

# REGIONAL CLIMATE MODELING STUDY FOR THE CARPATHIAN REGION USING REGCM4 EXPERIMENTS

*PIECZKA I.<sup>1</sup>, BARTHOLY J., PONGRÁCZ R., ANDRÉ K., KIS A., KELEMEN F.D.*

**ABSTRACT.** – Regional climate modeling study for the Carpathian region using RegCM4 experiments. The newest model version of RegCM is adapted with the ultimate aim of providing climate projection for the Carpathian region with 10 km horizontal resolution. For this purpose, first, coarse resolution reanalysis data and global climate model outputs are used to drive 50 km resolution model experiments, from which the outputs are used to provide necessary boundary conditions for the fine scale model runs. Besides the historical runs (for the period 1981-2010), RCP4.5 scenario is also analyzed in this paper for the 21st century. These experiments are essential since they form the basis of national climate and adaptation strategies by providing detailed regional scale climatic projections and enabling specific impact studies for various sectors.

**Keywords:** validation, climate projections, RCP4.5, temperature, precipitation.

## 1. INTRODUCTION

The current study is focusing on regional climate modeling of the Carpathian Region with 10 km horizontal resolution. We aim to evaluate the influence of the coarse resolution driving data, which provide initial and lateral boundary conditions (ICBC) for fine scale model experiments. Besides historical runs, climate projection runs are also planned to complete using new RCP (Representative Concentration Pathway) scenarios (van Vuuren et al. 2011), which estimate the increase of radiative forcing by the end of the 21<sup>st</sup> century relative to the preindustrial conditions. In this paper simulation results using the RCP4.5 scenario (Thomson et al. 2011) is presented for the Carpathian Region. Section 2 provides a general description of the climate model, summarizes the model experiments, and briefly introduces the reference data used for validation. In Section 3 our simulation results are discussed, whereas Section 4 concludes the main findings.

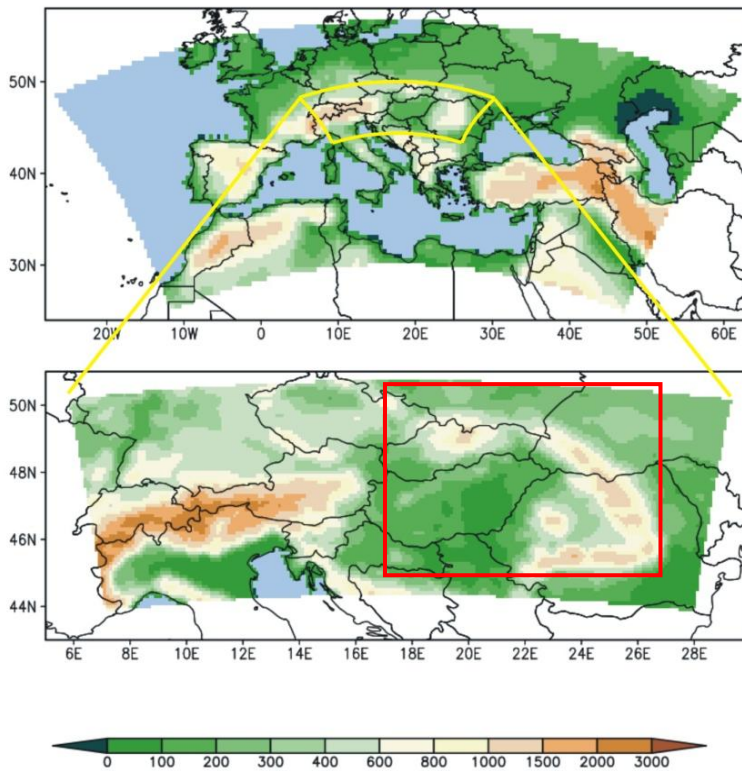
## 2. DATA

The adapted RegCM4 model is a limited-area, hydrostatic, compressible, sigma-p vertical coordinate model maintained at ICTP (International Centre for

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<sup>1</sup> Eötvös Loránd University, Department of Meteorology, Budapest, Hungary  
E-mail: [pieczka@nimbus.elte.hu](mailto:pieczka@nimbus.elte.hu)

Theoretical Physics), Trieste, Italy. Description of model equations and parameterizations can be found in Elguindi et al. (2011) in detail. We have used the model settings agreed as default within the MedCORDEX project (Somot et al., 2012) at 50 km horizontal resolution, with the modification of activating the subgrid Biosphere-Atmosphere Transfer Scheme (BATS) scheme. 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). The 50 km resolution RegCM-outputs serve as an input for further downscaling using 10 km as a horizontal resolution for a smaller domain covering Central Europe with special focus on the Carpathian Region. The topography of the integration domains (after removing the buffer zones) used in the present research can be seen in Fig. 1.



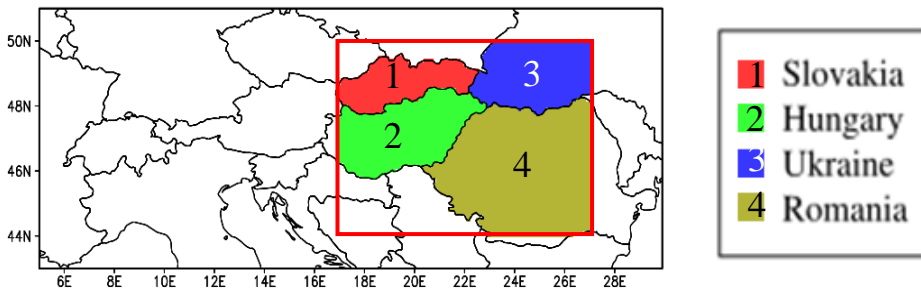
**Fig. 1. Topography of the integration domains. Top: RegCM4.3 with 50 km resolution providing ICBCs for the nested model runs (MedCORDEX domain). Bottom: Integration domain of the nested RegCM4.3 with 10 km resolution (the red box indicates the Carpatclim area). Height is expressed in meters.**

For the purpose of validation we used the 1981–2000 time period from the Carpatclim database. This is a high resolution homogeneous gridded database covering 1961–2010 for the Carpathian Region with  $0.1^\circ$  horizontal resolution,

containing all the major surface meteorological variables (Szalai et al. 2013). Daily temperature and precipitation datasets were separated from the downscaling portal, of which monthly, seasonal, and annual means were calculated for the validation domain (44–50°N, 17–27°E), and compared to the simulated values.

Past climate conditions were simulated for the period 1981–2000 (1980 was used as a spin-up year) with ICBCs from our 50 km horizontal resolution RegCM4.3 run driven by ERA-Interim reanalysis data (available on-line from 1979 to 2014), hence, this experiment is named E-10km. Another simulation, named H-10km, was carried out for the period 1950–2099 (1950 was used as a spin-up year) using the ICBCs from our 50 km horizontal resolution RegCM4.3 run driven by the HadGEM2 (Hadley Centre Global Environment Model version 2, Collins et al., 2011) global climate model (GCM). From 1950 to 2005 historical forcings were taken into account, whereas from 2006 to 2099 the RCP4.5 scenario (Thomson et al., 2011) was applied.

In case of the validation, instead of presenting individual bias maps for temperature and precipitation, we evaluate the results of the model simulations using Taylor-diagrams (Taylor, 2001), which contains complex statistical information including standard deviation, correlation coefficient, and root mean squared error (RMSE) compared to the reference data. For this regional scale analysis four main subregions were defined, namely, Slovakia, Hungary, Ukraine, and Romania (Fig. 2).

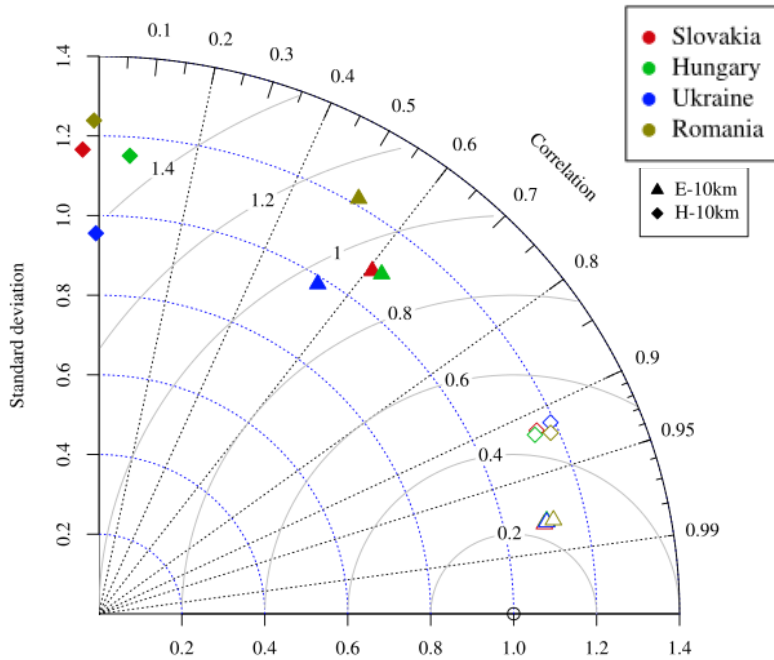


**Fig. 2.** *Subregions within the integration domain defined for regional scale analysis*

### 3. RESULTS

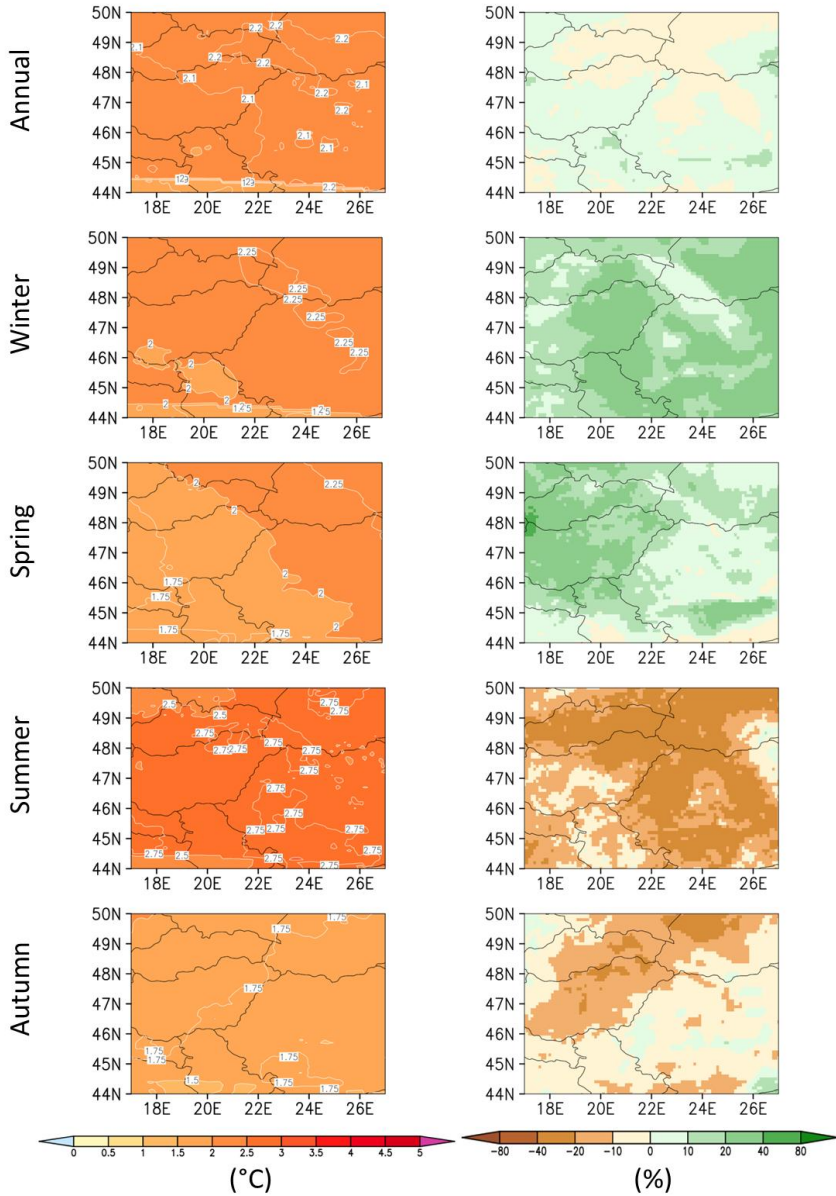
The complex Taylor-diagram in Fig. 3 suggests that the RegCM simulations are generally able to well reproduce the major statistical characteristics of temperature in all the four subregions. The standard deviations of simulated temperature are close to measured values, the correlation coefficients are above 0.9 in case of both experiments, and the RMSE values are quite small. E-10km results perform better than H-10km results because driving data for E-10km are based on ERA-Interim, which are highly related to the reference data (i.e., measurements). In case of precipitation the influence of the driving data is higher than in case of the

temperature. For the different subregions the model exhibits different skills in simulating precipitation, which can be due to the high spatial and temporal variabilities of this climatic element. Correlation coefficients are similar for the different subregions, however, standard deviation fits the best to the measurements in case of the Ukraine, for the other three subregions it is somewhat overestimated.



**Fig. 3. Regional validation of temperature (empty symbols) and precipitation (filled symbols) using Taylor-diagram for the 1981–2000 period.**

Results of the climate projection by 2021–2050 relative to the 1971–2000 reference period are summarized in Fig. 4 for annual and seasonal mean temperature and precipitation. The projected climate change signal is clear in case of temperature. 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, 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 20<sup>th</sup> 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. 4.** Simulated annual and seasonal mean changes of temperature (left) and precipitation (right) by 2021–2050 (reference period: 1971–2000)

#### 4. CONCLUSIONS

On the basis of our study it can be concluded that RegCM is sensitive to the driving data, as the completed experiments with ERA-Interim and HadGEM2 outputs as ICBCs resulted in somewhat different statistical characteristics and bias

patterns. However, the model is able to acceptably simulate the past climatology of the area when using “perfect” boundary conditions (i.e., ICBCs from a reanalysis).

For the 2021–2050 period the model simulation projects warmer conditions throughout the whole year, less precipitation in summer and autumn, and more precipitation in winter and spring.

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