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BIOCLIMATIC CHARACTERISTIC OF BANAT

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Abstract: This paper analyzes thermal environment condition in Banat on the basis eighteen year long data series in the period 1992-2008. Two thermal indexes (*TI*), suggested by World meteorological organization, are used, heat index and wind chill index. Analysis shows that mean annual *TI* were lower than mean annual air temperatures that indicate considerable influence of wind on feeling temperatures in Banat. Analysis also shows that *TI* increased at rate 0.7°C per decade that is likely to be due to a rise in air temperature under global warming and urban development. Besides *TI* growth, increasing trend of frequency of *TI* in heat stress categories is found (1.63 days per years). Frequency of *TI* in cold stress categories shows a trend of a decrease (0.26 days per years). Unfavorable thermal conditions during the summer have Zrenjanin, while during the winter time Kikinda.

Key words: climate change, heat index, wind chill index, Banat

Introduction

People are strongly related to the nature that surrounds them and directly or indirectly acts on them. The atmosphere is a part of the environment with which majority living organisms are continually faced, so condition of the body can be interpreted as a response to the physical and chemical state of the atmosphere. People have changed the primary composition of the atmosphere which reflects unfavorably on the whole living world, and therefore the man. Impact of human activities on the atmosphere involves increasing the concentration of gaseous pollutants and particulate matter in the atmosphere, with an emphasis on increasing the greenhouse gases that lead to global warming, destruction of the ozone layer and increase in UV radiation.

Bioclimatic research of climate impacts on human body play a significant role in the assessment of the quality of life of the population and environment specific area. It is now well known that weather conditions have a major impact on

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human health and the weather elements in the human body may act individually or in combination. Therefore, research of climate impacts on human body play a significant role in the assessment of the quality of life of the population and environment specific area. The fact is that in recent decades in spatial planning, medicine and tourism more emphasize the importance of bio-climatic characteristics of the area. Most of the research in this field was done by scientists from the fields of medicine, while a small part by climate scientists – biometeorology (Eurowinter Group, 1997; Verein Deutscher Ingenieure [VDI], 1998; Hoppe, 1999; Kalkstein, 2000; Mihailović, Arsenić, Lalić, Radlović, & Koči, 2001). There are a small number of papers in the area biometeorology of Vojvodina. Considering the fact that long-term forecasts are announcing a temperature rise in the following decades and the more frequent occurrence of extreme temperature, this is certainly an area that should continue to devote much more attention.

Heat indices

In medical and biometeorological science and practice there are a number of empirical expressions, which elements that determine a person's sensation of heat put into the relationship. They are a measure of the relative level of comfort that feels modeled the human body in a given environment. There are over a hundred different indices to assess the effect of heat and cold on the human body in different environmental conditions. All of them can be divided into two basic categories: (a) indices that combine meteorological and physiological parameters, and (b) indices based only on meteorological parameters. First group index is based on the formula of thermal balance. This group index is a difficult for the implementation because it includes lot of parameters that require complicated measurements, so very often these parameters are taken as constant. Indices of the second group are also called simple meteorological indices or direct indices. Due to its feasibility and easier interpretation by the user, second group of indices are more applicable and they are often used by national weather services around the world. In warm conditions, direct indices usually consist of combinations of air temperature and some measure for humidity. In cold conditions they combine air temperature and wind velocity. There are also indices that combine temperature with several other meteorological elements. Most commonly used simple thermal indices are: Heat Index (Stedman, 1979a, 1979b, 1984; Rothfusz, 1990), Wind Chill Index (Osczevski & Bluestein, 2005), Net Effective Temperature (Li & Chan, 2000) and Humidex (Masterton & Richardson, 1979).

Data and research methodology

Due to the simplicity and less demanding in terms of data, for assessing the impact of weather conditions on the man, simple thermal indices were used in this study. Comparing the available meteorological data with the most frequently used simple indices, Heat Index and Wind Chill Index were selected for the analysis. These two indexes, together with net effective temperature, for analysis were recommend the World Meteorological Organization (WMO, 2004). Due to connection of Heat Index and Wind Chill Index with possible effects on human body, they were given advantage over, also recommended, net effective temperature.

Heat Index (HI) is the temperature the body feels when air temperature (T) and the relative humidity (RH) are combined (Mihailovic et al., 2001). The index does not take into account the direct solar radiation, wind and clothing. This index is a defined by Robert Steadman (Steadman, 1979a, 1979b, 1984). Based on table generated by Steadman, National Climatic Data Center USA (NCDC) has developed a formula in the following form (Rothfusz, 1990):

$$HI = -42.379 + 2.04901523T + 10.14333127RH - 0.22475541TRH - 6.83783 \cdot 10^{-3}T^2 - 5.481717 \cdot 10^{-2}RH^2 + 1.22874 \cdot 10^{-3}T^2RH + 8.5282 \cdot 10^{-4}TRH^2 - 1.99 \cdot 10^{-6}T^2RH^2 \quad (1)$$

where T is the air temperature and RH is relative humidity. In equation (1) temperature and heat index are expressed in degrees Fahrenheit (^oF), while the relative humidity in percent (conversion: $T(^oC) = \frac{5}{9}(T(^oF) - 32)$). It is important to note that equation (1) is effective when the temperature is greater than 26.7ºC and relative humidity is at least 40%. In the comparison to the Stedman table equation has an error of calculation of ±1.3 ^oF.

Wind Chill Index (WCI) combines the air temperature (T) and wind speed (v) to indicate the temperature that the human body feels. The index does not take into account the direct solar radiation, wind and physical activity. Formula defined Siple and Passel (1945), and has been reworked Osczevski and Bluestein (2005). A revised formula is as follows:

$$WCI = 35.74 + 0.6215T - 35.75v^{0.16} + 0.4275Tv^{0.16} \quad (2)$$

where T is the air temperature expressed in degrees Celsius (°C), and v is wind speed in ms^{-1}.

For the analysis of thermal conditions, data from three main meteorological stations (GMS) in Banat (Banatski Karlovac, Kikinda and Zrenjanin|) were used. The data on air temperature (°C), relative humidity (%) and wind speed (ms^{-1}) measured in three local time terms (7, 14 and 21 hours) for the period 1992-2008. years were used.

Thermal indexes (TI) were calculated using equations (1) and (2) with respect the following rules (Browning & Walawender, 2009): (a) when the ambient temperature was greater than 26.7°C equation (1) were used; (b) when the air temperature was between 10°C and 26.7°C TI was considered to be TI equal to the air temperature; (c) when the ambient temperature was below 10°C equation (2) were used. The Heat Index and Wind Chill Index are divided into four categories that are associated with the degree of effects on the human body as shown in Table 1.

Table 1. Thermal stress categories

HI	Thermal stress	WCI	Thermal stress
27 ºC to 31 ºC	(I) caution	0 ºC to -10 ºC	(I) low
32 ºC to 34 ºC	(II) extreme caution	-10 ºC to -25 ºC	(II) moderate
41 ºC to 53 ºC	(III) danger	-25 ºC to -35 ºC	(III) high
≥54 ºC	(IV) extreme danger	≤ -35ºC	(IV) extremly high

The analysis of TI values at 7, 14 and 21 hours, the average annual and seasonal (summer and winter) values of TI, the absolute maximum and minimum and the frequency of days with certain categories of TI was analised. Average summer (TI_l) and winter average (TI_z) values were calculated as the arithmetic average of the daily average TI values during the three summer months (June, July, August) and three winter months (December, January, February), respectively. Value of TI_z was calculated as the average of January and February TI for the indicated year, and TI in December prior year. The average value of the initial winter the observed period (1992. year) was calculated based on data for January and February of that year. Average annual (TI_g) values were calculated as the arithmetic mean of all the average daily value in one year. For purposes of calculating the frequency of days with certain categories of TI for each day is defined the maximum and minimum. The frequency of days with the categories from cold stress was determined using the minimum daily TI, and in terms of heat stress due to the use of maximum daily TI. Trends of meteorological elements were calculated using linear regression.

Results

Figure 1 shows *TI* in the 7, 14 and 21 hours, and the difference between *TI* and *T* in Banat in the period 1992-2008. Lines of different colors correspond to limits heat stress categories shown in Table 1. Figure 1 shows that the highest and lowest *TI* values were in the first two categories of heat stress and that are rarely crossed in the third category. The differences between *TI* and *T* are more oftem negative than positive. The largest, positive and negative, differences between *TI* and *T* were in Banatski Karlovac +5.3°C and -11.6°C, respectively.

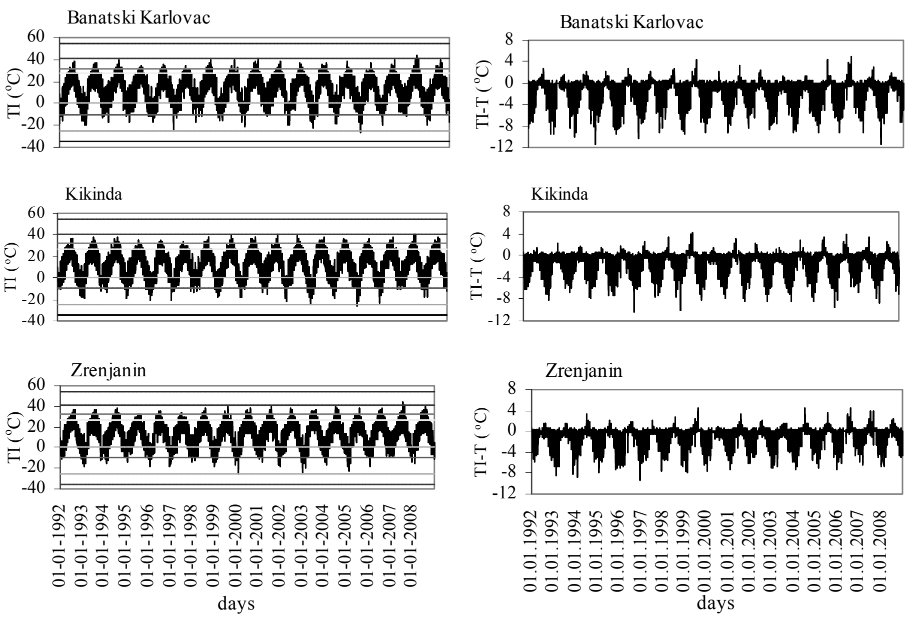

Figure 1. Valuse of *TI* and the difference between *TI* and *T* in the Banat region in the period 1992-2008.

The monthly distribution of absolute daily maximum and minimum *TI* during the seventeen-year period in the Banat is shown in Figure 2. Negative minimums were reported between October and April, while the maximums above 27°C appeared between April and October. Extremely low absolute minimums in the category of high stress due to cold (-25 to -35oC) occurred in January and February. Extremely high absolute maximums in the danger category (41 to 53°C) in the Banatski Karlovac and Zrenjanin occurred in July and August, while in Kikinda TI not enter into this category. An absolute minimum of -26.5°C was recorded in Kikinda, 09.02.2005, at the temperature of -24.0°C and wind speed of 0.8 ms^{-1}. The absolute maximum of 43.8°C was recorded in Zrenjanin, 24.07.2007, at a temperature of 42.1°C and a relative humidity of 23%.

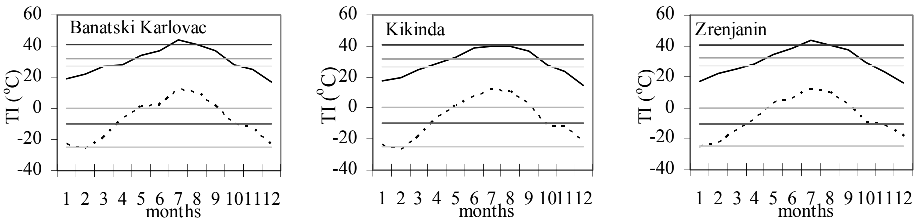

Figure 2. Monthly distribution of absolute daily maximum and minimum of *TI* in the Banat during the period 1992-2008.

Figure 3 shows that in all three settlements average annual heat index (TI_g) less than the average annual air temperature (T_g). TI_g and T_g the most distinguish in the Banatski Karlovac (-1.3°C) where wind speed is highest, while the least differ in Zrenjanin (-0.8°C), where the wind is weakest. This indicates large impact of wind on feeling temperatures. It is also noticeable slight increase in both parameters. Faster growth of TI_g (0.7°C per decade) compared to T_g (0.5°C per decade) was recorded in Zrenjanin due to declining of wind speed.

Since the categories that cause stress usually occur during summer and winter time, the average value of these seasons are the best indicator of the thermal condition areas. From Table 2 can be seen that the most unfavorable values of seasonal TI were in Kikinda that has the lowest TI_z and the highest TI_l. The most unfavourable values of TI_z and TI_l were in 2003.

Figure 4 shows the average number of days with TI values that can cause stress. Gray line refers to values above 27°C, while the black line refers to negative values. Average number of days in the categories that can cause stress was higher for low values of TI (107) than high values of TI (61). It is noticed decline in the number of days in the categories that can cause stress with low TI values (1.63 days per year) and an increase in the number of days with high TI values (0.26 days per year).

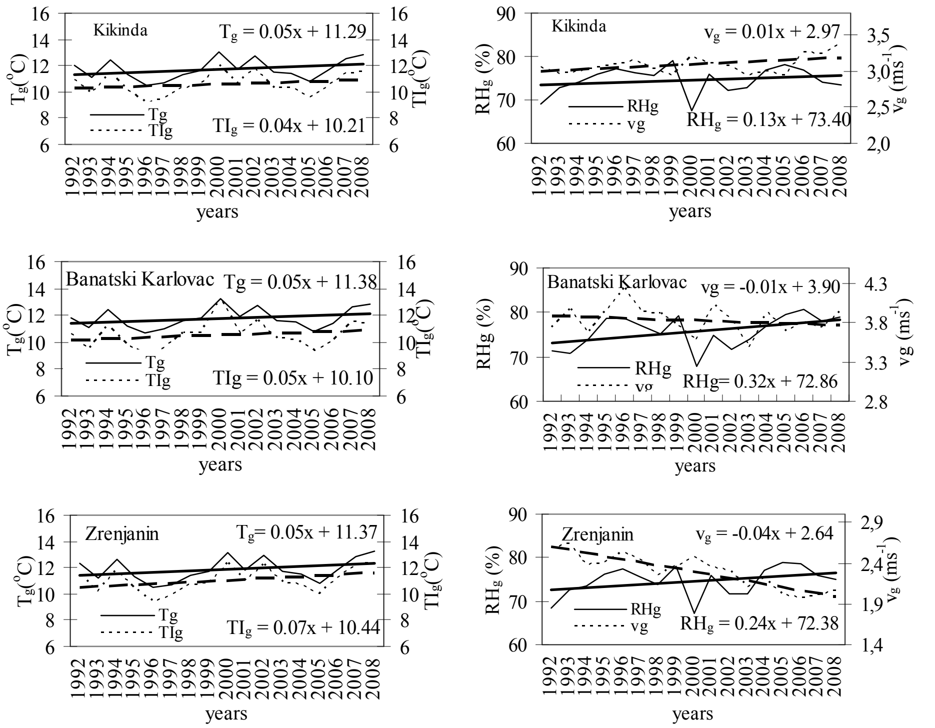

Figure 3. Average annual heat index (TI_g), air temperature (T_g), wind velocity (v_g) and relative humidity (RH_g) in the Banat in the period 1992-2008.

The total average annual number of days with low values that may cause stress was highest in Kikinda (112.2). Kikinda has the highest frequency of occurrence TI below -25°C, and the lowest TI_z value in the Banat, which makes it settlement with most adverse winter thermal conditions. Zrenjanin has the most favorable winter thermal conditions due to largest TI_z values and the lowest frequency of occurrence of TI values below 0°C, and the most unfavorable summer thermal conditions due to high TI_l values and the highest frequency of occurrence of TI values over 32°C.

Table 2 Average winter (TI_l) and summer (TI_z) thermal indexes in Banat in the period 1992-2008.

	TI_z			TI_l		
	Kikinda	Banatski Karlovac	Zrenjanin	Kikinda	Banatski Karlovac	Zrenjanin
1992	-0.8	-1.6	-0.2	23.2	22.6	23.1
1993	-3.7	-4.3	-3.0	21.5	21.3	21.6
1994	0.3	-0.1	0.8	22.5	21.9	22.5
1995	-0.2	-0.6	0.6	21.6	21.2	21.2
1996	-3.8	-4.3	-3.1	20.8	20.8	20.5
1997	-2.3	-1.4	-1.1	20.5	20.7	20.4
1998	1.4	1.6	2.2	22.0	22.1	22.0
1999	-3.8	-3.2	-3.0	21.5	21.4	21.2
2000	-1.7	-1.0	-1.2	22.9	22.9	22.8
2001	0.7	1.3	1.4	21.5	21.3	21.4
2002	-1.4	-1.3	-0.2	22.9	22.5	22.9
2003	-5.7	-4.6	-4.3	23.8	23.1	24.0
2004	-2.4	-2.6	-1.6	21.3	21.1	21.3
2005	-3.4	-3.0	-2.2	20.8	20.4	20.6
2006	-2.8	-2.8	-1.3	21.4	20.8	21.4
2007	1.9	1.8	3.4	23.2	23.0	23.5
2008	-1.0	-1.1	0.6	22.2	21.8	22.7
TI	-1.7	-1.6	-0.7	22.0	21.7	21.9

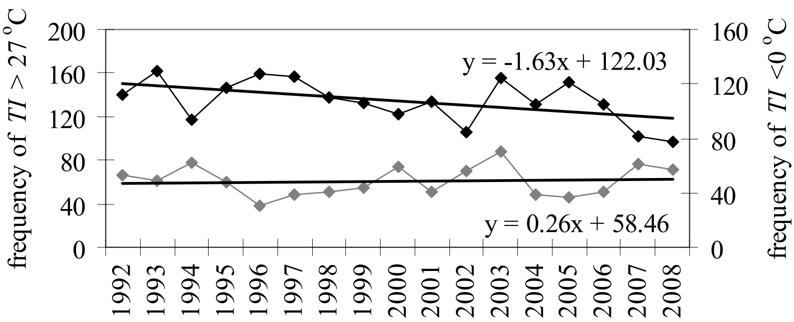

Figure 4. Average annual number of days with *TI* values that can cause stress in the Banat in the period 1992-2008. year

Conclusion

Ever since the analysis of the effects of climate change on human health began, the study of the thermal environment becomes more and more important. Considering increased mortality and morbidity in terms of heat stress and the announcement of more frequent occurrence of extreme temperatures, study of the thermal environment in Serbia has not received sufficient attention.

In this study we investigated how the thermal conditions in the Banat suitable for life, and whether there are major differences between the thermal conditions of the studied settlements. Analysis of the thermal indexes showed considerable influence of wind on feeling temperatures in Banat. The average annual thermal indexes are lower than the average annual air temperature in all settlements. Thermal indexes tend to rise, which is primarily a result of increased temperature due to global warming and urbanization. Frequency of *TI* in heat stress categories shows a trend of increase while frequency of *TI* in cold stress categories shows a trend of a decrease. Zrenjanin has the most unfavorable summer thermal conditions due to high TI_l values and the highest frequency of occurrence of *TI* values over 32°C. Kikinda is settlement with most unfavorable winter thermal conditions in the Banat due to the highest frequency of occurrence *TI* below -25°C, and the lowest TI_z value.

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