Modelli climatici regionali alla scala convettiva: strumenti per lo studio delle precipitazioni estreme.

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ENEA, Casaccia,
8 Novembre 2024

My way to Convection-Permitting Model Climate applications

Extreme precipitations

MM5-NCAR WRF-NCAR

RegCM4/5-ICTP

WRF-NCAR
ENEA

Weather Research and applications

Conventional and unconventional (InSAR) data integration and 3D assimilation

CPM application for weather research and forecasting (regional meteo-hydrological alert system)

PBL studies in urban environment

Process study in complex orography regions

Regional Climate Research and applications

Stabilization strategies of NH-RegCM for CP applications

CORDEX-FPSCONV experiment

Ensemble climate prediction system based on CPMs (EUCP)

HPE Detection methods trough CPMs (XAIDA)

Convection-Permitting scale applications for the Mediterranean area

ENEA

Atmospheric convection in numerical models

Why

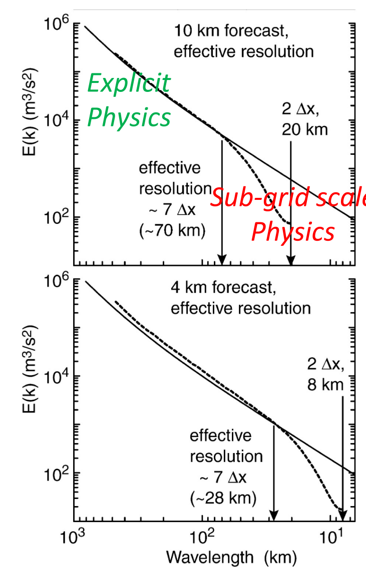
- To simulate convective precipitation
- To feedback the large scale as the convection influences mesoscale dynamics by:
  - ✓ changing vertical stability
  - ✓ changing and redistributing heat and moisture
  - ✓ affecting surface heating and radiation trough clouds

CPMs | **<4 km (finer)** | cumulus scheme switched off

Advantages: Improvement of **early onset of convection**; No “**drizzle problem**”;
Better represent **sub scale** (TIME/SPACE) **processes/interactions** crucial for a realistic representation of local climate and extremes;
Reduced uncertainty;
Investigate **new insights** possibly coming out at these scales in complex topography and/or morphology areas.

Drawbacks: Running at km-scale is **computationally demanding**;
Steeper gradients can induce to **numerical instabilities** not easily manageable;
(Usually) small domains have to be treated carefully to manage artificial information which can possibly derive from “reflections” at domain borders (which also contribute to instability).

https://doi.org/10.1175/MWR2830.1



>10 Km | Cumulus schemes

1)Activation → Trigger function
2)Intensity → Closure Assumptions Vertical Distribution → Vertical assigned profile

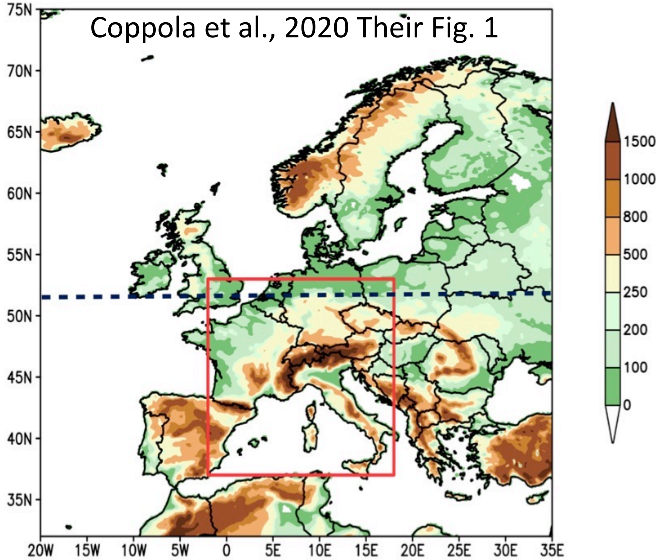
4-10 km | Cumulus schemes still needed

Some assumptions in Cum. Schemes are violated and deep convection is insufficiently resolved to be modeled explicitly. [Prein et al., 2015]

Some Climate Application: multi-model Ensemble Euro-CORDEX FPS-CONV and EUCP

WCRP CORDEX FLAGSHIP PILOT STUDIES

EUCP European Climate Prediction system



Multi-model approach

-Build *robustness* of evidences from single-model studies

-*Generalize* some aspects arising from single-area studies

-Provide a collective *assessment* of our *modelling* capacity at the *km-scale* and build robust evidences for *climate change* projections

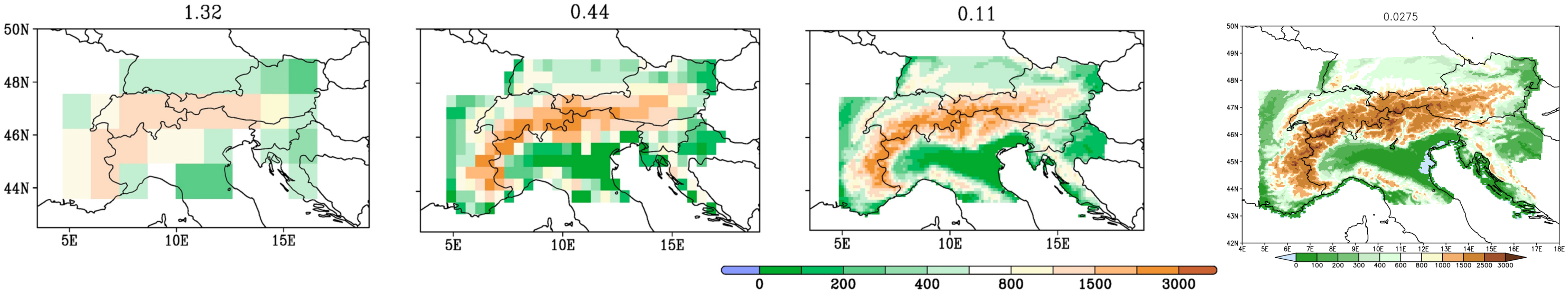
Coppola, E., Sobolowski, S., Pichelli, E. *et al.* A first-of-its-kind multi-model convection permitting ensemble for investigating convective phenomena over Europe and the Mediterranean. ***Clim Dyn* 55, 3–34 (2020). https://doi.org/10.1007/s00382-018-4521-8**

Ban, N., et al. (2021) The first multi-model ensemble of regional climate simulations at kilometer-scale resolution, part I: evaluation of precipitation, **Climate Dynamics. doi:10.1007/s00382-021-05708-w**

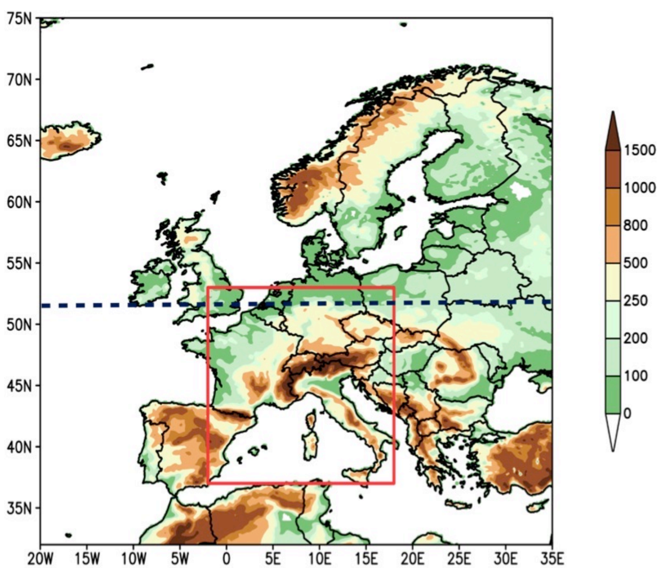
Pichelli, E. et al. (2021) The first multi-model ensemble of regional climate simulations at kilometer-scale resolution part 2: historical and future simulations of precipitation, **Climate Dynamics, doi:10.1007/s00382-021-05657-4**

Grid Resolution

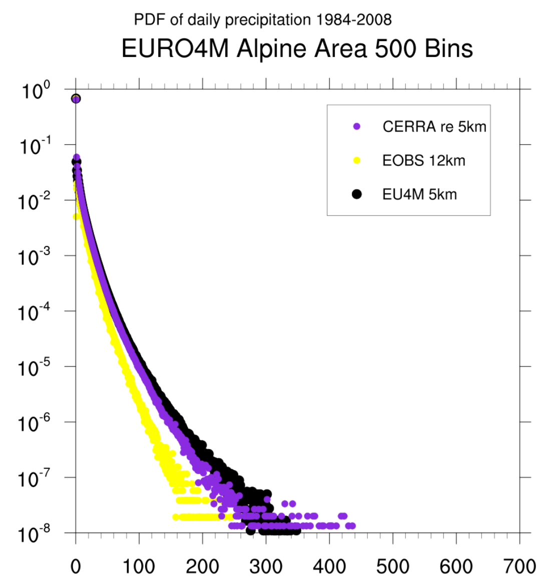
https://doi.org/10.1002/2014JD022781



12km 527x477x**24**



3km 575x605x**41**



Resolution matters even for the benchmark choice

Evaluation simulations (Ban, N., et al. 2021)

Group	Group Name	Model	Grid Spacing	Intermediate step grid spacing/ Model/Domain
IPSL	Institut Pierre-Simon-Laplace (FR)	WRF381BE	3	15/WRF/EURO-CORDEX
BCCR	The Bjerknes Centre for Climate Research (NO)	WRF381BF	3	15/WRF/EURO-CORDEX
AUTH	Aristotle University of Thessaloniki (GR)	WRF381BG	3	15/WRF/EURO-CORDEX
CICERO	Climate and Environmental Research (NO)	WRF381BJ	3	15/WRF/EURO-CORDEX
FZJ	Research Centre Jülich (DE)	WRF381BB	3	15/WRF/EURO-CORDEX
IDL	Instituto Dom Luiz (PT)	WRF381BH	3	15/WRF/EURO-CORDEX
UCAN	Universidad de Cantabria (ES)	WRF381BI	3	15/WRF/EURO-CORDEX
UHOH	University of Hohenheim (DE)	WRF381BD	3	15/WRF/EURO-CORDEX
WEGC	University of Graz (AT)	WRF381BL	3	15/WRF/EURO-CORDEX
ICTP	International Centre for Theoretical Physics (IT)	RegCM4	3	12/RegCM4/Europe
DHMZ	Meteorological and Hydrological Service (HR)	RegCM4	4	12/RegCM4/Europe
KNMI	Royal Netherlands Meteorological Inst. (NL)	HCLIM38-AROME	2.5	12/RACMO/Europe
HCLIMcom	HARMONIE-Climate community (DK, NO, SE)	HCLIM38-AROME	3	12/ALADIN/Europe
CNRM	Centre National de Recherches Meteorologiques (FR)	CNRM-AROME41t1	2.5	12/ALADIN/Med-CORDEX
GERICS	Climate Service Center (DE)	REMO	3	12/REMO/Europe
UKMO	Met Office Hadley Centre Exeter (UK)	UM	2.2	No*
ETHZ	ETH Zürich (CH)	COSMO-CLM	2.2	12/COSMO-CLM/Europe
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici (IT)	COSMO-CLM	3	12/COSMO-CLM/Euro-CORDEX
KIT	Karlsruhe Institute of Technology (DE)	COSMO-CLM	3	25/COSMO-CLM/Europe
GUF	Goethe University Frankfurt (DE)	COSMO-CLM	3	12/COSMO-CLM/Euro-CORDEX
BTU	Brandenburg University of Technology (DE)	COSMO-CLM	3	12/COSMO-CLM/Euro-CORDEX
JLU	Justus-Liebig-University Giessen (DE)	COSMO-CLM	3	No

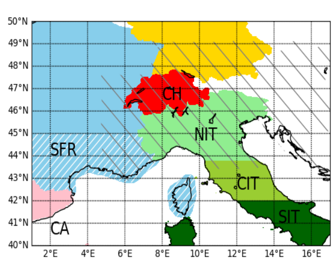
In total, we analyze 23 simulations with ~3km grid spacing (no deep convection parametrization, CPMs) and 22 simulation with > 12 km grid spacing (parametrized convection, RCMs).

6 different regional climate models are represented in the ensemble.

10-year long simulations (**2000-2009**) driven by ERA-Interim reanalysis.

*UKMO does not use an intermediate nesting step, but provide the simulation data at the 12 km grid spacing for comparison

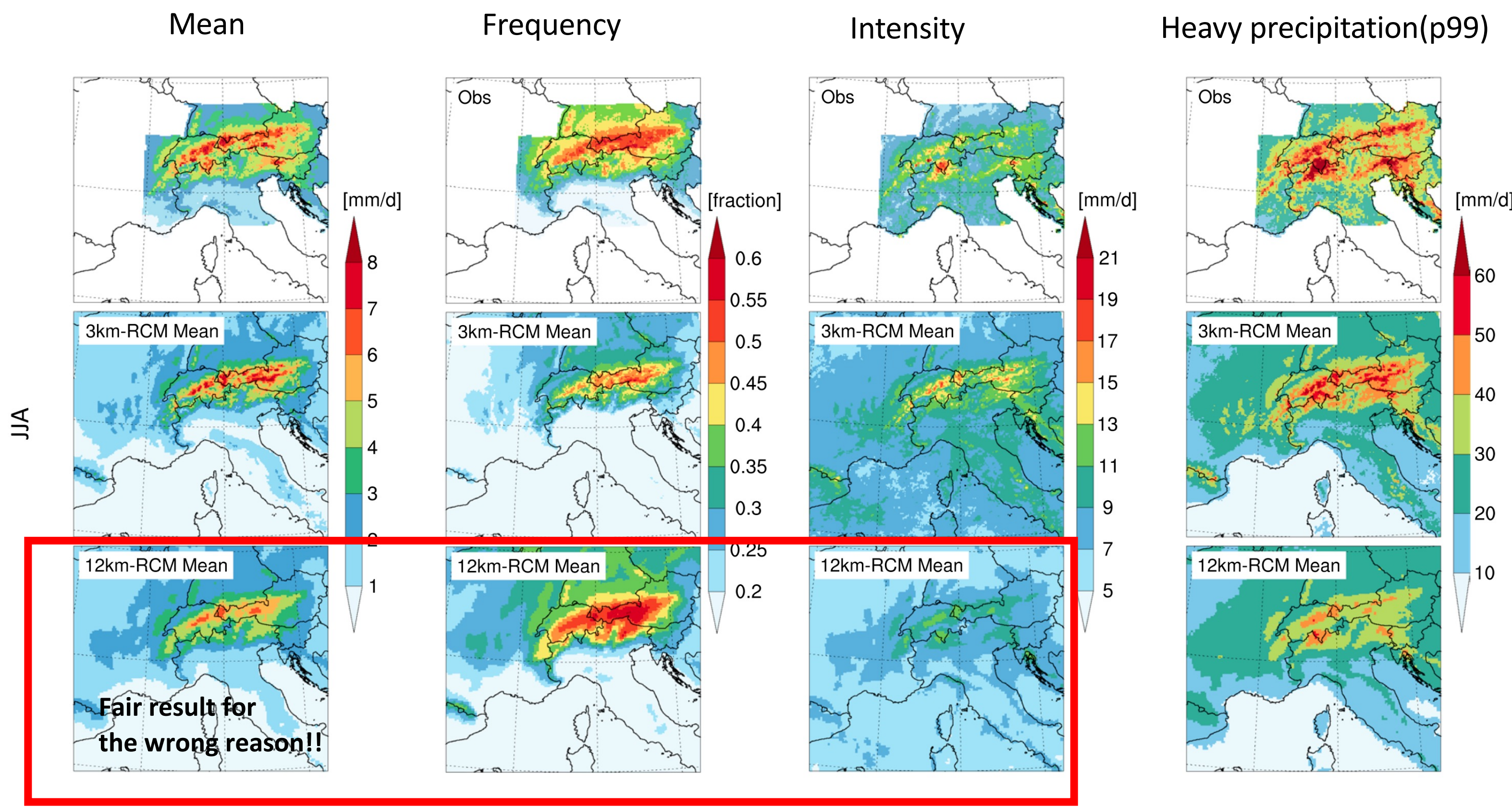
High resolution (dt, dx) Observations



Observations	Area	Grid Resolution	Time Resolution	Period
EURO4M-APGD	Alpine region	5 km	Daily	1971-2008
RdisaggH	Switzerland	1 km	Hourly	2003-2010
COMEPHORE	France	1 km	Hourly	1997–2006
GRIPHO	Italy	3 km	Hourly	2001-2016

Multi-model mean of daily precipitation in the summer season

(Ban, N., et al. 2021)



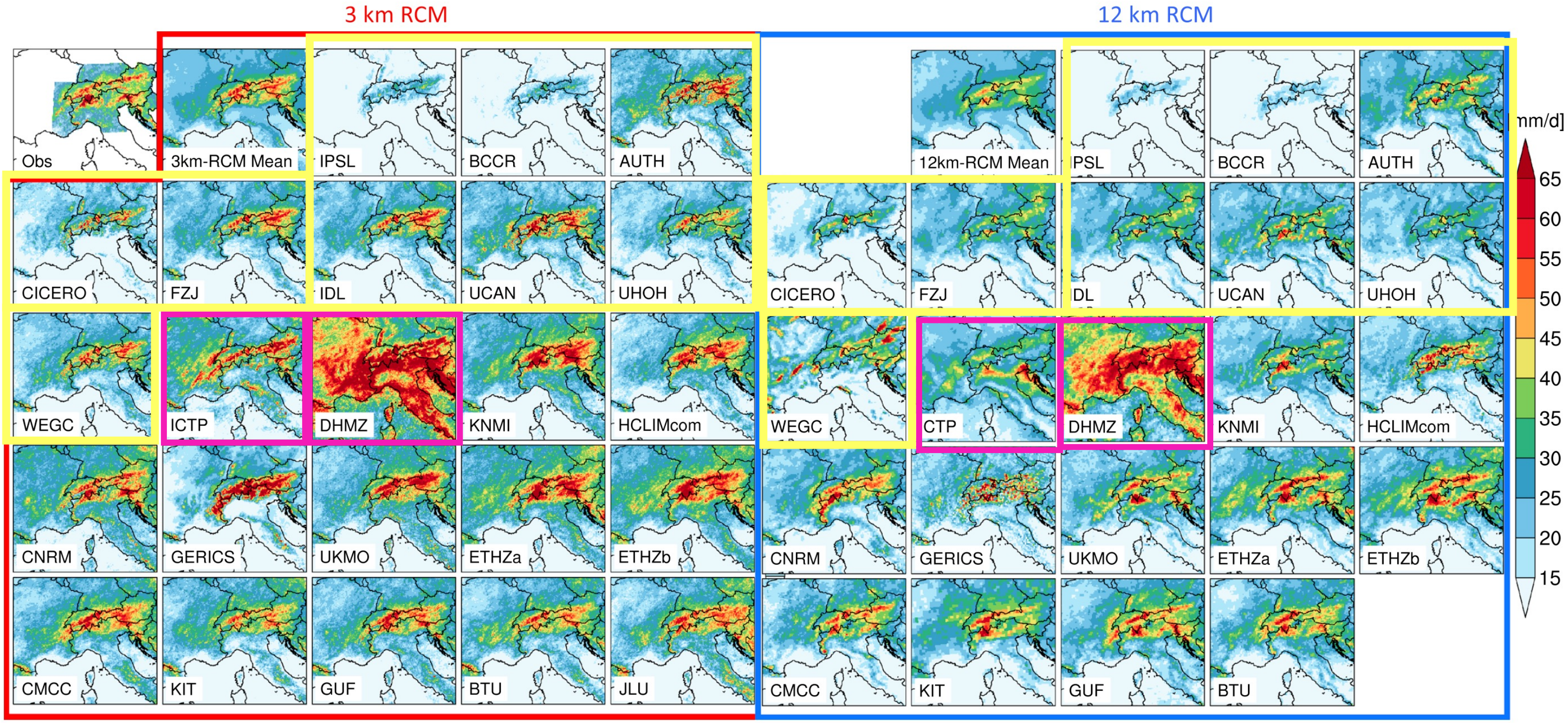
ABBREVIATION	DEFINITION	UNIT
Mean	Mean Precipitation	mm/d
Freq	Wet day/hour[a] frequency	[fraction]
Int	Wet day/ hour[a] intensity	[mm/d] / [mm/h]
pXX	XX percentile[b] of daily/hourly precipitation	[mm/d] / [mm/h]

→ 12 km RCM mean shows a large **underestimation** of precipitation **intensity**, and **overestimation** of precipitation **frequency**

→ 3 km CPM mean show better performance in reproducing the spatial patterns of precipitation, driving toward an improvement of the long-standing "*drizzle problem*" with coarse resolution models

Heavy daily precipitation in the summer season

(Ban, N., et al. 2021)

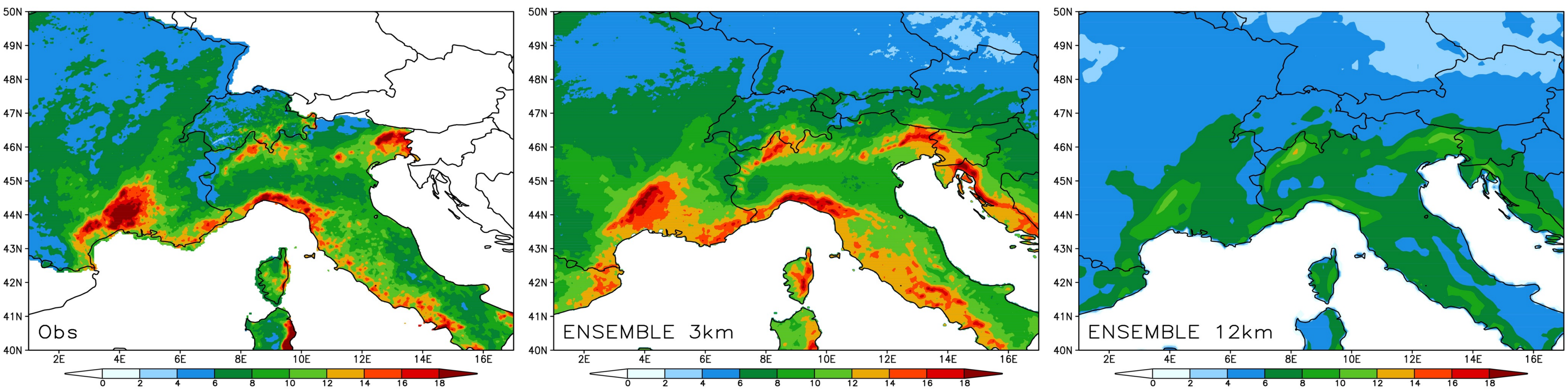


→ Large variability between the models, but a clear difference between the 3km and 12 km RCMs

Multi-model mean of heavy h**ourly** precipitation in the fall season

(Pichelli et al., et al. 2021)

1996-2005 (p99.9)



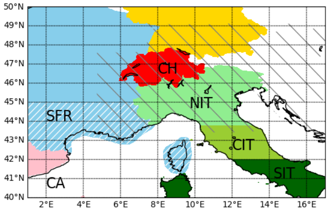
Misure

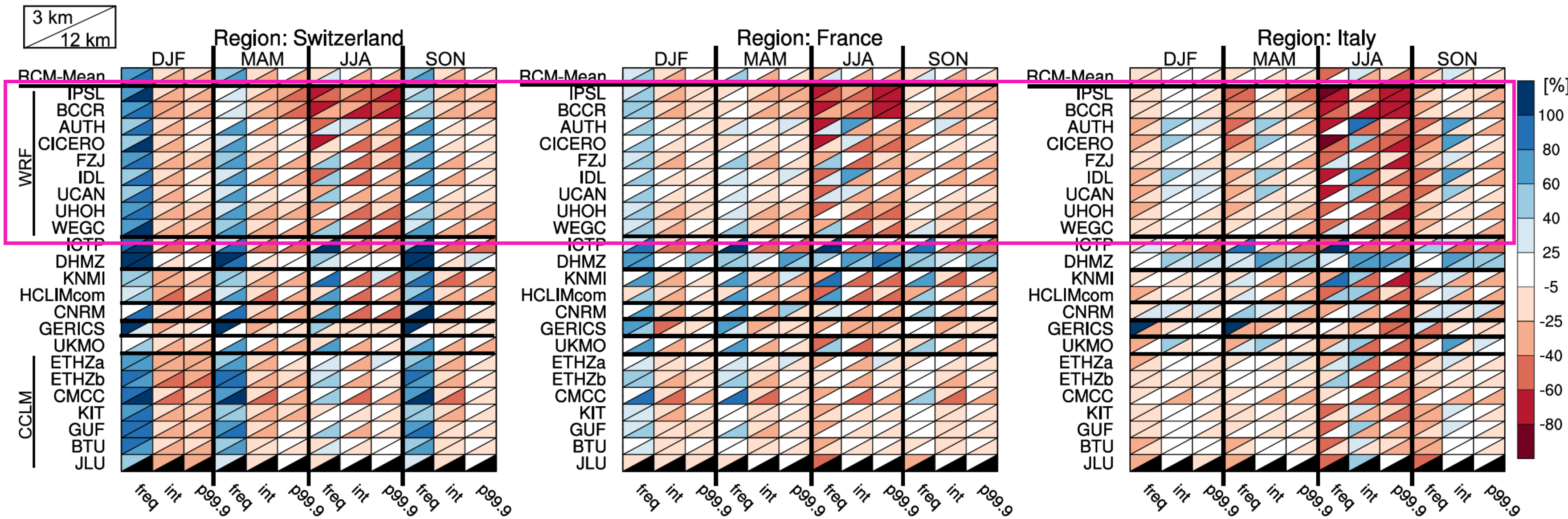
Modelli alta risoluzione

Modelli bassa risoluzione

Relative bias for hourly precipitation

(Ban, N., et al. 2021)



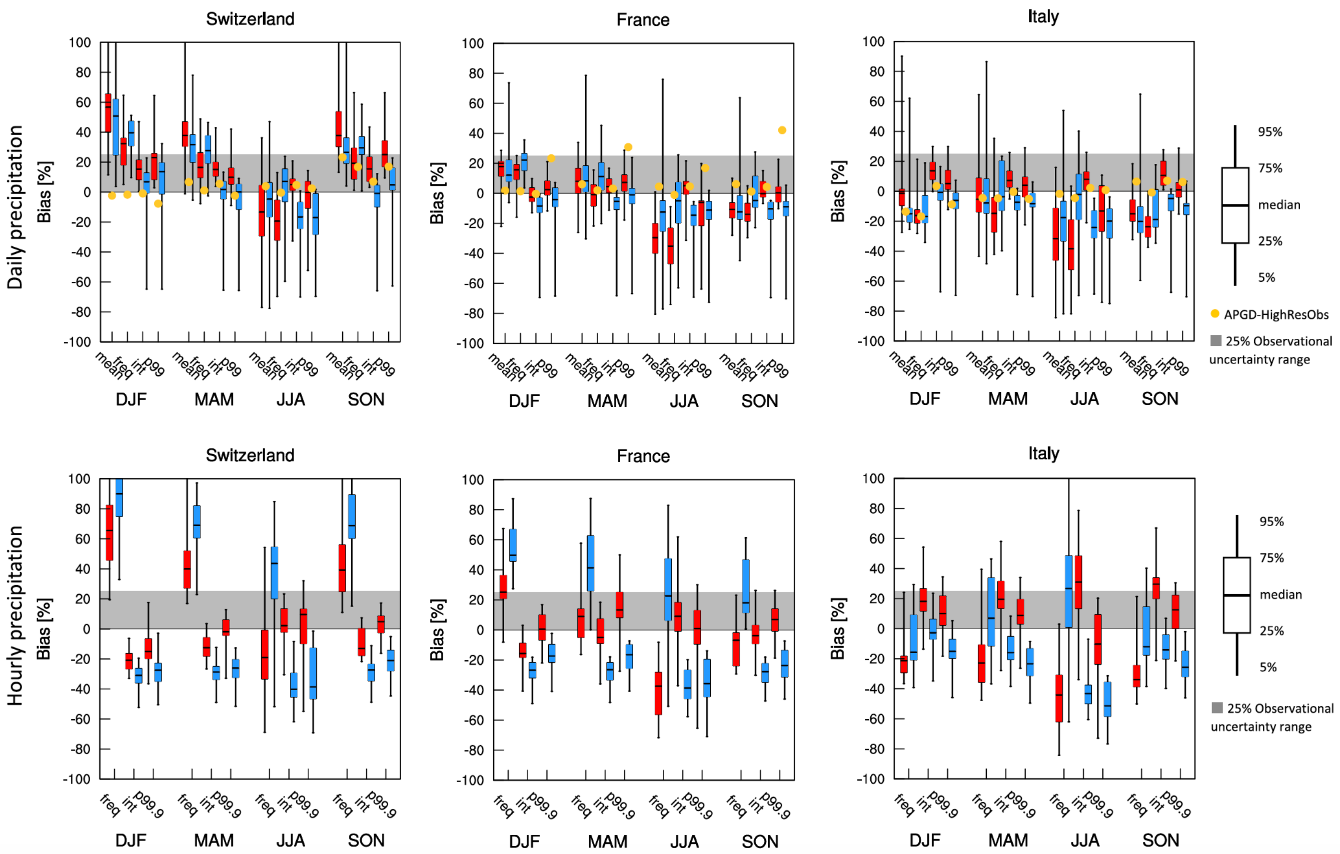


→ Overestimation of precipitation frequency and underestimation of precipitation intensity in almost all seasons and especially over Switzerland

→ The biases are more pronounced in the 12 km models

→ The ensemble mean shows a reduction in biases for km-scale simulations, although some exceptions exist

Precipitation uncertainty (Ban, N., et al. 2021)



→ Larger differences between RCMs and CPMs at sub-daily scale;

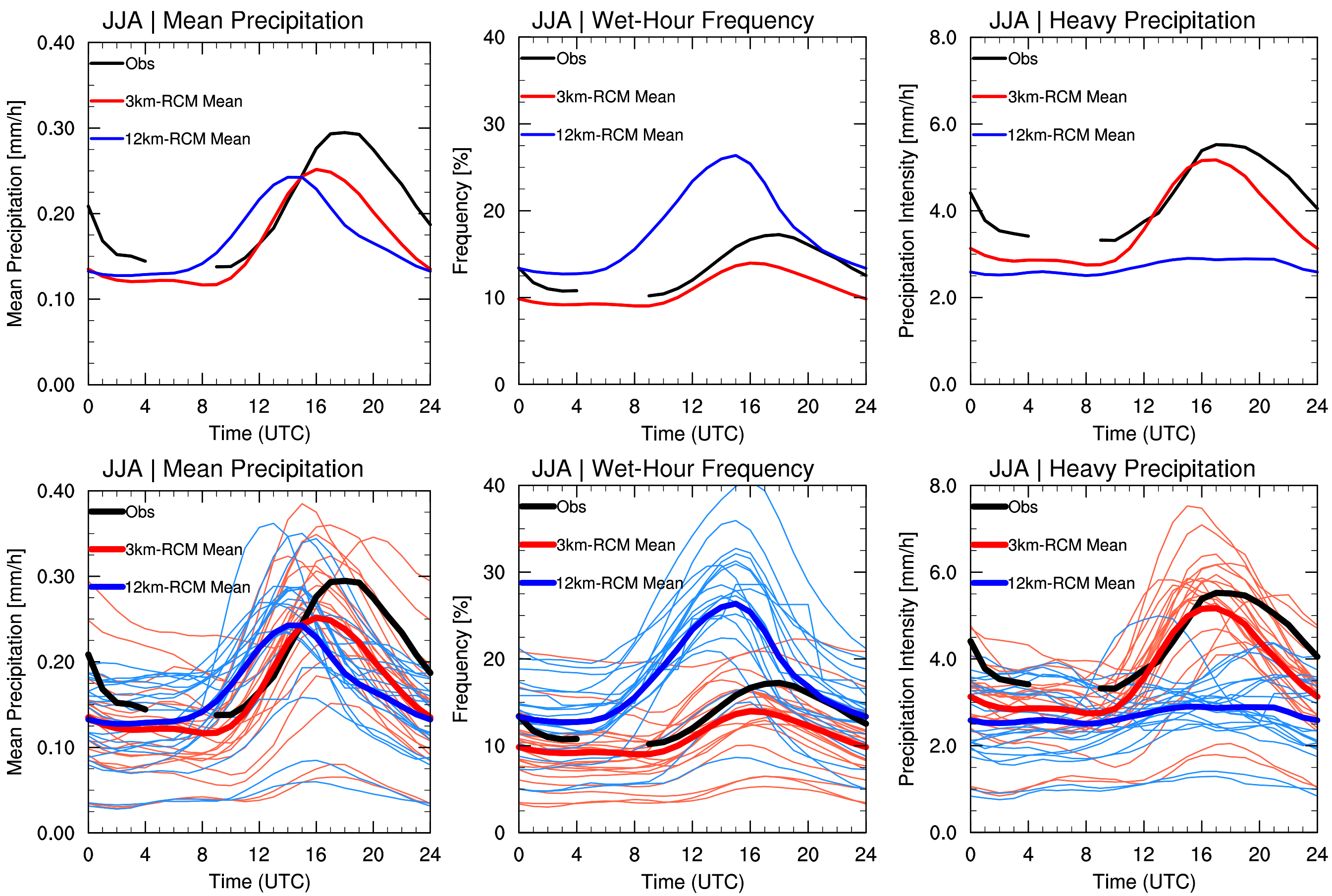
→ Smaller biases for CPMs at the hourly scale;

→ **Smaller uncertainties** for CPMs at the hourly scale (all regions, most indices and seasons);

→ side note: differences between the two observations can be larger than 20%

Diurnal cycle of summer precipitation

-SWITZERLAND-



→ The ensemble mean of km-scale simulations shows superior performance to the ensemble mean of coarse resolution simulations over Switzerland (current slide) and France and Italy (next slide)

→ However, a large spread exists even within the km-scale ensemble

Model Projections

(Pichelli, E., et al. 2021)

INSTITUTE	CP-RCM	Resolution (km)	Driving RCM	Resolution (km)	GCM
KNMI (**) The Royal Netherlands Meteorological Institute	HCLIM38-AROME	2.5	RACMO	12	EC-Earth
DMI- MET Norway- SMHI (**) HARMONIE-Climate community	HCLIM38-AROME	3	HCLIM38-ALADIN	12	EC-EARTH
CNRM (**) Centre National de Recherches Meteorologique	CNRM-AROME41t1	2.5	CNRM-ALADIN63	12	CNRM-CM5
ICTP (**) Abdus Salam Internatinal Centre for Theoretical Physics	RegCM4	3	RegCM4	12	HadGEM
KIT Karlsruhe Institute of Technology	CCLM5	3	CCLM4	12	MPI-ESM-LR
BTU Brandenburg University of Technology	CCLM5	3	CCLM4	12	CNRM-CM5
ETHZ (**) Federal Institute of Technology, Institute for Atmospheric and Climate Science	CCLM	2.2	CCLM	12	MPI
ETHZ (**) Federal Institute of Technology	CCLM	2.2	CCLM	12	pgw
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
FZJ-IBG3-IDL Research Centre Julich Institute Dom Luis	WRF3.8	3	WRF3.8.1CA	15	EC-EARTH
BCCR The Bjerknes Centre for Climate Research	WRF3.8	3	WRF3.8.1CA	15	NorESM1

12 CPMs ~3km grid spacing

11 RCMs (*) ~ 12/15 km

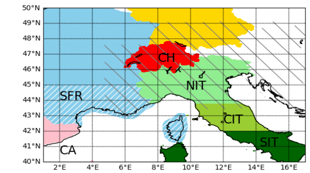
5 different regional climate models are represented in the ensemble.

10-year long simulations (Historical period: **1996-2005**; Future projection: **2090-2099**) driven by CMIP5 GCMs.

CORDEX-FPS Convection Community model members + (**) EUCP (European Climate Prediction system) model members

2090-2099
Hourly Pr. change
(Pichelli, E., et al. 2021)

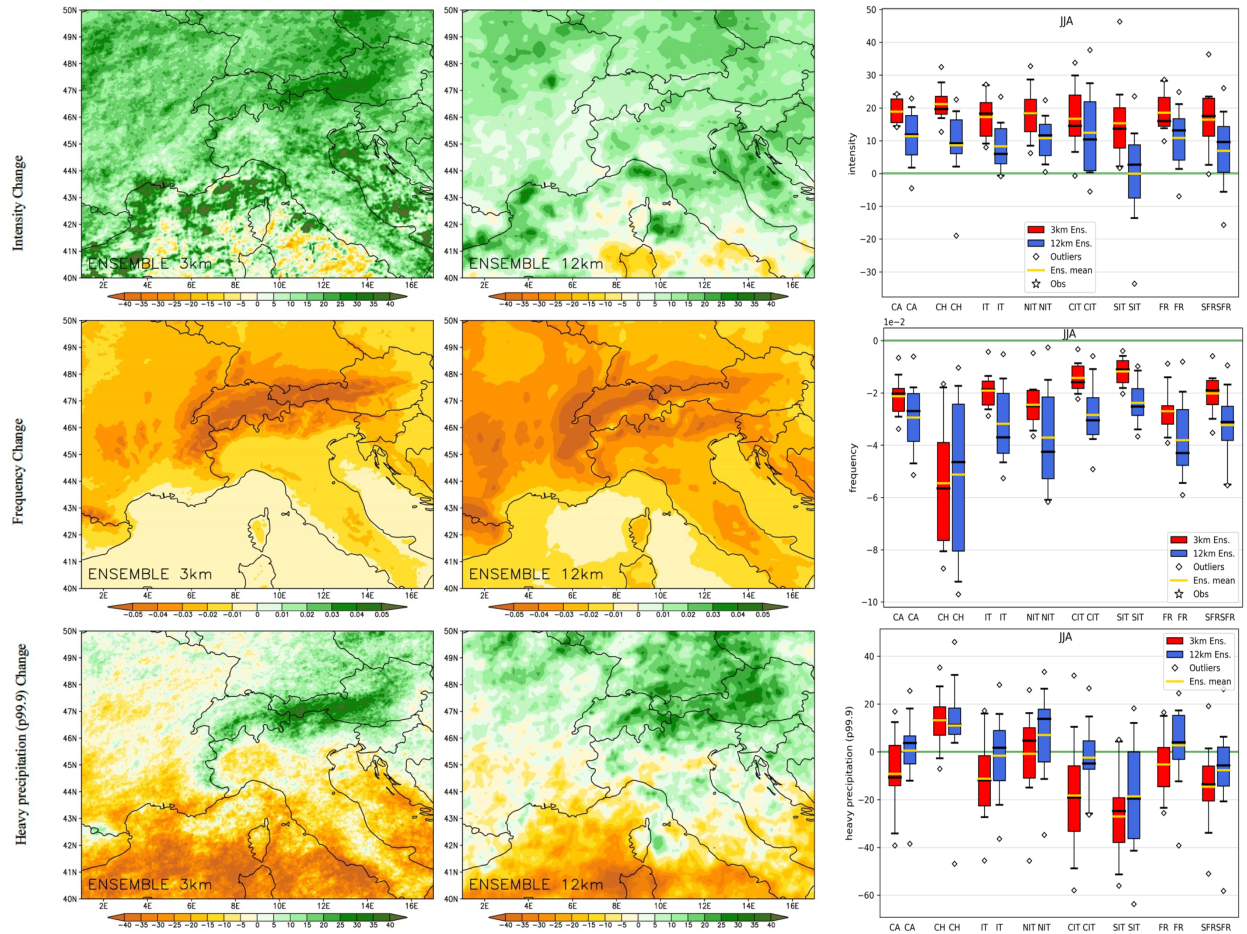
- At the hourly time scale the patterns of change in **agreement** between CPM-e and RCM-e
- CPM-e shows an **intensification** of its **response** mainly across the orography in JJA
- for **HPE** largest changes over the Alps and western Mediterranean; switch of sign compared to the RCMs over part of northern Italy (subalpine region) and central-northern France
- **smaller uncertainty** for frequency and intensity; **higher sign agreement** (int., P99.9) among CPMs over SIT and SFR (not for RCMs)



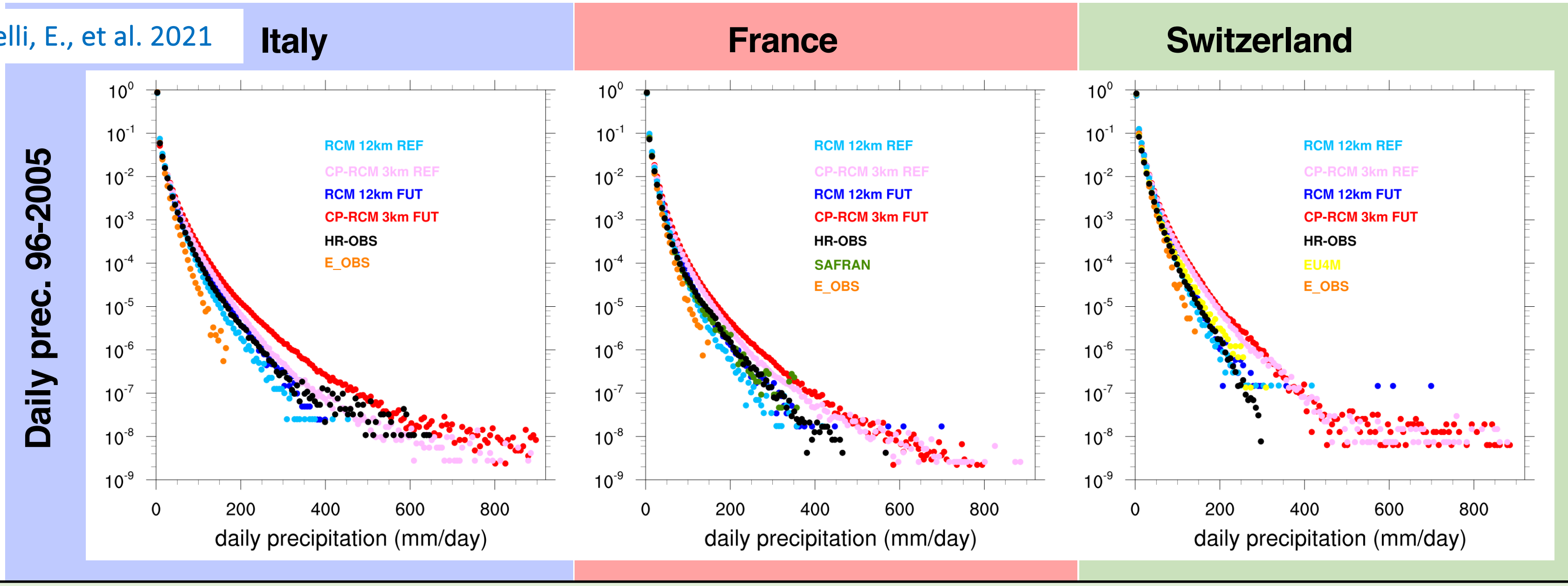
JJA

3 km

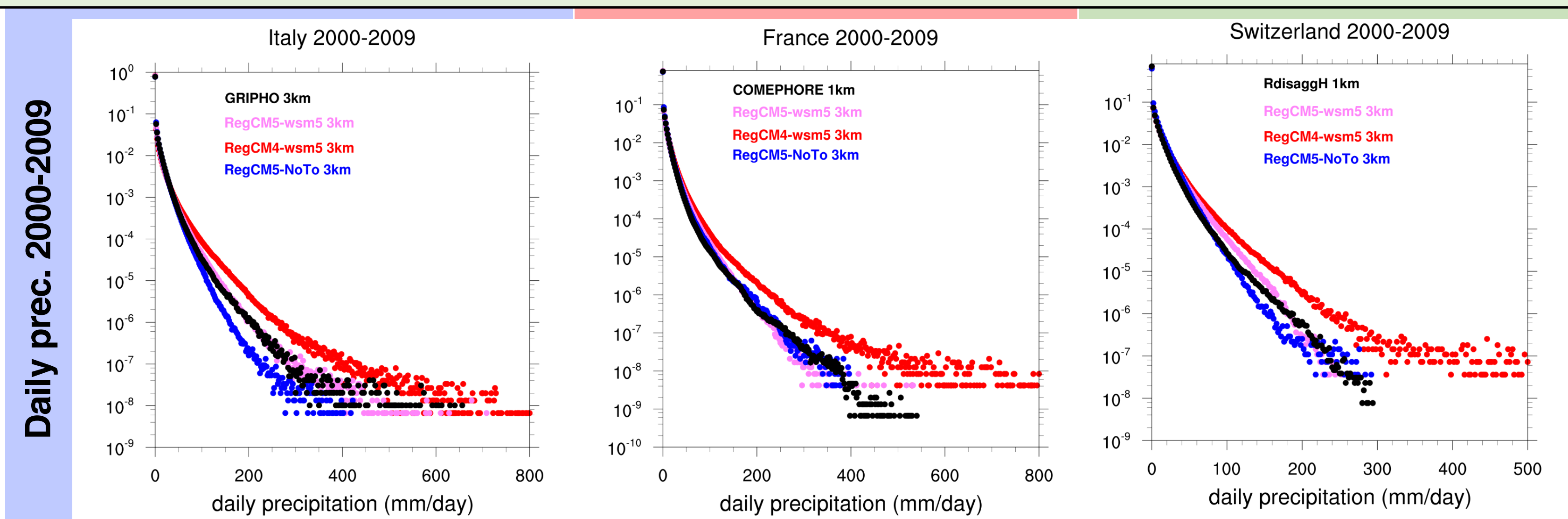
12 km



From RegCM4.7.1 (MM5) to RegCM5 (Moloch)

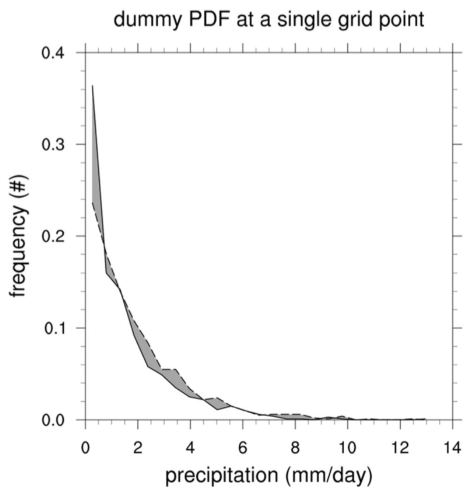


Giorgi et al. (2023) The fifth generation regional climate modeling system, RegCM5: Description and illustrative examples at parameterized convection and convection-permitting resolutions. **Journal of Geophysical Research: Atmospheres, 128, e2022JD038199. https://doi.org/10.1029/2022JD038199**



A measure for the Added Value (AV): pr

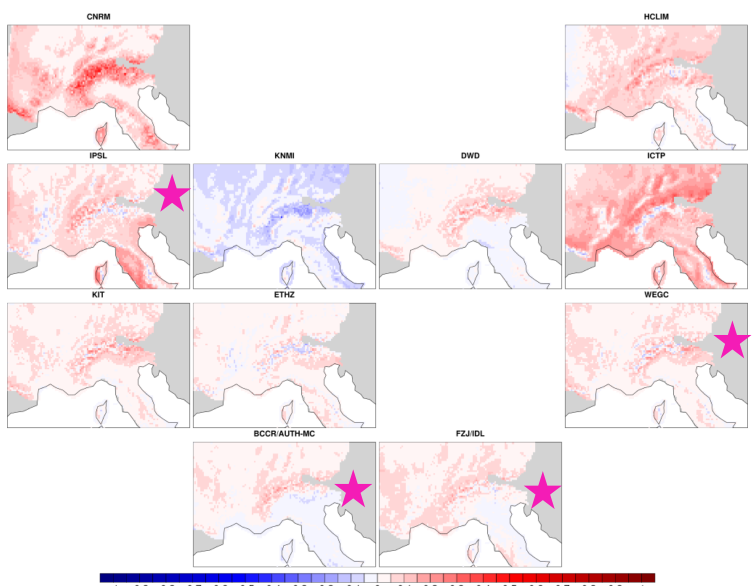
Ciarlo et al. (2021) https://doi.org/10.1007/s00382-020-05400-5



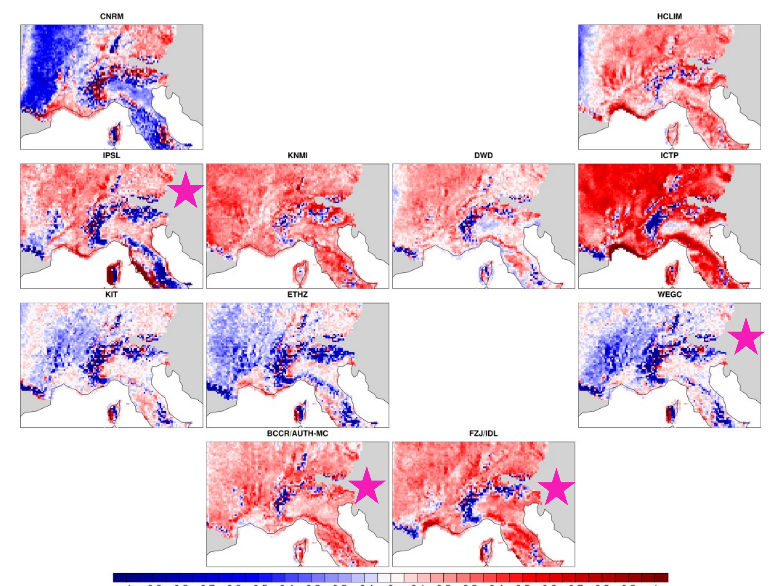
$$D_M = \frac{\Sigma_{\nu=1}^{\nu_t} \left| \left(N_M - N_O \right) \Delta \nu \right|}{\Sigma_{\nu=1}^{\nu_t} \left(N_O \Delta \nu \right)}.$$

Relative probability difference

$$A_i = D_{RCM} - D_{CPM}$$



ens-mem-av-pr-1hr-CPM-rcm-cond-cro-0-100



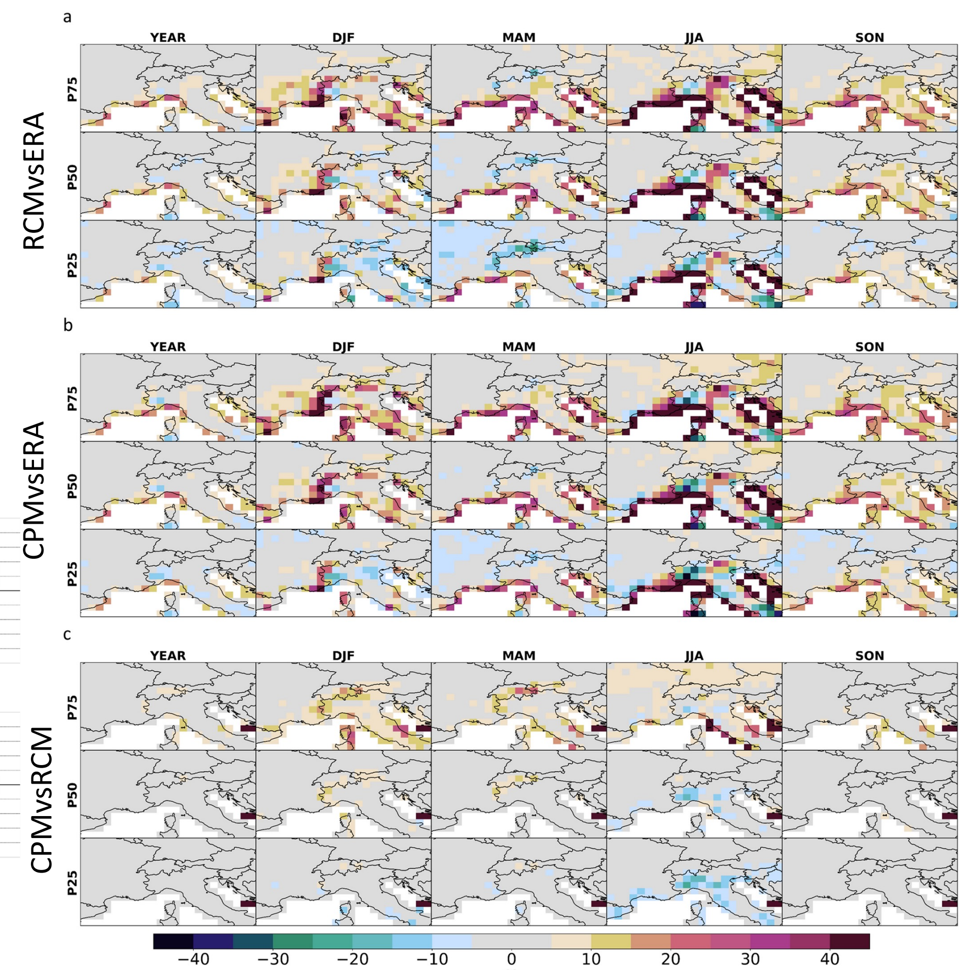
ens-mem-av-pr-1hr-CPM-rcm-cond-cro-99-100

A measure for the Added Value (AV): tasmax

Soares et al. (2022) https://doi.org/10.1007/s00382-022-06593-7

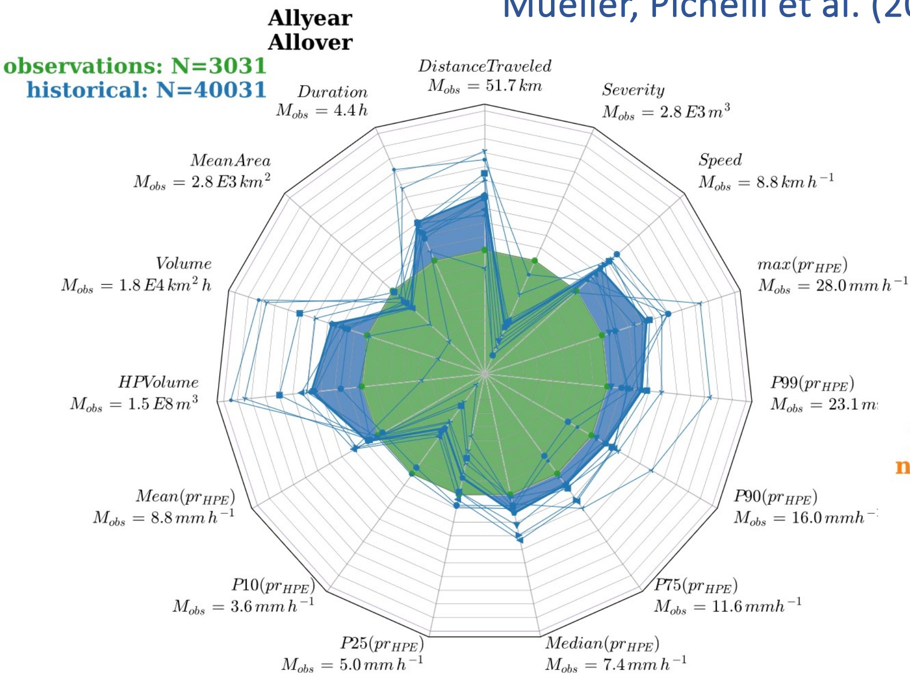
$$S_{mr} = \sum_{1}^{n} \min\left(Z_{mr}, Z_{\text{obs}}\right)$$

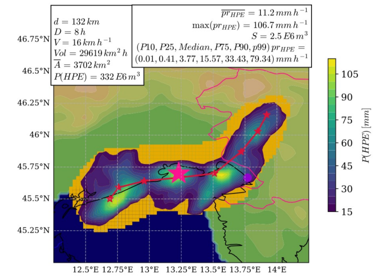
$$DAV = 100 \times \frac{S_{hr} - S_{lr}}{S_{lr}}$$



The CPMs to study storms response to warming climate

Mueller, Pichelli et al. (2023) https://doi.org/10.1007/s00382-023-06901-9





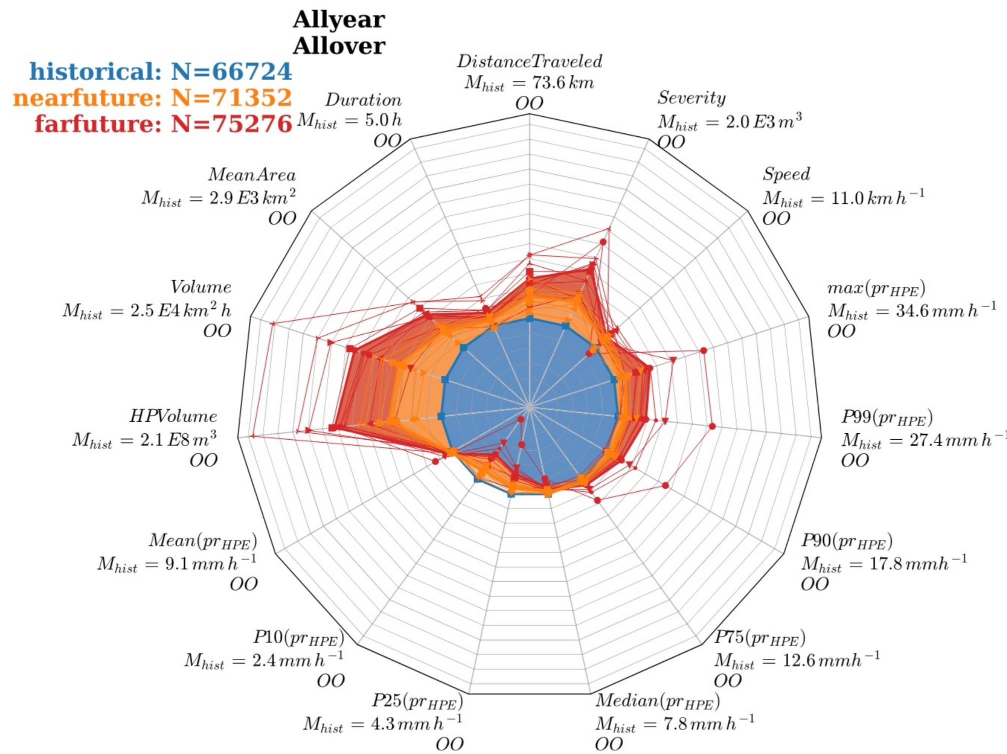


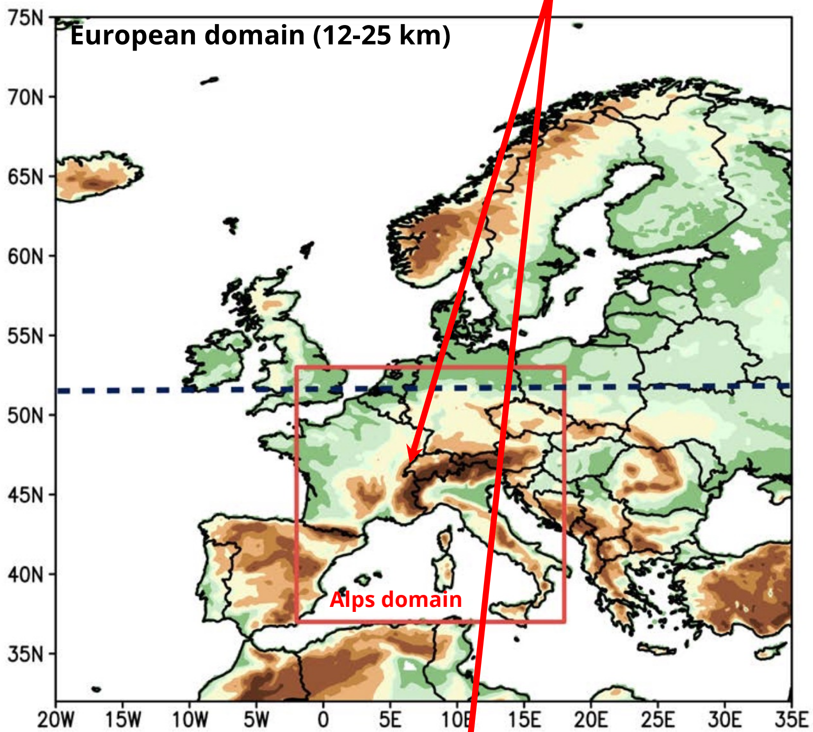
Table 3 Definitions of all variables and HPE properties used in this study

	Property	Definition
General Properties	pr_{HPE} $[mm\,h^{-1}]$	The precipitation field associated with a HPE
	N $[-]$	The total number of HPEs identified
	OF $[time^{-1}]$	Occurrence frequency, defined as the number of HPEs identified by unit time
	OFD $[time^{-1}\,area^{-1}]$	Occurrence frequency density, defined as the number of HPEs identified by unit time a area.
Eulerian Properties	P(HPE) $[mm]$	Accumulated heavy precipitation, given by the integration of pr_{HPE} for a given locatio
	P(HPE)/$P(total)$ [%]	Heavy precipitation fraction, with P(total) being total accumulated precipitation.
Lagrangian Properties	$mean(pr_{HPE})$ $[mm\,h^{-1}]$	The mean precipitation rate of a HPE
	$max(pr_{HPE})$ $[mm\,h^{-1}]$	The maximum precipitation rate of a HPE
	$P\tau(pr_{HPE}$ $[mm\,h^{-1}]$	The τ-th percentile of the precipitation field of a HPE
	D[h]	The *Duration* of a HPE. (A HPE occurring only for a single time step will be attribute 1 h of duration.)
	$\overline{A}$ $[km^2]$	The *Mean Area* of a HPE, averaged over its *Duration*, *D*
	Volume $[km^2h]$	The geometrical volume of a HPE $:= D \times \overline{A}$
	HPVolume $[m^3]$	Heavy precipitation volume of a HPE, given by the integration of its precipitation fiel
	d $[km]$	The *Distance Traveled* of a HPE, given by sum of distances measured between the HP troids at each time step during its life time
	V $[km\,h^{-1}]$	The *Speed* of propagation of a HPE, given by the division of *Distance Traveled* by *Duration*: $\frac{d}{D}$.
	Intensity $[mm\,h^{-1}]$	$\overline{((P75, P90, P99, max)(pr_{HPE}))}$, that is the mean of percentiles 75, 90 and 99 as well as of the maximum of pr_{HPE}
	Severity $[m^3]$	$D \times \alpha \times mean(pr_{HPE}) \times \overline{A} \times \frac{V_{max}}{V}$ with $\alpha = \frac{1}{1000}$ and $V_{max} = 35\,ms^{-1}$

Selection of disastrous storms

Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

Spatio-temporal constraint
DT : the event occurs in the ALP3 domain area in the 2000-2009 decade



2000-2009

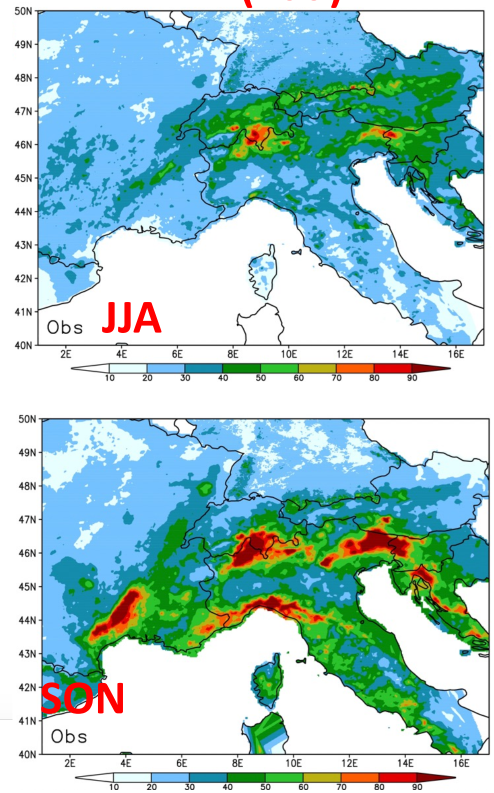
ERA-Interim driven sim. at the CP scale

time

CORDEX-FPSCONV

Coppola et al. (2020)
DOI: 10.1007/s00382- 018-4521-8

HPE (P99)



Pichelli et al. (2021) DOI:10.1007/s00382-021-05657-4

Severe Impact

North East Italy affected area (DI BERNARDO et al. 2003)

https://www.monzatoday.it/cronaca/monza-alluvione-2002-brianza.html

Ecosystem damages

Human casualties/injuries

Economical losses

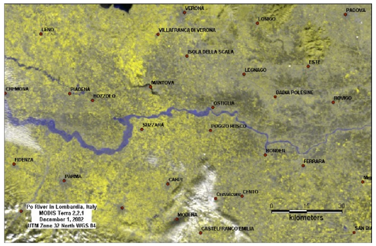
WCRP CORDEX FLAGSHIP PILOT STUDIES

XAIDA

XAIDA	Date	Region	Description	Impact	Main area
1	**Jul. 2009** (23/07/07)	Austria Bavaria (South Germany)	Cold front inducing severe thunderstorms and hail; interaction between the convergence line and the foehn.	60 000 hectare arable lands devastated. Damages 15 Mln Euro.	South Germany 8-13.5E 47.5-50
2	**Jun. 2009** (22-25/6/09)	Austria Bavaria (South Germany)	-Convective orographic precipitation induced by persistent large-scale forcing due to a shallow North Atlantic trough. -354 mm of rain at the Steinholz station. (lower Austria, northern foothills of the Eastern Alps); estimated return period of more than 100 years (Godina and Müller 2009). -Bavaria: 70mm/day	-Seven districts in lower Austria were already affected. Several rivers (Ybbs, Melk, Erlauf, Traisen, Perschling) were flooded. -Lower Austria 60 Mln Euro claims. -Bavaria Traunstein affected by the flooding owing to rising tributaries.	13-16E 47.4-48.5/6N
3	**Sept. 2007** (18/09/07)	Slovenia	-Cold front was moving from the west Europe towards the Alps and the prefrontal SW moist winds caused quasi-stationary convection over the north-western parts of Slovenia; -Forcings: continuous (12 hrs from 8AM) flow of moist air from SW, strong instability, wind shear in the lower troposphere, orographic effects; -precipitation: 303 mm/24h or 157 mm/2h	catastrophic flash floods 6 casualties, 60 over 210 municipalities were reporting flood, damages for 200 Mln Euro	13.8-14.5E 46-46.7N
4	**Aug. 2005** (14-23/08/05)	Central and Eastern Europe (Austria, Switzerland, Germany)	-The low pressure system "Norbert" moved over the warmed-up Mediterranean and remained temporarily over the Gulf of Genoa and the Adriatic (Vb-depression), inducing wet flow and rain over the northern flank of the Alps -precipitation: Austria 120 mm and 240 mm; Switzerland: 150 mm	Alpine floods; 1-in-100-year flows Switzerland (14-23/08): 1.9 Mrd Euro Austria (19-23/08): 500 Mln Euro Germany (20-23/08): 185 Mln Euro	7-9.5E 46-47N
5	**Nov. 2002** (23-27/11/02)	Italy	Persisting North-Atlantic trough inducing wet-unstable air toward Alps. Liguria-North Apennines: 170 mm/day (Nov. 24); 470 mm total Lombardia-North Alps 130 mm/day (Nov. 25th); 400 mm total Friuli-Eastern Alps 320 mm/day (Nov. 25); 700 mm total	Floods. 20 years return time exceeded (Scrivia, Toce); several damages around affected areas. no casualties	NAL 8-10E 45.5-46.5N
6	**Sept. 2002** (8-9/09/02)	France	Heavy precipitation system affected the Gard region (Southern France) generated by an upper-level cold North-Atlantic trough, with wet pre-frontal flow. Precipitation: 400 mm/day	Floods destroyed numerous cars, houses, factories and commerce and 24 casualties were recorded. Total amount of damages ascended to 1.2 Bln Euros (Huet et al., 2003)	42.5-45.6N 1-6E
7	**Aug. 2002** (5-13/08/02)	Southern and Eastern Europe Italia Austria Slovenia	In August 2002 two Mediterranean low pressure systems developed, evolving from the West Mediterranean sea toward the north-east, causing heavy rain. 5-6/08 Liguria-Italy 180mm 10-13/08 Germany, Austria (400 mm) and Central Italy	Floods and flash floods. River Elbe catchment: over 11 Bln Euros (64% Czech Republic, 27% of Germany). Austria: 2 Bln Euro damage; 10000 houses damaged. Germany: 180 bridges damaged, 740 km of roads, 538 km of railway. Europe: several casualties	43.5-50N 6-17E 7.5-10E 43.7-44.7N

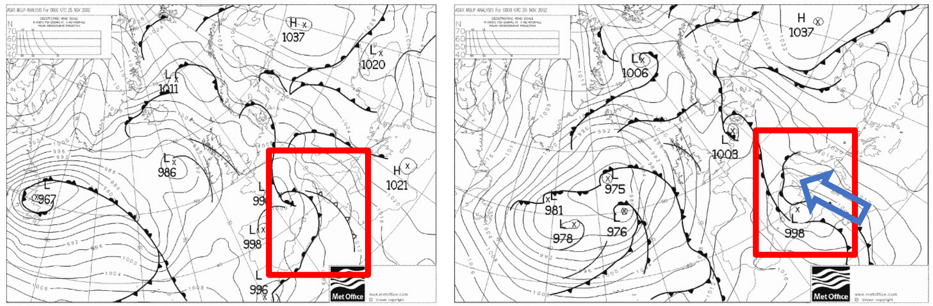
Flooding: 22 Nov. - 2 Dec. 2002 Northern Italy (Po/ Adda/ and tributary rivers, NWI; Friuli VG area, NEI)

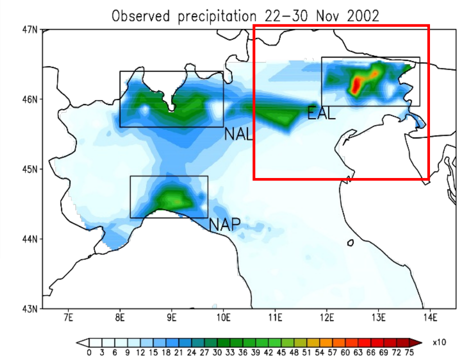
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196



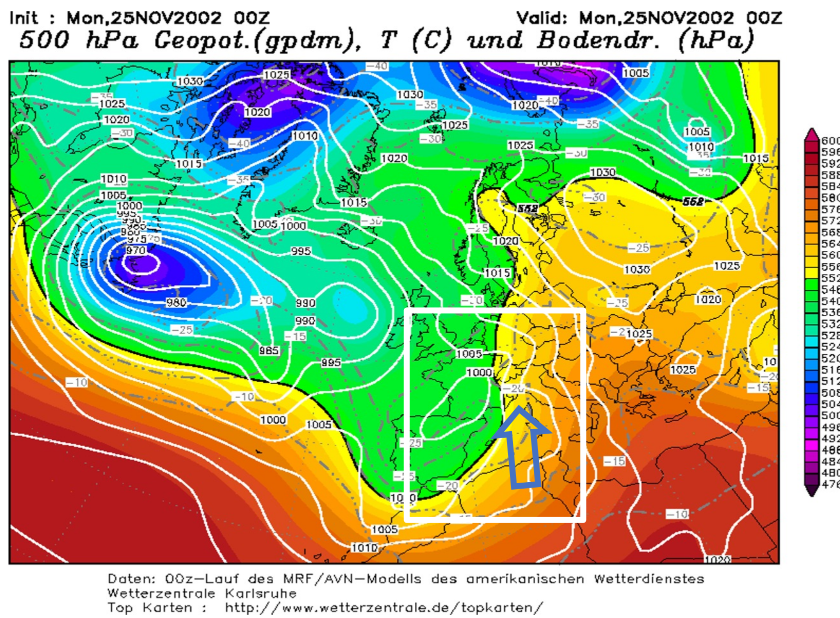
Satellite (MODIS Terra) picture of the Po river in Northern Italy

Surface fronts and MSLP



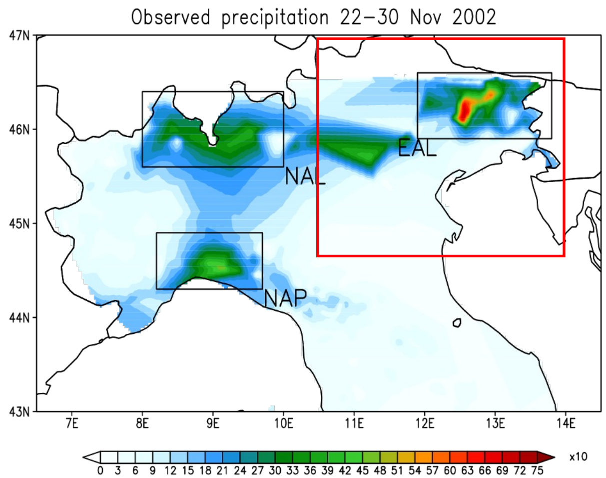


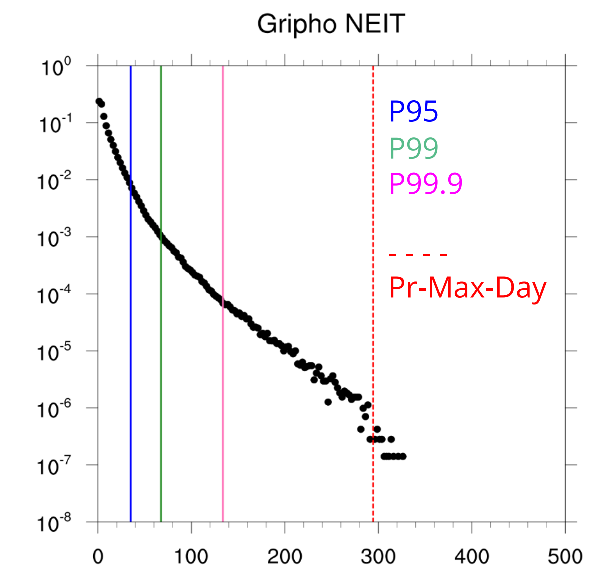
A North-Atlantic **upper-level trough entered the Western Mediterranean** inducing unstable humid south-westerly winds over Northern Italy (black arrows on pressure maps), slowly evolving eastward (finally leaving a cut-off low on the Eastern Mediterranean). Interaction with orography induced persistent thunderstorms across Alps, Apennines and Po Valley.



The precipitation related to this event was heavy and continuous because of the **long persistence of the wet southerly winds**, hitting areas with saturated grounds because of precipitation of previous weeks. Moreover the high freezing level (from 1900m to 2900m) contributed to increase the amount of water discharged (Milelli et al., 2006, https://doi.org/10.5194/nhess-6-271-2006).

Flooding: 22 Nov. - 2 Dec. 2002 Northern East Italy





daily precipitation distribution over Friuli (NE-Italy)

2002	22NOV	23NOV	24NOV	25NOV	26NOV	27NOV	28NOV	29NOV	30NOV		MAX EVENT
OBS max	214.5	14.4	75.9	294.5	261.3	26.1	1.7	101.7	7.7	46.1-46.5 12.5-13.3	705.5

>P99.9 (133.6 mm/d)

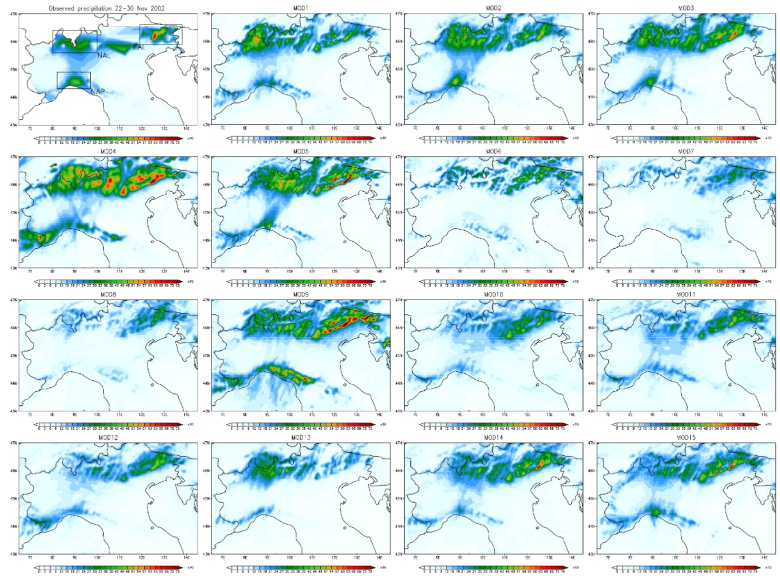
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

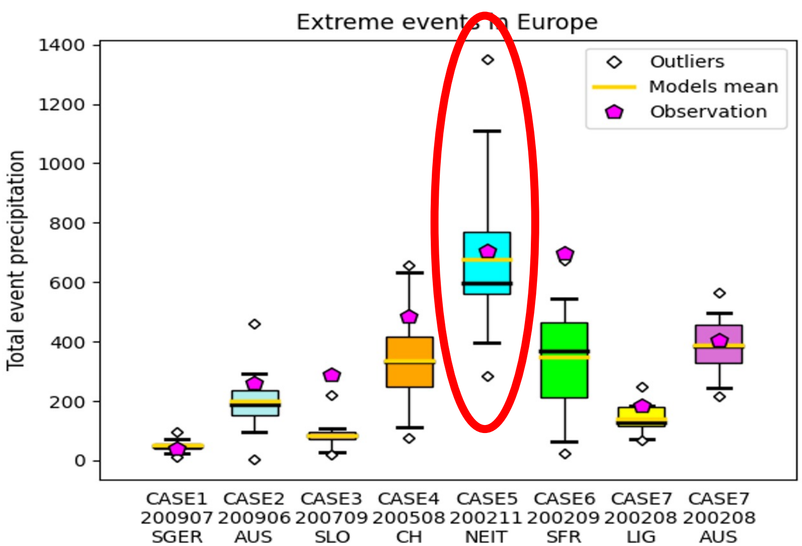
The precipitation event: observed and modeled

Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

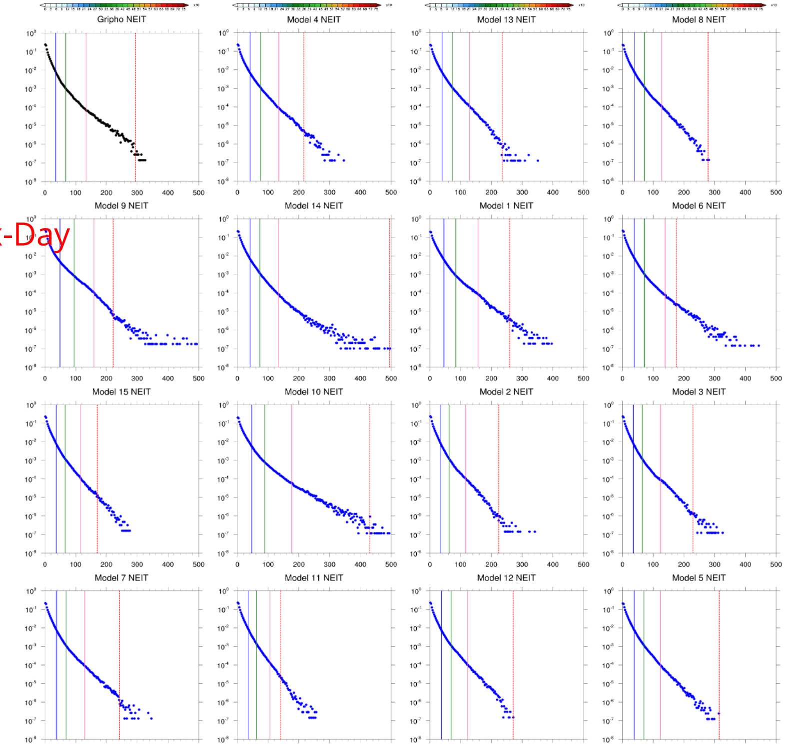
Institute	cpRCM	dx(cpRCM)[km]	Driving RCM	dx(RCM)[km]	RCM domain
AUTH	WRF381BJ (A)	3	WRF	15	EURO-CORDEX
FZJ	WRF381BB	3	WRF	15	EURO-CORDEX
IPSL	WRF381BE (A)	3	WRF	15	EURO-CORDEX
UHOH	WRF381BD	3	WRF	15	EURO-CORDEX
BTU	COSMO-CLM (B)	3	COSMO-CLM	12	EURO-CORDEX
CMCC	COSMO-CLM (B)	3	COSMO-CLM	12	EURO-CORDEX
GUF	COSMO-CLM (B)	3	COSMO-CLM	12	Med-CORDEX
JLU	COSMO-CLM (B)	3	ERAINT	–	–
KIT	COSMO-CLM (B)	3	COSMO-CLM (B1)	25	Europe
ETHZ	COSMO-pompa_5.0 (C)	2.2	COSMO-CLM	12	Europe
CNRM	CNRM-AROME41t1 (C)	2.5	CNRM-ALADIN62 (C1)	12	Med-CORDEX (spectral nudging)
HCLIM-Com	HCLIM38-AROME (D)	3	ALADIN62	12	Europe
KNMI	HCLIM38-AROME (D)	2.5	RACMO	12	Europe
ICTP	RegCM4 (E)	3	RegCM4 (A)	12	Europe
UKMO	UM (F)	2.2	ERAINT	–	–

Mueller et al. (2022, their Table 1) https://doi.org/10.1007/s00382-022-06555-z





P95
P99
P99.9
- - - -
Pr-Max-Day



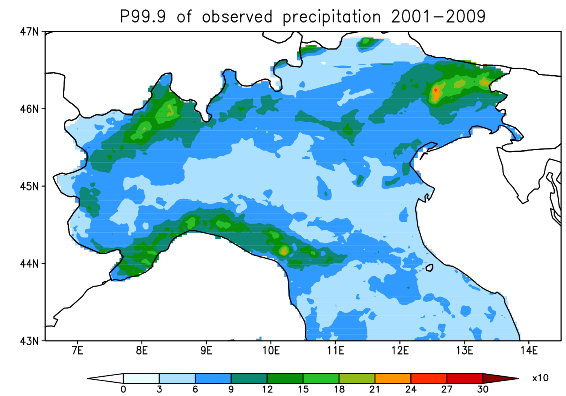
CPMs able to represent HPEs driven by well set forcing (orographic and/or cold fronts), failing in representing HPEs driven by more complex interactions (ex. pre-frontal flow, MCS formation).

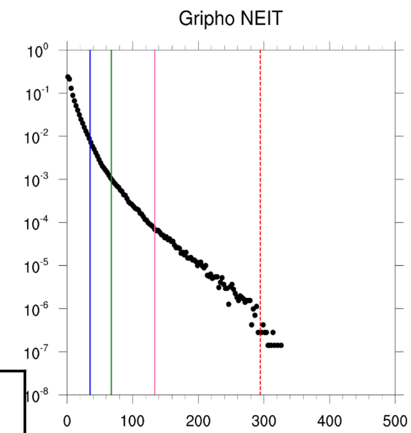
Detection of disastrous-like storms

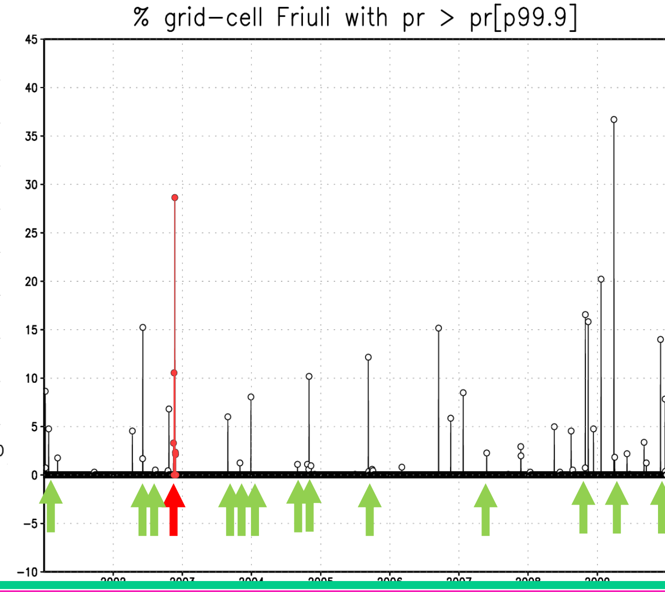
Method based daily precipitation extremes

Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

Chen et al., 2024 https://doi.org/10.5194/egusphere-egu24-2525

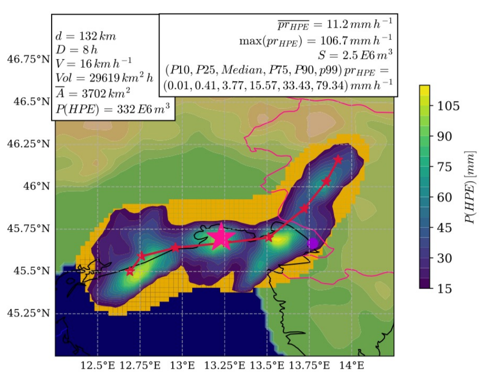




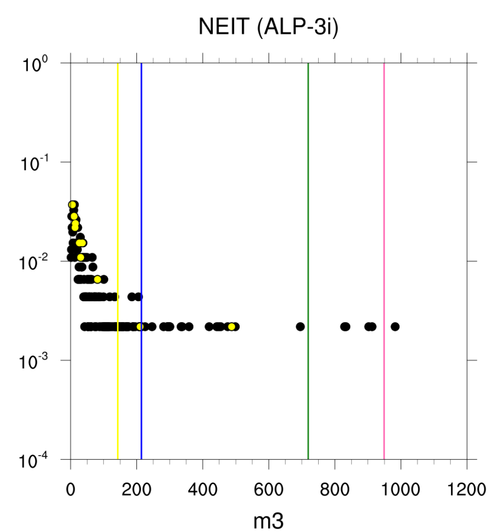


ex	SON	DJF	MAM	JJA
Obs	30	11	7	11

Method based on storm tracks



Mueller et al. (2023, their Table 1)
https://doi.org/10.1007/s00382-023-06901-9



ex	SON	DJF	MAM	JJA
Obs	15	8	9	17

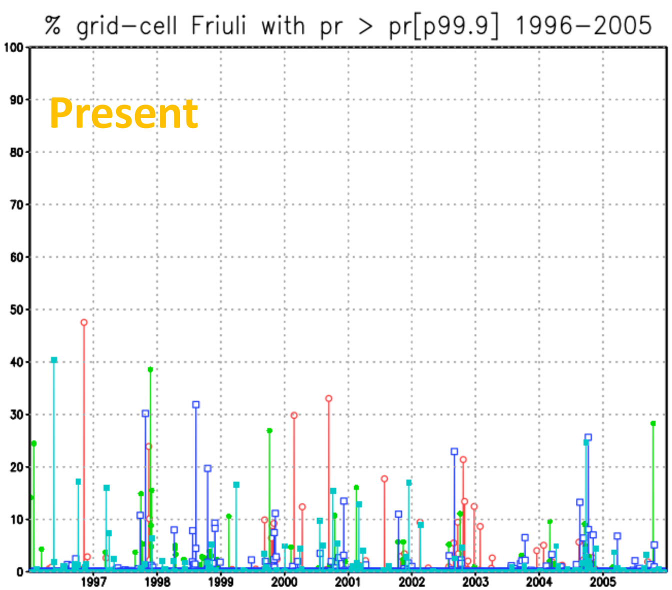
The precipitation event in the CP-models world: projections

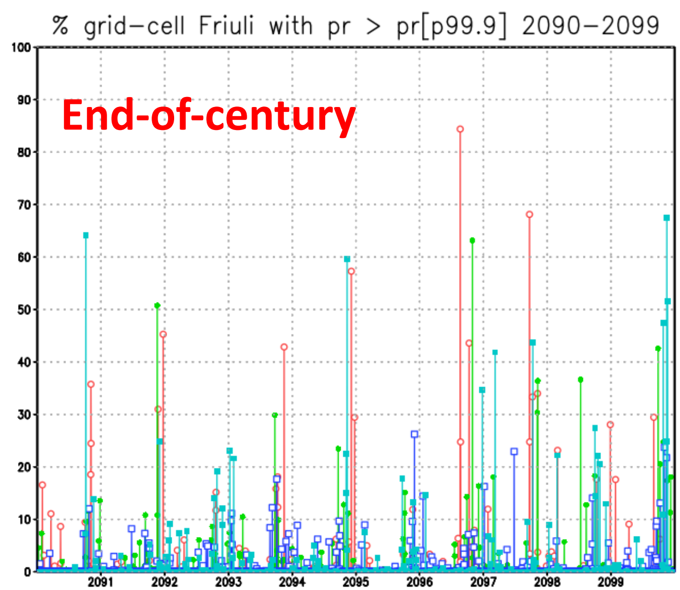
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

Institute	cpRCM	dx(cpRCM) [km]	RCM	dx(RCM) [km]	GCM
CMCC	CLMcom-CMCC-CCLM5-0-9 (E)	3	CCLM (E1)	12	ICHEC-EC-EARTH
CNRM	AROME41t1 (B)	2.5	ALADIN63 (B1)	12	CNRM-CERFACS-CNRM-CM5
DWD	CLMcom-DWD-CCLM5-0-15 (E)	3	CCLM4 (E1)	12	MOHC-HadGEM2-ES
ETHZ	COSMO-crCLIM (F)	2.2	COSMO-crCLIM (F)	12	MPI-M-MPI-ESM-LR
HCLIMcom	HCLIM38-AROME (D)	3	HCLIM38-ALADIN (D)	12	ICHEC-EC-EARTH
ICTP	RegCM4-7-0 (A)	3	RegCM4-7-0 (A)	12	MOHC-HadGEM2-ES
JLU	CLMcom-JLU-CCLM5-0-15 (E)	3	–	–	MPI-M-MPI-ESM-LR
KIT	CLMcom-KIT-CCLM5-0-14 (E)	3	CCLM4 (E1)	25	MPI-M-MPI-ESM-LR
KNMI	HCLIM38h1-AROME (D)	2.5	RACMO (D1)	12	EC-Earth23 (D2)
MOHC	HadREM3-RA-UM10.1 (C)	2.2	–	–	MOHC-HadGEM2-ES

Mueller et al. (2023, their Table 1) https://doi.org/10.1007/s00382-023-06901-9

SON	CNRM	ETHZ	HCLIMcom	ICTP
HIST	45	47	40	32
RCP85	83	68	52	43





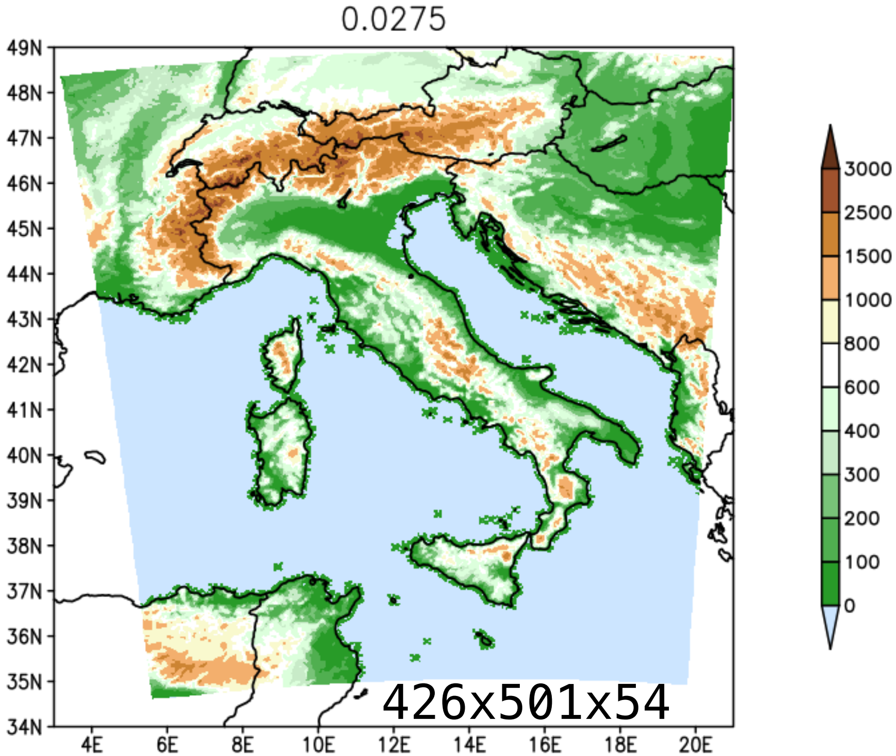
More HPEs hitting **larger areas**

Chen et al., 2024 https://doi.org/10.5194/egusphere-egu24-2525

WCRP CORDEX FLAGSHIP PILOT STUDIES

CPMs @ ENEA

in collaborazione con M. Antonelli



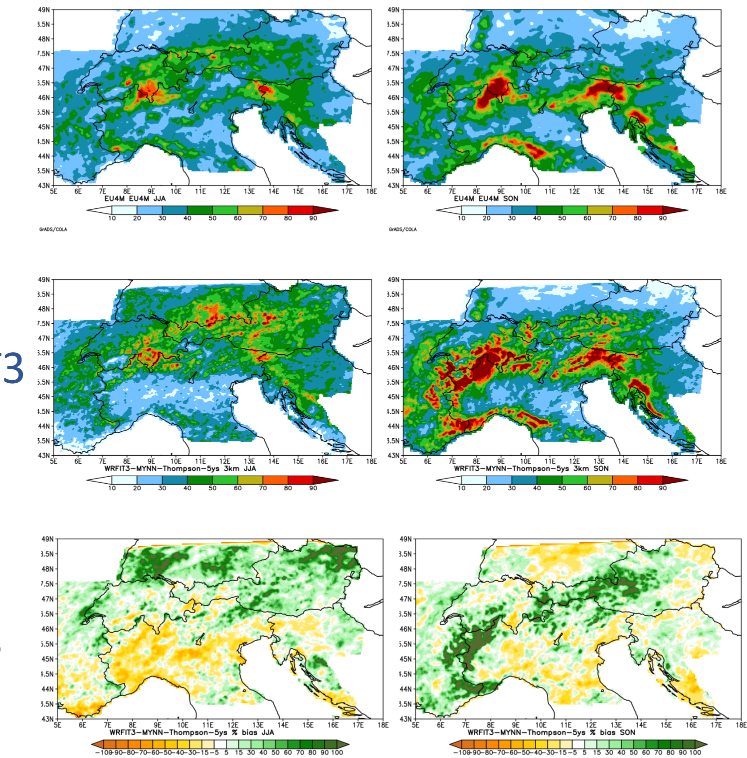
Heavy daily precipitation (mm/day) 1981-85

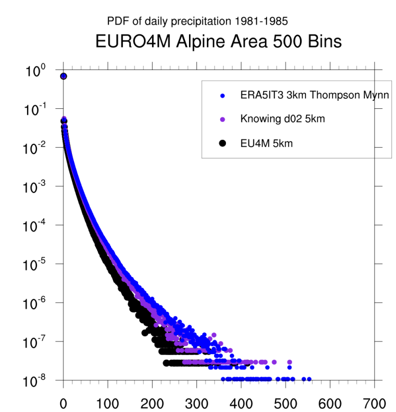
JJA SON

Obs

ERA5IT3

%Bias





Run [RES]	microphysics	PBL	surface layer	LSM	Cumulus	Lake	Parent
ERA5IT3 [3 km]	Thompson	MYNN	Monin-Obukhov (Janjic) scheme	NoahMP	Off	On	15 km

Grazie!!

ENEA, Casaccia,
8 Novembre 2024