Impacts of climate change on extreme river flows: is bias correction advisable for analysis?

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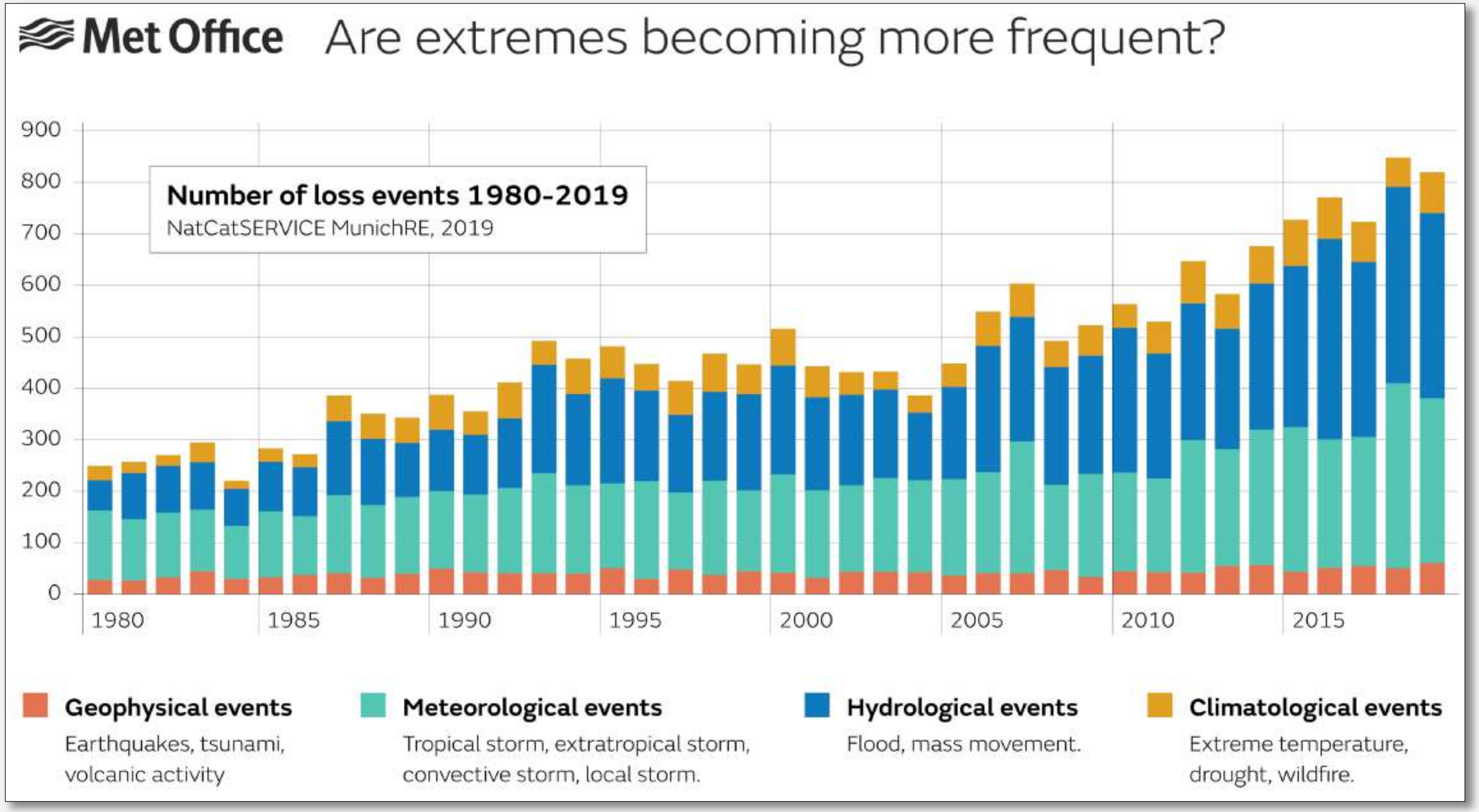
Outline

1. Why is important to simulate hydroclimate extreme events and how can I calculate them
2. Climate change impacts on drought hazards over Europe
3. Climate change impacts on flood hazards over Italy

In recent decades, extreme events have affected millions of people, with staggering costs in human suffering and economic losses.



Source: Munich RE

IDENTIFYING FUTURE DISASTER RISK BECOMES ESSENTIAL FOR DEVELOPING ADAPTATION MEASURES TO PROTECT POPULATIONS AND VITAL ACTIVITIES IN OUR COMMUNITIES.

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News & Views | Published: 13 March 2023

Hydroclimatology

Floods and droughts are intensifying globally

Melissa M. Rohde

Nature Water **1**, 226–227 (2023) | Cite this article

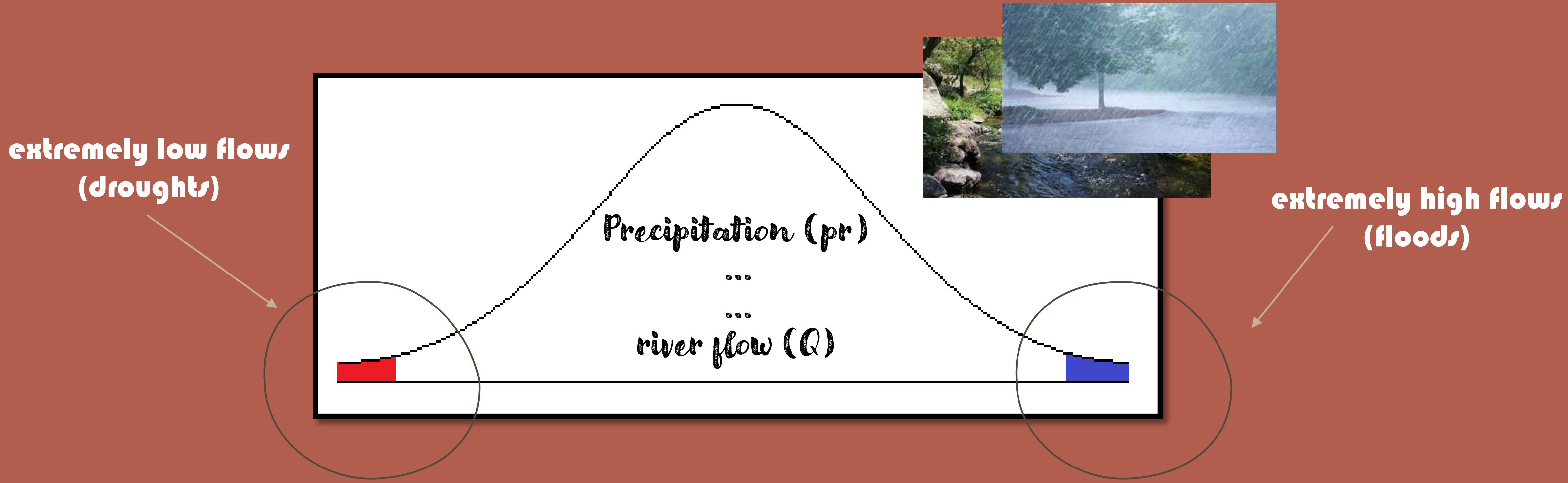
1094 Accesses | **22** Citations | **2370** Altmetric | Metrics

Satellite data show hydroclimatic extreme events are increasing in frequency, duration, and extent under warming conditions.

STRONG CORRELATION BETWEEN THE GLOBAL MEAN TEMPERATURE AND THE TOTAL INTENSITY OF EXTREME EVENTS

Extreme value theory

✓ Extreme value theory (EVT, Coles, 2001) identifies **extreme events**, characterized by either **very small** or **very large** values.



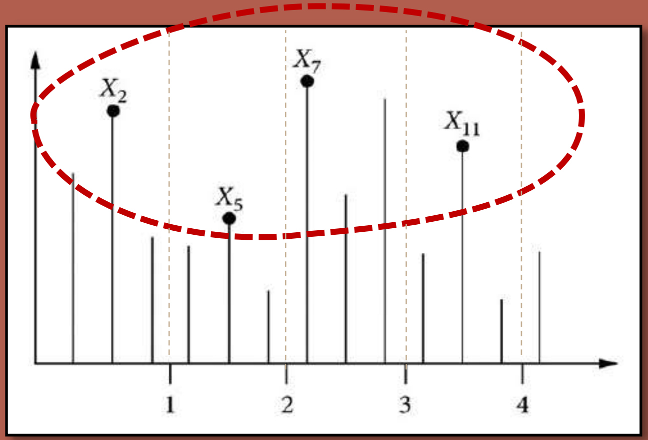
Extreme value theory

✓ The traditional method in the EVT is the **block maxima** (BM).

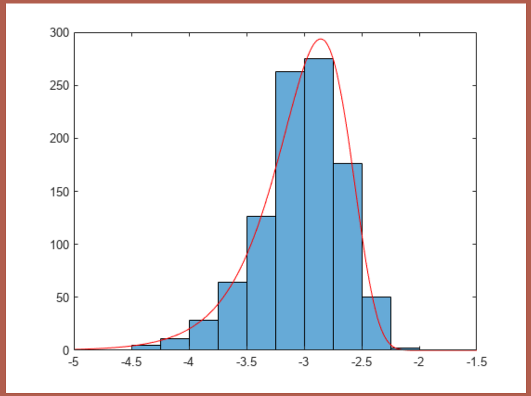
EASY TO APPLY

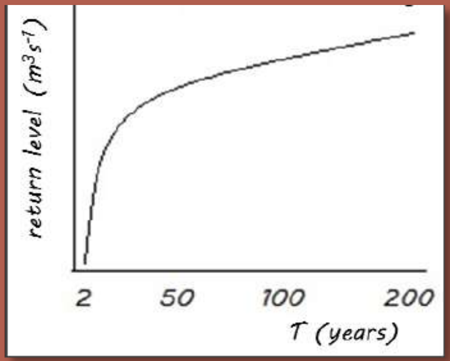
ENSURES THE INDEPENDENCE OF THE EVENTS: NO OVERLAPPING IN THE BLOCKS

BLOCKS OF EQUAL SIZE



Statistical model: fitting to a probability distribution





Estimation of parameter

Outline

~~Why is important to simulate hydroclimate extreme events and how can I calculate them?~~

2 Climate change impacts on drought hazards over Europe

3 Climate change impacts on flood hazards over Italy

Impacts of climate change on European minimum flows under global warming of 1.5, 2, and 3 °C

EGU General Assembly

Show affiliations

García-Valdecasas Ojeda, Matilde ; Di Sante, Fabio ; Coppola, Erika

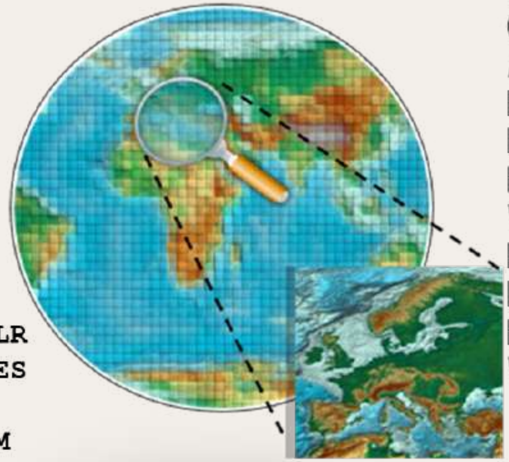
Drought is a recurring hazard in Europe, affecting various sectors and causing a wide range of socioeconomic and environmental consequences. Global warming is very likely to significantly alter the water cycle across Europe, with serious implications for terrestrial hydrology. As a result, hydrological droughts are expected to become more frequent and severe in this region. In this framework, this preliminary study assesses the impact of climate change on extreme river droughts for the entire European region using a large ensemble based on 44 EURO-CORDEX simulations under the business-as-usual emision scenario (RCP8.5). For

The main aims was:

- ✓ To select "the best distribution" to fit low river flows in Europe as a proxy of hydrological droughts.
- ✓ To analyze future drought hazards in Europe.

Annual minimum 7-day streamflow was analyzed using the following scheme:

CNRM-CM5
CanESM2
CM5A
EC-EARTH
MPI-ESM-LR
HadGEM2-ES
MIROC5
NorESM1-M



CCLM4-8-17
COSMO
ALADIN63
HIRHAM5
REMO2015
RegCM4.6
WRF381P
RACMO22E
REMO2009
RCA4
WRF361H

EURO-CORDEX (Jacob et el., 2014)

45 GCM-RCM COBINATIONS

HISTORICAL RCP 8.5

Daily total runoff

CHYM-ROFF
Routing with scheme derived from CHyM

RIVER FLOW FROM STATIONS

RIVER FLOW SIMULATED

7-day minimum flow

ANNUAL MINIMUM VALUES IN THE NON-FROST SEASON

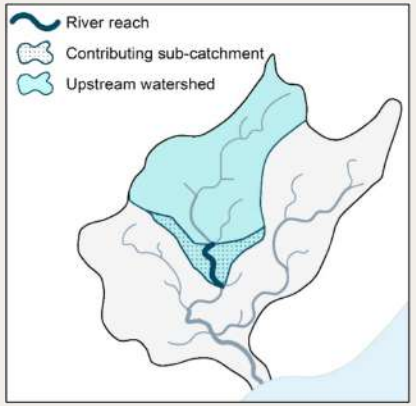
REFERENCE PERIOD
1995-2014

1.5 °C warming level

2 °C warming level

3 °C warming level

Relative to the preindustrial period (1861-1900)



Forzieri et al. (2014): Period of the year in which the **monthly average temperature** in **the upstream area drops below zero** in at least 23 out of 30 years (reference length)

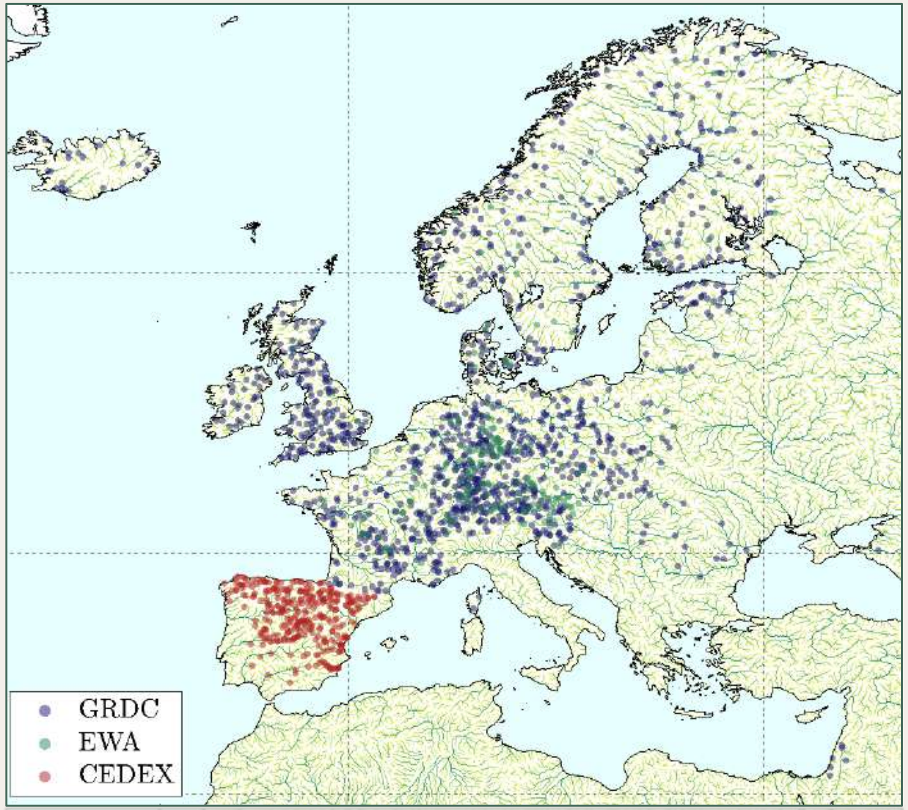
WHAT IS THE BEST DISTRIBUTION TO ADJUST THE MINIMUM FLOW IN EUROPE?

Selection of river station

- Daily discharge from three sources:
  - ✓ **GLOBAL:** Global Runoff Data Center (GRDC) archive
  - ✓ **EUROPE:** European Water Archive (EWA)
  - ✓ **SPAIN:** Anuario de aforos digital (CEDEX)
- Selection of river stations with **30 years** of data from 1961-2019 **and less than 20% of missing values**.
- **Quality control** and deduplication (Gudmundsson et al., 2018; Gudmundsson and Seneviratne, 2016)

1561 river stations

- Distinction of **nonfrost seasons** to ensure that the low flow is due to lack of precipitation and not because the water is in form of snow.
- Computation of the annual **7-day minimum flow**.



WHAT IS THE BEST DISTRIBUTION TO ADJUST THE MINIMUM FLOW IN EUROPE?

Distribution fitting

Six 3-parameter probability **distributions**

- ✓ Generalized Extreme Values (GEV)
- ✓ Generalized Logistic (GLO)
- ✓ Generalized Pareto (GPA)
- ✓ 3-parameter lognormal (LN3)
- ✓ Pearson Type III (PE3)
- ✓ 3-parameter Weibull (WEI)

→

Three Goodness-of-fit **(GOF) tests**

- ✓ Kolmogorov–Smirnov (KS)
- ✓ Anderson-Darling (AD)
- ✓ Cramér-Von Mises (CVM)

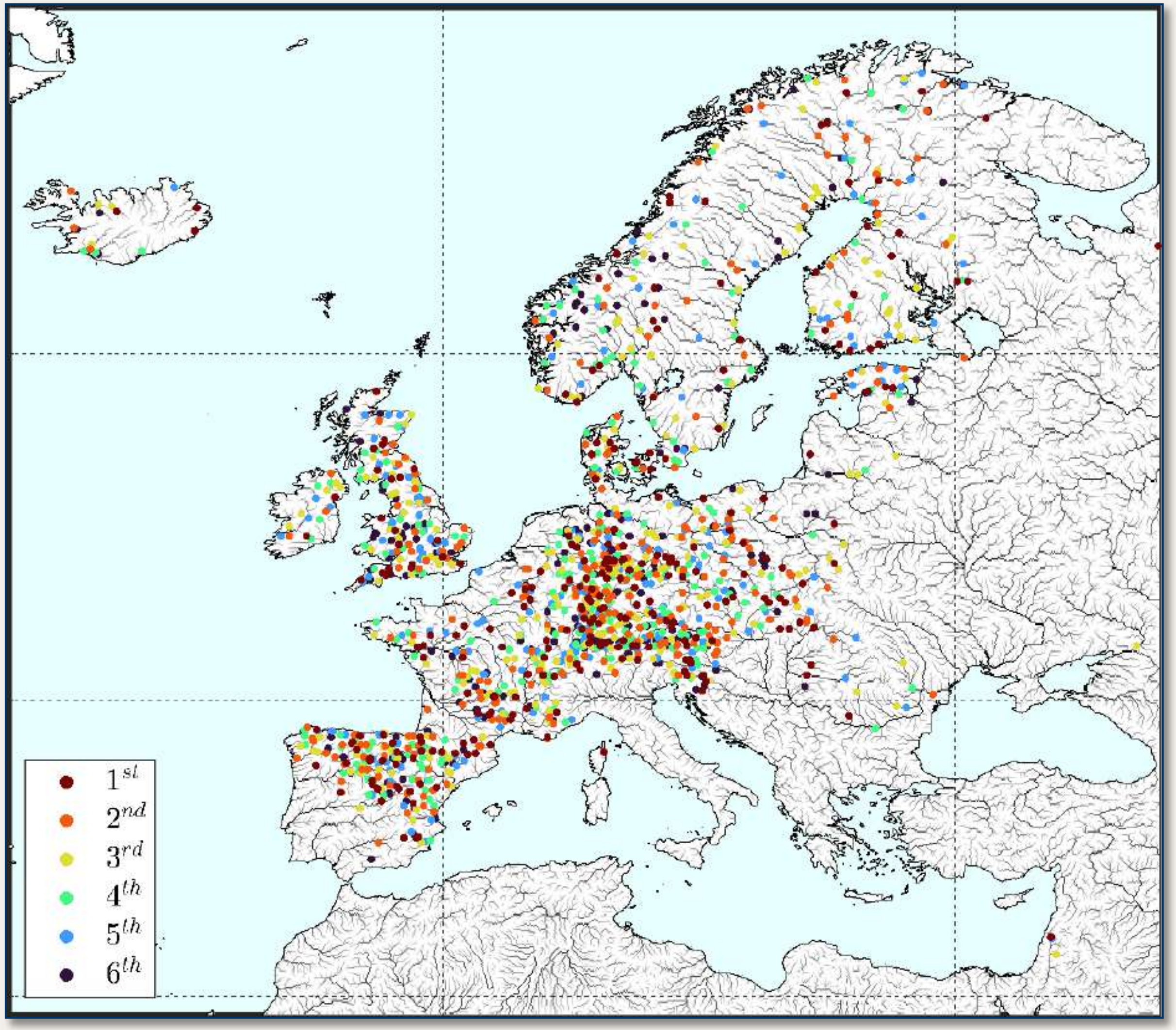
BY USING THE P-VALUES OF THE GOF TESTS WE CAN ESTABLISH A RANK OF DISTRIBUTIONS FOR EACH STATION

HIGHER P-VALUES INDICATE HIGHER PROBABILITY THAT THE DATA COMES FROM A GIVEN DISTRIBUTION

Selection of the extreme distribution

Rank sum of the six probability distributions (GEV, GLO, LN3, PAR, PE3, and WEI) according to the three Goodness-of-Fit tests (KS, AD, and CVM).

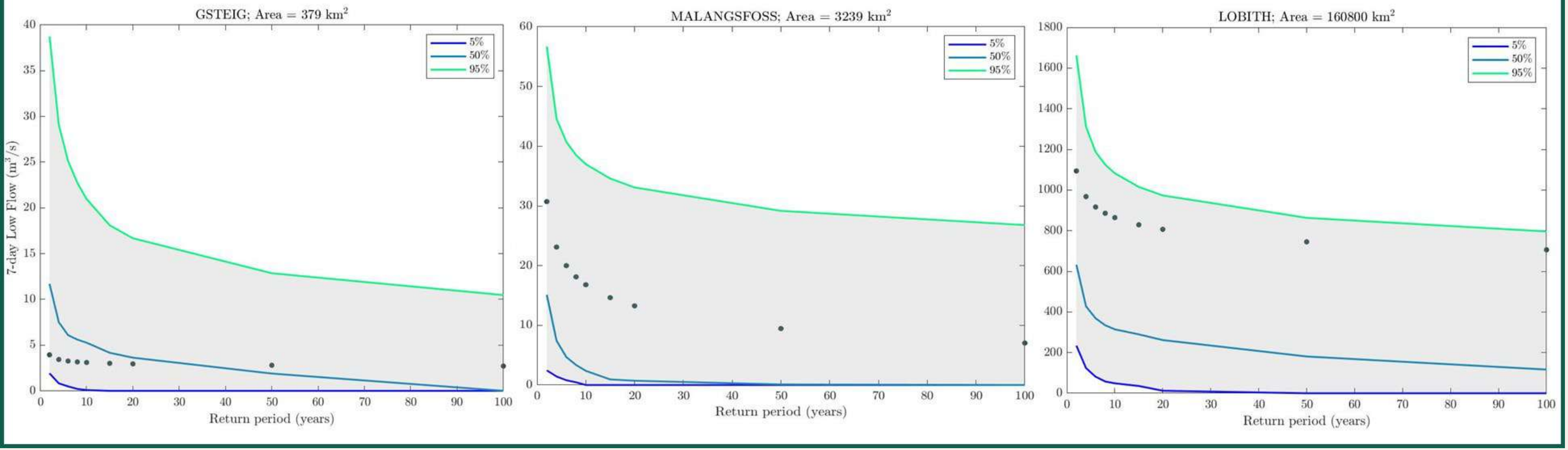
	GEV	GLO	LN3	PAR	PE3	WEI
KS	**5418**	5194	4859	4954	5251	5084
AD	**5424**	5126	4916	4864	5274	5168
CVM	**5390**	5199	4899	4873	5294	5123



Rank sum order for GEV according to AD

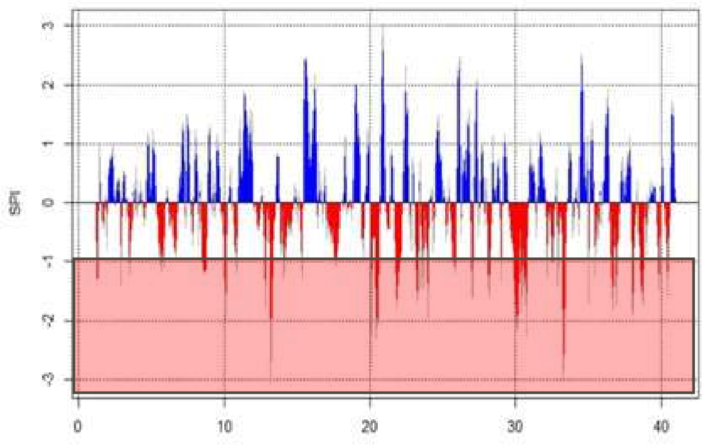
EVALUATION OF THE MULTI-MODEL PERFORMANCE

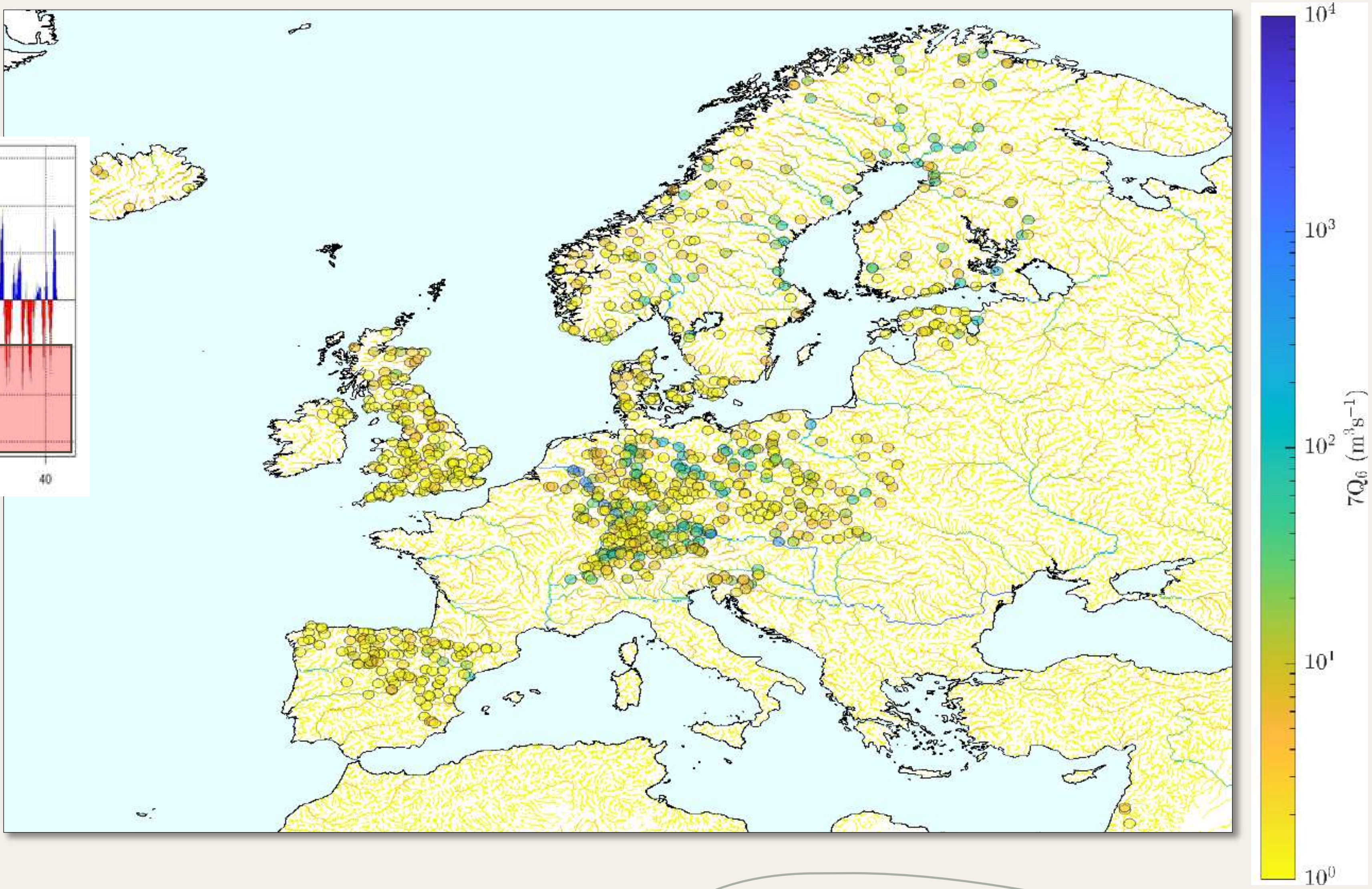
Low-flow versus return period curves for multi-model ensemble members percentiles (5, 50, and 95%) and observations at **small** (drainage area < 1.000 km^2) (Gsteig, Lutschine river, CH), **medium** (1.000 km^2 < drainage area < 10.000 km^2)(Malangsfoss, Malselva, NO), and **large** (drainage area > 10.000 km^2) (Lobith, Rhine River, LN) river stations.



EVALUATION OF THE MULTI-MODEL PERFORMANCE

P(occurrence) = 0.16



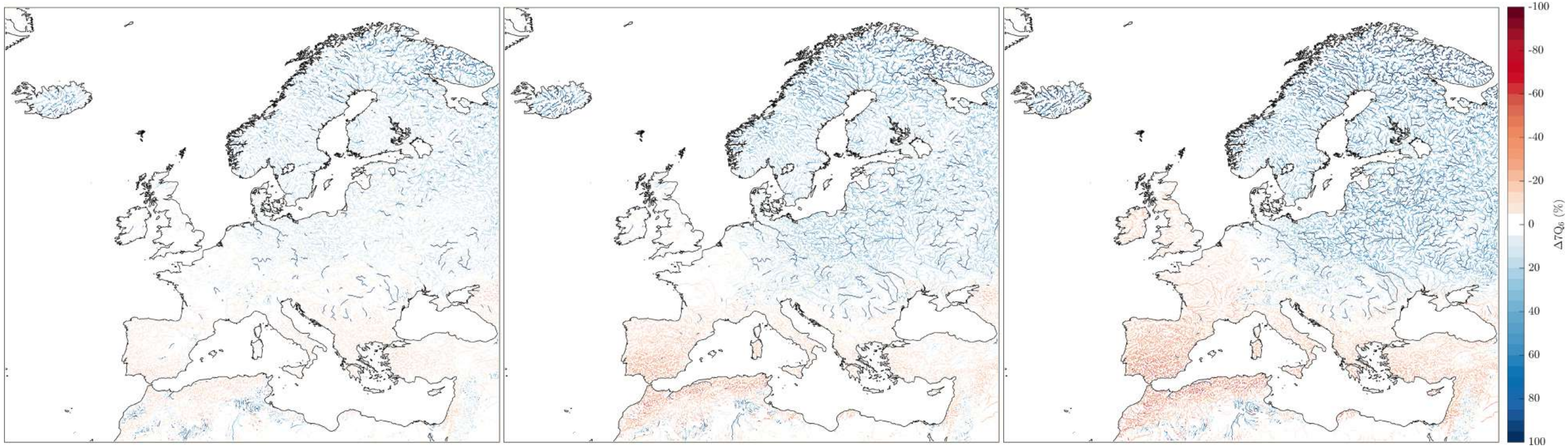


7Q6 from the multi-model ensemble for the nonfrost season. Dots show the corresponding 7Q6 values for the river stations analyzed.

Changes in the 7Q6

For 1.5º, 2º and 3ºC of warming level related to preindustrial levels

1.5 ºC WARMING LEVEL	2 ºC WARMING LEVEL	3 ºC WARMING LEVEL



1. GEV SEEMS TO BE A DISTRIBUTION APPROPRIATE TO APPROXIMATE THE LOW FLOW FOR THE NON-FROST SEASON IN EUROPE.

2. CHYM-ROFF PERFORMS REASONABLY WELL THE MINIMUM FLOW IN EUROPE WHEN IT IS COMPARED TO OBSERVATIONAL VALUES.

3. FOR GLOBAL WARMINGS OF **1.5°**, **2°** AND **3°**C ABOVE PRE-INDUSTRIAL LEVELS, A DECREASE IN LOW FLOW IS EXPECTED IN THE MEDITERRANEAN, EXTENDING TO OTHER REGIONS FOR THE HIGHEST LEVELS OF WARMING.

Outline

~~Why is important to simulate hydroclimate extreme events and how can I calculate them?~~

~~Climate change impacts on drought hazards over Europe~~

3 Climate change impacts on flood hazards over Italy

Journal of Hydrology
Volume 615, Part A, December 2022, 128628

Research papers

Climate change impact on flood hazard over Italy

Matilde García-Valdecasas Ojeda [a b c], Fabio Di Sante [a b], Erika Coppola [a], Adriano Fantini [a], Rita Nogherotto [a b], Francesca Raffaele [a], Filippo Giorgi [a]

- ✓ This study aimed to assess **future flood hazards** in Italy using a **model chain approach** based on **climate and hydrological modeling** at **high spatiotemporal resolution.**
- ✓ The study also evaluated **the effect of using bias-corrected outputs** to simulate **river flow**.

CLIMATE SYSTEM

CLIMATE FORCINGS

Dynamical downscaling

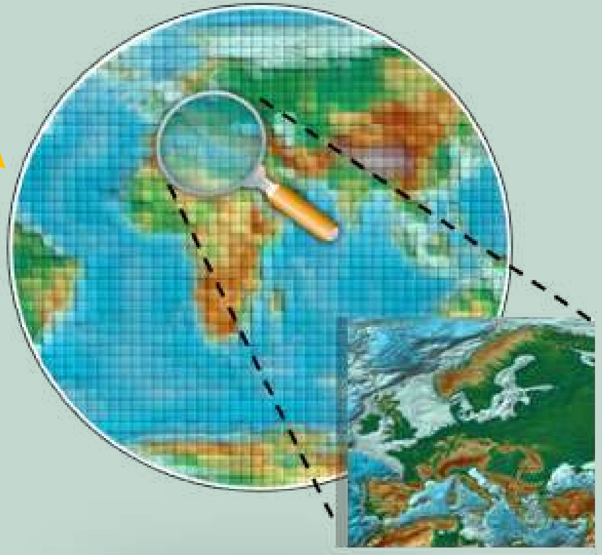
INCREASING THE SPATIOTEMPORAL RESOLUTION

Reanalysis:
ERA-Interim (Dee et al., 2011)

Historical GCM:
MOHC-HadGEM2-ES (Collins et al., 2011)

Projected GCM: MOHC-HadGEM2-ES
- 2020-2049
- 2070-2099

RCP8.5



Reanalysis regionalized:
RegCM-ERA

Historical GCM Regionalized:
RegCM-HAD

Projected GCM Regionalized:
- RegCM-HAD 2020-2049
- RegCM-HAD 2020-2049

RCP8.5

ICTP REGIONAL CLIMATE MODEL (REGCM, GIORGI ET AL., 2012)

Source image : own elaboration using the DEM provided by Kevin M. Gill (https://www.flickr.com/photos/53460575@N03/5853039006/)

CLIMATE SYSTEM

CLIMATE FORCINGS

Bias correction of precipitation and temperature

IMPROVING THE QUALITY OF THE OUTPUTS?

MULTIVARIATE BIAS CORRECTION (MBCn) (Cannon, 2018)

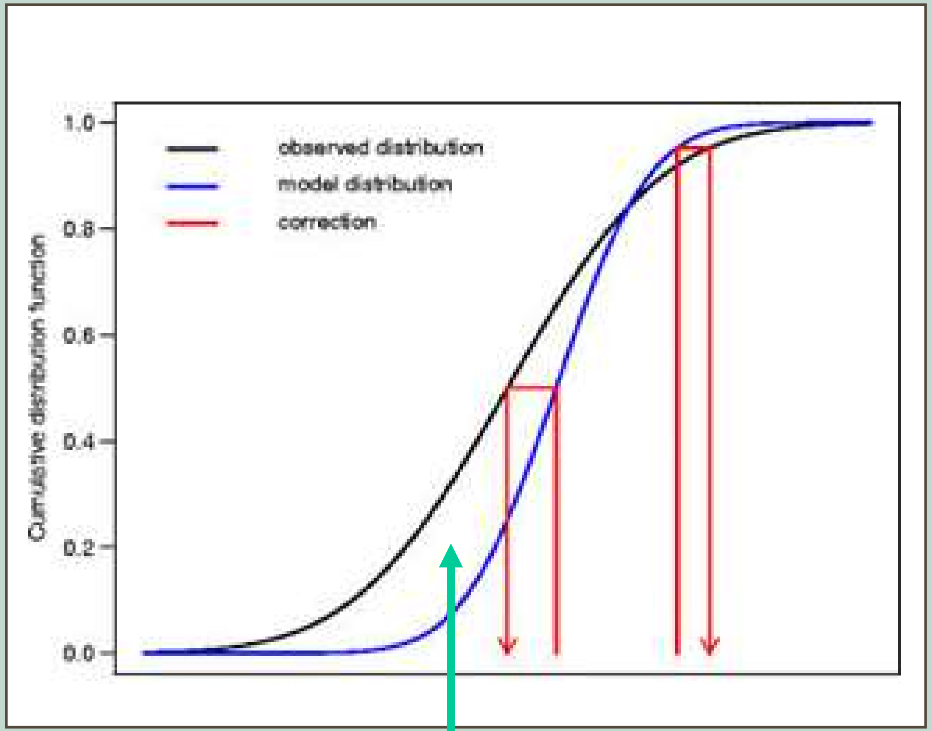
3-hr 12-km climate forcings

Reanalysis regionalized:
RegCM-ERA

Historical GCM Regionalized:
RegCM-HAD

Projected GCM Regionalized:
- RegCM-HAD 2020-2049
- RegCM-HAD 2020-2049

RCP8.5



3-hr 12-km bias-corrected climate forcings

Reanalysis regionalized and bias corrected:
RegCM-ERA-BC

Historical GCM Regionalized and bias corrected:
RegCM-HAD-BC

Projected GCM Regionalized and bias corrected:
- RegCM-HAD-BC 2020-2049
- RegCM-HAD-BC 2020-2049

RCP8.5

REFERENCE DATASETS: ERA5 for temperature and **GRIPHO** for precipitation

HYDROLOGICAL SYSTEM

HYDROLOGICAL MODELING

sub-daily climatological values

climate forcings

Precipitation and temperature

Observations:
- GRIPHO (Fantini et al., 2021)
- Italian thermometer network (CIMA, 2014)

Reanalysis regionalized: RegCM-ERA

Historical GCM regionalized: RegCM-HAD

Reanalysis regionalized and bias corrected: RegCM-ERA

Historical GCM regionalized and bias corrected: RegCM-HAD

Projected GCM regionalized:
RegCM-HadGEM
- 2020-2049
- 2070-2099

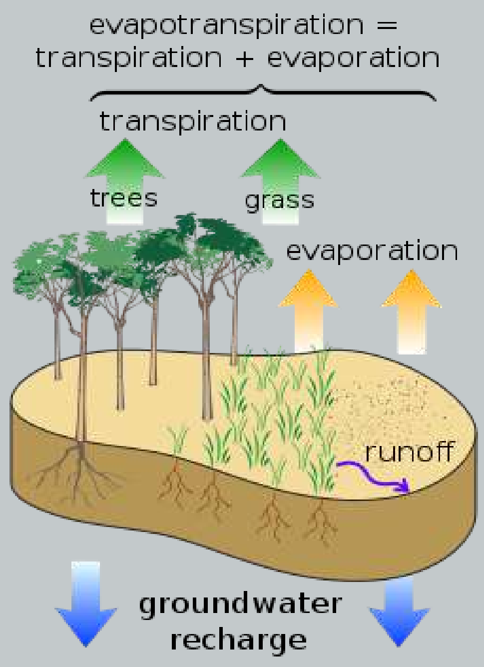
Projected GCM regionalized and bias corrected: RegCM-HadGEM-BC
- 2020-2049
- 2070-2099

RCP8.5

sub-daily hydrological values

Observations:
Italian River flow networks

CHyM (Coppola et al., 2007)



source image: M.W. Toews (https://commons.wikimedia.org)

river flow

CHyM evaluation

CHyM performance
Stations vs. CHyM-OBS
CHyM + RegCM performance
Stations vs. CHyM-ERA
CHyM-OBS vs. CHyM-ERA
CHyM + RegCM + HadGEM2 performance
CHyM-OBS vs. CHyM-HAD
CHyM + BC + RegCM + HadGEM2 performance
CHyM-OBS vs. CHyM-HAD-BC

CHyM projections

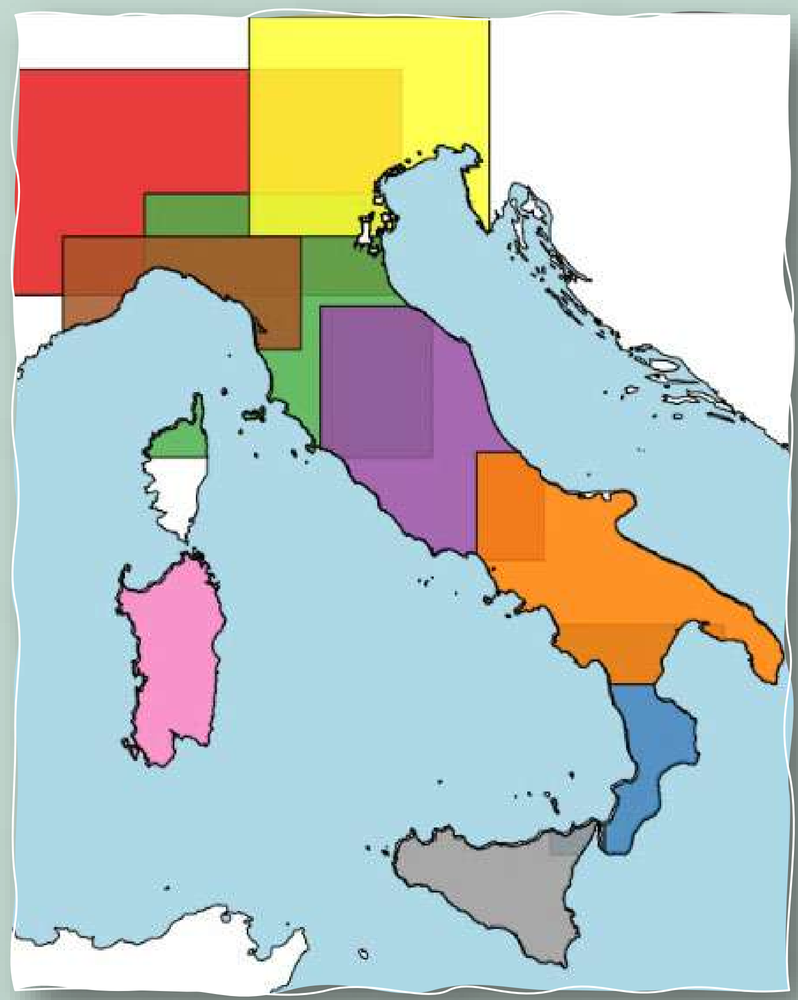
CHyM projections
Changes for the near future:
CHyM_2020-2049 vs. CHyM_1976-2005
Changes for the far future:
CHyM_2070-2099 vs. CHyM_1976-2005

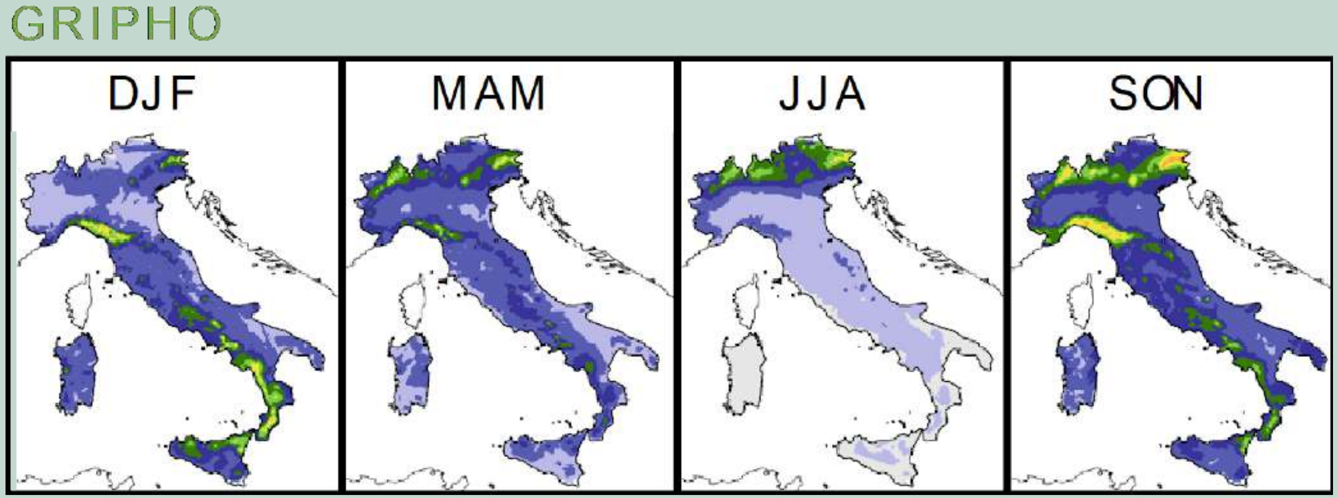
CHyM projections bias corrected
Changes for the near future:
CHyM_2020-2049 vs. CHyM_1976-2005
Changes for the far future:
CHyM_2070-2099 vs. CHyM_1976-2005

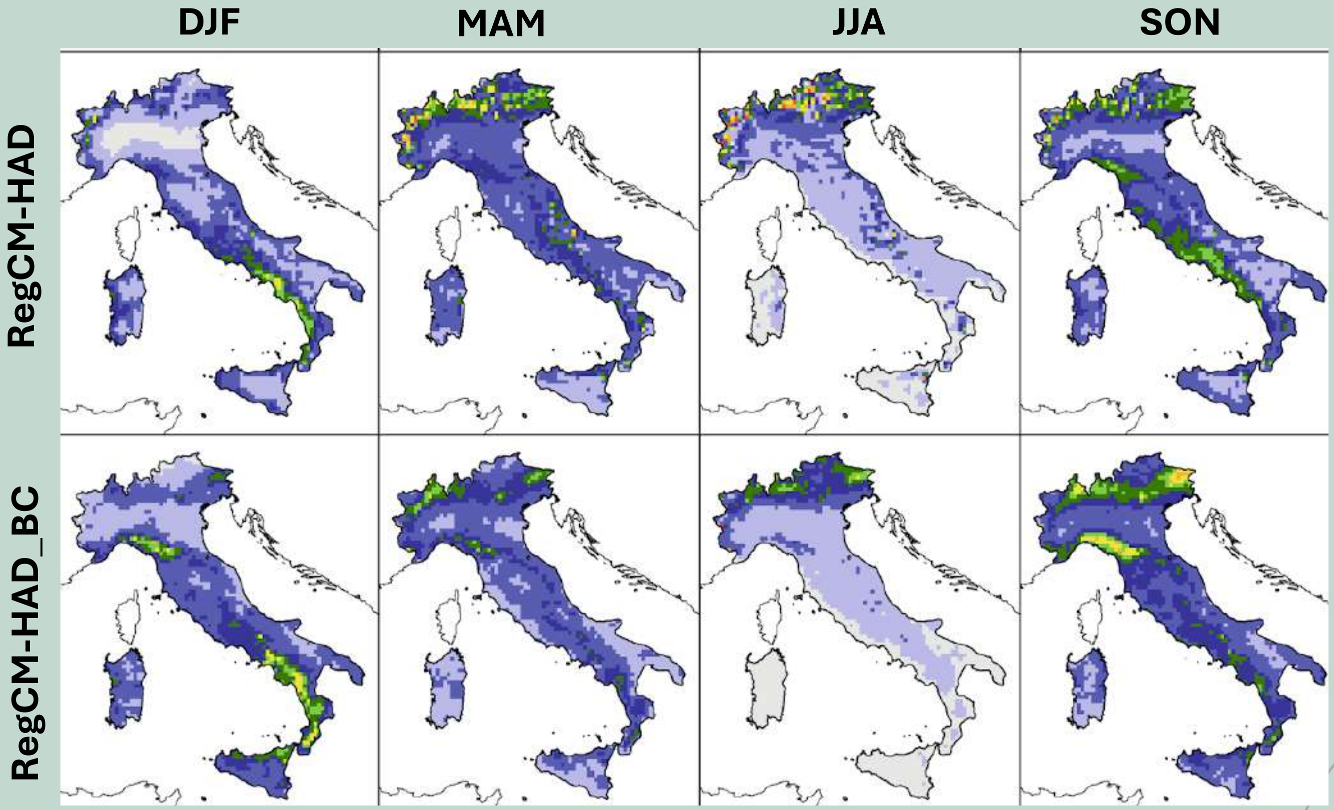
- **9 domains** covering the entire Italian territory:

  (1) Po basin
  (2) Liguria
  (3) North-Eastern Italy
  (4) Central-Northern Italy
  (5) Central Italy
  (6) Central-Southern Italy
  (7) Calabria
  (8) Sicily
  (9) Sardinia

- **HydroSHEDS Digital Elevation Model** (DEM) at 90 meters of spatial resolution.
- **Calibration parameters** according to Coppola et al. (2014).



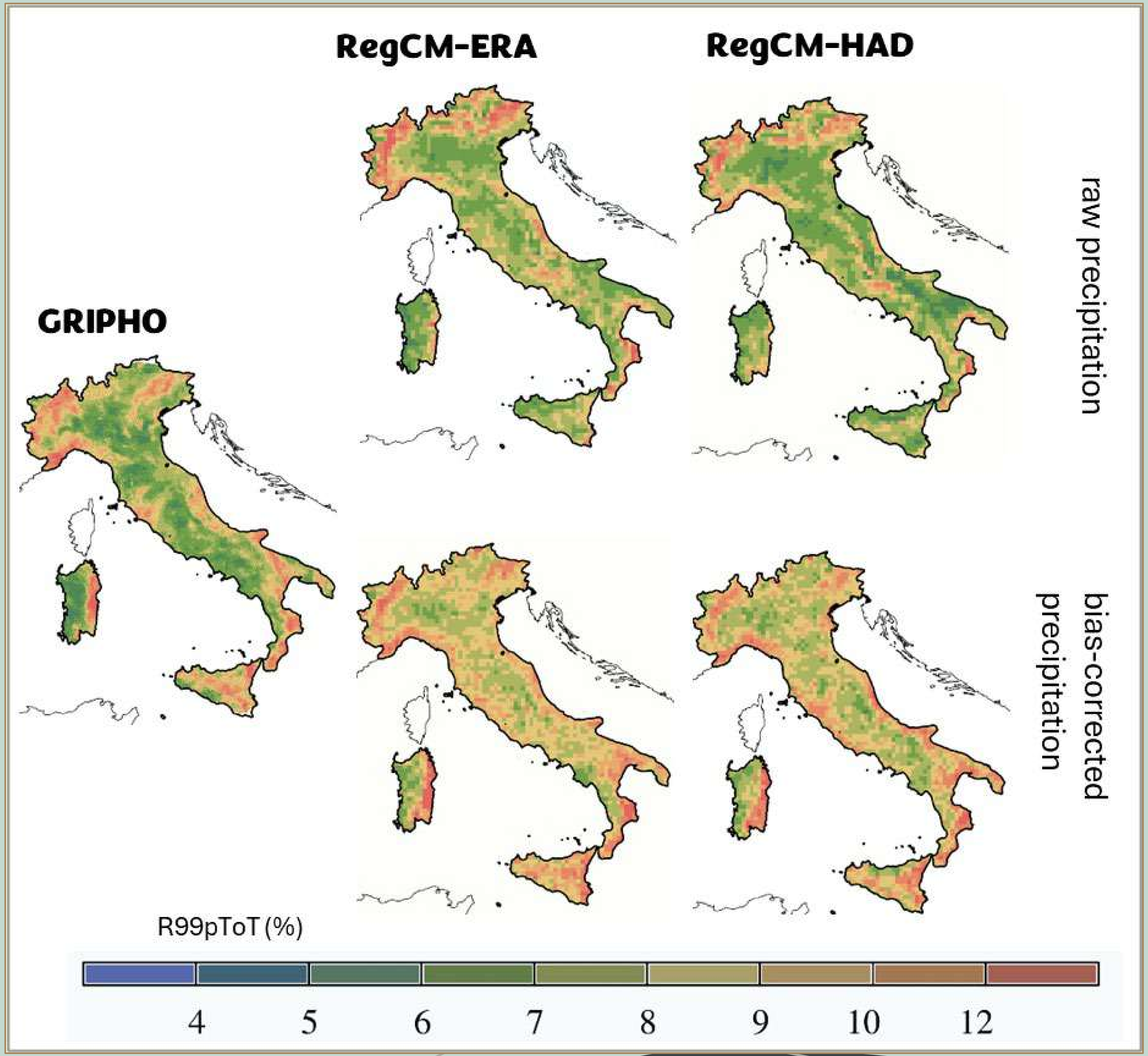




When we compare mean precipitation values from the reference datasets with those from **RegCM** we can see that it **is able to capture** the main **precipitation patterns**. However, the values are **better represented when** we used **bias correction**.

Evaluation of the model performance

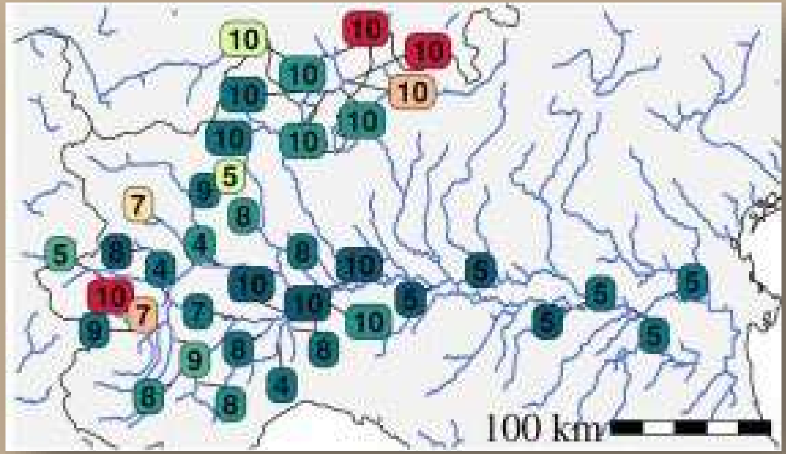
- **RegCM captures** the main patterns of **GRIPHO extreme precipitation**.
- Bias correction **is not able to correct** deficiencies in terms of extremes.



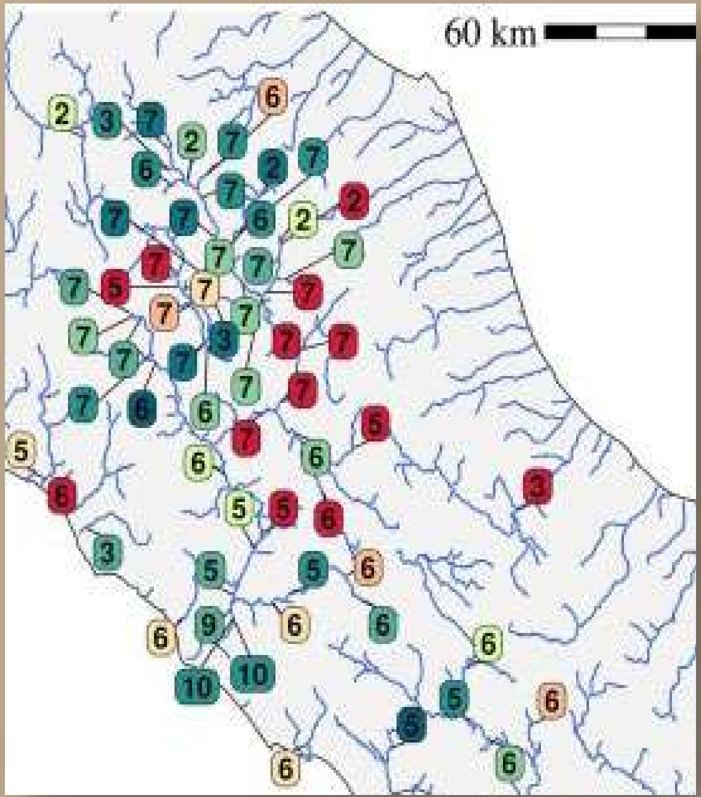
Extreme precipitation values (R99pToT, %) for observations (GRIPHO), raw, and bias-corrected RegCM precipitation outputs.

HYDROLOGICAL MODEL PERFORMANCE: CHyM-OBS

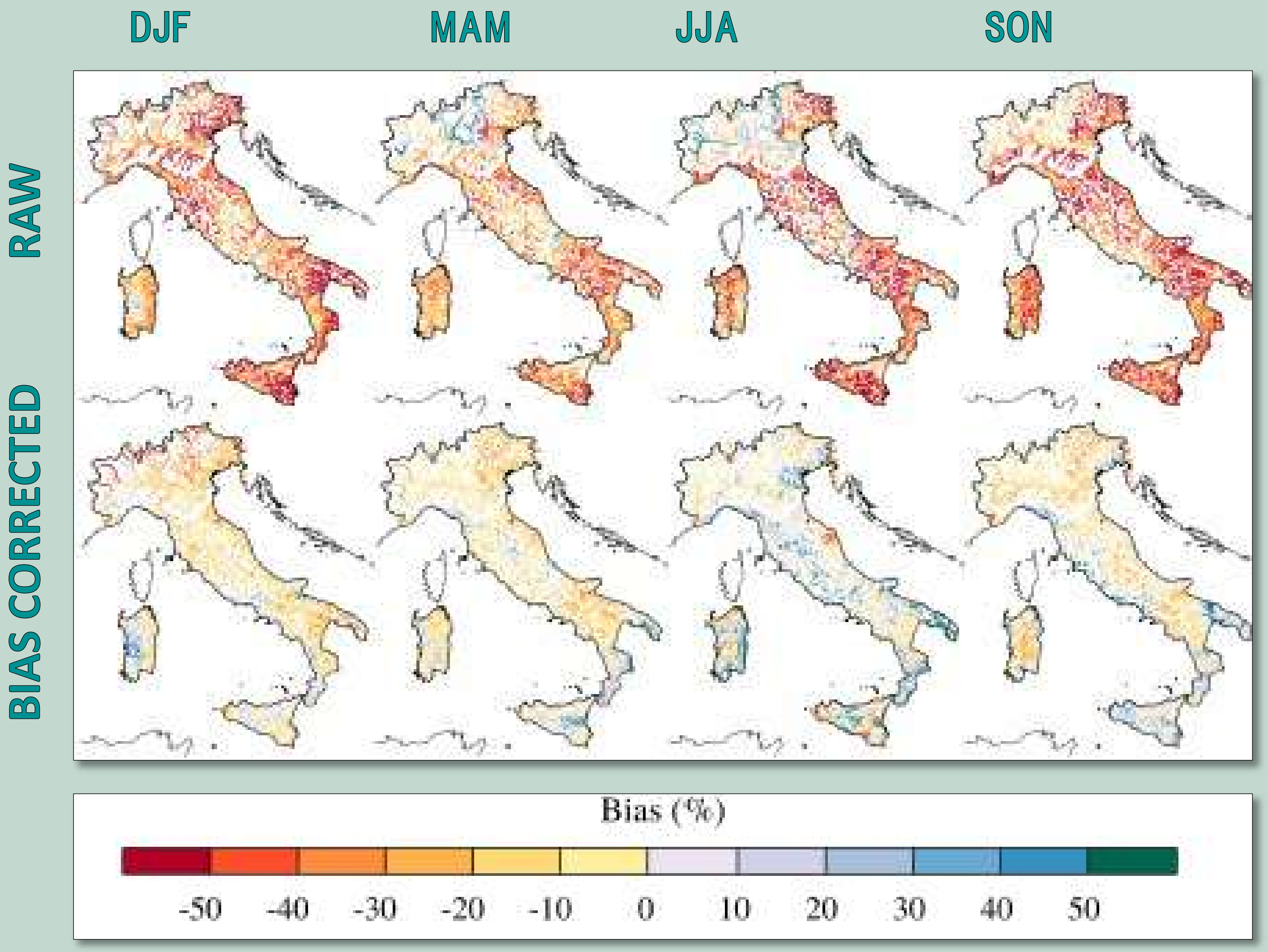
Po basin



Central Italy basin

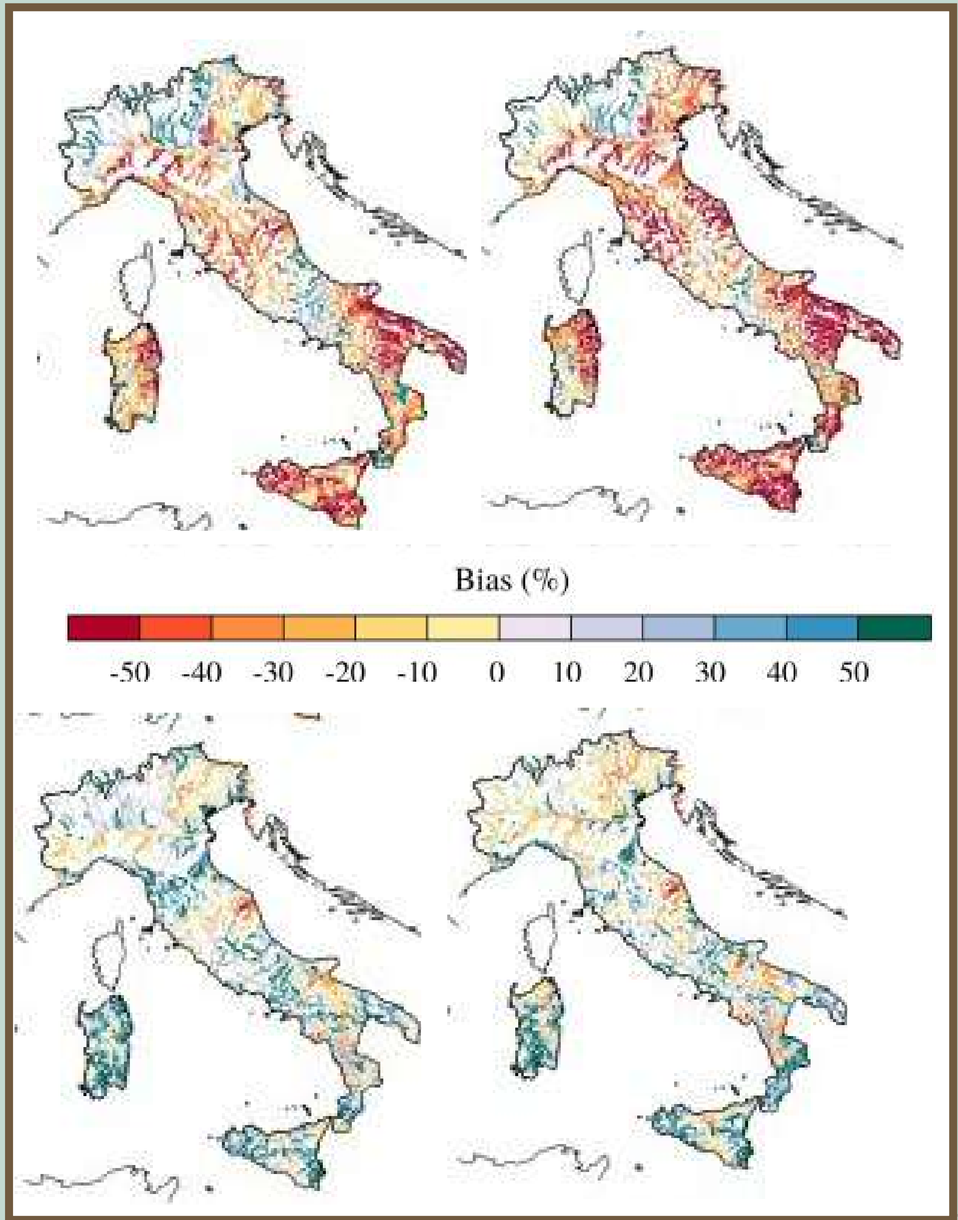


CHyM-HAD



Comparison of raw (climate forcings from RegCM-HAD) and bias corrected (climate forcings from RegCM-HAD_BC) mean flow expressed as differences in relation to CHyM-OBS (climate forcings from observations).

WITH RAW CLIMATE FORCINGS



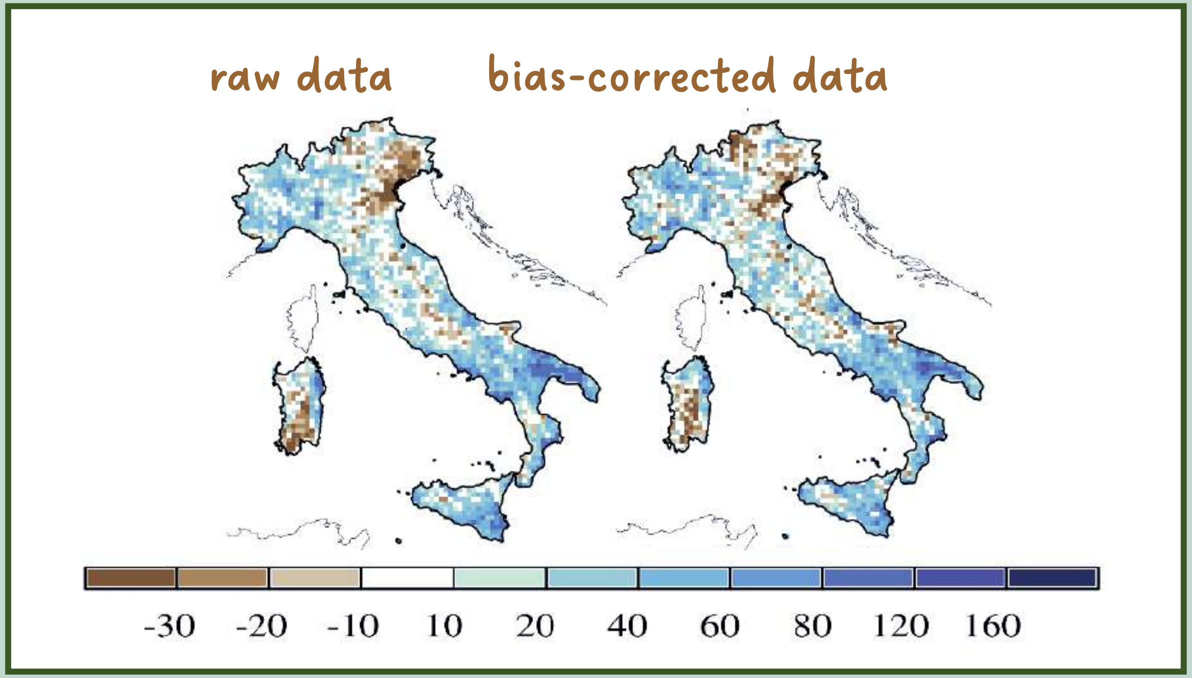
Differences in Q100 in relation to CHyM-OBS (climate forcing from observations)

WITH BIAS CORRECTED CLIMATE FORCINGS

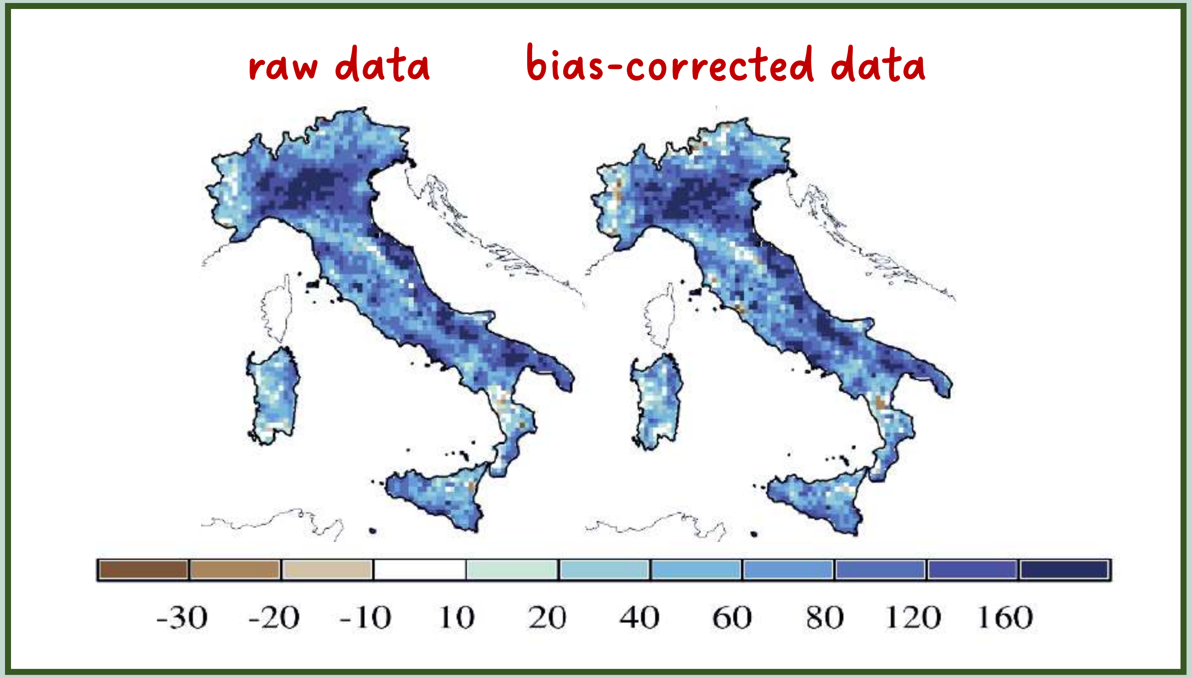
PROJECTED CHANGES IN PRECIPITATION

EXTREME PRECIPITATION R99ptot change (%)

2020-2049



2070-2099

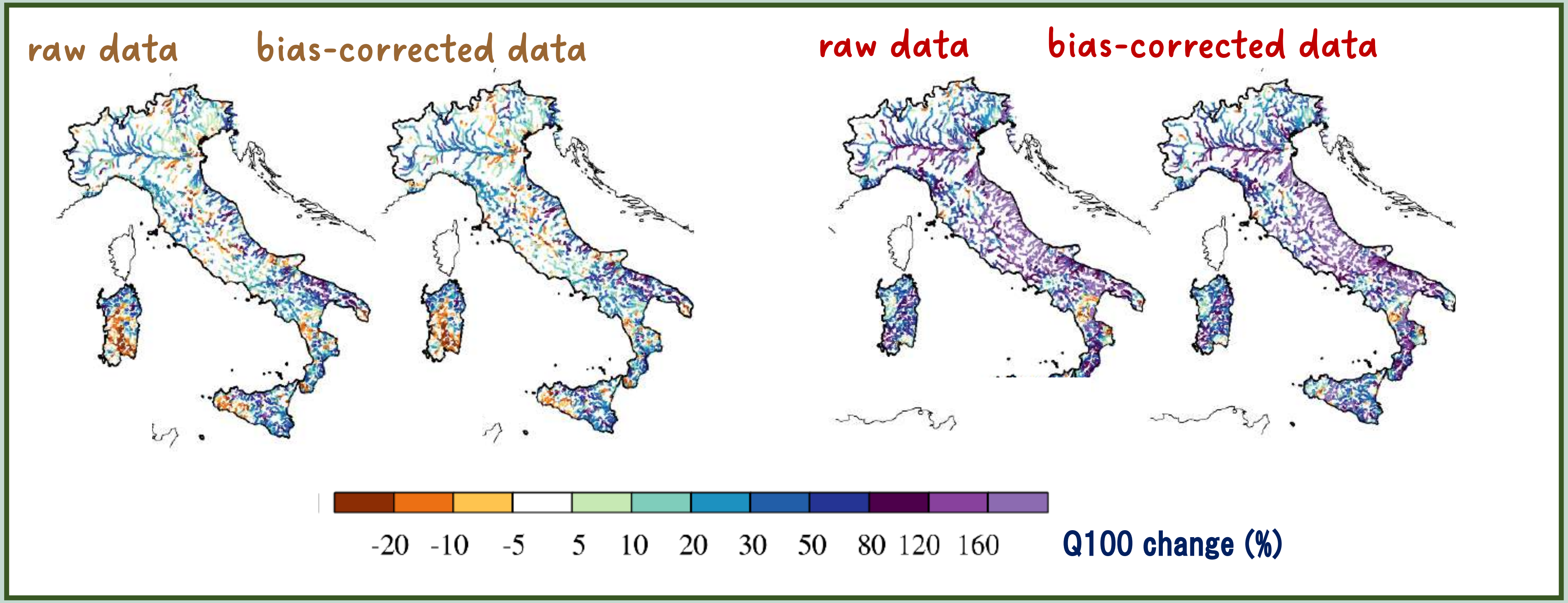


PROJECTED CHANGES IN RIVER FLOW

CHANGES IN HIGH FLOW

2020-2049

2070-2099



1. REGCM HAS A GOOD PERFORMANCE CAPTURING PRECIPITATION PATTERNS OVER ITALY.
2. CHYM REPRODUCES WELL THE RIVER FLOW OF THE ITALIAN BASINS.
3. ALTHOUGH BIAS CORRECTION BETTER CAPTURES MEAN PATTERS OF PRECIPITATION, IT HAS MORE PROBLEMS CORRECTING EXTREME VALUES.
4. FOR RIVER FLOW, BIAS CORRECTION SEEMS TO BETTER CORRECT THE EXTREME VALUES.
5. PROJECTIONS OF EXTREME PRECIPITATION AND RIVER DISCHARGE WITH AND WITHOUT BIAS CORRECTION PRESENT A SIMILAR SIGNAL OF CHANGE.

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ANY QUESTION?