

MESO's CAFE

(Computer-Aided Forecasting Exhibition)



Severe Weather Forecasting and the Use of Atmospheric Stability Indices

Brian hit the spot when he said that storm chasing is not like "Twister". Catching the big one involves a lot of time and energy and the help of many people, not just one. If it was this simple, why are our bags packed for next years chase 2 days after we get home? If you are like me it's probably because you can't wait to get back to Tornado Alley.

Severe weather forecasting, in reality, is not going to be learned from a textbook. Yes, it helps, but knowledge *and* experience is the key to any successful storm chase. I have been studying severe thunderstorms and tornadoes for many years, but knowing the conditions that lead up to and beyond the initial outbreak is key. Forecasting is like a fingerprint. No two synoptic and upper level conditions are going to be the same. They may have similar characteristics, but this is where your knowledge and experience comes into play. It is your job as a forecaster to include as many "what could happens" into your forecast as possible.

There are many "forecasting tools" that can be utilized to your benefit. All of these are important, and none should be overlooked. You should try to get as much information as possible before you attempt to make an accurate forecast. One of the most useful tools that a forecaster can use is called the Skew-T diagram. This diagram shows the atmosphere in its vertical, and tells us such things as temperature, dewpoint, and winds at different levels. With a Skew-T, you can actually trace an air parcel from the surface all the way up to well and beyond the 100mb level, so you can see how the forces of nature will act upon it.

What do I mean by "forces of nature"? We all know that for the most part the lapse rate (temperature change with height) is negative as we ascend through the troposphere. When a parcel of air is forced upward, either by frontal activity or other forces, it cools. If this parcel of air is forced high enough, it will begin to condense, and this is when we will see the little white puffy cauliflower-shaped cumulus clouds. The air parcel has reached its Convective Condensation Level (CCL). Further lifting of the air parcel beyond its condensation level will allow it to become lighter than the environmental temperature, which is the Level of Free Convection (LFC), thus causing it to rise freely until the temperature of the parcel is the same as the environmental temperature. We call this the parcel's Equilibrium Level (EQ). It is not uncommon to see supercells with cloud heights of 12 miles. The two processes responsible for this are evaporation and condensation. When air evaporates it cools, and when it condenses it warms.

It is important to analyze the current state of the atmosphere before you analyze what is to be expected. Often times the anticipation lets us forget that what is going on now is just as important as what is expected to happen later. Let's take a possible scenario. You are analyzing a Skew-T diagram over Wichita, Kansas the morning that you plan to chase. You notice that the skies have not cleared out and you know from experience that you will need a little more moisture in order to get the deep convective cells that you seek. After reading the morning sounding, you view the forecast sounding for twelve hours later and there is a big difference in the variables. If things don't begin to change soon, you know that the forecast sounding will not verify (be proven correct). So if you still want to have a good chase day, it would be wise of you to monitor the data hourly so you can make any adjustments that may be needed.

Here are some of the variables that should be noted:

Lifted Index (LI)

The Lifted Index shows the stability of an air parcel. It is computed by lifting the parcel of air from the surface to the 500mb level then comparing the temperature of the air parcel to that of the environmental air temperature. Through the forces of nature explained above, the temperature of the air parcel may be much higher than the surrounding air, causing it to be unstable in a sense that it wants to be displaced vertically. As the air parcel becomes saturated, its physical state is transformed from a gas to a liquid state, and in doing so (condensation) the energy absorbed is called latent heat. Once this "latent" heat is added to the air parcel, it now becomes lighter and warmer than its surrounding air. We look for negative numbers with this index. The more negative the number, the more unstable the air is. Put another way, the more negative the number, the more potential there is for a stronger thunderstorm. Values of zero or below are a good indicator of general thunderstorms. Severe thunderstorms are possible when the values reach -4 or so. When *MESO* tracked the tornadic supercell near Coldwater, Kansas on Memorial Day 1999, Lifted Indices were in the -12 to -14 range, indicating a very unstable atmosphere.

Total Totals Index (TT)

The Total Totals Index combines the effect of the atmospheric lapse rate, and low level moisture. It is computed by using the Cross Totals Index (the 850mb dewpoint minus the temperature at 500mb), and the Vertical Totals Index (the 850mb temperature minus the 500mb temperature). An index of 50 is a good starting point for thunderstorms. Scattered thunderstorms may be prevalent with values between 52-55, and anything above 56 will yield scattered severe thunderstorms with the possibility of scattered tornadoes.

There is a false sense of security when using this index. It is not meant to be used for the sole purpose of severe thunderstorm forecasting. High lapse rates and cold mid level temperatures will yield a high Total Totals number, but it does not take into consideration the low-level moisture that is needed for deep convection.

Sweat Index (SWEAT)

This stands for the severe weather threat index. This index evaluates severe weather potential by combining the effects of low level moisture at the 850mb level, convective instability from the TT Index, jet maxima from the 850mb and 500mb wind speed, and warm air advection noted by using the veering directional shear between 850mb and the 500mb levels. This will tell the forecaster if ordinary or severe convection can be expected. Values over 300 indicate the potential for severe

storm development, and values over 400 will favor tornadic storms. SWEAT Indices were exceeding 600 during the 5/31/99 tornado near Coldwater, Kansas.

< 272: unlikely

273 to 299: general storms; slight risk of severe storms

300 to 400: storms approaching severe limits; moderate risk of severe storms

401 to 600: few severe storms with isolated tornadoes; strong risk

601 to 800: scattered tornadoes; high risk

CAPE (Convective Available Potential Energy)

CAPE is the amount of energy an air parcel might have when lifted. The CAPE is a reflection on the strength of the updrafts within a thunderstorm. This is only potential energy. It must be released. This energy is released once the air parcel reaches up and beyond its level of free convection. When viewing a Skew-T diagram, the air parcels CAPE is measured to the right of the temperature line. The bigger the distance between the parcel line and the environmental temperature line, the greater the CAPE. The higher the value, the more speed the updraft can obtain.

There are a couple things I would like to mention about CAPE. Just because you have a very high CAPE value, lets say 6000 J/kg which is not uncommon in severe weather scenarios, does not necessarily mean you are going to see severe thunderstorms. Often times a "capping inversion" will exist just above the surface (warmer air aloft). The air parcel cannot rise above this until something comes along and boots the inversion out of the way. Let's say that you are viewing a Skew-T that yields a CAPE reading of 6000 J/kg but you notice that the air parcel line crosses to the left of the environmental temperature line. This is where the atmosphere is capped and the air parcel temperature is less than the surrounding air, so it will tend to sink. This type of scenario should be watched very closely since an explosive situation could erupt once the cap is broken and the air is allowed to break through the cap. Once the cap is broken a severe cell could be formed in a matter of minutes. And if other conditions are met such as Helicity values, a tornado could be forming soon.

Severe convection can also occur when CAPE is weak and storm-relative helicity values are high. Helicity is a measurement used to denote the potential for helical flow into a thunderstorm (cork screw). It is computed by examining the vertical wind profiles and storm motion.

CAPE: 800-1500: weak

1501- 2500: moderate

> 2501: strong

Bulk Richardson Number (BRN)

The Bulk Richardson Number measures the relative importance of instability and vertical wind shear as a predictor of storm type.

< 10: unlikely

11 to 49: supercell storms

> 50: Multi-cell/squall line formation

Here are some other stability indices that may be useful to you. I will give a brief explanation of the index.

Showalter Stability Index (SSI)

This index is another way to measure instability of the air parcel.

> 3: no activity expected

0 to 2: showers and isolated thunderstorms possible

-2 to 0: thunderstorms probable

-4 to -2: severe storms possible

< -4: severe storms are probable as well as tornadoes.

Storm Relative Helicity (SRH)

This measures the helical flow into a moving thunderstorm.

150-299: weak

300-449: moderate

> 450: strong

Energy Helicity Index (EHI)

Measures the wind energy available to the storm.

< 2: unlikely

2 to 2.4: tornadoes possible but not likely long lived

2.5 to 2.9: tornadoes more likely

3.0 3.9: strong to violent tornadoes

> 4: violent tornadoes

Sample Soundings

The Completely Stable Atmosphere:

In this case the atmosphere is completely stable. The parcel temperature does become slightly warmer than the environmental temperature, but it is well below the Lifted Condensation Level (LCL) so no convection will be allowed to occur. The air is stable for three main reasons in this sounding:

1. The air at the surface is too dry
2. The air at the surface is too cold
3. The air in the upper levels is too warm to allow the surface air to rise through it.

These are the days when you forecast sunny, clear skies!!

The Potentially Unstable Atmosphere:

This was an atmospheric sounding taken in the morning. If you look at the air parcel line (the thin red line) you see that it is to the left of the environmental temperature line (thick black line on the right) except for a small portion of atmosphere at about 750mb. This only yielded us 23 J/kg of CAPE, which is virtually nothing. In this case air would not rise at all. It would tend to sink since at this time since it is heavier and more dense.

Notice on the legend to the right of the Skew -T where the CAP reads 2.7. This is a rather large cap, and would take some work in the upper levels as well as the lower levels to get this removed. This is typical in the early morning hours. Air that is cooled during the night through "radiational cooling" sinks to the bottom of the warmer upper levels, causing a temperature inversion.

We call this a "potentially unstable atmosphere" because all it would take is some temperature and moisture advection into the area to make this sounding unstable. Look at the air parcel line at the surface. It is very close to the environmental temperature line. As the morning progresses, sunshine will heat the lower levels (remember that surface heating will not occur above 850mb) and as this happens the air at the surface will become much warmer than the air above it. As the air continues to warm, the air parcel line will become further away from the environmental temperature line, giving us a higher CAPE reading. The Lifted Index will also show a smaller number as this transition is taking place. What would happen if more cooler air moves into the area due to an upper level trough? As the trough approaches, cooler air will be brought into place. This in turn drives the environmental temperature line further to the left (signifying a decrease in temperature) causing the two lines to be further apart, which will produce a higher CAPE reading.

Later in the day, thunderstorms erupted near the area of this sounding and took some roofs off of houses as well as uprooted some trees. This is why it is important in severe weather forecasting to know what changes are expected to take place.

The Completely Unstable Atmosphere:

Notice that for the entire sounding the air parcel equals or exceeds the environmental temperature line. The atmosphere is slightly capped at about 800mb, where you see the air parcel line cross to the left of the environmental temperature line. The forecaster would not have to worry about a cap this small, since uneven surface heating would definitely be enough to break such a small cap. There is also a small amount of CAPE below the cap, and the momentum from this CAPE will also assist in the removal of the cap.

If I was a forecaster looking at this sounding, I would note the following:

CAP: 0.3 degrees

CAPE: 1995 J/kg

CINH: 1

MPL: 77mb

HEL: -35

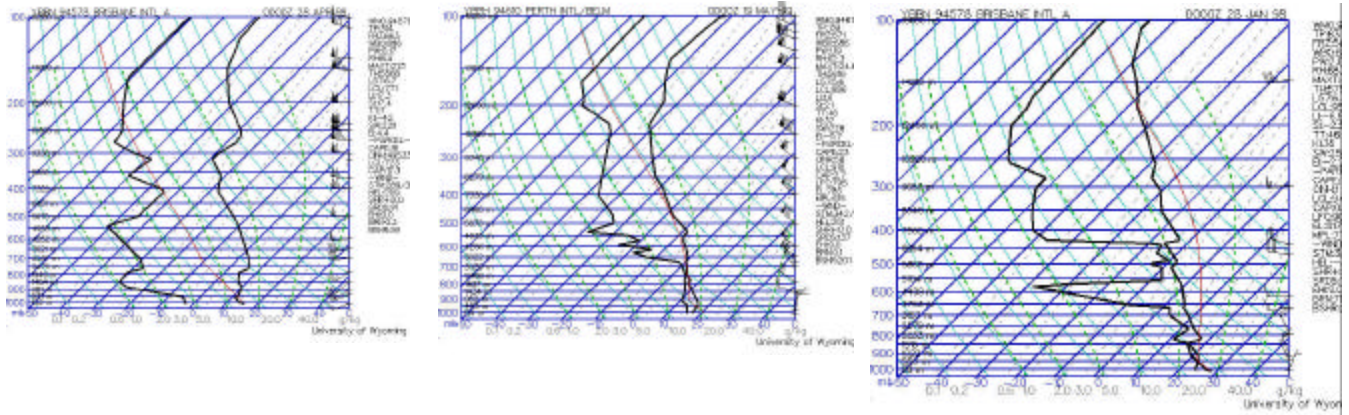
LI: -6.5

In this case we have a moderately unstable atmosphere, as shown by the LI of -6.5, and a CAPE of 1995 J/kg. CINH (convective Inhibition) is how much work it will take to overcome the CAP. With a cape this high and a CINH of only 1, you can assure yourself that you will have thunderstorms today. But will these storms be severe? In this case probably not. We do not have the wind energy available in the upper levels to support the organized structure that a severe storm requires. Notice how the winds are not showing a particular flow pattern, they are erratic at times and weak (as shown by the negative helicity values (HEL)). In order for a thunderstorm to become severe, we should have increasing wind speed with height, and we call that speed shear.

Without this, the updraft becomes choked off and the cell will begin to die.

Notice how the dewpoint line (thick black line on the left) migrates way to the left of the sounding. This indicates much dryer air since the temperature-dewpoint lines are further apart. This will cause evaporation of the water molecules as they fall through this layer, thus cooling the air.

As this air evaporates and cools, it has no choice but to travel downward towards the surface, causing wind damage in some cases.



Keep in mind that when you do your forecast for severe weather, you must include all of the indices in your final decision. You cannot depend on just one. And like I stated before, the more practical knowledge and experience you gain, the better you will become at forecasting one of Mother Nature's finest, the tornadic supercell. Good luck!!

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<http://www.mcwar.org>