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

Periodic activity report

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Section 1 Project objectives and major achievements during the reporting period

1.1 Project objectives, relation to state-of-the-art

1.1.1 Project main goal

The main goal of CECILIA has been to provide climate change impacts and vulnerability assessment in targeted areas of Central and Eastern Europe (CEE). We targeted our analysis on selected key areas of specific interest to the region. The floods and droughts which occurred in recent summers in the region highlight the importance of the hydrologic cycle and water management in Elbe and Danube river catchments in response to the occurrence of precipitation extremes. Impacts on agriculture and forestry affecting the economy of countries in the region were supposed to be studied as well. The 2003 heat wave demonstrated the importance of the health impacts of extreme conditions that could also lead to considerable changes in air quality, both regionally and in major urban centres.

The aim of the project has been to assess the impact of climate change at the regional to local scale for CEE using very high resolution simulations in order to capture the effects of the complex terrain of the region. This goal was expected to be achieved mainly using very high resolution RCMs run locally for targeted areas. From the viewpoint of climate change scenario production two time slices were planned, for 2020-2050 and 2070-2100. Changes in weather patterns and extreme events have been addressed within the project as they affect the sectors important for the economies and welfare of individual countries in the region. Uncertainties were planned to be evaluated by comparing results with those from previous projects (PRUDENCE, ENSEMBLES). The selected applications of the CECILIA outputs were supposed toward water resources and management, agriculture, forestry, air quality and health. In addition, CECILIA was expected to improve the access of CEE researchers to information and tools for climate change research by providing an efficient use and access to the results of previous and ongoing EC projects which the proposed research will benefit greatly from, e.g.:

- "Modelling the Impact of Climate Extremes (MICE)"
- "Statistical and regional dynamical downscaling of extremes for European regions (STARDEX)".
- "Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects" (PRUDENCE)
- "ENSEMBLE-based Predictions of Climate Changes and their Impacts" (ENSEMBLES)
- "Quantifying the Climate Impact of Global and European Transport Systems" (QUANTIFY)

Thus, the project CECILIA aimed to integrate world leading European expertise in regional climate modelling with high resolution impact studies to provide new policy relevant information on climate change and its interactions with society at the regional scale. It was expected also to feed into adaptation and mitigation strategies in targeted areas.

1.1.2 Key issues

Emphasis was given to application of regional climate modelling studies at a resolution of 10 km for local impact studies in key sectors of the region. Very high resolution simulations over this region are necessary due to the presence of complex topography and land use features. Impacts on large urban and industrial areas modulated by topographical and land-use effects resolved at the 10 km were outlined to be investigated. The high spatial and temporal resolution of national observational networks and of regional model experiments was expected to feed into investigations of consequences for weather extremes in the region. Comparison with the results based on statistical downscaling was also supposed to be provided. Statistical downscaling methods for verification of the regional model results were planned to be developed and applied, and assessments of their use in localization of model output for impact studies were expected to be performed. The objectives were outlined to be achieved through the following tasks:

- *To collect, assess and make available for first local impact studies the scenarios and climate simulations produced in previous relevant projects where available. (WP1)*
- *To adapt and develop very high resolution RCMs for the region (10 km grid spacing) and perform regional time-slice nested runs driven by ERA40 data and by GCMs for selected GHG change scenarios. (WP2)*
- *To verify the model results, compare RCM and statistical downscaling results, analyze and develop the methods for verification, particularly at local scales, to provide the scenarios. (WP3)*
- *To estimate the effect of global climate change on extreme events in the region, including the assessment of the added value of high-resolution for the simulation of the relevant processes and feedbacks. To evaluate uncertainties in regional projections by comparing results from previous projects (WP4)*
- *To assess (using high resolution downscaling results) the impacts of climate change on the hydrological cycle and water resources over selected catchments; the effects of climate change on the Black Sea (WP5)*
- *To study (based on the high resolution downscaling results) the impacts of climate change on agriculture and forestry, carbon cycle and selected species (WP6)*
- *To study (based on the high resolution downscaling results) the impacts of climate change on health and air quality (photochemistry of air pollution, aerosols) (WP7)*

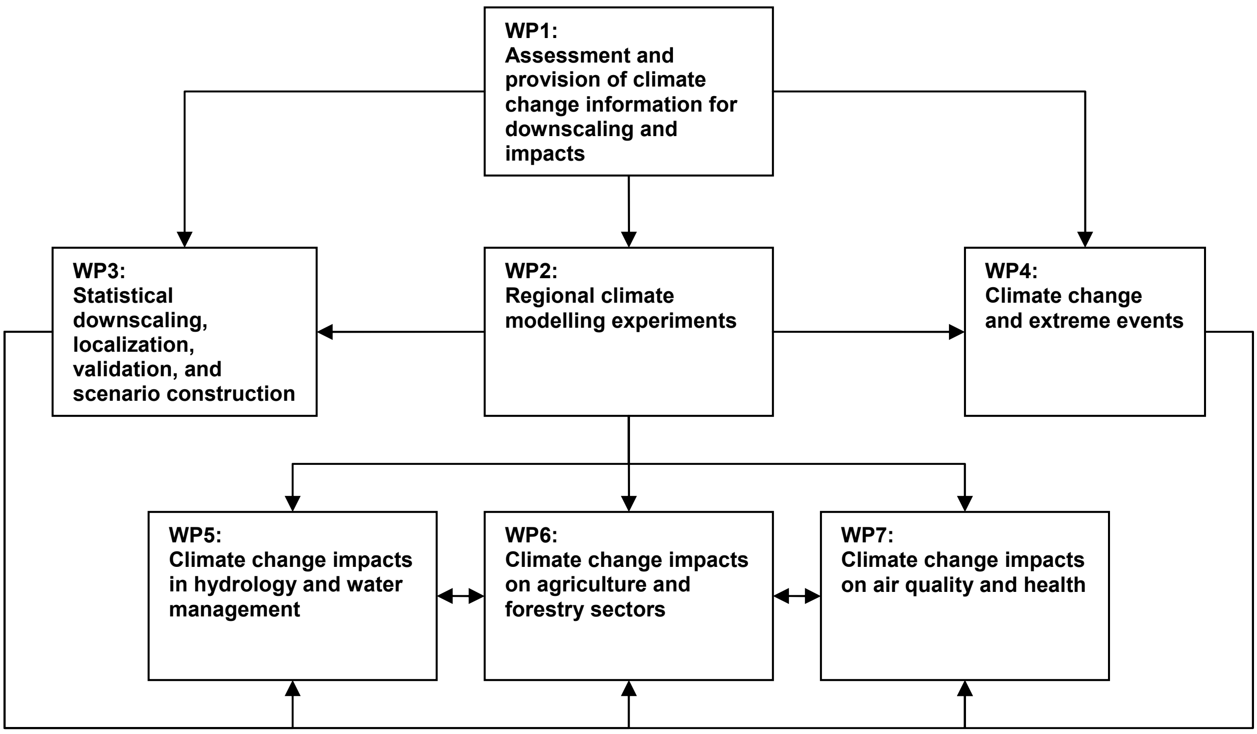


Figure 1. *Interactions between the workpackages*

1.1.3 Technical approach

The project CECILIA brought for the first time very high resolution localization of climate change scenarios into the targeted areas of CEE. Improving upon the project ENSEMBLES where Europe-wide scale has been adopted at high resolution, here we have addressed even higher resolution on a significantly smaller domain. This higher resolution enables not only more detailed description of the topography and land use, but it allows to introduce new processes, as interactive interaction of climate change and air quality, subgrid effects etc. However, it requires the adaptation of parameterizations available at coarser resolution. One of the main objectives of this project was to adapt a few of the models used for ENSEMBLES (ALADIN-Climate and RegCM) for very high resolution (grid spacing of 10 km) simulations over selected sub-domains. The assessment of the role of significant but previously not resolved topographical features and land-use patterns was supposed to be provided in these experiments as well as the evaluation of the sensitivity of the simulations to the choice of the model domain. Development of new features in the parameterization of high resolution physics in the models was expected (e.g. cloud microphysics, chemistry of urban areas etc.). This provides a connection with the EC FP6 Project QUANTIFY, which has aimed at quantifying the impact of transportation on climate change. In the region of CEE the need for high resolution studies is particularly important due to the appearance of complex topography features as Alps, Carpathians basin and smaller mountain chains and highlands in most of the countries that significantly affect the local climate conditions. A resolution sufficient to capture the effects of these topographical and associated land-use features is necessary as illustrated in Fig. 2, where comparison of topography representation in different resolutions is presented in the detailed view on the Czech Republic.

The most reliable source of information on the evolution of the atmospheric environment in the next decades comes from RCMs. It was demonstrated in PRUDENCE that the major source of uncertainty for RCM was the driving GCM. It is thus essential to use at least two GCMs (ARPEGE and ECHAM5). Since ARPEGE and ALADIN have been written and developed to work with each other and RegCM has been used already with ECHAM5 as well, it is natural to use these two pairs. As the forcing GCMs introduce their own systematic errors in the regional climate, a first step consists of forcing the high resolution RCM with data as close as possible to observation. The ERA40 dataset provides a good forcing at 150 km resolution, the other 3 RCM simulations are snapshots driven by GCM conditions: 1961-1990, 2021-2050, and 2071-2100.

Statistical downscaling (SDS) is an alternative approach to get high resolution insight to climate change issue. SDS consists of seeking statistical relationships between the variables simulated well by GCMs and the surface climate variables of interest. These relationships are usually trained on observed data and then applied to the control and perturbed GCM outputs, the former serving for verification and the latter for climate change scenario construction. As for the methods, the majority of SDS studies employ linear methods, most notably multiple linear regression and canonical correlation analysis. Nonlinear methods have recently begun to emerge as well. The added value in the project consists mainly in a complex inter-comparison of performance between the dynamical and statistical models. The ability to simulate extreme values is also of great importance. RCMs even at high resolutions of less than 20 km still do not provide site-specific information required in many impact models, which becomes relevant especially in regions with complex topographical features as typical in focal areas of the project. Methods for localization of model outputs have been proposed based on regression against geographical variables, with the residuals being interpolated using geostatistical methods. An alternative procedure is a MOS-like approach using model variables as predictors.

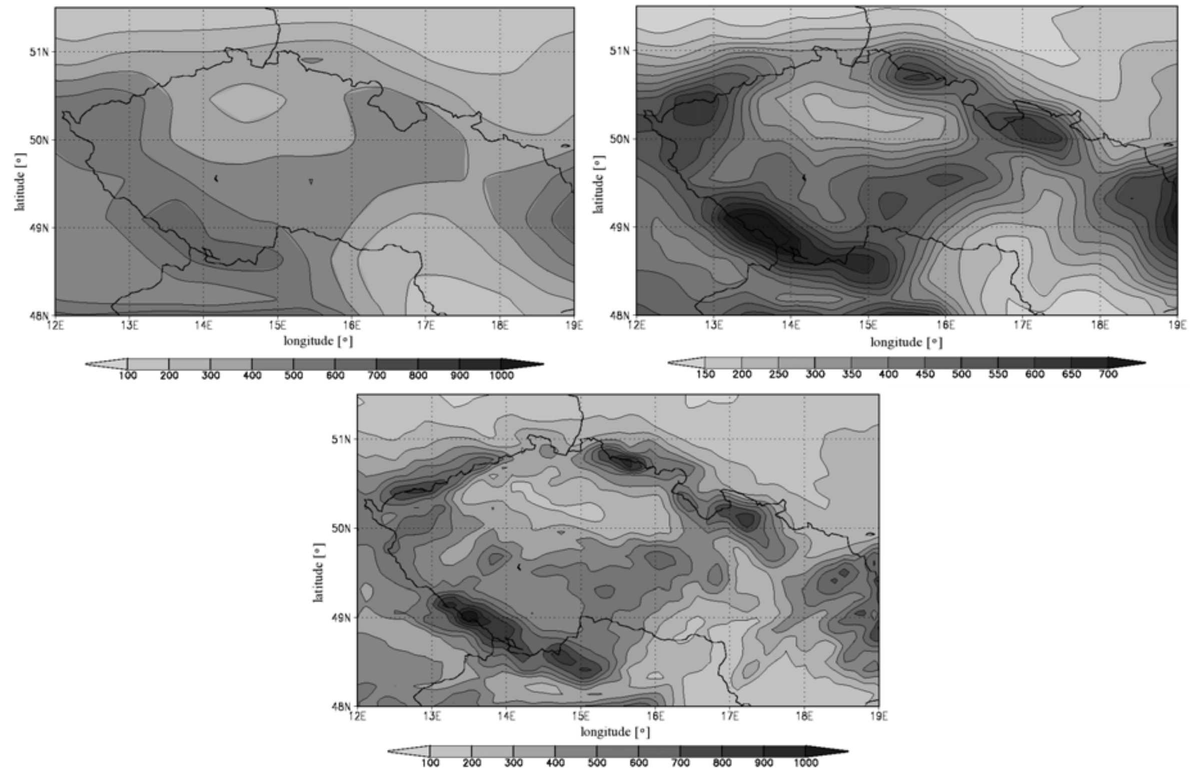


Figure 2. *Detail of topographical features seen in ENSEMBLES' 50 km resolution (upper left) and 25 km (upper right) and 10 km for CECILIA proposal (bottom panel).*

Previous results showed the possibility of the changes of statistical distribution of climate parameters in our targeted domains. Despite the relative agreement of climate-change scenarios concerning the changes in extremes over this region, a significant uncertainty remains with regard to their exact magnitude and the attribution of the causes for these changes. Some studies have highlighted the role of large-scale circulation changes, but land-atmosphere interactions are clearly of key relevance as well. Moreover, certain aspects central to this issue are often not well represented in GCMs (land surface heterogeneity, complex topography, convection), or even in RCMs. Very high-resolution simulations can help investigating some of these open questions and can yield more accurate estimates of future changes in extreme weather events over the targeted regions. Other issues that need investigation are the effects of domain size on the simulated processes, choice of parameterizations and boundary conditions.

The impacts of climate change on hydrology are estimated using scenarios for changes of climatic inputs to a hydrological model. Improved models have been developed to simulate water quantity and quality involving representation of the physical processes. The climate change has potential effects on the components of the water balance (precipitation, evaporation, soil moisture, groundwater recharge and river flows) and their variability over time. In a river basin the hydrological variability over time is influenced by variations in precipitation over all the time scales. Flood frequency is studied in high resolution scenarios of climate change which bring more precise information based on better definition of the catchments. The frequency of low flows is affected primarily by changes in the seasonal distribution of precipitation, year-to-year variability, and the occurrence of prolonged droughts. Climate change has the potential to affect all of these factors in a combined way that is not yet clearly understood. The local effects of climate change on soil moisture will vary not only with the degree of climate change but also with soil characteristics where high resolution of the simulations might be of the great importance. Groundwater is the major source of water, particularly in rural areas in arid and semi-arid regions, but there has been very little research on the potential effects of climate change. The great number of hydrological studies has focused on potential changes of streamflow. To estimate the impact of climate change on the hydrological resources, mathematical rainfall-runoff models were outlined to be used for the reference basins. These basins are selected based on the assessment of the vulnerability of water resources and corresponding adaptation measures. The models can be applied both in the case of present regime and regimes of climate change scenarios taken from downscaled results. When taking the results of statistical downscaling the use of weather generators is required to obtain inputs for most hydrological models, in the case of very high resolution RCMs both spatial and time resolution could be satisfactory for direct input to the basin models. The assessment of water quality changes and impacts on availability and management of surface water resources are important as well. This implies the analysis of hydrological balance changes, nutrient (N, P) concentrations and eutrophication in a river network with reservoirs used for drinking water supply and recreation.

The increased content of CO_2 in the air stimulates photosynthesis. At the same time, higher ambient CO_2 allows to reduce the transpiration intensity through decreased stomatal conductance, especially under higher temperatures. This should lead to improved water use efficiency by plants and thereby to a lower probability of water stress occurrence. The impact of the changed weather regime brought about by the CO_2 increase is referred to as "indirect effect" or "weather effect". The most important weather variables that directly determine the crop yield are solar radiation, precipitation and temperature. If no management response (e.g., other cultivars, change in the planting date or soil water conserving practices) is applied, cereals in general yields typically decrease with increasing temperature due to a shortening of phenological phases. On the other hand, the crop response to high temperatures clearly depends on the character of the temperature increase as well as the developmental stage of the crop. There are major gaps between the actual and attainable yields of crops, attributable largely to pests, diseases and weeds. Therefore predicting the potential distribution of all pests, both indigenous and introduced, plays a key role in determining the effects of global change effects on agricultural, horticultural and forest ecosystems. The distribution and intensity of current key pests and diseases may be affected, leading to changed effects on yield and on control measures such as pesticides and integrated pest management. However, as it was stated in the IPCC (2001) only modest progress has been made in understanding pests response to climate change since the last comprehensive overview.

Climate change and other pressures will alter future carbon (biomass) storage in forests, but the regional extent and direction of change is still unknown. Research reported since the early nineties confirms the view that the largest and earliest impacts induced by climate change are likely to occur in mountainous and boreal forests, where changes in weather-related disturbance regimes and nutrient cycling are primary controls on productivity. Forest growth has increased during the past several decades in European forests; climate warming, increasing CO_2, increased nitrogen deposition, and changes in management practices are factors that are assumed to be behind the increase. The impacts of temperature and CO_2 have been shown in experiments and are extrapolated by model calculations.

The concentration of air pollutants depends on both anthropogenic and climate factors. A main issue is the quantity of emissions of primary pollutants as well as of precursors of secondary pollutants. Long range transport to the target regions was supposed to be taken into account by simulation for the whole Europe, driven by RCM runs with a grid resolution of 50x50 km. These simulations then can constrain nested higher resolution runs (10x10 km) for a smaller domain focusing in CEE both for present and future climate. The key species are ozone, sulphur, nitrogen and PM, which have a central role in tropospheric chemistry as well as the strong health impacts. Emphasis is given to future key species exceedances of the EU limits for the protection of human health, vegetation and ecosystems as well as WHO guidelines. Another risk factor for the human health, which finally goes hand in hand with the issue of air quality through the chemistry of pollutants, are heat waves, and in certain extent even cold waves. The summer of 2003 encompassed one of the most severe heat waves on record in central and western Europe causing both human losses and damage to natural ecosystems. First guess of possible impacts of climate change on mortality and attempt to split the direct effect of heat and cold waves from the effects of air quality can be made on the basis of this study. Climate change may affect exposures to air pollutants by a) affecting weather and thereby local and regional pollution concentrations; b) affecting anthropogenic emissions including adaptive response of increased fuel combustion for fossil fuel-fired power generation; c) affecting natural sources of air pollutant emissions; and d) changing the distribution and types of airborne allergens. In addition, the chemical composition of the atmosphere may in turn have a feedback effect on the local climate. Weather is also associated with energy demands (e.g., for space heating and cooling) that could alter patterns of fossil fuel combustion. In particular, individual responses to extremely hot weather can result in large increases in air conditioner use. In addition, high temperatures cause increased VOC evaporative emissions when people run motor vehicles. The health effects of air pollution are broad and diverse, including dramatic episodes of increased mortality at high concentrations. In humans, the pulmonary deposition and absorption of inhaled chemicals can have direct consequences for health. Nevertheless, public health can also be indirectly affected by deposition of air pollutants in environmental media and uptake by plants and animals, resulting in chemicals entering the food chain or being present in drinking-water and thereby constituting additional sources of human exposure. Furthermore, the direct effects of air pollutants on plants, animals and soil can influence the structure and function of ecosystems, including their self-regulation ability, thereby affecting the quality of life. The most sensitive groups include children, older adults and persons with chronic heart or lung disease.

1.1.4 Expected achievements/impact

Although the broad response of global climate to increased greenhouse gas concentrations is well established, many unknowns remain in the regional details of projections of future climate change. Thus, the central internal objectives of CECILIA have been to improve regional climate scenarios and their localization for climate impacts models, and comparing these results against the results of previous and ongoing projects to assess the added value of dynamical downscaling at very fine scales. The general aim of CECILIA was to improve Europe's ability to assess the consequences of global climate change at the local scale, and on this basis to assist to formulate more precise response strategies and more scientifically based negotiating positions. Such an effort assists in the successful implementation of the FCCC (Framework Convention on Climate Change) and the Kyoto Protocol, for the negotiations in the post Kyoto process and in regulations to mitigate the possible consequences of climate change as concluded by IPCC. Very high resolution and better regional predictions are required to guide long term planning in sectors such as agriculture and energy.

Several key issues connected with climate change have become of interest in recent years, such as the occurrence of extremes or effects on air quality, with potentially severe impacts on the quality of life, health and safety. The occurrence of these extreme events, in some cases causing loss of human lives or extensive damages and costs, is affected by the relation between extremes and climate change which can be better explored using high resolution climate modelling. Results allow us to evaluate the vulnerability of different sectors in the regions. CECILIA will provide high resolution tools to help anticipate and ameliorate the adverse impacts of climate change on humans both at the individual and at the societal level. It will help to identify and exploit positive impacts. It provides demonstrations of the use of these tools in important economic, environmental or social sectors where the impacts of climate change are likely to be felt. Results of simulations generated within the project are expected to be available for other interested institutes in Europe, with the possibility of use in national projects on climate change impacts over the targeted area.

Climate change represents a major factor affecting the global and European environments. Natural ecosystems will become stressed if climatic zones shift at a faster rate than the ecosystems can migrate. Changing availability of natural resources such as water supply may adversely affect the sustainability of European activites. A more stressed environment will be even more vulnerable to natural hazards. CECILIA with high resolution climate simulation can help foresee and reduce the adverse impacts on the local environment and natural resources of the targeted regions. It can also provide mitigation information to reduce the hazards concerning these important factors. Concerning the environment, CECILIA, similarly as the EC project QUANTIFY, provides a platform for reducing the gap between climate change and air quality sciences, putting together traditional aspects of climate change impacts and impacts on air quality.

This project brings very high resolution localization of climate change scenarios into the targeted areas of CEE, with the added value of climate scenarios produced locally. This provides necessary policy relevant information concerning the local adaptation and/or mitigation measures. Moreover, it is providing know-how and tools which can be further used for the analysis of the climate change development and climate change impacts on different sectors of the society in the target region. With the emphasis on former Eastern Block countries the CECILIA project is providing new access and contacts for researchers from this area to the European research activities and thus it helps to bridge existing gaps. An important point of innovation consists in the fact that very high resolution climate information will allow application in integrated climate change impact studies, which is in turn providing for the first time necessary policy relevant information for decision makers and local authorities in the region.

1.2 Objectives, work performed, contractors involved and the main achievements in the period

In the last period of the project, after the preparation of models by modelling groups and impact parts in the first year and further tuning and tests within the second year, the main emphasis of the project was to complete high resolution RCM scenarios simulations for targeted areas driven by GCM. High resolution simulations by six regional climate models centered over Czech Republic (two models), Hungary (two models), Romania and Bulgaria were performed for present day climate simulation (1961-2000) as well as for two time slices of climate change A1B scenario, i.e. mid-century run of 2021-2050 and end-of-century one 2071-2100. Further analysis of RCM results, their localization and comparison to driving data to analyse the added value of high resolution simulations for complex terrain of Central and Eastern Europe and comparison of other methods of downscaling, i.e. statistical sownscaling filled the agenda of the project in this period as well. For the impact part it was supposed to perform selected analysis of climate change impacts based on the high resolution climate change scenarios constructed using the simulations performed within the project.

1.2.1 WP1

There were basically no tasks already in WP1 for the last period of the project except some support of other WPs when comparing the results with the outputs of previous projects, like the 21st century under the A1B scenario by the ARPEGE simulation at 50 km (CNRM) and the RegCM3 simulation at 25 km grid spacing over Europe (ICTP, available from ENSEMBLES project). ICTP, CNRM and DMI were mostly involved in this support.

1.2.2 WP2

The main objective of WP2 was to produce simulations on targeted domains for a past period (1961-1990/2000) driven by ERA40 reanalysis, as well as a reference period and two scenario time slices (2021-2050 and 2071-2100) based on AR4-A1B GCM projections. During the last period of the project, the main activity was to run and exploit the scenarios at CUNI, CHMI, ELU, OMSZ, NMA, NIMH. Some models were run twice, because improvements were proposed (RegCM alpha and RegCM beta). The summary of the results is presented in Fig. 3 and 4.

The exploitation of the data consisted to deliver the data in suitable format to DMI for the building of CECILIA database which should survive to the project. Due to practical problems in data conversion, there was certain delay in data supply to the database from a few partners, but it is completed now. However, the data have been distributed to the partners of the other WPs for direct use in native format so that the statistical adaptation, the study of the extremes, the driving of hydrological, agronomic (including forestry) and pollution models has been possible during the course of the project.

The simulations have been compared to existing projects (FP5-PRUDENCE and FP6-ENSEMBLES) involving coarser resolution regional models over Europe under cooperation to ICTP, CNRM and DMI. The CECILIA results are in agreement with older results when there is an agreement between the models (temperature rise, summer precipitation decrease). There are also aspects (winter precipitation), where the inter-model spread already observed in PRUDENCE and ENSEMBLES is confirmed at higher resolution by CECILIA. In this case, climate change is necessary described by a probability distribution. Indeed, the disagreement on the sign may either mean a strong uncertainty about the response (with possibly a sign more probable than its opposite), or an absence of response.

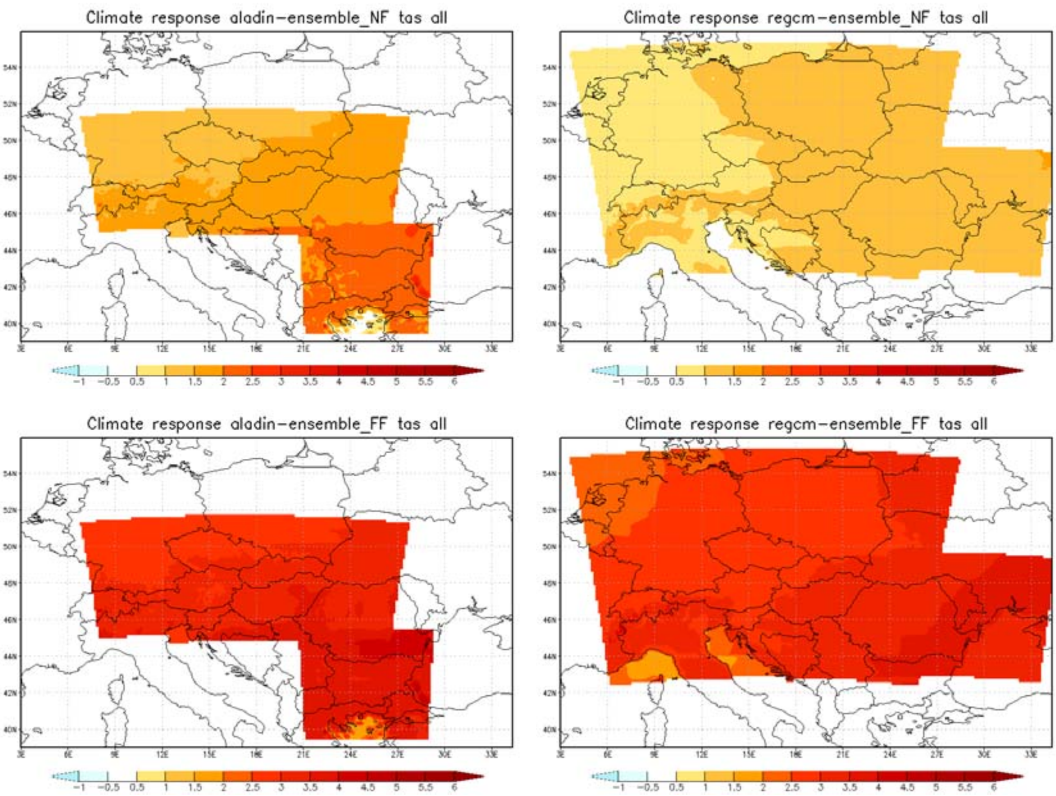


Figure 3. *Climate change signal of annual mean temperature (°C) for 2021-2050 (upper panels) and 2071-2100 (bottom panels) against 1961-1990, composites from ALADIN-Climate models (left panels) and from RegCM models (right panels) for Central and Eastern Europe.*

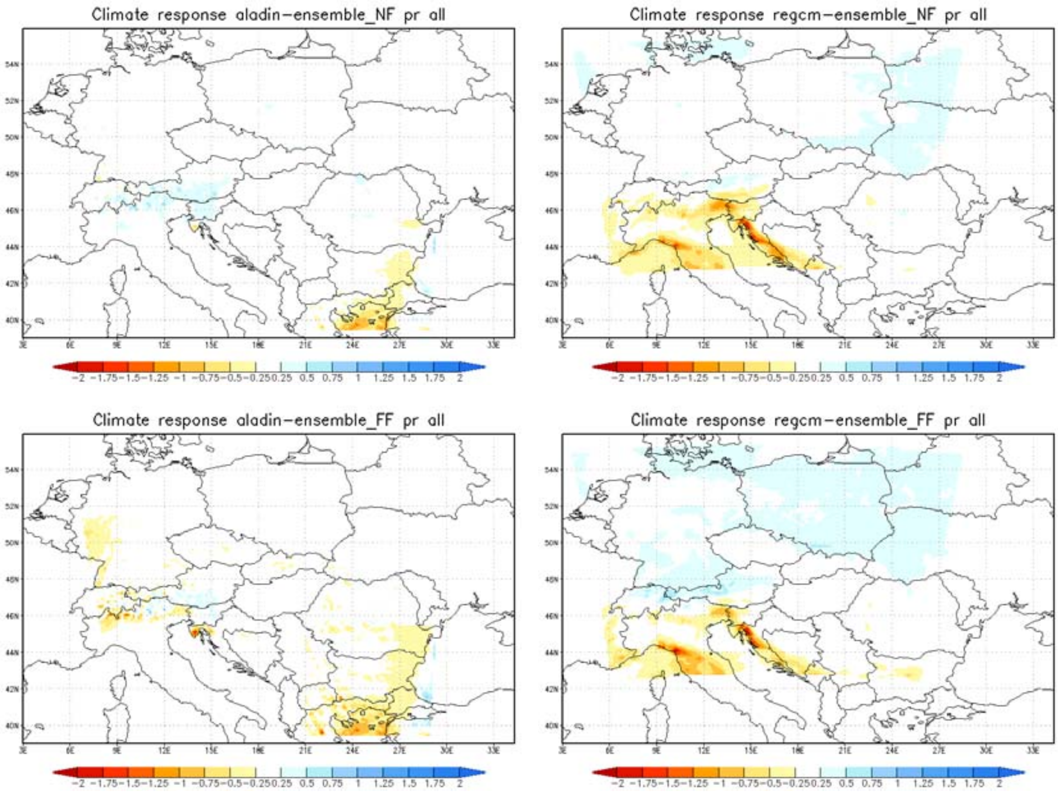


Figure 4. *Climate change signal of annual mean precipitation (mm/day) for 2021-2050 (upper panels) and 2071-2100 (bottom panels) against 1961-1990, composites from ALADIN-Climate models (left panels) and from RegCM models (right panels) for Central and Eastern Europe.*

The second objective of WP2 was to explore the possible improvements of high resolution regional climate modelling by testing new parameterization schemes better adapted to this resolution. BOKU has tested a new approach of subgrid representation of snow over the mountains, which improves hydrology in Alpine region. AUTH has tested improvements in the convection scheme to take into account the fact that part of the small scale motions are explicitely described by the dynamics at that resolution. WUT has explored an alternative the boundary layer scheme to improve low cloud representation. CUNI has made experiments with humidity thresholds for cloud formation. These improvements relate to RegCM and could be used in further regional studies.

1.2.3 WP3

The main tasks of WP3 in the last reporting period was finally to use the common region observed data prepared within the WP3 activities in previous period for intensive comparison of the downscaling methods, i.e. statistical downscaling techniques between themselves and with respect to the dynamical downscaling by the RCMs involved, model ALADIN-Climate/CZ and RegCM. This work has been performed mainly by IAP, BOKU, CUNI and CHMI. The validation of statistical (multiple linear regression, multiple linear regression on data stratified by circulation types, canonical correlation analysis, various kinds of non-linear methods, including neural networks, classification-based methods, and stochastic downscaling approach) and dynamical (ALADIN-Climate/CZ, RegCM/CZ) downscaling models was conducted on the common central European area along the Czech-Slovak-Austrian-Hungarian borders for daily temperature. The model outputs were validated against observed data interpolated onto a 10 km grid of the ALADIN-Climate/CZ RCM, to which also RegCM's outputs were interpolated. Analyzed were characteristics of temporal and spatial structure, namely, the 1-day lag autocorrelation (persistence) and spatial autocorrelation. It can be summarized that RCMs systematically overestimate persistance while underestimate spatial autocorrelations. This behaviour is different from statistical downscaling models, for which underestimation of both temporal and spatial autocorrelations is typical.

To construct specific regional climate change scenarios using full advantage of information from RCM simulations it was found that some method of bias correction has to be used especially for precipitation. Different methods were tested within the activities of WP3 and finally applied in most scenarios constructed. The evaluation of their performance was done by comparing the original model data (reanalysis driven, control) and the corrected model data with observational data. The example of BOKU technique presented in Fig. 5 is based on using the differences of the empirical cumulative density functions of model and observation and it is applied to the model data so that the statistics of the observations are retained. The method uses correction factors that correct the model data depending on the CDF values. The correction factors are defined either as an additive correction, which was used e.g. for the temperature data or as a multiplicative correction which was used e.g. for precipitation.

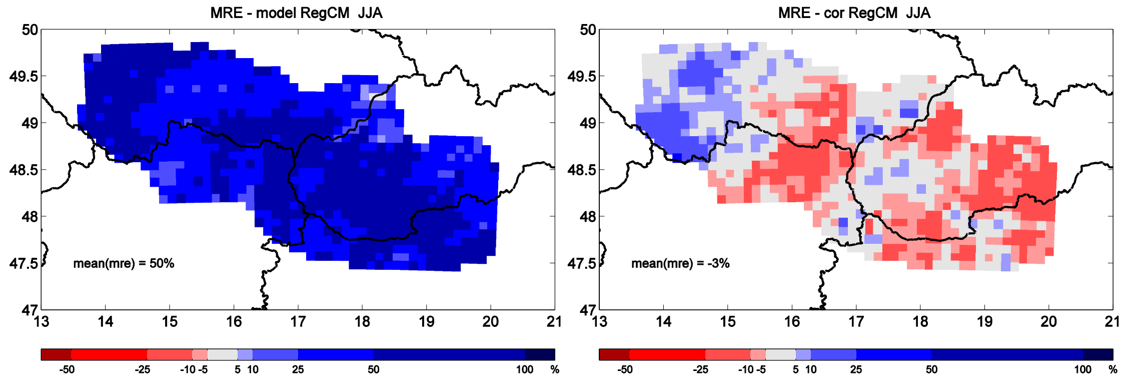


Figure 5. *Spatial distribution of mean relative errors of the monthly means for the model (left) and the corrected model (right) for precipitation (simulation by the RegCM model, run at CUNI and postprocessed at BOKU).*

Another important issue is the model output localization based on statistical downscaling techniques, developed and adapted for the project. Some effort was done by CUNI updating the results achieved and combining the localization postprocessing with the bias reduction method.

1.2.4 WP4

In the last reporting period, WP4 focused on the addition of the 10 km high-resolution model simulation and the high-resolution observational datasets in the analysis using the list of 131 climate and extreme weather indices that was defined in D4.1. The indices data base stored at DMI (http://cecilia.dmi.dk/) served as basis for the analyses in the last reporting period of CECILIA WP4. It was extensively used by the partners for their individual tasks and will be made publicly available after the publication of the CECILIA special issue. The outputs from the 10 km high-resolution simulations were analyzed in various Central and Eastern European domains by the partners, focusing on trends and on the validation with observational indices. This was done by individual partners for their domain (CHMI, CUNI, OMSZ, ELU, NMA, NIMH), a synthesis for the whole CECILIA region including an inter-comparison with pre-existing RCM data sets was provided by ETH and DMI (see Fig. 6).

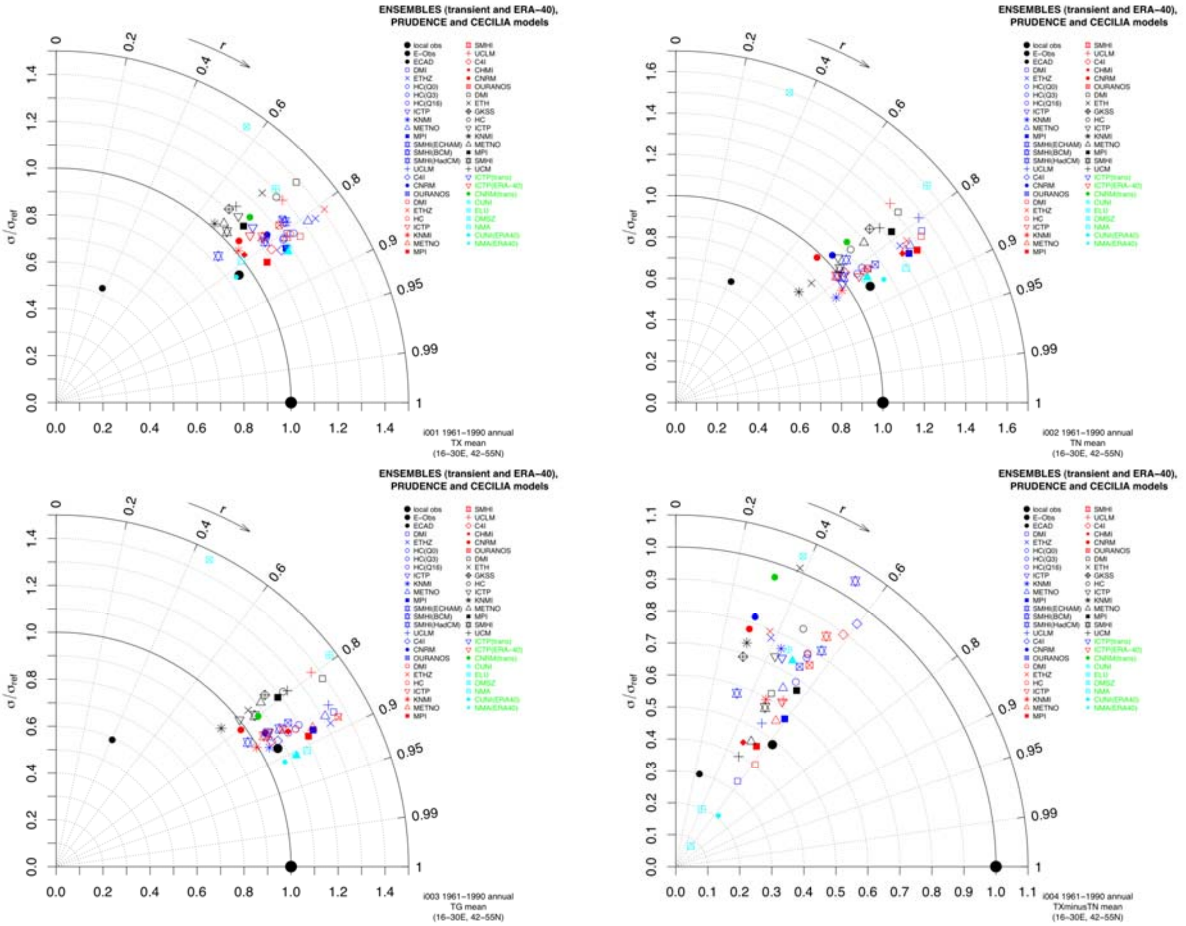


Figure 6. *Taylor plots including the ENSEMBLES transient (blue symbols) and ERA-40 (red symbols) simulations, the PRUDENCE RCMs (black symbols), as well as the CECILIA driving and high-resolution runs (green model acronyms, cyan symbols for the high-resolution runs) compared against the local observations. For comparison, also the ECA&D and the E-Obs observations are included (also relative to the local observations). As mentioned in the text, the CECILIA driving runs from ICTP coincide with the respective ENSEMBLES runs with the same model and consequently share the same symbols and colors. (Top left) maximum temperature, (top right) minimum temperature, (bottom left) mean temperature, (bottom right) daily temperature range. Displayed are annual values for the period 1961–1990 and for the East European domain (16°E–30°E, 44°N–55°N). σ denotes the spatial standard deviations (normalized by the standard deviation of the observations) and r the correlation coefficients.*

Moreover, sensitivity experiments investigating feedback processes that are relevant for the occurrence of extreme events were carried out and investigated. These highlight the role of land-atmosphere coupling for temperature variability in Central and Eastern Europe. Also, temperature extremes, as investigated by climate extreme indices and PDFs, are strongly affected by the absolute value and to a smaller extent also by changes in temporal variability of soil moisture. This is mainly due to intra-seasonal as well as inter-annual soil moisture variability.

A study investigating the impact of soil moisture on temperature extremes showed a strong impact of soil moisture deficit (as expressed by the standardized precipitation index SPI) in particular for the upper quantiles of temperature extreme indices. This is the case in a Southeastern domain (encompassing Bulgaria and Romania) with a soil-moisture limited evapotranspiration regime.

1.2.5 WP5

One of the main tasks of WP5 partners (CHMI, IAP, FRI, NIHWM and NMA) concerning the climate change impacts on hydrology and water management in the last reporting period was to continue the simulations of monthly river flow under changed climate conditions, this time using as input data the new ALADIN and RegCM models results with 10 km spatial resolution obtained in WP2. For Hron river basin, Slovakia and for two catchments of Jihlava River, Czech Republic, the climate characteristics were simulated by the ALADIN climatic model (10 km resolution). Runoff values simulated for time period of 2021-2050 are from January to April and from August to September lower than 1971-2000, from May to July both values are essentially without any change and from October to December when the values are higher than the reference period 1971-2000. The mean monthly flow simulation for Ialomita and Buzau area, Romania, was based on the RegCM model (10 km resolution) results for the same periods (2021-2050, 2071-2100). The simulated monthly discharges present, also, an increasing in winter - spring period, especially for the near future period (2021-2050) and a general decreasing for the end of the century period (2071-2100). These last results were compared with the results of simulations based by RegCM (25 km resolution) results.

The simulations of flood occurrence during 2021-2050 and 2071-2100 in the Dyje catchment (the final profile Podhradí, catchment area 1756 km^2) based on the ALADIN scenarios were also calculated (D.5.7). The comparison of this last results with the runoff simulated based on the global climatic model shows some differences which are caused by different approaches of downscaling. All the flood waves were evaluated, the return time period maximum discharges were calculated based on ALADIN climate scenarios and Tab. 1 presents the results. It is obvious that based on the ALADIN climate scenarios, the return time period peak discharges could be about 10% higher in future. It is also important to stress that the whole process of flood simulation is very uncertain and it is strongly dependent on the ALADIN-CE climate scenarios.

Table 1. *Comparison of measured and simulated return time period maximum year discharges.*

Retur period [year]	Discharge based on measurement (1933-2009) [m^3/s]	Discharge based on measurement and simulation 1961-2000 [m^3/s]	Discharge based on measurement and simulation 2021-2050 [m^3/s]	Difference [%]	Discharge based on measurement and simulation 2071-2100 [m^3/s]	Difference [%]
1000	681	685	806	18	756	11
500	595	602	703	18	663	12
200	491	500	578	18	551	12
100	419	429	491	17	472	13
50	353	363	412	17	399	13
20	274	282	316	15	309	13
10	220	227	250	14	248	12
5	172	176	191	11	191	11

Another aim of WP5 was to explore water quality responses in a temperate, stratified reservoir to climate change scenarios (D5.8) that were modelled with the atmosphere-catchment-reservoir simulation system developed and described within previous deliverables (esp. D5.4). The scenarios of climate change were developed using the pattern scaling techniques from the outputs of 3 global and 2 high-resolution regional climate models, representative scenarios for the development of emissions of greenhouse gases and aerosols, and a range of climatic sensitivity to emissions. The anticipated climate change with its increase in temperature and impacts to the runoff can affect water quality in water bodies especially due to three groups of factors: changes in runoff paths through the soil, changes in the hydrologic conditions and modifications of hydrodynamics and seasonal mixing and stratification pattern. Water quality in the reservoir will be worsened by the increase in the scale of anoxia in the water column due to the smaller volume of hypolimnion and higher sedimentation rates under the conditions of decreased pool of accumulated water. All these phenomena together will mean a higher stress on aquatic ecosystem, especially on the littoral communities and fish.

To ensure future water requirements for the population, industry and agriculture, certain structural and non-structural measures are needed (D5.9). The adaptation measures to climate changes, proposed by NIHWM for Buzau-Ialomita area, are based on estimated future water resources and on the analysis concerning the vulnerability of these resources presented in D5.5.

Finally, deliverable D5.10 aimed to identify the role of regional sea surface temperature anomalies on extreme precipitation in Romania under present and A1B conditions. For the observed analysis, we used daily precipitation amounts from 104 Romanian stations to build a seasonal time series of extreme precipitation for the period 1961-2000. Canonical correlation analysis of the observed extreme precipitation and sea surface temperatures (SSTs) over the Mediterranean and Black Seas suggests that local extreme precipitation is significantly affected by the Black Sea surface temperatures in winter. This result is confirmed for present climate by sensitivity experiments with a regional climate model in which the Black Sea surface temperature is raised by 2 K. As for the A1B scenario conditions, analyzed in the present project, the SST variability seems to have an important impact especially on the climate of the regions situated in the vicinity of the Black Sea. Extreme precipitation characterized by higher amounts are likely to occur both in summer and season, especially over South-Eastern part of Romania, due to a higher precipitable water amount present in the air column.

1.2.6 WP6

WP6 aimed at three topic – (i) agriculture, inclusive drought, crop production and pest; (ii) forestry, inclusive forest growth, mortality and pests; and (iii) carbon, focusing on changes in the land carbon sink and productivity of forest and grassland ecosystems. All simulation were used to draw the recommendations on improved agriculture and forest management under regional climate change scenarios. Objectives of WP6 during the last reporting period are compliant with the following list of deliverables: D 6.5 Report about the expected changes of occurrence and activity of pests and diseases on selected crops and forest ecosystems (IAP, FRI, CHMI); D 6.6 Report about the sensitivity analysis of the selected agriculture crops and the most vulnerable forest stands to climate change impacts (FRI, IAP, BOKU, CHMI, WUT); D 6.7 Report about the integrated assessment of climate change and air pollution impacts on C-cycle in agriculture and forest ecosystems (FRI, WUT, ELU); and D 6.8 Recommendations and development of management options for an improved land use systems in agricultural crop production and forest management under the regional climate change scenarios (FRI, IAP, BOKU, NMA, CHMI, NIMH).

In the Marchfeld, NE Austria, the results of simulations indicate a shortening and an earlier occurrence of phenological development stages of winter wheat and spring barley yields, as well as yield stagnation or decrease in the near future for these current cultivars. An exception presents NCAR PCM, with a slight increase of winter wheat as well as spring barely yield on medium soils. The interannual yield variability of both crops would increase for almost all soils, which leads to a higher economic risk for farmers. Without fertilizing CO_2 effect, mean yield would stronger diminish, especially on sandy and shallow soils. As recommendations and development of management options, a shift of average sowing dates, a replacement of ploughing by minimum tillage and direct drilling as well as support irrigation and improved irrigation efficiency for winter wheat and spring barley were studied. A replacement of ploughing by minimum tillage and direct drilling within the 2035 scenario would lead to an increase of mean yield of winter wheat (up to 10 %) and of spring barley (up to 8 %) in 2035. Further recommendations for the target area would be crop rotation (less summer crops), applying surface mulch (reduction of evaporation) and change to more drought and heat tolerant cultivars in the midterm (adapting breeding strategies).

At least parts of the territories of Austria, Czech Republic, Germany, Hungary, Poland, Romania, Slovakia, Switzerland and Ukraine show an increase in the mean production potential as a whole (expressed in terms of effective global radiation and number of effective growing days). This is however not true for the Pannonian and Mediterranean parts of the domain where increases in the water deficit will further limit rainfed agriculture. The increase in the severity of the 20-year drought deficit and the more substantial water deficit during the critical part of the growing season are very likely over the central and western part of the domain. Sowing conditions during spring will deteriorate due to the unfavourable weather that might increase the preference given to winter crops, which is already likely due to their ability to withstand spring drought stress events. Harvesting conditions in June (when harvest of some crops might take place in the future) are not improving beyond the present level. The rainfed agriculture will face more climate-related risks, but the overall conditions will likely allow for acceptable yield levels in most of the seasons. Risk of extremely unfavorable years resulting in poor economical return is likely to increase as well.

The potential occurrence of the Colorado potato beetle and the European corn borer was examined in the same domain. The results show the likely widening of the pests' areas and an increase in their generation number. According to the HadCM-high scenario, the increase of the ratio of arable land affected by the occurrence of third generation of Colorado potato beetle in 2050 is about 45% higher, and the occurrence of a second generation of the European corn borer is nearly 61% higher.

In the S-E Romania, simulation results indicate that in 2020-2050 the climate may he have important effects upon crops and they are conditioned by an interaction between the current climate changes on a local scale, severity of climate scenario-forecasted parameters, increased CO2 concentrations influence on photosynthesis, and the genetic nature of plant types. Winter wheat can benefit from the interaction between increased CO2 concentrations and higher air temperatures, while maize is vulnerable to climate change, mainly under hot and droughty conditions.

The results show that during the climate change in Bulgaria in the 21st century, most vulnerable will be: a) spring agricultural crops, due to the expected precipitation deficit during the warm half-year; b) crops cultivated on infertile soils; c) crops on non-irrigated areas; d) arable lands in south-east Bulgaria where even during the present climate, precipitation quantities are insufficient for normal growth, vegetation and productivity of agricultural crops. Adaptation options in Bulgarian agriculture were considered like measures for improving irrigation under climate changes, measures for improve management, use and protection of water resources in irrigated agriculture, adaptation measures to improve management efficiency and use of existing irrigation systems and elaboration of technological and technical means for irrigation, and adaptation measures for use of rational and economically viable irrigation regimes. A questionnaire on adaptation options in agriculture was developed and disseminated. Finally, the following options were recommended as feasible adaptation options: changes in irrigation, changes in sowing dates, changes in crop cultivars and varieties, and new crop zoning.

Impacts of predicted climate change on forest ecosystems sensitivity to atmospheric deposition of sulphur and nitrogen were studied in Poland. The increase of critical loads (CL) estimated for future time slices in two selected (mainly coniferoud) forest regions (the Karkonosze domain in the Sudety natural-forest region and the Kampinos domain in the Mazowsze-Podlasie natural-forest region) means an enhancement of tolerance of the terrestrial ecosystems to acidifying and eutrophying depositions. However, due to estimated increase of nitrogen deposition, the significant increase in exceedances of CL of nutrient nitrogen was predicted. Therefore, the summary effect of climate change on the ecosystem protection against eutrophication caused by excess atmospheric deposition of nitrogen is negative for the structure and functioning of the ecosystems. The main risk which potentially results from the permanent nutrient nitrogen critical load exceedance is the loss of biodiversity in the present species constitution of ecosystems.

Climate change impacts studies on forests indicated that beech (*Fagus sylvatica*) and spruce (*Picea abies*) production will decline at species receding edge (lower limit), while significant increase in production is projected at the leading edge, in the higher elevations. The mortality pattern differs between the species. In case of oak (*Quercus sp.*), almost no change in production is projected in the lower elevations, while the growth slightly increases (by 3-9% on average) in the elevations above 600-1 300 m a.s.l.. Such response is accompanied by unchanged mortality over the all span of natural conditions. Analysis of bark beetle (*Ips typographus*) related risk to spruce stands in Fig. 7 indicates that one-generation increase of bark beetle (comparing to 1961-1990) will occur over 42% in 2021-2050 and over more than 90% of current distribution of spruce stands in 2071-2100 in Slovakia. The third generation is the highest reached in the current distributional range of spruce. Recommendations for optimized forest management are mainly aimed at optimizing forest distribution and species composition to respond the projected changes in forest production, natural mortality as well as changes in pest's activity. The maintenance of valuable genetic material is addressed as well.

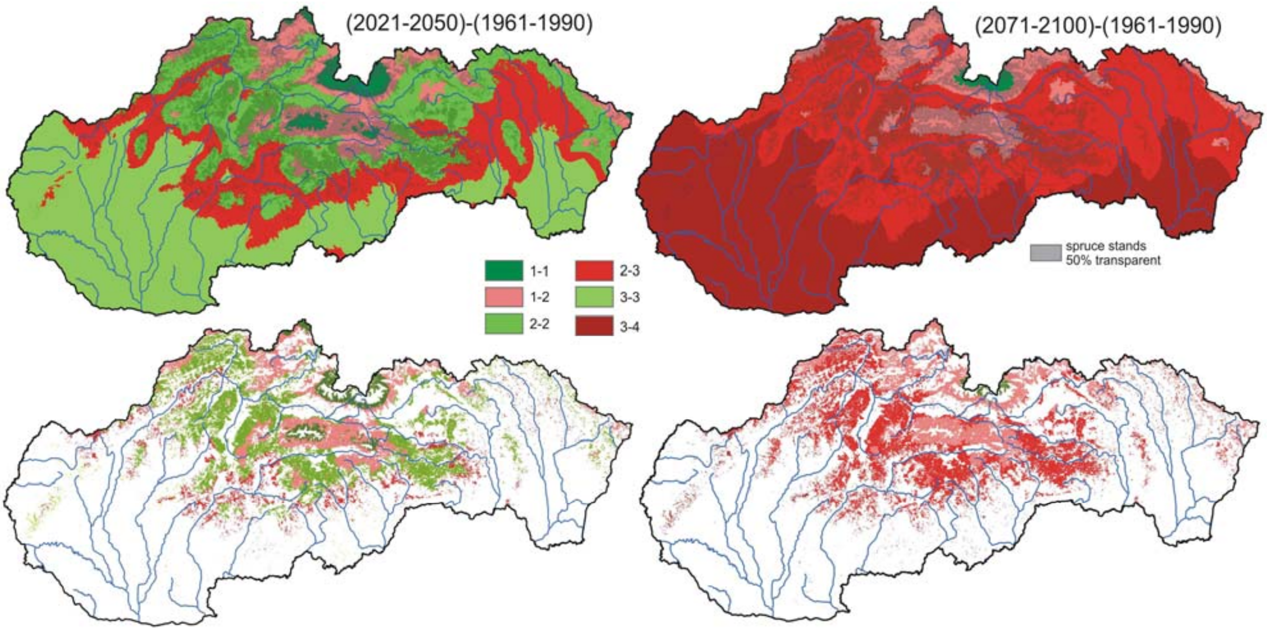


Figure 7. *Differences in number of generations projected to develop in the NFC/FFC vs. the reference climate. The upper row describes the differences in full number of developed generation (Example: 1-2 – number of developed generations increased from 1 to 2) in the whole of country, the bottom row describes the increase in bark beetle generations within actual distribution of spruce.*

Carbon cycle related simulations were conducted in Slovakia and Poland. No feedback mechanism between climate change and carbon cycle was detected for the Kampinos pine forest, Poland. It will likely remain carbon sink in the future. For the Čifáre Turkey oak forest, Slovakia, we found positive feedback between changes in the carbon cycle and climate change. This feedback has implications on timber production. In case of the managed grassland we found negative feedback between carbon cycle and climate change. Assuming unchanged management, due to the increasing ambient CO_2 concentration the grassland will be a lower source of CO_2 to the atmosphere than it is currently. For croplands because of the lack of information on management and fate of carbon we were not able to detect any feedback mechanism. According to our results the annual cycle of agricultural productivity will be modulated in the future, mainly because of the CO_2 fertilization effect. The changes might be beneficial as productivity might increase in the first half of the growing season (i.e. winter wheat production might increase).

We state the following problems and the corrective actions undertaken during the period. BOKU states that for the crop model inputs were used the GCM ECHAM 5, HadCM 3 and NCAR PCM with different emission scenarios. The bias of the RCM was too big and could not be used for the target area. Hereby a correction of the RCM data before using as model input is necessary.

The IAP team working hand in hand with BOKU and CHMI partners came to the same conclusion as BOKU colleagues regarding the use of RCM data in the crop modeling exercises. However it was concluded that it is worthwhile and still relevant to use RCM outputs (despite rather unreliable results at the local scale) for an overview analysis. In case of crop modeling exercise the methodology and scenarios were developed with BOKU partners.

1.2.7 WP7

The main objective of WP7 was to model the interaction between climate and air quality by predictions of present and future air pollution levels and loads in the target regions on Central Eastern Europe. Particulate matter (PM) and ozone, which are priority species regarding human health as well as sulfur dioxide and nitrogen dioxide, having complex impacts on the human health and the ecosystems, were chosen as key species. Six modeling groups from five countries were involved in WP7 activity, i.e.: WUT (WP leader), CUNI, CHMI, AUTH, BOKU, and NIMH.

During 3rd reporting period Regional Climate Models coupled to Air Quality Models have been applied for high resolution (10 km x 10 km) photochemical runs in the targeted areas of CECILIA project, namely: CUNI domain (Central-Eastern Europe), WUT domain (Central-Eastern Europe, centered over Poland), BOKU domain (Central-Eastern Europe, centered over Hungary) and NIMH domain (Bulgaria). The majority of partners (BOKU, CUNI and WUT) used RegCM3(Beta)-CAMx modelling system driven by ECHAM5 Global Climate Model outputs under A1B scenario of IPCC. NIMH used ALADIN-CMAQ modelling system driven by ARPEGE Global Climate Model outputs.

For the third reporting period the main objectives of WP7 were Key species concentrations files from higher resolution runs (10x10 km) for specific smaller domains in Central Eastern Europe for control run and future projection (**Deliverable D7.3**), Analysis and evaluation of the results, comparison of the higher resolution runs (10x10) with the lower resolution runs (50x50) for the specific domain (**Deliverable D7.4**), and Present and future key species exceedances of the EU limits and WHO guidelines, health effects (**Deliverable D7.5**). The main WP7 achievement is completing the air quality simulations for present and future climate (four decadal time slices) for all established targeted areas of CECILIA. For the validation of the modeling systems, the simulations were performed for the present day decade, 1991-2000, with ERA-40 meteorological fields to drive RCM. To study climate impacts on air quality, the simulations were performed for three decades with RCM forced by GCM: 1991-2000 as control run, and two future decades 2041-2050, and 2091-2100 for investigating the near future (NF) and far future (FF) climate response.

In order to study exclusively climate impacts on air quality, the anthropogenic emission were kept constant at the values of year 2000 for all time slices. For CUNI and BOKU domains emissions databases were prepared based on EMEP data, with area and point sources treated as surface area emissions. For the Pannonian countries, a detailed 5 km x 5 km emissions inventory from the year 1995 was used for the spatial distribution of the EMEP 50 km data. For Poland, the emission model was developed, based on a detailed 1 km x 1 km emissions inventory of area and point sources for reference year 2000. For large points sources, a detailed emission and stack parameters database was prepared. Finally, area sources were treated as surface area emissions, while large point sources were simulated individually. For Bulgaria emissions were prepared based on TNO high resolution (0.25° x 0.125°) area and point sources inventory. Finally, area sources were treated as surface area emissions, while for large point sources 3D emission file was produced with zero-values at the surface and non-zeros at the respective model levels.

The guidelines for models evaluation and results analysis has been prepared (see D7.4 Appendix). Final evaluation exercise showed satisfactory to weak performance of modelling systems, depending on the pollutant under concern. The best performance was obtained for summer O_3, while the worst for NO_2. For PM_{10} and SO_2 we obtained reasonable good evaluation results, with better model performance for long-term estimates than for short-term ones. Seasonal species variation was well captured. Extreme values were simulated much better with those models, which employed detailed emission inventory and proper treatment of point sources. The reasonable performance of the applied modelling tools for the present time simulations justifies its use for future time projections.

The main conclusions from high resolution simulations are that climate change impacts on air pollution levels and loads are small to moderate, and have different direction depending on pollutant under concern. For all investigated species the differences between near future (NF) and control run (CR) as well as between far future (FF) and CR are bigger that those between FF and NF. For ozone, concentrations are increasing with climate change. The highest increase in O_3 concentrations occurs in Southern Europe. If the response of the ozone concentration to a changing climate is compared between the model runs with different spatial resolution (BOKU domain), the found absolute differences of ±2 ppbv are much smaller. The 10 km calculation also leads to higher $AOT40_{crops}$ values over the mountains of the Alps and the Carpathians and over Italy and Western Croatia. Over Poland and Hungary the results of the two model calculations are very similar. The concentrations of SO_2 are also increasing with climate change. For NIMH domain the maximum differences are about 2 ppbv that is of order of 10% from the maximal values. These maximums are distributed mainly in the region of the main pollution sources, thermal power plants. Also deposition of all acidifying species (SO_x, NO_x, NH_x) are increasing in future climate. The exception is sulphur deposition in the vicinity of large point sources which is decreasing with descending trend in future climate. For WUT domain, the maximum differences are of order of 10% (NH_x), ±20% (SO_x), and 35% (NO_x) from the maximal values. These maximums are distributed mainly in the mountains areas within the domain: Bohemian Forest, Ore Mountains, Sudety Mountains and Carpathian Mountains. In opposite, PM_{10} and $PM_{2.5}$ concentrations are decreasing with climate change. For WUT domain, the maximum differences (FF-CR) were about 4 $\mu g/m^3$ that is of order of 10% from the maximal values.

The key species exceedances of the EU limits (relating to human health and to vegetation) and of WHO guidelines were calculated as well. In the target region of CECILIA, the number of O_3 exceedance days per year is increasing in the FF decade (see Fig. 8), however, the allowed number of such days is not overshot. The $AOT40_{crops}$ and $AOT40_{forest}$ values are increasing in future climate, causing in FF climate exceedances in the majority of CEE countries, which have no exceedances in present climate. Annual limit values for PM_{10} and $PM_{2.5}$ are not exceeded for both CR and FF, while short-term PM_{10} limit values are exceeded in FF period only in some urban areas. For the majority of targeted domains, there were no exceedances of both SO_2 criteria relating to human health and vegetation. The exceedances occurred only in the surroundings of large point sources for both CR and FF, without relevant change of the shape and area of these regions between the time slices.

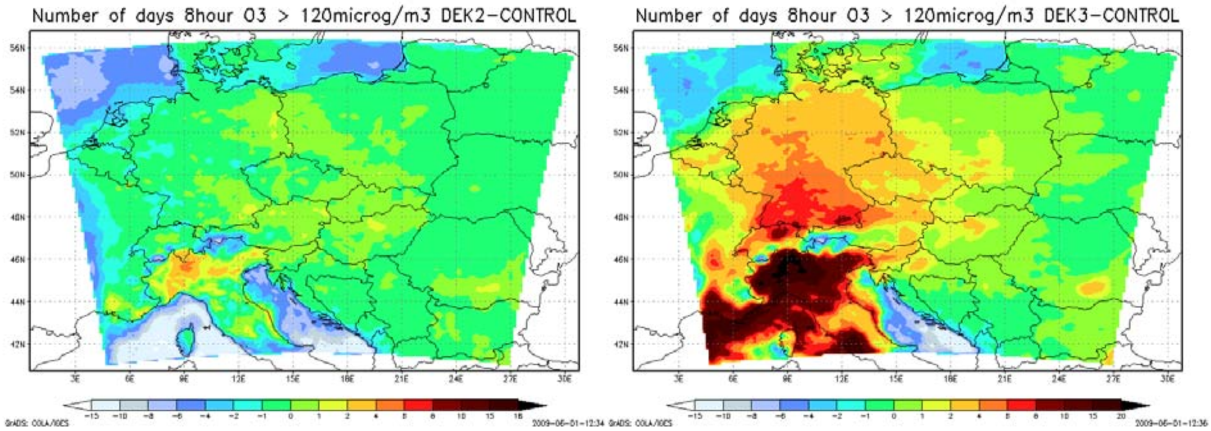


Figure 8. *Climate change impact on number of days per year with 8-hours ozone concentration above the threshold of 120 µg/m³ in terms of the difference for 2041-2050 period (left panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

The comparison between partners predictions were performed for the areas covered by two domains (for Poland WUT vs. CUNI domain; for Bulgaria NIMH vs. CUNI domain) in respect to SO_2 annual levels. The results highlight the differences in the set up of modelling systems. The Polish and Bulgarian large point sources were treated individually (Poland) and as elevated area sources (Bulgaria) in the simulations (see D7.5), while for all countries in the CUNI domain point sources were treated as surface area sources, thus causing significant overestimation of concentrations in the vicinity of the large point sources.

For assessing possible health effects, the case study for Poland was performed. We estimated the adverse health effects caused by $PM_{2.5}$ air pollution for present day decade as well as for both future decades. Estimated average and population average exposures to $PM_{2.5}$ in Poland decreased in future decades. The differences between both exposures of the present day decade 1991-2000 in comparison to two future climate decades were statistically significant. Results indicate that climate change might reduce the exposure to PM air pollutants and resulting premature death estimates in the region under concern.

1.3 Problems during the period, corrective actions

Significant problem of the project, which was the delay of the high resolution simulations of mainly RegCM family partners, arised from the technical problems with data transfer, from significant bias of precipitation results on smaller domains and from bug and recalculation of driving fields from ENSEMBLES ICTP run at 25km resolution driven by ECHAM5. This problem affected the progress on further result analysis and impact studies, even though the simulations from ALADIN partners for some targeted areas are available basically in due time and thus some work on the results analysis and impact studies can be started in time. The extension of the project significantly helped to overcome this problem and thus finally it was possible to include high resolution simulations of the project at least into some impact studies.

Finally, technical problems (disk crashes, data conversion, etc.) resulted in delay with contribution the simulation data of some partners into the project database. At final time of the report submission, all models are in the database.

Section 2 Workpackage progress of the period

2.1 WP 1

2.1.1 Workpackage objectives

There were no tasks in WP1 for the last period of the project except some support of other WPs when comparing the results with the outputs of previous projects, like the 21st century under the A1B scenario by the ARPEGE simulation at 50 km (CNRM) and the RegCM3 simulation at 25 km grid spacing over Europe (ICTP, available from ENSEMBLES project).

2.2 WP2

2.2.1 Workpackage objectives

The main objective of WP2 is to produced simulations on targeted domains for a past period (1961-1990 driven by ERA40 reanalysis), a reference period (1961-1990 driven by GCM data) and two GCM driven scenario time slices (2021-2050 and 2071-2100) based on AR4-A1B GCM projections. A second objective is the test of improved physical parameterizations better suited for 10 km horizontal resolution.

In the last period of the project the main emphasis in WP2 of the project was to complete high resolution RCM scenarios simulations for targeted areas driven by GCM. High resolution simulations by six regional climate models centered over Czech Republic (ALADIN, RegCM), Hungary (ALADIN, RegCM), Romania (RegCM) and Bulgaria (ALADIN) were performed for present day climate simulation, so called control (1961-2000) as well as for two time slices of climate change A1B scenario, i.e. mid-century run of 2021-2050 and end-of-century one 2071-2100.

Two climate change simulations have been supposed to be used for driving experiments to produce 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.

2.2.2 Progress towards objectives

During the last reporting period of the project, there were four deliverables to be delivered. D2.4 RCM simulations forced by models was originally due Month 24, but after the extension of the project due Month 30. The simulations for this deliverable were completed early for some models (ELU, OMSZ), later for the others. Most of them were completed in time, CUNI was a bit delayed with respect to the largest domain and NMA due to re-run of the model for final version with the precipitation bias removal.

Another deliverable D2.5 due Month 26 (33 after extension) supposed production of the database at DMI server. Due to some delays of D2.4, only two models were in time (month 26) on the server. A third one was almost ready to upload, but a disk crash without recovery delayed the delivery. A fourth one was delivered at month 39. At final time of the report, all models are in the database.

The deliverable D2.6 due at the end of the project dealt with the analysis of scenarios, comparison with ENSEMBLES (2021-2050) and PRUDENCE (2071-2100) responses. Due to the status of

D24, a draft version was delivered at month 36, the final version at month 42 (end of the project). The deliverable D2.7 due at the end of the project dealing with the second task of WP2, i.e. report on possible improvements in very high resolution climate simulation has been produced at the end of the project including the most of results available from further model tests.

2.2.2.1 CUNI

At the beginning of the last reporting period (M24) the ERA40 driven simulation was completed (with additional decade 1991-2000) and all the time slices driven by ICTP@25km ENSEMBLES simulation (driven by ECHAM5 and completed till the end of century) were already running in parallel and at about the end of first decade. There were certain delay with respect to the large domain of integration, the largest among all the simulating areas, covering full central Europe region and completely including CHMI and both Hungarian areas which enables extensive comparisons. However, it was not feasible to restart all the simulations with proposed improvement of RegCM for 10km resolution reducing the precipitation bias significantly, at least in summer. To assess the impact of the bias in climate change signal, short one decade simulations were performed for each time slice, i.e. 1991-2000 driven by ERA40 (through ERA40 run of ICTP@25km) and both control (1991-2000) and future time slices (2041-2050, 2091-2100). These “beta” version runs were used for driving air quality model for WP7 as well.

Basic information on climate change signal for temperature in near future time slice (2021-2050) and end-of-century time slice (2071-2100) against the control period of 1961-1990 for the central Europe can be seen in Fig. 9 and Fig. 10, respectively, in terms of annual mean temperature difference. To investigate the individual seasonal dependence of this signal Figs. 11 and 12 present the analysis of differences of results for seasonal means for time slices studied against the control period. The signal of about 1°C is typical for near future time slice in Central Europe while at the end of the century it is about 3°C which is consistent with usual climate change A1B scenario for this region. Clearly, it is not uniform, while for mid-century runthe signal is basically increasing to the east, end of century display significant impact mainly around the Mediterranean. In individual seasons there is increase of the signal to the northeast in both time slices for winter, the strong effect in Mediterranean is a pattern of summer.

Relevant information on climate change signal for precipitation in near future time slice (2021-2050) and end-of-century time slice (2071-2100) against the control period of 1961-1990 for the central Europe can be seen in Fig. 13 and Fig. 14, respectively, in terms of annual mean precipitation relative difference. To investigate the individual seasonal dependence of this signal Figs. 15 and 16 present the analysis of results for seasonal means.

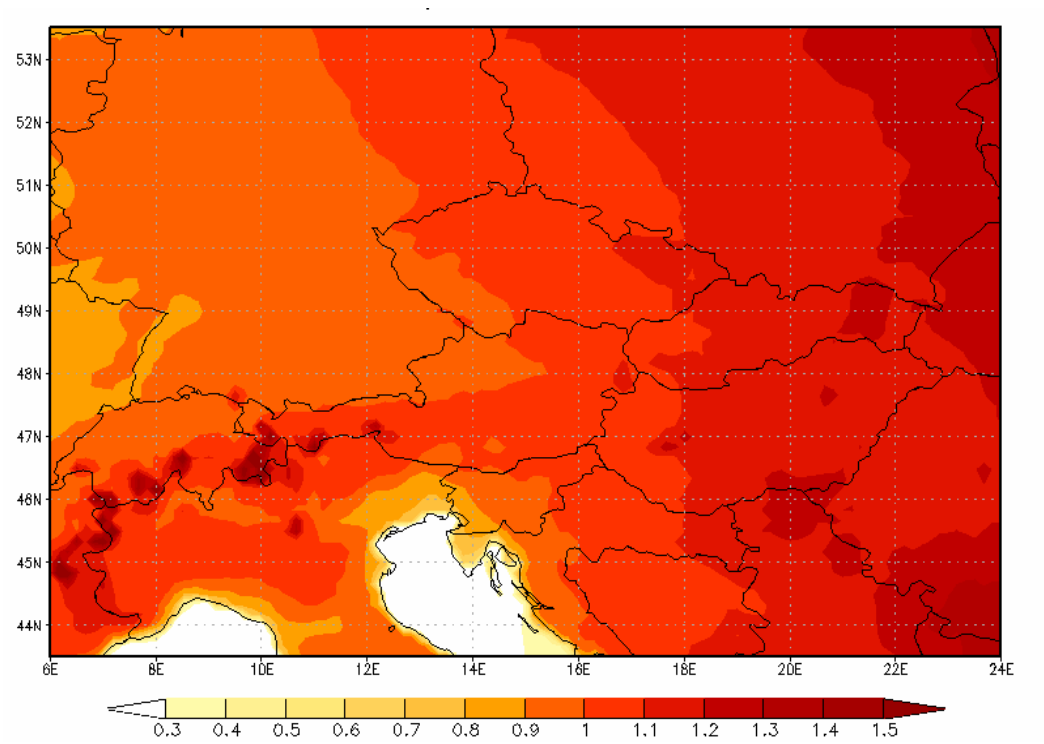


Figure 9. *Climate change signal for annual mean temperature (°C) in near future time slice (2021-2050) against (1961-1990).*

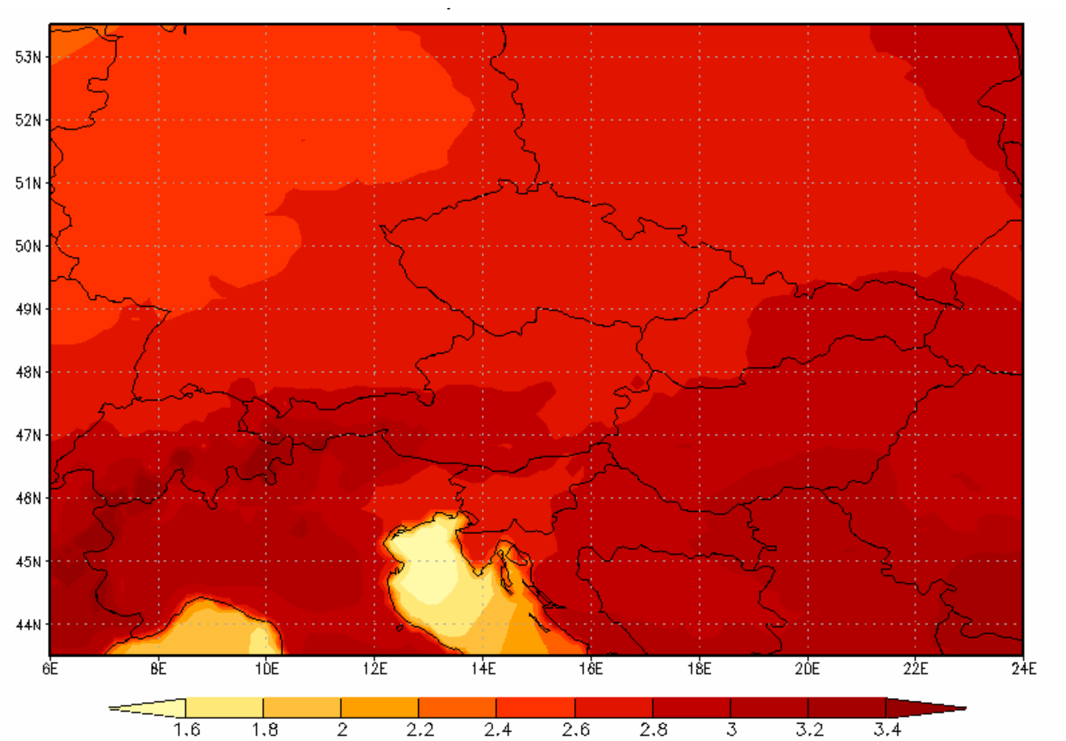


Figure 10. *Climate change signal for annual mean temperature (°C) in far future time slice (2071-2100) against (1961-1990).*

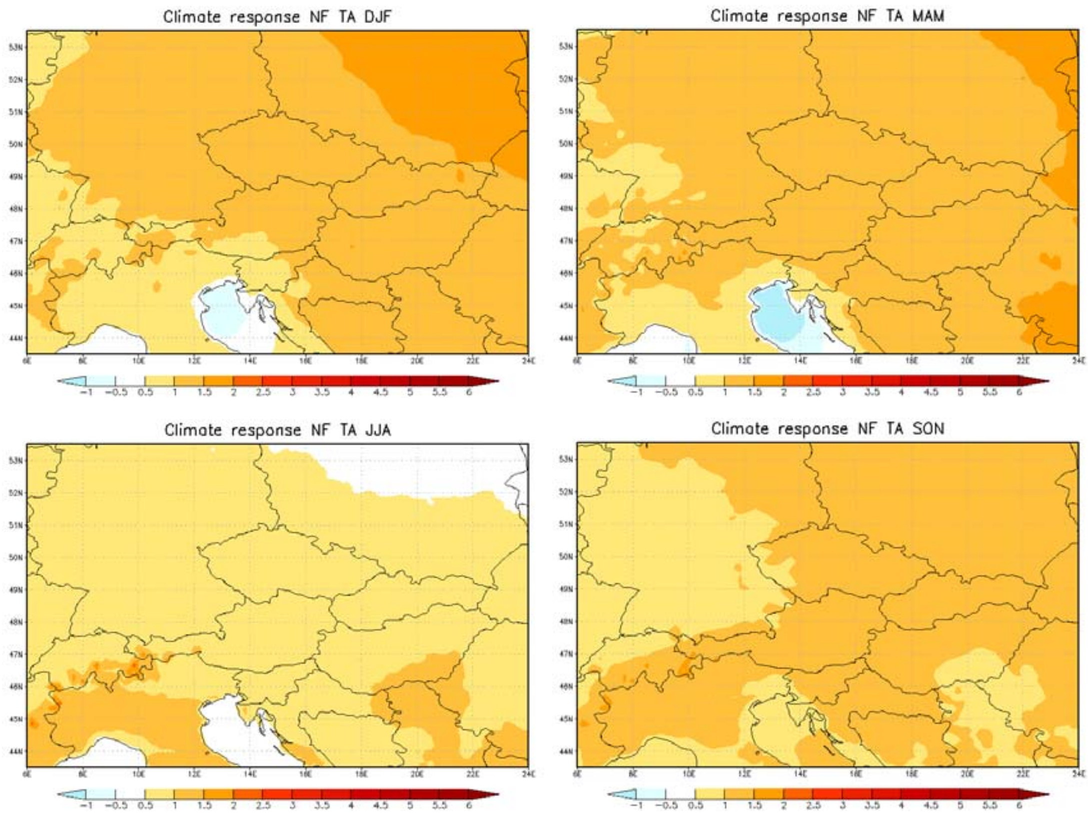


Figure 11. *Climate change signal for seasonal mean temperature (°C) in near future time slice (2021-2050) against (1961-1990).*

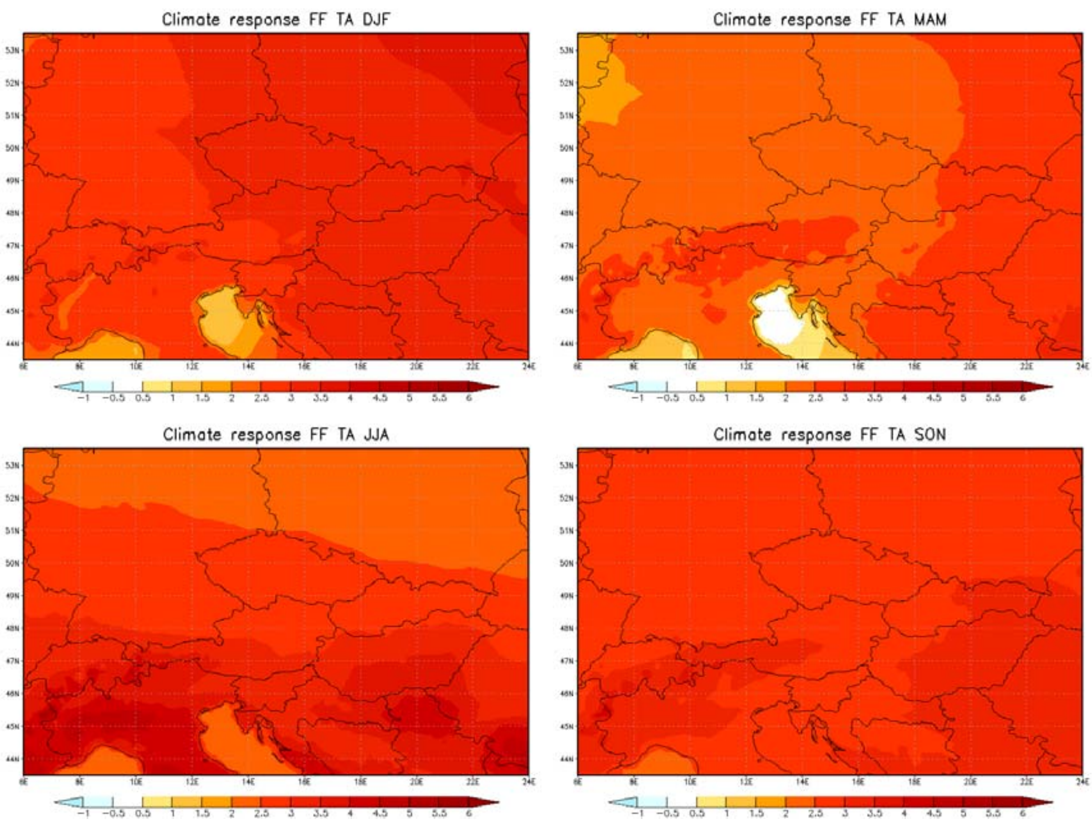


Figure 12. *Climate change signal for seasonal mean temperature (°C) in near future time slice (2021-2050) against (1961-1990).*

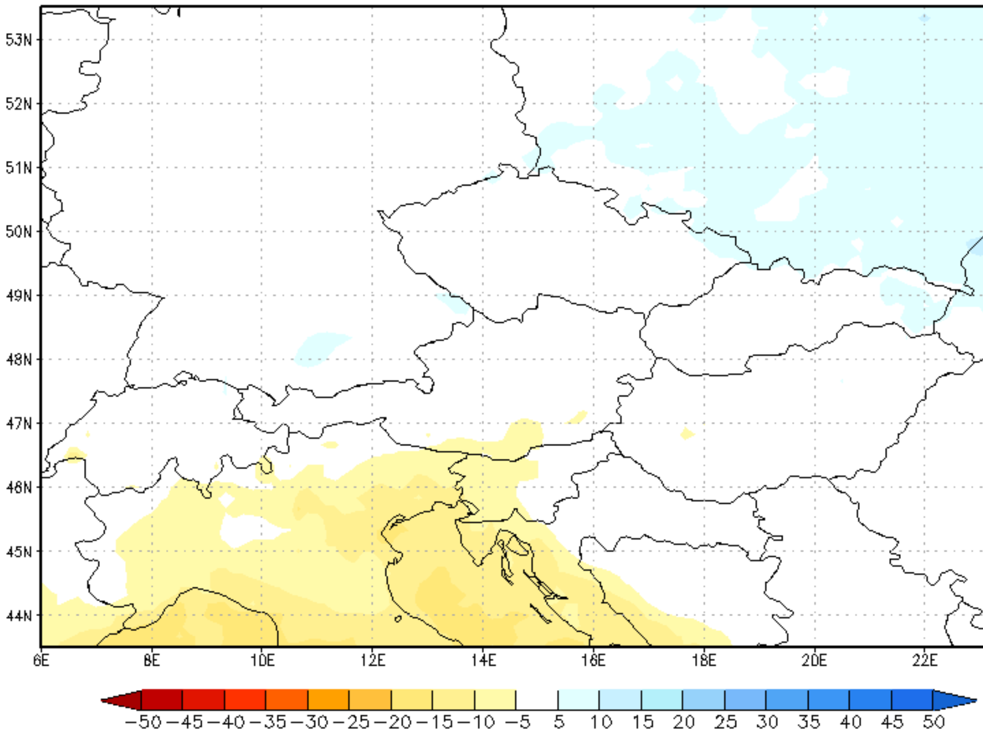


Figure 13. *Climate change signal for annual mean precipitation (relative difference in %) in near future time slice (2021-2050) against (1961-1990).*

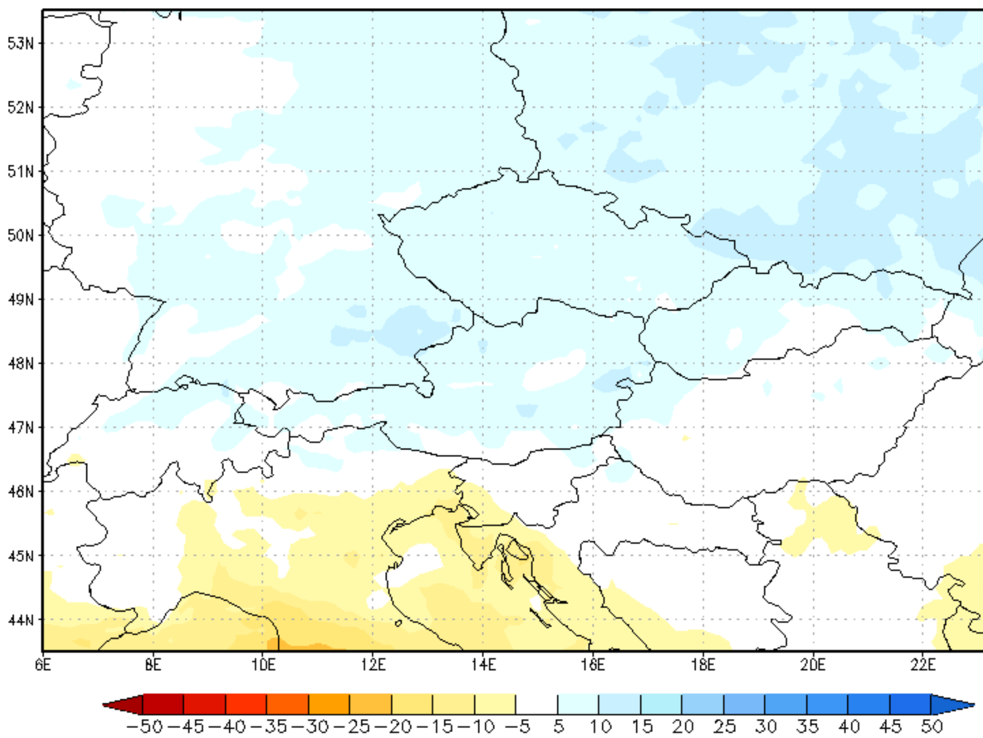


Figure 14. *Climate change signal for annual mean precipitation (relative difference in %) in far future time slice (2071-2100) against (1961-1990).*

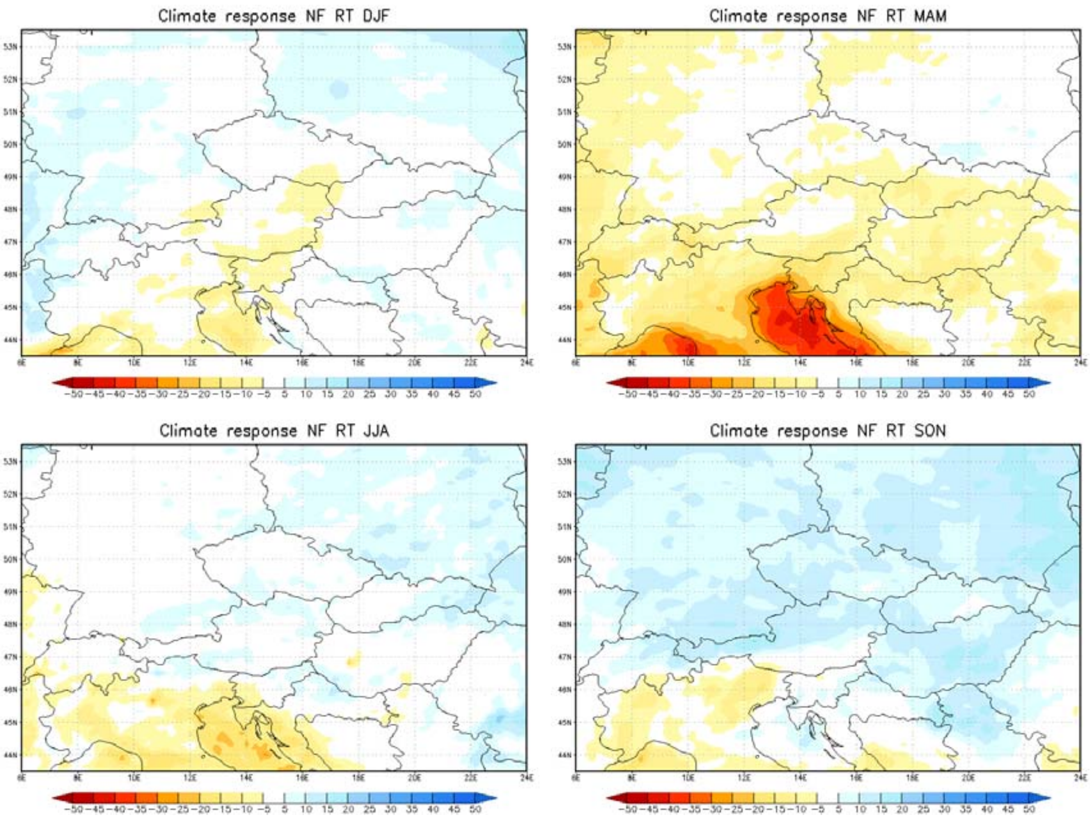


Figure 15. *Climate change signal for seasonal mean precipitation (relative difference in %) in near future time slice (2021-2050) against (1961-1990).*

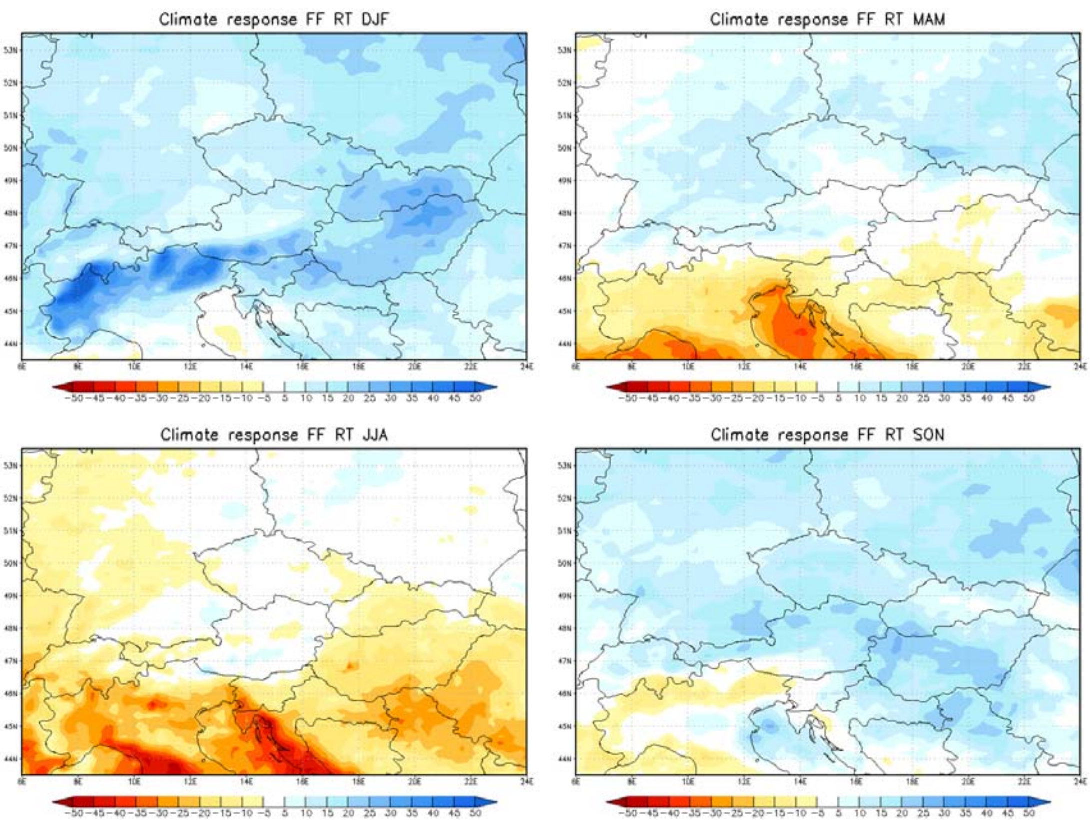


Figure 16. *Climate change signal for seasonal mean precipitation (relative difference in %) in far future time slice (2071-2100) against (1961-1990).*

In annual mean there is quite weak signal in precipitation change in the Central Europe, with the devide in this area moving to the east a bit when going to farer future. The existence of such a devide can be seen in most IPCC AR4 GCMs simulations as well, but in coarser resolution it could be hard to find the shift. In seasons the signal remains rather insignificant with slight increase of precipitation, except spring Mediterranean drying in both time slices and stronger even in summer at the end of century. The end-of-century winter brings more increase of precipitation in connection to elevated areas.

2.2.2.2 CHMI

At the end of year 2 the ERA-driven simulation was achieved as well as the control and near future time slices of the GCM-driven simulations were run. During the reported period final experiment dealing with A1B scenario and driving data obtained from relevant ARPEGE-Climate has been executed covering the period 2070-2100 ("far future time slice"). Processed data has been consequently disseminated to the other WPs in frame of CECILIA in txt, dbf and/or GRIB data format and the WP2 group has been lending significant support for their work. However, the post-processing of ALADIN output has been significantly delayed by crash of post-processing server with prolonged waiting period for replacement and furthermore by the loss of some data and necessary software. These and affiliated problems persisted throughout the reporting period delaying more project activities (most importantly effective netCDF production for DMI archive).

The bias correction applying a quantile-quantile approach has been applied to the ALADIN-Climate/CZ data for mean, maximum and minimum air temperature, precipitation, relative humidity, wind-speed and solar radiation over the selected target regions. An investigation of both original and bias-corrected data has been launched into properties of simulated fields focusing on trends behaviour in Fig. 17 and 18 of temperature and precipitation, respectively, and changes of temperature extremes (Fig. 19) as well as in the investigation of snow characteristics. The obtained results should serve as a basis for further development of ALADIN-Climate/CZ model aiming at description of regional/local climate in resolution higher then that of 10km as used in the frame of CECILIA project.

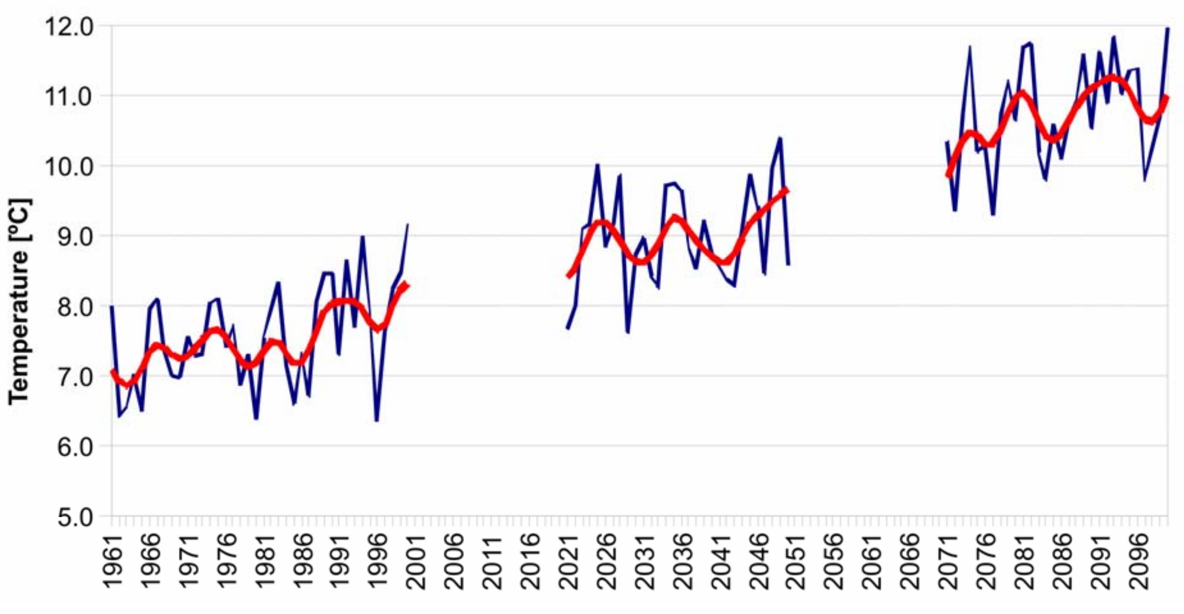


Figure 17. *Inter-annual temperature time series (annual and spatial averages) for the Czech Republic as recorded in the station network of CHMI (1961-2000) and projected by ALADIN-Climate/CZ. Smoothed by Gaussian low-pass filter for 10 years (red curve).*

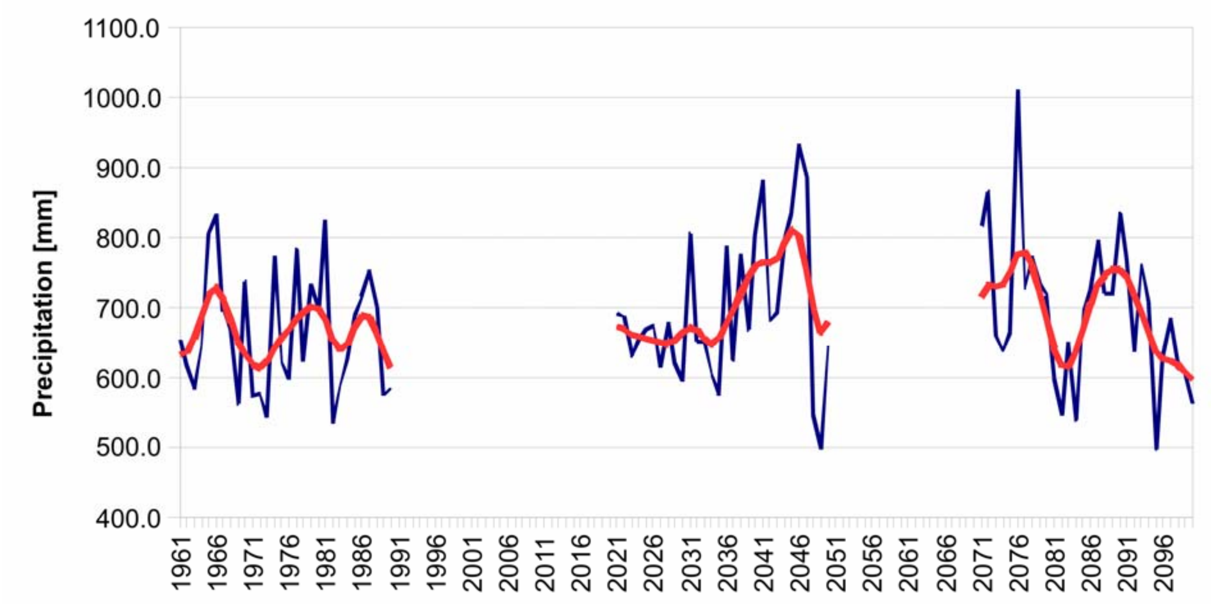


__Figure 18.__ Inter-annual precipitation time series (annual and spatial averages) for the Czech Republic as recorded in the station network of CHMI (1961-1990) and projected by ALADIN-Climate/CZ. Smoothed by Gaussian low-pass filter for 10 year (red curve).

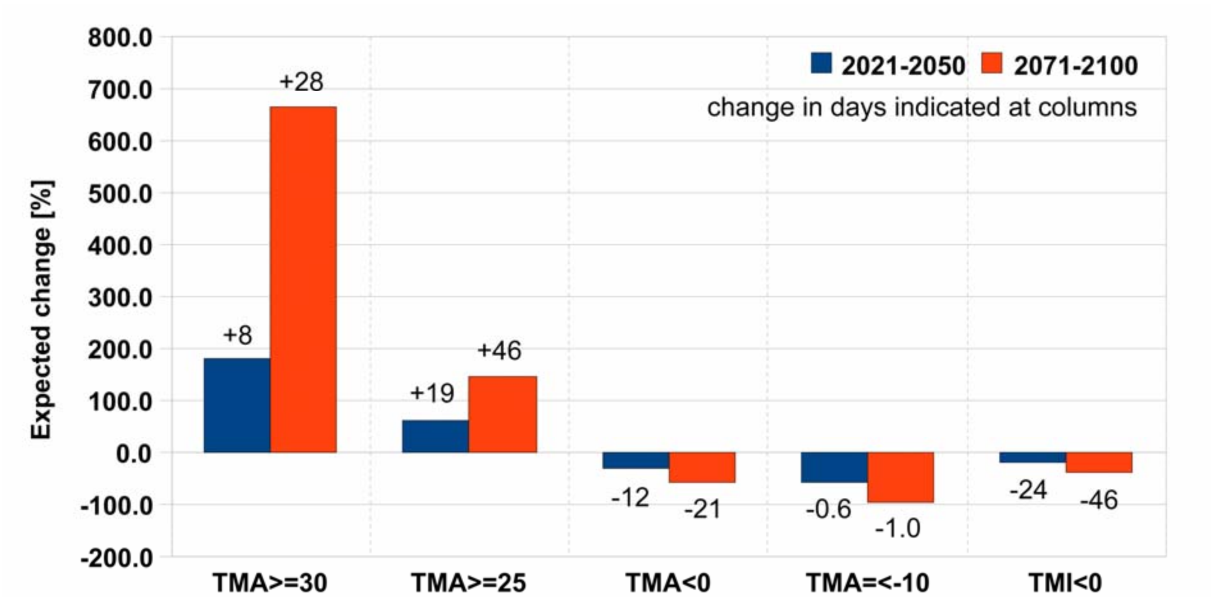
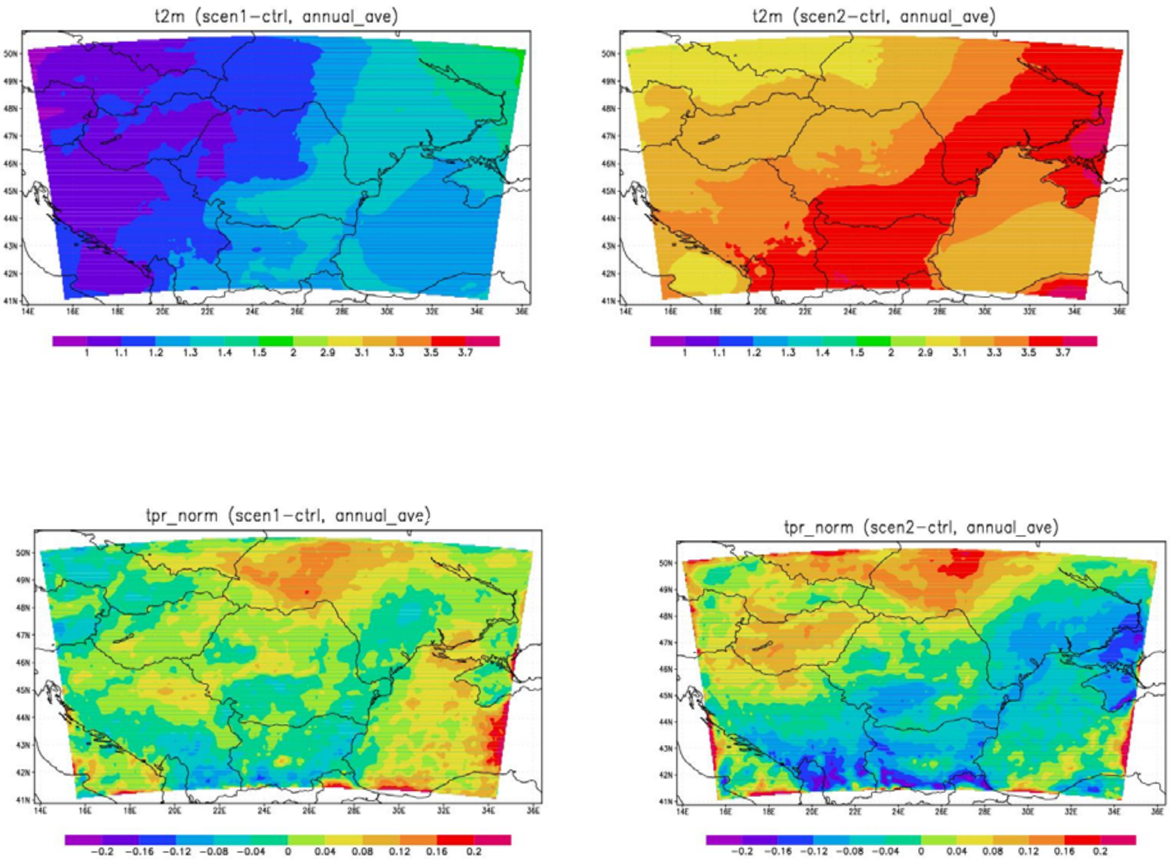


__Figure 19.__ Expected change in annual number of days daily maximum (TMA) and minimum (TMI) temperature over (or below) the defined threshold against the reference period 1961-1990.

Further investigation focused on evaluation of the regional climate model simulations driven by ERA-40 re-analysis that were performed by all WP2 partners and the comparison to the same type of simulations from the ENSEMBLES project. The study should be a basis for the prepared paper aiming to identify a possible added value of CECILIA regional climate model simulations.

2.2.2.3 NMA

All simulations (ERA40- and GCM- driven) had been performed with an older version of RegCM (alpha version). The simulations have been rerun with RegCM beta version, which has much better performance, especially for precipitation when used in Eastern Europe. Fig. 20 shows the annual average response of temperature and precipitation for the two periods of the scenario A1B.



2.2.2.4

Figure 20. *Annual mean temperature anomaly (top, °C) and precipitation anomaly (bottom, %) for 2021-2050 (left) and 2071-2100 (right)*

2.2.2.5 ELU

By month 24, the RegCM simulations were accomplished for the 1960-1990 period (1960 is used for spin-up only) with 10 km horizontal resolution. Based on the previous test runs the following options were selected in the 31-year long experiments: Grell (1993) and Fritsch & Chappell (1980) convective schemes with 18 vertical levels, time step 30 s on the grid of 120 × 100 gridpoints with the central point at 47.5°N, 19.5°E.

Two experiments for the 1960-1990 were completed using the initial and boundary conditions from ERA-40 datasets (with 1° resolution), and the ECHAM5-driven RegCM datasets (with 25-km horizontal resolution). Another two 10-km horizontal resolution experiments were accomplished for the future, namely, for 2021-2050 and 2071-2100 periods using the ECHAM5-driven RegCM datasets (with 25-km horizontal resolution) as the initial and lateral boundary conditions. Output datasets have been provided to the CECILIA-server in the appropriate format (daily mean and monthly mean values for all agreed parameters). Temperature and precipitation changes have been analyzed for the target region (i.e., the Carpathian basin). From the results simulated seasonal changes of temperature are shown in Figs. 21 and 22 for time slice 2021-2050 and 2071-2100, respectively. The similar maps are shown for seasonal changes of precipitation in Figs. 23 and 24.

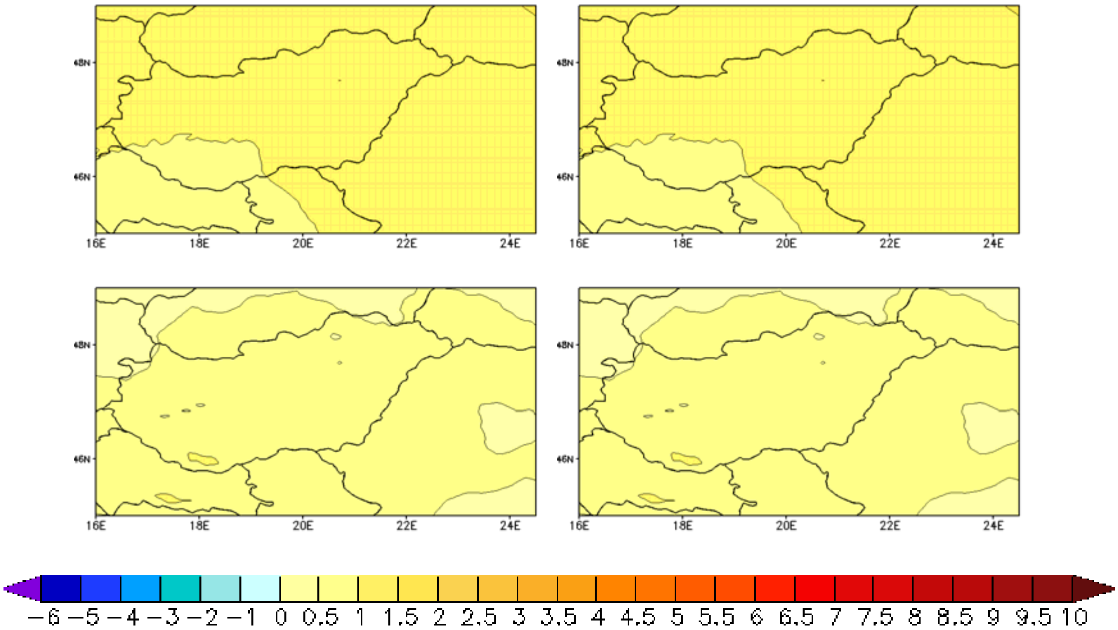


Figure 21. *Simulated seasonal temperature change for the Carpathian basin for the period 2021-2050 (reference period: 1961-1990).*

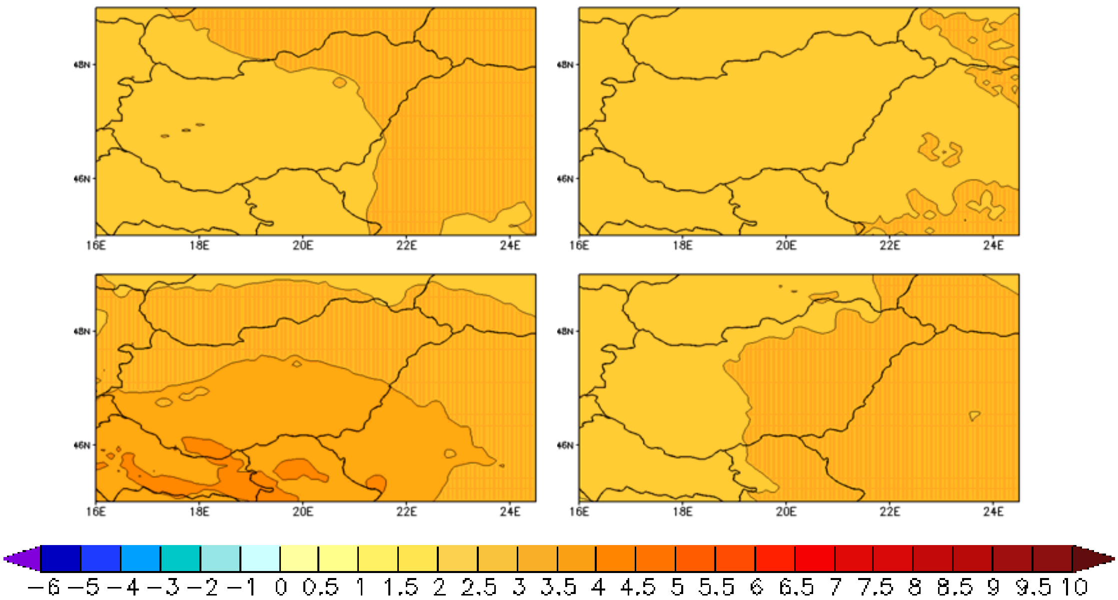


Figure 22. *Simulated seasonal temperature change for the Carpathian basin for the period 2071-2100 (reference period: 1961-1990).*

Temperature change in the simulated regional climate is evident in all season for both time slices. Warming is expected in all subregions of the integration domain, the spatially averaged seasonal changes for the Hungarian grid points are projected as follows: +1.1 °C in winter, +1.6 °C in spring, +0.7 °C in summer, and +0.8 °C in autumn by 2021-2050, and +2.9 °C in winter, +2.8 °C in spring, +3.5 °C in summer and +3.0 °C in autumn by 2071-2100 (relative to the 1961-1990 reference period).

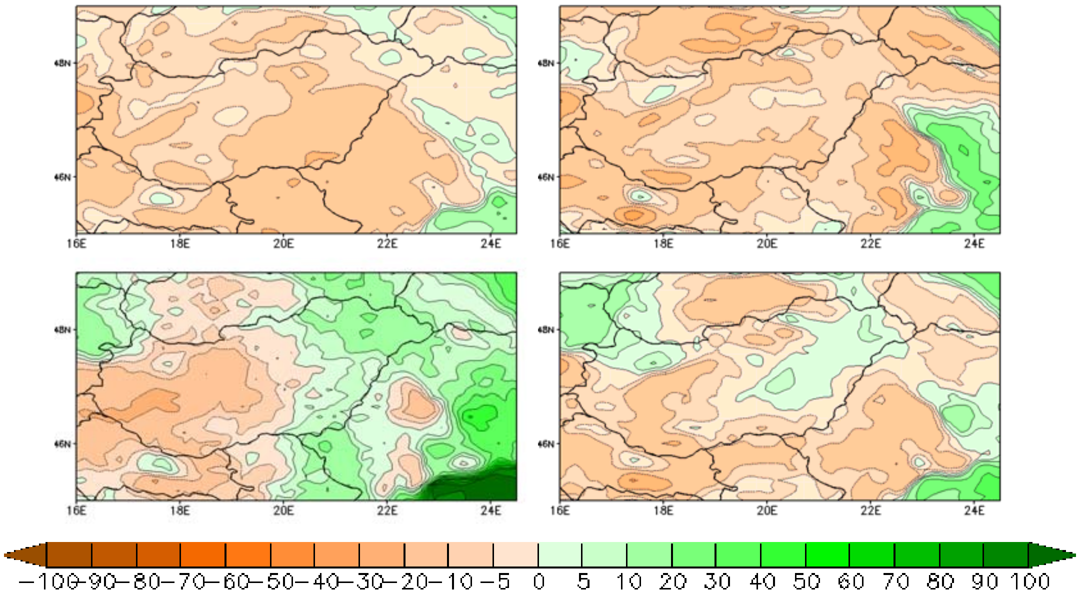


Figure 23. *Simulated seasonal precipitation change for the Carpathian basin for the period 2021-2050 (reference period: 1961-1990).*

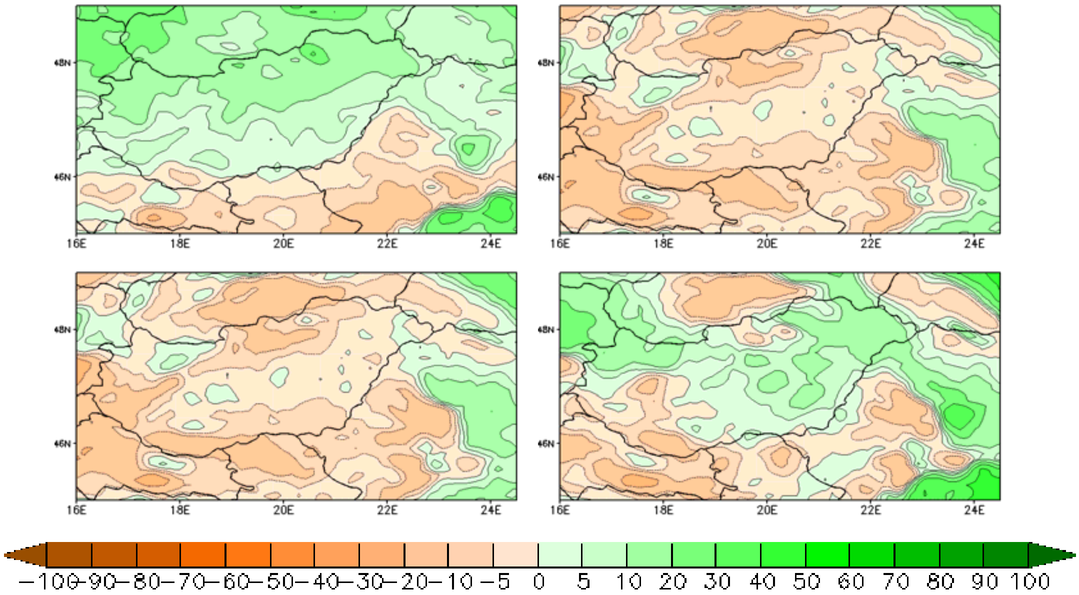


Figure 24. *Simulated seasonal precipitation change for the Carpathian basin for the period 2071-2100 (reference period: 1961-1990).*

Precipitation seasonal changes in the simulated climate are naturally far more variable in space than temperature. For Hungary, in general, drier climate is projected for 2021-2050, especially, in the eastern, and southern part of the country. The spatially averaged expected seasonal changes for Hungary are as follows: -9% in winter, -10% in spring, -2% in summer, and -4% in autumn. The largest precipitation decrease is expected close to southern edges of the Alps, which can be caused by the shadowing effect of the mountain, the weakening of the uplifting force. In the southeastern part of the domain (outside of Hungary) a large precipitation increase is expected in every season, which can be related to stronger low level easterlies in future climate. If we look at the end of the 21st century, for Hungary, in general, winter and autumn are expected to become wetter than in the reference period (by 8% and 5% on spatial average), especially, in the northern part of the country. Drier summers (by 18%) and slightly drier springs (by 5%) are projected for 2071-2100 compared to 1961-1990. For the entire domain summer is expected to become drier in general, however, the southeastern part of the domain is projected to become wetter by 2071-2100 as well, as by 2021-2050.

2.2.2.6 NIMH

NIMH had run the ERA-driven simulations at the beginning of the last reporting period. During this period the scenarios have been completed. Fig.25 shows the precipitation response in winter and Fig.26 shows the precipitation response in summer. In winter there is a weak reduction of precipitation in the south, irrespective of the period. In summer, the drying concerns the whole country, with maximum in the east at mid-century and in the north at the end of the century.

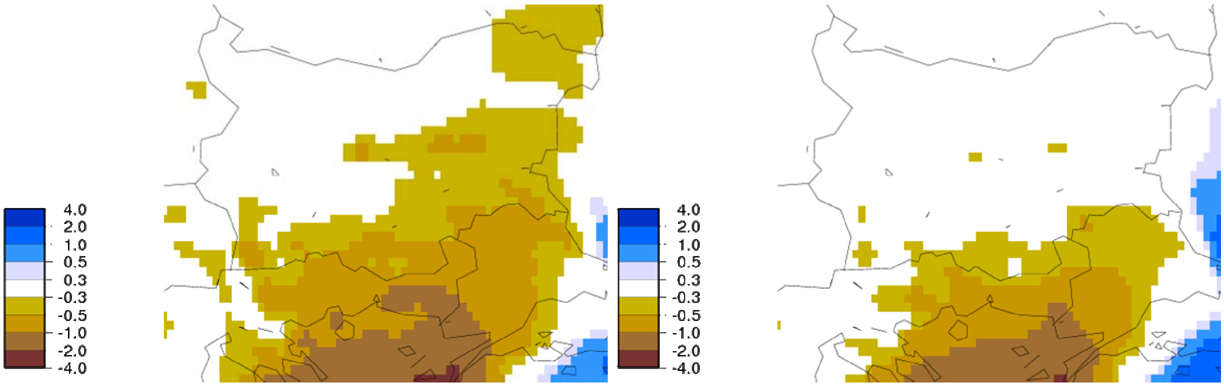


Figure 25. *Winter precipitation response (mm/day) over Bulgaria for 2021-2050 (left) and 2071-2100 (right) wrt 1961-1990*

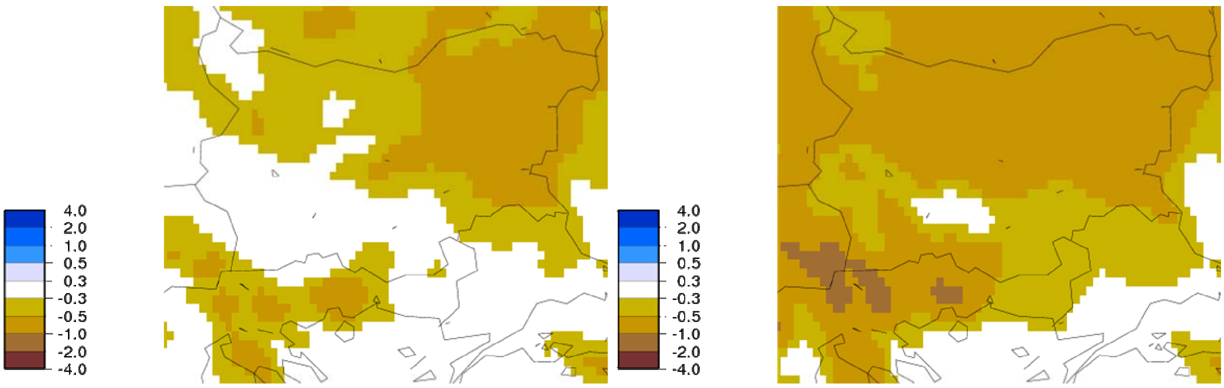


Figure 26. *Summer precipitation response (mm/day) over Bulgaria for 2021-2050 (left) and 2071-2100 (right) wrt 1961-1990*

2.2.2.7 OMSZ

All simulations with ALADIN over Hungary were complete at the beginning of this reporting period. OMSZ has processed the data to enter the project database and analyzed various aspects of the simulations. Basic information on climate change signal for temperature in near future time slice (2021-2050) and end-of-century time slice (2071-2100) against the control period of 1961-1990 for the Hungarian region can be seen in Fig. 27 and Fig. 28, respectively, in terms of annual mean temperature difference. To investigate the individual seasonal dependence of this signal Figs. 29 and 30 present the analysis of differences of results for seasonal means for time slices studied against the control period.

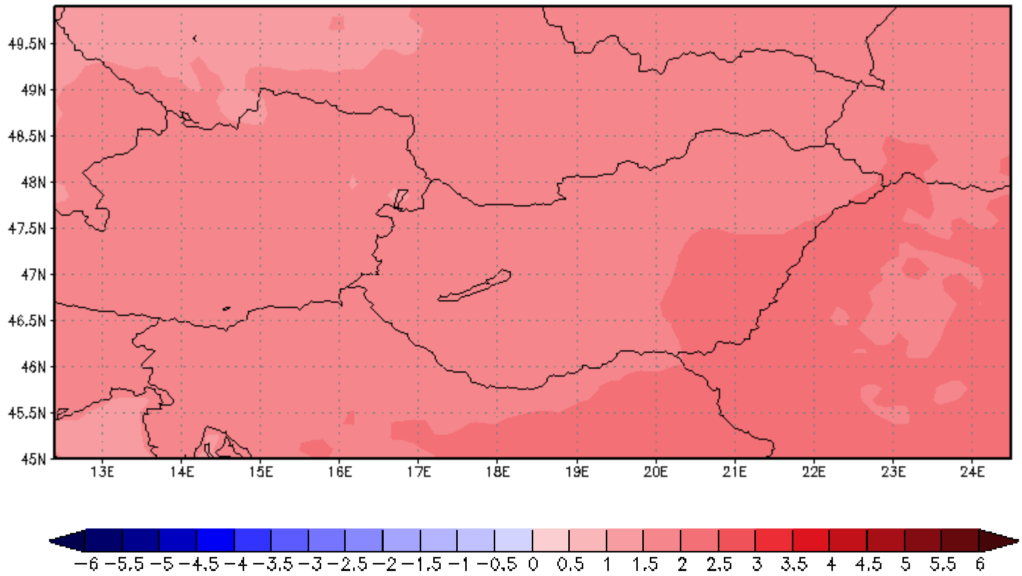


Figure 27. *Climate change signal for annual mean temperature (°C) in near future time slice (2021-2050) against (1961-1990).*

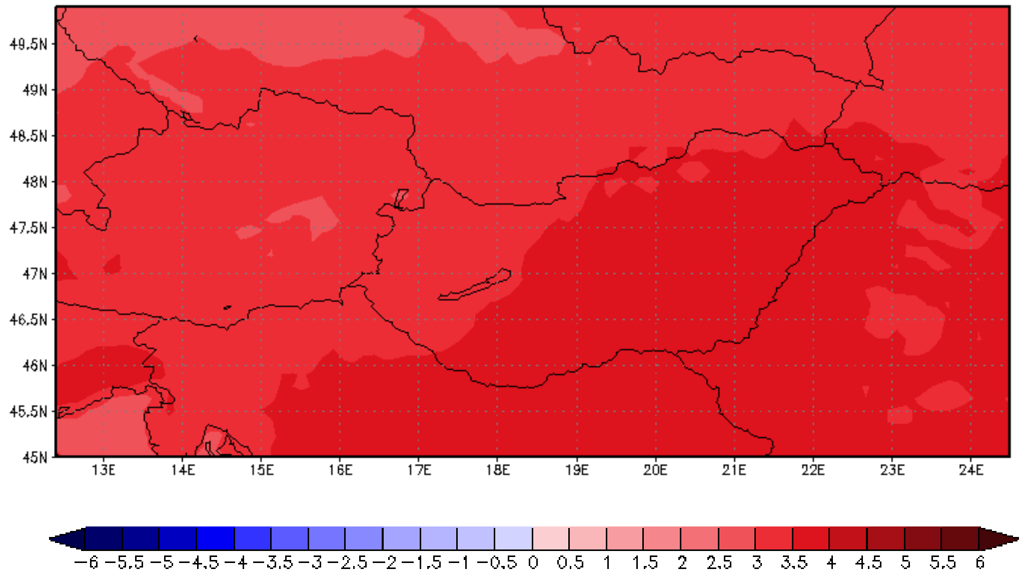


Figure 28. *Climate change signal for annual mean temperature (°C) in far future time slice (2071-2100) against (1961-1990).*

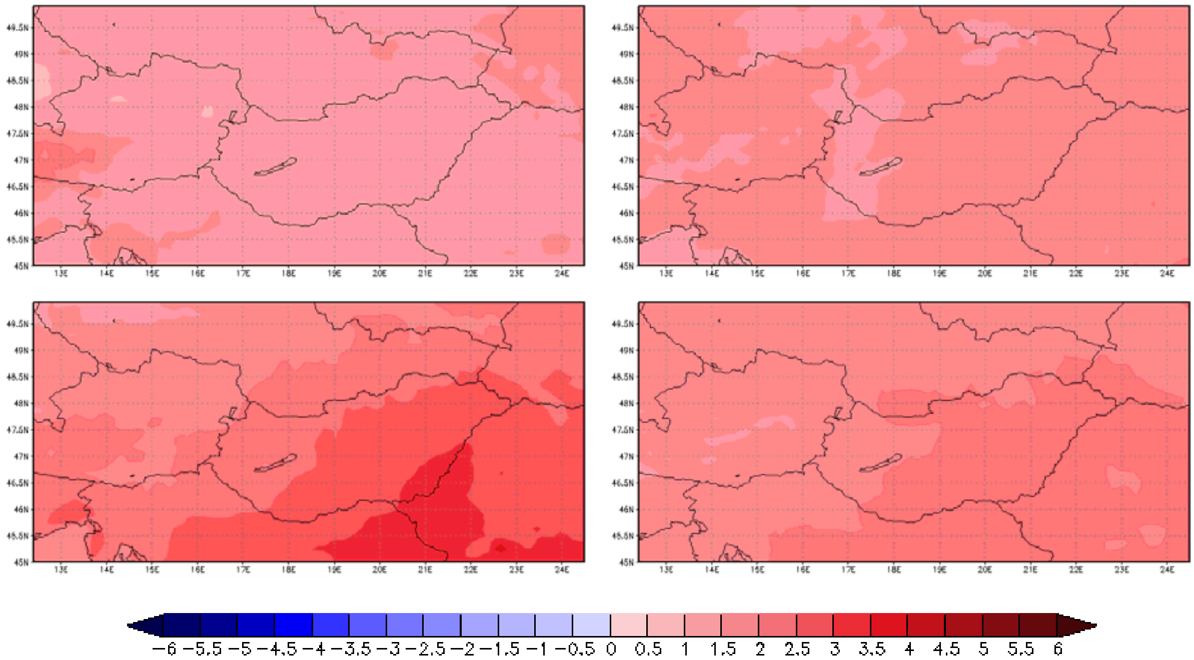


Figure 29. *Climate change signal for seasonal mean temperature (°C) in near future time slice (2021-2050) against (1961-1990), winter (upper left), spring (upper right), summer (bottom left), autumn (bottom right).*

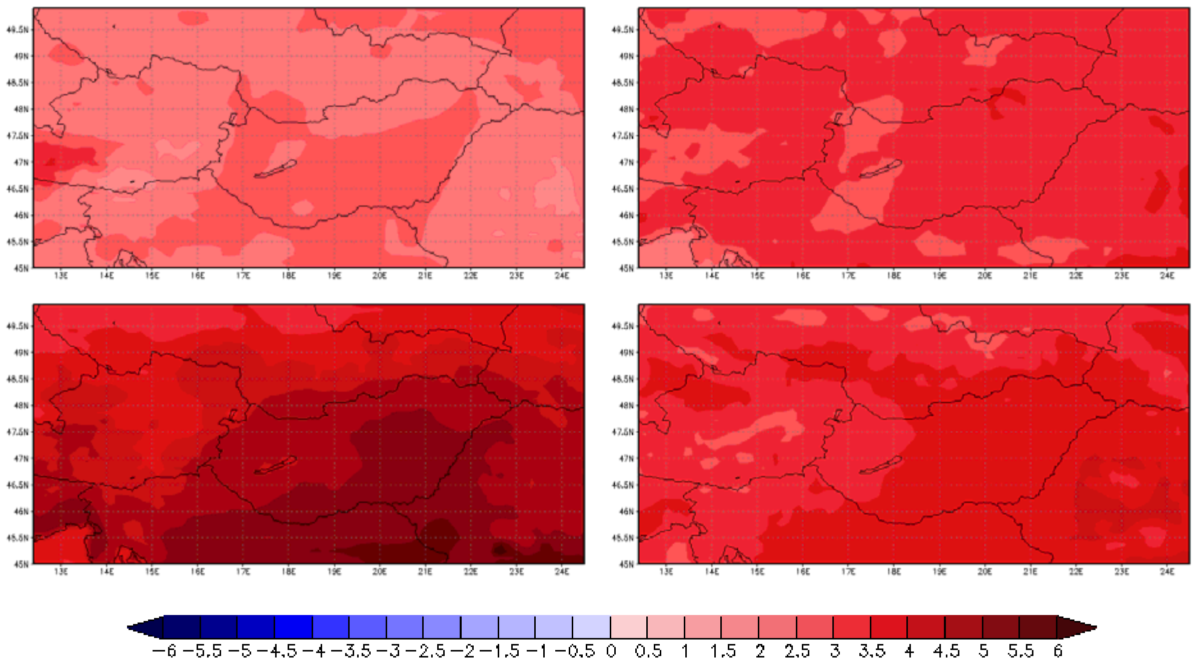


Figure 30. *Climate change signal for seasonal mean temperature (°C) in far future time slice (2071-2100) against (1961-1990), winter (upper left), spring (upper right), summer (bottom left), autumn (bottom right).*

Relevant information on climate change signal for precipitation in near future time slice (2021-2050) and end-of-century time slice (2071-2100) against the control period of 1961-1990 for the Hungarian domain can be seen in Fig. 31 and Fig. 32, respectively, in terms of annual mean precipitation relative difference. To investigate the individual seasonal dependence of this signal Figs. 33 and 34 present the analysis of results for seasonal means.

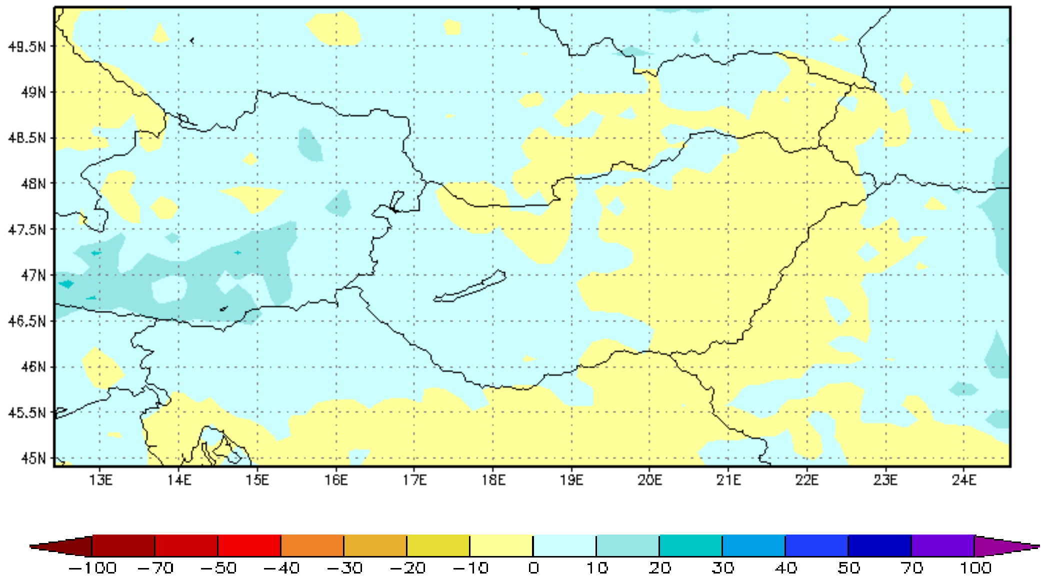


Figure 31. *Climate change signal for annual mean precipitation (relative difference in %) in near future time slice (2021-2050) against (1961-1990).*

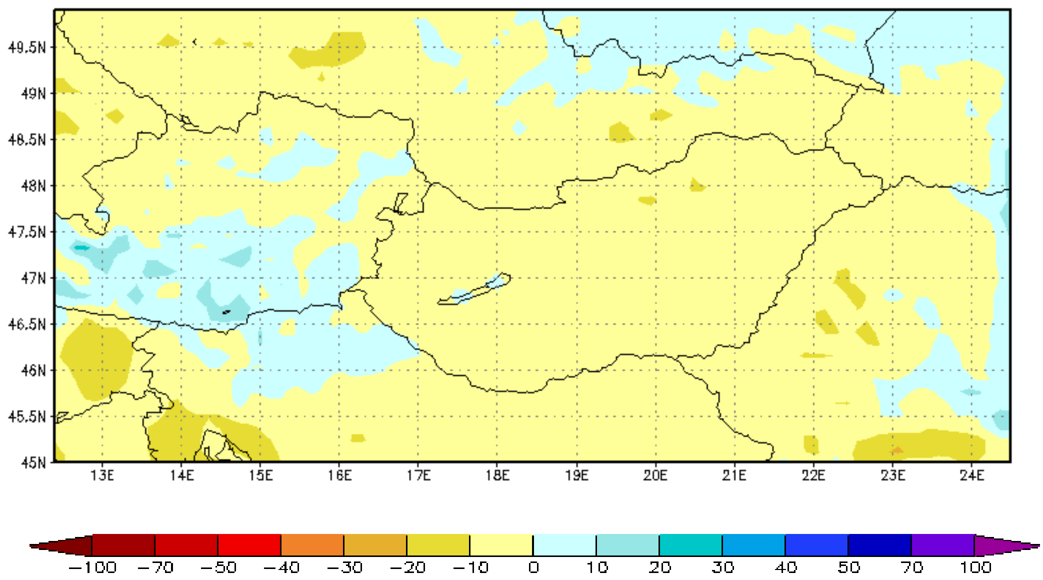


Figure 32. *Climate change signal for annual mean precipitation (relative difference in %) in far future time slice (2071-2100) against (1961-1990).*

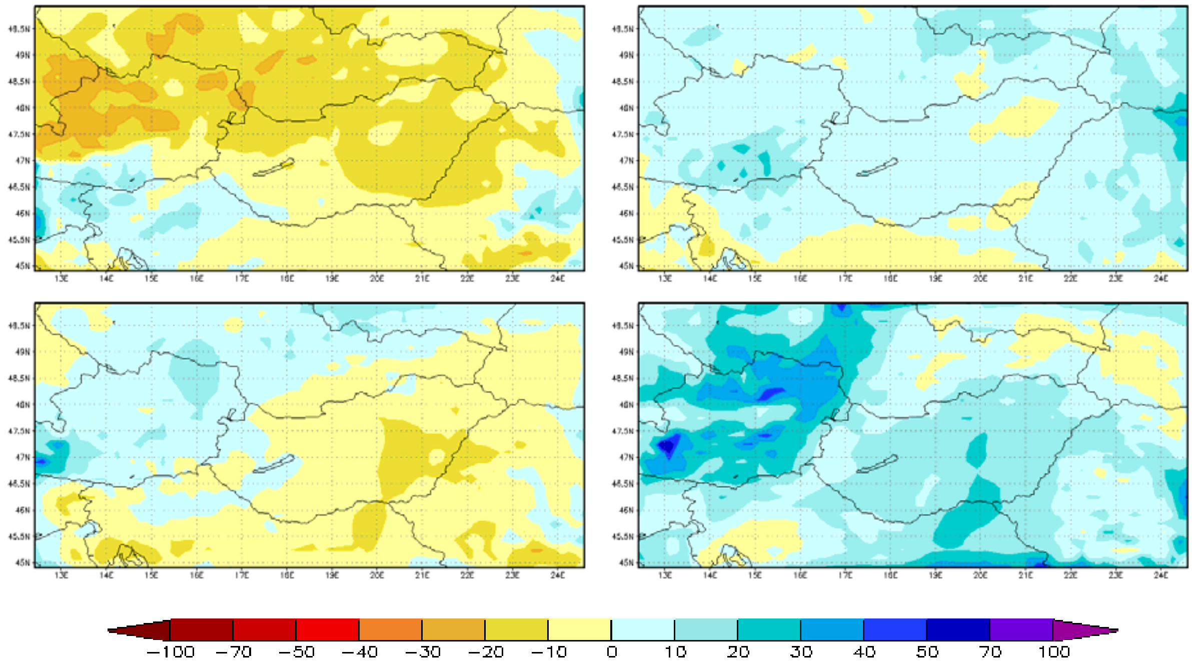


Figure 33. *Climate change signal for seasonal mean precipitation (relative difference in %) in near future time slice (2021-2050) against (1961-1990).*

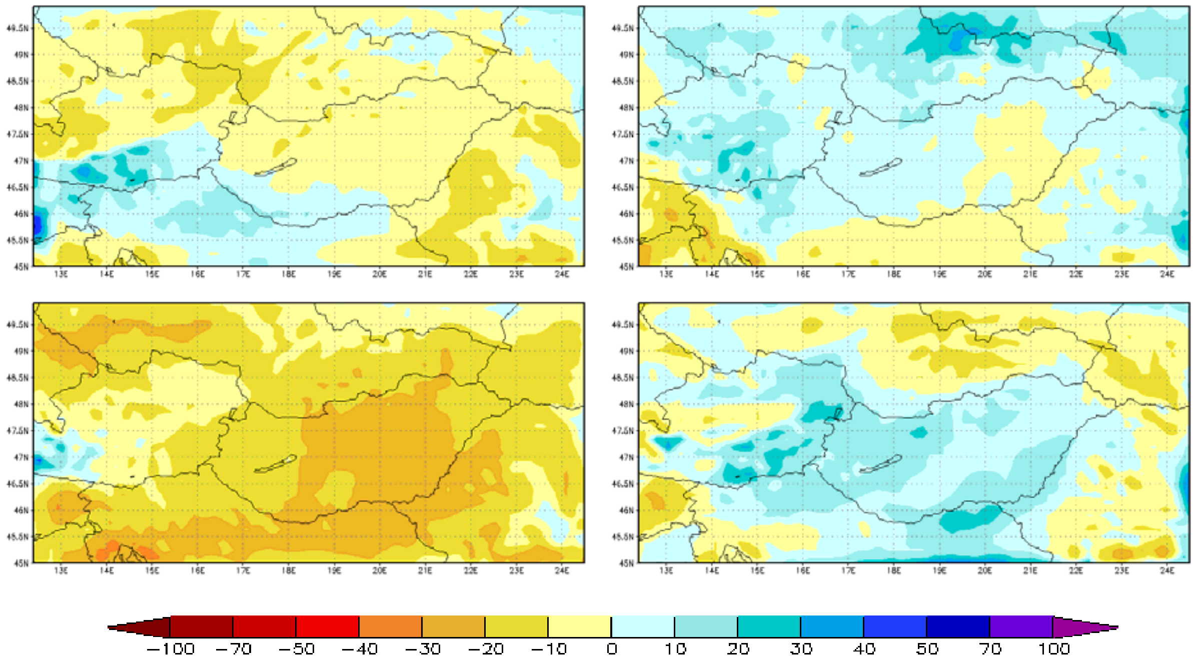


Figure 34. *Climate change signal for seasonal mean precipitation (relative difference in %) in far future time slice (2071-2100) against (1961-1990).*

2.2.2.8 DMI

WP2 activities started at the beginning of the last reporting period with respect to the preparation of the database environment and analysis of available results of individual partner's simulations, their comparison to previous results available from ENSEMBLES and PRUDENCE projects.

A high spatial resolution of a regional climate model will give a higher degree of realism to the description of orographic effects. In previous studies there have been indications that a higher resolution of a regional climate model will lead to a better quality of the extreme tail of the precipitation intensity spectrum. This improvement is not just due to the decreased aggregation, but is probably also due to the more explicit description of precipitation, i.e., that a smaller fraction of the precipitation needs to be parameterised as sub-grid convective precipitation.

In the CECILIA project outputs we have access to data from two driving models: The CNRM ARPEGE stretched-grid global simulation with around 50km grid distance over Europe, and the ICTP RegCM RCM simulation in 25km resolution from the ENSEMBLES project. High-resolution simulations in about 10km grid distance have been performed by the OMSZ, CHMI and NIMH (the latter two not shown here as delayed in submission to the database) with ALADIN for the ARPEGE driving simulation and by CUNI, NMA and ELU with RegCM for the ICTP RegCM driving simulation. In Fig. 35 we show the average annual precipitation for the control period 1961-1990 for these simulations and compare to two sets of observations. This comparison would have been better using reanalysis-driven data; however, there are currently only high-resolution reanalysis-driven data from two of the four models (CUNI and NMA). This analysis employs data from the CECILIA extremes database created under WP4.

It is clear that orographic effects are larger for the high-resolution simulations than for the lower-resolution driving simulations. However, when comparing to observations, as depicted in Figs. 35g and 35h from the ENSEMBLES E-OBS 25km data set and from the CECILIA station data, respectively, there seems to be too much precipitation in the CUNI and OMSz high-resolution simulations.

A problem with absolute magnitudes of precipitation can be dealt with through scaling, provided that the intensity spectrum is realistic. This is being checked in Fig. 36, where the ratio between the wet-day 99th percentile, corresponding to a 1-2 year return time, and the median (50th percentile) wet-day intensity is shown for the summer season. First of all, a comparison of the two observation-based panels illustrates that the E-OBS data at 25km grid distance shows a much weaker tail of the intensity distribution than the individual CECILIA stations, in particular in heavy-tail areas like eastern Romania. The gridding of daily observations is known to cause a weakening of the intensity tail (ENSEMBLES deliverable D5.18), and the density of stations forming the basis of E-OBS is particularly low in the area under investigation here. The documentation in ENSEMBLES D5.18 suggests that a 99th percentile in E-OBS in general would be roughly 70% of what it should be; this reduction might be even larger because of the low station density in the study area. It is therefore probable that the high-resolution simulations actually are more realistic than the lower-resolution ones regarding the tail of the precipitation intensity spectrum.

The ICTP 25km simulation exhibits very high values over large areas, not confined to mountains; hence, this simulation probably exaggerates the intense precipitation in summer. The high-resolution simulations have high values in mountainous areas, roughly corresponding to the CECILIA station data.

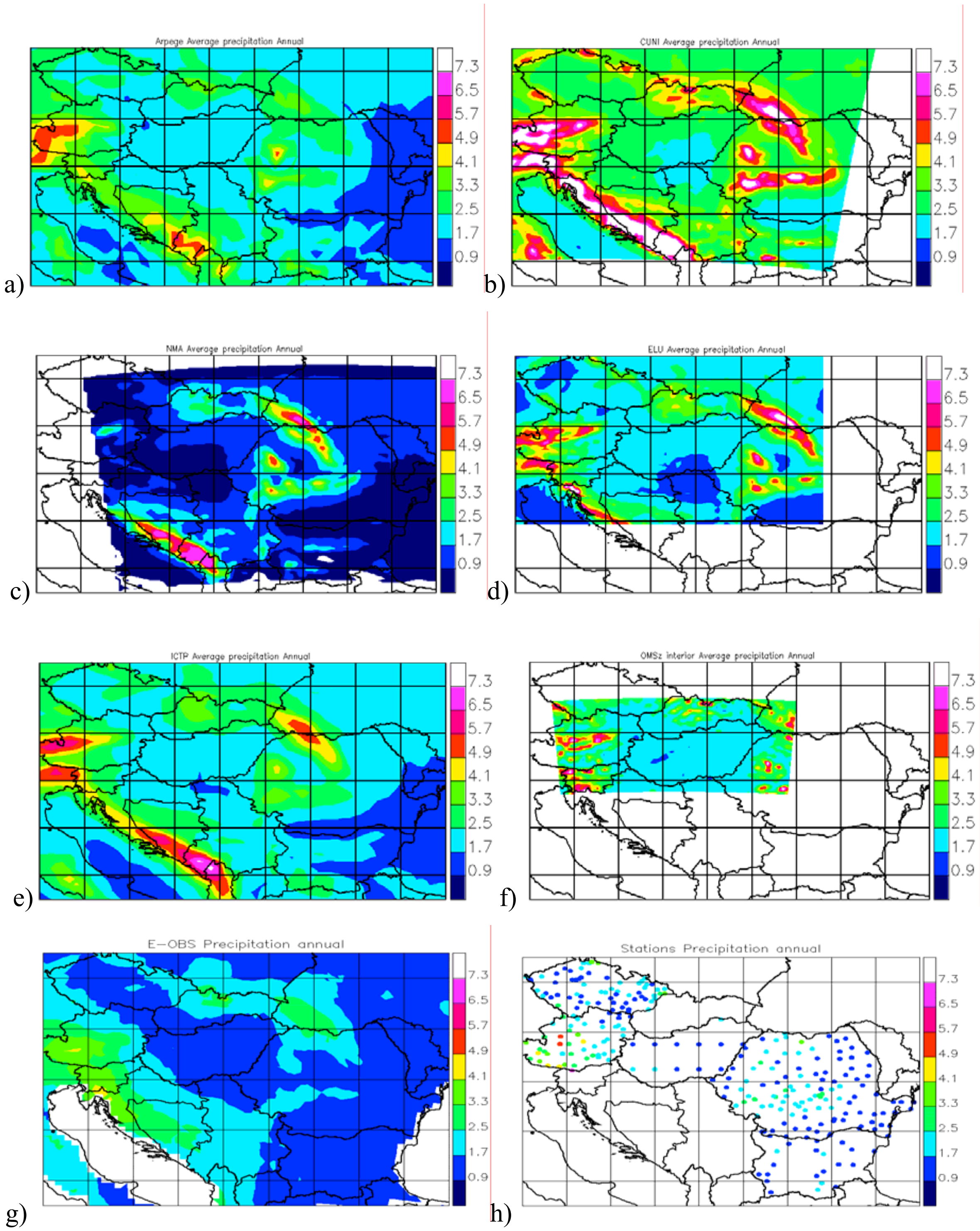


Figure 35. *Average annual precipitation (mm/day) from the CECILIA driving simulations (panels a and e), high-resolution simulations (panels b,c,d,f) and from observations (panels g and h).*

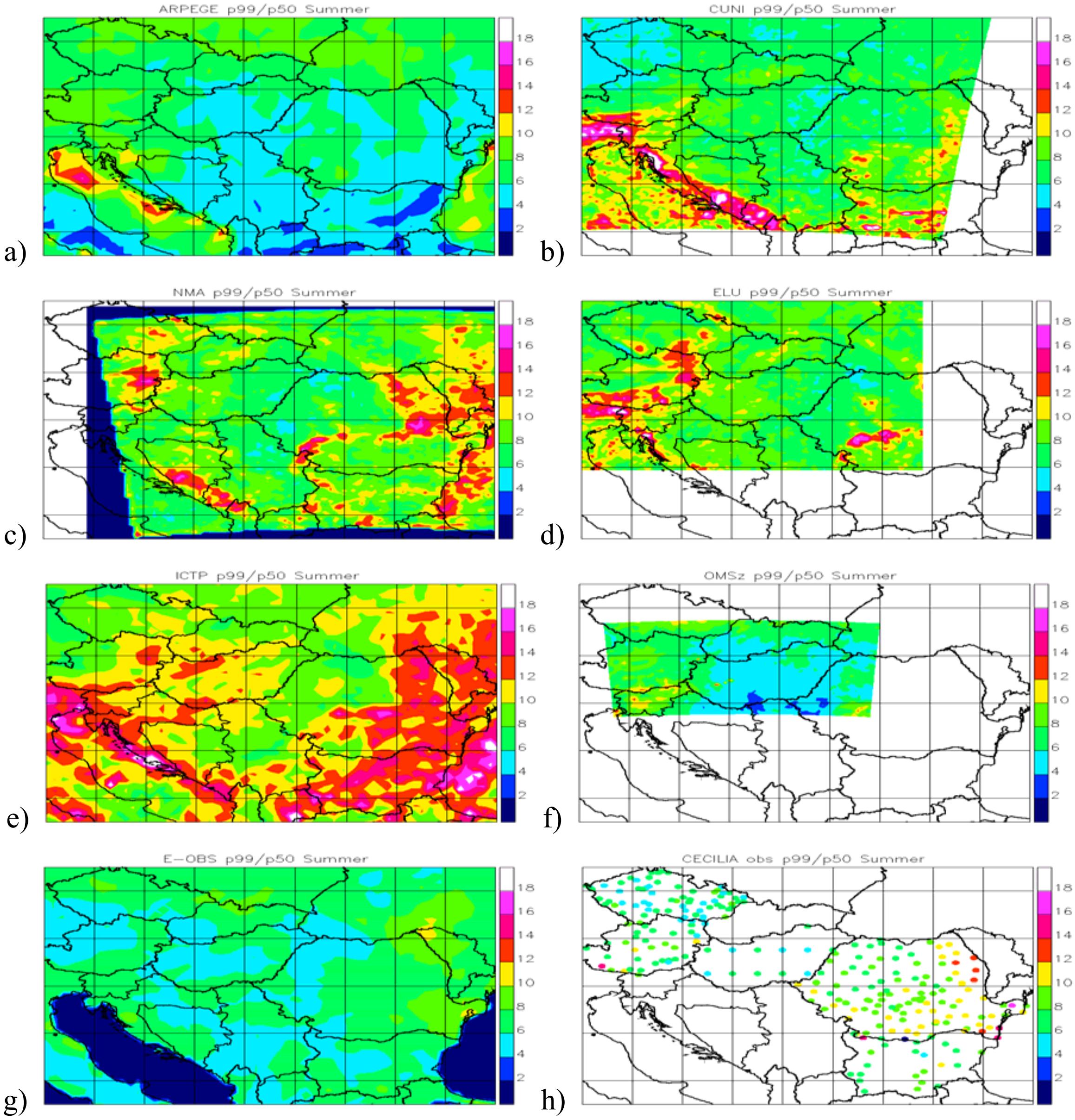


Figure 36. *Ratio between 99th percentile and median for summer, calculated from wet days, from the CECILIA driving simulations (panels a and e), high-resolution simulations (panels b,c,d,f) and from observations (panels g and h).*

2.2.2.9 CNRM

The CNRM has produced one of the two GCM simulations with ARPEGE (resolution 50 km over Europe) and provided the 6-hourly lateral boundary conditions to 3 of the RCMs (CHMI, OMSZ and NIMH). In addition, a similar set of RCM simulations (ERA-driven, 3 time slices GCM-driven) has been produced with ALADIN over France at 12 km resolution to test the feasiblility of the ARPEGE-ALADIN coupling in climate mode at such a resolution. Moreover, in addition to coordination of the workpackage, CNRM has produced a second step validation of the regional simulations. Each modelling partner in CECILIA has looked at his own model, and the present report shows a few examples of this validation. CNRM has considered the 6 models as a bundle and compared the ERA-driven systematic errors, as well as the GCM-driven responses (time-slices 2021-2050 and 2071-2100) to the result of 6 models extracted from FP5-PRUDENCE as well as FP6-ENSEMBLES archives. To avoid a large number of geographical maps difficult to compare, we have worked at country level, considering for 5 countries (Czech Republic, Slovakia, Hungary, Romania, and Bulgaria) the spatial averages of the models covering this country. The whole results are available in deliverable D2.6. Figs. 37-39 show an example for winter and summer temperature over Hungary (the country covered by 5 models out of the 6). One can see a reduced systematic error in summer and a good agreement on the response on the country-scale when compared with coarser regional models.

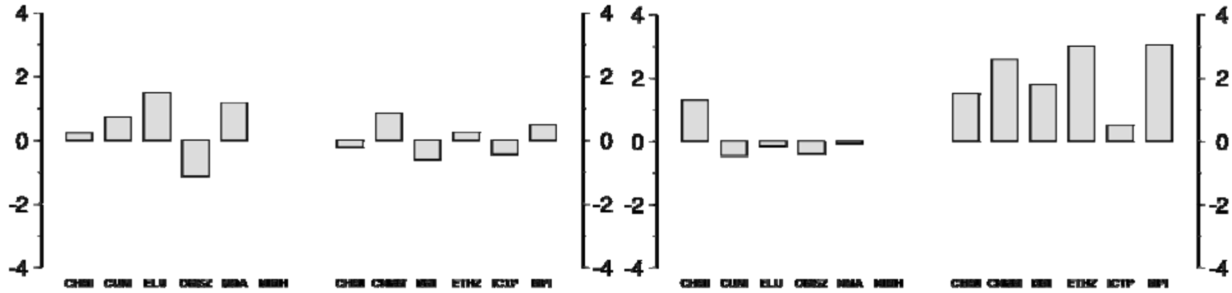


Figure 37. *Mean systematic error over Hungary for winter (left) and summer (right) temperature (°C) for 5 CECILIA models and 6 ENSEMBLES models.*

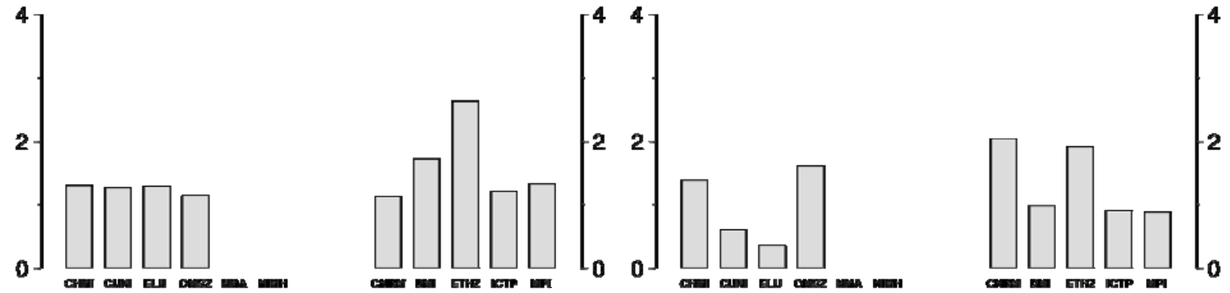


Figure 38. *Mean response over Hungary for winter (left) and summer (right) temperature (°C) for 5 CECILIA models and 5 ENSEMBLES models: 2021-2050 versus 1961-1990.*

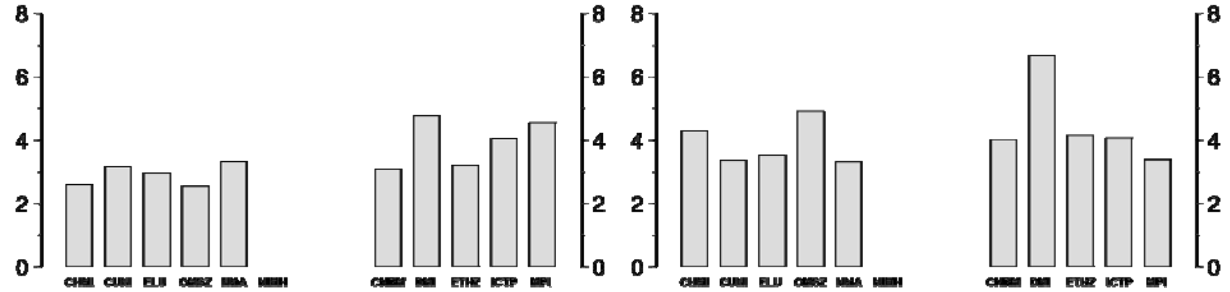


Figure 39. *Mean response over Hungary for winter (left) and summer (right) temperature (°C) for 5 CECILIA models and 5 PRUDENCE models: 2071-2100 versus 1961-1990. Note than the scale is different from Figure 5.*

The aim of CECILIA is to refine the horizontal resolution beyond the country scale, and the added value of the 10-km resolution will be discussed in two forthcoming scientific papers. When analyzing very local scale (typically the nearest grid point of a given city) the uncertainty becomes larger, because the natural climate variability is large in mid-latitudes, and not tempered by spatial averaging. Fig. 40 shows the probability density function for Prague (in fact the nearest grid point) precipitation response with CUNI model. This probability takes just into account the natural variability of 30-year averaging (i.e. the sampling uncertainty), not the model uncertainty. However the sign of the response is uncertain, except for winter second time-slice.

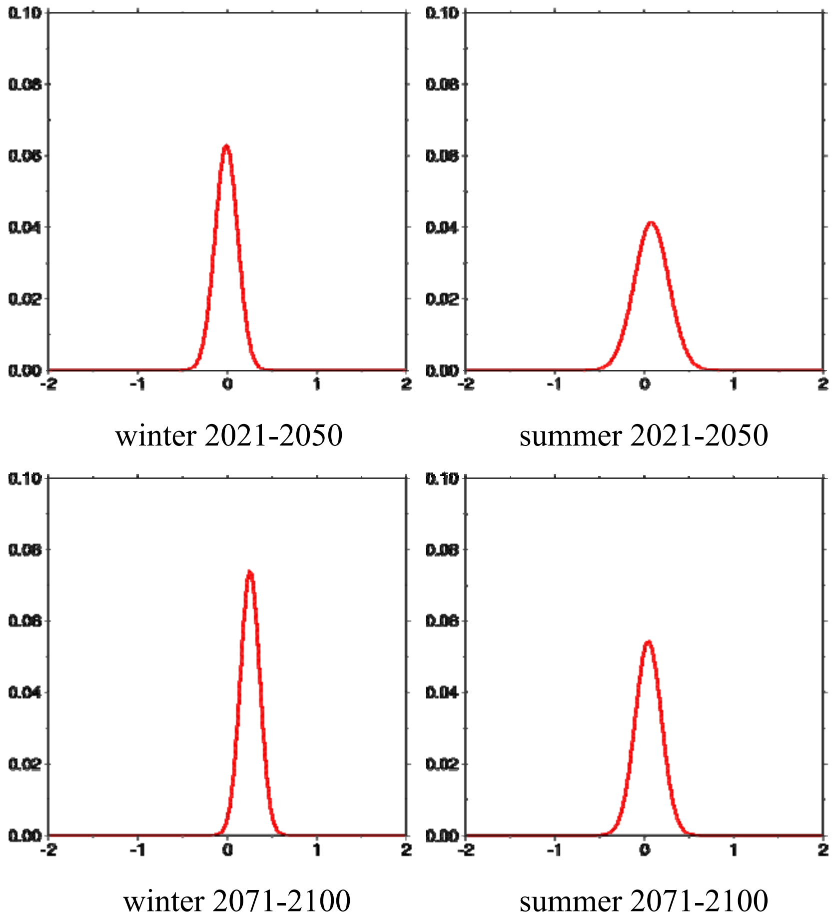


Figure 40. *Probability density function (K^{-1}) for the precipitation response over Prague with CUNI model.*

2.2.2.10 AUTH

After some preliminary tests in previous periods WP2 activities connected to D.2.7 with parameterizations tests and improvements studies started at the beginning of the last reporting period. Regional climate simulations have been performed over the greater European area for three individual years using three convective parameterizations, a) the Grell scheme with Arakawa-Schubert (AS) closure assumption, b) the Grell scheme with Fritsch-Chappell (FC) closure assumption and c) the MIT scheme. The comparison of the model results of near surface temperature with near surface temperature observations indicates a cold bias with both Grell scheme configurations (see Fig. 41). This bias is significantly reduced when the MIT convective scheme is introduced, even during months of low convective activity (see Fig. 41). The temperature differences between the Grell (with either AS or FC closure schemes) and the MIT scheme are largest in the lower troposphere extending up to 700 hPa. In terms of total precipitation, no systematical differences between Grell and MIT schemes are observed throughout the year for the European domain but the convective portion of total precipitation is greater in the MIT scheme simulations. For the central Eastern Europe region MIT scheme simulations generally produce more precipitation during the warm season than Grell simulations while for the southern Eastern Europe region the MIT precipitation enhancement is small and not systematically positive. It is evident that the cause of the differences between the convective schemes is the more intense convection in the MIT scheme configuration which in turn imposes a more effective drying of the atmosphere, less low-level clouds, more short-wave solar radiation absorbed from the ground and hence warmer low level temperatures.

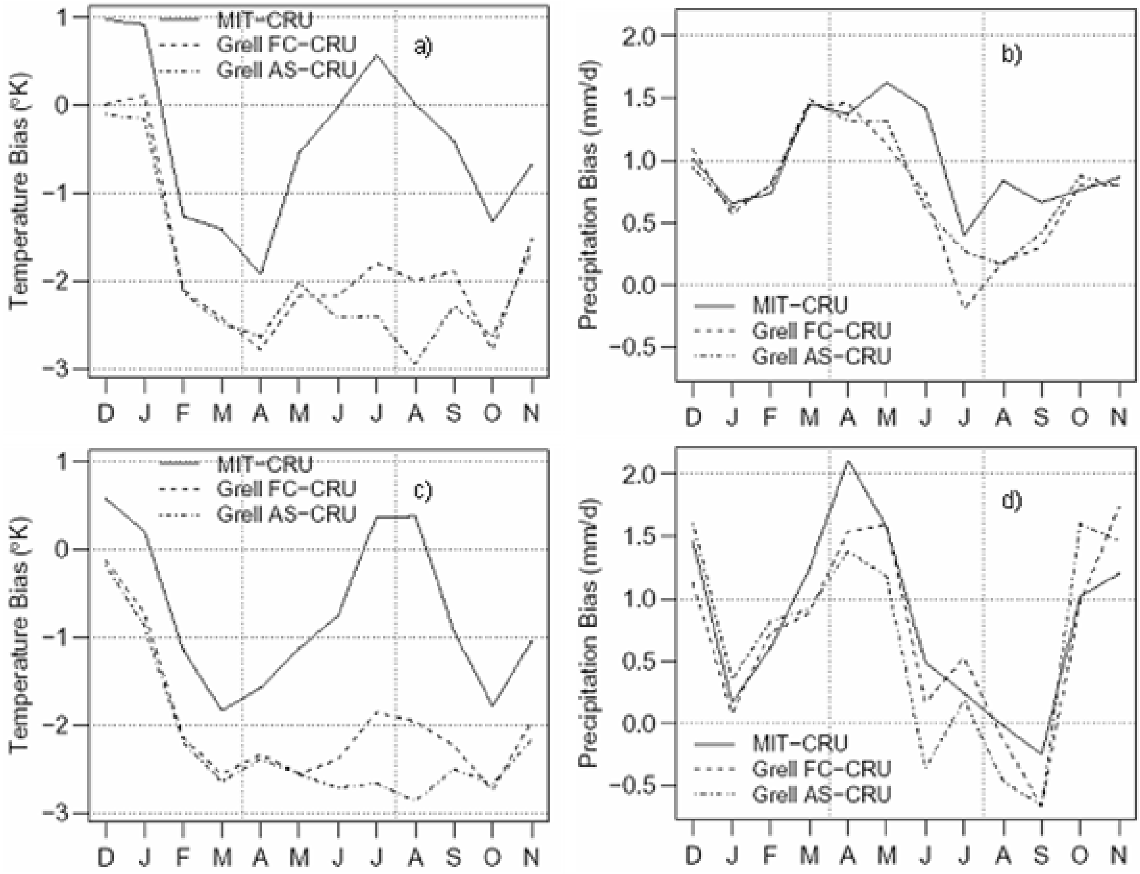


__Figure 41.__ Seasonal variability of the mean monthly bias of Temperature at 2m and Precipitation from the CRU gridded dataset for CEE and SEE sub-regions for the MIT, Grell-FC and Grell-AS convective schemes. The monthly values were calculated from the three study years.

2.2.2.11 BOKU

After some preliminary tests in previous periods WP2 activities connected to D.2.7 with parameterizations tests and improvements studies started at the beginning of the last reporting period. An investigation of an improved snow accumulation and snow melt within the Alpine region requires a good representation of the precipitation. As the first results of the standard CECILIA RegCM3 version (alpha) showed too much precipitation within the Alpine region, systematic tests of different domains and lateral boundary conditions have been applied, to find the most appropriate set-up for this application.

Simulation 2(a) showed lot of precipitation over Alps and some grid points with enormous snow accumulation. To overcome this problem simulation 2(b) and 2(c) are done and these three simulations (a,b,c) were compared with lateral boundary conditions (ICTP-25km simulations), RegCM3 ouput from CUNI, Prague and MM5 output from Reclip-More Project. It was suspected that there might be a problem in the quality of boundary conditions. This conclusion led to drive the model with high resolution recently released ERA-Interim data. Interface for RegCM3 ERA-Interim was written and first 1 year test simulation was done and compared with the above mentioned 6 other simulations. Results were highly encouraging showing significant improvement of precipitation simulation in ERA-Interim driven runs. These results set the basis of new study of comparing different lateral boundary conditions and nesting strategies. The simulation 3 are a set of simulations done with three different lateral boundary conditions (ERA-Interim, ERA40, NCEP) with 3 different spatial resolutions (0.75,1.125,2.5 degree) and different domain resolutions (90km,30km,10km). Results from 8 simulations at finest domain (10km) were compared and presented at EGU2009. The simulations driven directly (without intermediate nests) with ERA-Interim 0.75 degree and ERA40-1.125 degree showed more realistic results than any other simulation. It was suspected that this improvement of directly driven ERA-Interim and ERA40 simulations could be merely because of the effect of domain size. To verify this hypothesis, a 10km simulation is done for the big domain used for intermediate 30km simulations (covering almost whole Europe) and compared the results with previous simulations. The hypothesis that high resolution ERA-Interim/ERA40 10km simulations without intermediate domain produced better results because of small domain size was verified. The results for precipitation bias and temporal correlation are shown in Fig. 42 and 43.

As best performing set up for our sub-scale investigations we choose RegCM CECILIA alpha version forced with 0.75 degree ERA-Interim lateral boundary conditions and the small domain. This set-up was used for a six year integration using the standard and a sub-scale version of RegCM3. The main effect of the used sub-scale scheme is a better resolving of the topography within complex terrain and a more realistic representation of land-use. For this study we compare the results of a high resolution RCM with 10 km grid spacing and a sub-scale version with a grid spacing in the surface scheme of 1 km. With 1 km resolution it is possible to resolve the major Alpine valleys more realistically. The higher resolution gives a better representation of the altitudes and thus the temperatures and snow accumulation and melt. With 10 km spacing an underestimation of low altitudes below 600m and also an underestimation of very high elevations above 2400 m is observed. The different representation of land use in the coarse and fine resolution is shown in Fig. 44 for a region on the Alpine main ridge. The white colour represents glaciers, grey is tundra and dark green is forest. More details and results are given in deliverable D2.7.

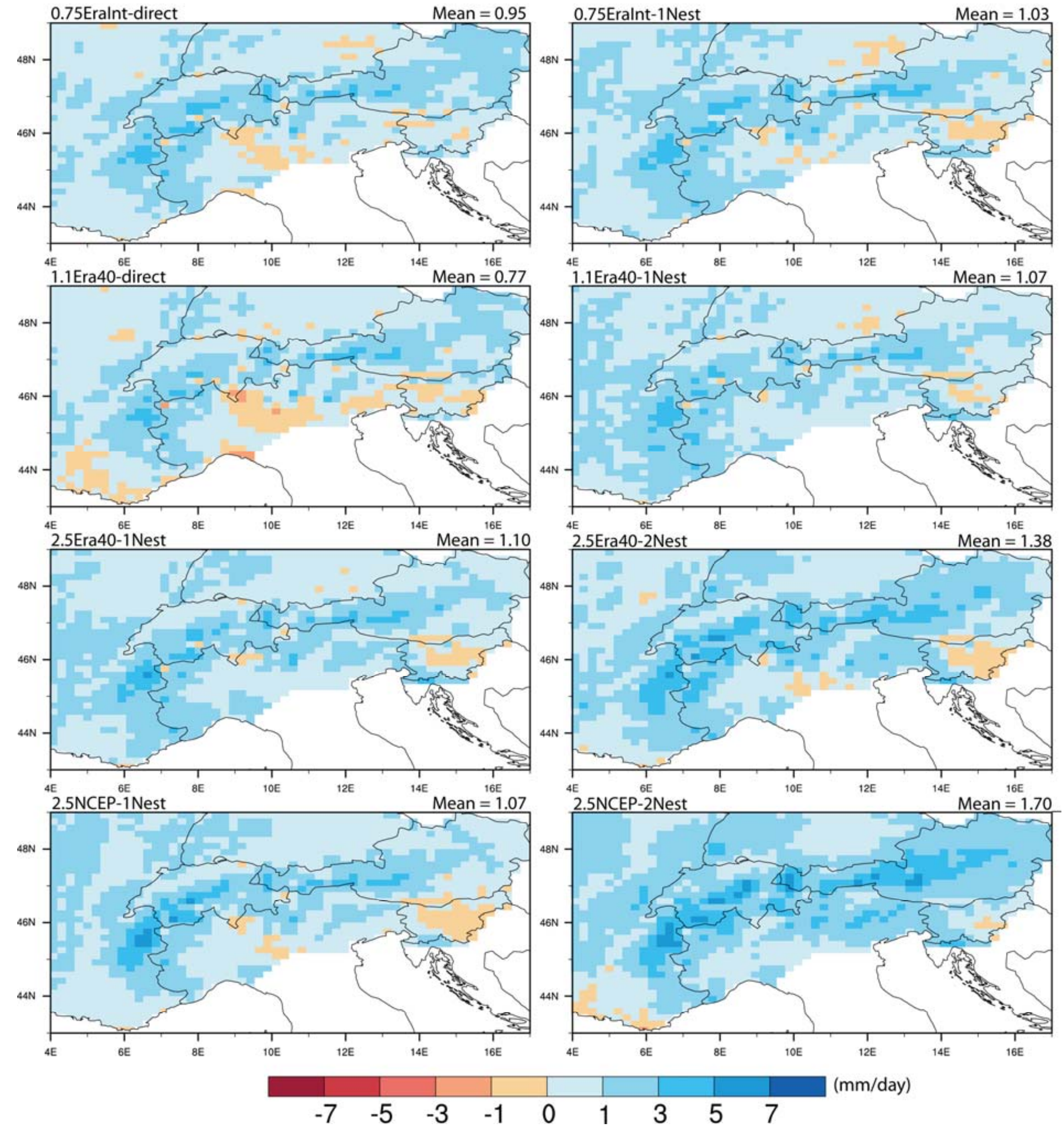


Figure 42. *Precipitation bias of RegCM3 forced with different lateral boundary conditions for the year 1999.*

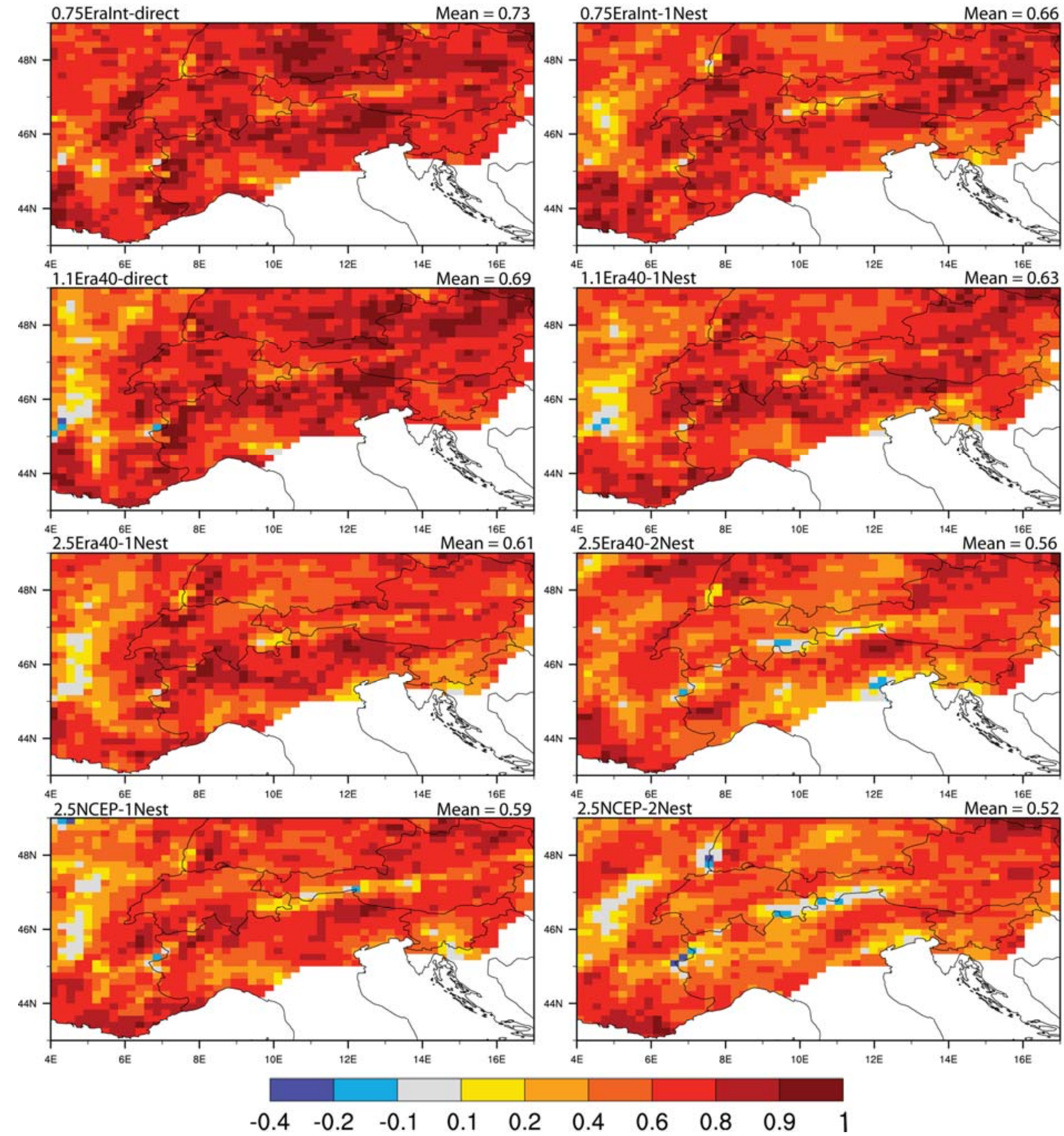


Figure 43. *Temporal correlation of the monthly mean precipitation of RegCM3 forced with different lateral boundary conditions for the year 1999.*

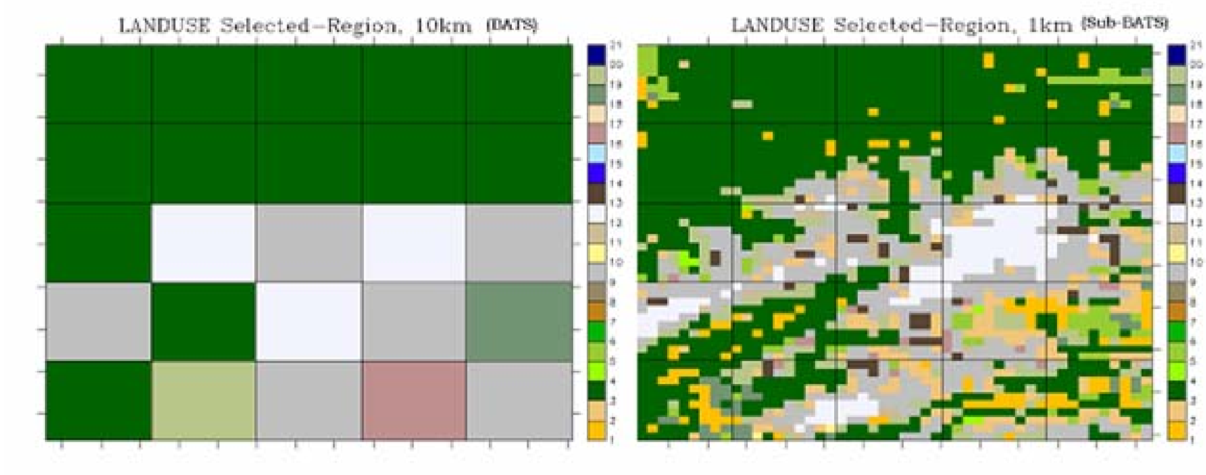


Figure 44. *Different representation of the land use types in the coarse (left) and fine (right) resolution for a region on the Alpine main ridge.*

2.2.2.12 WUT

WUT developed an alternative (improved) parameterization of the atmospheric boundary layer (ABL) within the climate model (RegCM3) in the first two years of the project. During third CECILIA reporting period, the work toward achievements of Deliverable D2.7 objectives, i.e. possible improvements in very high resolution climate simulation (Month 43) has been completed.

The primary goal of this work was to estimate sensitivity of climate projections within the atmospheric boundary layer (ABL) over central Europe. Since results of climate projections could significantly depend on a parameterization scheme within a climate model, the work was pursued through developing of an alternative (improved) parameterization of the atmospheric boundary layer (ABL) within the climate model (RegCM3).

During second reporting period, an improved non-local parameterization scheme of the convective boundary layer was developed. The parameterization involved a modified procedure (with respect to the scheme proposed by Troen and Mahrt, 1986, and followers) for calculating (i) the boundary-layer height, (ii) non-local terms for the momentum and scalar fluxes, and also (iii) entrainment fluxes for momentum and scalars. Fig. 45 shows the agreement of the dimensionless heat flux H/H_o, and the dimensionless momentum flux R_x/u_*^2, obtained from the modified parameterization scheme, with results of the large-eddy simulation model (LES). The convective scheme was described by Sorbjan (2009). Since the convective scheme is insufficient for a proper treatment of the diurnal variation of the atmospheric boundary layer, the work was subsequently continued in 2009, when the improved parameterization of the stable (nocturnal) boundary layer was worked out. The parameterization of both stable and convective cases was implemented within a single-column boundary layer model (developed especially for CECILIA project).

The improved parameterization scheme developed for stable conditions includes cases of both stable and very stable stratification when the Richardson number is overcritical (Ri > 0.2) (the current RegCM model does not include such an option). Fig. 46 shows the flux-gradient expressions as functions of the Richardson number Ri, $f_m(Ri)=\tau/(\kappa zS)$ for the momentum flux, and $f_h(Ri)=H/[(\kappa zS)^2 S\Gamma]$ for the heat flux, where κ is the von Karman constant, z is height, S is the wind shear, and Γ is the potential temperature gradient. The above functions are employed within the scheme. The empirical functions $f_m(Ri)$ and $f_h(Ri)$ were evaluated based on measurements collected during the SHEBA experiment in the Arctic in 1999 (data provided by Dr. A. Grachev, NOAA) and CASES-99 experiment in Kansas). It should be mentioned that the resulting Prandtl number $Pr = K_m/K_h$ (not shown), defined as a ratio of the eddy viscosity and diffusivity, decreases with the increasing *Ri* (note that all previous schemes, in which *Pr* is assumed to increase with *Ri,* are incorrect). We also assumed that $Q/[(kzS)^2 Sg]=f_h(Ri)$, where *Q* is the humidity flux and *g* is the humidity gradient. **The resulting paper**, entitled "An Evaluation of the Flux-gradient relationship and gradient-based scaling in the stable boundary layer" has been accepted for publications in "Boundary-Layer Meteorology" (Sorbjan and Grachev, 2009).

Preliminary results of RegCM model sensitivity to changes of parameterizations within the atmospheric boundary indicated, that the new scheme could significantly improve the performance of climate models within the atmospheric boundary layer.

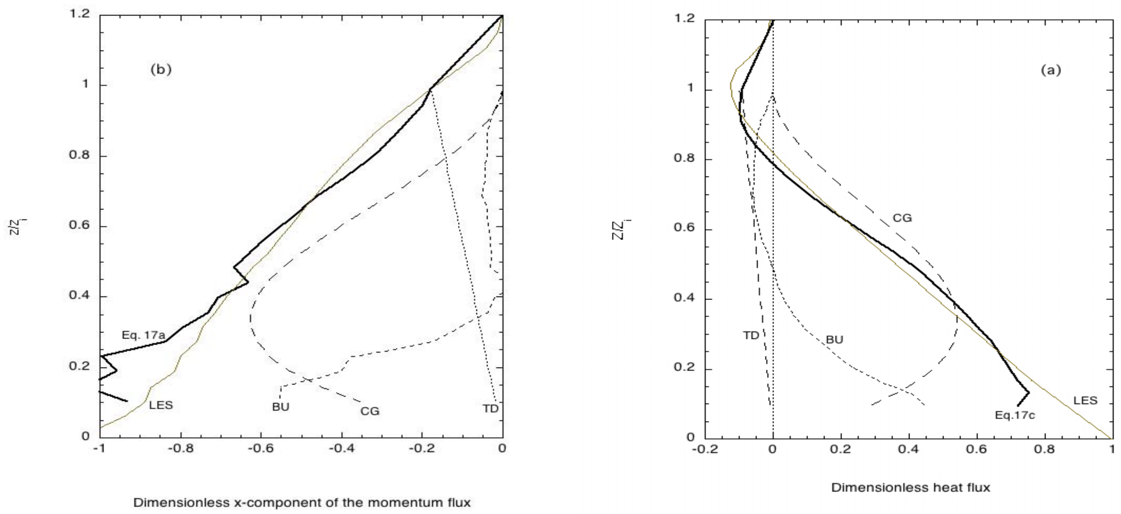


Figure 45. *Dimensionless values of: (a) the dimensionless heat flux* H/H_o, *and (b) the dimensionless momentum flux* R_x/u_*^2, *obtained from the modified parameterization scheme (thin line) and from the LES model (thick line) of Sorbjan (2005). The local, countergradient and entrainment contributions to the fluxes are indicated by letters LOC, CTG, and ENT (Sorbjan, 2009).*

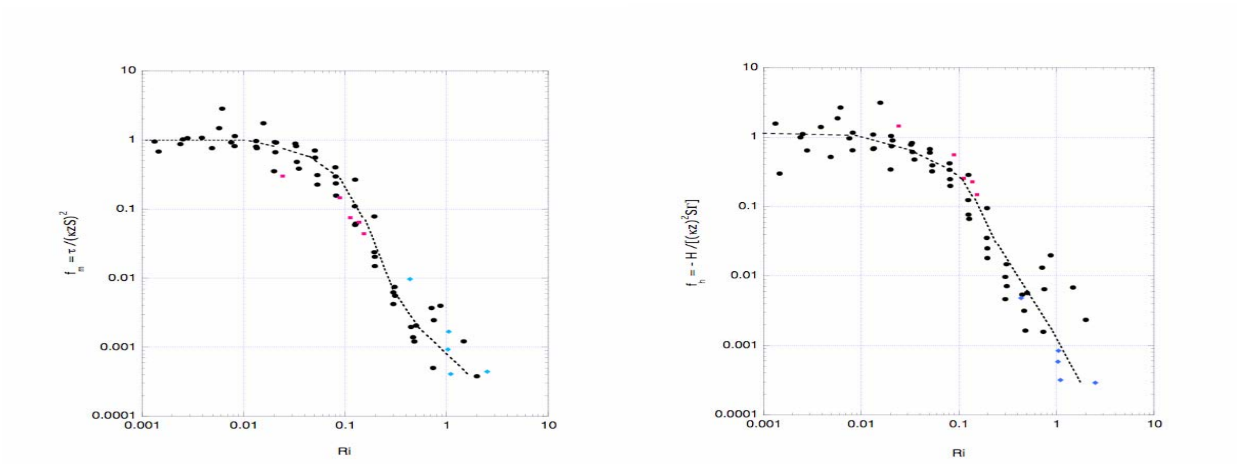


Figure 46. *Dependence of the empirical dimensionless functions: (a)* $f_m(Ri)$ *for momentum* τ, *and (b)* $f_h(Ri)$ *for heat flux H, on the Richardson number Ri. The SHEBA data are marked by black points. The CASES-99 data are marked by red squares (strong turbulence) and blue diamonds (weak turbulence). Note that S is the local wind shear,* Γ *is the local temperature gradient,* κ *is the von Karman constant, and z is height (Sorbjan and Grachev, 2009).*

In addition, very high resolution Regional Climate Model (RCM) simulations for the targeted area of Central and Eastern Europe have been started at WUT, as the added value within the project. The RCM model applied is the improved version of RegCM3 for high resolution use – RegCM3-Beta. As WUT is participating in WP7 activity (*Climate change impacts on air quality and health*), where air quality (AQ) modeling was planned for the region of Poland, the decision of simulating climate change within the targeted area for AQ modeling at WUT was undertaken.

The RegCM3-Beta model was implemented at WUT in second reporting period for so called *WUT domain*, centered over Poland (52.00°N, 19.30°E) with 120 x 109 grid points in x and y direction, respectively. The map projection choice was Lambert conformal. A 10 km resolution simulations over the WUT domain were completed for extended control period (1991-2000) and two scenario time slices (2041-2050 and 2091-2100) forced by ECHAM-5 GCM. The meteorological output fields of RegCM3-Beta version were used to drive offline the air quality model CAMx at WUT.The results of temperature differences of decades 2041-2050 and 2091-2100 against 1991-2000 period are shown in Figs. 47 and 48, respectively.

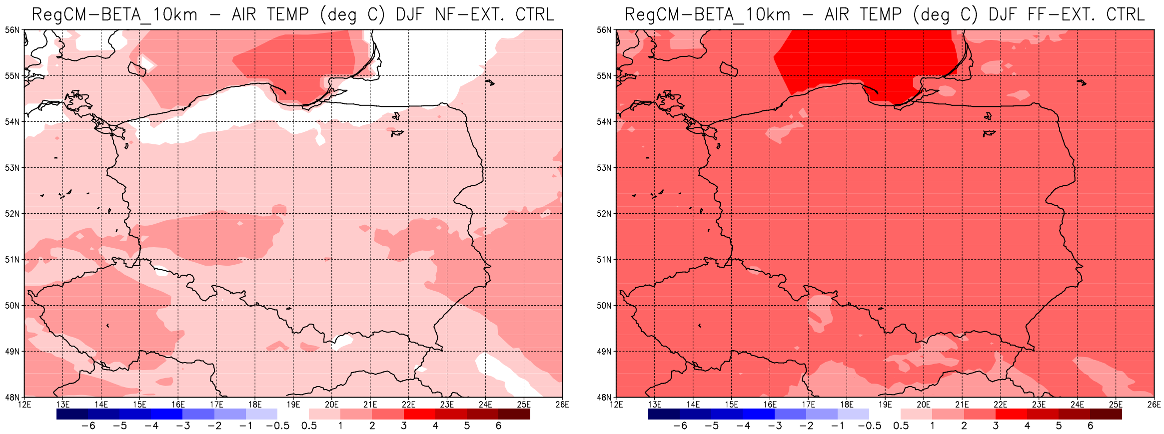


Figure 47. *Changes of winter temperature (°C) in 2041-2050 (left panel) and 2091-2100 (right panel) relative to 1991-2000 period for WUT domain.*

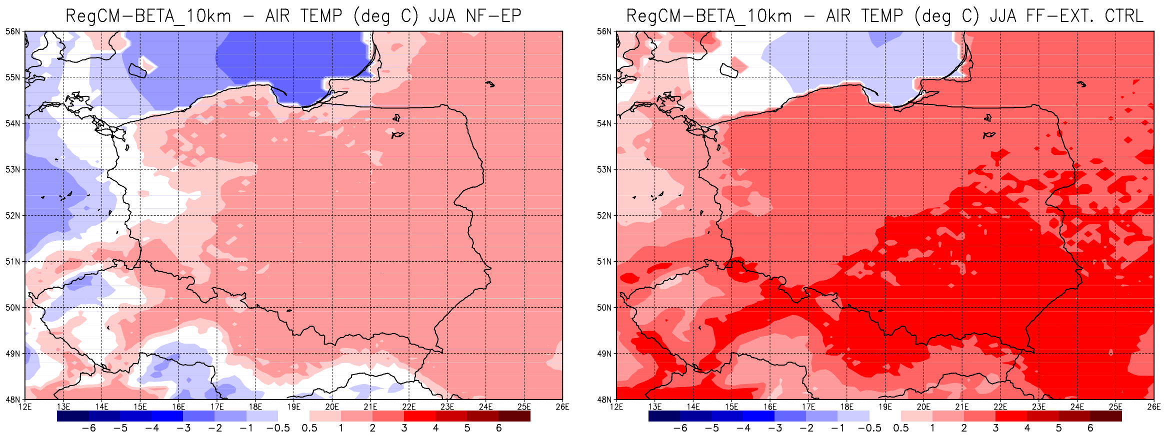


Figure 48. *Changes of summer temperature (°C) in 2041-2050 (left panel) and 2091-2100 (right panel) relative to 1991-2000 period for WUT domain.*

2.2.3 Deviations from the project workprogramme

The delay in the production of RCM scenarios, mentioned and explained in Year 2 Periodic Activity Report was recovered at the end of the project, thanks to the 7-month extension of the contract. WP2 has thus achieved what was in the project workprogramme. Due to technical problems, certain delay happened with the completion of the database at DMI, which is an important legacy of CECILIA. This have been recovered already and all the model simulations results are in database now.

2.2.4 References

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Zanis P., C. Douvis, I. Kapsomenakis, I. Kioutsioukis and D. Melas (2009): A sensitivity study of the Regional Climate Model (RegCM3) to the convective scheme with emphasis in central eastern and southeastern Europe, Theoretical and Applied Climatology, 97, 327–337, DOI 10.1007/s00704-008-0075-8.

2.3 WP3

2.3.1 Workpackage objectives

WP3 consists of four main objectives relying on statistical procedures. It makes use of outputs from WP1 and WP2, namely the outputs from global and regional climate models, and by application of a variety of statistical methodologies, it transposes them into meteorological datasets to serve as inputs into impact models in WPs 5, 6, and to a lesser extent also WP7. Some outputs from WP3 also enter WP4 where extreme events are analyzed. The four main objectives of WP3, as described in the DoW, are:

(i) construction of statistical downscaling (SDS) models,
(ii) development and implementation of techniques for localization of RCM outputs,
(iii) validation of SDS and RCM models,
(iv) construction of climate change scenarios.

Seven institutions contributed to the work in WP3 during the reporting period: IAP, CUNI, CHMI, ELU, OMSZ, NMA, and BOKU.

2.3.2 Progress towards objectives

During the last reporting period, the work was mainly conducted on objectives (iii) and (iv). The work concentrated on finalizing the extended validation of SDS and RCM models (D3.3, Assessment of the applicability of RCM and SDS models in the impact target areas by their validation according to relevant criteria; ranking of the models if possible), the construction of climate change scenarios (D3.4, Climate change scenarios for near future (time slice 2020-2050) and D3.5, Climate change scenarios for end of century (time slice 2070-2100)), and comparisons with results from other projects (D3.6, Comparison with results of ENSEMBLES). Some additional work on localization of RCM outputs updating results for objective (ii) was also carried out.

2.3.2.1 IAP

For climate change scenarios construction (D3.4, D3.5) the input weather series used in agricultural and hydrological climate change impact experiments in Czechia were mostly prepared by the stochastic weather generator Met&Roll (Dubrovský et al., 2000; Dubrovský et al., 2004), whose parameters were modified according to the climate change scenarios derived from GCM simulations. Two approaches were used to derive the climate change scenarios from GCM simulations: delta approach and the pattern scaling. Because the delta approach was used to derive the scenarios from the daily GCM outputs (available only for shorter time slices), it was applied only for the time slice 2081-2100. More details are presented in the CECILIA deliverable D3.5. The pattern scaling method, which is the preferred method, was used when the scenarios were derived from the monthly GCM outputs, which is available for much longer periods compared to the daily outputs.

The "pattern scaling" method (Dubrovsky et al., 2005) is based on an assumption that the change of each climatic characteristic is linearly proportional to the change in global mean temperature. The set of standardised changes of all relevant climatic characteristics and for all month is called a standardised climate change scenario. In our case, the relevant climatic characteristics are: daily average and extreme temperatures, daily precipitation sum and daily global solar radiation. Humidity and wind speed, which are also needed for some impact models, are added by the resampling method because of the incompleteness of the GCM databases. The scenarios derived from the monthly GCM outputs include changes in the means and standard deviations of monthly values of individual climatic characteristics. The changes in temperature means are given in terms of Celsius degrees, changes in all other climatic characteristics (including standard deviations of monthly temperatures) are given in terms of percentage.

Advantages of the pattern scaling method include: (i) The standardised scenarios may be derived (using the linear regression) from a long GCM-simulated time slice (e.g. 1961-2100) which implies a lower sampling error and thereby higher robustness of the scenarios (compared to the delta approach commonly applied to shorter time slices). (ii) The change in global mean temperature, which is used to scale the standardised scenarios, may be estimated by a simpler (compared to GCM) one-dimensional energy-balance model MAGICC, which models evolution of the global temperature in response to chosen emission scenario, climate sensitivity and several other model parameters. This approach allows scaling of the standardised scenarios derived from GCMs run at a single emission scenario for a set of user-selected combinations of emission scenario and climate sensitivity.

The construction of the standardised scenarios proceeds as follows. The standardised scenarios are derived from the GCM-simulated time series of monthly averages of climatic characteristics using a linear regression, in which the global mean temperature is the independent variable, and the respective climatic characteristic is a dependent variable. The standardised scenarios for the CECILIA project were derived from the most recent GCM simulations (SRES-A2 emission scenario) made for the IPCC 4th Assessment Report. Specifically, SRES-A2 runs were used. This emission scenario assumes the highest GHG emissions of the four marker emission scenarios, so that it implies highest signal-to-noise ratio and thereby the lowest error in estimating the standardised scenario.

The standardised scenarios for temperature and precipitation were produced for 11 GCMs. The differences between scenarios derived from individual GCMs are due to differences in the GCMs (related to different parameterization of sub-grid phenomena, different spatial resolution, different representations of Earth surface, etc) and natural climate variability (the latter may be effectively modelled by the stochastic weather generator, which is linked to the climate change scenarios). To account for the inter-GCM variability in the given climate change impact analysis, we can either use scenarios from all available GCMs, or to use a subset of GCMs which consists of those GCMs which are among the best (in terms of the fit between observed climate and GCM-simulated climate). Considering the number of GCMs, we used the latter approach. Based on the earlier validation tests the triplet of GCMs was used to define the standardised scenarios: HadCM3, ECHAM5 and NCAR-PCM, which satisfy the above conditions (simultaneously, the benefit of this triplet is that the chosen GCMs belong to the most frequently worldwide used GCMs, which allows comparison of results obtained with these scenarios with results of other authors).

The increase in global mean temperature ΔT_G was estimated by one-dimensional energy-balance model MAGICC. To account for the uncertainties in climate sensitivity and emission scenarios, all possible combinations of the four marker emission scenarios (SRES-A1, SRES-A2, SRES-B1 and SRES-B2) and three values of climate sensitivity (low = 1.5 K, middle = 2.6 K, high = 4.5 K) were used to drive MAGICC while estimating the value of ΔT_G.

In addition to the scenarios derived using the pattern scaling method, the scenarios derived from daily GCM outputs were used. In addition to the climatic characteristics involved in the scenarios derived from the monthly data, these scenarios include also changes in daily variability. The scenarios were derived by comparing the statistics (means or standard deviations) derived for the future (2081-2100) vs. present (1961-90) periods. Sampling errors were estimated from the multiple simulations with stochastic weather generator.

In work for D3.3, a validation of statistical (multiple linear regression, multiple linear regression on data stratified by circulation types, canonical correlation analysis) and dynamical (ALADIN-Climate/CZ, RegCM/CZ) downscaling models was conducted on the common central European area along the Czech-Slovak-Austrian-Hungarian borders, defined for D3.2 for daily temperature. The model outputs were validated against observed data interpolated onto a 10 km grid of the ALADIN-Climate/CZ RCM, to which also RegCM's outputs were interpolated. Analyzed were characteristics of temporal and spatial structure, namely, the 1-day lag autocorrelation (persistence) and spatial autocorrelation. For an example of results, see D3.3; here we only state that RCMs systematically overestimate persistance while underestimate spatial autocorrelations. This behaviour is different from statistical downscaling models, for which underestimation of both temporal and spatial autocorrelations is typical.

2.3.2.2 CUNI

In the final project period, the CUNI activities within WP3 focused on postprocessing and analysis of high-resolution data for the CECILIA common domain (see deliverable D3.1 for a detailed description of this region, as well as characterization of the respective dataset of observations). Generation of daily data in the 10 km resolution by the statistical downscaling methods has been finalized; they have been validated against gridded observations and compared with the RCM outputs (RegCM3 and ALADIN-Climate/CZ, run at CUNI and CHMI, respectively). Since the RCM outputs turned out to be superior to the series generated by statistical downscaling in most respects, the primary attention has then been turned to the techniques for bias correction and localization of the RCM data. A composite postprocessing procedure has been implemented, able to generate data with reduced systematic errors and with resolution surpassing the 10 km step of the original model grids. This procedure was then applied to the RCM-simulated data representing the control climate, as well as near (2021-2050) and far (2071-2100) future. The respective climate change scenarios have been constructed and results for raw RCM data have been compared to those obtained through the corrective procedures.

For statistical downscaling, validation and ranking in D3.3within the first two years of the project, the validation activities of CUNI were concentrated on the assessment of downscaling techniques, both statistical and dynamical, for the region of the Czech Republic, and identification of the best approach or approaches. The results are documented in deliverable D3.3. In the final period, similar validation has been repeated for the gridded data in the CECILIA validation domain, with analogical results: Most statistical downscaling methods (multiple linear regression, local linear models, RBF neural networks and multilayer perceptrons) were able to simulate series of local daily temperature (mean, maximum or minimum) quite well, but they failed to capture the shape of the statistical distribution of daily precipitation. The method of analogues, while delivering realistically shaped distributions, produced series with severely distorted temporal structure (most notably, the temporal persistence in the series was severely underestimated). Both representatives of the RCMs (RegCM3, run at CUNI and ALADIN-Climate/CZ, run at CHMI) exhibited substantial biases of mean values (e.g., the very strong wet bias of the RegCM model), but deviations of the shape of statistical distribution of the target variables (especially precipitation) from reality were usually less severe than in case of the outputs of statistical downscaling. Since the most serious systematic errors of the RCMs could be corrected by additional postprocessing (see below), the outputs of the regional models were picked as a preferable source of high-resolution data for further analyses.

As a continuation of effort on localization of the model outputs (D3.2) at CUNI, a low-parametric alternative to the percentile-matching bias-corrective procedure applied at BOKU was implemented and used to modify data representing daily maximum and minimum temperature and daily precipitation, generated by the RegCM3 and ALADIN-Climate/CZ models. The initial validation has been carried out for the model runs driven by the ERA-40 reanalysis. The method was demonstrated to successfully rectify major systematic errors in the model data: It was able to reduce substantially the bias of mean values, amend the spread of the values and bring a more realistic number of dry/wet days in case of the precipitation series (Fig. 49). A substantial improvement was also achieved for the representation of extreme tails of the statistical distributions of the target variables, including the highest/lowest quantiles, important for reliable assessment of the occurrence of extreme phenomena. However, some of the problems associated with the RCM outputs remained unsolved even after the correction, at least to some extent (e.g., sometimes unrealistic temporal persistence in the time series and potentially distorted physical consistency of the multivariate fields). A more detailed description of the corrective technique and an illustration of its results are presented in update of deliverable D3.2.

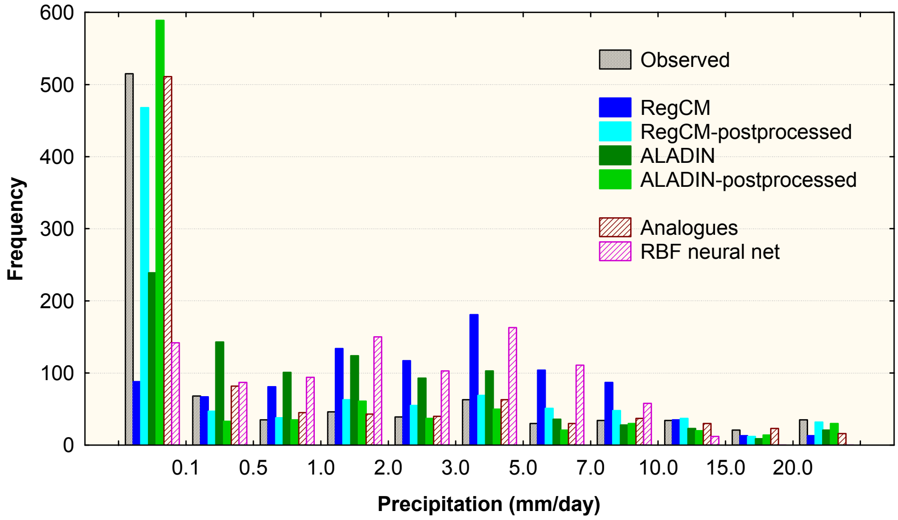

Figure 49. *Distribution of values of daily precipitation in the series obtained by different downscaling methods, dynamical or statistical (displayed for a grid point located at 49°00' N, 15°28' E) – JJA season. The RCM runs as well as the statistical downscaling mappings were driven by the ERA-40 data; for details on the statistical downscaling techniques, see deliverable D3.3.*

After testing of the bias-corrective procedure on the outputs of the ERA-40-driven RCMs, application for the GCM-embedded regional model runs followed for future climate & climate scenarios construction effort (D3.4 & D3.5). Validation of the results for the control period 1961-1990 verified the skill of the algorithm, which was then applied to daily temperature and precipitation data representing near (years 2021-2050) and far (2071-2100) future, as simulated by the RegCM model. Climate change scenarios have been constructed from the original as well as corrected data, for mean values as well as other characteristics of the distribution of the target variables. It was shown that the correction exhibits a tendency to amplify the increase of daily temperature, maximum or minimum. Typically, for different seasons and grid points, this additional increase ranged between 0 and 2 °C for the period 2071-2100. Similar behavior was also observed for precipitation: In seasons when precipitation increase was simulated in the original RCM data, correction further increased it. The correction also magnified the spatial variability of the simulated changes, increasing the originally relatively small differences between changes simulated in close grid points of the validation domain. Selected illustrative results and their discussion are presented as a part of deliverables D3.4 (scenarios for the period 2021-2050) and D3.5 (period 2071-2100).

Following the implementation of simple localization procedures for the region of the Czech Republic, employed and tested during the first two years of the project (D3.2), localization of the RCMs was now also applied for the gridded observations in the CECILIA common validation domain. Several approaches were tested, focusing on transformation of daily data or monthly means, using local or global approach to the construction of the transfer function. Attention was paid particularly to techniques compensating for a simplified representation of the terrain elevation in the RCMs. It was shown that localization can substantially improve the model outputs for temperature-related characteristics, the relation of which to terrain elevation is very strong and well represented by the CECILIA regional models. By using the model-simulated vertical gradient, the correction could be applied for the climate data in the control period as well as for simulations of the future, on daily basis. The localization was carried out and tested for precipitation data as well; in this case, however, the connection of daily/monthly precipitation sums to terrain elevation was weaker and less realistically simulated by the RCMs (especially the RegCM model). The eventual improvement achieved by precipitation localization was therefore rather small on average and its benefit usually less significant compared to sources of error not related to the elevation mismatch. For additional details on the localization techniques applied at CUNI see deliverable D3.2.

To obtain fields of temperature and precipitation both devoid of major systematic errors and detailed enough to be used for studies at very fine scales, bias-correction and localization were combined. The application was carried out for the outputs of the RegCM model, for maximum and minimum daily temperature and daily precipitation in the periods 1961-1990 (control climate), 2021-2050 (near future) and 2071-2100 (far future). While usually generating fields with spatial patterns close to reality, the procedure did not produce data which could be considered completely flawless. Specifically, insufficient density of the network of weather stations providing the observations seems to be a limiting factor for this type of postprocessing: In the 10 km grid, some local areas were underrepresented or characterized by an anomalously behaving measuring site, which introduced artifacts and unrealistic values into the postprocessed climatic fields, located usually in a vicinity of a single node of the original model grid (Fig. 2.25 in D3.2). The CUNI's point-wise debias approach, although actually retaining the maximum amount of details available from local observations, may therefore be replaced with a correction constructed for a broader local area in future postprocessing applications. For more details and examples see deliverable D3.2., an example of the combined effect of bias correction and localization is shown in Fig. 50.

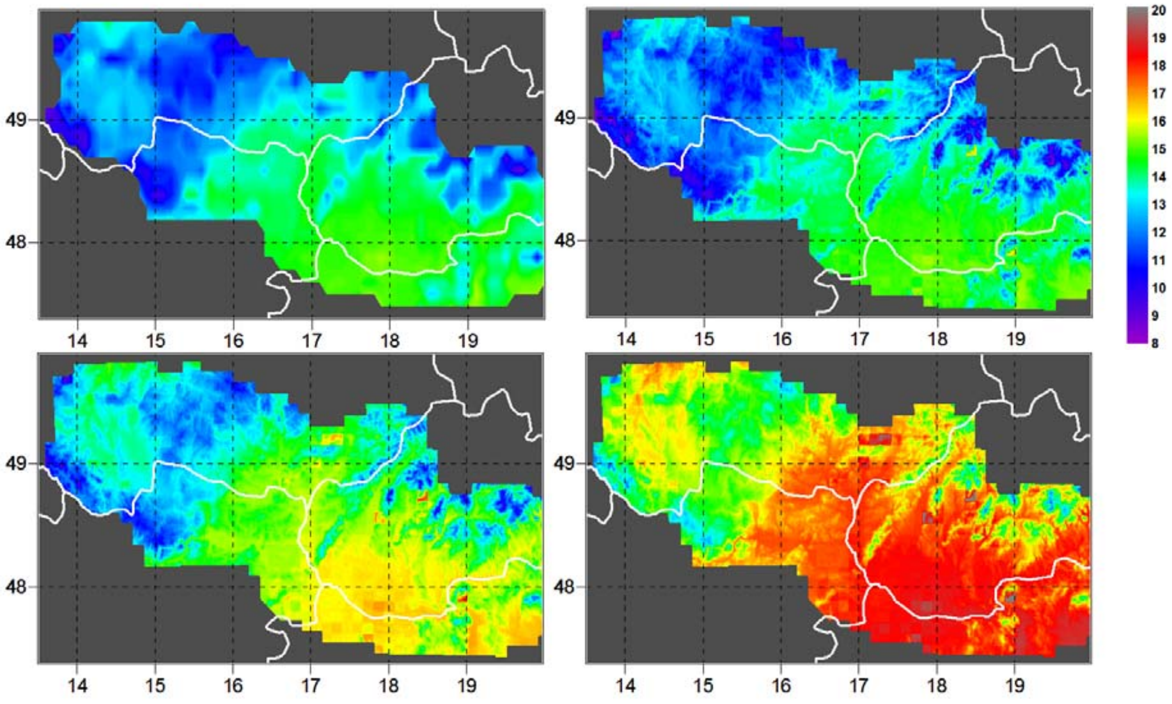

Figure 50. *Annual mean of maximum daily temperature (°C): Data simulated by the RegCM model after the bias correction (top left), localized data for the control period 1961-1990 (top right) and the future periods 2021-2050 (bottom left) and 2071-2100 (bottom right)*

In order to better capture the spread of the systematic errors or the state-of-the-art regional climate simulations, as well as of the projected changes, intercomparison of the results with selected 14 ENSEMBLES models was done by the CUNI team for the region of Central Europe, along with validation targeted at the area of the Czech Republic. Unlike in the CECILIA deliverable D2.6, the focus here was especially on the spatial patterns of temperature and precipitation, rather than mean values for relatively large target regions. For details, see deliverable D3.6.

2.3.2.3 CHMI

Outputs of regional climate models are biased to some extent, resulting either from biases in driving GCM or from given RCM itself (smoothed orography, parametrization etc.). In climate change scenarios constructions (D3.4 and D3.5) such biased outputs can lead then to biased results for computed extreme indices. For analysis of extremes (within WP4) as well as for various impact studies (within WP5 and WP6), correction of ALADIN-Climate/CZ outputs (RCM driven by GCM ARPEGE with the IPCC A1B emission scenario) was carried out for the area of the whole Czech and Slovak Republics, for both time slices, near (2021-2050) and distant (2071-2100) future. The model outputs correction was performed for the area of the whole Czech and Slovak Republics and Lower Austria were station data were available in needed detail.

Data were processed at daily scale and meteorological elements involved were mean, maximum and minimum air temperature, precipitation, relative humidity, wind speed and sunshine duration. In the case of sunshine duration, recalculation into global radiation sums (outputs of the model) had to be carried out, for this Ångström formula was applied. The model data were corrected according to validation results carried out for the period 1961-1990. For this task a gridded dataset of station observation was created (details about methodology can be found in D3.1). All input station observations were quality controlled and homogenized on daily scale and then recalculated to the ALADIN-Climate/CZ grid of 10 km horizontal resolution. Daily station measurements in a vicinity of each grid point were first reduced on the grid point's (model's) altitude by a local linear regression and then weighted averaged to a grid point location according to their distance form the grid point. The inverse distance (1/d) factor was used as a weight for air temperature, while $1/d^3$ factor was taken for precipitation.

Gridded dataset of station observations was then compared with the past climate (1961-1990) GCM driven ALADIN-Climate/CZ simulations in each grid point. According to relationship between these two datasets (validation details are given e.g. in Skalak et al., 2008), outputs of A1B scenario integrations of the future climate were corrected applying the approach of Déqué that is based on a variable correction using individual percentiles. After the correction, the model outputs are fully compatible with the station (measured) data. The gridding and all data processing including the presented analysis were done by ProClimDB database software (free download from http://www.climahom.eu/) for processing of climatological datasets.

2.3.2.4 NMA

For statistical downscaling validation and applicability of both downscaling methods comparison in D3.3 the statistical downscaling models (SDMs) used by the NMA in the CECILIA project are based on the canonical correlation analysis (CCA). These models have been developed for the mean temperature (94 stations covering the entire Romania) and precipitation total (16 stations covering a southeastern area, used for the impact studies in CECILIA). In the previous work it was found that in the case of precipitation it is difficult to find a single skilful SDM for the entire Romanian area, due to the complex Romanian topography. Compared to the previous studies, taking into consideration the impact needs, the SDMs were constructed for monthly values.

The temperature field at 850 mb (T850) has been considered as predictor for temperature while the sea level pressure (SLP), geopotential heights at 500 mb (H500) and specific humidity at 850 mb (separately or in combination) have been tested as predictors for precipitation. The predictor area and optimum predictor combination (number of EOFs used in CCA and number of CCAs used in SDM) has been selected so that the SDM skill (defined as correlation between observed and estimated values as well as fraction of the explained variance of estimated values from the total observed variance) is highest.

The temperature SDMs have been developed over the warm (May-October) and cold seasons, respectively, considering the respective monthly anomalies together. For precipitation, the SDMs have been developed for each of the four seasons (DJF, MAM, JJA, SON). The stability of the skill, calculated over the independent data set, has been tested, considering three validation intervals: 1961-1980 (fitting 1981-1999), 1981-1999 (fitting 1961-1980), 1991-2007 (fitting 1961-1990). The last validation interval has been considered in order to see if the SDM is capable to reproduce the extreme events during the last decades using the models calibrated over the 1961-1990. For temperature, the skill is high and stable, the highest values being for the western and intra-Carpathian area. The mountain stations present the highest skill, showing that the surface conditions are less important in these cases. In case of precipitation, skillful SDMs have also been obtained, but the skill (even if it is significant at almost all stations) is lower. Since the explained variance is lower, the magnitude of the observed anomalies is not always well reproduced, compared with the temporal evolution which is better reproduced.

Calibrated over the period 1961-1990, these models have been used to produce the scenarios for the near (2021-2050) and far (2070-2099) future. The predictors simulated by 9 GCMs (8 ENSEMBLES stream 1 simulations, http://cera-www.dkrz.de/WDCC and ARPEGE) under the A1B emission scenario have been used as inputs in SDMs. The results are presented in Tab. 2, further in detail in the deliverables D 3.4 and D3.5. The GCMs used as inputs in the SDMs are: EGMAM (FUB) -3 runs, ECHAM5 -3 runs, BCM2 and INGV. The ensemble mean of the SDM projections based on these GCM outputs have been calculated in order to reduce the uncertainties. The full range of the SDM projections for all GCM inputs is also presented.

Over the period 2021-2050, under the A1B scenario, it expected a temperature change ranging between 0.6°C and 1.9°C (mean 1.0°C) for winter, 0.5°C and 1.7°C (mean 1.1°C) for spring, 1.2°C and 2.1°C (mean 1.6°C) for summer and 0.7°C and 1.8°C (mean 1.4) for autumn. This result is in agreement with those obtained from the ensemble mean of 8 ENSEMBLES RCMs, except for winter when the SDM signal is lower. The following RCMs were considered: CNRM-ARPEGE, DMI-ARPEGE, DMI-ECHAM5, HadRM3Q0-HadCM3Q0, MPI-REMO-ECHAM5, SMHIRCA-BCM2, SMHIRCA-ECHAM5, KNMI-RACMO2-ECHAM5. The precipitation is very likely to slightly decreased in winter months over the entire region and over plain area in some other months. Not significant change is generally dominant during the spring, summer and autumn, with some increase in May.

Table 2: *Spatial average (over 94 stations) of the monthly temperature change in Romania for the 2021-2050 against 1961-1990, under A1B scenarios derived from the SDM projections driven by various GCMs.*

	BCM2	EH5-1	EH5-2	EH5-3	FUB1	FUB2	FUB3	INGV
Winter	0.7	0.6	1.0	0.7	1.6	1.0	1.9	0.9
Spring	1.1	0.5	1.3	1.0	1.7	1.2	1.0	0.8
Summer	1.8	1.5	1.7	1.4	1.6	1.2	1.4	2.1
Autumn	1.0	1.5	1.8	1.7	1.4	0.7	1.6	1.3

Similar procedures presented for the deliverable D3.4 have been applied for the time slice 2070-2099 for D3.5. The SDMs have been applied to the same GCMs presented in D3.4 and ARPEGE GCM and the results show that the highest warming is projected for summer (up to 4°C over the southern-soutwestern regions). The lowest values are projected for spring. The patterns for winter, spring and autumn show higher values for northwestern regions. On the spatial average, the projected warming over Romania for 2070-2099 under A1B scenario is about 2.6°C for winter, 2.3°C for spring, 3.3°C for summer and 2.7°C for autumn. These results were compared to those obtained directly from the ENSEMBLES RCM simulations. The two signals are similar (the SDM signal is a little bit lower for the southern regions), showing that the SDM results are robust. Comparing the results obtained for each SDM projection, it has been found that the climate signal is dependent on the driver GCM, same conclusion being obtained for the RCMs. The precipitation is projected to decrease during the winter and summer months. For the other two seasons (spring and autumn) no significant changes are expected according to these projections, except for November and some stations in March. The climate signal is similar for various GCM drivers giving more robustness to the results, especially for summer when similar findings are obtained from GCMs and RCMs, according to the results presented by the IPCC AR4 as well as ENSEMBLES project.

2.3.2.5 ELU

The statistical downscaling technique was applied to the Carpathian basin using the scenario experiments of RegCM for 3 time slices: 1961-1990, 2021-2050, 2071-2100. AT-700 hPa geopotential height data (at 00 UTC) from the ECHAM-driven RegCM experiments with 25 km horizontal resolution served as the predictor variable for the region covering the previously defined large-scale region. Gridded temperature and precipitation fields for the region covering Hungary (32 grid points, lat-long: 46°-49°N, 16°-23°E) were generated using the downscaling technique, and compared to the results of the RegCM experiments using 10 km horizontal resolution (and using the same 25 km horizontal resolution ECHAM-driven RegCM simulations that provided input fields for the stochastical model).

Analysed predictors are circulation types (40 types - 10 types/season) in terms of seasonal averages of cluster centers (AT-700 hPa) and time series of daily codes (1961-1990, 2021-2050, 2071-2100) providing seasonal frequency distribution. Outputs for temperature are seasonal mean, seasonal standard deviation and expected seasonal change of mean and standard deviation for future time slices. Similarly, for precipitation it is seasonal mean, seasonal standard deviation, moreover seasonal frequency of wet days and seasonal mean on wet days only, for future time slices the expected seasonal changes (mean, standard deviation, frequency, wet mean). Summary of the results for the stochastical-dynamical downscaling model under A1B scenario using RegCM model simulations for Hungary for temperature shows seasonal warming expected between 0.1-0.7 °C, while the spatial average of annual warming is likely to be around +0.3°C. As for the precipitation, in general both the frequency and the amount of precipitation are expected to decrease (by 0-8%).

2.3.2.6 BOKU

A method for a post-processing model bias correction was investigated using daily data obtained from the regional climate model RegCM3 driven by reanalysis data. The evaluation of the performance was done by comparing the original model data and the corrected model data with observational data. The model data used here are from the high-resolution climate simulation run by RegCM3 with grid spacing of 10 km for the time period 1961-2000 covering the central and eastern part of Europe. The correction method is based on using the differences of the empirical cumulative density functions of model and observation and it is applied to the model data so that the statistics of the observations are retained. The method uses correction factors that correct the model data depending on the CDF values. The correction factors are defined either as an additive correction, which was used e.g. for the temperature data or as a multiplicative correction which was used e.g. for precipitation. The correction factors are calculated on a monthly basis.

A split sample test was applied to evaluate the method. The data of the period 1961-1985 was used to calculate the correction factors and these were used then to correct the data of 1986-2000. This corrected data was then verified against the observations of this period (see Fig. 51 for an example of the validation results). The method is simple to implement and it shows very good improvement of the model data for the main statistical parameters for temperature (maximum, minimum, mean), relative humidity and precipitation although the mean absolute error is reduced only very little, because the temporal correlation is not improved. Statistical indices related to the CDF like mean and variance are improved. The correction method for temperatures and relative humidity performs very well and can be used for model output correction without any limitation. For precipitation a number of problems occur because the distribution of precipitation is not improved in all aspects of precipitation statistics.

To compare the skills of the bias correction, a whole set of standard statistical parameters are calculated. The indices are calculated for every single grid point and than averaged over the whole area. For precipitation a clear improvement for all quintile depending indices like mean, intensity etc, can be seen. All indices are close to 1 which indicates a good fit with observations. Only for the very extreme values like the 3 maximum daily precipitation sums no improvement can be seen. For temperature maximum for all indices an improvement is observed. For the average values and not percentiles up to 80 the bias nearly vanishes. At the 95 percentile the bias is improved but still reaches more than 1.5 K and only a small effect is seen at the mean absolute error. This can be explained by no improvement of the temporal correlation. For temperature, maximum biases of the model are nearly normal distributed but shifted to the left, which indicates a cold bias. After bias correction the biases are symmetric around zero and nearly 50 % of the biases are within ± 1 K and more than 80 % fall within ± 2 K. A similar improvement occurs for precipitation. Here the model precipitation biases are shifted to the right side, which indicates an overestimation of precipitation. After bias correction, more the 45 % of the biases are within ± 0.5 mm per day. The spatial distribution of the precipitation bias indicates that precipitation is overestimated by 50 % within the whole area. After bias correction, the area average bias is reduced to 3 %. But it can be seen that at individual grid points, relative biases of ±25% still occur.

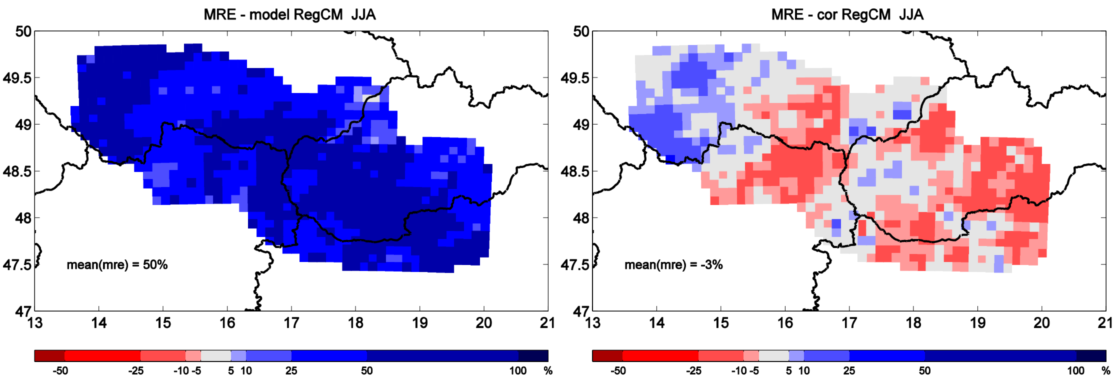

Figure 51. *Spatial distribution of mean relative errors of the monthly means for the model (left) and the corrected model (right) for precipitation (simulation by the RegCM model, run at CUNI and postprocessed at BOKU).*

For application of this method to the climate change scenarios the regional climate control run 1961 till 2000 forced with GCM has been calibrated with observations and has been applied to the two scenario periods. Bias corrected data are available for the CECILIA Central Europe region on daily time step for minimum temperature, maximum temperature, relative humidity, and precipitation.

2.3.3 Deviations from the project workprogramme

There was a slight delay in delivering D3.3 (validation). The delay has two causes: first, a delay in delivery of D3.1 (datasets), which was due to the impossibility to distribute raw data, and a consequent necessity to conduct additional calculations in order to create technical series. Second, the production and making avilable of RCM outputs was also slightly delayed, which did not leave enough time for their evaluation. The problems was fixed within the project extension and the deliverable was delivered in accordance with the changed schedule, i.e., by month 28.

The postponement of D3.3 had a consequence in the necessity to postpone D3.4 and D3.5 (construction of scenarios for 2021-2050, 2071-2100) since the construction of scenarios is partly dependent on the validation of downscaling methods. Moreover, some high resolution RCM simulations were delayed as well. However, the most of work on D3.4 and D3.5 was completed follwing the extended deadlines.

2.4 WP 4

2.4.1 Workpackage objectives

The main objectives of WP4 are following the DoW as follows:

- Analyses from observational datasets of various measures of extreme weather events and related processes for present-day climate in Central and Eastern Europe, using both regional as well as local datasets in participating countries as covered by the WP2 10 km simulation.
- Determination of suitable percentiles of precipitation and temperature, as well as extremes indices (based on WMO, STARDEX) for the validation of the present-day experiments and assessment of climate-change simulations.
- Validation of present-day climate simulations with regard to extremes based on global and regional climate simulations at scales of 50 km down to 10 km. Assessment of the added value of 10 km simulations in focus regions (Czech Republic, Carpathian basin, Romania, and Bulgaria).
- Estimates of the effects of climate change on extreme weather events based on pre-existing GCM and RCM output as well as 10 km WP2 simulations; in particular analyses of changes in droughts and heatwaves, as well as in heavy-precipitation intensity distributions, with detailed analyses in focus regions.
- Process analyses of important feedbacks using sensitivity experiments; assessment of impact of model resolution and domain size on the analyzed processes.

After the analysis of the observed data in terms of extremes and further long list of other impact characteristics and indices as well as the same in the outputs of driving models and previous results of other projects during the first reporting periods of the project. In the last period the main objective of workpackage WP4 was planned to complete the analysis of the impact of climate change on the occurrence of extreme weather events in Central and Eastern Europe based on high resolution simulations provided by CECILIA project itself (D4.4), especially in the future time slices simulations. Process analyses of important feedbacks (*e.g.,* land-atmosphere coupling) was planned within D4.5 in the last reporting period. The impact of model resolution and domain size on the analyzed processes was supposed to be investigated.

2.4.2 Progress towards objectives

The main goal of the WP4 connected to D4.4 was extensive analysis of the outputs from the 10-km high-resolution simulations in various Central and Eastern European domains by the partners. It was performed for Czech Republic by CHMI, IAP, and CUNI, Carpathian basin by ELU and OMSZ, Romanian domain by NMA and for Bulgaria by NIMH. The results of these extensive analyses are documented in D4.4 and are thus not repeated here.

Moreover, ETH and DMI provided a synthesis analysis for the whole CECILIA region, including an intercomparison with pre-existing RCM data sets. Fig. 52 displays as an example Taylor plots (Taylor 2001) showing the spatial standard deviations σ (normalized by the standard deviation of the reference observations) and the spatial correlation coefficients r of the PRUDENCE, the ENSEMBLES and the CECILIA driving (CNRM, ICTP) and high-resolution (CUNI, ELU, NMA, OMSZ) simulations, compared against the local station observations (reference).

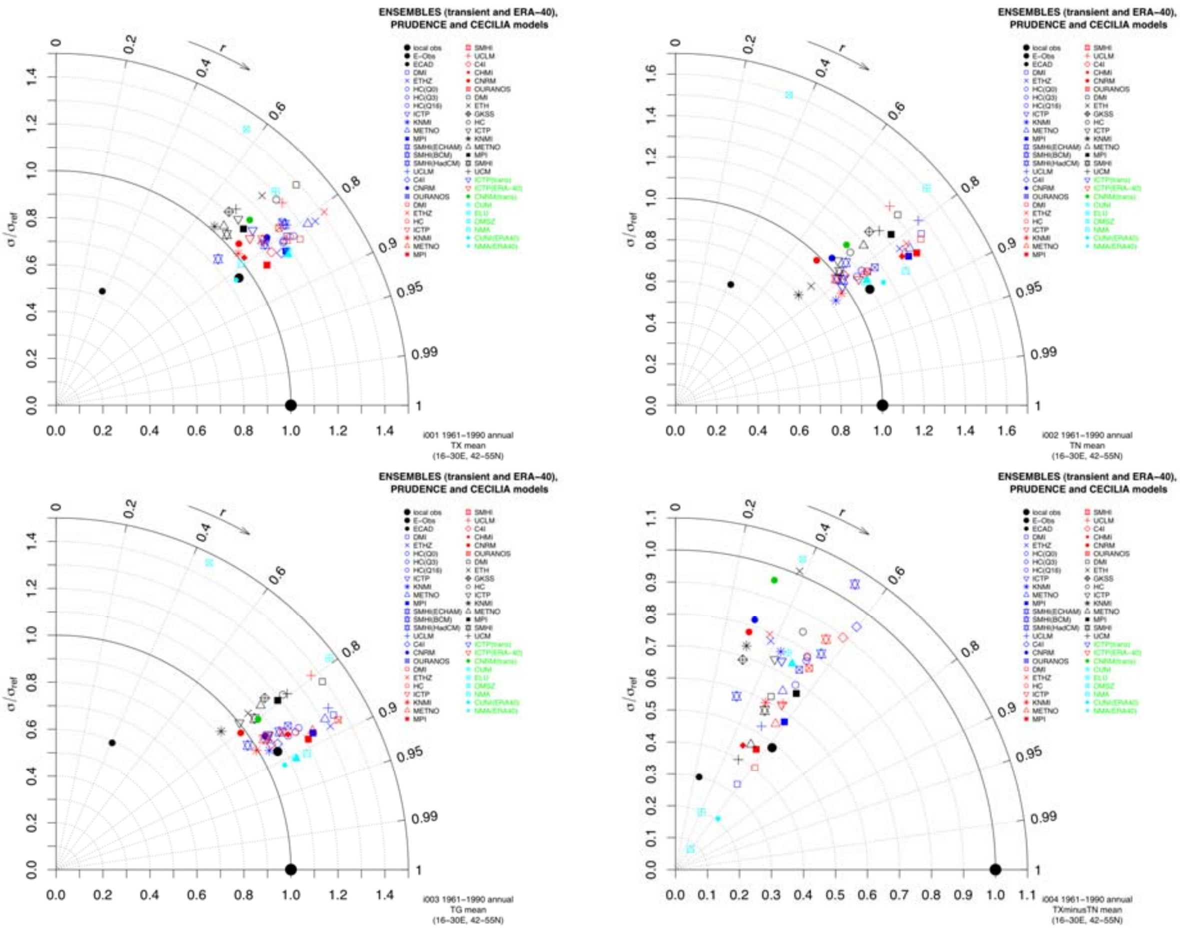

Figure 52. *Taylor plots including the ENSEMBLES transient (blue symbols) and ERA-40 (red symbols) simulations, the PRUDENCE RCMs (black symbols), as well as the CECILIA driving and high-resolution runs (green model acronyms, cyan symbols for the high-resolution runs) compared against the local observations. For comparison, also the ECA&D and the E-Obs observations are included (also relative to the local observations). As mentioned in the text, the CECILIA driving runs from ICTP coincide with the respective ENSEMBLES runs with the same model and consequently share the same symbols and colors. (Top left) maximum temperature, (top right) minimum temperature, (bottom left) mean temperature, (bottom right) daily temperature range. Displayed are annual values for the period 1961–1990 and for the East European domain (16°E–30°E, 44°N–55°N).* σ *denotes the spatial standard deviations (normalized by the standard deviation of the observations) and r the correlation coefficients.*

For comparison, also the ECA&D and the E-Obs observations are included in the plots (also relative to the local observations). The statistics are derived from the annual indices values of the period 1961–1990 and for the East European domain (16°E–30°E, 42°N–55°N). Note that the CECILIA runs from ICTP coincide with the respective ENSEMBLES runs with the same model (thus sharing the same symbol and color). Moreover, note that the CECILIA high-resolution runs do not cover the whole region and thus might not be fully representative for the analyzed domain.

Overall, the spatial agreement between the models and the local station observations is good for mean, maximum and minimum temperature (Fig. 52, top and bottom left panels). This is the case both in terms of the spatial variability, which is however often overestimated in the models; and in terms of the spatial correlation with the local observations, which varies mostly between 0.6 and 0.9 for these indices. The spread between the models becomes larger for the daily temperature range (bottom right), with most models showing lower spatial variability compared to the local observations. Moreover, the spatial correlation between the local observations and the models decreases to below 0.6. Note the underestimation of the spatial variability in ECA&D in all cases, which is likely due to its limited spatial resolution.Another important task of WP4 covered by D4.5 was to assess the impact of climate change on different processes and feedbacks in climate system in high resolution. The purpose of these sensitivity experiments was to isolate specifically the role of land–atmosphere coupling in projected changes in inter-annual climate variability during the extra-tropical summer season following the work of Seneviratne et al. (2006) and Koster et al. (2004). Changes in climate variability are a very important factor for life and society, often more than changes in mean climate, in particular related to changes in extreme events. For this purpose, ETH, ICTP and NMA conducted RCM experiments with coupled and uncoupled land-surface and atmospheric model parts. In the latter case, the evolution of soil moisture in the model is prescribed and the two-way coupling of the atmosphere and soil moisture is removed. This allows the investigation of the one-way effect of soil moisture on the atmosphere.

Fig. 53 displays the temperature variability for JJA for three time slices and coupled (left column) and uncoupled simulations (right column) with the RegCM3 model (ICTP). In the coupled simulation, an increase in temperature variability is evident when the near (2021-2050) and far (2071-2100) future is compared with the present-day period. The same comparison for the uncoupled simulation shows that the increase in temperature variability is much less or almost zero in some areas for both the near and far future.

Further experiments conducted by ETH also highlighted the role of land-atmosphere coupling for temperature variability. Moreover, temperature extremes, as investigated by climate extreme indices and PDFs (Fig. 54), are strongly affected by the absolute value and to a smaller extent also by changes in the temporal variability of soil moisture. This is mainly due to intra-seasonal as well as inter-annual soil moisture variability.

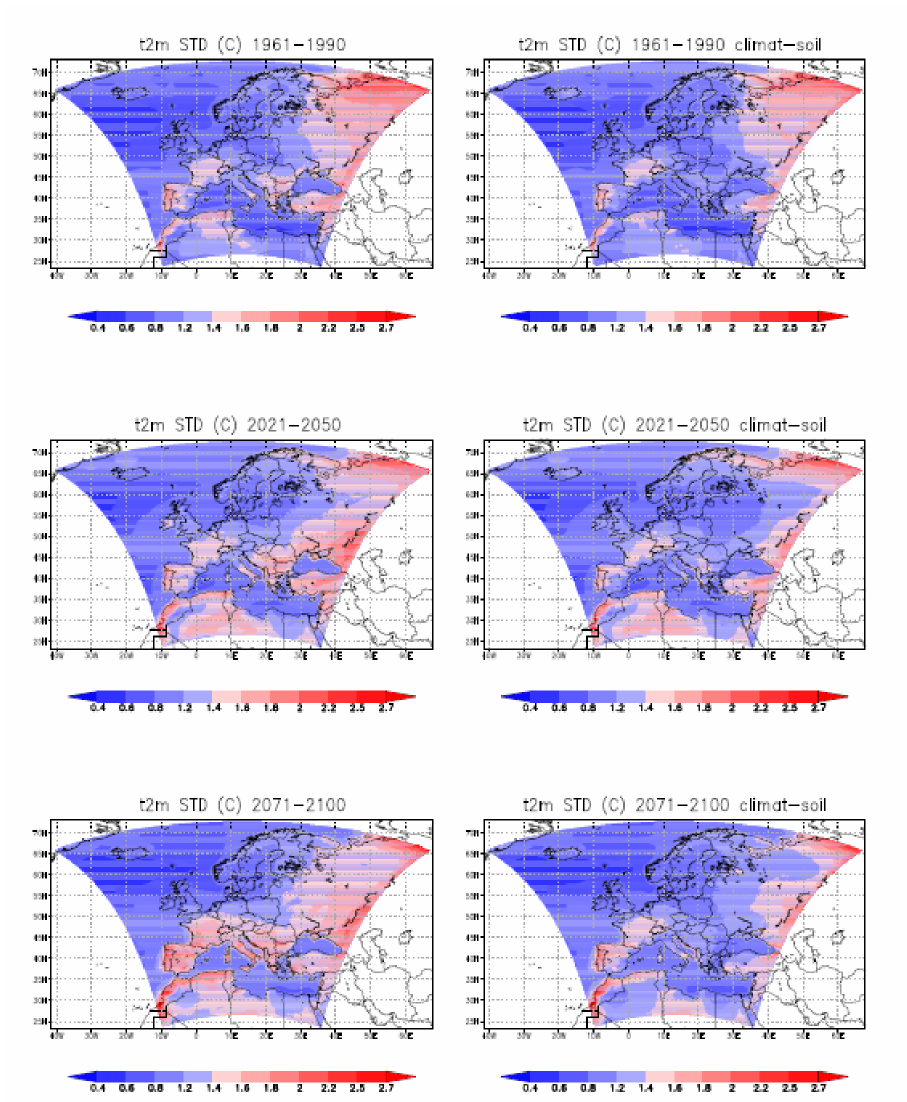

Figure 53. *Standard deviation of summer (June–August) temperature in coupled (left column), uncoupled (right column), present day (top row), near future (middle row) and far future (bottom row).*

In addition to these experiments, CUNI was investigating parameterization setups to further reduce precipitation bias. The first experiment of the set was based on adjusting the internal parameters *rh0land* and *rh0oce* in RegCM „beta“ version, the second one described in this report using a modified function of fractional cloud coverage (s-shaped function) in RegCM „alpha“ version. Comparing the two experiments, it was shown that the simple modification of fractional cloud coverage parameters does not have the expected effect on precipitation. Both modifications end up affecting more the convection than large-scale precipitation. To get the intended bias reduction, more tuning needs to be done.

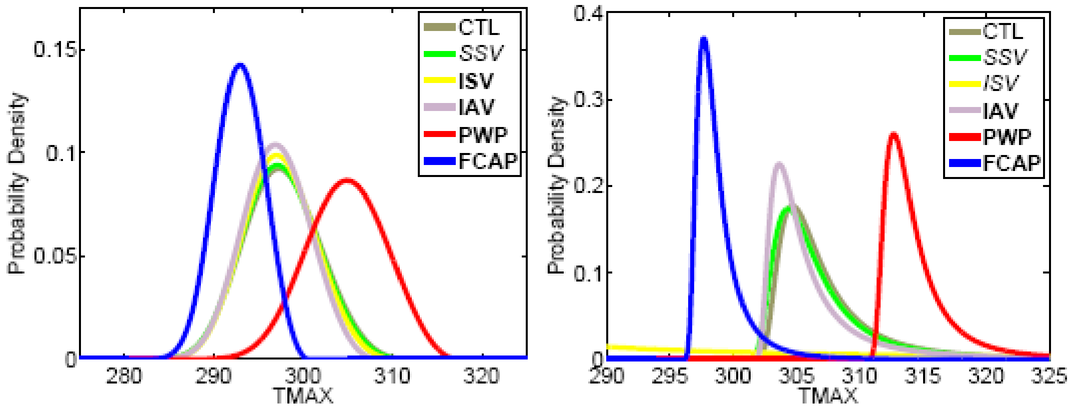

Figure 54. *PDFs of daily Tmax [K] (left) and of summer Tmax block maximas [K] (right) using a GEV fit in both cases. The PDFs are based on the mean Eastern European subdomain values and the summer period 1959-2006. The numerical experiments correspond to a control simulation (CTL), and sensitivity experiments investigating the impact of prescribed soil moisture with the CLM RCM (SSV: removed synoptic-scale soil moisture variability, ISV: removed intra-seasonal soil moisture variability, IAV: removed interannual soil moisture variability, PWP: soil moisture set to plant wilting point (dry), FCAP: soil moisture set to field capacity (wet)). Simulations with bold legend entries are significantly different from CTL at the 5% level according to the two-sided Kolmogorov-Smirnov test. (Jaeger and Seneviratne 2010)*

A main activity in WP4 (led by ETH together with DMI and CHMI) consisted in the extreme database that was put together in the course of the project as part of deliverables D4.1-D4.4. Based on the list of climate and extreme weather indices that was defined in deliverable D4.1, ETH, DMI and CHMI worked on the implementation of the final list of 154 indices (131 main indices with 23 variants for some indices) in three software tools (R, Matlab, and ProClimDB, respectively). These tools were used by the WP4 partners to compute the indices from the climate model outputs (PRUDENCE, ENSEMBLES, CECILIA simulations) and from the observational data sets (ECA&D, local observations from the WP4 partners). Moreover, significant effort was invested in order to make the calculation of the indices in the three software tools compatible, and to ensure the consistent computation of the indices from the various data sources. The database is stored at DMI at the following location: http://cecilia.dmi.dk/. It will be made publicly available after the publication of the CECILIA special issue. An article will document the list of considered indices and provide first analyses of the computed data (Seneviratne et al., 2010, in preparation for CECILIA special issue). These indices are the basis for completed and ongoing studies carried out by the WP4 partners. The last deliverable (D4.6) provides an overview of the main results, reports and publications from the CECILIA WP4. In the following, some highlights from different partners are shown. For a complete list of the publications and reports, as well as more scientific results, refer to D4.6.

2.4.2.1 ETH

One study at ETH investigated the impact of soil moisture on temperature extremes (Hirschi et al. 2010, in prep). Using quantile regression (Koenker 2005) and the various observational and modeling data sets from the CECILIA indices database, the relation of hot temperature extremes (as expressed by the indices i001 - Tmax, i061 - TX90p, and i053 - HWDI90 from the data base) with soil moisture deficit (as expressed by the standardized precipitation index, SPI, McKee et al. 1993) in Central and Eastern Europe was investigated. In a Southeast domain (encompassing Bulgaria and Romania) with a soil moisture-limited evapotranspiration regime, the analysis reveals that such a relation is in particular present when looking at the upper quantiles of the temperature extreme indices (i.e., the stronger extremes, see Fig. 55, right panel). Such a quantile dependency of the relation is not apparent in the more energy-controlled regime of the Northwest domain (not shown).

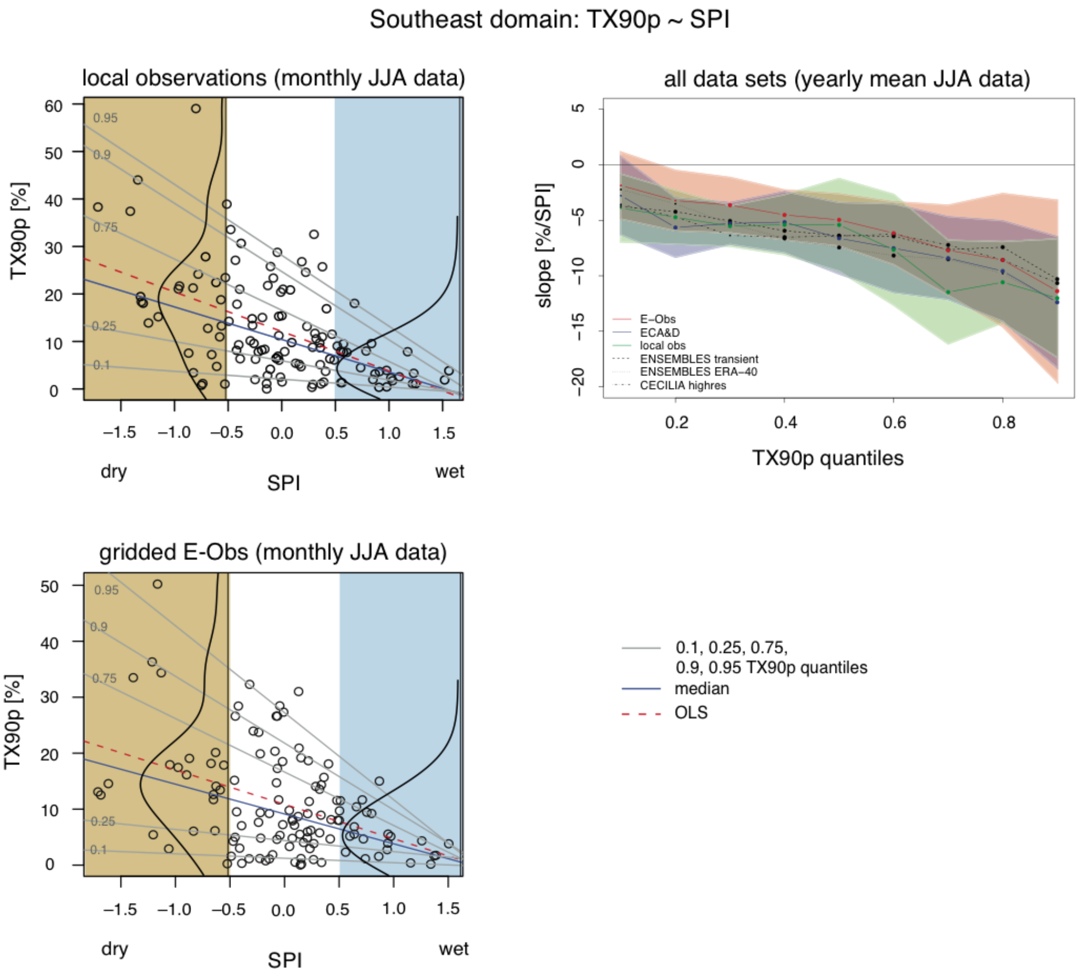

Figure 55. *(Left panels) Scatter plots of monthly JJA TX90p vs. SPI from the local observations (top) and from the gridded E-Obs (bottom), average values for the Southeast domain and the period 1961-2000. Also shown are estimated PDFs for wet and dry conditions respectively, as well as the regression lines for the ordinary least squares regression (OLS) and for a selection of distinct quantiles (i.e., median, 0.1, 0.25, 0.75, 0.9, 0.95). (Right) Quantile regression slopes of the 0.1-0.9 quantiles of mean yearly JJA TX90p in relation to SPI for the three analysed observational data sets and for the regional climate models. Significant slopes on the 5% significance level (two-tailed test) are denoted with a bold dot. In case of the models, the ensemble median slopes are shown, and dots are displayed as significant when at least 75% of the respective models are significant. Moreover, +/- one standard errors are displayed as shadings for the observational datasets.*

2.4.2.2 DMI

DMI is currently preparing a publication for the CECILIA special issue, which focuses on the added value of the high-resolution simulations (Christensen et al. 2010, in prep.). The high-resolution simulation seems to have problems with the overall precipitation amounts, which are too high. Conversely, the percentile ratios are smaller than for the driving simulation in spite of the expectation of higher extremes with higher model resolution. This indicates that the high-resolution spectrum is not just a scaled version of the lower-resolution spectrum, but rather that the spectrum has somehow been shifted towards higher values. Further analyses should clarify this deviation.

2.4.2.3 CHMI

CHMI focused both on methodological aspect of extreme indices processing and carrying out calculations for the area of the Czech Republic. Many of the tasks were done in cooperation with IAP. For the indices calculation and the area of the Czech Republic itself, technical series of 268 climatological stations were available. The 268 station positions with technical series were also recalculated (interpolated) into the ALADIN-Climate/CZ grid of 10 km horizontal resolution. Correction of ALADIN-Climate/CZ outputs (RCM driven by GCM ARPEGE with the IPCC A1B emission scenario) has been carried out for the area of the whole Czech and Slovak Republics, for both time slices, near (2021-2050) and far future (2071-2100) (details about methodology can be found in Deliverable D3.1). Results of indices calculation were then compared using original (biased) and corrected RCM outputs (done in cooperation with IAP). In the same way, also correction and comparison for RegCM has been processed.

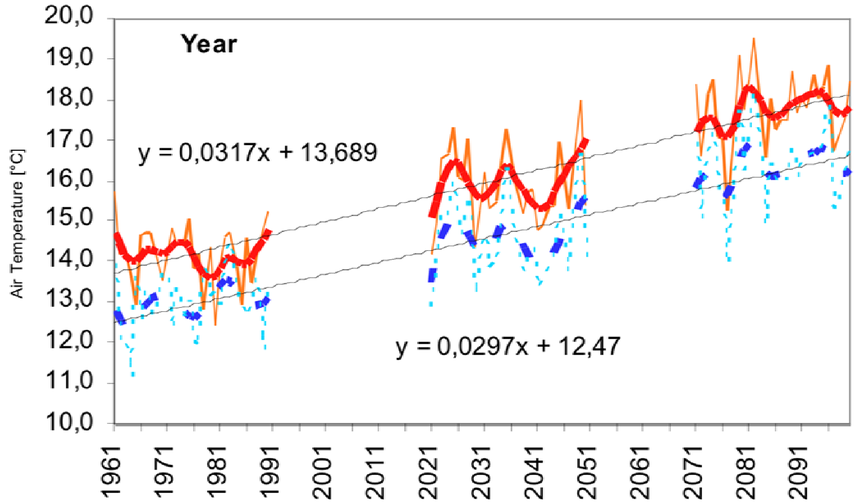

Figure 56. *Corrected and uncorrected maximum temperature [°C] for Czech and Slovak lowland regions in the periods 1961-2100 (solid red line – corrected model outputs; dashed blue line uncorrected outputs).*

2.4.2.4 ELU

Simulated winter and summer daily maximum temperature are projected to increase by both future time slices relative to the reference period (1961-1990). In Hungary the projected changes are about 1 °C by the middle of the 21st century, and about 3 °C in winter and 4 °C in summer by the end of the 21st century. The projected winter warming is larger than the summer warming for the 2021-2050 period, while for the 2071-2100 it is smaller. The summer warming patterns in Hungary follow a zonal structure, the largest temperature increase is expected in the southern regions.

Summer days (when T_{max} is larger than 25 °C) may occur mainly in May-September in Hungary. In the reference period 6-20% of the total days are simulated as summer days, which means about 22-73 days in a year. Evidently, in the mountainous subregions (e.g., the Eastern Alps or the Carpathians), less summer days occur than in the lowlands of Hungary. By the near future (2021-2050) it is not likely to change too much in Hungary (the increase is only about 1-3%, which is not exceeding a week). However, by the end of the century (2071-2100) the annual percentage of summer days is likely to increase by about 7-14% in Hungary (left panel of Fig. 57). This implies that the annual number of summer days is projected to exceed 110 days in a year in the southern part of the country, and may even reach as much as 120 days per year.

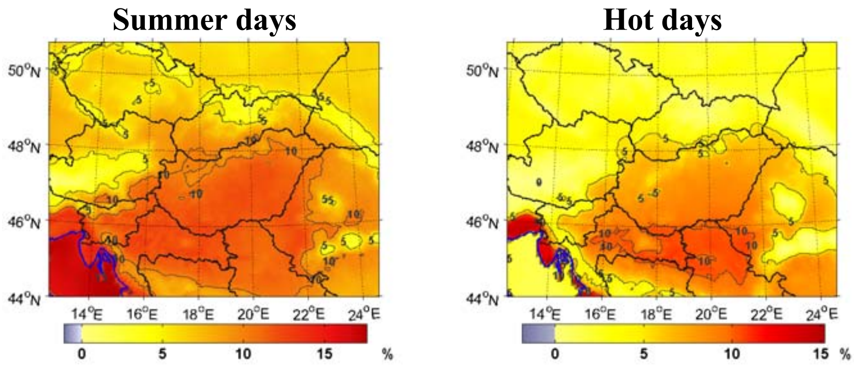

Figure 57. *Projected mean change of annual percentage of summer and hot days by 2071-2100 (reference period: 1961-1990)*

2.4.2.5 IAP

IAP conducted analyses of extreme indices for the Czech republic in collaboration with CHMI. Observations as well as most climate model simulations are generally in accord with the hypothesis that the hydrologic cycle should intensify and become highly volatile with the greenhouse gas induced climate change, although uncertainties of these projections as well as the spatial and seasonal variability of the changes are much larger than for temperature extremes. In this study (Kyselý and Beranová, 2009), we examine scenarios of changes in extreme precipitation events in 24 future climate runs of 10 regional climate models, focusing on a specific area of the Czech Republic (central Europe) where complex orography and an interaction of other factors governing the occurrence of heavy precipitation events result in patterns that cannot be captured by global models. The peaks-over-threshold analysis with increasing threshold censoring is applied to estimate multi-year return levels of daily rainfall amounts. Uncertainties in scenarios of changes for the late 21st century related to the inter-model and within-ensemble variability and the use of the SRES-A2 and SRES-B2 greenhouse gas emission scenarios are evaluated. The results show that heavy precipitation events are likely to increase in severity in winter and (with less agreement among models) also in summer. The inter-model and intra-model variability and related uncertainties in the pattern and magnitude of the change is large, but the scenarios tend to agree with precipitation trends recently observed in the area, which may strengthen their credibility. In most scenario runs, the projected change in extreme precipitation in summer is of the opposite sign than a change in mean seasonal totals, the latter pointing towards generally drier conditions in summer. A combination of enhanced heavy precipitation amounts and reduced water infiltration capabilities of a dry soil may severely increase peak river discharges and flood-related risks in this region.

2.4.2.6 OMSZ

The daily temperature and precipitation indices resulting from Aladin-Climate simulations (AA) for two time slices: 2021-2050 and 2071-2100 versus control run forced by ERA40 (AE) were analysed for Hungary. The rate of “hot days” (Fig. 58) increasing is expected more than 10% in the period 2021-2050 on the Great Plain and it is more than 20% almost on the whole territory, excluding the mountainous area, in the period 2071-2100.

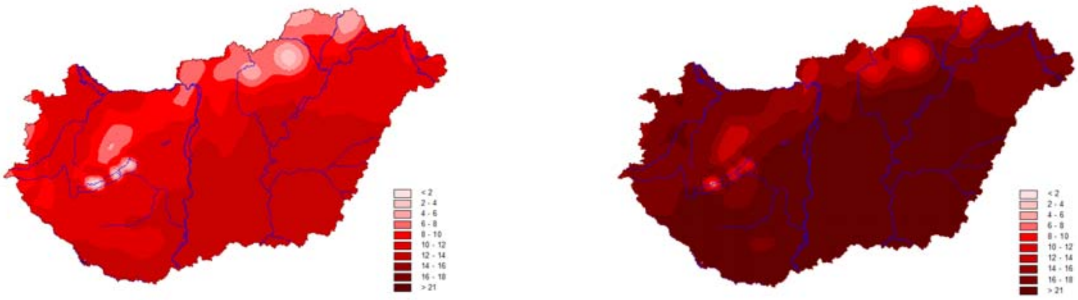

__Figure 58.__ CECILIA index 066 percentage of days with Tmax ≥ 30°C AA(2021-2050)-AE(1961-1990) and AA(2071-2100)-AE(1961-1990).

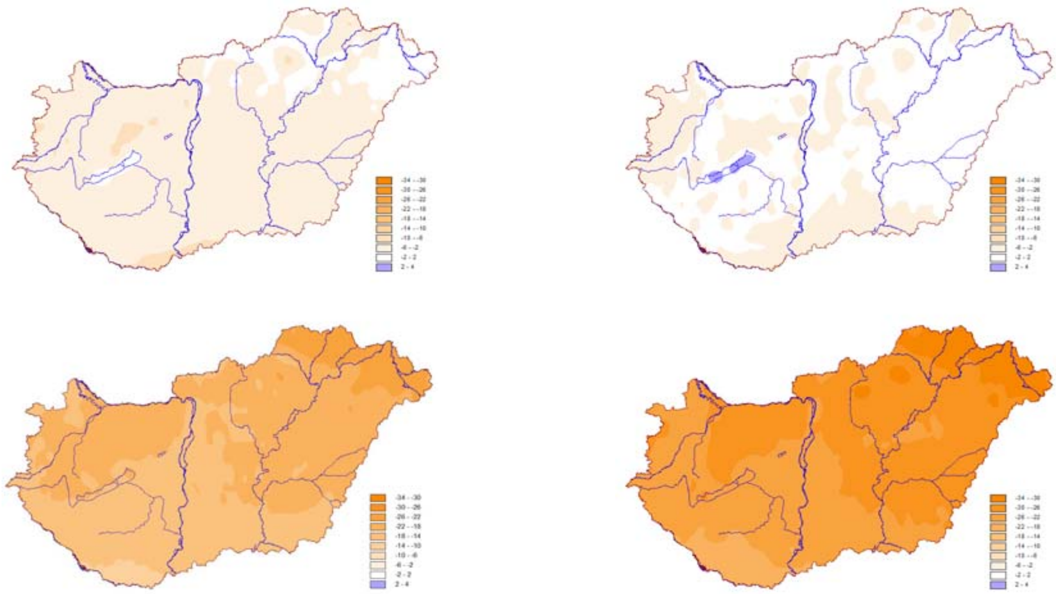

__Figure 59.__ CECILIA index 078 percentage of wet days AA(2021-2050)-AE(1961-1990) and AA(2071-2100)-AE(1961-1990) for DJF on the top and for JJA at the bottom.

Regarding the percentage of wet days (number of days where daily sum ≥ 1mm / total number of days) index (Fig. 59); there is an obvious decreasing in summer in projections versus the control run, especially in the 2071-2100 period. The order of negative change in the far future, in summer is larger, around -25% on the extended part of the country. The negative change in winter is approximately -15%, the spatial distribution shows a north eastern growth in both projection and season. These changes in the number of wet days pose a major challenge for agriculture in Hungary.

2.4.2.7 NIMH

On the background of ALADIN-Climate simulations of NIMH for Bulgarian region (for annual average climate change signal see Fig. 60) the analysis of CECILIA indices was performed. Obviously, winters will be milder at the end of this century reaching up to 10°C and even more in some areas of Bulgaria. Recent summers will gradually disappear as it will be more hot with average maximum air temperatures often above 30°C in most lowland areas in the country. Ice days will decrease, higher minimum temperature will affect the period of vernalisation in winter and crop growth in summer. It is clear that by increasing maximum and minimum air temperatures will caused respective increase of mean air temperature both in winter and summer.

The number of summer days increases up to 90 days in the period 2021-2050, see Fig. 61. Percentage of summer days is projected to rise from 18-20 % nowadays to more than 40 % in most flat locations in south Bulgaria. The hot days would increase as well , up to 30 % till the end of the 21st century.

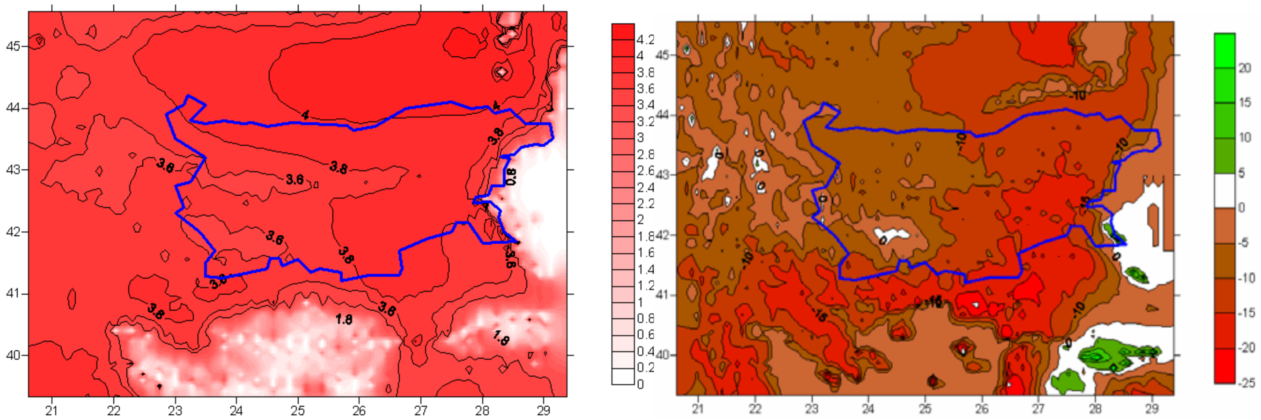

Figure 60. *ALADIN Climate change scenarios in Bulgaria for the end of the 21st century, relative to 1961-1990, annual temperature changes (°C, left), annual precipitation changes (%, right)*

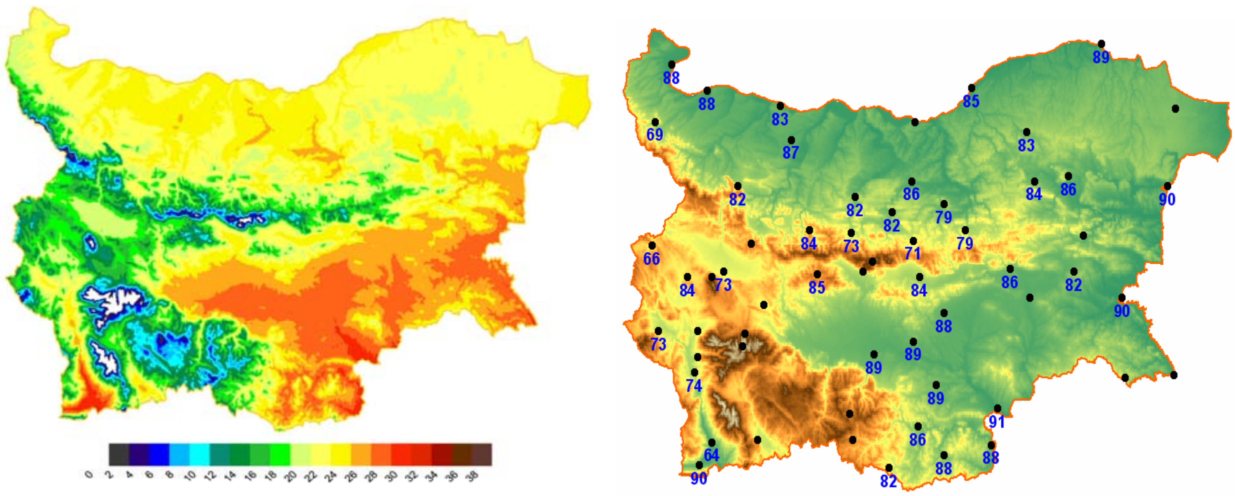

Figure 61. *Summer days (Tmax>25°C) , 1961-1990 (left). 2021-2050 (right)*

2.4.2.8 ICTP

ICTP was responsible for deliverable D4.5. Please refer to the respective report for an overview of its WP4-related research highlights.

2.4.2.9 AUTH

Large-scale circulation patterns, such as the ones connected to the North Atlantic Oscillation (NAO) or northern hemisphere atmospheric blocking, are known to control westerly flow of air into the European continent, thus affecting local weather and climate. Their effects on temperature and precipitation changes were investigated in detail over Europe using data from General Circulation Models (GCMs) and Regional Climate Models (RCMs) used as driving models in the framework of the project.

The analysis of both sets of data (GCM and RCM) for present period (control 1960-2000) shows a good agreement to the observed NAO effects over Europe, i.e. warm and wet over North-Eastern Europe and dry over the Mediterranean when NAO is in the positive phase (positive NAO Index, top rows in both cases). The magnitude of these effects is found larger during the negative phase, the changes in temperature being the largest over Scandinavia and the Baltic Sea. Central Europe, the target area in CECILIA, does not present large significant anomalies. The analysis also reveals a good agreement between models.

As for future changes comparison of three sub periods (1950 -2000, 2001-2050 and 2051-2100) reveals that the above described changes of the same sign and location are found in the future, becoming larger in the course of the 21st century and largest in the last 50-years. The effects were found in average daily mean temperature and in daily maximum and minimum temperatures as well. The effects in daily minimum temperatures are found to cover greater areas. In the case of precipitation, Mediterranean (and its northern surrounding area) is found to become drier for positive changes of NAO Index, while central and northern Europe experience more wet weather.

Concerning the blocking activity, the duration of the blockings did not appear to be as long in the RCMs as in the reanalysis data (ERA40), this being a known feature of the blocking activity simulation in General Circulation Models (GCMs) as well. Our analysis shows significantly lower temperatures and precipitation over central Europe during blockings, while Scandinavia and the Baltic Sea is warmer and drier.

2.4.3 References

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2.4.4 Deviations from workprogramme

The redefinitions of indices and the time-consuming software crosschecking led to some delay in the work programme of WP4 at the beginning of the last reporting period, which affected the finalization of D4.2 and D4.3, but with respect to the extension it did not imply any problem for further work. Further delay with processing the high resolution outputs of the CECILIA simulations came from delays of the completion of these simulations.

2.5 WP 5

2.5.1 Workpackage objectives

The main objectives of the WP5, defined in DoW, are following:

- Analysis based on high resolution CECILIA RegCM outputs of the climate change impact on hydrological resources in the Central and Eastern Europe;
- Analysis of the climate change impact on the flood events;
- Assessment of the managed water resources, demand and vulnerability and corresponding adaptation measures for present and projected climates;
- Assessment of impacts of the climate change on water quality: changes of nutrient (N, P) concentrations and eutrophication in a reference river network with reservoirs used for drinking water supply and recreation, and;
- Study of the impacts of global change signal on local climate variability of air-sea coupled modes for the Western Black Sea coast.

In order to assess the impact of the climate changes in hydrology and the water management, four reference river basins were chosen: Ialomita–Buzau area (19 040 km^2) from Romania, Dyje river basin (17,800 km^2), which are the tributaries of the Danube river, and Vltava basin (11 500 km^2) from Czech Republic, and Hron river basin (5 465 km^2), from Slovakia. Five participants are involved in WP5: NIHWM and NAM from Romania, IAP and CHMI from Czech Republic, and FRI from Slovakia. In the final reporting period the impact studies based on high resolution CECILIA simulations belong to the main objectives.

Another task of this WP is to test the atmosphere-river network-reservoir modelling system for the simulations of hydrology and water quality. For the assessment of the vulnerability of water resources in changed climate conditions, over the Romanian study area the present and future water demand ware estimated and the adaptation measures are proposed in this last report.

The impact of climate change on interconnection between hydrological conditions and Black Sea is another task in this reporting period as well.

2.5.2 Progress towards objectives

In order to evaluate the climate change impacts on hydrology, four deliverables were planned for the last project year. It was D5.7 Simulations of the sensitivity of reference basins using the balance between the demand and water resources and flood events under the present and future conditions with or without climate change, D5.8 Scenario studies for the assessing responses of the physical and hydrobiological characteristics in the river network and reservoirs to anticipated climate, land use and nutrient source changes in the catchments, D5.9 Adaptation measures proposed in the reference basins due to the climate change impact, and D5.10 Local air-sea interaction changes on the Western Black Sea coast under different climate conditions, relevance to regional sustainable development.

Moreover, in this period all the partners of WP5 NIHWM, CHMI, NMA, IAP and FRI continued the simulations of monthly river flow in climate change conditions for update of D5.4 based this time on new input data from completed simulations of ALADIN and RegCM3 models at 10 km spatial resolution obtained in WP2; both of these climate models using the A1B scenario for the development of emissions of greenhouse gases and aerosols.

The potential impact of climate change on river runoff in the Hron river basin with the outlet in Banska Bystrica (area of 1766 km2) was evaluated by FRI based on outputs of the ALADIN-Climate model, the possible changes in the mean monthly runoff for the time horizons of 2021-2050 and 2071-2100 were estimated. Changes in monthly precipitation totals, mean monthly air temperature and relative air humidity were considered for each month as differences between the long-term mean monthly outputs from the ALADIN-Climate model run (uncorrected outputs) in the reference period of 1961-1990 and future time horizons of 2021-2050 and 2071-2100. Percentage changes in the long-term mean monthly precipitation and changes in the long-term mean monthly air temperature for the future time horizons in comparison with the reference period of 1961-1990 are presented in Fig. 62. The monthly runoff series were simulated using the hydrological balance model with changed input climate data, and differences in the seasonal runoff distribution in the reference and future time horizons were estimated and compared (Fig. 63).

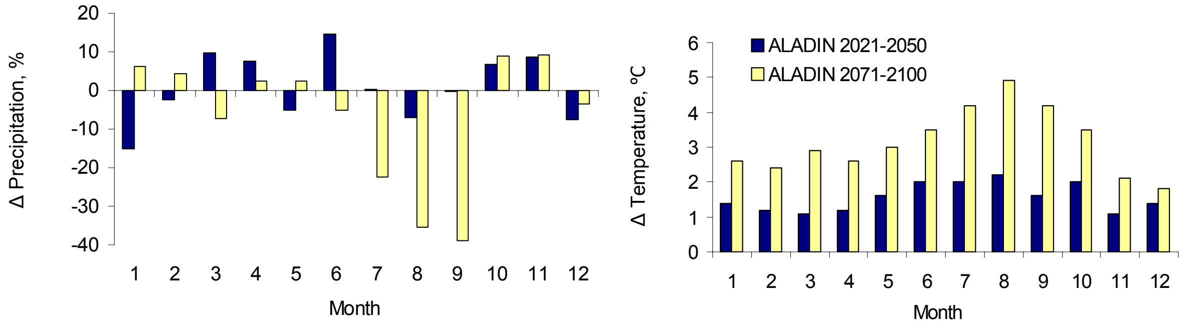

Figure 62. *Hron river basin - Changes of mean monthly precipitation and mean monthly air temperature in time horizons of 2021-2050 and 2071-2100 in comparison with the reference period of 1961-1990.*

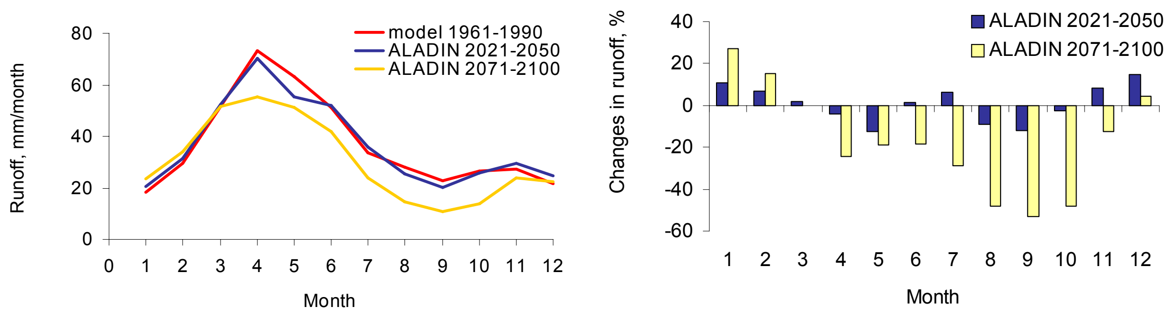

Figure 63*. Hron river basin – Values (in mm/month) and percentage changes of mean monthly runoff for the time horizons of 2021-2050 and 2071-2100 compared to the reference period of 1961-1990.*

Presented results of modelling the long-term mean monthly runoff indicate future changes in the seasonal runoff distribution in the upper Hron river basin. According to the ALADIN-Climate runs, an increase in the long-term mean monthly runoff can be expected from November/December till February/March. The highest relative increase in mean monthly runoff in comparison with the reference period can be expected in January and December, i.e., +10-15%

(+2 mm/month) in 2021-2050 and +27% (+5 mm/month) for January in 2071-2100. This increase could be caused by an increase in air temperature during winter and a shift in the snow melting period from the spring months to the winter period. This can result in certain decline in the long-term mean monthly runoff occuring in April and May, the decrease in monthly runoff could occur in May of 2021-2050 at -12.5% (-8 mm/month) and at about -25% in April of 2071-2100. Main decrease of the runoff appears in August/September/October in 2071-2100 of -53% (-12 mm/month). In 2021-2050 there is a slight increase in runoff in June/July, i.e., +6 % (+2 mm/month). This increase may be due to the increase in precipitation in 2021-2050 in comparison with the period of 1961-1990 (which generally was considered as a dry period). The decrease in runoff in August/September in 2021-2050 and 2071-2100 is mainly caused by the increase in air temperature (+2.2ºC in 2021-2050 and +4.9ºC in 2071-2100).

A similar runoff simulations considering the climate change based on outputs of ALADIN regional climate model computed for 10 km grid was made at CHMI for two catchments of Jihlava river (to the gaugestation Ptáčov with catchment area 963,8 km^2 and Ivančice with catchment area 2682,2 km^2) and two time periods (2021-2050 and 2071-2100). The differences in the mean monthly values of the flow, between the 1971-2000 simulation and the ALADIN‘s scenarios are shown in Fig. 64. Runoff values for time period of 2021-2050 are from January to April and from August to September lower than 1971-2000 simulation, from May to July both values are essentially without any change and from October to December the ALADIN's values are higher than 1971-2000 simulation. For the period of 2071-2100 the ALADIN's runoffs are generally lower than 1971-2000 simulation. All ALADIN's runoff profiles are basically similar in both time periods. Runoff simulations based on outputs of ALADIN regional climate model were then compared to runoff simulations done for scenarios of 3 global climate models (ECHAM3, HadCM3 and NCAR-PCM) made by IAP (Fig. 65).

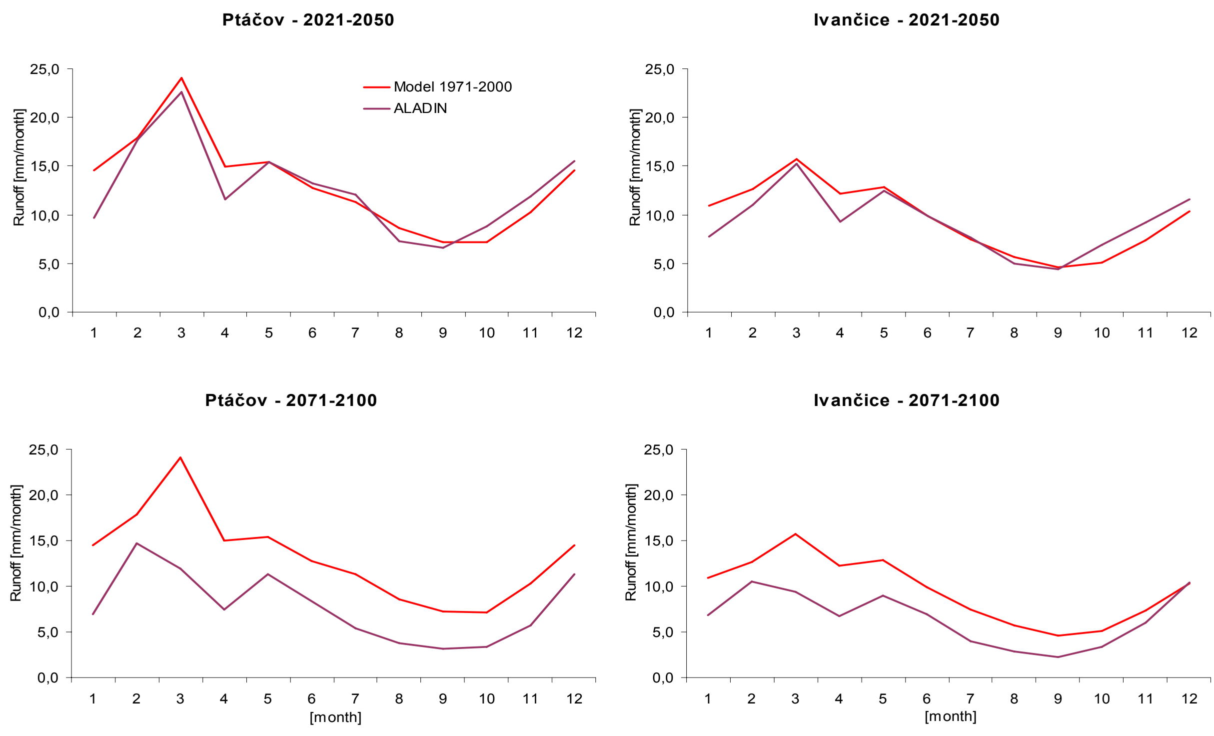

Figure 64. *Comparison of simulated runoff 1971-2000 with ALADIN scenarios for time periods 2021-2050 and 2071 -2100 at Ptáčov and Ivančice.*

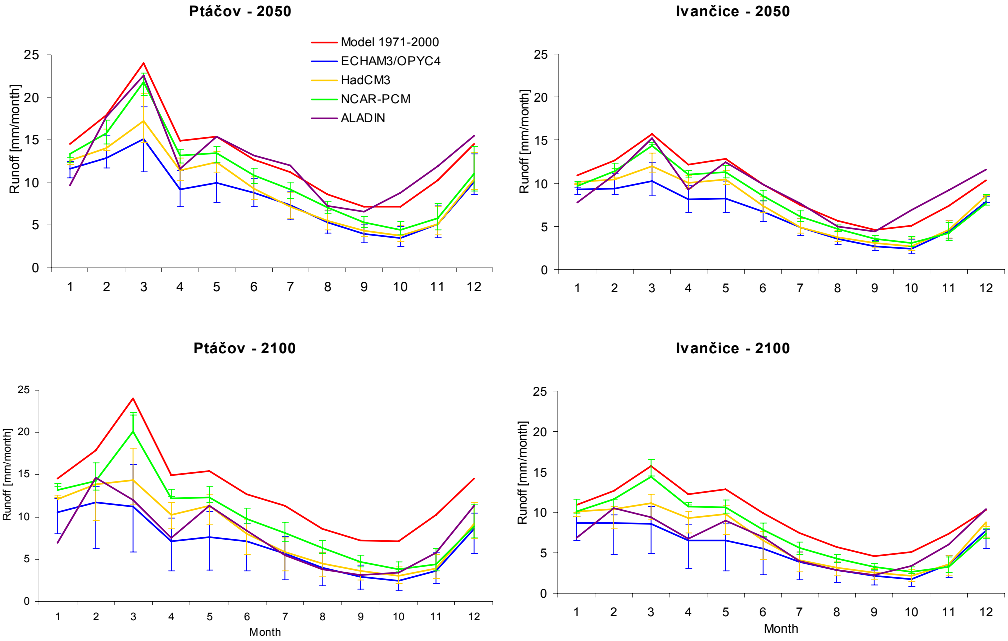

Figure 65. *Comparison of IAP's and ALADIN's runoff simulations for the time periods of 2050 and 2100.*

This comparison shows some differences between runoff simulations based on IAP's and ALADIN's scenarios, which might be caused by different approaches of downscaling – statistical one by IAP and dynamical one applied by ALADIN. Moreover, ALADIN's driving model is other than the three GCMs used by IAP. The differences are significant especially for the period of 2050, when the ALADIN's runoff simulations are higher than IAP's simulations except January and April. For the period of 2100 the IAP's and ALADIN's runoffs correspond better except January (ALADIN's runoffs are lower) and from November to December (ALADIN's runoffs are higher).

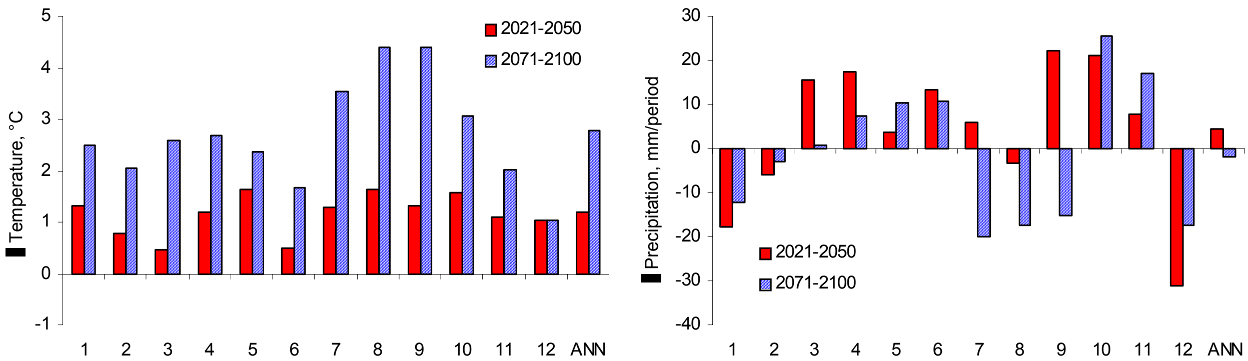

Figure 66. *Changes in temperature and precipitation at the Rimov catchment in the 2021–2050 and 2071–2100 periods referenced to the 1971–2000 period predicted with the ALADIN 10×10 km regional climate model.*

Impacts of high-resolution climate modelling projection by the ALADIN 10×10 km regional model on monthly river flow were also studied at the Vltava River basin (Czech Republic) for the catchment of Rimov. The changes in temperature and precipitation predicted with this model for this catchment (Fig. 66) show consistent trends with the other Central European localities, i.e. Dyje and Hron catchments. The seasonal patterns of runoff and their difference changes are shown in Fig. 67. The climate change impacts on flow conditions varied seasonally and significantly differed for the near and far future periods. For the near future (2021-2050) period, not so significant decrease was obtained for the mean annual runoff value and the runoff decrease was distributed through the year with the winter minimum. For the far future (2071-2050) period, the mean runoff decreased by ca 50% and a serious drop in the summer and autumn runoff values by up to ca 80 % was modelled.

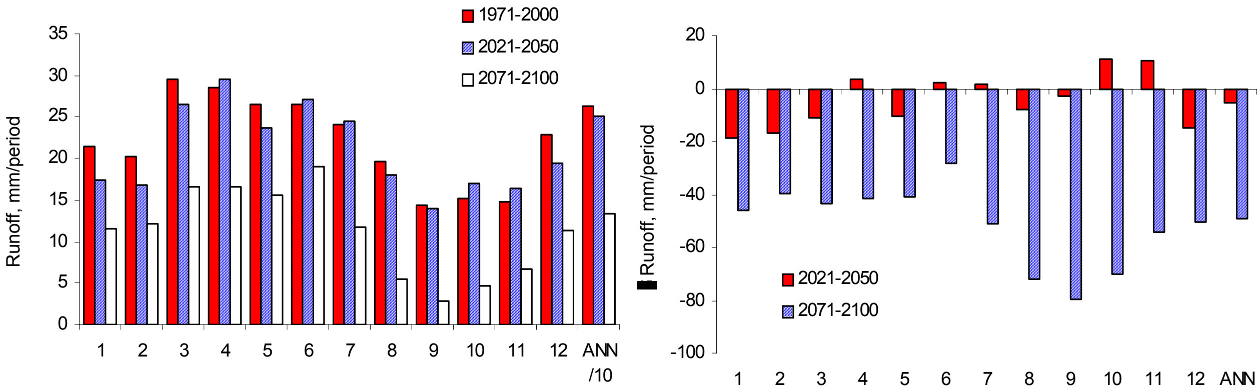

__Figure 67.__ The monthly and annual mean runoff values and their changes simulated at the Rimov catchment according to ALADIN's climatic predictions for the time horizons of 2021-2050 and 2071-2100.

Using as input data the results of regional climate model in 10 km resolution NIHWM made the new hydrological simulations of mean monthly discharge in each analyzed sub-basins of Buzau - Ialomita area. With the modifications of climatic parameters, provided by NAM in grid with the values of each parameter needed in the hydrological model for each of analysed sub-basins, the differences between the parameters for two time horizons 2021-2050 and 2071-2100 and reference period were estimated (see Fig. 68).

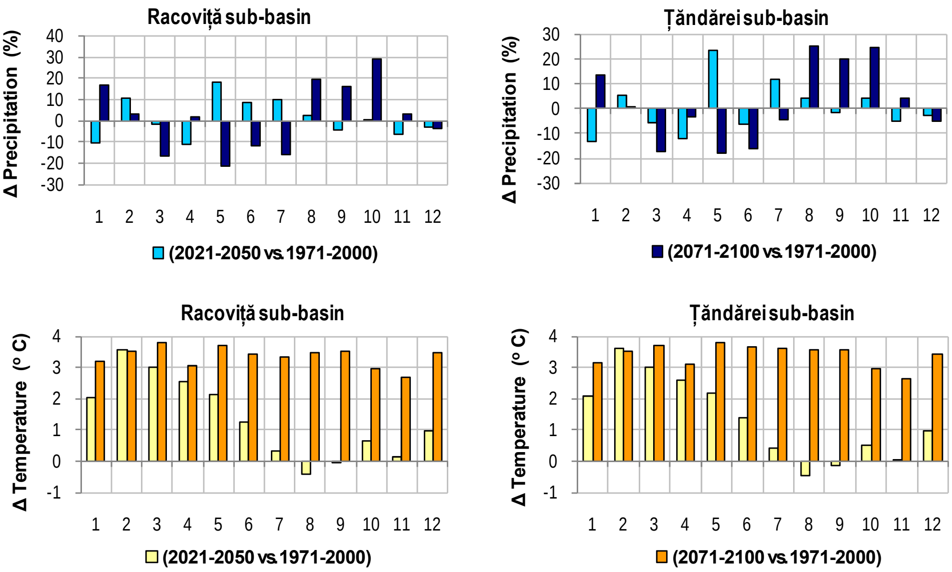

__Figure 68.__ Monthly differences between the values of precipitation and temperature simulated for the future periods 2021-2050 and 2071-2100 in comparison with the reference period 1971-2000.

Using the results of RegCM in 10 km resolution, the mean monthly average discharges for the two future periods were estimated. The results of these last simulations were compared with the results of simulations made using the outputs of RegCM in 25 km. For the hydrometrical stations situated at the outlets of Ialomita and Buzau rivers, Fig. 69 shows the comparison between the mean monthly discharges in actual regime and in changed climate conditions provided from the simulations using RegCM3 in 10 and 25 km resolution. Similar comparison is made also for mean annual discharges (Fig. 70).

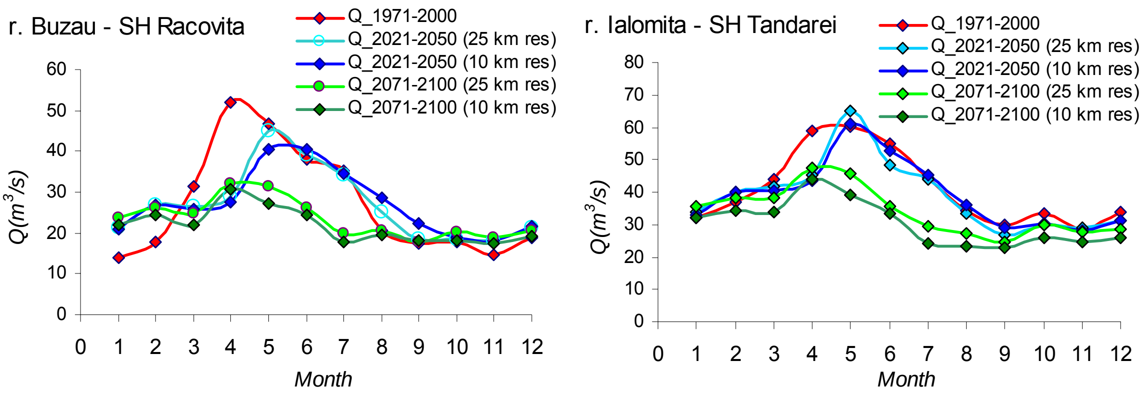

Figure 69. *Comparison of mean monthly discharges modification in climate change conditions from RegCM with 10 and 25 km resolution.*

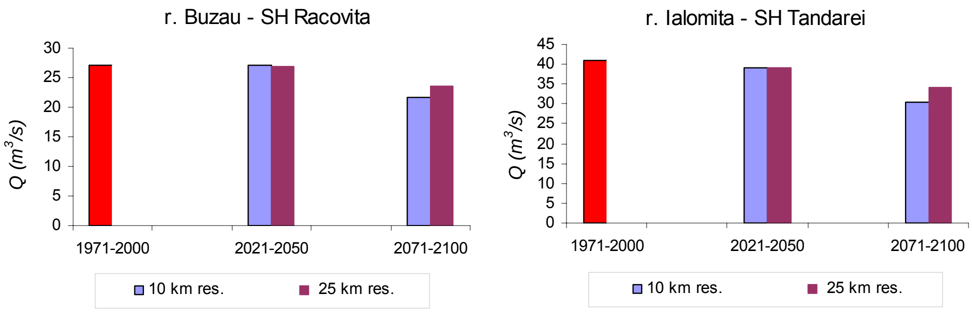

Figure 70. *Comparison of mean annual flow modification in climate change conditions from RegCM with 10 and 25 km spatial resolution.*

The analysis of the hydrological scenarios results shows that in Ialomita-Buzau area, the mean annual flow decreases in future by 15-20% in near future period (2021-2050) and by 30-40% in far future (2070-2100), especially due to the increasing of evapotranspiration. The variation of mean monthly flow presents a reduction from the lowland to the highland, having a uniform trend in parallel with overall decrease.

Generally, it could be concluded that the hydrological modelling based on the regional climate models indicate notable seasonal changes of the flow in all pilot basins for both of the investigated time horizons. During the winter and early spring periods, an increase in the long-term of mean monthly flow could be observed. The period of increase in flow could occur from November/December to February/March. This increase could be caused by the increase in air temperature and a shift of the snow melting period the from spring months to the winter period. These changes were locally specific, apparently in connection with the geographical position and altitude of the catchment. During the months of winter and spring, an increase of flow was modelled at those river profiles where significant parts of catchments are situated in mountainous areas (i.e., Hron and Buzău/Ialomița). A moderately increased flow was simulated in spring, also, in the uppermost catchments of the Vltava basin. At lowland river sections, the decreases of flow occurred in winter and spring in all the basins. In the months of summer and autumn, a significant reduction in river flow was modelled for all climatic models in all basins, apparently due to the increase in evapotranspiration. In addition to the general drop in runoff, the predicted climate change induced also amplification in the seasonal inequality of flow, which might have important implication for the management of water resources.

The impact of climate change in flood occurrence (D5.7) was analyzed by CHMI on the upper part of the Dyje catchment. Its area is 1756 km^2, the closing profile is watergauge station Podhradí. The catchment is proper for testing of future flood occurrence, because there is no significant reservoir (Fig. 71), which could strongly influence the hydrological regime. For the calculation the HYDROG rainfall-runoff model was used (this model is used for operation discharge forecast for Dyje catchment since 2003 in CHMI). The input data for the HYDROG model were precipitation, temperature and snow water equivalent outputs from ALADIN-CE in 6h step. The input data for the HYDROG model were divided into 20 Thiessen polygons – for each polygon the closest ALADIN calculation point was selected (Fig. 71).

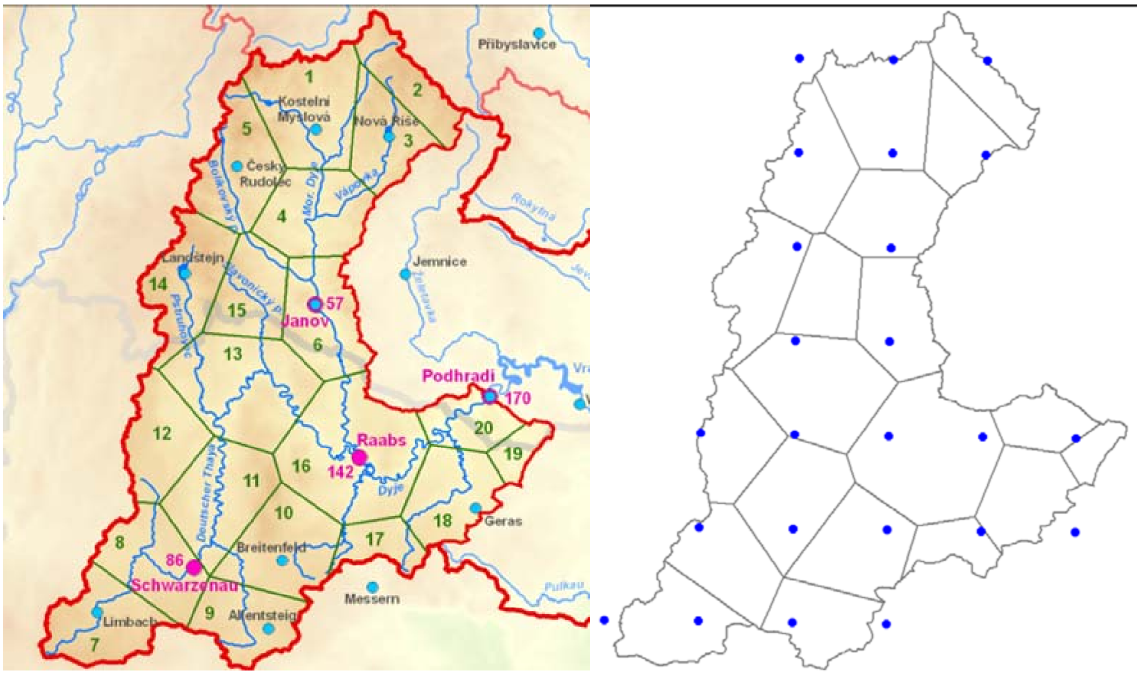

Figure 71. The map of the upper part of the Dyje catchment (left). The Thiessen polygons compared with the ALADIN calculation points (right).

First of all, the simulation of past period (1961-2000) was done. All the flood waves were evaluated, the return time period maximum discharges were calculated. The results were only few percent different from the return time period maximum discharges derived from measured data (1933-2008) (see Tab. 3). Then the simulations of ALADIN climate scenarios were done in the same way, e.g. 2021-2050 and 2071-2100. The example of simulated flood waves is shown in Fig. 72. Again the maximum year discharges were evaluated and the return time period maximum discharges were calculated. The missing data (2000-2020, 2050-2070) were randomly selected from measured maximum year discharges in many variants. Then the average return time period maximum discharges were calculated. This was done for 1933-2050 period, then for the 1933-2100 period (see Tab. 3). It is obvious that based on the ALADIN climate scenarios, the return time period peak discharges could be about 10% higher in future. It is also important to stress that the whole process of flood simulation is very uncertain and it is strongly dependent on the ALADIN-CE climate scenarios.

Table 3. *Comparison of measured and simulated return time period maximum year discharges.*

Retur period [year]	Discharge based on measurement (1933-2009) [m^3/s]	Discharge based on measurement and simulation 1961-2000 [m^3/s]	Discharge based on measurement and simulation 2021-2050 [m^3/s]	Difference [%]	Discharge based on measurement and simulation 2071-2100 [m^3/s]	Difference [%]
1000	681	685	805.6	18	755.72	11
500	595	602	702.5	18	663.46	12
200	491	500	577.6	18	550.68	12
100	419	429	491.3	17	471.94	13
50	353	363	411.5	17	398.55	13
20	274	282	315.7	15	309.36	13
10	220	227	250.2	14	247.63	12
5	172	176	190.8	11	190.82	11

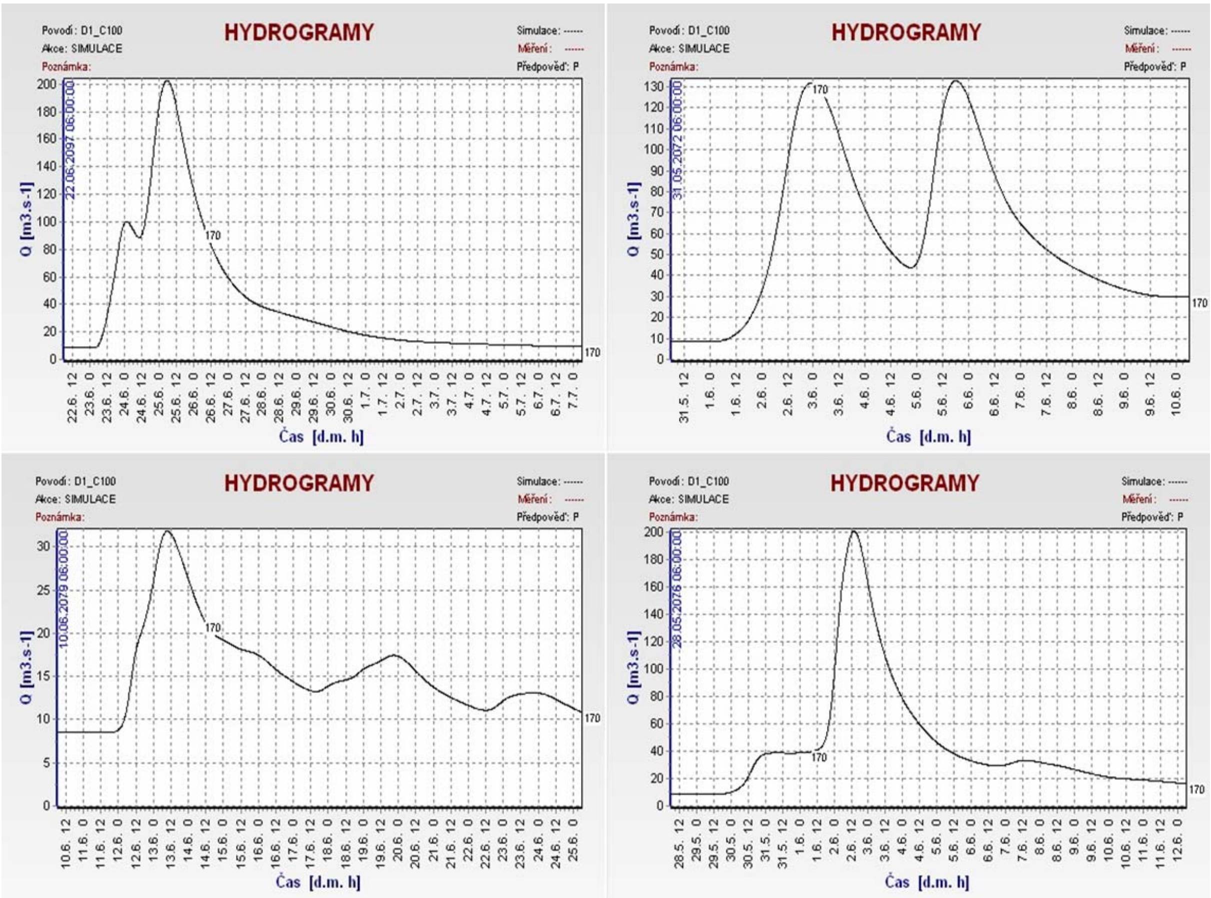

Figure 72. *Examples of simulated flood waves from period 2071-2100.*

Another aim of WP5 was to explore water quality responses in a temperate, stratified reservoir to climate change scenarios (D5.8) that were modelled with the atmosphere-catchment-reservoir simulation system developed and described within previous deliverables (D5.4). The scenarios of climate change were developed using the pattern scaling techniques from the outputs of 3 global and 2 high-resolution regional climate models, representative scenarios for the development of emissions of greenhouse gases and aerosols, and a range of climatic sensitivity to the emissions.

The anticipated climate change with its increase in temperature and impacts to the runoff can affect water quality in water bodies especially due to three groups of factors: (i) changes in runoff paths through the soil, i.e., proportion of surface, subsurface, and shallow/deep groundwater runoffs that carry significantly different composition of solutes and particulates, (ii) changes in the hydrologic conditions that may affect the extent of water level fluctuation in water resources with storage function and consequently exert more stress to the aquatic ecosystem by damaging littoral zone and by increasing area loads of nutrients with eutrophication impacts, and (iii) modifications of hydrodynamics and seasonal mixing and stratification pattern that can influence a complicated bunch of often antagonistic processes among autochthonous organic matter production and decomposition, utilisation, cycling and retention of nutrient.

The modelling results clearly indicated that the reservoir water yield will significantly decrease (by up to 50±30% in the far future period of 2071−2100) as a result of the decreased runoff from the catchment, increased flow variability with prolonged periods of low river discharge, and increased evaporation losses from the reservoir water surface. Therefore, reservoir water level fluctuation will significantly increase. Water quality in the inflow into the reservoir from the catchment will decrease due to increased export of DOM from its natural sources in catchment soils and increased concentrations of P originating mainly from point sources (i.e., municipal waste water discharges). Reservoir trophic state will deteriorate only moderately because of increased P retention within both the stream network of the catchment and the reservoir itself under the conditions of longer water residence times in water bodies and higher temperature. Water quality in the reservoir will be worsen by the increase in the scale of anoxia in the water column due to the smaller volume of hypolimnion and higher sedimentation rates under the conditions of decreased pool of accumulated water. All these phenomena together will mean a higher stress on aquatic ecosystem, especially on the littoral communities and fish.

After the study concerning the vulnerability of water resources presented in the previous report (D 5.5), NIHWM propose for Buzau – Ialomita area a series of adaptation measures in order to ensure future water requirements for the population, industry, agriculture. The adaptation measures to climate changes are based on estimated future water resources and on the analysis concerning the vulnerability of these resources. The role of the adaptation measures is to achieve a new equilibrium between the available water resources and the demands of the utilities in the conditions of climate changes.

As in every water balance, the equilibrium can be made either acting for the increase in water availability at the sources, or by reduction of the demands, either both components – water resource and water demands. The increase in available water resources is made by:

- Use of groundwater in case of drought or by aquifer replenish;
- Reutilization of purged used waters as an alternative to the use of freshwater and its use not for drinking purposes;
- Water desalinization;
- Encouraging the use of inferior quality water for specific purposes;
- Realization of new reservoirs in the distribution systems in order to create compensation capacities;
- Realization of new interconnections between water supply systems;
- Use of water from dead volumes of reservoirs (through pumping from floating installations.

The structural measures pursue the realization of new infrastructures or the physical change of certain existent ones in view of increasing the water availability at the source and at the same time, the mitigation of the effects of discharge monthly distribution, as a result of climatic changes. The main envisaged structural measures are:

- The accomplishment of the Azuga dam and reservoir in view of supplying water to the population from the Sinaia – Comarnic area;
- Improvement of Bolboci, Pucioasa and Dridu dams and reservoirs performance parameters on the Ialomita River;
- Rehabilitation and aggradation of the Siriu dam on the Buzau river in view of increasing the capacity of the reservoir;
- The accomplishment of the Surduc – Buzau with complex use;
- Accomplishment of an inlet dam at Dramboca on the Buzau river and a derivation from the Buzau River and the Ialomita River;
- Accomplishment of Siret-Bragan channel on the sector between Buzau and Ialomita rivers, with reversible operation, for water supply for the population and for irrigation in the Ialomita, Buzau and Mosistea catchments.

Although the climate changes affect each individually, the issue of adaptation measures is for human communities and society in general. If the major measures are the ones adopted by the society, individual persons can take their own measures in order to cover their water demands in the conditions of climatic changes. The following individual measures are recommended:
- Solutions for the collection, storing and use of precipitation water;
- The realization of reservoirs in depressions, or by excavating through small dams, with the water level under the terrain level;
- The use of certain agricultural crops with less water demands, or resistant to higher temperatures (dry farm).

In Romania there are no studies regarding the change of water demands as a result of climate changes. There is a single study which deals with agricultural crops. The main measures which regard the reduction of water demands are:
- Changes in water policy;
- Water allocation according to priorities;
- Change in water price;
- Changes in irrigation technology and crop type;
- Use of water conservation techniques;
- Measures for water conservation.

We must point out that there is no universal accepted definition for the water conservation notion, this term being often used in the sense of water saving by an efficient or wise use. The population does not always agree the notion of efficiency because there are different degrees of efficiency. For example, the efficient water use in the urban environment could come from the reduction in the volume of the toilet water tank, car wash restrictions, etc., actions which impose a change in lifestyle.

Currently, water conservation has several meanings. It means collecting, saving, reduction or recycling. The adaptation measures proposed by the society (or communities) are structural measures and have the purpose of achieving new infrastructure or physical modification of existing ones to increase the availability of water and also to minimize the effects of monthly distribution of flows due to climate changes. As the climate scenarios made in the frame of the project cover almost all the country, then, given that the methodology used to analyze the hydrological regime in terms of climate changes can be applied to other river basins, this study can continue.

The increase of knowledge level on vulnerability and climate changes impacts in Romania will support the effective adaptation of preventive policies with efficient cost. Moreover many of the proposed adaptation measures are those that will prove beneficial even in the absence of climate changes impacts and those that can be implemented with low costs.

The research results on climate change impacts on water resources involve the developing of new criteria and technical design and construction of dams, making water management systems less sensitive to changes in hydrological regime due to the impact of variability and climate change. There is also the need to develop new procedures for the operation of water management systems that can take into account the uncertainty degree in the hydrological regime due to development, particularly climate changes.

In the reported period, NMA was in charge with the study of local air-sea interaction changes on the western Black Sea coast under different climate conditions and its relevance to regional sustainable development (D5.10). Local factors like topography and the vicinity of sea modulate the global climate change signal. Thus, high resolution regional experiments have to assess the influences of variability due local factors on the projection of climate change at smaller spatial scales. Coastal areas are particularly vulnerable to climate variability and change (IPCC, 2007). The key issues analyzed in the present report are precipitation-related changes which could be further related to maritime storms and flooding. They have implications for coastal socio-economic activities and ecosystems. Flooding from rainstorms may become worse if higher temperatures lead to increasing rainfall intensity during severe storms. Shore erosion is another issue which could be related to high precipitation events.

In the previous reported period we have identified the SST-related patterns of observed extreme precipitation over Romania. The time evolution of the coupled mode shows an interdecadal pattern with higher (lower) SST anomalies over the Black Sea for the period 1961-1979 (1980-1995), corresponding to the warm (cold) phase of Black Sea surface temperatures defined by Oguz et al. (2006). The observed signal has been further used to design sensitivity experiments using a regional climate model.

The regional model used by NMA was the RegCM originally developed by Giorgi et al. (1993a, b) and later upgraded as described in Pal et al. (2007). For the present experiment we use the standard version of the model (see Pal et al. 2007) with the Grell convection scheme and the resolvable precipitation scheme of Pal et al. (2000). The model domain covers the Romanian domain defined in CECILIA project at a grid point spacing of 10 km.

Regional climate experiments have been performed to isolate the effects of Black Sea SSTs on local climate and especially on precipitation. First, the control simulation is performed (referred to as CTRL) for 15 summer and winter months. In the second set of simulations (referred to as WSEA) the surface temperature of the Black Sea is modified with an uniform temperature increase of 2 K and unchanged lateral boundary conditions. The driving lateral boundary conditions are taken from the fields obtained with the regional model RegCM3 at 25km grid point spacing over the European domain. These European simulations are driven at the lateral boundaries by meteorological fields from a corresponding global simulation with the ECHAM5 model under forcing from the SRES-A1B IPCC greenhouse gas scenario. The first 4 days are removed from the first month of the season in all model results to allow for model spin up. This is sufficient time for a balance to be reached between the lateral boundary forcing and the regional climate model dynamics.

The WSEA experiments allow us to separate the local effects of the Black Sea SST from large scale effects and other influences. Note that the 2 K SST anomaly over the Black Sea is consistent with observations of SST interdecadal variability (Oguz et al., 2006). Fig. 73 shows the difference composite of precipitable water integrated on air column for the sensitivity and control experiments. Larger amounts of precipitable water are identified for both winter and summer when SST is raised by 2 K, under A1B conditions. However, the differences in SLP between sensitivity and control experiments are smaller under A1B scenario compared with the present climate. These facts suggest that the local response to SST variability under A1B scenario conditions is thermodynamically-driven. This local response may lead to an enhancement of precipitation variability especially over the regions situated in the vicinity of Black Sea. The variability enhancement of atmospheric precipitable water influences the vulnerability to flash floods in South - Eastern regions of the Romanian territory situated near the Black Sea.

The climate vulnerability is seasonally dependent. Under A1B scenario, a higher amount of precipitation is likely to occur when higher SSTs over the Black Sea are present (Fig. 73). However, more regional experiments have to be done in order to analyze the projection of climate change signal on local and regional scales at higher confidence levels. Also, the results suggest the importance of a full Black Sea representation (coupled air-sea experiments) for local/coastal climate change assessment. In both summer and winter the most exposed land areas to SST influences (precipitation, precipitable water on air column, winds) are the coastal areas and the Southern part of Romanian territory (Fig. 74). In summer, we could expect that Black Sea SST will rise as the climate change is progressing; this could imply more extreme precipitation (see Fig. 74 – atmospheric precipitable water) especially over the coastal regions and Eastern Romania. Further experiments are needed with larger simulation in order to assess in more detail this mechanism.

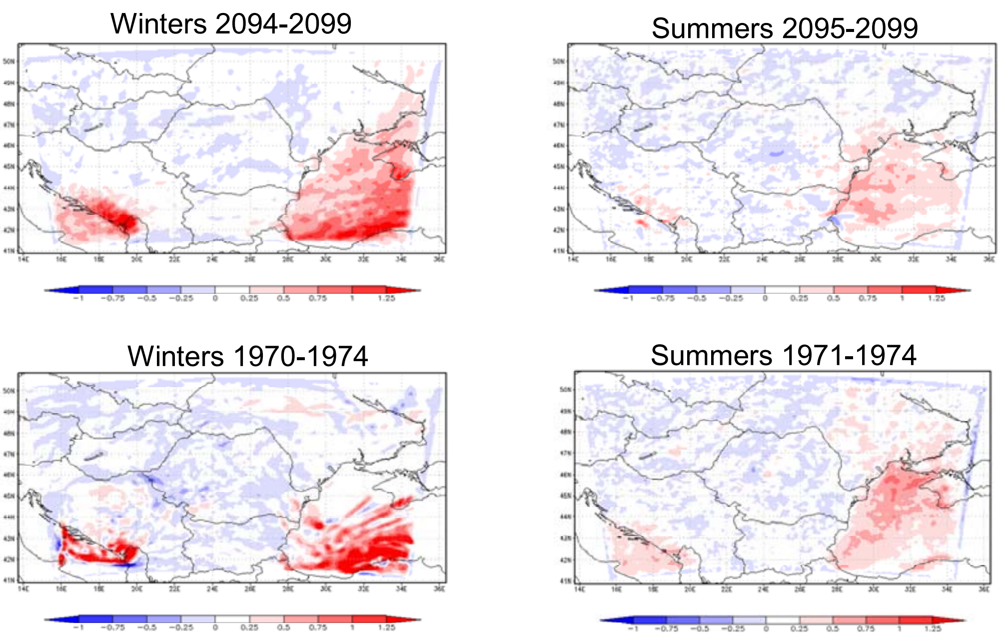

Figure 73. *Precipitation difference (mm/day). WSEA minus CTRL in present climate and under A1B scenario conditions.*

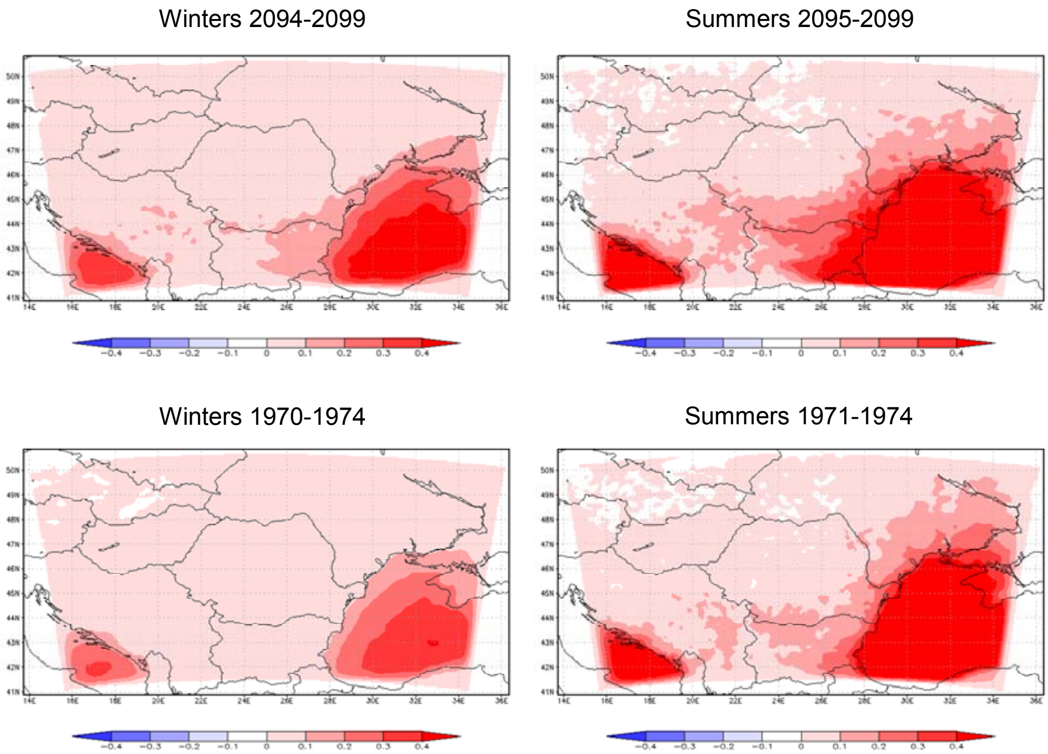

Figure 74. *Precipitable water integrated on air column (from surface up to 300 hPa) (mm). WSEA minus CTRL in present climate and under A1B scenario conditions.*

2.5.3 Deviations from workprogramme

Generally the works are performed following the working plan achieving the requirements of the milestone M5.3. Some delays with respect to later availability of high resolution simulations were recovered finally.

2.6 WP 6

2.6.1 Workpackage objectives

The objectives of WP 6 consist of climate change impacts assessments on selected agriculture crops, forest ecosystems and carbon cycle, including other risks of climatic variability. These are related to climatic extremes with special focus on drought, which is considered to be the most important climate hazard for plant production under the expected climate change. From biotic agents the special attention is paid to the future extend and potential damage caused by the pest and diseases. Main tasks as defined in DoW are:

- Assessment of the change in crop yield and its quality under the different climate scenarios for the selected regions under current production and land-use systems.
- Assessment of the change in forest tree growth under the different climate scenarios for the selected regions under current management systems.
- Assessment of climate change effects on soil water balance: the water use and loss in agricultural crop production and drought impacts on growth and development of the agricultural crops.

- Sensitivity analysis of the selected agriculture crops and the most vulnerable forest stands to climate change impacts
- Expected changes of occurrence and activity of pests and diseases on selected crops and forest ecosystems
- Integrated assessment of climate change and air pollution impacts on forest ecosystems in selected region
- Impacts of climate change on C-cycle in agriculture and forest ecosystems
- Adaptation analyses, recommendations and development of management options for improved land use systems in agricultural crop production and forest management under the regional climate change scenarios.

Last five objectives were in certain extent contributing to the tasks of the final reporting period and thus considered in work on completing the appropriate deliverables.

2.6.2 Progress towards objectives

Objectives of WP6 during the last reporting period are compliant with the following list of deliverables defined in DoW:

- D 6.5 Report about the expected changes of occurrence and activity of pests and diseases on selected crops and forest ecosystems (IAP, FRI, CHMI) – due Month 36.
- D 6.6 Report about the sensitivity analysis of the selected agriculture crops and the most vulnerable forest stands to climate change impacts (FRI, IAP, BOKU, CHMI, WUT) – due Month 36.
- D 6.7 Report about the integrated assessment of climate change and air pollution impacts on C-cycle in agriculture and forest ecosystems (FRI, WUT, ELU) – due Month 43.
- D 6.8 Recommendations and development of management options for an improved land use systems in agricultural crop production and forest management under the regional climate change scenarios (FRI, IAP, BOKU, NMA, CHMI, NIMH) – due Month 43.

The scheduling of deliverables in DoW with extension took into account the delay of main simulations within WP2 and thus enabled to include finally the studies based on high resolution regional climate change simulations. Some tasks are in general similar to the COST734 activity, most partners involved in WP6 are cooperating in other levels including e.g. activity COST 734.

2.6.2.1 IAP–CHMI–BOKU

During the last reporting period study using outputs of RCM ALADIN was carried over the area of Central Europe. The domain covers of the regional climate model ALADIN, at a 10-km resolution the entire area of Central Europe between latitudes 45° and 51.5° N and longitudes 8° and 27° E, including at least partly the territories of Austria, Czech Republic, Germany, Hungary, Poland, Romania, Slovakia, Switzerland and Ukraine. The whole domain and the final maps were interpolated to 1 km resolution using digital terrain model (Fig. 75).

The weather series that was the input for the subsequent analysis were prepared by a weather generator, which was calibrated with the RCM-simulated weather series (for the period of 1961-1990). To generate a weather series for two future time periods (2021-2050 and 2071-2100), the WG parameters were modified according to 12 climate change scenarios produced by the pattern scaling method. The standardized scenarios derived from four Global Climate Models (HadCM, NCAR-PCM, ECHAM) were scaled by low, middle, and high values of global temperature change estimated by the MAGICC model (assuming three combinations of climatic sensitivity and emission scenarios).

Extreme weather events that are a natural cause of climate variability such as drought, frosts or heat waves can also have severe consequences for crops. In the same time timing of the key field operations (i.e. sowing and harvest) depends the weather conditions influencing yield quantity and quality in each given season.The first aim of the study was to develop a methodology that would enable a sophisticated and flexible analysis of various agroclimatic indicators. The results of this effort were summarized into the AgriClim software package that provides range of agroclimatic indicators including: i) duration of growing season and of the vegetation summer, ii) number days suitable for sowing and harvesting; iii) accumulated water deficits during key parts of growing season (April-June); iv) number of growing degree days without significant water stress v) snow cover presence/absence during days with Tmin < -5°C and -15°C and duration of snow cover; vi) probability of serious frost damage to winter field crops; and vii) number of days during cereal anthesis with daily maximum temperature over 32 and 35°C.

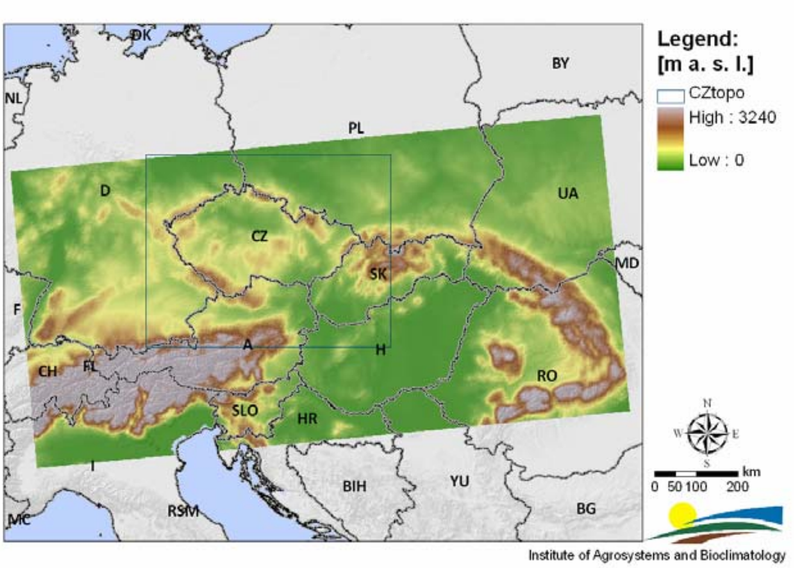

Figure 75. *Domain of ALADIN RCM model with representation of altitude in 10x10 km resolution.*

The control run used observed boundary conditions (ERA40) and covered the period 1961-2000 with 1961-1990 period being used as a baseline to train a weather generator. Then parameters of weather generator were perturbed based on the outputs of representative set of Global Circulation Models (including HadCM, NCAR-PCM, ECHAM) for various levels of climate system sensitivity and emission scenarios. This novel procedure significantly improves the reliability of RCM based projections combining RCM resolution while accounting for GCM related uncertainties.

The selected agroclimatic indices were then calculated for each of over 10 000 grid points. The soil properties that were required for indices ii – iv were derived from the FAO 1:1000 000 soil map. The outputs of the control run were compared with 1 km resolution AgriClim runs for the Czech Republic and part of Austria based on the observational data (1961-2000) from 125 Czech and 35 Austrian weather stations. The values of the evaluated agrometeorological characteristics were calculated at the individual stations and were eventually interpolated over the territory depending on the parameter involved.

The complete results are part of the reports and two journal papers (Journal of Agriculture Sciences due to be published in 2010). At this point the effect of climate change on the duration of effective growing season between 2021-2050 is demonstrated in Fig. 76 as well as significant shifts in the agroclimatic zones affecting e.g. potential for vine production in Fig. 77.

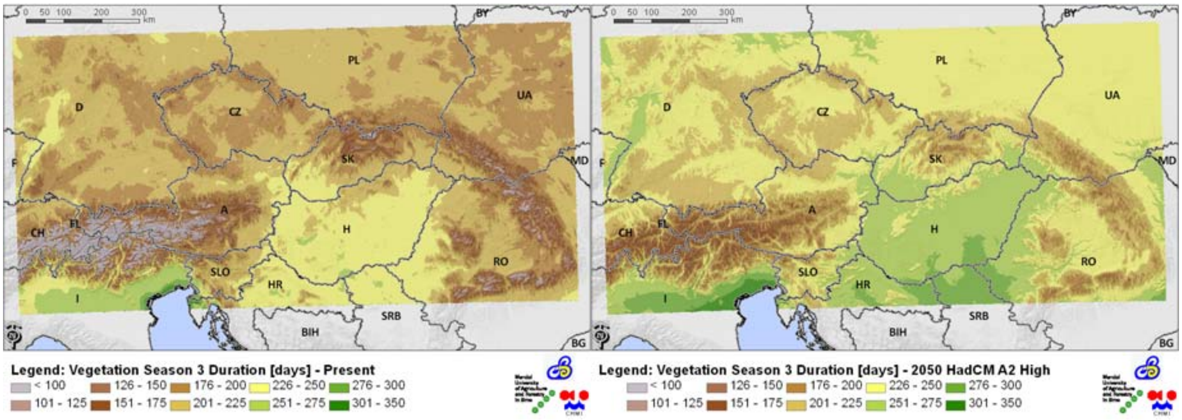

__Figure 76.__ Duration of growing season (continuous period with mean air temperature above 5°C and minimum daily temperatures above -2°C for the present (1961-2000) and expected conditions (SRES-A2 high climate sensitivity and HadCM3 global circulation model).

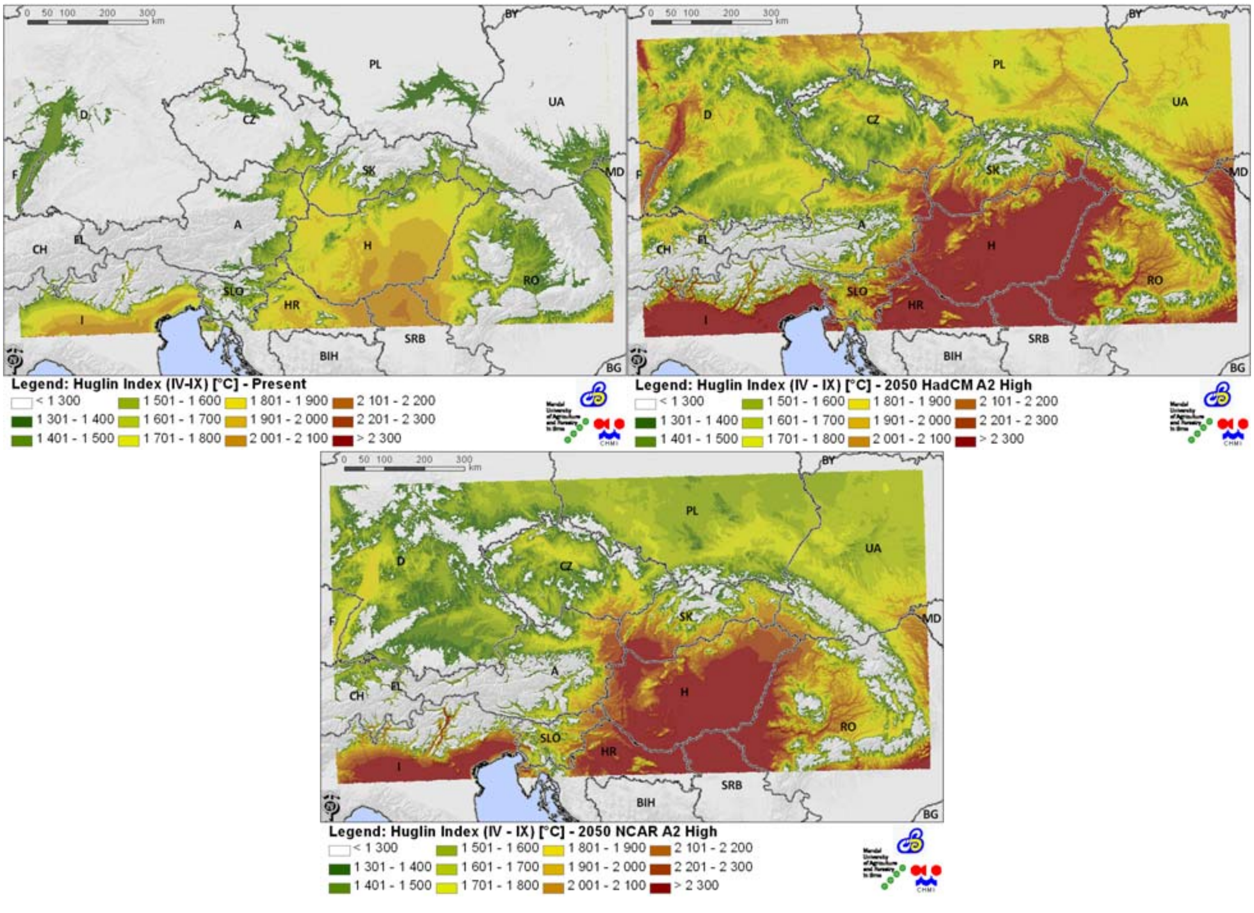

__Figure 77.__ Example of the Hughlin index (indicating climate dependent suitability for vine production) for the present (1961-2000) and expected conditions. Future climate conditions are based on the combination of SRES-A2 high climate sensitivity and HadCM3 and NCAR-PCM global circulation models.

The key findings of the regional RCM based runs could be summarized as follows: (i) The extent of the presently most productive areas will be reduced and replaced by warmer but drier conditions, which are less suitable for rainfed farming; ii) While the trends of the changes expected in lowlands are mostly negative according to the production potential of rainfed crops, the higher elevations will most likely experience improvement of their agroclimatic conditions; iii) Diary oriented agriculture (based on permanent grassland) at higher altitudes could suffer through an increased evapotranspiration demand combined with the decrease of precipitation leading to the intolerable water deficits; iv) The areas that are already warm and relatively dry we will experiencing 20-year drought intensity three times as frequently and water deficits that have not been encountered before; v) Farmers will most likely be able to take advantage of earlier start of growing season at least in the lowland areas as the proportion of days suitable for sowing will increase; vi) Most of the changes listed might occur within less than 4 decades, which will pose serious adaptation challenges for farmers and governmental policies. The rate of the change might be so high that the concept of agroclimatology as a near static description of overall farming conditions might lose it relevance due to perpetual change.

The analysis of potential distribution of two pest species could be summarized as follows: In case of Colorado potato beetle (CPB) the simulations for the expected climate scenarios show the apparent trend of a widening of the pests' climatic niche and increase of the number of generations based on the temperature increase predicted by various scenarios. The complete bivoltine population would occupy 16.8% of arable land, while the area occupied by the third generation increases to 68.5% (HadCM-high). On the other hand, a marked decrease in the climatic favorableness for CPB development under ECHAM-high is simulated in northern Serbia (Vojvodina region), where the significant temperature increase according to the mentioned scenario causes the high-temperature limitation for the pest's development and subsequent decrease of about one generation. A similar trend in the increase of the high temperature limitation is also seen in the NCAR-PCM-high and HadCM-high scenarios, which show all of Hungary, Croatia, and the north of Italy having a decrease in the number of generations.

The European corn borer (ECB) will benefit from expected temperature increase and prolonged growing season. At the same time, the emergence of bivoltine populations and a further increase to a third generation in the warmest areas is indicated. The lowland areas presently occupied by the univoltine population are likely to be replaced by a bivoltine population, which only slightly exceeds the original areal of univoltine one. HadCM-high presumes the prevailing increase of about one generation, which will probably result in the presence of a third generation in the eastern part of Austria, north of Italy, and western part of Germany (Rhine valley), where there are currently two generations per season. The NCAR-PCM-high scenario assumes a wider spread, covering a major part of Hungary, Croatia, and the whole simulated part of Italy. Significantly, a third generation is predicted to emerge in 17.8% of arable land in the domain (NCAR-PCM-high), which has serious implications on production risk.

The methodology used both for agroclimatic index study and CLIMEX pest distribution runs enabled to cover large territory. The findings are crucial for tailoring the right adaption responses to the expected changes.

2.6.2.2 BOKU

Higher temperatures and lower summer precipitation in the next decades imply higher water demand for the main crops in the target area Marchfeld, NE Austria. If not compensated by irrigation, longer and more frequent phases of drought and heat stress can occur. Higher temperatures will also shorten the growth period especially of winter wheat. Time available for photosynthesis and assimilation will be reduced, resulting in yield depression. Rising CO_2 concentrations in the atmosphere will partly mitigate drought stress by allowing higher water use efficiency of crops by stomata control. CO_2 also has a fertilizing effect on cereals producing larger and more vigorous plants, higher total dry matter yields and, mostly, greater quantities of harvestable products (Acock and Acock 1993) This effect will partly compensate the growth depression. This study addresses deliverables D 6.6 and D 6.8.

For the crop model input the GCMs ECHAM 5, HadCM 3 and NCAR PCM with different emission scenarios were used. The bias of the RCMs was too big and thus they could not be used for the target area. Hereby a correction of the RCM data before using as model input is necessary. Nine scenario sets for 2035 (2020-2050) were used to estimate the uncertainty of climate change impact on the future winter wheat and spring barely yields. The results of the simulations indicate a shortening and an earlier occurrence of phenological development stages of the two crops, as well as yield stagnation or decrease in the near future. An exception presents NCAR PCM, with a slight increase of winter wheat as well as spring barely yield on medium soils. The interannual yield variability of both crops would increase for almost all soils, which leads to a higher economic risk for farmers. Without fertilizing CO_2 effect, mean yield would stronger diminish, especially on sandy and shallow soils.

As recommendations and development of management options for an improved land use systems in agricultural crop production under the climate change scenarios a shift of average sowing dates, a replacement of ploughing by minimum tillage and direct drilling as well as support irrigation and improved irrigation efficiency for winter wheat and spring barley were studied. A replacement of ploughing by minimum tillage and direct drilling within the 2035 scenario would lead to an increase of mean yield of winter wheat (up to 10 %) (Fig. 78) and of spring barely (up to 8 %) (Fig. 79) in 2035. This effect is mainly a result of improved water supply for the crops and a decrease of unproductive water losses.

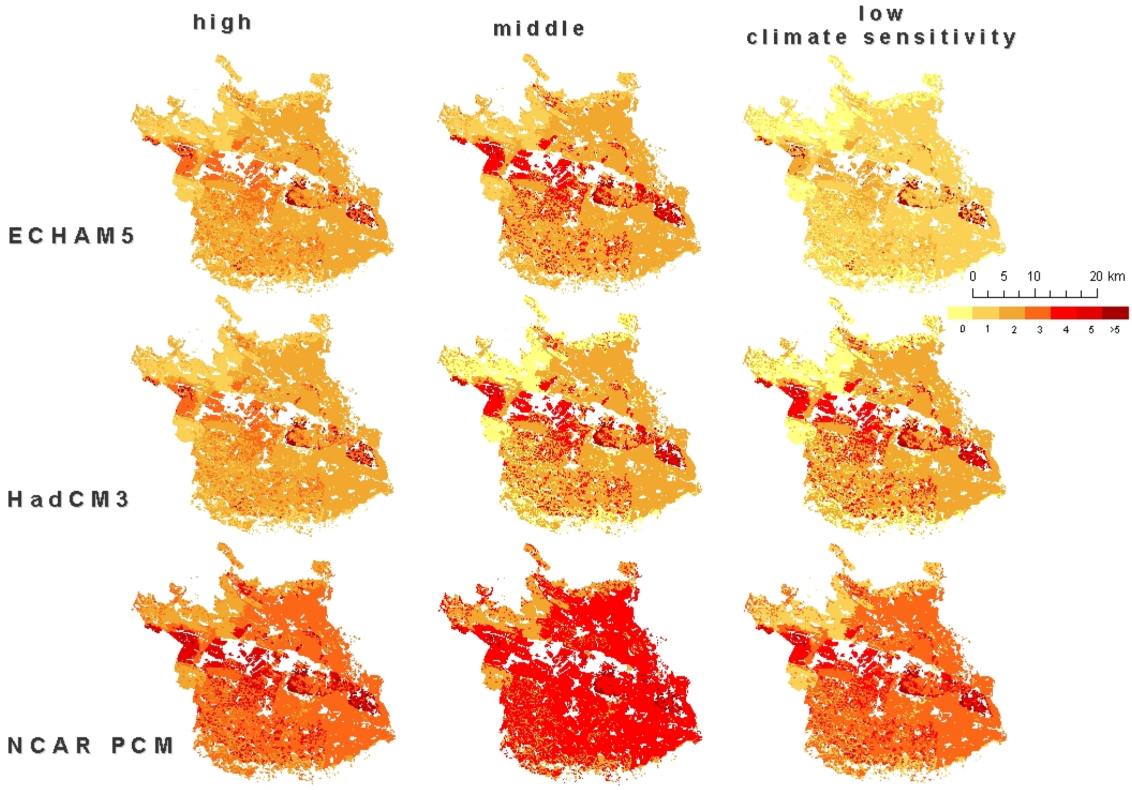

Figure 78. Relative change of winter wheat yield [%] if ploughing is replaced by minimum tillage in the Marchfeld region in the 2035 scenario.

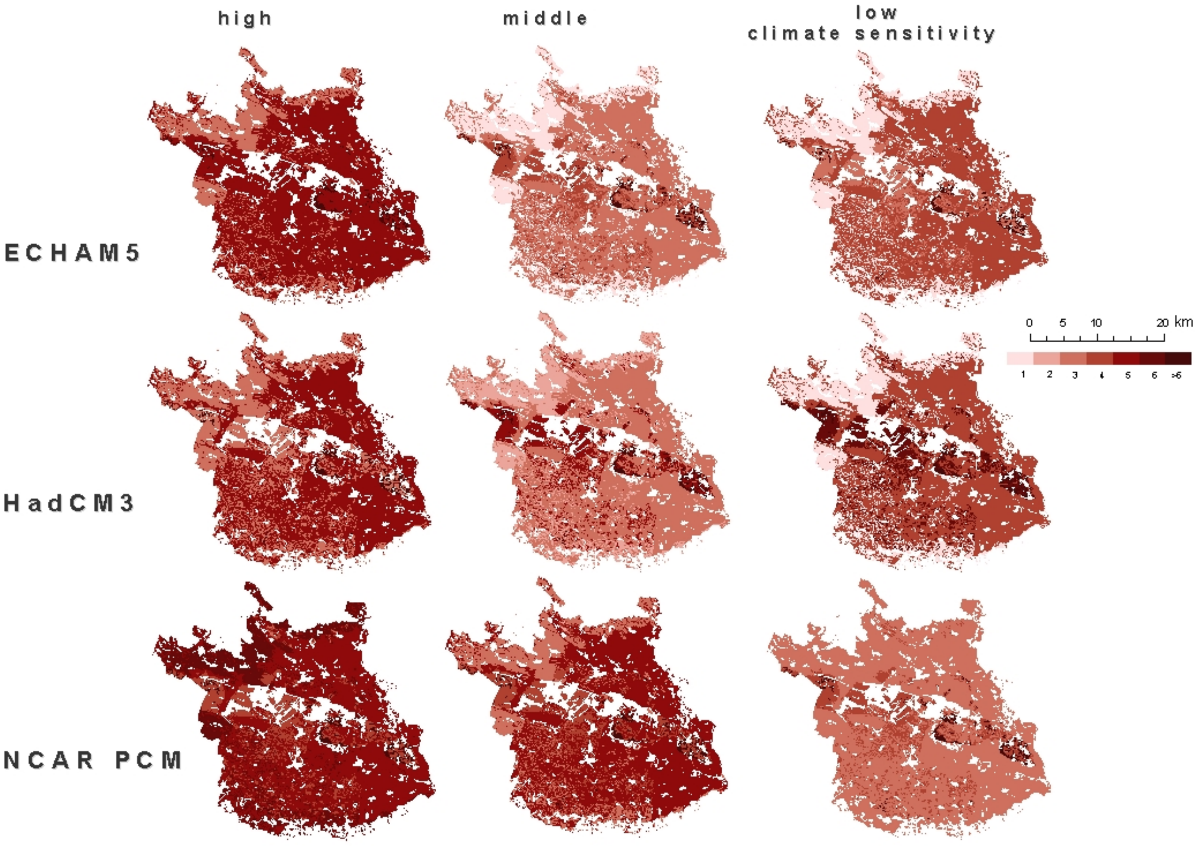

Figure 79. *Relative change of spring barley yield [%] if ploughing is replaced by minimum tillage in the Marchfeld region in the 2035 scenario.*

Presently in the Marchfeld region wheat and barley fields are not irrigated due to economical reasons. Irrigation systems in the target area are existing and in use for other cultivars. Whether in future a utilization of these systems for the two analyzed crops will be reasonable, that will be a decision of the agro-economics. In order to answer the question related to the quantity of water required in the near future in the study area to stabilize yields, the simulation option "automatic when required" for irrigation and water management was activated in the model. Compared to current conditions optimal irrigation of winter wheat would require between -3 and 33 mm more water per year (area-weighted average) in 2035. Irrigation of spring barley had to be increased between 11 and 42 mm per year (area-weighted average). Further recommendations for the target area are crop rotation and surface mulch (reduction of evaporation).

2.6.2.3 NMA

The results confirm the possibility of the application of the CERES-Wheat and CERES-Maize models for climate change impact assessment on agriculture in Romania. Both models were successfully evaluated regarding to the phenological development and grain yield. This study addressed deliverables D 6.6 and D 6.8.

Analyzing the results simulated on the grounds of 2020-2050 climate change estimations made by regional climate models highlighted that the future climate evolutions may he have important effects upon crops and they are conditioned by an interaction between the following factors: current climate changes on a local scale, severity of climate scenario-forecasted parameters, how the increased CO_2 concentrations influence photosynthesis, and the genetic nature of plant types. Winter wheat can benefit from the interaction between increased CO_2 concentrations and higher air temperatures, while maize is vulnerable to climate change, mainly in the case of a scenario predicting hot and droughty conditions.

A comparative analysis of the results obtained showed that future changes in regional scenario-based climate evolutions can have negative effects upon yield increase, development and formation. For both analyzed crops, the vegetation season gets shorter and there are fewer days available to reaching full ripeness. This shortening of the vegetation season is more marked in maize crops than in winter wheat. Such a forcing is mainly due to a probable increase in air temperature, estimated by the regional model.

As to the possible effects of climate change upon yields, they depend on the genetic type (C_3 or C_4), direct effects of increased CO_2 concentrations on photosynthesis, local conditions and the severity of changes in climate evolution according to the two scenarios. Thus, maize yields decrease at every analyzed station in comparison with the current clime case, due to higher temperatures leading to shorter vegetation seasons associated with water stress, mainly during the phenological stage of grain formation and filling. In winter wheat, grain yields are higher than in current clime conditions at every station of the six analyzed, due to a positive effect of increased CO_2 concentrations in the atmosphere (from 330 ppm to 450 ppm) upon photosynthesis and water use, which counterbalances the negative effect of a shorter vegetation period.

2.6.2.4 ELU–FRI–WUT

Regarding the carbon cycle related impact study the main aim was to simulate the carbon cycle of forest and agriculture ecosystems using high resolution climate data provided by WP2 and to estimate the possible feedback between carbon cycle and climate change taking into account the effects of air pollution as well. This was in close connection to deliverable D 6.7 "Integrated assessment of climate change and air pollution impacts on C-cycle in agriculture and on forest ecosystems", which was completed during the third reporting period. The deliverable was submitted in due time of the project lifetime, the contractors involved were ELU, FRI and WUT.

The Polish target area was the Kampinos National Park, which is located in Central Poland not far from Warsaw (Pine forest). The Slovak target area is the forested region near Čifáre (Turkey oak forest). In this reporting period ELU synthesized the forest related measurement data provided by FRI and WUT. Using the measurement data from both sites ELU calibrated BIOME-BGC using the methodology of Cienciala and Tatarinov (2006). During the previous reporting periods ELU calibrated BIOME-BGC for the simulation of grassland and cropland related carbon cycle to be performed in Hungary.

Using the output of different high resolution climate models provided by WP2 of the CECILIA project ELU performed model simulations to estimate present and future evolution of the carbon cycle components at the Hegyhátsál agricultural region (Hungary), at the Kampinos National Park and at the Čifare forest. The modelling design, the calibration procedure and the ancillary data used for the simulations are described in Deliverable D 6.7 in detail.

For the forest related carbon cycle impact study ELU analyzed the evolution of the carbon content of the IPCC pools and also the evolution of exchange of carbon dioxide between the biosphere and the atmosphere. BIOME-BGC based model simulation results for Kampinos forest (Poland) show that there can be large differences between the results obtained with the different of ecophysiological parameterizations but the tendencies in evolution of carbon pools, increments and carbon fluxes are almost the same. Carbon content of IPCC pools is increasing continuously during the simulation period (1935-2100). This means that Kampinos forest will likely remain carbon sink in the future. Biomass (stem and root) increments are remaining at the same level (or showing a slight increasing tendency) until 2050, but decreasing tendency is expected afterwards.

We could not detect any feedback mechanism between climate change and carbon cycle of the Kampinos forest.

Nitrogen deposition has a significantly bigger impact on plants' growth and carbon uptake than elevated atmospheric CO_2-concentration, though its effect differs between the parameterizations. In case of Kampinos forest this increased uptake can partly compensate the negative impacts of climate change so as the resulting effect is unchanged carbon sequestration capacity of the forest in the future relative to the present day conditions.

The Čifáre forest (Slovakia) related simulations suggest that carbon content of IPCC pools might increase continuously, thus the unmanaged temperate oak forest Čifáre will likely remain a net carbon sink in the future. This finding is corroborated by the simulated net ecosystem exchange (NEE) data. We found a negative impact of climate change on plant increments: higher mean annual air temperatures strongly decrease stem and root increments (Fig. 80). This latter might have a serious impact on timber production, if the results are representative to managed forests.

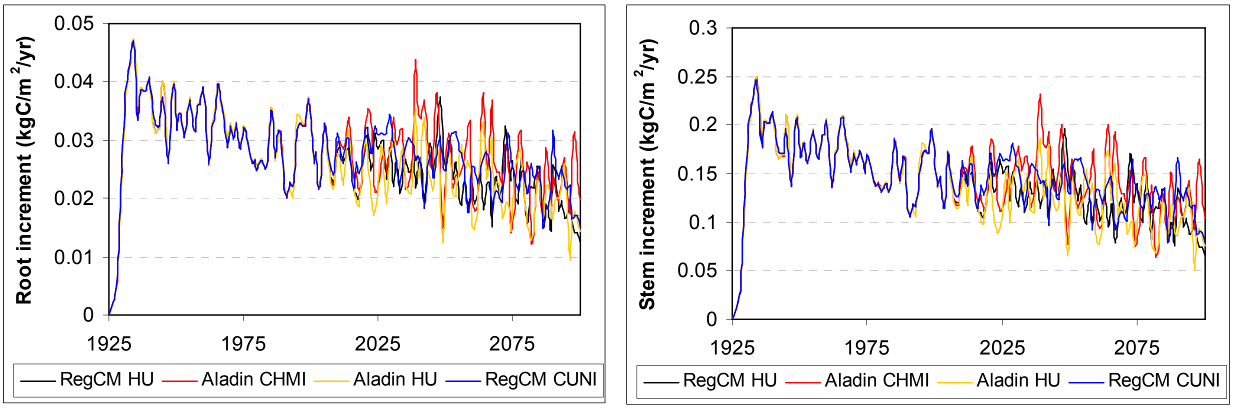

Figure 80. *Simulated evolution of root and stem carbon increment for the Čifáre forest from 1925 to 2100 using the climate data provided by the different regional climate models.*

Climate change and air pollution have a joint impact on the biosphere/atmosphere CO_2-exchange: the magnitude of both gross primary production (GPP) and total ecosystem respiration (Reco) are increasing. The net effect is a slight decrease in the magnitude of NEE (i.e. less carbon is sequestered by the forest in the future as compared to the present day conditions) which may be interpreted as a positive feedback for climate change: with less increment plants can uptake less CO_2 from the atmosphere. The result is increasing atmospheric CO_2 concentration which causes stronger greenhouse effect of the atmosphere, which increases the mean temperatures even further. We found that the increasing nitrogen deposition has a significant impact on the forest carbon cycle: N stimulates plants' growth so they can take up more CO_2 from the atmosphere. This reduces the positive feedback caused by increasing mean annual temperature.

For the agriculture related carbon cycle impact study ELU analyzed the evolution of the carbon dioxide flux between the atmosphere and the vegetation. For managed grassland carbon stock changes were also estimated. Simulations related to the managed grassland (Hungary) suggest that the increasing CO_2 concentration and increasing nitrogen deposition caused by air pollution increase both the carbon release (total ecosystem respiration) and the carbon-fixing (gross primary production). These two effects compensate each other, therefore the net biospheric carbon uptake (NEE) will not change significantly in the examined period (we predict a slight increase in the magnitude of carbon uptake). The effect of increasing CO_2 concentration is proved to be higher than the effect of increasing nitrogen deposition.

Grass mowing decreases the soil carbon and therefore the total carbon content of the ecosystem. Examining the separated effects of increasing CO_2 concentration and nitrogen deposition it was found that the increasing CO_2 concentration can compensate a certain part of the carbon loss caused by harvesting. After taking into account the carbon content of the mowed grass it was found that net biome production (NBP) will change in the future toward lower emission of CO_2. This NBP change means that the ecosystem will be a carbon source to the atmosphere, but the source intensity is mitigated to some extent by the joint impact of increasing air pollution and climate change. This means a small negative feedback to climate change if we compare the results to the present day situation when the CO_2 release is higher.

The cropland related simulations (Hungary) show that although the net biospheric carbon exchange (NEE) seems to be unchanged in the future, the two large carbon fluxes (GPP and Reco) and also net primary production (NPP) will increase in magnitude as the consequence of climate change and increasing air pollution (Fig. 81). Increasing nitrogen deposition and CO_2 concentration will amplify the changes, but there is no simple answer about the importance of the two pollutants. Taking into account both the unchanged NEE (biospheric carbon balance from the atmospheric point of view) and the increasing NPP (which causes increasing anthropogenic CO_2 emission caused by human and animal consumption) we were not able to estimate the direction and magnitude of the carbon cycle related feedback to climate change and air pollution. Human intervention substantially alters the carbon cycle of croplands, and at present we do not have enough information to estimate the fate of cropland carbon cycle in the future. Definitely more research is needed in this topic.

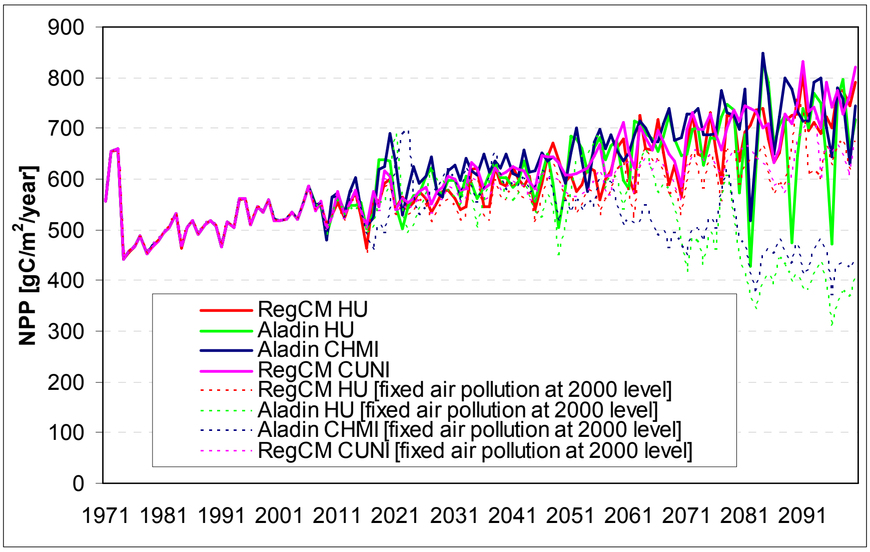

Figure 81. *Modelled evolution of agricultural net primary production between 1971 and 2100 based on the regional climate model simulations. Solid lines show the estimated net primary production (NPP) with climate change and air pollution impact, while dashed lines show the effect of climate change alone without the air pollution impact (N deposition and CO_2 concentration were held at their respective year 2000 value).*

According to our results the annual cycle of agricultural NEE will be modulated in the future, mainly because of the CO_2 fertilization effect. The changes might be beneficial as productivity might increase in the first half of the growing season. Some models indicate that without the air pollution effect there can be decrease in productivity and by 2100 crop growth might even decrease.

2.6.2.5 FRI-CHMI

Presented impact studies have been conducted in Slovakia, the Central Europe within the frame of deliverables D6.5, D6.6 and D6.8. The country belongs to the temperate continental bioclimatic zone. Forest growth, regeneration and survival are expected to be constrained mainly by water availability in this region. Forest responses to climate change are supposed to be both positive and negative, depending on site conditions and regional variability of climate. Bark beetles (mainly *Ips typographus* and *Pityogenes chalcographus*) and some defoliators (*Lymantria dispar*, *Lymantria monacha*) are the most important insect pests in this region.

SIBYLA growth simulator (Fabrika, Ďurský 2005) was used to model the climate change impacts on selected forest trees production and natural mortality. Growth responses to respective environmental parameters are formalized according to Kahn (1994). Analysis of climate change impacts on bark beetle development was based on the model PHENIPS (Baier et al. 2007). This algorithm was applied spatially by calculating a total sum of degree days for all grid points of used RCMs in Slovakia. Increase in number of generations, spatial variability of such increase and shift of the onset of infestation are analyzed.

Used climate data are organized at meteorological stations for the reference climate (1961-1990) and in 10x10 km grid of ALADIN Climate CZ for the future climate (2021-2050, 2071-2100). The output of global climate model ARPEGE-Climat (Meteo-France) was used as the driving data of the regional model. A1B emission scenario indicated the expected development of CO_2 emissions.

We describe the variability of climate change induced changes in the production and natural mortality of spruce, beech and oak in relation to the altitudinal vegetation zones (AVZ hereinafter). Because the total volume production and cumulative volume of death trees (m^3) (TVP/CVDT hereinafter), which are primarily produced by growth simulations are not comparable through the span of natural conditions covered by the experimental design, we investigate the changes in the ratio of TVP/CVDT under the reference climate and future time slices.

The changes in production of spruce and beech exhibit a similar response along the elevation gradient or AVZ (the example of spruce in the Fig. 82. In general, beech and spruce production declines at species receding edge (lower limit), while significant increase in production is projected at the leading edge, in the higher elevations. In the 8^{th} AVZ the increase of production is extreme, reaching on average 30% in case of spruce and even 80% in case of beech. However, this zones covers only a minor part of forests in the Europe, with severe climate conditions restricting the growth under the reference climate. The mortality pattern is not as clear as that of production and it varies between the species. In case of oak, almost no change in production is projected in the lower elevations, while the growth slightly increases (by 3-9% on average in both future time slices) in the 5^{th} and 6^{th} AVZs. Such response is accompanied by unchanged mortality over the all span of natural conditions covered by the experimental design (Fig. 83).

The area providing climatic conditions suitable for the full development of the second generation of *Ips typographus* within the current distribution range of spruce will increase by 30% in 2021-2050 in comparison to 1961-1990. Significant areas (7% of the current range of spruce distribution) with potential for the full development of the third generation are expected to appear in this period. This will continue up to 53% in 2071-2100. The fourth generation is not expected to occur in the current distributional range of spruce at all. The spring emergence of bark beetle will be accelerated by 5 days in 2021-2050 and 12 days in 2071-2100 (the average shift over the all country).

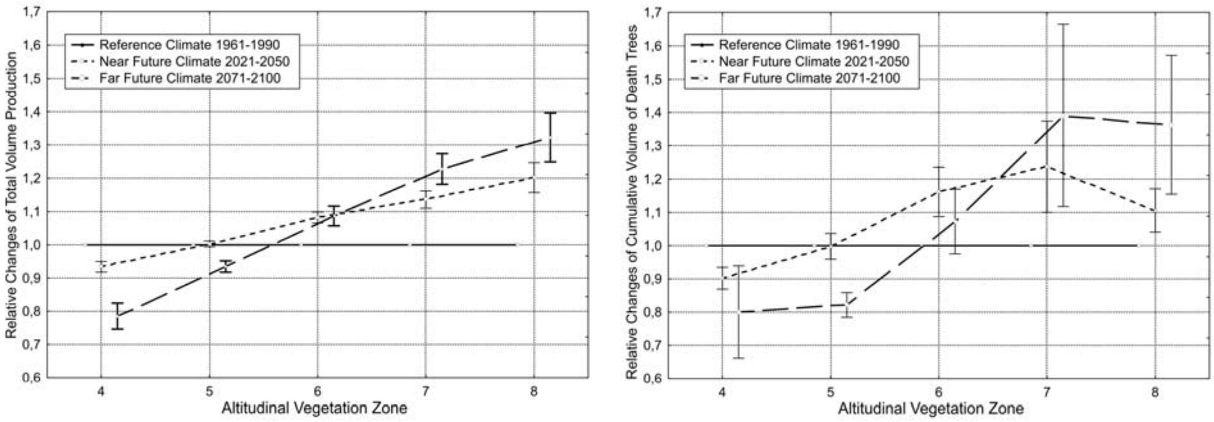

Figure 82. *The response of changes in spruce production and mortality to the elevation gradient.*

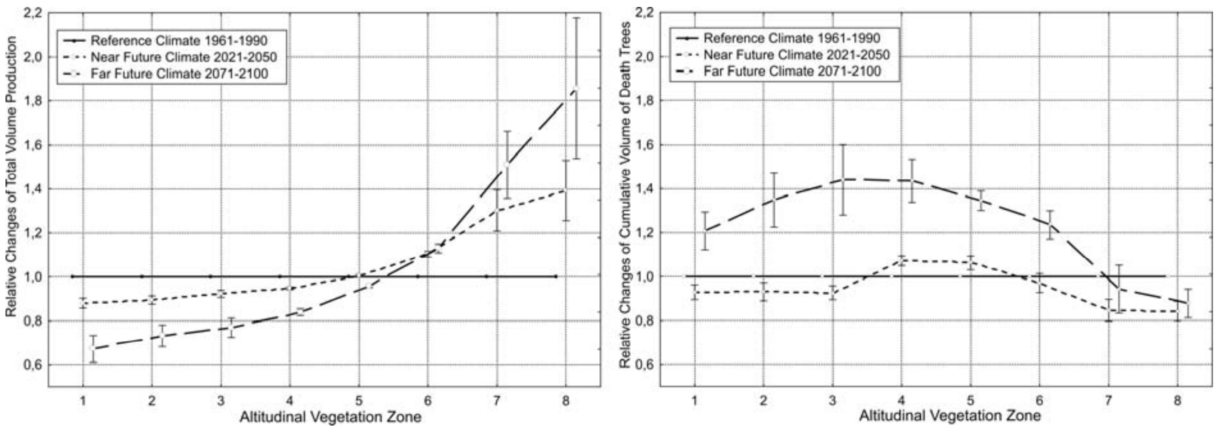

Figure 83. *The response of changes in beech production and mortality to the elevation gradient.*

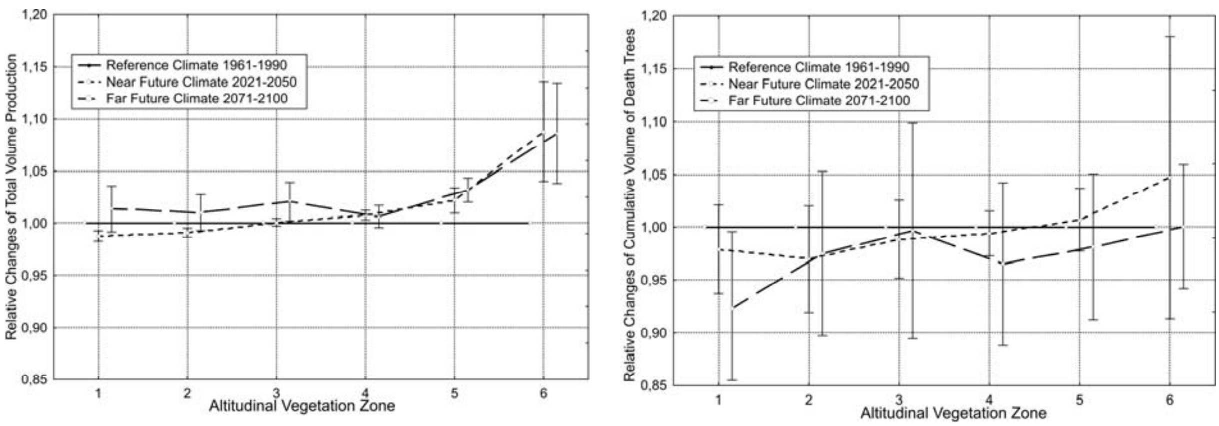

Figure 84. *The response of changes in oak production and mortality to the elevation gradient.*

Further, we investigated the emergence of areas, where the number of bark beetle generations is expected to increase, thereby altering the bark beetle related forest disturbance regime. We found that in the 2021-2050 most of spruce stands (58%) remains in the regions with two-generation regime. 42% of spruce stands will be faced to the one-generation increase of bark beetle pressure. In 2071-2100, almost all regions within the actual distribution of spruce will be faced to one-generation increase of bark beetle (Fig. 85).

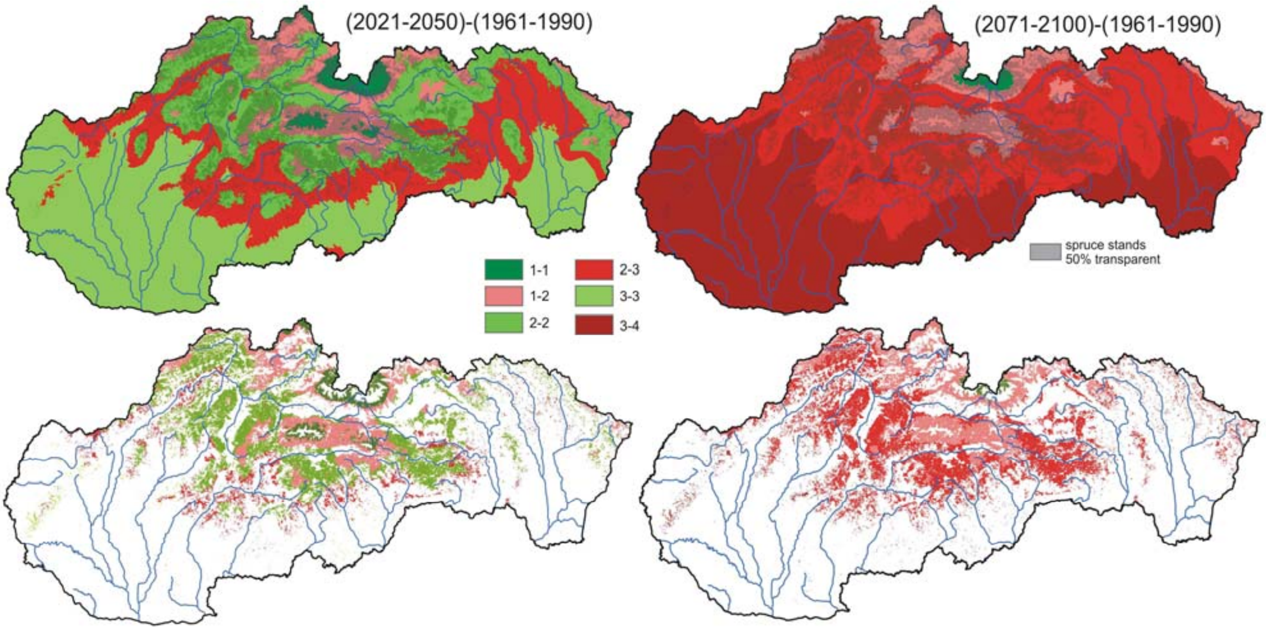

Figure 85. *Differences in number of generations projected to develop in the NFC/FFC vs. the reference climate. The upper row describes the differences in full number of developed generation (Example: 1-2 – number of developed generations increased from 1 to 2) in the whole of country, the bottom row describes the increase in bark beetle generations within actual distribution of spruce.*

Recommendations on improved forest management are mainly aimed at optimizing forest distribution and species composition to respond the projected changes in forest production, natural mortality as well as changes in pest's activity. The main points processed in the D 6.8. aim at the (i) reduction of monocultures with vulnerable species (mainly spruce) and increase the share of mixed coniferous-deciduous forests and deciduous forests; (ii) increase of the share of drought tolerant forest tree species, in the elevations where the drought is expected to became more pronounced; (iii) preference of beech (in 4-8 AVZ) and oak (in 4-6 AVZ), which natural mortality is projected to remain more-less constant and their periodic defoliations do not result in disruption of supply of forest goods and services and (iv) promotion of small-scale regeneration and reduction of the rotation length. Part of recommendations focuses on the conservation and use of valuable genetic sources and promoting the biodiversity to face the climate change impacts.

2.6.2.6 WUT

During third CECILIA reporting period the main WUT objective was to study impacts of predicted climate changes on forest ecosystems sensitivity to atmospheric deposition of sulphur (S) and nitrogen (N). Sensitivity of natural ecosystems to atmospheric pollution is quantitatively characterized by so called "critical loads" (CL) specifying this amount of atmospheric deposition of a given pollutant which is safe for their structure and functioning. In case of atmospheric deposition of N two major adverse effects are recognized i.e. acidification caused simultaneously by N and S deposition and eutrophication caused by nutrient N solely. Critical load of acidity are represented by a function defined by three quantities: $CL_{max}(S)$, $CL_{min}(N)$ and $CL_{max}(N)$, while critical load of eutrophication by $CL_{nut}(N)$. To calculate critical loads a number of biogeochemical input parameters are needed of which some key parameters are directly dependant on climatological factors. The recently internationally approved methodology to calculate and map CL is based on the Simple Mass Balance model (UBA, 2004). In our study we applied this methodology for two forested domains in Poland, with a distinction into coniferous, deciduous and mixed forests. Selected domains are characterized by different localization, air pollution pressure, meteorological conditions, soil and forest type and current forest health condition (Fig. 86).

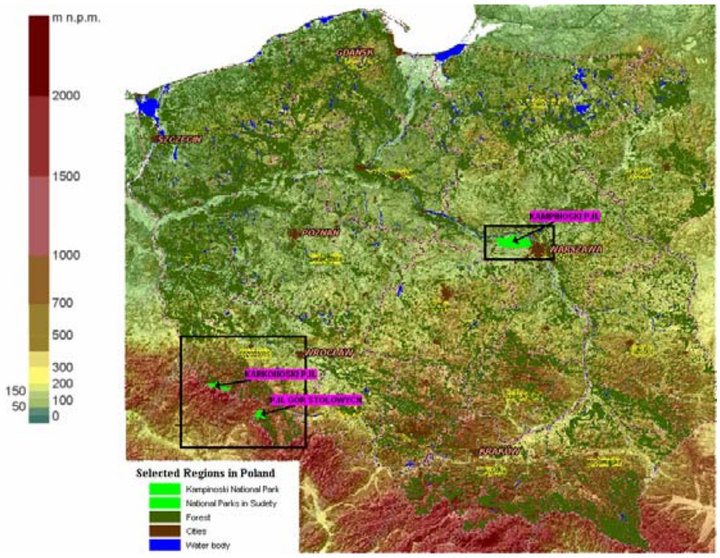

__Figure 86.__ The area of Poland with chosen domains and National Parks considered in the study.

The first domain, referred as Karkonosze domain, is situated in the mountain climatic zone of west-southern part of Poland and belongs to the Sudety natural-forest region. The region represents a great ecological value and is protected by two Polish National Parks (NP): Karkonoski NP and NP of Stolowe Mountains. The second domain, referred as Kampinos domain, is situated in central part of Poland and belongs to the Mazowsze-Podlasie natural-forest region. The unique feature of that region is localization of Kampinoski NP in the vicinity of Warsaw agglomeration. The coniferous forests prevail in both domains.

Climate scenario and control data was produced by WP2 of the CECILIA project. We used output of RegCM (CUNI) simulations performed in fine resolution of 10 x 10 km. For assessing climate change impacts on critical loads exceedances, deposition fluxes of S and N were calculated at WUT with coupled regional climate-air quality RegCM (WUT)-CAMx modeling system. According to the RegCM (CUNI) simulations for control period (1961-1990) and two future periods (2021-2050 and 2071-2100), with bias correction applied to precipitation data, the Karkonosze domain, situated in the mountain area, is characterized by lower average temperature and higher precipitation sum than Kampinos domain situated in lowland area of central Poland. The average temperature during control period oscillates around 8°C in Kampinos domain and around 6.5°C in Karkonosze. The average annual precipitation oscillates around 550 mm in Kampinos and around 780 mm in Karkonosze. The most intensive climate changes in both domains are expected in the period 2021 - 2050. Within the entire period (1961-2100) combined from the three particular thirty years periods, the estimated increase in temperature amounts to 3.6°C (Kampinos) and to 3.7°C (Karkonosze). Estimated increase in annual precipitation amounts to 68 mm (Kampinos) and to 79 mm (Karkonosze).

Calculation of present CL show that in average the Kampinos NP with its lower range of $CL_{nut}(N)$ and $CL_{max}(S)$ is more sensitive to nutrient N deposition and acidifying S and N depositions, and therefore more vulnerable to eutrophication and acidification than the NP from Karkonosze domain. The above reported changes in temperature and precipitation modified the present CL. Figs. 87, 88 show the changes of CL in selected domains during the considered periods.

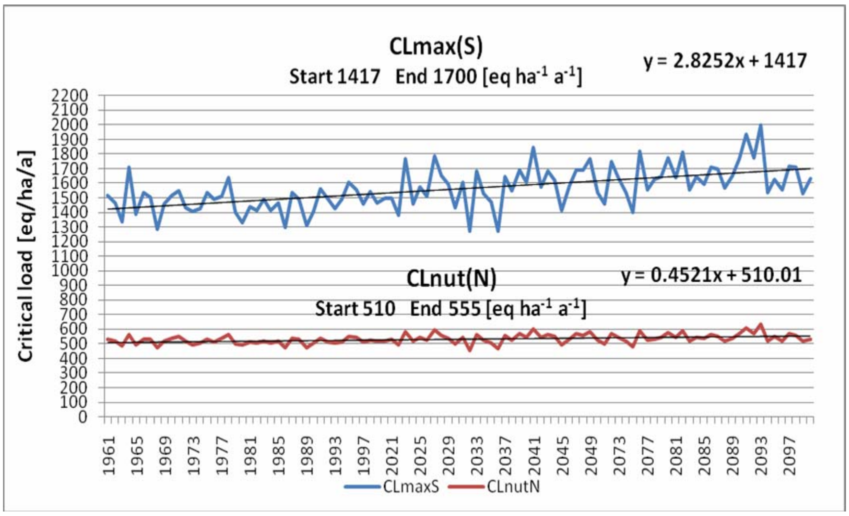

Figure 87. *Changes in critical loads ($CL_{max}(S)$ and $CL_{nut}(N)$) [eq ha^{-1} a^{-1}] between 1961 and 2100 in Kampinos domain. Within the entire 1961 - 2100 period a linear continuity was assumed.*

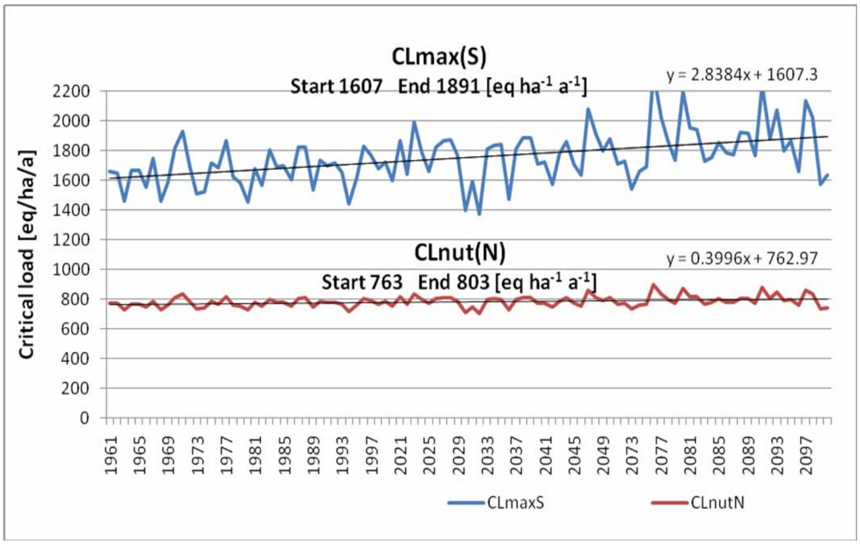

Figure 88. *Changes in critical loads ($CL_{max}(S)$ and $CL_{nut}(N)$) [eq ha^{-1} a^{-1}] between 1961 and 2100 in Karkonosze NP domain. Within the entire 1961 - 2100 period a linear continuity was assumed.*

In case of the Kampinos domain the increase in CL_{max}(S) will amount to 283 eq ha^{-1}a^{-1}and for CL_{nut}(N) the increase will be much lower reaching just 45 eq ha^{-1}a^{-1}. For the same time span, extending from 1961 to 2100 in the Karkonosze domain the CL_{max}(S) values are expected to increase also by about 300 eq ha^{-1}a^{-1} while the CL_{nut}(N) values by 40 eq ha^{-1}a^{-1}. The apparently lower level of changes of CL_{nut}(N) in the both studied areas is resulting from their dependence on precipitation changes only. The above reported increases of critical loads mean, in terms of ecological effects, an enhancement of tolerance of the terrestrial ecosystems, residing in both selected domains, to acidifying and eutrophying depositions. Thus, the predicted raise in temperature and precipitation result in a protective effect for the considered ecosystems.

According to the RegCM(WUT)-CAMx simulations for extended control period (1991-2000) and two future decades (2041-2050 and 2091-2100) the estimated trend of S and N depositions in the entire analyzed period in Karkonosze domain is an upward one. For Kampinos domain, the increasing trend was predicted for N deposition, and decreasing trend for S deposition. However, deposition of S in Karkonosze had significantly lower value in the beginning of analyzed period

(369 eq $ha^{-1}a^{-1}$ in 1991) compared to Kampinos (574 eq $ha^{-1}a^{-1}$). The same can be noted for N deposition in 1991: 694 eq $ha^{-1}a^{-1}$ in Karkonosze compared to 816 eq $ha^{-1}a^{-1}$ in Kampinos.

No significant changes in the exceedance of $CL_{max}(S)$ were found for both domains within the three considered decades. There are two factors liable for this, on one hand the drop in S deposition in Kampinos and small increase in Karkonosze and on the other hand a much stronger quantitative increase in $CL_{max}(S)$ values in both domains. The development of the resulting exceedances of $CL_{nut}(N)$ within the studied time span and the both studied areas was noticeably. The direct reason for this increasing trend is the constantly growing trend in N deposition, weakly compensated by the minor changes of $CL_{nut}(N)$. However, without this increase of CLs, their exceedances would be higher. Figs. 89, 90 show the changes in exceedances of $CL_{nut}(N)$ induced by climate changes in both domains throughout the entire 1991-2100 period.

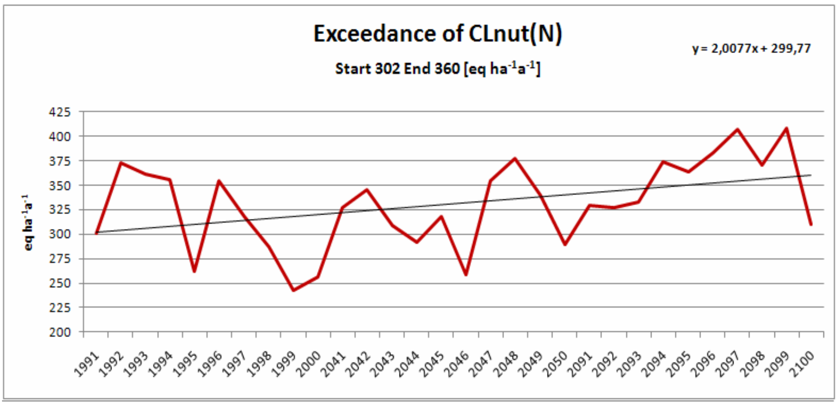

Figure 89. *Changes in exceedances of $CL_{nut}(N)$ [eq ha^{-1} a^{-1}] between 1991 and 2100 in Kampinos domain. Within the entire 1991 - 2100 period a linear continuity was assumed.*

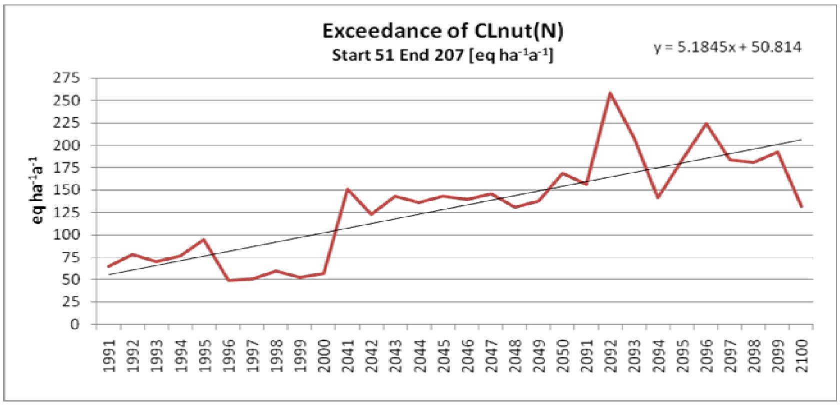

Figure 90. *Changes in exceedances of $CL_{nut}(N)$ [eq ha^{-1} a^{-1}] between 1991 and 2100 in Karkonosze domain. Within the entire 1991 - 2100 period a linear continuity was assumed.*

In ecological terms the effect of climate changes on the ecosystem protection against eutrophication caused by excess deposition of nitrogen is negative for the structure and functioning of the ecosystems existing in the both domains and National Parks residing within them. The main risk which potentially may result from the permanent nutrient nitrogen critical load exceedance is the loss of biodiversity in the present species constitution of ecosystems. The trends of changes of critical loads and their exceedances induced by climate changes, derived in this studies, reflect with a fair approximation the national and European evolution of sulphur and nitrogen deposition effects to ecosystems. Results of this study should contribute to the scientific effort underpinning the negotiations the Gothenburg Protocol of the Convention on Long-Range Transboundary Air Pollution.

2.6.2.7 NIMH

Various climate change scenarios were applied during the last part of the CECILIA project. Those simulated from the HadCM3 model show significant summer warming in the western Balkan countries and Spain projected for 2080. Air temperatures during this time of the year are expected to increase between 5^o and 8^oC over some of the countries in the southern European region. Although several uncertainties in relation to future precipitation exist, the HadCM3 model shows precipitation slight increases during the winter and precipitation reductions during the summer in the region of the Central Europe. Summer precipitation is projected to decrease also into the Eastern Europe. For example, in some areas in Romania its reduction would be up to 50% in 2080. In North Europe summer precipitation is expected to increase.

All HadCM3 climate change scenarios used in the RoIMPEL crop simulation model projected a shorter vegetative and reproductive growing season for maize and winter wheat during the 21^{st} century. These changes were caused by the predicted temperature increase of the climate change scenarios. Maturity dates for maize are expected to occur between 10 days and 30 days earlier in the 2050s. The climate change scenarios for the 2080s projected a decrease in maize growing season by 15 to 40 days. This will cause a shift in harvest maturity dates for maize in southern Europe from September to August at the end of the 21^{st} century. Winter wheat showed a decrease in growing season duration for the 2020s, varying between 3 days and 10 days. The transient HadCM3 climate change scenarios predicted that harvest for winter wheat would be approximately one to two weeks earlier in the 2050s, and between two to three weeks earlier in the 2080s.

The yield changes of winter wheat and maize in Central and Eastern Europe show different trends depending on the latitude, altitude, soil properties as well as the time slices during the current century (Figs. 91, 92). Significant increases in winter wheat yield are projected for the 21^{st} century in the northern and central European countries with slight decreases/increases in the Mediterranean region. The major cause for this change in impact is that many crops, such as wheat belong to the group of C_3 crops, which are more sensitive to changes in CO_2 concentration than the group of C_4 crop, such as maize. Crop yield decreases in southern Europe (e.g. areas in Romania and Bulgaria) would be observed for spring-sown crops such as maize. This crop is likely, therefore, to move to north or to higher altitude areas in the south.

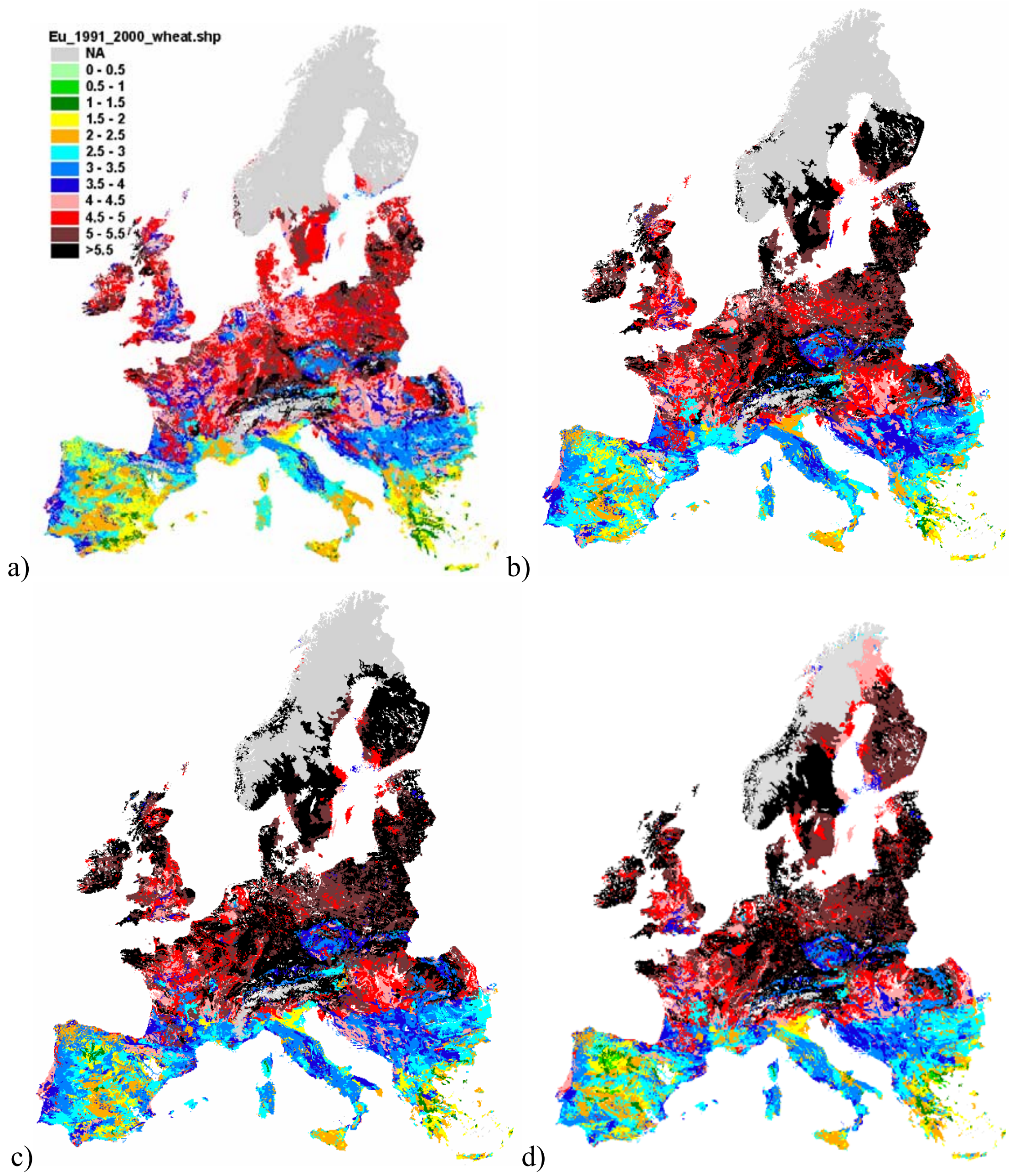

Figure 91. *Winter wheat yield (in t/ha) under recent climate conditions (a: 1991-2000) and HadCM3 A2 climate change scenarios for the 21st century (b: 2011-2020; c: 2041-2050; d: 2071-2080)*

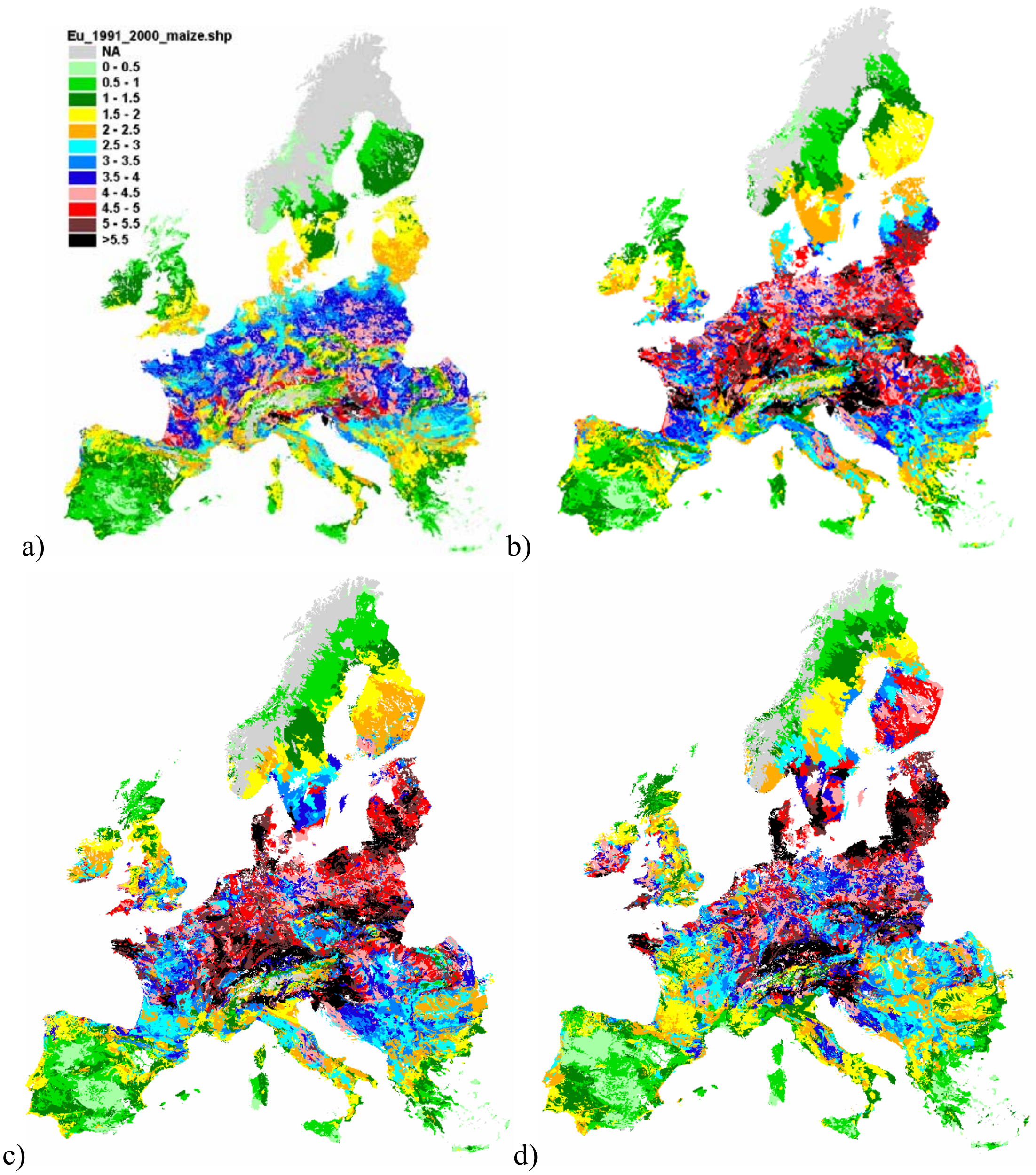

Figure 92. *Maize yield (in t/ha) under recent climate conditions (a: 1991-2000) and HadCM3 A2 climate change scenarios for the 21st century (b: 2011-2020; c: 2041-2050; d: 2071-2080)*

In a second case study it was found that as a result of expected warming crop-growing duration of sunflower over the Balkan Peninsula is projected to decrease, especially at the end of the 21st century The yield changes in the selected region show different trends depending on the latitude, altitude, soil properties as well as the time slices during the current century (Fig. 93).

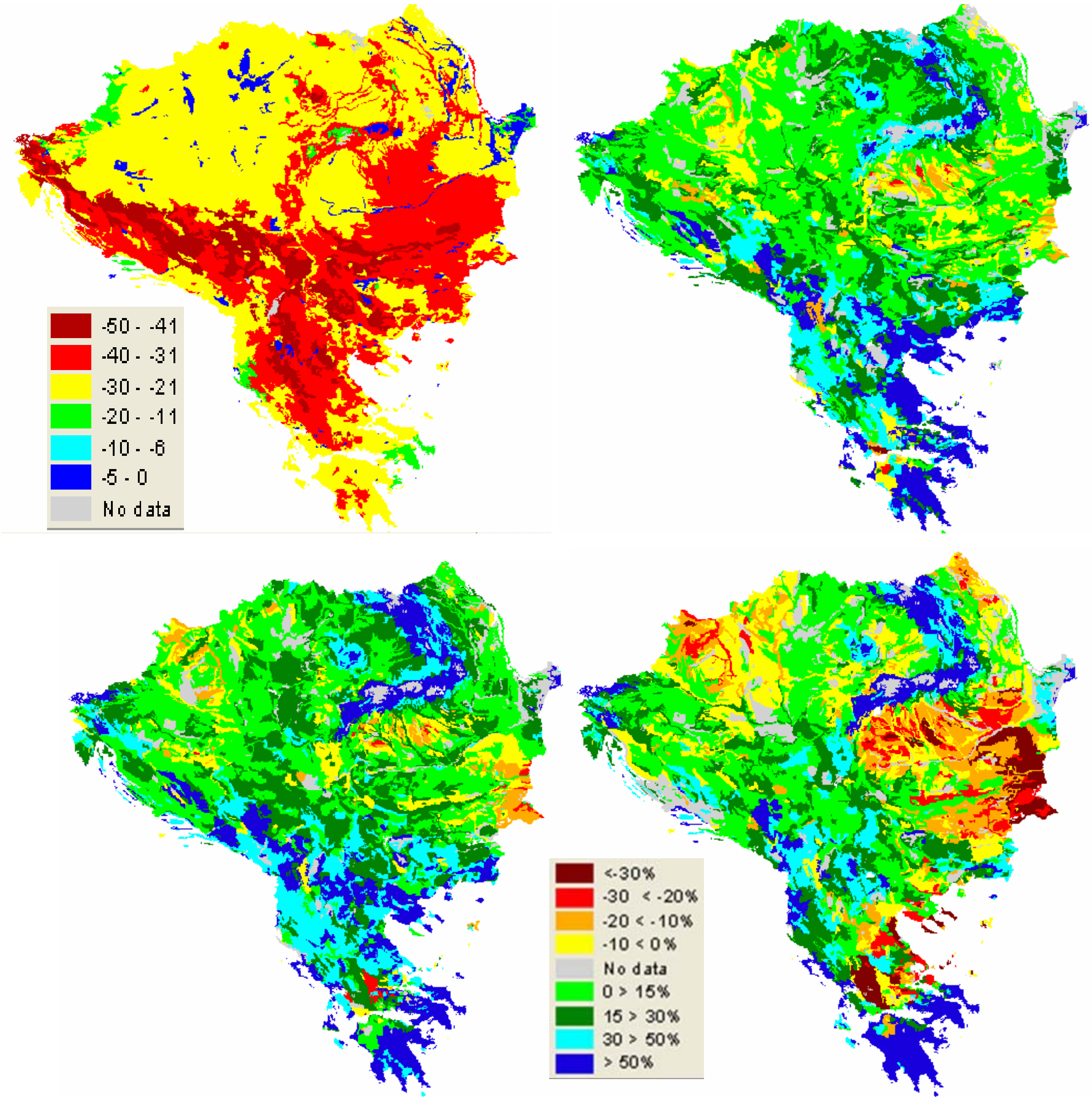

Figure 93. *HadCM3 B2 changes for the Balkan Peninsula of sunflower growing duration (upper left, in days, 2071-2080 relative to current climate) and in in sunflower yield (in %) for 2011-2020 (upper right), 2041-2050 (bottom left) and for 2071- 2080 (bottom right), relative to current climate; RoIMPEL model.*

More detailed analysis for Bulgarian region was performed. The soil classification showing the local conditions is presented in Fig. 94. In Fig. 95 the development of winter wheat yields based on the climate change scenarios from HADCM3 are compared for two scenarios A2 and B2 as well as for several time slices of this century. All the results show that during the climate change in Bulgaria in the 21st century, most vulnerable will be: a) spring agricultural crops, due to the expected precipitation deficit during the warm half-year; b) crops cultivated on infertile soils; c) crops on non-irrigated areas; d) arable lands in south-east Bulgaria where even during the present climate, precipitation quantities are insufficient for normal growth, vegetation and productivity of agricultural crops.

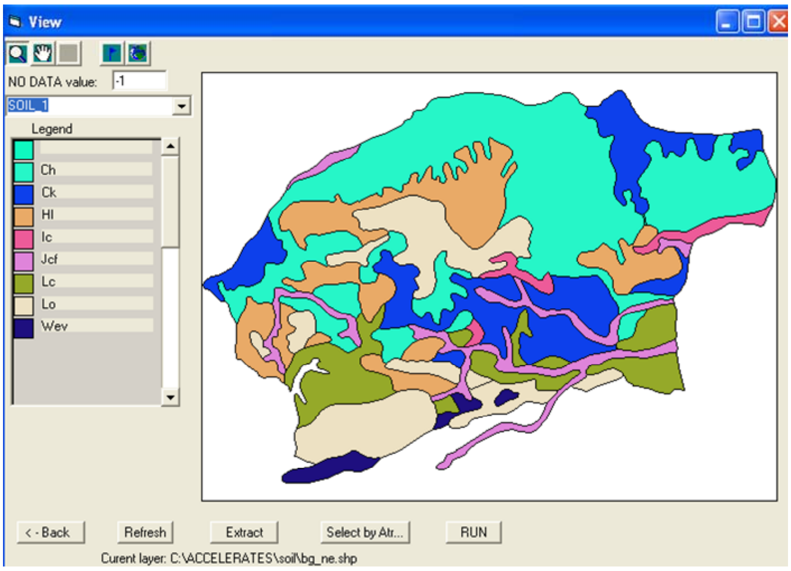

Figure 94. *Soil classification for Bulgaria.*

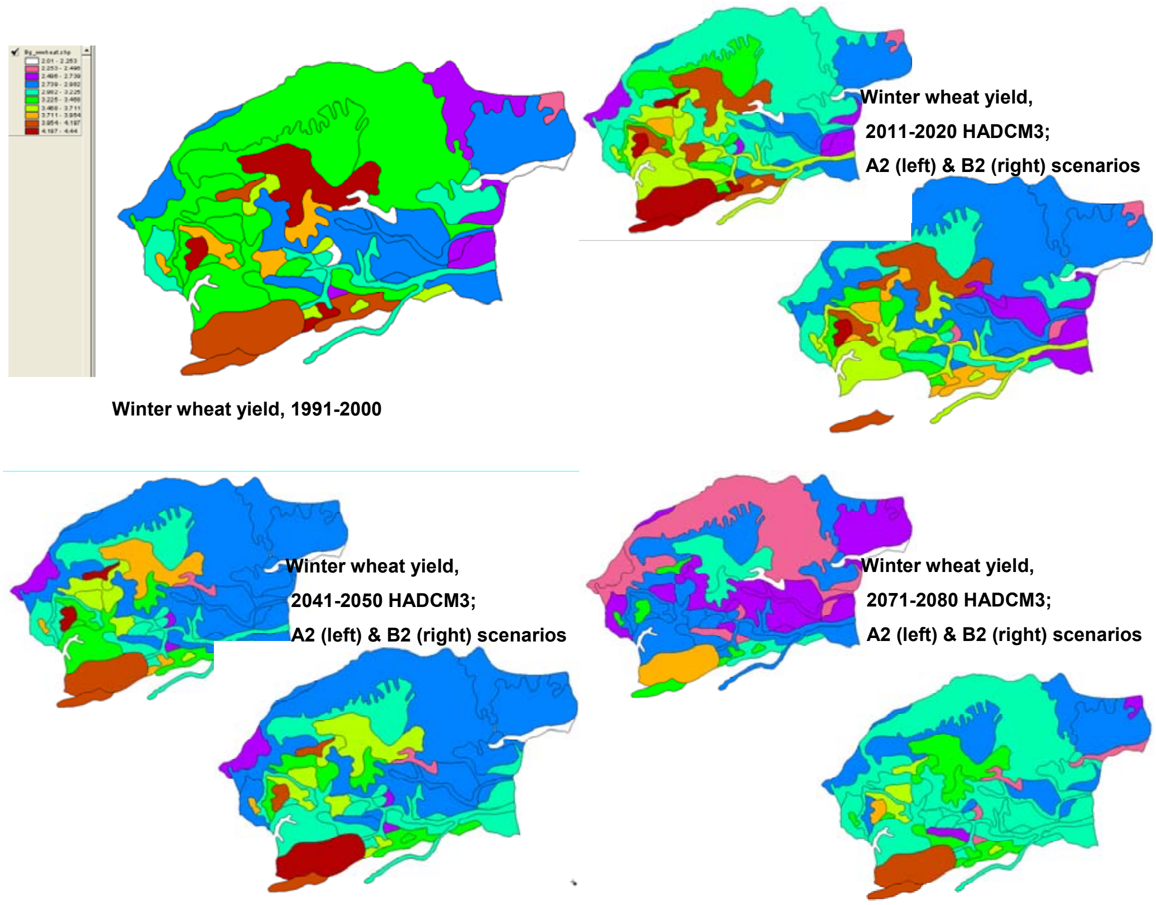

Figure 95. *Winter wheat yield based on HADCM3, A2 and B2 scenarios comparison for 2011-2020 (upper right), 2041-2050 (bottom left) and for 2071-2080 (bottom right).*

Important issue of climate change impacts in crop production are adaptation measures in agriculture. In connection to WP5 assessment, improving measures towards the irrigation under climate change conditions. Main options are

- improvement of management, use and protection of water resources in irrigated agriculture;
- improving the efficiency of the management and use of the existing irrigation facilities and elaboration of the technological and technical facilities for irrigation;
- use of rational and economically sound irrigation regimes for the irrigated crops and elaboration of the technologies for cultivation of crops in the conditions of droughts and water deficit.

Measures for management improvement, use and protection of water resources in irrigated agriculture consist of

- establishing the impact of climate changes and drought on the quantity and quality of water resources used in irrigated agriculture;
- assessing the needs of water for irrigation of agricultural crops under climate changes and preparing long term projections for the required water resources to be used in agriculture
- determination the optimal dates and water quantity for irrigation of the maize for various climate scenarios are carried out in NIMH, using computer system for agrotechnological decision taking DSSAT. The calculations are taken in regard to biophysical and economic analysis of the final yield and the received profit from the maize
- During limited precipitation in summer, irrigation facilities must be used, oriented towards design and operation of irrigation facilities, which use water resources in an economical way and have very low water transportation losses during irrigation.
- Gravitee feed irrigation and flooding of beds and rice fields should be used as a last resort, only when proven to be effective.
- Main and distribution canals of old irrigation systems must be coated to bring to minimum losses from filtration. Permanent canals in irrigation systems must be afforested on sufferance strips to utilize filtered water and to cover them aiming at the reduction of the physical evaporation from water surface in the canals

For adaptation measures to improve management efficiency and use of existing irrigation systems and elaboration of technological and technical means for irrigation following steps could be done

- To prepare up-to-date strategy and new program for the rehabilitation and restructuring of irrigation management and improving the efficiency of use of the existing irrigation infrastructure;
- To change legislation and regulation in the irrigation sector taking into consideration the altered agricultural conditions, the experience from the reforms carried out so far and to ask for free use of the technologically established hydromeliorative infrastructure and service facilities on the territory of the associations;
- To implement proper educational and training programs with emphasis on major issues on the involvement of users of water and the general public on drought problems;
- Preparation of information materials for water users on the benefits and good practices of agricultural crop irrigation.

Measures for adaptation to use of rational and economically viable irrigation regimes include

- Determining the vulnerability of agricultural crops under climate changes, long term droughts and water deficit in the major agroclimatic regions in the country, respectively their impact on the quantity and quality of the yield from them;
- Reassessment of the water and irrigation norms and legislative provisions of irrigation, new zoning for the irrigated crops in the country;
- Development and application of optimized irrigation regimes for the major agricultural crops for various agroclimatic regions in the country;
- Research on the effect from irrigation and sustainability of yields under various water saving methods and irrigation technologies;
- Creation and application of mineral fertilization systems and integrated weed fight during cultivation of agricultural crops under irrigation conditions;
- Application of proper moisture preserving technologies and techniques for soil treatment in irrigated lands;
- Adaptation and introduction in practice of information and advisory system for irrigation necessity forecast and defining the parameters of the irrigation regime for the irrigated crops;
- Technology changes for irrigated crop cultivation in various agroclimatic regions under water shortage conditions;
- Use of new cultivars and hybrids that adapt better to water deficit.

Example of measures on irrigation management is shown for the case study of maize crop irrigation under climate change in Bulgaria. The DSSAT Seasonal Analysis program was run in order to determine the most appropriate timing and water amount of irrigation applications under the expected climate change during the growing season of maize. Both biophysical and economic analyses were done. The strategic analysis was done in respect to the simulated value of harvest maize yield and net return. The tested treatments of the irrigated numerical experiment assumed maize growth and development under rainfed conditions, different date(s) and water amount of irrigation. In a similar way, the economic analysis of the Seasonal Analysis computer program calculates means, standard deviations, maxima and minima of the economic returns, and plots these as box plots, cumulative function plots, or mean-variance diagrams. Formal strategy evaluation of all treatments is carried out using mean-Gini stochastic dominance. In contrast to the biophysical analysis returns per hectare of the 6th treatment are lower than returns of the 4th and 5th treatments due to more water being applied. By running the "Strategy Analysis" option of the Seasonal Analysis program, the mean-Gini dominant treatment of the irrigated experiment can be calculated, in terms of the costs and prices used to analyze it. Actually, the dominant treatment was the 5th treatment - 40 mm water applied per every day (total 3 days) of irrigation.

One domain of recommended and feasible adaptation options are changes in irrigation. It was already mentioned adaptation in agriculture to a changing climate will occur in several forms, including for example technical innovations, changes in agricultural land areas, and changes in use of irrigation. As the climate warms there will likely be shifts toward greater use of irrigation systems to grow crops in Bulgaria. It is considered that available soil moisture for maize crop cultivation in the country is insufficient for normal crop growth even under current climate. Many farming technologies, such as efficient irrigation systems, provide opportunities to reduce direct dependence on natural factors such as precipitation and runoff. Improvements allow greater flexibility by reducing water consumption without reducing crop yields. The use of more efficient irrigation systems can be expected due to the need for tighter water management practices in order to counter increased demand. Water losses through seepage and evaporation in canal and flood irrigation systems can be minimized by lining the canals with cement or switching to pipe irrigation systems. The significantly higher costs of production related to irrigation systems will most likely result in shifts to less water demanding uses in areas where there are higher rates of moisture loss. Using more groundwater for crop irrigation is also a perspective way. First of all, however, the irrigation systems available till 1990s should be restored in the country.

Another adaptation option can be in changes in sowing dates. The sowing dates of crops in Bulgaria would shift under the GCM climate change scenarios in order to reduce the yield loss caused by an increase in temperature. The selection of an earlier sowing date for maize will probably be the appropriate response to an increase in temperature. This change in planting date will allow the crop to develop during a period of the year with cooler temperatures, thereby increasing the growth duration, especially the grain filling period. The simulation results show that the sowing date of maize in experimental station Carev brod (Northeast Bulgaria) should occur at least 2 weeks earlier in the 2080s under the ALADIN scenario, relative to the current climate conditions. It should be noted, however, that although changes in sowing date are a non-cost decision that can be taken at the farm-level, a large shift in sowing dates probably would interfere with the agrotechnological management and other crops, grown during the remainder of the year.

One more option to adapt to climate change impacts in agriculture can provide changes in crop cultivars and varieties. Crop diversification allows farmers to cope with climate variation from year to year. This type of adaptation will likely occur at the farm system level. Switching from monocultures, which are more vulnerable to climate change, pest and diseases to more diversified agricultural production systems will also help farmers in coping with changing climatic conditions. Seed banks that maintain a variety of seed types provide an opportunity for farmers to diversify to counter the threat of climate change or to develop a profitable specialization. Another option for adaptation is to use different hybrids and cultivars. There is an opportunity for cultivation of more productive, later or earlier-maturing, disease- and pest-tolerant hybrids and cultivars. Switching from maize hybrids with a long to a short or very short growing season projected an additional decrease of final yield under an eventual warming in Bulgaria. However, using hybrids with a medium growing season, would be beneficial for maize productivity. The expected thermal and humid conditions in Bulgaria will permit to vary the assortment of many fruit and vegetable crops. Grape and fig production is expected to increase in the future. The climate in South Bulgaria is influenced by the Mediterranean. Warming may cause natural northward shift of some agricultural crops and trees grown in the upper areas of neighboring countries such as Greece and Turkey. Technological innovations, including the development of new crop hybrids and cultivars that may be bred to better match the changing climate, are considered as a promising adaptation strategy. However, the cost of these innovations is still unclear.

Last measure discussed here is new crop zoning, i.e. move of location of production of individual crops. The greatest part of the national wheat and maize production under the current climate is concentrated in the areas with elevation below 800 m. New zoning of crop cereal production in agricultural land areas with elevation below 1000 m due to expected warming can be proposed. In this case, the agricultural land area for cultivation of cereal crops will increase approximately by 50, 000 ha.

2.6.3 Deviations from workprogramme

There have been no significant departures from the workprogram during the last reporting period except the consequencies of the delay of CECILIA high resolution simulations. Finally, some application of these more detailed results of climate change signal were performed within the extension of the project and some previous results of climate change impact assessment in agriculture and forestry were successfully updated.

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2.7 WP 7

2.7.1 Workpackage objectives

The main objective of WP7 was to analyse the interaction between climate change and air quality by simulations of present and future air pollution levels and loads in the target regions on Central Eastern Europe. Particulate matter (PM) and ozone, which are priority species regarding human health as well as sulfur dioxide and nitrogen dioxide, having complex impacts on the human health and the ecosystems, were chosen as key species.

The concentration of air pollutants depends on anthropogenic, geophysical and climatic factors. Climate change may affect exposures to air pollutants by many ways. The health effects of air pollution are broad and diverse, including dramatic episodes of increased mortality at high concentrations. According to current knowledge, among air pollutants, PM and ozone have the stronger health impacts. The pulmonary absorption and deposition of inhaled pollutants can have direct consequences for health. Public health can also be indirectly affected by deposition of air pollutants in environmental media and uptake by plants and animals, resulting in chemicals entering the food chain or being present in drinking-water and thereby constituting additional sources of human exposure (e.g. heavy metals, PAHs). Furthermore, the direct effects of air pollutants on plants, animals and soil can influence the structure and function of ecosystems, including their self-regulation ability, thereby affecting the quality of life (WHO, 2000). The most sensitive groups include children, older adults and persons with chronic heart or lung disease.

The individual tasks of the WP7 were defined by DoW:

- Exploitation of the sensitivity of air-pollution levels to potential climate change based on data analysis of long simulations of offline chemistry air quality models (AQM) driven by Regional Climate Models (RCMs) for present climate and for future projections.
- Comparison of air-pollution levels simulated by online and offline regional air-quality models during certain episodes of the present climate.
- Estimation of the key species exceedances of the EU limits for the protection of human health, vegetation and ecosystems as well as WHO guidelines for present climate and for future projections.

Six participants from five countries, i.e.: WUT from Poland (WP leader), CUNI and CHMI from Czech Republic, AUTH from Greece, BOKU from Austria and NIMH from Bulgaria are involved in WP7 activities.

To study climate effects on air quality, coupling of regional climate models with atmospheric chemistry/aerosols models is required. At the beginning of the 3rd reporting period modeling tools, i.e. the couple of RCM and CTM was prepared at CUNI, BOKU and NIMH, getting ready at WUT finally in addition to original plan use supplied driving fields from climate simulations. The couples were already tested and validated in the second reporting period for use in Air Quality (AQ) modeling in the targeted areas of the CECILIA project for their further tasks, in particular the high resolution simulations (10x10 km) for present day climate and future climate projection.

2.7.2 Progress towards objectives

For the third reporting period WP7 main objectives was written in its:

- **Deliverable D7.3**, i.e.*: Key species concentrations files from higher resolution runs (10x10 km) for specific smaller domains in Central Eastern Europe for control run and future projection.* That Deliverable, led by CUNI, was completed and submitted in 43rd month of the project.
- **Deliverable D7.4**, i.e.*: Analysis and evaluation of the results, comparison of the higher resolution runs (10x10) with the lower resolution runs (50x50) for the specific domain.* That Deliverable, led by CUNI, was completed and submitted in 43rd month of the project.
- **Deliverable D7.5**, i.e.*: Present and future key species exceedances of the EU limits and WHO guidelines, health effects.* That Deliverable, led by WUT, was completed and submitted in 43rd month of the project.
- **Milestone M7.4**, i.e.: *Simulations of the offline AQMs driven by RCM for a specific smaller domains in Central Eastern Europe with 10 x 10 grid resolution*. That Milestone, led by CUNI was completed as a preparation work for D7.3.
- **Milestone M7.5**, i.e.: *Results from the analysis of the output of the simulations of the offline chemistry AQMs driven by RCM for Europe with 50x50 grid resolution*. That Milestone, led by CUNI was completed as a preparation work for D7.4.

- **Milestone M7.6**, i.e.: *Results from the analysis of the output of the simulations of the offline chemistry AQMs driven by RCM for specific smaller domains in Central Eastern Europe with 10x10 grid resolution*. That Milestone, led by CUNI was completed as a preparation work for D7.4.
- **Milestone M7.7**, i.e.: *Results from the calculations of present and future key species exceedances of the EU limits and WHO guidelines for a specific smaller domains in Central Eastern Europe with 10x10 grid resolution*. That Milestone, led by WUT was completed as a preparation work for D7.5.

During 3rd reporting period Regional Climate Models coupled to Air Quality Models have been applied for high resolution (10 km x 10 km) photochemical runs in the targeted areas of CECILIA project, namely: CUNI domain (Central-Eastern Europe), WUT domain (Poland), BOKU domain (Pannonian countries) and NIMH domain (Bulgaria). The majority of partners (BOKU, CUNI and WUT) used RegCM3(Beta)-CAMx modelling system driven by ECHAM5 Global Climate Model outputs under A1B scenario of IPCC. NIMH used ALADIN-CMAQ modelling system driven by ARPEGE Global Climate Model outputs.

Under **Deliverable D7.3** the simulations of RCM were used to drive offline the air quality models for the four decadal time slices:

- The present day decade, 1991-2000, for the validation of the modeling system, RCM driven by the ERA-40 meteorological fields.
- The present day decade, 1991-2000, the so-called control run, using lateral boundaries for RCM the meteorological fields from GCM model.
- The near future (mid-century) decade, 2041-2050, for investigating the mid-century climate response, RCM simulations driven by the meteorological fields from GCM model.
- The far future (end-century) decade, 2091-2100, for investigating the end-century climate response, using as lateral boundaries for RCM the meteorological fields from GCM model.

Key species concentrations: O_3, NO_2, PM_{10}, $PM_{2.5}$ and SO_2, as well as depositions of SO_x, NO_x and NH_x from high resolution runs for present climate and for future projection have been completed and results are discussed in partners contributions.

Within **Deliverable D7.4** the final validation assessment as well as the comparison of the driving runs at 50 km resolution and at 10 km resolution for selected domains have been performed. For this purposes, in the course of the work for previous deliverables, the guidelines for such an validation and results analysis has been prepared (see D7.4 Appendix), which can be basically used for inter-comparisons between the model realizations both comparing the model performance at different scales and for different periods of simulations as well.

For the fulfilling the objectives of **Deliverable D7.5**, we applied WHO non-binding air quality guidelines for Europe (WHO, 2000, 2005), as well as legally binding standards for ambient air pollutants set in the framework of EU legislation (EC, 2008), namely limit values for protection of human health and critical levels for protection of vegetation. For ozone the accumulated ozone exposure values over a certain threshold (AOT) were applied. AOT40 values were calculated for the period April to September ($AOT40_f$), which is considered as a measure for the impact of ozone on forests and for the period May to July ($AOT40_c$), which is considered as a measure for the impact of ozone on crops. The sum of the differences between the hourly mean ozone concentration (in ppb) and 40 ppb for each hour when the concentration exceeds 40 ppb, accumulated between 8:00 and 20:00 hours (CET) during the period is calculated. The exceedances were calculated as the non-negative differences between the limit values/critical levels/air quality guidelines and the average concentrations for the present day and the end-century decades.

For assessing possible health effects, the case study for Poland was performed. We estimated the adverse health effects caused by $PM_{2.5}$ air pollution for present day decade as well as for both future decades.

The high (10 km x 10 km) resolution simulations for the specific domains have been performed with Regional Climate Models (RCM) coupled to Air Quality Models (AQM). The majority of partners (AUTH, BOKU, CUNI and WUT) used RegCM3-CAMx modelling system driven by ECHAM5 Global Climate Model outputs. The model RegCM was originally developed and further improved by Giorgi et al. (1999). For more details on the use of the model see Elguindi at al. (2006). For targeted domains simulation the improved version of RegCM3 for high resolution use – RegCM3-Beta with high resolution precipitation bug corrected (Pal et al., 2007) was used.

Meteorological fields generated by RegCM drive CAMx transport, chemistry and dry/wet deposition. A preprocessor utility was developed which takes RegCM's outputs and convert them to fields and formats accepted by CAMx. Biogenic emissions of isopren and monoterpenes are calculated as a function of 2m temperature, global radiation and land-use by Guenther et al. (1993,1994). The same horizontal modelling grids with Lambert map projection were used for RegCM and CAMx models. In vertical, 18/23 vertical σ-levels, were used in RegCM3. Chemical initial and boundary conditions are taken from 50 km resolution run for whole Europe by Krueger et al. (2008) or Katragkou et al. (2009).

CAMx is a complex third-generation Eulerian Grid Model developed at ENVIRON International Corporation (ENVIRON, 2006). Simulations have been carried out using CAMx v. 4.40. It uses mass conservative and consistent transport numerics in parallel processing. It allows for integrated "one-atmosphere" assessments of gaseous and particulate air pollution over many scales ranging from sub-urban to continental. CAMx simulates the emission, dispersion, chemical reactions and removal of pollutants in the troposphere by solving the pollutant continuity equation for each chemical species on a system of nested three-dimensional grids. The chemistry mechanism invoked was Carbon Bond version 4 (Gery et al., 1989), including 117 reactions – 11 of which are photolytic – and up to 67 species (37 state gases, up to 18 state particulates and 12 radicals). The domain's vertical profile contained 12 layers of varying thickness, extending up to 450 hPa.

NIMH used ALADIN RCM coupled to CMAQ modelling system from US EPA. ALADIN-CMAQ was driven by ARPEGE Global Climate Model outputs (for detailed description see 2.1.2.5 NIMH).

In order to study exclusively climate impacts on air quality, the anthropogenic emission were kept constant at the values of year 2000 for all time slices. Emission database for 50 km resolution runs is based on the UNECE/EMEP database (http://webdab.emep.int/). The detailed explanation of emission database preparation for 50 km runs is given by Krüger et al. (2008). For targeted domains 10 km simulations, emission database for seven pollutants PM_{10}, $PM_{2.5}$, SO_2, NO_x, NH_3, CO and NMVOC (VOC) have been prepared.

For BOKU and CUNI domains, as well as for part of WUT domain excluding Poland, emissions were calculated with the emission model of BOKU-Met based on data from the UNECE/EMEP database for the year 2000, available in 50 km x 50 km EMEP grid resolution. For the Pannonian countries (Austria, Czech Republic, Hungary, and Slovakia), a detailed 5 km x 5 km emissions inventory from the year 1995 (Winiwarter and Zueger, 1996) was used for the spatial distribution of the EMEP data. Area and point sources were treated as surface area emissions.

For Poland at WUT simulations, the emission model EMIL was developed for the CECILIA project, based on a detailed 1 km x 1 km emissions inventory of area and point sources for reference year 2000. For Large Combustion Plants (LCPs), with a stack height, $h \geq 100$ m, a detailed emission and stack parameters database was prepared. The created point sources database contains data for 220 stacks. Finally, area sources were treated as surface area emissions, while large point sources were simulated individually.

For NIMH simulations in Bulgarian region emissions were prepared by interface programs AEmis and PEmis. Input to them was TNO high resolution (0.25°x0.125°) inventory (Visschedijk and van der Gon, 2005). The inventory is produced by proper disaggregation of the EMEP 50-km inventory data base. GIS technology was applied to produce 10x10 km input to AEmis and PEmis. The TNO inventory is elaborated for Area Sources and Large Point Sources separately, distributed over 10 SNAPs (CORINAIR methodology). Large point sources are treated as area sources, but specific effective height of release is assigned to a given SNAP category. Finally, area sources were treated as surface area emissions, while for large point sources 3D emission file is produced with zero-values at the surface and non-zeros at the respective model levels.

2.7.2.1 BOKU

In addition to previous 50km full Europe simulations, at BOKU photochemical model runs with CAMx were performed with a spatial resolution of 10 km using the meteorological fields of RegCM3(Beta) performed at ELU for Panonia region. The configuration of CAMx was the same as for the 50 km-runs (Deliverable 7.2). The model had 12 vertical layers of varying thickness, extending up to 450 hPa. With a domain size of 118 by 98 cells, it covered Hungary, Slovakia, and Czech Republic as well as eastern Austria, southern Poland and western Romania within the area of interest of CECILIA.

As concentrations at the lateral boundaries hourly concentrations from the corresponding runs with the 50 km model were taken. Clean-air conditions were assumed at the model top. As in other runs of the project, the emissions for the year 2000 based on EMEP data with a spatial resolution of 50 km were taken for all calculated years in order to restrict differences between the decades to climate effects. For the countries Czech Republic, Austria, Slovakia, and Hungary, these emissions were distributed to a spatial resolution of 5 km.

High resolution calculations were made for three decades, namely 1991-2000 with RegCM-data driven by reanalysis ERA40 for the validation of the model, 1991-2000 with meteorological data driven by the GCM ECHAM as the control run, and for the end-century decade 2091-2100, also GCM-driven to investigate the climate response. The mid-century-decade 2041-2050 has only been calculated with 50 km resolution. Since differences in the results for ozone were small here, the calculation of this decade with 10 km resolution was skipped.

Fig. 96 shows the decadal average of the ozone volume mixing ratio for the summer season (JJA) for the control run in 10km resolution as well as the difference of this value calculated for the end-century decade. By the end of the century the seasonal ozone volume mixing ratio average increases in the whole model domain with a gradient of the difference ranging from about 5 ppb in the west to about 1 ppb in the east. This result agrees qualitatively and quantitatively with those found in the 50 km-resolution runs (Deliverable 7.2). Differences between the runs with high and low spatial resolution were investigated in Deliverable 7.4.

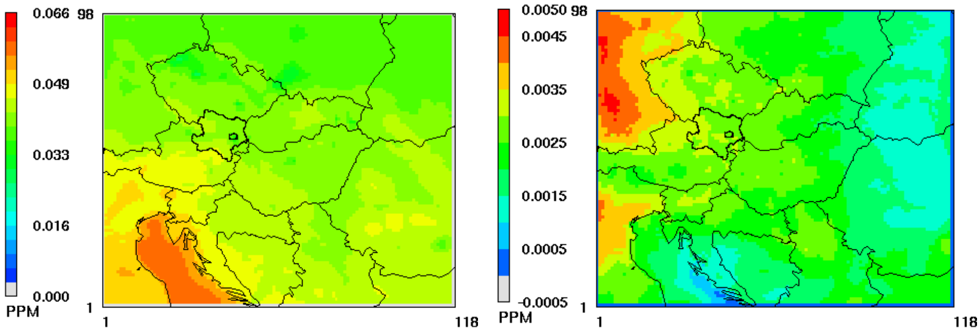


Figure 96. *Left: Decadal average (1991-2000) of the ozone volume mixing ratio in the summer season (JJA) from the control run in 10km resolution. Right: Difference in the ozone volume mixing ratio between the end-century run (2091-2100) and the control run.*

Within the CECILIA project at BOKU photochemical model runs with CAMx were performed for three decades with two different spatial resolution, namely 50 km and 10 km. For a direct comparison of the two resolutions, the 50 km results were interpolated to the grid of the high resolution runs. Fig. 97 displays the difference between the control-runs for the decadal average (1991-2000) in the average ozone volume mixing ratio in summer (JJA). In most of the model domain the ozone in the 10 km runs is slightly higher by less than 5 ppbv. In the urban centers Prague, Vienna, and Budapest a decrease is observed. The industrial centers in the south of Poland and the north of Czech Republic show a remarkable increase of ozone with increasing resolution in the west of these regions and a decrease in the east. At the Adriatic Sea there is a decrease along the west coast and an increase at the east coast. For the other two calculated decades very similar differences are found.

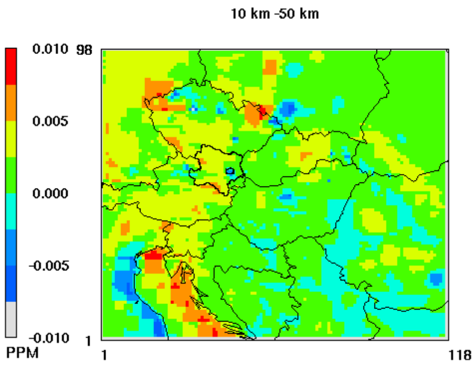


Figure 97. *Difference in the average ozone volume mixing ratio for the control decade (1991-2000), RegCM driven by ECHAM) in summer (JJA) between runs with 10 km and 50 km spatial resolution.*

If the response of the ozone concentration to a changing climate is compared between the model runs with different spatial resolution, the found absolute differences of ±2 ppbv are much smaller. Fig. 98 compares the change of the ozone volume mixing ratio between the decade at the end of the century (2091-2100) with the control decade (1991-2000) for the two spatial resolutions. With the 10 km resolution the climate response is somewhat less than with 50 km in most of the model domain except of the very north. However, the 10 km calculation shows an effect of the model boundary in the results, which might be a reason for this discrepancy.

It had been observed, that the solar radiation, which drives the photochemical production of ozone, was generally lower in the 10 km calculations made by BOKU than in the 50 km calculations. It was caused by a higher cloud water content in the 10 km-RegCM-results used. This might be a reason for the smaller climate response in the high-resolution runs. It certainly is the reason for the decrease of ozone in the urban areas, since the nightly titration of ozone by nitrogen oxides is not effected by photolysis. Therefore a higher resolution leads to higher NO_x-

concentrations at night near the emission sources and less ozone. On the other hand, an increase of urban plumes with high ozone concentrations due to higher spatial resolution of the model is not observed, since this depends on photochemistry.

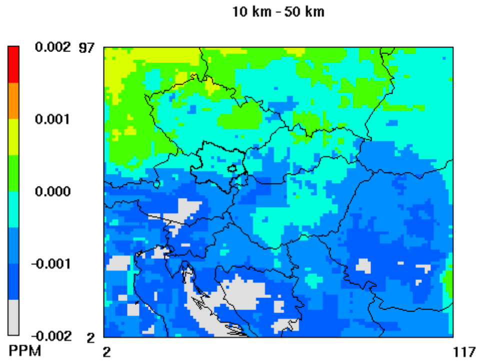


Figure 98. *Difference of the climate response in the seasonal ozone average between 10 km and 50 km spatial resolution model runs in summer (JJA).*

Also AOT40 values were calculated for the periods May to July ($AOT40_c$) and April to September ($AOT40_f$), which are considered as a measures for the impact of ozone on crops and on forests, respectively. It was compared, how the values for $AOT40_c$ (May-July) differ between the model runs with different spatial resolution. Again the data from the 50 km-run were interpolated to the 10 km-grid and the differences are displayed. Fig. 99 (left panel) shows the difference in the calculated average of $AOT40_c$ for the control period (1991-2000) between the two runs. The highest difference is found over the Adriatic Sea. The 10 km calculation also leads to higher $AOT40_c$ values over the mountains of the Alps and the Carpathians and over Italy and Western Croatia. Over Poland and Hungary the results of the two model calculations are very similar.

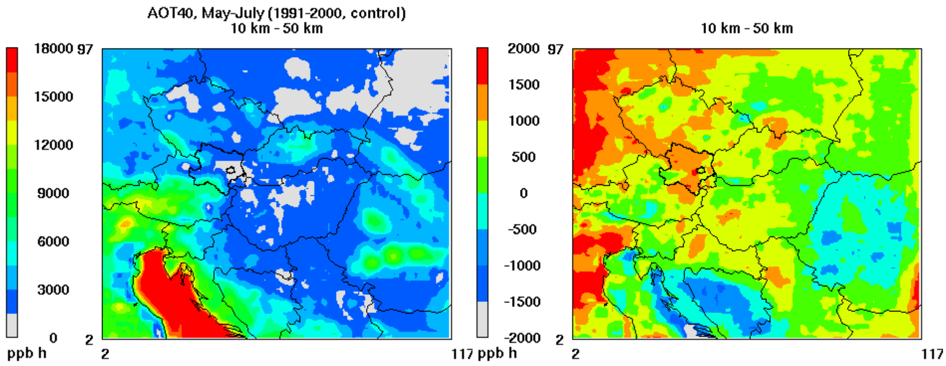


Figure 99. *Left: Difference of the decadal average of $AOT40_c$ (May-July) for the control period (1991-2000) between the model runs with 10 km and 50 km spatial resolution. Right: Difference of the decadal climate response (difference of 2091-2100 to 1991-2000) in $AOT40_c$ (May-July) between the model runs with 10 km and 50 km spatial resolution.*

The response to climate change differs much less between the model runs with different resolution. In Fig. 99 (right panel) the difference in the climate response (difference of 2091-2100 to 1991-2000 in $AOT40_c$, May to July) between the runs is displayed. In most of the domain the values are between +1000 ppb h and –1000 ppb h with negative values over Romania, Bosnia-Herzegovina and Western Croatia. Only at the western border of the domain the differences are higher, which might be caused partly by boundary effects of the high-resolution model.

It has been also investigated, how the EU critical level of 9 000 ppb h for the $AOT40_c$ value in the crops growing season May to July is exceeded in the model calculations. The data for the control period (1991-2000) and for the end-century decade (2091-2100) from the 50 km-runs are shown in Fig. 100.

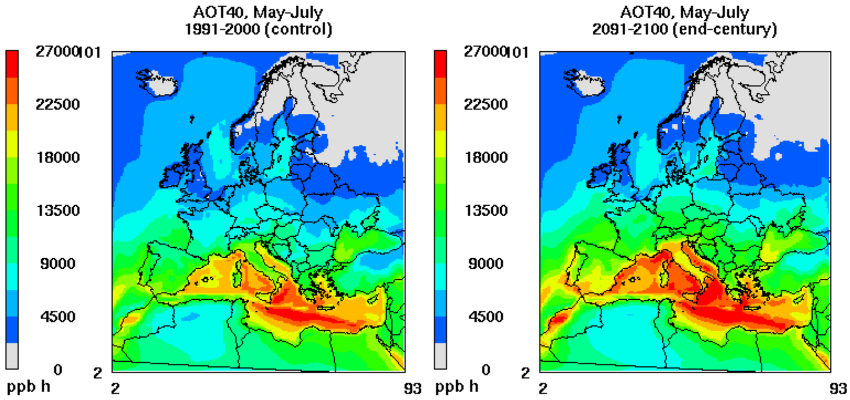


Figure 100. *Average of the AOT40$_c$ for May to July in the BOKU calculation with 50 km spatial resolution for the present decade 1991-2000 (left panel), and for the end-century decade 2091-2100 (right panel). Critical level for crops (EU), AOT40$_c$ = 9 000 ppb h.*

A gradient with lower values in the north and higher values in the south is observed. The highest values are found over the Mediterranean Sea. With climate change, the AOT40$_c$ values are increasing. The highest increase occurs in Northern Italy and over the Iberian Peninsula. With present day conditions (1991-2000) the critical level for crops (9 000 ppb h) is not exceeded north of the Alps and the Black Sea. In the calculation with future climate (2091-2100) the AOT40$_c$ values become higher and the limiting line of 9 000 ppb h is shifted to the north causing exceedances of critical level for crops in the majority of CEE countries with no exceedances in present climate. These are: Germany, Austria, Czech Republic, Slovakia and Bulgaria.

Fig. 101 displays the AOT40$_c$ values for the present day and the end-century decades calculated for BOKU domain in high 10 km resolution. The values are generally higher than in the coarse resolution run. With present day conditions (1991-2000) only over Poland and Ukraine the limit of 9 000 ppb h is not exceeded. The highest values are found over the Adriatic Sea and over Italy. With far future climate (2091-2100) a further increase is observed. The high increase over Southern Germany may be attributed to boundary effects of the model. In the target region of CECILIA the increase is strongest in a belt stretching from Austria over western Hungary and Serbia to Bulgaria.

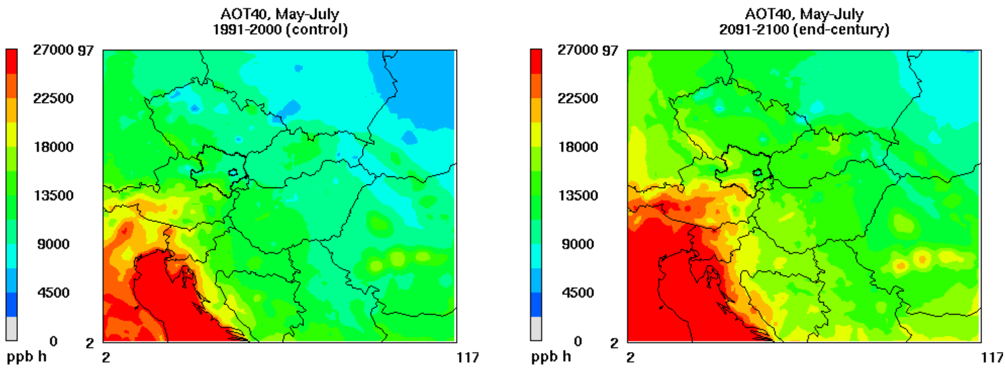


Figure 101. *Average of the AOT40$_c$ for May to July for the BOKU domain with 10 km spatial resolution for the present day decade 1991-2000 (left panel), and for the end-century decade 2091-2100 (right panel). Critical level for crops (EU), AOT40$_c$ = 9 000 ppb h.*

The differences between the end-century- (2091-2100) and the control-decade (1991-2000) in the AOT40$_c$ are shown in Fig. 102 for the 50 km and the 10 km runs. With the coarse resolution an increase over most of Europe is observed. Only over Africa, the north of the Atlantic Ocean and

Northern Russia there is a decrease. The highest increase occurs in Northern Italy and over the Iberian Peninsula. In general, the calculated increase with climate change is of similar basic patterns in the 10 km resolution run, with slightly elevated values in the simulation region and of course, more local details. The high increase over Southern Germany may be attributed to boundary effects of the model.

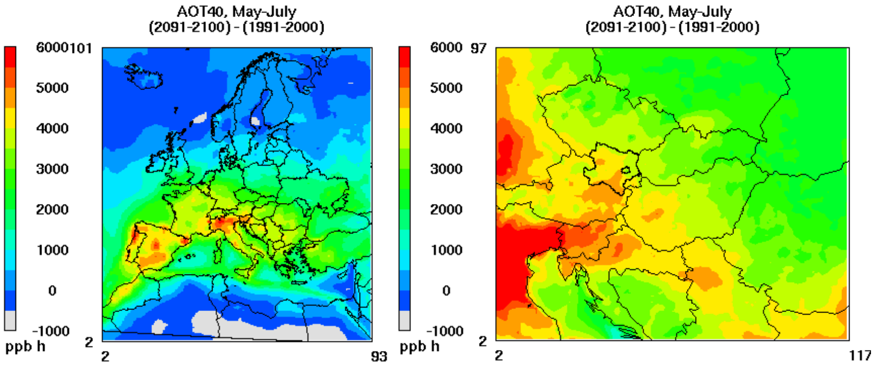


Figure 102. *Difference in AOT40$_c$ (May-July) between the end-century run (2091-2100) and the control run (1991-2000) for the runs with 50 km (left) and 10 km (right) spatial resolution.*

2.7.2.2 CUNI

In the first two years of the project the model couple RegCM-CAMx was prepared and tested on 10 km resolution domain of CUNI driven by ERA40 reanalysis run of ICTP for ENSEMBLES using RegCM and by CAMx run performed by BOKU at full Europe domain using meteorology of the same ICTP run. Nearly full 1991-2001 simulation was performed, later on at the beginning of this reporting period completed and then analysed.

Regional climate in this study is simulated using model RegCM while chemistry and transport are solved by model CAMx. For the project the interface or meteorological pre-processor for the coupling of the regional climate model with air-quality model was developed, see D7.1. The pre-processor utility was used to provide the meteorological fields generated by RegCM to drive CAMx transport, dry/wet deposition and through the temperature, radiation and humidity chemical reactions as well. We use 23 vertical σ-levels reaching up to 70 hPa at 10km of resolution for RegCM configuration, the same horizontal grid for CAMx. Initial and boundary conditions are taken from 50 km resolution run for whole Europe by Krueger et al. (2008) or Katragkou et al. (2009). In our setting CB-IV chemistry mechanism is used (Gery et al.,1989). As the first step, the distribution of pollutants is simulated off-line for time slice of 10 years, period of 1991-2000 driven by reanalysis ERA40. These results are used for validation of the model run against the observation from selected stations.

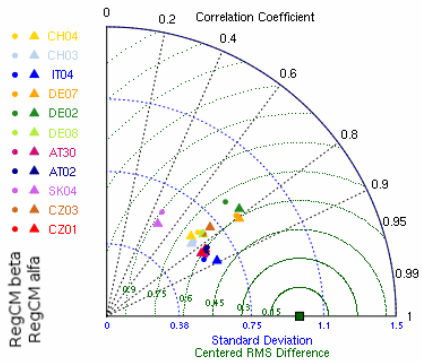


Figure 103. *Monthly average of ozone concentration, Taylor diagram of two versions of RegCM (alfa and beta–high resolution precipitation bug corrected) against observations, 1991-2000, ERA40 driven.*

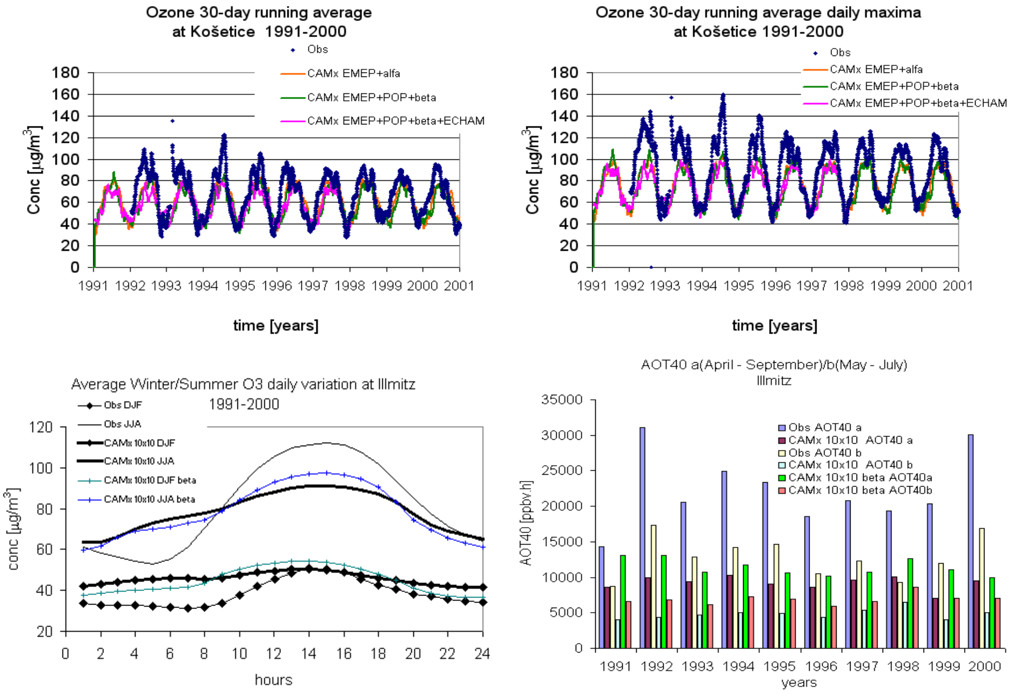


Figure 104. *Ozone characteristics from different model versions compared to observation at station Kosetice (above) and Illmitz (bottom) for 1991-2000.*

Example of monthly average ozone concentration comparison is presented in Fig. 103 in terms of Taylor diagram with sensitivity test to precipitation bug. Reasonable agreement can be seen, but deeper insight into the behaviour of the outputs can be seen from time series of the ozone concentration presented in Fig. 104. Clearly, even the version with corrected high resolution precipitation bug (RegCM(beta)) is underestimating daily variations, and reliability of reproducing some other parameters like AOT40 is not so high. Underestimation of the ozone concentration by the model especially during warm season appears for most stations of the Central Europe. Basically, high resolution runs brings slight improvement of the results for most of selected stations. Problems with emission data could probably account for these deviations at least partially.

Concerning the future scenario runs, A1B results of 10 km resolution simulations for 2041-2050 and 2091-2100 time slices are presented in Fig. 105 in terms of ozone concentration difference against the control run 1991-2000 for summer season. The development of the impact on air quality can be seen not only in term of the concentration changes but e.g. in terms of number of days with exceedance of certain threshold shown in Fig. 106. Clearly, 2041-2050 time slice shows not so well developed effects for near future while at the end of century the 2091-2100 time slice indicates quite significant impact. Results for other species from the model are available as well, e.g. for exceedances of SO_2 and PM_{10} limit values, see Figs. 107 and 108. Climate change impact on other characteristics can be analysed, like AOT40 (see Fig. 109) or maximum concentrations (see Fig. 110).

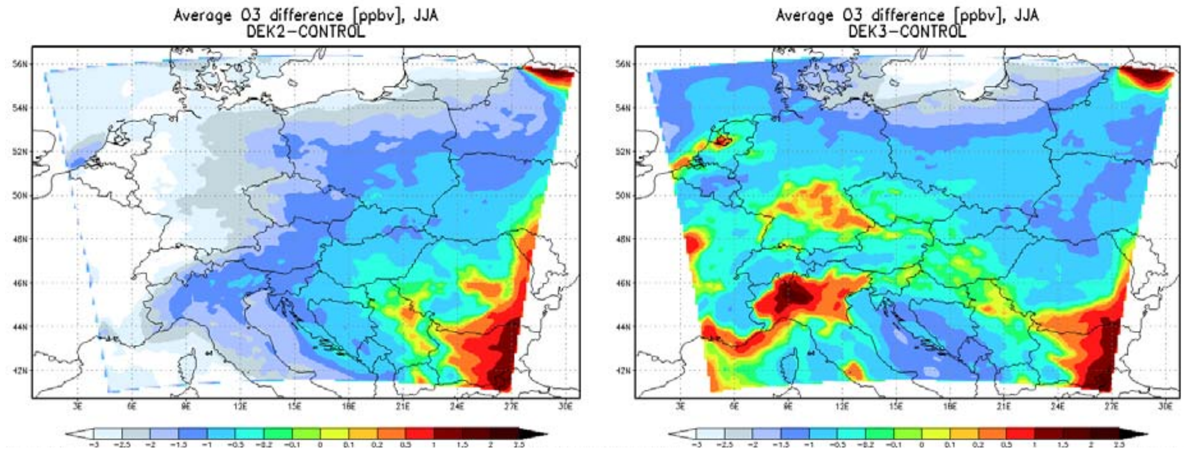


Figure 105. *Climate change impact on summer season ozone concentration (in ppbv) in terms of the difference for 2041-2050 period (left panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

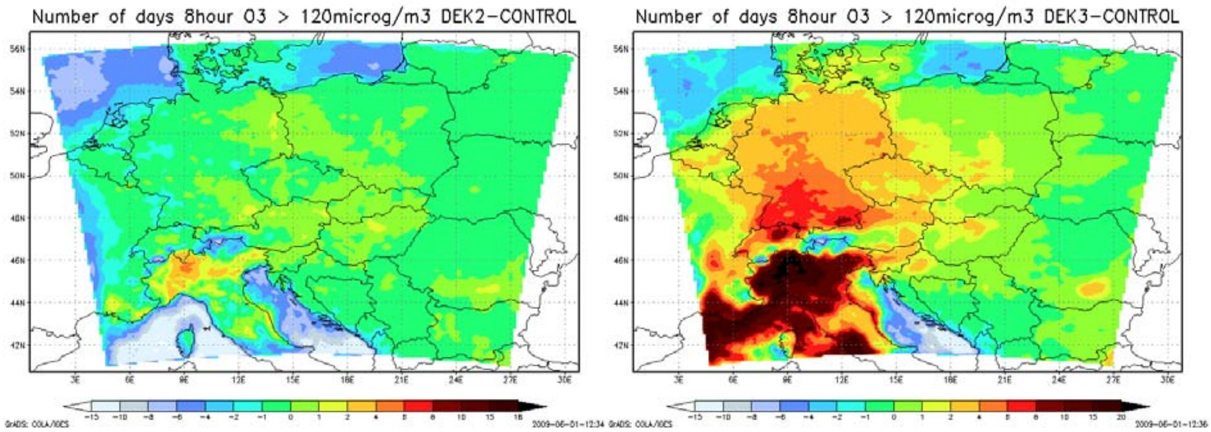


Figure 106. *Climate change impact on number of days per year with 8-hours ozone concentration above the threshold of 120 μg/m^3 in terms of the difference for 2041-2050 period (left panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

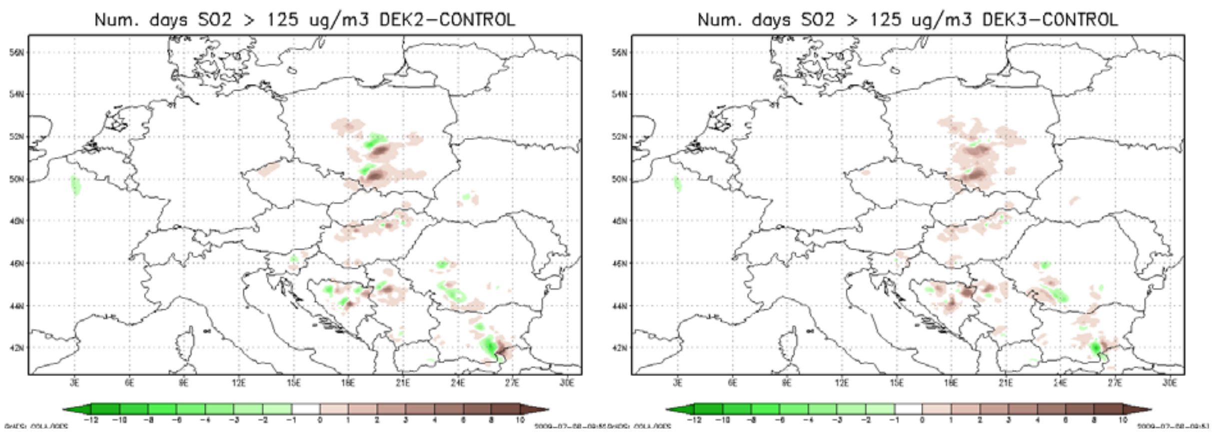


Figure 107. *Climate change impact on number of days per year with 24-hours SO_2 concentration above the threshold of 125 μg/m^3 in terms of the difference for 2041-2050 period (left panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

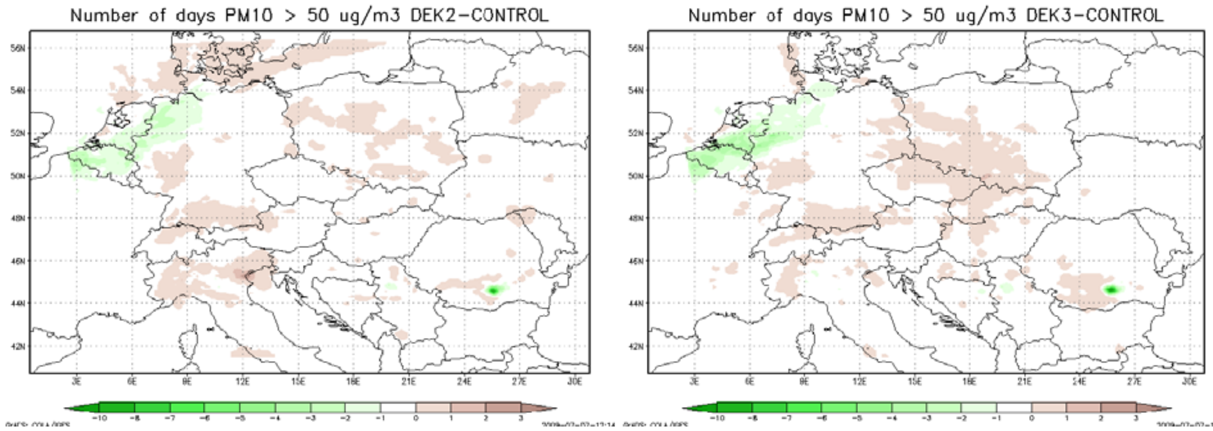


Figure 108. *Climate change impact on number of days per year with 24-hours PM_{10} concentration above the threshold of 50 μg/m^3 in terms of the difference for 2041-2050 period (left panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

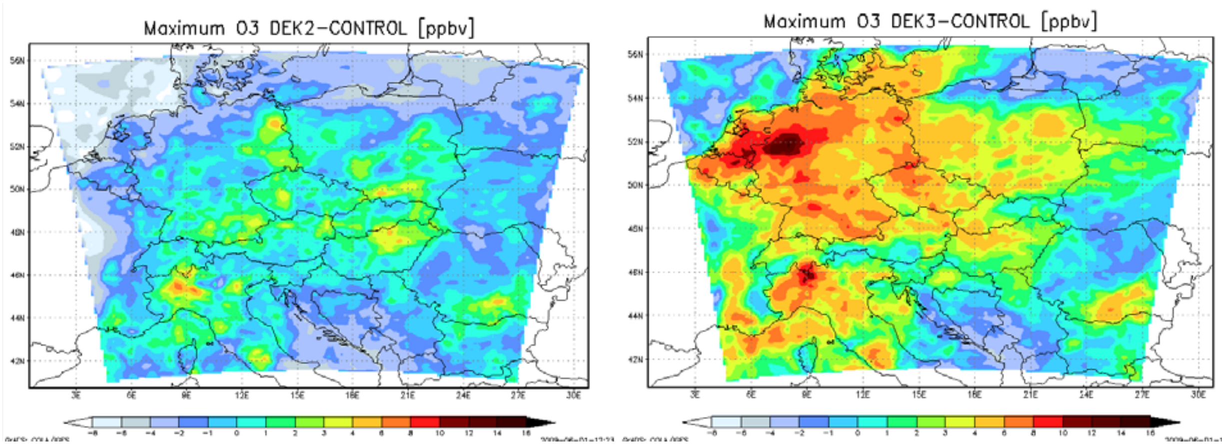


Figure 109. *Difference in average annual ozone maxima between years 2041-2050 (left panel) and 2091-2100 (right panel) against control period 1991-2000.*

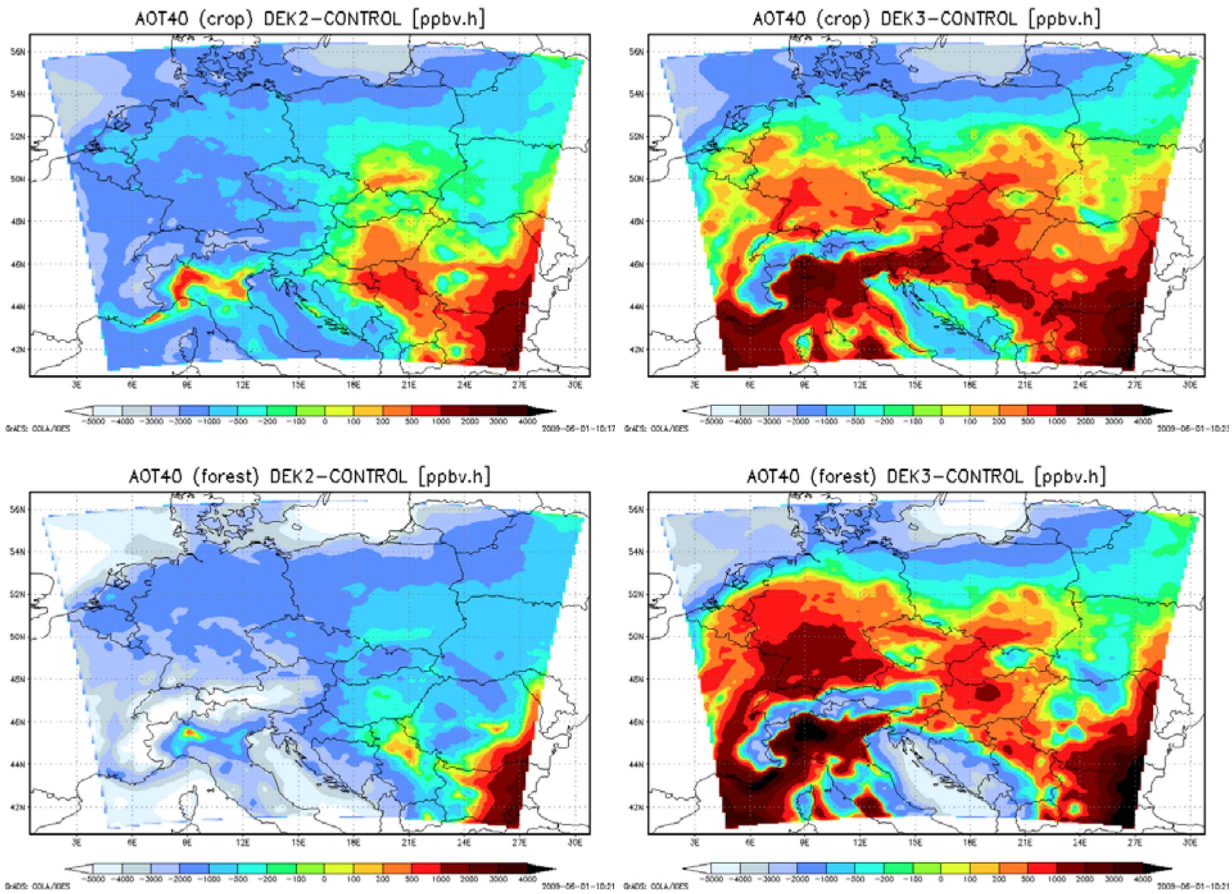


***Figure 110**. Difference in AOT40 for crop impacts assessment (May-July, upper panels) and for forest impacts assessment (April-September, lower panels) between years 2041-2050 (left panels) and 2091-2100 (right panels) against control period 1991-2000.*

2.7.2.3 AUTH

The regional climate model RegCM3 was used to drive off-line the air quality model CAMx for four long-term climate-air quality European simulations in 50 km resolution. The first simulation covered the decade 1991-2000 and RegCM3 was forced by the ERA40 reanalysis dataset (ERA experiment). This work served as a perfect lateral boundary condition experiment. The same decade was repeated with different RegCM forcing, in order to investigate the sensitivity of the climate model to external forcing. The General Circulation Model (GCM) EHCAM5 forced the regional climate model RegCM3 (ECHAM experiment).

The Global Ocean Surface Temperature (GISST), a set of SST (Sea Surface Temperature) data in monthly 1° area grids, was used to constrain the SST of the RegCM3 simulation. GTOPO30 Terrain and GLCC Landuse datasets, with 3 minutes resolution were used for the model topography and landuse respectively. The Grell scheme with Fritsch-Chappell closure was used for the convective parameterization of the model simulation. The meteorological output fields of RegCM3 were used to drive offline the air quality model CAMx.

CAMx run with coarse grid spacing over Europe in a spatial resolution of 50 km x 50 km, identical to the grid defined for the meteorological runs. The domain's vertical profile contained 12 layers of varying thickness, extending up to 450 hPa. Hourly anthropogenic emissions of gaseous and particulate pollutants were compiled and provided by BOKU. Biogenic emissions were calculated using the RegCM-CAMx interface at a 6-hour basis. Biogenic and anthropogenic emissions were combined with AddEmiss software developed by BOKU. All emissions were treated as surface area emissions. Initial and boundary (top and lateral) conditions corresponded to concentrations of clean air. The chemistry mechanism invoked was Carbon Bond version 4 (CB4).

Different RegCM forcings result in changes in surface ozone ranging between ±5 ppb, while all model parameterizations and anthropogenic emissions remained unchanged. The area showing the greatest sensitivity in O_3 during winter was central and southern Europe while in summer north and central continental Europe. As indicated by the 500 hPa GH, used here as an index of atmospheric circulation, the ECHAM run reveals a more steep GH gradient along the west-east axis of Europe with lower GH over the west Atlantic and UK (more cyclonic conditions) and higher GH over eastern Europe (more anticyclonic conditions) during winter and lower GH over Russia (more cyclonic conditions) during summer. The differences in both zonal and meridional wind fields are associated with the differences in the circulation patterns. Furthermore the differences in near surface air temperature and incoming solar radiation were partly explained by the differences in atmospheric circulation. Solar radiation appeared to be the parameter mostly controlling the ozone concentrations during summer. The impact of changes in biogenic VOCs was mostly clear during summer, when biogenic emissions are higher, but for both seasons significant. Our model simulations indicate, however, that ozone production is mainly NO_x limited. Nitrogen oxide concentration changes are very small (well below 2 ppb) and exclusively due to changes in meteorology. However, they strongly affected surface ozone in our modeling system, especially in winter, when NOx emissions are higher. The results of this work were submitted to the journal *Atmospheric Chemistry and Physics* (Katragkou et al., 2009).

Two future simulations were performed with the ECHAM/RegCM/CAMx modeling system: the first covered the decade 2041-2050 (DEK2) and the second 2091-2100 (DEK3). RegCM3 was forced by the ECHAM5 global circulation model using the IPCC A1B scenario to provide forcing for the future decades. Comparison of the DEK2 and DEK3 simulations show that changes in meteorology and thus air quality mainly occur during the last decade of the century. Our model simulations yielded average decadal changes of tropospheric ozone in the range of 1-2 ppb for the mid decade of the century and higher ozone increase (up to 5 ppb) in the 2090s. The response of ozone to climate change varied in magnitude depending on season and geographical location. During summer ozone increase is stronger towards the end of the century with the most sensitive areas being west and central continental Europe. Temperature changes were also stronger for the 2090s ranging between 2-5 K. Higher temperatures were found over southern Europe and the Mediterranean. Different circulation patterns between the present and future decades are closely related to changes in temperature, cloudiness and incoming solar radiation which altogether affect surface ozone concentrations. The spatial agreement between changes in incoming solar radiation patterns and those in surface ozone suggest solar radiation modulates in a decisive way changes in future ozone concentrations. Biogenic emissions are also found to be considerably higher towards the end of the century in comparison to the mid-century emissions, following the stronger increase of temperature and incoming solar radiation changes. Results of this work were submitted to the journal Journal of Geophysical Research (Katragkou et al., 2010).

Simulated ozone concentrations were validated using surface O_3 measurements from the EMEP database (www.emep.int). All EMEP stations are situated in rural areas, are, thus, eligible for comparison with model species extracted by 50km x 50 km grid cells. Sixty nine EMEP stations were selected from the database for comparison with model results, fulfilling the criteria of 75% completeness of data set. Validation of model results was necessary in order to assure the quality and credibility of delivered output. The statistics calculated were the Fractional Gross Error (*FGE*) and the Modified Normalized Mean Bias (*MNMB*).

$$FGE = \frac{2}{N}\sum_i \left| \frac{f_i - o_i}{f_i + o_i} \right| \qquad MNMB = \frac{2}{N}\sum_i \left(\frac{f_i - o_i}{f_i + o_i} \right)$$

where *f* represents the CAMx mean daily values and *o* the mean daily O_3 observations. *FGE* calculated for the period 1990-2001 was ranging between 20-35 % while *MNMB* was within the range of ± 15% indicating a satisfactory model performance.

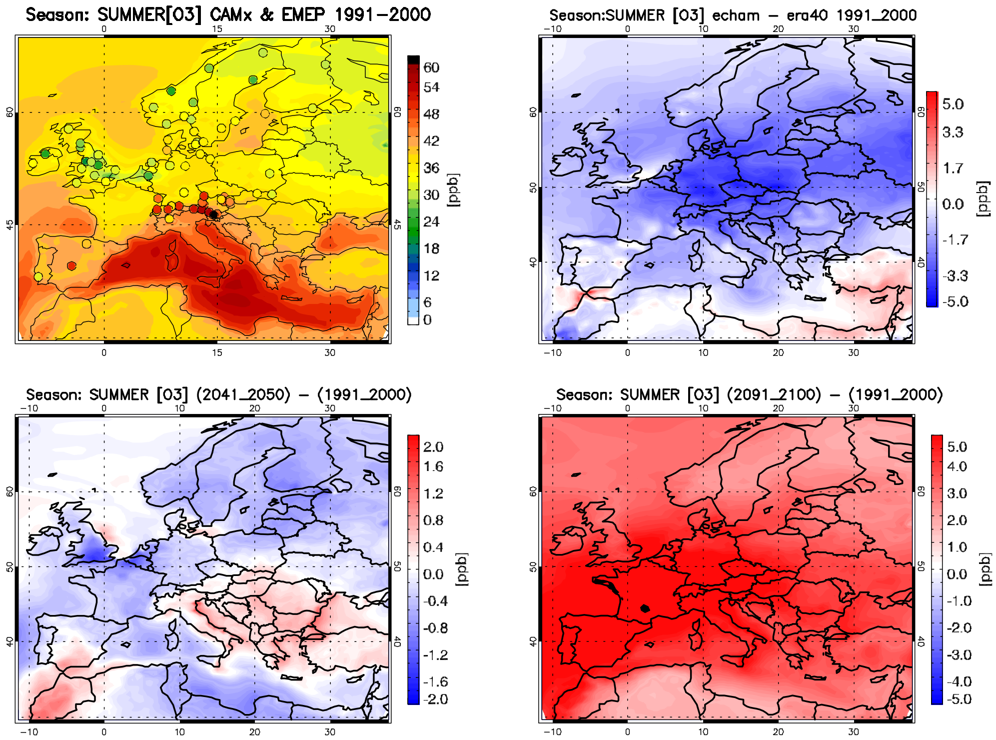


***Figure 111**. a) Seasonal average surface ozone concentration for summer 1991-2000 (ERA experiment) and comparison with EMEP measurements (overplotted). b) Changes in surface ozone between the ERA and ECHAM experiment averaged over the summer season c) Changes in surface ozone between the DEK2 and ECHAM simulation averaged over the summer season d) Changes in surface ozone between the DEK3 and ECHAM simulation averaged over the summer season.*

The simulated ozone fields with the modeling system RegCM3/CAMx for present day decade (1991-2000), near future (2041-2050) and far future decade (2091-2100) were used to calculate ozone exceedances in terms of $AOT40_f$ exceedances. It should be mentioned that as a long-term objective for the protection of forests a maximum AOT40 value of 10000 ppbv h is considered. (European Communities, 2002).

The main results are similar with those illustrated in Fig. 111 published by Krüger et al. (2008). In the near future decade 2041-2050, $AOT40_f$ goes down over most of Europe except of the Iberian Peninsula and southeast Europe, while there is a strong increase over most of Europe in the far future decade 2091-2100.

2.7.2.4 WUT

At WUT the RegCM3(Beta)-CAMx modelling system was implemented and validated for the WUT modelling domain, centred over Poland (52.00°N, 19.30°E) on a grid with 120 x 109 points and a resolution of 10 km. The original emission model EMIL (EMIssion modeL) was developed during third reporting period (see Deliverable D7.3). The model applies for Poland and creates the so called second-level emission database for the high resolution 10 km photochemical runs performed at WUT. Emission database applied for other, than Poland, countries belonging to modelling domain remains zero-level (based on EMEP inventory).

One of the main added value to the project was development of a detailed emission and stacks parameters database for a Large Combustion Plants (LCP) sources (with a stack height that is equal or above 100 m; h ≥ 100 m) for PM_{10}, $PM_{2.5}$, SO_2, NO_x, NH_3 and NMVOC (see Deliverable D7.3 for details). Thus simulation of pollution plume from point sources was possible and constitutes the largest differences between air pollution modelling at WUT and at CUNI, AUTH and BOKU, where in CAMx simulations all sources were treated as surface area sources.

Results of the WUT modelling system runs for PM_{10}, $PM_{2.5}$ and SO_2 are presented in Figs. 112, 113 and 114, respectively. Left panels show calculated annual mean levels for the control period (1991-2000). The highest PM_{10} and $PM_{2.5}$ levels were obtained for the central and southern Poland. It should be pointed out, that in second-level detailed emission database prepared for Poland, emissions of PM and SO_2 were significantly higher than in zero-level database based on EMEP inventories. For SO_2 the highest concentrations were obtained for Silesia region in Poland as well as for Hungary and Ukraine. The high SO_2 concentrations calculated for Hungary and Ukraine are due to the treatment of LCP sources as surface area sources in zero-level emission database. Results of comparison between pollutant levels for control and for future periods given as differences in Figs. 112-114 (middle and right panels) show that climate change impacts on air pollution levels are small to moderate, and have different direction depending on pollutant concerned. For PM, decrease in concentrations (up to -3.5 μg/m^3) in future decades relative to control period in most of the countries is predicted. The exception of that trend is noted only for the Northern Germany, where slight increase in 2041-2050 period is observed. For SO_2 higher concentrations (up to 3.5 μg/m^3) are predicted in the future. The highest increase is expected for Upper Silesia region in Poland as well as for Northern Hungary.

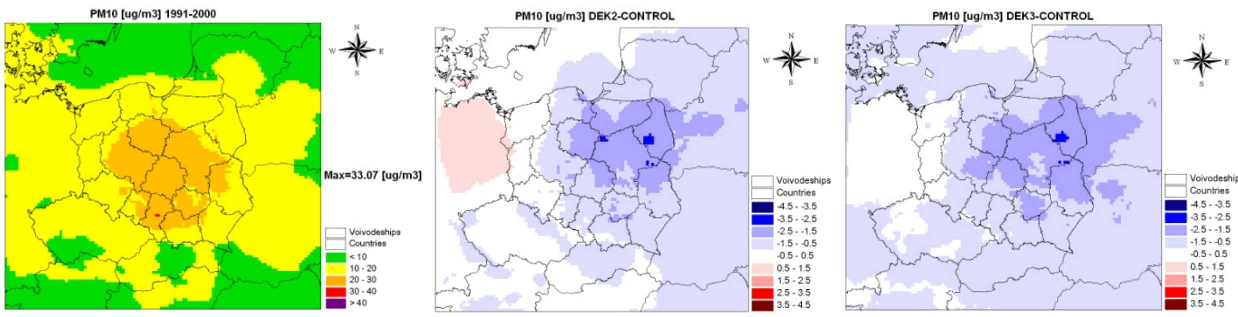


Figure 112. *Annual mean PM_{10} concentrations [μg/m^3] at WUT domain for control run 1991-2000 (left panel), and climate change impacts on PM_{10} concentrations in terms of the differences [μg/m^3] for 2041-2050 period (middle panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

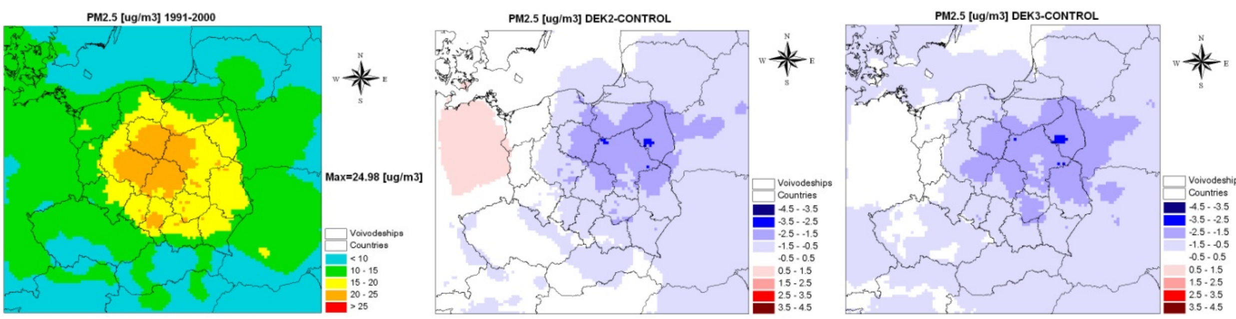


Figure 113. *Annual mean $PM_{2.5}$ concentrations [μg/m^3] at WUT domain for control run 1991-2000 (left panel), and climate change impacts on $PM_{2.5}$ concentrations in terms of the differences [μg/m^3] for 2041-2050 period (middle panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

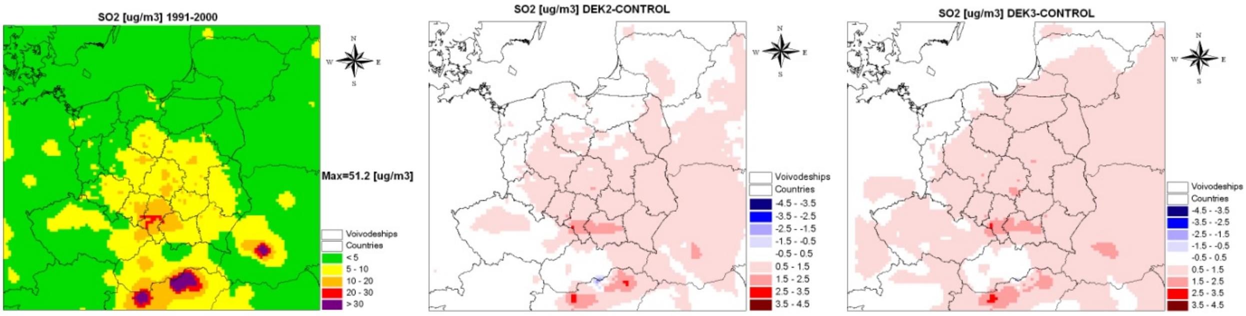


Figure 114*. Annual mean SO_2 concentrations [µg/m^3] at WUT domain for control run 1991-2000 (left panel), and climate change impacts on SO_2 concentrations in terms of the differences [µg/m^3] for 2041-2050 period (middle panel) and 2091-2100 period (right panel) against the control period 1991-2000.*

Left panels of Figs. 115, 116 and 117 show the distribution of total deposition calculated for the control period of oxidized sulphur, oxidized nitrogen and reduced nitrogen, respectively. The high deposition of sulphur were obtained for central-southern part of the domain, while for rest of the domain deposition is smaller. For oxidized nitrogen the deposition is smaller and its distribution is different. For the southern-western part of domain as well as for the Baltic coast line, bigger depositions were obtained. For reduced nitrogen the biggest depositions were calculated for Southern Germany, Belarus and Central Poland. Results of comparison between S and N deposition for control and for future periods given as differences in Figs. 115-117 (middle and right panels) show that climate change impacts on air pollutants deposition are small to moderate, and that climate change is causing increase in deposition of all acidifying species. The increase has growing trend from near to far future. The exception is sulphur deposition in the vicinity of large point sources in Poland, Ukraine and Hungary which is decreasing with descending trend in future climate. The increase of species deposition is most probably due to increase of precipitation (wet deposition) and wind speed (dry deposition) in future climate in the region under concern. The biggest increase of total deposition is predicted for the mountains areas within the domain: Bohemian Forest, Ore Mountains, Sudety Mountains and Carpathian Mountains.

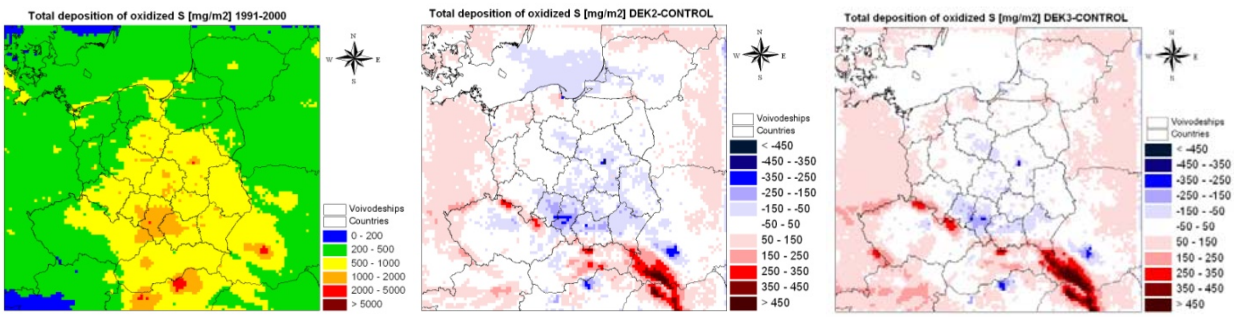


Figure 115*. Total deposition of oxidized sulphur [mg/m^2] for control run 1991-2000 (left panel), and climate change impacts on total deposition of oxidized sulphur in terms of the differences [mg/m^2] for 2041-2050 (middle panel) and 2091-2100 (right panel) against the control period 1991-2000.*

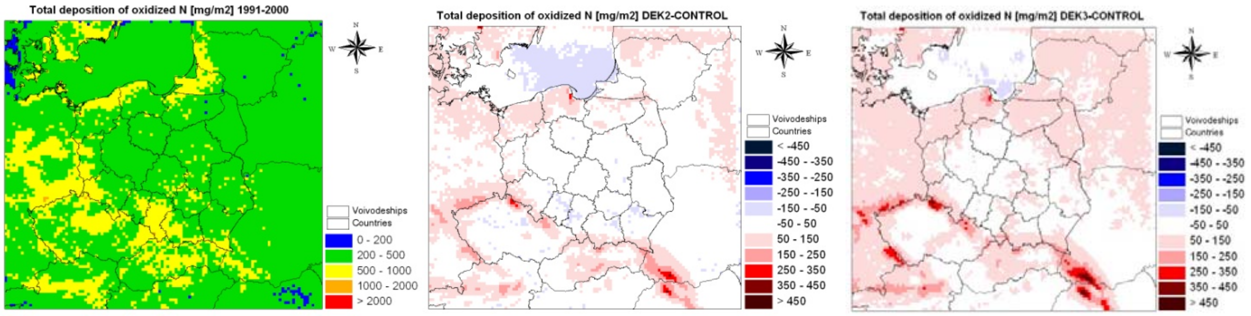


Figure 116*.Total deposition of oxidized nitrogen [mg/m^2] for control run 1991-2000 (left panel), and climate change impacts on total deposition of oxidized nitrogen in terms of the differences [mg/m^2] for 2041-2050 (middle panel) and 2091-2100 (right panel) against the control period 1991-2000.*

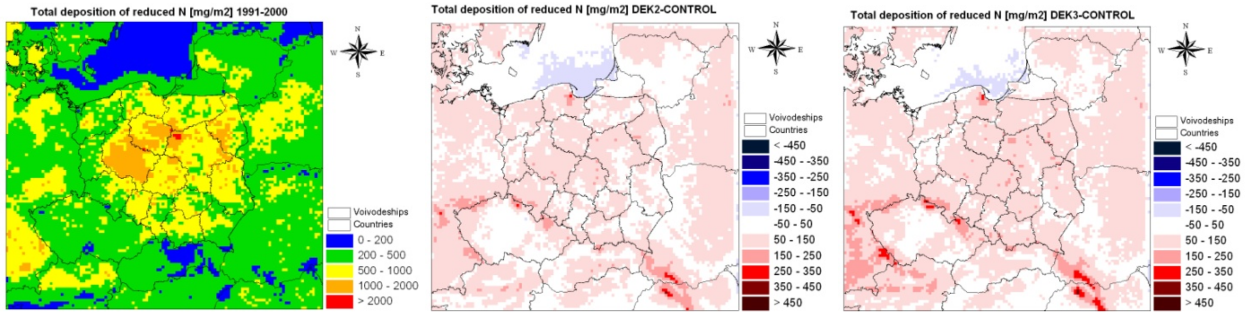


Figure 117*. Total deposition of reduced nitrogen [mg/m^2] for control run 1991-2000 (left panel), and climate change impacts on total deposition of reduced nitrogen in terms of the differences [mg/m^2] for 2041-2050 (middle panel) and 2091-2100 (right panel) against the control period 1991-2000.*

For the purpose of WP7 of CECILIA and Deliverable D7.4, *Guidelines for operational evaluation of the AQ-CTMs under WP7 of the CECILIA project* have been prepared by a group leader, Katarzyna Juda-Rezler (see D7.4 APPENDIX). The paper addresses Air Quality – Chemical Transport Models (AQ – CTMs) evaluation in terms of operational evaluation, which is aiming on comparing model results with measurements of species concentrations for a specific time period.

For final evaluation performance, a subset of parameters, which characterise the general uncertainties estimation, was applied. The subset consists of the following measures: NMB (Normalized Mean Bias), RMSE (Root Mean Square Error), with its systematic ($RMSE_s$) and unsystematic ($RMSE_u$) part, NMSE (Normalized Mean Square Error), correlation coefficient (r), IA (Index of Agreement) and FAC2 – a fraction of predictions within a factor 2 of observations. The formulas are given in D7.4 APPENDIX.

RegCM-EMIL-CAMx modelling system was evaluated for PM_{10} and SO_2 concentrations using observations from EMEP (http://www.emep.int) and EIONET-Airbase (http://air-climate.eionet.europa.eu) databases. For PM_{10} evaluation, data from IfT (Leibniz Institute for Tropospheric Research, Germany) research station Melpitz were also used. The Melpitz research station is one of the European station with the longest PM observations. For the reference year 2000, 30 stations for PM_{10} and 93 for SO_2 were available for model evaluation. Unfortunately, in Poland, there was only one such station for PM_{10} and 5 stations for SO_2. Both qualitative analysis (scatter plots, time series) and quantitative analysis were performed.

For evaluation of annual mean model predictions, the scatter plots of the predicted versus observed annual mean PM_{10} and SO_2 concentrations in 2000 together with calculated values of statistical indices are given in Fig. 118, whereas the values of statistical indices are given in the Tab. 4 as well. For annual means, evaluation results indicate a satisfactory model performance for both pollutants, however model performance for SO_2 is better than for PM_{10}. For PM_{10}, the observations are in general underestimated.

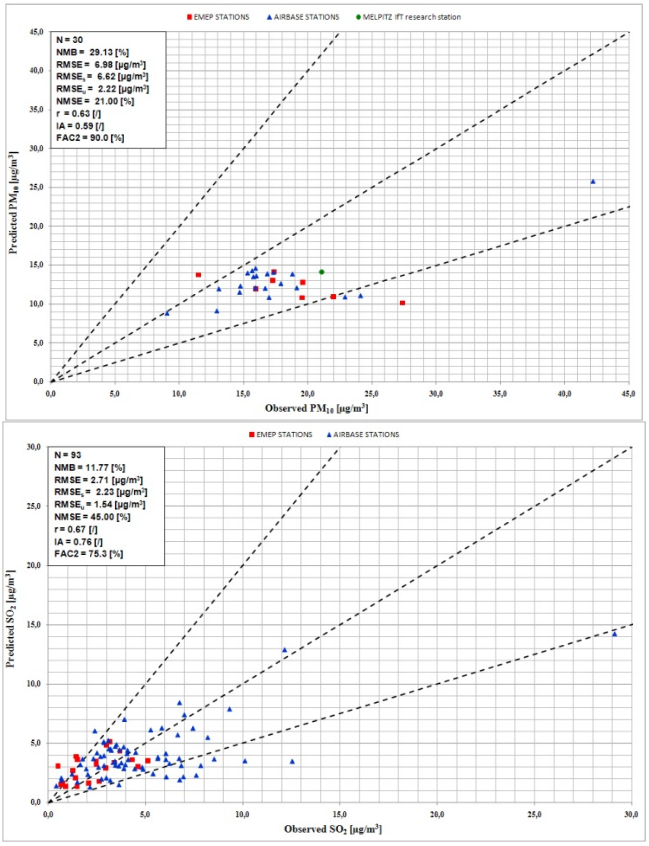


***Figure 118**. The scatter plot of the predicted and observed annual mean PM_{10} levels (left panel) and annual mean SO_2 levels (right panel) for WUT domain (year 2000). Dashed lines indicate perfect agreement (middle line) and a difference of a factor of 2.*

***Table 4**. Evaluation results of the RegCM–EMIL–CAMx modelling system for 2000 reference year.*

Statistical measures	PM_{10} annual mean	PM_{10} daily mean	SO_2 annual mean
N – number of samples	30	10 188	93
NMB – Normalised Mean Bias [%]	29.13	27.20	11.77
RMSE – Root Mean Square Error [$\mu g/m^3$]	6.98	12.92	2.71
$RMSE_s$ – Systematic Root Mean Square Error [$\mu g/m^3$]	6.62	10.85	2.23
$RMSE_u$ – Unsystematic Root Mean Square Error [$\mu g/m^3$]	2.22	7.02	1.54
NMSE – Normalised Mean Square Error [%]	21.00	73.20	45.00
r – Correlation coefficient [/]	0.63	0.33	0.67
IA – Index of Agreement [/]	0.59	0.55	0.76
Predictions within a factor of 2 of the observations [%]	90.00	64.00	75.30

The scatter plot of the predicted versus observed daily mean PM_{10} levels in 2000 is given in Fig. 119, while the statistical indices are given in Tab. 4 as well. Moreover the time series of daily mean PM_{10} values are presented for two stations: IfT research station in Melpitz, Germany and Kuznia, Poland (Fig. 120).

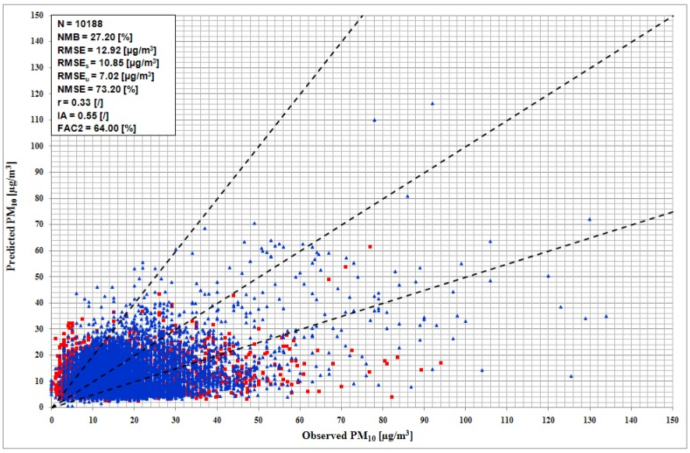


***Figure 119**. The scatter plot of the predicted and observed daily mean PM_{10} levels for WUT domain (year 2000). Dashed lines indicate perfect agreement (middle line) and a difference of a factor of 2.*

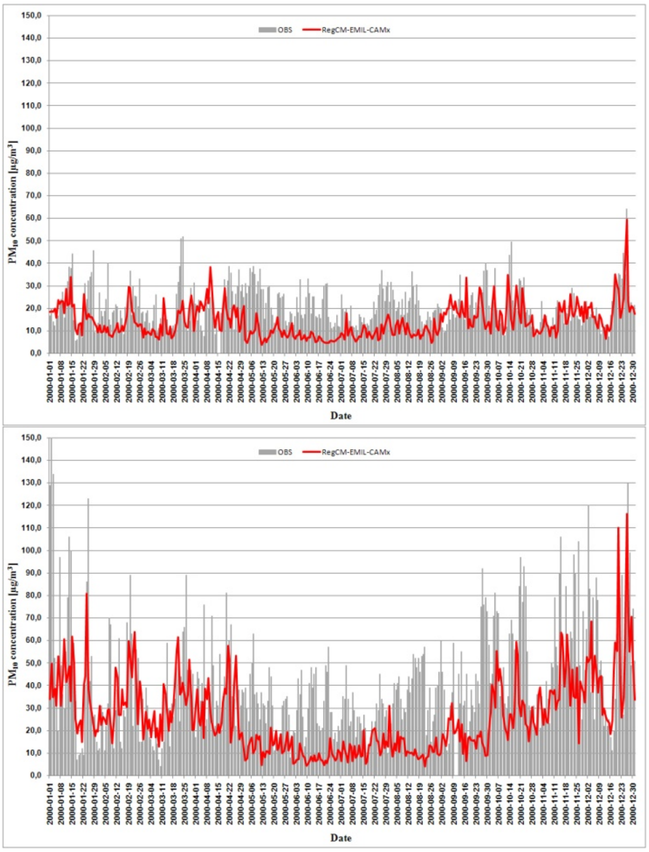


***Figure 120**. Observed and calculated PM_{10} time series of daily mean concentrations at Melpitz IfT research station, Germany (left panel) and at Kuznia, Poland (right panel) – year 2000. Observed data from Melpitz by courtesy of dr Gerald Spindler (IfT, Leipzig, Germany).*

As it can be seen in Tab. 4 for daily mean predictions, evaluation results indicate poorer model performance than for annual means. This is quite understandable taking into account the specific of PM_{10} air pollution, which is due to both natural and anthropogenic sources, moreover it is both primary and secondary pollutant. Still, when comparing predicted and observed time-series it can be noted that during winter, the patterns of measured PM_{10} levels are fairly well simulated by the

RegCM-EMIL-CAMx modelling system. For Melpitz research station winter PM_{10} levels, specially for January and October-December, are well predicted by model and peak values are well captured. During summer the model performance is worse. For Polish station Kuznia, model performance is better in winter than in summer as well. Overall, the predicted pattern of measured time series in Kuznia is poorer than in Melpitz, however model is also able to capture peak, up to 115 $\mu g/m^3$, values.

Summarizing, the ability of the modelling system to simulate PM_{10} and SO_2 concentrations in Central-Eastern Europe is promising. Detailed emission data provided by the emission model EMIL play important role in improving the model performance.

In order to assess present and future key species exceedances of the EU limits and WHO guidelines, we applied WHO (2000, 2005) non-binding air quality guidelines (AQG) for Europe, as well as legally binding standards for ambient air pollutants set in the framework of EU legislation, namely limit values (LV) for protection of human health and critical levels (CLev) for protection of vegetation. We calculated exceedances for PM and SO_2. For the of AQ standards review see deliverable D7.5.

Results show, that annual LV for PM_{10} (40 $\mu g/m^3$) is not exceeded for present day and far future decades (see Fig. 112). Also for the majority of the domain, the number of exceedance days is less than 35 per year, thus EU LV is not overshot (Fig. 121). The highest values occur in the hot spot areas in Poland - surroundings of densely populated urban areas. For the end-century decade the PM_{10} levels are decreasing.

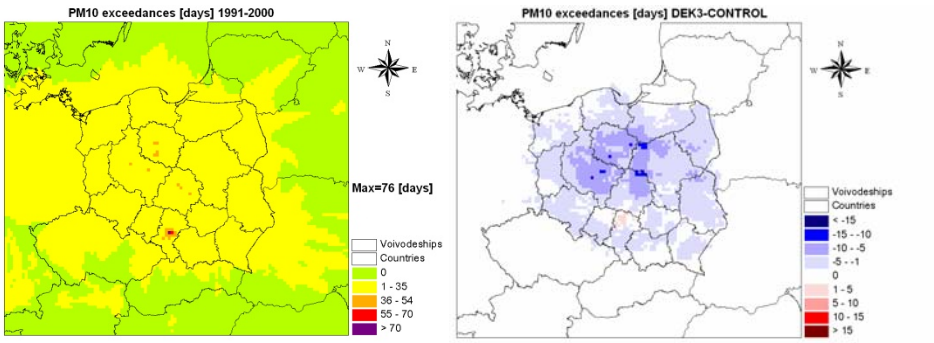


***Figure 121**. Number of exceedances [days] over PM_{10} limit value of 50 $\mu g/m^3$ at WUT domain for present day decade 1991-2000 (left panel) and climate change impacts on PM_{10} limit value exceedances in terms of the differences [days] for the end-century decade 2091-2100 against the present day decade (right panel).*

The annual mean levels of $PM_{2.5}$ for the WUT domain are shown in Fig. 113. For the present day decade the annual EU non-binding $PM_{2.5}$ standard (25 $\mu g/m^3$) is not exceeded. However, the AQG set by WHO (10 $\mu g/m^3$) is exceeded for the majority of the domain. With climate changes, also $PM_{2.5}$ levels are decreasing for the majority of the domain.

Figs. 122 and 123 present exceedances of daily and hourly SO_2 limit values, respectively. On the majority of the domain, there is no exceedances of the daily LV for SO_2 for the present day and far future decades. The exceedances occur in the surroundings of LCP where the limit value is not met (number of days with daily mean levels over 125 $\mu g/m^3$ is bigger than 3). The maximum number of exceedance days was estimated for Northern Hungary. Except of few grid points, there is also no exceedances of the hourly LV for SO_2 both for present and future decades (no hours with hourly mean concentration exceeding 350 $\mu g/m^3$). The exceedances occur in the surroundings of LCP in Hungary and in Poland, however the number of hours with mean levels over 350 $\mu g/m^3$ is not bigger than 24, thus the LV is met.

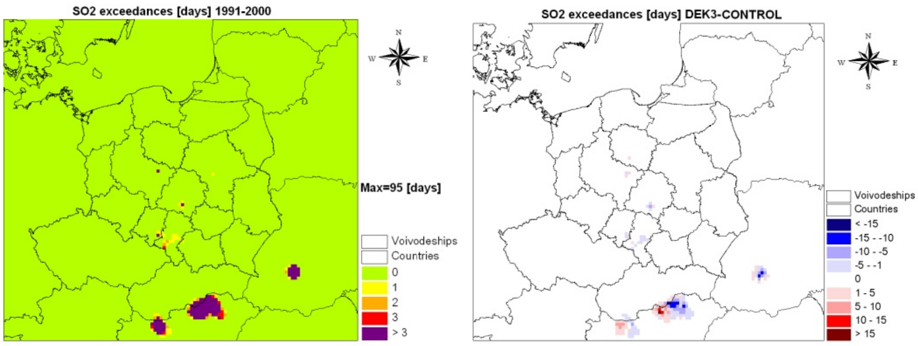


***Figure 122**. Number of exceedances [days] over SO_2 daily limit value of 125 µg/m^3 at WUT domain for the present day decade 1991-2000 (left panel) and climate change impacts on SO_2 limit value exceedances in terms of the differences [days] for the end-century decade 2091-2100 against the present day decade (right panel).*

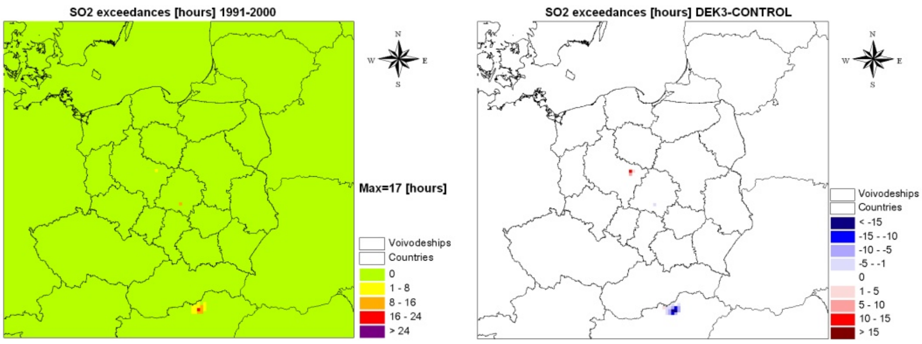


***Figure 123**. Number of exceedances [hours] over SO_2 hourly limit value of 350 µg/m^3 at WUT domain for the present day decade 1991-2000 (left panel) and climate change impacts on SO_2 limit value exceedances in terms of the differences [hours] for the end-century decade 2091-2100 against the present day decade (right panel).*

Fig. 124 presents the calculation results in terms of exceedances of SO_2 critical level (for the protection of vegetation). It can be noticed that exceedances area in Poland is slightly wider for end-century decade in comparison to present day decade.

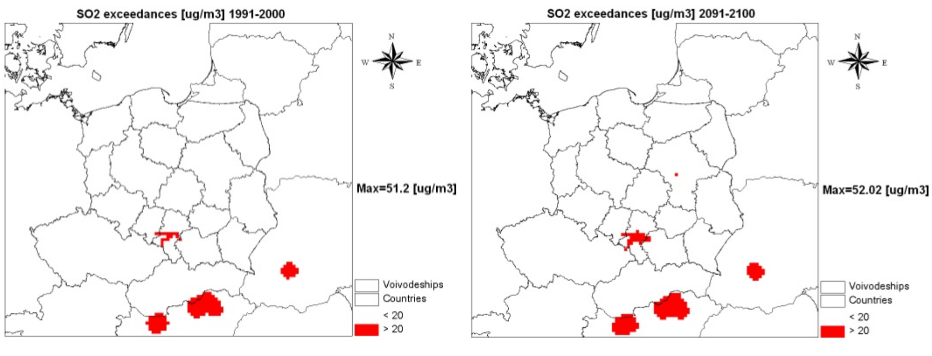


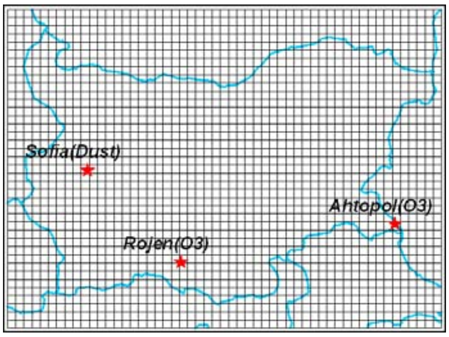
***Figure 124**. Exceedances [µg/m^3] of SO_2 annual critical level of 20 µg/m^3 at WUT domain for the present day decade 1991-2000 (left panel) and for the end-century decade 2091-2100 (right panel).*

2.7.2.5 NIMH

The climatic version of the operational weather forecast model ALADIN was applied for simulating 3 time slices: 1960-2000 (Control Run, CR), 2020-2050 (Near Future, NF) and 2070-2100 (Far Future, FF), following the IPCC scenario A1B (CECILIA WP1 and WP2). The calculations are made for an area covering Bulgaria region with resolution of 10 km. The created meteorological database is used to estimate the impact of climate changes on air quality.

A modeling system was created on the base of US EPA Models-3 tool (MM5, CMAQ and SMOKE) and a number of interface FORTRAN programs and Linux scripts capable to long-term simulation for a nested region with resolution of 10 km covering Bulgaria. TNO emission inventory for 2000 is used for all time slices. The chemical boundary conditions (BC) are extracted from a database containing results of 50-km RegCM3/CAMx runs over Europe made by AUTH. CMAQ boundary points values are calculated off-line in AUTH, results downloaded to a server in NIMH. There, the BC input files are being prepared in-line by another interface program during the simulations. For year 2000, some scenarios are run, results compared with measuring data. The comparisons point out the good simulation quality of the System.

There are quite few measurements in the territory of Bulgaria capable to be used for comparison with calculations. There is no EMEP station in the ALADIN/CMAQ domain. The automated and sampling stations, operated by Bulgarian EPA are placed in the most polluted areas – big cities and industrial regions and cannot be used for comparison with the model results that more or less describe background conditions. Only one official background station exists in the country – the peak Rojen, Rhodopi mountain (41N41, 24E44, altitude 1700 m), but there is no regular ozone and PM measurements available in the investigated period. Fortunately, during all the year 2000 in the frame of research project (Donev et al., 2002; Georgiev and Donev, 2006) hourly ozone measurements have been performed at peak Rojen and Ahtopol, small town at Black sea cost (42N05, 27E57, altitude 10 m). This data were the main source for validating the model results. Another set of measurements is dust probes sampling on daily basis in NIMH, Sofia (49N39, 23E23, altitude 550 m). The station is placed on the south-east vicinity of the town at a highways crossroad. No special measures were taken to distinguish particles by size. Nevertheless, this data is also used for comparison with PM_{10} model results. The measurement points are shown in Fig. 125.



	Anthropogenic sources		Natural sources	Both types
Scenario	AS	LPS	BgS	BC
A (basic)	Y	Y	Y	Y
B	Y	Y	Y	
C	Y	Y		Y
D	Y	Y		

Figure 125. *Measurement points in NIMH domain (left) and scenarios description (right).*

For year 2000 four scenarios, presented in Fig. 125, were calculated. The aim is to estimate the importance of biogenic emissions and the boundary conditions. The lack of boundary conditions means zero-values of all variables in all boundary points.

In Fig. 126 the yearly variation of the row data and three model scenarios are displayed. It is clearly seen that Scenario A demonstrates more or less good agreement with measurements. The biggest discrepancy is in Rojen for the first 3 months of the year. In that period problems with measurement equipment happened; there is a big gap in data (February – March). Scenarios B and D demonstrate quite low ozone levels (less than one third of the basic case) that reflects the extremely high importance of the use of reliable boundary conditions for obtaining realistic model results. The smaller the region of calculation is the more important BC are.

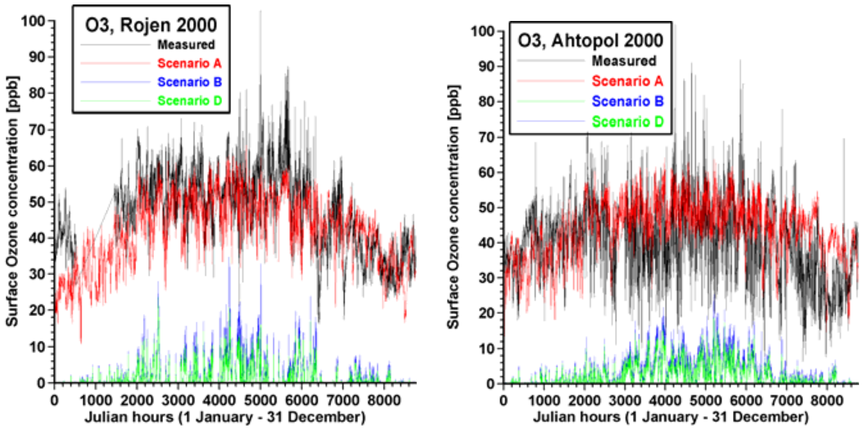


Figure 126. *Yearly variation of measured and calculated ozone (1-hour data).*

As it can be noticed in Fig. 127, the results of Scenario C (Basic Scenario with Biogenic emissions switched off) are much close to those of Scenario A (two left graphs). The exclusion of biogenic emissions slightly decreases the ozone values. All this shows that in the Basic case the fluxes through the boundaries are dominating in ozone formation leading to the so called "VOC-saturated" regime.

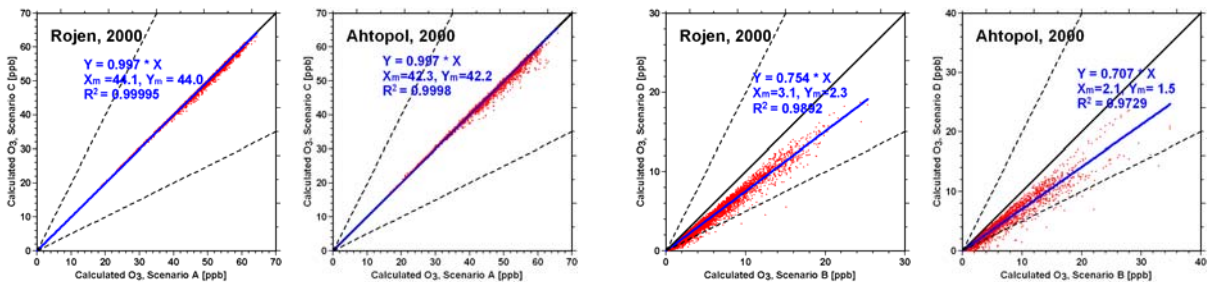


Figure 127. *Scenarios comparison: A vs. C (left two graphs) and B vs. D (right two graphs)*

In contrary, the right two graphs in Fig. 127 (cases with zero fluxes through the boundaries, Scenarios B and D) show that the biogenic emissions are very important – the ozone values become 20-30% lower when this emission source is switched off.

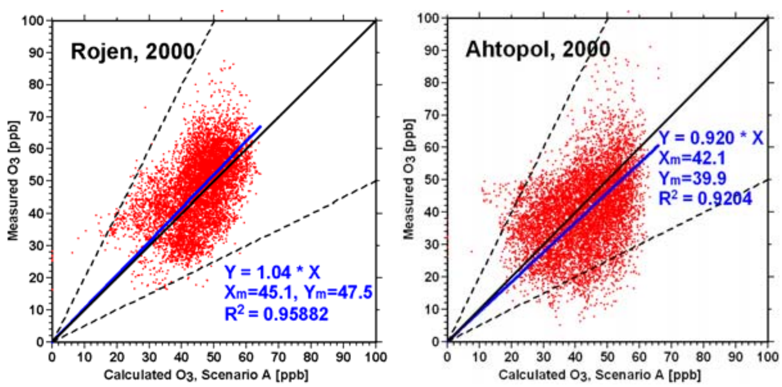


Figure 128. *Scatter diagrams of measurement and modeled (Scenario A) 1-hour data.*

The scatter diagrams of Scenario A *vs.* measurements are displayed in Fig. 128. Almost all scatter points are into FAC2 boundaries (dashed lines). The fitting lines are quite close to the ideal fitting line showing slight underestimation of measurement data in Rojen and somewhat bigger (but still small) overestimation in Ahtopol. The correlation coefficients of both fits are quite high that reflects the good quality of the simulation.

High ozone concentrations can cause damages on plants, animals and human health. In fact, when the effects from high ozone levels are studied, one should look not at the ozone concentrations but on some related quantities. The following four quantities were calculated (see e.g. Zlatev and Syrakov, 2004):

- **$AOT40_c$ values,** which are damaging crops when they exceed 3000 ppb.hours.
- **$AOT40_f$ values,** which are damaging forests when they exceed 10000 ppb.hours.
- **NOD60 (**Number Of Days in which the day-time 8 hours running averages over ozone concentration exceed the critical value of 60 ppb). If the limit of 60 ppb is exceeded at least once during a given day the day is considered “bad”. People with asthmatic diseases have difficulties in “bad” days. The requirement is often relaxed to maximum 25 “bad” days in the period April-September.
- **ADM** (Averaged Daily Maxima) of the ozone concentrations in the period from April 1 to September 30. This quantity is not directly related to some particular damaging effects. However, it is convenient to validate the model results when this quantity is used.

Table 5. *Ozone indexes calculated from measurement and simulation (Scenario A) data*

Stations	**Index**	**$AOT40_c$**	**$AOT40_f$**	**NOD60**	**ADM**
	Period (2000)	MJJ	AMJJAS	AMJJAS	AMJJAS
Rojen	Measured	20300	29300	27	59.3
	Calc.(Sc. A)	18500	26800	7	54.4
Ahtopol	Measured	8020	12700	12	54.1
	Calc.(Sc. A)	17100	24100	7	53.6

In Tab. 5, the calculated ozone indices for both measurement stations are presented. The calculated and measured ADMs are quite close for both stations while quite big differences in the other ozone indices can be noticed. The reason is the sensitivity of these indices to the model and measurement errors, discussed in detail in Zlatev and Syrakov (2004). In any case, it is seen that both calculated and measured indices overcome 1.5-2 times the respective thresholds. The calculated AOT40 values are closer to the measured ones for Rojen than for Ahtopol. The calculated NOD60 are rather different from the measured ones. Both of them are about and under the threshold of 25 days.

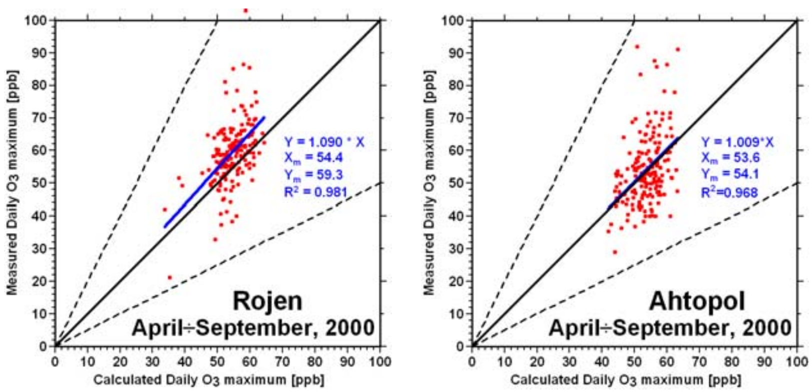


Figure 129. *Scatter diagrams of measured vs. calculated Daily Maxima.*

As far as the best way to compare ozone data is the usage of daily maxima, in Fig. 129 the scatter diagrams of measured *vs.* calculated daily maxima for both stations are displayed. One can notice that the fitting lines are very close to the ideal line, correlation coefficients being over 0.95. This figure also support the conclusion made interpreting Fig. 128. The simulation results are rather good and can be used with certainty investigating the climate change impact on pollution levels. All statistics required in the frame of CECILIA WP7 (Juda-Rezler, 2009) are presented in Tab. 6.

Table 6. *Statistical criteria for validation of ALADIN/CMAQ ozone results (year 2000)*

Station Name	Ahtopol		Rojen	
	observation	m. prediction	observation	m. prediction
Location	coastal		mountain	
Latitude, dec.	42.12		41.88	
Longitude, dec.	27.95		24.73	
Altitude, m.	29		1750	
Measured pollutant	ozone		ozone	
Measurement frequency	1 hour		1hour	
Number of valid measurements/m.predictions	8614	8760	7776	8760
Data completeness, %	98.3	100	88.8	100
Summer (JJA) mean, microgram/m^3	87.37	99.57	107.38	98.92
Maximal 8-hour mean, microgram/m^3	90.74	87.34	101.68	93.72
93.15th perc. (from 8-h. daily max.), microgram/m^3	123.42	112.62	133.36	114.58
AOT40 (for veg. protection), ppb.h	9392.97	14956.24	14127.92	14401.65
MB (from 8-h. daily max.), microgram/m^3	3.40		7.97	
NMB (from 8-h. daily max.), %	3.75		7.84	
NMSE (from 8-h. daily max.), %	5.68		4.15	
RMSE (from 8-h. daily max.), microgram/m^3	21.22		19.88	
RMSEs (from 8-h. daily max.), microgram/m^3	13.15		15.19	
RMSEu (from 8-h. daily max.), microgram/m^3	16.64		12.81	
r (from 8-h. daily max.)	0.52		0.61	
IA (from 8-h. daily max.)	0.70		0.71	
EXV (from 8-h. daily max.), %	13.00		23.27	
FAC2 (from 8-h. daily max.),%	97.96		99.69	
RPtvE (from 8-h. daily max.)	0.09		0.14	

Analogous conclusion, but not with the same certainty, can be derived from the comparison of calculated PM_{10} concentration in NIMH, Sofia, and the measured daily Total Dust Content (TDC). The main difficulty is that there are not direct measurements of PM_{10} and its estimation from TDC is quite uncertain. In the literature, various ratios PM_{10}/TDC are described (mainly from 0.2 to 0.7) depending on many different factors including the source categories and weather conditions. As to make at least qualitative conclusion about CMAQ simulation quality, two cases are displayed in Fig. 130. In the first one, calculated PM_{10} is compared with 0.15*TDC. In the second graph, TDC is replaced with a sample containing only the measurements with dust concentrations less than 60 $\mu g/m^3$. The reason of this modification is that the big measured values are probably obtained in windy days when big (and heavy) particles can get on the filter. It is supposed that in such a way obtained sample the particles are suspended in the air and it is called Total Suspended Particulate (TSP) which differs from TDC. It can be seen from both scatter diagrams that CMAQ calculations simulate in a satisfactory way the reasonable estimates of measured PM_{10} (the ratio PM_{10}/TDC at the lower limit of its reference values). All this confirms again that the ALADIN/CMAQ system is able to give reliable assessment of climate change impact on air quality.

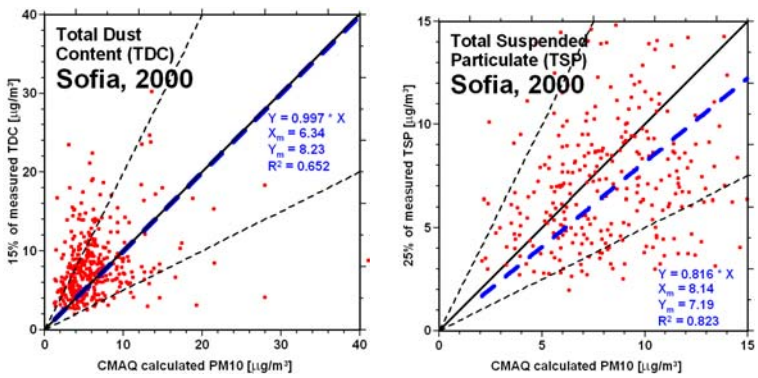


Figure 130. *Comparison of calculated PM_{10} and the measured dust (estimated PM_{10}). Right graph contains measured dust concentrations less than 60 $\mu g/m^3$, only.*

The evaluation of ALADIN/CMAQ simulations showed that the modelling system has a satisfactory performance with respect to O_3. Despite the using boundary conditions from another modelling system (RegCM3/CAMx with resolution 50 km) the basic spatial and temporal O_3 patterns are captured by the model. The best simulation quality refers summer time daily maximums. There are essential discrepancies when estimating the O_3 indexes recommended by EU Ozone Directive. The reasonable performance of the ALADIN/CMAQ system for the present time simulations justifies its use for future time projections. The PM comparisons also support qualitatively this conclusion.

Following the technology just described, the 10-year period (1991-2000) of the CECILIA Control Run (CR) was simulated. The results of this simulation can be used both for estimating "climatic" pollution levels typical for the now-a-day period and for investigation of inter-annual variations of the air quality. In the left panel of Fig. 131, the "now-a-day climatic" ozone field is presented compared with the field of 10-year mean ADM. One can notice some resemblance between space patterns but the values are quite different – the maximum of climatic ozone field is of order of the minimum of ADM-field.

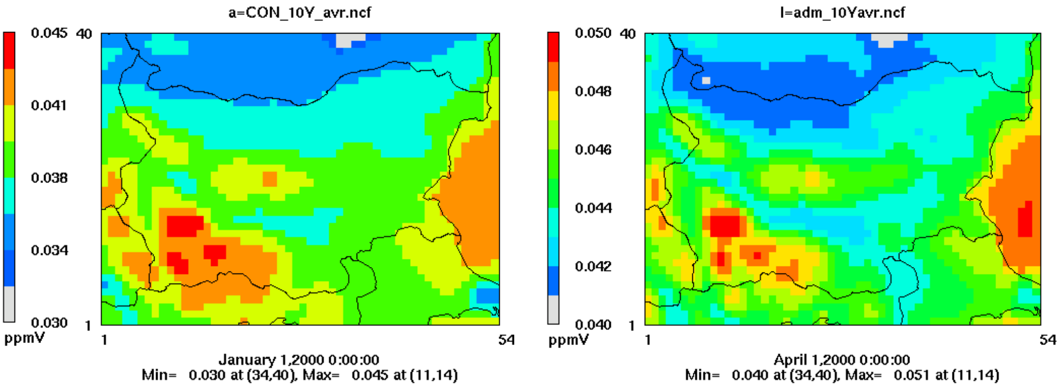


Figure 131. *10-year mean ozone concentration (left) and ADM (right), Control Run.*

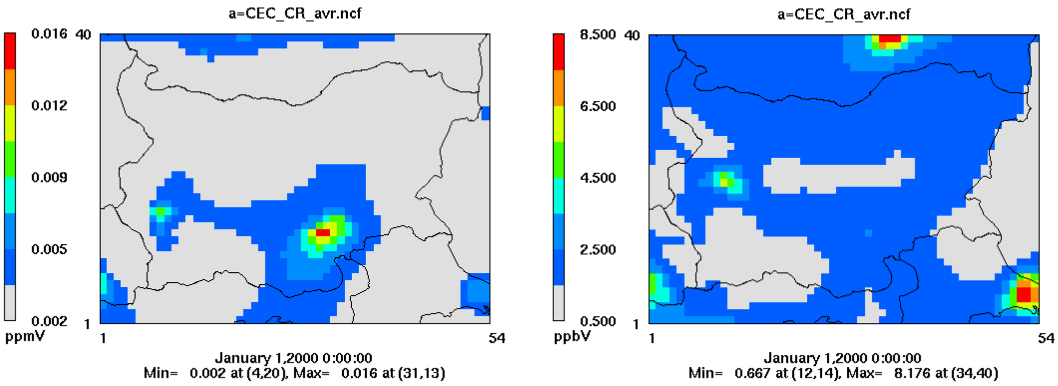


Figure 132. *10-year averaged fields of SO_2 (left) and NO_2 (right), Control Run.*

The SO_2-pollution (Fig. 132) has a well expressed maximum around the main source in the area - the three neighboring lignite coal burning thermal power plants (TPP Mariza-Iztok) in southeast Bulgaria and secondary maximum in west Bulgaria, around the TPP Bobov dol. In the NO_2-field the most populated areas form the respective maximums. They are in the region of Sofia (inside the country) but most of all they are expressed outside Bulgaria – towns of Bucharest (Romania, up) and Istanbul (Turkey, down-right). In the remaining part of Bulgaria, the NO_2 pollution levels are more or less evenly distributed. The minimums are well connected with the mountain areas (Balkan mountain in the middle, Rila-Rodipi mountains down-left and Sacar mountain down-right) as well as with Black sea area.

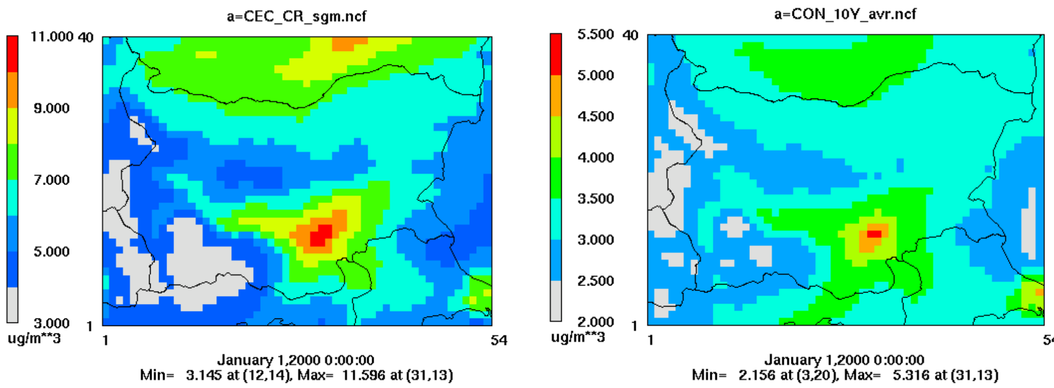


Figure 133. *10-year averaged fields of PM_{10} (left) and particulate sulphate (right), Control Run.*

In Fig. 133 the “climatic” fields of PM_{10} and PSO4 are displayed. The both fields are most or less similar that can be expected. Their main maximums are again around the most powerful PM source – TPP Maritza-Iztok in the centre. The two other spots are due to Istanbul (Turkey) and Bucharest (Romania). No other peculiarities in PM distribution can be noticed.

Similarly, the simulations for the near (2041-2050) and far (2091-2100) future decades were performed. The space distribution of the interpreted above 4 main pollutants (SO_2, NO_2, PM_{10} and Ozone ADM) are presented in Fig. 134 and 135 for near and far future periods, respectively.

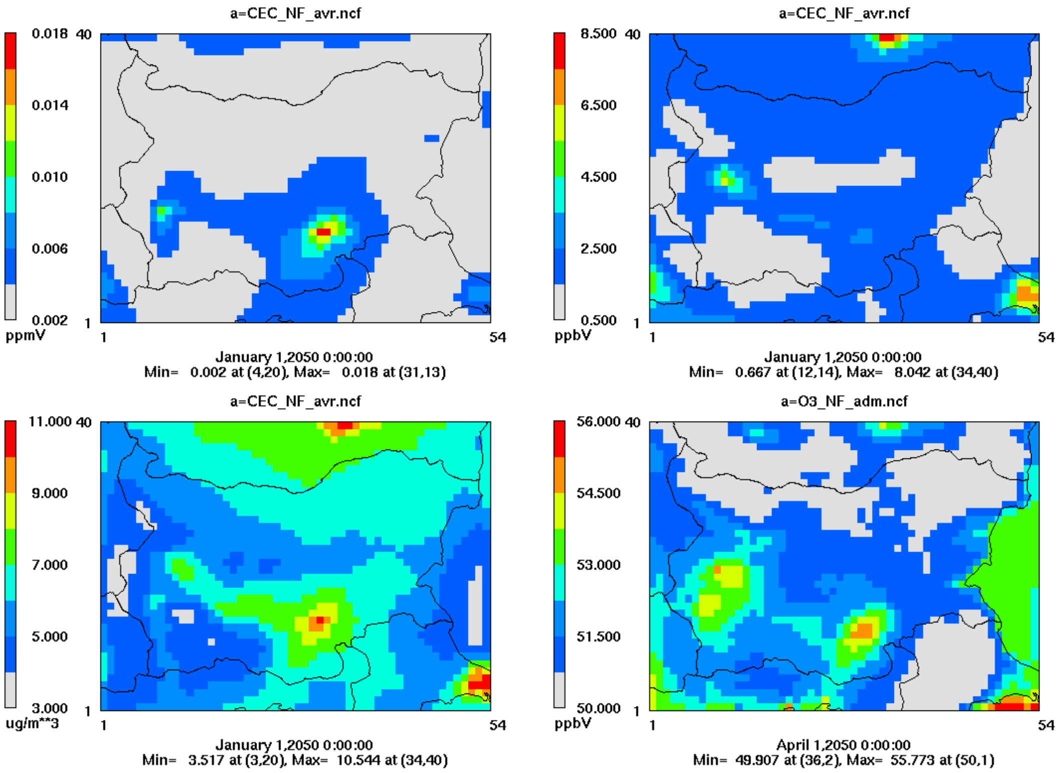


Figure 134. *10-year averaged fields of SO_2 (upper left), NO_2 (upper right), PM_{10} (bottom left) and ozone ADM (bottom right) for Near Future (2041-2050).*

It is clearly seen that the main pollution sources are well expressed again. More or less, all fields show almost the same special distribution as the respective pollutants from the Control Run.

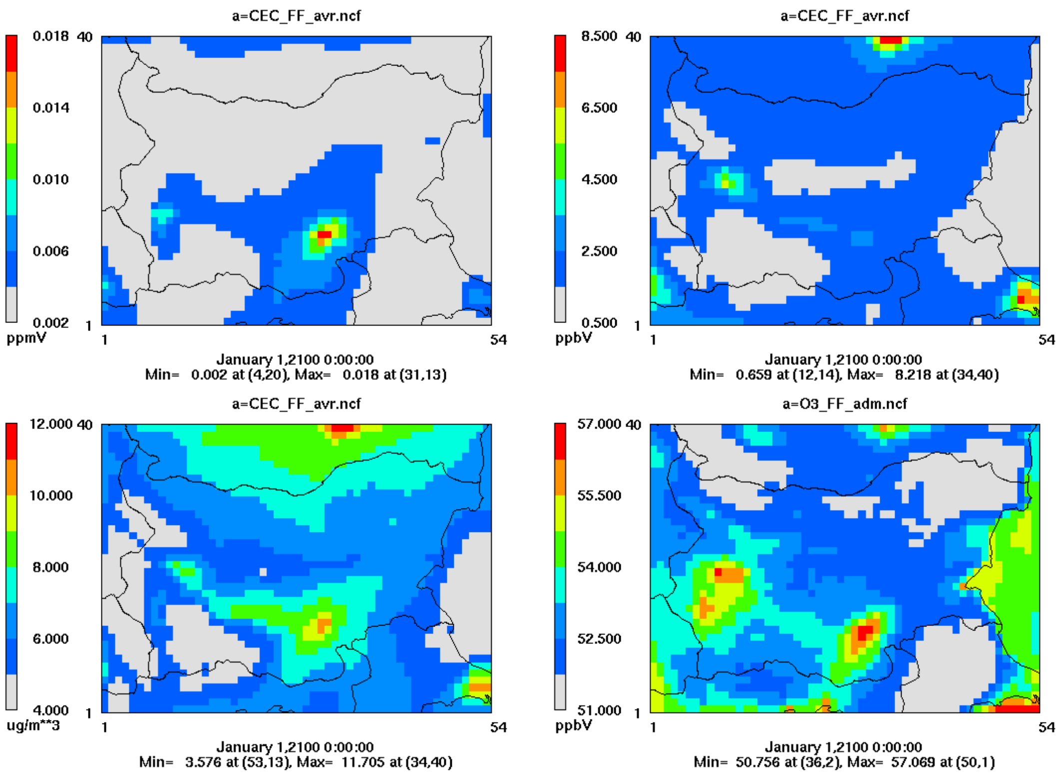


Figure 135. *10-year averaged fields of SO_2 (upper left), NO_2 (upper right), PM_{10} (bottom left) and ozone ADM (bottom right), Far Future (2091-2100).*

In Figs. 136, 137 and 138 the special distribution of the differences in 10-year mean concentrations for the 3 time slices are presented for SO_2, NO_2, and O_3, respectively. It can be clearly seen, that the differences are not very big as a whole. For all 3 species the differences between near future (NF) and control run (CR) as well as between far future (FF) and CR are bigger that those between FF and NF.

For SO_2 (Fig. 136) the maximum differences are about 2 ppb that is of order of 10 % from the maximal values. These maximums are distributed mainly in the region of the main pollution source (TPP Mariza-Iztok) or in their plumes. The highest values of this differences are observed in the Far Future against the Control Run. The differences between the Far and Near future are rather small (please notice the different scale).

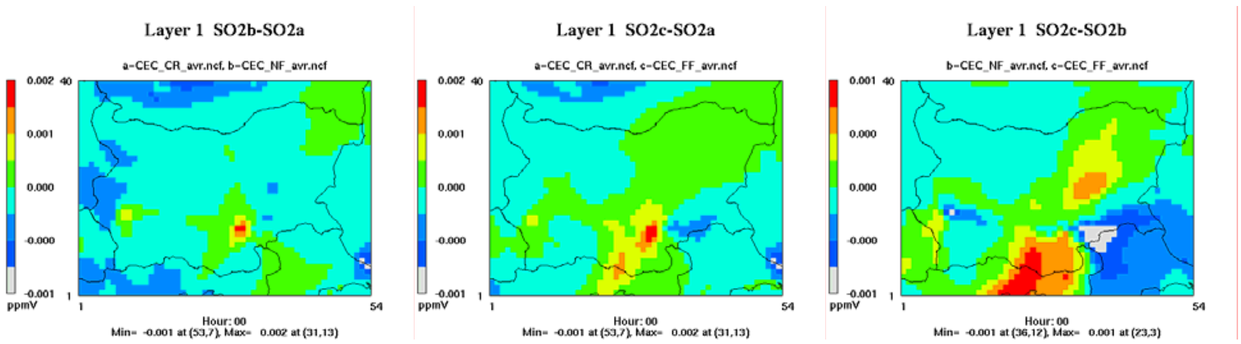


Figure 136. *Differences in the 10-year SO_2 mean fields for "NF-CR" (left), "FF-CR" (middle) and "(FF-NF) (right).*

The mean NO_2 concentration is arising from period to period almost in the whole domain (Fig. 137). Only in the regions of Istanbul and Bucharest negative values can be noticed. The differences "FF-CR" show again biggest values and spatial distribution. In prevailing part of the domain, NO_2 concentrations differences are close to zero. The highest differences are relatively small in comparison with concentration maxima – about 5 % that is below the uncertainty level.

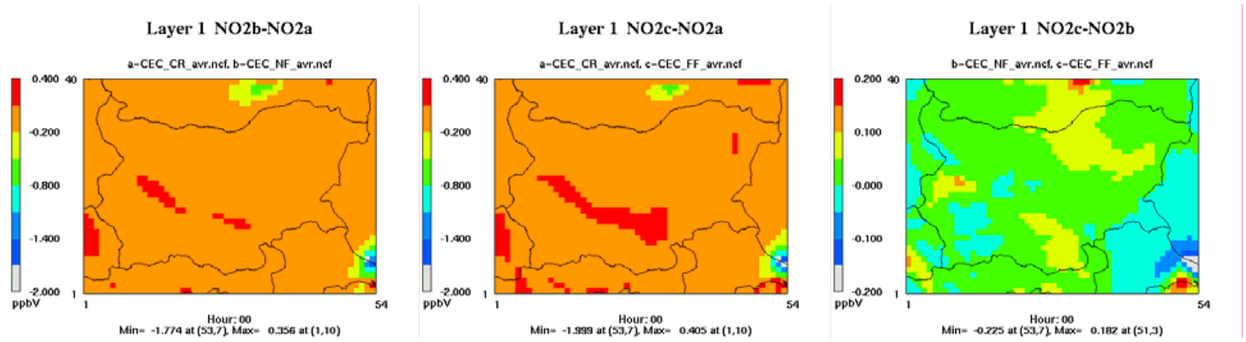


Figure 137. *Differences in the 10-year NO_2 mean fields for "NF-CR" (left), "FF-CR" (middle) and "(FF-NF) (right).*

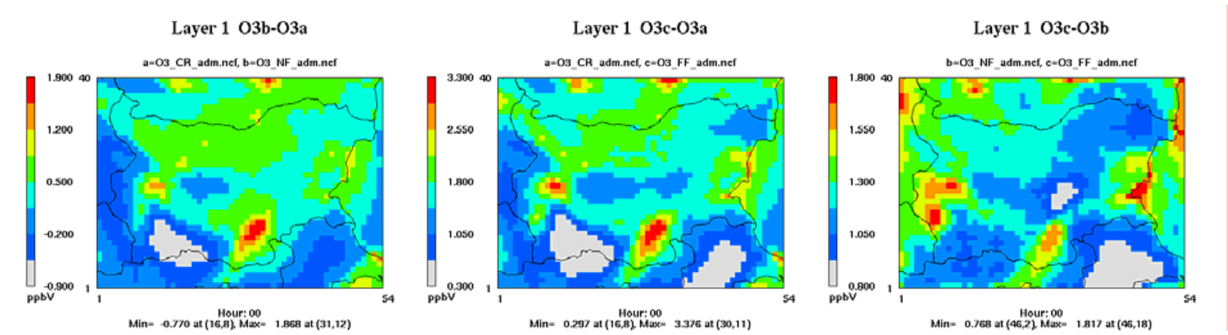


Figure 138. *Differences in the 10-year ozon ADM fields for "NF-CR" (left), "FF-CR" (middle) and "(FF-NF) (right).*

For Ozone ADM (Fig. 138) the biggest differences are between FF and CR. The highest values are over 3 ppb, that is again about 5 % of ADM maxima, i.e. not significant. There is a definite separation between positive and negative difference values in both cases (NF-CR) and (FF-CR) – they are positive in the plain parts of the domain and negative in the mountain areas. The mean ADM concentration is arising from period to period almost in the whole domain. Again the plumes of the main pollution sources show maximal values, but that time a new source appear at the Black Sea cost – the Lokoil refinery near the town of Burgas.

At NIMH exceedances of SO_2 critical level were analysed for Bulgaria. Results presented in Fig. 139 show that exceedances can be observed only in two regions, around the thermal power plants Mariza-Iztok and Bobov dol. There is no relevant change of the shape and area of these regions between the time slices. The change of the concentrations is also not relevant, however, the exceedance area is slightly wider for the end-century decade. The maximal concentrations of the NO_2 and the PM_{10} are far below the recommended annual thresholds.

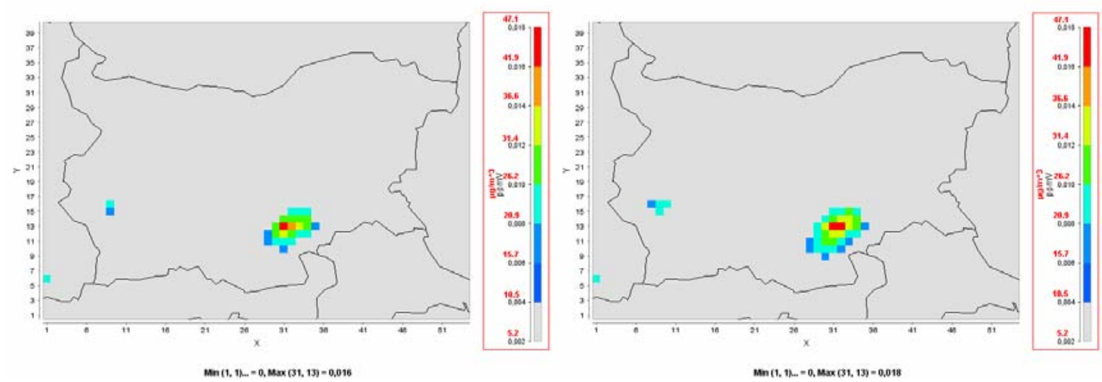


Figure 139. *Exceedances [µg/m³] of SO_2 annual critical level of 20 µg/m³ (~ 0.008 ppmv) for CR (left panel) and FF (right panel).*

To enable smooth and fast performance of the demanding simulations, adaptation of the calculation flow to be run on GRID was considered (additional activity). The motivation for using the GRID technology for this application is two-fold. Firstly, the GRID provides access to huge computational and storage resources that are not available within our local workstation. Secondly, the GRID provides a failover capability – i.e. even if some cluster is down temporarily, there will be other resources available for completing the work within particular timeframe. As it can be seen from the calculation flow, the application consists of several scripts, where the output of one script is dependent on the other. These dependencies have been successfully wrapped-up in one master script that is submitted to the GRID as a job and thus completing the computation for the whole period consists in submitting a series of consecutive GRID jobs. The jobs require MPI support and the main part of the computational time is taken by the MM5 end CMAQ computations. In both cases a locally verified version of mpich2 is used and deployed on-the-fly as part of the job.

The total size of the input data for one GRID job is approximately 3.5 GB, when initial and boundary conditions for one-month simulation are included. These data are stored at the GRID storage elements. The output generated is less than 1 GB. Obviously, since the jobs for later time periods are dependent on the previous ones, the parallelism can only be achieved by using high number of CPUs with MPI. For all computations at least 8 CPUs have been used. The application is fully gridified, except the post-processing and analysis of the data, which is done at the local workstation.

These types of computations can be run in batch mode, when results for instance for the periods 1991-2000, 2041-2050, 2091-2100 are needed. The past periods are used for calibration and verifications of the modeling system. Unfortunately, due to some limitations of the underlying organization and scripting of the sub-applications, it is not possible to run the computations in fully automatic mode. A manual intervention is required in order to resolve the failures and continue. Thus, it is important to avoid the waiting time in the queue for the jobs, especially since they require high number of processors. More efficient usage of the GRID resources was achieved using the JTS service for managing advanced reservations. The application was benefited from the experience and the advices of colleagues from the BAS Institute of Parallel Processing (IPP-BAS), who have already developed some impressive GRID applications.

High parallel efficiency of this application is observed and it is worth also to point out that on the grid one is able to find resources with more modern CPUs, which provide much faster execution than what it can be achieved locally. The current GRID implementation of this application is adequate for the needs and it makes it possible to run several different scenarios in parallel, which is interesting question for the future work. In this work mostly the resources from IPP-BAS provided within the framework of the EU 7FP SEE-GRID-SCI project were used.

2.7.2.6 WUT – Health effects case study for Poland

Hundreds of new epidemiological studies in 1990's and 2000's have indicated that the current air pollution levels are capable of harming public health. From the ambient air pollution mixture the attention has focused especially on particulate matter (PM). Out from the entire PM mass, it is especially the fine particulate matter ($PM_{2.5}$) that has been associated with a number of adverse health effects (e.g. Pope and Dockery, 2006). The impact assessments have estimated that $PM_{2.5}$ causes annually over 800 000 premature deaths worldwide (Cohen et al., 2005); 350 000 in Europe alone (Watkiss et al., 2005). $PM_{2.5}$ air pollution is one of the major environmental health problems in the developed world.

Estimation of adverse health effects caused by $PM_{2.5}$ air pollution is usually based on combination of outdoor concentrations of pollutant with exposure-response functions. Most of the published studies use ambient concentrations of $PM_{2.5}$ at different home addresses as a proxy of exposure. The exposure to $PM_{2.5}$ has been associated with a number of health effects all over the world in hundreds of epidemiological and toxicological studies. The integrated assessment studies for $PM_{2.5}$ has focused on long-term mortality impact because the major part of adverse health and economical impacts of PM are due to long-term mortality (e.g. EPA, 1999) in comparison to other adverse health effects (e.g. morbidity). Long-term mortality is the adverse health effect caused by chronic exposure to $PM_{2.5}$ air pollution and it has usually been described in $PM_{2.5}$ assessment studies by estimating the annual average $PM_{2.5}$ concentrations. The exposure-response functions used in these studies are based on epidemiological cohort studies or on the results of expert elicitation studies.

In the framework of Deliverable 7.5, we estimated the adverse health effects caused by $PM_{2.5}$ air pollution in Poland for the present day 1991-2000, near future 2041-2050, and end-century 2091-2100 decades. The aim of the study was to estimate how climate change will impact the exposure for $PM_{2.5}$ air pollution. The calculations were based on $PM_{2.5}$ concentrations calculated at WUT with ECHAM5-RegCM3(Beta)-CAMx modelling system. The results obtained for the present day decade are shown in Fig. 140.

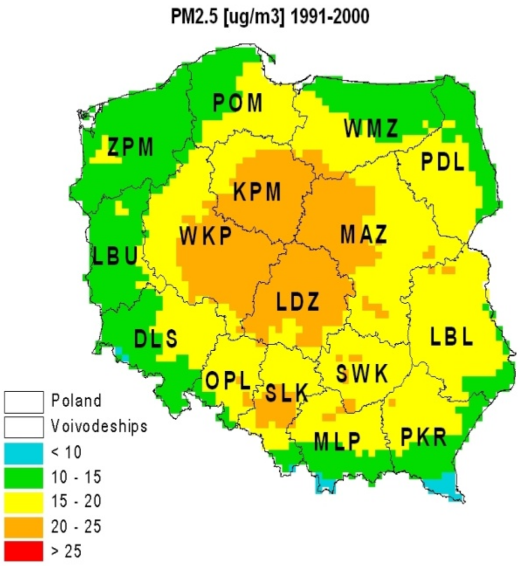


Figure 140. *Annual mean $PM_{2.5}$ concentrations [$\mu g/m^3$] in Poland calculated for present day decade 1991-2000.*

The background mortality data are from the Polish National Institute for Health. Analytica, a Monte-Carlo simulation program, was used to estimate uncertainties for premature death estimates. The average exposure levels for different provinces (Voivodeships) were calculated with ESRI ArcMap version 9.3. Exposure-response functions are based on literature. In the following calculations we assume that exposure is equal to outdoor concentration of $PM_{2.5}$ in the location of population. The average exposure of the population to $PM_{2.5}$ was estimated with two different methods:

(i) Average exposure over the grids

(ii) Population average exposure

The population average exposure was calculated with following equation:

$$E = \sum_i C_i \frac{Pop_i}{Pop}$$

In this equation, E is exposure for $PM_{2.5}$ (unit: µg/m^3), C is $PM_{2.5}$ concentration (unit: µg/m^3), *Pop* is number of population. In this case population average exposure has been estimated separately for (i) Poland and for different provinces and (ii) for different years. The results for Poland are presented in Fig. 141.

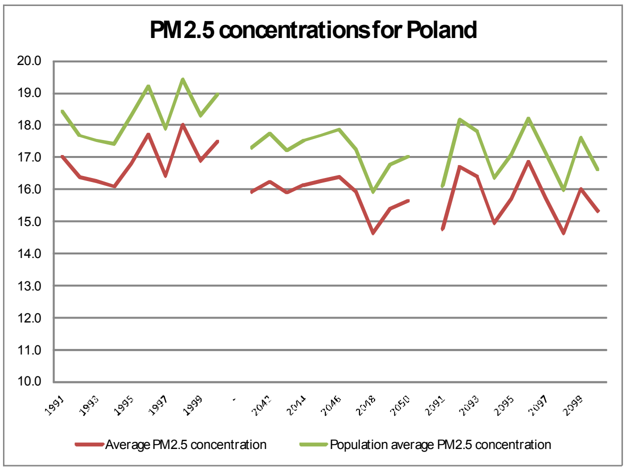


***Figure 141**. Average and population average exposure for $PM_{2.5}$ in Poland for the time slices 1991-2000, 2041-2050, and 2091-2100. For statistical tests see Table 7.*

The results of *t*-test for the difference between considered time slices for both average and population average exposure are given in Tab. 7.

***Table 7.** t-test results. A two sample location test of the null hypothesis was used to test if the means of two different time blocks results are equal. t-test value less than 0.05 means that the means of two samples are different. According to t-test, for both average and population average exposure the difference between the present day decade 1991-2000 and the both future decades is statistically significant. The difference between the near future decade 2041-2050 and the end-century decade 2091-2100 was statistically insignificant for both average and population average $PM_{2.5}$ exposure.*

	Average $PM_{2.5}$ concentration	Population average $PM_{2.5}$ concentration
1991-2000 vs. 2041-2050	0.001	0.001
1991-2000 vs. 2091-2100	0.002	0.003
2041-2050 vs. 2091-2100	0.652	0.712

The premature mortality was calculated with following equation:

$$M = M_b \times E \times (ER/100)$$

In the equation, M is premature death due to $PM_{2.5}$ air pollution, M_b is background non-accidental mortality in Poland in year 2000, E is exposure level, and ER is exposure-response function (% change in mortality due to 1 µg/m^3 $PM_{2.5}$ exposure). For value of ER, we used the estimates from European expert elicitation study that evaluated exposure-response function for $PM_{2.5}$ air pollution (Tuomisto et al., 2008). Tuomisto et al. (2008) study provided two different mean values (EDM and PDM) for E and the results have been estimated with both of these. In addition the premature deaths were estimated with Monte Carlo simulation using both of these estimates. Fig. 142 shows the estimated premature deaths for different provinces for year 2000, while the premature deaths estimates for present day and future climate are presented in Deliverable D7.5.

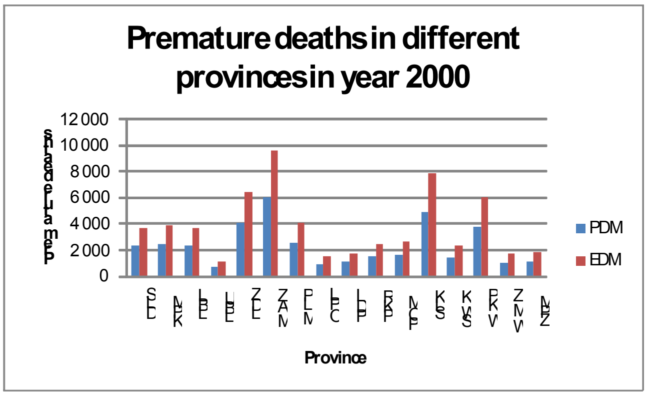


Figure 142. *Premature deaths in different provinces in Poland estimated for year 2000. The premature deaths have been estimated by using both EDM and PDM exposure-response functions. See Fig. 16 in D7.5 for province acronyms and localisation.*

Estimated population average exposures to $PM_{2.5}$ in Poland were 18.3 µg/m^3, 17.2 µg/m^3 and 17.1 µg/m^3 for three considered time slices 1991-2000, 2041-2050, and 2091-2100, respectively. Corresponding values for average $PM_{2.5}$ concentrations over Poland were 16.9 µg/m^3, 15.8 µg/m^3 and 15.7 µg/m^3, respectively. For both average and population average exposures the differences between the present day decade 1991-2000 and the both future decades are statistically significant. Results indicate that climate change might reduce the exposure to PM air pollutants and resulting premature death estimates in the region under concern. However impact of emission and population changes were not taken into account in our study.

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2.7.3 Deviations from workprogramme

In the third reporting period BOKU performed 10 km runs for Hungarian region with the CAMx photochemical model driven by the RegCM results from ELU. There were some delays in connection to the availability of high resolution simulations. There were no other significant changes in the workprogramme.

2.8 List of deliverables

Del. No	Deliverable title (with WP identification code)	WP No.	Lead partner	Estimated person months	Used person months[1]	Due date	Actual delivery date[2]
D1	D8.1 Project web site established	8	CUNI	1		Month 1	Month 1
D2	D8.2 Project Presentation	8	CUNI	1		Month 4	Month 5
D3	D4.1 Measures and indices to be validated, which observational data sets to be used for the validation of extremes, plan of the analyses to be performed under D4.2, D4.3, D4.4, D4.5, and D4.6	4	ETH	12		Month 6	Month 7
D4	D5.1Description of the rainfall-runoff models and of the reference basins, a revision of flood events from the analyze period, the input data, the schematization of the reference basins.	5	NIHWM	16		Month 6	Month 7
D5	D6.1 Report about the results of the crop yield and forest tree growth changes influenced by climate change, regional conditions and management systems	6	FRI	8		Month 6	Month 6
D6	D8.3 Workshop with potential endusers and stakeholders	8	CUNI	1		Month 6	Month 12
D7	D1.1 Assessment of climate change information for CEE from previous projects	1	ICTP	12		Month 12	Month 13
D8	D1.2 Provision of climate change information from previous projects for first-stream impact work.	1	CNRM	11		Month 12	Month 12
D9	D3.1 Observed data for SDS models building, output localization, up-scaling, and model validation: station data and reanalysis data for SDS predictors	3	CHMI	10		Month 12	Month 21
D10	D5.2 Calibration of the monthly river flows over the selected period (1970-2000) and the rainfall-runoff models according to the flood events over the same period.	5	NIHWM	18		Month 12	Month 12
D11	D5.3 Analysis of natural conditions, climate, hydrology, development of land use, surface water quality, and water management during the period from the 1960s to the present.	5	FRI	20		Month 12	Month 12
D12	D6.2 Results of the drought damage potential and crop water use efficiency as influenced by climate change effects and regional conditions (IAP, BOKU, CHMI, NIMH, NMA, FRI).	6	NMA	27		Month 12	Month 14
D13	D7.1 Coupling of the AQM's to the RCM's. Development of the pre-processors to convert RCM-output to AQM-input.	7	BOKU	26	0.4	Month 12	Month 13
D14	D8.4 Progress Report 1	8	CUNI	3		Month 13	Month 13
D15	D1.3 ARPEGE simulation at 50 km grid for the 21st century under the A1B scenario for WP2	1	CNRM	8		Month 18	Month 20

[1] Number of person-months spent during the third reporting period
[2] Asterisk marks revised deliverables

D16	D1.4 RegCM3 simulation at 25 km grid for the 21st century under the A1B scenario for WP2	1	ICTP	8		Month 18	Month 24
D17	D2.1 RCM simulations forced by observations	2	CUNI	35		Month 18	Month 24
D18	D3.2 RCM output localization methods	3	BOKU	16	8.5	Month 18	Month 43*
D19	D4.2 Analysis of observational datasets and of selection of pre-existing RCM data sets according to the decisions made in D4.1	4	DMI	28	1.7	Month 18	Month 25
D20	D5.4 Description, calibration, sensitivity and uncertainty analysis of the atmosphere-river network-reservoir modelling system and simulation of monthly river flow considering climate changes, comparison of results	5	IAP	6	6.1	Month 18	Month 43*
D21	D7.2 Key species concentrations from the European runs for 4 * 10 years with 50 km resolution based on CBM-IV chemistry with sulphur, analysis of the output of the offline chemistry AQMs for future projections and for the control period.	7	AUTH	17		Month 18	Month 20
D22	D2.2 forcing files from ARPEGE for ALADIN runs	2	CNRM	8		Month 19	Month 20
D23	D2.3 forcing files from RegCM for RegCM runs	2	ICTP	2		Month 19	Month 24
D24	D2.4 RCM simulations forced by models	2	OMSZ	59	21.3	Month 30	Month 36*
D25	D3.3 Assessment of the applicability of RCM and SDS models in the impact target areas by their validation according to relevant criteria; ranking of the models	3	IAP	22	8.5	Month 24	Month 43*
D26	D4.3 Corresponding analyses of the CECILIA driving-model simulations, links between large-scale circulation patterns and extreme events	4	ETH	15	3	Month 24	Month 30*
D27	D5.5 Present and future water demand.	5	NIHWM	2		Month 24	Month 24
D28	D5.6 Report on local air-sea interaction on the western Black Sea coast in present climate conditions.	5	NMA	6		Month 24	Month 24
D29	D6.3 Recommendations to improve effective use of water in the different production systems	6	BOKU	15		Month 24	Month 24
D30	D8.5 Progress Report 2	8	CUNI	3	2	Month 25	Month 27
D31	D2.5 production of the database	2	DMI	6	1.5	Month 33	Month 48
D32	D3.4 Climate change scenarios for near future (time slice 2020-2050)	3	NMA	18	6.5	Month 33	Month 40
D33	D3.5 Climate change scenarios for end of century (time slice 2070-2100)	3	ELU	18	10.6	Month 36	Month 37
D34	D5.7 Simulations of the sensitivity of reference basins using the balance between the demand and water resources and flood events under the present and future conditions with or without climate change	5	CHMI	5	8.2	Month 36	Month 42

D35	D5.8 Scenario studies for the assessing responses of the physical and hydrobiological characteristics in the river network and reservoirs to anticipated climate, land use and nutrient source changes in the catchments.	5	IAP	2	2	Month 36	Month 44
D36	D6.4 International workshop and course for decision makers on the effective use of water in agricultural crop production	6	BOKU	6	1	Month 30	Month 31
D37	D6.5 Expected changes of occurrence and activity of pests and diseases on selected crops and forest ecosystems	6	IAP	13	11	Month 36	Month 43
D38	D6.6 Sensitivity analysis of the selected agriculture crops and the most vulnerable forest stands to climate change impacts	6	FRI	26	20.6	Month 36	Month 43
D39	D7.3 Key species concentrations files from higher resolution runs (10x10 km) for control run and future projection	7	CUNI	46	23.7	Month 33	Month 37
D40	D4.4 Corresponding analyses on the CECILIA high-resolution simulations	4	NMA	43	27.8	Month 36	Month 41
D41	D4.5 Sensitivity experiments for feedback processes (land-atmosphere coupling) and their analysis	4	ICTP	12	7	Month 40	Month 43
D42	D2.6 analysis of scenarios, comparison with ENSEMBLES (2021-2050) and PRUDENCE (2071-2100) responses	2	CNRM	51	41.4	Month 43	Month 43
D43	D2.7 report on possible improvements in very high resolution climate simulation	2	DMI	45	22	Month 43	Month 43
D44	D3.6 Comparison with results of ENSEMBLES	3	CUNI	8	2	Month 43	Month 43
D45	D4.6 Report and/or peer-reviewed papers documenting the WP4 studies.	4	ETH	12	12.2	Month 43	Month 46
D46	D5.9 Adaptation measures proposed in the reference basins due to the climate change impact	5	NIHWM	6	7	Month 43	Month 36
D47	D5.10 Local air-sea interaction changes on the western Black Sea coast under different climate conditions, relevance to regional sustainable development.	5	NMA	3	2	Month 43	Month 42
D48	D6.7 Integrated assessment of climate change and air pollution impacts on C-cycle in agriculture and on forest ecosystems	6	ELU	13	8.13	Month 43	Month 43
D49	D6.8 Recommendations and development of management for an improved land use systems in agricultural crop production and forest management under the regional climate change scenarios	6	FRI	19	10.1	Month 43	Month 43
D50	D7.4 Analysis and evaluation of the results, comparison of the higher resolution runs (10x10) with the lower resolution runs (50x50) for the specific domain	7	CUNI	17	18.5	Month 43	Month 44
D51	D7.5 Present and future key species exceedances of the EU limits and WHO guidelines, health effects.	7	WUT	8	6.6	Month 43	Month 44

D52	D8.6 Final Plan for using and disseminating knowledge	8	1	1	2	Month 43	Month 43
D53	D8.7 Report on raising public participation and awareness	8	1	1	1	Month 43	Month 43
D54	D8.8 Month 36 Final workshop, information and outputs for endusers, policy and decision makers, local authorities etc. (throughout the project period as well)	8	CUNI	2	2	Month 43	Month 43
D55	D8.9 Final Report	8	CUNI	5	11	Month 45	Month 48

2.9 List of milestones

Milestone No.	Milestone name	WP number	Date due	Actual delivery date	Lead contractor
M1	M2.1: The integration domains and RCM parameterizations are defined	2	Month 6	Month 6	CNMR
M2	M3.1: datasets prepared, validation criteria formulated, list of variables for impacts agreed	3	Month 6	Month 12	IAP
M3	M4.1: Decision on which measures and indices of extremes should be part of the analyses of WP4 and detailed implementation plan resulting from D4.1	4	Month 6	Month 6	ETH
M4	M6.1: Selection of agricultural and forest regions, Data base on historical data and other model input data, Preparation of the GIS tools	6	Month 6	Month 12	FRI
M5	M1.1: Provision of data from available climate change simulations for first-stream impact work	1	Month 12	Month 12	ICTP
M6	M3.2: SDS methods developed	3	Month 12	Month 12	IAP
M7	M5.1: Calibration of the models using the data over the selected period (1970-2000); Observed data analyses of local air-sea interaction at western Black Sea coast; Calibration and testing of water quality in the modelling system.	5	Month 12	Month 12	NIHWM
M8	M6.2: Calibration and validation process of the selected models (water balance, drought indices and growth) for the main selected crops, crop rotations and forest ecosystems.	6	Month 12	Month 12	FRI
M9	M7.1: Selection of the air-pollution episodes to be simulated from the offline and online chemistry AQMs	7	Month 12	Month 12	AUTH
M10	M1.2: Provision of driving fields from intermediate scale experiments for very fine scale targeted simulations	1	Month 18	Month 18	CNRM
M11	M2.2: The observation driven simulations are ready for other WPs	2	Month 18	Month 24	CUNI
M12	M3.3: RCM output localization methods developed and verified on ERA40 RCM runs	3	Month 18	Month 26	BOKU
M13	M7.2: Simulations of the offline chemistry model CHIMERE and/or CAMx driven by RCM for Europe with 50x50 grid resolution.	7	Month 18	Month 18	AUTH
M14	M2.3: The scenarios and references RCM simulations are ready for other WPs	2	Month 30	Month 30	OMSZ
M15	M2.4: The sensitivity experiments to improved physical parameterizations are analyzed	2	Month 40	Month 40	AUTH
M16	M3.4: validation and comparison of RCM and SDS models completed	3	Month 24	Month 24	IAP

M17	M5.2: Simulation of flow in the case of modified regime; Evaluation of the water demand in present and future conditions; Regional experiment design for air-sea interaction phenomena at western Black Sea coast.	5	Month 24	Month 24	NIHWM
M18	M6.3: Simulated results of the sensitivity of crops and management on crop water use. Results on potential drought damage, water use efficiency and crop water use under the selected climate scenarios. Results about the sensitivity analysis and integrated assessment of the most vulnerable forest stands to climate change and air pollution impacts on forest ecosystems.	6	Month 24	Month 24	BOKU
M19	M7.3: Results from the comparison of key species levels simulated by the offline and online regional AQMs.	7	Month 24	Month 36	WUT
M20	M2.5: The database is ready for access inside the project	2	Month 33	Month 33	DMI
M21	M7.4: Simulations of the offline AQMs driven by RCM for a specific smaller domains in Central Eastern Europe with 10 x 10 grid resolution.	7	Month 28	Month 28	CUNI
M22	M3.5: climate change scenarios for both time slices completed	3	Month 36	Month 36	IAP
M23	M5.3: Assessment of the vulnerability of reference basins and the adaptation measures; Impact study and assessments of climate change in water quality; Assessment of local changes in air-sea interaction modes under different climate conditions and their relevance for regional sustainable development.	5	Month 36	Month 36	NIHWM
M24	M6.4: Results on management options for improving effective use of water under climate scenarios in the various agricultural production systems. Results on impacts of climate change on C-cycle in agriculture and forest ecosystems.	6	Month 36	Month 36	IAP
M25	M7.5: Results from the analysis of the output of the simulations of the offline chemistry AQMs driven by RCM for Europe with 50x50 grid resolution.	7	Month 30	Month 30	AUTH
M26	M7.6: Results from the analysis of the output of the simulations of the offline chemistry AQMs driven by RCM for specific smaller domains in Central Eastern Europe with 10x10 grid resolution.	7	Month 33	Month 36	WUT
M27	M7.7: Results from the calculations of present and future key species exceedances of the EU limits and WHO guidelines for a specific smaller domains in Central Eastern Europe with 10x10 grid resolution	7	Month 36	Month 40	WUT
M28	M2.6: The database is in public access and a report on the gain of high resolution in the local description of climate responses is available	2	Month 43	Month 43	DMI
M29	M3.6: comparison with ENSEMBLES outputs finished	3	Month 43	Month 43	IAP
M30	M4.2:: Finished analyses of extremes based on both pre-existing and CECILIA model output	4	Month 43	Month 43	ETH
M31	M6.5: Final report written and papers submitted. Adaptation analyses, recommendations and development of management options for improved land use systems in agricultural crop production and forest management under the regional climate change scenarios	6	Month 43	Month 43	FRI

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Section 3 Consortium management

The CECILIA project has been completed. The significant problem with the delay of high resolution simulations of the project was solved when application for the project extension by 7 month was approved. Thus, all the simulations were completed and their outputs provided for climate change impact assessment. Some impact studies were performed within the last reporting period using this high resolution data, some previous work was updated using them as well.

3.1 Consortium management tasks and their achievement; problems which have occurred and how they were solved

3.1.1 Project management

The overall aim of the management of CECILIA was to ensure a smooth running of the project. This was supposed to be achieved through the following objectives:

- application quality management procedures
- application financial management procedures
- maintenance of the documents for the project
- maintenance of on-line information tools of the project
- to ensure appropriate co-operation among the WPs and related projects

The following sub-sections describe the basic ideas of the organization and management of CECILIA. Details were fixed in the Consortium Agreement (CA) signed by all the partners.

3.1.2 Management structure

Management structure of CECILIA was proposed to cover all possible problems and aspects of the smooth running of the project using maximum of the human resources and - at the same time - minimising the overhead associated with project management in both a general and a technical sense. The organisational hierarchy of the project is outlined in the following:

The Project management has been assured by the following relevant roles: a) Project Manager, b) Workpackage Leaders, c) Team Leaders, and by means of the Scientific Steering Group. Fig. 143 clarifies the relations between the above groups and roles.

The CECILIA co-ordinator, namely CUNI, was responsible for the overall management of the project as specified in the contract with European Commission (EC). For this purpose, the co-ordinator nominated:

a) A **Project Manager (Jiří Mikšovský)**, who was resuming overall responsibility for all the day-to-day project co-ordination matters, assisting and supporting the co-ordinator. The project manager was responsible for:

- monitoring the performance and progress of the project against time and cost plans
- making proposals to amend the plans if unexpected situations arise
- scheduling meetings and distributing minutes
- dissemination and promotion of project activities and results

- maintaining the on-line information tools, web page of the project.

Each partner nominated a **Team Leader (TL)** who was responsible for managing the team within his company. The TL was the official appointee of his institution for management communication and matters with the Coordinator or Project Manager. **WP Leaders (WPL)** represented their WPs in the **Scientific Steering Group** (**SSG**). The SSG was co-chaired by the Project Coordinator and the Project Manager. The SSG monitored progress against time and cost and co-ordinated and controlled the overall project work and activities. Decisions taken by the SSG were binding for the consortium for the duration of the project. All the decisions of SSG have been unanimous.

Workpackage Leaders (WPLs) were responsible for the performance of work packages. Specific tasks for WPLs were to ensure accomplishment of the technical objectives of the Workpackage, to report to the Project Manager, to log major decisions related to the progress of the work package, to co-ordinate the issue of deliverables associated with the WP, to flag insufficient quality or unacceptable delays in the contribution of individual members, to co-ordinate the production of external papers in topics dealing with their activities. For each workpackage, the WPL was appointed by the partner, which was designated as responsible partner for the specific WP.

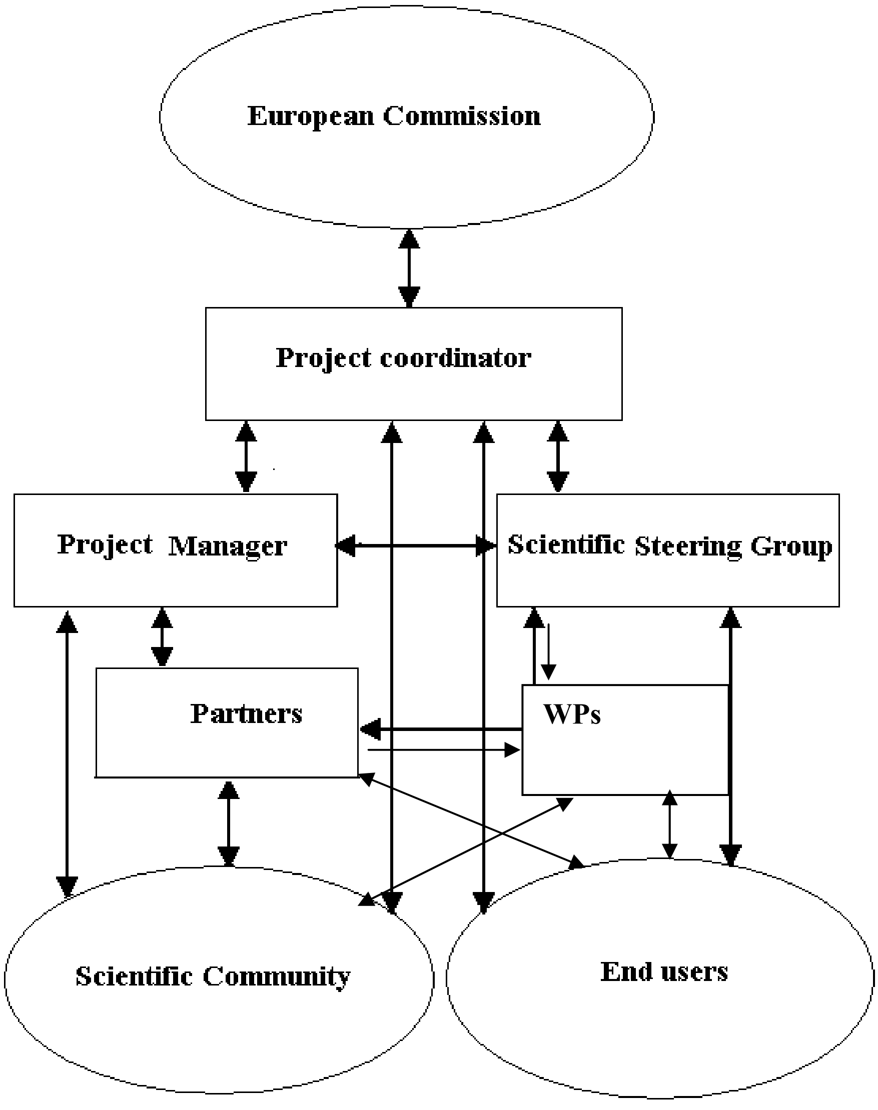


Figure 143: *Management structure*

Workpackage Teams (WPTs) were formed by specialized staff provided by the Partners. Each Workpackage Team was chaired by a WPL, and it was in charge of carrying out the technical work as described in the DoW. Each key deliverable of the project was reviewed by the SSG.

3.1.3 Coordination of the project, project meetings

The significant problem with the delays of some partners high resolution future climate simulations within WP2 (mostly when using RegCM, due to problems with driving fields transfer and finally certain bug discovered, big domain at CUNI) arises in the second year of the project and needed the solution as it was clear it would have consequencies in all subsequent applications of the model simulations in climate change impact assessment studies. The problem was carefully considered and discussed both at SSG and between TLs at our regular meetings; finally the decision was made to apply for the project extension by 7 month till December 2009. This was basically only possibility to provide time enough for impact WPs to asure at least some studies will be based on CECILIA internal high resolution simulations. Indeed, this extension was approved and thus all the simulations were completed and their outputs provided for climate change impact assessment WPs. Some impact studies were performed within the last reporting period using this high resolution data, some previous work was updated using them as well.

There were three meetings during the last reporting period. The first one was held in M 30 in Dunajska Streda, Slovakia, with a few local stakeholders. Here the final decission for extension application came from. The second meeting was held in Chalkidiki, M 37, with coordination of final work to complete all the project tasks and with planning of the final CECILIA project meeting. This was scheduled for M 42 to Prague and project presentation for local stakeholders or decision makers was planned. Presentations from the meetings were published in restricted part of the Project web, engine for communication, uploading, downloading and team sharing of the deliverables were mainained on the web, as well as other electronic tools for maintaining the project documents and communication.

Progress in the work on the project as well as management issues were discussed on SSG and Management Meetings held in connection with Project meetings which were supposed to be scheduled at least each 9 months and they were followed by technical workshops in order to co-ordinate our work. The meetings included review of any reports due to be delivered shortly afterwards, so that Formal Document Reviews will be the principal quality control that will be exercised on the project. During these meetings the Project Manager and Project Coordinator, together with SSG discussed the situation with the delay which was partially seen during the review of the progress in WP2 during the Varna meeting and checked the **risk management** plan, trying to minimize the problems with the high resolution simulations delays. Proposed strategy of peer to peer provision of data immediately as they are available, i.e before often the long term procedure of their archiving in formats which the impact people were not so familiar with. This worked finally, although this resulted in certain delay of the database building.

3.1.4 Project communication, cooperation with other projects

The communication flow between the partners was continuous. Extensive use of e-mail was made for the day to day communication between partners of the consortium. A web site (Deliverable D8.1) promoting the CECILIA results and disseminating information about the project was launched in Month 1 of the project lifetime. All technical documentation generated by the Project are exchangeable in electronic format, according to a set of guidelines agreed at kick-off meeting and defined in CA. Reports are written to a project standard using a common word processor. Exchange of information occured mainly by e-mail and file transfer over Internet. A WEB project document repository was made available by the Co-ordinating Partner, there is restricted domain on the Project web pages for these documents, as well as part for downloading and uploading all the project materials. Telephone and fax were used in urgent needs only. Ordinary mail was used for strictly formal correspondence, i.e. when executive signatures were required.

Links with other related projects (ENSEMBLES, CLAVIER, COST 734 - CLIVAGRI) were maintained through an active information exchange process and by attending other projects' meetings by the Project Coordinator. Some communication to new projects (WATCH, MEGAPOLI) started as they appeared, in the later even CUNI being a partner. Significant cooperation with EC project ADAGIO and COST 734 activity through numerous personal overlapping in the area of agriculture impacts was developed, common meeting was organized twice in Austria which brought to us more visibility and connection to end-users of these studies, stakeholders and decision makers.

3.1.5 Using and disseminating knowledge

The results of the climate change simulations generated within the CECILIA project are getting to be available for other interested institutes, universities and research centres in Europe. These data are already available via web access through DMI server, although at the moment password protected, after final report approval they will be publicly available. Meanwhile, access is granted upon request. Some results might be available on CD-ROMs or DVDs. Climate change impact data will be used for further impact research and policy studies and the results of these studies (e.g. in the project deliverables) will be available as well. Both the reports and data generated during the project might contribute to the development of the next IPCC assessment report and, of course, the results are already shared and intercompared with other projects (ENSEMBLES, COST 734, etc.). Spreading the results of the climate change simulations to non-participating institutes and countries of targeted region can significantly increase the efficiency of the project.

There is one important point of the CECILIA dissemination & exploitation strategy, i.e. communication with end-users, stakeholders or policy makers to provide the necessary and reliable information directly as well as having the feedback to the project, especially from end-users for impact studies. This is planned now to be kept throughout the whole project duration instead of the original concept of a single meeting as required for D8.3. The original task following DoW was to hold a single meeting with endusers in the beginning of the project period (Month 6). More efficient way organizing the meeting with endusers whenever having working project meeting in targeted region has been found, however, mainly because of more often occasion for communication of the actual results and feedback and better availability of local endusers at the meetings. Thus, we had a few endusers for a presentation in Dunajska Streda Meeting and Project presentation meeting during Final Meeting in Prague. Actually, the efficiency of the Prague’s meeting was not so high as expected, unfortunately, it came to the period directly before the Copenhagen COP15 and thus decision makers and stakeholders were not so much interested.

3.2 Contractors contributions, changes in responsibilities and changes to consortium itself

All the partners were contributing quite actively to the project working either with their or other data or model tools. Significant degree of the cooperation between the partners in framework of individual workpackages was achieved, most of the contractors were well established in the appropriate topics already at the beginning of the project and in further closer cooperation in framework of WPs teams building continued.

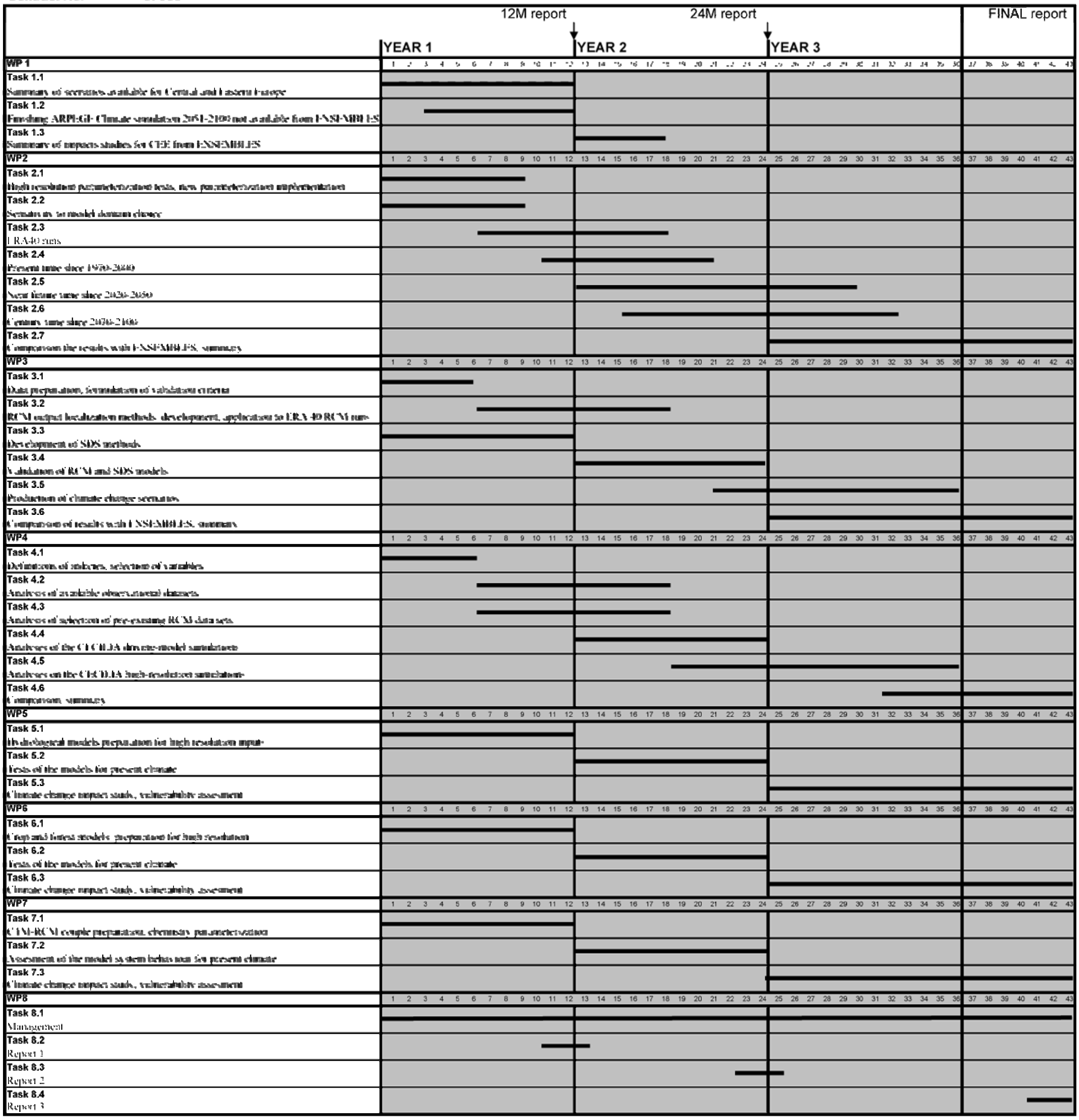
There were no changes in responsibilities, consortium and no changes in the contract except the finance neutral extension of the project. We did not continue toward the adding of new partner as it was started with National Center for Scientific and Applied Preventive Medicine (CNSPMP), Moldova, which expressed the interest to get closer to CECILIA project using our simulations for impact studies in Moldova, especially for health effects, as well as for validation of the simulations and climate change scenario construction for their territory. The difficulties of official procedure were too strong, so that we remained at the level of informal communication and we had the representative of the institute at our project meeting in Slovakia, where closer contacts with some partners have arised.

3.3 Project timetable and status

Table 8. *Frontlined barchart of the CECILIA project status and timetable*

PROJECT BARCHART and STATUS

Acronym CECILIA
Contract No. 37005



The CECILIA project has finished. Unfortunately, during the second year significant, although partial delay of the high resolution simulations appeared, which had the consequences in the third year of the project in timing of impact studies. In the third year massive use of the results from project high resolution simulations was supposed, thus the delay of them affected some applications. The SSG treated carefully the situation with the delay in WP2 and its consequencies for the Project during the last Management meetings and adopted the strategy to minimize the problems. However, although the proposed strategy of peer to peer provision of data which are available for impact studies worked in some extent, for full achievement of project objectives the extension of the project, as unanimously considered by SSG, was the sole solution.

The present, i.e. final status of the project is presented in Tab. 8. Certain delay of the reporting should be mentioned, mainly due to much longer process of getting audit certificates at some partners.

Annex – Final plan for using and disseminating the knowledge

1 Exploitable knowledge and its Use

The results obtained do not contain explicitly exploitable knowledge and thus there is no direct commercial application.

2 Dissemination of knowledge

The dissemination activities section should include past and future activities and will normally be in the form of a table maintained by the coordinator or any other person charged with controlling the dissemination activities**.**

In Table 9, the publication and presentation outputs of CECILIA are shown for the third period of the project (items 1-135, produced during the first two project periods, were given in the previous reports; please note, that due to technical correction in the database, numbering of the items may differ from the one used in period reports for years 1 and 2).

Table 9a. *CECILIA publications and presentations: References*

No.	Reference
136	Pongracz R., Bartholy J., Szabo P., Gelybo Gy. (2009): A comparison of observed trends and simulated changes in extreme climate indices in the Carpathian basin by the end of this century. International Journal of Global Warming, 1, pp. 336-355.
137	Bartholy J., Pongracz R., Torma Cs., Pieczka I., Kardos P., Hunyady A. (2009): Analysis of regional climate change modelling experiments for the Carpathian basin. International Journal of Global Warming, 1, pp. 238-252.
138	Pongrácz R., Bartholy J., Gelybó Gy., Szabó P. (2009): Detected and expected trends of extreme climate indices for the Carpathian basin. In: Bioclimatology and Natural Hazards (eds: Strelcova, K., et al.), pp. 15-28. Springer.
139	Bartholy J., Pongrácz R., Gelybó Gy., Kern A. (2009): What climate can we expect in Central/Eastern Europe by 2071-2100? In: Bioclimatology and Natural Hazards (eds: Strelcova, et al.), pp. 3-14. Springer.
140	Rodica MIC, C. CORBUS, Gianina CHIRILA, Aristita BUSUIOC, Mirela PANCESCU, Evaluarea impactului potential al schimbarilor climatice asupra regimului hidrologic din bazinele hidrografice Buzau si Ialomita, Conferinta Internationala a INHGA 'Managementul resurselor de apa in conditii extreme', Bucuresti 22-24 septembrie 2008.
141	Rodica MIC, Ciprian CORBUS, Elisabeta OPRISAN, Participarea INHGA la realizarea obiectivelor proiectul CECILIA - 'Evaluarea impactului si a vulnerabilitatii la schimbari climatic in centru si estul Europei', Simpozionul CORINT 'Cercetarea romaneasca in Programul Cadru 6 de Cercetare-Dezvoltare, Inovare si Actiuni Demonstrative al Uniunii Europene', Sinaia, 8-11 octombrie 2008.
142	R.P. MIC, C. CORBUS, G. NECULAU, A. BUSUIOC, Potential impact of climate changes on the hydrological regime in the Buzau and Ialomita river basins, Geophysical Research Abstracts, Vol. 11, EGU2009-11828.
143	Ciprian Corbus, Rodica Mic, Gianina Neculau, Aristita Busuioc, Estimarea modificarii regimului hidrologic din bazinele hidrografice Buzau si Ialomita sub impactul potential al schimbarilor climatice., Sesiunea Anuala de Comunicari Stiintifice a Institutului de Geografie cu tema 'Cercetarea geografica si modificarile mediului', Bucuresti, June 19, 2009.
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	PLINIUS11-0, 2009, 11th Plinius Conference on Mediterranean.
145	Elisabeta Oprisan, Gestionarea resurselor de apa in condi□iile schimbarilor climatice. studiu de caz., Conferinta stiintifica anuala a INHGA, 21-22 octombrie 2009.
146	Ciprian Corbus, Rodica Mic, Marius Matreata, Estimarea impactului schimbarilor climatice asupra regimului hidrologic - rezultate obtinute din participarea la proiecte international, Conferinta organizata de revista Intercity Magazin si de Ministerul Mediului cu titlul : Solutii moderne si investitii specifice pentru diminuarea riscului la inundatii si alunecari de teren, Bucuresti, 26 noiembrie 2009.
147	Bartholy J., Pongrácz R., Torma Cs., Pieczka I., Hunyady A. (2009): Regional climate model experiments for the Carpathian basin. 89th AMS Annual Meeting/21st Conference on Climate Variability and Change. http://ams.confex.com/ams/pdfpapers/147084.pdf. Phoenix, AZ. 5p.
148	Pongrácz R., Bartholy J., Szabó P. (2009): Analysis of expected change of extreme climate indices in the Carpathian basin by 2071-2100. 89th AMS Annual Meeting/21st Conference on Climate Variability and Change. http://ams.confex.com/ams/pdfpapers/147107.pdf. Phoenix, AZ. 5p.
149	Pongrácz R., Bartholy J., Szabó P., Pieczka I., Torma Cs. (2009): Simulated trends of extreme climate indices for the Carpathian basin using outputs of different regional climate models. EGU2009-11837. Geophysical Research Abstracts, Vol. 11, 11837. CD-ROM. EGU General Assembly 2009
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151	Bartholy J., Csima G., Horányi A., Hunyady A., Pieczka I., Pongrácz R., Torma Cs., Szépszó G. (2009): Regional climate models for the Carpathian basin: validation and preliminary results for the future. EGU2009-12509. Geophysical Research Abstracts, Vol. 11, 12509. CD-ROM. EGU General Assembly 2009
152	Pongracz R., Bartholy J., Szabo P., Kovacs G. (2009): Trend analysis of extreme climate indices using simulated temperature and precipitation time series for the Carpathian basin. EMS & ECAM 2009: Abstracts & Programme. European Meteorological Society. Toulouse, France. EMS2009-486
153	Horányi A., Csima G., Szabó P., Szépszó G., Bartholy J., Hunyady A., Pieczka I., Pongrácz R., Torma Cs. (2009): Application of a regional climate model mini-ensemble for the Carpathian Basin. EMS & ECAM 2009: Abstracts & Programme. European Meteorological Society. Toulouse, France. EMS2009-319
154	Bartholy J., Pongracz R., Torma Cs. (2009): RCM-based climate prediction for the Carpathian basin using RegCM simulations. EMS & ECAM 2009: Abstracts & Programme. European Meteorological Society. Toulouse, France. EMS2009-482
155	Bartholy J., Pongracz R., Torma Cs., Pieczka I., Hunyady A. (2009): Regional climate modeling at the Eötvös Loránd University. Summer School on Climate Variability & Climate Change: Estimating and Reducing Uncertainties. Visegrád, Hungary. 8-17 June 2009.
156	Bartholy J., Pongrácz R., Kovács G., Torma Cs., Török O., Pieczka I., Szabó P. (2009): Analysis of simulated trends of extreme climate indices with special emphasis on agricultural impacts using regional model outputs for the Carpathian Basin. International symposium on Climate change and adaptation options in Agriculture. Vienna, Austria. 22-23 June 2009.
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159	T. Hlásny, T., Turčáni, M., 2009. Insect pests as climate change driven disturbances in forest ecosystems. In: Střelcová , K., Mátyás, C., Kleidon, A., Lapin, M., Matejka, F., Blaženec, M., Škvarenina, J., Holécy, J. (Eds.), Bioclimatology and Natural Hazards. Springer, Netherlands, pp. 165-178.
160	K. Hlavčová, K., Szolgay, J., Kohnová, S., Hlásny, T. 2008. Simulation of hydrological response to the future climate in the Hron river basin. Journal of Hydrology and Hydromechanics, 56, 3, 163-175
161	Szolgay, J., Hlavčová, K., Parajka, J., Lapin, M., Kohnová, S., Hlásny, T.: Climate Change

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163	Štěpánek, P., Zahradníček, P., Skalák, P. (2009): Gridded dataset of daily values of various meteorological elements created for Central Europe in the period 1961-2000. Conference on the Spatial Interpolation Techniques in Climatology and Meteorology, Budapest, Hungary, 11 - 15 May 2009
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165	Stepanek, P., Farda, A. and Skalak P. (2009): RCM ALADIN-Climate/CZ simulations of 2021-2050 and 2071-2100 climate over the Central Europe region with emphasis on analysis of extreme events. EMS Annual Meeting Abstracts, Vol. 6, EMS2009-187-1 (9th EMS / 9th ECAM)
166	Štěpánek, P., Zahradníček, P., Huth, R. (2010): Interpolation techniques used for data quality control and calculation of technical series: an example of Central European daily time series. Idojaras (submitted)
167	Štěpánek, P., Farda, A. and Skalák P. (2009): Czech and Slovak Republic according to RCM ALADIN-Climate/CZ outputs in the periods 2021-2050 and 2071-2100. In: Pribullova, A., Bicarova, S. (eds.), Sustainable Development and Bioclimate - Reviewed Conference Proceedings. Geophysical Institute of the Slowak Academy of Sciences and Slovak Bioclimatological Society of the Slovak Academy of Sciences., Stara Lesna, 2009, pp 58-59. ; ISBN: 978-80900450-1-9
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173	Farda, A.; Skalak, P.; Stepanek, P. (2007): Dynamical downscaling in the Central Europe - very high resolution experiment with Aladin model in climate mode. EMS7/ECAM8 Abstracts, Vol. 4, EMS2007-A-00549 (7th EMS Annual Meeting / 8th ECAM, San Lorenzo de El Escorial, Spain, 01 - 05 October 2007)
174	Štěpánek, P., Skalák, P. and Farda, A. (2008): RCM ALADIN-Climate/CZ simulation of 2020-2050 climate over the Czech Republic. In: Rožnovský, J., Litschmann, T. (eds): Bioklimatologické aspekty hodnocení procesů v krajině (Mikulov 9. - 11.9.2008). CD-ROM. ISBN 978-80-86690-55-1
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	Churáňov, Czech Rep.
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186	Juda-Rezler K., 2009. Modelling the Impact of Climate Changes on Particulate Matter Levels over Poland, 30th NATO/SPS International Technical Meeting on Air Pollution Modelling and its Application 18-22.05.2009, San Francisco, USA
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188	Kyselý, J., Beranová, R., Picek, J., Štěpánek, P., 2008: Simulation of summer temperature extremes over the Czech Republic in regional climate models. Meteorol. Zeit., 17, 645-661.
189	Sorbjan Z., 2009. Improving non-local parameterization of the convective boundary layer. Boundary-Layer Meteorology, 130, 57-69
190	Sorbjan Z. and A. Grachev, 2010. An Evaluation of the Flux-Gradient Relationship in the Stable Boundary Layer. Submitted to Boundary-Layer Meteorology (Submitted on 10 Aug 2009, revised on 11 Dec 2009, currently in print)
191	Csima Gabriella, Horányi András (2008): Validation of the ALADIN-Climate regional climate model at the Hungarian Meteorological Service Idôjárás 112, 3-4, 155-177 2008
192	Szépszó G., Csima G., Horányi A.: Validation of different regional climate models over the Carpathian Basin. EMS8/ECAC7 2008.10.01
193	Szépszó G., Csima G., Horányi A.: What details can the regional climate models add to the global projections in the Carpathian Basin? 2nd Lund Regional-scale Climate Modelling Workshop,Lund, Sweden
194	Szépszó G., Csima G., Horányi A.: What details can the regional climate models add to the global projections in the Carpathian Basin? 2nd Lund Regional-scale Climate Modelling Workshop,Lund, Sweden
195	Csima G.: ALADIN-Climate: latest achievements at the Hungarian Meteorological Service ALADIN / HIRLAM 19th Workshop / All--Staff Meeting,Utrecht, Netherland
196	Csima G.: High resolution experiments with the ALADIN-Climate EMS Annual Meeting 2009 & European Conference on Applications of Meteorology,Toulouse
197	Szépszó G., Csima G., Horányi A., Szabó P: Uncertainties in the climate projections - from the climate modelling perspective Conference on Facing the Future, the Climate Summit in Copenhagen and beyond,Central European University, Budapest
198	Csima G.: Experiments with the ALADIN-Climate regional climate model ECMWF Member States Visit,OMSz, Budapest
199	Krüger B. C., E. Katragkou, I. Tegoulias, P. Zanis, D. Melas, E. Coppola, S. Rauscher, P. Huszar and T. Halenka, 2008: Regional decadal photochemical model calculations for Europe concerning ozone levels in a changing climate, Quarterly J. of the Hungarian Meteorol. Service, Idojaras, 112, 3–4, 285–300.
200	Katragkou, E., P. Zanis, I. Tegoulias, D. Melas, 2009: Tropospheric ozone in regional climate-air quality simulations over Europe: Future climate and sensitivity analysis. Proceedings 30th NATO/SPS International Technical Meeting on Air Pollution Modelling and its Application.
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206	Halenka, T., Belda, M., Miksovsky, J., 2010: Regional Climate Change Scenarios in High Resolution for Central and Eastern Europe. Geophysical Research Abstracts, Vol. 12, EGU2010-13159, EGU General Assembly 2010
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Table 9b. *CECILIA publications and presentations: Specification of type, audience and partners involved*

No.	Type	Date	Audience type	Country	Audience size	Partner(s) involved
136	Journal	05.31.09	Research	Hungary, Slovakia, Romania		ELU
137	Journal	05.31.09	Research	Hungary, Slovakia, Romania		ELU
138	Other	01.31.09	General public	Hungary, Slovakia, Romania, Austria		ELU
139	Other	01.31.09	General public	Hungary, Slovakia, Romania, Poland, Czech Republic, Germany		ELU
140	Oral presentation	09.22.08	Research	Romania		NIHWM, NAM
141	Oral presentation	10.10.08	Research	Romania		NIHWM
142	Poster	04.25.08	Research	All		NIHWM, NAM
143	Oral presentation	06.19.09	Higher education	Romania		NIHWM, NAM
144	Proceedings	09.10.09		All		NIHWM, NAM
145	Oral presentation	10.22.09	Hydrology and water management	Romania		NIHWM
146	Oral presentation	11.26.09	General public	Romania		NIHWM
147	Proceedings	01.12.09	Research	Hungary, Slovakia, Austria, Romania, Czech Republic	10000	ELU
148	Proceedings	01.12.09	Research	Hungary, Slovakia, Austria, Romania, Czech Republic	10000	ELU
149	Poster	04.20.09	Research	Hungary, Slovakia, Romania, Austria	10000	ELU
150	Poster	04.20.09	Research	Hungary, Slovakia, Romania, Austria, Czech Republic	10000	ELU
151	Oral presentation	04.21.09	Research	Hungary, Slovakia, Romania, Austria	10000	ELU
152	Poster	09.28.09	Research	Hungary, Slovakia, Austria, Romania	1000	ELU

153	Oral presentation	09.28.09	Research	Hungary, Slovakia, Austria, Romania	1000	ELU
154	Poster	09.28.09	Research	Hungary, Slovakia, Austria, Romania, Czech Republic	1000	ELU
155	Oral presentation	06.16.09	Higher education	Hungary, Slovakia, Romania, Austria, Czech Republic	60	ELU
156	Poster	06.22.09	General public	Hungary, Slovakia, Austria, Romania, Czech Republic	100	ELU
157	Poster	11.17.09	Research	Hungary, Slovakia, Austria, Romania, Czech Republic	100	ELU
158	Journal	12.22.09	Forestry	Slovakia		National Forest Centre
159	Journal	02.20.09	Forestry	Slovakia		National Forest Centre
160	Journal	11.20.08	Hydrology and water management	Slovakia		FRI
161	Other	11.10.08	Hydrology and water management	Slovakia		FRI
162	Poster	04.22.09	Research	CZ, SK		CHMI
163	Oral presentation	05.14.09		CZ, SK		CHMI
164	Oral presentation	10.06.09	Research	CZ, SK		CHMI
165	Poster	10.01.09		CZ, SK		CHMI
166	Journal	05.24.10	Research	CZ, SK, AT, HU		CHMI
167	Journal	10.05.09	Research	CZ, SK		CHMI
168	Poster	10.02.08		CZ		CHMI
169	Oral presentation	09.17.08		CZ		CHMI
170	Poster	09.11.08		CZ		CHMI
171	Poster	04.18.08		CZ		CHMI
172	Oral presentation	02.05.08		CZ		CHMI
173	Poster	10.05.07		CZ		CHMI
174	Proceedings	09.11.08		CZ, SK		CHMI
175	Journal	11.24.08	Research	CZ		CHMI
176	Oral presentation	10.01.09	Research	Europe		IAP, CHMI, CUNI
177	Oral presentation	04.21.09	Research	Europe		IAP, CUNI, CHMI
178	Oral presentation	09.19.08	Research	Czech Rep.		IAP
179	Oral presentation	10.23.07	Higher education	Czech Rep., Germany		IAP
180	Oral presentation	05.22.07	Research	Northern Europe, USA, Canada		IAP
181	Oral presentation	05.22.07	Research	Northern Europe, USA, Canada		IAP
182	Poster	05.06.09		CZ		CHMI
183	Journal	02.01.10		Poland		WUT
184	Journal	02.01.10		Central Eastern Europe		WUT
185	Journal	02.01.10		-		WUT
186	Oral presentation	02.01.10		-		WUT
187	Oral presentation	02.01.10		Poland		WUT
188	Journal		Research	Europe		IAP, CHMI
189	Journal	02.04.10		-		WUT
190	Journal	02.04.10		-		WUT
191	Journal			Hungary		OMSZ
192	Poster	10.01.08		Hungary		OMSZ
193	Proceedings	05.04.08		Hungary		OMSZ
194	Poster	05.04.09		Hungary		OMSZ

195	Oral presentation	05.12.09		Hungary		OMSZ
196	Oral presentation	10.01.09		Hungary		OMSZ
197	Oral presentation	11.04.09		Hungary		OMSZ
198	Oral presentation	11.12.09		Hungary		OMSZ
199	Journal	2008	Research			BOKU, AUTH, CUNI, ICTP,
200	Proceedings, Oral	2009	Research	World		AUTH
201	Journal	2009	Research			AUTH, BOKU, CUNI, ICTP
202	Journal (submitted)	2010	Research			AUTH
203	Journal	2008	Research			CUNI
204	Proceedings (book)	2008	Research	World		CUNI
205	Poster	2010	Research	World		CUNI
206	Poster	2010	Research	World		CUNI
207	Proceedings (book)	2010	Research	World		CUNI
208	Proceedings (book)	2010	Research	World		CUNI
209	Proceedings	2009	Research	World		CUNI

There is special issue of CECILIA Project for Climate Research under preparation with following list of foreseen papers.

1) Project CECILIA - Climate change impact assessment for Central and Eastern Europe in high resolution (T. Halenka)
2) Climate Change impact assessment over Central and Eastern Europe from the CMIP3-GCM and ENSEMBLES-RCM ensemble simulations (E. Coppola, F. Giorgi)
3) CECILIA regional climate simulations for present climate – validation and intercomparison (Petr Skalák, Michel Déqué, Aleš Farda, Michal Belda, Gabriella Csima, Rita Pongratz, Mihaela Caian, Valery Spiridonov)
4) CECILIA regional climate simulations for future climate – analysis and comparison of climate change signal (A. Farda, T. Halenka, P. Skalak, M. Deque, G. Csima, J. Bartholy, C. Torma, C. Boroneant, M. Caian, V. Spiridonov)
5) Comparing regional scenarios of mean and extreme climate conditions for Hungary. (Bartholy, J. Csima, G., Lakatos, M., Pongracz, R., Torma, Cs.)
6) A comparative validation of statistical and dynamical downscaling models on a dense grid in central Europe (Jiri Miksovsky, Radan Huth, Petr Stepanek, Zuzana Chladova, Ales Farda, Michal Belda)
7) Effect of statistical bias correction on RCM-computed extremes (Herbert Formayer, Jiri Miksovsky, Petr Stepanek, Patrick Haas, Michal Belda, Petr Skalak)
8) Climate change and extreme events in Central and Eastern Europe: The CECILIA statistical indices and extreme database (Sonia I. Seneviratne, Ole B. Christensen, Martin Hirschi, Fredrik Boberg, Petr Stepanek, Vesselin Alexandrov, Judit Bartoly, Constanta Boroneant, Herbert Formeyer, Tomas Halenka, and Monika Lakatos)
9) Effects of resolution on extremes in regional climate simulations of the CECILIA project (Christensen, O.B., and F. Boberg)
10) Potential impact of climate changes upon water resources and water management, hydrological cycle and flood occurrence: case studiesover Central and Eastern Europe.

(Rodica Mic, Josef Hejzlar, Kamila Hlavcova, Ciprian Corbus, Stanislav Lejska, Elisabeta Oprisan, Lucie Brezkova)

11) Climate change impacts on water supply and water quality from the drinking water reservoir Rimov, Czech Republic (Josef Hejzlar, Martin Dubrovsky, Jan Turek)

12) Climate change impacts and potential adaptations in agricultural crop production in Central and Eastern Europe – critical aspects, regional differences and common trends (Josef Eitzinger, Miroslav Trnka, Martin Dubrovsky, Sabina Thaler, Daniela Semerádová, Petr Hlavinka, Eva Kocmánková, Vesseling Alexandrov, Bernard Siska, Josef Takac, Elena Mateescu, Catalin Simota, Zdeněk Žalud)

13) Climate change impacts on forest growth, pests and carbon balance in Central Europe – the use of high resolution climate change scenarios (Tomáš Hlásny, Zoltán Barcza, Marek Fabrika, Borbála Balázs , Galina Churkina, Jozef Pajtík, Róbert Sedmák, Lenka Zajíčková, Marek Turčáni)

14) On the effect of climate change on regional air quality over Europe: concept, evaluation and future projections (Katarzyna Juda-Rezler, Prodromos Zanis, Dimiter Syrakov, Magdalena Reizer, Hristo Chervenkov, Peter Huszar, Dimitris Melas, Eleni Katragkou, Ioannis Tegoulias, Bernd C. Krüger, Wojciech Trapp and Tomas Halenka)

15) Potential climate change impacts on ozone and PM levels over Central and Eastern Europe from high resolution simulations (P. Huszar, K. Juda-Rezler, T. Halenka, H. Chervenkov, D. Syrakov, B., Krueger, P. Zanis, D. Melas, M. Reizer, W. Trapp and M. Belda)

Guest editors Tomas Halenka and Erika Coppola

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3 Publishable results

There are no exploitable results.