THE EFFECT OF THE THERMAL COMPONENT CHANGE ON REGIONAL CLIMATE INDICES IN SERBIA

by

Marko M. JOKSIMOVIĆ [a]*, Mirjana R. GAJIĆ [a], Snežana M. VUJADINOVIĆ [a], Rajko M. GOLIĆ [a], and Darko B. VUKOVIĆ [b]

[a] Faculty of Geography, University of Belgrade, Belgrade, Serbia
[b] Geographical Institute "Jovan Cvijić" of the Serbian Academy of Sciences and Arts, Belgrade, Serbia

Original scientific paper
DOI: 10.2298/TSCI150430105J

The study of climate changes is most often based on the analysis of time series of temperature and precipitation in urban areas and the increase in the emission of gases having a greenhouse effect. On the other hand, the selection of representative and relevant stations and comprehensive analysis of climate indicators lead to better and more exact assessments on climate changes at the regional level. In order to connect climate changes with agricultural, biological, socio-economic, and tourism databases, the paper deals with the dynamic analysis of changes in thermal component expressed through the values of regional climate indices in four climatological stations with different geographical positions in Serbia. There are significant differences between the two time series data (1961-1990 and 1991-2013) on temperature and humidity, precipitation, insolation, and wind speed. However, after using the climatic indices as a tool for assessing climate changes, the results of the study suggest the relative influence of the thermal component on the change of climate indices, with a slight increase in the index of significance for human activities. Relying on the results of this alternative approach to the study of climate changes, the fact remains that the climate is not fixed but highly variable factor that should be taken into consideration in terms of monitoring, evaluation, and management of the area.

Key word: *climate index, evaluation, thermal component, climate changes, conditions*

Introduction

The period of regular, instrumental study of global climate is relatively short, and climatological analyses show many fluctuations over a period of the last 100 years. Earlier studies have pointed to climate changes, that is, shift of colder and warmer periods during the Quaternary [1]. The emergence of an increase in air temperature over shorter periods, especially after the medieval *Little Ice Age*, is often explained by the emission of heat and greenhouse gases. On the other hand, some researchers of sunspots have highlighted the accelerated loss of solar heat due to the increase in sunspots by 2020, which would lead to a new cold period [2]. Based on

* Corresponding author; e-mail: dell_mare@yahoo.com

dendrochronological measurements and extrapolation with the number of sunspots, some authors point to an increase in air temperature over the last 11,400 years, but underline that the significant thermal increase is currently decreasing due to sunspot activity [3, 4]. Accordingly, there is a period of stability in the solar radiation and, consequently, the planet cooling. In 2013 and 2014, there have been some changes in relation to the dominant trend of the air temperature increase. This is proven by the satellite images CryoSat 2010-2014 specialized in the surfaces under the ice, where there is obvious significant increase in area and thickness of ice in the Arctic [5]. On the other hand, measurements in the Antarctica also indicate an increase in ice mass [6]. This tendency is considered by some authors as an argument [7] that is opposing the apocalyptic predictions of the Intergovernmental Panel on Climate Change [8].

In studying the effects of climate changes two approaches are visible. The first is the choice of reference climate stations in the region, analysis, and quantification of the existing data on the basis of which the forecasts of the future climate are made [9, 10]. Another approach is based on adapting the general atmospheric circulation models at regional and local level [11, 12]. The use of this model is based on the assumption that the general circulation model (GCM) simulates the atmospheric circulation better than the climatic elements in the troposphere which are too sensitive to local processes (convection, cloudiness, turbulence) [13].

The effects of climate changes are monitored on the basis of events (heat waves, droughts, heavy rain, flooding, and destructive winds) in densely populated areas or places where the population migrates seasonally [14]. In this way, the analyses often bypass rural, thinly populated, and unpopulated areas. The biggest concern for the rise in temperature is in the areas with the highest population density. Symbolically, the poles of population growth coincide with the poles of growth in air temperature. Expressed air temperature increase is felt at a distance of about 50 km from the cities and industrial regions showing their more local and less global character. Therefore, the analysis of climate changes on the basis of data obtained from the climate stations in big cities can lead to catastrophic assessment of research results for the future [15-17].

Climate changes in Serbia

Climate indices, the diagnostic tools of which are used for defining climate and understanding climate changes, have developed over time and proved to be objective methods of forecasting the human activities such as agriculture, transport, and tourism. Using several climate indices, the researchers show climate changes in Turkey as well as the correlation among some indices [18]. Based on 27 indices on daily values of air temperature and precipitation, the climate changes were determined in Greece in the last 60 years [19]. Changes in seven climate indices related to temperature or precipitation in Serbia were estimated for future period.

In addition to air temperature and precipitation, sunshine duration is important element of the bioclimatic indices. The period of reduced insolation 1960-1980, associated with greater cloudiness, was replaced by the period of greater insolation in the last 30 years caused by the domination of the high pressure system [20]. Data analysis for Europe (1970-1985; 1985-2000) showed a statistically significant influence of the North Atlantic Oscillation (NAO) on cloudiness and solar radiation, especially during autumn and winter [21]. Although the increase in insolation in Europe over the last 30 years is evident, it has been found in some papers that earlier there were also alternating periods of higher and lower insolation. In addition to natural factors for reducing the insolation, the aerosols of industrial origin are also mentioned as influential anthropogenic impacts [22]. Changes in seven climate indices related to temperature or precipitation in Serbia were estimated for future period according to SRES-A1B and SRES-A2 scenarios [23]. The increase in air temperature has also been influenced by change in land use together with reducing the green areas which increases the albedo and thus the air temperature of the troposphere increases, too. This conclusion is in connection with the allegation that climate changes are most felt in the most populated areas.

Authors who have studied climate changes in Serbia believe that they are to a great extent influenced by the NAO, El Nino Southern Oscillation (ENSO), and Arctic Oscillation (AO). Anthropogenic greenhouse effects are not yet proven or they are considered less relevant [24, 25]. In temperate latitudes, where there is also Serbia, there is a non-linear climate system the properties of which are chaotic, which makes difficult the numerical modeling and forecasting [26]. Based on the analysis of air temperature variability, it was concluded that the air temperature in Serbia has increased in the last 50 years. Global warming is felt, but only in the last decade of the 20th and beginning of the 21st century, unevenly on the territory of Serbia. The largest increase in air temperature is observed in Vojvodina, the Peripannonian belt, the Timok region and south-western Serbia (stations: Belgrade, Palic, Negotin, Zajecar, and Loznica) [27]. The papers of authors of regional climate studies also confirm similar results [28-31]. In order to reduce climate changes solely on scientific ground, reminding that there were considerable temperature fluctuations in the past, the climate changes in Serbia in the form of an increase in air temperature have precisely been defined as climatic extremes and extreme climate events [32].

Although several efficient methods of investigation of the impact of climate changes on tourism are developed and it is pointed to spatial and temporal benefits of certain regions at the European level, the papers on bioclimatic indices in Serbia are rare. The influences of bioclimatic indices, that is thermal load on the health and recreation have been investigated in the examples of Zlatibor and Belgrade [33], as well as the effects of climate changes on tourism trends on Brezovica (Shar Mountain) [34].

The consequences of climate changes are mainly attributable to the negative effects on the population of Serbia. The scenarios and modeling based on the theory of global warming often show the catastrophic future of climate and consequences for economy. Without going into reasons for the creation of professional and media images on climate changes and the possible political, economic and other goals of such campaigns, the idea in this paper is to point to the changes and predict the regime of the thermal component in the regional examples through bioclimatic indices. Indirectly, selected indices are of a general nature, can be applied to the general activities of the population in the environment. Changes in these indices are changes in objectively the most suitable time for activities.

Methodology and data

The report from the conference in Davos [35] harmonized the main impacts of climate changes on areas of importance for tourism:

- direct effects: changes in the amount and distribution of precipitation, extreme weather events, and increase in air temperature,
- indirect effects on the environment: loss of biodiversity and aesthetic values, increase in the level of the World Sea,
- adverse impacts on the mobility of tourists, and
- and, indirect consequences for the economy and political stability in some countries.

There are many papers which analyze and predict climate changes in the context of tourism. The mentioned investigations can be divided into five groups: statistical models of the behaviour of certain groups of tourists in the context of weather and climate [36, 37]; impacts of climate changes on some destinations [38-40]; evaluation of weather and climate as a tourism conditions, that is, resources [41-44]; simulations of the impact of climate changes on tourism development [45]; economic impacts of climate changes on tourism [46, 47]. In these papers, the authors deal with the impacts of climate changes on national tourism or on the established tourist regions of the Alps and the Mediterranean.

In terms of tourism, factors can be singled out affecting the seasonal and off-season movements of tourists in continental destinations such as Serbia. In the summer season these are: insolation, intensity of solar radiation, cloudiness, air temperature, humidity, wind speed, thermal comfort, ultraviolet radiation, substrate temperature, and albedo. In the winter season of importance is the thickness of snow cover, insolation, air temperature, snow reflection, and wind speed. In general, the following is classified in the off-season factors: air temperature, humidity, precipitation, insolation and wind speed. Climatic elements can be classified according to the importance for different types of destinations (coastal, urban, and mountain) [48]. In the context of this paper, only the groups of elements that affect the urban and mountain destinations will be discussed (tab. 1).

Table 1. Importance of climate variables in urban and mountain destinations

Urban centres	Index	Mountain centres	Index
Thermal component	5.98	Precipitation	6.04
Precipitation	5.77	Thermal component	5.84
Insolation	5.14	Insolation	5.55
Wind speed	4.75	Wind speed	5.41

* Source: [48]; Explanation: the thermal component (temperature and humidity), precipitation – dry weather has predominantly positive impact, wind – absence of strong winds has a positive impact, and insolation – greater insolation has a positive impact

For the purpose of indexation of climate in tourism, climate indices have been developed including sets of climatological and meteorological parameters. By quantification of the objective climatological data, legalities of their action on the subjective feeling of tourists are derived [49]. Tourism climate index (*TCI*), developed in the eighties of the last century [50] was used to point to the impacts of climate changes on urban tourism in North America [44]. Cities were ranked by attractiveness of climate and the correlation performed with the model of future climate changes. The results pointed to the increase, that is, decrease in the attractiveness of some destinations. The same methodology proved to be suitable for the forecasts of climate impacts in the Mediterranean [51, 52] and continental destinations in Europe.

Unlike countries that rely on coastal tourism, climate has a minor influence on the organization of tourism in Serbia as a continental country. It is evident that among climatic elements significant for mountain destinations in Serbia, air temperature, insolation, and precipitation, especially in the form of snow, take special place in strategic documents. However, in the master plans climate data are often only superficially analyzed, without a detailed evaluation and review of the basic bio-climatological indices, laws affecting the seasonality, extreme weather conditions, *etc.* [53-56]. In cities, spas and other destinations, climate impacts are interpreted through seasonal advantages or disadvantages for visits and activities (*e. g.* the abilities to swim in the rivers, lakes, *etc.*). Thus, the air is analyzed as a fixed factor of destination development, not as a variable factor affecting tourist motivation, movement and consumption during the year. Therefore, in this paper we started from the assumption that the changes in the thermal component have contributed to the change of climate indices and thereby the conditions are changed in the tourist centres.

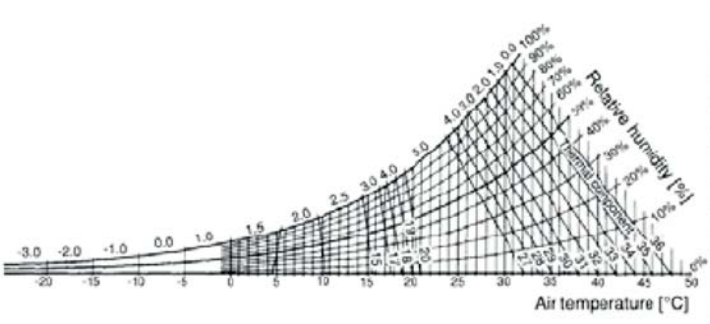
Starting from the issue of the paper, authors' intention is to establish the link between the variability of the thermal component (temperature and relative humidity) and the value of *TCI* as well as the maximum summer air temperature with an index of summer weather for the periods 1961-1990 and 1991-2013 through the analysis of relevant climate indicators in four selected tourist destinations in Serbia.

The methodology of the paper is based on a regional approach to the analysis of climate data for the four traditional tourist centres in Serbia, which are classified according to the number of overnight stays in the leading ones in their respective categories (urban, mountain, spa, and other centres). According to Koppen's classification, Palic, Novi Sad, and Sokobanja are in CFWBX climate (warm, moderately humid climate, with minimum precipitation in winter and maximum precipitation during summer), while Zlatibor is within DFWBX climate (wet and cold temperate climate with warm summer, maximum precipitation in late spring and early summer) [57]. Although grouped into two climates, all stations are characterized by distinct geographical location, that is, regional specificities*.

We are of opinion that the microclimate position greatly affects the climate elements on the basis of which indices are calculated.

Destinations also vary according to the motif of tourism and are the representatives of various types of climate: Palic – vacation, sports and recreation, congress, and nautical centre; Novi Sad – centre of urban forms of tourism; Zlatibor – mountain resort with a mixed offer, and Sokobanja – spa centre with a mixed offer.

The *TCI* is a method which, based on two bioclimatic (daylight comfort index and daily comfort index) and three individual climate elements (insolation, precipitation, and wind speed), evaluates climatic conditions for tourism. The variables are evaluated by points from –2 to 5 (fig.1).



Points	R [mm]	S [h]	W [m/s]
5.0	≤ 14.9	> 10	< 0.8
4.5	15-29.9	9-10	0.8-1.5
4.0	30-49.9	8-9	1.6-2.5
3.5	50-59.9	7-8	2.6-3.3
3.0	60-74.9	6-7	3.4-5.4
2.5	75-89.9	5-6	5.5-6.7
2.0	90-104.9	4-5	6.8-7.9
1.5	105-119.9	3-4	-
1.0	120-134.9	2-3	8.0-10.7
0.5	135-149.9	1-2	-
0.0	150-209	0-1	> 10.7
-0.5	-	-	-
-1.0	210-269.9	-	-
-1.5	-	-	-
-2.0	270-329.9	-	-

Figure 1. Diagram for the evaluation of the thermal comfort and table for evaluating the average monthly amount of precipitation (*R*), the mean daily insolation (*S*), and mean monthly wind speed (*W*) [50]

* Palic (102 m alt., 46°06'N, 19°46'E), Novi Sad – Rimski Sancevi (86 m alt., 45°20'N, 19°51'E), Zlatibor (1,028 m alt., 43°44'N, 19°43'E), Sokobanja (300 m alt., 43°39'N, 21°51'E).

The *TCI* is calculated on the basis of the formula:

$$TCI = 8tc + 2tc_d + 4R + 4S + 2W \tag{1}$$

where *tc* is the ratio of maximum daily air temperature and minimum daily relative humidity, tc_d – ratio of the mean daily air temperature and mean daily relative humidity, *R* – mean monthly total precipitation, *S* – mean daily insolation, and *W* – mean monthly wind speed.

The maximum amount of *TCI* may be 100, and climate benefits are assessed descriptively as: *the ideal weather* (90-100), *excellent* (80-89), *very good* (70-79), *good* (60-69), *acceptable* (50-59), *possible* (40-49), *undesirable* (30-39), *highly undesirable* (20-29), *extremely undesirable* (10-19), and *impossible* (–30-9). To calculate the *TCI*, air temperature and relative humidity are most valued. The advantage of *TCI* is that it can be calculated for all climatological stations. The basic lack of *TCI* is the fact that this index does not fit all tourist activities (*e. g.* skiing, water sports or wind sports for which different climatic elements are of priority) [52]. Moreover, given that the microclimate modifiers also affect the activity of tourists, the results should be treated with reserve. Despite the shortcomings we believe that based on the above mentioned index, the periods of favorable climate can objectively be allocated for recreational activities of tourists and the population of Serbia in general.

Davies climate index of summer weather (*LI*) is based on three parameters: air temperature, insolation, and precipitation [58]:

$$LI = (18TL_{\max} + 0.217S) - (0.276N) + 320 \tag{2}$$

where $TL_{\max}$ is mean monthly maximum air temperature in three summer months, *S* – the average daily insolation in three summer months, and *N* – the amount of precipitation in three summer months.

After calculating the *TCI*, the chain indices of the *TCI* increase (decrease) are defined and the thermal component increase (decrease) in the two mentioned periods to obtain the difference. The same process led to the difference in the chain indices increase (decrease) of summer weather index and air temperature. The *TCI* and *LI* are based on a different methodology which allows perceiving the changes from a different angle – at the level of the year and at the level of the summer season.

In this paper two databases are used: geographical and climatological. The subject of the dynamic data analysis was two statistical time series of climate data (1961-1990 and 1991-2013). Forecasting the *TCI* values for the next decade was carried out as logarithmic regression.

Results

Based on the available data from meteorological yearbooks 1961-2013 of the Federal Hydrometeorological Institute (FHMI) and the Republic Hydrometeorological Service of Serbia (RHMS) [59], we will deal with changes in key bioclimatic elements in the last 53 years. Compared to the period 1961-1990, average monthly air temperature in the period 1981-2010 increased in Palic by 0.7 °C, in Novi Sad 0.5 °C, Zlatibor 0.2 °C, and Sokobanja 0.8 °C. Mean maximum air temperature in Palic increased by 0.7 °C, in Novi Sad 0.5 °C, Zlatibor 1.3 °C, and Sokobanja 0.8 °C. Daily average relative humidity in the last 30 years is lower in Palic by 2.4%, in Novi Sad 0.8%, Zlatibor 0.8%, and in Sokobanja it is higher by 3.6%. The total duration of sunshine increased in Palic for 128.7 hours, in Novi Sad 110.9 hours, Zlatibor 74.2 hours, and Sokobanja for 113 hours.

Based on these data, changes in the amount of the *TCI* are also expected as well as differences between the examined periods 1961-1990 and 1991-2013 (fig. 2). In all stations the average monthly values of the *TCI* are increasing (on average, 9 months a year in Zlatibor, 8 months in Palic, 6 months in Novi Sad, and 11 months in Sokobanja), and seasonal variations are also visible.

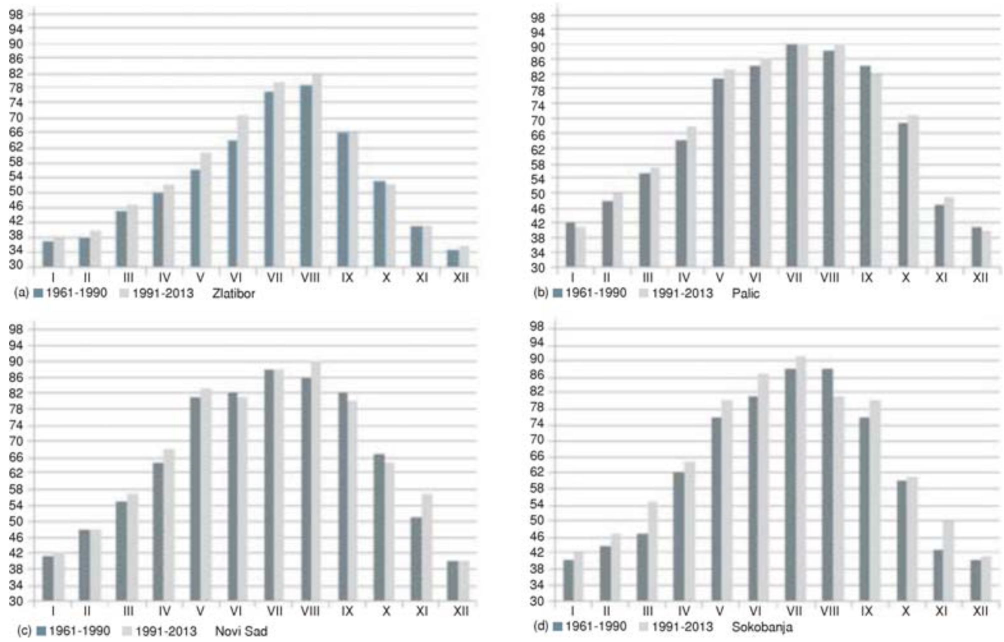


Figure 2. Monthly amount of the *TCI* for the periods 1961-1990 and 1991-2013

The average annual values of the *TCI* for the first period range from 53 on Zlatibor to 66 in Palic, while in the second period they increased from 55 on Zlatibor to 67 on Palic. The range of minimum and maximum monthly values of the *TCI* in the first period was from 35 (December) on Zlatibor to 90 (July) on Palic, and in the second one from 36 (December) on Zlatibor to 91 (July) in Sokobanja. The increases of three or more points can be observed on Zlatibor in May, June, August, September, and October; on Palic in April; in Novi Sad in April, August, and November; in Sokobanja in February, March, April, May, June, July, September, and November. A drastic reduction is only observed in Sokobanja in August.

In the examined periods there is an evident influence of the thermal component (*TC*) on the increase of the *TCI* value (figs. 3 and 2). The relationship of the *TC* and *TCI* is represented by chain indices of increasing (decreasing) values between the periods 1961-1990 and 1991-2013. The impact of the *TC* on the *TCI* is reflected in the consistent growth lines on the graphs. On Zlatibor, the greatest impact of the *TC* on *TCI* is in May and June. On Palic, the *TC* influenced the *TCI* in April, June, and October. In Novi Sad, the impact of the *TC* is apparent only in winter months. In Sokobanja, the *TC* influence is the highest in March, October, November, and December.

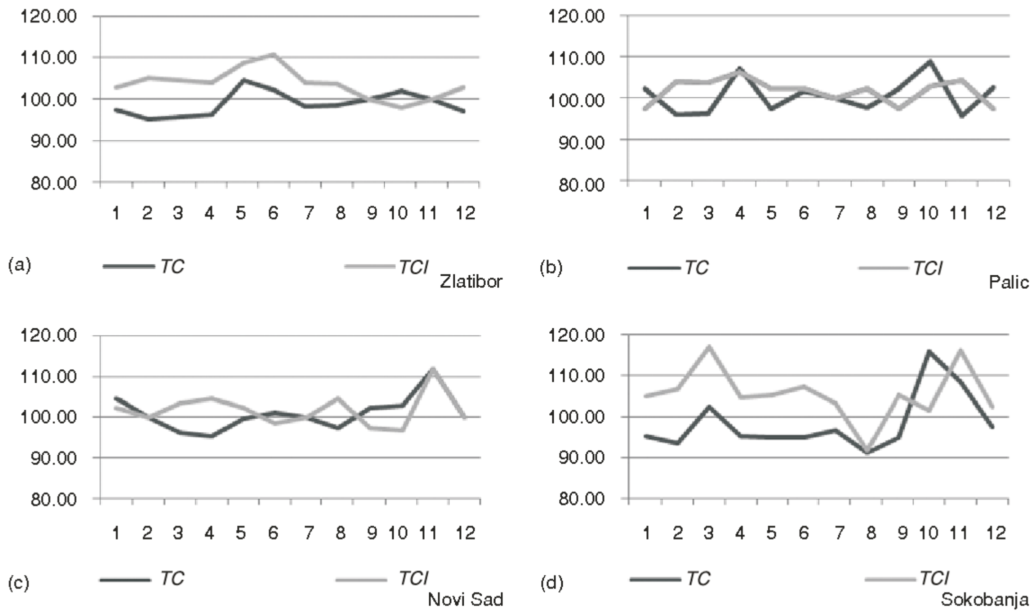


Figure 3. Chain indices of thermal component and *TCI* (1961-1990 and 1991-2013)

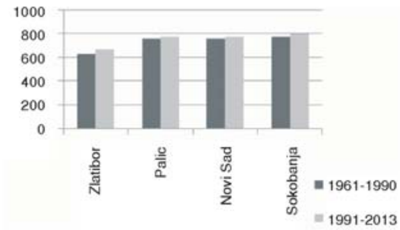
The difference between the chain indices of the *TCI* and *TC* (tab. 2) points to the unequal impacts of the *TC* throughout the year, that is, weak correlation. It is obvious that the *TCI*, besides temperature and humidity, is significantly affected by insolation, precipitation, and wind in some months. Equal values of rise (fall), that is, the highest correlation index (0.00) is recorded on Zlatibor in September and November, on Palic in July and in Novi Sad in February, July, and December.

Table 2. Difference in values of chain indices of the *TCI* and *TC*

Difference (*TCI* – *TC*)	1	2	3	4	5	6	7	8	9	10	11	12
Zlatibor	5.33	10.26	8.70	7.85	4.46	8.62	5.55	5.36	0.00	–3.81	0.00	5.63
Palic	–4.82	8.17	7.15	23.54	4.88	8.61	0.00	4.49	–4.82	16.22	8.34	–4.94
Novi Sad	–2.15	0.00	7.15	9.03	2.76	–2.45	0.00	7.15	–4.94	–6.06	–0.08	0.00
Sokobanja	9.76	13.20	14.48	9.45	10.26	12.40	6.71	0.79	10.26	–14.26	7.65	4.94

In terms of the *LI*, the values are increasing at all stations (tab. 3). The largest increase is recorded on Zlatibor, from 628 to 666, and the lowest in Novi Sad from 760 to 776. The share of the T_{max} in the *LI* is also increasing. On Zlatibor the share of T_{max} during summer months of the period 1991-2013 is higher on average by 2.2%, on Palic by 1.01%, in Novi Sad by 1.20%, and 0.86% in Sokobanja. According to all, as opposed to the impact of the *TC* on the *TCI*, the T_{max} share in *LI* shows significant correlation. Differences in results of the *TCI* and *LI* are the consequence of different methodology, namely, the impact of humidity and wind speed as the segments of the thermal component in the *TCI*.

Table 3. Index of summer weather for the periods 1961-1990 and 1991-2013

	T_{max} share in *LI* (%)	
	1961-1990	1991-2013
Zlatibor	60.74	62.97
Palic	63.80	64.81
Novi Sad	64.38	65.59
Sokobanja	64.82	65.68

Based on the improvement of climate conditions for tourism and calculating the logarithmic regressions, a representative *TCI* trend is predicted for four stations (fig. 4), which indicates a gradual increase in the average annual values over the next 10 years. On Zlatibor and in Sokobanja, expected increases are up to 4% and by about 2% in Novi Sad and Palic. The calculated and predicted values should be viewed with caution, given the numerous climate modifiers such as extreme climatic situations and phenomena that have characterized the last decade.

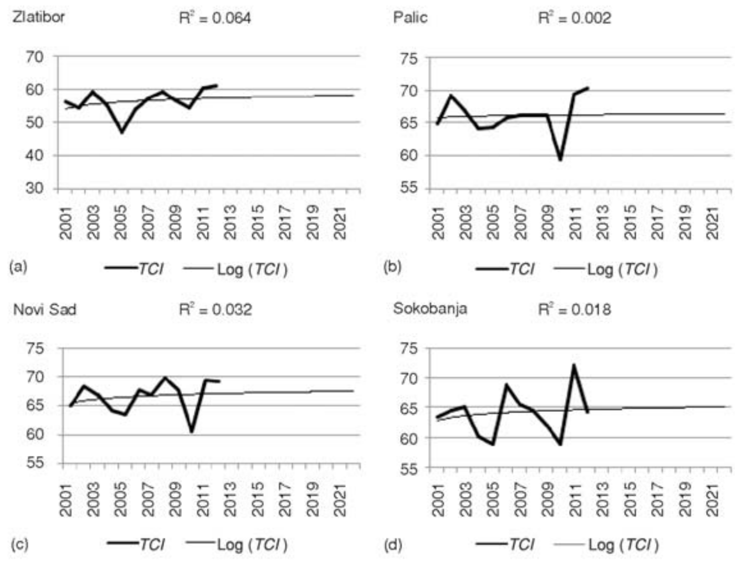


Figure 4. Predicted average annual *TCI* values

Discussion and conclusion

The results indicate spatial and temporal variations of the *TC* in bioclimatic indices on the basis of which the chart of steady growth trend cannot be derived. The index values indicate the clear differences between the stations of the Pannonian and mountain macro region of Serbia (fig. 2). Climate conditions for the activity of tourists and residents are more favourable on Palic and in Novi Sad than in Sokobanja and on Zlatibor. However, the number of months with the best weather for tourism (> 80) has increased in two stations: on Zlatibor from 0 to 2, in Sokobanja from 3 to 5. By the increase in the *TCI* value for February, May, June, July, and August in the last 20 years, the tourist season is qualitatively improved on Zlatibor**, and July and August are singled out (category excellent). On Palic, tourist season has also been extended to March (acceptable), while August moved from the category excellent to the category ideal. The least changes are recorded in Novi Sad, and August is qualitatively better in the last 23 years. The expansion of season can be observed in Sokobanja with weather of over 50 points in two months (March and October). Also, periods with excellent ideal weather extended to May, June, July, August, and September while previously they referred exclusively to the summer months. The number of months with undesirable weather for tourism on Zlatibor (< 40) decreased from 3 to 2.

Consideration of climate hazards, climate change and its impact on some tourism activities in general and the possibility of predicting bioclimatic indicators must affect the more pragmatic planning of tourism at the local, regional, and national level. Within the framework of the Hamburg tourism model, the correlation is established between the accessibility of destination, the concentration of population and income on one side and air temperature on the other side [60]. A noticed trend is that cooler destinations with increasing air temperatures become more attractive, while the tourist value decreases to warmer tourist destinations. Based on the results of this paper and indicated legalities and trends of tourist demand in the cities, we come to the conclusion that the mountain and sub mountain destinations in Serbia will become more attractive during the year, especially in summer and spring months.

The investigation of the influence of the thermal component on the values of climate indices showed spatial and temporal diversity. The fact that the thermal component most influenced the increase of the *TCI* in certain months (in less than 6 months per year) and the increase in the *LI* in the summer months indicates its relative importance compared to other variables. In other words, the increase in the average annual temperature did not necessarily condition the improvement of the conditions for tourism in all months. On Zlatibor, the *TC* influenced the extension of autumn season, spring, and autumn season on Palic, winter one in Novi Sad and autumn and winter season in Sokobanja.

In addition, small spatial coverage and the necessity of interpolation of data, that is, focusing on the data obtained from the climatological station are the deficiencies of the *TCI* and *LI* methodologies. In the study of ideal climatic conditions for tourism and other activities of the population, objective questions that would be addressed in the future are: the impact of extreme climatic situations on the seasonal movements of tourists, the impacts of temperature and precipitation increases on mountain destinations, regionalization based on bioclimatic parameters, and the like. The increase in air temperature at high altitudes has already set a challenge to the researchers, spatial planners, and other actors on planning and management of the existing and

** In winter months *TCI* cannot be viewed in the context of the ski tourism, which implies a different evaluation of elements (especially of snowfalls) planned winter resorts. The results of the paper focus on the fact that the climate is not fixed, unchanging input in the spatial planning of tourism, but it is changing and the changes must be effectively monitored and evaluated.

Acknowledgment

This paper presents the result of the research projects176008 and III47007, funded by the Ministry of Education, Science, and Technological Development of Republic of Serbia.

References

[1] Lockwood, J. G., Abrupt and Sudden Climatic Transitions and Fluctations: a Review, *International Journal of Climatology, 21* (2001), 9, pp. 1153-1179
[2] Rivas-Martinez, S., *et al.*, Worldwide Bioclimatic Classification System, *Global Geobotany, 1* (2011), 1, pp. 1-634
[3] Solanki, S. K., *et al.*, Evolution of the Sun's Large-Scale Magnetic Filed since the Maunder Minimum, *Nature, 408* (2000), 68111, pp. 445-447
[4] Solanki, S. K., *et al.*, Unusual Acitivity of the Sun During Recent Decades Compared to the Previous 11.000 Years, *Nature, 431* (2004), 7012, pp. 1084-1087
[5] ***, ESA, CryoSat, http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat/Arctic_sea_ice_up_from_record_low
[6] Hobbs, W. R., *et al.*, New Perspectives in Observed and Simulated Antarctic Sea Ice Extent Trends Using Optimal Fingerprinting Techniques, *Journal of Climate, 28* (2015), 4, pp. 1543-1560
[7] Radovanović, M., The Increasing of the Ice Surface in the Arctic – Is This also the Consequence of Global Warming?, *Journal of the Geographical Institute "Jovan Cvijić" of the Serbian Academy of Sciences and Arts, 64* (2014), 3, pp. 383-386
[8] ***, Intergovernmental Panel on Climate Change, http://www.ipcc.ch/
[9] Southworth, J., *et al.*, Consequences of Future Climate Change and Changing Climate Variability on Maize Yields in the Midwestern United States, *Agricultural Ecosystems & Environment, 82* (2000), 1-3, pp. 139-158
[10] Southworth, J., *et al.*, Changes in Soybean Yields in the Midwestern United States as a Result of Future Changes in Climate, Climate Variability, and CO_2 Fertilization, *Climate Change, 53* (2002), 4, pp. 447-475
[11] Murphy, J., Predictions of Climate Change over Europe Using Statistical and Dynamical Downscaling Techniques, *International Journal of Climatology, 20* (2000), 5, pp. 489-501
[12] McGuffie, K., Henderson-Sellers, A., Forty Years of Numerical Climate Modelling, *International Journal of Climatology, 21* (2001), 9, pp. 1067-1109
[13] Palutikof, J. P., *et al.*, The Simulation of Daily Temperature Time Series from GCM Output. Part I: Comparison of Model Data with Observations, *Journal of Climatology, 10* (1997), 10, pp. 2497-2513.
[14] Matzarakis, A., Climate Change and Adaptation at Regional and Local Scale, in: *Tourism and the Implications of Climate Change: Issues and Actions Bridging Tourism Theory and practice* (Eds. J. Jafari, C. A. Liping), Emerald Insight, London, 2010, pp. 237-259
[15] Gavilan, R., *et al.*, Bioclimatic variations in Madrid. A study on local climate change (in Spanish), in: *Vegetation and Climate change* (Ed. F. Gomez Mercado, J. F. Mota Poveda), Servantes publication, University of Almeria, Almeria, Spain, 2001, pp. 243-256
[16] Andjelković, G., Anthropogenic Heat Release in the Atmosphere of Belgrade (in Serbian), *Bulletin of the Serbian Geographical Society, 82* (2002), 2, pp. 56-67
[17] Andjelković, G., *Belgrade Heat Island – Characteristics, Causes, Consequences* (in Serbian), Faculty of geography, Belgrade, 2005
[18] Deniz, A., *et al.*, Spatial Variations of Climate Indices in Turkey, *International Journal of Climatology, 31* (2011), 3, pp. 394-403
[19] Kioutsioukis, I., *et al.*, Statistical Assessment of Changes in Climate Extremes over Greece (1955-2002), *International Journal of Climatology, 30* (2010), 11, pp. 1723-1737
[20] Sanchez-Lonrenzo, A. *et al.*, Spatial and Temporal Trends in Sunshine Duration over Western Europe (1938-2004), *Journal of Climate, 21* (2008), 22, pp. 6089-6098

[21] Chiacchio, M., Wild, M., Influence of NAO and Clouds on Long-Term Seasonal Variations of Surface Solar Radiation in Europe, *Journal of Geophysical Research, 115* (2010), D10, pp.1-10
[22] Matuszko, D., Weglarczyk, S., Relationship between Sunshine Duration and Air Temperature and Conteporary Global Warming, *International Journal of Climatology*, (2014), DOI: 10.1002/joc.4238
[23] Kržić, A., *et al.*, Changes in Climate Indicies for Serbia According to the SRES-A1B and SRES-A2 Scenarios, *Climate Research, 49* (2011), 1, pp. 73-86
[24] Radovanović, M., *et al.*, Global Climate Changes – Antidogmatron, *Geographica Pannonica, 10* (2006), pp. 9-13
[25] Unkašević, M., Tošić, I., Trends in Temperature Indicies over Serbia: Relationship to Large Scale Circulation Patterns, *International Journal of Climatology, 33* (2013), 15, pp. 3152-3161
[26] Laprise, R., Regional Climate Modeling, *Journal of Computational Physics, 227* (2008), 7, pp. 3641-3666
[27] Ducić, V., *et al.*, Atmospheric Circulation and the Precipitation Variability in Serbia for period 1949-2004 (in Serbian), *Bulletin of the Serbian Geographical Society, 90* (2010), 2, pp. 85-96
[28] Lazić, L., *et al.*, Analysis of the Temperature Characteristics and Trends in Novi Sad Area (Vojvodina, Serbia), *Geographica Pannonica, 10* (2006), pp. 14-21
[29] Nikolić, J., *et al.*, Atmospheric Natural Disasters in Serbia – Management Experience and Economic Effects, *Journal of the Geographical Institute "Jovan Cvijić" of the Serbian Academy of Sciences and Arts, 63* (2013), 3, pp. 239-254
[30] Unkašević, M., Tošić, I., Seasonal Analysis of Cold and Heat Waves in Serbia during the Period 1949-2012, *Theoretical and Appled Climatology, 120* (2015), 1-2, pp. 29-40
[31] Unkašević, M., Tošić, I. An Analysis of Heat Waves in Serbia, *Global and Planetary Change, 65* (2009), 1-2, pp. 17-26
[32] Andjelković, G., Climatic Extremes in Serbia: Definitions, Types and Classification (in Serbian), *Bulletin of the Serbian Geographical Society, 90* (2010), 4, pp. 125-146
[33] Pecelj, M., *et al.*, Bioclimatic Index of Heat Input (HL) as a Function of Health Tourism on the Example of Zlatibor and Belgrade (in Serbian), *Proceedings*, International Scientific Conference „Problems and Challenges of Modern Geographical Science and Teaching", Kopaonik, Serbia, 2010, pp. 621-626
[34] Redžić, V., Impact of Global Warming on Tourism Trends in the Tourist Center „Brezovica" (in Serbian), *Ecologica: Science, Economy, Experience, 71* (2013), pp. 559-562
[35] UNWTO, UNEP, WMO (group of authors), *Climate Change and Tourism - Responding to Global Challenges*, United Nations World Tourism Organization, Madrid, 2008
[36] Maddison, D., In Search of Warmer Climates? The Impact of Climate Change of Flows of British Tourists, in: *The Amenity Value of the Global Climate* (Ed. D. Maddison), Earthscan, London, 2001, pp. 53-76
[37] McKercher, B., Lew, A., Tourist Flows and the Spatial Distribution of Tourists, in: *A Companion to Tourism* (Eds. Lew, A. *et al.*), Blackwell Publishing LTD, London, 2004, pp. 36-48
[38] Hamilton, J. M., *et al.*, Effects of Climate Change on International Tourism, *Climate Research, 29* (2005), 3, pp. 245-254
[39] Koenig, U., Abegg, B., Climate Changes and Winter Tourism in the Swiss Alps, *Journal of Sustainable Tourism, 5* (1997), 1, pp. 46-58
[40] Moreno, A., Climate Change and Tourism – Impacts and Vulnerability in Coastal Europe, Ph. D. thesis, Maastricht: Universitaire Pers Maastricht, The Netherlands, 2010
[41] Belen Gomez, M., Weather, Climate and Tourism – a Geographical Perspective, *Annals of Tourism Research, 32* (2005), 3, pp. 571-591
[42] de Freitas, C. R., Tourism Climatology: Evaluating Environmental Information for Decision Making and Business Planning in the Recreation and Tourism Sector, *International Journal of Biometeorology, 48* (2003), 1, pp. 45-54
[43] Gonzalez, R. R., *et al.*, Experimental Evaluation of Standard Effective Temperature – a New Biometeorological Index of Man's Thermal Discomfort, *International Journal of Biometeorology, 18* (1974), 1, pp. 1-15
[44] Scott, D., *et al.*, Climate Change and the Distribution of Climatic Resources for Tourism in North America, *Climate Research, 27* (2004), 2, pp. 105-117
[45] Matzarakis, A., Endler, C., Climate Change and Urban Bioclimate: Adaptation Possibilities, *Proceedings*, The Seventh International Conference on Urban Climate, Yokohama, Japan, 2009
[46] Berritella, M., *et al.*, A General Equilibrium Analysis of Climate Change Impacts on Tourism, Research Unit Sustainability and Global Change Working Paper FNU-49, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany, 2004

[47] Callaway, J. M., *et al.*, *Economic Effects of Climate Changes in Montenegro: First View* (in Serbian), UNDP office in Montenegro, Podgorica, 2010
[48] Scott, D., Lemieux, C., Weather and Climate Information for Tourism, *Procedia Environmental Sciences, 1* (2010), Jan., pp. 146-183
[49] Joksimović, M., *et al.*, Tourism Climatic Index in the Valorisation of Climate in Tourist Centers of Montenegro (in Serbian), *Bulletin of the Serbian Geographical Society*, 93 (2013), 1, pp. 15-34
[50] Mieczkowski, Z., The Tourism Climatic Index: a Method of Evaluating World Climates for Tourism, *The Canadian Geographer, 29* (1985), 3, pp. 220-233
[51] Amelung, B., Viner, D., Mediteranean Tourism: Exploring the Future with the Tourism Climatic Index, *Journal of Sustainable Tourism, 14* (2006), 4, pp. 349-366
[52] Perch-Nielsen, S. L., *et al.*, Future Climate Resources for Tourism in Europe Based on the Daily Tourism Climatic Index, *Climatic Change, 103* (2010), 3-4, pp. 363-381
[53] Aćimović, S., *et al.*, *Master Plan of Zlatibor-Zlatar Tourist Destination* (in Serbian), Faculty of Tourism and Hospitality Managment, Singidunum Univeristy, Belgrade, Serbia, 2007
[54] ***, ECOSIGN (2007), Master Plan Stara Planina (in Serbian), http://jpstaraplanina.rs/index.php/en/master-plan-
[55] ***, Horwath HTL (2009) – Master Plan of Kopaonik Tourist Resort – Final Report of Business Master Plan, Belgrade: Ministry of Economy and Regional Development of the Republic of Serbia, http://www.kopaonik.rs/kopaonik/wp-content/dokumenti/pdf/Horwath-Master-plan-Kopaonik.pdf
[56] ***, USTC (2007) – Master Plan of Tourism Development with Business Plan for Tara Mountain and its Suroundings (in Serbian), Bajina Basta: Ustanova Sportsko-turisticki centar, http://mtt.gov.rs/download/sektor-za-turizam/master-planovi/Tara%20Sazetak.pdf
[57] Mihailović, D. T., *et al.*, Climate Change Effects on Crop Yields in Serbia and Related Shifts of Koppen Climate Zones under the SRES-A1B and SRES-A2, *International Journal of Climatology*, (2014), early view
[58] Davies, N. E., An Optimum Summer Weather Index, *Weather, 23* (1968), 8, pp. 305-317
[59] ***, Republic Hydrometeorological Service of Serbia – RHMZ, http://www.hidmet.gov.rs/
[60] Hamilton, J. M., *et al*., Climate Change and International Tourism: a Simulation Study, Research Unit Sustainability and Global Change Working Paper FNU-31, Hamburg University and Centre for Marine and Climate Research, Hamburg, Germany, 2003

Paper submitted: April 30, 2015
Paper revised: June 11, 2015
Paper accepted: June 15, 2015