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Tornado climatology of Austria

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Abstract

After several decades of little work, a revised tornado climatology for Austria is presented. Tornadoes seldom form in the alpine areas, however, near the eastern flanks of the Alps, favourable conditions for tornado genesis are found. Whereas in the alpine regions less than 0.3 tornadoes per 10,000 km^2 a year touch down (averaged for provinces or major parts of a province), we can count 0.9 in the greater Graz area, 1.0 in the greater Linz area and 1.2 tornadoes per 10,000 km^2 a year in the greater Vienna area, suggesting the existence of so-called tornado alleys. As these regions are the most populated areas of Austria, there is a possible population bias in the dataset. The overall average for Austria is 0.3 tornadoes per 10,000 km^2 a year.

The database consists of 89 tornadoes, one landspout and six waterspouts, with a total of 96 events. The seasonal peak is in July with a maximum probability of tornadoes in the late afternoon and early evening hours. Every fifth tornado occurs in the hour after 5 p.m. The maximum intensity determined for a tornado in Austria was T7 on the TORRO-Scale (F3 on the Fujita-Scale), the most common intensity is T2 on the TORRO-Scale (F1 on the Fujita-Scale). © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Alfred Wegener previously reported several tornadoes in Austria and its former crown lands in his classic book “Wind- und Wasserhosen in Europa” (Wegener, 1917). Two devastating tornado outbreaks not only challenged scientists in the first third of the 20th century, but also were some of the worst ever recorded on the territory of modern

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Austria. Databases (Pühringer, 1973) reach back to 1910. In 1916 a tornado caused enormous damage in Wiener Neustadt, leaving 32 people dead and 328 wounded (Dörr, 1917). After some work on this case and its archive material it was possible to determine this tornado as an F3 event on the Fujita scale (Fujita, 1981) or T7 tornado on the TORRO scale (Meaden, 1976).

In 1927 two tornadoes went through the eastern parts of Styria, leaving a 35-km track of devastation. Thanks to the fine work of Wegener (1928) both events were easily classified as F3 or T6 tornadoes. This historical outbreak has a counterpart in southern Styria in 1998, when two tornadoes, classified as F2 and F3 (T4–5 and T5) caused damage of about 20 million Euro (Holzer, 1998). These strong tornadoes are the most prominent ones, and also outline the areas most often hit by severe tornadic storms in Austria.

This paper overviews not only the prominent examples of tornado formation in Austria, it also describes the state of knowledge of intensity and distribution in space and time. Local topographic conditions are held responsible for the formation of "tornado alleys" (Dotzek et al., 1998) in some parts of the country. The long-term goal is to provide a reliable dataset for Austria in order to support scientific and economic interests and also the exchange of information on the Central European scale within the TorDACH group (a network for tornado research in the countries of Germany (D), Austria (A) and Switzerland (CH)) and other organisations. Then possible consequences of the findings are to be discussed.

The paper is organised as follows. In Section 2 the data acquisition methods are presented. Section 3 outlines tornado intensities and their distribution in space and time. Sections 4 and 5 present discussion and conclusions.

2. Acquisition of data

The dataset is very inhomogeneous (Fig. 1). Although Pühringer (1973) tried to establish a reliable dataset, we have only fragmental records for the 20th century. Whereas we know of 71 tornadoes in the years from 1946 to 1971, an average of 27 tornadoes per decade, we only know of nine events before and of only 12 tornadoes after that period of time. For Pühringer reliable records as weather service reports were available from 1946. Before that year, very few records are found. The first tornado report for the territory of modern Austria dates back to 1910 (Wegener, 1916). A second data gap is suspect after the work of Pühringer, from 1972 to 1993, when not more than five tornadoes appear in the data base, only allowing an average of 2.3 events per decade. Since 1998 new efforts have been made within TorDACH to get information on as much as possible tornado events. Seven tornadoes were found in the period from 1994 to 1999. No events were reported in the years of 1996, 1997, and 1999, but as many as three tornadoes and one funnel cloud were sighted in 1998. Some additional historical tornado records were discovered during this work. Taking in account all these difficulties in the dataset, only the period from 1946 to 1971 (Pühringer, 1973) is seen as reliable and representative enough for some parts of the statistics. The whole TorDACH

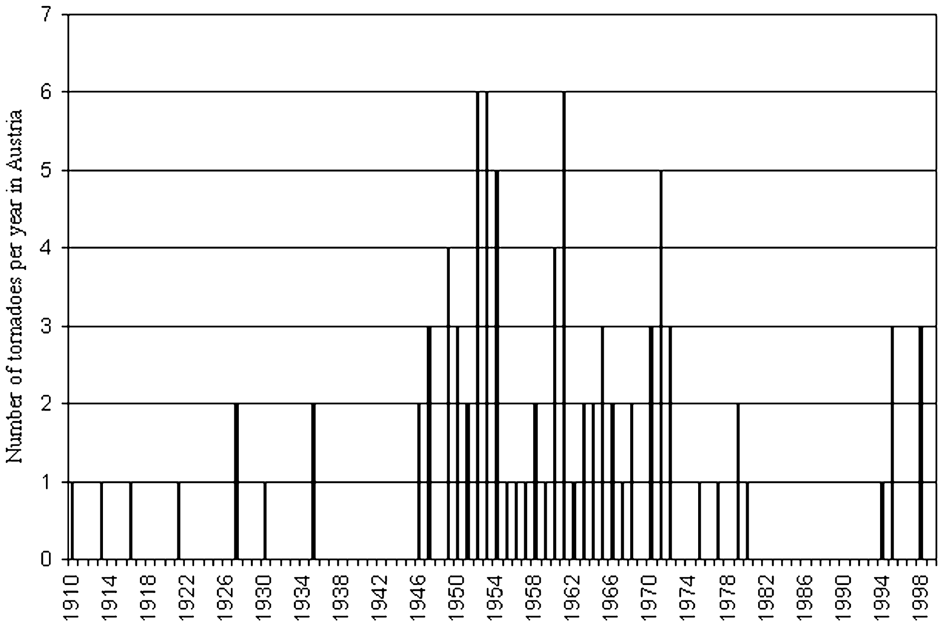

Fig. 1. Number of tornadoes per single year.

database for Austria consists of 89 tornadoes, one landspout and six waterspouts, with a total of 96 events, and one additional funnel cloud event.

3. Intensities and distribution in space and time

Taking the whole database in account, the most frequent intensity observed is T2 with eight events or 28%, followed by T3 and T4 tornadoes, reaching 17% each (Fig. 2). Ten percent of all events are T0 but also T5, and 7% each were T1 and T6 tornadoes. One event (equal 3%) was rated as a T7, the Wiener Neustadt event of 1916. Wind speeds of 82 to 93 m s^{-1} (or about 315 km h^{-1}) are therefore the maximum values proved for Austria. The more summarising *F*-scale values are given in Table 1. The Austrian distribution is far away from the mean distribution figures proposed by Brooks and Doswell (2000), especially for the weaker values. This fact will be discussed later.

The distribution by month (Fig. 3) shows the maximum in July with 28 out of 96 events, followed by August with 20, June with 15 and May with 13 tornadic storms. January and October are the only months when no tornado events have occurred so far. The maximum probability for tornado formation is found in the late afternoon and early evening hours. Twenty percent of tornadoes were reported in the hour after 5 p.m. (Fig. 4).

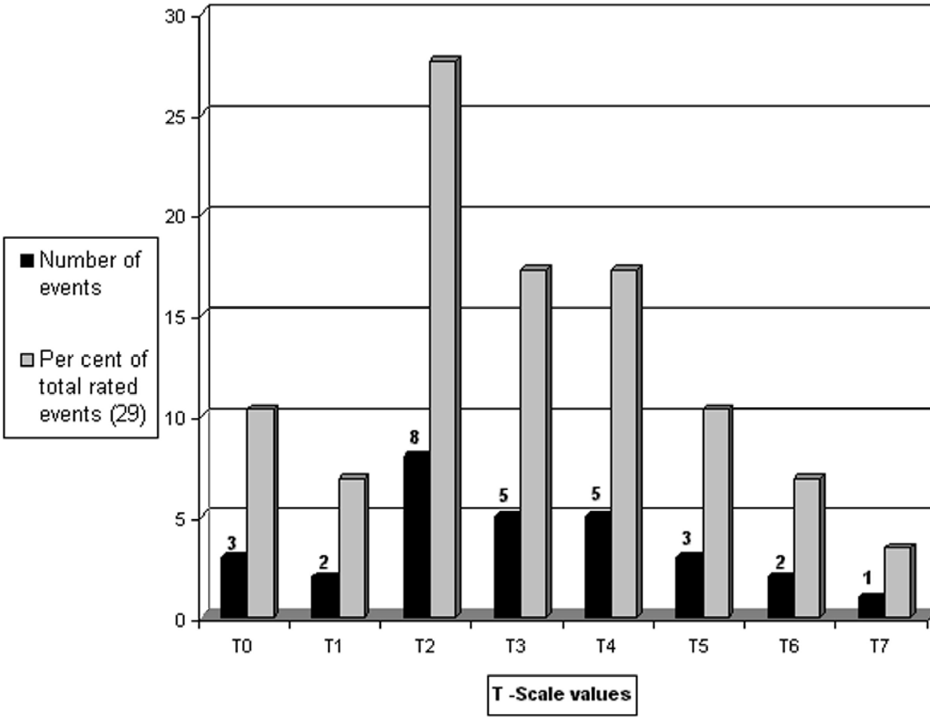

Fig. 2. *T*-scale values of rated tornadoes in Austria.

Taking the most representative dataset of Pühringer (1973) as basis, we can find an average of 2.7 (with a standard deviation of 1.8) tornadoes per year in Austria. Record years were 1952, 1953 and 1961 with six tornadoes each, followed by 1954 and 1971 with five tornadoes each year. Whereas in the alpine regions less than 0.3 tornadoes per 10,000 km^2 a year are counted (averaged for provinces or major parts of a province), we can count 0.9 in the greater Graz area, 1.0 in the greater Linz area and 1.2 tornadoes per 10,000 km^2 a year in the greater Vienna area (Fig. 5). The overall average for Austria

Table 1
F-scale values of rated tornadoes in Austria

F-scale values	Number of events	Percent of total events (%)
F0	5	17
F1	13	45
F2	7	24
F3	4	14
F4	0	0
F5	0	0

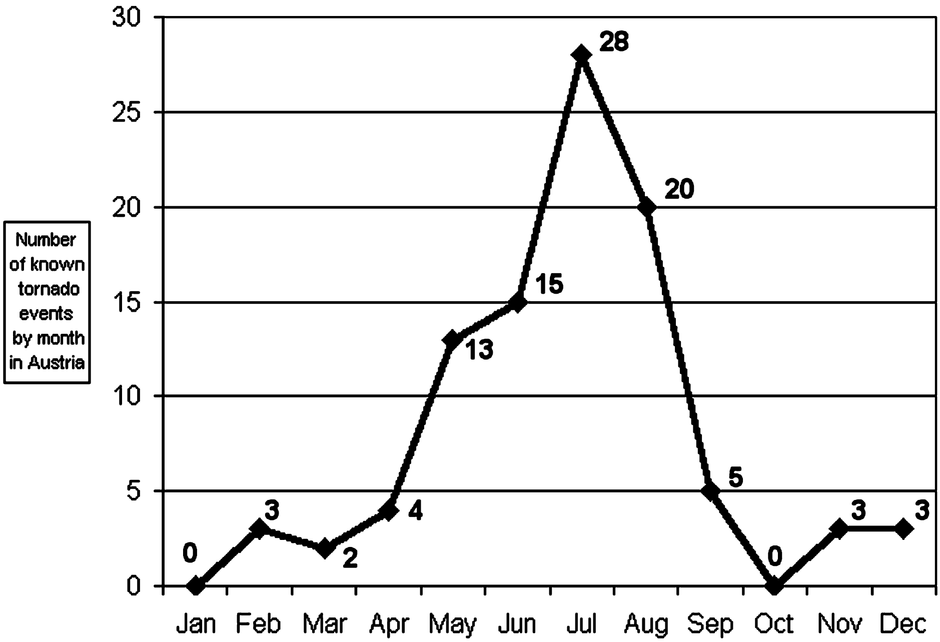

Fig. 3. Tornadoes by month in Austria.

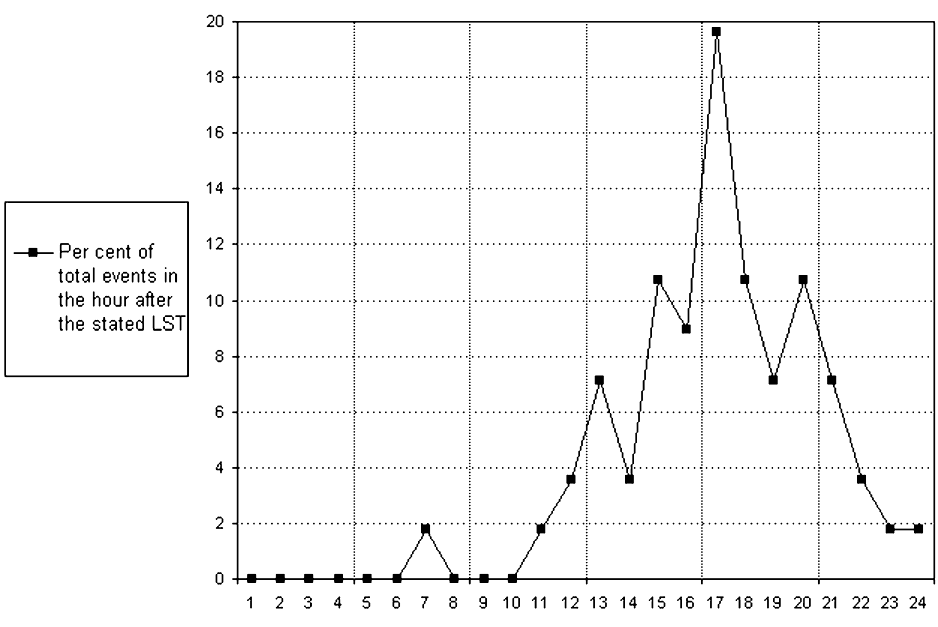

Fig. 4. Tornadoes by hour in Austria.

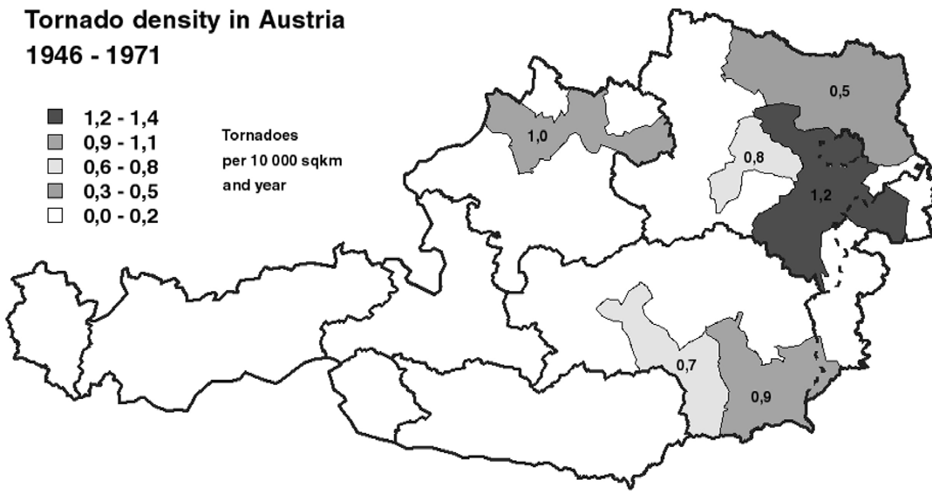

Fig. 5. "Tornado alleys" in Austria (regions $\geq$ 0.3 tornadoes year^{-1} 10^{-4} km^{-2}).

(area: 83,855 km^2) is 0.3 tornadoes per 10,000 km^2 a year. That number seems to be slightly higher than in the neighbouring country of Germany (Dotzek et al., 1999; Dotzek, 2001), but only if we believe the dataset of Pühringer (1973) to be representative.

Some districts in the Austrian "tornado alleys" even have an average of 3 tornadoes per 10,000 km^2 a year, very similar to the mean values calculated for Florida (NWS, 1993), but the areas in question are quite small then and the statistical errors may be large. One reason for local accumulations in Austria is the topography. The Alps act as a barrier to low level cold air masses from the Northwest, while from the Southeast a low-level inflow of moist and warm air from the Mediterranean can sustain for some time. These favourable conditions also reflect in extraordinary high probabilities of hailstorms, especially in eastern Styria (Müller, 1974). Due to high values of low level wind shear, there seem to be good conditions for the formation of supercells where mountainous and flat terrain get in contact (Dotzek et al., 1998). Similar conditions are found in and near the Danube river valley.

The statistical accumulations also may partly be produced by higher observing and reporting probabilities in densely populated areas. It is very striking that the three most populated areas (Vienna, Linz, and Graz) are on top of the list, and climatological and topographical comparable regions with low population figures range well behind, like parts of the province of Burgenland in the east of the country.

It seems that different synoptic settings are responsible for the accumulation of tornado events in the southeastern and northern parts of Austria. Whereas tornadoes in Styria often seem to occur in the environment of quasi stationary or stalled cold fronts lying over the eastern Alps, tornadoes in the River Danube Valley preferably seem to occur in the environment of prefrontal squall lines (van Delden, 2000) or mesoscale convective systems (MCS) approaching from the western sector, similar to the preferred environment for severe hailstorms in this area (Kurz, 2000). These are only preliminary results and based on few events analysed during the last several years within TorDACH. Therefore, the sample at this time is relatively small. Investigation on the whole historical dataset should be made.

4. Discussion

Future goals are the harmonisation of the European tornado data sets, especially data exchanges with countries neighbouring Austrian tornado regions, like Germany, Slovenia, the Czech Republic (Munzar, 2000), Slovakia, Italy (Bechini, 2000), Switzerland (Schmid et al., 2000) or Hungary (Geresdi and Horvath, 2000). This would be necessary to establish a reliable central European map of tornado densities, not limited by dozens of national borders. First steps were already made by Dotzek et al. (2000) who proposed a "tornado code" for European tornado records.

The question of whether the high tornado probabilities in some regions of Austria, particularly the densely populated eastern areas, are real or only result of the small sample size in the dataset should be cleared up within the next years. The number of tornadoes in the time before and after the dataset of Pühringer (1973) seems to be much too small whereas the number of tornado events given in the dataset of Pühringer seems to overestimate in some periods, maybe produced by misinterpretation of microburst damages. But if the high numbers are confirmed, effort should be made in forecasting Austrian tornadoes and the installation of a warning system should be considered, at least for the most affected towns and urban areas. If the high values are real, there is a serious threat to towns like Vienna, Graz or Wiener Neustadt. Vienna has already been affected four times since the end of World War II, fortunately by relatively weak storms. Tornadoes have occurred five times in or near both Graz and Wiener Neustadt in the last 90 years.

Compared with the work of Brooks and Doswell (2000) and its statistical extrapolation, the number of weak tornadoes is probably underestimated. The Austrian distribution appears to be very similar to the one of the US in the 1920s, when most of the weaker tornadoes were not detected. Taking in account these findings together with the number of F2 cases seen as the most reliable part of the dataset, we would end up with at least three times as much tornadoes as we know from at the moment (Table 1). Assuming the underestimation is the same everywhere, this would mean that tornado densities in some small parts of Austria are comparable with those in the US Plains. What it makes difficult to compare such statistical relationships is the very poor understanding and knowledge of tornado formation in Austria. Only a very few cases were studied by means like doppler radar yet. We do not exactly know at this time, whether most Austrian tornadoes do form in a supercell environment or not. Only official weather office counting and research could help to establish a more realistic dataset with deeper understanding of tornado formation over highly complex terrain like the Alps and its surroundings. Also, more public information on tornadoes would be appreciated. Yet, enough Austrians even do not exactly know what a tornado looks like. Many reports do, for example, mention a column of smoke as description of the phenomenon. Therefore, some events probably are not recognized as a tornado by the eyewitnesses and not reported to the media or to the national weather service, even if they were noticed.

5. Conclusions

Historical works on tornadoes and recent events in Austria were collected and studied in order to set up a reliable dataset and to allow an estimate of the real number and distribution of tornadoes. The main results are:

1. Historical records of fatal cases already suggest reasonable tornado activity.
2. Based on the most reliable data, 0.3 tornadoes per 10000 km^2 a year occur in Austria.
3. Defined regions have much higher tornado densities, due to topographical effects.
4. On average 2.7 tornadoes per year are counted in Austria.
5. Statistical considerations suggest still higher numbers of weak cases.
6. Highest tornado frequencies are in July.
7. Daytime peak is in the late afternoon hours together with the thunderstorm maximum.

In future international efforts should be made to improve the knowledge on European tornadoes and the conditions favourable for their formation over complex topography in order to understand the often sharply defined regions with high tornado activity.

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