Climate Change projections over the Mediterranean region and future challenges

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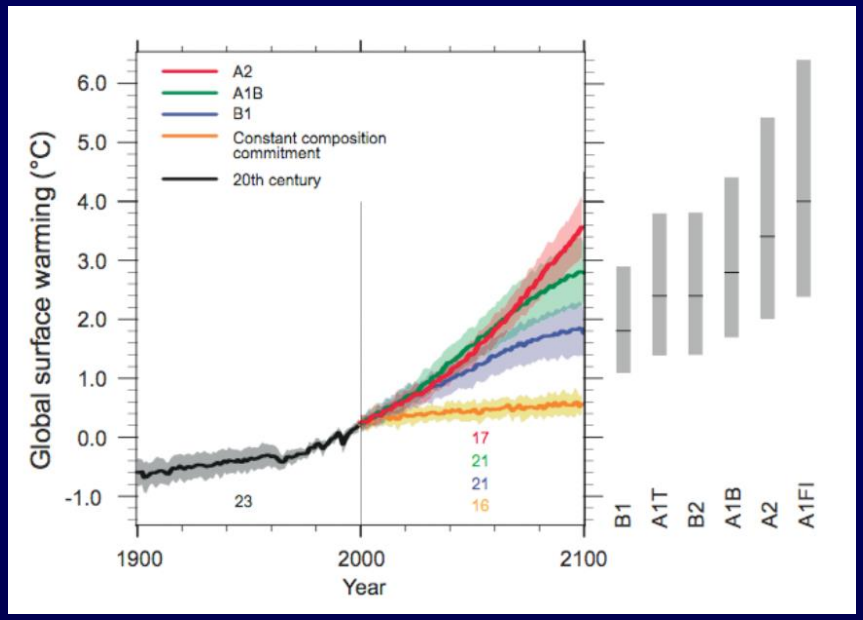
Abdus Salam ICTP, Trieste

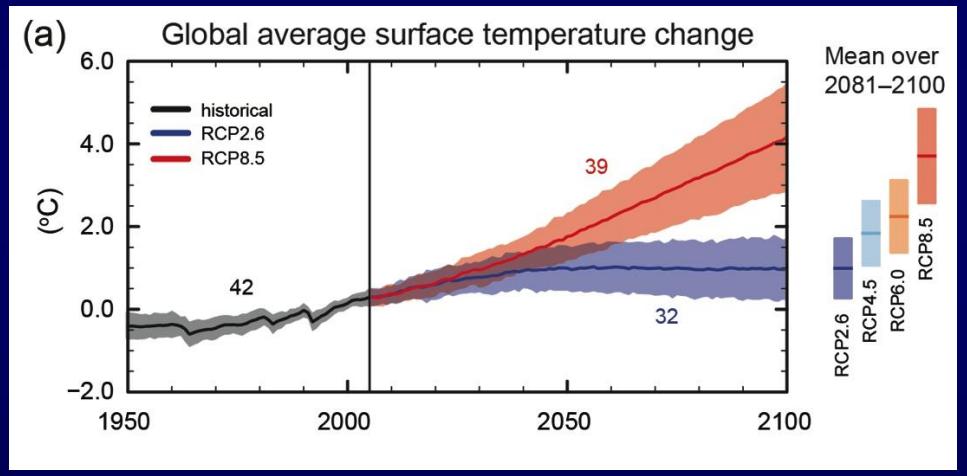
Climate change impacts in the Mediterranean region, Montpellier, Oct. 2017

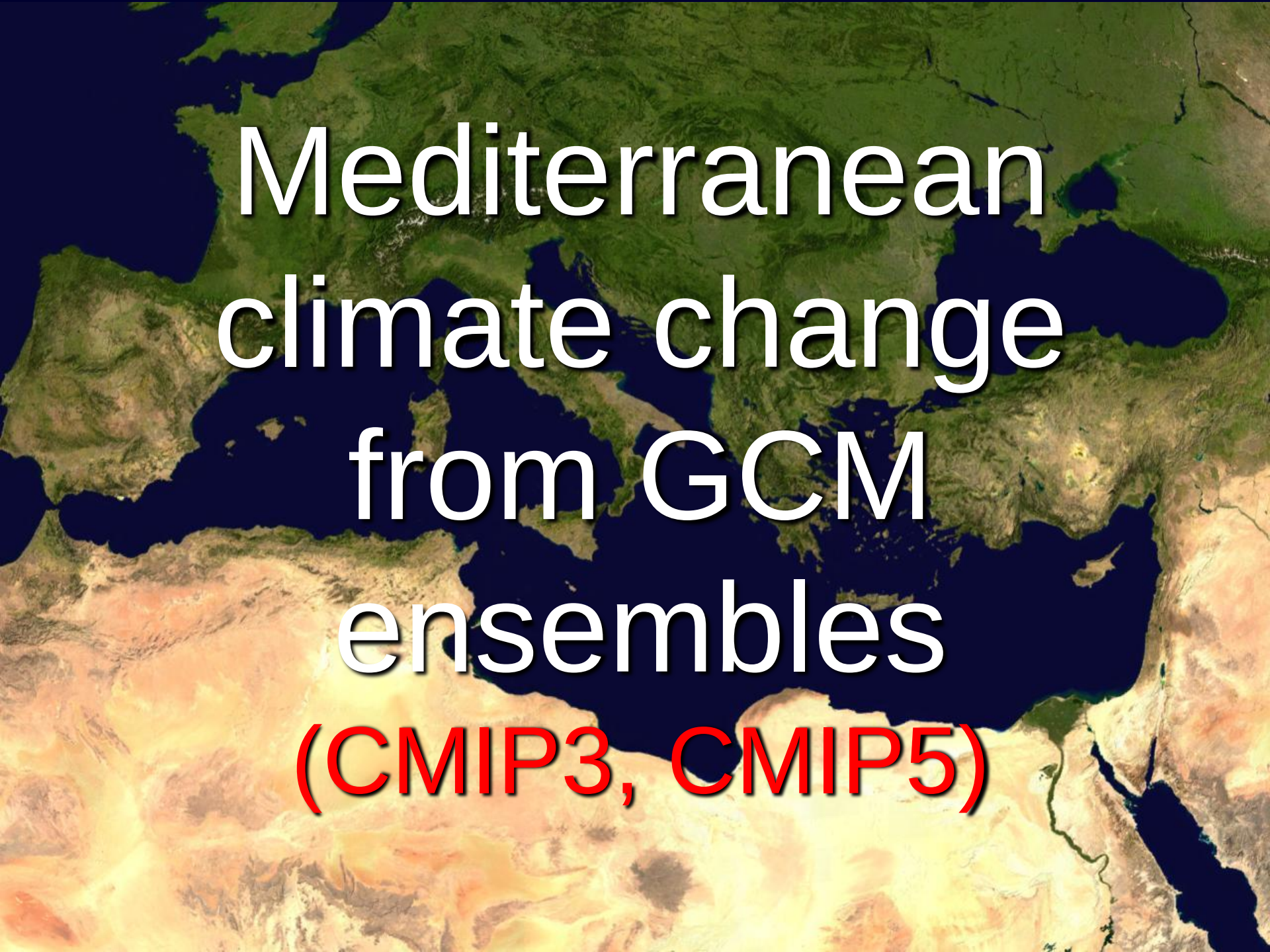
IPCC : Global temperature change projections for the 21st century

AR4 (2007)

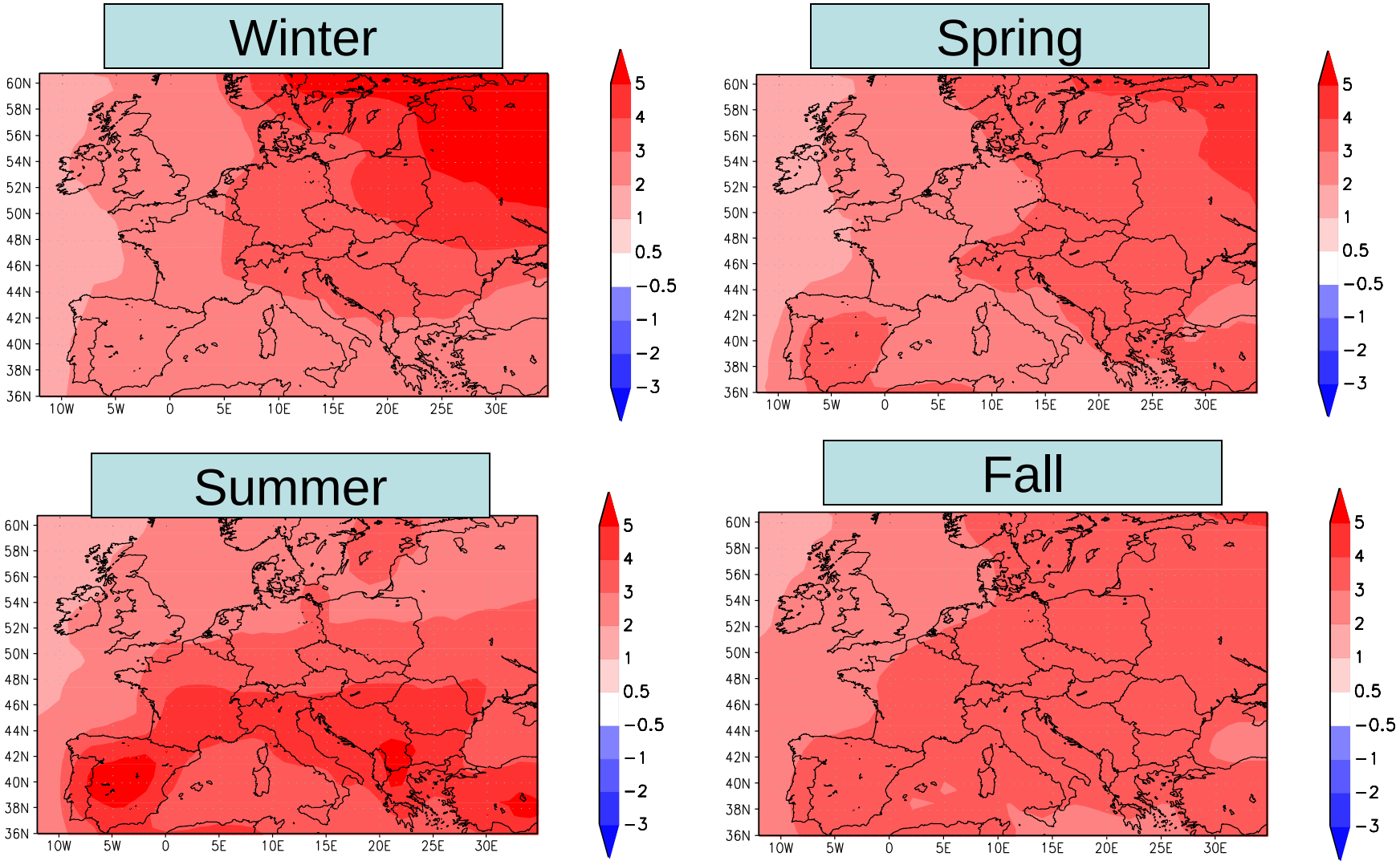


AR5 (2013)

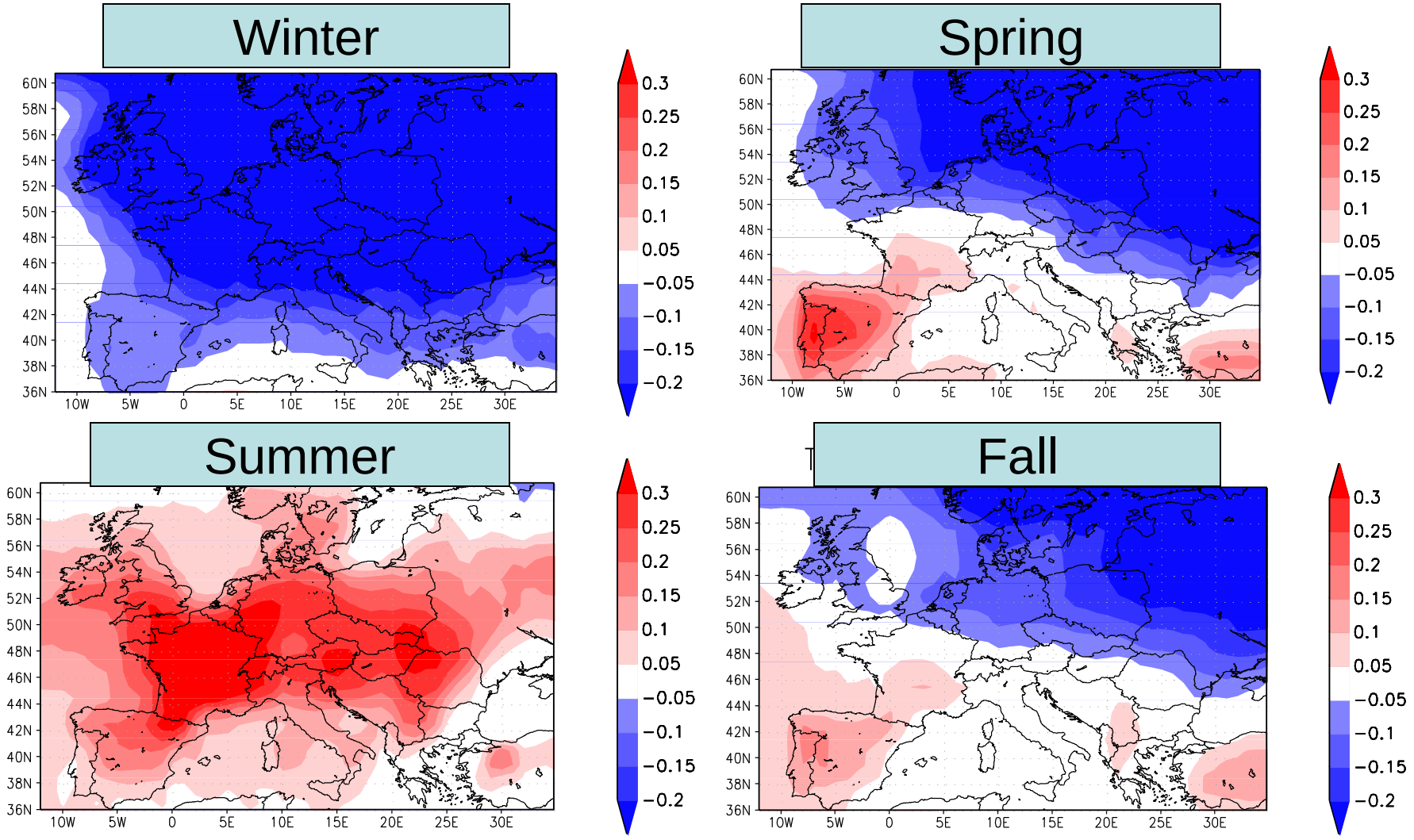



Mediterranean
climate change
from GCM
ensembles
(CMIP3, CMIP5)

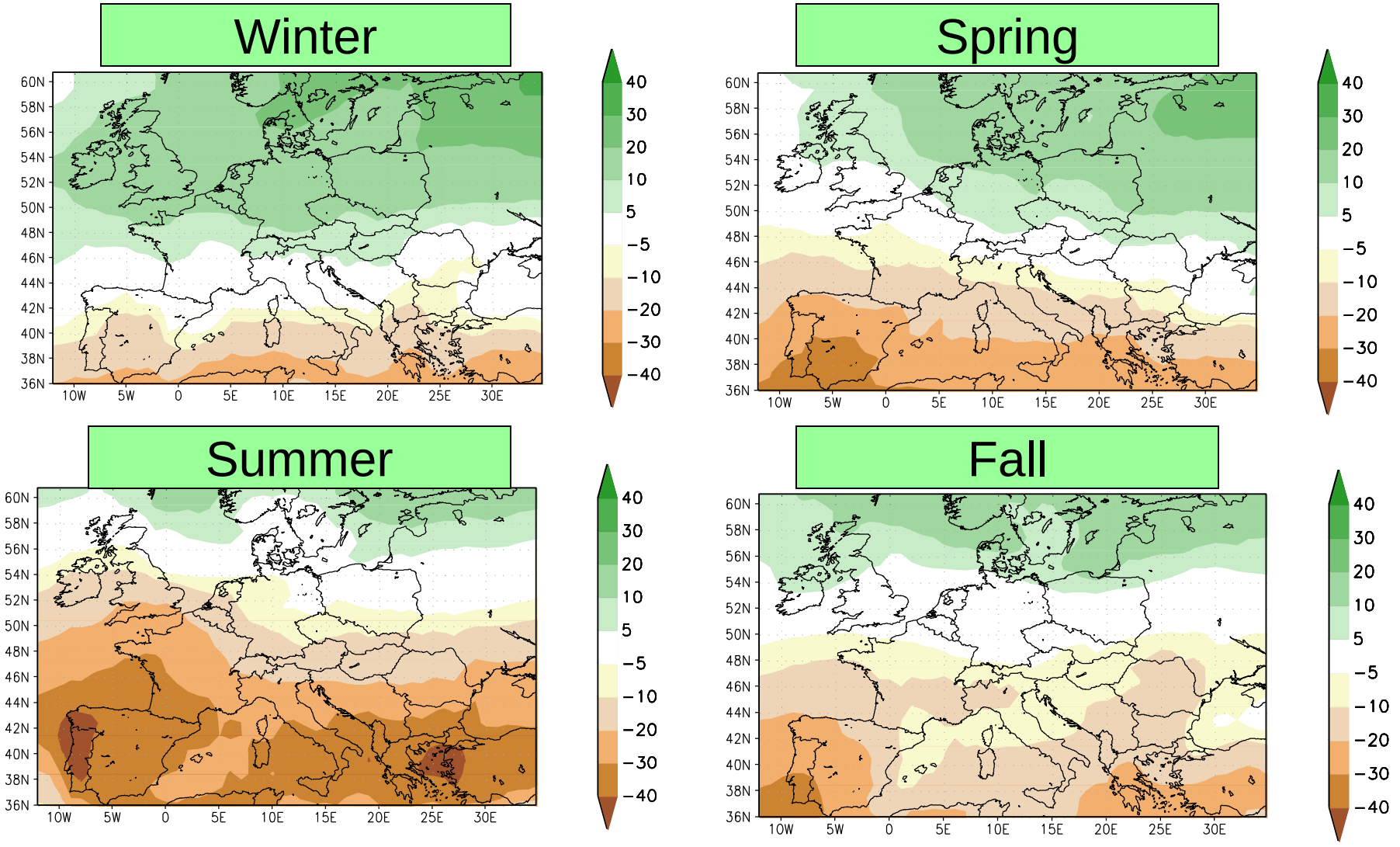
Temperature change, CMIP3
A1B Scenario, 20 AOGCMs

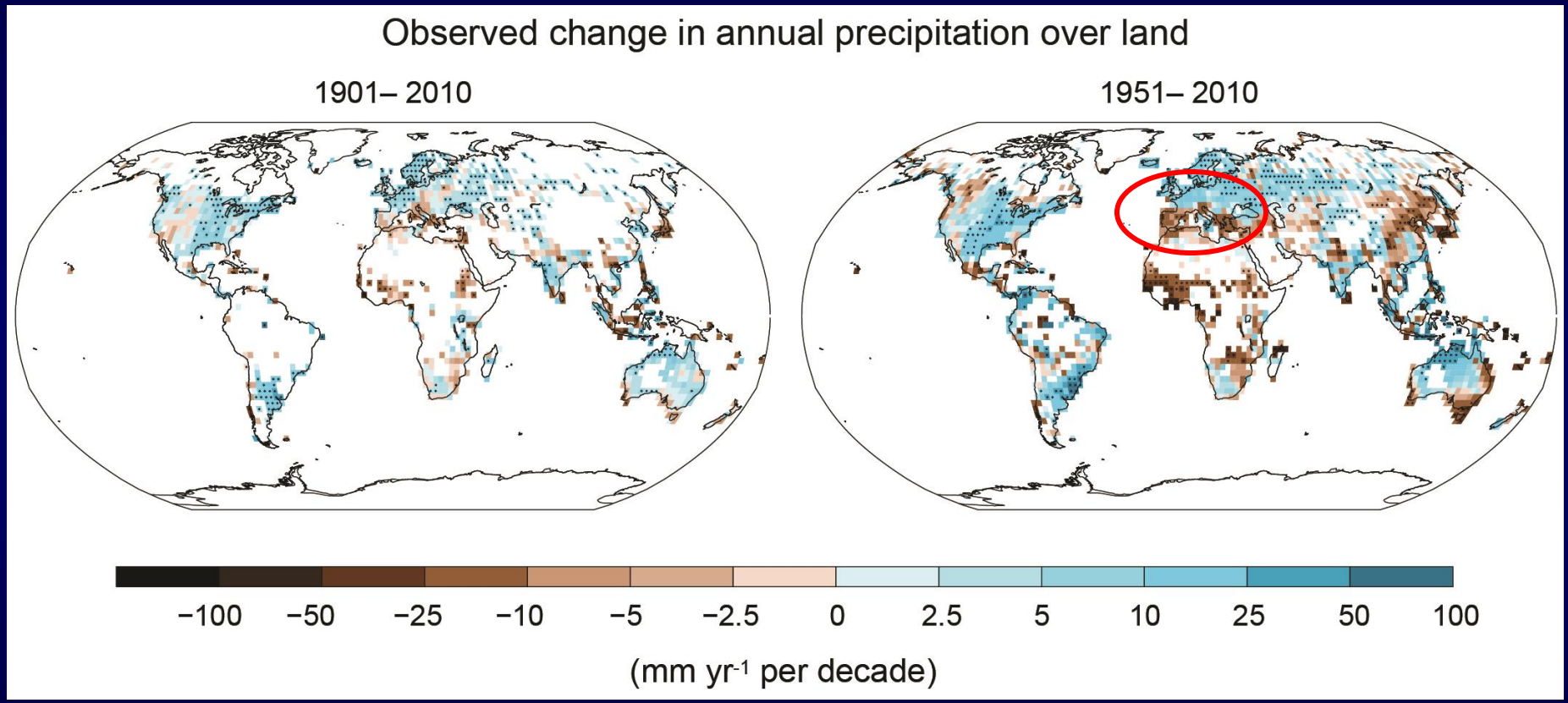


Temperature variability change, CMIP3 A1B Scenario, 20 AOGCMs

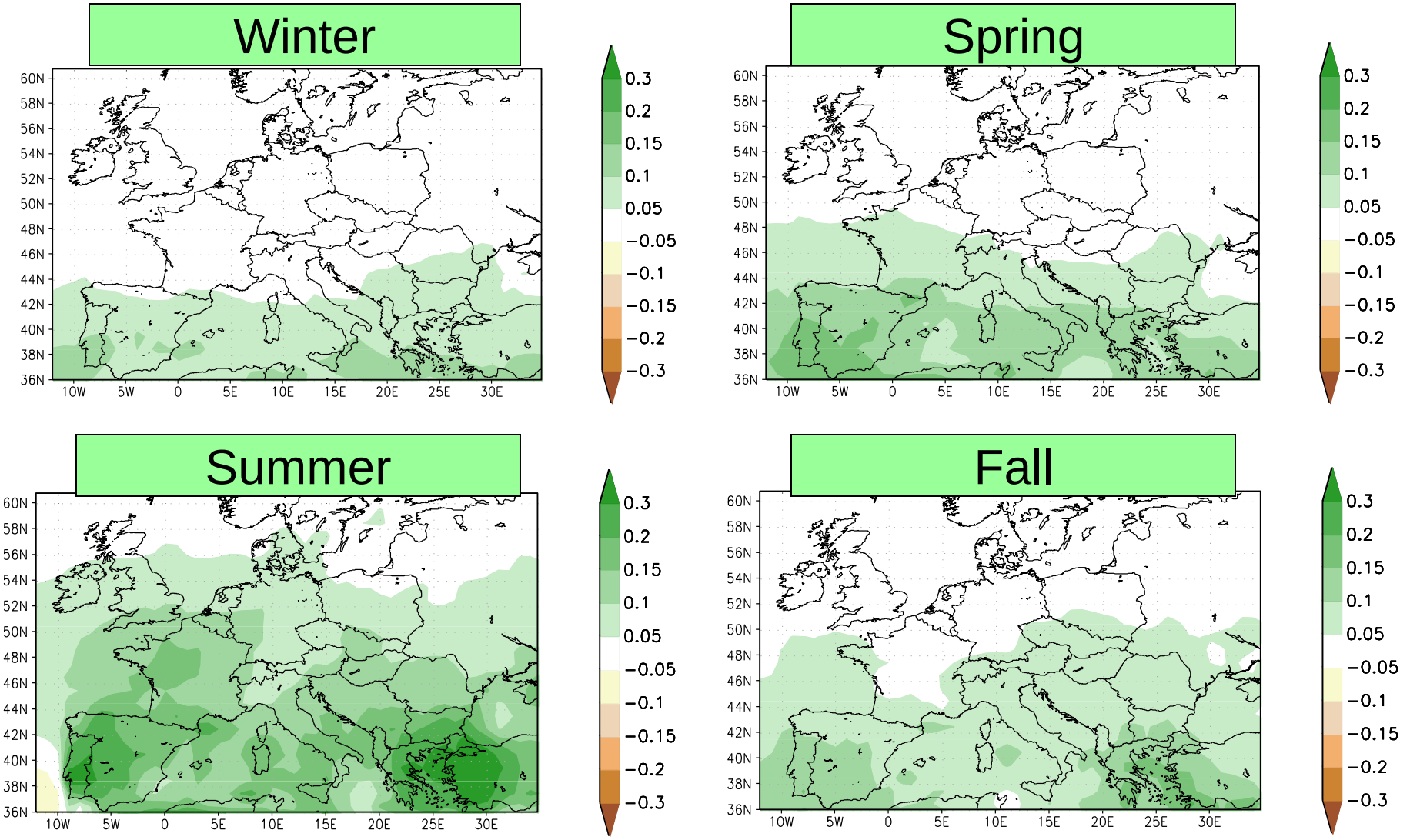


Precipitation change, CMIP3
A1B Scenario, 20 AOGCMs




Observed change in annual precipitation over land
1901– 2010
1951– 2010
−100
−50
−25
−10
−5
−2.5
0
2.5
5
10
25
50
100
(mm yr-1 per decade)

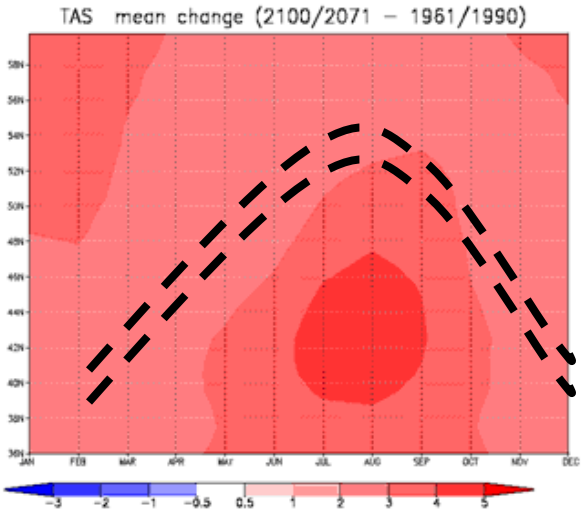
Precipitation variability change, CMIP3 A1B Scenario, 20 AOGCMs

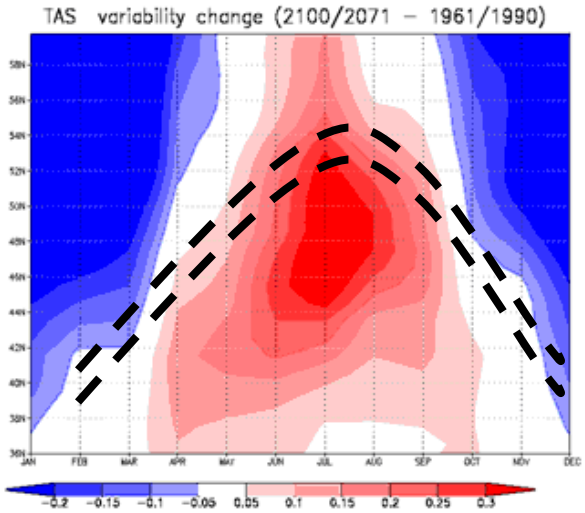


The European Climate Change Oscillation (ECO)

(A1B, 2071-2100 minus 1961-1990, Giorgi and Coppola, GRL 2007)

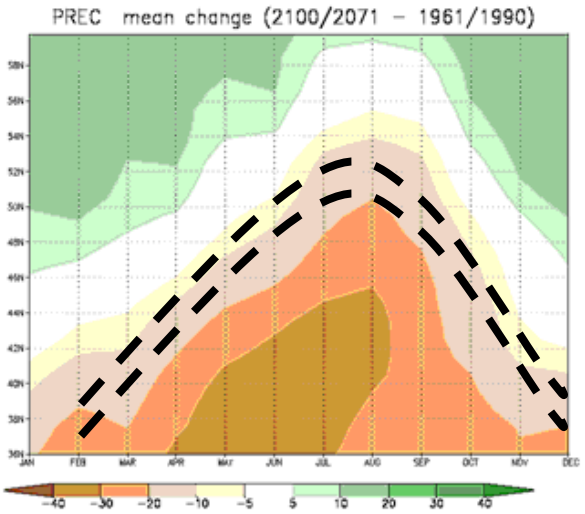
T-Mean

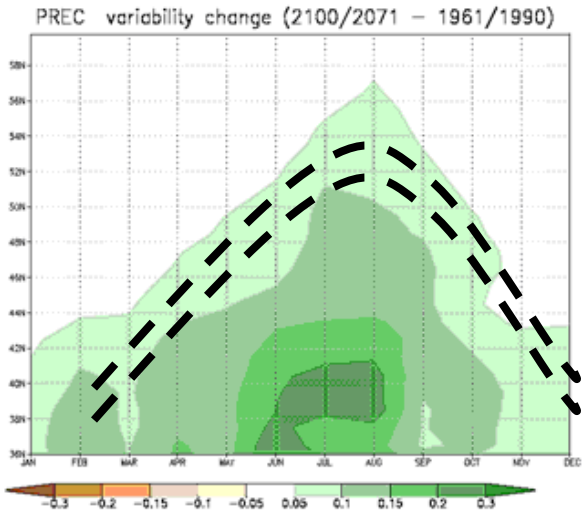




T-Var

P-Mean

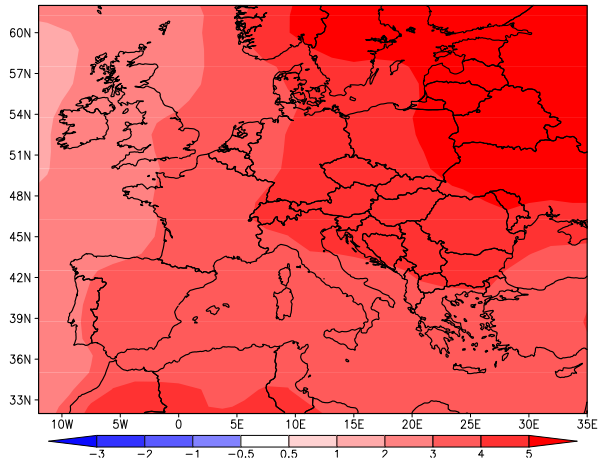




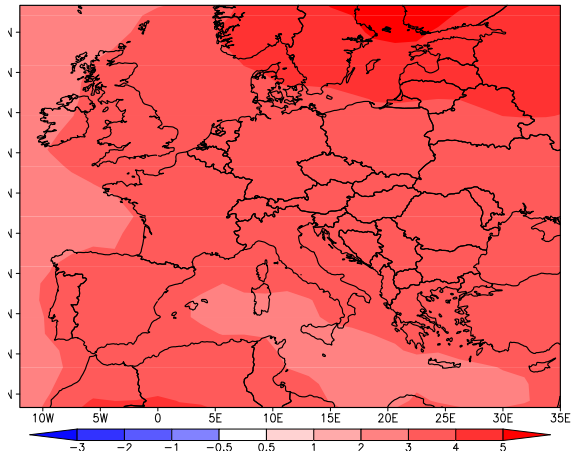
P-Var

Temperature change (2071-2100), CMIP5 RCP8.5 Scenario, 21 AOGCMs

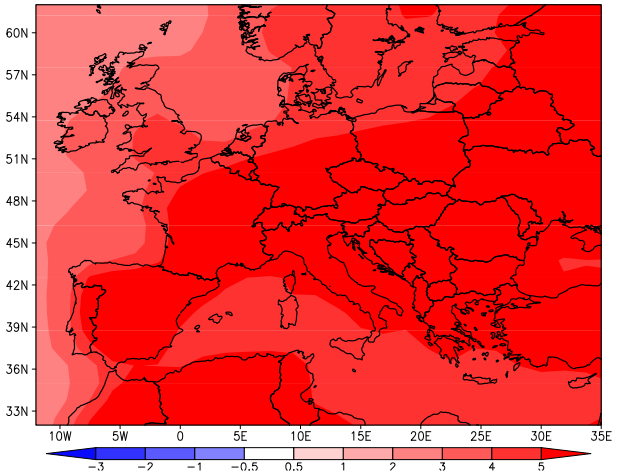
Winter



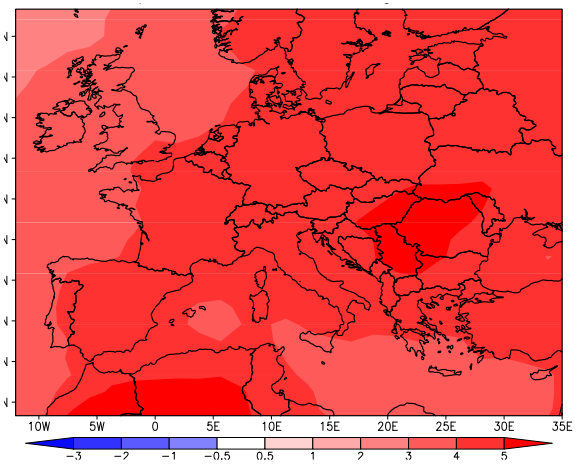
Spring



Summer

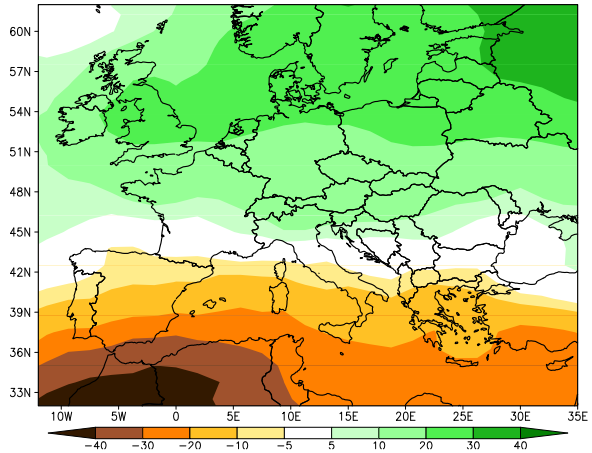


Fall

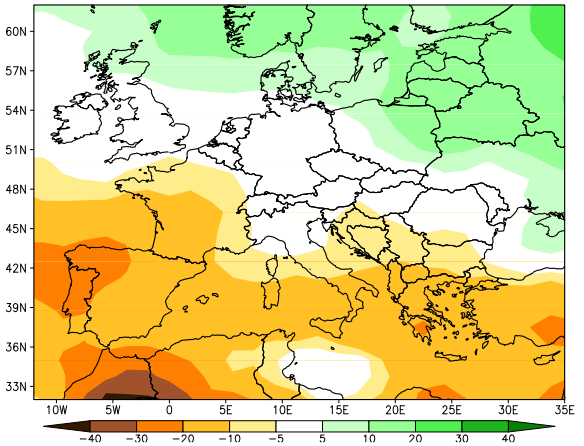


Precipitation change (2071-2100), CMIP5 RCP8.5 Scenario, 21 AOGCMs

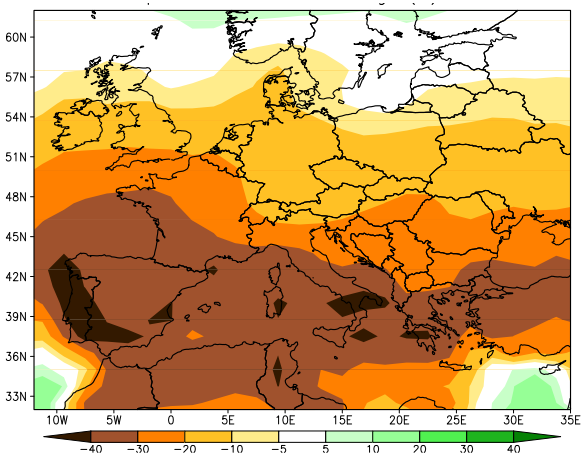
Winter



Spring



Summer



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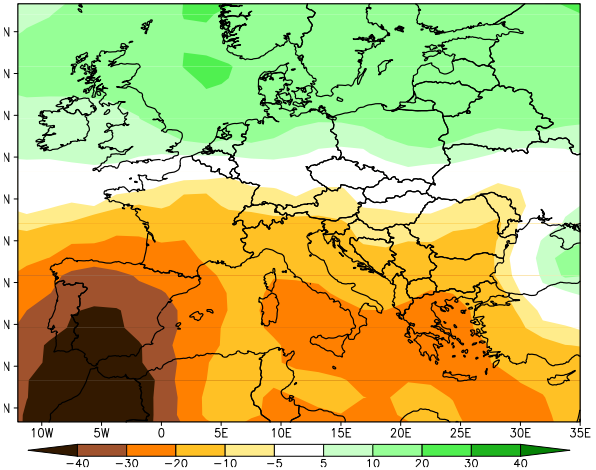
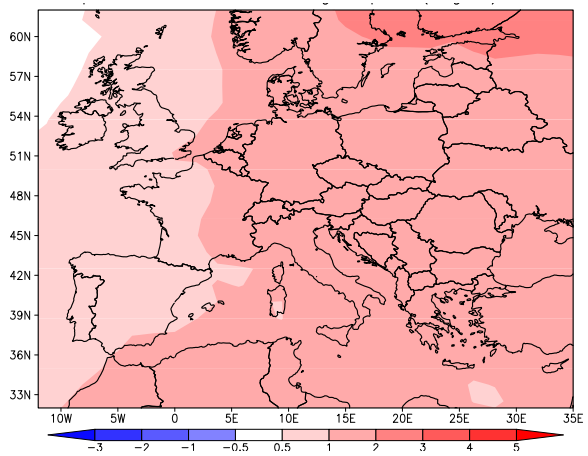
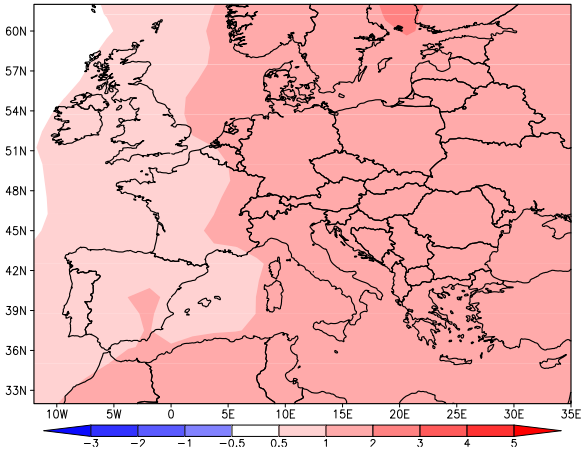


Temperature change (2071-2100), CMIP5 RCP2.6 Scenario, 9 AOGCMs

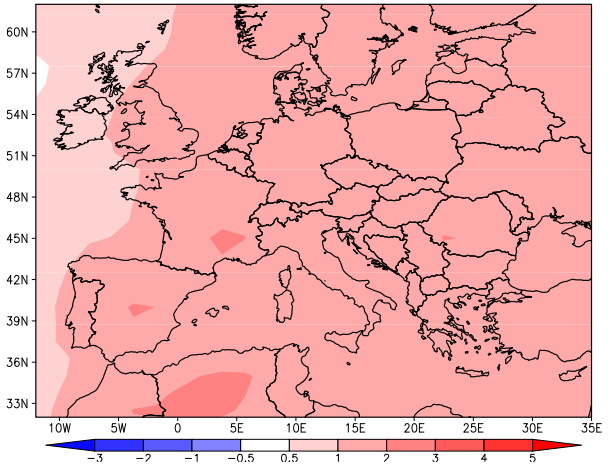
Winter



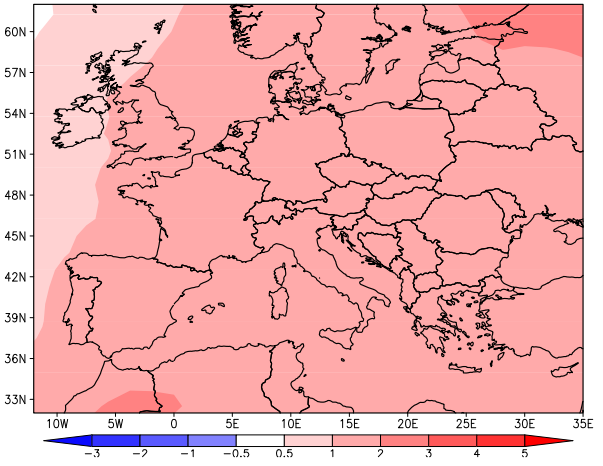
Spring



Summer

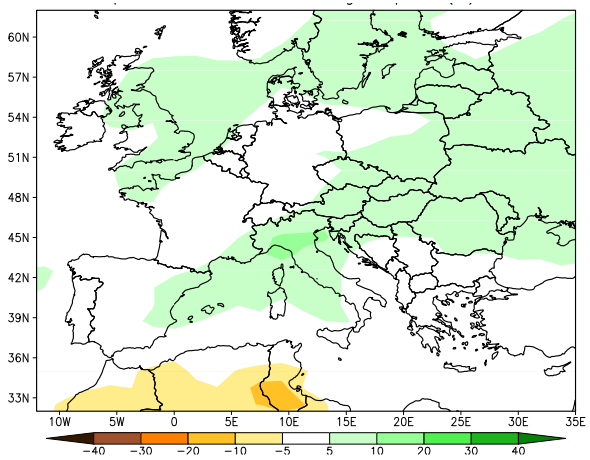


Fall

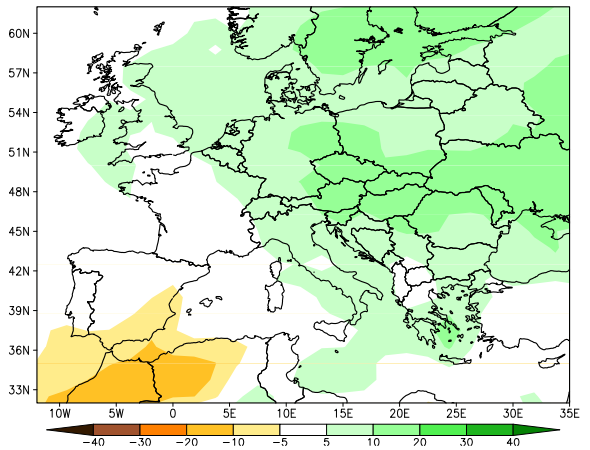


Precipitation change (2071-2100), CMIP5 RCP2.6 Scenario, 9 AOGCMs

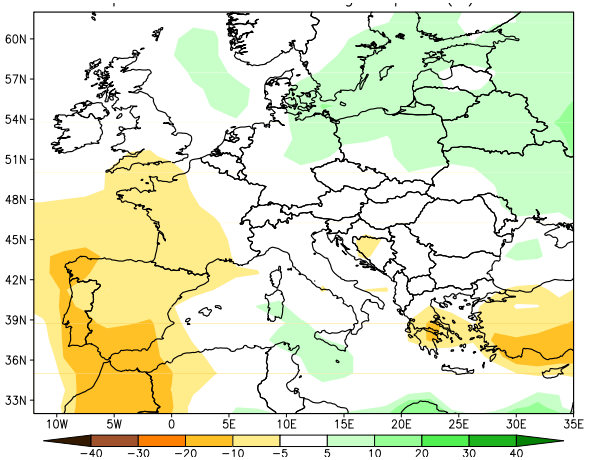
Winter



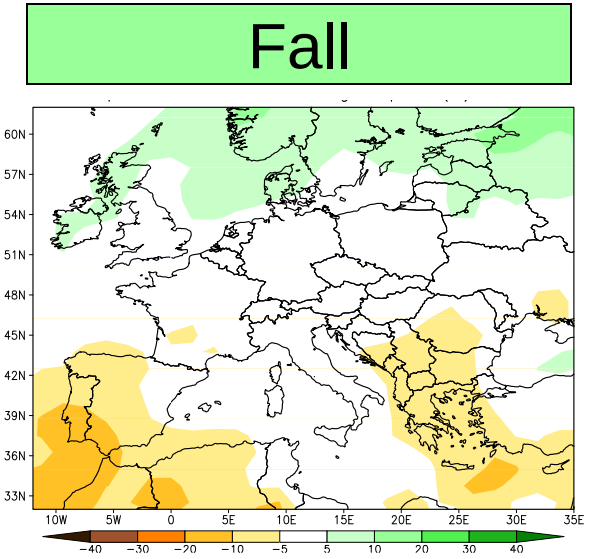
Spring



Summer

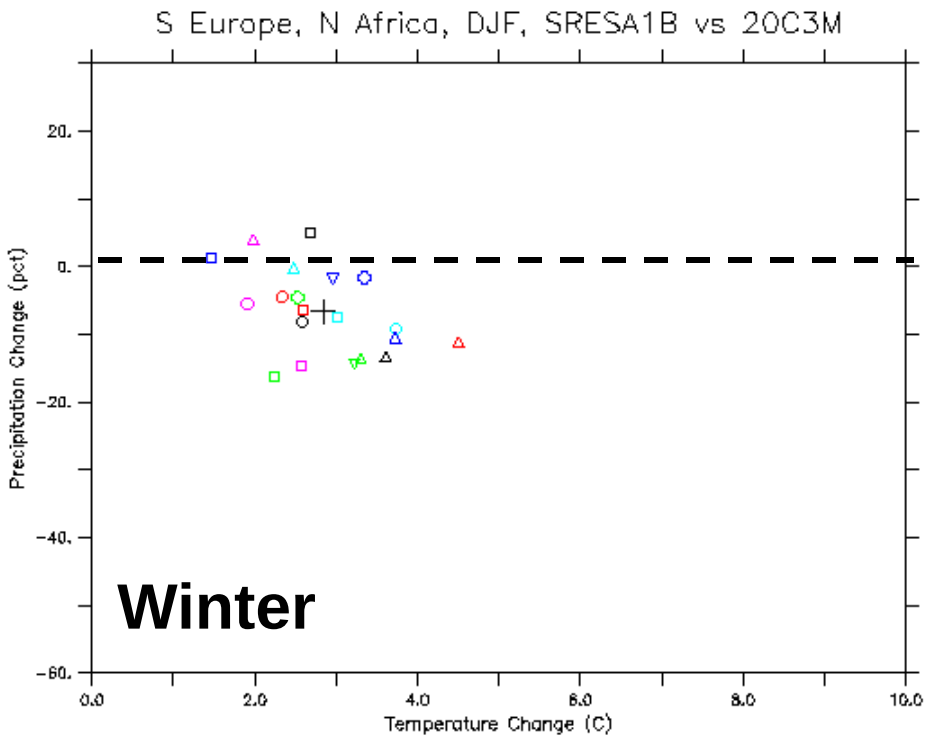


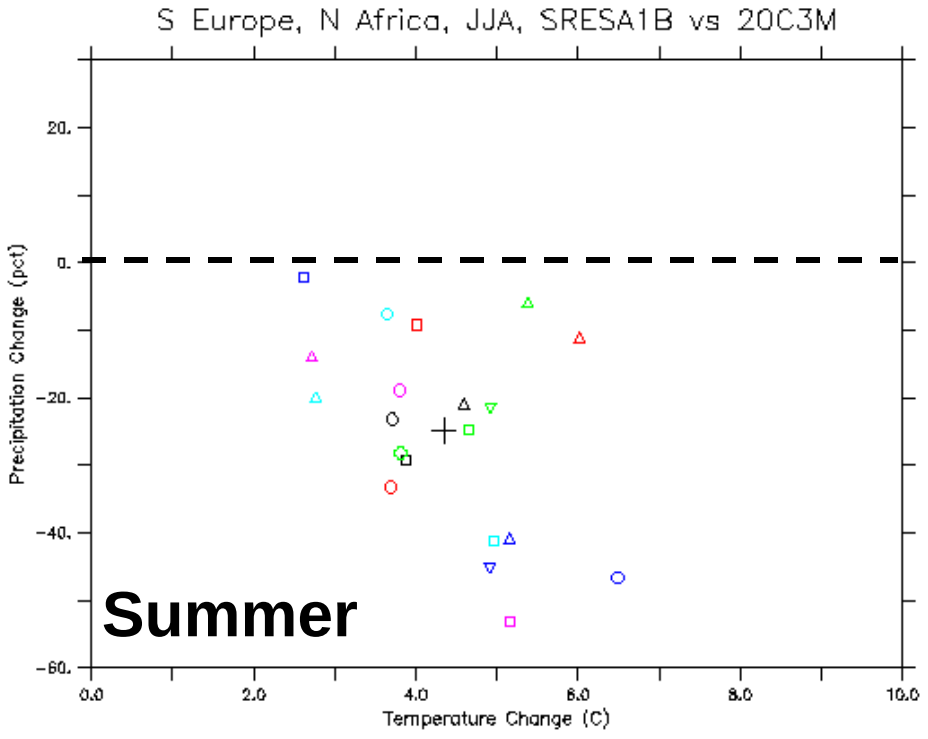
Fall



Projections of temperature and precipitation change over the Mediterranean in 21 CMIP3 AOGCMs

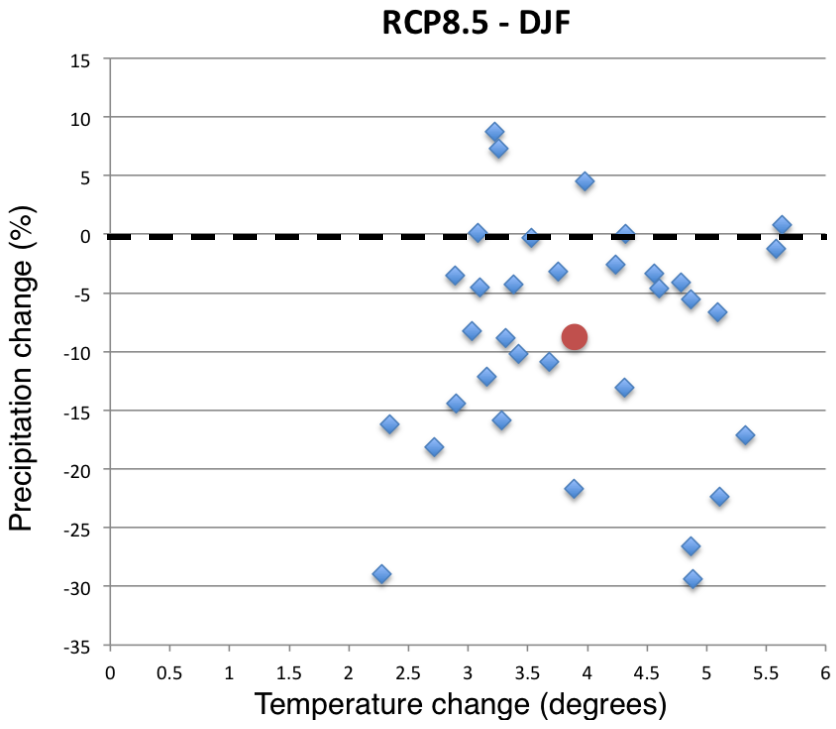
Scenario A1B, 2090-2100

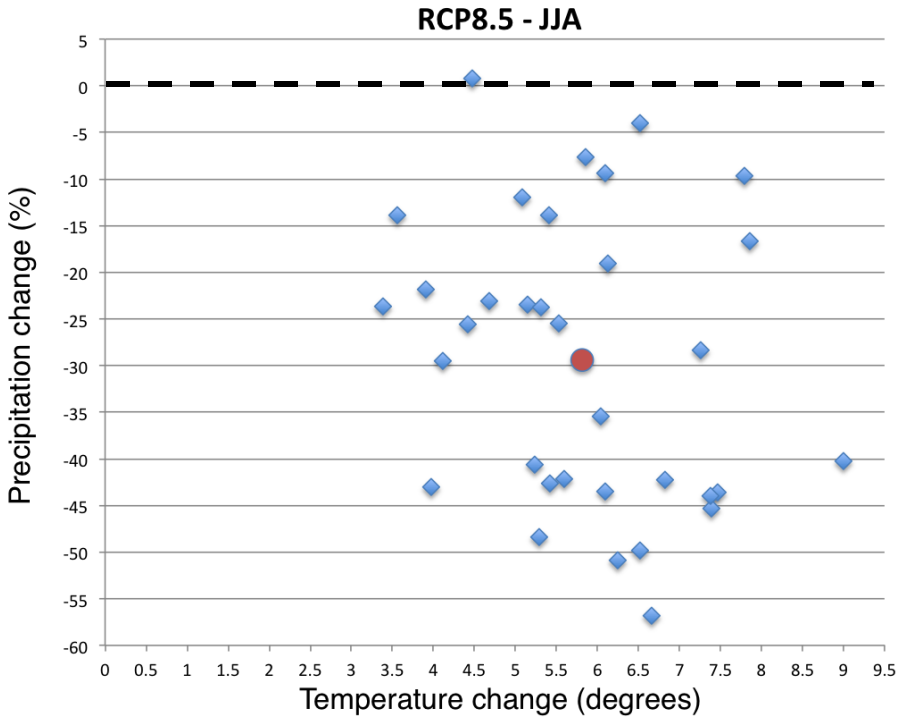




Projections of temperature and precipitation change over the Mediterranean in 32 CMIP5 AOGCMs

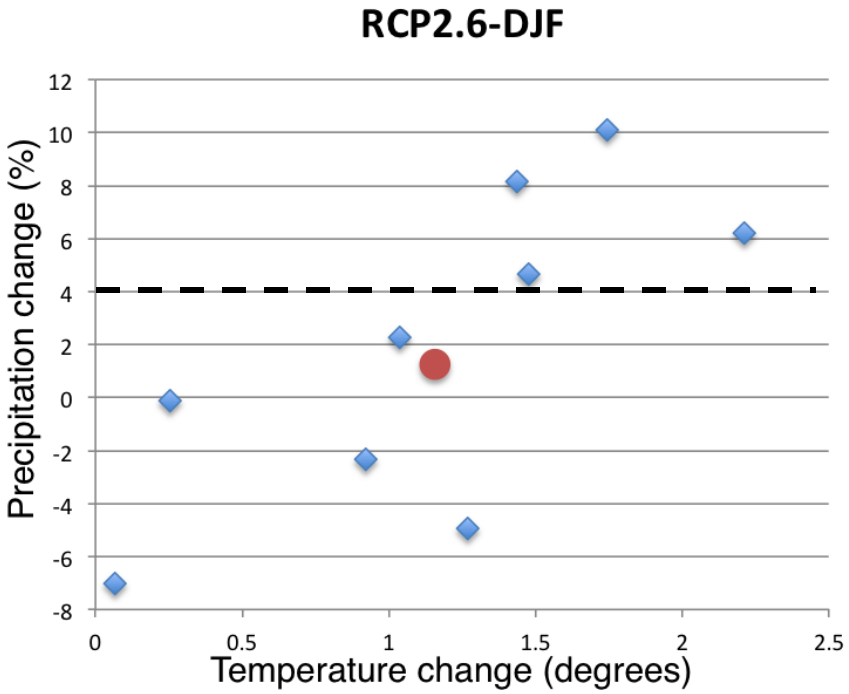
Scenario RCP8.5, 2071-2100

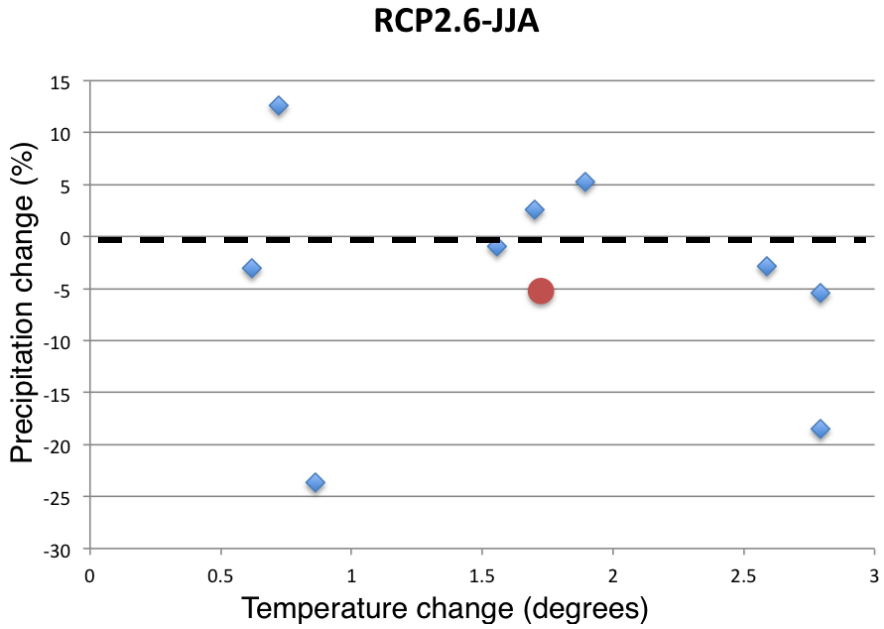




Projections of temperature and precipitation change over the Mediterranean in 9 CMIP5 AOGCMs

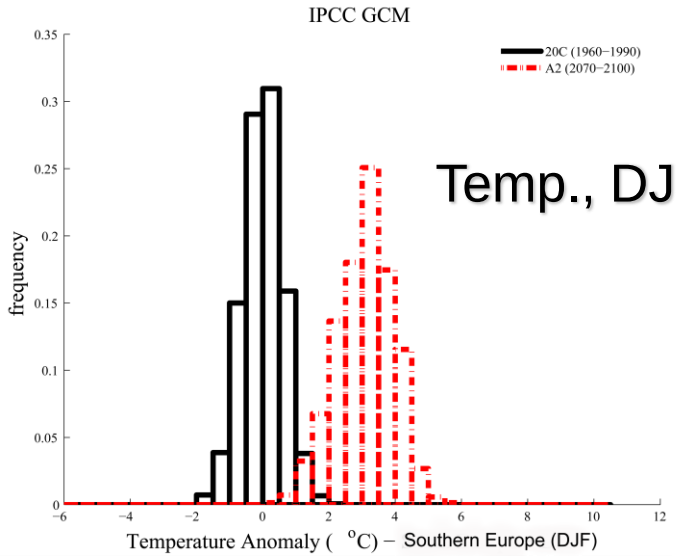
Scenario RCP2.6, 2071-2100



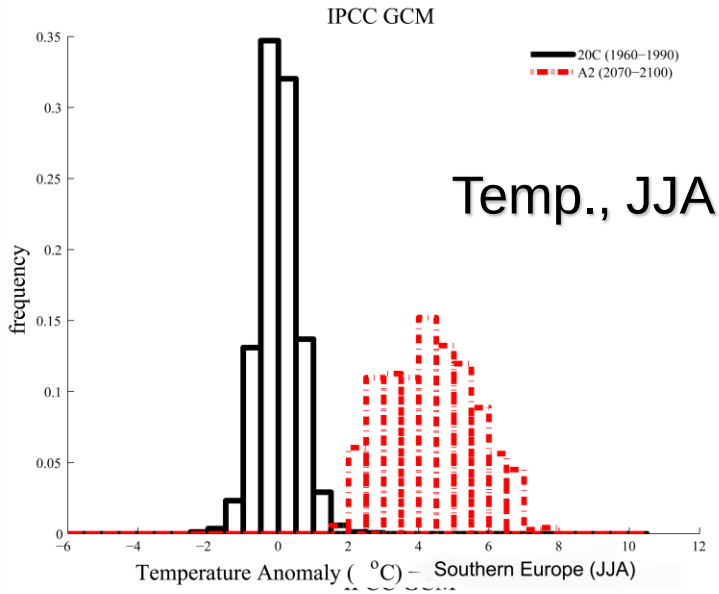


Change in seasonal precipitation distribution

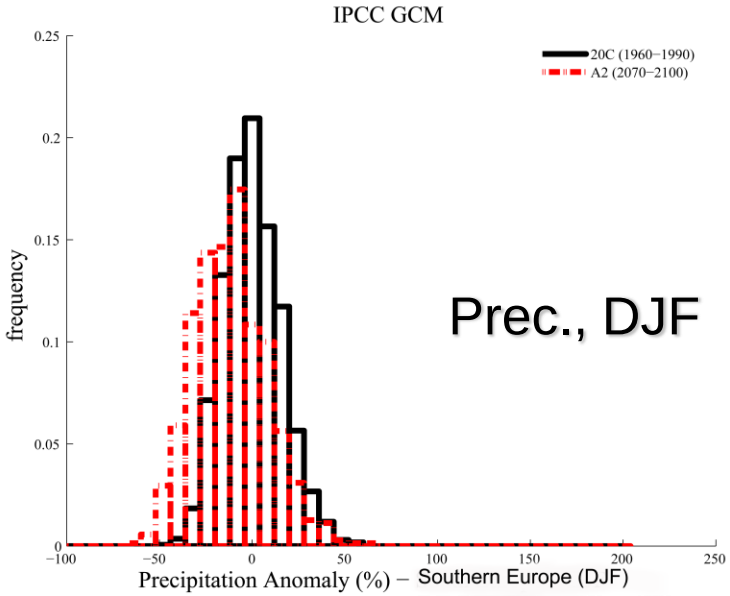
CMIP3 Ensemble (%, 2071-2100 minus 1961-1990),



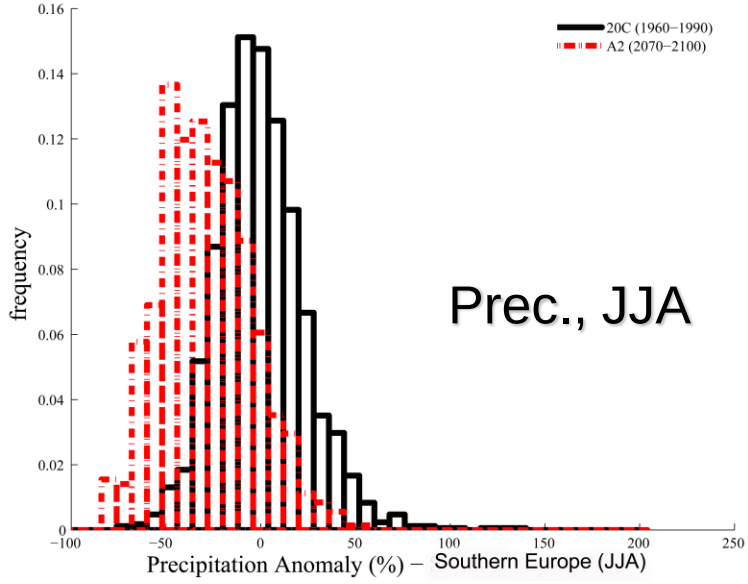
Temp., DJF



Temp., JJA



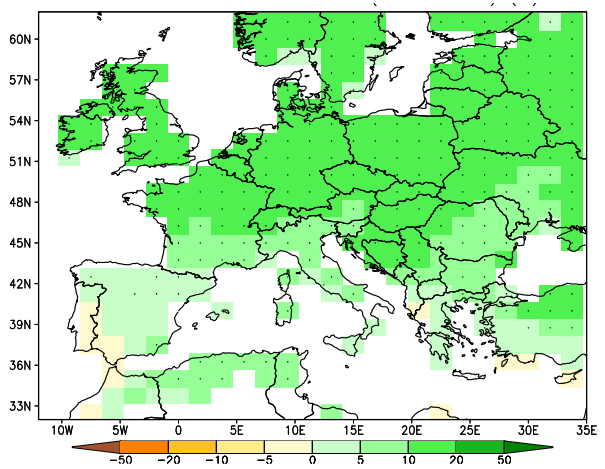
Prec., DJF



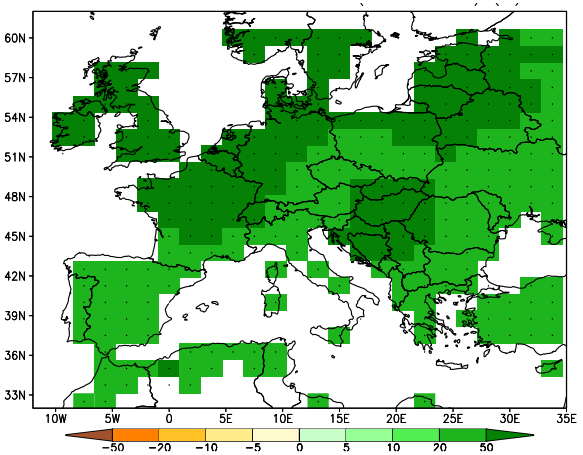
Prec., JJA

Trends in hydroclimatic indices (2006-2100) RCP8.5, 9 CMIP5 AOGCMs (Giorgi et al, 2014)

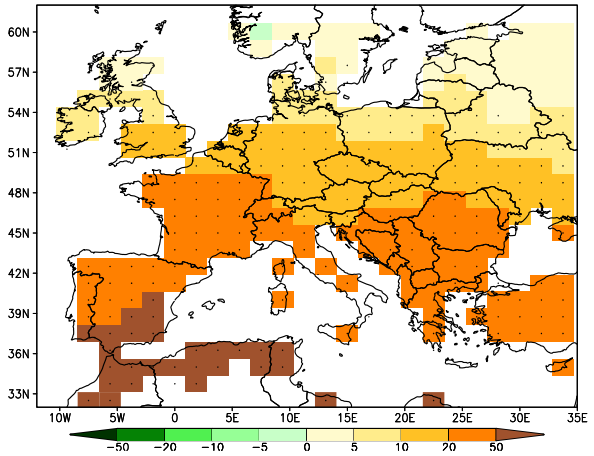
SDII



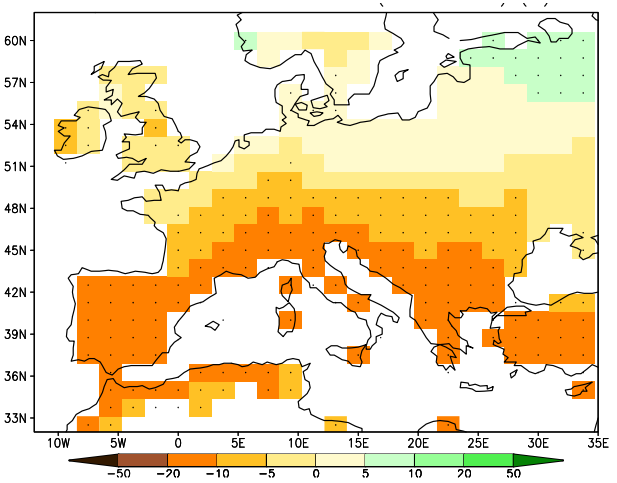
R95Tot



Dry Spell Length

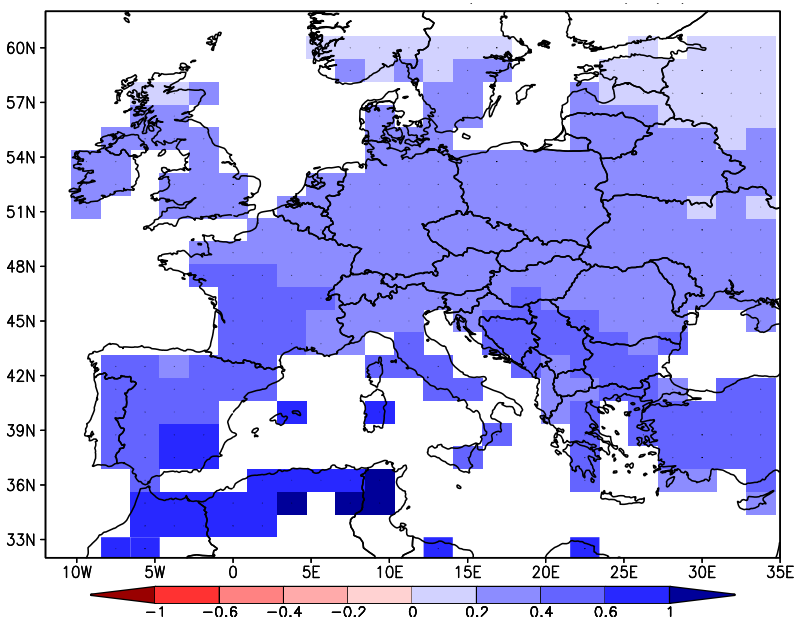


Wet Spell Length

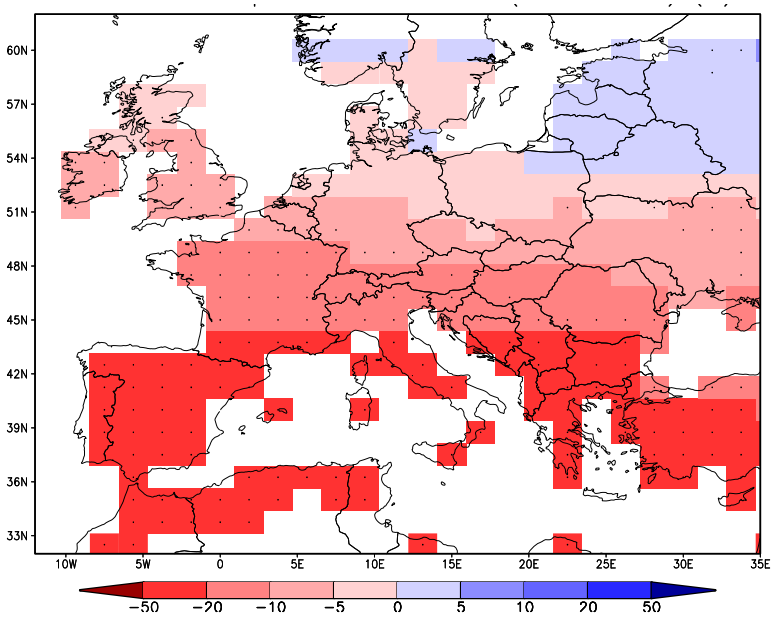


Trends in hydroclimatic indices (2006-2100) RCP8.5, 9 CMIP5 AOGCMs (Giorgi et al. 2014)

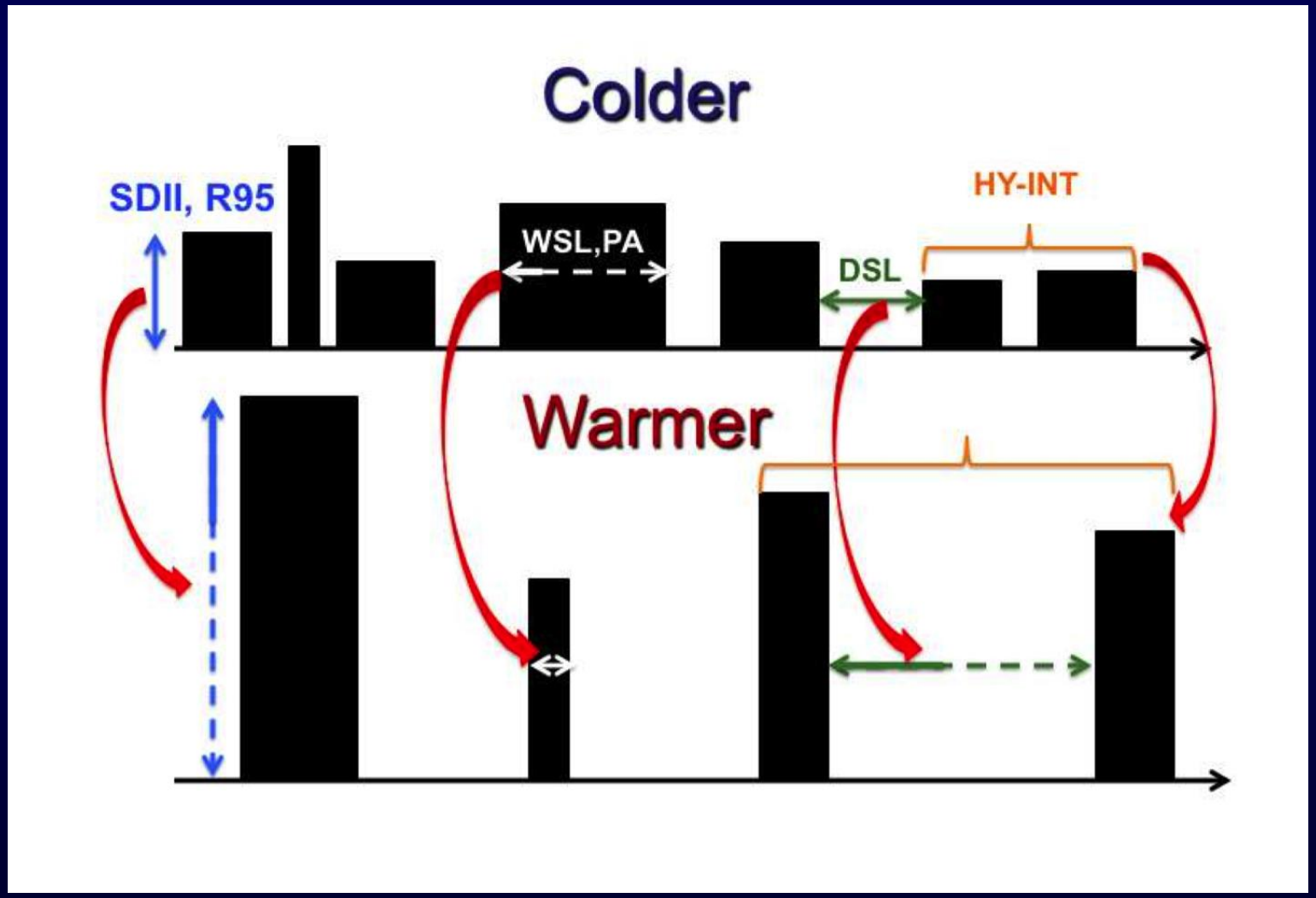
HY-Int

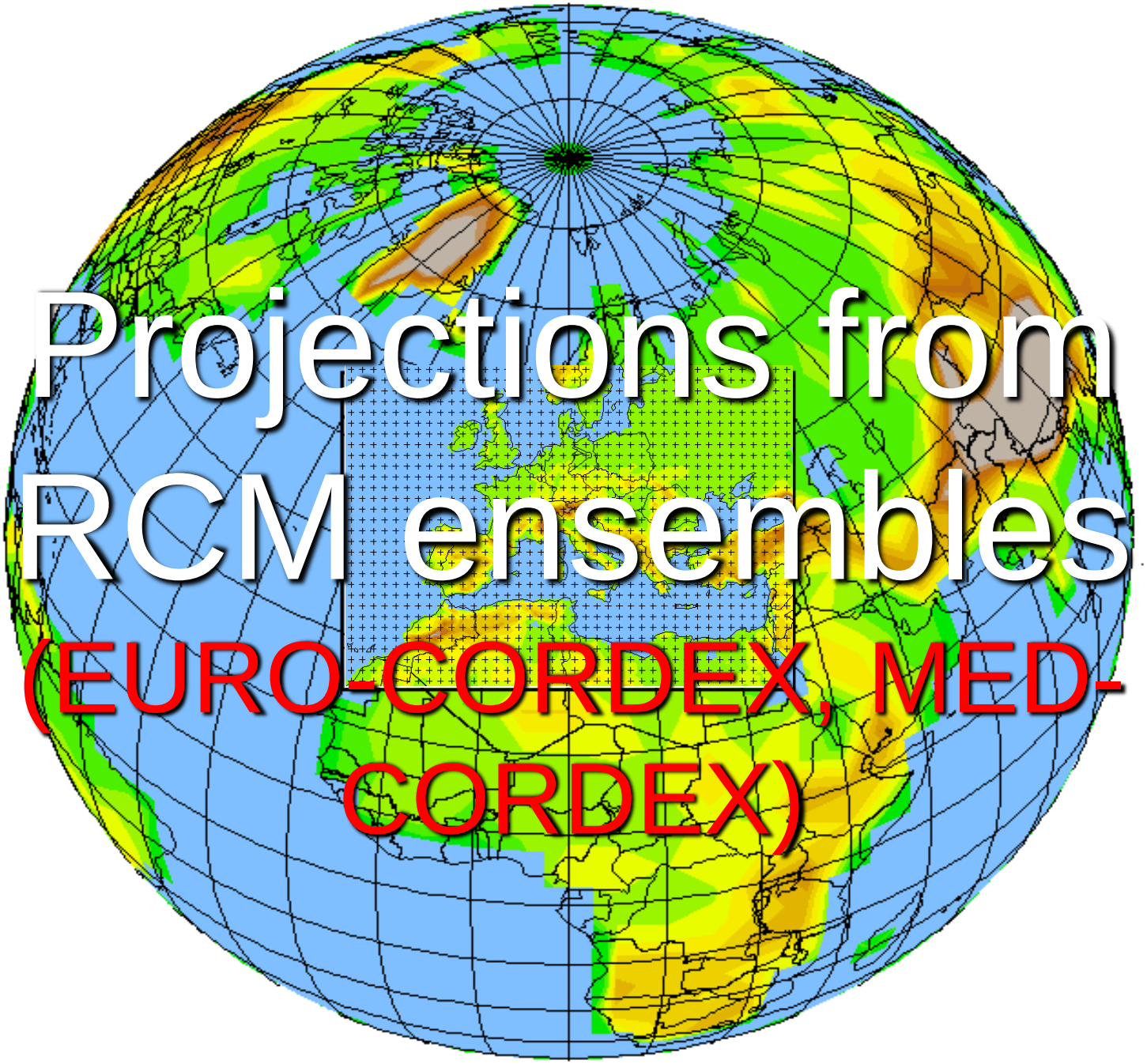


Prec. Area



Hydroclimatic response to global warming emerging from the analysis of multiple interconnected indices (Giorgi et al. 2014)



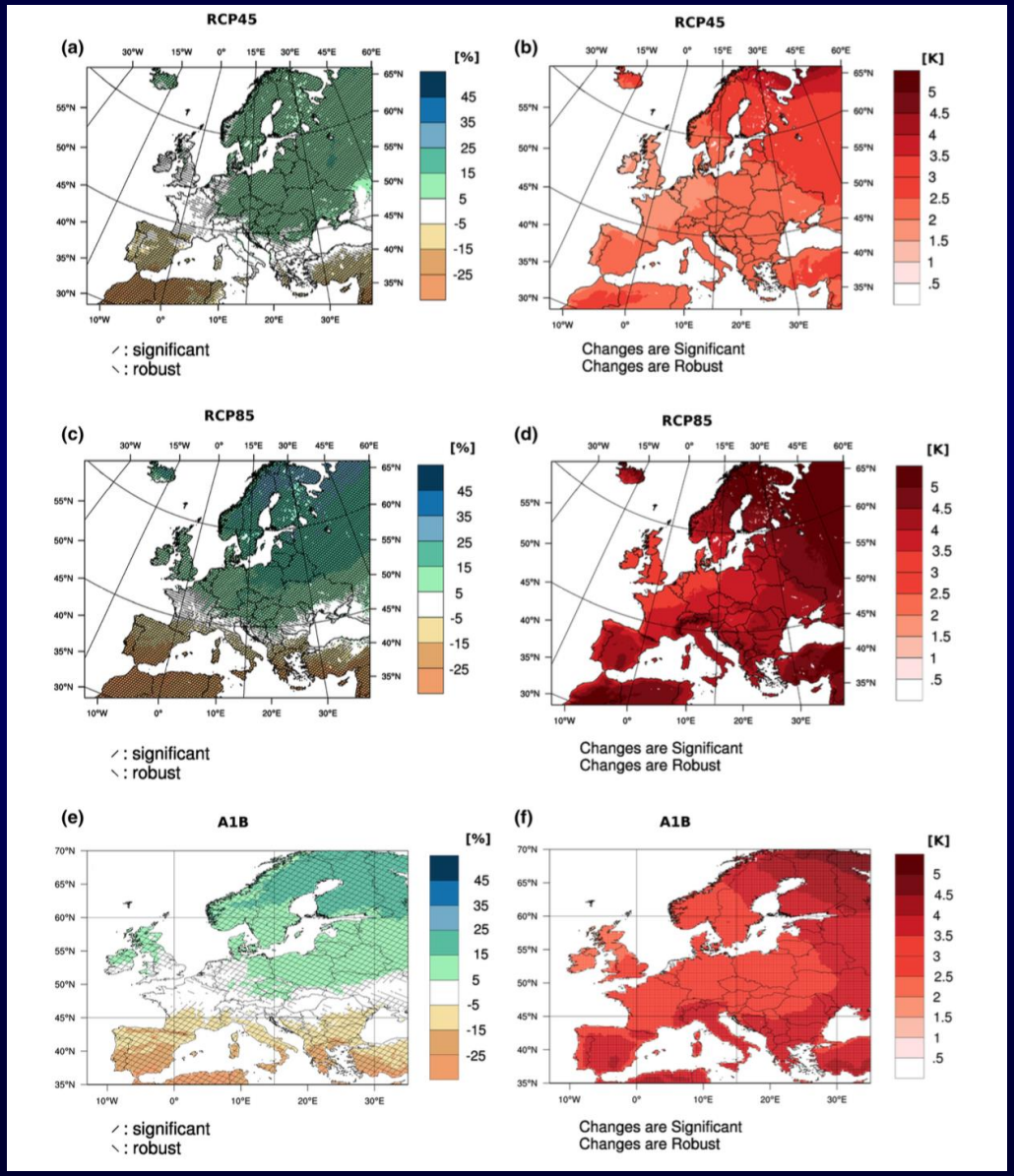


Projections from RCM ensembles

(EURO-CORDEX, MED-CORDEX)

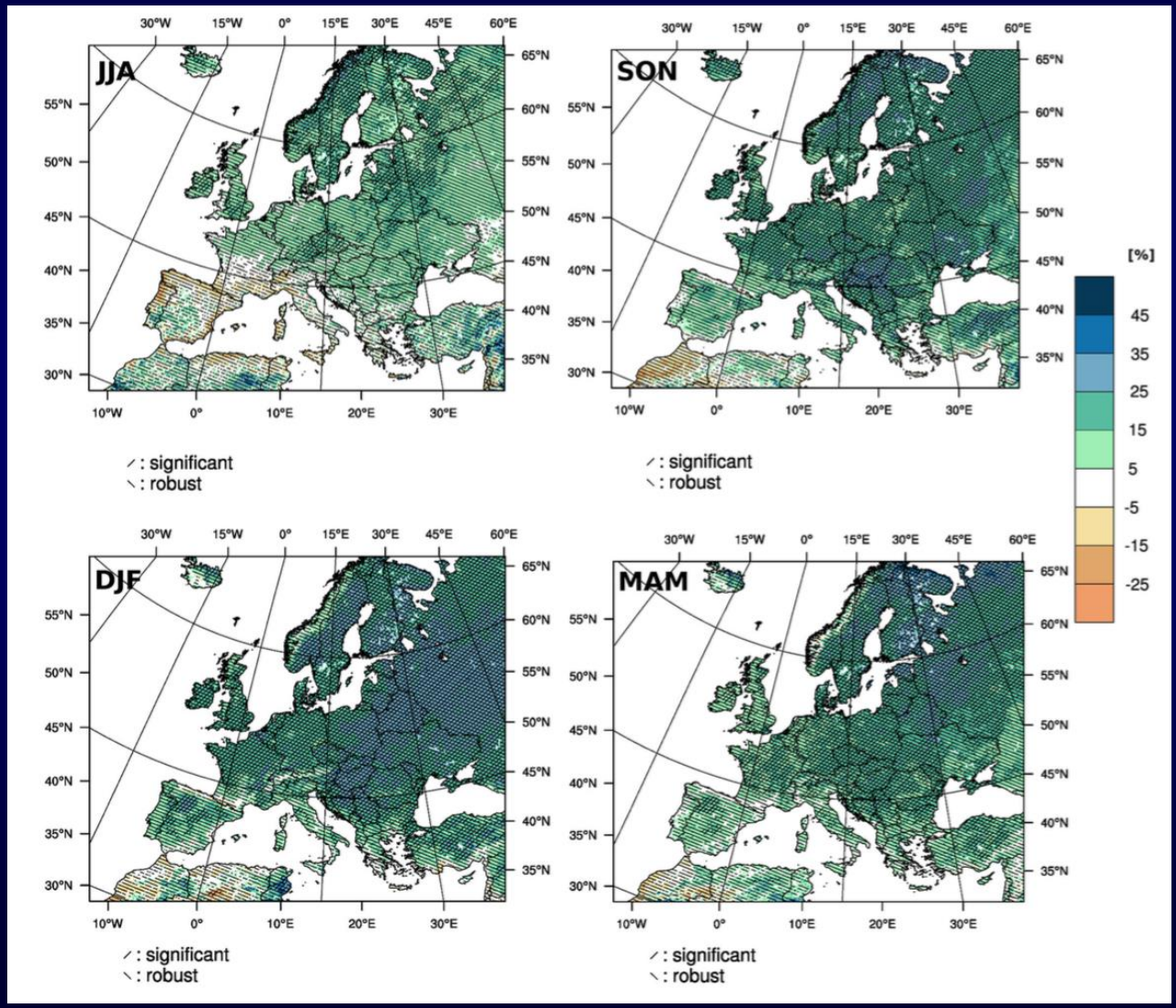
Change in mean annual precipitation (left column) and temperature (right column) in different RCM ensembles

2071-2100
minus
1971-2000

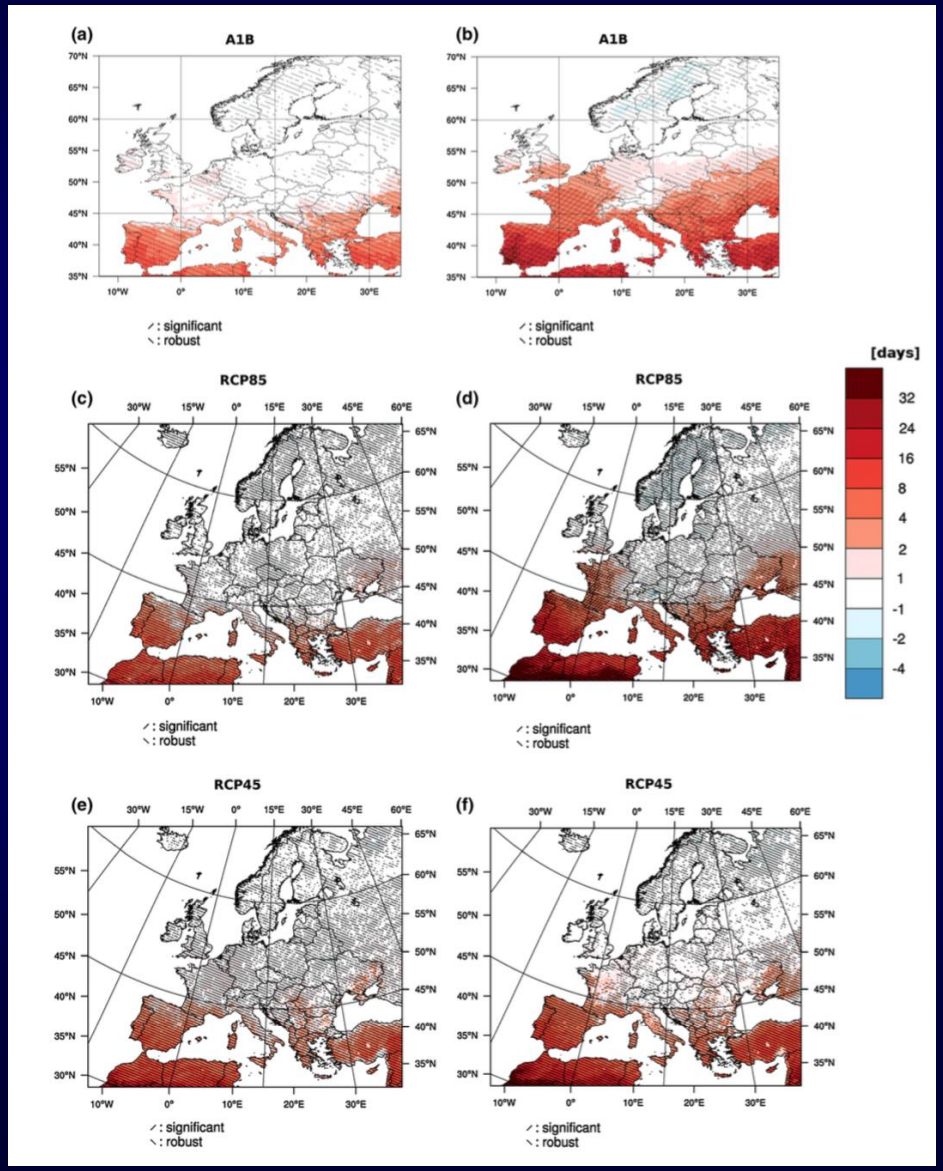


Jacob et al.
2014

Change in mean annual heavy precipitation (95%) in the EURO-CORDEX ensemble (RCP8.5, 2071-2100 minus 1971-2000)



Change in mean annual “long” dry spell (95%) in different RCM ensembles (2071-2100 minus 1971-2000)

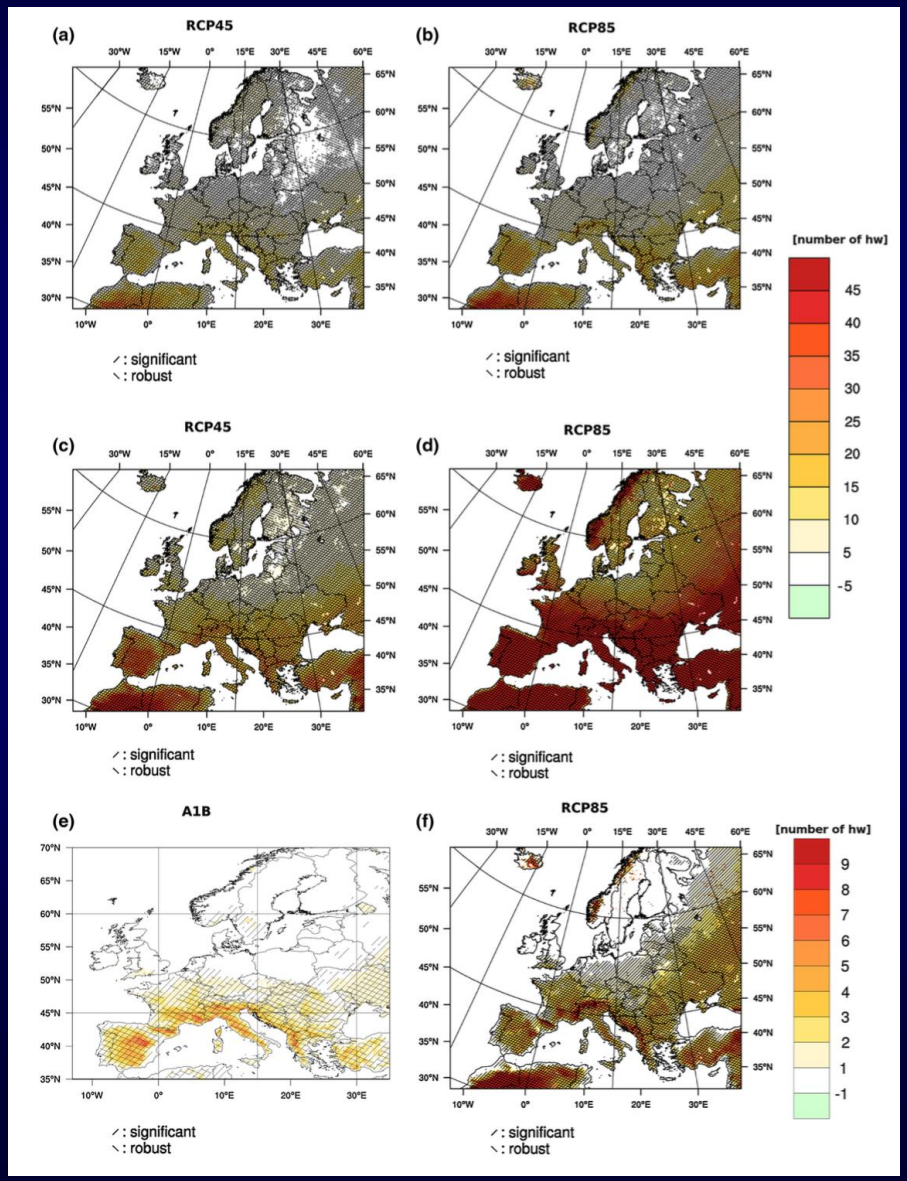


Change in warm season heat waves in different RCM ensembles

2021-2050
minus
1971-2000

2071-2100
minus
1971-2000

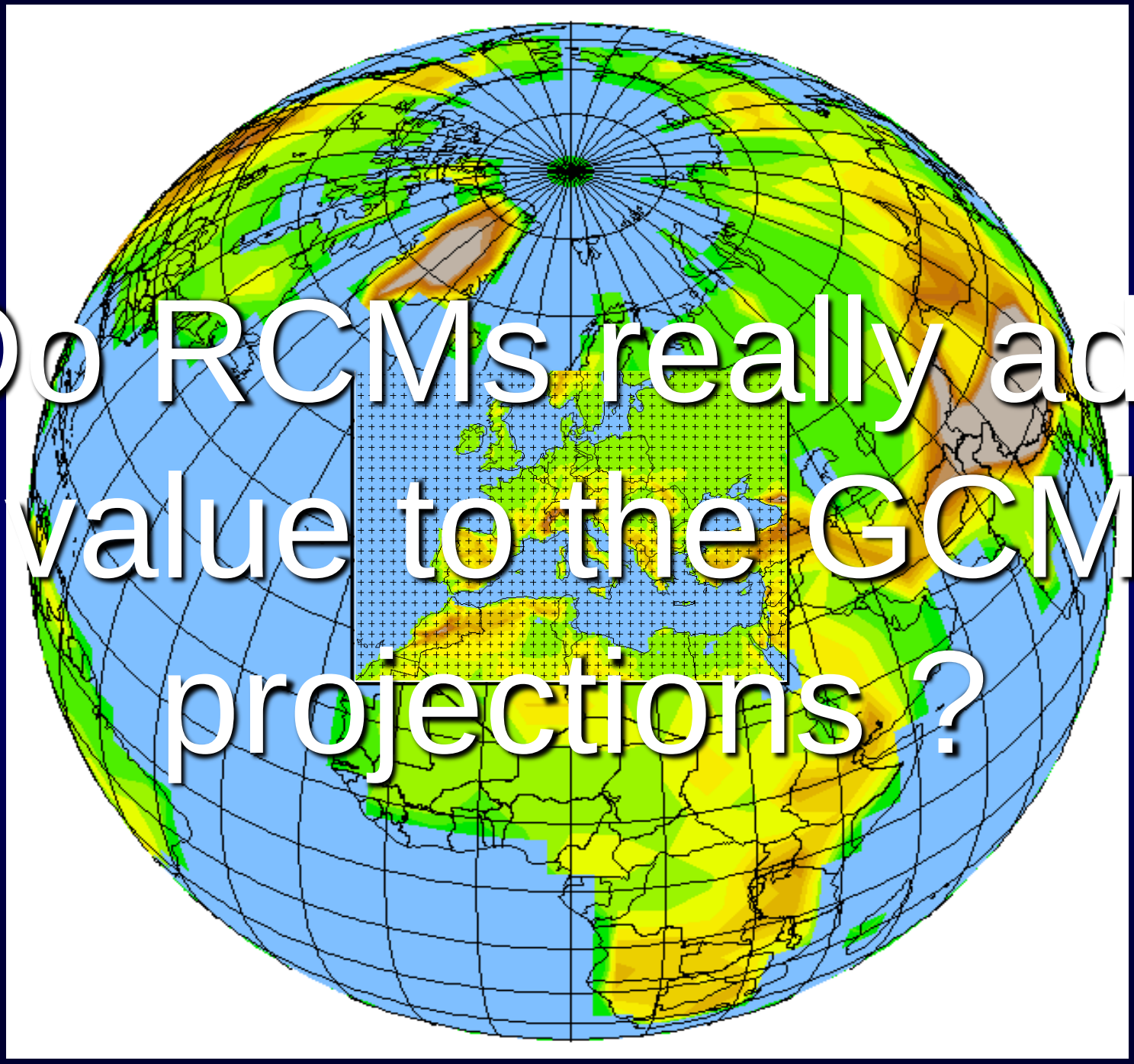
2071-2100
minus
1971-2000



3cd > 99%

3cd > 99%

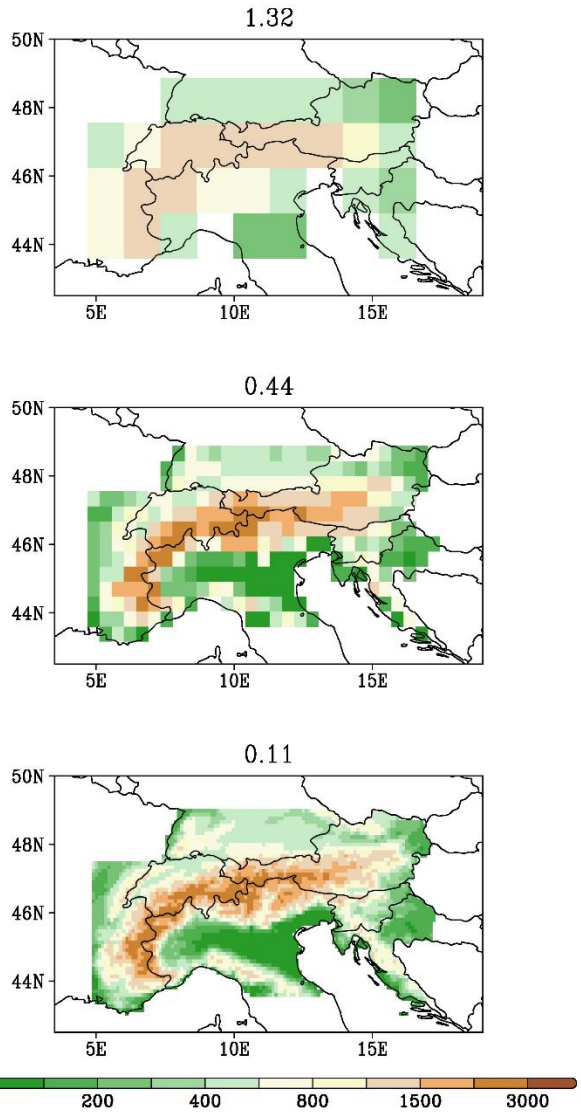
5cd > 5C



Do RCMs really add value to the GCM projections ?

Torma et al. (2015), Giorgi et al. (2016)

DATA



Horizontal resolutions: 1.32°, 0.44° and 0.11°

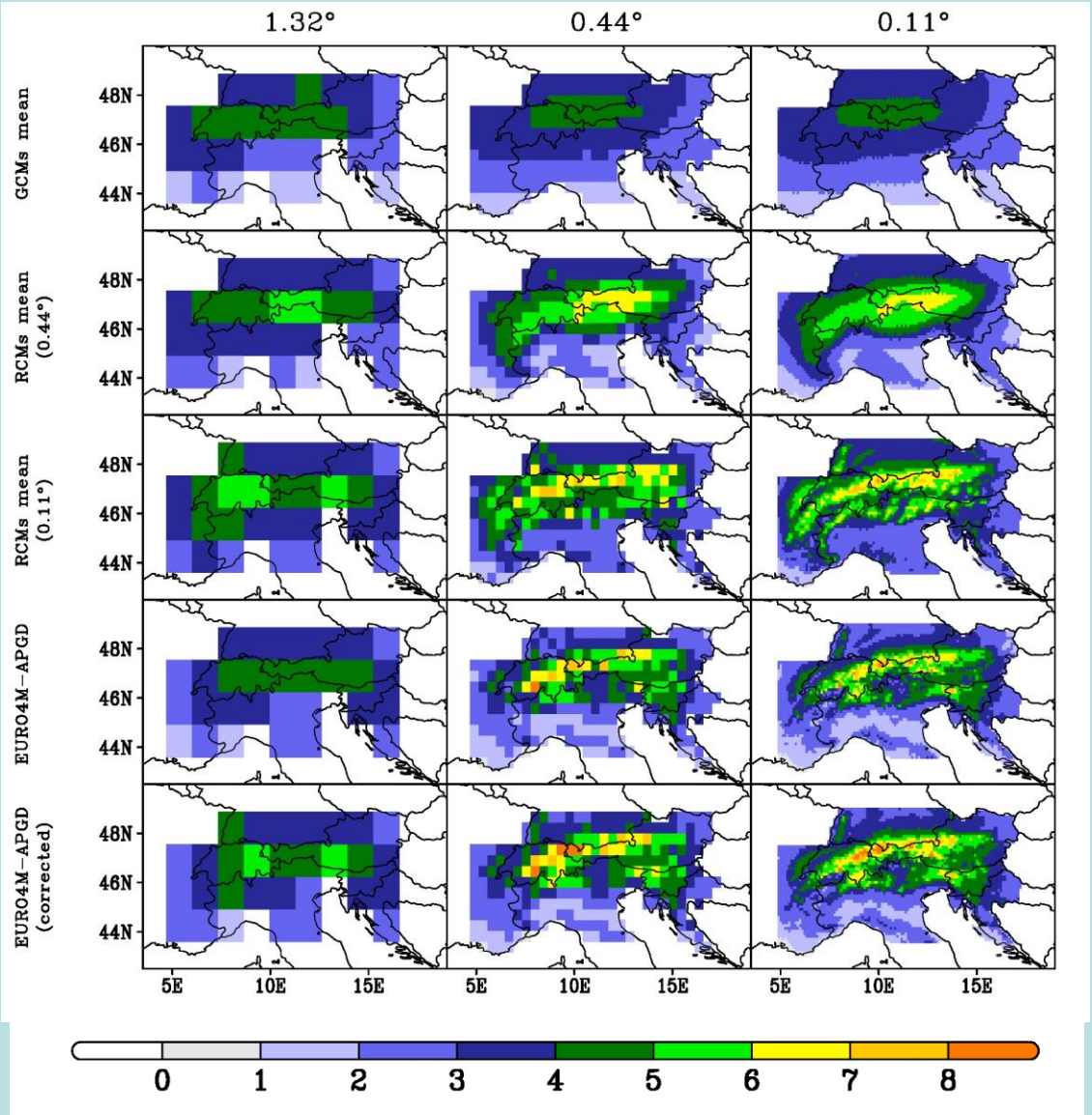
GCMs :
- MPI-ES-MR
- EC-EARTH
- CNRM-CM5
- HadGEM-ES

RCMs:
- CCLM
- RACMO
- ALADIN
- RegCM4.3
- RCA4

Reference period: 1975-2004
Future period: 2070-2099

Observational data: EURO4M-APGD (Isotta et al., 2014)

Added value:Simulation of spatial patterns of precipitation - Summer



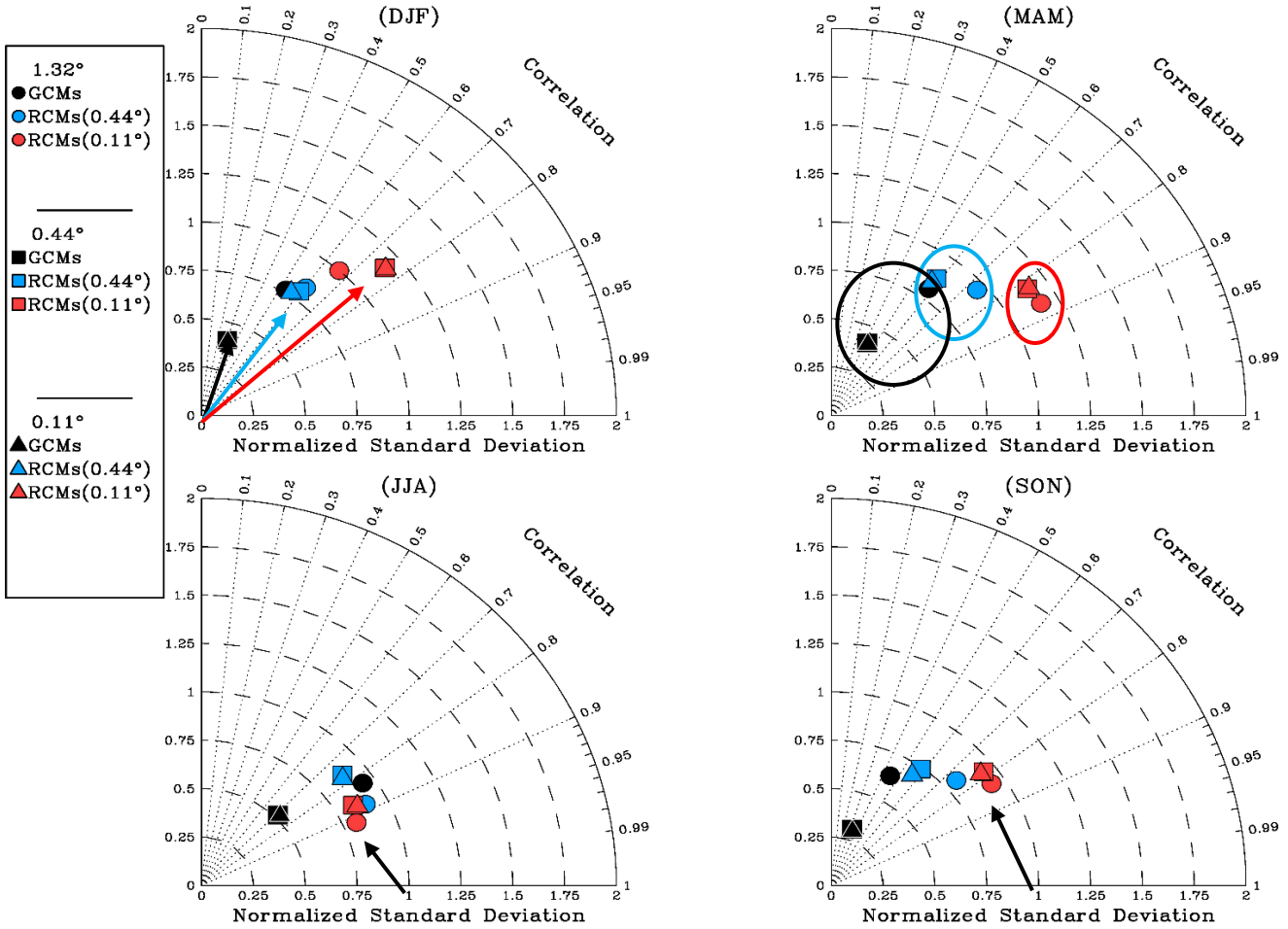
Higher resolution

Increasing details in precipitation spatial distribution

Fine scale AV

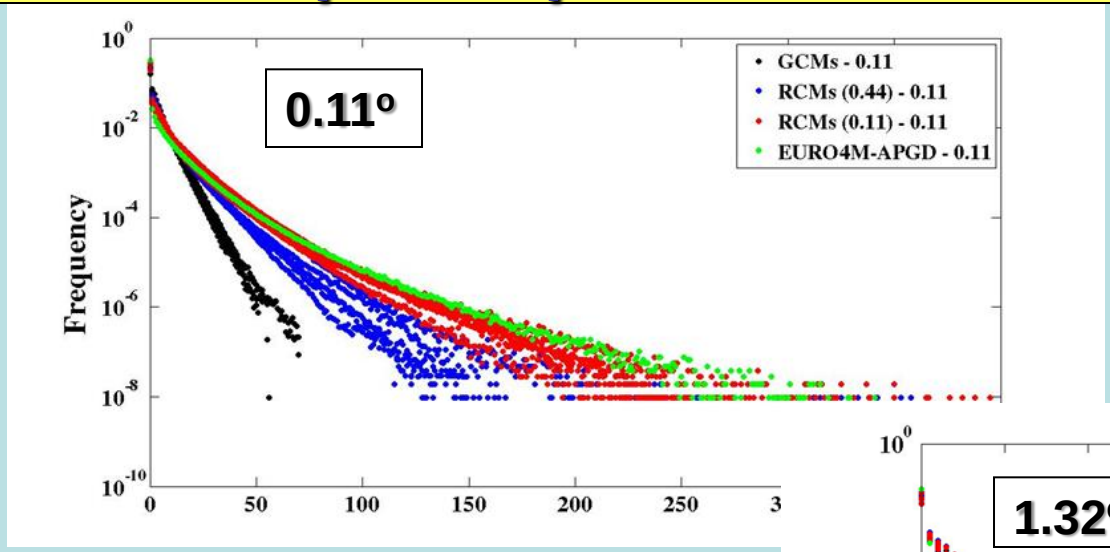
Taylor diagrams for mean seasonal precipitation

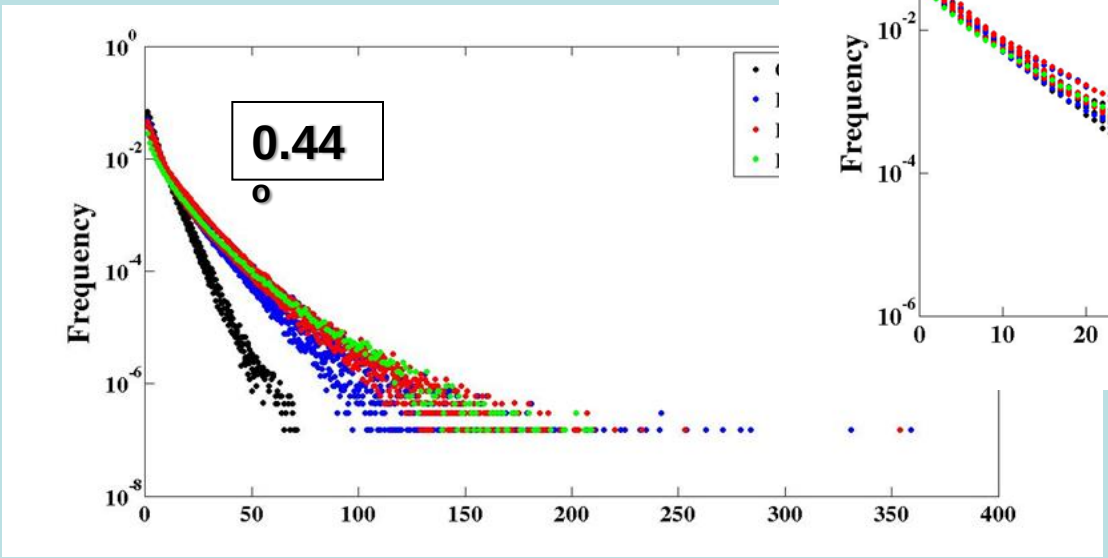
1976-2005

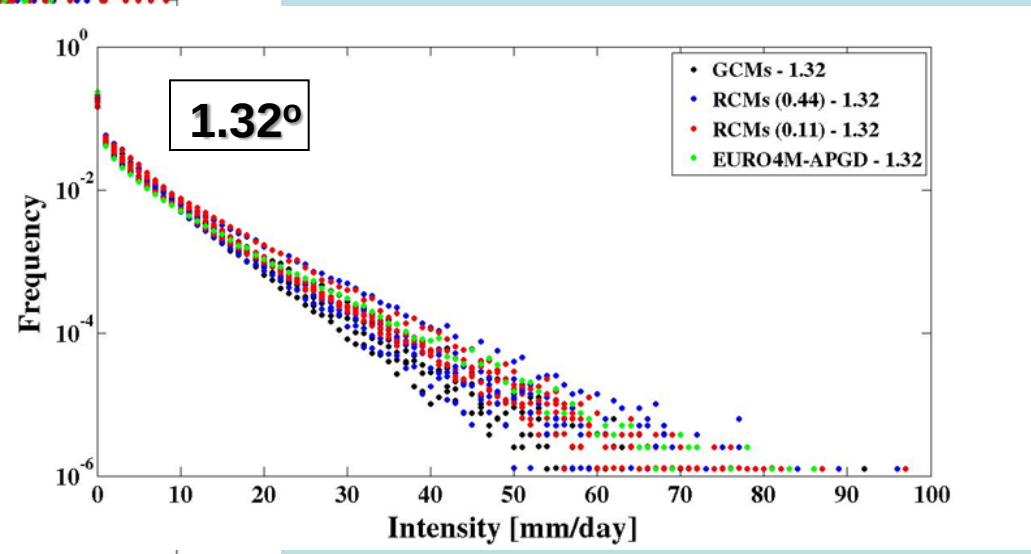


AV is found also when the data are upscaled at the GCM resolution

Added value: Simulation of daily precipitation intensity PDF

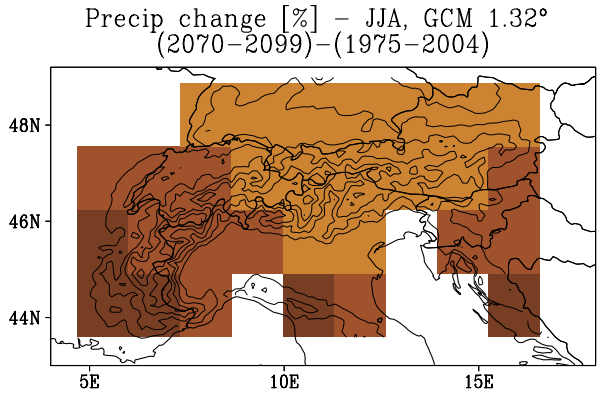




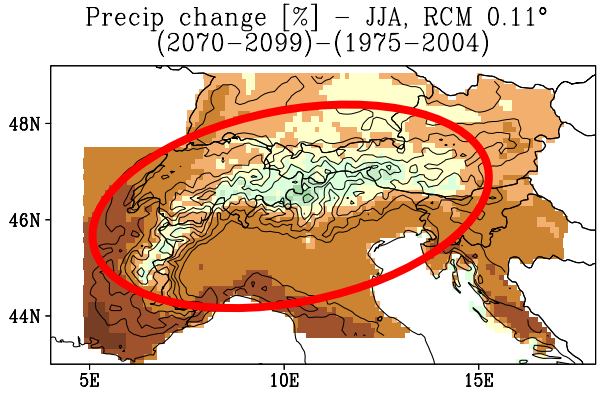


RCMs are always closer to OBS (also when upscaled)

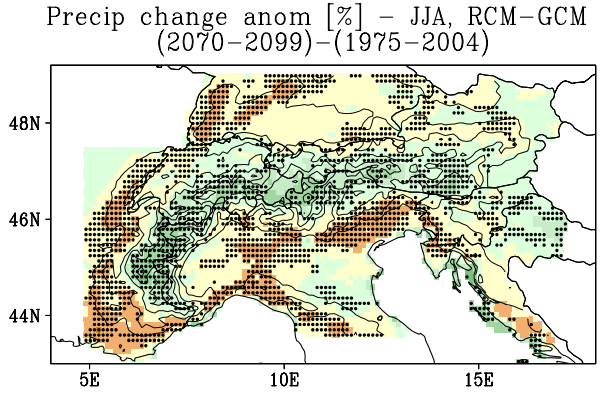
Summer precipitation change



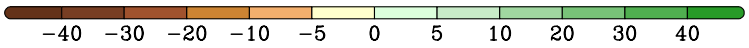
GCMs



RCMs
0.11°

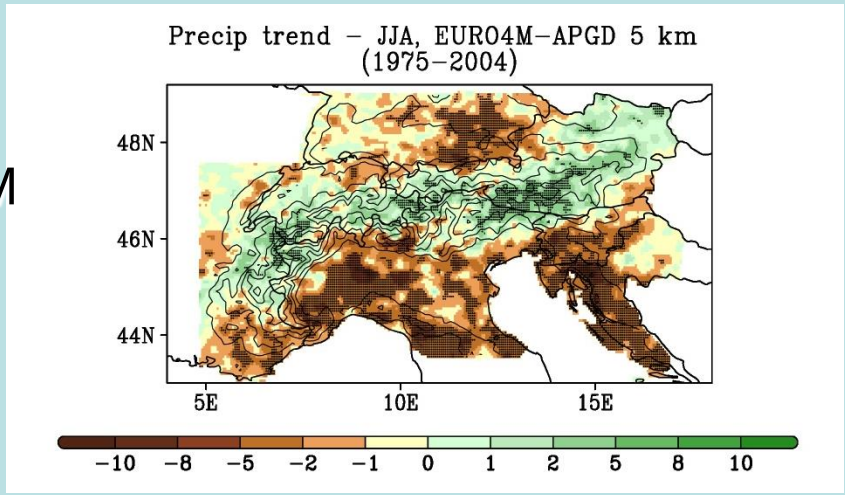


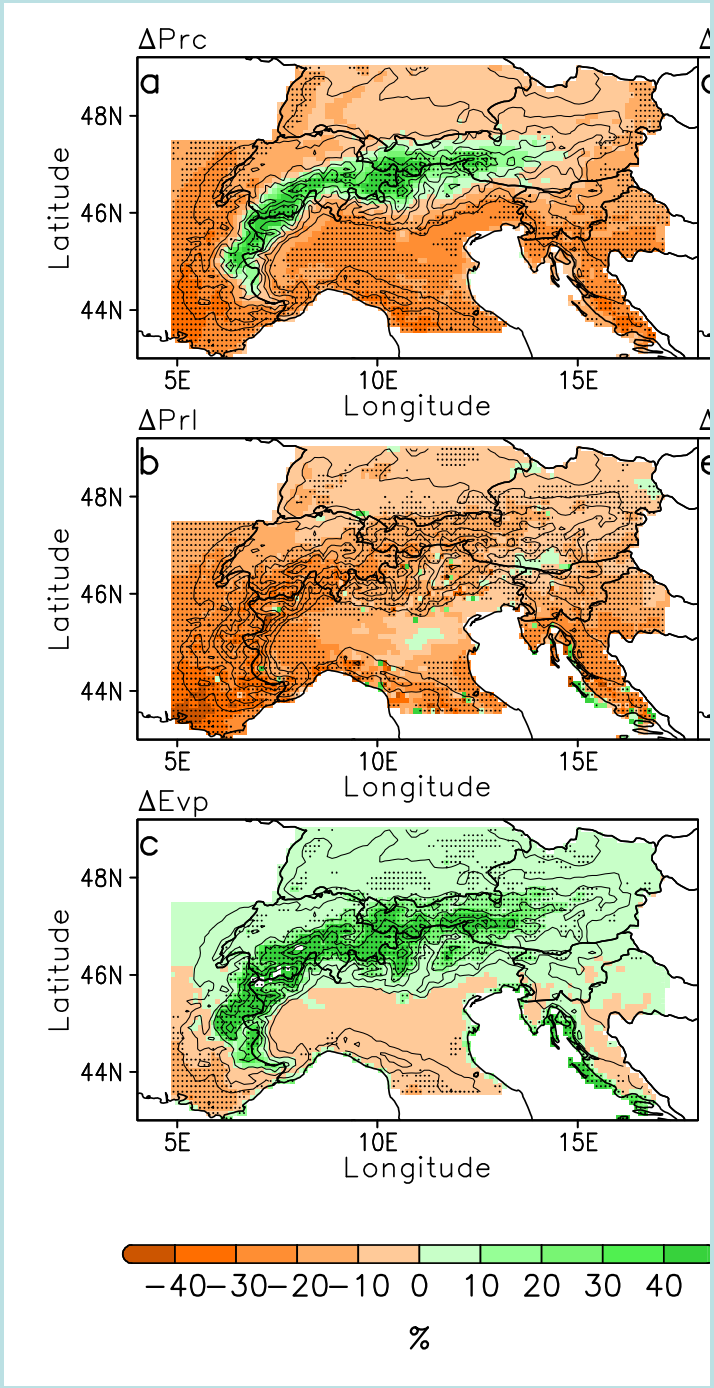
RCM – GCM
Anomaly



mm/day/century

Observed summer precipitation change (1975-2004)



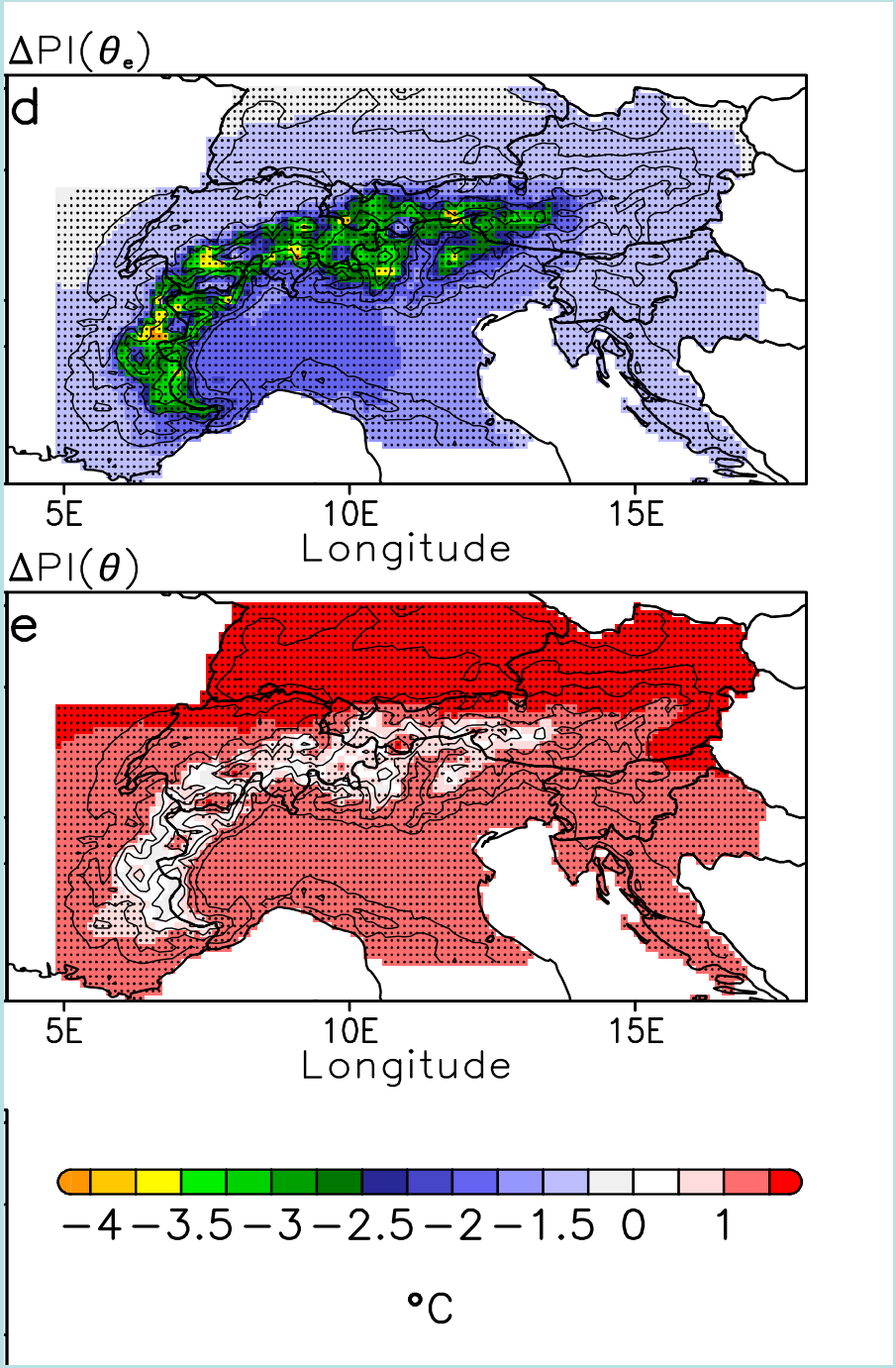


Convective

Non Convective

Evaporation

Summer precipitation change



Including moisture

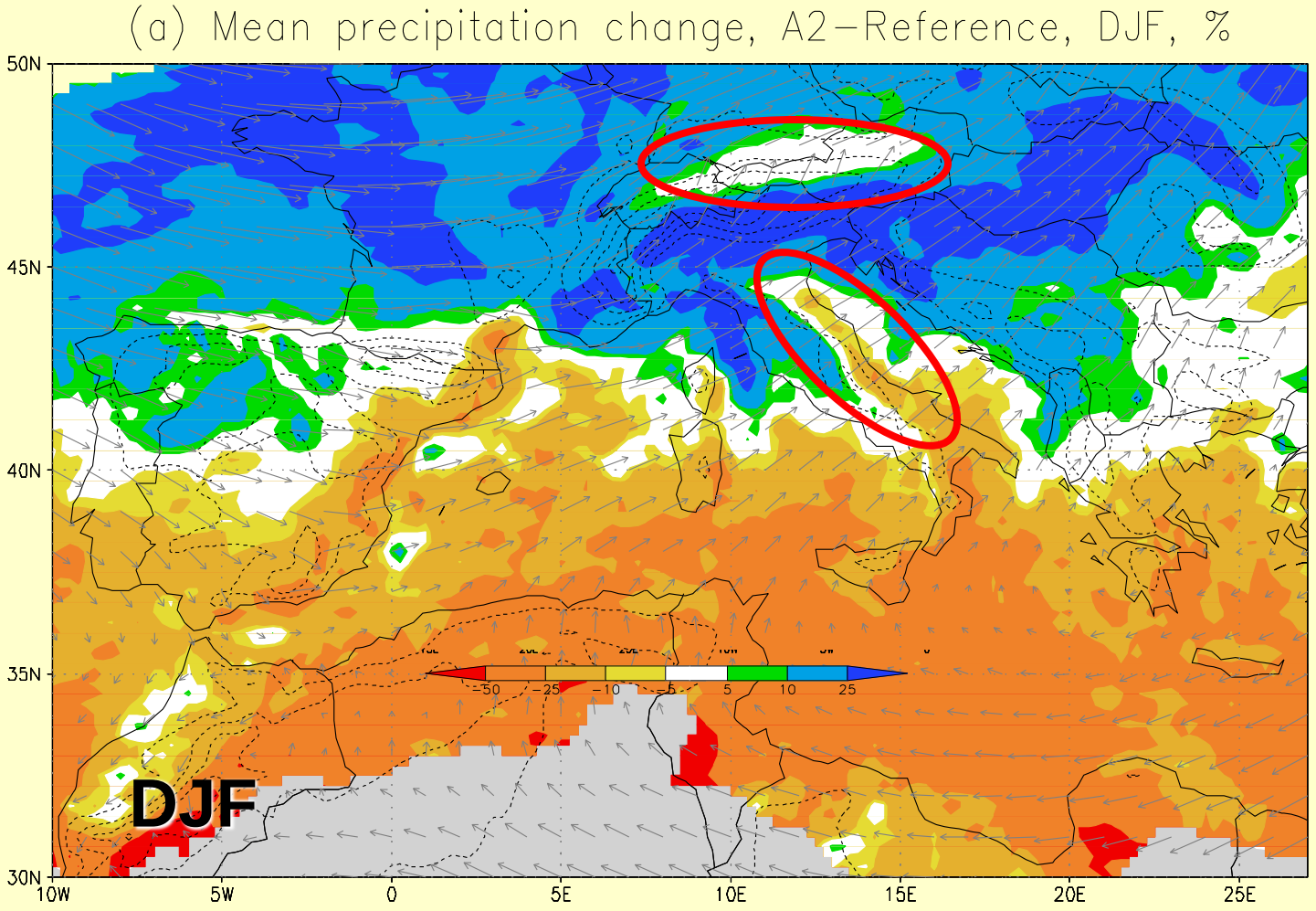
Not including moisture

Change in potential instability index

Conclusions

- RCM-based multiple lines of evidence point to an increase of summer precipitation over the mountainous regions of the European Alps under global warming (even with general drying of the region projected by GCMs)
  - Good performance of the RCMs in the reference period (and AV compared to the GCMs)
  - Model agreement in the mesoscale signal (RCMs)
  - Plausible driving underlying process (increased instability and convection)
  - Consistency with observed trends
- Example of the AV of RCMs in the simulation of climate change signals (one of the few)

Winter precipitation change (%)- dx=20 km
A2 (2071-2100) – Control (1961-1990) (Gao et al. 2005)



Summary of current projections

GCM simulations indicate some robust signals over the Mediterranean region

- Maximum warming an drying in the warm season under high end scenarios at mid to long range time horizons (virtually all models of the last two generations). Drying over the southern regions and wetting over the northern ones (e.g. Alps) in the winter (ECO behavior).
- Increase of interannual variability of temperature and precipitation, especially in the warm season
- Change of the hydrologic regime to less frequent but more intense, extreme and concentrated (in space and time) events.

Summary of current projections

RCM simulations

- At the broad scale the basic patterns of change are similar to those found in the GCMs (as can be expected).
- When focusing on smaller scales, (sometimes surprising) differences can occur between RCM and GCM derived experiments because of processes associated with local forcings (topography, coastlines)
- Relatively high horizontal resolution is needed to clearly see these surprises.

Future challenges in Mediterranean climate projection

Larger GCM and RCM ensembles

- Larger GCM ensembles will be produced as part of CMIP6.
- Larger RCM ensembles will be produced as part of EURO-CORDEX and COPERNICUS.
- Although qualitatively the basic regional scale change signals will likely remain unchanged, at the quantitative level it will be necessary to combine all this information into coherent messages for VIA application, possibly at all resolved spatial scales.
- There will be the need to assess the value and limitations of post-processing techniques, such as bias-correction and pattern scaling.

Future challenges in Mediterranean climate projection

Higher resolution (meaning higher than ~ 10 km)

- The move to very high resolution, convection permitting (CP), models (1-3 km), may produce some significant surprises at local scales.
- This step is unavoidable, but it may be unfeasible for a number of years to use CP models in “climate mode” for the whole basin.
- If the interest is on individual events (extremes) an event-based basin-wide CP approach may be useful
- Otherwise probably some sub-regions may be identified (based on good reasons) for more detailed CP simulation approaches (e.g. Alps).

Future challenges in Mediterranean climate projection

Coupled model development

- Air-sea, aerosol-climate and biosphere-atmosphere feedbacks can be important at the regional scale.
- Still somewhat inconsistent messages on air-sea coupling from ocean-atmosphere coupled simulations.
- Aerosol effects are definitely important, but they still have not been studied in a projection context (CORDEX aerosol FPS).
- I am not aware of interactive vegetation experiments specific for the Mediterranean region.

Future challenges in Mediterranean climate projection

Including the human dimension

- Land use management-change is being addressed in a CORDEX FPS.
- Major emphasis on cities, especially coastal megacities (C40) → Urban modeling.
- Large interest in renewable energies (wind, solar) → Assessing better the wind variable.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