SIMULATED REGIONAL CLIMATE CHANGE IN THE CARPATHIAN BASIN USING USING ENSEMBLES MODEL SIMULATIONS

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1. INTRODUCTION

Spatial resolution of global climate models (GCMs) are inappropriate to describe regional climate processes; therefore, GCM outputs may be misleading to compose regional climate change scenarios for the 21st century. In order to provide better estimations for regional climate parameters, fine resolution regional climate models (RCM) can be used (Giorgi, 1990). RCMs are limited area models nested in GCMs, i.e., the initial and the boundary conditions of RCMs are provided by the GCM outputs. In order to estimate the regional climate change expected in the Carpathian Basin located in Central/Eastern Europe, outputs from several RCMs (from the completed European project ENSEMBLES, (van der Linden and Mitchell, 2009)) are summarized and analyzed using A1B scenario (Nakicenovic and Swart, 2000).

For the selected target region covering the latitude 44°-50°N, and longitude 14°-26°E, composite maps of projected temperature and precipitation changes are generated using the RCM simulations (with 25 km spatial resolution) for the periods of 1961-1990 (as the reference period), 2021-2050, and 2071 2100. The main aim of the present study is compile a range of possible regional climate change scenarios, which provide estimation for the mean projected changes for the 21st century as well, as the uncertainty of the projections.

First, the project ENSEMBLES is briefly introduced. Then, in order to estimate the bias of the different RCMs, ERA-40 driven runs are compared to the so-called E-OBS datasets containing daily temperature and precipitation values. For the evaluation of annual, seasonal, and monthly projected climatic changes, GCM-driven runs of the reference and the future periods are compared. Finally, changes of extreme climate indices by the end of the 21st century are analyzed.

2. THE ENSEMBLES PROJECT

The ENSEMBLES project (van der Linden and Mitchell, 2009) has been funded by the European Union 6th framework programme. The project was accomplished between 2004 and 2009 with the leading of the UK Met Office and 66 institutes from 20 countries (mostly from Europe) participated.

The main aims of the research program were the following:

- to develop an ensemble climate prediction system on seasonal to centennial time-scales;
- to quantify and reduce the uncertainty in modelling climate change;
- to link the outputs of the ensemble prediction system to a range of applications.

The involved RCMs used 25 km horizontal resolution, and the driving lateral and boundary conditions are provided by three different GCMs, namely, (i) ECHAM developed by the Max Planck Institute in Hamburg (Roeckner et al., 2006), (ii) HadCM developed by the UK Met Office Hadley Centre (Gordon et al., 2000; Rowell, 2005), and (iii) ARPEGE developed by Météo-France (Déqué et al., 1998).

The applied scenario in the RCM experiments for 1951-2100 runs is the SRES A1B, for which the estimated CO_2 concentration levels by 2050 and by 2100 are 532 ppm, and 717 ppm, respectively (Nakicenovic and Swart, 2000). In the present analysis, temperature and precipitation outputs are used.

3. VALIDATION OF THE RCM RESULTS

In order to estimate the bias of the different RCMs, ERA-40 (European Centre for Medium-range Weather Forecast, ECMWF, re-analysis dataset described in Uppala et al., 2005) driven runs are compared to the so-called E-OBS datasets containing gridded daily temperature and precipitation values for Europe (Haylock et al., 2008). The validation results suggest that the models are able to reconstruct the temperature sufficiently. In case of precipitation, simulated values usually significantly overestimate the observations, except in summer when mostly underestimations are found.

4. ANALYSIS OF FUTURE REGIONAL TEMPERATURE TRENDS

For the evaluation of annual, seasonal, and monthly projected climatic changes, GCM-driven runs of the reference and the future periods are compared. All

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of the evaluated RCM simulations suggest that the temperature of the Carpathian basin is projected to increase significantly in each month and season. The projected annual warming is about 1-2 °C, and 3-4 °C for 2021-2050, and 2071-2100, respectively. Annual and seasonal mean projected changes for Hungary are shown in Figs. 1-3, separated according to the driving GCMs. Fig. 4 presents the spatial structure of composite maps containing projected changes by the mid- and the late-century. Evidently, the projected warming is larger by 2071-2100 than by 2021-2050. The largest mean warming (3.5-4 °C) is likely occur in the region in summer by 2071-2100.

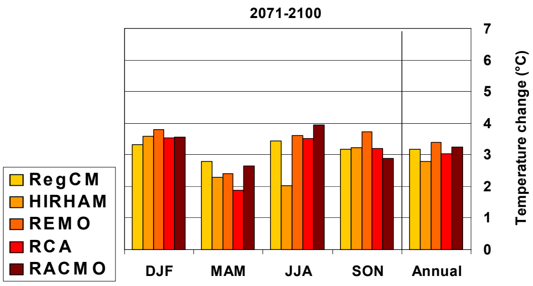

Fig. 1: The projected temperature changes in Hungary by 2071-2100 using ECHAM as driving GCM (reference period: 1961-1990). All changes are significant.

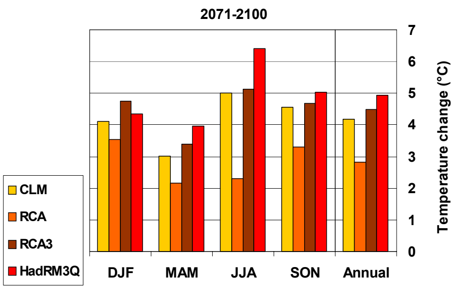

Fig. 2: The projected temperature changes in Hungary by 2071-2100 using HadCM as driving GCM (reference period: 1961-1990). All changes are significant.

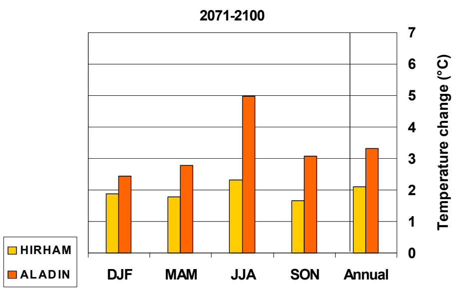

Fig. 3: The projected temperature changes in Hungary by 2071-2100 using ARPEGE as driving GCM (reference period: 1961-1990). All changes are significant.

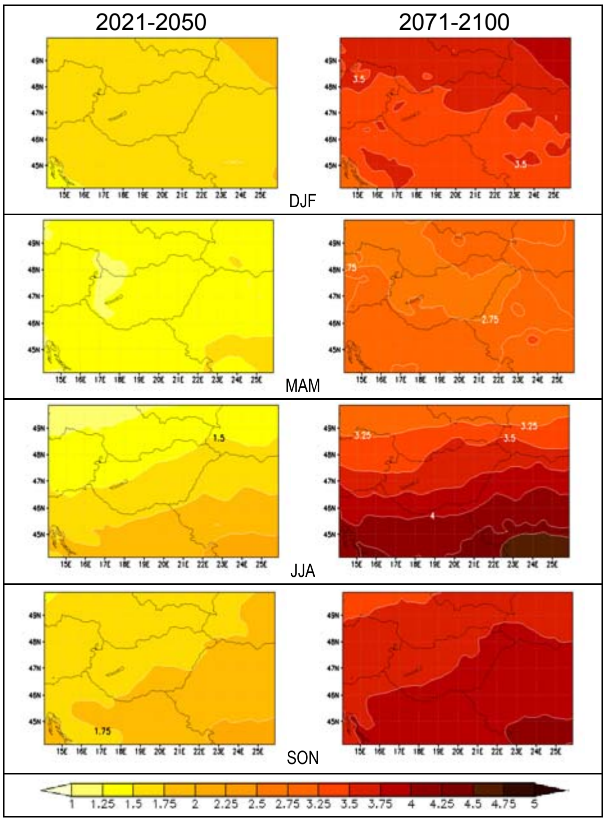

Fig. 4: Composite map of the projected seasonal mean temperature changes (°C) by 2021-2050 and 2071-2100 (reference period: 1961-1990)

5. ANALYSIS OF FUTURE REGIONAL PRECIPITATION TRENDS

In case of precipitation, the annual sum is not expected to change significantly in the Carpathian basin. Annual and seasonal mean projected changes for Hungary are shown in Figs. 5-7, separated according to the driving GCMs.

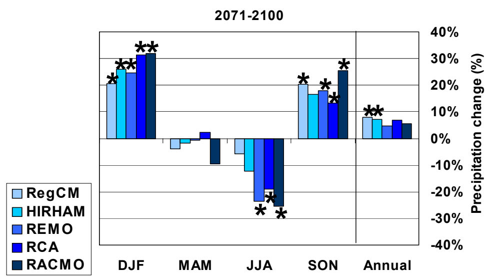

Fig. 5: The projected precipitation changes in Hungary by 2071-2100 using ECHAM as driving GCM (reference period: 1961-1990). Significant changes are indicated by *.

Most of the RCMs suggest that the winter and fall precipitation is likely to increase, while summer and spring precipitation is projected to decrease during the 21st century.

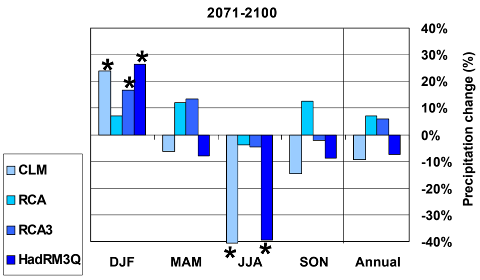

Fig. 6: The projected precipitation changes in Hungary by 2071-2100 using HadCM as driving GCM (reference period: 1961-1990). Significant changes are indicated by *.

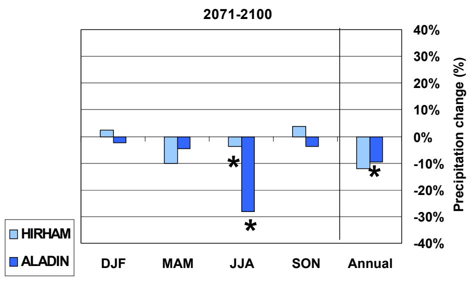

Fig. 7: The projected precipitation changes in Hungary by 2071-2100 using ARPEGE as driving GCM (reference period: 1961-1990). Significant changes are indicated by *.

Fig. 8 presents the spatial structure of composite maps containing projected seasonal precipitation changes by the mid- and the late-century. The mean change by 2021-2050 is not likely to exceed 10% in absolute value in neither season. By 2071-2100 remarkable increase (15-20%) and decrease (10-20%) are projected in winter and in summer, respectively.

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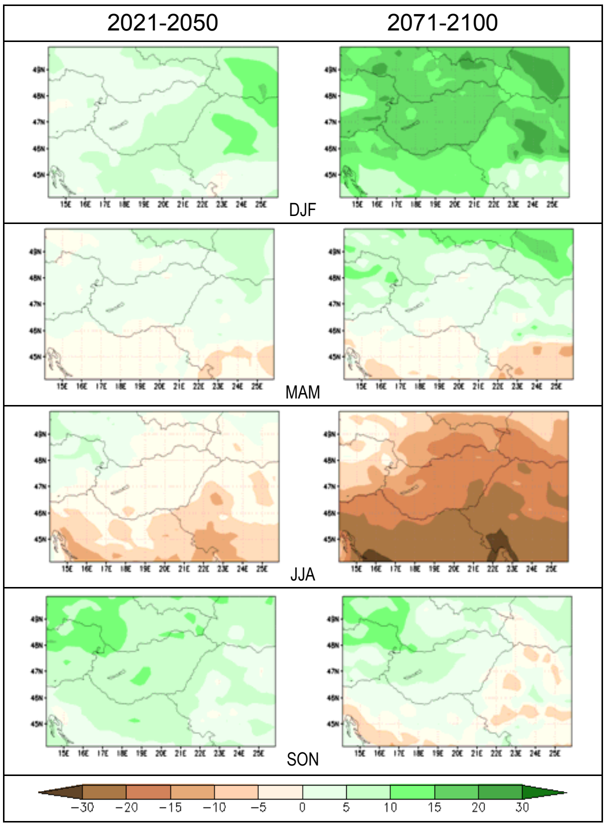

Fig. 8: Composite map of the projected seasonal mean precipitation changes (%) by 2021-2050 and 2071-2100 (reference period: 1961-1990)

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