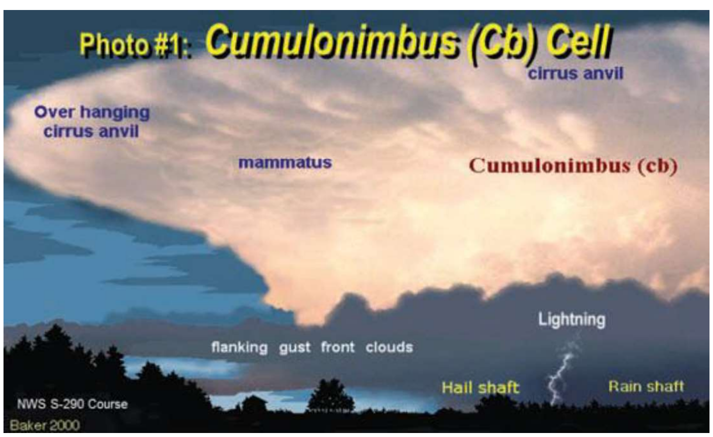
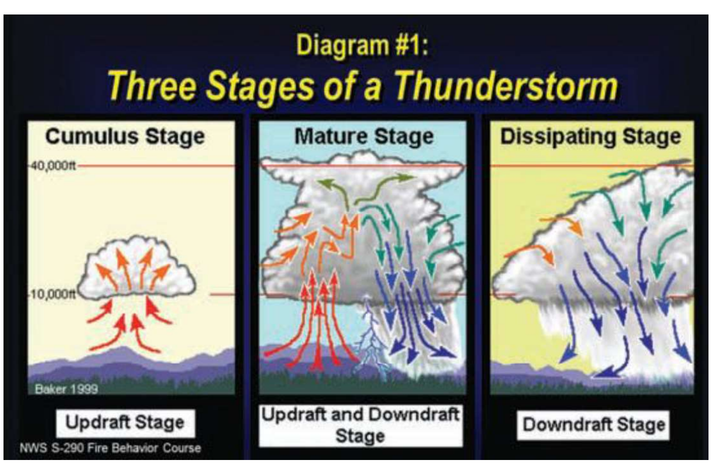
# WEATHER TO FLY

BY DAN GUDGEL

# "Ingredients for Trouble"

I recently conducted some meteorological training to a group of firefighters in regard to weather effects on fire behavior. In that training, I realized that the same information in regard to the state of the atmosphere relevant to fire behavior would also be useful. While I have covered much of this information in past articles in one form or another, a summary reminder for aviators fits nicely with our on-going safety-of-flight discussions **[Federal Aviation Administration(FAA) Safety Campaign "Got Weather" Website:** *<www.faa.gov/about/initiatives/got_weather>* **]**. So what trouble am I referencing in my article's title? I am fond of reminding all that a thunderstorm is *"Mother Nature's Severe Weather Generator."* Any severe weather that might come to a pilot's mind is present in and around a thunderstorm or Cumulonimbus (Cb) cloud-type **[See Photo #1: "*Cumulonimbus (Cb) Cell*"]**:



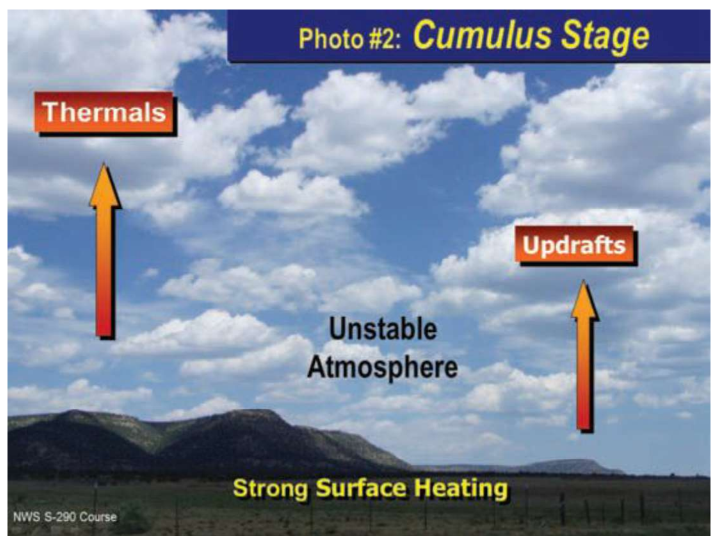




- Icing;
- Turbulence (severe to extreme);
- Lightning;
- Hail;
- Strong Wind; both straight-line (downbursts) and rotational (tornadic);
- Lowered Cloud Ceilings (loss of terrain/obstruction clearance);
- Heavy Rain (degradation of visibility); and,
- Surface Flash Flooding (runway hydroplaning, sailplane crew dangers).

Given that the presence of a strong convective cell or Cb cloud-type bodes ill for aviators, it behooves us to understand what atmospheric state leads to the thunderstorm development. The life cycle of a thunderstorm is characterized by three distinct stages **[See Diagram #1: "*Three Stages of a Thunderstorm*"]:**

- Cumulus;
- Mature; and,
- Dissipating.

The *Cumulus* stage **[See Photo #2: "*Cumulus Stage*"]** is typically the most appealing to soaring pilots. At this point in the thunderstorm life cycle, the developing cell is characterized by updrafts only. The *Mature* stage **[See Photo #3: "*Cb Mature*




***Stage*"]** begins with the onset of either precipitation and/or lightning (thunder) first observed. By the way, the occurrence of precipitation is defined as either rain or virga (rain not reaching the ground) and marks the presence of downdrafts as well as updrafts within the same Cb cell. The last stage of the thunderstorm is the *Dissipating* stage **[See Photo #4: "*Cb Dissipating Stage*"]**. The Cb begins to disappear as only downdrafts are present and the cell is essentially raining or drying itself to destruction. There are still risks or challenges in flying near a Cb in either the *Cumulus* or *Dissipating* stages but the *Mature* stage, just as the name implies, is where all the aforementioned dangers can be present. Subsequently, the soaring pilot must fully understand the atmospheric mechanisms underway and the possible adverse conditions in the vicinity of the cell.

Much like a fire needs three elements to occur (heat, oxygen, and fuel), so does a thunderstorm need three essential elements to mature. The absence or insufficiency of any of these elements eliminates the possibility of thunderstorm development.


Photo #4: Cb Dissipating Stage

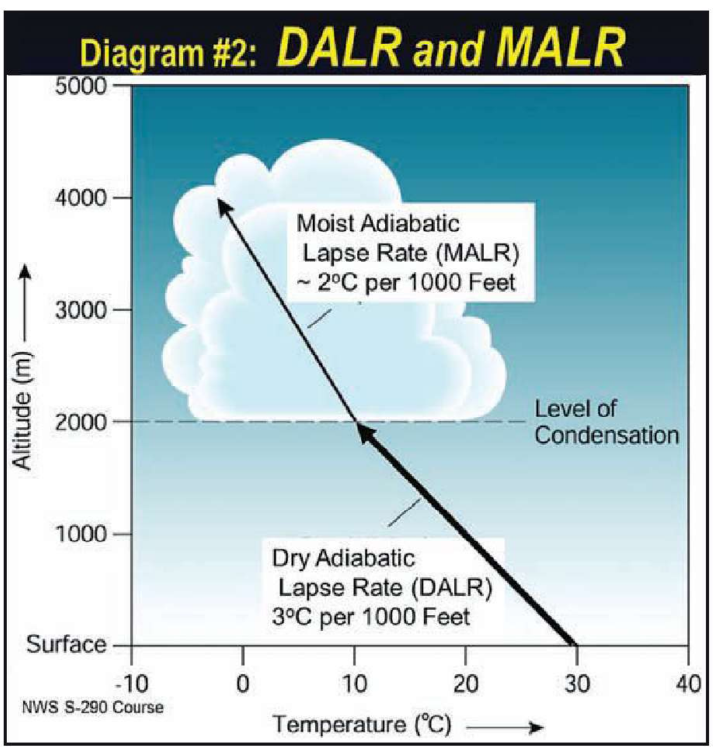



Diagram #2: DALR and MALR

Those elements are:

- Lift Initiation
- Instability; and,
- Adequate Water Vapor.

*Lift Initiation* could vary between terrain-forcing of air upward (orographic or ridge lifting), frontal-slope lifting, or simply uneven surface heating that leads to air buoyancy or the process soaring pilots know as a "thermal." *Instability* is a function of the vertical temperature profile. If the atmosphere is unconditionally unstable over the lowest layer next to the surface, air displaced upward will be warmer than the ambient (surrounding) air even as the *Adiabatic Process* **[See Definition: "*Adiabatic Process*"]** cools the displaced parcel. Thus, in an unstable atmosphere, the displaced air parcel is more buoyant because its temperature is higher and therefore its density lower than the ambient air.

*Adequate Water Vapor* acts as a fuel source for thunderstorm growth. A dry parcel of air moved upward will cool at the Dry Adiabatic Lapse Rate (DALR) of 3.0 degrees Celsius (°C) per 1,000 feet of increased altitude **[See Diagram #2: *"DALR and MALR"*]**. The buoyancy force at any specified altitude or level in the atmosphere of an air parcel rising is directly proportional to the difference between the ambient air's temperature and the rising air parcel's temperature. For any given surface temperature cooling at the DALR, soaring pilot's know this temperature difference (°C) as the definition of the "*Thermal*

*Index*" **[See Diagram #3: "*Thermal Index*"]**. If sufficient water vapor is present in combination with instability and lifting, the ensuing dry adiabatic cooling process lowers the temperature of the air to its dew point temperature. When an air parcel cools to its dew point temperature, water vapor saturation occurs and subsequently the water molecules in the rising air change phase from the gaseous phase (water vapor) to their liquid state (small water droplets). The energy that it took initially to have had the water molecule change its phase to the gaseous or vapor state (latent heat) is released with the condensation process into the rising air. This release of energy slows the rate of cooling of that air parcel from the DALR constant 3.0°C/1000 feet to that of the Moist Adiabatic Lapse Rate (MALR) **[See Diagram #2: "*DALR and MALR*"]**. Unlike the DALR, the MALR rate-of-cooling is not a constant because the amount of water vapor present at saturation is a function of temperature. Realistically, the ascent of an air parcel along the MALR is not a true adiabatic process, because loss of mass also occurs due to the precipitation process **[See Diagram #4: "*The Moist Adiabatic Process*"]**. Warmer air has a greater capacity to hold water vapor before reaching saturation. While a surface-based dry convection process (thermal) has moved air to altitudes as high as 24,000 feet above sea level over the Great Basin of Nevada, the strength of the dry air updraft is relatively weaker on average than a rising air parcel that has reached its dew point temperature, begun the condensation process, and now rises and cools at the MALR. Furthermore, the slower cooling of the air as the result of the moist adiabatic process enables a rising air parcel in a developing thunderstorm to remain buoyant or ascend to a higher altitude at a more vigorous updraft velocity (inside the cumulus/Cb cloud).

With an initiating lifting mechanism, an unstable atmosphere, and adequate water vapor, the atmosphere responds with the release of a tremendous amount of energy from the latent heat of evaporation that ultimately supports thunderstorm development. Underscoring the message, a review of the elements necessary and the resulting thunderstorm development is hoped to keep the aviator wary to any one or combination of the resulting adverse conditions associated with a thunderstorm. In the next installment of "Weather To Fly" we'll continue to discuss the aspects in the evolution of the thunderstorm life cycle.

**Diagram Credits:** NOAA/National Weather Service ***"S-290 Fire Behavior Course"***