Project No. 037005

CECILIA

Central and Eastern Europe Climate Change Impact and Vulnerability Assessment

Specific targeted research project

1.1.6.3.I.3.2: Climate change impacts in central-eastern Europe

D2.1: RCM simulations forced by observations

Due date of deliverable: 1st December 2007
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Start date of project: 1st June 2006 Duration: 36 months

Lead contractor for this deliverable: CUNI

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

D2.1 – RCM simulations forced by observations

RCM simulations in WP2

The overall main objective of WP2 is to produce simulations on targeted domains for a past period (1961-1990) driven by ERA40 reanalysis as well as for a reference period (1961-1990) and two GCM driven scenario time slices (2021-2050 and 2071-2100) based on ENSEMBLES 6FP EC IP A1B GCM projections. Two models have been supposed to be used aiming primarily at producing high resolution (10 km) climate change scenarios over four target areas, ALADIN-Climate family using stretched climate change transient run by ARPEGE/Climat for ENSEMBLES project, RegCM family using RegCM transient ENSEMBLES run for whole Europe in 25km resolution driven by transient run of ECHAM5. While the stretched ARPEGE run provides reasonable resolution in targeted regions for direct application of 10 km resolution RCM, the difference between 10 km resolution of RegCM and the resolution of other common global models is too large, that is why the double-nesting using 25 km RegCM run is necessary. The daily data from the simulations will be put in a common database.

Beside this primary task the validation of basic characteristics is supposed as well in framework of preliminary tests. More detailed validation and analysis of parameters used for impact applications was scheduled in WP3 and 4 later on, the model responses are to be compared with coarser results from existing simulations to assess the gain of a higher resolution. Another objective is the test of improved physical parameterizations better suited for 10 km horizontal resolution, based on the simulations results when some problems or possible improvement identified. This will provide the information on further development of the models for very high resolution, unfortunately, due to time limited for delivery of the results to the impact studies our major simulations cannot benefit from these experiments.

Deliverable objectives

Preliminary objective of the deliverable was to define the new high resolution models from the existing material (RegCM and ALADIN), following the milestone M2.1 the individual partners settled their integration domains to be ready to perform the simulations driven by reanalysis fields, which is necessary for further validation of the models performance. The main objective of the deliverable is production of the high resolution runs based on the reanalysis data in targetted areas for the period of 1961-90, allowing spinup of the models with use of beginning of 1960 as starting time, moreover, it is supposed to extend the period till the end of 2000 by most of partners involved. As a source of reanalysis data, ERA 40 database has been used, however, with some differences between the partners.

Progress towards objectives

Following the milestone M2.1 the integration domains and RCM parameterizations were defined. In adition to the Fig. 1, where the integration domains of partners involved in the simulation are plotted, Tab. 1 provides the definitions of the regions and information on models used by individual partners. Note that OMSZ and ELU share the same domain for direct results comparison. Tab. 2 provides the information on the model characteristics, more details see below in connection with the description of individua partners experiments.

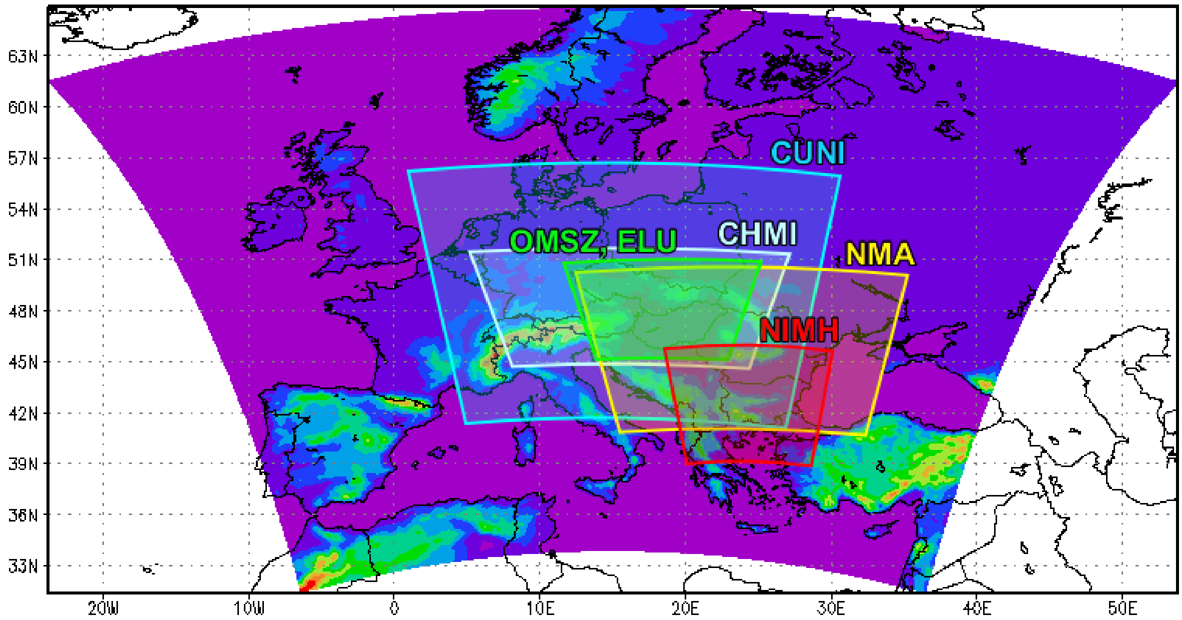


Figure 1: *Integration domains for individual partner simulations*

Table 1: *Individual partners model and region*

partner	model	resolution	domain size	domain location (centre)	boundary forcing
CUNI	RegCM	10 km	184 x 164 x 23	49.0 N, 15.8 E	ERA 40 RegCM@25
CHMI	ALADIN-Climate	10 km	160 x 102 x 43	48.52 N, 17.27 E	ERA 40
NMA	RegCM	10 km	156 x 102 x 18	46.0 N, 23.5 E	ERA 40
NIMH	ALADIN-Climate	10 km	105 x 80 x 31	42.5 N, 25.0 E	ERA 40
OMSZ	ALADIN-Climate	10 km	94 x 72 x 18	47.5 N, 18.5 E	ERA 40
ELU	RegCM	10 km	94 x 72 x 18	47.5 N, 18.5 E	ERA 40

Table 2: *Individual partners model specifications*

partner	model	numerics	Vertical coordinate	radiation	convection	surface
CUNI	RegCM	difference	sigma	CCM3	Grell (Fritch&Chappell)	BATS
CHMI	ALADIN-Climate	spectral	hybrid	ACRANEB	Bougeault	ISBA
NMA	RegCM	diference	sigma	CCM3		BATS
NIMH	ALADIN-Climate	spectral	hybrid	FMR	Bougeault	ISBA
OMSZ	ALADIN-Climate	spectral	hybrid	FMR	Bougeault	ISBA
ELU	RegCM	diference	sigma	CCM3		BATS

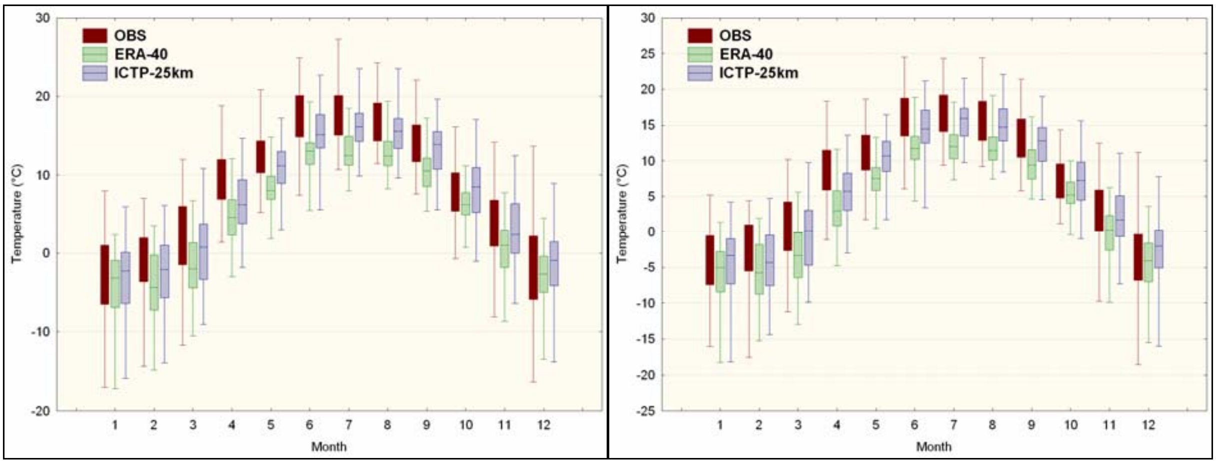
For use of ERA 40 the analysis of the impact of bigger jump between the resolution was performed, mostly no problem considered, but improvement of the results declared at CUNI, that is why ENSEMBLES ERA 40 RegCM@25km data are used to drive the simulation for reanalysis data. Other short term simulations were performed to test individua settings, NMA has tested two domains with RegCM (one covering only Romania, the other a larger area) and two convection schemes. Improvements were obtained with the larger domain, but double nesting does not bring any relevant improvement. ELU and OMSZ agreed on the central domain of simulations for the Carpathian basin. ELU tested vertical resolution, parameterization scheme, and time resolution with RegCM. OMSZ compared climate simulations with 10km and 25km versions of ALADIN for a 10 years period (1960-1969), NIMH performed a preliminary 10-year simulation (1990-1999) with ALADIN over Bulgaria. Simulated 2m temperature was compared with station observations, and showed that reasonable downscaling up to 10 times finer resolution than ERA40 can be obtained by regional climatic models. DMI started to prepare the database which will host the simulations results.

Individual partner simulations

CUNI

As for parameterization used by CUNI, default setting of RegCM3 is used. The model RegCM used here was originally developed by Giorgi et al. (1993a,b) and then has undergone a number of improvements described in Giorgi et al. (1999), and, finally, Pal et al. (2005). The dynamical core of the RegCM is equivalent to the hydrostatic version of the mesoscale model MM5. Surface processes are represented via the Biosphere-Atmosphere Transfer Scheme (BATS) and boundary layer physics is formulated following a non-local vertical diffusion scheme (Giorgi et al. 1993a). Resolvable scale precipitation is represented via the scheme of Pal et al. (2000), which includes a prognostic equation for cloud water and allows for fractional grid box cloudiness, accretion and re-evaporation of falling precipitation. Convective precipitation is represented using a mass flux convective scheme (Giorgi et al. 1993b) while radiative transfer is computed using the radiation package of the NCAR Community Climate Model, version CCM3 (Giorgi et al. 1999). This scheme describes the effect of different greenhouse gases, cloud water, cloud ice and atmospheric aerosols. Cloud radiation is calculated in terms of cloud fractional cover and cloud water content, and the fraction of cloud ice is diagnosed by the scheme as a function of temperature. Our setting of convection is Grell scheme with Fritsch & Chappell closure scheme. For more details on the use of the model see Elguindi at al. (2006).

In framework of work on D2.1 CUNI has started the simulation based on reanalysis, both directly from ERA40 and, due to the too big step between ERA40 resolution (more than 100km) and RegCM planned resolution of 10 km, from RegCM reanalysis run of ICTP for ENSEMBLES project in 25 km. Preliminary results presented in Fig. 2 show the comparison of surface temperature for selected grid points and station measurements (with approximately similar topography height) for first six years of the simulation (1961-66). The advantage of the double nesting can be seen, it looks to be general feature of the simulation. More detailed analysis for the first decade will be provided later when completed.



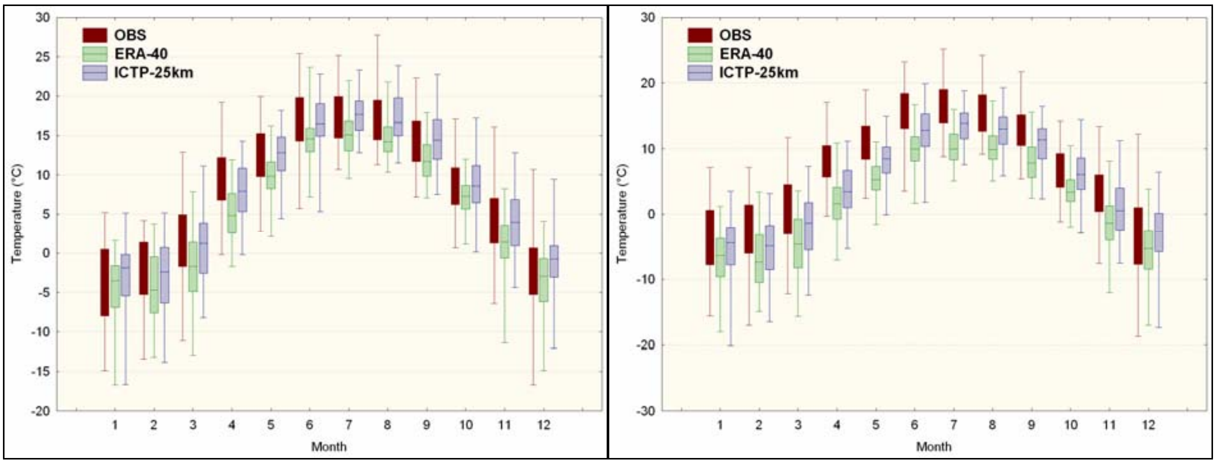


Figure 2: *Simulations driven directly by ERA40 and ICTP25km run based on ERA40 vs. stations measurements for Zatec (upper left), Havlickuv Brod (upper right), Holesov (bottom left) and Husinec (bottom right), mean daily temperature.*

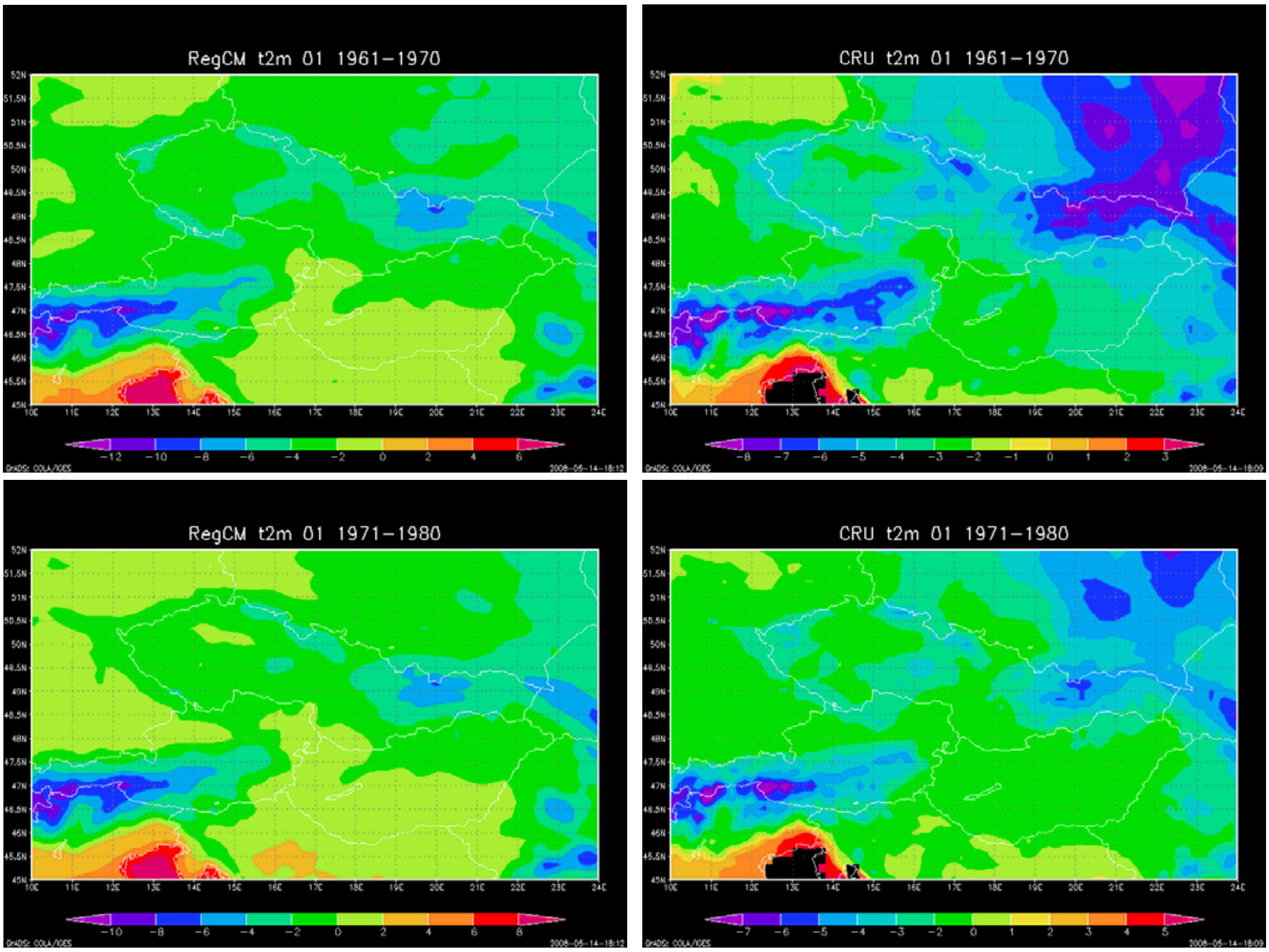
Final setup:

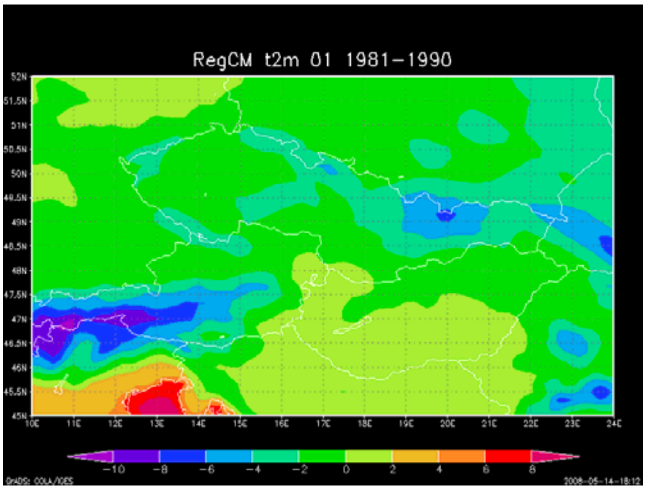
ERA40 through ICTP ENSEMBLES ERA40 run with RegCM@25km, resolution 10 km

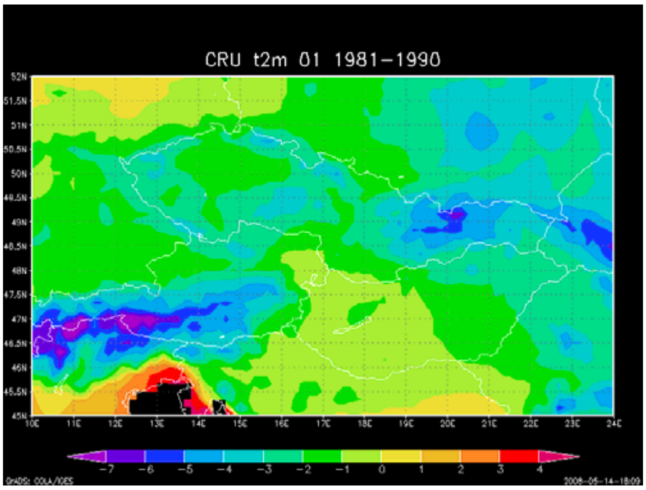
Results example:

Simulations vs. CRU (10‘):

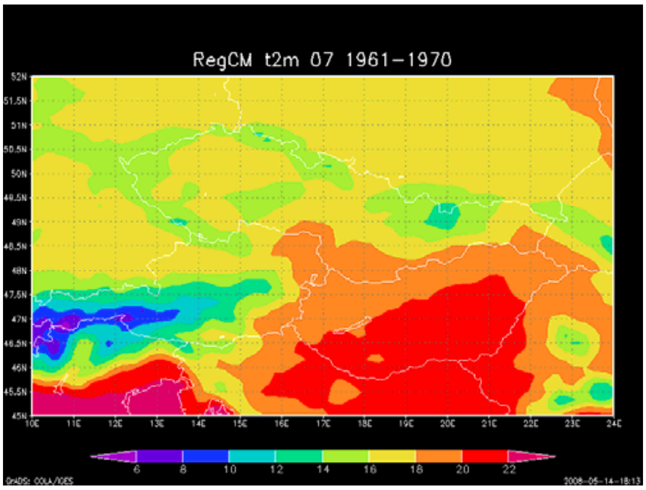
January

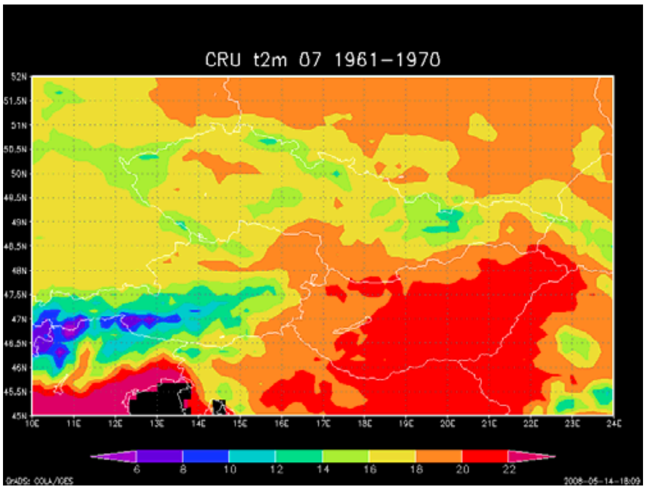


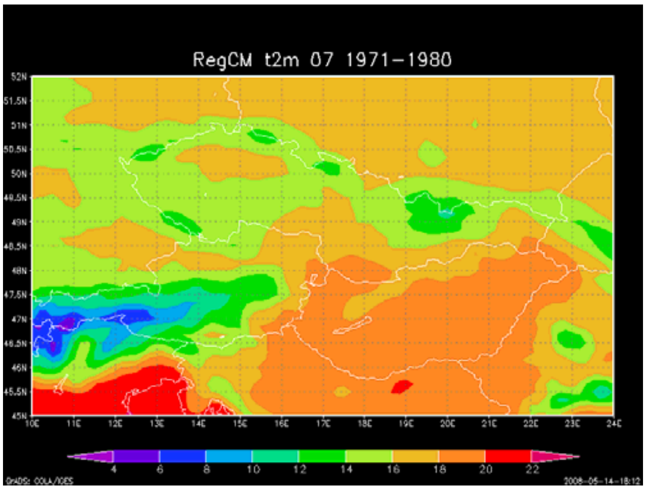

RegCM t2m 01 1981–1990

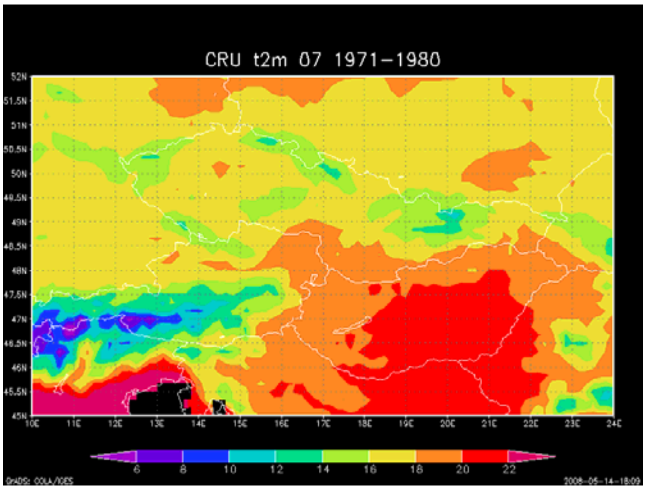

CRU t2m 01 1981–1990

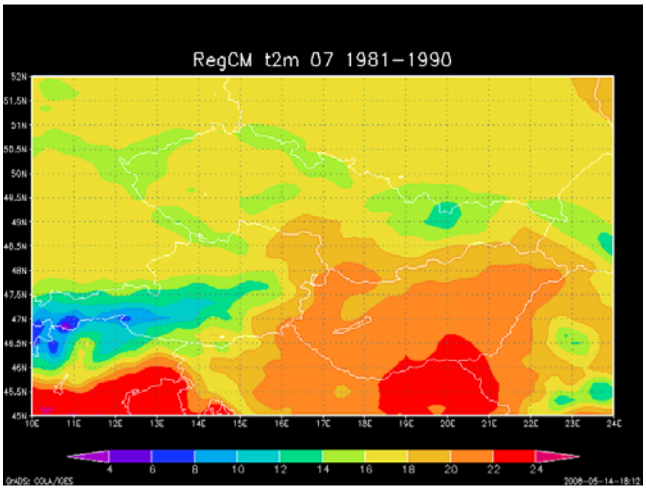
July

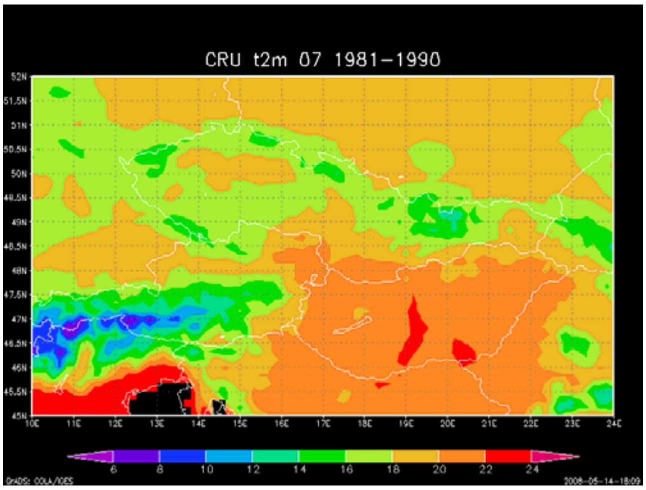

RegCM t2m 07 1961–1970


CRU t2m 07 1961–1970

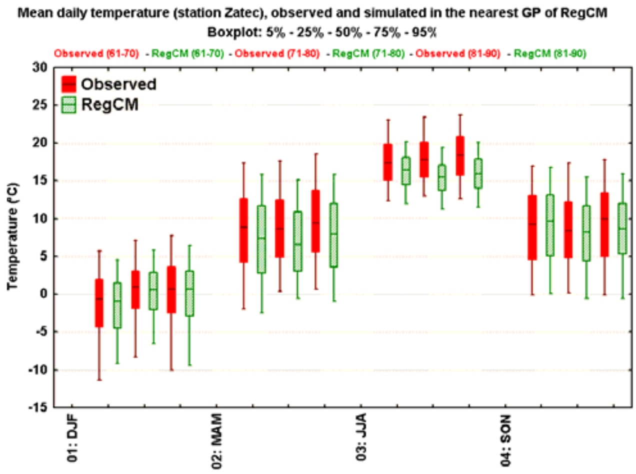

RegCM t2m 07 1971–1980

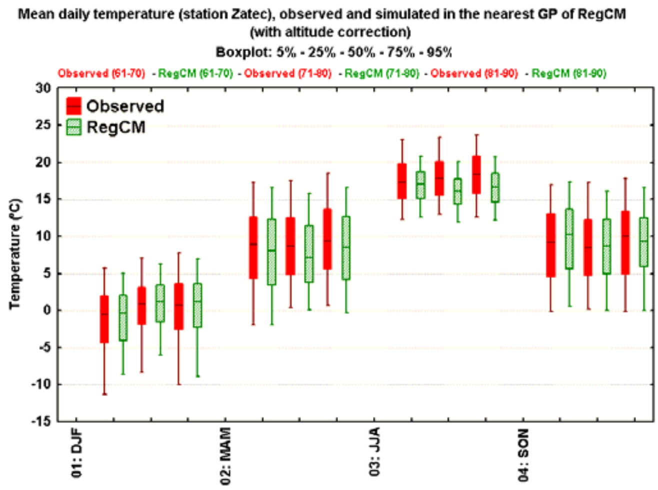

CRU t2m 07 1971–1980

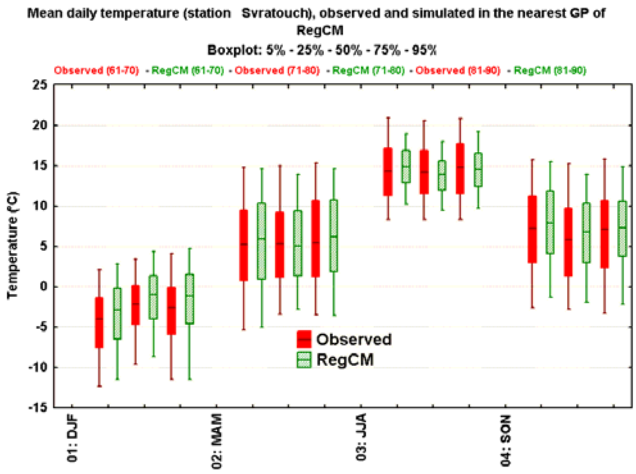


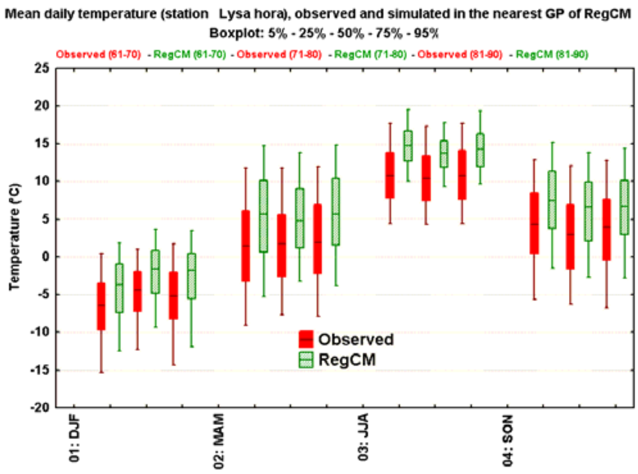


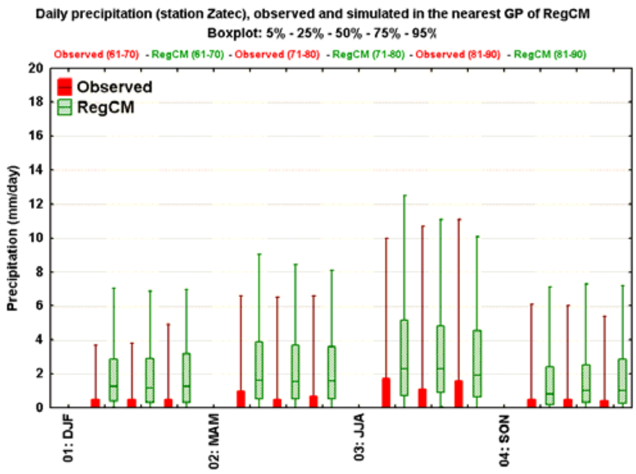
Grid points vs. stations measurements

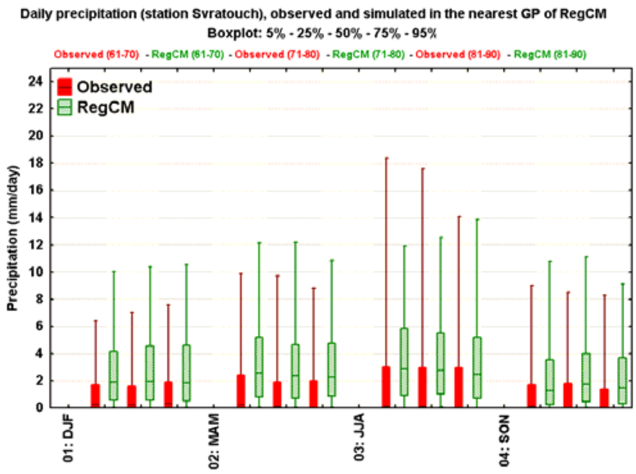


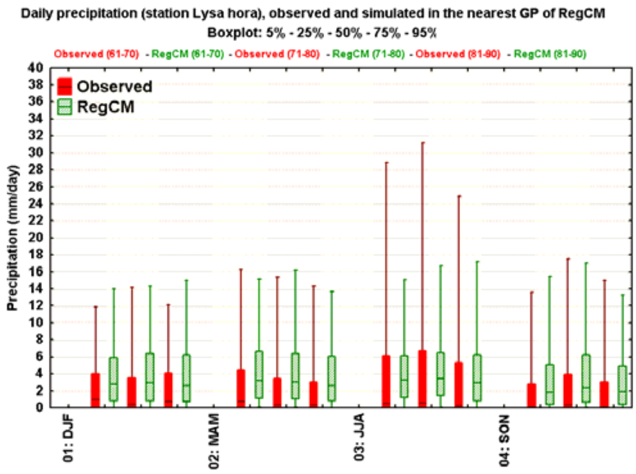












NMA

Another partner using the RegCM3 model is NMA. The model has been prepared for implementation on a PC Linux Cluster (7 nodes, 17 processors dual, available operationally on June) and first tests started. We tested for the time being two versions, bot with 18 vertical levels. Small domain of 104x102 points was centered on 46N,25E, and a bigger domain of 156x102 points on horizontal centered on 46N,23.5E, as seen in Figs. 3 and 4 where the results of test simulations shown for precipitation and temperature, respectively. A second test was done for convection parameterization, Grell scheme (Figs. 3c, 4c) compared to Emanuel scheme (Figs. 3e, 4e). A third experiment was conducted to test the double nesting (get a smoother resolution increase from ERA40 2.5 deg to 10 km), and a fourth test was done to assess the effect of aerosol forcing. The simulation takes 24 hours for one year on this project dedicated machine.

Results were preliminary compared against CRU data for total precipitation (Fig. 3b for small domain and Fig. 3d for big domain) and 2m temperature (Figs. 4). Precipitation field is overestimated mainly over steep topography, and additional tuning for LBC effect on precipitation (vertical velocity) is needed. The 2m temperature presents a too small meridional gradient that might impact on a lower zonal wind connected to evaporation/convection at sea/land areas which should be further investigated. These experiments are very preliminary and not yet conclusive, but we can notice improvement when increasing the domain both for 2m temperature and especially for precipitation. This might be connected to the lateral boundary effect that impacts more on the smaller domain. For our domain Grell convection scheme seems to approach better the observed pattern and to less overestimate it. We cannot take any conclusion from the aerosol forcing effect for now, apart a very slight improvement for the short experiment (autumn season) done. Double nesting, for the period tested does not bring a relevant improvement (in the same time being more costly). We intend to make one longer test in order to confirm the need of work on LBC specification.

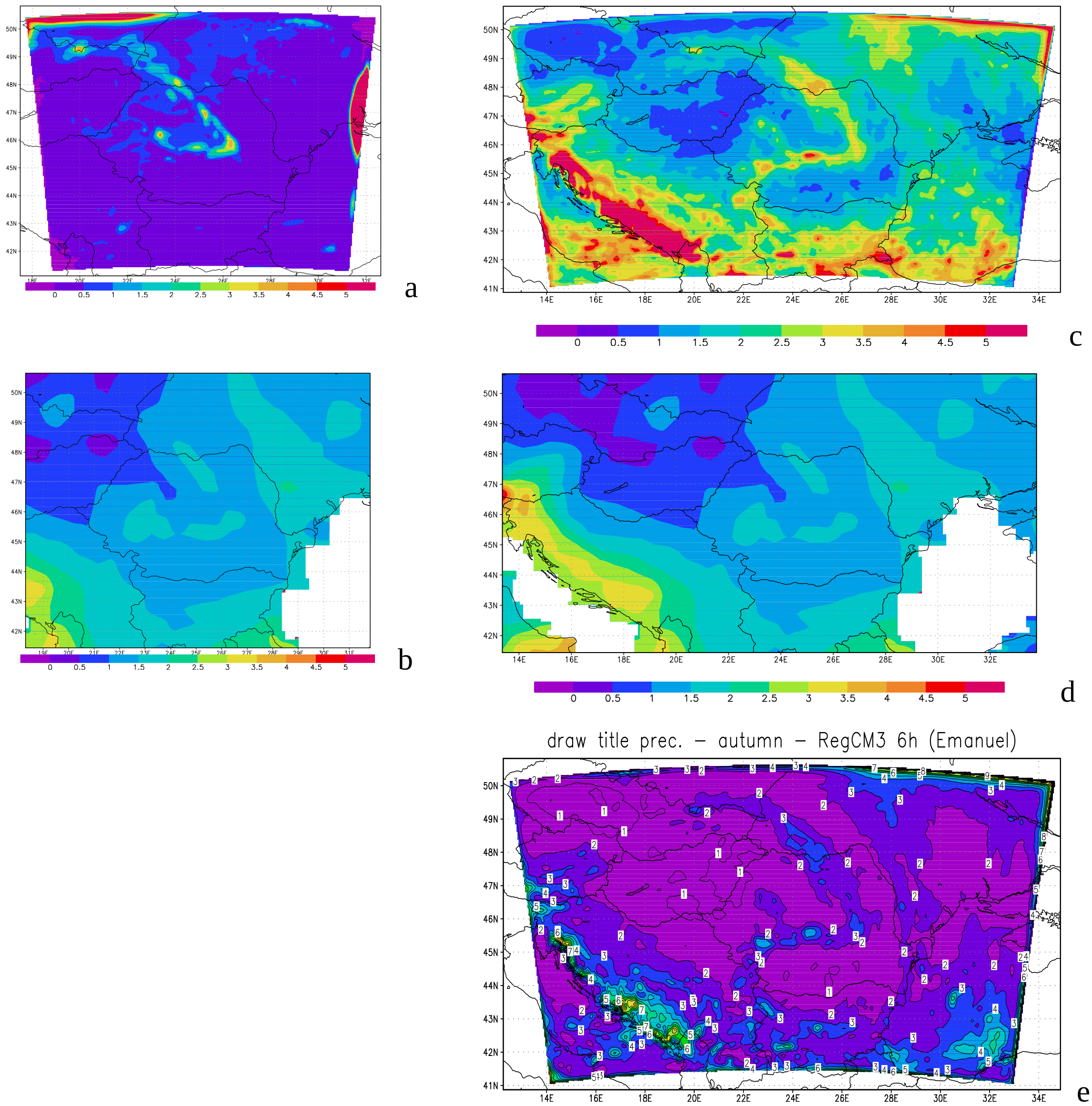


Figure 3: *precipitation mm/day average over season, autumn (SON 1959-1960) a) Regcm simulation small domain, Grell, b) CRU data, c) Regcm simulation big domain , Grell d) CRU data big domain and e) Regcm simulation big domain, K. Emanuel*

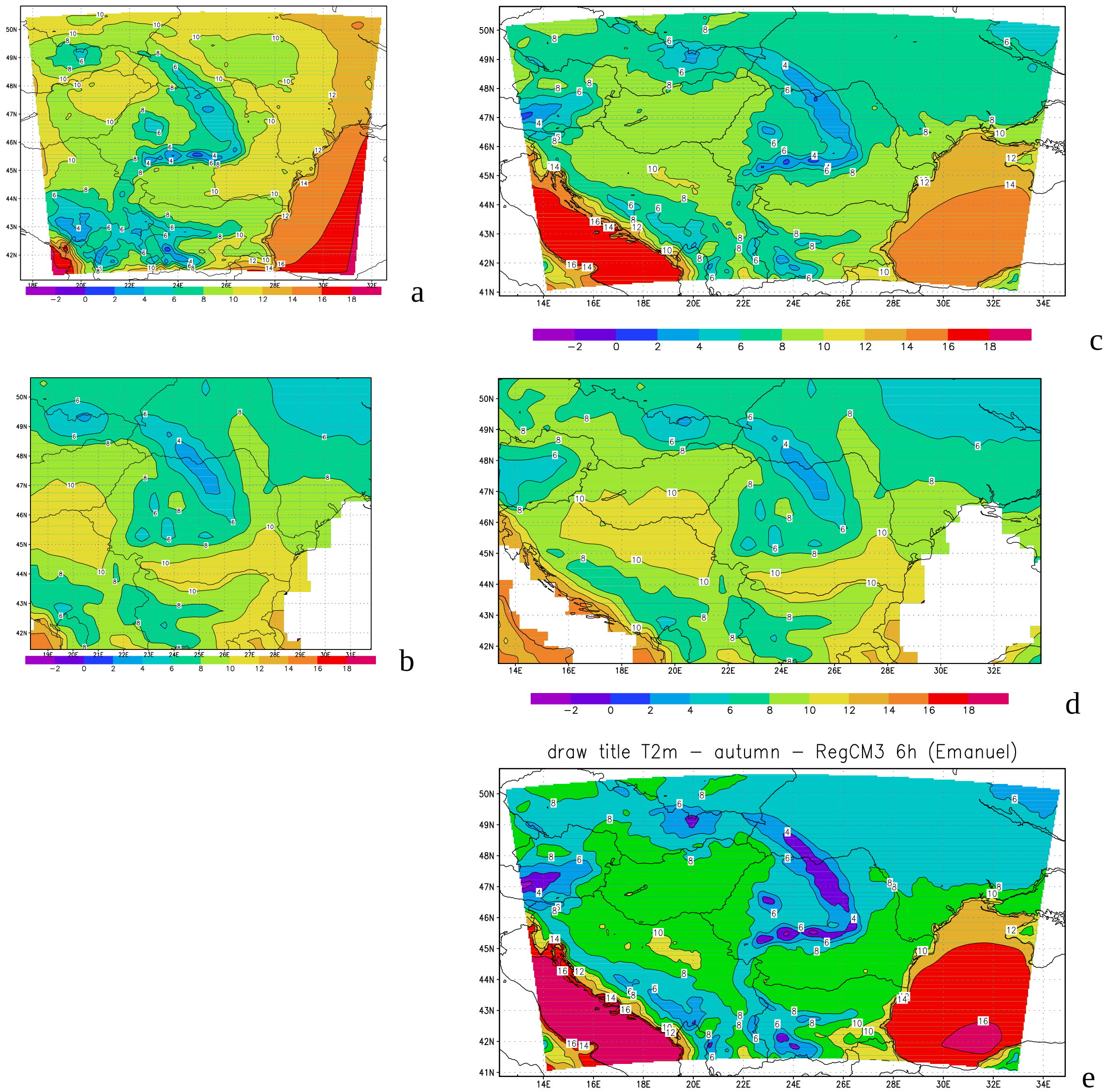


Figure 4: *As Fig. 17 for temperature 2m (°C)*

Final status

1. Basic description of the model used

a) Settings

- radiation :Kiehl et al. 1996; cloud absorbtion/scattering: Slingo, 1989
- surface transfer: BATS (Biosphere-Atmosphere Transfer Scheme, Dickinson,1993) “force-restore” (Deardoff,1978) ; 20 veg.types);
- PBL: Holtslag et al. 1990, non-local diffusion (counter-gradient fluxes)
- convection : Grell (closure Fritsch-Chappell);
- large-scale precipitation: explicit SUBEX (Pal, 2000); evap: Sundqvist, 1989
- exponential relaxation for coupling method (6 hr frequency; 6 points)

The pre-run testing implied, for now, no model calibration but only configuration design: coupling ratio (showed small impact on short-term runs), domain (bigger domain indicated sensibly better results) and coupling area extent and method (needs more investigation), convection scheme (Grell - less precipitating).

b) The domain

The domain was centered at (45N,26E) and it has (156*102*18) regular points (10km) on a Lambert secant (at 30N and 60N) conformal projection plane. Numerical scheme asked a 40s time step. Coarser coupling domain (ERA40 data) borders on a regular lat/lon grid are: 30N-75N, -15W-42.5E. The coupling data in the simulation are from ERA40 analysis interpolated at 0.5deg. resolution for the coarser domain (i.e.a coupling ratio of 4-5 over the domain), with 6 points width for the coupling area (Black Sea Coast needs to be represented at high resolution).

2. Results example

Regional climate has been simulated for 1961-1990 (1960 spin-up year).

a) comparisons vs. CRU – we used for now CRU 0.5 deg.

This comparison emphasized larger-scale (CRU scale) systematic biases as: warmer winters and too colder summer-autumns by RegCM3 JJA and SON all these being shown also in station comparison. Precipitation are overestimated all seasons (mainly convective in winter and autumn), but small scale features are reproduced (Fig.1).

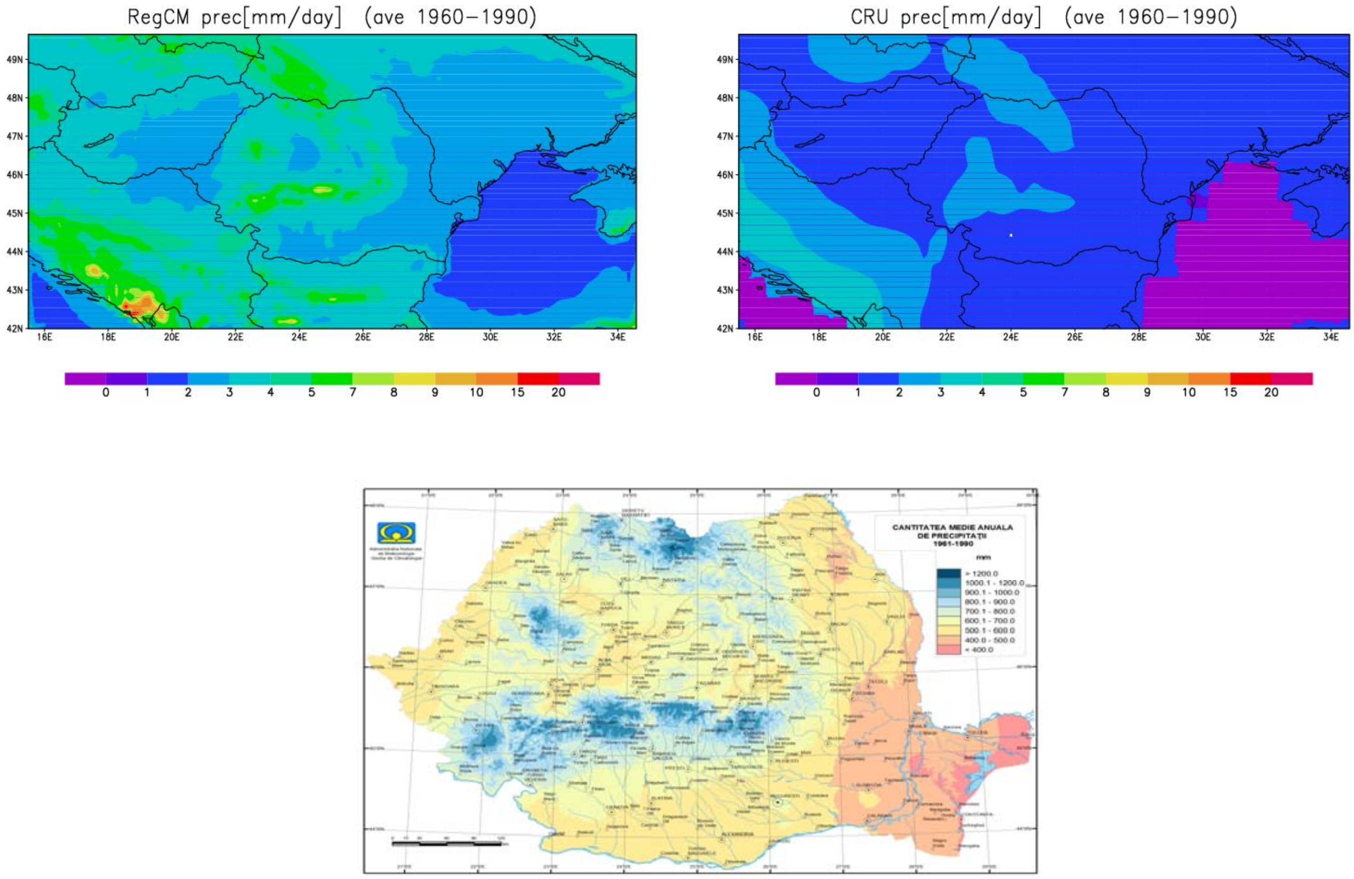
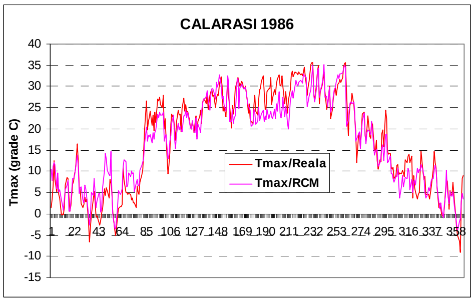


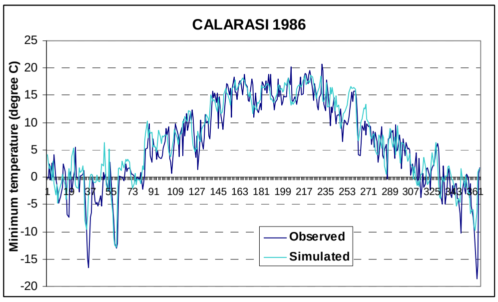
Fig. 1: daily precipitation amount (average 1961-1990) by RegCM3 (up left), Cru (up, right) and annual observed amount for the same period (down).

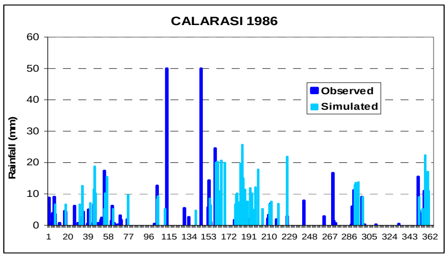
b) comparison vs. stations in the region.

Thse comparisons have been made for impact areas: agro-meteorolgic and hydrologic, as average over the period and also for extreme years.

The 2 pilot area for draught impact: Calarasi and Buzau and compared against station data for the extreme year 1986 (Fig.2)







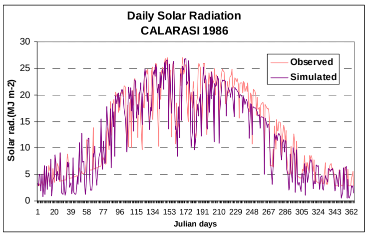


Fig. 2 a) Observed vs. simulated Tmax (up,left), Tmin (up, right), precipitation (down, left), net solar radiation (down, right) in 1986 draught year at Calarasi.

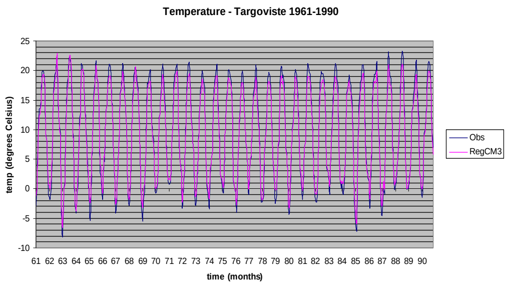
These comparisons indicate max temperatures negative bias (responsible for the colder average T2m in the second half of the year), as correlated to the negative bias in solar radiation. In winter (a less efficient short wave radiation bias) indicates warmer T2m average in spite of more frequent snow cover (long wave budget / cloudiness and surface exchange should be here analyzed).

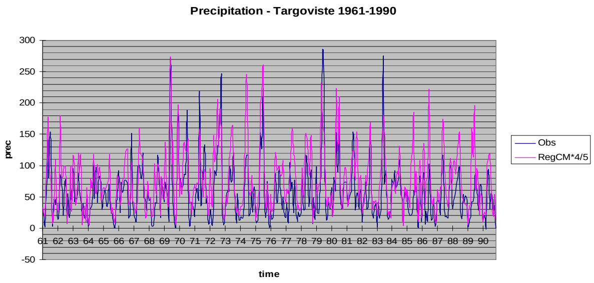
Precipitation indicates to be overestimated mainly in the small values class (it rains too often in small amounts) that leads to a total amount overestimation but also to unrealistic conditions for crop growth: for these, even small daily rain can change dramatically the phenological cycle.

Over the year, station comparison at hydrological impact pilot station (here shown Targoviste, on the Ialomita river middle basin) shows:

- the same smaller amplitude in temperature seasonal vatiation (warner winters and colder summers (Fig.3), and

- good precipitation event representation but systematic overestimation (here precipitation was scaled by a factor of 4/5 for RegCM2 just to emphasise the good appearance of the extreme events, as the floods of: Oct. 1972, July 1975, June 1979; it is interesting to note a skill decrease the last 10 years, a stronger overestimation compared to observations).





3. Current/future work

Currently, results analysis focuses on following problems:

- coupling (specification and parameters);

- physics (systematic: radiation bias in autumn, precipitation overestimation (both convective and large-scale), t2m under-estimation);

- extreme events over pilot impact areas

ELU

Another partner running regional climate model RegCM to simulate the climate of the Carpathian basin using three time-slices as agreed with the other partners involved in the project is ELU. In the mean time, the other Hungarian partner, the Hungarian Meteorological Service (HMS), selected regional model ALADIN to make simulations for the same region. Thus, comparison of the two RCM results is possible for the Carpathian basin. For the Milestone M2.1 by month 6, ELU and OMSZ agreed on the central domain of simulations (excluding the buffer zones for the RCMs) using both RegCM and ALADIN (Fig. 5). The geographical location of the central domain can be characterized by the following four corners (Table 3), and the central point of the domain:

Table 3: *parameters of the ELU domain.*

SW	45.20°N	14.00°E
SE	45.15°N	23.10°E
NW	49.75°N	13.35°E
NE	49.70°N	23.55°E
Center point	47.5°N	18.5°E

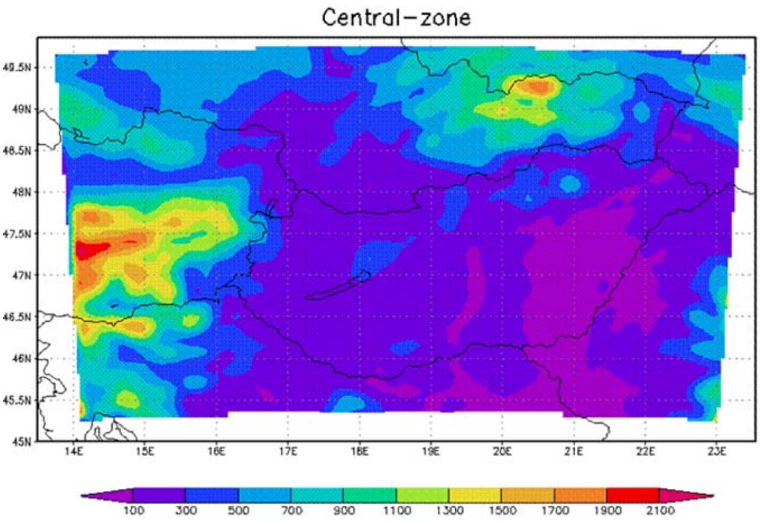


Figure 5: *Spatial extension of the main domain for RegCM and ALADIN*

Several test simulations were accomplished for the 1960-1990 period in order to choose the best parametrization schemes, and other conditions used with RegCM optimized for the selected domain. As NMA partner it was the case of different convective parameterizations test at 10 km horizontal resolution, Emanuell scheme has been compared to Grell (Fritsch & Chappell closure) scheme. Different number of vertical levels (both convective schemes, 10 km horizontal resolution) was tested as well with all predefined options, i.e. 14, 18 and 23 vertical levels. To estimate the efficiency of the runs, different temporal resolutions of 20 and 30 sec with Emanuell scheme, both for 18 and 23 vertical levels, at 10 km horizontal resolution were tested. Benefit of higher resolution was analysed testing the simulation based on ERA-40 / 1° res., with Grell scheme, 18 vertical level, at spatial resolution of double nesting at 45 km and 10 km afterwards, as well as direct nesting at 20 and 10 km resolution. To obtain some information on sensitivity to model domain size the same setting (Emanuell scheme, 18 vertical levels, 10 km horizontal resolution) was used with central point: 47.5°N, 19.5°E for 94 × 74 gridpoints, and 110 × 90 gridpoints and 140 × 120 gridpoints.

OMSZ

The main concern of preparations were the determination of the proper domain for the CECILIA integrations. On the one hand discussions and adjustments were carried out with the Eotvos Lorand University and on the other hand some comparative tests were realised with 10km and 25km versions of ALADIN for a 10 years period of 1960-1969. The main objective of the latter comparison was to see whether the integrations for the high resolution small domain give also reasonable results compared to the 25km version with bigger domain size (the outputs of both models were verified with respect to the CRU datasets). The results advocate (Fig. 6) that the small, but higher resolution domain results seem reasonable, therefore that domain can be used in the later stage for CECILIA simulations (Fig. 7).

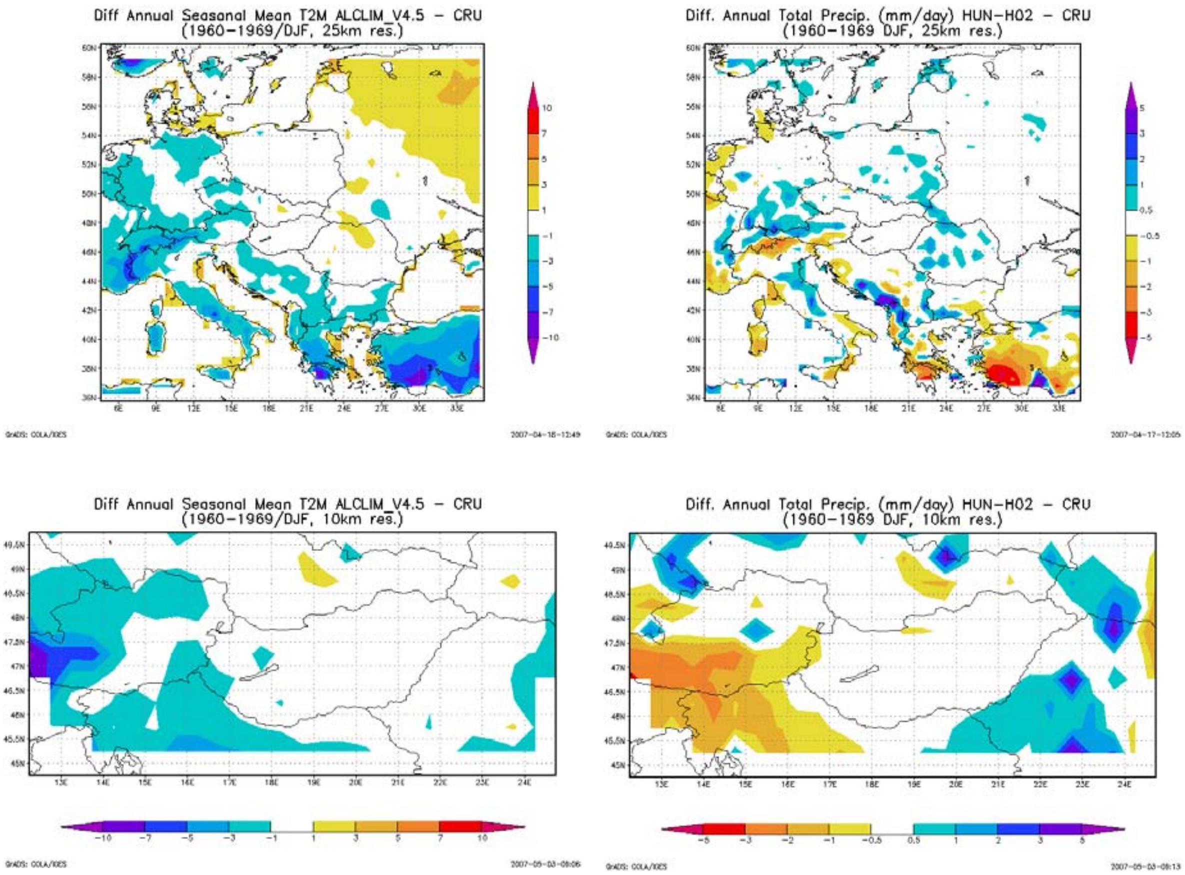


Figure 6: *Comparison of ALADIN/Climate simulations for 25km and 10km resolutions with bigger and smaller domains respectively. On the top the 25km simulations and on the bottom the 10km resolution simulations can be seen. Left: mean temperature, right: mean precipitation for the winter period compared to the CRU data.*

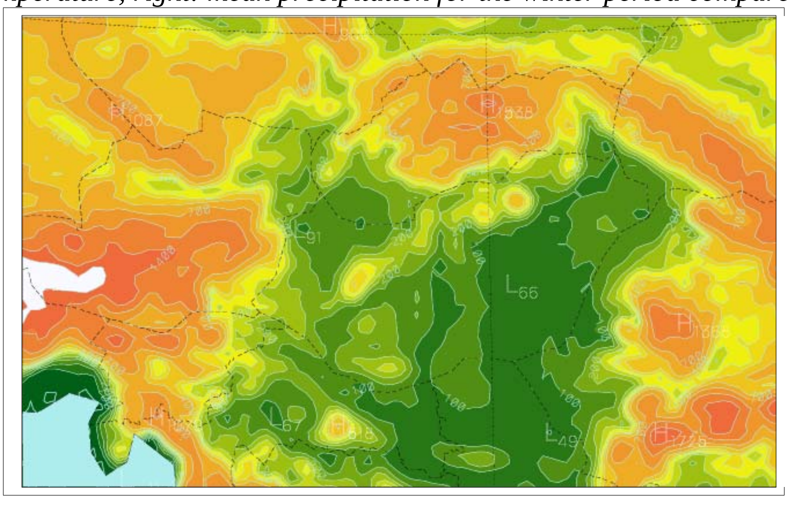


Figure 7: *The domain and orography of ALADIN/Climate for the CECLIA integrations*

Final status:

- Model version: ALADIN-Climate V4.5
- Domain: Charpatian Basin (lat: 44.64 – 50.01 N; lon: 12.44 – 25.22 E)
- Horizontal resolution: 10 km
- Integration period: 1958 – 2000
- Evaluation period: 1961 – 1990 (for Cecilia project)
- LBC: ERA-40; coupling: 6h
- Dynamics: Spectral model

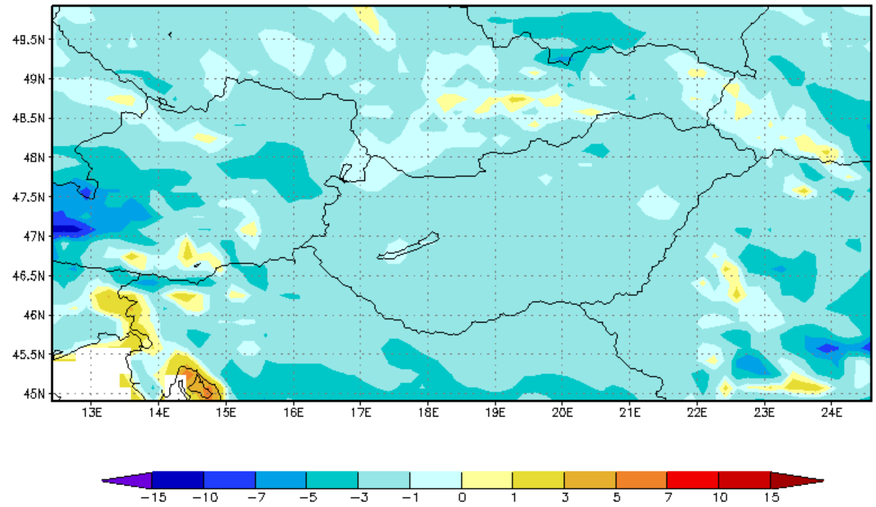
Hydrostatic
Hybrid vertical coordinates
SISL advection scheme
LBC: Davies-scheme
Prognostic variables: surface pressure, temperature, horizontal wind components, specific humidity

- Physics: FMR radiation scheme
  ISBA scheme for soil
  Bougeault scheme for deep convection
  Ricard and Royer scheme for large scale cloudiness
  Smith scheme for large scale precipitation

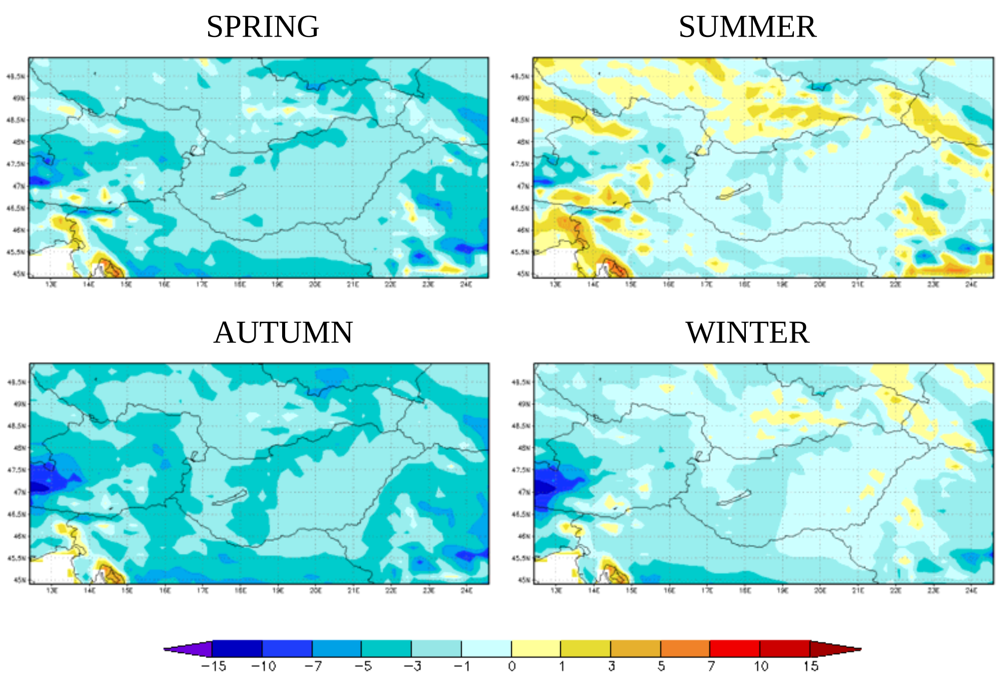
Results example:

Temperature

Difference of annual mean temperature (FC – CRU(10') [C])

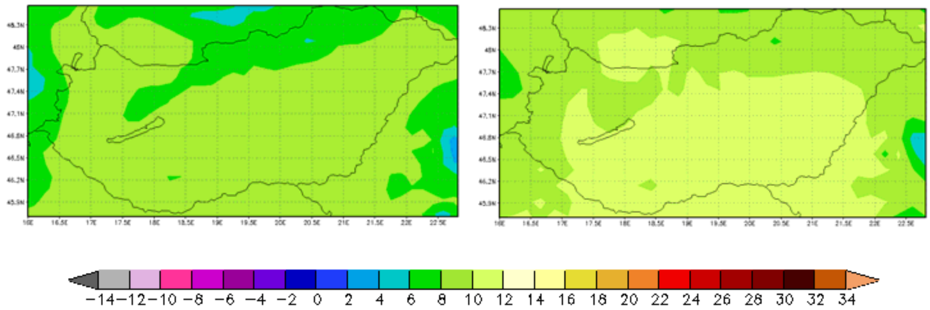


Difference of seasonal mean temperature (FC – CRU(10') [C])



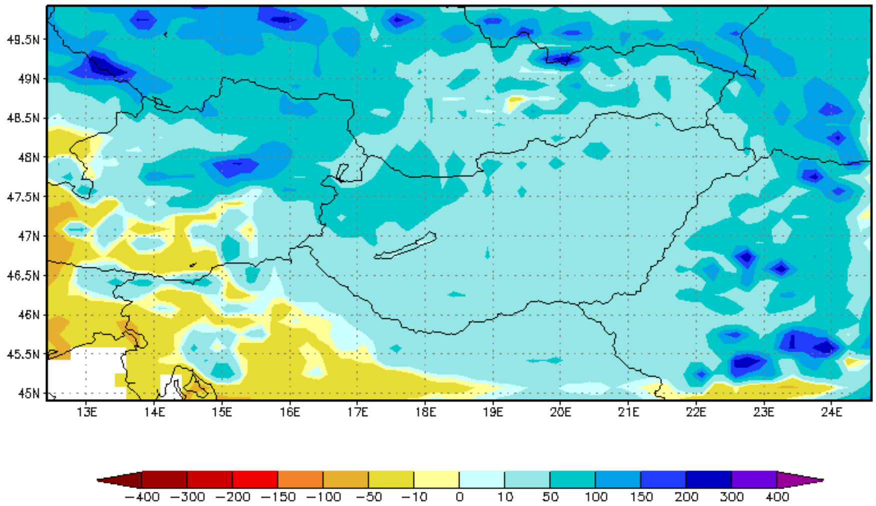
Annual averaged temperature fields [C]

Forecast | Hungarian gridded observation



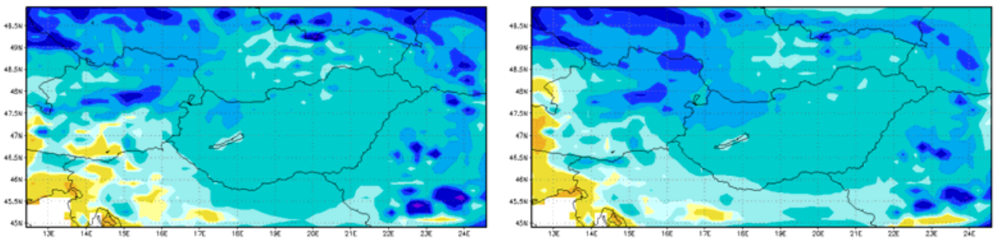
<u>Precipitation</u>

Annual relative difference of precipitation
[FC – CRU(10')]/CRU(10') [%]

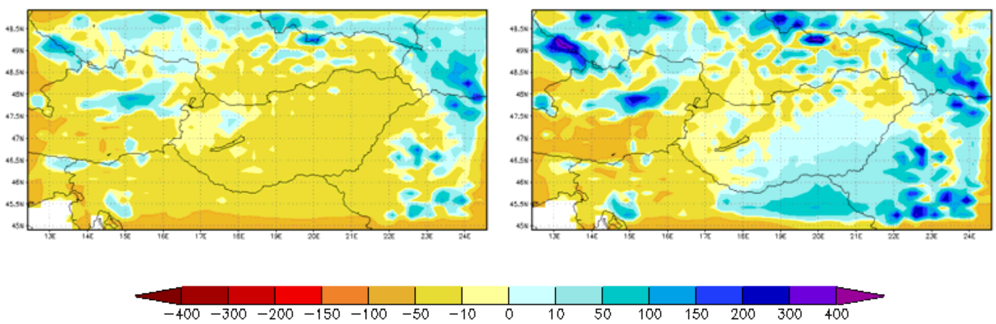


Seasonal relative difference of precipitation
[FC – CRU(10')]/CRU(10') [%]

SPRING | SUMMER

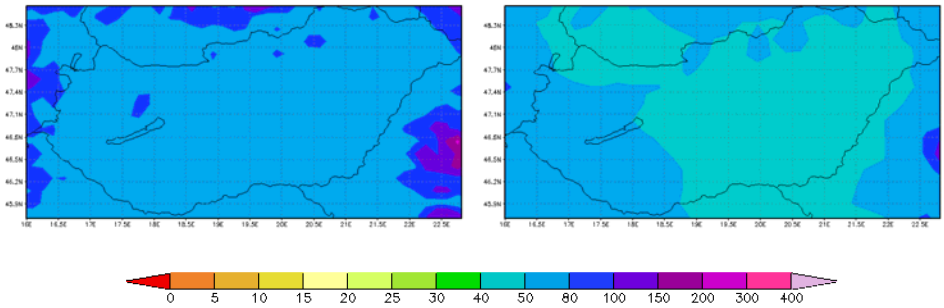


AUTUMN | WINTER



Annual averaged precipitation fields [mm/month]

Forecast Hungarian gridded observation



CHMI

At CHMI, most effort has been focused on development of ALADIN-CLIMATE/CZ version of model. Some new problems appeared when making experiments in 10 kilometers resolution which were analysed and solved. Preliminary integration area was selected and tested in accordance with milestone M2.1. The actual configuration of model covers integration area (C+I) 192 x 102 points with spatial resolution 10 km and 43 levels. With time step of 450 s this configuration consumes 6-7 hours of CPU time per model-month at NEC SX6.

Concerning the scientific point of view direct coupling with ERA-40 in its native resolution has been tested and compared to “nested” approach when an intermediate step in coupling process has been introduced: 10 kilometer resolution experiment has been driven by 25km resolution ENSEMBLES ERA-40 experiment and not directly with ERA-40 data. Additionally, coupling of ALADIN-CLIMATE/PRG with ARPEGE/CLIMATE present climate run has been tested to detect possible problems and caveats during the whole process. Resolution of 25km has been used because of availability of such a data from related ENSEMBLES experiments allowing us more straightforward evaluation of obtained results. During the second half of the year test integration has been launched to verify overall model performance when operating in 10 km resolution. Unfortunately, some unfavorable development has been detected when evaluating obtained results leading to an effort to explain reasons by assessing influence of more distinguished potential causes (e.g. influence of latest parameterizations changes, resolution + domain extension or coupling technique – direct approach counter “nested” one). Additional care has been aimed on investigating of model output quality in areas important for impact modelers community. Particularly snow cover and diurnal temperature range field has been matter of interest.

NIMH

Another region for CECILIA integration is centred above the Bulgarian territory and covered by the ALADIN model run at NIMH. Preliminary tests with ERA40 data were made using direct transition from 1.5 deg. (~120 km) horizontal resolution (60 vertical levels) of ERA40 data to 12 km horizontal resolution (31 vertical levels) was experimented. The reason of that was not only economy of computation time but the fact that it is unlikely to obtain some real signals only by using intermediate interpolation. We used the integration domain of the Bulgarian-ALADIN operative version. The South-West corner is at 39.8deg/20deg and the North-East one at 46.4deg/31.6deg. It is illustrated in Fig. 8. The synoptic stations used for evaluation are shown in the same figure. The model runs 10 year period starting from 1990.

For validation of the model comparing 2m temperature measurements against the model result we used we used the ‘*best correlated*’ neighbour grid point from 4 surrounding points for each station. This localization technique attempts to reduce the effect of the discrepancy between the model ‘land use’ field and the real one. Any interpolation of the surrounding grid points may use points over different land cover (see, forest, snow area, etc., especially in the complex terrain). Fig. 9 shows the correlation between the stations and the nearest gridpoint. Considering 2m temperature validation against observations it seems that reasonable downscaling up to 10 time's finer resolution could be obtained by regional climatic models. Moreover, other tests showed that ERA40 re-analyses give realistic opportunity for verification even over area with complex topography and terrain.

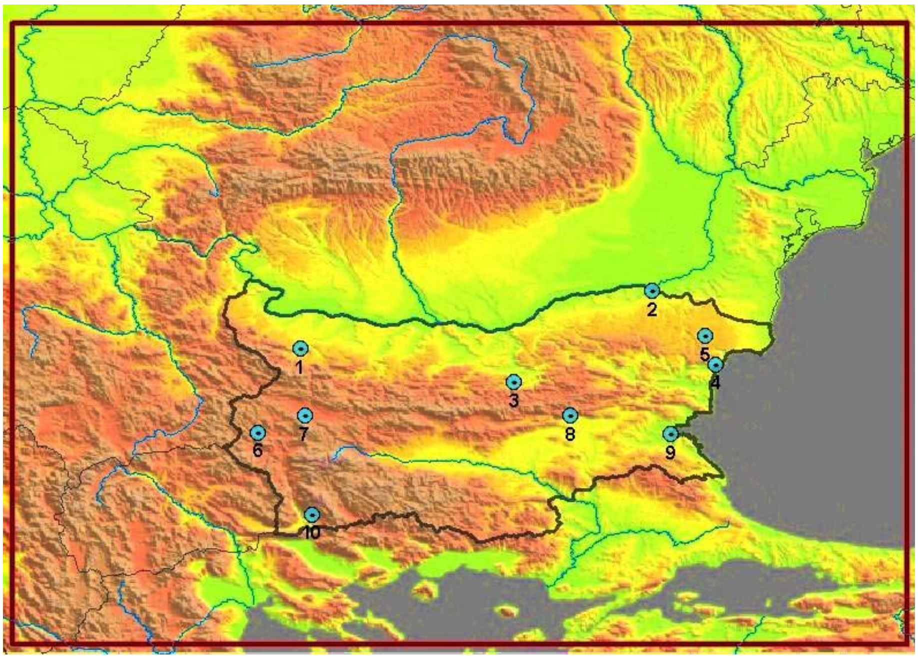


Figure 8: *Location of the synoptic station on the domain*

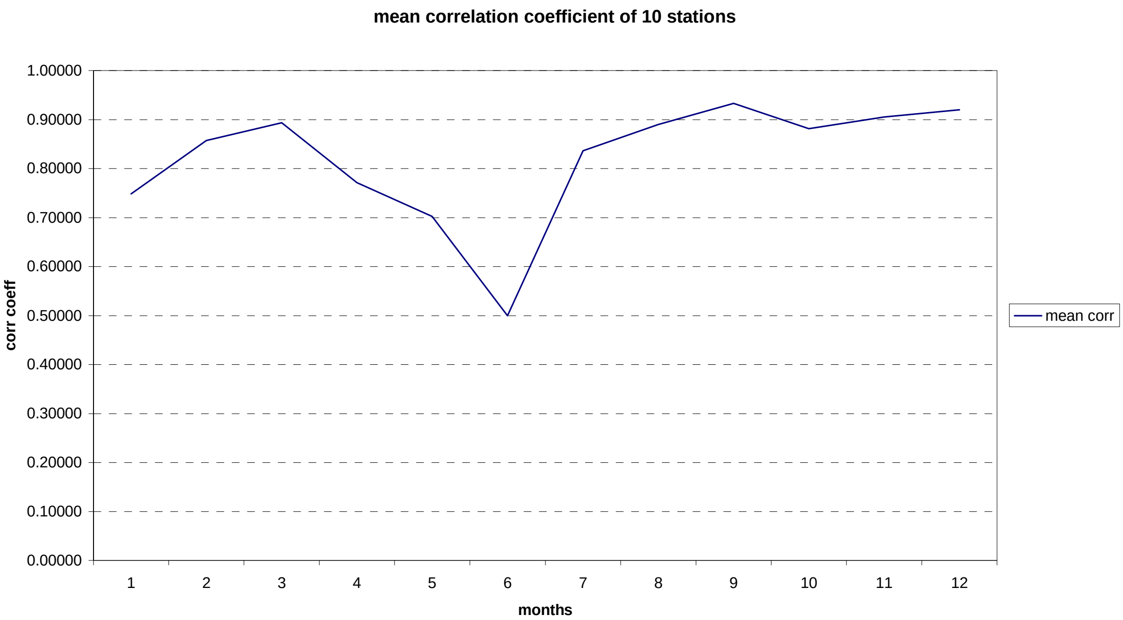


Figure 9: *Correlation between 10 years monthly mean model and observed temperature.*