CIRCULATION INFLUENCE ON CLOUDINESS IN POZNAŃ

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Manuscript received: October 24, 2014
Revised version: July 22, 2015

Szyga-Pluta K., 2015. Circulation influence on cloudiness in Poznań. *Quaestiones Geographicae* 34(3), Bogucki Wydawnictwo Naukowe, Poznań, pp. 141–149, 4 figs, 5 tables. DOI 10.1515/quageo-2015-0021, ISSN 0137-477X

Abstract: The frequency of occurrence of cloud cover was analysed taking into consideration its circulation-related conditioning. The atmospheric circulation types according to Osuchowska-Klein (1978) classification were used. The study was made based on diurnal climatological observations carried out in Poznań-Ławica in years 1966–1998. It was found that the cloudless skies and small cloudiness were associated with anticyclonic types of atmospheric circulation and the east macrotype. Moderate cloudiness occurred equally at cyclonic and anticyclonic circulation types. Larger cloud coverage of the sky was associated with cyclonic circulation, especially with the west macrotype.

Keywords: cloudiness, Osuchowska-Klein classification, atmospheric circulation types, Poznań

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Introduction

Apart from radiation factors, the circulation of the atmosphere plays a decisive role in shaping individual elements of the climate, including the cloud cover. The size and type of cloud cover depends on specific synoptic situations. The structure of pressure systems in the pressure field and the directions of air inflow determine the nature of circulation and allow us to single out so-called circulation types. The objective of the study consists in establishing the size of general sky cloud cover and the cloud types with reference to the circulation of the atmosphere in Poznań according to the classification authored by Osuchowska-Klein (1978). The issue of the frequency of occurrence of days with varying cloud cover sizes during the year in Poznań has been previously discussed in connection with types of atmospheric circulation, however in accordance with the classification of Lityński (1969, Tamulewicz 2000, Szyga-Pluta 2009). This classification was also used to analyse the dependences of cloud cover sizes over Warsaw (Baranowski 1996). The structure of cloud cover over Poland according to circulation types as per Lityński's (1969) classification was the subject of research conducted by Żmudzka (2007). The impact of atmospheric circulation on the cloud cover over Kraków was analysed by Matuszko (1998, 2002), who relied on a calendar of synoptic situations for the upper River Vistula basin, elaborated by Niedźwiedź (1992). In turn, the classification authored by Osuchowska-Klein (1978) was used among others by Kossowska-Cezak (1997) and Mrugała (2000/2001), who researched the impact of atmospheric circulation on rainfall. Kirschenstein (2003) analysed factors determining the circulation of rainfall in north-western Poland and cloud cover in Koszalin (Kirschenstein 2004), while Kolendowicz (1991) used the said classification to establish the dependence between storms and elements of circulation. Baranowski (2008), who attempted to determine the impact of atmospheric circulation on the temperature field, also availed himself of the classification elaborated by Osuchowska-Klein (1978). This classification was also taken upon consideration in connection to the thermic weather types by Baranowski and Kirschenstein (2009).

Materials and methods

The present study is based on daily observations of cloud cover size performed at the Poznań-Ławica weather station of the Polish Institute of Meteorology and Water Management (IMGW) at 06.00, 12.00 and 18.00 UTC in the years 1966–1998. Cloud cover was analysed in octas, i.e. with the sky divided into eight sections, where 0 refers to a cloudless sky, 1–3 to slight cloud cover, 4–5 to moderate cloud cover, 6–7 to significant cloud cover, and 8 to total cloud cover. Furthermore, use was made of atmospheric circulation types according to the classification of Osuchowska-Klein (1978, 1991, 1998). This classification is characterised by considerable subjectivity, taking into consideration the two main elements of circulation that directly determine the conditions under which the weather develops in a given area: the direction of advection of air masses and the type of pressure system. Individual types of circulation correspond to specific atmospheric pressure systems at sea level and the standard of location of pressure systems over the North Atlantic and Europe, being the result of the appropriate inflow direction of air masses over Poland in the cyclonal and anticyclonal circulation. Osuchowska-Klein (1973) distinguished 13 types of circulation divided into 4 macrotypes: cyclonal and anticyclonal, and western and eastern (Table 1). The inflow direction of air masses was adopted as the principle for including circulation types in the second group. The western circulation macrotype includes all circulation types that are characterised by the inflow of air masses from the western – 'maritime' – sector, located west of the north-south direction. The eastern circulation macrotype covers types distinguished by the inflow of masses from the eastern – 'continental' – sector, situated east of the north-south direction.

Table 1. Macrotypes of the atmospheric circulation according to B. Osuchowska –Klein (1973).

Circulation Macrotypes	Circulation Types
Cyclonic	A, CB, E_0, F, B, D, BE
Anticyclonic	C_2D, E_2C, E, E_1, D_2C, G
West	A, CB, D, B, F, G, C_2D, D_2C
East	E_0, E, E_1, E_2C, BE

Explanation: A – west, CB – north-west, D – south-west, B – south, F – south-east, C_2D – west, D_2C – south-west and south, G – central, E_2C – north-west, E_0 – north-east and east, E – north-east, E_1 – south-east and east, BE – south transitional between cyclonic and anticyclonic, X – unclassified

An analysis was conducted of the monthly and annual distribution of general cloud cover in the years 1966–1998. Circulation conditions for the researched period are characterised by a calculated frequency of occurrence of individual atmospheric circulation types during the year according to the classification elaborated by Osuchowska-Klein (1978, 1991, 1998).

A verification of the significance of the relation between the size of cloud cover and types of atmospheric circulation was conducted by means of a χ^2 test. The conditional probability of occurrence of specific sky cloud cover under successive types of atmospheric circulation was calculated. Moreover the frequency of occurrence of cloud types depending on the atmosphere circulation types was considered.

The annual course of cloud amount

Over the year, the vicinity of Poznań most frequently experienced total cloud cover (30.1%), significant cloud cover (19.3%) and cloudless skies (10.0%) (Table 2). Cloudless skies were usually observed in the colder half of the year. The maximum frequency occurred in October (14.6%), and subsequently in January and February. Total cloud cover was also experienced in a similar period, i.e. from November to February, with a frequency of 44–52% (the maximum in December). Low and moderate cloud cover were most frequent in the warmer part of the year. The annual course of occurrence of significant cloud cover (7/8) was only slightly diversified.

The mean total cloud cover in Poznań in the research period is 66% (Fig. 1), which is a little higher comparing to the average in the second

Table 2. Frequency of occurrence (%) of cloud cover in Poznań (1966–1998).

Months	Cloudiness (octas)								
	0	1	2	3	4	5	6	7	8
I	13.7	2.7	3.1	3.0	2.5	4.4	6.0	18.7	45.9
II	13.4	3.6	4.6	4.0	2.7	4.4	7.1	16.4	43.7
III	10.0	5.8	5.9	6.7	4.2	6.5	10.4	20.2	30.4
IV	8.2	5.5	7.9	8.3	5.3	8.4	12.9	20.0	23.4
V	8.8	7.5	8.7	9.0	6.4	10.4	13.0	17.9	18.2
VI	7.6	6.6	7.4	8.8	5.6	10.7	13.9	21.4	17.9
VII	7.8	7.7	8.4	8.0	6.5	11.5	13.6	21.3	15.2
VIII	7.9	8.8	9.7	9.5	6.3	11.2	12.8	18.7	15.1
IX	7.9	6.4	8.1	6.6	5.7	10.6	12.3	21.4	21.1
X	14.8	5.3	5.6	6.5	4.6	6.1	9.1	19.1	28.7
XI	9.4	3.5	4.2	5.0	2.7	3.8	5.9	19.9	45.6
XII	10.8	2.1	3.5	3.5	1.9	3.5	5.4	17.5	51.8
Year	10.0	5.5	6.4	6.6	4.5	7.6	10.2	19.4	29.7

half of the 20th century – 64% (Woś 2010). The lowest cloudiness occurred in summer (58%) and in spring (63%). The higher cloudiness characterised the cold period of the year (70–71%). The minimum cloud cover was in July (56%), while the highest in November (77%). The results for the longer period presented by Woś (2010) differ slightly, the lowest cloudiness was in August (54%) and the highest in December (77%). During the year the period of lower cloudiness, between April and August can be distinguished and of higher cloudiness in the rest of the year. The distribution of the annual averages was already documented in studies of e.g. Merecki (1914), Warakomski (1963). According to Żmudzka (2007) in the period 1951–2000 the highest cloud cover in Poland occurred the most frequently from November to January and fluctuated from 79–84%. The lowest one appearred the most often in September, May and August with the average between 46 and 52%.

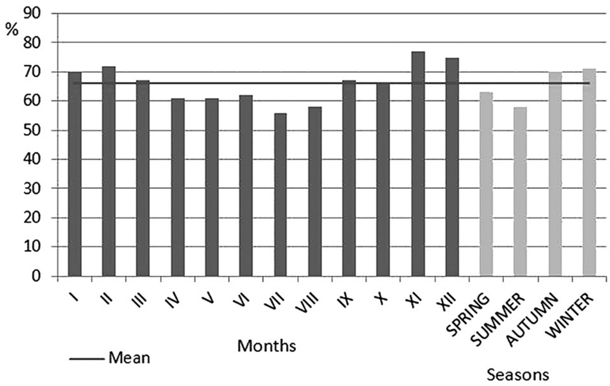

Fig. 1. Mean annual course of cloudiness in Poznań (1966–1998).

The annual course of cloud types frequency

The research results prove that *Stratocumulus* clouds have the greatest share in the cloud cover occurring in Poznań across a year (Table 3). *Altocumulus* and *Cirrus* clouds come next. *Cirrocumulus* clouds are the least frequent.

The frequency of appearance of particular cloud types during the seasons also changes. In spring and in autumn *Stratocumulus* and *Altocumulus* clouds are observed the most often, in summer – *Cumulus* and *Altocumulus* clouds and in winter – *Stratocumulus* and *Stratus* clouds are the most frequent formation. The analysis of the annual course of the frequency of occurrence of cloud types in Poznań proves that the clouds with distinct seasonal changes are:

– *Cirrus* – with summer maximum and winter minimum. The frequency clearly decreases in June and July after the maximum in May and the second increase in August.
– *Cumulus, Cumulonimbus* and *Altocumulus* – the annual course is symmetrical with maximum in summer and minimum in winter.
– *Stratocumulus* and *Stratus* – the annual course is reversed comparing to *Cumulus* and *Altocumulus* clouds. *Stratocumulus* and *Stratus* appear most often in the cold part of the year and least frequently in the warm part of the year.

The annual course of frequency of *Altostratus* and *Nimbostratus* is not very differentiated. Weakly marked maximum occurs in the cold part of the year and minimum in the warm part of the year.

Table 3. Frequency of occurrence (%) of cloud types in Poznań (1966–1998).

Months	Cloud types									
	Ci	Cc	Cs	Ac	As	Ns	Sc	St	Cu	Cb
I	11.2	0.4	1.1	12.5	3.8	3.1	37.9	20.7	6.8	2.5
II	13.6	0.2	1.7	13.7	4.5	3.6	35.0	16.1	8.7	2.9
III	20.0	0.5	2.1	15.7	4.3	3.6	29.4	7.5	11.9	5.0
IV	22.8	1.0	1.5	19.7	4.1	3.4	20.6	4.0	16.6	6.4
V	25.5	1.0	1.5	20.5	3.2	2.9	14.6	3.1	21.6	6.2
VI	21.5	0.8	1.3	22.5	3.2	2.8	14.2	2.4	23.5	7.7
VII	20.7	1.6	0.9	23.6	3.2	3.0	13.7	2.4	23.8	7.1
VIII	25.2	1.1	1.1	24.7	3.0	2.8	13.8	2.6	20.4	5.2
IX	20.9	1.0	1.0	23.4	3.6	3.4	22.6	4.4	15.4	4.3
X	19.2	0.8	1.2	20.4	3.7	3.5	27.6	9.5	11.3	2.9
XI	11.5	0.3	1.1	15.0	4.1	3.9	34.1	18.4	9.5	2.0
XII	10.2	0.2	0.8	10.9	3.6	2.9	37.5	24.3	7.0	2.5
Spring	22.9	0.8	1.7	18.8	3.8	3.3	21.1	4.7	17.0	5.9
Summer	22.5	1.2	1.1	23.6	3.1	2.9	13.9	2.5	22.6	6.7
Autumn	17.5	0.7	1.1	19.9	3.8	3.6	27.7	10.3	12.3	3.1
Winter	11.6	0.3	1.2	12.4	4.0	3.2	36.8	20.4	7.5	2.6
Year	19.2	0.8	1.3	19.2	3.6	3.2	23.6	8.5	15.7	4.8

The annual course of the frequency of occurrence of circulation types

An analysis of the average annual frequency of circulation types (Fig. 2) disclosed that during the period 1966–1998 the following types occurred most frequently over a given year: north-western CB, south-eastern and eastern E_1, north-eastern E and south-western D, south-western and western D_2C, and western A. The following types occurred most rarely: central G, southern indirect BE, southern B and north-western E_2C. The period taken upon consideration covers two circulation epochs. Differences in the frequency of occurrence of individual types are the consequence of occurrence of different circulation epochs (Osuchowska-Klein 1987). One of the more significant features was the weakening of zonal atmospheric circulation and the activation of blockade-type meridional processes in the last epoch of the preceding century, characterised by an extremely large frequency of the north-western cyclonal circulation CB and north-eastern anticyclonal circulation E.

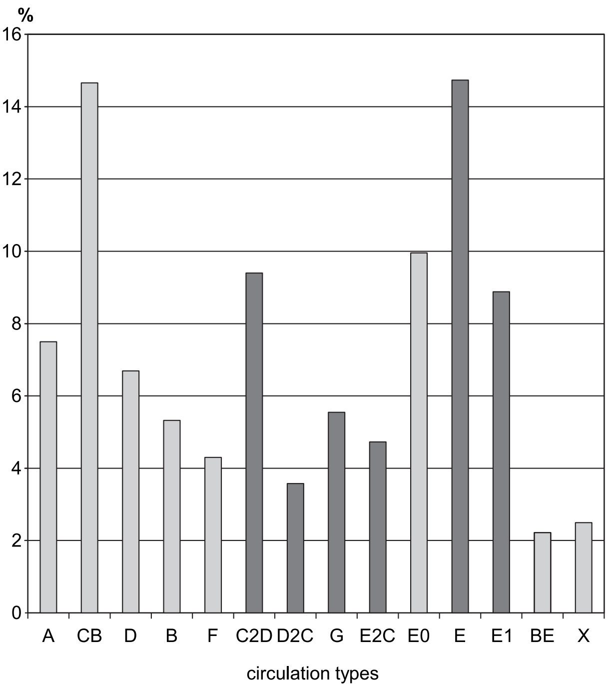

Fig. 2. Frequency of occurrence of atmospheric circulation types according to Osuchowska-Klein (1966–1998).

Such a distribution differs somewhat from the frequency of circulation types previously obtained by Osuchowska-Klein (1975). When analysing the period 1900–1965, she organised circulation types in classes according to the frequency of occurrence thereof, obtaining a very large and large annual frequency for the following types: E, CB. C_2D, E_1, A, D, E_0. According to Kirschenstein (2004), the distinguished types also occurred most frequently in the period 1961–1980, however only E, CB, C_2D and E_1 maintained their places in the sequence. Similar results were obtained by Baranowski (2003) for the period 1971–1995.

The frequency of circulation types' occurrence in seasons changes as following (Fig. 3). In spring the type north-east E (17.5%) had the greatest

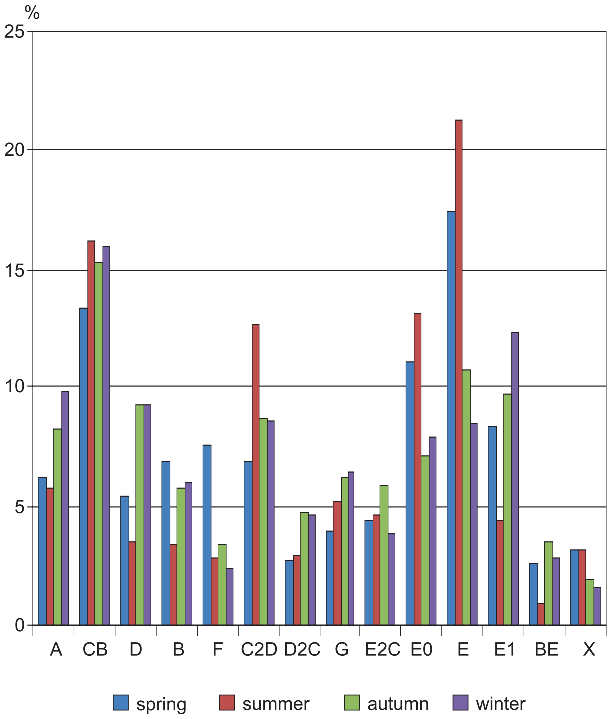

Fig. 3. Frequency of occurrence of atmospheric circulation types in seasons according to Osuchowska-Klein (1966–1998).

impact, than north-west CB (13.8%) and north-east and east E_0 (11.0%). In summer the situation was similar. The type north-east E (21.2%) had the highest frequency, then CB type (16.2%), E_0 (13.2%) and C_2D (12.7%). The most frequent in autumn was CB (15.3%), E (10.7%), E_1 (9.7%) and D (9.2%). Also in winter the north-west cyclonic type CB (16.0%) was the most frequent, then E_1 (12.3%), A (9.8%) and D (9.2%).

On the basis of an analysis of the data it was determined that the frequency of cyclonal circulations in Poznań was only slightly greater than that of anticyclonal types (Table 4). The cyclonal circulation types accounted for 50.6% days in the year, while the anticyclonal types – for 46.9% days.

Amongst the cyclonal circulation types, a decisive advantage over the year was held by the north-eastern CB (14.7%), with the north-eastern and eastern E_0 (10.0%), western A (7.5%) and south-western D (6.7%) types coming next. The south-eastern F type occurred most rarely (4.3%). As regards anticyclonal types, the north-eastern E was the most frequent (14.7%), with the western C_2D (9.4%) and south-eastern and eastern E_1 (8.9%) coming next. The south-western and

Table 4. Frequency of occurrence (%) of atmospheric circulation types according to Osuchowska-Klein (1966–1998).

Circulation type		Months												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Cyclonic	A	9.8	9.5	10.6	5.1	2.8	5.4	6.2	5.8	8.4	7.2	9.2	10.3	7.5
	CB	13.1	10.5	15.0	16.1	9.2	16.0	19.6	13.1	13.8	14.1	18.0	17.1	14.7
	E_0	8.9	8.0	6.0	13.5	13.6	16.4	12.0	11.4	9.6	5.0	6.7	8.1	10.0
	F	0.8	6.7	4.3	9.8	8.7	4.4	1.8	2.3	2.7	3.8	3.5	3.1	4.3
	B	5.2	4.9	6.2	7.3	7.2	4.5	2.2	3.3	4.0	6.2	6.9	5.9	5.3
	D	8.5	8.8	6.7	4.9	4.7	3.6	2.7	4.1	7.8	9.6	10.2	9.0	6.7
	BE	2.8	1.6	3.4	2.2	2.0	0.8	0.2	1.9	2.4	3.5	4.4	1.5	2.2
	Σ	49.1	50.1	52.3	59.0	48.2	51.1	44.7	41.9	48.8	49.3	58.9	55.0	50.6
Anticyclonic	C_2D	8.8	9.4	7.8	7.0	6.0	8.6	17.2	12.2	10.7	8.2	7.0	9.8	9.4
	E_2C	4.0	4.9	3.8	4.4	5.0	6.3	3.0	4.7	8.9	4.4	4.2	3.4	4.7
	E	9.3	10.9	12.8	15.4	24.2	20.0	22.2	21.5	13.8	10.1	8.3	7.7	14.7
	E_1	14.8	14.4	13.6	6.0	5.3	3.3	2.6	7.1	6.8	10.9	11.5	10.6	8.9
	D_2C	4.9	3.1	3.4	1.9	2.7	3.1	2.2	3.3	3.2	6.0	4.9	4.1	3.6
	G	7.8	5.3	4.2	3.1	4.5	4.6	5.1	5.8	5.3	9.4	3.7	7.5	5.5
	Σ	49.5	47.9	45.7	37.7	47.7	46.0	52.4	54.6	48.7	49.0	39.5	43.1	46.9
X		1.4	2.1	2.0	3.3	4.1	2.9	2.9	3.4	2.5	1.7	1.6	1.9	2.5
West		58.8	58.1	58.4	55.2	45.9	50.3	57.0	50.0	56.0	64.4	63.3	66.8	57.0
East		39.8	39.8	39.6	41.5	50.0	46.8	40.1	46.6	41.5	33.9	35.1	31.3	40.5

Explanation: Table 1.

southern D_2C (3.6%) occurred least frequently. During the warm half-year period, the cyclonal types gained a very slight advantage. The frequency of cyclonal types was greater during the cold half-year period. During the year, cyclonal types occurred just a bit more frequently in April (59.0%), November (58.9%) and December (55.0%), while anticyclonal types – in August (54.6%) and July (52.4%).

The connection between general cloud cover and circulation types

When analysing the conditional probability of occurrence of specific sky cloud cover depending on the type of circulation, one may observe that the cloudless sky is first and foremost related to anticyclonal types of atmospheric circulation (Table 5). A high-pressure weather system is often characterised by a lack of cloud cover. The greatest probability of occurrence of cloudless weather was observed for the following circulation types: G (24.8%), E_1 (23.2%) and D_2C (17.9%). The occurrence of a cloudless sky was determined mainly by the inflow of air from the southeast sector. It was least frequently connected with cyclonal types, and in particular with A (3.3%), F (3.5%) and CB (3.7%).

Anticyclonal circulation was more frequently conducive to slight cloud cover (1–3). The E type was predominant amongst anticyclonal types (27.0%). However, also the great probability of occurrence of slight cloud cover was observed for the type D_2C (26.7%) and then G (26.3%). Circulation types from the east were less conducive to such cloud cover. Tamulewicz (2000) proved also that the slightly cloudy days are connected to the anticyclonal circulation.

Moderate cloud cover (4–5) was connected with both cyclonal and anticyclonal circulation types. The greatest probability of occurrence was observed for the anticyclonal north-western direction E_2C (14.9%), and then for the north-eastern circulation E (14.4%). Cloud cover of this size was impacted to a slightly greater degree by circulation types from the western direction.

Significant cloud cover (6–7) was connected primarily with cyclonal and eastern circulation. This occurred with the greatest probability under circulation type CB (41.2%). A considerable influence was also exerted by circulations E_0 (36.4%) and A (36.1%). It confirms the results obtained by Tamulewicz (2000) that the cloudy days appear most often during the cyclonal circulations.

Atmospheric circulation had a similar impact on total cloud cover. This occurred with a greater probability in cyclonal situations. Amongst cyclonal circulations, total cloud cover was connected primarily with type F (46.6%) and B (40.8%). Western circulation types had the greatest impact on the occurrence of total cloud cover.

Table 5. Conditional probability (%) of occurrence of cloud cover depending on the given atmospheric circulation type according to Osuchowska-Klein classification in Poznań (1966–1998).

Circulation type	Cloudless	Slightly cloudy	Partly cloudy	Cloudy	Overcast
A	3.3	12.3	13.2	36.1	35.0
CB	3.7	12.6	12.8	41.2	29.7
D	7.1	17.4	14.0	33.8	27.7
B	4.7	12.5	9.7	32.3	40.8
F	5.4	12.3	10.4	25.3	46.6
C_2D	8.3	21.1	12.5	28.2	30.0
D_2C	17.9	26.7	12.5	22.9	19.9
G	24.8	26.3	11.5	15.9	21.5
E_2C	10.8	23.4	14.9	26.5	24.4
E_0	3.5	12.7	10.9	36.4	36.5
E	13.4	27.0	14.4	25.1	20.2
E_1	23.2	18.5	8.2	18.7	31.3
BE	15.8	21.2	10.2	25.1	27.7
X	8.8	23.2	13.3	27.8	26.9

Explanation: Table 1.

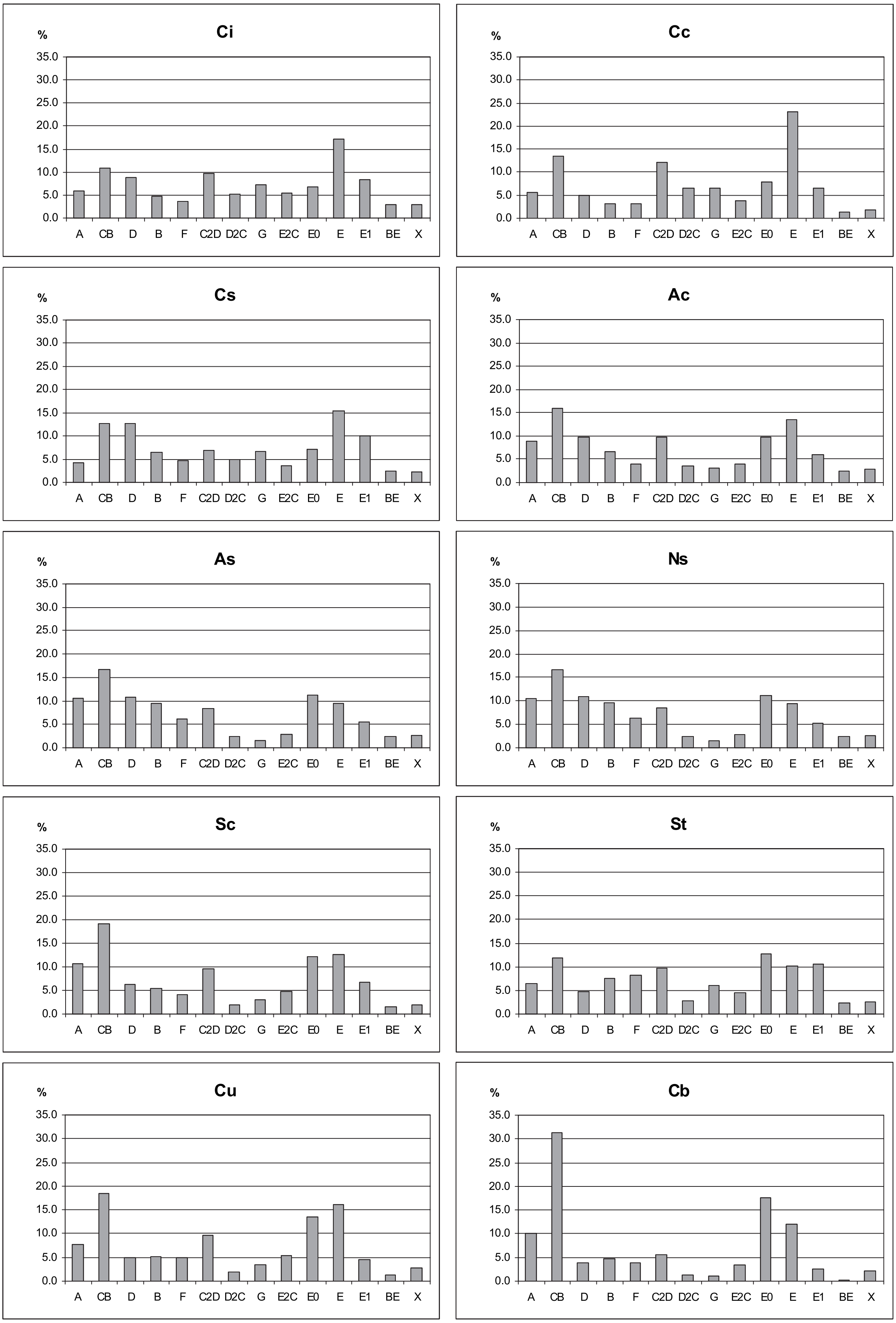

Fig. 4. Frequency of occurrence of cloud cover depending on the given atmospheric circulation type according to Osuchowska-Klein classification in Poznań (1966–1998).

Similarly, the greatest number of overcast days are the result of these types of circulation (Tamulewicz 2000).

It was also demonstrated by Żmudzka (2007) that there is the influence of atmospheric circulation (according to Lityński classification, 1969) on the size of cloudiness over Poland. In summer the east advection (negative deviation) and the west one (positive deviation) mainly influenced the cloudiness magnitude. The lower cloud cover in autumn is due to the circulation from the south sector. The very high cloudiness in November is characterised by the lack of a distinct air advection over Poland.

The circulation types and the cloud types

The analysis of the average frequency of occurrence of particular cloud types in the research period in Poznań leads to conclusion that the high clouds *Cirrus*, *Cirrocumulus* and *Cirrostratus* appear mainly during the anticyclonic circulation E and CB (Fig. 4). The earlier research results taking into account the Lityński classification (1969) proved also that the high clouds are favoured by the anticyclonal situations (Szyga-Pluta 2009). The CB circulation is connected also with the following cloud types: *Altocumulus*. *Altostratus*, *Nimbostratus* and *Stratocumulus* and the convection clouds *Cumulus* and *Cumulonimbus*. *Stratus* appears most often during the north-east and east circulation E_0. It was also proved by Żmudzka (2007) that the NE_C and E_C (according to Lityński classification, 1969) influence strongly the *Stratus* clouds to appear in summer and the NW_C – the *Cumulonimbus* clouds in winter. The cyclonal circulations favour the occurrence of *Altostratus*, *Nimbostratus* and *Cumulonimbus* clouds mainly. Other types of clouds seem to form depending mainly on the local factors.

Conclusions

An analysis of the size of cloud cover and types of atmospheric circulation over Poznań-Ławica in the years 1966–1998 demonstrated the following:

1. Total cloud cover, significant cloud cover and cloudless skies occurred most frequently during the year. Cloud cover sizes 4/8 and 1/8 were observed least frequently. Cloud cover was least diversified during the summer months, i.e. July and August, and most diversified during the winter period, from November to February.
2. The types of atmospheric circulation according to the classification of B. Osuchowska-Klein that occur most frequently during the year are the following: E, CB, E_0, C_2D and E_1. The following circulation types occurred the least frequently: D_2C, F, E_2C, B and G.
3. A cloudless sky and slight cloud cover were connected with anticyclonal types of atmospheric circulation, and with types from the south-east. Moderate cloud cover occurred in an equal degree for both cyclonal and anticyclonal types. Western macrotypes were decisive for this size of general cloud cover. Cyclonal types were conducive to significant and total sky cloud cover.
4. The occurrence of high clouds is influenced by anticyclonal circulation while the lower clouds appear mainly during the cyclonal types.

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