Validation of the REMO regional climate model over the Carpathian Basin

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Introduction

A couple of years ago two RCMs were adapted at the Hungarian Meteorological Service (HMS): the ALADIN/Climate model developed by Météo France on the basis of the internationally developed ALADIN modelling system and the REMO model developed by the Max Planck Institute for Meteorology (MPI-M) in Hamburg. It is anticipated in Hungary that these models will be able to give realistic regional climate estimations for the next few decades particularly for the area of the Carpathian Basin. This area of interest is especially important considering the fact that one of the largest climate projection uncertainties can be found over the Basin as it was already identified by several international climate projects (e.g. PRUDENCE).

Various versions of the REMO model had already been tested all over the world for different geographical domains and for different past periods, however recently further validations and tests had been started also at the HMS. In two longer simulations the impact of the lateral boundary forcings were investigated: in one case the ERA40 data was used as the LBC-s and in another case the global ECHAM5/MPI-OM control run provided the large scale forcings. The simulations were achieved for a domain covering Central and Eastern Europe with 25 km horizontal resolution. The model results were compared to various observational datasets: on the one hand to the CRU-dataset over Europe and on the other hand to the detailed gridded Hungarian database over Hungary. The presentation is going to briefly summarise the first validation experiments of the REMO model in Budapest.

Description of the model

Dynamical characteristics – based on the Europa Model (German Weather Service's former NWP model):

- Gridpoint model;
- Rotated spherical coordinate system with *Arakawa* staggering (C-type);
- Hybrid vertical coordinates;
- Prognostic variables (2D and 3D fields): surface pressure, temperature, horizontal wind-components, water-vapour content and cloud-water content;
- Two-time level explicit leapfrog scheme with semi-implicit correction;
- Computational modes of the numerical solutions filtered by an *Asselin*-filter;
- Hydrostatic model – the finest possible, plausible resolution is about 10 km;
- Davies' relaxation scheme for the proper treatment of LBCs.

The REMO was developed 15 years ago on the basis of the "Europa Model" together with the inclusion of the global atmospheric circulation model ECHAM4's physical parameterization package.

Physical parameterization package – based on global ECHAM4 general circulation model:

- Prediction of the soil temperature by solving the diffusion equation using a five-layer model;
- Vertical diffusion and surface fluxes calculated based on the *Monin–Obukhov* similarity theory;
- Runoff scheme based on catchment consideration including sub-grid scale variations of field capacity over inhomogeneous terrain;
- Longwave radiation after *Morcrette* and shortwave radiation after *Fouquart* and *Bonnell*;
- Cumulus convection based on the mass flux scheme described by *Tiedtke* with modifications after *Nordeng*.

The summer-drying problem

The summer drying problem (SDP) over the Danube catchment area is a relatively known problem of the RCMs. In the framework of the **RAACS** project (Regionalization of Anthropogenic Climate Change Simulations) it was already recognised that many RCMs (including also REMO) simulate too dry and too warm summer climate over Central and Eastern Europe for the second half of the 20th century. Later on, in the **MERCURE** (Modelling European Regional Climate, Understanding and Reducing Errors) project an important task was to understand and reduce this model bias referred to as SDP. The main conclusion from this project was that for most of the participating models the systematic errors in the dynamics appear to be an important cause for the summer drying. On the other hand in the case of some models deficiencies in the land surface parameterisations contributed significantly to the excessively dry model climate.

Despite of the efforts and results mentioned above the exact cause of the summer drying problem was not identified, therefore the elimination of the bias was not yet possible. The results of investigations in the **PRUDENCE** project have shown that the summer warm bias (compared to CRU data) still exists in majority of the participating RCMs, therefore no model developments in between improved the situation substantially.

Simulation with REMO 5.0 for the ERA40-period

As it was indicated above the summer drying problem is still an open and acute issue strongly influencing the uncertainty of past and ongoing climate change projections in Central and Eastern Europe. This issue as well as other factors determining the uncertainty in climate change projections will therefore be addressed within the **CLAVIER** (Climate ChAnge and Variability: Impact on Central and Eastern EuRope – **http://www.clavier-eu.org**) project. In this project REMO 5.0 was adapted for the area of interest at the Hungarian Meteorological Service using 25 km horizontal resolution. An approximately 40-year simulation was achieved for the period of 1957–2000, which was driven by the ECMWF ERA40 re-analysis data.

The model results were compared to various observational datasets:

- the 10-minute (approximately 20 km) version of CRU-database and
- the gridded (0,1-degree resolution) Hungarian observational dataset.

The departure fields between the model results and the observational data are visualised at monthly, seasonal and annual scale mostly concentrating on the period 1961–1990 for the following parameters:

- mean temperature,
- mean relative humidity,
- mean wind speed,
- precipitation amount and
- diurnal temperature cycle.

The evaluation results

Precipitation

Investigating the annual precipitation amounts the main orographic characteristics can be immediately noticed: around the two highest orographic features in Europe (the Swiss, Italian and Austrian ranges of the Alps and the ridge of the Carpathian Mountains) the model overestimates the precipitation – which is pronounced not in the peaks (where the underestimation is typical), but over the slopes. The error of overestimation exceeds sometimes even the 150% (related to the observed precipitation) in the Alpine region. At the same time opposite tendencies can be detected in other elevated parts of Europe – like the Adriatic side of the Alps, the Dinarian Mountains or the Apennines.

Over Hungary a separation line can be noticed which isolates the too wet and too dry regions of the model: North from the Carpathians REMO overestimates the amount of precipitation, while over large part of the Basin and for the Southern part of Europe it provides too dry past climate (this fact might reflect the difficulty to provide reliable precipitation estimates for the Hungarian territory). Otherwise the simulation for Hungary is fairly realistic: the departures from the observations generally don't exceed 10% (only at the Southwest regions).

The summer mean precipitation for the 30 years has similar distribution like in the annual case: the too wet and too dry regions predicted by the model are nearly the same, there are some differences only in the (generally larger) degree of misestimation. In winter the relative amount of wet areas increases. This tendency is further maintained in spring, where the dry regions are focused only on a small spot of the Adriatic Sea. Contrary to that, in autumn the underestimation is dominant almost on the entire study area, and its magnitude grows seriously at the Adriatic coast exceeding even 50%.

Temperature

The departure fields of the mean temperature do not show such large temporal and spatial variance. In the case of annual results the model overestimates the observed values with 1-3 degrees everywhere, however over Bulgaria it is even higher.

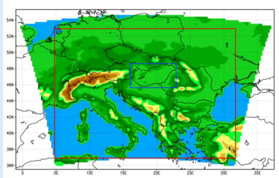
The same is typical also in spring, but in summer the overheating grows up to 3-5 degree over the southern regions (Italy, Balkan Peninsula, Southern Hungary). Then the overestimation is rather moderate in autumn and in winter, when the model is quite perfect.

Relative humidity (only for Hungary)

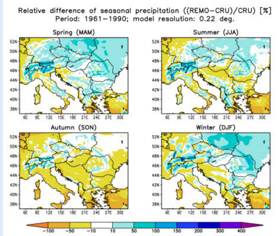
In good accordance with the precipitation results the model simulates too dry climate over Hungary during the major part of the year, the only exception is the northern part of the country in winter and spring. The highest positive departures occur during the summer and autumn months: the differences reach 30 percent over Southwest Hungary.

Diurnal temperature cycle: at each season the model overestimates the daily temperature range over the Alpine region and Appennines, however everywhere else the underestimation is the typical feature.

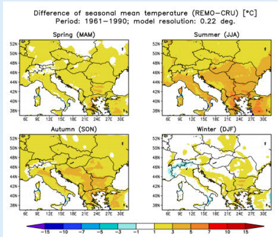
Wind speed (only for Hungary): a bit too strong wind – however the errors do not exceed 2 m/s.The simulation reflects realistically the spatial distribution of the seasonal wind speed, nevertheless the simulated structure is slightly smoother than that of the observations.



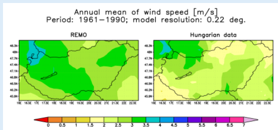
*Orography of the domain to be used both for the long past integration (1957–2000) and for the transient climate change simulation (1951–2050). The domain consists of 101*81 gridpoints and its horizontal resolution is approx. 25 km (exactly 0,22 degree). The red rectangle represents the evaluation domain with respect to the CRU dataset and the blue one indicates the verification area with respect to the Hungarian gridded dataset.*



Relative difference of the seasonal precipitation between the model results and the 10-minute resolution CRU dataset (reference: CRU dataset) for the period of 1961–1990.



Difference of the seasonal mean (2m) temperature between the model results and the 10-minute resolution CRU dataset for the period of 1961–1990.



The annual mean (10m) wind speed for the model results (left) and for the gridded Hungarian observational dataset (right) for the period of 1961–1990.

Transient climate change simulation with REMO 5.0

Within the CLAVIER project the climate change investigations will focus on the near future, therefore long transient simulations with different REMO-versions will be carried out for the period between 1951 and 2050 using high (10 and 25 km) horizontal resolution. The lateral boundary conditions for the regional simulations will be provided by the global ECHAM5/MPI-OM control and scenario runs with the A1B greenhouse gas emission scenario for the future projections.

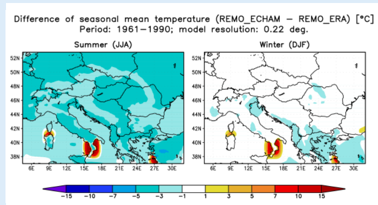
At the HMS the first simulation on 25 km resolution has already been finished. The target area and the grid distance is the same as in the case of the former ERA40 experiment (see above). For the time being the outcomes were evaluated for the past period of 1961–1990 through intercomparisons not only with observations (not shown), but also with the "reference" results of the ERA40 experiment. The primary goal for the latter inter-comparison was to better understand the impact of the lateral boundary conditions for the REMO regional climate model: whether "perfect" boundary conditions provide more realistic estimates or simulated, but more consistent ones (the ECHAM5 boundary conditions are in good physical consistency with the REMO model's internal dynamics and physics) provide better results compared to the observations. The validation was concentrating on the relative and absolute seasonal differences of the two main parameters (mean temperature and precipitation).

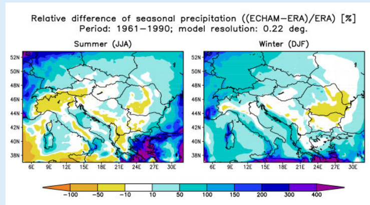
The preliminary results

Investigating the seasonal precipitation it can be concluded, that some of the earlier features remained also valid for the ECHAM-driven case: the model results again too large precipitation over the highest mountains (however the errors over the southern slopes of the Alps are reduced), whilst over the lower elevated features the underestimation is rather typical. But the strong overestimation over the northern part of the domain (and an especially intensified humid pattern in the vicinity of the border of the domain) appears as new characteristic. That overestimation exists during every season, but it is most emphasized in summer. Looking at the departure fields between the two experiments the largest positive differences (i.e. the simulations forced by ECHAM resulted more precipitation than the ERA40 one) can be immediately noticed over the north-western and the south-eastern corners of the validation domain.

Regarding the seasonal mean temperature it can be noted, while the simulation driven by reanalyses overestimates the summer temperature almost over the entire domain and the errors exceed even the 5 degree for the southern part of the domain, in the case of the ECHAM5 experiments the errors are significantly reduced, moreover at the northern part of the region rather the underestimation becomes typical. According to the departure fields between the two experiments it can be seen, that the model with the ECHAM lateral boundary conditions gives systematically lower temperature values everywhere within the domain (the only "unrealistic" exceptions can be seen along certain land-sea contours, both in summer and winter). The prediction of winter temperature is quite similar in both cases: the differences between the two experiments do not exceed the 1 Celsius degree over large part of the domain.

Difference of the seasonal (left: summer, right: winter) mean (2m) temperature between the model results driven by ECHAM and by the ERA40 reanalyses for the period of 1961–1990.





Relative difference of the seasonal (left: summer, right: winter) precipitation between the model results driven by ECHAM and by the ERA40 reanalyses (reference: ERA40 experiment) for the period of 1961–1990.

Summary, open issues

In this poster a short overview was given about the various validations of the REMO regional climate model. The summer drying problem (SDP) was diagnosed also based on the Hungarian data. Studying the impact of the finer horizontal resolution for the SDP it was concluded, that the resolution increase doesn't improve the model predictions. The experiment for the ERA40 period confirms the significant errors in temperature and especially in precipitation over the Carpathian Basin in the summer and autumn months. The results based on the control part of the long transient climate change simulation have proved the significant influence of lateral boundary conditions: the model driven experiment (when not the "perfect" reanalysis data, but the ECHAM5/MPI-OM simulated model data are used as boundary conditions) results obviously improved temperature simulations. For the precipitation the situation is a bit more complicated: the drying over the Basin is rather unchanged, but the overestimation over the northern part of the domain is intensified.

There are several **open issues** to be considered regarding the further validation of the REMO 5.0 regional climate model, which are as follows:

1. The precipitation overestimation appears not over the highest Alpine peaks, but just in the lower points – what is the main reason for that?
2. Is there a physical relation between the overestimation of the precipitation over the Alps and the underestimation over the Carpathian Basin?
3. What is the reason for the large precipitation overestimation in the climate change simulation in the vicinity of the north-western and south-eastern corners of the verification domain? Is it related to the lateral boundary effects or something else?
4. Does the temperature overestimation come from the day-time or the night temperature?

Nevertheless according to the recent results as a general conclusion one can say, that the model is far from being perfect requiring further improvements and tests in the future. It can be pinpointed with large confidence, that the SDP is a very complex issue, it is influenced by several factors, which all may contribute to its existence, therefore all of them should be correctly understood for its extenuation.

Additional information

For any other information about the climate dynamic activities of the Hungarian Meteorological Service, please look at the following poster (abstract nr. EGU2008-A-07728):

Gabriella Csima: Validation of the ALADIN-CLIMATE regional climate model at the HMS

and/or visit the following websites:

- http://www.met.hu/en/ and then follow the link „Climate modelling"
- http://www.met.hu/palyazat/nkfp_klima2005.php (only in Hungarian)
- http://www.clavier-eu.org
- http://www.cecilia-eu.org

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