Submitted (on 21 October 2002) to *Atmospheric Research* for the ECSS2002 special issue.

Tornadoes on the territory of the Czech Republic: From early medieval chronicles to the "internet society"

Martin Setvák [(1)] *, **Milan Šálek** [(2)], **Jan Munzar** [(3)]

[1)] Czech Hydrometeorological Institute, Na Šabatce 17, CZ-14306 Praha 4, Czech Republic
[2)] Czech Hydrometeorological Institute - Regional office Brno, Kroftova 43, CZ-61667, Czech Republic
[3)] Institute of Geonics, Czech Academy of Sciences, Drobného 28, CZ-60200 Brno, Czech Republic

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 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 the 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 Wahlburg (1911) and Wegener (1917). During the "socialist" period the term *"tornado"* was rarely 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 (1993) and Šálek (1994), 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 between 5 and 8 cases per year. This increase is a result of several important factors which are discussed in detail in the last section of this paper.

This paper is a compilation of authors' presentations at the Toulouse "Eurotornado 2000" and Praha "ECSS 2002" conferences, which are combined to summarise the complex tornado history and present stage of tornado documentation and research in the area of the Czech Republic.

Keywords: *tornado, waterspout, damaging winds, severe convective storm*

* Corresponding author, Fax: +420 24403 2442, E-mail address: setvak@chmi.cz

1. Introduction

The first historically documented civilization in the territory of present 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). Although the Boii used writing to communicate for trade purposes (using Greek or Etruscan alphabets), their official religion, enforced by druids, prohibited writing. Therefore, no local, written records are preserved from those times. A similar situation occurred when the country was ruled by Germanic tribes (end of 1st century B.C. – 4th century A.D.) and at the beginning of Slavic settlement (from about 6th century). The only preserved written documents from those times are those from the Roman Empire and typically record battles or political issues related to this region. Therefore, it is not surprising that the first tornado record is from a much later period, 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 to come.

2.1. Tornado of 30 July 1119, Prague - Vyšehrad

The first major chronicler of Czech history was Cosmas (1045 – 1125). An important feature of his chronicle is that he made a clear difference between events that he only heard about (*"according to old legends..."*) and events which he witnessed himself or which occurred during his life. In his "*Chronica Boemorum*", written between 1119 – 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):

> *Anno dominice incarnationis MCXVIIII. III. kal. Augusti (Jul.30), feria vero IIII, cum esset iam inclinata dies, ventus vehemens, immo ipse Satan in turbine ab australi plaga repente irruens super solarium duccis in urbe Wissegrad antiquum murum et eo firmissimum funditus subvertit; et inde magis - est admirandum - ex utraque parte, anteriori et posteriori, integra et inconcussa manente medietas palacii solo tenus est eruta, et cicius, quam tu festucam frangeres, trabes inferiores et superiores cum ipsa domo impetus venti fregit in frusta et dispersit. Fuit autem hec tempestas adeo valida, ut quacumque parte incubuit, huius terre silvas et arbores plantatas et cetera sibi obstantia suo impetu prostravit"*

[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".

Latin > Czech > English translation of the text:

On 30 July on Wednesday, shortly before the evening, a strong wind like Satan himself in the form of a swirl hit suddenly from the southern side the princely palace of Vyšehrad castle, displaced the foundation of an old and very strong wall and so – which is stranger still – both sides, front and back, remained intact and unshaken, the middle of the palace was displaced to the ground and quicker than a man could break a spike, an impact of wind broke the upper and lower beams together with the house itself into bits and scattered them. This gale was so strong, that wherever it raged in this land its strength displaced forests, grafts and everything that stood in its way.

Since this event occurred almost in the backyard of his "office" (he was Dean of Vyšehrad's Chapter), it is very likely that he either saw the event himself or at least made a detailed damage survey shortly afterwards. Unfortunately, the original copy as well as and the oldest copies of his 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:

Anno 1144, II Iddus Maii, videlicet in ipsa die pentecostes, nimis horribile et nostre etati inauditum apparuit monstrum iuxta castra ducis Ottonis, intuente et aliis quam pluribus proceribus necnon et innumerabili populi multitudine. Nam circa meridiem magna serenitate existente visa est a prefatis personis atra columna ascendere a terra usque ad sumitatem nubium, in cuius circuitu rotabatur impetus turbinis. Cumque niteretur ad prenoctatum locum pervenire, visum est a celi fastigio triangulum signum nimii candoris et miri acuminis sibi obviam venire, quod preculso infando monstro trasid id usque ad ima terre. Facto autem intervallo quasi unius hore iterum visa est alia columna tenebris densior et impetu turbinis validior eodem modo se a terra elavare, contra quam denuo eterum signum in modum splendidissime zone, in cuius medietate signum sancte crucis videbatur apparens, mira celeritate eam pertusit et usque ad superficiem terre pressit. Cumque ex militibus quidam audacter causa contemplandi accessissent, obvolutis obtulibus discesserunt, non enim valebant materiem tanti monstri intueri, sabulo et minutis lapillis circa faciem eorum rotantibus et evulsis fruticibus aciem oculorum eorum prepedientibus.

Latin > Czech > English translation of the text:

The prince Ota with other noblemen and a lot of people witnessed a horrible event which occurred on 14 May 1144 AD. Around noon, in fine weather, they were watching a dark column developing from the ground to the clouds with a strong vortex inside. When the column was approaching, another triangular monster formed in the sky and defeated the former one. After about an hour another very dark column accompanied by even stronger vortex was seen. Against it, another

sign in the shape of a very clear circle appeared, in the centre of which a holy cross was seen; this sign very quickly suppressed the monster to the ground. When some of the noblemen courageously approached the place in order to watch it more closely they had to turn back, protecting their eyes against sand, small stones and other debris.

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. Of special interest is that 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 in 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:

Principe autem exeunte de castro Pragensi magna vis ventorum cum turbine exorta est. Unde quendam equitem sequentem principem deiecit de ponte ante castrum, cuius equus mortuus est ex casu, ipse vero sanus evasit. Campanarium etiam ligneum cum campanis infra muros sanctae Mariae corruit eadem hora vi ventorum magna impellente, et aliae plures ruinae factae sunt in civitate et per villas...

Latin > Czech > English translation of the text:

When the prince was coming out of Prague castle, a great gale and a swirl hit and hurled down one horseman who was riding behind the prince, throwing him from the bridge before the castle. His horse died in the fall, but he escaped unscathed. Also, a wooden bell-tower with bells inside the walls of the church of Saint Mary collapsed in that hour by the strong impact of the winds, and many other damages were caused in the town and in 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 very 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 may 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 lower number of documented tornado records over most of these centuries is the simple fact that the authors of this paper admit a rather partial access to the old chronicles. A more detailed study of old chronicles has been carried out by Brázdil and Dobrovolný (2002), although even this may not be fully comprehensive. Another possible explanation may be a "sociological" one – that 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 – e.g. the "Hussite wars" (1420-1434), the "Thirty Years' War" (1618-1648) and the Czech "Dark Age" that followed (17th and most of the 18th cent.). This explanation has almost certainly influenced the total number of documented cases. Of course, climate oscillations 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). Indeed, this could have been the most important factor for some of these periods.

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 must have played its role as well.

In the last two decades of the 16th century the number of 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 favourable 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 dissipation 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) – 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 (Table1). 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[2], 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 tornado of 13th October 1870 in Brno 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 analysed by Gregor Mendel (the founder of genetics and a meteorologist) 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 (and 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.

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

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 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 hours and had a track of about 190 km (Figure 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 metres). 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 in one storm. 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) is known for the next seven decades. A comparison with the tornado records from neighbouring 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 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 almost ignored – damage phenomena were simply attributed to "damaging winds" accompanying convective storms and the term "tornado" was almost forbidden – both by journalists as well as by most of meteorologists. A "tornado" was something that was related to the U.S. Great Plains, but had no official presence in Central Europe. However, a few meteorologists had no hesitation in using this term, but they were not taken seriously. If journalists reported a tornado event, it was almost always described in other terms (often incorrectly).

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 1119-1993 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 Lanžhot (Šálek 1994). Three additional cases followed in 1996, 1997 and 1998, also

thoroughly documented by professional meteorologists and published in the Czech *Meteorological Journal* (not referenced here). 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 at 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, 2002, in "Internet resources"). 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 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[3]. 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[4]) is approaching that of neighbouring Germany (Dotzek 2002, in "Internet resources").

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 reaches Czech

[3] 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.

[4] The area of the Czech Republic is 78864 km^2, whereas the area of Germany is 356732 km^2.

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 popularisation of tornadoes, 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, 2002, in "Internet resources"). Part of the project was devoted to the documentation of all severe convective weather events (namely 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 which we hope to maintain even after the present GACR grant period is over, and which 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 digitised and given to meteorologists for documentary or study purposes. Here are some of the most interesting cases of this period:

- On 19 April 2000, the first Czech tornado was recorded on videotape (and also by a still camera). This tornado, although weak, was largely 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), mainly 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 a high tropospheric jet stream and a strongly

sheared environment (at low- to mid- levels, with a typical supercell hodograph). However, there were very low 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 hours after the "formal" sounding time).

- Another significant tornado outbreak of that year occurred on the 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 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. Figure 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 two 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 two years due to this year's large 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 three 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 a certain number of cases which have escaped their 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).

Figure 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 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.

Figure 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. Given the relatively low total number of recorded cases and the present uncertainty in F-scale rankings, no attempt to construct a lin-log graph of the distribution of tornadoes by F-scale (Brooks, Doswell, 2001) has been made so far.

Figure 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 that this is mainly mountainous forested area with a lower population density and poorer 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. In contrast to the first area, if funnel cloud observations were included into this map, the northern part of this "gap" would vanish (the southern part of this area and the southwest part of the country would remain tornado and funnel-cloud free). It is intended that this distribution pattern will be studied further in future with the aid of radar and lightning detection network observations.

The most important result both of the past and, more particularly, the most recent tornado-related work is that most of the Czech community have 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 neighbouring 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.

Acknowledgements

This research was supported by the Grant Agency of the Czech Republic, project #205/00/1451. The authors of this paper wish to thank *in memoriam* Marián Wolek (**U**2002), former deputy director of CHMI, for his long-term support of research of severe convective storms and of the European Conference of Severe Storms 2002. Our acknowledgement is also addressed to Jan Kouba for his excerpts from the old Czech chronicles, to John Tyrrell, Lubor Kysučan and Petr Durna for their help with language corrections and translations, and finally to all people whose information contributed to the Czech tornado climatology and statistics.

References

Brázdil R., Dobrovolný P., 2003: Documentary evidence on severe convective storms in the Czech Lands since AD. 1500. *Atmos. Res.* **58** (*in this issue*)

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.
Dotzek N., 2001: Tornadoes in Germany. *Atmos. Res.* **56**, 235-253.
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. *Verhandlungen des Naturforschenden Vereines in Brünn*, **9**, 229-245.
Munzar J., 1993: Tromby (tonáda) na území České republiky v letech 1119 – 1993. Zborník dejin fyziky XI, Voj. akadémia SNP, Liptovský Mikuláš, 69-72 (in Czech).
Munzar J., 1998: Gregor Mendel and the tornado in Brno on 13th October, 1870. *Moravian Geographical Reports*, **6**, 53-60.
Šálek M., 1994: Silné bouřky na Moravě spojené s výskytem tromby v obci Lanžhot dne 26.5.1994. *Meteorologické zprávy*, **47**, 172-177 (in Czech).
Wegener A., 1917: Wind-und-Wasserhosen in Europa. F. Vieweg & Sohn, Braunschweig.

Internet resources:

Setvák M., Šálek M., 2002: Tornadoes and similar phenomena at the territorry of the Czech Republic and Slovakia. http://www.chmi.cz/torn.
Dotzek N., 2002: TorDACH Germany. http://www.tordach.org/de.
Řezáčová D., Pešice P., 2002: Severe convective phenomena in the territory of the Czech Republic (grant GACR 205/00/1451). http://www.ufa.cas.cz/html/meteo/stormcz.

Figure 1. Drawing of a tornado from *Orbis Sensualium Pictus* (Comenius, 1658). This reproduction comes from a 1685 re-print from Levoča (Slovakia) 4-language version (Latin, German, Hungarian and Czech).

Fig. 1. Bahn der Windhose vom 11. Mai 1910 in West-Böhmen.

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

Figure 3. Tornado of the 20 July 2001 south of Brno. (Photo courtesy of Pavel Ambrož)

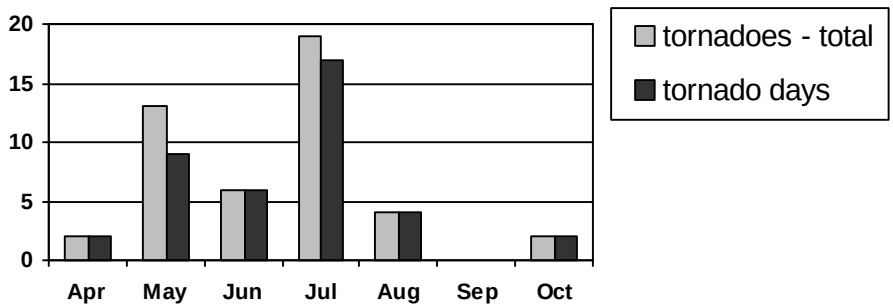

Figure 4. Total number of tornadoes and tornado days (a day with at least one tornado) by month – based on Table 1.

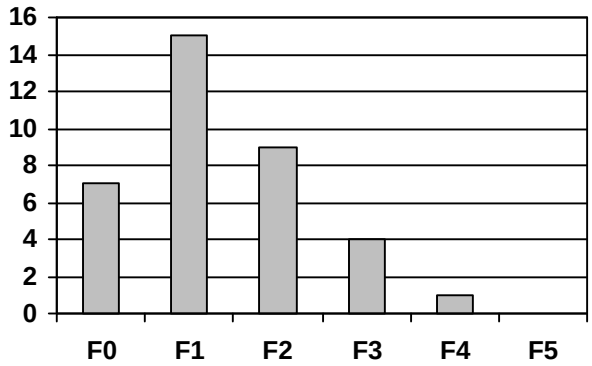

Figure 5. Total number of tornadoes by F-scale – based on Table 1.

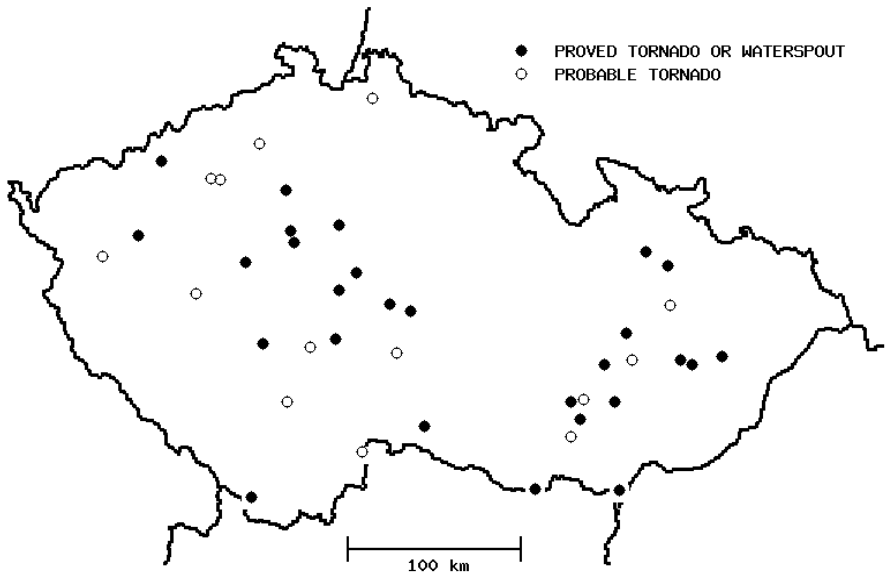

Figure 6. Geographical distribution of recorded Czech tornadoes.

Table 1. Known cases of tornado occurrences in the territory of the present Czech Republic. Summary of (Munzar 1993), (Setvák and Šálek, 2002, in "Internet resources") and (Lacinová 2002) . Funnel clouds without proved touchdown, downbursts and microbursts are not included here. The geographical coordinates are approximate only. Question marks indicate uncertainty.

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	?	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
1811-06-07	~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	?	Jistebnice u Tábora	49.49	14.53	?		T?
1824-07-27	?	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
1910-05-11	~16:00-19:30, ~3.5 hours	České Budějovice – Karlovy Vary	49.00 – 50.25	14.50 – 12.80	F3?		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	F2 (F3?)		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?
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 sec (?)	Vranovice (distr. Prostějov)	49.40	17.10	?		T?
2001-08-03	~ 17:00, (??? - minutes)	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

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 water spout

Remark: The tornado intensity is estimated here using Fujita scale; in case of ambiguous classification the nearest possible intensity class accompanied with the question mark is mentioned.