Added value of Regional climate modelling. Where to look for it and how: two examples from Med and EURO-CORDEX ensemble.

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Why the European Alps

- Area characterized by complex, fine scale topographical features which strongly modulate local climate characteristics
- Availability of a high quality, high resolution gridded dataset: EURO4M-APGD (Isotta et al. 2014)
  - Daily precipitation gridded onto a 5 km regular grid
  - Homogenized data from more than 8000 stations
  - Long period of coverage: 1971-2008
- Availability of ensembles of RCM projections from EURO-CORDEX and MED-CORDEX
  - Multiple driving GCMs and nested RCMs
  - Two nominal resolutions: 0.11°, 0.44°
  - Easy accessible open data

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Added value questions examined

- Do the RCMs improve the representation of given present day precipitation statistics compared to the driving GCMs?
  - Downscaling to fine scales
  - Upscaling to GCM-like scales
- Is the RCM climate change signal different from that of the driving GCMs?
- Statistics examined:
  - Spatial distribution of precipitation
  - Daily precipitation intensity PDFs
  - Daily precipitation intensity extremes

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Added value metrics used

- All data are intercompared on common grids of different resolutions: 1.32°, 0.44°, 0.11°
  - Historical period: 1976-2005
  - Future period: 2070-2099
- Spatial precipitation pattern: Taylor diagram
  - Spatial correlation
  - Spatial standard deviation
  - Centered RMSE
- Daily precipitation intensity PDF
  - Kolmogorov-Smirnov (KS) Distance
- Daily precipitation extremes: R95 (fraction of total precipitation above the 95th percentile on an annual basis)
  - Mean
  - Correlation coefficient

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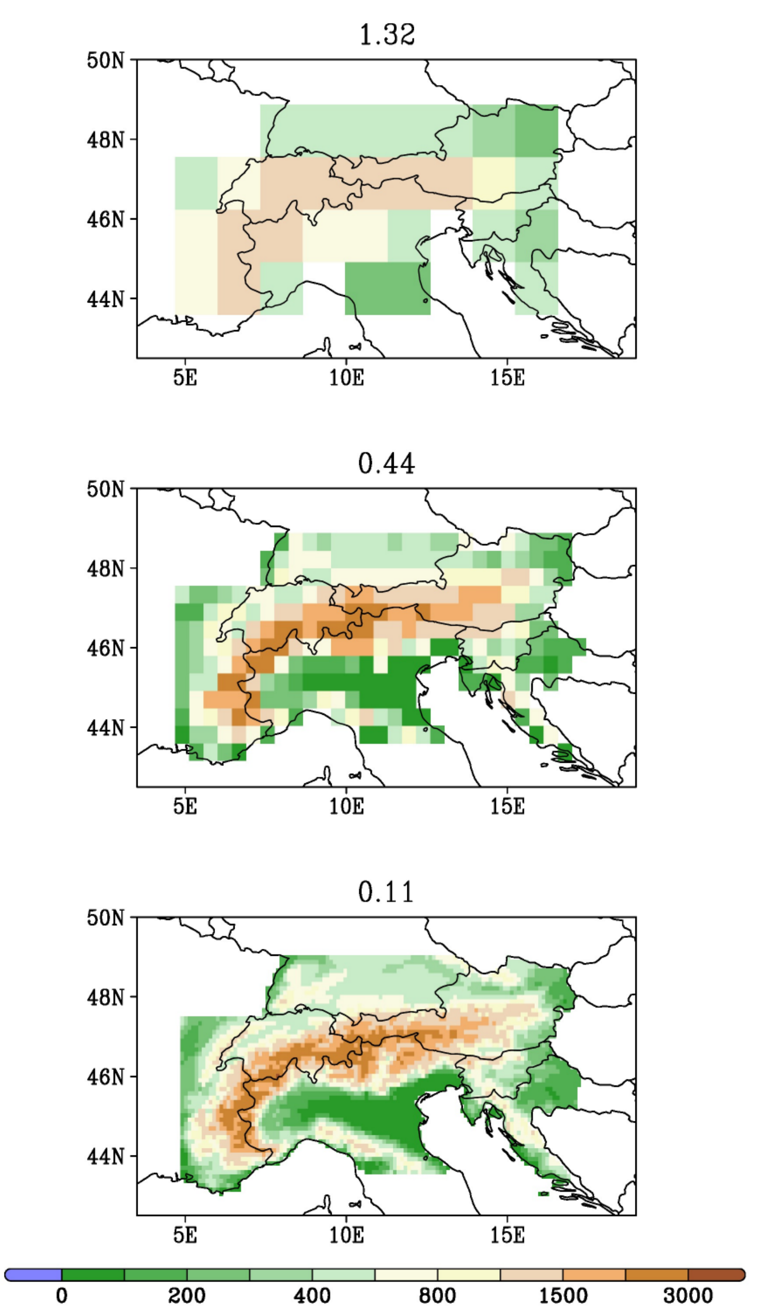
Analysis grids (topography)

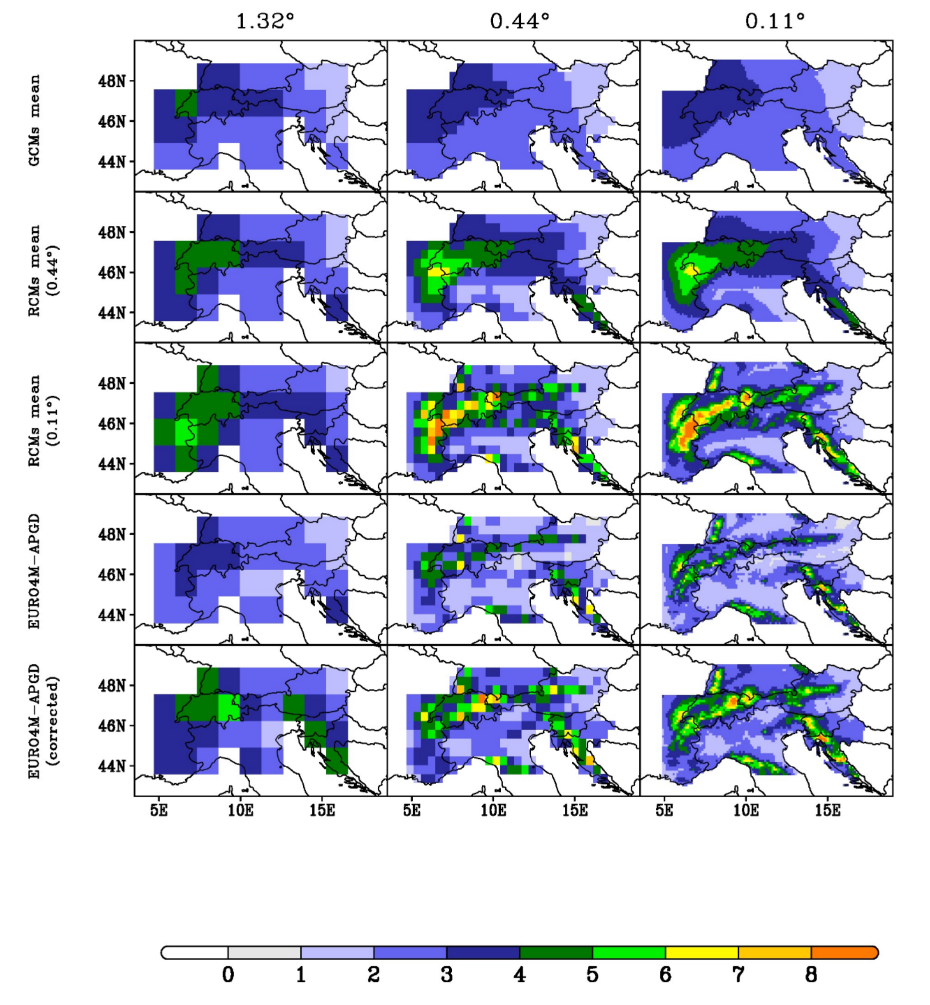


Model ensembles

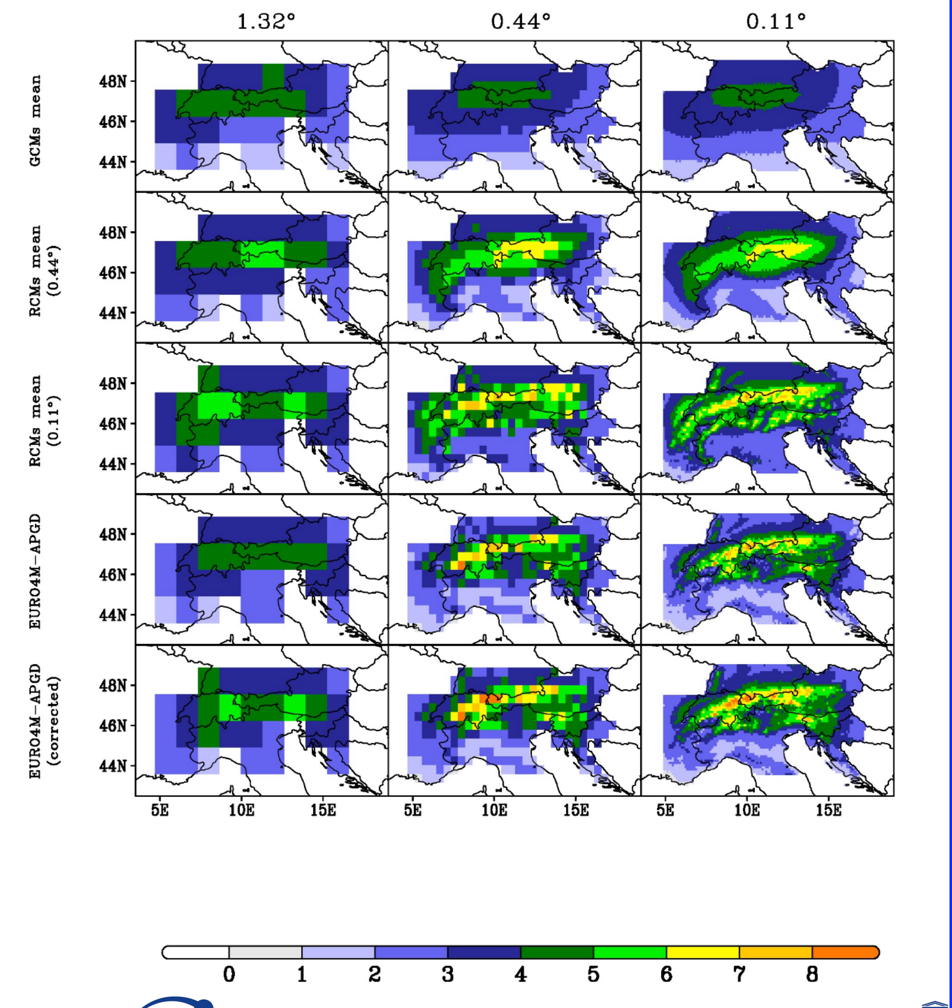
Model	Modelling group	Resolution	Reference
a, CNRM-CM5	Centre National de Recherches Meteorologiques and Centre Europeen de Recherches et de Formation Avancee en Calcul Scientifique, France	1.40625 º x 1.40625 º	Voldoire et al., 2012
b, EC-EARTH	Irish Centre for High-End Computing, Ireland	1.125 º x 1.125 º	Hazeleger et al., 2010
c, HadGEM2-ES	Met Office Hadley Centre, UK	1.875 º x 1.2413 º	Collins et al., 2011
d, MPI-ESM-LR	Max Planck Institute for Meteorology, Germany	1.875 º x 1.875 º	Jungclaus et al., 2010
ALADIN (a-MC)	Centre National de Recherches Meteorologiques, France	0.44 º/0.11 º	Colin et al., 2010
CCLM (d-EC)	Climate Limited-area Modelling Community, Germany	0.44 º/0.11 º	Rockel et al., 2008
RCA4 (c-EC)	Swedish Meteorological and Hydrological Institute, Rossby Centre, Sweden	0.44 º/0.11 º	Kupiainen et al., 2011
RACMO (b-EC)	Royal Netherlands Meteorological Institute, The Netherlands	0.44 º/0.11 º	Meijgaard van et al., 2012
RegCM4 (c-MC)	International Centre for Theoretical Physics, Italy	0.44 º/0.11 º	Giorgi at al., 2012

Ensemble mean seasonal precipitation (1976-2005)

Winter (DJF)



Summer (JJA)



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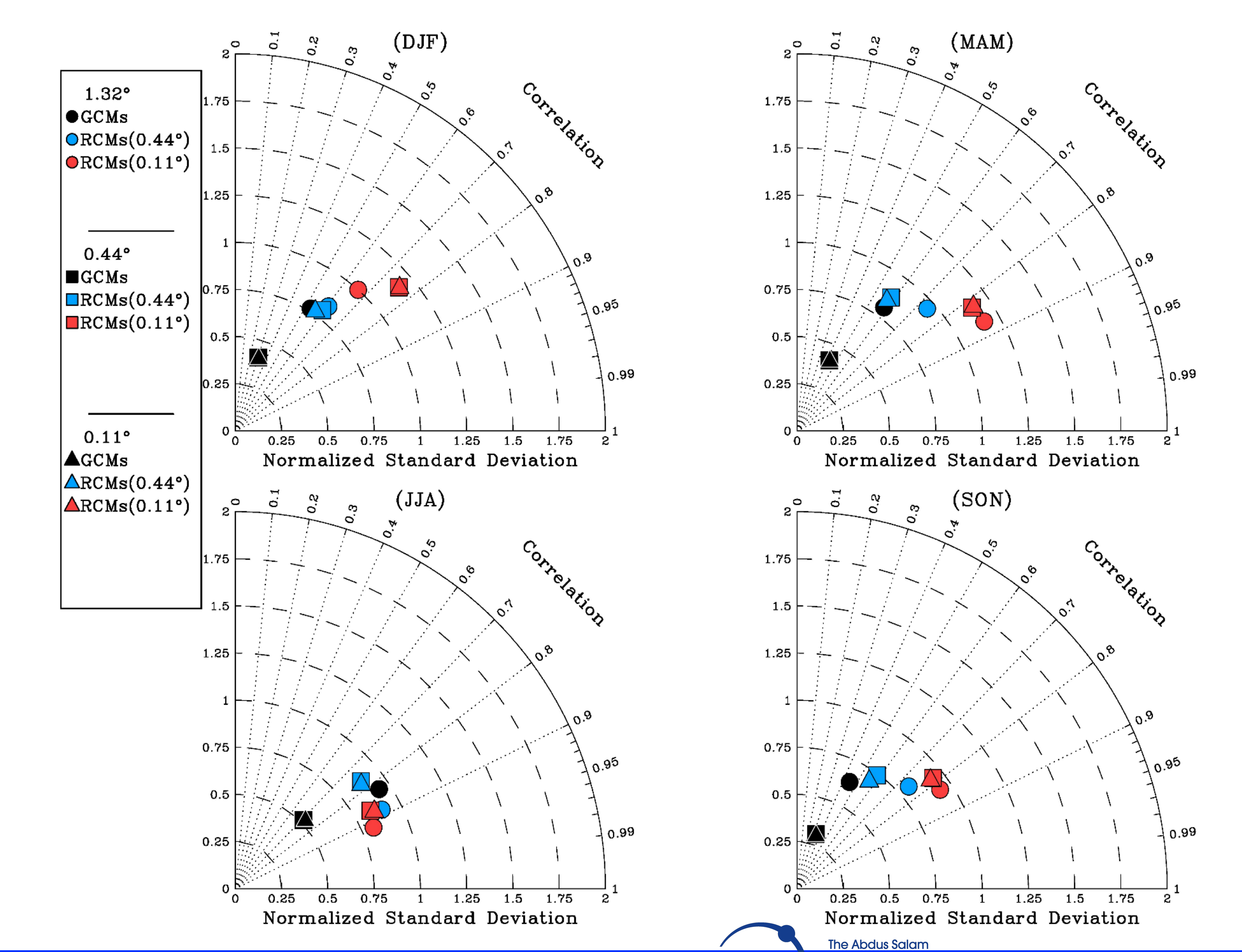
Taylor diagram of mean seasonal precipitation (model vs. obs, 1976-2005)



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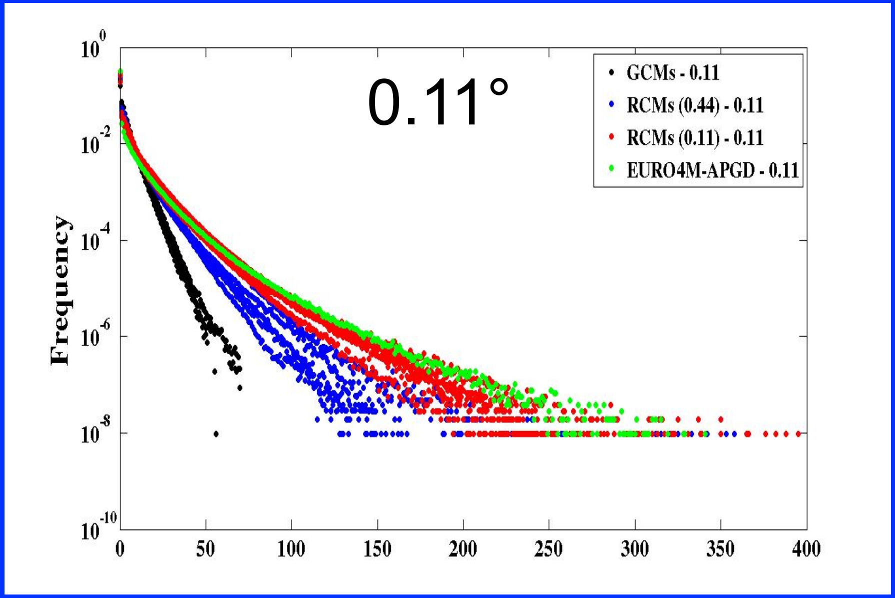
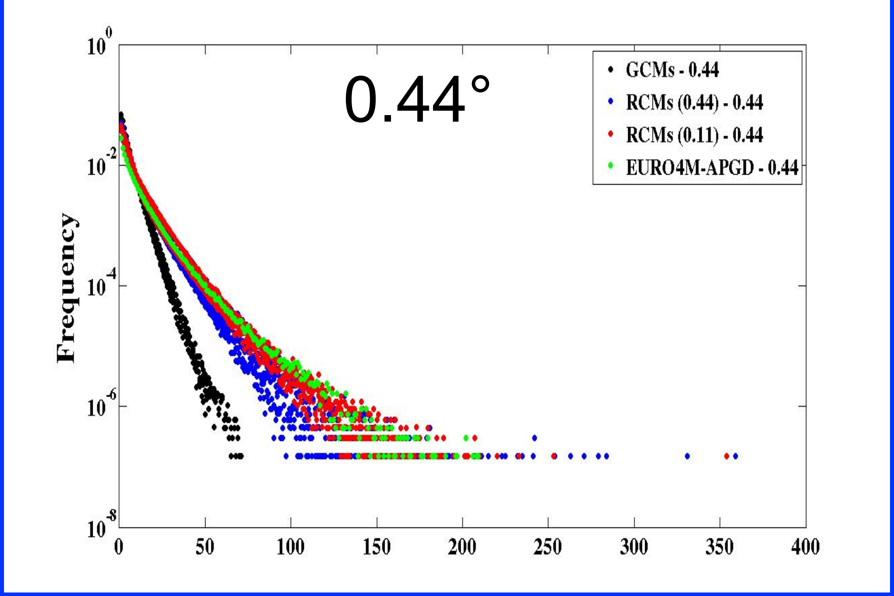
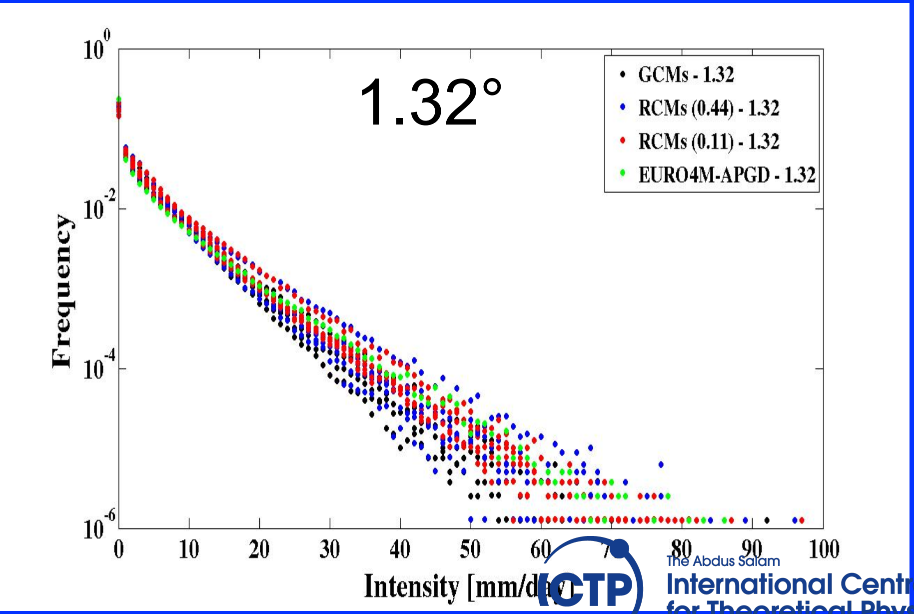
Daily precipitation PDFs on different grids

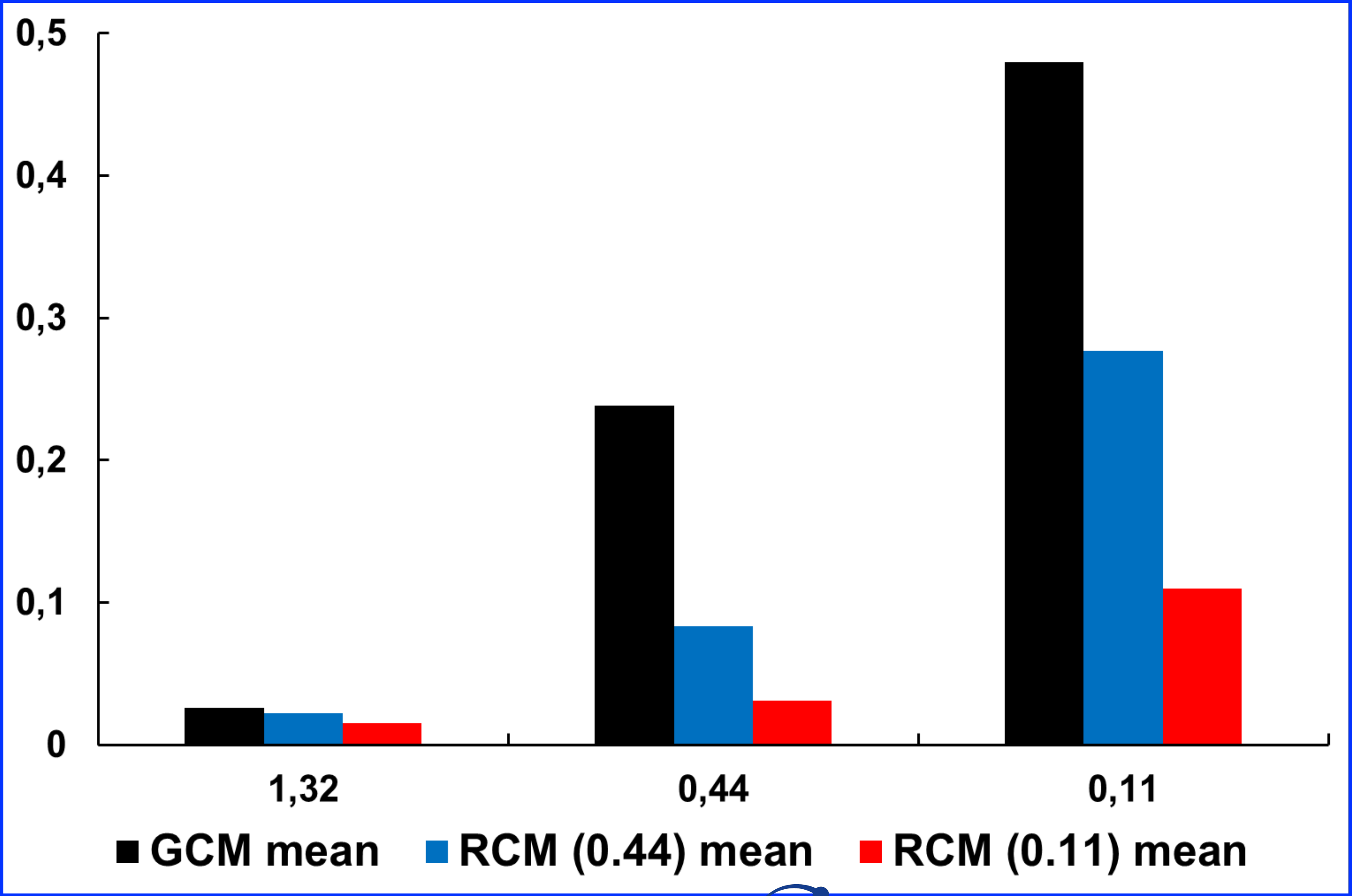




1976-2005



Ensemble mean KS distance for different resolution grids (1976-2005)



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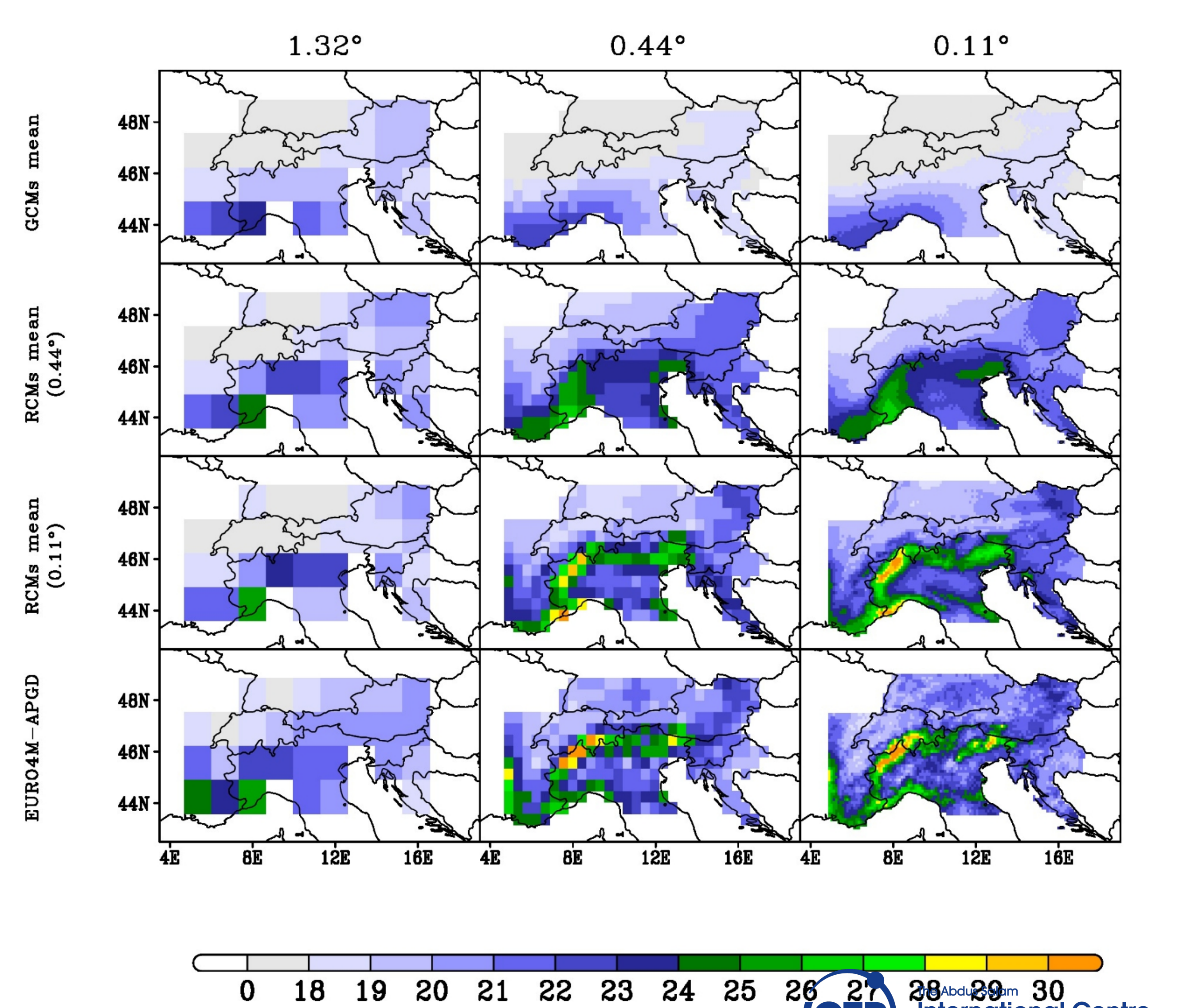
Ensemble mean R95 for different resolution grids (1976-2005)



Mean

19.5

21.5

22.1

22.2

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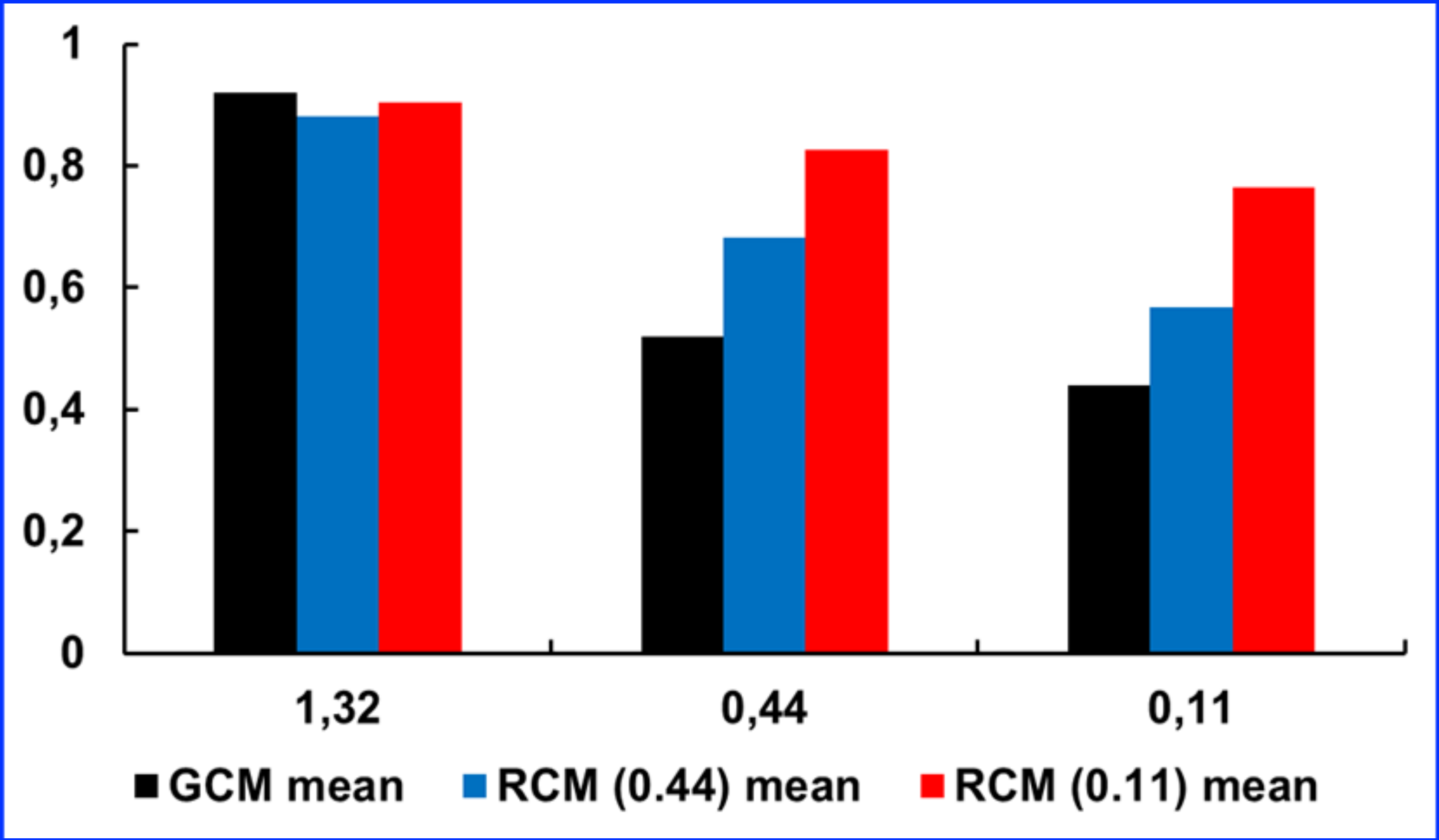
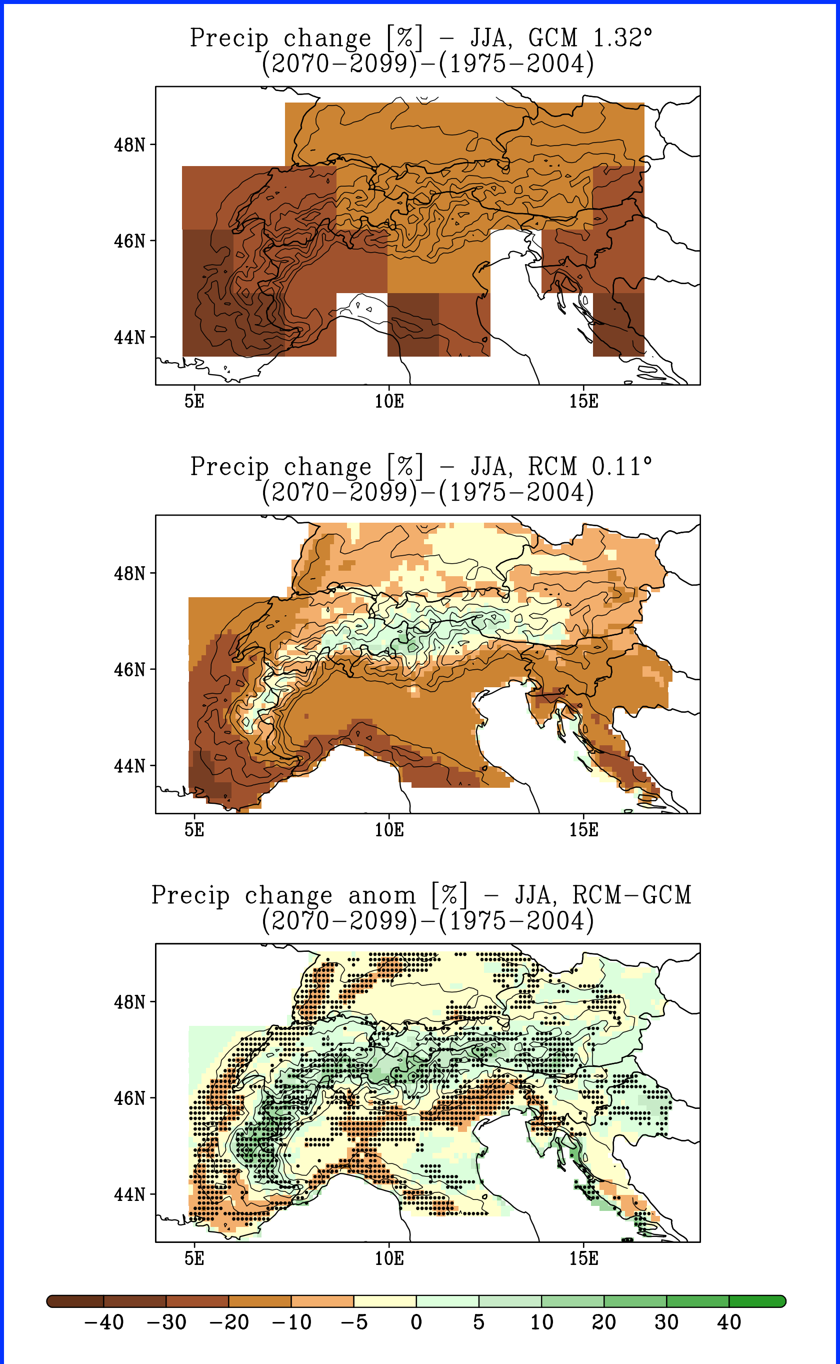
Correlation between simulated and observed R95 for different resolution grids (1976-2005)



Torma, Cs., F. Giorgi, and E. Coppola (2015), Added value of regional climate modeling over areas characterized by complex terrain Precipitation over the Alps, **J. Geophys. Res. Atmos.**, 120, 3957–3972, doi:10.1002/2014JD022781.



mm/day/century

GCMs

RCMs 0.11°

RCM – GCM Anomaly

Is added value reflected in the climate change projection? **Summer precipitation change**

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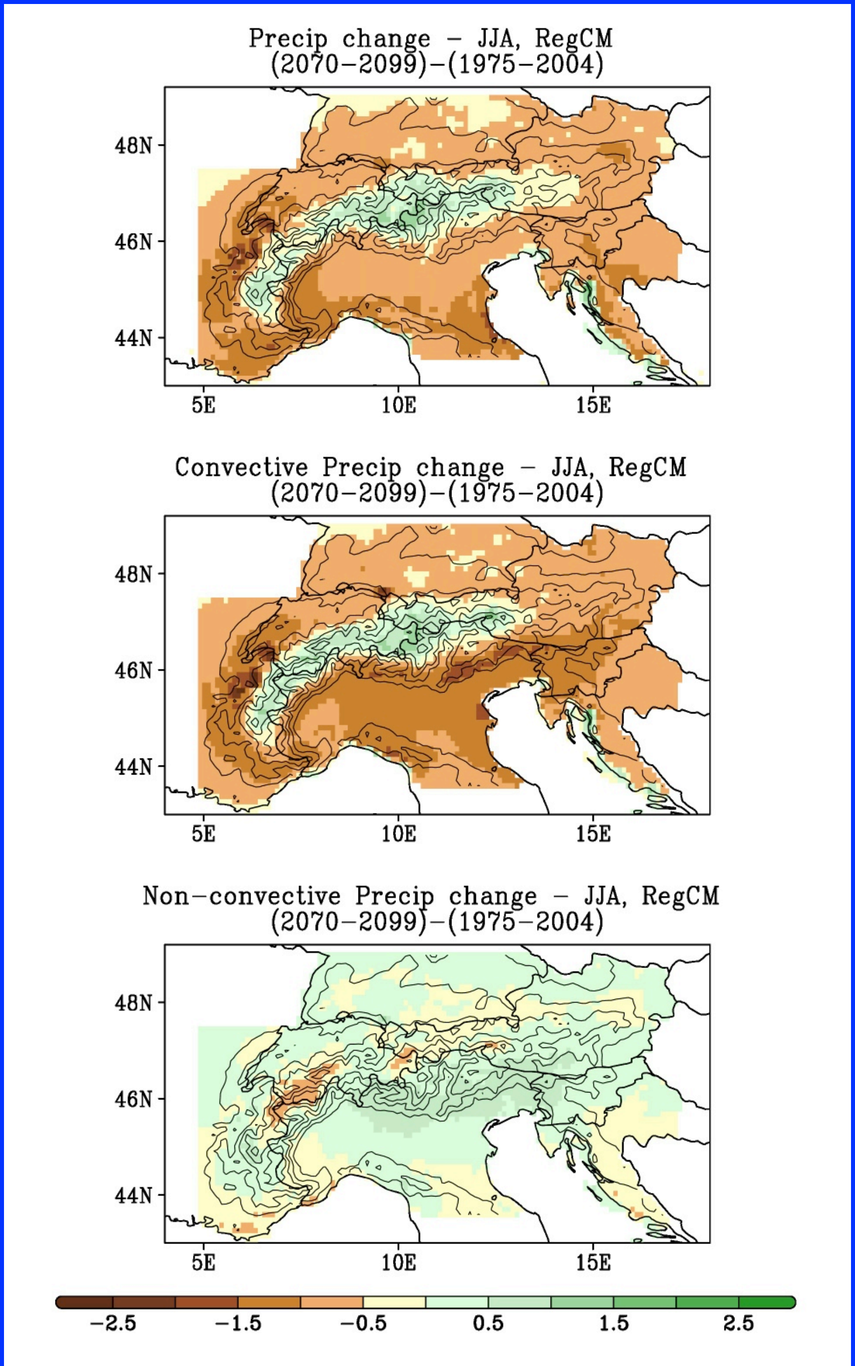
Summer precipitation change RegCM (0.11°)



mm/day/century

Total

Convective

Non-Convective

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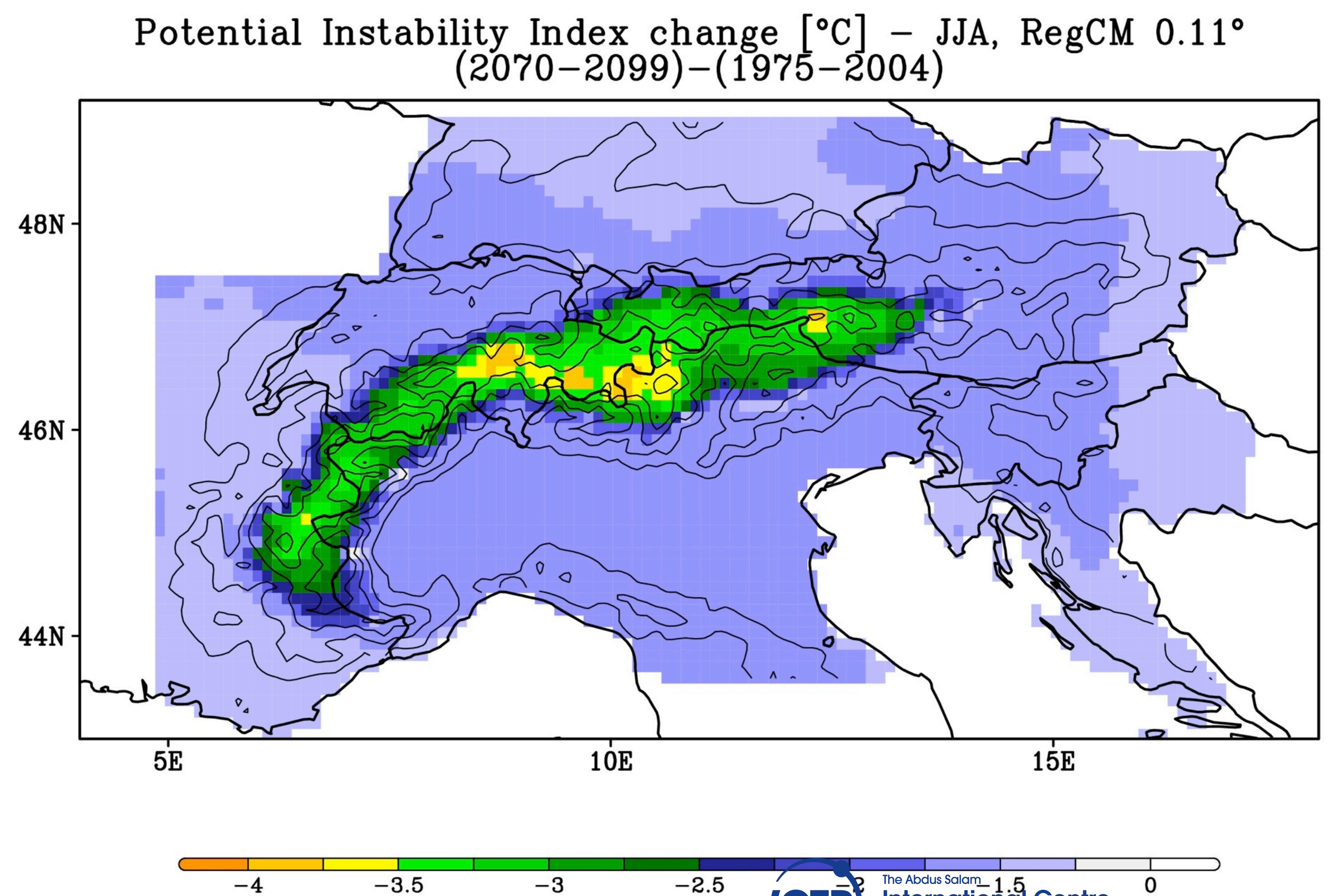
Change in potential instability index



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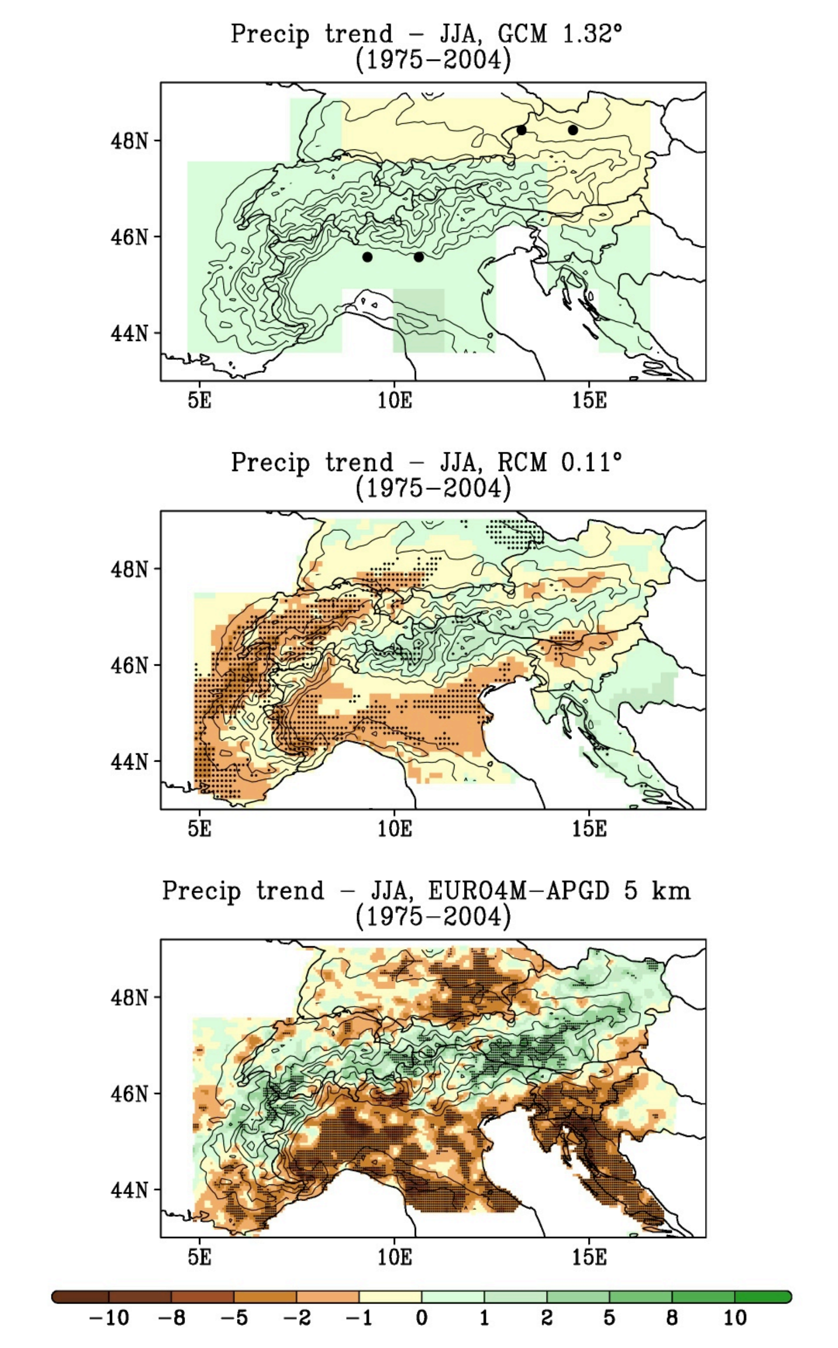
Summer precipitation trend during 1975-2004



mm/day/century

GCMs

RCMs
0.11°

Observations
EURO4M-APGD

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Summary

- We found substantial AV of RCM downscaling in all precipitation metrics considered, with this AV increasing with the resolution of the RCMs.
- The AV was clearly associated to the fine-scale topography characterizing this region
- RCM results were mostly better than the driving GCM ones for the metrics considered also when upscaled at the coarse GCM scale
- AV obtained with the RCM downscaling is due to physically consistent processes (i.e., topographical forcing on precipitation) and not simply to a high-resolution disaggregation of the GCM fields
- fine-scale topographical detail of the Alpine chain substantially modulates the precipitation change signal in the RCMs compared to those in the driving GCMs
- The fact that the precipitation change signal in the high-resolution RCMs shows patterns substantially different from those of the driving GCMs points to the caution that needs to be taken when using GCM projections for regional impact applications
- RCMs can play an important role in the study of climate change over regions characterized by complex topography, particularly concerning fine-scale spatial information and higher-order climate statistics which are important for impact sectors related to water resources, agriculture, and natural disaster prevention

What about other regions?

- Assessing the performance of RCMs over various EU regions against HR observations using both Med- and EURo-Cordex
- Does increased resolution (0.44 → 0.11 deg) provide real benefits compared ti HR OBS?
- Do modelled precipitation climate extremes show significant Added Value?

TOOLS

- 9 ERA-Interim driven, double nested Med- and EURO-CORDEX Regional Climate Models
- HR observation datasets over 9 different European regions
- 2 common analysis grids at 0.11 and 0.44 degrees resolution
- Precipitation undercatch correction with UDEL dataset (Matsuura and Willmott 2010, UDEL V3.01) when applicable

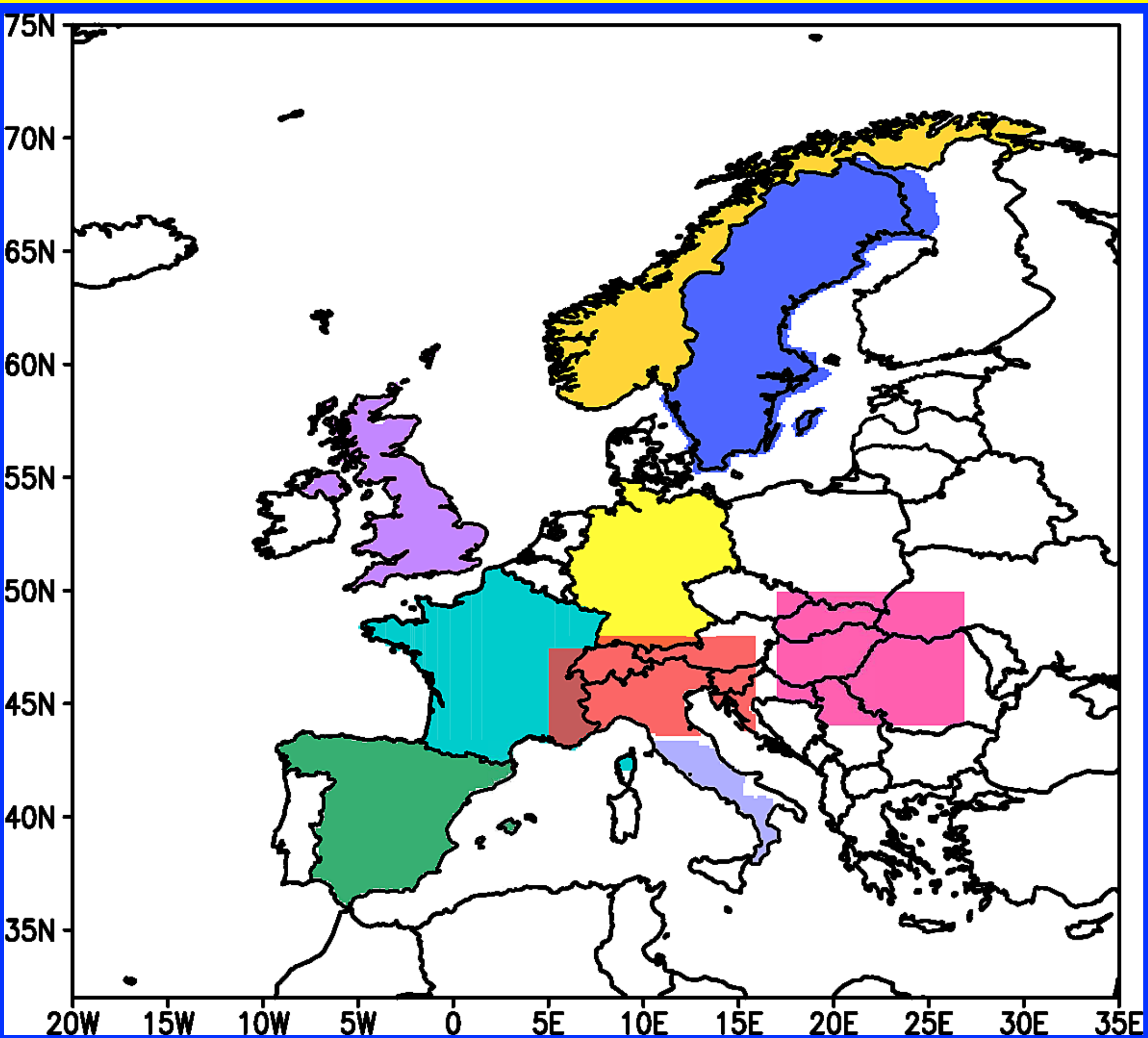
HR Obs. datasets over 9 regions

Dataset	Institution	Region	Period	Resolution	Reference
EURO4M-APGD +	MeteoSwiss	Alps	1971-2008	5km	Isotta et al. (2013)
Spain02 +	Santander Meteorology Group	Spain	1971-2010	0.11 deg	Herrera et al. (2010)
SAFRAN	Meteo-France	France	1958-2013	8km	Vidal et al. (2010)
UK gridded dataset o+	UK Met Office	United Kingdom	1990-2010	0.11 deg	Perry et al. (2009)
KLIMAGRID o	METNO	Norway	1957-2013	1km	Mohr (2009)
PTHBV o	SMHI	Sweden and part of Finland	1961-2010	4km	Johansson (2002)
CARPATCLIM +	Hungarian Meteorological Service	Carpathians	1961-2010	0.10 deg	Szalai et al. (2013)
REGNIE o+	DWD	Germany	1961-2009	1km	Rauthe et al. (2013)
CETEMPS gridded dataset +	CETEMPS, University of L'Aquila	Italy	2000-2014	0.11 deg	Not released yet

o = covered by EURO-CORDEX only

+ = undercatch-corrected with UDEL data

HR Obs. datasets over 9 regions



9 Regional Climate Models @ 0.11 and 0.44 deg resolution

Model	Institution	
CCLM4-8-17	CLMcom	EURO-CORDEX
HIRHAM5	DMI	
INERIS-WRF331F	IPSL	
RACMO22E	KNMI	
RCA4	SMHI	
ALADIN5.2	CNRM	Med-CORDEX
RegCM4.4	ICTP	
CCLM4-8-18	GUF	
PROMES	UCLM	

Analysis period: 1989-2008; 1990-2008 (UK); 2000-2010 (Italy)

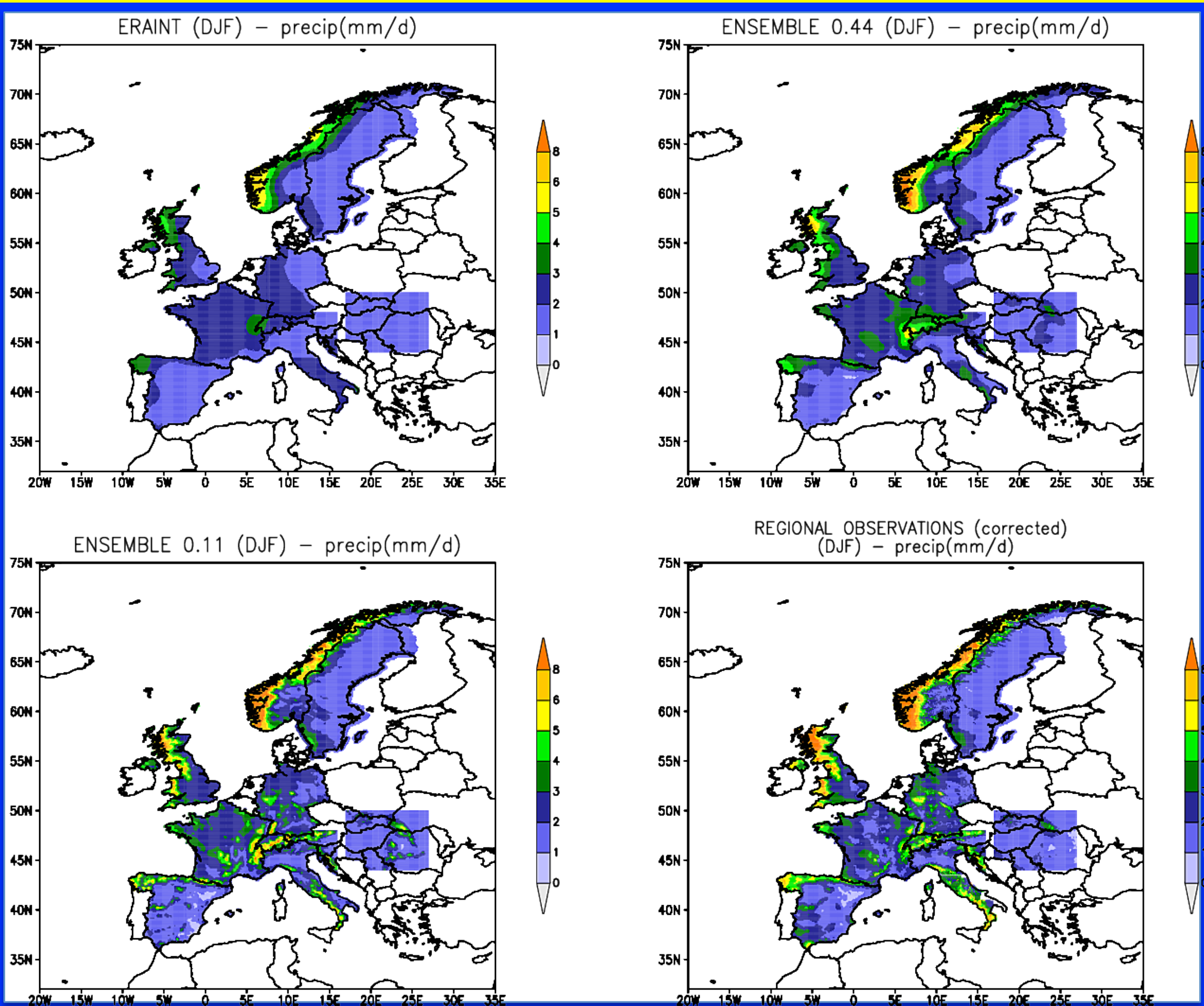
Precipitation performance indices with emphasis over extremes

Index	Description
RMSE, mean, bias	Standard statistics.
TAYLOR	Taylor diagrams: spatial correlation, std.dev. and centered RMSE.
KL	Symmetrized Kullback-Leibler divergence for PDFs. (>1mm / day)
SDII *	Mean daily precipitation intensity. (mm / day)
DDF *	Mean frequency of dry days. (%)
CDD95 *	95th percentile of dry spell length. Replaces CDD. (No. days / year)
Psum>R95obs *	Total precipitation above the reference 95th percentile of observed daily precipitation. Replaces R95p. (mm / year)

* = daily precipitation indices

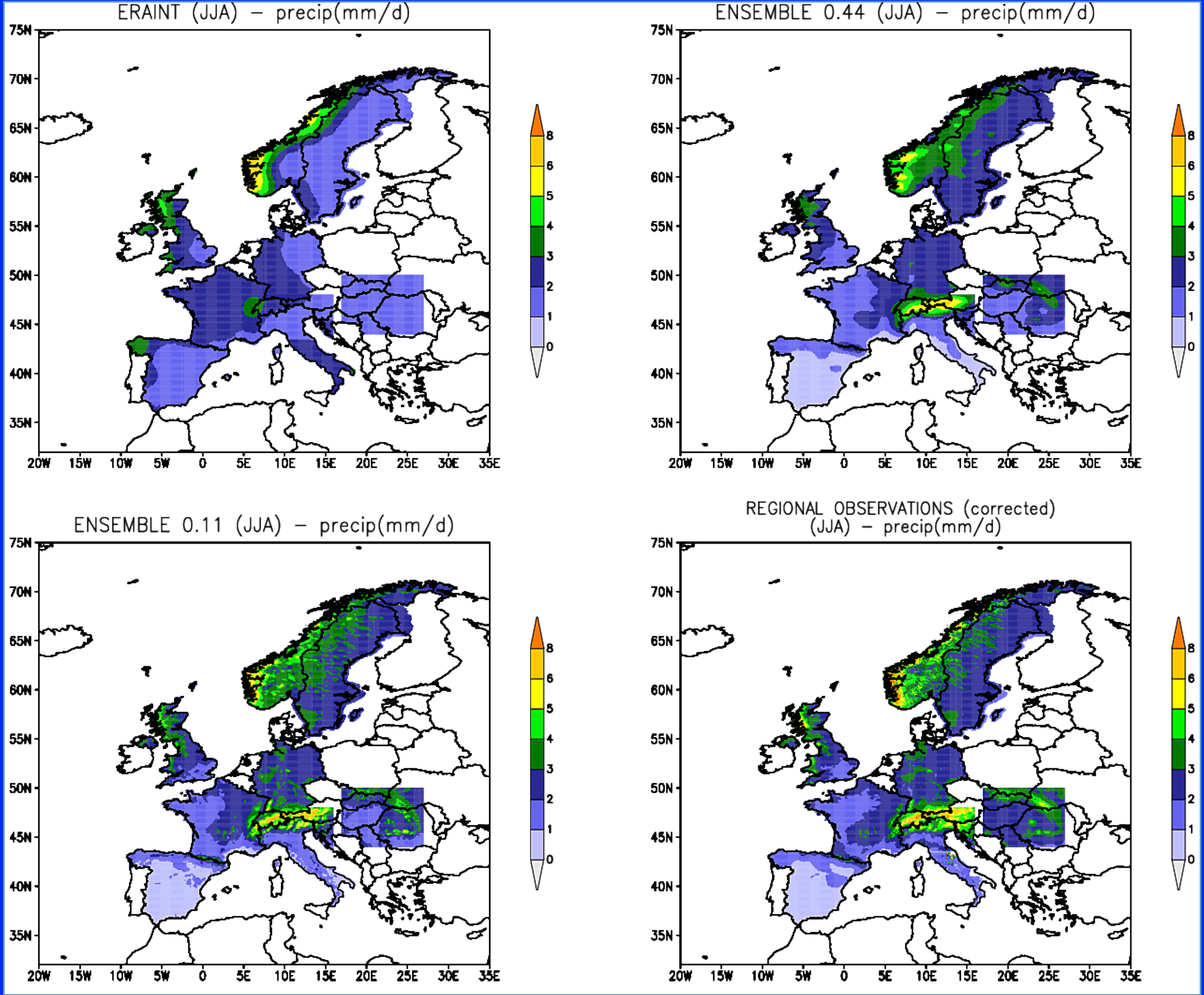
Results for mean precipitation

DJF



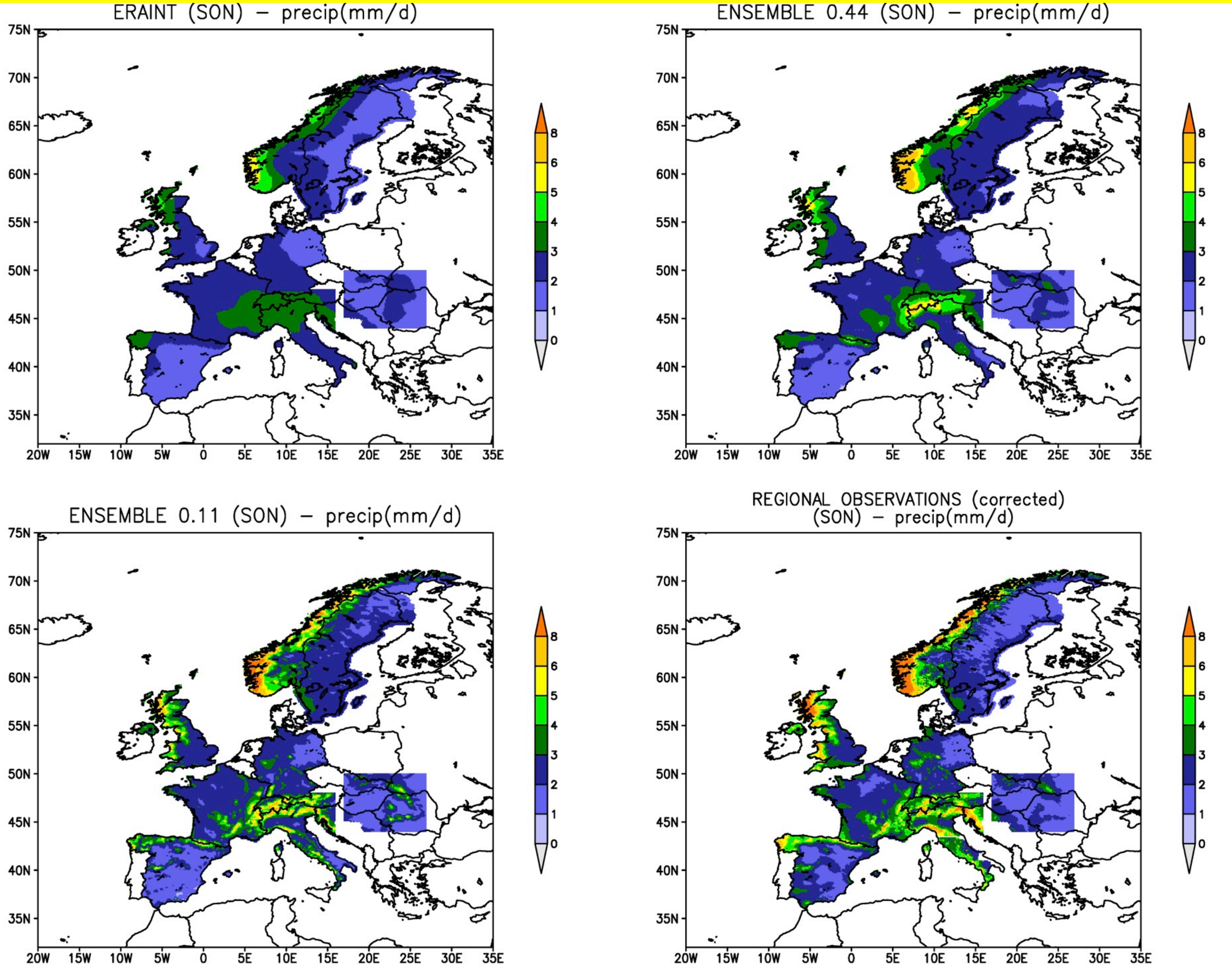
Results for mean precipitation

JJA



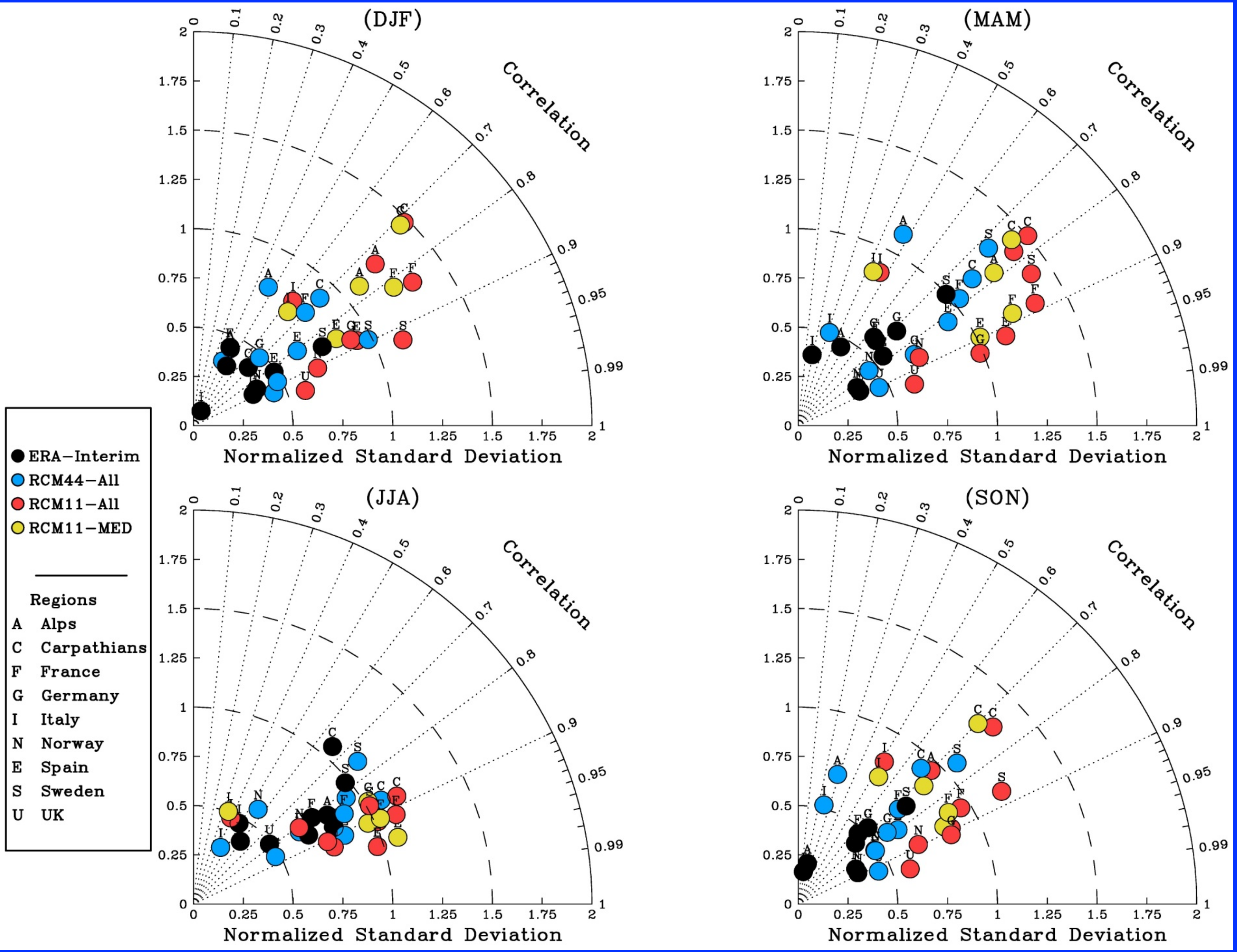
Results for mean precipitation

SON



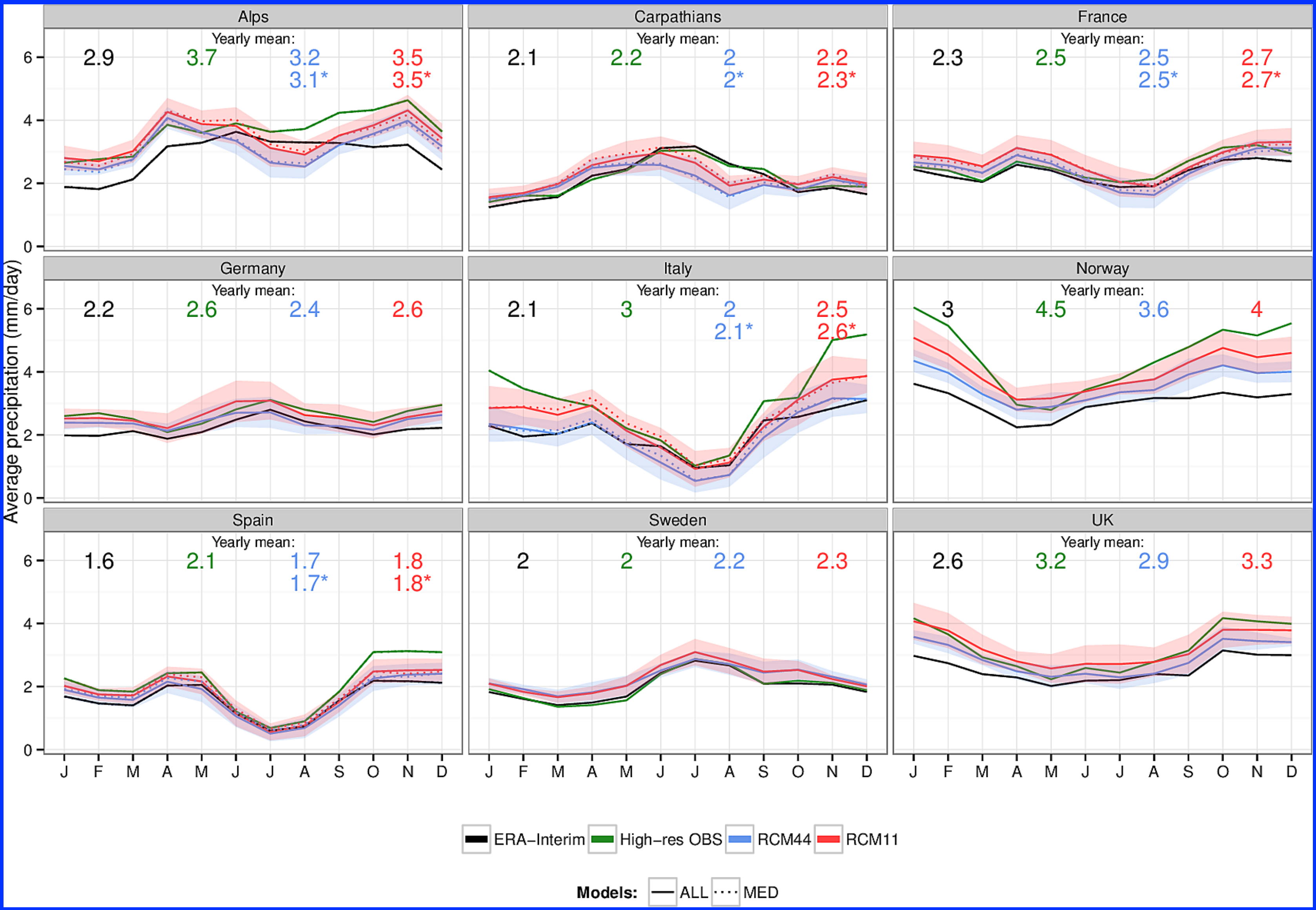
Results for mean precipitation

Taylor plots

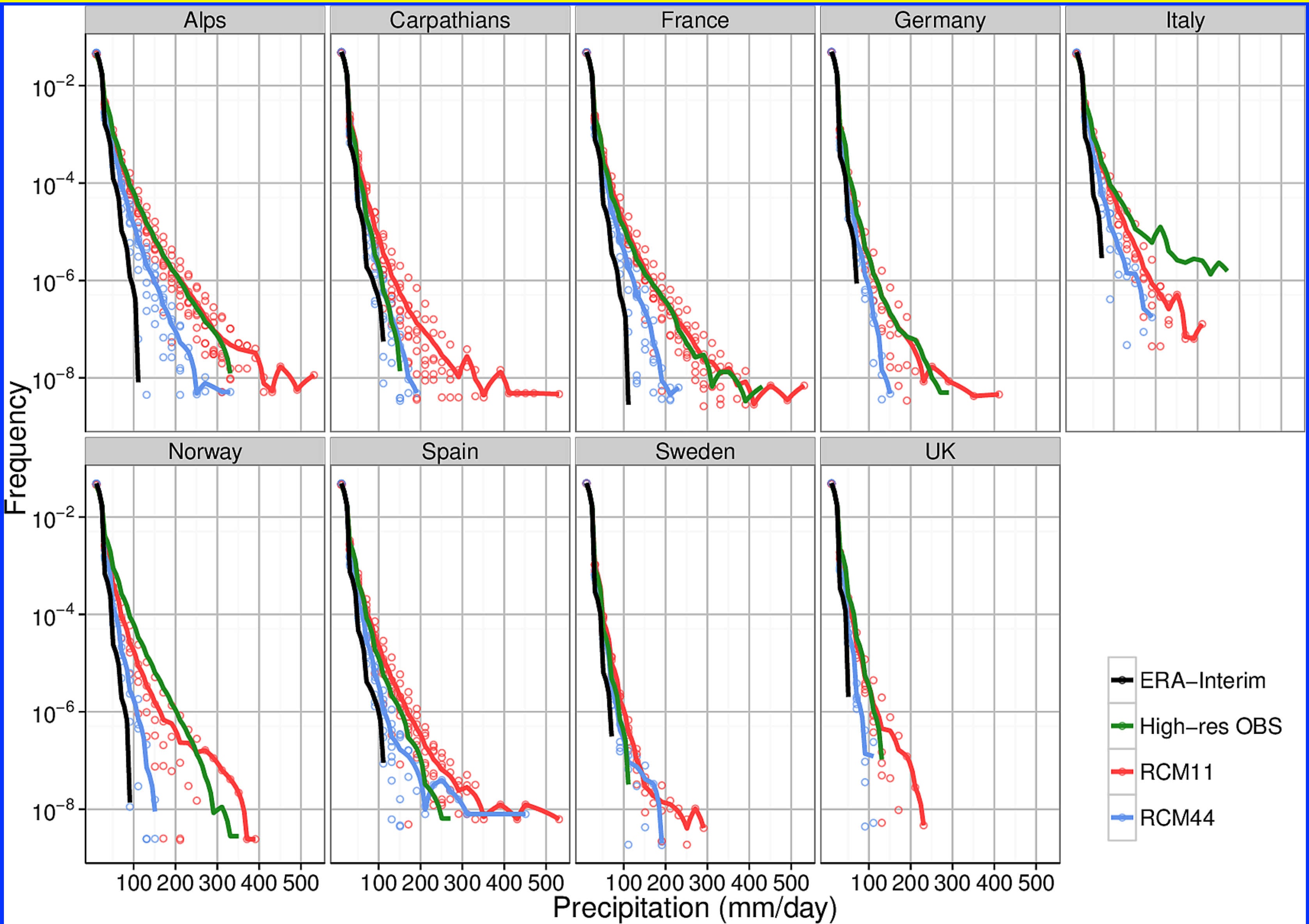


Results for mean precipitation

Annual cycle

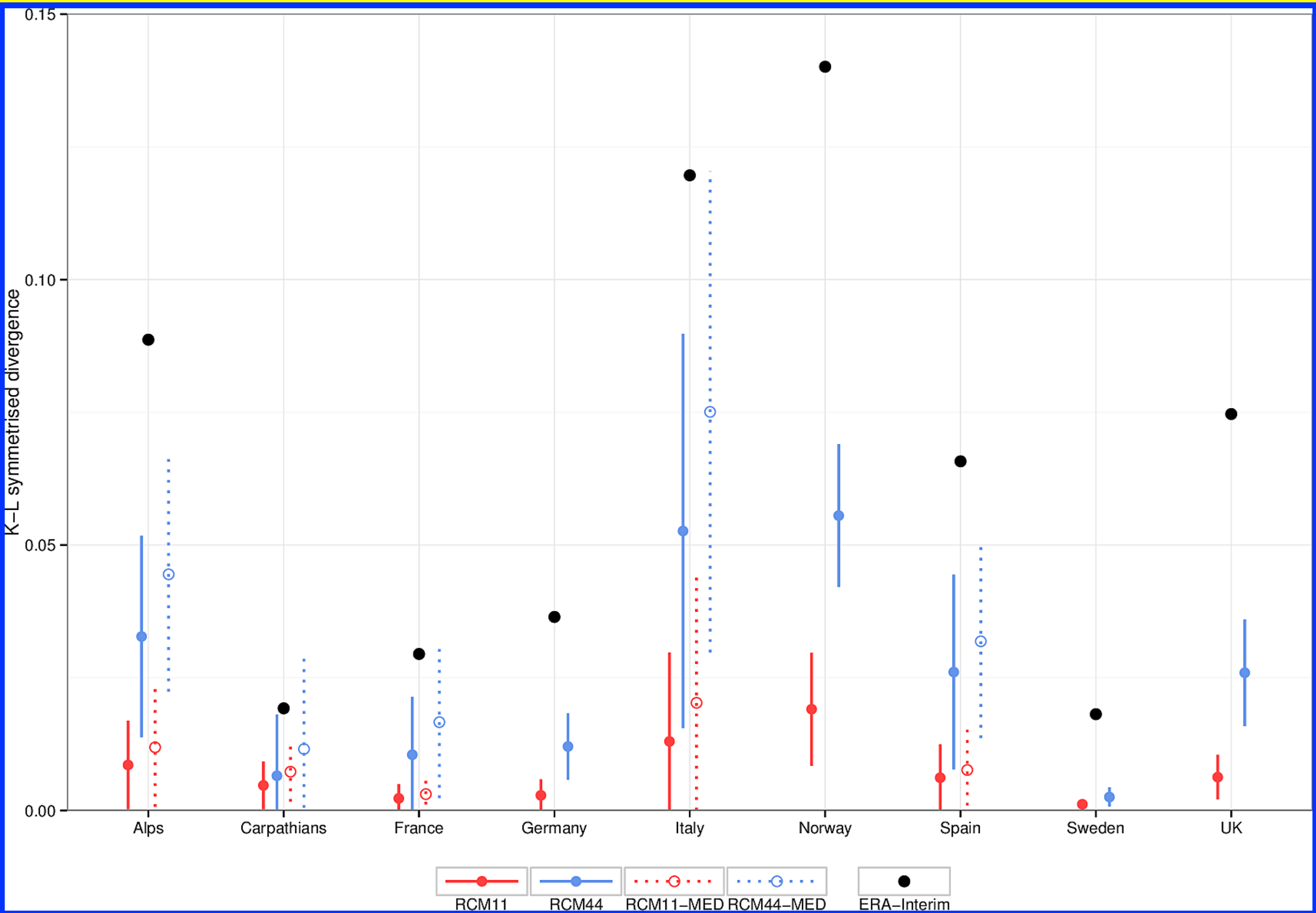


Results for daily PDFs



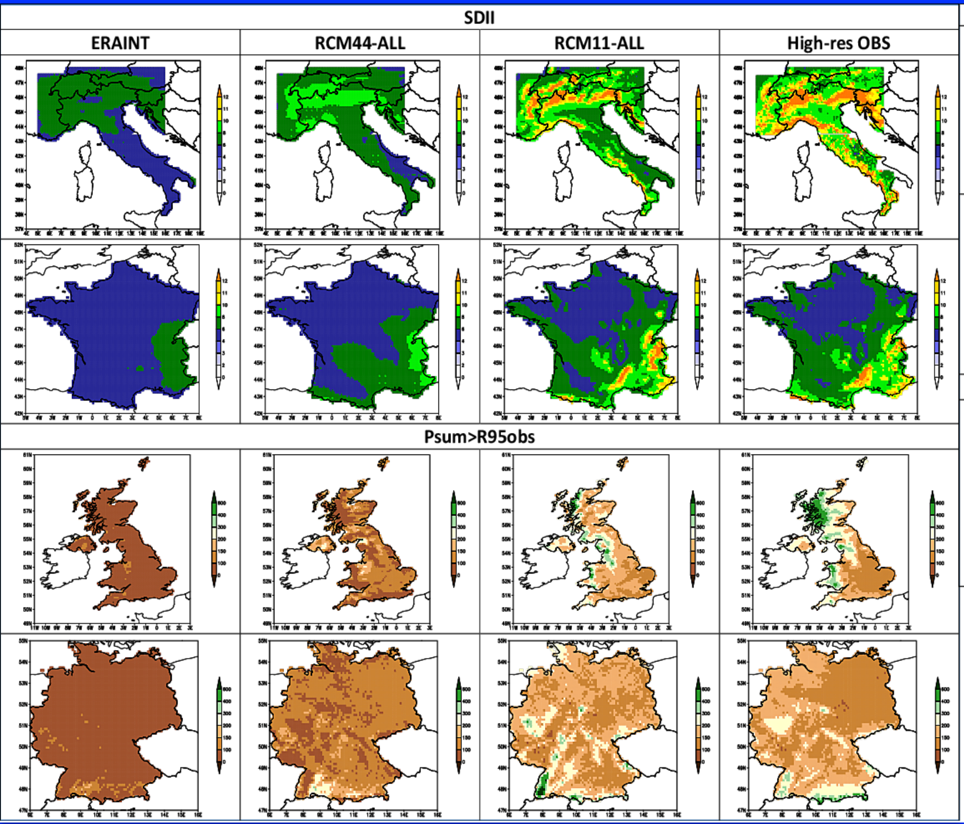
Results for daily PDFs

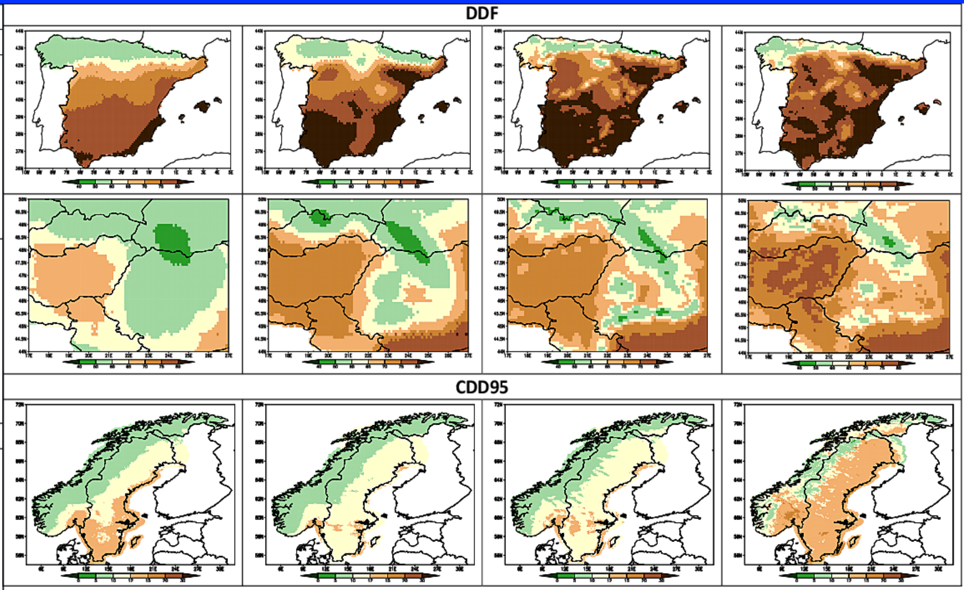
Kullback-Leibler divergence



Results for daily precipitation indices

Selected maps

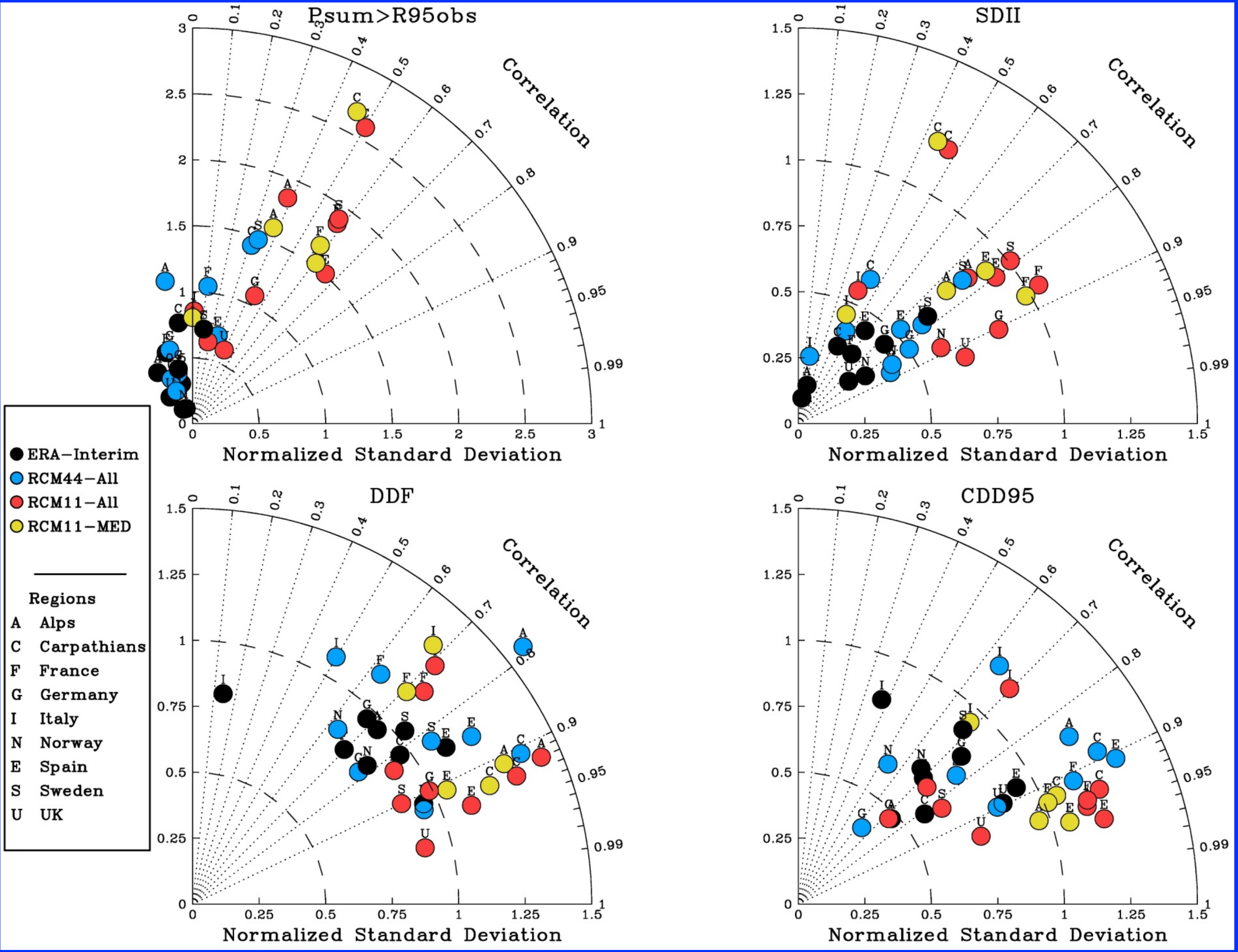




Fantini A., Raffaele F., Torma C., Bacer S., Coppola E., Giorgi F., Ahrens B., Dubois C., Sanchez E. Assessment of multiple daily precipitation statistics in ERA-Interim driven Med-CORDEX and EURO-CORDEX experiments against high resolution observations. Submitted to Climate Dynamics, 2016

Results for daily precipitation indices

Taylor plots

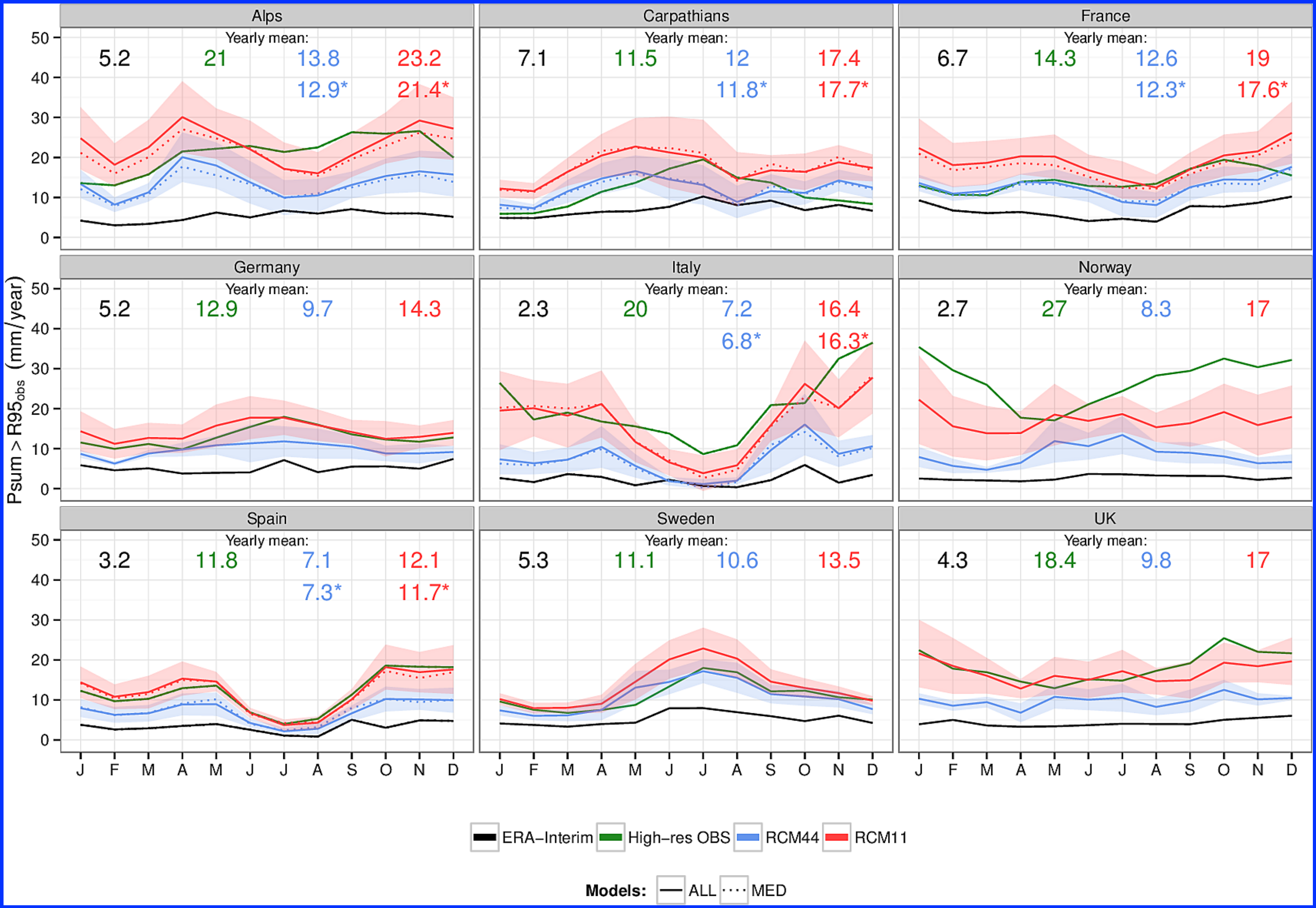


Results for daily precipitation indices

SDII

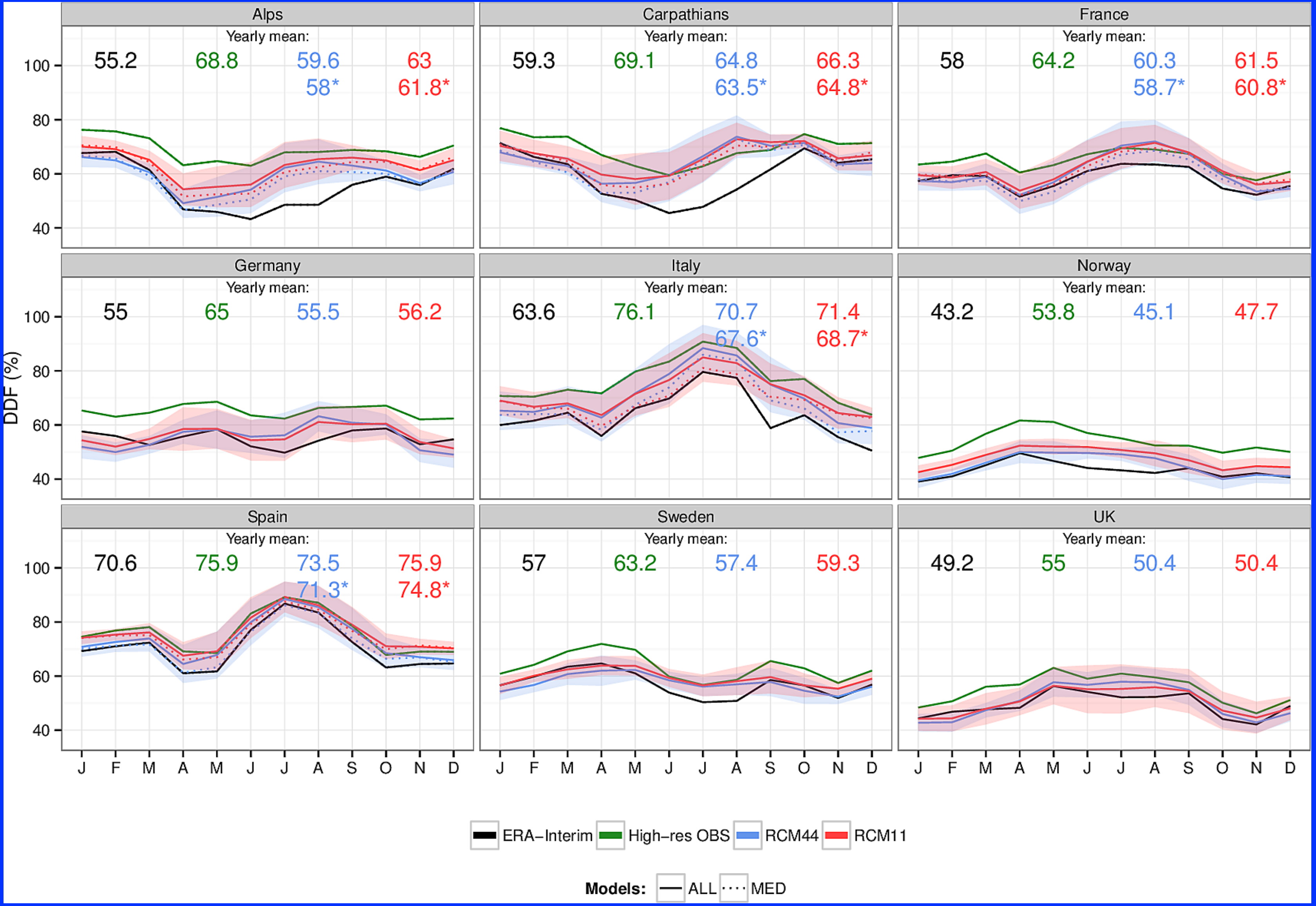
Results for daily precipitation indices

Psum > $R95_{obs}$



Results for daily precipitation indices

DDF



Summary

- The ensembles show high skill in reproducing most climate features of the observed regions, with some notable exceptions
- In most metrics, there is strong Added Value in the high-resolution 0.11 degrees ensemble
- Some metrics (e.g. DDF and CCD95 in some regions) still indicate deficiencies in the model's description of precipitation processes maily due to the drizzle fenomenon that is not solved by the increased resolution
- EURO-CORDEX and Med-CORDEX models perform on par
- The quality, homogeneity and resolution of observations is crucial to model assessment, especially for high resolution