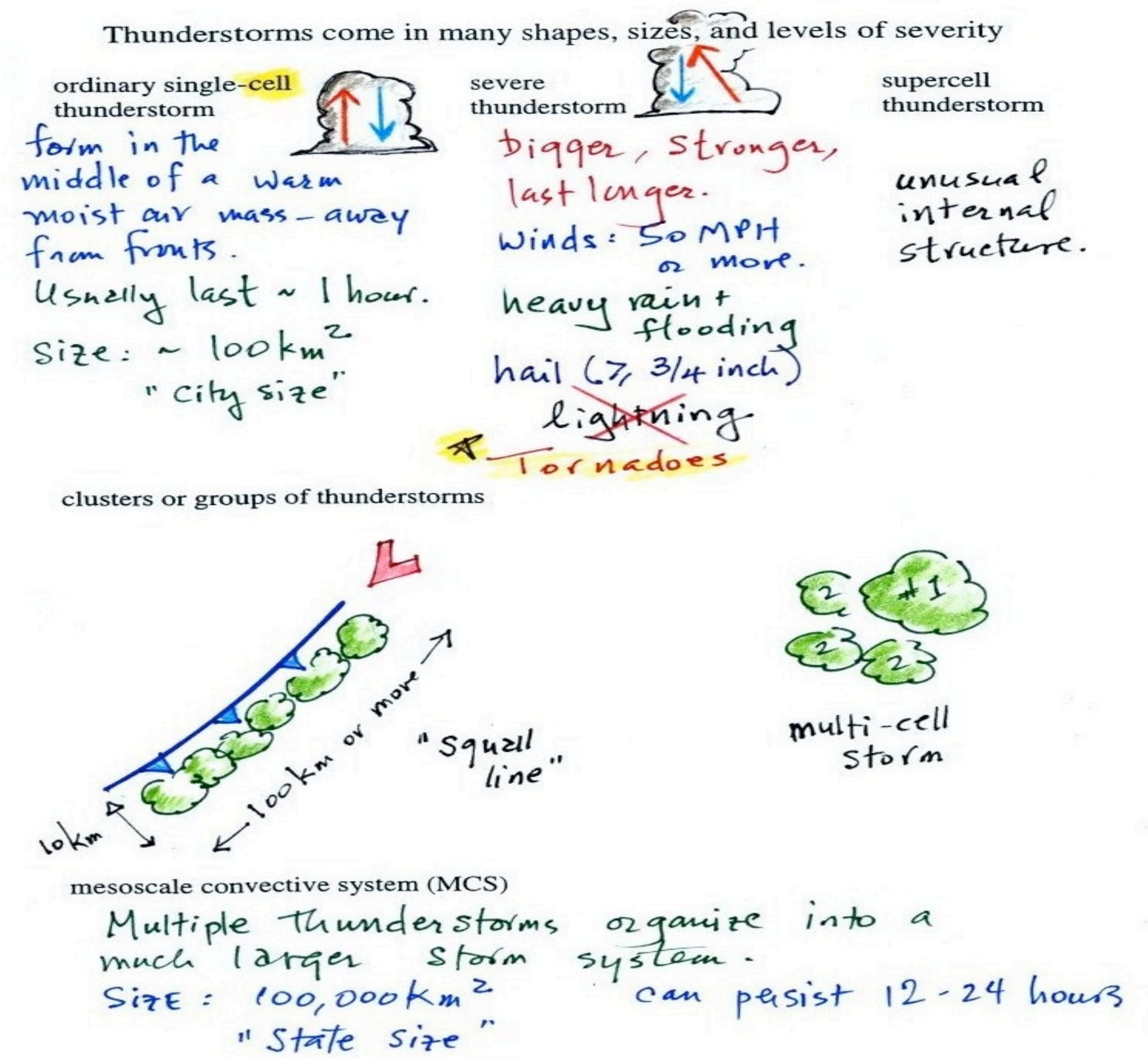
Module 10 - Lecture 30

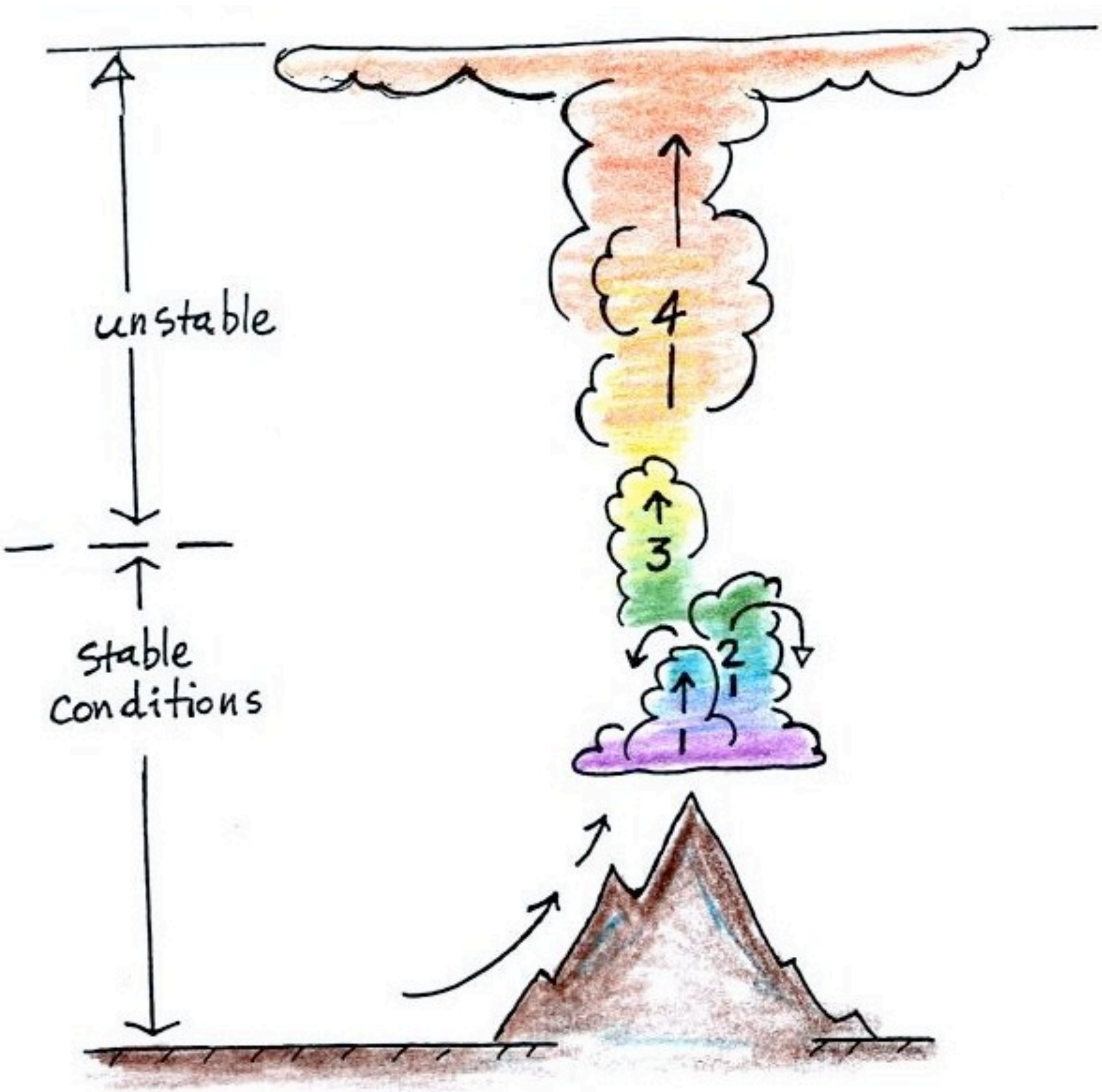
Thunderstorms produce a variety of interesting and potentially destructive phenomena such as lightning, strong winds, hail, heavy rainfall, and tornadoes. In this lecture, we will study ordinary single-cell or air mass thunderstorms, where cell is defined as a single storm unit. Most summer thunderstorms in Tucson are of this type.

Thunderstorms have different sizes and levels of severity. Storms with strong updrafts can produce large hailstones. The single-cell thunderstorms that we will be studying have a straight vertical updraft. Tilted updrafts are found in severe and super cell thunderstorms. Sometimes the tilted updraft will begin to rotate and produce tornadoes.

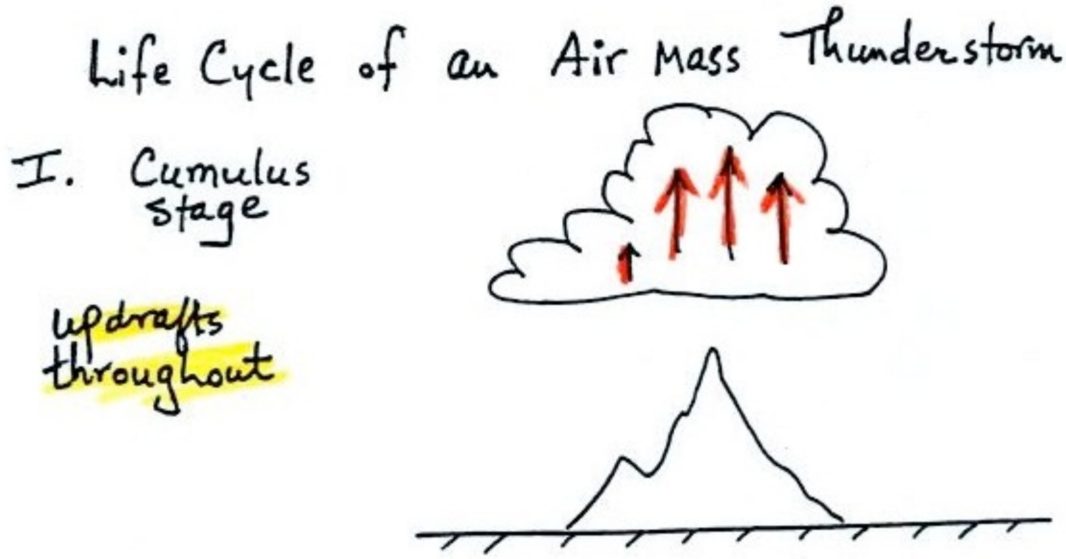
Thunderstorms often form in clusters or lines, often ahead of cold fronts. We will not cover mesoscale convective systems, which are much larger, "state size" storm systems that can last 12 to 24 hours.



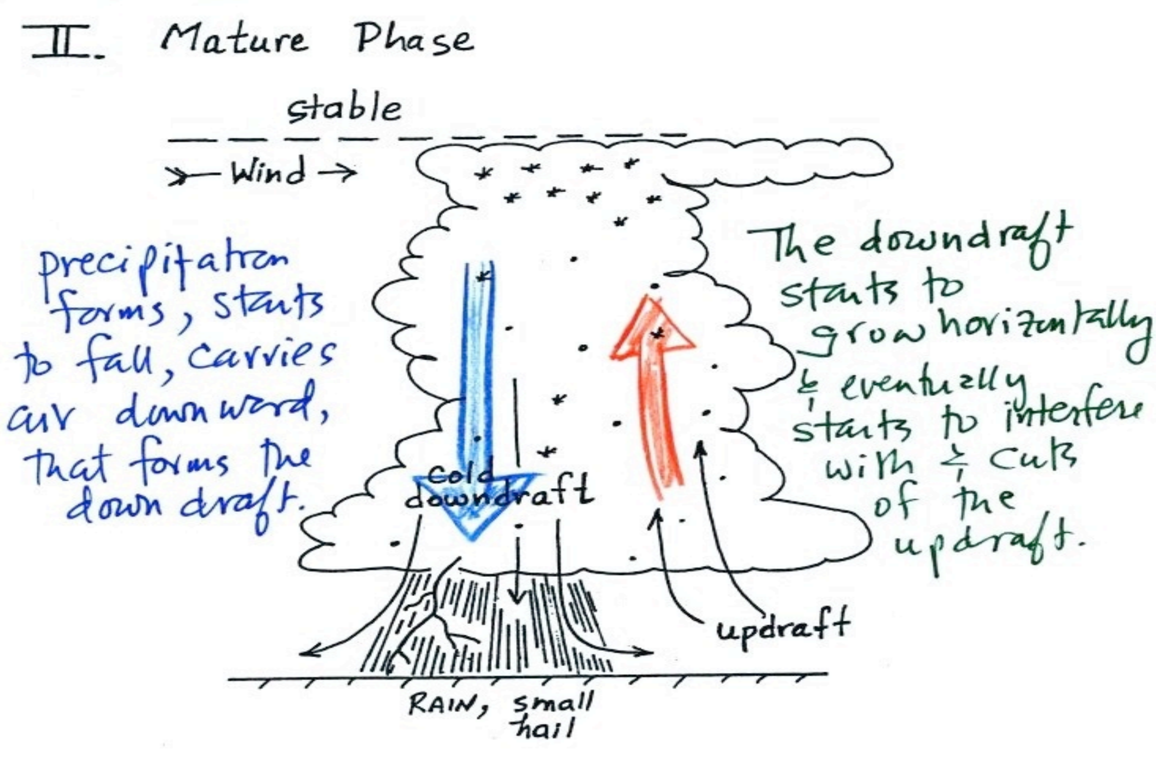
Air must be lifted above the level of free convection in order for a thunderstorm to develop. The process of thunderstorm development, shown in the figure below, often takes the better part of a day. Early in the morning, the atmosphere is stable because rising air tends to be cooler and denser than the surrounding air. Instead of rising, the air sinks back down toward the ground (Point 1). As the day progresses, the ground becomes warmer. By noon, air parcels can rise higher but not to the lifting condensation level (Point 2). Finally around mid-afternoon (Point 3), air is lifted to the lifting condensation level and then to the level of free convection. Now the air parcel is warmer and less dense than the surrounding air (Point 4), and explodes upward on its own. The result is a spectacular thunderstorm that occurs in Tucson during the July and August monsoon season.



There are three stages in the life of a thunderstorm. In the **Cumulus Phase**, the cloud contains only updrafts.

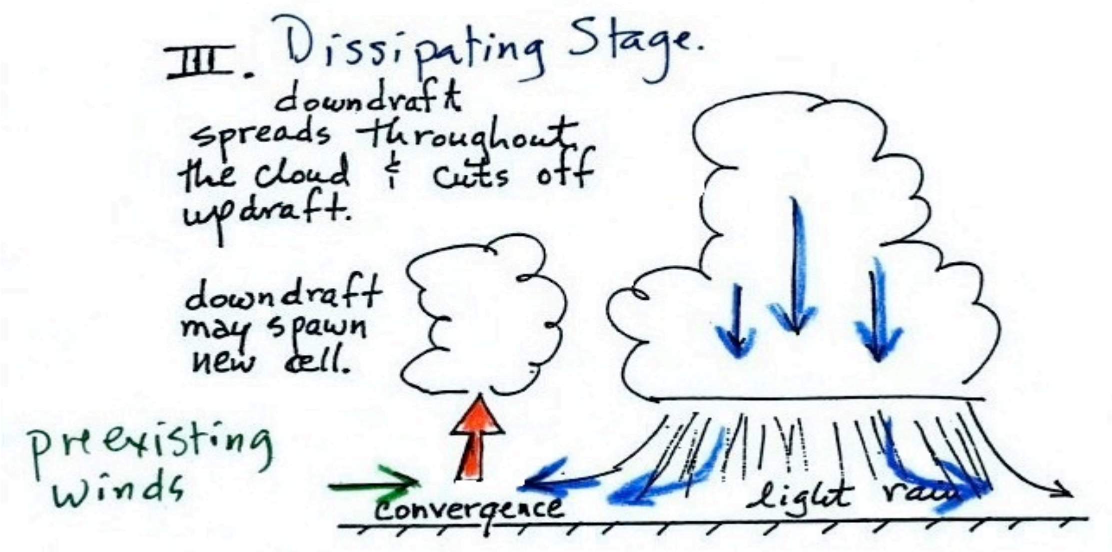


Once water droplets inside the cloud have grown to a certain size, rain drops begin to fall and drag air downward with them. This marks the beginning of the **Mature Phase**, in which the cloud contains both updrafts and downdrafts. The falling precipitation also pulls in dry air from outside the thunderstorm, a process called entrainment. Precipitation mixes with the drier air and some of the rain drops evaporate. The evaporation strengthens the downdraft because evaporation cools the air and makes it denser. The thunderstorm is strongest in the mature stage because at this stage the heaviest rain, strongest winds, and most of the lightning will occur.

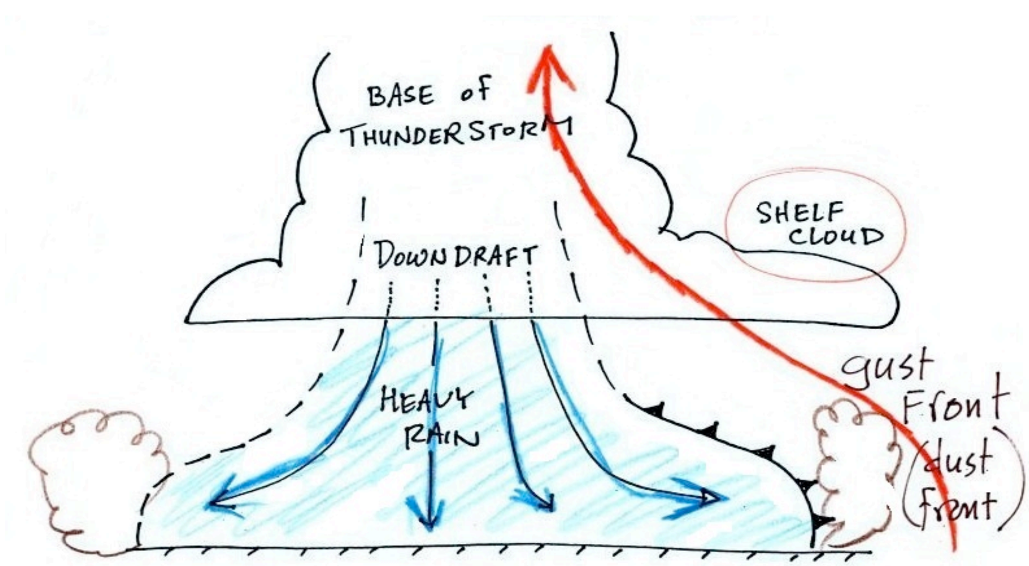


In the **Dissipating Stage,** the downdraft spreads horizontally throughout the inside of the cloud and interferes with the updraft. The downdraft eventually fills the entire cloud interior until the cloud contains only weak downdrafts.

Note how the winds from one thunderstorm can cause a region of convergence on one side of the original storm and lead to the development of new storms. Preexisting winds refer to winds that were blowing before the thunderstorm developed. Convergence between the preexisting wind and the thunderstorm downdraft winds creates rising air that can initiate a new thunderstorm. A **multicellular thunderstorm** is composed of multiple cells, with each thunderstorm cell at one of the three stages we discussed in this lecture.



The picture below shows some of the features at the base of a thunderstorm. The cold downdraft spilling out of a thunderstorm hits the ground and begins to move outward from underneath the thunderstorm. The leading edge of this outward moving air is called a **gust front**. You can think of it as a dust front because the gust front winds often stir up a lot of dust here in the desert southwest.



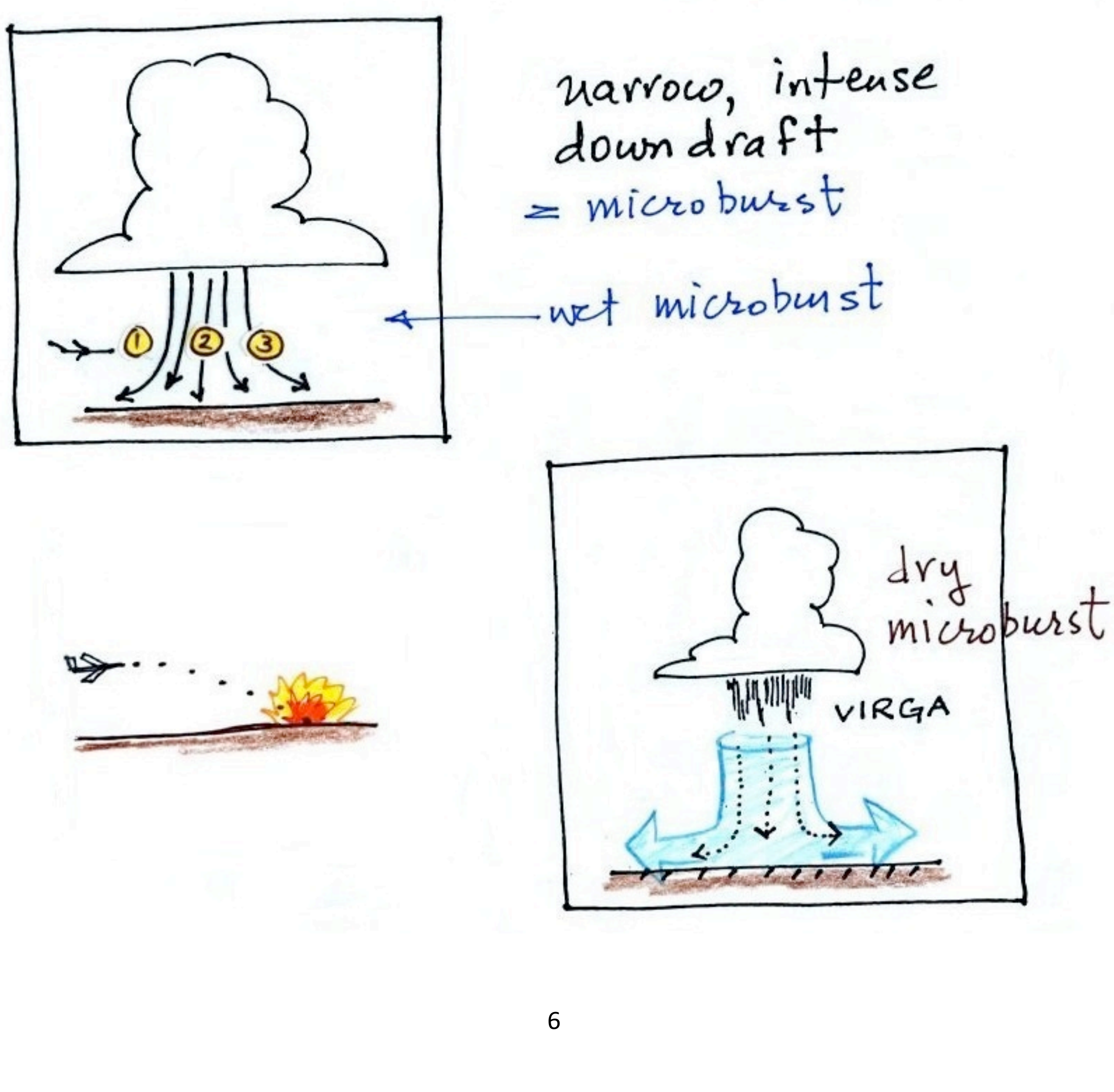
The gust front in this picture (taken near Winslow, Arizona) is moving from the right to the left. Visibility in the dust cloud can drop to near zero which makes this a serious hazard to automobile traffic. Severe dust storms like this are called **haboobs**.

The following picture shows a **shelf cloud**. Warm moist air is lifted by the cold air behind the gust front, which is moving from left to right in this picture. The fact that the shelf cloud is so close to the ground indicates that the air did not require much cooling before reaching its dew point, becoming saturated and forming a cloud. In other words, the air was very moist.

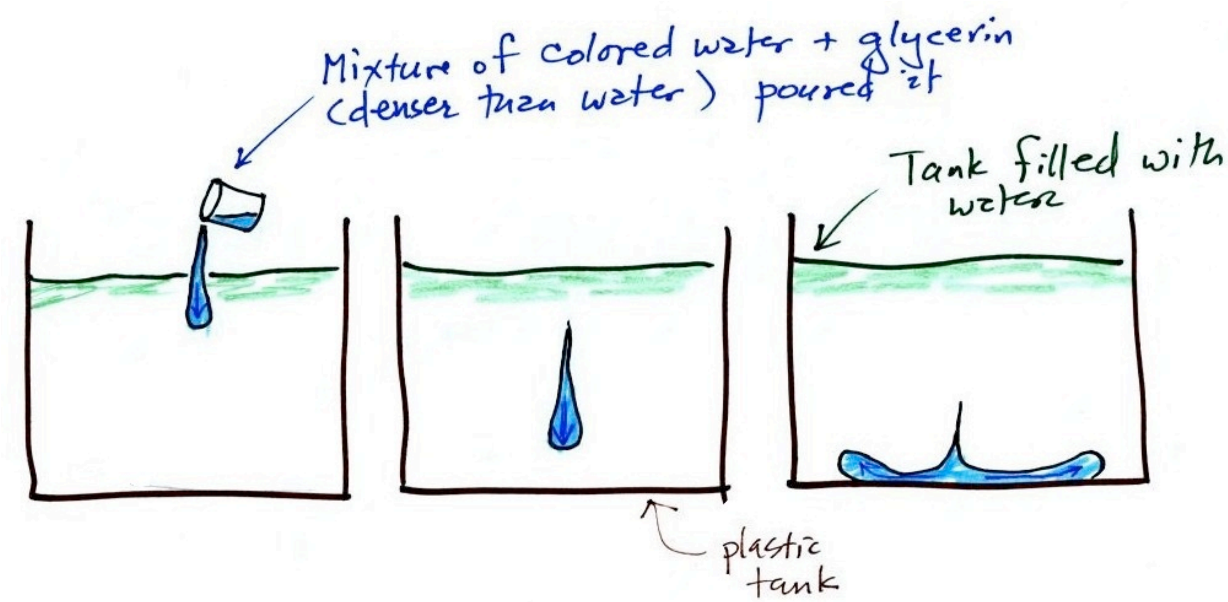
A narrow intense downdraft is called a **microburst**. At the ground, microburst winds are known to reach up to **165 miles per hour** over a limited area; most tornadoes have winds of 100 miles per hour or less. Microburst winds can damage homes (especially mobile homes that are not tied to the ground), uproot trees, and blow over a line of electric power poles. This seems to happen every summer in Tucson.

Microbursts are a serious threat to aircraft, especially when they are close to the ground during landing or takeoff. An inattentive pilot encountering headwinds at Point 1 might cut back on the power. Very quickly the plane would lose the headwinds (Point 2) and then encounter tailwinds (Point 3). The plane may lose altitude so quickly that it would crash into the ground before corrective action could be taken.

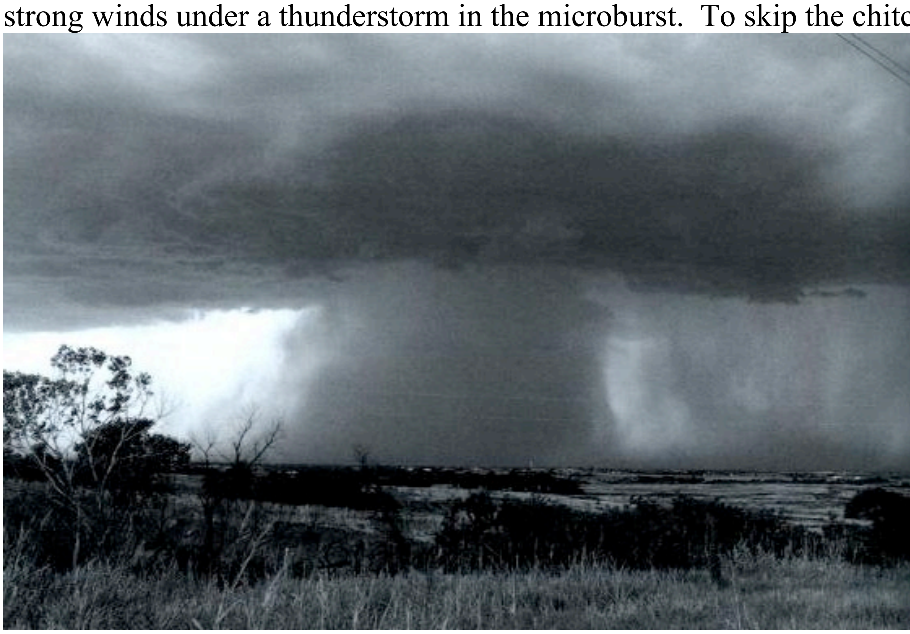
Falling rain could warn of a wet microburst. In other cases, dangerous dry microburst winds might be invisible. The virga or evaporating rain will cool the air, make the air denser, and strengthen the downdraft winds.



A simple demonstration can give you an idea of what a microburst might look like. A large plastic tank is filled with water, which represents the atmosphere. A colored mixture of water and glycerin, representing the cold, dense air in a thunderstorm downdraft, is poured into the tank. The colored liquid sinks to the bottom of the tank and spreads out horizontally in the same way that the cold downdraft air hits the ground and spreads out horizontally. Downdrafts are very strong winds whose speeds approximtely equal that of fastest surface wind gusts.

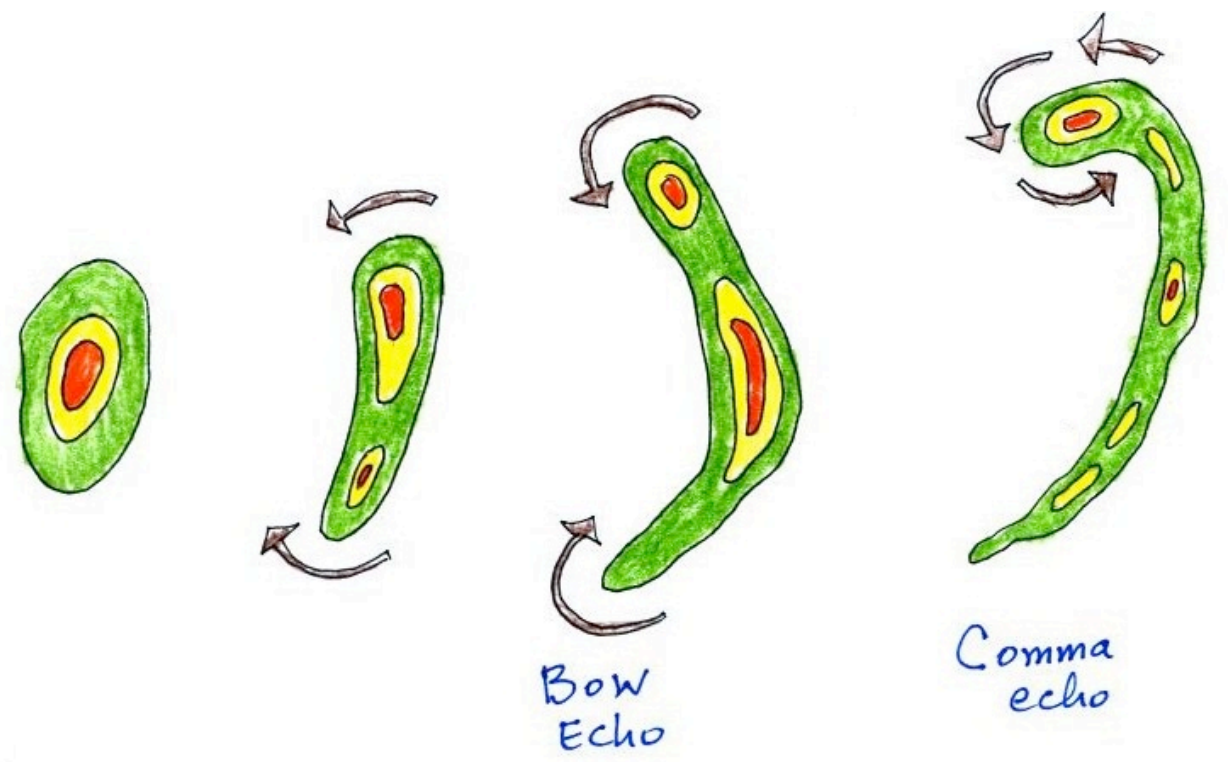


Here is a picture of a wet microburst, a narrow intense thunderstorm downdraft and rain. Here also are two videos from YouTube. The first video (http://videos.kansascity.com/vmix_hosted_apps/p/media?id=4735598) shows a microburst from some distance away. Veg for the first 30 seconds…it's a comerical. The second video (http://www.youtube.com/watch?v=TkavH9aZue8) was taken in the heavy rain and strong winds under a thunderstorm in the microburst. To skip the chitchat, jump to 1:06.



A microburst is a violent but short-lived and localized event. [A derecho](http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm#definition) (http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm#definition) is a less known phenomenon that produces straight line winds (derecho is Spanish for "straight"). A derecho is longer lived (30 minutes to a few hours) and can affect a much larger area. Derecho winds are produced out ahead of a fast moving line of thunderstorms or a mesoscale convective system. Winds must, by definition, be greater than 58 miles per hour and can exceed 100 miles per hour. The strong winds can be found tens to hundreds of miles ahead of or along the advancing storm.

The line of thunderstorms will often appear as a "bow echo" on radar. The sketch below shows development of a single large thunderstorm into a bow echo and eventually into a comma echo. In this figure the line of storms is moving toward the right. Derecho winds would be found out in advance of the moving line. Tornadoes sometimes form in the counterclockwise and clockwise spinning motions found at the top and bottom of the comma echo.



The figure below (source http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm) shows a shelf cloud forming at the front edge of an approaching derecho. It would be hard to distinguish this from a shelf cloud forming at the front of a normal gust front.