

EGU 2014: May, 1st 2014 - Vienna, Austria

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^o Coupled Model Intercomparison Project (CMIP5) **over the Euro-Mediterranean Region**.



DATA & METHODOLOGY

Modelled Precipitation



Model name	Lat x Lon (degrees)	Institute (Institute 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
- RCP8.5 scenario

1966-2005
2061-2100

DATA & METHODOLOGY

CMCC climate models

CMIP5 models
involved in this study

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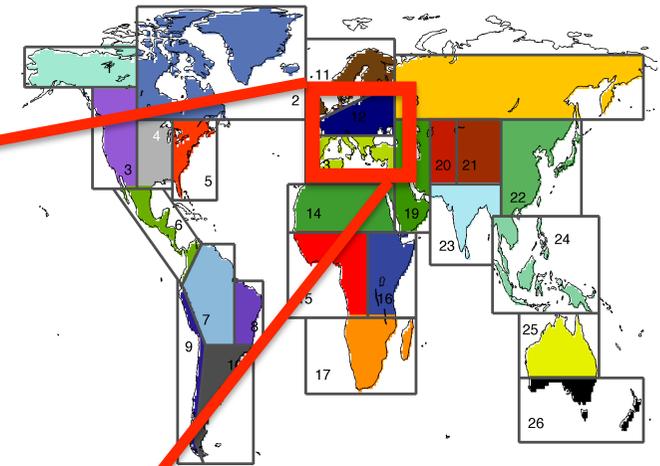
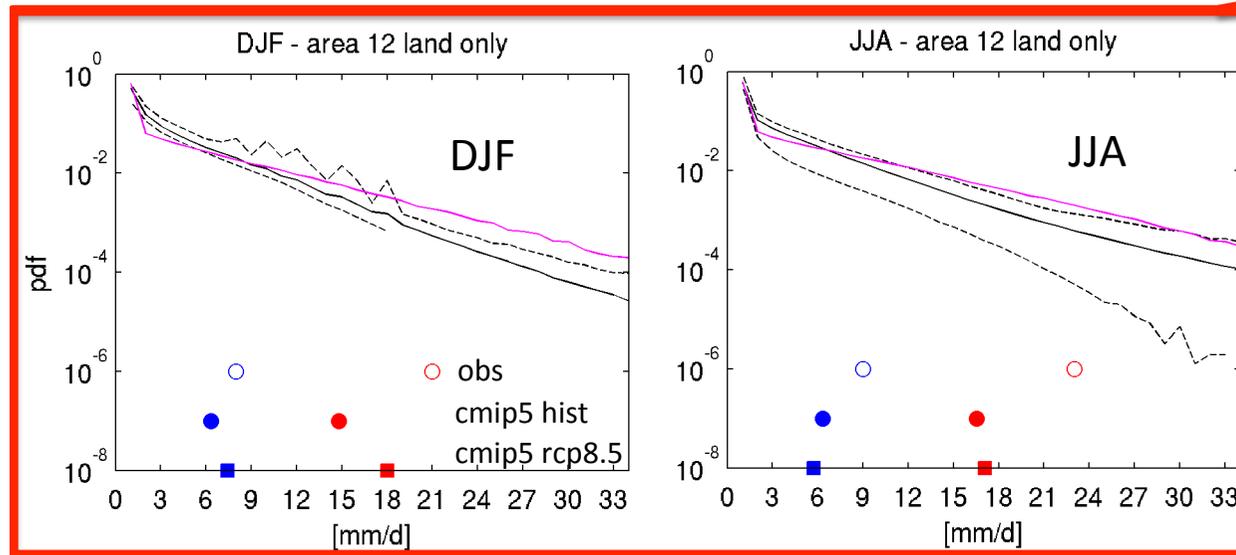
DATA & METHODOLOGY

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.**

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)

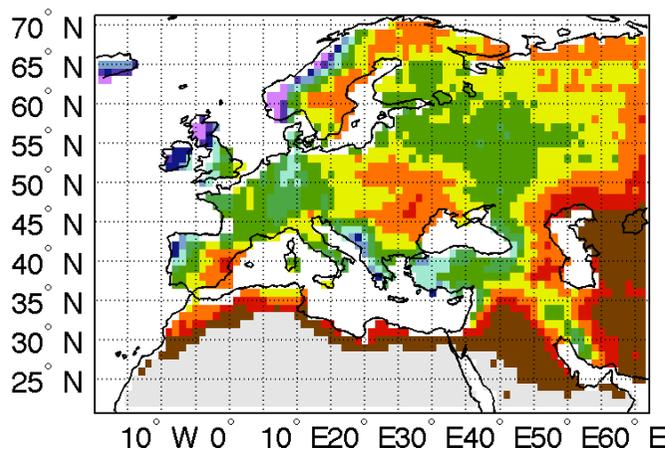
blue= 90p
red= 99p

RESULTS

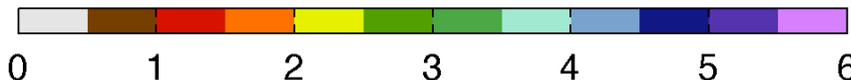
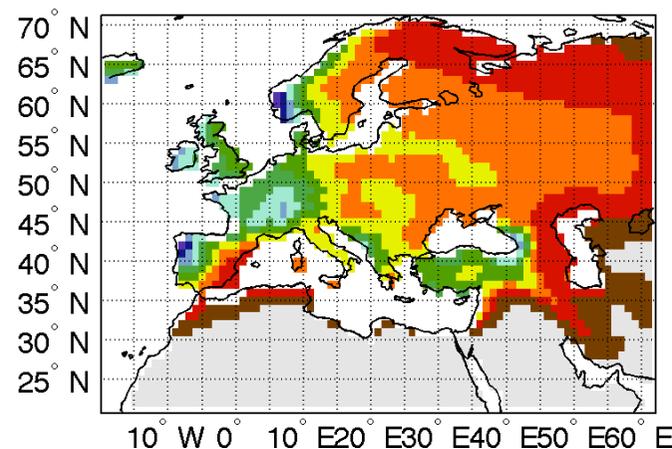
Average precipitation [mm/d] during 1997-2005

DJF

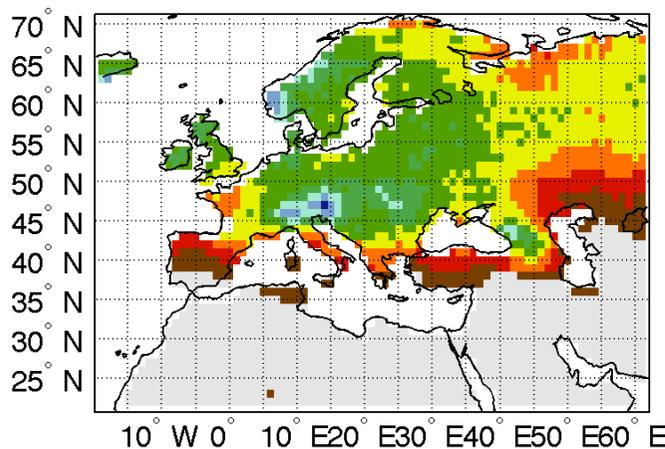
djf GPCP total precipitation



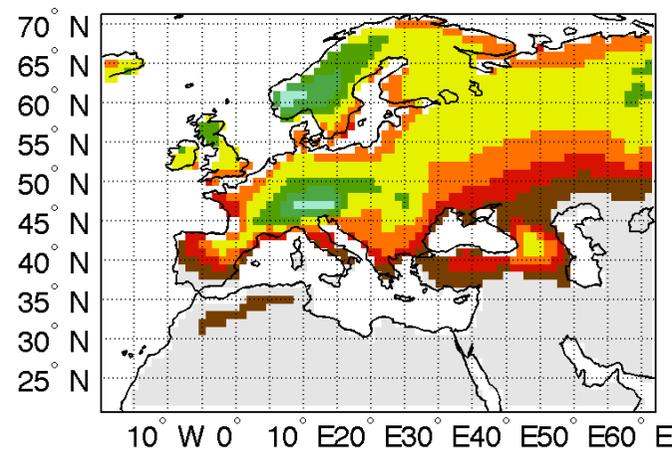
djf CMIP5 total precipitation



jja GPCP total precipitation



jja CMIP5 total precipitation



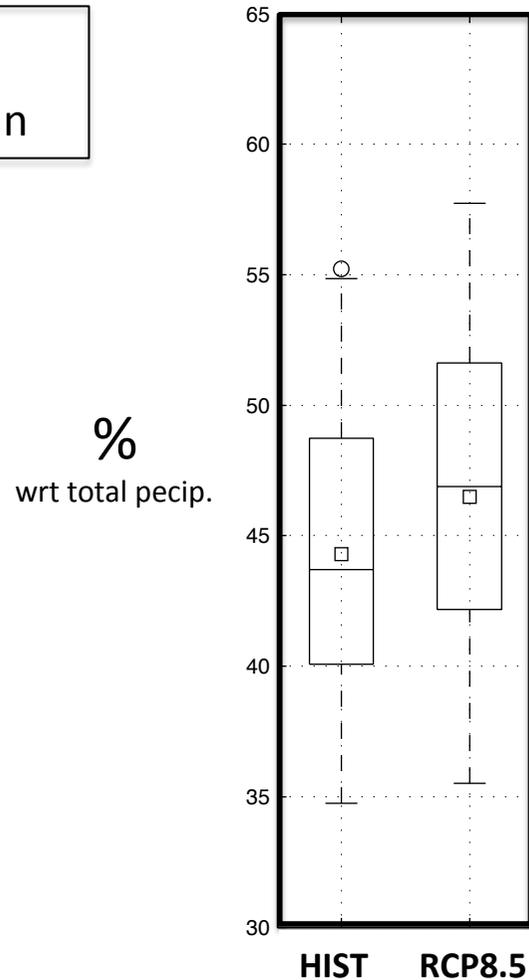
JJA

OBS (GPCP)

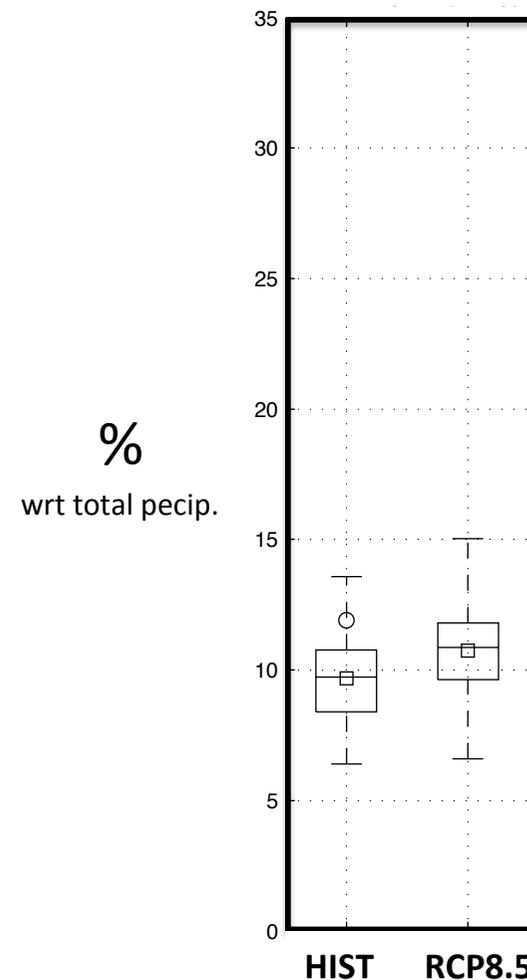
CMIP5 models

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



heavy (>90p)



extreme (>99p)

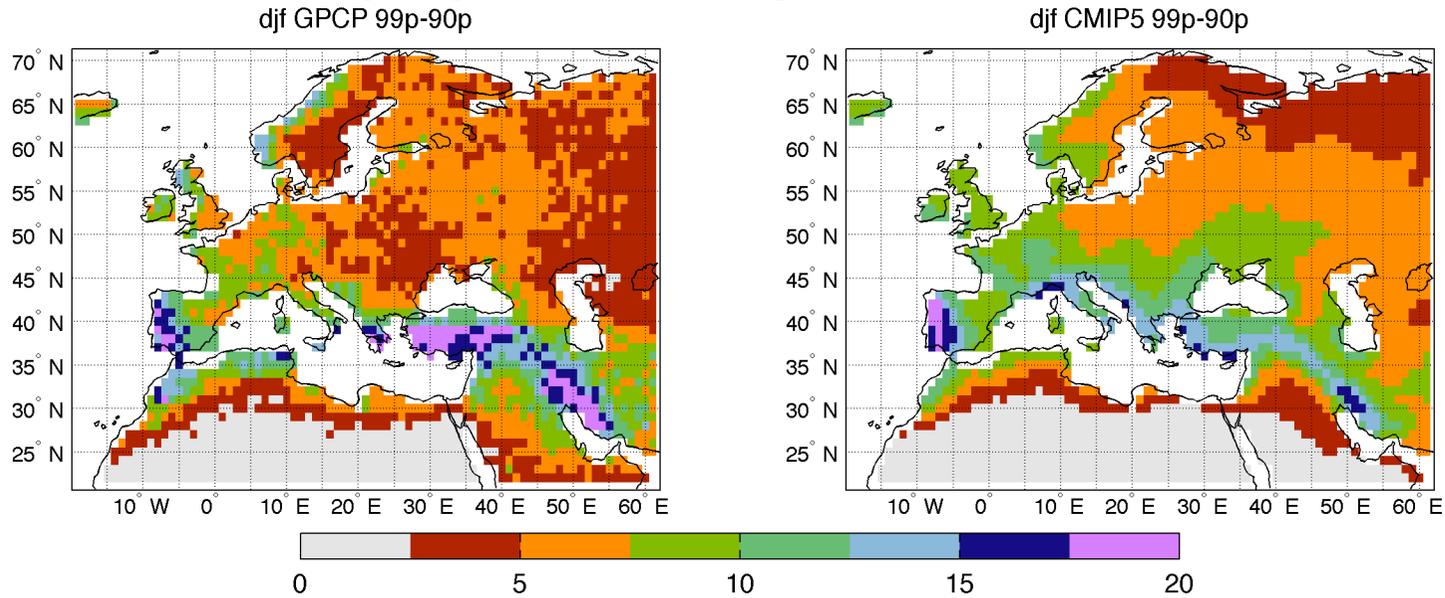
Ref:

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.

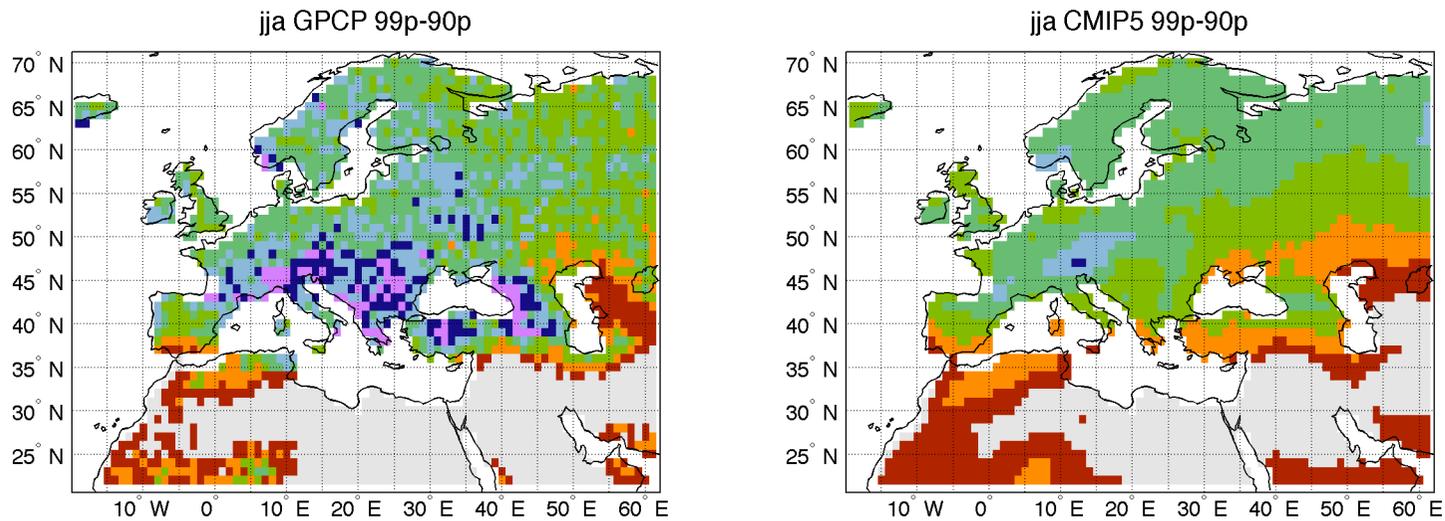
RESULTS

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

DJF



JJA



OBS (GPCP)

CMIP5 models



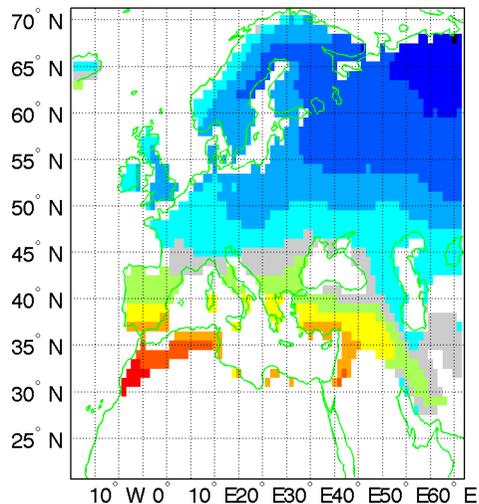
total precipitation, 90p and 99p-90p **CHANGES IN A WARMER CLIMATE** (% increase in 2061-2100 wrt 1966-2005)

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

Average

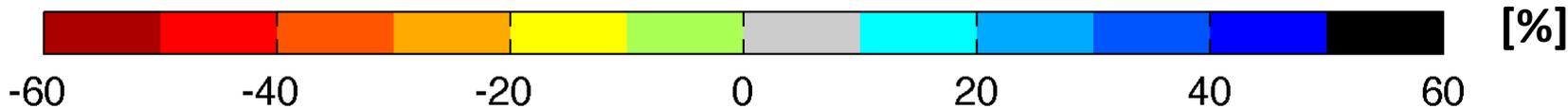
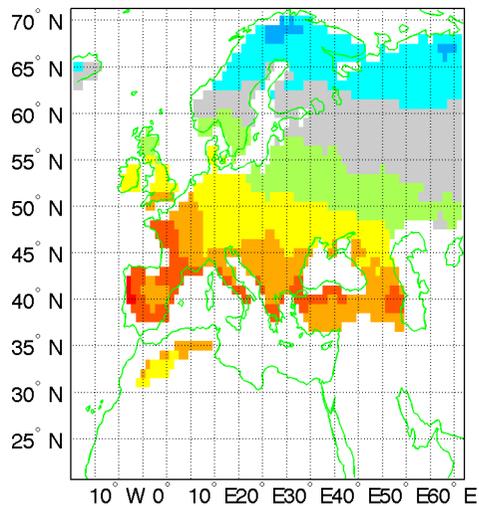
djf 2061:2100-1966:2005 tot prec % incr.

DJF



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

JJA



total precipitation, 90p and 99p-90p **CHANGES IN A WARMER CLIMATE** (% increase in 2061-2100 wrt 1966-2005)

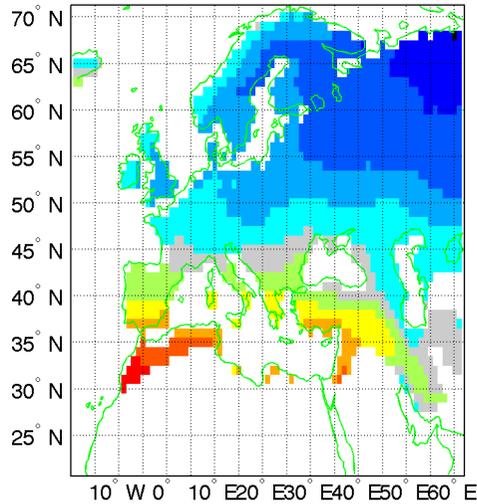
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Average

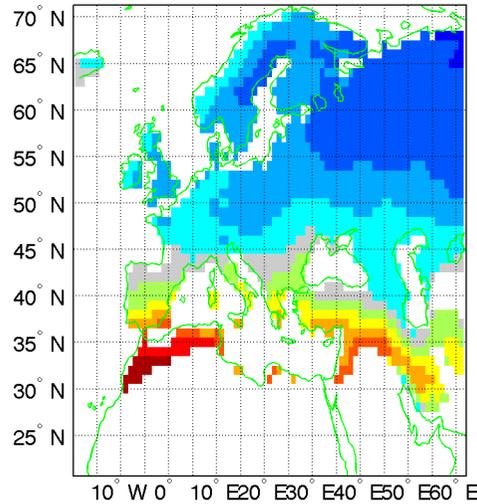
90p

DJF

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

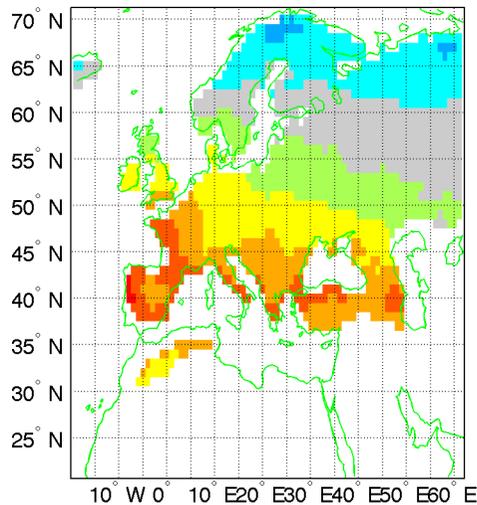


djf 2061:2100-1966:2005 90p % incr.

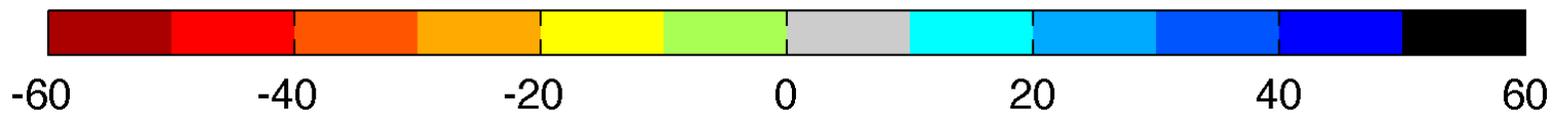
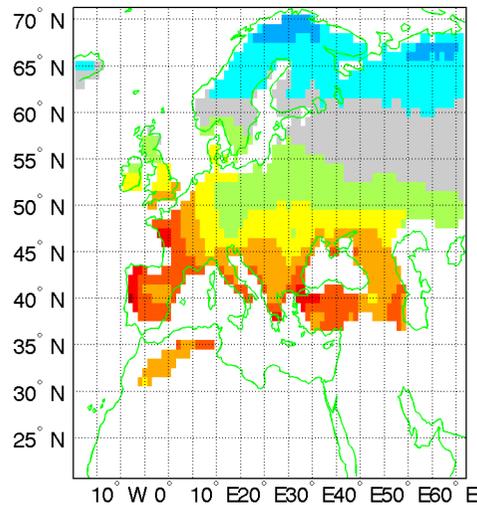


JJA

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

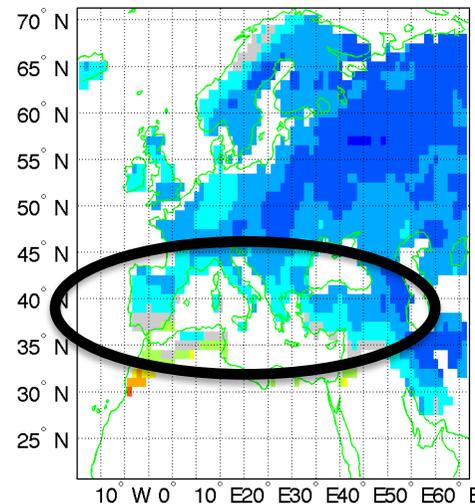
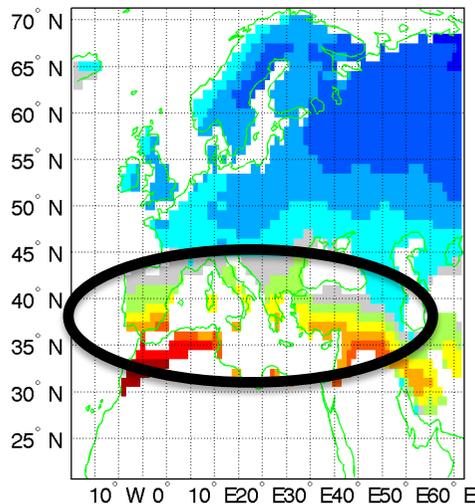
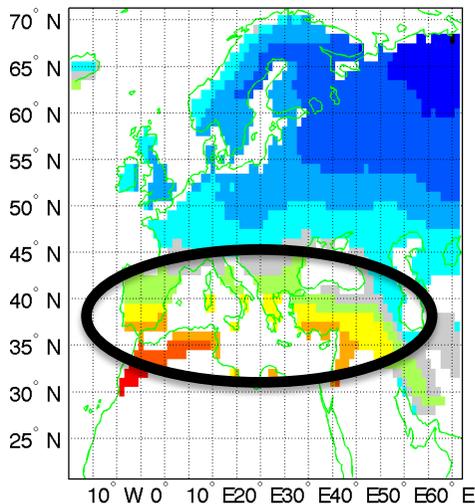
99p-90p

DJF

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

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

djf 2061:2100-1966:2005 99p-90p % incr.

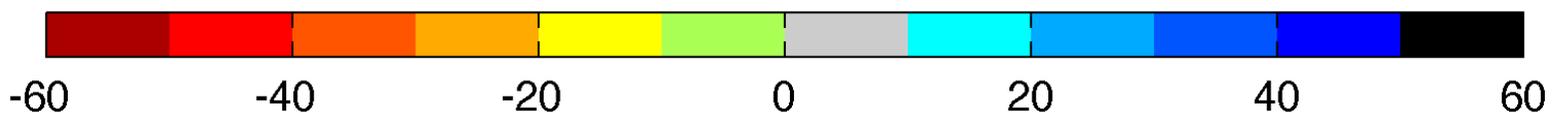
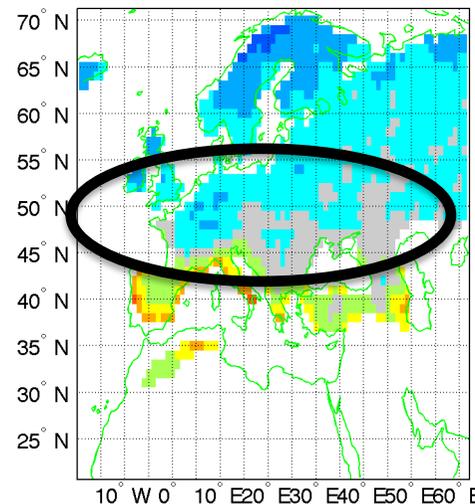
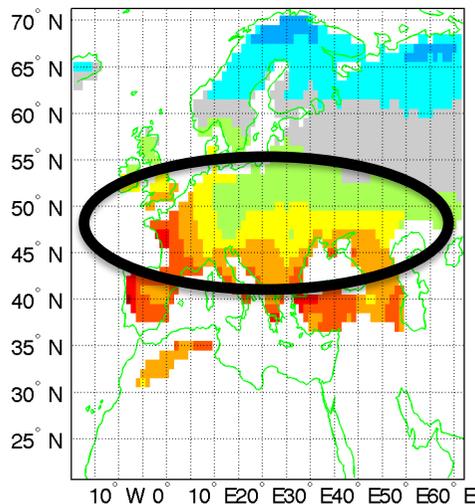
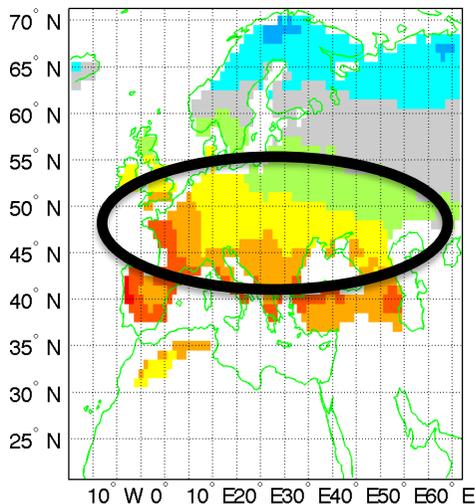


JJA

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

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

jja 2061:2100-1966:2005 99p-90p % incr.



RESULTS

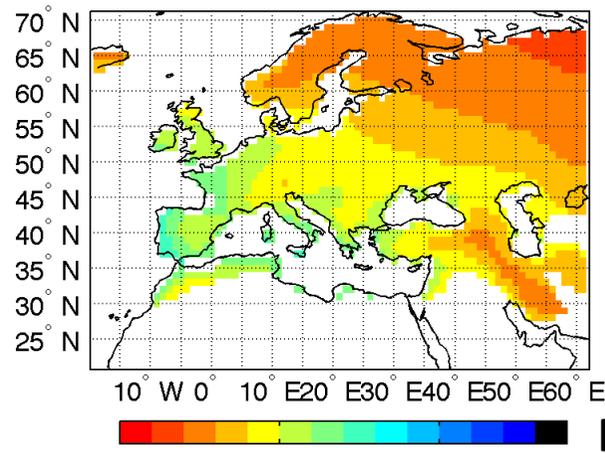
Integrated Water content [Kg/m²]

HISTORICAL

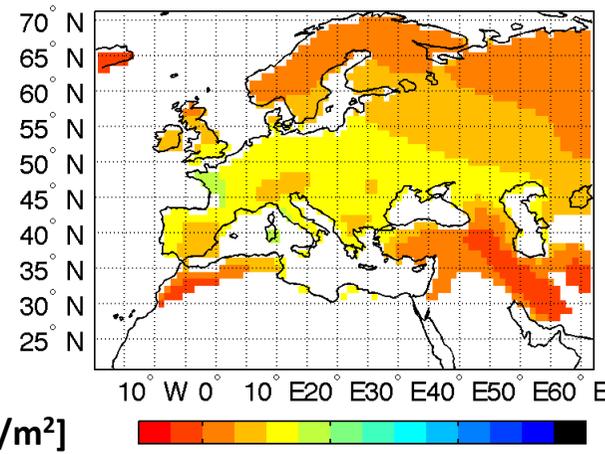
changes in RCP85

DJF

djf 1966:2005 WCONT



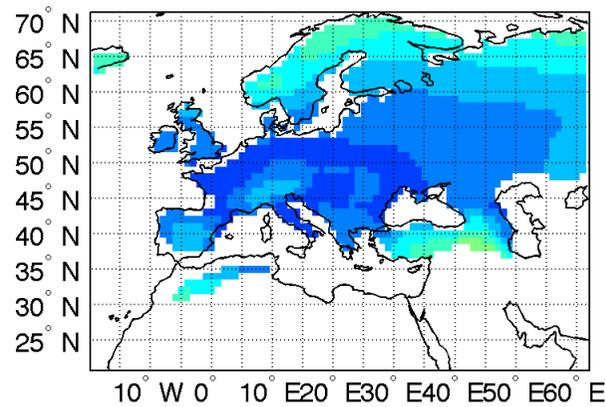
djf 2061:2100-1966:2005 WCONT



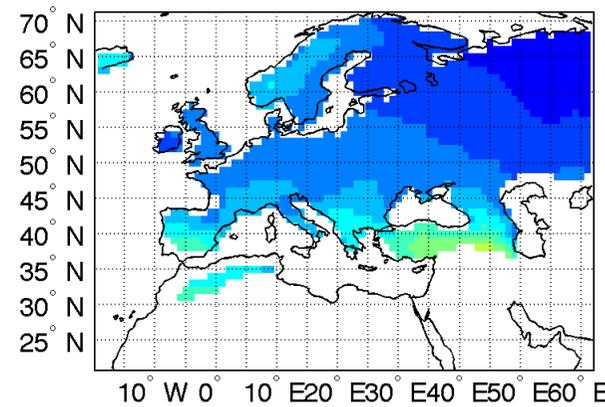
0 10 20

jja 1966:2005 WCONT

JJA



jja 2061:2100-1966:2005 WCONT



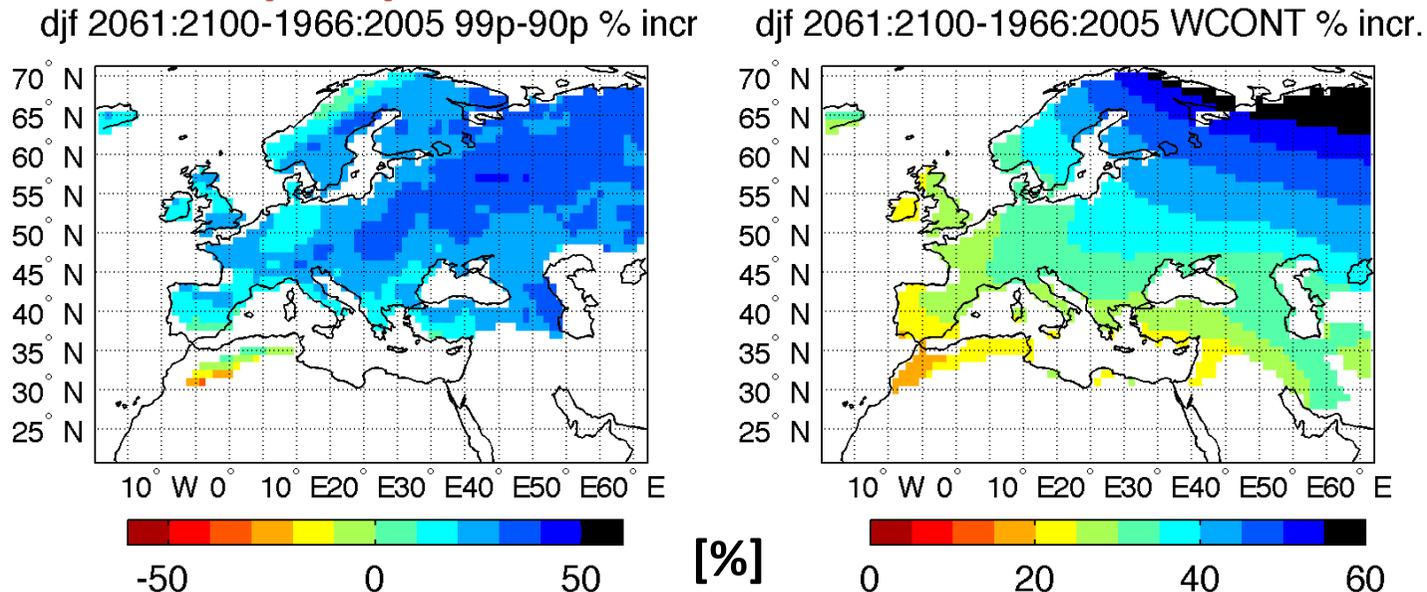
*regions with pr<0.5 mm/day are masked (white)

99p-90p and WCONT CHANGES IN A WARMER CLIMATE (% changes in 2061-2100 wrt 1966-2005)

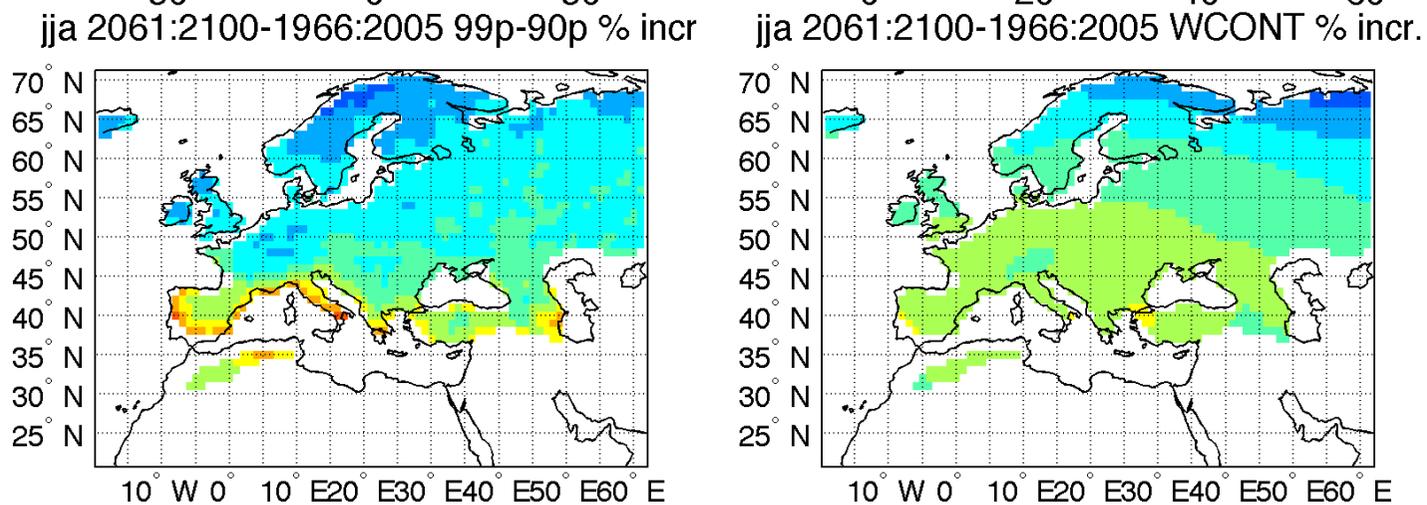
99p-90p

WCONT

DJF



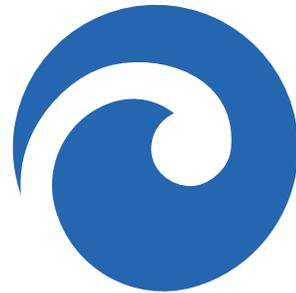
JJA



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)

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 also 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.



cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici

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Thank you



EGU 2014: May 1st 2014 Vienna, Austria

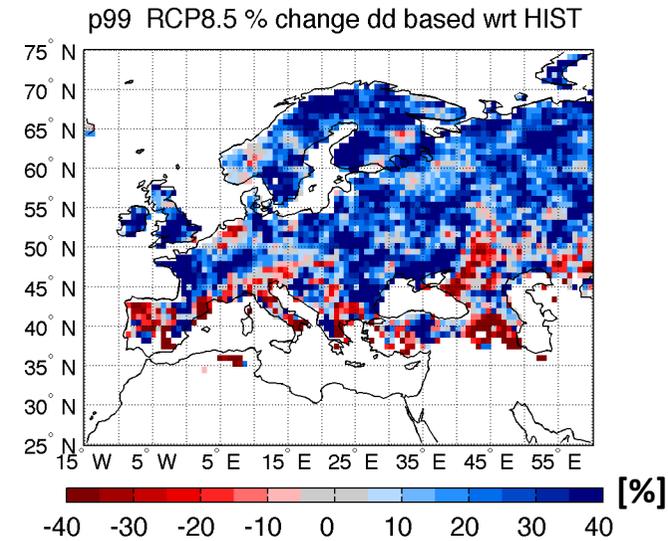
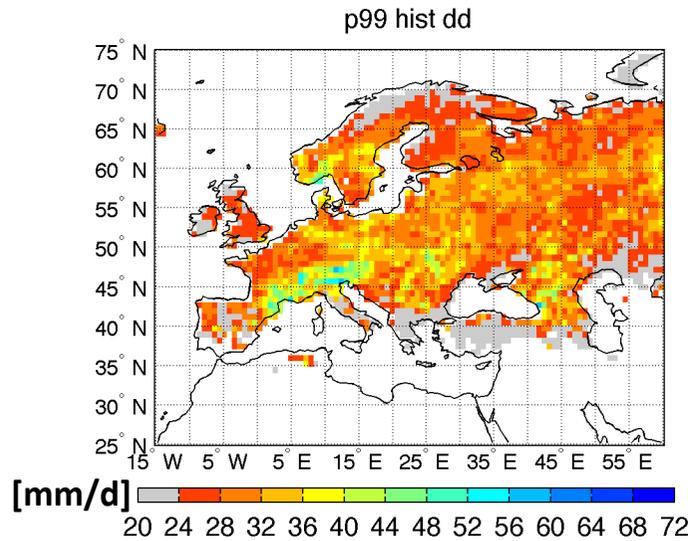


JJA 99p projections at daily or sub-daily time scale
(% changes in 2081-2100 wrt 1986-2005)

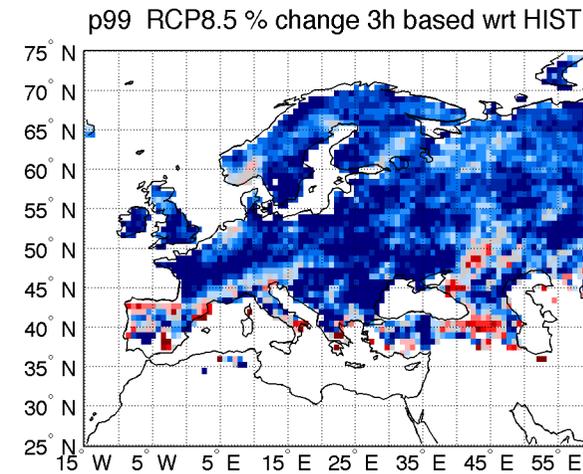
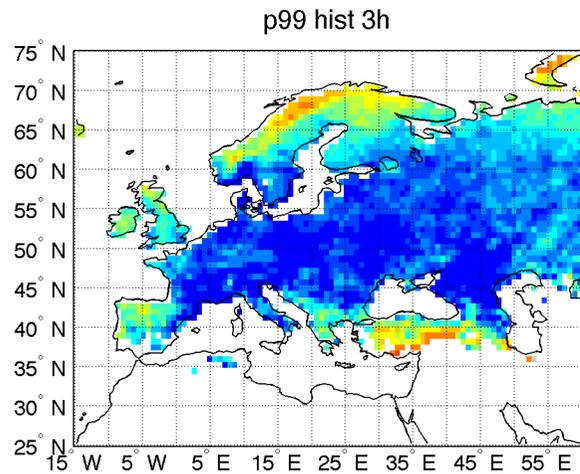
historical 99p

99p projection

daily



3 hourly



White patterns over land indicate regions with seasonal precipitation lower than 0.2 mm/d).

CONCLUSIONS

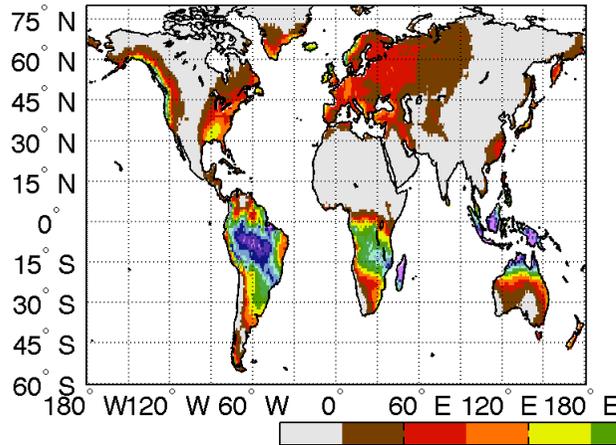
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3. The regions affected by strong stretching of the right tail of precipitation event distribution in the future correspond to strong increased availability of water vapour content in the atmospheric column.
4. Future projections of extreme rainfall events based on a daily time scale, underestimate the % increase over the Central Europe, if compared to 3 hourly based results.

RESULTS

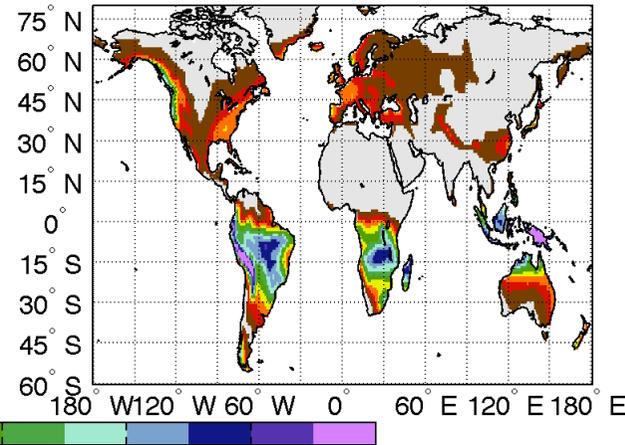
TOTAL PRECIPITATION [mm/d] during 1997-2005

DJF

djf GPCP total precipitation

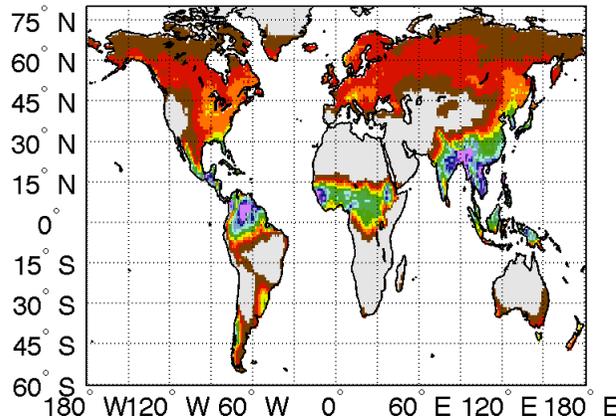


djf CMIP5 total precipitation

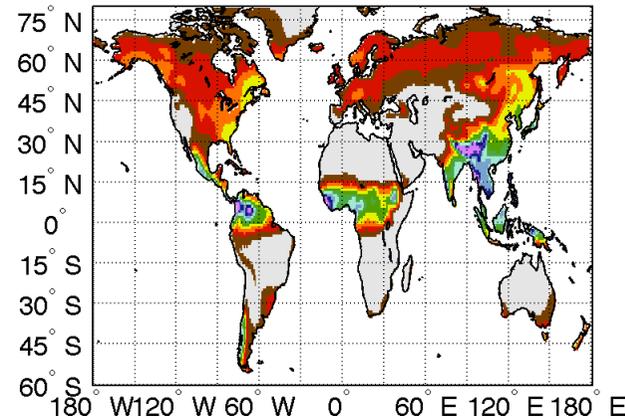


JJA

jja GPCP total precipitation



jja CMIP5 total precipitation

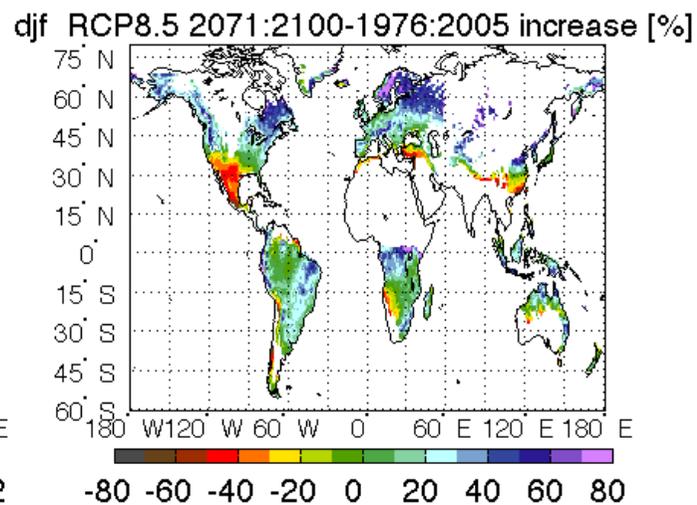
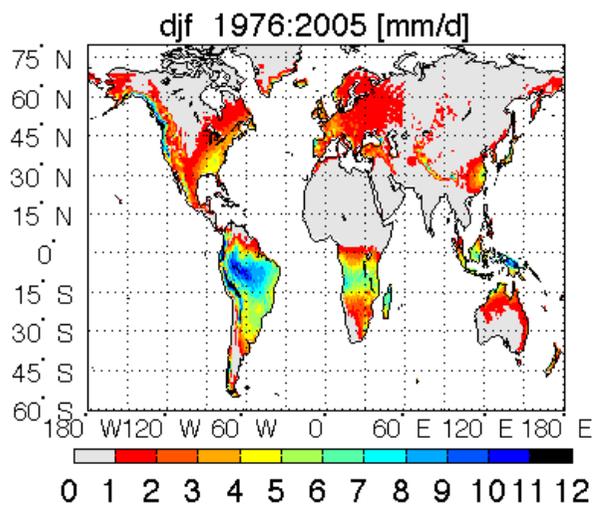


OBS (GPCP)

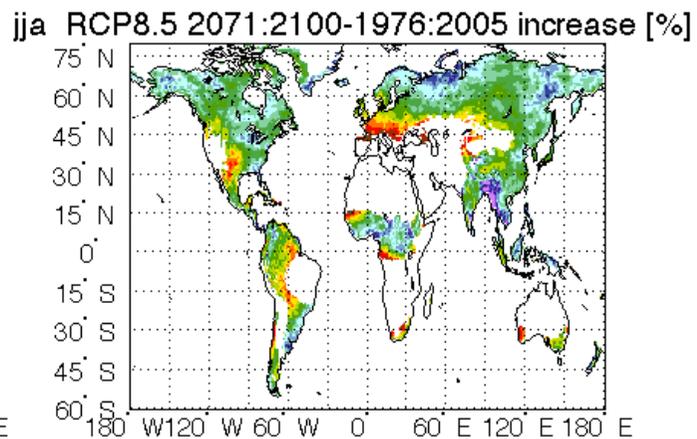
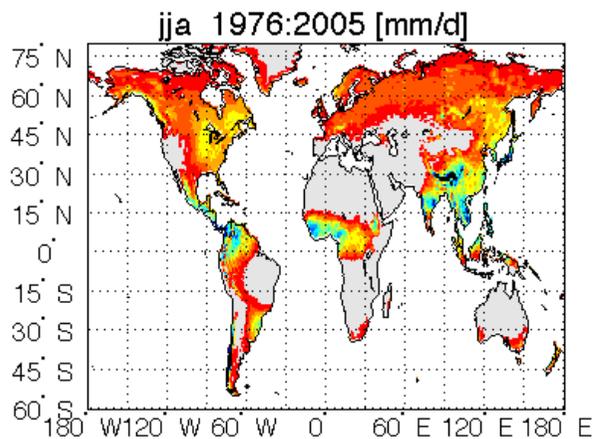
CMIP5 models

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

DJF



JJA

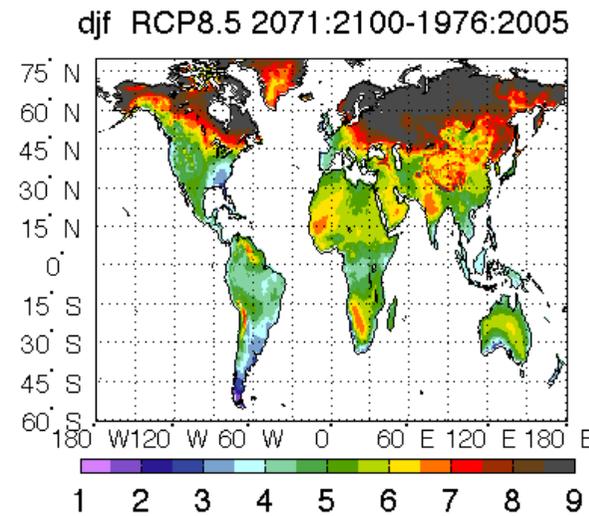
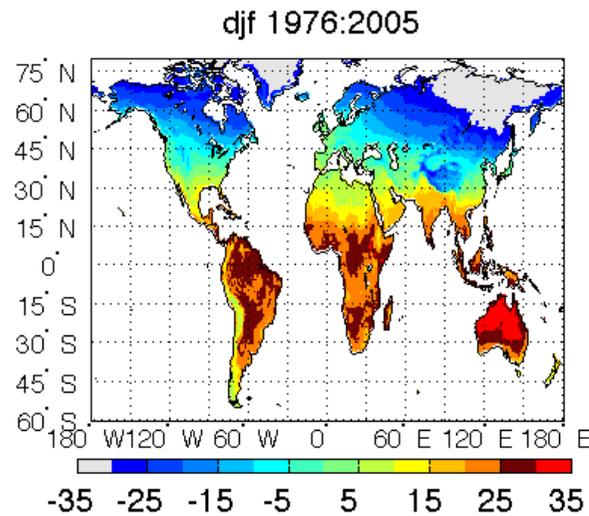


HISTORICAL

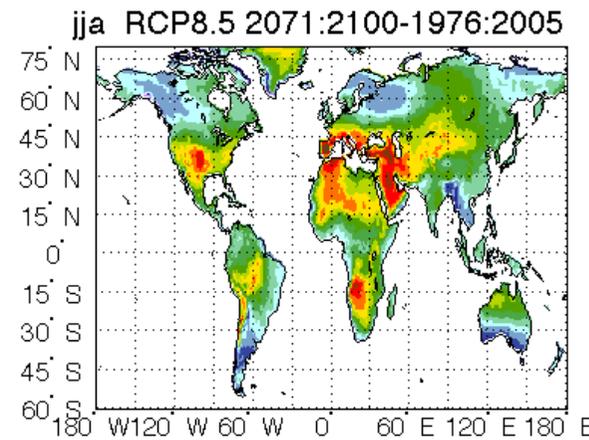
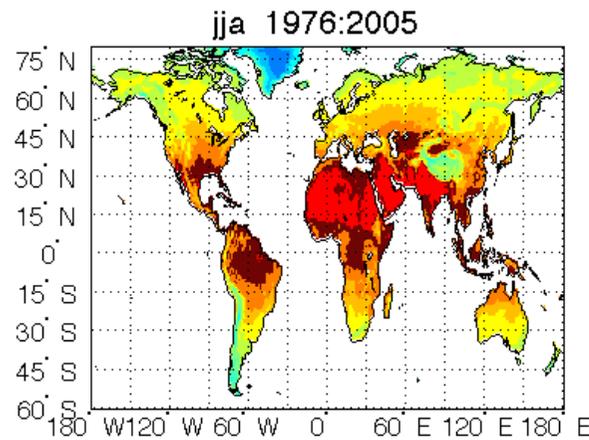
increase in RCP8.5

T2m [°C] CMCC-CM

DJF



JJA

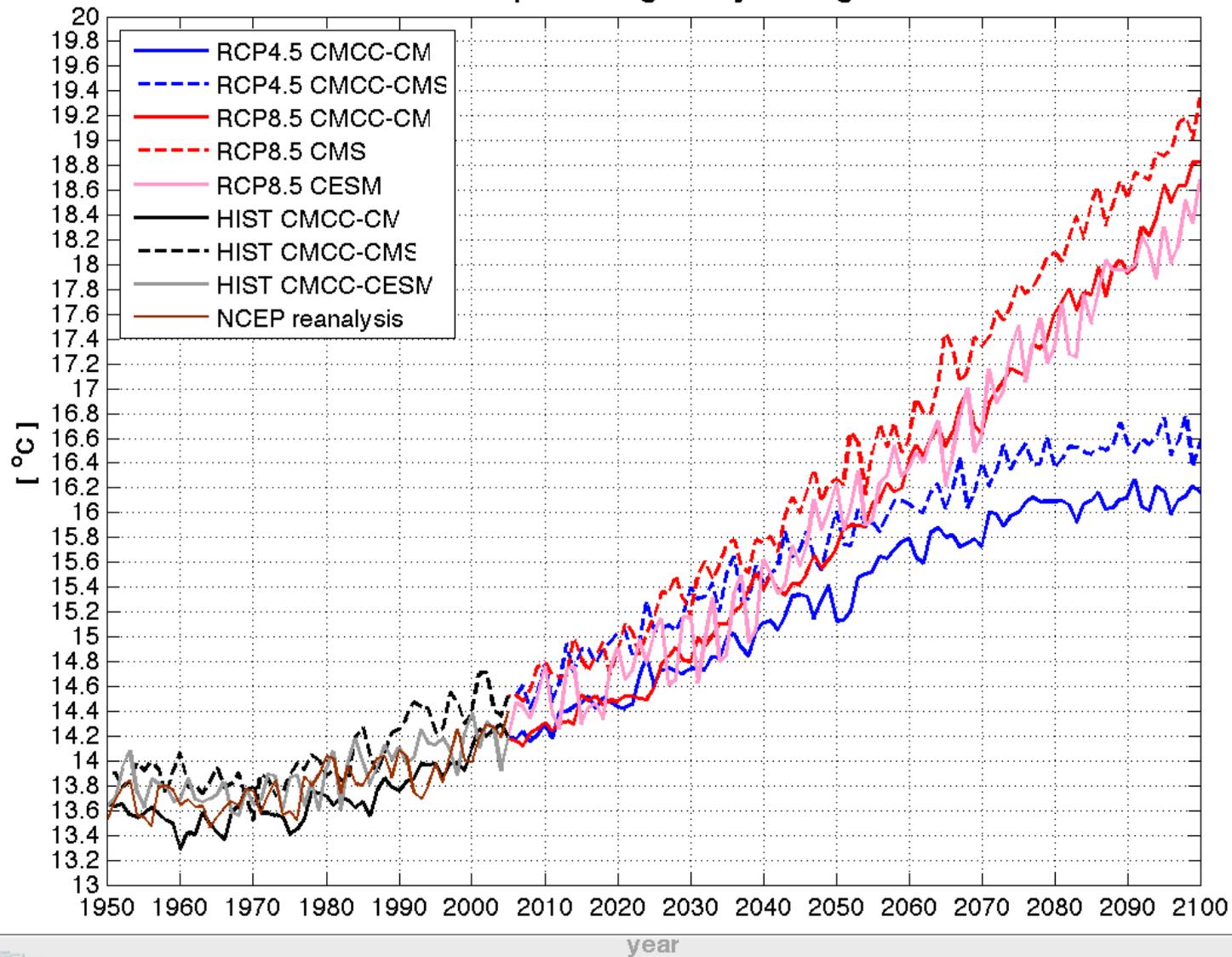


HISTORICAL

increase in RCP8.5

The CMCC-CM CGCM: model output

2M temperature globally averaged

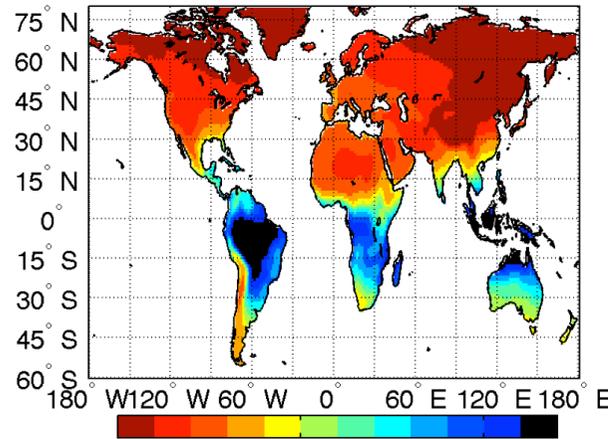


RESULTS

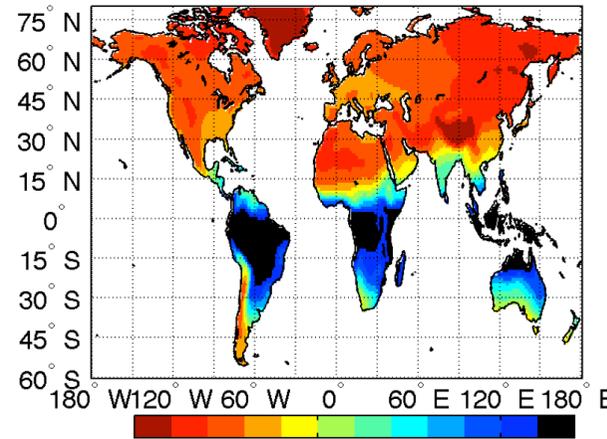
Atmospheric water vapour content

DJF

djf 1966:2005 WCONT

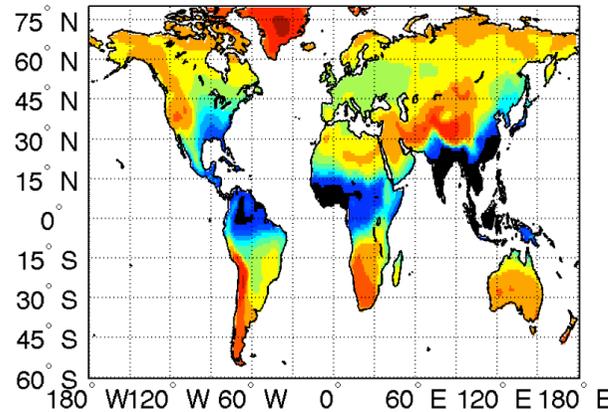


djf 2061:2100-1966:2005 WCONT

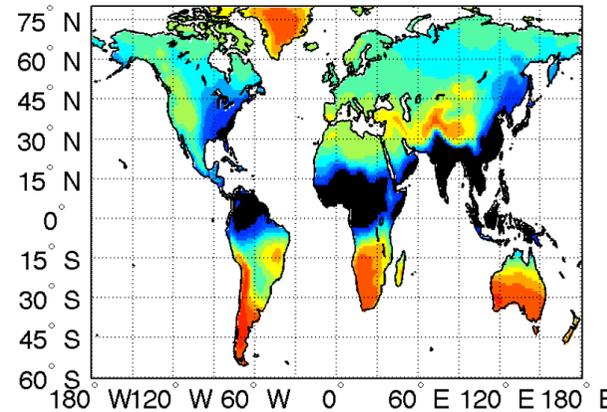


JJA

jja 1966:2005 WCONT



jja 2061:2100-1966:2005 WCONT



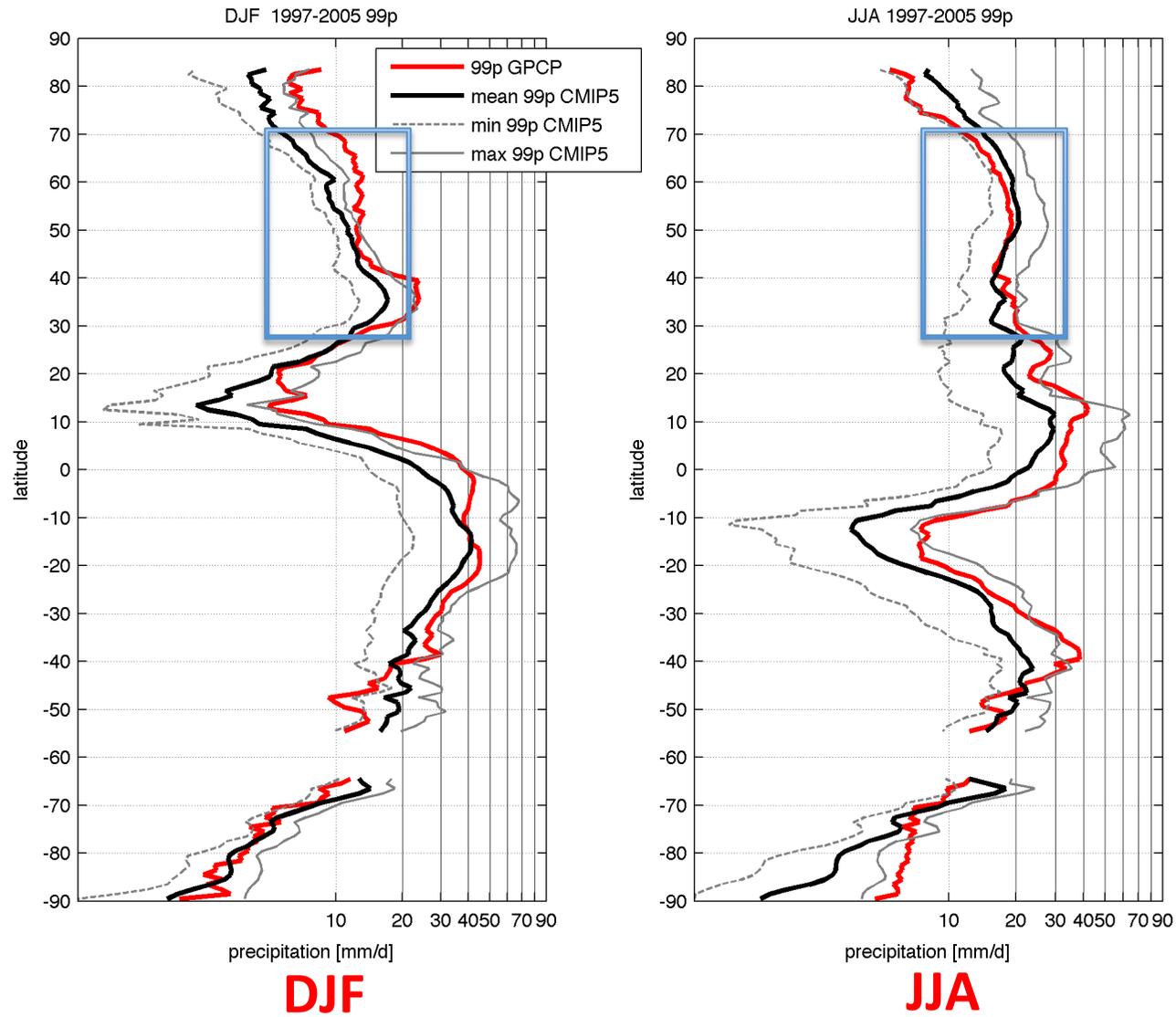
water vapour content
[Kg/m²]

water vapour content increase
[Kg/m²]

RESULTS

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

LATITUDE



DJF

JJA

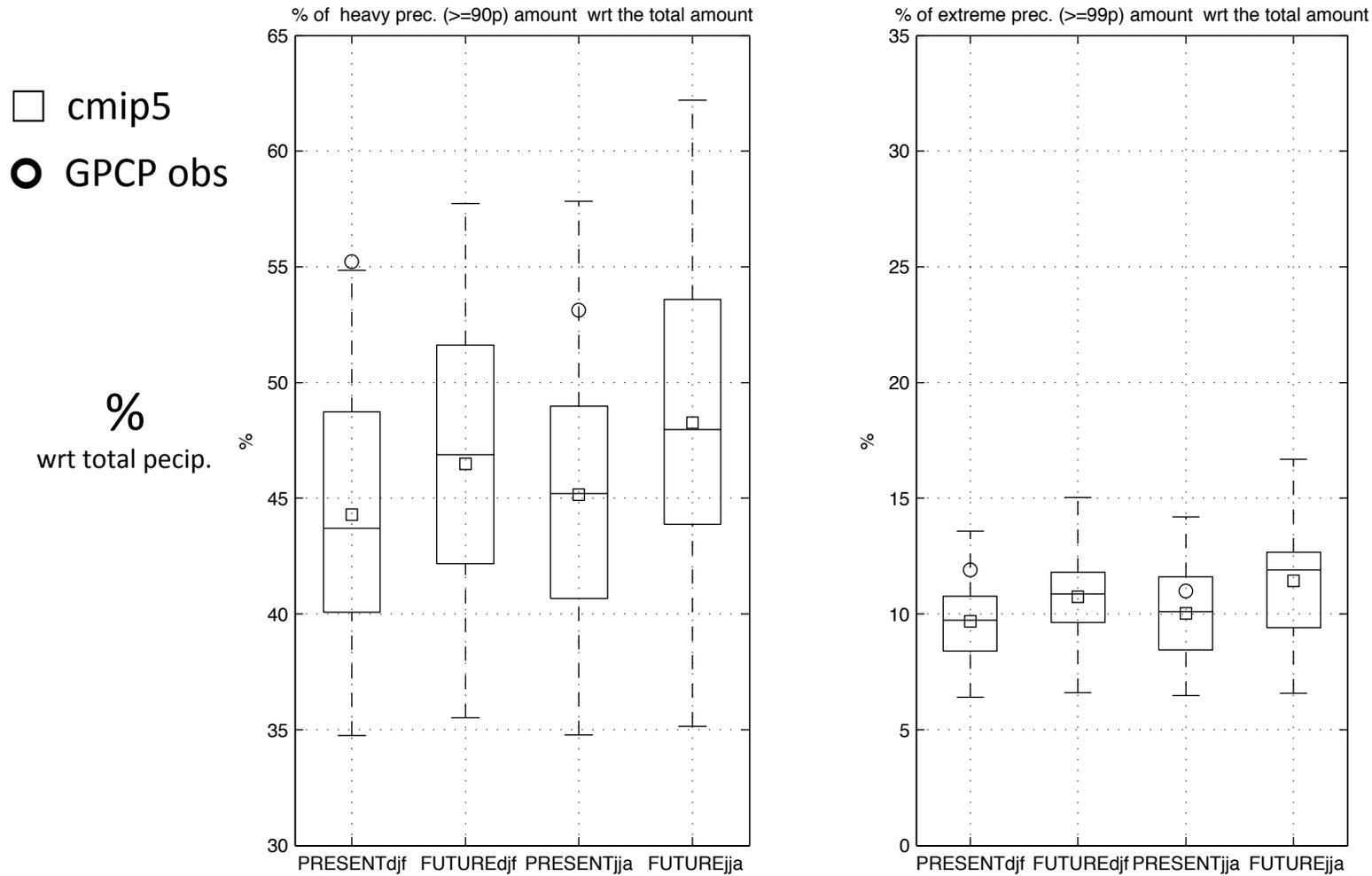


EGU 2014: May 1st 2014 Vienna, Austria



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

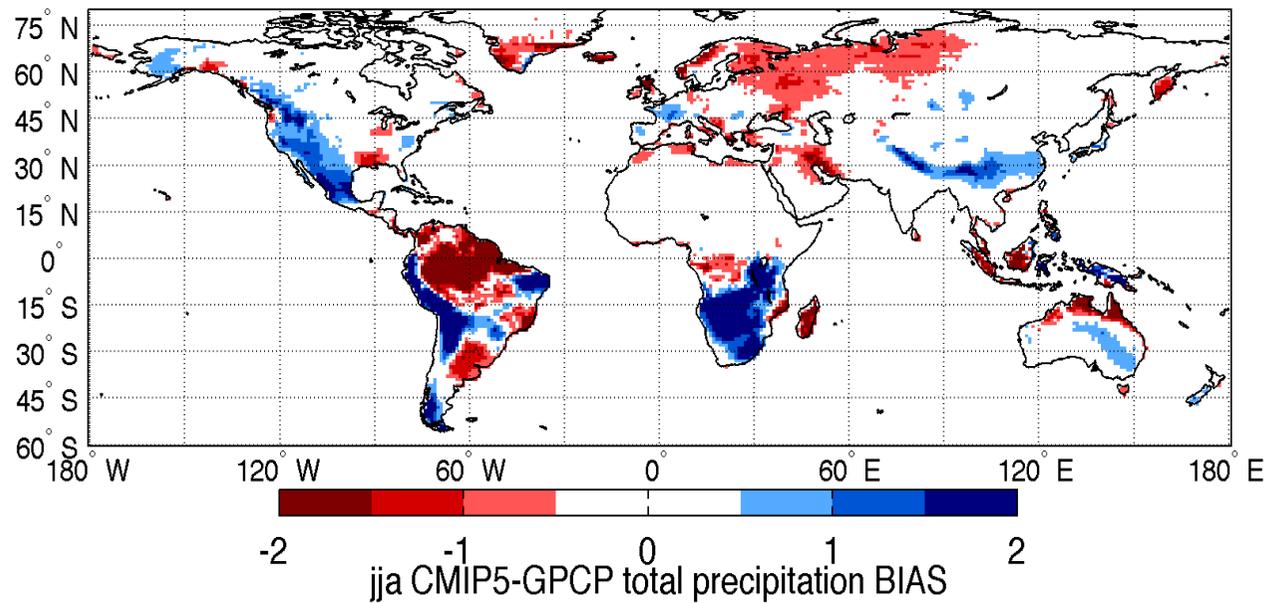


DATA & METHODOLOGY

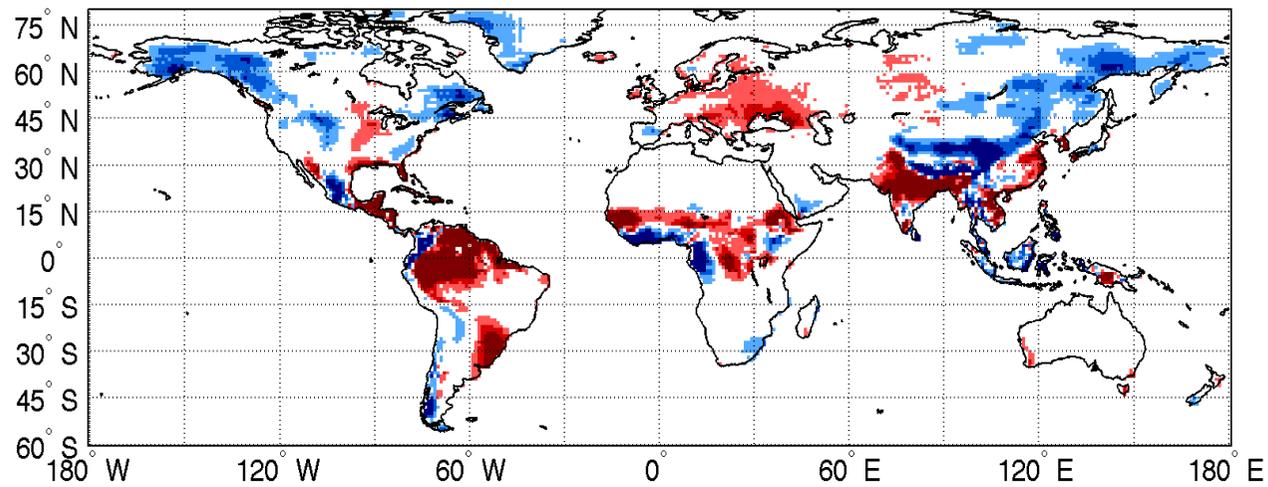
CMIP5 models
involved in this study

Model name	Lat x Lon (degrees)	Institute (Institute 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



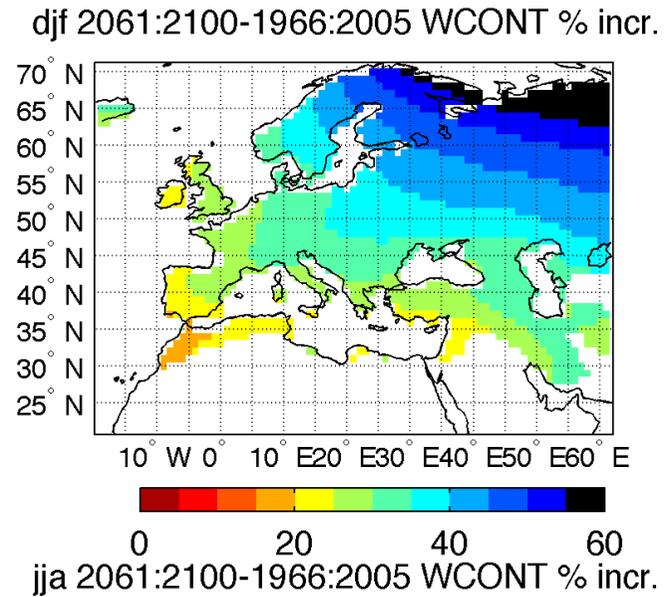
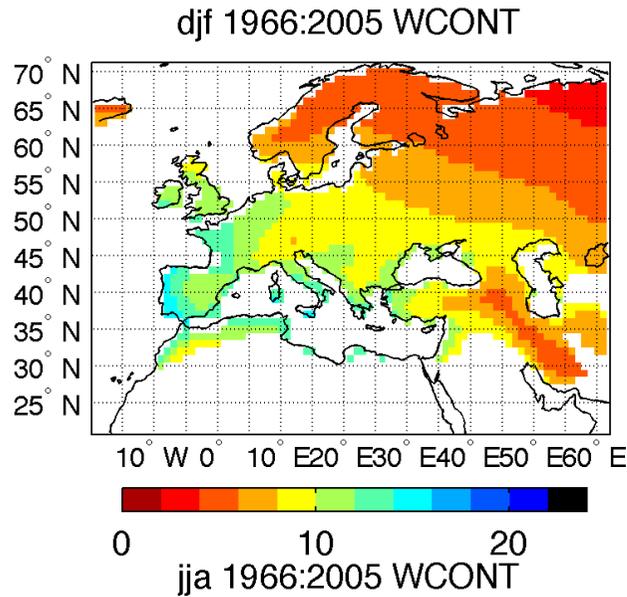
jja CMIP5-GPCP total precipitation BIAS



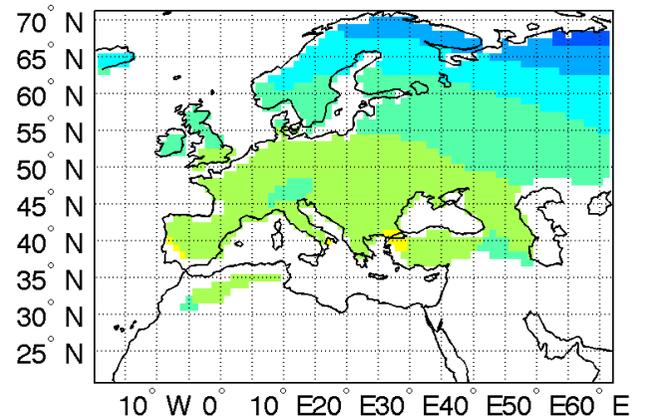
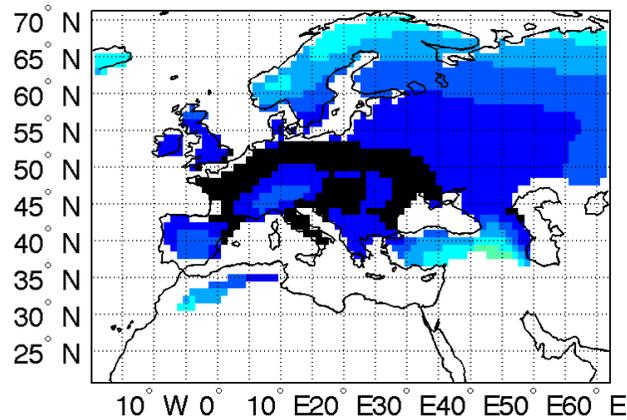
RESULTS

Integrated Water content [Kg/m²] increase [%]

DJF



JJA



HISTORICAL

RCP85 increase