Chapter 3

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Solar Conditions of North-Eastern Poland in 1981-2005

Scope and methods of the study

Solar radiation is the basic source of energy required for physical, chemical and biological processes on the Earth, as well as being the main climate-forming factor.

One of the meteorological elements reflecting solar conditions is the intensity of solar radiation. This unusually important element is a frequent subject of research [BRYŚ 1994, BRYŚ 2002a and b, KUCZMARSKA, PASZYŃSKI 1964, OBRĘBSKA-STARKLOWA *et al.* 2006, PODSAWCZYŃSKA-BIENIAS 2000/2001], but unfortunately, it is quite rarely measured at meteorological stations.

Measurable parameters of energy or duration of its supply include intensity of solar radiation, insolation and cloudiness. Insolation is the meteorological factor which reflects the degree to which the clouds covering the sky reduce the time of the solar radiation supply. An interest in alternative sources of energy supply has encouraged a more in-depth analysis of this element. MORAWSKA-HORAWSKA [1984], analysing the years of 1891-1980 in Kraków, considered an increase in air pollution to be the likely main cause of the decline in insulation in the latter years of that period, following a simultaneous decline in cloudiness. KOŹMIŃSKI and MICHALSKA [2004] characterized insolation in Poland for 1966-2000, and using the cluster analysis they distinguished five regions with the highest sums of insolation. The assessment of the extreme values and the analysis of tendencies of changes in the period in which extreme values of the sums of insolation occurred, carried out by BINIAK and ŻYROMSKI [2006] in 1962-2002 for Wrocław made it possible to establish a significant relation describing a change of this period in terms of monthly values. A determined trend was of a declining character. Solar conditions, and more precisely, the value of insolation and its effect on the potato yield in the province of Olsztyn were subject to analysis in the research carried out by GRABOWSKI [1995].

Cloudiness is the basic element affecting the radiation balance, and thus the thermal balance of the Earth's surface. It results in a decrease in energy radiated

from the surface layer of soil, which affects a decrease in temperature fluctuations and the probability of ground frosts [HUTOROWICZ 1982], drought, excessive precipitation, floods, storms and hailstorms [ŻMUDZKA 2005b]. Unfortunately, this element, unlike thermal characteristics, is relatively rarely discussed. A more in-depth analysis concerning cloudiness, as well as the number of sunny and cloudy days for the area of Poland, was carried out by ŻMUDZKA [2003, 2004, 2005a and b]. The author established that the occurrence of both sunny and cloudy days was related to the distribution of pressure in a large spatial scale, which affected the type and the direction of air mass advection. However, the circulation processes over an area stretching from the North Atlantic to Central Europe and over South-Eastern Europe revealed the highest impact.

The research into cloudiness performed in the second half of the twentieth century in Poland made it possible to distinguish three periods: up to 1981, when an increase in cloudiness was observed, 1982-1992, when negative deviations from the mean value of cloudiness prevailed, and 1992-2000, when an increase in cloudiness was again recorded [ŻMUDZKA 2004]. In the research concerning the period of 1951-2000, ŻMUDZKA [2004] did not observe any anomalously cloudy years after 1980. 1982 was the sunniest year not only in the 25-year period under discussion, but also in the entire 50-year period. In the years of anomalously low cloudiness, anti-cyclonic situations occurred mainly with the southern inflow of air (in winter, autumn and summer), as well as with the northern one (in spring and summer), while anomalously high cloudiness was favoured by anticyclonic situations and an inflow of air from the north-eastern sector in spring and autumn and from the western sector in summer [ŻMUDZKA 2003, ŻMUDZKA 2004].

The area of north-eastern Poland [NOWICKA, GRABOWSKA 1989, GRABOWSKI 1996] is characterized by higher cloudiness than other areas of Poland. This is confirmed by the research covering the area of the entire country [ADAMCZYK, USTRNUL 2006]. Those authors observed in January, for most circulation types, a zonal distribution of cloudiness with the highest values in the Pomeranian Lake District and the Mazurian Lake District. The amount of cloudiness in summer was significantly much lower, and its distribution was more chaotic than in winter. As far as the time of the day is concerned, cloudless weather occurred most frequently in the evening and least often at noon, which in the warm period of the year was caused by the development of convection, and in the cold period by lingering inversion layers [MATUSZKO 1991].

Material and methods

Meteorological data concerning the cloudiness of the area of north-eastern Poland originated from five synoptic stations in Elbląg, Kętrzyn, Mikołajki, Olsztyn and Suwałki (Fig.1) and covered a period of 25 years (1981-2005).

Cloudiness was determined in a scale from 0 to 8, where 0 means cloudless sky and 8 the condition of total cloudiness. On this basis, the mean monthly and annual values of cloudiness were determined [HUTOROWICZ 1982, ŻMUDZKA 2003]. A description of sunny and cloudy days was prepared on the basis of mean daily

values of cloudiness. The number of sunny and cloudy days was also determined. A sunny day was considered to be a day on which the mean daily cloudiness in the scale of 0-8 did not exceed 2 while a cloudy day was considered to be a day on which exceeded 6 [GRABOWSKI 1996].

The variability of mean annual values of cloudiness, the number of sunny and cloudy days is presented and the trend of temporal variability of the examined elements has been determined [ŻMUDZKA 2005b]. The calculated multi-year means and values of standard deviation are used to indicate anomalous years.

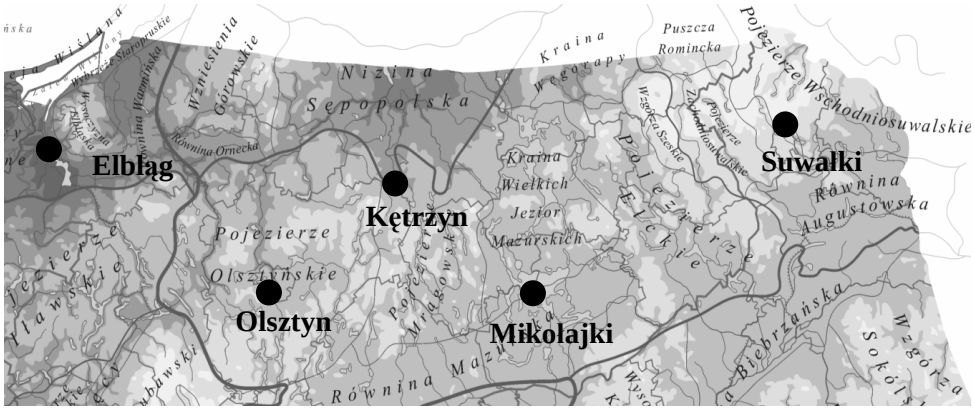


Fig. 1. Localisation of meteorologicla stacion of Institute of Meteorology and Water Managment

Discussion of results

The amount of cloudiness in the period under analysis ranged from 4.58 in Kętrzyn to 5.71 in Mikołajki; on average between 5.13 and 5.30 (Table 1). The mean cloudiness in the Mazurian Lake District in 1951-1960 varied from 5.2 to 5.6 [HUTOROWICZ 1982], and in 1951-1970, in the Warmia and Mazury area [NOWICKA, GRABOWSKA 1989], it fluctuated between 4.9 and 6.1. For another period, of 1971-1990, GRABOWSKI [1996] established more diversified values of cloudiness, amounting on average to 4.5 near Olsztyn and 5.4 in the area around Kętrzyn. The value of the standard deviation was similar for the entire region, and it ranged from 0.20 to 0.22. On the basis of the performed analyses, there were more years of anomalously high cloudiness observed (3-5) than years of anomalously low cloudiness (2-5).

The mean number of sunny days ranged from 37 in Mikołajki to 47 days in Suwałki (Fig. 2). The number of cloudy days changed on average from 149 in Kętrzyn to 161 in Mikołajki (Fig. 3), while the mean number of cloudy days in Poland amounted to 166 [ŻMUDZKA 2005], accounting for 45.4% days in a year. The earliest study concerning this element for the Mazurian Lake District was

prepared by HOHENDORF [1956] on the basis of data from 1881-1930. The area of the study also covered the following lake districts: Iława, Olsztyn, Giżycko and Suwałki, as well as the Augustów Plain. In the period under discussion, the mean cloudiness was 5.4, at a mean value for Poland of 5.1. This value was by 0.2 higher than in 1981-2005. The number of sunny days ranged from 28 to 45, and the cloudy days from 140 to 160. The studies prepared for the period of 1951-1965 revealed that the mean number of sunny days in Elbląg was 28.4, and cloudy days – 159.2, i.e. there were less of them than in the examined 25-year period [HUTOROWICZ 1982]. In 1951-1970, the number of sunny days ranged from 10 to 50, and of cloudy ones – from 130 to 196 [NOWICKA, GRABOWSKA 1989]. RADOMSKI [1968] for the period of 1951-1965 determined the mean cloudiness in Olsztyn at the level of 5.35, the number of sunny days at the level of 38, and cloudy days – 143. The mean number of sunny days in 1971-1990 [GRABOWSKI 1996] was 30, which was 11 days less, while the mean number of cloudy days was 150, five days less than the values established for the period under analysis. The mean number of sunny days in Poland in 1966-2000 was 22 days (5.9%) [ŻMUDZKA 2005b].

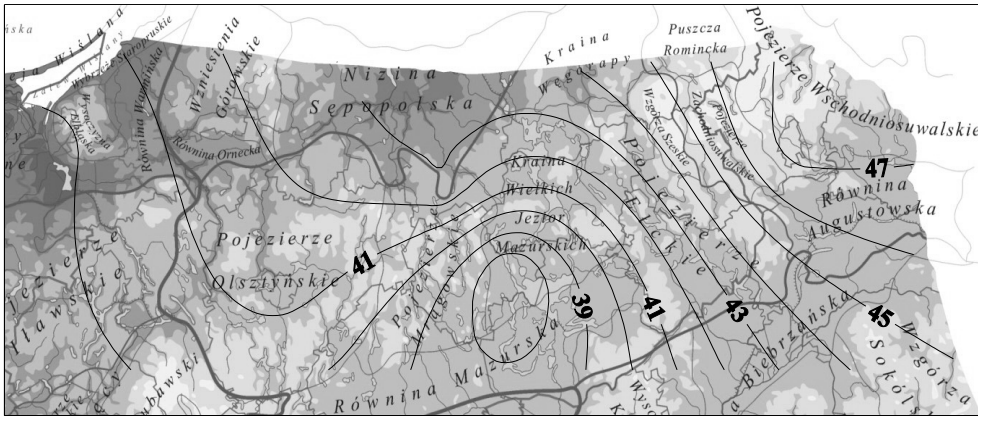


Fig. 2. Number of sunny days in the period of 1981 – 2005 in north-eastern Poland

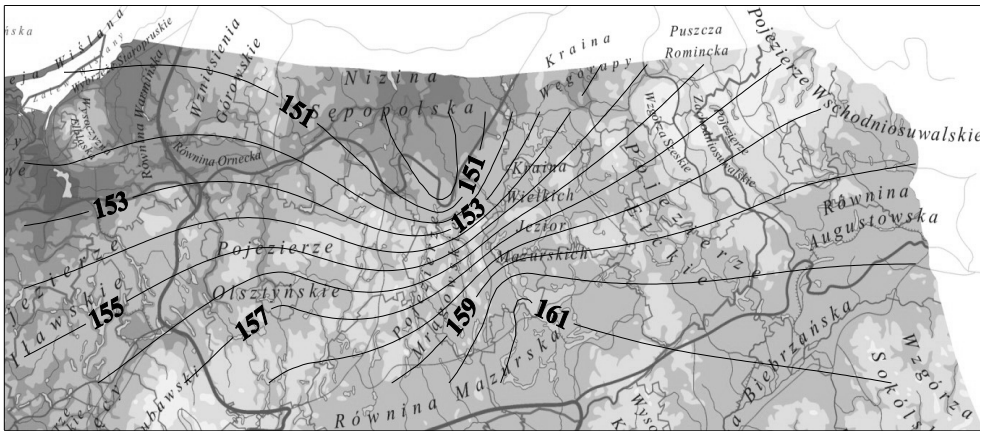


Fig. 3. Number of cloudy days in the period of 1981- 2005 in north-eastern Poland

Table 1

Essential characteristics of cloudiness in the period of 1981 – 2005 in north-eastern Poland

Cloudiness		Elbląg	Kętrzyn	Mikołajki	Olsztyn	Suwałki
Minimum		4.71	4.58	4.95	4.67	4.86
Mean		5.14	5.13	5.30	5.25	5.19
Maximum		5.55	5.49	5.71	5.60	5.59
σ		0.21	0.20	0.22	0.21	0.20
$\bar{x} - \sigma$		4.93	4.93	5.08	5.04	4.99
$\bar{x} + \sigma$		5.35	5.33	5.52	5.46	5.39
Anomalously low cloudiness	years	**1982** **1992**	**1982** 1983 1992	1995 2000 **2002** **2003** 2005	**1982** 2005	**2002** 2005
	frequency [%]	8	12	20	8	8
Anomalously high cloudiness	years	1981 **1985** 1997 **2001** **2004**	1994 1996 **1997** 2001 **2004**	1981 1984 **1985** 1993	1984 **1985** 1993 **2001** 2004	**1981** 1984 **1993**
	frequency [%]	20	20	16	20	12

^ **data in bold** – similar course of elements in all tables

Table 2

Essential characteristics of sunny days in the period of 1981 – 2005 in north-eastern Poland

Sunny days		Elbląg	Kętrzyn	Mikołajki	Olsztyn	Suwałki
σ		10	10	9	9	11
$\bar{x} - \sigma$		29	33	28	32	37
$\bar{x} + \sigma$		49	53	46	50	59
Anomalously low number of sunny days	years	**1985** 1997 **2001** **2004**	**1997** 2001 **2004**	1983 **1985** 2001	1985 1993 **2001** 2004	**1981** 1985 **1993** 2001
	frequency [%]	16	12	12	16	16
Anomalously high number of sunny days	years	**1982** **1992** 1996	**1982** 1986 1992 2002	1996 2000 **2002** **2003** 2005	1981 **1982** 2005	1986 1994 2000 **2002** 2005
	frequency [%]	12	16	20	12	20

Table 3

Essential characteristics of cloudy days in the period of 1981 – 2005 in north-eastern Poland

Cloudy days		Elbląg	Kętrzyn	Mikołajki	Olsztyn	Suwałki
σ		13	14	14	15	12
$\bar{x} - \sigma$		139	135	146	142	147
$\bar{x} + \sigma$		165	163	174	172	171
Anomalously low number of cloudy days	years	**1982** 1989 1990 **1992** 1999	**1982** 1999	1995 **2002** **2003**	**1982** 1989	1987 1988 1990 **2002** 2003
	frequency [%]	20	8	12	8	20
Anomalously high number of cloudy days	years	1981 1984 **1985** 1996 1998 **2001** **2004**	1994 1996 **1997** **2004**	1981 1984 **1985**	1984 1994 1996 **2001**	**1981** 1984 1985 **1993** 2004
	frequency [%]	28	16	12	16	20

A normal number of sunny days ranged from 28 in Mikołajki to 58 in Suwałki, i.e. from 8 to 16% of the total number of days in a year. The number of cloudy days varied between 135 (which is 37% days in a year) in Kętrzyn, and 175 (47% days in a year) in Mikołajki. The frequency of years with anomalously low cloudiness was lower (by 8 to 20%) than years with an anomalously high value of this element (between 12 and 20%). The frequency of years with an anomalous number of sunny days was similar both as regards positive and negative anomaly. There were more years, on average, with an anomalously high number of cloudy days than years with an anomalously low number of such days. They were observed most often in Elbląg (48% in total). On the basis of the calculations performed, it can be assessed that the best solar conditions occurred in Kętrzyn and the worst in Mikołajki. A comprehensive analysis of three elements (i.e. cloudiness, sunny days and cloudy days) made it possible to distinguish, years with anomalously favourable solar conditions for individual locations (i.e. characterized by low cloudiness, a low number of cloudy days and a high number of sunny days) (Tables 1, 2, 3), and years with anomalously unfavourable solar conditions (i.e. characterized by high cloudiness, a large number of cloudy days, and a small number of sunny days) (Tables 1, 2, 3). At least one such year occurred for each of the locations. Anomalously favourable solar conditions occurred, e.g. in 1982 in Elbląg, Kętrzyn and Olsztyn, and in 2002 in Olsztyn and Suwałki, while anomalously unfavourable solar conditions occurred, among others in 1985 in Elbląg and Mikołajki, in 2001 in Elbląg and Olsztyn, and in 2004 in Elbląg and Kętrzyn. The number of anomalous years was similar in all locations. In 2001, there were anomalously few sunny days in the entire region.

The number of sunny days varied from 19 in Mikołajki in 1985 (Fig. 6) to 75 in Kętrzyn in 1982 (Fig. 5). The minimum number of sunny days in Kętrzyn and Suwałki (Fig. 8) was 10 days higher as compared to the values recorded in Mikołajki, and the maximum number was even 19 days higher. The lowest number of cloudy days was recorded in Olsztyn (122) in 1982, and the highest was in Mikołajki (193) in 1984. Taking into account the values of standard deviation, the course of sunny days was less varied than that of cloudy days. The determined trends of changes indicated a decreasing number of sunny days in Olsztyn (Fig. 7), Kętrzyn (Fig. 5) and Elbląg (Fig. 4), and a growing trend of cloudy days. A different situation was recorded in Suwałki and Mikołajki, where the number of sunny days grew and the number of cloudy days decreased. Statistically significant tendencies were observed only in Mikołajki, it was also there that the coefficient of the growth rate revealed the highest absolute value (a = 0.7062 for sunny days and a = -1.0715 for cloudy days).

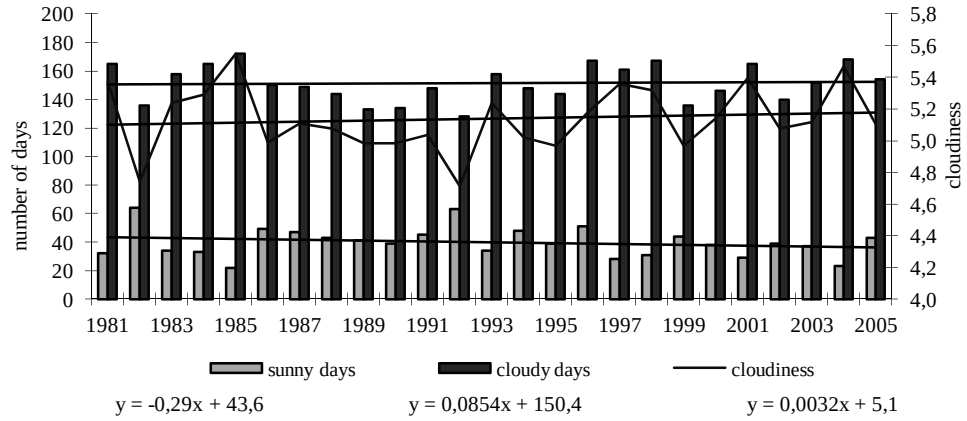


Fig. 4. Solar condition in Elbląg in the period of 1981-2005

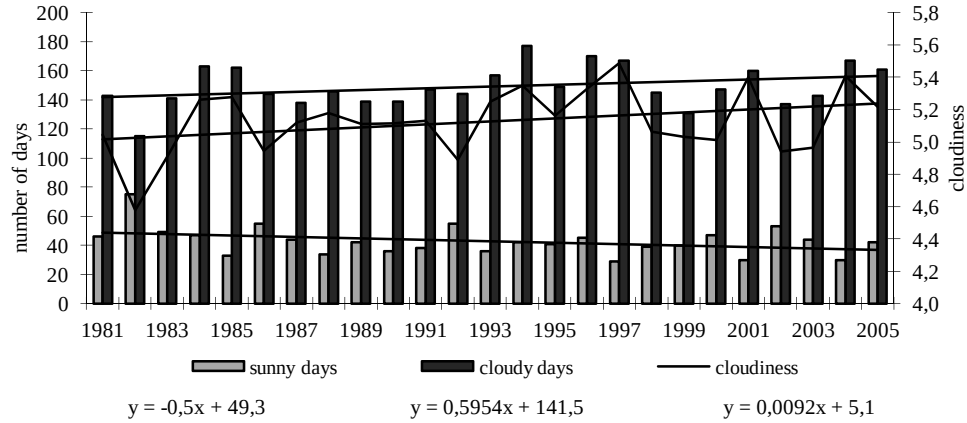
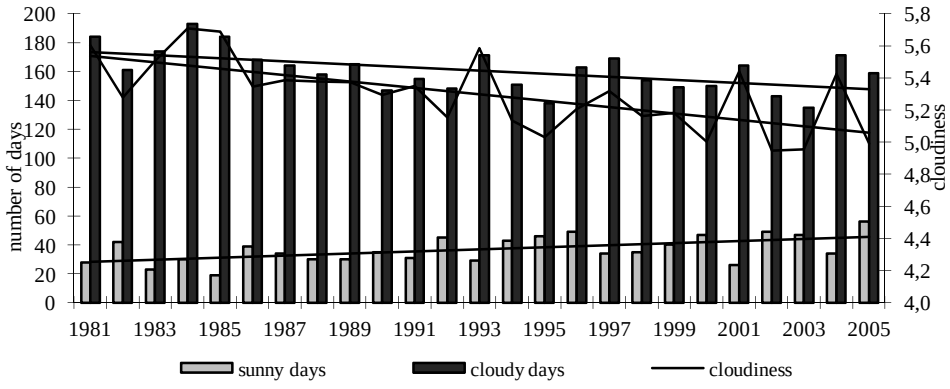


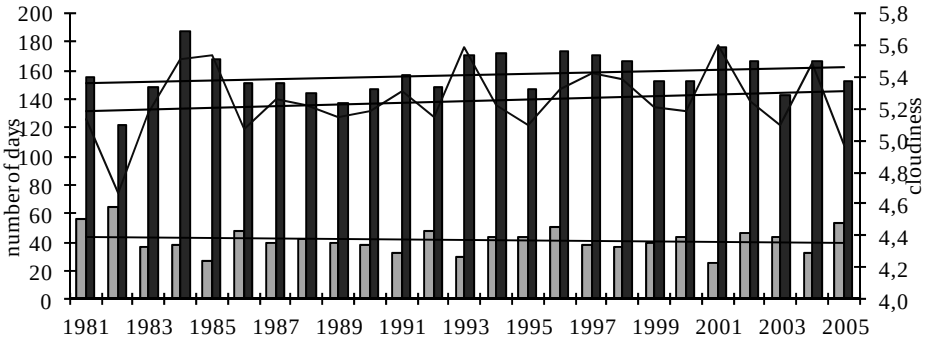
Fig. 5. Solar condition in Kętrzyn in the period of 1981-2005



y = 0,7062x + 27,6* y = -1,0715x + 174,7* y = -0,0199x + 5,6*

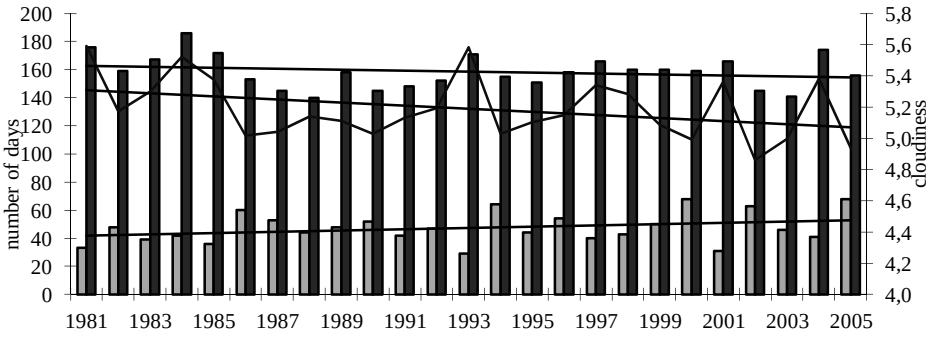
* – statistically significant with α = 0,05 – applies to all tables and

Fig. 6. Solar condition in Mikołajki in the period of 1981-2005



y = -0,2115x + 44,2 y = 0,4877x + 150,7 y = 0,0053x + 5,2

Fig. 7. Solar condition in Olsztyn in the period of 1981-2005



y = 0,4538x + 41,5 y = -0,3385x + 162,9 y = -0,0099x + 5,3

Fig. 8. Solar condition in Suwałki in the period of 1981-2005

As follows from the research, the cloudiness was most varied in individual years, while it had a similar course in the locations under analysis. The decreasing tendency of cloudiness in Mikołajki demonstrated the highest rate (a = -0.020) and it was statistically significant.

The mean number of sunny days in individual months was the lowest in Mikołajki and the highest in Suwałki. Mean monthly values of cloudiness expressed on an eight point scale did not reveal any large differences between individual locations. In specific months, they ranged from 4.0-4.3 in August to 6.2-6.5 in December. At all stations, the lowest cloudiness was recorded in July and August and the highest was in November, December and January. The pattern of monthly means demonstrated a growth of cloudiness in June (Fig. 9). A similar course of monthly mean cloudiness was recorded in Kraków in the last century [MATUSZKO 2003]. On the other hand, in the period of 1951-1965 in Elbląg, the maximum cloudiness occurred in November when it amounted on average to 6.7 [HUTOROWICZ 1982].

Taking into consideration circulation conditions, ŻMUDZKA [2005B] claimed that in the last 20-30 years of the 20th century, the value of cloudiness over Poland was slightly and insignificantly reduced. However, in winter, during the period of increased cyclonic activity resulting in bays of low pressure or low centres lingering over the Central Europe, conditions for the development of high cloudiness are created. A similar distribution of pressure also occurred in the period of cloudy days in summer. Anomalously sunny periods occurred generally in anticyclonic circulation, and anomalously cloudy periods with cyclonic circulation. In the opinion of the author, the region with the highest cloudiness was the central part of the Pomeranian Lake District, and not as in previous years, the north-eastern area of Poland [ŻMUDZKA 2003].

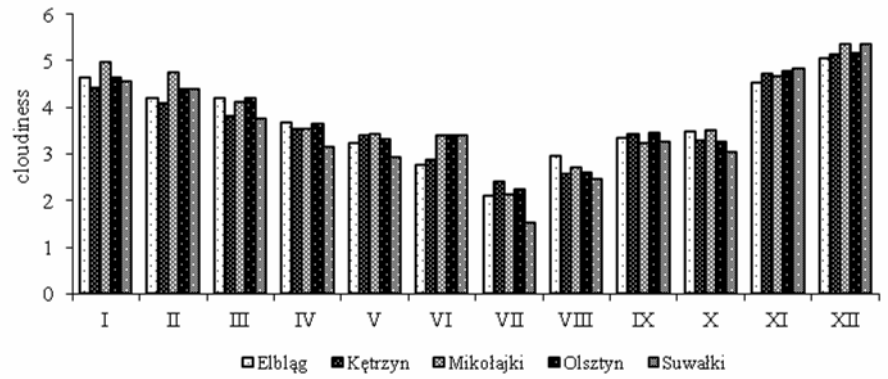


Fig. 9. Distribution of monthly means cloudiness in the period of 1981-2005 in north-eastern Poland

The number of sunny days in north-eastern Poland ranged from 1-2 in November and December, to 5-6 in May and August (Fig. 10), and it was similar to the pattern of means for the area of Poland in 1966-2000. ŻMUDZKA [2005b] reports that in May and August there occurred, on average, up to three sunny days more

than the average value for Poland. The June minimum was at the level of 2.5-3.5 days. The number of sunny days varied from 5% in December, to 17% in May and August, and the average number of sunny days accounted for 11% days a year.

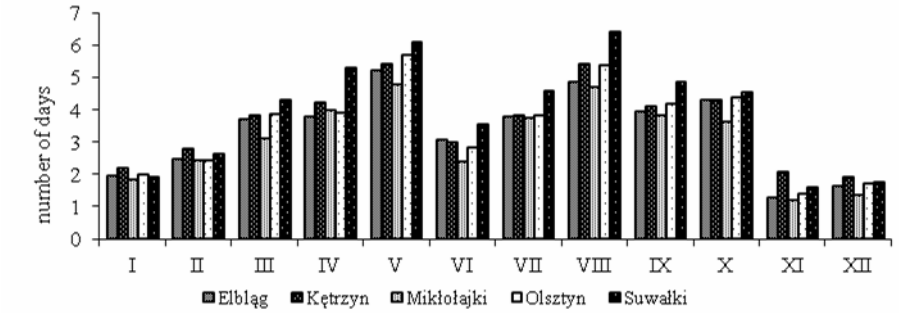


Fig. 10. Distribution of monthly means number of sunny days in the period of 1981-2005 in north-eastern Poland

The variability of the number of cloudy days was much higher than those of sunny days. The lowest number of cloudy days was recorded in August, from 6 to 7 (21% days in a month), and the highest from 20 to 22 in December, which accounted for 69% days in a month. On an annual scale, the average share of cloudy days in the region was 43% (Fig. 11). The average number of cloudy days in north-eastern Poland in comparison to the data included in "Climatic atlas...." [1990] for 1951-1970 was higher only in June and September, and lower in other months of the vegetative period.

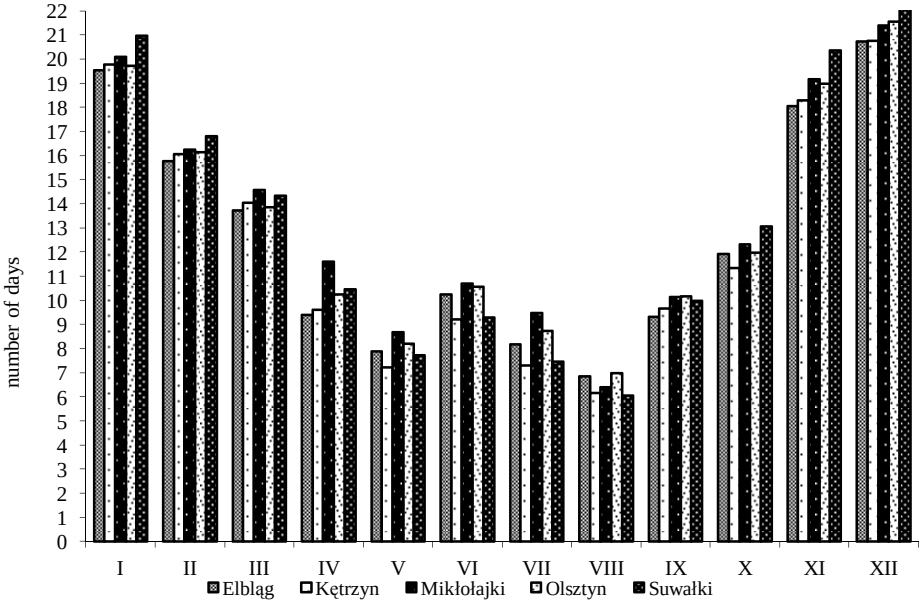


Fig. 11. Distribution of monthly means number of cloudy days in the period of 1981-2005 in north- eastern Poland

Conclusions

1. Solar conditions represented by the values of cloudiness and the number of sunny and cloudy days, varied from the most favourable in Suwałki and Kętrzyn, to the least favourable in the area around Mikołajki. A growing tendency of the number of sunny days was statistically significant only in Mikołajki.
2. The mean number of sunny days ranged from 37 in Mikołajki to 47 days in Suwałki, while the mean number of cloudy days varied from 149 in Kętrzyn to 161 in Mikołajki.The mean monthly number of sunny days in north-eastern Poland ran from 1-2 in November and December, to 5-6 in May and August, while the number of cloudy days varied from 6-7 in August to 20-22 in December.
3. The value of cloudiness in the period under analysis fluctuated, on average, between 5.13 and 5.30.A comprehensive analysis of cloudiness and the number of sunny and cloudy days made it possible to estimate that the best solar conditions occurred in Kętrzyn, and the worst in Mikołajki.

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