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Number of days with thunderstorm in the area of Bydgoszcz in the years 1971–2010 using the example of the Bydgoszcz-Airport weather station

Abstract: The paper analyses the occurrence of thunderstorms in Bydgoszcz in the multi-annual period 1971–2010 based on data from the Bydgoszcz-Airport weather station – ref. EPBY according to ICAO (International Civil Aviation Organization). The article examines variations in monthly, seasonal and annual mean values of weather elements. The calculation pertaining to selected elements of descriptive statistics involved regression analysis. Based on the linear function the author determines the direction and trends of changes of the analysed elements in time. Analysis of this data leads to the conclusion that the number of thunderstorms in the examined forty-year period declined, but also a decrease in the frequency of this phenomenon was observed in Bydgoszcz. The highest number of storms in the examined multi-year period in the whole year (29) and in the warm half-year (28) was recorded in 1973 and in 1997, and the lowest in 2003 (only 6). The studies indicate a significant downward trend in the number of storms occurring in the multi-annual period 1971–2010.

Keywords: dangerous phenomena, thunderstorm, airport, Bydgoszcz.

1. Introduction

Observation of the occurrence of dangerous atmospheric phenomena is affected by certain errors arising from the observer's subjective assessment. According to Bielec-Bąkowska (2001), this is a result of differences in the predispositions of observers, location of weather stations, noises in the environment, and problems with accurate determination of the direction from which the thunderstorm arrives, the point at which it starts and ends as well as its intensity.

Thunderstorm is an electrometeor defined as "any visible or audible manifestation of atmospheric electricity as short intense flashing (lightning) or clap and rumble (thunder) inside a *cumulonimbus* (Cb) or in between the cloud and the surface of the Earth" (Janiszewski, 1988). Moving air masses create general conditions in which thunderstorms develop, which can be a threat to human life and health, and lead to damage to property. In the opinion of (Changnon, 2001; Kolendowicz, 2005), damage to property induced by thunderstorms is mainly caused by atmospheric electricity manifested as lightnings and thunders, but also by strong wind gusts, hail, whirlwinds, and strong rainfall which may cause local floods. Atmospheric circulation is responsible for transport of moisture and heat energy that are directly associated with moving air masses. Thus, atmospheric circulation can be deemed one of the main reasons causing storms and determining their intensity and duration (Bielec-Bąkowska, 2002). There are also important local factors affecting the occurrence of thunderstorms that arise from the geographical and topoclimatic conditions of a specific location. The above-mentioned conditions can contribute to increasing convection over a given area, at the same time affecting the frequency of storms.

The occurrence and development of storm cells testifies to atmospheric instability. The conditions of atmospheric instability are described by comparing the changes in air temperature with the thermal stratification curve. The result is the indicator of atmospheric instability – convective available potential energy (CAPE), expressed as J kg^{-1} – showing how much atmospheric energy can be utilised by the developing thunderstorm (Madany, 1996). The higher the CAPE is, the stronger the (convective) updraft is. This is corroborated by the comparison of CAPE with the development of *cumulonimbus* clouds (Cb), storms or tornadoes (Rasmussen and Blanchard, 1998; Schultz, 1989).

Due to abrupt atmospheric electricity discharges and the accompanying phenomena, such as turbulent wind, intense rainfall and whirlwinds, storms are often dangerous phenomena and are classified as extreme weather (Pruchnicki, 1999).

This paper aims to describe the occurrence of storms in the area of Bydgoszcz in 1971–2010. It evaluates the thunderstorm risk scale mainly based on observations of the frequency of storms.

2. Source material and research methods

The work makes use of meteorological observation data from the period 1971–2010 sourced from the Bydgoszcz-Airport Weather Stations (Fig. 1). In 1951–1982, a station of the Institute of Meteorology and Water Management (IMWM) operated at the airport (SZS code: 353170240) – ref. EPBY according to the ICAO (International Civil Aviation Organization) and the Military Aviation Meteorological Station – ref. EPBW according to the ICAO (International Civil Aviation Organization) that in 1983-2010 provided meteorological services for military and civil aviation and standardised climate measurements and observations. The stations were located on the hill within the premises of the Bydgoszcz-Szwederowo Air-

Figure 1. Location of the Bydgoszcz-Airport (EPBY) weather station – black circle (Source: https://www.google.com/maps)

port (φ=53˚05'N, λ=17˚58'E, h=72.0 m a.s.l.) about 3.5 km away from the city centre. They were free from anthropogenic impact, which guarantees their representative nature for the Bydgoszcz area. At the same time, both stations complied with the World Meteorological Organization's Standard No. 8 2010. In addition, according to Łaszyca (2018) the above-mentioned location meets the condition of the results being representative, which means they can refer both to the city of Bydgoszcz and to a wider area within a radius of several dozen kilometres.

Based on diurnal data, the author analysed the variability of monthly, seasonal and annual mean values of weather elements (number of days with thunderstorm) in the multi-annual period 1971–2010, and calculated selected elements of descriptive statistics. Regression analysis was carried out and based on the linear function, which allowed for determining the direction and trends of changes of the analysed elements in time. The study period was divided into two twenty-year periods – 1971–1990 and 1991–2010 – and it was examined whether the frequency of respective meteorological parameters increased or decreased over time. Two indicators used in that case were standard deviation and value range.

The adopted definition of a thunderstorm was consistent with that used by the IMWM network of weather stations since 1962. According to the above-mentioned definition, a thunderstorm is a thunder that can be heard within less than 10 seconds from the lightning flash, and a distant thunderstorm is when the thunder is heard after more than 10 seconds and can be accompanied by a lightning flash. The first thunder is considered the start of a thunderstorm, and a thunder not followed by another one within 15 minutes marks the end of a thunderstorm.

3. Days with thunderstorm

In the multi-year period 1971–2010 in the area of Bydgoszcz there were in total 570 days with thunderstorm, including 556 in the warm half-year (April–September), and only 14 in the cold half-year (October–March). In winter months there were only 4 days with thunderstorm, and none was recorded in November. Analysing the annual charts (Fig. 2), it can be concluded that the months featuring the highest number of days with thunderstorm were July (158 days with thunderstorm), followed by June, August and May. In April and September 17 and 22 days with thunderstorm were noted respectively.

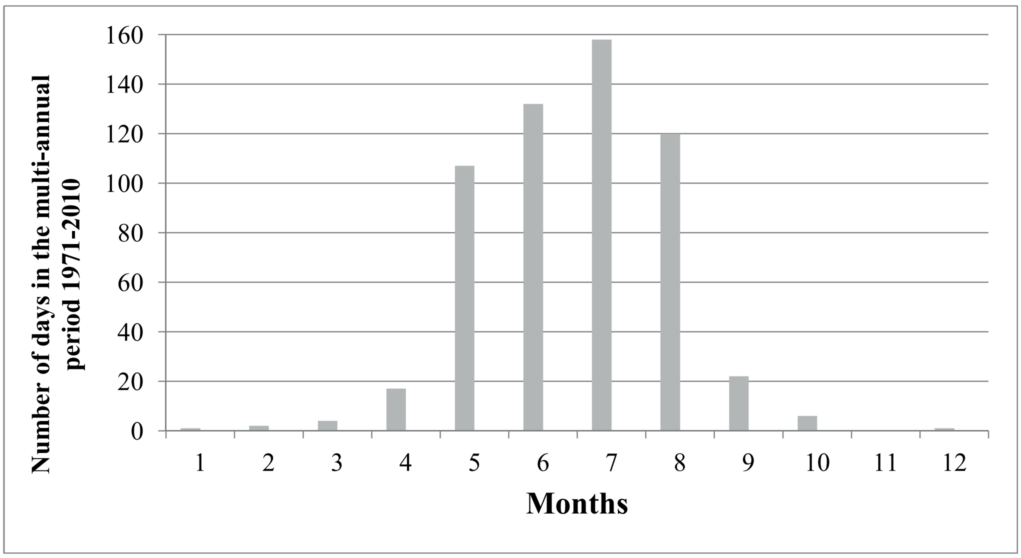

Figure 2. Annual variation of the total number of days with thunderstorm in the multi-annual period 1971–2010 in the area of Bydgoszcz – Authors own elaboration based on data obtained from the Bydgoszcz–Airport weather station

The highest number of storms in the whole year (29) and in the warm half-year (28) was recorded in 1973 and in 1997, while the lowest – only 6 – in 2003 (Table 1). The year 1973 featured the highest number of days with thunderstorm in May (8) and July (13). Every year, thunderstorms occurred in July and August only. In the examined months of the multi-annual period 1971–2010, the highest frequency of thunderstorms was noted in May and June – 95%. In September it was 45%, and in April 25%. The greatest variability of the above-mentioned indicator in time was recorded in June, due to the greatest intensity of its occurrence, followed by June, May and August.

The number of days with thunderstorm in each month of the warm half-year showed a downward trend as the years passed from 1971 to 2010 (Table 2). Such a trend occurred most frequently in May and June, and least frequently in August and April. As a result of such trends, with reference to the whole warm half-year and the whole year, a significant downward trend in the number of thunderstorms was observed in the multi-annual period 1971–2010. In the summer half-year, the number of days with thunderstorm declined by 1.62 day (Fig. 4), and in the whole year – by 1.68 day per 10 years (Fig. 3). A negative trend was also observed in the winter half-year.

Table 1. Mean multi-annual (1971–2010) number of days with thunderstorm in the area of Bydgoszcz including temporal variability characteristics (Authors own elaboration based on data obtained from the Bydgoszcz–Airport weather station)

Month Period	Mean	MAX Year	MIN Year	Range MAX-MIN	s
April	0.43	3 3 years	0 30 years	3	0.87
May	2.68	8 1973	0 1982, 1989	8	1.86
June	3.30	8 1971, 1980	0 1976, 1981	8	2.04
July	3.95	13 1973	1 8 years	12	2.75
August	3.00	8 1971	1 5 years	7	1.60
September	0.55	3 1997	0 22 years	3	0.71
January–December	**14.25**	**29** **1973, 1997**	**6** **2003**	**23**	**5.71**
April–September	13.90	28 1973, 1997	6 2003	22	5.53
October-March	0.35	2 1979, 2008	0 28 years	2	0.58

MAX – the highest mean value in the multi-annual period, MIN – the lowest mean value in the multi-annual period, s – standard deviation

Table 2. Variations in the number of days with thunderstorm (0-8) in the area of Bydgoszcz in the period from 1971 to 2010, including the coefficient of correlation and determination describing the linear relationship (Authors own elaboration based on data obtained from the Bydgoszcz–Airport weather station)

Month Period	Change over 10 years	Coefficient of determination R^2	Coefficient of correlation r
April	-0.05	0.0041	-0.0640
May	-0.46	0.0839	-0.2897
June	-0.47	0.0734	-0.2709
July	-0.50	0.0455	-0.2133
August	-0.03	0.0005	-0.0224

September	-0.11	0.0306	-0.1749
January–December	**-1.68**	**0.1185**	**-0.3442***
April–September	-1.62	0.1173	-0.3425*
October–March	-0.06	0.0147	-0.1212

critical value of the coefficient of correlation 0.3120 (α=0.05), 0.4026 (α=0.01)

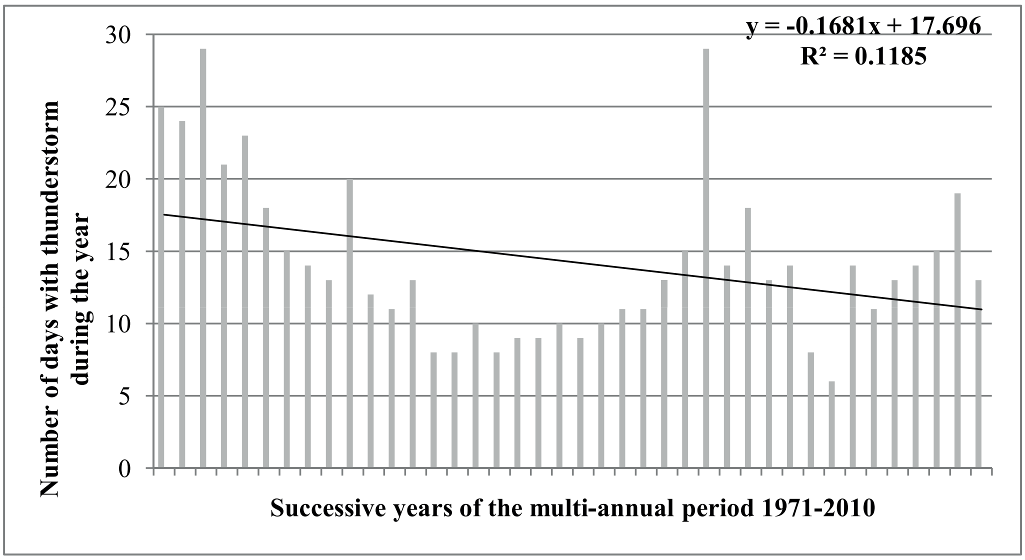

Figure 3. Downward trend in the number of days with thunderstorm during the year in the area of Bydgoszcz in the multi-annual period 1971–2010 (Authors own elaboration based on data obtained from the Bydgoszcz–Airport weather station)

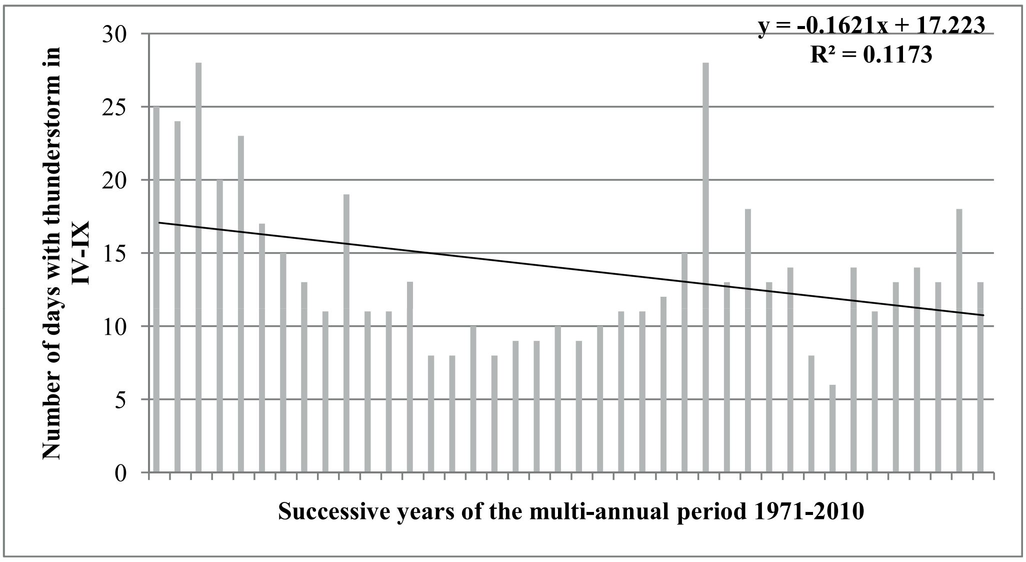

Figure 4. Downward trend in the number of days with thunderstorm in the warm half-year (April–September) in the area of Bydgoszcz in the multi-annual period 1971–2010 (Authors own elaboration based on data obtained from the Bydgoszcz–Airport weather station)

Comparing the temporal variability indicators in 1971–1990 and 1991–2010, it can be concluded that four out of six analysed months (May–August) featured a smaller dispersion of the number of days with thunderstorm relative to its mean, and a smaller range in the following twenty-year period in comparison with the preceding one. However, the temporal variability of the above-mentioned indicator increased in September. In April, and also with reference to the whole year and half-years, ambiguous situations were observed, whereas the standard deviation of the number of days with thunderstorm during the whole year and in the warm half-year was clearly smaller than in 1991–2010, compared to the previous multi-annual period 1971–1990 (Table 3). Analysis of this data leads to the conclusion that the number of thunderstorms in the examined forty-year period declined, but also a decrease in the frequency of this phenomenon was observed in the are a of Bydgoszcz.

Table 3. Comparison of indicators of temporal variability of the number of days with thunderstorm in the periods 1971-1990 and 1991-2010 in the area of Bydgoszcz (Authors own elaboration based on data obtained from the Bydgoszcz–Airport weather station)

Month Period	Standard deviation		Range (MAX-MIN)		Temporal variability
	1971-1990	1991-2010	1971-1990	1991-2010	
April	0.76	0.99	3	3	
May	2.40	1.15	8	4	-
June	2.58	1.30	8	5	-
July	3.42	1.92	12	8	-
August	1.69	1.56	7	6	-
September	0.60	0.83	2	3	+
January–December	6.55	4.78	21	23	
April–September	6.41	4.55	20	22	
October–March	0.60	0.57	2	2	

+ increased temporal variability, - decreased temporal variability

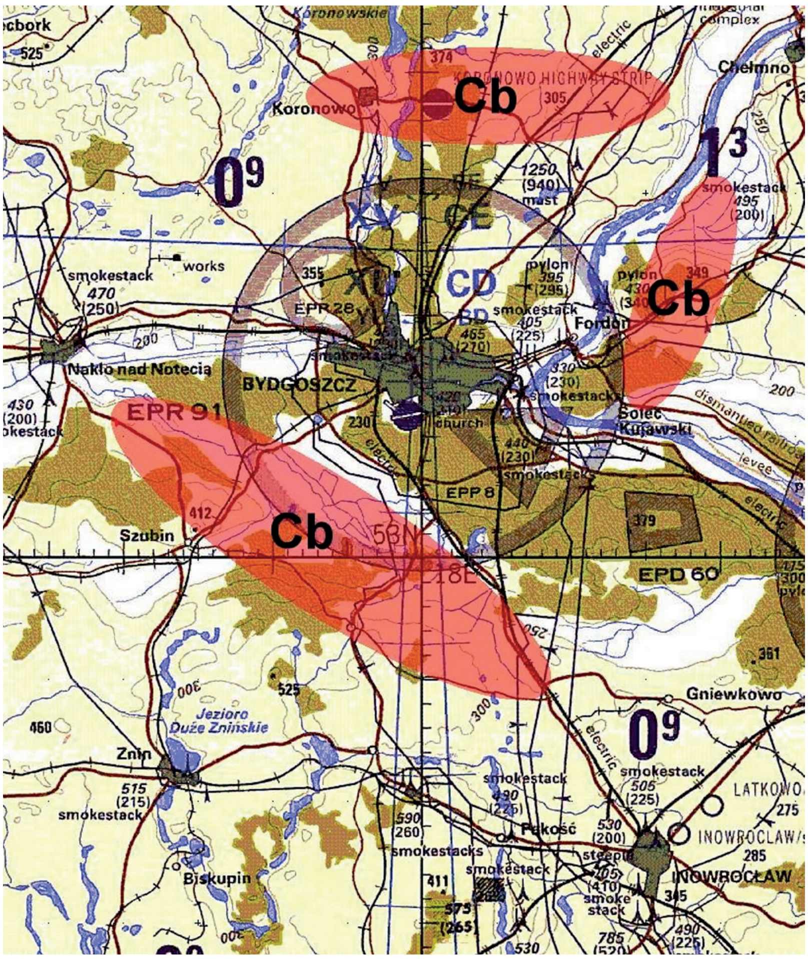

Figure 5. Development of Cb clouds and air-mass thunderstorms in the area of Bydgoszcz (Source: Author's own elaboration based on Lotnicza Mapa Polski ICAO w skali 1:500 000, 2021)

The surveys showed that many thunderstorms in the area of Bydgoszcz develop in the zones of weather fronts (cold fronts) with north-western, western and north-eastern cyclonic circulation. Thunderstorms develop when warm moist air is pushed upwards by cold air. Another type of thunderstorms occurring in Bydgoszcz is air-mass thunderstorms. They can develop due to topographic relief or specific thermal conditions. Thunderstorms can also develop inside a homogeneous air mass when the ground is strongly heated, which leads to an increase in atmospheric instability. The occurrence of such thunderstorms testifies to strong spatial instability. It depends on whether the point at which the ground is strongly heated is determined by special atmospheric conditions or by the physical characteristics of the specific area. Air-mass thunderstorms develop most often on land in the afternoon, and over the water areas they usually occur at night time. In the area of Bydgoszcz and the Airport (Fig. 5) air-mass thunderstorms develop near the Koronowo Reservoir and the Noteć Canal (for W and SW advection). They have their own paths of movement, most often heading in the direction of the Vistula to the area of Fordon where they stop and return towards the airport or move northwards along the Vistula. For eastern advection, air-mass thunderstorms develop along the Vistula and move westwards, mainly in the northern part of the city.

4. Discussion

According to studies carried out by Bielec-Bąkowska (2013) in Poland, the period of the highest thunderstorm activity usually lasts from May to August (approx. 80% of all cases). In the opinion of the above-mentioned author, in this season days with thunderstorm account for about 12–24% of all days and can be considered a typical phenomenon at that time of year. By contrast, thunderstorms or hail in the remaining months (particularly in winter) can be considered exceptional.

According to studies carried out by Lorenc (2005), the average number of days with thunderstorm in the area of Bydgoszcz in 1971–2000 was about 20. By contrast, Bielec-Bąkowska (2002) observed that depending on the region, the number of days with thunderstorm ranges from 15 in the north to 29 in the south of Poland. In own studies in the multi-annual period 1971–2010 on average 14 days with thunderstorm were noted. Comparing the multi-annual period 1971–1990 with the multi-annual period 1991–2010, a decline in the average number of days with thunderstorm and a decrease in the severity of thunderstorms was observed.

The studies corroborate the previous results of studies carried out by Stopa (1962) who divided Poland into 18 thunderstorm regions, where Bydgoszcz was included in the region of the Lower Vistula. This region features average values for Poland: number of days with thunderstorm (in May, June, July, in spring, in summer and during the year). Diurnal variations during the year show that the main maximum frequency of occurrence in this region is delayed by one hour in relation to the adjacent regions. A peculiar feature of the Lower Vistula region is that the first diurnal maximum frequency of thunderstorm in the whole year (beginning of thunderstorms) in this region is recorded at the latest in all Poland.

5. Conclusions

The studies led to the conclusion that in 1971–2010 thunderstorms developed most frequently in May and June – 95%, and the highest temporal variability was observed in July. In the respective months of the warm half-year the number of days with thunderstorm tended to decline as the years passed from 1971 to 2010. This trend was strongest in May and June. Based on the above-mentioned trends, with reference to the whole warm half-year and the whole year, a significant downward trend in the number of thunderstorms was observed in the years 1971–2010. Analysis of the temporal variability indicators for the examined forty-year period led to the conclusion that not only did the number of thunderstorms decline, but also a decrease in the frequency of their occurrence was observed in the area of Bydgoszcz.

The results of the study can be used to develop a climatological guide for the Bydgoszcz-Szwederowo Airport and help in operations carried out for the needs of meteorological services for civil aviation such as planning and insuring the flights of airplanes, helicopters, gliders, military drills and operations and safe parachute jumping.

In addition, this paper contributes new knowledge and addresses the gaps in literature on thunderstorms in the area of Bydgoszcz.

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