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VARIABILITY OF AIR MASSES OVER PODLASIE (NE POLAND) IN THE YEARS 2001–2010

Abstract: This paper concerns the frequency and duration of air masses over Podlasie (NE Poland) in the years 2001–2010. The synoptic maps in the Daily Meteorological Bulletin of the Institute of Meteorology and Water Management (IMGW 2001–2010) were the basis for the designation of six air masses observed over the area of Podlasie every day for 12.00 UTC. They were: arctic air (A), continental polar air (cP) partly transformed from old arctic air (oA), maritime polar air (mP), maritime warm polar air (mwP), old maritime polar air (omP), tropical air (T). The analysis shows that the most frequent air mass in the whole period was cP partly transformed from oA (approx. 33%) followed by omP (approx. 24%) and mP (19%). Tropical air occurred over Podlasie with the lowest frequency, with a value of only 3.6%. The frequencies of their occurrence varied from year to year. Less than 12% of cases (approx. 210) occurred for 4–20 days. The minimum values occurred for periods of more than 9 days (cP and omP masses, only). Slightly higher values occurred in the case of 7- to 9-day periods (6–14 cases 1.5%).

Key words: air masses, frequency, duration, Podlasie, NE Poland

Introduction and objective of the paper

Atmospheric circulation plays a very important weather-forming role, particularly at moderate latitudes (23°27’–66°33’N-S) and especially in the Northern Hemisphere, and is the main determining factor in the inflow of air masses. The masses also largely determine the course of short-term climate fluctuations. An understanding of the air masses occurring over a given region permits forecasting changes occurring at the synoptic scale (counted in hours or days) and even at the climatic scale (counted in seasons, years, or multi-annuals). The increasingly frequently observed changes in the intensity of extreme phenomena can also be related to changes in the frequency of occurrence of arctic and tropical air masses in particular. Atmospheric circulation also strongly affects the development of bioclimatic conditions. Therefore, the probability of occurrence of any effects induced by such changes is of significant interest, not only among climatologists.

The objective of this paper is to analyse, at the multi-annual and annual scale, the frequency and duration of occurrence of air masses over Podlasie (NE Poland) in the years 2001–2010, because this part of Poland is considered to be the region with the most continental climate type.

Literature review

The current literature regarding air masses is very extensive. In order to present the issue more clearly, the publications can be divided into several groups. The first group includes papers discussing the aspect of frequency of air masses for the entire area of Poland. The most important work is that by Rafałowski et al. (1955). It was the first publication of its type. In the following years, it was extended by further data by Bołaszewska and Reutt (1962). Both publications constitute a starting point for many other researchers own papers. They are often cited, e.g. in Paszyński and Niedźwiedź (1991) or Woś (2010). Other papers regarding Poland have been presented by, among others, Warakomski (1969), Misiewicz (1969), Więcław (1999, 2004, 2010), or Degirmendźić and Kożuchowski (2006).

Another group of papers is that of regional works. Unfortunately, not many of them were written for the area of Podlasie or its constituent parts. The first was by Kaczorowska (1958), where the author determined the frequency of air masses for the Białystok Voivodeship. Several papers also present the frequency for Suwałki, a city in the region of Podlasie, within the scope of analyses of data from other regions of Poland. Those include papers by Więcław (1999, 2004) or Szychta (2002), where the author distinguishes the division into air masses categorised as omA or omT. A large group of papers written by Niedźwiedź (1968, 1981, 2000, 2003) and other authors (Twardosz et al. 2011) mainly concerns the frequency of air masses in southern Poland. In other papers we can also find works about other regions of Poland, e.g. Buchert (2006) for the Poznań area, Kaszewski (1977) for the Middle East macroregion of Poland, or Michna and Paczos (1971) for the western Bieszczady Mountains.

Analyses of the frequency of air masses have also been conducted for specific towns, e.g. in Gumiński (1952), Kosiba (1952), Zinkiewicz and Warakomski (1959), Wiśliński (1975/76, 1977), Michna (1965, 1967), Niedziałek (1982), or Więcław (1995, 1998).

Another group includes papers where the frequency of air masses is combined with an analysis of individual meteorological elements. Those include papers by Tomaszewska (1964), regarding the aspect of extreme temperatures in various air masses over Warsaw, and a paper by Stopa (1964), describing conditions favourable to the development of storms in various air masses. Other examples have been published by Madany (1971), where the author describes ground frosts on air masses, and by Michałowski and Warakomski (1974), where the authors analyse in-mass precipitation.

Another example is the paper by Gluza (1978), determining the occurrence of typical days in air masses in the north-eastern macroregion. The paper by Niedziałek (1982) discusses the aspect of total radiation in various air masses. These are only examples: many such papers have been and still are being written.

In the description of the climate of a given region, the general characteristics are often accompanied by data on the frequency distribution of air masses. Examples of such works include those by Michna (1965), Kaszewski (2008), or Woś (2010).

There are also publications where the objective of the paper is to analyse the duration of air masses, such as the paper by Kotas (2011).

Material and method

The working material consisted of daily lower synoptic maps from the area of Europe from 00 UTC, published in the Daily Meteorological Bulletin of the Institute of Meteorology and Water Management (IMGW 2001–2012), which since 2010 have been available on line at http://pogodynka.pl/polska/mapa_synoptyczna/.

The air mass was determined over the area of Podlasie every day for 12 UTC by the interpolation method between two consecutive maps.

Masses marked on the maps were considered, but in the analyses they were generalised into six types: arctic air (A), continental polar air (cP), partly transformed from old arctic air (oA), maritime polar air (mP), maritime warm polar air (mwP), old maritime polar air (omP), tropical air (T). First, maritime arctic air (mA) and continental arctic air (cA) masses were qualified to old arctic air, next they were qualified to continental polar air, and were renamed as polar continental partly transformed from old arctic air. In problematic situations, German maps Deutscher Wetterdienst Offenbach (DWD) published at http://www.wetter3.de/Archiv/archiv_ukmet.html turned out to be useful.

The next stage of research involved the analysis of the calendar of air masses. The frequency of air masses was calculated for individual years, for individual seasons (spring (Mar–May), summer (Jun–Aug), autumn (Sep–Nov), and winter (Dec–Feb)) and for individual months. The duration of occurrence of air masses over Podlasie was also determined.

Results

Among the six types of air masses under discussion, the highest frequency in the period from 2001 to 2010 was that of polar continental air mass, partly transformed from old arctic air, at almost 33%, i.e. 119 days per year on average (Table 1). This air mass occurred most frequently in 2002 (approx. 41%; 151 days), and most seldom in 2009 (approx. 24%; 89 days) (Table 2). The occurrence of this air mass also has the highest variability in the analysed period. Over the course of the year it had the highest contribution in April (42%; approx. 13 days per month), as well as in March (almost 41%) and December (40%; 12 days both cases). The minimum values were reported in July, reaching 17% (approx. 5 days per month). This mass was a little more frequent in August (almost 22%; approx. 7 days), and in June (25%; approx. 8 days), so its lowest contribution was in summer. In the remaining months, the frequency of the inflow varied from approx. 31% to 37% (9–11 days on average).

Table 1. Mean (in %) annual course of frequency of air masses over Podlasie (NE Poland) in the years 2001–2010 by months and seasons

period /mass	A	cP *a)*	mP	mwP	omP	mP+ mwP+ omP	T
Jan	7.4	36.5	17.4	16.8	21.9	56.1	0.0
Feb	9.9	36.2	16.0	14.9	22.3	53.2	0.7
Mar	8.7	40.6	15.8	13.9	21.0	50.6	0.0
Apr	7.7	42.0	11.3	20.0	18.0	49.3	1.0
May	5.2	35.2	16.5	15.5	20.6	52.6	7.1
Jun	1.3	25.0	27.3	12.0	29.0	68.3	5.3
Jul	0.6	17.1	25.5	7.7	35.2	68.4	13.9
Aug	1.6	21.6	26.1	7.7	31.3	65.2	11.6
Sep	4.0	31.3	20.0	27.7	15.7	63.3	1.3
Oct	6.8	32.9	21.3	16.5	21.9	59.7	0.6
Nov	4.7	32.7	14.3	25.3	22.3	62.0	0.7
Dec	7.1	40.0	13.5	14.8	24.5	52.9	0.0
spring	7.2	39.2	14.6	16.4	19.9	50.9	2.7
summer	1.2	21.2	26.3	9.1	31.8	67.3	10.3
autumn	5.2	32.3	18.6	23.1	20.0	61.6	0.9
winter	8.1	37.6	15.6	15.5	22.9	54.1	0.2
year	5.4	32.6	18.8	16.0	23.7	58.5	3.6

a) cP – polar continental partly transformed from Arctic air

Table 2. Mean (in %) course of frequency of air masses over Podlasie (NE Poland) in the years 2001–2010

year/mass	A	cP *a)*	mP	mwP	omP	mP+ mwP +omP	T
2001	5.5	33.4	15.9	14.5	25.2	55.6	5.5
2002	6.6	41.4	13.7	14.8	18.9	47.4	4.7
2003	8.8	30.7	19.2	15.9	23.3	58.4	2.2
2004	9.3	33.3	22.7	13.4	21.3	57.4	0.0

year/mass	A	cP *a)*	mP	mwP	omP	mP+ mwP +omP	T
2005	7.1	37.3	20.0	11.5	23.3	54.8	0.8
2006	7.4	35.1	13.4	15.9	26.3	55.6	1.9
2007	4.1	29.6	20.3	18.1	21.6	60.0	6.3
2008	2.7	30.3	18.3	20.2	25.7	64.2	2.7
2009	2.2	24.4	24.1	18.4	26.8	69.3	4.1
2010	0.3	30.1	20.3	17.5	24.4	62.2	7.4
average from 10 years	5.4	32.6	18.8	16.0	23.7	58.5	3.6

a) cP – polar continental partly transformed from Arctic air.

Old maritime polar air is the second mass in terms of frequency, with a value of almost 24%, i.e. approx. 87 days per year. It had the highest contribution in 2009 (almost 27%; 98 days), and the lowest in 2002 (below 19%; 69 days). In the course of the year, its frequency was highest in July (35%; approx.11 days per month), as well as in August (31%; 10 days) and June (29%; 9 days). The lowest frequency was in September, reaching less than 16%, and also in April 18% (approx. 5 days both), and its lowest inflow was precisely in spring and autumn. In other months the frequency varied from approx. 21% to 24% (6–7 days on average).

The third most frequent air mass was mP, with a value of approx. 19%, i.e. 69 days per year on average. It reached its maximum inflow in 2009 (24%; 88 days on average), and the minimum in 2006 (13%; 49 days on average). In the course of the year, its highest frequency occurred in June (27%; approx. 8 days), as well as in July and August (25% and 26% respectively, i.e. approx. 8 days). It reached the lowest frequency in April (11%; slightly over 3 days). From January to April, a gradual decrease in the inflow of mP was observed. From April to June, its contribution increased, and then the frequency decreased again towards December.

Masses of mwP were recorded on 16% of days on average, i.e. approx. 59 days per year. It reached the highest frequency in 2008 (20%; 74 days), and the lowest in 2005 (almost 12%; 42 days). In the course of the year, its highest inflow occurred in September (almost 28%; approx. 8 days), and the lowest in July and August (almost 8%; approx. 2 days). Notice the very sharp increase of 20% between August and September.

Arctic air occurred over Podlasie with a frequency of more than 5%, i.e. approx. 20 days per year in the period analysed. It reached its highest value in 2004 (approx. 9%; 33 days), and its lowest in 2010 (0.3%; 1 day). In the course of the year, its contribution was highest in February (almost 10%; approx. 3 days per month), and lowest in July (0.6%; approx. 0.2 day per month). A substantial decrease in the inflow of A was also observed from February to July. From August, a gradual increase occurred until February, with a significant decrease in November to less than 5% (more than 1 day).

Tropical air occurred the most seldom over Podlasie (3,6%; 13 days per year). In 2004, this air mass was not recorded. In the course of the year, its maximum occurred in July (almost 14%, approx. 4 days), and in August (almost 12%, less than 4 days). From December to March, it did not occur at all, except in February, when it occurred occasionally with a frequency of 0,7% (about 0,2 days per month). Its frequency was observed to increase in late spring and in summer.

To better illustrate the results was made four charts (Figs 1–4). They present mean annual course of frequency of air masses over Podlasie by month and years, both in percent.

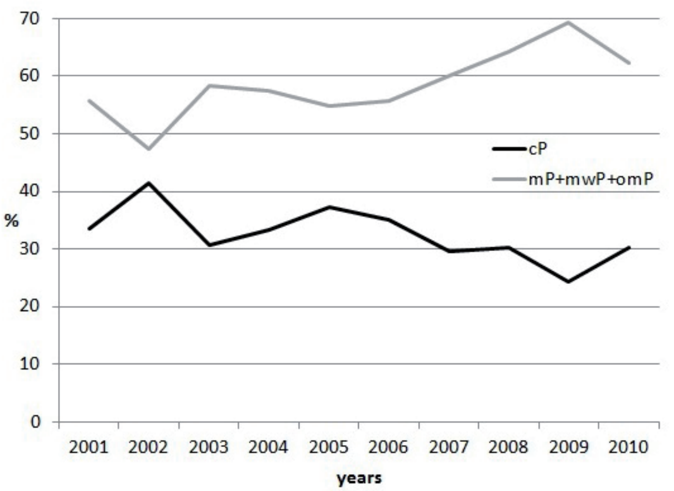

Fig. 1. Mean (in %) course of frequency of cP and cP+mwP+omP air masses over Podlasie (NE Poland) in the years 2001–2010

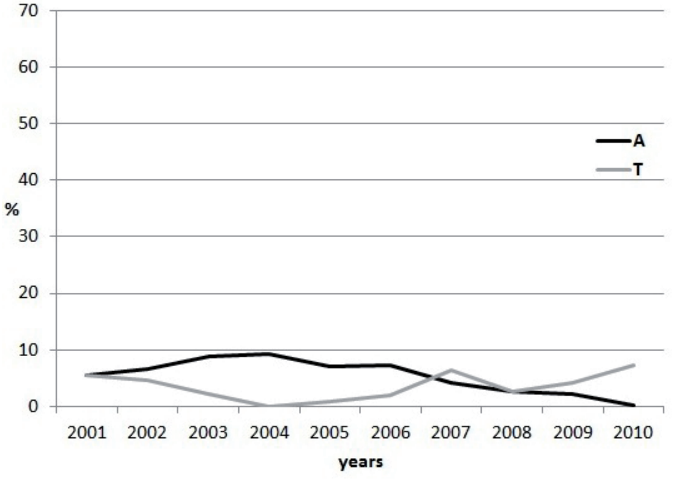

Fig. 2. Mean (in %) course of frequency of A and T air masses over Podlasie (NE Poland) in the years 2001–2010

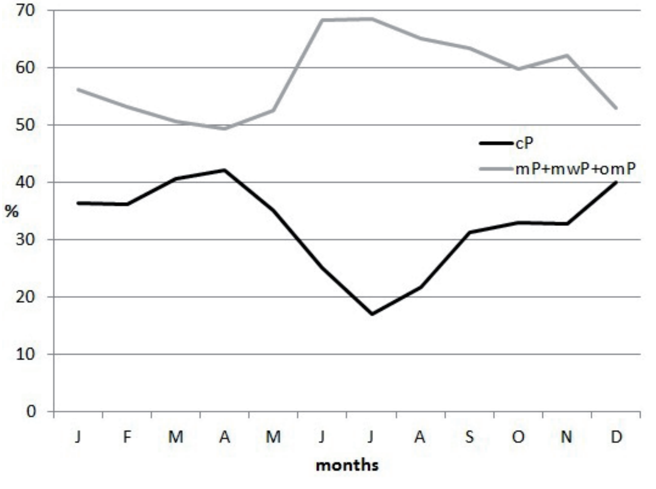

Fig. 3. Mean (in %) annual course of frequency of cP and mP+mwP+omP air masses over Podlasie (NE Poland) in the years 2001–2010 by months

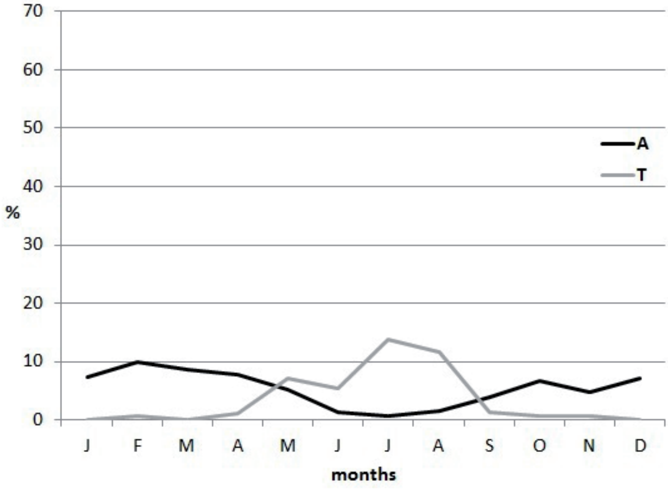

Fig. 4. Mean (in %) annual course of frequency of A and T air masses over Podlasie (NE Poland) in the years 2001–2010 by months

Duration of occurrence of air masses over Podlasie

The duration of occurrence of air masses over a given area is very significant for studies on the subject. Such data for Podlasie are presented in Table 3.

Air masses usually occurred over Podlasie for 1 day, i.e. in approx. 54% of all cases. A twice lower value was recorded for 2-day periods of occurrence. Less than 12% of cases (approx. 210) occurred for 4–20 days. The minimum values occurred for periods of more than 9 days, including periods of more than 10 days (1–3 cases in the specific period) representing less than 0.5%. Slightly higher values occurred in the case of 7–9-day periods (6–14 cases–1.5%). Notice that almost 90% of air masses occurred for periods of up to 3 days. This suggests that pressure systems occur with only a short duration.

The longest duration was of cP (partly transformed from oA), occurring over Podlasie for as many as 20 days in a row from Sep 30th to Oct 19th 2010. This was related to the occurrence during that time over the north of Poland of an extensive high which gradually expanded and weakened, causing the inflow of cP from the eastern sector. cP is also the mass with the highest number of cases of long occurrence over the region. Its contribution increased in the case of periods of more than 3 days in particular. Those lasting for 10 and more days were especially significant. The longest single case record of a mass occurring was reported from Jan 12th 2010 to Jan 28th 2012 (17 days), and it was in the afore-mentioned 20-day period.

Table 3. Number of cases with duration of occurrence of air masses over Podlasie (NE Poland) in the years 2001–2010

Number of days	A	cP *a)*	mP	mwP	omP	T	Sum	%
1	68	111	271	241	277	29	997	54.21
2	38	83	111	86	107	15	440	23.93
3	9	54	34	32	55	8	192	10.44
4	4	45	13	9	18	4	93	5.06
5	2	24	2	4	9	2	43	2.34
6	–	13		2	5	2	22	1.20
7	–	11	4	1	2	–	18	0.98
8	–	8	–	–	3	–	11	0.60
9	–	4	–	–	–	1	5	0.27
10	–	5	–	–	1	–	6	0.33
11	–	3	–	–	–	–	3	0.16
12	–	4	–	–	–	–	4	0.22
13	–	1	–	–	1	–	2	0.11
14	–	1	–	–	–	–	1	0.05
17	–	1	–	–	–	–	1	0.05
20	–	1	–	–	–	–	1	0.05
Sum	121	369	435	375	478	61	1839	100.00

a) cP – polar continental partly transformed from Arctic air.

In the case of other air masses, only single cases of longer occurrence over Podlasie were recorded, and these were for significantly shorter periods. The omP mass was recorded once for 13 days in a row within the decade (from Dec 21st 2007 to Jan 2nd 2008), and once for 10 days (from Dec 2nd to Dec 11th 2009). There was also a case of T air mass duration for 9 days, from Jul 10th 2010 to Jul 18th 2010.

In the case of the shortest periods of occurrence over Podlasie, omP masses were dominant, particularly below 4 days. The highest number of records concerned 1-day occurrences. An equally high number of recorded occurrences in this range, particularly in the case of 1-day occurrences, concerned the remaining polar maritime air masses, i.e. mP and mwP.

Masses of cP were observed in all periods, including single cases for longer periods of more than 10 days.

In the majority of years, a long duration of occurrence of air masses was observed, especially of cP and omP. A relatively high number of cases with a longer duration of air mass occurrence was recorded in 2010. In the cold season, these were of cP, and in the warm season T and mwP. In 2003, no cases of air mass occurrence with a duration of more than 8 days occurred, except for one 11-day period with cP (Feb 21st to Mar 3rd)

The above data are a bit problematic, however because the mass was determined for 12 UTC, the calculations did not consider interim daily changes related to the passing of atmospheric fronts causing a temporary change of mass. In other words, such long periods of occurrence of a given type of air mass do not necessarily mean its continuous occurrence. Therefore, these assumptions should be considered when interpreting the data.

Discussion

The comparison of results of analyses by various authors (Table 4) was supported by publications referring to Suwałki (Szychta 2002; Więcław 2004), Białystok (Kaczorowska 1958), Poznań (Buchert 2006), Lubelszczyzna in the middle east macroregion of Poland (Michna and Paczos 1986; Kaszewski 2008), and southern Poland (Niedźwiedź 2003). They are not fully comparable, however, due to the differing methods of distinguishing of air masses, and particularly due to varied periods considered. They do not even refer to a unified course of time. There are no new papers on the subject for this region.

In spite of the above, it is possible to draw certain conclusions. The comparison of the results of the above paper with the results of Kaczorowska (1958) reveals significant differences in the relationship between arctic and continental polar air masses. They both have more or less the same total value of approx. 40%, but in the earlier period, cP is predominant, and in the later period A air dominates. This may be related not to a change in their

Table 4. Comparison of results concerning mean annual frequencies of air masses (values expressed in %) based on papers by various authors

Mass	Poznań	Lubelszczyzna		southern Poland	Białystok	Suwałki		Podlasie	Poland
	Buchert (2006) 1965–1980	Kaszewski (2008) 1951–2000	Michna, Paczos (1986) 1951–1980	Niedźwiedź (2003) 1951–2000	Kaczorowska (1958) 1950–1953	Więcław (2004) 1971–1995	Szychta (2002) 1970–1995	author of the article 2001–2010	Bołaszewska, Reutt (1962) 1946–1956
A	4.8	1.4	10.7	8.9	3.0	20.3	6.6	5.4	3.7
oA	8.0	11.1		–	–		11.1	32.6	–
mA	1.5	–	–	–	–	–	2.3		–
omA	–	–	–	–	–	–	0.6		–
cP	11.8	18.3	22.9	24.1	34.0	13.4	14.7		29.3
mP	32.6	15.1	55.4	19.6	23.0	62.7	21.2	18.8	16.2
omP	27.0	37.9		35.8	38.0		30.4	23.7	48.8
mwP	12.6	12.3	8.4	8.1	–		10.9	16.0	–
T	0.7	0.0	2.6	3.5	2.0	2.2	1.3	3.6	2.0
oT	0.4	3.9					0.5		
mT	0.6	–	–	–	–	–	0.3	–	–
omT	–	–	–	–	–	–	0.1	–	–
cT	–	–	–	–	–	–	0.04	–	–
undefined	–	–	–	–	–	1.4	–	–	–

frequency, but to the manner of their determination on maps. In the case of polar air masses, the frequency is similar, although a decrease in fresh air in favour of old air is visible, whereas Kaczorowska would probably categorise mwP as the latter. In general, slightly lower values for total polar air were obtained in the case of the period from 2001 to 2010. In the case of tropical air, an increase in the frequency by 1.6% was observed, which is very significant for this type of air mass.

The analyses by Więcław (2004) reveal a substantial decrease in the frequency of A. This may be due to a different way of classifying arctic air. Practically all types of polar air showed a decrease in frequency except for mwP, which increased by 6%. The situation is similar in the case of tropical air, whose frequency of inflow over Podlasie has significantly increased since 1971.

The results of Szychta (2002) are similar. The author distinguished many more types of air masses (additionally mA, omA, oA, mT, omT, and cT), but she observed similar patterns.

The analyses of the Lubelszczyzna region (Michna and Paczos 1986; Kaszewski 2008) show the differences between arctic air and continental polar air. This may also be due different ways of classifying these mass types. But despite this, A and cP air are significantly more frequent over Podlasie. However, the total polar masses occurred more often over Lubelszczyzna in both cases. The results of tropical air occurrence are similar in both regions.

The Poznań area is different in terms of air mass frequency, and especially polar (total 72%), and arctic types (11,8%). The results also reveal diminished inflow of cP air. Tropical masses occurred significantly less frequently in the analysed period than over Podlasie.

The papers regarding Podlasie and southern Poland (Niedźwiedź 2003) show slight differences between these two regions. In the Niedźwiedź paper, polar and arctic masses are a bit more frequent. There is also a noticeably diminished share of continental air. The results for the occurrence of tropical air are similar in both cases.

The paper by Bołaszewska and Reutt (1962) concerning the Poland area shows that polar masses are more frequent and tropical and arctic masses are less frequent. The continental type has a similar value to that found over Podlasie.

The author of the paper revealed that the frequency of individual types of air masses for various regions of our country largely depend on the distance from their source.

Final conclusions

1. The most frequent air mass was cP (approx. 33%), followed by omP (24%) and mP (19%). Tropical air occurred over Podlasie with the lowest frequency. The value was 3,6%.
2. The values for cP increased from September to May (31–42%), and decreased in summer (June–August; 17–25%). The second most frequent mass (omP) usually occurred over Podlasie from June to August, with a value of approx. 30%. Their lower contribution was recorded in September and April (15.7% and 18%, respectively). Very large differences in frequency were also recorded for mwP with the minimum in July and August (7.7%) and maximum in September (27.2%). In the case of equally frequent mP masses, the maximum occurred from June to August (25–27%). A decrease in their inflow occurred in April, November, and December (11–14%). Tropical air masses with the lowest frequency of occurrence over the region did not occur at all from December to March. Very large differences in frequency were also recorded for mwP with the minimum in July and August (7.7%) and maximum in September (27.2%).
3. Less than 12% of cases (approx. 210) occurred for 4–20 days. The minimum values represent periods of more than 9 days, including more than 10-day periods (1–3 cases in the specific period) and constitute less than 0.5% of results. Slightly higher values occurred in the case of 7- to 9-day periods (6–14 cases constituting 1.5%).
4. Periods of up to 2 days usually concerned maritime polar air masses, whereas the frequency of 2-day occurrences of mwP largely decreased. More than 7 days of occurrence was only recorded for cP, omP, and one case for T. The former were prevalent. The longest duration of 20 days concerned cP.

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