GLOBAL CLIMATE MODELLS AND REGIONAL CLIMATE PROJECTIONS FOR THE 21ST CENTURY

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OUTLINE

I. Global climate modelling
II. Historical aspects
III. Regional climate modelling
IV. Joint EU projects on regional climate modelling (PRUDENCE, ENSEMBLES, CECILIA, CORDEX)
V. IPCC – 2007
VI. SREX -2012
VII. Progress and findings of IPCC – 2013-2014
VIII. Perspectives for the Polar region
IX. Perspectives for Central Europe

Questions

What are the implications of global warming for a **smaller region** like Europe, Carpathian-basin or Estonia?

How will the sea, the mountains alter the story?

Do global models tell us the full story or we need **extra tools**?

Regional Climate Prediction

- Aim: To understand the impact of global warming.
- General circulation models (GCMs): provide a general view of the global evolution of the atmosphere.
- GCMs are essentially the **same** as global **weather** prediction models but are run with much **coarser** resolution and allow the composition of the atmosphere to **vary in time** (e.g., more CO2)
- **Even leading GCMs only describe features of roughly 200-450 km in scale**.

• European weather is dominated by the midlattitude ciclons and land-water contrasts of smaller scale.

• In order to understand the implications of global changes on our weather, downscaling of the GCM predictions is required.

Downscaling methods

- Statistical downscaling
- Dinamical downscaling

Downscaling methods

- The traditional approach to use GCM output is through **statistical downscaling**, which finds the statistical relationship between **large-scale** atmospheric structures and **local** weather.
- Statistical downscaling either assumes **current** relationships will hold or makes simplifying assumptions on how **local** weather works.

Downscaling methods

Such statistical approaches may be a reasonable start, but may give deceptive or even wrong answers… since the relationships between the large scale atmospheric flow and local weather might change in the future.

Downscaling methods

- There is only one way to do this right… running full weather forecasting models at high resolution over extended periods, with the large scale conditions being provided by the GCMs….this is called **dynamical downscaling (nested modelling).**
- Such weather prediction models have very complete **physics** and high **resolution**, so we can expect realistic results

Downscaling

- Computer power and modeling approaches are now powerful enough to make **dynamical downscaling realistic**.
- **EU projects**

PRUDENCE PROJECT

MOTIVATION

- **Uncertainity of the clima projections**
- **Differences, variability of the model runs**
- **Extrems simulations, case studies (precipitation, temperature)**
- **Coordinated dynamical downscaling (modell simulations, comparison)**

PRUDENCE PROJECT

AIMS - CONTENT

- **Modeling 45%**
  (simulations, comparison)

- **Effect studies 45%**
  (hydrology, agriculture, forestry, ecosystems)

- **Climatepolicy, dissemination 10%**
  (publications: media, policy makers, economy)

List of RCMs with their driving GCMs used in the composite analysis

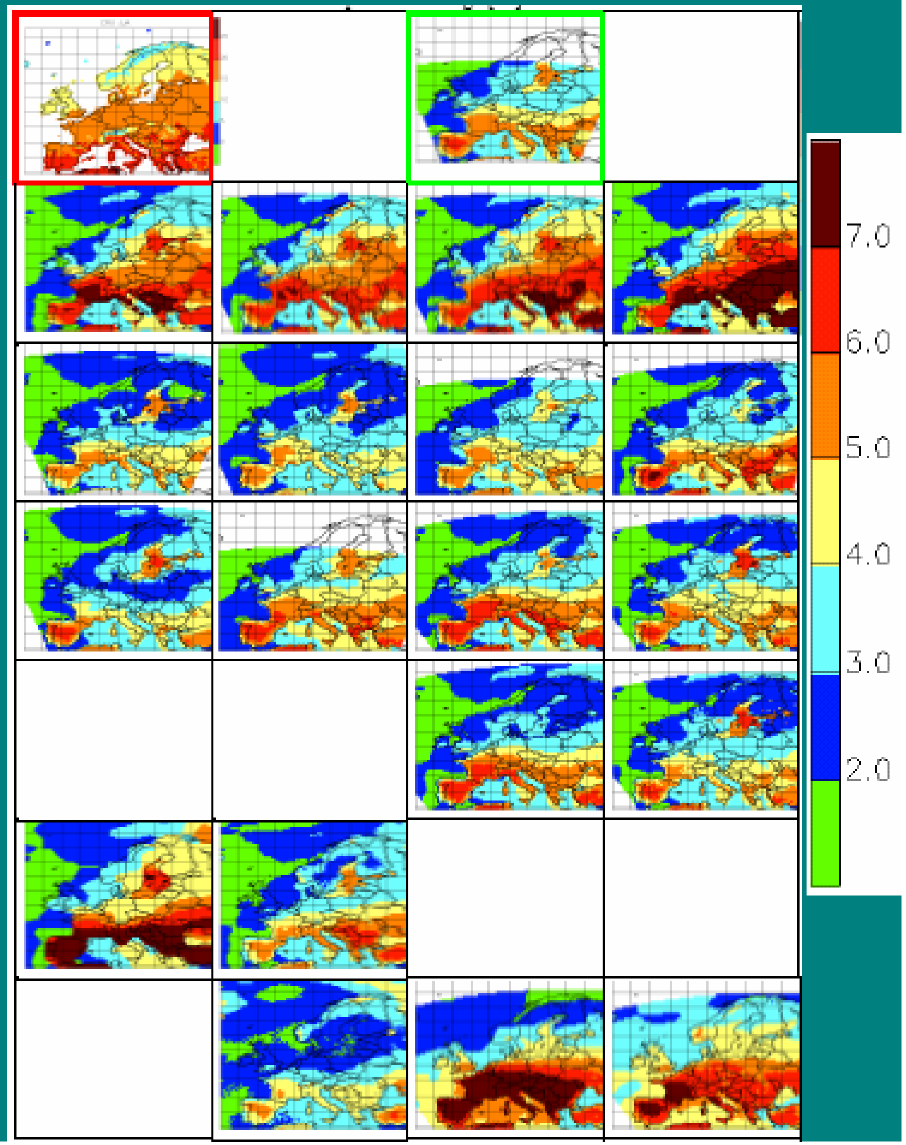
	Institute	RCM	Driving GCM	Scenario
1	Danish Meteorological Institute	HIRHAM	HadAM3H	A2, B2
2		HIRHAM	ECHAM5	A2
3		HIRHAM high res.	HadAM3H	A2
4		HIRHAM extra high res.	HadAM3H	A2
5	Hadley Centre, UK Met Office	HadRM3P (ensemble/1)	HadAM3P	A2, B2
6		HadRM3P (ensemble/2)	HadAM3P	A2
7	ETH (Zürich)	CHRM	HadAM3H	A2
8	GKSS	CLM	HadAM3H	A2
9		CLM improved	HadAM3H	A2
10	Max Planck Institute	REMO	HadAM3H	A2
11	Swedish Meteorol. and Hydr. Inst.	RCAO	HadAM3H	A2, B2
12		RCAO	ECHAM4/OPYC	B2
13	UCM (Universidad Complutense Madrid)	PROMES	HadAM3H	A2, B2
14	Int. Centre for Theoretical Physics	RegCM	HadAM3H	A2, B2
15	Norwegian Meteorological Institute	HIRHAM	HadAM3H	A2
16	KNMI (Netherlands)	RACMO	HadAM3H	A2
17	Météo-France	ARPEGE	HadCM3	A2, B2
18		ARPEGE	ARPEGE/OPA	B2

Climate scenarios for Europe based on PRUDENCE project

- EU-project: 2001-2005
- 19 regional climate model outputs for Europe
- Spatial resolution: 50×50 km^2
- Climate projections only for **2071-2100** (SRES **A2** and **B2**) Reference period: 1961-1990
- Using **three** OA-GCM-pair for the boundary conditions of the regional models: HadAM3H/HadCM3 (UK), ECHAM4/OPYC3 (DE), ARPEGE/OPA (FR)

Temperature change (19 model-runs) SUMMER (JJA) – PRUDENCE 2071-2100

SRES A2 scenario



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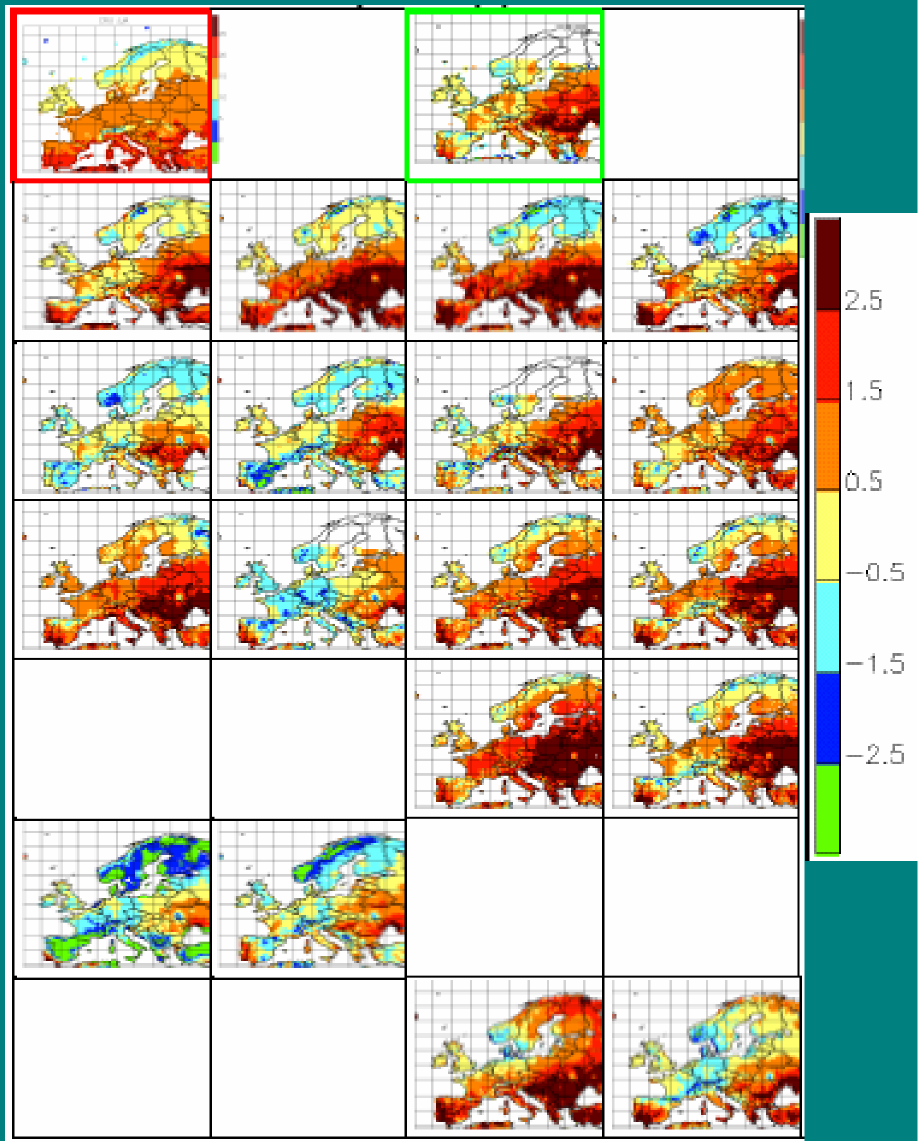
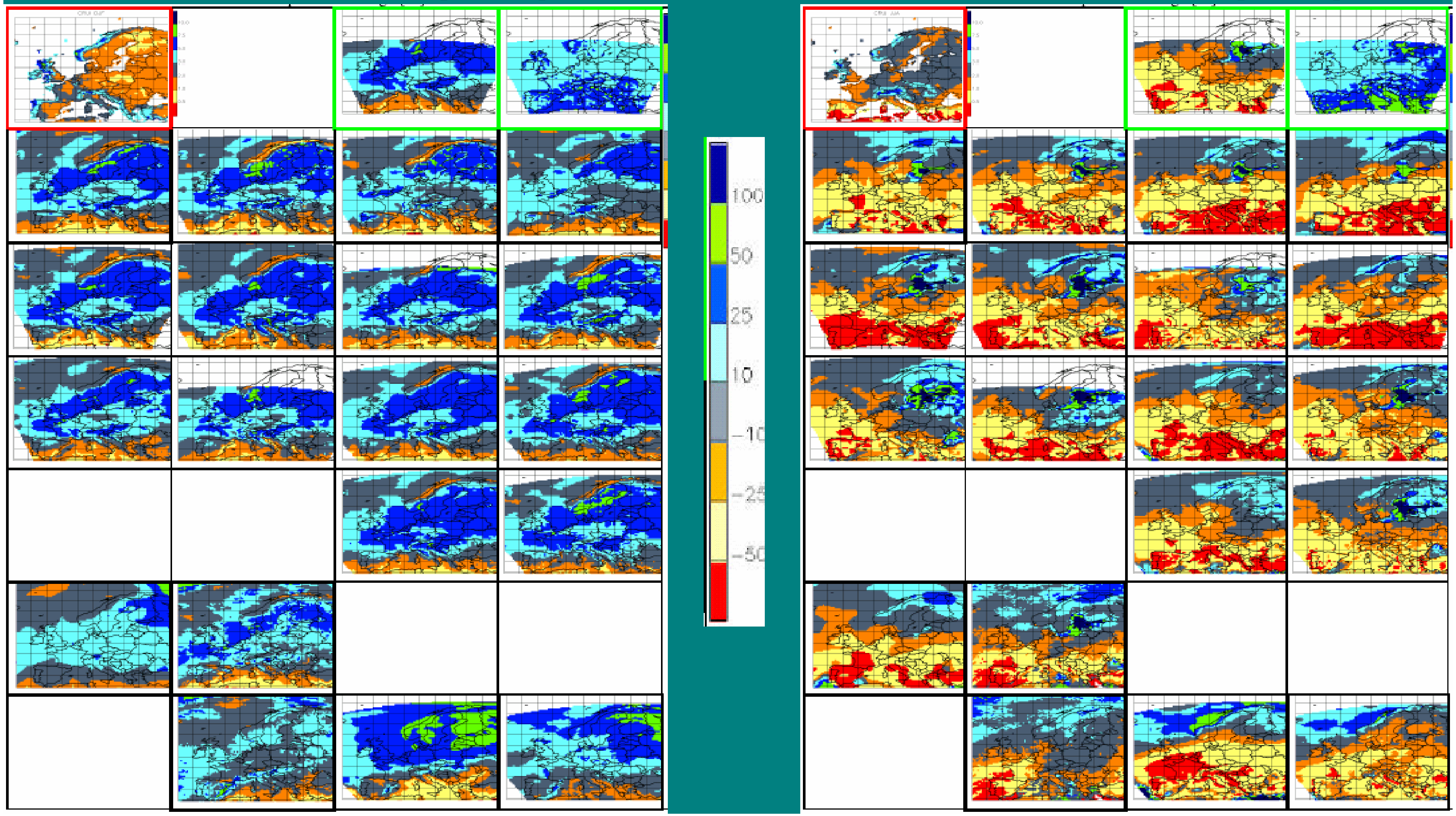
Temperature bias (19 model-runs) SUMMER (JJA) – PRUDENCE 1961-1990

Bias from CRU-data



Expected precipitation changes for 2071-2100 A2 scenario, PRUDENCE (19 model runs)

WINTER (DJF) **SUMMER (JJA)**



ENSEMBLES

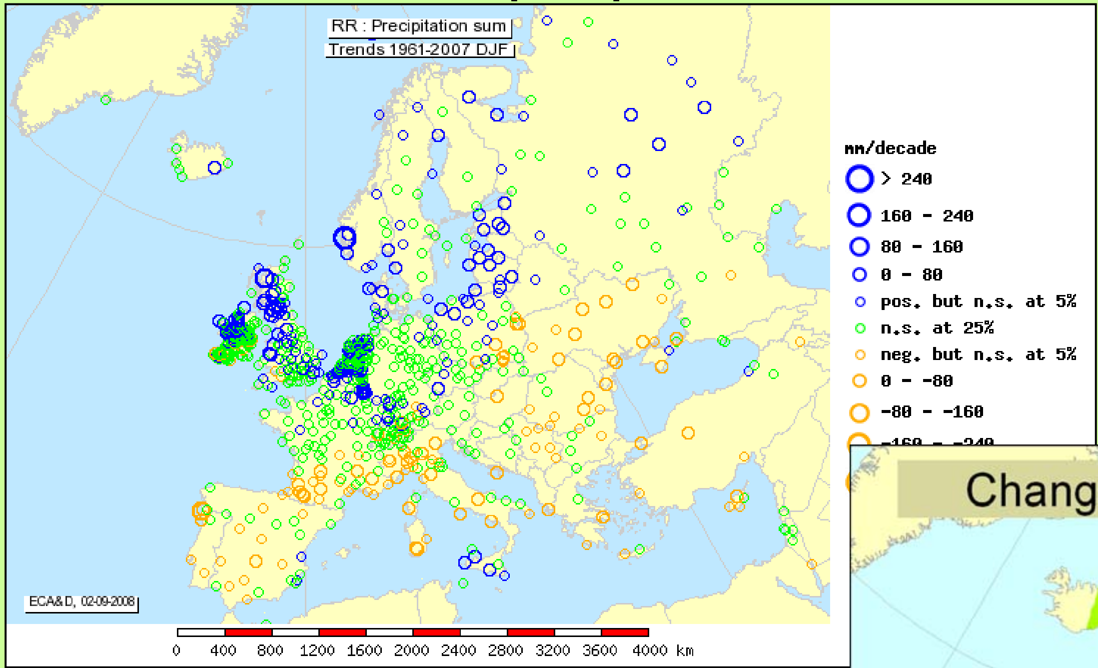
What new long-term climate information does ENSEMBLES offer?

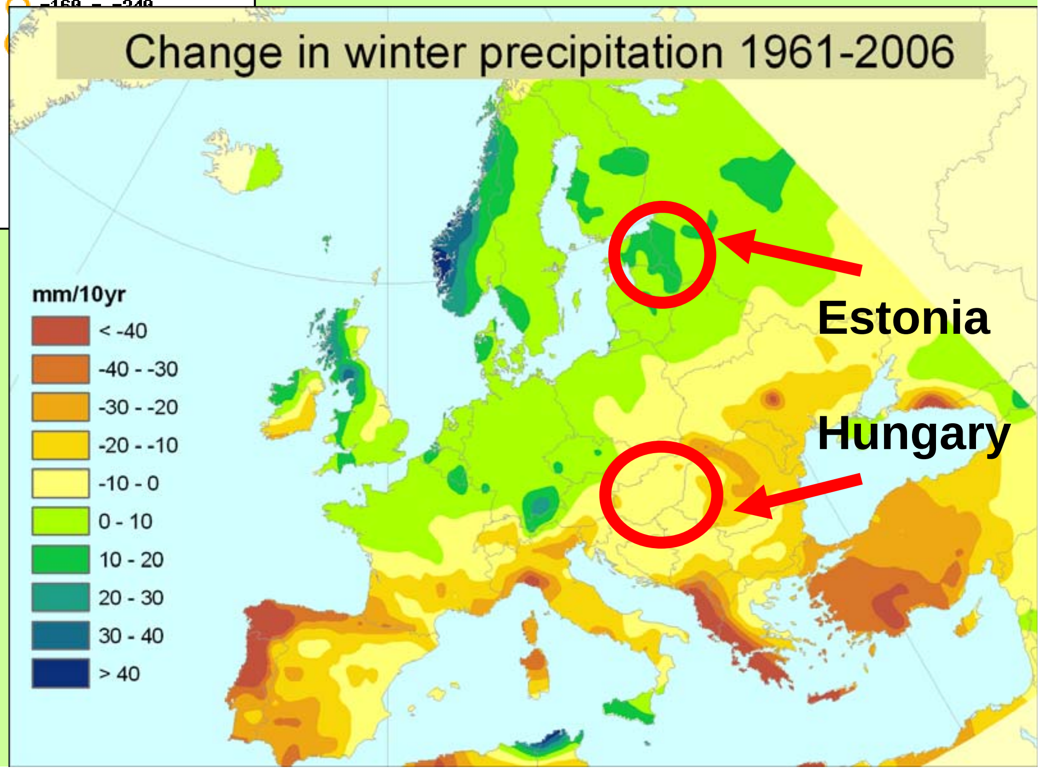
- A new daily interpolated observational dataset for surface climate over Europe (E-OBS)
- GCM projections assuming A1B and E1 emissions scenarios
- RCM projections (nested in GCMs) for A1B
- RCM-based PDFs (bivariate distributions; A1B emissions)

SYKE

Observed changes in the 1961-2006 period

station trends in winter precipitation

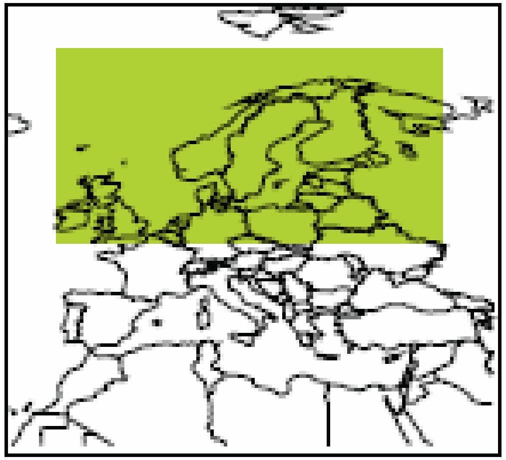




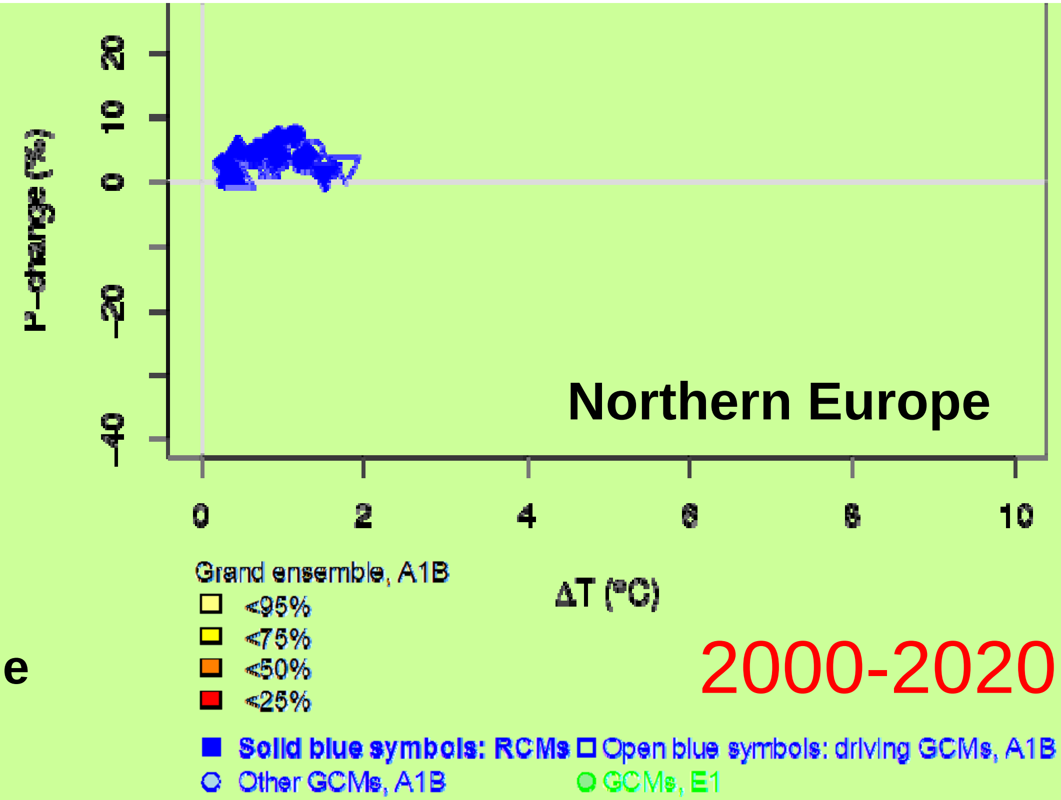
RCM and GCM projections

for the Northern and Southern part of Europe

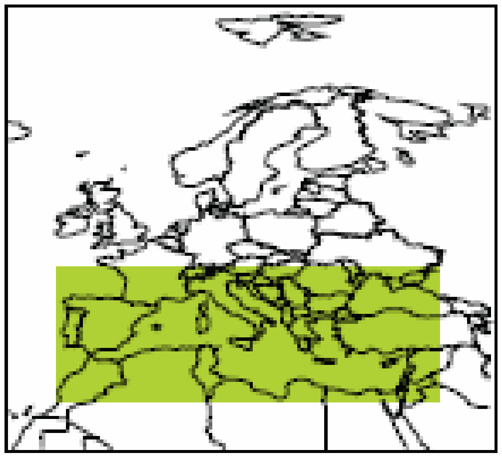
Source: John Caesar (Met Office)

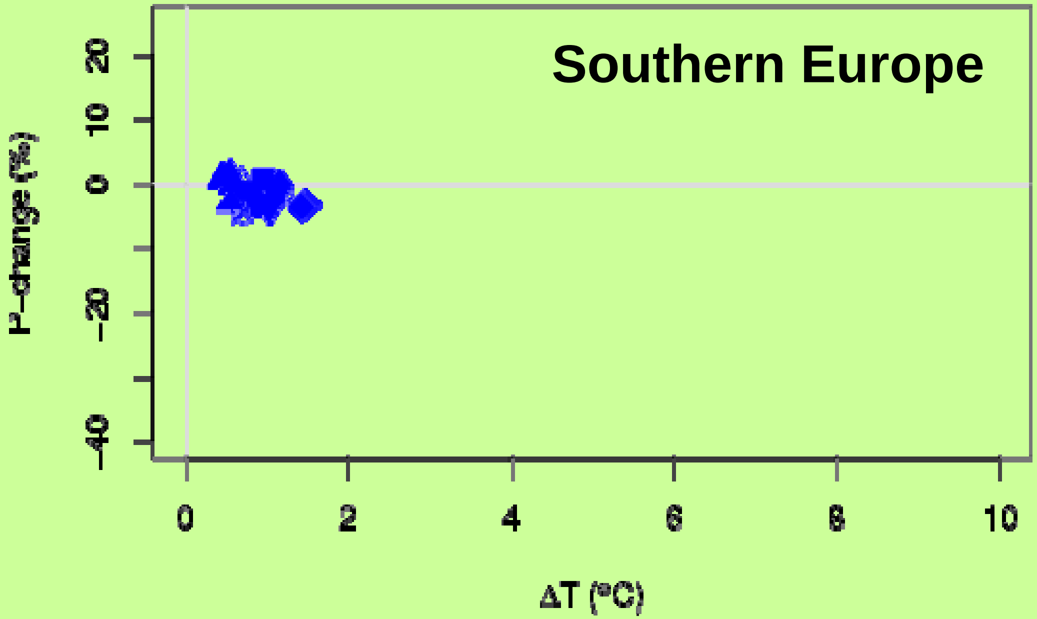


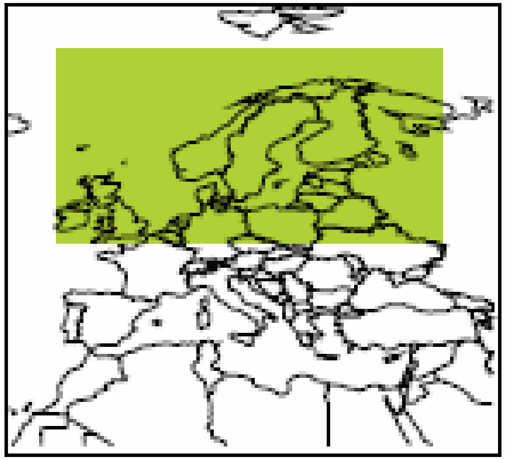
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

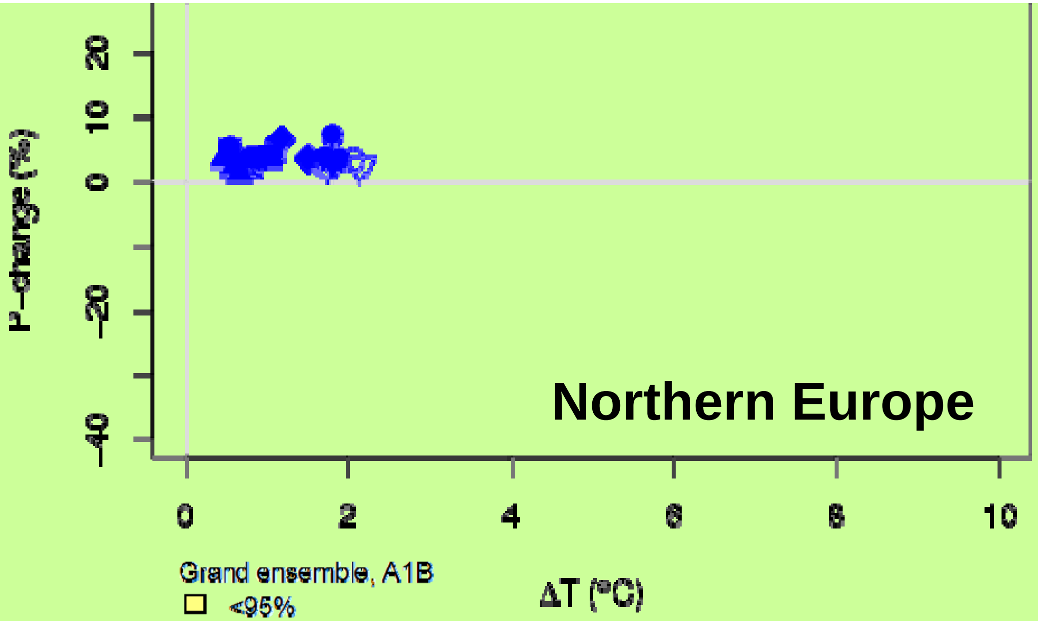


2000-2020









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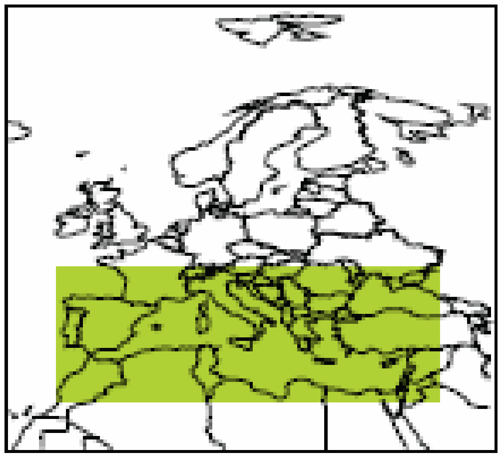
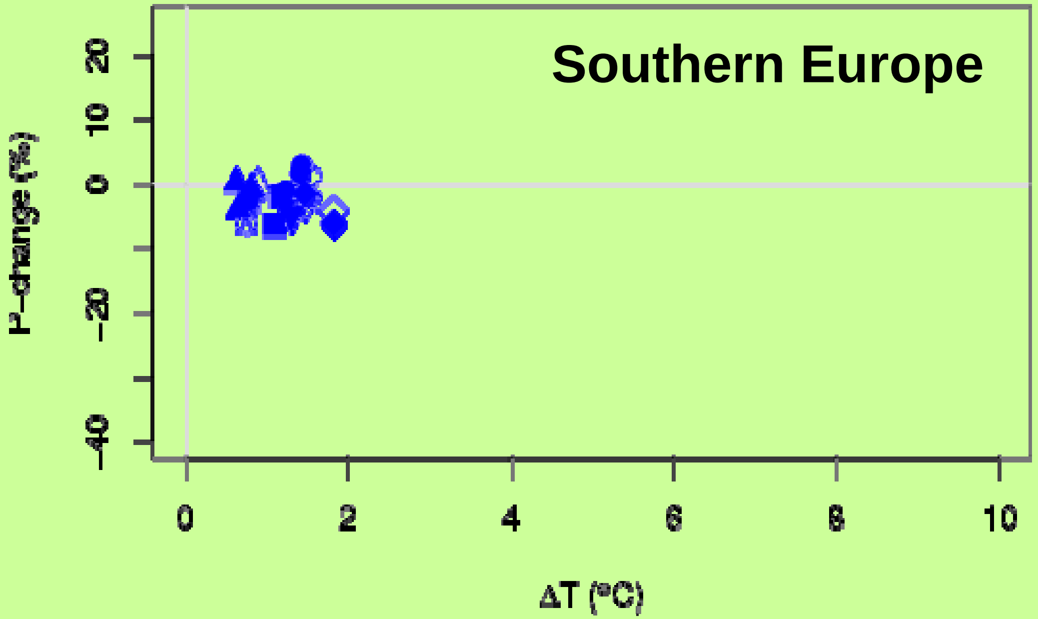
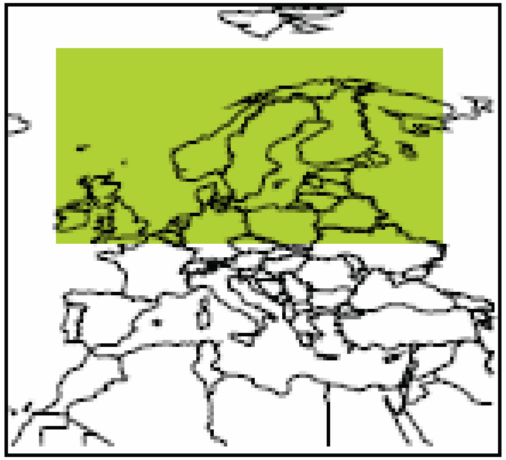
2010-2030







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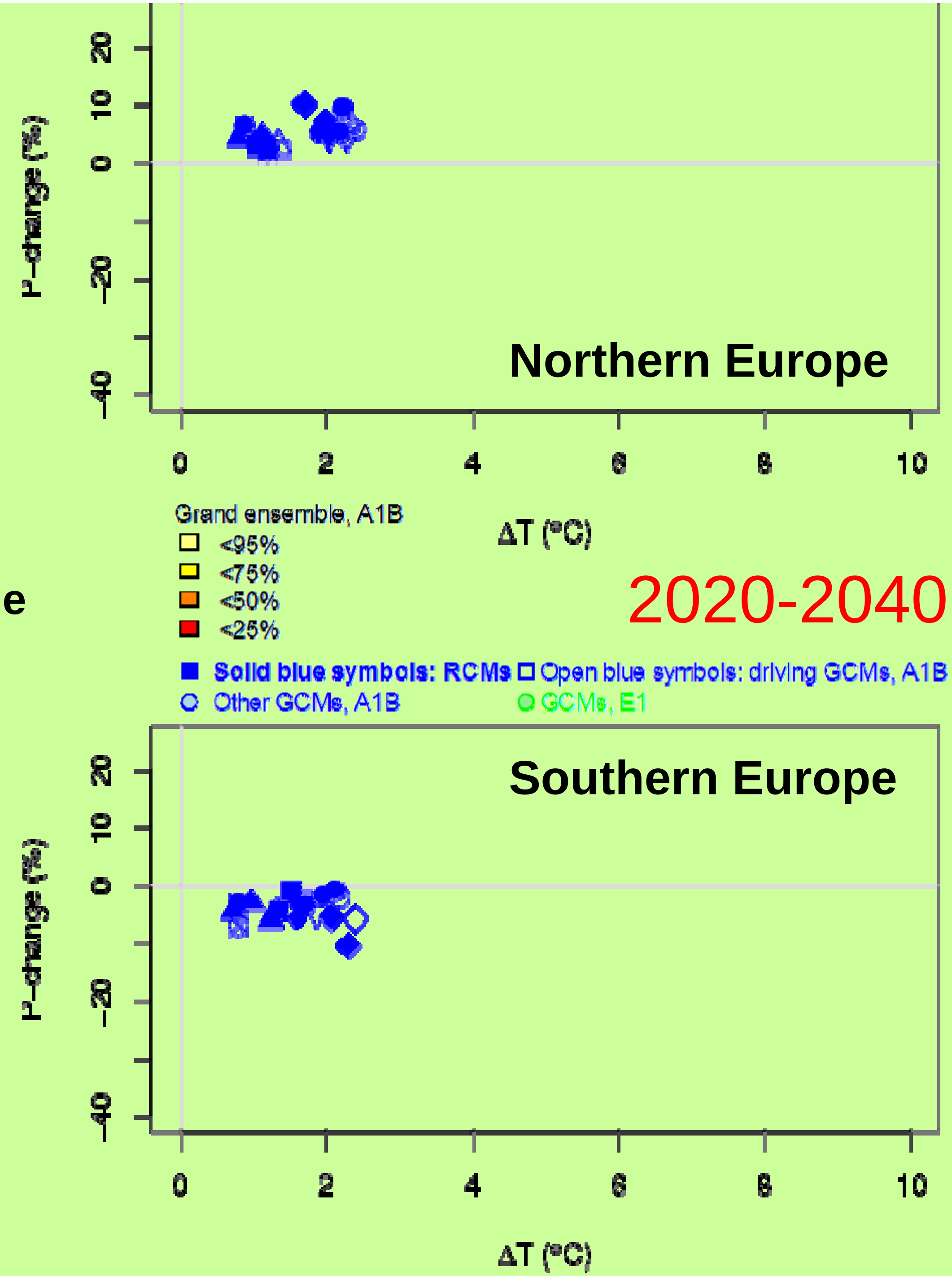

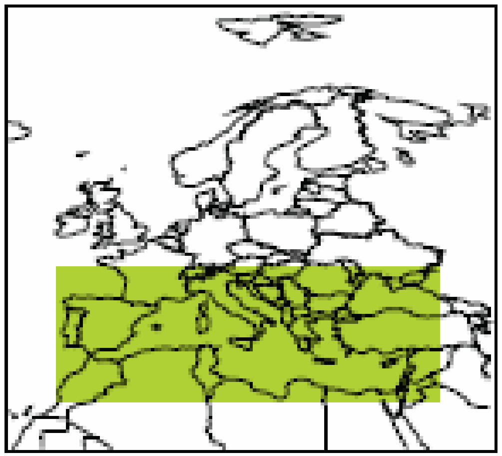

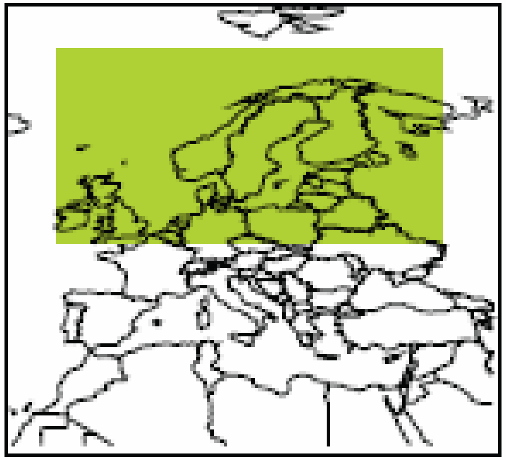

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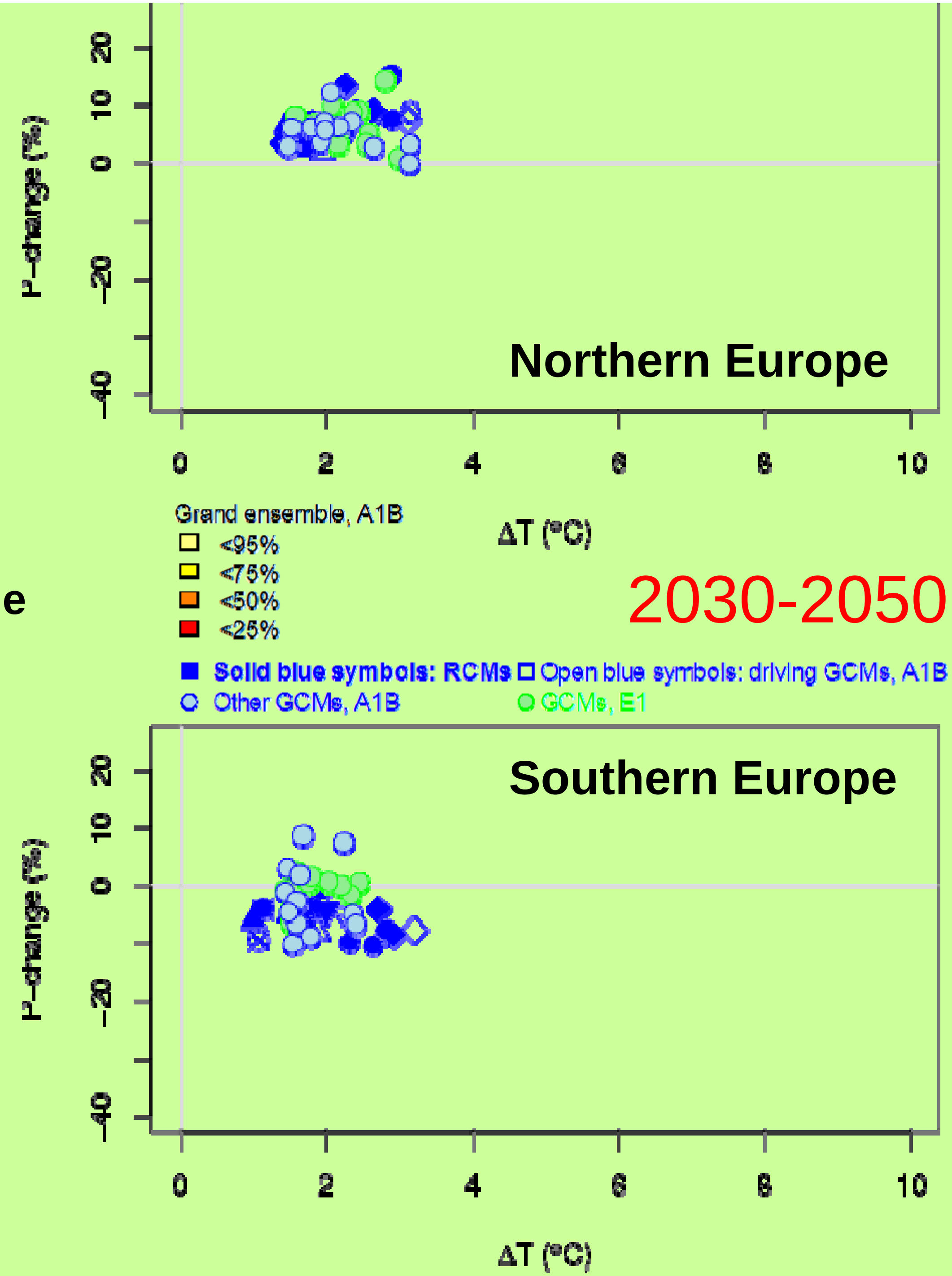

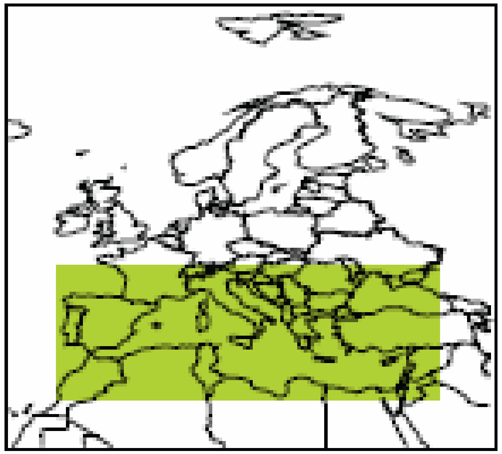

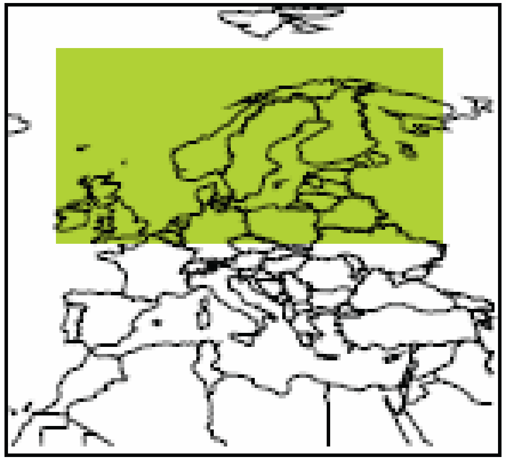

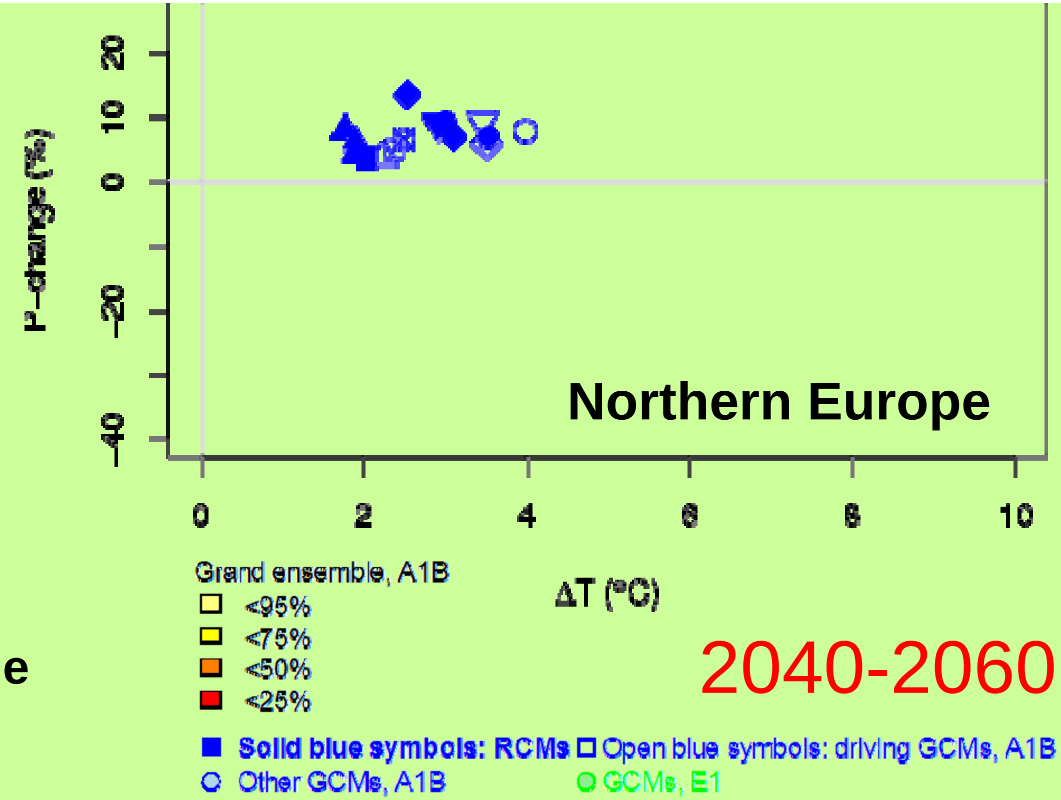

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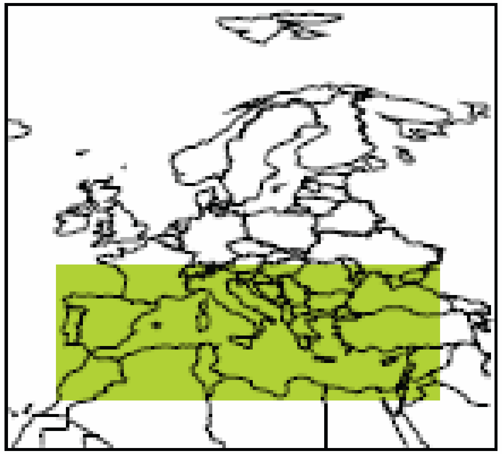
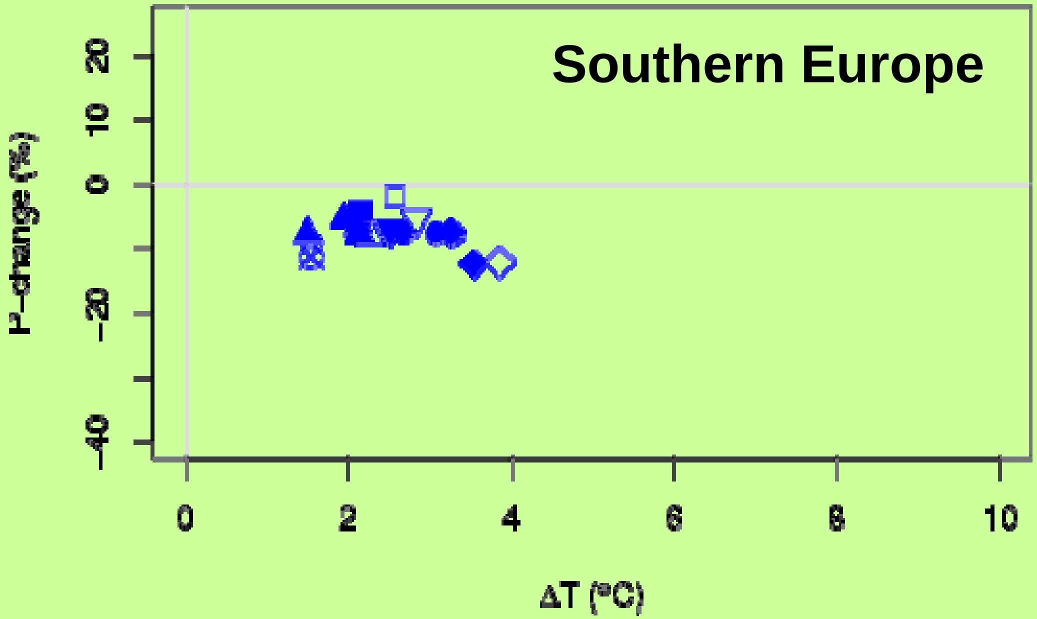
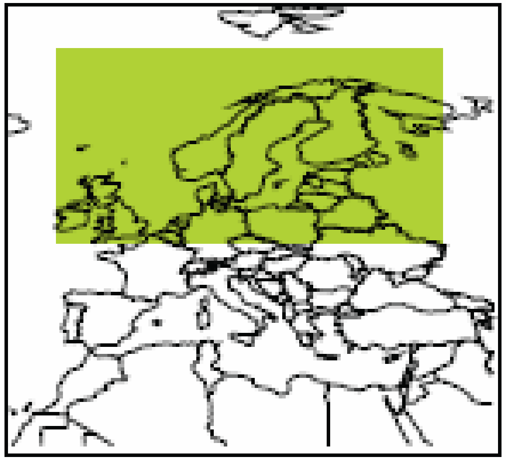
2040-2060







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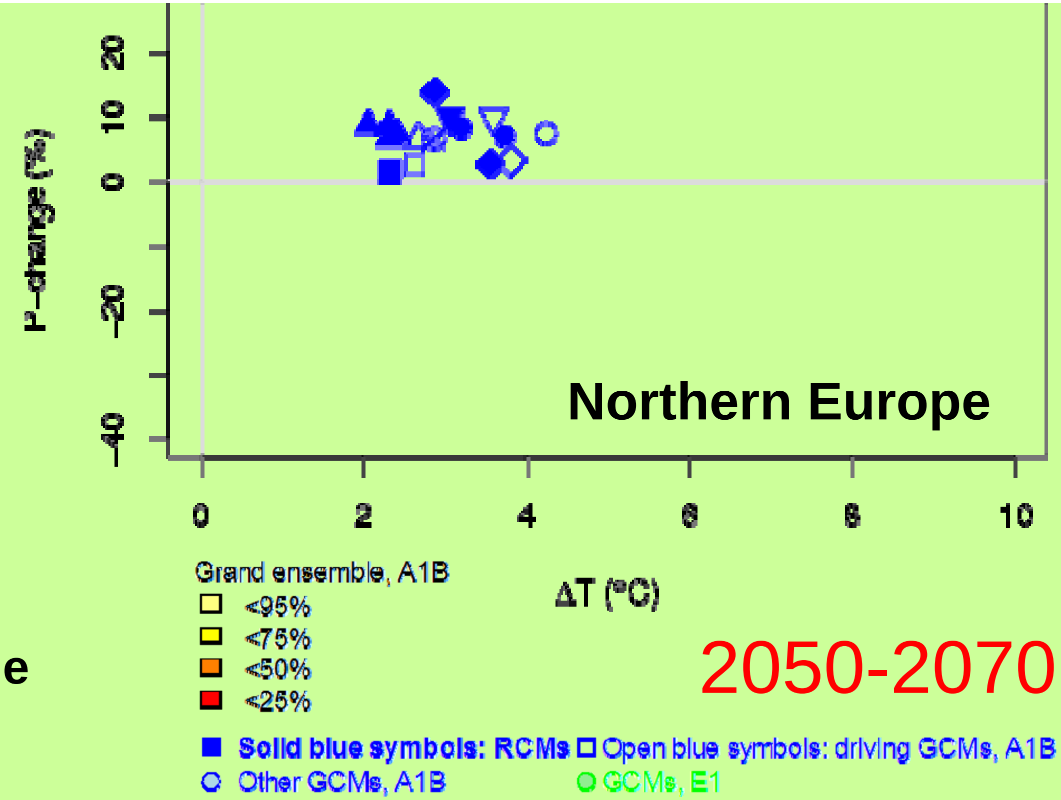
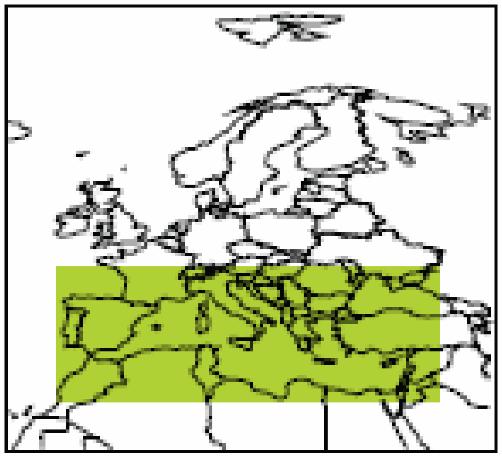
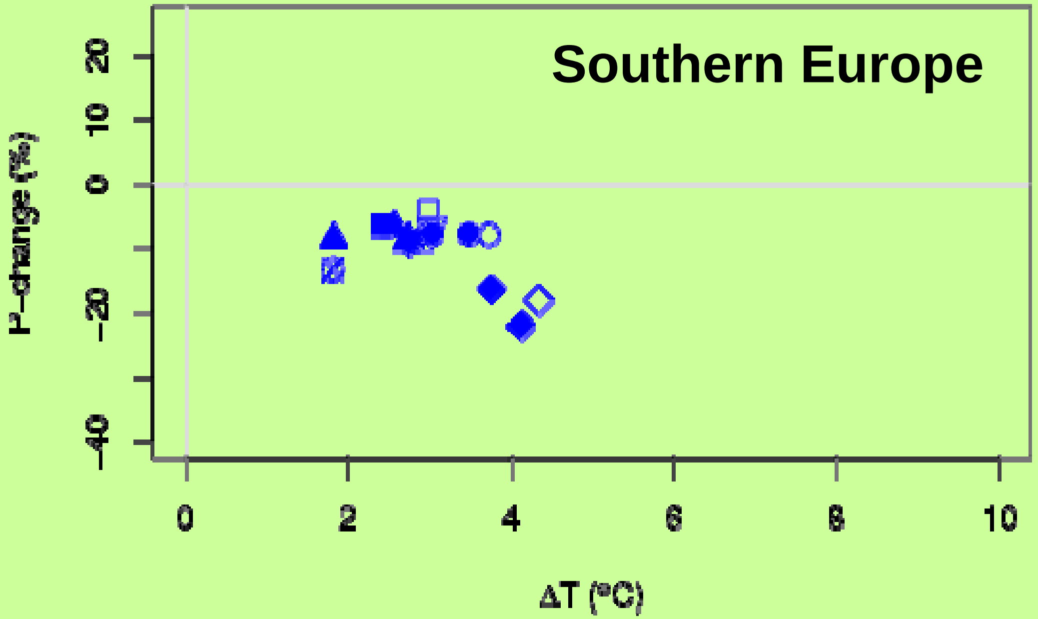
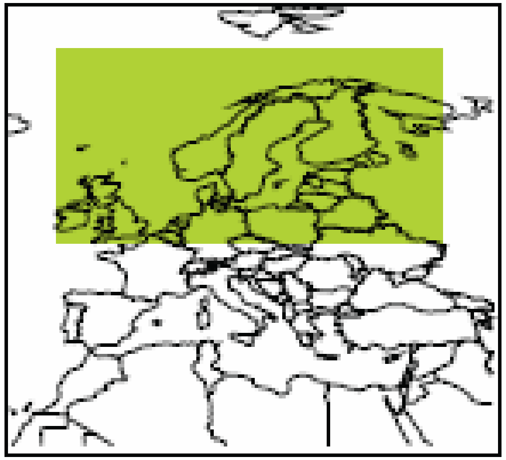


2050-2070







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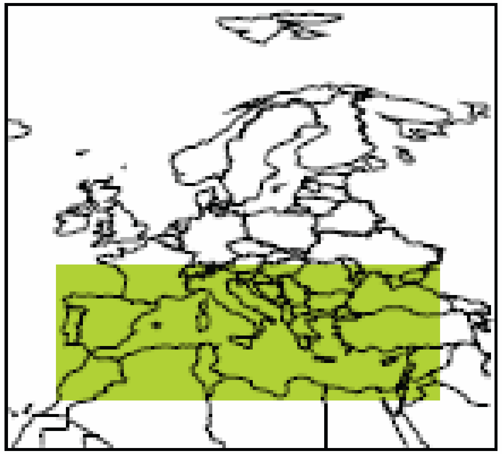

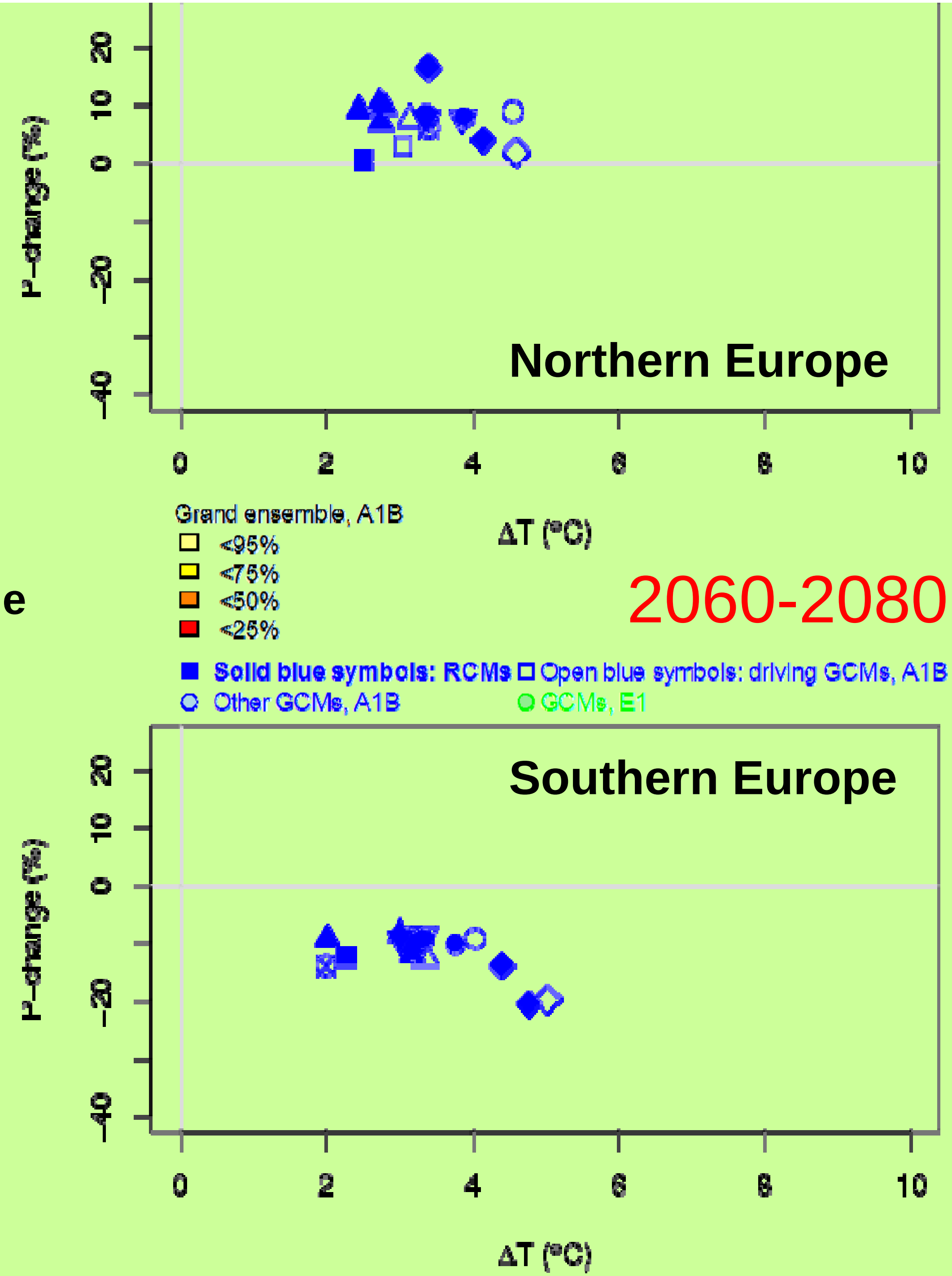

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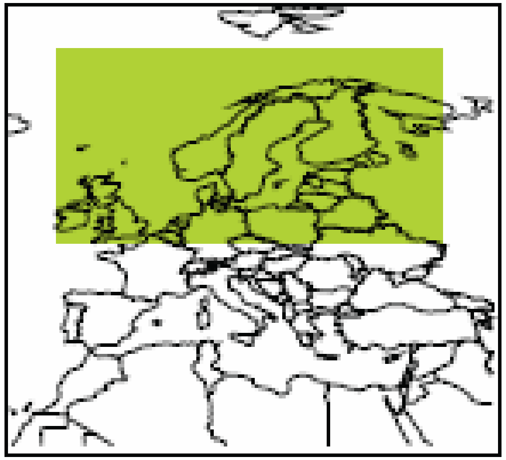
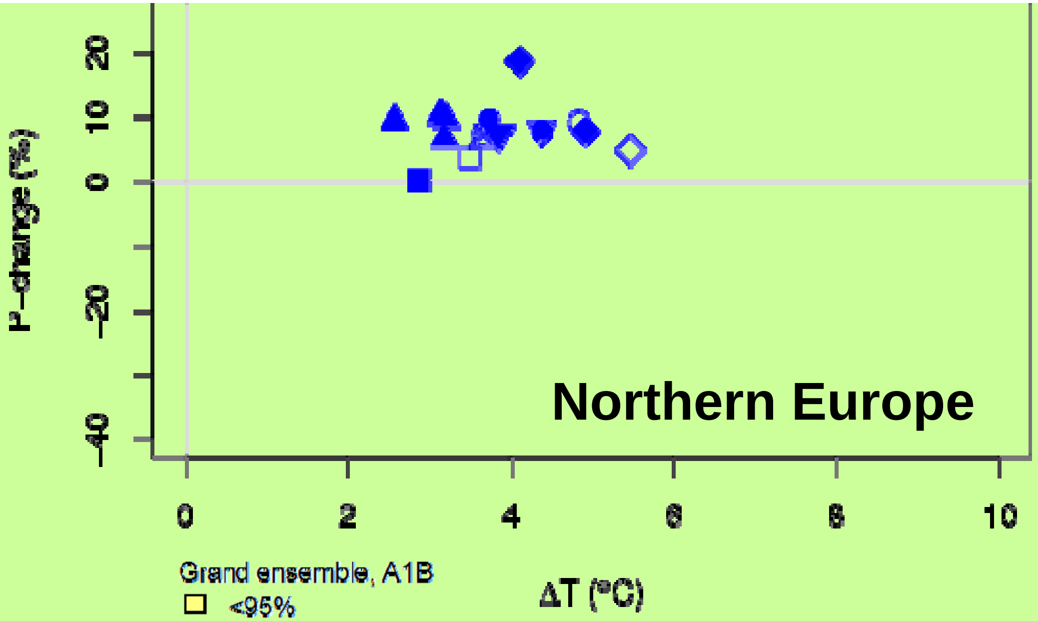
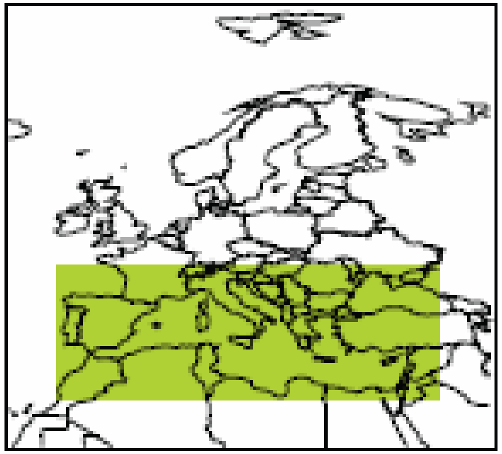
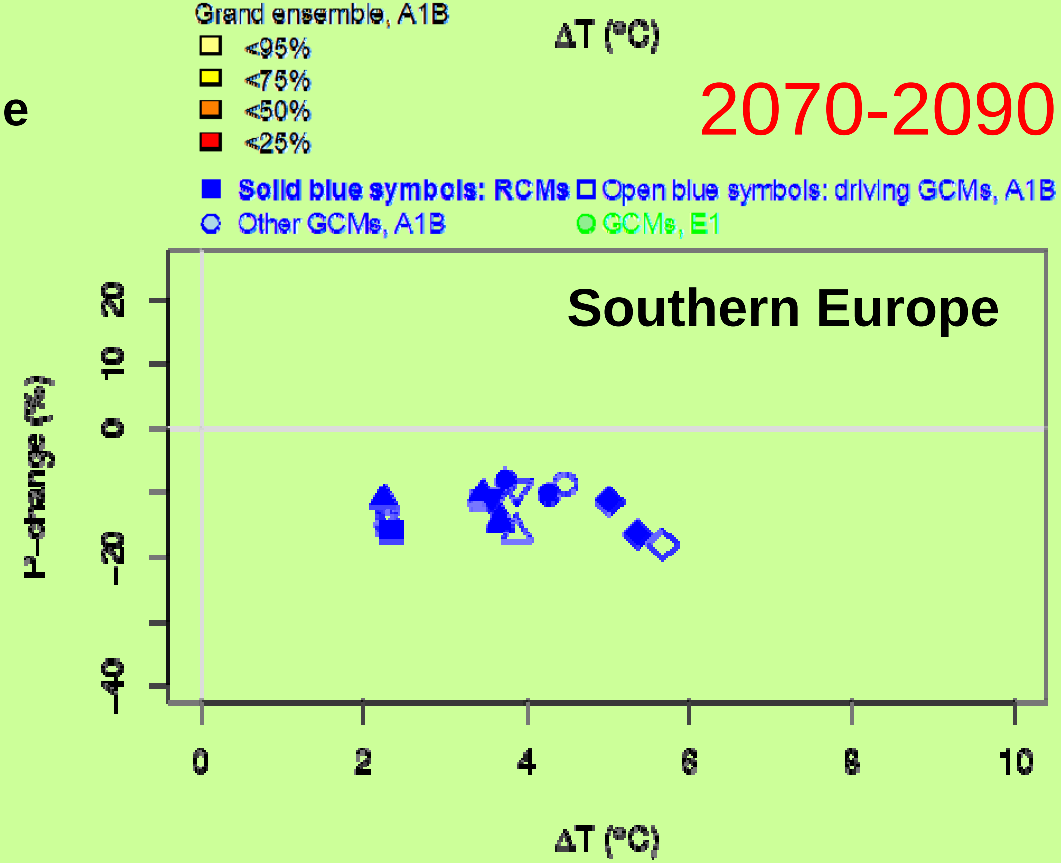
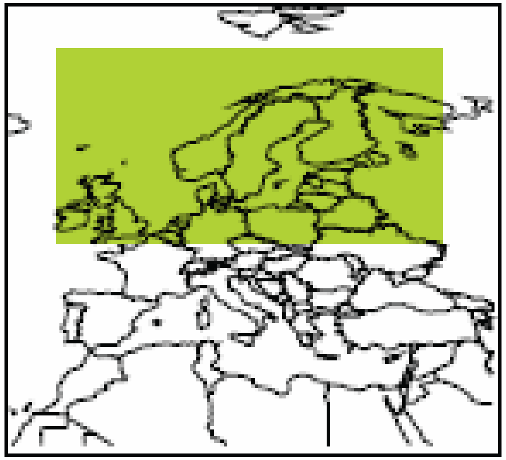


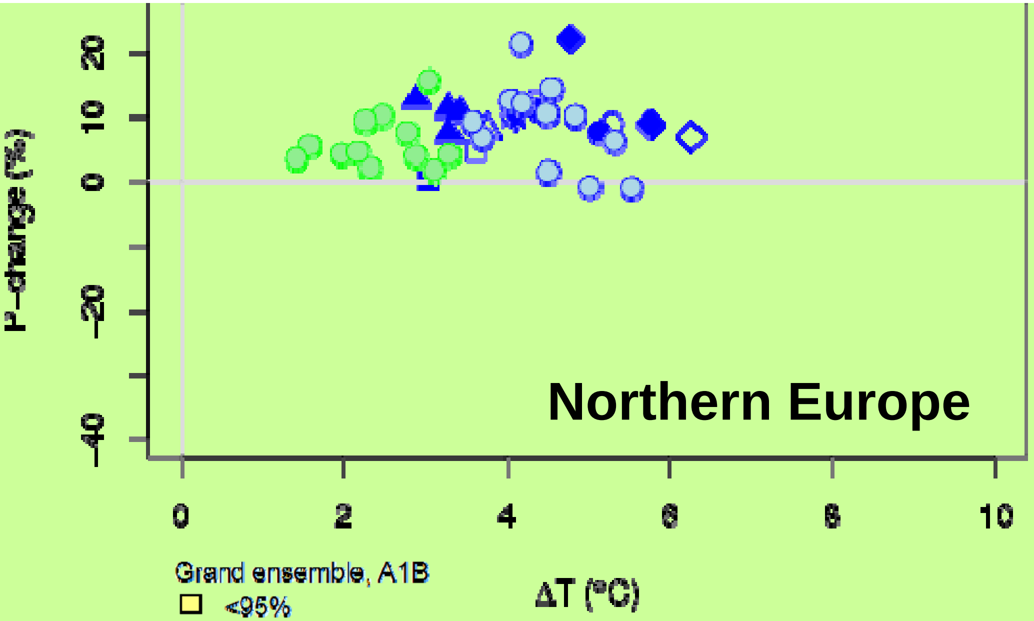


2070-2090







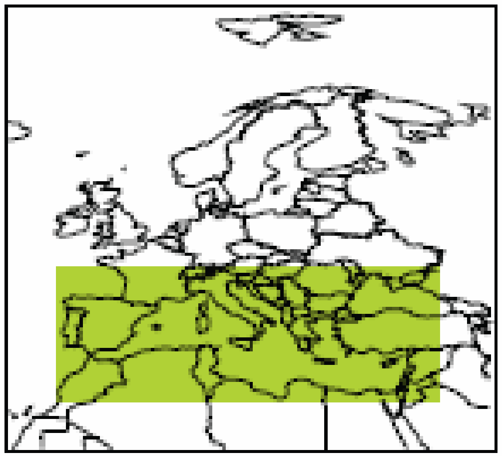


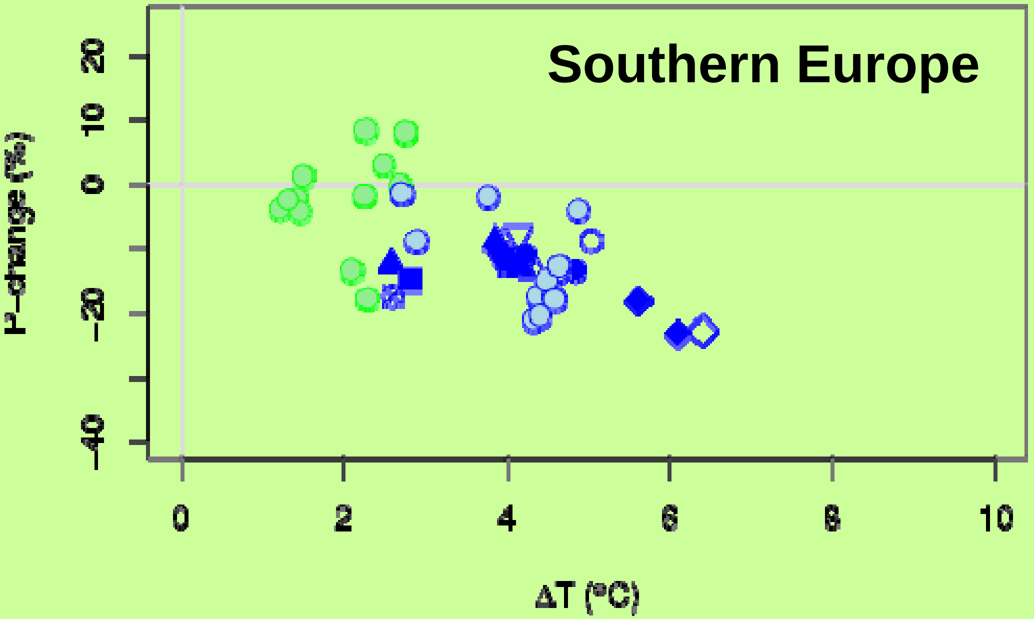
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

Grand ensemble, A1B
<95%
<75%
<50%
<25%

2080-2100

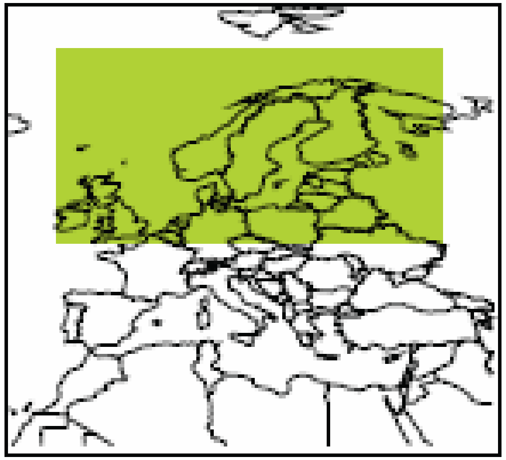
Solid blue symbols: RCMs
Open blue symbols: driving GCMs, A1B
Other GCMs, A1B
GCMs, E1





RCM-based joint PDFs

Source: Stefan Fronzek (SYKE), Philip Lorenz (MPI)



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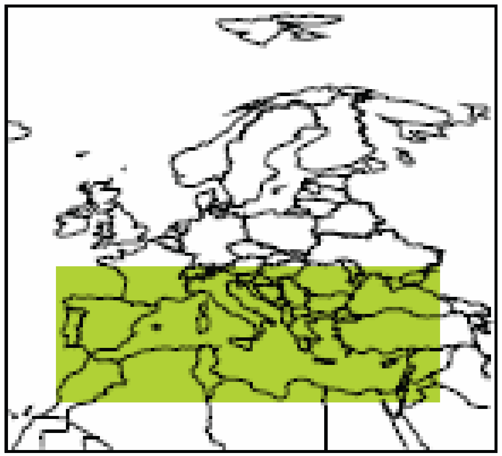

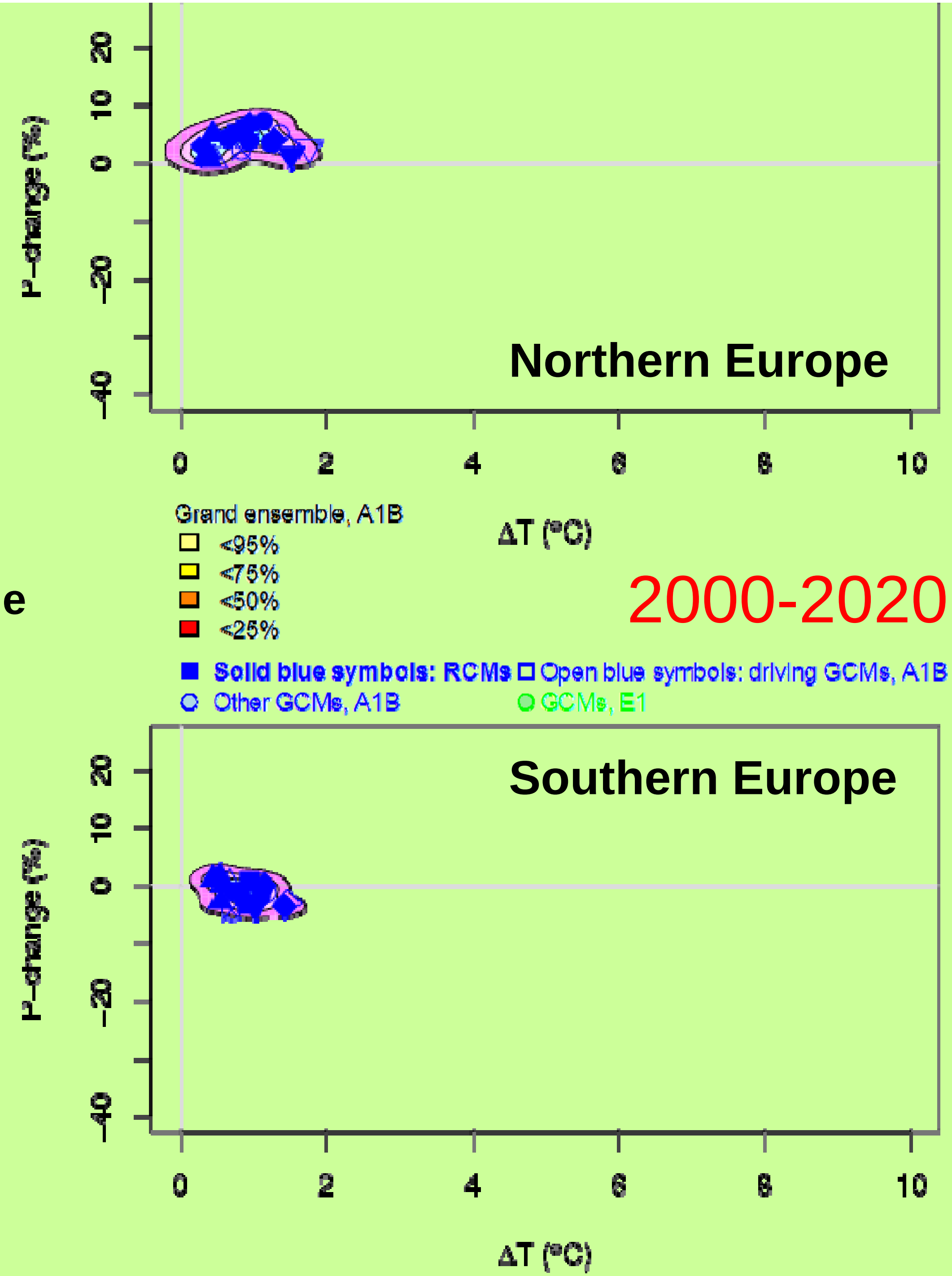

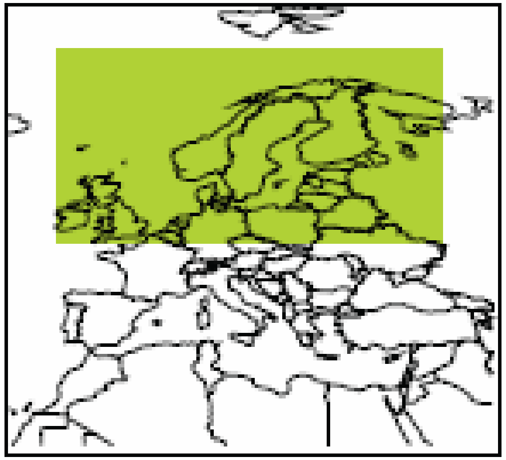

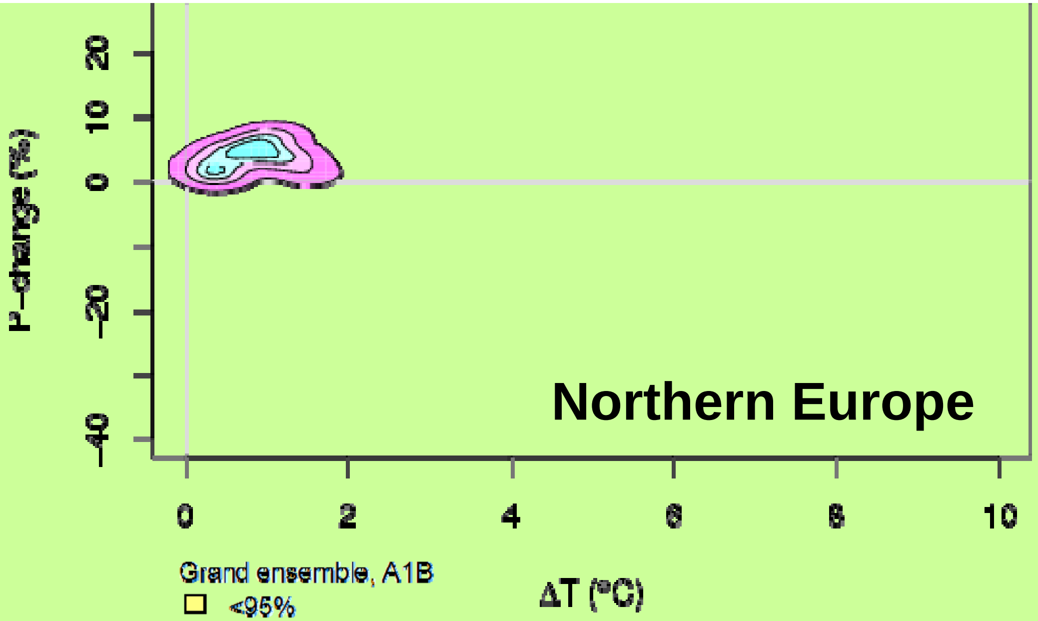

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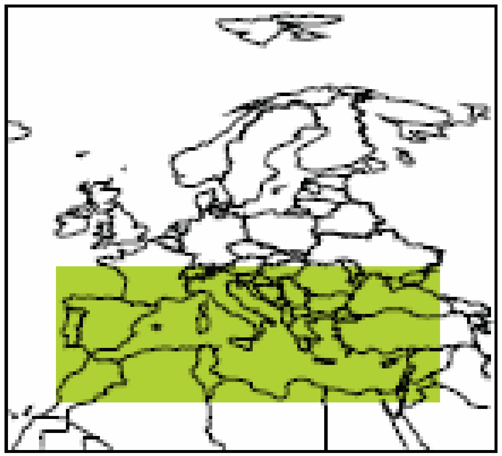
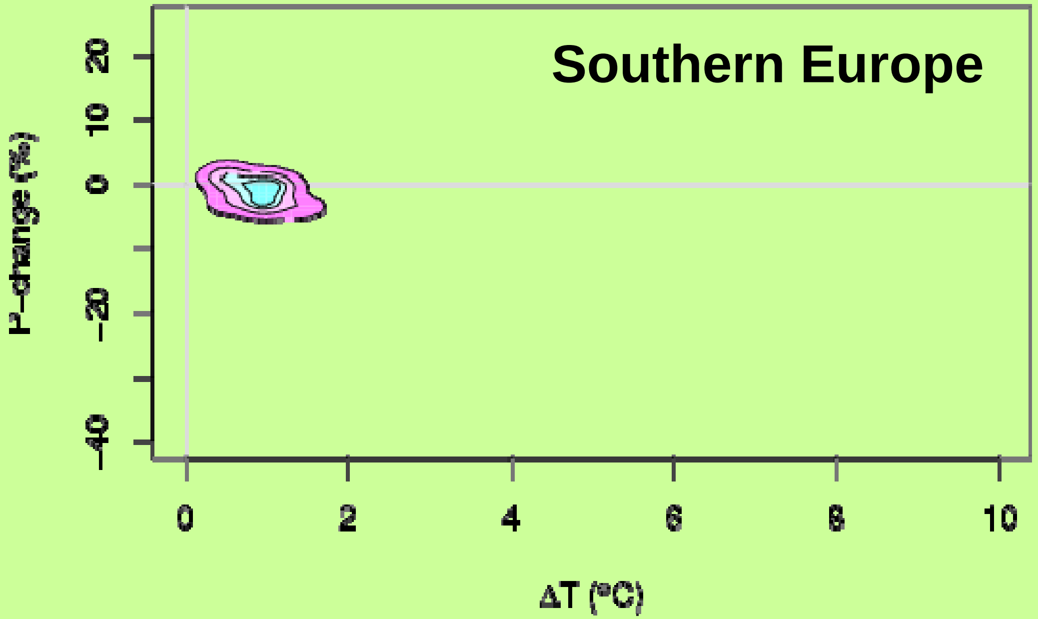
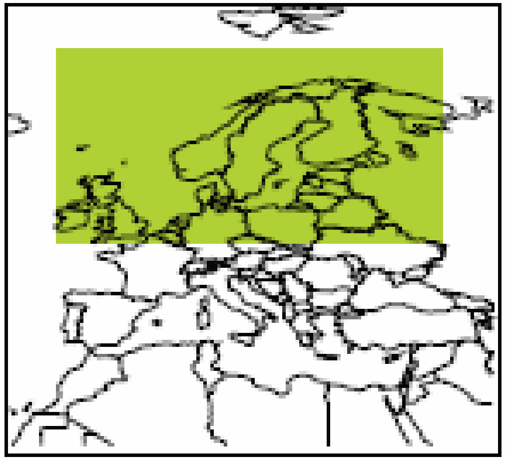
2000-2020







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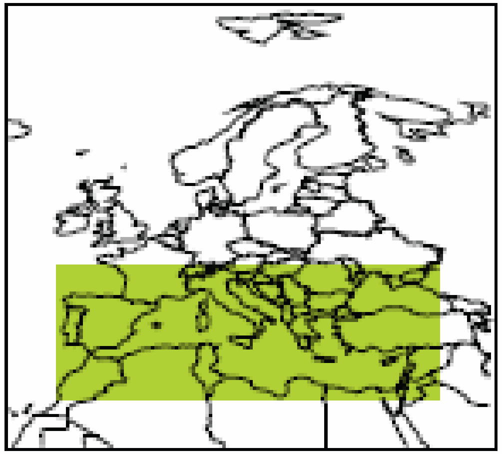
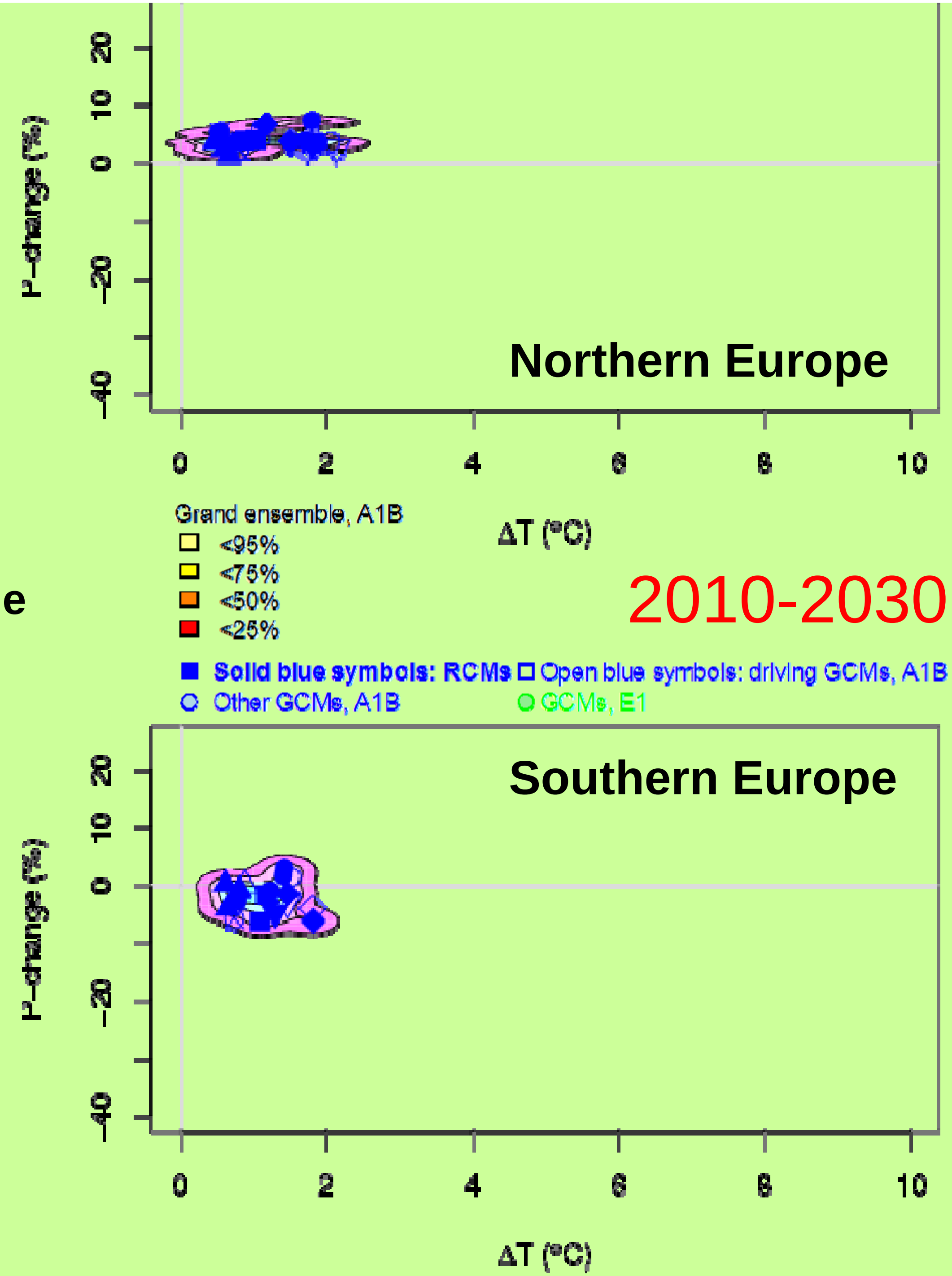
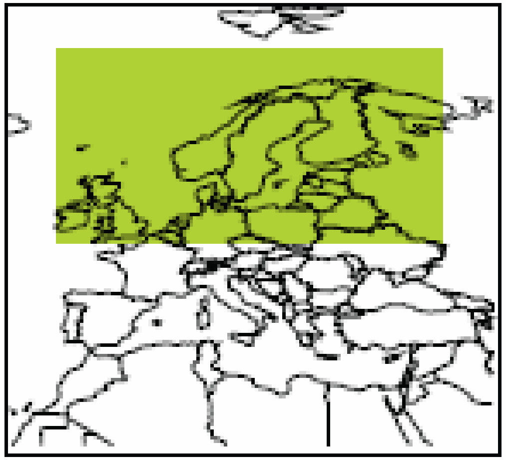




2010-2030



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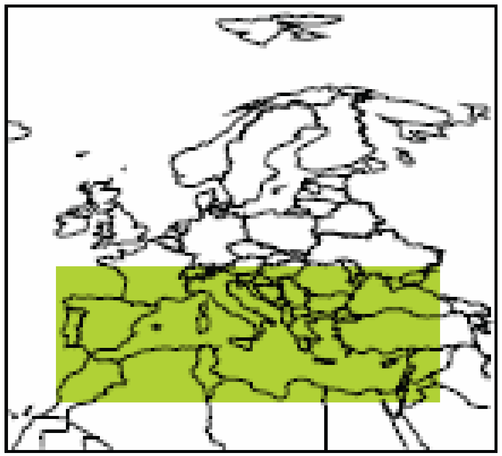
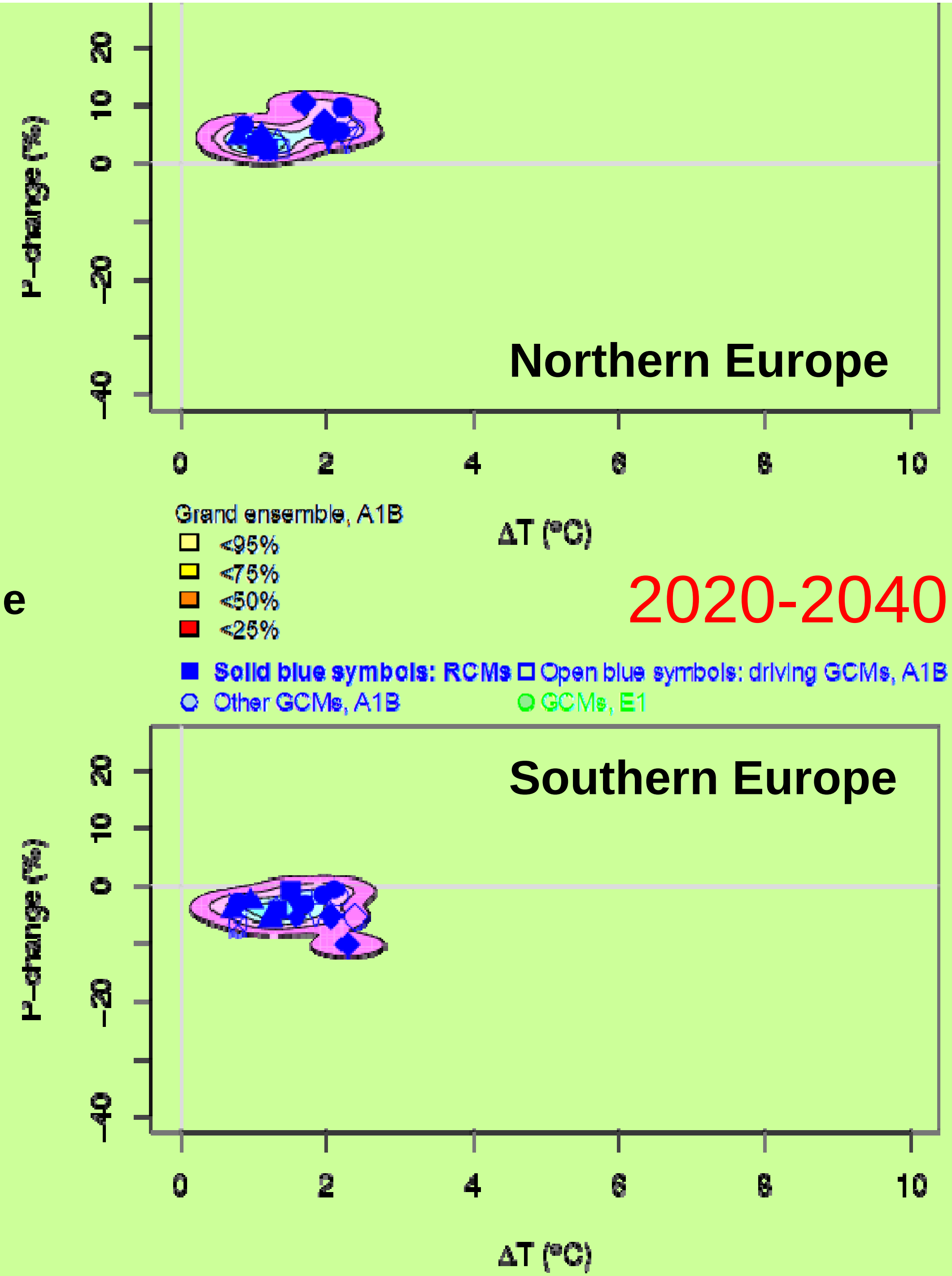
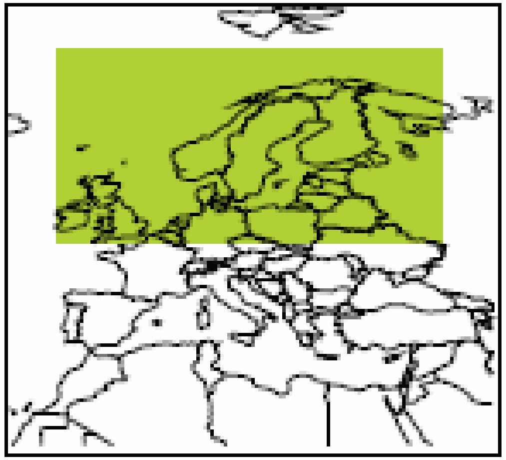
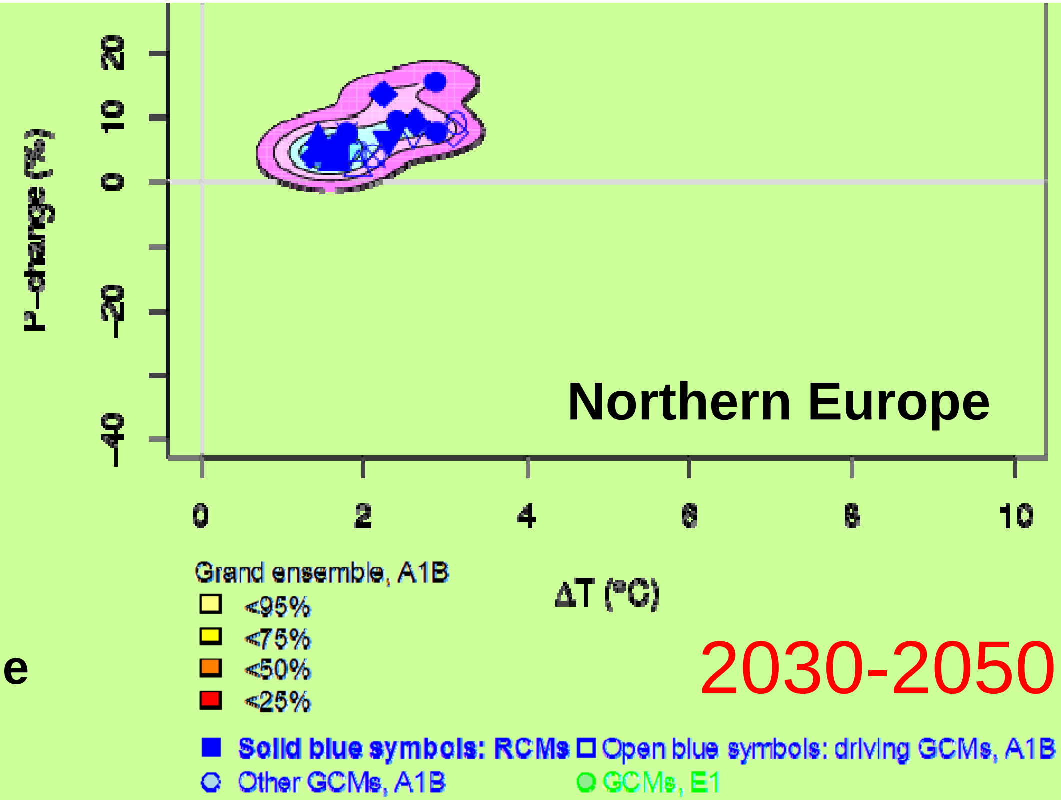


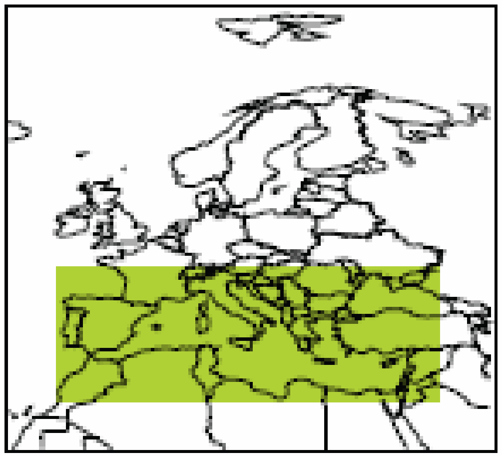


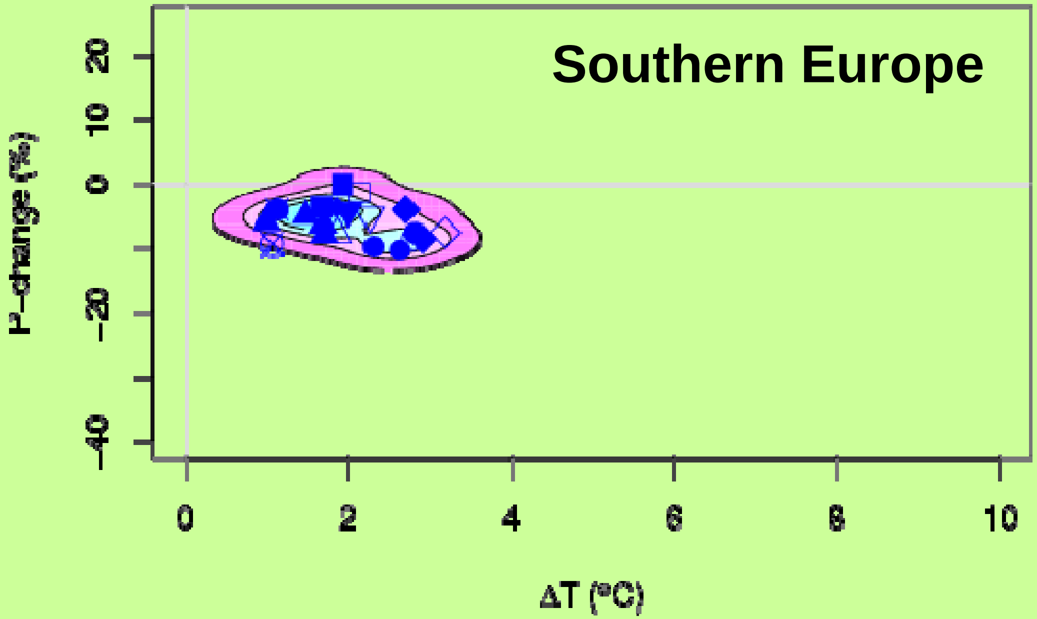


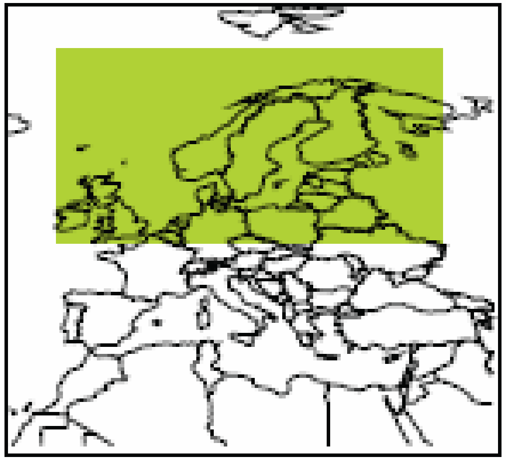


Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

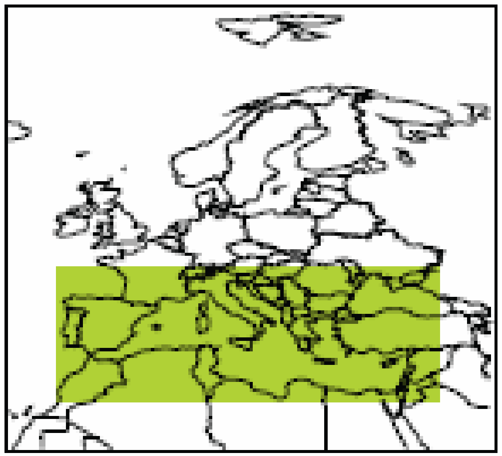
2030-2050

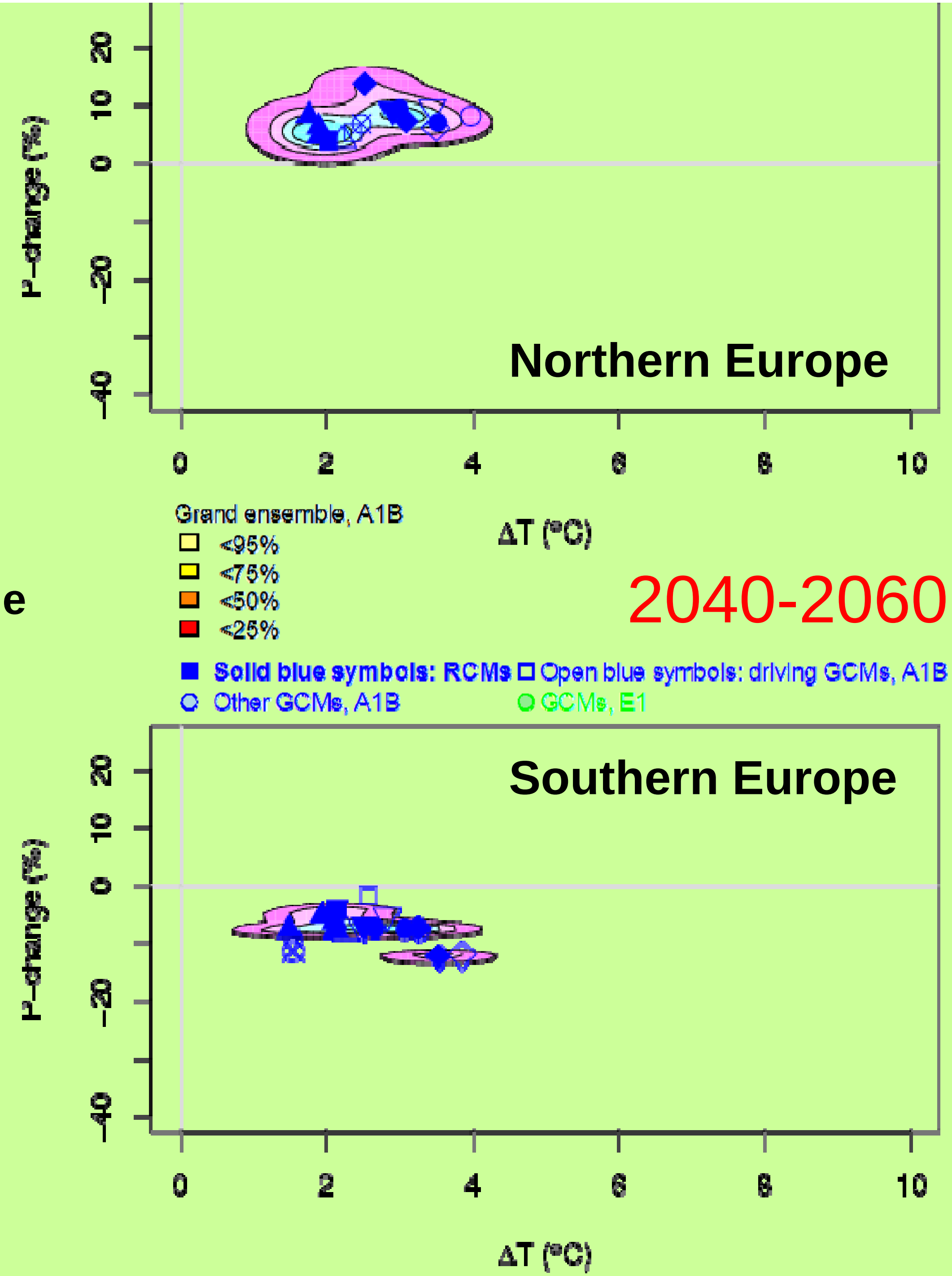


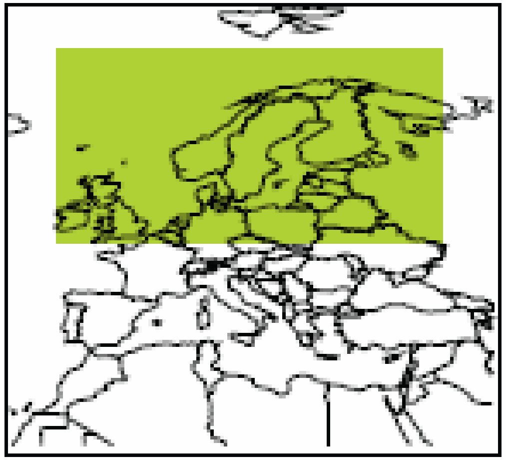




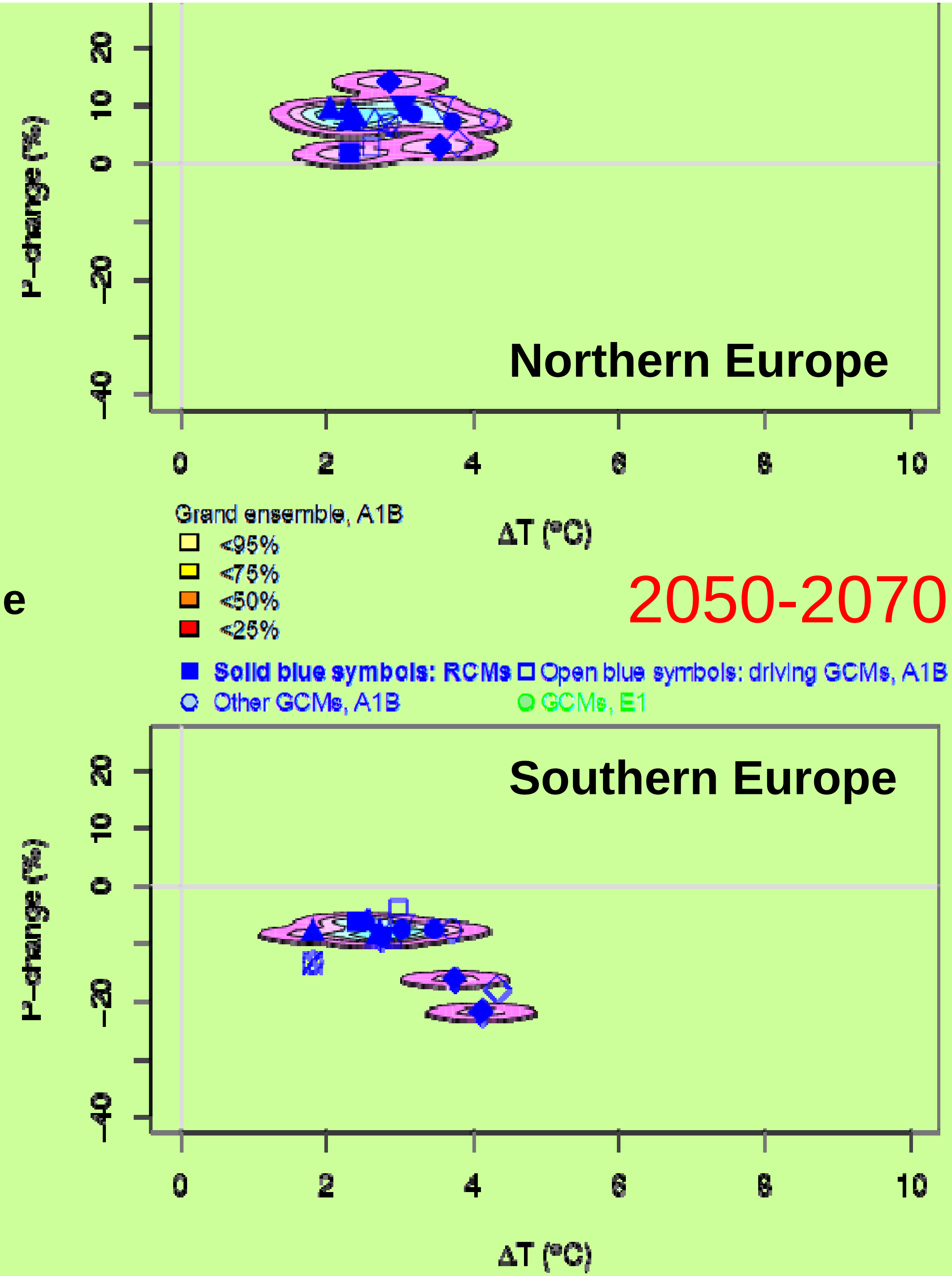
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

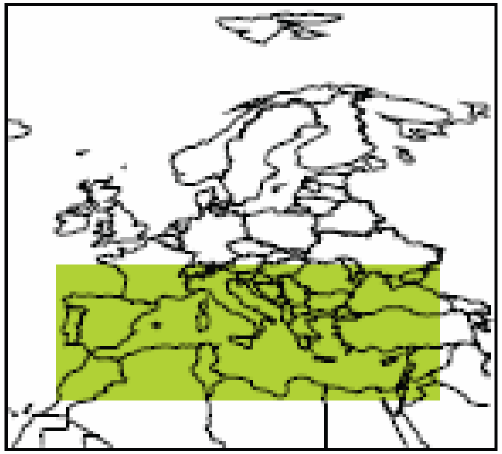


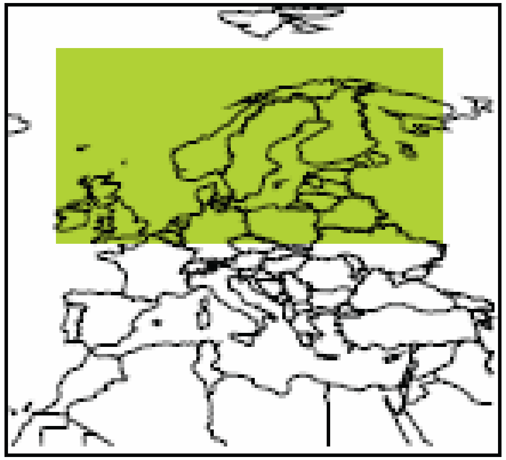




Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990







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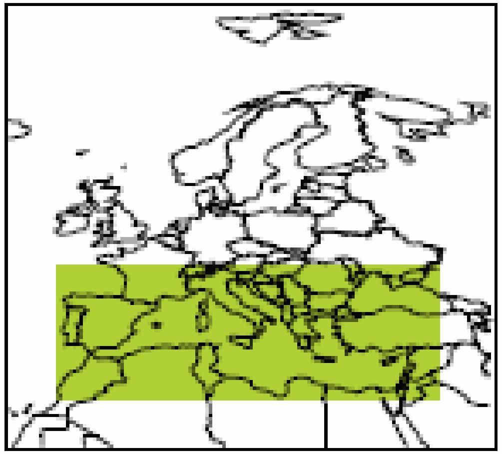
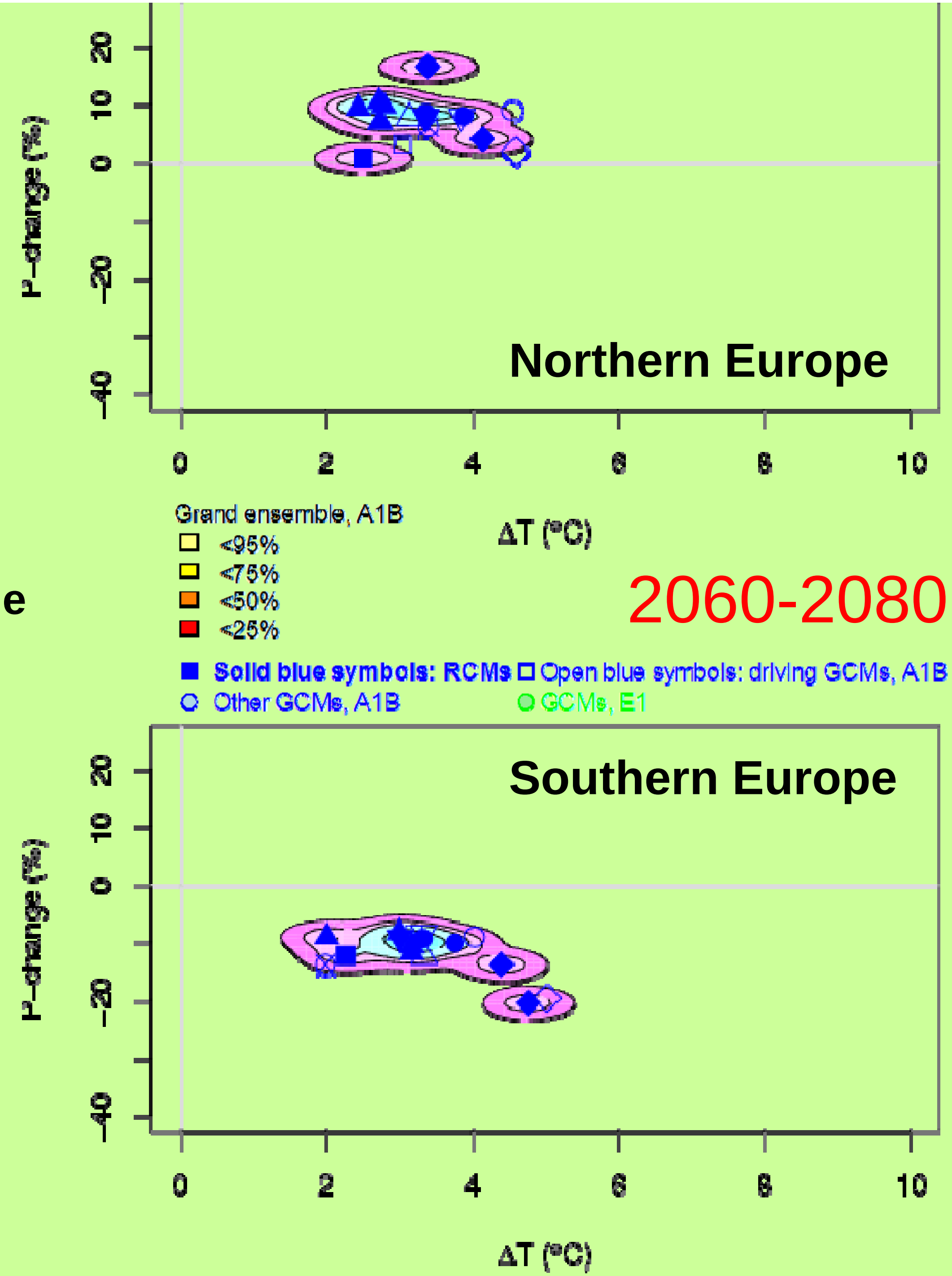
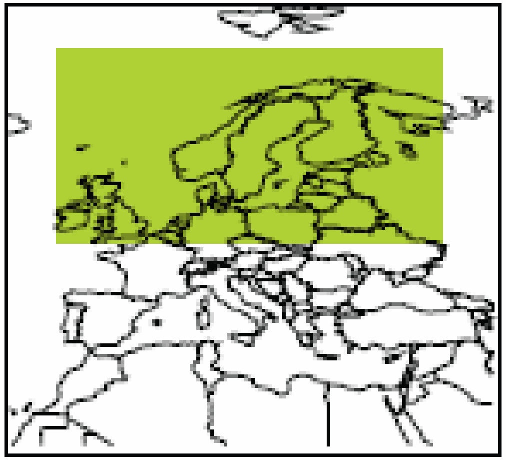
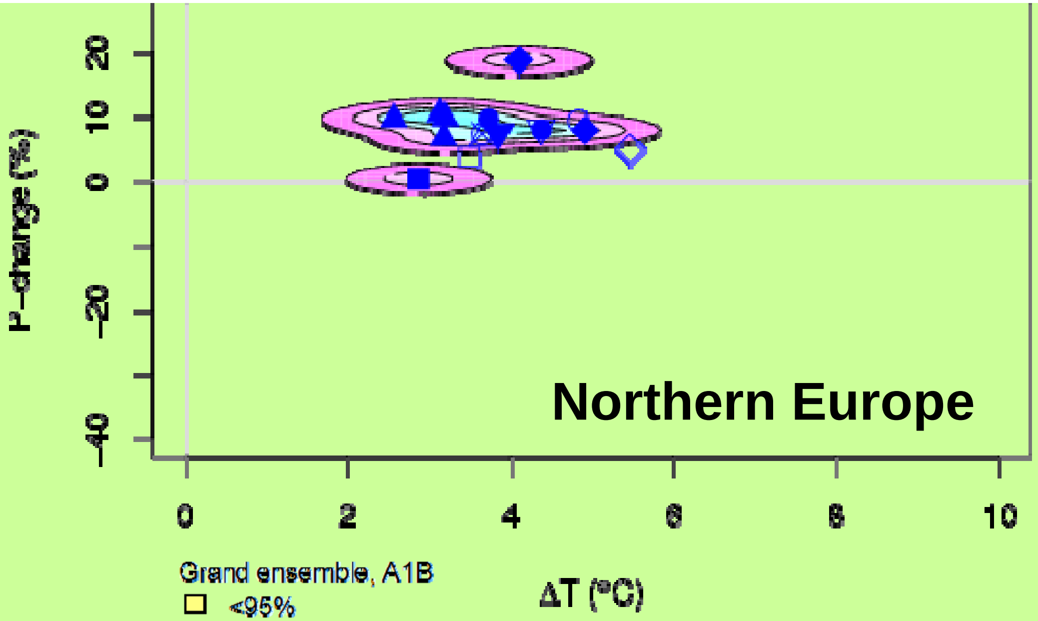




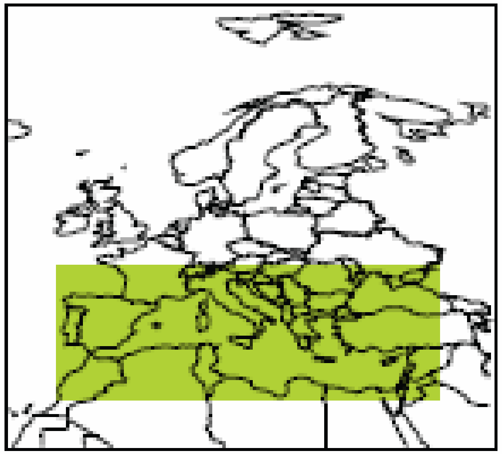


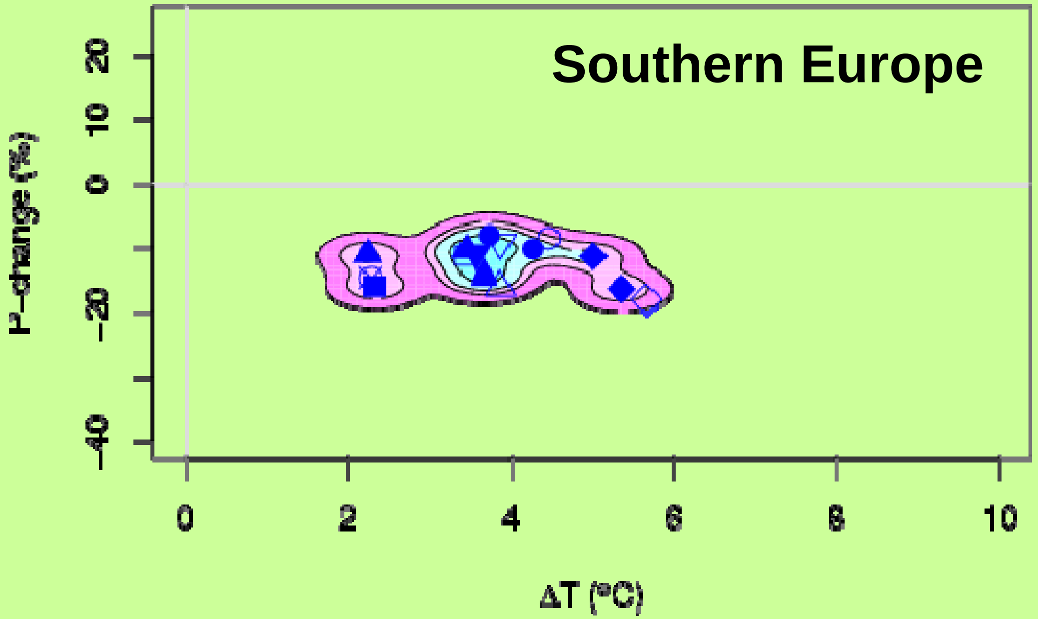


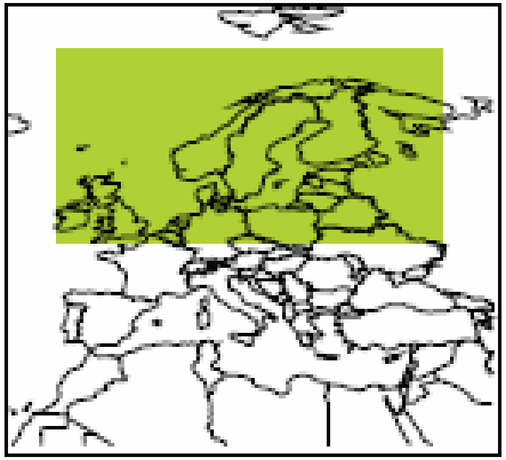
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

Grand ensemble, A1B
<95%
<75%
<50%
<25%
Solid blue symbols: RCMs Open blue symbols: driving GCMs, A1B
Other GCMs, A1B GCMs, E1

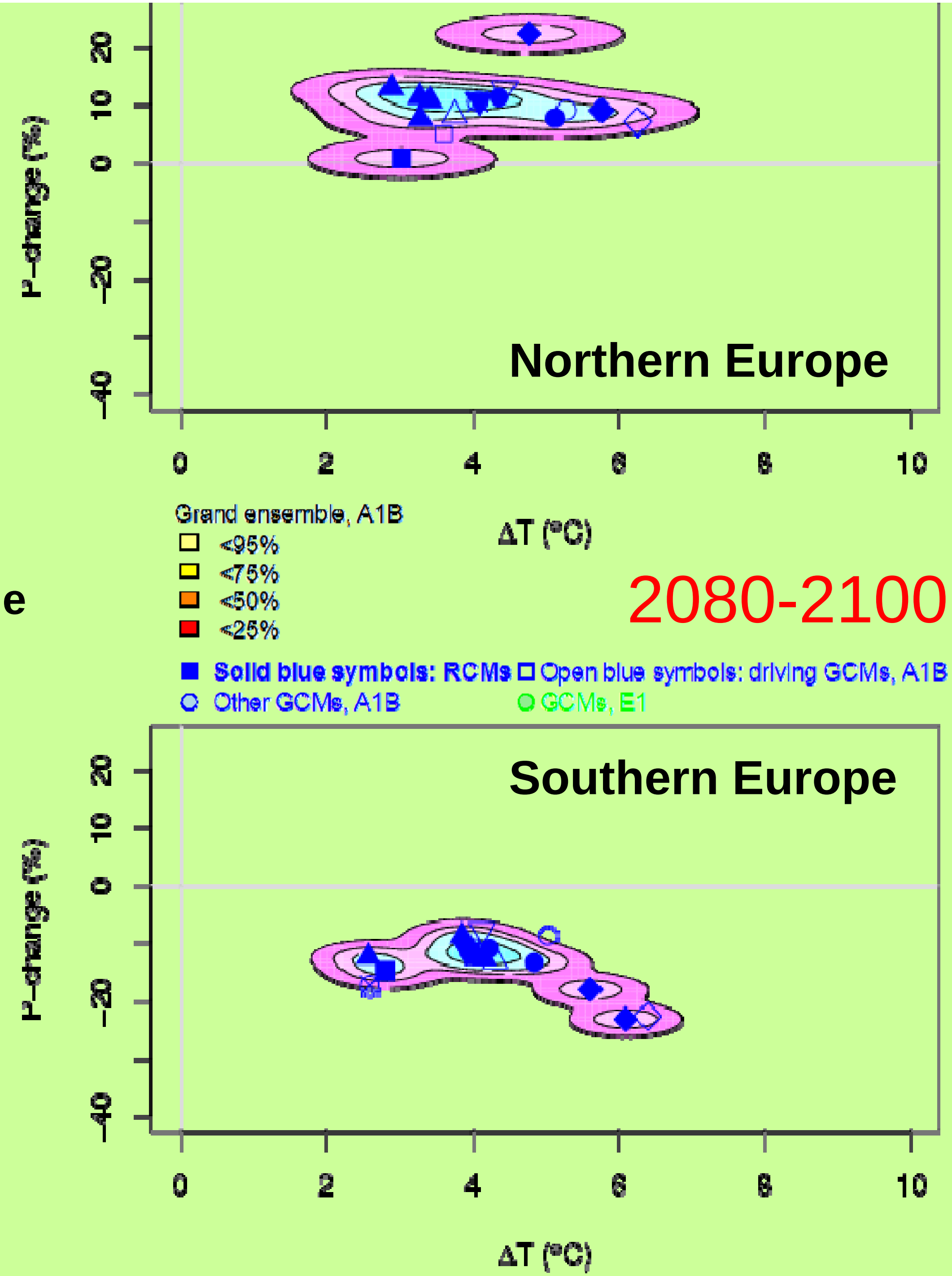
2070-2090

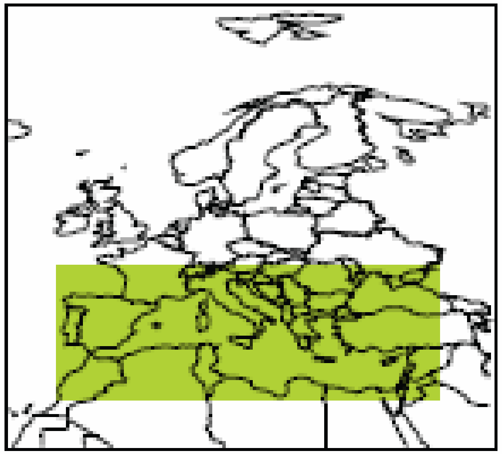




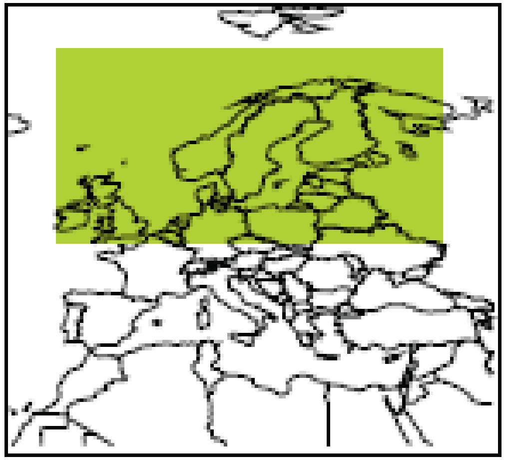


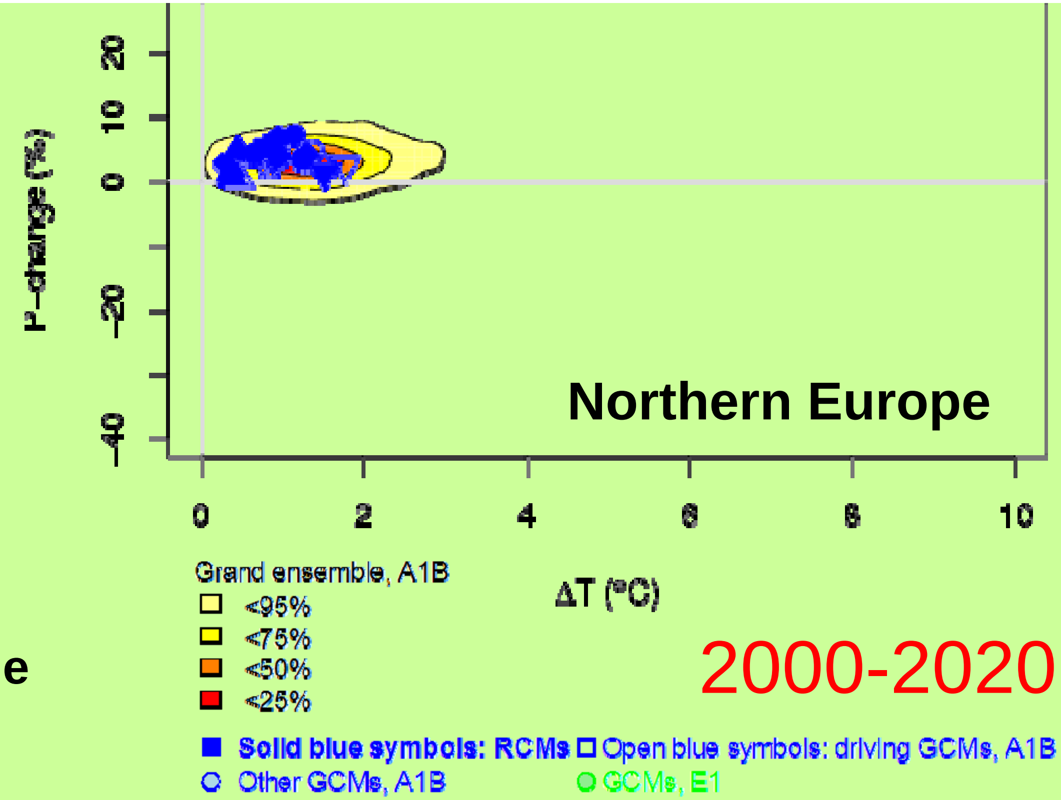
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990



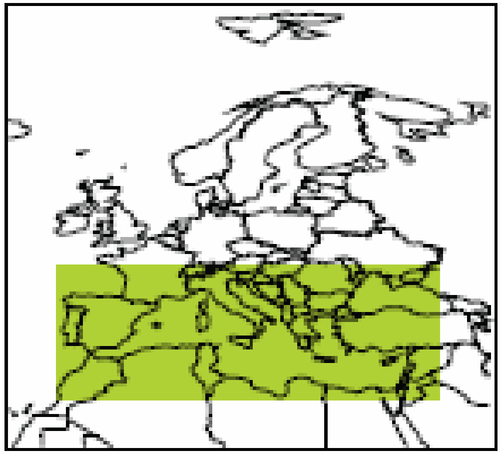


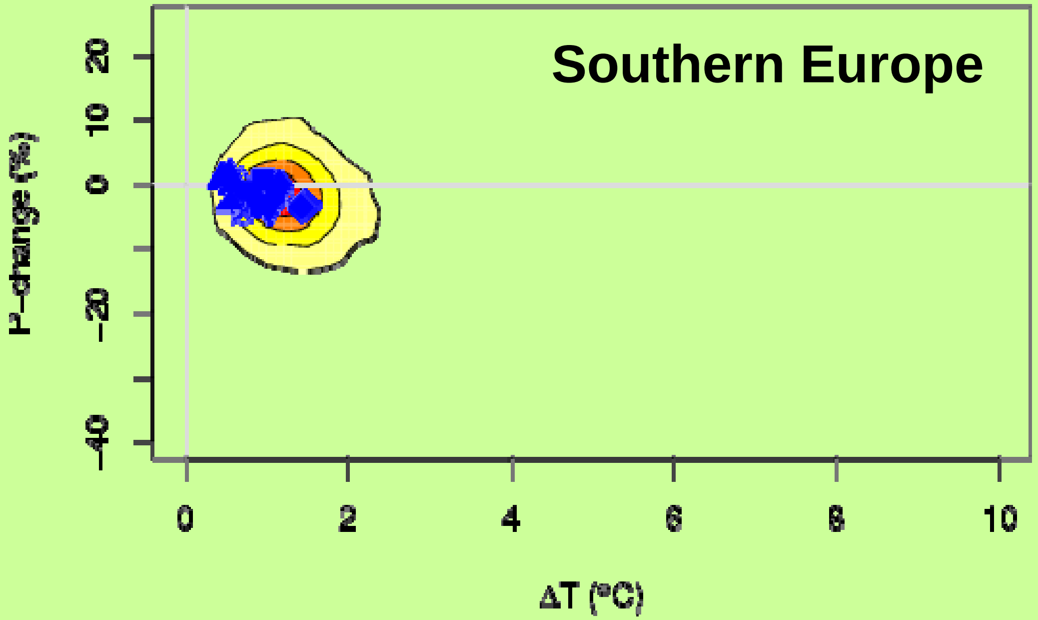
ENSEMBLES multiple projections intercomparison

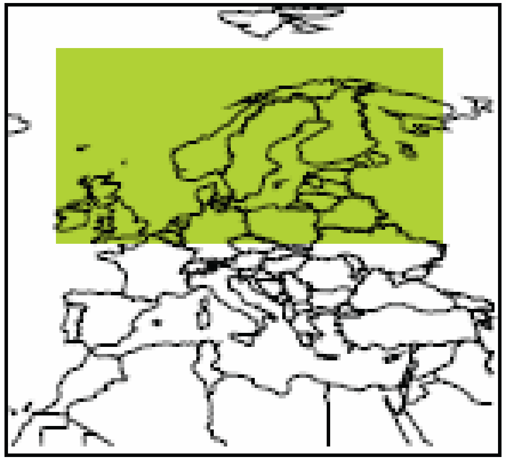




Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990







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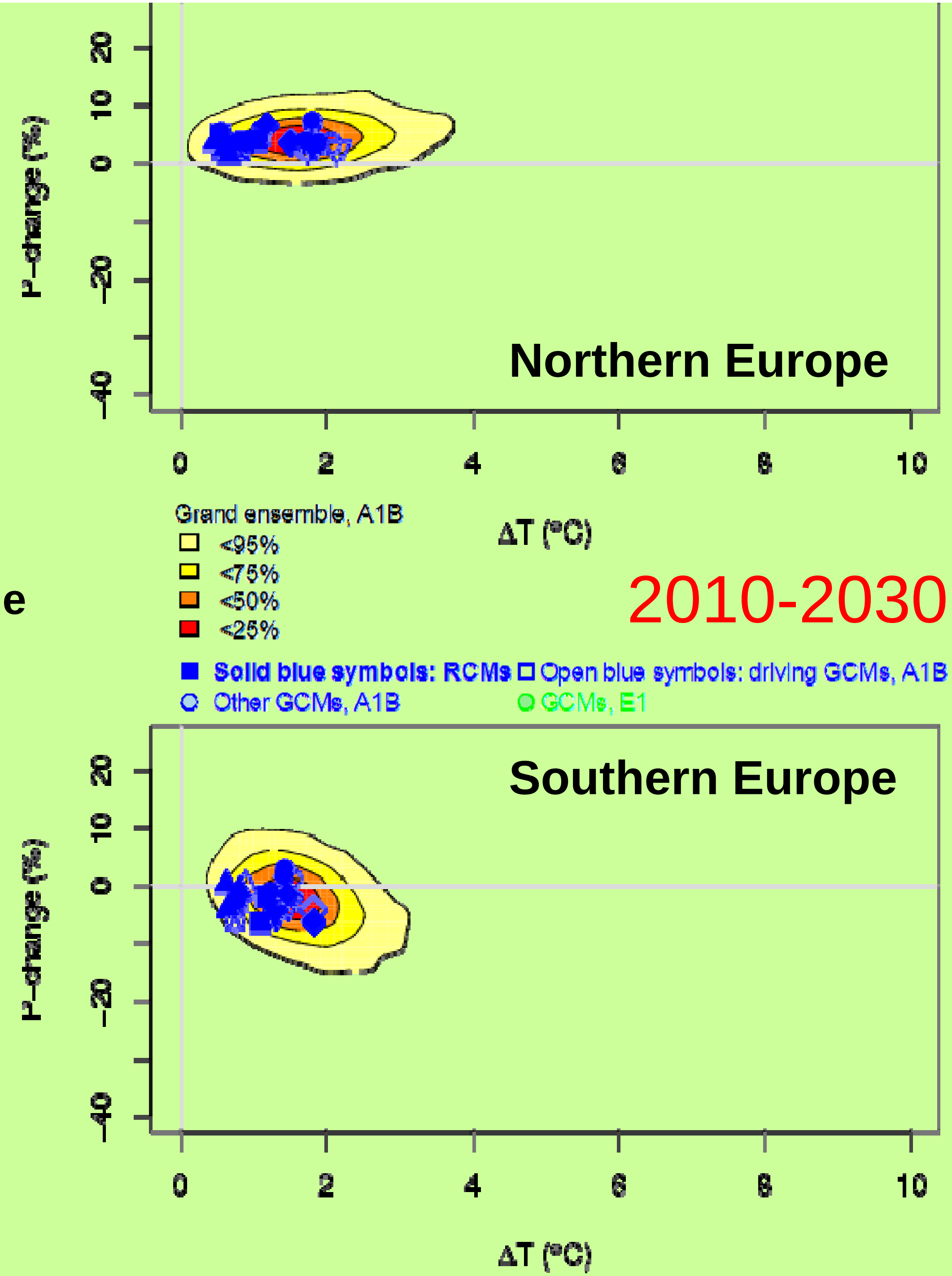
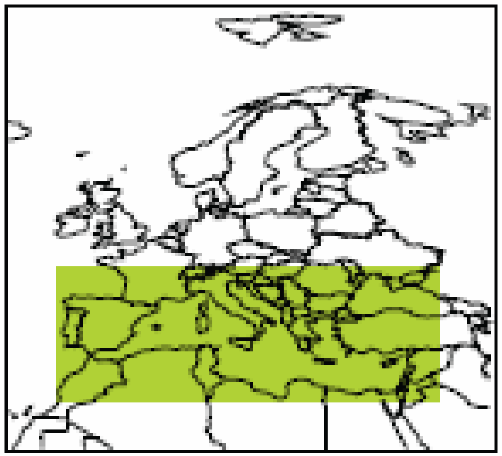
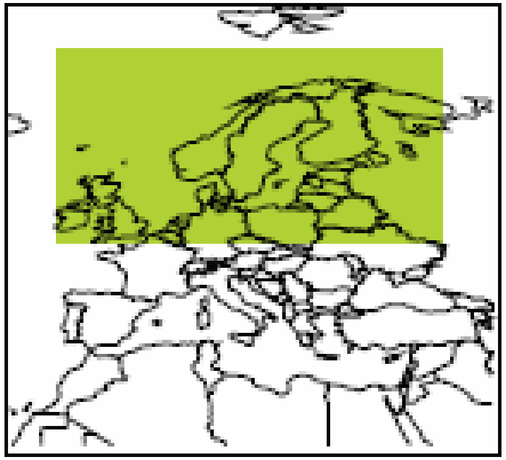
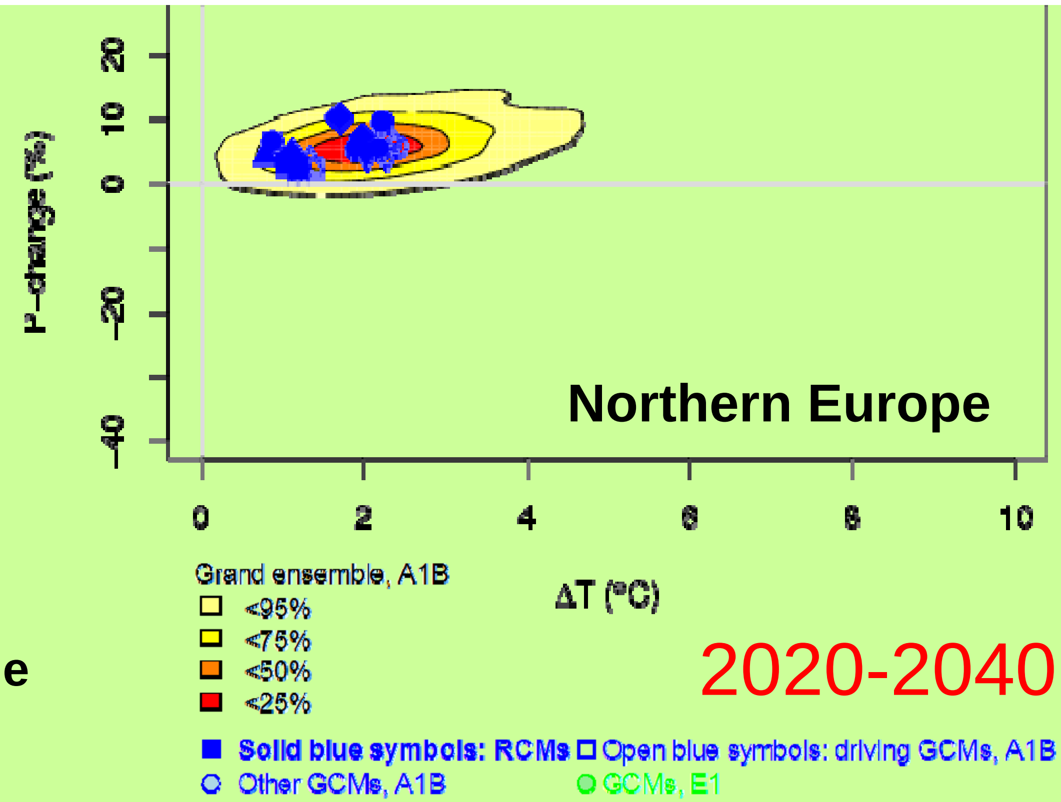
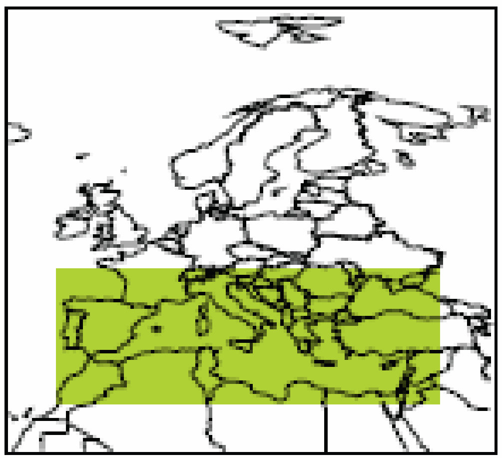


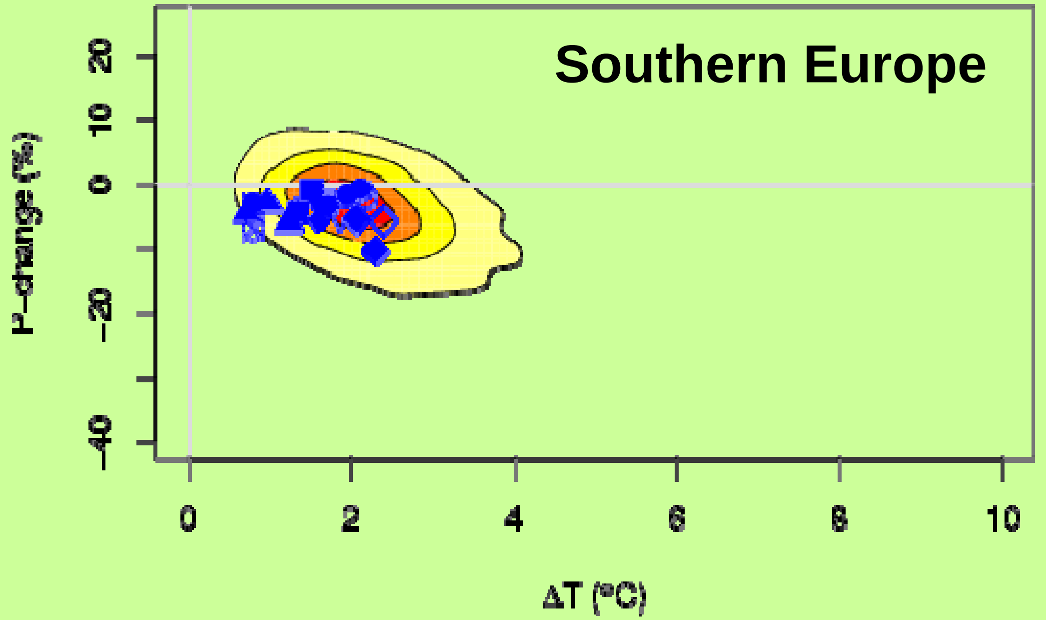


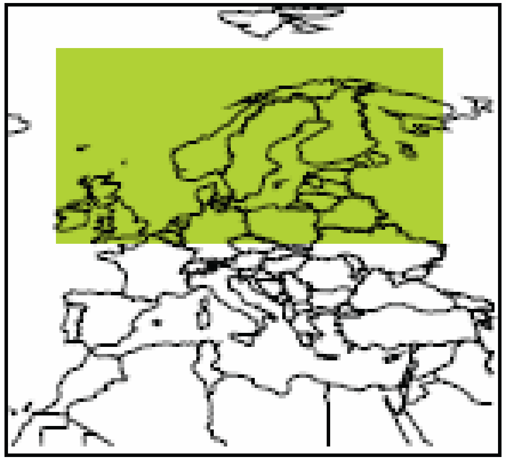


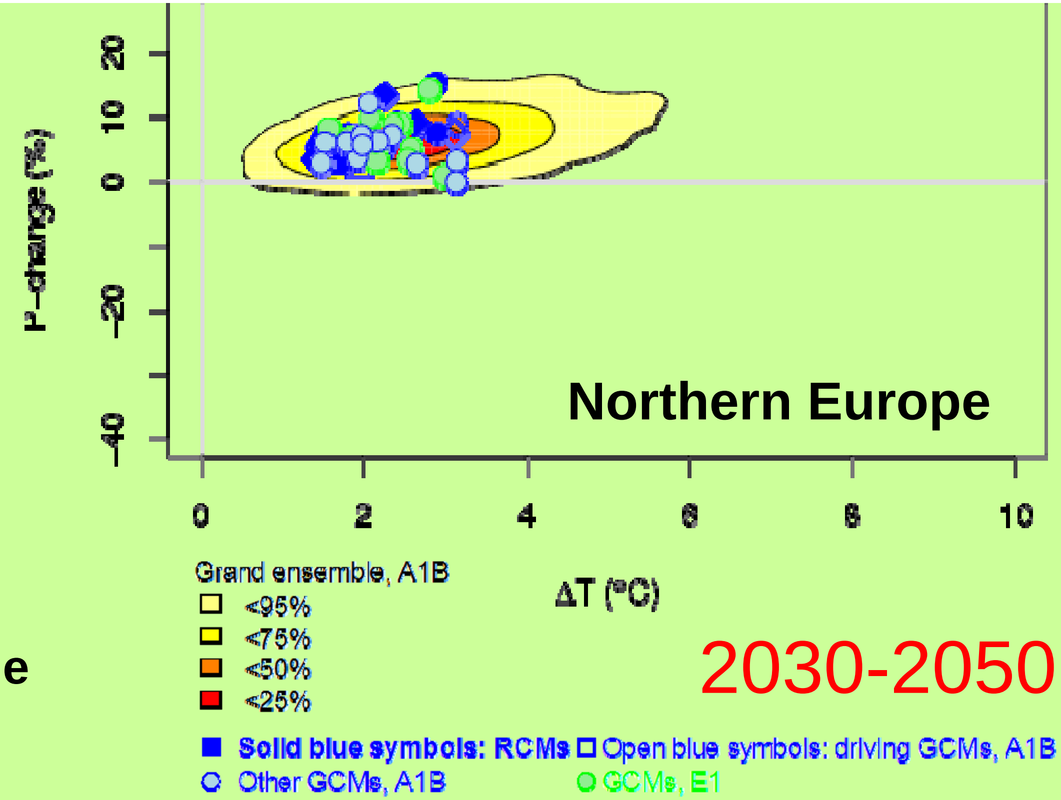


Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990



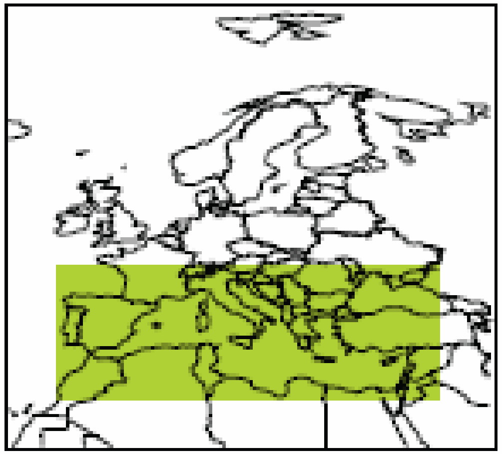


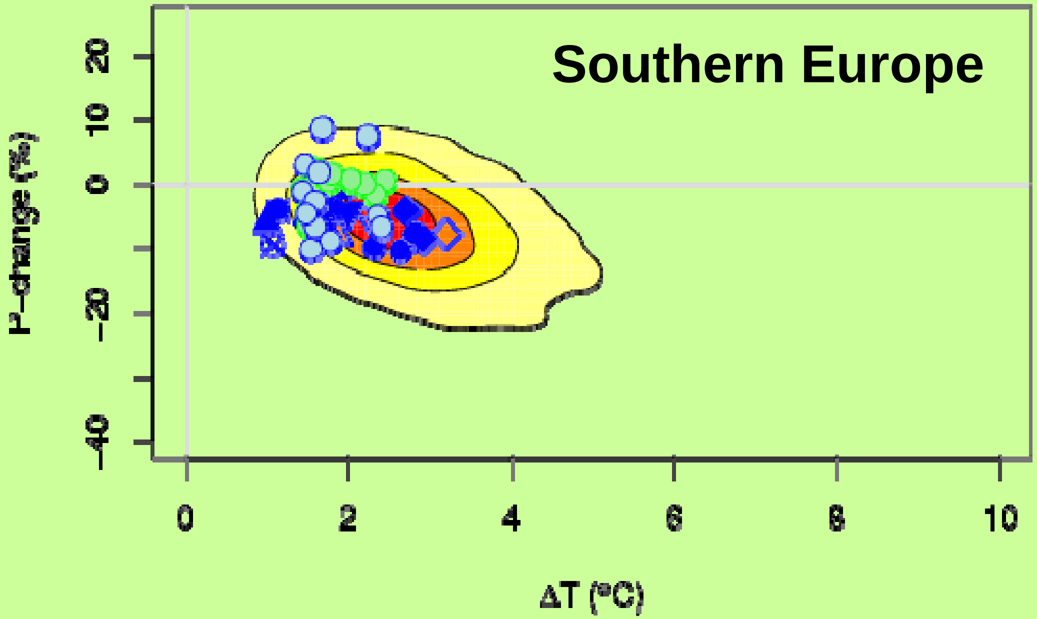


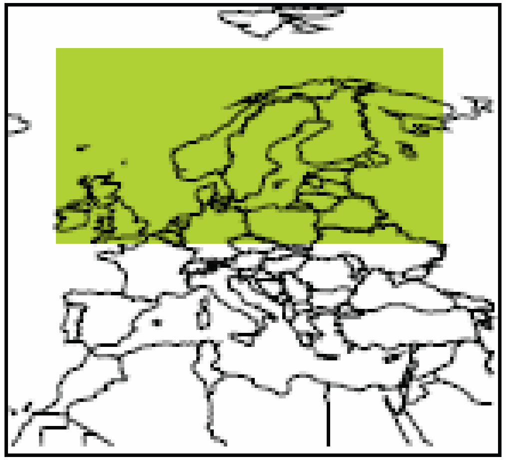


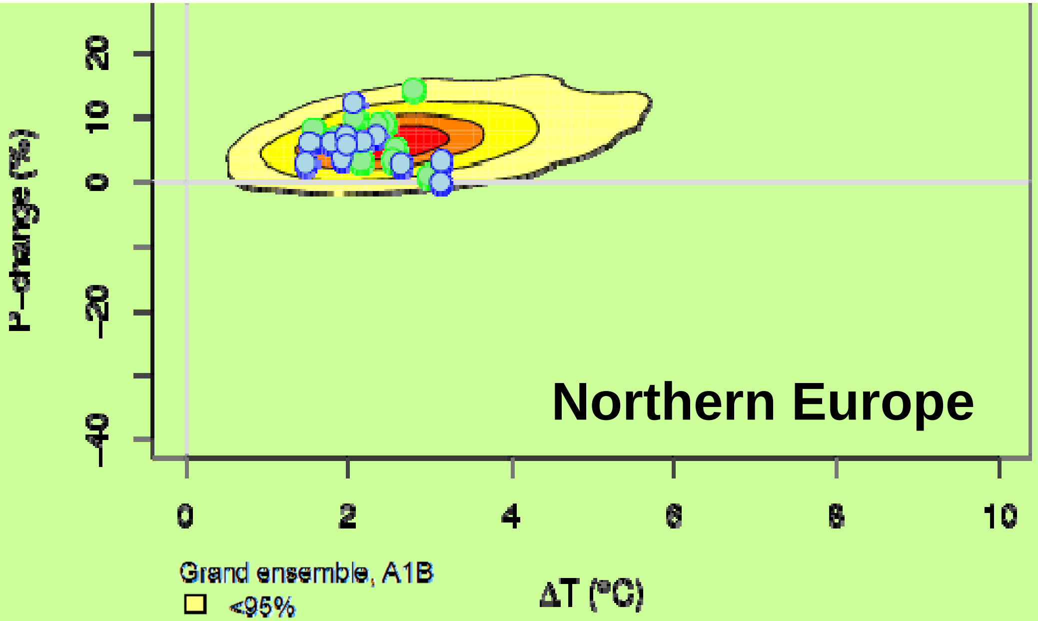
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

2030-2050







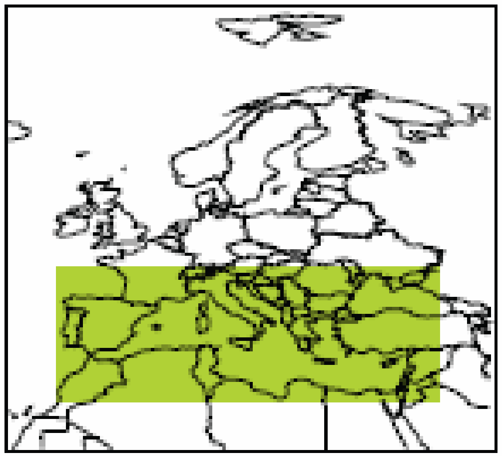


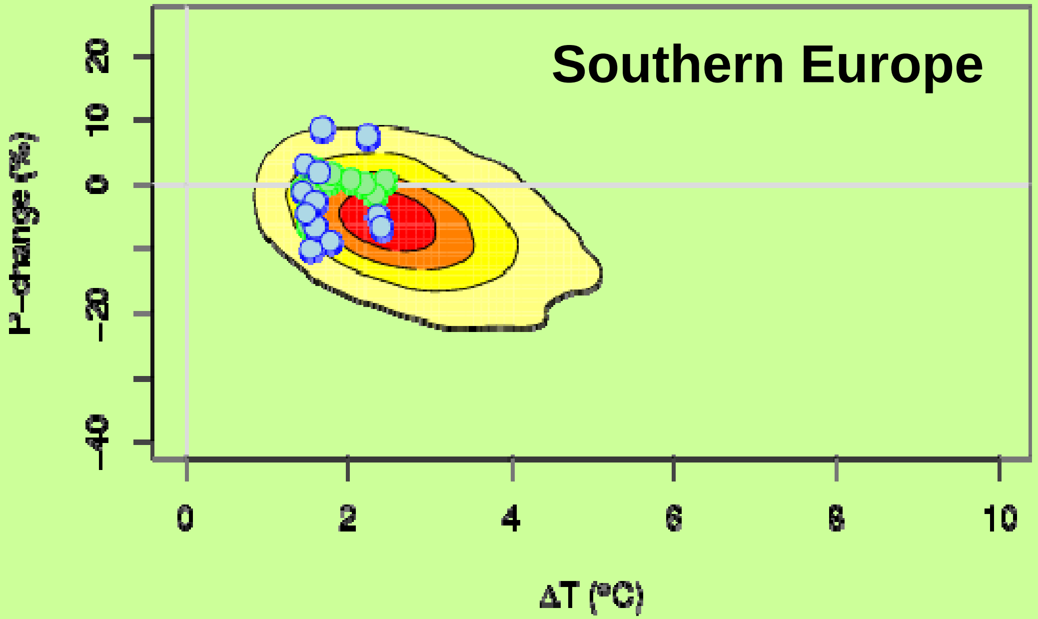
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

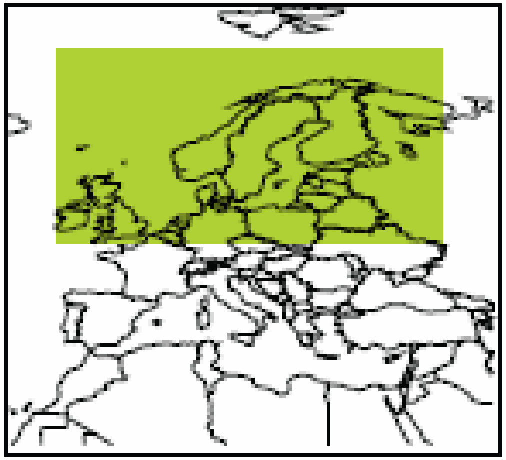
Grand ensemble, A1B
- <95%
- <75%
- <50%
- <25%

■ Solid blue symbols: RCMs □ Open blue symbols: driving GCMs, A1B
○ Other GCMs, A1B ○ GCMs, E1

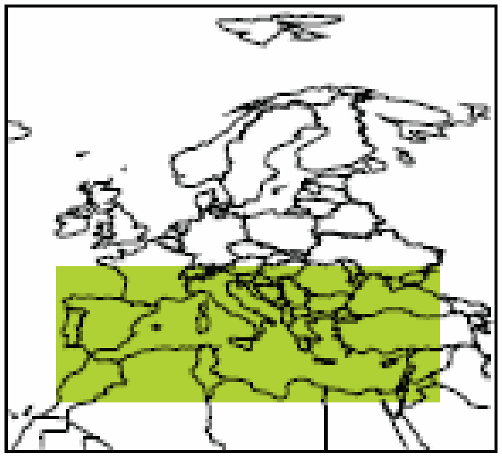
2030-2050



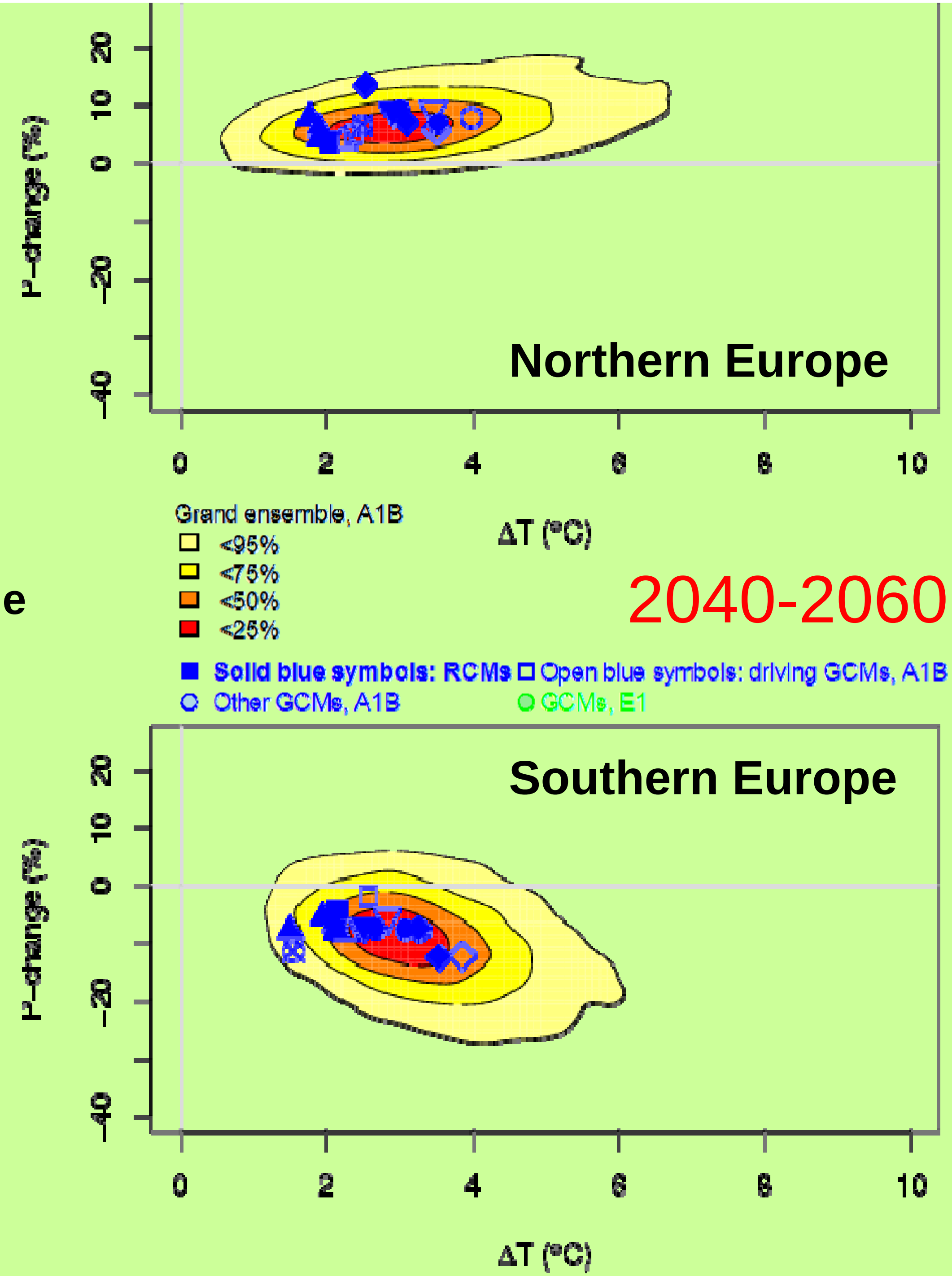


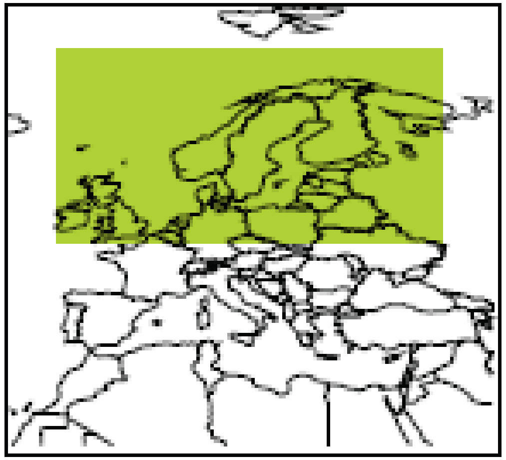


Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

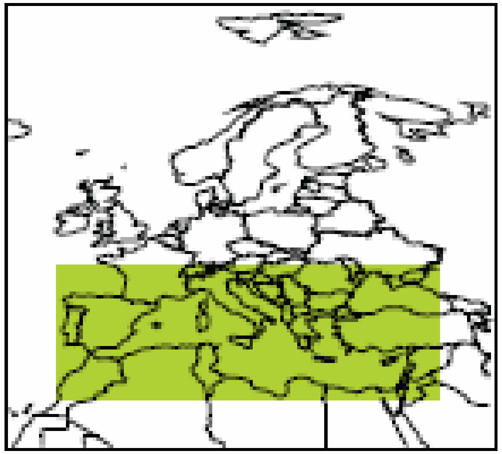


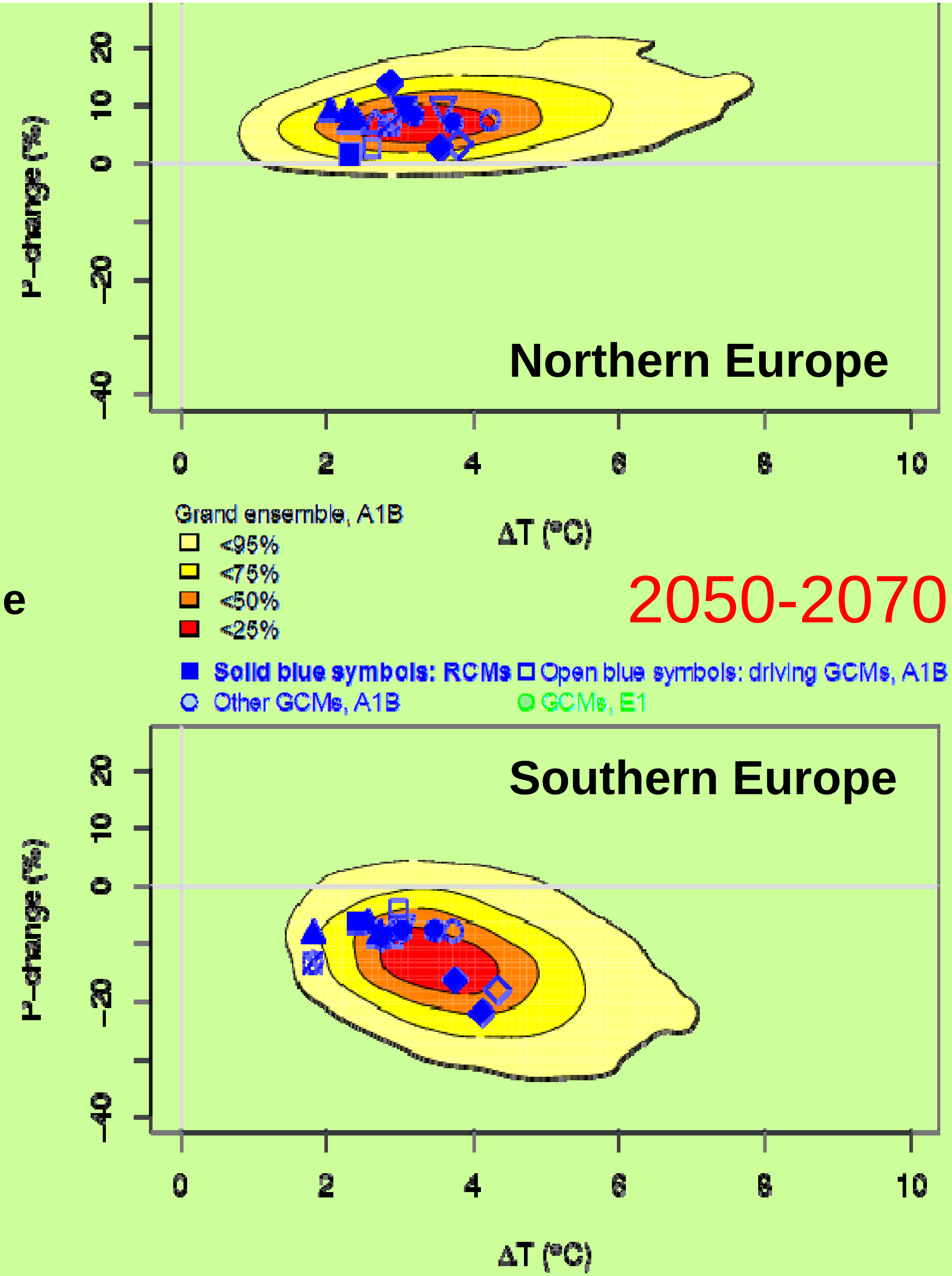
2040-2060



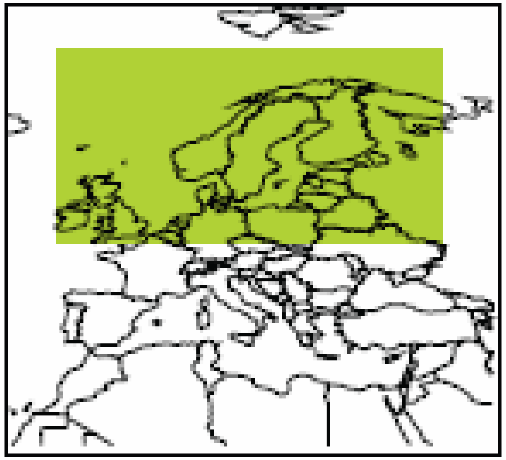


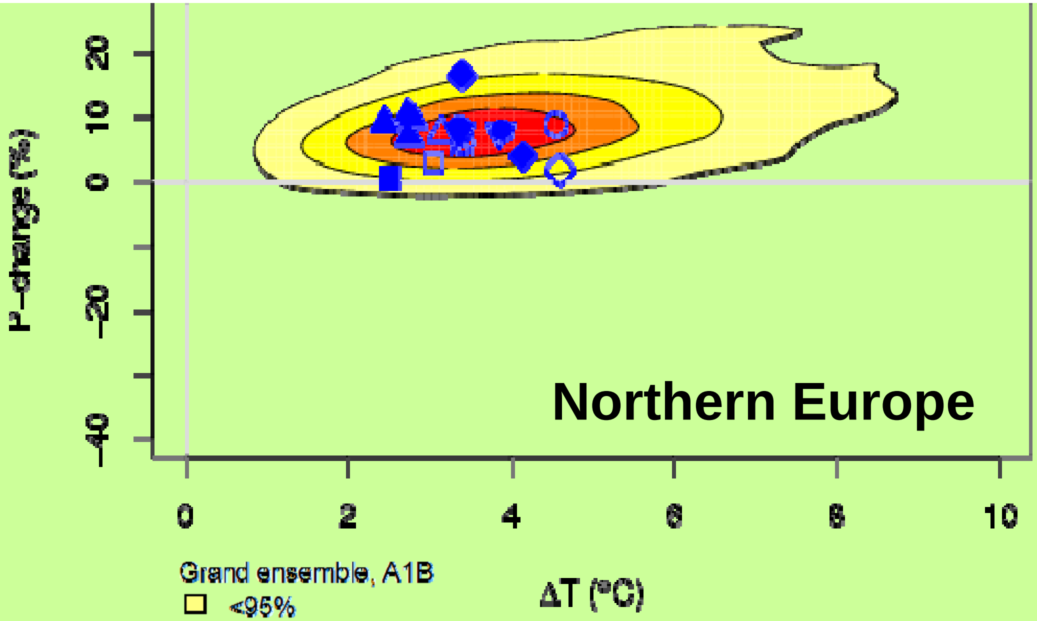
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990





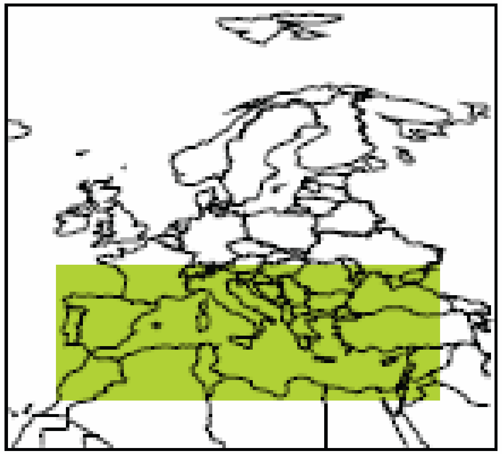
2050-2070

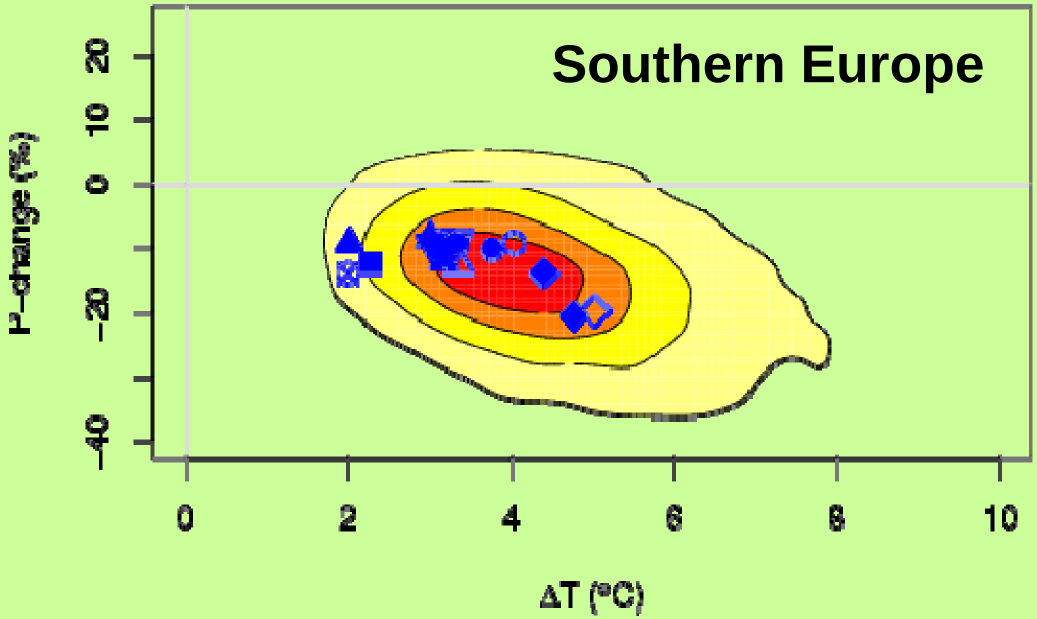


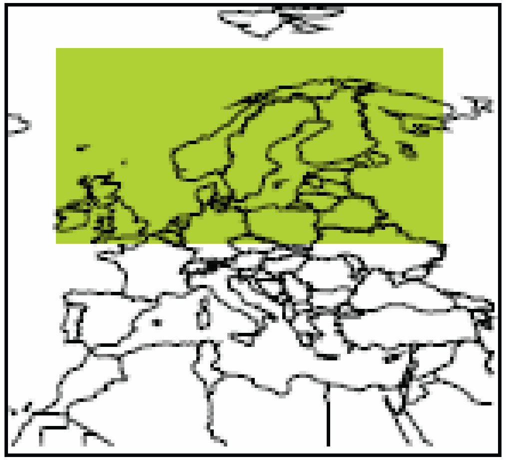


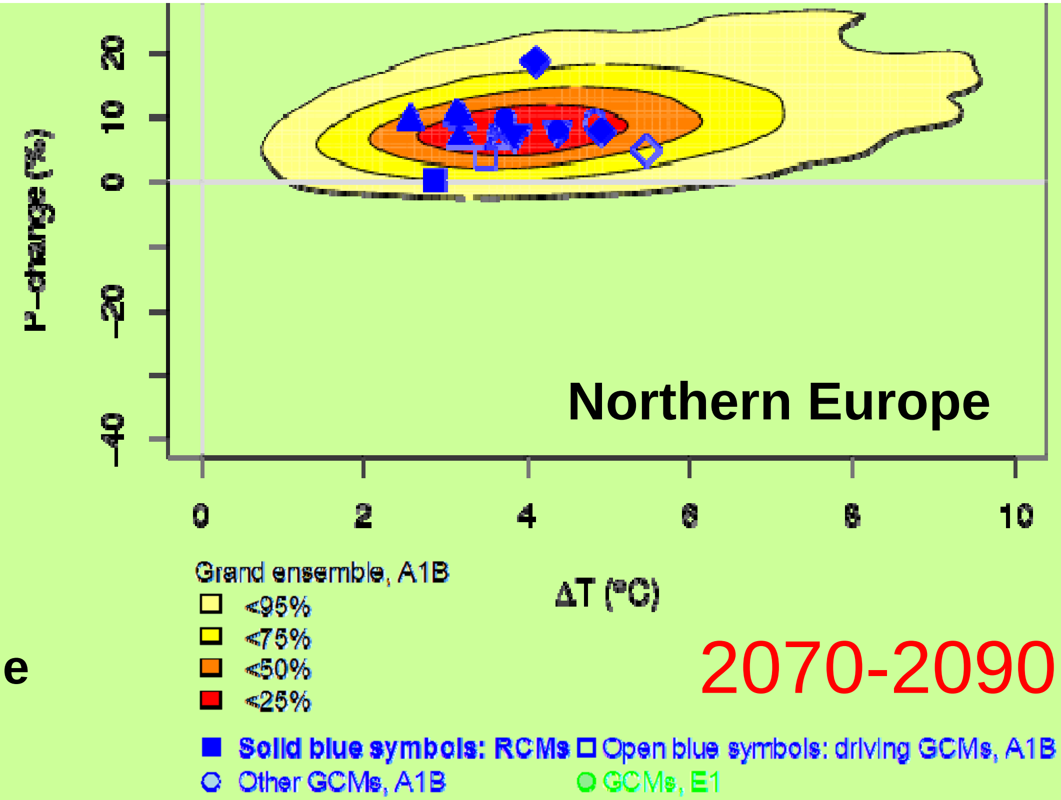
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

2060-2080

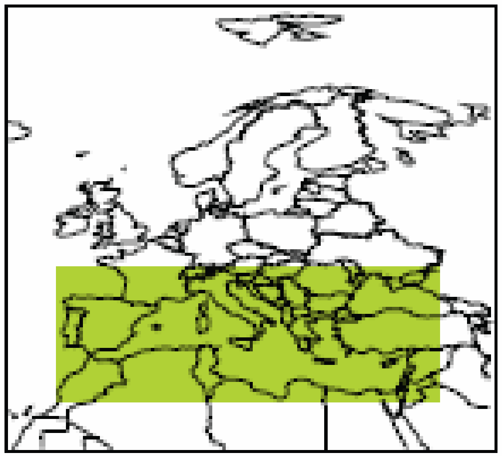


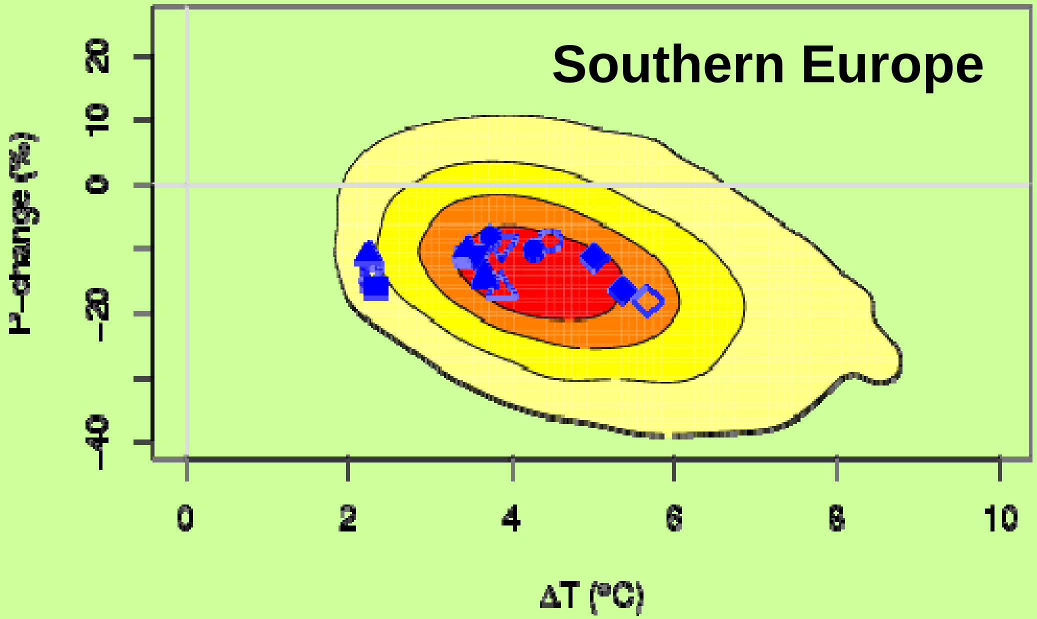


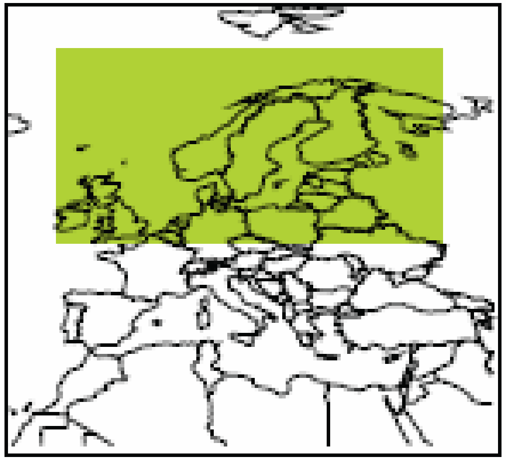




Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990







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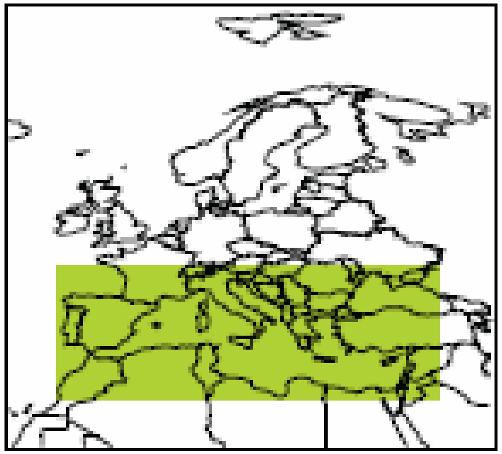
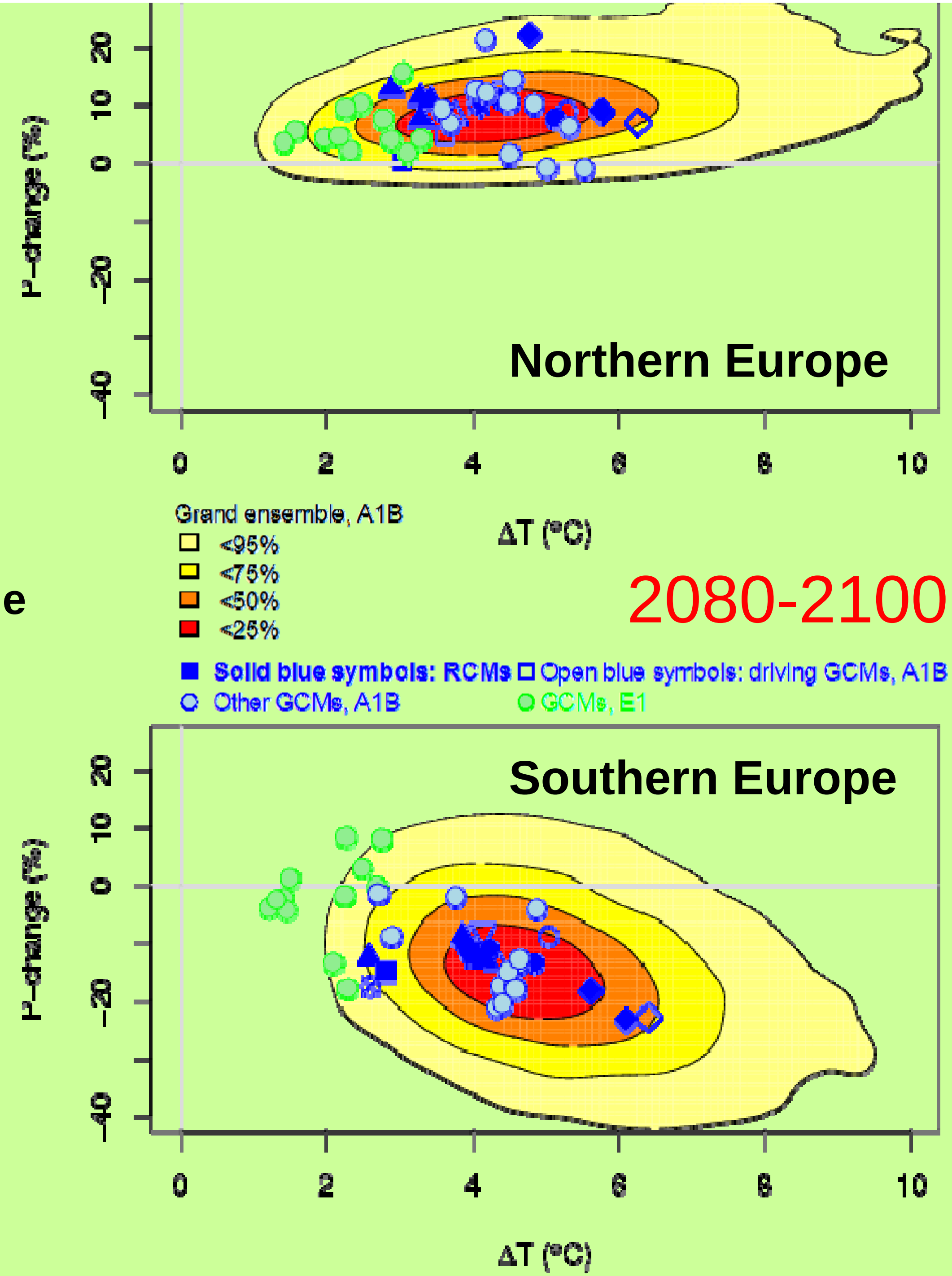
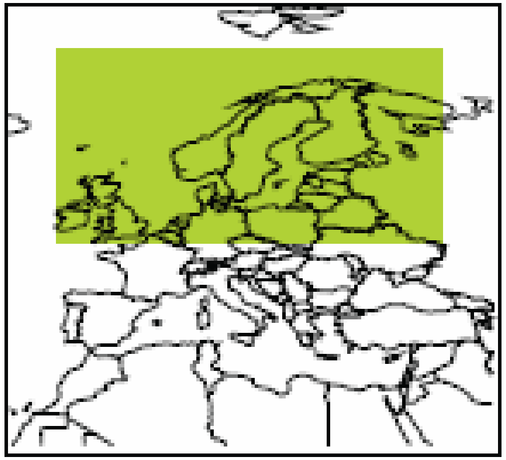
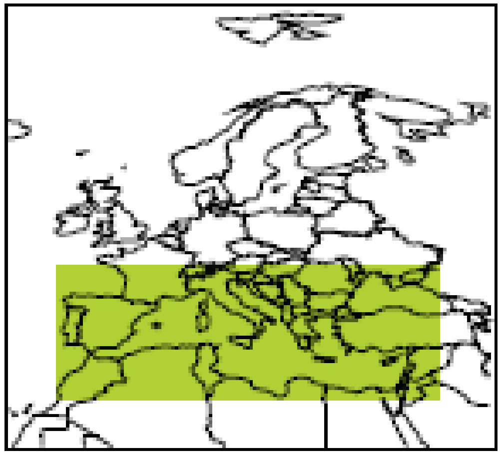
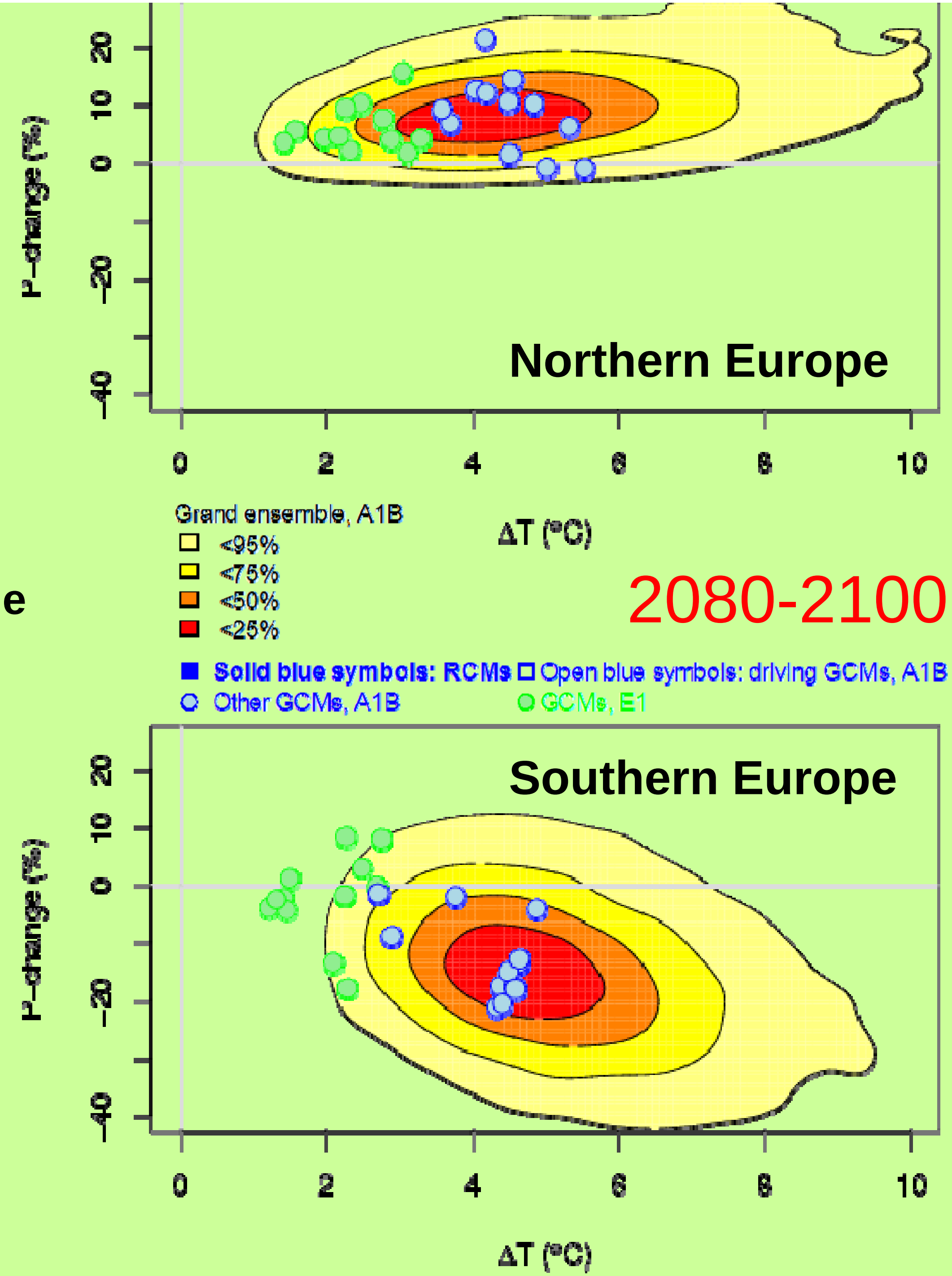










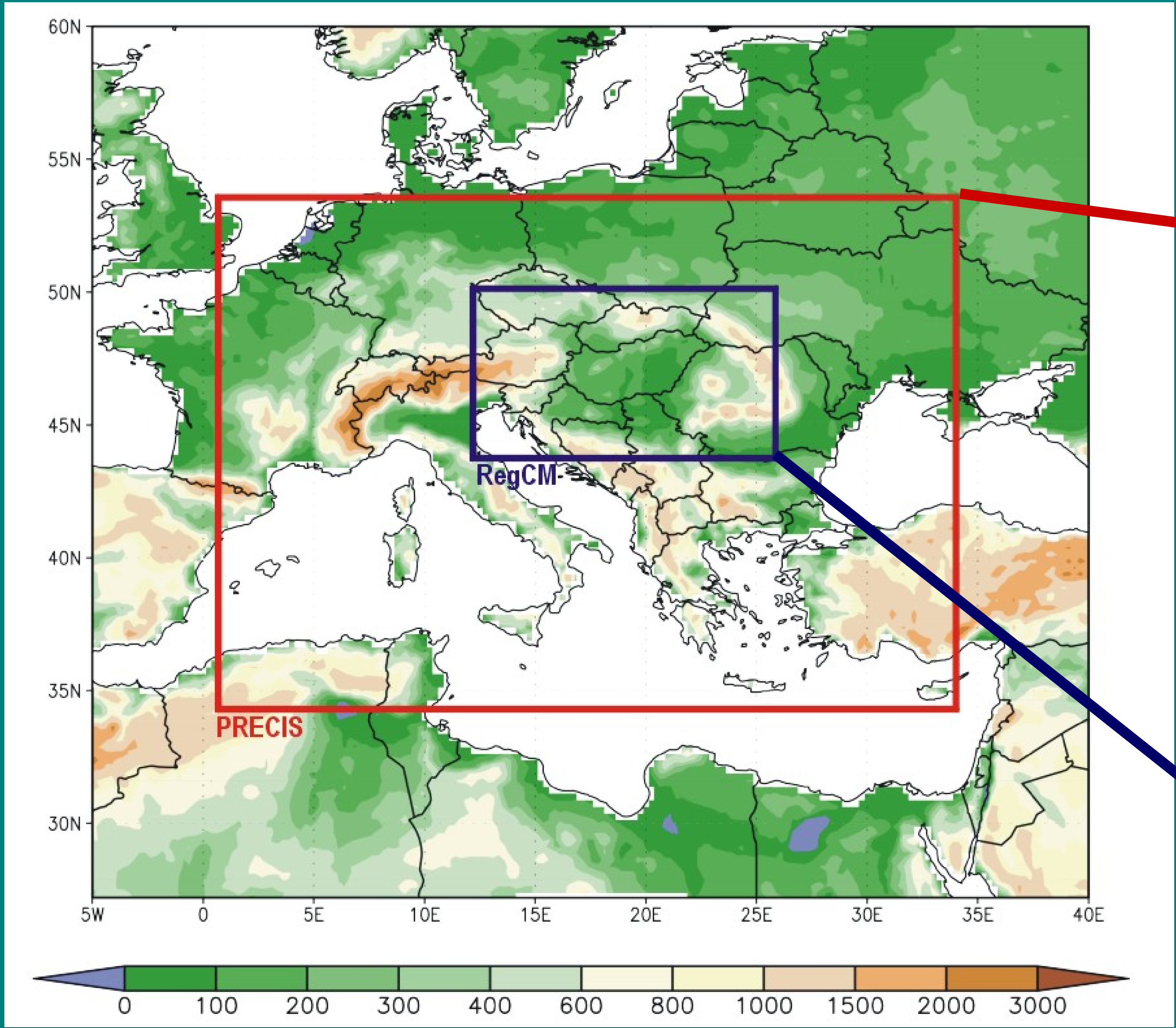
Projected mean annual temperature (°C) and precipitation (%) change relative to 1961-1990

Projections of mean and extreme climatological conditions for Central/Eastern Europe

Judit Bartholy

Department of Meteorology Eötvös Loránd University
Budapest, Hungary

Integration domain of the RCM experiments



Larger domain, 25 km spatial resolution: PRECIS

Smaller domain, 10 km spatial resolution: RegCM

RCM adaptations at the Dept. of Meteorology Eötvös Loránd University

RCM	PRECIS	RegCM/RegCM β
Developper	UKMO Hadley Centre	ICTP, Trieste IT
Start of adaptation	Autumn 2002	Autumn 2005
Horizontal resolution	25 km	10 km
Applied coordinates	Rotated spherical system	Lambert projection
Vertical levels	19 hybrid atmospheric + 4 soil layers	18 sigma atmospheric + 3 soil layers
Spin-up time	2 years	1 years
Integrations time intervals	5 min	1.5 min
Completed and planned experiments	CTL: 1961-1990 ERA40 CTL: 1961-1990 HadCM3 A2: 2071-2100 HadCM3 B2: 2071-2100 HadCM3 CTL+ A1B: 1951-2100 HadCM3	CTL: 1961-2000 ERA40 CTL: 1961-2000 ECHAM5 A1B: 2021-2050 ECHAM5 A1B: 2071-2100 ECHAM5 CTL/RegCM4 * (50 km): 1981-2010 ERA-Interim Planned (CORDEX): CTL+RCP4.5 RegCM4 * (50 km): 1950-2100 CTL+RCP8.5 RegCM4 * (50 km): 1950-2100

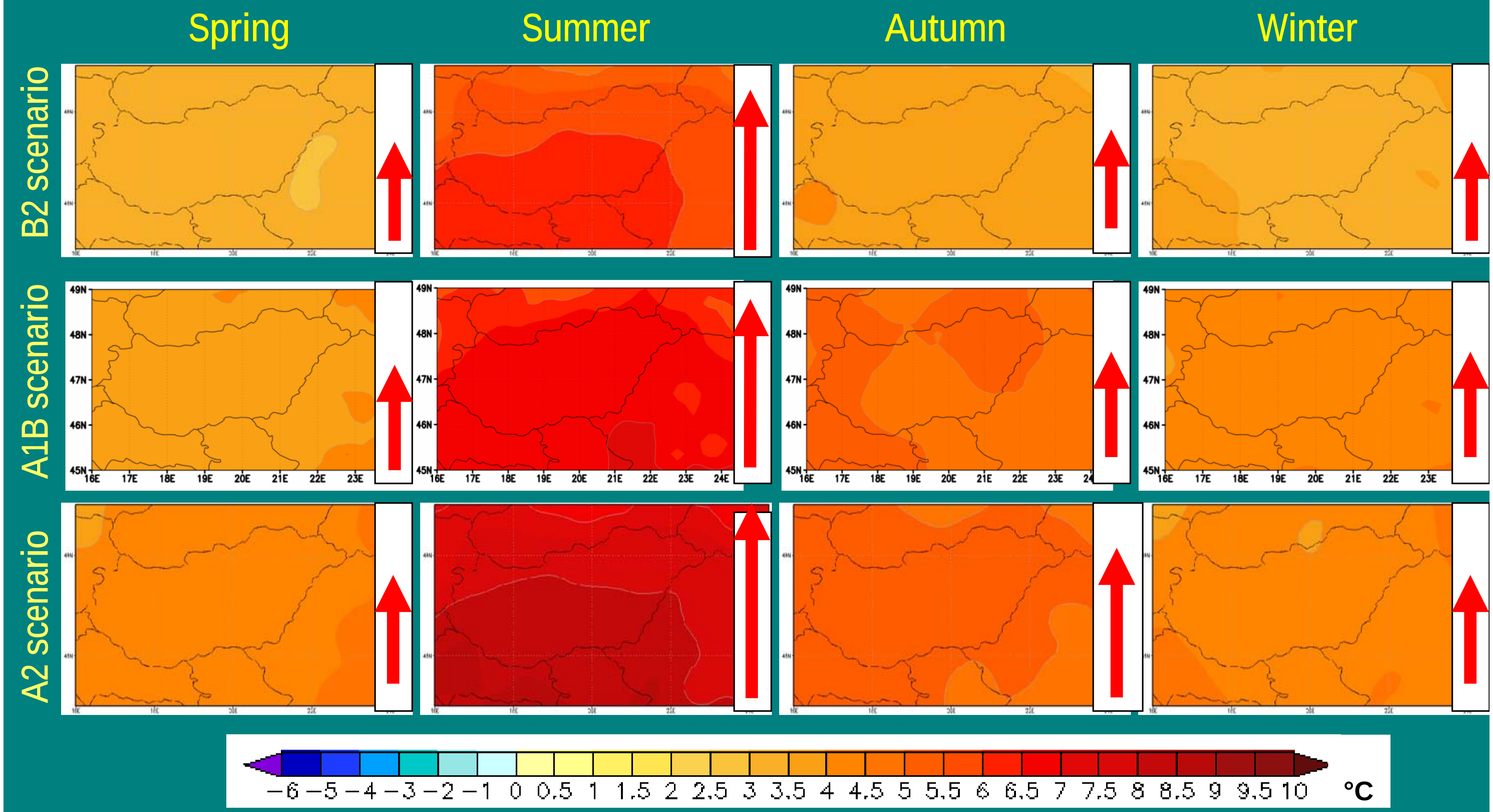
Results:

Climate change projections for the 21st century for the Carpathian basin

Analysis of different scenarios

using PRECIS simulations

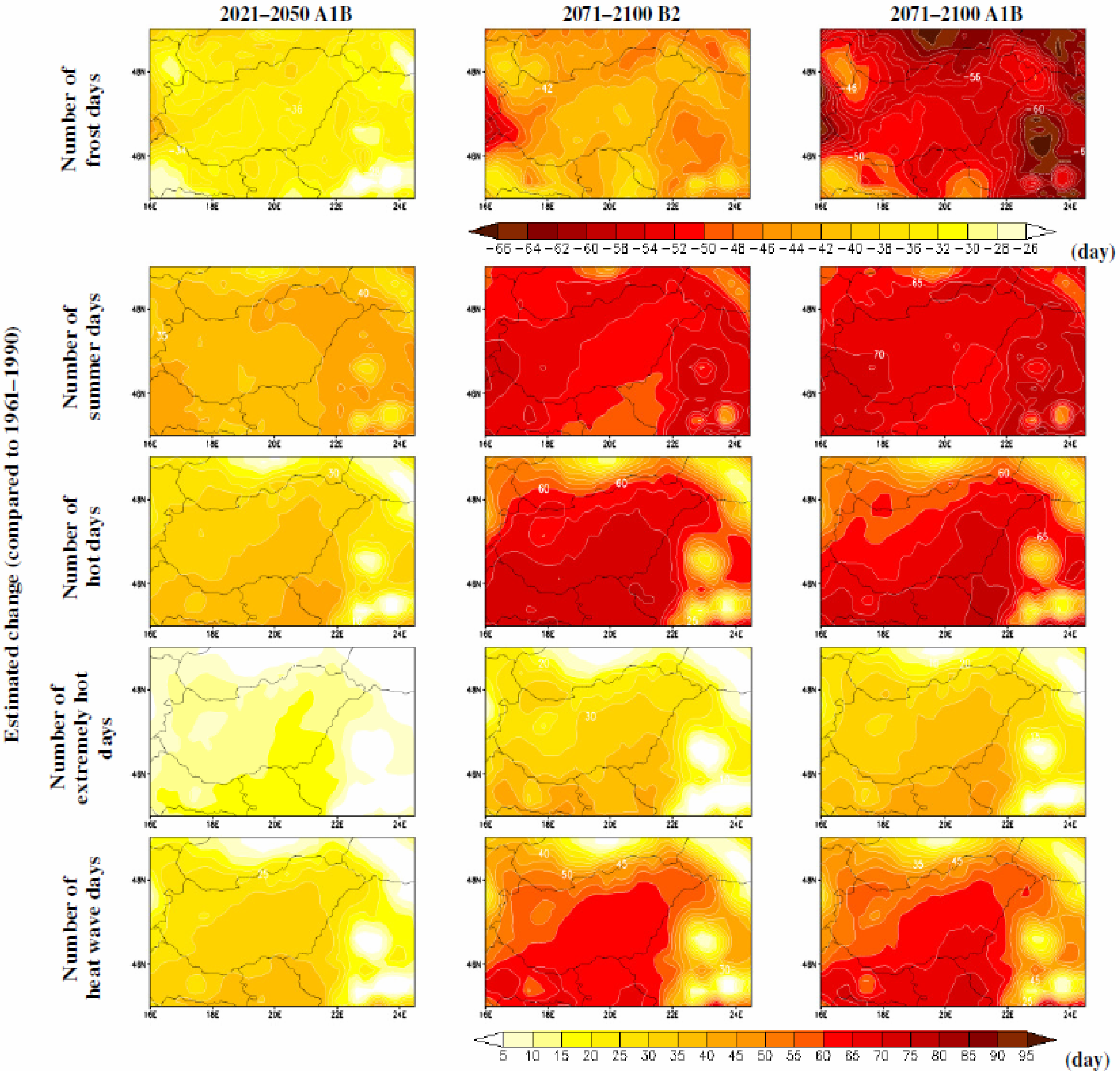
Simulated seasonal temperature change by 2071–2100 (reference period: 1961–1990)



Projected change: increasing temperature (especially in summer)

Pieczka et al., 2011

Temperature-related climate indices for projecting extreme conditions



1961-90 E-OBS/HU:

Number of frost day
(T_{min} < 0 °C)
93 days

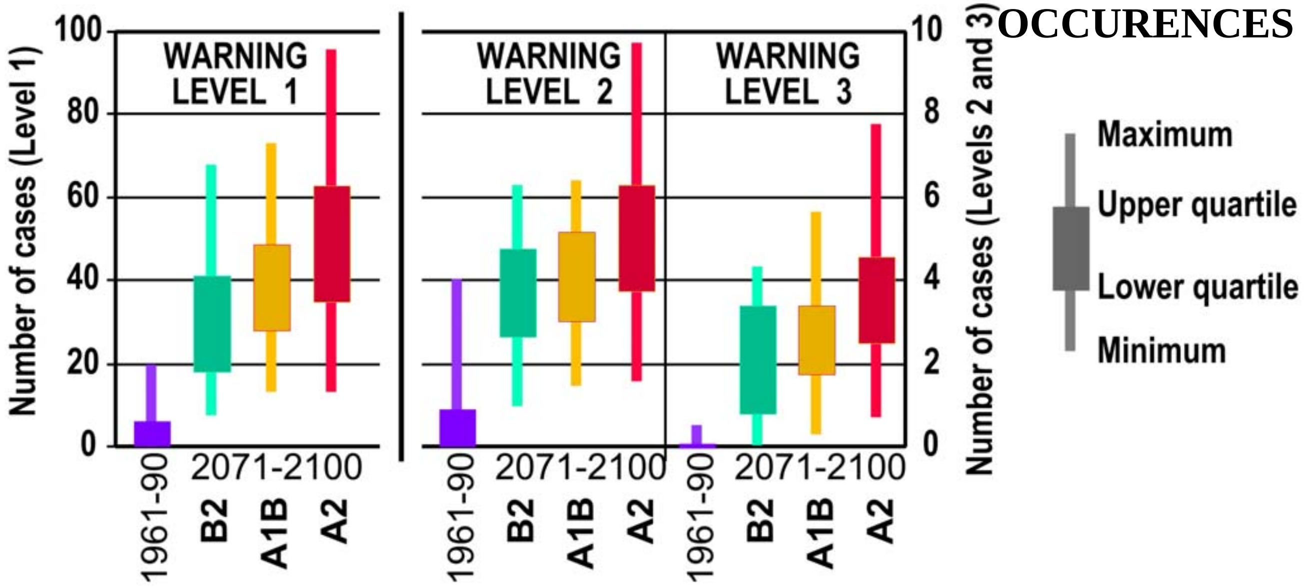
Number of summer days
(T_{max} > 25 °C)
67 days

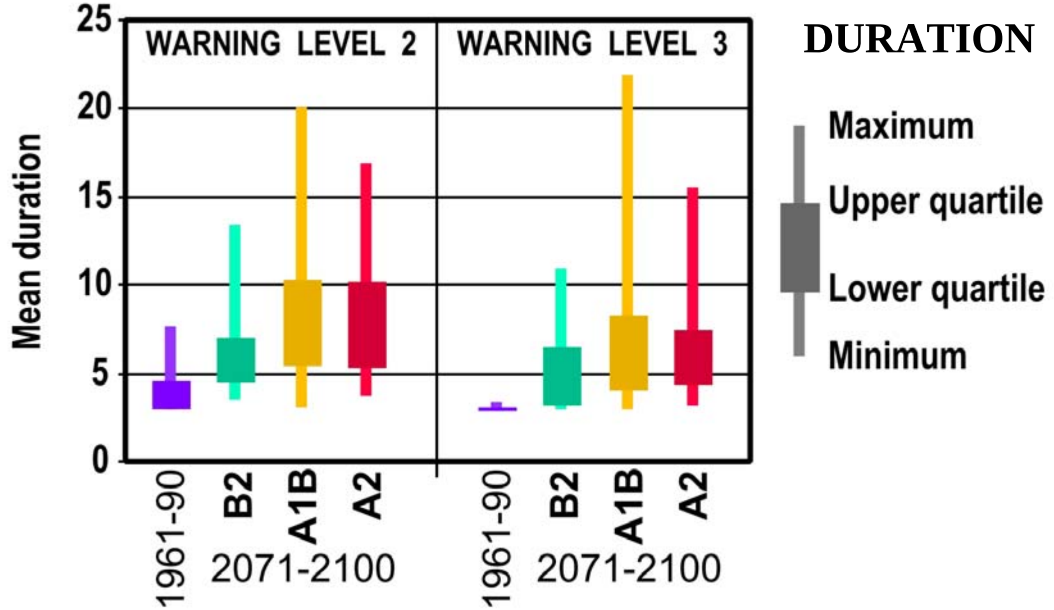
Number of hot days
(T_{max} > 30 °C)
14 days

Number of extremel hot days
(T_{max} > 35 °C)
0.3 days

Number of heatwav days
(T_{mean} > 25 °C)
4 days

Spatial mean and duration of heat wave warning levels (Carpathian basin: 229 grid cells)





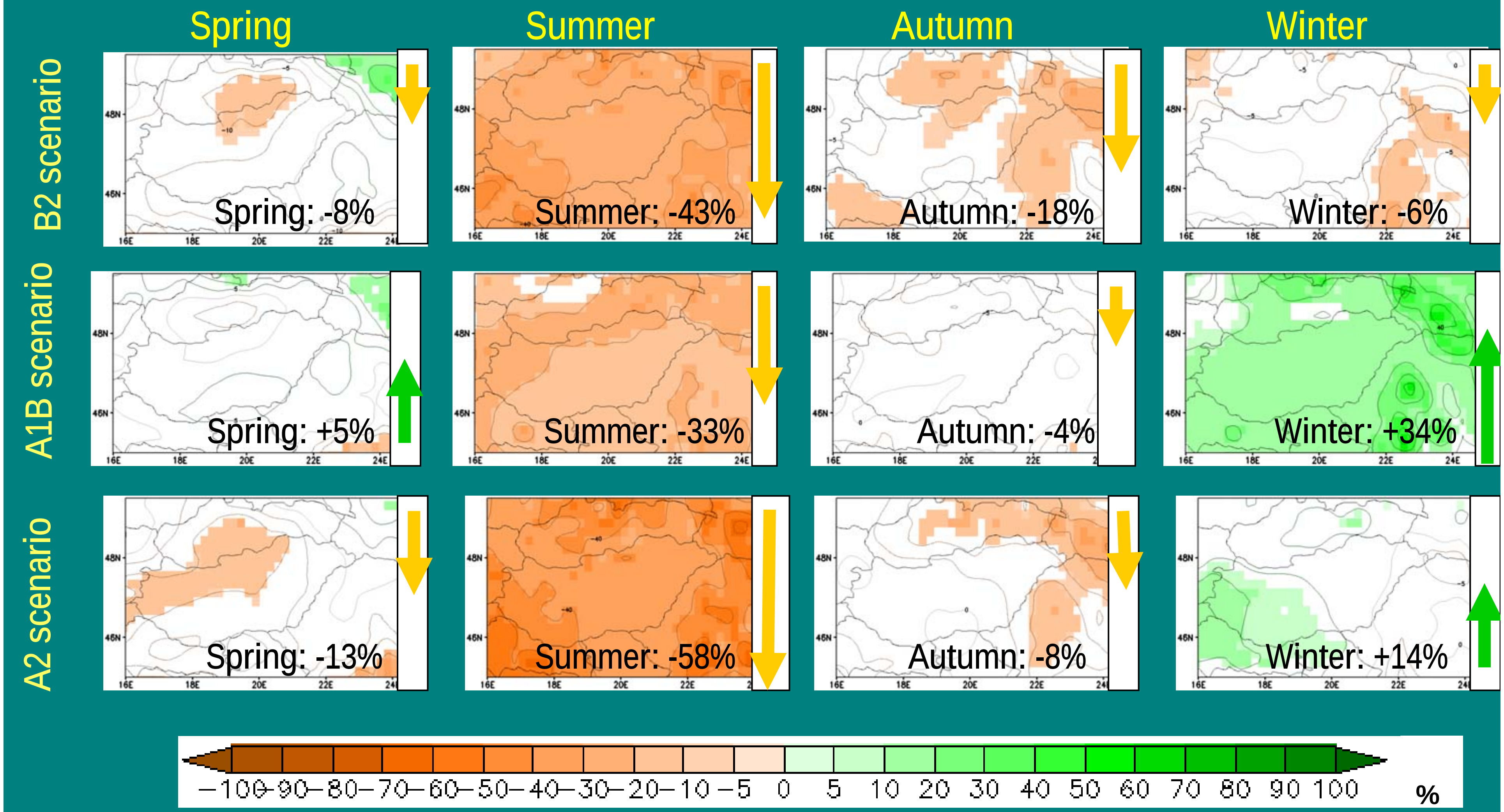
By the end of the 21st century

-- the occurrences of heat wave warning level cases are projected to change by ~10 times,

-- the mean duration of heat wave warning levels are projected to double

Pongrácz et al., 2013

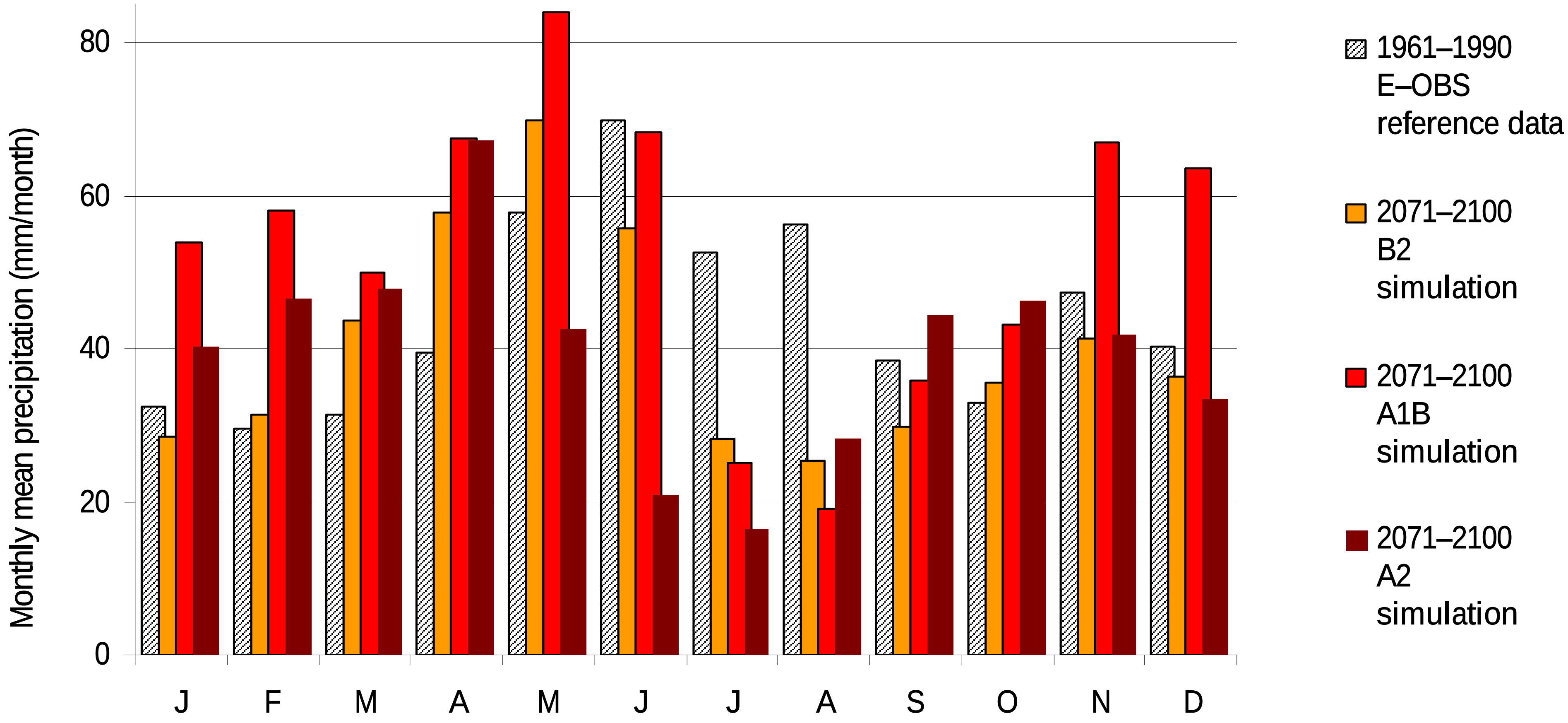
Simulated seasonal precipitation change by 2071–2100 (reference period: 1961–1990)



Projected change: summer decrease, winter increase

Pieczka et al., 2015

Annual distribution of monthly mean precipitation (mm/month)



Projected change: summer decrease, winter increase

Pieczka et al., 2015

Results:

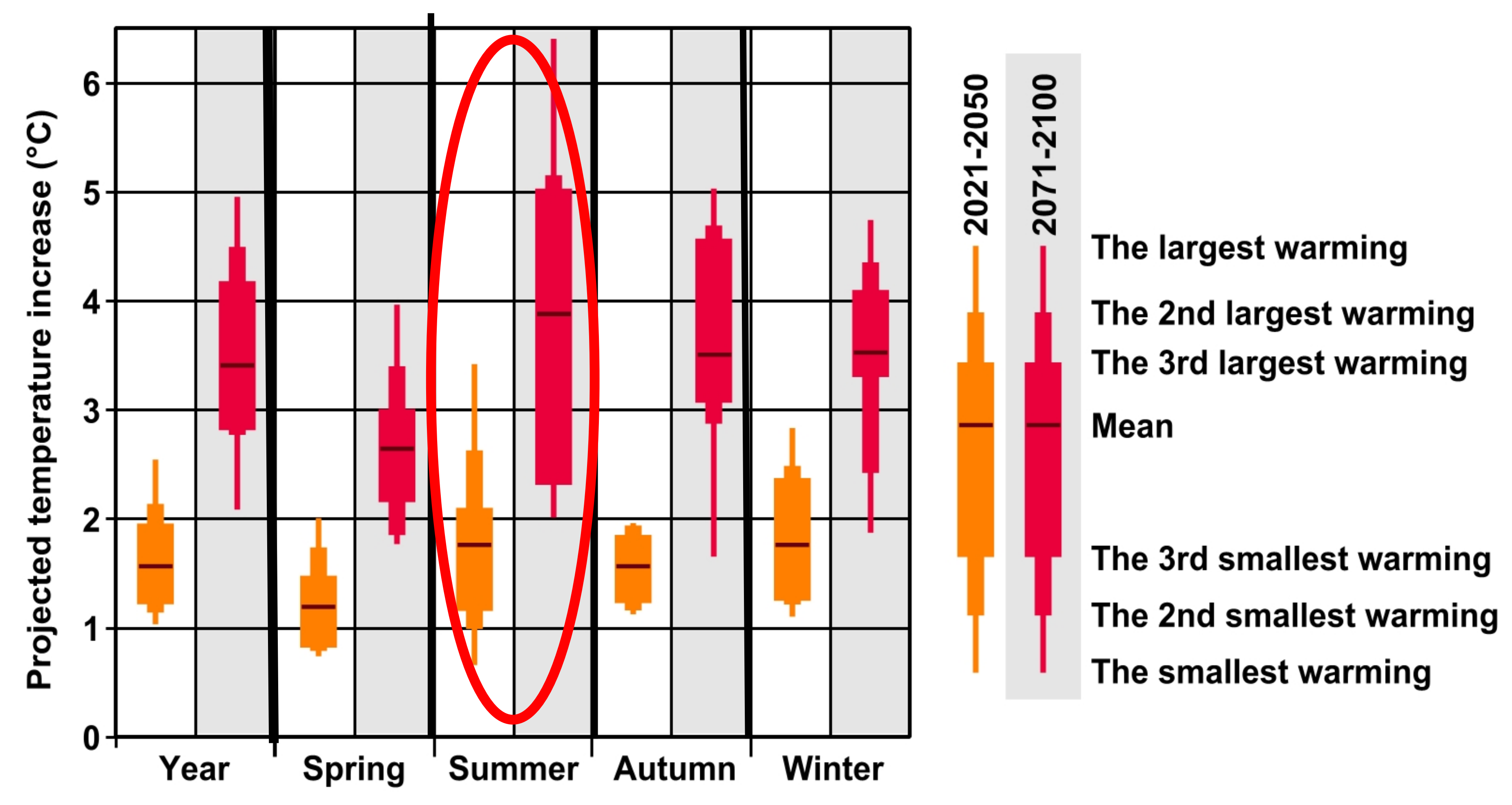
Climate change projections
for the 21st century
for the Carpathian basin

Analysis of different models
using

ENSEMBLES simulation outputs

Projected seasonal temperature change, A1B scenario

Reference period: 1961-1990



- Estimated warming by 2021-2050: 1-3 °C, by 2071-2100: 2-6 °C
- The largest seasonal warming is projected for summer
- The largest warming is projected by the HadCM-driven RCM simulations

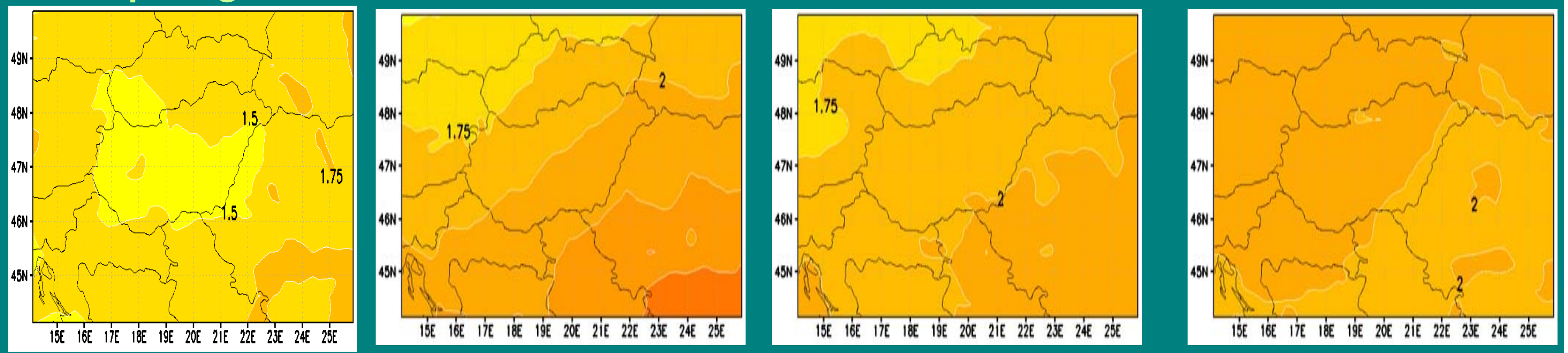
Pongrácz et al., 2011, Datasource: ENSEMBLES, 2009

Estimated seasonal temperature change: using 11 model simulation results for A1B scenario

(Reference period: 1961-1990)

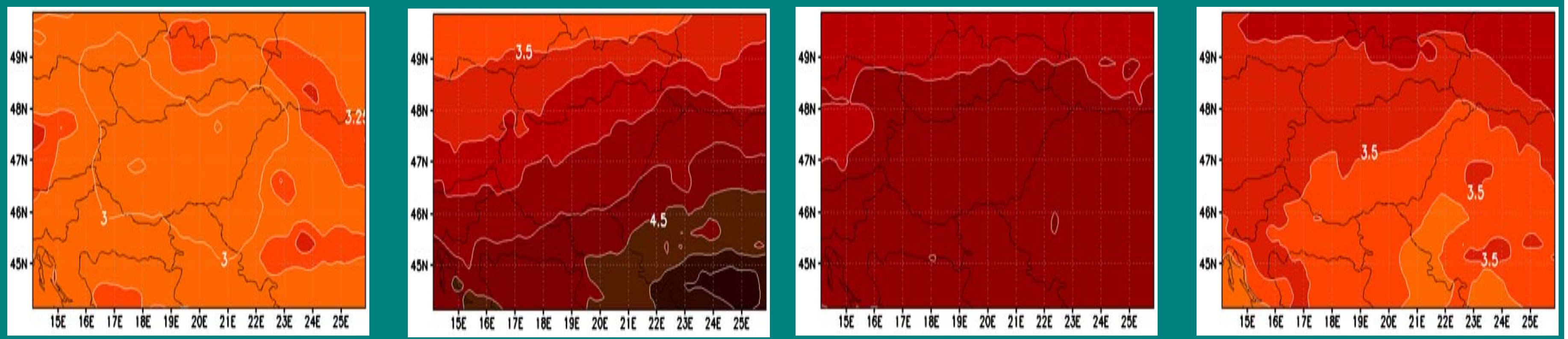
Spring | Summer | Autumn | Winter

2021-2050

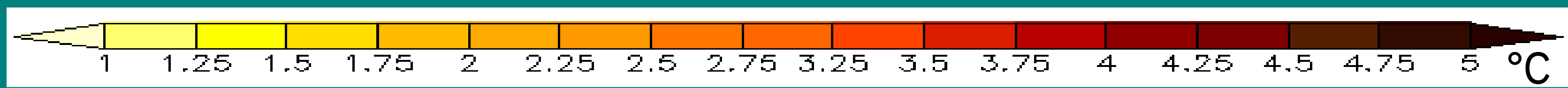


- Projected warming: 1.25 – 3.25 °C; the estimated warming is larger from North to South

2071-2100



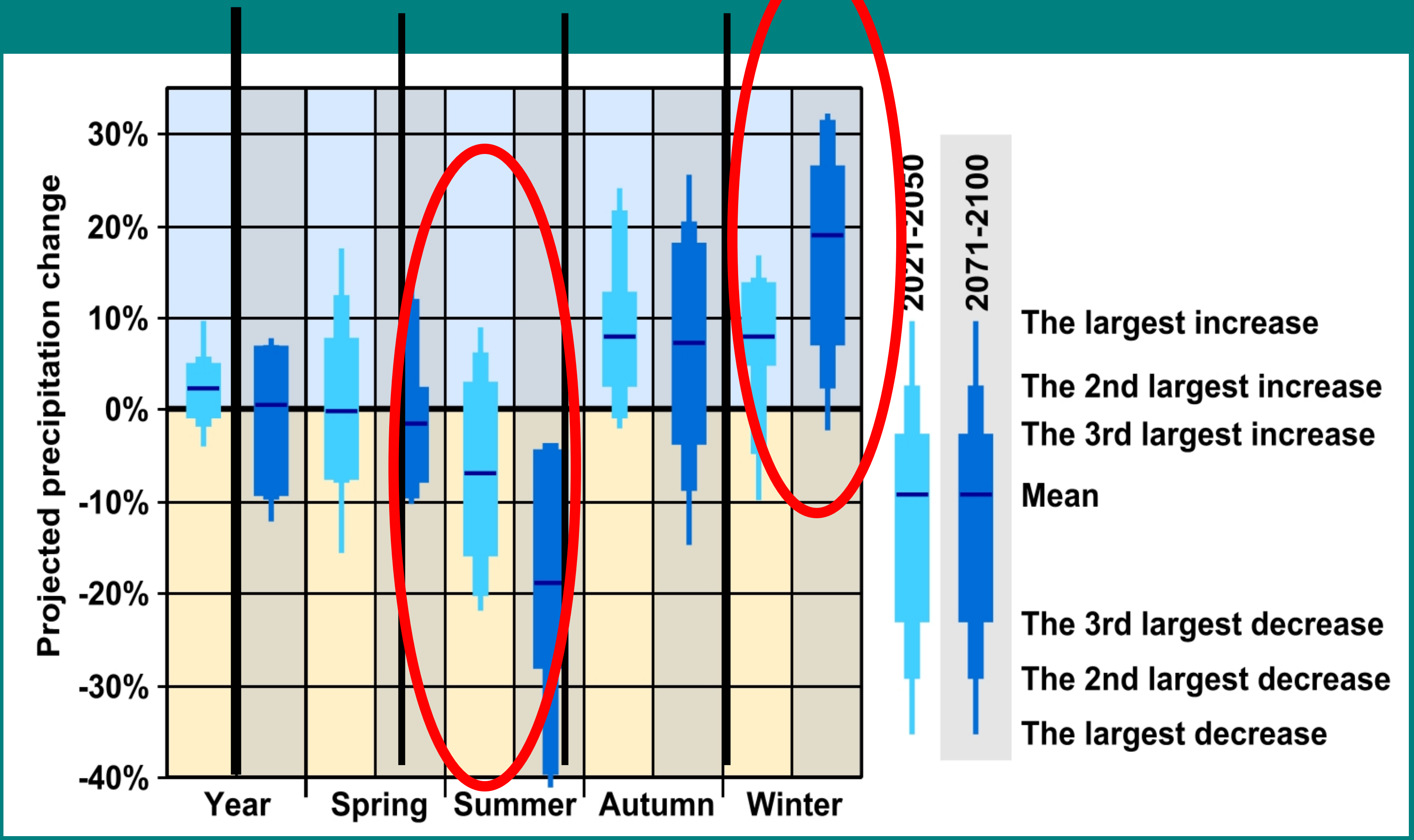
- Projected warming: 2.75 – 5 °C; the largest increase is estimated for summer



Pongrácz et al., 2015, Datasource: ENSEMBLES, 2014

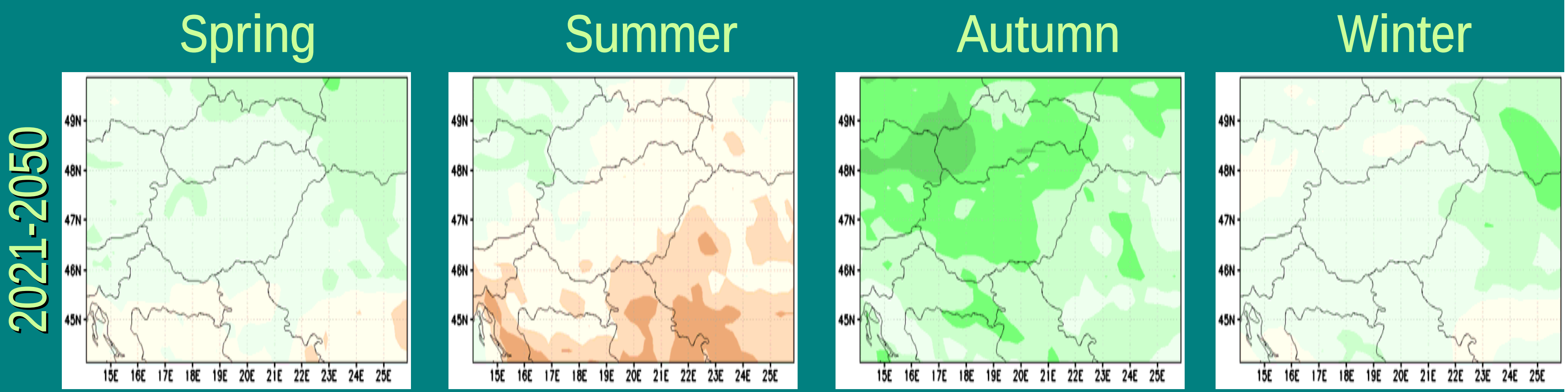
Projected seasonal precipitation change, A1B scenario

Reference period: 1961-1990

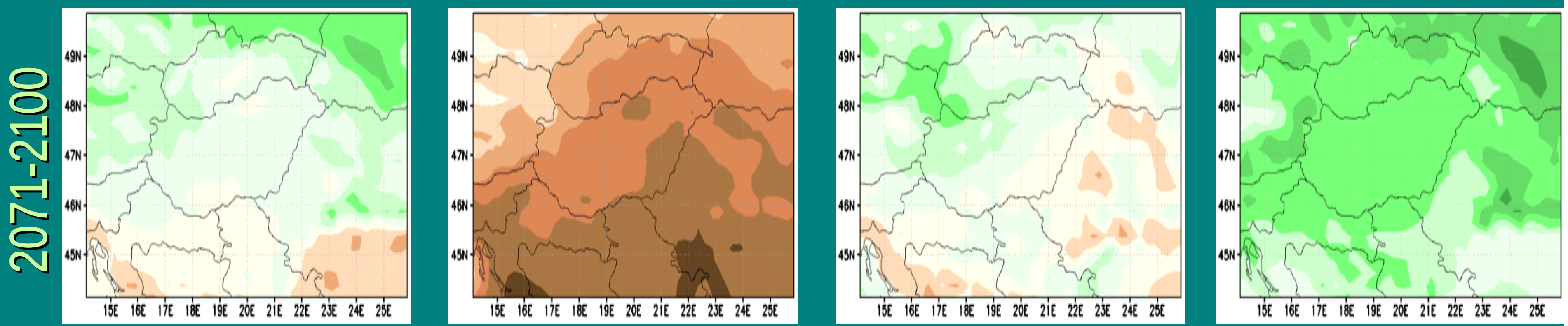


- 2021-2050: the projected changes don't exceed 15-20%, and mostly not significant
- 2071-2100: precipitation decrease is projected for summer (by 10-40%)
  precipitation increase is projected for winter (by 5-30%)

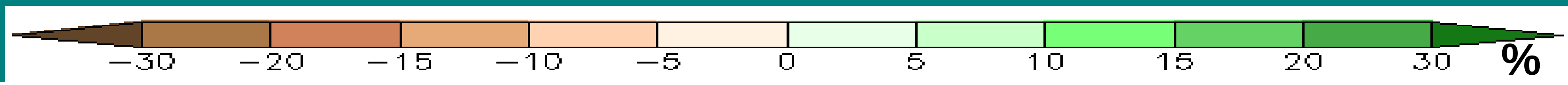
Estimated seasonal precipitation change: using 11 model simulation results for A1B scenario (Reference period: 1961-1990)



- Precipitation decrease in summer (~20%), the rest of the year: increase (~5-20%)

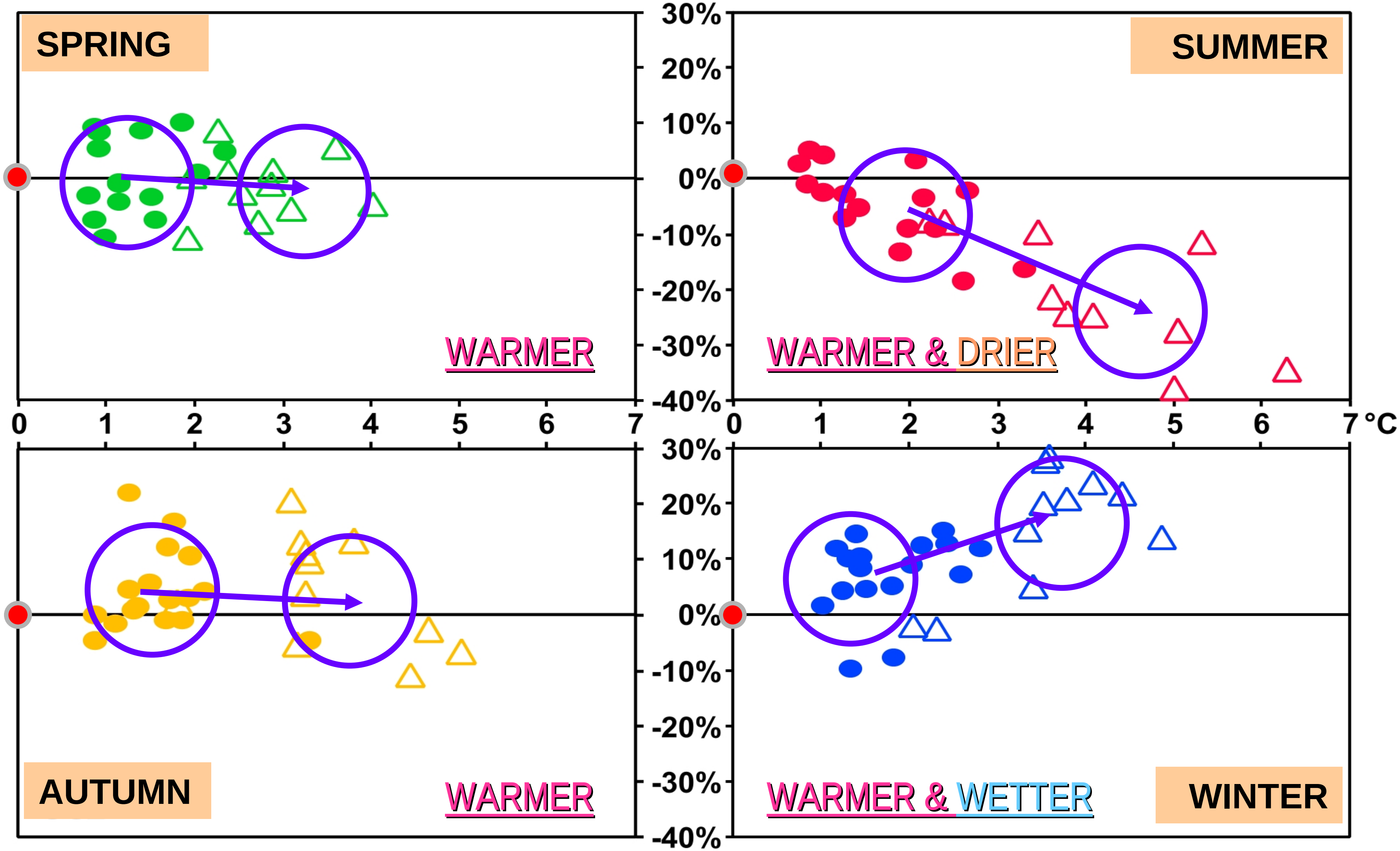


-The largest precipitation decrease / increase is projected for summer / winter (~30% / ~20%)



Projected temperature and precipitation change for Hungary

Reference period: 1961-1990



ENSEMBLES model simulations: ○ 2021-2050 △ 2071-2100

CONCLUSIONS

WHAT DO THE RCM-SIMULATIONS PROJECT FOR THE CARPATHIAN BASIN?

- TEMPERATURE

Warming is projected to continue:
The largest warming is estimated for summer
More frequent, more intense warm extremes
Less cold extremes

⇨ PRECIPITATION

Drier summers and wetter winters are projected
Longer and more frequent drought events in summer