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Perception of weather conditions during atmospheric thaw in the Szczecin Lowlands

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A b s t r a c t. The study was based on the results of daily measurements (taken at 1 pm) of air temperature and wind velocity and average diurnal temperatures of the air at the height of 200 cm above the ground, taken during the period from 1st November to 31st March in the years 1960/1961-1999/2000. The data were gathered at the agro-meteorological station at Lipki near Stargard, situated in the central part of the Szczecin Lowlands. For the evaluation of bioclimatic conditions, the wind chill index (*WCI*) was used, with the scale of heat perception defined by Maarouf and Bitzos. The perception of weather conditions was assessed during winter and spring thaw and during thawless periods. The analysis showed that the diurnal values of *WCI* index varied from about 370 do 1523 W m^{-2}. This made it possible to classify the days of this period within three categories of heat perception: comfortable, cool and cold, and a dominating category of perception during atmospheric thaw, independently of its duration, is cold. The appearance of atmospheric thaw is connected with improvement of heat perception, which is mainly illustrated by a decrease in the frequency of cold days and an increase in the frequency of cool days.

K e y w o r d s: wind chill index, atmospheric thaw, heat perception

INTRODUCTION

The last two decades of the previous century were characterized by distinct warming of the atmosphere and the strongest positive tendency was observed in winter and spring months (Kożuchowski and Żmudzka, 2001; Michalska and Kalbarczyk, 2005; Trepińska, 2002). A characteristic feature of the atmospheric conditions in the Szczecin Lowlands is great unpredictability of the weather, resulting mainly from inflow of air from the Atlantic Ocean, and the largest positive anomalies of air temperature are observed in the conditions of western cyclone circulation (Baranowski, 2001). In winter, cool and frosty periods are interspaced with intervals of warmer weather described as periods of atmospheric thaw. In the Szczecin Lowlands atmospheric thaw occurs on over 60% of days from November to March, reaching even 45 to 50% of the days during the coldest months of the year *ie* January and February. In the 40 year period from 1961 to 2000 the number of days with thaw in winter showed a statistically significant increase from 6 to 9 days per every 10 years (Czarnecka, 2004).

On the one hand, atmospheric thaw causing, on the whole, the thawing of the surface layer of soil, may be directly or indirectly responsible for damage in winter crops, on the other hand it can be a significant factor of growth in the winter soil retention (Czarnecka, 2005a). Frequent changes of the environmental temperature have a hardening effect on a human being, stimulating the organism to function efficiently by activating its immune system, but if the stimuli are too strong, in extreme thermal conditions of the environment, they cause overloading of the organism (Kozłowska-Szczęsna *et al*., 2004). To evaluate the usefulness of the climatic conditions in winter period for the needs of recreation, air temperature and wind velocity are taken into account. The complex index involving these two elements is the *WCI* (Wind Chill Index, in W m^{-2}), also called the index of convection losses of heat, by means of which heat perception by a human being dressed in so-called arctic clothing with thermal insulation of 4 clo, staying in the open air, can be defined (Błażejczyk, 2004).

The aim of this study is bioclimatic evaluation of the changeability of human heat perception during atmospheric thaw by means of the complex *WCI* index.

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EXPERIMENTAL PROCEDURES

The study was based on the results of daily measurements (taken at 1 pm) of air temperature and wind velocity and of average diurnal temperatures of air at the height of 200 cm above the ground, taken during the period from 1st November to 31st March in the years 1960/1961 – 1999/2000. The data were gathered at the agrometeorological station at Lipki near Stargard (φ53°21', λ14°58', h = 30 m a.s.l.), situated in the central part of the Szczecin Lowlands. For the evaluation of bioclimatic conditions, the wind chill index (*WCI*) was used. It was calculated according to the equation:

$$WCI = 1.162\ [(10.45 - \nu + 10\,\nu^{0.5})\,(33 - t)],$$

where: t – diurnal air temperature (°C), ν – wind velocity (m s^{-1}).

Maarouf and Bitzos (2001) assigned the following heat perception classes to particular *WCI* (W m^{-2}) values:

WCI (W m^{-2})	Classes of heat perception
below 58.3	– extremely hot
58.3 – 116.3	– hot
116.4 – 232.6	– too warm
232.7 – 581.5	– comfort
581.6 – 930.4	– cool
930.5 – 1628.2	– cold
1628.3 – 2326.0	– frosty
above 2326.0	– extremely frosty.

At least two-day periods with an average diurnal air temperature above zero, occurring after the first, at least three-day period with an average diurnal temperature below 0°C (Czarnecka, 2004), constituted atmospheric thaw. Two kinds of thaw were recognized. Winter thaw, after which cold and frost could return, and spring thaw, finishing the winter *ie* leading to a permanent rise in temperature above 0°C. The subject matter of the analysis comprised also winter thaw periods lasting continuously: up to 5 days, from 6 to 10 days, from 11 to 20 days, and more than 20 days.

All the analyses were carried out in a 24 h system, whereas the results in the figures and in the table are shown, for better clarity, in a 10 day period system.

The *WCI* index was calculated by means of the Bioklima program and the obtained results were graphically processed using Microsoft Excel.

RESULTS

As far as the Szczecin Lowlands are concerned, the first atmospheric winter thaw can appear here as early as at the beginning of November, but a distinct increase in the frequency of this phenomenon is observed from the beginning of the third decade of November (Fig. 1). During the calendar winter, from December to February, the frequency of atmospheric thaw varies from about 30 to 50%, and thaw is the most frequent in the third decade of December. Winter thaw occurs more often in January than in February. What is more, spring thaw can already start in January, however a clear rise in the frequency of permanent warming, finishing the winter, is observed not earlier than in the third decade of February. Warm periods occurring in early March are connected both with winter and spring thaw, but already the second decade of the month is characterized by domination of spring thaw. The values of the *WCI* index, calculated for all the days from November to March, for both cool and frosty and thaw days, varied from 369.6 to 1522.6 W m^{-2}, which means that the heat perception of weather conditions was within the three classes of comfort, cool and cold. In the 40 year period of 1960/1961-1999/2000, no *WCI* values above 1628.2 W m^{-2} were observed *ie* the values that reflect the risk of getting frostbite on unprotected parts of the body

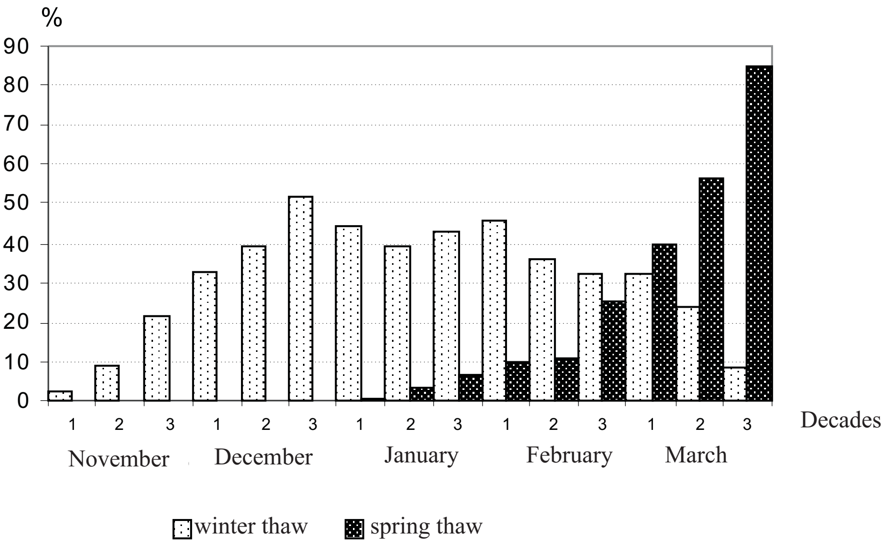


Fig. 1. Frequency (%) of winter and spring thaw (1960/1961 – 1999/2000).

exposed to the cold air even for a short time. This may, however, result from the fact that while calculating the *WCI* index, the air temperature and the wind velocity from the second time of measurement *ie* from the warmest period of the day, and at the same time from that of the highest velocity of wind were taken into account.

The human heat perception as defined by the *WCI* index in winter atmospheric thaw is shown in Fig. 2. During winter thaw, the distinctly most frequent category of heat perception is cool. Its frequency varies from about 60% in early November to nearly 80% in the last decade of March. Of the two remaining categories of heat perception, the situations described as cold occur more often. In early and mid December and in mid and late January, the cold perceptions occur in about 1/3 of the thaw days. The situations defined as comfortable are observed twice as many times as those described as cold only in the first decade of November and in the last decade of March.

During the spring thaw, finishing the spring, in the period from January to March, the most frequently observed category of perception is also cool, and the situations described as cold occur, on the whole, more often than comfort (Fig. 3). A slight advantage of comfort over cold is observed not earlier than in the second decade of March.

During thermal winter *ie* in periods of an average diurnal temperature below 0°C, contrary to the thaw periods, the dominating category of heat perception is cold, but very often there are also situations described as cool, whereas

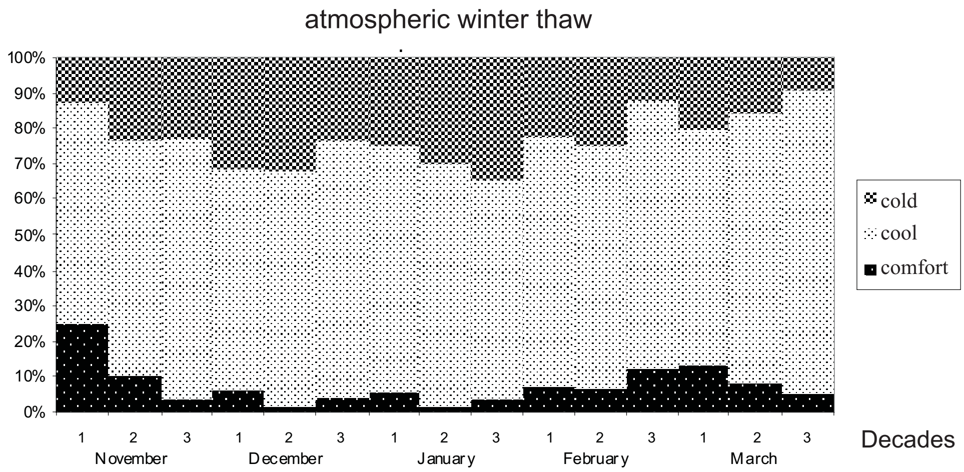


Fig. 2. Frequency (%) of categories of human heat perception in atmospheric winter thaw (1960/1961 – 1999/2000).

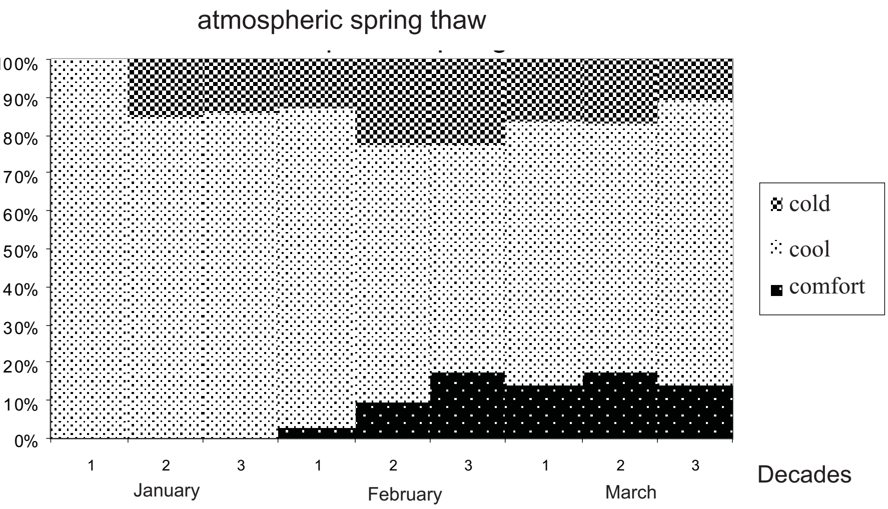


Fig. 3. Frequency (%) of categories of human heat perception in atmospheric spring thaw (1960/1961 – 1999/2000).

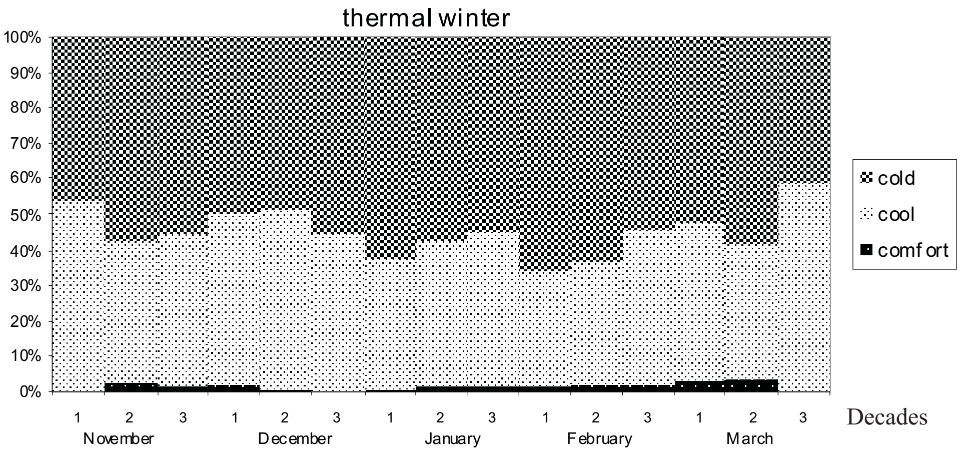


Fig. 4. Frequency (%) of categories of human heat perception during thaw-less periods (of thermal winter, average temperature < 0°C, 1960/1961 – 1999/2000).

comfort situations occur only sporadically (Fig. 4). The particularly high frequency of the occurrence of cool, above 60%, is characteristic for the first and second decades of February and the first decade of January.

Comparison of the three categories of heat perception in winter and thaw periods shows that the appearance of winter atmospheric thaw is responsible mainly for decrease in the frequency of heat perception within the category defined as cold and increase in the frequency of perception of cool, and a slight increase in the frequency of comfort (Table 1). The improvement of heat perception related to winter thaw shown in this way is most distinctly seen in February and in the second decade of March. Whereas a significant increase in the biometeorological situations described as comfort occurs at the end of the second and the beginning of the third decades of February. During spring thaw the largest change of heat perception as defined by the *WCI* index is also, in comparison to winter periods, characterized by an explicit decrease in the frequency of occurrence of cold and an increase in the frequency of cool. Quite large changes of heat perception connected with spring thaw are noticed in the first decade of February. Spring atmospheric thaw, beginning as early as January, causes a slight decrease in the frequency of perception of comfort, whereas a distinct increase in the frequency of this category starts from the third decade of February (Table 1).

The length of the periods of occurrence of winter atmospheric thaw is largely differentiated. Prevailing number of thaw periods does not exceed 5 days, but on average every two years there is thaw lasting continuously for more than 20 days (Czarnecka, 2005b). However, as it is seen in Fig. 5, the duration of winter thaw has only an insignificant influence on heat perception as defined by the *WCI* index. Clear domination of heat perception of cool is observed in all the studied thaw periods lasting for both 5 and more than 20 days, and the changes in the frequency of the three analysed categories of heat perception do not exceed 15 %. With the lengthening of the duration of winter thaw, first of all the frequency of the perception of cold decreases and the frequency of cool increases more than that of comfort. In the course of the longest winter atmospheric thaw periods *ie* those lasting for more than 20 days, the frequency of perception of cold is lower by 14% than in the case of thaw periods lasting for only up to 5 days, and the conditions described as comfort amount to less than 10% of all the cases. Such long atmospheric thaw periods reach, on the whole, the intensity of nearly 4°C, while the shortest ones, those up to 5 days, only 1.5°C (Czarnecka, 2005b). Distinct differences in the intensity of winter atmospheric thaw periods, depending on their duration, and only insignificant differentiation of heat perception, show that the applied *WCI* index is not too sensitive.

In the course of many years, distinct periodicity of atmospheric thaw is observed as in turns there are years with a very large number of thaw days and with a small number of such days. In the analysed 40 year period the largest number of days with winter thaw (85) was recorded in winter of 1983/1984, and not much smaller (78) in winter of 1997/1998. Whereas the smallest number of such days, from 10 to 20, was observed in: 1960/1961, 1969/1970, 1986/1987 and 1989/1990 (Czarnecka, 2004). Analysis of Fig. 6 shows that in the 40 year period of 1960/1961-1999/2000 the largest contribution of comfort was characteristic for winter thaw in 1974/1975 and then in 1976/1977 and in 1989/1990. On the other hand, very disadvantageous biometeorological conditions were observed in the thaw periods in winter in

T a b l e 1. Changes of frequency (%) of categories of human heat perception during atmospheric winter thaw and atmospheric spring thaw in comparison to thermal winter (average temperature < 0°C, 1960/1961 – 1999/2000).

Months	Decades	Winter thaw			Spring thaw		
		Comfort	Cool	Cold	Comfort	Cool	Cold
November	1	+25.0	+9.2	-34.2			
	2	+8.0	+25.8	-33.8			
	3	+2.1	+30.0	-32.4			
December	1	+4.4	+14.5	-19.0			
	2	+0.8	+16.1	-16.9			
	3	+0.4	+27.4	-31.8			
January	1	+4.9	+32.9	-37.9	-0.5	+63.0	-62.5
	2	+0.4	+26.4	-26.9	-0.9	+42.6	-41.7
	3	+3.0	+16.9	-19.9	-0.9	+41.2	-40.3
February	1	+6.4	+37.2	-43.5	+1.4	+52.2	-53.6
	2	+4.8	+33.8	-38.6	+7.2	+33.1	-40.3
	3	+10.3	+31.7	-42.0	+15.2	+16.2	-31.4
March	1	+10.2	+21.4	-31.6	+10.9	+25.5	-36.4
	2	+3.8	+39.1	-42.9	+13.4	+28.0	-41.4
	3	+4.5	+27.4	-31.9	+14.1	+16.0	-30.1

+ increase of frequency, - decrease of frequency.

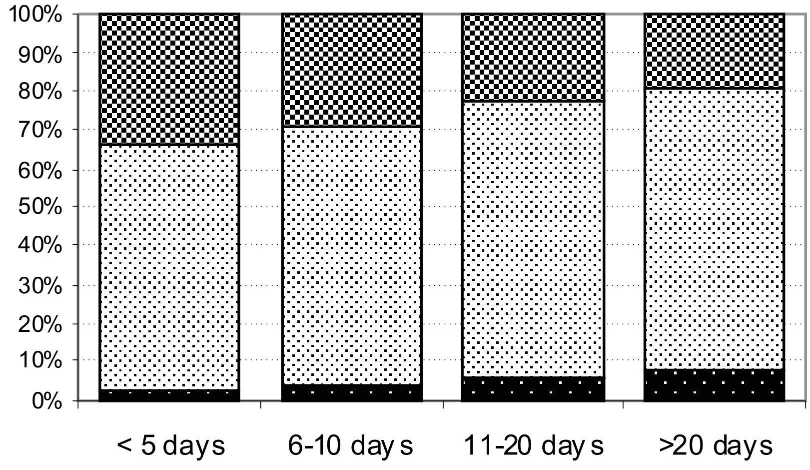
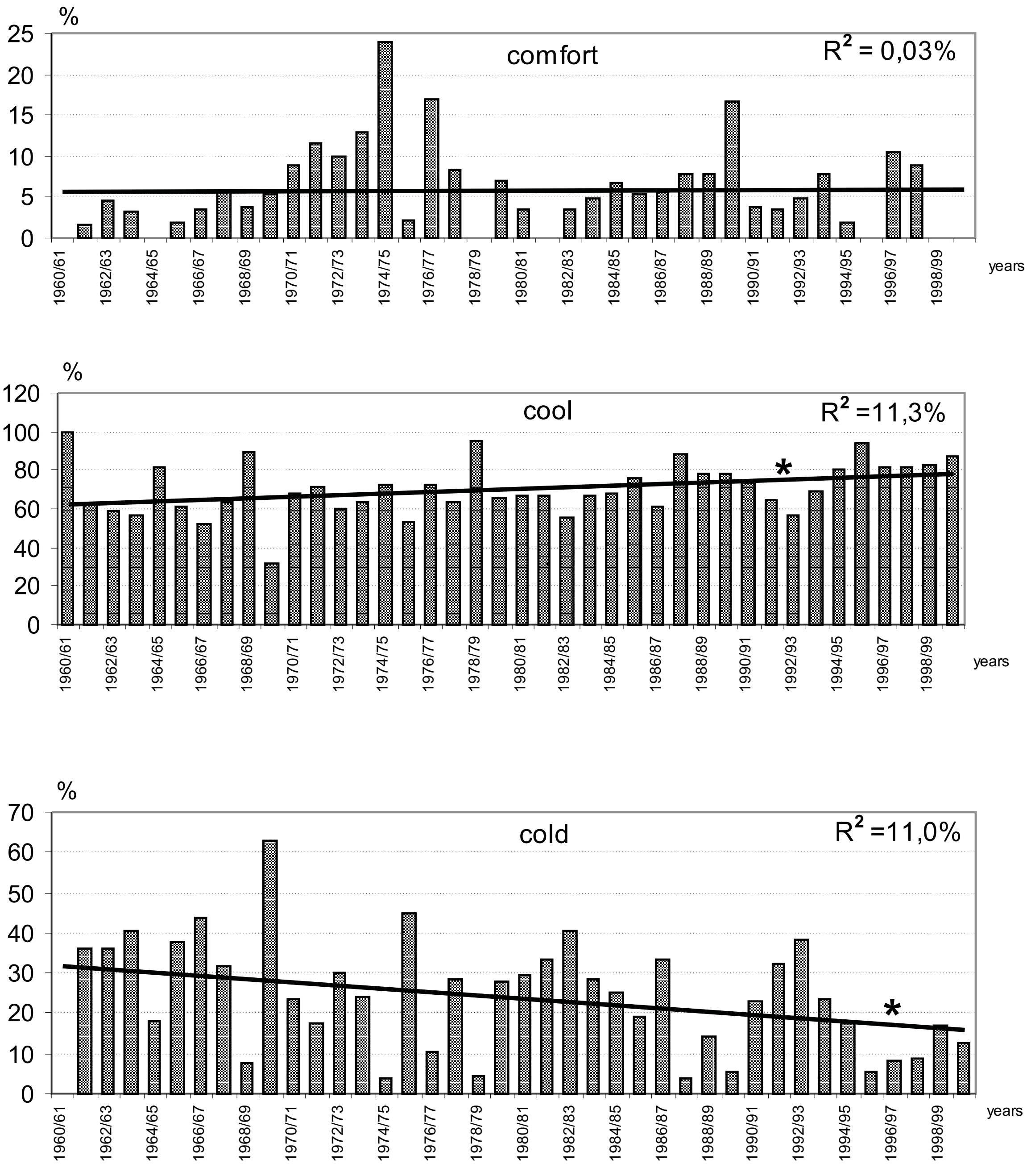


Fig. 5. Frequency (%) of categories of human heat perception in relation to the duration of the atmospheric winter thaw periods (1960/1961-1999/2000).



*significant at α=0.05

Fig. 6. Variability of the percentage contribution of human heat perception classes during atmospheric winter thaw (1960/1961 – 1999/2000).

heat perception was that of cold. In 1960/1961-1999/2000 there was a statistically significant positive tendency of days with the perception of cool and a negative tendency with that of cold. According to the values of regression coefficients, the contribution of days with winter atmospheric thaw accompanied by the perception of cool increased by about 4% every 10 years and by the same value the percentage of days with the perception of cold decreased. During the multi-year period, the changes of the contribution of the analysed categories of human heat perception in spring atmospheric thaw were very small – the contribution of days with the perception of comfort increased a little. Whereas

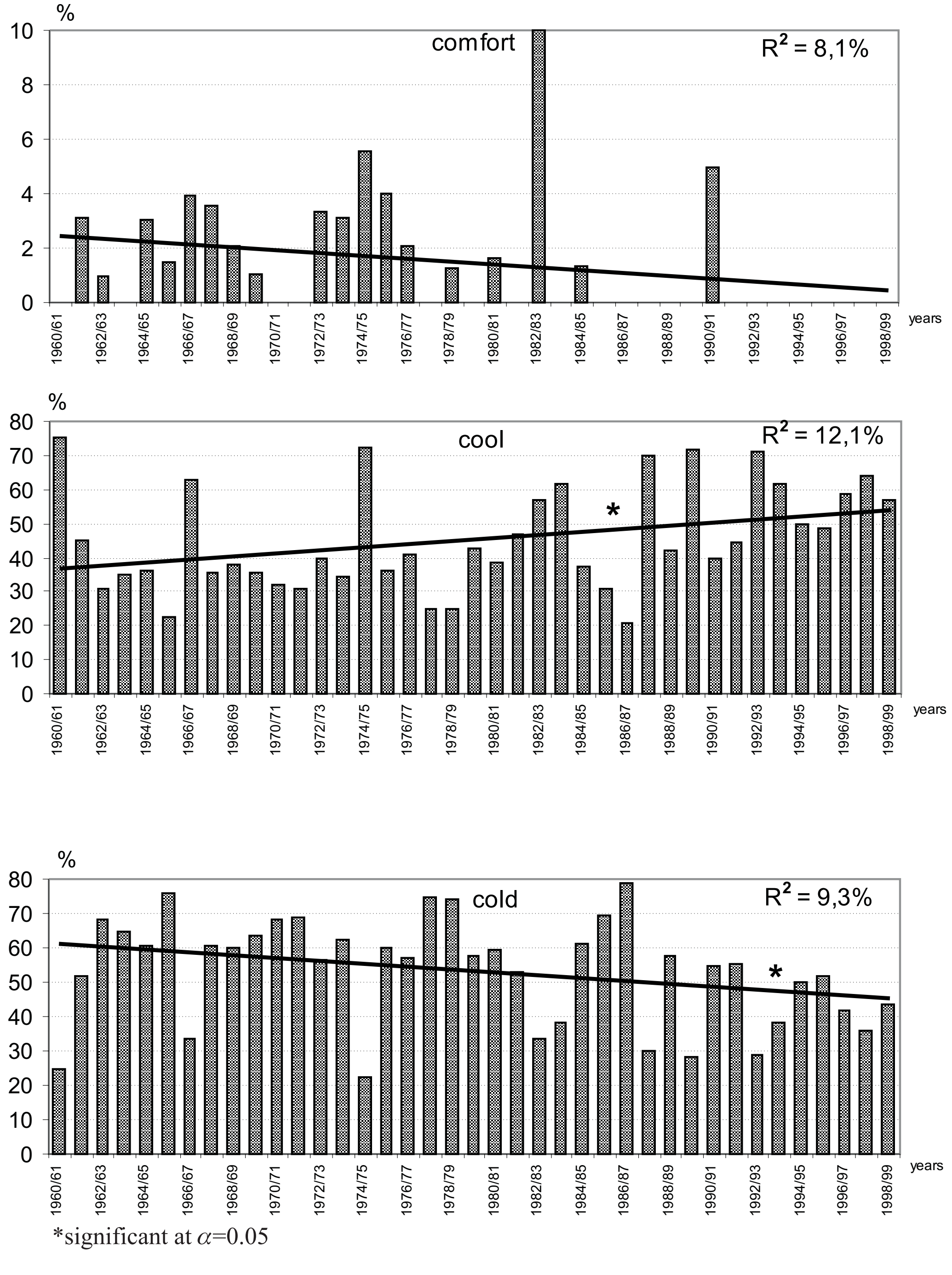


Fig. 7. Variability of the percentage contribution of humans heat feelings during thermal winter (average temperature <0°C, 1960/1961 – 1999/2000).

a clear positive tendency of the analysed phenomenon was observed in the thaw-less periods (during thermal winter). First of all there was an increase in the contribution of heat perception of cool (R^2=12.1%) and a decrease both in the perception of comfort and in that of cold (Fig. 7).

DISCUSSION

The index of wind chill *WCI*, along with the index of severity of the climate and the sensible temperature indicator, is the most frequently used index for the evaluation of heat perception in the winter period (Błażejczyk, 2004; Kozłowska-Szczęsna *et al.*, 2004; Kożuchowski, 2003; Papiernik, 2001). In recent years in Canada and the United States new complex biometeorological indices have been worked out for the evaluation of heat discomfort. These are the *WCT* – Wind Chill Temperature *ie* the cooling temperature and the *WCET* – Wind Chill Equivalent Temperature *ie* the equivalent of cooling by wind (Błażejczyk, 2004; Environment Canada, 2001; Osczevski and Bluestein, 2005; Shitzer, 2006), but they have not been applied on any large scale in national research programmes.

The studies by Kozłowska-Szczęsna *et al*. (1997) show that average values of the cooling by wind index – *WCI*, calculated for midday measurement in the period from December to March, varied, in the years 1961-1970, from 700 to 800 W m^{-2} in western Poland to about 900 W m^{-2} on the Baltic coast to over 1000 W m^{-2} in the north east of the country, and in the mountains they exceeded 1300 and 1600 W m^{-2}. The highest values of the *WCI* index are observed in January. In the north western part of the country, in the decade of the nineteen sixties, the *WCI* value obtained at midday amounted to 950 W m^{-2}, what corresponded to the feeling of cold (Krawczyk, 1997). The value of the *WC*I index obtained in this study was smaller by about 35 W m^{-2}, as it amounted to 914.9 W m^{-2} on all the days of January, both those with thaw and those without it. Thus January could be classified as the month of prevailing heat perception of cool.

Papiernik (2001) assumed that the measure of the sensible coldness was the surplus of the *WCI* quantity above 930 W m^{-2} *ie* the quantity that was the lower limit of the feeling of cold. The studies carried out in Łódź in the decade of the nineteen sixties showed that the length of that period amounted to 85.1 days, and in the decade of the nineteen nineties to only 64.9 days, and according to the author it was caused by the warming of the climate, particularly in the second and third 10 day periods of February and in the second 10 day period of January. This results in the reduction of the period of perceived cold. The tendency of the changes of the *WCI* index >930.5 W m^{-2} for Łódź is negative, as during 50 years (1951-2000) the number of cold days decreased from 91 to 65 (Kożuchowski, 2003; Papiernik, 2004). The same direction of changes (significant statistically) was observed in the present study, as during 1961-2000 the contribution of days with the feeling of coldness increased in the winter thaw by 4.3 every 10 years, in the thaw-less period by 4.5 every 10 years, whereas the contribution of cold days decreased respectively by 4.0 and 3.7 every 10 years. The fact of the climatic conditions growing milder has also been confirmed by Błażejczyk (2003), who assessed in his studies the changes of sensible temperature *STI.* The results of a 100-year observation series in Cracow (1901-2000) show a statistically significant positive tendency of increase of the *STI* index in January by 3.79°C per 100 years, and in the remaining months of the cool season of the year – positive tendencies of sensible temperature from 0.49°C in November to 3.01°C in March. The rising tendency of air temperature, particularly in winter is, according to Stopa-Boryczka and Boryczka (2003) a resultant of overlapping of the natural cycles and this explains the increase in temperature during winter periods in Warsaw by 3.93°C per 100 years. The anthropologic changeability amounts to only 0.1°C per 100 years.

CONCLUSIONS

1. The values of the *WCI* index vary from about 370 do 1523 W m^{-2} from November to March, and thus the days of this period can be classified within three categories of heat perception: comfort, cool and cold.
2. The prevailing category of human heat perception during atmospheric thaw, independently of its duration, is cool and the situation described as cold occurs slightly more often than those regarded as comfort.
3. The appearance of atmospheric thaw is connected with improvement of heat perception, which is mainly illustrated by a decrease in the frequency of cold days, and an increase in chilly days.
4. In the years 1960/1961-1999/2000 there was a statistically significant increase in the contribution of days with thaw accompanied by the feeling of cool and at the same time the contribution of cold days decreased.

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