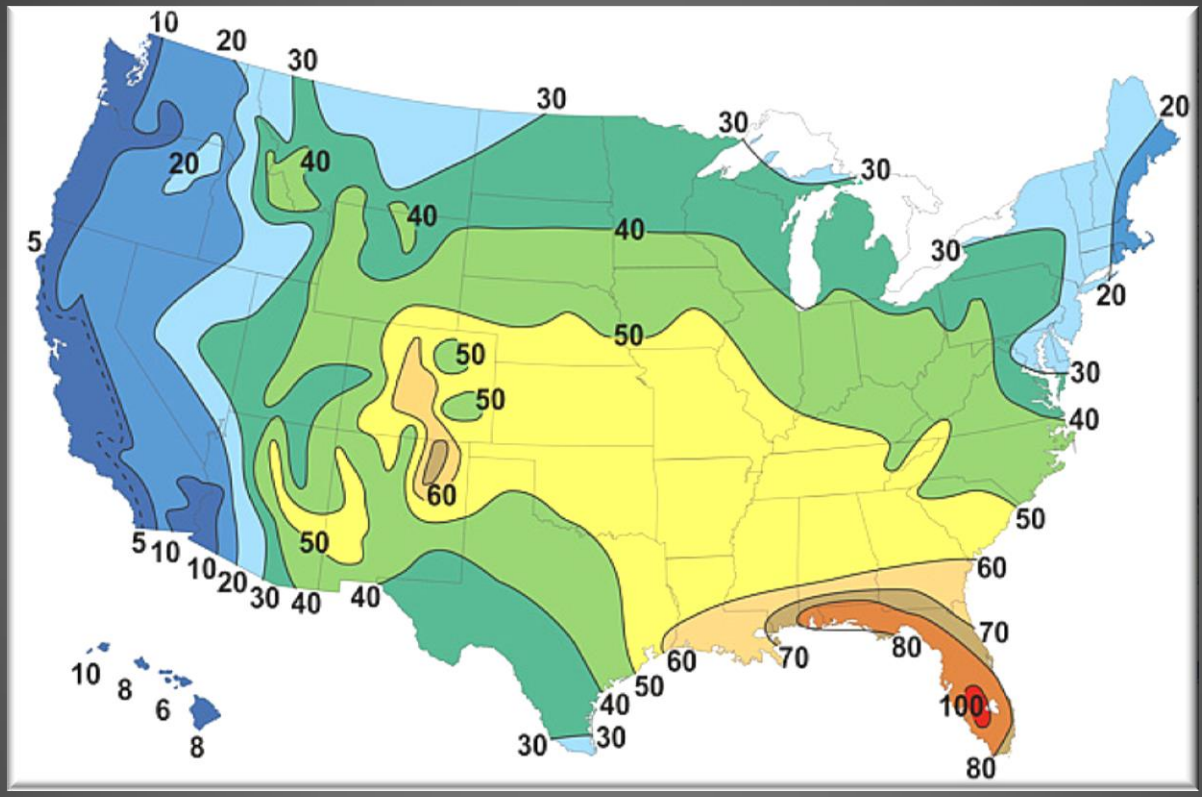
Thunderstorms

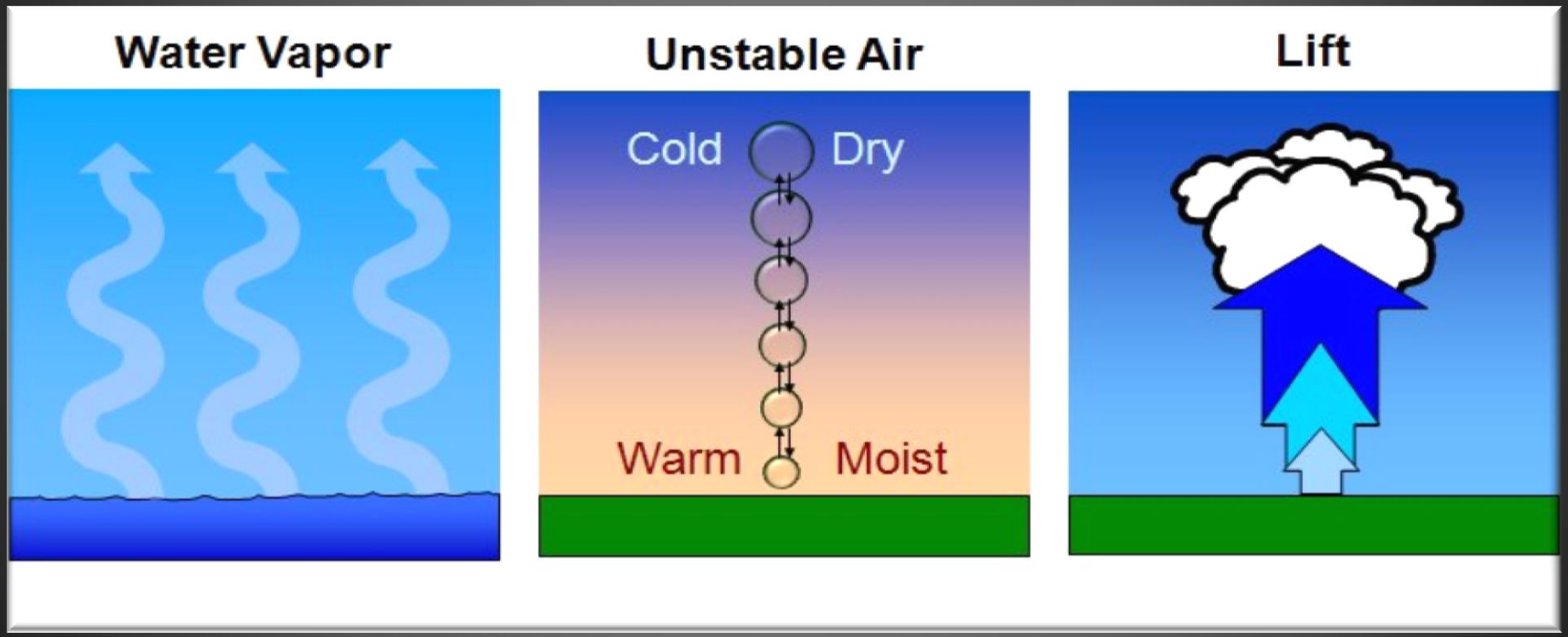
📖Thunderstorm – A storm produced by a cumulonimbus (CB) cloud, and always accompanied by lightning and thunder, usually with strong gusts of wind, heavy rain, and sometimes with hail.

Thunderstorm Frequency



The figure above shows the average number of thunderstorm days each year throughout the U.S. The most frequent occurrence is in the southeastern states, with Florida having the highest number 'thunder' days (80 to 100+ days per year).

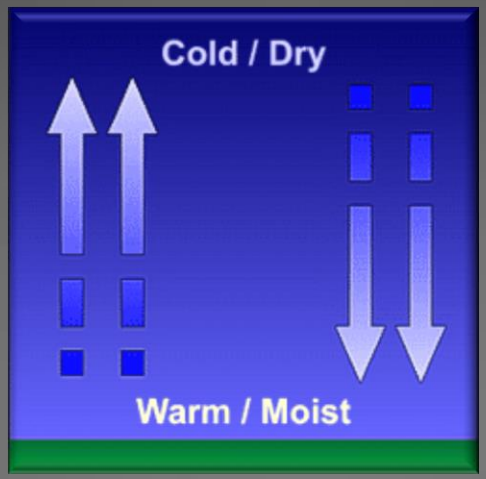
Necessary Ingredients for Thunderstorm Cell Formation



Thunderstorm Ingredient - Moisture

Typical sources of moisture are large bodies of water such as the Atlantic and Pacific oceans as well as the Gulf of Mexico. Warm ocean currents occur along east coasts of continents with cool ocean currents occur along west coasts. Evaporation is higher in warm ocean currents and therefore put more moisture into the atmosphere than with cold ocean currents at the same latitude.

Thunderstorm Ingredient - Instability



Air is considered unstable if it continues to rise when given a nudge upward (or continues to sink if given a nudge downward). An unstable air mass is characterized by warm moist air near the surface and cold dry air aloft.

In these situations, if a bubble or parcel of air is forced upward it will continue to rise on its own. As this parcel rises it cools and some of the water vapor will condense forming the familiar tall cumulonimbus cloud that is the thunderstorm.

Thunderstorm Ingredient – Lift

Typically, for a thunderstorm to develop, there needs to be a mechanism which initiates the upward motion, something that will give the air a nudge upward. This upward nudge is a direct result of air density.

Some of the sun's heating of the earth's surface is transferred to the air which, in turn, creates different air densities. The propensity for air to rise increases with decreasing density. This is difference in air density is the main source for lift and is accomplished by several methods.

(continued)

Thunderstorm Ingredient – Lift

Differential Heating

The sun's heating of the earth's surface is not uniform. For example, a grassy field will heat at a slower rate than a paved street. A body of water will heat slower than the nearby landmass. This will create two adjacent areas where the air is of different densities. The cooler air sinks, pulled toward the surface by gravity, forcing up the warmer, less dense air, creating thermals.

Fronts, Drylines and Outflow Boundaries

Fronts are the boundary between two air masses of different temperatures and therefore different air densities. The colder, more dense air behind the front lift warmer, less dense air abruptly. If the air is moist thunderstorms will often form along the cold front.

(continued)

Thunderstorm Ingredient – Lift

Drylines are the boundary between two air masses of different moisture content and separates warm, moist air from hot, dry air. Moist air is less dense then dry air. Drylines therefore, act similar to fronts in that a boundary exists between the two air masses of different densities. The air temperature behind a dryline is often much higher due to the lack of moisture. But the moist air ahead of the dryline has an even lower density making it more buoyant. The end result is air lifted along the dryline forming thunderstorms.

Outflow boundaries are a result of the rush of cold air as a thunderstorm moves overhead. The rain-cooled, more dense, air acts as a "mini cold front", called an outflow boundary. Like fronts, this boundary lifts warm moist air and can cause new thunderstorms to form.

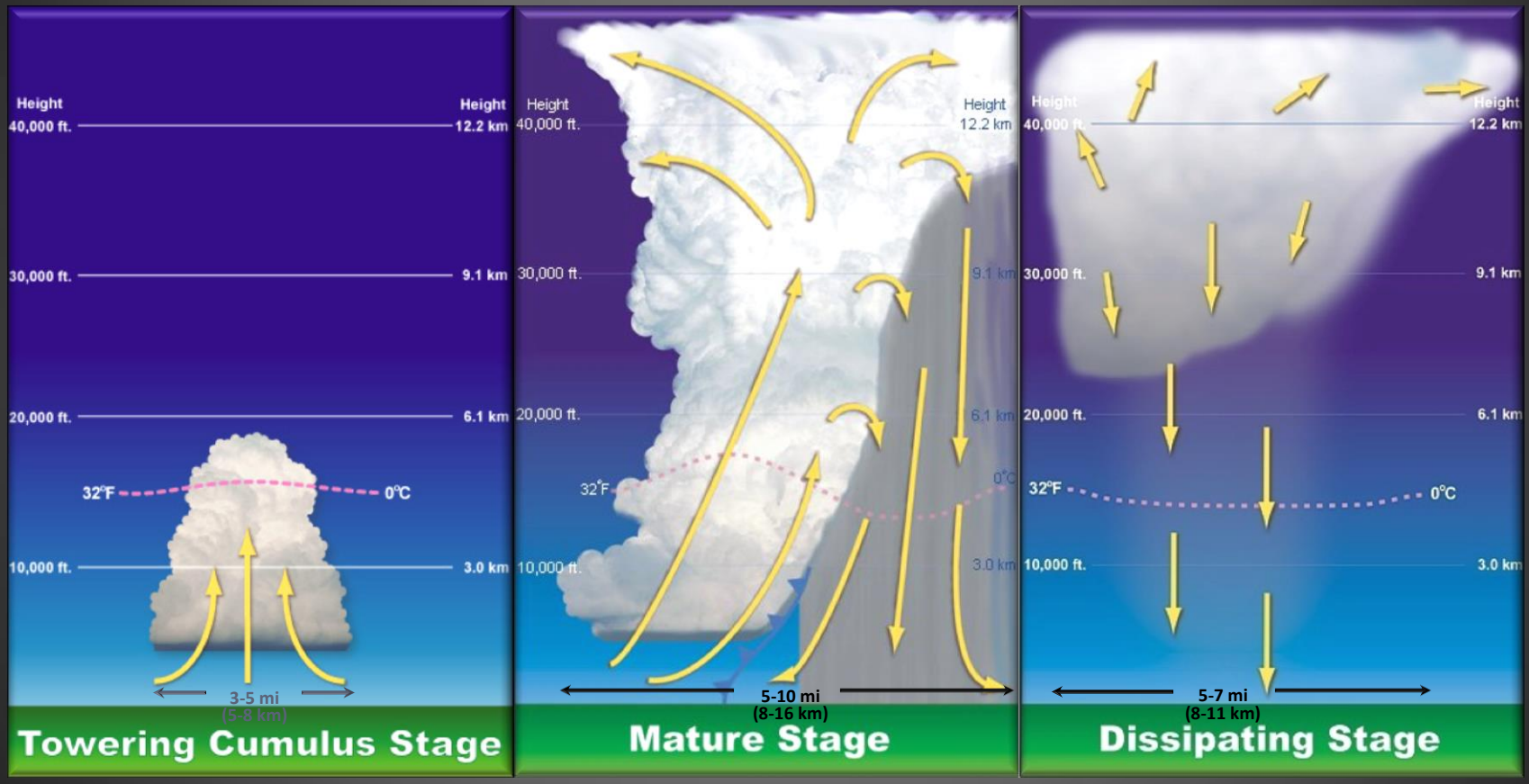
(continued)

Thunderstorm Ingredient – Lift

Terrain

As air encounters a mountain it is forced up because of the terrain. Upslope thunderstorms are common in the Rocky Mountain west during the summer.

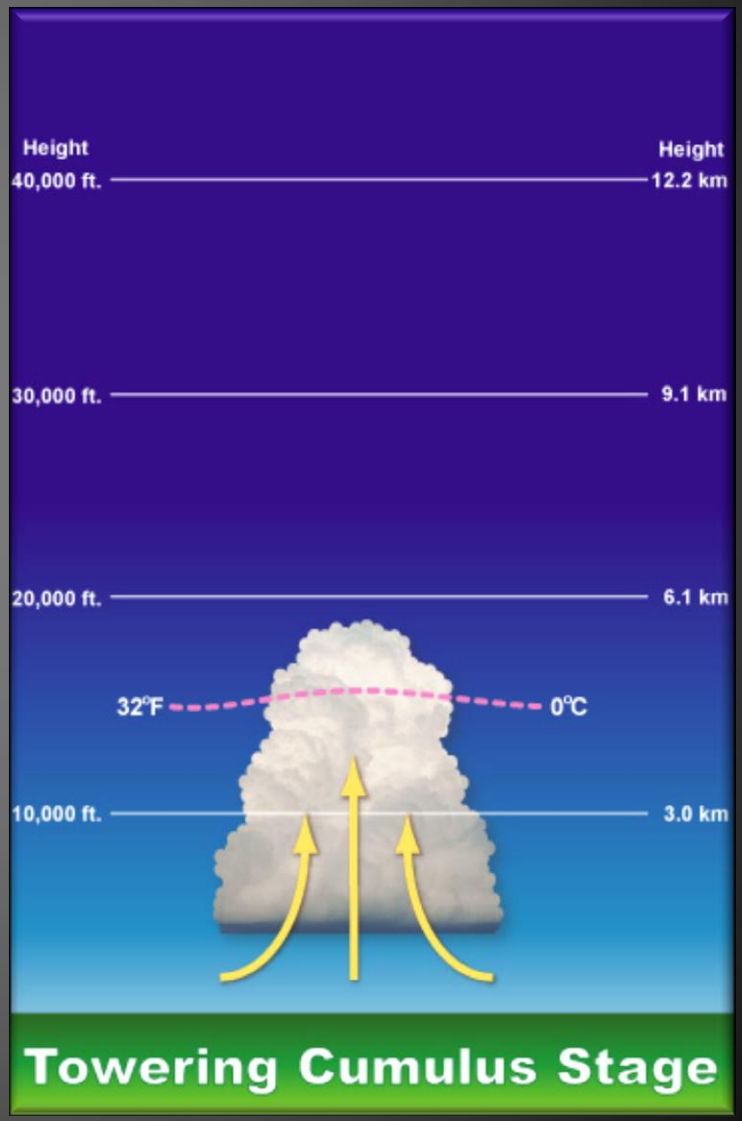
Thunderstorm Cell Life Cycle



Thunderstorm Cell Life Cycle

The Towering Cumulus Stage

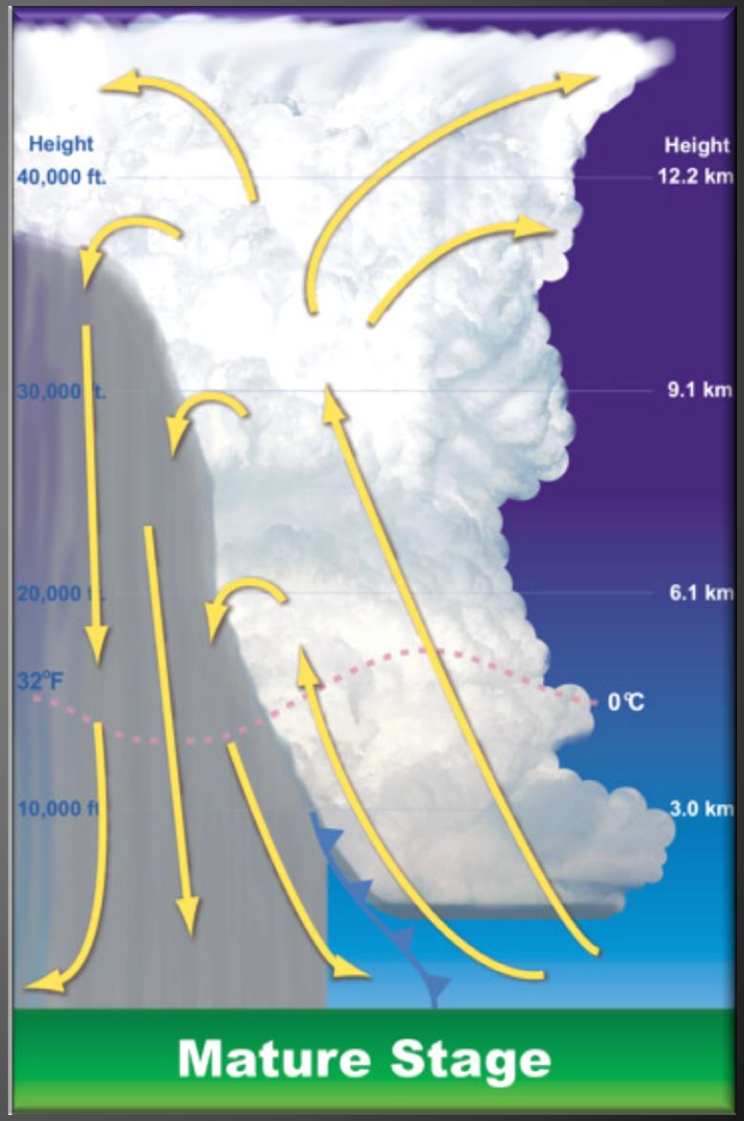
A cumulus cloud begins to grow vertically, perhaps to a height of 20,000 feet. Air within the cloud is dominated by updraft with some turbulent eddies around the edges.



Thunderstorm Cell Life Cycle

The Mature Cumulus Stage

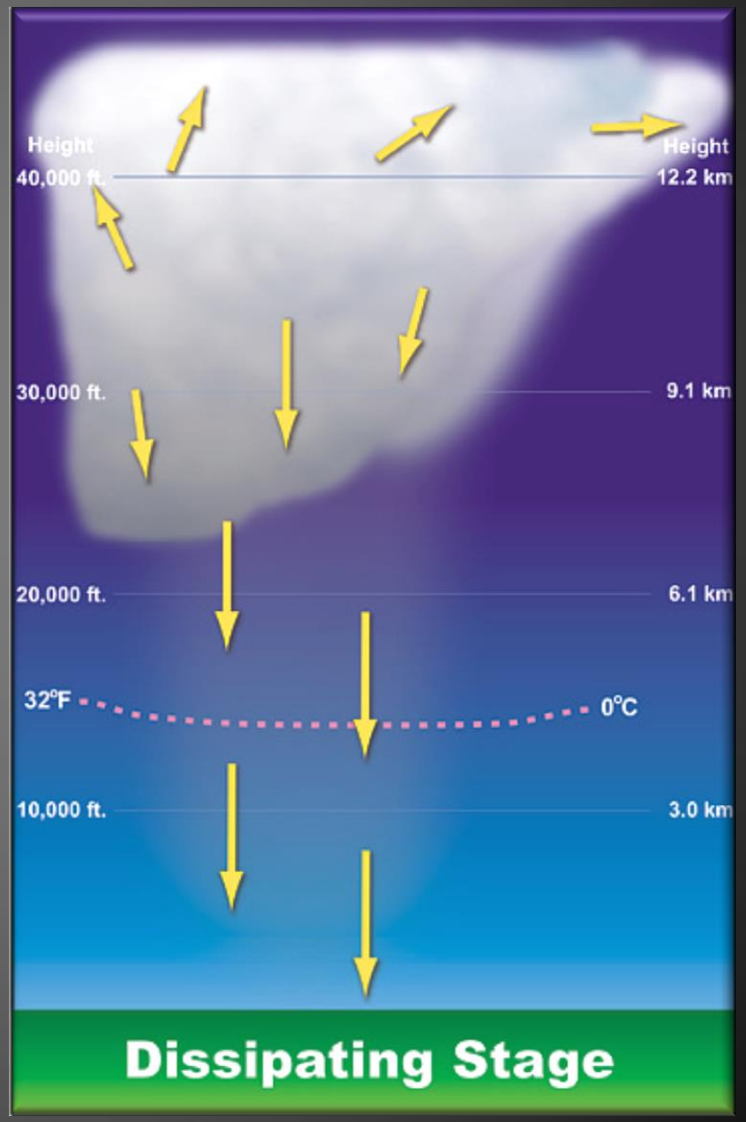
The storm has considerable depth, often reaching 40,000 to 60,000 feet. Strong updrafts and downdrafts coexist. This is the most dangerous stage when large hail, damaging winds, and flash flooding may occur.



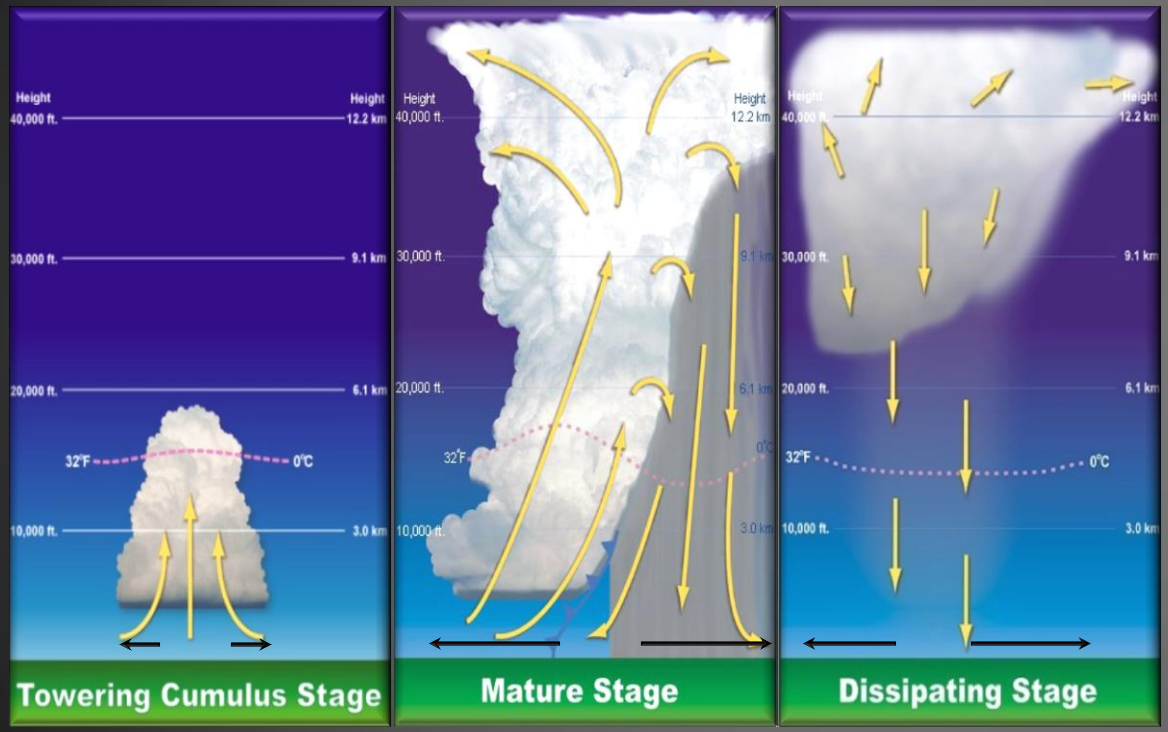
Thunderstorm Cell Life Cycle

The Dissipating Stage

The downdraft cuts off the updraft. The storm no longer has a supply of warm moist air to maintain itself and therefore it dissipates. Light rain and weak outflow winds may remain for a while during this stage, before leaving behind just a remnant anvil top.

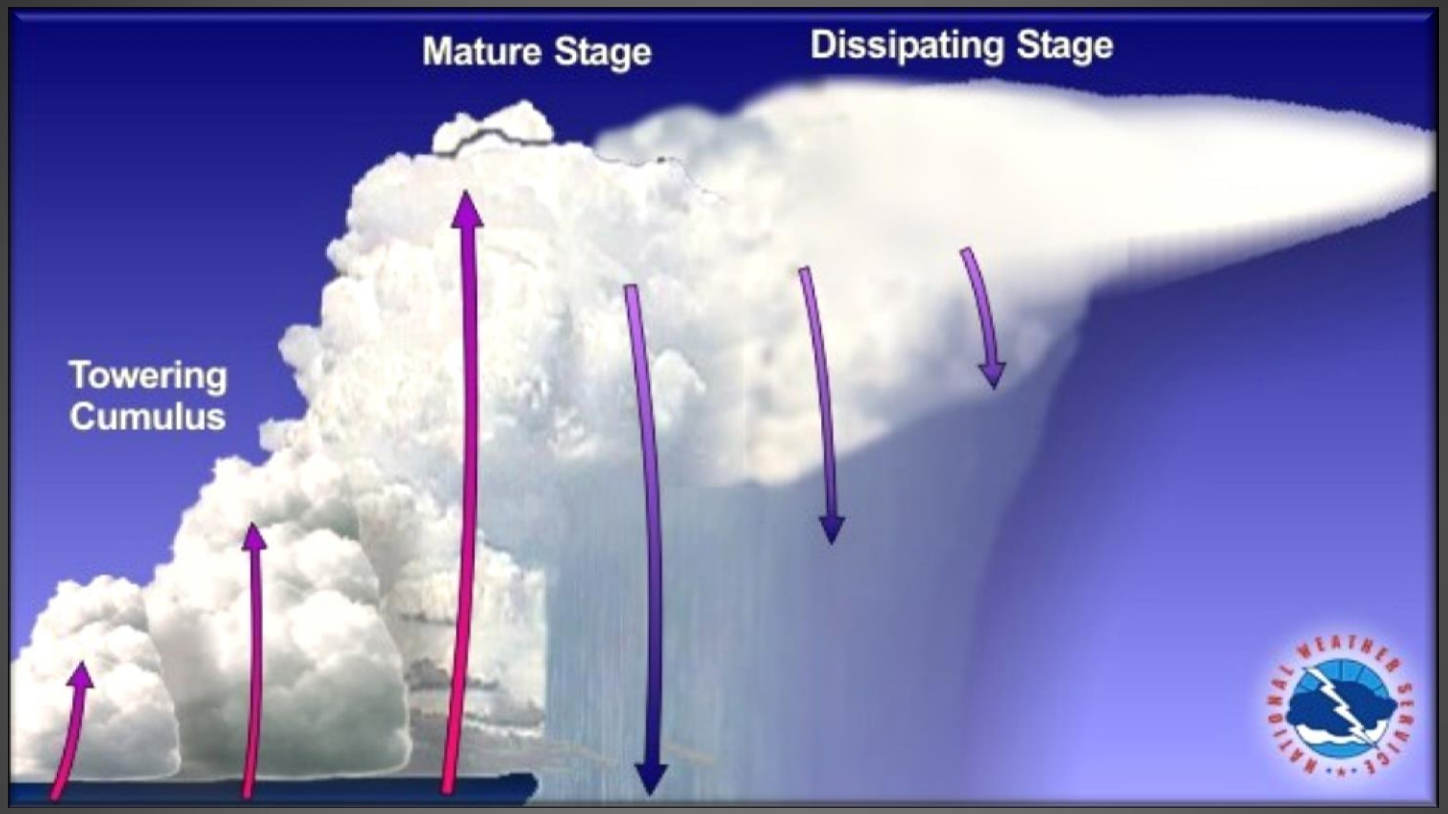


Single Cell



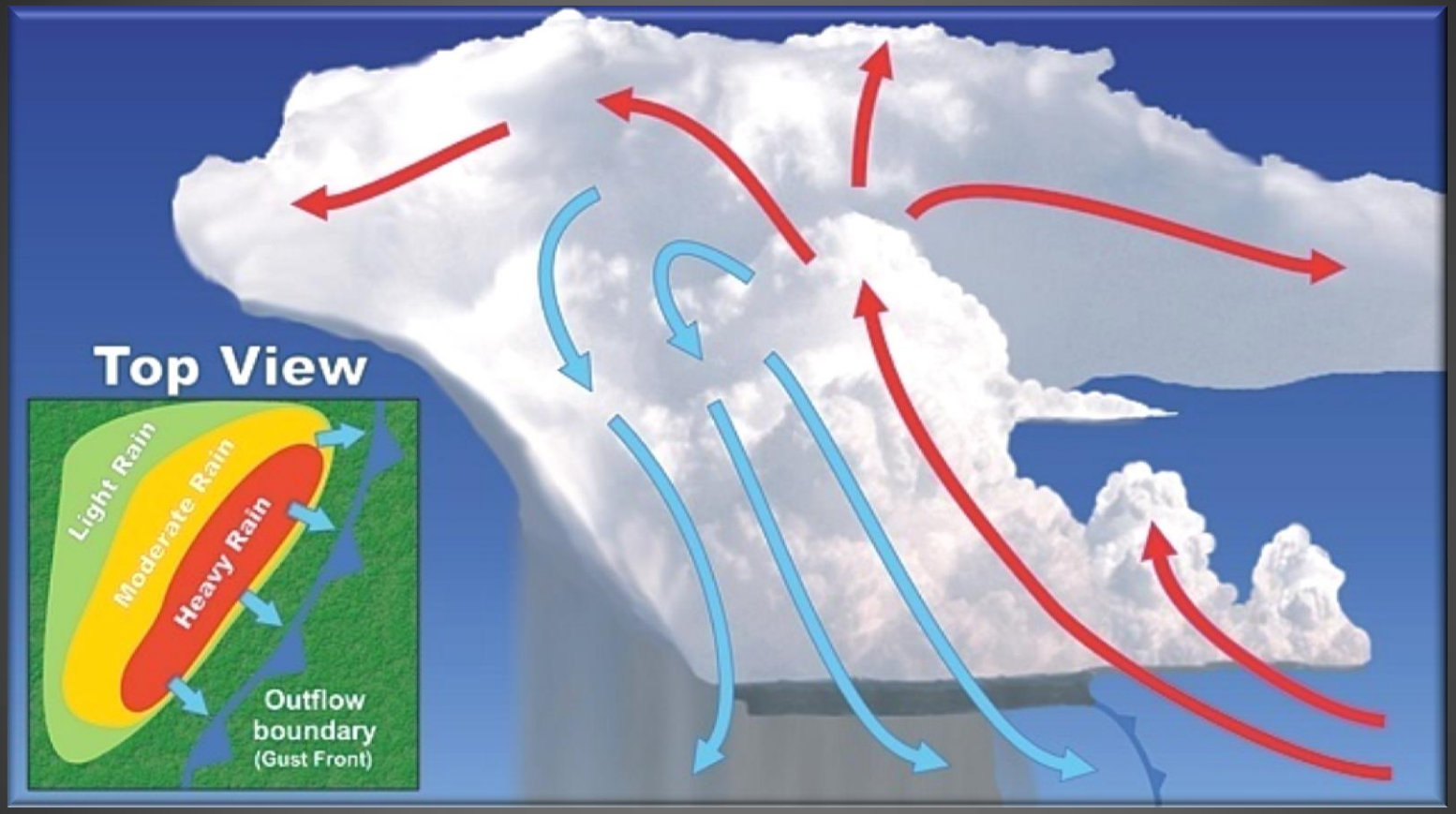
- Consists of one cell
  - Short lived (~30 min)
  - Also called “pulse” thunderstorm
  - Consist of a one time updraft and one time downdraft
  - Easily circumnavigated visually by pilots
    - Except at night or when embedded
  - Rare (almost all storms are multicell)

Multi-cell Cluster



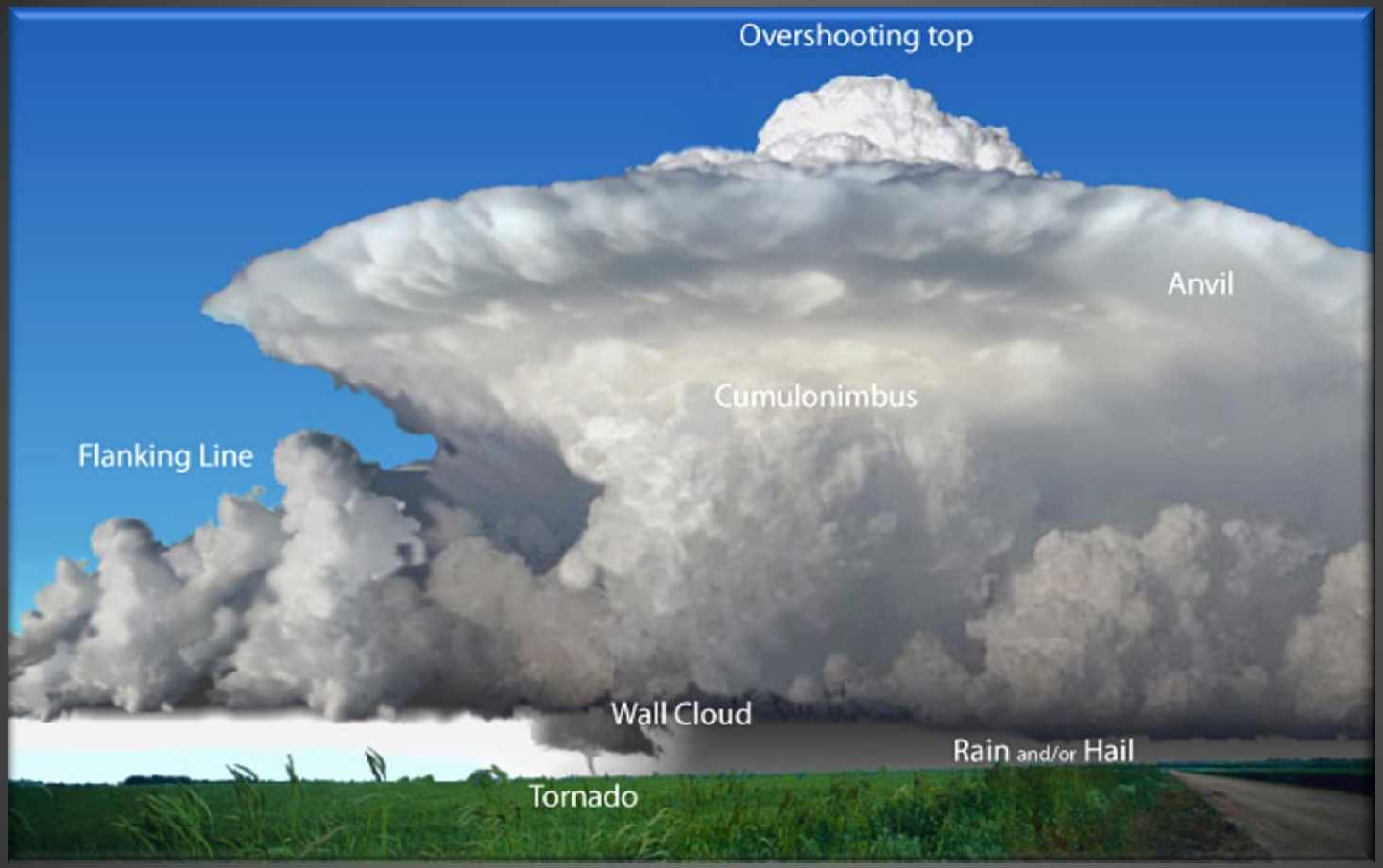
Thunderstorms often form in clusters with numerous cells in various stages of development merging together. The prevailing atmospheric conditions are such that as the first cell matures, it is carried down-stream by the upper level winds and a new cell forms upwind of the previous cell to take its place.

Multi-cell Line (Squall Line)



Sometimes thunderstorms will form in a line which can extend laterally for hundreds of miles. These squall lines can persist for many hours and produce damaging winds and hail. Updrafts, and therefore new cells, continually re-form at leading edge of system with rain and hail trailing.

Supercell



Supercell thunderstorms are a special kind of single cell thunderstorm that can persist for many hours. They are responsible for nearly all of the significant tornadoes produced in the U.S. and for most of the hailstones larger than golf ball size.

Supercell

The most ideal conditions for supercells occurs when the winds are veering or turning clockwise with height. For example, in a veering wind situation the winds may be from the south at the surface and from the west at 15,000. This change in wind speed and direction produces storm-scale rotation, meaning the entire cloud rotates, which may gives a striated or corkscrew appearance to the storms updraft.

Dynamically, all supercells are fundamentally similar. However, they often appear quite different visually from one storm to another depending on the amount of precipitation accompanying the storm and whether precipitation falls adjacent to, or is removed from, the storms updraft.

Based on their visual appearance, supercells are often divided into three groups: 1) **Rear Flank Supercell - Low precipitation (LP)**, 2) **Classic (CL)**, 3) **Front Flank Supercell - High precipitation (HP)**.

Low Precipitation (LP) Supercell

In LP supercells the updraft is on the rear flank of the storm, a barber pole or corkscrew appearance of updraft is possible, precipitation sparse or well removed from the updraft, often is transparent and you can’t see it, and large hail is often difficult to discern visually. Also, there is no "hook" seen on Doppler radar.

Classic Supercell

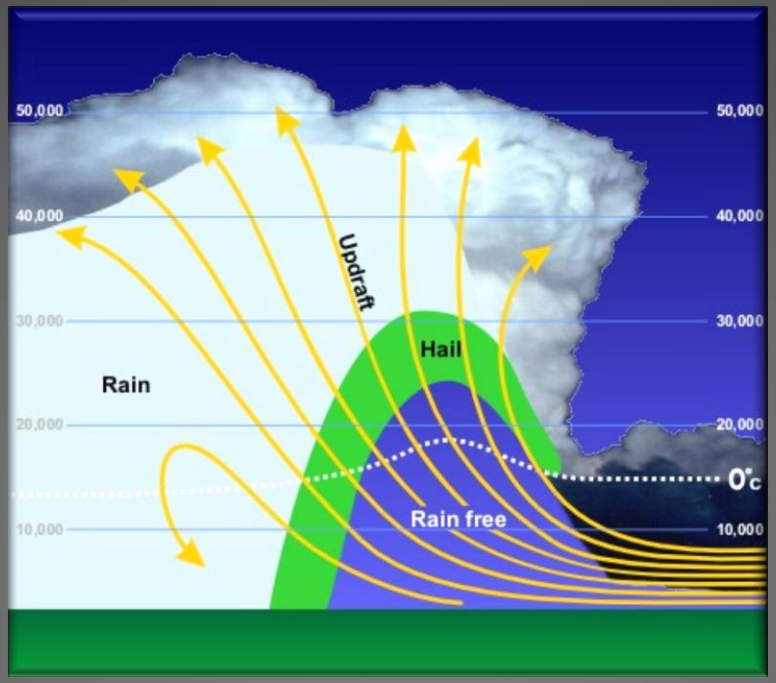
The majority of supercells fall in the "classic" category. These have large, flat updraft bases, generally has a wall cloud with it, striations or banding can been seen around the periphery of the updraft, heavy precipitation falls adjacent to the updraft with large hail likely, and have the potential for strong, long-lived tornadoes.

High Precipitation (HP) Supercell

HP supercells will have...

- the updraft on the front flank of the storm
- precipitation that almost surrounds updraft at times
- the likelihood of a wall cloud (but it may be obscured by the heavy precipitation)
- tornadoes that are potentially wrapped by rain (and therefore difficult to see), and
- extremely heavy precipitation with flash flooding.

Thunderstorm Hazards - Hail



Hail is precipitation that is formed when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere. Hail-stones grow by collision with supercooled water drops. (Supercooled drops are liquid drops surrounded by air that is below freezing which is a common occurrence in thunderstorms.) There are two methods by which the hailstone grows, wet growth and dry growth, and which produce the "layered look" of hail.

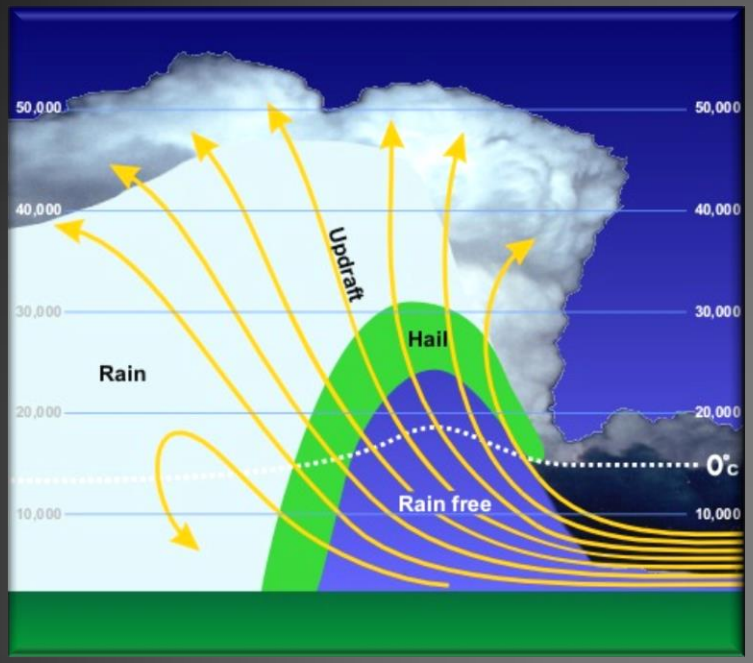
Thunderstorm Hazards - Hail

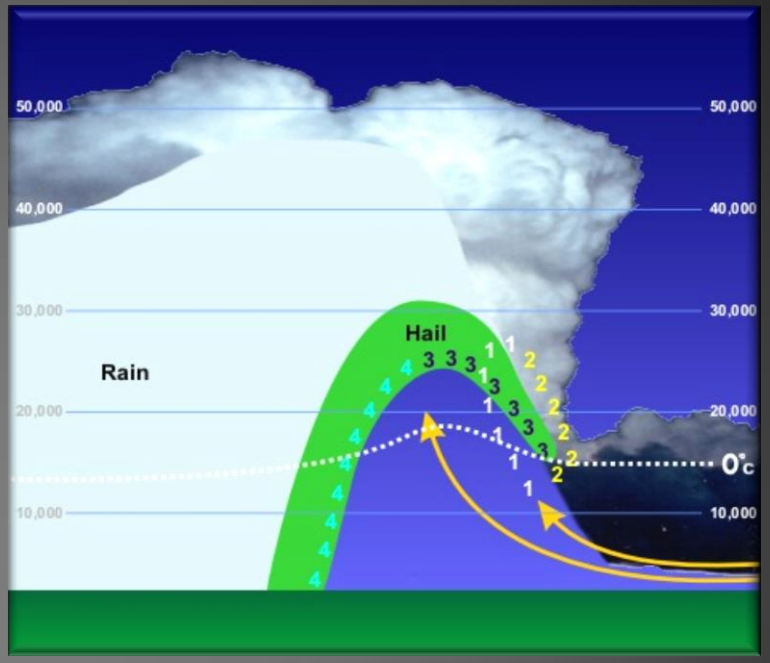
In **wet growth**, the hailstone nucleus (a tiny piece of ice) is in a region where the air temperature is below freezing, but not super cold. Upon colliding with a supercooled drop the water does not immediately freeze around the nucleus.

Instead liquid water spreads across tumbling hailstones and slowly freezes. Since the process is slow, air bubbles can escape resulting in a layer of clear ice.

With **dry growth**, the air temperature is well below freezing and the water droplet immediately freezes as it collides with the nucleus. The air bubbles are "frozen" in place, leaving cloudy ice.

Thunderstorm Hazards - Hail



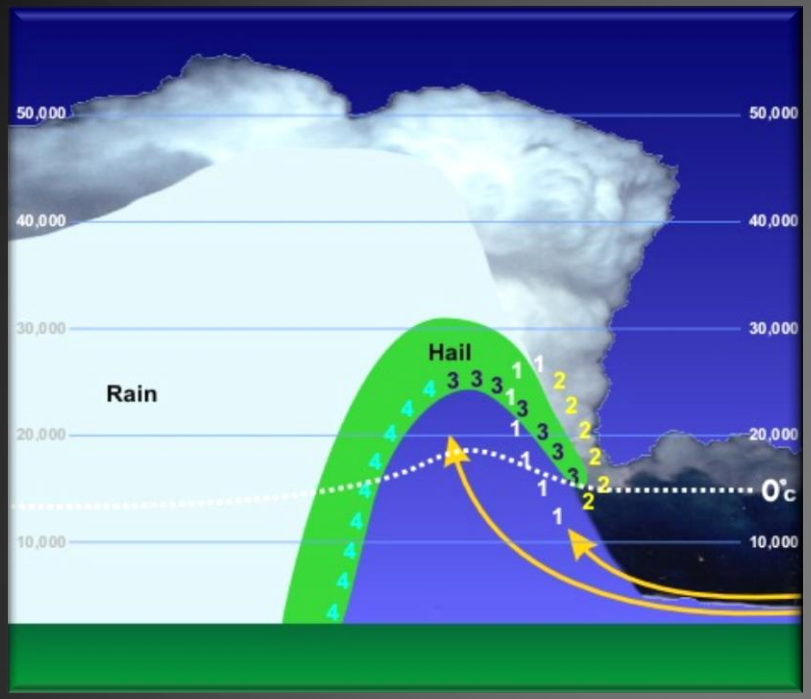


Strong updrafts create a rain-free area in supercell thunderstorms (left image). We call this area a WER which stands for "weak echo region".

This term, WER, comes from an apparently rain free region of a storm which is bounded on one side AND above by very intense precipitation indicted by a strong echo on radar.

This rain-free region is produced by the updraft and is what suspends rain and hail aloft producing the strong radar echo. (right image)

Thunderstorm Hazards - Hail



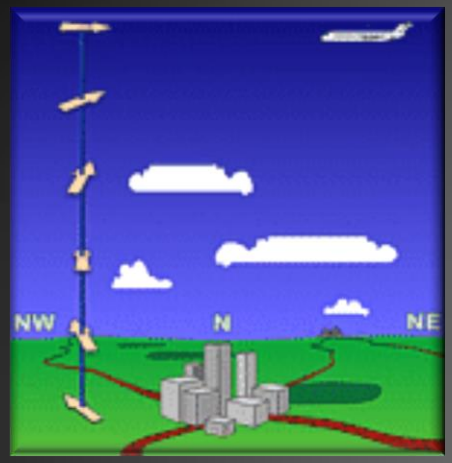
1. The hail nucleus, buoyed by the updraft is carried aloft by the updraft and begins to grow in size as it collides with supercooled raindrops and other small pieces of hail.

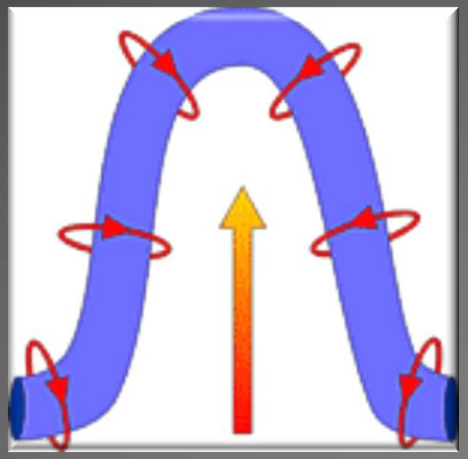
2. Sometimes the hailstone is blown out of the main updraft and begins to fall to the earth.

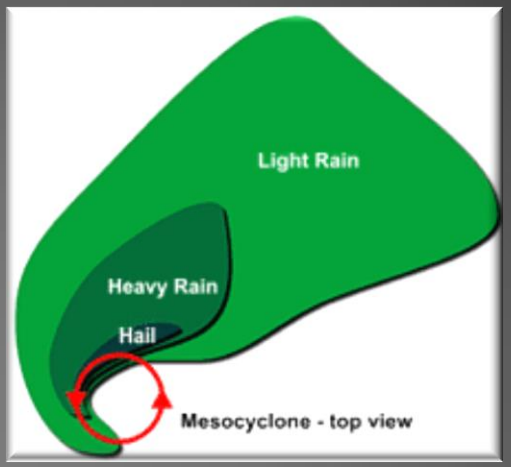
3. If the updraft is strong enough it will move the hailstone back into the cloud where it once again collides with water and hail and grows. This process may be repeated several times.

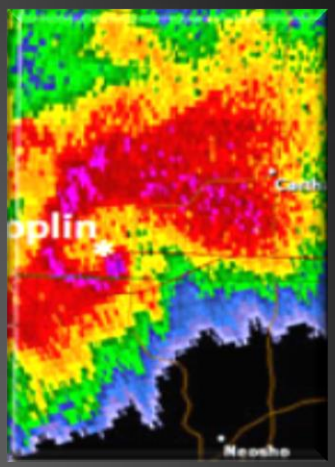
4. In all cases, when the hailstone can no longer be supported by the updraft it falls to the earth. The stronger the updraft, the larger the hailstones that can be produced by the thunderstorm.

Thunderstorm Hazards - Tornadoes









Most tornadoes are spawned from supercell thunderstorms. Supercell thunderstorms are characterized by a persistent rotating updraft and form in environments of strong vertical wind shear.

Wind shear is the change in wind speed and/or direction with height. The updraft lifts the rotating column of air created by the speed shear. This provides two different rotations to the supercell; cyclonic or counter clockwise rotation and an anti-cyclonic of clockwise rotation (see 2nd image above).

The directional shear amplifies the cyclonic rotation and diminishes the anti-cyclonic rotation (the rotation on the right side of the of the updraft in the illustration below left). All that remains is the cyclonic rotation called a mesocyclone.

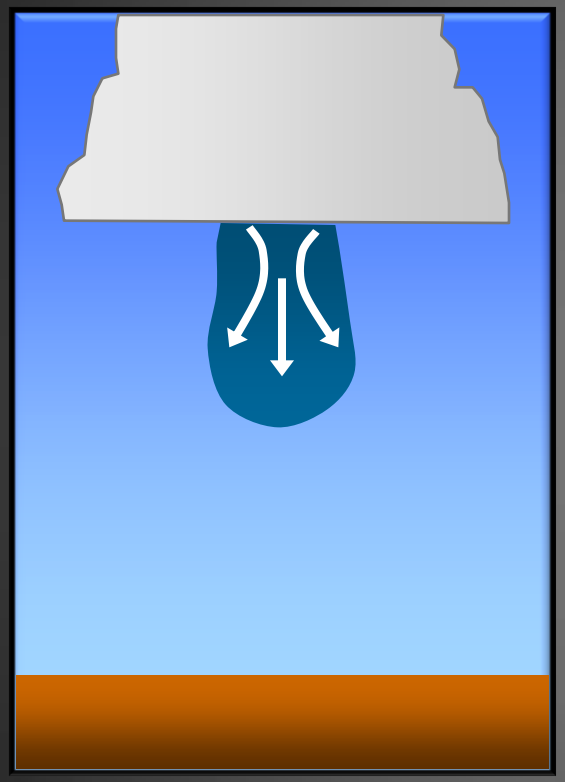
Thunderstorm Hazards - Tornadoes

The exact processes for the formation of a funnel are not known yet. Recent theories suggest that once a mesocyclone is underway, tornado development is related to the temperature differences across the edge of downdraft air wrapping around the mesocyclone.

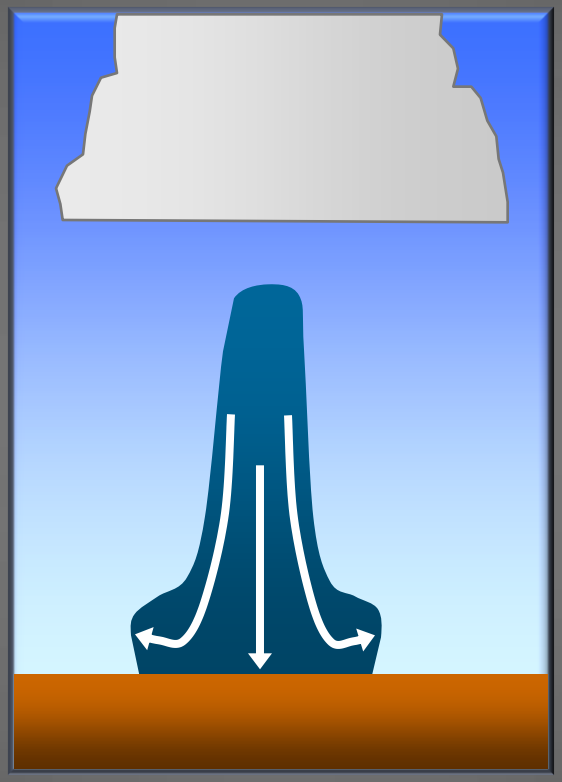
The funnel cloud of a tornado consists of moist air. As the funnel descends the water vapor within it condenses into liquid droplets. The descending funnel is made visible because of the water droplets. The funnel takes on the color of the cloud droplets, which is white.

After the funnel touches the ground and becomes a tornado, the color of the funnel will change. The color often depends upon the type of dirt and debris is moves over (red dirt produces a red tornado, black dirt a black tornado, etc.).

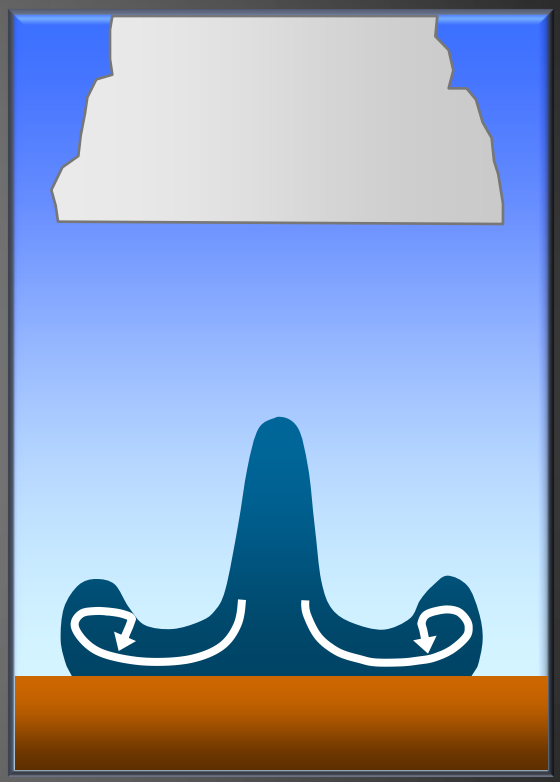
Downburst Lifecycle



FORMATION – Evaporation and precipitation drag forms downdraft



IMPACT – Downdraft quickly accelerates and strikes ground



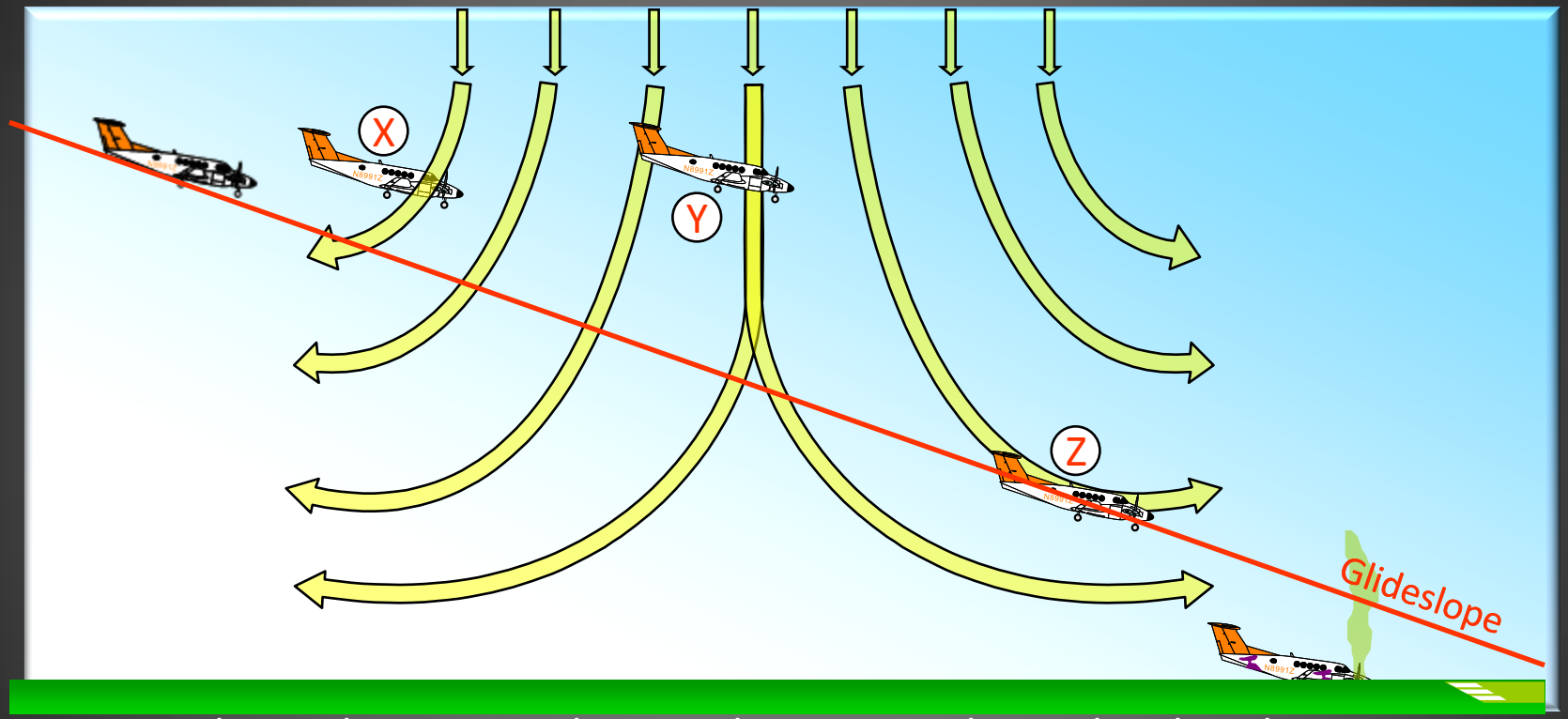
DISSIPATION – Downdraft moves away from point of impact

Microburst Types

- A dry microburst is associated with virga
  - Downdraft is driven by evaporative cooling of raindrops falling through dry, unsaturated air

- A wet microburst is associated with a concentrated rain shaft
  - Downdraft is driven by both evaporative cooling and precipitation drag of rain-drops dragging air to the ground

Landing in a Microburst



At point X, the airplane enters the microburst zone where a headwind causes it to balloon above the normal glideslope.

At the center of the microburst, point Y, there is a downdraft which causes the airplane to sink.

At point Z, the airplane enters the most lethal zone where a sudden tailwind causes the airplane to lose airspeed.

Sea Breeze Thunderstorm