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Original article

Long-term variability of the frequency and persistence of strong highs over Poland

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ABSTRACT

The paper discusses the spatial and temporal variability in the occurrence of strong highs over Poland in the period 1951-2015. It focuses in particular on the persistence of the systems in question and the changes in their long-term variability. The study was based on the average daily sea-level air pressure values obtained from NCEP/NCAR Reanalyses for 12 grid points. A day with a strong high was defined as a day with daily average pressure equal to or higher than 1030 hPa. Over the study period, a minor increase in the annual air pressure values (0.17-0.32 hPa/10 years) was identified, as well as evidence of an increase in the number of days with strong highs. These changes were the most distinct in December and in southern Poland. A majority of strong high occurrences were recorded during the cool half of the year, they covered less than the whole territory of the country and typically persisted for no more than two days. The longest spells with pressure equal to or greater than 1030 hPa lasted between 15 and 22 days depending on the region. Such long sequences of days with strong highs coincided with years when strong highs were particularly frequent, especially in the 1980s and 1990s. No specific trends in persistence or seasonality were identified.

KEY WORDS: air pressure, atmospheric highs, atmospheric circulation changes, Central Europe

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1. Introduction

Much of the current climate research worldwide is devoted to climate change. Since changes in the frequency of occurrence and in intensity of extreme events tend to have a greater impact on the environment and the society than changes in meteorological averages (WATSON ET AL., 1996), many of these studies are devoted to the occurrence of extreme events and their relationships with atmospheric circulation. Among the most popular topics in climatological literature published in recent years has been a strong increase in temperatures during the 20th and 21st centuries and an accompanying increase in the occurrence of heatwaves (HEINO ET AL., 1999; MEEHL & TEBALDI, 2004; STOTT ET AL., 2004; WIBIG, 2007; KYSELÝ & HUTH, 2008; WIBIG ET AL., 2009a; IPCC, 2013), including their direct impact on the society and health (VANDENTORREN ET AL., 2004; BŁAŻEJCZYK & MCGREGOR, 2007; DELLA-MARTA ET AL., 2007; BARRIOPEDRO ET AL., 2011). These changes are accompanied by an increase in minimum temperatures and the trend towards milder weather in winter (WIBIG & GŁOWICKI, 2002; PIOTROWICZ, 2003; GIORGI ET AL., 2004; ROWELL, 2005; VOSE ET AL., 2005;). This included less frequent coldwaves (WIBIG ET AL., 2009b) with their adverse impacts on the economy, daily life and the environment (ground freezing, damage to trees, ice phenomena, pest decimation, etc.).

The occurrence of heatwaves and coldwaves is typically linked to the effect of anticyclones and to air advection from the south (heatwaves) or north and east (coldwaves) sector (CASSOU ET AL., 2005; MAHERAS ET AL., 2006; DELLA-MARTA ET AL., 2007; KYSELÝ, 2008; USTRNUL ET AL., 2010; SANCHEZ-LORENZO, 2012). For this reason, understanding of the long-term variability in the occurrence of anticyclones, especially strongest ones, could bring us closer to an explanation of any changes in the occurrence of extreme events and, thus, potentially also helping in their forecasting.

The objective of this research was to estimate the long-term variability in the occurrence and persistence of strong highs over Poland during the period 1951-2015. Since the strongest highs were known to concentrate in the cool season special attention was paid to the strong highs occurred from October to March.

2. Data and method

The study used average daily sea-level pressure values from NCEP/NCAR Reanalyses made available by NOAA/OAR/EARL PAD, Boulder, Colorado, USA, (www.cdc.noaa.gov) for the period 1951-2015. The values at 12 grid points (P1-P12) from a 2.5° × 2.5° grid, located within or very close to the territory of Poland, were examined (Fig. 1). Due to the annual pressure course (peaking in winter and with minimum in the warm season) this study has defined the year as ranging from 1 July to 30 June (e.g. from 1 July 1951 to 30 June 1952) and the cold season as the period from 1 October to 31 March.

The set of data employed here is very popular in climatological research and is regarded as homogenous (Kalnay et al., 1996; Kistler et al., 2001). Certain doubts could be raised about the data from the 1950s and 1960s (due to a slightly different types of observations used in the reanalyses; Kistler et al., 2001), about data from high or low latitudes, and from high altitudes (Jones, 1987; Trenberth et al., 2001; Burt, 2007; You et al., 2013). However, the dataset concerning to the region that includes Poland has been tested on many occasions and no significant discrepancies have been discovered when compared to direct values from weather or aerologic stations (Woyciechowska & Bąkowski, 2006; Miętus, 2009; Szot & Kosowski, 2014).

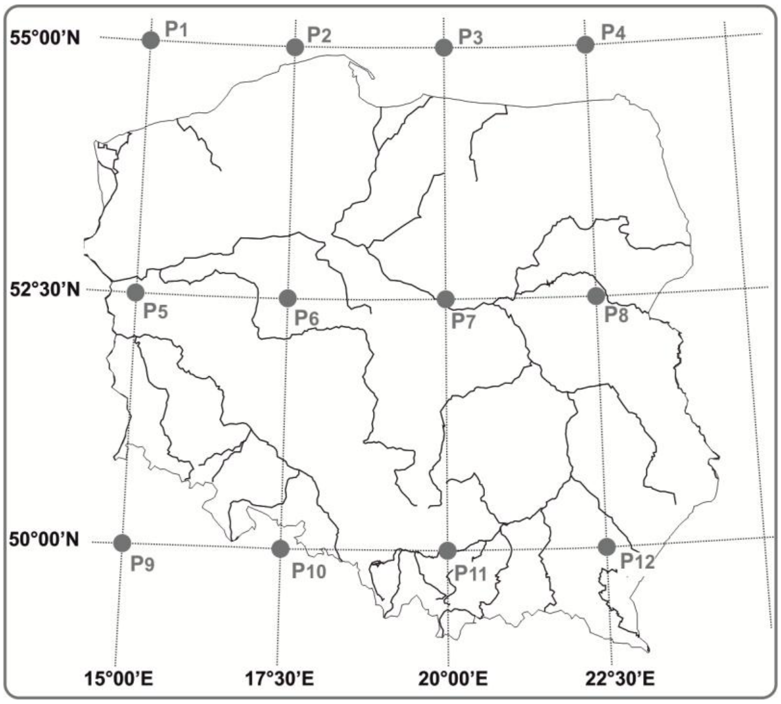

Fig. 1. Grid points used in the study

The study assumed that a day with a strong high (SHP) was a day with a pressure equal to or higher than 1030 hPa. This criterion is similar to the one adopted in other studies (i.e. pressure equal to or higher than 1035 hPa; Kłysik, 1995; Kożuchowski, 1995) and is close to the 95th percentile of all pressure values recorded over Poland and over the majority of the territory of Europe. A more thorough explanation of this specific choice can be found in previous studies devoted to the same topic (Bielec-Bąkowska, 2010a, 2010b, 2014; Bielec-Bąkowska & Piotrowicz, 2011).

The series of days with pressure equal to or higher than 1030 hPa was determined at specific grid points. This means that it was not the particular anticyclones or the time from their emergence to decay that was taken into account. For this reason in many of the cases a single strong high covered a large part of the country (and was "represented" by several of the grid points at the same time). This approach offered a chance to test regional patterns in the occurrence of such high-pressure values (and indirectly also helped determine the extent of these strong anticyclones). As an added value this reduced the scope of situations when the region would be on the periphery of a strong high and its influence of the country's weather would be limited.

The analysis was conducted both for each grid point and for all events when six or more grid points recorded the defined pressure values on the same day. The long-term variability in the persistence of strong highs was determined for the entire year and for each month, which were then tested for significance using the Mann-Kendall test (MANN, 1945; KENDALL, 1975)

3. Spatial and long-term pressure change

Poland's territorial size and its geographic location determine that the spatial and long-term air pressure variabilities do not vary much between its regions. This is confirmed by statistically significant (at $p<0.01$) values of the correlation coefficients of pressure changes between grid points, which were found to range from 0.61 to 0.88. The largest differences were identified between the south-west and north-east of the country. The average annual pressure values ranged from 1014.0 hPa (P1) to 1016.3 hPa (P10) and those of the cool half of the year (Oct-Mar) were higher than the averages by between approx. 0.1 hPa in the north-west and 1.6 hPa in the south-east (Table 1).

The average annual pressure values (derived from the 12 grid points) range from approx. 1013 hPa to 1019 hPa (Fig. 2A). The highest pressure values are typically recorded in October, with a secondary peak in January. During the warm half of the year, these values are noticeably lower, although there is a characteristic increase of the pressure values in May. This pressure course is the most typical in the central and southern parts of Poland, except in the latter region the main peak is in January (Fig. 2B). In the north the highest pressure values are recorded either in May or in October, while cyclonic activity tends to be more prevalent in January (WOŚ, 1995).

Table 1. Average air pressure values at particular grid points in the period 1951-2015

Index	Average pressure values at grid points [hPa]											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Annual	1014.0	1014.2	1014.3	1014.5	1015.2	1015.4	1015.4	1015.4	1016.3	1016.4	1016.1	1016.0
X-III	1014.1	1014.4	1014.7	1015.1	1015.7	1016.1	1016.2	1016.4	1017.2	1017.6	1017.6	1017.6
IV-IX	1014.1	1014.2	1014.2	1014.2	1014.7	1014.8	1014.7	1014.4	1015.2	1015.0	1014.6	1014.4

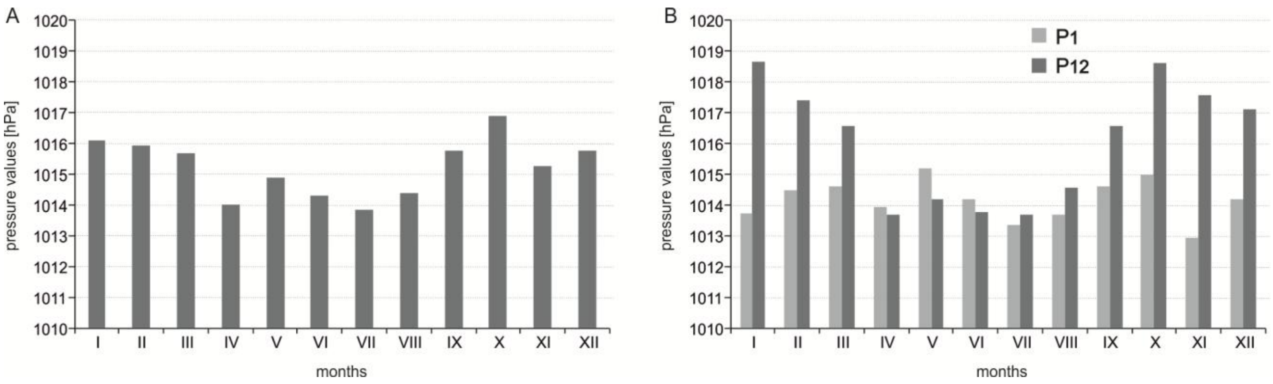

Fig. 2. Average monthly pressure values for 12 (A) and at selected (B) grid points in the period 1951-2015

The long-term air pressure changes indicate a slight trend towards an increase, but in northern part of Poland there are not statistical significant. This trend involves growth rates ranging from about 0.17 hPa per 10 years at P6 to approx. 0.32 hPa per 10 years at P9 (at $p<0.05$; Table 2 and Fig. 3). This is mainly an effect of an increase in average pressure values after 1960 and of changes in the warm half of the year. Within particular months, changes of long-term variability of air pressure values are typically small and statistically insignificant. In the cool season, the only noticeable increase is limited to December and to southern Poland (approx. 0.7 hPa/10 years). In the warm season, statistically significant (at $p<0.05$) changes are weaker. There cover most of the country's territory and are noticeable only from May to August and range from 0.28 to 0.51 hPa/10 years (Table 2).

Table 2. Tendency of the air pressure value changes [days/10 years] at selected grid points in the period 1951-2015

Grid points	Tendency [hPa/10 years] in particular months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
P1	0.17	0.07	-0.13	0.10	-0.02	0.01	0.21	0.26	0.23	-0.09	-0.11	0.39	0.05
P2	0.20	0.10	-0.16	0.11	0.01	-0.02	0.23	0.28	0.26	-0.03	-0.11	0.42	0.07
P3	0.21	0.12	-0.19	0.11	0.07	-0.02	0.26	0.31	0.30	0.03	-0.09	0.44	0.09
P4	0.18	0.11	-0.24	0.08	0.13	0.00	0.30	0.35	0.34	0.09	-0.08	0.44	0.11
P5	0.32	0.34	0.11	0.15	0.13	0.23	0.23	0.31	0.21	0.01	0.01	0.52	0.18
P6	0.30	0.31	0.04	0.15	0.15	0.21	0.26	0.32	0.20	0.04	-0.01	0.51	0.17
P7	0.28	0.29	-0.04	0.13	0.18	0.20	0.28	0.34	0.21	0.06	-0.02	0.51	0.17
P8	0.25	0.26	-0.11	0.11	0.21	0.20	0.32	0.39	0.24	0.10	-0.02	0.51	0.17
P9	0.44	0.53	0.35	0.23	0.29	0.44	0.34	0.43	0.26	0.15	0.14	0.66	0.32
P10	0.40	0.49	0.25	0.23	0.31	0.42	0.36	0.44	0.24	0.17	0.14	0.68	0.31
P11	0.37	0.45	0.16	0.23	0.34	0.40	0.38	0.46	0.21	0.17	0.14	0.67	0.30
P12	0.36	0.42	0.09	0.22	0.36	0.40	0.43	0.51	0.21	0.18	0.14	0.67	0.30

1.25 – value statistically significant at p<0.05

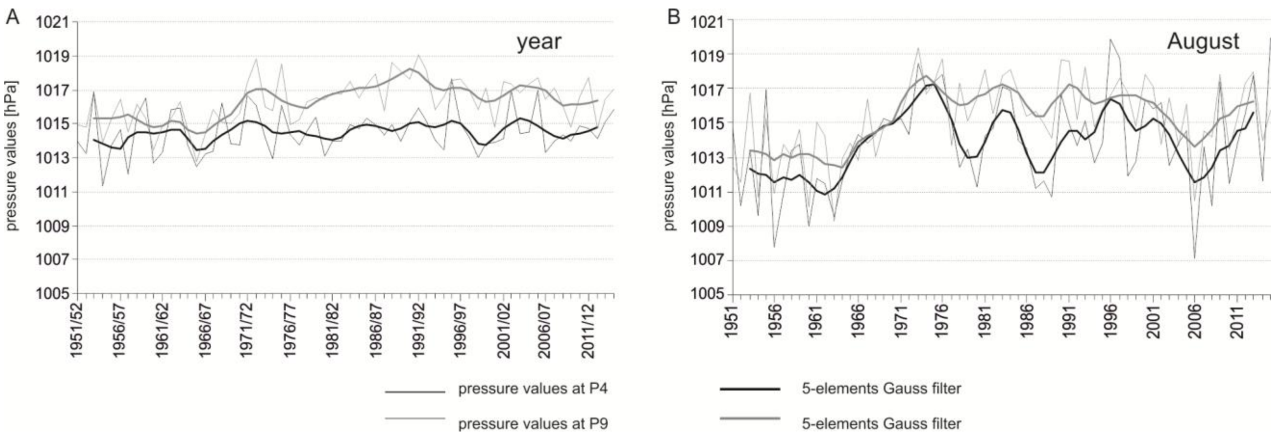

Fig. 3. Long-term variability of annual (A) and August (B) air pressure values at selected grid points in the period 1951-2015

4. Strong highs

A strong high (SHP) typically covers only a part of Poland's territory (80% of cases). During an average year, there are about 38 days when air pressure values equal or higher than 1030 hPa are noted at one or more grid points, of which about 80-90% such days are concentrated between October and March. The average regional number of days with SHP ranges from about 17 to 20 in a year. During the cool season, it tends to be lower by one day (Table 3), although at one of the grid points even 42 such days were noted during the study period (PIOTROWICZ ET AL., 2016). As in the case of the pressure values the highest number of days with SHP were recorded in the south and east, while the lowest number in the north-west of Poland. During the SHP days the average daily pressure values did not exceed 1050 hPa and ranged from 1045.1 hPa at P9 to 1049.4 hPa at P4.

During the study period, strong highs covered large part of the country (i.e. pressure equal or higher than 1030 hPa occurred at 6 or more grid points) on approx. 53% of days with SHP. This included about 20% of such days when the SHP was recorded at all the points covering the whole of the country (Table 4), which occurred on 7 days per average year.

January and February are the months with the highest frequency of days with SHP (on average about 3.7 days per month; Fig. 4A). Regional differentiation involve a typical February peak in the north and west of the country (on average 3.6-3.7 days) and a January peak along all the south and in the east (on average 3.7-4.6 days). Towards the warm season, the number of days with SHP rapidly decreases to sporadic numbers in summer. Strong highs become frequent again in autumn to the point that the north-west of the country features a noticeable secondary peak in October (Fig. 4B).

Table 3. Average number of days with air pressure equal to or higher than 1030 hPa (SHP days) at selected grid points in the period 1951-2015

Index	Number of days with pressure ≥1030 hPa											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Annual	17.7	18.3	18.2	19.2	17.3	18.0	18.0	18.2	18.4	20.0	18.9	18.4
X-III	16.0	16.8	16.8	17.9	16.0	16.8	16.9	17.4	17.6	19.3	18.4	18.0
IV-IX	1.7	1.5	1.4	1.2	1.2	1.2	1.0	0.8	0.9	0.7	0.5	0.5

Table 4. Number of days with air pressure equal to or higher than 1030 hPa (SHP days) at particular grid points in the period 1951-2015

Months	Number of SHP days at particular number of grid points							sum
	6	7	8	9	10	11	12	
I	23	26	43	11	19	23	100	245
II	23	19	17	18	22	22	123	244
III	23	19	26	20	14	17	50	169
IV	2	6	5	3	2	2	2	22
V	3	2	3	2	1	1	0	12
VI	0	0	0	0	0	0	0	0
VII	0	0	0	0	0	0	0	0
VIII	0	0	1	0	0	0	0	1
IX	3	4	3	1	4	2	8	25
X	15	14	21	13	12	25	29	129
XI	13	16	24	10	9	8	43	123
XII	18	28	27	20	14	18	94	219
sum	123	134	170	98	97	118	449	1189
% of all SHP days*	5.5	6.0	7.6	4.4	4.4	5.3	20.2	53.4

* % of all days with SHP at least one grid point during the study period

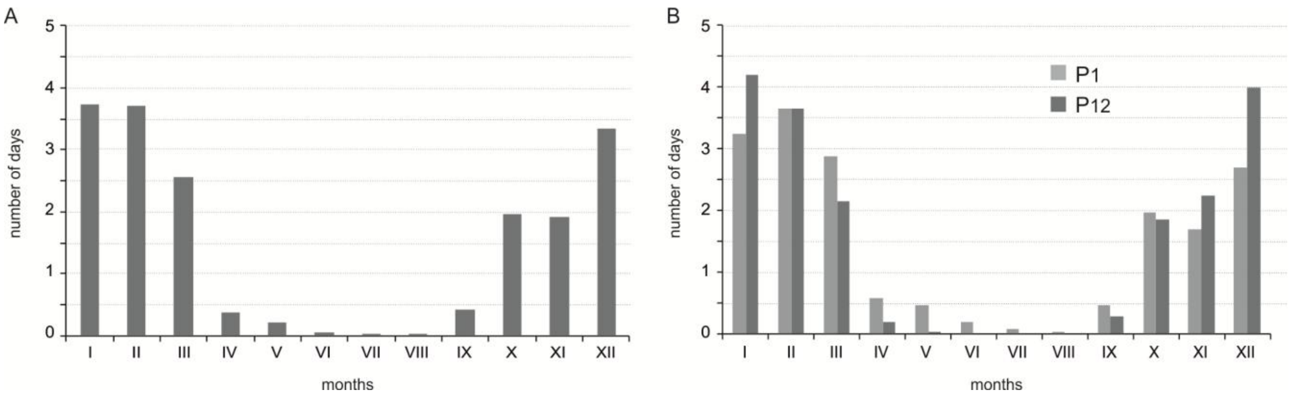

Fig. 4. Average monthly number of days with SHP for 12 (A) and at selected (B) grid points in the period 1951-2015

The study has not identified any clear change in the number of days with SHP at any particular grid point. Considering the annual values there is some evidence of an increase in the frequency of strong highs (especially in the south of Poland), but only statistically significant at P9 (about 1.2 day/10 years) (Table 5). What is notable, however, is how low the number of days with SHP is in the 1960s, and how it has been falling again since the turn of the 20th century (Fig. 5). Looking at individual months, noticeable change is only identified in isolated cases and it only encompasses large areas in December (0.3-0.5 day/10 years; Table 5).

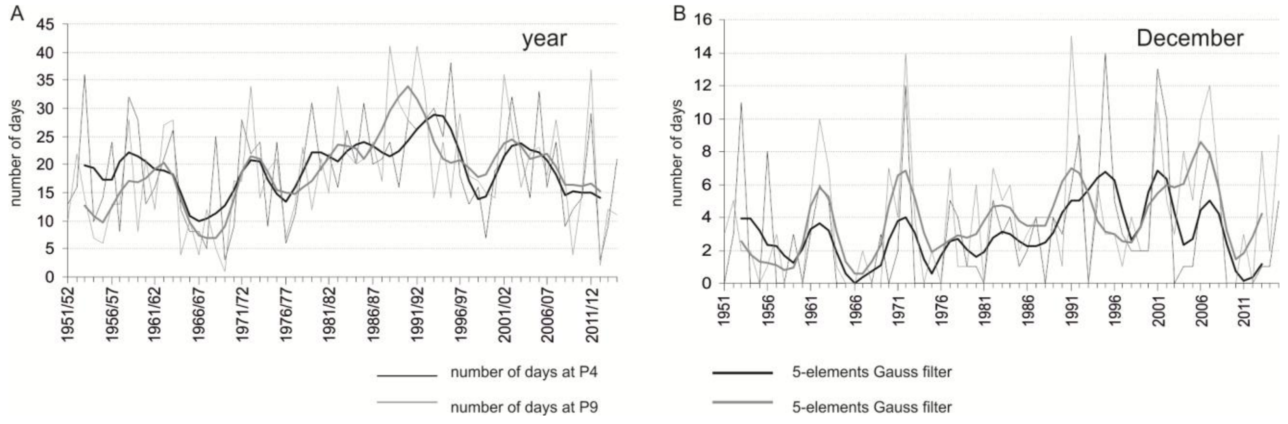

Fig. 5. Long-term variability of annual (A) and December (B) number of days with SHP at selected grid points in the period 1951-2015

Table 5. Tendency of number of days with SHP changes [days/10 years] at selected grid points in the period 1951-2015

Grid points	Tendency [days/10 years] in particular months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
P1	0.05	-0.04	0.00	0.02	0.08	-0.02	0.02	0.00	0.07	-0.10	-0.15	0.31	0.06
P2	0.04	-0.02	-0.05	0.06	0.09	-0.03	0.01	0.00	0.03	-0.07	-0.14	0.25	0.04
P3	0.12	-0.02	-0.14	0.04	0.09	-0.01	0.00	0.00	0.04	-0.05	-0.06	0.25	0.09
P4	0.18	-0.09	-0.24	0.07	0.06	0.00	0.02	0.00	0.04	0.17	0.03	0.22	0.31
P5	0.13	0.09	0.22	0.03	0.04	-0.01	0.01	0.00	0.04	-0.05	-0.09	0.39	0.62
P6	0.14	-0.03	0.12	0.05	0.05	0.01	0.00	0.00	0.03	-0.06	-0.12	0.38	0.38
P7	0.20	0.02	-0.04	0.09	0.04	0.01	0.00	0.00	0.04	-0.02	-0.09	0.32	0.37
P8	0.20	0.05	-0.14	0.08	0.05	0.00	0.00	0.00	0.04	0.04	-0.02	0.30	0.39
P9	0.16	0.29	0.30	0.06	0.02	0.01	0.00	0.00	0.08	0.04	-0.03	0.49	1.22
P10	0.21	0.16	0.16	0.06	0.02	0.00	0.00	0.00	0.06	0.02	-0.08	0.50	0.84
P11	0.19	0.11	0.12	0.04	0.01	0.00	0.00	0.00	-0.01	0.05	-0.02	0.42	0.65
P12	0.24	0.08	0.05	0.04	0.01	0.00	0.00	0.00	0.01	0.04	0.00	0.40	0.61

1.22 – value statistically significant at $p<0.05$

5. Sequences of days with SHP

Typically, high-pressure values over Poland are very short lived. During the study period, the overwhelming majority of them lasted for one or two days, accounting for between 61 and 68% of all sequences of days with SHP, depending on the grid point (Fig. 6). Of this value between 34.5% (P12) and 38.9% (P5) were single days with SHP (155-176 days, depending on the point). There were between 101 and 145 two-day sequences, which accounted for from about 23% (P3) to about 30% (P6) of all strings. Longer sequences were several times less frequent, specifically: 3-day sequences were half as frequent, 4-day sequences were three times less frequent, and 5/6-day were about four times less frequent (Fig. 6). Sequences with 7 or more days were very rare and only occurred in the cool season, including highly isolated cases of sequences of more than 10 days.

Depending on the region, the longest sequences of days with strong highs lasted from 15 to 18 days, aside from points P10 and P11, which each recorded one 22-day sequence. The latter sequence was linked to an event where a vast high-pressure area covering nearly the whole of Europe for many days and included several secondary high-pressure centres. The described synoptic situation began developing in early December of 1972 and lasted until mid-January the following year. In Poland, air pressure crossed the 1030 hPa value on 12 December to return below it on 2 January. However, the system did not decay and were it not for slight decrease in pressure on 3 and 11 January the sequence of days with high pressure would have lasted until 14 January and totalled 34 days. During this time, high pressure values were also recorded in other parts of Poland, but were not as long-lived. Indeed, pressure values higher or equal to 1030 hPa were recorded for 19 consecutive days at 10 or more points and for 9 days at 12 points.

The warm season had only 182 days when at least one grid point air pressure equal or higher than 1030 hPa was recorded. Synoptic situations with this pressure typically lasted for one day with some isolated cases of 6 days. The longest of these sequences included: 4 days from 28 September–1 October 2015, when a high pressure area covered the whole of the country; 5 days (twice) from 11-15 May 1980 and 30 September–4 October 1987, when a high pressure system dominated in the north-west; and 6 days from 14-19 April 2003, when the highest pressure was recorded in northern and central Poland.

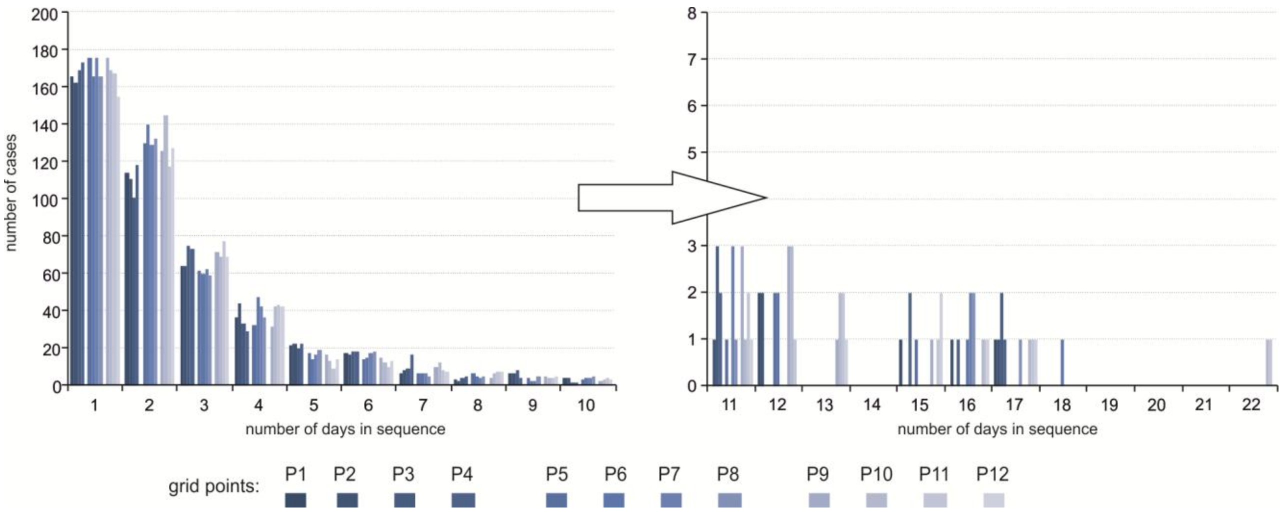

Fig. 6. Number and length of sequences of days with SHP occurred at particular grid points in the period 1951-2015

Looking at the sequences of days when the air pressure in question was recorded at all 12 grid points, an overwhelming majority (approx. 91%) of them were not longer than 4 days, and there were only 2 sequences longer than 7 days (Table 6). This does not mean that the high pressure systems represented by these sequences did not last longer. Indeed, they typically continued to persist for a few more days, but either the pressure values dropped below our criterion across the system, or a zone with values equal or higher than 1030 hPa shifted, leaving some of the grid points outside. The longest two sequences could serve as examples here: one was linked to an Atlantic high which affected the weather in Poland between 27 January and 20 February 1959. However, its movements and pressure value changes caused that the relevant sequences of days (equal or higher than 1030 hPa at 12 grid points) lasted only between 9 and 17 February (9 days). The other sequence is also the longest sequence of days with SHP covering the whole of Poland (11 days) and it occurred between 1 and 11 February 2012. This event was linked to a Russian high, which already recorded more than 1030 hPa at some grid points on 26 January. Between 29 January and 11 February these pressure values were present at 11 or 12 grid points, and on 12 February remained at five of them (overall 18 days with air pressure equal to or higher than 1030 hPa at least one grid point).

Due to a general shortness of sequences of days with strong highs (the overwhelming majority shorter than 6 days, including more than 60% of just 1-2 days, more than 75% of 1-3 days and about 90% of 1-5 days), their long-term variability of occurrence is very similar to the long-term variability in the number of days with strong highs. For this reason it would be particularly interesting to identify any variability patterns of strong highs lasting 6 or more days. It would be even more interesting since these persistent anticyclones exert a strong influence on the weather in Poland.

Table 6. Number and length of sequences of days with SHP recorded at all 12 grid points in the period 1951-2015

Index	Length of sequence [days]										
	1	2	3	4	5	6	7	8	9	10	11
Number of sequences	86	58	31	10	7	4	5	0	1	0	1

These long sequences of days with SHP (equal or higher than 6 days) rarely occur more than once per year and were absent during the 16 years of the study period (Table 7). Only in 5 of the years were there 3 such sequences and only once 4 such sequences (1992/1993). In all these cases, these sequences occurred in at least one point of a grid. The long-term variability in the occurrence of described sequences (equal or higher than 6 days) has not indicated any statistically significant trend. Periods of their highest frequency overlap with major increases in the frequency of days with strong highs: the turn of the 1950s, 1971/1972–1975/1976, the 1980s and 1990 (especially 1988/1989 and 1991/1992) and 2001/2002-2011/2012. Nor is there any change in the annual course of these long sequences occurrence, with most occurring in the cool season, typically in winter (Table 8). One pattern that emerges is that their number is similar even between November and March in north-western Poland, while elsewhere they peak in January or, more rarely, in February.

Table 7. Number of sequences of days with SHP lasting 6 or more days at particular grid points in the period 1951-2015

Year	Number of sequences at particular grid points											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
1951/52												
1952/53												
1953/54												
1954/55												
1955/56												
1956/57												
1957/58												
1958/59	**17**	**17**	**17**	**15**		**18**	**16**	**16**		**17**	**16**	
1959/60												
1960/61												
1961/62												
1962/63												
1963/64												
1964/65												
1965/66												
1966/67												
1967/68												
1968/69												
1969/70												
1970/71												
1971/72												
1972/73										**22**	**22**	
1973/74												

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2009/10												
2010/11												
2011/12	**15**	**16**	**17**		**15**	**16**	**16**	**17**			**17**	**17**
2012/13												
2013/14												
2014/15												
sum	40	41	45	50	37	36	38	42	44	46	42	41

number of sequences	1	2	3	4

17 – number of days in the longest sequence

(only two the longest sequences were marked)

Table 8. Sequences of days with SHP lasting 6 or more days at particular grid points in the period 1951-2015 – from October to March

Months	Number of sequences at particular grid points												
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	sum
X	2	2	2	2	3	2	2	2	1	1	2	2	23
XI	7	9	9	8	2	4	4	6	5	4	4	5	67
XII	10	9	8	8	10	9	9	6	8	12	10	9	108
I	8	8	9	11	9	10	11	13	16	16	14	13	138
II	9	8	9	13	10	8	8	10	12	10	9	9	115
III	4	5	7	8	3	3	4	5	2	3	3	3	50
IV	-	-	1	-	-	-	-	-	-	-	-	-	1
Sum	40	41	45	50	37	36	38	42	44	46	42	41	

6. Conclusions

During the study period, there was some evidence of a minor increase in the annual air pressure over Poland. This is more noticeable in the south (up to 2 hPa in south-western Poland) and in the warm season (up to more than 3 hPa in the south). In winter, this increase was even stronger, but statistically significant only in December and in southern Poland (about 4.4 hPa/65 years). These results confirm findings of earlier studies pointing to an overall increase in air pressure over Europe south of 55°N and its decrease in northern and eastern Europe (Schönwiese & Rapp, 1997, Bhend, 2005). This may be explained by a number of behavioural changes in pressure systems: i) a change in the location of the Atlantic highs (Davis et al., 1997; Piervitali et al., 1997), ii) a decline in the number of lows in Europe south of 55°N combined with an increase of their frequency in northern and north-eastern parts of the continent, and iii) a northward shift of cyclone tracks (Bartholy et al., 2006; Trigo, 2006; Bielec-Bąkowska, 2010).

This change was accompanied by similar changes in the frequency of days with SHP (air pressure equal to or higher than 1030 hPa) indicating a small increase in the frequency of occurrence of strong highs in Poland. Similar changes were also observed elsewhere in Central Europe (Bielec-Bąkowska & Piotrowicz, 2011; Cahynová & Huth, 2009, 2014; Kyselý & Huth, 2006, Bielec-Bąkowska, 2010b, 2014). They suggest a very substantial decrease in the number of the days in question in the 1960s (from 1 to about 10 days per year in Poland) and an increase in the 1980s and 1990s (up to more than 40 days per year and 17-20 days on average in Poland) followed by another decrease starting at the turn of the 20th century. During the year, an increase in the number of days with SHP concentrated primarily in December when it covered the country's entire territory except its northern regions. In other months, it was either negligible or there was evidence of a decrease. This ambivalent effect may be explained by much lower air pressure values that characterise anticyclones of the warm season.

A majority of strong highs occurred between October and March, typically covering only a portion of the country (about 80% of days). On average there were only 7 events in a year, when SHP covered the whole country. Most of the strong highs only persisted for up to 2 days and in 90% of cases for up to 5 days. During the cool season, the longest sequences of days with SHP lasted to 15-18 days with two grid points recording up to 22 days. During the warm season, the sequences were never longer than 6 days.

Sequences of 6 or more days tended to occur once a year. There were only six years with 3-4 such sequences. These years with the highest numbers of long sequences of days with SHP overlapped with periods of increased numbers of days with strong highs, especially in the 1980s and 1990s. Nevertheless, despite an increase in the persistence of highs and their accompanying cold periods in Europe, which lasted until 2000 (KYSELÝ, 2008), no clear trends of change in the persistence of strong highs or their annual pattern change were identified. This may be caused by a decrease in the number of days with SHP in the 21st century, which is accompanied by a decline in cold waves in Poland (WIBIG ET AL. 2009a, 2009b).

These results, combined with evidence of a slowdown in winter temperature increase (WÓJCIK & MIĘTUS, 2014), i.e. when strong highs are the most frequent, suggest that there is a need to investigate all pressure systems, regardless of their strength. This would help identify a change in the circulation over Poland and its influence on the occurrence of cold periods and heatwaves.

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