Deadly Tornadoes in Poland from 1820 to 2015

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ABSTRACT
Using historical sources derived from 12 Polish digital libraries, an investigation into killer tornado events was carried out. Although some of the cases took place more than 150 years ago, it was still possible to identify tornado phenomena and the course of events. This study has shown that historical sources contain dozens of tornado reports, sometimes with information precise enough to reconstruct the tornado damage paths. In total, 26 newly identified deadly tornado cases were derived from the historical sources and the information on 11 currently known was expanded. An average of 1–2 killer tornadoes with 5 fatalities may be depicted for each decade and this rate is decreasing over time. It was estimated that 5%–10% of significant tornadoes in Poland have caused fatalities and the average number of fatalities per significant tornado was roughly 0.27. Most of the cases were reported in late July and early August. The majority of deaths and injuries were associated with victims being lifted or crushed by buildings (usually a wooden barn). Most of these cases took place in rural areas but some tornadoes hit urban areas, causing a higher number of fatalities. The spatial distribution of cases included maxima in the central lowland and south-central upland of Poland. In a noticeable fraction of cases (38%), large hail occurred either before or after passage of the tornado.

1. Introduction
Tornadoes are among the most spectacular natural hazards that can pose a significant threat to life and property, and thus attract a lot of media attention. However, probably due to the infrequent occurrence of high-impact tornadoes in Poland, tornado reports have not been officially kept as they are, for example, in the United States. Therefore, it is not an easy task to create long-term climatological studies based on their occurrence, especially taking into account the temporal and spatial reporting inhomogeneities prevalent in Poland. These arise mainly from historical changes in the national borders, wars, political regimes, language diversity, and changing severe weather awareness.

For a long time, tornadoes in Poland were regarded by society as strange and rare phenomena reserved mainly for the territory of the United States (Dotzek 2001; Taszarek and Brooks 2015). Doswell (2003) described this situation as a self-fulfilling prophecy, in which denying the existence of tornadoes resulted in no record keeping of such events. However, tornado databases are likely to be more consistent over time, especially for intense spectacular events that cause significant property damage (Brooks and Doswell 2001; Verbout et al. 2006; Rauhala et al. 2012; Taszarek and Brooks 2015). This issue concerns especially deadly tornadoes that attract more public attention and are usually better documented in media reports. The studies on historical tornado cases in Europe (Wegener 1917; Groenemeijer and Kühne 2014; Antonescu et al. 2016) have shown that even old cases from previous centuries can be derived from archival sources.

On the basis of tornado reports in the European Severe Weather Database (ESWD; Dotzek et al. 2009) hosted by the European Severe Storms Laboratory (ESSL), Groenemeijer and Kühne (2014) estimated that tornadoes in Europe kill 45–60 people each decade (1900–2013 time frame). They suggested that due to problems related to tornado reporting the average fatality rate is probably higher and estimated the true value to be closer to 100–150.

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For comparison, in the United States, Ashley (2007) estimated the average number of tornado-related deaths per decade at 1000 since the 1880s, and 500 since the 1980s. Nowadays, 68%, 31%, and 1% of casualties are due to violent [F4–F5 on the Fujita (F) scale; Fujita 1971], strong (F2–F3), and weak (F0–F1) tornadoes, respectively.

Apart from numerous studies on tornado fatalities in the United States (e.g., Brooks and Doswell 2002; Merrell et al. 2005; Simmons and Sutter 2005, 2008; Ashley 2007; Ashley et al. 2008), little such research exists on killer tornadoes in Europe. In Poland, the climatology of tornadoes, taking into account the period 1899–2013, has been studied by Taszarek and Brooks (2015). However, while deadly tornado case studies exist (e.g., Gumiński 1960; Chmielewski et al. 2013; Popławska 2014; Taszarek et al. 2016), a comprehensive study on tornado fatalities in Poland is absent, mainly due to the lack of reports or insufficient data on killer tornadoes. The ESWD data used in studies by Taszarek and Brooks (2015), Groenemeijer and Kühne (2014), and Antonescu et al. (2016) contained only a few such cases; thus, fatality records were underestimated.

To improve the database of tornado fatalities in Poland, the aim of this study was to investigate historical records from the nineteenth and twentieth centuries. The analysis of such data is important to estimate the future threat of rare events that have the potential to create a major disaster (Doswell 2003). The 1820s were chosen as a starting point due to this time frame having the first available description of fatalities from tornadoes in Poland. Additionally, most of the archival sources in the digital libraries have been made available since the early nineteenth century.

This paper is organized as follows: in section 2 the methodology related to collecting tornado reports, quality control issues, intensity estimation, and a short overview of historical tornado studies are presented. Section 3 contains the results of the analysis while the last section provides a discussion and conclusions. The most important factual information on each killer tornado case (as derived from the scientific literature and historical sources) is presented in the appendixes.

2. Database and methodology
   a. Quality control assumptions

Cases with descriptions of considerable damage including fatalities provided no doubt that the described phenomenon was related to a tornado. In events with less severe damage, it was important to investigate whether the description may have been related to a severe straight-line wind event such as a downburst (Fujita and Wakimoto 1981). This issue concerned primarily the archival descriptions from the nineteenth and twentieth century when the term “tornado” (Polish: trwa powietrzna) was not well recognized in Polish media sources. Although archival sources sometimes contained detailed descriptions regarding long, narrow damage tracks and/or eyewitnesses mentioning a rotating cloud sticking onto the earth’s surface, the term “strong hurricane” was normally used. Conversely, some of the newspaper reports, especially from the late twentieth and twenty-first century, started using the term tornado commonly when convection-related wind gusts caused strong damage to infrastructure (without any characteristic tornado damage indicators). These issues represented a source of uncertainty when classifying such events.

In a quality control process in which credibility ratings were assigned, the most important issue (besides the name of the phenomenon that was assigned by the newspaper) was the description of the event and the inflicted damage. Cases with fatalities due to severe storms as described in the newspapers that lacked eyewitness funnel cloud reports or information about physical processes characteristic of tornadoes (objects and people lifted in the air, narrow and long damage path, debris and trees scattered in different directions, great destruction, etc.) were not considered. In cases where tornado (and/or a description suggesting the occurrence of a funnel cloud) was not mentioned but the report had information suggesting the presence of damage due to a vortex, a “case uncertain” rating was assigned. The same rating was also attributed to cases in which tornado or a visible funnel cloud was mentioned, but the overall information about the event and damage was too limited. Cases for which descriptions provided no doubt about the presence of a vortex phenomenon, (the presence of a funnel cloud along with the description of a typical tornado damage), received a “case confirmed” rating. The last credibility rating (“case fully verified”) was assigned to cases in which damage was described in detail (usually in numerous sources), and where a reconstruction of the event along with the tornado damage track was possible.

To perform an additional quality control of the analyzed cases, twentieth- and nineteenth-century reanalysis data (Compo et al. 2011) were used for cases since 1870, mainly to check whether simulated synoptic-scale conditions were in general conducive to the occurrence of severe convective storms (e.g., an increased midlevel flow, the presence of a thermal boundary, the passage of a trough) on days with alleged tornadoes. Since the authors were aware of the spatial and temporal limitations of the reanalysis data, only the general synoptic pattern was taken into consideration. This in particular helped to ensure whether the event was plausible rather than excluding it from the analysis. In cases with
suspicious or limited descriptions that in addition took place in an unfavorable synoptic pattern, a case uncertain rating was assigned. In addition, the geostrophic wind at 500 hPa was used to estimate the general motion of the thunderstorm (and of approximately the tornado) in cases where the description of the event did not allow for such an estimate. However, we acknowledge that the real tornado motion might have differed from this estimate due to left- or right-turning supercells.

b. Inhomogeneity factors

Numerous factors influenced tornado reporting and availability of reports in media sources. The most important ones refer to political and social contexts, Poland’s changing borders, and world wars, which resulted in the decline in interest in atmospheric phenomena. From 1795 to 1918, the territory of Poland was under German, Austrian, and Russian occupation, and never gained independence. However, Polish nationality and the awareness of one’s cultural identity remained. Numerous Polish newspapers operated on a regional scale. As Antonescu et al. (2016) suggested, development of national and regional newspaper-type publications was the main factor that influenced the spatial distribution and temporal evolution of tornado databases. In this study, regional libraries, that covered almost the whole modern-day territory of Poland (except the southwestern and northeastern areas), were accessed. The highest number of archival newspaper editions was available for the second half of the nineteenth and first half of the twentieth century. During the socialistic period from 1945 to 1989 any information on catastrophic events was difficult to find, thus resulting in a low number of tornado reports (Taszarek and Brooks 2015). A similar situation also happened in Romania (Antonescu and Bell 2015) and the Czech Republic (Setvák et al. 2003) during the 1970s and 1980s. The existence of tornadoes was not officially recognized and the word tornado was barred from both official meteorological and mass media reports (Antonescu et al. 2016).

Since 2000, advances in communication technologies and development of tornado databases and thunderstorm observer networks have led to a rapid surge in tornado reporting both in Poland (8–14 yr⁻¹ Taszarek and Brooks 2015) and Europe as a whole (200–300 yr⁻¹ Groenemeijer and Kühne 2014). This suggested that before 2000, tornadoes were strongly underestimated in Europe.

c. Collecting tornado reports

In 1917, Alfred Wegener, a German meteorologist, geophysicist, and pioneer polar researcher, in his work Wind- und Wasserhosen in Europa (Wind and Waterspouts in Europe), published one of the first collections of tornado records in Europe, where he included a few tornado cases from the territory of western Poland (in that time these areas belonged to the German empire). His study was based mainly on tornado reports collected from a wide range of scientific literature and personal observations. The work of Wegener (1917) contained probably the oldest well-described killer tornado case that occurred over the current territory of Poland near Oleśnica on 11 September 1535. The tornado lifted wooden wagons, roofs, people, and even whole wooden houses. Over 60 masonry walls were demolished. According to original sources, five people died after being crushed under collapsed walls.

Tornado reports derived from the work of Wegener (1917), along with well-known Polish killer tornado cases from the twentieth and twenty-first century described in scientific literature [20 July 1931, Gumiński (1936); 15 and 16 May 1958, Rafałowski (1958); 20 May 1960, Salomonik (1960); 15 August 2008, Poplawska (2014); 14 July 2012, Taszarek et al. (2016)] were reported to ESWD. This resulted in a total of 11 killer tornado cases. However, initially only six of these contained information about fatalities, among which three had incomplete statistics on victims. Thus, all cases required an additional study.

To look for tornado descriptions, which are undocumented in scientific literature, and expand information about currently known cases, archival sources from the nineteenth and twentieth century were searched. This was done by browsing databases of several Polish digital libraries that contained original scans of various newspapers with local and national coverage (Table 1). These were studied using keyword searches like trąba powietrzna, huragan, and orkan (tornado, hurricane, and orcane). In some cases, an investigation was supported by performing web searches and obtaining original scientific papers in the library of IMGW-PIB (Polish Institute of Meteorology and Water Management–National Research Institute). In total, 26 newly identified killer tornado cases that occurred in the territory of Poland during the nineteenth and twentieth century were found.

Together with previous cases included in the ESWD, a total of 37 killer tornado cases are investigated in this paper. A summary of all cases with information about exact date, place, subjective estimate of strength on the F scale (Fujita 1971), damage path size, tornado motion, number of fatalities, assigned credibility rating, and cause of death is presented in Table 2.

d. Intensity estimation

As in ESWD, the original F scale was used to rate the intensity of tornadoes on the basis of damage descriptions. However, because of very limited information about the inflicted damage in historical cases, instead of using a traditional F0–F5 scale, we defined less accurate
categories that allowed for estimation of tornado intensity with some degree of approximation. Four categories (still using damage indications from the original F scale) were used to rate cases: F1/F2 (tornadoes bordering on weak and strong intensity), F2/F3 (strong tornadoes), F3/F4 (tornadoes bordering on strong and violent intensity), and F4/F5 (violent tornadoes). For example, if a case was rated F2/F3, it was assumed that both intensities were possible, but it was unlikely that the case was weaker than F2 or stronger than F3. None of the damage descriptions allowed for an F0/F1 intensity rating. Joint ratings were not used for the recent tornado cases (15 August 2008 and 14 July 2012), where damage surveys were detailed enough to assign a particular F-scale rating.

3. Results

a. Credibility rating

A total of 37 cases from the period 1820–2015 were responsible for 106 fatalities, providing an average of 2.9 fatalities per case (Table 2). Among all, 9 cases (24% of the data) were classified as “event fully verified.” That group consisted of 38 fatalities and included the most deadly case—the tornado of 14 May 1886 that passed through Krosno Odrzańskie and killed 13 people. The tornadoes were confirmed with relatively good credibility (case confirmed rating) in another 10 cases (27%). The case uncertain rating was assigned in 18 cases (49%) where tornadoes were likely, but the information was insufficient to ultimately confirm the event.

b. Decadal variation

Although the database contains no deadly tornadoes from the 1840s, 1970s, and 1980s, an average of one–two killer tornadoes with five fatalities may be depicted for each decade based on the records from the entire period of analysis (Fig. 1). It was hypothesized that the number of fatalities in the first half of the nineteenth century might have been higher, but the limited availability of historical sources from this period did not allow for investigation of more cases. The highest number of 20 fatalities and 6 killer tornadoes occurred in the 1880s, whereas the reporting “gap” was observed during the second half of the twentieth century. A similar gap was also pointed out by Dotzek (2001), Holzer (2001), Antonescu and Bell (2015), and Taszarek and Brooks (2015), and was justified as “certainly artificial,” resulting in the weather service, journalists, and the general public ignoring such events. During the socialist period, it was typical that tornadoes were virtually ignored—damage events were simply attributed to damaging wind gusts within convective storms, such that the term tornado was essentially forbidden (Setvák et al. 2003). After Poland transformed its political system in 1989, the situation changed and an increase in tornado reporting was observed (Taszarek and Brooks 2015).

The analysis showed that the average decadal number of tornado fatalities in Poland has decreased throughout time. Taking into account 40-yr intervals, an average of 10.5 fatalities per decade in the years 1860–99 decreased to 6.5 in the years 1900–39 to 3.0 in the years 1940–79 to only 1.2 in recent years (1980–2015). The last two values may be underestimated and be a result of underreporting issues during the socialist period. The same decrease since the 1930s was also observed in the United States (Ashley 2007). Simmons and Sutter (2005) have also shown that tornado casualties due to violent cases (F4–F5) have decreased significantly over the course of the twentieth century. Doswell et al. (1999) and Brooks and Doswell (2002) suggested that this decline can be
<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Nearest city</th>
<th>Rating</th>
<th>Time (UTC)</th>
<th>Path length</th>
<th>Path width</th>
<th>Motion</th>
<th>Deaths</th>
<th>Credibility</th>
<th>Cause of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30 Jun 1829</td>
<td>Turzyn</td>
<td>F1/F2</td>
<td>1700</td>
<td>10 km</td>
<td>800 m</td>
<td>No data</td>
<td>4</td>
<td>Case confirmed</td>
<td>4 drowned in an overturned boat</td>
</tr>
<tr>
<td>2</td>
<td>15 May 1830</td>
<td>Szamotuły</td>
<td>F2/F3</td>
<td>Evening</td>
<td>20 km</td>
<td>No data</td>
<td>SE–NW</td>
<td>1</td>
<td>Case confirmed</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>3</td>
<td>27 Jun 1833</td>
<td>Węgrzynów</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>16 km</td>
<td>No data</td>
<td>SW–NE</td>
<td>2</td>
<td>Case uncertain</td>
<td>2 crushed in a building</td>
</tr>
<tr>
<td>4</td>
<td>12 May 1851</td>
<td>Czarsznica</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>1</td>
<td>Case confirmed</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>5</td>
<td>18 Jul 1851</td>
<td>Bobrowniki</td>
<td>F2/F3</td>
<td>1450</td>
<td>15 km</td>
<td>No data</td>
<td>SW–NE</td>
<td>3</td>
<td>Case uncertain</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>6</td>
<td>18 Jul 1851</td>
<td>Szopienice</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>10</td>
<td>Case uncertain</td>
<td>10 crushed in a building</td>
</tr>
<tr>
<td>7</td>
<td>1 Jun 1853</td>
<td>Wieciecha</td>
<td>F1/F2</td>
<td>1600</td>
<td>5 m</td>
<td>50 m</td>
<td>SW–NE</td>
<td>1</td>
<td>Case confirmed</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>8</td>
<td>29 Jul 1862</td>
<td>Zerków</td>
<td>F3/F4</td>
<td>1400</td>
<td>8 km</td>
<td>2000 m</td>
<td>SW–NE</td>
<td>3</td>
<td>Case fully verified</td>
<td>2 crushed in a building, 1 lifted</td>
</tr>
<tr>
<td>9</td>
<td>31 May 1866</td>
<td>Jarluty</td>
<td>F3/F4</td>
<td>1400</td>
<td>7 km</td>
<td>No data</td>
<td>SW–NE</td>
<td>2 (19?)</td>
<td>Case fully verified</td>
<td>7 lifted, 12 people missing</td>
</tr>
<tr>
<td>10</td>
<td>19 Jun 1871</td>
<td>Tuchola</td>
<td>F2/F3</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>SE–NW</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>11</td>
<td>12 Aug 1880</td>
<td>Naceślawice</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>12</td>
<td>15 Aug 1880</td>
<td>Rębowo</td>
<td>F1/F2</td>
<td>1450</td>
<td>7 km</td>
<td>No data</td>
<td>NE–SW</td>
<td>1</td>
<td>Case confirmed</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>13</td>
<td>9 Aug 1881</td>
<td>Wronczyn</td>
<td>F1/F2</td>
<td>Daytime</td>
<td>No data</td>
<td>No data</td>
<td>W–E</td>
<td>2</td>
<td>Case uncertain</td>
<td>2 crushed by falling debris</td>
</tr>
<tr>
<td>14</td>
<td>13 Jul 1884</td>
<td>Gostycznik</td>
<td>F1/F2</td>
<td>1700</td>
<td>No data</td>
<td>No data</td>
<td>W–E</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed by a falling debris</td>
</tr>
<tr>
<td>15</td>
<td>14 May 1886</td>
<td>Kronowo</td>
<td>F3/F4</td>
<td>1250</td>
<td>30 km</td>
<td>1200 m</td>
<td>SW–NE</td>
<td>13</td>
<td>Case fully verified</td>
<td>5 lifted, 3 crushed in a building, 5 drowned in an overturned boat</td>
</tr>
<tr>
<td>16</td>
<td>13 Aug 1888</td>
<td>Wałećwice</td>
<td>F2/F3</td>
<td>1530</td>
<td>25 km</td>
<td>No data</td>
<td>W–E</td>
<td>2</td>
<td>Case confirmed</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>17</td>
<td>24 Jul 1890</td>
<td>Modla</td>
<td>F2/F3</td>
<td>1300</td>
<td>35 km</td>
<td>200 m</td>
<td>W–E</td>
<td>3 (4?)</td>
<td>Case fully verified</td>
<td>3 crushed in a building, 1 person missing</td>
</tr>
<tr>
<td>18</td>
<td>30 Jul 1895</td>
<td>Rudka</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>30 km</td>
<td>No data</td>
<td>W–E</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed by a falling tree</td>
</tr>
<tr>
<td>19</td>
<td>7 Jul 1897</td>
<td>Pytowicze</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>30 km</td>
<td>No data</td>
<td>W–E</td>
<td>3</td>
<td>Case confirmed</td>
<td>1 crushed by a falling debris, 1 lifted in a droshky, 1 unknown causes</td>
</tr>
<tr>
<td>20</td>
<td>27 Jun 1905</td>
<td>Kamienica</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>3 km</td>
<td>No data</td>
<td>N–S</td>
<td>3</td>
<td>Case confirmed</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>21</td>
<td>30 Jul 1912</td>
<td>Pobikry</td>
<td>F2/F3</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>22</td>
<td>15 Aug 1922</td>
<td>Jedrzejów</td>
<td>F2/F3</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>W–E</td>
<td>8</td>
<td>Case uncertain</td>
<td>8 lifted</td>
</tr>
<tr>
<td>23</td>
<td>27 Apr 1926</td>
<td>Rowiska</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>10 km</td>
<td>No data</td>
<td>S–N</td>
<td>2</td>
<td>Case uncertain</td>
<td>2 lifted</td>
</tr>
<tr>
<td>24</td>
<td>4 Jul 1928</td>
<td>Jaktory</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>2</td>
<td>Case uncertain</td>
<td>2 lifted</td>
</tr>
<tr>
<td>25</td>
<td>20 Jul 1931</td>
<td>Lublin</td>
<td>F4/F5</td>
<td>1300</td>
<td>20 km</td>
<td>300 m</td>
<td>SW–NE</td>
<td>6</td>
<td>Case fully verified</td>
<td>3 lifted, 2 crushed by a falling debris, 1 lifted in a droshky</td>
</tr>
<tr>
<td>26</td>
<td>29 Jul 1936</td>
<td>Łążyn</td>
<td>F2/F3</td>
<td>1200</td>
<td>15 km</td>
<td>No data</td>
<td>SW–NE</td>
<td>4</td>
<td>Case confirmed</td>
<td>4 crushed in a building</td>
</tr>
<tr>
<td>27</td>
<td>21 Jul 1940</td>
<td>Borzymy</td>
<td>F2/F3</td>
<td>Daytime</td>
<td>10 km</td>
<td>600 m</td>
<td>SW–NE</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>28</td>
<td>13 Jun 1946</td>
<td>Żabrzeż</td>
<td>F1/F2</td>
<td>Daytime</td>
<td>No data</td>
<td>No data</td>
<td>S–N</td>
<td>1</td>
<td>Case uncertain</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>29</td>
<td>20 Aug 1946</td>
<td>Stronie Śląskie</td>
<td>F3/F4</td>
<td>Evening</td>
<td>20 km</td>
<td>1000 m</td>
<td>SW–NE</td>
<td>1</td>
<td>Case confirmed</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>30</td>
<td>15 May 1958</td>
<td>Rawa Mazowiecka</td>
<td>F3/F4</td>
<td>1600</td>
<td>20 km</td>
<td>800 m</td>
<td>SW–NE</td>
<td>2</td>
<td>Case fully verified</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>31</td>
<td>16 May 1958</td>
<td>Nowe Miasto nad Pilica</td>
<td>F3/F4</td>
<td>1530</td>
<td>13 km</td>
<td>200 m</td>
<td>SW–NE</td>
<td>1</td>
<td>Case fully verified</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>32</td>
<td>23 Jul 1958</td>
<td>Swaty</td>
<td>F1/F2</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>S–N</td>
<td>2</td>
<td>Case uncertain</td>
<td>Unknown causes</td>
</tr>
<tr>
<td>33</td>
<td>20 May 1960</td>
<td>Przeworski</td>
<td>F2/F3</td>
<td>1200</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>3</td>
<td>Case uncertain</td>
<td>1 crushed in a detailed train, 1 crushed in a building</td>
</tr>
<tr>
<td>34</td>
<td>20 May 1960</td>
<td>Żulice</td>
<td>F2/F3</td>
<td>1300</td>
<td>No data</td>
<td>No data</td>
<td>SW–NE</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>35</td>
<td>8 Jul 1996</td>
<td>Sachodobieckie</td>
<td>F1/F2</td>
<td>1700</td>
<td>No data</td>
<td>No data</td>
<td>S–N</td>
<td>1</td>
<td>Case uncertain</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>36</td>
<td>15 Aug 2008</td>
<td>Rusinowice</td>
<td>F3</td>
<td>1530</td>
<td>60 km</td>
<td>1000 m</td>
<td>SW–NE</td>
<td>2</td>
<td>Case fully verified</td>
<td>1 crushed in a building</td>
</tr>
<tr>
<td>37</td>
<td>14 Jul 2012</td>
<td>Wycinki</td>
<td>F3</td>
<td>1500</td>
<td>42 km</td>
<td>700 m</td>
<td>SW–NE</td>
<td>1</td>
<td>Case fully verified</td>
<td>1 crushed in a building</td>
</tr>
</tbody>
</table>
attributed to the advancement in tornado forecasting technology, improved communication, development of meteorological observer networks, better building construction techniques, development of a Doppler radar network, and the implementation of watch–warning processes. Sims and Baumann (1972) and Cohen and Nisbett (1998) pointed out that human perception and response to the threat of tornadoes may be influencing the number of fatalities across different regions. Complacency ("It can’t happen here!") and detachment from the natural environment and a general failure to embrace warning information may also be important factors in explaining human behavior during tornado events, and hence the number of fatalities (Biddle 1994). Authors speculate that the drop in fatalities over the decades in Poland may be due to advances in construction techniques and it is unlikely that the fatality rate will continue to decrease unless considerable improvements in tornado warnings are implemented.

In Poland, official tornado forecasts and warnings have never been performed by the Institute of Meteorology and Water Management-National Research Institute (IMGW-PIB) (Rauhala and Schultz 2009; Taszarek 2013). Up until 1997 when the so-called Polish millennium flooding took place (Kundzewicz et al. 1999), severe weather awareness in Polish society was relatively low. In the twenty-first century numerous advances in severe thunderstorm forecasting (e.g., the foundation of the Polish Storm Chasing Society and the development of PERUN lightning detection and Polish Doppler radar network (POLRAD) (Jurczyk et al. 2008; Taszarek et al. 2015) have been introduced and supported the growth in severe weather awareness. However, this has not led to an elimination of tornado casualties as evidenced by recent killer tornado events (15 August 2008 and 14 July 2012).

c. Monthly and diurnal distribution

All tornado cases occurred during late spring and summer from April to August (Fig. 2). The highest number of tornadoes (16) and fatalities (50) came from late July and early August. An increased number of killer tornado cases was also found in May when the highest number of strong/violent cases with 29 fatalities was reported. Early June consisted of only two reports. A similar pattern in significant (F2+) tornado occurrences (66 cases in the time frame 1899–2013) was also found by Taszarek and Brooks (2015).

The approximate time (±1 h) of the tornado occurrence was defined in 20 cases, while in another 13 cases it was possible to determine that the tornado occurred during daytime or evening hours. Among reports where the time was defined, the highest number of cases took place between 1400 and 1600 UTC. This is consistent with the findings of Groenemeijer and Kühne (2014), Taszarek and Brooks (2015), and Antonescu et al. (2016), who found that significant tornadoes in the central European region are most likely in the late afternoon.

d. Spatial distribution and tornado motion

Most of the cases (location denotes the most known or nearest place of fatality/fatalities caused by the tornado) took place in the central lowland and south-central upland part of Poland (Figs. 3a,d). Similar areas were also denoted in previous studies on tornadoes in Poland as conducive to significant tornado occurrence (Walczakiewicz et al. 2011; Lorenc 2012; Taszarek and Brooks 2015). However, the spatial distribution of population density may play a significant role in these data. It is possible that a greater number of tornado reports and fatalities came from areas that were simply more populated, especially when the tornado hit urban areas (Fig. 3c). In the provinces, the mean number of tornado cases per 100 years with values normalized to 10,000 km² was highest in the Silesian and Łódź Voivodeships, Poland (Fig. 3b). The most deadly cases (18 July 1851, 14 May 1886, 31 May 1866, 15 August 1922; Table 2) occurred in the Mazovian, Lubusz, Silesian, and Świętokrzyskie Voivodeships, Poland.

From the use of reanalysis data and descriptions of the events, it was possible to define tornado motion in 34
cases. It is worth underlining that almost all cases containing information about the direction of a tornado movement agreed with the 500-hPa geopotential pattern obtained from the reanalysis data. A majority of cases were associated with southwest (53%) and west (24%) airflow, while tornadoes occurring from south (12%) and southeast (6%) directions were less frequent. Similar findings were obtained by Suckling and Ashley (2006) who found that almost 70% of U.S. tornadoes were associated with west and southwest airflows.

e. Circumstances of death

It was possible to investigate the circumstances of death surrounding 87 of 107 fatalities. Almost 43% of the deaths happened outdoors while 44% were attributable to being inside buildings (Table 3). Around 13% of the deaths were associated with means of transportation such as boat, drosky, or train. Cases in which people were lifted into the air were usually associated with being in open space and devoid of appropriate shelter. Only a small fraction of cases were associated with deaths due to being crushed by a falling tree, what is known to predominantly cause fatalities in straight-line wind events according to ESWD records for Poland. In the United States, as was suggested by Brooks and Doswell (2002), fatalities within vulnerable housing stock continue to provide a major obstacle in reducing overall tornado death rates. The majority of these cases take place in mobile homes (44% of all cases; Ashley 2007).

f. Intensity rate

A noticeable fraction of cases (38%) contained descriptions about accompanying large and very large hail
before or after the passage of the tornado. This may suggest that tornadoes were predominantly associated with the presence of mesocyclones [convective cell that has a deep and persistent rotating updraft; Doswell and Burgess (1993); Davies-Jones et al. (2001)], which are known to be distinctive in producing large hailstones (Van Den Heever and Cotton 2004; Donavon and Jungbluth 2007).

On the basis of damage descriptions, 8 cases were classified as weak/strong (F1/F2), 19 as strong (F2/F3), 7 as strong/violent (F3/F4), and 1 as violent (F4/F5) in terms of intensity. Two deadly tornado cases from the twenty-first century with an accurate damage survey were rated as F3. The average path length computed from all cases where this information was available (22 cases) amounted to 19.1 km (maximum 42 km, minimum 3 km), while the average path width (12 cases) was estimated at 737 m (maximum 2000 m, minimum 50 m). Similar average path characteristics were obtained from European records of F3 and F4 tornadoes (Groenemeijer and Kühne 2014).

From the use of significant tornado frequency as assessed by Taszarek and Brooks (2015) for Poland (around 1–3 per year), it can be estimated that approximately 400 significant tornadoes occurred in the period 1820–2015. Assuming that 29–37 cases in our study reached significant intensity, this would indicate that around 5%–10% of significant tornadoes in Poland caused fatalities and the average number of fatalities per any significant tornado was about 0.27. Although a similar value (0.28) obtained by Groenemeijer and Kühne (2014) was assigned to F3 tornadoes, we hypothesize that due to incomplete knowledge on killer tornado cases in Poland and a presumably imperfect estimate in Taszarek and Brooks (2015), the true value is probably higher. Nevertheless, an estimation of 20 significant and 1–2 deadly tornadoes per decade, indicate that strong and deadly tornadoes are rather a rare phenomenon in Poland.

g. Comparison with other European countries

It is difficult to compare our results with other European countries because only a limited number of studies on deadly tornadoes have been published. In addition, even after the launch of ESWD, underreporting issues (especially considering southern and eastern European areas) have continued which limits the ability to compare databases between particular countries in a reliable way. However, as Groenemeijer and Kühne (2014) suggests, ESWD tornado data in central European countries (especially Germany) is more reliable and less susceptible to underreporting issues than the rest of Europe.

Considering ESWD deadly tornado records in the time frame 1820–2015 (Table 4) it can be defined that

<table>
<thead>
<tr>
<th>Location</th>
<th>Reason</th>
<th>No. of fatalities</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being outdoors</td>
<td>Hit by a falling debris</td>
<td>6 (7%)</td>
<td>37 (43%)</td>
</tr>
<tr>
<td></td>
<td>Crushed by a falling tree</td>
<td>3 (4%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lifted</td>
<td>28 (32%)</td>
<td></td>
</tr>
<tr>
<td>Being in the building</td>
<td>Crushed in a building</td>
<td>38 (44%)</td>
<td>38 (44%)</td>
</tr>
<tr>
<td>Being in means of transportation</td>
<td>Drowned due to overturned boat</td>
<td>9 (10%)</td>
<td>12 (13%)</td>
</tr>
<tr>
<td></td>
<td>Lifted in a droshky</td>
<td>2 (2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Derailed train</td>
<td>1 (1%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unknown causes</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 4. Deadly tornadoes in chosen European countries in the time frame 1820–2015 (source: ESWD).
the highest number of deadly tornadoes (53) was reported in Germany (which deal probably with the lowest ratio of underreporting issues among all European countries). Both the total number of fatalities (an average of 2–3 casualties per tornado) and mortality of the most deadly tornado case (9 September 1913, Helgoland, 14 casualties) show a similarity with Polish records suggesting a similar killer tornado threat.

The highest number of fatalities and thus the most deadly tornadoes were recorded in Italy where 275 people have been killed. Although the number of killer tornadoes in Italy was lower than in Poland and Germany (probably due to underreporting issues), the mortality rate was much higher. A similar situation was also observed in France where 23 tornadoes were responsible for 130 fatalities, including one of the most deadly European tornado (19 August 1845, Montville, France, 70 casualties). Large numbers of fatalities (106) within just 18 tornadoes and a most deadly case in Ivanovo, Russia (6 September 1984, 69 casualties), was observed in western Russia where population density is much lower than in central Europe and where tornado events are severely underestimated. Other countries such as Spain, Turkey, Austria, the Netherlands, and Romania demonstrated higher mortality rates than in Polish and German records, but due to small sample size and underreporting issues it is difficult to define how reliable these estimates are.

4. Summary and conclusions

Using historical sources derived from 12 Polish digital libraries and the time frame between 1820 and 2015, research to examine deadly tornado descriptions was conducted. Although some of the tornadoes occurred more than 150 years ago, it was still possible to identify them and the course of the events with relatively high credibility. This study has shown that historical sources contain dozens of tornado reports, sometimes with information precise enough to reconstruct tornado damage paths. Surprisingly, newspaper sources from the turn of the nineteenth and twentieth century turned out to be of better quality than those from the socialistic period in the second half of the twentieth century. In total, the Polish tornado climatology was expanded with 26 newly identified deadly tornado cases while the information on 11 currently known was updated. Although the analysis was under influence of temporal and spatial reporting inhomogeneities, several conclusions can be drawn.

1) An average of 1–2 killer tornadoes with 5 fatalities may be depicted for each decade and this rate is decreasing over time. It is estimated that around 5%–10% of significant tornadoes in Poland cause fatalities, while the average number of fatalities per any significant tornado amounts to roughly 0.27.

2) The majority of deaths and injuries were associated with victims being lifted or crushed by buildings (usually a wooden barn). Most of the killer tornadoes occurred in rural areas but some hit urban areas, causing a higher number of fatalities. Cases in which people were lifted into the air were usually associated with being in open space and devoid of appropriate shelter.

3) Killer tornadoes occur from late April to late August with the peak activity in late July and early August. They are the most likely in the late afternoon. These findings agree with those of Groenemeijer and Kühne (2014), Taszarek and Brooks (2015), and Antonescu et al. (2016) on significant tornado occurrence in the central European region.

4) Most of the cases took place in the central lowland and south-central upland part of Poland. Although this finding overlaps partly with Taszarek and Brooks (2015), it is possible that our results may have been influenced by a diverse spatial range of regional newspaper archives and spatial distribution of population density.

5) A majority of cases were associated with southwest and west airflows, which coincided with the results obtained for the United States by Suckling and Ashley (2006).

6) Last, a noticeable fraction of cases contained descriptions about accompanying large and very large hail. This suggested that tornadoes were predominantly associated with mesocyclones, which are known to be distinctive in producing large hailstones.

Acknowledgments. We thank Thilo Kühne and Artur Surowiecki for their contribution in investigating historical tornado cases in Poland and their support in this work. Special thanks go also to Joanna Gudowicz for her help in making tornado track maps. We appreciate also valuable comments of anonymous reviewers that helped to improve this study. This research was supported by the grant of Polish National Science Centre (Project 2014/13/N/ST10/01708). The leading author obtained the funds for the preparation of his doctoral dissertation within doctoral scholarship at the National Science Centre (Project 2015/16/T/ST10/00373).

APPENDIX A

In these appendices the most important factual information related to deadly tornadoes analyzed in this study (Table 2) is presented. The reference below each
case denotes the primary historical source of information on the event: name of the newspaper, release date, and the shortcut of the digital library (Table 1).

**Deadly Tornadoes in the Nineteenth Century**

**a. 30 June 1829, Turzyn, Poland (four fatalities, case confirmed)**

This case is probably one of the first reliable descriptions of a killer tornado in Poland. The tornado appeared in the vicinity of Wyszków in the Mazovian Voivodeship. A strong thunderstorm accompanied by hen’s egg–sized hail passed through Wyszków at around 1700 UTC. The half-mile tornado brought down trees, swept away roof tiles, and severely damaged a timber barge on the Bug River. As a result, four people were drowned. The tornado left a damage path of approximately 10 km.  

_Gazeta Polska_, 6 July 1829, EBUW

**b. 15 May 1830, Szamotuły, Poland (one fatality, case confirmed)**

A quickly moving thunderstorm with a “rotating column of air” was observed in the evening hours in Kiekrz near Poznań in the Greater Poland Voivodeship. Damage path extended from Kiekrz through Piątkowo up to Szamotuły where one person was crushed under the rubble of a windmill. Newspaper sources mention a “higher number of fatalities,” but do not specify the exact number. The tornado destroyed several buildings and killed a large number of animals. It moved from the southeast.  

_Powszechny Dziennik Krajowy_, 2 June 1830, EBUW

**c. 27 June 1833, Węgrzynów, Poland (two fatalities, case uncertain)**

This case occurred in the vicinity of Wyszogród in the Mazovian Voivodeship. The newspaper source does not use the term “tornado,” but the tornado phenomenon can be identified on the basis of the damage description. The destruction was arranged in a clear narrow damage path with a length of 16 km. Roofs and trees were torn while weakly constructed farm buildings were damaged and destroyed. Two people died as a result of being crushed under a collapsed barn.  

_Kurjer Warszawski_, 6 July 1833, EBUW

**d. 12 May 1851, Charsznica, Poland (one fatality, case confirmed)**

A severe thunderstorm was reported in Charsznica near Miechów in the Lesser Poland Voivodeship. The phenomenon called *tornado* destroyed and/or damaged 45 houses, uprooted hundreds of trees, and killed 23 head of cattle. One person died of an unknown cause while seven were injured. The tornado was preceded by large hail.  

_Goniec Polski_, 31 July 1851, WBC

**e. 18 July 1851, Bobrowniki, Poland (three fatalities, case uncertain)**

This case occurred in the neighborhood of Bytom in the Silesia Voivodeship. During a heavy storm that was called “hurricane” by a newspaper source, considerable damage was caused in several villages from Bobrowniki through Pyrzowice up to Zendek. The wind tore up roofs, snatched haystacks, and collapsed a few buildings. Three people died of unknown causes. The damage reports were arranged in a clear path of 15 km in length.  

_Goniec Polski_, 31 July 1851, WBC

**f. 18 July 1851, Szopienice, Poland (10 fatalities, case uncertain)**

A second significant tornado event dated 18 July 1851 was described in the church archives of Dąbrówka Mała. As the local priest Górecki (1994) writes in his article, after a sunny and hot day, a strong tornado occurred in the afternoon hours and in a few seconds demolished the zinc smelter near Szopienice (the Silesia Voivodeship). As a result, 10 workers from Dąbrówka Mała were killed after being crushed under the rubble. Additional information can be found on the grave of the victims at the cemetery in Bogucice: “On 18 July 1851, a tornado turned into rubble a zinc smelter and because of this the following workers were killed: Edward Kuczer, Wojtek Kasza, Grzeg Opaszewski, Wincenty Woźniok, Andrzej Stalmach, Jan Kuczer, Józef Nędza, Franciszek Bieloch, Łukasz Janta, Feliks Opaszewski.” However, except for this mention, the information on this event is very limited.  

**g. 1 June 1853, Wieliczka, Poland (one fatality, case confirmed)**

As Mr. Fischer, an eyewitness to the event, recalls, during a hot and sultry day at around 1530 UTC, approaching dark clouds were observed southwest of Lednica Górna in the Lesser Poland Voivodeship. Around 1600 UTC, a “bright baggy cloud with rotating funnel” started to descend to the land surface. It quickly passed from Rożnowa to Zabawa, leaving a damage path at a width of around 50 m. Trees, wooden piles, and people were lifted into the air. One child was killed but the circumstances remain unknown. The tornado was accompanied by a hailstorm.  

_Kurjer Warszawski_, 7 June 1853, EBUW

_Gazeta Codzienna_, 11 June 1853, POLONA
29 July 1862, Żerków, Poland (three fatalities, case fully verified)

A good description of tornado refers to Żerków in the Greater Poland Voivodeship. In details it was described in priest Łukasiewicz’s book about the history of the Żerków town (Łukasiewicz 1891). A tornado in the shape of a “large grey wedge” appeared at around 1400 UTC over the city and destroyed 30 buildings, tearing up roofs, uprooting trees, collapsing walls, and lifting furniture. One-third of the town was destroyed. As Łukasiewicz (1891) writes, a “large cloud causing havoc was rotating in a circle of about 2000 m diameter.” Thick brick walls were demolished and large trees were moved 200 m away. Fish and water sucked up from nearby ponds fell from the sky. The tornado moved to Raszewy on the northeast of Żerków where it totally destroyed brick stables and barns. Several people were lifted or crushed in the building including three fatalities: a miller in a destroyed mill, a shepherd buried by the rubble of a collapsed barn, and a male who was lifted in the air. A large number of farm animals were also killed.

Gwiazdka Cieszyńska, 16 August 1862, SBC Gazeta Polska, 4 August 1862, POLONA

31 May 1866, Jarłuty, Poland (7 fatalities, 12 missing, case fully verified)

A fatal tornado case in Humięcino and Jarłuty near Ciechanowice in the Mazovian Voivodeship was reported in several sources. A tornado with the look of a “rotating spindle” appeared in the afternoon hours near Jarłuty, felling numerous trees, destroying several buildings, and lifting animals. It was preceded by a potato-sized hailstorm that left a 9-in. layer of hail. Many people, trees, and items were lifted and carried at distances of up to 200 m. As a result, seven people were killed. A total of 17 people were injured while 12 went missing. This suggests that the total number of fatalities was probably higher and that this case may be one of the most deadly tornado cases in the Polish history. According to the descriptions, some of the injured and deceased experienced tearing of the limbs from the body, which indicates a large force of the tornado. In addition, on the exact extension of the tornado’s damage path, 20 km to the northeast, another tornado with a visible funnel and a damage track extending from Świętno to Budki was reported (Fig. A1). Therefore, it
is plausible that both cases at a distance of 45 km were produced by the same cyclic supercell.

Nadwiślanin, 8 June 1866, KPBC
Nadwiślanin, 17 June 1866, KPBC
Kurjer Warszawski, 19 June 1866, EBUW
Zorza Pismo Niedzielne, 26 June 1866, POLONA

j. 19 June 1871, Tuchola, Poland (five fatalities, case uncertain)

According to a short newspaper note, extensive damage due to a tornado was caused in the Tucholski district in the Kuyavian–Pomeranian Voivodeship (exact place was not specified). The tornado demolished numerous houses and farm buildings including a sheepfold where it killed “around 1000 sheep.” More than 2000 trees in a forest were damaged or uprooted. In one barn, five people died after being crushed under the rubble. This case is uncertain due to limited and ambiguous description.

Gazeta Warszawska, 6 July 1871, EBUW
Gazeta Warszawska, 24 June 1871, EBUW

k. 12 August 1880, Naceslawice, Poland (one fatality, case uncertain)

This incident took place in Naceslawice near Blaszki in the Łódź Voivodeship. A tornado tore up the roofs of several buildings, uprooted large trees, knocked down some parts of the forest, killed animals, and destroyed a sheepfold. As a result, a shepherd was crushed to death while two others were injured. The tornado was accompanied by large hail.

Gazeta Warszawska, 21 August 1880, EBUW

l. 15 August 1880, Rębowo, Poland (one fatality, case confirmed)

Around 1430 UTC, a “thick black rotating pillar in the shape of a funnel” was seen over Kazimierz near Konin in the Greater Poland Voivodeship. In Rębowo, it demolished seven houses and a windmill. One child was found dead, crushed under the wooden beams. Further, the tornado uprooted numerous trees, blew away a few roofs and barns in Bienieszewo, and sucked the water from a nearby pond before spilling it on the fields. The exact day of the event may be uncertain (up to one or two days).

Gazeta Warszawska, 20 August 1880, EBUW

m. 9 August 1881, Wronczyn, Poland (two fatalities, case uncertain)

During a severe thunderstorm in Wronczyn near Poznań in the Greater Poland Voivodeship, a tornado appeared and destroyed a newly built barn. Two people working in the field during harvest died, crushed under a collapsed pea stack. This case is uncertain since there is no explicit description of the tornado damage.

Goniec Wielkopolski, 12 August 1881, WBC

n. 13 July 1884, Gostycyn, Poland (one fatality, case uncertain)

This case occurred around 1730 UTC in Gostycyn near Tuchola in the Kuyavian–Pomeranian Voivodeship. As a newspaper source described it, a “crazy storm with a tornado” destroyed several farm buildings and damaged many roofs. A small building probably the size of a shed was lifted and dropped onto the roof of the inn. As a result, one woman was killed.

Gazeta Toruńska, 18 July 1884, KPBC

o. 14 May 1886, Krosno Odrzańskie, Poland (13 fatalities, case fully verified)

The most deadly tornado occurred in Krosno Odrzańskie in the Lubusz Voivodeship around 1230 UTC. During a severe thunderstorm that came from the southwest, a tornado described as a “dark cylinder cloud connected to the earth’s surface” caused massive destruction in the city (Köppen 1886; Von Bezold 1888). Archival sources speak of terrifying air howling, earth shaking, and hailstones exceeding 8 cm in diameter. Over 500 buildings were damaged or destroyed including a school, post office, St. Mary’s church tower, and the town hall (Fig. A2). More than 10,000 windows in the city were broken while some of the large trees were uprooted and lifted into the air. Bricks, tiles, beams, shutters, trees, glass, and industrial equipment...
were scattered throughout the whole city. Some people were lifted and carried considerable distances. As a result, five people died while another three were crushed under the rubble. Five people were drowned in the Oder River after their boat was hit by another boat that was lifted by the tornado. The tornado left a damage path of 30 km in length and 800–1200 m in width (Fig. A3).

_Gazeta Polska_, 22 May 1886, POLONA

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**Fig. A3.** Tornado damage track (solid black line) with 500-m buffer zone (white polygon) on 14 May 1886.

**Fig. A4.** Tornado damage track (solid black line) with 500-m buffer zone (white polygon) on 13 Aug 1888.
p. 13 August 1888, Walewice, Poland (two fatalities, case confirmed)

A large and powerful tornado with a significant hailstorm occurred on the right side of the Bzura River east of Łęczyca (Łódź Voivodeship) at around 1500–1600 UTC. It passed near Gosłub, Rogaszyn Lazin, Borówek, Walewice, and then moved toward Łowicz where it vanished (Fig. A4). The tornado severely damaged a few buildings, tore up roofs, and destroyed parts of nearby forests. In Walewice, a tornado with a large force demolished a few buildings and an old forest park in a couple of minutes. Two people were killed, but the cause of death is not provided.

Kurjer Warszawski, 3 August 1890, POLONA
Kurjer Codzienny, 23 August 1890, POLONA
Gazeta Świateczna, 17 August 1890, POLONA
Słowo, 29 July 1890, POLONA

q. 24 July 1890, Modła, Poland (three fatalities, one missing, case fully verified)

Numerous sources describe a tornado that occurred near Konin in the Greater Poland Voivodeship at around 1300–1400 UTC. A tornadic thunderstorm passed through Łukom, Trąbczyn, Rzgów, Modła, Stare Miasto, and Brzeźno, and left a narrow damage path (~200 m) of around 35 km in length (Fig. A5). The tornado destroyed a few windmills and barns, damaged numerous buildings, killed several animals, uprooted and demolished thousands of trees, and broke off roofs carrying them distances of a few hundred meters. Three people were found dead under the rubble of a brick barn in Modła. In Brzeźno, a man was lifted and was never found.

Kurjer Warszawski, 3 August 1890, POLONA
Kurjer Codzienny, 23 August 1890, POLONA
Gazeta Świateczna, 17 August 1890, POLONA
Słowo, 29 July 1890, POLONA

r. 30 July 1895, Rudka, Poland (one fatality, case uncertain)

This incident took place near Hrubieszów in the Lublin Voivodeship. During a “thunderstorm with a whirlwind,” dozens of buildings were destroyed. One man was killed by a falling tree. The description of the event is insufficient to uniquely identify the phenomenon as a tornado.

Kurjer Warszawski, 24 August 1895, EBUW

s. 7 July 1897, Pytowice, Poland (three fatalities, case confirmed)

A westerly moving tornadic thunderstorm caused significant damage northwest of Radomsko in the Łódź Voivodeship. In Chorzenice and Holendry near Pajęczno, almost all the buildings were destroyed. Damage was also reported near Janki, Dubidze, Wiewiec, Wola Wiewiecka, Wola Blakowa, Lgota, Bieliki, Brudzice, and Pytowice. Many windmills and
barns were destroyed while a “thousand people lost their homes.” Three people were killed: one by a flying roof near Dubidze, the second near Pytowice after being lifted inside a cart (with two other people were seriously injured), and the third victim was found near Holendry but the cause of death remains unknown. Walnut-sized hail destroyed large areas of crops, injured a few people, and killed birds. Newspaper sources are not consistent when it comes to the number of fatalities and use of the tornado term. Although the damage description is indicative of a strong vortex, the damage reports extending to a distance of 30 km and in some places 10 km wide may suggest an accompanying downburst.

Gazeta Świąteczna, 25 July 1897, BCUW  
Kurjer Warszawski, 17 July 1897, BCUW  
Tydzień, 25 July 1897, ŁBC

APPENDIX B

Deadly Tornadoes in the Twentieth Century

a. 27 June 1905, Kamienica, Poland (three fatalities, case confirmed)

This incident occurred in Kamienica near Kartuzy in the Pomeranian Voivodeship, probably on 27 June 1905. An eyewitness described the tornado as a “pillar in the air” that damaged several houses breaking off roofs and lifting household and agricultural equipment. Three people were killed and several were injured but the circumstances remain unknown.

Głos Śląski, 8 July 1905, POLONA  
Głos Śląski, 13 July 1905, POLONA

b. 30 July 1912, Pobikry, Poland (one fatality, case uncertain)

A tornado was reported in Pobikry village in the Podlaskie Voivodeship. According to a newspaper source, a “whirlwind” destroyed everything in its path, killing 24 cows and 4 horses. Large trees were uprooted and destroyed. One man died by being crushed under the rubble of a building while several people were seriously injured. Although the term tornado is mentioned in the newspaper report, this case is uncertain due to limited information on inflicted damage.

Kurjer Warszawski, 3 August 1912, POLONA

c. 15 August 1922, Jędrzejów, Poland (eight fatalities, case uncertain)

During a severe thunderstorm in the area between Jędrzejów and Olkusz in the Lesser Poland Voivodeship, a tornado occurred and broke off roofs and overturned railway wagons. In one village, eight children were lifted into the air and thrown onto a field, causing their deaths. This case is uncertain due to limited information available.

Orędownik Ostrowski, 13 September 1922, KPBC

D. 27 April 1926, Rowiska, Poland (two fatalities, case uncertain)

During a severe thunderstorm in the Masovian Voivodeship, a strong wind damaged a few hundred buildings. The most intense damage was reported near Skiermiewice in Rowiska where according to a newspaper source, a tornado occurred and completely destroyed a whole village, leaving behind a 10-km damage path. Severe damage was also reported in neighboring Maków, Kreżce, and Dąbrowice. The tornado uprooted and damaged large trees. Two children were lifted and killed. Although two media sources use the term tornado and describe considerable damage, this case is uncertain due to an ambiguous description.

Głos Polski, 29 April 1929, ŁBC  
Lech Gazeta Gnieźnieńska, 30 April 1926, WBC

e. 4 July 1928, Jaktory, Poland (two fatalities, case uncertain)

On this day, extremely severe thunderstorms with plausible quick-moving derecho (Hinrichs 1888) swept through the country from the west, causing 62 fatalities. Meteorological sources indicated wind gusts exceeding 40 m s⁻¹ in Bytom and Gliwice, and damage to almost 1000 buildings. Around 1200 UTC, a plausible tornado occurred near Radzym in the Masovian Voivodeship. The tornado “completely destroyed” Jaktory village including brick buildings. As a result, two girls on the field were lifted and found dead in the treetops. Information on this case is limited.

Słowo Pomorskie, 12 July 1928, BBC  
Orędownik Ostrowski, 10 July 1928, WBC

f. 20 July 1931, Lublin, Poland (six fatalities, case fully verified)

This case is unique because it passed through a considerable part of a large city with dense infrastructure, thereby causing a lot of damage. Also, it is one of the most famous tornadoes in Polish history since, according to a research article by Gumiński (1936), the wind that caused damage in Lublin (the Lublin Voivodeship) produced a dynamic pressure equivalent to a wind speed of between 110 and 145 m s⁻¹. If this estimate was correct, it would indicate an F5 intensity—the strongest tornado ever recorded in Polish history. Although winds destroyed 50-cm-thick brick walls, overturned railway wagons (some of them were moved a few meters away from the rail), overthrew industrial chimneys and bent
iron structures, this estimate is highly uncertain since no
typical F5 damage was reported. Instead, F4 damage
was plausible (Fig. B1). The tornado appeared at around
1700 UTC southwest of Lublin and moved northeasterly
along the Bystrzyca River as a “dark mass in the shape
of a funnel with rumbling and whistling wind.” Wooden
buildings, sawmills, and barns in the suburbs of Lublin
were razed to the ground. The slaughterhouse, sugar
factory, and other industrial buildings had their metal
roofs blown away and found a few kilometers farther
downwind. A city bus was lifted and smashed. The
tornado left behind a narrow damage path with a
length of approximately 20 km (Fig. B2). It demolished
Zemborzyce village and severely damaged Wrotków,
Tatary, Wólka, Trześcinów, and Hajdów. The tornado
caused in total 6 fatalities and over 100 injuries including
several serious. One man died after being lifted and
thrown against electric wires. Three people were lifted
into the air while two others were crushed by falling
debris.
Ziemia Lubelska, 21 July 1931, POLONA
Ziemia Lubelska, 22 July 1931, POLONA
This incident occurred near Chełmża in the Kuyavian–Pomeranian Voivodeship at around 1200 UTC. A tornadic thunderstorm damaged and destroyed hundreds of buildings including windmills and barns. The biggest damage was reported in the Łążyn, Dębiny, and Rzeczków villages where 80% of the buildings were destroyed. Four people died crushed under the rubble of collapsed buildings. In Łążyn, a church tower was knocked down. The tornado up-rooted large trees and hurled roofs. As witnesses described, a “whirlwind” was preceded by giant hen’s egg-sized hail.

Kurjer Bydgoski, 30 July 1936, KPBC
Warszawski Dziennik Narodowy, 29 July 1936, EBUW

The source information for this case is an eyewitness report. A tornado came from the southwest and hit the Borzymy village in the Warmian–Masurian Voivodeship. A single farm brick building was destroyed and parts of the roofs were whirled into the air. A farmer inside a building was found dead under the rubble. The dog of a farming family was blown away and found dead in the area of Grądzie village 3 km farther away. One bus was thrown off the road. The damage path was estimated at 600 m in width and 10 km long. This case occurred presumably on 21 July 1940 but the exact date is uncertain.

T. Kühne 2015, personal communication.

According to information from a book on the history of Zabrzeg city in the Silesia Voivodeship (Wrzoł and Tyc 1998), a tornado knocked down a sizeable part of the forest and broke off a few roofs. As a result of this incident, one person died from an unknown cause. The information on this case is limited and uncertain.

Kurjer Bydgoski, 30 July 1936, KPBC
Warszawski Dziennik Narodowy, 29 July 1936, EBUW

h. 21 July 1940, Borzymy, Poland (one fatality, case uncertain)

i. 13 June 1946, Zabrzeg, Poland (one fatality, case uncertain)
j. 20 August 1946, Stronie Śląskie, Poland (one fatality, case confirmed)

A large and strong tornado occurred near Stronie Śląskie in the evening. "A dark cloud with a loud noise" occurred near Śnieżnik Mountain and then moved northeast to the Czech Republic border. The wind was so powerful that large objects and animals were moved a considerable distance. A large number of animals were killed. The tornado demolished telegraph poles, large trees, damaged Strachocin village, and destroyed three other villages: Janowa Góra, Sienna, and Stronie Śląskie. The tornado left a large damage path of 10 km long and 1000 m wide in a spruce forest. In total 1 person was killed while 10 went missing. The total length of the damage path was estimated to be around 20 km (Fig. B3).

Rzeczpospolita, 28 August 1946, BCUMCS
Rzeczpospolita, 26 August 1946, BCUMCS

k. 15 May 1958, Rawa Mazowiecka, Poland (two fatalities, case fully verified)

A strong thunderstorm passed through central Poland in the evening hours. A large tornado was reported at Rawa Mazowiecka in the Masovian Voivodeship. The tornado demolished 52 buildings and damaged 75, which accounted for 40% of the town (Rafalowski 1958). Almost 90% of the buildings had their roofs blown away. Severe damage on the path of the tornado was also reported in Dziurzdzy, Petryńów, Julianów, Stare Pole, Czerwionka, and Kaleni villages (Fig. B4). In total 107 buildings in these villages were severely damaged. A total of 2 people died from unknown causes and over 100 were injured (including 22 seriously).

Dziennik Polski, 16 May 1958, MBC
Głos Koszaliński, 16 May 1958, ZBC

FIG. B4. Tornado damage track (solid black line) with 500-m buffer zone (white polygon) on 15 May 1958.

FIG. B5. Tornado damage in Nowe Miasto nad Pilicą due to tornado on 16 May 1958 (Photograph: M. Wisławski).
1. 16 May 1958, Nowe Miasto nad Pilicą, Poland (one fatality, case fully verified)

The day after the event in Rawa Mazowiecka, another tornadic thunderstorm occurred in the same region and caused significant damage and one fatality (Morawska 1959). A large funnel “connecting earth with the cloud base” was seen in the afternoon hours in Nowe Miasto nad Pilicą and was preceded by hen’s egg-sized hailstones. A tornado lifted and overthrew a large bus with children that “rolled a few times” (Fig. B5). It also lifted animals and people, and spilled fish from the nearby Pilica River onto the surrounding fields. The whole event lasted only a few minutes and left a damage path of 13 km in length (Fig. B6). Almost 80% of all buildings were damaged, half of them severely. Large trees were uprooted or

![FIG. B6. Tornado damage track (solid black line) with 500-m buffer zone (white polygon) on 16 May 1958.](image)

![FIG. C1. (a) Tornado damage near Balcerzowice (Photograph: A. Hawalej), and (b) Sieroniowice (Photograph: R. Dimitrow) on 15 Aug 2008.](image)
twisted. A total of 17 people were injured (including 8 seriously). Severe damage was also reported in Wólka Gostomska, Potycz, and Brzostowiec villages where almost 50 buildings were demolished.

*Dziennik Bałtycki*, 17 May 1958, BBC
*Dziennik Bałtycki*, 19 May 1958, BBC

*m*. 23 July 1958, Swaty, Poland (two fatalities, case uncertain)

This incident occurred during a series of severe thunderstorms on 23 July 1958. Peak intensity was reached in the vicinity of Ryki in the Lublin Voivodeship where a tornado was reported. In several villages, the tornado damaged tens of buildings. Two people died from unknown causes. Although the term *tornado* is used in a newspaper report, this case is uncertain since only a scant description is provided.

*Slowo Ludu*, 25 July 1958, SWBC

An extremely severe thunderstorm with probable downburst clusters and tornadoes passed through the Subcarpathian and Lublin Voivodeships in the late afternoon hours. According to numerous newspaper sources, 425 buildings were destroyed, thousands of buildings were damaged (600 severely), and 77 people were injured. The most severe damage was reported in Niechobrz, Raclawówka, and Przybyszówka villages near Rzeszów where the tornado was visible (*Salomonik 1960*). In these villages, almost 50% of the buildings were destroyed and the debris was scattered a few hundred meters away. In Niechobrz, metal pylons were ripped from concrete foundations. Severe damage was also reported in Przeworsk district where a strong wind derailed a train near Urzejowice village. As a
result, 1 person died and 13 were injured (including 8 severely). In Gorliczyna, one person died after being crushed by a tree. Another fatality was reported in Białoboki village due to unknown causes. Given the large number of damage reports in this area and the lack of typical tornado damage, it was not possible to determine tornado tracks even though funnels were reported. Given 35 m s\(^{-1}\) wind gust measured at the Rzeszów meteorological station and the widespread damage reports, it may be plausible that the damage and fatalities were due to a downburst cluster (Fujita and Wakimoto 1981) or a derecho with embedded tornadoes.

Dziennik Polski, 20 May 1960, MBC
Dziennik Polski, 21 May 1960, MBC
Nowiny Rzeszowskie, 21 May 1960, PBC
Nowiny Rzeszowskie, 22 May 1960, PBC
Nowiny Rzeszowskie, 23 May 1960, PBC
Nowiny Rzeszowskie, 24 May 1960, PBC

o. 20 May 1960, Żulice, Poland (one fatality, case uncertain)

This incident occurred probably within the same thunderstorm complex that passed through Rzeszów and Przeworsk districts. The most severe damage was reported southeast of Tomaszów Lubelski in the Lublin Voivodeship. Winds with a great force scattered to distant places roofs, chimneys, boards, and household equipment. Dozens of animals were killed in ruined barns. In Żulice village, two children were seriously injured and one died crushed under the rubble of the building. The whole village was destroyed while some of the debris was found 200 m away. Over 300 buildings in Ulhówek were demolished. Severe damage was also
reported in Chodywańce and Chorząńka. Even though the term tornado was used, it was not possible to determine the tornado damage track. 

*Nowiny Rzeszowskie*, 21 May 1960, PBC

*Nowiny Rzeszowskie*, 22 May 1960, PBC

p. 8 July 1996, Suchodębie, Poland (one fatality, case uncertain)

This event took place in Suchodębie village near Kutno in the Łódź Voivodeship at around 1700 UTC. After a series of thunderstorms throughout the day, a tornado described by a newspaper source as “a swirling funnel” came from the south and either destroyed or damaged 30 buildings, farm equipment, and cars. One man was killed as a result of being crushed by a broken-off roof.


**APPENDIX C**

**Deadly Tornadoes in the Twenty-First Century**

*a. 15 August 2008, Rusinowice, Poland (two fatalities, case fully verified)*

A series of significant tornadoes passed in the afternoon hours through the Opole, Silesian, and Łódź Voivodeships, leaving behind a total damage track of 110 km in length and a maximum width of 1500 m. Severe damage was caused to 1624 buildings, forests, and infrastructure (Chmielewski et al. 2013). Two people died while 60 were injured. The tornadoes lifted cars, demolished brick walls, arched power poles, blew out buildings, and brought down trees (Fig. C1). An analysis of the satellite, radar, aerial photography, damage survey, and global forest change project data (Hansen et al. 2013) made it possible to establish three tornado tracks (Popławksa 2014; Fig. C2). The deadly tornado occurred at around 1530 UTC in Rusinowice where one person died after being crushed inside a building. Another person was killed in Kalina by a falling tree. Before vanishing south of Leg in the Silesian Voivodeship, the tornado left behind a damage path of 60 km with a highest intensity of F3.

*b. 14 July 2012, Wycinki, Poland (one fatality, case fully verified)*

An isolated cyclic supercell occurred on 14 July 2012 on the border of the Kuyavian–Pomeranian and Pomeranian Voivodeships (Taszarek et al. 2016). An analysis of satellite, radar, aerial photography, damage survey, and global forest change project data allowed us to establish four tornado damage tracks (Fig. C3). Tornadoes damaged 105 buildings, caused 1 fatality, 10 injuries, and felled 500 ha (1 ha = 10^4 m^2) of Bory Tucholskie forest leaving an impressive path with a maximum width of 700 m. The deadly tornado occurred at around 1500 UTC near Zdroje village, and up to Smetowo Graniczne left a 42-km damage path with the maximum intensity up to F3. It passed through Kaliebie Lake (Fig. C4) and then moved to Wycinki village where it lifted a summer house killing one man.

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