Tornadoes

The unpredictable and destructive nature of tornadoes, defined by The National Weather Service as "a violently rotating column of air in contact with the ground and pendant from a thunderstorm," frequently results in deadly consequences for the people and paths it crosses. It is because of its mysterious and often erratic nature that tornadoes have been widely studied and researched by scientists, leading to a better and ever growing understanding of the atmospheric conditions which give rise to the **spiraling vortex** known as the tornado.

- Tornado Alley
- Measuring Tornado Intensity
- References

Links to learn more about Tornadoes

- Tornadoes
- Scientific American: Turn! Turn! Turn!

Further Informational Links

- Suffolk County Community College Home Page
- Suffolk County Community College Honors Home Page
- Suffolk Community College Earth and Space Sciences Home Page

E-mail

As a student in Professor Mandia's ES17 Honors class I was given the opportunity to explore the Internet in an effort to relate my findings to the educational requirements of the class. Upon entering the course, each student was given a weather topic to research. In addition to the ongoing research which was expected of us we were given weekly assignments via the computer. Using the ES17 Honors Website we were to look up the weekly project. The projects consisted of the steps used in making and designing a web page of our own, based on our topic and our compiled research findings. Each project built on what we learned the week before, beginning with how to create a web page using HTML tags and ending with how to add colors, backgrounds, links and pictures. Each new task was introduced to us using step-by-step descriptions as well as illustrations and examples. Throughout the course we were encouraged to discuss and/or ask questions of Professor Mandia concerning any problems or difficulties we encountered. The use of e-mail figured prominently into the course as well. After completing each weekly assignment, Professor Mandia viewed our disk and e-mailed us his opinions and comments on our work. Frequently, we would e-mail him back with any questions or comments we had. Since each student in the class had their own e-mail account we would often discuss any problems we had concerning our project or classwork.

Before beginning this web site project I had no previous computer experience. I was first introduced to a computer upon going away to my first year of college, where I used it exclusively for e-mail purposes. In attempting to start this project I had to learn simple computer skills which I had no knowledge of, such as typing in WordPad, saving text, opening a saved file and copying material from one disk to another. Ultimately I was intimidated by what I knew nothing about. However, with each project, and consequently an increase in time spent on the computer, I gained self assurance and a greater understanding of the many benefits which a computer and the Internet has to offer. Looking back on the course and work involved I am extremely grateful that I had the opportunity to learn computer skills which will last me a lifetime.

Next Page

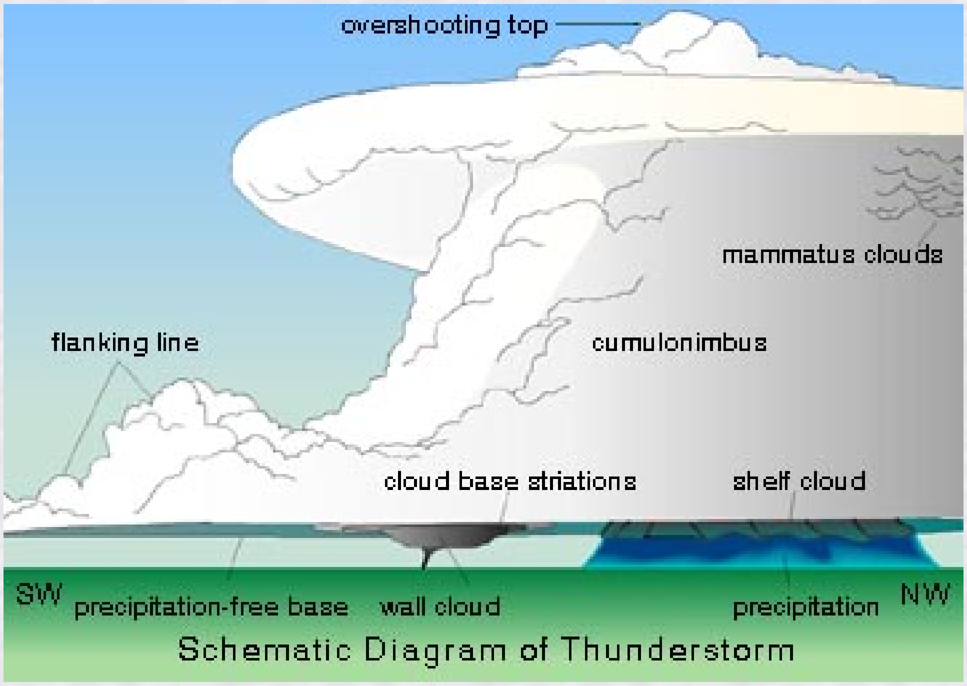
Back to main Tornado page

Thunderstorms

In its earliest stages, tornadoes are said to stem from **thunderstorms**. Thunderstorms are formed within three distinct stages, the first being the *cumulus-stage*. Certain atmospheric conditions which are present during the thunderstorm, such as moisture in the unstable air and some sort of lifting force, creates atmospheric instability. Unstable air, which is warm and moist, rises when a lifting mechanism is present. Surface heating, which acts as the primary lifting force, heats the air near the ground. The air, in turn, becomes buoyant and begins to rise, otherwise known as an **updraft**. These updrafts, warm, moist swells of rising air, eventually begin to cool.

As this occurs the air begins to condense into a *cumulus cloud*. The interactions between the rising and cooling air result in the development of a positive feedback mechanism. As the warm air within the cloud continues to rise, it eventually cools and condenses. The condensation releases heat into the cloud, warming the air. This, in turn, causes it to rise adiabatically. The process continues and works to form a towering cumulus cloud.

During the *mature-stage*, the second stage in thunderstorm development, the condensed solid and liquid water, within the upper-levels of the cloud, begins to fall, causing a **downdraft**. The velocity of the downdraft is strengthened by further evaporational cooling and frictional drag. **Frictional drag** occurs when the rain or snow drags down the surrounding colder air, which in turn increases the velocity of the downdraft. As the mature-stage thunderstorm develops, the cumulus cloud continues to increase in size, height and width. The resulting *cumulonimbus cloud*, with its anvil-shaped top, in some instances vertically extends over ten miles in length.



The last stage of the thunderstorm, the *dissipation-stage*, occurs when the strength of the updrafts diminish while the downdrafts remain. Thunderstorms mainly dissipate when there is no longer any lifting agent which can continue and fuel the updrafts.

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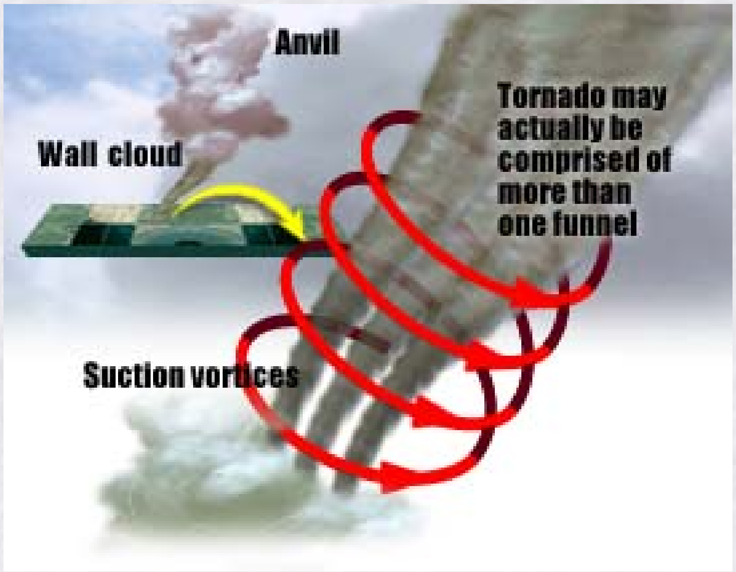
Next Page

Previous Page

Back to main Tornado page

Tornadoes emerge in the updraft of a thunderstorm, when the rising air begins to rotate, forming a **vortex**. **Wind shear**, "a change in wind speed and direction with height," causes the air to initially move and begin its rotation. The rising upcurrents within the cloud flow in the direction of the wind. The upcurrents are deflected as they rise, when they meet with wind from a different direction, and begin their spiraling rotation. This rotation occurs because of a behavior called **vorticity**. "Moving air has a natural tendency to turn around an axis at right angles to its direction of movement" (Allaby, pg. 48). It is this deflection which either begins or intensifies the rotation in the upcurrent.

The principle of the *conservation of angular momentum* explains why the vortex is inclined to spin. Because the rotating air at the center of the cloud stretches downward, due to pressure differences, the vortex becomes narrower. This reduction in the radius of rotation increases its angular velocity.



Differences in pressure is what causes the vortex to extend downward toward the ground. The lowest pressure within the cloud is found at the center of the vortex. Since the center of the vortex is a low pressure area, the surrounding air rushes into the vortex, cooling the air and lowering the pressure inside. As USA Today explains, "cooling condenses water vapor in the air into the tornado's familiar funnel-shaped cloud." When the bottom of the vortex extends to the base of the wall cloud, the pressure is still lower than the atmospheric pressure at ground-level. Described by Michael Allaby, although the difference is small the "core pressure then equals the ordinary atmospheric pressure at a height of about 3000 feet. That is enough to pull part of the wall cloud all the way to the ground," resulting in a tornado.

When the tornado has more than one vortex rotating around its center, the smaller vortices are termed **suction vortices**. Air around the tornado is turbulent because the air which is drawn in by the upcurrent crosses uneven ground and meets obstacles such as buildings and trees. The turbulence creates eddies in the air. These eddies can rotate either cyclonically or anti-cyclonically, and at a much greater speed than the tornado itself. The eddies are fueled by their own rotational speed as well as by the velocity of the tornado and mesocyclone above it. Suction vortices account for an increase in the intensity of the tornado.

Next Page

Previous Page

- Back to main Tornado Page

Tornadoes occur within a variety of different types of storms. The largest and most destructive stem from a long, rotating thunderstorm, or **supercell**. Within a supercell storm the force of the upcurrent is so strong that the air sweeping into the anvil goes over the upper part of the upcurrents and is cleared of the downcurrents. When the upcurrents and downcurrents separate, a stable convective cell is formed, with warm air rising in the upcurrents and cool air sinking in the downcurrents. This is what occurs within a supercell. A **mesocyclone**, the speed with which a large volume of air races up the main core of the upcurrent, creates intensely low pressure beneath the cloud. This draws in more air, fueling the low, and results in gale-force winds.

Tornadoes can also be found along **squall lines** as well. A squall line is a line of thunderstorms which can be several miles thick, hundreds of miles long and more than 30,000 feet tall. Squall lines are formed in the same way thunderstorms are created and develop strong upcurrents and downcurrents. The wind during these storms, near the cloud tops, blow from a different direction than the lower-level winds. This change in wind direction is responsible for dispersing high-level air which in turn sets the lower-levels spinning.

Along the storm's **gust front**, termed by the Encyclopedia of Climate and Weather as "the boundary between the evaporatively cooled downdraft of the storm and the warm, moist air feeding the storm's updraft," air is again being drawn into the low pressure region fueling the storm's powerful updraft. In a severe squall, wind speeds can reach 100 MPH. Essentially, the atmospheric conditions during a squall line storm can lead to tornadic activity.

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Next Page

Previous Page

Back to main Tornado page

At the base of a mesocyclone or supercell storm, rotation occurs which makes fragments of cloud turn. As the speed increases, part of the cloud falls below the base of the main cloud. Tornadoes can form under this type of descended cloud, called a **wall cloud**. A wall cloud is a cyclonically rotating air pattern in which the lower part of the cloud, with no precipitation present, takes humid air into the thunderstorm's main updraft. The wall cloud looks like a solid color cloud attached to the bottom of the main cloud and is an indication of possible tornado formation since it is a lowering of the cumulonimbus cloudbase.

Mammatus clouds can also be a sign that tornadoes will develop. Mammatus clouds are created as ice crystals within the anvil sublime into the dry air above them. They are a sign that the anvil of the storm is extremely large and the upcurrents extremely violent.

Hail is yet another sign that tornadic activity may occur. Hail is formed when droplets are carried above the freezing-level of the cloud by strong updrafts. Hailstones grow by repeated freezing and partial melting. As the hailstones rise and fall they eventually move toward the rear of the cloud and fall in the downdraft. As with mammatus clouds, hail results from strong upcurrents, one of the primary ingredients for tornado formation.

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Next Page

Previous Page

Back to main Tornado page

The funnel cloud of a tornado consists of moist air. As the funnel descends the water vapor within it condenses into liquid droplets. The liquid droplets are identical to cloud droplets yet are not considered part of the cloud since they form within the funnel. The descending funnel is made visible because of the water droplets. The funnel takes on the color of the cloud droplets, which is white. As the funnel begins its descent the air on the ground is already rotating because it is being drawn into the upcurrent. Due to the air movement, dust and debris will begin rotating, often becoming several feet high and hundreds of yards wide. Because there is so much energy associated with the moving air it produces a great deal of noise, almost like the roaring sound of a freight train. Tornadic damage results from the force of its winds, yet it is the violent upcurrent and difference in pressure which lifts the large objects in its path.

After the funnel touches the ground and becomes a tornado, the color of the funnel will change. Air will be carried into the upcurrent, taking any dirt or dust in its path with it. All loose material spirals upward and the funnel will become brown or gray.

At the center of the tornado, the vortex is open and the air is clear. Winds within the center are normally between 200 MPH and 300 MPH. The base of the funnel can grow to be about 400 yards across, yet they can be smaller as well.

Next Page

Previous Page

Back to main Tornado page

Dust devils are *whirlwinds* and are not associated with a cloud. Caused by convection, dust devils occur in dry places, such as deserts. In the desert there are many temperature differences between different surfaces. As the air heats the ground the surrounding air, by conduction, is heated. Due to the adiabatic process, as the air is warmed it rises and expands, becoming less dense. Over a different surface the heating may take place at a much faster rate because of different surface property characteristics. In both places the pressure will fall, but it will fall faster over the surface where the air rises the fastest. The difference in pressure between the surfaces is small yet it is sufficient to set up a flow of air. The vorticity of the air is enough to make it turn, and it begins spiraling. As it rises to conserve its angular momentum the speed increases. All loose objects around the dust devil, such as dirt and dust, are raised along with the air, hence making the whirlwind visible.

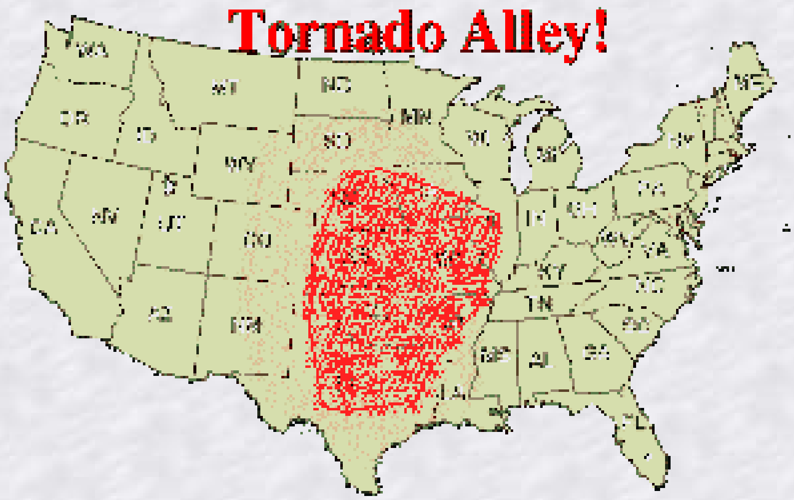
Waterspouts are formed in oceans and can actually be true tornadoes, if the cloud or storm drifts out over the sea. Waterspouts can develop on their own as well. On a hot day water is heated by the sun. The temperature warms the air which is in contact with the water and produces strong convection upcurrents. The upcurrents are moist due to the large amount of evaporated water carried into the warm air. As the air rises, adiabatic cooling occurs. The water vapor will condense and when the temperature of the air cools to the dewpoint temperature, clouds develop. The unstable air can start to rotate by the addition of inflowing air and a waterspout can result.

Nonsupercell thunderstormscan produce tornadoes as well. Those which do occur along the storm's gust front, or *gustnadoes*, are not connected with condensation funnels and are short-lived. Nonsupercell thunderstorms, causing tornadoes which occur due to formation along the lines of cumulonimbus clouds produce *landspouts*. Associated with weak thunderstorms they are short-lived.

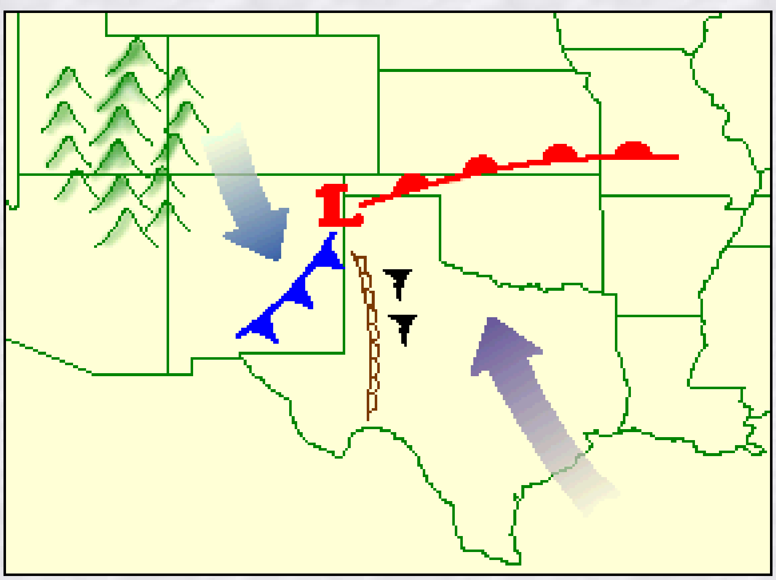
Next Page

Previous Page

Back to main Tornado page



The prevelance of tornadoes increases in some areas of the country more than in others. Tornadoes in the United States occur most frequently in ten states. Otherwise known as *Tornado Alley*, the states involved are Alabama, Arkansas, Florida, Iowa, Kansas, Mississippi, Missouri, Nebraska, Oklahoma and Texas. In the southern states the peak time for tornadoes occurs between March and May, and again in November. In the northern states the number of tornadoes peak during April and June. Common to all of these ten states is their location. They all lie to the east of a line which runs from Nebraska to Texas, marking the boundary of the Great Plains. Weather systems develop over the Great Plains resulting in severe weather patterns. The topography of these states is such that masses of warm moist air, termed tropical maritime air, sweep up from the Gulf of Mexico and the Caribbean Sea due to a lack of mountain barriers. During the spring months, the earth begins to warm, which adds to the layer of warm moist air which is close to the ground. While this is occurring over the Central Plains, cool dry air masses, termed maritime polar, often sweep in from the north or northeast. This cool air is trapped in by the Rocky Mountains and rides close to 10,000 feet above the warmer air below. The jet stream, coming from the west, acts to mix the already unstable air within the turbulent atmosphere.



According to Lutgens and Tarbuck, authors of "The Atmosphere," there are 770 tornadoes reported per year in the United States. Although tornadoes occur during every month of the year, the months of greatest activity in the United States occur between April and June. The months between December and January are reported to have the least tornadic activity. "Typically, 54% of all tornadoes take place during the spring. Fall and winter, on the other hand, together account for only 19%" (Lutgens, Tarbuck).

The average tornado travels at around 45 kilometers per hour, follows a path of about 26 kilometers long, and has a diameter of between 150 and 600 meters. Most tornadoes move toward the northeast, within the zone of southwest winds, and form ahead of a cold front, which is associated with the narrow, vertically developed clouds tornadoes form in.

Next Page

Previous Page

Back to main Tornado page

Measuring the severity of a tornado is done using a variety of techniques. The **Fujita scale** "assesses the effects of tornadoes and calculates the force needed to produce these effects." The intensity scale ranges from weak ratings to violent ratings. Beginning with ratings of F-0 and F-1, wind speeds range from 40-112 MPH and light to moderate damage is experienced. A rating of strong, F-2 and F-3, results in wind speeds of 113-206 MPH. The resulting damage is considerable to severe. The most violent tornadoes, categorized as F-4 and F-5, result in devastating damage, with wind speeds from 207-318 MPH.

Because of the unpredictable aspects of severe thunderstorms and tornadoes they are often hard to forecast and predict. Meteorologists try to predict tornadic activity using **Doppler Radar**, which directly measures the wind speed of the tornado. Conventional radar transmits short pulses of electromagnetic energy. Depending on the strength of the signal returned, the intensity of the storm can be determined. The difference in time between when the signal was sent out and returned indicates the distance of the storm. Doppler radar functions in this way, yet has an added ability. Doppler radar is able to detect motion directly. Described by Lutgens and Tarbuck, "Air movement in clouds is determined by comparing the frequency of the reflected signal to that of the original pulse. The movement of precipitation toward the radar increases the frequency of reflected pulses, whereas motion away from the radar decreases the frequency." The frequency changes are then assessed in terms of speed. Doppler radar has the ability to detect the formation of mesocyclones, from which tornadoes develop. Essentially, Doppler radar has given meteorologists the opportunity to better understand the atmospheric conditions associated with tornadic activity.

Next Page

Previous Page

Back to main Tornado page

References

- Allaby, Michael. *Tornadoes*. Facts on File. New York, N.Y., 1997.
- Cappella, Chris. *USA Today* [web page]; http://www.usatoday.com/weather/wtwist0.htm. [Accessed 13 Oct 1997].
- Demopolis, Michael. *Tornado Basics* [web page]; http://www.geocities.com/Vienna/3885/tornado.htm. [Accessed 13 Oct 1997].
- Lutgens, Frederick. Tarbuck, Edward. *The Atmosphere*. Prentice Hall. New Jersey. 1998.
- Powell, Corey. [web page]; http://www.sciam.com/explorations/052096explorations.html. [Accessed 13 Oct 1997].
- Schneider, Stephen. *Encyclopedia of Climate and Weather*. Oxford University Press. New York, 1996. pgs. 764-768.
- Tufty, Barbara. *1001 Questions Answered About Hurricanes, Tornadoes and Other Natural Disasters*. Dover Publications, Mineola, N.Y. 1987.

Previous Page

Back to main Tornado Page