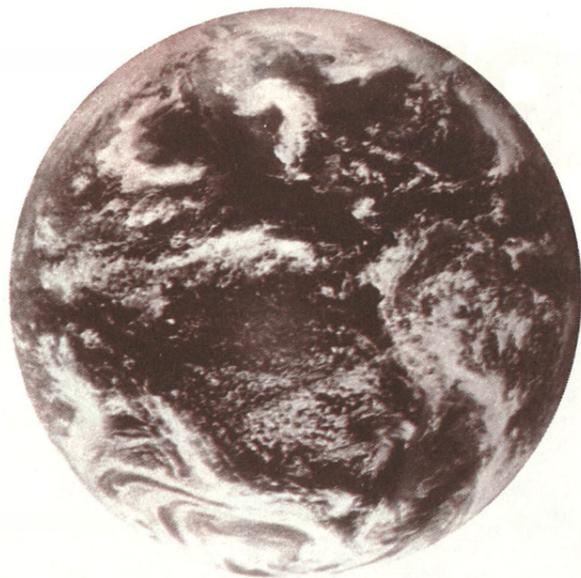


TORNADO



*Cover: A tornado, exploding the earth beneath it, ploughs through the countryside near Topeka, Kansas, May 3, 1977.
Photo: Fritz Mendell, The Topeka Capital-Journal.*

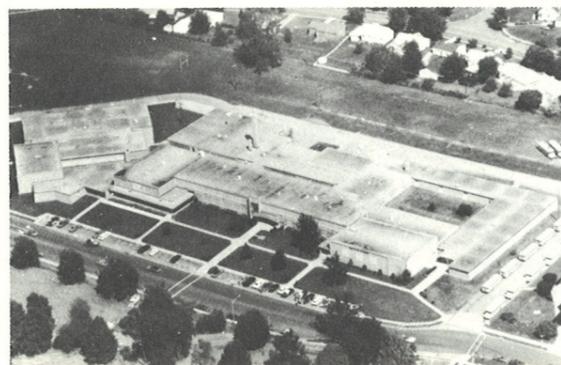


Of all the winds that sweep this planet's surface, tornadoes are the most violent.

THEIR TIME on Earth is short, and their destructive paths are rather small. But the march of these short-lived, local storms through populated areas leaves paths of terrible destruction. In seconds, a tornado can transform a thriving street into a ruin, and hope into despair.

It is the mission of NOAA, the U.S. Commerce Department's National Oceanic and Atmospheric Administration, to lessen the destructive and demoralizing effects of natural catastrophe. The National Weather Service, a major element of NOAA, provides the Nation's first line of defense against such destructive atmospheric phenomena. Through its tornado and severe thunderstorm watches and warnings, the National Weather Service gives persons in threatened areas time to find shelter. Through its disaster preparedness program, the National Weather Service educates community authorities and the general public on how to respond when threatened by severe storms.

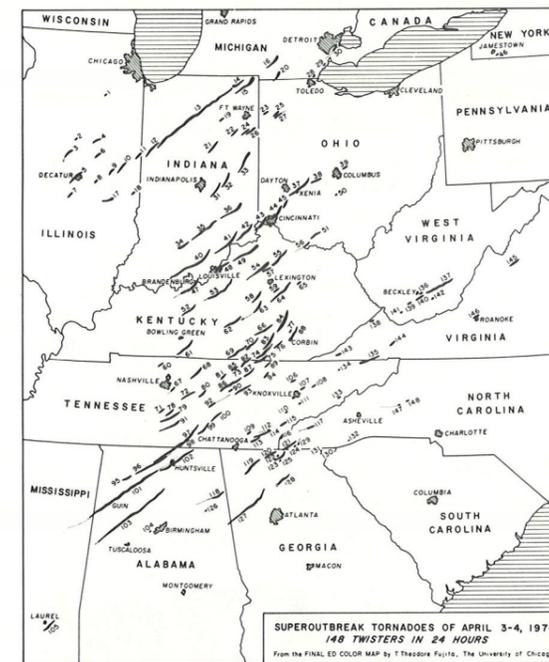
This booklet is part of that warning and preparedness service. It tells what tornadoes are and what they can do, when and where they are most likely to occur, what they look like, and what you can do to minimize their destructive, possibly lethal effects.



School days will never be the same at Xenia, Ohio, where an April 3, 1974, tornado demonstrated its incredible power by crushing the town's high school. Fortunately school was not in session when the storm struck. Photo: Superintendent of Schools, Xenia, Ohio.



The life cycle of a tornado is illustrated in these snapshots taken June 1, 1965, near Freeman, South Dakota. From a thunderstorm cloud a tornado forms (1) and enlarges after it descends to earth (2). A second funnel begins to form (behind the windmill, 3); the second funnel dissipates as the main funnel begins to thin out (4) and finally disappears. Photo: Willis Wipf.



Called the Super Outbreak, a rash of 148 tornadoes on April 3-4, 1974, struck 11 states and Canada causing 315 deaths and more than \$600 million in damage. Their tracks in the United States are plotted on this map by Dr. T. Theodore Fujita of the University of Chicago.

TORNADOES are short-lived local storms containing high-speed winds usually rotating in a counterclockwise direction. These are often observable as a funnel-shaped appendage to a thunderstorm cloud. The funnel is initially composed of nothing more than condensed water vapor and is itself a cloud.

However, when the circulation of the funnel reaches the ground, it usually picks up dust and debris, which eventually darkens the entire funnel. Tornadoic damage can occur on the ground even though the visible condensation funnel does not seem to reach the ground.

Scientists now believe that the tornado begins within an intense thunderstorm cloud and then develops downward to the Earth's surface. Not all thunderstorms will spawn tornadoes, but when the proper weather conditions are present (unseasonably warm and humid air at the Earth's surface, cold air at middle atmospheric levels, and strong upper level "jet stream" winds), severe thunderstorms and tornadoes are more likely to occur. Tornadoes sometimes occur with several smaller vortices rotating inside and around the wall of the parent tornado.

On the average, tornado paths are only a quarter of a mile—about one-half km—wide and seldom more than 15 miles—about 25 km—long. Tornadoes usually move from the south, southwest or west at about 30 mph—about 50 kph. But it's the longer lived tornadoes that usually move at more than 40 mph—about 65 kph—that are responsible for most of the tornado-related deaths. For example, during the afternoon and evening of April 3 and the early morning hours of April 4, 1974, 148 tornadoes across 13 States killed more than 300 people, injured more than 6,000, and caused \$600 million in damage. There were many large, long-lived tornadoes in that "super outbreak" of tornadoes. On March 18, 1925, the Tri-State tornado traveled 219 miles—about 350 km—across Missouri, Illinois, and Indiana in about 219 minutes and killed 689 people.

The Violent Winds

TORNADO FORMATION requires the presence of layers of air with contrasting characteristics of temperature, moisture, density, and wind flow. Complicated energy transformations produce the tornado vortex. Many theories have been advanced as to the type of energy transformation necessary to generate a tornado, but none has won general acceptance. The two most frequently encountered visualize tornado generation as either the effect of thermally induced rotary circulations, or as the effect of converging rotary winds. Currently, scientists seem to agree that neither process generates tornadoes independently. It is more probable that tornadoes are produced by the combined effects of thermal and mechanical forces, with one or the other force being the stronger generating agent.

If there is some question as to the causes of tornadoes and why they move the way they do, there is no question about the destructive effects of these violent storms. Every tornado is capable of great destruction. It can topple buildings, roll mobile homes, uproot trees, hurl

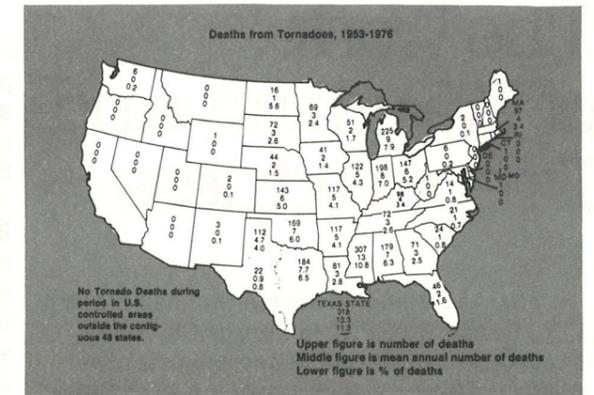
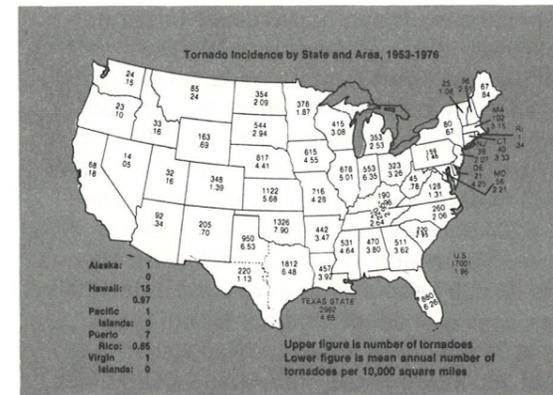
people and animals through the air for hundreds of yards—hundreds of meters—and carry lethal windborne missiles. For example, in 1931, a Minnesota tornado carried an 83-ton—about 80-metric-ton—railroad coach and its 117 passengers 80 feet—about 25 meters. In 1975, a Mississippi tornado carried a home freezer for more than a mile—about 2 km.

Tornadoes do their destructive work through the combined action of their strong rotary winds, the impact of windborne missiles, and the partial vacuum in the center of the vortex. As a tornado passes over a building, the winds twist and rip at the outside and at the same time push the upwind walls inward. The dynamic pressure reduction pushes downwind walls outward. The ripping winds and windborne missiles at the outer edges of a tornado's funnel "open" most structures and eliminate the damage that could otherwise be caused by the explosive effect of the partial vacuum in the center of the tornado.

Mobile homes are particularly vulnerable to strong winds and windborne missiles. Their relatively large surface area to weight ratio and thin cladding makes them prone to being rolled over and to penetration by missiles. Even if tied down they should be evacuated for more substantial shelter. Mobile home parks should have tornado shelters for their residents if located in tornado prone areas.



A tornado tore to shreds most of this mobile home park on June 8, 1974, but for 80 residents a positive plan and quick action paid off as they found safety in the concrete shelter club house at the center of the picture. Photo: Colorado Prestressers Association.



From 1953 through 1976, killer tornadoes occurred in 36 states with the maximum threat area east of the Continental Divide. They occurred in every month and during both day and night. The greatest potential for casualties from tornadoes is not necessarily where the greatest number of tornadoes occur, but where there is a high tornado incidence, a dense population, and many mobile homes or poorly constructed wood frame houses without basements. Mississippi with only 3.1 percent of the tornadoes and a moderate population density, has experienced the second greatest percentage (10.8) of the total tornado-related deaths. Oklahoma's 7.9 mean annual number of tornadoes per 10,000 square miles (25,900 square kilometers) is the highest.

TORNADOES OCCUR in many parts of the world and in all 50 States. But no area is more favorable to their formation than the continental plains and Gulf Coast of the U.S., and no season is free of them. Normally, the number of tornadoes is at its lowest in the United States during December and January, and at its peak in May. The months of greatest total frequency are April, May, and June.

In February, the center of maximum frequency lies over the central Gulf States. Then, during March this center moves eastward to the southeast Atlantic States, where tornado frequency reaches a peak in April. During May, the center of maximum frequency moves to the southern plains States, and in June, northward to the northern plains and Great Lakes area as far east as western New York State. The reason for this drift is the increasing penetration of warm, moist air from the Gulf while contrasting cool, dry air still surges in from the north and northwest; tornado frequency is greatest where these air masses wage their wars. Thus, when the Gulf States are substantially "occupied" by warm air systems after May, there is no cold

air intrusion to speak of, and tornado frequency drops. This is the case nationwide after June. Fall and winter cooling permits fewer and fewer encounters between warm and over-riding cold systems, and tornado frequency returns to its lowest level in midwinter.

The mathematical chance that a specific location will be struck by a tornado in any one year is quite small. For example, the probability of a tornado striking a given point in the area most frequently subject to tornadoes is 0.0363, or about once in 250 years. In the far western States, the probability is close to zero.

But tornadoes have provided many unmathematical exceptions. Oklahoma City has been struck by tornadoes 32 times since 1892. Baldwin, Miss., was struck twice by tornadoes during a 25-minute period on March 16, 1942. A third of Irving, Kans., was left in ruins by two tornadoes which occurred 45 minutes apart on May 30, 1879. Austin, Tex., had two tornadoes in rapid succession on May 4, 1922, and Codell, Kans., was struck three times, in 1916, 1917, and 1918—each time on May 20.

The Work of Warning and Preparedness

At NOAA's National Severe Storms Forecast Center (NSSFC), in Kansas City, Mo., Commerce Department meteorologists constantly analyze conditions over the 48 contiguous States in order to keep the country informed as far ahead of destructive events as possible.

Tornado Watch areas from the NSSFC identify areas approximately 100 miles—160 km—wide by 250 miles—400 km—long where weather conditions suggest a high probability of tornadoes. Then, local officials of the National Weather Service, working with SKYWARN spotter networks, law enforcement agencies, and other emergency forces, detect and track severe storms and tornadoes, and issue warnings for areas in their path.

On May 6, 1975, the actions of the Kansas City unit and the Omaha, Neb., office of the National Weather Service provided enough warning to keep recorded history's most damaging tornado from taking as large a toll in life as it did in property. Shortly after noon CDT, the NSSFC issued a tornado watch for Omaha. One might have expected the apathy that most big cities are noted for. But there was none in Omaha that day. The people were alert—watching—waiting.

Between 1:00 p.m. and 2:00 p.m., CB radio spotters activated their network. At 2:05 p.m., the Omaha Forecast Office issued a severe thunderstorm warning, based on radar, that included the city. The warning was sent to the spotter network, broadcasters, the Police and Sheriff's Department, and to other emergency officials via the NOAA/NWS and CD/NAWAS dissemination systems. At 3:15 p.m., another severe thunderstorm warning valid until 4:30 p.m. was issued. At 4:09 p.m., a spotter reported a tornado south of Omaha. Strong radar confirmation led to a 4:15 p.m. tornado warning for the Omaha area. A few minutes later sirens were sounded.

At 4:29 p.m., the tornado roared into the southwest corner of the city, took a northeast path through homes, apartments, an industrial area, across Interstate 80, into the crowded business area, and lifted on the north side in Benson Park about 4:58 p.m. It was 600 yards—550 meters—wide, packed 150-200 mph—240-320 kph—winds, and traveled about 9 miles—15 km—on the ground. Officials estimate 31,000 people lived or worked in the 200-block area that caught the full fury of the storm. When it was all over, there were 3 dead, about 200 injured, and more than 2,000 homes, apartments, or businesses destroyed or damaged.

That only three people lost their lives seemed incredible. The Omaha World Herald headlined: "IT COULD HAVE BEEN WORSE, BUT TORNADO ALERT WORKED." Officials who surveyed the wreckage estimated that the death toll could have been anywhere from 300 to 500 or higher. They credited the low loss of life to the early warnings by Civil Defense sirens and those issued over radio and TV. Local newspapers also played an important role in the education of the public on what to do in severe weather. When alarms sounded, people knew what to do and did it.



It was a near thing May 6, 1975, at the AK SAR BEN race track near Omaha, Nebraska, as a tornado swept past. See text. Photo: Bob Dunn.

TORNADO WATCHES are issued by the NSSFC in Kansas City, Missouri, for areas potentially threatened by tornadoes and severe thunderstorms. These watches specify a time period and an area where tornado probabilities are highest. Tornadoes may still occur outside the watch area(s) or time frame(s). Watches are teletyped directly to local NWS Offices and disseminated to the general public via commercial radio and TV and NOAA Weather Radio. In addition to the public, the watch activates law enforcement officers, civil defense personnel, organized radio spotter groups, and others to be prepared in case a warning is issued. In many areas these groups literally form the eyes of the community.

Watches are not warnings. A watch means tornadoes are possible. During a watch, people should watch for threatening weather and listen to radio and TV for more information.

Community Action

BECAUSE THE destructive effects of a tornado are usually concentrated in a relatively small area, much of the burden of warning, evacuation, and shelter falls to communities and individual citizens. Tornado detection requires a dense network of storm reporters and a reporting procedure within each tornado watch area. The National Weather Service receives help from more than 1,000 SKYWARN networks, and could use the help of many more.

Each network is organized around the needs of the area being served. In many locations, trained observers stationed about 2 miles—3 km—apart are established around the population center to be protected, with the heaviest concentration of observers to the southwest. In other areas with small populations, everyone is part of the network, and anyone who sees a tornado must report it promptly. Nationwide, these networks are made up of thousands of public-spirited citizens and organizations. SKYWARN volunteers

Otherwise, activities should not be disrupted. If you see threatening weather take shelter immediately.

TORNADO WARNINGS are issued by local National Weather Service Offices when a tornado has been sighted or indicated by radar. Warnings describe the area that could be affected. This area is determined from the location, size, direction (which can be erratic), and speed of movement of the storm. Since tornadoes are not always indicated by radar or sighted, *warnings may not always be given*. People should be alert to the possibility of such storms whenever threatening conditions occur.

When a warning is received, persons close to the storm should take cover immediately. Others should be prepared to take cover if threatening conditions are sighted.

know that their work saves lives and that they are the backbone of the tornado warning service. If you want to help, contact the nearest National Weather Service Office. Amateur and CB radio organizations are very important to SKYWARN. SKYWARN observers and the public are told of the possibility of severe weather by the watches issued by the NWS. When a watch is in effect, observers are asked to notify the nearest National Weather Service, law enforcement or Civil Defense office when a tornado is sighted, describing the storm, its location, and direction of movement.

A community warning network cannot be completely effective despite all efforts to improve its coverage and response time. There is always the chance that a tornado will not be detected or that a report will not get through to the National Weather Service. Nevertheless, a community warning network—complete with spotters, a functional emergency warning center, and sirens—will go a long way toward protecting a community during a tornado emergency.

Individual Safety Tips

- When a tornado threatens, your immediate action can save your life!
- STAY AWAY FROM WINDOWS, DOORS, AND OUTSIDE WALLS! PROTECT YOUR HEAD!
- In homes and small buildings, go to the basement or to an interior part of the lowest level—closets, bathrooms, or interior halls. Get under something sturdy.
- In schools, nursing homes, hospitals, factories, and shopping centers, go to pre-designated shelter areas. Interior hallways on the lowest floor are usually best.
- In high-rise buildings, go to interior small rooms or hallways.
- In mobile homes or vehicles, leave and go to a substantial structure. If there is no shelter nearby, lie flat in the nearest ditch, ravine, or culvert with your hands shielding your head.

(NOTE: The Defense Civil Preparedness Agency has several publications on shelters for nuclear blasts and fallout protection. Some of these could serve as tornado shelters. To request information write DCPA, Washington, DC 20301.

TORNADO WATCH: Tornadoes and severe thunderstorms are possible.

TORNADO WARNING: Tornado detected, take shelter immediately.

LISTEN TO RADIO, TELEVISION, OR NOAA WEATHER RADIO for latest National Weather Service bulletins.

Tornadoes Are Only One of a Thunderstorm's Killer Elements

- LIGHTNING IS A MAJOR KILLER. Stay indoors and away from electrical appliances when storms are nearby. If you are caught outside, stay away from and lower than high or conductive objects.
- THUNDERSTORM RAINS cause flash floods. Be careful where you take shelter.
- WINDS. Very strong straight-line winds can cause great damage.
- LARGE HAIL. A rare killer but very damaging.

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