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Tornadoes within the Czech Republic: from early medieval chronicles to the "internet society"

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Abstract

This paper addresses the historical documentation of tornadoes and the awareness of tornadic events in the area of the present Czech Republic throughout the last nine centuries. The oldest records of tornado occurrence in the region can be found in chronicles from the first half of the 12th century—the two most interesting of these are presented here in translation from the original Latin texts. Several other cases of possible tornadoes and waterspouts can be found in chronicles from the 12th and 13th centuries. However, from the descriptions of the events, it is not always clear if the phenomenon was a tornado, waterspout, dust swirl, or if it was of a non-tornadic nature. From the 14th to 19th centuries, tornado records are rather scarce for the region. However, this is likely to have a non-meteorological explanation. Gregor Mendel's (1871) essay "*Die Windhose vom 13. October 1870*" can be considered as a distinctive "breakpoint" in the documentation history of tornadoes in the territory of the present Czech Republic, followed later by the work of Edler von Wahlburg [Das Wetter 28 (1911) 135] and Wegener [Wind-und-Wasserhosen in Europa. F. Vieweg & Sohn, Braunschweig, 1917]. During the "socialist" period, the term "*tornado*" was seldom used and they were poorly understood, producing a view that "tornadoes do not occur in Central Europe". The situation began to change with the works of Munzar [Tromby (tonáda) na území Èeské republiky v letech 1119–1993. Zborník Dejin Fyziky, vol. XI. Voj. Akadémia SNP, Liptovský Mikuláš, pp. 69–72, 1993 (in Czech)] and Šálek [Meteorol. Zpr. 47 (1994) 172], and new records showed that about one tornado per year occurred between 1994 and 1999. Finally, between 2000 and 2002, the number of documented tornadoes in the Czech Republic was five to eight cases per year.

Keywords: Tornado; Waterspout; Damaging winds; Severe convective storm

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1. Introduction

The first civilization in the territory of the Czech Republic is associated with Celtic tribe Boii (about 4th–1st century BC), who gave the western part of the country[1] its Latin name: Bohemia (*Boiohaemum* = the home of Boii). Since Boii, as well as their conquerors—Germanic tribes (end of 1st century BC–4th century AD) and early Slavic settlers (from about 6th century) did not use writing, no local written records can be expected from those times. The earliest known recorded tornado is from the beginning of 12th century.

2. Early medieval chronicles: 12th and 13th centuries

During the second half of the 11th and the beginning of the 12th centuries, from which the oldest Czech written documents come, the writing skills needed to document important events were confined to a small class of educated people—clergymen working behind walls of monasteries and chapters. The language and alphabet of those old documents is Latin, which was the language of educated people for many centuries.

2.1. Tornado of 30 July 1119, Prague–Vyšehrad

The first major chronicler of Czech history was Cosmas (1045–1125). In his "*Chronica Boemorum*", written between 1119 and 1125, is the oldest known record of a Czech tornado (Table 1), which occurred on 30 July 1119 at Vyšehrad (Czech rulers' seat by then):

> In the year of our Lord 1119, 3rd Kalends of August, on the fourth Feria day, as the day was declining to its end, a strong wind, as if Satan himself in a whirlwind [turbine] from the southern direction rushing in upon the solar[2] of the duke in the town of Wissegrad destroyed completely the ancient wall although it was very firm; and even more—it is to be wondered at—from another part, anterior and posterior, the middle of the palace whole and unshaken, the remainder is dug up, and very quickly, as you would break a stalk, the force of the wind broke and wantonly scattered the lower and upper beams with the house itself. This storm moreover was strong to that point, as it threw itself upon whatever part, whose woods and planted shrubs of the land and other obstacles it flattened with its force.[3]

[1] The territory of the present Czech Republic covers three historical "lands": *Bohemia* (the western part of the country), *Moravia* (the most of eastern part of the country) and a fraction of *Silesia* (the north-easternmost part of the Czech Republic). All of these have a common language: Czech, and are usually referred to as the "Czech lands".

[2] Room in a medieval building that benefited from exposure to the sun (private room of the owner of the castle).

[3] Translations from Latin (for 1119, 1144 and 1255) by Margaret Lantry, Department of Ancient Classics, University College Cork, Ireland. The original Latin texts can be found at http://www.chmi.cz/torn or will be provided by the corresponding author upon request.

Unfortunately, the original and the oldest copies of this chronicle were lost or burned, so the text above is a compilation from more recent copies (Bretholz, 1923). According to the damage description, it appears that this event might have been one of the strongest tornadoes (F4?) ever recorded in Bohemia.

2.2. Tornadoes of 14 May 1144 (place unknown)

In "*Annales Gradicenses et Opatovicenses*" (Emler, 1875) is the following record:

> In the year 1144, twice Ides of May, namely on the day of Pentecost, unheard of in our time a horrible portent [monstrum] appeared near the encampment of the duke Otto, while along with many others of the nobility and also the multitude of the lower classes looking on. About midday during a great calm, a dark column was seen by many of the aforementioned people ascending from the earth to the top of the clouds, in whose force it was rotating with the circuit of a whirlwind. Whenever it tried to reach the aforementioned place, a triangular sign of very great brightness was seen from the height of the sky and to meet itself with wonderful acuity, which with the unnatural portent crossed to the very depths of the earth. However after an interval of almost one hour another column darker and with stronger force of a whirlwind was seen in the same manner to raise itself from the earth, against which again in the same manner in the most bright region, in whose center was seen appearing the sign of the holy cross, it bored with astonishing speed and drove into the very surface of the earth. Whenever some soldiers boldly had come to contemplate the cause, they departed, for they could not look on the matter of such a portent, with sand and little pebbles blowing in their faces and uprooted trunks hindering the keenness of their eyes.

Although it is not known where in the Czech lands this event occurred, there is no doubt that the record gives an account of the development of two tornadoes. In modern language, this record would be a description of the evolution of a condensation funnel and a dust whirl underneath it and their subsequent merging. Apparently, this record describes the "first storm chasers" ever documented in history.

2.3. The Prague Castle tornado of 8 April 1255

In the years following Cosmas' death, several authors continued his work, writing their own chronicles. Later, several of these originally independent chronicles were merged to form the so-called "*Cosmae Pragensis Chronica Boemorum cum Continuatoribus*" (Emler, 1874), in which is the following record:

> When the ruler[4] was leaving Prague's castle a great force of winds rose with a whirlwind [turbine]. Whence a horseman following the ruler was thrown from the

[4] From the original Latin text, it is not quite clear here if the person was indeed the ruler of the country or some other prince (could be both).

Table 1
Known cases of tornado occurrences in the territory of the present Czech Republic

Date (yyyy–mm–dd)	Time (UTC) and duration	Location (local name)	Latitude (North)	Longitude (East)	Intensity	Note	Type
1119–07–30	late afternoon	Vyšehrad, Prague	50.06	14.42	F4 (F3?)		T
1144–05–14	noon, early afternoon	???					T
1255–04–08	?	Prague Castle	50.09	14.39	F0		T?
1585–07–06	late afternoon	Neznašov (distr. České Budějovice)	49.21	14.36	F3		(T)
1586–?	?	Orlík (distr. Písek)	49.51	14.17	F1	falling fish	W
1597–06–19	~ noon	Litoměřice	50.54	14.13	?		F,T?
1598–07–14	?	Březno (distr. Louny)	50.36	13.73	F0		F,T?
1761–06–23	night	Nová Ves u Mladé Vožice (distr. Tábor)	49.54	14.75	F1	falling fish	W
1811–07–06	~ 16:00	Lomnice u Rýmařova (distr. Bruntál)	49.88	17.42	?		W
1812–06–14	?	Janušov u Rýmařova (distr. Bruntál)	49.95	17.25	?		W
1818–05–10	afternoon	Jistebnice u Tábora	49.49	14.53	?		T?
1824–07–27	~ 16:00	Fojtka (distr. Liberec)	50.77	15.05	?		T
1830–05–24	?	Brno	49.20	16.61	?		F,T?
1831–05–02	~ 15.30	Louny	50.35	13.81	F2		(T)
1870–10–13	~ 13:00	Brno	49.19	16.61	F1 (F0?)		T
1972–05–25	?	Příbram	49.01	49.69	?		T
1910–05–11	~ 16:00–19:30, ~ 3.5 h	České Budějovice (start)–Karlovy Vary (end)	49.00 (start), 50.25 (end)	14.50 (start), 12.80 (end)	F3		T
1925–08–11	~ 23:00	Jablonec n. N.	50.72	15.17	F2		T
1947–08–31	?	Praha–Ruzyně	50.10	14.38	?		T?
1950–05–20	~ 15:15–15:30, ~ 3 min	Čimice, Chabry (north of Prague)	50.14	14.44	F3		T
1981–10–11	?	Rájec–Jestřebí (distr. Blansko)	49.40	16.64	?		T

1985–07–21	~ 13:40, ~ 1–2 min	Hlubočec (distr. Opava)	49.84	17.97	F2 (F3?)		T
1987–08–09	14:36, ~ 1 min	Plzeň	49.75	13.37	F1 (F0?)		T
1993–07–16	?	Spálené Poříčí (south of Plzeň)	49.61	13.60	?		T
1994–05–26	18:45, 4–10 min	Lanžhot (distr. Břeclav)	48.73	16.97	F1 (F0?)		T
1996–07–08	15:10, 5–10 min	Rajnochovice, Hostýnské vrchy (distr. Kroměříž)	49.40	17.82	F1		T
1997–06–27	23:10	Díly (distr. Rokycany)	49.77	13.62	F2 (F3?)		(T)
1998–07–21	~ 22:00	south of Monastery Teplá (distr. Karlovy Vary)	49.95	12.87	F2		(T)
2000–04–19	15:15, 10–20 min	Studnice (distr. Vyškov)	49.38	16.89	F1	photo, video	T
2000–06–11	16:00, ~ 15 min	Málkov (distr. Chomutov)	50.45	13.33	F3 (F2?)		T
2000–07–02	~ 14:00	Krasíkovice (distr. Pelhřimov)	49.46	15.23	F2		T?
2000–07–04	14:56, ~ 5 min	Dražovice (distr. Vyškov)	49.19	16.95	?		T
2000–07–08	~ 15:00	Přestavlky (distr. Přerov)	49.39	17.49	F1		T
2000–07–30	~ 14:00	Popovice (distr. Beroun)	49.93	14.02	F0	photo	T
2001–05–31	~ 15:10, ~ 3–4 min	Vyšehořovice (distr. Praha–východ)	50.12	14.77	F0		T
2001–05–31	???, ~ 1 min	Dušníky nad Vltavou (distr. Mělník)	50.30	14.34	F1		T
2001–05–31	~ 15:00 (???)	Vilémovice, Mrzkovice (distr. Havlíčkův Brod)	49.68	15.34	F2		T
2001–05–31	14:30–14:40, ~ 10–15 min	Milošovice (distr. Kutná Hora) – Velká Paseka (distr. Havlíčkův Brod)	49.71	15.17	F3	photo, video	T
2001–05–31	~ 14:00, ~ 3–4 min	Kochánov/Střížkov (distr. Benešov)	49.79	14.78	F2		T
2001–07–07	15:50 (???)	Lipno (distr. Český Krumlov)	48.72	14.07	F0	video	W
2001–07–20	~ 14:00, ~ 1 min	north of Velká Bystřice (distr. Olomouc)	49.67	17.43	?		T?

(continued on next page)

Table 1 (*continued*)

Date (yyyy–mm–dd)	Time (UTC) and duration	Location (local name)	Latitude (North)	Longitude (East)	Intensity	Note	Type
2001–07–20	~ 12:30, ~ 10–15 min	Stařechovice (distr. Prostějov)	49.53	17.07	F2	video	T
2001–07–20	12:10, ~ 7 min	south of Brno	49.10	16.68	F1	photo	T
2001–07–20	~ 12:00, ~ 15 s (?)	Vranovice (distr. Prostějov)	49.40	17.10	?		T?
2001–08–03	~ 17:00, (???–min)	Chlum u Třeboně (distr. Jindřichův Hradec)	48.95	14.95	F1		T?
2001–08–04	~ 16:15–16:30, ~ 5 min	Tučapy (distr. Kroměříž)	49.36	17.58	F0		T
2002–05–14	~ 12:25–12:45, ~ 20 min	Hevlín (distr. Znojmo)	48.75	16.31	F1		T
2002–07–10	~ 15:10–15:30, ~ 10 min	Žlutice (distr. Karlovy Vary)	50.06	13.15	F1		T
2002–07–13	~ 15:00–16:00, ~ 5–10 min	Sázava (distr. Kutná Hora)	49.88	14.91	F1		T
2002–07–16	~ 13:05–13:20	Žabčice (south of Brno)	49.01	16.61	F1 (F0?)		T?
2002–08–07	~ 12:20–12:50	Dačice (south of Telč)	49.08	15.44	F0 (F1?)	video	T
2002–08–07	~ 13:15, ~ 2 min	Nová Bystřice (distr. Jindřichův Hradec)	49.00	15.16	F1		T

Summary of Munzar (1993), Setvák and Šálek (2003) in "Internet resources" and Lacinová (2002). Funnel clouds without proved touchdown, downbursts and microbursts are not included here. The geographical coordinates are approximate only. Tornado intensity is estimated using the Fujita scale; in case of ambiguous or uncertain classification, the nearest possible intensity class accompanied with a question mark is noted.

Type of phenomena: T: proved tornado; (T): very likely tornado (as based on damage character, no witnesses); T?: uncertain cases (possible tornado—but not verified yet or unclear); W: waterspout.

bridge before the walls, whose horse died from the fall, he himself escaped healthy. At the same hour it ruined the wooden campanile with bells inside the walls of St Mary driven by the great force of winds, and much other destruction was caused in the city and the villages.

Although this event does not describe any damage that can be directly attributed to the whirlwind that is mentioned (possibly a tornado?), it does demonstrate a particularly important fact: that the early medieval chroniclers typically logged only those events that affected directly the upper social strata of society, their seats and property, or the most important towns, buildings, bridges, etc. Therefore, many destructive events that might have occurred in rural areas almost certainly escaped the attention of early medieval chroniclers.

Another problem arises when trying to interpret the records of the old chronicles: the terminology. When working with the original texts, there is a lack of clarity as to what the chronicler understood by a particular term. This problem is even more important when working with translations of the original texts. It is not unusual that the meaning of certain words (e.g., those used to describe a tornado) may have changed over the centuries, so it is important to know their meaning at the time the original text was written, as well as at the time of any translations. Therefore, a (Latin) text translated by two persons can give two different meanings—in one case attributing the wind damage to "gusty winds" or "stormy weather", while the other translation may indicate a whirlwind (tornado?) having occurred.

3. 14th–18th centuries

As the centuries passed by, writing chronicles became widespread—almost every castle, town and even many small villages had their own chroniclers, who recorded the most important events in their own immediate world. Gradually, Latin lost its monopoly. German influence spread into the Czech lands and literacy became much more widespread. As a result, some local chronicles were written in German or Czech languages, thereby introducing German and Czech names for various forms of whirlwind. It would be reasonable to suppose that this would result in more tornadoes being recorded. However, this does not appear to have happened, with the exception of two decades at the end of the16th century.

One of several possible explanations for the low number of documented tornado records over most of these centuries is the simple fact that the authors of this paper admit having only limited access to the old chronicles. A more detailed study of old chronicles has been carried out by Dobrovolný and Brázdil (2003), although even this may not be fully comprehensive. Another possible explanation may be a "sociological" one—in times of deep political pressure and instability, or during war, the interest of nations and chroniclers has always been elsewhere, leading to a decline in the attention devoted to natural phenomena (compare with Dotzek, 2001). Such a situation occurred in Czech lands for significant periods during these centuries—for example, the "Hussite wars" (1420–1434), the "Thirty Years' War" (1618–1648) and the

Czech "Dark Age" that followed (17th and most of the 18th centuries). This explanation has almost certainly influenced the total number of documented cases. Of course, normal interannual variability and various components of climate change cannot be excluded as a reason for the lower number of tornado records in certain periods (e.g., The "Little Ice Age" of Central Europe—lasting for the entire 17th and first half of 18th century).

As can be seen from Table 1, there are two gaps in the historical record of Czech tornadoes. The first one starts with the 14th century and lasts till second half of the 16th century, and the other lasts for most of the 17th and 18th centuries. Since these periods can be only partially explained by political instability (see above), climate might have played a role as well. Reasons for these gaps can only be speculative.

In the last two decades of the 16th century, tornado reports temporarily increased. Given the absence of tornado reports before and after this period, this must have been either a period of general increase of interest in natural phenomena or a period of very favorable conditions for tornado development. The first explanation seems quite likely since this was during the reign of the Emperor Rudolph II—well known for his support of science (namely astronomy), alchemy and astrology.

The most significant difference between these records and the chronicles of the 12th and 13th centuries is that the cases from the end of 16th century occurred either in rural country or smaller towns, where they did not escape the attention of the chroniclers. As can be seen from Table 1, the Czech chronicles of that time also describe at least two cases of "raining fish". In 1586, the record speaks about a waterspout (*wasserhose*) sucking water and fish (carp and pike) from two ponds and their consequent dispersion

Fig. 1. Drawing of a tornado from *Orbis Sensualium Pictus* (Comenius, 1658–1685). This reproduction comes from a 1685 re-print from Levoča (Slovakia) four-language version (Latin, German, Hungarian and Czech).

over the surrounding countryside. A record from 1761 describes a strong midnight thunderstorm followed by heavy rain, accompanied by falling fish (''resembling trout'')—which can be explained only by a tornado sucking out water (and fish) from nearby ponds or a river...

In the second half of the 17th century, the first known ''Czech'' drawing of a tornado was made (Fig. 1). It comes from *Orbis Sensualium Pictus* (Comenius, 1658–1685)—a language textbook for children, accompanied by pictures, republished many times in various languages. Comenius, originally a Moravian priest and teacher, wrote this well-known textbook during his exile stay in Amsterdam. Therefore, this drawing is only loosely connected with Czech lands. It is not known whether he witnessed this tornado (or rather, a waterspout) himself during his long pilgrimage through many parts of Europe, or whether he used some older drawing published elsewhere.

4. 19th century

By the 19th century, the number of known Czech and Moravian tornado cases began to increase again (Table 1). This is in agreement with records from Germany (Dotzek, 2001). Most of these tornado records were collected by Wegener (1917), the common reference source for tornado information for Germany, Austria and Czech lands[5], for the 19th and early 20th centuries. However, one of the most important cases of the 19th century—the 1870 tornado in Brno—escaped Wegener's attention.

The Brno tornado of 13th October 1870 can be considered as one of the milestones in the history of documenting tornadoes in the Czech lands. The reason for this is that it was very well described and analyzed by Gregor Mendel (the founder of genetics and a meteorologist, as well) in his work (Mendel, 1871). Recently, this was discussed and translated from the original German text into English by Munzar (1998). Mendel's description of the event itself and his analysis of damage caused by the tornado (*Windhose*) could serve as an example of tornado documentation and damage survey even in most recent years. One of the interesting aspects of this work was that he devoted special attention to the tornado's rotation. He witnessed this himself and stressed the fact of anticyclonic spin; he apparently realized that this was a unique exception from the ''general rule''. Therefore, Mendel's work can be regarded as the beginning of the modern era of tornado documentation and research in the Czech lands.

5. 20th century

As can be seen from Table 1, tornado records from Czech lands for the first seven decades of the 20th century are very scarce. However, the first of these records is quite

[5] At the time of writing his book, the Czech lands were part of the Austrian monarchy.

exceptional—not only for the detailed description by Edler von Wahlburg (1911), but also for the length of the event.

The tornado of the 11th May 1910 (Edler von Wahlburg's, 1911 paper incorrectly dates this as 15th May) was first recorded close to České Budějovice. It lasted for almost 3.5 h and had a track of about 190 km (Fig. 2). Edler von Wahlburg described periods during this event when no contact between the funnel cloud and the ground was observed, and other periods when heavy damage was caused by the tornado (the width of the damage swath was about 60 to 65 m). From the description, however, it is not possible to distinguish whether it was one continuous event for the entire period, or if it was a series of several tornadoes occurring during the life of a persistent "parent" storm (likely a supercell). If the first is really true, then it was the longest lasting tornado ever recorded in the territory of Czech lands.

As can be seen from Table 1, only one tornado case (1950) was recorded for the next seven decades. A comparison with the tornado records from neighboring countries—Germany (Dotzek, 2001) or Austria (Holzer, 2001)—indicates that this "gap" is certainly artificial, resulting from the widespread practice of the weather service, journalists, and

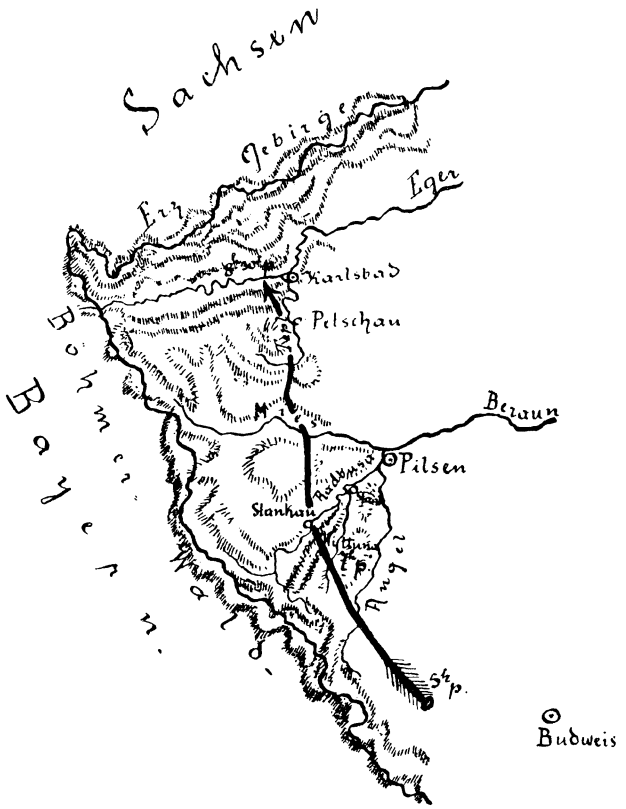

Fig. 2. Track of the 11 May 1910 tornado (from Edler von Wahlburg, 1911).

public alike all ignoring these events. This can be understood for the war periods and communist era, but there is no reasonable explanation for the period between the 1st and 2nd World Wars.

For the socialist period (1948–1989), it was typical that tornadoes were virtually ignored—damage events were simply attributed to "damaging winds" accompanying convective storms and the term "tornado" was essentially forbidden—both by journalists and most meteorologists. A "tornado" was something that was related to the U.S. Great Plains, but had no "official" presence in Central Europe. Although a few meteorologists had no hesitation in using this term, they were not taken seriously. If journalists reported on a tornado event, it was almost always described in other terms.

The situation began to change at the beginning of 1990s, after the political changes. The fall of the "iron curtain" led to a much higher level of information exchange, and this has been further enhanced by the increasing use of the Internet.

The first recent attempt to summarize all known cases of tornado occurrences in the territory of the present Czech Republic was carried out by Munzar (1993). This work covered a total of 29 tornadoes between 1119 and 1993 and later became the core of the present Czech tornado database. Although this was a very limited edition, it influenced many other Czech meteorologists (including the first two authors of this paper).

A new chapter in tornado research in the Czech territory began in May 1994 when a comprehensive storm damage survey led to the identification of a tornado at Lanhot (Šálek, 1994). Three additional cases followed in 1996, 1997 and 1998, also thoroughly documented by professional meteorologists (Setvák et al., 1996; Sulan et al., 1998; Setvák, 1999). These four cases introduced a new approach for modern Czech meteorology, opening the door for the term "tornado" to be used in the Czech language.

Two other factors had an important role in increasing tornado awareness among the Czech community in the second half of 1990s. The first of these was closer contacts between the Czech Hydrometeorological Institute (CHMI, the National Weather Service) and the National Severe Storms Laboratory (NSSL, Norman, Oklahoma), between 1994 and 1997. Although focused primarily on satellite data, this link brought to CHMI new insights into severe convective storms and related severe weather.

The second factor was the establishment of a Czech web site devoted to tornadoes (Setvák and Šálek, 2003). This web site, active since mid-1996, not only provides basic information about tornadoes in general (their definitions, possible appearance, relation to convective storms, etc.), but summarizes all the known cases in the region of present Czech Republic and brings detailed information about individual cases where available. Also, it provides contact addresses for reporting a tornado, including instructions what information is important to meteorologists that witnesses could provide. Finally, detailed safety instructions (not only for tornadoes, but for all possible hazards associated with severe convective storms) can be found there. The web site is in Czech and English; however—since the main goal of the pages is to inform the Czech public in the Czech language—the English version is much briefer. The possible role of the web site on number of documented cases is discussed below.

By the end of 1990s, it seemed that the average rate of tornadoes in the Czech Republic is about one tornado a day (i.e., a day with one or more tornadoes) per year. However, the

general public's awareness of tornadoes is still very low, so that some cases are likely to escape documentation. Hence, the actual tornado frequency could still be higher.

6. Years 2000–2002

The probability that this is so is amply demonstrated by the data for the last three years, 2000–2002[6]. As can be seen from Table 1, the total number of tornadoes has increased by several times, so that the mean tornado frequency (normalized by area[7]) is approaching that of neighboring Germany (Dotzek, 2003).

There appear to be two main reasons for this increase. Firstly, there is the impact of the web site (mentioned above) and the increased use of the Internet by the general Czech public by 1999–2001. The evidence for this is that most of the tornado or funnel cloud reports and/or additional information now reach Czech meteorologists by e-mail messages to the addresses provided at the tornado web site. This has been helped by the attention devoted to some of the tornadoes by the mass media. Altogether, the popularization of tornadoes (perhaps related to the popular movie, "Twister"), and severe convective storms in general, has created a noticeable increase of tornado awareness among the general Czech public. It is even possible to speak about certain feedback effects: the more tornado-related information meteorologists provide to public, the more they get back in the form of tornado reports.

Secondly (although not of secondary importance), the Grant Agency of the Czech Republic (GACR) provided a national grant to study severe convective phenomena. This three-year grant (2000–2002) funded a joint project between the Institute of Atmospheric Physics (IAP) of the Czech Academy of Sciences, and CHMI (Řezáčová and Pešice, 2003). Part of the project was devoted to the documentation of all severe convective weather events (mainly, tornadoes) that occurred during this period. It was not only finance to do the work that made the project significant, but also the official "authorization" of tornado-related activities being carried out by CHMI and IAP scientists. In the years that preceded the grant, all tornado-related activities were supported unofficially, but during the grant period, these became part of the official program of CHMI and IAP.

In particular, it was the combined impact of each of these factors at the same time that resulted in the significant progress of tornado documentation and a raised awareness of tornado events in the Czech Republic. This created a certain momentum in tornado research that we hope to maintain even after the present GACR grant period is over, and that should become a part of CHMI's official mission.

As can be seen from the notes to Table 1, many of the recent tornadoes were either photographed or captured on video (by occasional observers). Most of these photos and videos have been digitized and given to meteorologists for documentary or study purposes. Here are some of the most interesting cases of this period.

[6] Although the authors are aware that the year 2000 belongs formally to the 20th century, they decided to merge this year with the years 2001 and 2002 because of their common "tornado characteristics" and temporal coverage by the national grant, as described later in this paper.

[7] The area of the Czech Republic is 78,864 km^2, whereas the area of Germany is 356,732 km^2.

- On 19 April 2000, the first Czech tornado was recorded on videotape (and also by a still camera). This tornado, although weak, was widely publicized by media and drew the attention of many people to these phenomena.
- The strongest tornado (F2–F3) of the same year occurred on 11 June 2000. It took a place near Málkov village in the western part of the Czech Republic. Besides the damage it caused, it was the first known Czech tornado that caused a car to levitate. The tornado lifted a small Škoda car occupied by an elderly couple, about 2 m above the road pavement, tore off the car's hood and sucked out all their belongings from the car's trunk. Fortunately, they survived this "flight" without injury, landing on a small tree that broke and softened the car's final descent.
- On 31 May 2001, five tornadoes were spawn by two independent storms (one of them being a "textbook" supercell) in the central and western part of the country. The strongest tornado of that day (F2–F3, generated by the supercell) caused a damage swath about 500 m wide and about 5 km long. It was captured at its weakening stage on a video, showing (for the first time ever in the Czech lands) a multiple vortex structure and a well-pronounced strong upward motion within one of the suction vortices. This day was characterized by the presence of an upper-tropospheric jet stream and a strongly sheared environment (at low- to mid-levels, with a typical supercell hodograph). However, there were only modest CAPE values (250 J kg^{-1}; the sounding station was located about 70 km downwind from the place where the tornado occurred approximately 2.5 h after the "formal" sounding time).
- Another significant tornado outbreak of that year occurred on 20 July 2001 in the eastern part of the country. In contrast to the previous case, this day was accompanied by relatively high CAPE values (2070 J kg^{-1}), with one of the four documented

Fig. 3. Tornado of the 20 July 2001 south of Brno (photo courtesy of Pavel Ambrož).

tornadoes being observed only 5 km away from the sounding station at 12:00 UTC—at the time of the sounding. Also, contrary to the case of the 31 May 2001, this tornado outbreak occurred when the only measured wind shear was limited to the boundary layer. Fig. 3 shows this tornado as observed from a distance of 7 km.

Although it is still too early to make any conclusive statements about the year 2002, it appears that the number of documented cases might be slightly lower in comparison with the previous 2 years. However, the 2002 statistics may change slightly after the final processing of all of the year's cases. It is unfortunate that the care devoted to documentation of the 2002 cases has been somewhat lower compared with the previous 2 years, owing to this year's major floods in the country.

7. Summary and discussion

All the evidence suggests that the total number of tornadoes recorded on the territory of the Czech Republic before year 2000 is significantly lower than was the actual frequency. This can be illustrated further by the fact that many elderly people claim to have seen a tornado or funnel cloud in the more distant past, although without being able to recall the actual date. Therefore, only the last 3 years (2000–2002) can be considered as reasonably representative of the real tornado frequency in the country. However, the authors of this paper are aware that still there may be many cases that have escaped detection, even during this period—for example, night time cases, weak events, or tornadoes accompanying downbursts along strong gust fronts (and thereby "masked" by them).

Fig. 4 shows the distribution of Czech tornadoes by month. At first sight, it appears somewhat different from monthly tornado frequencies recorded in surrounding countries—Austria (Holzer, 2001) and Germany (Dotzek, 2001). It corresponds to these by having a maximum in July, but it differs in that it shows a secondary maximum in May and a marked decrease in June. However, given the relatively low total number of all recorded cases, this distribution would be quite different if June had encountered a similar tornado outbreak as that of 31 May 2001 or 20 July 2001. The occurrence of such an

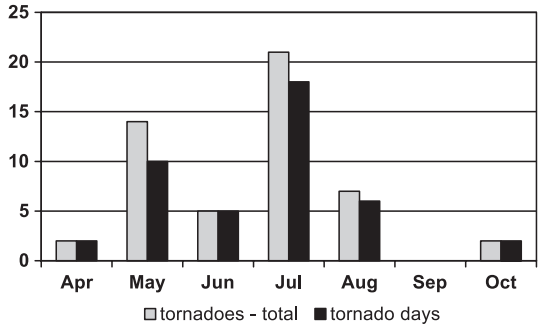

Fig. 4. Total number of tornadoes and tornado days (a day with at least one tornado) by month-based on Table 1.

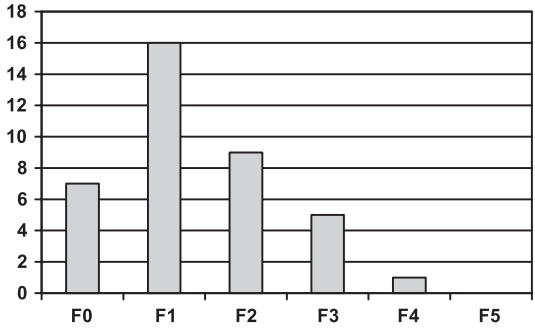

Fig. 5. Total number of tornadoes by F-scale-based on Table 1.

outbreak would have changed the total number of recorded tornadoes, but not significantly change the number of tornado days (number of days with at least one tornado). It is intended to examine and test this monthly pattern of tornado events with the help of observations from the radar and lightning detection network.

Fig. 5 indicates that the total number of the weakest events (F0) is much lower than could be expected from typical probability distribution (Brooks and Doswell, 2001). This may result from either a lower detection efficiency for the weakest events, and/or an overestimation of the F-scale attributed to recorded cases. Since the experience of Czech meteorologists in carrying out damage surveys was quite low before year 2000, a revision of the F-scale ranking for the past Czech events (Table 1) is planned in near future.

Fig. 6 shows the spatial distribution of tornadoes recorded over the territory of the Czech Republic. From this distribution map, there appear to be two large areas without tornado records. The one at the southwest part of the country can be explained by the fact

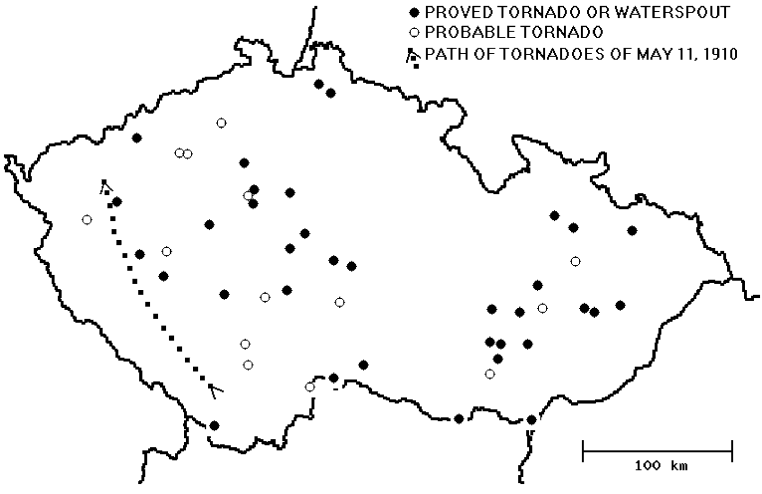

Fig. 6. Geographical distribution of recorded Czech tornadoes.

that this is mainly a mountainous, forested area with low population density and poor observation conditions, so many cases may have escaped detection for these reasons. Such explanations are unlikely for the other "tornado-free" region—the central part of the country. Any explanation for this "gap" remains speculative at this time.

The most important result both of the past and, more particularly, the most recent tornado-related work is that most of the Czech community has already accepted that tornadoes do occur in the Czech Republic and represent a definite threat. Although tornado warnings are unlikely to be issued in the Czech Republic in the immediate future, the general public is at least already aware of the tornado hazard. At the same time, the provision of safety information is increasing, particularly through the Internet. Finally, since many severe convective storms are "cross-border" events, the collaboration between scientists from neighboring countries and the establishment of a pan-European institution concerned with severe convective storms research (e.g., *a European Severe Storms Laboratory*) are highly desirable.

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References

Bretholz, B., 1923. Die Cronik der Böhmen des Cosmas von Prag. MGH SRG NS II. Weidmannsche Buchhandlung, Berlin 1923 (La) Lib. III, Cap. XLV. p. 219.

Brooks, H., Doswell III, C.A., 2001. Some aspects of the international climatology of tornadoes by damage classification. Atmos. Res. 56, 191–201.

Comenius, J.A., 1658, 1685. Orbis sensualium pictus (The Visible World). First printed in Nüremberg by Michael Endter in 1658.

Dobrovolný, P., Brázdil, R., 2003. Documentary evidence on strong winds related to convective storms in the Czech Republic since AD 1500. Atmos. Res. 67–68, 95–116 (this issue).

Dotzek, N., 2001. Tornadoes in Germany. Atmos. Res. 56, 235–253.

Dotzek, N., 2003. TorDACH Germany. http://www.tordach.org/de.

Edler von Wahlburg, E.S., 1911. Die Windhose von 15.Mai 1910 in West-Böhmen. Das Wetter 28, 135–141.

Emler, J., 1874. Cosmae Pragensis Chronica Boemorum cum continuatoribus. FRB II., 1, Praha 1874, p. 310.

Emler, J., 1875. Annales Gradicenses et Opatovicenses. Prameny dějin českých. FRB II., 2, Praha 1875, p. 398.

Holzer, A.M., 2001. Tornado climatology of Austria. Atmos. Res. 56, 203–211.

Lacinová, M., 2002. Vyhodnocení výskytu tornád na území dnešní České republiky od počátků českého písemnictví do roku 1999. Dissertation work, Charles University, Prague (in Czech).

Mendel, G., 1871. Die Windhose von 13. October 1870. Verh. Nat. Ver. Brünn 9, 229–245.

Munzar, J., 1993. Tromby (tonáda) na území České republiky v letech 1119–1993. Zborník Dejin Fyziky, vol. XI. Voj. Akadémia SNP, Liptovský Mikuláš, pp. 69–72. In Czech.

Munzar, J., 1998. Gregor Mendel and the tornado in Brno on 13th October, 1870. Morav. Geogr. Rep. 6, 53–60.

Řezáčová, D., Pešice, P., 2003. Severe convective phenomena in the territory of the Czech Republic (grant GACR 205/00/1451). http://www.ufa.cas.cz/html/meteo/stormcz.

Šálek, M., 1994. Silné bouřky na Moravě spojené s výskytem tromby v obci Lanžhot dne 26.5.1994. Meteorol. Zpr. 47, 172–177 (in Czech).

Setvák, M., 1999. Tornáda na území České republiky. Vesmír 78, 557–662 (in Czech).

Setvák, M., Šálek, M., 2003. Tornadoes and Similar Phenomena at the Territory of the Czech Republic and Slovakia. Czech Hydrometeorological Institute, Prague, Czech Republic. http://www.chmi.cz/torn.

Setvák, M., Židek, D., Hradil, M., 1996. Tornáda na severovýchodní Moravě a Slezsku 8. července 1996? Meteorol. Zpr. 49, 143–146 (in Czech).

Sulan, J., Setvák, M., Novák, P., 1998. Silná konvektivní bouře v Čechách v noci z 27.-28.6.1997. Meteorol. Zpr. 51, 118–125 (in Czech).

Wegener, A., 1917. Wind-und-Wasserhosen in Europa F. Vieweg & Sohn, Braunschweig.