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Temporal variations in the atmospheric pressure curve in the Bydgoszcz area

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Abstract. Atmospheric pressure, the meteorological parameter describing pressure conditions in an area, was analysed based on daily values. The mean atmospheric pressure in the Bydgoszcz area in the examined multi-annual period from 1971 to 2010 was 1006.4 hPa. Comparison of the mean value of atmospheric pressure calculated for the periods from 1971 to 1990 and from 1991 to 2010 revealed bi-directional differences between them. The atmospheric pressure curve featured high year-to-year variability in the examined 40-year period. In Bydgoszcz, there was a statistically insignificant downward trend in mean annual atmospheric pressure (0.2 hPa/10 years) from 1971 to 2010.

Key words:
airport,
annual and multi-annual curve,
atmospheric pressure,
Bydgoszcz

Introduction

Atmospheric pressure is an essential meteorological parameter subject to continuing variations in time and space. It is a fundamental climate feature measured by synoptic and weather stations. It triggers global, regional and local atmospheric circulation. Its global distribution is the basis for drawing synoptic maps and its trends and rate of variations are used in weather forecasting. The dictionary of meteorology (*Słownik Meteorologiczny* 2003) defines atmospheric pressure (air pressure) as the pressure exerted by air on all objects. Mean atmospheric pressure at sea level is 1013.25 hPa (760 mmHg) and it decreases at higher altitudes. Pressure variations in time and space play a significant role in the development of atmospheric processes. Due to these variations, variations are also registered in the curves of other weather elements, in particular cloud cover, direction and speed of wind, air temperature and humidity and atmospheric precipitation. The atmospheric pressure curve in consecutive years can be differ significantly from the averaged curve based on multi-annual values. Chromow (1977) claims that "diurnal variations in atmospheric pressure are due to diurnal variations in air temperature, atmospheric vibration caused by diurnal temperature oscillation, and atmospheric tides reinforced by resonance with oscillations of the atmosphere".

Not only does atmospheric pressure affect human mood and general well-being but it can also be felt on an airplane, during mountaineering and in a high-speed lift. It is a crucial parameter taken into account by airplane crews flying at high altitudes; for instance, at an altitude of 10 km the pressure is only 25% of that at sea level. Pressure variations are an essential element of weather forecasting when the so-called pressure trend, that is, pressure variations over the past three hours before the synoptic observation, is taken into account.

Climate phenomena in Bydgoszcz cannot be discussed without considering them in comparison with the climate conditions, including circulation conditions, of Poland and Europe, which, nonetheless, themselves do not form closed and uniform climate wholes (Schmuck 1959). In

meteorological terms, the climate of Europe is mainly influenced by atmospheric pressure centres such as the all-year-round Icelandic Low and Azores High. The Icelandic Low is deeper, and its activity is the highest in winter, while it is less active in summer when the weather formation in Poland is largely affected by the Azores High reaching far to the east (Woś 1994). The origin of these pressure patterns is associated with the general atmospheric circulation on the globe and is modified by temperature differences between the waters of the North Atlantic and European and Asian mainland. At the same time, pressure oscillations occur between the North Atlantic and tropic latitudes – the so-called North Atlantic Oscillation (NAO). For big longitudinal differences in pressure, that is, when the northerly pressure gradient is high (NAO+), the air from over the Atlantic moves along the parallels from the west to the east – over Europe. By contrast, when the pressure drops in the Azores High and, simultaneously, is raised in the Icelandic Low (NAO$^-$), the pressure gradient decreases, and meridional or eastward circulation intensifies. This results in the influx of air from the east or from the north or south (Boryczka 1998).

In respective seasons of the year, the weather and climate processes are largely affected by the Siberian High in winter and the South Asian Low in summer. In spring, the Arctic Sea High very often develops from Scandinavia to the south, and in autumn a high-pressure pattern moves from southern Europe (Kożuchowski 1998, 2011; Woś 1999).

Materials and methods

This paper presents a general overview of the curve of monthly, seasonal and annual values of atmospheric pressure measured at the level of the weather station in the Bydgoszcz area from 1971 to 2010.

The atmospheric pressure curve in Bydgoszcz was analysed using data dating back to the period from 1971 to 2010, derived from the Bydgoszcz-Airport Weather Stations. From 1951 to 1982, a station of the Institute of Meteorology and Water Management operated at the airport (SZS code: 353170240) – (Fig. 1) – 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 from 1983 to 2010 provided meteorological services for military and civil aviation and standardised climate measurements and observations. The stations were situated within the premises of the Bydgoszcz-Szwederowo Airport on a lowland plateau (Fig. 1) φ=53˚05'N, λ=17˚58'E, h=72.0 m a.s.l., about 3.5 km from the city centre, and met the standards of the World Meteorological Organisation No. 8 2010. In addition, the above-mentioned location meets the condition for the results to be considered representative, which means they can be applied to both the city of Bydgoszcz and a wider area within a radius of ~100 km (Łaszyca 2018).

Mean atmospheric pressure, as a meteorological parameter describing pressure conditions in the examined area, was analysed for months, seasons (DJF, MAM, etc), summer and winter half-years, and years. Basic statistics were utilized to show the results. The data were checked and homogenised using the Standard Normal Homogeneity Test (Alexandersson 1986) modified by Štěpánek (2008). The data series was determined to be homogeneous. Regression analysis was conducted and, based on the linear function, the direction and trends of variations in time were determined. In addition, the study period was divided into two twenty-year

Fig. 1. Location of the study area
Source: www.orangesmile.comcommonimg_country_maps_cities poland-map-cities-1.jpg and https://plb.pl/historia

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Fig. 2. Meteorological plot of the Institute of Meteorology and Water Management - National Research Institute (author: E.Z. Łaszyca)

periods – from 1971 to 1990 and from 1991 to 2010 – and examined for significant variations in the pressure curve over time.

Results

Atmospheric pressure

The annual curve of mean multi-annual air pressure in the Bydgoszcz area was typical of the temperate, transitional climate of Poland. A characteristic feature of that curve was that the mean pressure was higher in the cold half-year (Oct-Mar) and lower in the warm one (Apr-Sep) (Fig. 3).

In the examined multi-annual period from 1971 to 2010, the mean annual atmospheric pressure measured at the level of the weather station in the Bydgoszcz area was 1006.4 hPa, 1005.8hPa in the warm half-year, and 1007.0 hPa in the cold half-year (Table 1). Looking at respective months, the highest atmospheric pressure in the multi-annual period was recorded in October, when the mean pressure was 1007.9 hPa, followed by 1007.6 hPa in February and 1007.3 hPa in January. The lowest mean atmospheric pressure in Bydgoszcz was noted in April, with the multi-annual mean being 1004.5 hPa, and the next lowest in June, at 1005.0hPa, and July and December, at 1005.9 hPa. Considering the maximum and minimum mean monthly atmospheric pressures, it can be concluded that the highest atmospheric pressure in the examined multi-annual period was observed in February 1975 (1017.5 hPa) and the lowest in December 1981 (992.8 hPa).

Atmospheric pressure was extremely variable between corresponding periods of successive years in the multi-annual period. This is evidenced by the standard deviation values and the mean monthly extreme pressure in the period from 1971 to 2010 presented in Table 2. The highest standard deviation and highest range of values were recorded in January, followed by February, December, November, October and March, representing the months of the cold half-year – mostly the winter months.

Variations in atmospheric pressure from year to year are associated with the frequency of cyclonic and anticyclonic patterns. Due to the frequency of such patterns in the examined 40-year period, significant pressure variations occurred; January 1992 (1016.6 hPa) and November 1993 (1016.4 hPa) (Fig. 3). The range between extreme mean monthly values of atmospheric pressure for the examined period was 24.7 hPa (max. 1017.5 hPa, and min. 992.8 hPa).

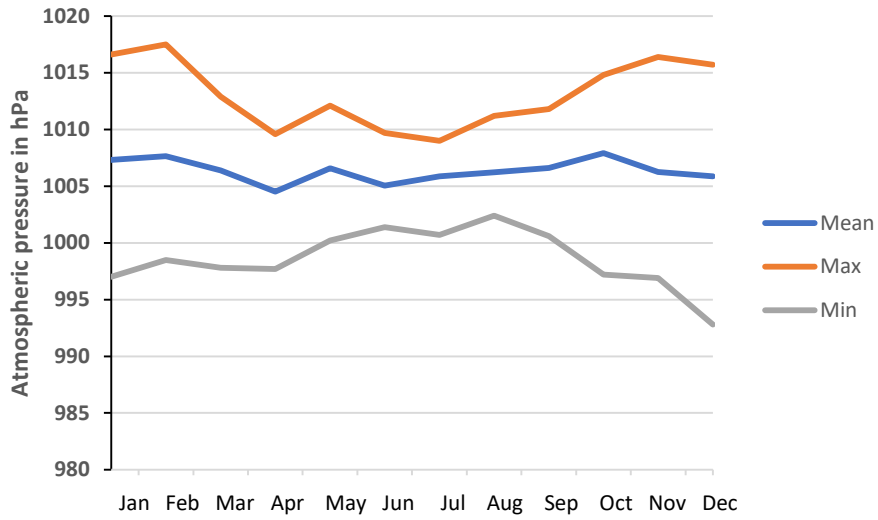

Fig. 3. Annual curves of multi-annual means, maximum (Max) and minimum (Min) mean monthly atmospheric pressure measured at the level of the weather station in the Bydgoszcz area

In the examined multi-annual period from 1971 to 2010, the highest mean annual pressures in Bydgoszcz were noted in 1975 (1008.5 hPa) and in 1991 and 2003 (1008.4 hPa). The lowest pressures were recorded in 2010 (1004.5 hPa) and 2000 (1004.6 hPa) (Fig. 4).

The pressure curve shows two- or three-year oscillations; a high-pressure year is followed by one with lower pressure, while this rhythm is subject to numerous disturbances. Despite considerable variations in atmospheric pressure year on year, no trend of variations in atmospheric pressure was found to be statistically significant in the examined multi-annual period of 1971 to 2010 in Bydgoszcz. Nevertheless, the mean annual atmospheric pressure tended to decrease by 0.017 hPa/year (Fig. 4).

Comparison of the mean value of atmospheric pressure calculated for the periods from 1971 to 1990 and from 1991 to 2010 revealed bi-directional differences between them (Fig. 5). From 1991 to 2010, pressure was higher in January, March, May, July, November and December as compared against the same months in the period from 1971 to 1990, and lower in February, April, June, August, September and October. The biggest increases in pressure (Fig. 5) were observed for the winter months (January, November, and December), and were 2.0, 1.1, and 0.6 hPa, respectively. In contrast, the biggest decreases were recorded in September and August at 1.3 and 0.9 hPa, respectively. However, the mean annual atmospheric pressure in the multi-annual period from 1991 to 2010 increased by only 0.1 hPa compared with the period from 1971 to 2010.

Based on the comparison of temporal variability ratios for mean atmospheric pressure in the period from 1991 to 2010 (the second 20-year period) against those in the period from 1971 to 1990 (the first 20-year period), it can be concluded that increased temporal variability was observed in six out of 19 analysed cases (Table 2). This referred to January, April, July, November, all year and winter. For eight analysed time steps, mean atmospheric pressure in the multi-annual period from 1991 to 2010 was less variable than in the preceding 20-year period. In other cases, no clear differences in the extremes of the mean atmospheric pressure were found in the compared 20-year periods.

Discussion and conclusions

Variations in the atmospheric pressure field over Europe occur annually. In winter, strongly developed high-pressure patterns prevail and low-pressure patterns are typical of summer. The atmospheric pressure curve for consecutive years can differ

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Table 1. Mean multi-annual (1971–2010) atmospheric pressure measured at the level of the weather station in the Bydgoszcz area (hPa) including temporal variability characteristics

Month Period	Mean (hPa)	MAX (hPa) Year	MIN (hPa) Year	Range (hPa) MAX-MIN	SD (hPa)
Jan	1007.3	1016.6 (1992)	997.0 (2008)	19.6	5.9
Feb	1007.6	1017.5 (1975)	999.0 (1999)	18.5	5.5
Mar	1006.4	1012.9 (1974)	997.8 (1988)	15.1	4.1
Apr	1004.5	1009.6 (2010)	997.7 (1998)	11.9	2.8
May	1006.6	1012.1 (1992)	1000.2 (1984)	11.9	2.7
Jun	1005.0	1009.7 (1973)	1001.4 (1980)	8.3	2.4
Jul	1005.9	1009.0 (1982)	1000.7 (1998)	8.3	2.0
Aug	1006.2	1011.2 (1973)	1002.4 (1989)	8.8	2.2
Sep	1006.6	1011.8 (1977)	1000.6 (1984)	11.2	2.9
Oct	1007.9	1014.8 (1985)	997.2 (1973)	17.6	4.2
Nov	1006.3	1016.4 (1993)	996.9 (2010)	19.5	4.4
Dec	1005.9	1015.7 (1972)	992.8 (1981)	22.9	5.4
Jan-Dec	**1006.4**	**1008.5 (1975)**	**1004.5 (2010)**	**4.0**	**1.1**
Apr-Sep	1005.8	1007.9 (1976)	1003.1 (1998)	4.8	1.1
Oct-Mar	1007.0	1010.6 (1996)	1003.0 (2000)	7.6	2.0
Mar-May	1005.8	1008.5 (1976)	1003.1 (1983)	5.4	1.5
Jun-Aug	1005.7	1008.5 (1976)	1002.7 (1980)	5.8	1.3
Sep-Nov	1006.9	1010.8 (1975)	1002.1 (1990)	8.7	2.1
Dec-Feb	1007.0	1013.0 (2004)	1000.0 (2000)	13.0	3.5

Explanations: MAX – highest mean value in multi-annual period, MIN – lowest mean value in multi-annual period, SD – standard deviation

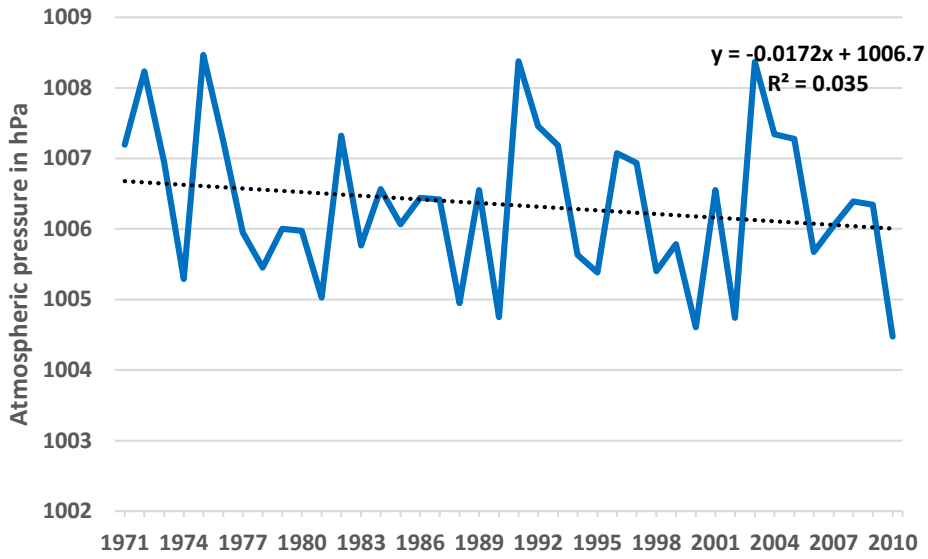

Fig. 4. Downward trend in mean annual atmospheric pressure measured at the level of the weather station in the Bydgoszcz area from 1971 to 2010

significantly from the averaged curve based on multi-annual values.

The annual curve of mean multi-annual air pressure in the Bydgoszcz area was typical of the temperate, transitional climate of Poland. A characteristic feature of that curve was that the mean pressure was higher in the cold half-year and lower in the warm one. Such distribution of atmospheric pressure is characteristic for most of Poland (Trepińska 2007; Sikora 2008; Bilik et al. 2014; Bielec-Bąkowska and Piotrowicz 2021).

Mean atmospheric pressure at sea level measured in Poznań is 1015.9 hPa (Woś 2010; Bielec-Bąkowska and Piotrowicz 2021). This value is corroborated in the *Climatic atlas of Poland* by Lorenc (2005), where the area of both Poznań and Bydgoszcz is situated between isobars corresponding to 1015 and 1016 hPa.

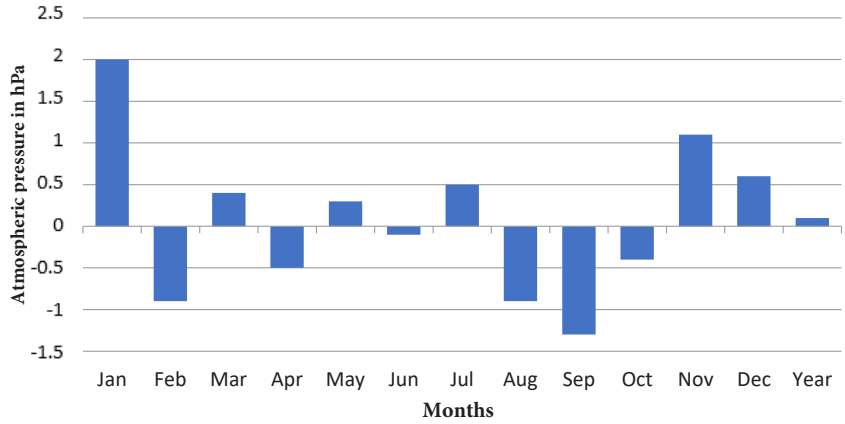

Fig. 5. Differences in mean monthly and yearly atmospheric pressure measured at the level of the weather station between periods 1971-1990 and 1991-2010

Table 2. Comparison of temporal variability ratios for atmospheric pressure measured at the level of the weather station in the Bydgoszcz area in the periods from 1971 to 1990 and from 1991 to 2010

Month Period	Standard deviation (hPa)		Range (MAX-MIN) (hPa)		Temporal variability
	1971–1990	1991–2010	1971–1990	1991–2010	
Jan	5.3	6.5	19.3	19.6	+
Feb	5.8	5.4	18.4	16.4	-
Mar	4.4	3.8	15.1	13.1	-
Apr	2.6	3.0	7.8	11.9	+
May	2.7	2.8	10.2	10.2	
Jun	2.7	2.1	8.3	6.6	-
Jul	2.0	2.1	7.2	8.3	+
Aug	2.3	2.0	8.8	6.6	-
Sep	3.2	2.6	11.2	8.4	-
Oct	4.6	3.8	17.6	14.1	-
Nov	3.8	4.9	17.2	19.5	+
Dec	5.5	5.6	22.9	17.6	
Jan-Dec	**1.0**	**1.2**	**3.7**	**3.9**	+
Apr-Sep	1.1	1.1	3.4	4.3	
Oct-Mar	2.1	1.9	6.1	7.6	
Mar-May	1.5	1.5	5.4	4.1	
Jun-Aug	1.5	1.1	5.8	4.3	-
Sep-Nov	2.2	2.1	8.7	7.5	-
Dec-Feb	2.7	4.2	9.9	13.0	+

Explanations: + increased temporal variability, - decreased temporal variability

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According to Bąk (2003), mean annual atmospheric pressure in the regions of Greater Poland and Kuyavia, which is also representative of the Bydgoszcz area, is 1005 hPa, oscillating in respective months from 1003 (April) to 1007 hPa (October). Diurnal pressure oscillations are obviously considerably larger (from 958 to 1035 hPa), which contributes to very high variability of local weather conditions. The performed measurements also showed similar atmospheric pressure – 1006.4 hPa. On the annual curve, atmospheric pressure was lowest in spring and summer (1005.8 hPa and 1005.7 hPa, respectively) and highest in winter and autumn (1007.0 hPa and 1006.9 hPa, respectively). Despite considerable variations in the mean atmospheric pressure year on year, no statistically significant trend in atmospheric pressure occurred in the examined multi-annual period in Bydgoszcz; only a statistically insignificant downward trend (-0.017 hPa/year) was observed.

The above-presented findings can be used for preparing climate guidelines for the Bydgoszcz-Szwederowo Airport to support the meteorological services of civil aviation.

In addition, this paper contributes new knowledge and addresses gaps in the literature on the atmospheric pressure curve in the Bydgoszcz area.

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