

**ESCI 107 – The Atmosphere
Lesson 14 – Thunderstorms/tornadoes**

Reading: *Meteorology Today*, Chapter 14

GENERAL

- **A *thunderstorm* is a storm that produces thunder and lightning.**
- **Thunderstorms are associated with cumulonimbus clouds.**
- **Thunderstorms are characterized by vigorous updrafts.**
 - **Normally the vertical motion in the atmosphere is very slow, on the order of centimeters per second (about one-tenth of a mile per hour).**
 - **In a thunderstorm, updrafts can easily exceed 50 mph, and have been observed at over 80 mph.**
 - **Thunderstorms require some lifting mechanism to start the initial upward motion. This mechanism can be any one of the four lifting mechanisms that we discussed earlier in the semester**
 - **orographic lifting**
 - **frontal wedging**
 - **convergence**
 - **convective mixing**

DISTRIBUTION OF THUNDERSTORMS

- **On average there are about 45,000 thunderstorms around the world every day.**
- **Most thunderstorms occur over land, and in the Tropics.**
- **Each year the U.S. experiences around 100,000 thunderstorms.**
- **Florida and the Gulf Coast experience the most thunderstorms in the U.S., because mT that moves over the hot land is very unstable.**
- **Eastern New Mexico and Colorado also experience numerous thunderstorms, due to mT air moving upslope toward the Continental Divide.**
- **The fewest thunderstorms occur on the West Coast, because mP air is very stable.**

AIR MASS THUNDERSTORMS

- **Air mass thunderstorms are associated with mT air.**
- **mT air is very moist and unstable.**
- **As it moves northward and westward from the ocean over the land it is heated from below.**
- **The heating is not even. Warm bubbles may form over areas where heating is more intense, creating updrafts.**
- **Cumulus clouds form in the updrafts as the clouds reach the convective condensation level (CCL).**
- **Some of the cumulus clouds continue to develop and form cumulonimbus clouds.**
- **Stages of development of air mass thunderstorms**
 - **Cumulus stage – strong updrafts build the storm**
 - **Mature stage – precipitation begins. Downdrafts form from both the frictional drag of the precipitation, and due to entrainment of dryer air and evaporation of precipitation.**
 - **Dissipating stage – downdrafts have shut off the updrafts that feed the storm. Clouds evaporate as the storm dissipates.**
- **Air mass thunderstorms often form over mountains or hills, due to differential heating.**
- **The sea-breeze is a common cause of air-mass thunderstorms along Florida's coast.**

GUST FRONTS AND DOWNBURSTS

- **You might expect that the thunderstorm downdrafts would be warm, since the air parcels would experience adiabatic warming.**
- **The downdrafts are actually cool because of two factors:**
 - **the mixing in of unsaturated, cooler air from outside of the thunderstorm**
 - **evaporation of precipitation into the air**
- **As the cool downdraft hits the ground it spreads out.**

- The leading edge of the downdraft acts like a miniature cold front, and is called the *gust front*. As the gust front passes the wind become (not surprisingly) gusty, and the temperature drops.
- The lifting of warm, moist air along the gust front can trigger new thunderstorm development.
- If the downdraft is very strong it is called a *downburst*. Downbursts can be quite damaging to trees, building, power lines, and airplanes. They are often mistaken for tornadoes by people who experience them.
- A very narrow downburst is sometimes called a *microburst*.

SEVERE THUNDERSTORMS

- A thunderstorm is classified as *severe* if any one of the following conditions are met:
 - It produces winds in excess of 50 knots (58 mph).
 - It produces hail larger than one inch in diameter.¹
 - It produces a tornado
- Severe thunderstorms are often produced beneath the jet stream or other region of strong upper level winds.
- Severe thunderstorm watches and warnings.
 - *Severe Thunderstorm Watch* – Conditions are favorable for a severe thunderstorm to form.
 - *Severe Thunderstorm Warning* – A severe thunderstorm is actually occurring.

SINGLE-CELL, MULTI-CELL, AND SUPER-CELL THUNDERSTORMS

- Thunderstorms are also classified according to the number and strength of the updrafts, or *cells*.
 - In a *single-cell* thunderstorm there is only one main updraft and downdraft. Most air mass thunderstorms are of this variety.
 - If there is more than one updraft present than we have a *multi-cell* thunderstorm.

¹ Prior to January 5, 2010 the cutoff was $\frac{3}{4}$ inch diameter.

- If there is a single, large updraft that is rotating then we have a *super-cell* thunderstorm.
- The vertical profile of the winds determines whether the storm will be single-, multi-, or super-cell.

SQUALL LINES

- Squall lines are narrow, fast moving lines of thunderstorms that occur a hundred or so miles ahead of a cold front.
- Squall lines sometimes form along the *dryline*, a boundary between cT and mT air over West Texas, Oklahoma, and Kansas.

TORNADOES

- Tornadoes are rotating columns of air that form beneath some severe thunderstorms.
- Tornadoes form and sustain themselves due to *vortex stretching*.
 - Vortex stretching refers to what occurs when a column of air that is initially rotating only slowly is stretched along the axis of rotation. As the column of air stretches it also becomes skinnier. Because of conservation of angular momentum, as the column becomes skinnier it begins to spin faster.
 - Vortex stretching occurs in your bathtub or sink, and is why a whirlpool often forms in a draining bathtub.
 - This vortex stretching can occur in a thunderstorm updraft, and can cause the vortex to rotate at incredible speeds (over 250 mph!).
- Small tornadoes can form due to the vertical wind shear near the ground.
 - Initially, the rotation will be along a horizontal axis, but the thunderstorm updraft can tilt the rotation to the vertical, and then stretch it.
 - Tornadoes formed in this manner can spin either clockwise or counterclockwise.
- The larger, and most devastating tornadoes form from super-cell thunderstorms.

- The updrafts in super-cell thunderstorms already are slowly spinning in a counterclockwise (cyclonic) direction. This is often referred to as a *mesocyclone*.
- The tornado, and vortex stretching, occur within the mesocyclone.
- Tornadoes formed in this manner always rotate counterclockwise.
- The vast majority of tornadoes spin counterclockwise.
 - This is not directly due to the Coriolis force acting on the tornado, because tornadoes are too small to directly feel the effects of the Earth's rotation.
 - The preferred rotation is a result of the upper level wind patterns that are usually associated with severe thunderstorms.
- A tornado may have multiple suction vortices.
- Although the visible part of the tornado usually extends from the cloud and moves toward the ground, the suction in the tornado is actually upwards.
- The cloud forms in the vortex because pressures are low enough to cause the air to adiabatically cool to saturation.
- *In order to be classified as a tornado, the vortex must reach the ground. Otherwise, it is just reported as a funnel cloud.*
- A tornado that occurs over water is called a *waterspout*.

TORNADO CLIMATOLOGY

- Tornadoes can occur during any month of the year.
- Tornadoes have been reported in every state of the U.S.
- Most tornadoes, however, occur during the Spring, and over the Great Plains.
 - this is because the conditions for forming severe thunderstorms (the collision of mT air with cP air) often occur in this region at this time of year.
- Since most tornadoes form in the mT air ahead of a cold front, where the prevailing flow is southwesterly, most tornadoes move toward the northeast.

TORNADO INTENSITY

- Tornado intensity is measured on a scale created by Dr. Ted Fujita, a noted tornado researcher. It is referred to as the *F-scale*.

- Since tornado winds cannot be measured directly, the *F*-scale is based on the damage caused by the tornado.
- The *F*-scale goes from *F0* to *F5*, with *F0* being light damage, and *F5* being incredible damage.

DOPPLER RADAR AND TORNADO DETECTION

- Doppler radar operates off of the principle that radiation reflected off of an object will change frequency if the object is in motion. If the object is moving toward the receiver the frequency will be higher, and if moving away it will be lower.
- A Doppler radar can give the wind speed, in addition to showing where precipitation is occurring.
- Doppler radar is very useful for tornado forecasters because a Doppler radar can indicate the presence of a mesocyclone in a thunderstorm, and give warning that a tornado may be occurring.
- Most TV meteorologists never use the Doppler capabilities of the Doppler radar. It is amusing how they always make a big deal of advertising that they are using Doppler radar, when for their purposes it doesn't make a bit of difference to them. It just makes them sound that much more impressive, I guess.

TORNADO SAFETY

- Pay attention to the TV or radio when thunderstorms are in your area, and listen for the issuance of Tornado Watches or Tornado Warnings.
- Keep a battery operated AM or FM radio available.
- You may want to purchase a *weather-band* radio.
 - The National Atmospheric and Oceanic Administration (NOAA), the parent organization of the National Weather Service, operates radio stations that continually broadcast weather information.
 - Radios that can receive these broadcasts are relatively inexpensive, and can be bought at most electronic stores.

- Some of these radios even have alarms on them that will sound if a tornado watch or warning has been issued.
- A *Tornado Watch* means that the conditions are ripe for tornado formation, and that tornadoes are possible.
- A *Tornado Warning* means that a tornado has been spotted.
- If a *Tornado Warning* has been issued, do the following (Note: The following indented paragraphs have been taken directly from the National Oceanic and Atmospheric Administration web site
<http://www.spc.noaa.gov/faq/tornado/safety.html>)
 - ***In a house with a basement:*** Avoid windows. Get in the basement and under some kind of sturdy protection (heavy table or work bench), or cover yourself with a mattress or sleeping bag. Know where very heavy objects rest on the floor above (pianos, refrigerators, waterbeds, etc.) and do not go under them. They may fall down through a weakened floor and crush you.
 - ***In a house with no basement, a dorm, or an apartment:*** Avoid windows. Go to the lowest floor, small center room (like a bathroom or closet), under a stairwell, or in an interior hallway with no windows. Crouch as low as possible to the floor, facing down; and cover your head with your hands. A bath tub may offer a shell of partial protection. Even in an interior room, you should cover yourself with some sort of thick padding (mattress, blankets, etc.), to protect against falling debris in case the roof and ceiling fail.
 - ***In an office building, hospital, nursing home or skyscraper:*** Go directly to an enclosed, windowless area in the center of the building -- away from glass. Then, crouch down and cover your head. Interior stairwells are usually good places to take shelter, and if not crowded, allow you to get to a lower level quickly. Stay off the elevators; you could be trapped in them if the power is lost.
 - ***In a mobile home:*** Get out! Even if your home is tied down, you are probably safer outside, even if the only alternative is to seek shelter out in the open. Most tornadoes can destroy even tied-down mobile homes; and it is best not to play the low odds that yours will make it. If your community has a

- tornado shelter, go there fast. If there is a sturdy permanent building within easy running distance, seek shelter there. Otherwise, lie flat on low ground away from your home, protecting your head. If possible, use open ground away from trees and cars, which can be blown onto you.
- **At school:** Follow the drill! Go to the interior hall or room in an orderly way as you are told. Crouch low, head down, and protect the back of your head with your arms. Stay away from windows and large open rooms like gyms and auditoriums.
 - **In a car or truck:** Vehicles are extremely dangerous in a tornado. If the tornado is visible, far away, and the traffic is light, you may be able to drive out of its path by moving at right angles to the tornado. Otherwise, park the car as quickly and safely as possible -- out of the traffic lanes. [It is safer to get the car out of mud later if necessary than to cause a crash.] Get out and seek shelter in a sturdy building. If in the open country, run to low ground away from any cars (which may roll over on you). Lie flat and face-down, protecting the back of your head with your arms. Avoid seeking shelter under bridges, which can create deadly traffic hazards while offering little protection against flying debris.
 - **In the open outdoors:** If possible, seek shelter in a sturdy building. If not, lie flat and face-down on low ground, protecting the back of your head with your arms. Get as far away from trees and cars as you can; they may be blown onto you in a tornado.
 - **In a shopping mall or large store:** Do not panic. Watch for others. Move as quickly as possible to an interior bathroom, storage room or other small enclosed area, away from windows.
 - **In a church or theater:** Do not panic. If possible, move quickly but orderly to an interior bathroom or hallway, away from windows. Crouch face-down and protect your head with your arms. If there is no time to do that, get under the seats or pews, protecting your head with your arms or hands.
 - **Keep monitoring the radio or TV for updated information.**

TWO TORNADO SAFETY MYTHS

(see <http://www.spc.noaa.gov/faq/tornado/index.html#Safety> for more information)

- **You should open the windows of your house to equalize the pressure. – No longer considered to be true.**
- **The southwest corner of a basement is the safest place in a tornado. – No longer considered to be true.**