# Fine Scale Climate Change Analysis: from Global Models to Local Impact Studies in Serbia

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**Abstract.** Climate change studies involve changes in climate system of global long-term scales with effects on regional and local climates, down to short-range time scales, like weather hazards and extremes. Climate studies significantly contribute to the future strategic planning in economic development and thereby must produce results with high level of confidence. Global climate models simulations of the past and future climate are initial step in climate change research, but their coarse resolution data are unable to provide useful information for analysis on national levels. In this paper is presented workflow algorithm of the procedures necessary to convert coarse global climate system projected changes to fine scale data with included effect of small scale features and reduced model bias impact.

**Keywords:** climate change, climate model, bias correction

## 1 Introduction

Global climate models (GCMs) are designed to resolve large scale physical processes of the atmosphere-ocean-land system on coarse-grid resolution, and obtained data are insufficient for regional or local impact assessments. Downscaling of the GCM data can be statistical or dynamical. Statistical downscaling considers creation of statistical relations between simulated and observed data, and their application on the future climate projections. Dynamical downscaling of GCM data is much more complex and involves climate simulations with the nested regional climate model (RCM) with finer resolution. The second approach is much more expensive in computing time but enables smaller scale features of the climate system to react on global scales climate changes, which makes this method more reliable for the use in climate change studies. Model bias, i.e. systematic model error, is reduced applying downscaling on higher resolutions, but still remains with considerate effect on results quality. Usual approach in presenting model data, to avoid impact of model bias, is "delta" approach (difference of climate values obtained from the model future climate and past climate simulations). For impact studies this approach is


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insufficient, and it usually requires use of daily model data as input for other models (crop models, hydrology models, etc.) or for calculation of different indices, which are not linearly dependent on model output data. In this case bias correction of daily model data must be applied. Model bias is a consequence of different parameterizations used in model and imperfect input data. It changes in time and space and is different for each model.

Coarse RCM simulations using SRES/IPCC scenarios A1B and A2 (Nakicenovic eta al., 2000, IPCC, 2007) with statistical bias correction using EOBS gridded data are applied so far in impact studies in Serbia, and documented in Initial and Second National Communication of Republic of Serbia (Djurdjevic et al., 2011, Rajkovic et al., 2014, and references within).

In this paper is presented downscaling of the global model CMCC simulation for the period 1971-2100 to fine scale using nested model NMMB for the South East Europe region, performed under the ORIENGATE project (Djurdjevic and Krzic, 2013a). Future climate simulation is done according to extreme RCP8.5 scenario (IPCC, 2013). Period of simulation 1971-2000 is used for model bias correction of daily temperature data. Interpolation of daily temperature data is done for the territory of Serbia using all available observations from national network, and near boundary available data from border countries. Observations are interpolated on model grid. The same dataset of observations and interpolation method is used for climate analysis in project related to the renewal of viticulture zoning (Ivanisevic et al., 2015). Using model and observed data, for each month and for each grid point are created correction functions, which are applied on the past and future climate simulation results. After applying bias correction we can assume that model bias is reduced to minimum. Use of corrected model data is shown with short analysis of annual and seasonal temperature change and change of several climate indices related to temperature extremes.

## 2 Model Simulation

Regional climate model simulation is done for the period 1971-2100, using RCP8.5 scenario (IPCC, 2013). Global climate model CMCC-CM (Scoccimarro et al., 2011) simulations are used as boundary conditions. GCM resolution is 0.75°. Dynamical downscaling with NMMB model (Djurdjevic et al., 2013b) is done to the 0.06° resolution, for the SEE region presented in Fig. 1. High-resolution model simulation can resolve fine scale features and increase quality of the summer convective precipitation, which is related to the non-hydrostatic mode of simulation.

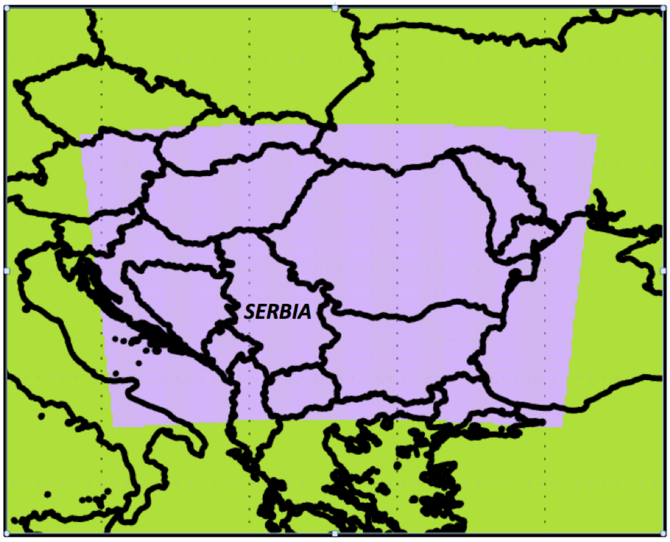


**Fig. 1.** NMMB domain of simulation for the period 1971-2100 using RCP8.5 scenario (purple)

Comparison of the GCM and RCMs resolutions is presented in Fig. 2, together with original 0.004° DEM topography dataset. RCM 0.25° resolution is used for regional coupled atmospheric-ocean EBU-POM model simulations using SRES A1B and A2 IPCC scenarios, which is so far used for regional and national climate studies and documents Initial and Second National Communication for Serbia (Djurdjevic et al., 2011, Rajkovic et al., 2014). Fig. 2 evidently shows deficit of GCM resolution and large improvement in increasing RCM resolution, having in mind complexity of Serbian terrain. High resolution approach enables climate change analysis on local scales. More on NMMB performance in climate simulations can be found in Djurdjevic and Krzic (2013a).

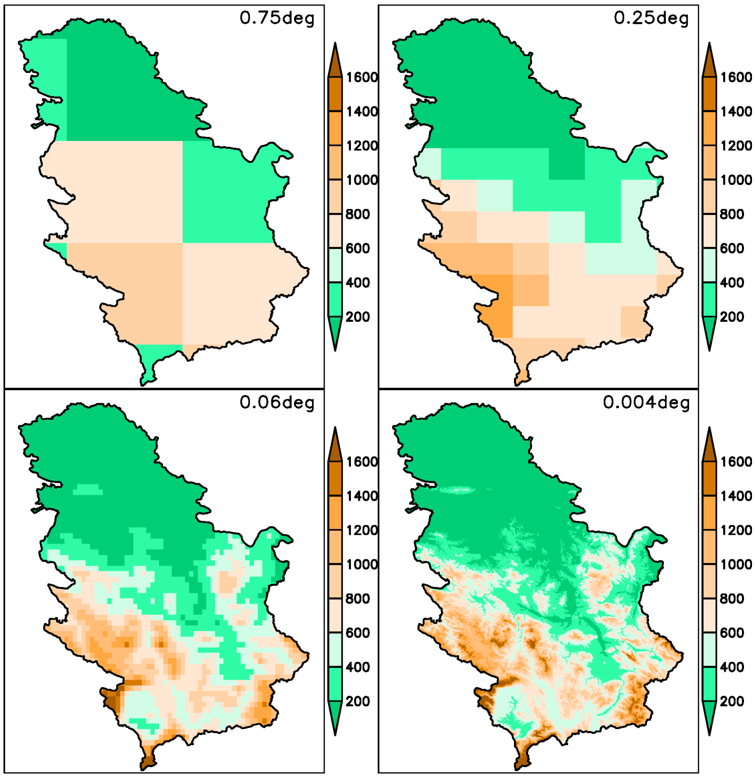


**Fig. 2.** Topography on GCM (upper left), coarse RCM (upper right), fine RCM (lower left) and DEM (lower right) resolutions.

## 3 Bias Correction

Bias correction of the model data in time and space it is necessary to produce daily data interpolated on model grid for the reference period 1971-2000. For interpolation are used all available observations for daily maximum, minimum and mean temperature from 103 sites from national network and 32 sites near border from surrounding countries. Interpolation of daily data is done for the territory of Serbia using method of successive corrections (Cressman, 1959). This method is in use usually for numerical weather forecast purposes and represents optimal combination of simplicity, computational efficiency and quality of the obtained interpolated data. It is used for the climate analysis in project national viticulture zoning (Ivanisevic et al., 2015).

Statistical bias correction is done creating correction functions for each model grid point, for each month and for each temperature separately, under the assumption that cumulative density functions of the model and observed data have the same values.

Model and observed temperatures is assumed to follow Gaussian distribution. In Fig. 3 is presented example for one month mean temperature probability and cumulative density functions of model and observed data, and obtained correction function, which has function to assign to model data appropriate observed value. More about statistical bias correction can be found in Ruml et al. (2012).

After creating correction functions they are applied on model data for three 30-years periods, base period 1971-200 and two future climate periods 2011-2040 and 2071-2100.

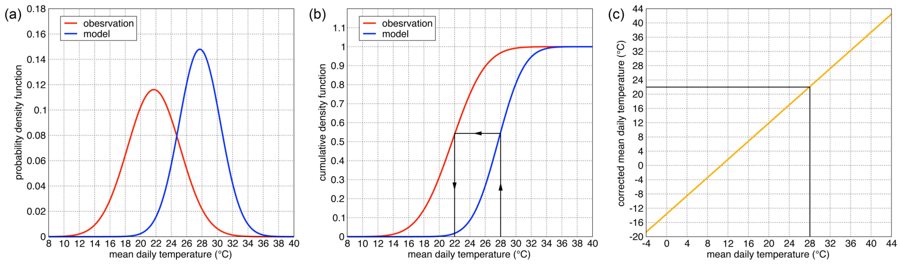


**Fig. 3.** Probability density functions (a), cumulative density functions (b) for the observed and model mean daily temperature data, and the correction function (c).

## 4 Results and Discussions

Corrected model results have model bias reduced to the minimum. Such data are can be used in different impact studies, under the assumption that model bias will not have impact on the quality of the derived conclusions (Ruml et al., 2012).

In Fig. 4 and Fig. 5 are presented mean annual and seasonal temperature changes, for the periods 2011-2040 and 2071-2100 with respect to the period 1971-2000 according to the RCP8.5 scenario, respectively. Temperature change during the period 2011-2040 shows increase in all seasons. Mean annual temperature change is in the range 1.6-2.0°C, but with larger values over lower altitudes and during the winter period with increase over 2.6°C in the large part of the country. During the period 2071-2100, in other words during after one century period, expected mean annual temperature change is over 5.6°C over the large part of the country with maximum changes going over 6.4°C. Again, largest projected change is for the winter season. In both periods fall season has larger increase in temperature than spring and summer.

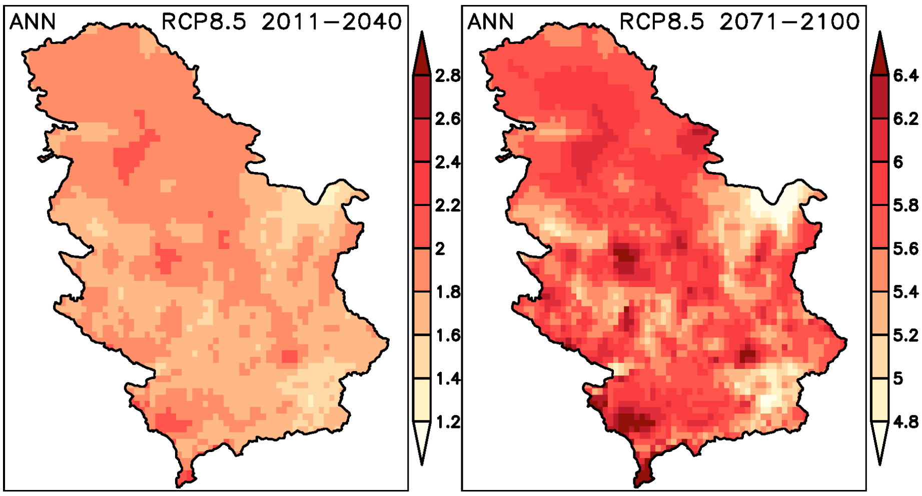


**Fig. 4.** Mean annual temperature change for the periods 2011-2040 and 2071-2100 with respect to the period 1971-2000, according to the RCP8.5 scenario.

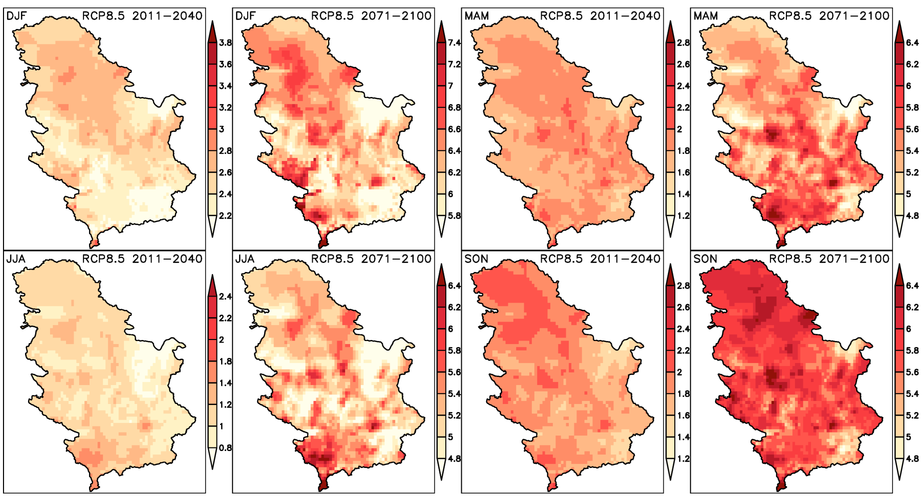


**Fig. 5.** Mean seasonal temperatures change for the periods 2011-2040 and 2071-2100 with respect to the period 1971-2000, according to the RCP8.5 scenario.

Several extreme temperature indices related to temperature extremes are selected for analysis in this paper. Number of ice days (ID, maximum temperature $T_x$<0°C) and frost days (FD, minimum temperature $T_n$<0°C) changes are shown in Fig. 6. During the period 2011-2040 decrease in ID and FD with respect to 1971-2000 is significant. Decrease of FD is larger in lower altitudes, which is related to temperature decrease pattern. ID decrease is higher in higher altitudes because it already reached point of very rare event in lower altitudes. During the period 2071-2100 decrease in ID and in FD is significantly larger in higher altitudes. This is related to the fact that by the end of the century can be accepted that in lower altitudes temperatures bellow 0°C almost never appear.

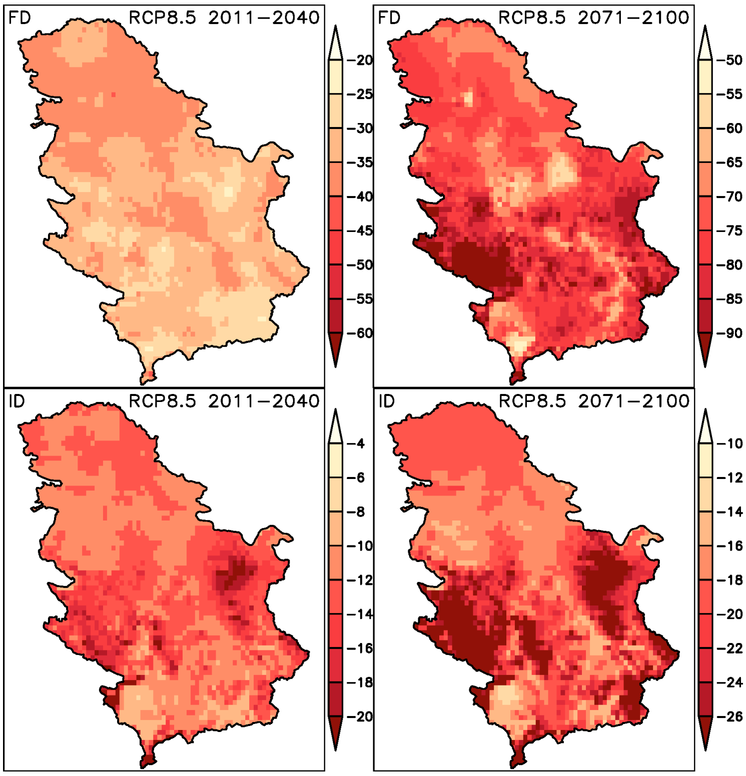


**Fig. 6.** Number of frost (FD) and ice days (ID) change for the periods 2011-2040 and 2071-2100 with respect to the period 1971-2000, according to the RCP8.5 scenario.

Number of summer days (SU, $T_x$>25°C) and tropical nights (TR, $T_n$>20°C) are shown in Fig. 7. During the period 2011-2040 increase in SU over 16 days in most part of the country shows significant expansion of the summer season. TR is appearing over lower altitudes and increase is up to 10 days. By the end of the century SU increase goes over 60 days, which suggests expansion of summer season by two months. TR increase is over 30 over the large part of the country, which means that climate over the territory of Serbia by the end of the century will reach subtropical/tropical climate characteristics.

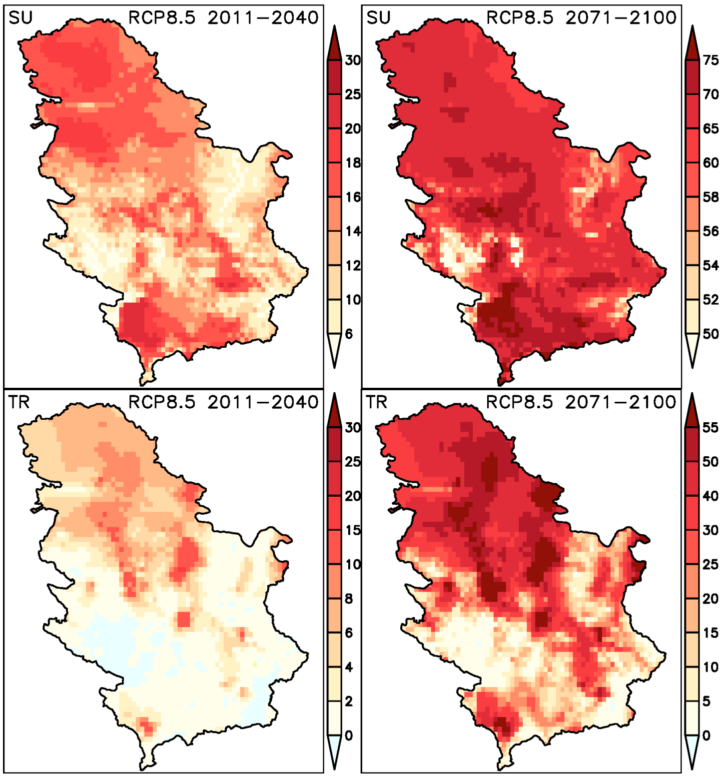


**Fig. 7.** Number of summer (SU) and tropical nights (TR) change for the periods 2011-2040 and 2071-2100 with respect to the period 1971-2000, according to the RCP8.5 scenario.

Other analysis (not shown here) shows extension of the growing season length 20-30 days during the period 2011-2040 and over two months by the end of the century. Increase in tropical days ($T_x$>35°C) also confirms climate change pattern toward much lower latitudes climate. Precipitation change in general shows some increase in annual cumulative values with highest increase during the spring season during the period 2011-2040. During the other seasons in some areas is expected small reduction. During the period 2071-2100 annual precipitation is decreasing over 10%, with significant reduction during summer season (over 40%), which is the season with highest precipitation values. This suggests high risk of summer draught hazards.

## 5 Conclusions

In this paper is given short review of the current work on high resolution climate change analysis with the main goal to obtain reliable model data. They can be used in development of national adaptation strategies and planning of the future economic development, which is mostly related to the agriculture and thereby closely connected to the climate factors. Serbia is a country with small-scale terrain features with economy mostly based on local landowners agricultural production, which is the reason for the high resolution approach. Following work will be focused on improvement of the interpolation method with further quality check of the collected observations. Database of corrected model daily precipitation data will be created. Having high resolution of daily temperature and precipitation data with reduced bias enables model data use by experts from other disciplines (biology, medicine, hydrology, agriculture, forestry, etc.) and production of the reliable information for the decision makers.

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