Milankovitch Anniversary Conference, September 2014 - Belgrade, Serbia

Heavy precipitation events over the Euro-Mediterranean region in a warmer climate: results from CMIP5 models

Enrico Scoccimarro, Silvio Gualdi, Alessio belucci, Matteo Zampieri, Antonio Navarra

CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici (Euro-Mediterranean Centre on Climate Change), Bologna, Italy
INGV - Istituto Nazionale di Geofisica e Vulcanologia (National Institute for Geophysics and Volcanology), Bologna, Italy

Istituto Nazionale di Geofisica e Vulcanologia

MOTIVATION & OBJECTIVES

In the past years many studies have been undertaken to analyze intense precipitation events using coupled and uncoupled General Circulation Models (GCMs) (Wetherald and Manabe 1999, Kharin and Zwiers 2000, Hegerl et al. 2004, Kharin et al. 2007, Hegerl et al., 2007, Kiktev et al. 2007, Carril et al. 2008, Min et al. 2009, Seager et al. 2012)

Model projections indicate intensification of extreme precipitation in a warming climate leading to wet areas getting wetter and dry areas getting drier (Chou et al. 2009)

The aim of this work is to verify and quantify changes in the right tail of the precipitation distribution, under a warmer climate, using state of the art coupled simulations carried out within the 5° Coupled Model Intercomparison Project (CMIP5) over the Euro-Mediterranean Region.

DATA & METHODOLOGY

Modelled Precipitation

Model name	Lat x Lon (degrees)	Institute (Institude ID)
BNU-ESM	2.8 x 2.8	College of Global Change and Earth System Science, Beijing Normal University (GCESS)
CCSM4	**0.9 x 1.5**	National Center for Atmospheric Research (NCAR)
CMCC-CESM	3.7 x 3.7	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
CMCC-CMS	1.9 x 1.9	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
CMCC-CM	**0.8 x 0.8**	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
CNRM-CM5	**1.4 x 1.4**	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique (CNRM- CERFACS)
CSIRO-Mk3-6-0	1.9 x 1.9	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence (CSIRO-QCCCE)
CanESM2	2.8 x 2.8	Canadian Centre for Climate Modelling and Analysis (CCCMA)
FGOALS-s2	1.6 x 2.8	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences (LASG-IAP)
GFDL-CM3	2.0 x 2.5	NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)
GFDL-ESM2G	2.0 x 2.5	NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)
GFDL-ESM2M	2.0 x 2.5	NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)
HadGEM2-CC	**1.2 x 1.8**	Met Office Hadley Centre (MOHC)
HadGEM2-ES	**1.2 x 1.8**	Met Office Hadley Centre (MOHC)
INM-CM4	**1.5 x 2.0**	Institute for Numerical Mathematics (INM)
IPSL-CM5A-MR	**1.2 x 2.5**	IPSL-CM5A-LR Institut Pierre-Simon Laplace (IPSL)
MIROC5	**1.4 x 1.4**	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (MIROC)
MPI-ESM-MR	1.9 x 1.9	Max Planck Institute for Meteorology (MPI-M)
MRI-CGCM3	**1.1 x 1.1**	Meteorological Research Institute (MRI)
NorESM1-M	1.8 x 2.5	Norwegian Climate Centre (NCC)

For this analysis we use daily precipitation fields from a subset of the CMIP5 multimodel ensemble, consisting of simulations of the XX (HISTORICAL) and XXI (under the RCP8.5, a rising radiative forcing pathway leading to 8.5 W/m2 in 2100) century climate performed with 20 coupled ocean-atmosphere climate models.

Observed Precipitation

Daily data from the Global Precipitation Climatology Project (GPCP, Bolvin et al., 2009), of the period 1997-2005.

Analysed periods: - HISTORICAL 1966-2005
- RCP8.5 scenario 2061-2100

DATA & METHODOLOGY

CMCC climate models

CMIP5 models involved in this study

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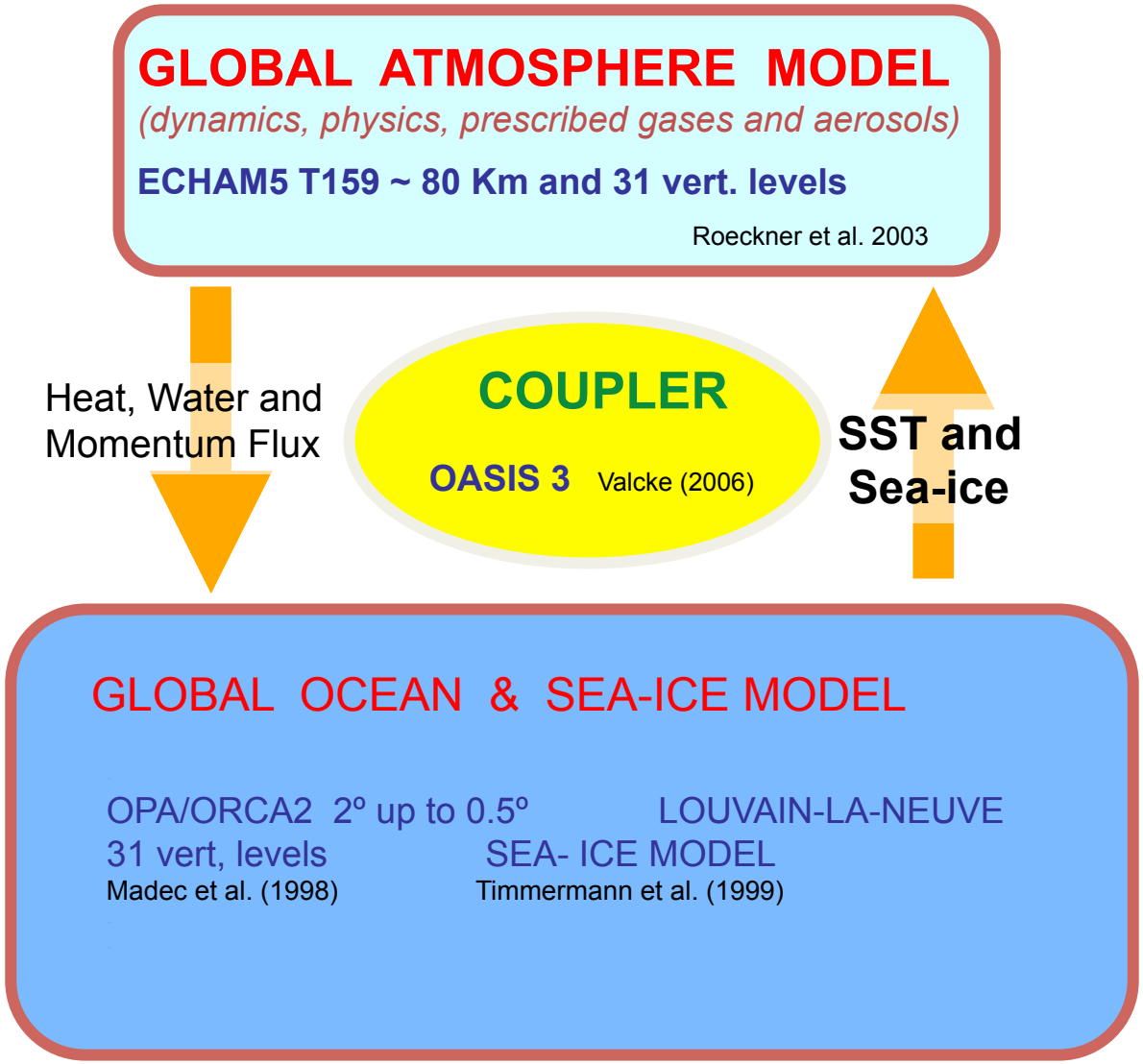
The CMCC-CM MODEL:
A fully coupled General Circulation Model



Ref: Scoccimarro E., S.Gualdi, A.Bellucci, A.Sanna, P.G. Fogli, E.Manzini, M.Vichi, P.Oddo, A.Navarra (2011)
Effects of Tropical Cyclones on Ocean Heat Transport in a High Resolution Coupled General Circulation Model
Journal of Climate, doi: 10.1175/2011JCLI4104.1.

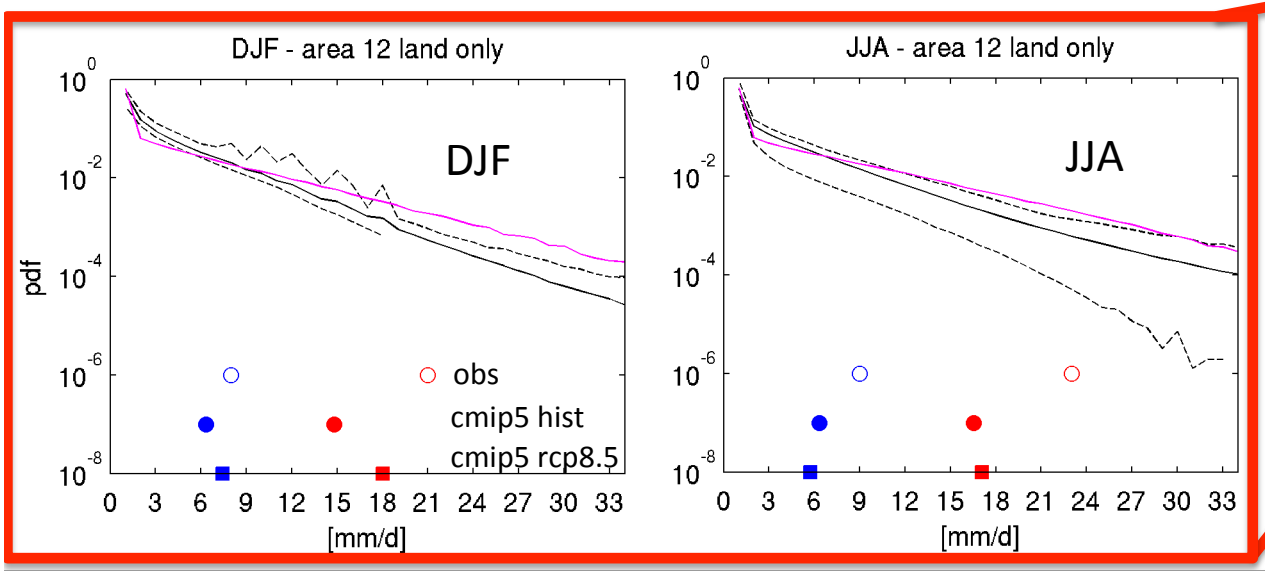
DATA & METHODOLOGY

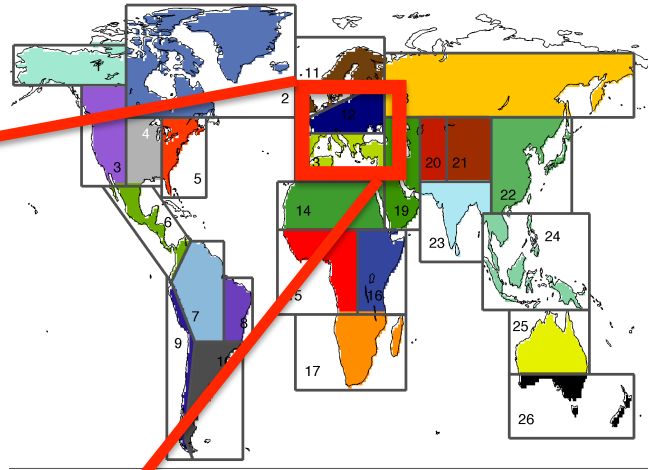
For the considered periods (1966-2005 2061-2100) we computed the difference between **99th** and **90th** **percentiles** of precipitation **(**hereafter **99p-90p)** **for each model, on the corresponding original spatial grid, for winter (DJF) and summer (JJA).**

90p is considered as the threshold to define a **heavy rainfall event.**

99p is considered as the threshold to define an **extreme rainfall event.**

99p-90p is used **to quantify the width of the right tail of the precipitation distribution** over the two investigated periods.





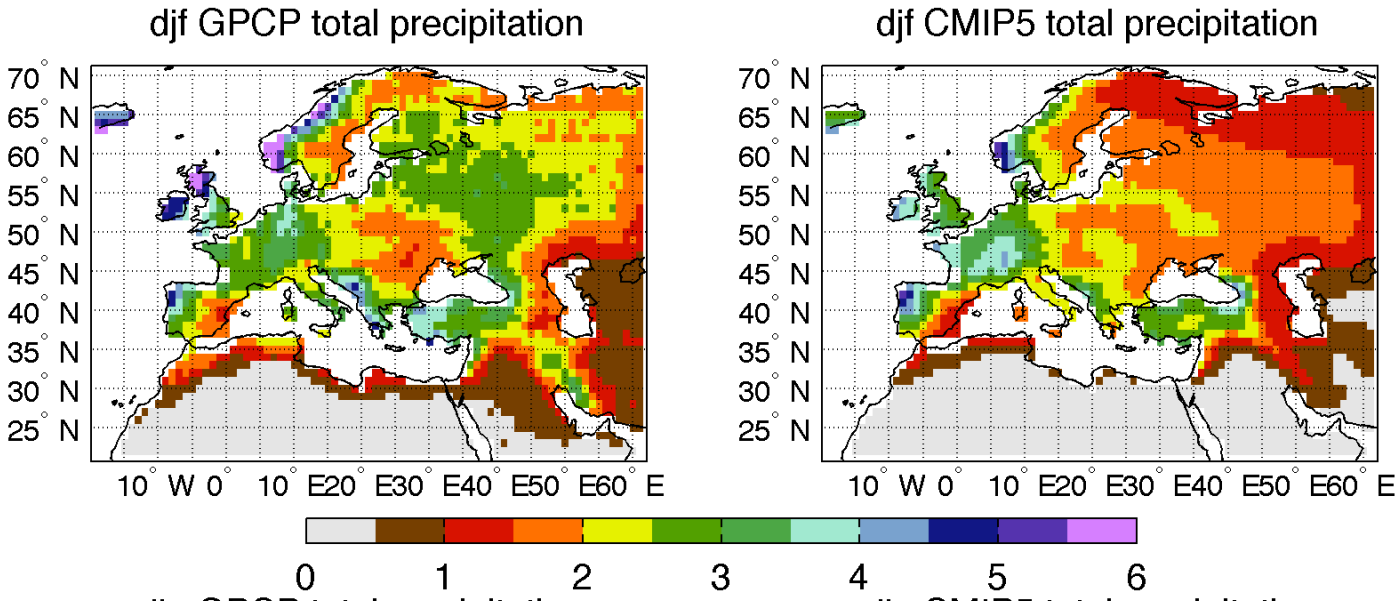
(IPCC, 2012)

blue= 90p

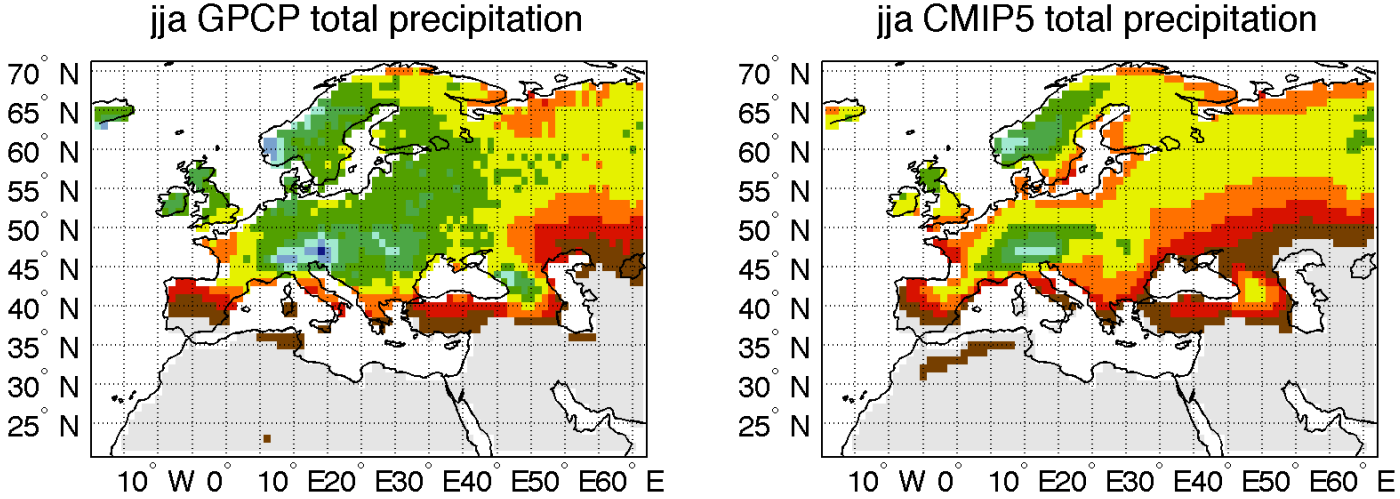
red= 99p

Average precipitation [mm/d] during 1997-2005

DJF



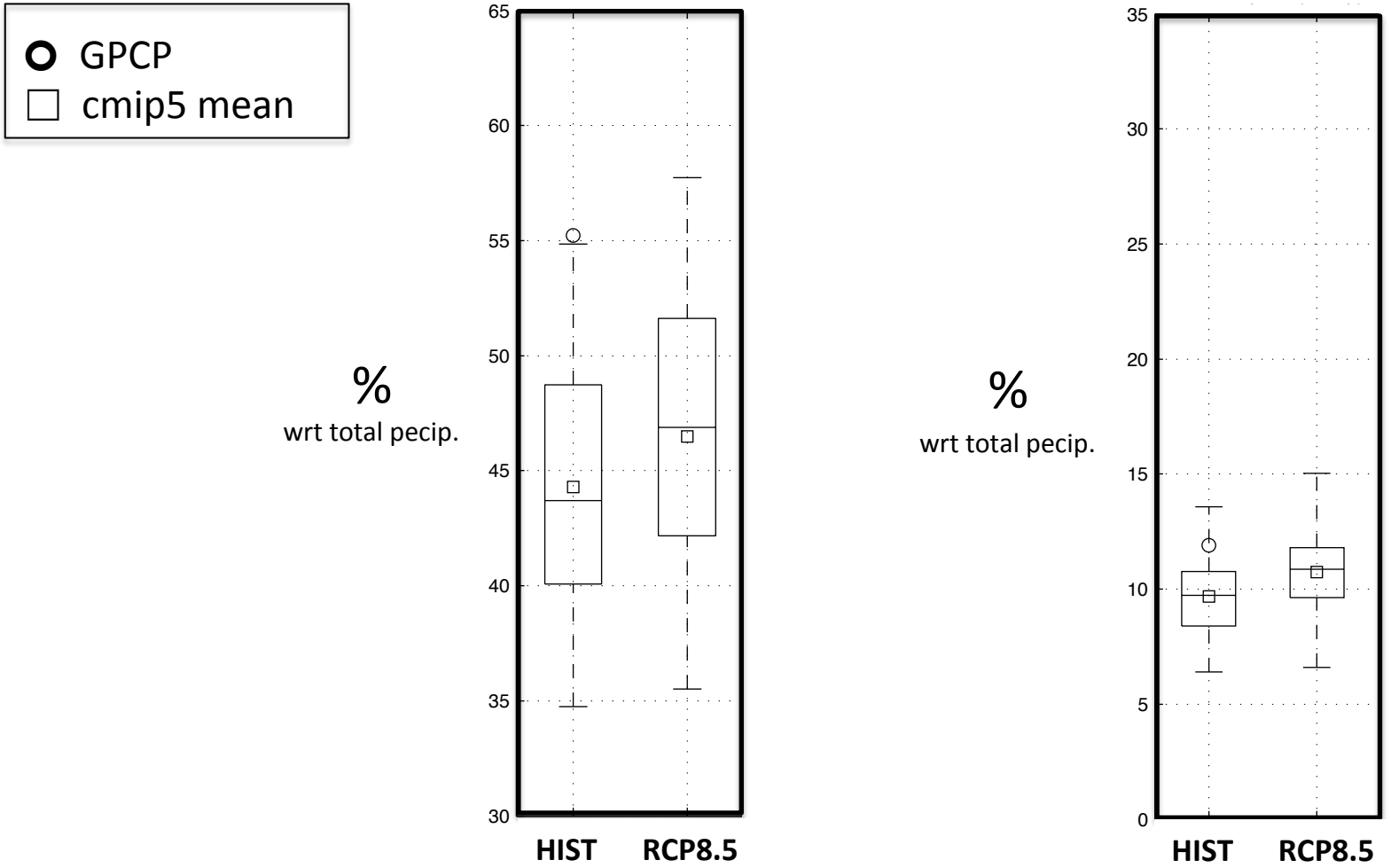
JJA



OBS (GPCP) CMIP5 models

RESULTS

AMOUNT OF WATER (% wrt total precipitation) associated to heavy (>90p) and extreme (>99p) events during PRESENT (1966:2005) and FUTURE (2061-2100) at global scale

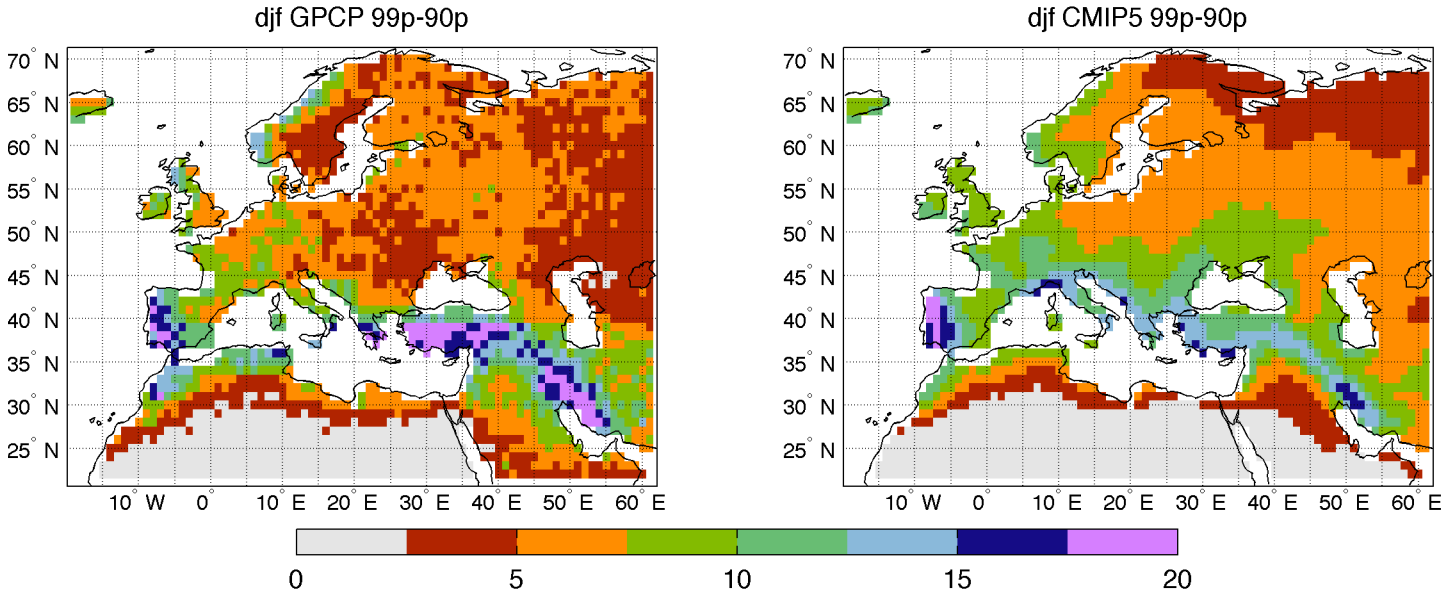


Ref:

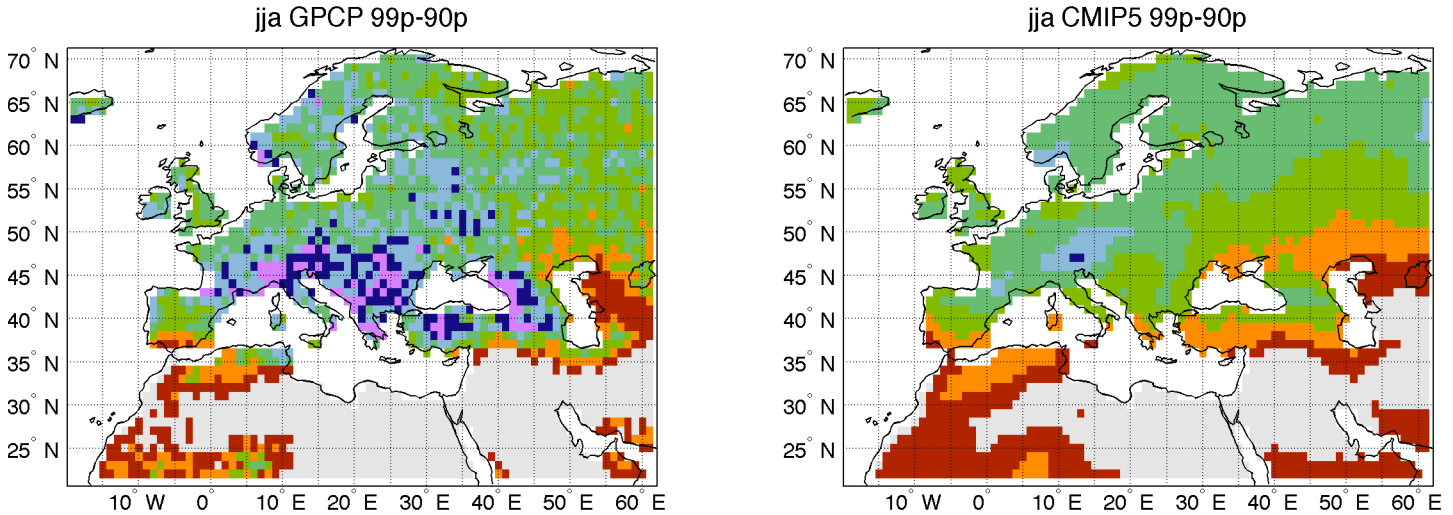
*Scoccimarro, E., S. Gualdi, A. Bellucci, M. Zampieri, A. Navarra: "**Heavy precipitation events in a warmer climate: results from CMIP5 models**", Journal of Climate, 2013 - doi: 10.1175/JCLI-D-12-00850.1.*

99p-90p [mm/d] during 1997-2005

DJF



JJA



OBS (GPCP)

CMIP5 models

total precipitation, 90p and 99p-90p CHANGES IN A WARMER CLIMATE

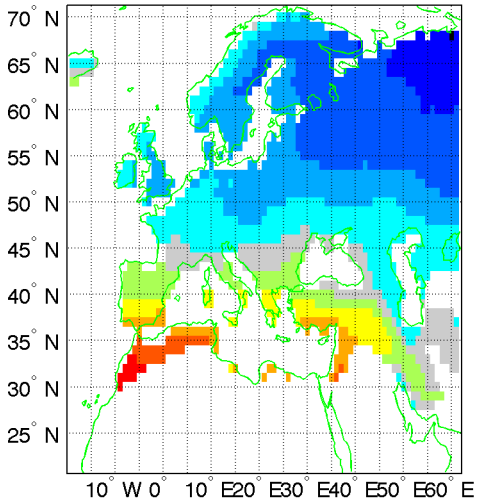
(% increase in 2061-2100 wrt 1966-2005)

*regions with pr<0.5 mm/day are masked (white)

Average

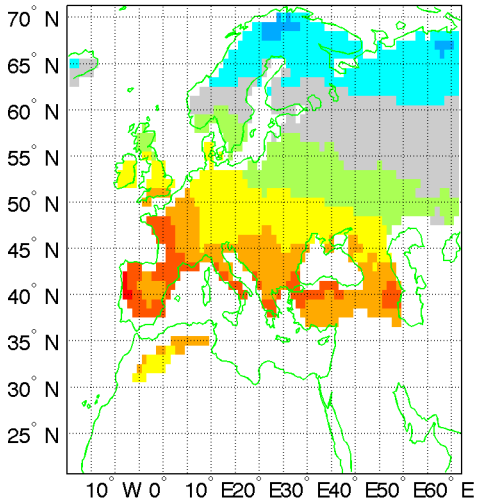
DJF

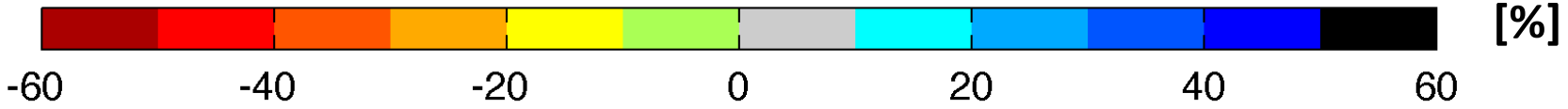
djf 2061:2100-1966:2005 tot prec % incr.



JJA

jja 2061:2100-1966:2005 tot prec % incr.





total precipitation, 90p and 99p-90p CHANGES IN A WARMER CLIMATE

(% increase in 2061-2100 wrt 1966-2005)

*regions with pr<0.5 mm/day are masked (white)

Average **90p**

DJF

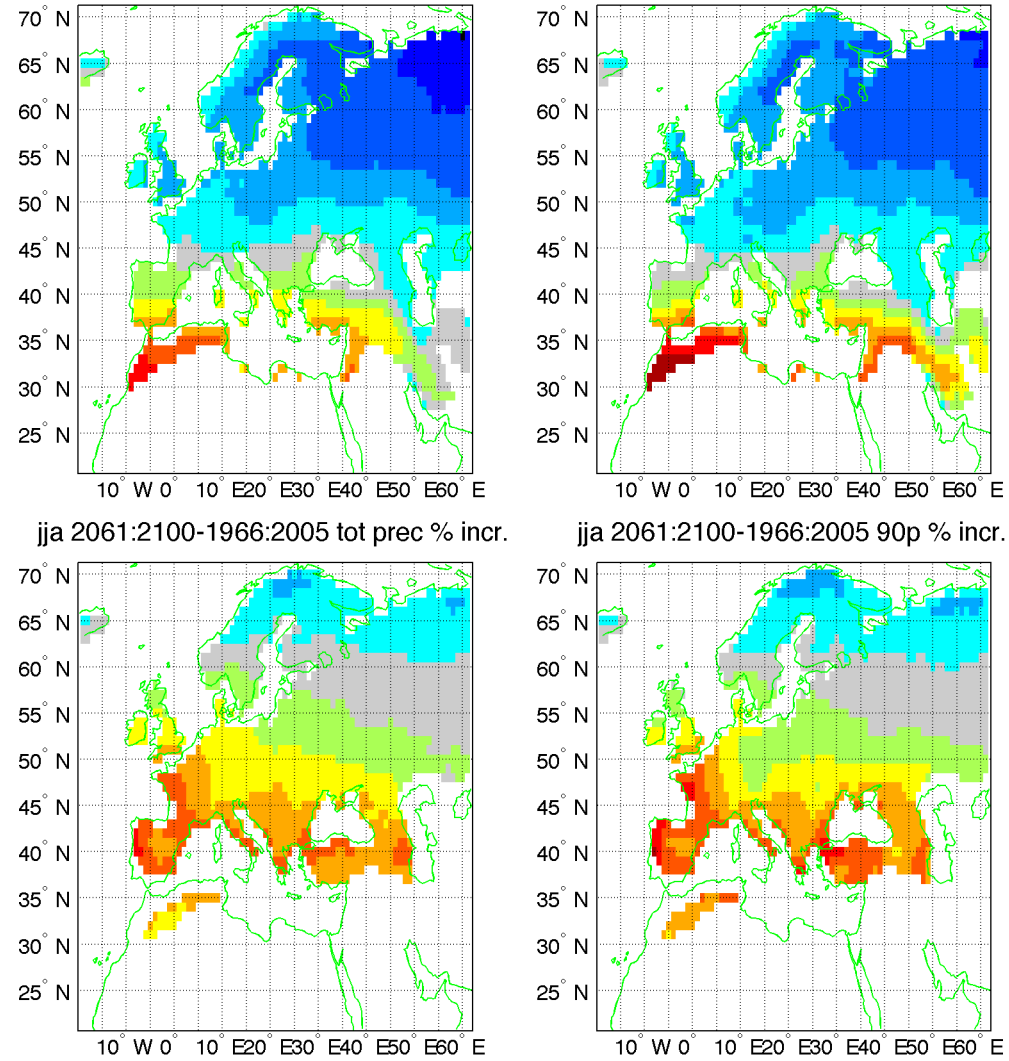
djf 2061:2100-1966:2005 tot prec % incr.

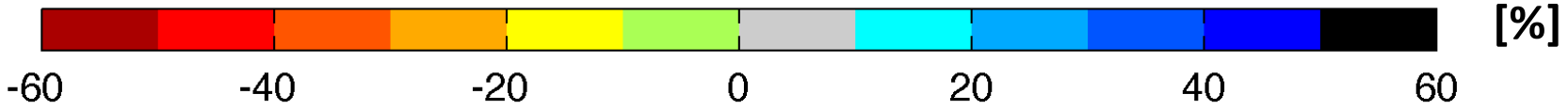
djf 2061:2100-1966:2005 90p % incr.

JJA

jja 2061:2100-1966:2005 tot prec % incr.

jja 2061:2100-1966:2005 90p % incr.

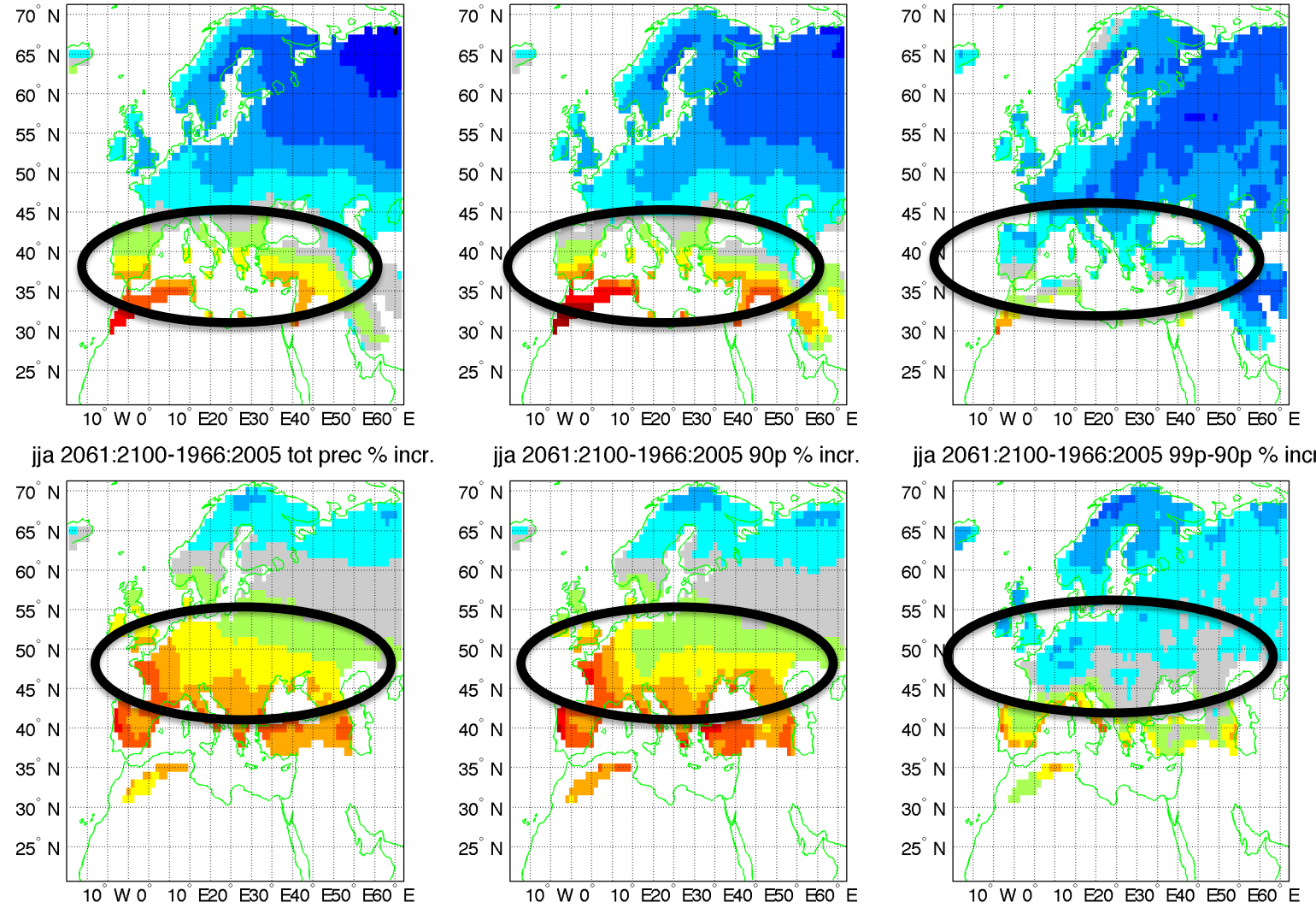


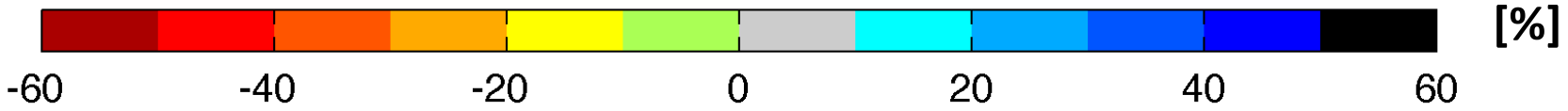


total precipitation, 90p and 99p-90p CHANGES IN A WARMER CLIMATE

(% changes in 2061-2100 wrt 1966-2005)

	Average	90p	99p-90p
DJF	djf 2061:2100-1966:2005 tot prec % incr.	djf 2061:2100-1966:2005 90p % incr.	djf 2061:2100-1966:2005 99p-90p % incr.
JJA	jja 2061:2100-1966:2005 tot prec % incr.	jja 2061:2100-1966:2005 90p % incr.	jja 2061:2100-1966:2005 99p-90p % incr.



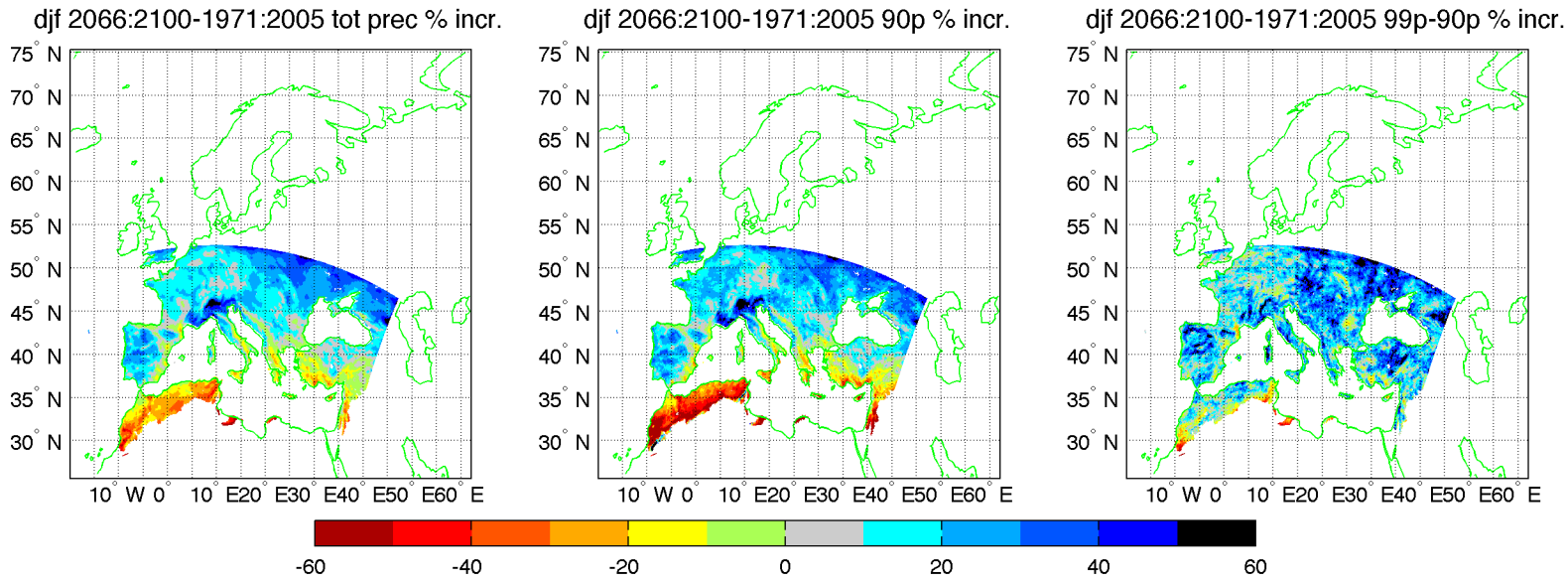


total precipitation, 90p and 99p-90p CHANGES IN A WARMER CLIMATE

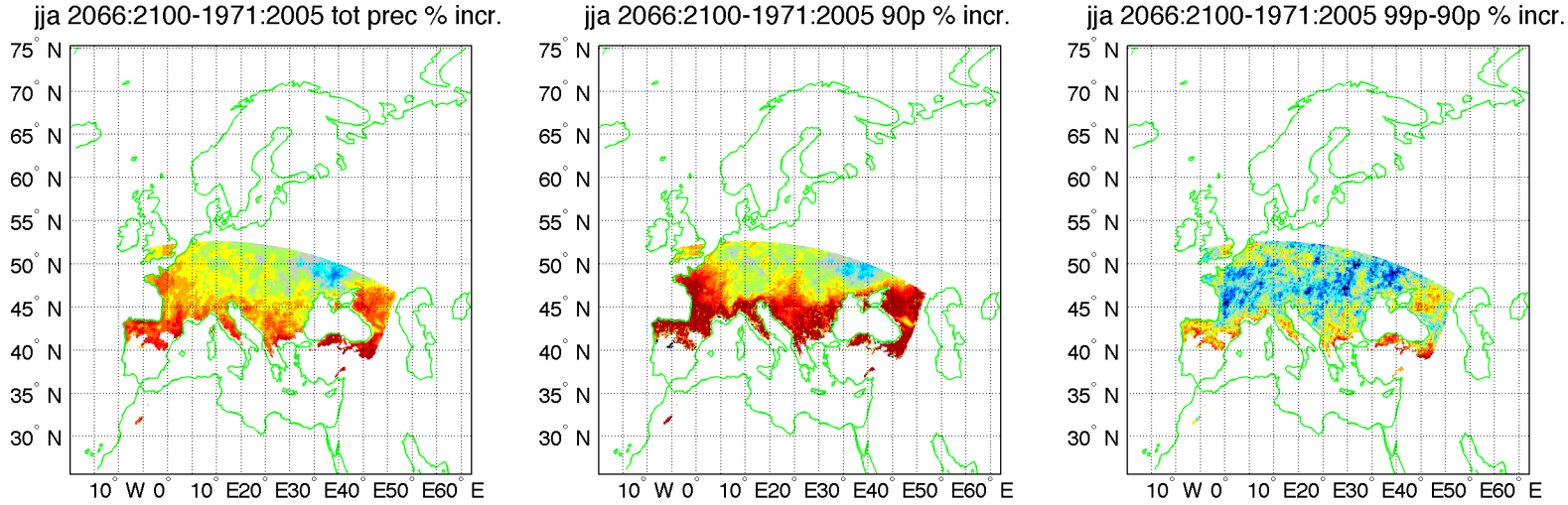
(% changes in 2061-2100 wrt 1966-2005) in COSMO-CLM (14 km)

Average | 90p | 99p-90p

DJF



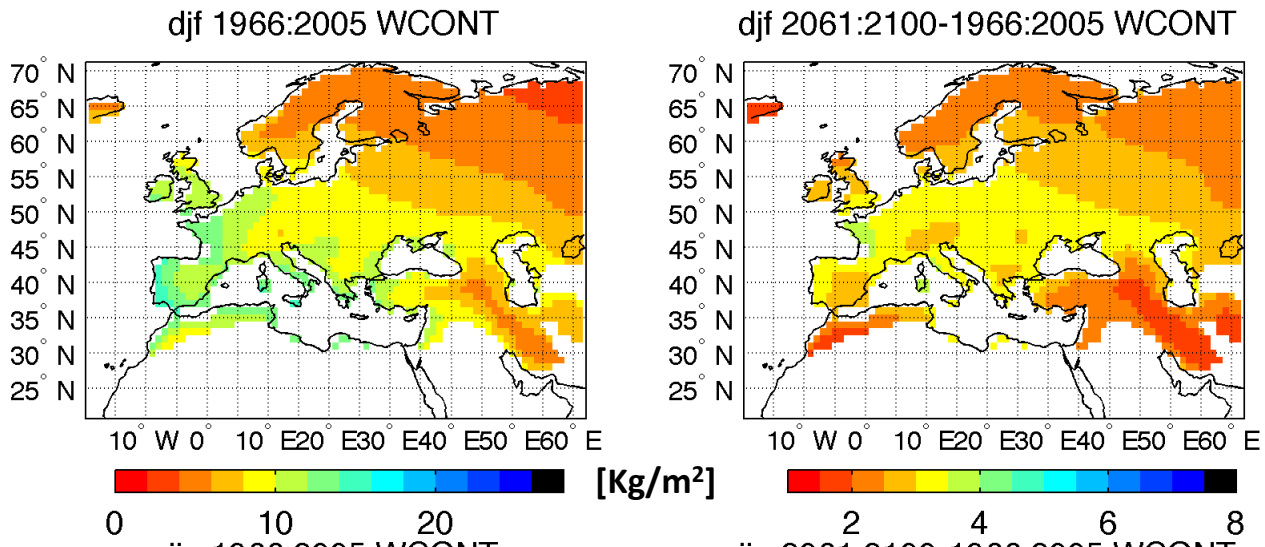
JJA



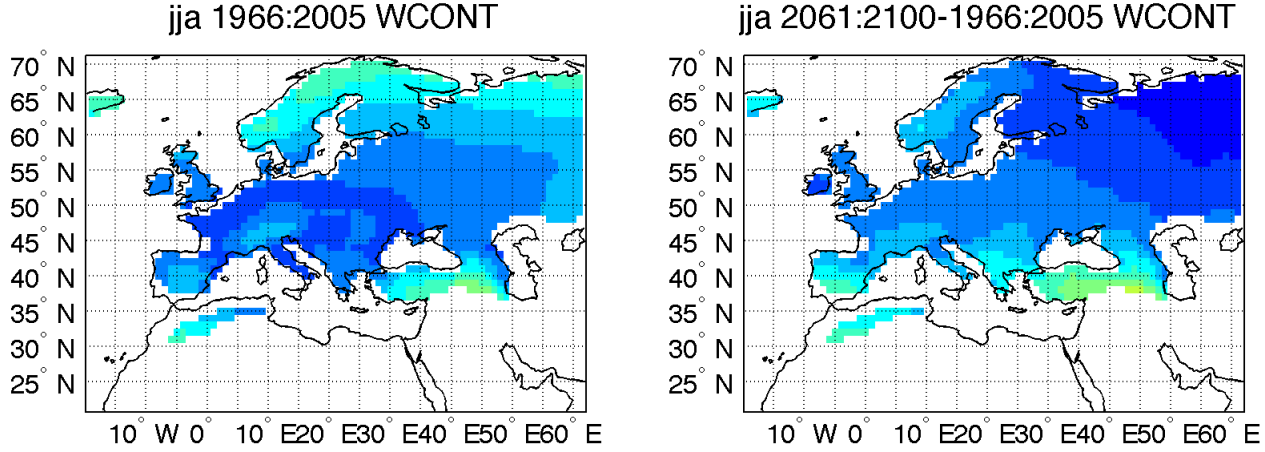
Integrated Water content [Kg/m^2]

HISTORICAL **changes in RCP85**

DJF



JJA



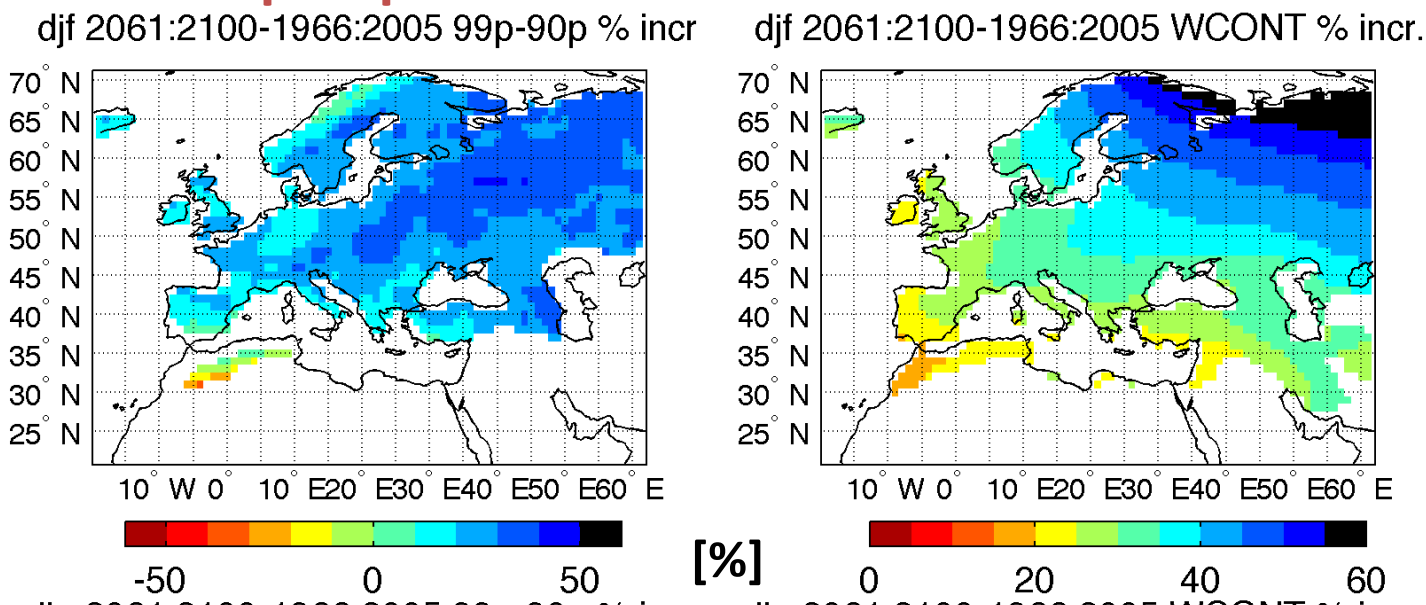
*regions with pr<0.5 mm/day are masked (white)

99p-90p and WCONT CHANGES IN A WARMER CLIMATE

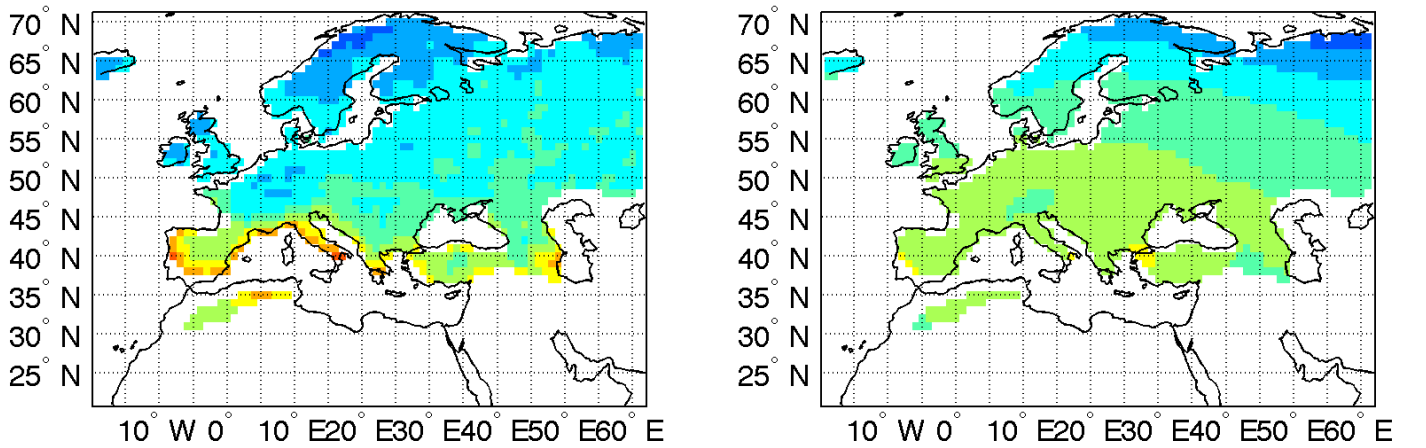
(% changes in 2061-2100 wrt 1966-2005)

99p-90p **WCONT**

DJF



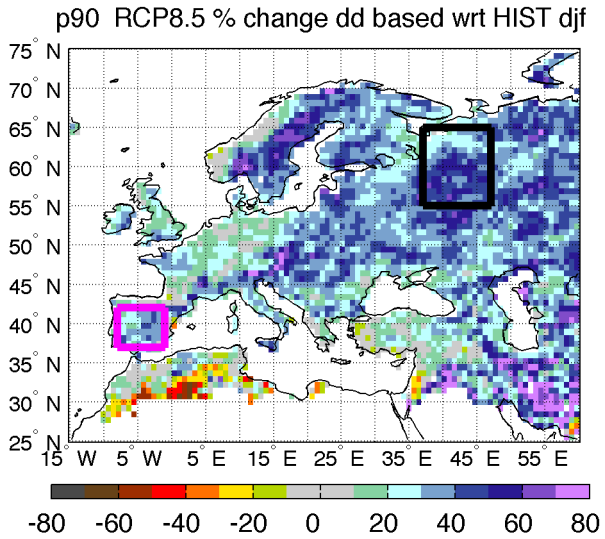
JJA



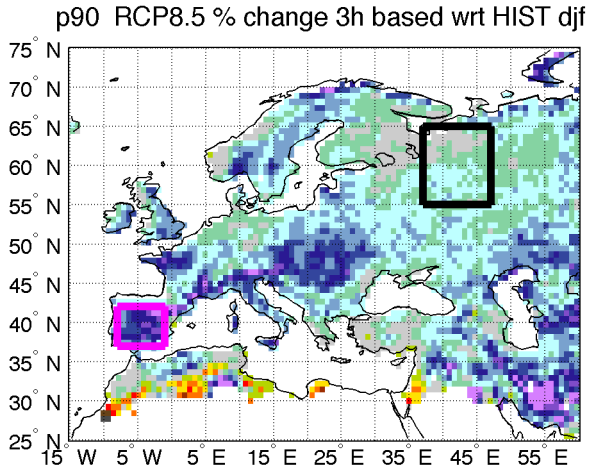
The disparity between increased moisture from C-C and a much smaller increase (or reduction!) in the amount of total precipitation ensures that there will be a shift in the nature of precipitation events to more intense and less frequent rains: the 'it never rains but it pours' syndrome (Trenberth 1998-2003-2011

90th percentile (90p) precipitation projection during DJF CMCC-CM model only

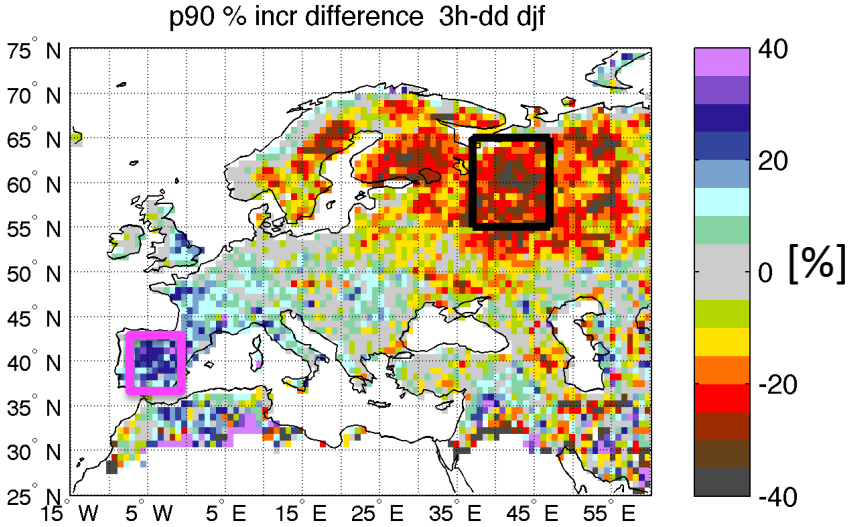
DAILY Based projections



3 HOURLY Based projections

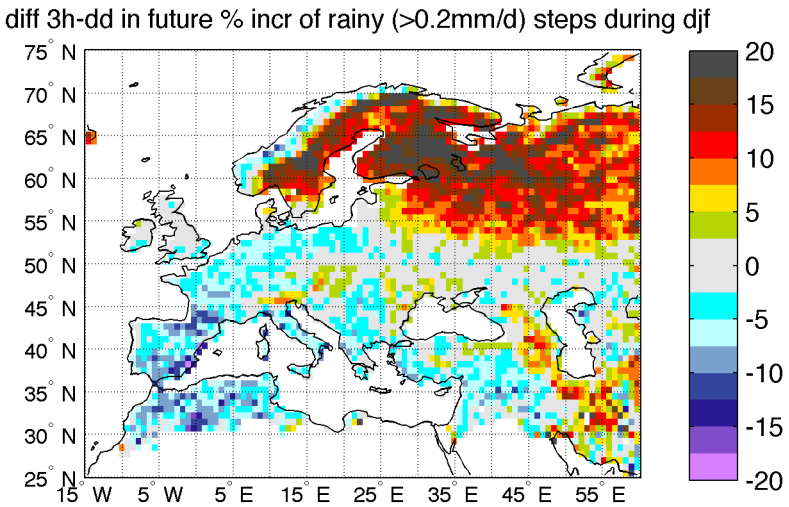


% DIFFERENCE IN PROJECTED 90th PERCENTILE PROJECTIONS 3hourly based wrt daily based



90th percentile (90p) precipitation projection during DJF CMCC-CM model only

% DIFFERENCE IN PROJECTED
NUMBER OF RAINY STEPS (>0.5 mm/d)
3hourly based wrt daily based



% DIFFERENCE IN PROJECTED
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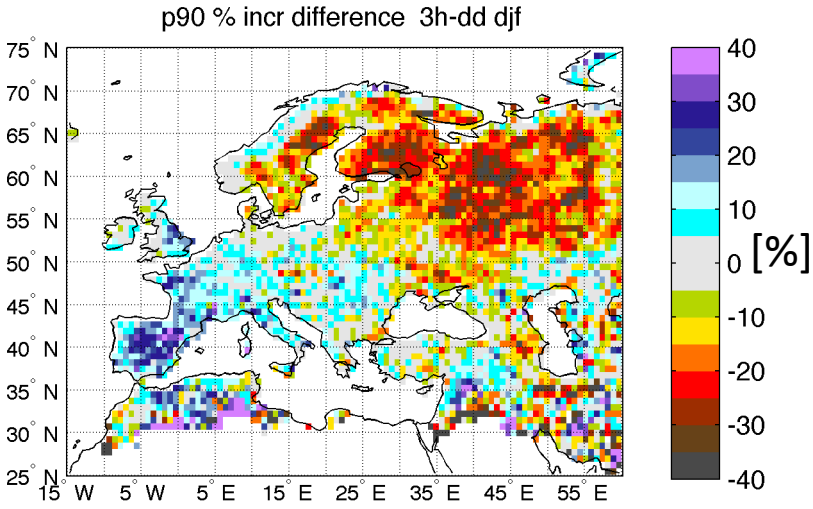

CONCLUSIONS

1. The difference between 99th and 90th percentile (**99p-90p**) of the daily precipitation resulting from a set of twenty CMIP5 simulations, is used to quantifying potential changes in the width of the right tail of precipitation distribution, thus to the range of values attributable to an heavy (greater than 90p) precipitation event.

2. A stretching of the right tail of precipitation event distribution is found at the end of the RCP8.5 scenario (2061-2100) if compared to the historical (1966:2005) period. This is evident over the Euro-Mediterranean basin even over regions showing a decrease in the averaged precipitation.

3. The regions affected by strong stretching of the right tail of precipitation event distribution in the future correspond to strong increased availability of water vapour content in the atmospheric column.

4. Daily based "90p projections" exceed/downsize the corresponding 3 hourly estimate over N-E Domain / Spain coherently with a different spreading of the high frequency precipitation events in the two regions.

Heavy precipitation events over the Euro-Mediterranean region in a warmer climate: results from CMIP5 models

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Thank you !

References:

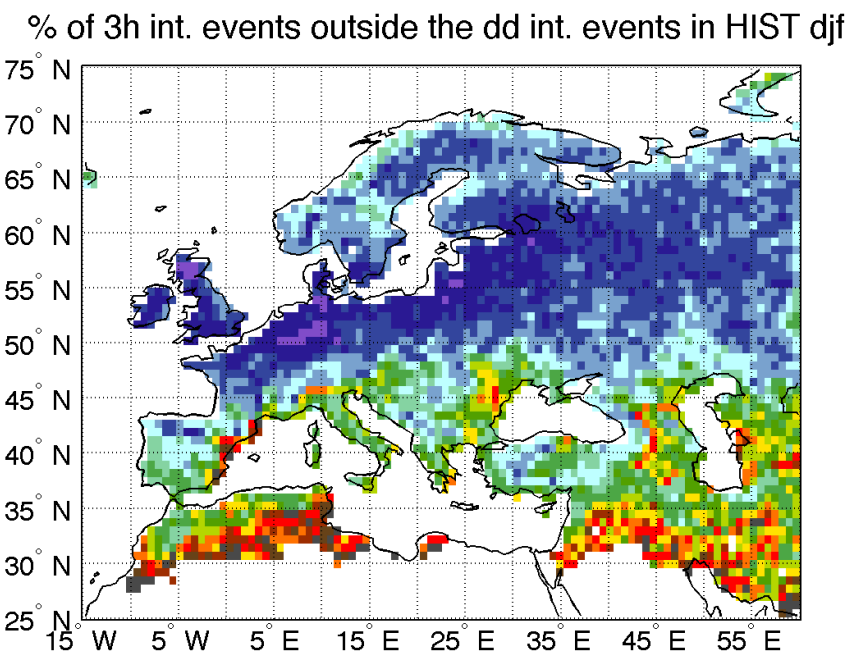
- *Scoccimarro, E., S. Gualdi, A. Bellucci, M. Zampieri, A. Navarra, 2013:* ***Heavy precipitation events in a warmer climate: results from CMIP5 models****,*
Journal of Climate - doi: 10.1175/JCLI-D-12-00850.1.

- *Scoccimarro E., S. Gualdi, A. Bellucci, M. Zampieri, A. Navarra, 2014:* ***Heavy precipitation events over the Euro-Mediterranean region in a warmer climate: results from CMIP5 models****.*
Regional Environmental Change – under revision.

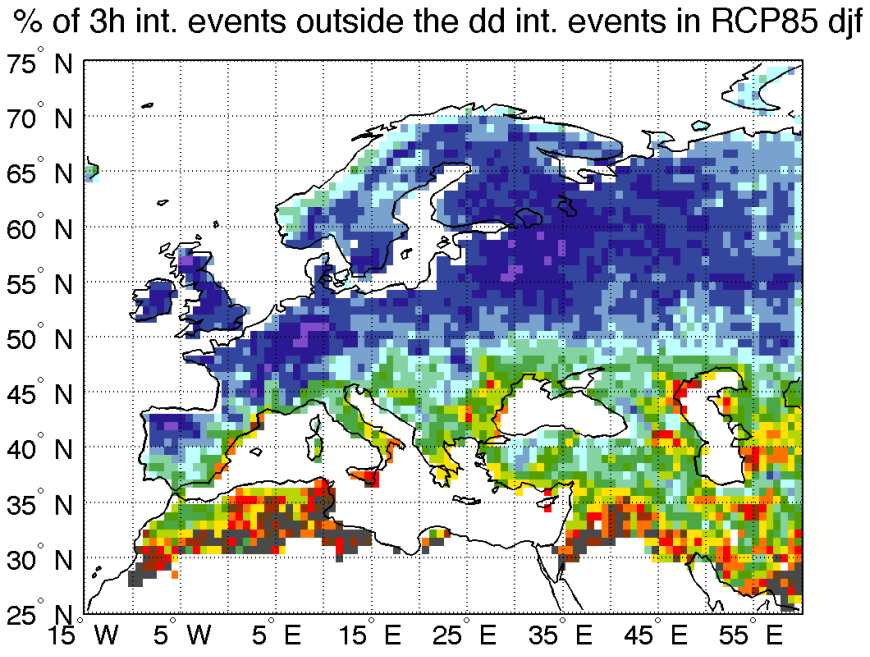
- *Scoccimarro E., G. Villarini, M. Zampieri, P.G. Fogli, A. Bellucci, M. Vichi, S. Gualdi:* ***Intense precipitation events over Europe: projections dependence on daily/sub-daily time scale definition.***
in preparation.

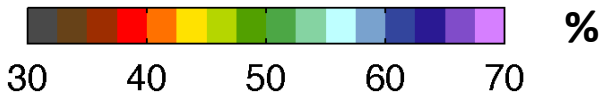
% of 3hourly intense events non synchronous with daily intense events

HIST



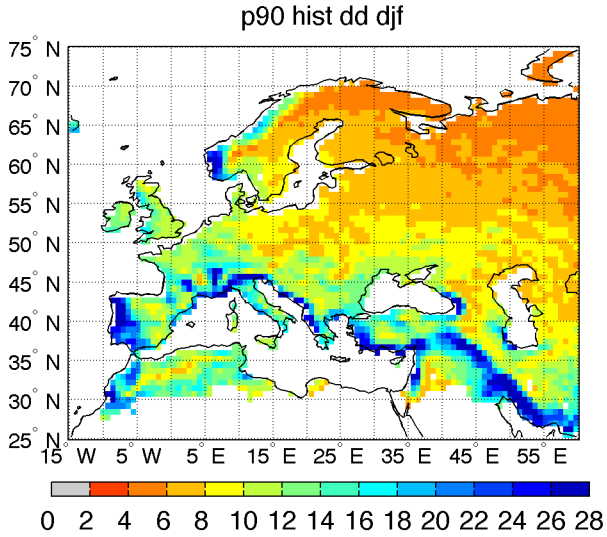
RCP85

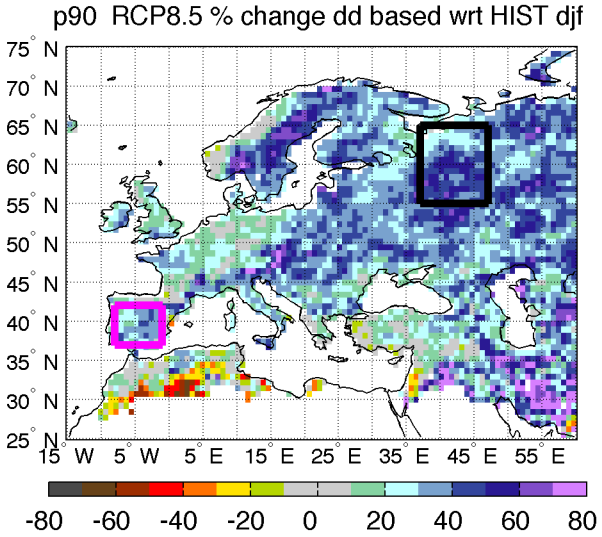




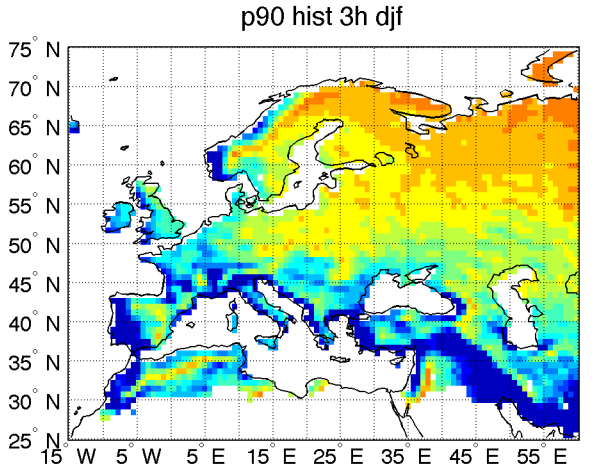
TIME SCALE DEFINITION DEPENDENCIES
DJF FUTURE PROJECTIONS: 90th percentile (90p) of precipitation

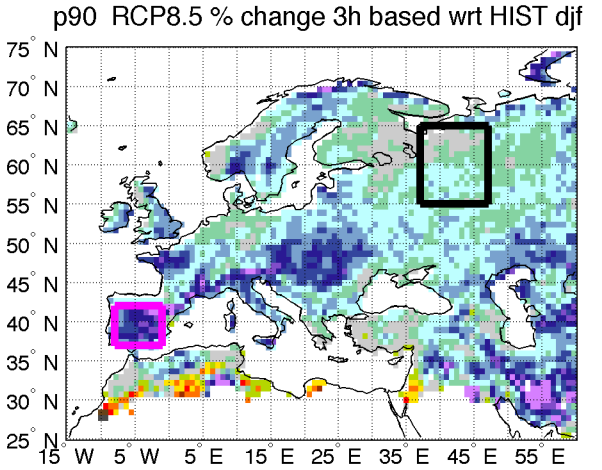
DAILY based





3 HOURLY based

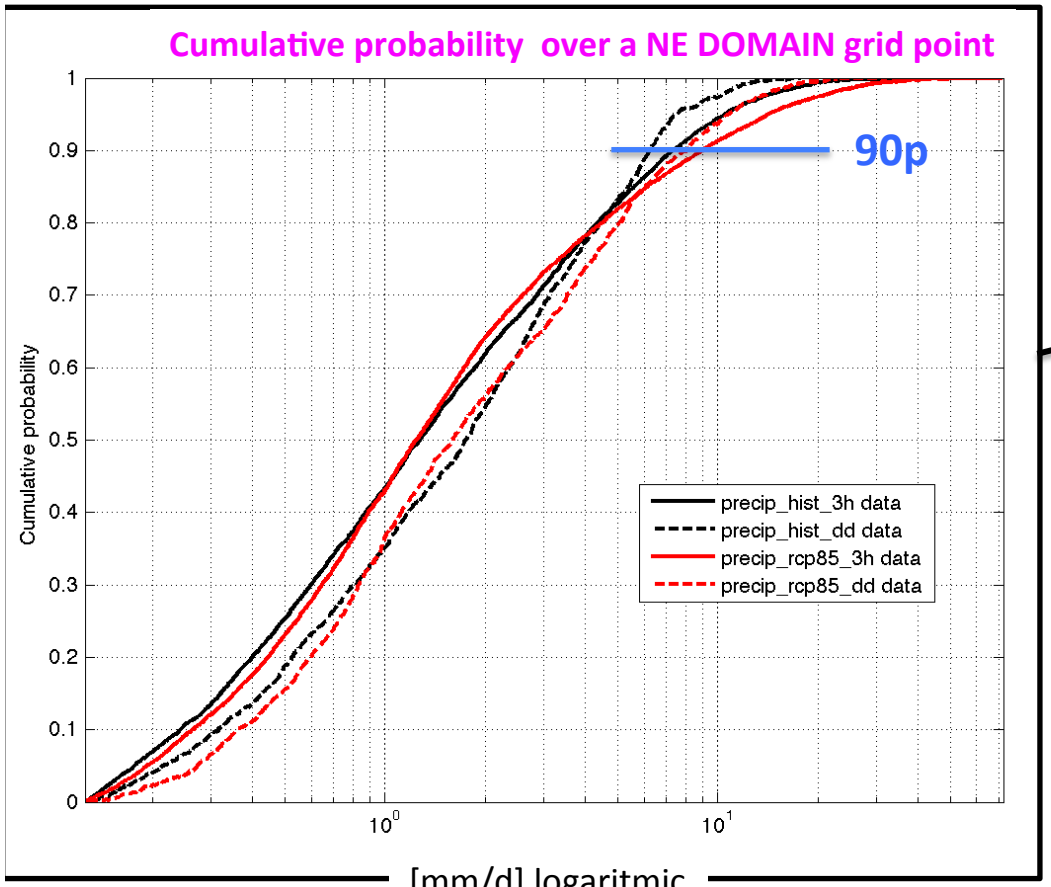




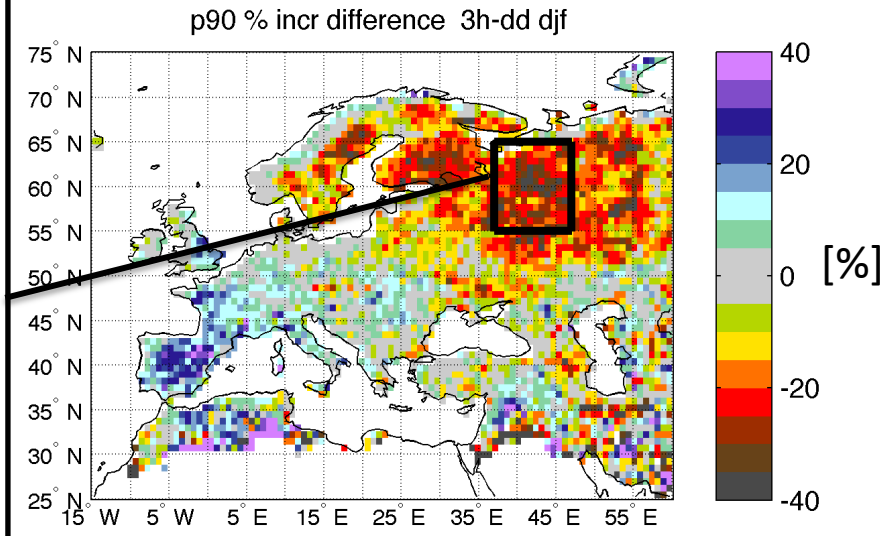
HISTORICAL [mm/d]

RCP85 [% changes]

Cumulative probability over NE Domain



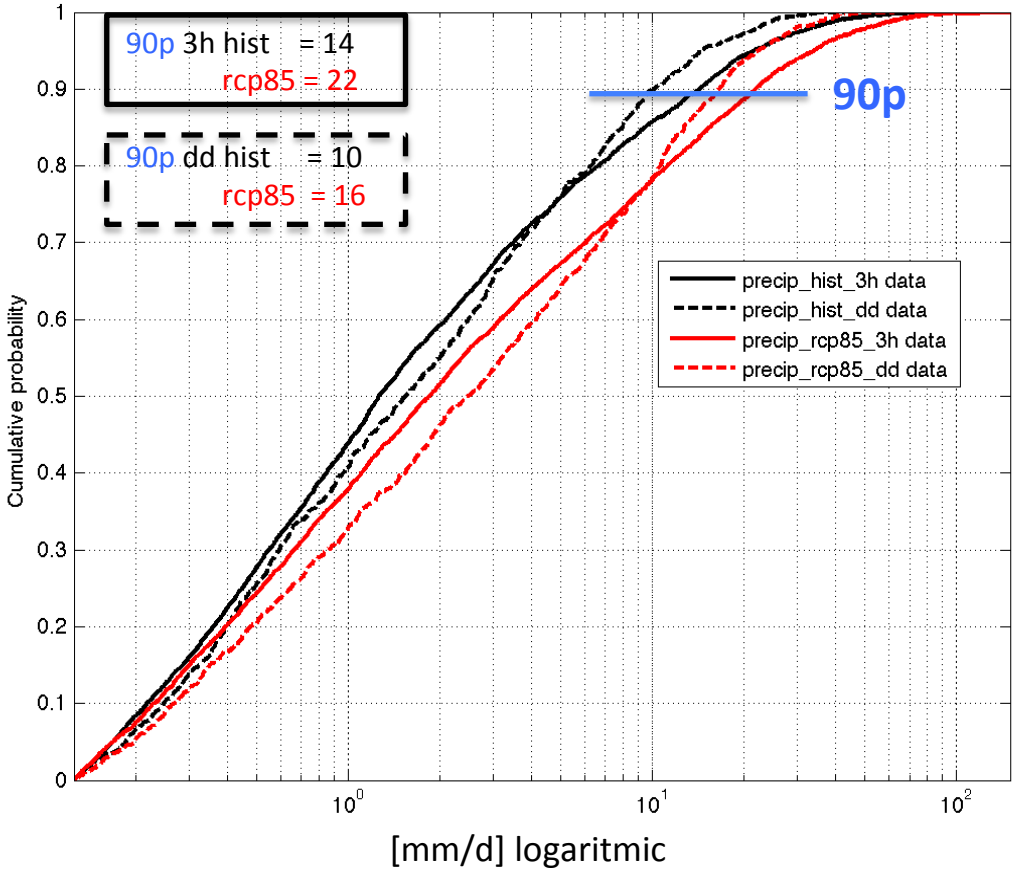
3 HOURLY - DAILY



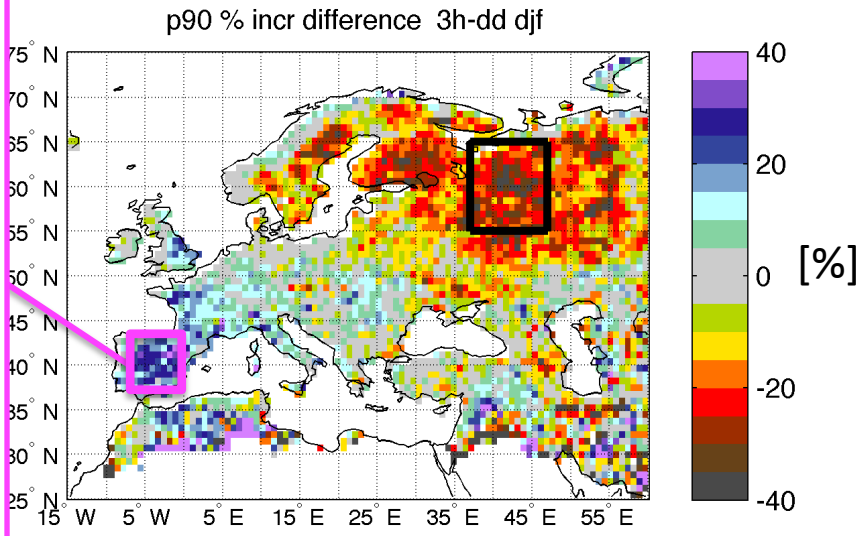
- At **90p** (0.9 in the CDF), the distance between continue lines (3h based projection) is smaller than the distance between dashed lines (dd based projection)
- No differences in 85p (0.85 in the CDF) projections

Cumulative probability over Spain

Cumulative probability over a SPAIN grid point



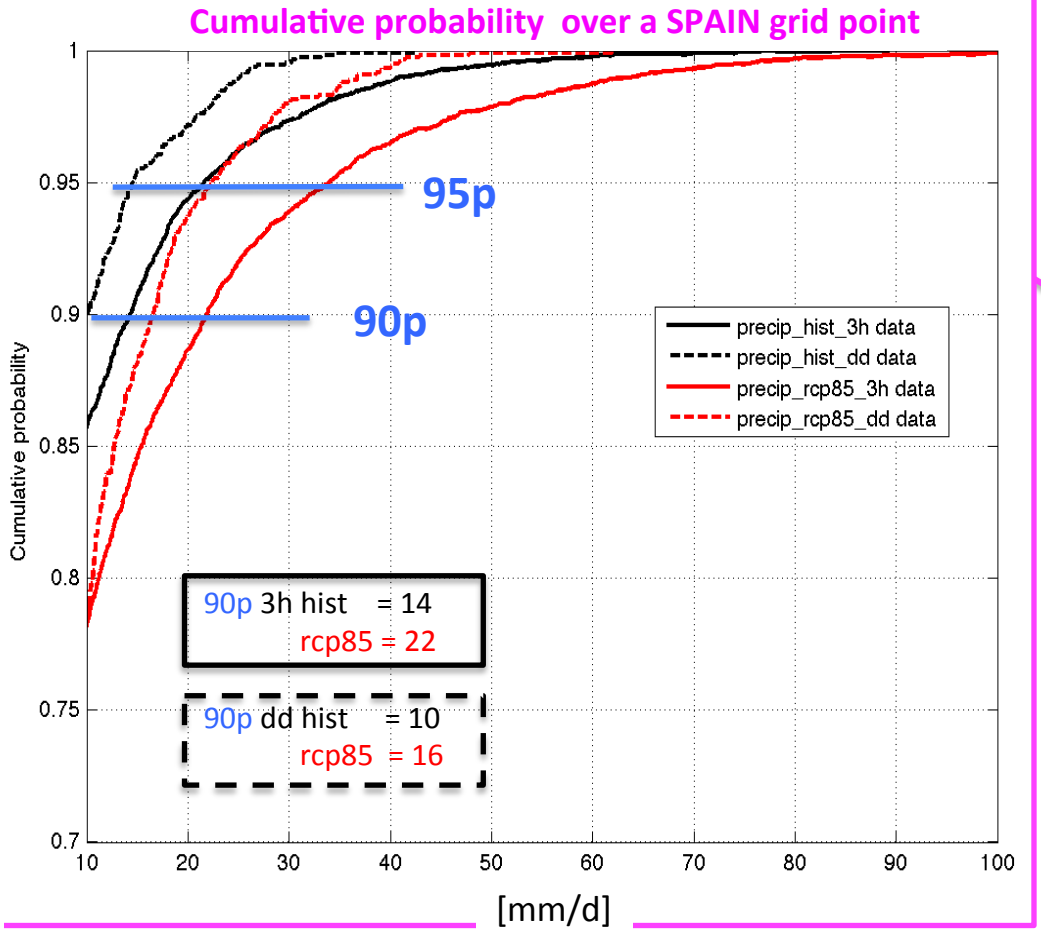
3 HOURLY - DAILY

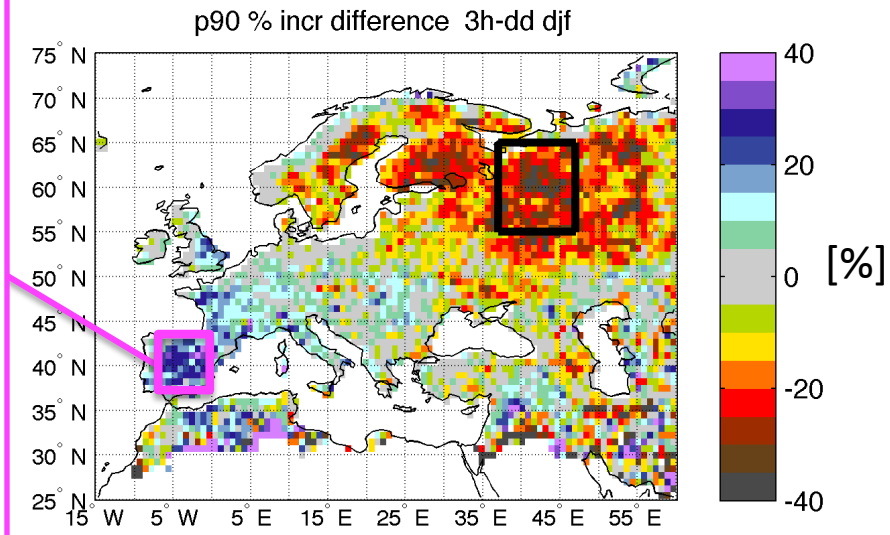


- At **90p** (0.9 in the CDF), the distance between continue lines (3h based projection) is greater than the distance between dashed lines (dd based projection)
- No differences in 80p (0.8 in the CDF) projections

Cumulative probability over Spain

3 HOURLY - DAILY





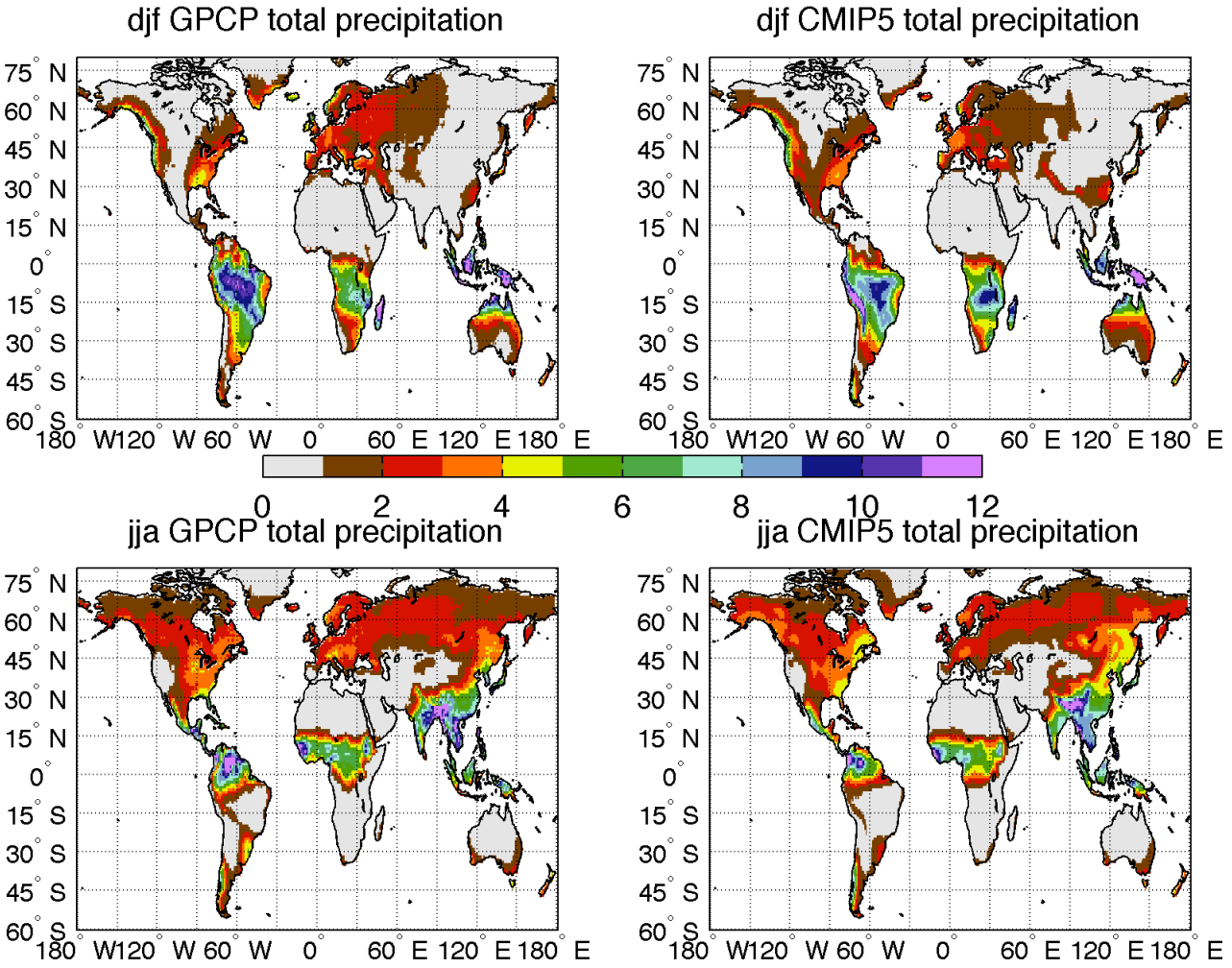
- At **90p** (0.9 in the CDF), the **distance between continue lines** (3h based projection) is **greater than** the distance between **dashed lines** (dd based projection)
- At **95p** this effect is even more pronounced

RESULTS

TOTAL PRECIPITATION [mm/d] during 1997-2005

DJF

JJA



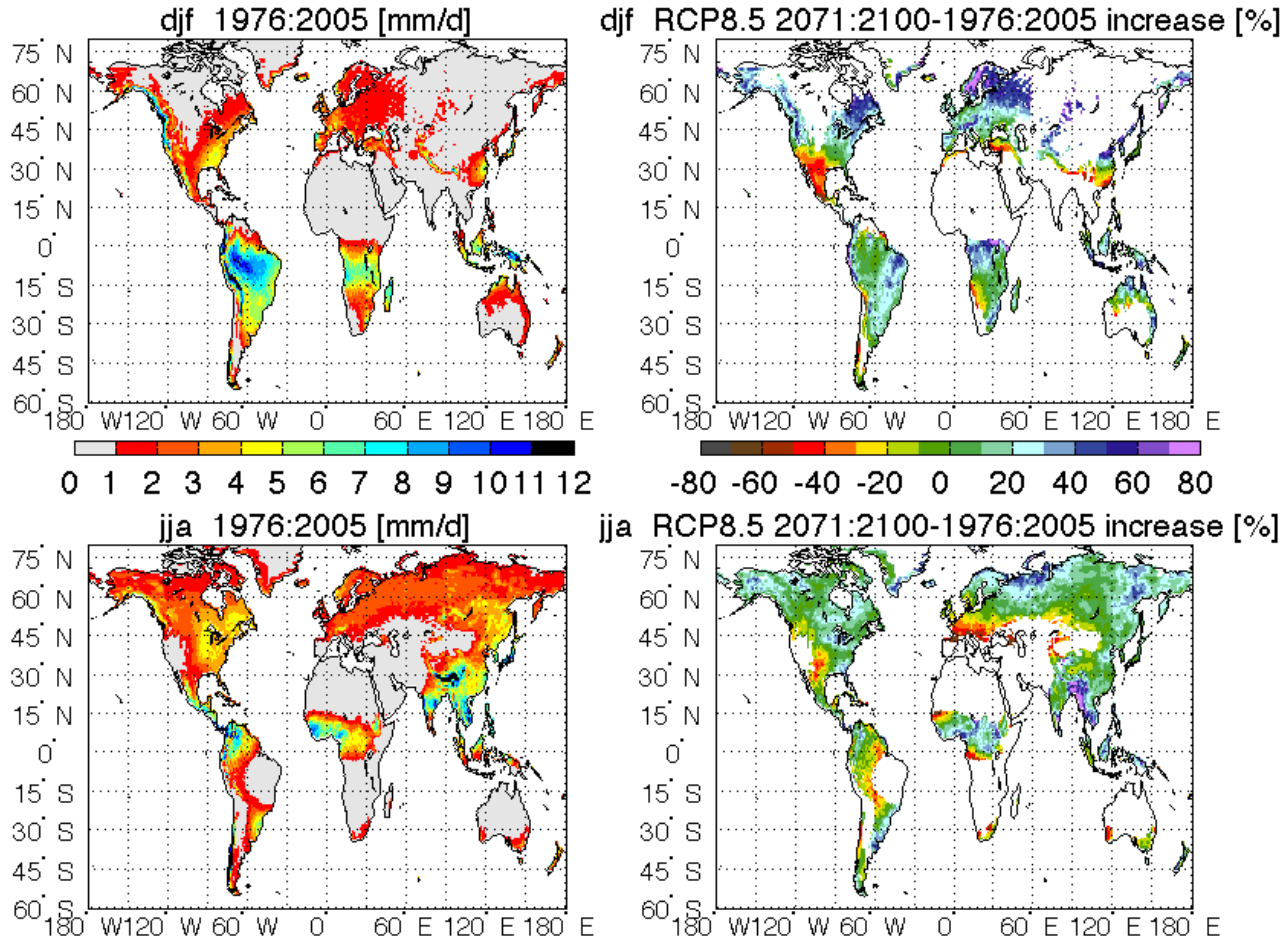
OBS (GPCP)

CMIP5 models

Precipitation CMCC-CM (values <1 mm/d masked)

DJF

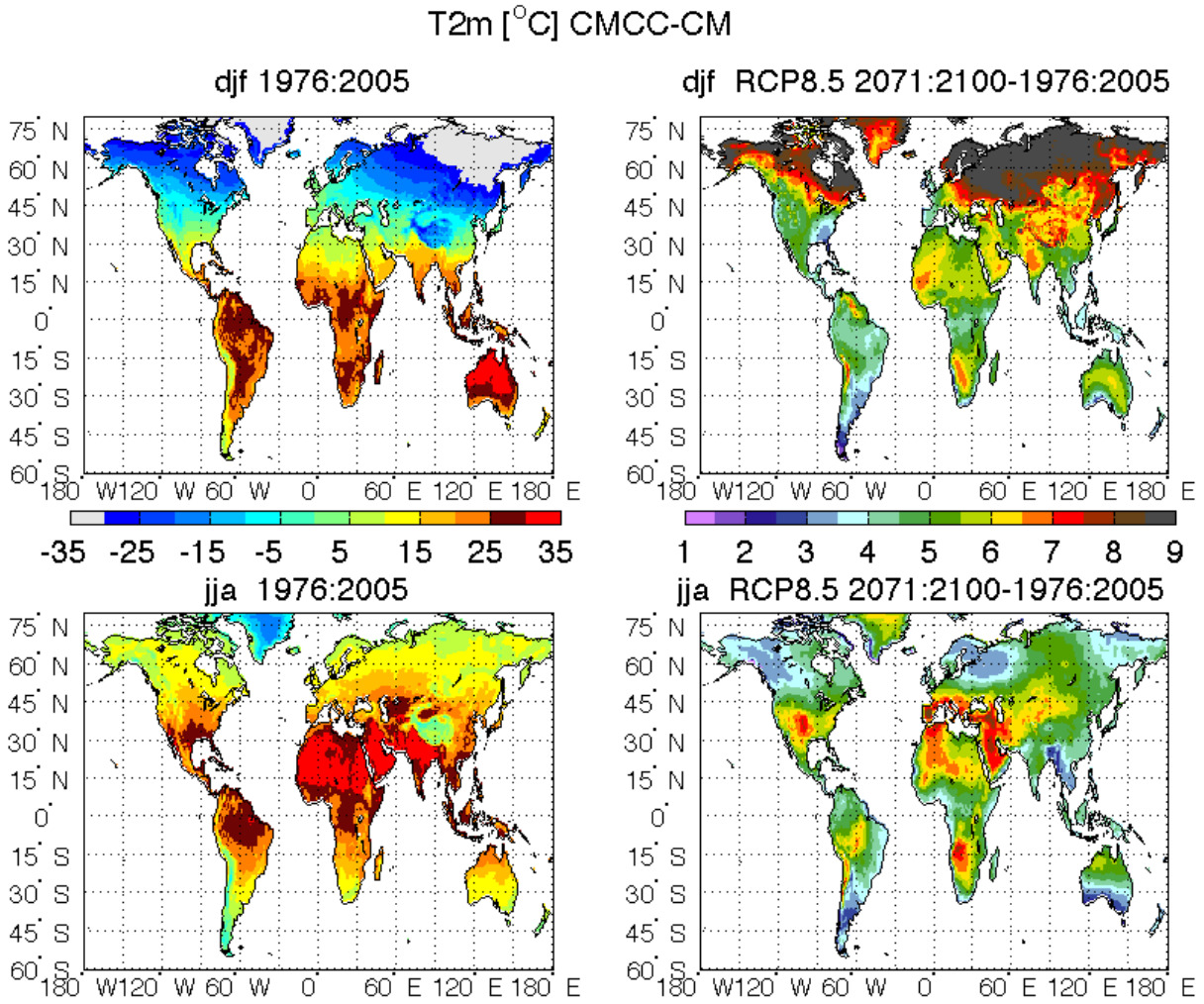
JJA



HISTORICAL **increase in RCP8.5**

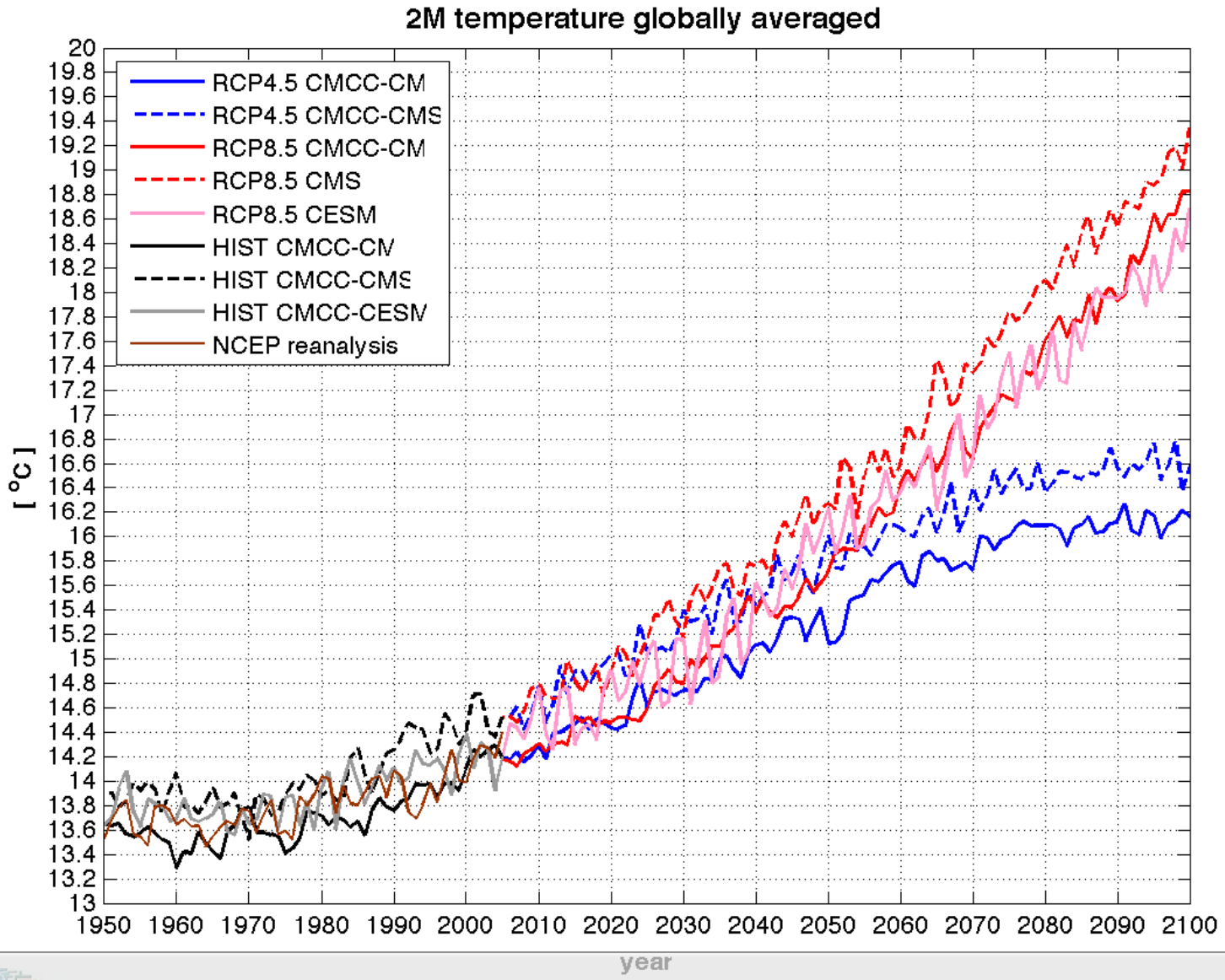
DJF

JJA



HISTORICAL **increase in RCP8.5**

The CMCC-CM CGCM: model output

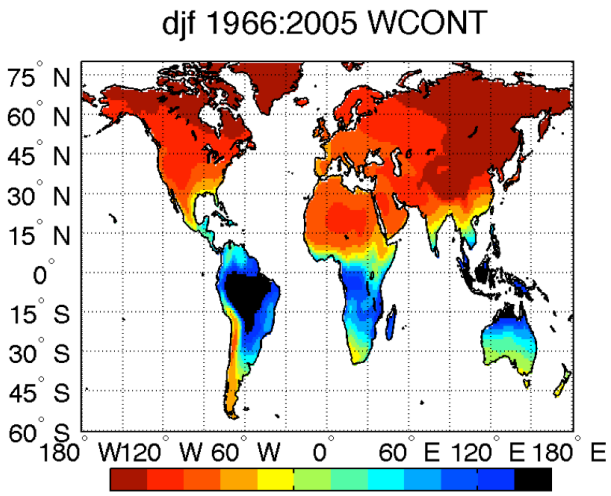


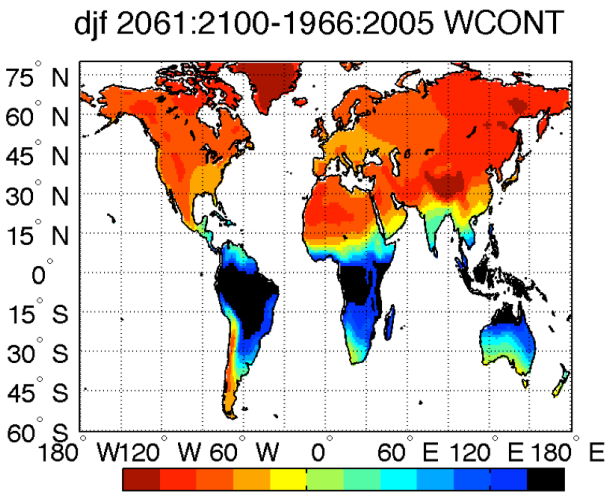
RESULTS

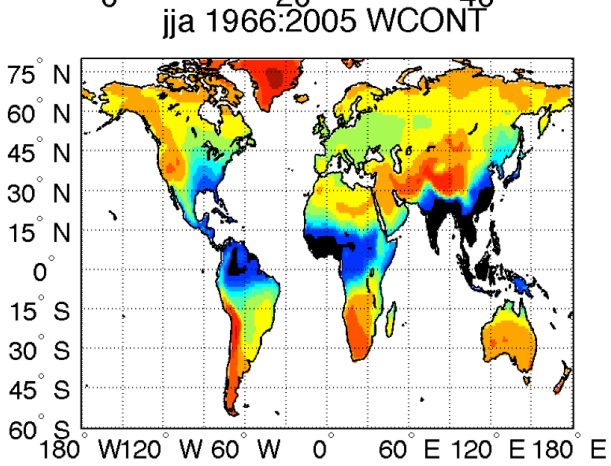
Atmospheric water vapour content

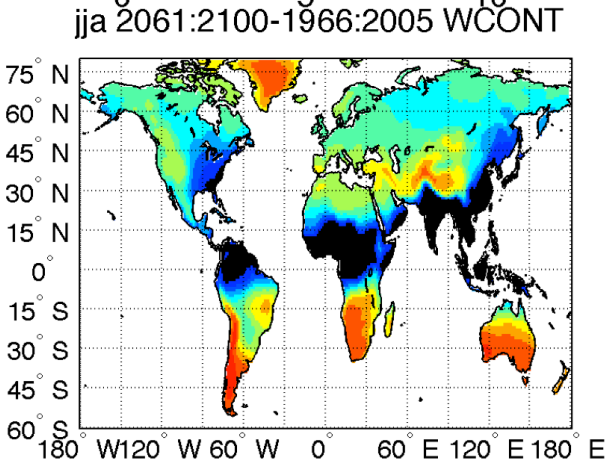
DJF

JJA









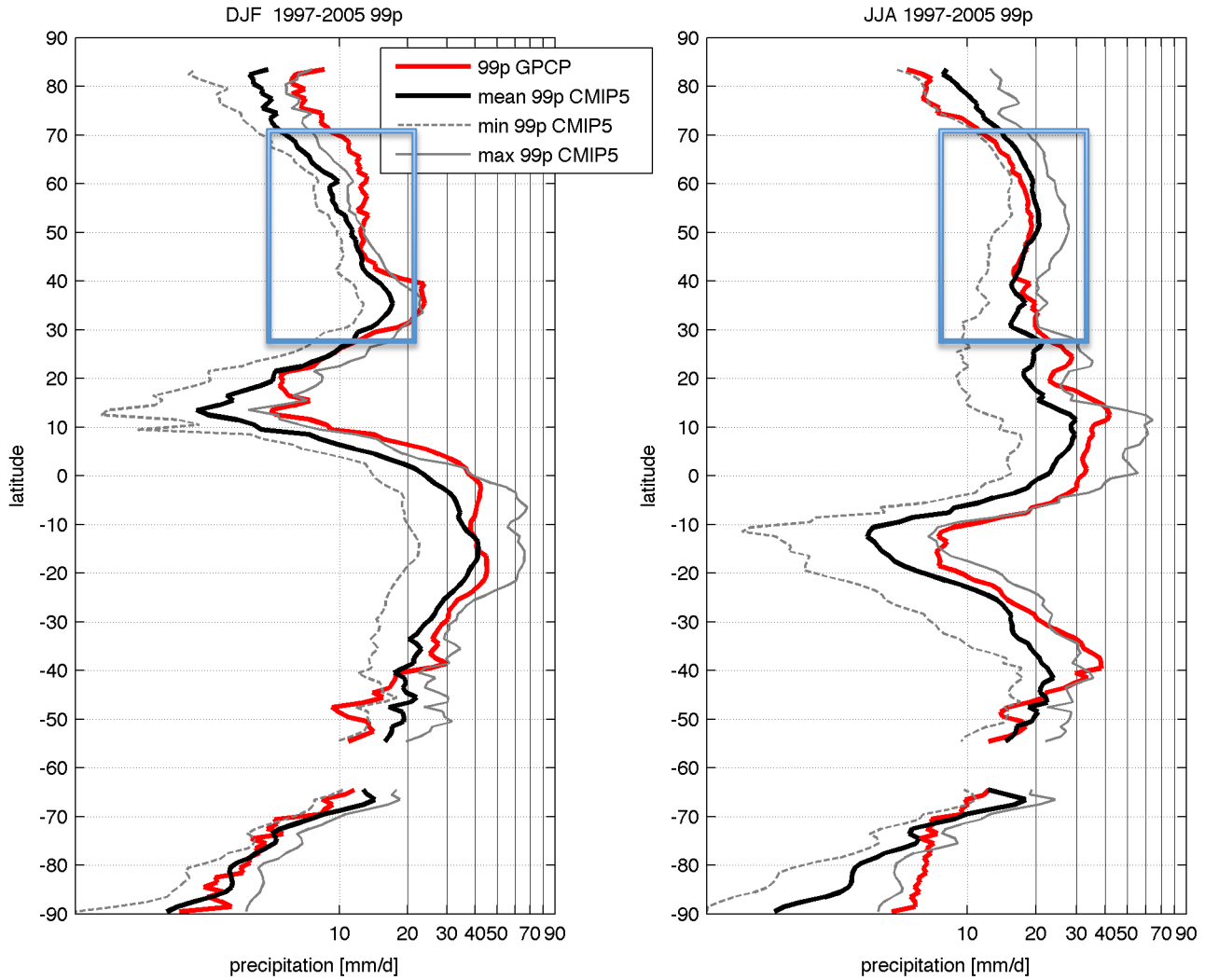
water vapour content [Kg/m^2]

water vapour content increase [Kg/m^2]

RESULTS

99th percentile (99p [mm/day]) of total precipitation over land during 1997-2005

LATITUDE



DJF JJA

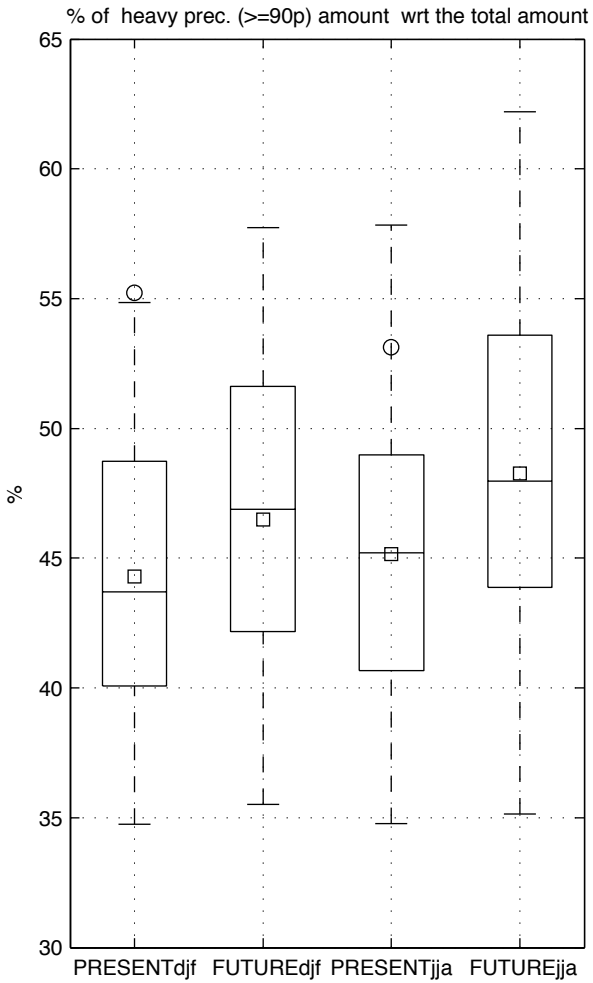
RESULTS

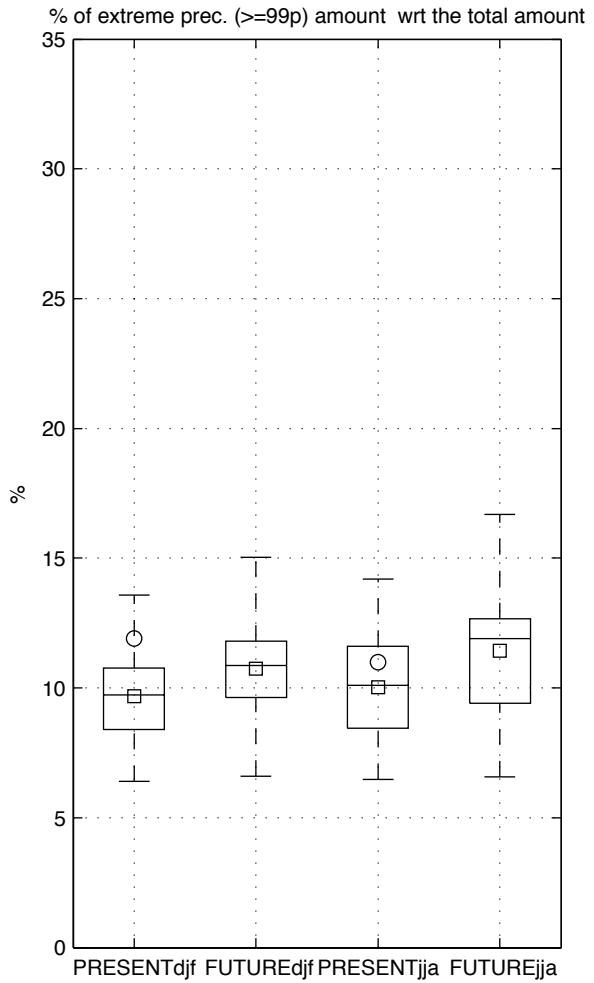
AMOUNT OF WATER (% wrt total precipitation) associated to heavy (>90p) and extreme (>99p) events during PRESENT (1966:2005) and FUTURE (2061-2100) at global scale

□ cmip5

O GPCP obs

% wrt total pecip.



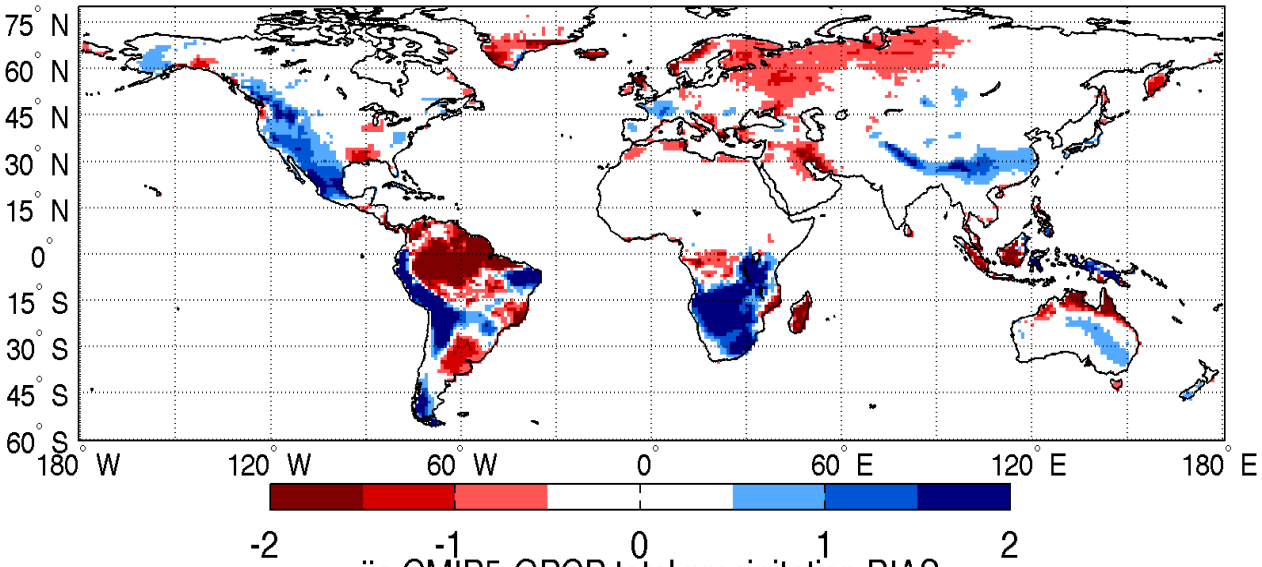


DATA & METHODOLOGY

CMIP5 models involved in this study

Model name	Lat x Lon (degrees)	Institute (Institude ID)
BNU-ESM	2.8 x 2.8	College of Global Change and Earth System Science, Beijing Normal University (GCESS)
CCSM4	**0.9 x 1.5**	National Center for Atmospheric Research (NCAR)
CMCC-CESM	3.7 x 3.7	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
CMCC-CMS	1.9 x 1.9	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
CMCC-CM	**0.8 x 0.8**	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
CNRM-CM5	**1.4 x 1.4**	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique (CNRM- CERFACS)
CSIRO-Mk3-6-0	1.9 x 1.9	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence (CSIRO-QCCCE)
CanESM2	2.8 x 2.8	Canadian Centre for Climate Modelling and Analysis (CCCMA)
FGOALS-s2	1.6 x 2.8	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences (LASG-IAP)
GFDL-CM3	2.0 x 2.5	NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)
GFDL-ESM2G	2.0 x 2.5	NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)
GFDL-ESM2M	2.0 x 2.5	NOAA Geophysical Fluid Dynamics Laboratory (NOAA GFDL)
HadGEM2-CC	**1.2 x 1.8**	Met Office Hadley Centre (MOHC)
HadGEM2-ES	**1.2 x 1.8**	Met Office Hadley Centre (MOHC)
INM-CM4	**1.5 x 2.0**	Institute for Numerical Mathematics (INM)
IPSL-CM5A-MR	**1.2 x 2.5**	IPSL-CM5A-LR Institut Pierre-Simon Laplace (IPSL)
MIROC5	**1.4 x 1.4**	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (MIROC)
MPI-ESM-MR	1.9 x 1.9	Max Planck Institute for Meteorology (MPI-M)
MRI-CGCM3	**1.1 x 1.1**	Meteorological Research Institute (MRI)
NorESM1-M	1.8 x 2.5	Norwegian Climate Centre (NCC)

djf CMIP5-GPCP total precipitation BIAS



jja CMIP5-GPCP total precipitation BIAS