A KANSAS CITY AREA GUIDE TO

# SEVERE THUNDERSTORMS AND TORNADOES


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# and

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by

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This guide is designed to provide information about the causes and nature of severe thunderstorms and tornadoes. It also contains some severe weather safety rules and a glossary of severe weather terms. The examples used in it are taken from weather events which are likely to be familiar to Kansas City area residents.

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*Cover Photo: The tornado of 20 May 1957, which eventually struck Ruskin Heights, Missouri, as it passed near Ottawa, Kansas.*

# SEVERE THUNDERSTORMS AND TORNADOES

What causes tornadoes and other severe weather? The answer to that question involves two separate but related studies. First, meteorologists seek to understand the large scale weather patterns that produce intense thunderstorms. Secondly, the thunderstorm itself is examined to learn the small scale processes that lead to formation of the severe weather.

## LARGE SCALE WEATHER PATTERNS

Severe weather forecasters look for several key features on the weather maps when formulating a Tornado Watch. Warm, moist air at low levels is one of the prime ingredients looked for when tornado forecasting. To the public it is sultry or muggy air -- usually drawn inland from over the Gulf of Mexico toward an approaching low pressure area. Above this, the presence of a warm, dry layer of air in the low to middle levels of the atmosphere (say up to 10,000 feet) is another prime ingredient and often serves to distinguish severe thunderstorms from the more common non-severe thunderstorms. At upper levels the air is usually cold and dry.

Also, forecasters look for areas of low pressure in the middle and upper levels of the atmosphere, generally moving from west to east. These upper level systems (called "troughs") usually cause rising air motion ahead of them. A jet stream (a narrow, high level band of winds with speeds up to 200 mph) is also found associated with these upper level disturbances.

Finally, solar heating often intensifies the thunderstorm process; hence, the late afternoon and early evening peak for tornado occurrences. As the surface of the earth heats, moist air in the lower layers is warmed and rises. The warmer the air, the faster it rises, as in a hot air balloon. This rising moist air produces all types of cumulus clouds, including cumulonimbus (thunderstorm) clouds. Additional heat is released as the water vapor in the rising air condenses to form visible clouds. If all ingredients are present in the correct proportions, this released heat can lead to the formation of severe thunderstorms and tornadoes.

Severe thunderstorms do not occur randomly in the moist air, but normally form along lines of converging winds or other boundaries such as cold or warm fronts. Often, intense squall lines form well ahead of advancing surface fronts.

Tornadoes are known in many parts of the world but nowhere are they as common as in the central and southern United States. The geography of the central plains, with the Gulf of Mexico to the south and the Rocky Mountain and high plateaus to the west make this region the tornado capital of the world. Only here are the ingredients for tornadoes brought together so frequently. Also, the very strong tornadoes which occasionally strike in this country are virtually unheard of elsewhere.

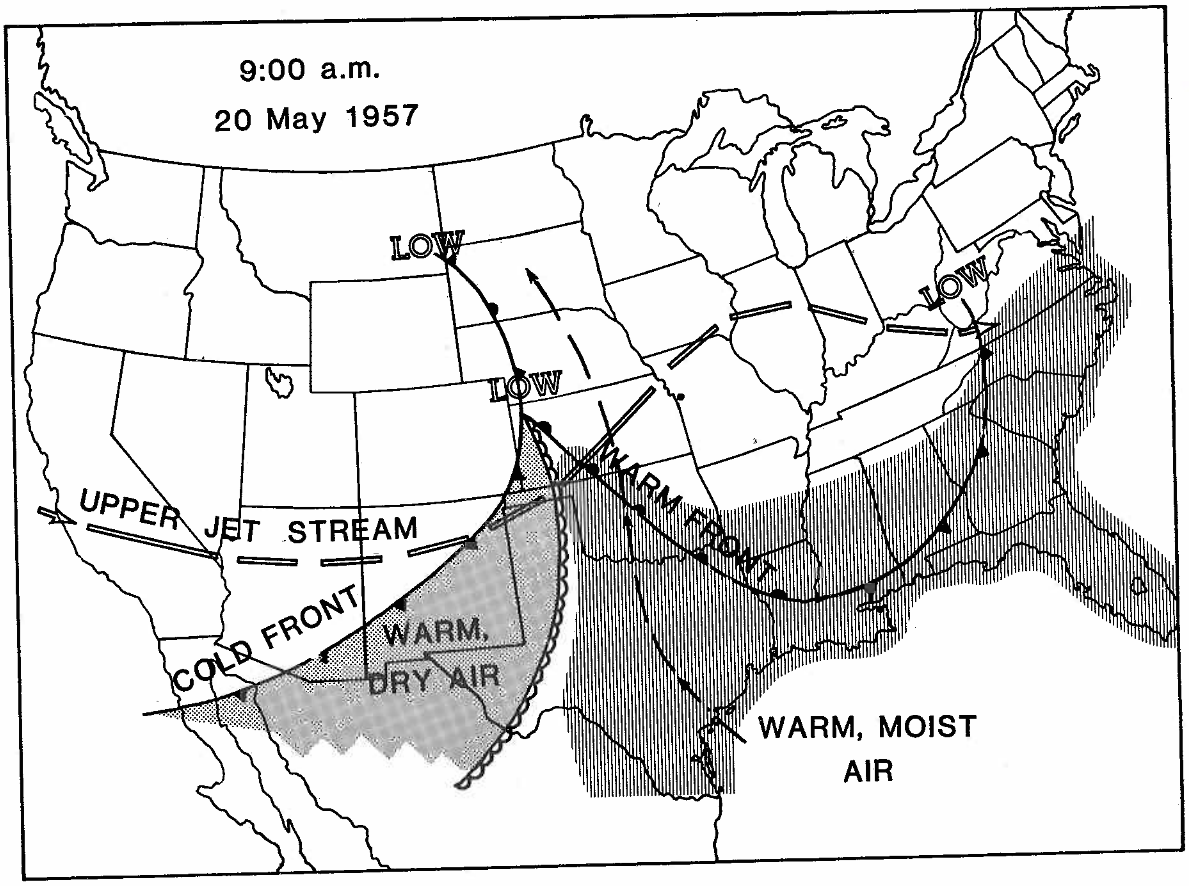



*Fig. 1. Weather map showing main ingredients which led to the tornado outbreak of 20 May 1957. Low-level winds bringing warm, moist air northward are shown as the thin dashed arrows. Other features are as labelled.*

For an example of how these weather patterns develop, consider the case which produced the infamous tornado on 20 May 1957 which devastated Ruskin Heights, Missouri. As shown in Fig. 1, at 9:ØØ a.m. of the fateful day, a weather system lay west and southwest of Kansas City with strong low-level winds forcing the warm front (which lay across southwest Kansas and Oklahoma) northeastward toward Kansas City. This push of warm, moist air toward the threatened area was bounded on the west by a counterclockwise flow of warm, dry air from the desert southwest. The boundary between the moist and the dry air at the surface is shown by the scalloped line. Aloft, jet stream winds raced in gentle curves around an upper trough in Colorado and New Mexico.

Thus, the ingredients needed for an outbreak of severe weather were brought together that afternoon, as the heating from the sun warmed the low-level air still more, creating a tendency for the low-level air to rise. This enhanced the rising motion ahead of the upper-level disturbance.

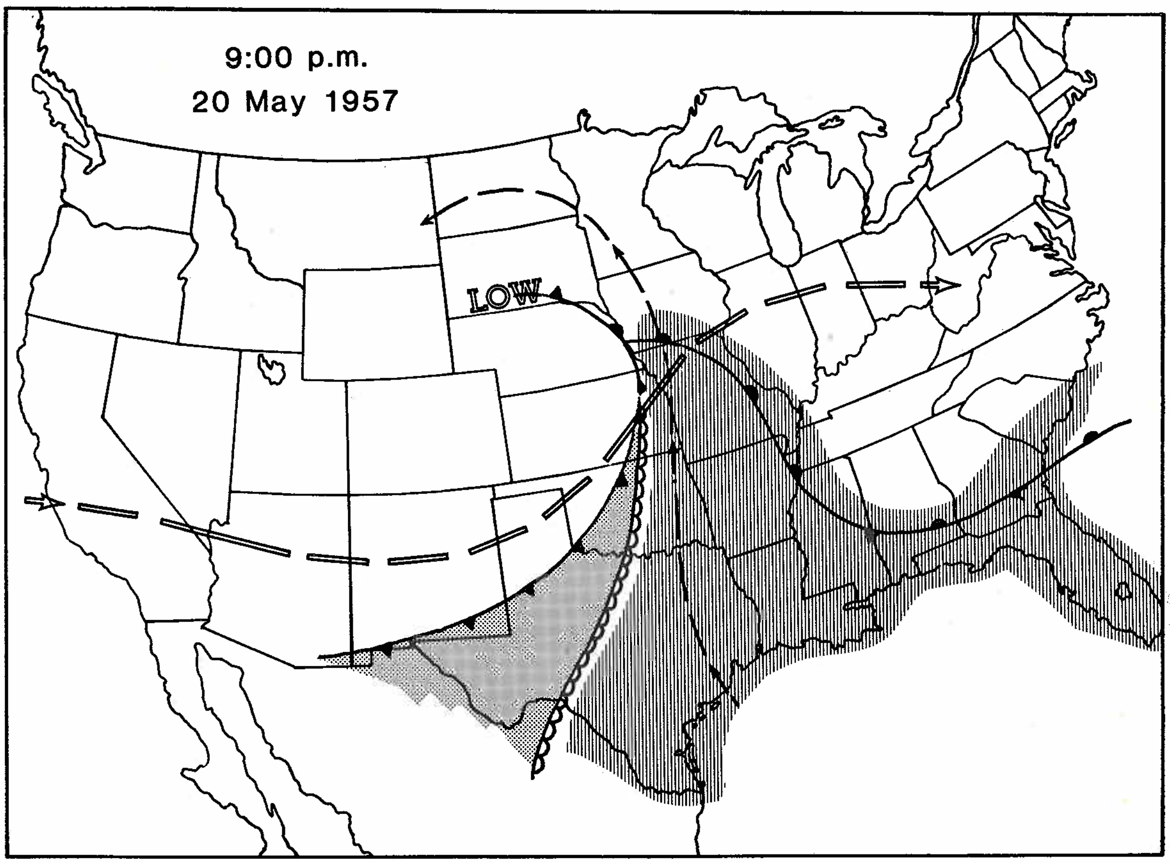



*Fig. 2. Similar to Fig. 1, except conditions are shown at a time near the end of the severe weather outbreak.*

By 11:ØØ a.m., the first tornado of the day was underway in eastern Colorado. Tornadoes and severe thunderstorms spread across southern Nebraska and northern Kansas during the afternoon. The most severe activity was generally under the upper jet stream as it intersected the advancing warm front (Fig. 2) - a quite typical situation for progressive-type outbreaks (those with a moving zone of concentrated severe weather). This area of severe weather was approaching the Kansas City area by 6:ØØ p.m. A second, more localized outbreak of tornadoes developed in northeast Oklahoma about 5:ØØ p.m. ahead of the advancing dry air, and continued on past 11:ØØ p.m. that night. By midnight, a total of 35 tornadoes had occurred.

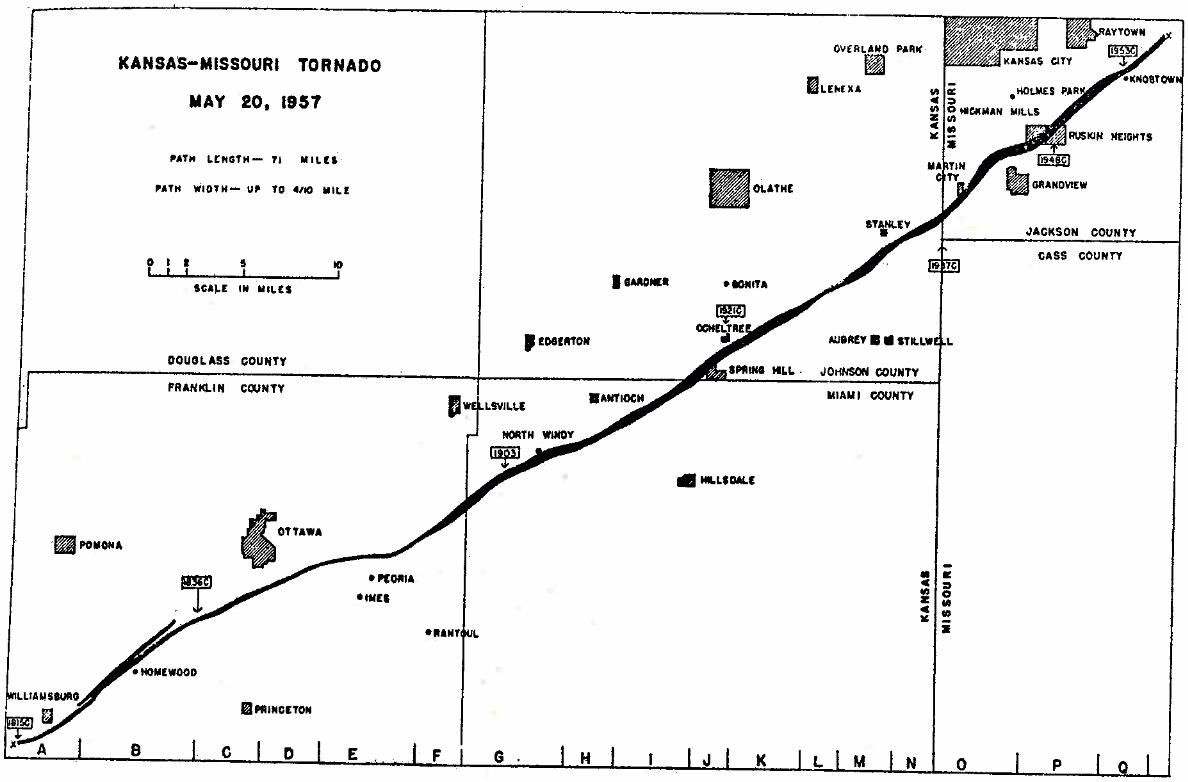
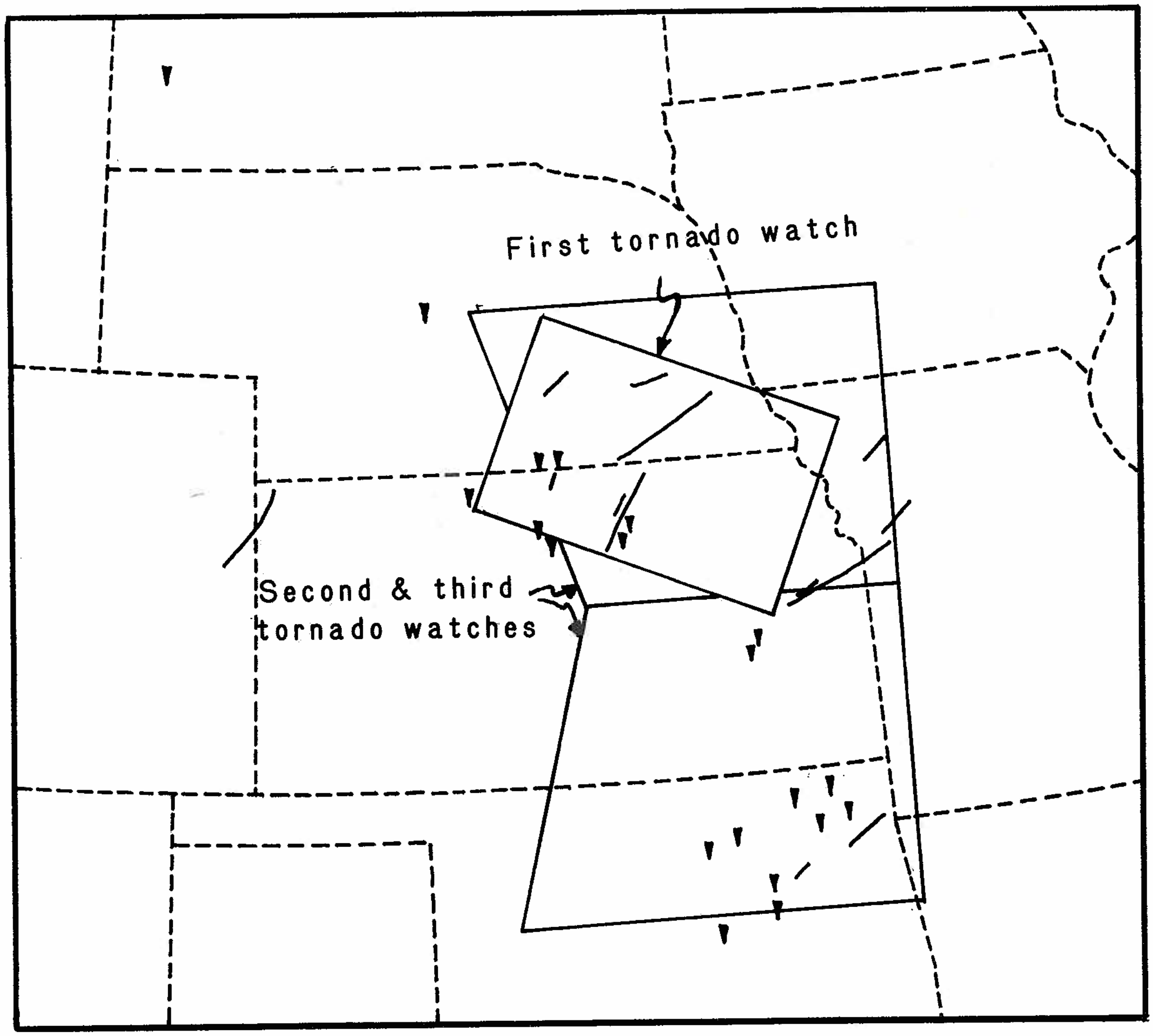



*Fig. 3. Map showing the path of the devastating tornado which hit Ruskin Heights.*

The tornado which eventually slammed into the Kansas City suburb of Ruskin Heights first touched down southwest of the small Kansas town of Williamsburg (Fig. 3) at 6:15 p.m. Well before this, at 11:ØØ a.m., the severe weather forecaster on duty in Kansas City had issued the tornado watch shown on Fig. 4. Between 3:15 and 4:1Ø p.m., two more tornado watches were issued (also shown), this time including the Kansas City area. These watches, combined with the developing weather, had persons in the affected areas at a high state of readiness to react to any tornadoes which might occur.




## Reported Tornadoes 20 May 1957

*Fig. 4. Tornadoes and tornado watches of 20 May 1957. Brief touchdowns are shown by dark triangles, while long-tracks are depicted by lines.*

As a result, tornado warnings spread quickly ahead of the violent tornado as it moved northeastward at 40-45 mph toward Kansas City. News of the approaching storm was relayed by volunteer storm spotters to radio and TV broadcasters. As the storm passed near Ottawa, Kansas, it appeared as shown on the cover. Note the low cloud structure (a wall cloud) beneath which the tornado is occurring. Also, a multiple vortex phase is revealed by Fig. 5, in which the tornado is actually composed of 2 (or more) smaller whirls which rotate around each other. This storm was obviously large and dangerous. The tornado entered the heavily populated suburb of Ruskin Heights about 7:45 p.m., near the end of its 71-mile track. At that time, its damage path was over one-third of a mile wide, as wide as it had been at any point along the track.

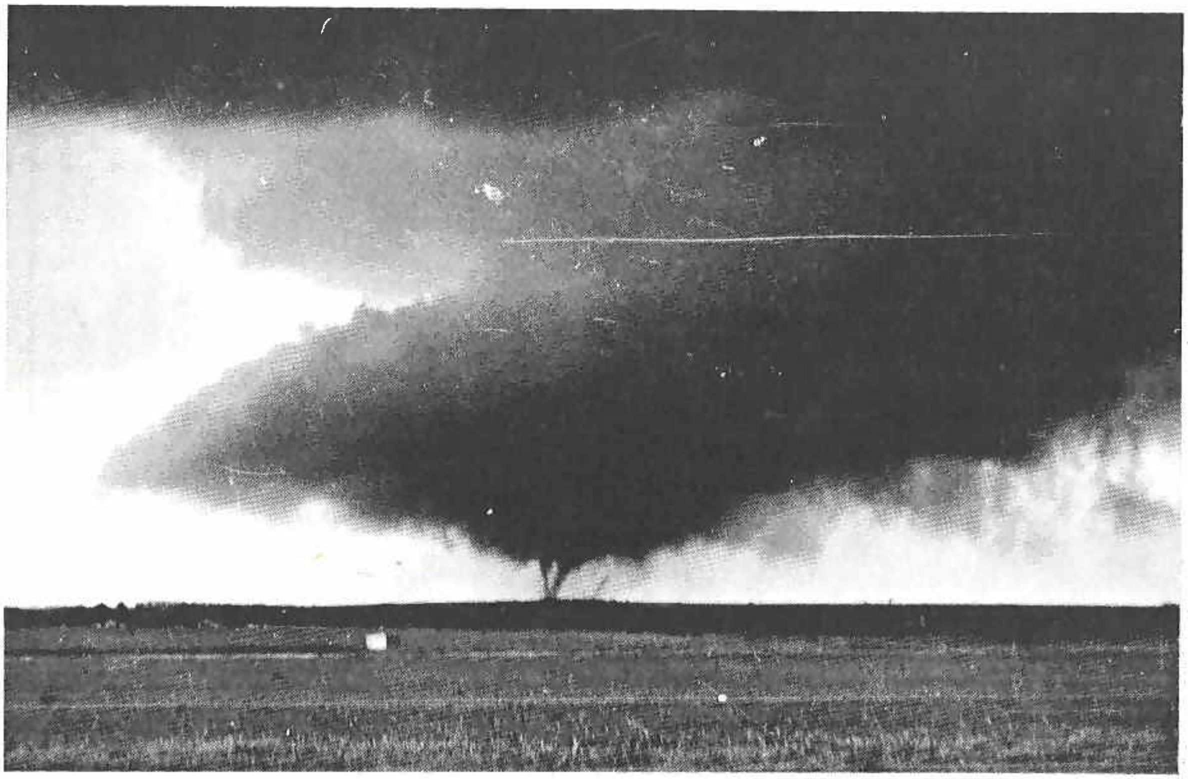


*Fig. 5. Another view of the Ruskin Heights storm near Ottawa, Kansas, showing a multiple vortex phase of the tornado.*

Within Ruskin Heights, the devastation was tremendous. Witnesses observed multiple vortices, and those within the path heard the characteristic roar of the tornado as it approached. Even today, more than 25 years later, people of Kansas City still remember vividly their experiences of that night. All told, 37 people died. There is no doubt that had there been no tornado watches and warnings, this violent tornado could have claimed many, many more lives.

## STORM SCALE STRUCTURE: THE ORDINARY THUNDERSTORM

Thunderstorms are quite common events in most places of the world. At any one time, about 2000 such storms are occurring all over the globe. By far the majority of thunderstorms are beneficial: they provide needed rainfall and, by their electrical activity, change atmospheric nitrogen into forms which are necessary for plant growth. In the United States, only about 10% or less of the total number of thunderstorms produce severe phenomena (tornadoes, hail, and strong straight winds). Less than 10% of the total of the severe storms are accompanied by 1 or more tornadoes. Thus, less than 1% of all thunderstorms are tornadic.

Almost two-thirds of all tornadoes are classified as weak - these have winds around 100 mph, short and narrow damage paths, and last only a few minutes. About one-third of the tornadoes are in the strong category - with winds around 200 mph, paths a few hundred yards wide and several miles long, and may last several minutes. In the same way that only a very few thunderstorms produce any sort of tornado, only a small fraction of tornadoes can be classified as violent (about 2%). Such tornadoes can have winds up to about 300 mph, path widths of from several hundred yards up to a mile, path lengths from several tens of miles up to 300 miles long, and lifetimes from several tens of minutes up to 3 hours. Although violent tornadoes are only a tiny part of the annual tornado total, they account for nearly 70% of tornado deaths and a large part of the damage.

In order to examine severe thunderstorms and tornadoes, the ordinary thunderstorm needs to be considered to see how severe storms differ. The ordinary thunderstorm shares two features with its more spectacular cousins. First, in order to be called a thunderstorm, there must be lightning present to produce thunder. Lightning is the single phenomenon which, year in and year out, is responsible for most thunderstorm-related fatalities. The electrical discharge which is called lightning may take place entirely within the thunderstorm cloud, it may flash from one cloud to another, it can travel from within the cloud into the air, or it may reach many miles from the cloud to objects on the ground. It is the cloud-to-ground discharge which usually produces deaths. Since such deaths usually occur one at a time, they are rarely newsworthy on a national level. However, lightning is a potential killer in any thunderstorm and so safety precautions are necessary. The best protection is to stay indoors or in an automobile. See NOAA Publication PA-75009 ("Thunderstorms") for more details.

The second facet of an ordinary thunderstorm shared with the severe variety is its basic building block, the cell. Each thunderstorm is composed of one or more cells. These cells follow a life cycle which typically lasts about 30 minutes. The first stage in the cell life cycle is when cumulus clouds develop into towering cumulus (Fig. 6). All thunderstorms develop from cumulus clouds, but only a few cumulus clouds go on to become thunderstorms. During this first stage, the cell is composed entirely of rising air (updraft), has little or no precipitation within it, and none is reaching the ground - thus, the cell is invisible to weather radars which only detect precipitation. However, the water condensing in the updraft does produce the very small water droplets which make up a visible cloud.

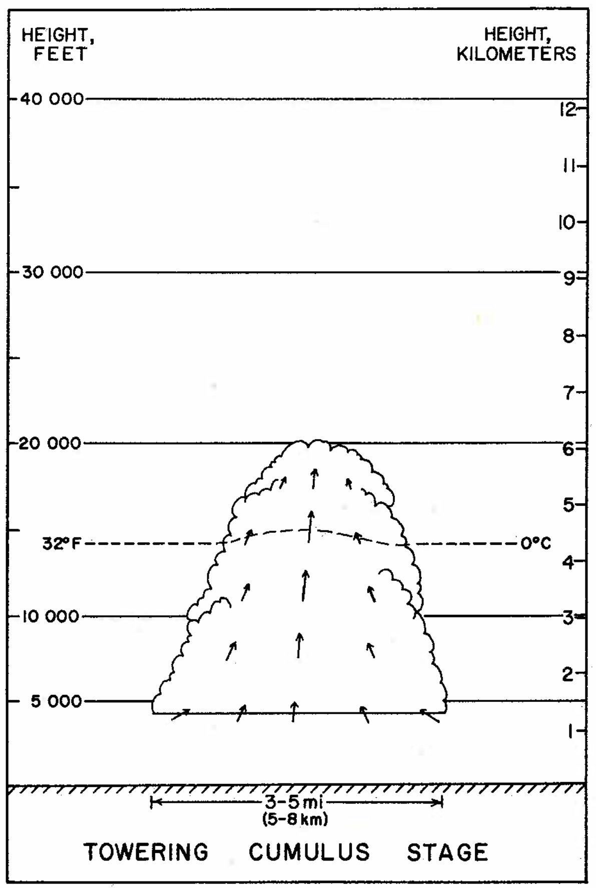



*Fig. 6. Schematic diagram of the towering cumulus stage in thunderstorm cell development.*

When the storm reaches the freezing level (that is, where the air temperature aloft reaches 32°F or 0°C), it begins to form precipitation. When this occurs, the cell