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THERMIC REGIME AND AIR TEMPERATURE TRENDS IN ŠUMADIJA REGION (SERBIA)

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Abstract: Subject of this paper is analysis of mean, absolute maximum and absolute minimum air temperatures (on a monthly and annual scale) in order to represent certain climatic characteristics of Šumadija region (Serbia). Data from 10 meteorological stations located in this region were used in the analysis for the period 1961–2010. Based on available data it is concluded that similar climate conditions are met in the whole region and the spatial variations of air temperatures are relatively small. Mean annual air temperatures varied from 11–11.6°C in most of meteorological stations. The only exception is Belgrade where slightly higher mean annual air temperature of 12.3°C was calculated, which along with micro-location influence of this station indicates the presence of urban heat island effect. In order to determine potential air temperature changes in Šumadija region, the trends of the climatic element are examined using Mann-Kendall test and Sens slope estimation. Calculated trends of mean annual air temperatures indicate increase in almost all stations and they are statistically significant on the confidence levels from 95 to 99.9%. Contrary to the trends of mean annual air temperatures, absolute maximum air temperature trends have statistically significant increase only in six stations (at four stations confidence level is 99%, and 95% at one station and 90% at another one). Other four stations do not have statistically significant trends of absolute maximum air temperatures. Absolute minimum air temperatures do not have statistically significant trends.

Key words: air temperatures, Mann-Kendall test, Sens slope estimation, Šumadija region, Serbia

Introduction

In recent years, great attention of the world scientific and general public was directed towards climate changes and their impact on the genesis of climate and weather caused disasters. Today, climate changes are generally referred to as the negative consequences of anthropogenic impacts on certain climatic elements. The fact is that the global surface air temperature increased during the twentieth century more than half a degree and that the last decade of the twentieth century was the warmest since regular temperature measurements have generally been accepted. The positive trend continued in the beginning of the XXI century.

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On the other hand, among the prominent climate scientists exists opinion (based on detailed calculations) that if the longer period of data is observed, actually there is no global warming and that the shorter periods of warmer climate occurred earlier in history as well. Also, they believe that the hypothesis of a crucial impact of carbon dioxide amount in the atmosphere on global temperatures rise is exaggerated, and that warming is not occurring in all parts of the world, but only in certain areas. These attitudes are sometimes supported in the media, so Vienna "Standard" presented the results of research from Harvard, where among other things is written that: "In the Middle Ages around the world it was warmer than it is today" (Anđelković, 2009).

The availability of a large number of numerical data, especially from a second half of the twentieth century, both at global and local scales, allow exact analysis and detailed studies of the climate with the focus on air temperature and precipitation. Different statistical methods, including trend analysis of individual climate elements play an important role in the mentioned studies. To examine the trends of certain climatic and hydrological elements Mann-Kendall test and Sen's slope estimation methods are often applied. Those methods were used to examine changes in the amount of precipitation on Stara Planina (Milovanović, 2005), to investigate the changes in air temperature in Serbia and Belgrade's heat island (Milovanović, 2015), as well as for the analysis of annual and seasonal changes in flow in certain rivers of Serbia (Kovačević-Majkić & Urošev, 2014). In this paper Mann-Kendall test and Sen's slope estimation methods will be applied to investigate the changes in air temperature on the territory of one of the central authorities in Serbia — Šumadija.

According to Salmi et al. (2002) this test is very convenient when monotonic trend (without seasonal or cyclic variations) exist in the data, while the Sen's method is very useful in slope estimation and shows changes in units per time (in this paper °C/year). Those methods could be applied on the time series with lacking data, and on the time series independent from distribution. Also, they are not sensitive on errors and outliers.

Study area

Šumadija represents subregion of Peripannonian Serbia within the Pannonian macroregion with area coverage of 8,569 km^2 (Milanović Pešić, 2015) and with the average density of 1,305 inhabitants per km^2. This area is located between 43º 35' 39" and 44º 50' 32" N and 20° 13' 36" and 21º 24' 34" E. On the territory of Šumadija, there is a geographical center of Serbia. In 2011 Serbian Republic Geodetic Authority announced, on the basis of combination of several methods,

that the geographic center of Serbia is located in Drača, 8 km west from Kragujevac, at coordinates φ = 44º 01' 13" N and λ = 20° 49' 27" E. On the basis of the Spatial Units Register of the Republic of Serbia, using GEOMEDIA program it was found that 617 settlements from 35 municipalities belong to Šumadija, with 22 municipalities located entirely in this territory (Milanović Pešić, 2015).

Considering aspect of regional geography, borders of this territory are represented by rivers. The northern border is the river Sava (from the mouth of Kolubara river up to its mouth to the Danube), and then the Danube (from the mentioned point of the Sava River near Belgrade to the mouth of the Velika Morava River between villages Dubravica and Šalinac). On the east border is Velika Morava River, from its mouth to the Danube to the meeting point of Južna and Zapadna Morava, between Stalać and Varvarin on the locality Ključ. The southern border is the Zapadna Morava River, to the mouth of Dičina River. Southwestern border is defined by rivers: Čemernica, Dičina and Mala Dičina up to the top of the Rajac Mountain. Western boundary starts from the north slopes of this mountain where there is a spring of the Slap River which goes to the north where it meets small river Vrelo and together they flow to the river Kojića reka which is tributary of the river Slavkovačka reka. This river is border till its mouth to the river Ljig (in the village Kadina luka), and then further by the river Ljig till its mouth to the Kolubara river.

Based on climate regionalization of Serbia proposed by Ducić & Radovanović (2005), Šumadija belongs to the **A-1-a** and **A-2-a** climate areas. The area **A-1-a** covers flat terrains of Peripannonian Serbia (so called lower Šumadija), low and isolated hills and mountains and the valley of the Velika Morava River. According to Rakićević (1980), larger part of this climate area is continental with average annual air temperature above 11ºC (Belgrade 12.3ºC) while on the mountain terrains air temperature is below 11ºC. The climate area **A-2-a** covers southern lowland part of Šumadija and mountains (Rudnik, Kotlenik, Gledićke planine). The only climatologic station on higher terrains is located on the mountain Rudnik, however because of frequent air temperature inversions, further terrain examinations are needed. Average air temperature in this region is between 9–11°C, whereby only the highest peaks have air temperature below 7°C.

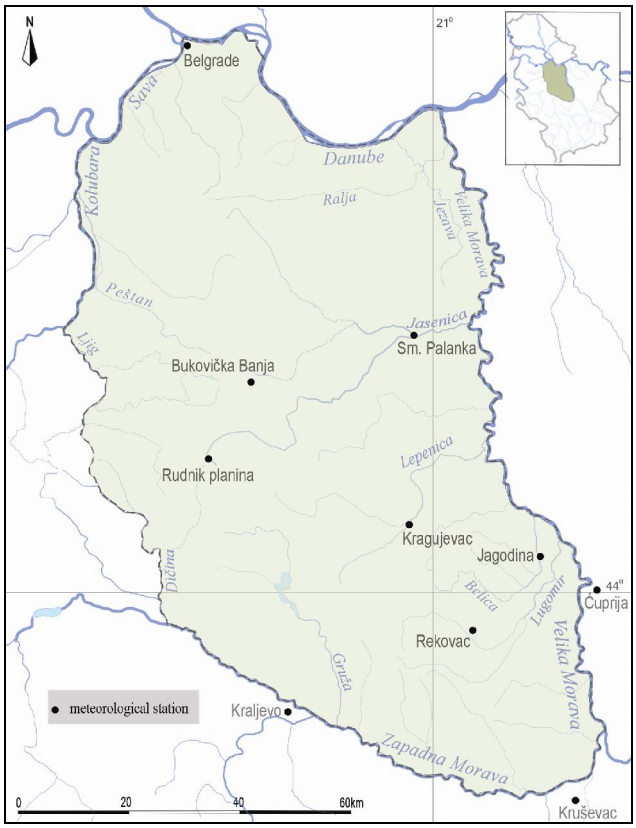

Figure 1. Meteorological stations in Šumadija

Spatial distribution of climate elements in Šumadija is influenced by geographic location, atmospheric circulation, relief and its variability, river valleys orientation, distribution and size of water surfaces and vegetation, urbanization and other factors. Based on the software IDRISI and three-dimensional model of Šumadija it was noted that a substantial part of the territory has an altitude below 300 m a.s.l. (68.4%) which affects the characteristics of air in this area (Milanović Pešić, 2015). River flows are mainly oriented towards the main border rivers of Šumadija, which has an impact on atmospheric circulation, while the water reservoirs affect the microclimate of the area. From ancient Šumadija forests only a small area under the oak, bitter oak, beech and hornbeam remained, while the highest parts of the Rudnik Mountain cover conifers, establishing specific microclimate conditions. The climate of Šumadija and the whole of Serbia as well are influenced by air masses from the Atlantic

Ocean and the continental polar masses that occur over the northern Europe and western Siberia (across the Volga and the Ural-Caspian Sea region they penetrate to our country) (Šegota, 1976). Air masses from the Atlantic are characterized by high humidity and moderate temperatures, while continental polar masses by low temperatures in winter, relatively high in summer and dry weather conditions during the whole year (Rakićević, 1960).

Data and methodology

In order to evaluate certain climate characteristics of Šumadija, mean monthly and mean annual values, absolute maximum and absolute minimum air temperatures from 10 meteorological stations for the period 1961–2010 are analyzed in the paper. For several meteorological stations there is no 50 year time series of observations (shorter periods of observation are marked under the table). For the analysis of microclimate conditions in this area, the density and height arrangement of stations are not sufficient. Climatologic station on the mountain Rudnik is located at 700 m a.s.l. and it is the only one that presents the general climatic characteristics of mountain regions, but does not provide an adequate climatologic picture of Rudnik's peaks whose height exceeds 1,000 m. Other climatologic stations are located at the altitudes between 121–366 m a.s.l. In order to obtain a more accurate picture of air temperatures in this area, beside stations in Šumadija data from stations Kruševac and Ćuprija (located in the surrounding area) were analyzed.

Beside analysis of mean monthly and mean annual values, the absolute maximum and the absolute minimum air temperatures in this area, trends of these climate elements were examined using Mann-Kendall nonparametric test (which is not sensitive to extreme values) and the Sen's slope estimation of trends. Confidence intervals of 90%, 95%, 99% and 99.9% were used and based on the level of significance of trends, gradation of changes was made.

Results and discussion

Mean monthly and mean annual values of air temperature

Analysis of air temperature on the territory of Šumadija shows that all parts of the area have similar conditions and that variations are relatively small. At most climatologic stations mean annual air temperature ranges from 11°C to 11.6°C. Exceptions are Belgrade (12.3°C), Rekovac (10.6°C) and Rudnik (9.5°C) (Table 1). The highest mean annual air temperature (12.3 °C) in this area is calculated for Belgrade (44°48′ N; 20°28′ E; 132 m a.s.l). Although there are stations that are located on approximately same latitude and altitude such as Smederevska

Palanka (44°22′ N; 20°57′ E; 121 a.s.l — mean annual air temperature 11.3°C), the data indicate that Belgrade has a higher air temperature.

Table 1. Mean monthly, mean annual air temperature (°C) and trends (°C/year) in Šumadija (1961–2010 period)

Station	φ	λ	h (m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual	Trend (°C/year)
Belgrade-observ.	44.48	20.28	132	0.9	3.1	7.4	12.7	17.7	20.7	22.4	22.1	17.8	12.7	7.3	2.4	12.3	*** 0.03
Bukov. Banja[1]	44.18	20.33	265	0.1	2.1	6.2	11.2	16.2	19.3	21.0	20.7	16.4	11.4	6.2	1.5	11.0	/
Ćuprija	43.56	21.22	123	-0.3	1.8	6.1	11.4	16.4	19.5	21.1	20.7	16.4	11.2	6.2	1.3	11.0	** 0.02
Jagod.	43.59	21.14	115	0.1	2.3	6.7	12.1	17.1	20.3	22.0	21.6	17.2	11.8	6.4	1.6	11.6	* 0.022
Kraguj.	44.02	20.56	185	0.4	2.4	6.5	11.5	16.4	19.6	21.4	20.9	16.7	11.7	6.7	1.9	11.3	*** 0.027
Kralj.	43.43	20.42	215	-0.1	2.4	6.7	11.7	16.4	19.6	21.3	21.0	16.7	11.6	6.4	1.4	11.3	** 0.019
Kruševac	43.34	21.21	166	-0.3	2.1	6.4	11.6	16.5	19.7	21.3	21.0	16.6	11.4	6.2	1.3	11.1	*** 0.057
Rekovac	43.52	21.06	251	-0.3	1.6	5.7	10.9	15.8	18.9	20.5	20.1	15.9	10.7	5.8	1.1	10.6	* 0.018
Rudnik pl.	44.08	20.31	700	-0.7	0.7	4.5	9.3	13.9	16.8	18.6	18.8	15.2	10.6	5.4	0.7	9.5	* 0.027
Smed. Palanka	44.22	20.57	121	0.2	2.2	6.4	11.6	16.7	19.8	21.5	21.0	16.7	11.5	6.5	1.7	11.3	** 0.045

[1]Period 1961–2006.; trend (/ — no statistical significance; + — confidence interval 90%, α=0.1; * — confidence interval 95%, α=0.05; ** — confidence interval 99%, α=0.01; *** — confidence interval 99.9%, α=0.001)

From the analysis of the data from all climatologic stations in this area it can be concluded that Belgrade is 1 to 1.7°C warmer than the rest of the stations. Similar results are achieved by Milovanović (2015), based on the data from 22 climatologic stations for the period 1949–2008. He stated that Belgrade is warmer by 1.1°C compared to its environment, thus confirming the effect of the urban heat island. The presence of Belgrade urban heat island was confirmed earlier by Unkašević (1994) and Anđelković (2003). The main growth factors of air temperature in the cities are: different Sunrays heating of soil (heat island is more pronounced in summer and in the early evening), anthropogenic emissions of the heat (heat island is more pronounced in winter and late at night), and greenhouse gas emissions (heat island is of rather uniform intensity) (Anđelković, 2003). Urban or urban heat island as a phenomenon of higher air temperature in the cities comparing to their environment, represents the most important consequence of the impact of urbanization on topoclimate scale. The lowest mean annual air temperature for the period 1961–2010 is calculated for

the Rudnik (9.5°C). According to the amplitudes of air temperature it can be concluded that the highest degree of continentality shows climate in Jagodina (amplitude of 21.9°C), while with increasing altitude air temperature amplitude decreases (the lowest value is on the Rudnik — amplitude of 19.5°C).

Results shown in the Table 1 indicate average values for the whole period, but it is important to emphasize that the differences between years can be considerable. If difference between the mean annual air temperature for the period 1961-2010 and the smallest mean annual temperature throughout the series is observed as a "cold" the years 1969, 1976, 1978, 1980, 1985 and 1991 stand out, lower by 0.9 to 1.5°C than the average values. If difference between the mean annual air temperature for the period 1961-2010 and a maximum mean annual temperature recorded throughout the series is observed as a "hot" the years 1994, 2000, 2002, 2007, 2008 and 2009 stand out, when the mean annual air temperature was higher by 1.4–2°C on the average for the whole series.

The calculated trends in mean annual temperatures, made by application of Mann - Kendall test and Sen's slope estimation of trend lines show that at almost all stations there is a statistically significant increase (at a confidence levels of 95% to 99.9%). The only exception is station Bukovička Banja, where there is no statistically significant trend. The highest mean annual temperature increase is in Kruševac (0.057°C/year), Belgrade (0.03°/year) and Kragujevac (0.027°C/year).

By comparison of the data from the Table 1 it can be noticed that there is high regularity in changes of temperature (there is match of the maximum and minimum at all stations). The hottest summer is in Belgrade (21.7°C), then in Jagodina (21.3°C). For the most part of Šumadija, the average temperature of summer months is in the range from 20.3°C to 20.8°C. With the increase of altitude there is temperature decrease, and the lowest average summer temperature is on the station Rudnik (18.1°C). On all stations the warmest month is July. For most stations the mean July temperature is around 21°C, and the highest one is in Belgrade (22.4°C). The only exception is station Rudnik, where August is hotter than July for 0.2–0.4°C.

The calculated trends of mean July and mean August air temperatures (Table 2) show that almost all stations have statistically significant increase (on the confidence levels from 95% to 99.9%). It can be noticed that the July temperature trends are more pronounced, since five of 10 stations analyzed show a significant increase in air temperature (stations Belgrade, Ćuprija, Jagodina, Kragujevac and Kraljevo). From the analysis of trends of mean August air

temperatures it can be seen that very significant increase exists at two stations (Kragujevac and Rekovac). Observing spatial distribution of stations, it can be concluded that the most pronounced increase of summer temperatures is in places located in the valleys and river basins.

Table 2. Mean air temperature trends (°C/year) in July and August in Šumadija

Station	φ	λ	h (m)	VII	Trend (°C/year)	VIII	Trend (°C/year)
Belgrade-observatory	44.48	20.28	132	22.4	*** 0.054	22.1	** 0.053
Bukovička Banja[1]	44.18	20.33	265	21.0	** 0.040	20.7	* 0.047
Ćuprija	43.56	21.22	123	21.1	*** 0.045	20.7	** 0.043
Jagodina	43.59	21.14	115	22.0	*** 0.052	21.6	* 0.054
Kragujevac	44.02	20.56	185	21.4	*** 0.058	20.9	*** 0.050
Kraljevo	43.43	20.42	215	21.3	*** 0.042	21.0	** 0.044
Kruševac	43.34	21.21	166	21.3	/	21.0	/
Rekovac	43.52	21.06	251	20.5	** 0.037	20.1	*** 0.050
Rudnik planina	44.08	20.31	700	18.6	* 0.038	18.8	+ 0.040
Smederevska Palanka	44.22	20.57	121	21.5	** 0.075	21.0	* 0.070

[1]Period 1961–2006.; trend (/ — no statistical significance; + — confidence interval 90%, α=0.1; * — confidence interval 95%, α=0.05; ** — confidence interval 99%, α=0.01; *** — confidence interval 99,9%, α=0,001)

According to the data from the Table 1, in substantial part of the Šumadija area, the mean air temperature in winter months ranges from 0.8–1.3°C. The warmest winters are in Belgrade, where the seasonal mean air temperature is 2.1°C and it is significantly higher than in other meteorological stations, which contributes to the fact of the urban heat island presence. The mean air temperature of the winter months from 1.6°C is calculated only in Kragujevac. The coldest winters are on Rudnik Mountain, where the mean winter air temperature amounted 0.3°C in observing period. The coldest month at all stations is January. The highest mean air temperature in January is in Belgrade (0.9°C), and the lowest in Rudnik (-0.7°C). The negative mean air temperatures in January are recorded in Ćuprija, Kruševac, Rekovac and Kraljevo.

Table 3. Mean air temperatures trends (°C/year) in January in Šumadija

Station	φ	λ	h (m)	I	Trend (°C/year)
Belgrade-observatory	44.48	20.28	132	0.9	/
Bukovička Banja1	44.18	20.33	265	0.1	/
Ćuprija	43.56	21.22	123	-0.3	/
Jagodina	43.59	21.14	115	0.1	/
Kragujevac	44.02	20.56	185	0.4	*** 0.050
Kraljevo	43.43	20.42	215	-0.1	*** 0.050
Kruševac	43.34	21.21	166	-0.3	/
Rekovac	43.52	21.06	251	-0.3	/
Rudnik planina	44.08	20.31	700	-0.7	+ 0.063
Smederevska Palanka	44.22	20.57	121	0.2	/

[1]Period 1961–2006.; trend (/ — no statistical significance; + — confidence interval 90%, α=0.1; * — confidence interval 95%, α=0.05; ** — confidence interval 99%, α=0,01; *** — confidence interval 99.9%, α=0,001)

Unlike the trends of summer air temperature, the trends analysis of January mean air temperatures are not extreme (Table 3). Of the 10 analyzed meteorological stations only in two is recorded statistically significant increase in the confidence level of 99.9% (Kragujevac and Kraljevo, 0.05°C/year), while in one is recorded January mean air temperature increasing at a confidence level of 90 % (Rudnik Mountain, 0.063°C/year).

Extremely high air temperatures

On the Šumadija territory, as well as the entire Serbia, extremely high air temperatures occur due to the cyclonic activity development in the lower latitude of the eastern Atlantic Ocean and the western Mediterranean Sea. At that time, over Serbia runs intense heat advection in southwestern current, which leads to the thermal ridge forming. Thermal ridge is followed by the high pressure ridge in the ground giving it a dynamic character (Radinović, 1981). Also, very high air temperatures can occur at zonal situations, usually when the zonal currents have moved north to the axis at about 50 °N (Anđelković, 2009).

Extremely high temperatures are not spatially restricted in Šumadija, as well as in other parts of Serbia, and can almost occur in any location. However, the only regularity that can be observed is that the air temperatures over 40°C do not appear in the areas above 500 m a.s.l. Considering hipsometry of Šumadija area, it can be concluded that around 7,856 km^2 (91.7%) of observed territory is affected by extremely high air temperatures.

Based on the data from the Table 4, it can be concluded that the absolute maximum air temperatures are above 40°C at all observed meteorological stations (except Rudnik planina station). The highest air temperature in Šumadija has been recorded in July 2007 in Smederevska Palanka (44.9°C) and represents a valid absolute air maximum for Serbia. As of July 1988, in Smederevska Palanka, one of the hottest cities in Serbia, air temperatures above 40°C were recorded 5 times in the analyzed period (1961–2010). These high air temperatures are conditioned by the valley position of the city, micro-location of the meteorological station and physical-geographical factors in the local area. Namely, in the mid-twentieth century forest belt around Smederevska Palanka territory was deforested during the land consolidation, which somewhat changed microclimate conditions. On the other hand, meteorological station is located in a clearing on a slight hill.

Table 4. Absolute maximum air tempareture (°C) in Šumadija and years in which thay recorded (1961–2010)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	Trend (°C/year)
Belgrade-observ.	20.7 2001	23.9 2008	28.9 1977	32.2 2003	34.9 1996	37.4 2002	43.6 2007	40 2000	37.5 2008	30.7 2009	28.4 1990	22.6 1989	43.6 2007	** 0.068
Bukov. Banja [1]	20.4 1993	23 1998	31 2001	31.5 1998	36 1969	37 1972	39 1965	40.2 1994	36.7 1994	34.4 1991	27.3 1996	21.3 1989	40.2 1994	/
Ćuprija	20.6 2002	23.8 1977	29 2001	33 1998	35.4 1969	40.1 2007	44.6 2007	42.7 1994	38 1987	32.7 1991	28 1990	21.4 2010	44.6 2007	** 0.071
Jagodina	17.6 2001	23.5 1990	28 1977	32.5 1985	36.1 1969	39 1972	42 2007	43 1994	36.5 1987	32.5 1991	28 1990	20 1970	43 1994	/
Kragujev.	20.6 2002	24.2 2008	29.4 2001	31.4 2003	35.4 2008	39.4 2007	43.9 2007	40.4 1994	37.4 1987	32.6 1991	27.6 1990	21 2010	43.9 2007	** 0.067
Kraljevo	20 2007	25.5 1977	30.3 2001	32.1 1985	34.8 1969	39.2 2007	43.6 2007	41 1994	37.3 1987	32.8 1991	28.6 1990	22 2009	43.6 2007	+ 0.041
Krušev.	20.4 2007	24.2 1977	29.6 2001	31.9 1985	35.5 1969	39.6 2007	43.7 2007	42.4 1994	36.8 2009	33.8 1991	27.4 1990	21.7 2010	43.7 2007	** 0.068
Rekovac	19.8 2007	24.5 2008	30.1 2001	32.2 1985	35 1969	39.5 2007	43.2 2007	40.3 1998	37 2008	33.1 1991	27.5 1990	20 2010	43.2 2007	* 0.052
Rudnik plan.[2]	16.8 2002	22.5 1966	25 1977	28.3 1968	33.3 1969	34.4 2007	38.9 2007	36.4 2007	32.7 2008	28.7 1991	25.1 2004	17.3 1989	38.9 2007	/
Smed. Palanka	20.6 2007	24.4 2008	28.3 1977	31.2 1989	35.6 2008	39.7 2007	44.9 2007	41.7 1994	37.4 1987	32.5 1991	28 1990	21.6 2010	44.9 2007	/

[1]Period 1961–2005 [2]Period 1965–2009; trend (/ — no statistical significance; + — confidence interval 90%, α=0,1; * — confidence interval 95%, α=0,05; ** — confidence interval 99%, α=0,01; *** — confidence interval 99,9%, α=0,001)

Besides Smederevska Palanka, extremely high air temperatures in July 2007 were recorded in Ćuprija (44.6°C), Kragujevac (43.9°C), Kruševac (43.7°C), Kraljevo (43.6°C) and Belgrade (43.6°C). Settlements Smederevska Palanka, Kraljevo and Ćuprija, which are located in the valley, are known as "heat islands of Serbia". Although Belgrade is noted as an island of heat, it is interesting that the capital has not the highest recorded air temperature in Šumadija. The absolute maximal air temperature achieved in Belgrade was 1.3°C lower than the value in Smederevska Palanka.

On Šumadija territory, the lowest absolute maximal air temperature was recorded in Rudnik (38.9°C), as a function of altitude. The warmest month is July at most meteorological stations, and it is August in Bukovička Banja and Jagodina. Data in the Table 4 show slightly lower values of absolute maximum air temperature recorded in Bukovicka Banja (40.2°C) and Rekovac (43.2°C). One of the reasons is the altitude, because meteorological stations are located between 251 and 265 m a.s.l.

Analyzing absolute maximum air temperature data by months and years of their appearing, it can be concluded that the absolute monthly maximums are recorded after 1990 in most meteorological stations. We can mention air temperature data for Kragujevac, where the absolute monthly maximums for 8 months of the year are recorded after year 2000, and in the period 1990–1994 for three months of the year. According to the Table 4, as very warm months in the monitored period the following can be distinguished: May 1969 (in Bukovička Banja, Ćuprija, Jagodina, Rekovac, Kraljevo, Kruševac, Rudnik), September 1987 (in Ćuprija, Jagodina, Smedervska Palanka, Kragujevac and Kraljevo), October 1991 (in Bukovička Banja, Ćuprija, Jagodina, Rekovac, Kragujevac, Kraljevo, Kruševac, Smederevska Palanka and Rudnik), August 1994 (in Bukovička Banja, Ćuprija, Jagodina, Kragujevac, Kraljevo, Kruševac and Smederevska Palanka) , March 2001 (in Bukovička Banja, Ćuprija, Kragujevac, Kraljevo, Kruševac and Rekovac), June and July 2007 (Belgrade, Ćuprija, Jagodina, Kragujevac, Kraljevo, Kruševac, Rekovac, Smederevska Palanka and Rudnik).

The calculated absolute maximum annual temperature trends (Table 4) show that statistically significant increase is recorded at six meteorological stations (in four at a confidence level of 99%). According to calculated data there are no statistically significant trends at four other stations. Also, the recorded absolute maximum annual temperature is increasing mostly in Ćuprija (0.071 °C/year), Kruševac (0.068°C/year), Belgrade (0.068°C/year) and Kragujevac (0.067°C/year).

Extremely low air temperatures

On Šumadija territory absolute minimum air temperature varies between -19.5°C in Bukovička Banja and -30.5°C in Smederevska Palanka (Table 5). The absolute maximum air temperature in Šumadija is also recorded in Smederevska Palanka, which supports the above mentioned factors that cause the extreme air temperature occurrence in this settlement. On the basis of calculated data for the fifty years period it is concluded that the lowest air temperatures are in January in all analyzed stations, as well as the absolute recorded minimum ranges between -20°C and -30°C. This indicates that studied area does not belong to the coldest areas of Serbia. Analyzing available data, it can be noted that the lowest absolute minimum temperatures are recorded in the valley areas (Smeredevska Palanka -30.5°C. Kruševac -28.1°C and Kragujevac -27.6°C), and the hilly and mountainous areas are characterized by higher air temperatures (Bukovička Banja -19.5°C and Rudnik -20.6°C). The absolute minimum air temperature of -21°C was registered on 24 January 1963 in Belgrade. For comparison, on the same day air temperature was -27.6°C in Kragujevac. and -26.9°C in Rekovac, and the day before (23 January) absolute minimum air temperature was registered in Smederevska Palanka (-30.5°C), Bukovicka Banja (-23.6°C) and Kraljevo (-23°C). These data also indicate presence of urban heat island in Belgrade and the great influence of local factors. It is noticeable that Belgrade has a slightly higher air temperature in other winter and spring months. Analyzing the absolute minimum air temperatures between the meteorological stations by months, the biggest difference in one month is observed for the February minimum, which is in Belgrade for 1.8°C higher compared to Rudnik and even for 10.4°C higher than Ćuprija. These minimums occurred in three days period of the same year.

On monthly level, frost appearances in Šumadija are possible until May (the exception is only Belgrade) and temperatures below zero can occur from September. During the analyzed period extremely cold weather was recorded in January, March and December 1963 (in Belgrade, Kragujevac, Kraljevo, Kruševac and Smederevska Palanka), September 1970 (in Belgrade, Bukovička Banja, Jagodina, Kraljevo, Kruševac and Rudnik), March and October 1971 (in Bukovička Banja, Jagodina, Kruševac and Smederevska Palanka), November 1975 (in Belgrade, Bukovička Banja, Ćuprija, Jagodina, Kragujevac, Kraljevo, Kruševac, Rekovac and Smederevska Palanka), September 1977 (in Ćuprija, Kragujevac, Rekovac and Smederevska Palanka), May 1978 (at all meteorological stations), February 1985 (at all meteorological stations except Rudnik), October 1997 (in Belgrade, Rudnik), April 2003 (at all meteorological

stations except Jagodina), March 2005 (in Ćuprija, Kragujevac, Rekovac and Smederevska Palanka), January and December 2006 (Rudnik).

Table 5. Absolute minimum air tempareture (°C) in Šumadija and years in which thay recorded (1961–2010)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	Trend (°C/y)
Belgr.-observ.	-21.0 1963	-15.4 1985	-12.4 1987	-3.4 2003	1.6 1978	4.6 1962	9.3 1964	6.7 1981	0.6 1970	-4.5 1997	-8.0 1975	-15.1 1967	-21.0 1963	/
Bukov. Banja [1]	-19.5 1967	18.4 1985	-16.0 1971	-5.8 2003	-1.1 1978	4.0 1968	6.4 1965	6.1 1965	-3.5 1970	-6.6 1971	-16 1975	-16.9 1967	-19.5 1967	* 0.132
Ćuprija	-27.1 1987	-25.8 1985	-17.3 2005	-8.1 2003	-3.2 1978	1.0 1990	4.1 1993	3.6 1980	-3.3 1977	-8.0 1991	-18.6 1975	-20.8 2009	-27.1 1987	/
Jagod.	-25 1987	-22.5 1985	-15.1 1971	-5.4 1977	-2.4 1978	3.5 1962	4.0 1981	4.0 1981	-4.1 1970	-8.6 1971	-18.5 1975	-19.0 1967	-25.0 1987	/
Kraguj.	-27.6 1963	-23.8 1985	-18.3 2005	-5.8 2003	-0.6 1978	2.7 1962	7.2 1980	4.6 1981	-2.2 1977	-6.6 1991	-16.4 1975	-20.7 1962	-27.6 1963	/
Kralj.	-24 1967	-23.6 1985	-14.4 1963	-6.3 2003	-1.6 1978	2.9 2005	7.0 1984	3.1 1984	-1.8 1970	-5.6 1988	-17.4 1975	-19.2 1962	-24.0 1967	/
Krušev.	-28.1 1963	-23.7 1985	-17.2 1963	-6.1 2003	-1.1 1978	2.9 1962	5.8 1993	3.0 1981	-3.0 1970	-7.3 1971	-21.4 1975	-23.9 2009	-28.1 1963	/
Rekov	-27.3 1987	-25.3 1985	-18 2005	-8.0 2003	-2.3 1978	2.0 2005	5.0 1993	1.6 1981	-4.0 1977	-7.3 1979	-18.3 1975	-20.0 2009	-27.3 1987	/
Rudnik plan.[2]	-20.6 2006	-17.2 1991	-17.3 1987	-6.1 2003	-1.1 1978	3.1 2001	6.0 1971	5.2 1981	-4.5 1970	-7.8 1997	-11.3 1973	-15.5 1967	-20.6 2006	/
Smed. Palanka	-30.5 1963	-25.7 1985	-20.7 2005	-7.8 2003	-0.8 1978	1.5 1962	6.5 1971	5.1 1980	-3.3 1977	-7.3 1971	-16.5 1975	-23.6 1962	-30.5 1963	/

[1]Period 1961–2005 [2] Period 1965–2009; trend (/ — no statistical significance; + — confidence interval 90%, α=0.1; * — confidence interval 95%, α=0.05; ** — confidence interval 99%, α=0.01; *** — confidence interval 99.9%, α=0.001)

The calculated trends of absolute minimum annual air temperature, made by Man-Kendall test and Sens slope estimation generally show that statistically significant changes are not observed. Statistically significant increase in the minimum air temperature at a confidence level of 95% is recorded only in Bukovička Banja (0.132 °C/year).

Conclusion

Analyses of mean monthly and annual air temperature in Šumadija for the period 1961–2010 indicate that all parts of the studied area have similar conditions and that variations are relatively small. Mean annual air temperatures are in the range

from 11 to 11.6°C at most meteorological stations. Exceptions are Belgrade (12.3°C) with noted urban heat island effect, as well as Rekovac (10.6°C) and Rudnik (9.5°C) due to the increase of altitude. Based on the air temperature amplitudes, it can be concluded that Jagodina territory (amplitude of 21.9°C) is the most continental part, while amplitudes decrease with altitude increasing, and the lowest is on Rudnik planina (19.5°C). The calculated trends of mean annual air temperature indicate statistically significant increase at almost all meteorological stations, at 9 out of 10 analyzed stations. The results indicate statistically significant increase at a confidence level of 99.9% at three stations, confidence level of 99 % at other three stations, and confidence level of 95% at remaining three stations. Statistically significant trend is not recorded only on Bukovička Banja.

The mean air temperature of summer months ranges from 20.3 to 20.8°C in the most part of Šumadija. The warmest summers are in Belgrade (21.7 °C), and then in Jagodina (21.3°C). All meteorological stations record July as the warmest month, with mean temperature of about 21°C at most observed stations. According to calculated trends of mean air temperatures in July and August, statistically significant increase can be noted at almost all meteorological stations. It was also noted that the July temperature trends are more pronounced, since five of 10 analyzed meteorological stations record a statistically significant increase in the confidence level of 99.9 %, and at three stations a growth in the confidence level of 99%. Analyzing spatial distribution of meteorological stations at which the most significant trends of the increase are recorded, it can be concluded that the most pronounced increase of summer air temperatures is in basin areas.

The mean winter months air temperatures are 0.8–1.3°C in most part of Šumadija; the warmest winters are in Belgrade (2.1°C) and the coldest in Rudnik (0.3°C). The coldest month is January at all analyzed stations, with mean temperature about 1 °C in most of observation stations. As opposed to the summer air temperature trends, analysis of the mean January temperature trends is not distinct. Of 10 analyzed meteorological stations only two (20%) record statistically significant temperature increase at the confidence level of 99.9%, while one (10%) records slight increase at a confidence level of 90%.

According to analyzed data, the absolute maximum air temperature could reach over 40°C at all meteorological stations (except Rudnik planina). The highest air temperature in Šumadija is recorded in Smederevska Palanka (44.9°C) on 24 July 2007 and represents a valid absolute maximum of air temperature for Serbia. The warmest month is July in most stations, and August in Bukovička

Banja and Jagodina. Calculated trends of the absolute maximum annual temperatures indicate the following: statistically significant increase at the confidence level of 99 % is registered at four stations (40%), one station (10%) is at the confidence level of 95 % and one station (10%) at the confidence level of 90%. Data from other four analyzed stations (40%) indicate no statistically significant trends.

Absolute minimum air temperatures range between -20°C and -30°C on the Šumadija territory, which indicates that the studied area does not belong to the coldest areas of Serbia. According to calculated data for the fifty years period it can be concluded that the lowest air temperatures are in January at all meteorological stations. The calculated trends of absolute minimum annual temperature do not indicate statistically significant changes.

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