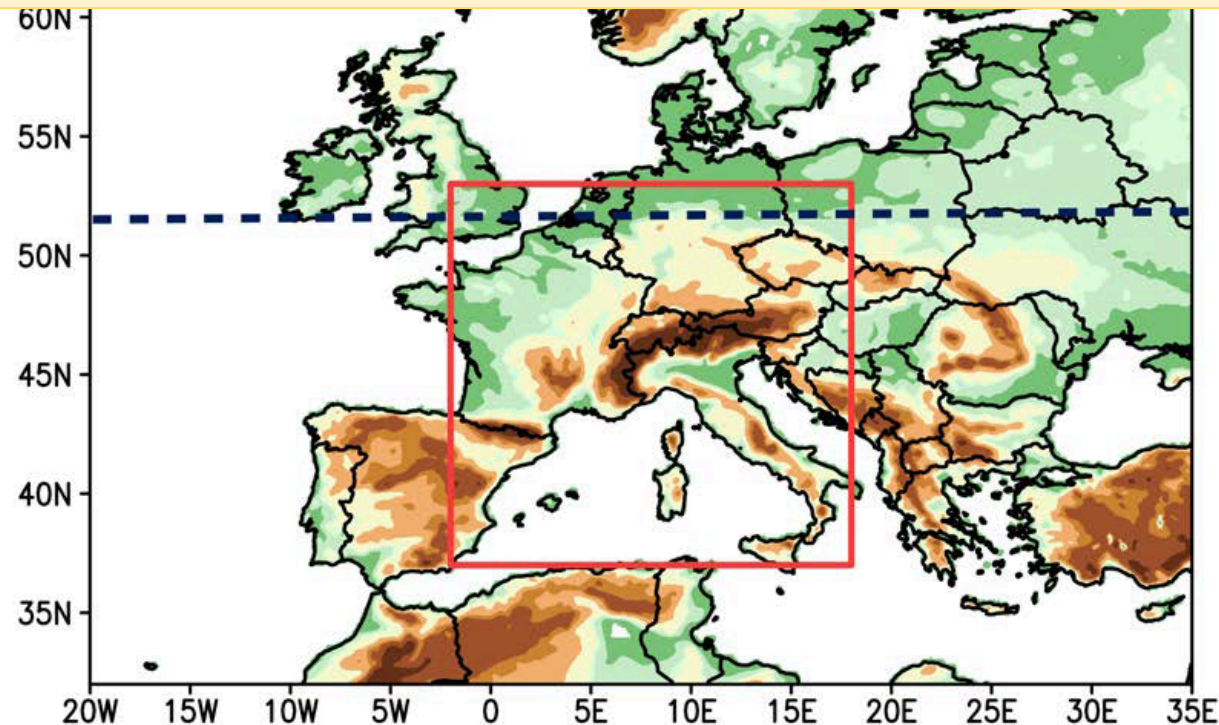
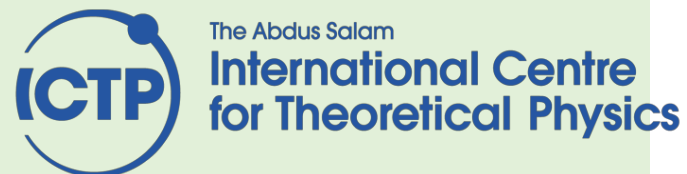


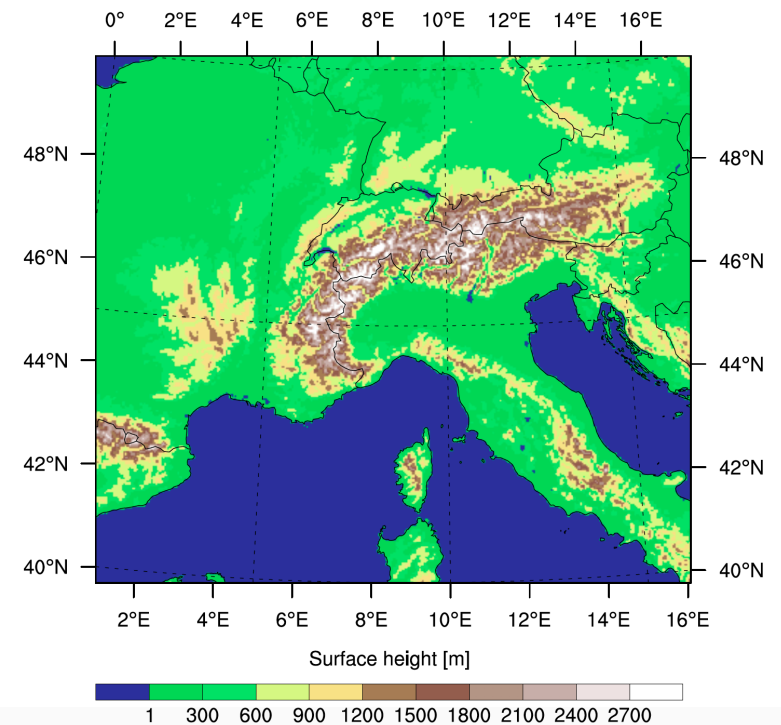
# Precipitation projections of the first multi-model ensemble of regional climate simulations at convection permitting scale

Pichelli Emanuela ([epichell@ictp.it](mailto:epichell@ictp.it))

Coppola Erika, Sobolowski Stefan, Ban Nikolina, Giorgi Filippo, Stocchi Paolo, Alias Antoinette, Belušić Danijel, Berthou Segolene, Caillaud Cecile, Cardoso Rita M., Chan Steven, Christensen Ole Bøssing, Dobler Andreas, de Vries Hylke, Goergen Klaus, Kendon Elizabeth J., Keuler Klaus, Lenderink Geert, Lorenz Torge, Mishra Aditya N., Panitz Hans-Juergen, Schär Christoph, Soares Pedro MM., Truhetz Heimo, Vergara-Temprado Jesus.



# Overview



**3 km convection permitting simulations (CP-ENS) over common alpine domain**

**VS**

- high resolution observations
- 12 km conv. parameterized intermediate simulations (CR-ENS)

**The first multi-model ensemble of regional climate simulations at kilometer-scale resolution, Part I: Evaluation of precipitation**

**Ban et al. (Under review)**

**The first multi-model ensemble of regional climate simulations at kilometer-scale resolution, Part 2: future precipitation projections**

**Pichelli et al. (Under review)**

INSTITUTE	CP-RCM	Resolution (km)	Driving RCM	Resolution (km)	GCM
KNMI (**) The Royal Netherlands Meteorological Institute	HCLIM38-AROME	2.5	RACMO	12	EC-Earth
ICTP (**) Abdus Salam International Centre for Theoretical Physics	RegCM4	3	RegCM4	12	HadGEM
CNRM (**) Centre National de Recherches Meteorologique	CNRM-AROME41t1	2.5	CNRM-ALADIN63	12	CNRM-CM5
KIT Karlsruhe Institute of Technology	CCLM5	3	CCLM4	12	MPI-ESM-LR
BTU Brandenburg University of Technology	CCLM5	3	CCLM4	12	CNRM-CM5
ETHZ (**) (a) Federal Institute of Technology, Institute for Atmospheric and Climate Science	CCLM	2.2	CCLM	12	MPI
ETHZ (**) (b) Federal Institute of Technology	CCLM	2.2	CCLM	12	pgw
FZJ-IBG3-IDL Research Centre Jülich Institute Dom Luis	WRF3.8	3	WRF3.8.1CA	15	EC-EARTH
DMI- MET Norway- SMHI (**) HARMONIE-Climate community	HCLIM38-AROME	3	HCLIM38-ALADIN	12	EC-EARTH
UNIGRAZ-WEGC Wegener Center for Climate and Global Change, University of Graz	WEGC-CCLM5	3	WEGC-CCLM5	12	MPI-ESM-LR
UK Met OFFICE (**) Met Office Hadley Centre Exeter	UM	2.2	No intermediate RCM		HadGEM
BCCR The Bjerknes Centre for Climate Research	WRF3.8	3	WRF3.8.1CA	15	NorESM1

# Ensembles and numerical experiment strategy

12 CP simulations available

CMIP5 GCM projections

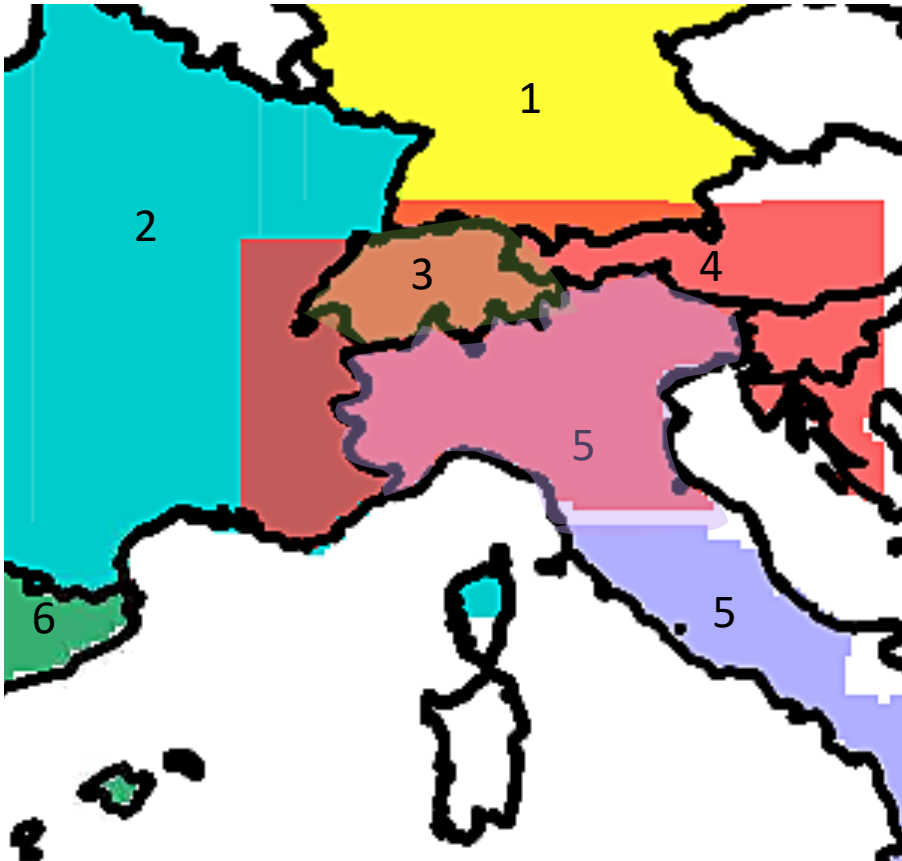


12/15 km  
Intermediate domain



3 km alpine domain

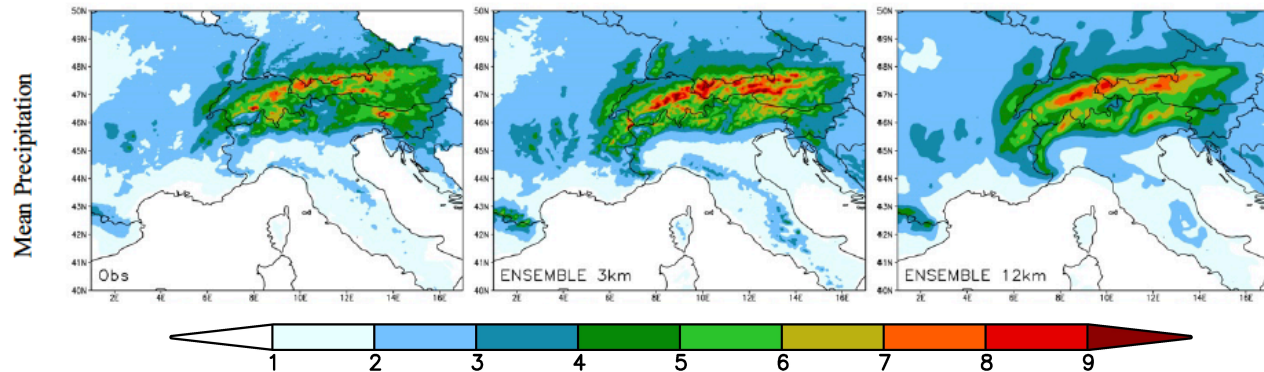
# High resolution observations



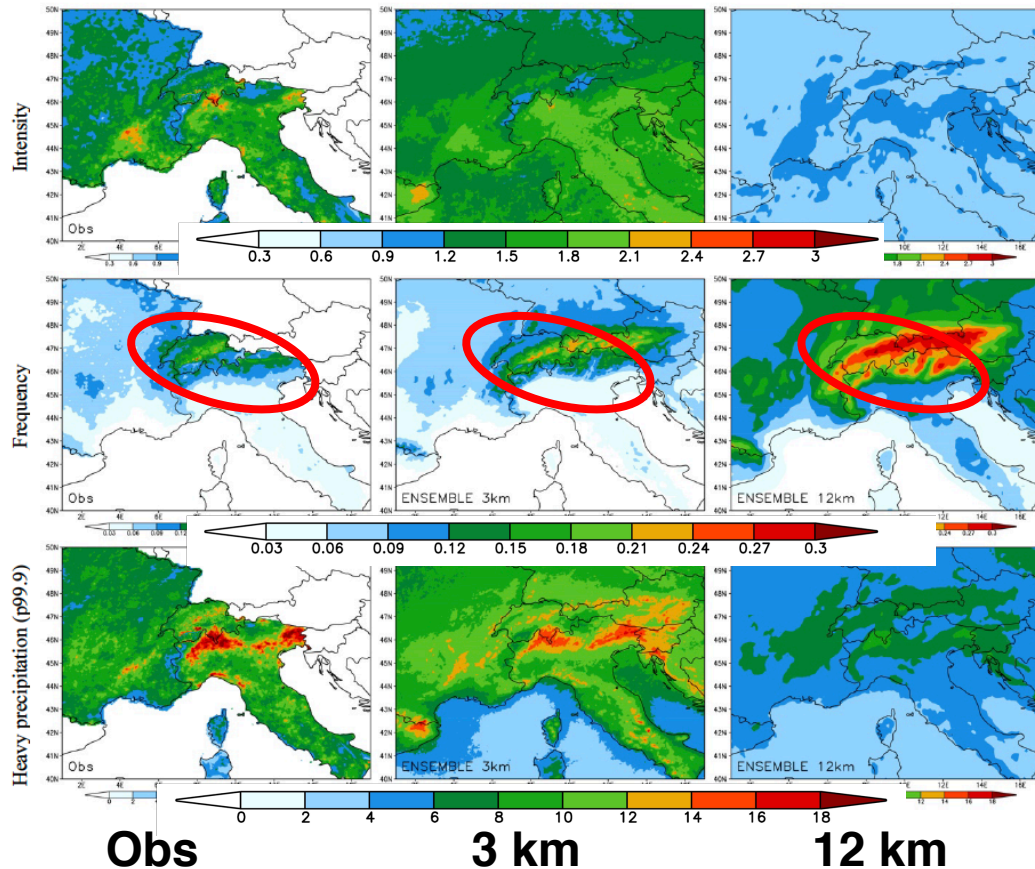
	Dataset	Grid Res.	Time Res.	Period
1	REGNIE (D)	0.02x0.008 deg	daily	1996-2005
2	COMEPHORE (FR)	1 km	hourly	1997-2006
3	RdisaggH (CH)	1km	hourly	2003-2010
4	EURO4M-APGD	5 km	daily	1996-2005
5	GRIPHO (IT)	3 km	hourly	2001-2010
6	Spain02 (SP)	12 km	daily	1996-2005



## JJA - Daily precipitation



## JJA - Hourly precipitation



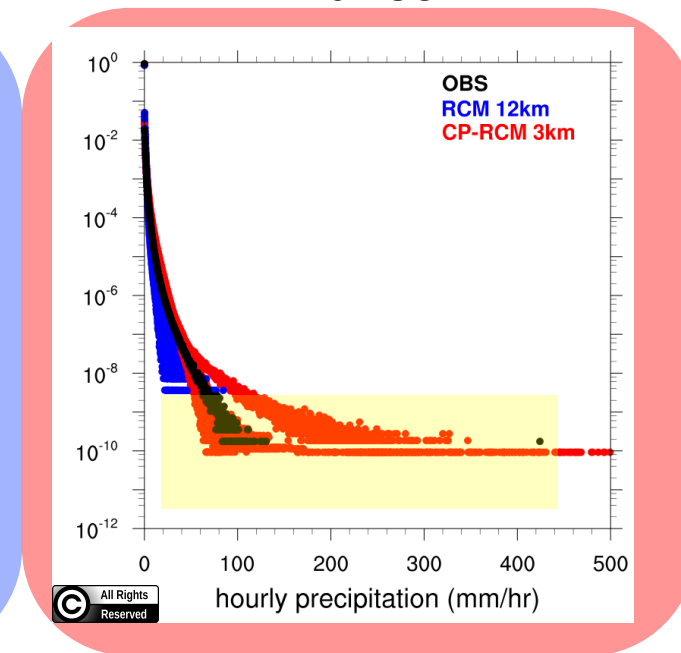
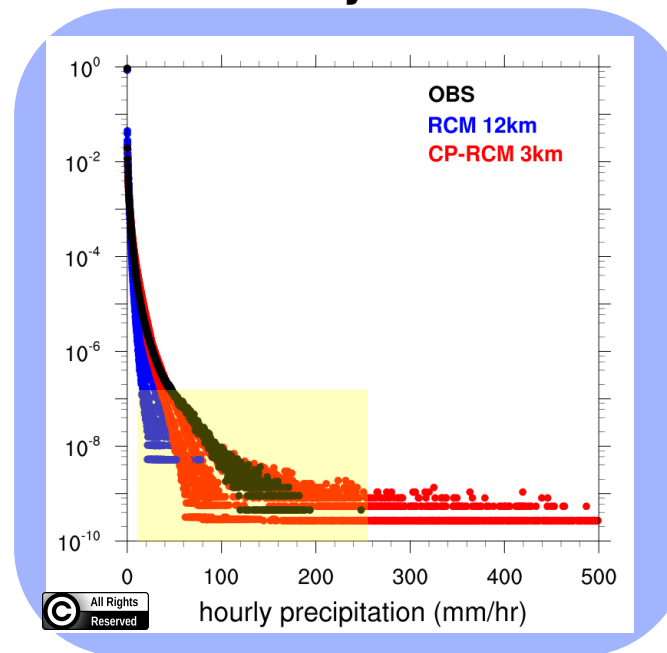
1996-2005

CP-ENS outperforms the CR-ENS better representing spatial features of precipitation field across the whole domain.

## Annual PDFs

Italy

France



The CPRCM ensemble, covers the observed distribution within its spread but produces much longer tails, where intermediate simulations underestimate.

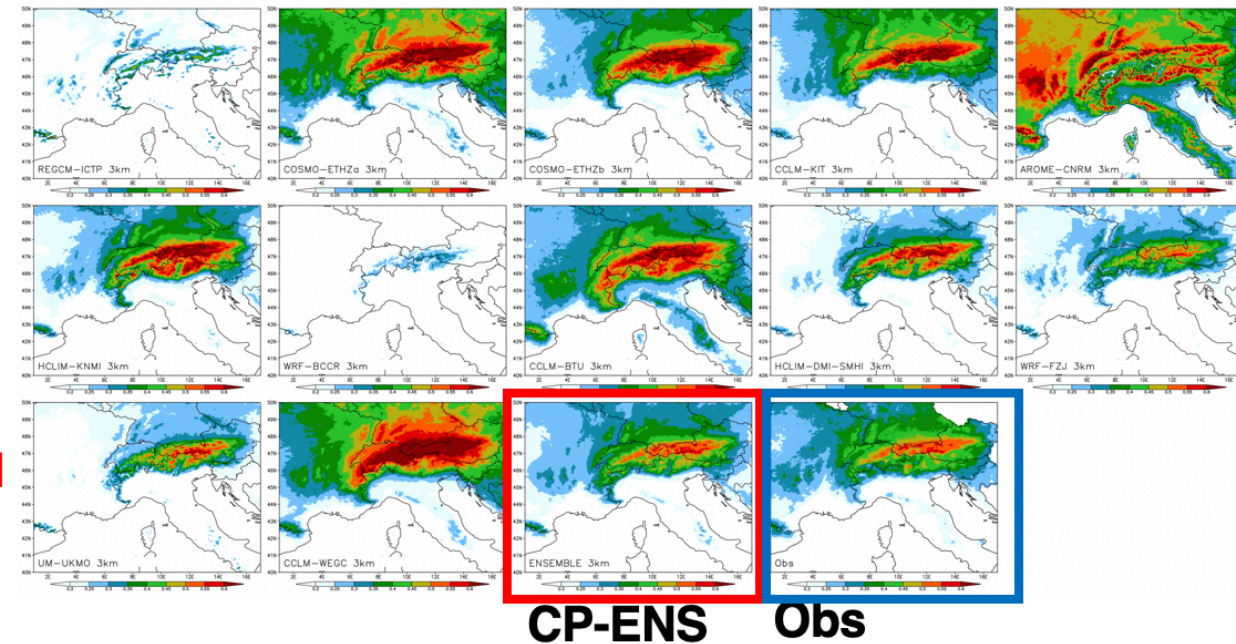
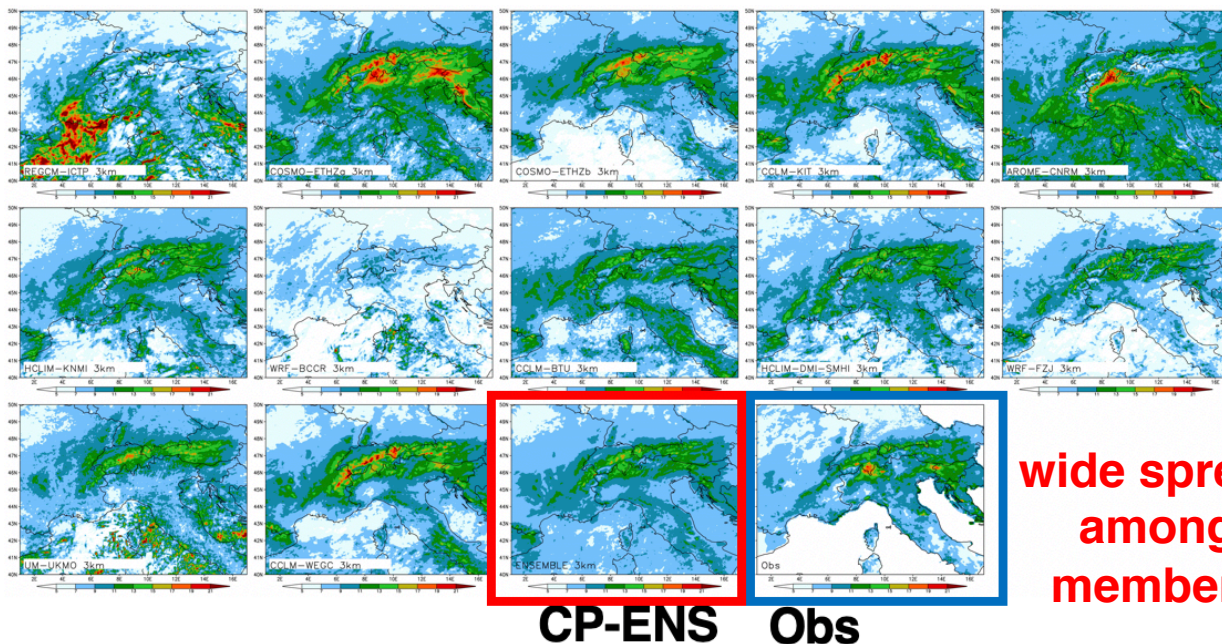


# 3 km wet-day intensity

1996-2005-JJA

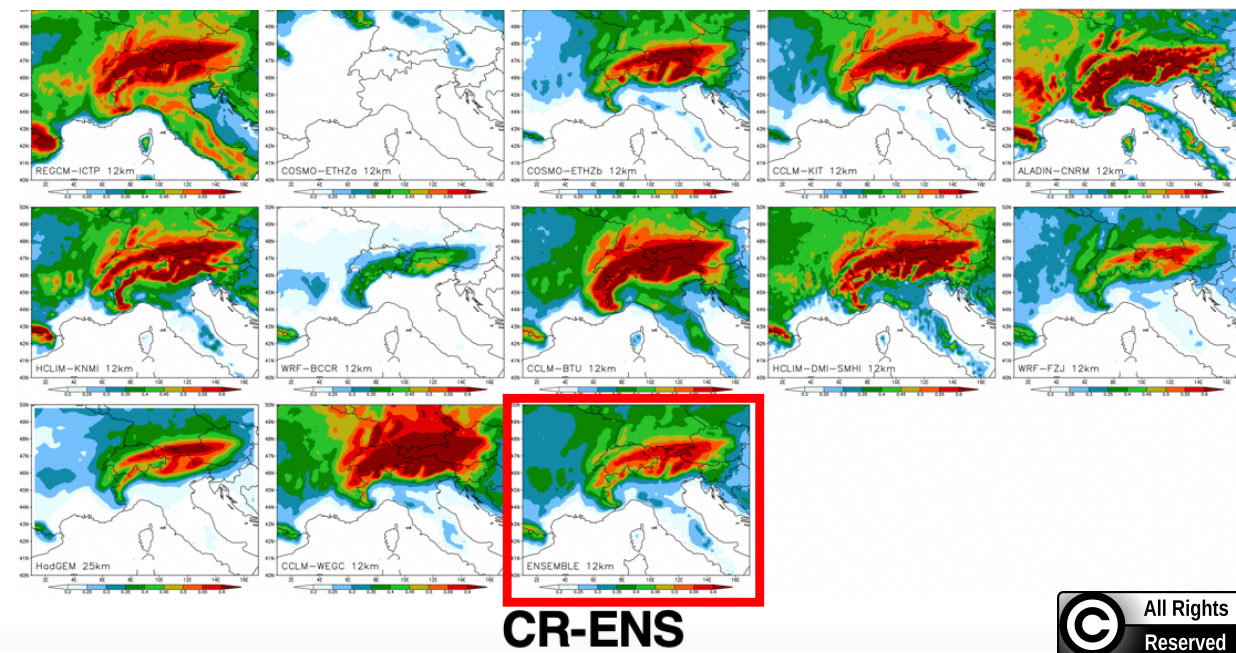
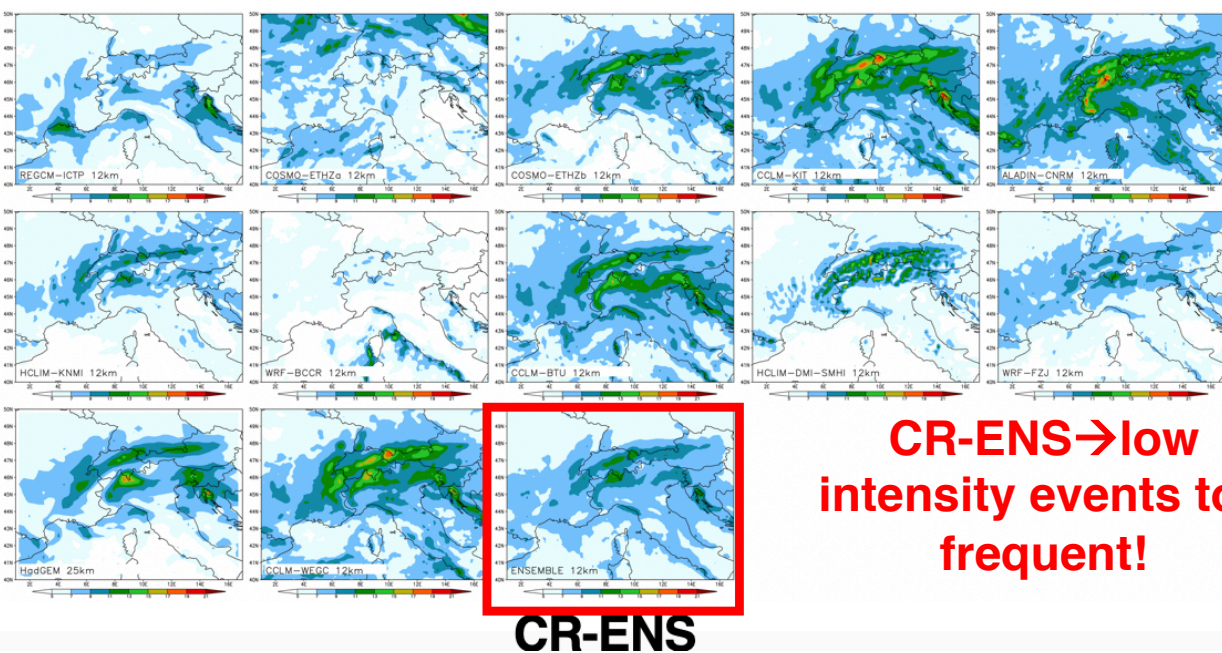
# wet-day frequency

3 km



12 km

12 km





1996-2005 JJA day cycle

Obs

3 km

12 km

hr. precip

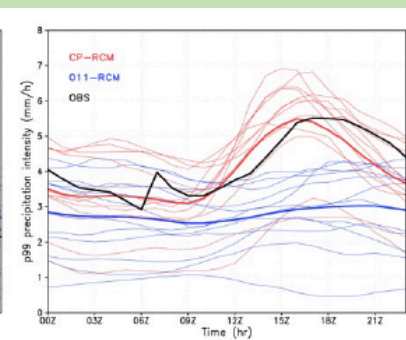
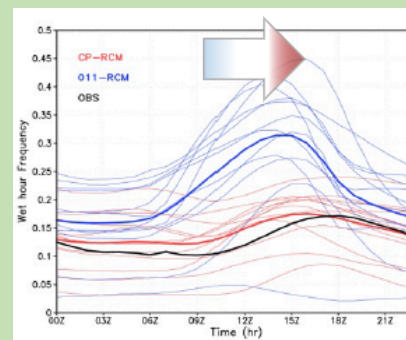
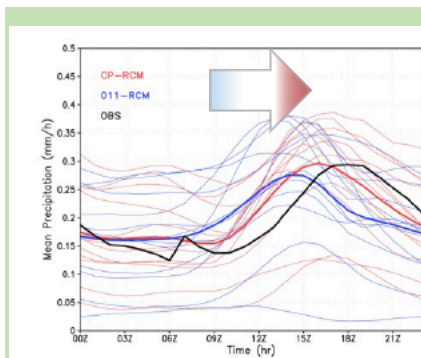
wet hour intensity

frequency

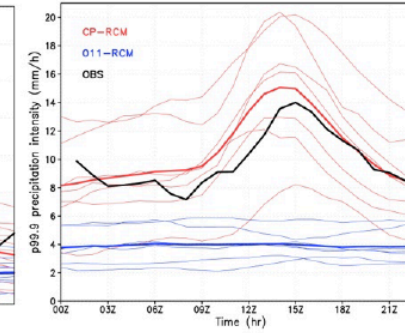
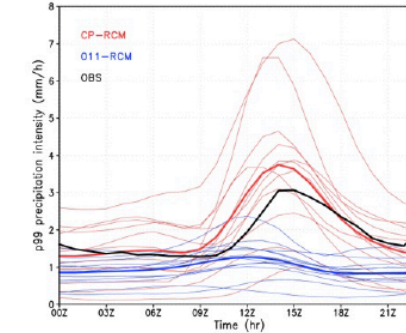
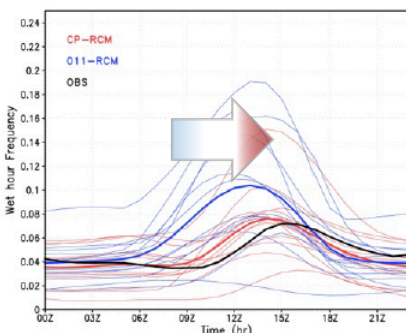
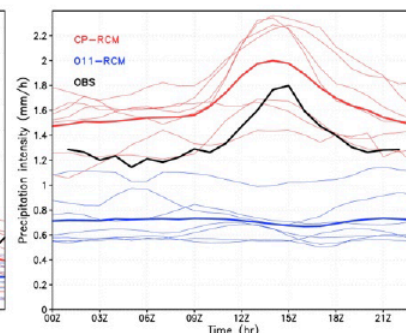
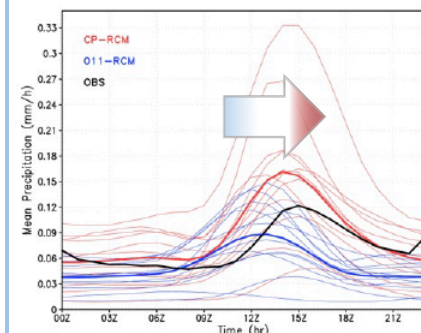
P99

P99.9

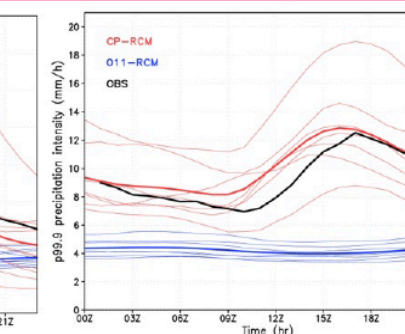
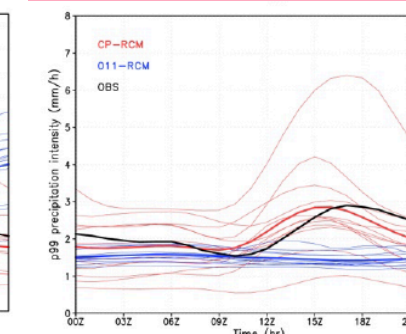
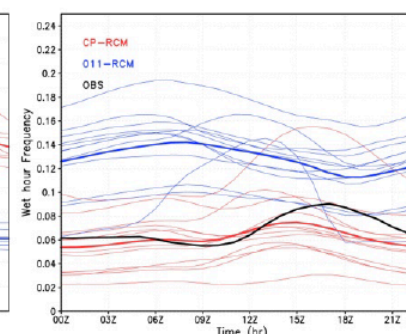
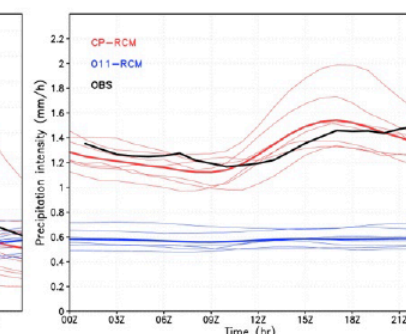
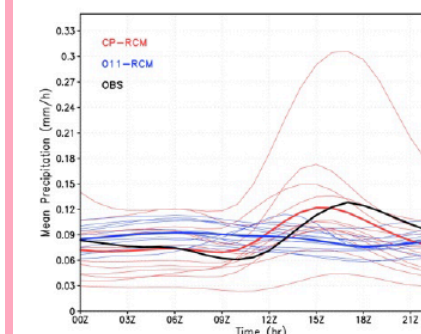
Switzerland



Italy

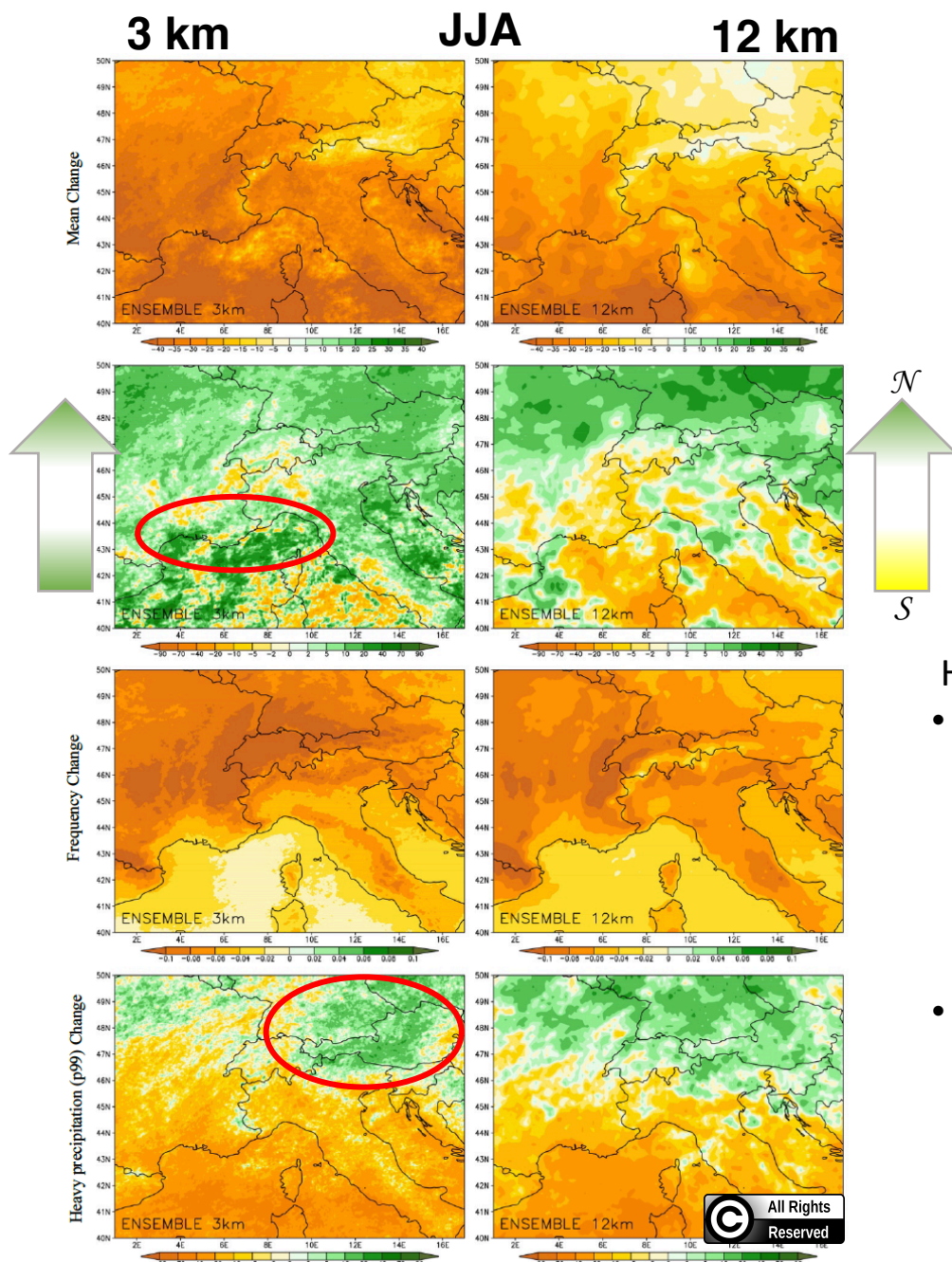


France



CP-ENS recovers the deficiency of the CR-ENS in producing too often too low intensity precipitation and to correct the early triggering of diurnal convection

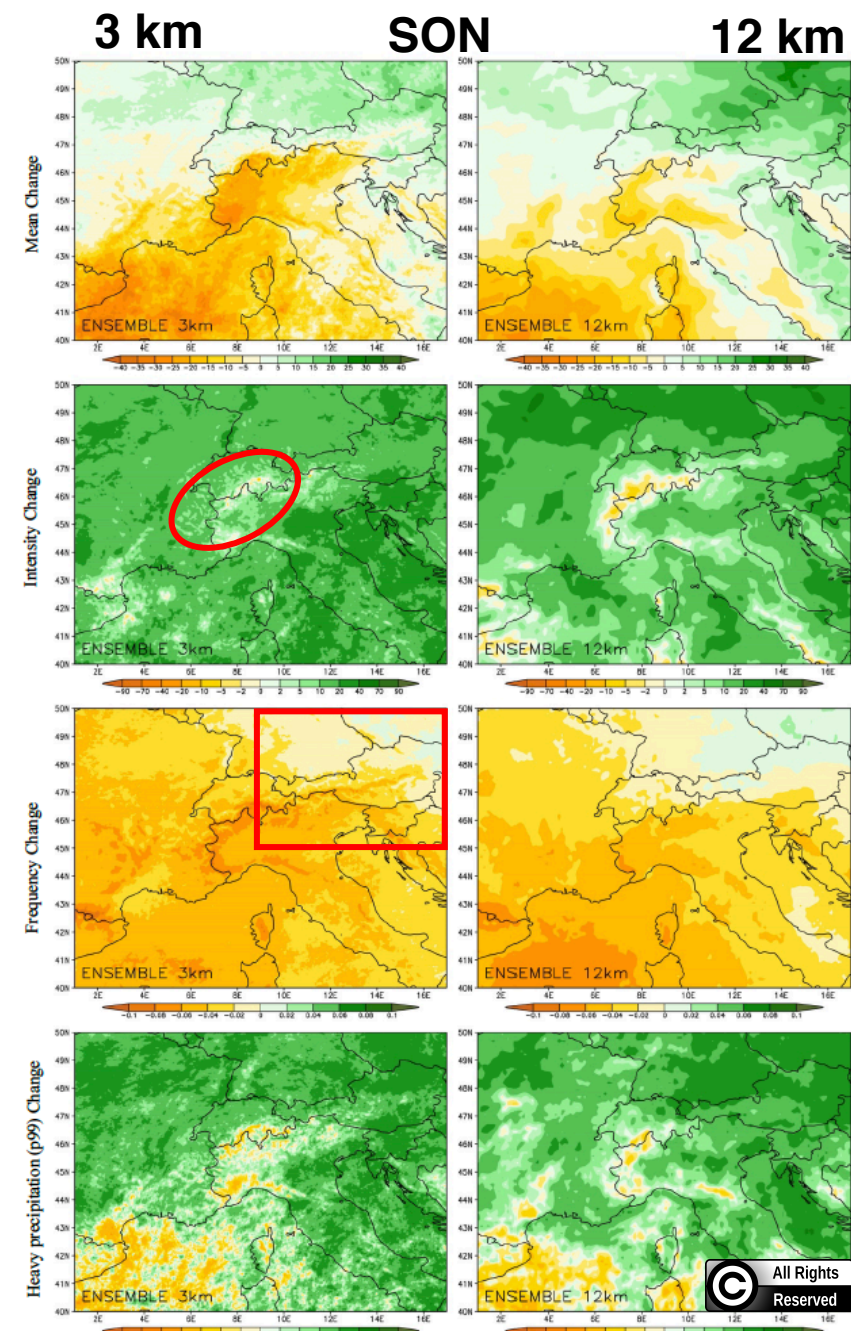




## 2090-2099 Daily precip. change

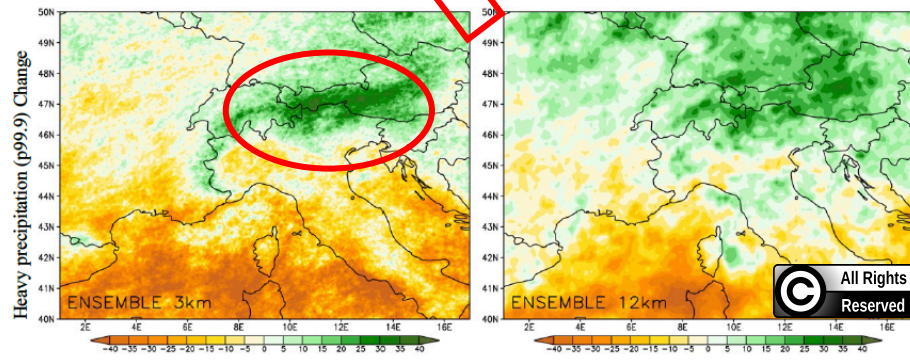
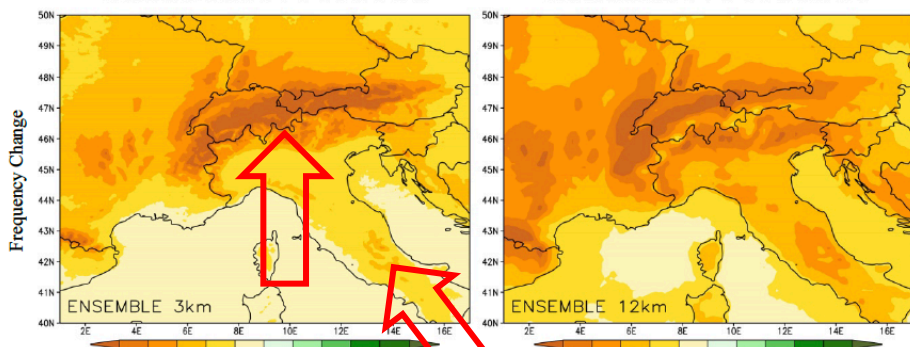
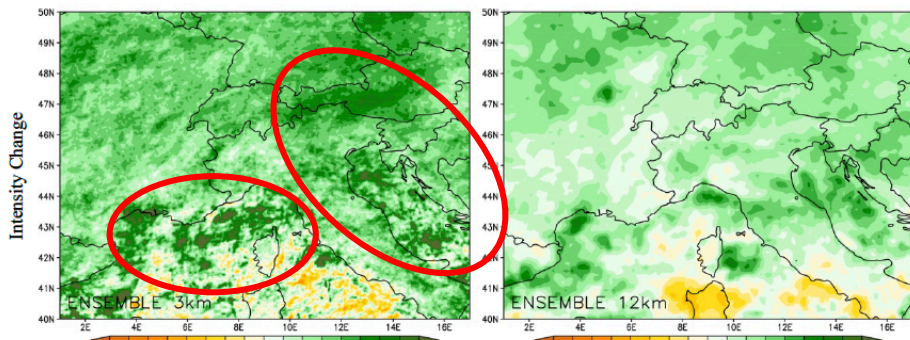
### Highlights:

- CP-ENS refines and enhances the projected patterns of change, locally modifying the sign of the daily precipitation intensity change respect with CR-ENS especially in JJA.
- in JJA, heavy precipitation exhibits intensification over the eastern Alps and the northern part of the domain





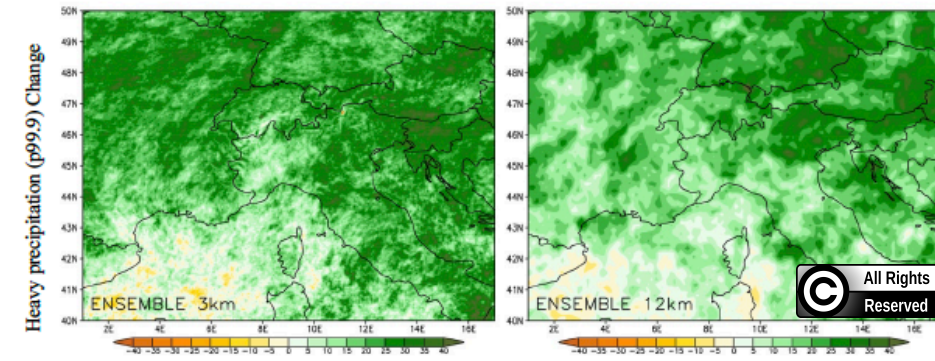
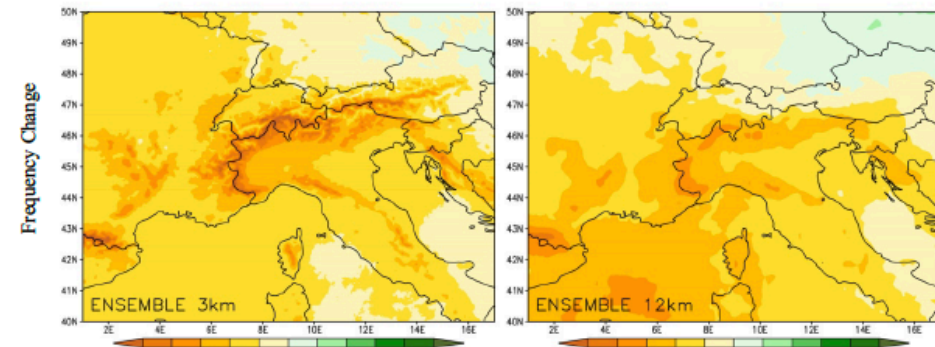
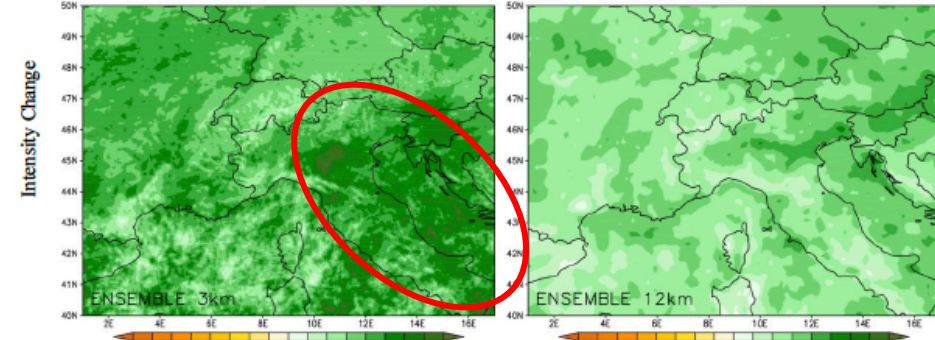
3 km JJA 12 km



2090-2099  
Hourly precip. change

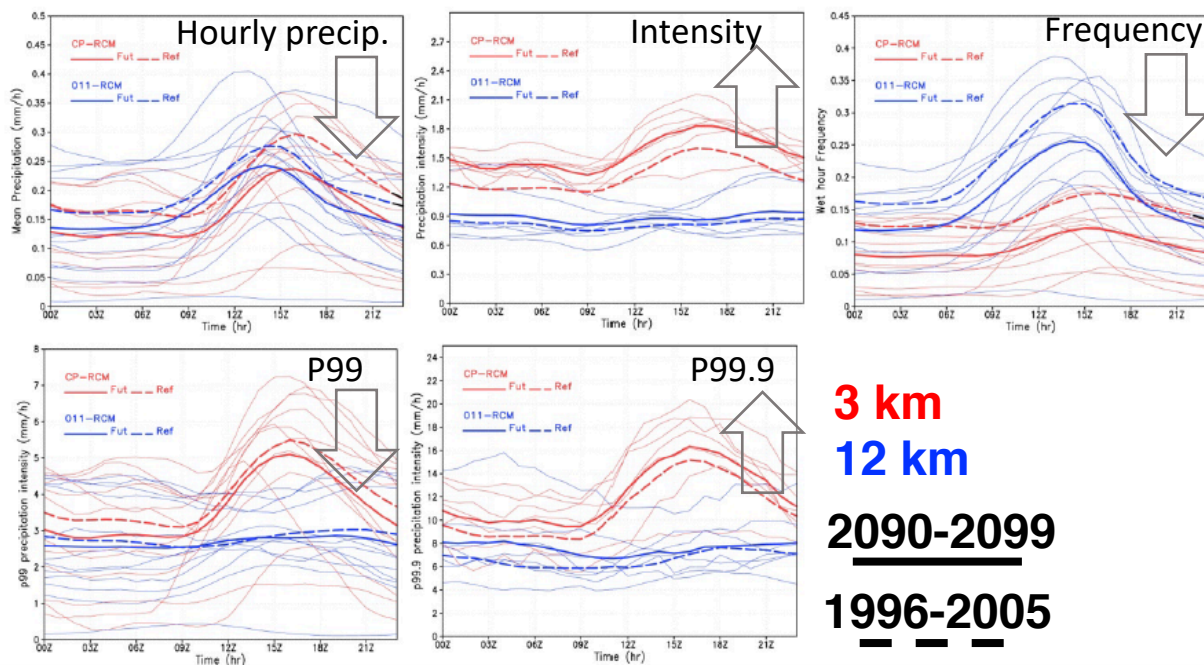
- Highlights:
- At the hourly time scale the patterns of change are in better agreement between CP-ENS and CR-ENS
  - CP-ENS shows an intensification of its response mainly across the orography in JJA, across western Europe and Adriatic regions in SON

3 km SON 12 km

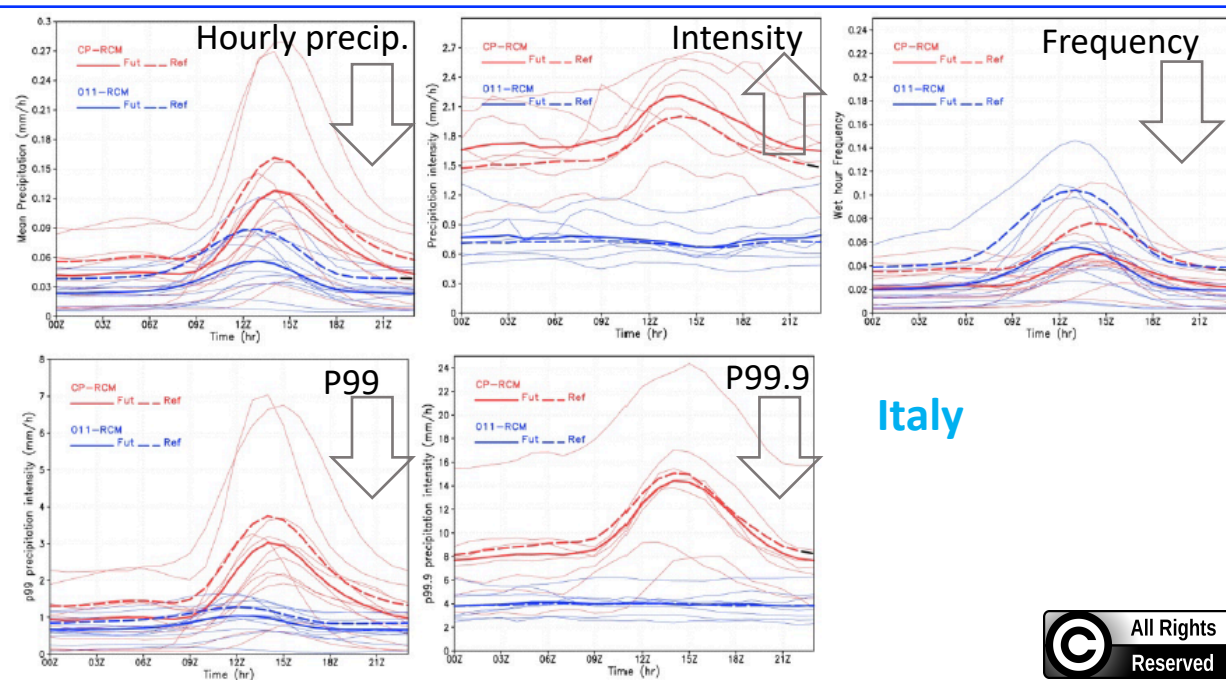
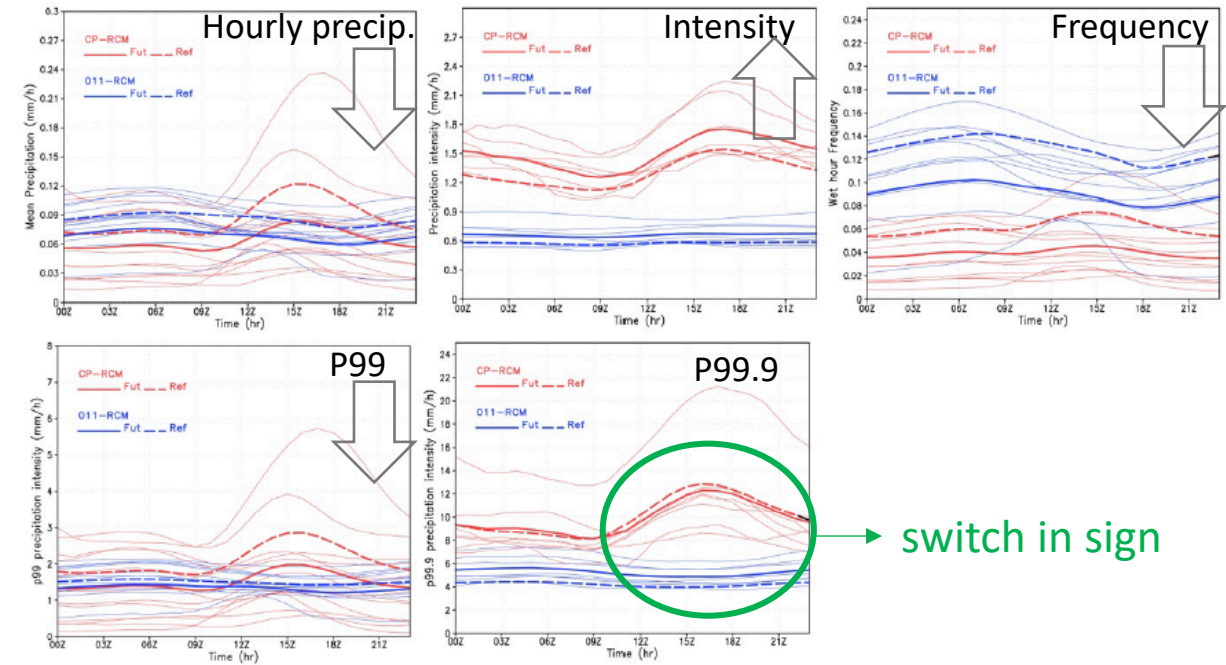




## Switzerland



## France



## Summer diurnal cycles

- The two ensembles show coherent change signals between historical and projection simulations;
- The changes are bigger for the CP-ENS around the peaks, except for the wet-hour frequency;
- wet-hour precipitations show an increase of intensity but with decreasing frequency besides the area;
- The most extreme precipitation intensity (P99.9) increases over Switzerland, and decreases over Italy and France. Over France the change also switches in sign moving from CR-ENS to CP-ENS

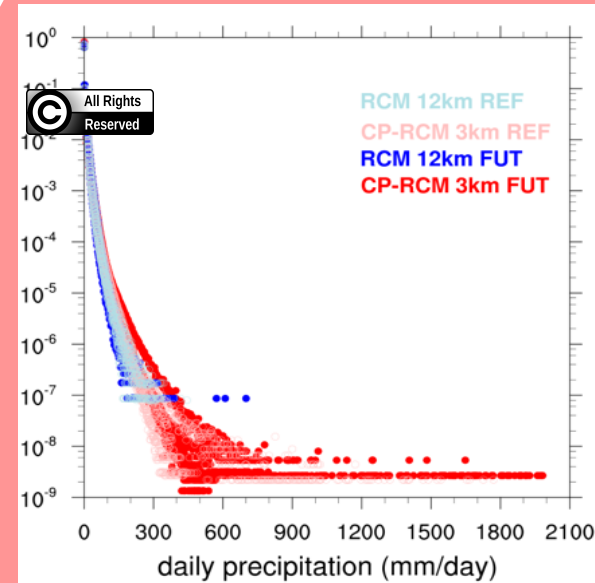
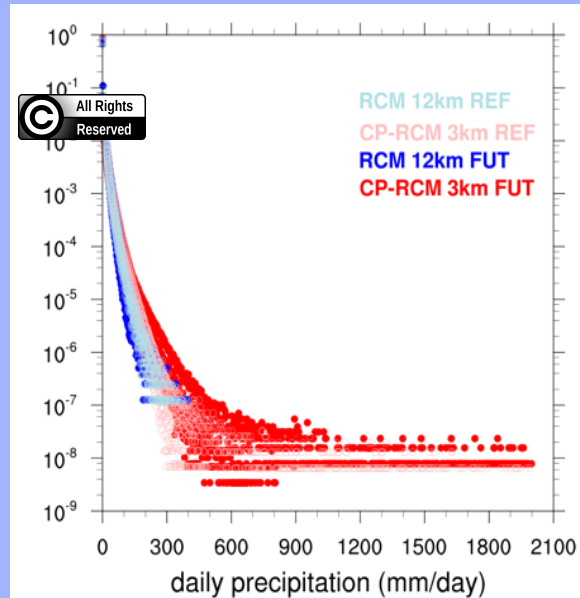
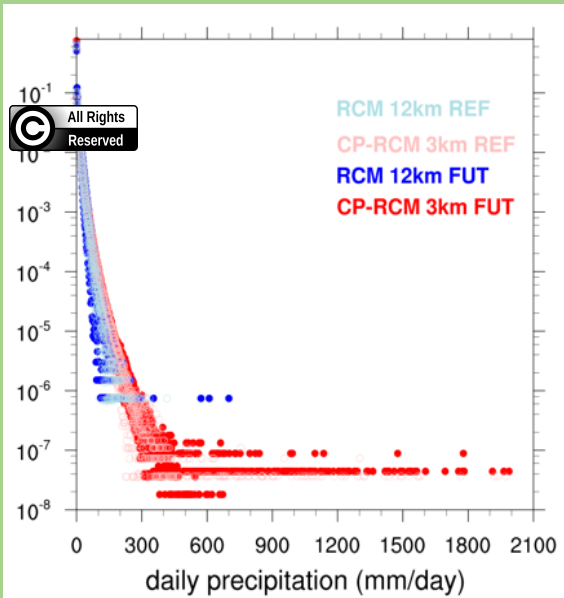


## Switzerland

## Italy

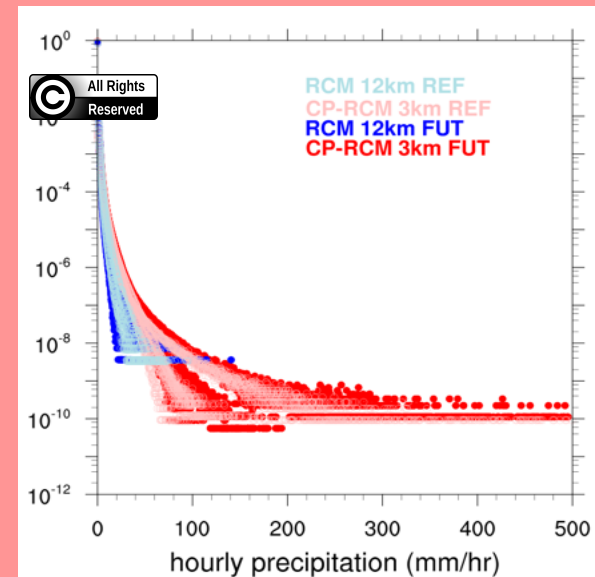
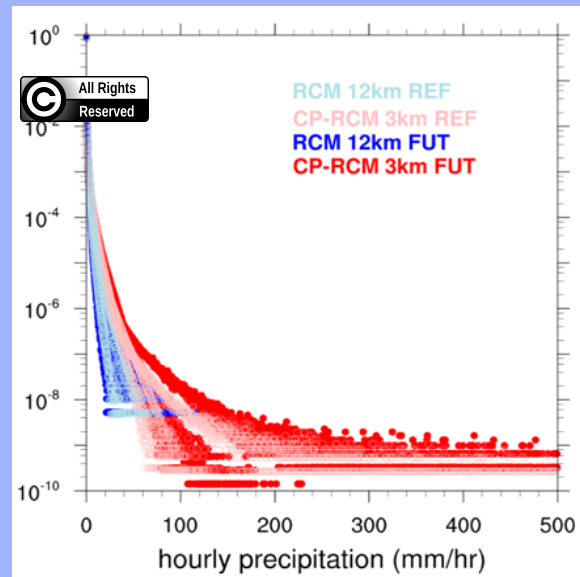
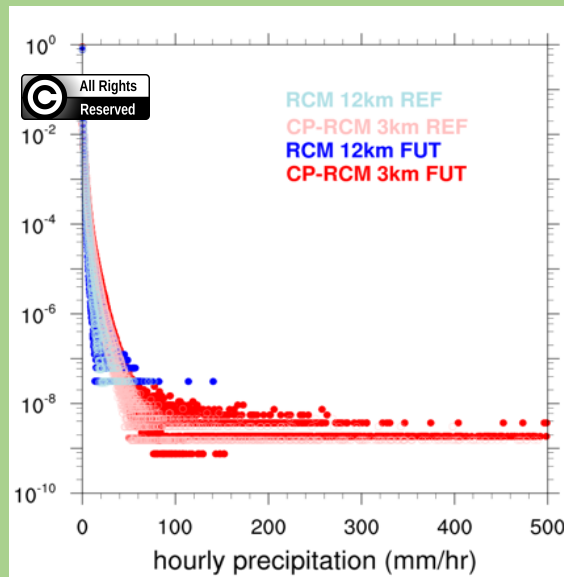
## France

Daily prep.



For the PDF the CP-ENS (reddish circle) shows larger positive change than CR-ENS (bluish circles) for high to extreme precipitation thresholds over the three regions for hourly precipitation and especially over Italy for the daily one.

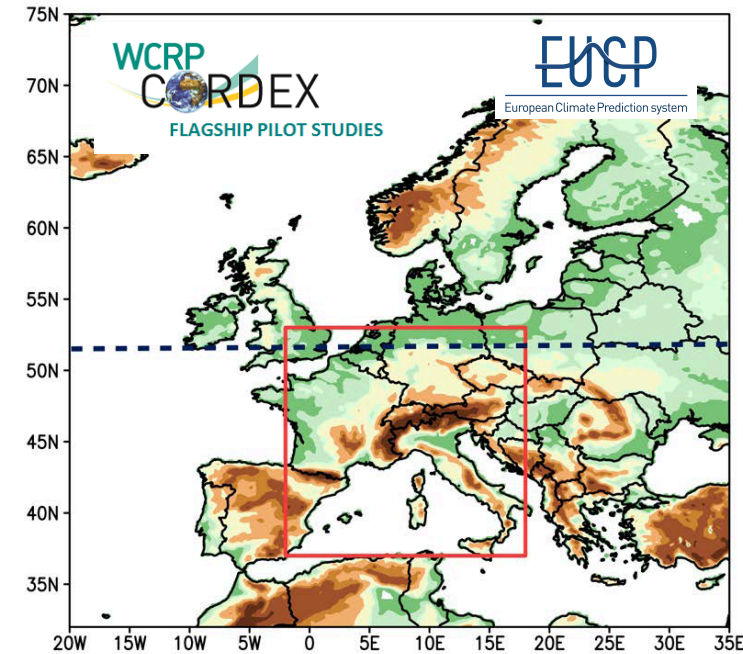
Hourly prep.



# Summary

## Evaluation analysis:

- The spatial patterns of precipitation are better represented by the ensemble mean of km-scale simulations than by the ensemble of the coarse resolution driving ones;
- The diurnal cycles of summer precipitation are improved by the km-scale simulations, recovering the deficiency of the driving simulations in producing too often too low intensity precipitation and to correct the early triggering of diurnal convection;
- Large spread exists among ensemble members, but the potentialities of the ensemble-based approach at the CP scales are promising and screen-off by possible single model misleading conclusions.



## Projection analysis:

- The km-scale simulations refine and enhance the projected patterns of change from coarser resolution ones and **modify the sign of the daily precipitation intensity change and of heavy precipitation** over some targeted regions;
- At the km-scale an increase of amplitude of **change for the diurnal cycle** of mean, intensity, frequency and extreme precipitation is found;
- A **larger positive change for high to extreme events for hourly precipitation** is found.

