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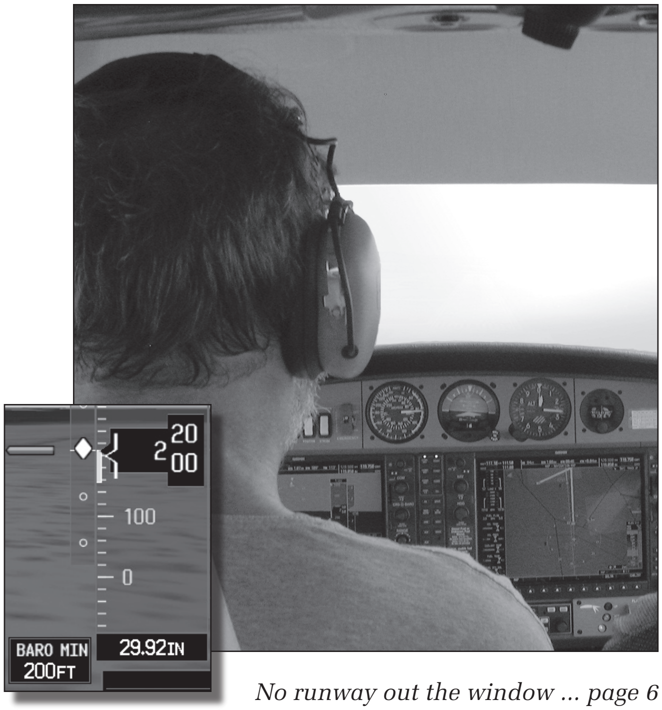

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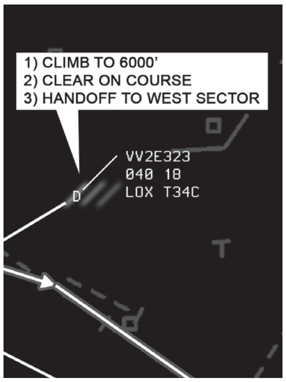

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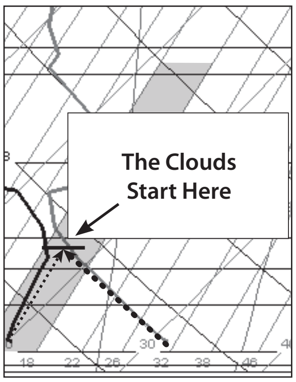

Storm insight ... page 14

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CONVECTION ON THE SKEW-T

Thunderstorms are predicted for your route, but how likely are they to pop up at your destination? A Skew-T might help you know.

by Scott C. Dennstaedt

Mix a generous amount of low-to mid-level moisture and conditional instability with an abundance of outside energy (or lift) and you can brew some serious convection. Often pilots are taught the numbers game with respect to various indices forecasters use for predicting thunderstorms—a highly negative lifted index may mean big storms—without having a clue where these numbers come from.

And maybe that's OK, but if you want to play the thunderstorm guessing game at a higher level, take a look at the graphical Skew-T diagram to help explain them, as well as give you insight as to whether t-storms will be likely at a specific spot, such as your fuel stop or your destination.

A Matter O' Energy

Thunderstorms are all about energy management. It generally starts with potential energy, existing as unstable air. Rising air can turn that stored potential energy into kinetic energy, or energy in motion. Looking at the reservoir of potential energy tells you a lot about how quickly thunderstorms may develop and how severe they may be.

Convection is the vertical transport of heat in the atmosphere and creates those white, puffy cumulus clouds that can be seen on fair-weather days. Cumulus clouds require a combination of insolation (surface heating), coupled with instability and moisture near the surface. Take away any one and it's dang hard to produce cumulus clouds.

Deep convection, or a thunderstorm, requires a similar environment except that some form of outside energy contribution is always required to take a congested cumulus cloud to the mature thunderstorm stage. Thunderstorms develop at a particular time and place for a reason, even though it is often difficult to forecast where and when dangerous convection might occur.

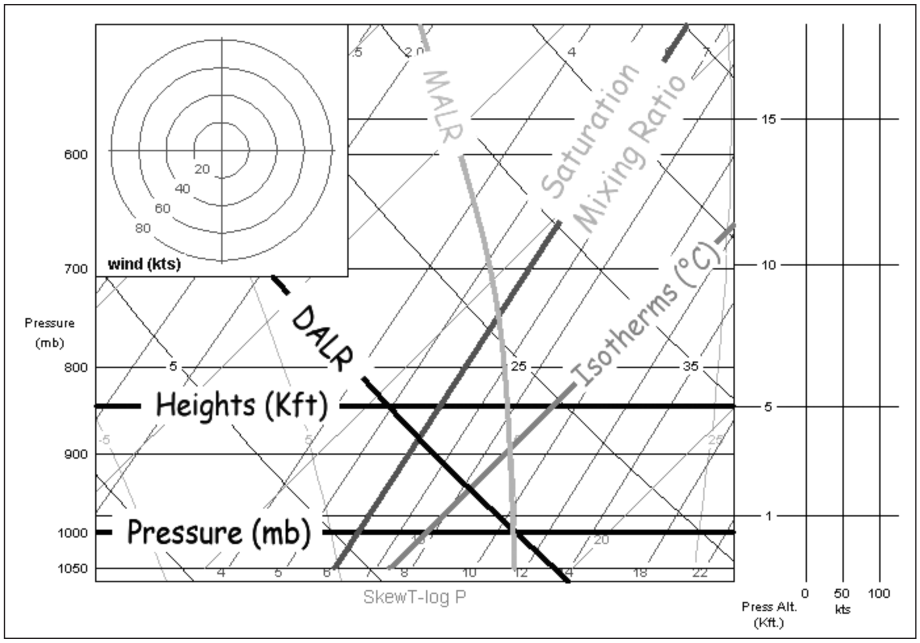
To make some educated guesses, though, we call up the website http://rucsoundings.noaa.gov and enter the FAA identifier for the airport (or airports, separated by commas) that we want to explore.

The Skew-T diagram we see is really graph paper with six kinds of "grid" lines (see caption). On this graph, two lines are plotted: a red line showing temperature as a function of pressure (or altitude) from the surface through 150 mb (about 45,000 feet) and a blue line showing dewpoint to the same altitude. Some websites can display data through 10 mb, (well into the stratosphere).

Lifting the Air

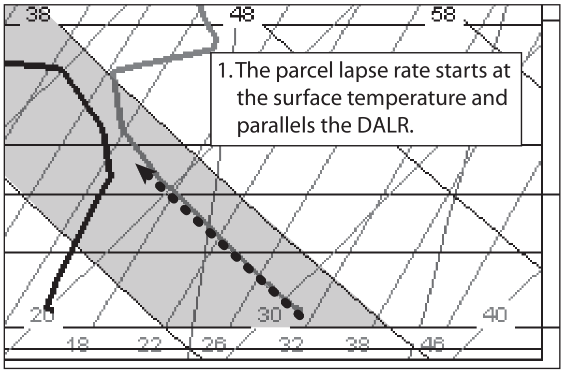
Now we need to lift some air from the surface and see what happens. If you put your cursor in the plot where the red temperature line meets the bottom of the diagram and click, a magenata line is drawn for you. This line is the parcel lapse rate.

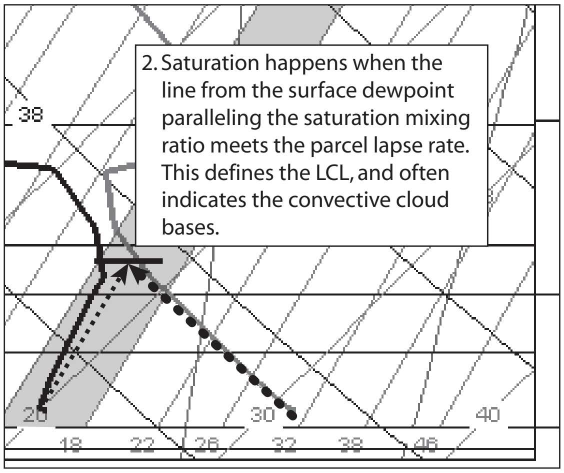
There are five rules that shape this line. Rule number one: Warm air is less dense than cold air and rises. Rule number two: As unsaturated air ascends, it will expand and cool at the dry adiabatic lapse rate. Rule number three: As saturated air ascends, it will expand and cool at the moist adiabatic lapse rate. Rule number four: As a parcel of air ascends, it does not exchange heat or mass with the environment. Rule number five: All air parcels start at the surface with the same temperature and dewpoint as the environment. (There are several variants of rule number five.)

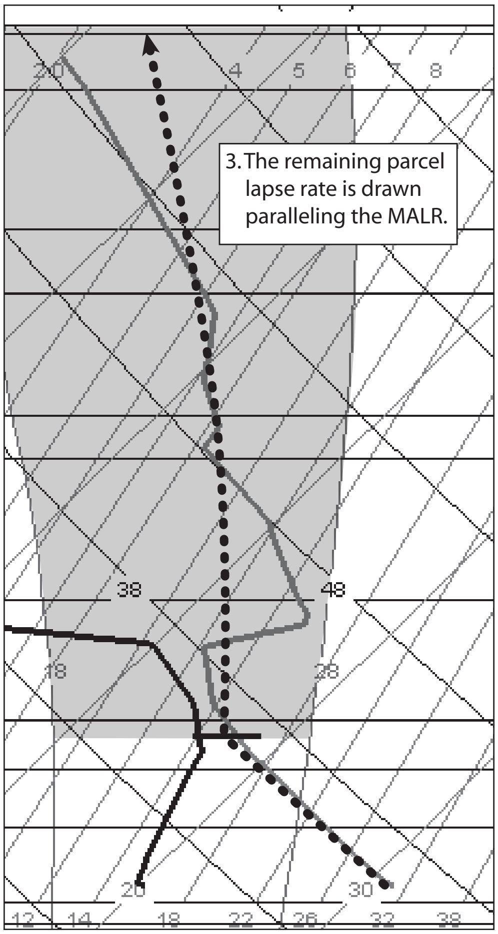


Left: *The Skew-T background is six sets of lines: temperature (isotherms) in degrees Celsius, pressure in millibars on the left edge, pressure altitude in thousands of feet on the right edge, dry-adiabat lines (DALRs) moist-adiabat lines (MALRs) and saturation mixing ratio lines. Winds at each pressure/altitude are shown to the right of the chart.*

*Since the name of the game is watching what happens to a lifted parcel of air, the first step is plotting its behavior on the Skew-T as a parcel lapse-rate line. Locate the temperature at the surface and draw a parcel lapse-rate line parallel to the closest dry adiabatic lapse rate (**top right**). Saturation occurs where the parcel's temperature (the line you're drawing) intersects with the mixing ratio line drawn from the surface dewpoint temperature (**middle right**). This is called the lifted condensation level (LCL) and often represents the convective cloud bases. Above the LCL, the line follows the slightly-curved moist adiabatic lapse rate which varies with temperature. (**bottom right**).*







We assume that the surface-based parcel starts out unsaturated. As stated in rule number two, a rising, unsaturated, air parcel will cool at the dry-adiabatic lapse rate or three degrees Celsius for every 1000-foot gain in altitude. So the magenta line starts by running parallel to the closest dry adiabats.

The magenta line continues upward until the parcel reaches saturation which happens when the temperature *of the parcel* cools to the dewpoint temperature *of the parcel*. Similar to the temperature in the parcel, dewpoint also decreases with height, but at a lower rate. This rate is defined by a constant saturation mixing ratio.

Starting at the dewpoint at the surface, we parallel the saturation mixing ratio lines until crossing the magenta line. This point of intersection is called the lifted condensation level (LCL). The LCL approximates the bases of cumuliform clouds and is drawn on the Skew-T as a black, horizontal bar.

When the magenta parcel lapse-rate line crosses the LCL, it's now saturated and rule number two no longer applies. According to rule number three, if a saturated parcel is lifted, it is assumed to remain saturated and will cool off at the moist adiabatic lapse rate. This lapse rate isn't constant like its dry counterpart, so the remainder of the parcel lapse rate (magenta line) will follow a curved, moist-adiabatic lapse rate.

So What If?

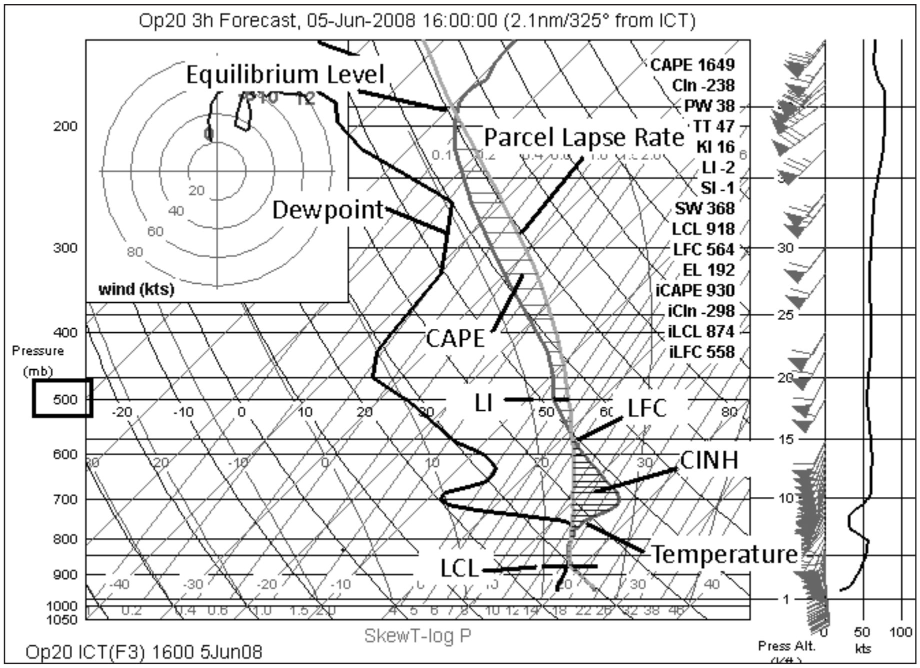
Forecasting happens as we compare the parcel lapse (magenta line) to the environmental temperature (red line) at a particular pressure (or height).

Rule number one states that warm air is less dense than cold air. So if the environment is colder than the parcel at a given altitude, it will tend to ascend on its own (like a hot air balloon) without any outside energy contribution. The environment is said to be unstable with respect to the parcel. The greater the temperature difference, the greater the instability. If the environment is warmer than the parcel the environment is said to be stable.

There are lots of useful items that can be determined from the techniques just described. This includes the level of free convection (LFC), equilibrium level (EL), lifted index (LI) and the convective available potential energy (CAPE), just to name a few. You can also determine what barriers to convection may exist aloft. This is called convective inhibition. Many of these indices are calculated automatically and displayed on the Skew-T diagram.

Free Convection

Similar to the LCL, the LFC is just another altitude. The LFC is the height to which air must be lifted to achieve positive buoyancy (instablity). Above this altitude, the parcel lapse (magenta line) will remain warmer (to the right of) the environment (red line). You can always calculate an LCL, but the LFC may be undefinable in



***Left:** The lifted condensation level (LCL) represents the bases of the convective clouds, about 4000 feet on this chart. The level of free convection (LFC) is the point that air can begin to accelerate on its own (about 15,000 feet here). The equilibrium level (EL) usually marks the top of the convective activity (about 40,000 feet here). Unless there is lifting action to bring surface air past 15,000 feet, thunderstorms are unlikely today.*

stable air. An LFC is always at or above the LCL.

The lower the LFC, the less vertical lift (outside energy) needed to start convection rolling. Daily heating normally lowers the LFC—one of the reasons convection is more likely in the afternoon and early evening.

Just like many pilots take note of the freezing level before departing, I like to know the LFC. When cumulus towers start to punch through the LFC along my route, there's a good chance that deep convection is in the works.

Lifted Index

The LI is perhaps the most familiar convective index to a pilot. LI is simply the temperature difference (in degrees Celsius) between the environment (red line) and the parcel (magenta line) at 500 mb. This is referred to as a surface-based LI since the parcel was lifted from the surface.

A negative LI implies the parcel is warmer than the environment. The greater the negative value, the larger the positive buoyancy and the faster the parcel can accelerate. Values of -4 and lower increase the risk for severe weather if thunderstorms actually form. A positive LI means the temperature at 500 mb is warmer than the lifted parcel temperature at 500 mb. A large positive LI is indicative of a stable atmosphere.

Equilibrium Level

The EL is the height where saturated air switches over from having positive buoyancy to being negatively buoyant. Essentially, the parcel lapse rate crosses over the environmental temperature first at the LFC, and then crosses over again at the EL. The EL is the upper limit on the rising parcel of air and often caps thunderstorm growth.

In the case of deep convection, a parcel of air can shoot several thousand feet above the EL. This is called an "overshooting thunderstorm top" and is usually seen on a satellite image protruding out of the top of the thunderstorm anvil.

CAPE

While CAPE has many variants, it's one of the most widely used indices to assess convective potential. It requires some basic calculus to compute, but graphically it's simply the region where the parcel lapse rate (magenta line) is warmer than the environment (red line). In other words, it's the area of positive buoyancy on the diagram between the LFC and the EL.

While the lifted index is highly dependent on the environmental temperature at 500 mb, CAPE is like summing up all of the possible lifted indices on the chart from the LFC through the EL. CAPE is an energy parameter and is measured in joules per kilogram (J/kg).

By definition, CAPE must be greater than or equal to zero. The higher the value of CAPE, the more potential energy is available for thunderstorm development. The environmental CAPE for deep convection is often in the range of 1000-2000 J/kg. However, values higher than 5000 J/kg sometimes occur. Higher values of CAPE mean faster-growing updrafts and quicker thunderstorm development.

Since the parcel of air we have been discussing was lifted from the surface, this index is called surface-based CAPE or SBCAPE. There are other variants that represent tweaks of rule number five.

Convective Inhibition

While CAPE must be greater than zero, the area on the diagram below the LFC where the parcel temperature is colder than the environmental temperature is referred to as convective inhibition (CINH). You can think of CINH as the strength of the capping temperature inversion, or the amount of outside energy contribution needed to overcome the negative buoyancy in the lower atmosphere and carry a parcel of air above the LFC into the area of positive buoyancy.

When CINH is less than 50,

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hold at SXC on a southwest holding course. Just follow the chart, right?

Thanks for Nothing

Well, it was right. Now it's wrong. This author's inquiry, at the behest of a check-pilot co-worker in casual workplace conversation, spurred an FDC NOTAM for both of KAVX's approaches. The approaches were designed when cell-phone towers were only a glimmer in the eyes of Silicon Valley entrepreneurs. Our inquiry spurred the FAA to re-evaluate the approach path for obstacles.

Federal regulations allow private property owners to build or install something as high as 200 feet above ground level without approval from the FAA, as long as the object is at least 3.29 nm from the airport. FAA Order 8260.19D sets forth the instrument-approach-design criteria for the crack regs team in Oke City. Wade through some technical stuff and you see that the TERPSters need to evaluate sloping areas around the airport, and see if the obstacles are jutting into the plane. If so, the approach altitudes need to be adjusted upward to account for them. Looks like they found some.

If FDC NOTAMs aren't your pleasure reading, the NOTAM for the VOR/DME or GPS-B says you need to tack on a 200-foot increase for everything except MDA, which went up by 120 feet. Instead of staying at one altitude from FAF to MAP, you get to descend a death-defying 80 feet. Well, at least it gives you something to do.

There is a similar NOTAM for the VOR or GPS-A that adds 200 feet to the published hold-in-lieu, FAF, and missed-approach altitudes. Also plan to add 80 feet to your MDA and increase the required visibility to 1-1/4 miles from one mile.

After completing the research for this article, I had two reactions. The law of unintended consequences is alive and well—sorry to those of you trying to get into Avalon when the clouds are low. And, also, that perhaps the FAA is actually in the business of protecting the safety of pilots and the public. Better a NOTAM with slightly higher minimums than an aircraft getting a massage courtesy of a cell-phone tower.

Jeff McNamee is a Gold Seal CFI and a regular IFR *contributor who stirs up trouble from his home in Central Florida.*

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a weak cap exists. When CINH is above 100, a moderate cap exists. Finally, any CINH value over 200 implies a strong cap requiring a lot of outside energy to break through the cap to become full-fledged thunderstorms.

No Perfect Predictor

There's no such thing as a perfect index. Even a highly negative surface-based LI and high surface-based CAPE will often miss a low-level temperature inversion that caps convection. Warm air riding up and over cold air at the surface may exhibit a strong low-level inversion but have significant instability above the inversion triggering elevated convection.

All these indices combine both moisture and instability within the same index. What happens if either moisture or instability is absent? The index is likely not going to trigger a threshold of concern. According to thunderstorm expert Dr. Charles Doswell III, moisture and instability can evolve independently and come together just moments before the initiation of deep convection. This can surprise the most astute forecaster.

So, there's no way to know there will or won't be t-storms for sure. But with a Skew-T and a bit of study, you'll have an extra edge.

Scott Dennstaedt is a CFI and former meteorologist. His website is www.avwx-workshops.com.