# 591 REGIONAL CLIMATE MODEL EXPERIMENT USING REGCM SUBGRIDDING OPTIONS IN THE FRAMEWORK OF MED-CORDEX

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## 1. INTRODUCTION

Our research group is participating in the Med-CORDEX international initiative of the CORDEX (Coordinated Regional Climate Downscaling Experiment) program in the framework of WCRP (World Climate Research Program). Our specific aim is to contribute to the complex regional climate modelling database with RegCM experiments with 50 km horizontal resolution using subgridding option in order to take into account subgrid processes. As being part of the Med-CORDEX initiative, our model domain contains the MED-44 CORDEX area covering the Mediterranean region of Europe (Fig. 1, upper panel). The 50-km horizontal resolution outputs serve as initial and lateral boundary conditions (ICBC) for the fine resolution (10 km) RegCM4.3 experiment for a smaller domain focusing on Central Europe (Fig. 1, lower panel).

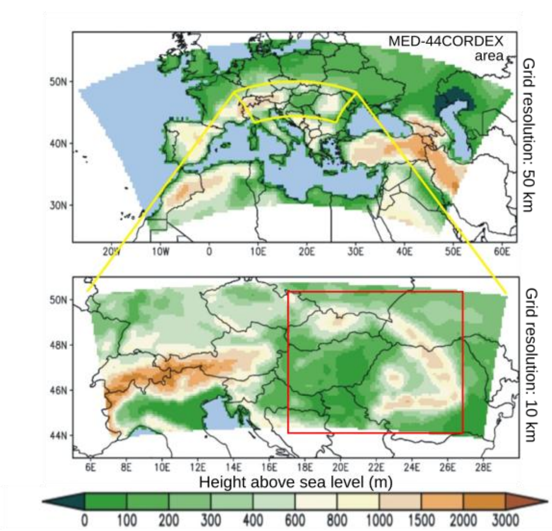


Fig. 1: Topography of the integration domains for the RegCM4.3 simulation at 50 km (top) and 10 km (bottom) horizontal resolution. The red rectangle indicates the Carpathian Region the focus area of the 10 km resolution experiment.

The domain of our earlier fine resolution RegCM experiments (Bartholy et al., 2009; Pongrácz et al., 2010; Torma et al., 2011) has been substantially extended from 12000 gridcells to about 25000 gridcells, moreover, in the previous study we used RegCM3 model version, and emission scenarios (Nakicenovic and Swart, 2000) instead of the new Representative Concentration Pathways (RCP) scenarios (van Vuuren et al., 2011).

First, the model RegCM is introduced in section 2. Section 3 discusses model validation using two different ICBCs, (i) from datasets of ERA-Interim reanalysis, and (ii) from simulation outputs of HadGEM2 global climate model (GCM). Preliminary projection results using RCP4.5 scenario are presented and discussed in section 4. Finally, the main conclusions are summarized in section 5.

## 2. REGIONAL CLIMATE MODEL REGCM

Regional climate model RegCM originally stems from the National Center for Atmospheric Research/ Pennsylvania State University (NCAR/PSU) Mesoscale Model version MM4 (Dickinson et al., 1989; Giorgi, 1989). It is a 3-dimensional, limited-area, hydrostatic, compressible, sigma-p vertical coordinate model maintained at ICTP (International Centre for Theoretical Physics), Trieste. It was originally developed by Giorgi et al. (1993a, 1993b) and later modified and improved by Giorgi and Mearns (1999) and Pal et al. (2000). Description of model equations and possible parameterizations available in the latest version can be found in Elguindi et al. (2011) in detail. In our simulations we used the model settings agreed as default within the Med-CORDEX project (Somot et al., 2012) at 50 km horizontal resolution, 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.

For the detailed regional analysis several subregions are defined within the integration domains (Figs. 2 and 3).

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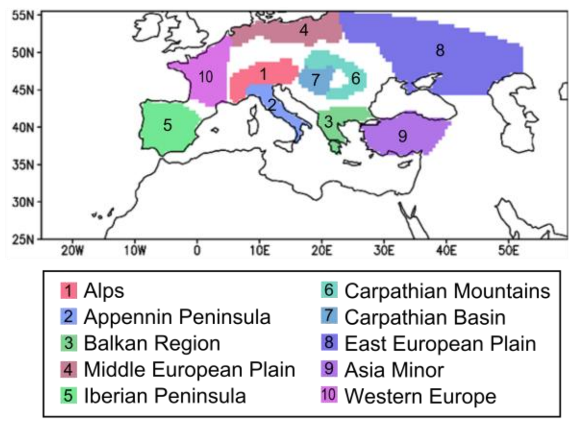


Fig. 2: Subregions within the integration domain defined for regional scale analysis for the 50-km model runs.

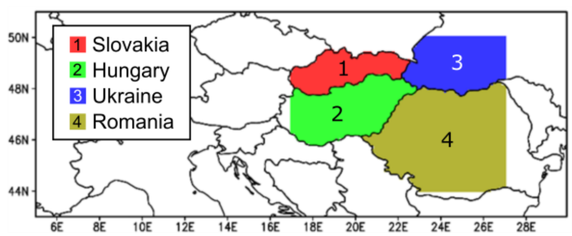


Fig. 3: Subregions within the integration domain defined for regional scale analysis for the 10-km model runs

## 3. VALIDATION RESULTS

In order to test the model capability in reproducing past climatic conditions we carried out a detailed validation for the period 1981-2000. As a reference we used gridded database both for temperature and precipitation. In case of the 50-km resolution model simulations RegCM outputs are compared to the E-OBS (Haylock et al., 2008) database, whereas in case of the 10-km resolution RegCM outputs the homogenized CarpatClim (Szalai et al., 2013) data are used for the comparison (the spatial extension is indicated by a red box in Fig. 1).

Fig. 4 contains the average temperature biases of the 50 km horizontal resolution RegCM simulations. The maps clearly shows that the annual and the seasonal biases of the ERA-Interim driven simulation (E–50km) are smaller than the biases of the HadGEM2 driven simulation (H–50km). In general, the temperature is underestimated in Africa and the Mediterranean region, whereas it is overestimated at the northeastern part of the domain (e.g., East European Plain) where continental climate is present.

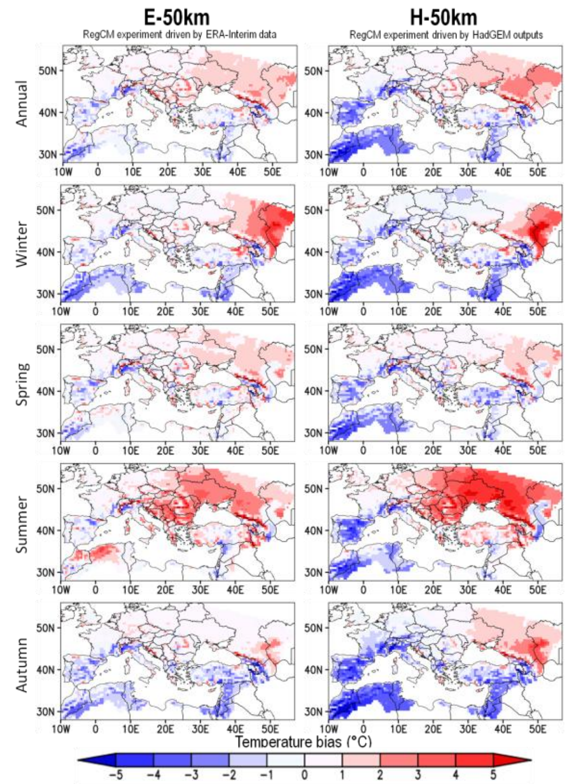


Fig. 4: Annual and seasonal mean temperature biases of the 50-km RegCM simulations, 1981-2000.

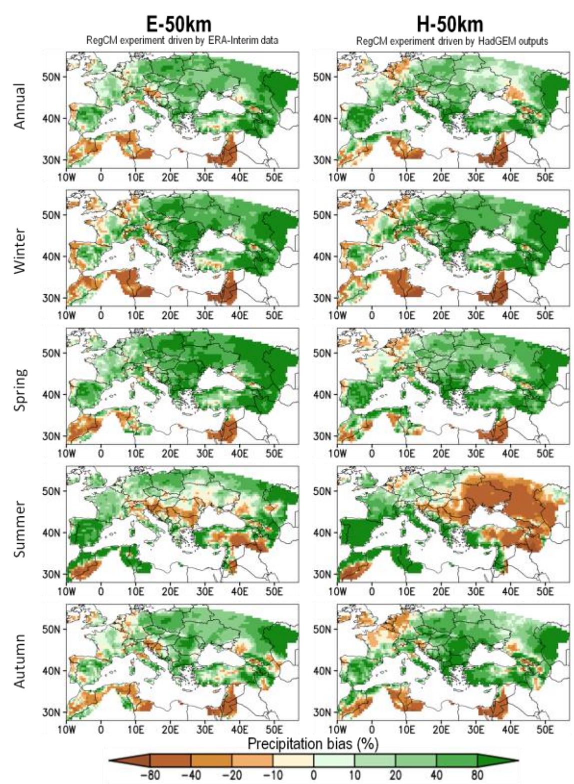


Fig. 5: Annual and seasonal mean precipitation biases of the 50-km RegCM simulations, 1981-2000.

Average annual and seasonal precipitation biases are shown in Fig. 5. Based on the maps precipitation is generally overestimated in the entire domain. However, RegCM outputs suggest drier climatic conditions in Africa and the Middle East. Morover, a large underestimation can be found in the eastern part of the domain, especially, in the East European Plain when the ICBCs are provided by HadGEM2.

Complex evaluation is possible using Taylor diagrams (Taylor, 2001) where standard deviations of simulated and reference data can be compared, and root-mean squared error (RMSE) and correlation coefficient between the two datasets are also indicated. This tool is used in our detailed regional scale analysis for the 10 and 4 subregions in case of the 50-km and 10-km resolution experiment, respectively. Fig. 6 summarizes the results for the 10 subregions both for temperature and precipitation. Evidently, temperature is much more precisely simulated than precipitation. Furthermore, when ERA-Interim reanalysis is used as ICBCs RegCM outputs result in more appropriate reconstruction of recent past climate of all the subregions within the domain than in case of the ICBCs from HadGEM2. Among the subregions, the least successful results are generated for the Balkan Region (according to standard deviation values) and the East European Plain (according to the correlation value).

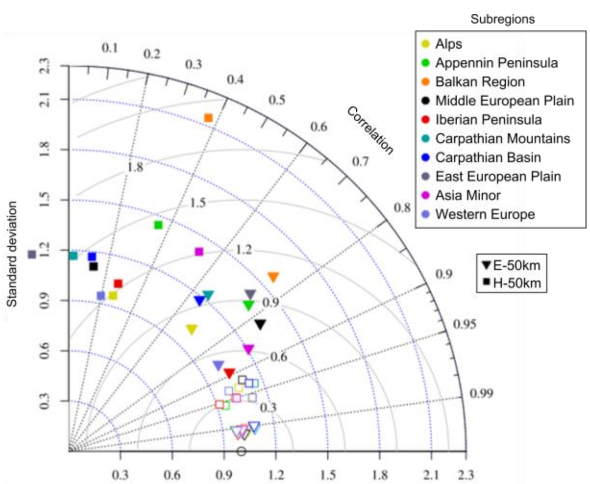


Fig. 6: Taylor-diagram for the time series of temperature (empty symbols), and precipitation (filled symbols) of the 50-km RegCM simulations.

Similarly to the results for the 50 km resolution simulation, the 10 km horizontal resolution model simulation is also evaluated. The average temperature biases are shown in Fig. 7. The annual temperature differences are smaller when the HadGEM2 provided the ICBCs than in case of the ERA-Interim. However, slightly larger underestimation can be seen in winter and autumn for the HadGEM2-driven run than the ERA-Interim-driven run. In general, the temperature of the mountainous regions are underestimated.

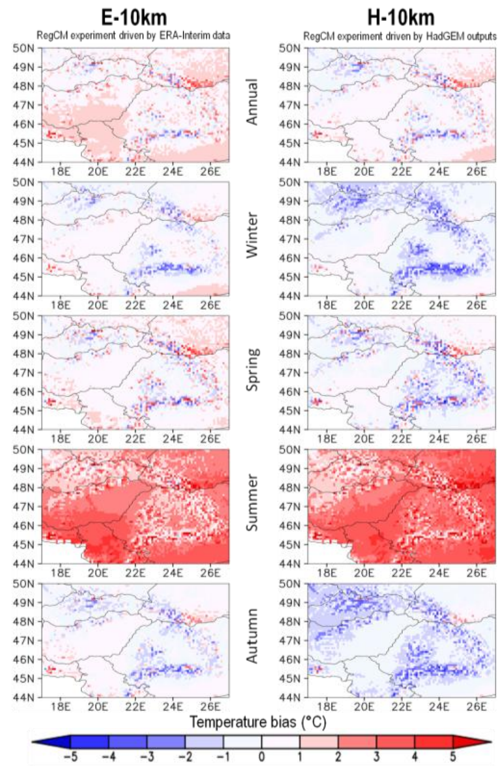


Fig. 7: Annual and seasonal mean temperature biases of the 10-km RegCM simulations over the Carpatclim region, 1981-2000.

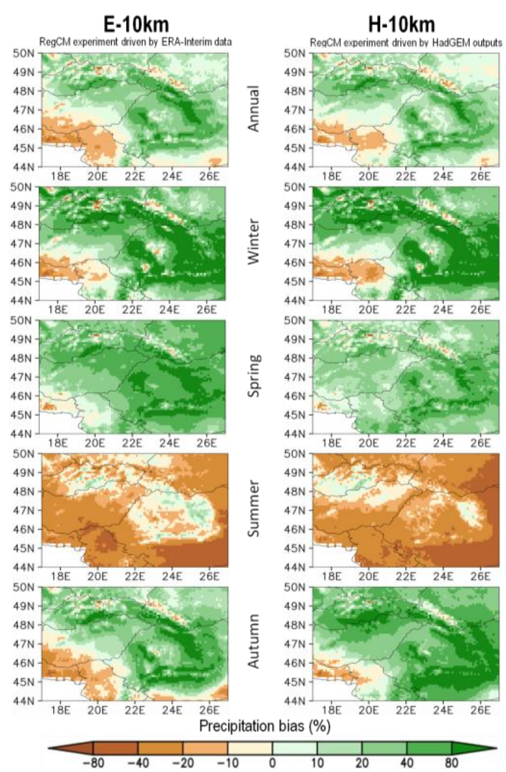


Fig. 8: Annual and seasonal mean precipitation biases of the 10-km RegCM simulations over the Carpatclim region, 1981-2000.

The precipitation bias maps in Fig. 8 suggest that simulated values generally overestimate the reference CarpatClim data, except in summer. Concerning the spatial distribution of bias values, the precipitation conditions in the southwestern part of domain is underestimated in all the four seasons (the least underestimation is in spring) as well, as on annual scale.

Taylor-diagram of the four subregions is presented in Fig. 9, which shows that ERA-Interim-driven RegCM outputs resulted in more precise reconstruction of recent past climatic conditions in all the four subregions than in case of the HadGEM2-driven run.

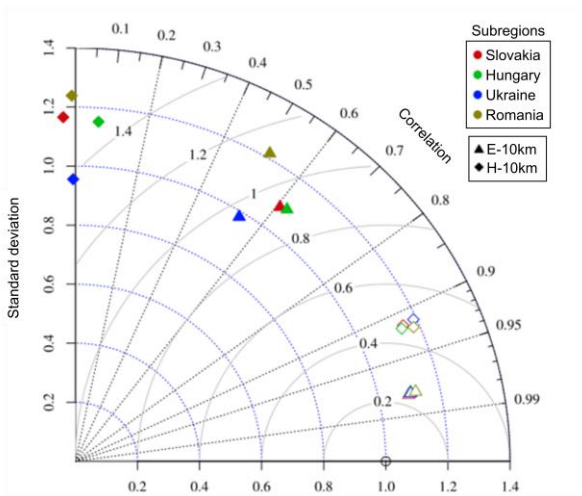


Fig. 9: Taylor-diagram for the time series of temperature (empty symbols), and precipitation (filled symbols).

## 4. PROJECTIONS

Results of the 50 km horizontal resolution climate projection by 2021–2050 and 2071–2100 relative to the 1971–2000 reference period are summarized in Figs. 10 and 11 for temperature and precipitation, respectively.

The projected warming signal is clear in case of both the annual and the seasonal temperature values, which is larger over land than over the sea. In both future periods the largest seasonal warming is estimated in summer.

In general the annual and seasonal mean precipitation is projected to increase in the northern parts of the domain and decrease in the southern regions.

For detailed regional scale analysis Box-Whisker diagrams are used to illustrate the variability of seasonal mean temperature in three different time slices (i.e., 1971-2000, 2021-2050, 2071-2100). Here the results for winter and summer are shown in Fig. 12. The projected warming trends are clearly seen in all the subregions. Moreover, the inter-annual variability of winter mean temperature is larger than that of summer.

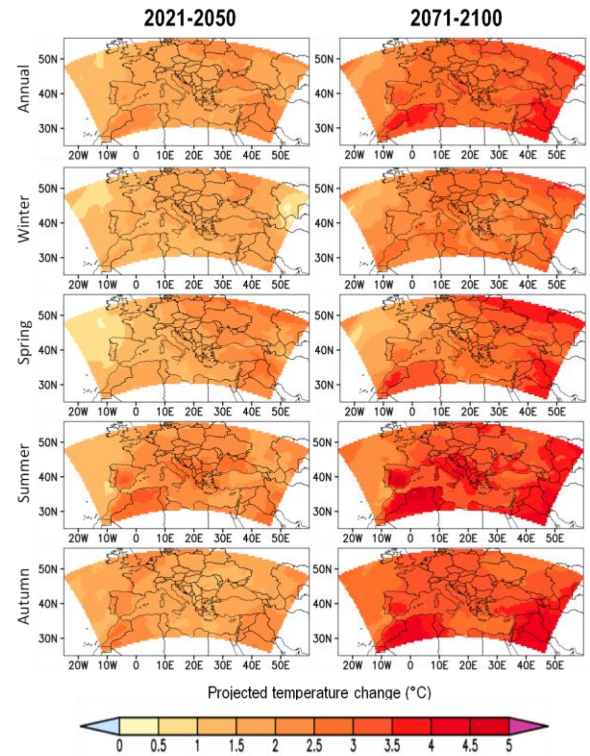


Fig. 10: Projected annual and seasonal mean temperature changes using the RCP4.5 scenario, reference period: 1971-2000.

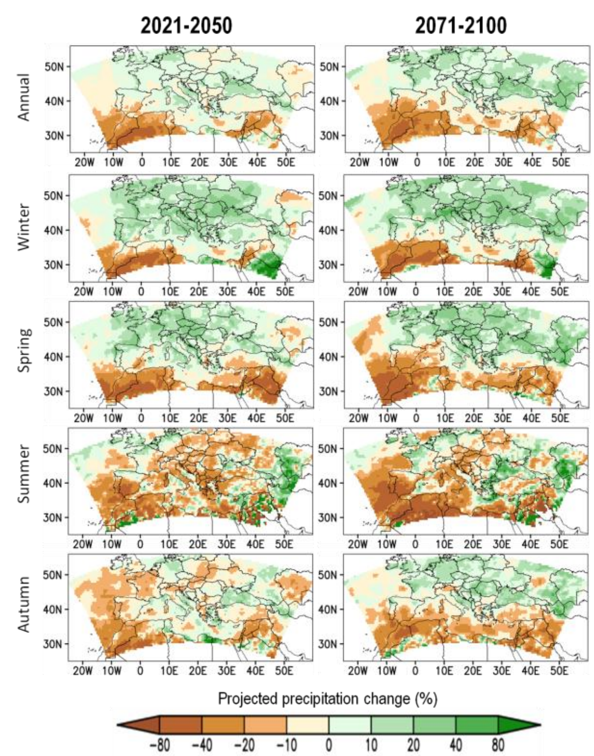


Fig. 11: Projected annual and seasonal mean precipitation changes using the RCP4.5 scenario, reference period: 1971-2000

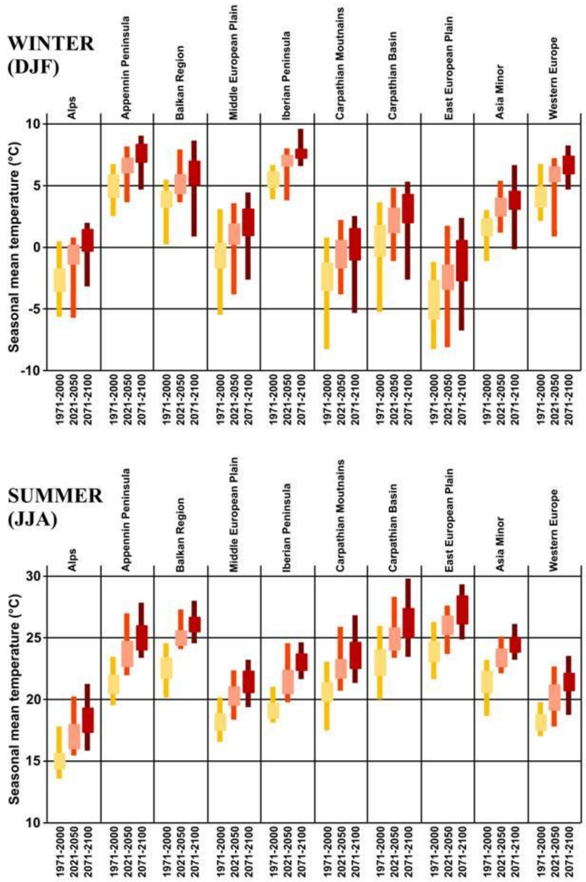


Fig. 12: Box-Whisker diagrams of spatial average values of winter (top) and summer (bottom) mean temperature in the 10 subregions of the MED-44 CORDEX domain. The presented time slices are 1971-2000, 2021-2050, 2071-2100.

Temperature and precipitation projection results for the 10 km horizontal resolution RegCM4.3 simulations focusing to the Carpathian region are shown in Fig. 13.

The projected climate change signal is clear in case of temperature (left panel of Fig. 13). The highest warming (2.5–3 °C) is estimated in summer, in the other seasons the estimated temperate increase is slightly less, only around 2 °C. In case of precipitation (right panel of Fig. 13), regional drying is projected in summer (and in most part of the domain in autumn too), whereas in winter (and in most part of the domain in spring too) wetter conditions are estimated compared to the late 20th century. These opposite projected trends are likely to result in very little changes in the annual mean precipitation, which will not exceed about 12% in the entire Carpathian Region. However, they also highlight the importance of further analysis including precipitation-related extremes (i.e., droughts and excessive rain/snow).

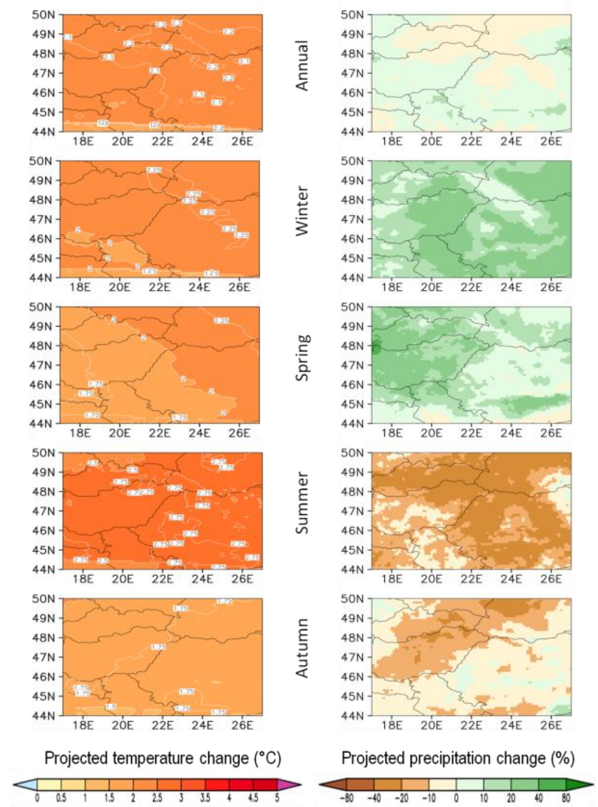


Fig. 13: Projected annual and seasonal mean temperature (left) and precipitation (right) changes using the RCP4.5 scenario, reference period: 1971-2000.

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## REFERENCES


Bartholy, J., Pongrácz, R., Torma, Cs., Pieczka, I., Hunyady, A., 2009: Regional climate model experiments for the Carpathian basin. In: *Proceedings, 89th AMS Annual Meeting*. http://ams.confex.com/ams/pdfpapers/147084.pdf

Dickinson, R., Errico, R., Giorgi, F., Bates, G., 1989: A regional climate model for the western United States. *Clim. Chang.*, 15, 383-422.

Dickinson, R.E., Henderson-Sellers, A., Kennedy, P.J., 1993: Biosphere-atmosphere Transfer Scheme (BATS) Version 1e as Coupled to the NCAR Community Climate Model. *NCAR Technical*

*Note* NCAR/TN-387+STR, DOI: 10.5065/ D67W6959

Elguindi, N., Bi, X., Giorgi, F., Nagarajan, B., Pal, J., Solmon, F., Rauscher, S., Zakey, A., Giuliani, G., 2011: Regional climatic model RegCM user manual version 4.3. 32p. ITCP, Trieste, Italy.

Giorgi, F., 1989: Two-dimensional simulations of possible mesoscale effects of nuclear war fires. 1. Model description. *J. Geophys. Res*., 94, 1127-1144.

Giorgi F., Marinucci M.R., Bates G.T., 1993a: Development of a second generation regional climate model (RegCM2). Part I: Boundary layer and radiative transfer processes. *Mon. Wea. Rev.* 121, 2794-2813.

Giorgi, F., Marinucci, M.R., Bates, G.T., DeCanio, G., 1993b: Development of a second generation regional climate model (RegCM2). Part II: Convective processes and assimilation of lateral boundary conditions. *Mon. Wea. Rev.* 121, 2814-2832.

Giorgi, F., Mearns, L.O., 1999: Introduction to special section: regional climate modeling revisited *J. Geophys. Res.* 104, 6335-6352.

Giorgi, F., Francisco, R., Pal, J., 2003: Effects of a subgrid-scale topography and land use scheme on the simulation of surface climate and hydrology. Part I: Effects of temperature and water vapor disaggregation. *J. Hydrometeor.*, 4(2): 317-333.

Haylock, M.R., Hofstra, N., Klein Tank, A.M.G., Klok, E.J., Jones, P.D., New, M., 2008: A European daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006. *J. Geophys. Res.: Atmospheres*, 113(D20).

Nakicenovic, N., Swart, R., Eds., 2000: *Emissions Scenarios.* A Special Reports of IPCC Working Group III, Cambridge University Press, Cambridge, UK. 570p.

Pal, J.S., Small, E., Elthair, E., 2000: Simulation of regionalscale water and energy budgets: representation of subgrid cloud and precipitation processes within RegCM. *J. Geophys. Res.* 105(29), 567-594.

Pongracz R., Bartholy J., Kovacs G., Torma Cs., 2010: Analysis of simulated mean and extreme climate trends for the Eastern/Central European region based on RegCM outputs using A1B scenario. *90th AMS Annual Meeting*. http://ams.confex.com/ams/pdfpapers/158358.pdf

Somot, S. et al., 2012: The Med-CORDEX initiative: towards fully coupled Regional Climate System Models to study the Mediterranean climate variability, change and impact. *Geophysical Research Abstracts*, 14, 6080).

Szalai, S. et al., 2013: Climate of the Greater Carpathian Region. Final Technical Report. www.carpatclim-eu.org

Taylor, K.E., 2001: Summarizing multiple aspects of model performance in a single diagram. *J. Geophys. Res.: Atmospheres*, 106(D7), 7183-7192.

Torma, Cs., Coppola, E., Giorgi, F., Bartholy, J., Pongracz, R., 2011: Validation of a high resolution version of the regional climate model RegCM3 over the Carpathian Basin. *J. Hydrometeor*., 12, 84-100.

van Vuuren, D.P., Edmonds, J.A., Kainuma, M., Riahi, K., Thomson, A.M., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J.-F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., and Rose, S., 2011: The representative concentration pathways: an overview. *Climatic Change*, 109, 5-31. DOI: 10.1007/s10584-011-0148-z.