Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Tornadoes in Germany: intensity, temporal and spatial distribution

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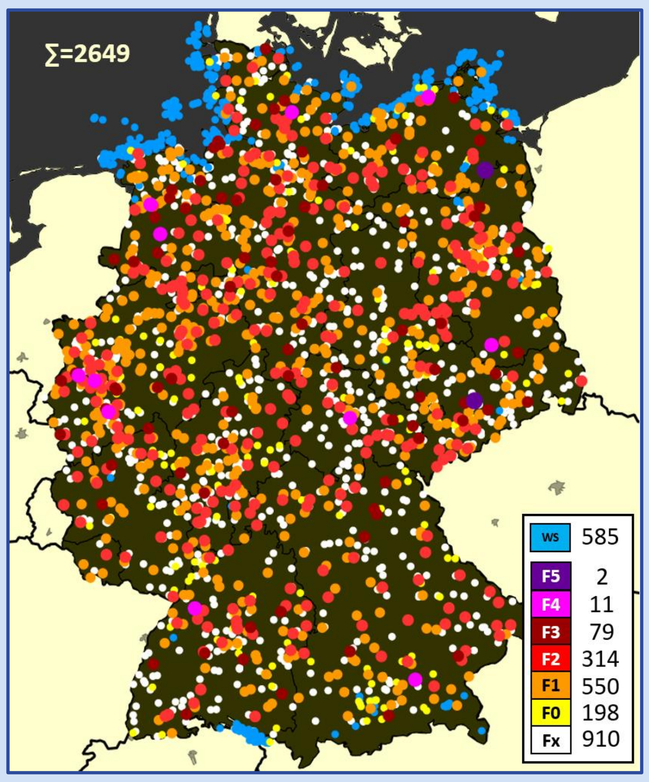
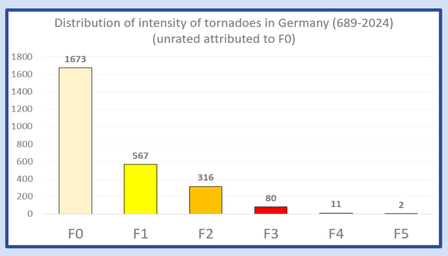
A detailed statistical analysis of tornadoes in Germany is conducted based on the European Severe Weather Database, using all quality-controlled tornado reports and focusing on the period 2000–2024. This is the first comprehensive analysis since the publication by Dotzek (2001). Since that study, 1,222 additional reports (covering the years 2000–2024) have been added to the database. The results illustrate the current temporal and spatial distribution of tornadoes in Germany and aim to raise awareness of potential tornado risks.

Data

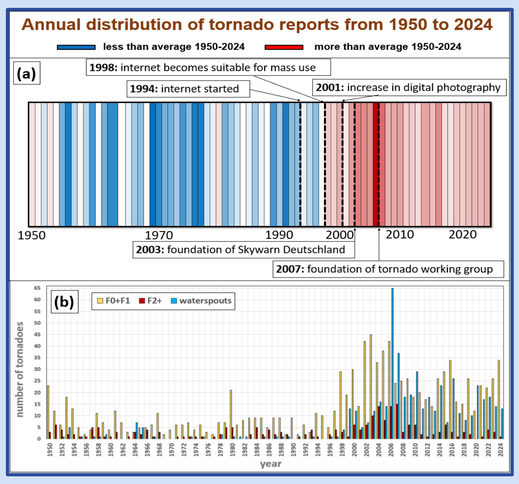


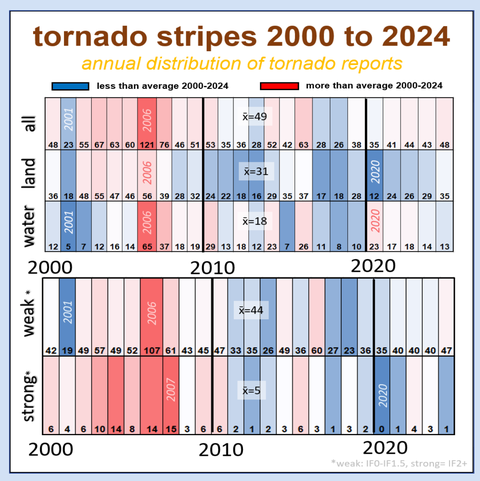
All reports with a quality level of QC1 or QC2 were used. Most of the statistical analyses focus on 2000–2024, when, thanks to the internet, digital photography, and emerging observation networks, thorough statistical analysis became possible. For the spatial distribution and the development of tornado occurrence numbers, the entire dataset was considered. Unrated tornadoes were assigned to the F0 category (see Grünwald and Brooks 2011). This yields a realistic intensity distribution.



Temporal development of tornado reports

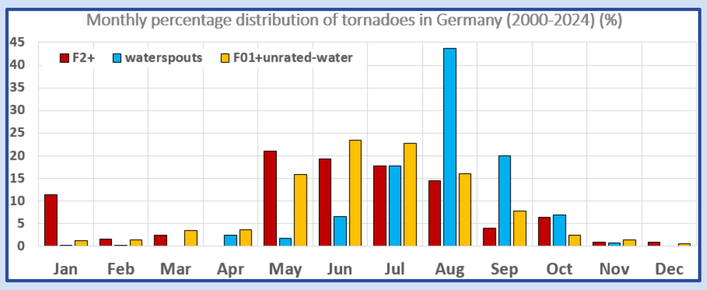
A clear increase in the number of tornado reports can be identified around the year 2000. In the decades before 2000, the average annual number of tornadoes fluctuated between 9 and 14 cases, rising to 49 for the period 2000–2024. The reasons for this increase are primarily non-meteorological, as illustrated in the graphic below. Since 2000, no clear long-term trend in the number of reports can be identified; instead, a year-to-year variability is evident, depending on the occurrence of dynamic weather situations. A distinct maximum appears around 2006, mainly attributable to waterspouts, while minima are found during the periods 2011–2013 and 2017–2020.





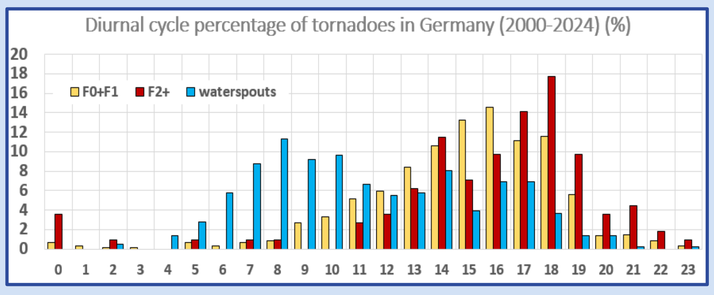
Annual cycle

The total number of tornadoes shows a clear maximum during the warm half of the year. Weak tornadoes peak in June and July, while significant tornadoes occur most frequently in May, followed by a gradual decrease over the summer months. A secondary maximum is observed in January. Waterspouts exhibit a distinct peak in August.



Diurnal cycle

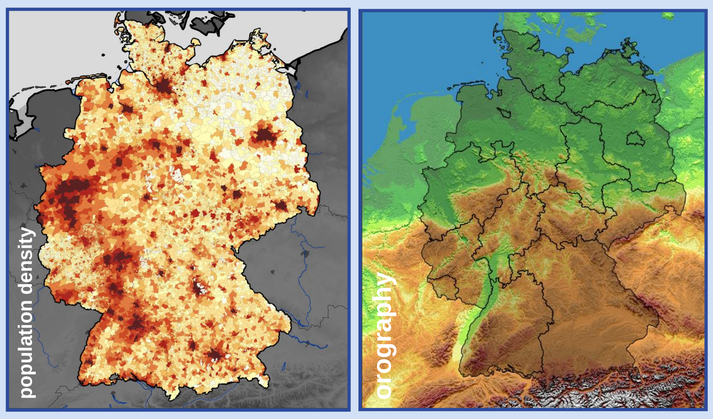
Excluding waterspouts, most tornadoes occur in the afternoon and evening, with 62% of cases between 11:30 and 17:30 UTC. Weak tornadoes peak between 14:30 and 16:30 UTC, while significant tornadoes occur later on average, between 16:30 and 18:30 UTC. The diurnal cycle of waterspouts is more evenly distributed, showing a maximum during the first half of the day.



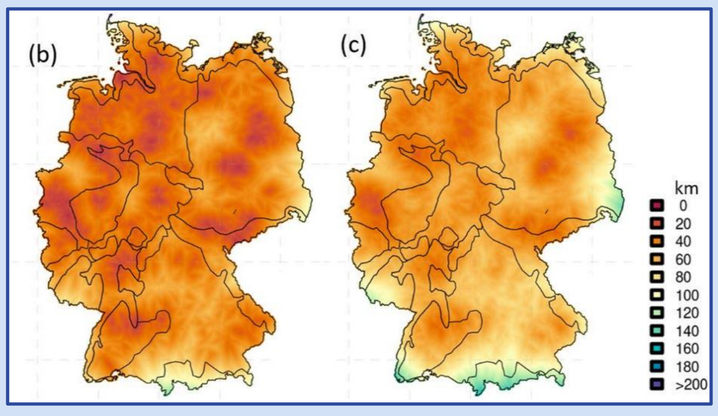
Spatial distribution

Tornadoes occur almost anywhere in Germany. Tornado density maps reveal that some of the density maxima correspond to areas of higher population density, while others are associated with complex orography, such as local maxima north or northeast of mountain ranges. In northern Germany, significant tornadoes are more evenly distributed. How orography can influence tornado formation is shown in Wapler and Beyer (2022).

Population density (left) and orography (right).



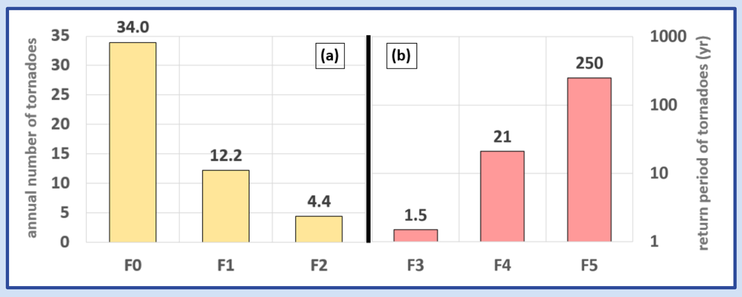
Distance (on a 1km² grid) to the 5th closest (left) and 10 closest (right) tornado.



Annual number of tornadoes and missing reports

In his 2001 study, Dotzek found that the recorded number of tornadoes in Germany ranged between 4 and 7 per year. Based on extrapolations, he estimated an actual annual number of 15 to 25 tornadoes. Our study reveals an even higher annual number of reported cases. However, it is still likely that the real number of tornadoes occurring each year in Germany exceeds the currently recorded figures. Using the intensity distribution and an idealized strength ratio of Fn+1/Fn = 0.36 for mesocyclonic tornadoes, the potential number of such tornadoes can be extrapolated. This extrapolation suggests that approximately one F1 and 34 F0 tornadoes per year are missing from the statistics. Additionally, non-mesocyclonic waterspouts are likely underreported, particularly those occurring at night.

Extrapolated (a) mean annual number of tornadoes with intensities F0 (including unrated), F1 and F2, excluding waterspouts. (b) return period of tornadoes with intensities F3, F4 and F5.



Further information

Beyer, A., Wapler, K. and Kühne, T. (2025): Tornadoes in Germany: intensity, temporal and spatial distribution. Meteorol. Zeitschrift, accepted.

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