THE ROLE OF GLOBAL MITIGATION IN REGIONAL CLIMATE CHANGE IN CENTRAL/EASTERN EUROPE

Rita Pongrácz*, Judit Bartholy, Ildikó Pieczka
ELTE Eötvös Loránd University, Institute of Geography and Earth Sciences
Department of Meteorology, Budapest, Hungary

1. INTRODUCTION

Different scenarios consider possible future pathways mainly related to the start of the substantial reduction of anthropogenic greenhouse gas emission. The Representative Concentration Pathways (RCP) scenario family is defined on the basis of radiative forcing changes by 2.6, 4.5 and 8.5 W/m^2 (van Vuuren et al., 2011) with the timeframe of the end of the 21st century relative to the pre-industrial era. The RCP4.5 assumes that the global anthropogenic emission of greenhouse gases (GHG) will start to decrease in the 2040s, while the RCP8.5 can be considered as a business-as-usual scenario, with increasing GHG emission and no mitigation until 2100. The RCP2.6 is the only scenario among the three analyzed scenarios that assumes immediate reduction of anthropogenic GHG emission, so the Paris Agreement can be fulfilled.

In this study, the projected regional climate change is compared as the function of the radiative forcing change and global climatic response. For this purpose, we completed RegCM4.3 simulations at 50 km horizontal resolution using the same global climate model (i.e., HadGEM2-ES, Collins et al., 2011) but using the three different RCP scenario, as initial and lateral boundary conditions (ICBC) for the entire MED-44 CORDEX area (Ruti et al., 2016) covering the extended Mediterranean region of Europe (i.e., 30°-50°N, 10°W-45°E). The projections for different European regions within the MED-44 CORDEX area are analyzed by Pongrácz et al. (2016). The comparison of these HadGEM-driven simulations to another set of RegCM simulations driven by the MPI-ESM global climate model (Jungclaus et al., 2013; Stevens et al., 2013) is published by Bartholy et al. (2019)

Then, these simulations were further downscaled to 10 km horizontal resolution for a smaller domain covering Central Europe (Fig. 1) with special focus on Hungary (Pieczka et al., 2018; 2019). The reference period is defined as 1981-2010, and the target period is defined as the last three decades of the 21st century (i.e., 2071-2100). The mean projected changes of monthly, seasonal and annual mean temperature and precipitation totals as well, as frequency, intensity and duration of extreme events (represented by extreme climatic indices) are analyzed.

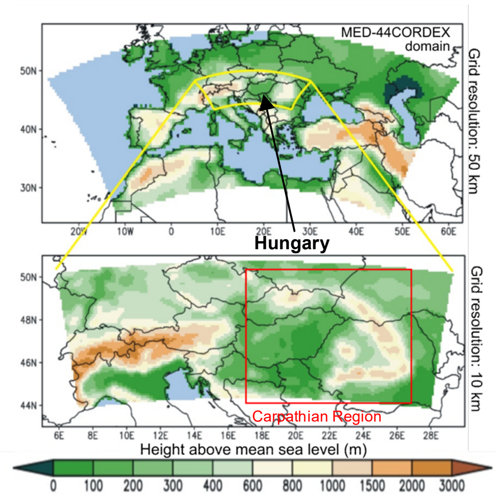

Fig. 1: Topography of the integration domains.

2. REGCM REGIONAL CLIMATE MODEL

The RegCM stems from the National Center for Atmospheric Research/Pennsylvania State University (NCAR/PSU) Mesoscale Model version MM4. It is a 3-dimensional, sigma-coordinate, primitive model, originnally developed by Giorgi et al. (1993a, 1993b), and currently available from the ICTP (Abdus Salam International Centre for Theoretical Physics located in Trieste, Italy).

The latest version of this model (RegCM5) has been launched already, but our simulations use the RegCM4.3 (Elguindi et al., 2011) with the modification of activating the subgrid Biosphere-Atmosphere Transfer Scheme (BATS). Therefore, the land surface processes are modelled by BATS version 1e (Dickinson et al., 1993) with the treatment for subgrid variability of topography, and land cover is determined using a mosaic-type approach (Giorgi et al., 2003). Each grid cell is divided into 25 subgrid cells. As a result, in our simulation the size of the land surface grid cell is 10 km × 10 km horizontally. The affect of the selection of the cumulus parametrization is discussed in Pieczka et al. (2017).

* *Corresponding author address*: R. Pongracz, Dept. of Meteorology, Eötvös Loránd University, Pázmány st. 1/a. Budapest, H-1117; Hungary; e-mail: pongracz.rita@ttk.elte.hu

3. RESULTS: TEMPERATURE PROJECTIONS

First, monthly mean projected temperature changes are compared for the three RCP scenarios for all the 12 months (shown here separately for the four seasons in Figs. 2-5 starting with winter, then, spring, summer, and finally, fall). The spatial average warming for the country is shown on the maps for each month, and each scenario.

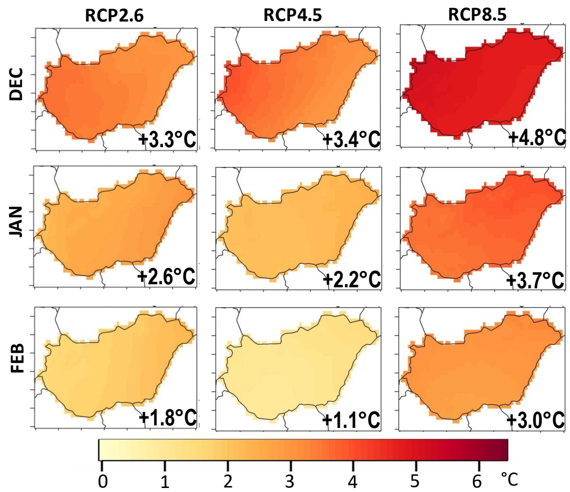

Fig. 2: Projected monthly mean warming for Hungary during winter by 2071-2100, reference period: 1981-2010.

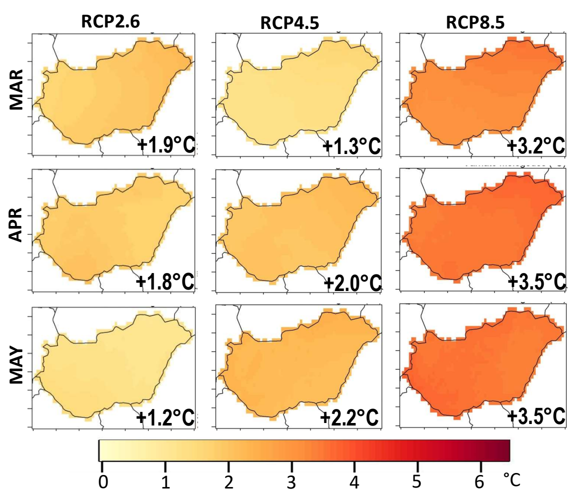

Fig. 3: Projected monthly mean warming for Hungary during spring by 2071-2100, reference period: 1981-2010.

Overall, RCP8.5 projects the greatest warming globally (e.g., IPCC, 2021) due to the direct link between the radiative forcing and temperature. This is also reflected in the projected regional warming in Hungary with higher changes compared to the other scenarios by the end of the 21st century. The projected monthly mean changes in Hungary ranges from 3.0°C to 6.1°C, with the highest values in the three summer months (with July, August, and June in decreasing order, Fig. 4), followed by the fall months (with September, October, November in decreasing order, Fig. 5). The smallest temperature changes are projected for February (Fig. 2) and March (Fig. 3) when considering RCP8.5.

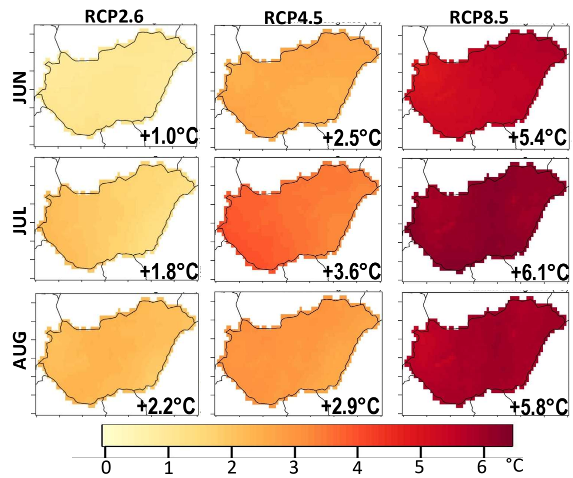

Fig. 4: Projected monthly mean warming for Hungary during summer by 2071-2100, reference period: 1981-2010.

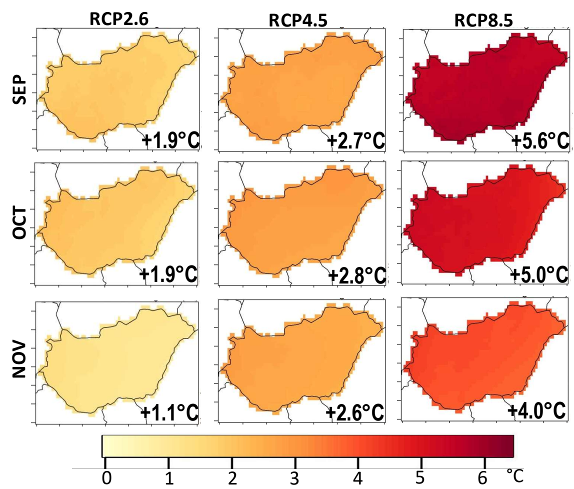

Fig. 5: Projected monthly mean warming for Hungary during fall by 2071-2100, reference period: 1981-2010.

The difference between the other two RCP scenarios (i.e., RCP 2.6 and RCP4.5) is much less, especially in winter (Fig. 2) and spring (Fig. 3), compared to the projected warming for the RCP8.5 scenario (Fig. 6). However, the greatest temperature changes are projected in different months, namely, 3.6°C in July for RCP4.5 (Fig. 4), and 3.3°C in December for RCP2.6 (Fig. 2). The smallest monthly mean warming is projected in June (1.0°C, for RCP2.6, Fig. 4) and February (1.1°C, for RCP4.5, Fig. 2).

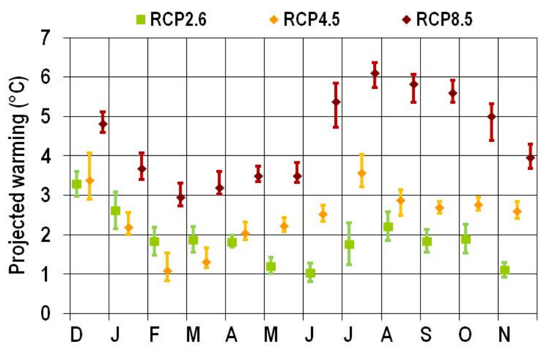

Fig. 6: Annual distribution of projected monthly mean warming for Hungary by 2071-2100, compared to the reference period 1981-2010.

4. RESULTS: PRECIPITATION PROJECTIONS

Similarly to the analysis of projected temperature changes, monthly mean precipitation changes are also shown in Figs. 7-10 grouped according to the season (winter in Fig. 7, spring in Fig. 8, summer in Fig. 9, and fall in Fig. 10).

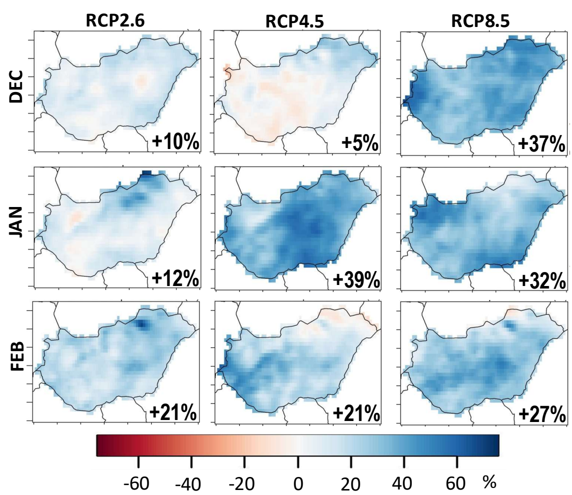

Fig. 7: Projected monthly precipitation change for Hungary during winter by 2071-2100, relative to the reference period 1981-2010.

The monthly projections for precipitation are evidently more variable than for temperature. Both increasing and decreasing precipitation may be likely in a given month under a specific scenario in different parts of the country, e.g., in June (all the three scenarios project wetter trend in some parts of Hungary and drier trends in other parts, as shown in the top row of maps in Fig. 9).

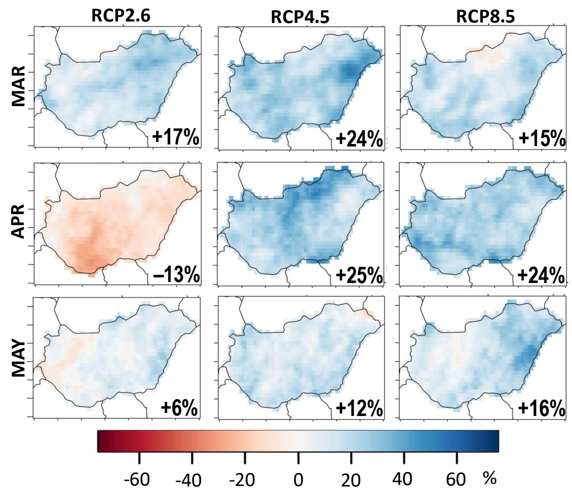

Fig. 8: Projected monthly precipitation change for Hungary during spring by 2071-2100, relative to the reference period 1981-2010.

The greatest precipitation decrease is projected in July for both RCP4.5 and RCP8.5 (Fig. 9), these projections are substantial over the entire area of the country (-44% and -34%, respectively). However, when RCP2.6 is considered, the greatest drying trend is much less than for the other two scenarios, and it is projected in October and April (by -17% and -13%, respectively).

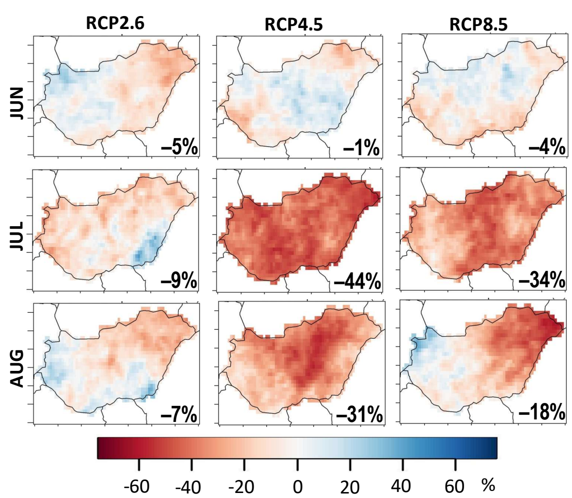

Fig. 9: Projected monthly precipitation change for Hungary during summer by 2071-2100, relative to the reference period 1981-2010.

The projections are dominated by precipitation increase by the late-century relative to the reference period, i.e., 1981-2010. The greatest trend towards wetter conditions is projected in winter (Fig. 7), namely, in December for the RCP8.5 (37%), January for the RCP4.5 (39%), and February for the RCP2.6 (21%).

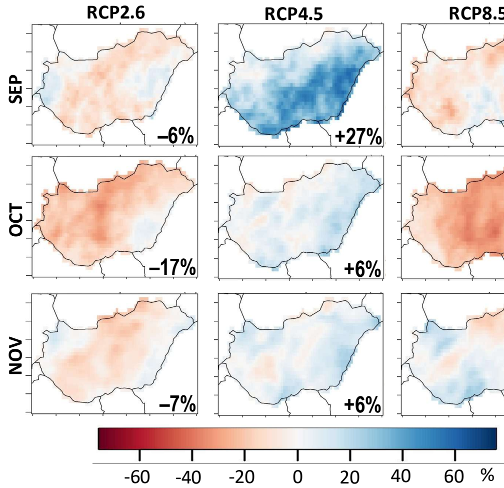

Fig. 10: Projected monthly precipitation change for Hungary during fall by 2071-2100, relative to the reference period 1981-2010.

Since there is no direct connection between the precipitation change and the radiative forcing change, the projections do not depend on the scenario. The overall annual distribution of the projected changes is quite similar for the different scenarios (Fig. 11), namely, wetter winters and springs, drier summers, and relatively smaller changes in fall.

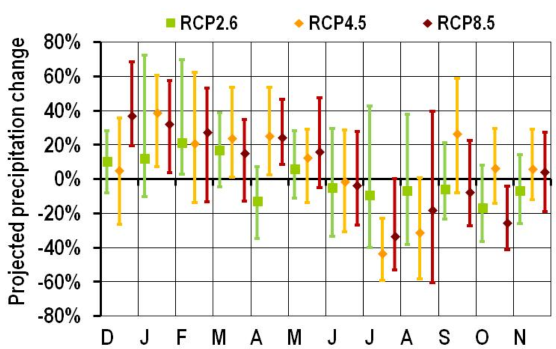

Fig. 11: Annual distribution of projected monthly mean precipitation change for Hungary by 2071-2100, relative to the reference period 1981-2010.

The continental climatic conditions of Hungary are represented by May, June, and July being the wettest months, while January and February being the driest months throughout the year. The projections imply that the difference between the winter and the rest of the year will be smaller than in the past, and drought events will be more likely to occur in July and August, especially if the RCP4.5 or the RCP8.5 scenario will be realized. The eastern part of the country is especially vulnerable to such changes since the Great Hungarian Plain is the main agricultural land of the country, which can be highly affected by summer drought and winter inland water hazard.

5. RECOMMENDATIONS

The results presented here can serve as the basis of the Hungarian national climate and adaptation strategies for detailed regional scale impact studies (e.g., agriculture, water management, public health issues, energy sector, etc.). Decision-makers may use these results to develop appropriate local, regional, or national level strategies to cope with the inevitable adverse effects due to global warming.

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