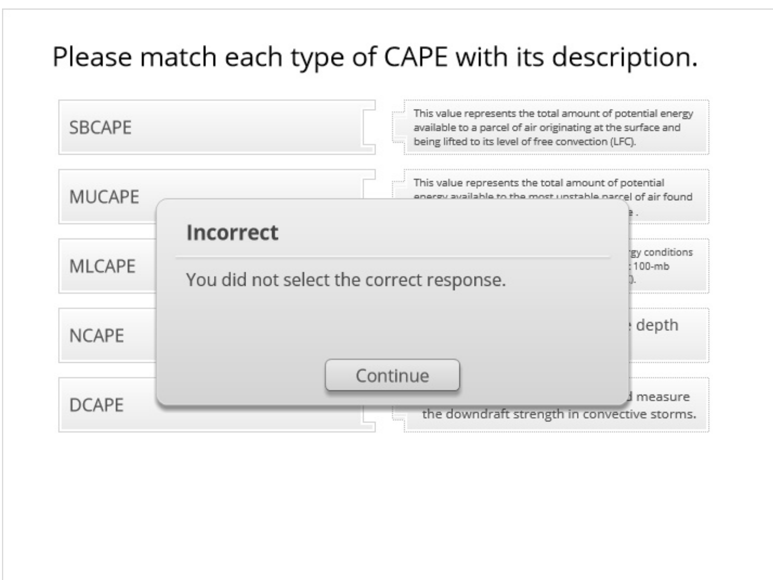
Feedback when incorrect:

You did not select the correct response.

Correct (Slide Layer)



Incorrect (Slide Layer)



2.5 Results Slide

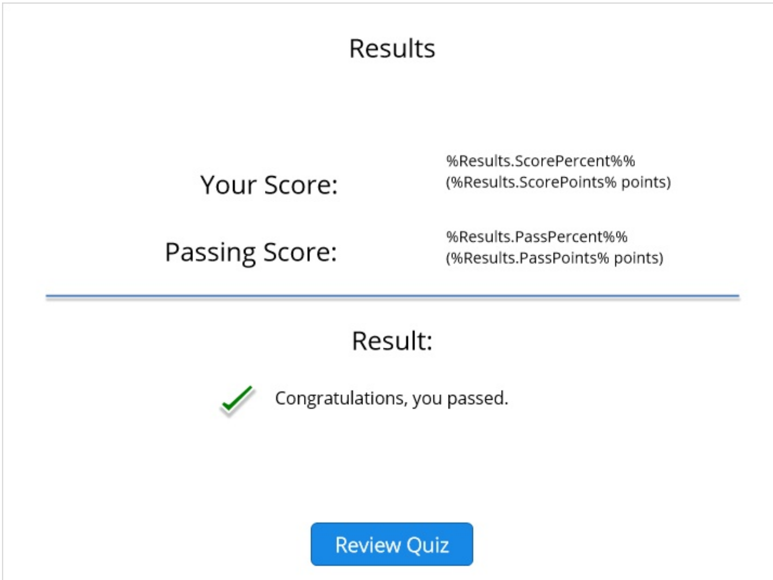
(Results Slide, 0 points, 1 attempt permitted)

Results for
2.1 Which of the following is true about CIN?
2.2 Which of these is commonly used to estimate the cloud base from surface-based convection?
2.3 Low freezing levels indicate that hail will have less time to grow in an updraft and a larger period of time to melt as it falls to the surface.
2.4 Please match each type of CAPE with its description.

Result slide properties

Passing	70%
Score	

Success (Slide Layer)



Failure (Slide Layer)