Changes in extreme temperature and precipitation and their effects on the hydrological cycle of the Alpine region

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Italian Society for Climate Sciences
SISC
Venice Mestre - 17-19 October 2018
Sixth Annual Conference
Recent trends in climate sciences, adaptation and mitigation

Overall scope

present and discuss results on **extreme events** in **precipitation** and **temperature** over the Euro–Mediterranean region, and their possible effects on the **hydrological cycle** in the Alpine area.

These results have been obtained from analyses conducted in the framework of the **NextData project**, using data collected or produced within the project.

Outline

- **Precipitation extremes in the global projections: a new metrics**
- **Precipitation extremes in regional simulations**
- **Heat waves and impacts on Alpine hydrological cycle**

Projected changes in extreme precipitation over the Euro-Mediterranean

(Global) Models and Observed Data

Daily Modelled Precipitation

- HISTORICAL 1966-2005
- RCP8.5 scenario 2061-2100

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)

Observed Precipitation

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

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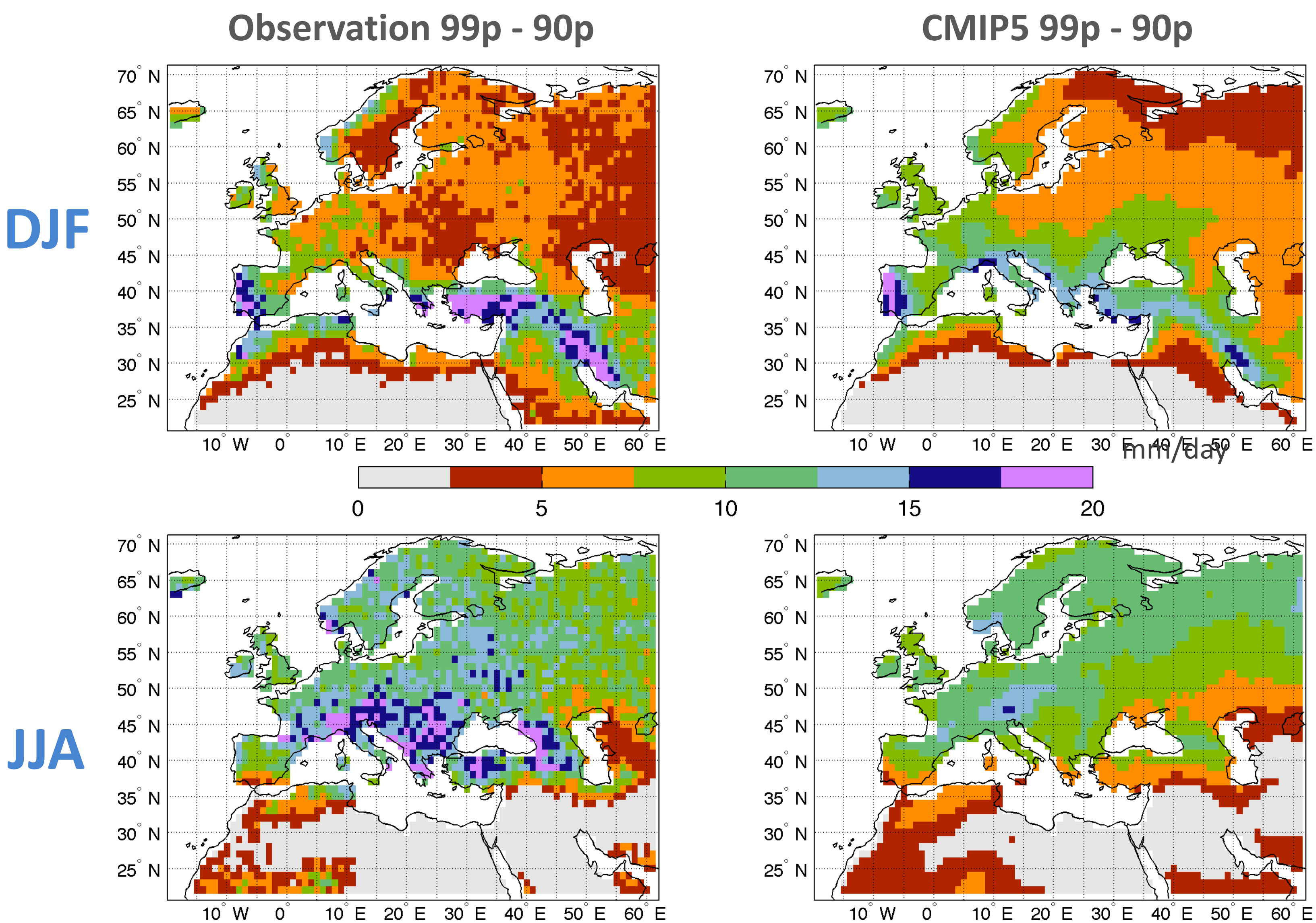
99p-90p [mm/d] during 1997-2005



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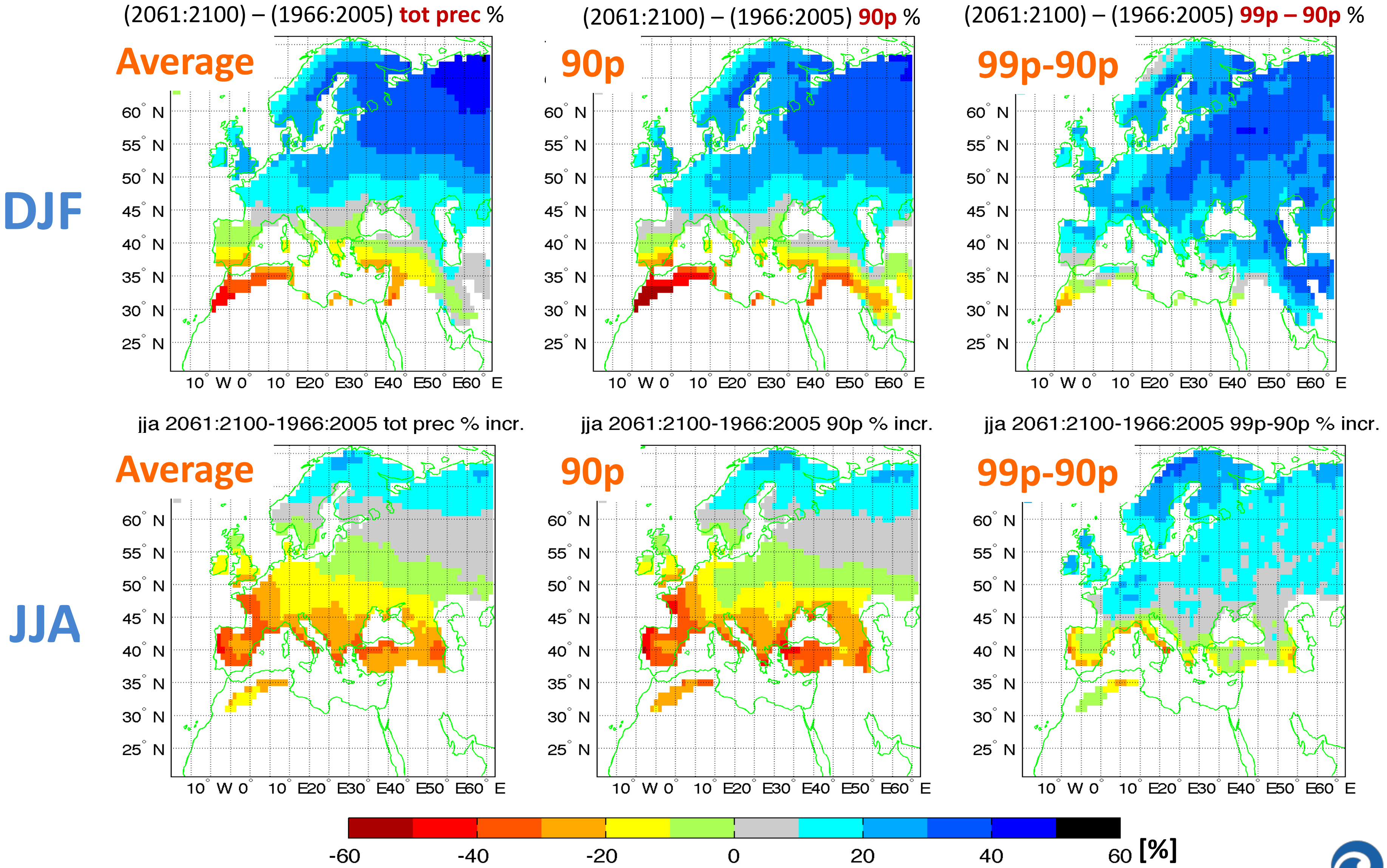
Change (%) in 2061-2100 wrt 1966-2005 (RCP8.5)



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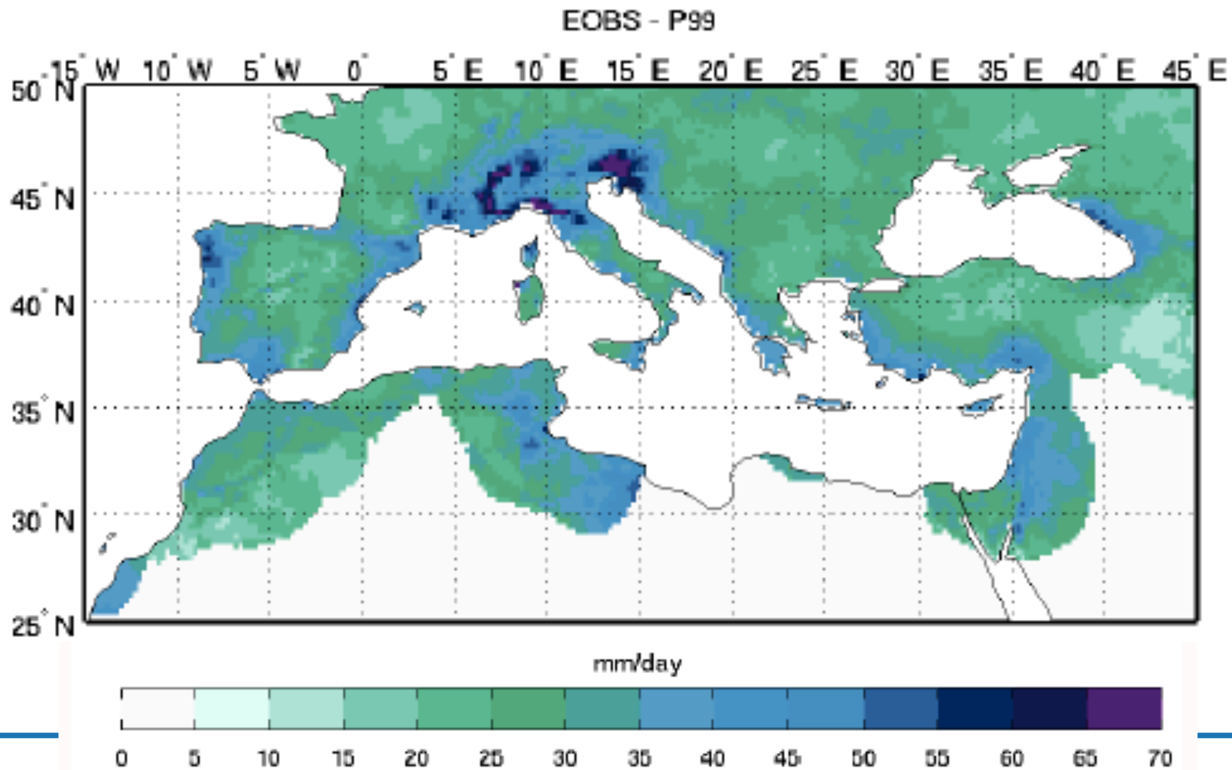
P99 value

- The value of precipitation for each grid point above the 99% of the values in the time series of daily precipitation in rainy days (P>1 mm/day)
- gives an immediate visualization and estimate of the intensity of extreme precipitation events in different areas



- Largest values in the eastern and western parts of the alpine arc and northern Appennines range.
- Large values in the northwestern part of Iberia, and along coastal areas

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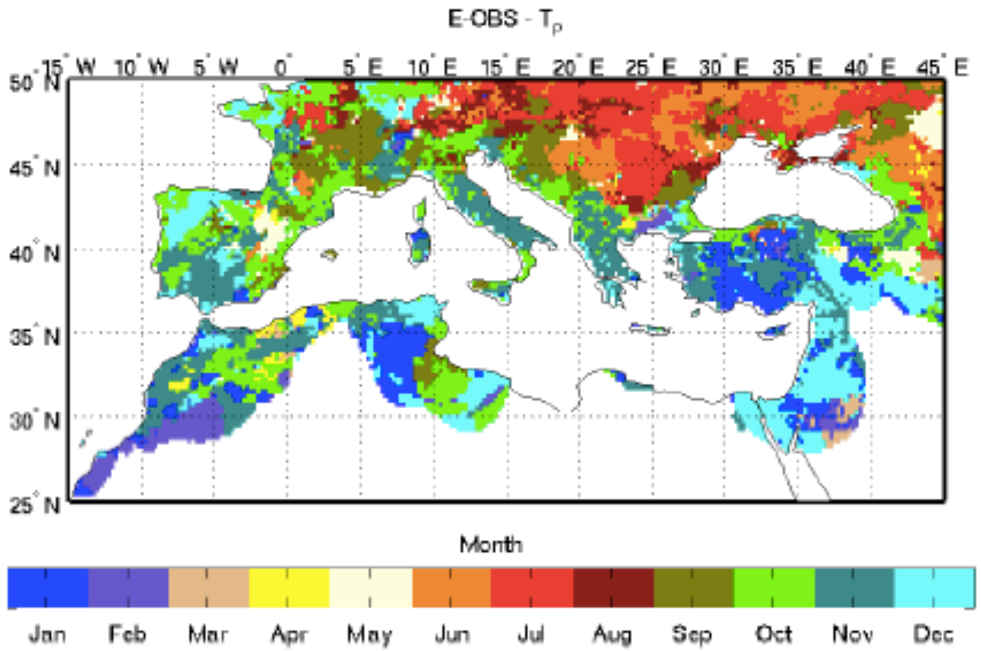
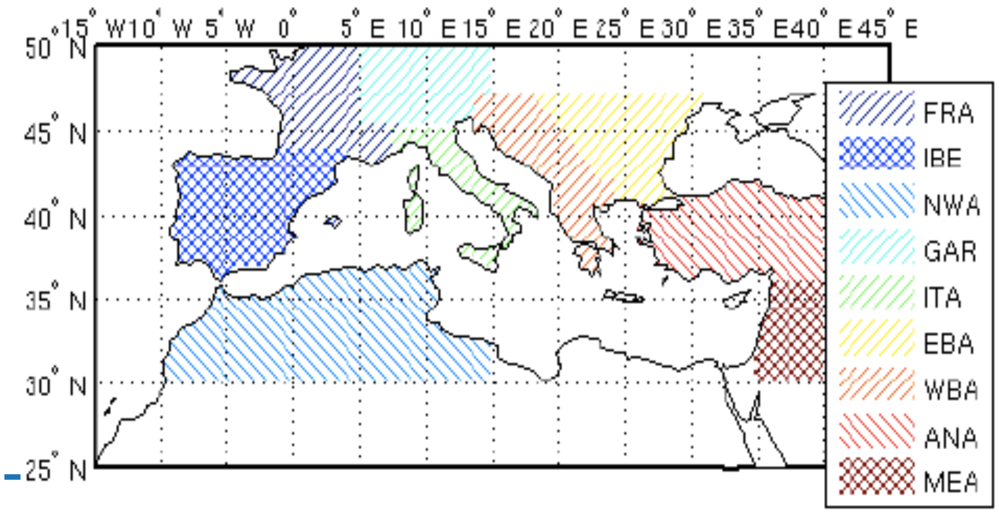
P99 timing

• Is computed from the histogram of all the values in the time series such that P>P99, selecting the most populated monthly bin in the histogram.

• In **Central and Eastern Europe** most of the extreme events in **summer**.

• In **Western and Southern Europe** maximum during **autumn and winter**.





• It can be used to infer physically-based criteria to divide the domain in coherent sub-regions and relevant seasons

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(Regional) Models and Data

N.	NAME	RES. (km)	C.	PERIOD
-	E-OBS	25	O	1979-2011
1	ERA-Interim	75	R	1979-2011
2	MERRA	50	R	1979-2011
3	JRA-55	50	R	1979-2011
4	CMCC	50	A	1979-2011
5	CNRM	50	A	1980-2011
6	ENEA	50	A	1982-2011
7	GUF	50	A	1979-2011
8	ICTP	50	A	1979-2011
9	IPSL	50	A	1989-2011
10	LMD	50	A	1979-2011
11	UBEL	50	A	1989-2008
12	UCLM	50	A	1989-2011
13	CMCC_HI	12	A	1979-2011
14	CNRM_HI	12	A	1980-2011
15	GUF_HI	10	A	1979-2011
16	ICTP_HI	12	A	1979-2011
17	IPSL_HI	20	A	1989-2011
18	UCLM_HI	12	A	1989-2011
19	CMCC_C	50	C	1979-2011
20	CNRM_C	50	C	1979-2011
21	ENEA_C	50	C	1982-2011
22	IPSL_HI_C	20	C	1989-2011
23	LMD_C	50	C	1979-2011
24	UBEL_C	50	C	1989-2008

- Observational dataset: E-OBS (v11) at 25 km resolution
- Three reanalysis datasets (including the common forcing of model data)
- 21 models from MedCORDEX, with different resolution and configurations:
  - ✓ 15 atmosphere-only, 6 coupled
  - ✓ 14 at the base resolution (50 km), 2 at intermediate resolution (20 km), and 5 at high (~10 km) resolution
  - ✓ one pair of coupled-uncoupled higher resolution simulations

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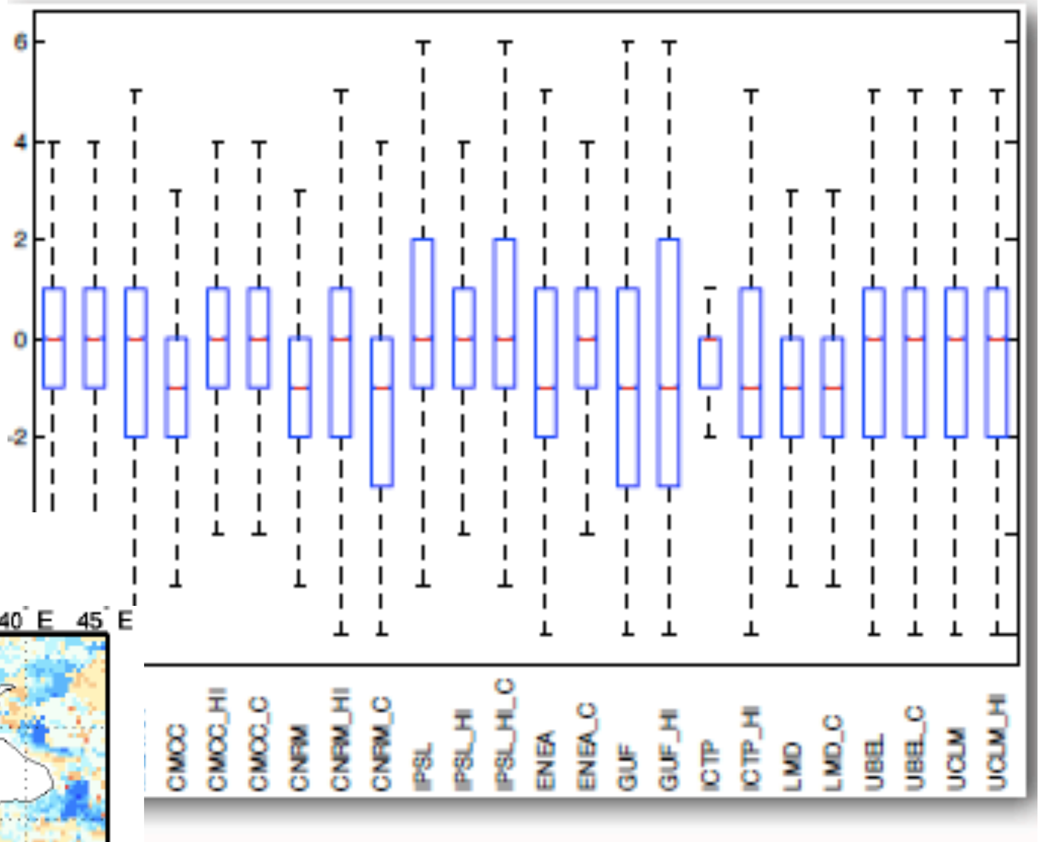
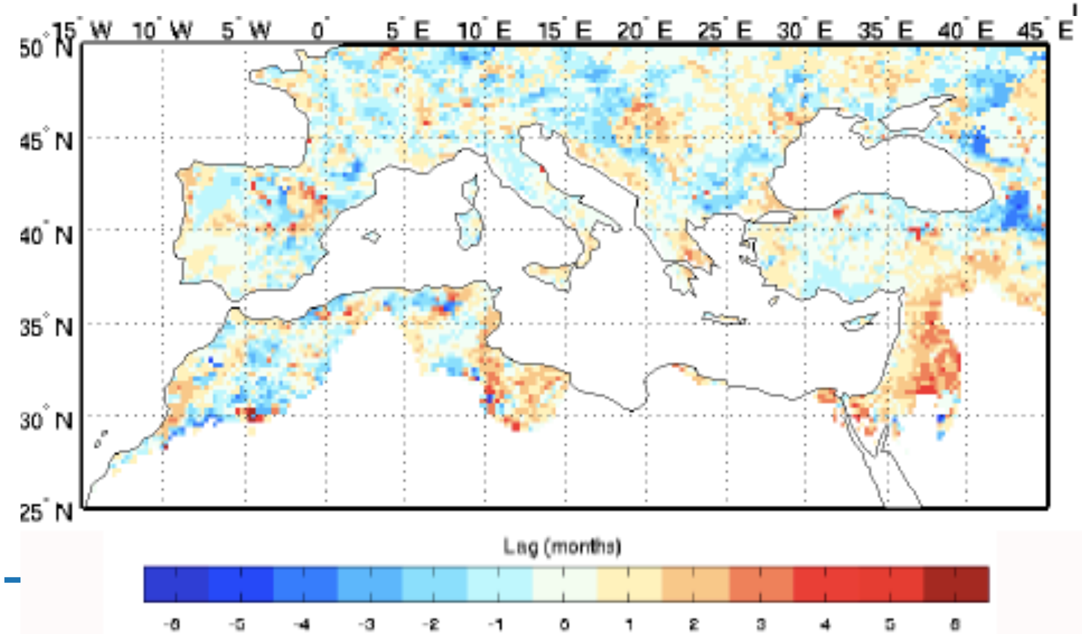
Overall, the main dipole between summer extremes in Central Europe and winter-autumn extremes in South/West Europe **well captured by all models**.

T_{p99} Lag between models and E-OBS

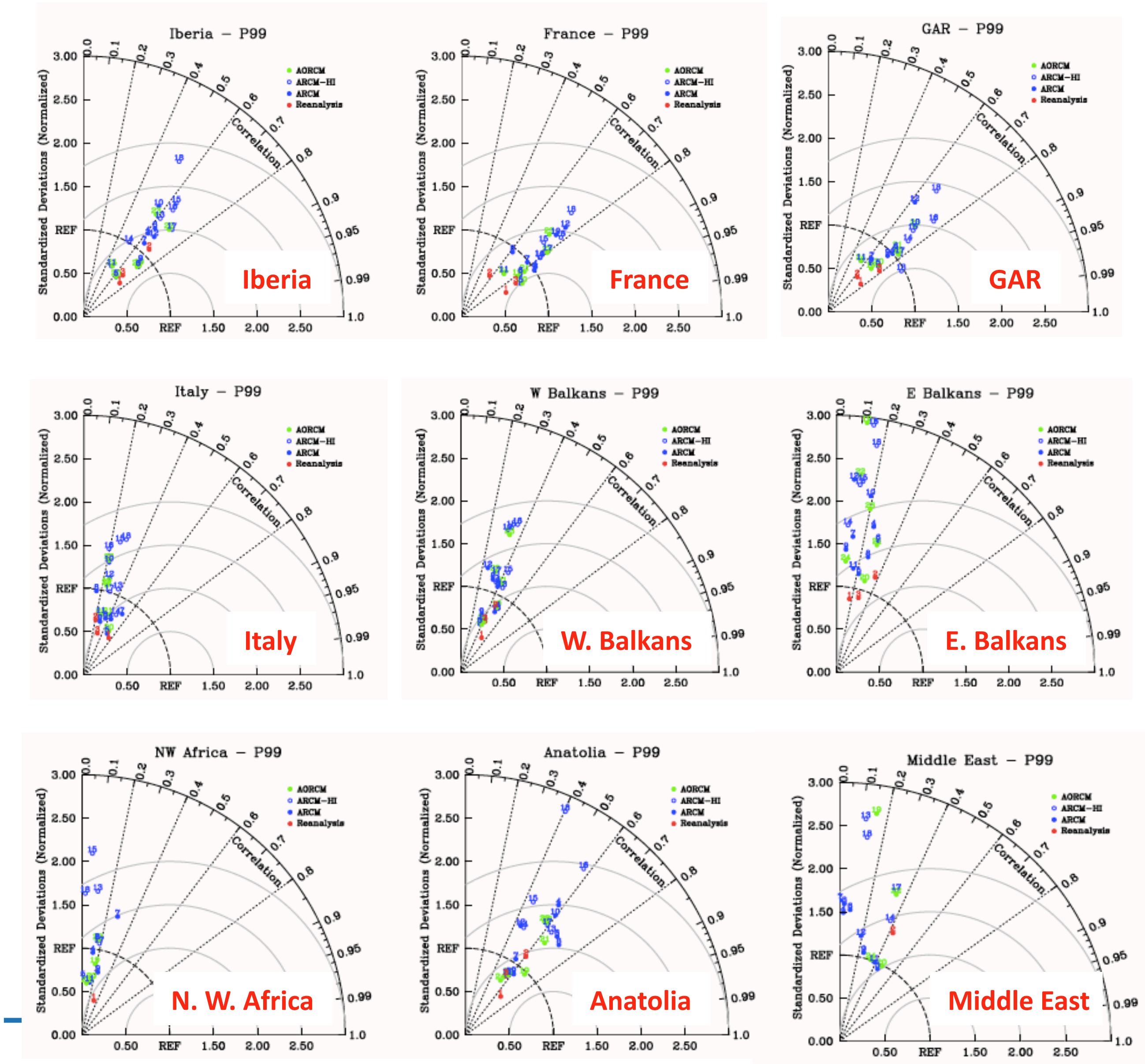


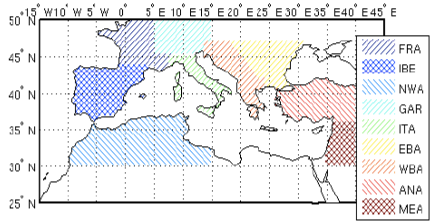
Locally, shifts of up to 2-3 months can be noticed between different models.

Ensemble mean – T_{p99} Lag difference



Taylor diagrams of the P99 model with E-OBS as a reference





- **Best skill:** Iberia, France, Great Alpine Region, Anatolia.
- **Worst skill**: Eastern Balkans, North Africa and Middle East.
- Larger skill spread between different regions than between different models.

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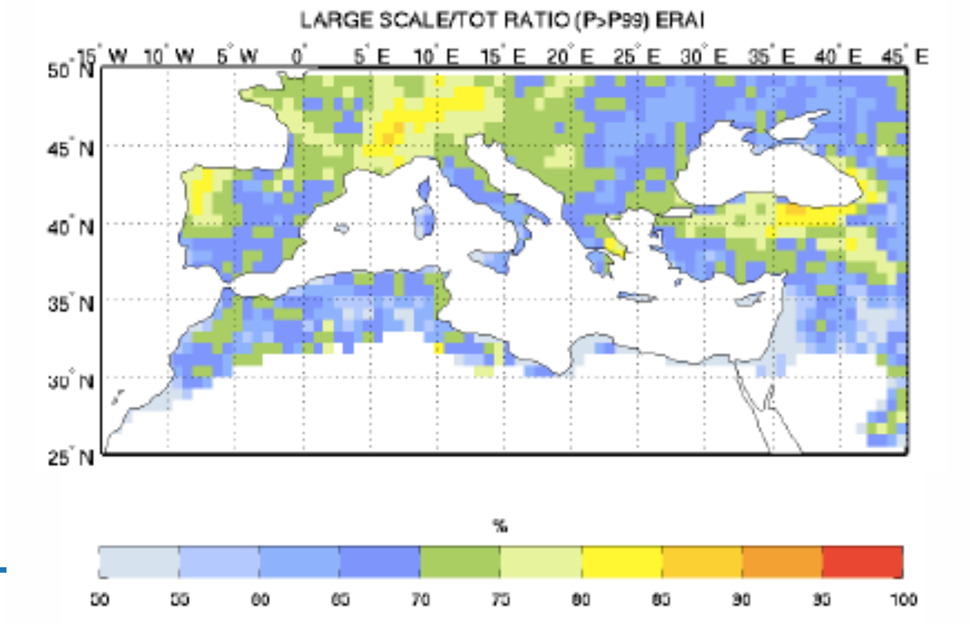
Questions:

• Why the skill in reproducing observations exhibits a larger spread between different regions than between different datasets (models)?

✓ Focus on the different contributions to extreme events from **large scale** and **convective precipitation**.

Ratio of large scale to total precipitation for extreme events



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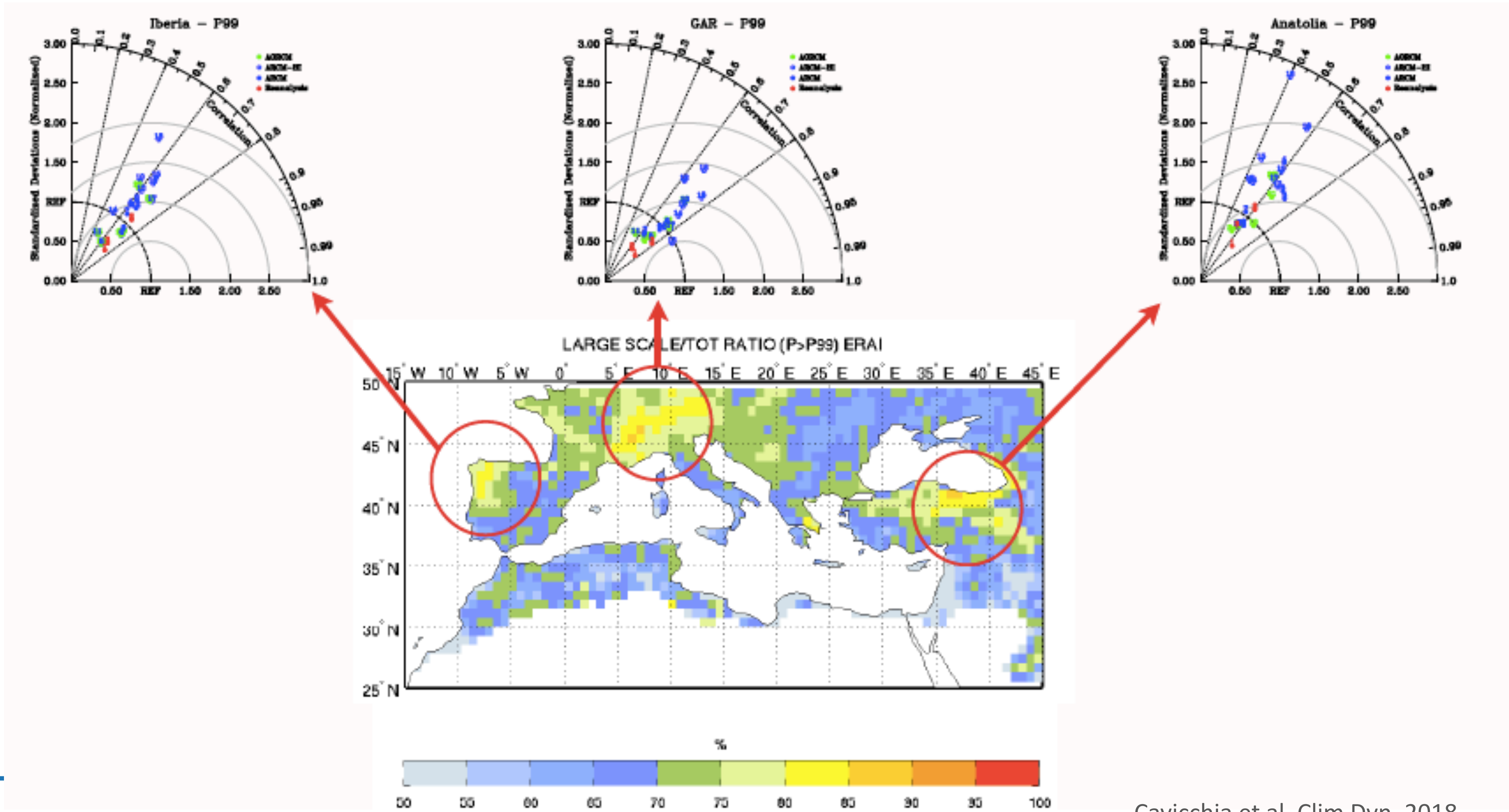
• In the regions where all models tend to show a **better performance** extreme events are **dominated by large scale precipitation**.



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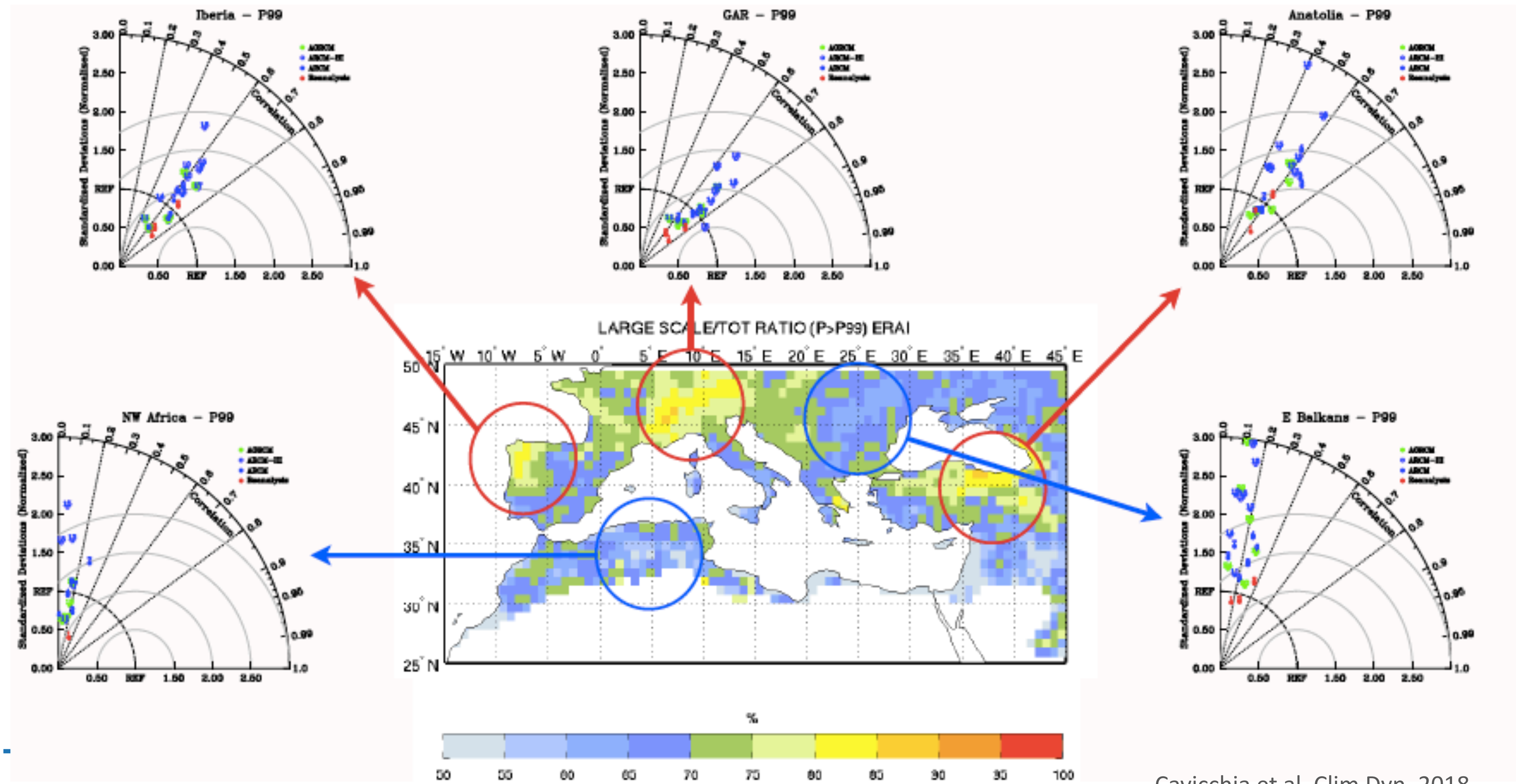
• In the regions where all models tend to show **bad performance, large scale** precipitation provides a **smaller contribution to extremes**



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Heat Wave Magnitude Index (HWMId)

The HWMId *(Russo et al JGR 2015)* **is computed from daily maximum temperature and it allows characterizing the *duration* and the *amplitude* of an heat wave with a single number:**

- A heat wave is defined as a period during which **Tmax exceeds the 90th percentile (T90)** computed on a 31 day window and a 30–year **reference period (1980-2010)**

- Over this period the magnitude is defined by summing a function of the interquartile spread **Σ (Tmax-T25)/(T75-T25)**

- The HWMId is defined as the maximum magnitude of the heat waves occurred in **1 year period**, zero if no heat waves occurred

Data: 20th Century Re–analyses:
- **20C-2 *from 1871*** *(NOAA, Compo et al. 2011)*
- **20C-2c *from 1851*** *(NOAA, Compo et al. 2015)*
- **ERA-20c *from 1900*** (ECMWF, Woodruff et al., 2011)

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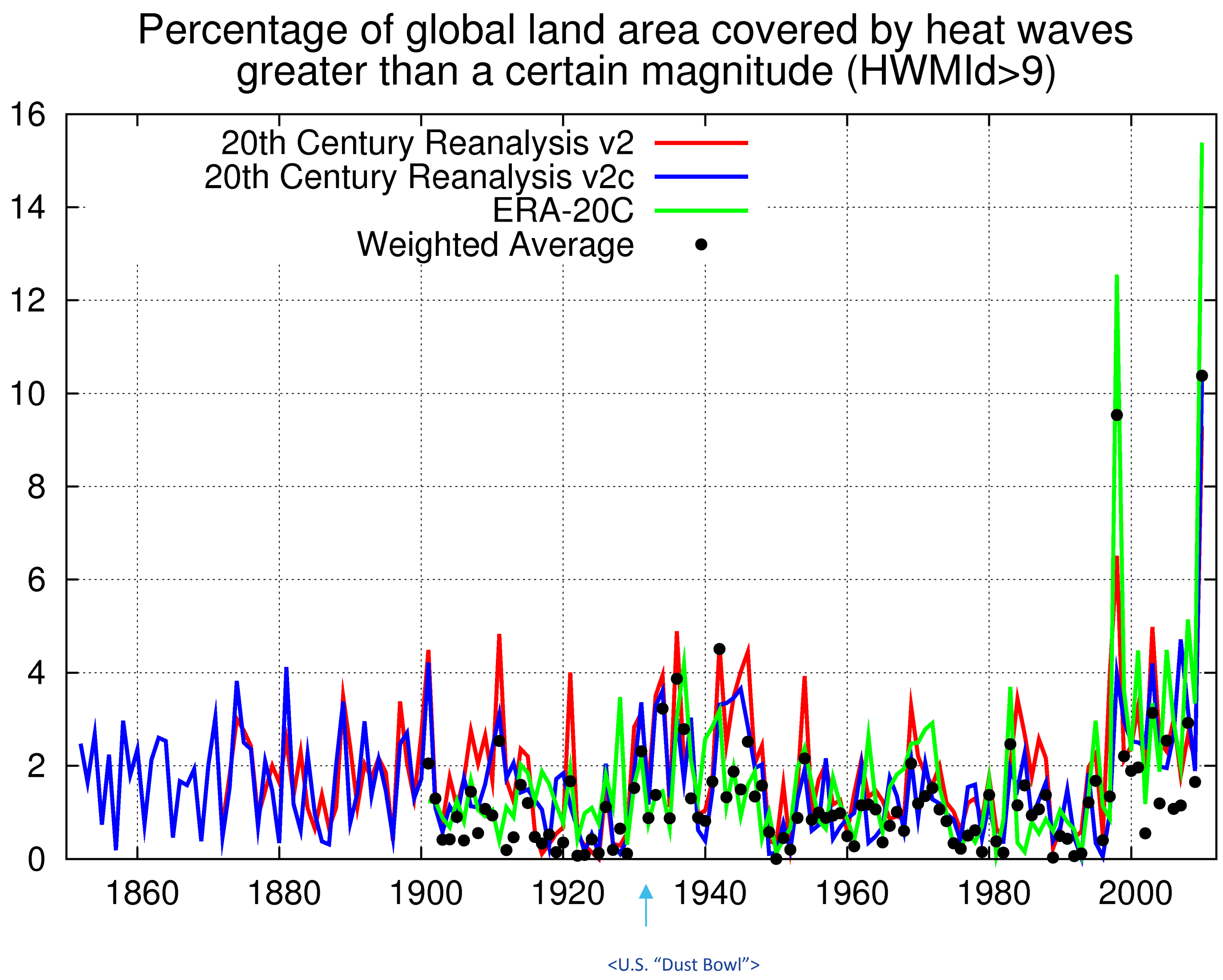
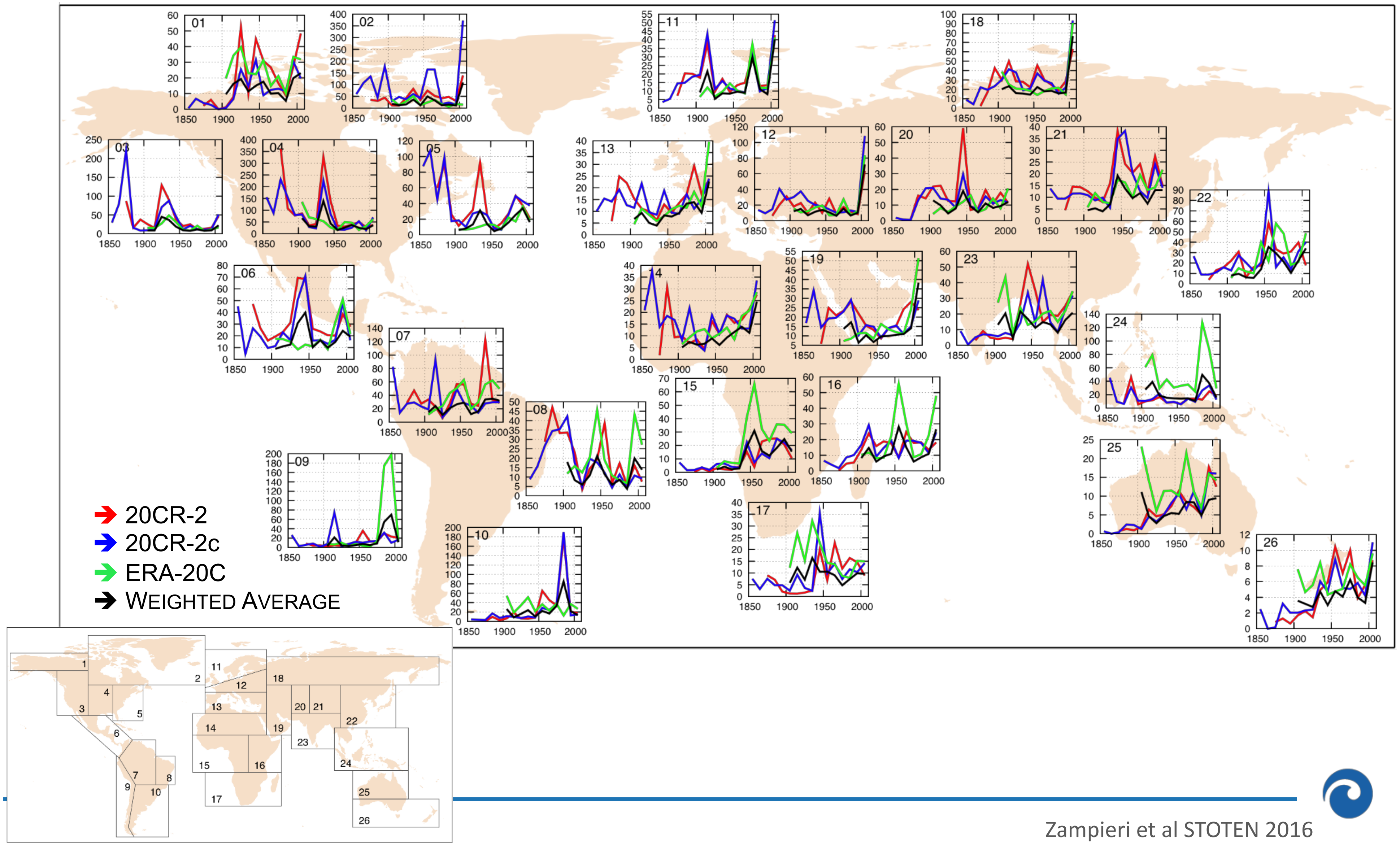

Percentage of global land area covered by heat waves
greater than a certain magnitude (HWMId>9)
20th Century Reanalysis v2
20th Century Reanalysis v2c
ERA-20C
Weighted Average
16
14
12
10
8
6
4
2
0
1860
1880
1900
1920
1940
1960
1980
2000
<U.S. "Dust Bowl">

Decadal maximum Heat Wave Magnitude Index over IPCC-SREX regions since 1850s



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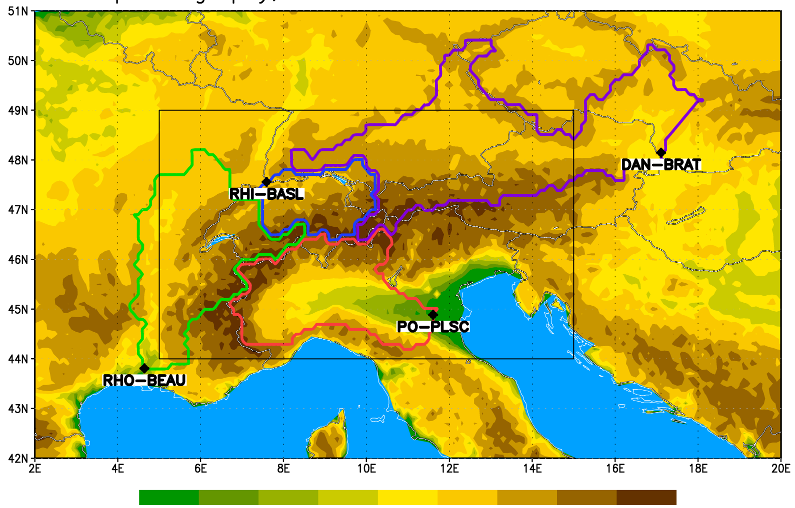
Trend Towards Earlier River Discharge Peaks

Alps orography, river basins and station distribution

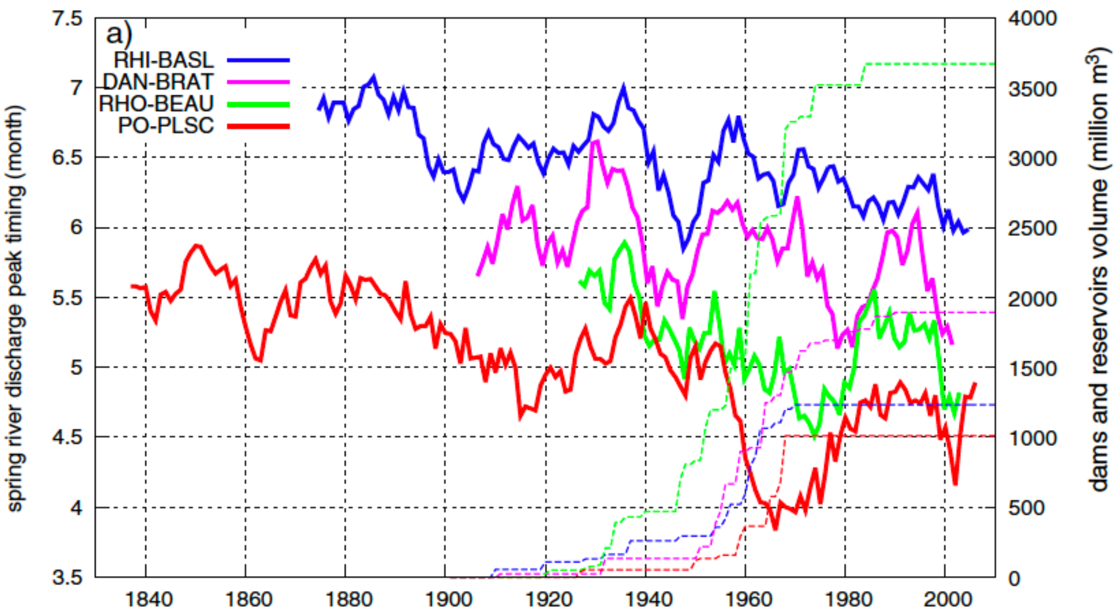


Global Runoff Data Center
(GRDC, http://www.bafg.de) and from local regional authorities.

HISTALP (1801– 2003)
CRU TS 3.10.01 (1901–2009)
Re–analysis 20C-2c (1871-2010)

- Limited effect of snow-melting
- Limited effect of dams
- **Shift towards earlier (winter) precipitation and larger liquid ratio**
- The 20 Century Reanalysis (20C-2) is capturing this trend

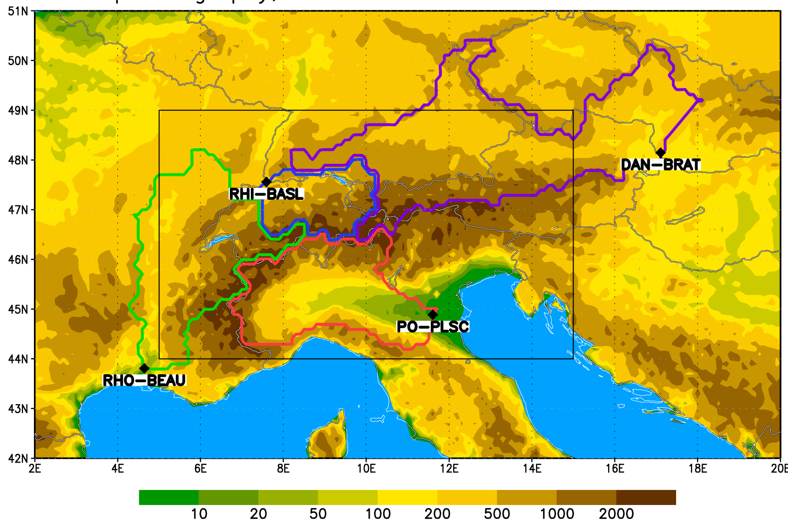
SPRING RIVER DISCHARGE TIMING



Zampieri et al STOTEN 2015

HWMId and Summer River Discharge over the Alps

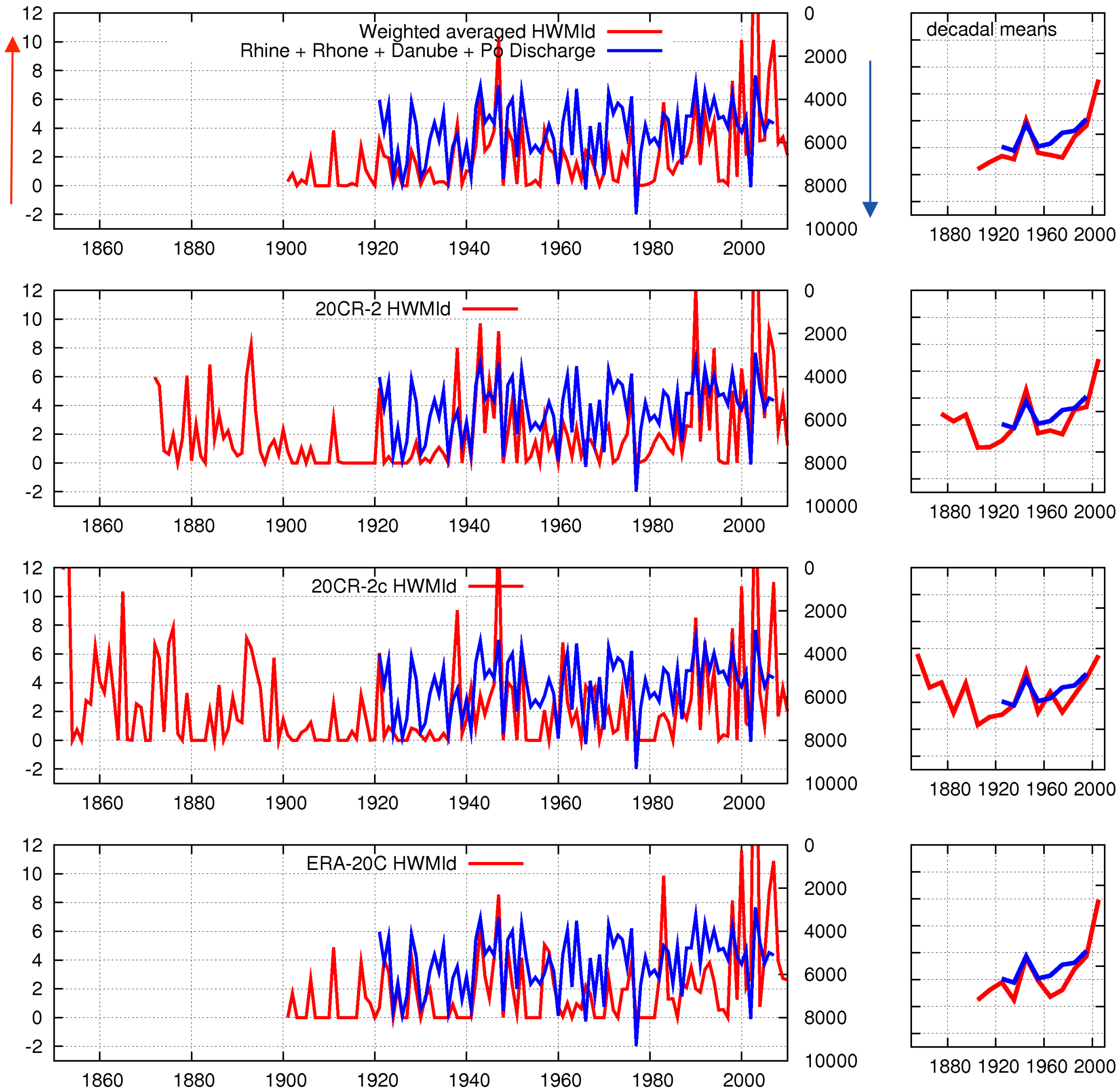
Alps orography, river basins and station distribution



Linear correlation between HWMI and river discharge over the Alps

Period	Weighted mean	20CR-2	20CR-2c	ERA-20C
1921–1960	−0.72	−0.62	−0.56	−0.64
1921–2007	−0.48	−0.54	−0.46	−0.39

HWMId over Alps and River Discharge in August (m^3/s)



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- In the Euro-Mediterranean region, a stretching (increase of **99p-90p**) of the right tail of the precipitation distribution is found in the RCP8.5 scenario simulations (2061-2100) compared to the historical period (1966:2005). This is evident also over regions showing a decrease in the averaged precipitation.

- We have provided a characterization in space and time (new metrics) of extreme precipitation events in the Euro-Mediterranean region based on E-OBS data and state-of-the-art climate models (MedCORDEX).

- There is a large spread in model performance in reproducing the statistics of extreme precipitation events in different regions.

- Models appear to perform better in regions where a large contribution to precipitation extremes comes from large scale precipitation.

- We found a consistent earlier spring discharge of more than two weeks per century in the basins located north of the Alps (Rhine and Danube), and more than three weeks per century in the basins located to the south (Rhone and Po).

- Heat wave occurrence and magnitude (HWMId) is significantly correlated to negative anomalies of river discharge originated over the Alps.

Thank you!

- Cavicchia L., E. Scoccimarro, S. Gualdi and co-authors**, 2018:** Mediterranean extreme precipitation: a multi-model assessment. **Clim. Dyn**., DOI 10.1007/s00382-016-3245-x.
- Scoccimarro E., S. Gualdi, A. Bellucci, M. Zampieri, A. Navarra, **2016**: Heavy precipitation events over the Euro-Mediterranean region in a warmer climate. **Regional Env. Change**, doi:10.1007/s10113-014-0712-y.
- Zampieri M., S. Russo, S. di Sabatino, M. Michetti, E. Scoccimarro and S. Gualdi, **2016**: Global assessment of heat wave magnitudes from 1901 to 2010 and implications for the river discharge of the Alps. **Sci Total Environ**., 571, 1330–1339.
- Zampieri, M., E. Scoccimarro, S. Gualdi and A. Navarra, **2015**: Observed shift towards earlier spring discharge in the main Alpine rivers. **Sci Total Environ**, 503, 222-232.