Assessment of climate change impacts on Serbian viticulture based on regional climate model predictions

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Abstract
The possible effects of climate change on viticulture in Serbia were assessed using regional climate simulations for two periods: 1961–1990, a standard reference period for the present climate, and 2071–2100 under the SRES A2 scenario. After a statistical bias correction was applied to the daily temperature and precipitation data from regional climate model outputs, several climatic variables and climate-viticulture suitability indices were calculated. It was found that projected changes may have numerous potential impacts on Serbian viticulture by the end of the century. Warmer and prolonged growing season with greater heat accumulation and longer frost-free period with decline in frost frequency likely will affect grape ripening and composition, alter wine styles and induce shifts in varietal suitability in the traditional wine regions. Also, an expansion of areas suitable for viticulture is expected in the future. Increases in the length and warmth of the growing season and reduced risk of frost and freeze damage will likely improve the viticulture potential in marginal and elevated areas, which might become climatically suited to the production of good quality wines.

Key words: regional climate model prediction, grapevine, Serbia

Introduction

In the last twenty years, the state of the viticulture in Serbia has been deteriorated, due to unfavorable economic and political situation in the country. An additional challenge for wine production in Serbia is imposed by climate change and this study is aimed to offer better insight into possible implications of future climate change for Serbian viticulture at the end of 21st century.

Climate is one of the most important factors controlling grape and wine production from selection of a suitable grapevine (*Vitis vinifera* L.) varieties to the type and quality of wines produced (Gladstones, 1992). There are a number of papers addressing the potential effects of climate change on European viticulture (e.g. Neumann and Matzarakis, 2011; Malheiro et al., 2010), but little research has been focused on the part of Europe where Serbia is situated. An increase of precipitation in high latitudes and a decrease in the Mediterranean area are predicted for a future warmer climate in Europe (IPCC, 2007). A location of boundary between these zones with different precipitation trends differs in climate projections, depending on the model and/or emission scenario applied. Serbia is located right in that part of Europe, where the transition zone in precipitation trend is expected to be positioned. Thus, it is necessary to use a RCM capable to physically resolve processes that occur at scales smaller than those of GCM. Also, since the Balkans are under the significant influence of the Mediterranean and Adriatic Seas, it is desirable to use a RCM coupled with ocean model in climate simulations in this area. The Coupled Regional

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Climate Model (CRCM) EBU–POM (Eta Belgrade University–Princeton Ocean Model) that may generate useful climate forecasts for this part of Europe (Djurdjevic and Rajkovic, 2008, Gualdi et al., 2008), was used in this study.

It should be emphasized that the assessment of the possible impact of climate change on viticulture in Serbia was based only on climatic parameters. The other influencing factors (e.g. soil characteristics and topography) were not considered, as well as the direct effects of increased concentration of atmospheric carbon dioxide.

Materials and methods

An atmospheric component of CRCM used in the study is the limited area model Eta/NCEP (Janjić, 1994; Mesinger et al., 1988). The model was developed at University of Belgrade and later improved and run operationally at NCEP. An oceanic component is the Princeton ocean model (POM), a three-dimensional, primitive equation numerical model, developed by Blumberg and Mellor (1987). Detailed information of this combined modeling system and its performance can be found in Djurdjevic and Rajkovic (2008) and Gualdi et al. (2008). The integration domain of CRMC, used in climate simulations for this study, covers Euro-Mediterranean region spanning 4.9°W to 34.9°E and 28.5 to 44.5°N with a center at 15°E and 41.5°N. Atmospheric processes were simulated at a horizontal resolution of 0.25° (corresponding approximately to 30 km), with 32 vertical levels. The oceanic part had a resolution of 0.2° in horizontal direction. The CRCM was forced by the Atmosphere Ocean Global Circulation Model SX-G (Gualdi et al., 2008).

The assessment of the possible effects of climate change on viticulture in Serbia is based on an analysis of two EBU-POM model runs. The first, historical simulation covered 1961–1990, a standard reference period for the present climate (experiment 20c3m). The future simulation was done for the period 2071–2100 following the SRES A2 scenario, which is at the higher end of the SRES emissions scenarios (Nakicenovic et al., 2000). Given that the emissions growth rate since 2000 was greater than for the most fossil-fuel intensive of the IPCC emissions scenarios (Raupach et al., 2007), A2 was seen as the most realistic choice for far future scenario.

Method for correction of model bias, applied in the study, is based on the assumption that both observed and simulated data are well approximated by the same probability distribution function and that the relationships between them do not vary under climate change conditions. Bias correction functions for a given location were derived from observed and simulated daily precipitation and temperature (mean, maximum and minimum) data for the reference period 1961–1990 and then applied to present and future simulations. This approach, in literature is referred to as "quantile mapping", "histogram equalization" or "statistical bias correction" (Dettinger et al., 2004; Piani et al., 2010).

To evaluate climate change impacts on viticulture and shifts in viticultural suitable areas, we used following climatic variables and indices: growing season (1 April to 31 October) average, maximum and minimum temperature, growing degree-days (sum of daily mean temperatures exceeding the threshold of 10°C), growing season precipitation, the number of dry days (days with precipitation less than 1 mm), length of the growing season (the number of days between the starting and ending date, defined as the date of the fifth day of the first/last sequence of 5 consecutive days having daily mean temperature above the threshold of 10°C), length of the frost-free period (the number of days between a last frost in the spring and first frost in the fall), the number of days with frost, the number of days with temperatures below -

15°C, the number of days with minimum daily temperatures above 20°C, the number of days with maximum daily temperatures above 35°C.

Precipitation and temperature observations for all available climatological stations located in the traditional viticultural regions with complete data for the period 1961–1990 are used in the study (Fig. 1). In order to find out if there is a potential of expansion of vine growing in Serbia by the end of the century, few stations situated in marginal or elevated areas were taken under consideration (Fig. 1). Data were provided by the Republic Hydrometeorological Service of Serbia.

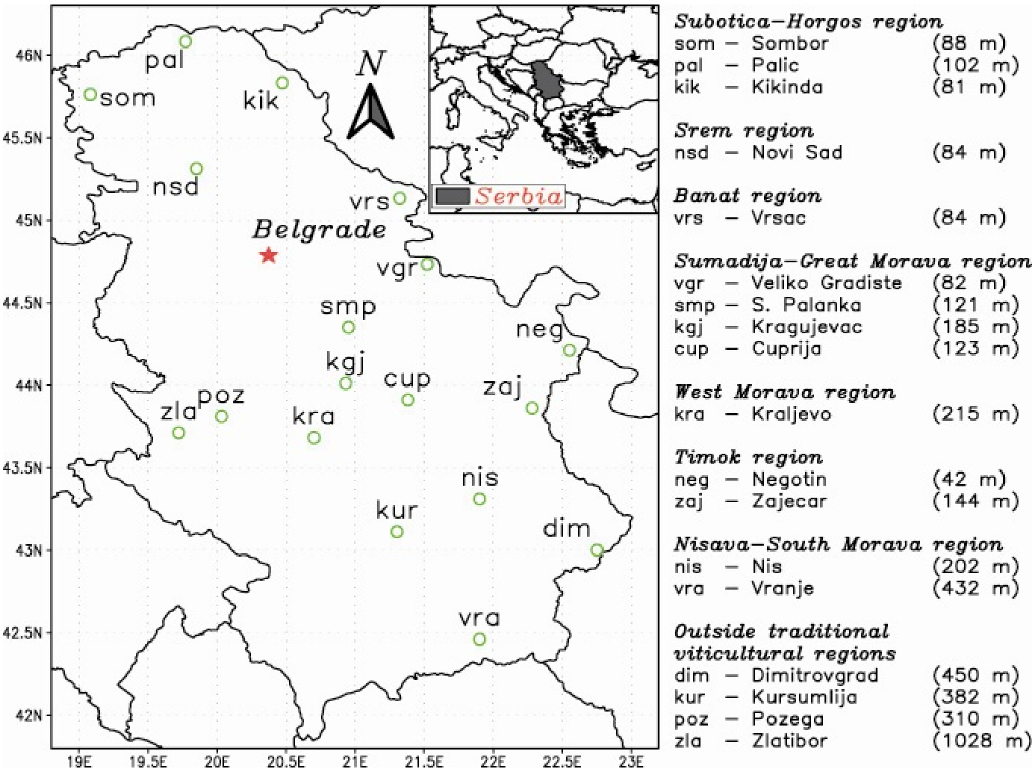

Fig. 1 Position of climatological stations and list of the main viticultural regions of Serbia with associated stations and their elevation

Results and discussion

Growing season temperatures and length have a major influence on ripening and quality of grapes. According to projected climate change, the growing season will become warmer and longer (Fig. 2a and 3a).

Average growing season temperature is projected to warm on average 4.4°C. Maximum growing season temperature is predicted to change more (on average 5.0°C) than minimum growing season temperature (on average 3.9°C). Projected changes of average growing season temperature suggest that Serbian vineyard regions will move from a warm to a very hot grouping by the year 2100 (according to climate scale of Jones, 2006), meaning that by the end of the century the traditional vineyard regions in Serbia might reach the upper limit of quality wine production. Marginal stations (Pozega, Dimitrovgrad, Kursumlija) will move from an intermediate to a hot grouping, while mountainous station Zlatibor will make transition from a too cool to a warm category by the end of the century. Significant increase in growing degree-days (on average 930 heat units) is expected (Fig. 2a).

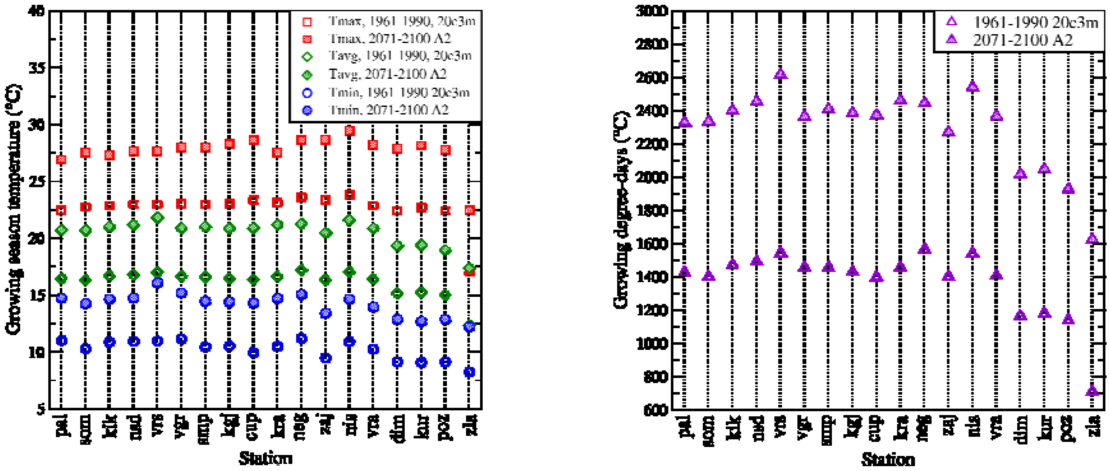

Fig 2. (a) Growing season average (Tavg), maximum (Tmax) and minimum (Tmin) daily temperature and (b) growing degree-days for the reference period 1961–1990 (experiment 20c3m) and the future period 2071–2100 under the SRES A2 scenario

Projected change of precipitation indicates that the climate may get drier by the end of the century (Fig. 3a) with an increase in the number of dry days (Fig. 3b).

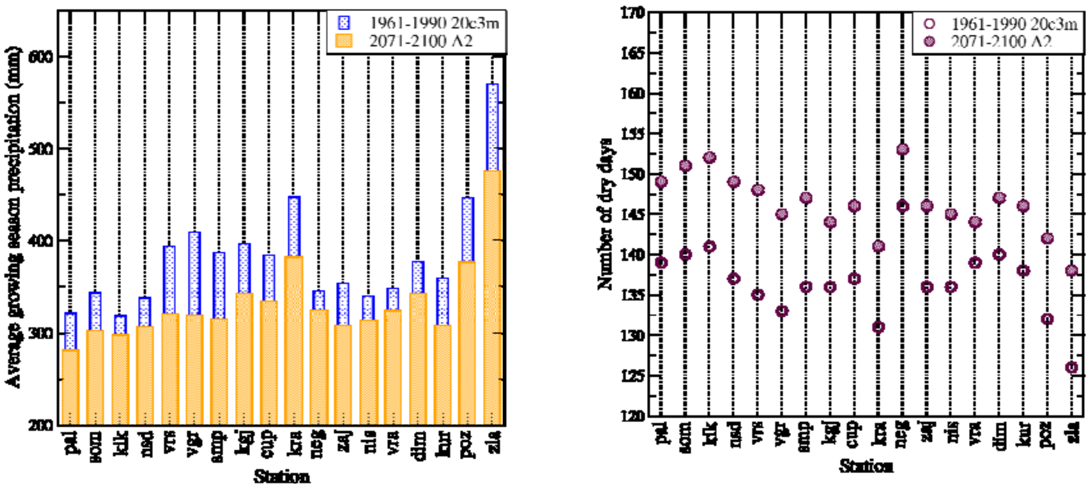

Fig. 3 Same as Fig. 2 but for (a) growing season precipitation and (b) number of dry days

The growing season is projected to lengthen by up to 50 days by the end of the century (Fig. 4a). Grape is expected to enter into the final phase of ripening one to two months earlier and under increasingly warmer conditions in the traditional vineyards regions of Serbia by the year 2100. That may affect grape ripening and composition, alter wine styles and induce shifts in varietal suitability. Increases in the length and warmth of the growing season will likely improve the viticulture potential in marginal and elevated areas. Frost-free period is expected to lengthen by 45 days on average in the traditional viticultural regions. (Fig. 4b). Elevated region of Zlatibor and Pozega region, currently having relatively short frost-free period, by the end of the century likely will attain an average length of the frost-free period for traditional vineyard regions.

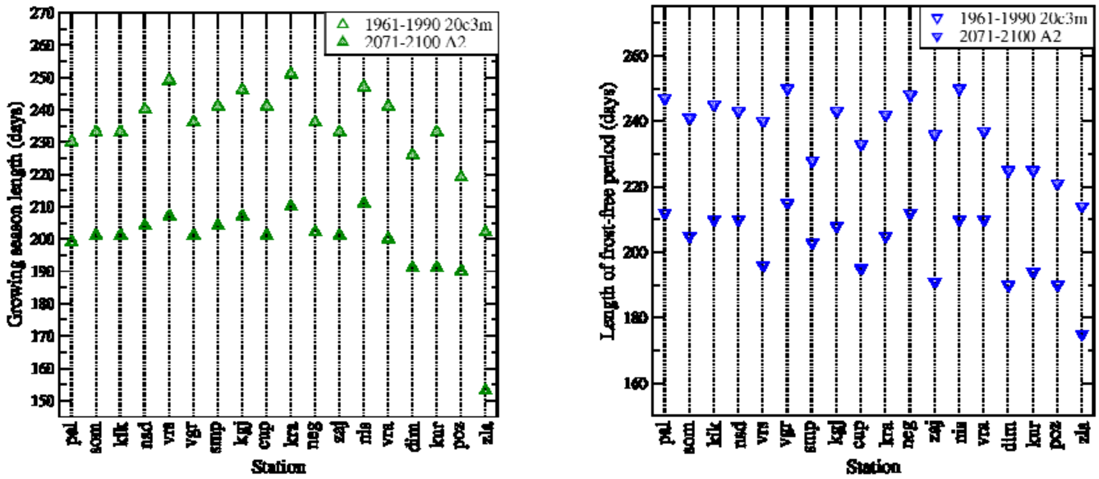

Fig.4 Same as Fig. 2 but for (a) growing season length and (b) length of frost-free period

Frost occurrence may present a restrictive factor for vine cultivation. Late spring frosts may damage young shoots, while early autumn frosts may injure maturing canes and ripening fruit. Extreme low temperatures in the winter may cause freezing injuries to vines. The minimum winter temperature that vine may withstand varies from –5 to –20°C (Winkler et al., 1974). Less frost days are predicted across the entire Serbian territory. Expected reduction of frost frequency at the end of the century is around 45 days (Fig 5a). By the end of the century, practically there will be no risk of winter damage to grapevines due to extreme low temperatures (Fig. 5b). Predicted reduction in frost frequency with longer frost-free period could lead to increased yields and quality of grapes and permit presently unachievable warmer climate grape varieties to be grown. Locations, currently unsuitable for vine growing because of frost and freeze risk, likely will not cope with that problem by the end of 21st century.

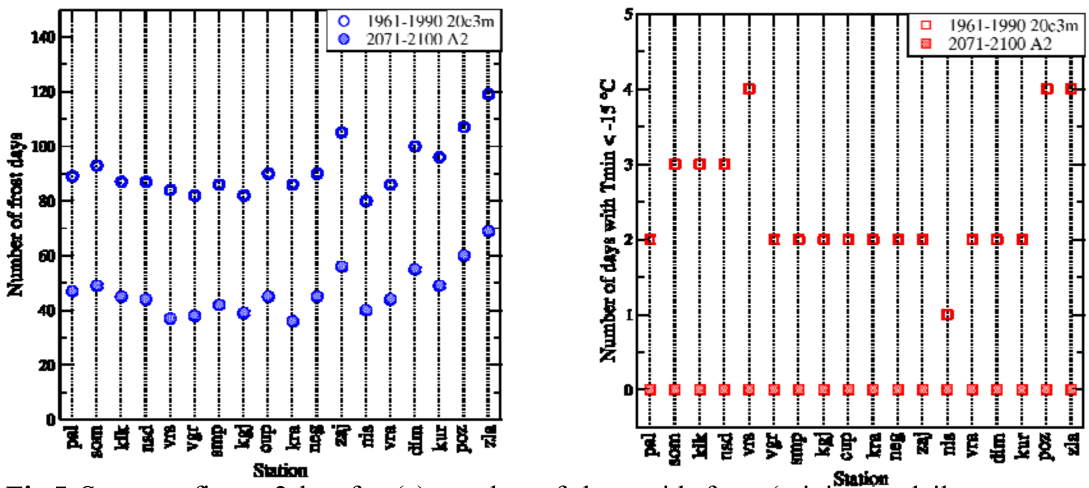

Fig.5 Same as figure 2 but for (a) number of days with frost (minimum daily temperature below 0°C) and (b) number of days with minimum daily temperature below –15°C

Higher temperatures may at first improve the early and mid-season ripening, but rise in minimum daily temperatures as grapes approach maturity (Fig. 6a), may affect the formation and ratio of compounds that give the color, aroma and flavor characteristics to grapes and wine (Kliewer, 1973; Kliewer and Torres, 1972).

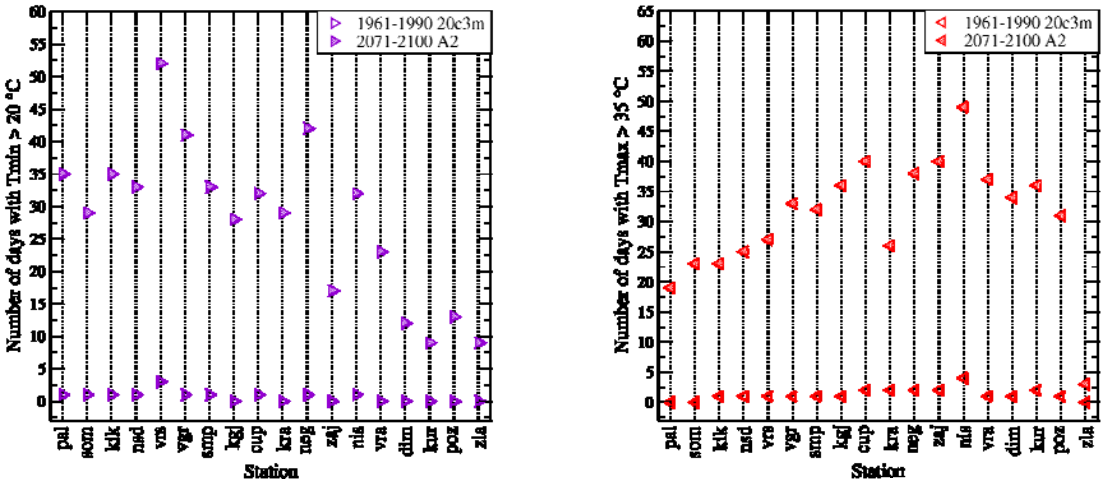

Fig.6 Same as figure 2 but for (a) number of days with minimum daily temperature > 20°C and (b) number of days with maximum daily temperature > 35°C

Summer temperatures are considered to be extreme when maximum daily temperatures exceed 35°C. The number of such days is predicted to increase considerably (Fig. 6b). These so-called “negative” temperatures for vine may cause partial or total inhibition of plant function, especially when associated with drought.

Conclusion

The results from this study present the first step in the planning of future vineyard development in Serbia. For creating the concrete adaptation and mitigation strategies for upcoming climatic conditions, further research has to be done taking into consideration: the climate projections uncertainties, the direct effect of increased atmospheric concentration of carbon dioxide, the influence of soil, topography and other environmental conditions, climate change impact on pests and diseases and possible physiological adaptation of vine to expected climate change.

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