www. ebscohost. com
www.gi.sanu.ac.rs, www.doiserbia.nb.rs,
J. Geogr. Inst. Cvijic. 65(1) (33–42)

Original scientific paper

UDC: 911.2:551.524(497.11)
DOI: 10.2298/IJGI1501033M

AIR TEMPERATURE CHANGES IN SERBIA AND THE BELGRADE HEAT ISLAND

Boško Milovanović[*1]
* Geographical Institute "Jovan Cvijić" Serbian Academy of Sciences and Arts

Received 18 February 2015; reviewed 02 March 2015; accepted 02 April 2015

Abstract: Climatic regionalization of Serbia was performed in the paper on the basis of data on air temperature from 23 meteorological stations and using cluster analysis. Applying Mann-Kendall test and Sen's slope estimates, temperature linear trends were investigated within each of the clusters, but also at each station individually. It has been shown that a positive linear trend is present in practically entire territory of Serbia and that it is very strong in Belgrade. Differences in air temperature between Belgrade and the cluster in which it is located were examined on an annual basis.

Key words: air temperature, cluster analysis, Mann-Kendall test, the urban heat island, Belgrade, Serbia

Introduction

According to Andjelković (2010), all cities form a structure called in climatology urban heat island, because it resembles the real islands, the appearance of which on the contour line maps is similar to the isotherms at temperature maps. In addition, the above structure is a field of higher air temperature in cold weather analogueto real islands that are in sunny weather warmed more than the surrounding sea. The same author as the main factors of growth in air temperature in cities, with consequences on the properties of the heat island states the following:

- different heating of the ground by sunlight (heat island is more pronounced in summer and in the evening)
- anthropogenic emission of heat (heat island is more pronounced in winter and late at night) and
- greenhouse gas emission (heat island is of quite uniform intensity).

[1] Correspondence to: b.milovanovic@gi.sanu.ac.rs

In studies of climate variability, in the instrumental period data are often used from the stations that have sufficiently long series of observations, and which are almost entirely located in cities or urbanized areas. Given that there are different opinions on whether the measurements carried out in these areas affect the image of climate changes in a wider area (the view that such influence does not exist or is insignificant and that the techniques of eliminating the influence of the heat island on data seriesare adequate suggest e.g. Parker, 2004; Hansen, Ruedy, Sato, & Lo, 2010, while the opposite view is represented by Yang, Hou, & Chen, 2011; Lim, Cai, Kalnay, & Zhou, 2005), it seems important to answer the following questions:

1. What is the spatial distribution of air temperature changes in Serbia?

2. What is the intensity of the Belgrade urban heat island?

3. Does the Belgrade urban heat island affect the conclusions about changes in air temperature in Serbia?

Used Data and Methodology

For the analysis of changes in air temperature data from 23 meteorological stations in Serbia were used in the period 1949-2008. In central Serbia and Vojvodina, 22 stations are evenly distributed, while for Kosovo and Metohija data were only available from the station Prizren (period 1949-2004). Filling in the missing values was done by reducing the data in the same period (Milosavljevic, 1963). In an analysis of data homogeneity on the temperature of air we relied on the results of Tošić (2004), who, analysing data from 30 stations in Serbia and Montenegro (of which 24 in Serbia) and using standard normal homogeneity test (Standard Normal Homogeneity Test - SNHT) - Alexandersson test, found that “all temperature series for the period 1951-2000 are homogeneous”. Given the fact that the station Vršac has not been tested in Tošić (2004), the homogeneity of the series is examined by the same methodology, for which the software AnClim was used (author Štepanek, P. 2005, AnClim- software for time series analysis. Dept. of Geography, Fac. of Natural Sciences, MU, Brno).

According to Domonkos (2006), two or more stationsare sufficient to create a reference series. Using aggravated mean values, the reference seriesare formed (weight coefficient obtained as the square of the correlation between test station and reference station). Zrenjanin and Veliko Gradište stations were used to test the homogeneity of the series at the station Vršac. The correlation coefficients of successive differences between Vršac and reference stations range from 0.96 to 0.97 for the temperatures. Meteorological Observatory of Belgrade, which has been studied, was established in 1887. It is located at 132m alt. 44° 48N; 20° 28E in the middle of an urban area of Belgrade (Andjelković, 2005).

In contemporary domestic literature there are only a few texts that deal with climate regionalization of Serbia (Milutinović, 1974; Savić, 1979; Rakićević, 1980). Analysing in detail the values of mean monthly air temperatures and precipitation, based on predefined criteria,that is, threshold values within specific climate classification, these authors defined separate climate regions of Serbia. A similar approach, but with the analysis of other (combined) climatic elements was applied by Kolić (1988) and Ducić & Radovanović (2005). According to Unal, Kindap & Karaca (2003), the main advantage of this approach is clear quantification of climate types, while significant drawback is the subjectivity in the selection of criteria for the specification of the climates, their types and subtypes.

Hierarchical (joining tree) cluster analysis is used in this paper to define the spatial climate unit. With no pre-specified criteria for the classification of climate (by which subjectivity in defining climate regions is reduced but not completely eliminated), time series with 23 stations on the territory of Serbia are compared. Those most similar to each other have been looked for and that in this way could constitute a separate spatial, that is, climactic unit. Therefore, the condition is set that the time series of stations within a group are as similar to each other and the more different from the time-series of the stations in other isolated groups.

Trends in air temperature within each cluster and at each station individually are tested by Mann-Kendall test, while Sen’s approach is chosen for trend slope estimatedue to poor sensitivity to outlayers. According to Salmi, Määttä, Anttila, Airola and Amnell (2002) this slope estimate represents the median of the value Q_i, which is calculated as follows:

$$Q_i = \frac{x_j - x_k}{j - k} \tag{1}$$

where j> k

The t-test is used to test the significance of the difference between the value of air temperature in Belgrade and air temperature in the cluster in which the station is.

Results and Discussion

When considering air temperature, based on the diagram distance (Figure 1) at each step in the clustering it can be seen that the distance between clusters increases from the 18th stage and especially from the 21st stage, which corresponds to the number of five clusters, that is, two clusters. However, it seems that the division into two clusters would be too rough. By cutting at the hierarchical level of 0.06 five clusters are obtained, whereas the stations Sjenica and Valjevo are separate variables. The largest cluster is number 1, which covers almost the entire Vojvodina (except the south-eastern Banat, that is, Vršac station) and the north-western part of central Serbia. The cluster 2 covers the area of south-east of Banat in the north, western slopes of the Carpathian-Balkan Mountains, part of the South Morava, Šumadija and the Great Morava. The cluster 3 consists of the Great Timok valley and Negotin Region. The cluster 4 covers the western and south-western Serbia (with Metohija), while the cluster 5 presents the extreme south and southeast of Serbia. The Table 1 and the Figure 2 show the grouping of stations in Serbia when considering air temperatures.

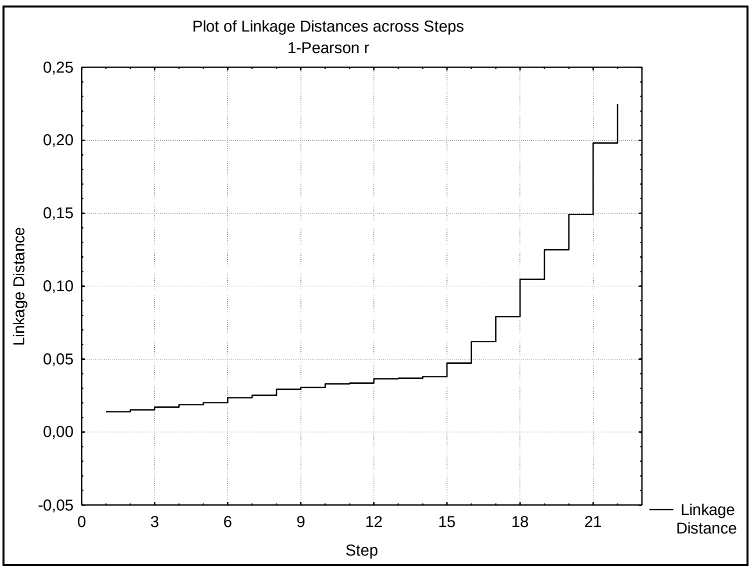

Figure 1. Diagram of distance during each step of cluster analysis

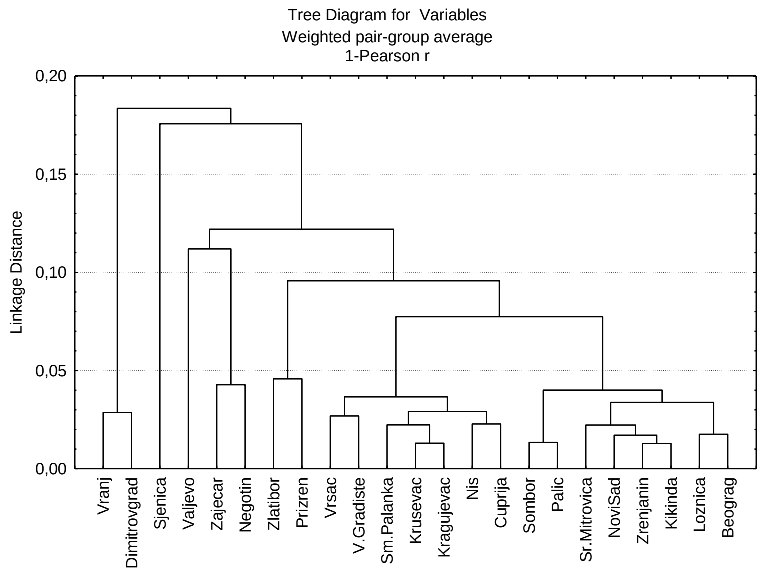

Figure 2. Tree Diagram of stations in Serbia for air temperature

Table 1. Belonging to the clusters of stations in Serbia (air temperature)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
	Belgrade	Ćuprija	Negotin	Zlatibor	Dimitrovgrad
	Loznica	Niš	Zaječar	Prizren	Vranje
Station	Kikinda	Kragujevac			Cluster 5
	Zrenjanin	Kruševac			Dimitrovgrad
	Novi Sad	SmederevskaPalanka			
	Palić	VelikoGradište			
	Sombor	Vršac			
	Sremska Mitrovica				

According to the values shown in the Table 2, the clusters 1, 3 and 4 show a statistically significant increase in air temperature. The station Belgrade is in the cluster 1 for which the effect of urban heat island was established by Unkašević (1994) and Andjelković (2005). Also, the trend in air temperature has been examined when the station is excluded from the calculation. However, although the trend slope line in this case is somewhat milder, even then there is a statistically significant increase in air temperature. The cluster 2 also shows an increase in air temperature (without statistical significance), while the cluster 5 shows a slight decrease in air temperature in 60 years observed.

Table 2. Results of trend analysis by clusters of mean annual air temperatures in Serbia

Cluster	Period	Teststatistic	Significance[2]	Trend slope °C/year
Cluster 1	1949-2008	2.404	*	0.014
Cluster 2	1949-2008	1.091		0.006
Cluster 3	1949-2008	2.832	**	0.017
Cluster 4	1949-2008	2.526	*	0.013
Cluster 5	1949-2008	-0.172		-0.001
Cluster 1 without air temperature In Belgrade	1949-2008	2.341	*	0.013

Certainly, a more detailed insight into the spatial distribution of the observed changes in climate elements is obtained by analysing data from each station individually. Since Ducić, Luković, and Milovanović (2008), analysing the trends of air temperature and precipitation in Serbia in the period 1949-2006, used the identical methodology the paper will give an overview of the results of those authors.

[2]In Tables 2 and 3 sign *** is level of significance of 0.001; ** level of significance of 0.01; * the significance level of 0.05.

Table 3. Results of trend analysis by stations of mean annual air temperatures in Serbia

Station	Period	Test statistic	Significance	Slope trend °C/year
Belgrade	1949-2008	2.781	**	0.017
Ćuprija	1949-2008	0.651		0.004
Dimitrovgrad	1949-2008	-0.663		-0.003
Kikinda	1949-2008	2.130	*	0.012
Kragujevac	1949-2008	2.086	*	0.012
Kruševac	1949-2008	1.684		0.008
Loznica	1949-2008	2.794	**	0.017
Negotin	1949-2008	3.087	**	0.019
Niš	1949-2008	1.244		0.007
Novi Sad	1949-2008	2.201	*	0.012
Palić	1949-2008	2.443	*	0.016
Prizren	1949-2008	2.341	*	0.013
Sjenica	1949-2008	2.679	**	0.015
Smed. Palanka	1949-2008	1.741		0.010
Sombor	1949-2008	2.118	*	0.013
Valjevo	1949-2008	2.252	*	0.014
VelikoGradište	1949-2008	0.293		0.002
Vranje	1949-2008	0.166		0.001
Zaječar	1949-2008	2.411	*	0.015
Zlatibor	1949-2008	2.571	*	0.013
Zrenjanin	1949-2008	2.124	*	0.012
Vršac	1949-2008	1.135		0.007
SremskaMitrovica	1949-2008	1.569		0.009

Based on the results in the Table 3 it can be concluded that in the period 1949-2008 at 22 stations there was an increase in mean annual temperature. The exception is Dimitrovgrad, where there has been a decrease in air temperature. At 14 stations there is a statistically significant change (at a significance level of 0.01-0.05). The largest increase in mean annual air temperature is observed in Metohija, south-western, western and north-western Serbia, central and northern Banat, Bačka, Belgrade and Negotin Region. In comparison to the period 1949-2006, positive change in air temperature affected considerably larger territory of Serbia.

To determine whether Belgrade has a significantly higher mean annual air temperature than the mean annual air temperature of the cluster in which it is located, the t-test has been used for independent samples (Table 4), while the t-test for paired samples (Table 5) is applied to get the answer to the question whether the air temperature in Belgrade significantly affects the mean air temperature in the cluster 1.

Table 4. Results of the t-test for independent samples (mean annual air temperature)

	Avg.temp of Belgrade	Avg.temp of the cluster 1 (without Belgrade)	t statistic	df	p level	St. dev. of Belgrade	St. dev. of the cluster 1 (without Belgrade)	F statistic	p level
Belgrade / Cluster 1 (without Belgrade)	12.17	11.07	7.833	118	0.001	0.790	0.749	1.114	0.678

Table 5. Results of the t-test for paired samples (mean annual air temperature)

	Avg. temp	St. dev.	N	Difference in avg. temp.	Difference in st.dev.	t statistic	df	p level
Cluster 1 (with Belgrade)	11.203	0.752	60	0.138	0.004	54.565	59	0.001
Cluster 1 (without Belgrade)	11.065	0.748						

Based on the results in the Tables 4 and 5, it can be concluded that Belgrade has a significantly higher air temperature than the cluster 1 (for about 1.1°C), and significantly contributes to the increase in mean annual air temperature in this cluster (for about 0.14°C).

Conclusion

By using hierarchical cluster analysis to data on mean annual air temperature in Serbia, five separate climatic units areallocated. It turned out that in almost entire territory (except the far south,that is, southeast of Serbia) an increasing trend in air temperature is present. This trend is most pronounced in Belgrade, then, for almost the entire territory of Vojvodina, the northern and north-western part of central Serbia, the valley of the Great Timok and NegotinRegion and to the west and southwest of Serbia. Also, it is confirmed that Belgrade is the urban heat island, which is annually warmer than its surroundings by about 1.1 °C and which contributes significantly to the increase in air temperature in the cluster in which it is located. By excluding this station from the cluster to which it belongs, the air temperature trend slope line becomes milder, but remains statistically significant.

As mentioned in the introduction, a certain group of factors is dominantin the formation of the urban heat island, depending on the season (changes in the radiation balance during summer, anthropogenic emissions of heat during winter). Therefore, the future research will also include the analysis of seasonal distribution of changes in air temperature in Serbia and Belgrade.

Acknowledgements
This paper presents the results of research on Project III 47007 funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

Anđelković, G. (2003). Osnovne karakteristike beogradskog urbanog ostrva toplote. *Glasnik Srpskog geografskog društva*, LXXXIII.

Anđelković, G. (2005). *Beogradsko urbano ostrvo toplote*. Geografski fakultet Univerziteta u Beogradu.

Domonkos, P. (2006). Application of objective homogenization methods: Inhomogeneities in time series of temperature and precipitation. *Időjárás*, *110* (1), 63-87.

Ducić, V., Luković, J., & Milovanović, B. (2008). Promene temperatura i padavina u Srbiji u drugoj polovini XX veka u sklopu globalnih klimatskih promena. *Prvi simpozijum „Zaštita prirode u Srbiji", Zaštita prirode 60/1-2*, (str. 641-653), Zavod za zaštitu prirode Srbije, Beograd.

Ducić, V., Radovanović, M. (2005). *Klima Srbije*. Zavod za udžbenike i nastavna sredstva, Beograd.

Hansen, J., Ruedy, R., Sato, M., & Lo, K. (2010). Global Surface Temperature Change. *Reviews of Geophysics*, *48*. doi:10.1029/2010RG000345.

Kolić, B. (1988). *Šumarska ekoklimatologija sa osnovama fizike atmosfere*. Naučna knjiga, Beograd.

Lim, Y.-K., Cai, M., Kalnay, E., & Zhou, L. (2005). Observational evidence of sensitivity of surface climate changes to land types and urbanization. *Geophysical Reearchs Letters, 32.* doi:10.1029/2005GL024267.

Milosavljević, M. (1963). *Klimatologija.* Naučna knjiga, Beograd.

Milutinović, A. (1974). Klima Jugoslavije po Kepenovoj klasifikaciji i modifikacija ove klasifikacije prema našim uslovima. *IX savetovanje klimatologa Jugoslavije*, Sarajevo-Stambulčić, SHMZ, Beograd.

Parker, D.E. (2004). Climate: Large-scale warming is not urban. *Nature, 432*, 290-290.

Rakićević, T. (1980). Klimatsko rejoniranje SR Srbije. *Zbornik radova Geografskog instituta PMF*, *27*, 29-41.

Salmi, T., Määttä, A., Anttila, P., Airola, T., Amnell, T. (2002). *Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates-the excel template application makesense*, Finish Meteorological Institute, Helsinki, Finland. Retrived from http://www.fmi.fi/organisation/kontakt_11.html.

Savić, S. (1979). Klimatska klasifikacija Jugoslavije po Kepenu. *Prilozi poznavanju vremena i klime SFRJ, 7,* SHMZ, Beograd.

Tošić, I. (2004). *Analiza vremenskih serija temperature i padavina*. Doktorska disertacija. Fizički fakultet – Institut za meteorologiju, Univerzitet u Beogradu.

Unal, Y., Kindap, T., Karaca, M. (2003). Redefining the Climate Zones of Turkey Using Cluster Analysis. *International Journal of Climatology, 23,* 1045–1055.

Unkašević, M. (1994). *Klima Beograda.* Naučna knjiga. Beograd.

Yang, X., Hou, Y., & Chen, B. (2011). Observed surface warming induced by urbanization in east China. *Journal of Geophyical Research, 116*. doi:10.1029/2010JD015452