

# LAPSE-RATE FUNDAMENTALS

*It's the foundation of what makes clouds benign or vicious, and explains much of the turbulence you'll find in clear air. If you want to take your WX savvy to a new level, start here.*

There are three inherent properties of the atmosphere that all pilots should understand: Warm air is always less dense than cold air, moist air is always less dense than dry air at the same temperature, and air always expands and cools as it ascends.

That's the simple part. Putting these concepts to work for you means understanding lapse rates. This discussion gets technical, but it has a payoff in a better understanding of the weather challenges ahead of you.

## A Reason of Lapse

A lapse rate is the change of atmospheric temperature over a given change of pressure or altitude. If you climb 1000 feet and the temperature *decreases* 1.7 degrees C, the lapse rate is +1.7 degrees C. Note that a decrease in temp is a positive lapse rate. If temperature increases 2.2 degrees in 1000 feet, the lapse rate is -2.2 degrees C. A negative lapse rate is a temperature inversion. A lapse rate of 0 is called an isothermal layer.

Now let's bust some balloons. Remember what you were taught about the "standard lapse rate," that for every 1000-foot gain in altitude the temperature decreases by 2 degrees C? Forget it. On a given day the actual environmental temperatures rarely match the standard lapse rate. Calculations of aircraft performance from your aircraft flight manual can rely on the standard lapse

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rate, but if you use it to, for example, estimate the freezing level, you'll be sorely disappointed (and usually wrong).

The environmental lapse rate in unsaturated air—air where the temperature and dewpoint are not equal—can be as large as 3 degrees C for every 1000 feet gain. That limit of 3 degrees C is called the dry adiabatic lapse rate, or DALR.

When the lapse rate of unsaturated air approaches the DALR, the air is considered quite unstable. This condition is quite common, especially within the planetary boundary layer (usually the first several thousand feet of air above the ground) during the afternoon. It's possible to get a super-adiabatic lapse rate of over +3 degrees C, but it typically stops by 500 feet AGL and we can ignore it for now.

When the air is saturated—that is, the temperature and dewpoint are equal—the lapse rate limit changes to the moist adiabatic lapse-rate (MALR). Unlike the DALR, the MALR varies with temperature. At warm temperatures, the MALR is significantly less than the DALR. For cold temperatures, the MALR can approach (but never exceed) the DALR. It's possible to have an area of saturated air cool faster than the MALR, but, again, we'll let that be for the moment.

To apply the concept of lapse rates, we need to add buoyancy.

What happens when you submerge a cork at the bottom of a bucket of water and let go? It pops to the top, because cork is much less dense than water. The cork has positive buoyancy. Similarly, if a parcel of air near the surface gets heated (maybe it was over a sun-baked parking lot), the air parcel's density decreases and becomes more buoyant. It rises like the cork.

How far will it rise? The cork rose until it reached a point where it was no longer less dense than its surroundings—surrounded by even less dense air at the surface of the water. This is the cork's equilibrium level. Actually, the cork had momentum and may have overshot the top of the water a bit before settling back.

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*Turbulence in clear air is tough to predict. If you have an idea of where the most unstable altitudes are, however, you can file or request altitudes to avoid the likely problem spots. Avoid altitudes with high positive lapse rates and changing winds.*



An air parcel also ascends, but only if the parcel remains intact and the temperature of the environment just above the parcel is cooler. If the temperature above the parcel is warmer, then the parcel has reached its equilibrium level and stops. Keep in mind that the parcel may overshoot its equilibrium level a bit from momentum, just like the cork.

When an air parcel rises it expands, because it's rising into a region of lower pressure aloft. The parcel's temperature decreases accordingly. The rate of cooling—or lapse rate—within this parcel is important. Rising unsaturated air cools at the DALR. Rising saturated air cools at the MALR. That's no surprise since these are Mother Nature's lapse-rate limits.

### Why Lapse Matters

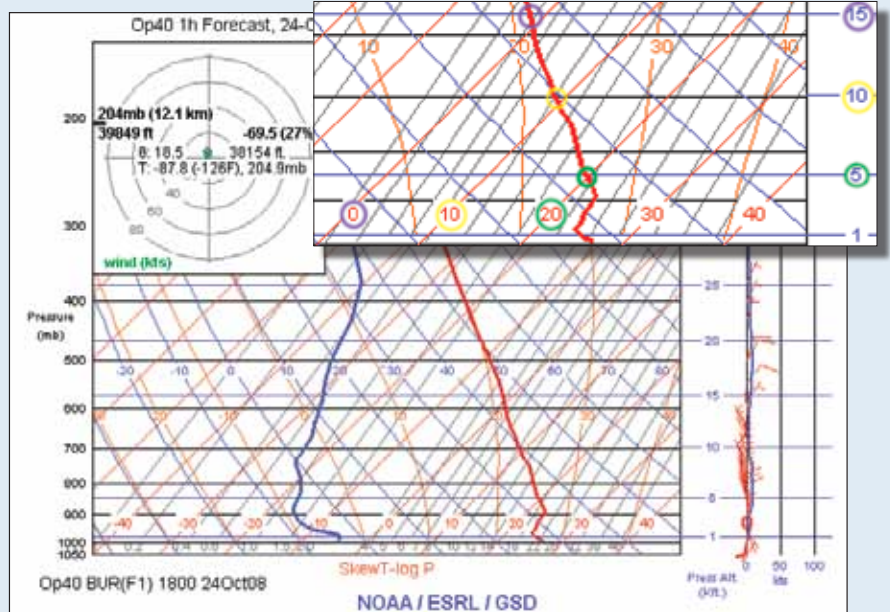
Let's apply this with a classic, building cumulus cloud. Given enough moisture, when unsaturated air is lifted upward, it expands and cools at the DALR and clouds may form. Now the rising air inside the cloud is cooling at the MALR. If the environment—the air outside and around the cloud—has a lapse rate that's higher than the MALR inside the cloud, then it cools faster with altitude than the parcel in the cloud can cool through expansion. The parcel is positively buoyant like the cork, and the cloud continues to grow. This is moist convection.

Beyond building clouds, large lapse rates promote the mixing of air and that's "bad" from a pilot's perspective. In unsaturated air, this is called dry convection. Large lapse rates near the surface (common on hot summer days) plus a strong prevailing wind cause moderate thermal turbulence. Large lapse rates aloft can be indicative of moderate or greater clear air turbulence especially when coupled with changes in wind speed and/or direction with height. Any time air is encouraged to mix, turbulence is possible. When it's discouraged to mix, the air is generally smooth.

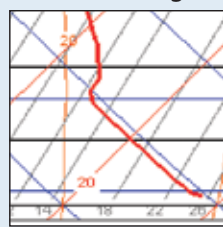
The larger the lapse rate (up to the limits), the more unstable the air, saturated or unsaturated. Larger lapse rates are typically created when the surface is warmed from below, the air is cooled

## STILL THE BEST TOOL IN TOWN: SKEW-T

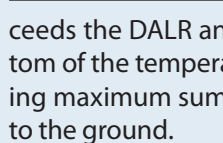
The best way to visualize the lapse rate is to use a thermodynamic chart called a Skew-T log (p) diagram. It plots the atmospheric temperature, dewpoint and wind as a function of pressure or altitude. While the diagram itself looks quite complex, it's the perfect tool to visualize the atmospheric lapse rate because it gives you a continuous profile of the temperature with height. The data for the chart can come from a radiosonde (weather balloon) or a forecast model such as the Rapid Update Cycle (RUC).



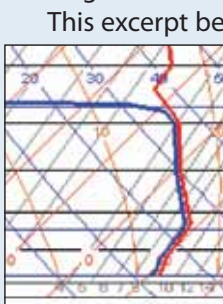
The Skew-T diagram above shows a rare day in Burbank, Calif., where the environmental lapse rate (thick red line) nearly matches the standard of two degrees C per thousand feet. It's just below 20 degrees at 5000 (green circles), about nine degrees at 10,000 (yellow) and about -2 at 15,000.



During the afternoon it's common for the environmental lapse rate to approach the dry adiabatic lapse rate (DALR) in the first few thousand feet of the surface (left). See how the red temperature line nearly parallels the blue reference lines which reflect the DALR?



A super-adiabatic lapse (right) is a lapse rate that exceeds the DALR and appears as a "foot" at the bottom of the temperature line. These are possible during maximum summer heating and only very close to the ground.



This excerpt below is a good example of a fairly deep, saturated layer that is approaching the moist adiabatic lapse rate (MALR). At the bottom, temperature and dewpoint (thick red and blue) parallel the temperature line—meaning no change in temp with altitude. Then they go almost straight up, following the slightly curved orange reference lines of the MALR. Structural icing in a moist adiabatic layer such as this can be intense. —S.D.



## WHAT IS THE LIFTED INDEX?

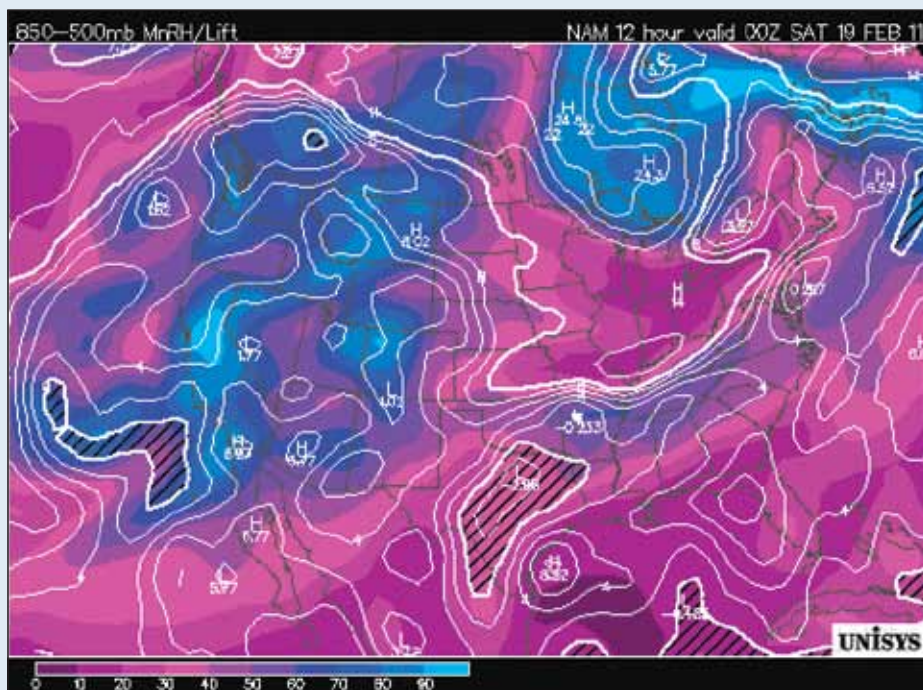
If you had a thorough primary training, you may have heard about the lifted index (LI). Usually the extent of this is that a negative LI means unstable air and implies a significant risk for thunderstorms. Conversely, a positive lifted index implies no risk for thunderstorms. This is, as the saying goes, “knowing enough to be dangerous.”

Placing aside any complex formula, the LI is just an acid test of sorts. It attempts to answer this question: If a saturated parcel of air is independently lifted to 500 mb (approximately 18,000 feet), will it be warmer or colder than the environment around it? In other words, will it float or will it sink? If the saturated air parcel is colder (more dense) than the environment, the LI will be positive (it’ll sink). If the saturated air parcel is warmer (less dense) than the environment, the LI will be negative (it’ll float). The LI is simply the difference between the environmental temperature at 500 mb and the temperature of the lifted parcel at 500 mb.

Thunderstorms develop when sufficient instability, moisture and lift are all present. The LI identifies the presence of two of these three ingredients: instability and moisture. The LI assumes that the third ingredient—lift—is omnipresent. Of course, lift isn’t always present in sufficient quantity. A LI can be highly negative, but without suf-

ficient lift, such as a front, convection isn’t likely. There’s also the possibility that a convective cap, such as a temperature inversion, is present. As no two convective events are the same, the LI has several variants. These include the surface-based LI, mean layer LI and the most unstable LI.

The LI forecast is a good benchmark to check before departing. Any negative LI should get your attention. You can find the LI online at <http://weather.unisys.com/nam/rh.php>. But don’t rely on it too much. There’s no such thing as a perfect convective index. —S.D



aloft or a combination of both. A classic example is lake effect snow. When cold air from Canada pours in over the warmer Great Lakes after the passage of a cold front, large lapse rates often occur, creating instability showers and significant precipitation.

Small lapse rates tend to inhibit any vertical mixing. The negative lapse rates of a temperature inversion inhibit vertical mixing and may lessen the threat of turbulence. A temperature inversion placed a few thousand feet above the surface may be enough to inhibit the development of convection even in the presence of a huge amount of instability aloft. Parcels of air expand and cool

more rapidly than the environment when an inversion exists.

Icing is typically the greatest in clouds that exhibit large saturated lapse rates. When saturated air approaches the MALR, a lot of moisture can be condensed out in a hurry. If the temperature is right, supercooled liquid water can exist in large quantities within these clouds. Cumulus clouds are examples of unstable, saturated parcels.

### A Jumping Off Point

This discussion far exceeds what most pilots care to know about the weather. However, if you take the time to learn how to apply this knowledge, you’ll have

a distinct advantage to know the altitude to expect the best (or worst) ride, where the icing will be the most intense, whether or not mountain waves will be an issue and where deep, moist convection will be likely or not so likely.

This study is more than one article can supply. But feel free to drop me a note if you have any specific questions, or would like to learn to use the Skew-T diagram and put this understanding to work. [IFR](#)

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