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INSIGHT

Tornadoes: Background and Forecasting

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Background

Severe thunderstorms and tornadoes affect communities across the United States every year, causing fatalities, destroying property and crops, and disrupting businesses. Tornadoes are narrow, violently rotating columns of air that extend from the base of a thunderstorm to the ground, sometimes producing winds that exceed 300 miles per hour. Tornadoes have been reported on all continents except Antarctica; however, they occur most commonly in North America, particularly in the United States, which reports approximately 1,200 tornadoes per year. Tornadoes occur across the United States but form frequently in three regions, shifting seasonally: (1) southern Plains (e.g., Texas, Oklahoma, Kansas), (2) Gulf Coast, and (3) northern Plains and upper Midwest (e.g., North and South Dakota, Nebraska, Iowa, Minnesota). Tornadoes occur mostly during spring and summer (**Figure 1**) and usually during the late afternoon or early evening. However, tornadoes can occur at any time. For example, a deadly storm system with several reported tornadoes touched ground overnight and traveled from Arkansas toward the Great Lakes between December 10 and 11, 2021. Peak winds of one "long-track" tornado reached approximately 190 miles per hour. Aspects of the event were rare, such as its timing, distance traveled, and geographic location.

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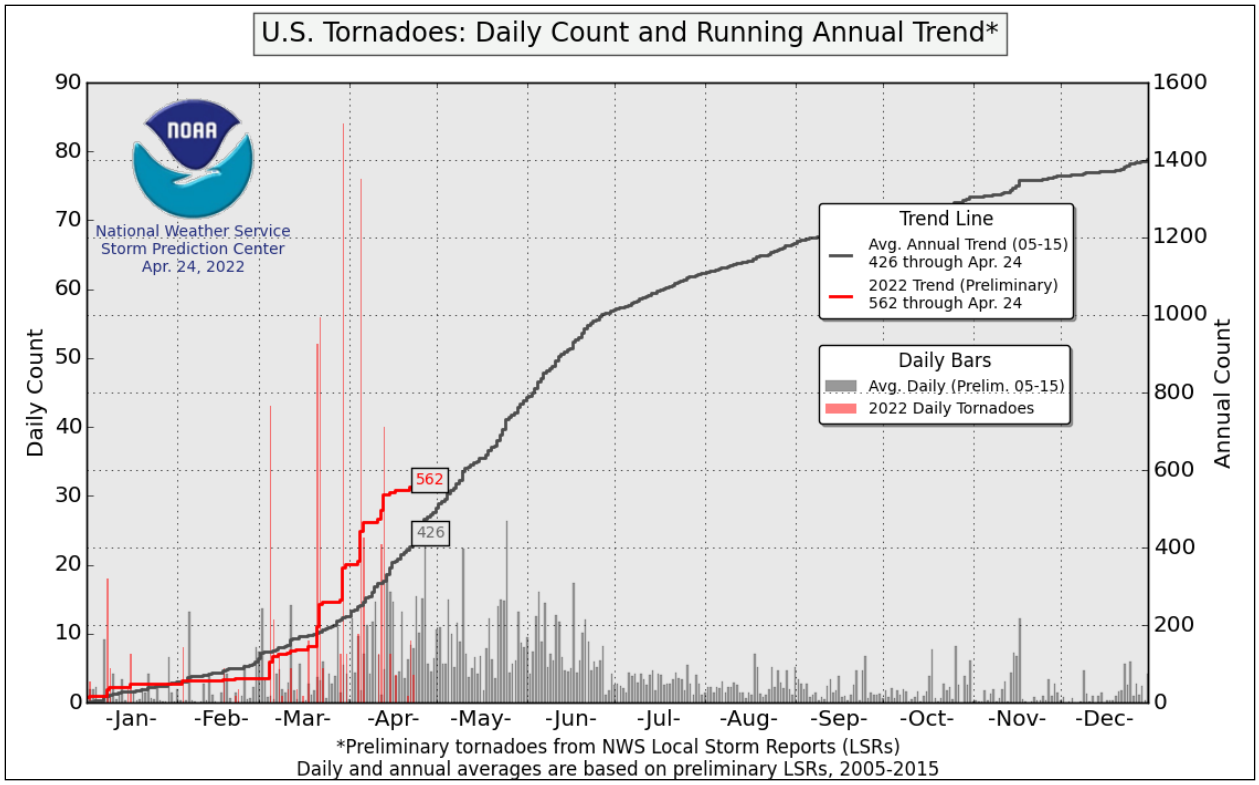
Figure 1. U.S. Tornadoes Daily Count and Running Annual Trend



Source: National Oceanic and Atmospheric Administration (NOAA), Storm Prediction Center, "Daily Counts and Annual Running Trend."

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 is intended to be a more robust and precise method of assessing a tornado's strength, and it 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: Three-second gusts are estimated at the point of damage based on a judgment of 8 levels of damage to the EF-scale's 28 indicators. These estimates vary with height and exposure. The 3-second gust is not equivalent to wind speeds measured in standard surface observations.

Forecasting, Detection, and Communication

Exactly how and why tornadoes form is not completely understood. Tornado formation is believed to be dictated mainly by storm-scale conditions in and around rotating thunderstorms with well-defined circulation. The National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS), at the discretion of the Secretary of Commerce, has statutory authority for weather forecasting and for issuing storm warnings (15 U.S.C. §313), including tornado forecasting and warnings. NWS provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas. Several NOAA programs, including the National Severe Storm Laboratory, also focus on 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 that 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 rear-flank downdraft, 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, recommended safety precautions for those at risk, and the WFO issuing the warning.

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, 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 over broadcasters, satellite digital audio services, direct broadcast satellite providers, cable television systems, and wireless cable systems.

Considerations

It is not clear whether the average number of tornadoes each year has changed over time, due to reporting issues, and if climate change has, or may, impact tornado frequency or intensity overall or in certain

circumstances (see here for more about the differences between weather and climate). Congress may consider whether and how federal agencies should continue research into potential connections between climate change and tornado activity and whether there are ways to mitigate any climate change-related impacts. Additional considerations for Congress may include how social, behavioral, and demographic factors play a role in tornado-related fatalities, as well as federal responsibilities in preventing and responding to damages from tornadoes and other wind-related events.

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