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Circulation-related conditions of variability of cloudiness in Poland in the second half of the 20th century

ELWIRA ŻMUDZKA

Department of Climatology, University of Warsaw

Abstract

The report presents the results of studies concerning variability of the magnitude of the average area cloudiness in Poland in the years 1951–2000, and its association with the characteristics of atmospheric circulation over central Europe. The description of the circulation conditions was made using the average monthly values of atmospheric pressure, pressure gradients, as well as vectors of geostrophic wind, determined with respect to the area contained between the parallels of 45 and 60°N and the meridians of 10 and 30°E. The dependencies were determined with the help of correlation coefficients and the regression equations. Besides, the macro-types of circulation were identified, conducive to the seasonally and annually anomalous cloudiness values. Likewise, the 50-year trends of changes in the circulation and nephological conditions were established.

Key words: cloudiness, variability, atmospheric circulation, Poland

1. Introduction

The variability of cloudiness, which in itself is one of the basic elements of climate and has at the same time high significance in the shaping of weather and climate, is – in contrast, for instance, to temperature or precipitation – relatively little known and constitutes quite rarely the subject of study. The present report shows the results of research on the variability of cloudiness in Poland in the second half of the 20th century. In addition, an attempt is presented of determining the dependence of cloudiness on the large-scale circulation conditions, and of determining the circulation conditions, that is – the frequencies of the circulation types – in the seasons and years featuring anomalous cloudiness intensities.

2. The data and the methods of study

The study reported made use of a vast observation data set from the territory of Poland (except for the mountains), and in particular – of the area averages of cloudiness from the consecutive years 1951–2000. The series was obtained on the basis of the average monthly cloudiness values from 48 synoptic stations of the Institute of Meteorology and Water Economy (IMGW), located across Poland at up to 300 m a. s. l. (see Fig. 1).

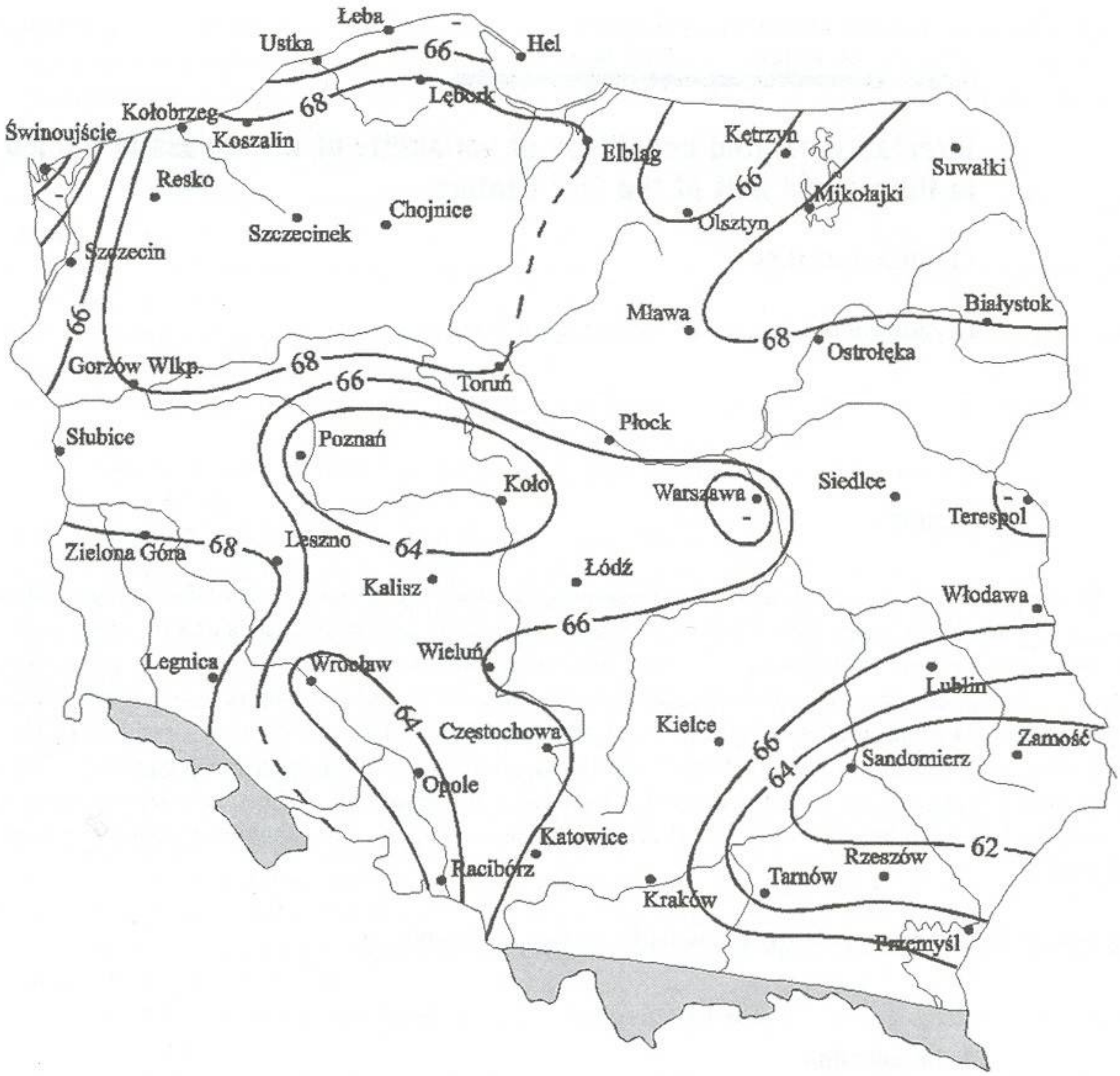

Fig. 1 Distribution of weather stations used in the study and mean annual cloudiness [%] in years 1951–2000

The variability of the cloudiness in Poland was described with the use of the basic characteristics and statistical methods: linear regression, Mann-Kendall rank test, cumulated deviation from the long-term average, and amplitude.

The description of the circulation conditions was made with the use of the average monthly values of the zonal and meridional circulation indicators, as well as the vector of the geostrophic wind, determined with respect to the area between the parallels of 45 and 60°N and the meridians of 10 and 30°E (Fig. 2). Likewise, the 50-year series of the monthly averages of air pressure at the point φ 52.5°N, λ 20°E, located close to the centre of the area considered, was taken into account.[1] Analysis was also carried out of the relations between cloudiness and frequency (number of days) of the definite macro-types of atmospheric circulation, distinguished in view of the character of pressure (cyclonal, anticyclonal, null) and the direction of inflow of the air masses (sectors corresponding to four main directions, with, for instance,

[1] The author would like to thank Professor K. Kożuchowski for making available the data concerning circulation conditions.

the following notation, $fN = 0.5\,fNW + fN + 0.5\,fNE$, where f = number of days). The classification used followed that of J. Lityński (Stępniewska-Podrażka, 1991; Pawłowska et al., 2000). The dependencies were determined with the help of the correlation coefficients and the simple and multiple regression. Further, the circulation types were determined conducive to the seasonal and annual anomalies of the intensity of cloudiness. It was assumed that the anomalous seasons and years were the ones, in which the cloudiness exceeded the 90% quantile or was below the value defined by the 10% quantile. Special attention was paid to the circulation conditions in the years with the extremely anomalous cloudiness values, here the respective quantile thresholds being 95% and 5%. The frequencies of the circulation types in the anomalous years were expressed in the percentages of the 50-year average. Besides, the long-term trends of change in cloudiness and in selected characteristics of atmospheric circulation were compared.

Fig. 2 The analysed area

3. The variability of cloudiness

There has been a slight decrease of cloudiness in the major part of the year in Poland in the second half of the 20th century (Fig. 3). The cloudiness decreased in a significant manner in May (Table 1). The values of the Mann-Kendall statistic, τ, are also significantly different from zero at the assumed level of 5% for September (upward tendency) and for winter (downward tendency).

Table 1 Linear trend coefficients *a* [%/year] and rank evaluation (τ – the values of the Mann-Kendall's statistics) of the trend of changes of cloudiness in Poland in years 1951–2000 (coefficients significant at the 0.05 are bolded) (Żmudzka 2003)

	Months											
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
a	−0.10	−0.06	0.07	−0.01	**−0.21**	0.07	−0.06	−0.11	0.18	−0.05	−0.10	−0.04
τ	−0.16	−0.14	0.06	−0.05	**−0.29**	0.09	−0.06	−0.17	**0.19**	−0.06	−0.16	−0.09

	Seasons				Year
	XII–II	**III–V**	**VI–VIII**	**IX–XI**	**I–XII**
a	−0.07	−0.05	−0.03	0.01	−0.04
τ	**−0.19**	−0.12	−0.07	0.01	−0.14

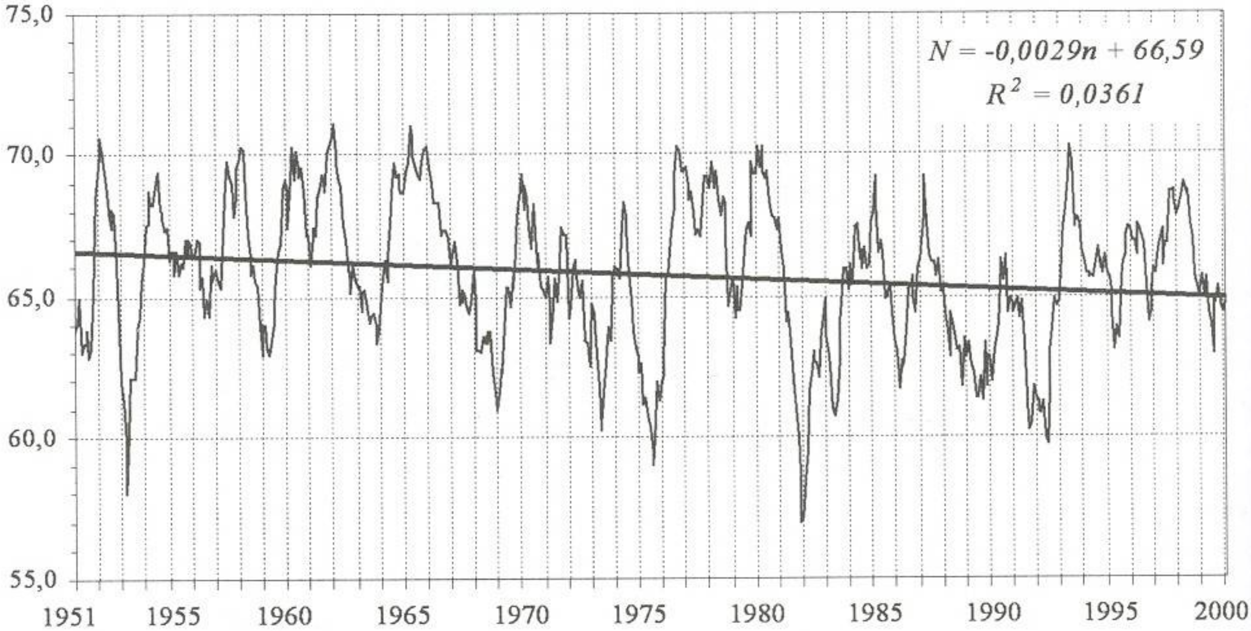

Fig. 3 Moving 12-monthly averages cloudiness in Poland in years 1951–2000 and their linear trend

A fuller image of fluctuations of the average cloudiness for the area of Poland in the seasons of the year and the entire year is provided by the curves depicting the cumulated divergence of cloudiness in the period 1951–2000 from the 50-year average (Figs. 4 and 5).

The shape of the curves in winter and in spring corresponds to the decreasing trend – in the first part of the period analysed the domination of the positive deviations was observed, and after 1973 – of the negative ones. An especially large increase of the accumulated deviations occurred in 1966–68 (the biggest cloudiness in the entire 50-year period considered having taken place in 1966). The beginning of the 1970s marks also a clear breaking point with respect to the nature of variability of cloudiness in summer and autumn. In the summers of the first half of the period between 1951

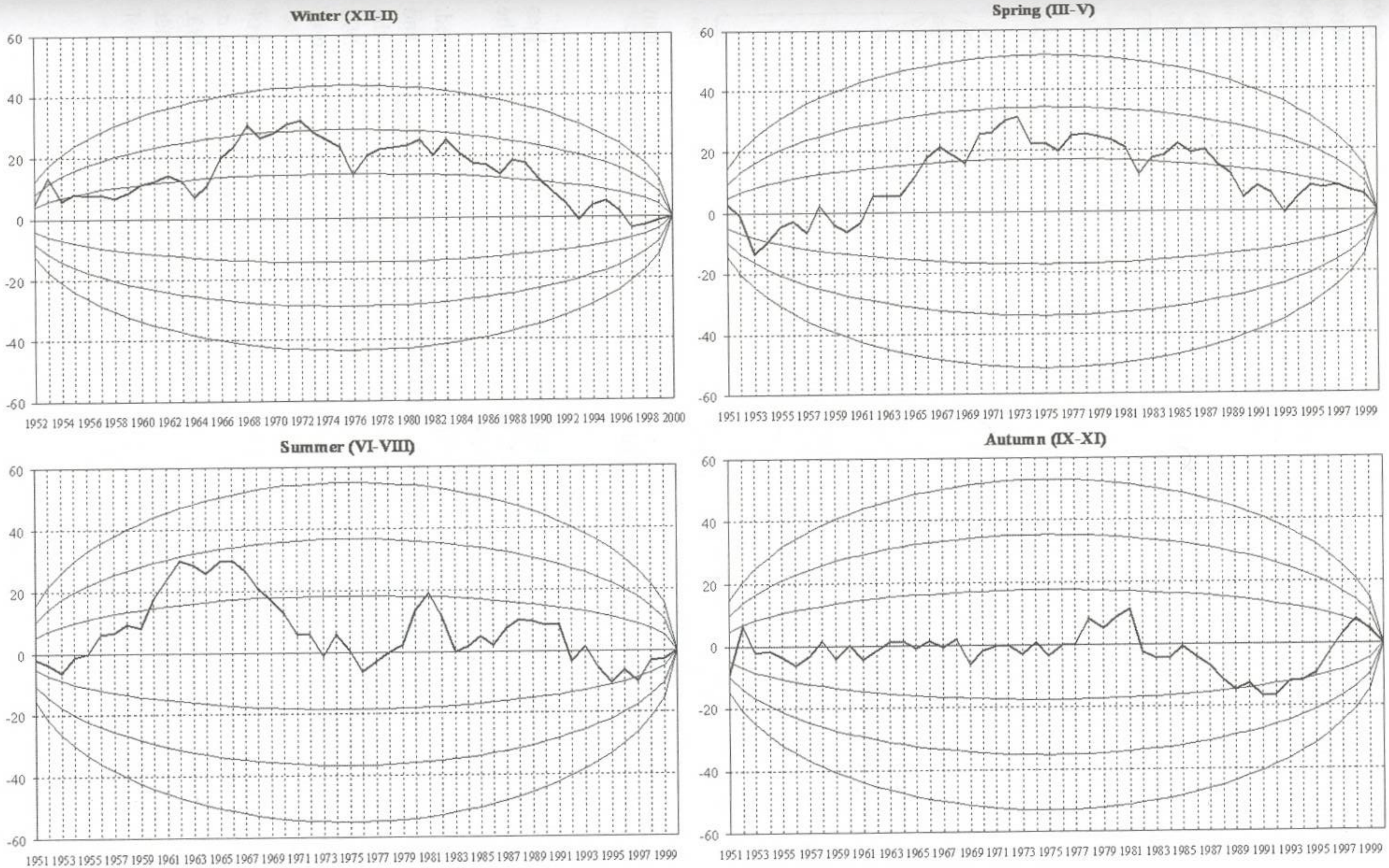

Fig. 4 Cumulative deviations of mean seasonal cloudiness from the 50-year means in Poland (1951–2000). The ranges of 1, 2 and 3 standard deviations are marked

and 2000 a clearly decreasing trend in cloudiness was observed: in the years 1953–62 almost exclusively positive deviations were noted, while in 1966–1976 – the negative ones dominated. The second half of the 50-year period began with a short period (1977–1981) of the positive anomalies, after which the domination of the negative deviations followed. Since 1997 the positive deviations dominate again.

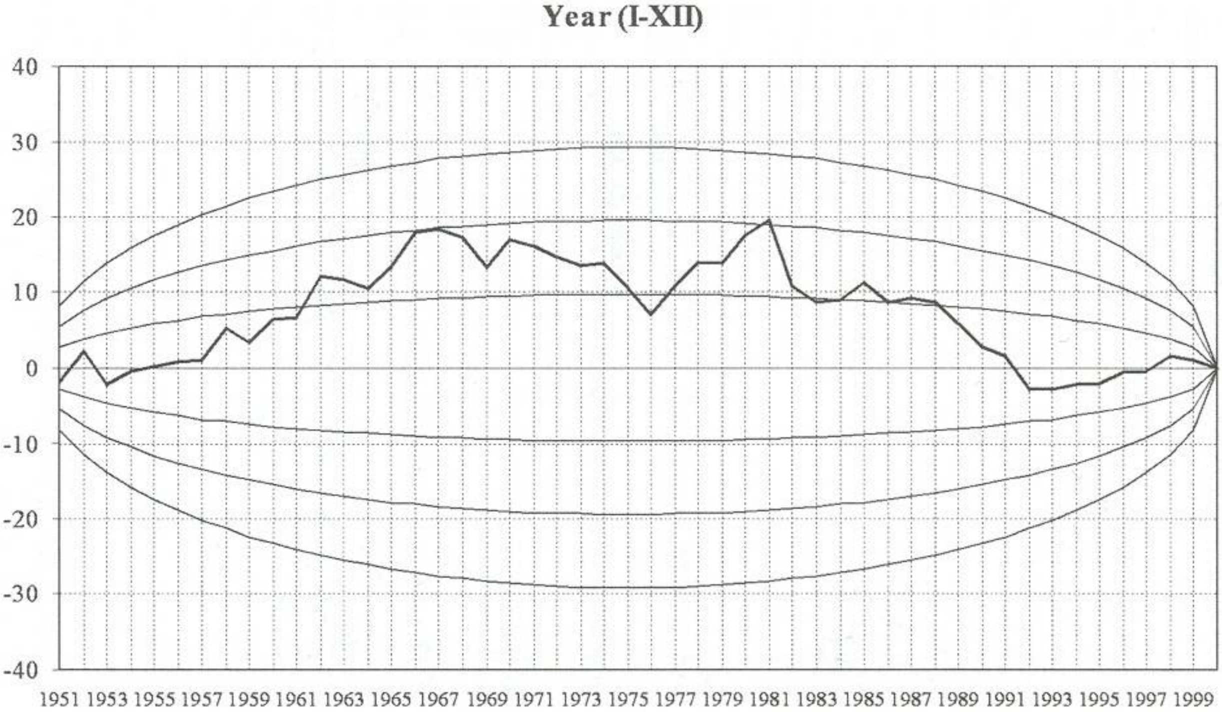

Fig. 5 Cumulative deviations of mean annual cloudiness from the 50-year means in Poland (1951–2000). The ranges of 1, 2 and 3 standard deviations are marked

In the autumns of the first half of the 50-year period analysed the cloudiness does not display any significant direction of change, to then increase in the second half. The passage from the negative to positive anomalies takes place in 1991.

The average annual cloudiness is gradually decreasing over the 50 years considered. In the years 1953–1981 the upward tendency was observed. The years 1953–1967 and 1976–1981 were the main periods of domination of the positive deviations from the long-term average. Then, in 1982–1992 the negative deviations dominated. After 1992 the positive deviations started to be more pronounced again (the gradual increase of cloudiness).

The cumulated deviations from the long-term averages in the particular seasons of the year and in the entire year do not exceed the value of three standard deviations σ_i (only in winter and a couple of times in the entire year they exceed the level of $2\sigma_i$), which is the evidence of the existence of fluctuations not differing in an essential manner from the random fluctuations (Drozdov, Grigoreva, 1972). The range of fluctuations of cloudiness, though, indicates its relatively high variability over time (Table 2).

Table 2 Variability range of spatially averaged cloudiness in Poland (1951–2000)

Characteristic	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean [%]	75	73	66	63	59	60	60	56	59	64	77	78
Maximum value [%] (year)	89 (1953 1966)	88 (1973)	82 (1985)	79 (1956)	78 (1962)	72 (1985)	78 (1980 2000)	68 (1956 1961)	76 (1978 1996)	82 (1952 1974)	90 (1958)	90 (1954 1959)
Minimum value [%] (year)	62 (1971)	48 (1976)	46 (1953)	46 (1953)	44 (1979)	42 (1992)	38 (1994)	38 (1973)	39 (1975)	41 (1951)	61 (1982 1984)	51 (1972)
Range [%]	27	40	36	33	34	30	40	30	37	41	29	39

Characteristic	Seasons				Year
	XII–II	III–V	VI–VIII	IX–XI	I–XII
Mean [%]	75	63	58	67	66
Maximum value [%] (year)	84 (1966)	72 (1970)	69 (1980)	82 (1952)	71 (1962)
Minimum value [%] (year)	66 (1976)	50 (1953)	46 (1992)	53 (1982)	57 (1982)
Range [%]	18	22	23	29	14

The change tendencies identified and an important part of variability of cloudiness in Poland can be explained by the direct impact from the atmospheric circulation.

4. Interrelations between cloudiness and atmospheric circulation

4.1 Cloudiness and the indicators of circulation over Central Europe

4.1.1. Cloudiness and the zonal and meridional components of atmospheric circulation

The western zonal circulation in Central Europe exerts a significant influence on the magnitude of cloudiness in Poland during the summer time, especially in July, bringing an increase of cloudiness and in November bringing a decrease (Table 3). The relation between cloudiness and the meridional component of the circulation is significant in February, September and in October.

During the entire year (except for November) atmospheric pressure over the territory of Poland has a significant impact on the intensity of cloudiness – an increase of pressure entails a decrease of cloudiness. The strongest influence on cloudiness is exerted by pressure in July (when it explains 64% of variance of cloudiness), as well as in March and in September.

Table 3 Linear correlation coefficients of spatially averaged cloudiness in Poland and local index of the zonal (*ZI*) and meridional (*MI*) circulation and atmospheric pressure (*pL*) in point [52.5°N, 20°E] (correlation coefficients significant at the 0.05 are bolded)

	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
ZI	−0.02	0.15	0.20	0.04	0.01	**0.33**	**0.46**	**0.37**	−0.01	0.15	**−0.37**	−0.04
MI	−0.04	**0.30**	−0.06	0.05	0.19	−0.10	−0.27	−0.08	**0.29**	**0.31**	−0.09	−0.12
pL	**−0.58**	**−0.44**	**−0.68**	**−0.48**	**−0.57**	**−0.50**	**−0.80**	**−0.56**	**−0.63**	**−0.58**	−0.24	**−0.53**

	Seasons				Year
	XII–II	III–V	VI–VIII	IX–XI	I–XII
ZI	−0.03	0.07	**0.52**	−0.19	−0.22
MI	−0.13	−0.06	−0.25	0.20	−0.01
pL	**−0.68**	**−0.58**	**−0.64**	**−0.46**	**−0.64**

4.1.2. Cloudiness and the geostrophic wind

In summer and at the turn of winter (mainly in November) the western component of the geostrophic wind exerts a more pronounced influence on the magnitude of cloudiness (the absolute values of the regression coefficients corresponding to the strength of association of cloudiness with the component V_W are bigger than the ones for the northern component V_N, see Table 4). In summer this component contributes to the increase of cloudiness, while at the turn of winter – to its decrease. It is worth noting that during these months the magnitude of cloudiness in Poland depends also significantly upon the velocity of the geostrophic wind (Table 5). In July, when the direction of the geostrophic wind represents the North-western sector, this correlation is positive, while in November, when the wind has the southern (SW) component – it is negative.

Table 4 Coefficients of the regression equations (*a*, *b*, *c*) and multiple correlation *I* between mean cloudiness in Poland and components of the geostrophic wind (V_W, V_N) and pressure (*pL*) in point [52.5°N, 20°E] (correlation coefficients significant at the 0.05 are bolded)

	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
$a(V_W)$	−0.19	−0.21	0.26	−0.43	0.92	**1.89**	**1.90**	1.11	0.26	0.37	**−1.49**	−0.29
$b(V_N)$	0.48	**1.84**	0.43	1.72	**3.08**	0.35	0.41	0.95	**4.33**	**1.88**	0.63	0.03
c(pL)	**−0.81**	**−0.76**	**−1.55**	**−1.56**	**−2.10**	**−1.70**	**−3.07**	**−2.02**	**−2.73**	**−1.44**	**−0.59**	**−0.66**
R	**0.59**	**0.60**	**0.69**	**0.53**	**0.66**	**0.61**	**0.84**	**0.61**	**0.78**	**0.70**	**0.54**	**0.54**

	Seasons				Year
	XII–II	III–V	VI–VIII	IX–XI	I–XII
$a(V_W)$	−0.04	−0.16	**2.10**	**−1.26**	**−1.36**
$b(V_N)$	0.30	0.75	0.43	**2.20**	**1.69**
c(pL)	**−0.91**	**−1.62**	**−2.39**	**−1.17**	**−1.57**
R	**0.68**	**0.59**	**0.72**	**0.61**	**0.72**

Table 5 Linear correlation coefficients of spatially averaged cloudiness in Poland and velocity of geostrophic wind (correlation coefficients significant at the 0.05 are bolded)

Months											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−0.08	−0.18	0.07	0.01	−0.02	0.02	**0.42**	**0.38**	0.07	−0.03	**−0.38**	0.08

Seasons				Year
XII–II	III–V	VI–VIII	IX–XI	I–XII
−0.12	−0.05	**0.34**	−0.23	**−0.36**

During the remaining parts of the year a stronger influence on cloudiness is exerted by the meridional component of the geostrophic wind. It has the most pronounced impact on the magnitude of cloudiness during the transitory seasons of the year, mainly in September and October, as well as in May, and also in February (when the geostrophic wind has the southern component ranging from WSW to SE). An intensification of the northern component leads to an increase of cloudiness over the entire year.

Air pressure in the middle of Central Europe exerts the strongest influence on the magnitude of cloudiness in the summer months – the increase of pressure is accompanied by the decrease of cloudiness. In the autumn and in the entire year cloudiness depends primarily upon the direction of inflow of the air masses – the meridional component. The role of atmospheric pressure can be compared to that of the western component. Among the directions of circulation a bigger significance ought to be assigned in summer to the zonal component, while in spring and winter – to the meridional one.

The western and the meridional components of the atmospheric circulation over Central Europe, along with atmospheric pressure in the middle of this area, explain together between 28 and 70% of variability of the average monthly cloudiness over Poland. The association between cloudiness and the circulation conditions is the weakest at the turn of winter (in November and December, $R = 0.54$). The strength of these associations increases in the warmer part of the year and attains maximum in July ($R = 0.84$). Strong interrelations are also observed in autumn (in September and October) and in March. In autumn the most important role is played by the meridional component (the highest value of the regression coefficient), while in summer and in spring – by the pressure in the middle of the area considered.

4.1.3. Cloudiness and the macro-types of atmospheric circulation

The relation between the magnitude of cloudiness and the direction of inflow of the air masses is significant in February, July and from September to November (Table 6). A significant influence is exerted in the summer by the advection from the East (negative correlation) and from the West (positive correlation), while in the autumn – from the southern sector, with which a decreased cloudiness over Poland is connected. Only in November situations with no distinct advection of air masses or situations with eastern advection over Poland result in increase of cloudiness. In February cloudiness is significantly modified by advection from the north (positive correlation) and from the south (negative correlation).

During the whole year the air pressure pattern influence significantly of formation of the cloudiness. The dependence of the magnitude of cloudiness upon the macro-types distinguished in terms of the character of circulation is the weakest in November, and the strongest in July. A definite increase of significance of the pressure configurations can also be observed in March, May and October.

Table 6 Linear correlation coefficients of spatially averaged cloudiness in Poland and frequency of macro--types of circulation after Lityński classification (correlation coefficients significant at the 0.05 are bolded)

	Months											
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Macro-types distinguished with respect to advection direction												
[N]	0.01	**0.37**	−0.03	0.14	0.22	0.05	0.01	−0.07	0.24	**0.34**	−0.09	0.05
[E]	0.01	−0.23	−0.20	−0.06	0.19	−0.20	**−0.36**	−0.23	0.23	−0.11	**0.33**	−0.04
[S]	0.00	**−0.28**	0.02	−0.15	−0.19	−0.14	0.06	0.11	**−0.45**	**−0.49**	−0.06	−0.02
[W]	0.04	0.12	0.18	−0.03	−0.17	0.24	0.24	0.18	−0.11	0.18	−0.26	0.06
[O]	−0.16	0.10	0.09	0.20	−0.22	0.06	0.11	0.12	0.10	0.19	**0.38**	−0.11
Macro-types distinguished with respect to pressure pattern												
[C]	**0.51**	**0.45**	**0.60**	**0.53**	**0.56**	**0.49**	**0.82**	**0.50**	**0.53**	**0.58**	**0.28**	**0.42**
[A]	**−0.51**	**−0.48**	**−0.67**	**−0.51**	**−0.70**	**−0.52**	**−0.76**	**−0.54**	**−0.58**	**−0.62**	−0.23	**−0.49**
[0]	0.00	0.13	0.27	0.09	**0.32**	0.06	−0.10	0.07	0.08	0.24	−0.07	0.22

	Seasons				Year
	XII–II	**III–V**	**VI–VIII**	**IX–XI**	**I–XII**
Macro-types distinguished with respect to advection direction					
[N]	−0.02	0.05	−0.07	0.13	−0.04
[E]	−0.05	−0.06	**−0.42**	0.23	0.18
[S]	0.07	−0.11	0.07	**−0.32**	−0.03
[W]	−0.07	0.04	**0.39**	−0.11	−0.17
[O]	0.20	0.15	0.16	0.24	0.06
Macro-types distinguished with respect to pressure pattern					
[C]	**0.61**	**0.59**	**0.65**	**0.55**	**0.71**
[A]	**−0.71**	**−0.68**	**−0.63**	**−0.48**	**−0.73**
[0]	**0.34**	0.24	−0.06	−0.09	0.25

4.1.4. Atmospheric circulation in the seasons and years with anomalous magnitudes of cloudiness

A definite reflection of the long-term variability of the magnitude of cloudiness is constituted by the frequency of appearance of the anomalous magnitudes. Thus, within the entire half-century considered, 1951–2000, attention is attracted first of all to the higher frequency of seasons with abnormally high cloudiness in the first two decades (Table 7). This was particularly pronounced for the winters and springs. Then, in the last two decades of the 20th century an increased frequency has been observed of the seasons with abnormally low cloudiness, while the seasons with exceptionally high cloudiness (extremely anomalous) have not occurred at all. The proportions were somewhat different in autumn – during the 1950s the years characterised by good weather were quite frequent, while at the end of the 20th century – the cloudy ones. As a consequence of such a distribution of the anomalous magnitudes of cloudiness in particular seasons, the years with extremely high cloudiness occurred only in the period 1951–1970. After 1980 no year occurred featuring abnormally high cloudiness.

Table 7 The borders of anomaly and extremely anomaly cloudiness in Poland in years 1951–2000 and their frequency (numbers) in subsequently decades: + = cloudy (with extremely cloudy), − = clear (with extremely clear)

A	Percentiles [%] 1951–2000	Winter XII–II		Spring III–V		Summer VI–VIII		Autumn IX–XI		Year I–XII	
+	>95.00	81.78		70.33		65.03		72.81		69.85	
	90.01–95.00	80.41–81.78		68.05–70.33		64.65–65.03		71.28–72.81		69.33–69.85	
–	5.01–10.00	69.60–69.99		54.39–56.22		50.93–51.58		58.14–61.59		61.41–62.27	
	≤5.00	69.59		54.38		50.92		58.13		61.40	
B	**decades**	+	–	+	–	+	–	+	–	+	–
	1951–1960	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	–	1 (1)	3 (2)	2 (1)	1 (1)
	1961–1970	2 (2)	1 (–)	4 (2)	–	1 (–)	–	–	1 (–)	2 (2)	1 (–)
	1971–1980	1 (–)	1 (1)	–	1 (1)	2 (1)	2 (–)	1 (1)	–	1 (–)	1 (–)
	1981–1990	1 (–)	–	–	2 (1)	–	2 (2)	–	1 (1)	–	1 (1)
	1991–2000	–	2 (1)	–	1 (–)	1 (–)	1 (1)	2 (1)	–	–	1 (1)

The year 1982 was strongly anomalous, having featured extremely low cloudiness, due to the very low cloudiness in the period between March and November (mainly in March, September and November). The very same year featured also the lowest area average precipitation total for the entire half-century 1951–2000 (extremely dry autumn and very dry spring and summer). Exceptionally good weather characterised also the years 1953 (spring, autumn) and 1992 (summer). On the other hand, the cloudiest were the years 1952, 1962 and 1966. In 1952 autumn was exceptionally cloudy, in 1962 – spring, and in 1966 – winter and spring.

In order to determine the circulation conditions, leading to the appearance of the anomalous seasons and years in terms of cloudiness, the average frequencies were calculated for particular years of the circulation types according to the classification of Lityński, and expressed in percentages of the long-term average for 1951–2000 (Fig. 6).

A significant role is played in the formation of the anomalous magnitudes of cloudiness by the character of the atmospheric pressure configuration – irrespective of the direction of inflow of the air masses the increase of frequency of the cyclonal configurations is conducive to the abnormally high cloudiness, while the increase of frequency of the anti-cyclonal configurations is conducive to the appearance of winters with abnormally low cloudiness. Besides, during the winter seasons with high

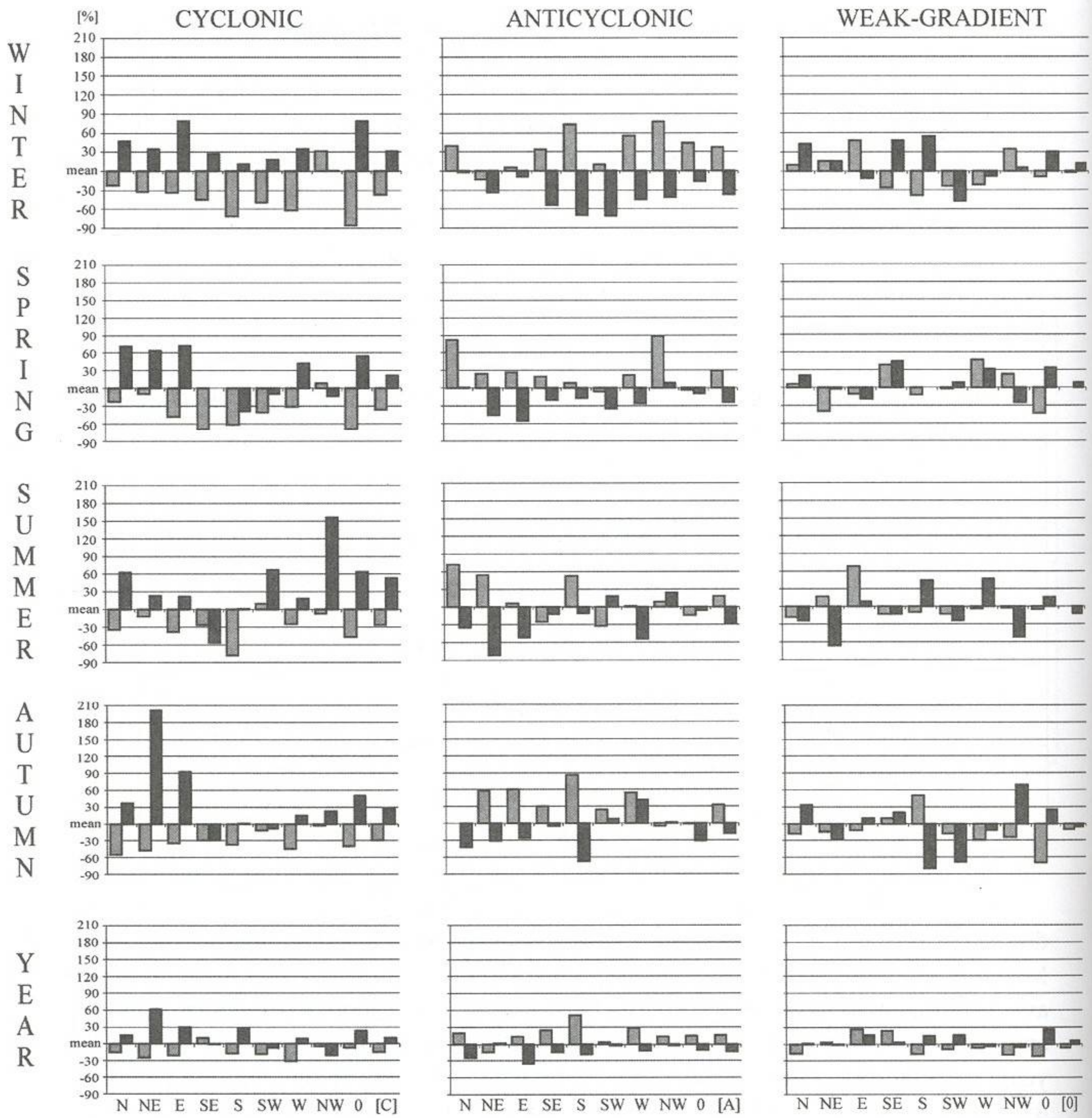

Fig. 6 Frequency (deviations % from mean 50-years) of circulation types (after Lityński classification) in seasons and years with anomalous cloudiness (█ – anomalously cloudy, ▒ – anomalously clear)

cloudiness the share of the circulation types with weak gradients and advection from the SE-S sector is characteristically increased, while for those with low cloudiness – mainly from the East.

During the remaining seasons of the year the "impact" of the atmospheric pressure configurations, especially in the cases of the cyclonal configurations, is modified by the direction of inflow of the air masses. The abnormally high cloudiness magnitudes appear to be facilitated by the higher than the 50-year average frequencies of the cyclonal types with the inflow of the air from the North-North-East – East sector (mainly in spring and autumn), from the West in spring, and from the North-West and South-West in summer. Thus, for instance, the average share of the NE_C type during autumns with high cloudiness is almost three times higher than on the average.

The seasons of the year with lower cloudiness are, on the average, the ones, during which a significant frequency is observed of the anti-cyclonal types with advection of the air masses from the North-West and North in spring, from the North, North-East and South in summer, and from the NE-S segment in autumn.

The results obtained indicate a significant role of both the character of the atmospheric pressure configuration and the direction of inflow of the air masses in the formation of the anomalous cloudiness magnitudes, this observation being confirmed by the results of analyses based upon the daily measurements (see, e.g. Baranowski, 2002; Kirschenstein, 1997; Matuszko, 2002). Air masses of a definite type usually flow in from a given direction (sector). As it has been demonstrated (Warakomski, 1969), air masses play a significant role in the shaping of both the magnitude of cloudiness and the composition of cloud cover. The influence of a given type of the air mass on the ephological conditions depends strongly upon the thermodynamic properties of this mass, its humidity, thermal horizontal heterogeneity, velocity of movement and transformation, and, as mentioned already, the nature of the pressure configuration, with which its inflow is associated. Hence, the indication of the circulation types (and of the air mass types, as well), whose increase of frequency is conducive to the appearance of the seasons anomalous with respect to cloudiness, has only a general character. The shares of the circulation types conducive for the exceptionally high or exceptionally low cloudiness on the scale of the entire country are in particular years significantly differentiated. One should also remember that the present study neglects the spatial differentiation of cloudiness over the territory of Poland. The most pronounced differentiation of the intensity of cloudiness takes place in the air masses of Pm, A and As types, somewhat smaller – in the Pms masses, and the smallest – in the Pk masses (Warakomski, 1969).

4.1.5. The long-term trends of change in cloudiness in Poland and the atmospheric circulation

The identified tendencies in the changes of the magnitude of cloudiness in Poland correspond to the changes in circulation conditions in the period analysed. The significant downward trend in the magnitude of cloudiness in May corresponds to the intensification of the southern circulation in this month (downward trend V_N) (Table 8), and mainly to the increase of the number of the days with anticyclonal settings featuring this particular direction of inflow of air masses (S_A I SW_A), as well as the centre of the high pressure area over Poland 0_A which significantly lower the magnitude of cloudiness. On the other hand, in September the main cause for the increase of cloudiness should be seen in the negative tendency of change in the atmospheric pressure (increase of the number of days with cyclonal types featuring the eastern direction of advection (E_C and SE_C), and the centre of the low pressure area over Poland 0_C with which cloudiness is positively correlated).

Table 8 Linear trend coefficients of changes of the western V_W and northern V_N components of geostrophic wind [ms^{-1}/year] and atmospheric pressure p in point [52.5°N, 20°E] [hPa/year] in years 1951–2000 (coefficients significant at the 0.05 are bolded)

	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
V_W	0.05	**0.08**	0.05	0.00	0.00	0.01	−0.00	−0.01	−0.02	0.01	0.01	0.02
V_N	0.02	0.02	−0.01	0.00	−0.01	−0.00	−0.00	−0.00	−0.00	0.01	0.01	**0.03**
p	0.07	0.06	−0.02	**−0.07**	−0.02	−0.02	0.00	0.02	−0.04	−0.03	0.00	0.03

	Seasons				Year
	XII–II	III–V	VI–VIII	IX–XI	I–XII
V_W	**0.05**	0.02	0.00	−0.00	**0.02**
V_N	0.02	−0.00	−0.00	0.01	0.00
p	0.05	−0.03	0.00	−0.02	−0.00

The period analysed is characterised by a significant increase of frequency of inflow of the air masses from the western sector (mainly from the SW-W segment), Tables 8 and 9. This increase was most pronounced in the winter season. When, however, we take into consideration the character of the pressure configuration, we can note that the statistically significant positive trends concerned mainly the inflow of the air masses from the West in the anti-cyclonal situations. It is also worth noting that an increase of frequency of the high pressure configurations took place in the years 1951–2000, irrespective of the direction of inflow of the air masses in all the seasons of the year except for autumn. The decrease of the magnitude of cloudiness in Central Europe as the consequence of intensification of the high pressure settings was indicated by, for instance, A. Henderson-Sellers (1986) and D. Matuszko (1998). From among the types of circulation considered there has been a radical decrease of frequency of southern and south-eastern cyclonal circulation in the winter season (and in the year), this observation being conform with the results concerning the variability of the circulation conditions, based on different kinds of classifications (Degirmendžić et al., 2000). Low frequency of these types of circulation is conducive to the appearance of the periods of good weather (see Fig. 6).

Table 9 Linear trend coefficients of changes of the frequency of selected makro-types of circulation after Lityński classification [number of days/year] in years 1951–2000 (coefficients significant at the 0.05 are bolded)

Circulation types	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
W+SW	0.10	**0.14**	0.12	−0.04	0.03	0.01	−0.03	−0.04	−0.03	0.03	0.06	0.05
W_A+SW_A	**0.07**	0.06	0.05	−0.02	0.02	0.02	0.00	0.02	0.00	0.01	0.04	0.02
E+NE	−0.05	−0.08	−0.06	−0.01	−0.05	−0.02	0.03	0.01	0.01	−0.07	−0.01	−0.01
E_C+NE_C	−0.01	−0.02	−0.02	−0.01	−0.02	−0.01	−0.03	−0.02	0.01	−0.02	0.01	−0.01

Circulation types	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
S	−0.07	−0.05	0.01	0.01	0.02	−0.02	0.02	−0.02	0.01	0.06	−0.01	−0.05
S_C	−0.03	**−0.05**	−0.02	0.02	0.00	−0.01	0.00	−0.03	−0.01	0.02	−0.01	−0.04
A	0.09	0.08	0.00	−0.06	0.07	−0.03	0.07	**0.13**	−0.04	−0.04	0.00	0.04

Circulation types	Seasons				Year
	XII–II	III–V	VI–VIII	IX–XI	I–XII
W+SW	**0.29**	0.11	−0.06	0.06	**0.40**
W_A+SW_A	**0.14**	0.04	0.03	0.05	**0.27**
E+NE	−0.17	−0.12	0.02	−0.07	−0.30
E_C+NE_C	−0.04	−0.05	−0.05	0.01	−0.13
S	−0.07	0.03	−0.06	0.07	−0.07
S_C	**−0.10**	0.01	−0.04	0.01	−0.14
A	0.19	0.02	0.16	−0.08	0.30

The identified trends in changes of cloudiness in Poland correspond, as well, to the differentiation of the changes of other climate elements in particular months. And so, for instance, there has been a significant increase of total radiation and temperature in Poland in May, accompanied by the decrease of precipitation, while in June and September – a negative trend of radiation and temperature, and a positive one of precipitation (Bogdańska, Podgorocki, 2000; Kożuchowski, Żmudzka, 2001; Żmudzka, 2002).

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E-mail: elwiraz@uw.edu.pl

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