Thunderstorms

At any given moment around the world, hundreds of thunderstorms are occurring. Many of them feature nothing more than a moderate breeze, heavy rain for a short while, and some lightening and thunder. Occasionally, however, these storms seem to run amuck and become violent; dropping heavy rains which cause flooding, producing hail that damages crops and property, and spawning tornadoes. In order to understand the process that produces severe weather, we need to look at the causes of thunderstorms first.

In order to set the stage for thunderstorm development, we need to understand some of the basic concepts and stages.

Convection refers to the vertical transport of physical properties of a substance due to instability. A good example of convection is the rising bubbles in a pot of boiling water. Another example is a cumulus “fair weather” cloud. Cumulus clouds are the puffy white clouds and resemble cotton balls.

In both instances, the boiling water and the cumulus cloud, we have a substance being heated from below. In the case of the boiling water, the pot holding the water is heated from below by the flame. The heat from the pot is transferred to the water. In the case of the cloud, the air is heated by the ground. The sun heats the ground, and the ground then transfers the heat to the layer of air next to it. When we heat something from below, whether it’s the air, or water, the heated portion becomes less dense than the unheated portion. Any fluid that is less dense than its surroundings wants to rise. This is true whether the fluid is water or air.

When we speak of stability in the atmosphere, we are referring to the tendency of a bubble of air to keep moving, once it’s been displaced. In this case, the displacing bubble of air is caused by the sun heating the ground, and in turn, the air above the ground. And when we speak of the bubble being displaced, we mean the vertical rising of the air bubble into the atmosphere. Our bubble of air will be forced to rise into the atmosphere, as long as it’s warmer than the air that surrounds it. So as long as the internal temperature of the air is warmer than the surrounding air, the “bubble of air” will rise. This is due to the fact that warm air is less dense than cold air.

As the bubble rises through the unstable environment, the air in the bubble begins to cool. When the bubble has cooled sufficiently, and the relative humidity of the bubble reaches close to 100%, the moisture in the bubble begins to condense. When condensation occurs, gaseous water vapor is converted to liquid water droplets, and the droplets in the bubble become visible. This visible water that has condensed is what we see as a cloud.

The three conditions we need in order for a cloud to turn into a thunderstorm are:

1) Unstable air. The temperature of the environment is cooler than the temperature inside the air bubble.
2) Lifting action. The sun heating the air near the surface can provide the lifting action. However, any type of front or mountainous terrain can also provide lifting action as well.
3) Moisture. The main source of energy in a thunderstorm is the energy released by the condensation of the vast amount of water vapor drawn into the storm by the updraft.

Now that we have a thunderstorm developed, let's now consider the three distinct stages:

1. Cumulus Stage
2. Mature Stage
3. Dissipating Stage

<u>Cumulus Stage</u>

While most clouds don't develop into thunderstorms, the first stage of a thunderstorm is always a cumulus cloud. Cumulus clouds that exhibit the vertical development necessary for thunderstorm formation are called cumulus congestus, or towering cumulus. The main feature of the cumulus stage is the updraft within the cloud. As the updraft continues upward, the storm grows both horizontally, and vertically. The updraft may extend from close to the earth's surface to several thousand feet above the cloud top, and may reach vertical speeds of up to 3,000 feet per minute or higher. As the updraft continues, the cumulus cloud will develop into a cumulonimbus cloud. As the cumulus cloud grows into a cumulonimbus cloud, the cloud droplets increase in size. The motion of the updraft keeps the droplets suspended in the cloud, as the droplets grow into raindrops.


Towering Cumulus


Towering Cumulus


Mature Cumulonimbus

Mature Stage

As the cloud droplets grow into raindrops, they become too heavy for the updrafts to hold them, and they begin falling out of the cloud. When the precipitation mechanisms begin in earnest, and rain begins falling out of the cloud, the thunderstorm enters what's known as the mature stage. The towering cumulus cloud has grown into a full-blown thunderstorm, and has become a cumulonimbus cloud. The top of the storm may penetrate so high into the upper atmosphere that the top may be blown away by the jet stream. This top is frequently called the anvil top, because of its flat anvil-like shape. As the raindrops begin falling through the cloud, they drag the surrounding air down with them. This produces a downdraft in the thunderstorm cloud, which serves to destroy the updraft that created the cloud in the first place. The speed of the downdraft can reach up to 2,500 feet per minute, or higher in severe storms.

At the bottom of the cumulonimbus cloud, the air is being forced down by the downdraft caused by the falling rain. As the air leaves the bottom of the cloud, it begins to fan out as it encounters the surface of the earth. This spreading out of air causes strong and gusty surface winds, capable of doing serious damage. This outward motion of the downdraft causes gust fronts to form and move away from the main thunderstorm column.

Dissipating Stage

As the mature stage of the thunderstorm progresses with time, the downdrafts continue to develop, and the updrafts are weakened. However, the downdrafts spell the death of the thunderstorm. Without the updrafts to drive the cloud formation, the rain gradually subsides, and the storm loses its power. Just because the thunderstorm has entered the dissipating stage is no indication that the storm is no longer capable of producing severe weather. The storm may still be producing characteristic thunderstorm weather; hail, heavy rains, tornadoes etc.

The type of thunderstorm we have just described is known as an Air Mass Thunderstorm. They form when air is lifted due to the heating from the sun. There are usually no fronts present in the areas where they form. However when a front enters the picture, it can trigger a thunderstorm. A front is defined as the boundary separating two air masses with different characteristics.

Cold, dry air is moving in and replacing warm, moist air. The warm air is being forced up, as the cold air moved under it. The cold air moved in under the warm air because cold air is denser than warm air.

As the warm air rises, it cools. When air saturation is reached, a cloud forms. If the air is forced high enough, the cloud will develop first into a cumulus cloud, and then a cumulonimbus cloud. This is known as a frontal thunderstorm.

Some Facts about Frontal Thunderstorms

Thunderstorms that develop along cold fronts are usually more severe than those associated with warm fronts or occluded fronts. This does not mean that severe weather cannot occur along warm or occluded fronts.

Ahead of some fronts, a squall line will develop. What causes these squall lines is unknown, but frequently these storms are more severe than the ones along the front. The line forms between 50 and 300 miles ahead of the front.

The 3 different atmospheric conditions that can be produced by thunderstorm development are:

Lightning- One of the most spectacular displays in nature is a large, brilliant flash of lightning, accompanied by a deep roar of thunder. Yet most flashes occur between clouds, with relatively few occurring between the clouds and the ground, as depicted below. The frequency of lightning flashed reaches a maximum as the cumulonimbus cloud reaches its maximum height. Then, as the storm enters the dissipating stage, the flashes become less numerous. However, the strength of individual flashes may remain very great. The exact processes that produce lightning are still not fully understood, and are the subject of considerable research. Precisely what mechanisms are at work in the clouds to produce such large electrical potentials largely remains a mystery.

It is believed that lightening has been a contribution factor in a number of airplane accidents in the past. One of the most notable was the crash of a Pan American jet several years ago. Pilots who witnessed the accident testified that the airplane was struck by lightening just before it crashed. Current planes are equipped with lightening diffusing strips which allow the electricity to pass along the strips and out the back or wings of the plane. The main issue with lightening and planes is the potential damage to the sensitive electrical controls of the plane. If the plane is hit by lightening at higher altitudes, the pilots have a few seconds to react and recover the plane. However if the plane is struck by lightening just as it is about to land or take off, the pilot has little to no reaction time and reaction room to recover the airplane. This is one reason that flights are often delayed due to electrical storms at airports.

Lightening striking airplane as it takes off from Osaka Airport, Aug 30, 2007.

Hail are balls or irregular lumps of ice ranging in size from that of a pea to 6 inches in diameter. Hail usually forms in areas of strong updrafts in the cumulonimbus cloud, and is usually produced during the mature stage. The freezing of super cooled water droplets forms hail. These are droplets that are at temperatures below 32° F but are still in a liquid state. When these droplets come in contact with an ice crystal or hailstone, they turn to ice. Repeated collisions, between falling and rising hailstones and super cooled water, leads to the growth in the size of the hailstone. Hail may be found at any level of the thunderstorm and may even fall some distance away from the storm itself. This can occur when hailstones are caught in the updraft and lifted until they are thrown out of the top or the sides of the storm.

Photos from Http:australiaseverereweather.com

Tornadoes are violent, circular whirlpools that hang from the bases of cumulonimbus clouds and extend to the ground. Those not reaching the ground are called “funnel clouds”. Not all tornadoes can be easily seen. Some tornadoes have no visible “condensation clouds” and can only be detected by the debris cloud at its base.

Some Basic Variables Associated with Tornadoes

Variable	Min. Observed	Max. Observed	Typical Value
Duration	1 minute	7 hours	10 minutes
Path Length	few feet	300 miles	2-5 miles
Width	few feet	5 miles	100 yards
Wind Speed	100 mph	280 mph	180 mph

Duration: The shortest tornado observed spent less than one minute in contact with the ground. On the other hand, the endurance champ was one estimated to have lasted seven hours. Research meteorologists believe that this particular tornado may actually have been made up of a series of tornadoes, combined into one gigantic tornado.

Path Length: The length of the path on the ground has been observed to vary from just a few feet to upwards of three hundred miles. The typical swath cut by a tornado is about 2 to 5 miles. Some tornadoes touch down for a short distance, then lift up off the ground for a short distance and then retouch the ground.

Width: The typical width of a tornado is about 100 yards. The widest one observed was associated with the storms that hit Xenia, Ohio, and did damage over an area five miles wide. This one was believed to be a combination of several individual tornadoes. More recent is the Greensburg, Kansas tornado that struck on May 4, 2007 was estimated to be 1.7 miles in width and traveled 22 miles.

http://em.wikipedia.org/wiki/Greensburg_Kansas

Wind: Finally, the wind observations are largely a matter of approximation. Research at Texas Tech University, the University of Oklahoma, and the National Severe Storms Laboratory show that the wind speed in a tornado is rarely over 200 mph. Of course, one of the problems with measuring winds in tornadoes is the fact that tornadoes have a bad-habit of destroying wind measuring devices as they pass over them. Indirect measurements are made by utilizing radar and observing the damage to man-made structures.

Some Interesting Facts About Tornadoes

- More people are killed each year by lightening strikes than tornadoes.
- Tornadoes can occur at any time of the day or night. The "best" time for them to occur is between 4pm and 7pm.
- The destructive forces of a tornado in order of importance:
    - High winds create a destructive pressure against walls, windows, etc.
    - The devastating effect of missiles propelled by the wind.
    - The collapse of high portions of a structure into the lower portion is a danger.
    - The explosion caused by the difference between the high pressure inside a structure, and the low pressure within the tornado.
- Nowhere on earths are tornadoes more common than right here in the U.S. It's estimated that each year about 200 tornadoes touch down, the bulk of them in the Midwest and the High Plains.

When forecasters for the National Weather Service feel that atmospheric conditions are favorable for severe weather to develop, they will issue a Tornado Watch. This means that no tornadoes have been sighted, but to watch for them, because things are right for a tornado to develop.

When a tornado is spotted on radar, or reported by law enforcement officials, the public, pilots, or meteorologists, a Tornado Warning will be issued. This means that a tornado has been sighted. When seeking shelter from a tornado, the best place to be is underground; either in a storm cellar or a basement.

If you are in a home or building with no basement, an area with reinforced inner walls is good. One of the worst places to go is your car. Tornadoes can easily pick up a car.