The right ingridients for hydroclimate modelling: an overview of the ICTP activity

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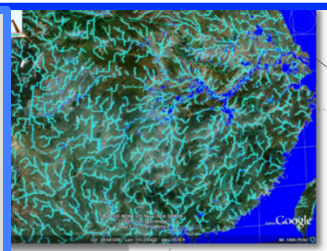
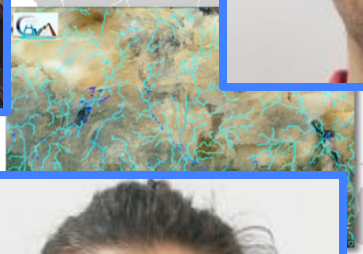

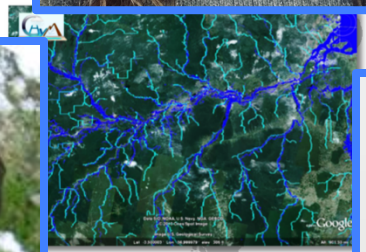


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1)Why do we want to do hydroclimate simulations

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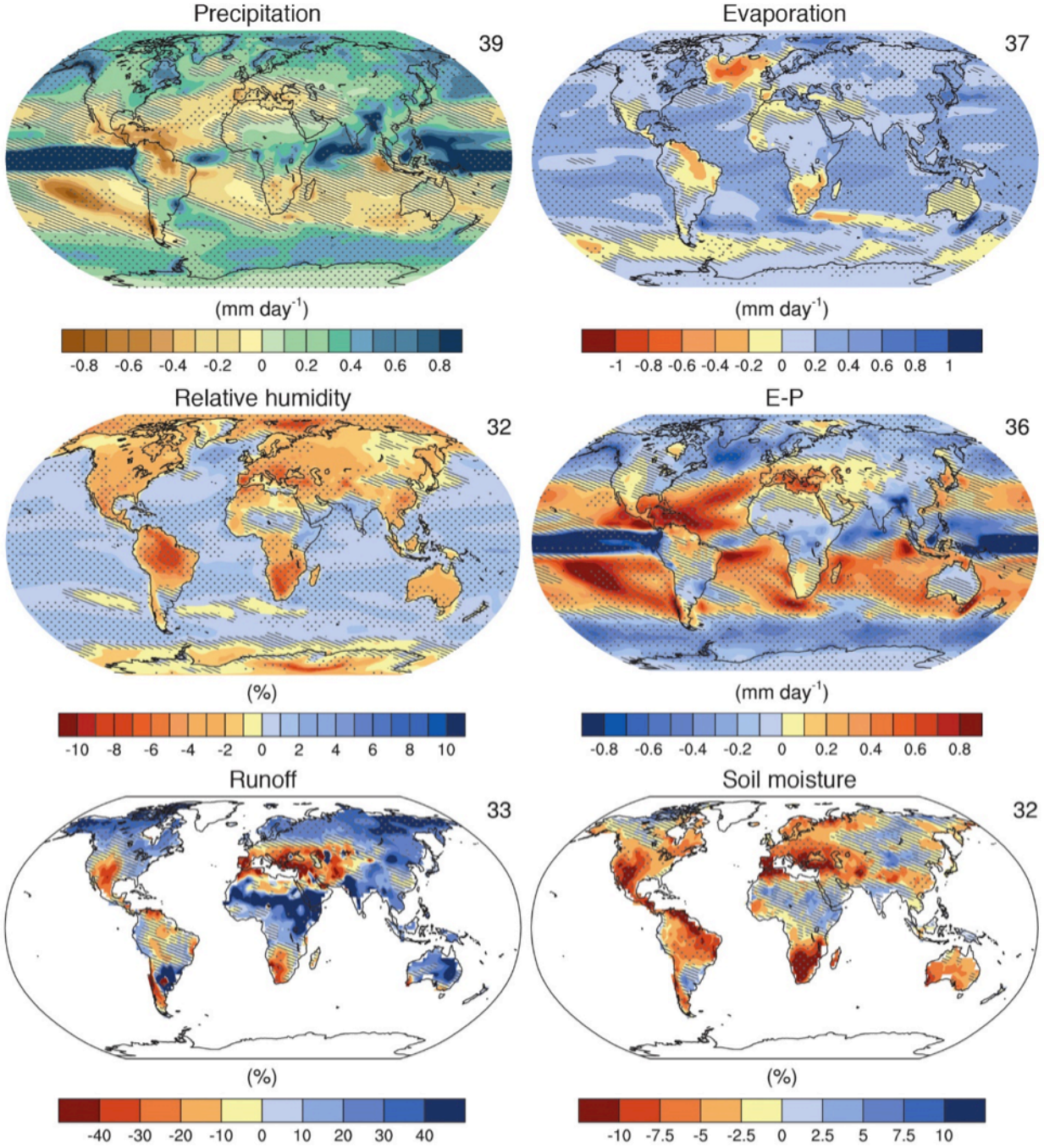
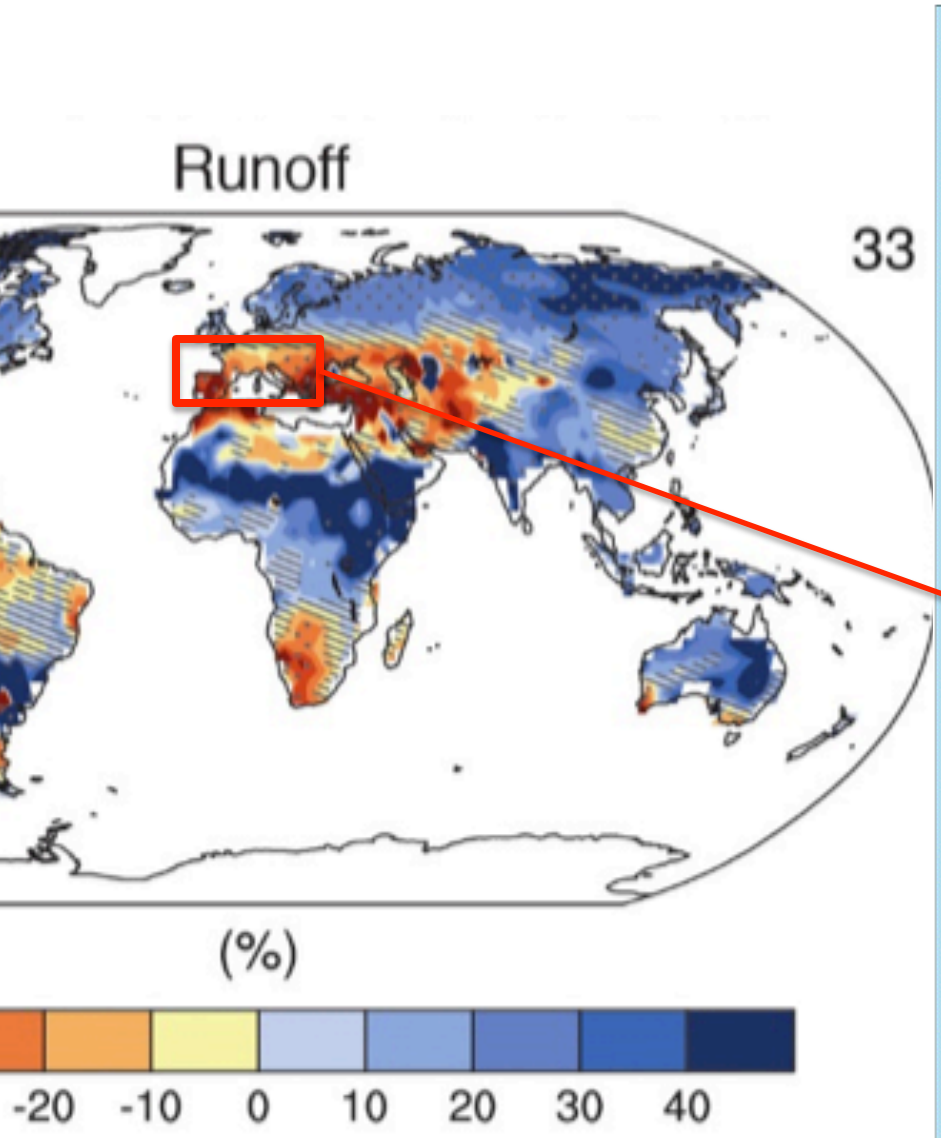
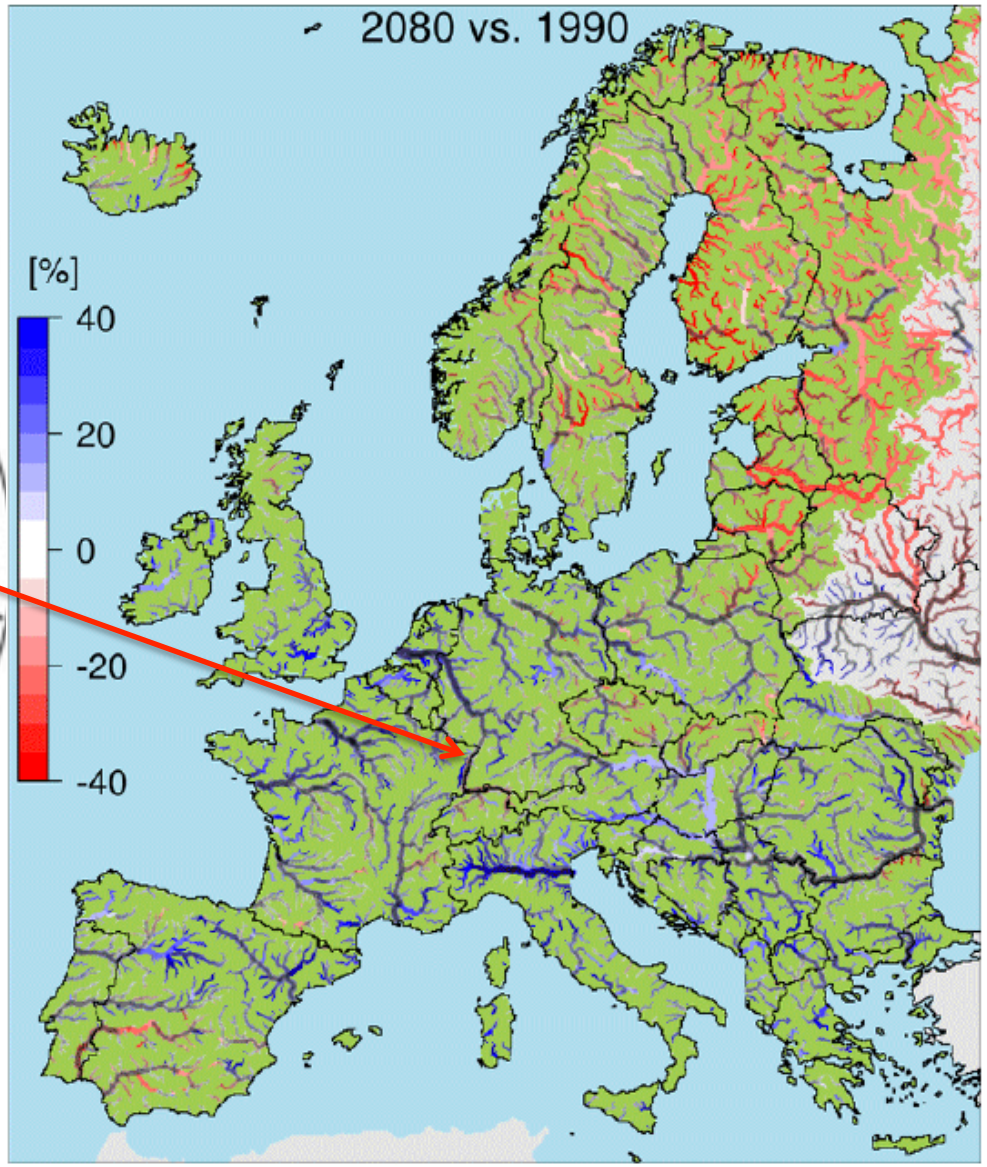
Annual mean hydrological cycle change (RCP8.5: 2081-2100)



Q(100)





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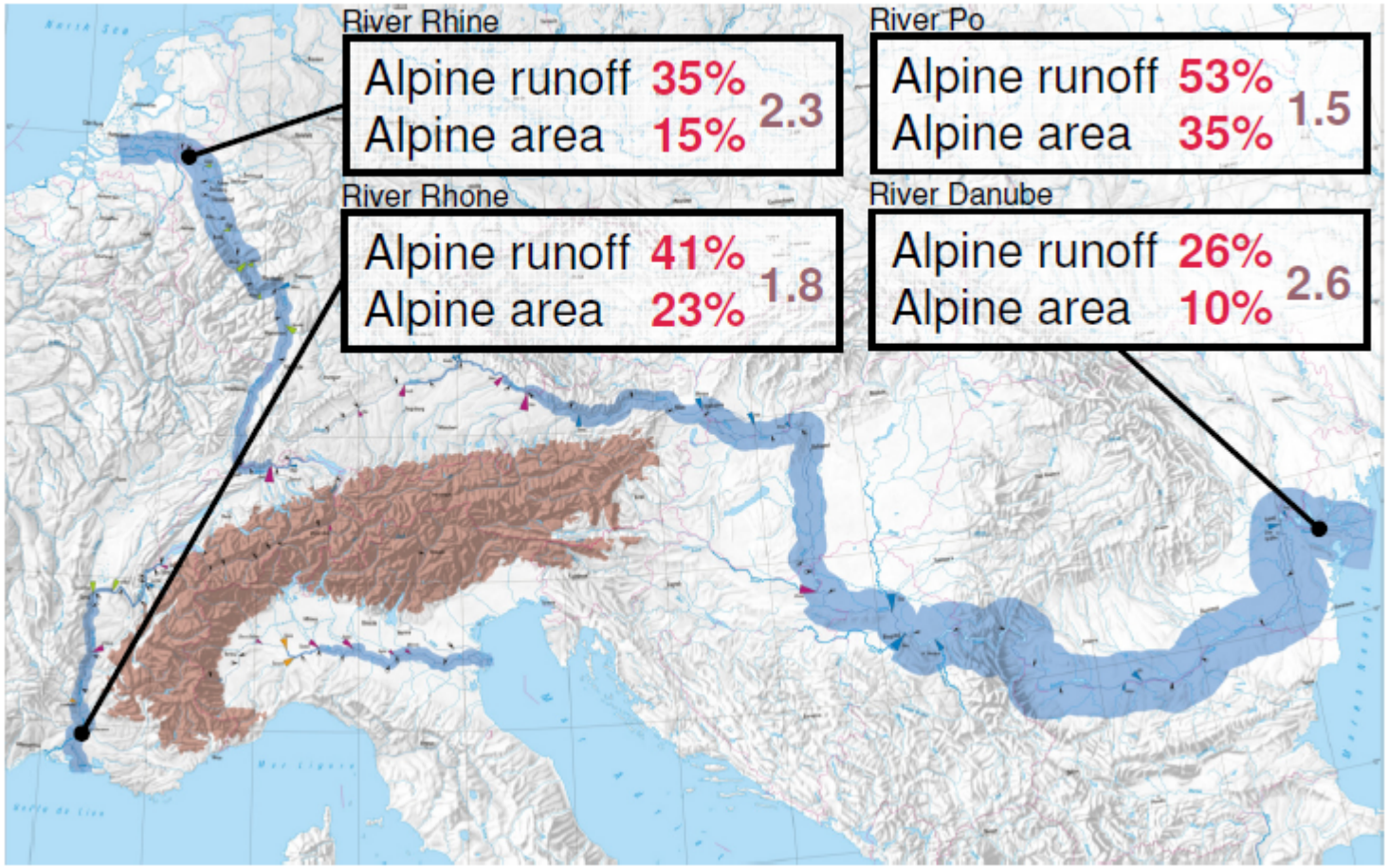
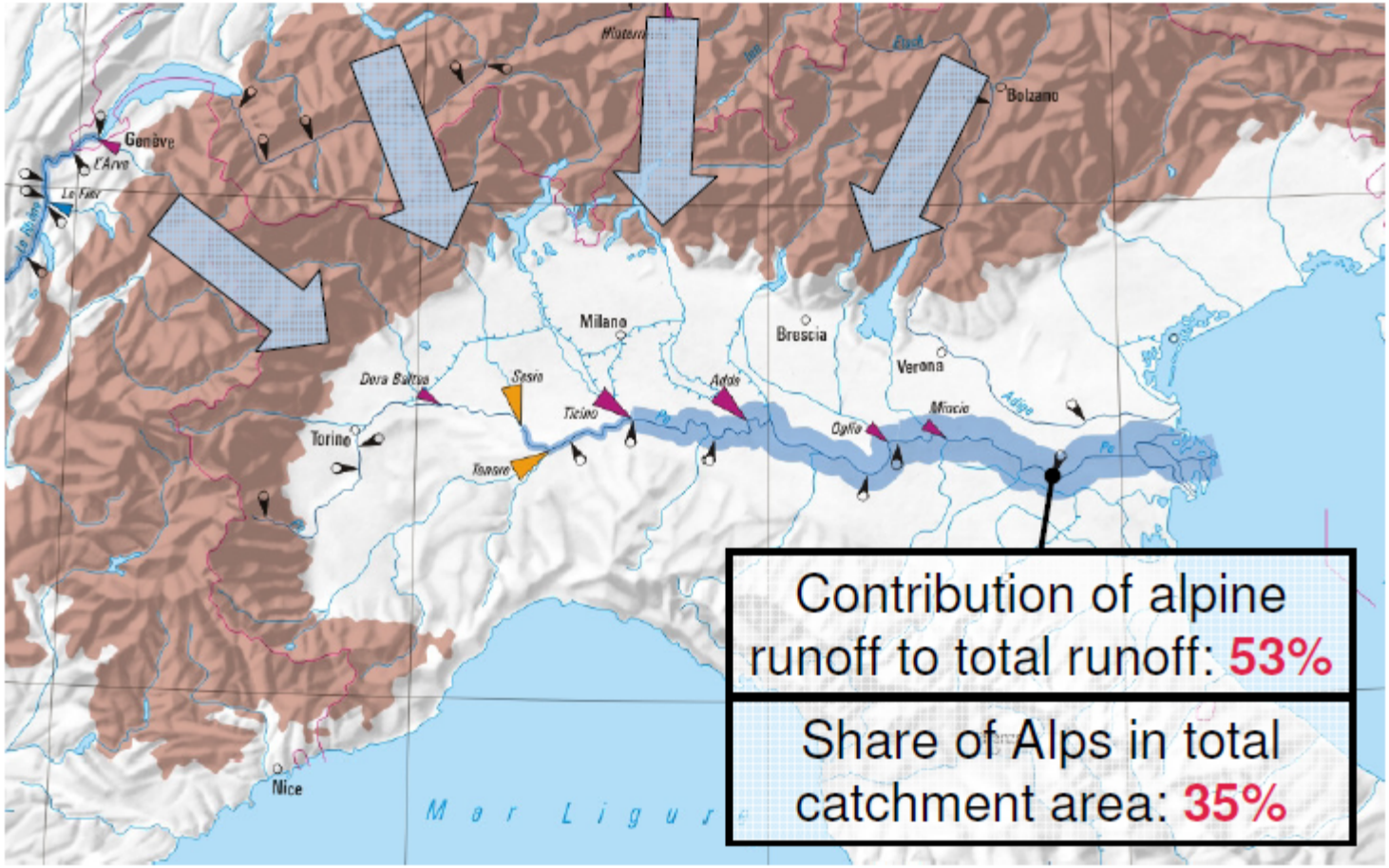
The Alps water tower of Europe: the 4 major rivers



The Alps water tower of Europe the river Po



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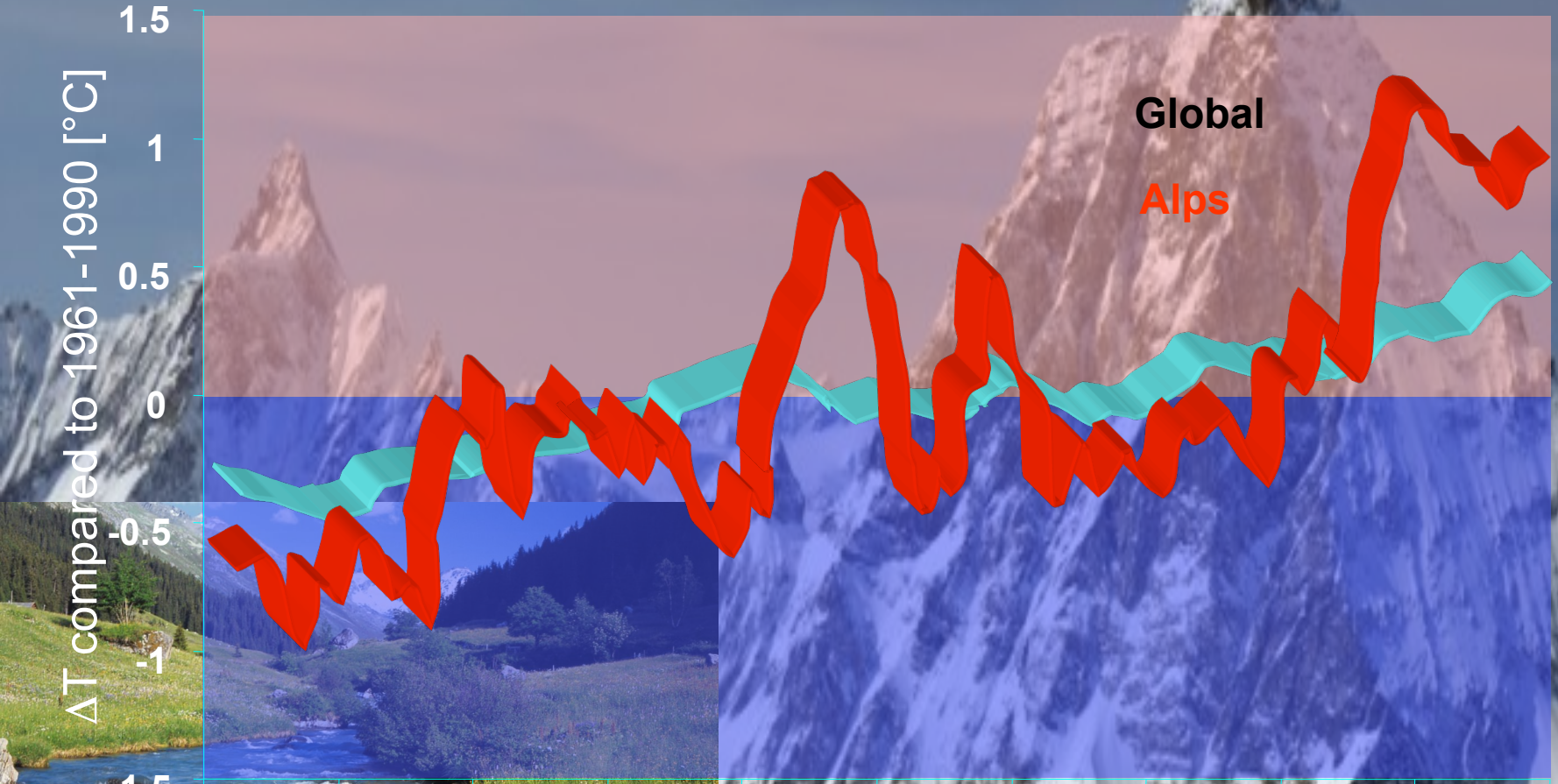
Evolution of global and alpine temperatures, 1901-2000



Beniston, 2000: Environmental Change in Mountains, Arnold, London

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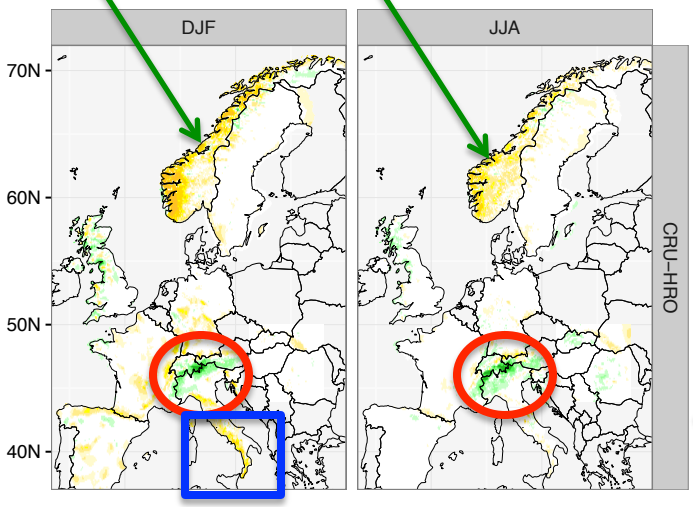
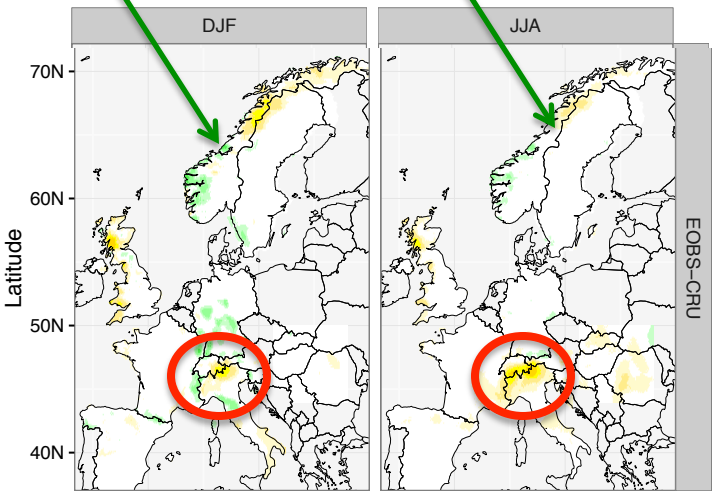
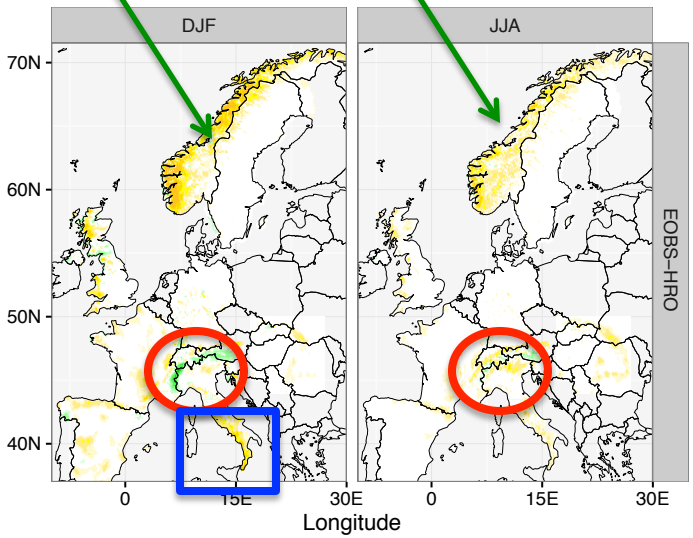
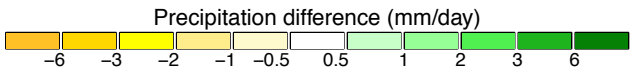
2)What do we need for hydroclimate simulations

Observation Uncertanty

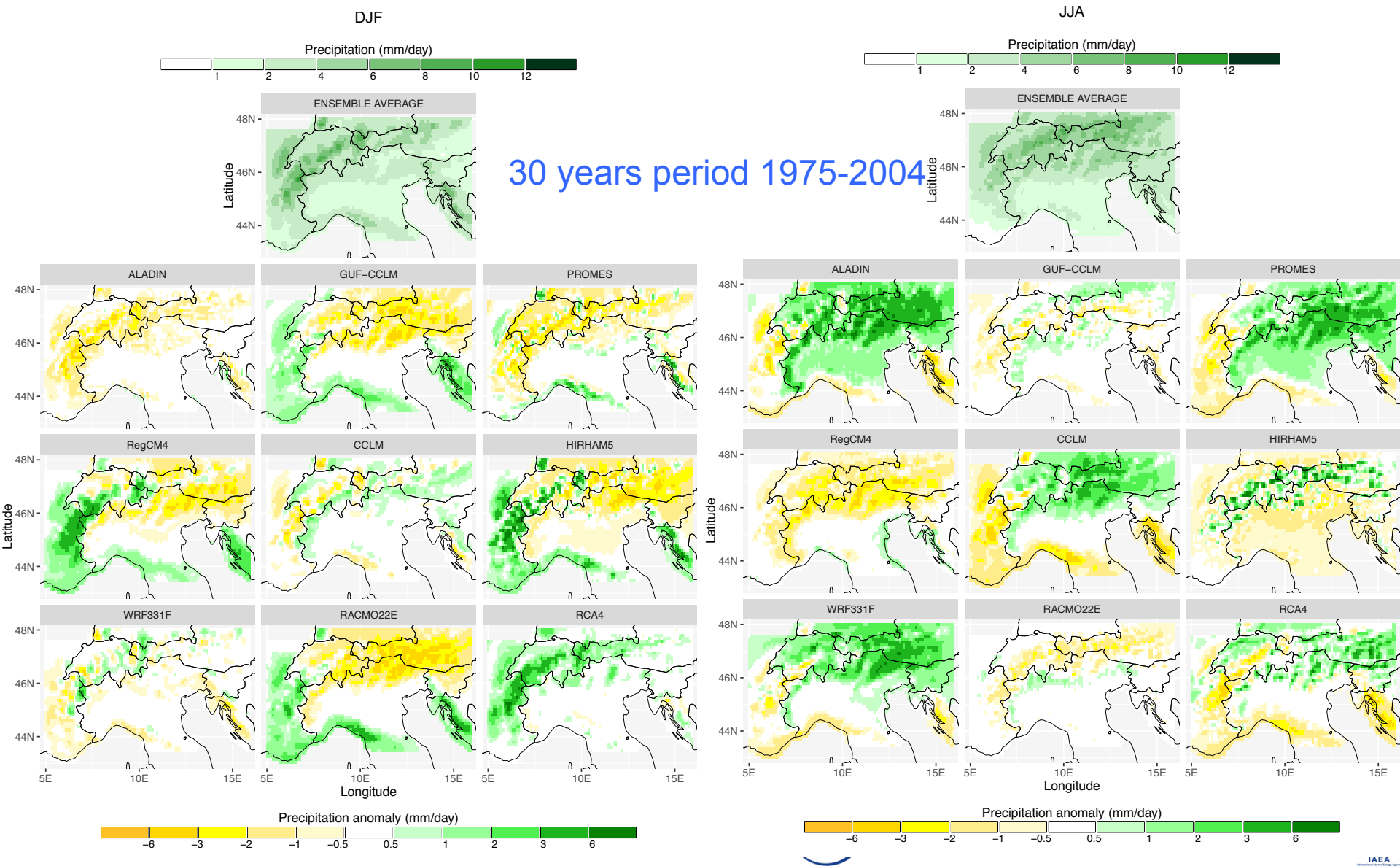






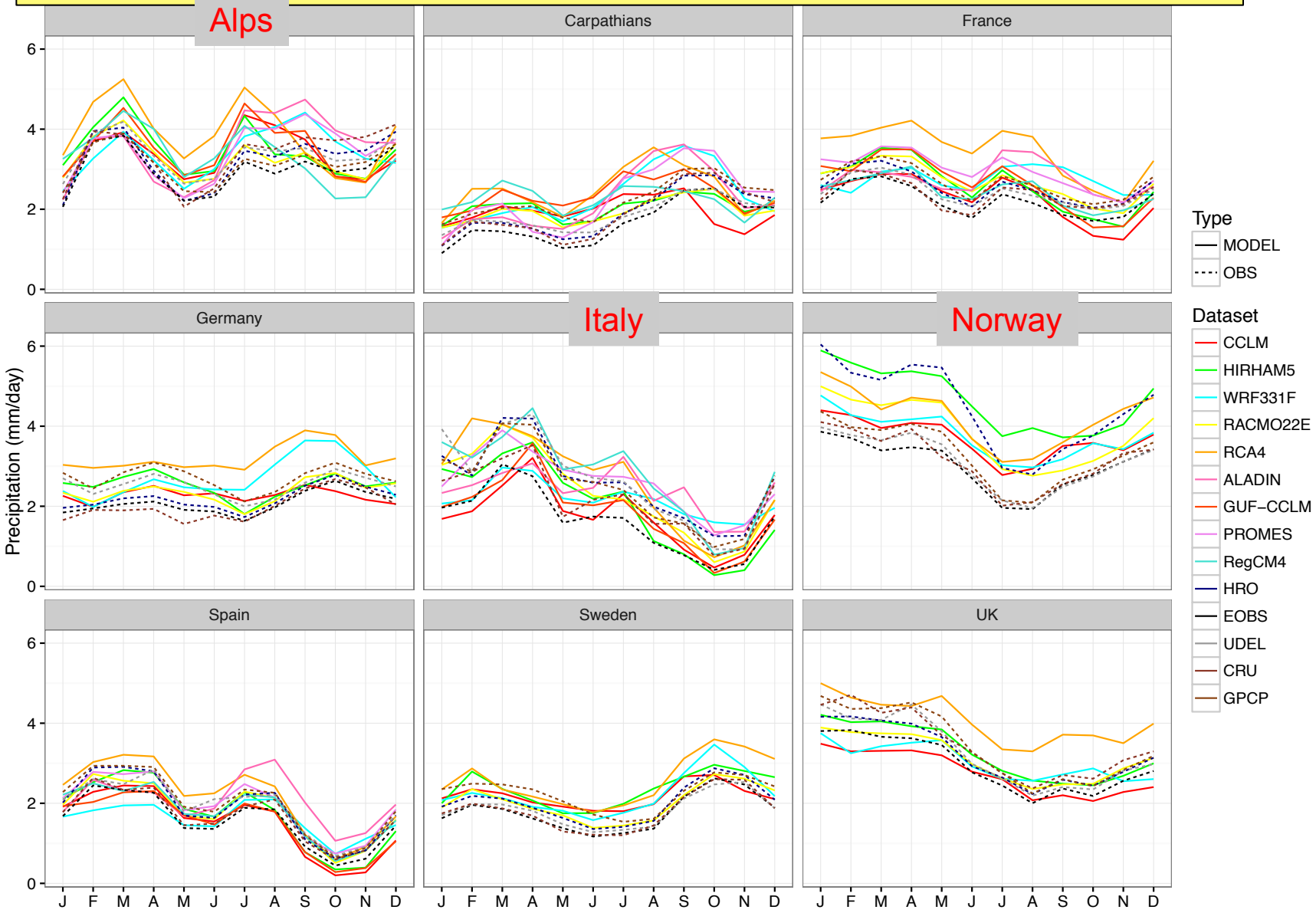


Model Uncertanty



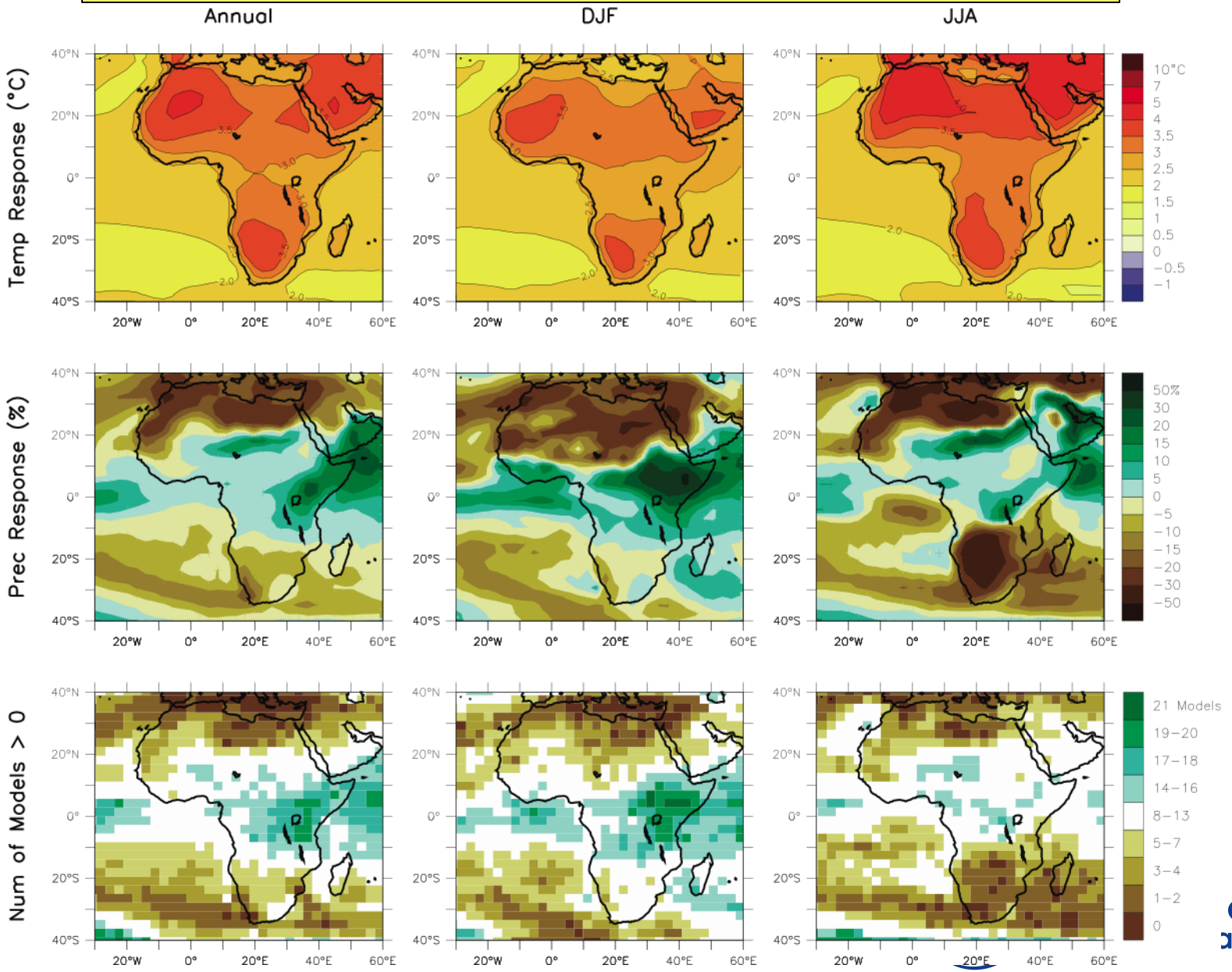
30 years period 1975-2004

Observation+Model Uncertanty



Beniston M,..., **Coppola E**,. The European mountain cryosphere: A review of past, current and future issues, *The Cryosphere Discuss.*, doi:10.5194/tc-2016-290, in review, 2017.

Model Uncertanty



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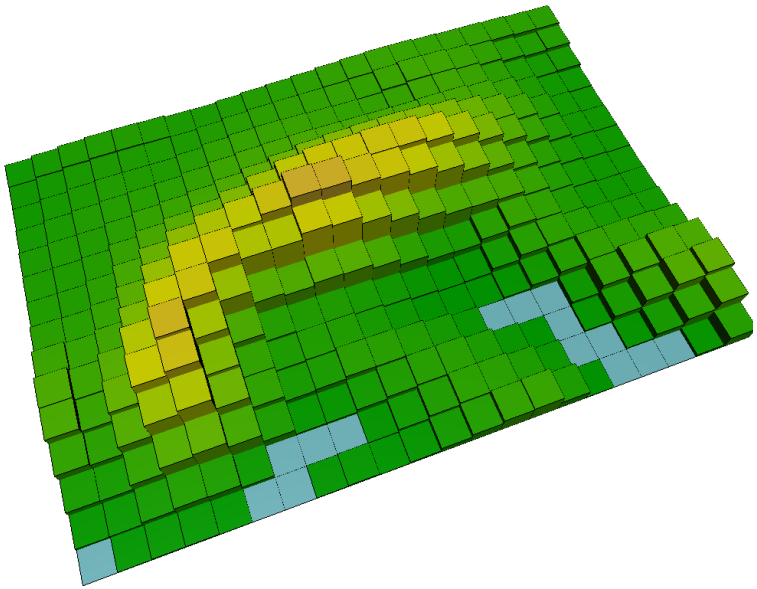
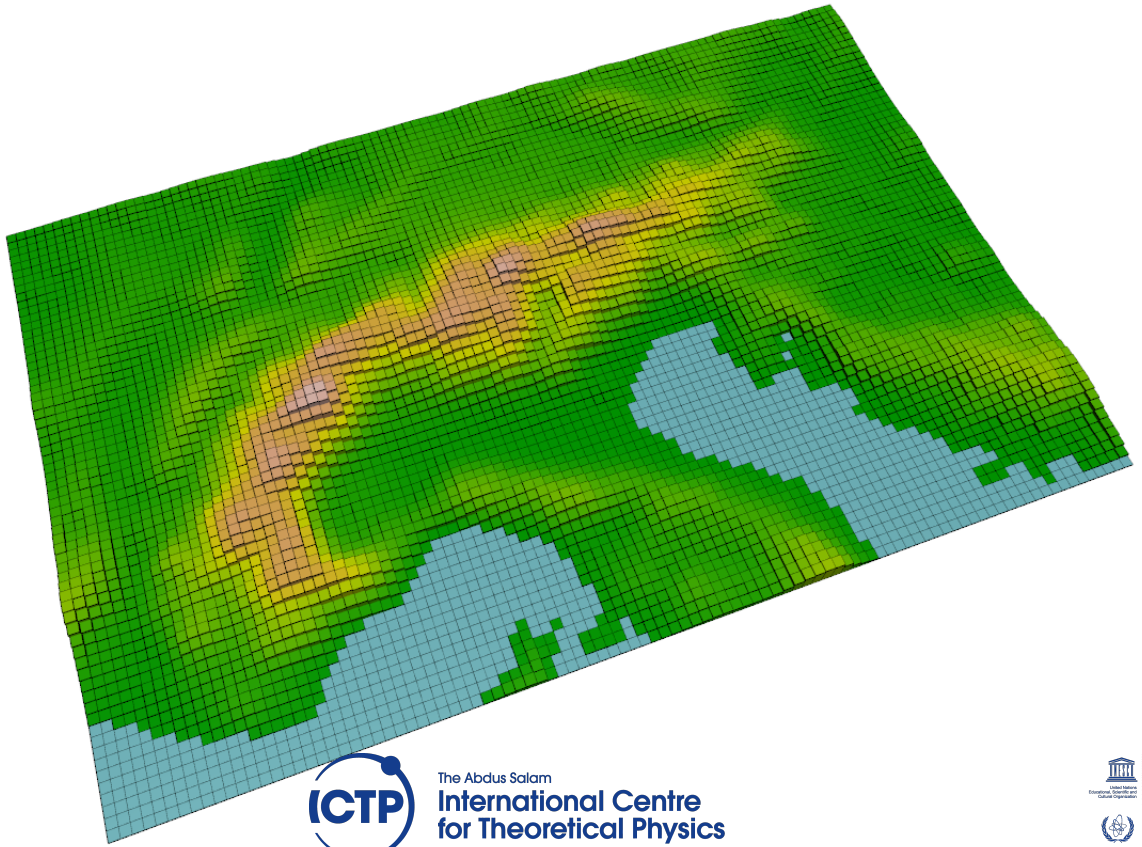
al Physics

Resolution- Grids



0.44

0.11



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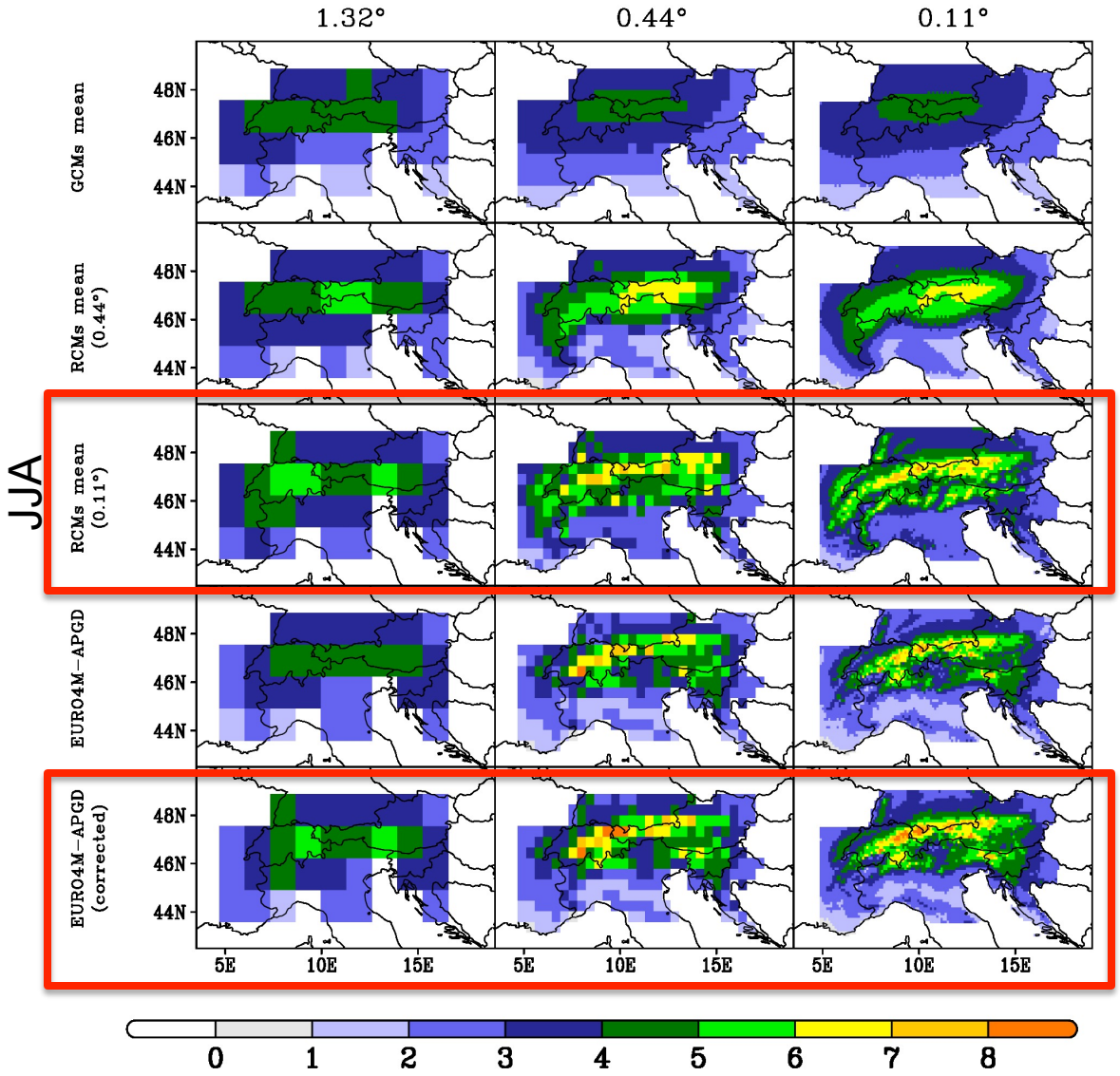
Simulation of spatial patterns of summer precipitation



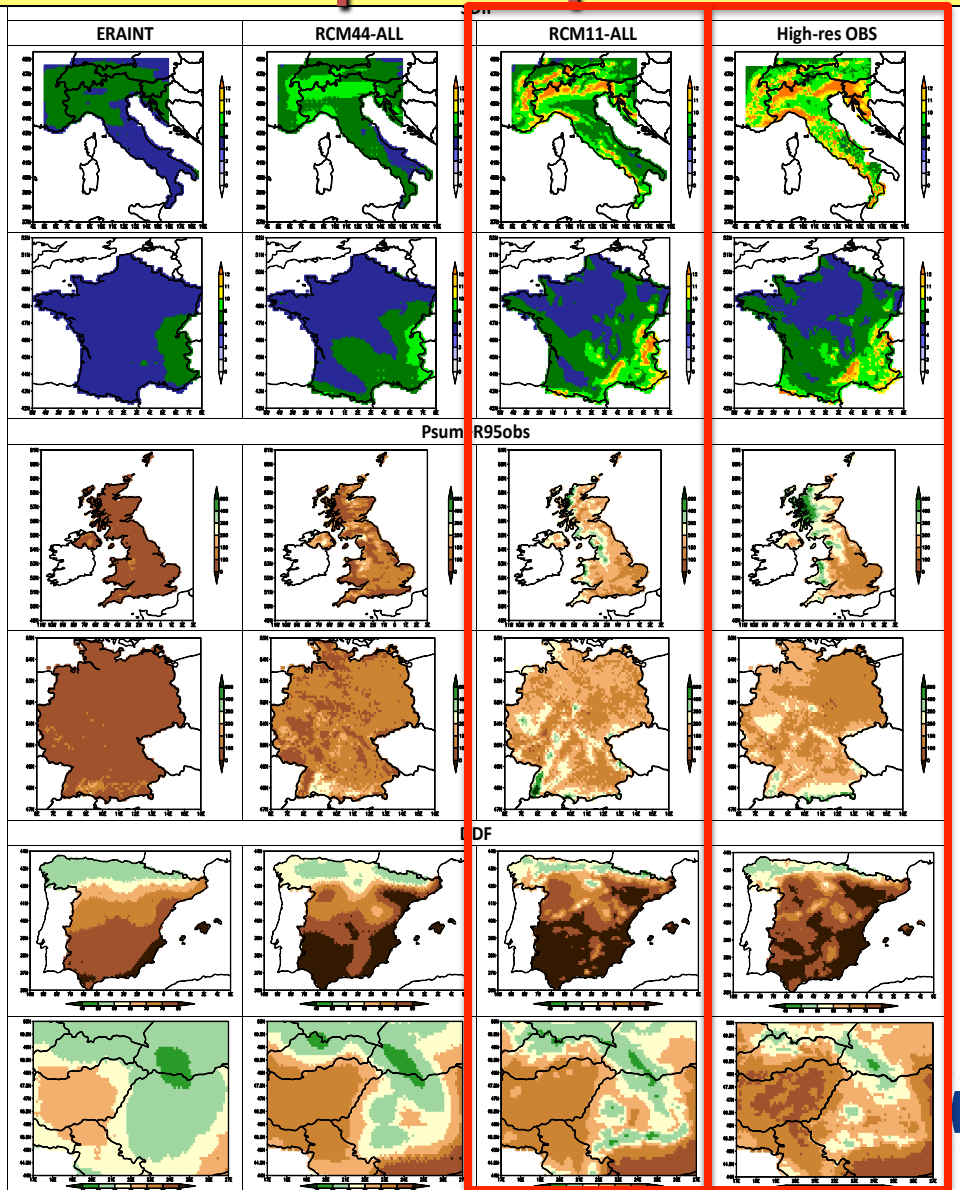
Higher resolution

Increasing details in precipitation spatial distribution

Fine scale AV

Torma et al., JGR, (2015)

Simulation of spatial patterns of extreme precipitation indices



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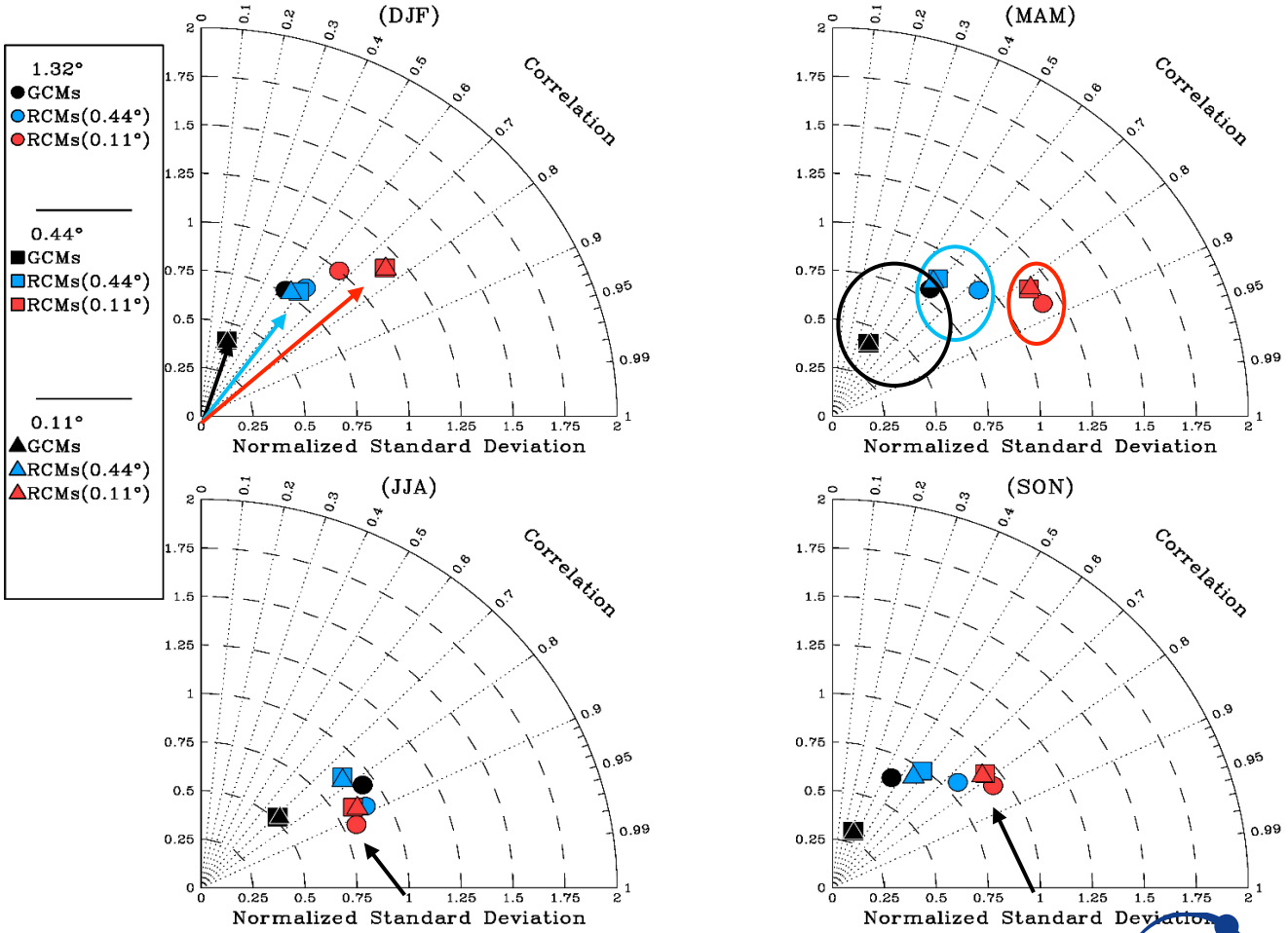
Taylor diagrams for mean seasonal precipitation

1976-2005



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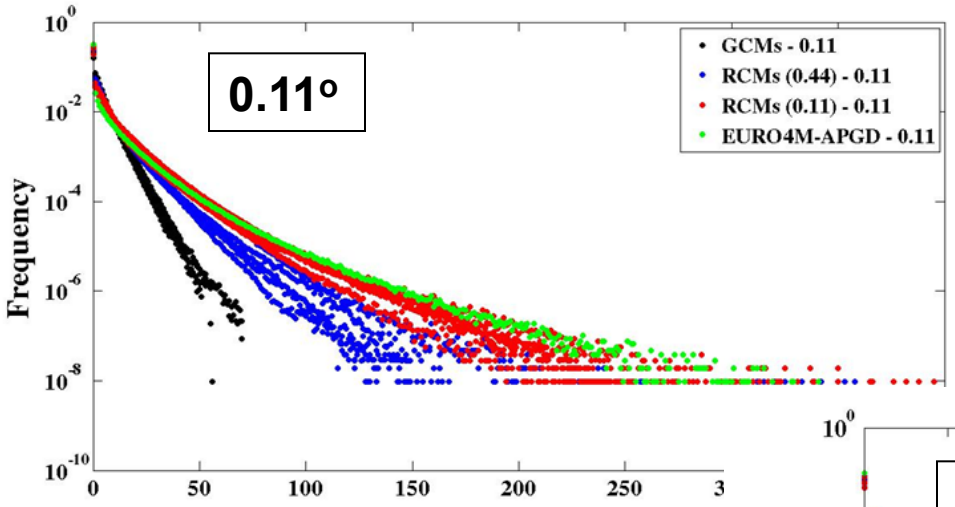
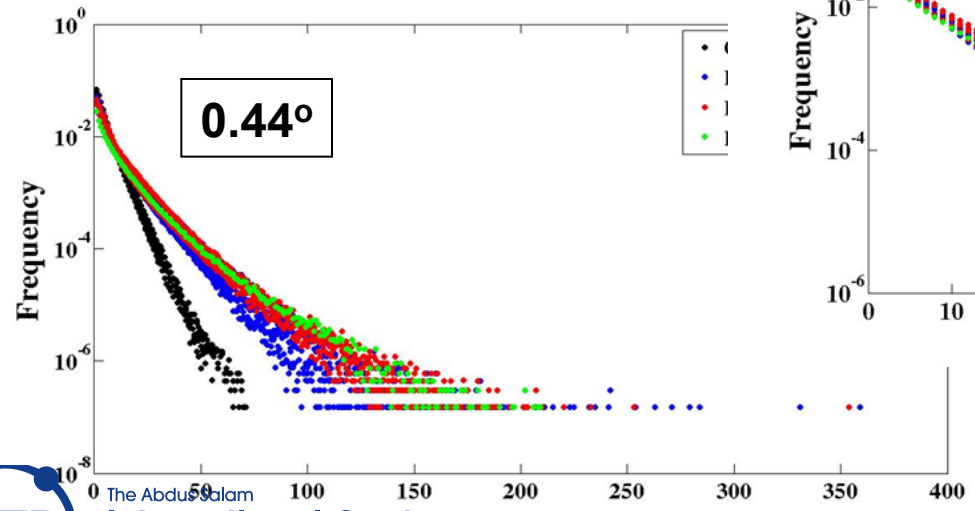
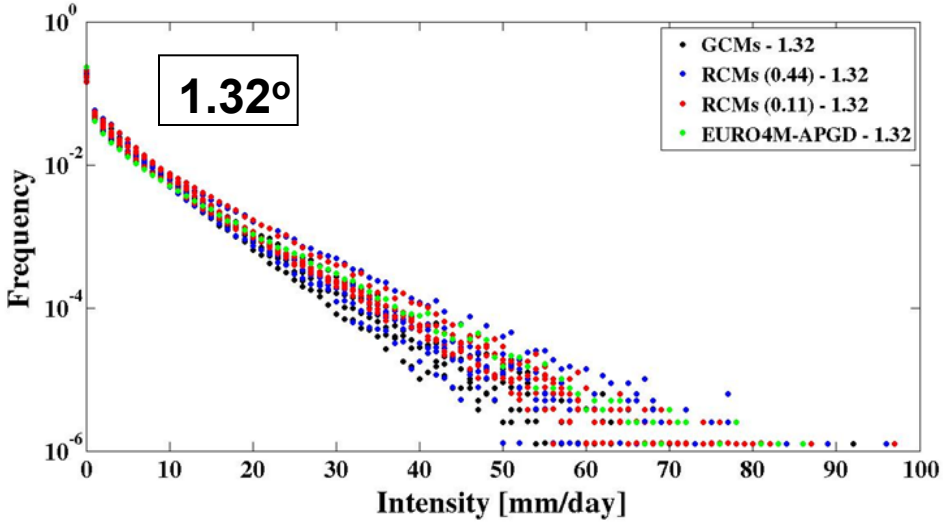
Added value: Simulation of daily precipitation intensity PDF



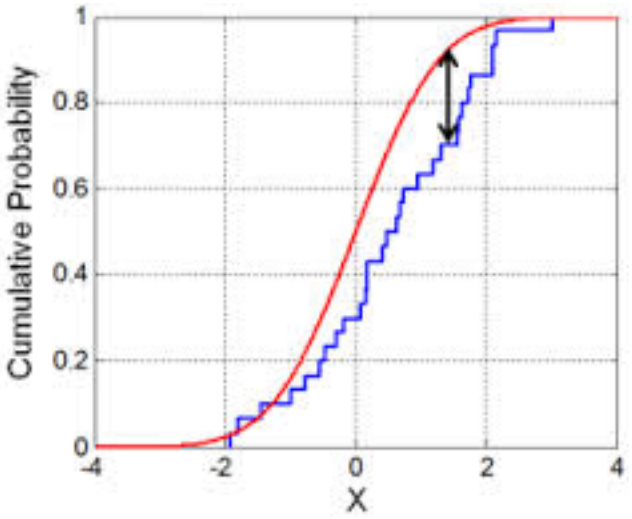


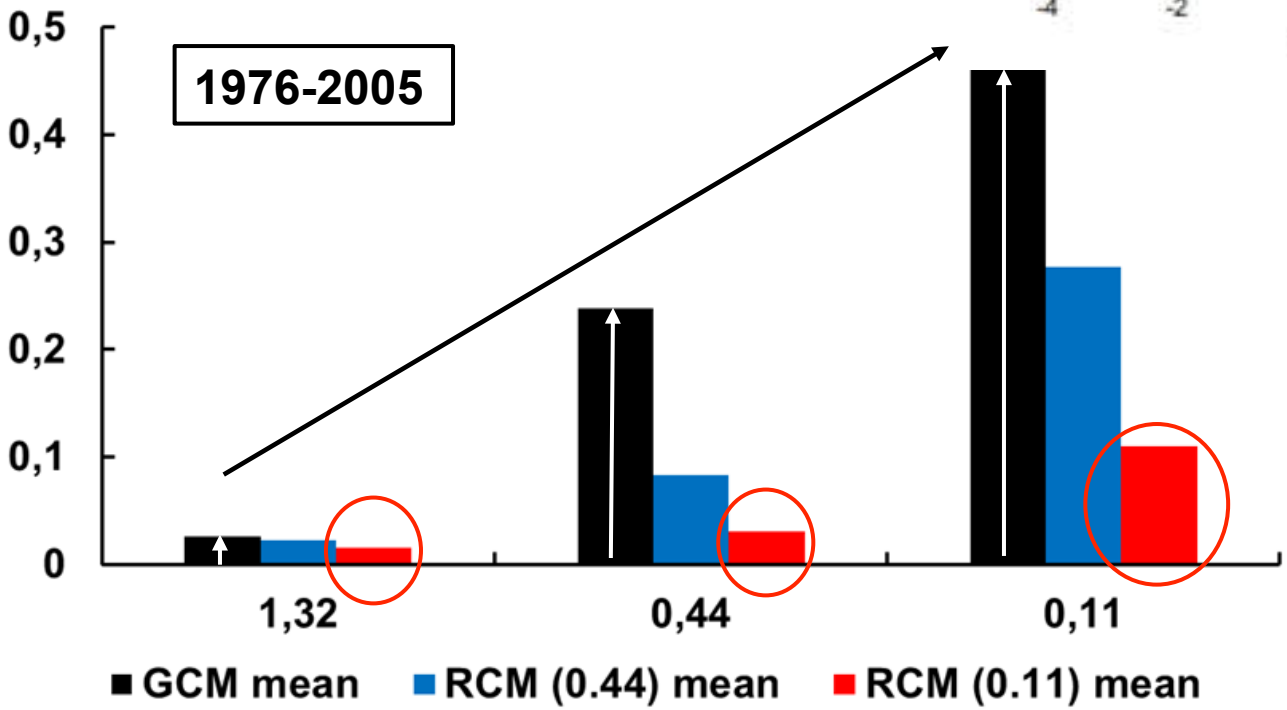


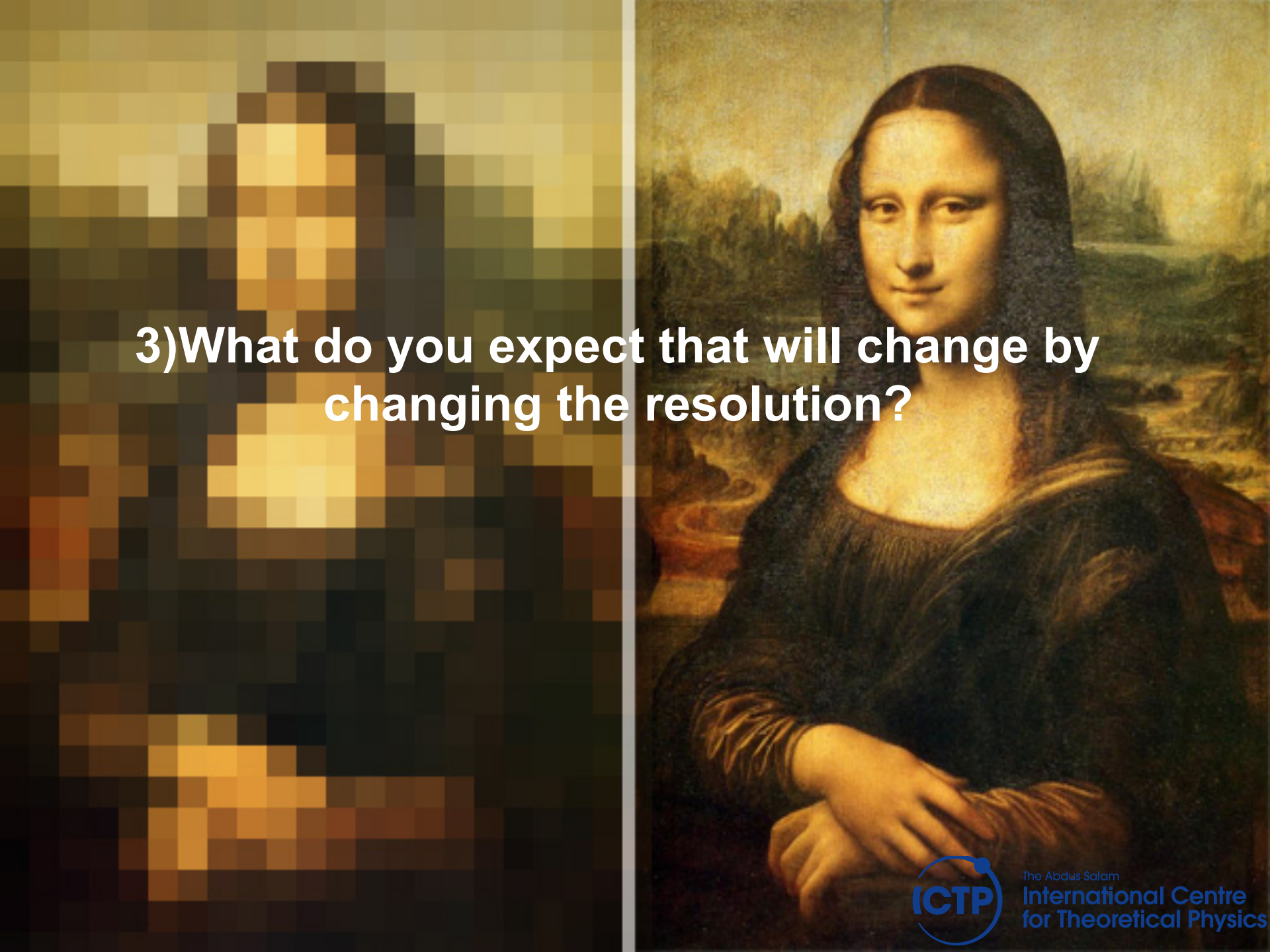
RCMs are always closer to OBS (also when upscaled)

Kolgomorov-Smirnov distance

$$d_{KS}(F,G) = sup_{t\in\mathbb{R}}|F(t) - G(t)|$$






3)What do you expect that will change by changing the resolution?
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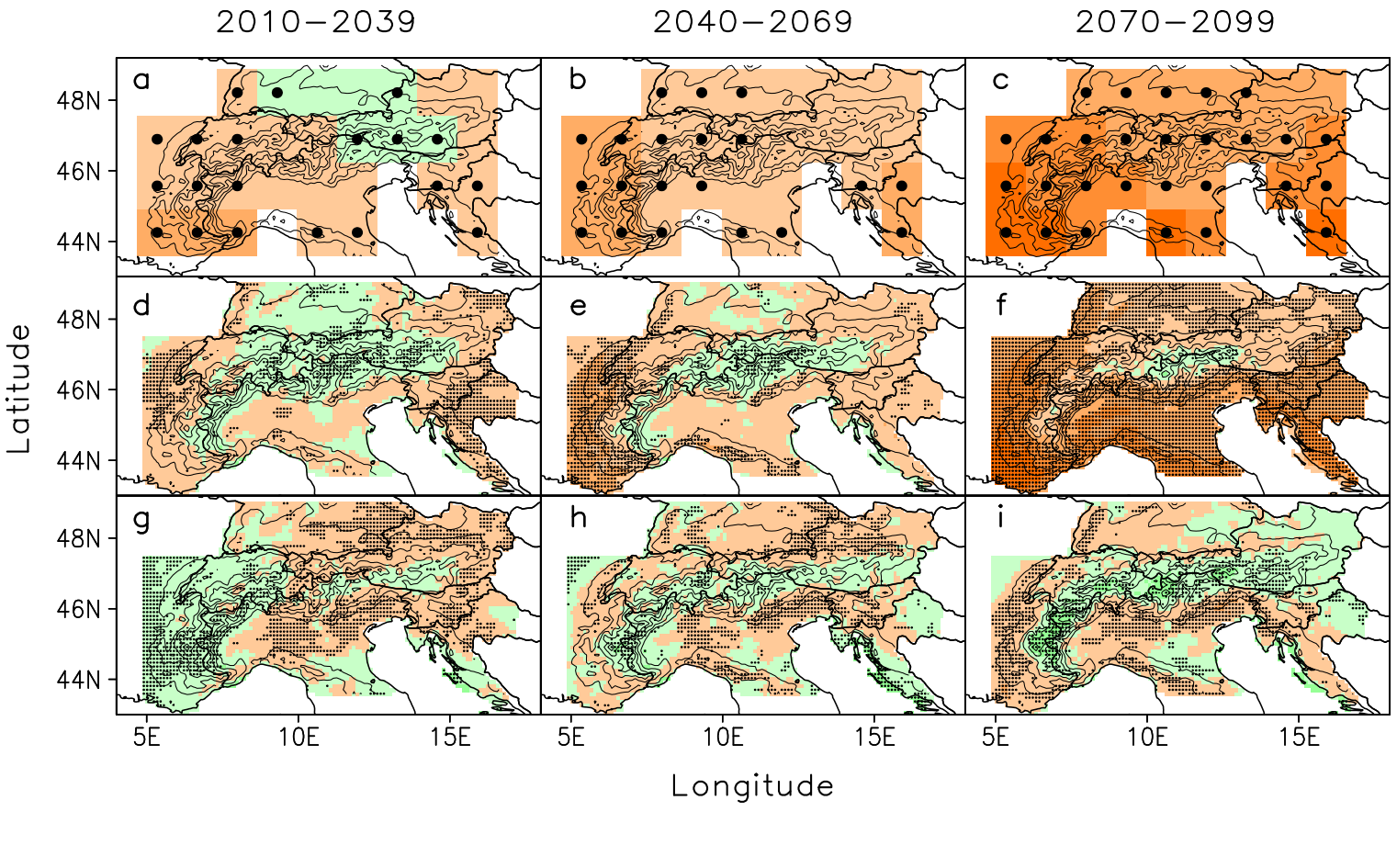
Summer precipitation change (%)



GCMs

RCMs 0.11°

Downscal. Signal

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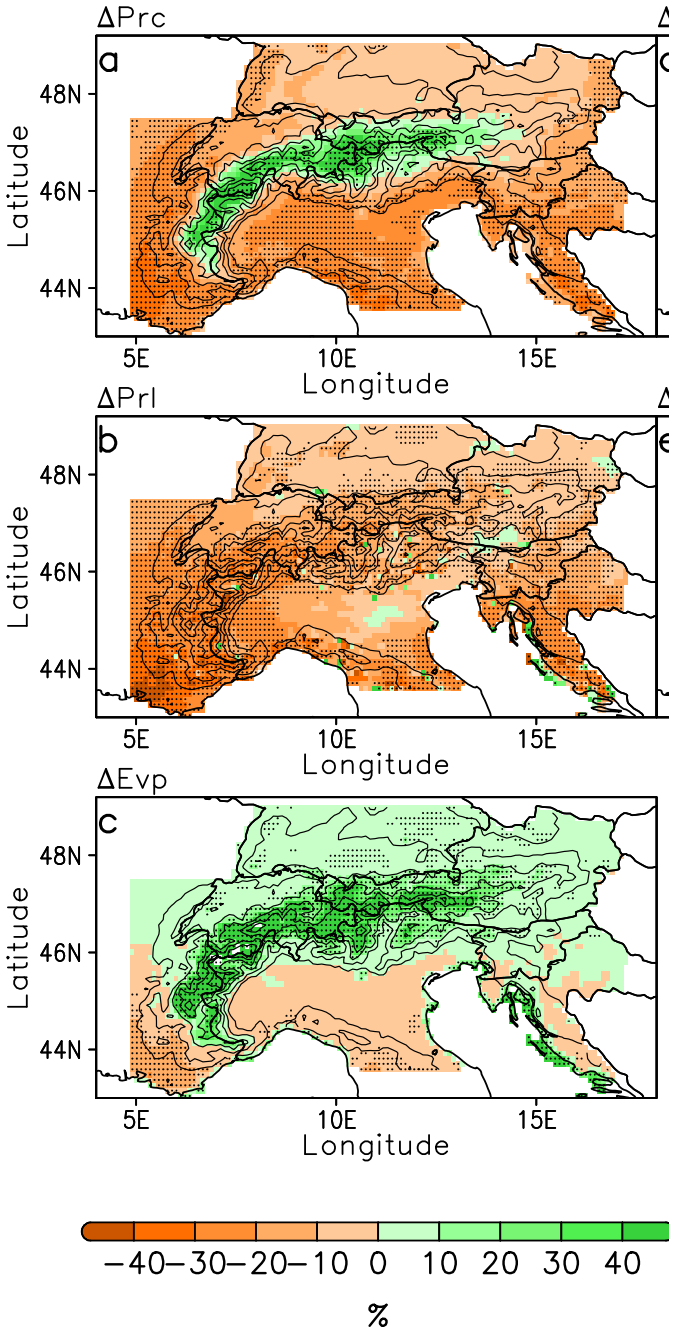


Convective

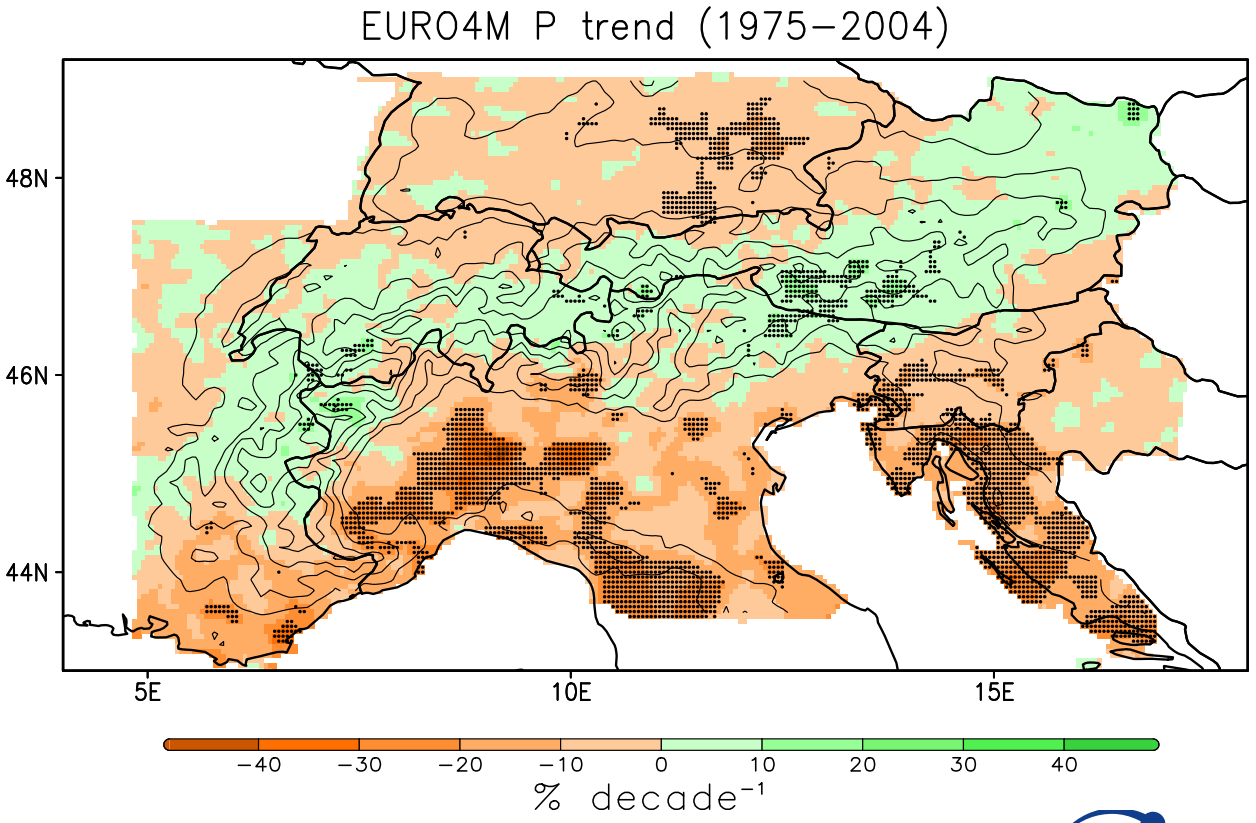
Non Convective

Evaporation

Summer precipitation change

Giorgi F, Torma C, Coppola E, Ban N, Schar C, Somot S, 2016. Enhanced summer convective rainfall at Alpine high elevations in response to climate warming. *Nature Geoscience*, **9:8**, DOI: 10.1038/NGEO2761

Observed summer precipitation trend during 1975-2004



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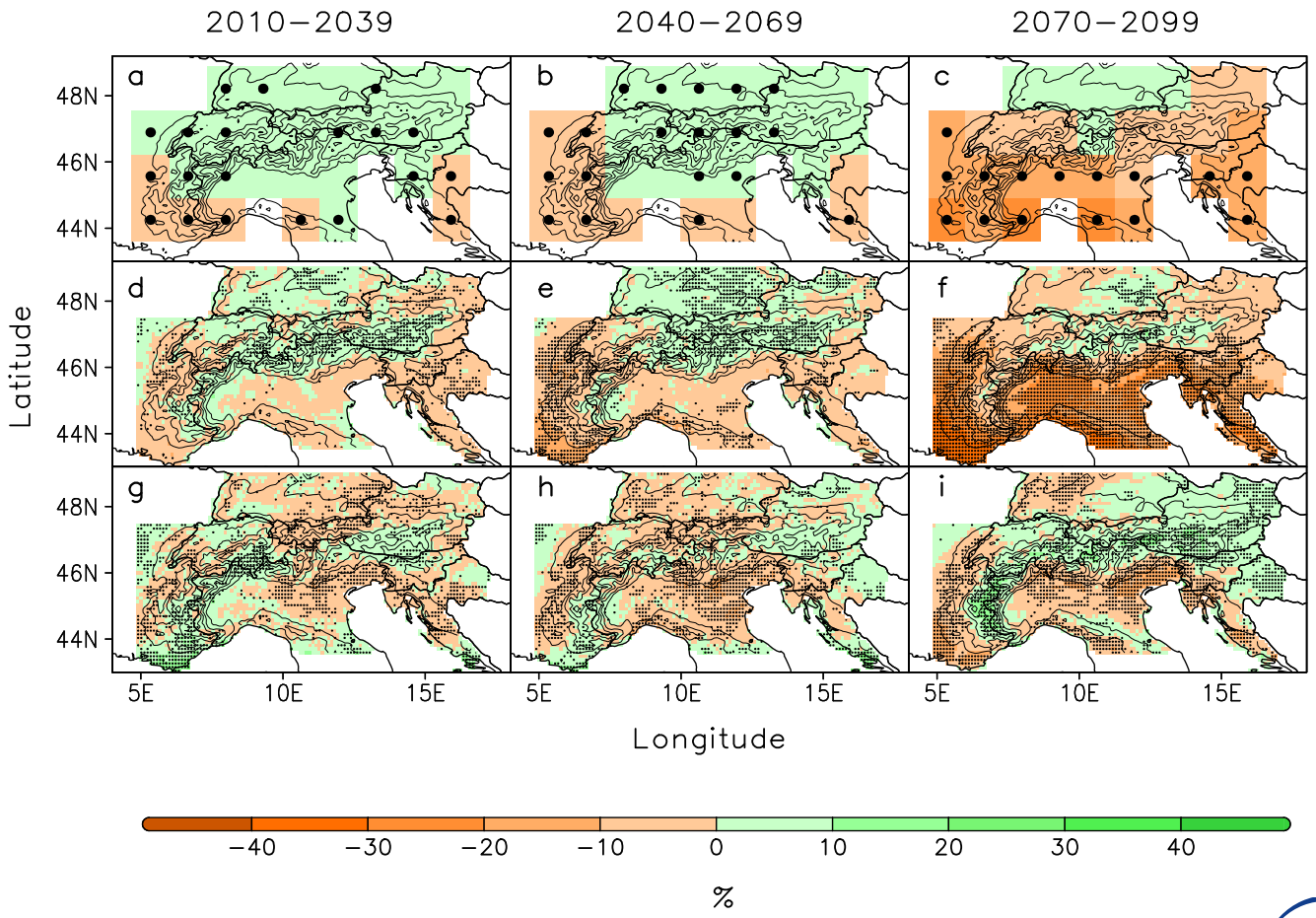
Change in summer precipitation R95 (%)



GCMs

RCMs 0.11°

Downscal. Signal

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Let's consider the SDR

- Regions that are dominated only by Snow Driven Runoff SDR are those **regions** in **which 50% or more of the annual runoff occurs in the period April-July**.
- Julian Day inside the **water year** (from October to September of the following year), on which each percentile of that year's annual flow occurred.
- Early, middle and late seasonal flows **represented by the 25th, 50th and 75th** DQFs (Date of Quarterly Flow).

Impacts - SDR change signal

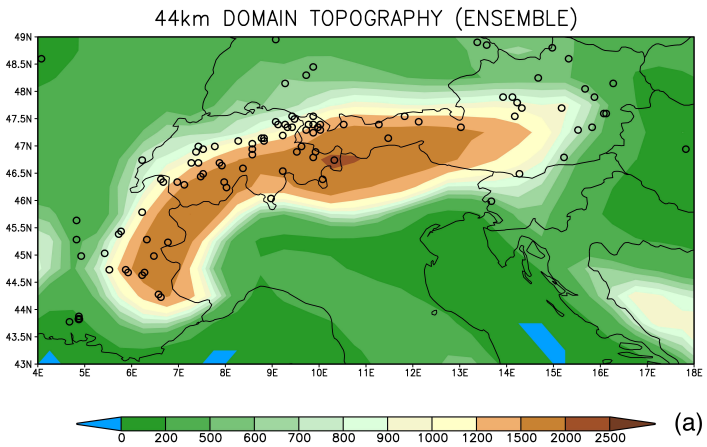
- In analogy with Rauscher et al. [2008] study done for western US, we considered only regions that are dominated only by SDR. Those **regions** are selected as areas in **which 50% or more of the annual runoff occurs in the period April-July**.
- Following Moore et al. [2007], we calculated the Julian Day inside the **water year** (from October to September of the following year), on which each percentile of that year's annual flow occurred.
- To investigate on the early, middle and late seasonal flows **we calculated the 25th, 50th and 75th** DQFs (Date of Quarterly Flow). These calculations were performed only for regions in which 50% or more of the annual runoff occurs in April-July.

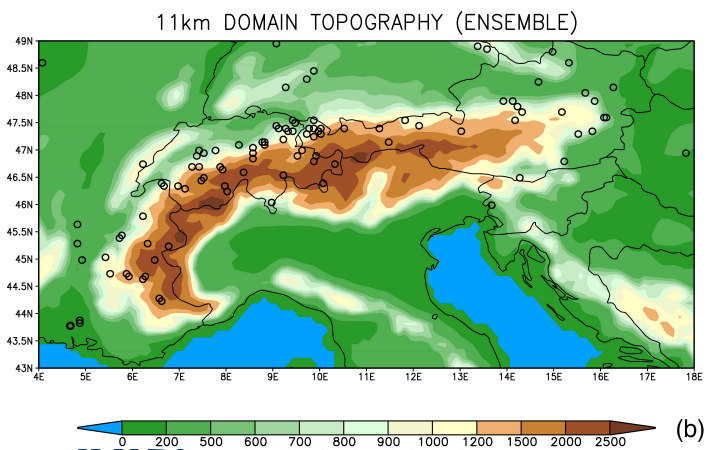
Impacts - SDR change signal - Models

Model	Resolution	Driven-model	Domain
ALADIN	0.11 deg – 0.44 deg	CNRM-CM5	Med-CORDEX
RegCM	0.11 deg – 0.44 deg	HadGEM	Med-CORDEX
RACMO22E	0.11 deg – 0.44 deg	EC-EARTH	Euro-CORDEX
CCLM4-8-17	0.11 deg – 0.44 deg	MPI-ESM-LR	Euro-CORDEX

Impacts - SDR change signal -OBS

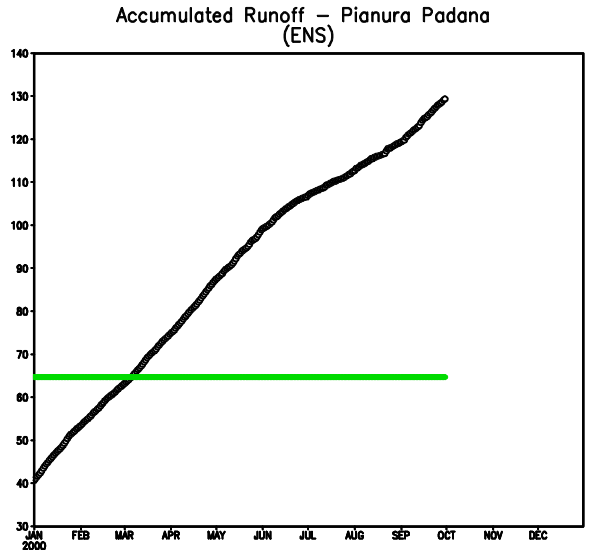
European Water Archive (EWA) observed runoff stations dataset over the Alps

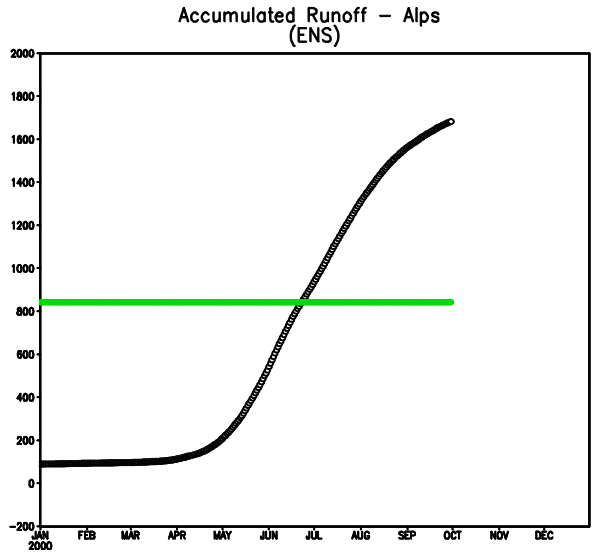


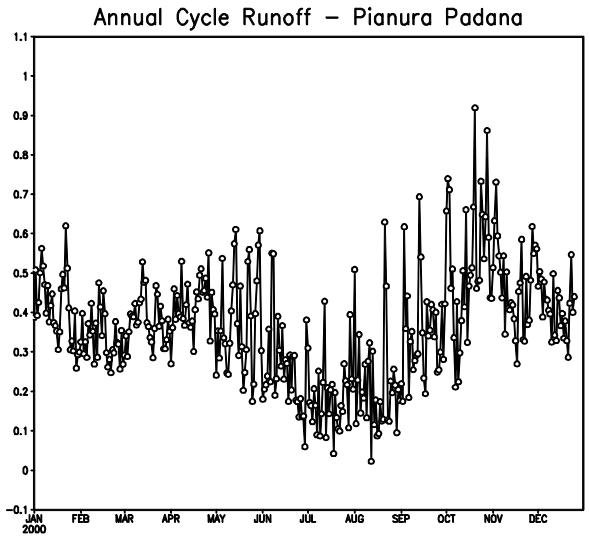


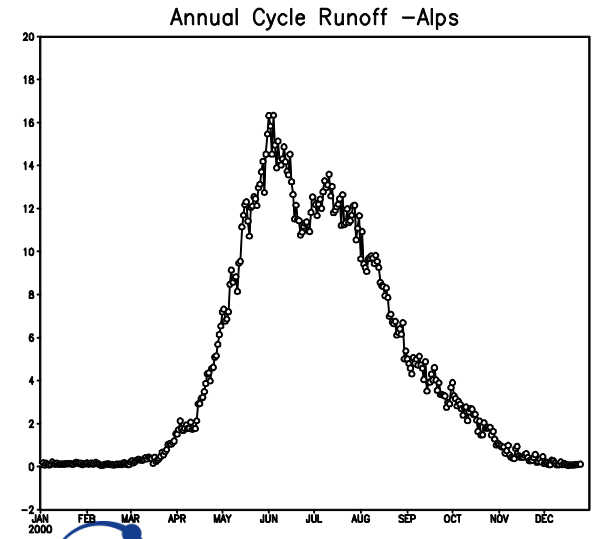
for Theoretical Physics

Methodology - MASK









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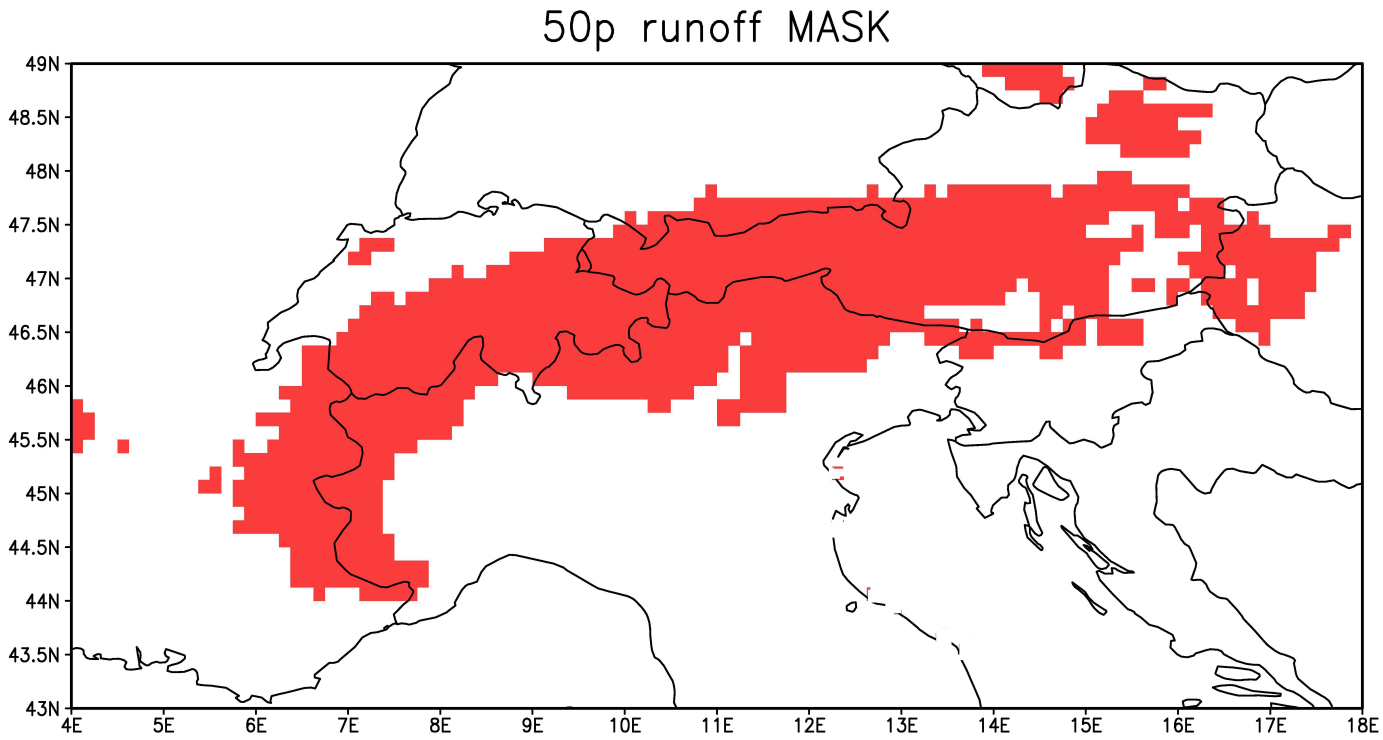
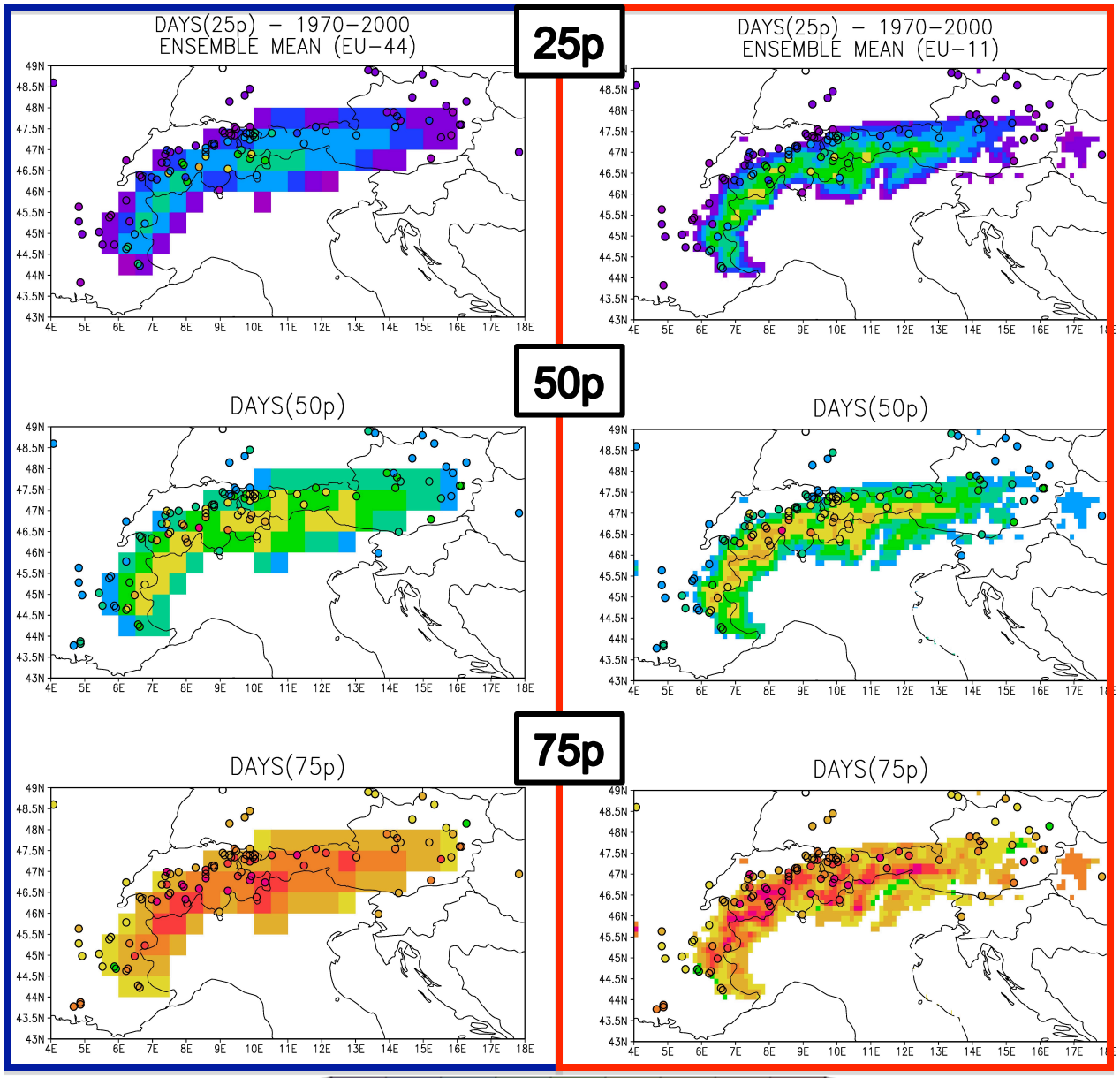
Methodology - MASK



Impacts - SDR change signal -Validation



0.44

0.11

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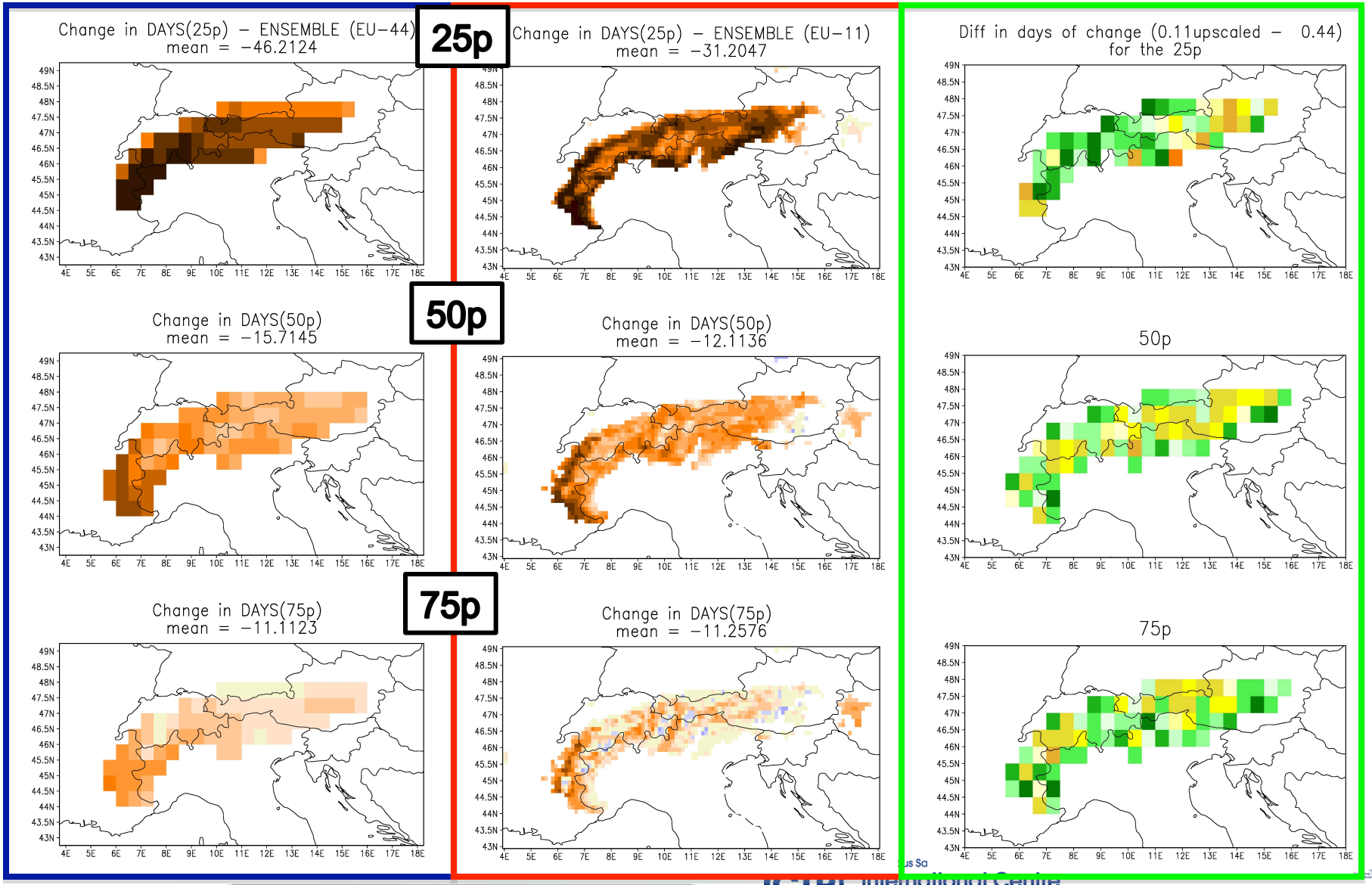
for Theoretical Physics

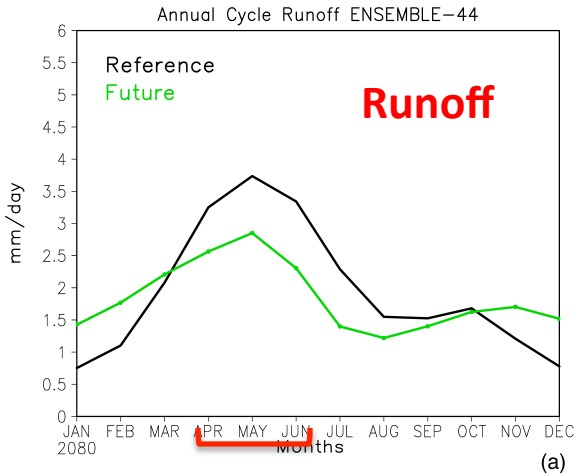
Impacts - SDR change signal- Results-Model ensemble change-days

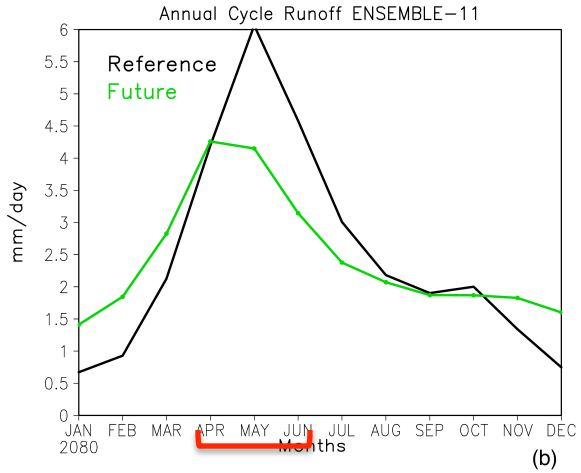
0.44 | **0.11** | **0.11-0.44**

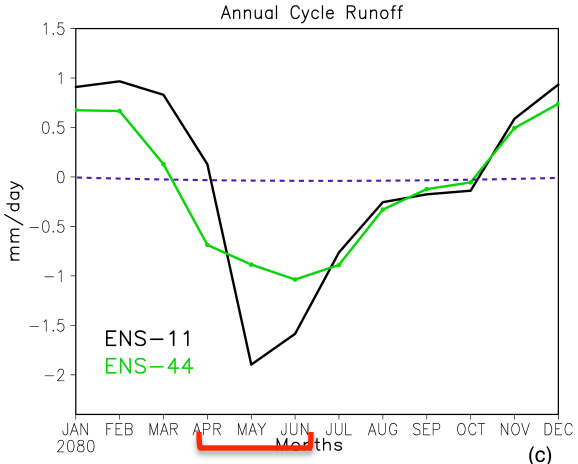


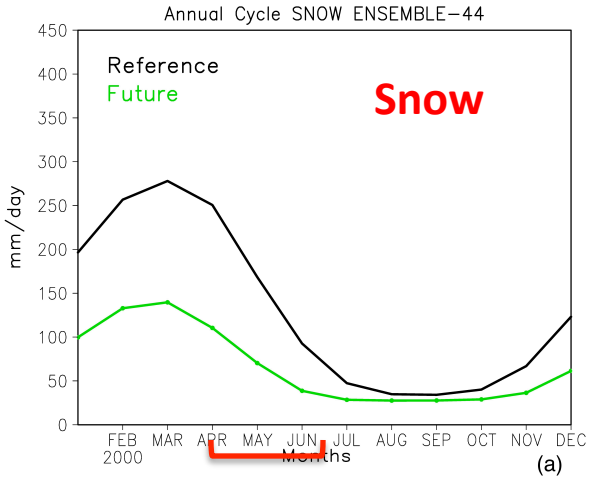
Coppola E, **Raffaele F, Giorgi F**, Impact of climate change on runoff timing over the Alpine region.
Climate Dynamics, DOI: 10.1007/s00382-016-3331-0

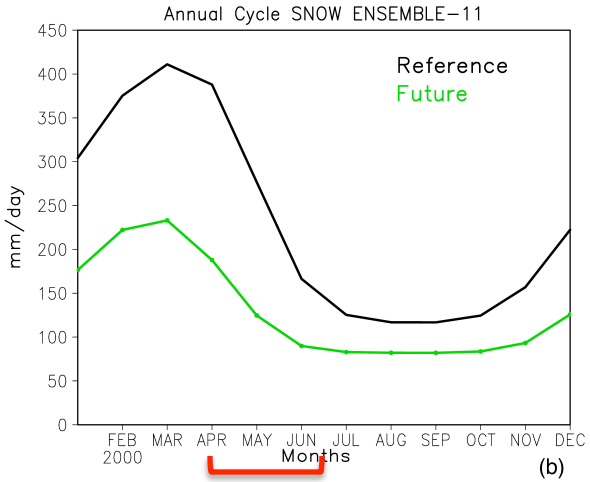
Discussion runoff change snow change

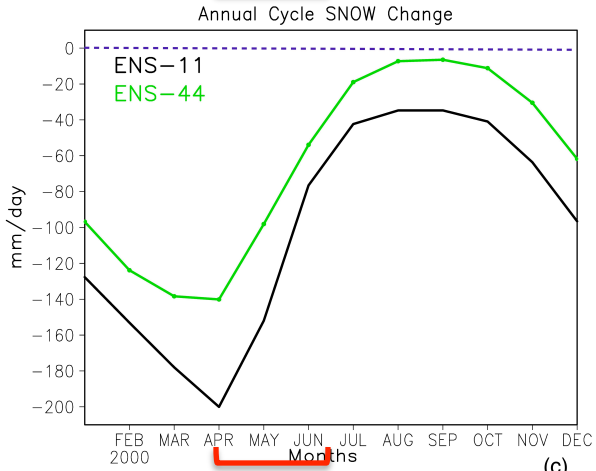










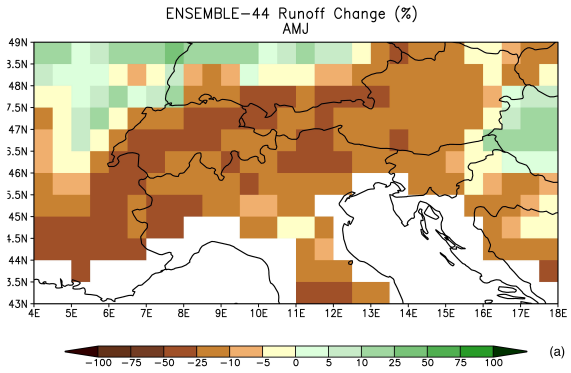


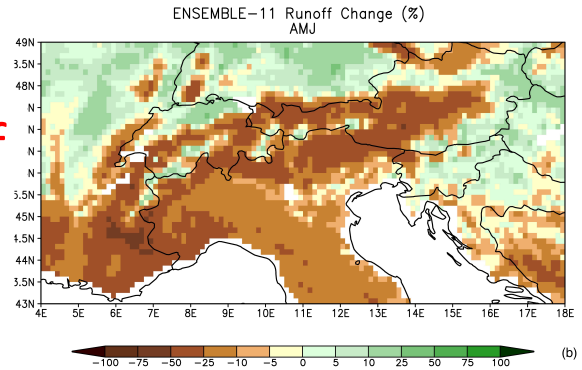
Impacts - SDR change signal- runoff and precipitation change

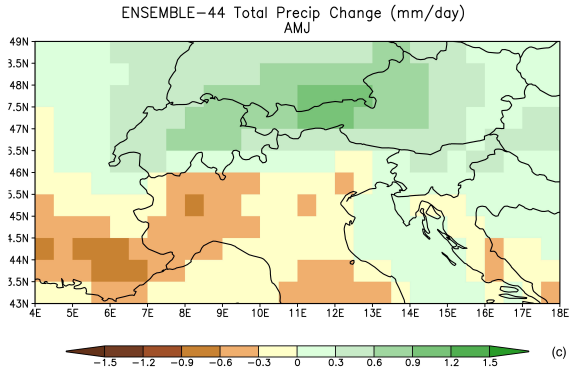
0.44 **0.11**

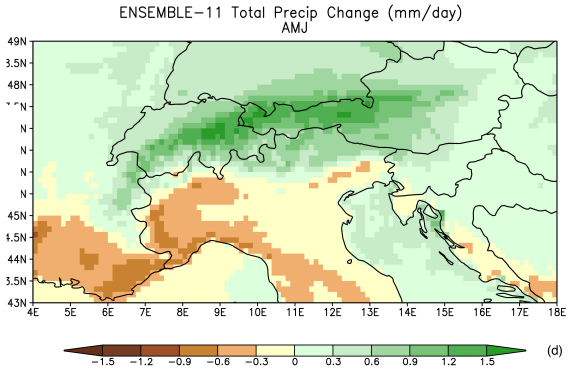
runoff

precip









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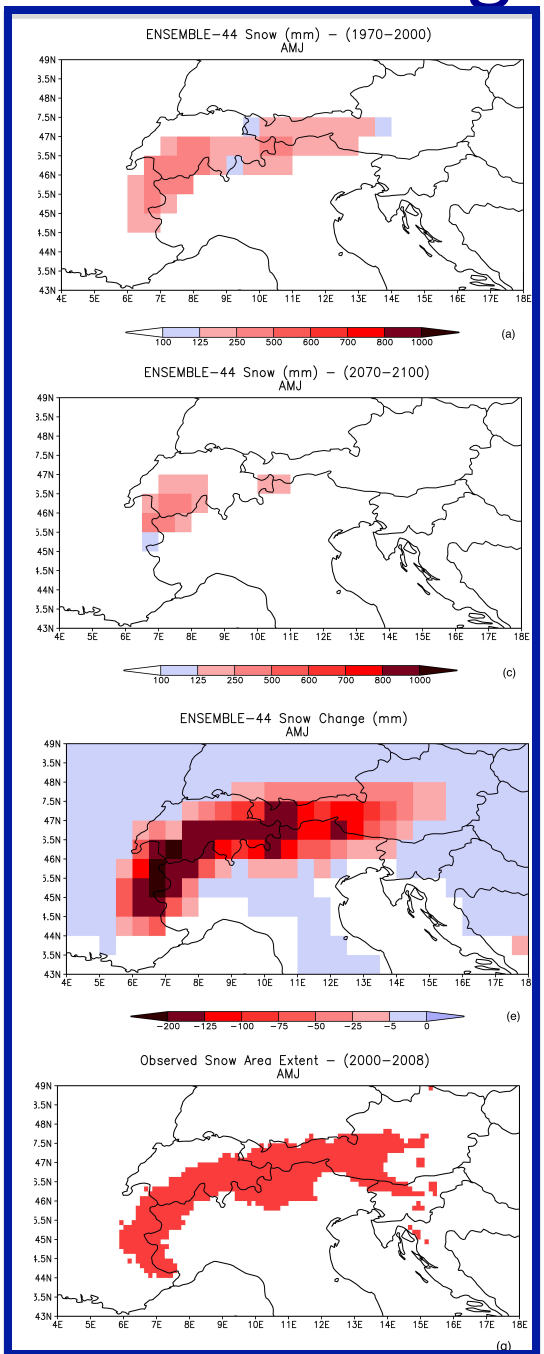
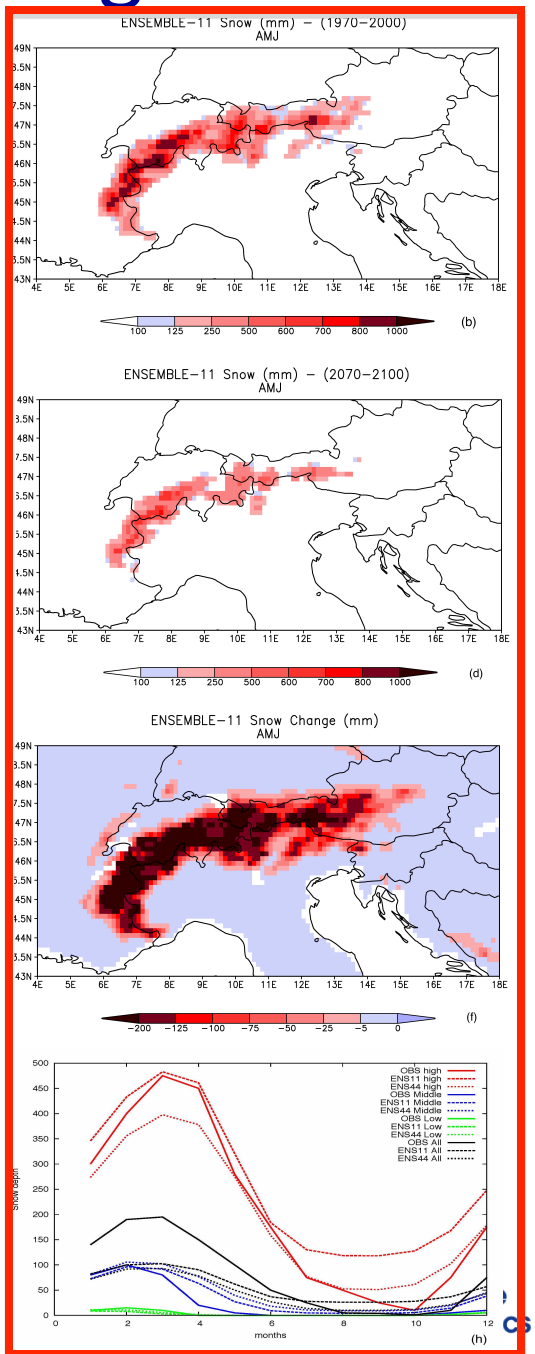
Impacts - SDR change signal-Snow change

0.44

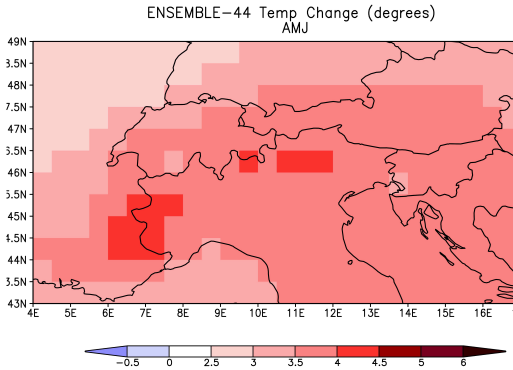


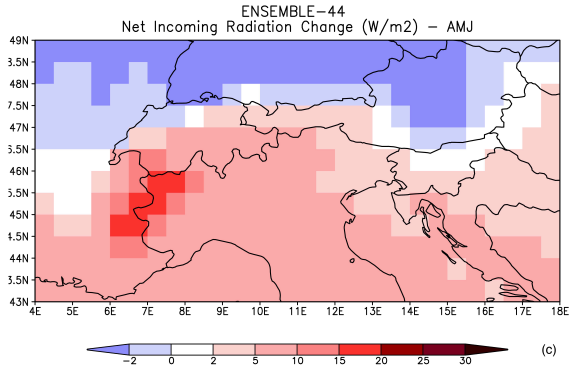


0.11

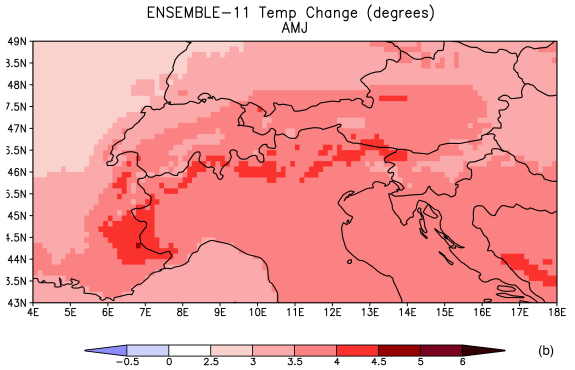
Impacts - SDR change signal- Temperature and Net surface shortwave radiation change

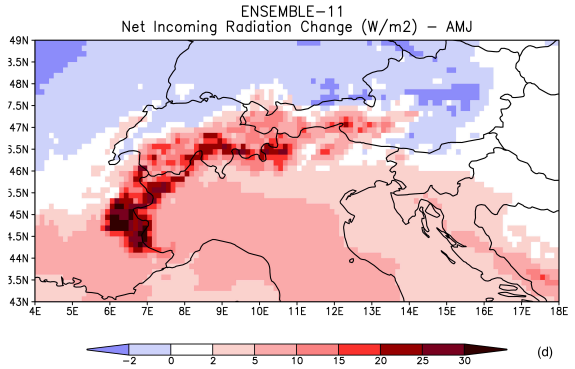
0.44





0.11





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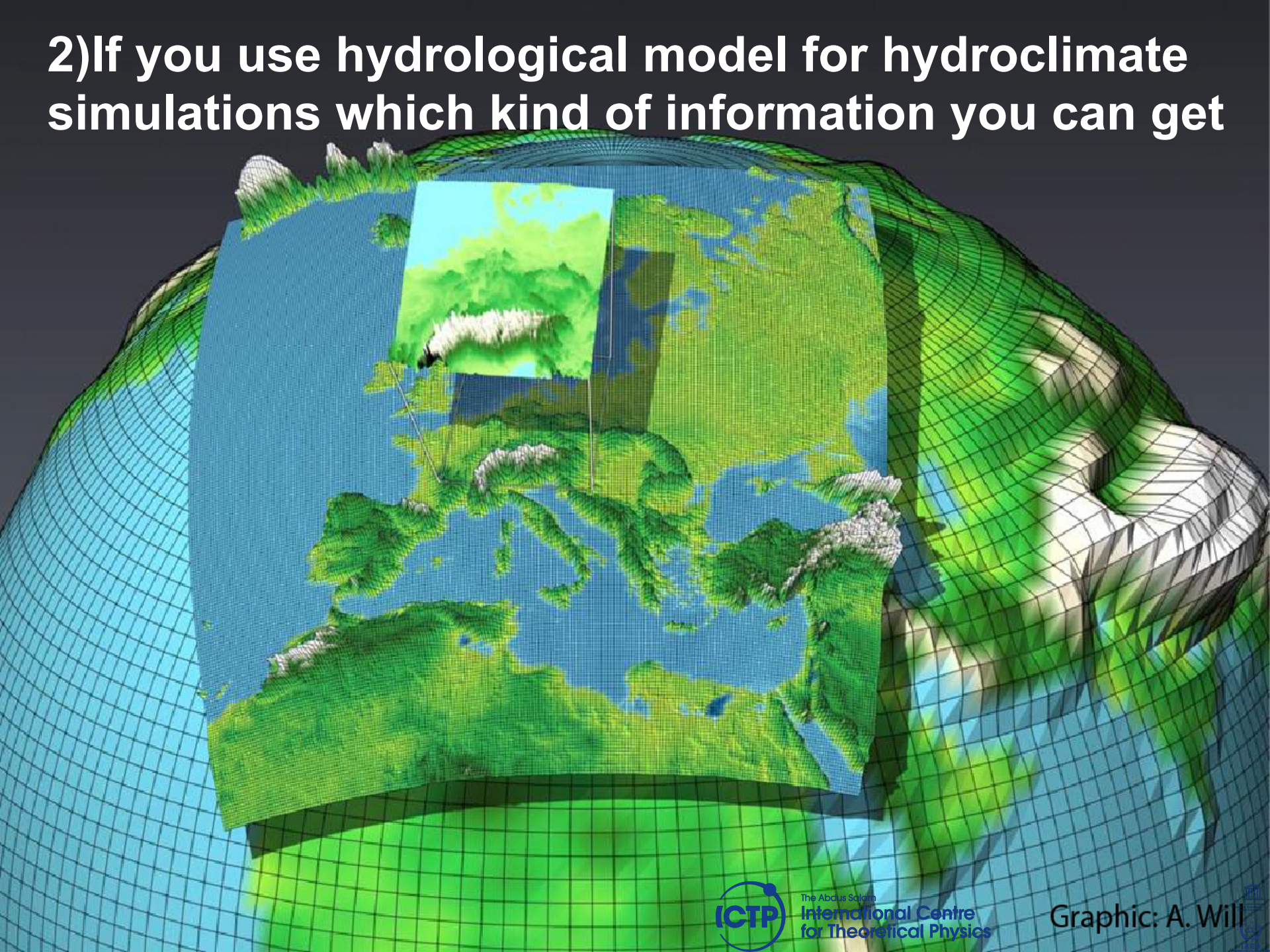
2)If you use hydrological model for hydroclimate simulations which kind of information you can get



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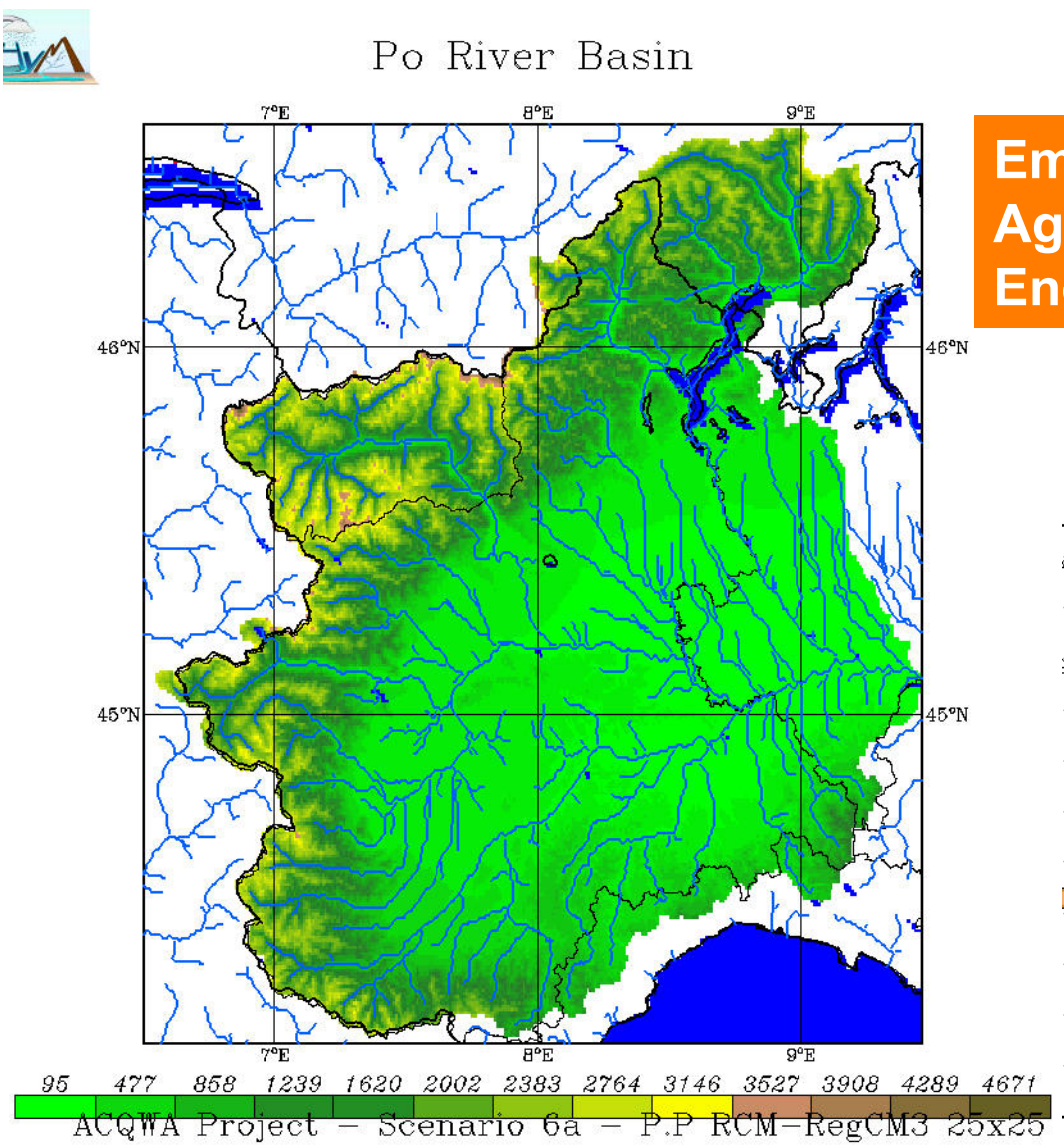
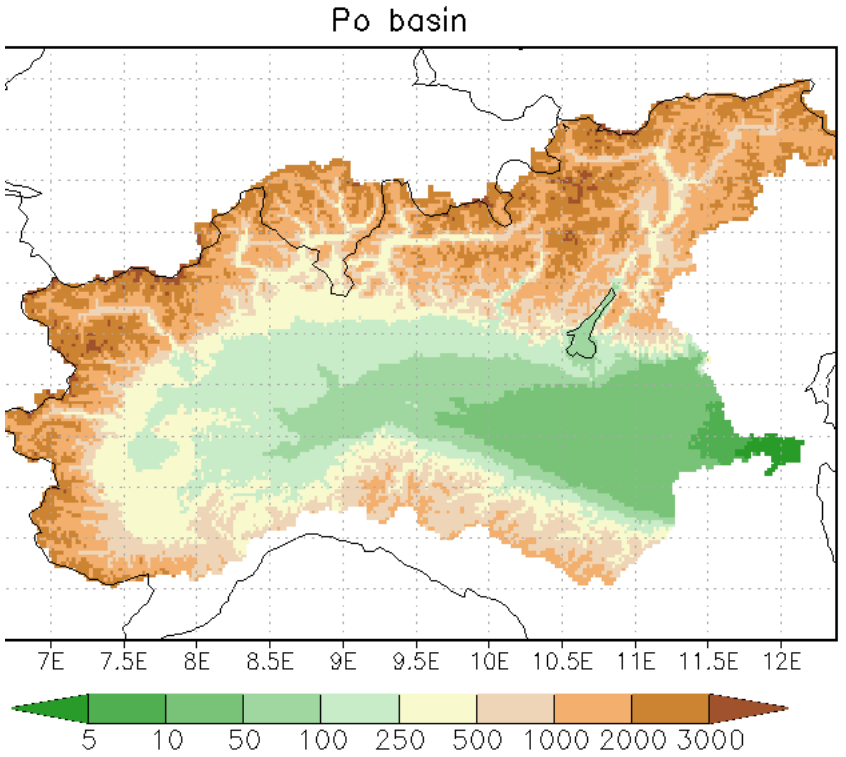
Graphic: A. Will



Employment	46%
Agricultural production	35%
Energy consumption	48%



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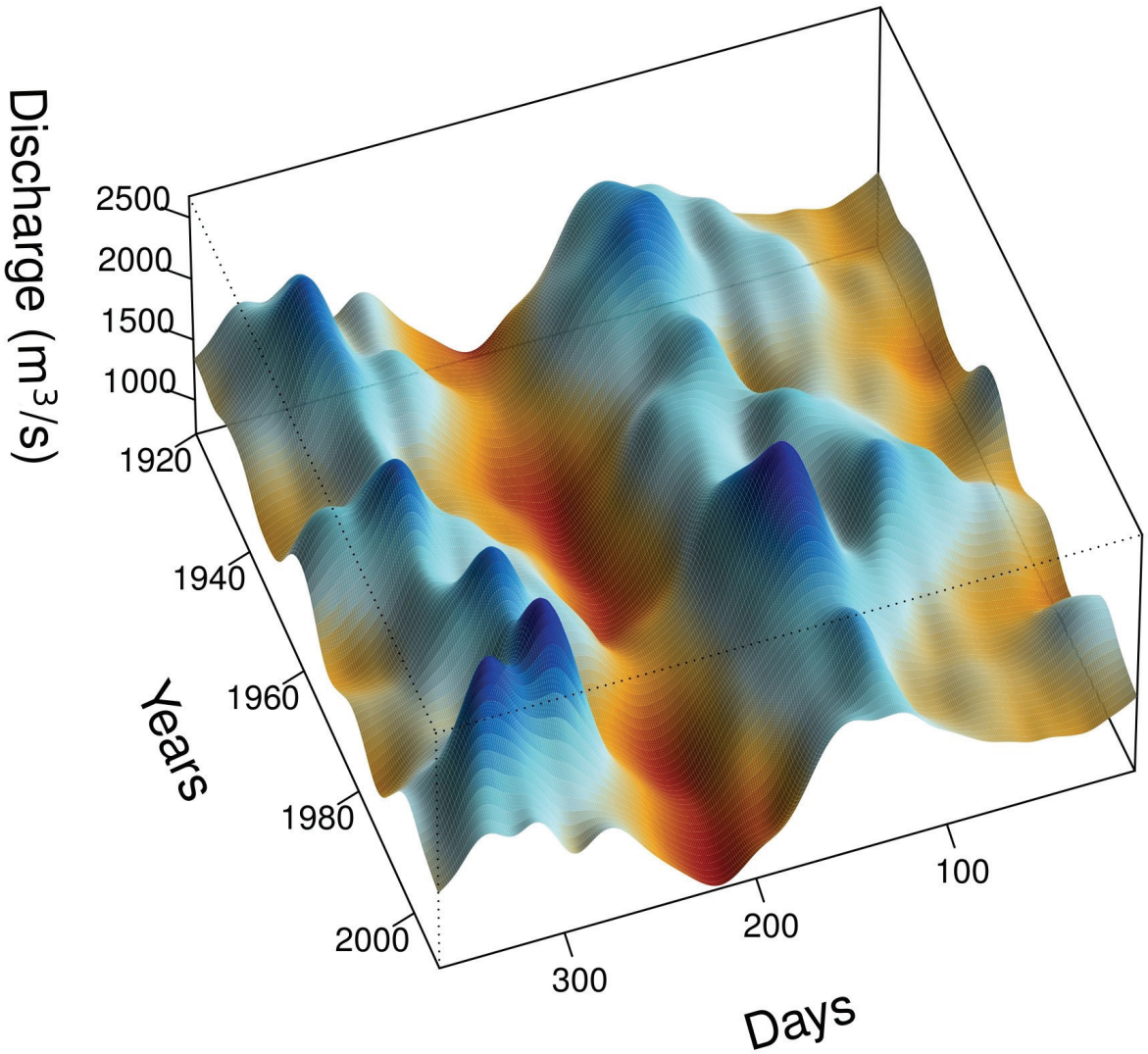
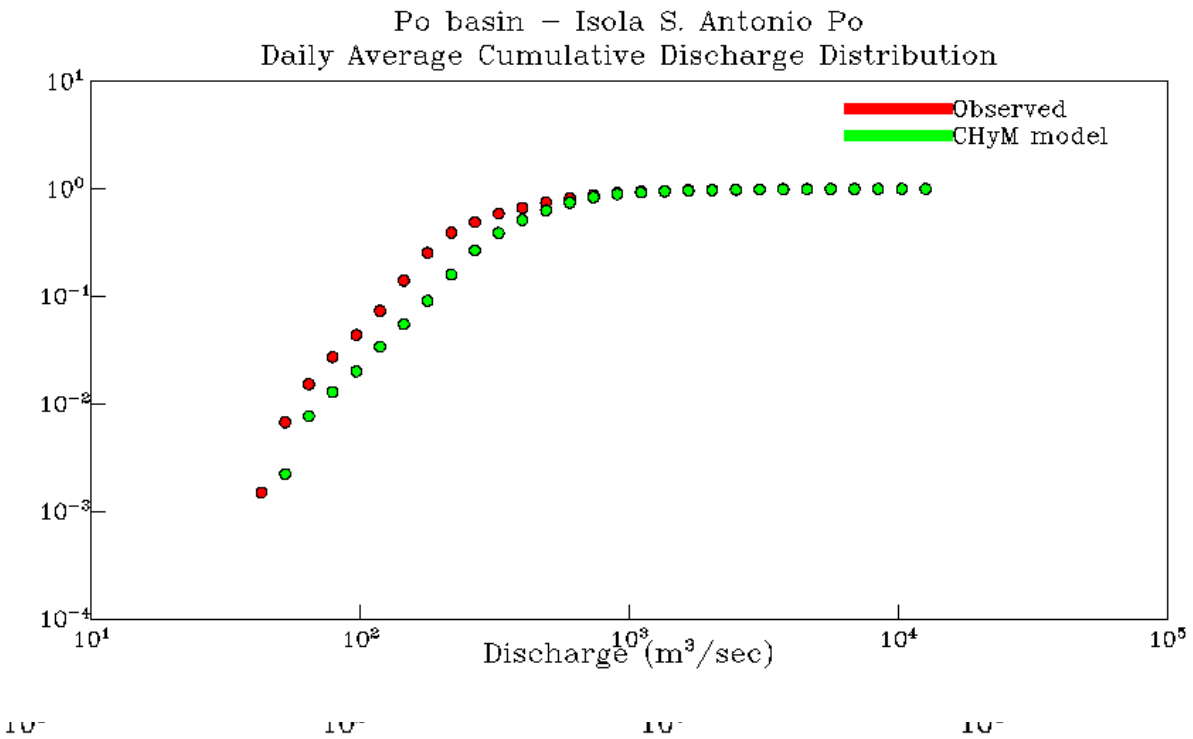
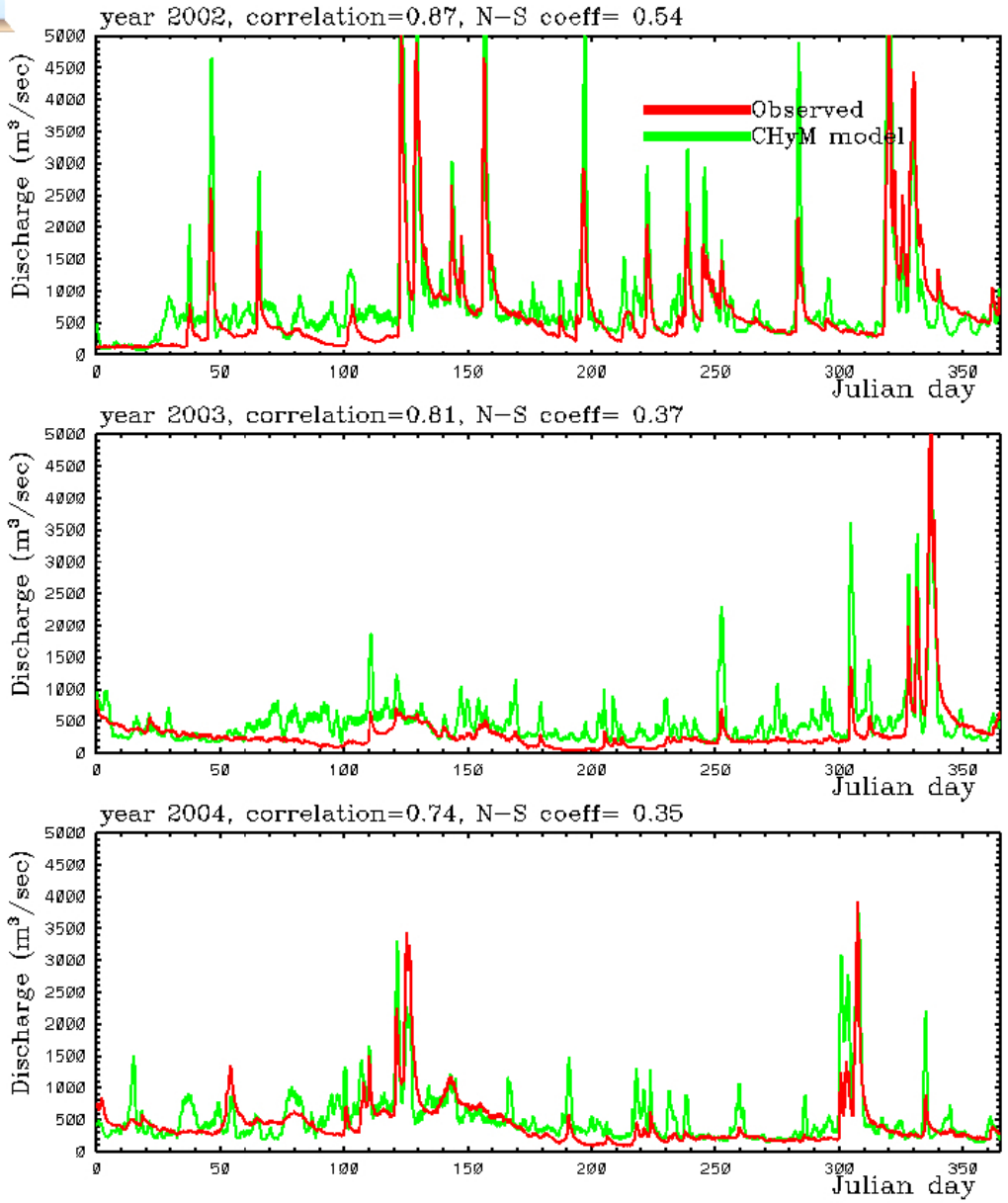


Montanari A., 2012





Isola S. Antonio Po (45.0379°N-8.8230°E)

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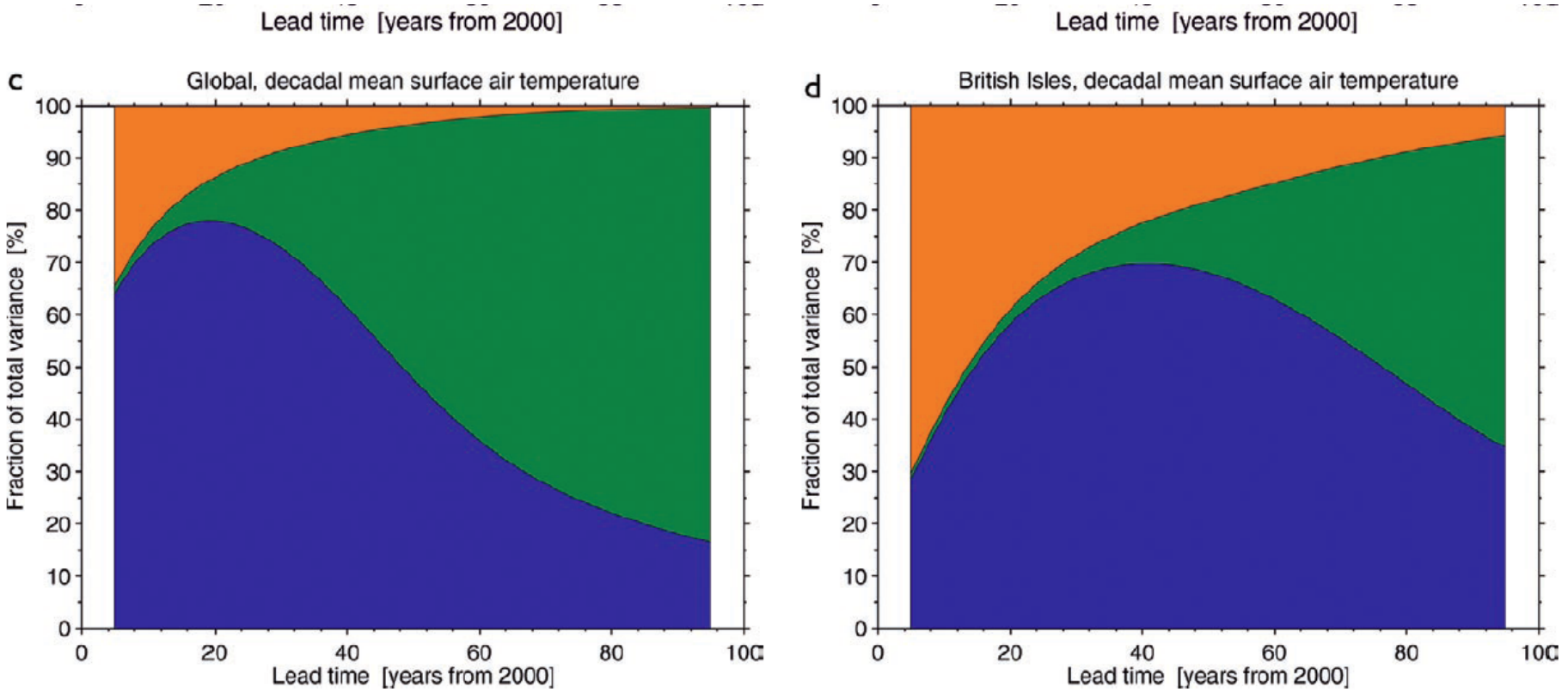
Relative Importance of Sources of Uncertainty on Decadal Surface Temperature



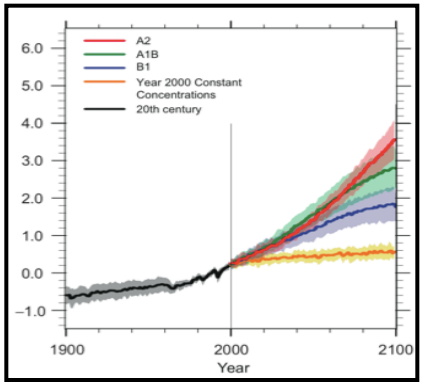
Climate internal variability

Climate models

Emissions scenarios

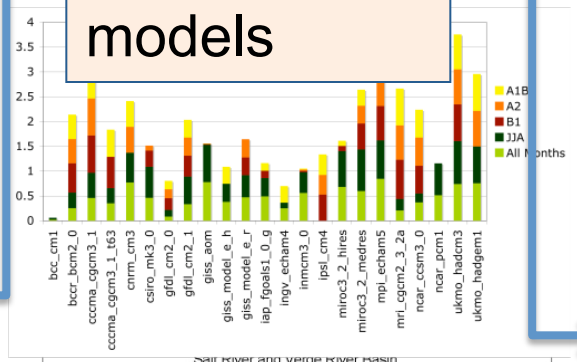
Hawkins and Sutton, BAMS 2009

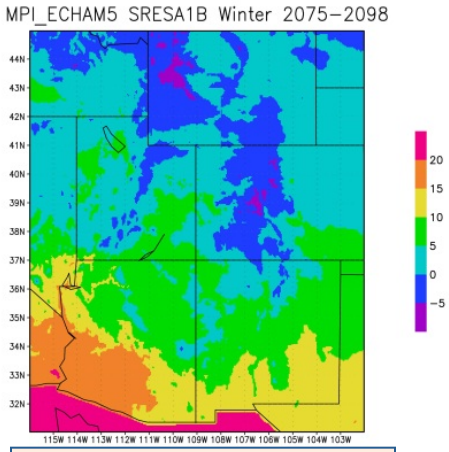
Model Chain: More Isn't Always More Certain



IPCC AR4 GCM projections

Select the "best" models



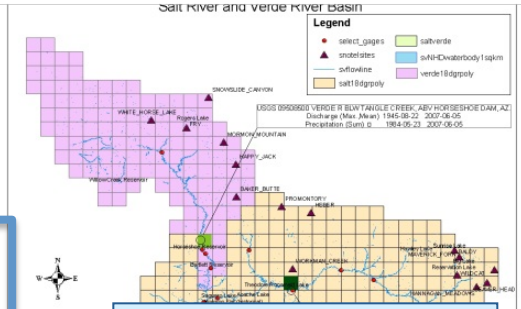


Spatial Downscaling

From approx. 200 km to 4 km.

Temporal Downscaling

From Seasonal to Daily



Hydrologic models

Hydrologic projections at watershed scale.

Water Management Models

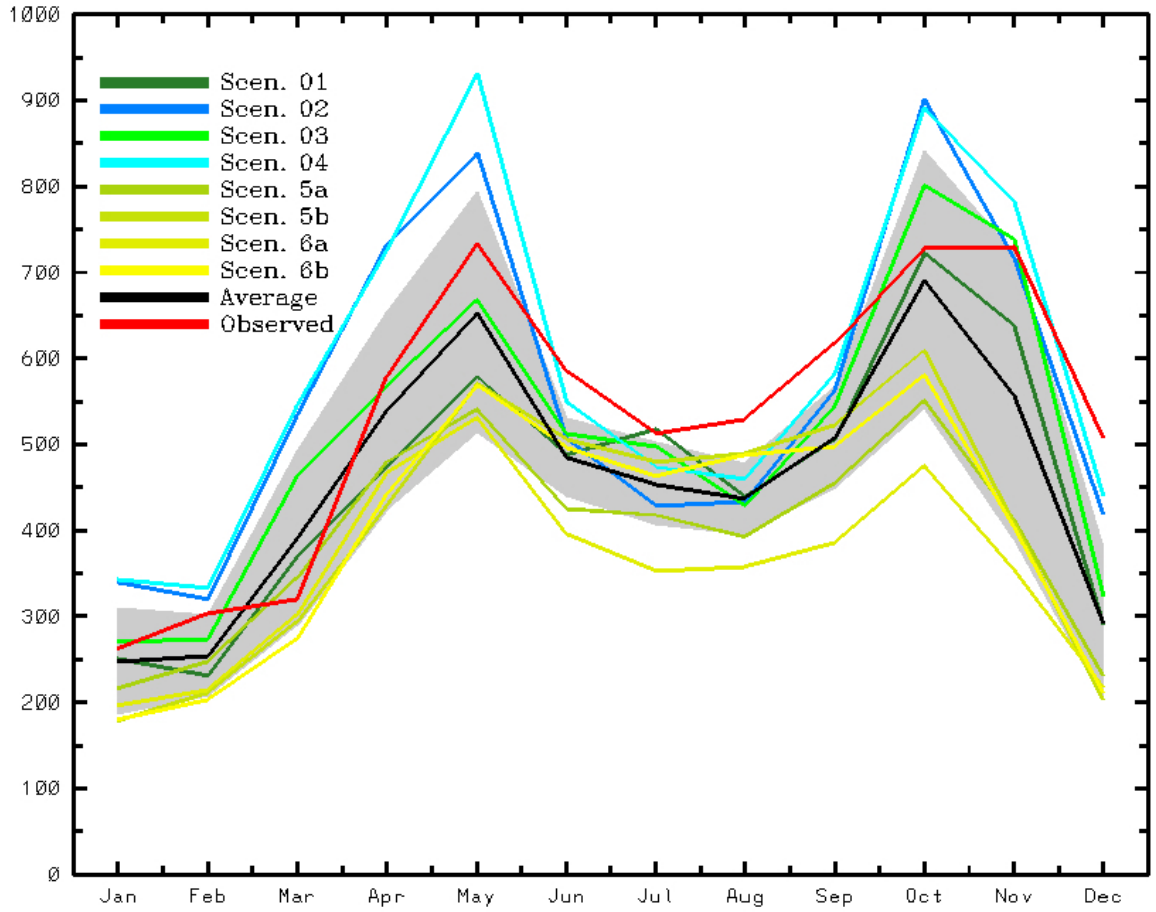
Evaluate Management Options

H.C. Hartmann

Scenario A1B
Time 1960-2050

Ref number of the Hydro simulation	Regional climate model simulation used as input
01	RCM-REMO 25x25 km
02	RCM RegCM 25x25 km
03	RCM REMO 10x10 km
04	RCM-RegCM 3x3 km
5a	Post processed RCM-REMO (25x25 km)
5b	Post processed RCM-REMO (10x10 km)
6a	Post processed RCM-RegCM3 (25x25 km)
6b	Post processed RCM-RegCM3 (3x3 km)

Monthly average discharge (m^3/sec) 1960–1990



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Coppola, et al., 2014

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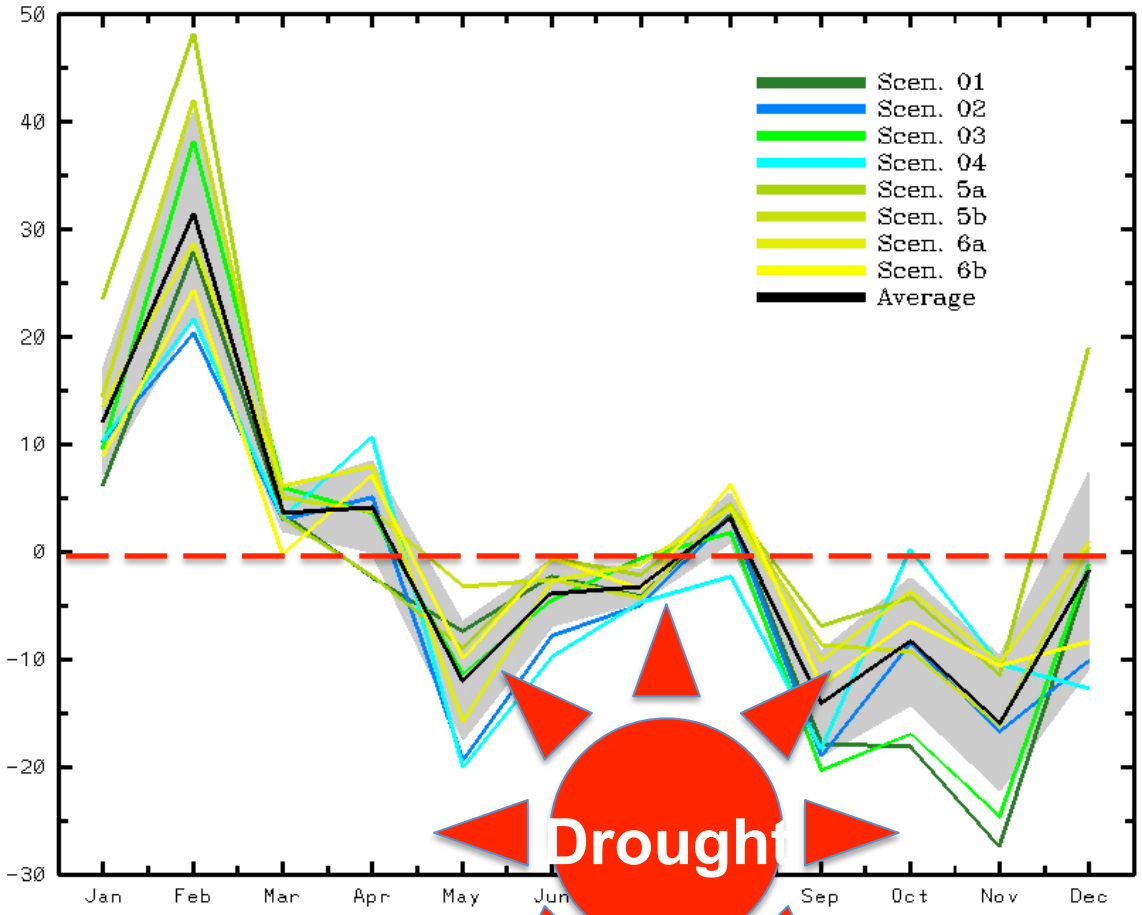
Discharge differences (%) 2020/2050−1960/1990



Isola S. Antonio Po (45.0379°N−8.[illegible]30°E)

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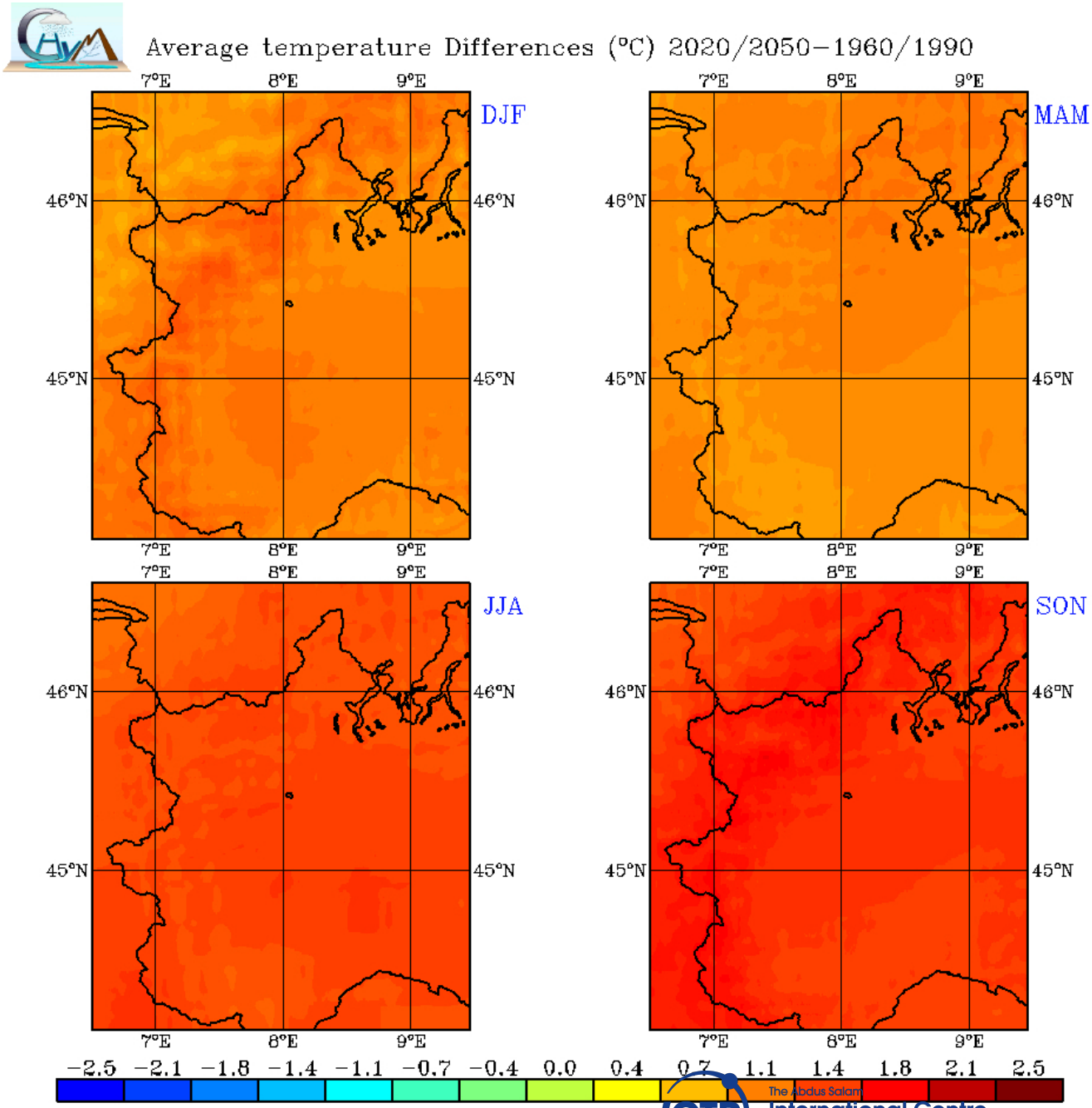
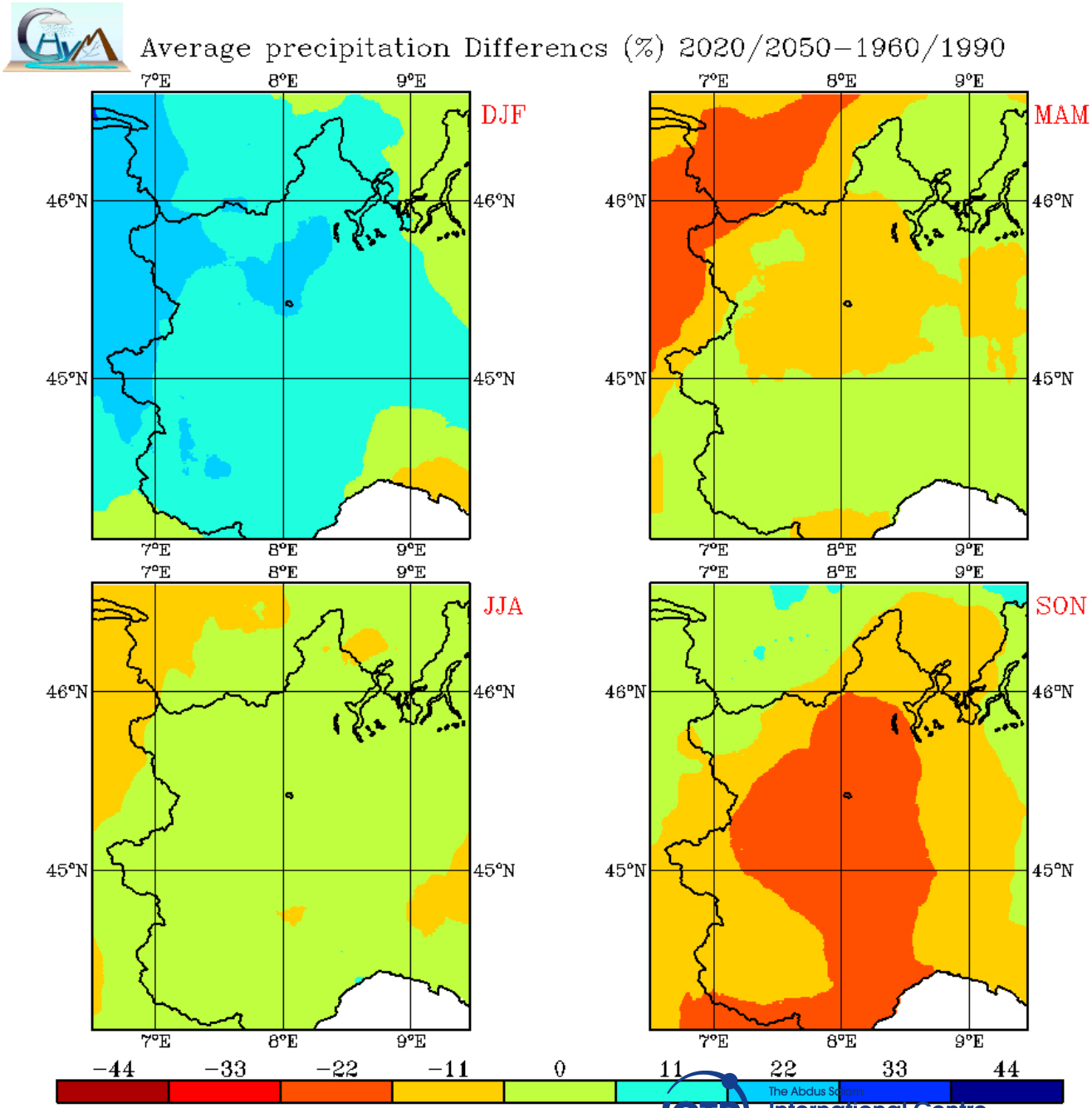
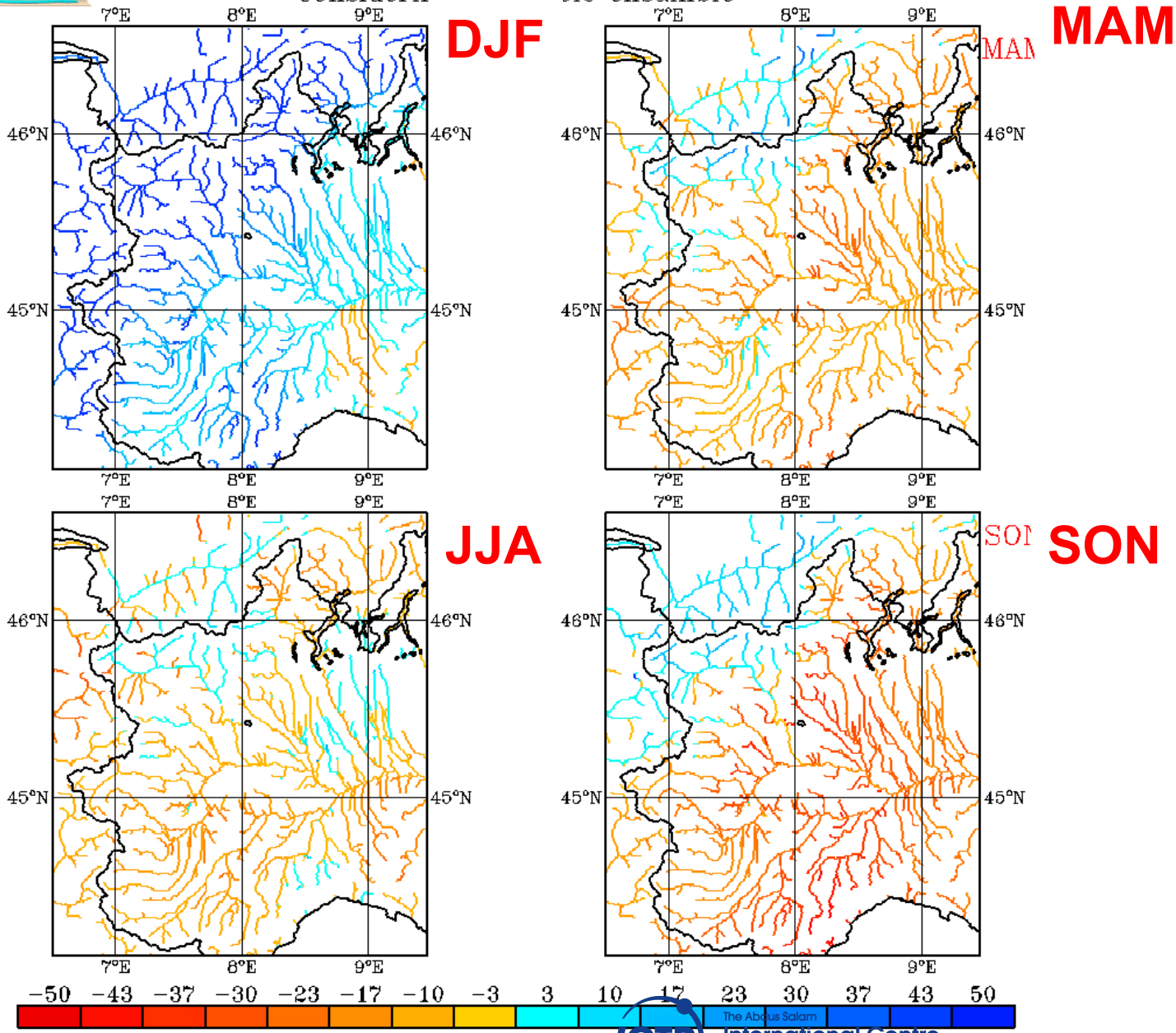




Discharge average variation (%) 2020/2050−1960/1990

considering the whole ensamble



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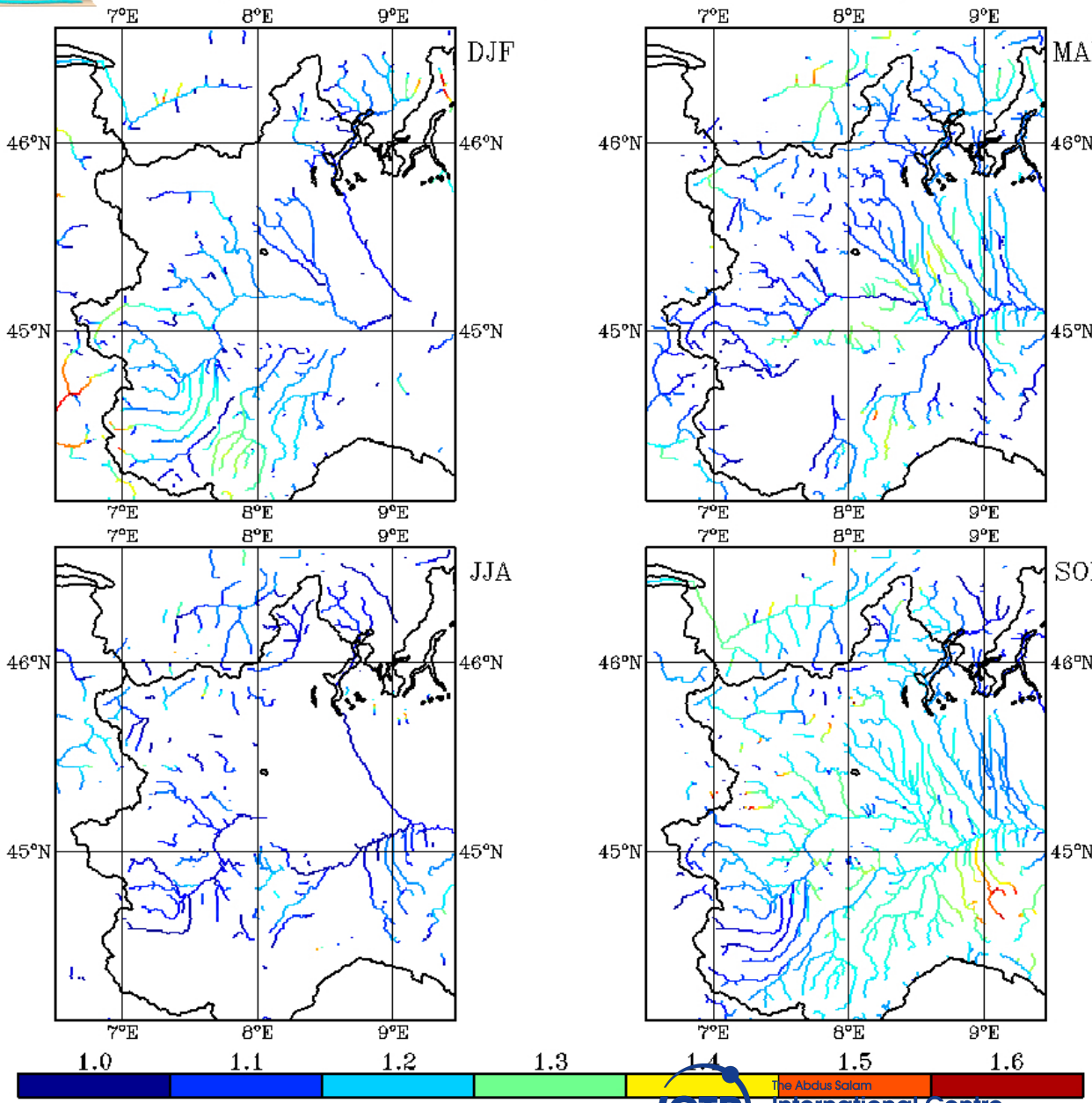
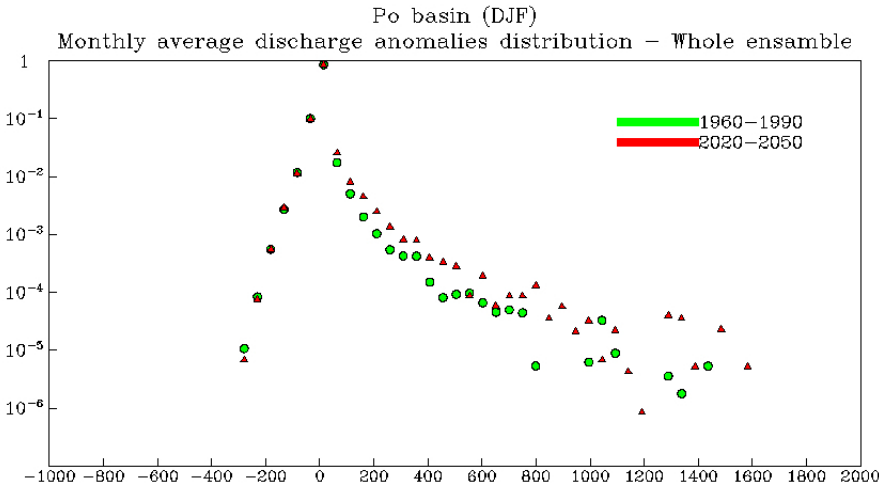
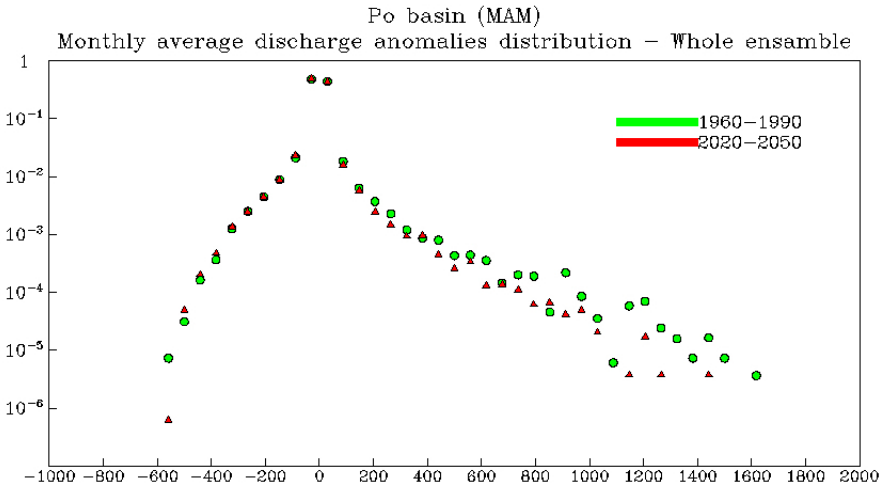
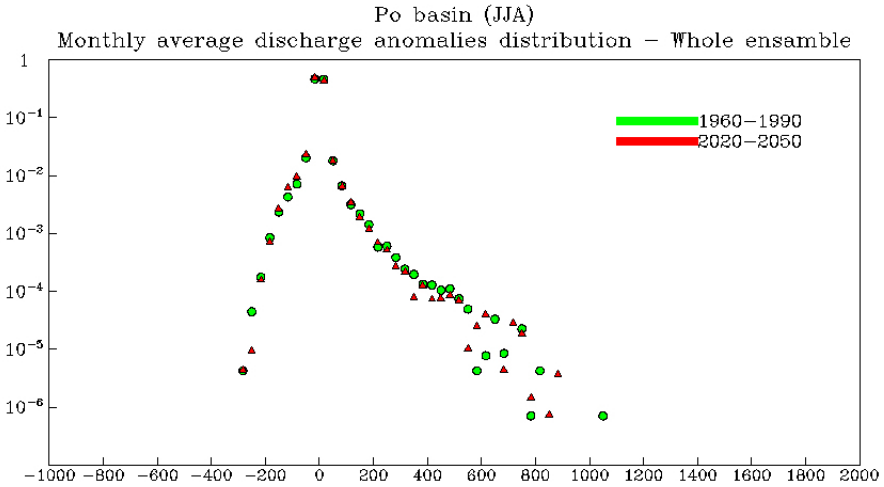
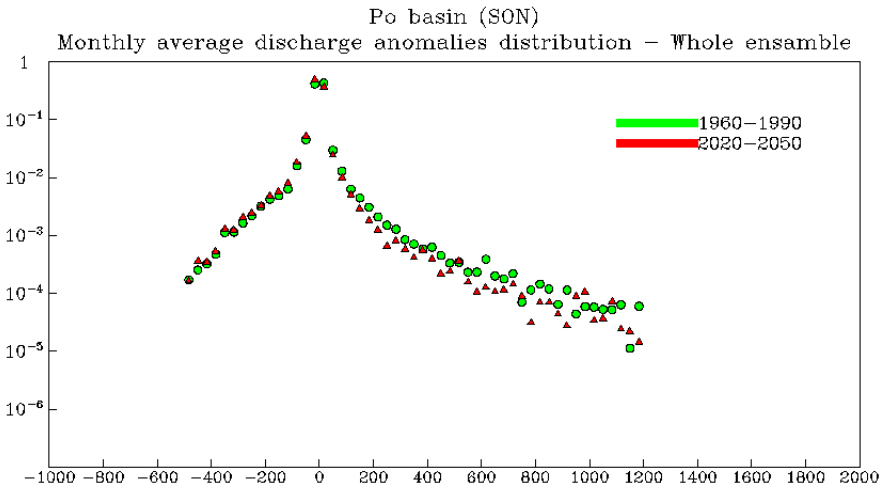











1)What next?

Convection Permitting and Climate

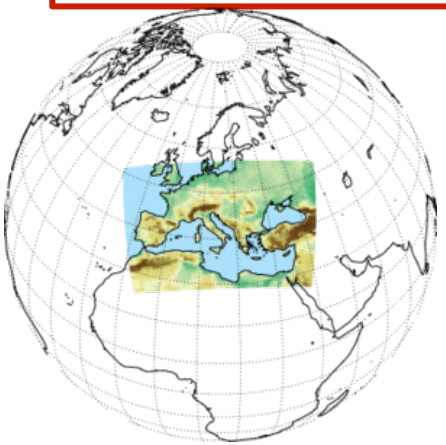
Convection Permitting and Climate

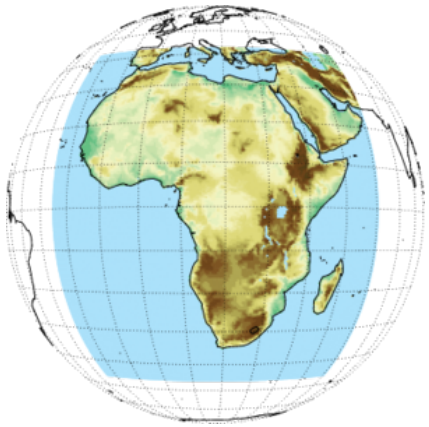
Climate activities at convection permitting scale

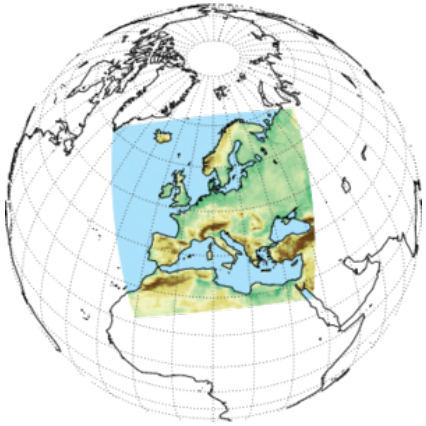
World wide project so far …

WCRP CORDEX
FLAGSHIP PILOT STUDIES

EUCP
European Climate Prediction system







a) **FPS-CPS** (**Euro-Mediterranean**)

b) **FPS-CPS** (**ELVIC** – Climate Extremes in the Lake Victoria Basin)

c) **EUCP** (**European Climate Prediction System**)

d) **FPS-CPS** South America (**La Plata**)

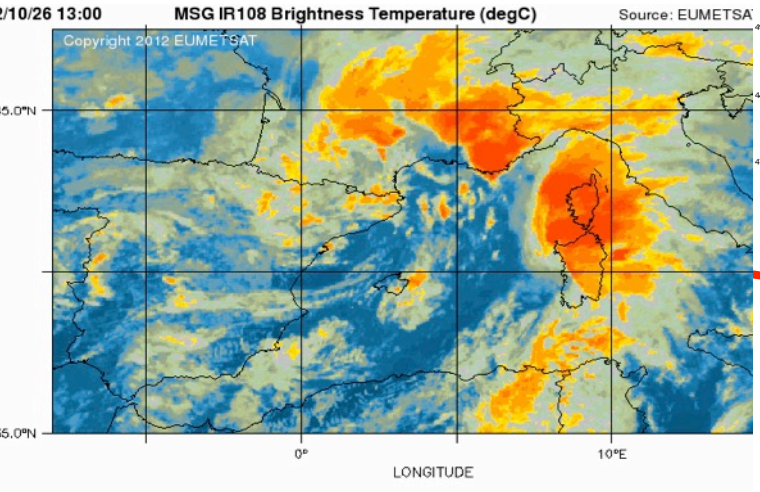
Where we are

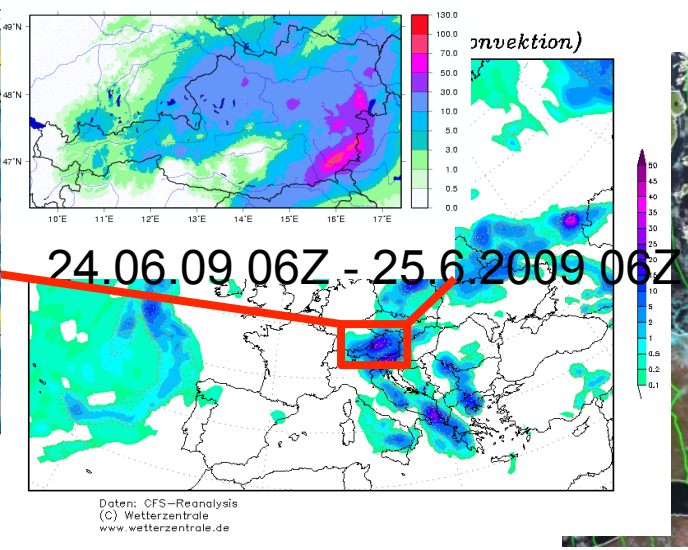
Up to date research work show that convection-permitting models do not necessarily better represent daily mean precipitation [*e.g., Chan et al. 2013, Berthou et al., 2018*] but have significantly better sub-daily rainfall characteristics with improved representation of the:

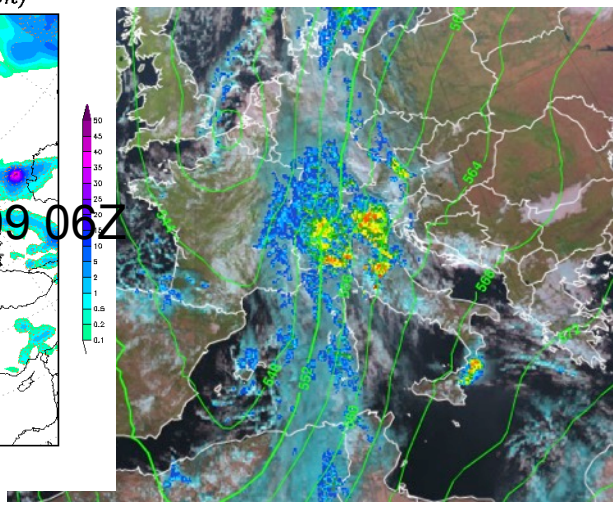
- **Diurnal cycle** of the amount, intensity and frequency of precipitation (*Ban et al. 2014, Kenond et al. 2012, Langhans et al. 2013, Prein et al., 2013, Fosser et al., 2014, Berthou et al., 2018*)
- **The spatial structure** of rainfall and its **duration-intensity** characteristics (*Kendon et al, 2012, Berthou et al., 2018*)
- **Intensity of hourly preciptiation extremes** (*Chan et al. 2014 Ban et.al 2014 Fosser et al. 2015*)
- **Orographic precipitation** (*Liu et al 2016*)

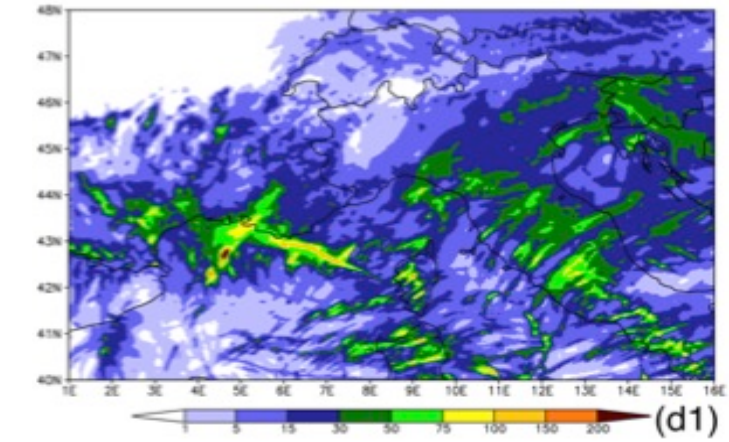
RegCM4.7.1 non-hydrostatic

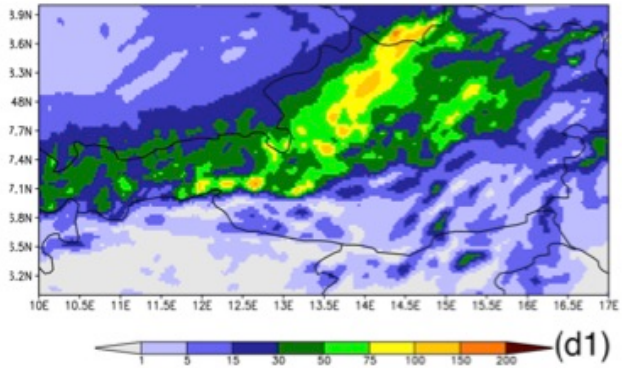
Convection permitting

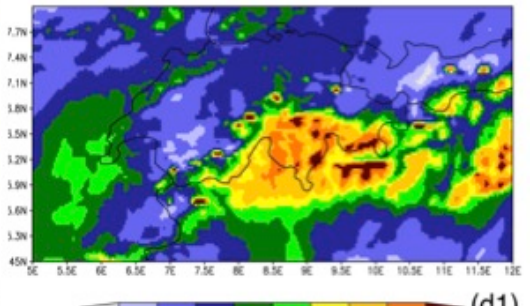












Coppolae et al, A first-of-its-kind multi-model convection permitting ensemble for investigating convective phenomena over Europe and the Mediterranean, Clim. Dyn., 10.1007/s00382-018-4521-8.

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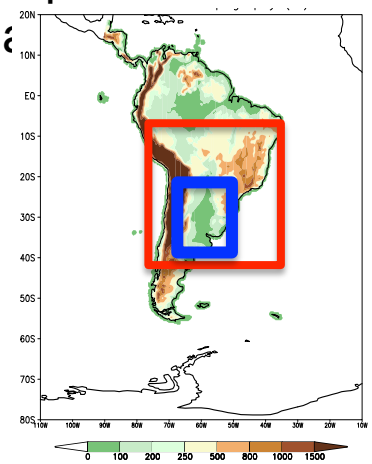
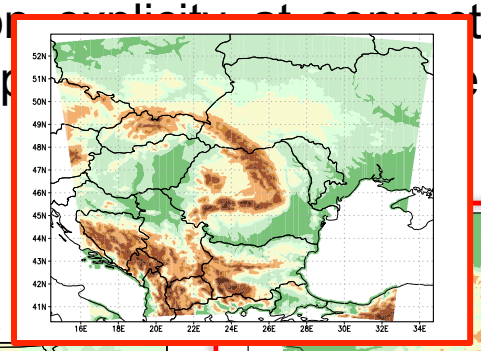
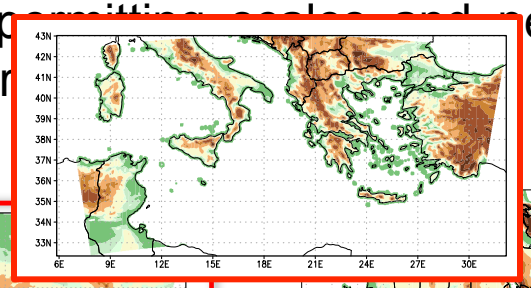
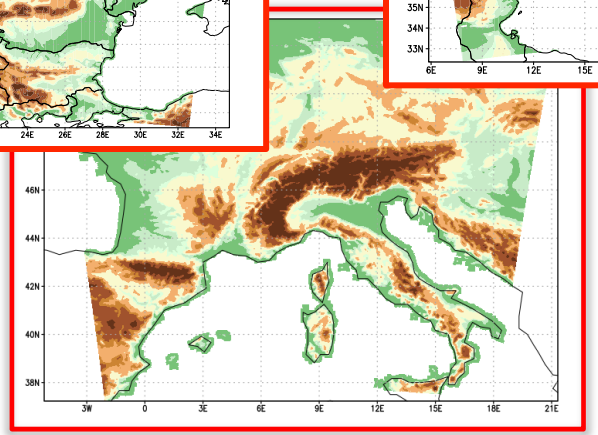
Convection permitting: Domains tested so far…

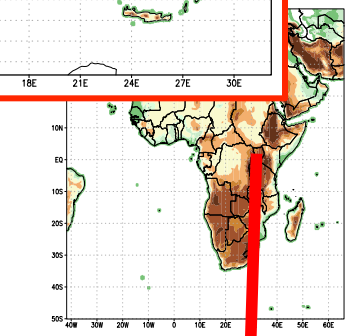
The purpuse of the work was testing the new non hydrostatic core trying to reproduce convection explicitly at convection permitting scales and perform a first

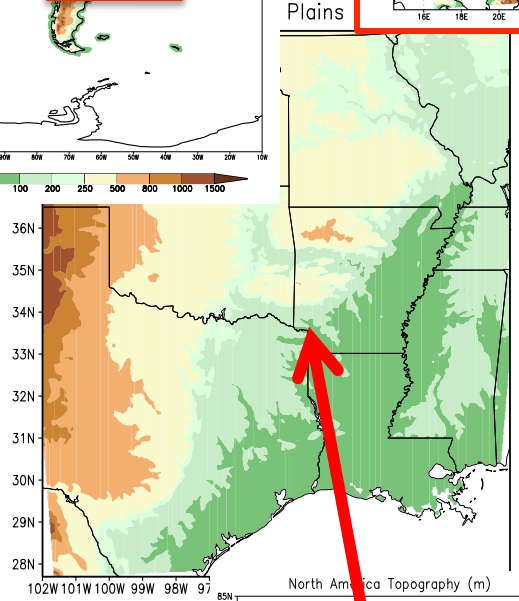


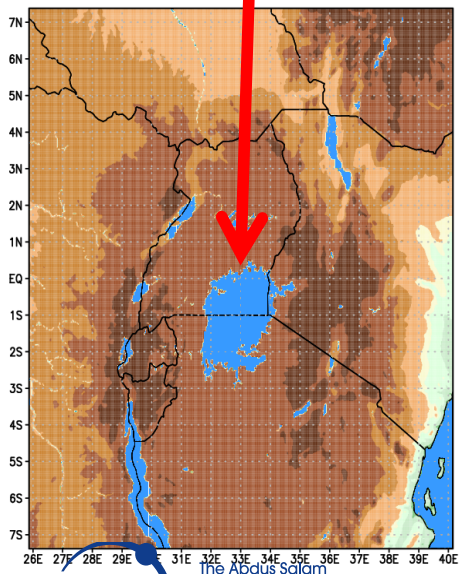


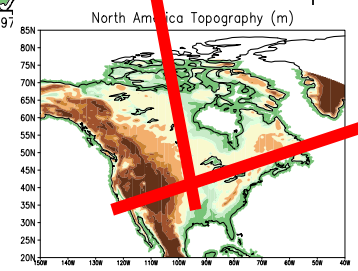


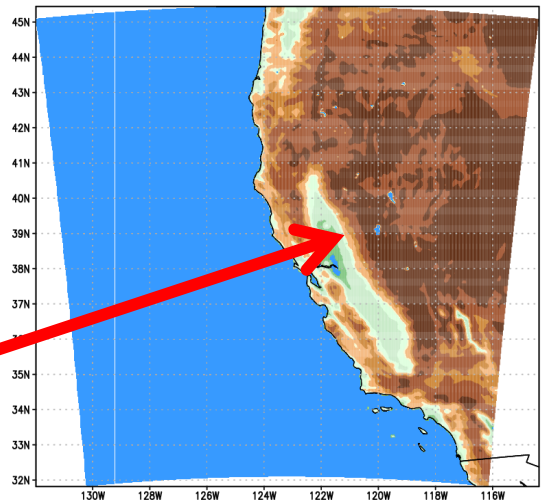












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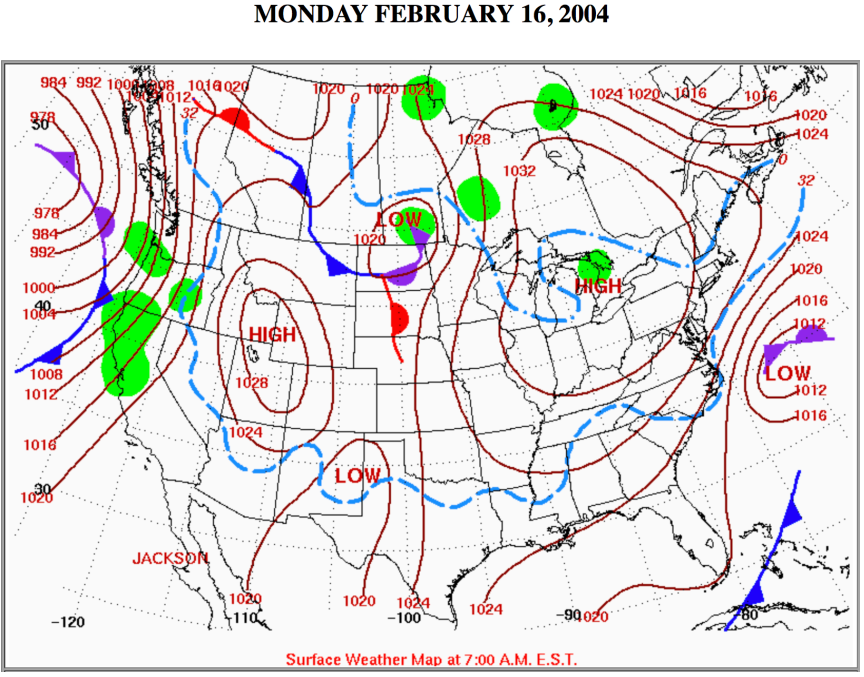
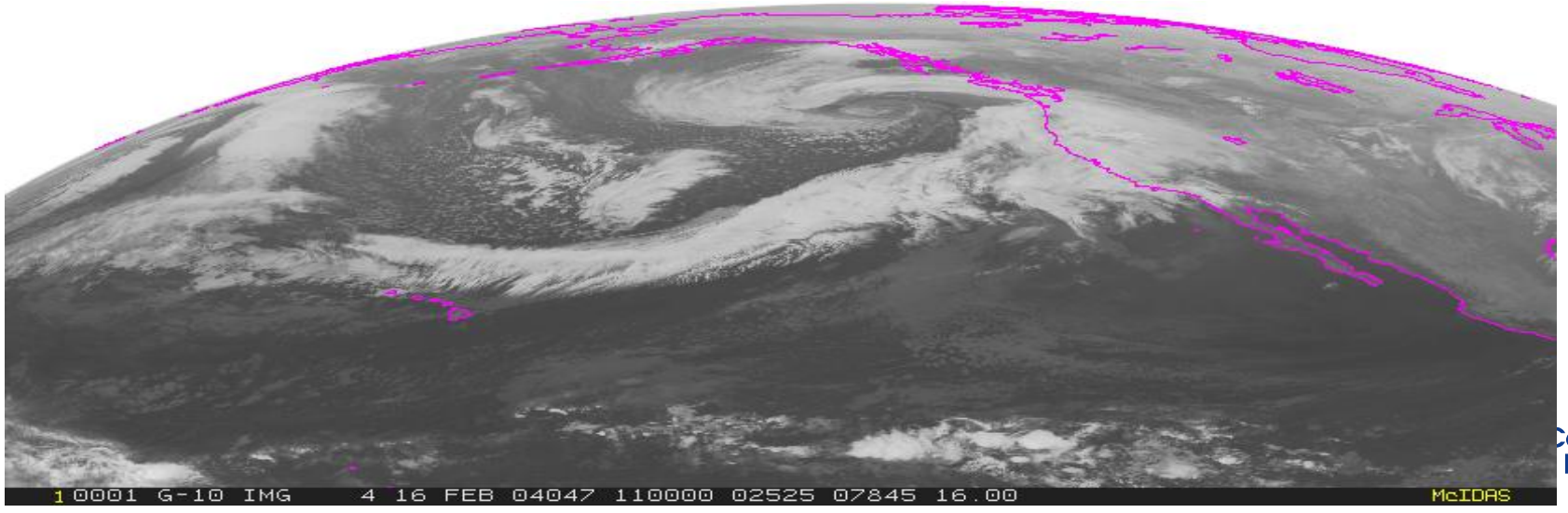
North California case : 16-18 February 2004 (*Ralph et al., 2006*)



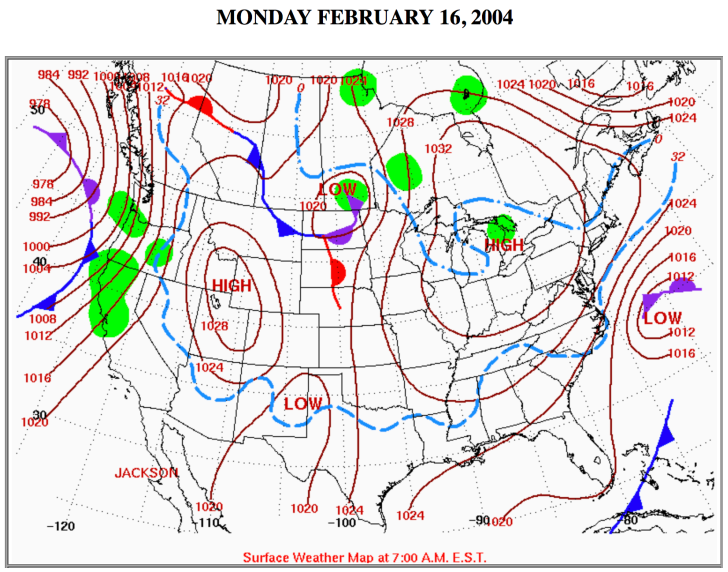
Prepared by the National Centers for Environmental Prediction, Hydrometeorological Prediction Center

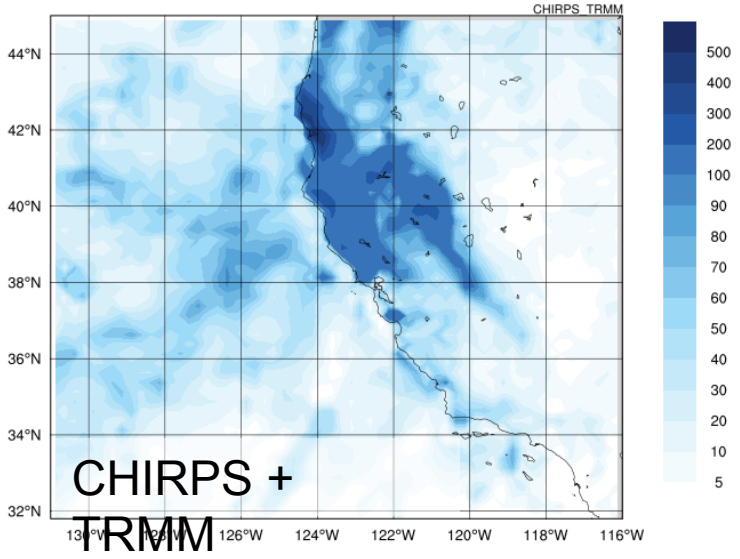


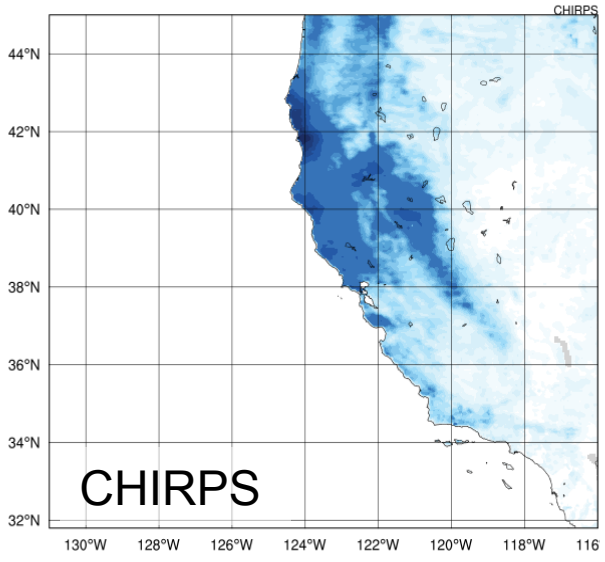
Centre
Physics

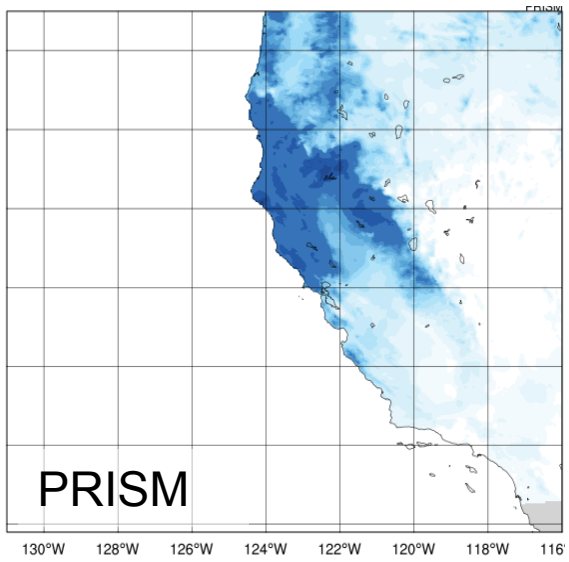
California case : Precipitation Accumulated in 96h (mm)

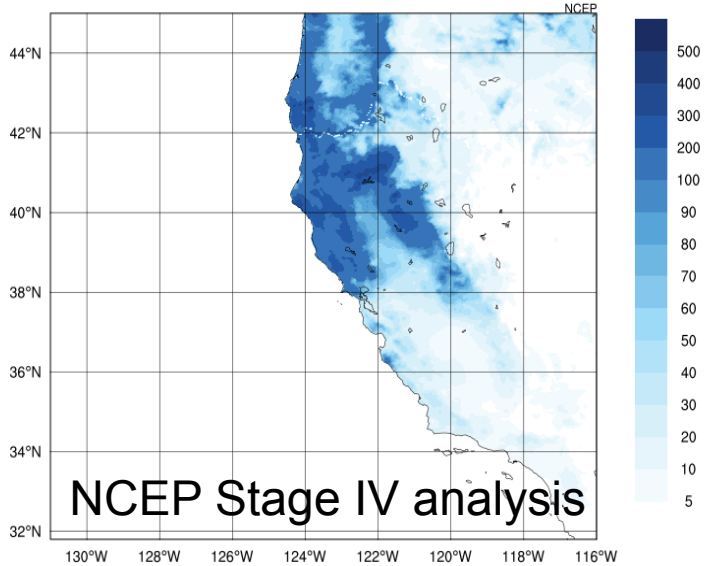
Observations



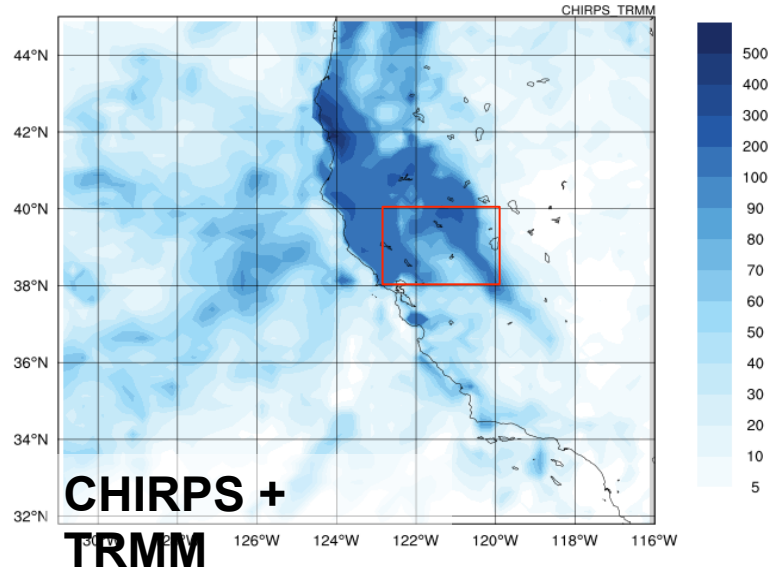


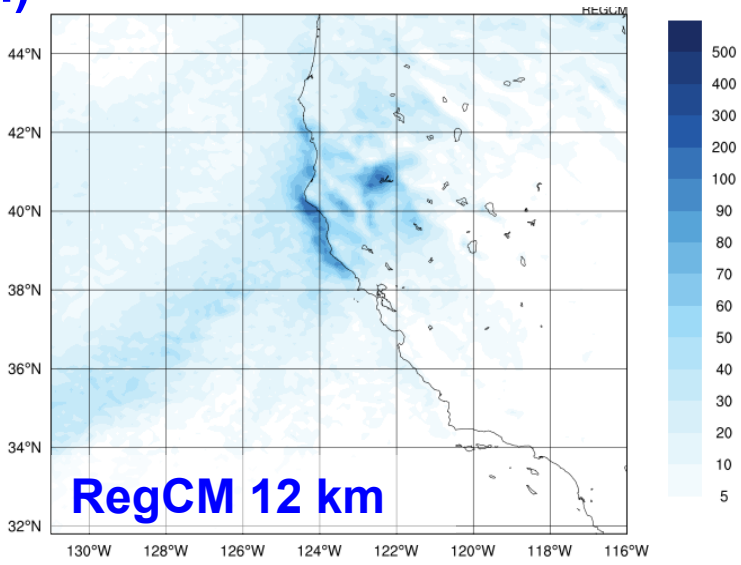


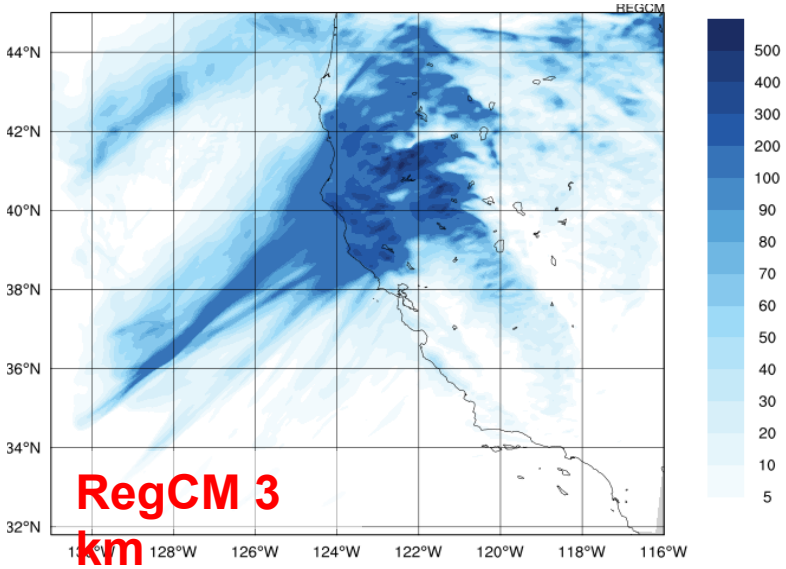


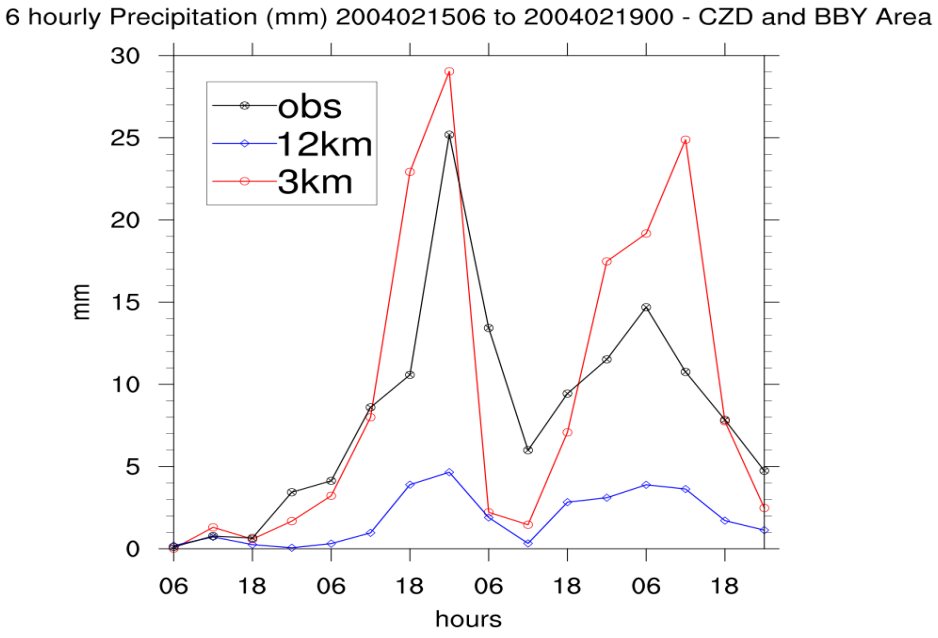


California case : OBS vs RegCM Precipitation Accumulated in 96h (mm)

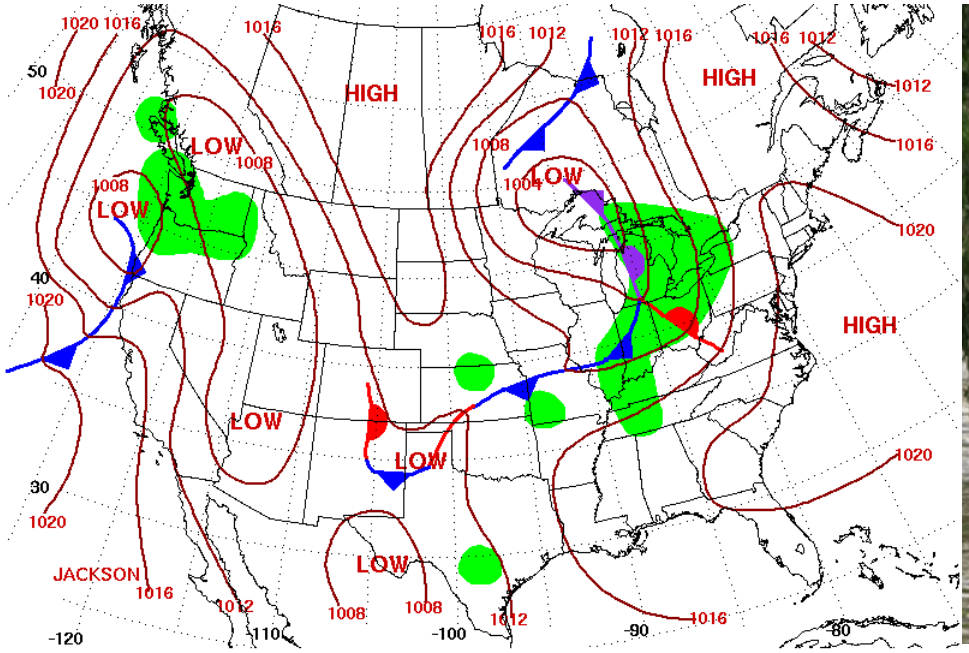






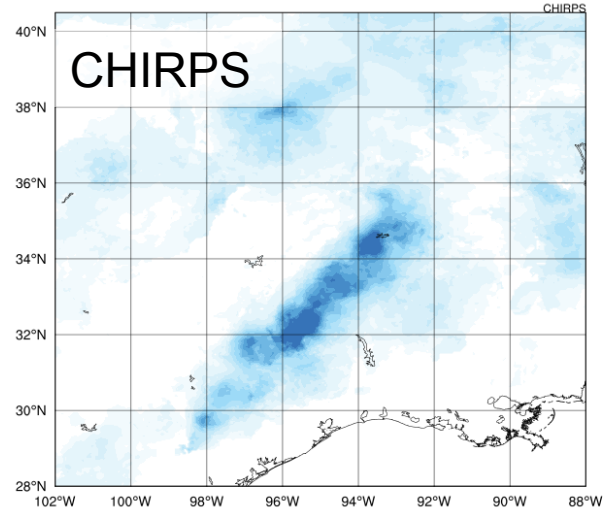


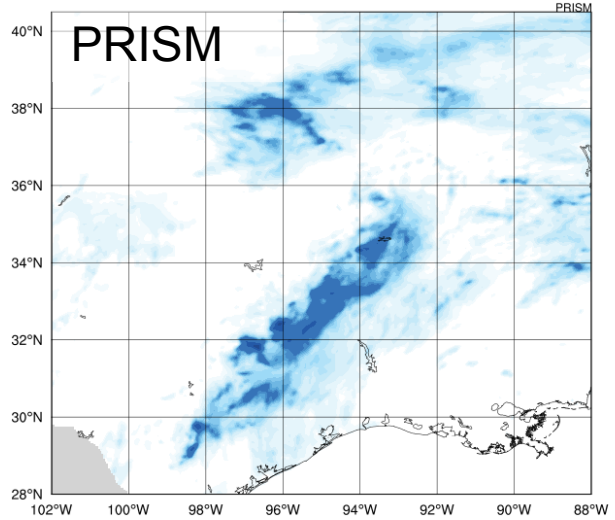
Northeastern Texas case : 9-11 June 2010 (R. W. Higgins *2011*)

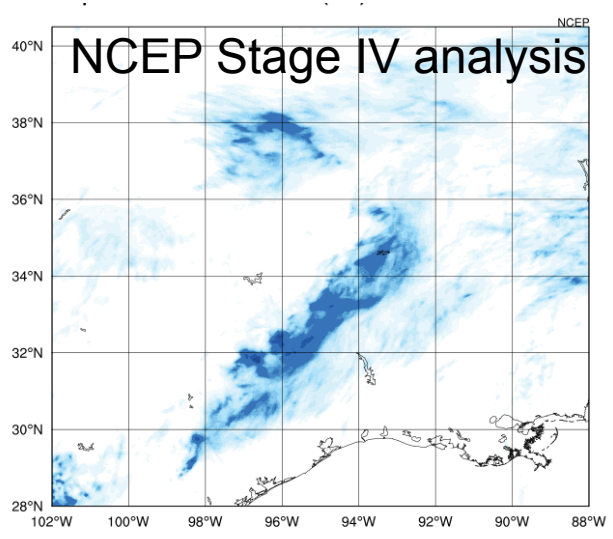


Surface Weather Map at 7:00 A.M. E.S.T.

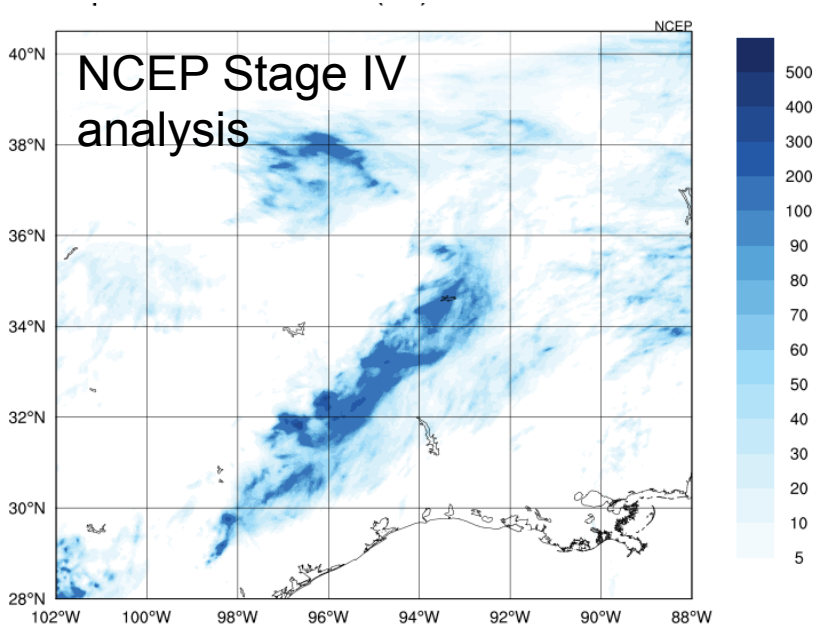
Prepared by the National Centers for Environmental Prediction, Hydrometeorological Prediction Center

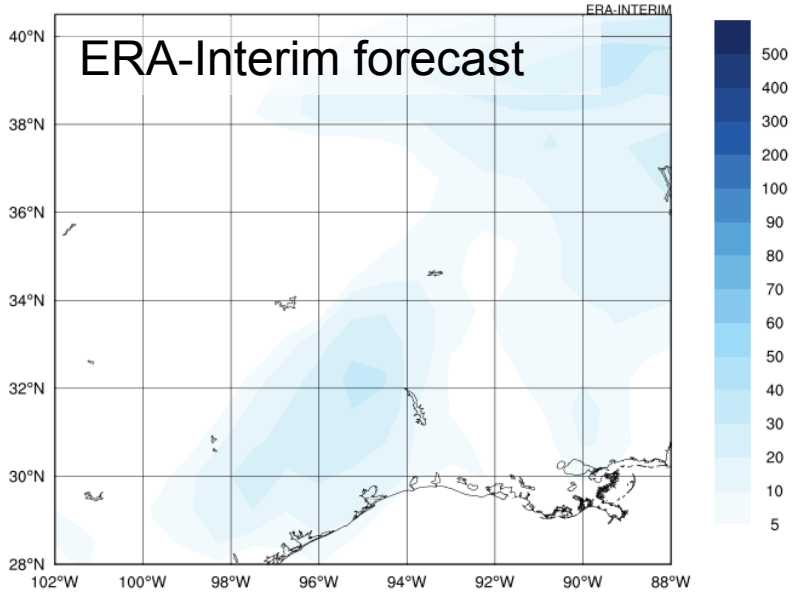


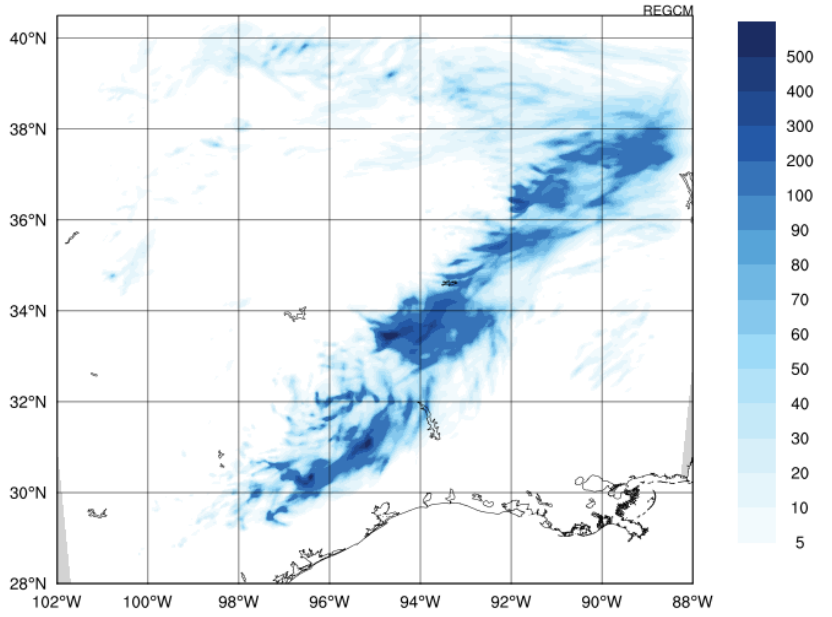


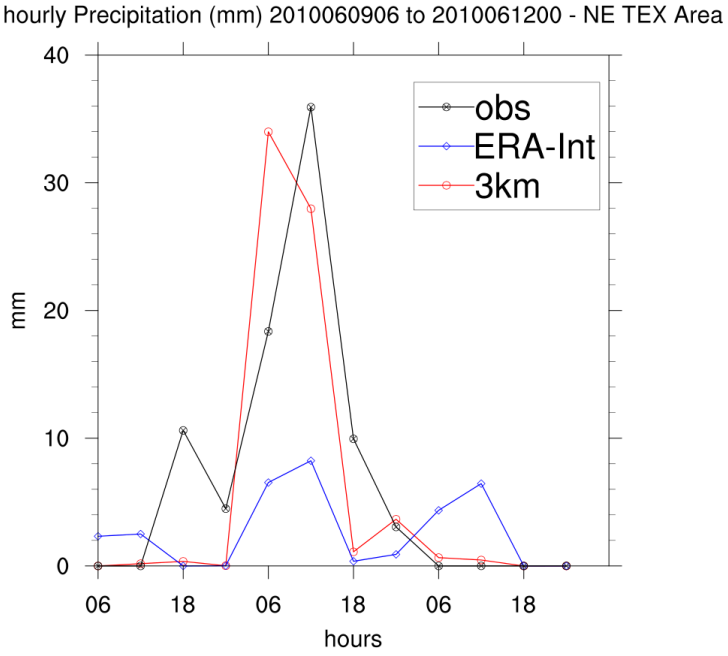


Northeastern Texas case : Comparison with RegCM
Precipitation Accumulated in 72h (mm)





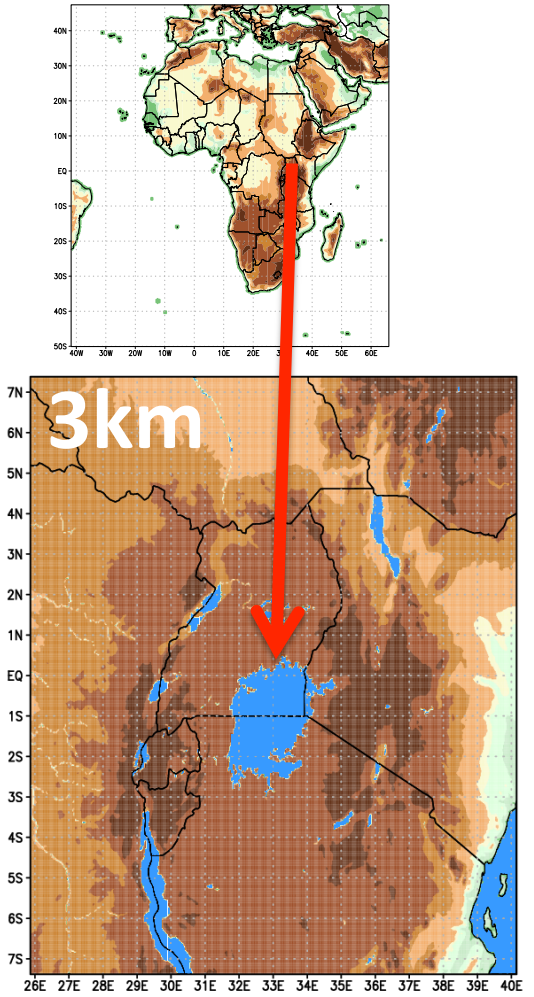




Lake Victoria case : 26-1 Dec 2009 (*SUN et. Al. 2009*)

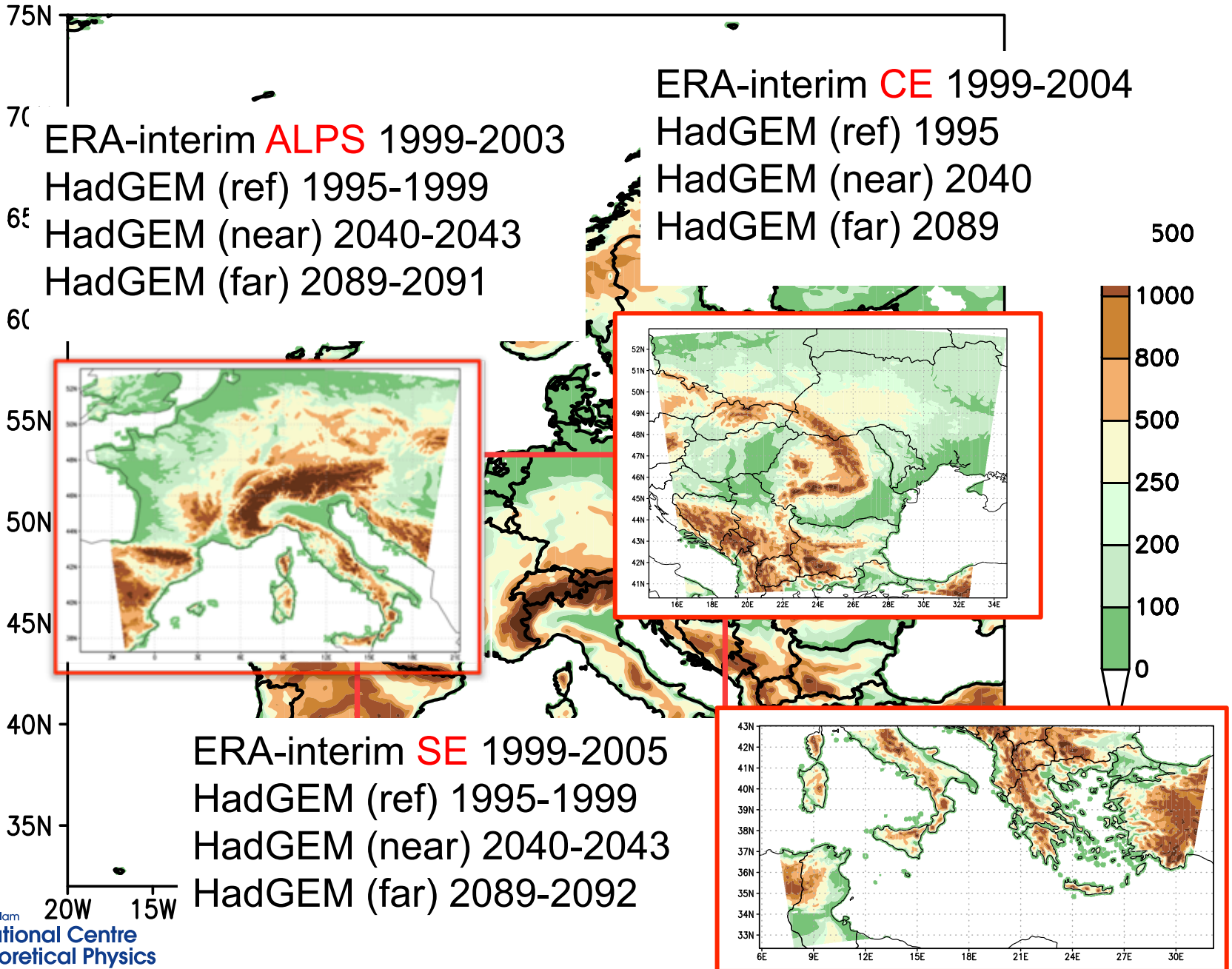
CORDEX Flagship Pilot Study (FPS) “ELVIC – climate Extremes in the Lake VICtoria basin”

A severe storm above Lake Victoria. (Photo: Tomaz Kunst / Shutterstock)

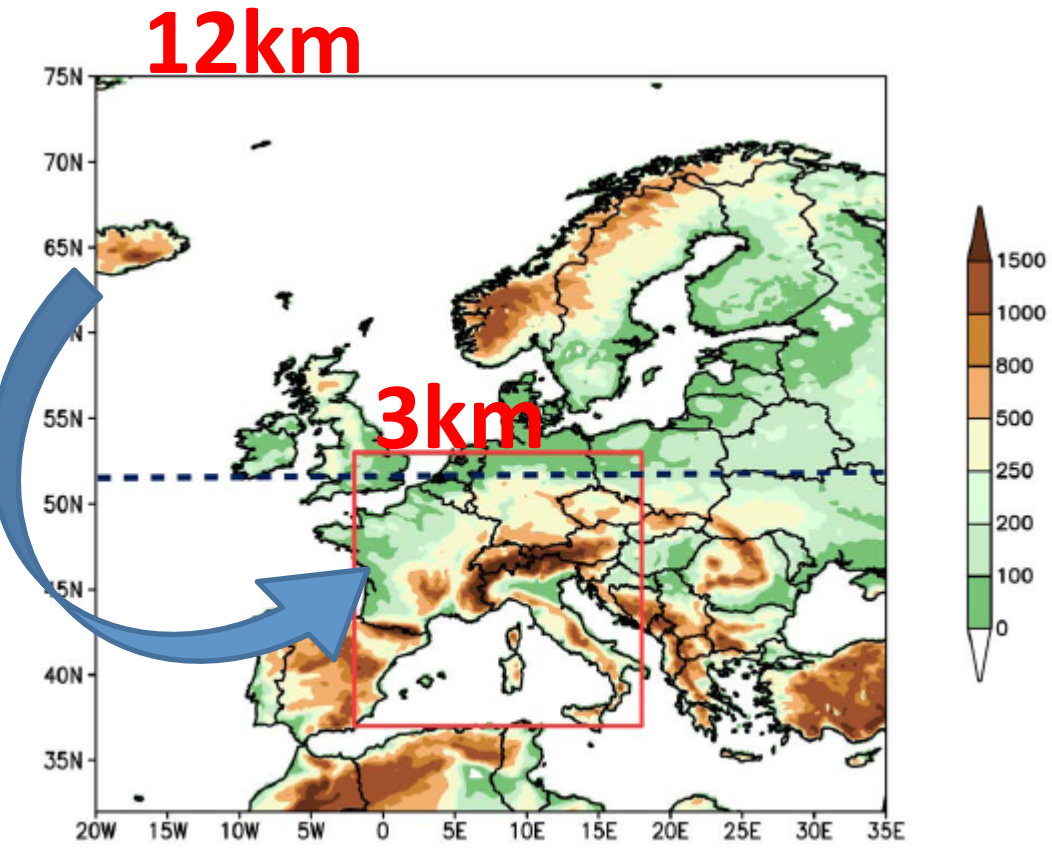


Lake Victoria can be so stormy at night because of the circulation (breezes) in the atmosphere above its enormous water surface; It is estimated that each year 3,000-5,000 fishermen perish on the lake due to nightly storms (Red Cross, 2014)

ICTP-EUCP CP domains



ICTP CP nesting strategy



RegCM	
12 Km	3 Km
Non-Hydro.	Non-hydro.
23 v-levels	41 v-levels
ERA-Int IC-BC	12KM IC-BC
530x530	575x605

The Abdus Salam International Centre for Theoretical Physics

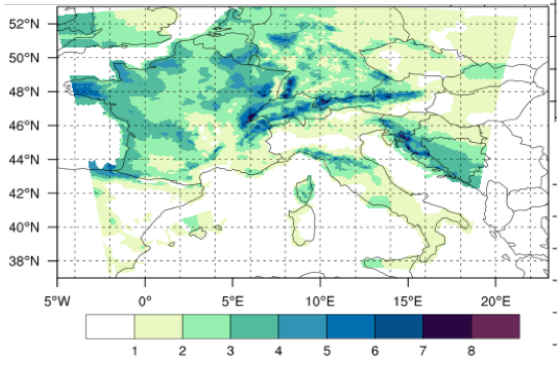
ALPS

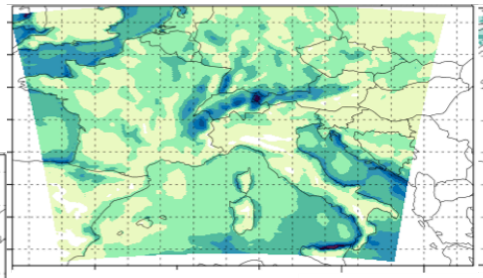
RegCM12km

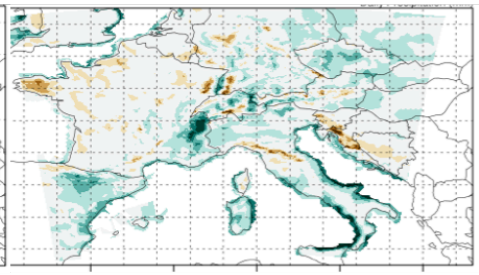
Bias : RegCM12km-OBS

DJF

1999-2001 - High Res.OBS (mm/day)

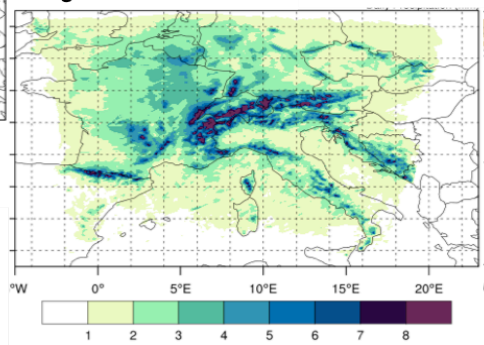


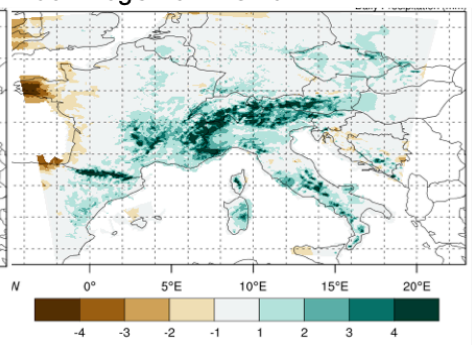




RegCM3km

Bias : RegCM3km-OBS



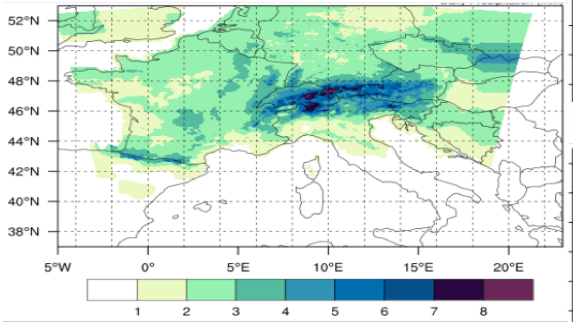


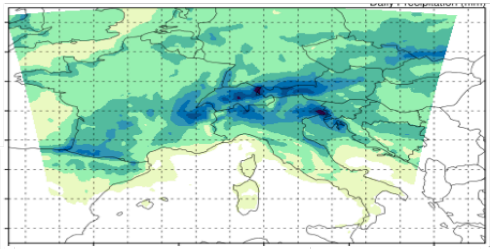
RegCM12km

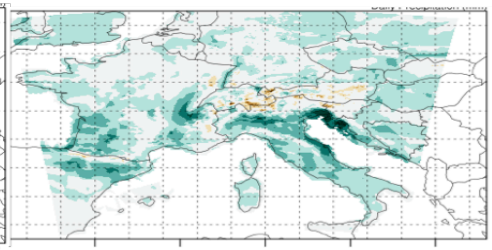
Bias : RegCM12km-OBS

JJA

1999-2001 - High Res.OBS (mm/day)

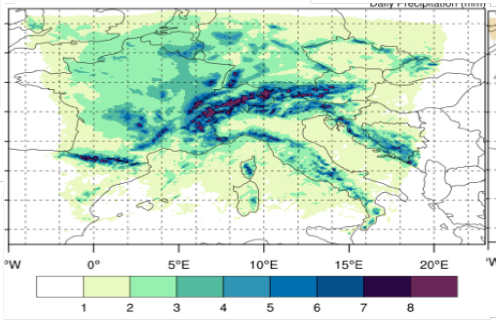


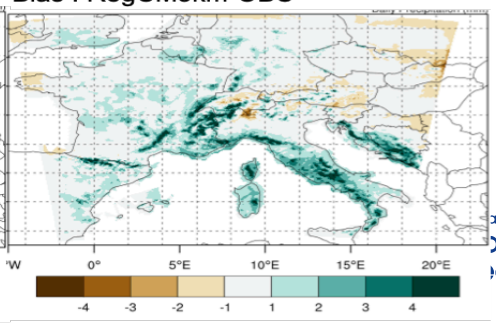




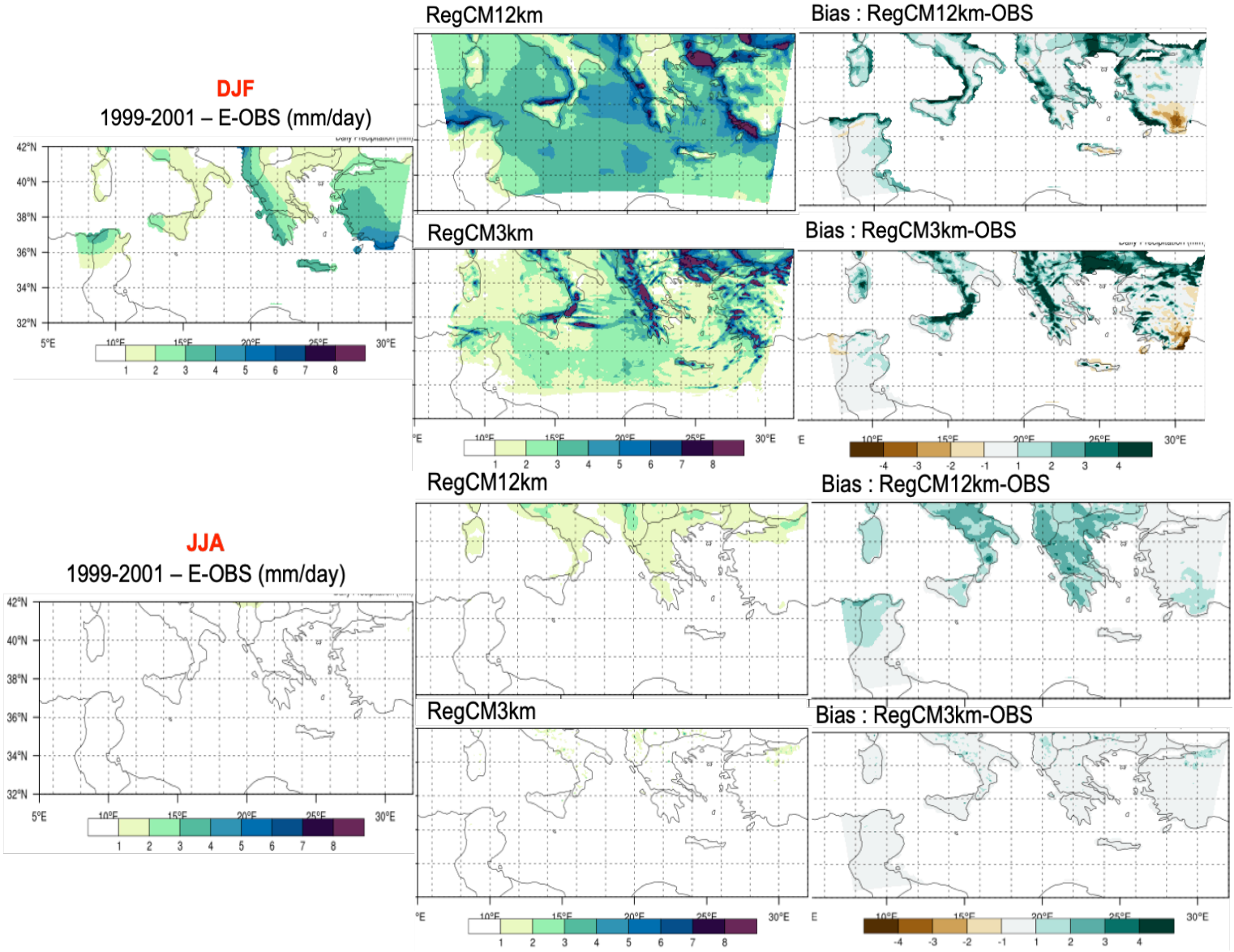
RegCM3km

Bias : RegCM3km-OBS





SE -Europe


RegCM12km
Bias : RegCM12km-OBS
DJF
1999-2001 – E-OBS (mm/day)
RegCM3km
Bias : RegCM3km-OBS
RegCM12km
Bias : RegCM12km-OBS
JJA
1999-2001 – E-OBS (mm/day)
RegCM3km
Bias : RegCM3km-OBS

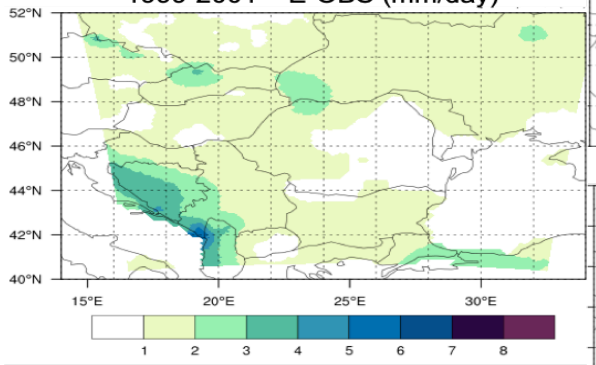
Central Europe

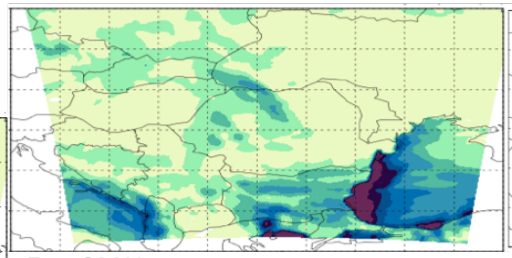
RegCM12km

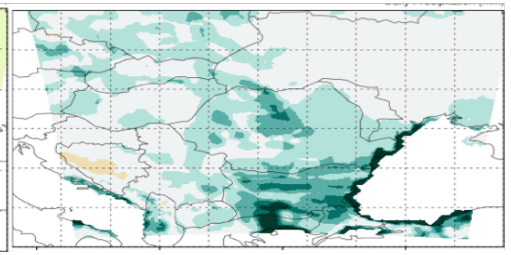
Bias : RegCM12km-OBS

DJF

1999-2001 – E-OBS (mm/day)

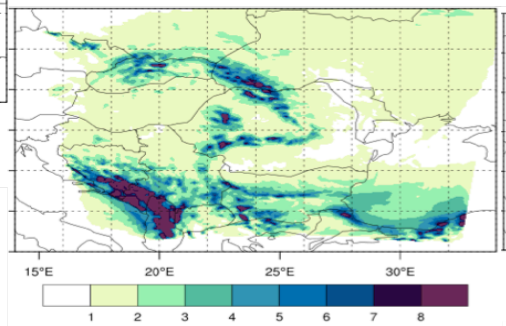


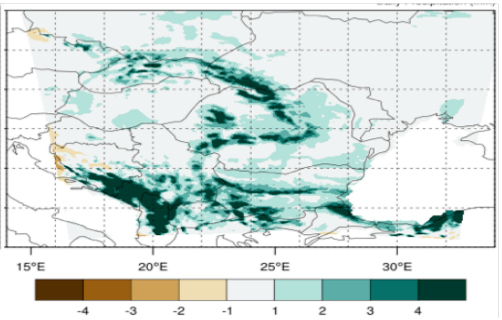




RegCM3km

Bias : RegCM3km-OBS



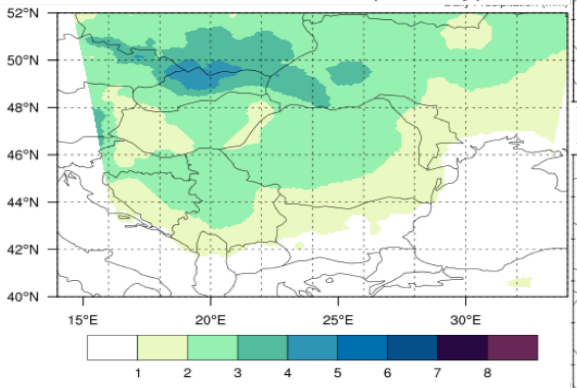


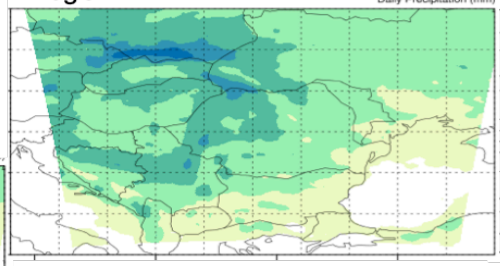
RegCM12km

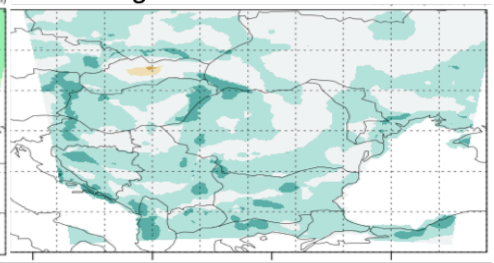
Bias : RegCM12km-OBS

JJA

1999-2001 – E-OBS (mm/day)

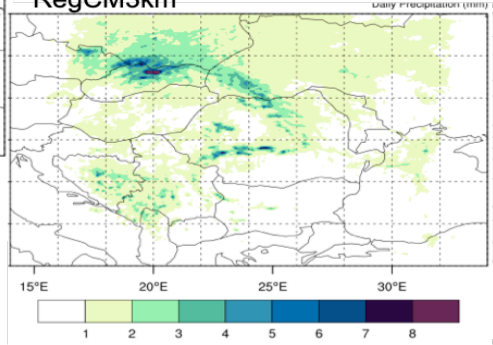


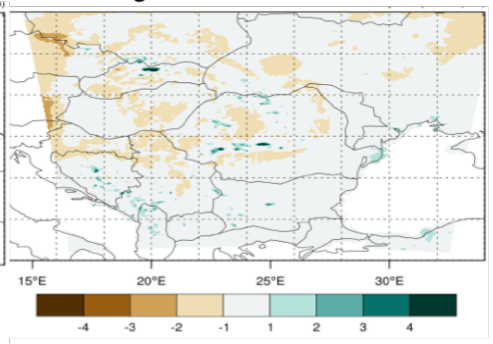




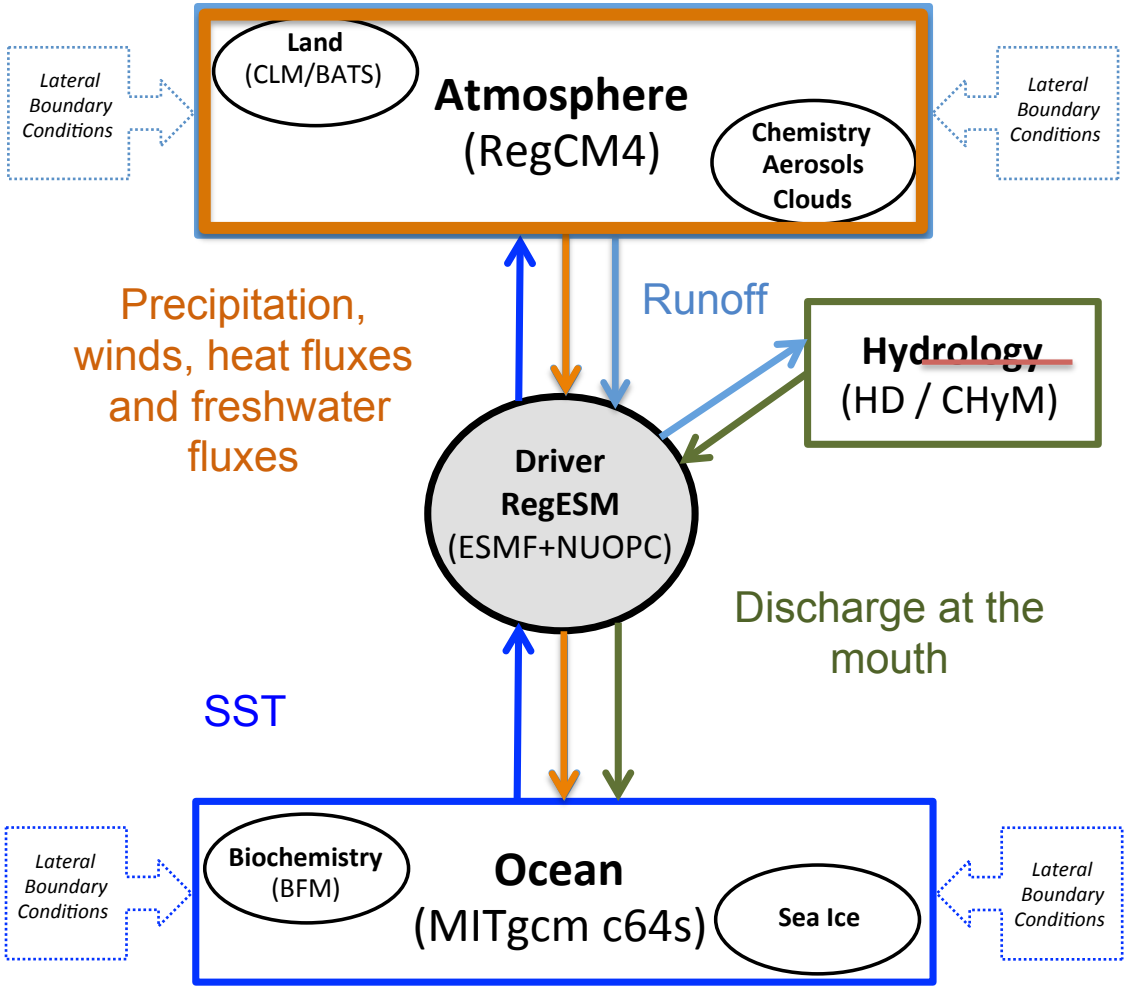
RegCM3km

Bias : RegCM3km-OBS





RegCM-ES



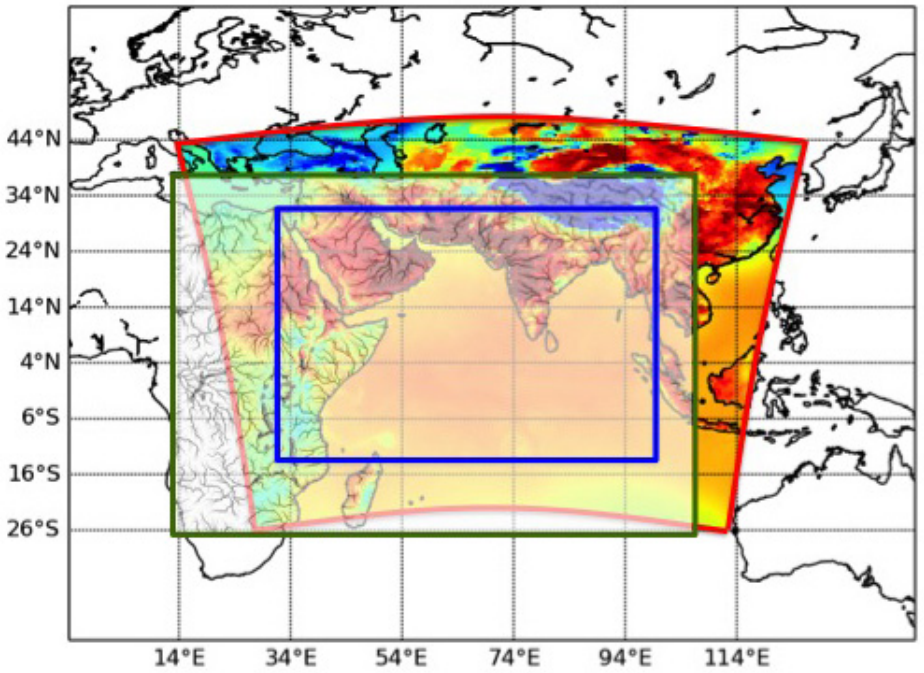
Sitz, L. E., **Di Sante, F.**, Farneti, R., Fuentes-Franco, R., Coppola, E., Mariotti, L., Reale, M., Sannino, G., Barreiro, M., Nogherotto, R., Giuliani, G., Graffino, G., Solidoro, C., Cossarini, C., and Giorgi, F. (2017). Description and evaluation of the eart system regional climate model (regcm-es). J Adv. Model. Earth Syst.

South Asia experimental design

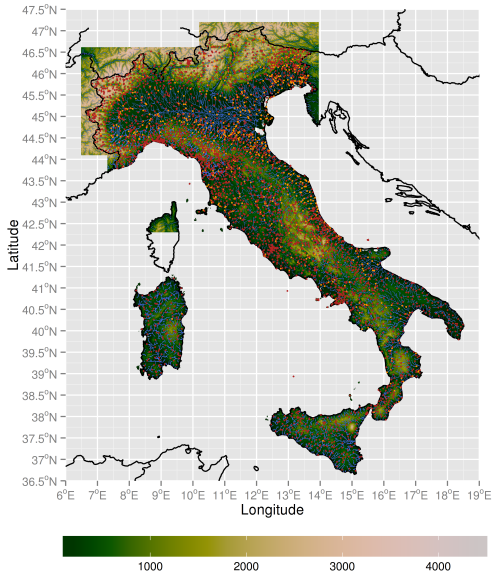
ATM:
Horizontal spatial Res. 50km
ICBC ERA Interim reanalysis 0.75°

OCN:
Horizontal spatial resolution 0.16°
ICBC MOM global integration 0.25°
and ORAP reanalysis 0.25°

HYD:
Horizontal spatial resolution 0.5° HD
and 0.12° CHyM



Application – Insurance companies
From the discharge climatology to the Flood hazard maps

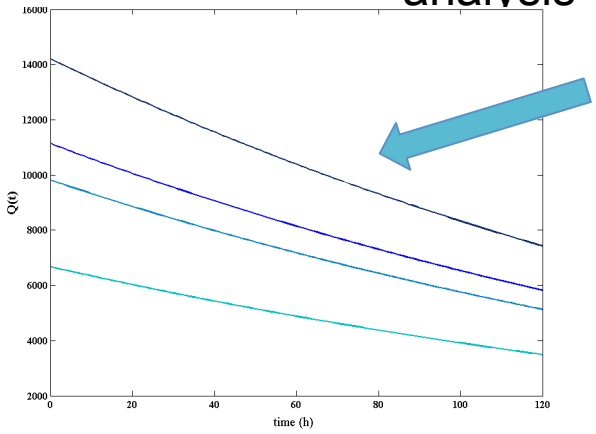


CHYM hydrological model or stations data

N-year discharge climatology

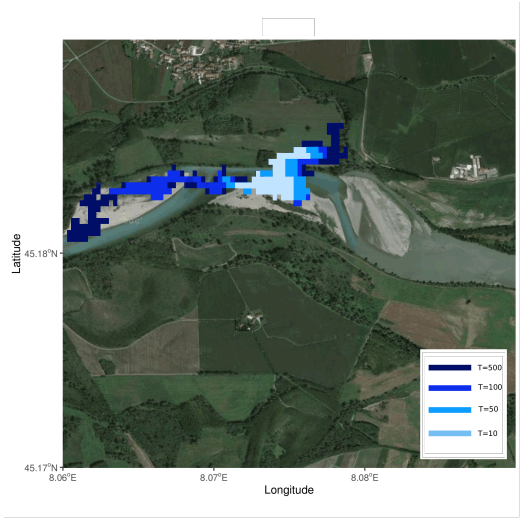
199 5 | 199 6 | 199 8 | 199 9 | 2000....

Statistical Flood Frequency analysis



Return periods (T)

Lisflood-ACC hydraulic model



Flood hazard maps

Summary

- There are region of the world where the impact of climate change is expected to be more severe than in others
- To be able to do some hydroclimate study we need to downscale climate simulation to the local scale
- Are we really able to better represent the reality if we increase the resolution of our climate models? YES if we have the instrument to asses it.
- Can we use the high resolution climate information as input of our hydrological model? YES we can, provided that we take also care to estimate the uncertainty of our final results.

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