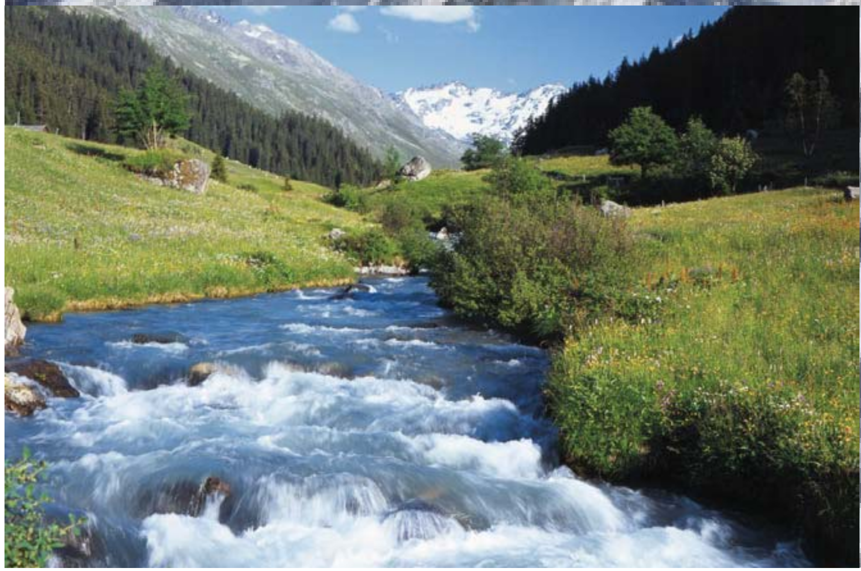
European Climate Research Alliance General Assembly, 7-8 March 2017

Climate change impact on the hydrological cycle for the Alpine region

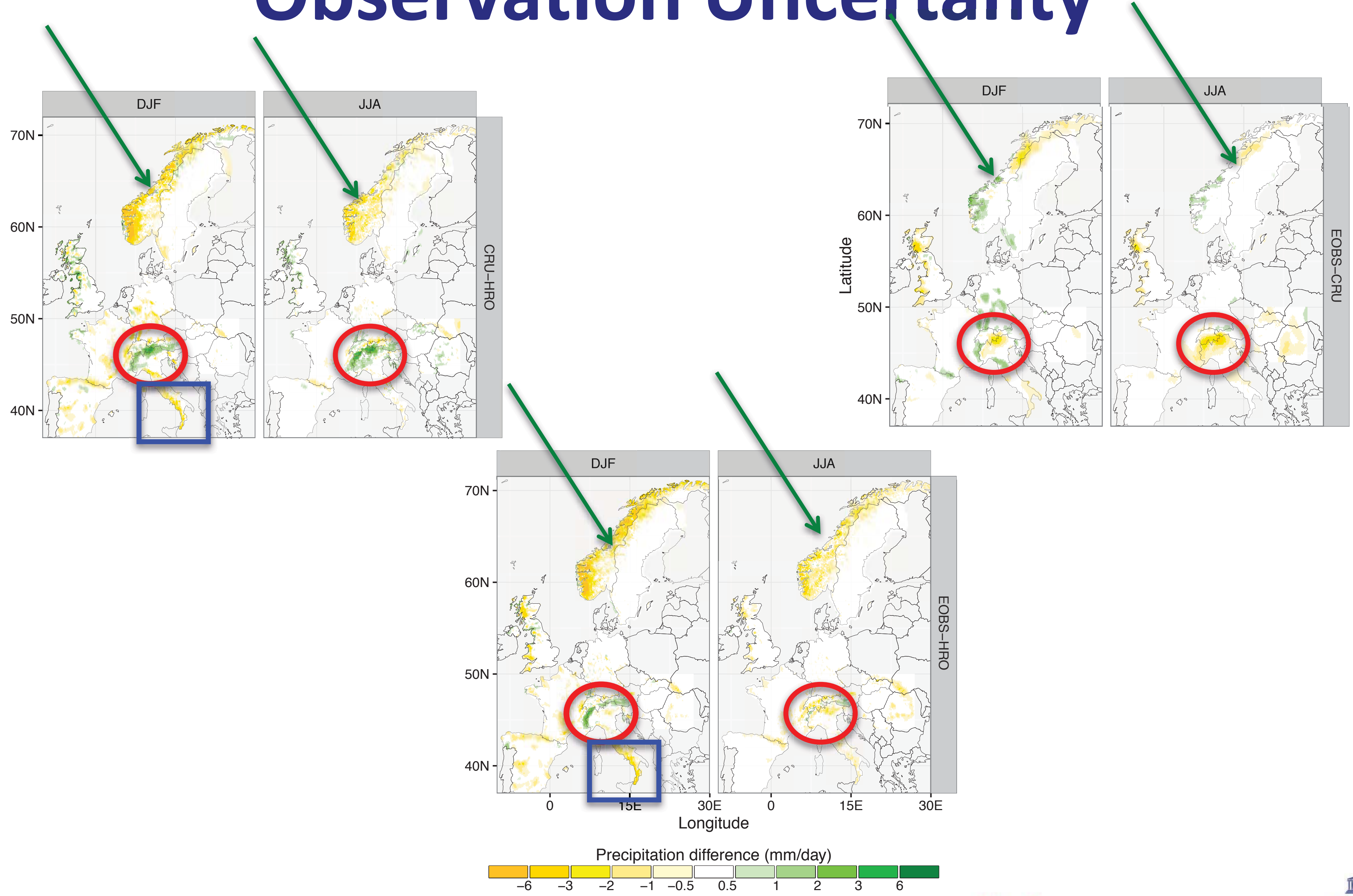
Erika Coppola, ICTP, Trieste



Outline

- Observation and Model uncertanty
- Added value over region of complex topography
  - reference climate
  - climate change signal
- Impacts - SDR change signal
- Impacts – Hydrological models
- Application – Insurance companies
- Summary

Observation Uncertanty



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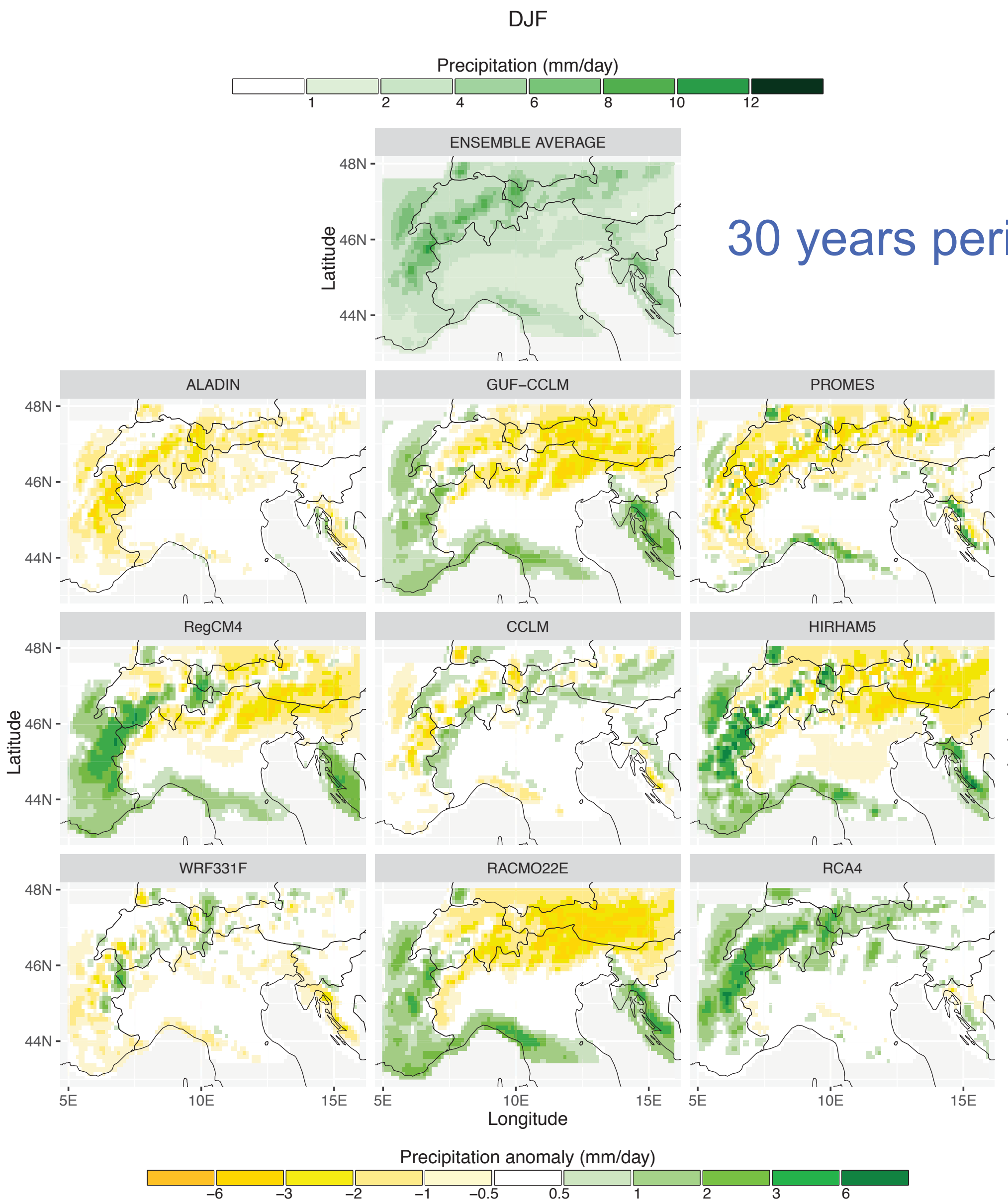
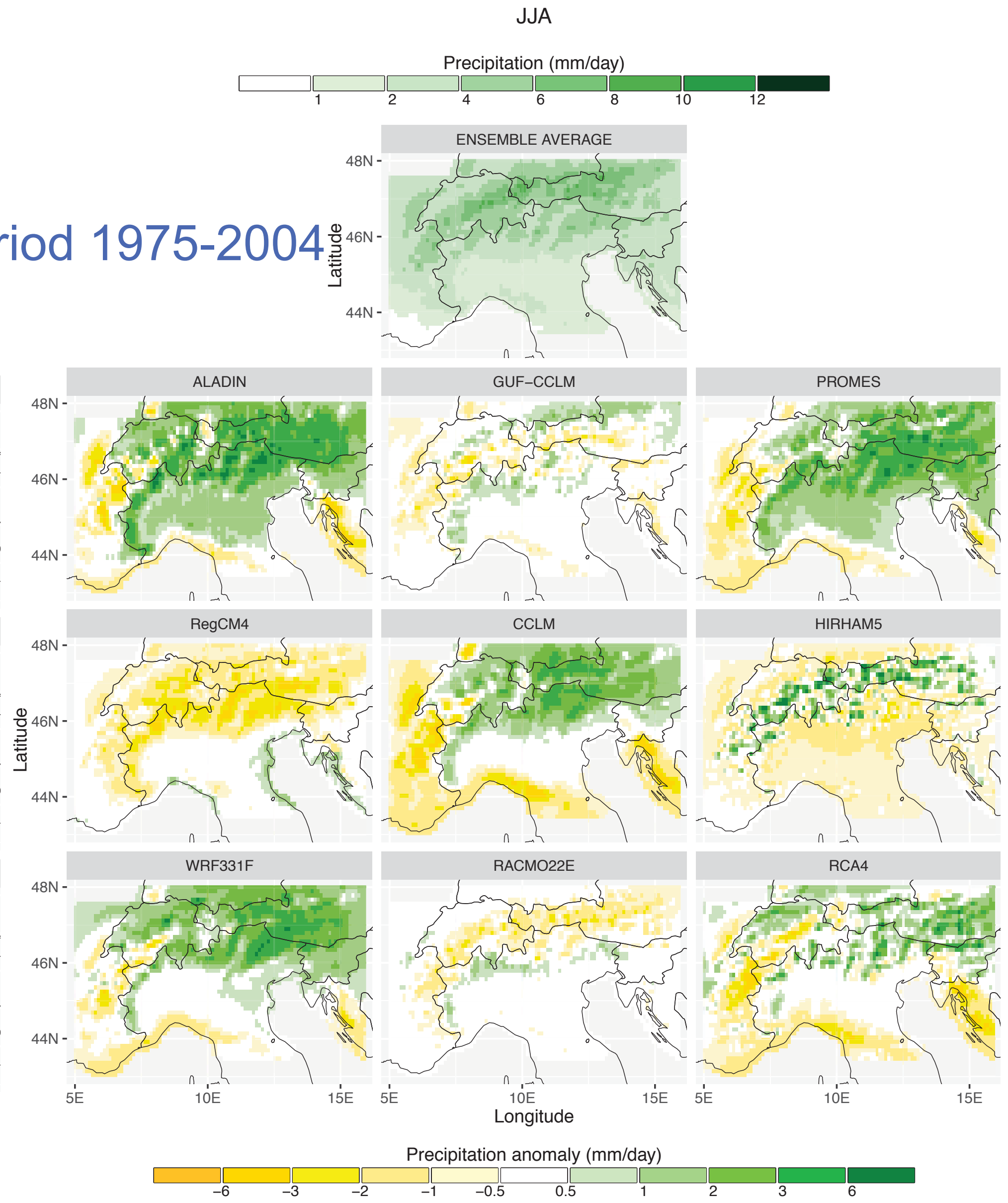
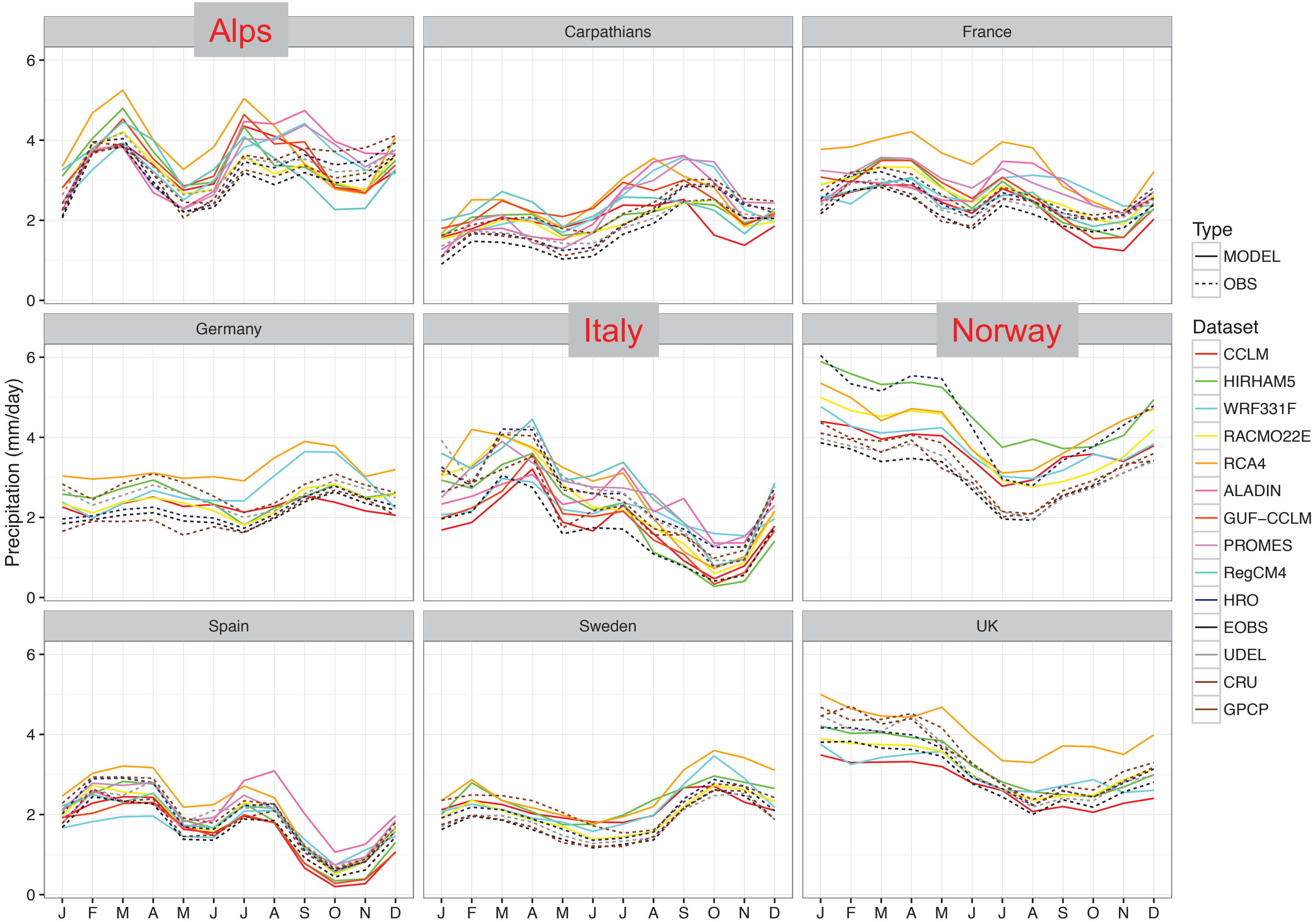
Model Uncertanty

30 years period 1975-2004



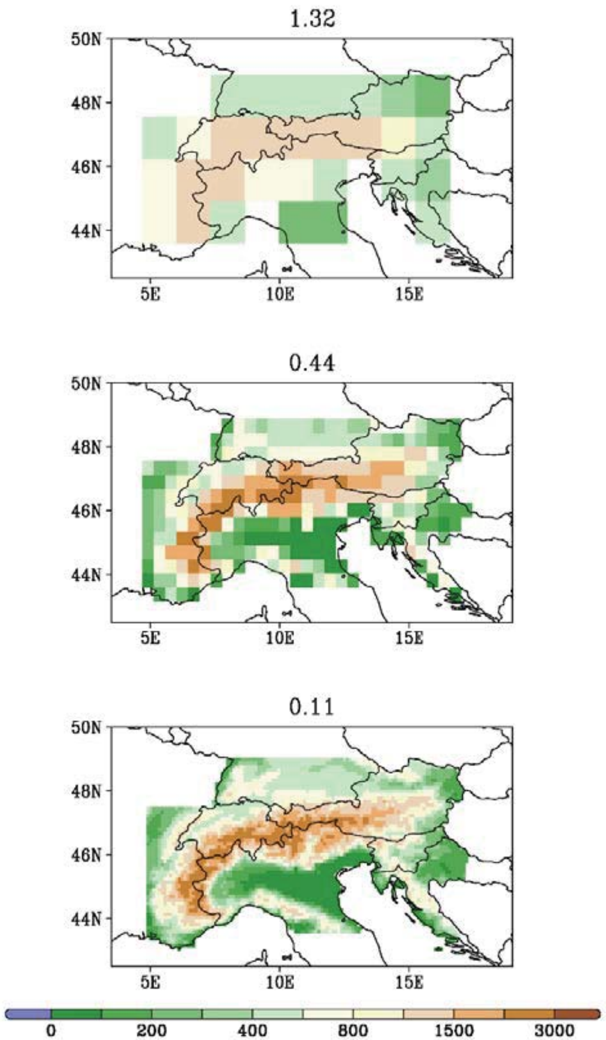


Observation+Model Uncertanty



Beniston M,..., **Coppola E**,. The European mountain cryosphere: A review of past, current and future issues, *The Cryosphere Discuss*., doi:10.5194/tc-2016-290, in review, 2017.

Search of AV over the Alps in the EURO/MED-CORDEX experiments



Horizontal resolutions: 1.32°, 0.44° and 0.11°

GCMs : → **RCMs:**

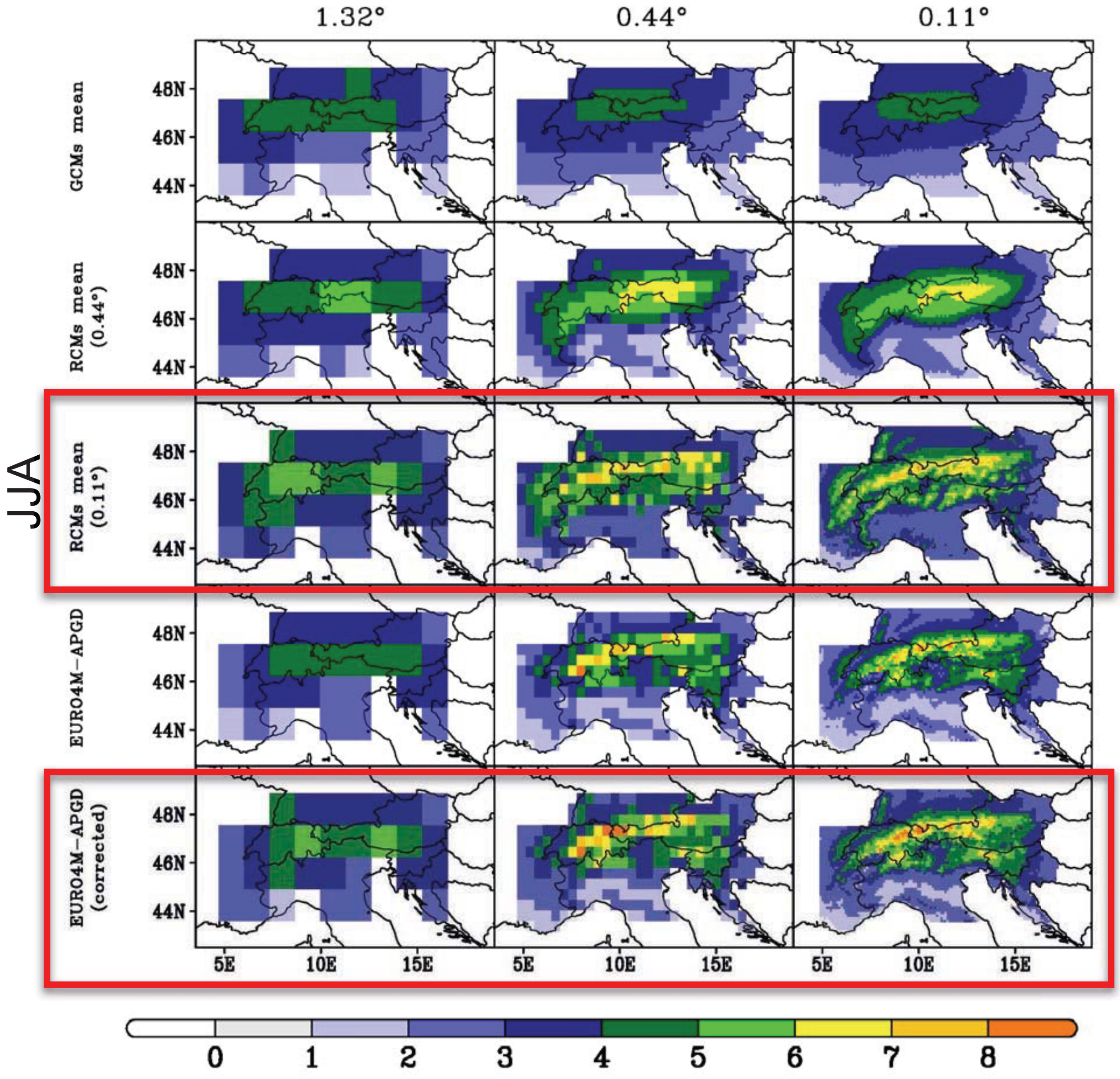
- MPI-ES-MR → CCLM
- EC-EARTH → RACMO
- CNRM-CM5 → ALADIN
- HadGEM-ES → RegCM4.3
- HadGEM-ES → RCA4

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

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

Torma et al. JGR (2015)

Simulation of spatial patterns of summer precipitation



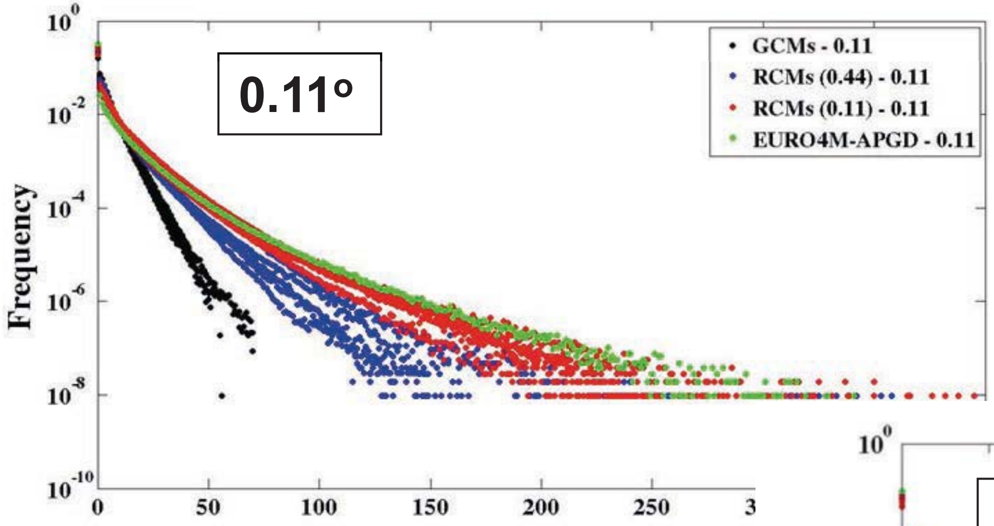
Higher resolution

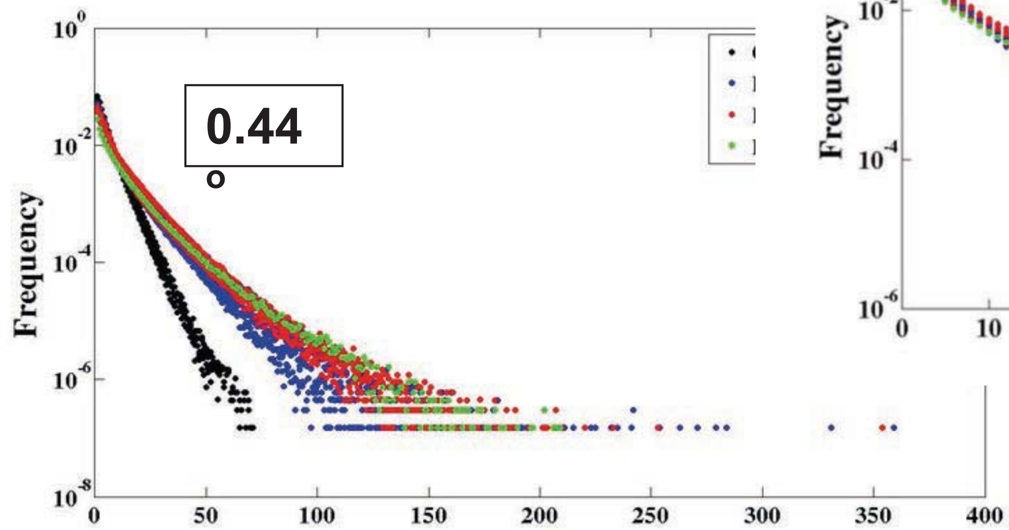
Increasing details in precipitation spatial distribution

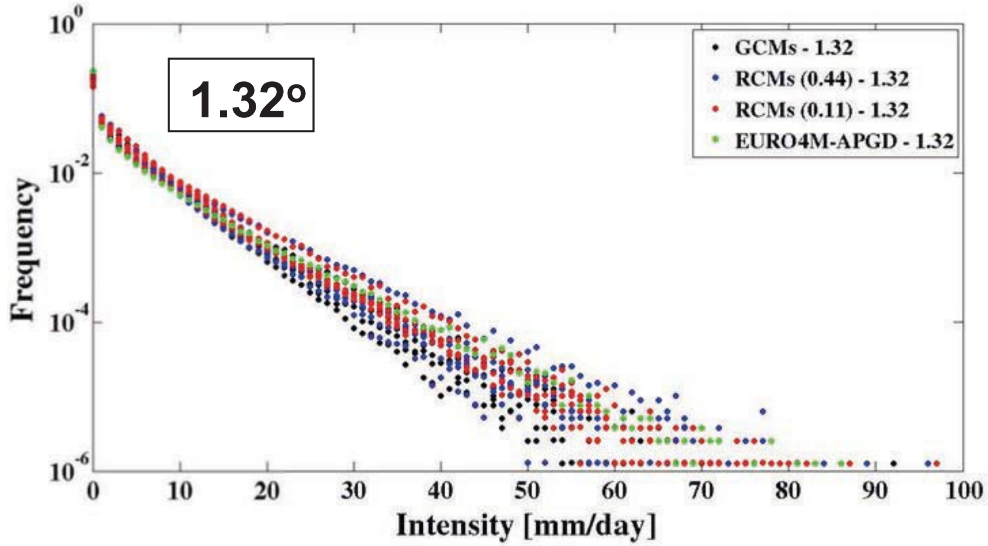
Fine scale AV

Torma et al., JGR, (2015)

Added value: Simulation of daily precipitation intensity PDF

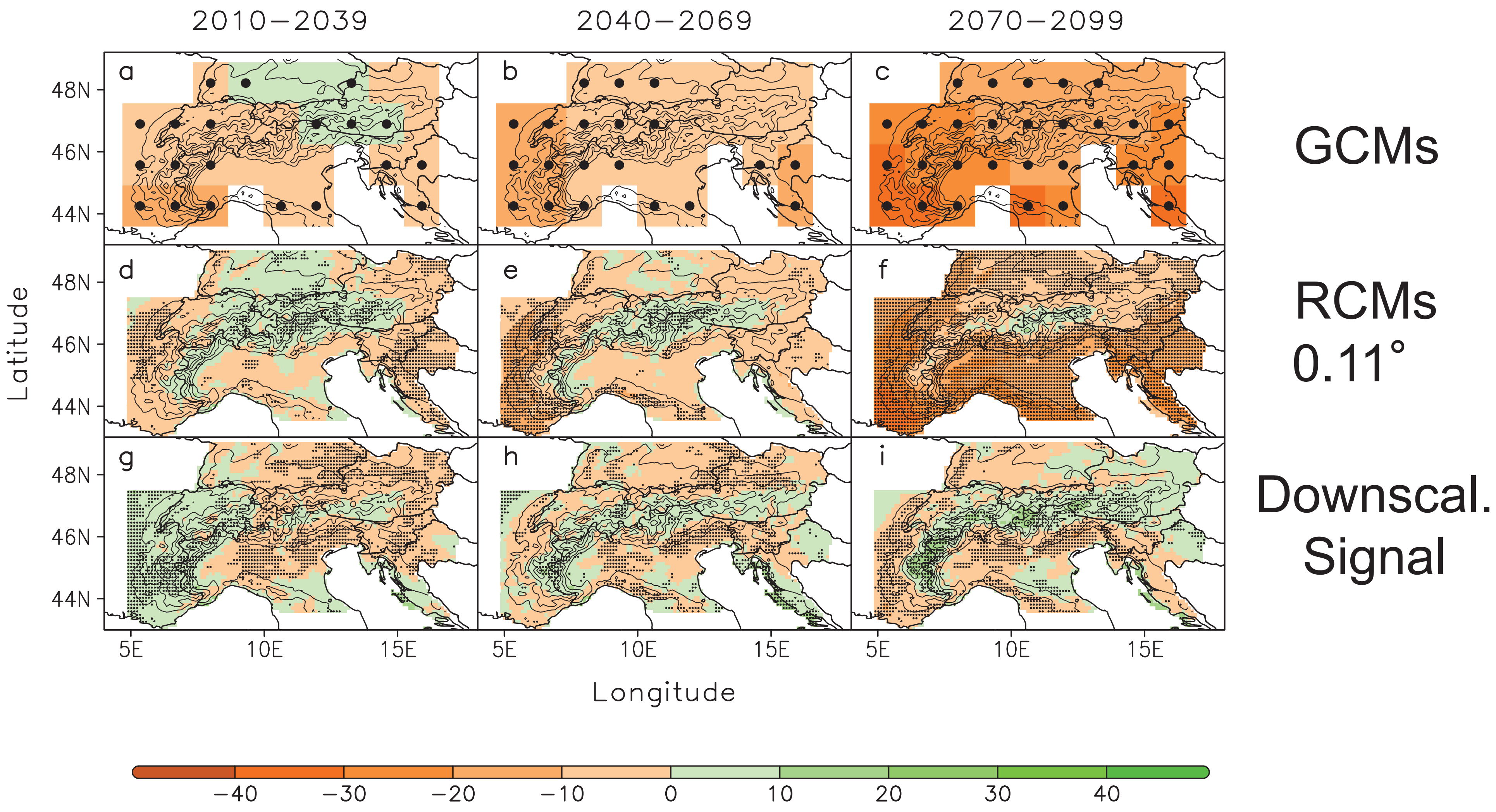




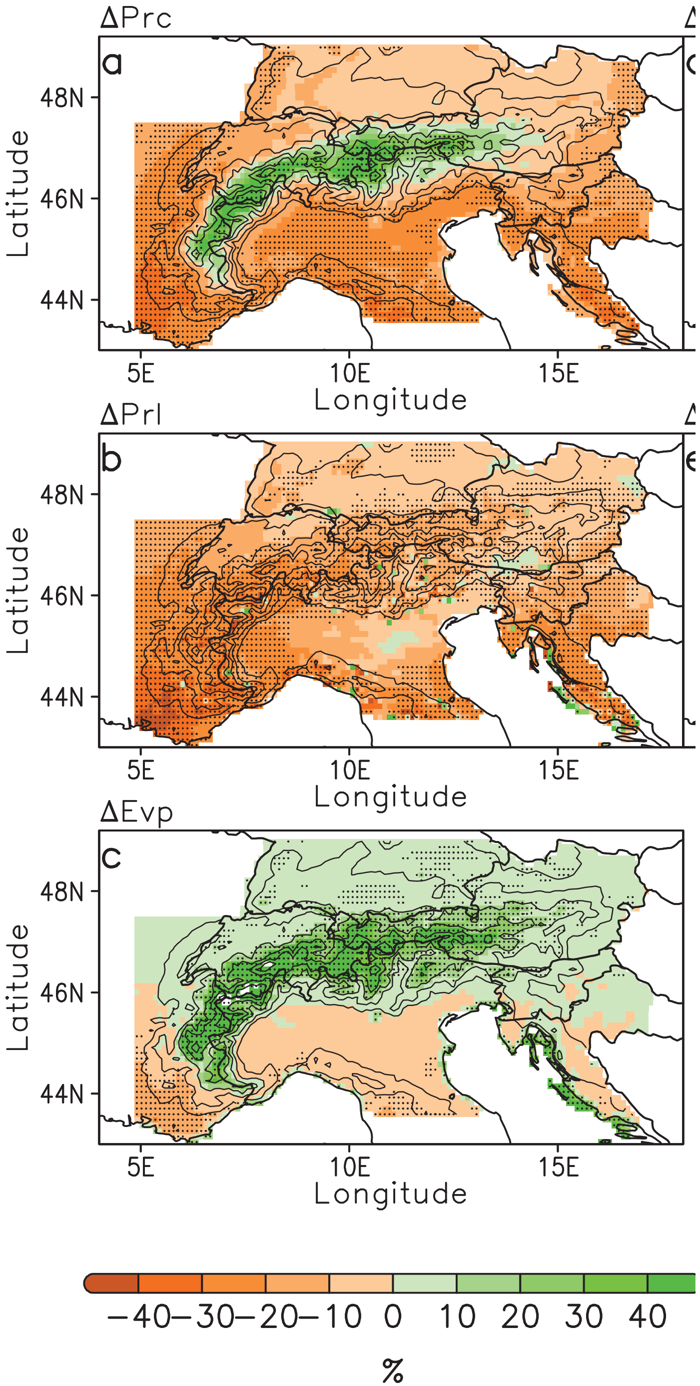


RCMs are always closer to OBS (also when upscaled)

Summer precipitation change (%)



Summer precipitation change



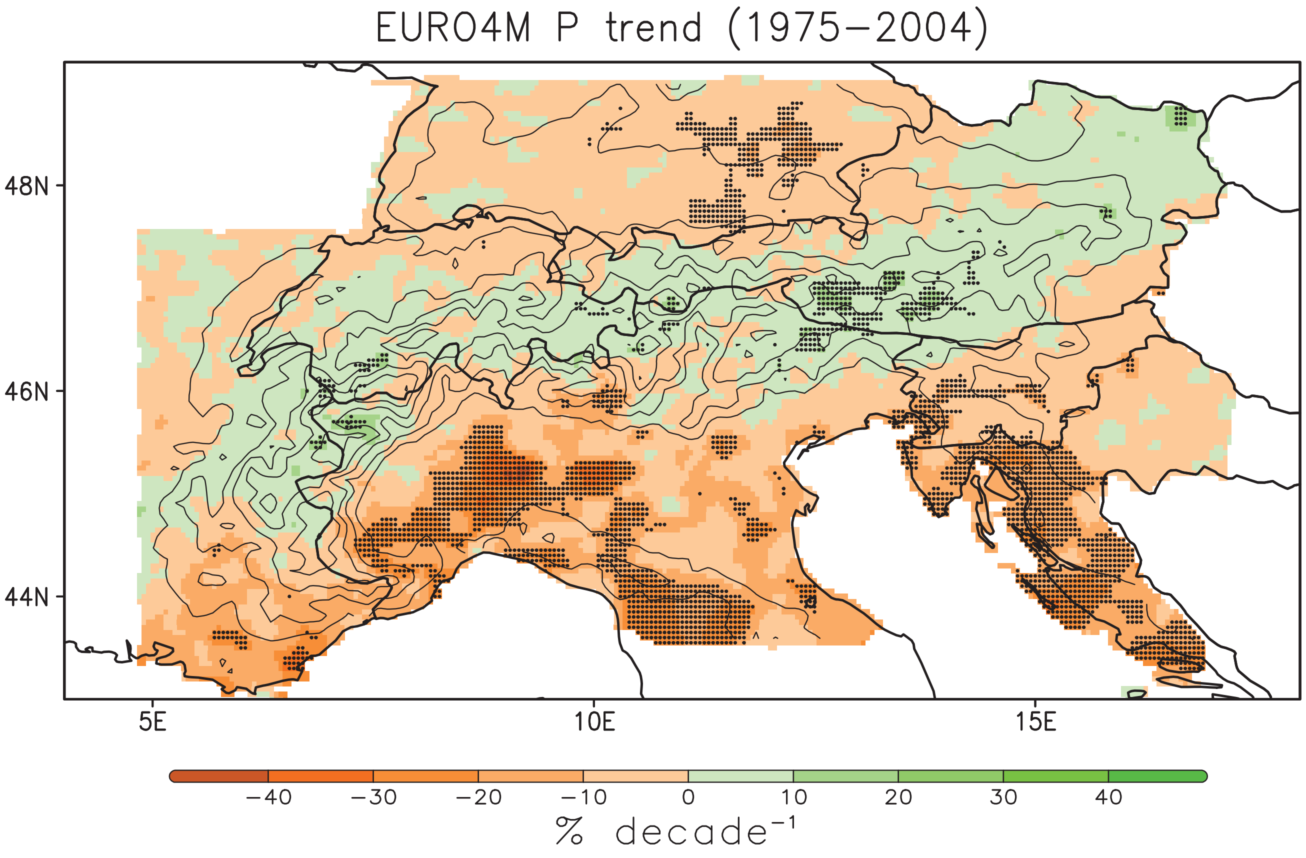
Convective

Non Convective

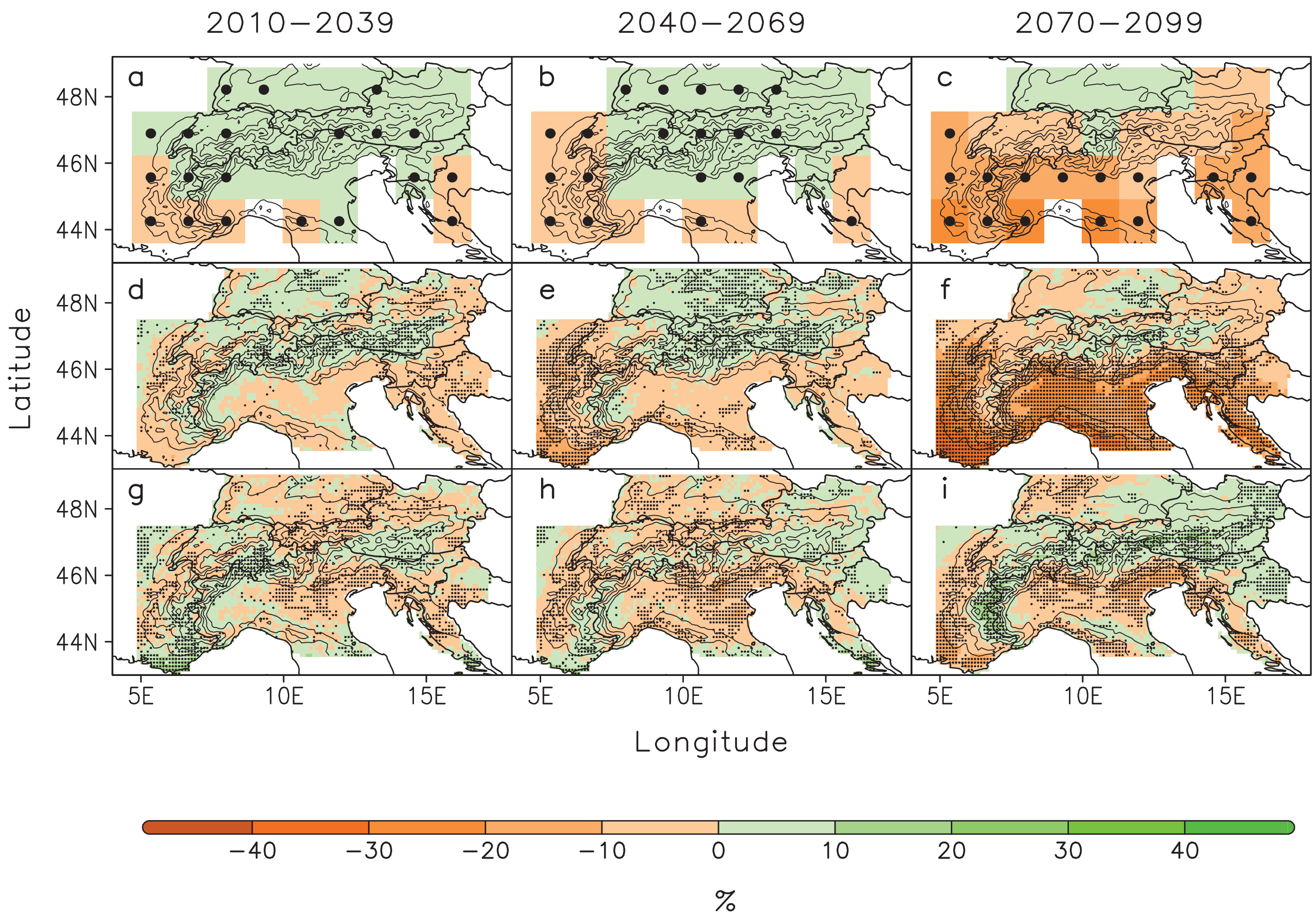
Evaporation

Giorgi F, Torma C, Coppola E, Ban N, Schar C, Somot S, 2016. Enhanced summer convective rainfall at Alpine high elevations in response to climate warming. *Nature Geoscience*, **9:8**, DOI: 10.1038/NGEO2761

Observed summer precipitation trend during 1975-2004



Change in summer precipitation R95 (%)



GCMs

RCMs 0.11°

Downscal. Signal

Impacts - SDR change signal

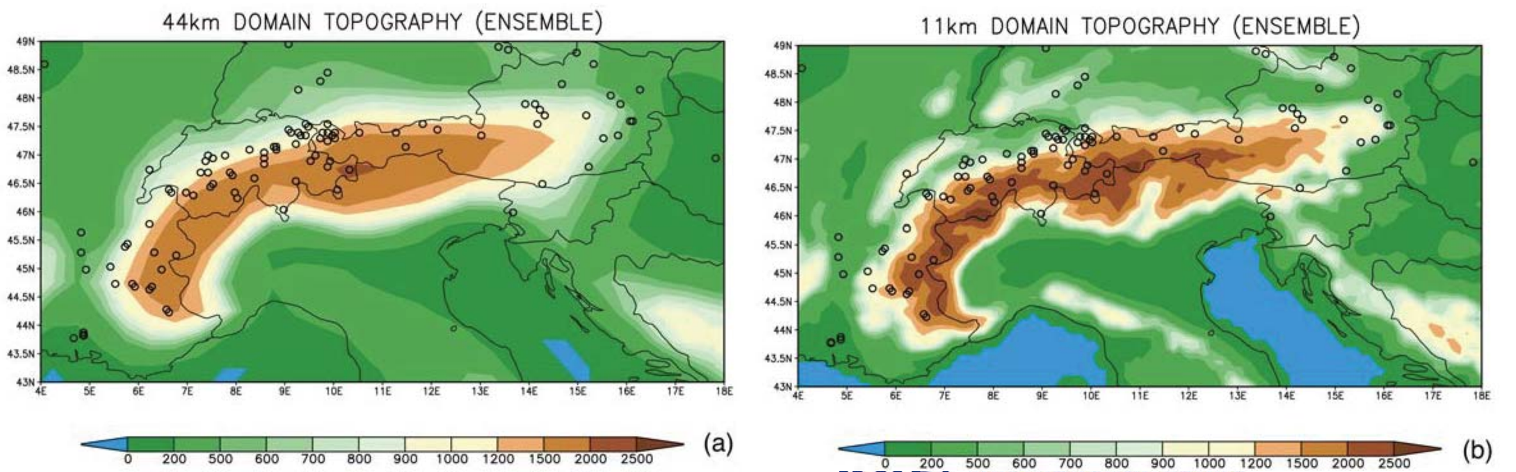
- In analogy with Rauscher et al. [2008] study done for western US, we considered only regions that are dominated only by SDR. Those **regions** are selected as areas in **which 50% or more of the annual runoff occurs in the period April-July**.
- Following Moore et al. [2007], we calculated the Julian Day inside the **water year** (from October to September of the following year), on which each percentile of that year's annual flow occurred.
- To investigate on the early, middle and late seasonal flows **we calculated the 25th, 50th and 75th** DQFs (Date of Quarterly Flow). These calculations were performed only for regions in which 50% or more of the annual runoff occurs in April-July.

Impacts - SDR change signal - Models

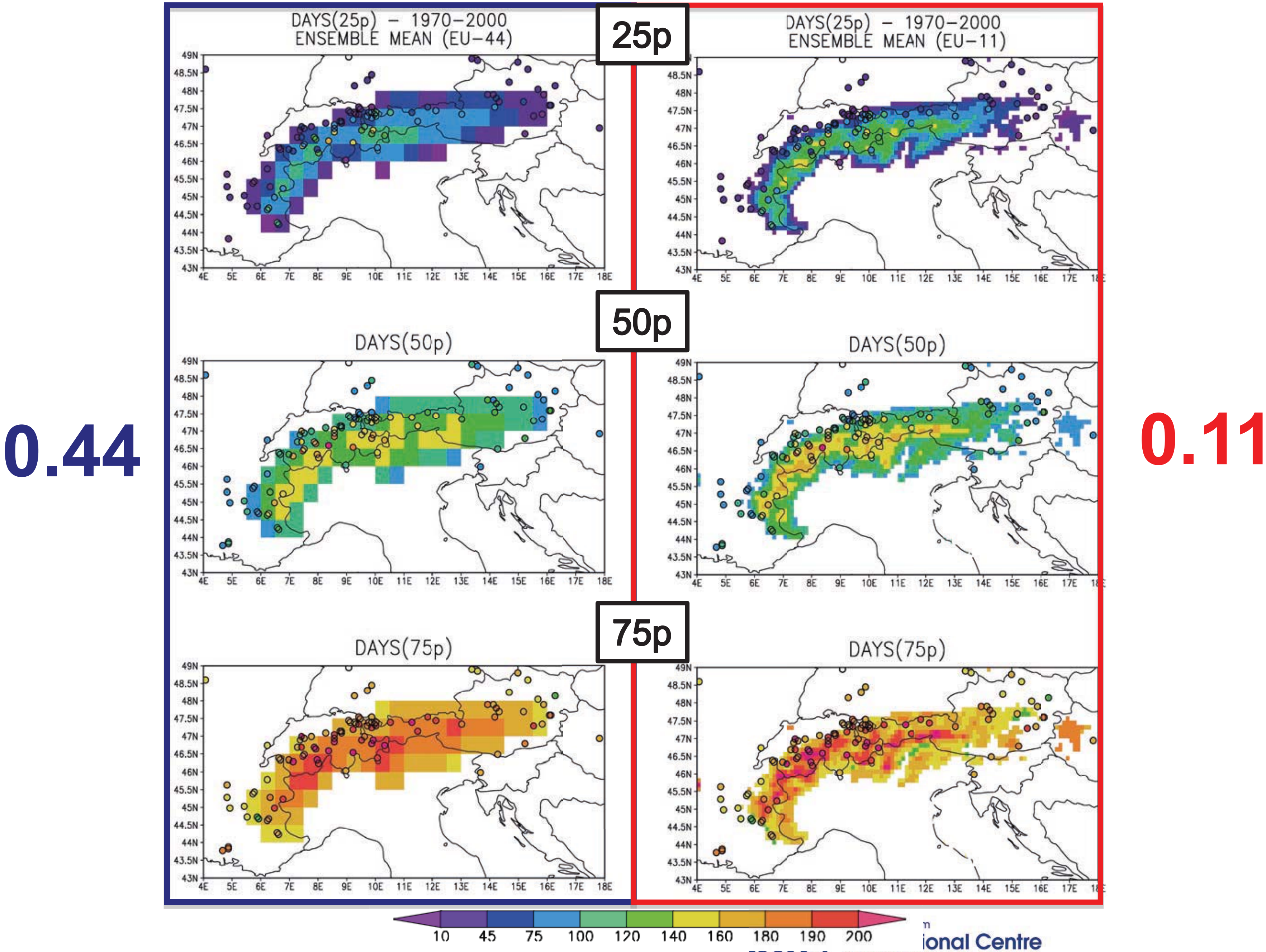
Model	Resolution	Driven-model	Domain
ALADIN	0.11 deg – 0.44 deg	CNRM-CM5	Med-CORDEX
RegCM	0.11 deg – 0.44 deg	HadGEM	Med-CORDEX
RACMO22E	0.11 deg – 0.44 deg	EC-EARTH	Euro-CORDEX
CCLM4-8-17	0.11 deg – 0.44 deg	MPI-ESM-LR	Euro-CORDEX

Impacts - SDR change signal -OBS

European Water Archive (EWA) observed runoff stations dataset over the Alps



Impacts - SDR change signal -Validation



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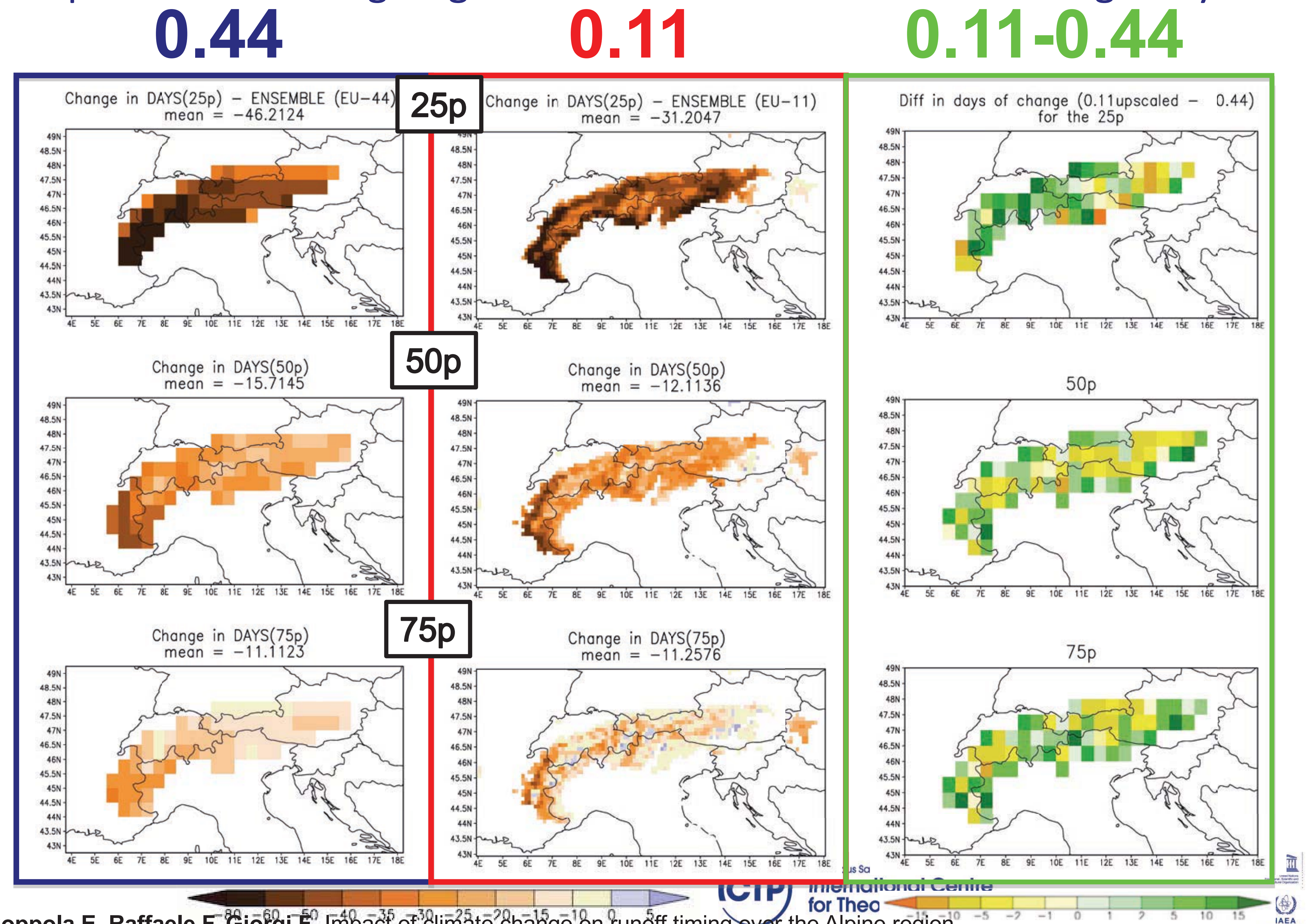
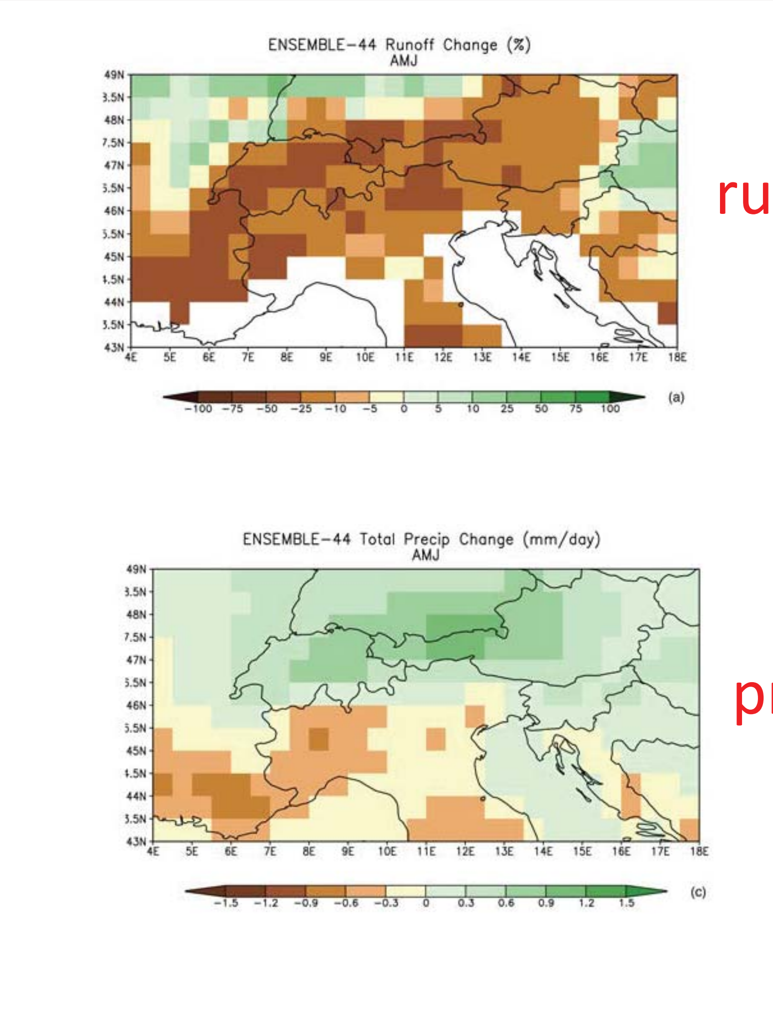
Impacts - SDR change signal- Results-Model ensemble change-days



Coppola E, **Raffaele F**, **Giorgi F**, Impact of climate change on runoff timing over the Alpine region.
Climate Dynamics, DOI: 10.1007/s00382-016-3331-0

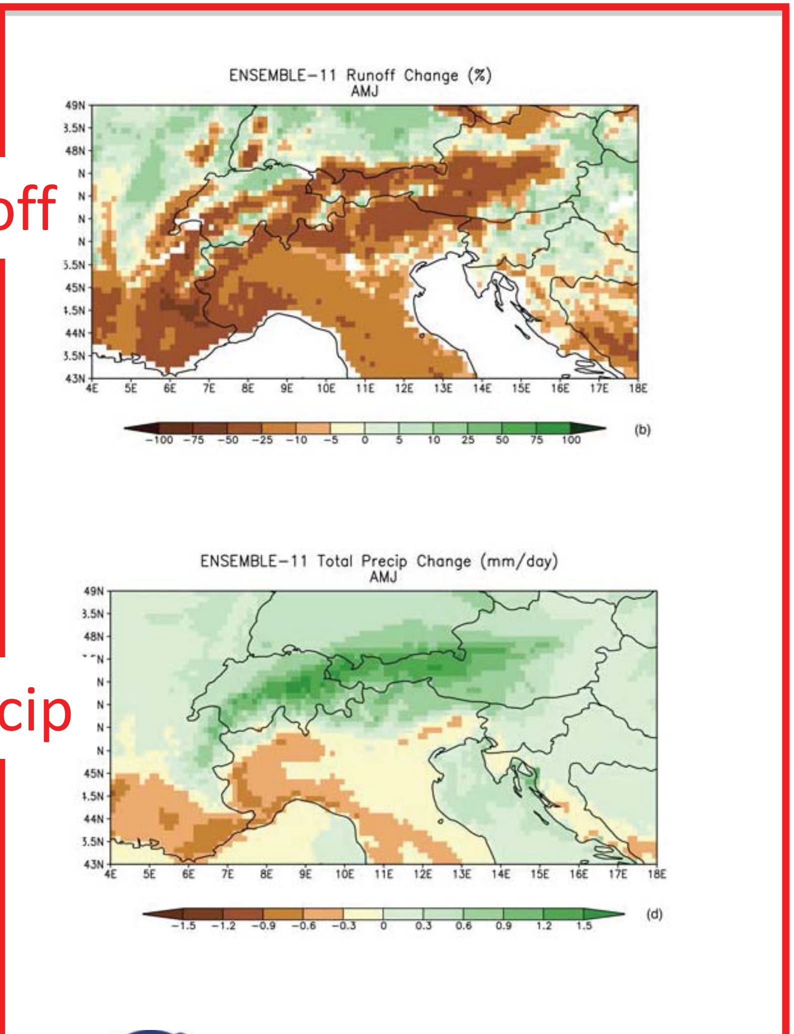
Impacts - SDR change signal- runoff and precipitation change

0.44 **0.11**

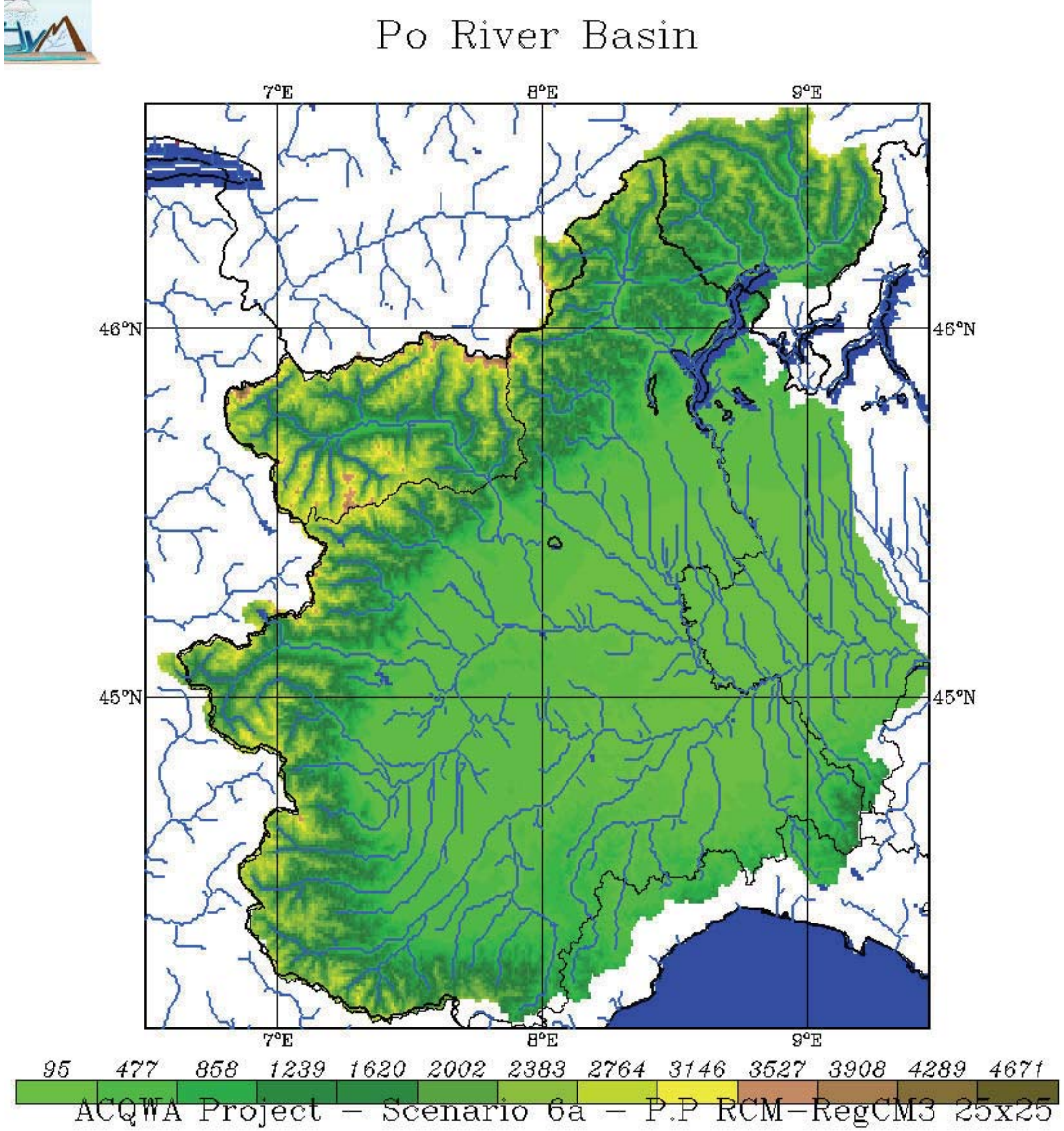


runoff

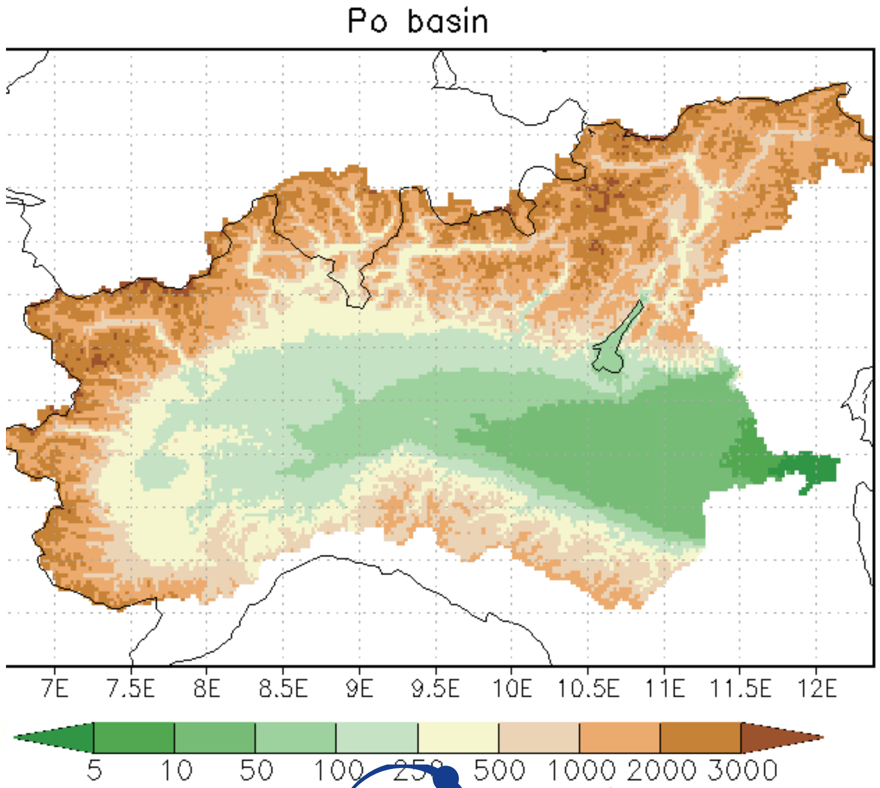
precip



Impacts – Hydrological models



Employment	**46%**
Agricultural production	**35%**
Energy consumption	**48**



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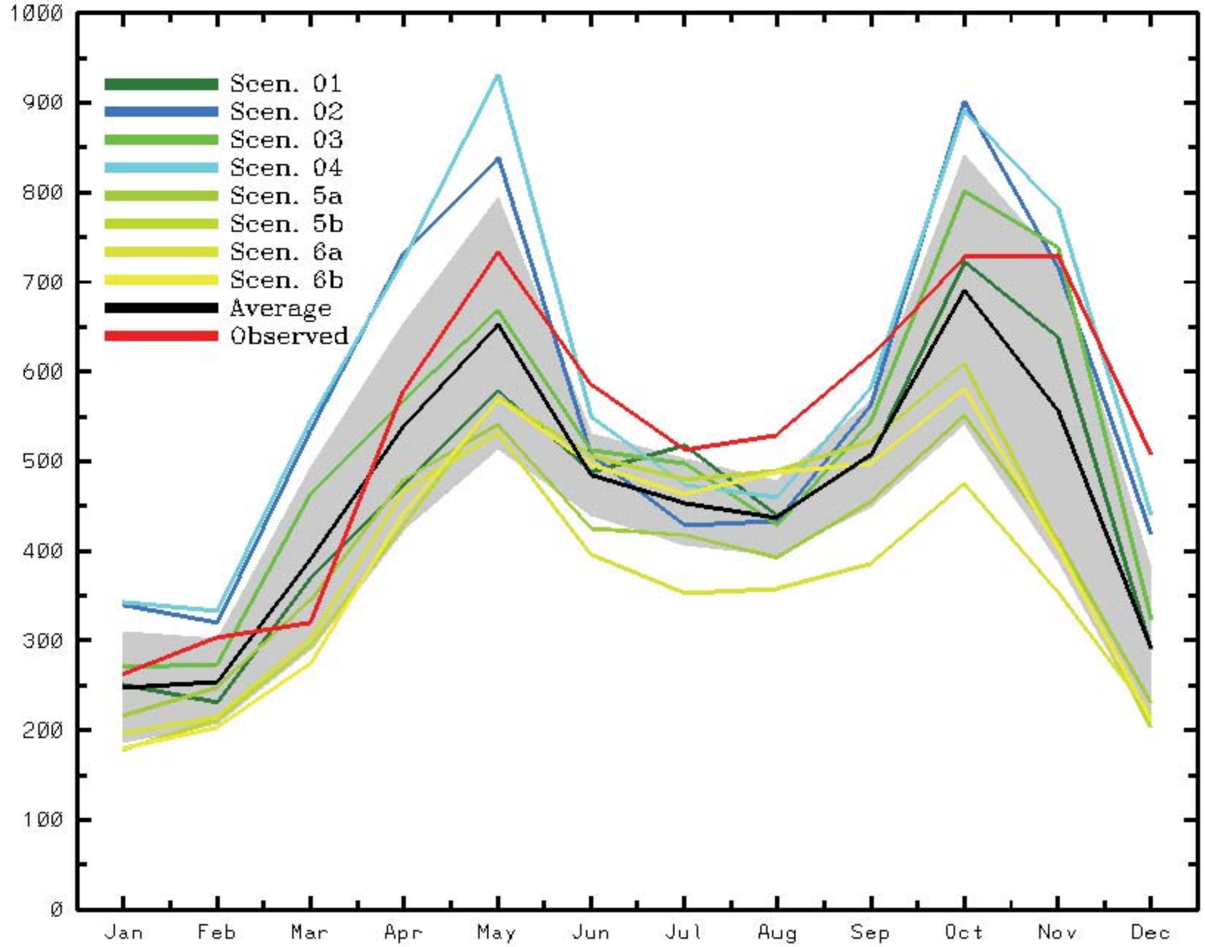
Impacts – Hydrological models

Average monthly discarge 1960-90



Isola S. Antonio Po (45.0379°N–8.8230°E)

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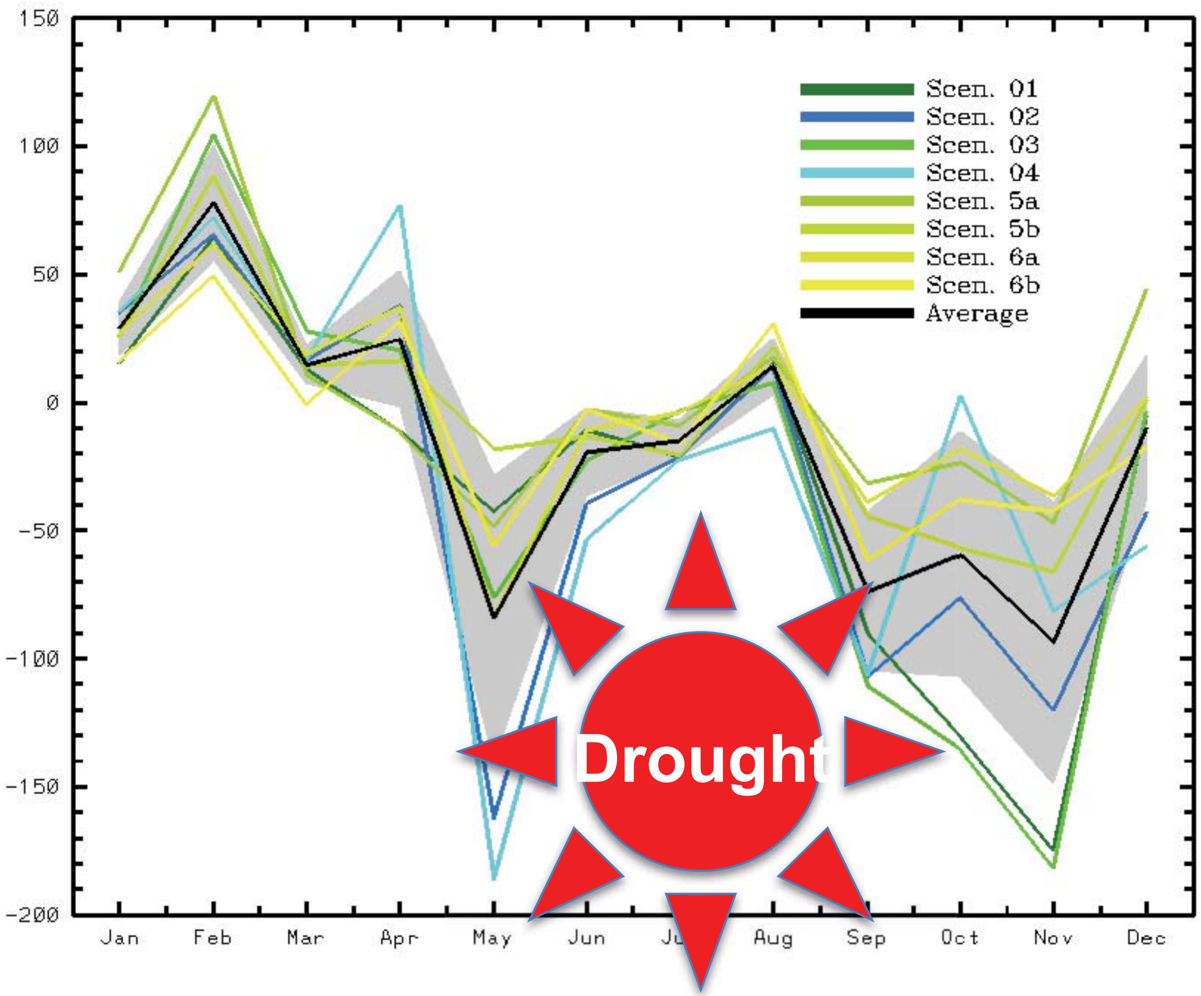
Impacts – Hydrological models

Average monthly discarge change 2050/2020 -1960/90



Isola S. Antonio Po (45.0379°N–8.8230°E)

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E. **Coppola**, M. Verdecchia, F. Giorgi , V. Colaiuda, B. Tomassetti, A. Lombardi, 2014,Changing hydrological conditions in the Po basin under global warming, *Science of the Total Environment*, doi:10.1016/j.scitotenv.2014.03.003

CORDEX-FPS on Convective phenomena over the Euro-Mediterranean sector

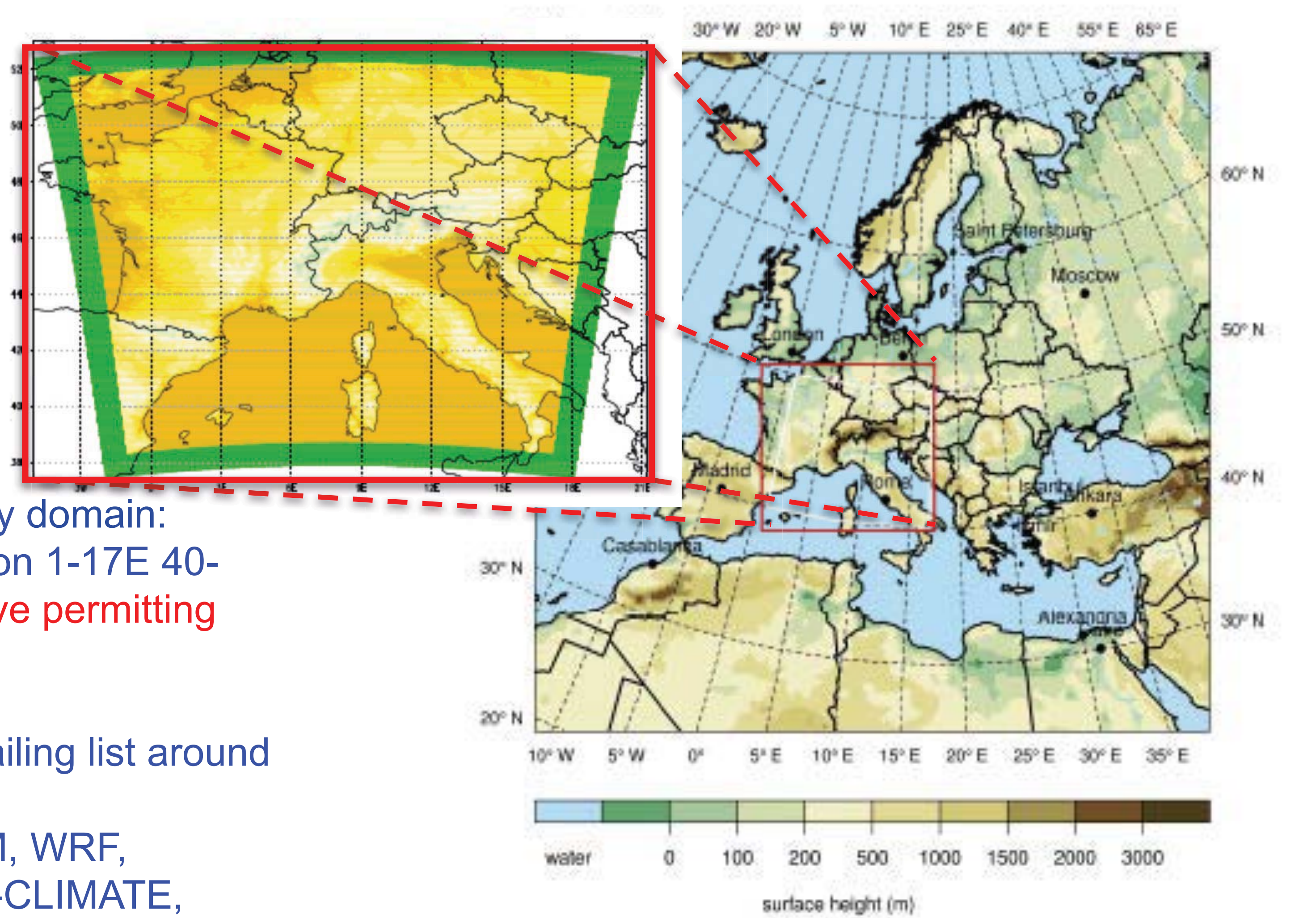

Figure: Illustration of location of FPS convection mandatory domain (red box). The actual region (1E – 17E; 40N – 50N) for final analyses is shown by the white box.

Agreed to a mandatory domain: Extended Alpine Region 1-17E 40-50N @ 3km, convective permitting simulations

Participants: 67 on mailing list around 38 at the kick-off
Models: COSMO-CLM, WRF, HARMONIE, AROME-CLIMATE, REGCM, REMO, UM-R

CORDEX-FPS on Convective phenomena over the Euro-Mediterranean sector

Science Aim 1: How do Convective events and associated damaging phenomena (heavy precipitation, wind storms, flash-floods) respond to changing climate conditions in different climatic regions of Europe?

Science Aim 2: Does an improved representation of convective processes and precipitation at convection permitting scales lead to upscaled added value?

Science Aim 3: Is it possible to augment costly convection-permitting experiments with physically defensible statistical downscaling approaches such as “convection emulators” that mimic CPMs and are fed by output of conventional-scale RCMs?

Summary

- The 0.11 ensemble is able to capture the timing of the SDR in the Alpine change. The 0.44 has a worse performance when compared to the stations.
- The response of SDR to climate changes is dominated by increases in winter temperatures (up to 4 C) and associated reductions in snow cover.
- The response of the SDR to global warming is dominated by the effect of the related reduction in spring snow cover. The 25th, 50th and 75th percentiles of SDR are shifted earlier in the year during the end-of-century time slice, with this effect being especially pronounced for the 25th and 50th percentiles in response to spring snowmelt
- The temperature increases reduce the amount of land covered by snow and hence the surface albedo (reflectivity). This results in an increase in the amount of surface absorbed solar radiation and further amplifies the surface warming, resulting in additional melting and a positive feedback (known as the snow-albedo feedback).
- For both ensemble model resolutions, the 25^{th} DQF largest changes are up to 80 days and are distributed all around the perimeter of the Alpine chain for the 0.11 resolution and more concentrated on the west side for the 0.44 resolution. The 50^{th} and the 75^{th} show changes up to 50 and 35 days respectively, but a different spatial distribution tighten to the topography is evident.

Summary continued

- The change in SDR decrease from the 25th to the 75th and this means that the annual hydrograph is widening and the time is moving backward with all happening earlier then the present day (Coppola et al.,2014).
- The main difference between the 0.11 and 0.44 resolution is in the spatial distribution of the change signal with a reduced time shift on the highest elevation for the 0.11 resolution.
- the topographic signal found in the change of runoff and SDR quantiles simulated by the 0.11 models is related to the persistence of snow cover over the highest Alpine peaks in the future time slice and the local increase of precipitation (convective) (Giorgi et al,2016), which also affects the details of the spatial patterns of warming over the Alps.
- Accurate simulation of changes in runoff timing requires **high resolution representation of the Alpine topography**. Early SDR can have several **impacts** and **consequences** for the **society** and **ecosystem**. The change in the hydrological cycle can increase **flood** in winter and spring, change the water load in the stream and lakes and therefore **change** the **aquatic ecosystem**. The change in timing of the runoff pick can be relevant for the **water storage regulation** for **hydropower** production, **agriculture** and **domestic usage** and all this can impact the **economy** of the region.

Coppola E., Raffaele F., Giorgi F., Impact of climate change on runoff timing over the Alpine region. DOI 10.1007/s00382-016-3331-0. *Climate Dynamics.*