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THE AIR TEMPERATURE VARIATIONS IN SZCZECIN AND ITS DEPENDENCE ON THE NORTH ATLANTIC OSCILLATION (NAO)

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Abstract

The basic features of annual course of air temperature (differentiated between the particular months and seasons) along with air temperature variations during the period between 1950 and 2009 together with the trends of changes are presented. In addition the dependence of air temperature on North Atlantic Oscillation (NAO) is exhibited.

Key words: air temperature, changeability, NAO index, Szczecin

INTRODUCTION

In the recent years, the problem of trends in changes and fluctuations of separate meteorological elements including air temperatures and the sum of precipitation has been widely discussed (Marsz 1999a, 1999b; Marsz and Styszyńska 2002a, 2002b). The problem has been considered as depending on different temporal and spatial scales. The aim of this research is to assess the potential results of changes in the environment and to explain the causes of those changes considering both the anthropogenic and natural factors. In the report of the Intergovernmental Panel on Climate Change (IPCC) from 2007 it was stated that most of the changes observed in the last 50 years should be ascribed to human activity. In 1900-2004 the observed temperature changes on Earth amounted to about 0.4-0.8°C. In Poland, in the second half of the 20th century, the average temperature rose by about 0.9ºC. The predominant part of this warming falls on 80's and 90's (Fortuniak et al. 2001) Also Filipiak (2004) confirms the occurrence of strong positive trend in temperature rise in a year and during winter and spring on the coast in the second half of the 20th century. Kir-

schenstein and Baranowski (2008) obtained similar results in Słupsk. Between 1950 and 2007 the increase in the air temperatures amounted to about 1.3ºC. In Słupsk the increase in air temperatures was the highest in winter and spring. Kirschenstein and Baranowski (2009) also analyzed the temperature change in Koszalin between 1861 and 2007 and found out that, within the period of the 147 years analyzed, the increase of the average air temperature was approximately 1.5ºC. December is the month in which the temperature in Koszalin increased by 2.2ºC, while in terms of year seasons it is spring, autumn and winter (increase by 1.7ºC).
The aim of this work is to analyze the changeability of thermal conditions in Szczecin, considering the changes determined with a coefficient of linear trends, and to investigate the relationship between North Atlantic Oscillation and the air temperature. According to Boryczka and Stopa-Boryczka (2007), there is a great dependency of thermal field on North Atlantic Oscillation in Europe during winter. The authors have found out that between 1825 and 2000 the air temperature in Europe was usually positively correlated with the changes in NAO. Similarly, Panfil and Dragańska (2004), after analyzing correlations between NAO and thermal conditions in northeastern Poland, found out there was a close relationship between changes in circulation and the temperature (especially from December to March). Also Kirschenstein and Baranowski (2009), when analyzing the relationships between the NAO circulatory changes and the air temperatures in Koszalin found out that, undoubtedly, the atmospheric circulation determined with the NAO index correlates closely with the air temperature between December and March. The air temperature shows a considerable phase coincidence: a positive NAO phase is accompanied by a rise in the monthly temperature average, while a negative NAO phase is accompanied by a decrease in the monthly temperature average. In January the phase coincidence is 58.5%, in February it is 73.5%, in March 63.3% and in December 70.1%. It was also observed that there appears a great negative phase coincidence in December (91.0%) and in February (92.5%), as well as a positive phase coincidence in March (93.1%) and December (75.9%). The bases on which the air temperature in Szczecin are investigated consider monthly measuring data from 1950-1970 and twenty-four-hour measuring data from 1971-2009. Szczecin is situated in the West Pomeranian Region. According to W. Okołowicz's classification (1978), Szczecin belongs to the region where climate is shaped by the influence of the Baltic Sea and the Atlantic Ocean, as well as by the local Szczecin River-Basin atmospheric circulation. In this area the air masses originated from the ocean, over the sea, and over the continent exchange their properties. This results in a great changeability of weather conditions.

AIR TEMPERATURE

The average annual air temperature in Szczecin amounts to 8.2ºC and it fluctuated between 6.1ºC in 1987 to 10.3ºC in 2007 (Fig. 1). The coldest 20 years were between 1969 and 1988. In this period, excluding the years from 1975 to 1983, the average year temperature was considerably lower from that of the other years. Between 1989 and 1996 the average annual temperature slowly increased, however in 1991, 1993, 1995, and 1996, the annual temperature was lower (Fig. 1).

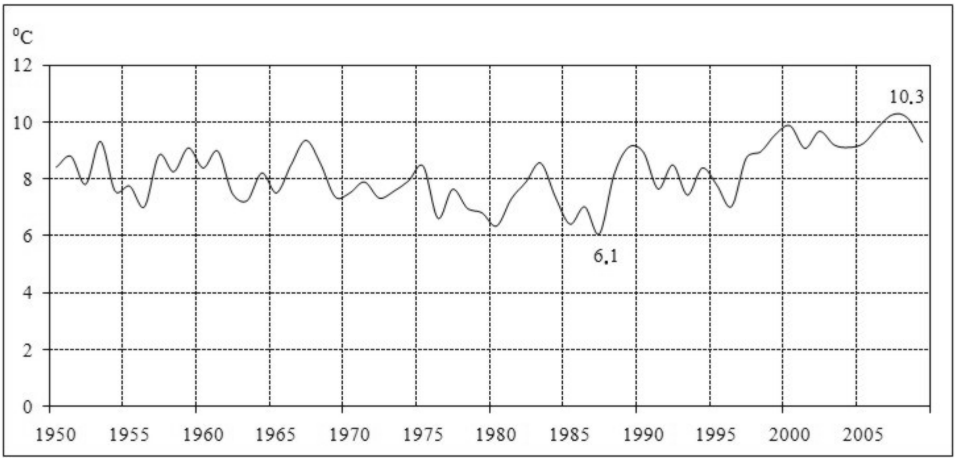


Fig. 1. Average annual air temperature (1950-2009)

After 1997 there was a rapid increase in temperature. Since 1998 the average annual temperature exceeded 9ºC, and between 2007-2008 it reached the level of 10ºC and even more. Average monthly air temperatures (Fig. 2) and average monthly, seasonal and five-year air temperature periods were studied in order to determine which of months had impact on an increase or decrease of the average annual air temperature (Table 1a-b). The collected data show that during the colder periods between 1969-1988 the fall of temperature was clearly visible in all the months. A similar situation took place after 1990. The increase of the average monthly air temperature was a clear consequence of the air temperature increase in almost all the months, especially winter ones. A special attention should be given to the period between 1950 and 1969. Although the average annual air temperature which was calculated for the five-year long period was the same as the average for a longer period, with the hottest five-year period between 1950-1954, it is worth to notice that there were very warm autumns (1950-1969) and very warm summer (with the exclusion of the five-year period between 1960-1964). The temperatures of September and October, and to some degree those of November between 1950-1964, had the main impact on the high autumn temperatures. Furthermore, the warm months between 1950-1969 were April and June.
July was the warmest month in Szczecin (17.6ºC), (Table 2). In particular years, the maximum temperature appeared also in August (25.0% of all the years), as well as in June (18.3%), and in 1993 it was in May (15.5ºC). January was the coldest month (-1.0ºC), (Table 2). The average monthly minimum appeared also in February (31.6%), in December (25.0% of all the years), in March (1.7%) and in November (1.7%). In the period studied, the average air temperature of winter months was over zero in 13 years. The years 2007 and 2008 were especially warm (Fig. 2). Moreover, in 5 years the average temperatures were sub-zero in all the winter months (years 1963, 1968, 1978, 1884, 1996), and in 1969 and 1976 the average monthly temperatures were sub zero from December till March. Ten years are characterized by sub zero temperatures in Szczecin, with the lowest of -3.0ºC in 1987 (Fig. 2). Frequent occurrence of maximum temperature in August and minimum in February seems to

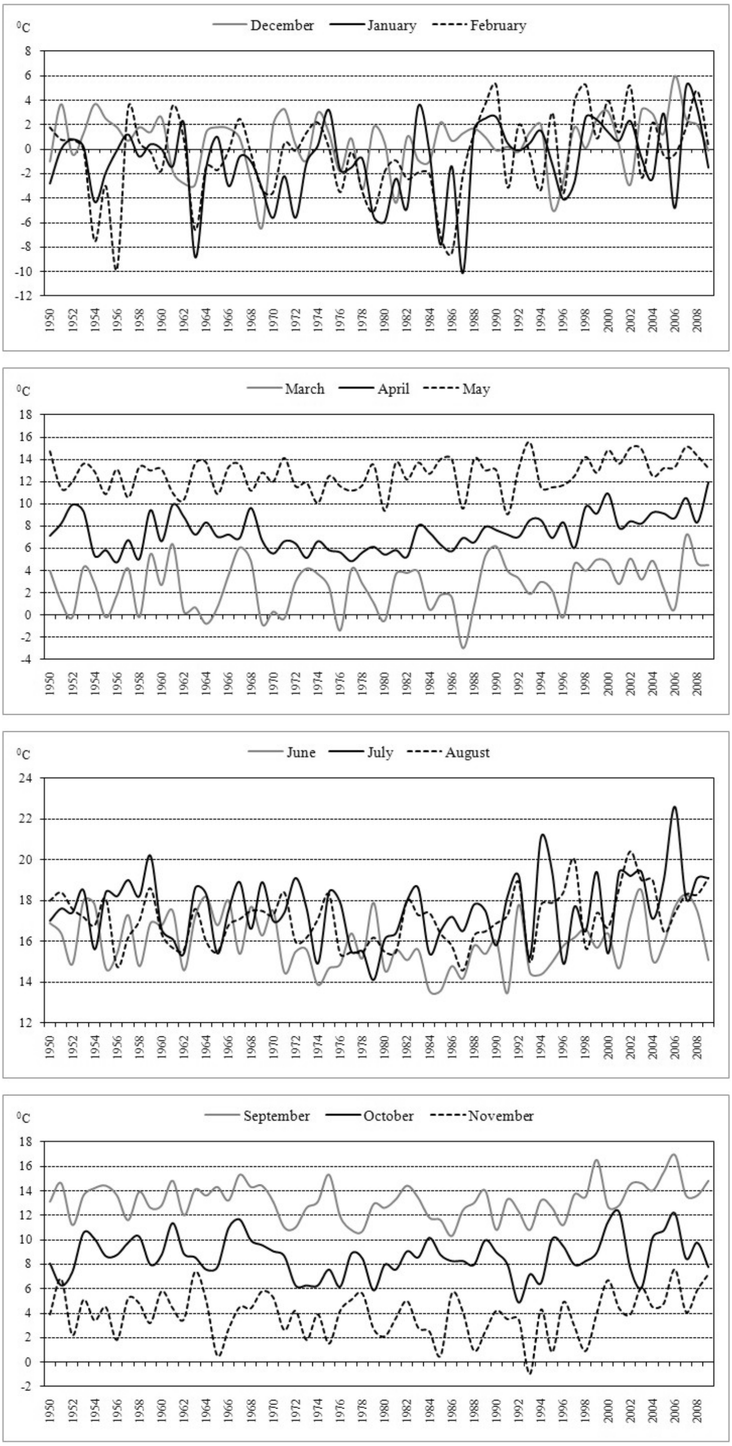


Fig. 2. Average monthly air temperature (1950-2009)

Table 1a

Average air temperature in five-year periods (1950-2009)

Year	January	February	March	April	May	June	July	August	Septem-ber	October	Novem-ber	Decem-ber
1950-1954	-1.2	-0.8	2.4	8.0	12.9	16.8	17.2	17.6	13.3	8.5	4.3	1.5
1955-1959	-0.2	-1.8	2.2	6.3	12.2	15.8	18.8	16.9	13.2	9.1	3.9	1.6
1960-1964	-1.9	-1.1	1.9	8.2	12.4	16.9	17.0	16.3	13.5	9.1	5.2	-0.7
1965-1969	-1.4	-0.6	2.9	7.5	12.3	16.8	17.5	16.9	14.3	10.0	3.6	-0.9
1970-1974	-2.8	0.1	2.2	6.0	11.9	15.4	17.2	17.0	12.2	7.3	3.6	1.6
1975-1979	-13	-2.4	1.8	5.6	12.1	15.8	16.3	16.2	12.3	7.4	3.8	-0.2
1980-1984	-2.0	-1.8	2.3	6.4	12.3	14.9	16.9	16.7	13.1	8.7	3.2	-1.0
1985-1989	-3.0	-2.5	1.3	6.7	12.9	14.8	17.1	15.9	12.3	8.7	2.7	1.4
1990-1994	1.0	0.1	3.7	7.8	12.5	15.2	17.9	17.2	12.1	7.1	2.9	0.7
1995-1999	-0.6	1.9	3.1	8.0	12.5	15.9	17.6	17.9	13.5	9.0	2.7	-0.6
2000-2004	0.3	2.1	4.1	8.9	14.2	16.4	18.1	18.7	13.7	9.6	5.1	1.3
2005-2009	1.0	1.2	3.9	9.7	13.8	16.9	19.6	17.9	14.9	9.8	5.9	2.3
Mean 1950-2009	**-1.0**	**-0.5**	**2.7**	**7.4**	**12.7**	**16.0**	**17.6**	**17.1**	**13.2**	**8.7**	**3.9**	**0.6**

Table 1b
Average air temperature in five-year periods (1950-2009)

Year	Spring	Summer	Autumn	Winter	Year
1950-1954	7.8	17.2	8.7	-0.2	8.4
1955-1959	6.9	17.2	8.7	-0.1	8.2
1960-1964	7.5	16.7	9.2	-1.2	8.0
1965-1969	7.6	17.1	9.3	-1.0	8.2
1970-1974	6.7	16.5	7.7	-0.4	7.6
1975-1979	6.5	16.1	7.9	-1.3	7.3
1980-1984	7.0	16.2	8.3	-1.6	7.5
1985-1989	7.0	15.9	7.9	-1.4	7.3
1990-1994	8.0	16.8	7.4	0.6	8.2
1995-1999	7.9	17.1	8.4	0.2	8.4
2000-2004	9.1	17.7	9.5	1.2	9.4
2005-2009	9.1	18.1	10.2	1.5	9.7
Mean 1950-2009	**7.6**	**16.9**	**8.6**	**-0.3**	**8.2**

prove that there appears a time shift of one month. This feature is typical of the areas located within a short distance from the Baltic coastline, which was suggested by Paszyński and Niedźwiedź (1991). Kirschenstein and Baranowski (2009) arrived at the same regularity when analyzing the temperature changeability in Koszalin. Additionally, Kirschenstein (2004), when analyzing precipitation in northern-western Poland, proved that in many stations located on the Northern littoral the maximum precipitation sum was shifted to August or happened more often in August than in July. This shift is connected with the cooling effect of the Baltic Sea, which causes not only the changes in annual air temperatures cloudiness or precipitation, but also other meteorological elements.

Amplitude is a very important characteristic of the annual air temperature course. It informs mostly about the range of monthly temperature fluctuation. The yearly amplitude, that is the difference between the monthly average of the warmest and the coldest month, was 20.7ºC and fluctuated from 15.3ºC (in 2000) to 28.0ºC (in 1956), (Fig. 3). Paszyński and Niedźwiedź (1991) claimed that the yearly temperature amplitudes that appear on the Southern part of the Baltic littoral are lower than those present in the low-land parts of Poland, where the amplitudes rise from West towards East from approximately 20ºC to 23ºC. The amplitudes present in the mountains turned out to be exceptionally low.

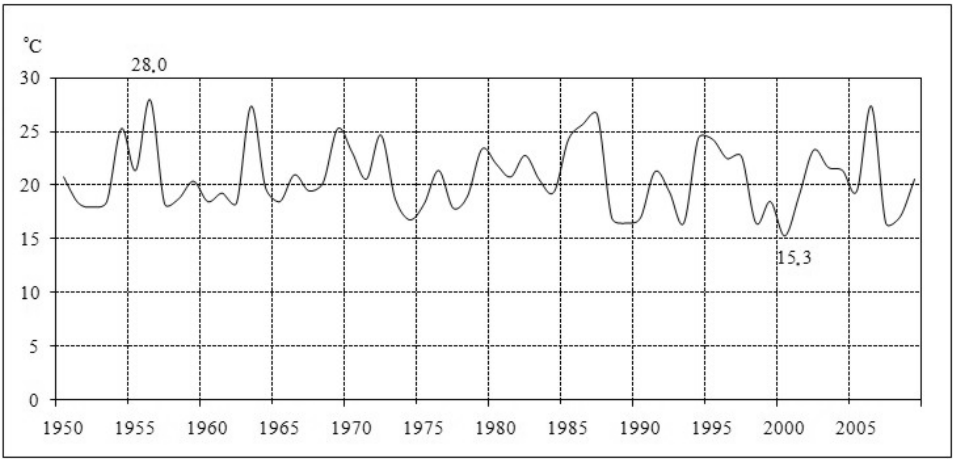


Fig. 3. Amplitude of average monthly air temperature (1950-2009)

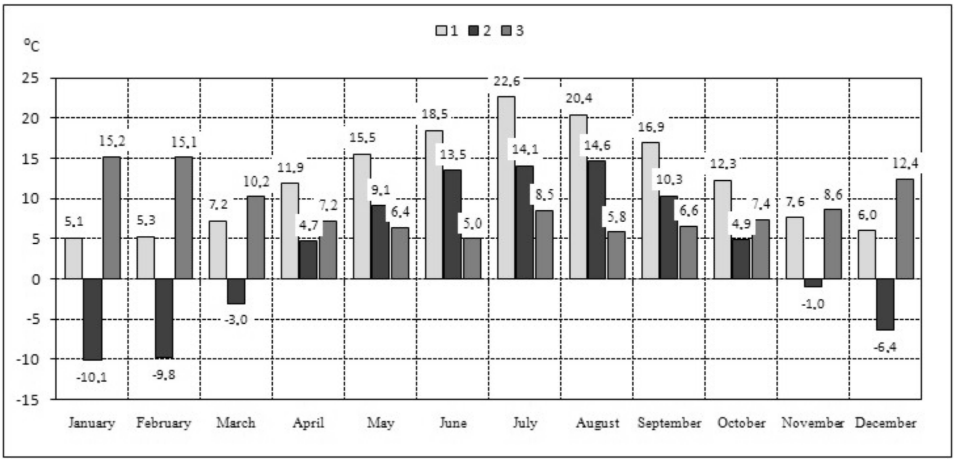


Fig. 4. The fluctuations of averaged monthly air temperature: the warmest month – 1, the coldest month – 2, amplitude of the warmest and the coldest month – 3 (1950-2009)

The Baltic Sea has a considerable influence on the low levels of air temperature amplitudes on the littorals. Its cooling influence in summer (especially at the beginning) and warming influence in winter makes the thermal contrast between outermost seasons less sharp. Whereas during transitory periods the Baltic Sea increases the thermal diversity between the spring and autumn, making the spring cooler and the autumn warmer.

It is also interesting to scale the fluctuation of average monthly air temperature (Fig. 4). Between the years of 1950-2009 the fluctuations between the warmest and the coldest month were noticeable in the winter months: in January the amplitude was 15.2ºC, in February 15.1ºC and in December 12.4ºC. The smallest fluctuations were observed in June (5.0ºC).

In the years 1971-2009 (24-hour air temperature means were plotted) the absolute

maximum temperature was 36.5ºC (31/07/1994), and the absolute minimum was -27.3ºC (14/01/1987).
The air temperature is characterized by considerable changeability between 1950-2009, which was shown in the analysis of the air temperature within the year seasons (Fig. 5). The summer was cool, with only 8 years where the average temperatures were higher than 18ºC. The warmest summer was in 2006 (19.2ºC) and the coolest in 1993 (14.9 ºC).

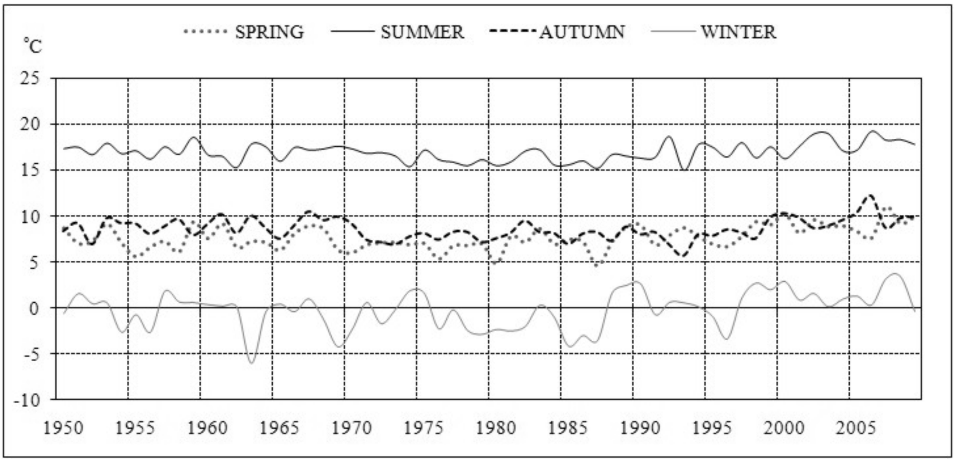


Fig. 5. Average air temperature in seasons (1950-2009)

Warm winters dominated between 1988-2008 (21 years), with only three years where the average temperature was subzero: 1991, 1995 and 1996. Warm winters also appeared in 1951-1953, 1957-1962, and 1974-1975. Cold winters appeared between 1976-1987. In this period only in 1983 the average temperature was above zero (0.2ºC). In addition cold winters appeared in 1954-1956 and 1963-1973, with the exclusion of 1965, 1967, and 1971. To sum up, the average temperature was above zero in 55.0% of years. The most freezing temperature -6.1ºC appeared in the winter of 1963, while the warmest in 2008: 3.4ºC (Fig. 5).
The autumn was very warm – in 100% of years it was warmer than the spring. The warmest autumn was in 2006 (12.2ºC), while the coolest was in 1993 (5.7ºC). On the other hand, the warmest summer was in 2006 (10.9ºC) and the coolest in 1993 (4.5ºC), (Fig. 5).
It was noted that the difference between the air temperatures in autumn and spring is a very important characteristic of the annual air temperature course (Fig. 6). In Szczecin, the 60 years average was 1.0°C and it fluctuated from 0.4ºC (2007) to 2.1ºC (1969). It indicates influences of the Baltic Sea and its warming in autumn and cooling in spring. According to Paszyński and Niedźwiedź (1991) the temperature difference between autumn and spring in central and southern Poland is constantly falling and is amounted to approximately 1°C.
Since the analysis shows that air temperature distribution in the studied period of many years is characterized by considerable fluctuations, a standard deviation has

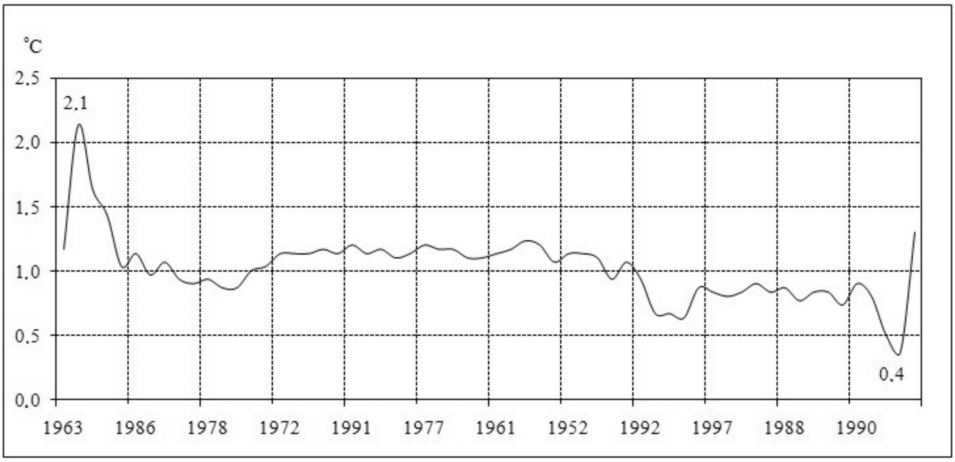


Fig. 6. Differences of air temperature in autumn (Sept-Nov) and spring (Mar-May)

been calculated which measures the level of air temperature deviation (monthly average, yearly average and seasonal average) from the 1950-2009 average value. The following conclusions can be drawn from the values of standard deviation (Table 2):

– in the yearly course deviation was observed from December to February (with the maximum occurring in February 3.4°C), the lowest deviation was observed in June and August (1.3°C);
– winter showed the highest deviation (2.0°C), while summer had the lowest (1.0°C).

The noticeable changes in the course of temperature records and its deviations from the six decades average are the result of thermal anomalies that occur with different frequency and intensity. The anomalies, impact atmospheric circulation that in turn is deciding of warm or cool air masses, both locally and regionally. In case of Poland the zonal circulation of moderate latitudes has a considerable influence on the air temperature distribution. Additionally, in Szczecin, the air temperature is under great influence the Baltic Sea, as well as the Szczecin Lagoon. The results show that the cool period of year is characterized by the greatest changeability in the six decades course. It seems that this period is under greater influence of fluctuating atmospheric circulation. In the warm period of the year, apart from the common atmospheric circulation, an important role is played by the solar energy fluxes and local weather conditions. At that time the radiation aspect and the developing local sea breeze circulation over the southern Baltic Sea and the Szczecin Lagoon have an influence on air temperature. In addition an important role is played by the physiographic diversity. Szczecin is located in the Odra valley in the close vicinity of the Lake Dąbie. The Wielecka Góra elevation (131 m above the sea level) is located on the outskirts of Szczecin. To the south of the city there is Bukowiec elevation (148.3 m above the sea level) on the Bukowe Wzgórza.

In order to determine the trends in air temperature fluctuations, the linear approximations were determined (Table 2). The air temperature in all of the year seasons rise, mainly in spring 0.0296ºC $year^{-1}$ and winter 0.0320ºC $year^{-1}$. The estimated values of

Table 2

Line trend factors and volume of air temperature increase in Szczecin (1950-2009)

Months and seasons	Mean 1950-2009 (ºC)	Standard deviation (ºC)	Line trend ºC $year^{-1}$	The increase of the temperature in the 60-year period (ºC)
January	-1.0	3.1	0.0349	2.1
February	-0.5	3.4	0.0517	3.1
March	2.7	2.2	0.0320	1.9
April	7.4	1.6	0.0331	2.0
May	12.7	1.5	0.0236	1.4
June	16.0	1.3	-0.0075	-0.5
July	17.6	1.6	0.0189	1.1
August	17.1	1.3	0.0214	1.3
September	13.2	1.4	0.0089	0.5
October	8.7	1.6	0.0048	0.3
November	3.9	1.8	0.0039	0.2
December	0.6	2.3	0.0095	0.6
Year	**8.2**	**1.0**	**0.0196**	**1.2**
Spring	7.6	1.3	0.0296	1.8
Summer	16.9	1.0	0.0109	0.7
Autumn	8.6	1.1	0.0059	0.4
Winter	-0.3	2.0	0.0320	1.9

the trends show clearly that, in the period of 60 years, a considerable grow in temperature took place in Szczecin: approximately 1.8ºC in spring and 1.9ºC in winter. A markedly lower increase took place in summer (0.0109ºC $year^{-1}$) and in autumn (0.0059ºC $year^{-1}$). The high temperature increase in winter is caused by a high increase of temperatures in January (0.0349ºC $year^{-1}$) and in February (0.0517ºC $year^{-1}$). The rising tendency was also present in all the spring months, with the biggest in April (0.0331ºC $year^{-1}$). The negative trend appeared only in June (-0.0075ºC $year^{-1}$), (Table 2). The above analysis shows that Szczecin experienced a considerable rise in air temperature in 1950-2009. February was the month with the highest average temperature increase, seasons – spring and winter. June was the month with the lowest trend, season – autumn. In the period studied 1950-2009 – the value of the coefficient of the linear trend was 0.0196ºC $year^{-1}$, which suggest a growth of the mean air temperature in Szczecin by 1.2ºC within the studied 60 years (Table 2).

NORTH ATLANTIC OSCILLATION VERSUS AIR TEMPERATURES

The atmospheric circulation is one of the major factors affecting the meteorological elements. In particular the North Atlantic Ocean determines the variability of air temperature and precipitation in the northwestern Poland. One of the methods that assess the influence of circulation on the weather conditions is the North Atlantic Oscillation (NAO) index. Its value depends on the difference of atmospheric pressure recorded on the sea level between two stations situated near the centers of the Icelandic Low and the Azores High. The NAO index have two distinct phases, which bring different weather conditions. In winter during the positive NAO phase (when Icelandic Low experience drop of pressure accompanied by a rise of pressure over the Azores High). Winters in Europe are warm and humid, because the air from the Atlantic Ocean moves from west towards east. However, during the negative NAO phase the decrease in pressure gradient leads to the drop in latitudinal airflow, which leads to drop in temperature in Europe (winters are dry and frosty).

There was an attempt to assess connections between NAO circulation changes and the air temperature. Monthly and seasonal values of NAO index (National Weather Service 2008) from years 1950-2009 were used in the research. The analysis shows that there is a large dependency of air temperature on NAO in winter (months Dec-Feb) and in March (see Fig. 7). Low correlation with the NAO index occurred from April to September and negative in June. In case of seasons, the correlation in winter amounted to (0.69), in autumn (0.25), spring (0.14), and it was negative in summer (-0.15).

High values of correlation coefficient in winter mean a close relation between the air temperature in Szczecin and NAO. Especially, in the cooler time of a year, the enhanced longitudinal pressure gradient between the Azores High and the Icelandic Low more heat from the Atlantic Ocean is carried to the atmosphere, and result in warmer winters.

The mutual dependence of air temperature on the NAO index is proved not only by the value of the correlation coefficient, but also by the graphs presenting the changes of the mean monthly air temperature and the NAO index in 1950-2009 (Fig. 8). The

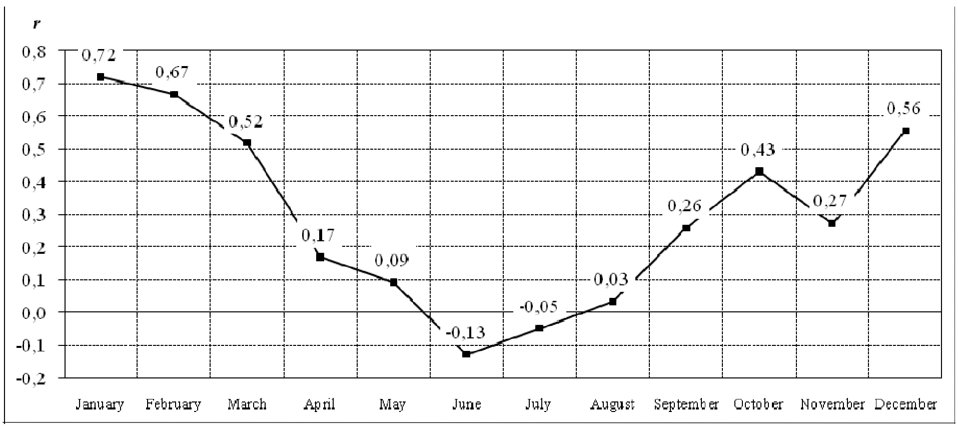


Fig. 7. Coeffcients of correlation (r) of air temperature and NAO index (1950-2009)

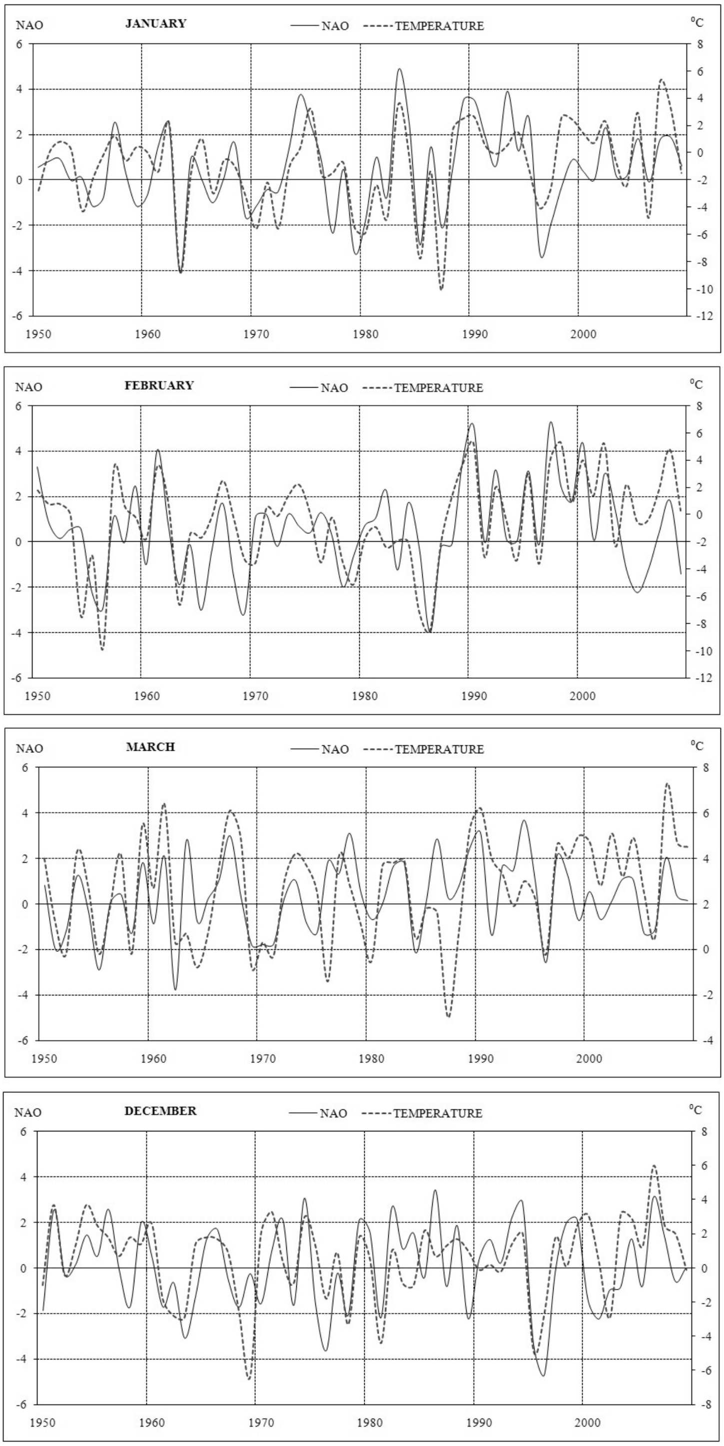
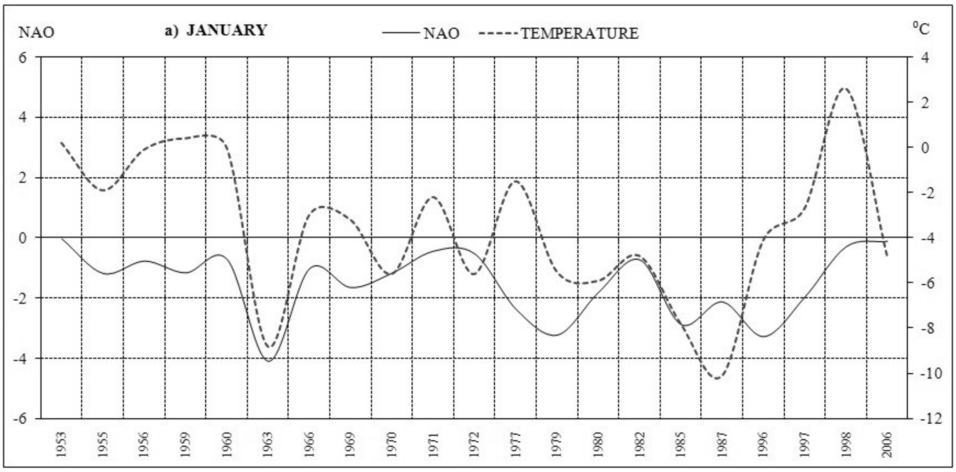


Fig. 8. Average monthly air temperature and NAO index (1950-2009)

graphs show that the distribution of both elements is similar. In the highlighted months (from December to March) a considerable phase coincidence (a positive NAO phase is accompanied by a rise in the mean monthly temperature, while a negative NAO phase is accompanied by decrease in the temperature). In case of both phases the coincidence amounts to respectively: in January 67.8%, in February 73.3%, in December 67.8%. Whereas taking into consideration the division into particular phases the following was observed: with the positive NAO phase the coincidence is 56.4% in January, 66.7% in February, 94.9% in March and 86.2% in December. When the phase is negative the coincidence is: 85.7% in January, 83.3% in February, in March only 38.1% and in December 50%. Taking into consideration the fact that in particular months the coincidence of positive and negative phase with the air temperature is varied, additional graphs of mean monthly temperature and the NAO index with the inclusion of the division into positive and negative NAO phase is presented in Fig. 9-12a, b.



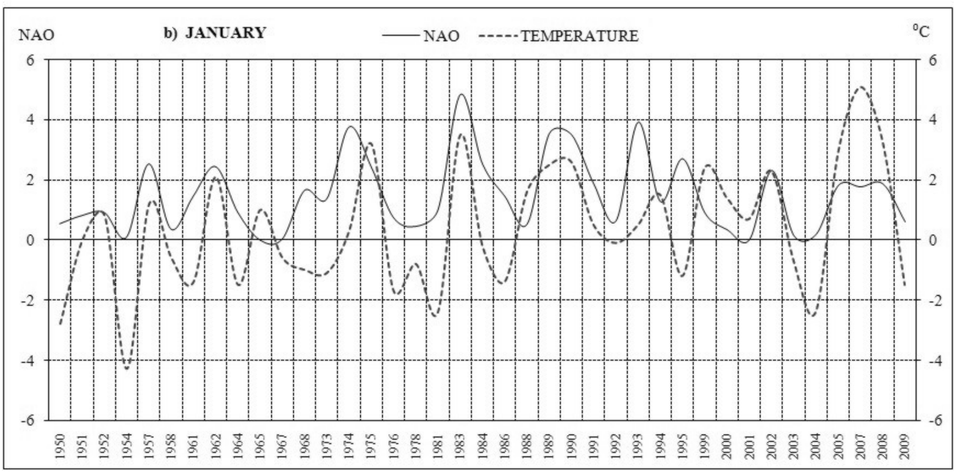


Fig. 9a-b. Mean monthly air temperature and NAO index: a – the positive phase of NAO, b – the negative phase of NAO

The graphs also prove that the appearance of the warmest and coldest months was closely connected to the appropriate NAO phases, e.g. when the NAO index reached maximum in January (4.82), the mean air temperature was 3.5°C (1983), whereas when the index was minimum (-4.09) the temperature was -8.8°C (1963). However, the warmest January (5.1°C in 2007) appeared with a lower NAO index of 1.77. Similarly, the coldest January (-10.1°C in 1987) appeared with the index of -2.12 (Fig. 9a-b).

Similar regularities appeared in the other months (February, March and December). Taking into consideration the extreme values of the NAO index the following relationships were discovered:

- in February – with the maximum index of 5.26 the average monthly temperature was 3.9°C (1997), with the minimum index of -4.02 the temperature was -8.5°C (1986), whereas the warmest February (5.3°C in 1998), had the index of 2.44 and a very warm February appeared in 1990 when the index

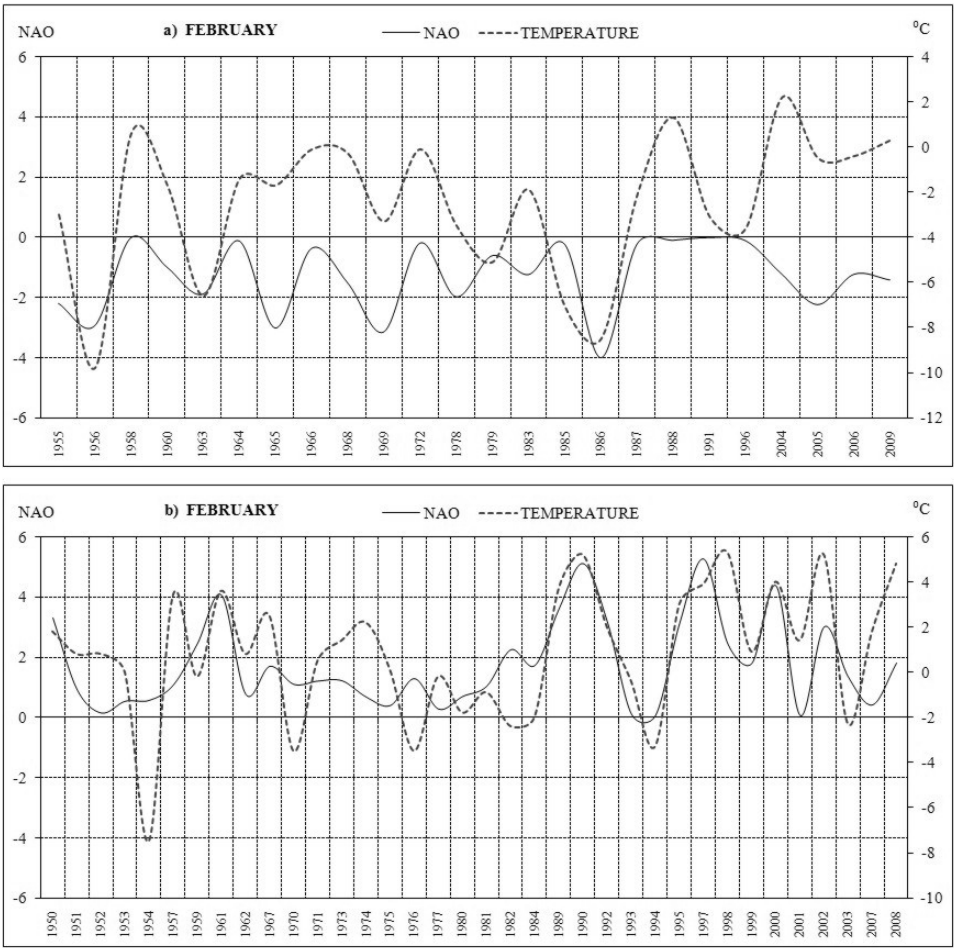


Fig. 10a-b. Mean monthly air temperature and NAO index: a – the positive phase of NAO, b – the negative phase of NAO

amounted to 5.11. The coldest February (-9.8°C in 1956) was with the index of -2.96 (Fig. 10a-b);

– in March, with maximum index 3.68, the average monthly temperature was 3.0°C (1994), with the minimum index -3.78 the temperature was 0.3°C (1962), whereas the warmest March (7.2°C in 2007), appeared with the index of 2.03, while the coldest was (-3.0°C in 1987) with the index of 0.29 (Fig. 11a-b);
– in December, with the maximum index of 3.42 the average monthly temperature reached 0.7°C (1986), with the minimum index -4.70 the temperature was -2.6°C (1996), whereas the warmest December (6.0°C in 2006), was with the index of 3.08, and the coldest (-6.4°C in 1969) with the index of -0.26 (Fig. 12a-b).

The analysis above shows that the atmospheric circulation determined by the NAO index correlates well with the air temperature from December to March. This is the result of an enhanced activity of barometric centres that are being shaped above

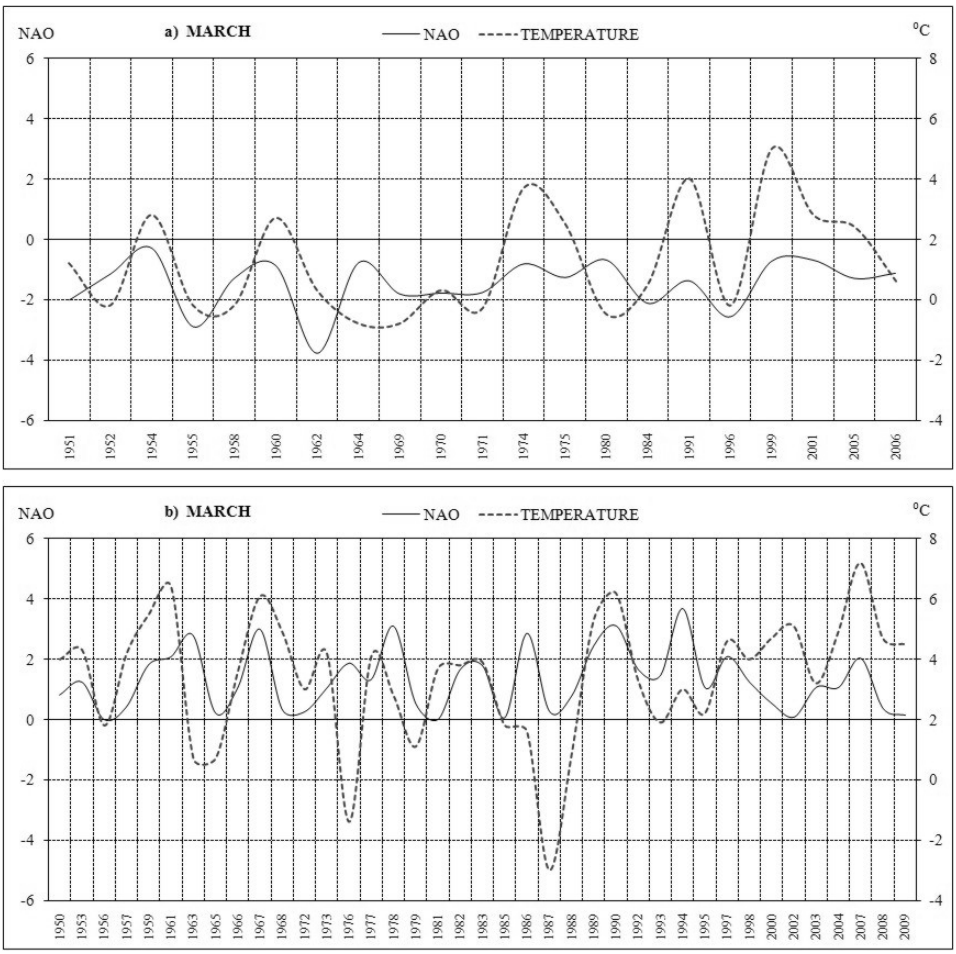


Fig. 11a-b. Mean monthly air temperature and NAO index: a – the positive phase of NAO, b – the negative phase of NAO

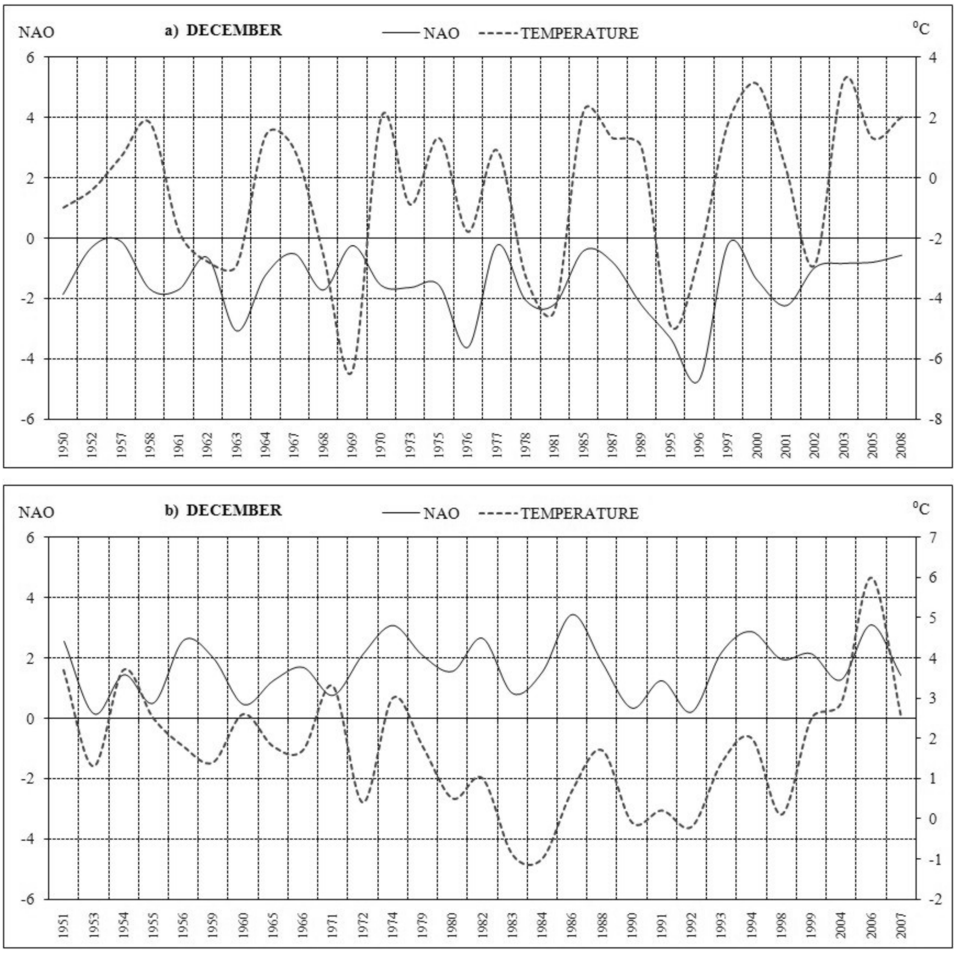


Fig. 12a-b. Mean monthly air temperature and NAO index: a – the positive phase of NAO, b – the negative phase of NAO

the Atlantic Ocean. In the warmer time of a year this influence decreases, especially during summer. However, that does not mean that at this time of a year there is no influence of the ocean on the distribution of air temperatures. In the warm time of a year the air coming from the Atlantic Ocean is cool, thus is often leading to cooler weather. Moreover, local determinants play a crucial role in this period. In case of southern Baltic coasts, the Baltic Sea has impact on moulding the temperature (with different intensity, but in all seasons). At the cold time of a year it causes a rise in temperature, in the warm time – a drop in temperature. In this way, the Baltic Sea diminishes the thermal contrast between seasons. The complexity of influence of factors on the distribution of temperature in Szczecin causes a great changeability, both in annual and many years' course.

CONCLUSION

The aim of this work is to analyse thermal conditions in Szczecin, considering the trends of changes determined with a coefficient of linear curve fits, and to investigate the relations between North Atlantic Oscillation and the air temperature. The annual courses of air temperature in Szczecin are characterized by a great changeability. It results from the changeable impact of circulation originated over the North Atlantic, over the Baltic Sea, and in the continental area, as well as some local determinants. The following conclusions can be drawn:

1) In the period studied the average air temperature was 8.2ºC and underwent considerable changes in particular years. At the beginning of the studied period (1950-1969), the average temperature calculated for the period of five years was at the level of the whole period average. During this period the autumn was relatively warm. Next, in the years 1969-1988, a distinct cooling of the climate was observed (the average annual temperature was much lower as compared with 60 years average). Between the years 1989-1996 the average annual temperature started to increase slowly, and exceeded 10ºC in 2007-2008. This warm period was a consequence of the temperature increase in almost all of the months. However winter months were especially warm in these years.
2) July turned out to be the warmest month, however the mean maximum appeared also in August and June. January was the coldest month, although the minimum also appeared in December and February. The fact that the maximum shifts to August and minimum shifts to February proves the one-month shift theory. It is a characteristic feature of the areas located within a close distance from the Baltic Sea. Summer seasons in Szczecin are cool (only 8 years showed the average temperatures higher than 18ºC). However, winters tend to be warm (increased average temperatures were recorded in winter seasons in 55% of the analyzed years). Autumn seasons tend to be very warm – temperature was higher in autumn than in spring in 100% of the analyzed years.
3) The monthly linear trends showed that the month with the highest increase in temperature was February, seasons – spring and winter. June was the month with the lowest temperature increase, season – autumn. The average year air temperature has increased by about 1.2ºC over the 60 years.
4) Atmospheric circulation determined by NAO has an undoubtedly considerable influence on the air temperature in Szczecin in winter months (Dec, Jan, Feb) and in March. It is clear considering high values of the correlation coefficient. The temperature shows a great conformity of phase (the rise in average monthly temperature corresponds to the NAO positive phase, whereas the drop in average monthly temperature corresponds to the NAO negative phase). For the both phases the estimated percentage of conformity amounts to respectively: in January – 67.8%, February – 73.3%, in March – 75.0% and in December – 67.8%. It was also observed that there is a great coincidence of negative phases in January (85.7%) and February (83.3%), and positive in March (94.9%) and December (86.2%).

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TENDENCJE ZMIAN TEMPERATURY POWIETRZA W SZCZECINIE I ICH ZALEŻNOŚĆ OD OSCYLACJI PÓŁNOCNOATLANTYCKIEJ (NAO)

Streszczenie

Celem pracy była analiza zmienności warunków termicznych w Szczecinie z uwzględnieniem tempa zmian określonego za pomocą współczynnika trendu liniowego oraz zbadanie zależności temperatury powietrza od Oscylacji Północnoatlantyckiej. Na podstawie przeprowadzonych badań stwierdzono, że przebiegi roczne temperatury powietrza w Szczecinie charakteryzowały się dużą zmiennością. Wynika ona ze zmiennego oddziaływania cyrkulacji znad Oceanu Atlantyckiego, wpływu Morza Bałtyckiego i oddziaływania obszaru kontynentalnego oraz uwarunkowań lokalnych. W wyniku przeprowadzonych badań uzyskano następujące wnioski:

1) W badanym okresie średnia roczna temperatura powietrza z wielolecia wyniosła 8,2ºC i w poszczególnych latach ulegała dużym wahaniom. Na początku badanego przedziału czasowego (1950-1969) średnia roczna temperatura obliczona dla okresu pięcioletniego była na poziomie średniej wieloletniej. W okresie tym bardzo ciepła była jesień. Następnie, w latach 1969-1988 (20 lat) wystąpiło bardzo wyraźne ochłodzenie (średnia roczna temperatura była niższa od średniej wieloletniej). W latach 1989-1996 średnia roczna temperatura ponownie stopniowo wzrastała i w latach 2007-2008 przekroczyła 10ºC. Ten ciepły okres był konsekwencją wzrostu temperatury prawie we wszystkich miesiącach, szczególnie ciepłe w tym czasie były miesiące zimowe.
2) Najcieplejszym miesiącem był lipiec, jednak średnie maksimum występowało również często w sierpniu i czerwcu. Najchłodniejszym miesiącem był styczeń, minimum często pojawiało się również w lutym i w grudniu. Wielokrotne występowanie maksimum w sierpniu i minimum w lutym świadczy o częstym przesunięciu o jeden miesiąc. Jest to cecha typowa dla obszarów położonych w niewielkiej odległości od wybrzeża Bałtyku.
3) Analiza temperatury powietrza w porach roku wykazała, że lato było chłodne, tylko w ośmiu latach średnia temperatura przekroczyła 18ºC, natomiast często występowały ciepłe zimy (łącznie w 55% lat średnie temperatury zimą były dodatnie), szczególnie w latach 1988-2008. Bardzo ciepła była jesień – w 100% lat temperatura była wyższa niż wiosną.
4) Analiza współczynników trendu liniowego wykazała, że miesiącem o najwyższym przyroście temperatury był luty, porami roku – wiosna i zima. Miesiącem o najniższym przyroście temperatury był czerwiec, porą roku – jesień. W badanym 60-leciu przyrost średniej rocznej temperatury powietrza wynosi około 1,2ºC.
5) Z analizy związków między zmianami indeksu NAO a temperaturą powietrza wynika, że w Szczecinie występuje duża zależność temperatury powietrza od Oscylacji Północnoatlantyckiej w miesiącach zimowych (XII-II) oraz w marcu, świadczą o tym duże wartości współczynnika korelacji. Pozytywnej fazie NAO odpowiada na ogół wzrost średniej miesięcznej temperatury, negatywnej fazie NAO – spadek średniej miesięcznej temperatury. W przypadku obu faz zgodność wynosi odpowiednio: w styczniu – 67,8%, lutym – 73,3%, marcu – 75,0% i w grudniu – 67,8%. Zaobserwowano także, że występuje bardzo duża zgodność faz ujemnych w styczniu (85,7%) i w lutym (83,3%) oraz dodatnich w marcu (94,9%) i w grudniu (86,2%).