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INFLUENCE OF ATMOSPHERIC CIRCULATION ON AIR TEMPERATURE AND PRECIPITATION IN THE BYDGOSZCZ–TORUŃ REGION IN THE PERIOD FROM 1921 TO 2000

Abstract: The following article presents the results of research on the influence of atmospheric circulation on air temperature and atmospheric precipitation in the Bydgoszcz-Toruń region (Poland) in the period 1921–2000. In order to do this, we have constructed a daily calendar of synoptic situations using criteria proposed by Niedźwiedź (1981). Daily values of air temperature and atmospheric precipitation were collected from the meteorological station in Toruń. Research results show that weather conditions in the study area are influenced predominantly by the direction of air mass advection and, to a lesser extent, by the prevailing type of isobaric system.

Key words: circulation types, air temperature, atmospheric precipitation, abnormal weather conditions, Poland.

Introduction

Atmospheric circulation is one of the climate-forming processes which determine the character and changeability of weather in a given area to a considerable extent. It demonstrates significant variability in time as well as in space. That is why the catalogues of circulation types prepared for some major areas (e.g. Poland, Central Europe) do not always manage to describe credibly the atmospheric circulation in a smaller area (e.g. in a mesosynoptic scale). Niedźwiedź (1981) clearly demonstrated this in creating the first catalogue of circulation types for an area in this scale, namely for the basin of the upper Vistula. Recently he has prepared a similar catalogue for 9 regions in Poland (Niedźwiedź 2006 and pers. comm). Working independently in the Department of Climatology at the Nicolaus Copernicus University, researchers have decided to prepare a catalogue of circulation types for the Bydgoszcz-Toruń region (hereafter B-TR).

The following study is based on this catalogue, which was constructed using Niedźwiedź's original idea (1981). Apart from the aforementioned catalogues, there are also others for the whole area of Poland, the most popular of which was proposed by Osuchowska-Klein (1978, 1992). This was prepared in a calendar form on the basis of synoptic maps at sea level for the period 1901–1990. Aside from the scale of the area covered, it also differs from Niedźwiedź's catalogue in outlining a smaller number of circulation types (13).

On the basis of these synoptic catalogues (and on the catalogue by Lityński (1969), a new version of which is discussed by Pianko-Kluczyńska (2007)), several studies have appeared which present the frequency of particular circulation types and their influence on the climate over selected periods of time. An extensive survey of them can be found in various studies, including Niedźwiedź (1981), Kaszewski (1992) and Ustrnul (1997).

The aim of the present study is to establish the extent of the influence of atmospheric circulation on air temperature and atmospheric precipitation in B-TR and to determine to what degree it is different when compared with other areas of Poland of a similar size.

Study area, data and methods

The study analyses in detail both the frequency of the appearance of particular synoptic situation types over B-TR, as well as their influence on air temperature values and atmospheric precipitation. B-TR is situated in the central part of Northern Poland (Central Europe) – Fig. 1.

As noted above, the study is based on the classification of synoptic situations proposed by Niedźwiedź (1981), which outlined 21 types of synoptic situations (Table 1). For the sake of clarity, common alphabetic signs for the direction of advection were used, with the addition of the index “a” for anticyclonic situations (high-pressure) and index “c” for cyclonic situations (low-pressure).

Table 1. Synoptic situations (types) used in the study (after Niedźwiedź 1981)

Type of circulation	Description of synoptic situations
Na, Nc	synoptic situations with air advection from the north
NEa, NEc	synoptic situations with air advection from the north-east
Ea, Ec	synoptic situations with air advection from the east
SEa, SEc	synoptic situations with air advection from the south-east
Sa, Sc	synoptic situations with air advection from the south
SWa, SWc	synoptic situations with air advection from the south-west
Wa, Wc	synoptic situations with air advection from the west
NWa, NWc	synoptic situations with air advection from the north-west
Ca	central anticyclonic situation, no advection, anticyclonic centre over the Bydgoszcz-Toruń region
Ka	anticyclonic wedge, sometimes a few unclear centres or a blurred area of high pressure, axis of ridge of high pressure
Cc	central cyclonic situation, cyclonic centre over the Bydgoszcz-Toruń region
Bc	cyclonic trough, blur area of low pressure or axis of cyclonic trough with different direction of air advection and front systems dividing different air masses
X	synoptic situations which cannot be classified and baric col,
NaS*, NcS*	synoptic situations with air advection from the northern sector
EaS*, EcS*	synoptic situations with air advection from the eastern sector
SaS*, ScS*	synoptic situations with air advection from the southern sector
WaS*, WcS*	synoptic situations with air advection from the western sector

Explanations: * classification proposed by authors

Lower synoptic maps downloaded from the website www.wetterzentrale.de for each day for the period 1881–2005 were used to compile a calendar of circulations for B-TR. The classifications of circulation types for each day were prepared on the basis of the direction of advection and the type of baric situation (in the latter case, the shape of isobars was also taken into consideration).

Fig. 1. Study area, the Bydgoszcz-Toruń region (B-TR)

In order to analyze the influence of synoptic situations on air temperature and atmospheric precipitation, the average daily (Ti), maximum (Tmax) and minimum (Tmin) values of air temperature and daily precipitation totals (P) from the meteorological station of the Institute of Meteorology and Water Management in Toruń, available for the period from 1921 onwards, were used in the present study.

With the aim of providing a more detailed analysis, anomalies of air temperature and atmospheric precipitation have been analyzed separately for four sectors (N, E, S, W), as well as for the situations Cc, Bc and Ca, Ka. Each sector comprises three directions of air advection; for example, sector N comprises the directions N, NW and NE and sector E comprises E, NE and SE. A weighted mean accounting for the number of advection cases from a given direction has been used to obtain correct values of temperature and precipitation anomalies. As a result of this division into sectors, the number of cases with intermediate directions (NE, SE, NW, SW) have been divided into two and added to the neighbouring sectors.

Results

The relative frequency of occurrence of selected types of synoptic situations in the period 1921–2000

The geographical location of Poland (including the B-TR) facilitates the occurrence of a great diversity of weather and climatic conditions. This results from the influence of large land masses in the east and the Atlantic Ocean in the west. The climatic relations in the area discussed, as well as those of the whole of Europe, are to a considerable extent conditioned by the presence of low pressure and high pressure centres in the vicinity. The major atmospheric systems shaping the weather conditions in Europe are the year-long Icelandic Low and Azorian High and, to a lesser extent, the seasonal winter Asian High and summer South-Asian Low (Woś 1999). The occurrence of the circulation types which have been distinguished is dependent on the mutual location and the degree of expansion of the aforementioned systems. Frequency of occurrence of synoptic situation types is quite variable from season-to-season (Osuchowska-Klein 1973; Niedźwiedź 1981; Kaszewski 1992).

In B-TR, similar to the whole of Poland, the zonal atmospheric circulation is strengthened in winter (DJF), which is proved by the fact that the Wc situation constitutes the majority (15.6%) while the frequency of the situation SWc increases (7.6%) in relation to other seasons, and situation Ka occurs less frequently (10.3%) (Table 2).

The role of Bc type (15.9%) and Ka type situations (15.3%) increases significantly in spring (MAM), whereas the western zonal circulation represented by situations Wc (8.6%), SWc (3.4%) and SWa (1.7%) is weakened (Table 2). This results from a significant decrease in the thermal contrast between the Atlantic Ocean and the Eurasian continent at this time. During summer, the Ka and Bc situations reach the highest frequencies in the whole year: 24.2% and 16.9% respectively. At the same time, when compared with spring, the western zonal circulation is slightly strengthened: Wc (10.0%) and Wa (7.1%) (Table 2). This significant role exerted by the Ka situation may be explained by, among others, the Azorian High extending greatly towards the North, the ridge of which often moves over Central Europe. In autumn (SON) the greatest change in atmospheric circulation is the considerable decrease in the frequency of the Ka situation (14.8%), and the slightly lower decrease in the Bc situation (8.9%). The western zonal cir-

Table 2. Seasonal and annual relative frequencies (%) of occurrence of synoptic situations in B-TR, 1921–2000

Type of circulation	DJF	MAM	JJA	SON	Year
Na	2.3	4.3	5.3	2.9	3.7
NEa	1.9	4.2	4.0	2.0	3.0
Ea	5.6	6.4	2.6	4.5	4.8
SEa	3.5	2.7	0.4	3.5	2.5
Sa	5.6	3.2	0.8	6.3	3.9
SWa	4.8	1.7	1.1	4.3	2.9
Wa	5.8	3.8	7.1	6.3	5.8
NWa	3.0	2.4	3.1	3.3	3.0
Ca	2.0	2.2	3.2	3.0	2.6
Ka	10.3	15.3	24.2	14.8	16.2
Cc	2.1	2.6	1.9	1.5	2.0
Bc	8.0	15.9	16.9	8.9	12.4
X	1.6	2.9	3.0	2.1	2.4
Nc	3.8	4.4	5.1	4.2	4.4
NEc	1.0	2.3	2.2	0.9	1.6
Ec	1.8	2.6	1.1	1.0	1.6
SEc	2.4	2.2	0.4	1.2	1.5
Sc	5.8	4.0	0.7	4.9	3.9
SWc	7.6	3.4	1.0	5.7	4.4
Wc	15.6	8.6	10.0	13.2	11.9
NWc	5.4	5.0	6.0	5.6	5.5

Explanations: see Table 1; DJF – winter; MAM – spring; JJA – summer; SON – autumn

culation is again strengthened, and occurs more frequently both in cyclonic – Wc (13.2%) and SWc (5.7%) – as well as in anticyclonic – SWa (4.3%) and NWa (3.3%) – patterns of circulation (Table 2). This is caused by more frequent movements of low pressure systems over the north of Europe.

Throughout the year the most frequent situations in B-TR were Ka (16.2%), Bc (12.4%) and Wc (11.9%). The least frequent were the cyclonic situations connected with the eastern zonal circulation: NEc (1.6%), Ec (1.6%) and SEc (1.5%) (Table 2). The average values from several years presented above may have undergone significant changes in particular years. This applies mainly to synoptic situations connected with zonal circulation.

The influence of atmospheric circulation on air temperature

Atmospheric circulation exerts the largest influence on air temperature in the cold half of the year, when the solar factor is significantly weakened. In this period air temperature changes are caused mainly by the advection of air masses of different physical properties.

In winter the greatest positive anomalies of air temperature (Ti, Tmax and Tmin) occur during the western zonal circulation (Fig. 2). They are slightly greater during cyclonic situations (e.g. Wc – Ti (4.5°C), Tmax (4.1°C) and Tmin (4.6°C)) than during anticyclonic ones (e.g. Wa – Ti (2.7°C), Tmax (2.4°C) and Tmin (2.6°C)) (Table 3, Fig. 2). This results from the cooling influence of the radiation factor during anticyclonic situations. Positive anomalies of Ti in winter during the western zonal circulation are greatest in comparison with other seasons (Fig. 3d). According to Niedźwiedź (1981), in the basin of the upper Vistula from 1966 to 1975, the highest Ti in winter occurred with Sc and SWc situations. This is caused by the frequent co-occurrence of foehn phenomena, which significantly increase temperature.

The greatest negative anomalies of air temperature are observable during the eastern zonal circulation represented by various situations, including Ea – Ti (-4.2°C), Tmax (-4.1°C) and Tmin (-4.2°C) as well as Ec – Ti (-1.7°C), Tmax (-1.8°C) and Tmin (-1.2°C) (Table 3, Fig. 2). Of particular note here is the cooling influence of the radiation factor during anticyclonic situations. During the eastern zonal circulation negative Ti anomalies in this season are the greatest of the whole year (Fig. 3b). This corresponds with the results obtained by Niedźwiedź (1981), which confirm a significant lowering influence of about 5.5°C exerted by these situations on Ti. Moreover, quite large negative anomalies of air temperature occur during the high pressure systems situated over B-TR: Ca – Ti (-2.5°C), Tmax (-1.3°C) and Tmin (-3.5°C) (Table 3, Fig. 2). These anomalies result mainly from the large loss of heat radiation during the night-time when slight cloudiness occurs, a phenomenon typical of anticyclones.

In spring, air temperature anomalies for most types are lower. Air advection from the northern sector (NW, N and NE) is characterized by considerable negative air temperature anomalies (the greatest of the whole year) (Fig. 3a), particularly noticeable during cyclonic systems, e.g. NEc – Ti (-3.2°C), Tmax (-4.3°C) and Tmin (-1.3°C) (Table 3, Fig. 2). According to Niedźwiedź (1981), the average cooling (-2.5°C) in the basin of the upper Vistula occurred during the Wa and NWa situations; however, in the western part of this region and in the Sandomierz Basin it co-occurred with the same situations as in B-TR, that is Nc and NEc.

The reason for the significant negative anomalies during this season is the cold Arctic maritime air masses occurring over the north of Europe. Because of low water temperature in the Norwegian and Baltic Seas the masses cannot be heated during their advection to Poland. The greatest negative anomalies of Tmin, however, do not occur during air advection from the North, but during the Ca situation – Tmin (-2.8°C) (Table 3) when, during rather long nights with very limited cloudiness, there is a high level of heat loss from the earth's surface owing to long-term upward radiation.

Positive air temperature anomalies are slightly lower than negative ones (Fig. 2). The highest values occur during the situations SWc – Ti (1.4°C), Tmax (1.2°C), Tmin (1.4°C) and Ea and Bc (Table 3, Fig. 2). During the Sa situation there is the greatest positive anomaly of Tmax (2.5°C). This is related to the combination of the influence of warm air advection and good solar conditions. Eastern zonal anticyclonic circulation leads to minor positive anomalies in Ti (0.7°C) (Fig. 3b), connected with the rapid warming of the land in the East.

In summer the degree of air temperature anomalies is influenced mainly by insolation conditions. The influence of circulation is not as significant as it is in winter, though it is noticeable. Positive anomalies of air temperature occur mainly during anticyclonic situations, when the influence of favourable insolation conditions accompanies the warm air advection, particularly during the situations SEa –Ti (2.0°C), Tmax (2.9°C), Tmin (2.6°C) and Sa – Ti (2.0°C), Tmax (2.6°C), Tmin (0.6°C) (Table 3, Fig. 2). Similarly, in the basin of the upper Vistula, the situations Sa and SWa bring about an increase in Ti of about 2.6°C (Niedźwiedź 1981). In summer the cyclonic circulation from the southern sector is characterized by the greatest positive anomalies of Ti (1.2°C) of the whole year (Fig. 3c).

Situations NEa, Ea and SEa, which in winter were characterized by very large negative anomalies of air temperature, in summer lead to rather high positive anomalies (in anticyclonic systems): SEa – Ti (2.0°C), Tmax (2.9°C) and Tmin (2.6°C) (Table 3). Air advection from the north, similar to the situation in spring, causes negative anomalies of air temperature in the following situations, amounting to Nc – Ti (-2.7°C), Tmax (-3.8°C), Tmin (-0.9°C) (Table 3, Fig. 2).

Table 3. Seasonal anomalies of air temperature (°C) and precipitation (mm) in B-TR occurring during particular synoptic situations, 1921–2000

Circulation type	DJF				MAM				JJA				SON			
	Ti	Tmax	Tmin	P	Ti	Tmax	Tmin	P	Ti	Tmax	Tmin	P	Ti	Tmax	Tmin	P
Na	-2.1	-1.3	-3.2	-0.5	-0.4	-0.3	-1.1	-0.5	-0.9	-1.2	-1.4	-2.6	-1.0	-0.5	-1.4	-1.1
NEa	-3.4	-2.8	-4.0	-0.7	0.8	0.6	-0.0	-0.6	1.1	1.0	0.7	-2.4	-0.4	0.6	-0.2	-0.9
Ea	-4.2	-4.1	-4.2	-0.5	1.2	1.0	0.3	-0.6	1.9	2.2	1.9	-1.8	-2.2	-2.5	-1.8	-0.9
SEa	-3.3	-3.3	-3.6	-0.6	0.1	-0.1	-0.1	-0.6	2.0	2.9	2.6	0.2	-2.1	-2.0	-2.1	-0.7
Sa	-0.5	-0.1	-1.0	-0.5	1.1	2.5	-0.2	-0.4	2.0	2.6	0.6	-1.4	0.5	1.3	-0.4	-0.9
SWa	3.0	2.9	2.8	-0.2	0.5	1.7	-0.6	-0.5	1.4	1.4	-0.2	-2.6	1.6	1.8	0.7	-0.7
Wa	2.7	2.4	2.6	-0.2	-0.9	-1.1	-1.2	-0.2	-1.0	-1.9	-0.5	-2.1	0.5	0.4	0.3	-0.5
NWa	0.8	0.9	0.3	-0.6	-1.8	-1.3	-1.7	-0.7	-1.2	-1.2	-0.9	-2.5	-1.2	-1.0	-1.3	-0.6
Ca	-2.5	-1.3	-3.5	-0.7	-0.2	0.9	-2.8	-0.9	1.0	0.9	-1.8	-3.3	-0.6	1.3	-2.4	-1.3
Ka	-1.0	-0.5	-1.6	-0.4	1.0	1.8	-0.7	-0.3	1.3	1.2	-0.3	-2.0	0.7	1.6	-0.1	-0.6
Cc	0.6	0.6	0.9	1.1	-0.9	-2.0	1.3	1.3	-1.7	-2.7	0.9	3.8	-1.1	-2.8	-0.3	1.7
Bc	0.4	0.6	0.6	-0.1	1.2	0.7	1.7	0.5	-0.2	-0.7	0.3	0.9	-0.3	-0.9	0.0	0.6
X	-0.6	-0.7	-1.3	0.2	1.0	1.5	0.4	0.5	0.7	0.1	-0.2	-0.1	1.0	1.3	0.7	0.0
Nc	0.3	0.7	0.7	-0.1	-3.1	-3.4	-1.7	-0.5	-2.7	-3.8	-0.9	-1.0	-2.0	-2.0	-1.0	-0.3
NEc	-2.2	-1.9	-2.2	-0.1	-3.2	-4.3	-1.3	0.2	-2.3	-3.6	0.0	0.7	-1.0	-1.3	-0.4	0.6
Ec	-1.7	-1.8	-1.2	0.2	-1.5	-3.1	-0.2	0.2	-0.7	-3.1	0.5	16.8	-2.8	-4.2	-1.7	-0.4
SEc	-2.7	-3.4	-2.5	0.2	0.5	-0.7	1.4	1.1	-0.9	-2.0	1.0	3.1	-3.6	-5.8	-1.9	3.0
Sc	1.3	0.8	1.3	0.7	0.5	0.4	0.1	0.6	2.0	1.4	2.5	-0.4	0.3	-0.4	0.4	1.0
SWc	3.5	3.0	3.3	1.0	1.4	1.2	1.4	0.8	1.6	1.4	0.8	-0.7	1.4	1.0	1.4	0.8
Wc	4.5	4.1	4.6	1.2	-0.2	-0.6	1.0	0.4	-0.5	-1.3	0.9	-1.0	1.3	0.6	1.9	0.7
NWc	2.5	2.4	2.8	0.6	-3.1	-4.0	-1.3	0.1	-2.5	-3.6	-0.5	-1.5	-0.3	-1.0	0.7	0.4

Explanations: see Table 1; Ti – average daily temperature; Tmax – average maximum temperature; Tmin – average minimum temperature; P – precipitation

Temperature anomalies have been calculated for the period 1921–2000, while anomalies for precipitation are for the period 1951–2000.

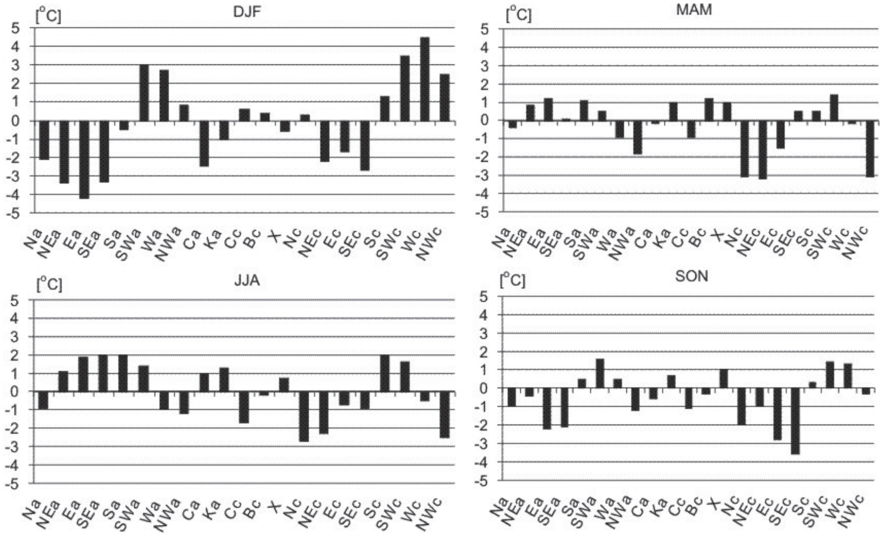

Fig. 2. Seasonal anomalies of mean daily temperature (°C) in B-TR occurring in particular synoptic situations, 1921–2000

Niedźwiedź (1981) found the same value of anomalies of Ti (-2.7°C) for the situations Nc and NEc. Large negative anomalies of air temperature result from several factors: a limited inflow of solar energy, cold air advection and frequent precipitation. To sum up, in summer during both cyclonic and anticyclonic western zonal circulation, one can notice minor anomalies of Ti (-0.7°C) (Fig. 3d), whereas the eastern zonal anticyclonic circulation leads to positive anomalies of Ti (1.1°C) (Fig. 3b).

In autumn negative anomalies of air temperature prevail, which begin to correspond with the pattern occurring in winter (Fig. 2). This means that eastern zonal circulation begins to cause negative anomalies of air temperature, particularly during cyclonic situations, e.g. SEc – Ti (-3.6°C), Tmax (-5.8°C), Tmin (-1.9°C) and Ec – Ti (-2.8°C), Tmax (-4.2°C), Tmin (-1.7°C) (Table 3, Fig. 2). This is related to a rapid cooling of extensive European and Asian land masses. However, the greatest negative anomalies of Ti in the upper Vistula basin were observed in the situations Na, NEa (-3.5°C), whereas the situations which were the coolest in B-TR, here caused only minor negative anomalies (Niedźwiedź 1981).

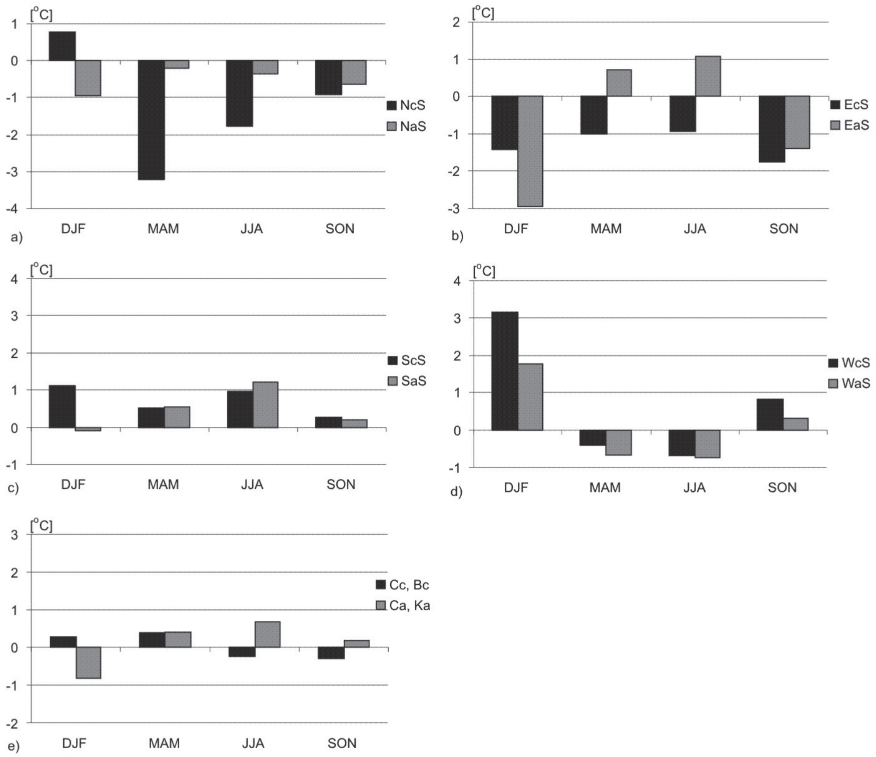

Fig. 3. Seasonal anomalies of mean daily temperature (°C) in B-TR occurring during advection of air masses from northern (a), eastern (b), southern (c), and western (d) sectors, as well as during synoptic situations Cc, Bc, Ca, and Ka (e), 1921–2000

Far fewer significant negative anomalies in B-TR during Na and NEa situations may be related to the warming influence of the Baltic Sea, over which the air masses move during these situations. Such an influence does not occur in the basin of the upper Vistula because of its location in southern Poland. Western zonal circulation in autumn brings about minor positive anomalies in B-TR: Wc – Ti (1.3°C), Tmax (0.6°C), Tmin (1.9°C) (Table 3, Fig. 2).

The situations Ca, Ka and Cc, Bc cause minor Ti anomalies throughout the year. Ca and Ka cause cooling (at 0.8°C) in B-TR during winter (Fig. 3e). In other seasons they bring about minor positive Ti anomalies (greatest in summer 0.7°C) (Fig. 3e). Situations Cc and Bc lead to positive Ti anomalies in winter (0.3°C) and spring (0.4°C) and negative ones in summer and autumn (-0.3°C) (Fig. 3e).

The influence of atmospheric circulation on the thermal character of winter

The location of the research area in a zone affected interchangeably by continental and oceanic climate regimes results in the significant variability of winter thermal conditions from year to year. In B-TR there occur both so-called 'continental winters' (characterized by low temperatures) and 'oceanic winters' (warm and humid) one after the other. Changes in frequencies of atmospheric circulation types were analysed by comparing and contrasting two selected oceanic winters – 1988/1989 (2.5°C) and 1989/1990 (2.9°C) – and two continental ones – 1928/1929 (-7.3°C) and 1946/1947 (-7.9°C).

The thermal character of winter is strictly connected with the location and activity of barometric systems over Europe and the areas immediately around it. Warm (oceanic) winters are characterized by a high degree of activity of western zonal circulation. During such winters we notice the following situations prevailing: SWa (16.9%), Wa (25.8%) and Wc (21.3%) (winter 1988/1989) or SWc (20.7%) and Wc (23.2%) (winter 1989–90) (Fig. 4).

At the same time eastern zonal circulation disappeared in winter 1988/89, and in winter 1989/90 only the situation Ea (1.2%) occurred (Fig. 4). The reason for such circulation is the mutual influence of two systems situated over the North Atlantic: the deep Icelandic Low and the extensive Azorian High, without the influence of any strong Asian High.

A reverse barometric pattern occurs during continental winters, when the western zonal circulation is weakened. The frequency of the occurrence of its characteristic circulation types fluctuates by around 5.0% (Fig. 4). Much more frequent are the situations Ea (24.7%) and Ka (15.7%) in winter 1928/29 and predominantly Ea (28.9%) in winter 1946/1947. This is due to the weakening of the Azorian High and Icelandic Low, accompanied by the extension of Asian High.

The influence of atmospheric circulation on atmospheric precipitation

The amount of atmospheric precipitation is influenced by several factors. One of them is the moisture content of the air. In order to be saturated with

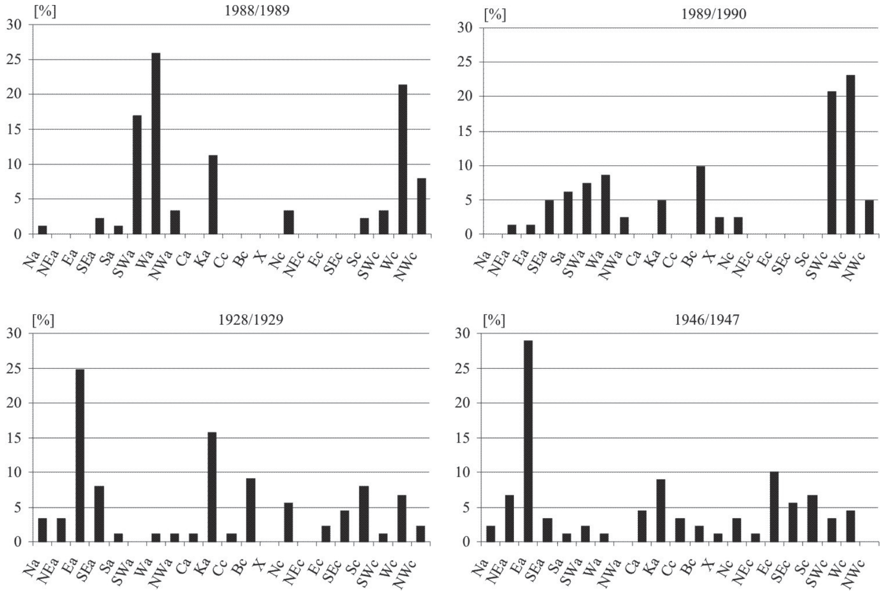

Fig. 4. Relative frequency of occurrence (%) of synoptic situations during very warm (1988/89 and 1989/90) and very cold (1928/1929 and 1946/1947) winters

vapour, air must move over areas rich in water for an extended period of time. For Europe, this area is generally the Atlantic Ocean. Orographic relations – that is, altitude and the exposure of slopes to humid air masses – do not exert a significant influence on atmospheric precipitation because of the typically lowland character of B-TR.

Table 3 and Figure 5 present anomalies of daily sums of atmospheric precipitation depending on the type of synoptic situation in particular seasons. In all seasons negative anomalies occur in anticyclonic situations, the biggest ones during Ca. In winter the sums of atmospheric precipitation are the lowest of the whole year. Also the anomalies of daily sums are in most cases the lowest during this season and only in three cases are they above 1.0 mm. The greatest positive anomalies are observed during western zonal circulation with the cyclonic situations Wc (1.2 mm), SWc (1.0 mm), and during the situation Cc (1.1 mm) (Table 3, Fig. 5). In general, positive anomalies occur with the same synoptic situations as the highest daily sums of atmospheric precipitation in south-eastern Poland (Niedźwiedź 1981).

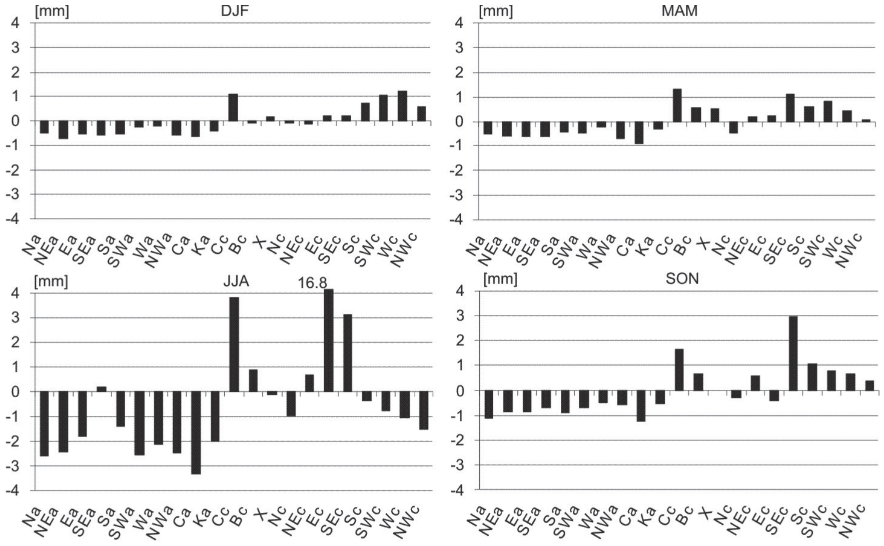

Fig. 5. Seasonal anomalies of daily precipitation totals (mm) in B-TR occurring in particular synoptic situations, 1951–2000

During western zonal circulation, humid polar maritime air moves over the research area, which brings a lot of vapour and leads to higher total atmospheric precipitation (0.9 mm) (Fig. 6d).

In spring, sums of atmospheric precipitation increase, related mostly to the increase in air temperature and the unsteadiness of the atmosphere. There are still low values for daily anomalies of precipitation sums. The greatest positive anomalies are observed during situations Cc (1.3 mm), SEc (1.1 mm) and SWc (0.8 mm) (Table 3, Fig. 5). Similar to the research area, the situations Cc and Bc were also characterized by the highest daily average values of precipitation in the basin of the upper Vistula (Niedźwiedź 1981).

In summer sums of atmospheric precipitation are greatest, owing to the high air temperature and good conditions for the formation of convective clouds. The greatest positive anomalies occur during situations Ec (16.8 mm), SEc (3.1 mm) and Cc (3.8 mm) (Table 3, Fig. 5). The first two situations occurred during the presence of active, so-called Genoa lows, which move from over Italy towards the north or north-east. They bring increased amounts of precipitation particularly in southern Poland. The highest precipitation in southern-eastern Poland (mainly in the mountains) oc-

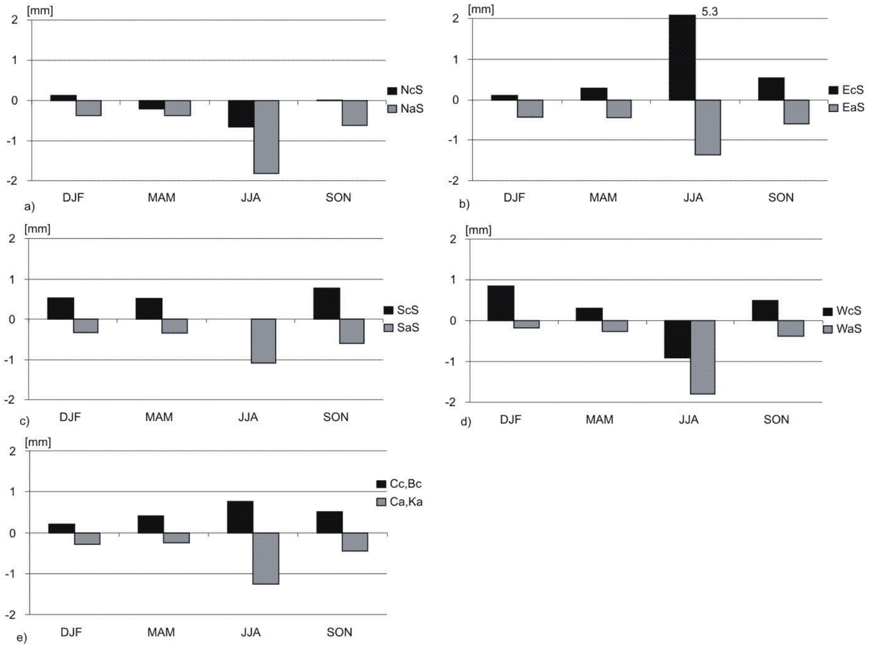

Fig. 6. Seasonal anomalies of daily precipitation totals (mm) in B-TR occurring during the advection of air masses from northern (a), eastern (b), southern (c) and western (d) sectors, as well as during the synoptic situations Cc, Bc, Ca and Ka (e), 1921–2000

curs during the situations Nc and NEc (Niedźwiedź 1981). During these situations air masses additionally move along the slopes and increase precipitation. In summer, cyclonic circulation from the eastern sector causes the greatest positive anomalies of precipitation (5.3 mm) in the whole year (Fig. 6b). The greatest negative anomalies obviously occurred during anticyclonic situations: Ca (-3.3 mm), SWa (-2.6 mm). Minor negative anomalies were also observed during western zonal circulation with the cyclonic situations NWc (-1.5 mm), Wc (-1.0 mm) and SWc (-0.7 mm) (Table 3, Fig. 5). The inflow of air from the western sector leads to negative anomalies of daily precipitation both in anticyclonic situations (-1.8 mm) and in cyclonic ones (-0.9 mm) (Fig. 6d). This may be connected with the lower amount of vapour in cooler polar maritime air.

In autumn the values of anomalies decrease in most synoptic situations. The highest positive values remain in situations SEc (3.0 mm) and Cc (1.7 mm) (Table 3, Fig. 5). In the upper Vistula basin the relation between precipitation and synoptic situations is the same as in summer (Niedźwiedź 1981).

The situations Ca and Ka, as well as Cc and Bc, cause significant anomalies of precipitation during the summer (Fig. 6e). The situations Ca and Ka bring about negative anomalies (-1.3 mm) in this season, whereas the situations Cc and Bc lead to positive precipitation anomalies (0.8 mm) (Fig. 6e).

The influence of atmospheric circulation on summer thermal and moisture conditions

As with winters, some summers in B-TR can be characterised as oceanic (cool and humid) while others are more continental (hot and dry). This variability is due to differences in frequencies of occurrence of particular synoptic situations. In order to demonstrate this influence, the years which are extreme in terms of temperature and precipitation are analysed here.

Hot summers (e.g. 1992: 19.7°C) are characterized by a marked dominance of the Ka situation (37.0%), whereas during cool summers (e.g. 1923: 15.2°C) the frequency of the Ka situation decreases to 22.8%, with a simultaneous strengthening of western zonal circulation Wc (18.5%), NWc (16.3%) and Wa (12.0%) (Fig. 7). The air coming over in summer from the west, in contrast to the winter, results in cooling.

Dry summers (e.g. 1989: 87.1 mm), similar to hot ones, are characterized by the dominance of the Ka situation (25%) (Fig. 8). The situations Bc and Na are also very common (18.5% and 10.9%, respectively). Humid summers (e.g. 1980: 557.1 mm) are characterized by a low frequency of the Ka situ-

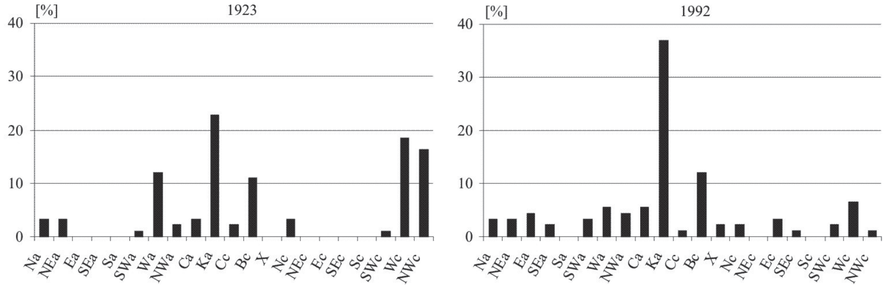

Fig. 7. Relative frequency of occurrence (%) of synoptic situations during very cold (1923) and very hot (1992) summers

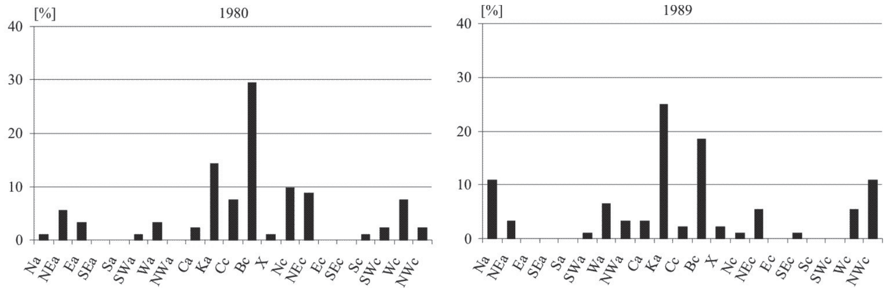

Fig.8. Relative frequency of occurrence (%) of synoptic situations during very wet (1980) and very dry (1989) summers

ation (14.1%) and an increase in the frequency of the Bc situation (29.3%) (Fig. 8). During years like these, cyclonic situations prevail significantly.

Summary and conclusions

1. In winter (DJF), the most frequent circulation types in B-TR from 1921 to 2000 were Wc (15.6%) and Ka (10.3%) (Table 2). In summer (JJA), two types were clearly dominant: Ka (24.2%) and Bc (16.9%). During the whole year, the most frequent circulation types were Ka (16.2%), Bc (12.4%) and Wc (11.9%) (Table 2).

2. The coldest circulation types in winter were Ea, NEa and SEa, for which temperature anomalies (differences from long-term average) varied between -3°C and -4°C (Table 3, Fig. 2). On the other hand, clearly the highest temperatures were associated with air masses coming from the western sector (positive anomalies exceeding 3°C have been noted for the types Wc, SWc, and Wa). In spring (MAM) and summer, clearly the coldest (with temperature anomalies of around -2–3°C) were those types bringing air masses from the northern sector (NEc, Nc and NWc), while the warmest temperatures (2–3°C above the norm) were connected with types SEa, Sa, and Sc (Table 3). In autumn (SON), similar to winter, the coldest were the types bringing air masses from the eastern sector, i.e. SEc (-3.6°C), Ec (-2.8°C), and Ea (-2.2°C) (Table 3, Fig. 2).

3. The greatest anomalies of precipitation were observed in particular synoptic types during the summer, while the lowest occurred during winter. In all the analysed seasons negative anomalies were noted during anticyclonic types, with a maximum in summer during the occurrence of circula-

tion type Ca (-3.3 mm) (Table 3, Fig. 5). Positive precipitation anomalies were characteristic of the majority of cyclonic situations, with maximums in summer during circulation type Ec (16.8 mm) (Table 3, Fig. 5).

4. Exceptionally warm winters in Poland are observed when the frequency of air masses coming from the west and south-west dominates (almost 50%, e.g., in winters 1988/1989 (2.5°C, mean temperature) and 1989/1990 (2.9°C)) (Fig. 4). On the other hand, exceptionally cold winters (1928/1929 and 1946/1947 with mean temperatures of -7.3°C and -7.9°C, respectively) were noted during the anticyclonic situation bringing cold air masses from the East (Ea type) (Fig. 4).

5. Exceptionally hot summers (e.g. in 1992 with an average value of 19.7°C) were noted when the frequency of circulation type Ka was very high (37% in 1992) (Fig. 7). Very cold summers (e.g. 1923) were noted when the frequency of type Ka was lower than average, while the frequencies of western types were significantly above normal (Wc – 18.5% and NWc – 16.3%).

6. Analysis of synoptic situations in very dry and very moist years shows that they differ mainly in terms of the frequency of occurrence of circulation types Ka and Bc. During very moist summers (e.g. in 1980) circulation type Bc dominated (29.3%), while in very dry summers (1989) circulation type Ka was the most frequent (Fig. 8).

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