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IAEA

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Regional Climate Modeling in high-resolution: Lessons learned from the EC FP6 CECILIA Project

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Regional Climate Modeling in high-resolution: Lessons learned from the EC FP6 CECILIA Project

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&
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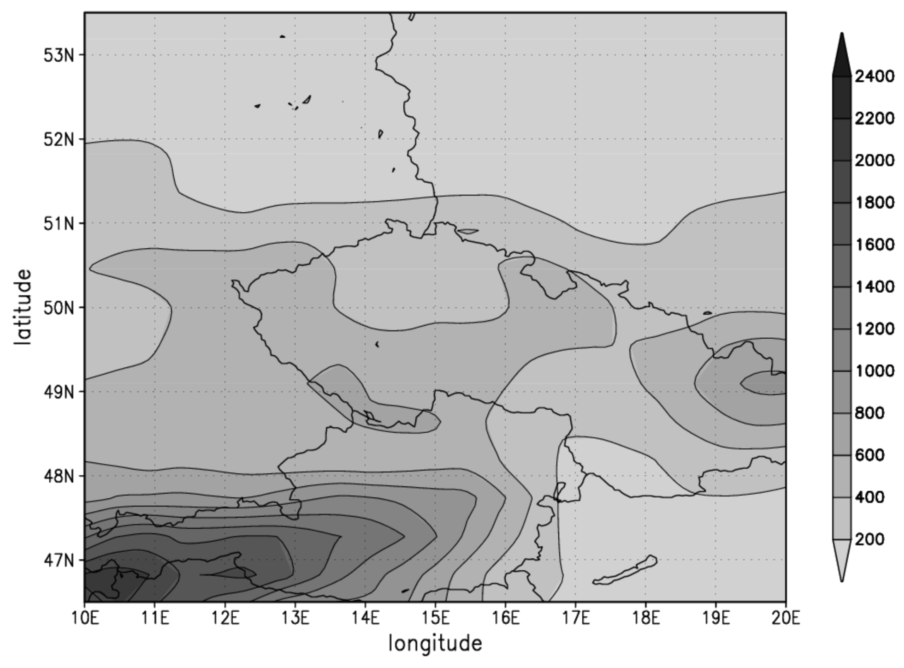
Outline

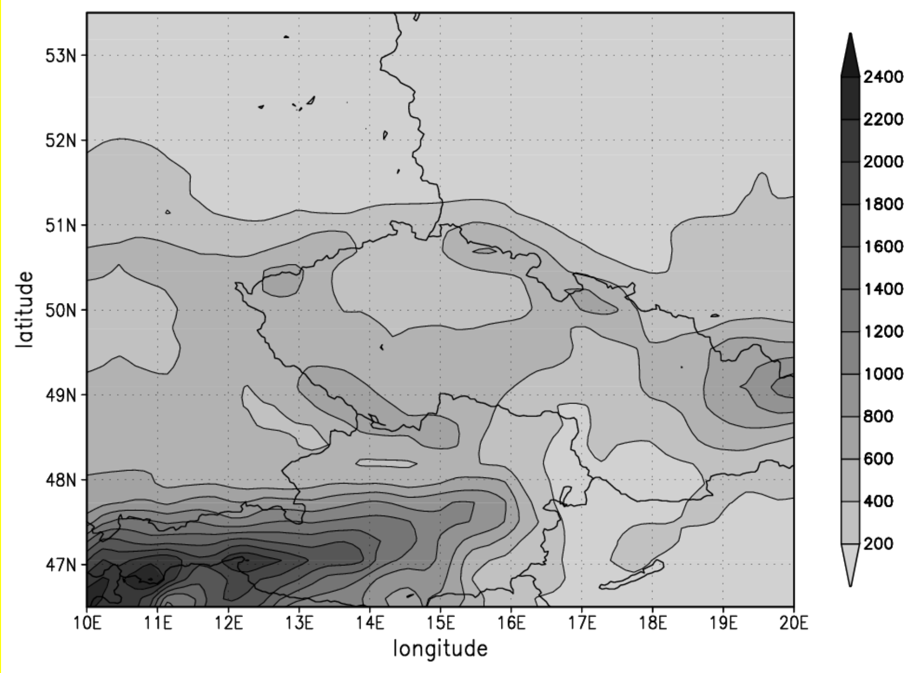
1. Why high-resolution RCM?
2. EC FP6 CECILIA Project
3. Climate change analysis for Central and Eastern Europe
4. Climate change impact assessment
5. Conclusions

Why high-resolution RCM?

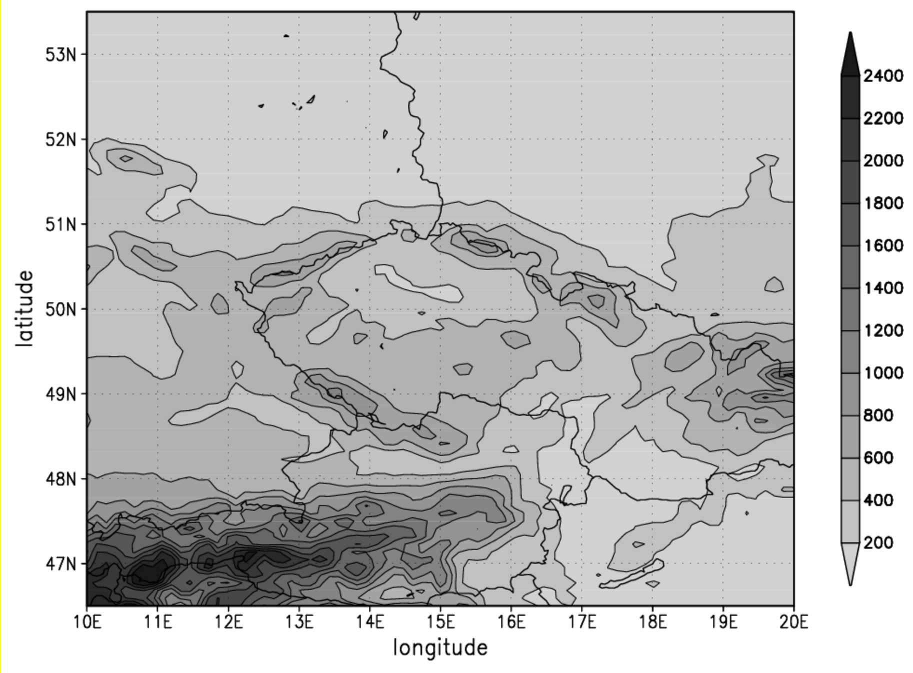
Why high-resolution RCM?

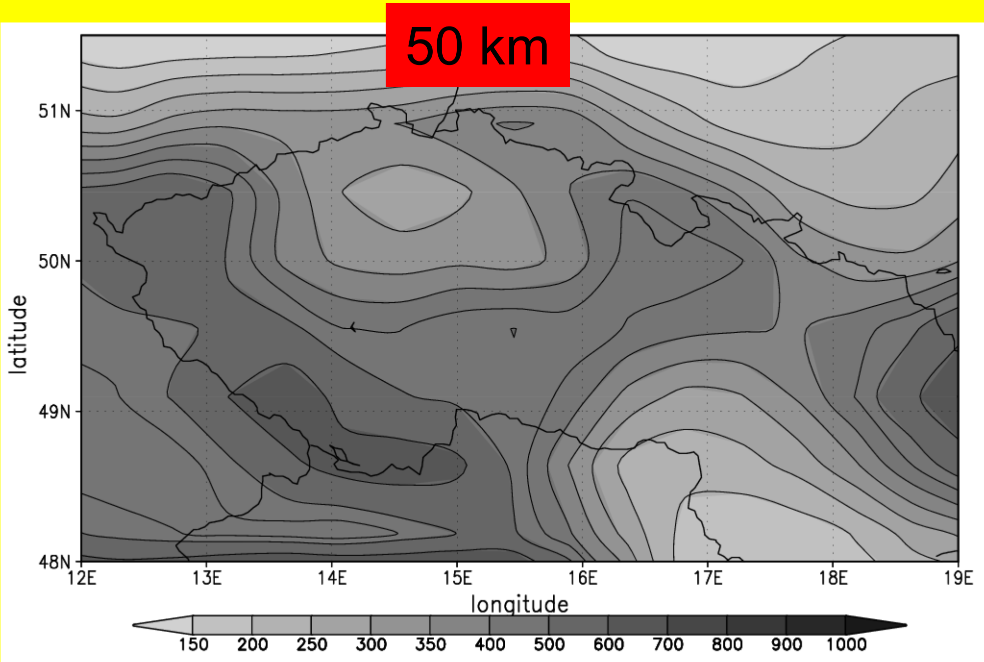
- RCMs as a tool for impact assessment to provide scientific basis for adaptation measures done mostly locally
- topography and land-use in complex terrain
- statistical interpretation of the results, get closer to station data and local information, localization
- more detailed analysis of local processes
- keeping RCM ahead of GCM aiming soon being cloud resolving

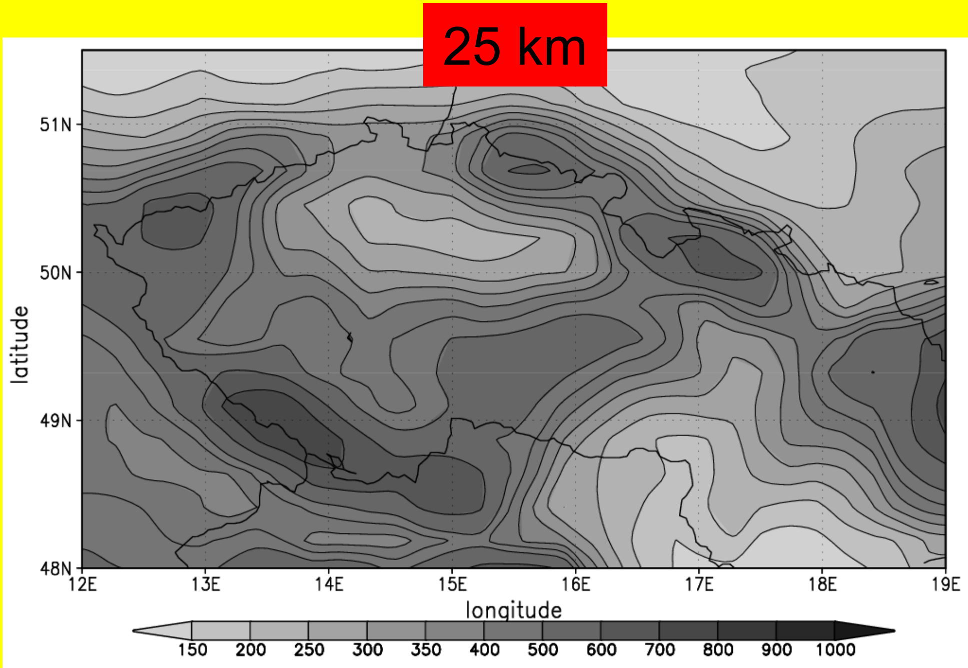




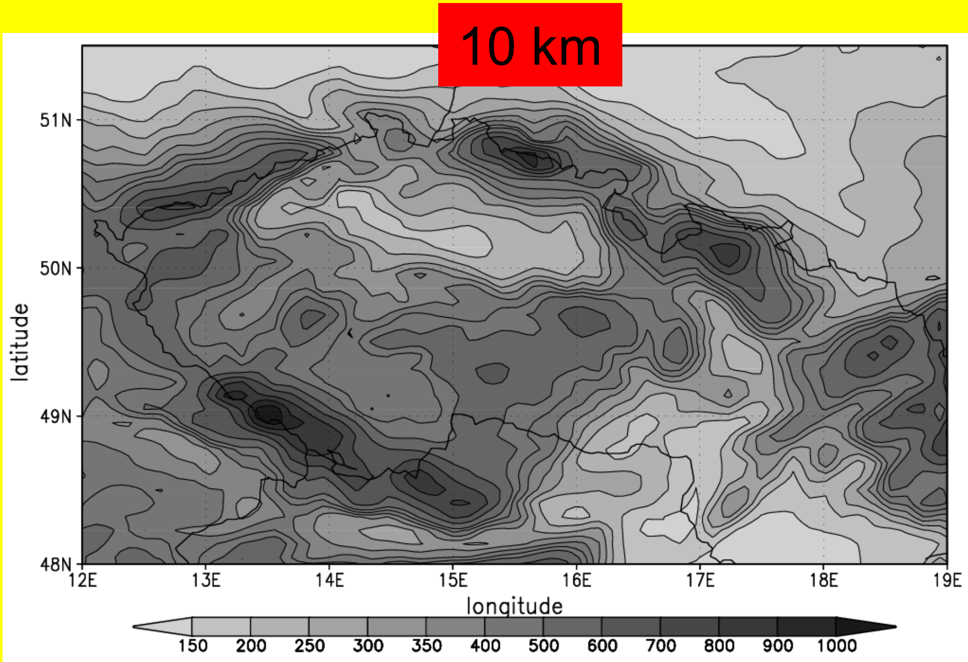
Why high-resolution RCM?







Why high-resolution RCM?



EC FP6 CECILIA Project

1 June 2006 – 31 May 2009
Extended till 31 December 2009

CECILIA - <u>C</u>entral and <u>E</u>astern Europe <u>C</u>limate Change <u>I</u>mpact and Vulnerabi<u>LI</u>ty <u>A</u>ssessment

- **The primary objective of the project is to provide very high resolution climate change simulations for impact and vulnerability assessment in important human activity sectors and natural ecosystems**

1.to integrate results from previous and ongoing modelling activities

2.to develop, adopt, adapt and use selected approaches to provide high resolution climate scenarios

- **Analysis on some key areas of specific interest to the region:**

  1. **the flood and drought conditions which occurred in recent summers over the region highlight the importance of the hydrologic cycle and water management in the Elbe and Danube river catchments in response to changes in the occurrence of precipitation extremes**
  2. **Impacts on agriculture and forestry influencing the economy of countries in the region are studied with emphasis on the main productions in the area**
  3. **The 2003 heat wave demonstrated the importance of extreme conditions that would also lead to considerable changes in air quality, both regionally and in major urban centres, with significant health impacts**

CECILIA Consortium

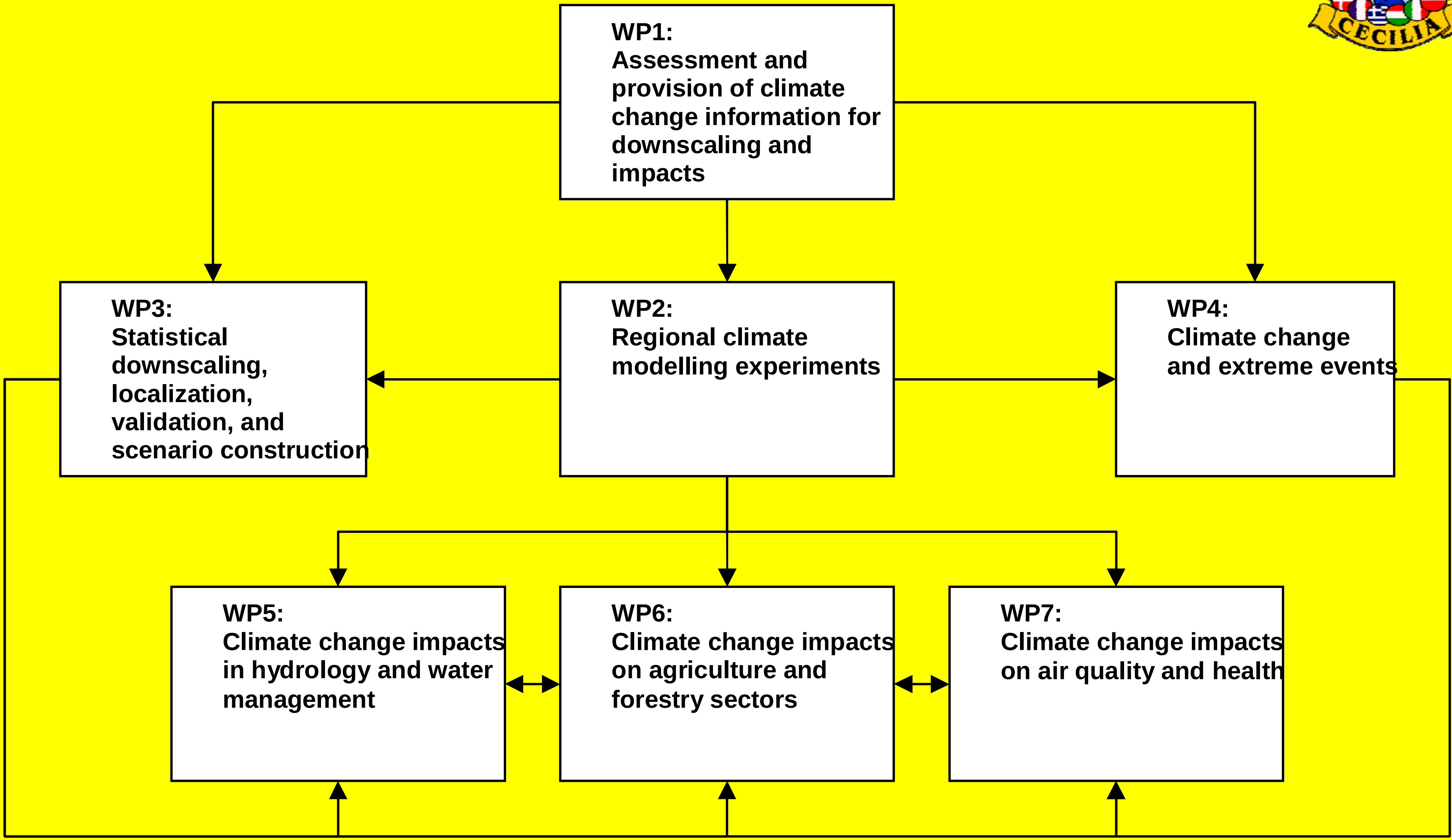
1. **CUNI, Czech Republic (coordinator)**
2. **ICTP, Italy**
3. **CNRM, France**
4. **DMI, Denmark**
5. **AUTH, Greece**
6. **CHMI, Czech Rep.**
7. **IAP, Czech Rep.**
8. **ETH, Switzerland**
9. **BOKU, Austria**
10. **NMA, Romania**
11. **NIMH, Bulgaria**
12. **NIHWM, Romania**
13. **OMSZ, Hungary**
14. **FRI, Slovakia**
15. **WUT, Poland**
16. **ELU, Hungary**

Connections

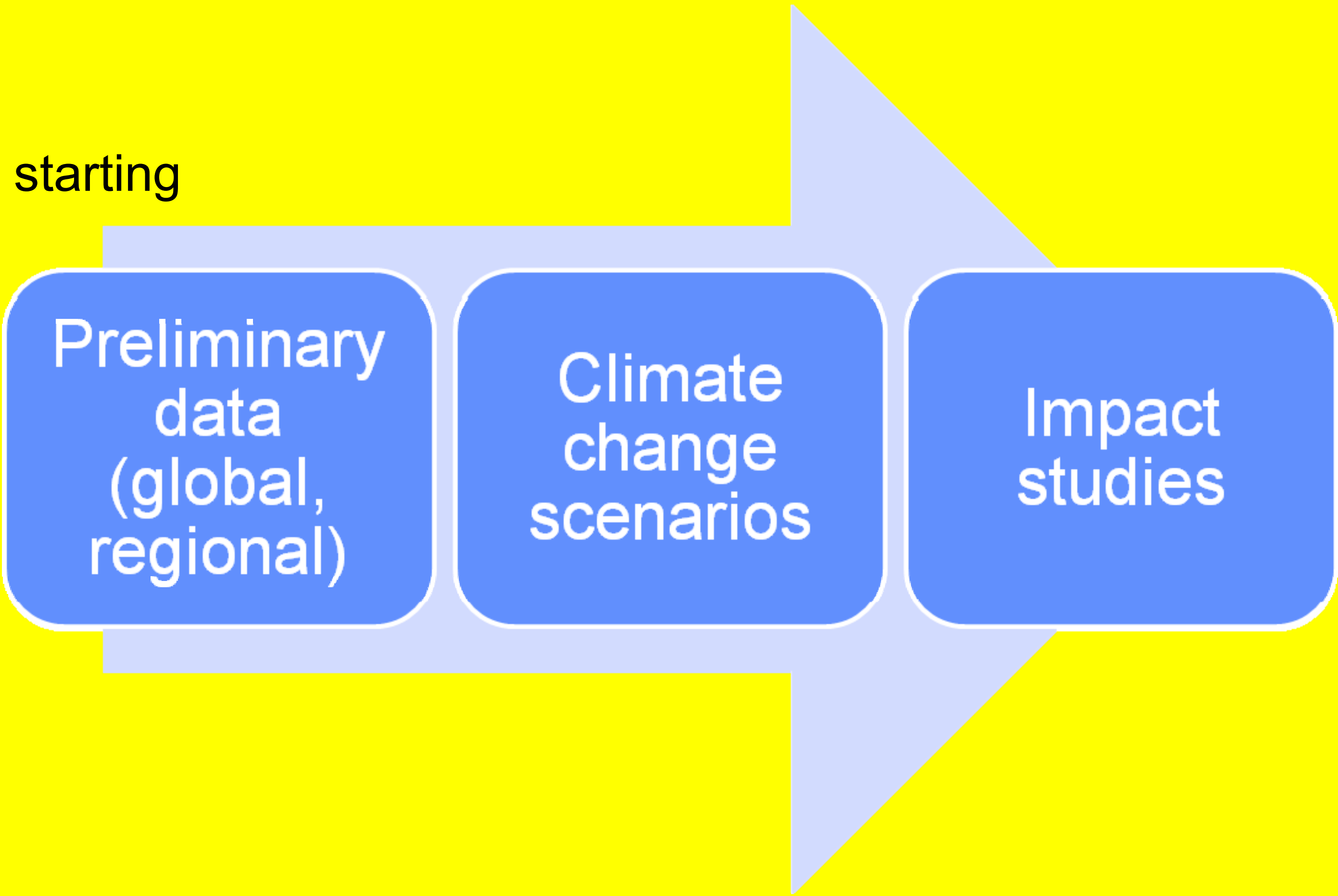
The proposed research will benefit greatly from previous and ongoing European projects and programmes with related objectives, e.g.:

- “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)
- COST 734 - Climate change impact in agriculture
- CLAVIER (STREP, EC FP6) – climate change impacts on agriculture, ecosystems, water management etc.

Interactions

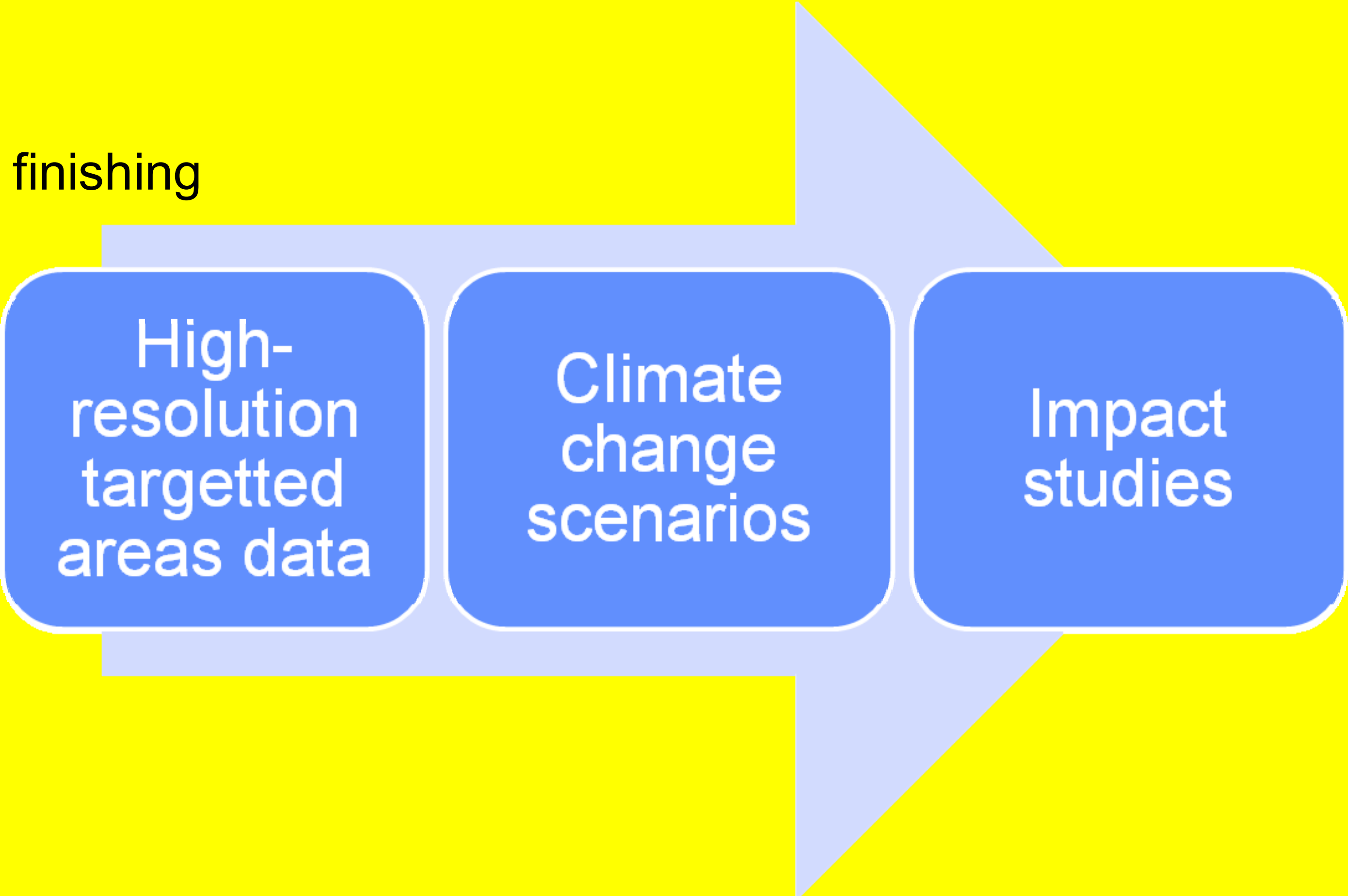


Basic scheme



Basic scheme

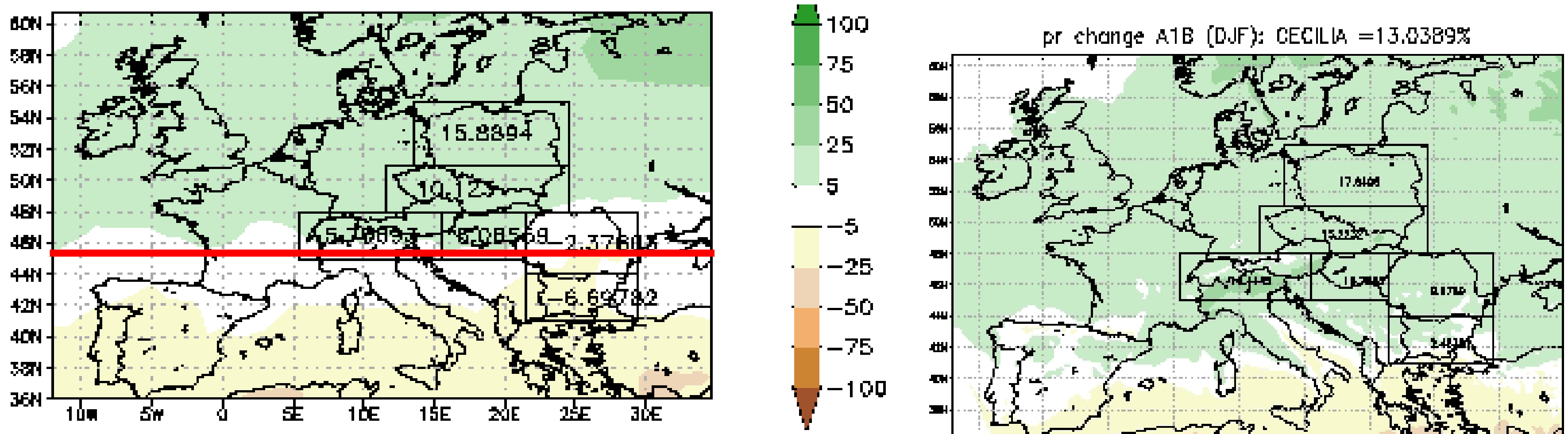
finishing



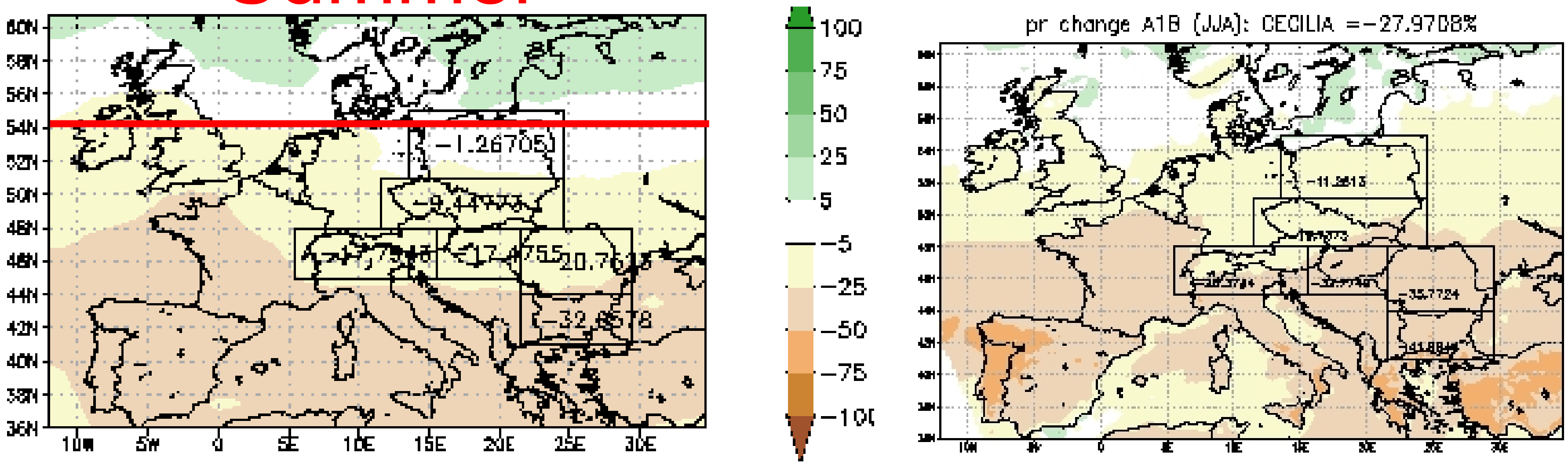
Climate change analysis for Central and Eastern Europe

WP1
First stream data, previous data available

Winter



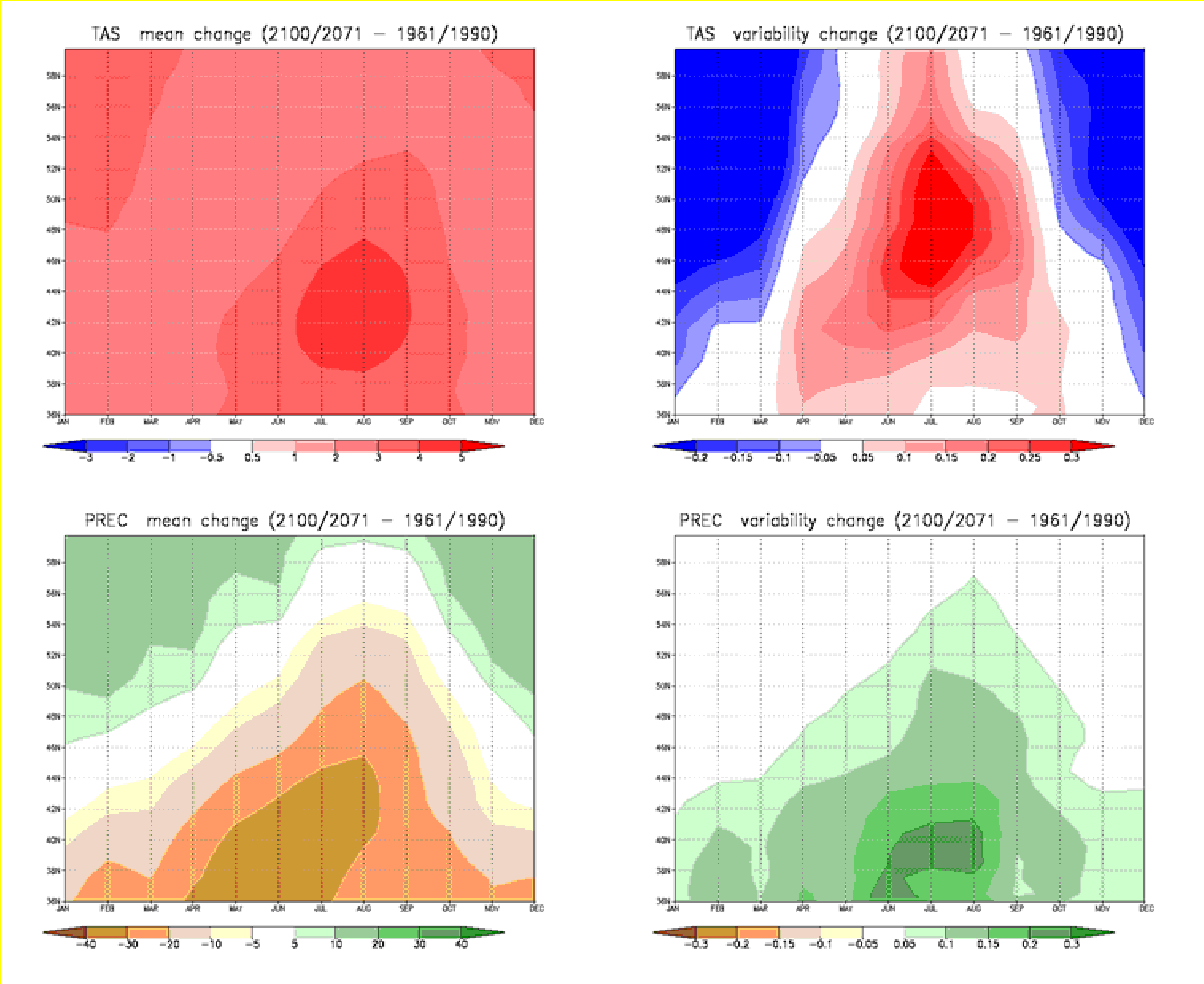
Summer



Precipitation change, 2071-2100,

A1B Scenario, 20 GCMs IPCC AR4 (left), ENSEMBLES RCMs (right)

European Climate change Oscillation

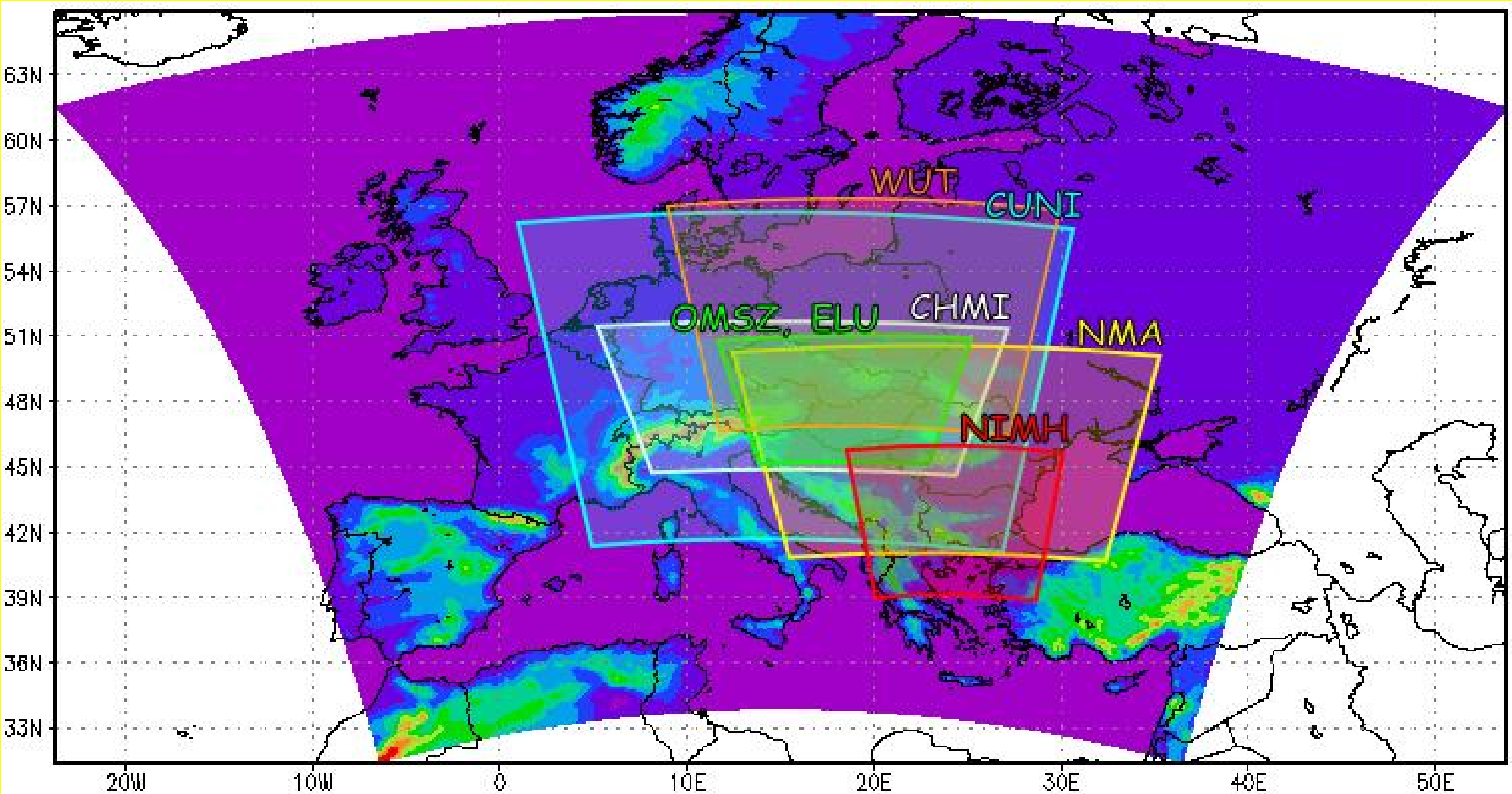


Monthly values of the zonally averaged changes in mean surface air temperature (top left panel), temperature interannual variability (as measured by the standard deviation, top right panel), mean precipitation (bottom left panel), precipitation interannual variability (as measured by the coefficient of variation) over Europe from the CMIP3 ensemble, A1B scenario, 2071-2100 minus 1961-1990. Units are degrees C for temperature and % of 1961-1990 values for mean precipitation (the coefficient of variation is unitless). The zonal average is taken over the region between 10 W and 25 E.

WP2
Regional climate modelling

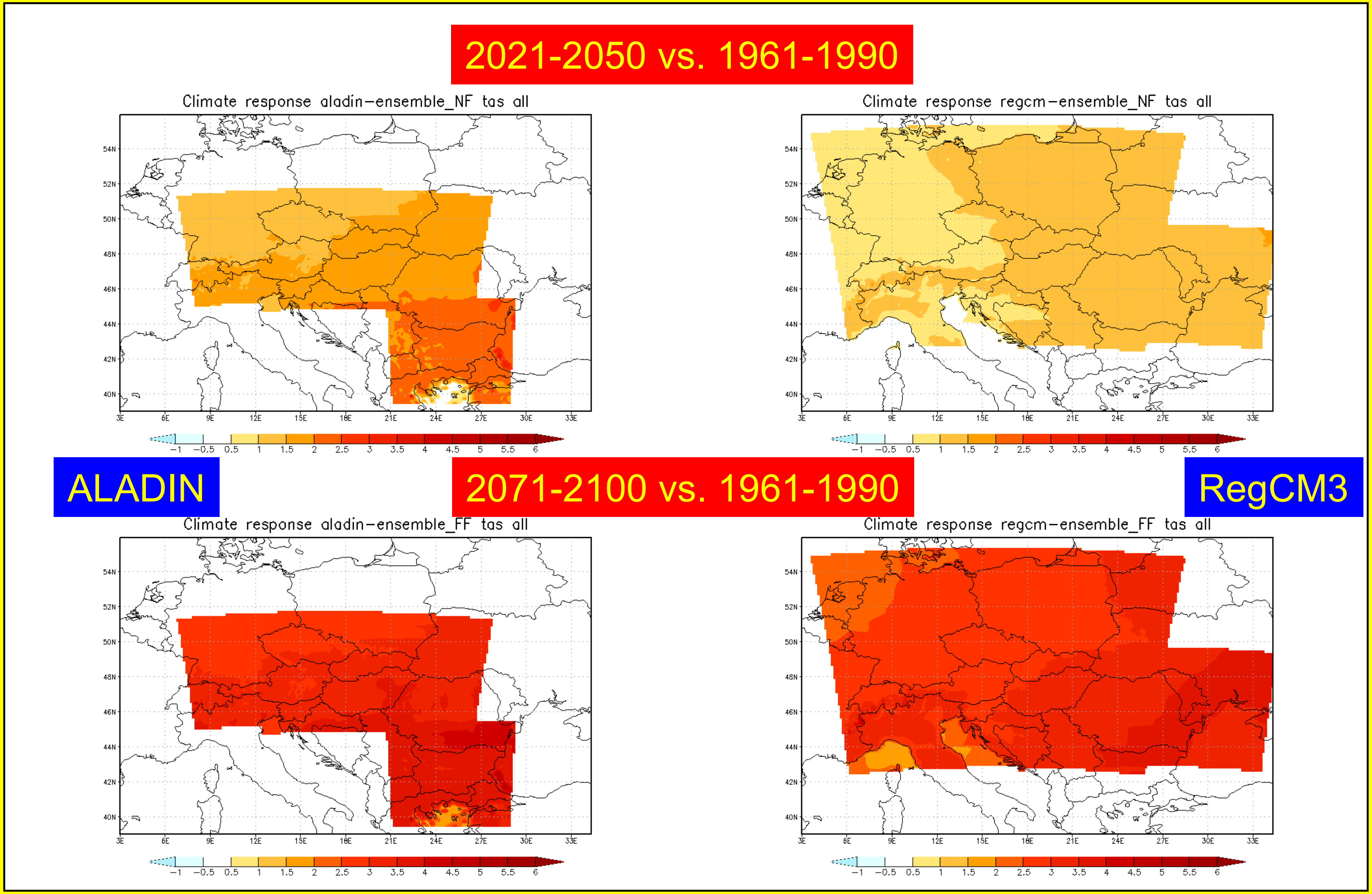
Prague, November 24-28, 2009

Simulation domains (10 km resolution)



CECILIA, EC FP6, 2006-2009, http://www.cecilia-eu.org

CECILIA simulations - temperature

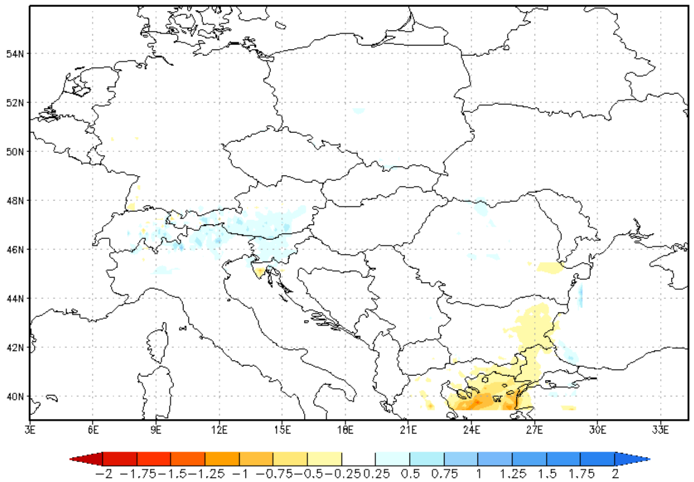


CECILIA, EC FP6, 2006-2009, http://www.cecilia-eu.org

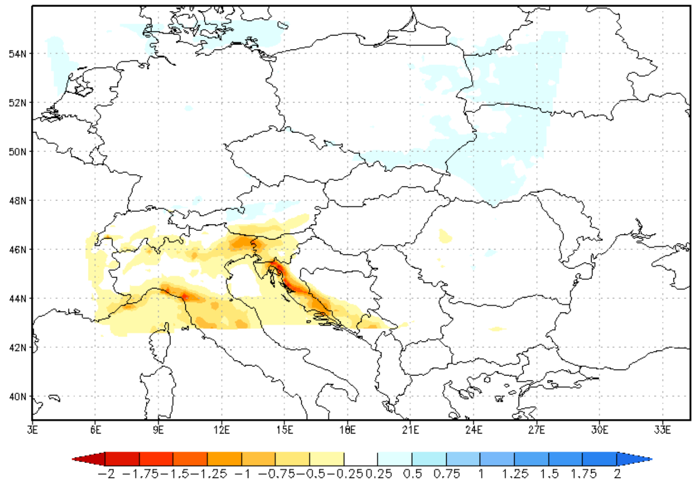
CECILIA simulations - precipitation

2021-2050 vs. 1961-1990

Climate response aladin−ensemble_NF pr all



Climate response regcm−ensemble_NF pr all

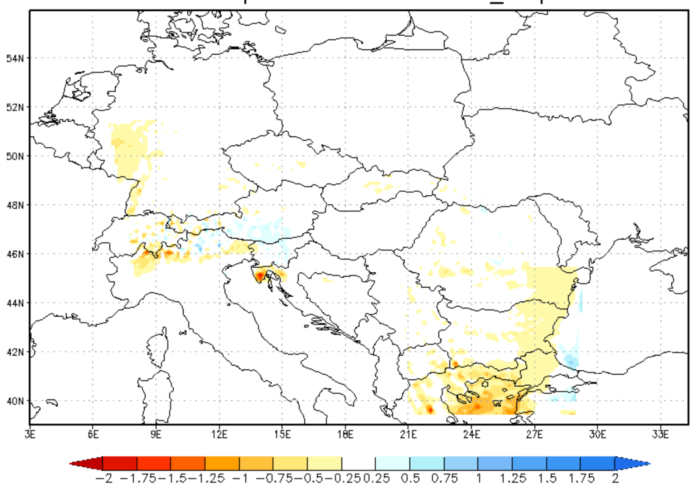


ALADIN

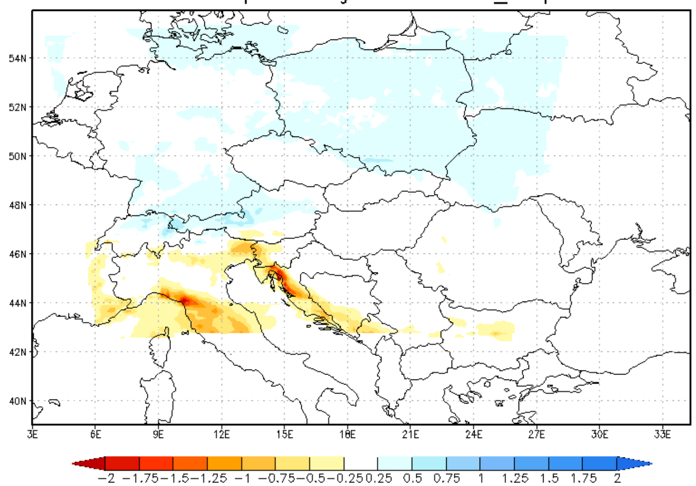
2071-2100 vs. 1961-1990

RegCM3

Climate response aladin−ensemble_FF pr all

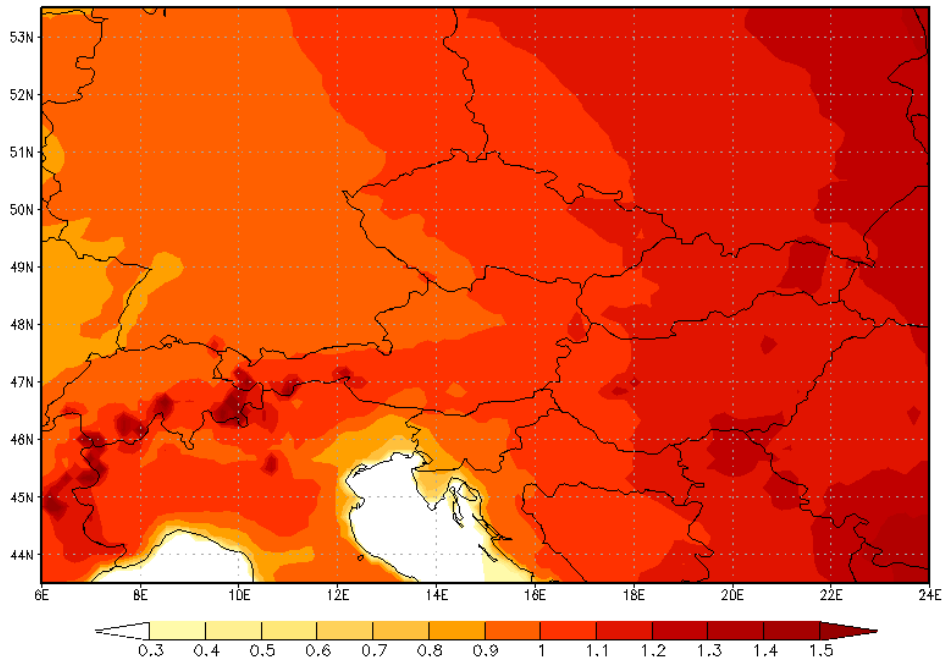


Climate response regcm−ensemble_FF pr all

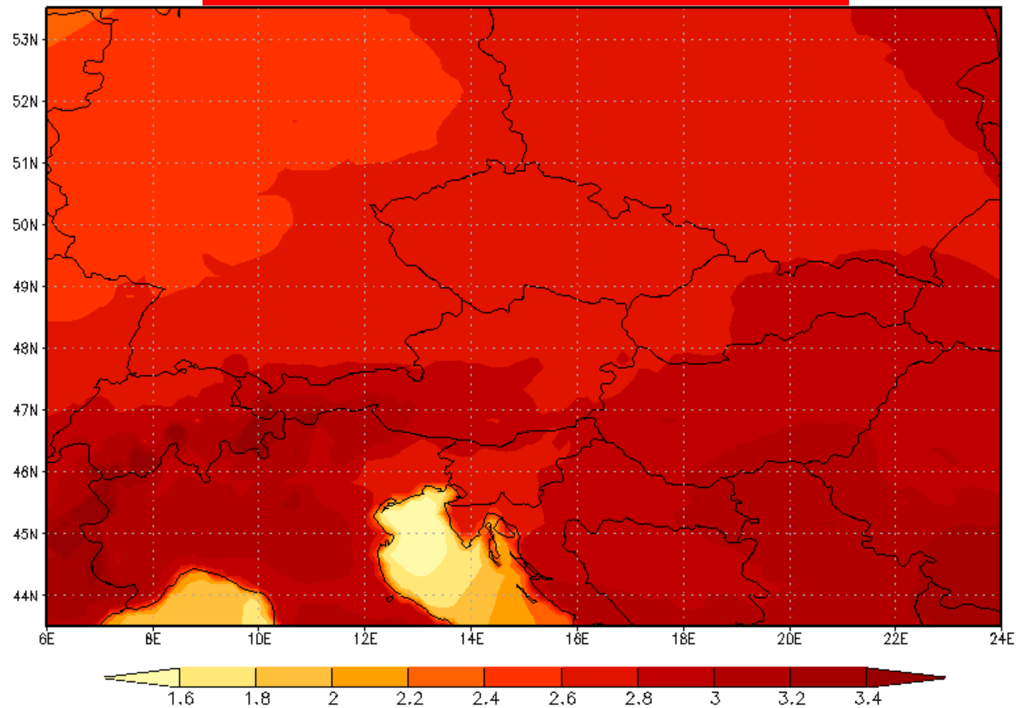


A1B scenario, driven by ECHAM5 driven RegCM@25km, temperature

2021-2050 vs. 1961-1990

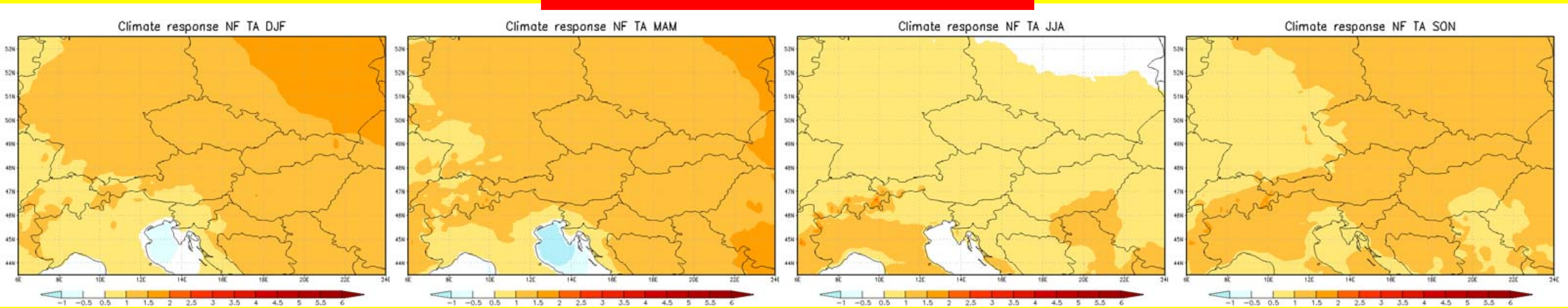


2071-2100 vs. 1961-1990

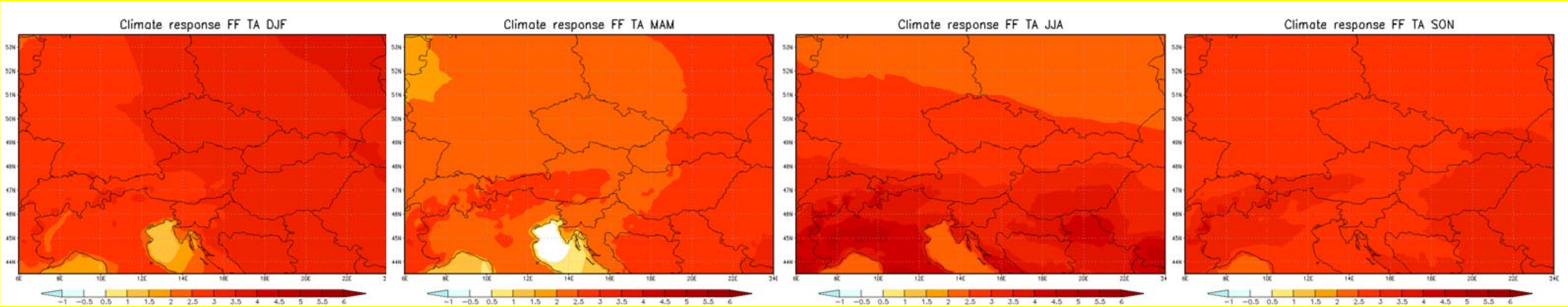


A1B scenario
temperature - seasons

2021-2050 vs. 1961-1990

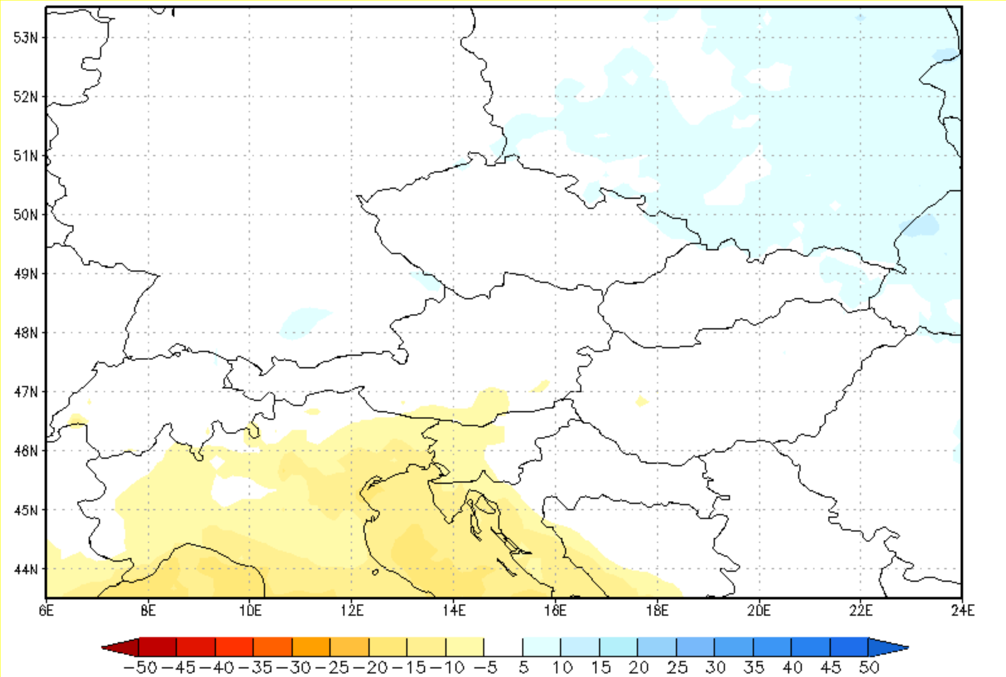


DJF MAM JJA SON



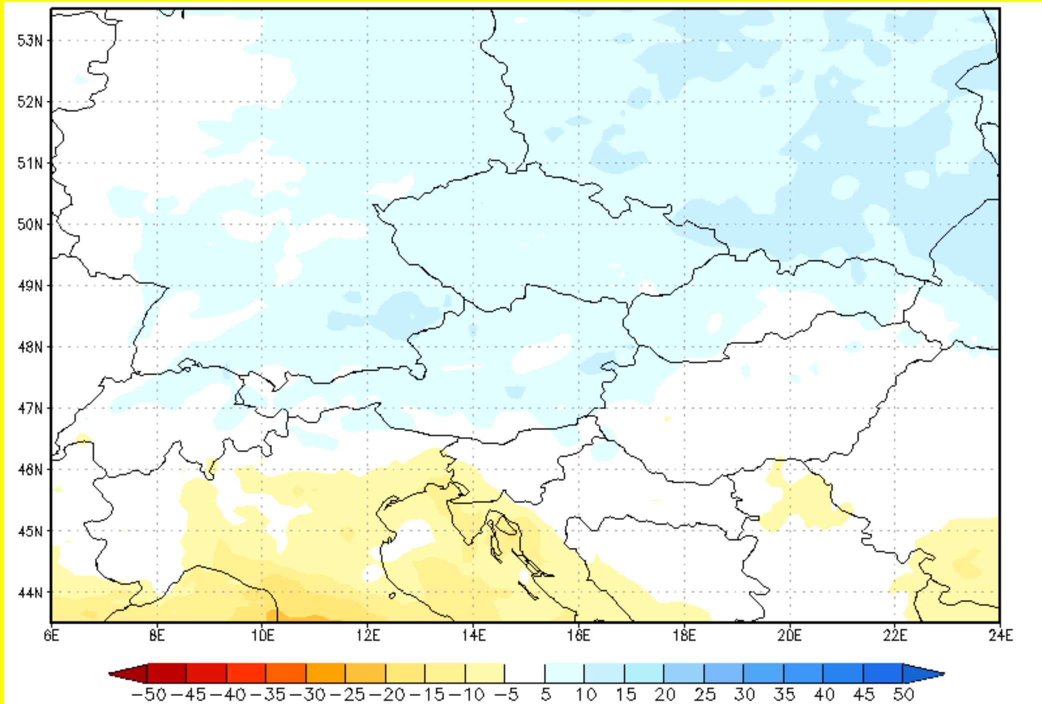
2071-2100 vs. 1961-1990

2021-2050 vs. 1961-1990



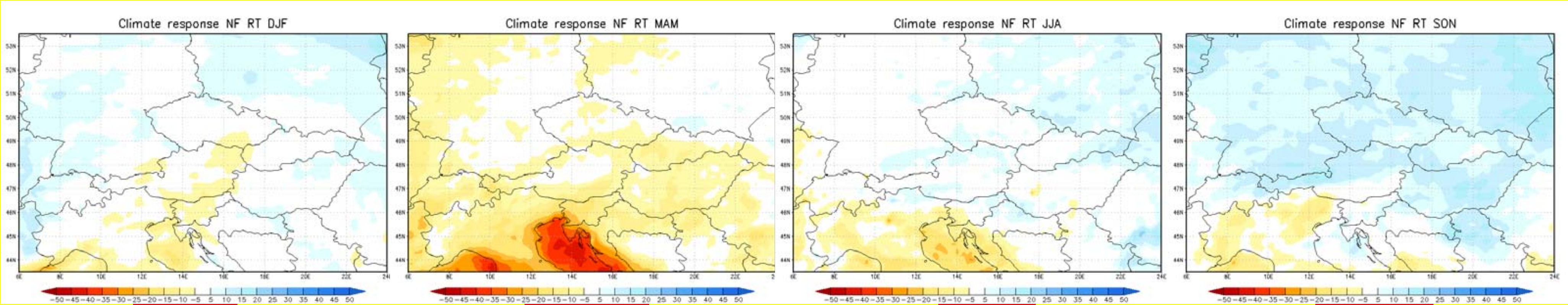
A1B scenario, driven by ECHAM5 driven RegCM@25km, temperature

2071-2100 vs. 1961-1990



A1B scenario
precipitation - seasons

2021-2050 vs. 1961-1990



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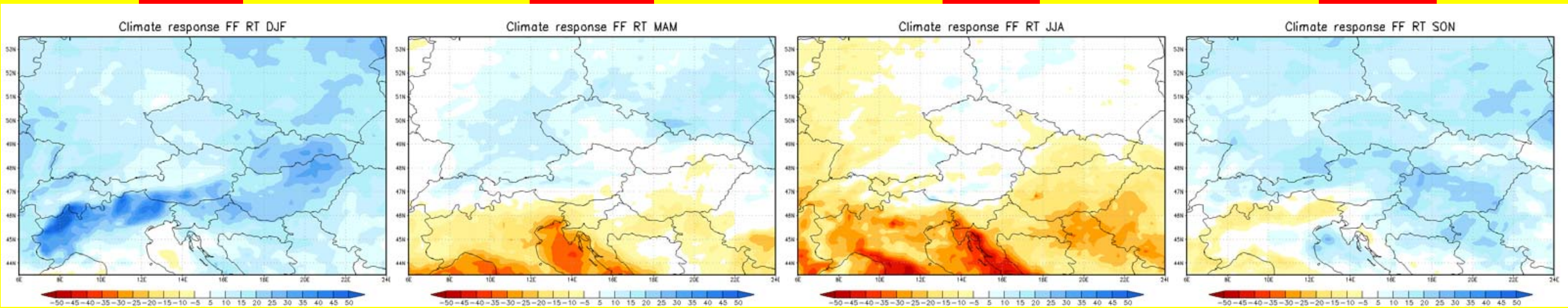
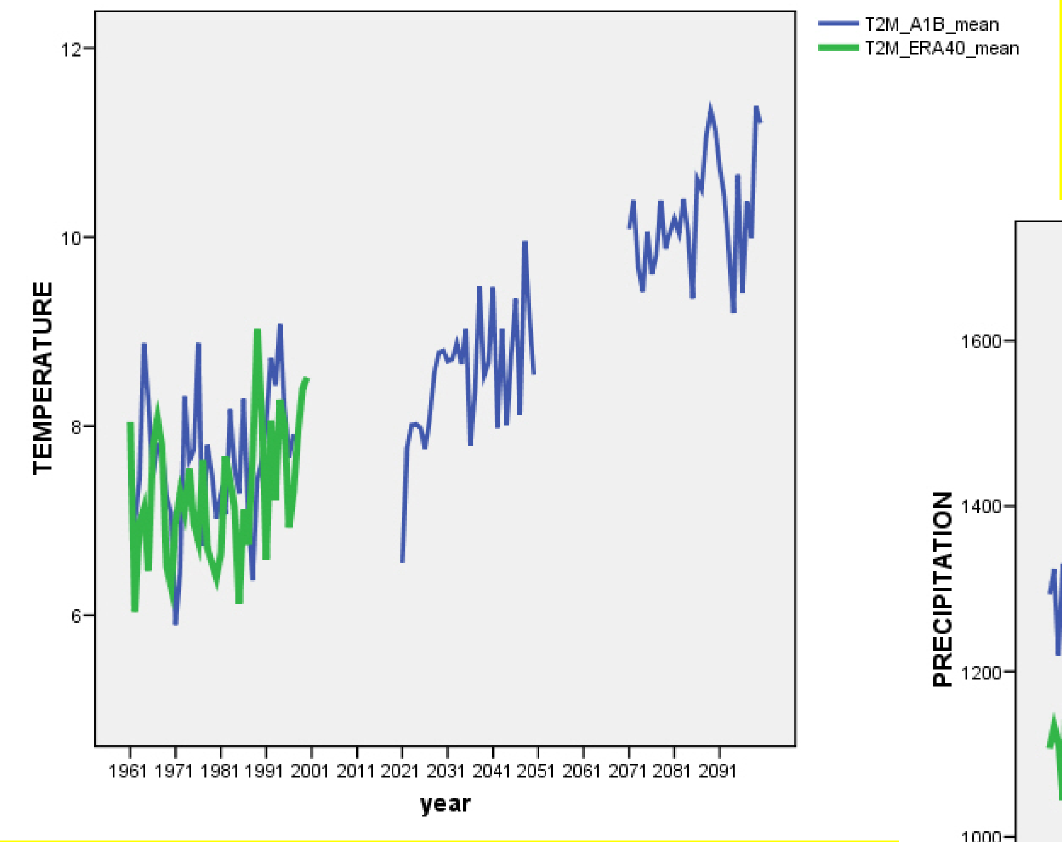


2071-2100 vs. 1961-1990

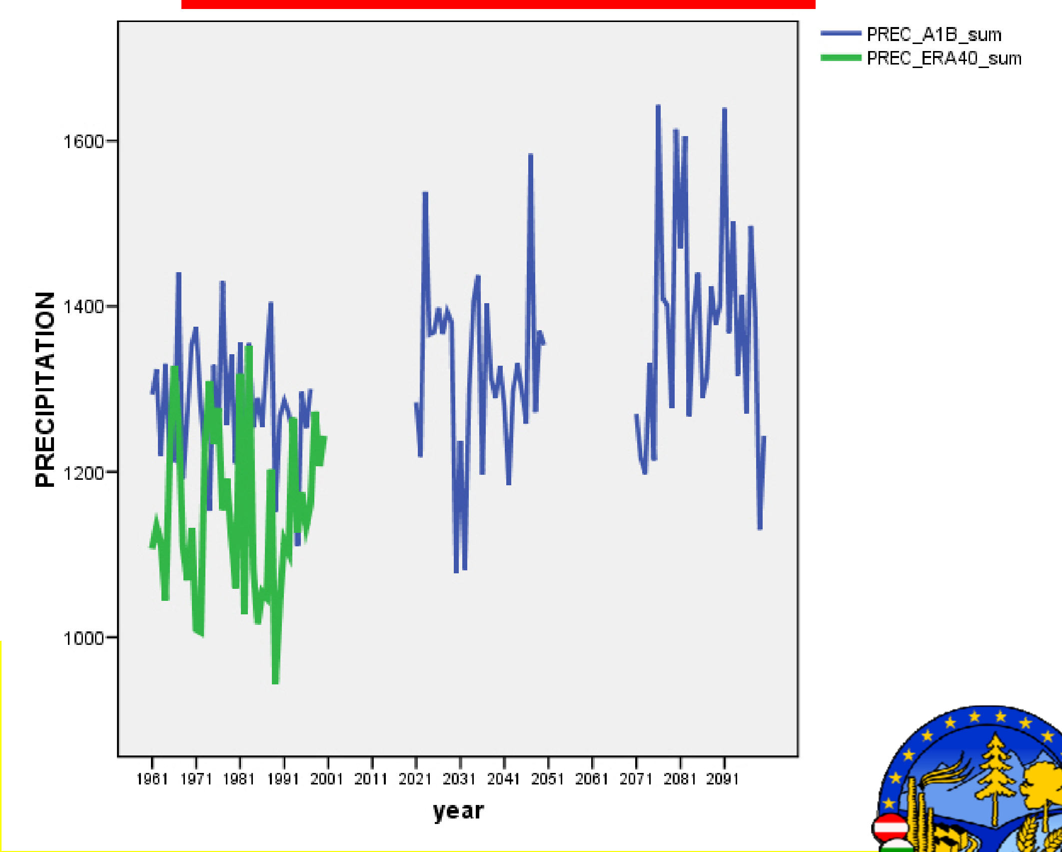
CECILIA, EC FP6, 2006-2009, http://www.cecilia-eu.org

Time series for A1B scenario, CZ region

Mean annual temperature

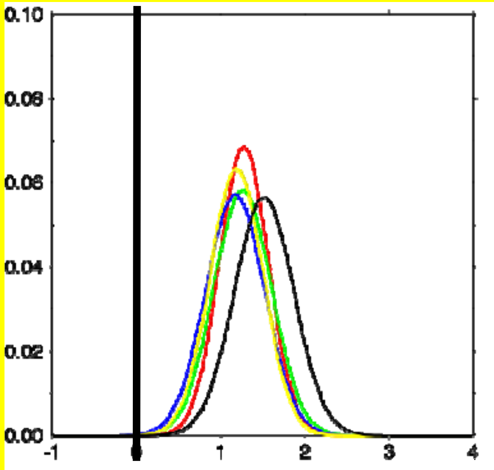


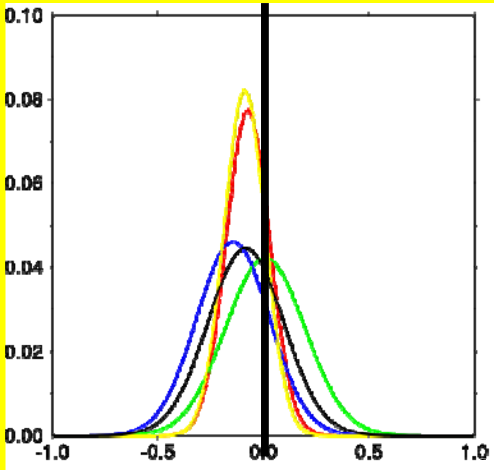
Total annual precipitation



Budapest changes 2021-2050

winter

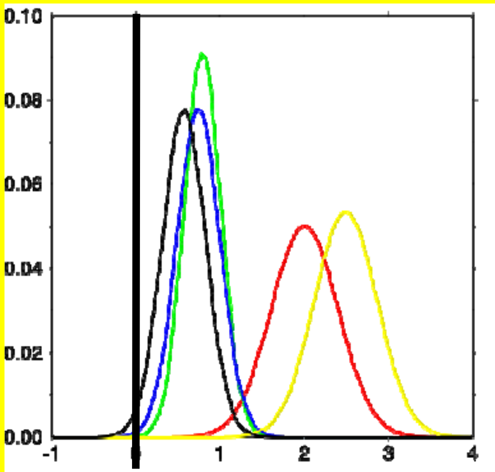


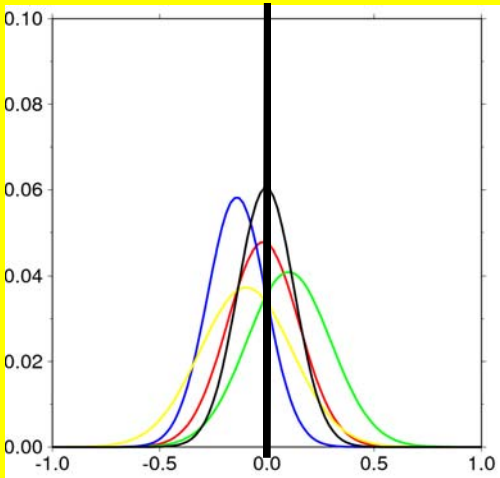


temperature

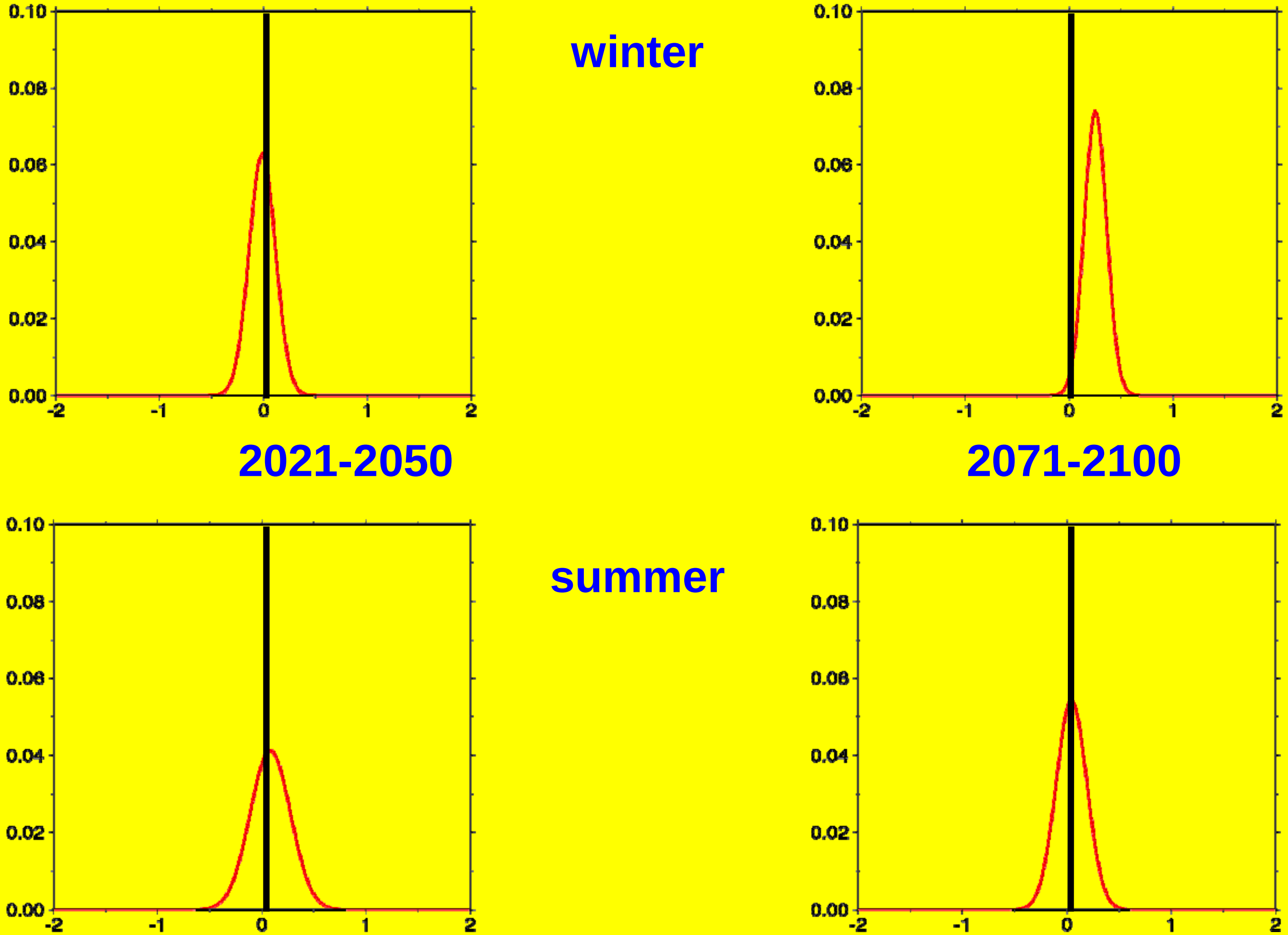
precipitation

summer





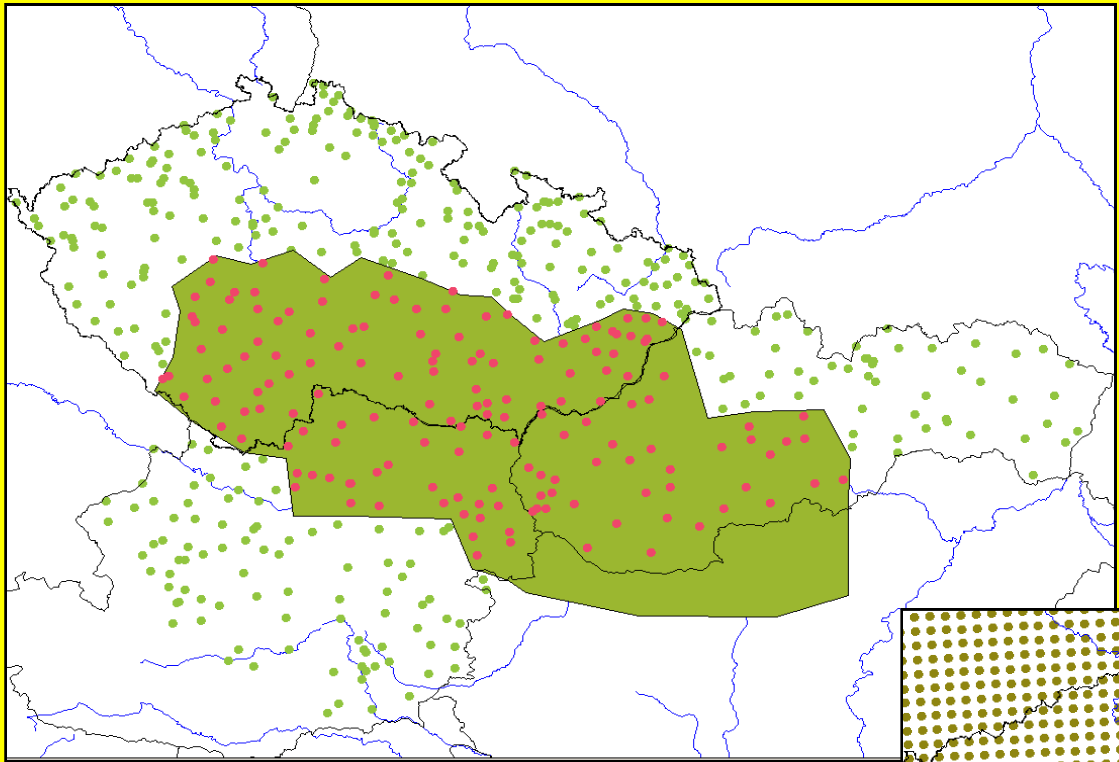
Prague precipitation change (mm/day)



WP3
Statistical downscaling, model verification and output localization

Prague, November 24-28, 2009

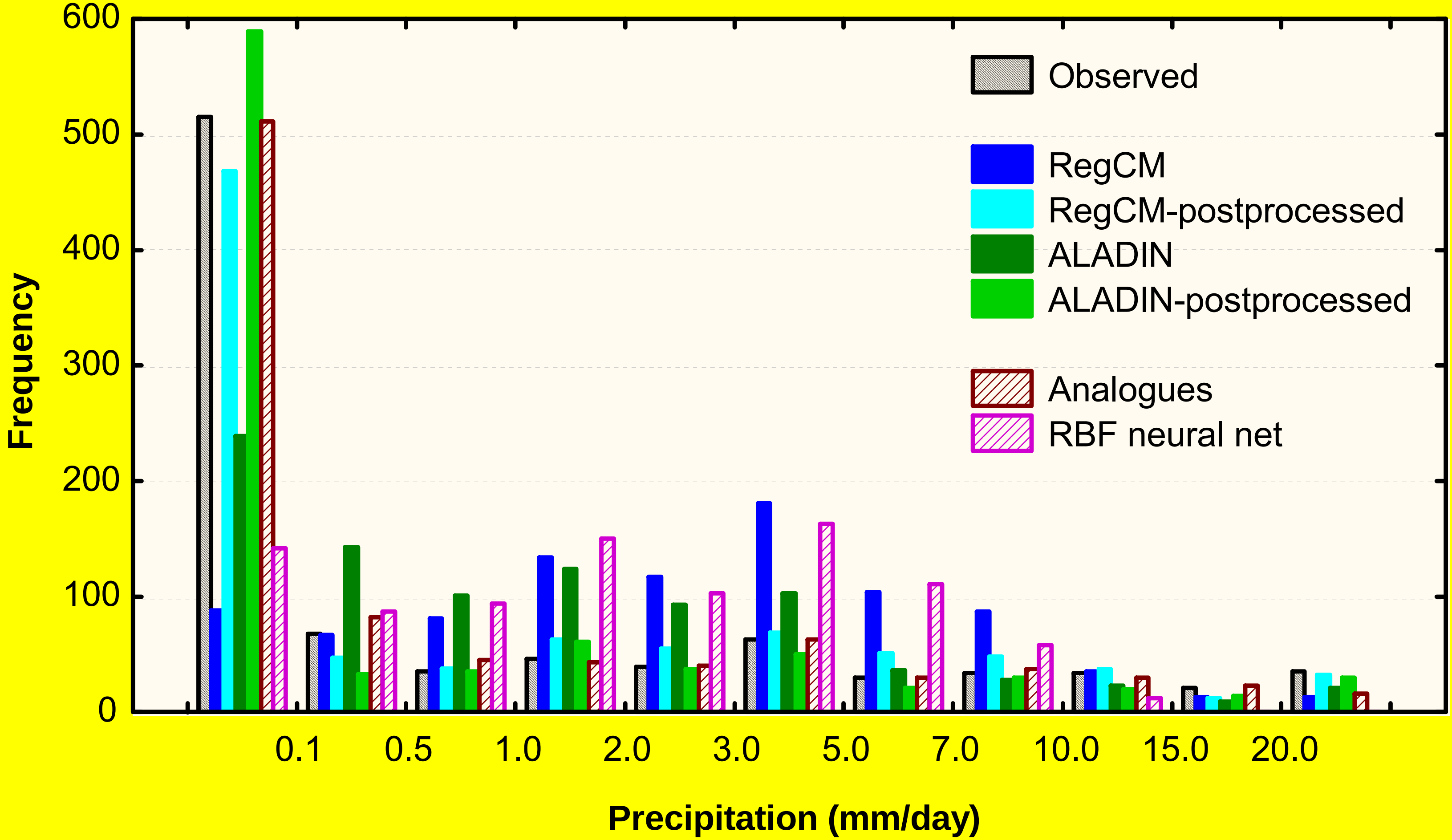
Preparation of datasets for detailed validation of climate models



Dataset of temperature series available from weather stations (◄) and its regularized version, suitable for validation of climate models (▼)

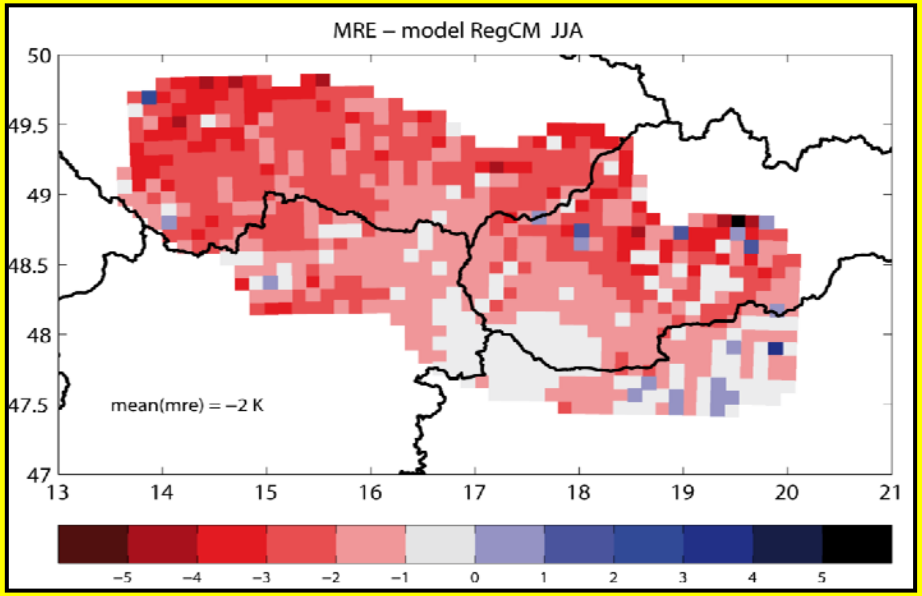
Source: Czech Hydrometeorological Institute

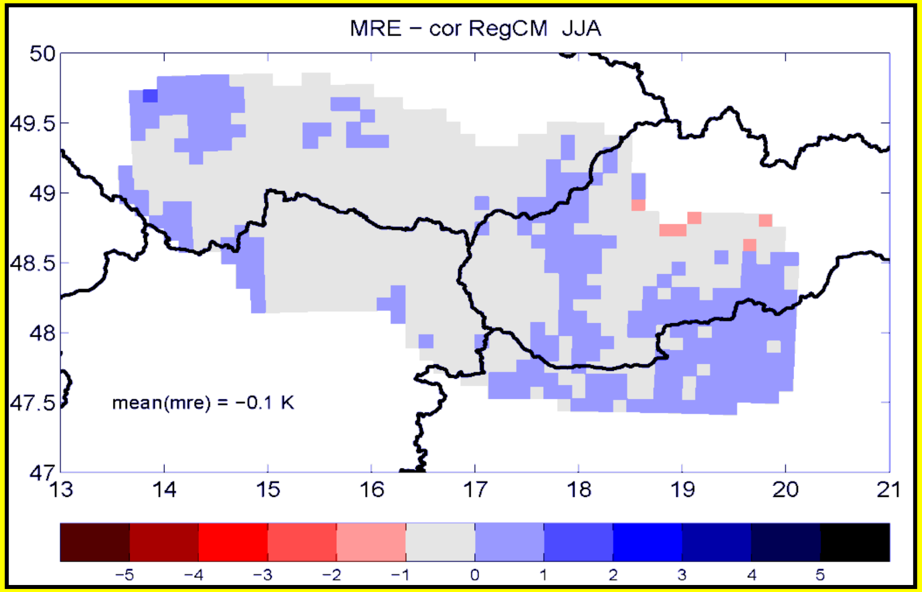
Statistical vs, dynamical downscaling



Distribution of values of daily precipitation in the series obtained by different downscaling methods, dynamical or statistical (displayed for a single 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.

Repairing the systematic errors of data simulated by climate models





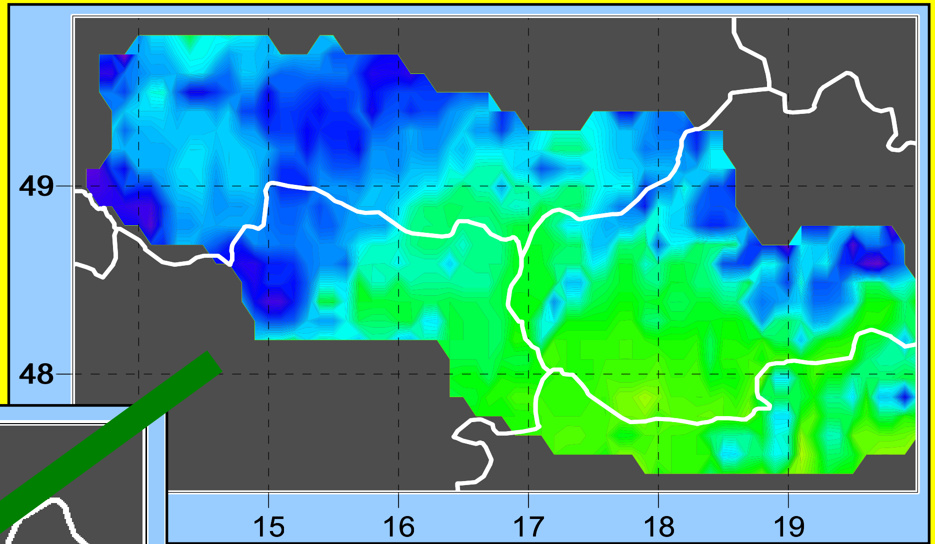
While most climate models suffer from some kind of systematic error(s), many of these can be corrected by further statistical transformations of the simulated fields

◄ Systematic errors of maximum daily temperature, simulated by the RegCM model in 10 km resolution (top) and their values in the corrected dataset (bottom)

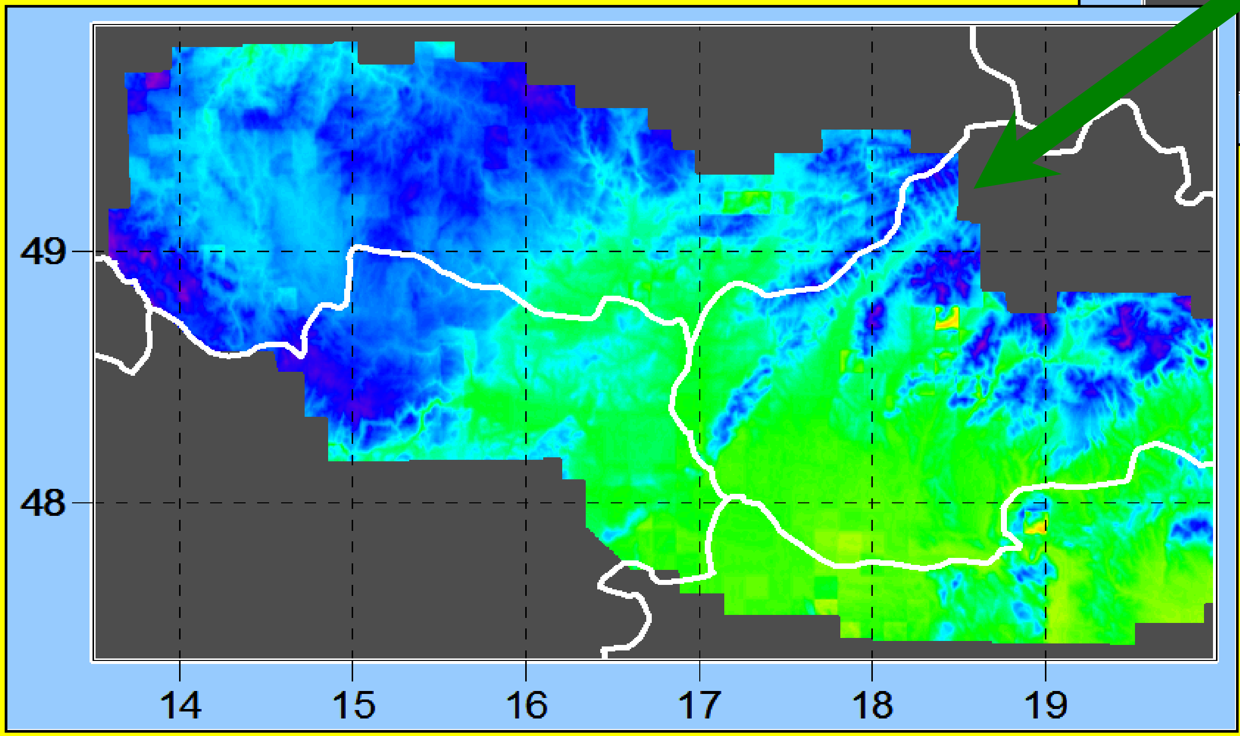
Source: Universität für Bodenkultur Wien

Increasing the resolution of model outputs

Even at the 10 km horizontal step of the CECILIA climate models, many terrain features still remain unresolved. This is also reflected in the fields of climate variables such as temperature. The missing details can be recovered by additional statistical transformations



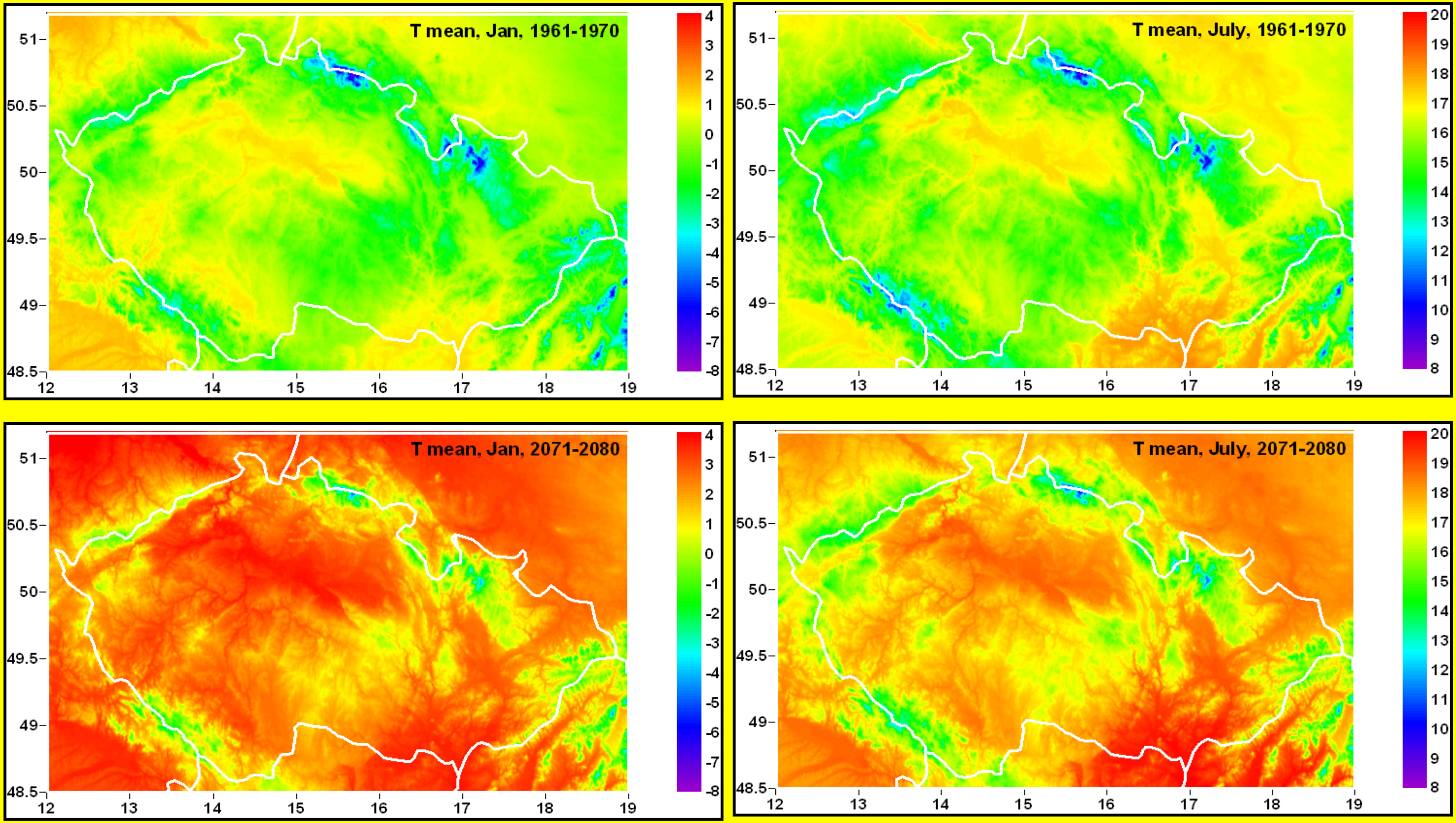
▲ Maximum daily temperature, simulated by the RegCM model in 10 km resolution …



◄ … and after transformation to 1 km resolution

Source: Charles University in Prague

Localized outputs of RegCM – Tmean, January



WP4
Extreme analysis, climate indices

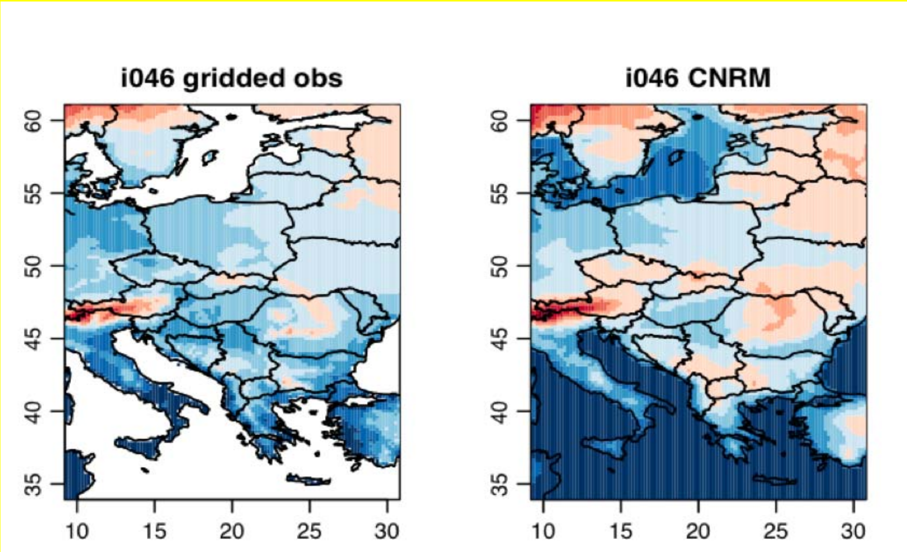
CECILIA extreme indices & database

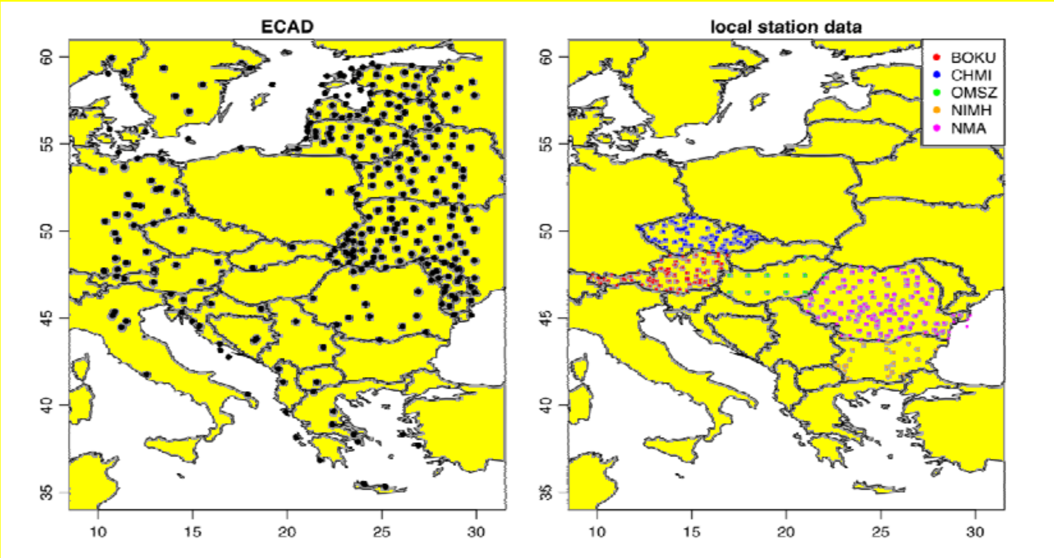
CECILIA WP4 has put together a data base with **131 indices for temperature and precipitation** based on:

observational data (European-wide and local datasets)

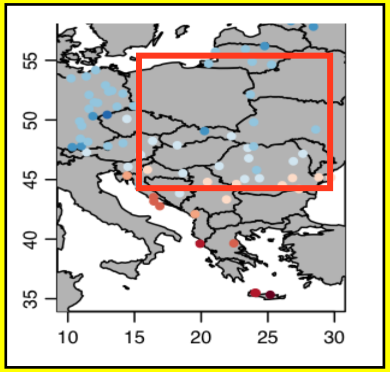
model simulations for 20th and 21st century (at resolution of 50➔10 km)

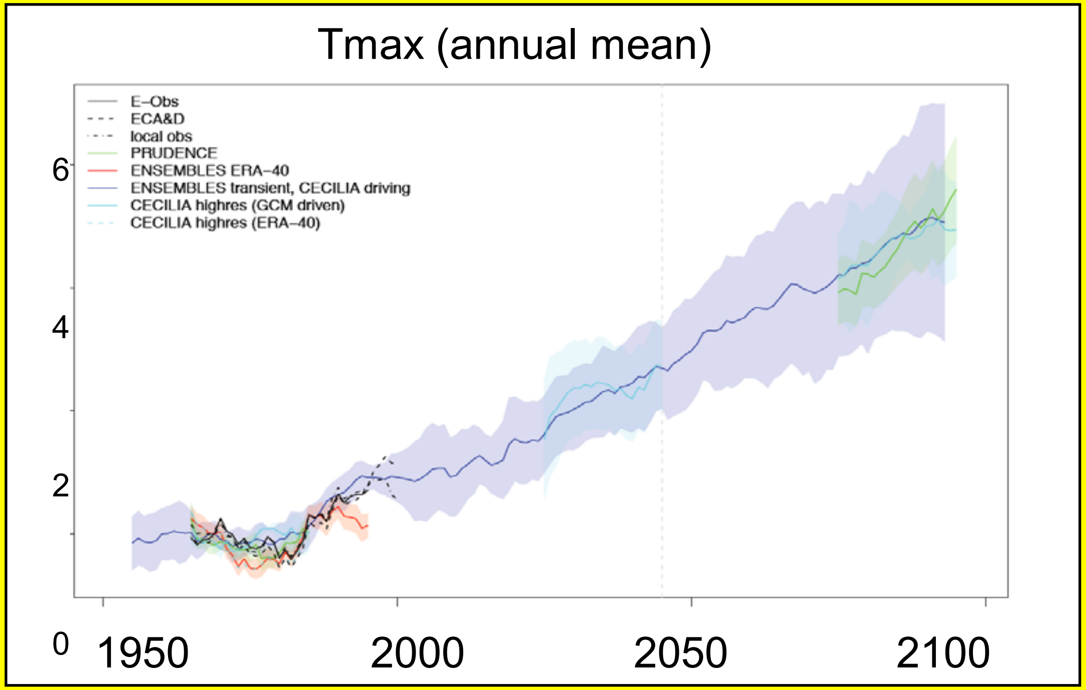
the data base will be freely available to the public after completion of the project





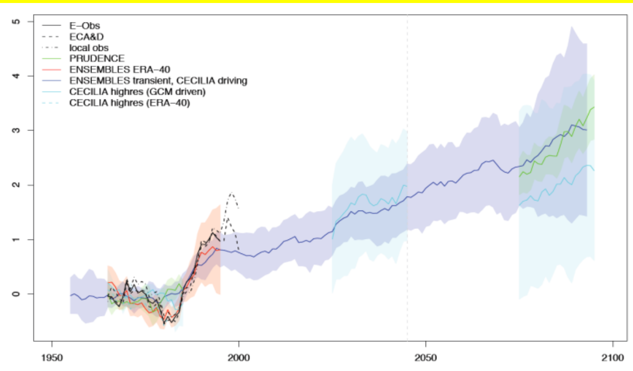
CECILIA WP4: Key Findings



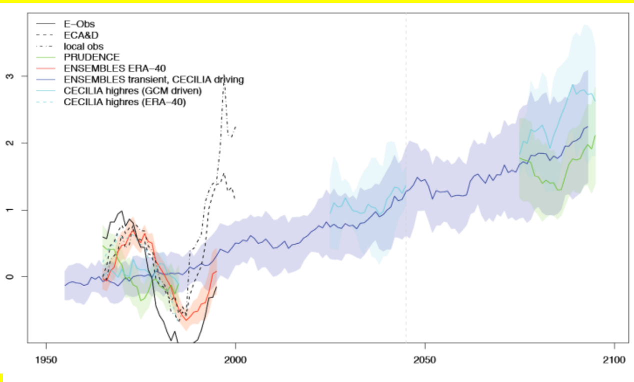


Major increase in mean Tmax (consistent with observations in present climate; +4 standard deviations by 2100)

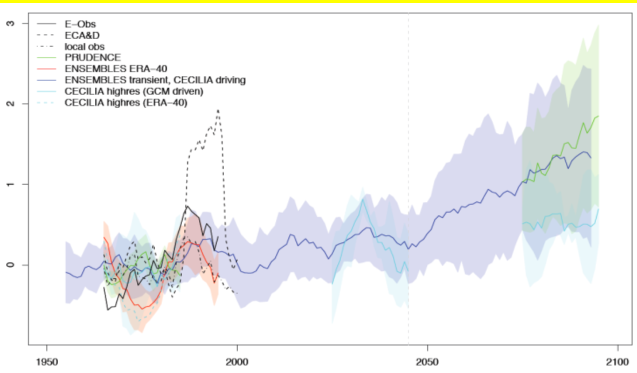
Heat wave duration index



Wet day mean precipitation



Consecutive dry days



Climate change impact assessment

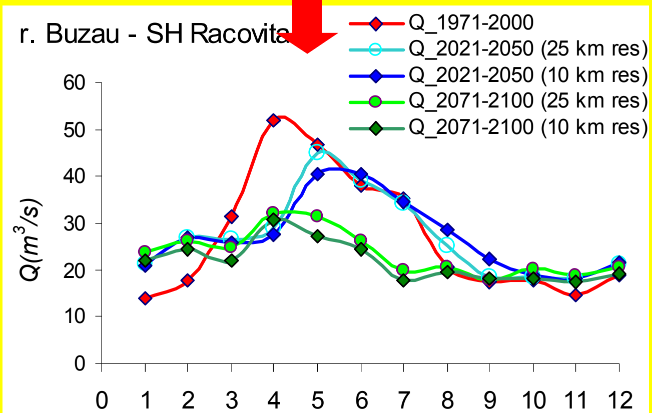
WP 5. Climate change impacts in hydrology and water management

► Analysis based on high resolution Regional Model outputs of the **climate change impact on hydrological resources** in the central and eastern Europe (NIHWM, CHMI, IAP, FRI).

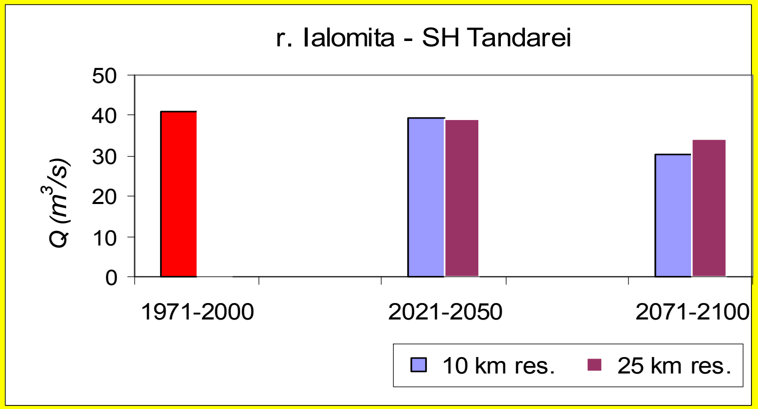
- Buzau and Ialomita river basins (Romania);
- Dije river basin (Czech Republic);
- Vltava river basin (Czech Republic);
- Hron river basin (Slovakia).

Outputs in a monthly time step of RegCM with 25 km and 10 km resolution.

Simulation of mean monthly discharges in different cross sections of each analyzed areas.



Mean monthly discharges



Mean annual discharge

Floods

Return 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 simulation 2021-2050 [m^3/s]	Difference [%]	Discharge based on 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

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

► Assessment of the managed water resources, **demand and vulnerability and corresponding adaptation measures** for present and projected climate (NIHWM).

➧Study area Buzau – Ialomita (Romania)

► Analyse of the **climate change impact on the flood events** (CHMI).

➧ **Dyje river basin**

The comparative simulations of rainfall-runoff events according to the outputs of climatic model was been done.

► 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 (IAP).

➧**Analyzed area - Vltava river basin**

- develop "atmosphere - river network - reservoir“ modelling system
- simulate hydrology, water quality, eutrophication.

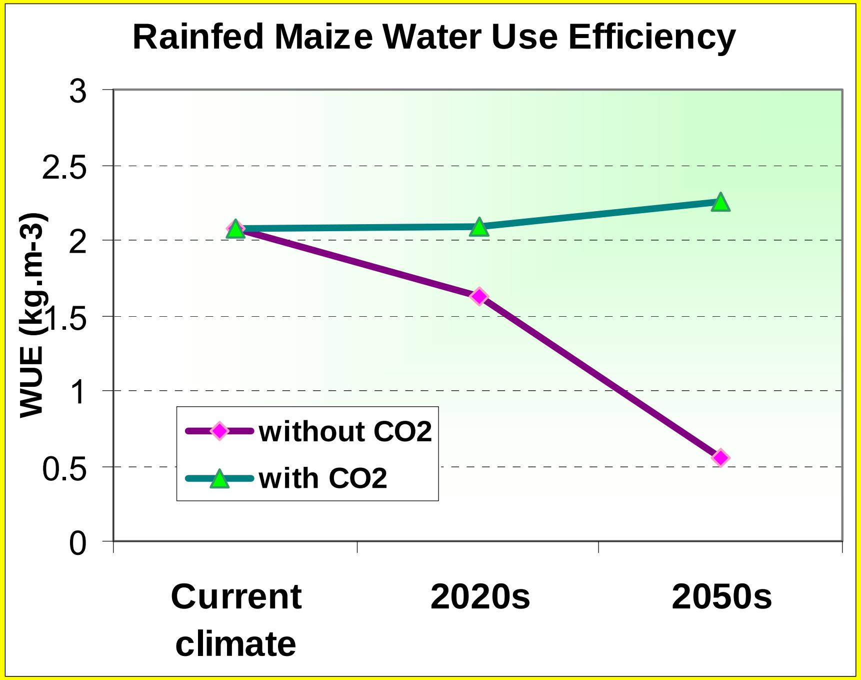
► Study of the **impacts of global change signal on local climate variability of air-sea coupled modes.** (NMA, NIHWM).

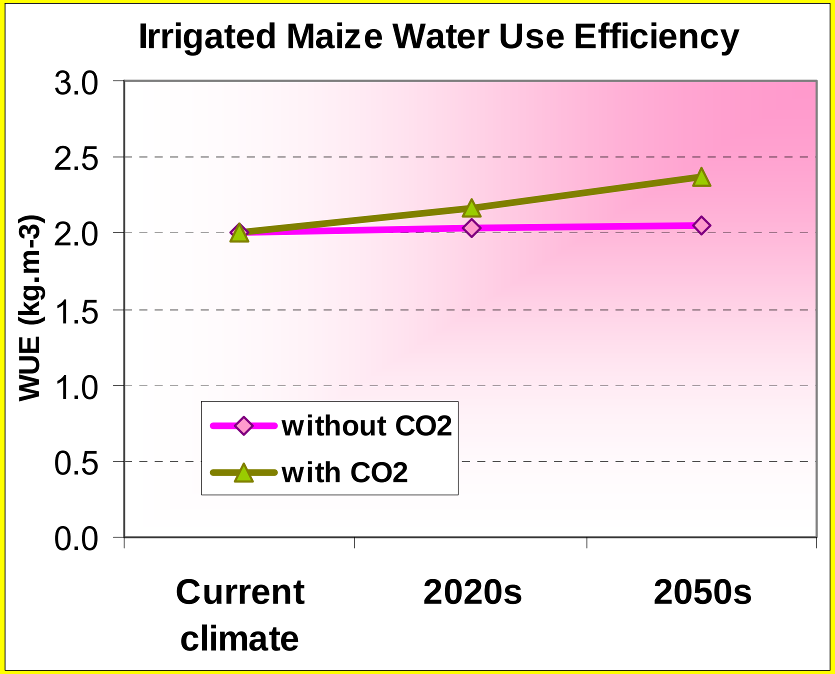
➧**Western Black Sea coast**

- Simulation of the present and future air-sea coupling characteristics: air and sea surface temperature, sea level, salinity, and wave heights

WP 6. Climate change impacts in agriculture and forestry

Water Use Efficiency





Water use efficiency for rainfed (left panel) and irrigated (right panel) maize crop (without/with CO2 effect) in the current and future climate conditions, at the pilot station Calarasi

AGRICULTURE adaptation options

⇒ **Recommendations and options to improve the genotype varieties and yields**

•Altered genetic coefficients, respectively for winter wheat the vernalization a photoperiod (P1V and P1D). For winter wheat the most suitable combinations can be the varieties with high or moderate vernalization and moderate or shorter photoperiod requirements.

⇒ **Recommendations to improve effective use of water by crops**

•Use of cultivars resistant to abiotic stresses (i.e. drought, high temperature) and resistance to specific diseases

•Using different soil classes

•Changing the seeding date and selection of cultivars with shorter germination and shorter growing season

•Application of irrigation and choose the most suitable irrigation method considering type of crop, soil type, technology, costs and benefits

•Changing the agricultural practices (for example: replacement of ploughing by minimum tillage and direct drilling) and crop rotation systems

•Perform periodical soil analysis and tests, in order to assess and correct the limiting factors which hinder the normal growth and development of plants (acidity, nutrient excess or deficit, etc.)

•Surface mulch (reduction of evaporation)

•Use of natural organic fertilizers, adapted to needs/demands

Impacts on forests

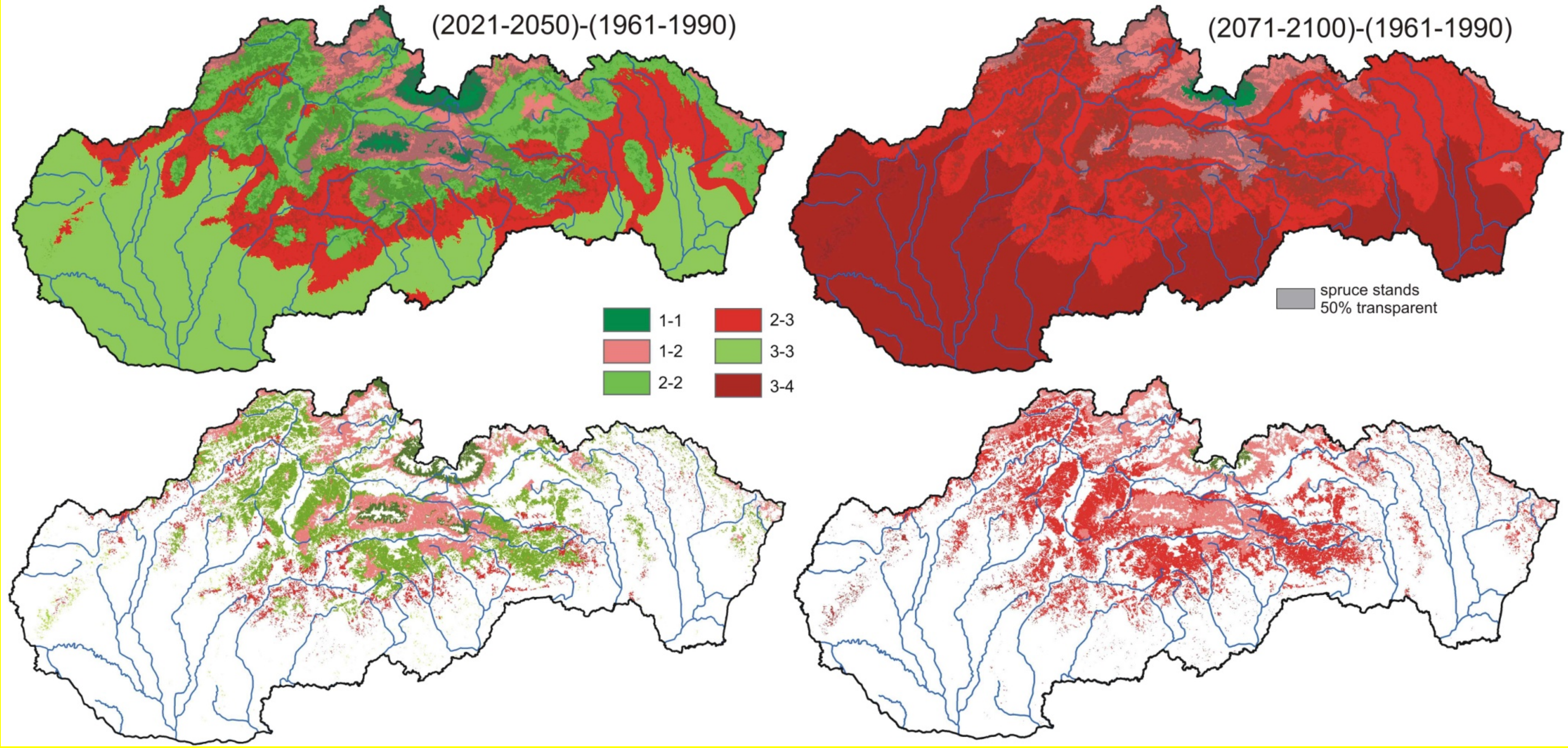
Production of the main forest tree species (spruce, beech, oak, fir) in CEE will be changed depending on the altitudinal/latitudinal gradient

- In mountain conditions up to 70% increased production of beech and spruce, 8-10% for oak
- Oak (*Quercus sp.*) appears very perspective to the future, constant mortality, increased production in higher elevations (5-6 AVZ)
- Production and mortality in 5-6th AVZ relatively unchanged for all species

Changes in pests distribution and population dynamics

- Gypsy moth outbreak ranges shifting to the upper distributional range of Turkey oak,
- Serious threat to beech stands from Gypsy moth (change of host)
- In case of spruce bark beetle, appearance of the 2nd and 3rd generation strikes most of spruce stands. 0-generation regime disappears
- Higher threat to mountain regions

AVZ – altitudinal vegetation zone



Differences in number of bark beetle generations projected to develop in the near future (left panels) and far future (right panels) vs. the reference climate. The upper panels showing the differences in full number of developed generation (Example: 1-2 – number of developed generations increased from 1 to 2) in the whole country, the bottom panels describe the increase in bark beetle generations within actual distribution of spruce.

CECILIA, EC FP6, 2006-2009, http://www.cecilia-eu.org

Forestry adaptation options

… towards silviculture, forest management and forest protection

- AVZ-specific changes in tree species compositions considering changes in species production and mortality
- Site specific increase of species diversity to allow for natural selection
- Increasing proportion of species with broad amplitude, mainly to the detriment of spruce
- Reducing harvest age, because of higher mortality of older stands
- Planning spatially differentiated pest management, mainly in regions where pests pressure is supposed to increase (in fact, bark beetle is the only candidate)
- Considering limitations to pest management by protected areas

Carbon

Motivation: the climate system is closely coupled with the carbon cycle. At present terrestrial vegetation mitigates climate change as it sequesters a huge amount of CO_2 (globally 0.9±0.6 GtC/year net uptake at present according to IPCC AR4)

Main question: what is the future evolution of the land carbon sink?

CECILIA approach: high resolution RCM data are used together with a detailed biogeochemical model at plot level with different biome types. Air pollution is also accounted for (CO_2 fertilization and nitrogen deposition)

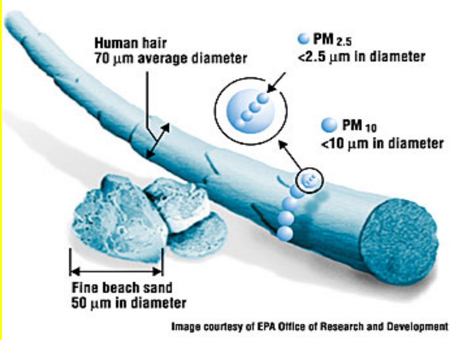
Main findings:

- Pine forest in Poland (Kampinos): no change in the carbon sequestration of the forest
- Turkey oak forest in Slovakie (Čifare): clear **positive** feedback – carbon sequestration capacity of the forest decreases
- managed grassland in Hungary (Hegyhátsál): small negative deedback as the source activity might decrease (smaller CO_2 source). Alternative management has a large effect so human decisions may substantially alter the carbon cycle of managed ecosystems.
- cropland in Hungary (Hegyhátsál): no clear results due to uncertainties caused by harvest but it seems that productivity in the first half of the year might increase which may have positive effect on winter crop productivity.

WP 7. Climate change impacts in air quality

Climate change impacts Air Quality!

Recognized air-pollutants related hazards:



Harmful effects for human health:

- Gases: **Ozone**, SO_2, CO, C_6H_6, heavy metals,……
- Particulate pollution: TSP, **PM_{10}, $PM_{2.5}$**

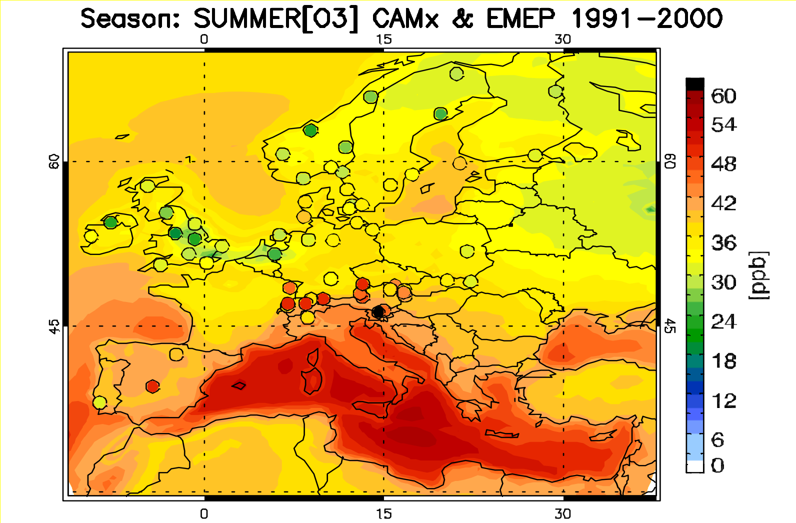
Harmful effects for ecosystems:

- Acidification (forests, lakes)
- Tropospheric ozone (vegetation, forests)
- Heavy metals deposition
- Eutrophication

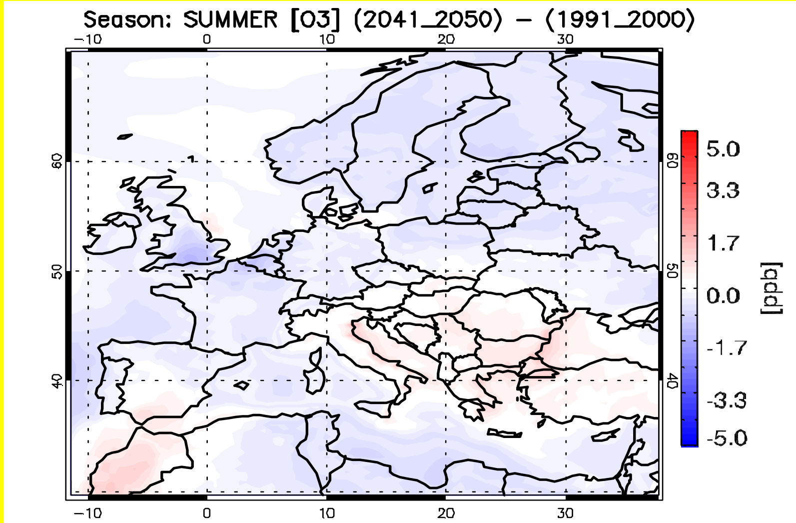
Harmful effects to materials, reduction of visibility,....

Climate Change Impacts on AQ – Europe (AUTH)
ECHAM5-RegCM3-CAMx; O_3: summer levels

1991-2000



(2041-2050)-(1991-2000)

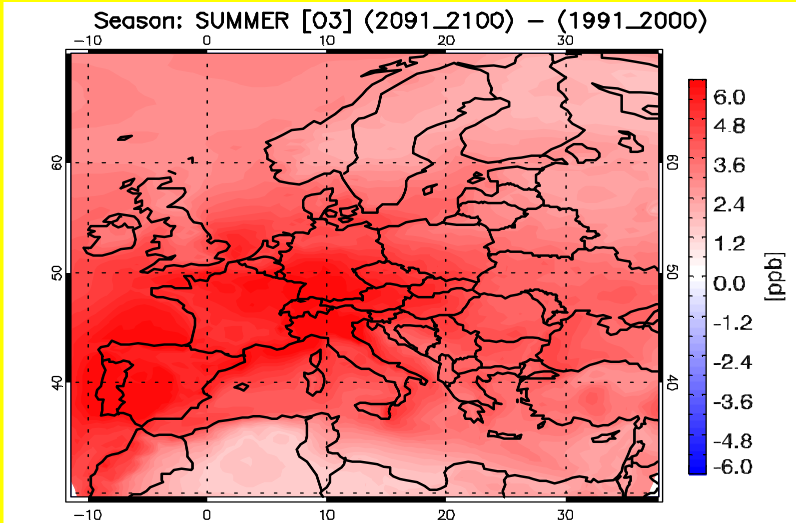


Comments:

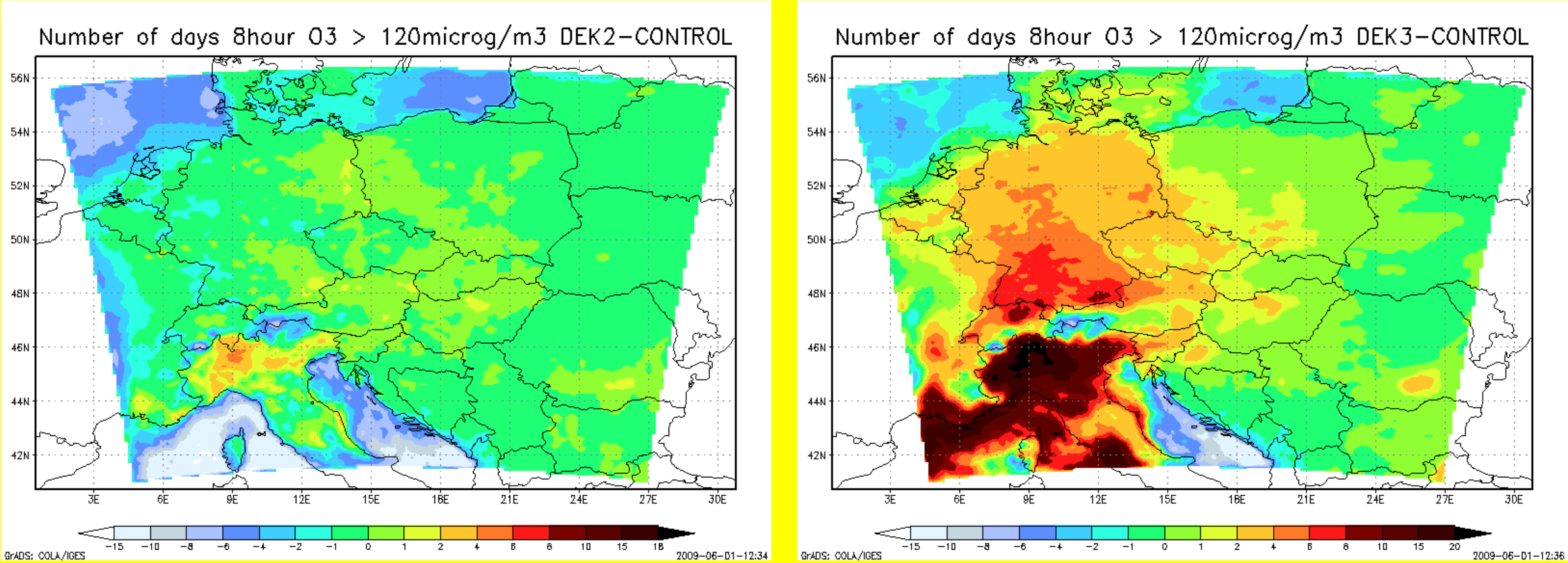
The future simulations of air quality show that the effect of climatic change to the levels of near surface ozone is small for the near future decade 2041-2050 but becomes important in the end of 21st century.

The future ozone changes are closely linked to the changes of meteorological parameters with solar radiation being the dominant modulating factor.

(2091-2100)-(1991-2000)



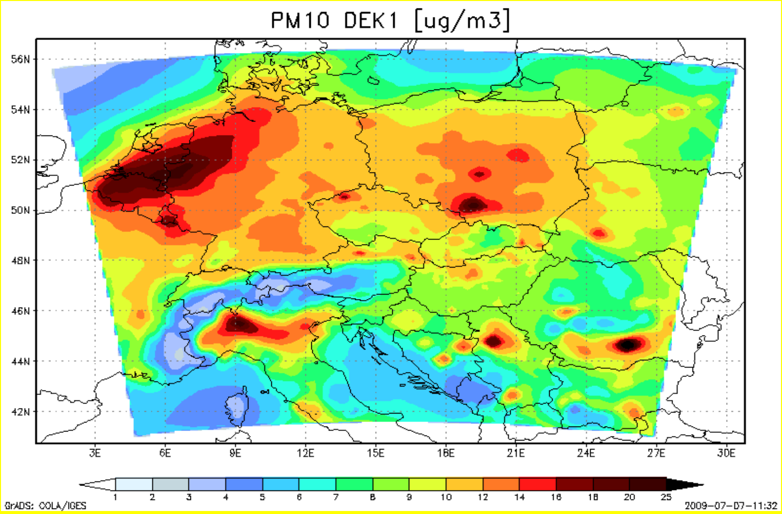
Ozone exceedance days



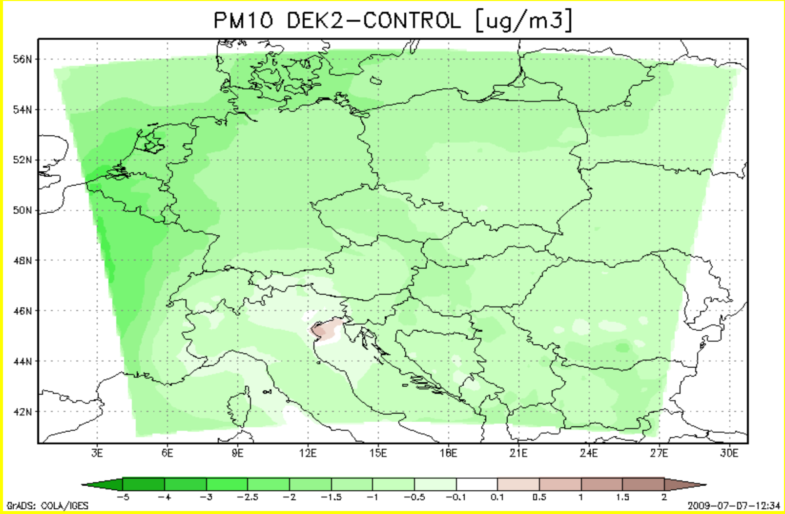
Climate change impact on number of ozone exceedance days, i.e. days per year with 8-hours ozone concentration above the threshold of 120 µg/m^3 (EU limit) in terms of the difference for 2041-2050 period (left panel) and 2091-2100 period (right panel) against the control period 1991-2000.

Climate Change Impacts on AQ – CCE Europe
ECHAM5-RegCM3-CAMx; PM_{10}: annual levels

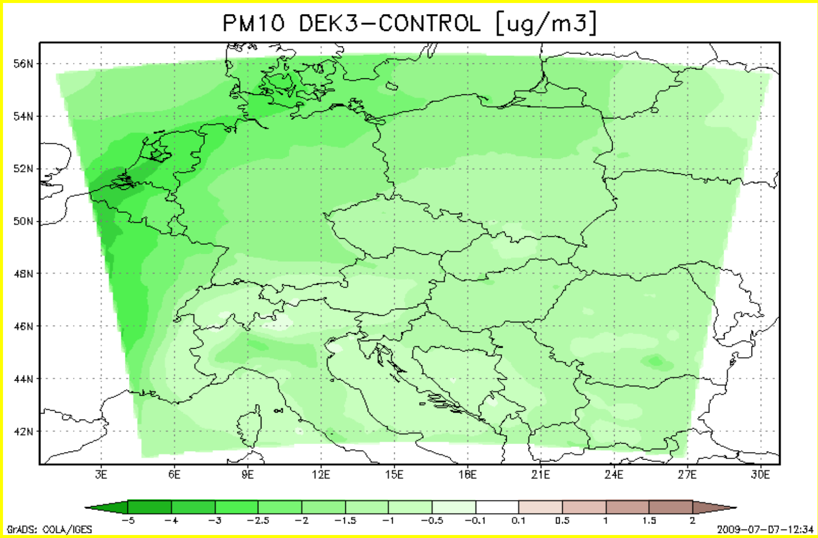
1991-2000



(2041-2050)-(1991-2000)



(2091-2100)-(1991-2000)



Comments:

The future simulations of air quality show that the effect of climate change to the levels of PM10 is slightly negative for the near future decade 2041-2050, and becomes more negative in the end of 21st century: decrease up to –2 µg/m3 in northern Europe.

Conclusions

- increase of precision, but not so much accuracy
- 10km resolution **seems** to bring some benefits for further postprocessing
- 10km resolution **seems** to provide useful more detailed information for further application in impact studies
- however, due to biases still difficult to use direct climate outputs for impact studies
- further development of the models, introducing better parameterizations and more efficient schemes should move the high resolution RCMs closer to become useful tools in climate change impact assessment, diminishing the need for statistical postprocessing.

Acknowledgment

Thanks for your attention

http://www.cecilia-eu.org

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