UDC: 551.524(497.113)
DOI: 10.2298/IJGI1303335M

SUMMER HAZARDS IN NOVI SAD

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Received 07 August 2013; reviewed 29 August 2013; accepted 01 October 2013

Abstract: Review of summer atmospheric condition that may influence on human health and environment in city Novi Sad, Serbia is depicted in this study. Frequency of tropical days, heat wave duration and severity and erithemal ultraviolet (UV) dose during summer months (June-August) are analyzed for the period 1981-2009. The frequency of tropical days and anomalies of maximum temperatures above normal were on the rise 0.63 ^{o}C and 0.07 ^{o}C per year, respectively. A very low occurrence of heat waves was typical in the 1980s and early 1990s. The longest heat waves were recorded in 2003 (lasting 12 days) and 2002 (11 days) while the strongest were in 2007 and 2003. An empirical formula for estimating the daily sum of the erithemal UV radiation from global radiation during summer months has been derived and applied for reconstruction. The daily erithemal UV doses were the greatest in 2000 and 2007, 3997.32 J/m^2 and 3818.11 J/m^2 respectively. Analysis shows an increasing trend of erithemal UV doses (11.52 J m^{-2} per year). Considering heat waves, number of tropical days, anomalies of maximum temperatures and erithemal UV doses the conclusion is that the most hazardous summer regarding the human health in Novi Sad was in 2000, 2003 and 2007.

Key words: tropical days, heat wave, erithemal UV dose

Introduction

Humans have always been aware that weather and climate affect their health and life quality because the atmosphere is a part of the environment with which the human organism is permanently faced. Many research activities in the second half of the 20th and early 21st century focused on extreme climate events due to their impact on human health and environment. During the summer, the impact of climate change on human activities and quality of life, among others, is the most expected through extreme hot conditions and increase of harmful ultraviolet (UV) radiation.

There is international scientific agreement that the world is getting warmer. During the 20th century, world average surface temperature increased by approximately 0.6°C, while the IPCC's Third Assessment Report (IPCC, 2001)

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projects an increase in average world surface temperature ranging from 1.4 to 5.8°C over the course of the 21st century. Although change in the average temperature can have significant long-term impacts to life on Earth, potential changes to extreme values or extreme climatic events may pose a greater threat in the immediate future. Climate change is predicted not only to increase the average temperature but also to change the frequency of extreme weather events increasing extremely hot days and decreasing extremely cold days (Patz, Engelberg & Last, 2000; Bartha, Pongracz & Bartholy, 2012). Numerous research found that high summer temperatures are harmful to human health (Michelozzi et al, 2007; WHO, 2009, Anderson & Bell, 2009) and that their impact is more serious when the extreme weather conditions prevail over extended periods (Unkasevic & Tosic, 2009; Smoyer-Tomic, Kuhn & Hudson, 2003).

Human exposure to solar UV radiation has important public health implications. Although stratospheric ozone ceased its decline in 1996 - primarily due to lower production of chlorofluorocarbons (CFCs) (WMO, 2011) - elevated levels of harmful UV radiation are still regarded as a cause for concern (Malinovic-Milicevic, Mihailovic, Lalic & Dreskovic, 2013). Because of increased concern for humans and living organisms, still there is a strong demand for (i) monitoring and forecast of the UV radiation and (ii) data on UV radiation in the past, in order to estimate long-term biological effects of this radiation (Reuder & Koepke, 2005; Malinovic-Milicevic & Mihailovic, 2011). In spite of many general recommendations true UV monitoring in Serbia is still in its infancy. Practically all of the pioneering steps made thus far, however, have been undertaken at the University of Novi Sad. The first step was measurement of UV index, started in 2003, followed by model development (Mijatovic et al., 2010).

The aims of this study were to analyze summer hazardous atmospheric conditions in Novi Sad. Target parameters in this study were tropical days, heat waves and erithemal UV radiation that were analyzed on the basis daily maximum temperature and UV index measurement during the summer (June, July and August). The analysis covered the period 1981–2009.

Study area, data and methodology

Novi Sad is second largest city of Serbia and seat of administrative organs of the northern Serbian province of Vojvodina. It is located in southern low part of Panonian plain (mostly from 80 to 86m a.s.l.), between 19°10' and 20°6' E and 45°10' and 45°6' N. Lies on the banks of the Danube river and Danube-Tisa-Danube canal, facing the northern slopes of Fruška Gora mountain. The total land area of the city is 699 km², while the urban area is 129.7 km² (Unger, Savic & Gal, 2011). Novi Sad has a temperate continental climate, with four seasons. The maximum daily temperature occurs in July or August, with absolute temperature of 41.6 °C recorded on 24 July 2007.

The data used in the study were obtained from Republic Hydrometeorological Service of Serbia (RHMSS) and University of Novi Sad. The observations of the daily maximum temperature ($T_{\max}$) for June-August period from 1961-2009, were taken in meteorological station Rimski Šančevi. The station is situated at 86 above mean sea level and its geographical coordinates are 45°20' N and 19°51' E. The daily sunshine duration data measured using Campbell–stokes sunshine recorder (burn method) were also used from the RHMSS for the 1981-2009 period. Technical and critical controls of these measurements were made by the RHMSS. The measured UV index data for the period 2003-2009 were used from measurement made by broadband Yankee UVB-1 biometer at the campus of the University of Novi Sad. Its output is a voltage signal that is then converted to the erythemally weighted UV irradiance and the UV index (UVI) using a multiplication constant.

There are many definitions of heat wave (Robinson, 2001; Frich et al., 2002; Beniston, 2004; Gosling McGregor & Páldy, 2007; WHO, 2009 etc), but there are no unique. To analyze heat wave duration and frequency, heat wave duration index ($HWDI$) recommended by the World Meteorological Organization (WMO, 2001) was applied in this study. It is defined as period when the daily maximum temperature more than five consecutive days exceeds the average daily maximum temperature by 5 C, the normal period being 1961–1990 (Frich et al., 2002). Since the definition of heat wave duration index ($HWDI$) is based on the heat wave duration rather than its intensity, to evaluate intensity of heat wave, the peak temperature (PT) and cumulative excess (CE) (sum of $T_{\max}$ above heat wave threshold) was also determined. According to Kyselý (2002), the cumulative excess (CE) is one of the most appropriate variable to characterize the intensity of heat waves. Tropical days imply days with a maximum temperature higher or equal than 30°C.

Target parameter regarding UV radiation is erythemal radiation because it is most commonly used in the public as UV index. Since no measurement of UV index before year 2003, the reconstruction technique based on the developing empirical formula to estimate the daily erythemal UV doses (ERY_d) by means of global radiation (G_d) under all sky conditions is used. The empirical formula, which was derived on the basis of the relationship between the daily values of ERY_d (calculated via measured UVI data) and G_d (calculated via an empirical formula using daily sunshine duration data) for June, July and August of the period 2003-2009 in Novi Sad (correlation coefficient R=0.922), has the form:

$$ERY_d = 190.6 G_d - 789.7 \tag{1}$$

Using this formula, we calculated the missing ERY_d values for the period 1981–2009.

Mann-Kendall test (Yue & Pilon, 2004; Helsel & Frans, 2006) and the least squares method was used for the determination of the statistical significance (p) and magnitude of trends.

Results and discussion

The total number of tropical days is illustrated in Figure 1. It can be seen that the highest numbers of tropical days ($T_{\max} \geq$ 30.0°C) was observed in 2003 (64 days), 2000 (54 days) and 1994 (52 days). Figure 1 also shows that the mean number of tropical days during the period 1981-2009 increased at rate of 0.63 days per year (p =0.009).

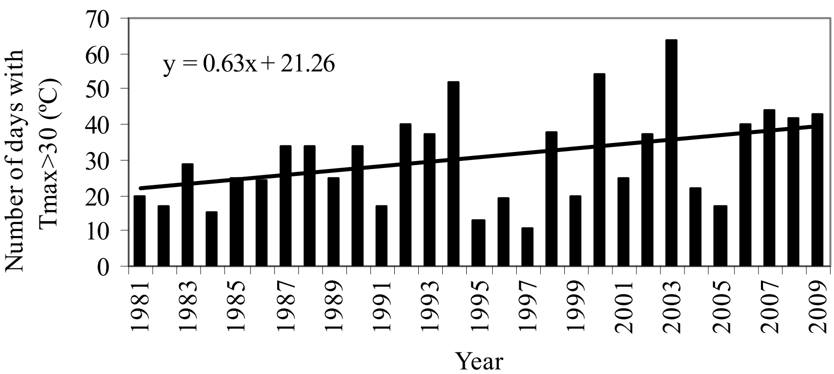

Figure 1. The annual number of tropical days in Novi Sad for the period 1981-2009.

The mean summer $T_{\max}$ expressed as anomalies from the long-term mean (1961–1990) is given in Figure 2. Most of the warmest summers (in terms of

T_{max} anomalies) during the observed period occurred 2003 (4.03°C), 2000 (3.46°C) and 2007 (3.26°C). Figure 2 also shows that the anomalies of T_{max} during the period 1981-2009 increased at rate of 0.07°C per year (p=0.012). Years with the highest T_{max} anomalies largely coincides with the number of tropical days and number of days in heat waves as confirmed by strong Pearson correlation coefficients (R=0.9 and R=0.8, respectively).

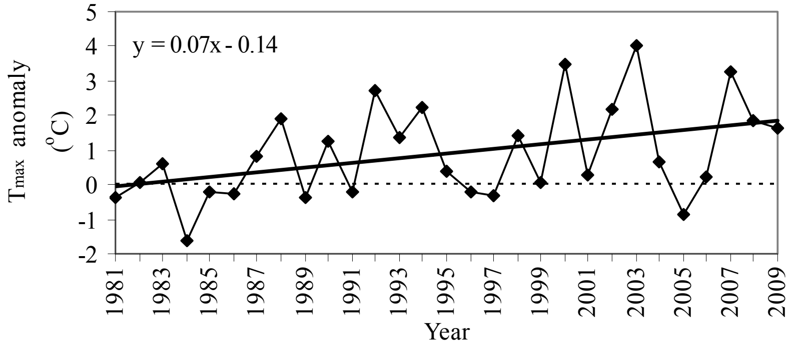

Figure 2. Anomalies of mean summer T_{max} from the long-term mean (1961–1990) in Novi Sad for the period 1981-2009.

There were 14 heat waves in 12 years in the period 1981-2009 in Novi Sad. As can be seen from Figure 3 a very low occurrence of heat waves was typical in the 1980s and early 1990s. During the first half of the observed period (to mid-90s of the 20th century) was observed only 4 heat waves, while in the second half of the observed period been recorded 10.

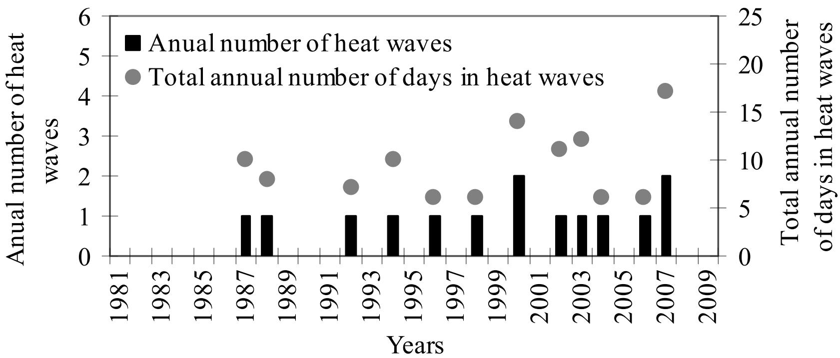

Figure 3. Annual number of heat waves and total annual number of days in heat waves in Novi Sad for the period 1981-2009.

Frequencies of the heat wave duration index ($HWDI$), cumulative excess (CE) and peak temperature (PT) in Novi Sad are illustrated in Figure 4. It shows the highest frequency of the shortest ($HWDI$ ≤8 days) and the weakest (CE ≤25°C) heat waves, while the longer and stronger waves occurred fewer times. The most common heat waves were with peak temperatures (PT) between 36 and 38°C.

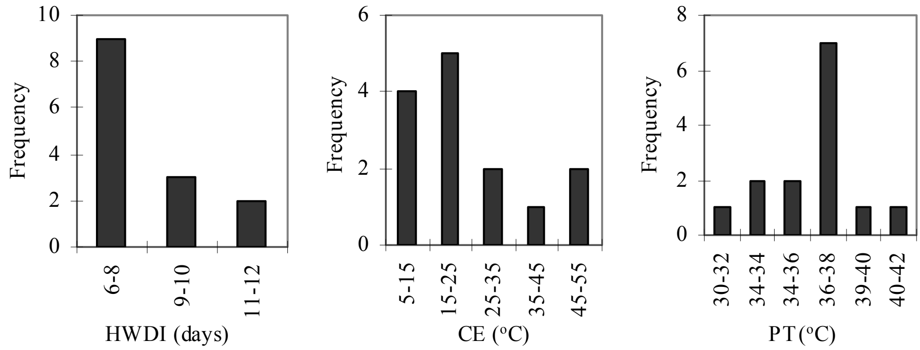

Figure 4. Frequencies of the heat wave duration index ($HWDI$), cumulative excess (CE) and peak temperature (PT) in Novi Sad for the period 1981-2009.

Characteristics of the longest and strongest heat waves are shown in Table 1. The longest heat wave in Novi Sad were recorded in 2003 ($HWDI$ =12 days). Then, follow heat waves recorded in 2002 ($HWDI$ =11 days), 1987 and 1994 ($HWDI$ =10 days) and 2007 ($HWDI$ =9 days). heat waves with the highest intensity was in 2007 (CE =47.2°C), 2003 (CE =45.5°C) and 2000 (CE =37.2°C). The highest pick temperature were 2007 (PT =41.6°C), 2000 (PT =39.5°C) and 2002 (PT =37.6°C).

Table 1. The longest and most severe heat waves in Novi Sad for the period 1981-2009.

Beginning date	$HWDI$ (days)	CE (°C)	PT (°C)
16.07.1987	10	19.7	36.2
25.08.1992	7	31.5	37.1
27.07.1994	10	10.7	35.5
17.08.2000	7	37.2	39.5
14.06.2002	11	32.1	37.6
03.06.2003	12	45.5	36.3
16.07.2007	9	47.2	41.6

Equation (1) was used to estimate daily erythemal UV doses for the summer months of period 1981-2002, as well as to fill data gaps between 2003 -2009. The following analysis refers to 29-year data set consisting of the estimated

(1981-2002) and the measured and the filled (2003-2009) erythemal UV dose (ERY_d) in Novi Sad. The summer ozone amount was calculated using the daily values for Novi Sad, which were measured using a total ozone mapping spectrometer (TOMS) and the ozone monitoring instrument (OMI) on NASA satellites (Nimbus-7, Meteor-3 and Earth Probe Aura) (NASA, 2010). The annual averages for the estimated daily summer erythemal UV doses and the summer total calculated ozone trends are depicted in Figure 5.

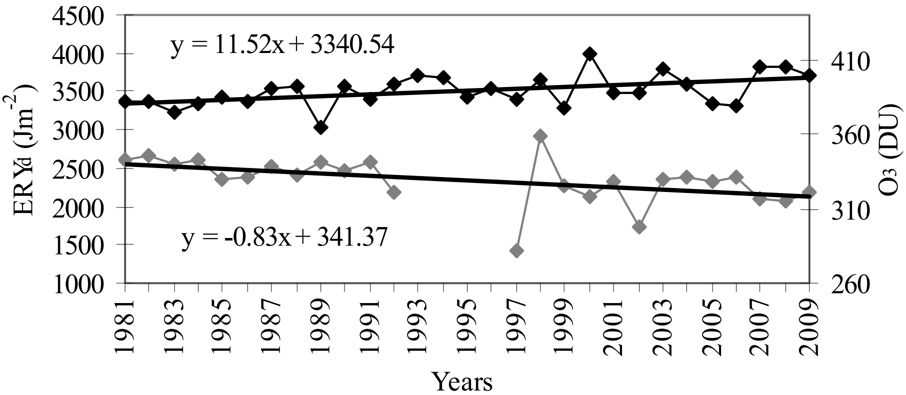

Figure 5. Annual averages of the daily summer erythemal UV dose (ERY_d) and summer total ozone (O_3) in Novi Sad for the period 1981-2008.

From Figure 5, (i) a decreasing trend in the total ozone since 1981 (-0.83 DU per year, p = 0.000) and (ii) an increasing trend in the erythemal UV dose (11.52 J m-2 per year, p = 0.006) can be observed. The daily summer erithemal UV doses were the greatest in 2000 and 2007, 3997.32 J m-2 and 3818.11 J m-2 respectively. Years with the highest ERY_d largely coincide with the annual number of tropical days, annual number of days in heat waves and overall annual $T_{\max}$ cumulative excess as confirmed by strong Pearson correlation coefficients of 0.7 in all three cases.

Considering parameters of heat waves (the heat wave duration index ($HWDI$), cumulative excess (CE), peak temperature (PT) and annual heat-wave occurrence), number of tropical days, $T_{\max}$ anomalies and summer erithemal UV doses the conclusion is that the most hazardous summer regarding the human health in Novi Sad was in 2000, 2003 and 2007.

Conclusions

In this paper, we have considered summer atmospheric condition that may influence on human health and environment in city Novi Sad, Serbia. Frequency of tropical days, heat waves duration and severity and erithemal UV dose are presented for the period 1981-2009. The following points can be made.

(1) Summers in Novi Sad became warmer, which shows an increase of annual frequency: numbers of tropical days, anomalies of maximum summer temperatures above normal, numbers of heat waves and the total number of days in the heat wave.

(2) A very low occurrence of heat waves was typical in the 1980s and early 1990s.

(3) The highest frequency of the shortest ($HWDI \leq 8$ days) and the weakest ($CE \leq 25$°C) heat waves, while the longer and stronger waves occurred fewer times.

(4) The longest heat waves were recorded in 2003 ($HWDI = 12$ days) and in 2002 ($HWDI = 11$ days), while the strongest heat waves were in 2007 ($CE = 47.2$°C) and 2003 ($CE = 45.5$°C).

(5) The erythemal UV doses had an increasing trend of 11.52 Jm-2 per year.

(6) Years with the highest erythemal UV dose largely coincide with the annual number of tropical days, annual number of days in heat waves and overall annual $T_{\max}$ cumulative excess.

(7) Considering parameters of heat waves ($HWDI$, CE, PT and annual heat-wave occurrence), number of tropical days, $T_{\max}$ anomalies and summer erithemal UV doses the conclusion is that the most hazardous summer regarding the human health in Novi Sad was in 2000, 2003 and 2007.

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