All About Tornadoes: The Science Behind Tornadoes

Tornadoes don't just pop into existence -- they develop out of thunderstorms, where there's already a steady, upward flow of warm, low-pressure air to get things started. It's kind of like when a rock concert erupts into a riot. Conditions were already volatile; they merely escalated into something even more dangerous.

Thunderstorms themselves form like many other clouds: A warm, moist air mass rises and cools, causing the water vapor to condense into clouds. However, if the updraft continues, this cloud mass will continue to grow and rise 40,000 feet (12,192 m) or more up into the troposphere, the bottommost layer of the atmosphere that we live in. A typical thunderstorm cloud can accumulate an enormous amount of energy. If the conditions are right, this energy creates a huge updraft into the cloud, but where does the energy come from?

Clouds are formed when water vapor condenses in the air. This change in physical state releases heat, and heat is a form of energy. A good deal of a thunderstorm's energy is a result of the condensation that forms the cloud. Every gram of water condensed results in about 600 calories of heat -- and another 80 calories of heat per gram of water results from freezing in the upper atmosphere. This energy increases the updraft temperature, as well as the kinetic energy of upward and downward air movement. The average thunderstorm releases around 10,000,000 kilowatt-hours of energy -- the equivalent of a 20-kiloton nuclear warhead [source: Britannica].

In supercell thunderstorms, the updrafts are particularly strong. If they are strong enough, a vortex of air can develop just like a vortex of water forms in a sink. This precursor to the tornado is called a mesocyclone, and is typically 2 to 6 miles (3 to 10 kilometers) wide. One a mesocyclone forms, there's a roughly 50 percent chance that the storm will escalate into a tornado in around 30 minutes.

Some tornadoes consist of a single vortex, but other times multiple suction vortices revolve around a tornado's center. These storms-within-a-storm may be smaller, with a diameter of around 30 feet (9 meters), but they experience extremely powerful rotation speeds.

The tornado reaches down out of a thundercloud as a huge, swirling rope of air. Wind speeds in the range of 200 to 300 mph (322 to 483 kph) aren't uncommon. If the vortex touches ground, the speed of the whirling wind (as well as the updraft and the pressure differences) can cause tremendous damage, tearing apart homes and flinging potentially lethal debris.

The tornado follows a path that is controlled by the route of its parent thundercloud, and it will often appear to hop. The hops occur when the vortex is disturbed. You've probably seen that it is easy to disturb a vortex in the tub, but then it will reform. The same thing can happen to a tornado's vortex, causing it to collapse and reform along its path.

Smaller tornadoes may only thrive for a matter of minutes, covering less than a mile of ground. Larger storms, however, can remain on the ground for hours, covering more than 90 miles (150 km) and inflicting near continuous damage along the way.

At this point, you might be wondering just how tornadoes eventually dissipate. Scientists still debate exactly how these deadly storms die, but one of the prime suspects is none other than the parent thunderstorm: the rotating mesocyclone. Tornadoes need instability and rotation. Disrupt the airflow, take away its moisture or destroy its unstable balance of hot and cold air, and it can't function. Often, a tornado will die because the cold outflow of air from falling precipitation upsets the balance.

Types of Tornadoes

Tornadoes come from mainly two types of thunderstorms: **supercell** and **non-supercell.**

Supercell: Tornadoes that come from a supercell thunderstorm are the most common, and often the most dangerous. A rotating updraft is a key to the development of a supercell, and eventually a tornado. There are many ideas about how this rotation begins. One way a column of air can begin to rotate is from wind shear – when winds at two different levels above the ground blow at different speeds or in different directions.

An example of wind shear that can eventually create a tornado is when winds at ground level, often slowed down by friction with the earth's surface, come from the southwest at 5 mph. But higher up, at 5000 feet above the same location, the winds are blowing from the southeast at 25 mph! An invisible “tube” of air begins to rotate horizontally. Rising air within the thunderstorm tilts the rotating air from horizontal to vertical – now the area of rotation extends through much of the storm.

Once the updraft is rotating and being fed by warm, moist air flowing in at ground level, a tornado can form. There are many ideas about this too.

Scientists still have many questions. As few as 20 percent of all supercell thunderstorms actually produce tornadoes. Why does one supercell thunderstorm produce a tornado and another nearby storm does not? What are some of the causes of winds moving at different speeds or directions that create the rotation? What are other circulation sources for tornadoes? What is the role of downdrafts (a sinking current of air) and the distribution of temperature and moisture (both horizontally and vertically) in tornadogenesis?

And, since not all tornadoes come from supercells, what about tornadogenesis in non-supercell thunderstorms?

Non-supercell: Non-supercell tornadoes are circulations that do not form from organized storm-scale rotation. These tornadoes form from a vertically spinning parcel of air already occurring near the ground caused by wind shear from a warm, cold, or sea breeze front, or a dryline. When an updraft moves over the spinning, and stretches it, a tornado can form. Eastern Colorado experiences non-supercell tornadoes when cool air rushes down off the Rocky Mountains and collides with the hot dry air of the plains. Since these types of tornadoes happen mostly over scarcely populated land, scientists are not sure how strong they are, but they tend to be small.

One non-supercell tornado is the *gustnado*, a whirl of dust or debris at or near the ground with no condensation funnel, which forms along the gust front of a storm.

Another non-supercell tornado is a *landspout*. A landspout is a tornado with a narrow, rope-like condensation funnel that forms while the thunderstorm cloud is still growing and there is no rotating updraft - the spinning motion originates near the ground.

Waterspouts are similar to landspouts, except they occur over water. Damage from these types of tornadoes tends to be EF2 or less.

Tornado Ratings

Tornadoes are among the most dangerous storms on Earth and, as meteorologists strive to protect vulnerable populations through early warning, it helps to classify storms by severity and potential damage. Tornadoes were origina-lly rated on the Fujita Scale, named for its inventor, University of Chicago meteorologist T. Theodore Fujita. The meteorologist created the scale in 1971 based on the wind speed and type of da-mage caused by a tornado. There were six levels on the original scale.-

F0 - Wind Speed: 40-72 mph (64-116 kph)

Light damage: Tears branches from trees; rips shallow-rooted trees from the ground; can damage signposts, traffic signals and chimneys

F1 - Wind Speed: 73 - 112 mph (117 - 180 kph)

Moderate damage: Roofing materials and vinyl siding can be displaced; mobile homes are highly vulnerable and can easily be knocked from the foundation or toppled; motorists can be sent careening off road and possibly flipped over

F2 - Wind Speed: 113 - 157 mph (181 - 253 kph)

Considerable damage: Well-established trees are easily uprooted; mobile homes are decimated; entire roofs can be ripped off houses; train cars and trucking hauls are knocked over; small objects become dangerous missiles

F3 - Wind Speed: 158 - 206 mph (254 - 332 kph)

Severe damage: Forests are destroyed as a majority of trees are ripped from the ground; entire trains are derailed and knocked over; walls and roofs are torn from houses

F4 - Wind Speed: 207 - 260 mph (333 - 418 kph)

Devastating damage: Houses and other small structures can be razed entirely; automobiles are propelled through the air

F5 - Wind Speed: 261 - 318 mph (419 - 512 kph)

Incredible damage: Cars become projectiles as they are hurled through the air; entire houses are completely destroyed after being ripped from the foundation and sent tumbling into the distance; steel-reinforced concrete structures can be seriously damaged [source: NOAA]

In February 2007, the Fujita Scale was replaced by the Enhanced Fujita Scale. The new "EF" scale is similar to its predecessor. It classifies tornadoes into six different categories (EF0 through EF5 instead of F0 through F5). Where the EF- scale differs, however, is in the number of criteria used to assess a tornado's level of damage. First, there are damage indicators -- objects that can be damaged in the tornado. These are classified from 1 (small barns) to 28 (softwood trees). Each damage indicator can also experience varying degrees of damage (DODs). Each DOD corresponds to estimated wind speeds.-

For example, a motel has 10 degrees of damage, ranging from broken windows (3) to the collapse of most of the roof (6) to complete destruction of the building (10). If a motel's windows are broken, but it doesn't sustain more extensive damage, the estimated lowest possible wind speed is 74 mph (119 kph), while the estimated highest possible speed is 107 mph (172 kph). Meteorologists average these speeds, meaning the expected wind speed is 89 mph (143 kph). An examination of the EF Scale reveals that 89 mph falls into the EF1 category, so the tornado is classified as an EF1. For more information about the EF scale, see the official NOAA Web site.

Tornado Characteristics

Wind Shear and Updraft: One characteristic that's generally necessary for a strong supercell — and subsequent tornado — is wind shear, a difference in the wind speed at varying altitudes or directions. Air currents are often more powerful at higher altitudes, for example, where jet streams can send them tumbling into a horizontal loop.

As the thunderstorm begins to form, the accompanying updraft can also encourage horizontal spin, but it's this next event that's key — for a thunderstorm to generate a tornado-spawning mesocyclone, the supercell's powerful updraft must succeed in raising, sustaining and tightening the central vortex at a near vertical alignment.

If this step is reached, powerful forces within the whirling mesocyclone can achieve a balance between the inward and outward flow of air and create what is known as the dynamic pipe effect. The low-pressure center of the vortex (the pipe) sucks additional air up into the storm and lengthens the rotating tube that could potentially become a funnel cloud.

Air Temperature: A second important component needed for supercell formation and tornadogenesis is warm air, especially in relation to parcels of air higher up in the atmosphere. Many, although not all, supercell thunderstorms associated with tornadoes form at the boundary between cold, dry air and warm, moist air.

At the border between these two air masses, the rising warm air helps ignite rotation by fueling the towering updraft that pulls additional warm air up in its wake. The powerful updrafts associated with thunderstorms are aided by uneven heating of the Earth's surface — one of the reasons they're common in the afternoon hours.

Once warm air reaches the top of the storm, it spills over the backside as a rear flank downdraft and is recycled back into the storm. If the air is too cold, the storm weakens and tornadoes don't form.

Moisture and Instability: Another ingredient necessary for tornadogenesis is moisture. All the warm air discussed in the last paragraph was moisture-laden saturated air that likely rode in from the tropics. As the air begins to rise, its dew point lowers and the moisture cools and condenses to form the storm cloud.

Water vapor releases incredible amounts of heat as it condenses into raindrops, and it's this heat that fuels the storm, revving up a convective cycle of moving air. Thunderstorms are super powerful, and all their energy and furious wind speeds create a positive feedback loop that propagates until the supercell reaches mammoth proportions.

It's also important to note that instability — the difference between the temperature and moisture levels of air from the bottom to the top of the parcel — works to intensify a storm.

Gravity Waves: Once the stage is set for a mesocyclone supercell, another atmospheric occurrence that could up the chances of a twister is a set of incoming gravity waves. Gravity waves are like ocean waves; disturbances in the fluid atmosphere, say powerful gusts of wind or soaring mountain ranges, can cause the air to ripple and roll. Enter the GrITs theory: Gravity wave Interactions with Tornadoes.

According to Tim Coleman and Kevin Knupp — the former a research scientist and the latter a professor in the department of Atmospheric Science at the University of Alabama in Huntsville — gravity waves can have an effect on storm development.

By studying information recorded from previous supercells and tornadoes, the two meteorologists found instances where atmospheric waves interacted with mesocyclones, compressing and shrinking them. By decreasing the size of a rotating object, you cause it to gain speed.

Coleman and Knupp, whose work was published in the March 2008 issue of the Monthly Weather Review, concluded that in cases where gravity waves interact with mesocyclones, they can potentially give a boost in terms of rotational speed — which might just jumpstart the formation of a tornado.

Raindrop Size: New research recently published in Geophysical Research Letters suggests that a storm's spread of raindrop sizes could be an indicator of the likelihood a tornado will form. (Raindrops vary in size depending on the conditions under which they're formed.)

Nathan Snook, a graduate research assistant, and Ming Xue, a professor in the School of Meteorology and Director of the Center for Analysis and Prediction of Storms — both at the University of Oklahoma — conducted a 3-D study of the microphysical conditions inside a supercell storm.

They studied a number of atmospheric variables and found that large raindrops tend to cluster together more than smaller ones, and are also less prone to evaporation. Since evaporation cools the air (as opposed to the heating that occurs with condensation) this means the air beneath a storm cloud will be warmer than if smaller drops were present — and we know that warm moist air is just the thing to fuel a massive supercell that spawns tornadoes.

But while this could help explain why a tornado doesn't debut with every supercell, tornadogenesis is still an elusive process. Many factors only just now being considered could also prove to be playing a key role in tornado formation

Tornado Size and Shape: Most tornadoes take on the appearance of a narrow funnel, a few hundred yards (meters) across, with a small cloud of debris near the ground. Tornadoes may be obscured completely by rain or dust. These tornadoes are especially dangerous, as even experienced meteorologists might not see them. Tornadoes can appear in many shapes and sizes.

Small, relatively weak landspouts may be visible only as a small swirl of dust on the ground. Although the condensation funnel may not extend all the way to the ground, if associated surface winds are greater than 40 mph (64 km/h), the circulation is considered a tornado. A tornado with a nearly cylindrical profile and relative low height is sometimes referred to as a "stovepipe" tornado. Large single-vortex tornadoes can look like large wedges stuck into the ground, and so are known as "wedge tornadoes" or "wedges". The "stovepipe" classification is also used for this type of tornado, if it otherwise fits that profile. A wedge can be so wide that it appears to be a block of dark clouds, wider than the distance from the cloud base to the ground. Even experienced storm observers may not be able to tell the difference between a low-hanging cloud and a wedge tornado from a distance. Many, but not all major tornadoes are wedges.

Tornadoes in the dissipating stage can resemble narrow tubes or ropes, and often curl or twist into complex shapes. These tornadoes are said to be "roping out", or becoming a "rope tornado". When they rope out, the length of their funnel increases, which forces the winds within the funnel to weaken due to conservation of angular momentum. Multiple-vortex tornadoes can appear as a family of swirls circling a common center, or they may be completely obscured by condensation, dust, and debris, appearing to be a single funnel.

In the United States, tornadoes are around 500 feet (150 m) across on average and travel on the ground for 5 miles (8.0 km). However, there is a wide range of tornado sizes. Weak tornadoes, or strong yet dissipating tornadoes, can be exceedingly narrow, sometimes only a few feet or couple meters across. One tornado was reported to have a damage path only 7 feet (2 m) long. On the other end of the spectrum, wedge tornadoes can have a damage path a mile (1.6 km) wide or more. A tornado that affected Hallam, Nebraska on May 22, 2004, was up to 2.5 miles (4.0 km) wide at the ground.

In terms of path length, the Tri-State Tornado, which affected parts of Missouri, Illinois, and Indiana on March 18, 1925, was on the ground continuously for 219 miles (352 km). Many tornadoes which appear to have path lengths of 100 miles (160 km) or longer are composed of a family of tornadoes which have formed in quick succession; however, there is no substantial evidence that this occurred in the case of the Tri-State Tornado. In fact, modern reanalysis of the path suggests that the tornado may have begun 15 miles (24 km) further west than previously thought.

Appearance: Tornadoes can have a wide range of colors, depending on the environment in which they form. Those that form in dry environments can be nearly invisible, marked only by swirling debris at the base of the funnel. Condensation funnels that pick up little or no debris can be gray to white. While traveling over a body of water (as a waterspout), tornadoes can turn very white or even blue. Slow-moving funnels, which ingest a considerable amount of debris and dirt, are usually darker, taking on the color of debris. Tornadoes in the Great Plains can turn red because of the reddish tint of the soil, and tornadoes in mountainous areas can travel over snow-covered ground, turning white.

Lighting conditions are a major factor in the appearance of a tornado. A tornado which is "back-lit" (viewed with the sun behind it) appears very dark. The same tornado, viewed with the sun at the observer's back, may appear gray or brilliant white. Tornadoes which occur near the time of sunset can be many different colors, appearing in hues of yellow, orange, and pink.

Dust kicked up by the winds of the parent thunderstorm, heavy rain and hail, and the darkness of night are all factors which can reduce the visibility of tornadoes. Tornadoes occurring in these conditions are especially dangerous, since only weather radar observations, or possibly the sound of an approaching tornado, serve as any warning to those in the storm's path. Most significant tornadoes form under the storm's updraft base, which is rain-free, making them visible. Also, most tornadoes occur in the late afternoon, when the bright sun can penetrate even the thickest clouds. Night-time tornadoes are often illuminated by frequent lightning.

There is mounting evidence, including Doppler On Wheels mobile radar images and eyewitness accounts, that most tornadoes have a clear, calm center with extremely low pressure, akin to the eye of tropical cyclones. This area would be clear (possibly full of dust), have relatively light winds, and be very dark, since the light would be blocked[citation needed] by swirling debris on the outside of the tornado. Lightning is said to be the source of illumination for those who claim to have seen the interior of a tornado.

Rotation: Tornadoes normally rotate cyclonically (when viewed from above, this is counterclockwise in the northern hemisphere and clockwise in the southern). While large-scale storms always rotate cyclonically due to the Coriolis effect, thunderstorms and tornadoes are so small that the direct influence of the Coriolis effect is unimportant, as indicated by their large Rossby numbers. Supercells and tornadoes rotate cyclonically in numerical simulations even when the Coriolis effect is neglected. Low-level mesocyclones and tornadoes owe their rotation to complex processes within the supercell and ambient environment.

Approximately 1 percent of tornadoes rotate in an anticyclonic direction in the northern hemisphere. Typically, systems as weak as landspouts and gustnadoes can rotate anticyclonically, and usually only those which form on the anticyclonic shear side of the descending rear flank downdraft in a cyclonic supercell. On rare occasions, anticyclonic tornadoes form in association with the mesoanticyclone of an anticyclonic supercell, in the same manner as the typical cyclonic tornado, or as a companion tornado either as a satellite tornado or associated with anticyclonic eddies within a supercell.

All About Tornadoes: Utah Tornadoes

Somewhat surprisingly, Utah has experience over 100 tornados in just the last two hundred years. Most of these were low-level, minimal damaging storms. For a complete report on Utah's tornado history, please continue to this following link.
http://newweb.wrh.noaa.gov/slc/climate/tornado.php

Below I have listed some of Utah's more significant and memorable tornados.

1.) 1999 Salt Lake City, Utah ***Utah's Most Destructive Tornado*

(August 11, 1999) -- A massive storm front hit the Salt Lake Valley at approximately 1:00pm Wednesday afternoon causing severe destruction and injury in the down town Salt Lake City area. The worst destruction was in the 300 West area near the Delta Center and the Triad Center. Homes in the upper avenues area of Salt Lake were also destroyed.

One person died and at least 49 others were hospitalized.

Further Details:
A quick-striking tornado touched down in the downtown area early Wednesday afternoon, causing an undetermined amount of damage. There were dozens of injuries.

The black funnel cloud uprooted trees and temporary buildings set up for a retailers convention close to 1 pm.

http://web.ksl.com/dump/news/cc/images/torn6lg.jpgIt also damaged the roof of the Delta Center, home of the Utah Jazz and the Wyndham Hotel where windows were blown out.

The downtown area looked like a disaster zone with trucks overturned, power lines down, windows blown out and shards of glass everywhere.

Police and fire-fighters attended to dozens of wounded people.

Helicopters landed in city streets to ferry the injured to hospitals.

One person was confirmed dead by the mayor's office.

National Weather Service meteorologist David Hogan says the tornado was classified as a low-end F-2, with winds over 100 miles-per-hour.

The streets became littered with shredded tents from the outdoor retailer show at the Salt Palace, which was evacuated because of a gas leak.

At the time, it was not known how many people, if any, were trapped beneath the collapsed tent.

Thousands of people witnessed this devastating storm. Many of the KSL crews were out working on other stories when they said the sky turned very dark--tinged with green. Then it was obvious a tornado was on the move.

As it gained momentum around fifth West and 100 South and roared toward the Delta Center the destruction was just starting.

The twister snapped power poles like toothpicks, blew out windows in the Delta Center and many other buildings downtown. It tore through the massive tent of the Outdoor retailers show. The storm tossed trucks and cars around like they were toys and shattered windows in hundreds of vehicles.

The extent of the damage in a downtown nine to ten block area is devastating. The extent of the injuries is staggering. Hundreds of cars are damaged--many destroyed. Buildings are badly damaged and there will need to be extensive work on power lines and gas lines. It packed a powerful punch.

Disaster, was narrowly averted when the tornado swept across the site of the new LDS Assembly Building snapping the boom, on a massive construction crane. About a thousand people were working on the new building when the storm struck.

Event Analysis: On August 11, 1999, an F2 tornado (having winds of 113 to 157 mph) did considerable damage as it tracked northeastward across the metropolitan area of Salt Lake City. One person was killed and over 80 people were injured--with 15-20 serious injuries reported. The tornado produced F0 wind damage at 12:41 PM from about 400-500 South/Navajo (1340 West) to about 300 South/Goshen (1040 West). The tornado reached F2 strength by 12:45 PM.

From 300 South/1040 West the tornado tracked northeast producing widespread damage at the Delta Center–including the destruction of one of the large outdoor tents set up for the Outdoor Retailers Convention. The collapse of the large tent facility killed one man: Allen Crandy. The tornado also damaged the Wyndham Hotel, which had to be closed for several days until the damage could be repaired.

From the Wyndham Hotel, the tornado continued its northeast track, knocking down scaffolding and shearing off a crane at the site of the LDS Church's new Assembly Hall that was under construction. Next, it went up Capitol Hill and along the southeast side of the Capitol, through Memory Grove, and up along the northwest portion of the Avenues–just barely missing the LDS Hospital. It then lifted off the ground at about Edge Hill/Terrace Hill (20th Avenue and P Street). Along its path through the Avenues, houses experienced from minor to major damage, with hundreds of trees either uprooted or damaged. Throughout much of the tornado's destructive path, vehicles were tossed around and many were damaged or totaled by falling trees.

This F2 tornado was on the ground from 12:45 PM to 12:55 PM (10 minutes). It traveled a distance of about 3-3/4 miles, and had a width of about 100 to 200 yards. From F0 to F2 intensity, the tornado traveled 4-1/4 miles, lasted 14 minutes, and traversed an elevation difference of 1,095 feet (from 4,225 feet to 5,320 feet).

Here are some other facts and figures about this destructive tornado:

1 death. 80 injuries.
300 buildings or houses were damaged, with 34 homes left uninhabitable.
500 trees were destroyed, and another 300 trees were significantly damaged.
A portion of Memory Grove was completely destroyed.
A major power outage occurred in the downtown area of Salt Lake City, Capitol area and portions
of the Avenues.
Total damage estimates: about $170 million dollars.

Images from the 1999 SLC Tornado

2.) Waterspout, American Fork River, Utah County

August 19, 1869, time unknown, 40 27'N, 111 43'W
Utah's first officially reported tornadic activity occurred on August 19, 1869. It was described as a "funnel-shaped waterspout" and apparently formed over the American Fork River
in American Fork Canyon, Utah County. Seven bridges were washed out and damages to roads
were estimated at $1,500.

3.) July 6, 1884; 1645 MST, 40 42' N', 111 03' W

This was the first recorded tornado in Utah that caused any deaths or injuries. According to Deseret News newspaper reports of July 7-10, 1884, on July 6, 1884, a seven year-old girl, named Kitty Wells, was killed by a tornado while camping with her family in an area about 23 miles east of Wanship, up the Weber River in Summit County. The tornado also injured at least two other people. This is the first recorded tornado in Utah that causing any deaths or injuries. Here are some accounts of the tornado that were taken from articles that appeared in the Deseret News shortly after the event took place:

"The party which left [Salt Lake City] Saturday morning was composed of [16 people].... They reached Peoa, nine miles from Wanship, the same night, and stayed there till morning. Their journey up the canyon next day was exceedingly difficult, owing to storms of hail and rain, with thunder and lightning, experienced at intervals during the day. About the middle of the afternoon the party halted at a saw mill where they rested...but finally...being but a quarter of a mile from the camping place, desired to push on and put up their tents for the night. They reached their destination--a beautiful grove of timber, about twenty-three miles from Wanship--at 4 o'clock in the afternoon, and the work of 'camping out' immediately commenced. One tent having been raised, the ladies and children all gathered in it for shelter, while the men were out putting up the others, making fires, tending teams, the cook getting supper ready, etc. In the center of the ladies' tent was large bale of bedding, not yet undone, and they were all sitting around it conversing, with the exception of Kitty Wells [a seven year old girl], who was standing on top of the bale. This was at fifteen minutes to six o'clock. Miss Kimball says that all at once she heard a whirling sound, swiftly approaching, and exclaimed to the others: 'something's coming,' but was laughed at by them, even after she had repeated her fears. Suddenly a terrific clap of thunder was heard, preceded by a blinding flash of lightning, the whirling or buzzing sound increased in intensity and before the frightened group could recover their speech, the fury of the tornado burst upon them. The whirlwind had made directly for the grove of pines in which the tent had been pitched, and tore through the woods with the force of a battery of artillery. Thirty trees were uprooted in an instant, twisted to splinters and dashed shivering to the ground. Three large pines fell with a crash right across the tent, the ridge pole gave way and one of the iron ends descending struck Miss Wells upon the right temple. Miss Kimball was hit, by one of the trees, across the back and right hip, and crushed with the rest of her companions under neath the falling ruin. The nurse girl, Miss Clark, received a slight injury in the foot. Mr. Frank Jennings, who with the other men had started for the tent on hearing the first sounds of the coming tornado, was felled to the earth by a tree as he was in the act of entering the tent, while the [male] cook narrowly escaped from a tree or branch, which flew past him with the speed of lightning, just grazing his skull.... The storm passed in a few seconds, making a roadway right through the forest and leaving devastation in its track. Miss Kittie was...bleeding from a ghastly wound in the head. She lived fifteen minutes afterwards and expired in her parents' arms. Miss Kimball and Miss Clark were the only others that were injured. The bale of bedding, which broke the fall of the trees and tent poles, undoubtedly saved several lives." (Deseret News, July 8, 1884)

"The tornado was about ten rods wide and struck the camp last evening. It tore up about thirty trees, three of which fell upon the tent, killing Miss Wells and injuring Miss Kimball and Mrs. Clark. Miss Kimball was severely hurt in the back and side, while Mrs. Clark's injuries were very slight." (Deseret News, July 7, 1884)

"Mr. Frank Jennings describes the appearance of the tornado which wrought the disaster at head of Weber Canyon, last Sunday, as follows: It was a great black cloud, funnel-shaped, eight or ten rods wide at the top, and narrowing down to about the width of a wagon road. It did not touch the ground, but now and then swooped down and rose again as it sped on its way. Its speed was almost as swift as thought, about it the air was in commotion and it whirled as it went, making a noise like the roaring of the waves of the sea. It twisted off branches of trees and shot them through the air with great velocity, broke in twain great trunks, three feet in diameter, and where it descended to the earth tore up threes by the roots. The grove in which the party's tent was pitched was one of the spots upon which it descended, and having crushed the tent and it inmates to the earth, lifted almost immediately, passed over and was lost to sight and hearing. 'It was a terrible sight,' says Mr. Jennings, 'one I had never seen before and never wish to see again.'" (Deseret News, July 9, 1884)

4.) Waterspout, Great Salt Lake, Salt Lake County

August 16, 1889, time unknown, 40 44'N, 112 12'W
A waterspout was observed over the south part of the Great Salt Lake near Garfield Beach, Salt Lake County. It lasted 30 minutes. The pavilion next to the railroad was covered by
an inch of water and an excursion boat was almost swamped.

5.) Tornado, near Woods Cross, Davis County

May 27, 1941, 1145 MST, 40 50'N, 111 55'W
A funnel cloud initially formed over the Great Salt Lake in Davis County and appeared as an intensely black cloud from which the typical twisting funnel descended, flicking the ground in four places along a zigzag path a few rods wide and approximately ten miles long. The tornado destroyed a barn and a pigpen located two and one-fourth miles southwest of Woods Cross. The tornado then struck near the South Bountiful Ward meeting house of the Church of Jesus Christ of Latter-day Saints. It shattered windows and broke and uprooted trees and utility poles. The roof and walls of an old brick residence were torn away. The roof of the meeting house and nearby double garage were also demolished. The tornado also did

slight damage to some residences and trees about a mile to the east of the meeting house. Total monetary damages were estimated at $4,000 to $5000.

On May 28, 1941, the *Salt Lake Telegram* newspaper reported the following information about the tornado: "Most of the damage, estimated at $5,000, was in the Bounitful area and was confined chiefly to farm buildings, telephone, telegraph and power lines. Parts of buildings were hurled almost 500 feet. Many windows were broken, and communication facilities between Salt Lake City and Ogden were partly disrupted 5 to 10 minutes. Power was cut off from about 100 homes around the Bountiful for almost an hour." The *Salt Lake Telegram* article was entitled "Botany Professor Gets Photos of Strange Utah Tornado," and contained the accompanying photographs of the tornado taken by Walter P. Cottam, a Professor of Botany at the University of Utah, who "was in Mueller Park, collecting plants for his botany classes, when he sighted the tornado, which had formed over [the] Great Salt Lake." Fortunately, Professor Cottam had a camera and "drove to the brow of the hill as the storm developed" and took what may be the first published photographs of a Utah twister. The *Salt Lake Telegram* article and pictures were obtained by Craig Wirth of *News 4 Utah* (KTVX) on May 14, 2000, from Mary Dringman, an 84-year-old resident of Salt Lake City, who had discovered the article and pictures in her mother's scrapbook.

6.) Tornado, Young Ward (near College Ward), Cache County *Intensity: F2*

January 22, 1943, between 1400 and 1500 MST, 41 41'N, 111 54'W
According to a Herald Journal newspaper report of January 29, 1943, "a week ago today...[or January 22, 1943, a] "cyclone struck" Young Ward "between 2 and 3 p.m. Friday in the midst of a severe snow storm, accompanied by heavy thunder and lightning. Above it all, the residents of Young Ward say, was heard the rumbling noise of the wind." The "buildings damaged lie within an area of a mile wide and two miles long."

Damages to chicken coops included: "part of one chicken coop [that] was blown...in a northeasterly direction for more than 200 yards," another "coop struck the roof of the home and then sailed over the house at a height of approximately 27 feet," and "a smaller coop, 22 feet by 31 feet, was carried into the air high over the three tops of the 45 feet high Black Willow trees standing closely together in a small grove, and boards from it were carried into a field more than a block away. Sheets of corrugated iron that had covered the coops were blown high into the air and carried more than three-quarters of a mile where they were scattered over the fields." Damages to other buildings included: "One third of the roof of a new barn, 40 feet square, was torn off and blown more than 200 yards away into the neighboring fields." A "large dairy barn...which previously had stood upright now resembles the leaning Tower of Pisa." A "garage for housing the school bus...is resting in Pelican Pond, about 100 yards from where it used to be." "Several tricks were played by the cyclone," including one woman who had "placed into a large cedar chest some baby clothes she had just ironed. The wind broke both windows, opened the lid to the cedar chest and carried the baby clothes through the window and out into the air." A short distance away, a man and two boys "were working in [a] chicken coop when the cyclone struck. The entire coop was lifted from its foundation and carried into the air, leaving [the man] and the boys standing on the floor. They didn't even get a scratch during the excitement."

Only one person was reportedly injured by the tornado: a seven-year-old girl, named

Delores Olsen, who "was cut by flying glass in the face and on the head." Damage estimates reached "upwards of $8,000" and "many chickens were lost during the catastrophe. Some were killed in the coops and others were carried away by the wind."

1.) Tornado, Bountiful, Davis County *Intensity: F2*

June 3, 1963, 1505 MST, 40 53'N, 111 53'W
A damaging tornado hit Bountiful, Davis County and moved in an east-northeast direction. The roof of the Bountiful Elementary School was ripped off doing $20,000 damage. Debris was scattered over a half-mile area along the tornado path. The storm tore the roof from the west side of a house across the street from the school. This roof then landed on an automobile in a nearby yard. Half a block away, a roof was removed from a shed and dumped into a small orchard 200 yards away. A Boxelder tree was stripped of all its limbs. A cottonwood tree with a truck three feet across was broken off a few feet above the ground and carried over a house. Two blocks away, the tornado touched down again and destroyed a two-car cinder black garage. The tornado skipped a half-mile up hill and destroyed one home under construction and damaged several others. In the same vicinity, several sheets of three-fourths inch plywood were removed from a stack and blown 300 feet through the air. One piece of wood was driven six inches into a telephone pole.

2.) Tornado, West Weber, Weber County *Intensity: F2*

August 14, 1968, 1045 MST, 41 15'N, 112 05'W
A tornado formed ahead of a storm front in West Weber, Weber County. It initially touched down in a wheat field and then moved in a northerly direction. It tore the roof from a milking parlor and lifted a man and boy off the ground and set them back down again. One of the man's legs was injured. The tornado ripped the roof from a barn and spread seven or eight tons of baled hay across the area. A storage shed was also destroyed. A new home that was occupied by a woman and four children was leveled but the occupants were not hurt. The roof of the home was deposited 120 feet away. Elsewhere, a truck and camper were lifted by the tornado and carried 30 to 40 feet and destroyed. A short distance away, the tornado damaged a barn, haystack and another home. Total damage was placed near $50,000. The tornado's path was 35 yards wide and had a length of one and one-half miles.

3.) Tornado, Anabella, Sevier County

April 19, 1970, 1320 MST, 38 42'N, 112 04'W
A tornado touched down in Anabella, Sevier County and damaged two trailers. The tornado "cut a path 40 feet wide and more than a mile long. A house trailer, measuring about 12 by 52 feet was lifted from its wood foundation and turned around about 90 degrees. Windows were broken in another nearby trailer." (Salt Lake Tribune, April 20, 1970). The tornado also "picked up and carried" a woman "about 30 feet as she was walking between her trailer home and a neighbor's place. `I don't know how far off the ground I was—a foot, I guess—but I know I wasn't touching the ground.... It was quite an experience,' [said the woman]. She said she had a headache after striking the ground." (Deseret News April 20, 1970.) According to a local newspaper, "the gust of

wind picked...up [the woman] and tossed her end over katilt for about twenty feet like a tumble weed. Her invective embellished comment was: 'Well I've heard of the Flying Nun but I never thought I'd be one.'" (Richfield Reaper, April 1970.)

4.) Tornado, north of Hanksville Airport, Wayne County

July 24, 1981, 1412 MST, 38 28'N, 110 42'W
A well-photographed red tornado (carrying red soil and dirt) touched down about three miles north of the Hanksville Airport in Wayne County. It occurred over a desolate area and was seen and photographed by Barbara Ekker, the official Hanksville weather observer

5.) Waterspout & Tornado, Utah Lake, Provo, Utah County

September 13, 1982, 1720 MST, 40 13'N, 111 43'W
A waterspout over Utah Lake went ashore at the Provo Airport and damaged a security gate
and small plane. The plane was tied down but the wind snapped the back wheel tie-down and flipped
the plane on its back. The path of the storm was about one-half mile long.

6.) Tornado, south of Roosevelt, Duchesne County

September 11, 1984, 1445 MST, 40 09'N, 110 04'W
A tornado was reported about 10 miles south of Roosevelt, near Myton, Duchesne County.
A car was carried 30 feet by the twister. Two outhouses were knocked over and a pig pen was
destroyed. Irrigation pipes were also scattered around the area.

7.) Waterspout, Great Salt Lake, Tooele County

June 26, 1985, 0530 MST, 40 42'N, 112 10'W
A waterspout formed over the south end of the Great Salt Lake in Tooele County and could be seen 20 miles to the east. It was seen by more than a dozen experienced weather observers and was well photographed and videotaped before it dissipated over water. This waterspout was analyzed in a 30-page article entitled "A Great Salt Lake Waterspout," Monthly Weather Review, Volume 119, Number 12, December 1991, American Meteorological Society, Boston, MA. According to this article, "A waterspout funnel and spray ring were observed under the cumulus [cloud] line over the Great Salt Lake for about 5 min[utes] shortly after sunrise on 26 June 1985. Videotaped features strongly suggested that the funnel rotation was anticyclonic. ... The funnel was about 40 m [131.2 feet] across. Cloud base was approximately 800 m [2,624.6 feet] about lake level and the cloud tower above the funnel topped at about 5.5-6.5 km [3.4-4.0 miles] above lake level."

8.) Waterspout, Great Salt Lake, Box Elder County

October 22, 1985, 1615 MST, 41 33'N, 112 52'W
A pilot reported a waterspout over the Great Salt Lake in Box Elder County. It was estimated
to be 700 feet high and drew water up from the lake. The waterspout formed following the passage
of a cold front.

9.) Tornado, Canyonlands National Park, Wayne County

August 31, 1986, 1430 MST, 38 22'N, 110 05'W
A tornado was observed over the Island-in-the-Sky area of Canyonlands National Park, Wayne County. It was on the ground 10 minutes in an undeveloped area and was seen by tourists and
personnel at the park.

10.) Tornado, Sandy, Salt Lake County

January 10, 1989, 0910 MST, 40 35'N, 111 53'W
A tornado produced a fair amount of damage to a south Sandy neighborhood during the morning hours of January 10, 1989. The tornado path began at about 11683 South and 1400 East to near 11400 South and 1380 East. The tornado's path was mile long and about 25 yards wide. Significant damage occurred to three roofs with minor damage to three others. The tornado tore a gaping hole in one roof. A camper that was bolted down at all four corners was lifted and thrown upside down into the street. Several fences were sheared off and the fence material was strewn about the neighborhood. Asphalt shingles were driven inch deep into both sides of one piece of the fence. A witness observed the tornado skipping down the street with debris blowing in a circular motion. Another witness said the tornado sounded like a train and caused his whole house to vibrate.

11.) Tornado, North Salt Lake, Davis County

June 2, 1993, 1620 MST, 40 50'N, 111 55'W
A tornado was spawned by a thunderstorm cell at about 5:20 PM at the Center Street Park in North Salt Lake. The tornado was first seen as a funnel cloud to the southwest of the park. Everyone took cover before the tornado struck the ball field which displayed a hit and miss pattern of debris damage to the northeast of the ball field. It was on the ground less than five minutes. Two people received puncture wounds from flying debris and many individuals were covered with mud and dirt. Large tree limbs were broken and a couple of two-foot diameter trees were uprooted. Shingles were blown off some roofs and the fence surrounding the tennis court was damaged. The tornado also shattered three windows and bent the passenger door of the mini-van parked on the south end of the park. This tornado caused about $15,000 in damages.

12.)Tornado, Chepeta Lake, Duchesne County *Intensity: F3*

August 11, 1993, 1750 MST, 40 50'N, 109 59'W
A high-elevation tornado touched down three times near Chepeta Lake (elevation 10,500 feet) about 25 miles north of Roosevelt in the Ashley National Forest of the Uinta Mountains, at about 6:50 PM on August 11, 1993. During the evening of August 11th, a line of thunderstorms moved across the Uinta Mountains. Below the thunderstorms, a tornado touched down three times. Its path width was up to a half mile wide.

The first touchdown occurred 12 miles southwest of an area known as White Rock Drainage. Only minor unorganized damage to 20 acres of forest was reported at this location. The second touchdown was the most significant. At the west fork of the White Rock Drainage the tornado began to knock down and uproot trees over a 600 acre area. The tornado moved northeast along the drainage, throwing trees on the south side of the drainage to the north. Similarly, trees on the north side of the drainage were tossed to the south. This organized multi-directional> nature of the damage is a classic signature and confirms the presence of a tornado.

The tornado lifted once more before touching down for the third and final time near Chepeta Lake Drainage. Here the twister damaged over 400 acres of forest. A troop of 125 scouts were camped near the area of the third touchdown. No one was injured, but four vehicles were damaged by the tornado. One truck was destroyed when two large uprooted trees fell on the vehicle—totally collapsing the roof.

The highest elevation where damage was found was at 10,800 feet—which makes this tornado the highest mountain tornado ever reported in Utah. (High-elevation tornadoes are rare in Utah. On December 2, 1970, a tornado occurred at the 8,000 foot level below Timpanogos Divide.)

13.)Tornado, Emigration Canyon, Salt Lake County

November 5, 1993, 1545 MST, 40 40'N, 111 46'W
A cold northwest flow over the Great Salt Lake produced snow squalls which spawned a weak tornado. The tornado was reported by several people, who described it as white at the top and
brown at the bottom—indicating it was picking up dirt. The tornado lasted about three minutes.

14.)Tornado, near Dutch John, Daggett County

May 5, 1999, 1500 MST, 40 54'N, 109 13'W
A tornado touched down over rangeland about 8 miles northwest of the Browns Park National Wildlife Refuge headquarters. Debris was thrown about 300 feet into the air.

15.)2 Tornadoes, 20 miles south of Park Valley, Box Elder County

September 19, 1999, 1415 MST, 41 37'N, 113 17'W
At about 3:15 PM on September 19, 1999, two F0 tornadoes touched down at the same time in an uninhabited area 20 miles south of Park Valley in Box Elder County. The two twisters were on the ground for nearly three minutes, and were caused by a line of severe thunderstorms that also produced small hail and brief but heavy rain. The tornadoes were video-taped by Neville Reeves of Clearfield, Utah. This was the first time in Utah's history that two or more tornadoes were photographed or video-taped on the ground at the same time in the same area. (However, on May 31, 1969, three tornadoes touched down at the same time in an uninhabited area about 10 miles southwest of Hanksville in southeastern Utah.)

16.)Tornado, Holladay, Salt Lake County

May 25, 2000 1720 MST, 40 39'N, 111 50'W
Around 6:20 PM, a small tornado (F0) was observed in the Holladay area with a funnel cloud and possible touchdown earlier in West Jordan and Murray. The tornado ripped apart a sheet metal roof of the receiving dock at the Albertson's store in Holladay/Cottonwood. Just to the north, at the Goodyear Tire Store, several cars had their windows blown out and the store sustained some minor damage (roof and signs). Total damage was estimated at about $100,000.

17.)Tornado, South/East portions of Manti, Sanpete County
Intensity: F2

September 8, 2002, 1250 MST, 39 26'N, 111 63'W
An F2 tornado began one mile south-southwest of Manti and moved northeast through Southeast Manti. The first mile of the tornado path was across open land, however the tornado produced some remarkable damage at the start. A 10X12 foot pioneer building was lifted, rotated 90 degrees, and moved 8 feet before being dropped back to the ground. At the south end of Manti, the tornado struck the Anderson Lumber business and did substantial damage. A 40 foot semi-trailer, loaded with insulation, was lifted and thrown onto Its side approximately 35 to 40 feet away. A large amount of debris, along with a 10X10 foot wooden shed, was thrown across Highway 89 and over the hill some 200 to 300 feet away. The wide swath of the tornado did considerable damage as it moved through the residential area in Southeast Manti. As the tornado exited the residential area, where some of the heaviest damage occurred, a 26 foot camp trailer was lifted and thrown to the west-northwest some 150 to 200 feet and disintegrated. The tornado continued across open farmland another half a mile or so before dissipating near the mountains. It has been determined that this was a high-end F2 tornado, with winds as high as 157 mph. The distance traveled was 2.75 miles, and the width was 800 feet. Time on the ground was approximately 15 minutes. Estimated damage is around $2,000,000.

Tornado Statistics for Utah: January 1950 to Present

Size of Tornadoes: Funnel diameter is usually 10 to 20 yards wide.
Largest reported funnel diameters: 440 yards wide on December 2, 1970; 800 feet wide on Septermber 8, 2002; 200 yards wide on May 30, 1986 and August 30, 1992; 100 to 200 yards wide on August 11, 1999; and 100 yards wide on May 6, 1981 and July 25, 1991.

Duration of Tornadoes: Usually only a few seconds to a few minutes.
Greatest amount of time on the ground: 15 minutes on July 9, 1962, July 25, 1991, August 30, 1992, July 24, 1998 and September 8, 2002.

Color of Tornadoes: Usual color- gray or brown.
Other colors: black on July 9, 1962; red on July 24, 1981; and white on December 2, 1970 and March 29, 1982. Tornado Statistics for Utah: January 1950 to the Present

Number of Tornadoes by Year:

1950	0	1970	5	1990	4
1951	0	1971	1	1991	5
1952	0	1972	0	1992	4
1953	2	1973	0	1993	6
1954	1	1974	0	1994	0
1955	3	1975	0	1995	2
1956	0	1976	0	1996	3
1957	1	1977	0	1997	1
1958	0	1978	1	**1998**	**8**
1959	0	1979	0	1999	5
1960	0	1980	0	2000	7
1961	1	1981	2	2001	4
1962	1	1982	3	2002	4
1963	1	1983	0	2003	4
1964	1	1984	6	2004	2
1965	5	1985	0	2005	4
1966	2	1986	3	2006	2

Number of Tornadoes by Month:

January	1	July	15
February	1	August	26
March	4	September	21
April	7	October	1
May	**31**	November	2
June	18	December	2
			Total 129

1967	2	1987	3	2007	1
1968	4	1988	1	2008	0
1969	3	1989	6	2009	3
				2010	1
				2012	1
					Total 129

Number of Tornadoes by Hour (MST)

1:00 AM	1	1:00 PM	14
2:00 AM	0	2:00 PM	18
3:00 AM	0	**3:00 PM**	**20**
4:00 AM	0	4:00 PM	13
5:00 AM	1	5:00 PM	10
6:00 AM	0	6:00 PM	6
7:00 AM	0	7:00 PM	4
8:00 AM	2	8:00 PM	3
9:00 AM	2	9:00 PM	0
10:00 AM	5	10:00 PM	0
11:00 AM	13	11:00 PM	0
12 Noon	16	12 Midnight	0
Unknown	1		**Total 129**

Number of Tornadoes by County

Beaver	6	Piute	1
Box Elder	11	Rich	3
Cache	4	**Salt Lake**	**15**
Carbon	1	San Juan	0
Daggett	1	Sanpete	10
Davis	11	Sevier	4
Duchesne	4	Summit	0
Emery	8	Tooele	5
Garfield	1	Uintah	6
Grand	5	Utah	9
Iron	5	Wasatch	0
Juab	1	Washington	2
Kane	0	Wayne	8
Millard	4	Weber	6
Morgan	1		**Total 132***

* Three of the above numbered tornadoes were counted twice because they traveled across county borders: June 5, 1953; May 4, 1961; and May 30, 1986.

Number of Injuries:	Number of Deaths:
2 people on July 8, 1989 1 male on August 14, 1968 1 female on April 19, 1970 1 male on April 23, 1990 2 people on June 2, 1993 1 female on May 29, 1996 5 people (or more) on August 20, 1998 **80 people (or more) on August 11, 1999** 1 female on September 3, 1999	**1 male on August 11, 1999** (Note: 1 young female was killed on July 6, 1884.)

Stated Monetary Damage by Tornadoes

$1,200	June 1, 1955
$5,000	June 16, 1955
$20,000	June 3, 1963
$2,000	August 28, 1964
$10,000	April 17, 1966
$15,000	November 2, 1967
$50,000	August 14, 1968
$5,000	May 29, 1987
$3,000	May 29, 1988
$25,000	September 17, 1989
$500	March 23, 1990
$1,500	September 23, 1992
$8,000	April 4, 1993
$50,000	May 3, 1993
$15,000	June 2, 1993
$500,000	May 29, 1996
$170,000,000+	**August 11, 1999**
$100,000+	September 3, 1999

$100,000	May 25, 2000
$2,000,000	September 8, 2002
$100,000	March 23, 2004
$173,011,200+	**Total**

Utah's Strongest Tornadoes

F-scale ratings (from the Fujita Intensity Scale) have been assigned to these strong Utah tornadoes based on damages caused by these twisters and their probably wind speeds:

F2	January 22, 1943	Young Ward
F2	June 3, 1963	Bountiful
F2	November 2, 1967	Emery
F2	August 14, 1968	West Weber
F2	May 29, 1987	Lewiston
F3	**August 11, 1993**	**Uinta Mountains**
F2	August 11, 1999	Salt Lake City
F2	September 8, 2002	Manti