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ASSESSMENT OF SENSIBLE CLIMATE IN WARSAW USING UTCI

Ocena klimatu odczuwalnego w Warszawie na podstawie wskaźnika UTCI

Streszczenie. W ciągu ostatnich dekad powstało około 100 różnych wskaźników służących do oceny wpływu warunków meteorologicznych na samopoczucie człowieka. W 2009 roku, wysiłkiem międzynarodowego zespołu badawczego, powstał nowy wskaźnik termiczny – UTCI (Universal Thermal Climate Index). Wskaźnik ten jest przejawem nowego podejścia w badaniach biometeorologicznych, gdyż w odróżnieniu od tradycyjnych wskaźników, uwzględnia skomplikowane procesy termoregulacyjne organizmu człowieka. Niniejsze opracowanie stanowi jedną z pierwszych prób oceny klimatu odczuwalnego Warszawy z zastosowaniem wskaźnika UTCI. W opracowaniu wykorzystane zostały codzienne dane meteorologiczne ze stacji Warszawa-Okęcie z wielolecia 2000–2009.

Słowa kluczowe: UTCI, klimat odczuwalny, wskaźnik biometeorologiczny, Warszawa
Key words: UTCI, sensible climate, biometeorological index, Warsaw

INTRODUCTION

For many years various complex biometeorological indexes have been used to assess sensible climate conditions. Initially a common approach was to use indices that took into account only a few chosen meteorological elements to show intensity of both direct and indirect impacts of atmosphere on human body. In 1960s first indexes based on human heat budget considerations were appeared. They base on heat exchange between human body surface and the environment, but still they passed over the complexity of physiological processes that take place in human organism as the response to atmospheric stimuli.

In the present research recently developed index has been applied – UTCI (*Universal Thermal Climate Index*) in order to characterise bioclimatic conditions in Warsaw. It considers not only heat flow between body surface and the environment but also heat exchange in the body itself – between its inner parts and outer layers. The present paper is one of the few first attempts to assess sensible climate of Warsaw using UTCI.

Daily meteorological data from Warszawa-Okęcie synoptic station derived from SYNOPs for 12:00 UTC were used for the calculations. The analysed period was 2000–2009. Mean radiant temperature (Tmrt) and UTCI values were calculated using BioKlima v.2.6 software package (http://www.igipz.pan.pl/geoekoklimat/blaz/BioKlima.htm).

UTCI INDEX

The UTCI is defined as the equivalent air temperature of the reference conditions, causing the same human physiological responses as in the actual thermal conditions. Therefore UTCI is the air temperature which would produce under reference conditions the same thermal strain as in the actual thermal environment (Błażejczyk et al. 2010).

UTCI bases on the Fiala multi-node model of the human heat balance. The model consists of two interacting systems of thermoregulation: the passive system, that takes into account physical aspects of heat transfer, occurring in the human body, as well as on its surface, and the active system which includes physiological thermoregulatory mechanisms, i.e. sweat secretion, shivering thermogenesis and the rate of skin blood flow. Input data to the model consists of meteorological parameters (air temperature – Ta, vapour pressure – vp, wind speed – va and mean radiant temperature – Tmrt[1]) and physiological parameters (metabolic heat, albedo of the body surface and clothing, coefficients of human body and clothing emissivity, thermal and evaporative clothing insulation). As a result, detailed information concerning the value of particular heat fluxes and intensity of physiological responses of an organism are obtained. UTCI replaces multi-dimensional output information from Fiala model by one-dimensional quantity expressed in °C.

For particular applications the special assessment scale of UTCI can be used. It bases on objective parameters, i.e. intensity of physiological reactions

[1] *Mean radiant temperature (Tmrt)* is defined as the uniform temperature of a hypothetical spherical surface surrounding the human body that would result in the same net radiation energy exchange with the body as the actual, complex radiative environment (Matzarakis et al. 2007)

to the fluctuating complex environmental conditions. Such approach distinguishes UTCI from the other biometeorological indexes. For most of them the assessment scales define subjective thermal sensations. However, the UTCI values represent the dimension of thermal strain on human being, and not thermal sensations measures (Tab. 1).

Table 1. UTCI thermal stress scale (Błażejczyk et al. 2010)
Tabela 1. Skala obciążeń cieplnych organizmu według wskaźnika UTCI (Błażejczyk et al. 2010)

UTCI (°C)	Stress category	Examples of physiological responses
> +46	extreme heat stress	Step decrease in total net heat loss. Averaged sweat rate > 650 g/h, steep increase.
+38 to +46	very strong heat stress	Core to skin temperature gradient < 1°C (at 30 min). Increase in rectal temperature at 30 min.
+32 to +38	strong heat stress	Averaged sweat rate > 200 g/h. Increase in rectal temperature in 120 min. Latent heat loss > 40W at 30 min. Instantaneous change in skin temperature > 0°C /min.
+26 to +32	moderate heat stress	Occurrence of sweating at 30 min. Steep increase in skin wettedness.
+9 to +26	no thermal stress	Averaged sweat rate > 100 g/h. Latent heat loss > 40W, averaged over time.
0 to +9	slight cold stress	Local minimum of hand skin temperature (use gloves)
−13 to 0	moderate cold stress	Skin blond flow at 120 min lower than at 30 min. Averaged face skin temperature < 15°C. 30 min face skin temperature < 15°C (pain).
−13 to −27	strong cold stress	Averaged face skin temperature < 7°C (numbness). Rectal temperature time gradient < −0,1°C/h.
−27 to −40	very strong cold stress	120 min face skin temperature < 0°C (frostbite). Steeper decrease in rectal temperature. Occurrence of shivering.
< −40	extreme cold stress	Rectal temperature time gradient < −0,3°C/h. 30 min face skin temperature < 0°C (frostbite).

SENSIBLE CLIMATE OF WARSAW

Until now there were published several studies regarded climate of Warsaw. Some of these publications were dedicated to bioclimatological conditions in the city (Kopacz-Lembowicz 1978, Kozłowska-Szczęsna et al. 1996, Błażejczyk

2002). The present paper is one of the first attempts of assessing sensible climate in Warsaw using the new generation index – UTCI.

In the analysed period 2000–2009 mean decadal UTCI values throughout the year vary in Warsaw between around −13°C at the end of December and January to about 24°C in the third decade of July, what corresponds to heat stress categories „moderate cold stress" and „no thermal stress" respectively (Fig. 1). However, in particular years those values may remarkably diverse from long-term mean values of UTCI. In the coldest days of January UTCI values can fall sometimes even to −40°C, what reflects „very strong cold stress". Absolute minimum of UTCI in the analysed period was −40.8°C and was observed on 2nd January 2002. Conversely in summer from mid-June until the end of July on some days UTCI values may overreach 32°C which indicates occurrence of strong heat stress. In the period 2000–2009 the highest UTCI value was 38.8°C (22nd June 2000).

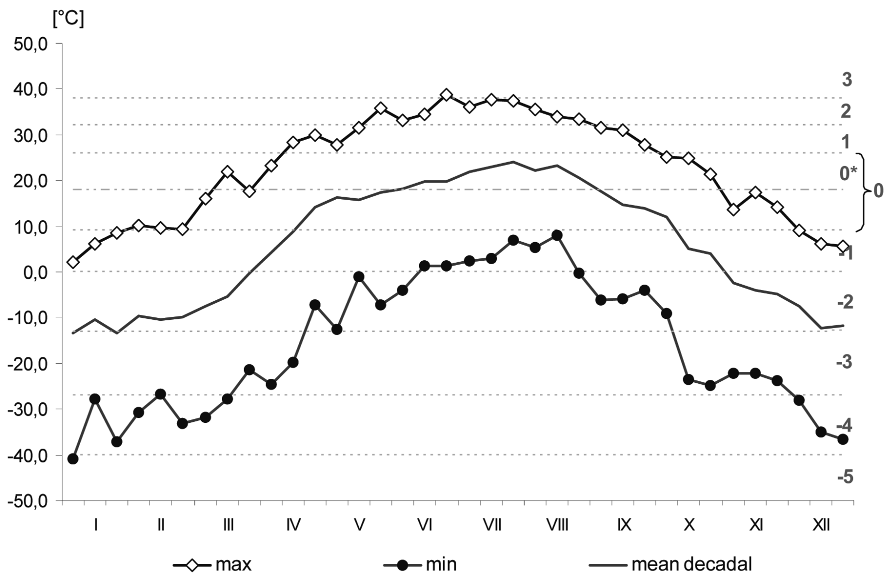

Fig. 1. Annual course of mean, maximum and minimum decadal UTCI values at 12:00 UTC at the station Warszawa-Okęcie (2000–2009)
3 – very strong heat stress, 2 – strong heat stress, 1 – moderate heat stress, 0 – no thermal stress, 0* – thermal comfort zone, −1 – slight cold stress, −2 – moderate cold stress, −3 – strong cold stress, −4 – very strong cold stress, −5 – extreme cold stress
Ryc. 1. Przebieg roczny wartości średnich dekadowych, maksymalnych i minimalnych wskaźnika UTCI o godz. 12:00 UTC na stacji Warszawa-Okęcie (2000–2009)
3 – bardzo silny stres ciepła, 2 – silny stres ciepła, 1 – umiarkowany stres ciepła, 0 – brak obciążeń cieplnych, 0* – komfort cieplny, −1 – łagodny stres zimna, −2 – umiarkowany stres zimna, −3 – silny stres zimna, −4 – bardzo silny stres zimna, −5 – nieznośny stres zimna

Thermoneutral conditions were occurring most of all during summer days. So called “thermal comfort zone”[2], which is represented by UTCI values ranging from 18°C to 26°C, was observed mainly at daytime on days from second decade of June until nearly end of August.

Considering the whole year the most frequent in Warsaw at 12:00 UTC were atmospheric conditions that don’t cause thermal stress (36% of cases). However, relatively often, in about 25% of analysed days, moderate cold stress occurred. Moreover, according to the UTCI values, all circumstances of cold stress were much more frequent (53%) during the whole year than heat stress classes (10%) (Fig. 2).

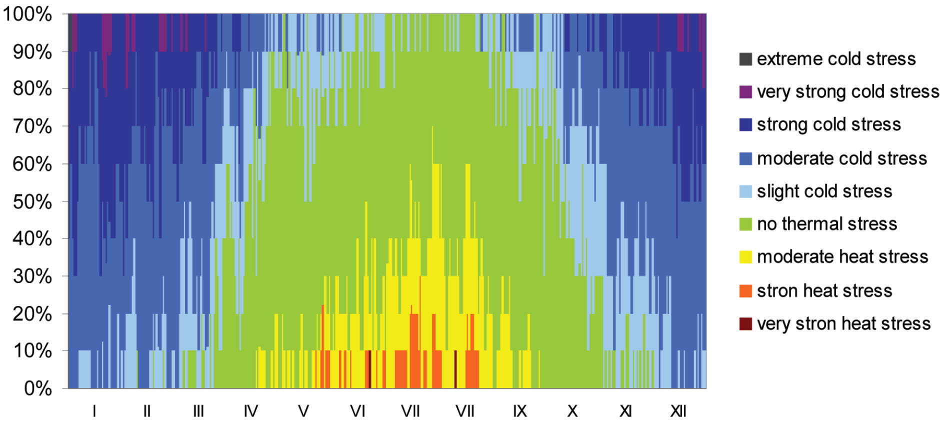

Fig. 2. The frequency of thermal stress categories by UTCI at 12:00 UTC at the station Warszawa-Okęcie (2000–2009)

Ryc. 2. Częstość poszczególnych stanów obciążeń cieplnych w ciągu roku według wskaźnika UTCI o godz. 12:00 UTC na stacji Warszawa-Okęcie (2000–2009)

From the end of April until the beginning of October at least 60% of analysed days are characterized by lack of thermal stress. At the same time thermal comfort is observed most frequently in the first half of May, through the whole June and in the majority days of August (Fig. 3). In July thermal comfort is achieved less frequently due to moderate and strong thermal stress that occur in this month quite often (40%). In the winter in the midday hours the lack of thermal stress hardly ever appears.

The analysis presented refers to the airport meteorological station Warszawa-Okęcie. In the centre of the city sensible climate significantly differs from bio-

[2] Thermal comfort zone — the range of ambient temperatures, associated with specified mean radiant temperature, humidity and air movement, within which a human in specified clothing expresses indifference to the thermal environment for an indefinite period (*Glossary of Terms for Thermal Physiology* 2003)

meteorological conditions observed in the airport (Kozłowska-Szczęsna et al. 1996). Namely, higher wind speed and a little lower air temperature in the airport are reflected in lower UTCI values at Warszawa-Okęcie in the comparison to the city centre (see paper of Błażejczyk in this volume). Therefore it is supposed that city centre would be characterised by lower frequency of cold stress and thermoneutral conditions but by higher frequency of days with heat stress. In the future this study is planned to be extended by analysing data from stations situated in various districts of the city, closer to its centre.

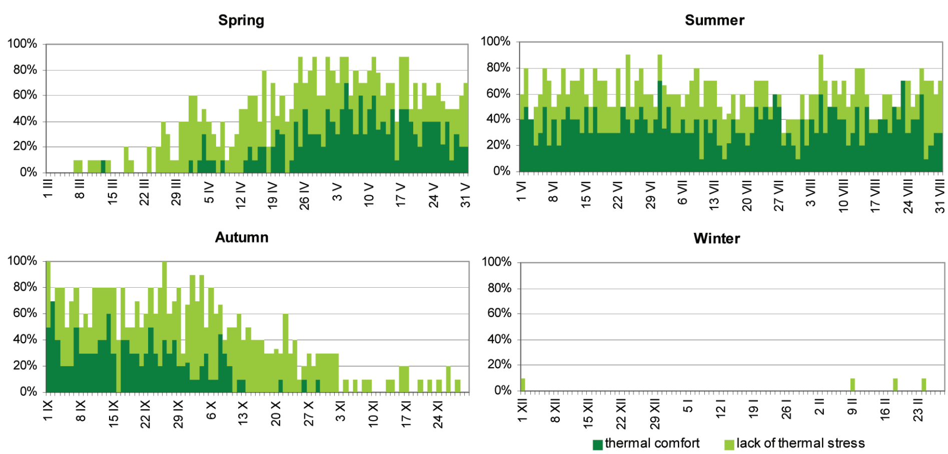

Fig. 3. The frequency of no thermal stress, including thermal comfort, in particular seasons by UTCI values at 12:00 UTC at the station Warszawa-Okęcie (2000–2009)
Ryc. 3. Częstość braku obciążeń cieplnych, w tym stanu komfortu termicznego, w poszczególnych porach roku według wartości wskaźnika UTCI o godz. 12:00 UTC na stacji Warszawa-Okęcie (2000–2009)

CONCLUSIONS

Analysis of sensible climate in Warsaw using UTCI revealed that during the year most often in the midday hours thermoneutral conditions occur. Among thermal stress categories, cold stress, with various intensity, predominates. However, we should also take into consideration that in the UTCI assessment scale cold stress conditions are represented by 5 categories and heat stress only by 4 classes.

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