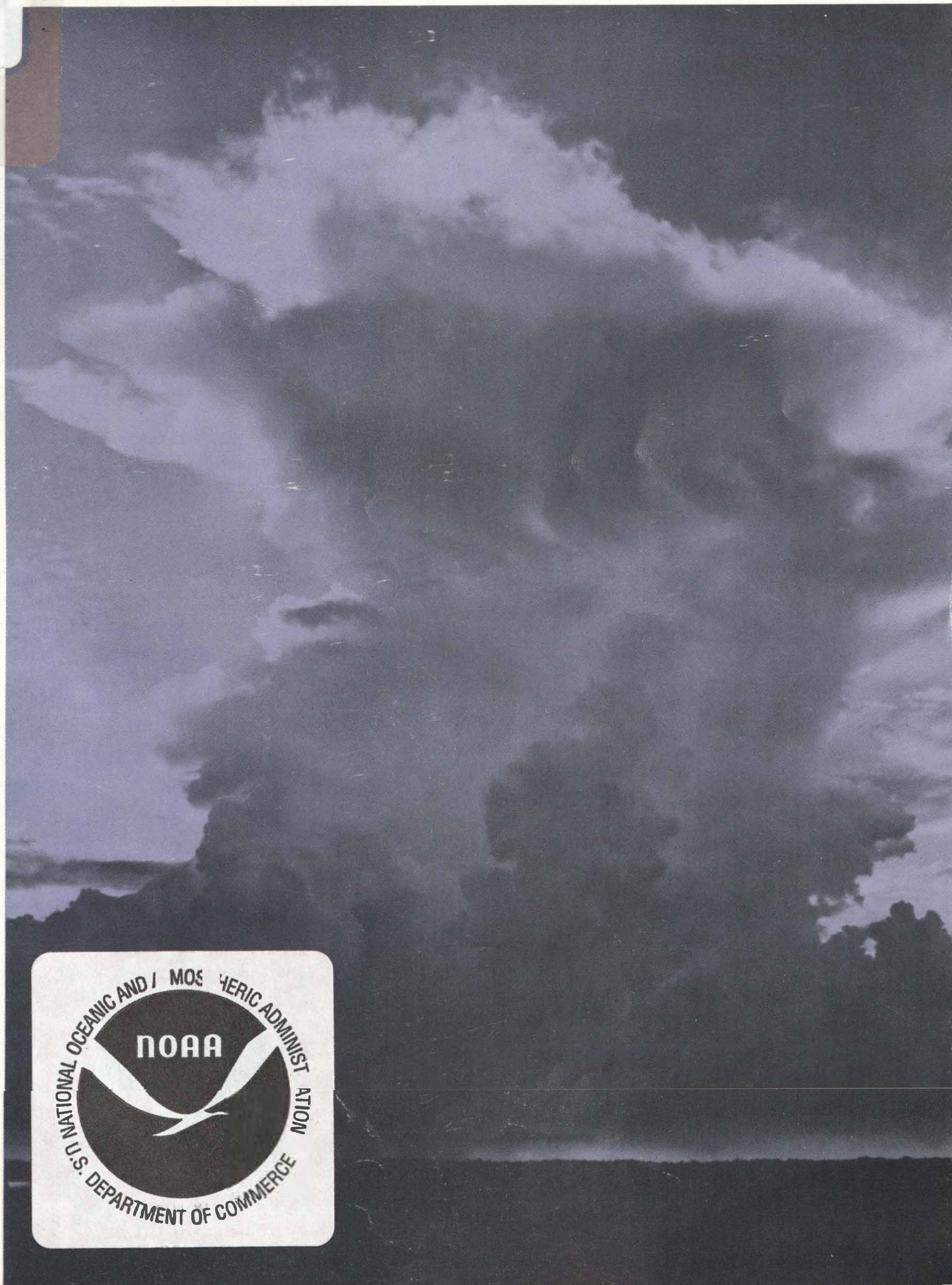
THUNDERSTORMS



U.S.
DEPARTMENT
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

THUNDERSTORMS

For most Americans, the Fourth of July, 1970, was an average summer holiday, the Saturday in a three-day weekend, a hot bright day to get out in, a day for beaches, picnics, celebrations, speeches, fireworks. But, for many, the fireworks were atmospheric, and got off to an early start; and the Fourth was a day for picking up the pieces.

The night before, north central Mississippi was swept by high winds, heavy rains, and almost continuous lightning, and a woman was killed when her mobile home collapsed and trapped her. A man out fishing drowned in Tennessee when fierce winds capsized his boat.

In Georgia, lightning, wind, and rain played havoc with some southwestern communities that night and early morning. North of Norman Park, at mid-morning on the Fourth, a man was struck and dazed by lightning. Later the same weather system caused wind and lightning damage around Crawford and Lexington, and relieved days of hot weather and weeks of drought.

A dawn waterspout started the day 40 miles southeast of West Palm Beach, Florida, and a lifeguard at Ormond Beach was fatally struck by lightning. Lightning destroyed a house at Chipley that afternoon, and a man was injured by lightning at New Smyrna beach. Key West had a funnel cloud aloft near evening.

Alabama had a small tornado south of Grove Hill toward mid-afternoon, and up in Virginia high winds injured a woman in a mobile home. Winds blew down car wash shelters in North Carolina, killing a man at Madison, and a Greenwood, South Carolina woman was fatally hit by lightning as she got out of her car.

A heavy cluster of storms north of New Orleans capsized boats on Lake Pontchartrain, where many Louisianans celebrated the Fourth on the water. Four persons, including a father and his two children, drowned. Lightning killed a man out in the woods east of Tickfaw. In Texas, tornadoes and high winds killed one and injured four that afternoon, and storms swept the area around Houston.

Late afternoon rains caused severe flash flooding in Oregon's Wheeler County, and an evening hailstorm damaged a thousand acres of wheat in Washington's Rattlesnake mountains.

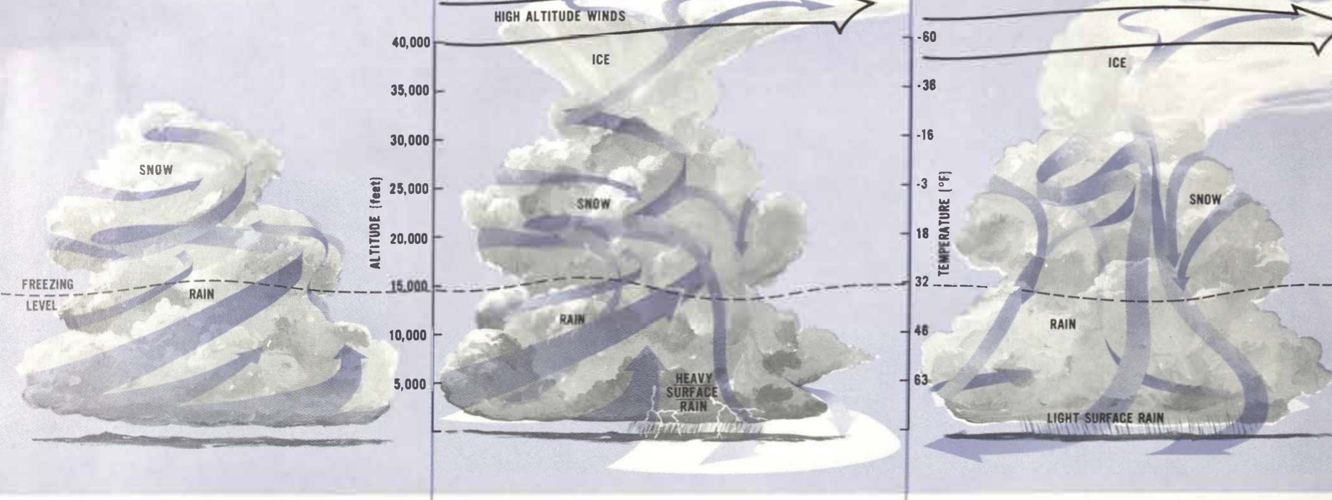
New York and Pennsylvania suffered under wide-ranging storms, and a funnel cloud over Lake Erie became a waterspout. Parts of Delaware were troubled by high winds, rains, and lightning set fires.

An average July day. In 17 states, a dozen Americans were killed, 16 more were injured, and millions of dollars' property and crop damage was done by the atmosphere's most familiar dramatic events—thunderstorms, and their destructive offspring: hail, lightning, high winds, heavy rains, and, smallest and most violent of all, the tornado.

It is estimated that at any given moment, some 1800 thunderstorms are in progress over the earth's surface. The frequency with which these giant generators of local weather occur, the quantity of energy they release, and the variety of forms this energy may take, make thunderstorms great destroyers of life and property. For a single household, a single family, they can produce as much tragedy as a war.

At NOAA, the U. S. Commerce Department's National Oceanic and Atmospheric Administration, much is being done to mitigate the destructive effects of thunderstorms. NOAA's National Weather Service keeps a round-the-clock, round-the-calendar watch on atmospheric conditions to provide routine forecasts for the United States, and to provide timely warning of severe storms. Commerce Department scientists in NOAA's Environmental Research Laboratories are probing these violent, shortlived storms to improve prediction techniques and to discover how to modify them beneficially.

This publication describes what thunderstorms are, how they form and how they die, and what you can do to prevent their doing violence to you.



Centered on converging surface winds, an updraft drives warm, moist air past condensation levels, where Cumulus clouds form. Vertical development is aided by air entering from sides, heat energy released by condensing water vapor, and outflow aloft.

Rain and snow begin to fall within the cloud and an ice phase appears in the towers. The formation and precipitation of solid or liquid particles marks the thunderstorm's mature stage, when a downdraft joins the updraft and lightning begins.

But eventually the downdraft destroys the parent cell. As surface winds shift from convergent to divergent, the updraft is cut off from its source of energy, precipitation weakens, stops, and the downdraft ceases.

Thunderstorms are generated by thermal instability in the atmosphere, and represent a violent example of convection—the vertical circulation produced in a fluid made thermally unstable by the local addition or subtraction of heat and the conversion of potential to kinetic energy. The convective overturning of atmospheric layers that sets up a thunderstorm is dynamically similar to convective circulations observed in the laboratory, where distinct patterns are generated in liquids by unequal heating.

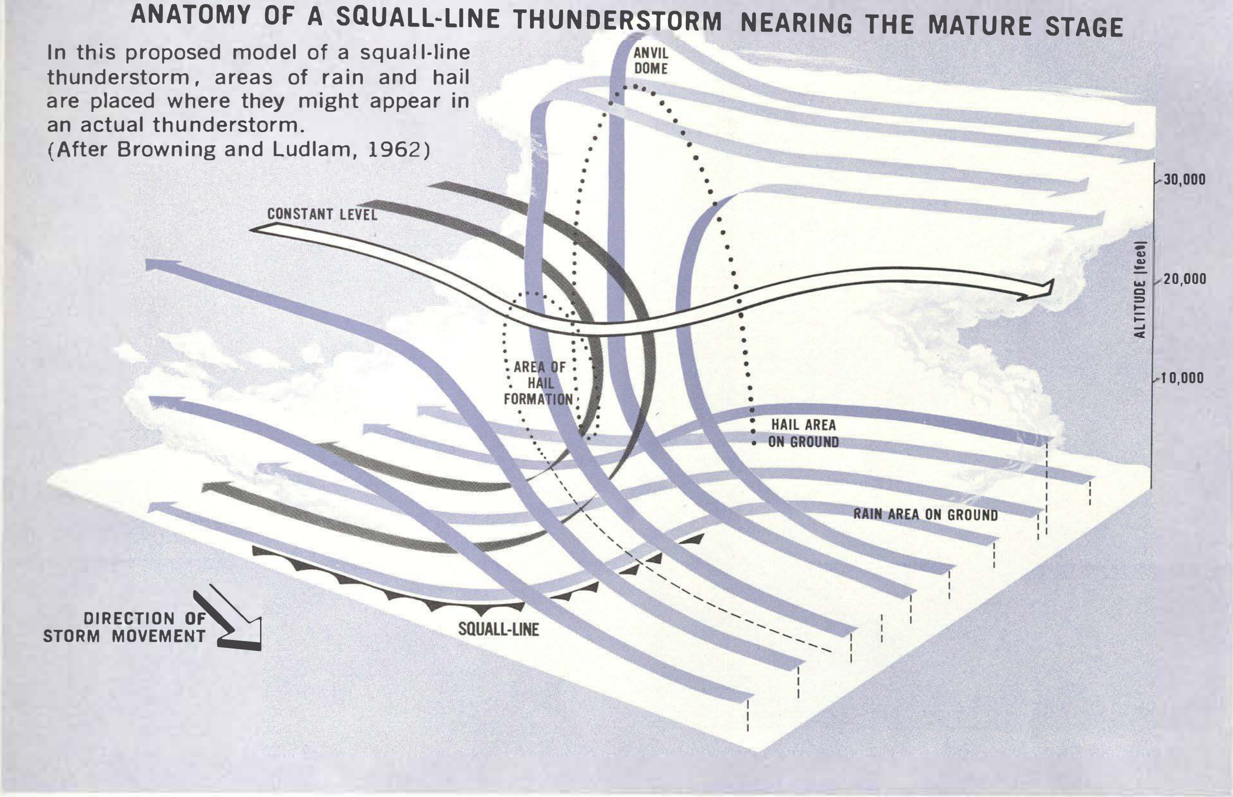
The orderly circulations produced in the laboratory are rarely encountered in the atmosphere, where areas corresponding to the rising core of laboratory convective cells are marked by Cumulus and Cumulonimbus clouds. Clouds are parcels of air that have been lifted high enough to condense the water vapor they contain into very small, visible particles. These particles are too small and light to fall out as rain. As the lifting process continues, these particles grow in size by collision and coalescence until they are large enough to fall against the updrafts associated with any developing convective clouds. Cumulus (for accumulation) clouds begin their towering movement in response to atmospheric instability and convective overturning. Warmer and lighter than the surrounding air, they rise rapidly around a strong, central updraft. These elements grow vertically, appearing as rising mounds, domes, or towers.

The atmospheric instability in which thunderstorms begin may develop in several ways. Radiational cooling of cloud tops, heating of the cloud base from the ground, and frontal effects may produce an unstable condition. This is compensated in air, as in most fluids, by the convective overturning of layers to put denser layers below less dense layers.

Mechanical processes are also at work. Warm, buoyant air may be forced upward by the wedge-like undercutting of a cold air mass, or lifted by a mountain slope. Convergence of horizontal winds into the center of a low-pressure area forces warm air near that center upward. Where these processes are sustained, and where lifting and cooling of the moist air continues, minor turbulence may generate a Cumulus cloud, and then a towering Cumulonimbus system.

The history of the vertical movement of air in the center of the Cumulus or Cumulonimbus cloud system is the history of each convective cell. Most thunderstorms have, at maturity, a series of several cells, each following a life cycle characterized by changes in wind direction, development of precipitation and electrical charge, and other factors.

In the first stage of thunderstorm development, an updraft drives warm air up beyond condensation levels, where clouds form, and where continued upward movement produces Cumulus formations. The updraft develops in a region of gently converging surface winds in which the atmospheric pressure is slightly lower than in surrounding areas. As the updraft continues, air flows in through the cloud's sides in a process called entrainment, mixing with and feeding the updraft. The updraft may be further augmented



ANATOMY OF A SQUALL-LINE THUNDERSTORM NEARING THE MATURE STAGE

In this proposed model of a squall-line thunderstorm, areas of rain and hail are placed where they might appear in an actual thunderstorm. (After Browning and Ludlam, 1962)

by a chimney effect produced by high winds at altitude.

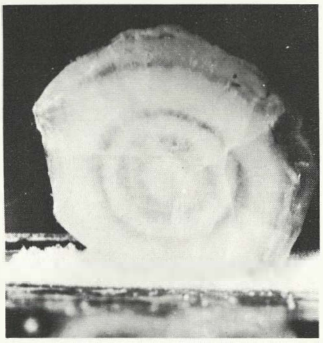
But a developing thunderstorm also feeds on another source of energy. Once the cloud has formed, the phase changes of water result in a release of heat energy, which increases the momentum of the storm's vertical development. The rate at which this energy is released is directly related to the amount of gaseous water vapor converted to liquid water.

As water vapor in the burgeoning cloud is raised to saturation levels, the air is cooled sufficiently to liberate solid and liquid particles of water, and rain and snow begin to fall within the cloud. The cloud tower rises beyond the level (3–5 kilometers) where fibrous streamers of frozen precipitation elements appear; this apparent ice phase is thought to be a condition of thunderstorm precipitation. The formation and precipitation of particles large enough and in sufficient quantity to fall against the updraft marks the beginning of the second, mature stage of the thunderstorm cell.

A thunderstorm's mature stage is marked by a transition in wind direction within the storm cells. The prevailing updraft which initiated the cloud's growth is joined by a downdraft generated by precipitation. The downdraft is fed and strengthened, as the updraft was, by the addition of entrained air, and by evaporational cooling caused by interactions of entrained air and falling precipitation. The mature storm dominates the electrical field and atmospheric circulation for several miles around. Lightning—the discharge of electricity between large charges of opposite sign—occurs soon after precipitation begins, a clue to the relationship of thunderstorm electrification and formation of ice crystals and raindrops.

At maturity, the thunderstorm cloud is several miles across its base and may tower to altitudes of 40,000 feet or more. The swift winds of the upper troposphere shred the cloud top into the familiar anvil form, visible in dry regions as lonely giants, or as part of a squall line.

On the ground directly beneath the storm system, the mature stage is initially felt as rain, which is soon joined by the strong downdraft. The downdraft spreads out from the cloud in gusting, divergent winds, and brings a marked drop in temperature. Even where the rain has not reached the ground, the thunderstorm's mature stage can be recognized by this cold air stream flowing over the surface. This is nature's warning that the thunderstorm is in its most violent phase. It is in this phase that the thunderstorm unleashes its lightning, hail, heavy rain, high wind, and—most destructive of all—the tornado. But even as it enters maturity, the storm has begun to die. The violent downdraft initially shares the circulation with the sustaining updraft, then strangles it. As the updraft is cut off from its converging low-level winds, the storm loses its source of moisture and heat energy. Precipitation weakens, stops, and the cold downdraft ceases. And the thunderstorm, violent creature of an instant, spreads and dies.



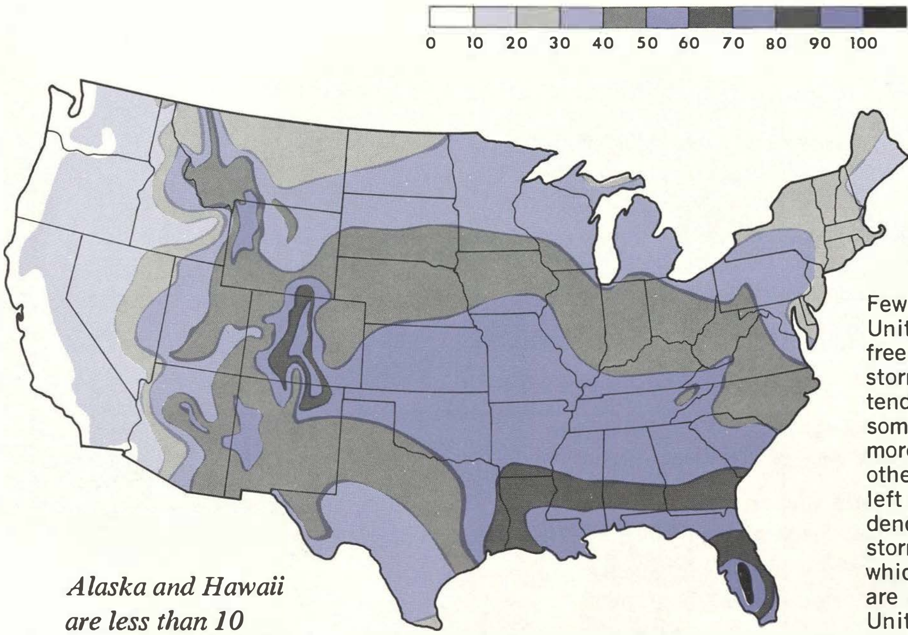
Unique, destructive offspring of thunderstorms.

LIGHTNING is a secondary effect of electrification within a thunderstorm cloud system. As a thunderstorm induces growing positive charge on the ground, the difference between the positive charge on the ground and negative charges in the clouds becomes great enough to overcome the resistance of the insulating air, and forces a conductive path for current to flow between the two charges. Lightning strokes represent a flow of current and may proceed from cloud to cloud, cloud to ground, or, where high structures are involved, from ground to cloud. In the United States, lightning kills more people each year, on the average, than hurricanes or tornadoes.

THUNDER is the sound produced by explosive expansion of air heated by the lightning stroke. The distance in miles to a lightning stroke can be estimated by counting the number of seconds between lightning and thunder, and dividing by five.

HAIL is precipitation in the form of rounded lumps of ice, called hailstones, and indicates an intensely active thunderstorm system. The layered inner structure of hailstones indicates that the stone grows by accretion of below-freezing liquid water on a growing ice particle, either by repeated lifting to freezing levels or by the long descent through strata of supercooled water.

TORNADOES are violently rotating columns of air that descend in the familiar funnel shape from thunderstorm (Cumulonimbus) cloud systems. A tornado vortex is normally several hundred yards in diameter, whirls usually in a counterclockwise direction (in the Northern Hemisphere), and contains winds which are estimated to exceed 300 miles per hour. Tornadoes occur on all continents, at any time of year, at any hour of the day. In the United States, their greatest frequency is in the spring during the middle and late afternoon. These small, shortlived storms are the most violent of all atmospheric phenomena, and, over a small area, the most destructive.



Alaska and Hawaii are less than 10

Few areas in the United States are free from thunderstorms and their attendant hazards, but some areas have more storms than others. The map at left shows the incidence of thunderstorm days—days on which thunderstorms are observed—for the United States.

THUNDERSTORM SAFETY RULES

1. Keep an eye on the weather during warm periods and during the passage of cold fronts. When Cumulus clouds begin building up and darkening, you are probably in for a thunderstorm. Check the latest weather forecast.

2. Keep calm. Thunderstorms are usually of short duration; even squall lines pass in a matter of a few hours. Be cautious, but don't be afraid. Stay indoors and keep informed.

3. Know what the storm is doing. Remember that the mature stage may be marked on the ground by a sudden reversal of wind direction, a noticeable rise in wind speed, and a sharp drop in temperature. Heavy rain, hail, tornadoes, and lightning generally occur only in the mature stage of the thunderstorm.

4. Conditions may favor tornado formation. Tune in your radio or television receiver to determine whether there is a tornado watch or tornado warning out for your area. *A tornado watch* means tornado formation is likely in the area covered by the watch. *A tornado warning* means one has been sighted or radar-indicated in your area. *If you receive a tornado warning,* seek inside shelter in a storm cellar, below ground level, or in reinforced concrete structures; stay away from windows.

5. Lightning is the thunderstorm's worst killer. Stay indoors and away from electrical appliances while the storm is overhead. If lightning catches you outside, remember that it seeks the easiest—not necessarily the shortest—distance between positive and negative centers. Keep yourself lower than the nearest highly conductive object, and maintain a safe distance from it. If the object is a tree. twice its height is considered a safe distance.

6. Thunderstorm rain may produce flash floods. Stay out of dry creek beds during thunderstorms. If you live along a river, listen for flash-flood warnings from the National Weather Service.

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