PROJECTED PRECIPITATION CHANGES IN CENTRAL/EASTERN EUROPE ON THE BASIS OF ENSEMBLE SIMULATIONS

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ABSTRACT. – Projected precipitation changes in Central/Eastern Europe on the basis of ENSEMBLE simulations. For building appropriate local/national adaptation and mitigation strategies, detailed analysis of regional climate change is essential. In order to estimate the climate change for the 21st century, both global and regional models may be used. However, due to the coarse horizontal resolution, global climate models are not appropriate to describe regional scale climate processes. On the other hand, regional climate models (RCMs) provide more realistic regional climate scenarios. A wide range of RCM experiments was accomplished in the frame of the ENSEMBLES project funded by the EU FP6 program, which was one of the largest climate change research project ever completed. All the RCM experiments used 25 km horizontal resolution and the A1B emission scenario, according to which CO2 concentration by 2100 is estimated to exceed 700 ppm, i.e., more than twice of the preindustrial level.

The 25 km spatial resolution is fine enough to estimate the future hydrology-related conditions in different parts of Europe, from which we separated and analyzed simulated climate data sets for the Central/Eastern European region. Precipitation is an especially important climatological variable because of agricultural aspects and flood-related natural hazards, which may seriously affect all the countries in the evaluated region. On the basis of our results, different RCM simulations generally project drier summers and wetter winters (compared to the recent decades). The southern countries are more likely to suffer more intense warming, especially, in summer, and also, more intense drought events due to the stronger Mediterranean impact.

Keywords: climate change, regional climate models, precipitation, drought, flood.

1. INTRODUCTION

Global warming induced changes in hydrology-related environmental conditions are major concerns in every Central/Eastern European country due to the strong potential effects through severe regional drought and flood events. In order to estimate future climate change global climate models (GCM) are well developped tools. However, GCMs are run at spatial resolution of 150-300 km, which makes them unable to make projections in regional scale, especially in case of hydrology-related conditions (i.e., precipitation). Hence regional climate models (RCM) driven by the GCM are used with 5-25 km horizontal resolution, which is a

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spatial scale where fine scale climatic processes and resulting climatic conditions might be better described.

The aim of this paper is to analyze precipitation changes projected for six Central/Eastern European countries (i.e., Austria, Czech Republic, Hungary, Romania, Slovakia, Slovenia) for the mid- and late 21st century by using several RCM simulations accomplished in the frame of the ENSEMBLES project (van der Linden and Mitchell, 2009).

2. DATA

In the present analysis, monthly precipitation sums calculated from 1951-2100 RCM simulation outputs of the ENSEMBLES project was used. The selected RCMs, their driving GCMs (which provide initial and lateral boundary conditions for the regional scale models), and the institutes accomplished the 150 year long RCM experiment are summarized in Table 1. All these RCM simulations used 25 km horizontal resolution and considered the SRES A1B scenario (Nakicenovic and Swart, 2000) for the future. According to this scenario the total world population is estimated to increase to 9 billion by 2050, and then, during the second part of the 21st century it is projected to decrease, the estimated total population by 2100 is 7 billion again. The scenario contains a balance between the different energy sources (nuclear, renewable, fossil fuel) and it provides a mid-line scenario for carbon-dioxide. The estimated CO_2 level is 532 ppm and 717 ppm for 2050 and 2100, respectively.

Table 1. ***List of selected RCMs, their driving GCMs, and the responsible institute***

RCM	Driving GCM	Institute
ALADIN	ARPEGE	CNRM, France
RACMO	ECHAM5	KNMI, Netherlands
RCA RCA	ECHAM5 HadCM3Q	SMHI, Sweden
REMO	ECHAM5	MPI, Germany
HadRM3Q0	HadCM3Q	HC, UK
RCA3	HadCM3Q	C4I, Ireland
HIRHAM HIRHAM5	ARPEGE ECHAM5	DMI, Denmark
RegCM	ECHAM5	ICTP, Italy
CLM	HadCM3Q	ETHZ, Switzerland

From the RCM output database covering the entire European continent, our selected domain contains 150-year-long precipitation data sets from the region between 43-51°N latitude and 9-30°E longitude. In our analysis, the selected countries are represented by the gridpoints within their borders, thus Austria contains 160 gridpoints, the Czech Republic 162, Hungary 227, Romania 422, Slovakia 103, and Slovenia 41.

3. PROJECTED MEAN PRECIPITATION CHANGES

For the evaluation of seasonal changes, the 30-year-long average amounts calculated for the RCM-runs of the reference (1961-1990) and the future periods (2021-2050, 2071-2100) are compared for all the gridpoints within the selected domain. For each RCM, the four seasonal precipitation changes are determined, and then, weighted composite mean values are calculated for each season. The applied weighting factors depend on the total numbers of ensemble members driven by the same GCM. Thus, in case of the RCM experiments driven by ECHAM, HadCM, and ARPEGE, the weighting factor is 1/15, 1/12, and 1/6, respectively (since these GCMs provide initial and lateral boundary conditions for 5, 4, and 2 RCM experiments). Fig. 1 shows the seasonal spatial structure of composite projected precipitation change by 2021-2050 and 2071-2100. On the base of these maps, the estimated changes for the late-century are larger than for the mid-century. More specifically, overall, future winters (summers) are very likely to become wetter (drier) than those in the past few decades.

In most of the southern regions, the projected summer changes by 2071-2100 exceeds 20% (including Slovenia, Hungary and Romania). The largest precipitation decrease (by 20-40%) in summer is estimated in case of Romania, consequently, summer drought is especially likely to hit this country.

In case of winter precipitation the estimated increase by the last three decades of the 21st century exceeds 20% in Slovenia, southern Austria, northwestern part of Hungary, moreover, in several regions of the Czech Republic, Slovakia, and northern Romania.

In autumn slight increase is projected for the entire domain but the estimate changes do not likely to exceed 10-15% in any subregions. In spring the selected domain is zonally divided into the northern and southern parts (i.e., slight increasing and decreasing trends, respectively), however, the projected changes are very small and mostly not significant.

After analyzing the composite maps, country-based evaluation of projected changes may result more focused information for further impact studies. For this purpose, gridpoint values of seasonal changes within a given country are averaged in order to determine the mean seasonal changes of the country. Fig. 2 summarizes the projected seasonal changes in mean precipitation sum for 2021-2050 and 2071-2100. The six presented graphs illustrate the relationship between the projected precipitation changes by the middle and by the end of the 21st century in the selected Central/Eastern European countries. Dashed lines indicate linear changes throughout the century, when the seasonal change is between the dashed line and the y-axis (x-axis) the projected change during the second part of the century is larger (smaller) than in the first part, thus implying accelerating (slowing or even oppositing) precipitation change.

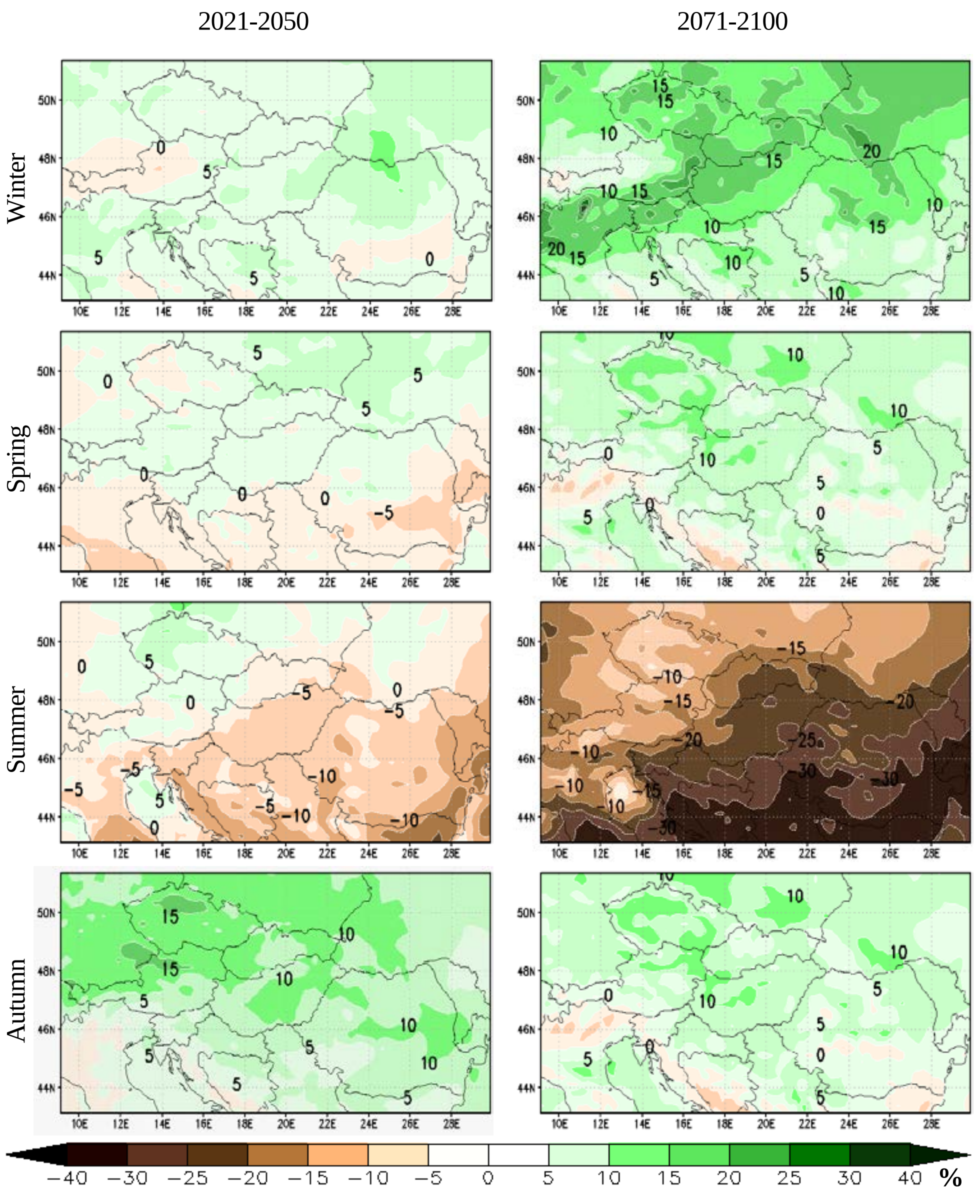

Fig. 1. ***Composite map of the weighted projected seasonal mean precipitation changes (%) by 2021-2050 and 2071-2100, reference period: 1961-1990***

Summer drying is projected for both periods in Slovenia, Slovakia, Hungary and Romania, which is likely to accelerate by the late-century. In Austria and in the Czech Republic summers only in the second part of the 21st century are likely to become drier than previously. Enhancing winter precipitation is also slightly accelerating in most of the countries (except in Romania). On the other hand, autumn precipitation changes (towards slightly wetter conditions) are estimated to slow down in the second half of the century in all of the selected Central/Eastern European countries.

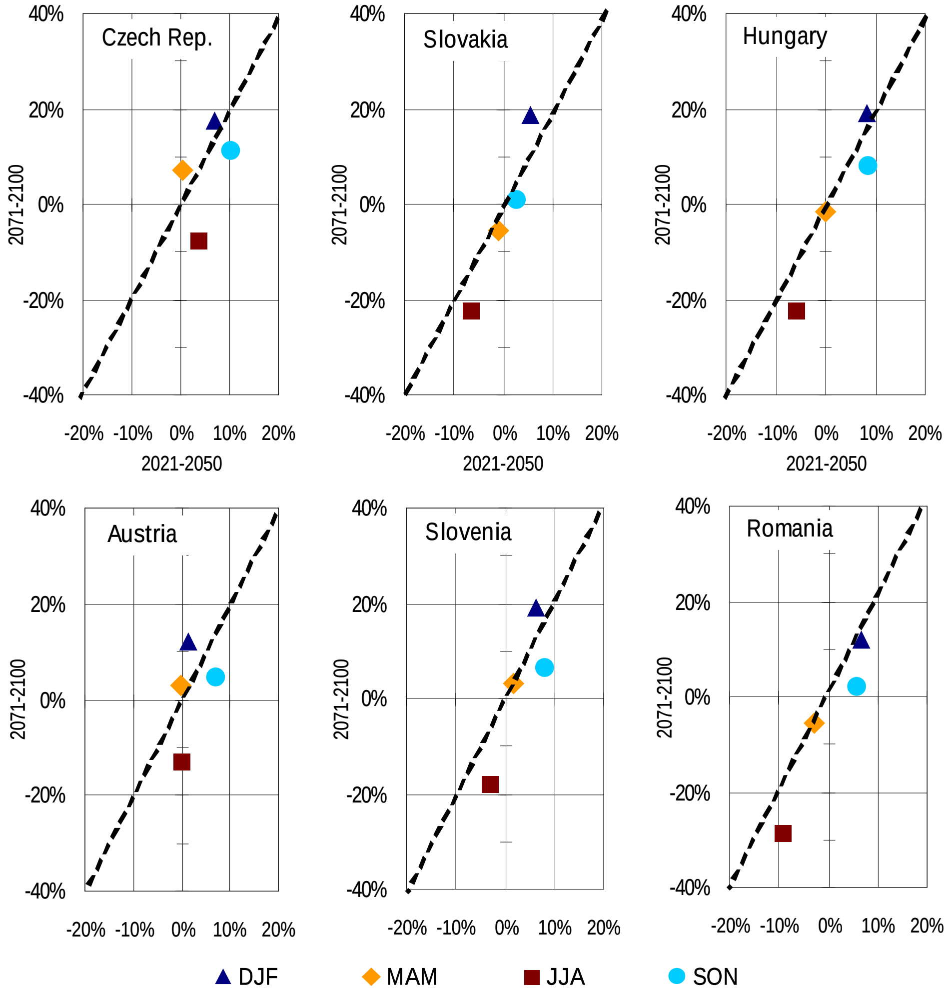

Fig. 2. ***Projected seasonal mean precipitation changes (%) by 2021-2050 and 2071-2100, reference period: 1961-1990***

4. PROJECTED CHANGES IN EXTREME INDICES RELATED TO PRECIPITATION

Regional climatological effects of global warming may be recognized not only in shifts of mean precipitation, but in the frequency or intensity changes of different climatic extremes. Detected trends of several climate extreme indices were analyzed and compared for the region (Bartholy and Pongracz, 2007) following the guidelines suggested by the joint WMO-CCl/CLIVAR Working Group on climate change detection (Karl et al., 1999). Precipitation-related indices include the number of wet days (using several threshold values defining extremes), the maximum number of consecutive dry days (CDD), the highest 1-day precipitation amount (RX1), the greatest 5-day rainfall total (RX5), etc. In this paper, due to page limits only one of them is shown, and only for Hungary.

In order to estimate the bias of the different RCM simulations, outputs from 1951-2000 were compared to the E-OBS datasets (Haylock et al., 2008) containing gridded daily precipitation values. The validation results suggest that the simulated values usually significantly overestimate the observations, except in summer when mostly underestimations were found (Pongracz et al., 2011). These biases of the raw RCM outputs are corrected using the monthly empirical distribution functions (Formayer and Haas, 2009), and then, extreme precipitation index time series are calculated from the corrected precipitation data sets for each grid point. Projected seasonal changes by 2021-2050 and 2071-2100 are determined relative to the 1961-1990 reference period.

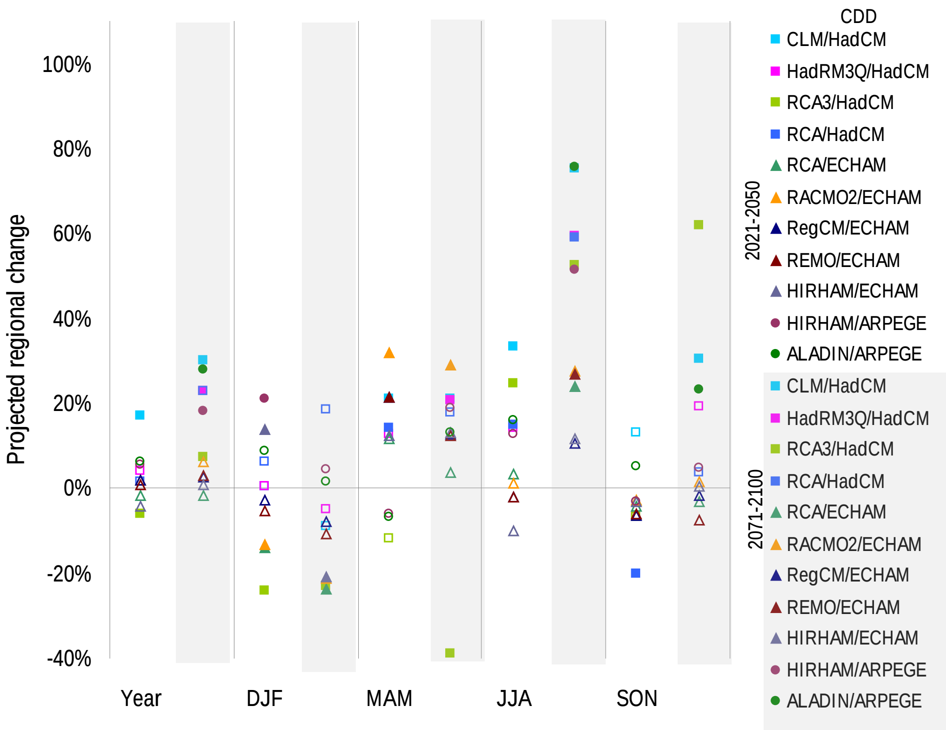

Fig. 3. ***Projected annual and seasonal change in CDD by 2021-2050 and 2071-2100 (indicated by grey shaded area) calculated for Hungary, reference period: 1961-1990***

Annual and seasonal climate index values of consecutive dry days (CDD) are defined as the longest period in a year or a given season with daily precipitation less than 1 mm. Analysis of CDD trends provide useful information for agriculture on the critical dry periods. For the selected target region, composite maps of projected seasonal change in CDD are generated using the RCM simulations for the periods of 1961-1990 (as the reference period), 2021-2050, and 2071-2100. Furthermore, trend coefficients are compared for all the seasons for the entire 21st century.

Results of CDD trend analysis for Hungary are shown in Fig. 3. The largest change by 2021-2050 is projected for spring and summer: 5 and 3 simulations (respectively) of the evaluated 11 RCM experiments project significant increase of CDD in Hungary, the projected change is 15-35% relative to the 1961-1990 reference period. The largest change by 2071-2100 is projected for summer: 9 simulations out of 11 RCM experiments project significant increase of CDD in Hungary, the projected change is 25-75% relative to the 1961-1990 reference period. The projected increase is larger in the southern part of the country than the northern regions.

5. CONCLUSIONS

Projected precipitation changes for six Central/Eastern European countries (i.e., Austria, Czech Republic, Hungary, Romania, Slovakia, Slovenia) have been analyzed for the middle and the end of the 21st century by using several RCM simulations provided by the ENSEMBLES database. On the base of the presented results, the following main conclusions can be drawn: (1) Future summers in the region are projected to become drier compared to the past few decades. The opposite is estimated for winters. (2) The largest summer precipitation decrease by 2071-2100 is projected for Romania, which is likely to exceed 20-40%. (3) The projected regional summer drying is very likely to accelerate in the second part of the 21st century. (4) Consecutive dry periods are likely to lengthen in the future, especially in summer.

The presented analysis and results might serve as a basis for further impact studies, which leads to develop essential national, regional, local adaptation and mitigation strategies in the coming decades.

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