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# THE EFFECT OF ATMOSPHERIC CIRCULATION ON THE OCCURRENCE OF THAWS IN POMERANIA

*Marek Chabior[1], Małgorzata Czarnecka[2]*

[1]Department of Marine Ecology and Environmental Protection, Agricultural University
ul. Kazimierza Królewicza 4, 71-550 Szczecin
e-mail: marekchabior@fish.ar.szczecin.pl
[2]Departament of Meteorology and Climatology, Agricultural University
ul. Papieża Pawła VI, 3, 71-459 Szczecin

A b s t r a c t. The analysis of atmospheric thaws was based on the mean daily values of air temperature recorded at 200 cm above the ground at 15 IMGW meteorological stations within the span of 1960/61-1999/2000. For the determination of the effect of atmospheric circulation on the frequency of thaws in Pomerania, Lityński's classification and also the indices of the North Atlantic Oscillation (NAO) according to Hurrell, Jones and Rogers were used. The vital role played by atmospheric circulation in determining atmospheric thaws in Pomerania was confirmed by statistically significant coefficients of correlation obtained for all of the applied indicators, the largest ones for the group of circulation directions from the western (SW, W and NW) and eastern (NE and E) sectors, including non-advective situations according to Lityński's classification. The spectrum analysis carried out showed that periodic character of the course of atmospheric thaws, with cyclic components of 5.5 and 8.1 years, is determined by similar changes of atmospheric circulation.

K e y w o r d s: temperature, Lityński's classification, NAO winter indices, periodicity

## INTRODUCTION

Variability of weather conditions is determined by the character of atmospheric circulation. Considerably higher number of mild winters, even six-fold in Pomerania, than that of frosty winters (Paczos 1982), is connected with the flow of air masses from over the Atlantic Ocean, and the largest positive anomalies occur in the conditions of western cyclonic circulation (Baranowski 2001). The essential role of atmospheric circulation in the formation of thermal conditions in Poland is confirmed, using various methods of circulation typology, by the results of many studies (Bąkowska 2005, Ustrnul, Czekierda 2002, Kożuchowski, Żmudzka

2002, Kożuchowski 2003). The objective of numerous analyses was also the estimation of the effect of atmospheric circulation over the North Atlantic, described by the North Atlantic Oscillation (NAO) indices, on the air temperature in the scale of the whole country, but also in the area of Pomerania (Filipiak 2003, Kożuchowski, Degirmendžić 2002, Marsz 1999, Marsz, Styszyńska 2001). Whereas, among sparse national publications dealing with thaws only two works are concerned with atmospheric circulation conditions of the phenomenon – Kuziemski's (1971) and Mrugała's (1987/1988). For these reasons the main aim of the present study was to determine the influence of atmospheric circulation on the frequency and cyclic character of the occurrence of thaw in Pomerania.

## MATERIAL AND METHODS

As the basic material, mean daily values of air temperature recorded at 200 cm above the ground in 15 meteorological stations (IMGW) collected during the periods from November to April in the years 1961-2000 were used. In the literature there is no unequivocal criterion of thaw, and the phenomenon is generally determined on the basis of maximum or mean daily temperature. In the present study, following Kuziemski's (1967) definition of thaw, a mean daily air temperature occurring during at least two successive days, but only after the first at least three-day period with a mean daily air temperature below 0$^{o}$C, was used as the criterion. The phenomenon determined in this way was expressed by means of a number of days. To present characteristic features of the circulation conditions, Lityński's classification of circulation types worked out for the whole country and recognized as one belonging to objective methods of typology (Kaszewski 1990) was used. The results of this classification, including 27 types of circulation, were published in calendars of circulation worked out by Stępniewska-Podrażka (1991) and Pawłowska *et al.* (2000). Analysing the relationships between the frequency of thaw and the directions and types of circulation, it was observed that a larger influence on the occurrence of thaw had the direction and smaller – the type of circulation. These are the reasons for which two groups of directions representing western (SW+W+NW) and eastern (NE+E) sectors together with zero (0) circulation were eventually selected for the analysis. Due to the fact that the occurrence of thaw is connected with the advection of warm masses of air from over the Atlantic Ocean, the effect of the North Atlantic Oscillation described by the indices worked out by Hurrell (1995), Rogers (1984) and Jones *et al.* (1997) were also analysed. The objective of the analysis were mean values for the period from December to March. For the analysis of the cyclic character of the changes in atmospheric thaws and circulation indices included in the present study, Boryczko's method (1998) was applied. The method consists in the approximation of chronological sequences of the measurements by sinusoids, accepting the periods successively every 0.1 year

## RESULTS AND DISCUSSION

The most frequent occurrence of atmospheric thaws and, in consequence, that of the thaw in the surface layer of soil is characteristic of the western regions of the country (Czarnecka 1990, Czarnecka 2005, Mrugała 1987, Mrugała 1987/ 1988). In Pomerania, the average number of days with atmospheric thaw varies from about 50 in Pojezierze Kaszubskie and Pojezierze Bytomskie and in Równina Charzykowska to almost 70 in the north-western and western regions (Fig. 1).

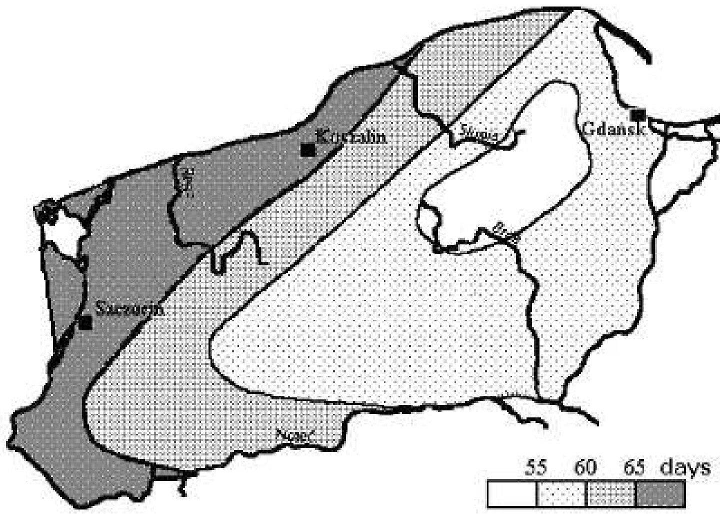
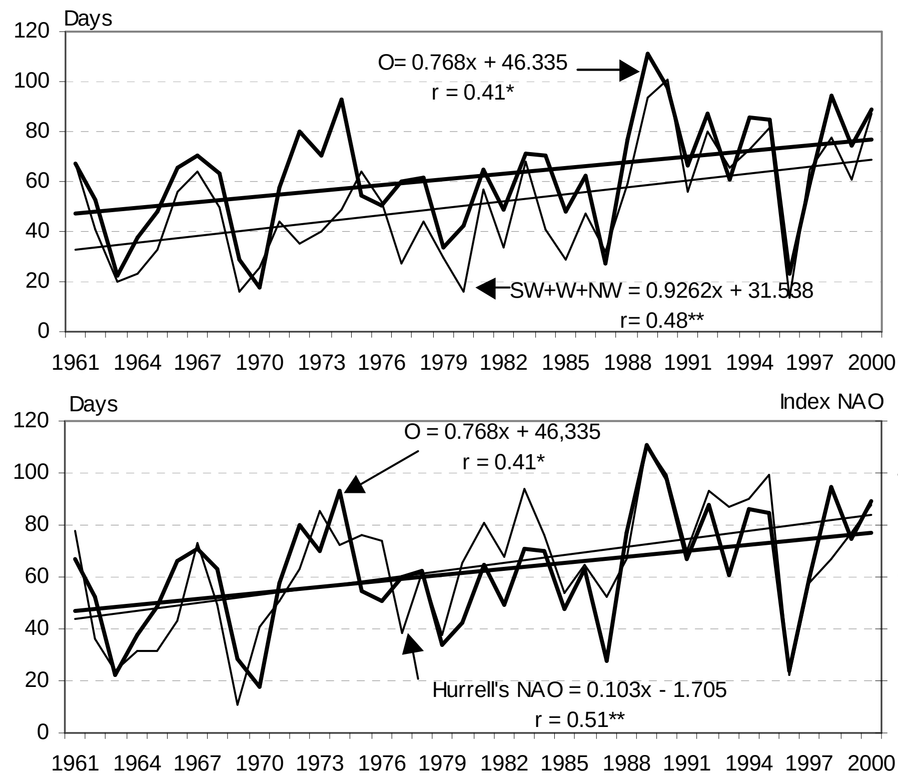



**Fig. 1.** Mean number of days with atmospheric thaw from December to March. Years 1961-2000.

Even in the coldest months of a year, i.e. January and February, atmospheric thaws occur during a period from 10 to 15 days and generally reach the intensity from 3 to 4°C (Czarnecka 2005). In the analysed period of 40 years the smallest number of thaw days, i.e. about 18, was recorded in the most snowy winter of 1969/70, whereas particularly thawy was the winter in 1988/89 in which thaw occurred in 111 days. That is as much as about 90% of the days of the period from December to March (Fig. 2). The random character of the phenomenon is reflected in very large coefficients of variation of the number of days with thaw which vary, depending on the station, from 34 to 46%.




r – correlation coefficient, significant at: *α = 0.05, **α = 0.01

**Fig. 2.** Variability and trends of the number of days with atmospheric thaw (O), of days with western circulation (SW+W+NW) according to Lityński and to Hurrell's NAO index in Pomerania from December to March. Years 1961-2000

Increase in the air temperature in winter and spring months, recorded in many works, also manifests itself in a rise in the frequency of occurrence of atmospheric thaws and, although less clearly, in an increase in their intensity (Czarnecka 2005). Despite large seasonal variability of the phenomenon in the years 1961-2000 the linear trend was statistically significant at $\alpha = 0.05$. In Pomerania the number of thawy days during the period from December to March showed an increase by 7.7 (Fig. 2) every ten years, and in individual stations by about 6 to 9 (Czarnecka 2004). The analysed period of forty years was also characterised by an increase in the frequency of occurrence of the western directions of circulation according to Lityński by about 9.3 days, and also by an increase in the value of Hurrell's NAO index by 1.0 – the above characteristics refer to both indices during each of the 10 year periods. A larger increase in thaw days was observed in the western part of Pomerania. The analysis for the months showed that a statistically significant trend of the frequency of atmospheric thaws took place only in January. Analysis of Figure 2 also shows that the variability of the number of days with atmospheric thaw in Pomerania in 1961-2000 showed a distinct similarity to the variability of days with grouped directions of circulation from the western sector according to Lityński's classification and also with the course of Hurrell's NAO winter index.

The directions of circulation grouped according to Lityński show close relations with the applied NAO indices and it is obvious that higher coefficients of correlation were obtained for the western sector, particularly the ones with Jones's index, which explains about 74% of the variability of days with SW+W+NW directions.

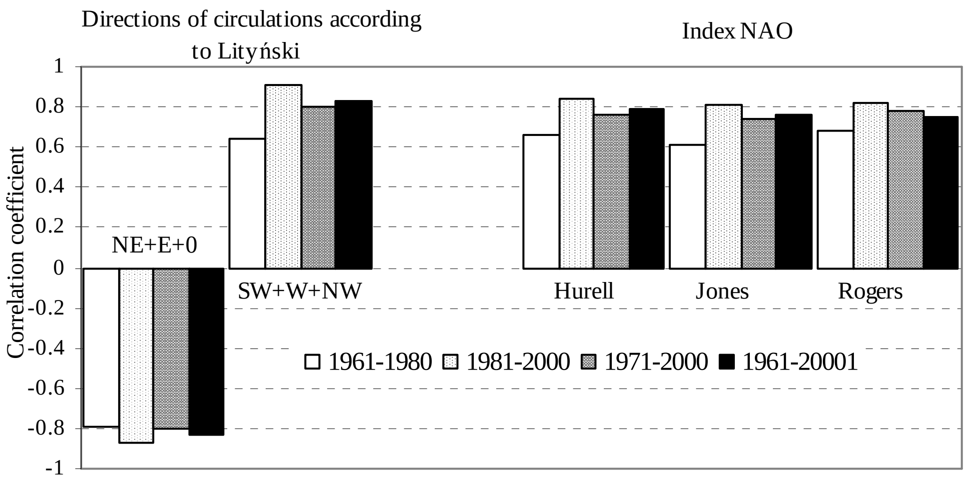



**Fig. 3.** Coefficients of linear correlation, significant at $\alpha = 0.01$, between the days with atmospheric thaw in Pomerania and the days with circulation from the western and eastern sector according to Lityński's classification and Rogers, Jones's and Hurrell's NAO winter indices in the accepted multiannual periods

Clearly larger consistency of the course of number of days with atmospheric thaw with the course of the applied indices of circulation in the second half of the analysed forty year period is confirmed by the results illustrated in Figure 3, in which correlation coefficients for the accepted in the present study forty year period were compared with the coefficients of correlation obtained for the twenty year periods included in the mentioned forty year period and also in the years 1971-2000 embracing "the last" circulation epoch. (Kożuchowski 1996, Marsz 1999). Strong and highly significant correlation ($\alpha = 0.01$) was observed between circulation directions and NAO indices and the number of days with thaw. The closest relationship between the frequency of atmospheric thaw and the circulation conditions was observed in the twenty year period of 1981-2000. The correlation coefficients for all the considered indices of circulation were higher than those in the thirty year period of the years 1971-2000. This may point to an increase in the impact of zonal circulation after 1980.

In all the considered periods the largest correlation coefficients were characteristic of the relationship between the thaw and the directions of circulation according to Lityński. They were generally slightly higher for the directions grouped from the western sector and lower for those from the eastern sector, including non-advective situations (0). Whereas, among the NAO indices the best description of the variability of atmospheric thaws was illustrated by Hurrell's index. A close relationship between the occurrence of thawy days and the circulation conditions in Pomerania is confirmed by the results of the analysis for individual IMGW meteorological stations presented in Table 1. In all the cases the analysed relationships were statistically significant at $\alpha = 0.01$. The highest coefficients of correlation, like in Pomerania, were obtained for the directions grouped according to Lityński's classification, which illustrates the role of local circulation system of high pressure from over Russia in the creation of the thermal conditions better than the NAO index. Hurrell's, Jones' and Rogers NAO indices gave an approximate description of the variability of days with atmospheric thaw. Although the differences of the correlation coefficients between the stations were not very large, their values for all the applied indices show that the atmospheric circulation determined the variability of atmospheric thaws a little more clearly in regions situated in the highest points of Pomerania (Chojnice, Kościerzyna), the regions of smaller on average frequency of thaws, whereas it was determined a little less clearly in the north eastern seaside part.

The large similarity of oscillation spectra of the occurrence frequency of atmospheric thaws to the course of the number of days with the grouped circulation directions, according to Lityński's classification and also to the values of Hurrell's, Jones's and Rogers's NAO indices, was confirmed by the analysis of the time series, the results of which are presented in Table 2 and Figure 4. The highest coefficients of multiple correlation for atmospheric thaws were obtained for the regression sinusoids of the periods of 5.5 and 8.1 years. An identical dominant cyclic component of a period of 5.5 years was also characteristic of the western sector of circulation (NW+W+SW) according to Lityński and also that of the NAO indices in which the most distinct was that of Jones's index. In the spectra of all the analysed indices of circulation, also cyclic components of the periods of about 8 years manifested themselves and the closest to the 8.1 thaw cycle was the one for Hurrell's and Jones's indices. The dominant character of the air temperature course of the 8-year periods in Poland was indicated by many authors. Boryczka and Stopa-Boryczka (2004) think that the horizontal component of the tidal resultant force of the Moon and the Sun is significant and that it probably causes an approximately 8-year periodicity of the circulation of atmosphere and air temperature. Analysis of Figure 4 shows also that the maxima of both the discovered cycles fall approximately in the same years.

**Table 1.** Coefficients of linear correlation, significant at $\alpha = 0.01$, between the number of days in the period from December to March and the number of days with circulation from the western sector according to Lityński's classification and Rogers, Jones' and Hurrell's NAO indices. Years 1961-2000

| Station | Directions of circulation by Lityński | | NAO Indices | | |
|---|---|---|---|---|---|
| | SW+W+NW | NE+E+0 | Hurrell's | Jones' | Rogers |
| Świnoujście | 0.77 | –0.78 | 0.72 | 0.70 | 0.72 |
| Lipki k. Stargardu Szcz. | 0.73 | –0.73 | 0.73 | 0.68 | 0.71 |
| Szczecin | 0.78 | –0.78 | 0.74 | 0.71 | 0.74 |
| Przelewice | 0.82 | –0.81 | 0.76 | 0.75 | 0.75 |
| Gorzów Wlkp. | 0.81 | –0.79 | 0.75 | 0.74 | 0.74 |
| Ustka | 0.74 | –0.79 | 0.70 | 0.65 | 0.72 |
| Resko | 0.77 | –0.76 | 0.77 | 0.74 | 0.73 |
| Koszalin | 0.78 | –0.77 | 0.75 | 0.73 | 0.74 |
| Chojnice | 0.85 | –0.77 | 0.81 | 0.80 | 0.75 |
| Kościerzyna | 0.82 | –0.80 | 0.77 | 0.77 | 0.73 |
| Szczecinek | 0.81 | –0.78 | 0.77 | 0.75 | 0.77 |
| Lębork | 0.73 | –0.78 | 0.70 | 0.68 | 0.73 |
| Rozewie | 0.74 | –0.76 | 0.69 | 0.66 | 0.73 |
| Gdańsk | 0.77 | –0.78 | 0.70 | 0.68 | 0.70 |
| Elbląg | 0.78 | –0.79 | 0.73 | 0.70 | 0.72 |

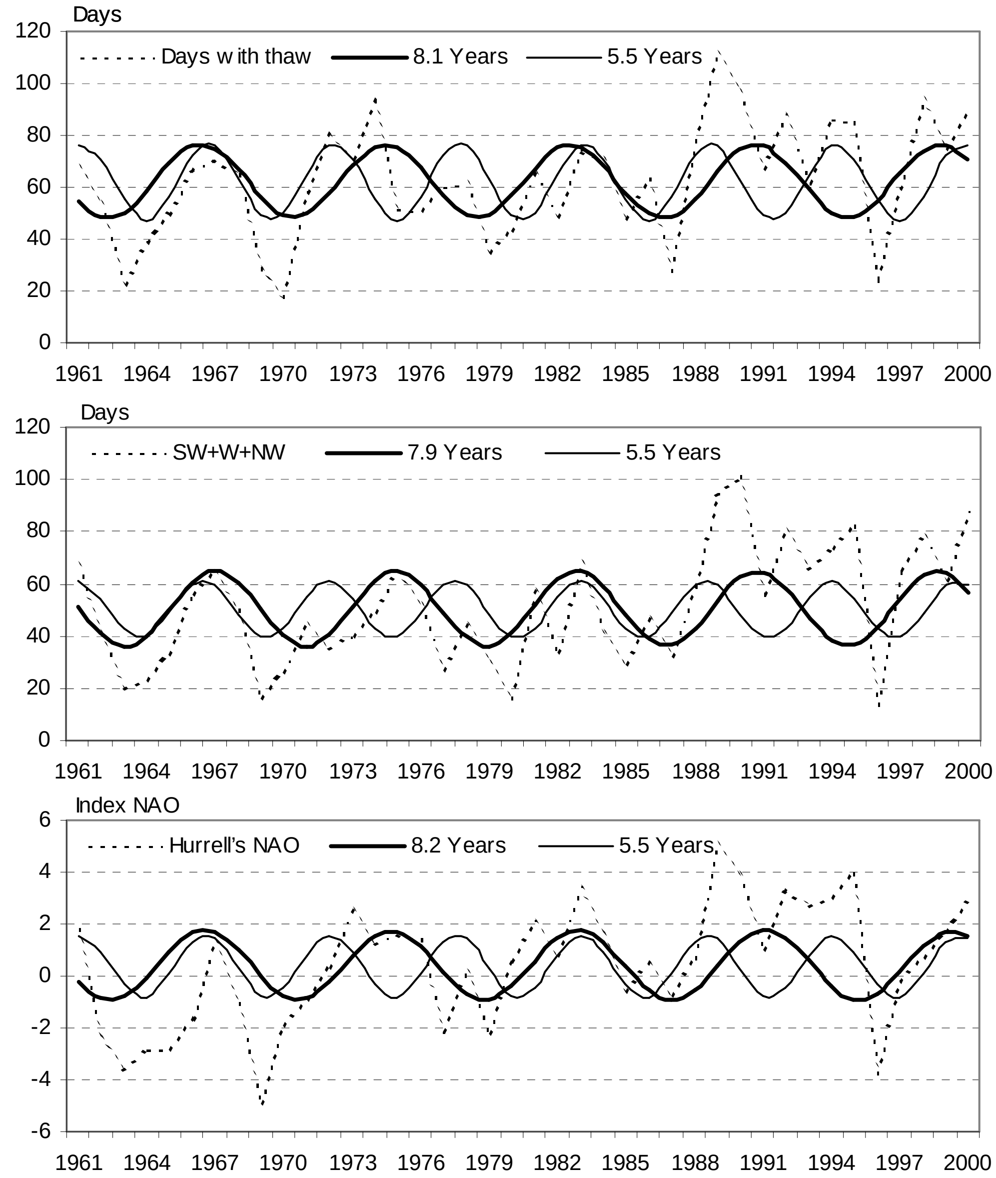



**Fig. 4.** Number of days with thaw and circulation from the western sector (SW+W+NW) according to Lityński and the values of Hurrell's NAO index, and their 5.5 year and about 8 year cycles in the period from December to March in Pomerania. Years 1961-2000

**Table 2.** Periods of the occurrence of atmospheric thaws, types of circulation according to Lityński and the NAO indices from December to March in Pomerania. Years 1961-2000

| Indices of circulation | Periods | Correlation coefficients |
|---|---|---|
| days with weather thaw | 5.5<br>8.1 | 0.47**<br>0.46** |
| days with SW+W+NW circulations | 7.9<br>5.5 | 0.45**<br>0.36* |
| days with NE+E+0 circulations | 5.6<br>19.2 | 0.50***<br>0.46** |
| Hurrell's index | 8.2<br>5.5<br>2.8 | 0.40**<br>0.36*<br>0.35* |
| Jones's index | 2.8<br>5.5<br>8.2 | 0.44**<br>0.43**<br>0.41** |
| Rogers index | 5.5<br>8.3 | 0.40**<br>0.39** |

significant at: *** $\alpha = 0.01$, ** $\alpha = 0.05$, * $\alpha = 0.1$

## CONCLUSIONS

1. Variability of the occurrence of atmospheric thaws in Pomerania is determined by the direction of circulation over the North Atlantic and Europe
2. In the years 1961-2000 the increase in the frequency of occurrence of atmospheric thaws in Pomerania resulted from the growing frequency of circulation from the western sector, described by the number of days with the SW+W+NW directions according to Lityński, and also by Hurrell's, Rogers and Jones's indices.
3. In the multi-annual variability of the occurrence of atmospheric thaws, similarly to the frequency of atmospheric thaws from the western sector according to Lityński classification and to the NAO indices, generally two common cyclic components of 5.5 and about 8.8 year periods are observed.

## REFERENCES

Baranowski D., 2001. Variability of the weather conditions in Poland determined by the type of circulation (in Polish). Pr. St. Geogr., UW, 29, 279-296.

Bąkowska M., 2005. Changes in the air temperature in Poland in the 20th century on The background of atmospheric circulation (in Polish). Promotio Geographica Bydgostiensia, 2, 153-180.

Boryczka J., 1998. Changes of the Earth climate (in Polish). Wyd. Akademickie Dialog, Warszawa, 1998.

Boryczka J., Stopa-Boryczka M., 2004. Cyclic fluctuations of temperature and precipitation (in Polish). Acta Agrophysica, 3(1), 21-33.

Czarnecka M., 1990. Dates of atmospheric thaws. Days with atmoepheric thaws from November to March. – Published in The Climatic Atlas of Elements and Phenomena Harmful to the Agriculture in Poland (in Polish). Pr. Zbior., Red. Cz. Koźmiński, T. Górski, B. Michalska, Puławy: IUNG, Szczecin, AR, 20-22.

Czarnecka M., 2004. Atmospheric thaw. Published in The Atlas of Resources and Climatic Threats in Pomerania (in Polish). Pr. Zbior, Red. Cz. Koźmiński, B. Michalska, AR Szczecin, 53.

Czarnecka M., 2005. Intensity of atmospheric thaws in Pomerania. Water – Environment – Rural areas (in Polish). 5, z. specj., (14), 83-92.

Filipiak J., 2003. The dependence of air temperature in the Polish seashore zone of the Baltic Sea on the North Atlantic Oscillation (in Polish). Wiad, IMGW, XXVI (XLVII), 3, 71-85.

Hurrell J., 1995. Decadal trends In the North Atlantic Oscillation: regional temperatures and precipitation, Science., 269, 676-679.

Jones P, D., Jonsson T., Wheeler D., 1997. Extension to the North Atlantic Oscillation using early instrumental pressure observations from Gibraltar and South-West Iceland, Int. J. Climatol., 17, 1433-1450.

Kaszewski B. M.,1990. A review of methods typology of atmospheric circulation, part II. Local and regional typologies (in Polish). Wiad. IMGW, 13(34), 1-4, 73-83.

Kuziemski J., 1967. Deliberations on the concept of the thaw (in Polish). Wiad. Sł. Hydrol. Meteorol., 3 (15), 3-4, 27-36.

Kuziemski J., 1971. Meteorological causes of thaw in Poland (in Polish). Pr. PIHM, Warszawa, 101, 3-23.

Kożuchowski K., 1996. Contemporary climatic changes in Poland on the background of the global changes (in Polish). Przegląd Geograficzny, LXVIII, 1-2, 70-98.

Kożuchowski K., 2003. Circulation factors of the climate in Poland (in Polish). Czasopismo Geograficzne, 74 (1-2), 93-105.

Kożuchowski K., Degirmendžić J., 2002. Circulation indices and the temperature in Poland Published in The North Atlantic Oscillation and its role in the determination of the variability of climatic and hydrologic conditions in Poland (in Polish). A. A. Marsza i A. Styszyńskiej, Wyd, Uczelniane AM Gdynia, 111-128.

Kożuchowski K., Żmudzka E., 2002. Atmospheric circulation and its influence on temperature variability in Poland (in Polish). Przegl, Geogr., 74(4), 591-604.

Marsz A.A., 1999. The North Atlantic Oscillation and the thermal regime of winters in north-western Poland and on the Polish coast of the Balic Sea (in Polish). Przegl. Geogr., 71, 3, 225-245.

Marsz A.A., Styszyńska A., 2001. The North Atlantic Oscillation and the air temperature over Poland (in Polish). Wyd. WSM, Gdynia.

Miętus M., 1996. Variability of local atmospheric circulation over northern Poland and its relation with the climatic elements (in Polish). Wiadomości IMGW, XIX(XL), 1, 9-30.

Mrugała Sz., 1987. Spatial distribution of atmospheric thaws of various intensity in Poland (in Polish). Biuletyn LTN, Geogr., 29(2), 47-52.

Mrugała Sz., 1987/1988. Types of circulation and air masses in relation to the occurrence of atmospheric thaws in Poland (in Polish). Annales UMCS, Sect, B 42/43, 10, 173-187.

Pawłowska J., Jankowska A., Pindor T., 2000. A calendar of atmospheric circulation types according to J. Lityński (1991-1999) (in Polish). IMGW, Warszawa.

Paczos S., 1982. Thermal and snow relations of winters in Poland (in Polish). Rozpr. hab., Wyd. UMCS, Lublin.

Rogers J., 1984. A comparison of the mean winter pressure distribution in the extremes of the North Atlantic Oscillation, W: H, van Loon (red,), Studies in climate, NCAR Technical Note 227, National Center for Atmospheric Research Boulder Co., 208-241.

Stępniewska-Podrażka M., 1991. A calendar of atmospheric circulation types (1951-1990) (in Polish). IMGW, Warszawa.

Ustrnul Z., Czekierda D., 2002. Extreme values o fair temperature in Poland in the second half of the 20th century in Poland on the background of circulation conditions (in Polish). Wiad. IMGW, XXV (XLVI), 4, 3-22.

## WPŁYW CYRKULACJI ATMOSFRYCZNEJ NA WYSTĘPOWANIE ODWILŻY NA POMORZU

*Marek Chabior*[1] *Małgorzata Czarnecka*[2]

[1]Katedra Ekologii Morza i Ochrony Środowiska, Akademia Rolnicza
ul. Kazimierza Królewicza 4, 71-550 Szczecin
e-mail: marekchabior@fish.ar.szczecin.pl
[2]Katedra Meteorologii i Klimatologii, Akademia Rolnicza w Szczecinie
ul. Papieża Pawła VI, 3; 71-434 Szczecin

S t r e s z c z e n i e . Odwilże atmosferyczne opracowano na podstawie średnich dobowych wartości temperatury powietrza z 200 cm n.p.g. z okresu od grudnia do marca z lat 1960/61-1999/2000 z 15 stacji meteorologicznych IMGW. Do określenia wpływu cyrkulacji atmosferycznej na częstość odwilży atmosferycznych na Pomorzu zastosowano klasyfikację Lityńskiego, a także wskaźniki Oscylacji Północnoatlantyckiej według Hurrella, Jonesa i Rogersa. Zasadniczą rolę cyrkulacji atmosferycznej w kształtowaniu odwilży atmosferycznych na Pomorzu potwierdziły statystycznie istotne współczynniki korelacji uzyskane dla wszystkich zastosowanych wskaźników, największe dla zgrupowanych kierunków cyrkulacji z sektora zachodniego (SW, W i NW) i wschodniego (NE i E) łącznie z sytuacjami bezadwekcyjnymi, według klasyfikacji Lityńskiego. Przeprowadzona analiza widmowa wykazała, że okresowość w przebiegu odwilży atmosferycznych, o składowych cyklicznych 5,5 i 8,1 lat, jest wymuszona podobnymi zmianami cyrkulacji atmosferycznej.

S ł o w a k l u c z o w e : temperatura, klasyfikacja Lityńskiego, zimowe wskaźniki NAO, okresowość