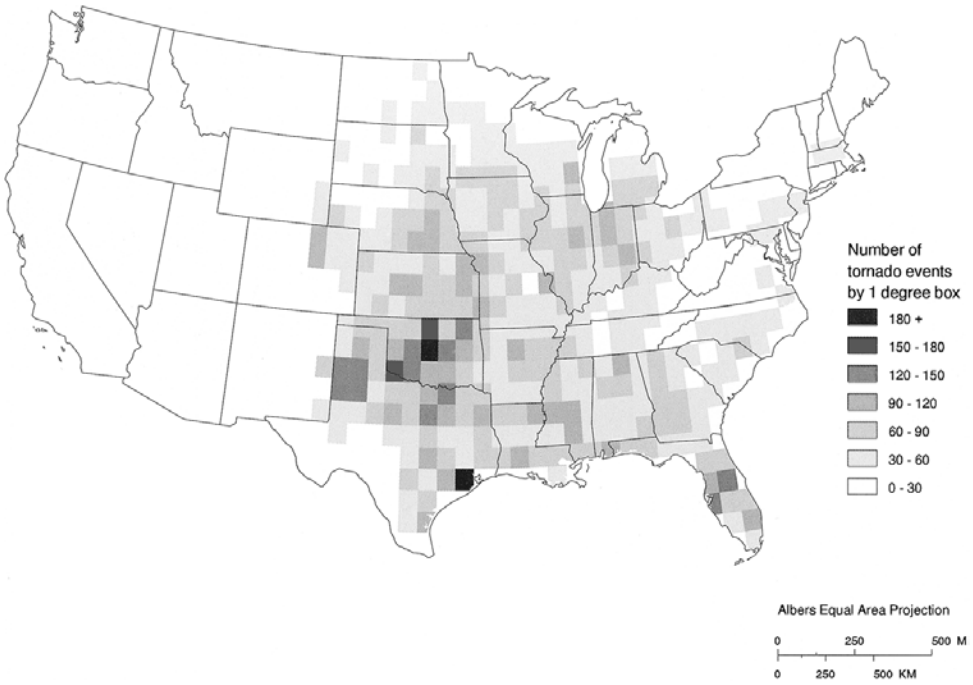
Tornadoes

The United States east of the Rocky Mountains is the most common site in the world for tornadoes to occur. Tornadoes strike most commonly in an area extending from Texas to the Dakotas. This is the area known as “tornado alley.” In the southern United States tornadoes occur most commonly in the months of March to May, whereas in northern states they occur most commonly in the summer months. However, every state has recorded tornadoes in every month of the year and at most times of day and night.



National summary of tornado occurrences, 1954-1983. (From Federal Emergency Management Agency: *Multi-hazard identification and risk assessment: a cornerstone of the national mitigation strategy,* Washington, DC, 1997, FEMA.)

Table 4-4 Tornado frequency by state

Rank	State	Number of tornadoes (1953-1991)	States with most frequent number of tornadoes per 100,000 km²
1	Texas	4949	Florida
2	Oklahoma	2204	Oklahoma
3	Florida	1762	Indiana
4	Kansas	1735	Iowa
5	Nebraska	1449	Kansas
6	Iowa	1229	Delaware
7	Missouri	1044	Louisiana
8	Illinois	1042	Mississippi
9	South Dakota	970	Nebraska
10	Louisiana	949	Texas

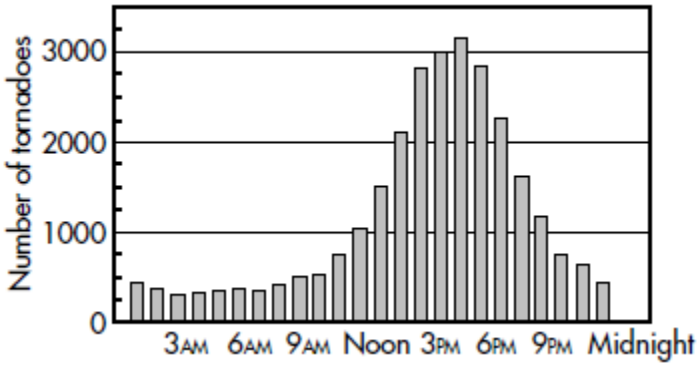
Data from National Climatic Data Center. In Lillibridge SR: Weather-related problems. In Noji EK: *The public health consequences of disasters,* New York, 1997, Oxford University Press.

Tornadoes are rotating columns of air that stretch from thunderclouds to the ground. Tornadoes most commonly occur as part of a severe thunderstorm, but they also occur in the front range of the Rockies and Southern Plains when warm air near the ground flows up slopes

on mountainsides. Tornadoes associated with super cells are usually weaker than other types of tornadoes, but these can be multiple. Tornadoes frequently accompany hurricanes. Here their most common location is to the right and ahead of the path of the hurricane. Tornadoes have been recorded at up to 10,000 feet elevation.

The typical tornado occurs within a severe thunderstorm. These are weather systems (tornado cyclones) that can be many miles in diameter. A tornado cyclone is usually at least 10 miles in diameter with a core that is about 1.5 to 2.5 miles in diameter. Not every tornado cyclone will produce a tornado. Tornadoes start as a horizontal spin of air resulting from the barometric pressure differentials created by areas of hot and cold air. This rotation occurs at a height of about 3 miles. Warm rising air then tilts the column so that the direction becomes vertical.

Distribution of tornadoes in the United States by month of occurrence. (Courtesy American Red Cross and Federal Emergency Management Agency.)



U.S. tornadoes by hour of day, 1950-1989. (Modified from Grazulis TP: *Significant tornadoes 1680-1991,* St. Johnsbury, Vt, 1993, The Tornado Project of Environmental Films. In Monmonier M: *Cartographies of danger: mapping dangers in America,* Chicago, 1997, University of Chicago Press.)

Storms that produce tornadoes are often described as having a dark greenish appearance. They are invariably accompanied by heavy rain and often by hail. Hail larger than 3/4 inch is only rarely associated with tornado formation. Single tornadoes usually form on the south side of hail precipitation near the interface between the updrafts and downdrafts of the thunderstorms.

Tornadoes travel at forward speeds of 30 to 70 mph. Their internal winds, however, can reach speeds of over 200 mph, resulting in a loud roar, sometimes described as sounding like a passing train.

Tornadoes go through several stages of development:

Laminar or funnel cloud stage: This is a horizontally rotating cloud formation that may either resolve or intensify and reach toward the ground.

Transition stage: At this stage the funnel cloud has moved toward the ground, and the rotation column of air forms a helical spiral.

Turbulent stage: This is the classic funnel-shaped cloud between the ground and the clouds.

Subsidiary suction vortex: These are secondary vortices that form alongside the main tornado.

Occasionally multiple tornado vortices occur. These are the result of mesocyclones with several mini-tornado cyclones within. Multiple tornadoes typically leave cycloidal tracks. Multiple tornadoes tend to increase in severity as their number increases. The severity of a tornado is described using the Fujita scale, which was developed in the late 1950s by Theodore Fujita, a meteorologist at the University of Chicago. Tornadoes may be transparent until they start to pick up debris and dust. Variations on tornadoes are waterspouts and land spouts. Waterspouts occur most commonly in the Gulf Coast and southeastern United States and in cold, late falls in the western United States. Land spouts are most common along the leading edge of cool air that results from the downdraft in a mesocyclone.

Tornadoes are monitored and forecast by the National Severe Weather Forecast Center in Kansas City, Missouri; Next Generation Radar Stations (NEXRAD) throughout the United States; the National Oceanic and Atmospheric Administration (NOAA); the University of Oklahoma at Norman, Oklahoma; local weather spotters; and the National Weather Service. Advances in the detection of tornadoes now provide an accuracy of prediction of more than 90% with approximately 20 minutes of warning time over most of the United States. The greatest deficiency in making this information available to potential tornado victims is the lack of local warning systems, such as sirens and alarms. Warning systems should be constructed so that they do not rely on electrical power supply because this is often knocked out in tornadoes and strong winds. Power horns operated with pressurized air are reliable.

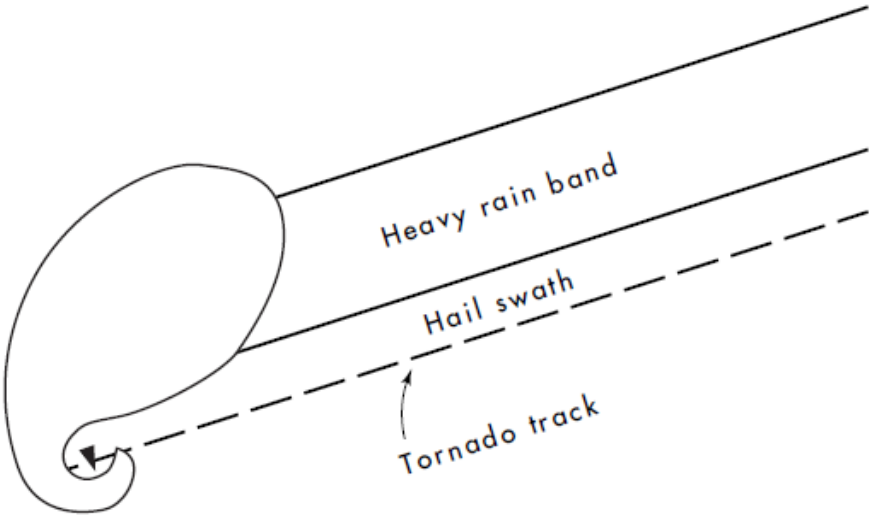


FIG. 4-8 Diagram of tornado track and associated hail swath. This pattern is typical of tornadic thunderstorms in the Midwest. (Modified from Agee EM and Asai T, editors: Cloud dynamics: an introduction to deep convective systems. In *Advances in earth and planetary sciences*, vol 13, Dordrecht, Netherlands, 1982, D Reidel.)

The National Severe Storms Forecast Center in Kansas City, Missouri, issues tornado watches. Local National Weather Service offices issue tornado warnings. Local officials may sound sirens in a tornado warning.

A *tornado watch* indicates that conditions are right for a tornado to develop and that the sky should be watched.

A *tornado warning* indicates that a tornado has been sighted or has been spotted on radar. Warnings give the location of the tornado and the area immediately affected by the warning.

The number of tornadoes reported may be fewer than actually occur. For example, it has been estimated that the number of tornadoes that actually occur in Arkansas is nearly four times greater than the number reported, whereas nearly 80% of the tornadoes that occur in Wisconsin are correctly recorded. Tornadoes that occur in uninhabited areas may not be recorded, and those distant from large human settlements may not be recorded as regularly as those that involve damage and human injury.

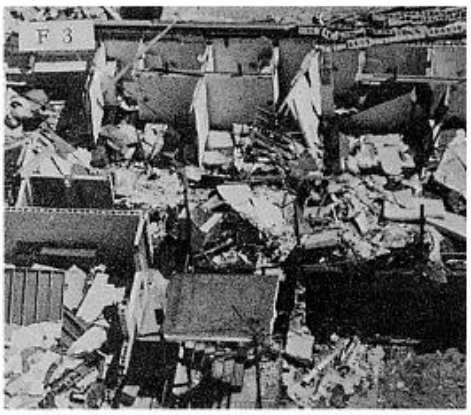
The threat of tornadoes is a product of the severity of tornadoes, the frequency with which they occur, and the damages and injuries they are most likely to cause. To take all of these factors into account, tornado “threat maps” have been proposed. Although these are not widely used, the example in Fig. 4-10 gives an idea of the unexpected risks that some states’ residents face because of tornadoes. In states such as Massachusetts and Connecticut tornadoes occur relatively infrequently, but when they do occur, they create huge problems for the communities affected.

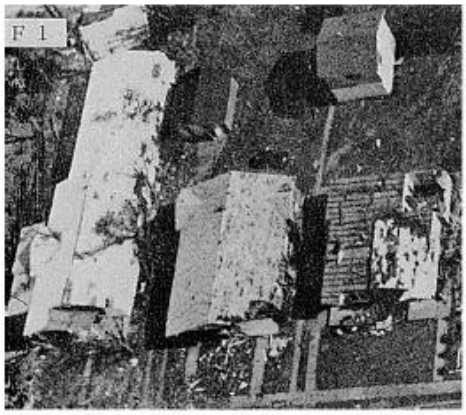
The greatest damage, injuries, and death in tornadoes result from flying debris. Direct wind damage is the second major cause of destruction. Although the number of recorded tornadoes in the United States has increased over the years, the number of tornado-related deaths has actually decreased considerably. Injuries and deaths from tornadoes are often clustered. One unfortunate example occurred in Alabama in 1994 when 22 out of 23 deaths were of members of a single church congregation. Another common pattern of casualties from tornadoes is that multiple members of a single family are injured or killed.

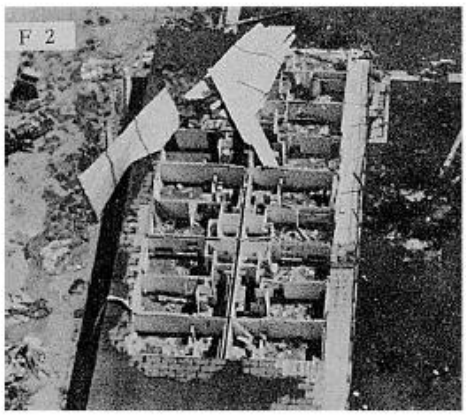
Injuries that result from tornadoes are often severe. Approximately 1 in 20 injuries is fatal, and 40% of all injured persons have to be hospitalized. The most common fatal injuries are multiple traumatic injuries, including those to the head and neck. Hospitalized patients are often treated for 3 weeks or more, indicating the complexity of injuries and just how serious they are. These data also indicate how important it is to seek protection from tornadoes. Although injuries to animals might be assumed to be similar to those of humans, there have been virtually no reports on animal injuries or deaths that result from tornadoes.

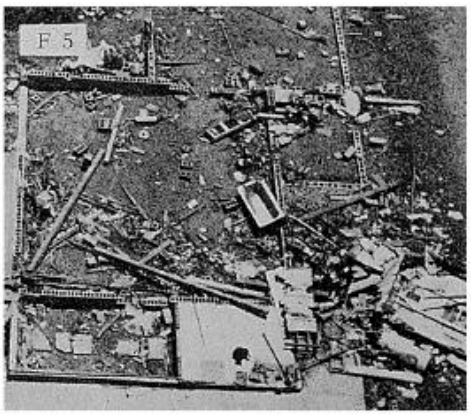
FUJITA SCALE FOR DAMAGING WIND

Scale	mph	Expected Damage
F 0	(40-72)	Light Damage
F 1	(73-112)	Moderate Damage
F 2	(113-157)	Considerable Damage
F 3	(158-206)	Severe Damage
F 4	(207-260)	Devastating Damage
F 5	(261-318)	Incredible Damage









Reference photographs distributed to U.S. weather stations for the assessment of tornado damage in the Fujita scale. (From Fujita TT: Tornadoes around the world, *Weatherwise* 56:83, 1973.)

Table 4-5 Characteristics of tornadoes

Fujita Scale	Wind speed (mph)	Typical path length (miles)	Path width	Severity of destruction	Frequency of occurrence (%)	Frequency of deaths (%)	Examples
F0	<73	<1.0	<17 yards	—	50	1	Damage to chimneys and sign boards; broken tree limbs; small and shallow-rooted trees uprooted
F1	73-112	1-3	18-55 yards	Minimal	35	7.5	Roof surface partially removed; mobile homes pushed off foundations; moving automobiles pushed from roads
F2	113-157	3.2-9.9	56-175 yards	Mild	10	20	Roof surfaces removed; mobile homes demolished; railroad cars overturned; large trees uprooted, snapped; lightweight objects thrown
F3	158-206	10-31.9	0.3-0.9 mile	Moderate	3	20	Roofs and walls removed from well-constructed buildings; trains overturned; large trees uprooted; heavy cars thrown
F4	207-260	32-99	1-3.1 miles	Severe	1	40	Well-constructed houses leveled; structures with foundations moved; heavy cars and large objects thrown
F5	>260	>100	>3.2 miles	Total	0.1	15	Extensive devastation; homes destroyed; trees debarked; cars thrown more than 100 yards; incredible phenomena occur

Data from Fujita TT: Tornadoes around the world; *Weatherwise* 56:83, 1973 National Climatic Data Center; and Golden JH, Snow JT in *National Weather Service natural disaster survey report*, Washington DC, 1991, National Oceanic and Atmospheric Administration.

Threat rating from tornadoes, 1953-1969. (Modified from National Oceanic and Atmospheric Administration: *Tornado preparedness planning*, Washington DC, 1978, NOAA