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AIR TEMPERATURE CHANGES IN SERBIA IN PERIOD 1949-2010 IN VIEW OF GLOBAL CLIMATE CHANGES

Ljiljana BRAŠANAC-BOSANAC, Tatjana ĆIRKOVIĆ-MITROVIĆ[1]

Abstract: *Global climate, biological, geological and chemical processes and natural ecosystems are interconnected, and changes in any of these components of the environment may affect humans and other living beings. According to the reports of the IPCC (2000, 2007, 2009) a single rate of global temperature growth that was observed during the twentieth century is the highest in the past millennium and it is closely connected with the greenhouse effects as a result of increased emissions of gases that cause this effect. Evaluation of changes in the average annual air temperature in Serbia in this paper was carried out on the basis of the results of climate modeling of the IPCC, by the most commonly used scenarios SRES A1B and SRES A2. It should be noted that by the global IPCC models, a problem of climate changes of specific climate parameters is observed in a planetary scale. If we want to get a fine structure of changes within particular regions for which can be crucial local effects such as complex orography, distribution and types of vegetation or soil, the results of these models are not accurate enough. Therefore, for the study of climate changes of the individual regions are used regional models in which the local characteristics of the selected region are accurately presented, so the results of these models have a more detailed structure. This paper analyzes the trend changes in the mean annual air temperature and the air temperature in the growing season, in the period from 1949 to 2010 (a series of 62 years), on the network of 32 meteorological stations in Serbia.*

Key words: air temperature, trend changes, Serbia.

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ПРОМЕНЕ ТЕМПЕРАТУРЕ ВАЗДУХА У СРБИЈИ У ПЕРИОДУ 1949-2010. ГОДИНА СА АСПЕКТА ГЛОБАЛНИХ КЛИМАТСКИХ ПРОМЕНА

Abstract: *Глобална клима, биолошки, геолошки и хемијски процеси и природни екосистеми међусобно су повезани, а промене у било којој од наведених компоненти животне средине могу утицати на човека и друга жива бића. Према извештајима IPCC-a (2000, 2007, 2009), јединствена стопа раста глобалних температура која је забележена током XX века, највећа је у протеклом миленијуму и уско је повезана са ефектом стаклене баште, као последицом повећане емисије гасова који изазивају тај ефекат. Процена промене просечне годишње температуре ваздуха у Србији у овом раду извршена је на основу резултата климатског моделирања IPCC-a, по најчешће коришћеним сценаријима сценарио SRES A1B и сценарио SRES A2. Треба нагласити да се глобалним IPCC моделима проблем климатских промена одређених климатских параметара посматра у планетарним размерама. Уколико хоћемо да добијемо фину структуру промена у оквиру појединих региона, за које могу бити пресудни локални ефекти као што су сложена орографија, расподела и врста вегетације или земљишта, резултати ових модела нису довољно прецизни. Зато се за истраживања климатских промена над појединим регионима користе регионални модели, у којима су локалне карактеристике одабраног региона прецизније представљене, па и резултати ових модела имају детаљнију структуру. У раду су анализирани трендови промена средње годишње и температуре ваздуха у вегетационом периоду, за период 1949-2010. година (низ од 62 године), на мрежи од 32 метеоролошке станице у Србији.*

Key words: температура ваздуха, тренд промена, Србија.

1. INTRODUCTION

In the analysis of climate changes including climate modeling, influence assessment, adaptation and adjustment, are used so called IPCC scenarios (IPCC 2000, 2007, 2009). They are alternative views of how specific measures or lack of their implementation may affect future emissions of greenhouse gases and how the future is uncertain in that sense. It is very uncertain that any path from the given scenario will appear in the form in which it is described. Scenario SRES A1B (IPCC) belongs to a group of moderate scenarios, and it includes a partial implementation of measures to reduce emissions of greenhouse gases, and predicts that the concentration of CO_2 at the end of the century will be about 700 ppm.

According to the results of IPCC models, the increase in mean annual temperature in Europe at the end of the twenty-first century (period 2071-2100) compared to the 1961-1990 climate normal, will be in the range of 2-3°C, if the increase in the concentration of greenhouse gases follows the scenario A1B. If the century ends up with a higher concentration that predict some "more aggressive" scenarios, the increase in temperature according to the results of other regional models can be twice as high compared to these values.

The results of these models are usually not accurate enough if we want to get the fine structure of changes within particular regions, for which can be crucial local effects such as complex orography, distribution and types of vegetation or soil. For this reason, for the study of climate changes in individual regions are used regional models, in which the local characteristics of the selected region are accurately presented, so the results of these models have a more detailed structure.

According to Popovic, T. et al. (2009) estimates based on climate modeling, using moderate scenarios, indicate that the annual temperature in Serbia until the end of the century will increase for 2.6°C. Warming will not be equal throughout the year, summer will be warmer for 3.5°C, fall for 2.2°C, winter for 3.2°C, and the spring for 2.5°C. It is expected the increase in frequency, intensity and duration of heat waves, while the projections for the number of frosty and icy days say that they will continue to decline.

Increasing of the maximum and minimum annual temperature, the amount and distribution of rainfall during the vegetation period, the frequency of extreme phenomena and other climate parameters have a wide range of effects, both on the forest ecosystem as whole and individual trees and directly affect the phenology of plants. Due to high temperatures is reduced the moisture content in the soil, which directly affects the vegetation, as indicated by numerous studies: Kolić, B., Gajić, M. (1975), Jovanović, B., Kolić, B. (1980), Kolić, B. (1988), Andrasko, K. (1990), (1992), Botkin, D.B., et al. (1992), Krstić, M., Ćirković, T. (2005), Belij, S. et al. (2007) and others.

This paper analyzes the trends of changes in the mean annual air temperature and the air temperature in the growing season, for the period from 1949 to 2010 (a series of 62 years), on the network of 32 meteorological stations in Serbia.

2. MATERIAL AND METHOD

For the purposes of this study are used data from the Republic Hydrometeorological Service of Serbia. Due to the reduction of degree of error, it was performed the averaging by altitudes or height zones in which are the studied meteorological stations (areas up to 200 m above sea level, areas of 200-500 m above sea level, areas of 500-1,000 m above sea level and the areas of more than 1,000 m above sea level).

To check the statistical significance of the values of the linear trend of the mean annual air temperature and the air temperature in the growing season, it was used a test of independence of the two statistical features (**t test**) according to the formula:

$$t = R\sqrt{\frac{n-2}{1-R^2}}$$

Based on the coefficient of determination (R^2) and the degree of freedom was determined the actual value of the t test, and based on the degree of freedom (n-2) and an appropriate level of risk 0.05 and 0.01 are determined the critical values of t test. For degree of freedom 60 (n-2 elements), the critical values of t-test are: $\mathbf{t_{(60;\,0,05)} = 2,00;\ t_{(60;\,0,01)} = 2,66}$.

By comparing the actual and the critical value of t test it was determined the statistical significance of the linear trend of the mean annual air temperature and air temperature in the vegetation period in Serbia in the period 1949-2010.

In order to study the variability of the temperatures, the standard deviation was used.

3. RESULTS

In Table 1 is shown trend of changes of the mean annual air temperature and air temperature in the vegetation period in Serbia for the period 1949-2010.

Table 1: *The trend of the mean annual air temperature and the temperature in the growing season in Serbia in the period 1949-2010 (°C / year)*

Meteorological station	Altitude (m)	The trend of the mean annual air temperature °C/per year		The trend of temperature in the growing season °C/per year	
The area 0-200 m above sea level					
Negotin	42	0,021	**	0,021	**
Zrenjanin	80	0,016	**	0,013	
Veliko Gradište	80	0,007		0,007	
Kikinda	81	0,015	**	0,015	*
Sremska Mitrovica	82	0,011	*	0,010	
Vršac	84	0,016	**	0,012	
Novi Sad	86	0,014	**	0,011	
Sombor	87	0,015	**	0,016	*
Banatski Karlovac	89	0,012	*	0,011	
Palić	102	0,018	**	0,021	**
Loznica	121	0,023	**	0,025	**
Smederevska Palanka	121	0,011	*	0,011	
Ćuprija	123	0,003		0,002	
Belgrade	132	0,020	**	0,020	**
Zaječar	144	0,015	**	0,014	*
Kruševac	166	0,012	*	0,011	
Valjevo	176	0,016	**	0,018	**
Kragujevac	185	0,013	*	0,013	*
The area 200-500 m above sea level					
Niš	204	0,009		0,009	
Kraljevo	215	0,010	*	0,008	
Leskovac	230	-0,000		0,001	
Požega	310	0,016	**	0,021	**
Kuršumlija	383	-0,003		-0,009	
Vranje	432	0,004		0,005	
Dimitrovgrad	450	0,000		0,001	
The area 500-1000 m above sea level					
Novi Pazar	545	0,017	**	0,016	*
Trgovište	600	0,011	*	0,014	*
Rudnik	700	0,024	**	0,028	**
The area above 1000 m above sea level					
Zlatibor	1.028	0,014	**	0,013	
Crni Vrh	1.037	-0,097	**	-0,11	**
Sjenica	1.038	0,014	**	0,013	*
Kopaonik	1.711	0,014	*	0,017	*

* Statistically significant trend in the probability ***p = 95%***
** Statistically significant trend in the probability ***p = 99%***

In order to study the variability of mean monthly temperature and analysis of dispersion from the average of the mean monthly temperature, the values of standard deviation of the mean monthly temperatures were also calculated (Table 2).

Table 2: *Standard deviation of the monthly and annual air temperature in Serbia in the period 1949-2010*

Meteorological station	Altitude (m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Negotin	42	2,7	3,2	2,5	1,5	1,5	1,3	1,3	1,7	1,2	1,3	2,0	2,0	0,8
Zrenjanin	80	2,7	3,5	2,5	1,7	1,6	1,5	1,4	1,7	1,6	1,5	2,2	2,1	0,8
Veliko Gradište	80	2,3	2,9	2,2	1,7	1,5	1,4	1,3	1,6	1,6	1,5	2,1	2,0	0,7
Kikinda	81	2,7	3,4	2,3	1,7	1,6	1,4	1,4	1,6	1,5	1,5	2,2	2,1	0,8
Sremska Mitrovica	82	2,4	3,2	2,3	1,6	1,6	1,3	1,2	1,4	1,5	1,5	2,0	2,1	0,7
Vršac	84	2,7	3,3	2,4	1,8	1,6	1,4	1,3	1,7	1,6	1,7	2,3	2,2	0,7
Novi Sad	84	2,7	3,5	2,4	1,7	1,6	1,4	1,3	1,6	1,5	1,5	2,1	2,2	0,8
Sombor	87	2,6	3,4	2,3	1,6	1,6	1,5	1,4	1,5	1,4	1,5	2,1	2,1	0,8
Banatski Karlovac	89	2,4	3,1	2,3	1,6	1,6	1,3	1,2	1,6	1,5	1,5	2,1	2,1	0,7
Palić	102	2,6	3,2	2,2	1,6	1,6	1,4	1,4	1,6	1,4	1,5	2,0	2,1	0,8
Loznica	121	2,4	3,3	2,3	1,6	1,6	1,4	1,2	1,5	1,3	1,5	2,1	2,1	0,8
Smed. Palanka	121	2,5	3,2	2,3	1,7	1,6	1,4	1,4	1,7	1,5	1,6	2,2	2,2	0,7
Ćuprija	123	2,4	3,1	2,2	1,7	1,5	1,3	1,4	1,7	1,6	1,6	2,2	2,1	0,7
Belgrade	132	2,5	3,3	2,5	1,8	1,8	1,5	1,5	1,8	1,6	1,5	2,3	2,1	0,8
Zaječar	144	2,5	3,1	2,4	1,6	1,5	1,3	1,4	1,7	1,5	1,4	2,0	2,3	0,7
Kruševac	166	2,4	3,1	2,3	1,7	1,5	1,3	1,3	1,7	1,5	1,6	2,3	2,3	0,7
Valjevo	174	2,4	3,2	2,2	1,6	1,5	1,3	1,3	1,6	1,4	1,5	2,1	2,1	0,7
Kragujevac	185	2,4	3,2	2,3	1,7	1,6	1,4	1,4	1,7	1,5	1,6	2,2	2,2	0,7
The area 0-200 m above sea level		**2,5**	**3,2**	**2,3**	**1,7**	**1,6**	**1,4**	**1,3**	**1,6**	**1,5**	**1,5**	**2,2**	**2,1**	**0,8**
Niš	204	2,3	3,0	2,3	1,8	1,6	1,4	1,5	1,8	1,6	1,6	2,3	2,2	0,7
Kraljevo	215	2,2	3,1	2,3	1,7	1,6	1,3	1,3	1,6	1,6	1,5	2,3	2,2	0,7
Leskovac	230	2,4	2,9	2,1	1,7	1,4	1,3	1,3	1,7	1,6	1,6	2,3	2,3	0,7
Požega	310	2,2	2,9	2,3	1,7	1,5	1,2	1,1	1,3	1,3	1,4	1,9	2,2	0,6
Kuršumlija	383	2,2	3,0	2,2	1,7	1,4	1,2	1,3	1,7	1,5	1,5	2,3	2,2	0,7
Vranje	433	2,1	2,7	2,2	1,7	1,5	1,3	1,3	1,8	1,6	1,5	2,2	2,1	0,6
Dimitrovgrad	450	2,2	2,7	2,1	1,6	1,4	1,2	1,3	1,6	1,5	1,5	2,2	2,0	0,6
The area 200-500 m above sea level		**2,2**	**2,9**	**2,2**	**1,7**	**1,5**	**1,3**	**1,3**	**1,6**	**1,5**	**1,5**	**2,2**	**2,2**	**0,7**
Novi Pazar	545	2,3	2,6	2,1	1,8	1,6	2,6	2,8	1,7	1,5	1,6	2,0	2,1	0,9
Trgovište	600	2,0	2,7	2,1	1,6	3,2	1,1	1,2	1,6	1,5	1,4	2,2	2,1	0,6
Rudnik	700	2,4	3,5	2,7	2,0	2,8	1,8	1,4	2,1	2,3	2,0	2,7	2,3	0,9
The area 500-1000 m above sea level		**2,3**	**2,9**	**2,3**	**1,8**	**2,5**	**1,8**	**1,8**	**1,8**	**1,8**	**1,7**	**2,3**	**2,2**	**0,8**
Zlatibor	1.028	2,3	3,0	2,5	2,0	1,8	1,4	1,4	1,8	1,7	1,7	2,4	2,1	0,7
Crni Vrh	1.037	2,6	3,7	3,2	3,0	2,6	2,7	2,4	2,5	2,7	2,4	3,1	2,8	2,1
Sjenica	1.038	2,6	3,1	2,5	1,6	1,4	1,2	1,2	1,5	1,4	1,6	2,3	2,5	0,7
Kopaonik	1.711	2,0	2,4	2,3	1,9	1,5	1,4	1,5	1,7	1,5	1,6	2,1	2,2	0,9
The area above 1000 m above sea level		**2,4**	**3,0**	**2,6**	**2,1**	**1,9**	**1,7**	**1,6**	**1,9**	**1,8**	**1,8**	**2,5**	**2,4**	**1,1**

By analyzing Table 2 it can be concluded that the values of standard deviation range between 1.1 (Trgoviste - June; Pozega - July) to 3.7 (Crni Vrh - February) and that the temperatures in the warmer part of the year are more stable than in the colder part of the year. Understandably, the greater variability of temperature in the winter months in some years is the result of the penetration of cold and warm air masses.

When the influences of western air masses are stronger, the winters are relatively warm, and when is dominant the influence of northern and northeastern polar masses, the winters are very cold. The greatest variability of mean monthly temperature is in February, and the lowest in June and July.

4. DISCUSSION AND CONCLUSION

According to the obtained results, the trend of changes in mean annual air temperature in Serbia for the period 1949-2010 (62 years) at most meteorological stations is positive (exceptions are Kursumlija and Crni Vrh). The greatest increases in the values of the linear trend have the meteorological stations Rudnik (0.024°C/annually), Loznica (0.023°C/annually), Negotin (0.021°C/annually) and Belgrade (0.020°C/annually), whereby the values of trend of changes are statistically significant at the 99% probability.

It is also noticeable the existence of territorial uniformity of trend of changes. For example, in Vojvodina the values of trend of changes in mean annual temperature are in the range of 0.011 ° C annually (MS Sremska Mitrovica), up to 0.018 ° C annually (MS Palic), where the values of trend are statistically significant at the probability of 95% for areas of Sremska Mitrovica and Banatski Karlovac, and for other meteorological stations in Vojvodina the values of trend of changes are statistically significant at the 99% probability.

Uniformity is also noticeable in the higher altitudes above 1,000 m (except MS Crni Vrh -0.097), and the value of the trend is 0.014°C annually, with statistical significance of 99% for all stations, except MS Kopaonik, where the value of the trend of changes of the mean annual temperature is statistically significant at the 95% probability.

Negative or minimally expressed positive trend of changes of mean air temperature is characteristic for the south-east of Serbia (Leskovac -0.00°C/ annually, Dimitrovgrad 0.000°C/annually), the areas along the valleys of the South and Great Morava (Vranje 0.003°C/annually, Nis 0.009°C/annually, Cuprija 0.003°C/annually), Veliko Gradiste (0.007°C/annually), but the values of the trend of changes at any meteorological station are not statistically significant.

When it comes to the trend of changes of air temperature during the growing season according to the obtained results, the trend of changes at the most meteorological stations is positive (exceptions are Kursumlija and Crni Vrh). The greatest increase in the values of the linear trend have meteorological stations Rudnik (0.028°C/annually), Loznica (0.025°C/annually), Negotin (0.021°C /annually), Palic (0.021°C/annually), Pozega (0.021°C/annually) and Belgrade (0.020°C/annually), whereby the values of trend of changes are statistically significant at the 99% probability.

Like in the trend of changes of the mean annual temperature, in the trend of changes in air temperature during the vegetation period is also noticeable the existence of territorial uniformity. In the area of Vojvodina (with the exception of Palic) the values of trend of changes of air temperature in the growing season ranges from 0.010°C annually (MS Sremska Mitrovica) to 0.016°C annually (MS Sombor), whereby the values of trend are statistically significant at the probability 95% for the area of Kikinda and Sombor, and for other meteorological stations values of trend of changes are not statistically significant.

Uniformity is also noticeable in height zones of 500-1,000 m above sea level and above 1,000 m (except for MS Rudnik and MS Crni Vrh), and trend values range from 0.013°C annually (MS Zlatibor and MS Sjenica) to 0.017°C annually (MS Kopaonik), with statistical significance of 95% for areas of Sjenica, Trgoviste (0.014°C/annually), Novi Pazar (0.016°C/annually) and Kopaonik, while for the area of Zlatibor the value of trend of changes in air temperature during the vegetation period is not statistically significant.

The negative trend of changes of air temperature in the growing season have Kursumlija (-0.009°C/annually) and Crni Vrh (-0.11°C/annually), while the value of the trend of changes in the area of MS Crni Vrh is statistically significant at the 99% probability, and the value of the trend of changes in the area of Kursumlija is not statistically significant.

Minimum expressed positive trend of changes of air temperature during the vegetation period is characteristic for south-east of Serbia (Leskovac 0.001°C/annually, Dimitrovgrad 0.001°C/annually), areas along the valleys of the South and Great Morava (Vranje 0.005°C/annually, Nis 0.009°C/annually, Cuprija 0.002°C/annually) and Veliko Gradiste (0.007°C/annually), but the values of the trend of changes at any weather station were not statistically significant.

The structure of the changes of annual air temperature in Serbia shows that the increase is caused primarily due to increase in summer temperatures and not due to the extremely higher winter temperatures as was emphasized in some reports of the IPCC which is opinion determined on the basis of paleoclimatic analogues in terms of domination of greenhouse gases effects (Ducic, V., Radovanovic, M., 2005).

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AIR TEMPERATURE CHANGES IN SERBIA IN THE PERIOD 1949-2010, IN VIEW OF GLOBAL CLIMATE CHANGES

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Summary

Prema većini prognoza, Srbiju kao i ceo region jugoistočne Evrope očekuju značajne promene klime u skorijoj budućnosti. Projekcije prema regionalnim klimatskim modelima predviđaju da će porast prosečne temperature na godišnjem nivou do kraja ovog veka iznositi od 2,4°C do 2,8°C prema optimističnom scenariju (SRES A1B), odnosno od 3,4°C do 3,8°C prema pesimističnom scenariju (SRES A2). Prema svim scenarijima očekuje se rast prosečne temperature, uz određene regionalne razlike, u svim delovima Srbije. Nesporno je da se klima menja i da će se menjati i u budućnosti, međutim, brzina, uticaji i posledice tih promena tokom XXI veka veoma su neizvesne, naročito u regionalnom smislu.

Prema dobijenim rezultatima sprovedenog istraživanja na većem delu Srbije trend promena srednje godišnje temperature i temperature vazduha tokom vegetacionog perioda, za period 1949-2010. godina je pozitivan, izuzetak su Crni Vrh i Kuršumlija. Najveći porast vrednosti linearnog trenda srednjih godišnjih temperatura i temperature vazduha tokom vegetacionog perioda imaju meteorološke stanice Rudnik, Loznica, Negotin i Beograd, pri čemu su vrednosti trenda promena statistički značajne pri verovatnoći 99%. Minimalno izražen trend promena srednje temperature vazduha i temperature vazduha tokom vegetacionog perioda odlikuje jugoistok Srbije, područja duž dolina Južne i Velike Morave, do Velikog Gradišta, ali vrednosti trenda promena ni na jednoj meteorološkoj stanici nisu statistički signifikantne.