13A.03 REGIONAL CLIMATE MODEL EXPERIMENTS FOR THE CARPATHIAN BASIN

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1. INTRODUCTION

The results from coarse resolution global climate models (GCM) can only be considered as a first-guess of regional climate change consequences of global warming. Regional climate models (RCM) nested in GCMs may lead to better estimations of future climate conditions in the European subregions since the horizontal resolution of these RCMs is much finer than the GCMs (IPCC, 2007). Expected regional climate change focused to the Carpathian basin (located in Central/Eastern Europe) is modelled by four different RCMs (Szepszo et al., 2008). Two of them (RegCM and PRECIS) are run by the Department of Meteorology, Eotvos Lorand University, Budapest (Bartholy et al., 2006; Torma et al., 2008). The other two RCMs are run by the Hungarian Meteorological Service (Csima and Horanyi, 2008, Szepszo and Horanyi, 2008): ALADIN (developed by the Meteo-France) and REMO (developed by the Max Planck Institute, Hamburg).

The present paper discusses the results from the regional climate modeling experiments. First, control run (1961-1990) of the RegCM model is analyzed, followed by the analysis of the control experiment using the PRECIS model. In the validation, seasonal temperature and precipitation mean values are used. Finally, the main conclusions of the paper are summarized in the last section.

2. REGIONAL CLIMATE MODELLING USING REGCM

Model RegCM was originally developed by Giorgi et al. (1993a, 1993b) and then modified, improved and discussed by Giorgi and Mearns (1999) and Pal et al. (2000). The RegCM model (version 3.1) is available from the Abdus Salam International Centre for Theoretical Physics (ICTP). The dynamical core of the RegCM3 is fundamentally equivalent to the hydrostatic version of the NCAR/Pennsylvania State University mesoscale model MM5 (Grell et al., 1994). Surface processes are represented in the model using the Biosphere-Atmosphere Transfer Scheme, BATS (Dickinson et al., 1993). The non-local vertical diffusion scheme of Holtslag et al. (1990) is used to calculate the boundary layer physics. In addition, the physical parametrization is mostly based on the comprehensive radiative transfer package of the NCAR Community Climate Model, CCM3 (Kiehl et al., 1996). The mass flux cumulus cloud scheme of Grell (1993) is used to represent the convective precipitation with two possible closures: Arakawa and Schubert (1974) and Fristch and Chappell (1980). The selected model domain covers Central/Eastern Europe centering at 47.5°N, 18.5°E and contains 120x100 grid points with 10 km grid spacing (Fig. 1). The target region is the Carpathian Basin with the 45.15°N, 13.35°E southwestern corner and 49.75°N, 23.55°E northeastern corner.

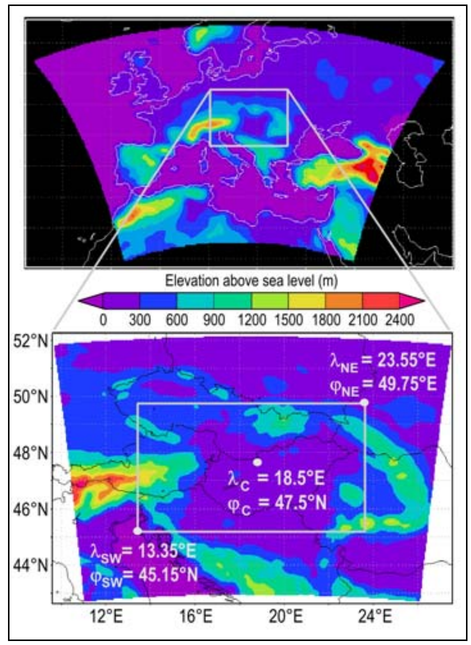

Fig. 1. Topography of the selected Central European domain used in model RegCM.

Model RegCM may use initial and lateral boundary conditions from global analysis dataset, the output of a GCM or the output of a previous RegCM simulation. In our experiments these driving datasets are compiled from the Centre for Medium-range Weather Forecasts (ECMWF) ERA-40 reanalysis database (Gibson et al., 1997) using 1° horizontal resolution, and in case of scenario runs (for 3 time slices: 1961-1990, 2021-2050, and 2071-2100, these are not presented in this paper since they are not fully completed yet) the ECHAM5 GCM using 1.25° spatial resolution. Several numbers of vertical levels (14, 18 and 23) may be used in the RegCM experiments, on the basis of our test runs, we selected 18 vertical levels in the 30-year long model experiments.

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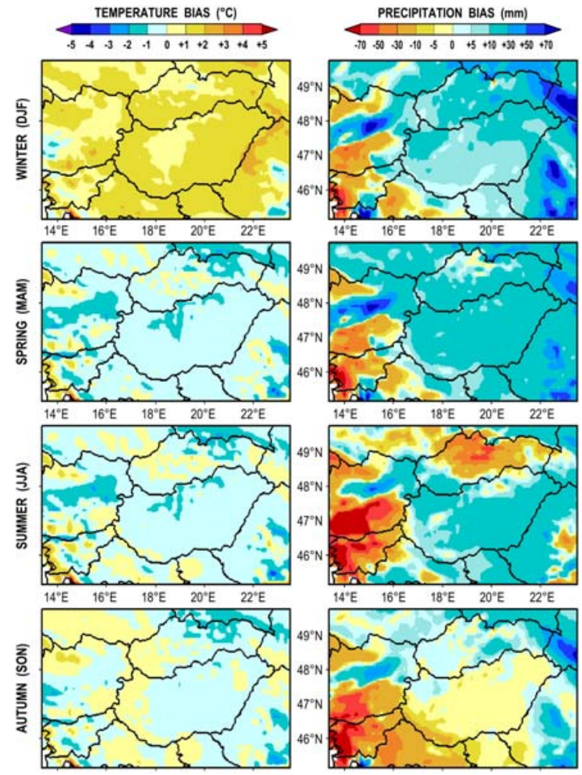

Fig. 2. Results of control runs (1961-1990) for Hungary: difference between RegCM and CRU seasonal mean data.

Fig. 2 compares the simulated and observed seasonal mean temperature (on the left) and precipitation (on the right). The observed data is represented by the CRU (Climatic Research Unit of the University of East Anglia) TS 1.0 (New et al., 1999, 2000) datasets. In case of temperature, the annual mean is very well reproduced by the RegCM simulations (the spatially averaged bias is 0.1°C), as well, as the seasonal mean in spring, summer, and autumn (the slight underestimation is between 0 and 1°C in most of the grid points, which is not significant at 0.05 level). The largest bias values are detected in winter, where the mean is slightly overestimated by about 0-2°C. Statistical hypothesis tests suggest that the winter temperature bias is not significant only in the middle part of Hungary. Larger differences can be detected in case of precipitation fields. Seasonal precipitation in the Carpathian Basin is overestimated by the RegCM simulations in winter, spring, and summer, while it is slightly underestimated in autumn (when the bias is not significant at 0.05 level inside the Hungarian borders). The smallest positive bias is found in winter (0-20 mm with not significant values in the southern part of Hungary), and the largest in spring (10-30 mm). Compared to other RCM simulation (e.g., those made in the frame in the European project PRUDENCE, Jacob et al., 2007), these bias values are acceptable, and can be considered quite good (Torma et al., 2008).

3. REGIONAL CLIMATE MODELLING USING PRECIS

The installation and the adaptation of the regional climate model PRECIS at the Department of Meteorology, Eotvos Lorand University (Budapest, Hungary) has started in 2004. At the beginning of our studies, version 1.3 was used but the results presented in this paper are from an updated model version (1.4.8). The PRECIS is a high resolution limited area model with both atmospheric and land surface modules. The model was developed at the Hadley Climate Centre of the UK Met Office (Wilson et al., 2005), and it can be used over any part of the globe (e.g., Hudson and Jones, 2002, Rupa Kumar et al., 2006, Taylor et al., 2007, Akhtar et al., 2008). The PRECIS regional climate model is based on the atmospheric component of HadCM3 (Gordon et al., 2000) with substantial modifications to the model physics (Jones et al., 2004). The atmospheric component of PRECIS is a hydrostatic version of the full primitive equations, and it applies a regular latitude-longitude grid in the horizontal and a hybrid vertical coordinate. The horizontal resolution can be set to 0.44°x0.44° or 0.22°x0.22°, which gives a resolution of ~50 km or ~25 km, respectively, at the equator of the rotated grid (Jones et al., 2004). In our studies, we used the finer horizontal resolution for modeling the Central European climate. Hence, the target region contains 123x96 grid points, with special emphasis on the Carpathian basin and its Mediterranean vicinity containing 105x49 grid points (Fig. 3). There are 19 vertical levels in the model, the lowest at ~50 m and the highest at 0.5 hPa (Cullen, 1993) with terrain-following σ-coordinates (σ = pressure/surface pressure) used for the bottom four levels, pressure coordinates for the top three levels, and a combination in between (Simmons and Burridge, 1981). The model equations are solved in spherical polar coordinates and the latitude-longitude grid is rotated so that the equator lies inside the region of interest in order to obtain quasi-uniform grid box area throughout the region. An Arakawa B grid (Arakawa and Lamb, 1977) is used for horizontal discretization to improve the accuracy of the split-explicit finite difference scheme. Due to its fine resolution, the model requires a time step of 5 minutes to maintain numerical stability (Jones et al., 2004). In the post processing of the RCM outputs, daily mean values are used.

In case of the control period (1961-1990), the initial and the lateral boundary conditions for the regional model are taken from (i) the ERA-40 reanalysis database (Gibson et al., 1997) using 1° horizontal resolution, compiled by the European Centre for Medium-range Weather Forecasts (ECMWF), and (ii) the HadCM3 ocean-atmosphere coupled GCM using ~150 km as a horizontal resolution. For the validation of the PRECIS results CRU TS 1.0 (New et al., 1999, 2000) datasets are used (as in case of the RegCM validation).

Fig. 3. Topography of the selected Central European domain used in model PRECIS.

During the validation process, we analyzed monthly, seasonal, and annual temperature mean values and precipitation amounts for the control period. Fig. 4 and Fig. 5 summarizes the seasonal differences between the simulated (PRECIS outputs) and the observed (CRU data) values in case of temperature and precipitation, respectively. Seasonal bias fields are presented on the left, while the frequency distribution of the difference values determined for the Hungarian grid points are shown on the right.

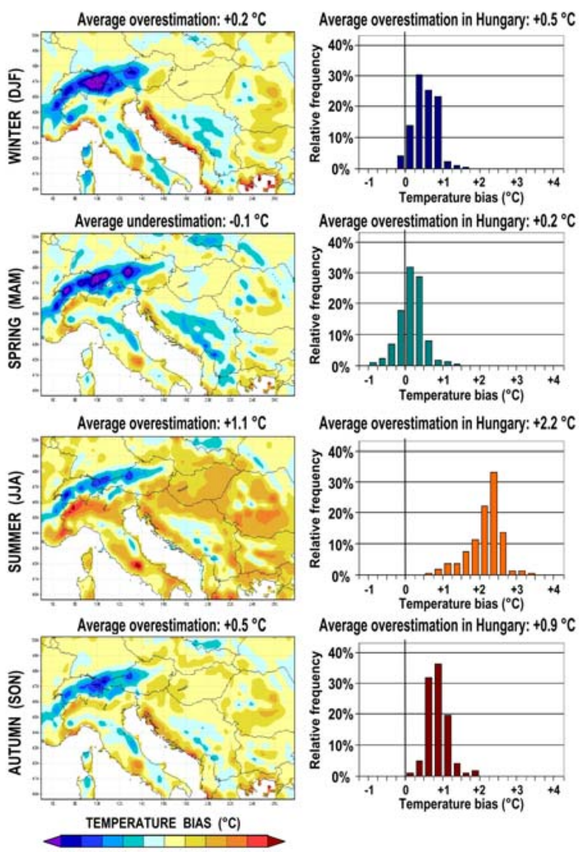

Fig. 4. Results of control runs (1961-1990) for Hungary: difference between PRECIS and CRU seasonal mean temperature data.

On the basis of the maps shown in Fig. 4, the seasonal mean temperature is well reproduced by the regional model in the Carpathian basin, the spatially averaged overestimation is less than 2.2 °C. Large overestimation can be seen in the high-elevated regions, especially, in the Alps (in winter and spring, the simulated mean temperature can be larger than the observed value by more than 5 °C). In Hungary, the largest overestimation is found in summer (+2.2 °C on average). According to the histograms the smallest difference values close to 0 °C are determined in spring (0.2 °C average overestimation), but also, the winter and the autumn daily temperature is overestimated by less than 1 °C in Hungary on average. Statistical hypothesis tests accomplished for each grid points show that in case of Hungary the bias values in spring and autumn are not significant at 0.05 level. The winter temperature bias values are also not significant at 89% of the country area. Only the summer bias values are significantly large at 0.05 level.

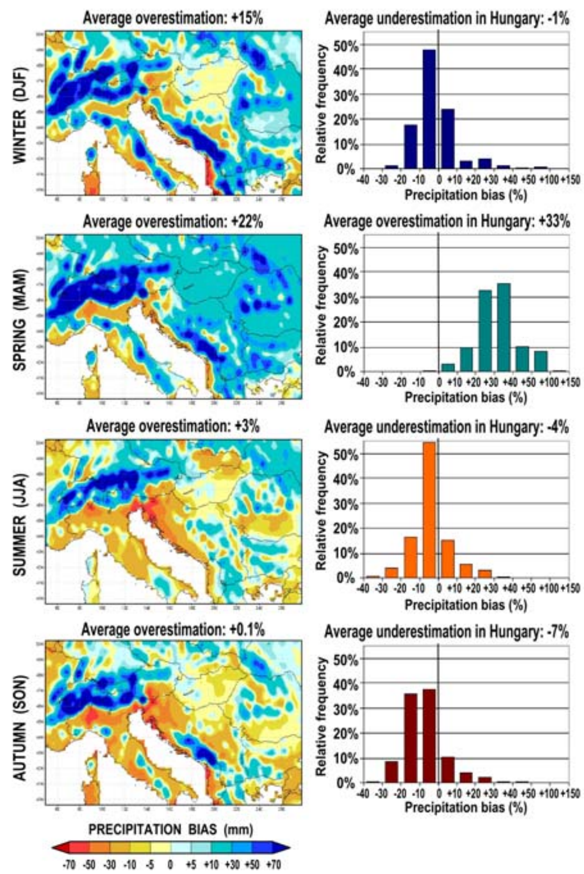

Fig. 5. Results of control runs (1961-1990) for Hungary: difference between PRECIS and CRU seasonal mean precipitation data.

Precipitation is far more variable both in time and in space than temperature. The spatially averaged precipitation is overestimated in the entire model domain, especially, in spring and winter (by 22% and

15%, respectively). According to the maps shown in Fig. 5, the precipitation of the high-elevated regions is overestimated (by more than 30 mm in each season), while the overestimation of the seasonal precipitation occurring in the plain regions is much less in spring than in the mountains. In summer and in autumn the precipitation is underestimated in the lowlands. The underestimation is larger in the southern subregions than in the northern part of the domain. In case of Hungary, the spring precipitation is overestimated (by 33% on average), while in the other three seasons the precipitation is slightly underestimated (by less than 10% on average) in the country. Inside the area of Hungary a meridional structure can be detected in winter, summer and autumn, namely, the precipitation in the western part is slightly overestimated, while in the eastern part it is underestimated. The precipitation bias values are not significant in most of Hungary in winter, summer, and autumn at 0.05 level. However, statistical hypothesis tests suggest that the spring bias values are significantly large (at 95% of all the gridpoints located inside the Hungarian borders), the bias is not significant only in the northeastern part of the country.

Temperature and precipitation bias fields of the PRECIS simulations can be considered acceptable if compared to other European RCM simulations (Jacob et al., 2007, Bartholy et al., 2007). Therefore, model PRECIS, as well, as RegCM can be used to estimate future climatic change of the Carpathian Basin.

4. CONCLUSIONS

In this paper, results of two regional climate models (RegCM and PRECIS) are discussed and compared for the Carpathian basin and its vicinity in the 1961-1990 reference period. In case of model PRECIS, in addition to the control experiment, the A2 scenario run is also completed for 2071-2100. Based on the results presenting here, the following main conclusions can be drawn.

1. In general, the seasonal mean temperature fields are slightly underestimated by the RegCM simulation (except winter) in Hungary and they are overestimated by the PRECIS simulation. The largest bias values are found in winter in case of RegCM (when the average overestimation is 1.3 °C), and in summer in case of PRECIS (when the average positive bias is 2.2 °C).

2. The seasonal precipitation fields for Hungary are usually overestimated by the RegCM simulations (except in autumn) with the largest bias values in spring. The seasonal precipitation in Hungary is generally slightly underestimated by the PRECIS simulation, except spring when the precipitation is overestimated significantly.

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