Congressional Research Service
Informing the legislative debate since 1914

IN FOCUS

Updated November 26, 2024

Tornadoes: Background and Forecasting

Tornadoes are narrow, violently rotating columns of air, extending from the base of a thunderstorm to the ground. They affect communities across the United States every year. Tornadoes can cause fatalities and injuries, destroy property and crops, and disrupt businesses. For example, a weather system on April 25-28, 2024, produced over 150 tornadoes (**Figure 1**), high winds, and large hail; it caused multiple deaths and injuries across parts of the Midwest and South, according to preliminary estimates from the National Oceanic and Atmospheric Administration (NOAA).

Tornadoes have been reported on all continents except Antarctica. They occur most commonly in North America, particularly in the United States, which reports approximately 1,200 tornadoes per year based on official data dating back to the 1950s. Tornadoes occur across the United States but form frequently in three regions: (1) southern plains (e.g., Texas, Oklahoma, Kansas), (2) Gulf Coast (e.g., Alabama, Florida, Louisiana, Mississippi), and (3) northern plains and upper Midwest (e.g., North and South Dakota, Nebraska, Iowa, Minnesota). Although tornadoes can form at any time, they occur mostly during spring and summer and usually during the late afternoon or early evening.

Classification

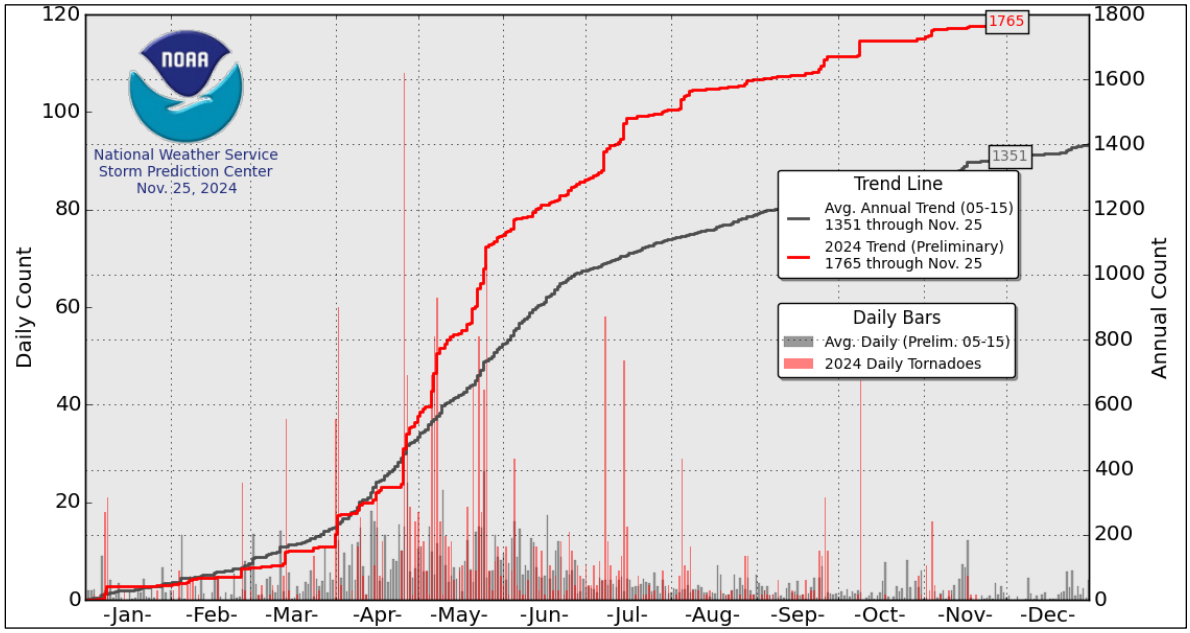
Experts estimate the strength or wind speed of a tornado by examining the damage it caused rather than by measuring actual wind speeds during an event. The Fujita, or F-scale, estimation method, developed in 1971, was used for over three decades, but its limitations prompted the development and adoption of a new scale in 2007, called the enhanced F-scale, or EF-scale (**Table 1**). The EF-scale uses 28 different types of damage indicators, such as building type, structures, and trees.

Table 1. Enhanced F-Scale

EF Number	3-Second Gust (mph)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200

Source: NOAA, Storm Prediction Center, "Enhanced F Scale for Tornado Damage."
Notes: EF = Enhanced F-scale. A 3-second gust is estimated at the point of damage based on the EF-scale's 28 damage indicators. The 3-second gust is not equivalent to wind speed measured in standard surface observations.

Figure 1. U.S. Tornadoes Daily Count and Running Annual Trend (as of November 25, 2024)



Source: NOAA, Storm Prediction Center (SPC), "Daily Counts and Annual Running Trend," November 25, 2024.
Notes: The 2024 U.S. daily occurrence and trend for preliminary tornadoes is shown in red, and the average daily and annual trend (2005-2015) is shown in gray. Because tornado reports come into forecast centers quickly, the trend for *preliminary tornadoes* reflects an estimate of the number of tornadoes. The National Climate Data Center and SPC analyze these reports to produce a final count, which may lower the count in cases where a tornado is reported more than once (NOAA, National Severe Storms Laboratory, "The Relationship Between Preliminary and Final Tornado Reports," February 13, 2009).

Forecasting, Detection, and Communication

Exactly how and why tornadoes form is not completely understood. Tornado formation is believed to be dictated mainly by conditions in and around rotating thunderstorms with well-defined circulation. The Secretary of Commerce, acting through NOAA's Administrator, has authority for weather forecasting and for issuing storm warnings (15 U.S.C. §313), including tornado forecasting and warnings. NOAA's National Weather Service (NWS) provides weather, water, and climate forecasts and warnings for the United States and its territories, adjacent waters, and ocean areas. Several other NOAA programs, including the National Severe Storms Laboratory, also focus on tornado research to improve observations, modeling, and instrument development, among other activities.

Forecasting and Detection

Severe thunderstorm and tornado forecasts are made by the NWS Storm Prediction Center (SPC) and by local weather forecast offices (WFOs). SPC forecasters use weather observations, numerical weather prediction models, and ensemble forecasting (running several models at one time) to determine if atmospheric conditions, temperature, and wind flow patterns may lead to the formation of severe weather. SPC issues three-day forecasts (convective outlooks) on a daily basis and mesoscale discussions of severe thunderstorm potential for the next six hours, with an emphasis on the next one to three hours, as warranted.

If conditions favorable for either multiple tornadoes or a single intense tornado continue to develop, SPC issues a tornado watch, which typically lasts six to eight hours. Such watches alert the public, emergency managers, storm spotters, broadcast media, and local WFOs that conditions have become favorable for the development of tornadoes. SPC aims to issue watches at least two hours before the first tornado event.

Forecasters and storm spotters recognize certain storm features from visual cues, such as the *forward* or *rear flank downdraft* (**Figure 2**), and particular patterns in Doppler radar images, such as the *tornadic vortex signature* (a region of intense concentrated rotation). WFOs issue tornado warnings when a tornado has been sighted or indicated by weather radar. The warning contains specific language about areas at risk, time frames, specific hazards, and recommended safety precautions for those at risk.

Communication

Several methods exist to communicate warnings to the public, including outdoor warning sirens, local television and radio stations, cable television systems, cell phone applications, Wireless Emergency Alerts, and NOAA Weather Radio All Hazards (NWR). NWS maintains and operates NWR, a nationwide network of radio stations broadcasting continuous weather information directly from the nearest WFO 24 hours a day, 7 days a week. NWR works with the Emergency Alert System, an automated system that allows NWS warnings to be disseminated by broadcasters, satellite digital audio services, direct broadcast satellite providers, cable television systems, and wireless cable systems.

Figure 2. Selected Components of Certain Thunderstorms

Source: NOAA, National Weather Service, "The Supercell Pt. 2."
Notes: A *forward flank downdraft* is the leading part of a supercell, with most of the heavy precipitation. A *rear flank downdraft* is a region of dry air subsiding on the back side of, and wrapping around, a cyclone (NOAA NWS, "Field Guide Glossary").

Congressional Considerations

Congress may continue to consider options related to improving forecasting, detection, and communication of tornadoes to reduce the loss of life and property. Some Members have introduced bills that would amend a NOAA tornado program to "rapidly" improve tornado forecasts, predictions, and warnings and to evaluate and potentially update the current tornado rating system. The bills also would require a pilot program for tornado hazard communication, including the improvement of social, behavioral, economic, risk, and communication sciences, among other actions.

In a November 2024 letter to House leaders and appropriators, 24 Members requested additional funding for NOAA's next-generation weather prediction system, including Radar Next, which may improve environmental data and products for "difficult-to-predict highly localized weather systems such as tornadoes." Congress could consider additional support for federal research into the application of machine learning, an artificial intelligence technique, to improve tornado forecasts. Improved lead time for warnings may provide additional time for people to find shelter.

NOAA has estimated that in 2024, April had the second-highest tornado count on record and May had the highest count, surpassing the 550 tornados of May 2003. However, experts have difficulty discerning if the average number of tornadoes each year has changed over time or if tornados are being reported more often today as a function of better detection, greater media coverage and verification efforts, more storm spotting and chasing, a growing population, and the advent of cell phone cameras. In addition, the science is unclear on if climate change has impacted, or may impact, tornado frequency or intensity overall or in certain circumstances. Congress may consider whether—and, if so, how—federal agencies should research potential connections between climate change and tornado activity.

Eva Lipiec, Specialist in Natural Resource Policy

IF12695

Disclaimer