Simulated regional climate change in the Carpathian Basin using ENSEMBLES model simulations

Judit BARTHOLY, Rita RONGRÁCZ, Erika MIKLÓS, Anna KIS

Department of Meteorology, Eötvös Loránd University, BUDAPEST, H-1117, Pázmány Péter st. 1/a. HUNGARY
E-mails: bari@ludens.elte.hu, prita@elte.hu, miklosera@yahoo.com, kisanna0610@gmail.com

ABSTRACT

Spatial resolution of global climate models (GCMs) are inappropriate to describe regional climate processes; therefore, GCM outputs may be misleading to compose regional climate change scenarios for the 21st century. In order to provide better estimations for regional climate parameters, fine resolution regional climate models (RCM) can be used. RCMs are limited area models nested in GCMs, i.e., the initial and the boundary conditions of RCMs are provided by the GCM outputs. In order to estimate the regional climate change expected in the Carpathian Basin located in Central/Eastern Europe, outputs from several RCMs (from the completed European project ENSEMBLES) are summarized and analyzed using A1B scenario. For the selected target region, composite maps of expected change in temperature and precipitation are generated using the RCM simulations (with 25 km spatial resolution) for the periods of 1961-1990 (as the reference period), 2021-2050, and 2071-2100.

In order to estimate the bias of the different RCMs, ERA-40 driven runs are compared to the so-called E-OBS datasets containing daily temperature and precipitation values. Then, for the evaluation of annual, seasonal, and monthly expected climatic changes, GCM-driven runs of the reference and the future periods are compared.

The results suggest that the temperature of the selected region is expected to increase in the whole year. This warming is about 1-2 °C, and 3-4 °C for 2021-2050, and 2071-2100, respectively. In case of precipitation, the annual sum is not expected to change significantly in the Carpathian Basin. The winter and autumn precipitation is likely to increase while summer and sometimes precipitation is projected to decrease during the 21st century.

Experiments used in the analysis

The table lists the participating institutes, their RCMs, the driving GCMs, and the integration periods

Institute	Global model	Regional model	Integration period
CNRM (Centre National de la Recherche Scientifique)	ARPEGE_RM.1	ALADIN	1951-2100
KNMI (Royal Netherlands Meteorological institute)	ECHAM5-r3	RACMO	1951-2100
SMHI (Swedish Meteorological and Hydrological Institute)	ECHAM-r1 HadCM3Q3	RCA RCA	1951-2100 1951-2100
MPI (Max-Planck-Institut für Meteorologie)	ECHAM-r3	REMO	1951-2100
C4I (Community Climate Change Consortium)	HadCM3Q16	RCA3	1951-2100
HC (Hadley Centre, United Kingdom Met Office)	HadCM3Q0	HadRM3Q0	1951-2100
ETHZ (Swiss Federal Institute of Technology Zurich)	HadCM3Q0	CLM	1951-2100
DMI (Danish Meteorological Institute)	ARPEGE ECHAM5-r3	HIRHAM DMI-HIRHAM5	1951-2100 1951-2100
ICTP (International Centre of Theoretical Physics)	ECHAM5-r3	RegCM	1951-2100

Project ENSEMBLES (http://ensembles-eu.metoffice.com)

Funded by the EU 6th framework program during 2004-2009

Participants: 66 institutes from 20 countries

Applied scenario: SRES A1B (estimated CO_2 level by 2050: 532 ppm, by 2100: 717 ppm based on Nakicenovic & Swart, 2000)

Outputs we used in the current analysis: monthly average temperature, monthly precipitation sum

Target period in the current analysis: 1951-2100

Reference period: 1961-1990

Horizontal resolution of RCMs: 25km

Target area of the current analysis: Carpathian basin (Hungary)

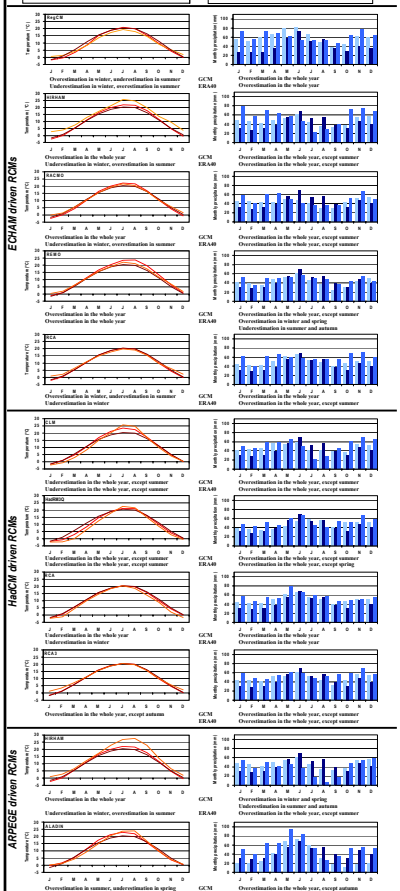
Driving GCMs: ECHAM (MPI)
HadCM3Q (HC)
ARPEGE (CNRM)

VALIDATION OF THE RCM RESULTS (Reference period: 1961-1990)

RCM simulations have been evaluated for both experiments driven by GCM and ECMWF ERA40 (Uppala et al., 2005) reanalysis. The simulated time series have been compared to the E-OBS database (Haylock et al., 2008), which is a daily gridded observational dataset containing precipitation and temperature for entire Europe. The results provide information on the regional climate model performances reconstructing the past climatic conditions.

AVERAGE MONTHLY TEMPERATURE, 1961-1990 — ERA40 driven RCM | GCM driven RCM | E-OBS control

AVERAGE MONTHLY PRECIPITATION, 1961-1990 — ERA40 driven RCM | GCM driven RCM | E-OBS control

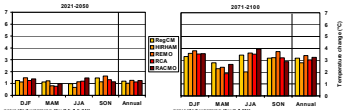


SUMMARY OF PROJECTED CLIMATE CHANGE BY 2021-2050 AND 2071-2100 IN THE CARPATHIAN BASIN, FOCUSING TO HUNGARY

Projected annual and seasonal temperature and precipitation changes are summarized for the middle and the end of the 21st century (relative to the reference period: 1961-1990).
The results are grouped according to the driving GCMs, and the spatial distribution of seasonal temperature and precipitation changes are shown as the composite of the each RCM results in the group.
All projected temperature changes are significant at 0.05 level using t-test, while in case of precipitation significant changes are indicated by * near the column.

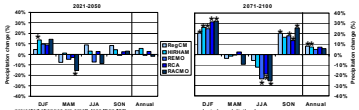
ECHAM driven RCMs

SEASONAL AND ANNUAL TEMPERATURE CHANGE PROJECTED FOR HUNGARY



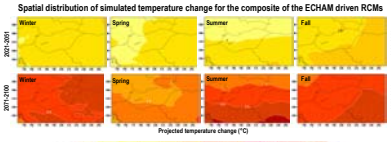
- projected warming (by 0.3-1.5 °C)
- the largest projected increase: in autumn (exceeding 1 °C)
- projected warming (by 2-4 °C)
- the largest projected increase: in winter (exceeding 3.2 °C)

SEASONAL AND ANNUAL PRECIPITATION CHANGE PROJECTED FOR HUNGARY

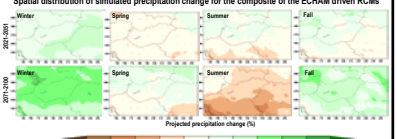


- projected changes are smart, less than 10%
- the largest projected precipitation change is in winter (by 5-15%)
- projected precipitation increase: winter (the largest changes) and autumn
- projected precipitation decrease: summer (larger) and spring (slight)

Spatial distribution of simulated temperature change for the composite of the ECHAM driven RCMs

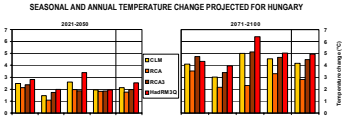


Spatial distribution of simulated precipitation change for the composite of the ECHAM driven RCMs



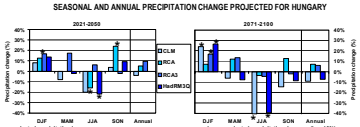
HadCM3Q driven RCMs

SEASONAL AND ANNUAL TEMPERATURE CHANGE PROJECTED FOR HUNGARY



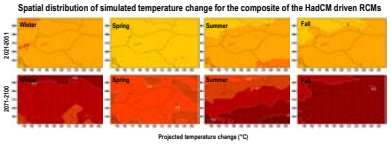
- projected warming (by 1-2.5 °C)
- the largest increase: winter and summer (exceeding 2 °C)
- projected warming (by 2-5 °C)
- ETHZ projects larger increase than SMHI
- the largest increase: summer (ETHZ, by 5 °C) and winter (SMHI, by 3.5 °C)

SEASONAL AND ANNUAL PRECIPITATION CHANGE PROJECTED FOR HUNGARY

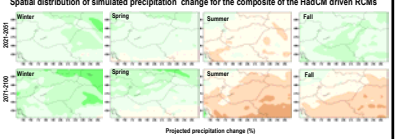


- projected precipitation increase: winter (by ~10%), autumn (ETHZ: by ~5%, SMHI: by ~25%)
- projected precipitation decrease: summer (by 15-20%), spring (by less than 10%)
- annual sum: projected precipitation decrease (by ~10%)
- mostly slight changes (not exceeding 10%), except summer in case of SMHI (~30% decrease is projected)

Spatial distribution of simulated temperature change for the composite of the HadCM driven RCMs

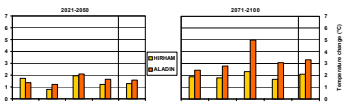


Spatial distribution of simulated precipitation change for the composite of the HadCM driven RCMs



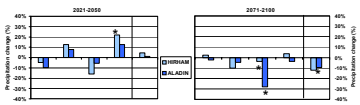
APREGE driven RCMs

SEASONAL AND ANNUAL TEMPERATURE CHANGE PROJECTED FOR HUNGARY



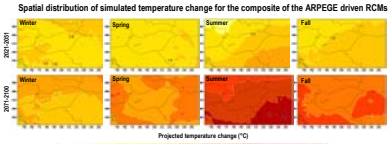
- projected warming (by 1-2 °C)
- the largest increase: in summer (by 2 °C)
- projected warming (by 2-5 °C)
- CNRM projects larger increase than DMI
- the largest increase: in summer (DMI: by 2.2 °C, CNRM: by 5 °C)

SEASONAL AND ANNUAL PRECIPITATION CHANGE PROJECTED FOR HUNGARY

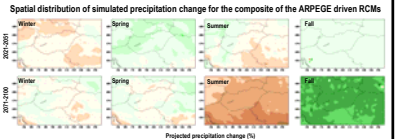


- projected precipitation increase: autumn (larger), spring (by ~10%)
- projected precipitation decrease: winter (larger in case of CNRM, by 10%), summer (larger in case of DMI, by ~15%)
- annual: slight increase is projected
- projected precipitation increase: autumn (exceeding 20% in case of CNRM), winter (by ~10%)
- projected precipitation decrease: summer (by 15-20%), spring (slight only)

Spatial distribution of simulated temperature change for the composite of the ARPEGE driven RCMs



Spatial distribution of simulated precipitation change for the composite of the ARPEGE driven RCMs

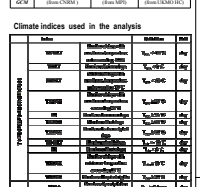


Summary of the extreme index analysis

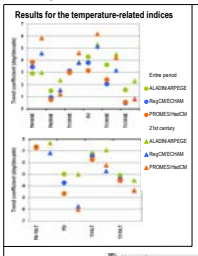
Experiments used in the extreme climate analysis

RCM	ALADIN (run by CNRM, France)	RegCM (run by ICTP, Italy)	PROMES (run by UCLM, Spain)
Reference	Gibelin and Déqué, 2003	Giorgi and Bi, 2000	Castro et al., 1993
Driving GCM	ARPEGE, RM5.1 (from CNRM)	ECHAM5-r3 (from MPI)	HadCM3Q0 (from UKMO HC)

Climate indices used in the analysis



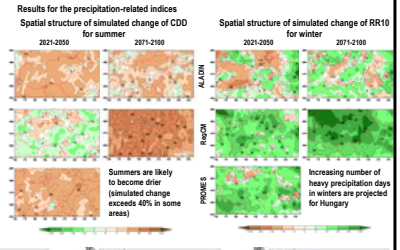
Results for the temperature-related indices



Results for the precipitation-related indices

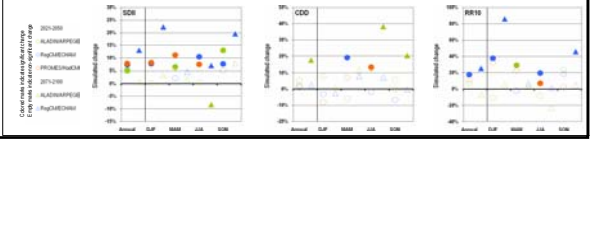
Spatial structure of simulated change of CDD for summer

Spatial structure of simulated change of RR10 for winter



Summers are likely to become drier (simulated change exceeds 40% in some areas)

Increasing number of heavy precipitation days in winters are projected for Hungary



REFERENCES

Castro, M., Fernández, C., Gaertner, M.A. (1993): Description of a mesoscale atmospheric model. In: Díaz, J.I., Lions, J.L. (Eds.) Mathematics Climate and Environment. Rech. Math. Appl. Ser. Mason, pp. 230-253.

Gibelin, A.L., Déqué, M. (2003): Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. Climate Dynamics, 20, pp. 327-339.

Giorgi, F. (1990): Simulation of regional climate using a limited area model nested in a general circulation model. J. Climate, 3, pp. 941-963.

Giorgi, F., Bi, X.Q. (2000): A study of internal variability of a regional climate model J. Geophys. Res., 105(D24), pp. 29503-29521.

Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New (2008): A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201

IPCC (2007): Climate Change 2007: Mitigation of Climate Change. An assessment report of IPCC Working Group III. Cambridge University Press, UK. 851p.

Nakicenovic N., Swart R. (2000): Emissions Scenarios. A special reports of IPCC Working Group III. Cambridge University Press, UK. 570p.

Uppala S. M., et al. (2005): The ERA-40 re-analysis Quarterly Journal of the Royal Meteorological Society. Vol. 131 (B), p. 2961-3012.

van der Linden P. and J.F.B. Mitchell (eds.) (2009):ENSEMBLES: Climate Change and Its Impacts: Summary of research and results from the ENSEMBLES project.Met Office Hadley Centre,UK,160p.

ACKNOWLEDGEMENTS. Research leading to this paper has been supported by the following sources: the Hungarian Academy of Sciences under the program 2005/TKI/246 titled Adaptation to climate change, the Hungarian National Science Research Foundation under grants T-048384, K-061854, K-78125, and K-67626, the Hungarian Ministry of Environment and Water under the National Climate Strategy Development project, the CC-WATERS project of the European Regional Development Fund (SEE/A/022/2.1/X), the European Union and the European Social Fund (TÁMOP-4.2.1/B-09/1/KMR-2010-0003).