



## Conditional probability of the daily minimum temperature in certain types of circulation on a seasonal basis in the Zywiec Valley in Southern Poland

PAULINA SZCZOTKA

Faculty of Biology and Earth Sciences, Institute of Geography and Spatial Management,  
Jagiellonian University, Gronostajowa 7, 30-387 Kraków, Poland  
E-mail: paulina20.marszalek@student.uj.edu

### ABSTRACT

Air minimum temperature is very important for the natural environment and human activity. This paper presents certain aspects related to the variability of daily minimum temperature of air in the winter (XII, I, II) in the Zywiec Valley, in relation to the synoptic situation in the valley. The analysis is based on the results of research carried out at one point node (the grid) obtained from the base Carpat Clim database. The node is located at the bottom of the Zywiec Valley in the period 1961-2010. The study was complemented with a comprehensive analysis of local conditions for atmospheric circulation and temporal variability over a 50 years period. For this purpose, the classification of types of atmospheric circulation (Niedźwiedź 1981) was used for the upper Vistula river basin. Extreme temperatures included an average minimum temperature of air exceeding the 90<sup>th</sup> and 95<sup>th</sup> percentile. The relationship between the extremes of air temperature and atmospheric circulation types was examined by analyzing the frequency of occurrence of extreme values and their conditional occurrence in each particular type of atmospheric circulation.

**KEY WORDS:** Zywiec Valley, conditional probability, minimum air temperatures, extreme values, atmospheric circulation

### Introduction

Air minimum temperature is very important for the natural environment and human activity. Apart from the circulation conditions needed for their existence, air minimum temperature is affected by relief and terrain type, local water balance and local vegetation (evapotranspiration). The Zywiec Valley is regarded as a geographic unit best known with respect to minimum air temperatures. The coldest winter, a so

called "winter of the century" occurred here in 1929. The coldest month was February 29<sup>th</sup>, and the minimum air temperature recorded that day was -40.6° C (Starkel 1999).

The Zywiec Valley's environmental conditions and related impact on local climatic conditions are very adverse to the health and life of the population living there. The concave landforms give rise to stagnant cold air and frequent thermal

inversions, which are a highly unfavorable weather phenomenon. They facilitate the formation of low stratus-type clouds, stratocumulus (St, Sc), prevent the formation of convection (vertical air movements) and horizontal air movement, which results in the weakening of local atmospheric circulation. They also contribute to the development and persistence of fog (Milata 1959).

The local terrain favors the long duration of the period of ground frost, hence agricultural problems, which are faced by the residents of the Zywiec Valley every year. Problems related to the change of the start and end dates of the period without the presence of ground frost play a key role, especially in the transitional seasons (spring and autumn). They influence the rate of plant growth, yield and labor in the fields. Any changes associated with the date of the beginning and end of the period without the occurrence of frost ground period are of immense importance (Bielec-Bąkowska & Piotrowicz 2011).

### Materials and methods

The minimum air temperature based on the Meteorological Dictionary (Niedźwiedź 2003), is the lowest recorded temperature of the air during a given period of time. This definition was developed on the basis of a relatively rich collection of data obtained from the CarpatClim database the climate database of the Carpathian Region (<http://www.carpatclim-eu.org>). The coordinates of the grid point used in this study are 49.70°N, 19.20°E. It is located at the bottom of the Zywiec Valley. All analyses in this study were prepared on the basis of daily resolution data and the longest possible sequence (1961-2010).

The CarpatClim database, was established in order to improve the availability of climate data. It has very

good temporal resolution (one day) and spatial resolution (0.1° x 0.1°). Because of access issues and limited duration of the study, the synoptic situation was identified with the type of atmospheric circulation. Moreover, taking into account the availability of various typologies and their application to the region of southern Poland a calendar of types of circulation was used for the analysis of the synoptic circulation - TN (Niedźwiedź 1981). The basis for the separation of 21 types of atmospheric circulation in the case of this calendar is the dominant barometric system and the direction of advection. The index "a" denotes anticyclonic systems (high-pressure) and "c" cyclonic systems (low-pressure). It should be noted that this typology is subjective and non-automatic (Ustrnul & Wypych 2011). At the beginning, the data were analyzed in relation to the spatio-temporal differentiation of minimum air temperature in certain types of atmospheric circulation in each of the four seasons (winter, spring, summer, autumn). The likelihood of the stated ranges of air temperature was also analyzed during the most frequently noted advection of air masses. As a result, synoptic situations were identified that are particularly conducive to the occurrence of the minimum air temperature. The final stage of this study was to investigate and determine the frequency and likelihood of occurrence of air minimum temperature in the types of atmospheric circulation in light of the classification of types of synoptic situations made by Niedźwiedź. On the basis of synoptic maps of Europe, 21 types of synoptic situations were distinguished in this study. To make the distinction easy, universally applied lettermarks were introduced to determine the direction of advection with the letter 'a' for anticyclonic, and 'c' for cyclonic

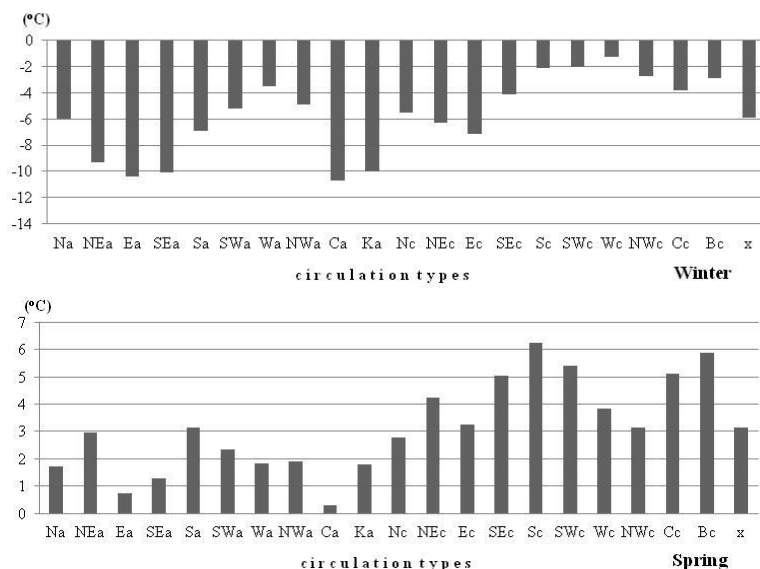
situations: Na, Nc—situations with an advection of air masses from the north, NEa, NEc—situations with an advection of air masses from the northeast, Ea, Ec—situations with an advection of air masses from the east, SEa, SEc—situations with an advection of air masses from the southeast, Sa, Sc—situations with an advection of air masses from the south, SWa, SWc—situations with an advection of air masses from the southwest, Wa, Wc—situations with an advection of air masses from the west, NWa, NWc—situations with an advection of air masses from the northwest, Ca—centre of high pressure, Ka—anticyclonic wedge, Cc—center cyclonic situation, Bc—cyclonic trough, x—situations which cannot be classified (Twardosz & Niedźwiedź 2001).

## Results

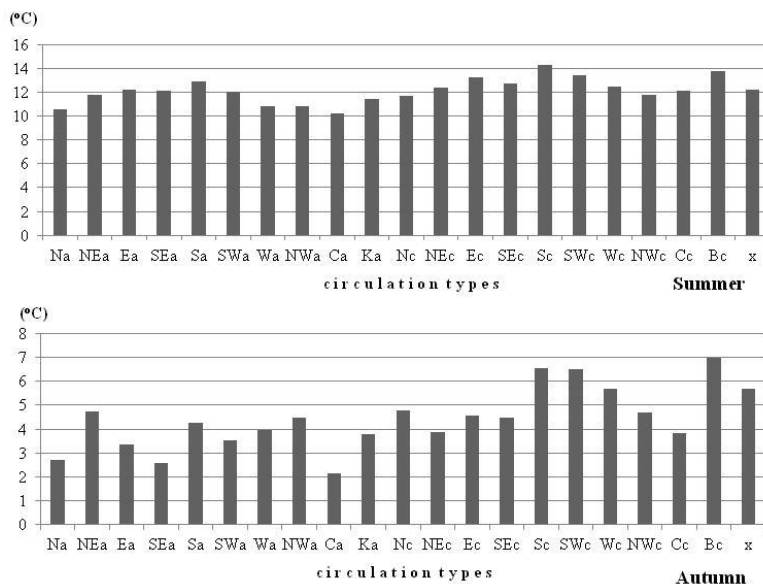
### Average minimum air temperature versus atmospheric circulation type

Among the 21 types of synoptic situations commonly studied, the most

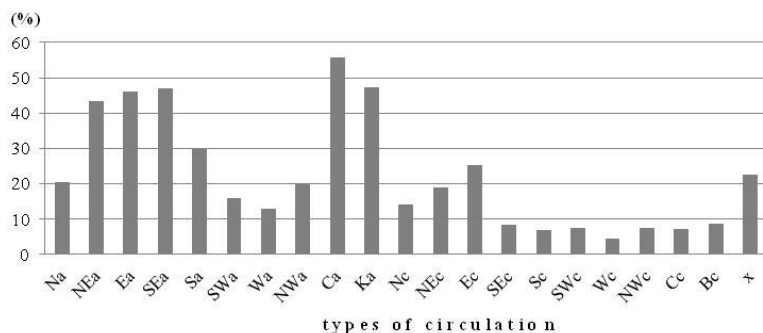
frequently occurring situations is the anticyclonic situation. In the Zywiec Valley, the lowest minimum temperature during the winter is observed in an anticyclonic situation, mainly in the Ca, Ka and advection of air masses from the east, NEa, E and SEa. Average minimum temperatures oscillate between Ca (-10.7°C), Ka (-10.0°C), while the NEa (-10.4°C), in the SEa (-10.1°C) and NEa (-9.3°C). During the examined time period, average minimum temperature in the spring was noted in the Ca (0.3°C), NEa (1.9°C), while in the Ka (1.8°C). Advection of air masses from the east, particularly in situations of Ea produced a great impact on the minimum temperature in the autumn. In the summer and autumn, as in the previous seasons, the lowest values were recorded during the anticyclonic situation: Ca, Ka, and advection of air masses from the east. The average minimum air temperature in the summer ranged from Ca (10.2°C), Ka (10.8°C), while in the autumn (2.1°C) and (3.8°C) respectively (Fig. 1 and 2).



**Figure 1a.** Average minimum air temperature in a certain type of atmospheric circulation in the winter and spring.



**Figure 1b.** Average minimum air temperature in a certain type of atmospheric circulation in the summer and autumn.



**Figure 2.** Conditional probability (%) of the daily minimum temperature the probability of  $< -10^{\circ}\text{C}$  in certain types of circulation in the winter.

### Conditional probability of the daily minimum temperature in certain types of circulation on a seasonal basis

All four seasons (winter, spring, summer, autumn) were identified across the floor of the Zywiec Valley for the examined fifty-year period for which the probability of occurrence of minimum temperature in the range of local air temperature has been calculated. The range of air temperature for the winter was

$\leq -10^{\circ}\text{C}$ , spring and autumn  $\leq 0^{\circ}\text{C}$ , and the summer  $\leq 10^{\circ}\text{C}$ .

The research showed that anticyclonic situations occurred more often than cyclonic situations in the study area during the winter (Fig. 3). The most frequent situations were: Ca (55.6%) and Ka (47.2%). The next most frequent situations were anticyclonic and cyclonic patterns with the advection from the east: Ea (46.0%), NEa (43.3%), SEa (46.9%).

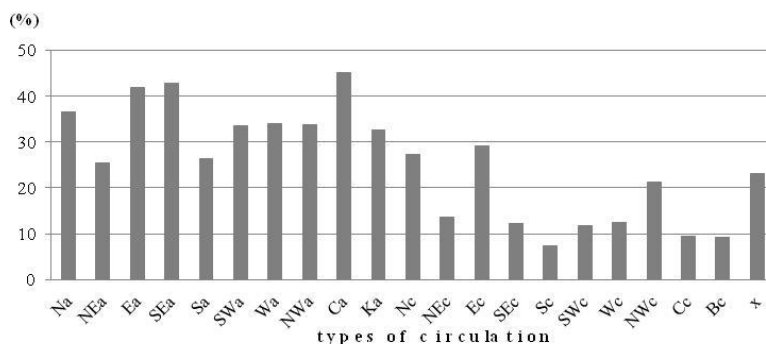
The least frequent situations were: Cc (7.0%), and NWc (7.3%).

In the spring, the highest probability of a minimum temperature of  $\leq 0^{\circ}\text{C}$  was recorded also in the Ca (45.2%), SEa (42.8%) and Ea (41.9%) (Fig. 4.). The least frequent situations were noted in: Sc (7.3%). On 23,0% of days, the daily minimum temperature  $\leq 0^{\circ}\text{C}$  occurred in X.

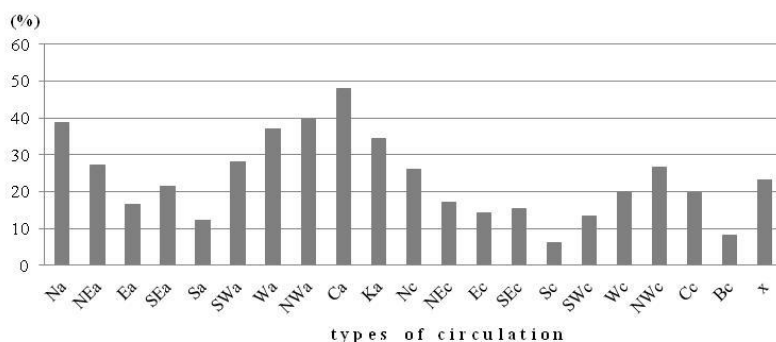
During the summer, the probability was greater during anticyclonic situations. The probability of  $\leq 10^{\circ}\text{C}$  minimum temperature is shown in Figure 5. The most frequent situations

were: Ca (48.1%) NWa (39.5%) Na (38.8%), and Wa (36.9%). The least frequent situations were: Sc (6.3%) and Bc (8.0%).

In the autumn the probability of  $\leq 0^{\circ}\text{C}$  minimum temperature reached higher values during anticyclonic situations (Fig. 6.) The most frequent situations were: Ca (37.8%), NWc (32.8%), SWa (32.7%). The least frequent situations were: Sc and Wc (11.0%), SWc (8.5%). On 11,5% of days, the daily minimum temperature  $\leq 0^{\circ}\text{C}$  occurred in X.



**Figure 3.** Conditional probability (%) of the daily minimum temperature the probability of  $< 0^{\circ}\text{C}$  in certain types of circulation in the spring.



**Figure 4.** Conditional probability (%) of the daily minimum temperature the probability of  $< 10^{\circ}\text{C}$  in certain types of circulation in the summer.

## Discussion and conclusions

This paper describes the effect of atmospheric circulation on the occurrence

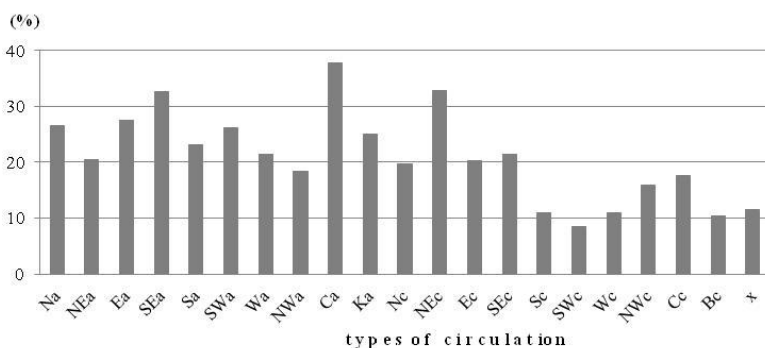
of the variability of daily minimum temperature of the air in the winter (DJF) in the Zywiec Valley, in relation to the

synoptic situation. Air minimum temperature is very important for the natural environment and human activity. Atmospheric circulation is crucial in shaping climate and weather conditions as well as the relationships between large-scale circulation and local weather, including the occurrence of extreme phenomena and events (Ustrnul *et al.* 2014).

Research has shown that atmospheric circulation has a decisive impact on the value and occurrence of minimum temperature in the Zywiec Valley in southern Poland. There are marked differences in the formation of thermal conditions due to terrain, terrain exposure (bottom of the valley) and elevation, resulting in more contrasting effects of the conditions of circulation in winter than in summer in valleys (Niedzwiedź 1981).

The research showed that during the winter anticyclonic situations occurred more often than cyclonic situations in the study area. From among 21 synoptic situations, the most favourable for the occurrence of minimum temperature are the: center of the high pressure zone (Ca), and the anticyclonic wedge (Ka). Advection of air masses from the east is also helpful: north-eastern (NEa), eastern (Ea) and south-eastern anticyclonic situations (SEa). Minimum temperature were found to follow similar patterns in each season.

The relationship between the extremes of air temperature and atmospheric circulation types was examined by analyzing the frequency of the occurrence of extreme values and their conditional occurrence in each particular type of atmospheric circulation.



**Figure 5.** Conditional probability (%) of the daily minimum temperature the probability of  $< 0^{\circ}\text{C}$  in certain types of circulation in the autumn.

## References

- Bielec-Bąkowska, Z., Piotrowicz, K. 2011. Wieloletnia zmienność okresu bezprzymrozkowego w Polsce w latach 1951–2006. *Prace i Studia Geograficzne*, 47: 77–86.
- Milata, W. 1959. Częstość inwersji względnych temperatury powietrza w Krakowie w latach 1954, 1955 i 1957. *Przegląd Geofizyczny*, 4 (12), 1: 19–23.
- Niedzwiedź, T. 1981. Sytuacje synoptyczne i ich wpływ na zróżnicowanie przestrzenne wybranych elementów klimatu w dorzeczu Górnej Wisły. Rozprawa habilitacyjna., Uniwersytet Jagielloński, Kraków.
- Starkel, L. 1999. *Geografia Polski, Środowisko przyrodnicze*. PWN, Warszawa.
- Twardosz, R., Niedzwiedź, T. 2001. Influence of synoptic situations on the precipitation in Kraków (Poland), *International Journal of Climatology*, 21: 467–481.
- Ustrnul, Z. 2000. Synoptic-climatic structure of the extreme air thermal phenomena in Poland. *Geographia Polonica*, 73, 2: 99–109.

Ustrnul, Z., Wypych, A. 2011. Ekstremalne wartości temperatury powietrza w Polsce w świetle różnych klasyfikacji typów cyrkulacji. *Prace i Studia Geograficzne*, 47: 87–95.

Ustrnul, Z., Wypych, A., Winkler, J. A., Czekierda, D. 2014. Late spring freezes in Poland in relation to atmospheric circulation, *Quaestiones Geographicae*, 33(3): 165–172.

## Streszczenie

Znaczenie temperatury minimalnej powietrza dla środowiska przyrodniczego i działalności człowieka jest niezmiernie ważne. Niniejsza praca przedstawia aspekty związane ze zmiennością dobowej temperatury minimalnej powietrza w okresie zimowym (XII-II) w Kotlinie Żywieckiej, w świetle sytuacji synoptycznych. Opracowanie bazuje na wynikach badań przeprowadzonych w jednym punkcie węzłowym pochodzącym z bazy CarpatClim, zlokalizowanym w dnie Kotliny Żywieckiej za okres 1961-2010. Studium zostało uzupełnione kompleksową analizą warunków cyrkulacyjnych i ich zmiennością czasową w ciągu 50-lecia. W tym celu zastosowano klasyfikację typów cyrkulacji atmosferycznej Niedźwiedzia (1981) dla dorzecza górnej Wisły. Za ekstremalne zjawisko termiczne uznano średnią temperaturę minimalną powietrza przekraczającą wartość progową 90 i 95 percentyla. Związki pomiędzy ekstremalnymi wartościami temperatury powietrza a typami cyrkulacji atmosferycznej rozpatrzono poprzez analizę częstości wystąpienia wartości ekstremalnych oraz ich warunkowego wystąpienia w danym typie cyrkulacji atmosferycznej.