CLIMATE CHANGE EFFECTS AND UV-B RADIATION IN THE VOJVODINA REGION (SERBIA) UNDER THE SRES-A2

by

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In this article we considered the extreme temperatures, precipitation and UV-B radiation in Vojvodina region, Serbia. We describe the actual climate conditions for the period 1981-2007 and applied a dynamic downscaling technique using the EBU-POM regional coupled climate model under the SRES-A2 scenario to assess the changes for the period 2021-2100. The results indicate that a warmer and drier climate in the Vojvodina region can be expected at the end of the century. Projection of climate indicates to a strong increase in the mean annual minimum temperatures, and much smaller increase in the mean annual maximum temperatures. The increase of both extreme temperatures is predicted to be the highest in the winter and the lowest in the summer. Mean annual precipitation is projected to increase toward the end of the first half of the 21st century and to decrease for the last 30 years of the 21st century. Precipitation amount will be the highest during the winter and spring. The model simulations show that, by the end of this century, annual mean UV-B dose will recover by 5.2%. Recovery will be faster in the first half of the 21st century and more slowly later on. The UV-B doses recovery is expected to be the highest during the autumn and spring.

Key words: *climate change, temperature, precipitation, UV radiation, Vojvodina region, Serbia*

Introduction

The anthropogenic climate change and the stratospheric ozone depletion affect ecosystems in various ways. Direct effects of the global climate change upon the human health are seen in increasing of the rates of death and morbidity, especially thermal-related diseases. Indirect impact of variations in the temperature and moisture on human health is reflected through

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the impact on agro-ecosystems, particularly on the cereal crop production [1]. Human exposure to the solar ultraviolet radiation has important public health implications. If a long-term increase of UV-B radiation due to stratospheric ozone depletion occurs, the incidence of various diseases of the skin, eyes and immune system will increase. Moreover, the increase of the UV radiation will cause adverse effects on the plant growth, photosynthesis and aquatic ecosystems [2].

Solar UV radiation, climate and other drivers of global change are undergoing significant changes and models forecast that these changes will continue for the remainder of this century [3]. The modifications in the climate are visible in different climate elements and indicators, but primarily in the air temperature and precipitation. The analyses of observed temperature in many different regions of the world have revealed that the average temperature increase of 0.13 °C per decade between 1956 and 2005 was approximately doubled in comparison to the previous 100 years from 1906 to 2005 [4]. A rise in the mean would not necessarily lead to a rise in the extreme temperature. Thus, recent studies are focused on changes in the extreme events which are particularly important evidence of climate change. Most studies indicated to a strong increase in the mean annual minimum temperatures, while the increase in the mean annual maximum temperatures was much smaller [5-8, *etc.*]. Beside the temperature extremes, it is also reported that the surface precipitation has had an upward trend in the mid to high latitudes. An increase of 10-50% has been observed during the last century over northern and western Europe [9]. However, in the Mediterranean region, the drying trends have been reported [10, 11], especially in the eastern Mediterranean [12]. According to Intergovernmental Panel on Climate Change [4] the basic projection is that the global surface air temperature and average annual precipitation are going to increase through the end of the century in all scenarios, although changes in the amount and intensity of precipitation will vary by the region.

Due to the short time-series measurements and dependence of UV radiation on various factors, it is difficult to determine global trends in surface UV radiation from the existing measurements. Measurements from some stations indicate that UV irradiance levels have been decreasing since the late 1990s, according to the observed ozone increases, although the recovery is not yet statistically significant because of the natural variability [13]. However, at some stations in the northern hemisphere UV irradiance still has a trend of an increase, as a consequence of the long-term changes in other factors that also affect the UV radiation, mainly the cloud cover, total ozone amount and aerosols [14]. The simulations of global climate models show that, by the end of this century it is expected the UV-B irradiances to recover with the levels at or below those measured prior to the onset of ozone depletion, by around 5-15% in the mid-latitudes [3]. However, these projections must be treated with caution because the changes in UV radiation in the 21st century will depend on changes in the ozone depletion induced by CFC and also on the evolution of clouds and other tropospheric factors (such as aerosols, surface albedo, and air pollution) all of which are influenced by the climate change, and their future is uncertain [15, 16].

In this study, we analyzed the observed trends of the extreme temperatures, precipitation and UV-B radiation during the past 27 years in Vojvodina region, Serbia. We also presented the projected future changes for the 2021-2100 period. The projections are based on the simulations performed using the EBU-POM regional climate model [17, 18] under the pessimistic SRES-A2 scenario defined by International Panel for Climate Change (IPCC Special Report on Emission Scenarios – SRES). In addition we attempt to estimate the UV-B radiation indices in the Vojvodina region (Northern Serbia). The purpose of this study is to: (1) raise awareness of the consequences of the climate change in this region, (2) contribute to the risk assessment, and (3) encourage the development of mitigation and adaptation strategies.

Materials and methods

Study area

The Vojvodina region is situated in the northern part of Serbia. This part of Serbia is highly important for the food production in Serbia, with a total surface area of 21,500 km^2 (fig. 1) and about population of 2 million people. The region is located in the southern part of the Pannonian plain (44°37'-46°11' N, 18°51'-21°33' E, and 75-641 m above sea level) and divided by Danube and Tisa rivers into: Backa in the northwest, Banat in the east and Srem in the southwest. The lowland is surrounded by the mountains, which have a significant impact on its climate characteristics. Vojvodina has a continental climate, with the elements of a sub-humid and thermal climate. The mean annual temperature is 11 °C, and the mean annual precipitation is 602 mm [19]. There are no really pronounced temperature differences between areas in Vojvodina due to the short distance between the northern and southern areas and the fact that this area is remarkably uniform in terms of geography [20]. Exposure to the air masses coming from the north and west, together with the big range of temperatures throughout the year, means that the continental characteristics of Vojvodina's climate are more pronounced, particularly in the summer and winter [21].

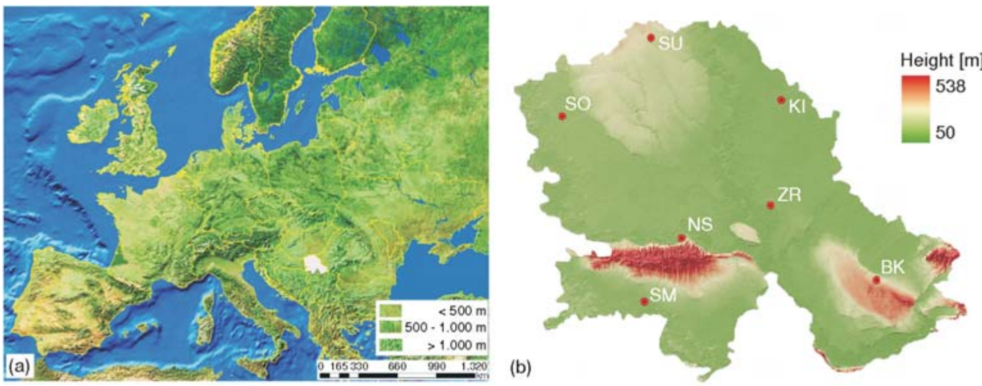

Figure 1. (a) Vojvodina region, Serbia in Europe and (b) the 7 sites used in the study: SO: Sombor, SU: Subotica, NS: Novi Sad, KI: Kikinda, ZR: Zrenjanin, BK: Banatski Karlovac, and SM: Sremska Mitrovica [22]

Data sources and methodology

The climatological data which are used to describe the actual climate conditions in the Vojvodina region are: the maximum and minimum temperatures and precipitation. The mean values of climatic data are calculated for the reference period 1981-2007 (in further text RP81-07) for: the spring March-May (Mar-May), the summer June-August (Jun-Aug), the autumn September-November (Sep-Nov) and the winter December-February (Dec-Feb). The data are provided by the Republic Hydrometeorological Institute of Serbia (RHMSS) for seven stations: Novi Sad, Subotica, Sombor, Kikinda, Zrenjanin, Banatski Karlovac and Sremska Mitrovica (fig. 1). During the observational period the locations of the stations were not changed. The measurements were performed every day using the same type of instruments. Technical and critical control of these measurements was made by the RHMSS.

The measured UV radiation data were used from the measurement made by broadband Yankee UVB-1 biometer at the campus of the University of Novi Sad (45.33° N, 19.85° E, 84 m above sea level). Due to the lack of measurement sites for UV-B radiation and the UV index (UVI) in the Vojvodina region, for the purpose of this study, beside measured values, we have included values calculated by the empirical formula based on linear correlation between the daily dose of the UV-B (UVB_d) and the daily dose of the global solar radiation (G_d) [22]. The empirical formula, which is derived on the basis of the relationship between the daily values of UVB_d (measured UVI data and the corresponding calibration factors) and G_d (calculated via an empirical formula) for the period April 2003 to December 2009 in Novi Sad, has the form:

$$UVB_b = 0.002507 G_d - 5.985 \quad (1)$$

This formula was used for estimating the daily UV-B doses for the selected places in the period 1981-2002, to fill data gaps between the year 2003 and 2007, as well as to estimate UV-B doses for the period 2021-2100. Taking into account the uncertainties in the determination of the instrumental calibration constant, the error of conversion to erythemal weighted UV irradiance and the error of quantization, the estimated maximal error of the measurements is less than 9% [23]. The performance of the empirical eq. (1) was evaluated by comparing the standard deviations and the Pearson coefficient of correlation between calculated and measured values. A very strong Pearson correlation (0.96) and a small difference between standard deviations (3.7%) indicate the reliability of this formula [24].

Data on expected climate conditions were obtained by applying a dynamic downscaling technique using the EBU-POM model and pessimistic SRES-A2 scenario for the greenhouse gas emissions. We chose the SRES-A2 emissions scenario since it was one of the 'marker' scenarios developed through the IPCC. The SRES-A2 scenario assumes heterogeneous world, with regional differences in development, high population growth, slower and more fragmented economic growth, a moderate increase in non-fossil energy sources and largely negative environmental implications. This is the only scenario in which forest cover continues to decline through 2100, and the associated CO_2 emissions from this change continue to grow (with approximately 2.2 times higher value of CO_2 concentration at the end of 21st century compared to presently observed 385 ppm). The SRES-A2 scenario is at the higher end of the SRES emissions scenarios (but not the highest), and this was preferred because, from an impacts and adaptation point of view, if one can adapt to a larger climate change, then the smaller climate changes of the lower end scenarios can also be adapted to. EBU-POM is an atmosphere-ocean regional coupled climate model [17, 18], and for this simulation horizontal resolution for the atmospheric part was 0.25° and for ocean horizontal resolution was 0.2°. Regional model simulations cover the period 1961-2100 with the initial and lateral boundary conditions taken from the ECHAM5/MPI-OM model [25]. For surface air temperature and daily precipitation model bias was removed using observed daily time series of the same variables over normal climate period 1961-1990 following so-called bias correction, statistical method [26]. We analyzed relative change of the model outputs for 2021-2050 and 2071-2100 periods (in further text P21-50 and P71-100, respectively) compared to the changes of meteorological parameters period RP81-07.

The slopes of the linear trends of the climatological data were computed using the least squares method. To obtain the change per decade (decadal trends) the slope was multiplied by ten. For the determination of significance level (p) of each trend we used the Mann-Kendall test [27].

Results and discussion

Comparison of the actual climate with the climate projection

During the period RP81-07, the atmospheric warming has accelerated in the Vojvodina region. The mean annual temperature was 11.3 °C, whereas the mean annual precipitation was 590 mm. Records indicate significant increase of the mean annual maximum and minimum air temperature at rates of 0.46 °C ($p = 0.022$) and 0.42 °C ($p = 0.039$) per decade, respectively. From figs. 2 (a) and 2 (b), it can be observed that the rise in the maximum temperatures was the highest in the south and west parts of Vojvodina region (SO, SM, and BK), while the rise in the minimum temperatures was the highest in the east (KI, BK, and ZR). The increase of both extreme temperatures was highest during the winter. The mean precipitation amount observed in the RP81-07 period show tendency of growth (45.42 mm per decade, $p = 0.01$) and increase of variability in all parts of the Vojvodina region. The fig. 2 (c) shows that the highest positive trend in annual precipitation was in NS (64.24 mm per decade, $p = 0.06$). Although the total annual precipitation increased, the seasonal records indicate positive and negative trends. During the summer, autumn and winter precipitation amount grew. In the spring, the northern part of the region points out on a decrease, while southern part of the region has increase of the precipitation.

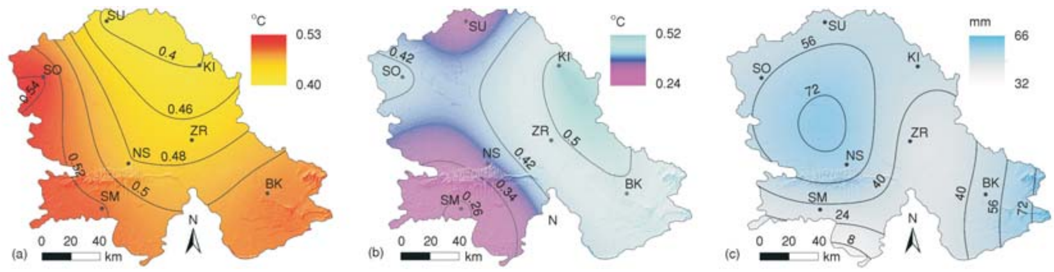

Figure 2. Decadal trends in (a) the maximum temperature [°C], (b) the minimum temperature [°C], and (c) the precipitation [mm] in the Vojvodina region for the period 1981-2007

According to the projections of regional climate models, significant climate change is expected in Vojvodina region in the near future. The comparison of the P21-50 and P71-100 model outputs against the observations for the RP81-07 period (fig. 3) indicate that, at the end of the century, a warmer and drier climate in the Vojvodina region can be expected. Figure 3 shows a strong increase in the mean annual minimum temperatures (5.4-10.4% higher in P21-50 and 51.3-58.1% higher in P71-100), and much smaller increase in the mean annual maximum temperatures (1.6- 2.9% higher in P21-50 and 23.0- 25.8% higher in P71-100) relative to the reference period. The increase of both extreme temperatures is predicted to be the highest in the winter and the lowest in the summer. The change in the precipitation is more complex. In the P21-50 period, the expected change in the amount of precipitation for Vojvodina region is positive (1.5-13.4%), while for the last 30 years of the 21st century, P71-100, the whole region is drier (with a decrease in the precipitation of 0.1-12.0%). The precipitation amount will be higher during the winter and spring, and lower during the autumn in both projected periods. The summer precipitation change in P21-50 is slightly positive (0.8%) and highly negative in P71-100 (24.0%).

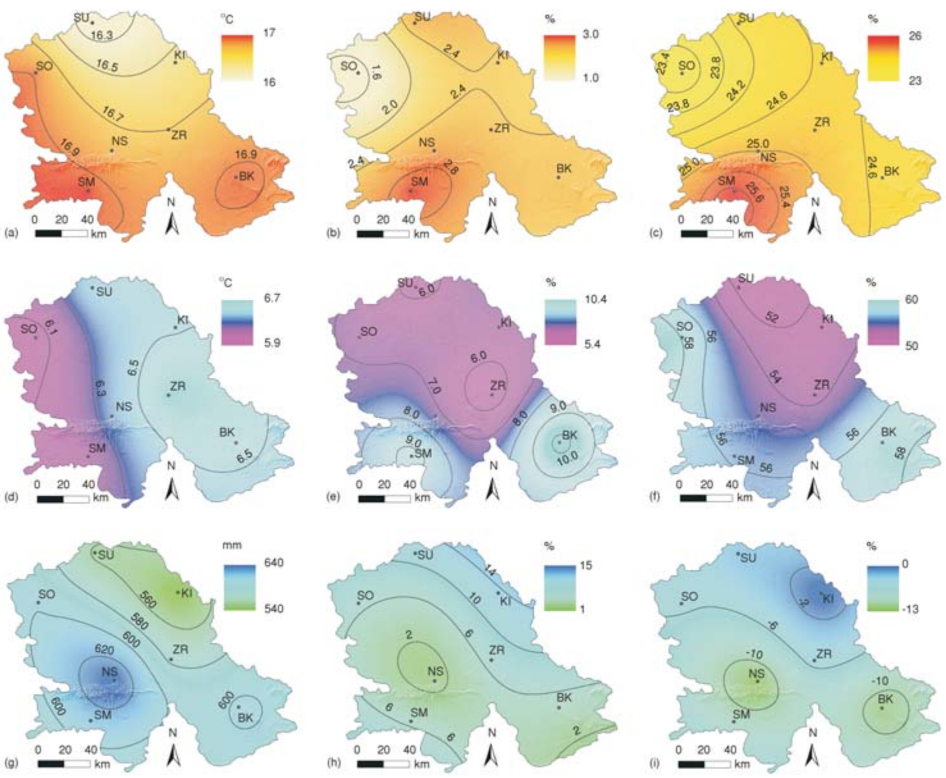

Figure 3. Spatial distribution of the multi-annual mean (for the RP81-07 period) of (a) the maximum annual temperatures, (d) the minimum annual temperatures, and (g) the annual sum of precipitations in the Vojvodina region and their relative changes [%] in P21-50 and P71-100 period (middle and right-hand panels)

Comparison of the actual UV-B radiation dose with the climate projection

The annual averages of the daily UV-B dose in Vojvodina region during the RP81-07 period raised at rate of 0.89 kJ/m^2 ($p = 0.003$). The highest trends of annual daily UV-B doses are in ZR (1.12 kJ/m^2, $p = 0.001$) and SO (1.11 kJ/m^2, $p = 0.001$). Since the UV-B doses reaching the ground in the Vojvodina region are the largest during the spring and summer, we focused our further analyses on those two seasons. Averages of daily spring ($UVB_{\mathrm{d,sp}}$) and summer ($\mathrm{UVB}_{\mathrm{d,sm}}$) UV-B dose and the spring ($O_{3,\mathrm{sp}}$) and summer ($O_{3,\mathrm{sm}}$) total ozone for the period 1981-2007 are shown in fig. 4. This figure shows statistically significant increasing trend in the daily UV-B dose in both seasons (1.82 kJ/m^2 per decade, $p = 0.010$ in the spring and 1.51 kJ/m^2 per decade, $p = 0.010$ in the summer). The ozone trend in the Vojvodina region declines approximately 5.30 DU per decade in both season. However, we found that this trend in spring season is not statistically significant.

The model simulations show that the annual mean UV-B dose will recover by 5.2%, in Vojvodina region by the end of this century. The annual mean UV-B dose was projected to decrease at somewhat higher rates in the first half of the 21st century and more slowly later on. The UV-B doses recovery is expected to be the highest during the autumn and spring. The compari-

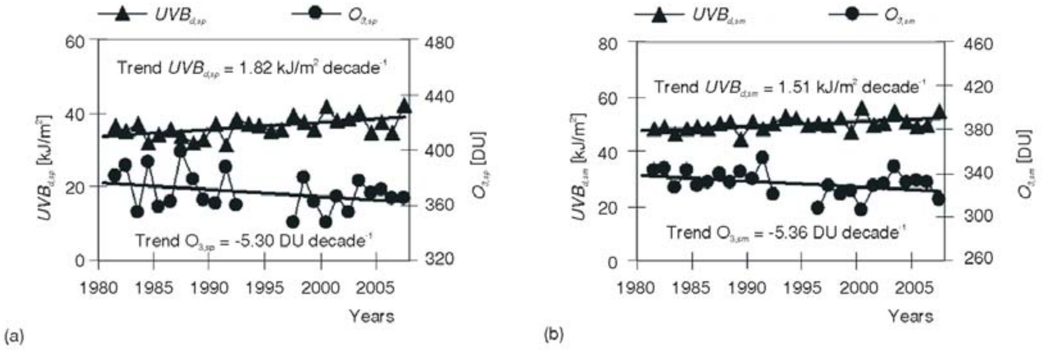

Figure 4. Decadal trends of the daily UV-B dose and total ozone trends for (a) spring and (b) summer season in the Vojvodina region for the period 1981-2007

son of the spring UV-B doses for the P21-50 and P71-100 periods against the observations for the RP81-07 period (figs. 5 (a) and 5 (b)) indicates slight higher recovery for the P21-50 period and the highest recovery in the northeast part of the region. When it comes to the summer UV-B doses (figs. 5 (c) and 5 (d)), two different regimes can be detected: negative changes occur during the P21-50 period, and positive changes occur during the P71-100 period (except in KI, where recovery in previous period was the largest).

It must be noted that the results should be treated with caution due to the fact that the empirical eq. (1) illustrates the present relationship between the global and UVB radiation. What will that relationship be during the 21st century depends primarily on change in cloud cover (in our equation is shown through the global radiation) and ozone amount (not taken into account which is a limitation of this formula). However, in spite of this limitation, the obtained recovery of the annual mean UV-B dose is consistent with those specified in [3].

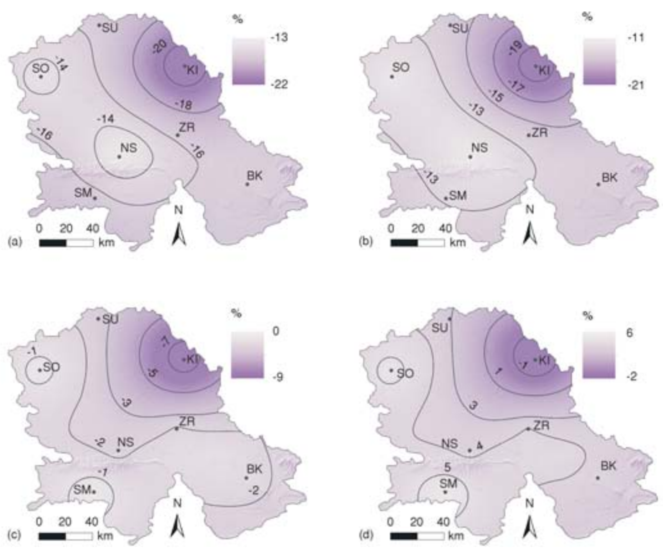

Figure 5. Relative changes [%] in the multi-annual mean of the UV-B dose for the P21-50 (left-hand panels) and P71-100 (right-hand panels) period compared to the multi-annual mean of the UV-B dose for the RP81-07 period for spring season – top panels, (a) and (b), and summer season – bottom panels, (c) and (d)

Conclusions

In this study, we considered the climate change effects in Vojvodina region, Serbia under the SRES-A2 scenario. To do that we analyzed the extreme temperatures, precipitation and UV-B radiation in Vojvodina region, Serbia, in order to offer evidence for assessing the climate change consequences and contribute to the risk assessment. We analyzed the changes in the maximum and minimum temperatures, the precipitation and UV-B dose observed during the period 1981-2007, while the assessment of the changes for 2021-2100 period is done using the results of downscaling with the ECHAM5 and regional EBU-POM model.

The results obtained for the period 1981-2007 suggest that the trends in the extreme temperatures are consistent with the global observations. The mean annual maximum and minimum air temperature records indicate significantly positive trend, and the highest rise in the winter. The annual precipitation amount is also increased. However, the seasonal records indicate both positive and negative trends. According to the results based on the dynamic downscaling of the EBU-POM coupled regional climate model, the extreme temperatures in Vojvodina region will increase. The records indicate a strong increase in the mean annual minimum temperatures, and much smaller increase in the mean annual maximum temperatures. The mean annual precipitation is projected to increase to the end of the first half of the 21st century and to decrease for the last 30 years of the 21st century. The precipitation amount will be higher during the winter and spring. The annual averages of the daily UV-B dose in Vojvodina region during the period 1981-2007 raised. The model simulations show that, by the end of this century, the annual mean UV-B dose will recover by 5.2%, faster in the first half of the 21st century and more slowly later on. The UV-B doses recovery is expected to be the highest during the autumn and spring.

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Nomenclature

G_d – daily dose of the global solar radiation, [kJm^{-2}]
$O_{3,\,sm}$ – summer total ozone, [DU]
$O_{3,\,sp}$ – spring total ozone, [DU]
p – trend significance level
UVB_d – daily dose of the UV-B radiation, [kJm^{-2}]
$UVD_{d,\,sm}$ – daily summer UV-B dose, [kJm^{-2}]
$UVD_{d,\,sp}$ – daily spring UV-B dose, [kJm^{-2}]

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