ANALYSIS OF CLIMATE CHANGE SCENARIOS FOR THE CARPATHIAN BASIN BASED ON NUMERICAL SIMULATIONS OF THE REGIONAL CLIMATE MODEL PRECIS

Theses of the PhD dissertation

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INVESTIGATED PROBLEMS, AIMS

Based on the assessments of the Intergovernmental Panel on Climate Change it is very unlikely, that the observed warming of the 20th century is entirely due to natural causes. The detected changes are very likely to be caused by anthropogenic activity. Beyond the increase of global mean temperature, the regional differences can also be seen from observational data.

For Hungary, statistically significant changes were detected in the observed temperature time series. The annual mean temperature has increased by almost 1 °C from 1901 to 2009. The warming rate in our region rises, as it can be seen from the analysis of different time slices. The precipitation trends are less clear: depending on the evaluated period trends can be either increasing or decreasing for the same season, and the changes are rarely statistically significant.

Climate change research is essential in Hungary because the Carpathian Basin is located at the intersection of regions with oceanic, continental, and mediterranean climate, therefore, even a moderate change may cause shift of climatic belts and can result in major changes in the climate of Hungary.

Global climate models are widely used to estimate the future climate change; however, for regional scale analysis their coarse resolution limits their applicability in assessment of the regional consequences of global warming. Therefore, to quantify the possible regional changes, the use of downscaling methods is needed.

The aim of my doctoral research was to produce and analyze climate change scenarios for the Carpathian Basin (with special focus on Hungary) using the PRECIS fine-resolution regional climate model (RCM). To validate the model and test its sensitivity three simulations were accomplished for the period 1961–1990. To analyze future changes and quantify uncertainties, the emission scenarios A2, A1B, and B2 were used. The results serve as essential input information for further studies in climate change adaptation and mitigation, and for determining possible national strategies.

APPLIED METHODOLOGY

In the presented studies after completing climate simulations with the PRECIS dynamical RCM using 25 km horizontal resolution, the outputs were statistically analyzed. The evaluation was accomplished by applying ensemble technique, namely, considering three different emission scenarios. This is an internationally recognized and novel approach in Hungary. The possible regional climate change focused on the Carpathian Basin is modelled by four different RCMs adapted in Hungary – three of them were run using A1B scenario only. PRECIS experiments are unique due to the additional two scenarios evaluated in the frame of this doctoral research.

In order to decide whether simply the finer resolution through interpolation or also the more accurate parameterizations of the physical processes accounts for the added value of the PRECIS regional model results compared to the driving global model outputs, the so-called Added Value Index (AVI) was calculated both for temperature and precipitation. AVI analysis suggests that the regional model significantly improves the precipitation results of the global model.

Since the statistical distribution of daily temperature values was not simulated sufficiently (although bias of the mean temperature is considered acceptable), a correction method based on monthly quantile matching has been applied. The use of the approach did not result in significant differences in the projected mean changes; however, it plays an important role in case of climate indices.

Differences between individual regions are illustrated by maps including the Carpathian Basin both for the validation of the model and the projected changes. Furthermore, the averages calculated from gridpoints located in Hungary are presented in tables and graphs. Projected changes of climate indices are also analyzed because from the viewpoint of adaptation studies they are considered more important than the projected mean changes of climatic variables (e.g., temperature and precipitation).

RESULTS AND CONCLUSIONS

Climate simulations for the Carpathian Basin have been completed using the PRECIS RCM with 25 km horizontal resolution. Based on the results the following main conclusions can be drawn:

(1) Evaluation of AVI clearly showed that due to the more detailed parameterization of physical processes the PRECIS model outputs provide useful additional information compared to the driving global model outputs, especially, in case of precipitation, which justifies the use of PRECIS in our region.

(2) Validation of model results has been carried out for 1961–1990 as the reference period. Among the three completed PRECIS experiments the most precise reconstruction of measurements is naturally in case of the simulation driven by the ERA-40 database. This suggests that the model is able to realistically represent the climate of the Carpathian Basin if accurate input data is provided.

(3) The mean seasonal errors compared to E-OBS data are mostly within ±1 °C and ±10 mm/month for the 1961–1990 period in all of the three model runs. The overestimation is larger than this only in case of summer temperature (2–3 °C) and spring precipitation (18–21 mm/month). Errors with the same order of magnitude were found when using ALADIN, RegCM and REMO models, thus, PRECIS is acceptable to analyze the climate of our region.

(4) Although the model simulates the mean values correctly, the distribution of raw daily temperature values differs significantly from the distribution derived from control measurements. Therefore, in order to analyze climate indices, a bias correction was necessary. For this purpose a correction method based on monthly quantile matching was applied. The resulted corrected data enabled to perform an extreme index analysis. The influence of this bias correction on mean changes is small, typically less than 0.1 °C.

(5) To quantify uncertainties due to anthropogenic activity simulations with three different emission scenarios (namely, A2, A1B, and B2) were completed for the end of the century. Since the results of these scenarios differ mainly on long term (e.g., on century scale), that is why for the near future it is sufficient to complete only one selected scenario experiment (here, A1B scenario).

(6) The simulations clearly project annual, seasonal and monthly mean temperature increase for the 21st century in the Carpathian Basin. In all the four seasons and the two different periods (i.e., 2021–2050 and 2071–2100) significant and nearly uniform warming is projected at 0.05 level in the country.

(7) The variability between the different emission scenarios is around 1 °C, except in summer, when it is doubled. The higher the estimated CO_2 concentration level in the scenario, the larger the amplitude of the projected warming.

(8) Not only the mean climatic conditions are likely to change, but also the distribution of the daily (and monthly) mean temperature tends to be modified, implying more frequent warm and hot periods and greater record hot conditions, and fewer cold periods than in the 1961–1990 reference period.

(9) The projected precipitation change involves more uncertainty than temperature change.

(10) Unlike in case of temperature, there is no clear connection between the projected regional precipitation change and the estimated atmospheric CO_2 level of the applied scenarios.

(11) According to the PRECIS simulations the annual distribution of monthly mean precipitation is very likely to change: in summer the precipitation is projected to decrease, while in winter to increase.

(12) Significant drying is projected in the region in summer. The annual number of wet days is likely to decrease, and in the meantime the largest length of consecutive dry days (CDD) is estimated to increase, thus a strengthening of drought and same drying tendency can be expected, which is very unfavorable for agriculture.

(13) Weather conditions associated with heavy precipitation are projected to clearly decrease in summer in all three simulations.

The database including numerous meteorological variables from PRECIS runs and the results of the presented studies can serve as an important basis for further impact studies to prepare for and adapt to possible climate change in the future.

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