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THE VERTICAL TEMPERATURE GRADIENTS IN THE AUTUMN/WINTER SEASON IN CRACOW

Abstract: The paper presents the variations in the vertical temperature gradients within 12 metres above the ground divided into three layers of air, as measured in the morning and two layers at midday, in various weather conditions in Cracow. Based on the gradients, the vertical temperature profile was analysed.

Key words: vertical thermal gradient, gradient module, temperature profile, synoptic situations, Cracow

1. Introduction

The paper aims to review the variation of vertical temperature gradients within 12 metres above the ground level (a.g.l) against the background of the autumn/winter synoptic conditions. Materials used included observations from the research station of the Jagiellonian University of Cracow, Institute of Geography and Spatial Management, Department of Climatology, located at the Cracow Botanical Gardens. The data included 1988-1998 thermometer records taken in the meteorological enclosure, at the elevations of 0.05, 0.5 and 2 m a.g.l., and on the northern Observatory's wall at 12 m a.g.l., at 7:00 CSE and at 13:00 CSE, between October and March. Also, the calendar of synoptic situations defining 21 types of synoptic situations with various air advection and type of air pressure centre (*a* – for high pressure and *c* – for low pressure) was used. Three air layers were identified. The thermometer at 0.05 m was used for the minimum values only and hence its reading was not taken into account at midday nor was a separate layer of air identified. The gradient values in each layer were translated into 100 metre lapse rates. A positive gradient value accounted for a temperature decrease with altitude, while a negative gradient reflected an inverted profile, i.e. a temperature increase with altitude (Radomski 1987).

2. Vertical diversification of temperature gradients in autumn/winter

During the research period, Cracow experienced mostly anticyclonic situations (more than 60 per cent), and western anticyclonic situations Wa (more than 10 per cent). Equally as frequent were the western cyclonic situations Wc and a anticyclonic wedge Ka. The least frequent system was the central cyclonic situation Cc (ca. 0.5 per cent) (Fig. 1). This provided a synoptic background to the review of the diversity of the vertical air temperature pattern.

Vertical temperature gradient values change with altitude. Typically, they diminish with elevation above ground level (Bac et al. 1998). In a free atmosphere, the mean gradient is 0.65°C/100 m (Lewińska 1991). It is much higher next to the ground (Mattsson 1961).

The highest gradient values were recorded in air layer 1, closest to the ground, in the morning. In February, under an anticyclonic situation with an advection of air masses from the south (Sa) the gradient reached 611.1°C/100 m (Fig. 6a). The lowest gradient values were recorded in layer 3. In November, at trough of low pressure (Bc), the morning gradient was 0.1°C/100 m (Fig. 3a). The same value was observed in December under the anticyclonic situation with an advection of air masses from the north-west (NWa) around midday (Fig. 4b). The highest gradient values in the layer 2 were recorded at midday. In March, in a north-western cyclonic situation the gradient reached the value of 226.7°C/100 m (Fig. 7b).

Comparing gradient values in cyclonic and anticyclonic situations against the air advection from the same direction in each layer (regardless of the +/- sign), higher values were observed in the anticyclonic situations at both times of the day. The greatest differences occurred in the morning in layer 1 during the air advection from the south; more than 300°C/100 m (February) (Fig. 6a), and ca. 250°C/100 m (January) (Fig. 5a).

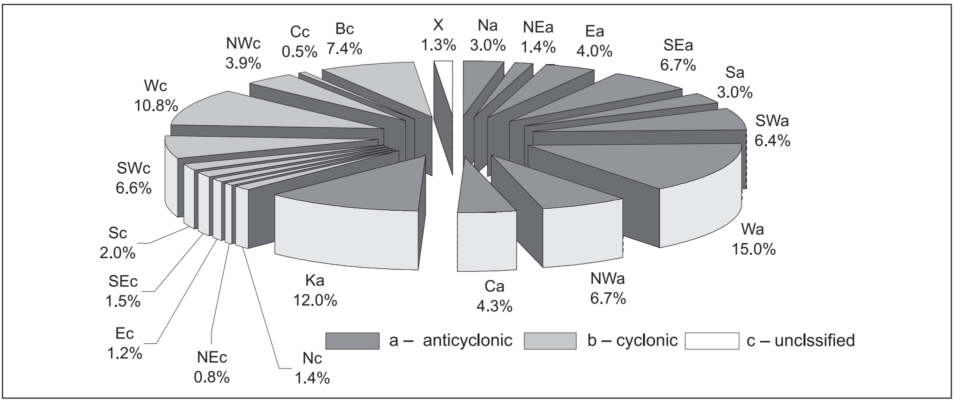

Fig. 1. The frequency of occurrence of different types of synoptic situations during the autumn/winter season in Cracow (1988-1998)

Ryc. 1. Częstość występowania określonych typów sytuacji synoptycznych w Krakowie w sezonie jesienno-zimowym w latach 1988-1998

The greatest differences between the gradient modules, in excess of 60°C/100 m between the air layers, occurred in the morning under the cyclonic and anticyclonic south-western situations (SWc and SWa), the western cyclonic (Wc) and western anticyclonic (Wa) situations, north-western cyclonic (NWc) and anticyclonic (NWa) situations, and the southern cyclonic (Sc) situations. In the latter situation (Sc), the differences were higher at midday. The single greatest difference of 569.4°C/100 m between layers 1 and 2 was recorded under the SWa situation in February (Fig. 6a). Some months produced relatively large differences in the Na and Nc as well as NEa and NEc situations (e.g. in November at Nc situation there was 136.7°C/100 m (Fig. 3b)). At the midday measurement, however, the differences grew even larger; in a central anticyclonic situation (Ca) and the anticyclonic wedge (Ka) (and at relatively high gradient values) the differences were greater than in the central cyclonic situation (Cc) and the trough of low pressure (Bc) (for the latter the recorded gradient was 70°C/100 m in December) (Fig. 4b). Similar gradient values at both measurement times were recorded in eastern and south eastern cyclonic and anticyclonic situations (Ea, Ec, SEa and SEc). In October, the difference recorded at 7:00 CSE between layers 1 and 2 was the mere 1.8°C/100 m (Fig. 2a). Therefore, it can be concluded that the gradient value differences between air layers depended on the direction of air masses advection rather than the pressure pattern.

3. Temperature profiles

The basic temperature patterns, i.e. insolation, inversion and isothermal types were defined using the +/- denominator of the vertical temperature gradient in the selected air layers. The project looked at the occurrence of those types across the whole vertical profile at the same time.

In the morning of all autumn/winter months, the inversion events were caused by such pressure patterns as the trough of low pressure (Bc) and the anticyclonic wedge (Ka), as well as both cyclonic and anticyclonic situations with southern or western advection (Fig. 2a-7a, 8). At midday, this pattern occurred only in December, under the SEc situation (Fig. 4b) and in February, under the Sc situation (Fig. 6b). This was not affected by the fact that in the layer 3 inversions lasted until midday during most of the synoptic situations as a result of the location of the "12 m" measurement point on a northern wall of the building, which had a warming effect on the thermometer indication. (In October, however, the temperature measured there tended to be lower than in the meteorological enclosure readouts because of the shade cast by the building (Trepińska, Matuszko 1994) (Fig. 2b)).

In the morning, there were no events of the insolation type pattern across the profile. This type occurred only in October in layers 2 and 3 at the Na and NEa situations, as well as at the NWc situation (Fig. 2a). At midday, the insolation pattern occurred in the anticyclonic and cyclonic situations with the northern (NEa, NWa, Nc and Na) southern (SEa, SWa, SWc, Sa) and western (Wc) advection, and under central cyclonic and anticyclonic situations (Ca and Cc), as well as the anticyclonic wedge (Ka) and the trough of low pressure (Bc) (Fig. 2b-7b, 9). In all those situations, apart from the northern

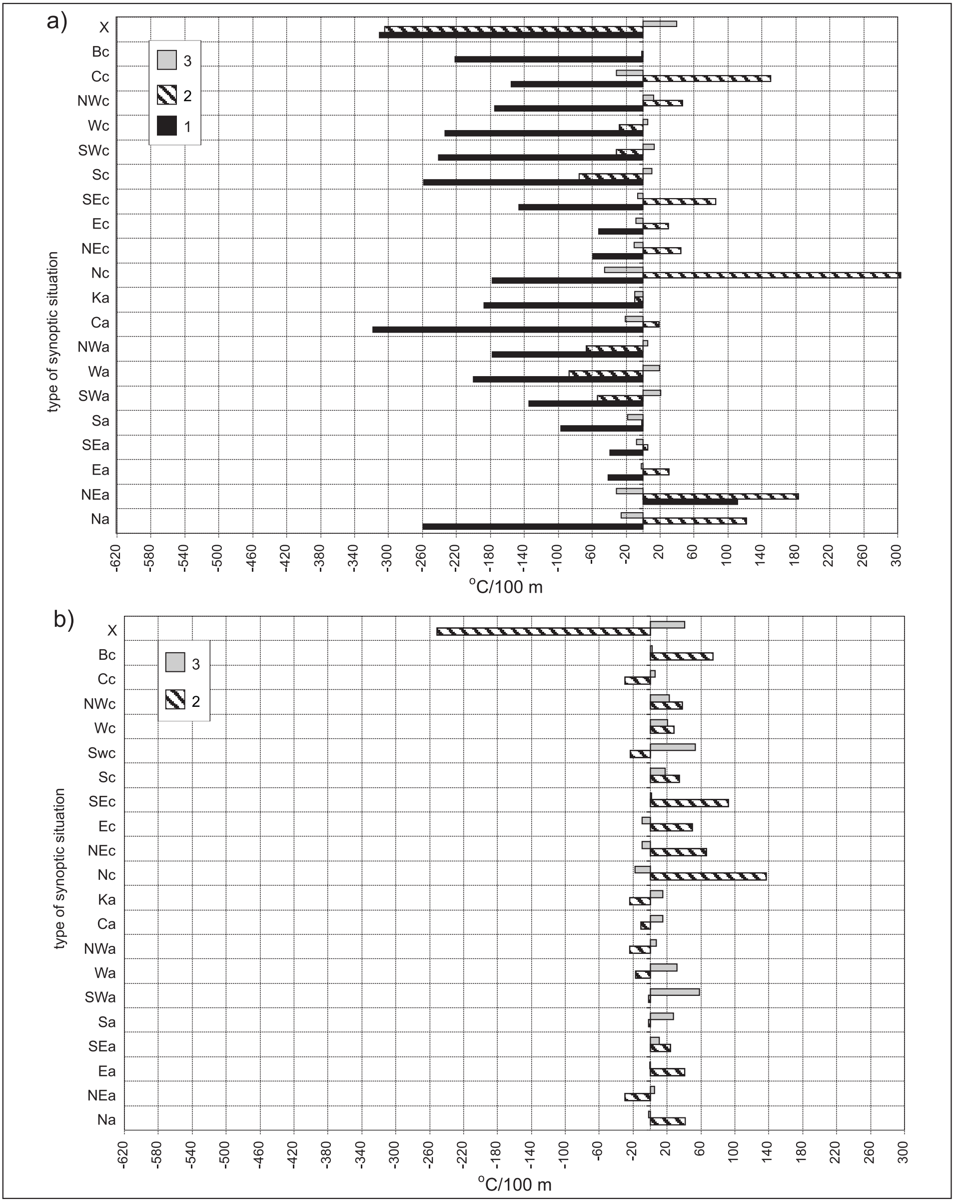

Fig. 2. The vertical temperature gradients (°C/100 m) in October in air layers: 1. (0.05-0.5), 2. (0.5-2) and 3. (2-12 m a. g. l.) at a) 7 a.m. and b) 1 p.m. CET in various types of synoptic situations in Cracow (1988-1998)

Ryc. 2. Pionowe gradienty termiczne w °C/100 m w październiku w warstwach: 1. (0,05-0.,5), 2. (0,5 -2) i 3. (2-12) m n.p.g. o godzinie 7.00 CSE (a) i 13 CSE (b), przy różnych typach sytuacji synoptycznej w Krakowie w latach 1988-1998

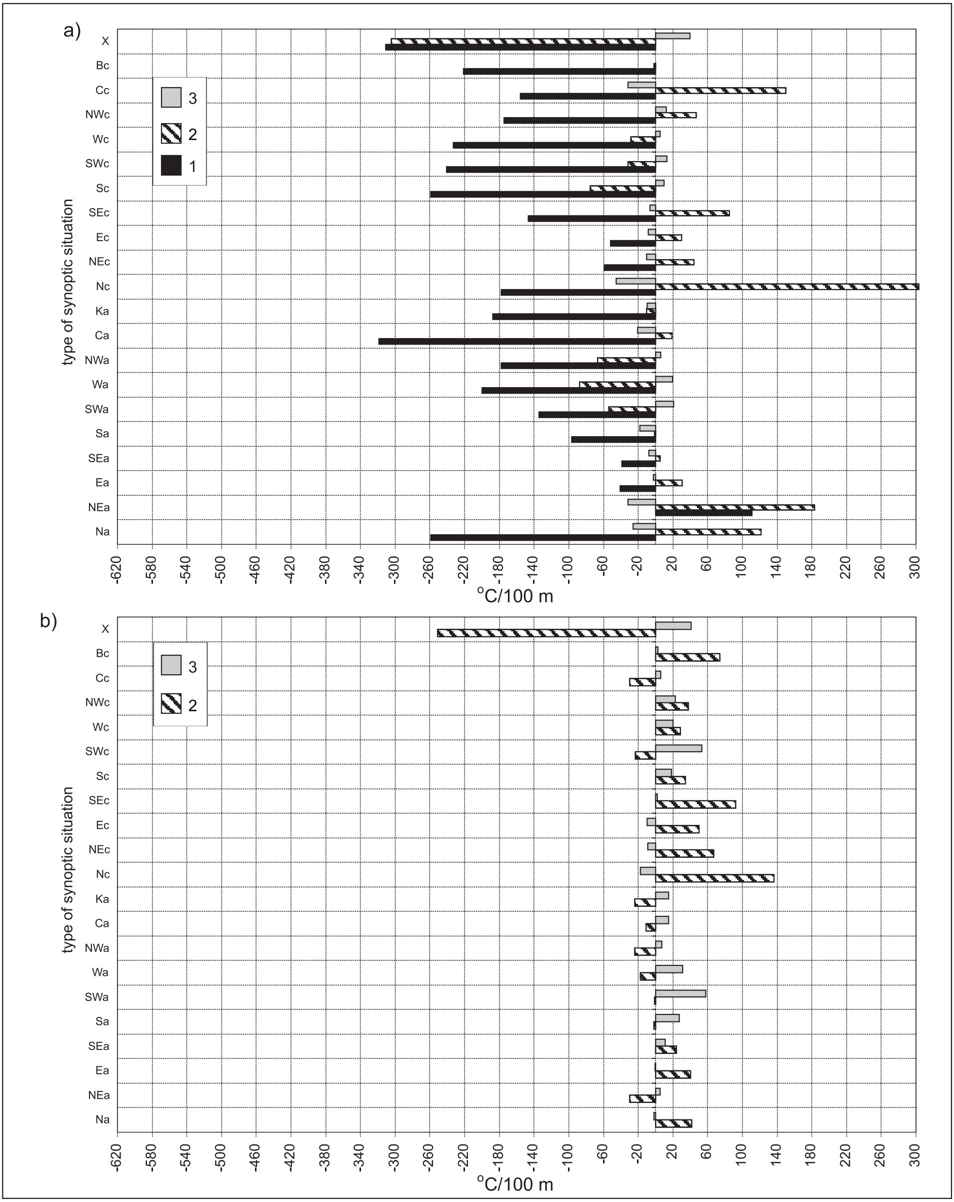

Fig. 3. The vertical temperature gradients (°C/100 m) in November in air layers: 1. (0.05-0.5), 2. (0.5-2) and 3. (2-12 m a. g. l.) at a) 7 a.m. and b) 1 p.m. CET in various types of synoptic situations in Cracow (1988-1998)

Ryc. 3. Pionowe gradienty termiczne w °C/100 m w listopadzie w warstwach 1. (0,05-0,5), 2. (0,5 -2) i 3. (2 -12) m n.p.g. o godzinie 7.00 CSE (a) i 13 CSE (b), przy różnych typach sytuacji synoptycznej w Krakowie w latach 1988 -1998

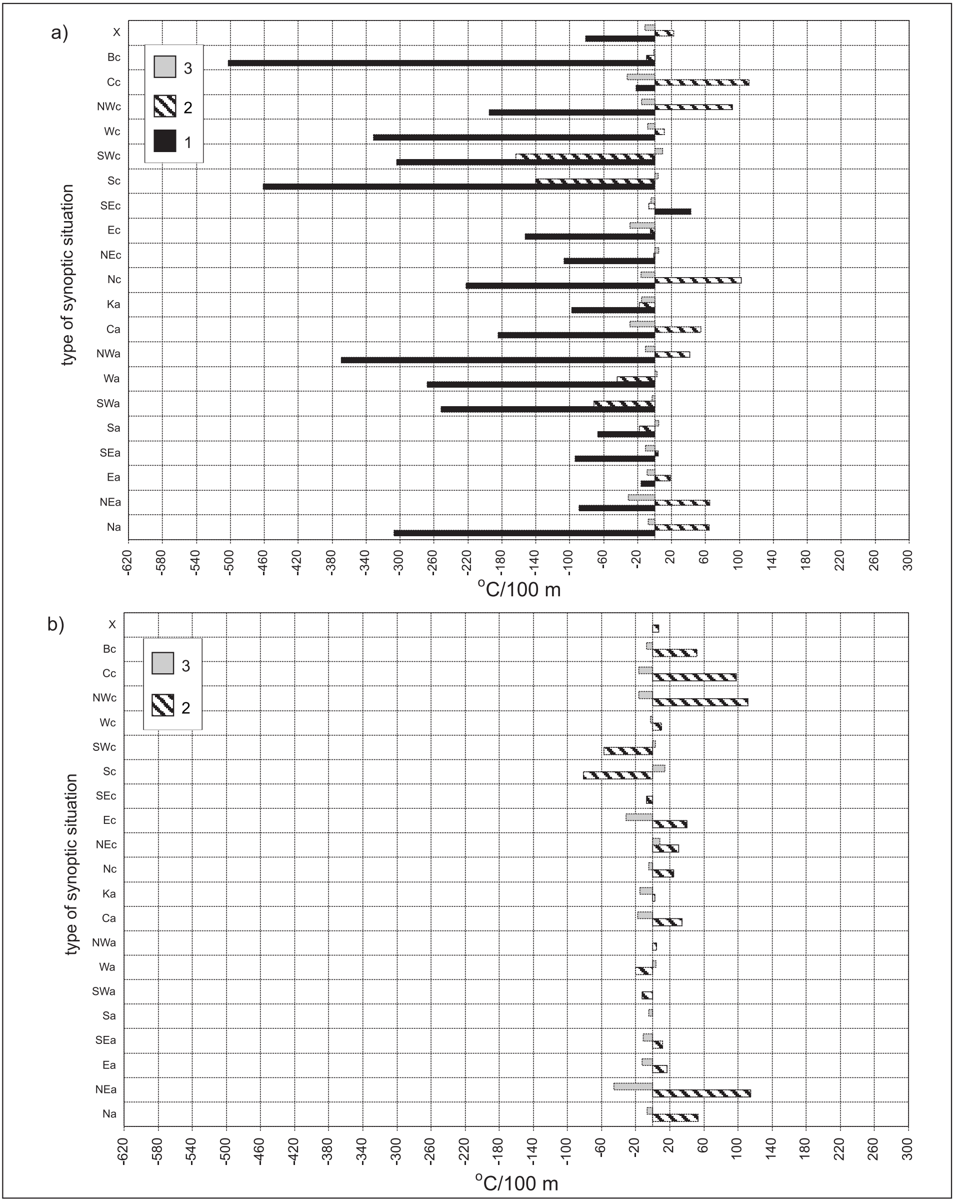

Fig. 4. The vertical temperature gradients (°C/100 m) in December in air layers: 1. (0.05-0.5), 2. (0.5-2) and 3. (2 -12 m a. g. l.) at a) 7 a.m. and b) 1 p.m. CET in various types of synoptic situations in Cracow (1988-1998)

Ryc. 4. Pionowe gradienty termiczne w °C/100 m w grudniu w warstwach 1. (0,05-0,5), 2. (0,5- 2) i 3. (2 -12) m n.p.g. o godzinie 7.00 CSE (a) i 13 CSE (b), przy różnych typach sytuacji synoptycznej w Krakowie w latach 1988-1998

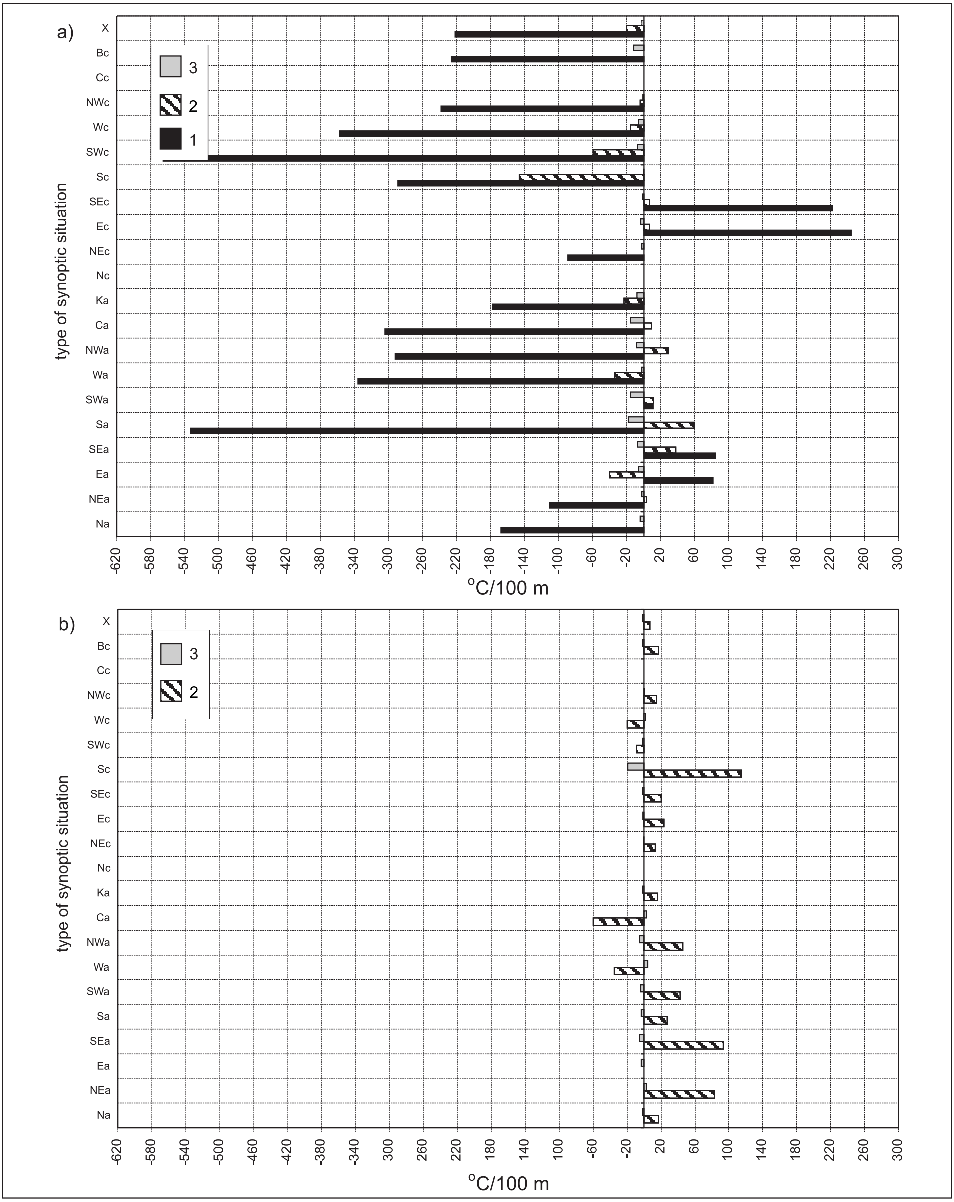

Fig. 5. The vertical temperature gradients (°C/100 m) in January in air layers: 1. (0.05-0.5), 2. (0.5-2) and 3. (2-12 m a. g. l.) at a) 7 a.m. and b) 1 p.m. CET in various types of synoptic situations in Cracow (1988 - 1998)

Ryc. 5. Pionowe gradienty termiczne w °C/100 m w styczniu w warstwach 1. (0,05-0,5), 2. (0,5 -2) i 3. (2 -12) m n.p.g.o godzinie 7.00 CSE (a) i 13 CSE (b), przy różnych typach sytuacji synoptycznej w Krakowie w latach 1988-1998

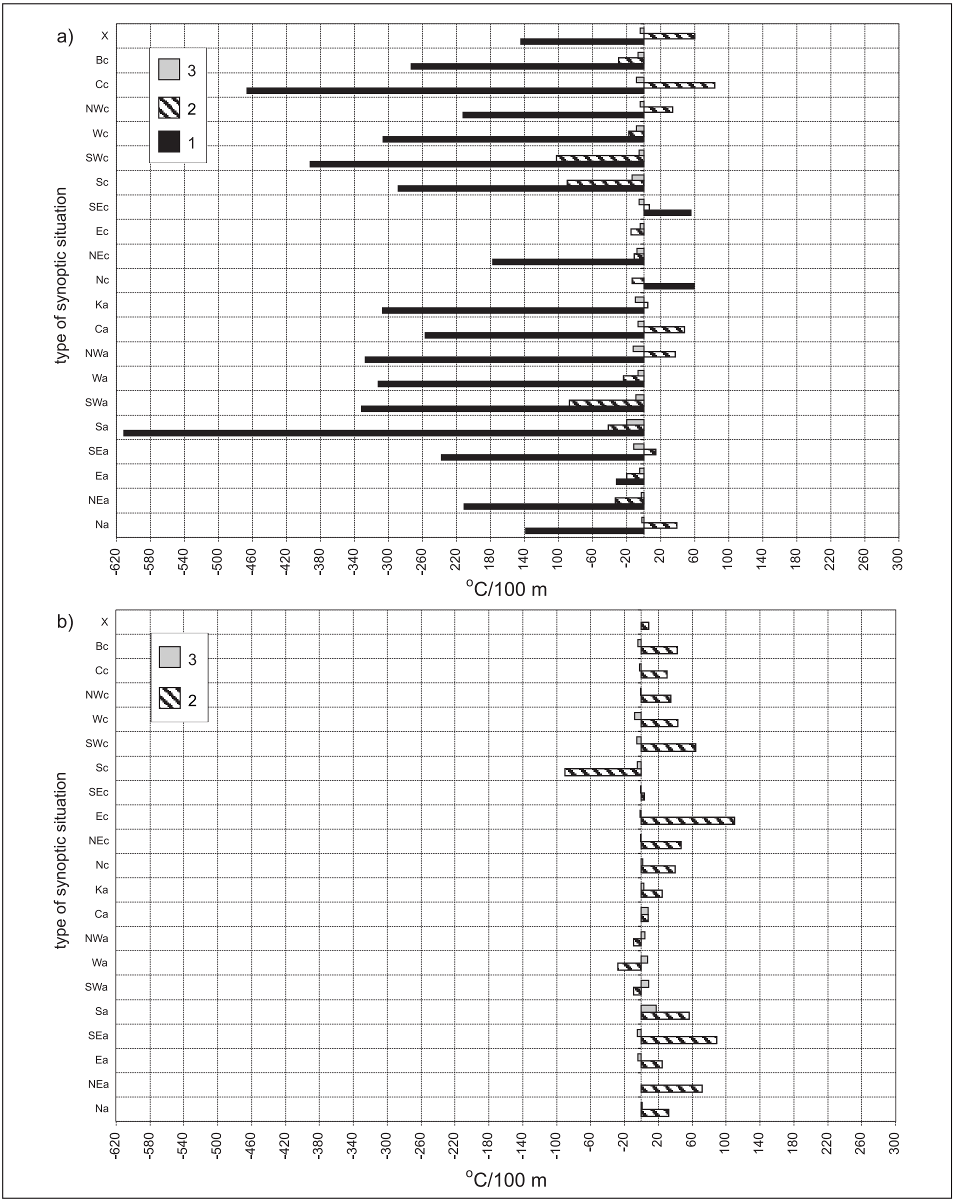

Fig. 6. The vertical temperature gradients (°C/100 m) in February in air layers: 1. (0.05-0.5), 2. (0.5-2) and 3. (2 -12 m a. g. l.) at a) 7 a.m. and b) 1 p.m. CET in various types of synoptic situations in Cracow (1988-1998)

Ryc. 6. Pionowe gradienty termiczne w °C/100 m w lutym w warstwach 1. (0,05 -0,5), 2. (0,5- 2) i 3. (2 -12) m n.p.g. o godzinie 7.00 CSE (a) i 13 CSE (b), przy różnych typach sytuacji synoptycznej w Krakowie w latach 1988-1998

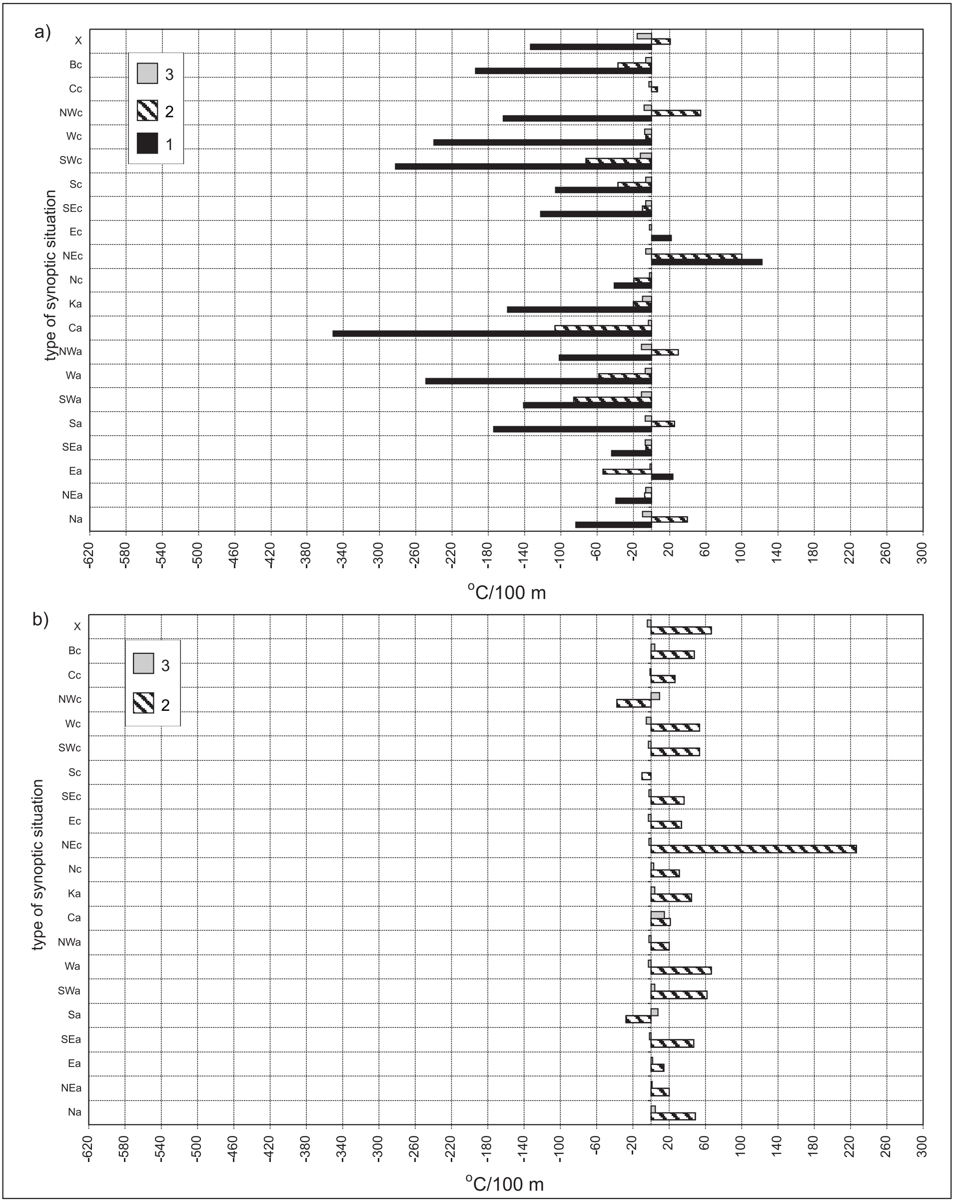

Fig. 7. The vertical temperature gradients (°C/100 m) in March in air layers: 1. (0.05-0.5), 2. (0.5-2) and 3. (2 -12 m a. g. l.) at a) 7 a.m. and b) 1 p.m. CET in various types of synoptic situations in Cracow (1988-1998)

Ryc. 7. Pionowe gradienty termiczne w °C/100 m w marcu w warstwach 1. (0,05-0,5), 2. (0,5-2) i 3. (2-12) m n.p.g. o godzinie 7.00 CSE (a) i 13 CSE (b), przy różnych typach sytuacji synoptycznej w Krakowie w latach 1988-1998

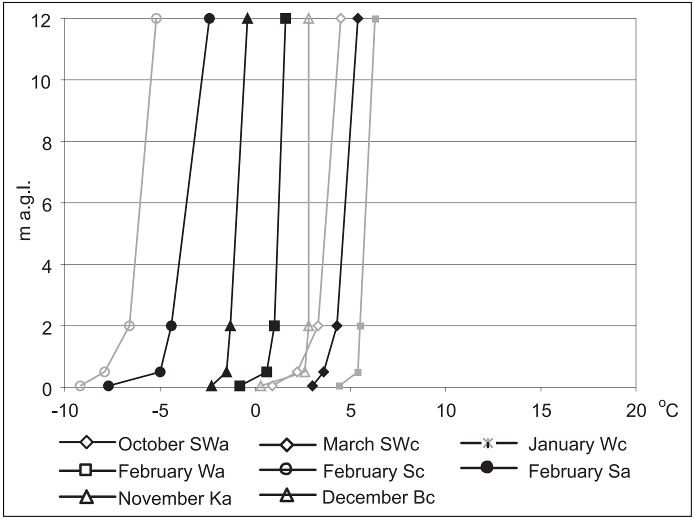

Fig. 8. Examples of inversion temperature profiles at 7 a.m. CET during the autumn/winter season in Cracow (1988-1998)

Ryc. 8. Wybrane inwersyjne profile termiczne o godz. 7 CSE w sezonie jesienno-zimowym w Krakowie w latach 1988-1998

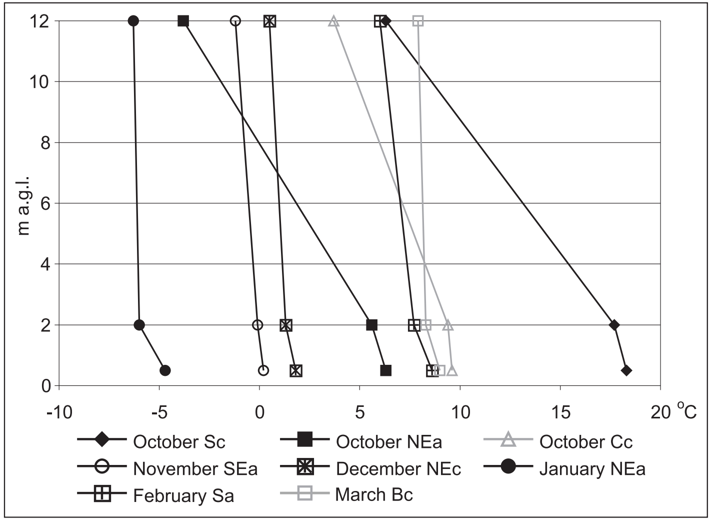

Fig. 9. Examples of insolation temperature profiles at 1 a.m. CET during the autumn/winter season in Cracow (1988-1998)

Ryc. 9. Wybrane insolacyjne profile termiczne o godzinie 13 CSE w sezonie jesienno- zimowym w Krakowie w latach 1988-1998 advection the profile represented the inversion pattern in the morning. This would indicate that in those situations inversion disappeared by midday and could be explained by the quick warming up of the ground and the air above it.

Cases of the isothermal pattern were few. It never occurred across the whole profile, but just in individual layers. In the morning, it occurred under the Ec situation in layer 1 (February) (Fig. 6a) and in layer 2 (March) (Fig. 7a); under the NEc situation in layer 2 (October) (Fig. 2a); and in a central cyclonic situation (Cc) in layer 1 (October) (Fig. 2a) and (March) (Fig. 7a). At midday, the occurrence was limited to anticyclonic situations, i.e. Ea (January), SEa and Sa (December) (Fig. 4b).

4. Conclusions

The study aimed to identify a relationship linking the thermal stratification of the lowest air layers with the synoptic conditions during autumn/winter in Cracow.

A clear relationship was found between the type of the synoptic situation and the value of the vertical temperature gradient. The greatest value of the gradient was recorded in layer 1 in February at 611.1°C/100 m under a Sa situation, while the smallest value occurred in layer 3 in November at 0.1°C/100 m under a Bc situation. The gradient depended on the pressure pattern, with anticyclonic situations producing greater gradient values than the cyclonic situations, at similar direction of air masses advection. Under the southern advection in February (morning, layer 1) it exceeded 300°C/100 m. However, it was the advection rather than the synoptic pressure pattern that was crucial for the difference between the gradients in the selected air layers. The greatest differences (over 60°C/100m) were measured in the morning at cyclonic and anticyclonic situations with the advection of air masses from south-west, west and north-west , and at midday with northern and north-eastern advection. Much smaller differences occurred in the cyclonic and anticyclonic situations with the advection of air masses from east and south-east.

In the morning, inversion events across the investigated profile occurred in both cyclonic and anticyclonic situations with southern and western advection. At midday, the inversion events were recorded only at SEc situation (December) and at Sc situation (February).

Most of the cases of the insolation pattern profile occurred at midday at anticyclonic and cyclonic situations with advection from the northern, southern and western sectors, as well as in central cyclonic and anticyclonic situations.

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Pionowe gradienty temperatury powietrza w sezonie jesienno-zimowym w Krakowie

Streszczenie

Niniejszy artykuł prezentuje duże zróżnicowanie pionowych gradientów temperatury w warstwach: 1 - 0,05–0,5 m n.p.g. (nad poziomem gruntu); 2 – 0,5-2 m n.p.g., i 3 – 2-12 m n.p.g. Dane dotyczące temperatury zanalizowano w zależności od warunków pogodowych sezonu jesienno-zimowego, określonych przy pomocy sytuacji synoptycznych (kierunek adwekcji mas powietrza i rodzaj układu barycznego: a – antycyklonalny, c – cyklonalny). Dane dotyczące temperatury powietrza pochodzą ze Stacji Klimatologicznej Zakładu Klimatologii Instytutu Geografi i Gospodarki Przestrzennej UJ w Krakowie (Ogród Botaniczny), z lat 1988-1998 (październik-marzec).

Najczęściej występowały układy wyżowe (ponad 60%). Największe gradienty zanotowano w warstwie 1, w lutym (-611,1°C/100 m, przy sytuacji synoptycznej Sa). Najmniejsze gradienty pojawiły się w warstwie 3 w listopadzie (0,1°C/100m, przy bruździe cyklonalnej Bc). Typ układu barycznego (antycyklonalny lub cyklonalny) miał wpływ na wartość gradientu. Przy sytuacjach antycyklonalnych obserwowano większe wartości gradientów niż przy sytuacjach cyklonalnych, dla tych samych kierunków adwekcji. Kierunek adwekcji miał wpływ na różnice w wartościach gradientów między poszczególnymi warstwami. Największe różnice występowały w sytuacjach cyklonalnych i antycyklonalnych przy adwekcji z pd.-zach., zach. i pn.-zach., zaś najmniejsze różnice przy adwekcji z pd.-wsch. i wsch.

Inwersja w całym profilu pomiarowym o godz. 7 występowała przy sytuacjach cyklonalnych i antycyklonalnych, przy adwekcji z pd. i zach. O godz. 13 taki profil temperatury wystąpił w grudniu przy sytuacji SEc i w lutym przy sytuacji Sc. Jednak o godz. 13 wystąpił także profil insolacyjny przy sytuacjach cyklonalnych i antycyklonalnych i napływie mas powietrza z pn., pd. i zach.

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