Convection-Permitting Models (CPMs) applications to characterize and detect extreme rainfall

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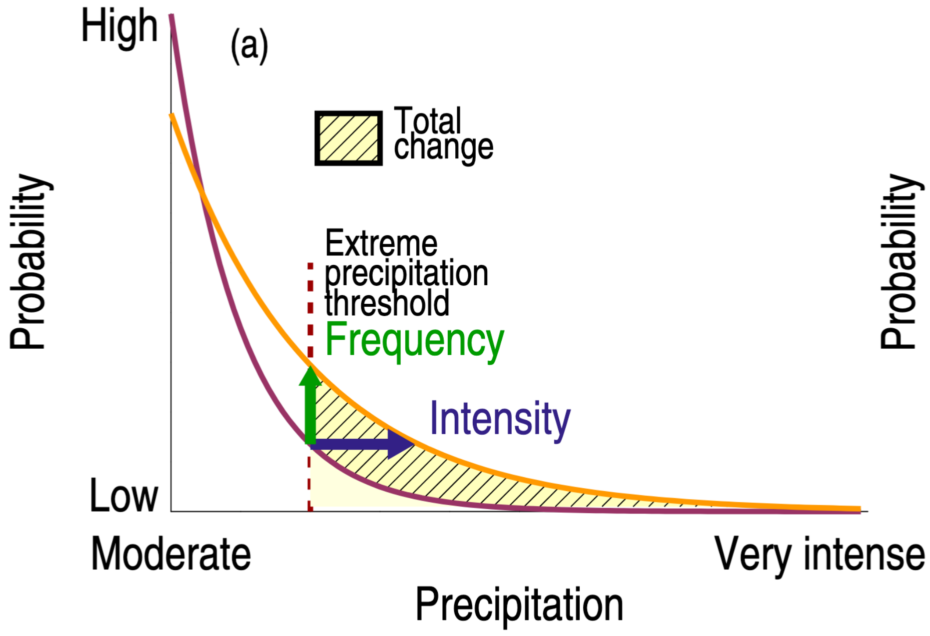
Heavy to extreme precipitation



Myhre et. al, 2019. https://doi.org/10.1038/s41598-019-52277-4

- Heavy precipitation is an episode of **abnormally high rain or snow (95th percentile)**. The definition of "**extreme**" is a **statistical concept** that varies depending on location, season, and length of the historical record.

- The **mechanisms** (perturbation, air mass water content and stability, interaction with local forcings, persistence, etc.) that generate an heavy/extreme event can be very **different among different regions**.

- Same amount of heavy/extreme precipitation over different areas can lead to **different response at ground** (in terms of floods).

Global characterization of extremes

Characterization of storms based on **physics of** rainfall, deep **convection** and **storm-size** influences their global distribution (based on TRMM radar data).

R) **excessive rainfall rates** (no truly deep-convection) [*ex. very moist convergent airflows, often exacerbated by orographic lifting, and increase of near-surface rainfall rates by the collision-coalescence process. Local shallow/medium conv. associated to thunderstorms*];

H) truly **intense convection** with intense radar returns reaching high altitudes (but without excessive rain rates) [*deep-convection; km-10km ordinary cells to supercells; convection intensity intended as magnitude of the convective scale vertical velocity in a convective cell, i.e. max height of 40/45dBz proxy by radars or lightning rates*];

RH) **high rainfall rates and intense convection** [*40/45 dBZ echo exceeding 9/20 km*].

The most intense convective cores are almost exclusively over land, regardless of size.

Table 1 Criteria used to select ~1000 strongest events in each category. Data Source: GPM Ku-band radar, 65S—65 N, data from full years 2015–2019 inclusive [33]

Category	Rain volume (mm/h•km^2)	Maximum near-surface dBZ	Maximum height 40 dBZ (km)
R-only small	0–5400	50–60	0–5
R-only medium	12,000–21,000	50–60	0–5
R-only large	> 225,000	50–60	0–5
H-only small	0–5400	0–45	9–20
H-only medium	12,000–21,000	0–45	9–20
R + H small	0–3900	50–60	9–20
R + H medium	15,000–21,000	50–60	9–20
R + H large	> 112,500	50–60	9–20

1000 strongest 2015-2019

Table 2 Range of rain area (km^2) for the events selected according to the criteria in Table 1 and displayed in Figs. 1, 2, 3, 4, and 5

Category	Minimum area (km^2)	Median area (km^2)	Maximum area (km^2)
R-only small	221	835	4566
R-only medium	859	4591	26,882
R-only large	36,064	109,321	432,890
H-only small	221	687	5646
R + H small	221	810	3540
R + H medium	1669	5229	12,840
R + H large	11,735	50,720	210,295

Zipser and Liu, 2021, https://doi.org/10.1007/s40641-021-00176-0

Global characterization of extremes

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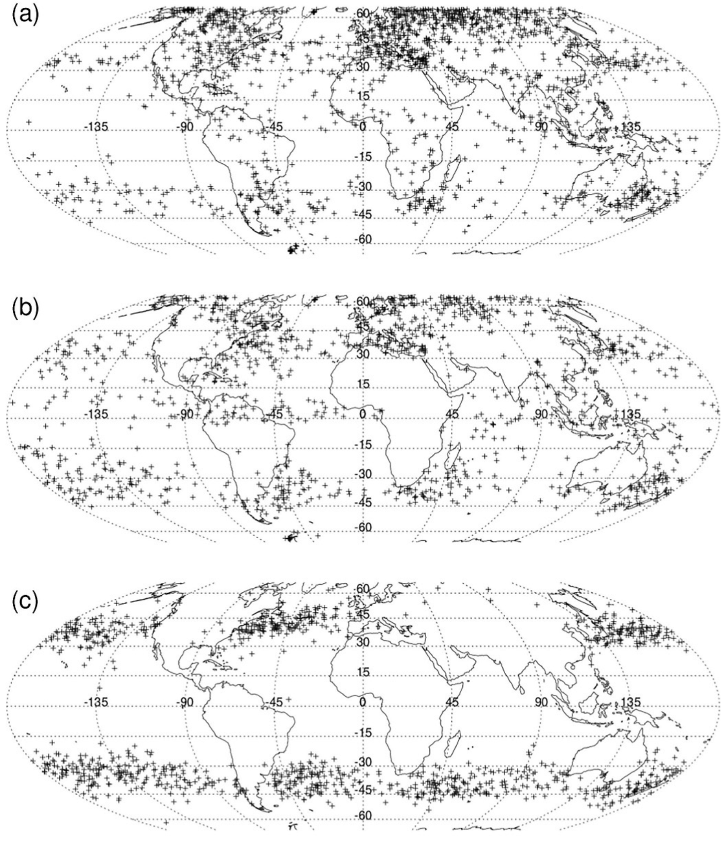

Fig. 1 **a** R-only small; **b** R-only medium; **c** R-only large

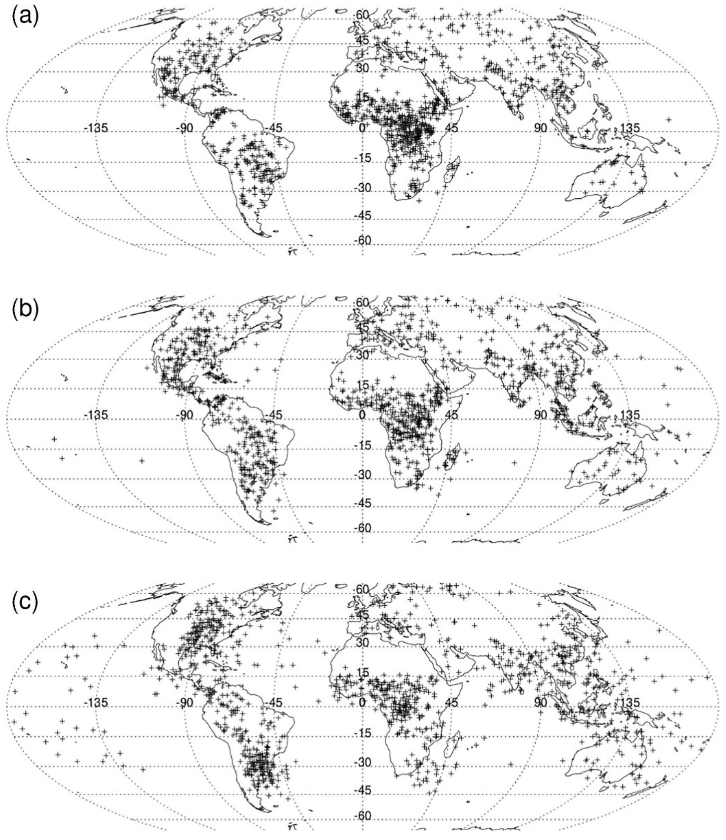

Fig. 3 **a** R + H small; **b** R + H medium; **c** R + H large

1000 strongest
2015-2019

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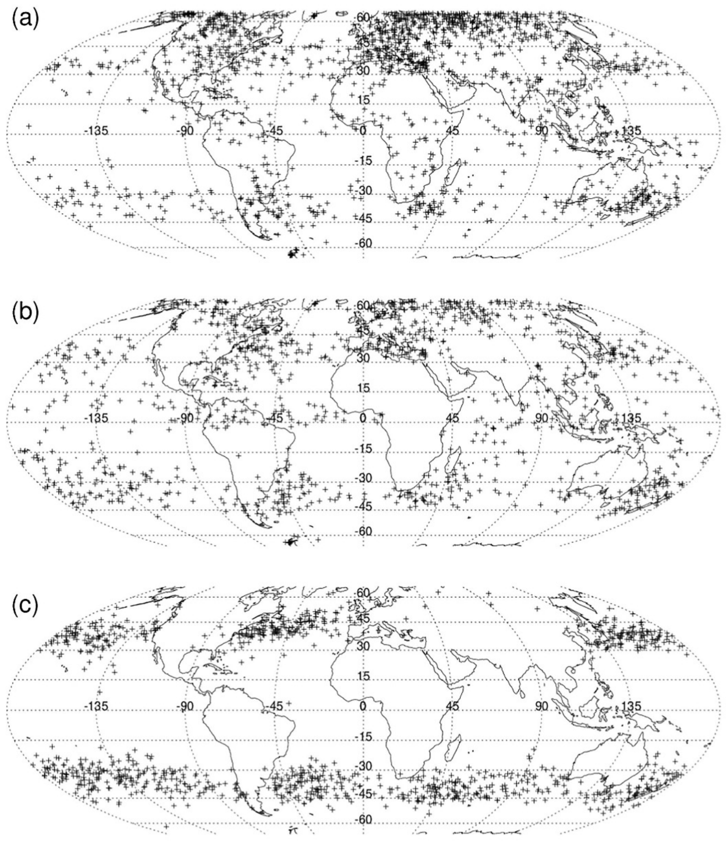

Fig. 1 a R-only small; b R-only medium; c R-only large

Small-R favored over **land**, no in the deep tropics.
High-elevation regions are not often selected;
lower-elevation regions (**NAM, EUR, ASIA**) favored and regions bordering the **MED-Sea**.

The R-large **oceans** favored along the **mid-latitude** storm tracks → **Atmospheric Rivers** are well represented in this category.

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RH-storms favored over **land**.

C-AFR RH-storms all sizes.

AUS rare RH-storms.

1000 strongest 2015-2019

RH-large a non-negligible percentage are found over **oceans** (small density).
RH-large strong concentration in the central and high plains of **NAM**.

From **RH-small** to **RH-large** over **SAM** from North to South.

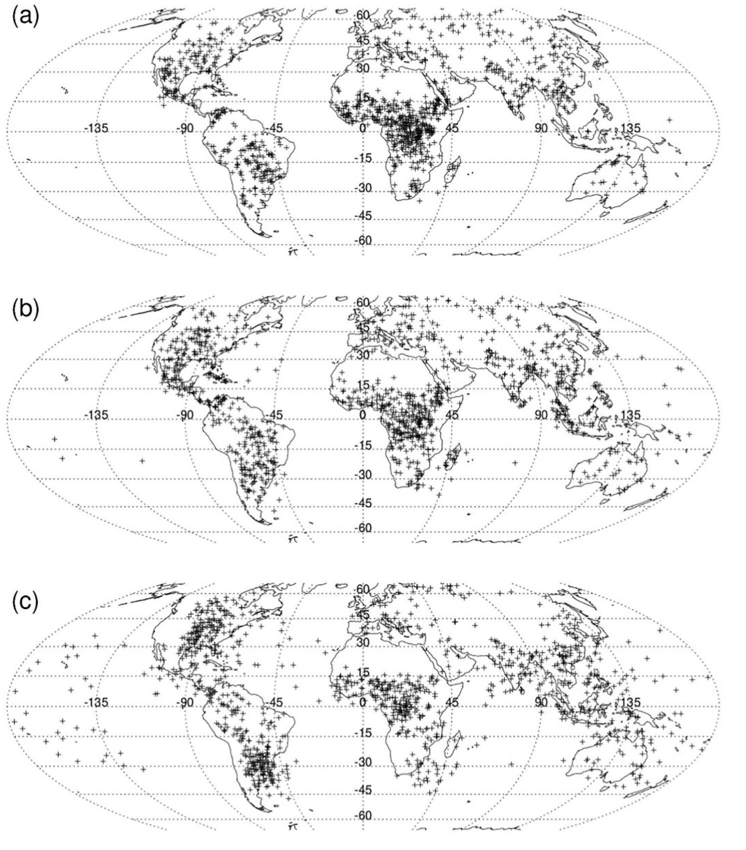

Fig. 3 a R + H small; b R + H medium; c R + H large

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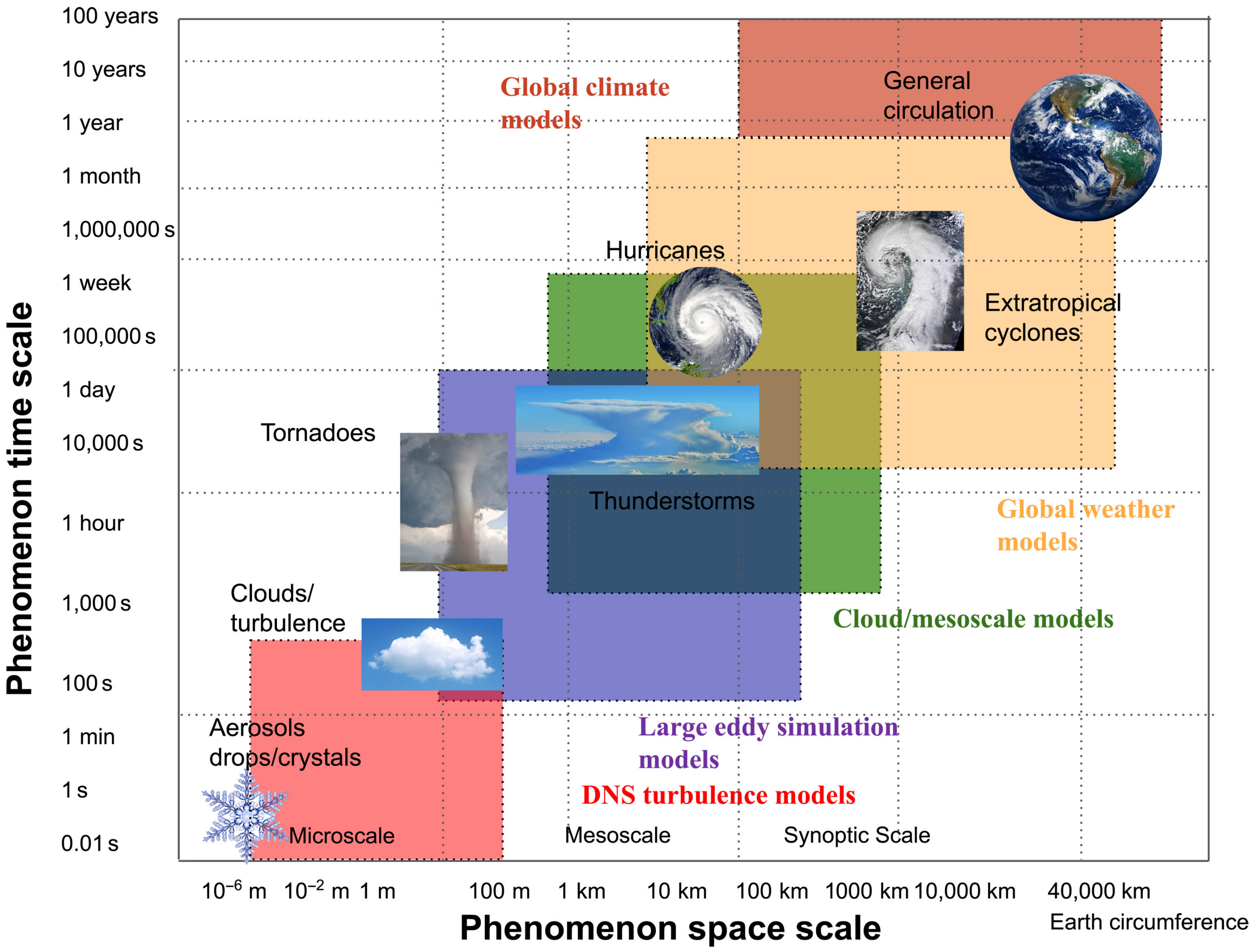
Intense convective **events** with **extreme** are found almost exclusively **over continents**.
Often associated to **severe impacts** (tornadoes, large hail, violent winds, or flooding rains).
They are projected to **increase in frequency and intensity under GW**.

Scales of the convection

Gettelman et al. (2022)
DOI: 10.1126/sciadv.abn3488



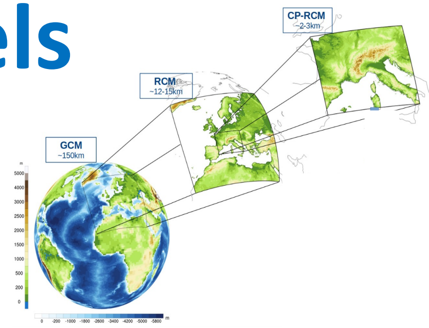
Earth's climate system is highly nonlinear and characterized by a wide range of spatial and temporal scales

Convection has spatial scales ranging m – 100 km (storms – MCS) and time scale from min-hour-day (sh-cum/d-cum/MCS)

how is it modeled?

Atmospheric convection in numerical models

10.22541/essoar.168987136.64498273/v1



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).

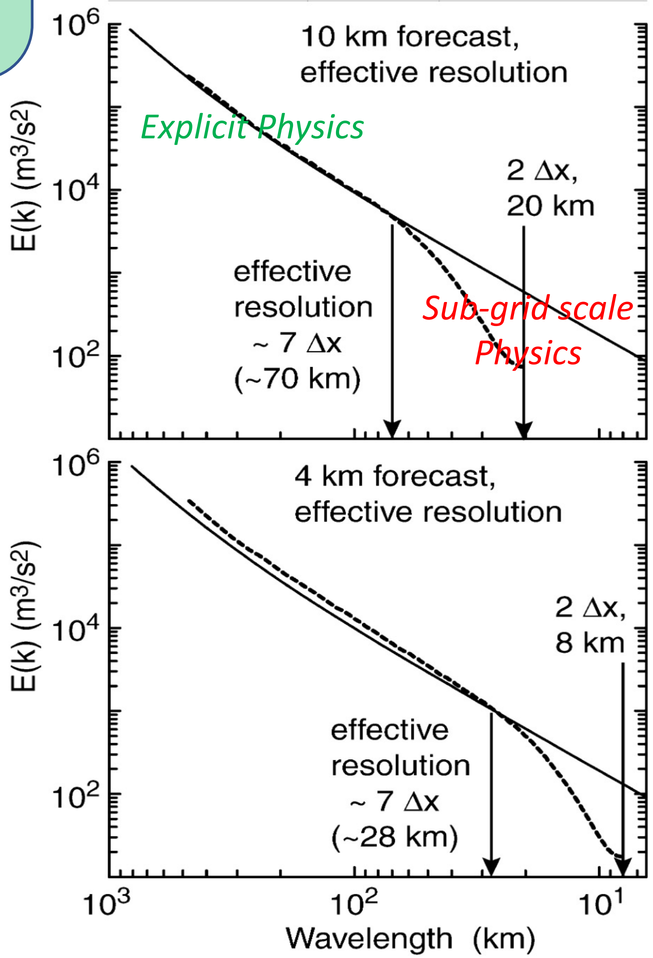
(*) To resolve the entrainment processes and turbulence within a cloud, a horizontal grid spacing finer than 100–250 m is generally required. Also at km-scale part of the cumulus spectrum remains unresolved!

>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]

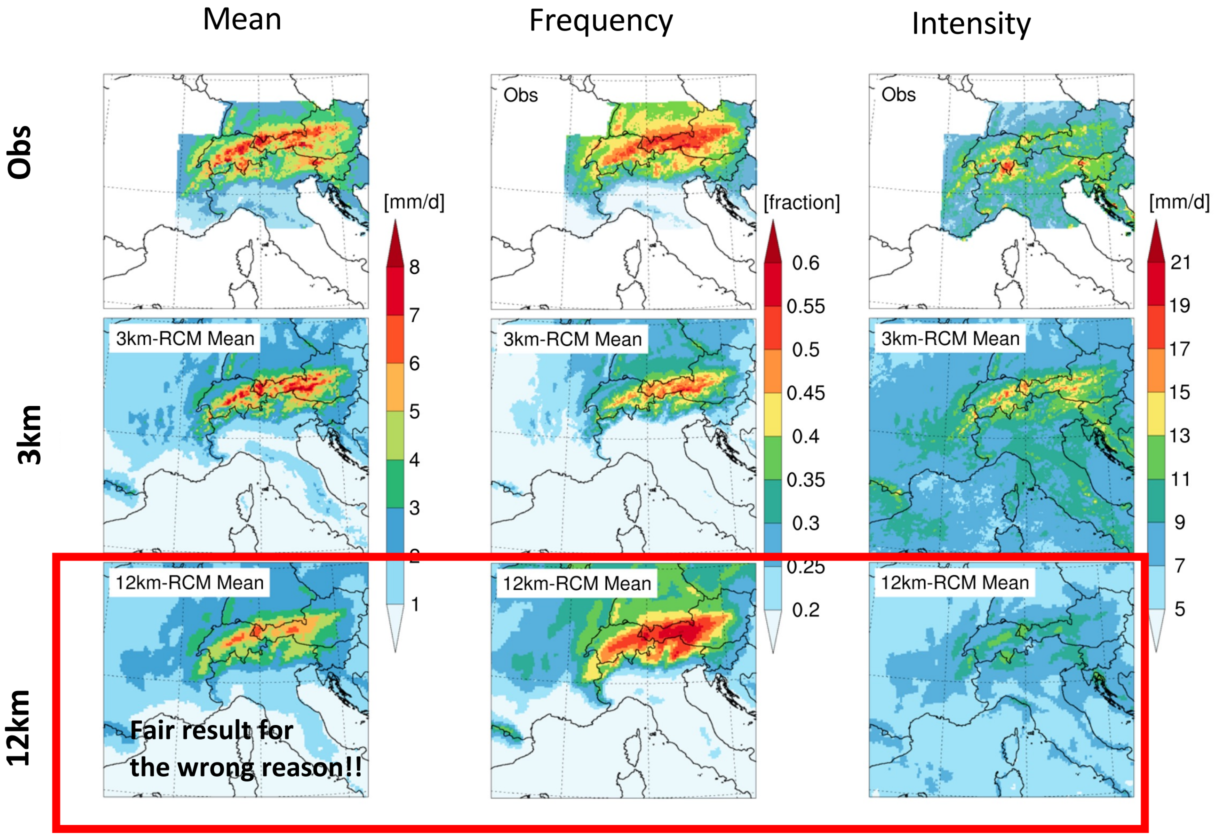


Skamarock 2004, https://doi.org/10.1175/MWR2830.1

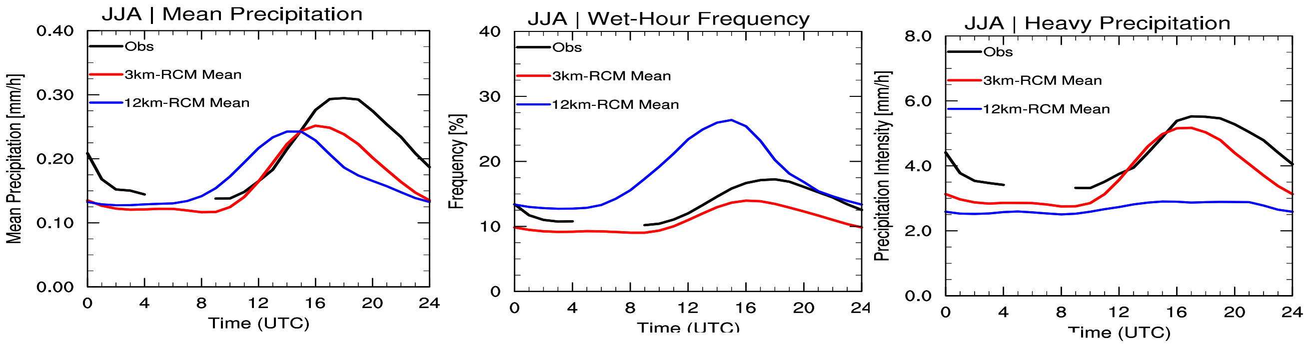
FPSCONV CPMs added value

Review in: Lucas-Picher et al. (2021) https://doi.org/10.1002/wcc.731

JJA 2000-2009



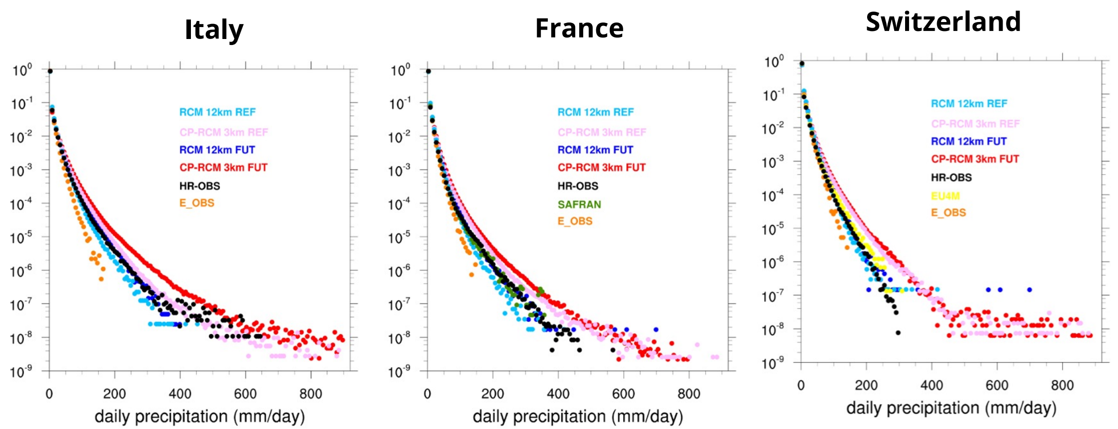
Diurnal cycle of summer precipitation – Switzerland 2000-2009



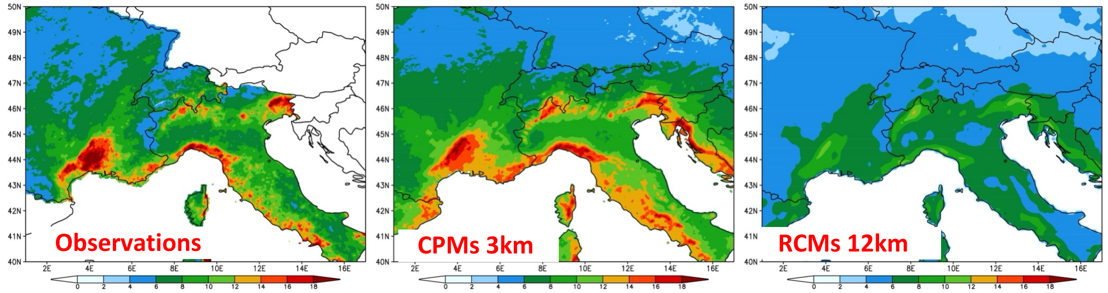
Ban et al. (2021) https://doi.org/10.1007/s00382-021-05708-w

SON 1996-2005

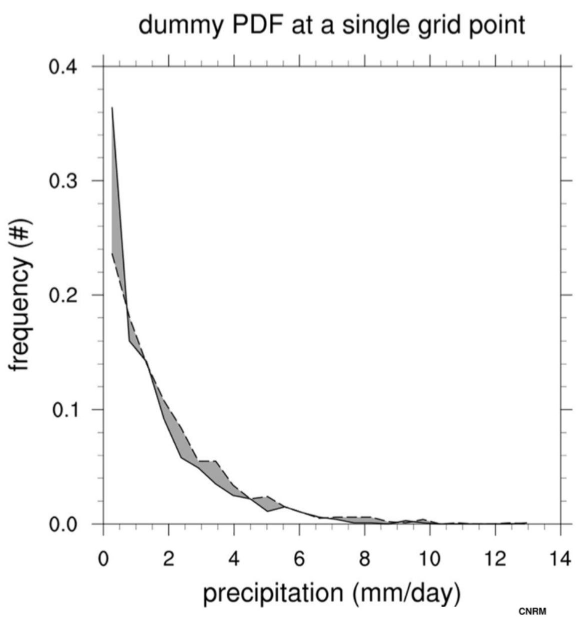
Pichelli et al. (2021) https://doi.org/10.1007/s00382-021-05708-w



Autumn Hourly heavy precipitation (p99.9) 1996-2005



The Convection-Permitting models (**CPM**) allow to represent the **most extreme precipitations** laying at the tail of a distribution, which is usually missed by cumulus-parametrized models.



A measure for the Added Value (AV): pr

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

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

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

Relative probability difference

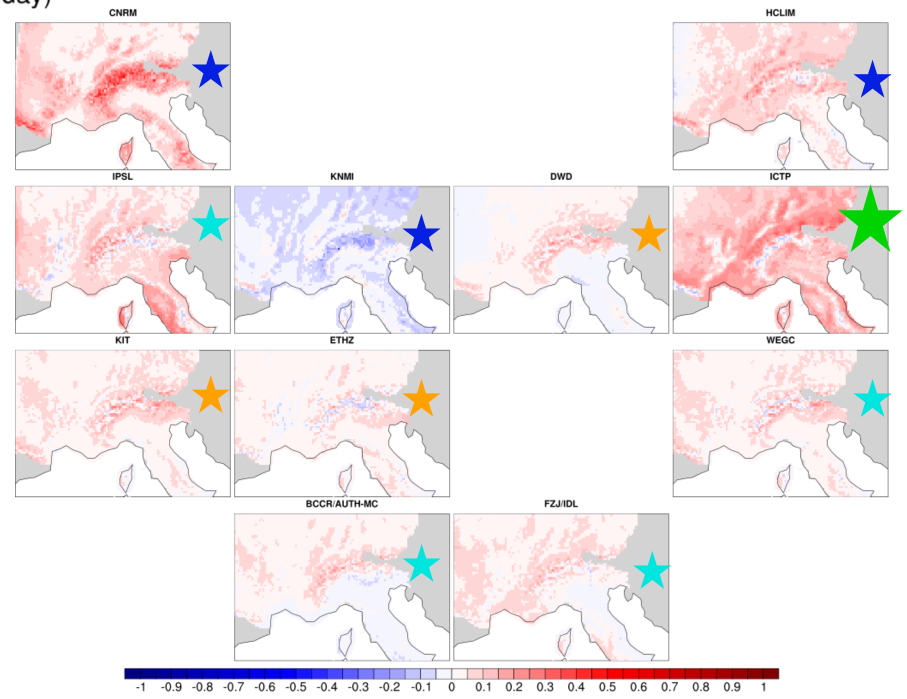
CP-RCM

AROME

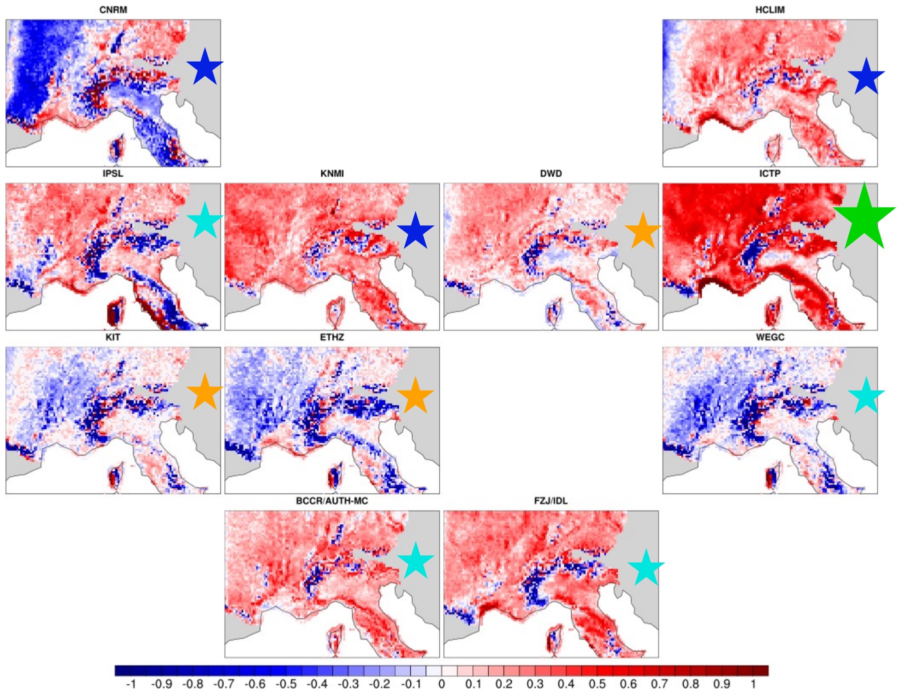
RegCM4

COSMO-CCLM5

WRF3.8



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



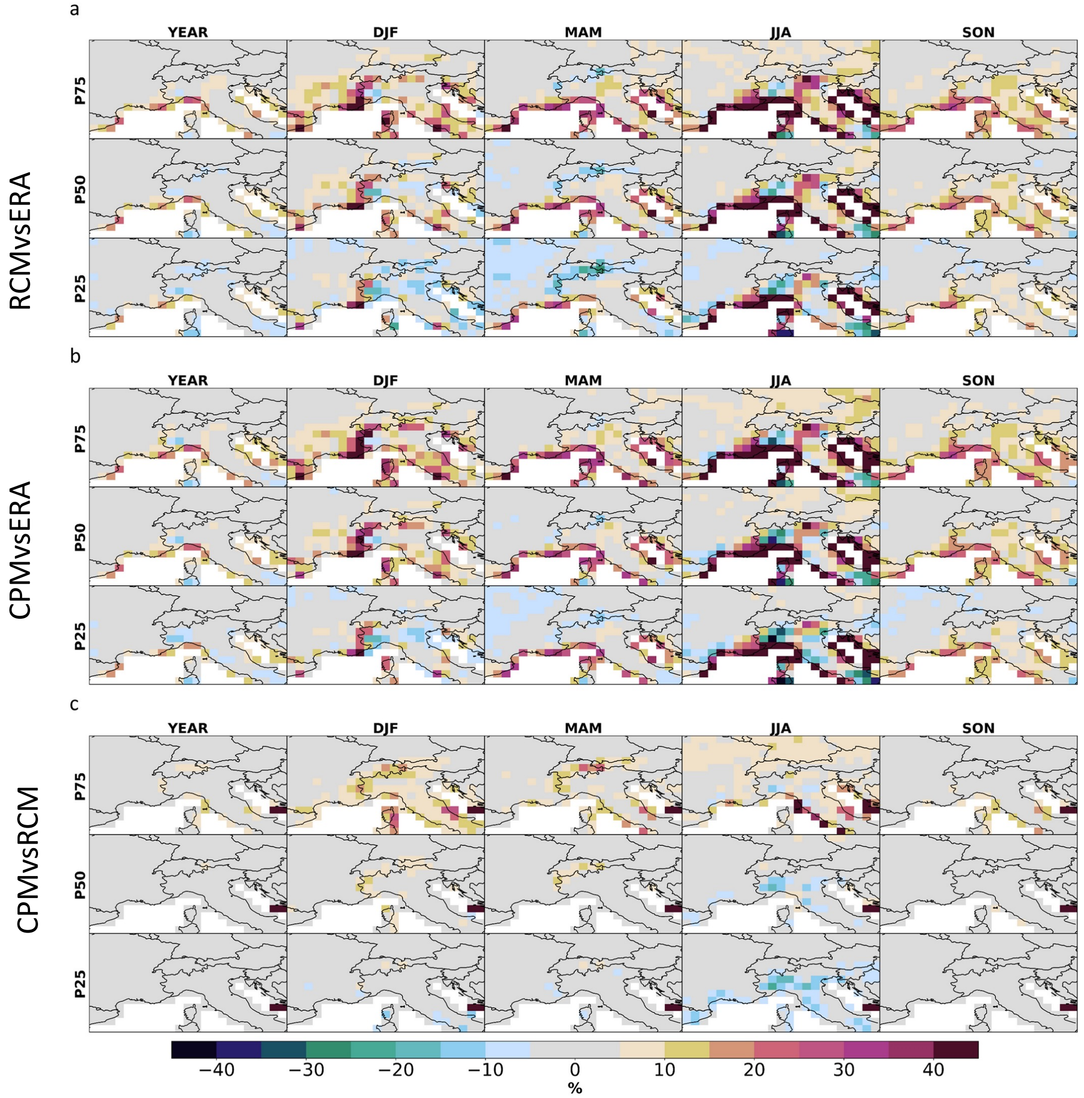
ens-mem-av-pr-1hr-CPM-rcm-cond-cro-99-100

A measure for the Added Value (AV): tasmax

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

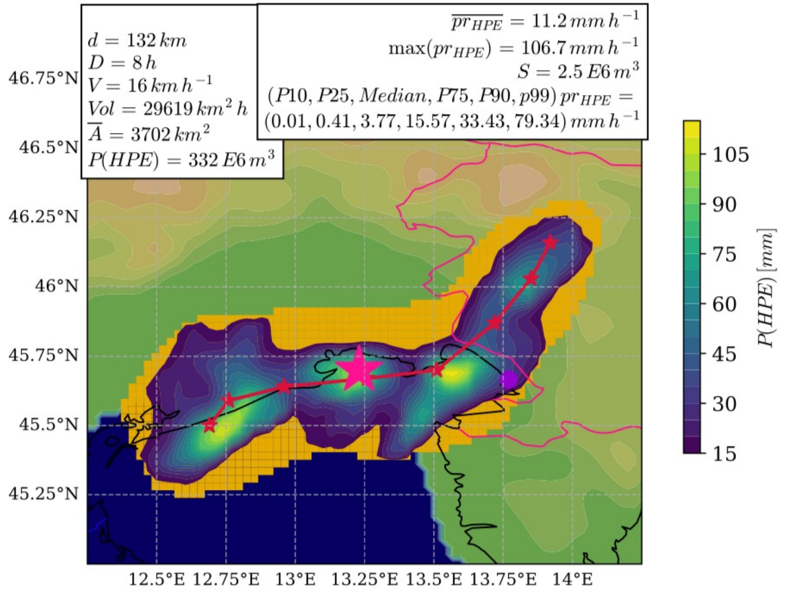
$$S_{mr} = \sum_{1}^{n} \min\left(Z_{mr}, Z_{\text{obs}}\right)$$

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



The CPMs to study storms response to warming climate

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



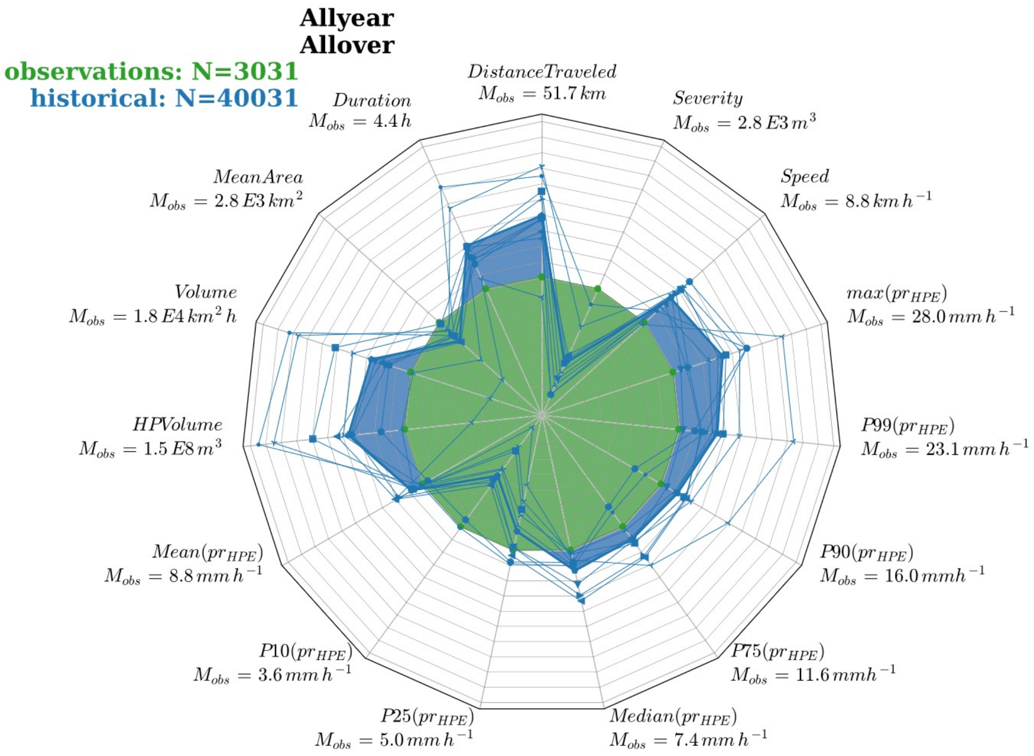


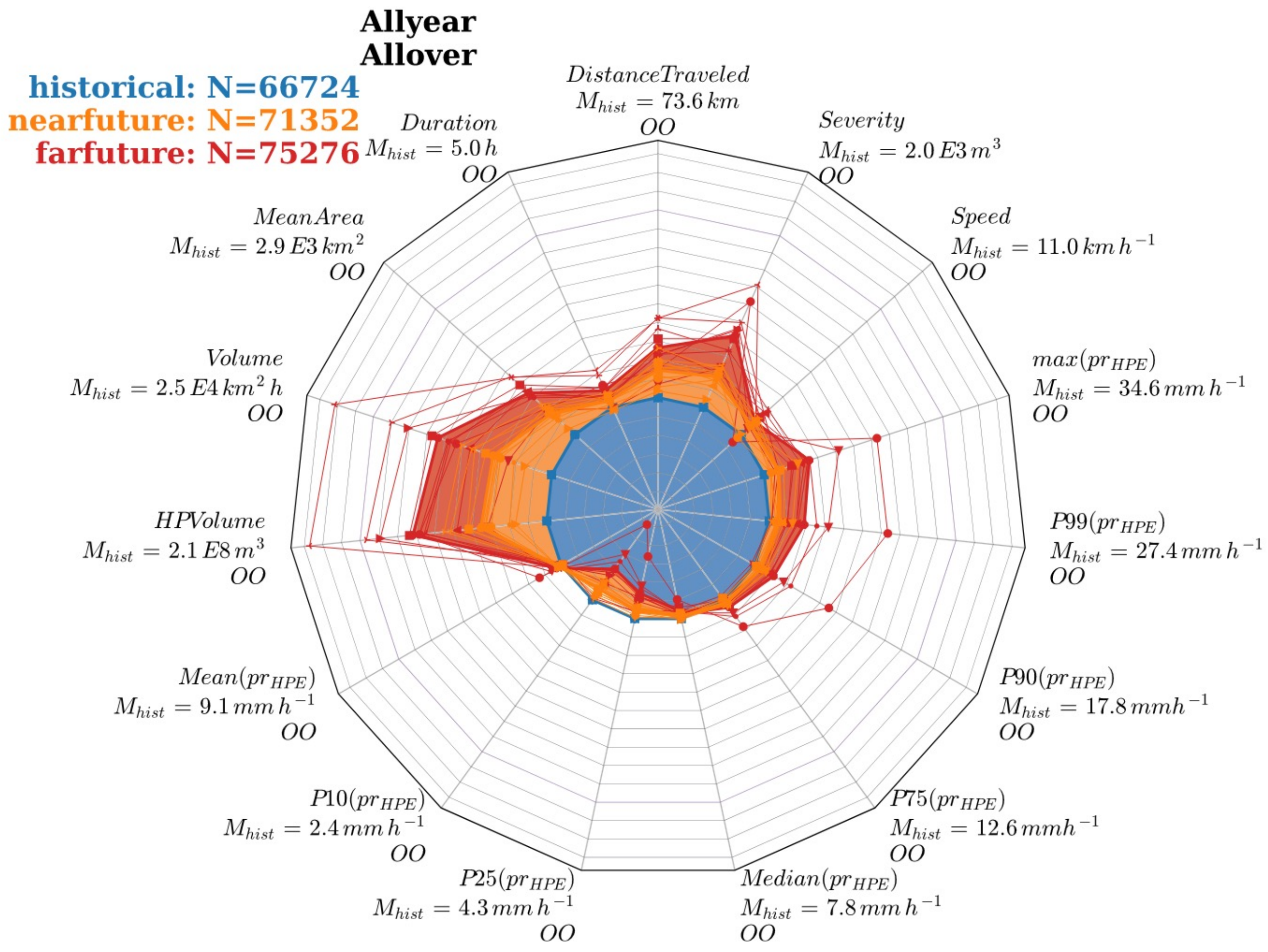
Table 3 Definitions of all variables and HPE properties used in this study

	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 and unit area.
Eulerian Properties	P(HPE) $[mm]$	Accumulated heavy precipitation, given by the integration of pr_{HPE} for a given location
	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 attributed with 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 field
	d $[km]$	The *Distance Traveled* of a HPE, given by sum of distances measured between the HPE's centroids 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 $V_{max} = 35\,ms^{-1}$

	% bias
Mean Area bias	−10%
Duration	+15%
Geometric volume	+13%
Mean(pr-HPE)	+5%
HPEvol	+18%
HPE p75/p90/p99	+17%
Severity	-20%

The CPMs to study storms response to warming climate

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



Mid-Century	% bias
Mean Area bias	+10%
Distance traveled	+12
Duration	+2%
Geometric volume	+17%
Mean(pr-HPE)	+1%
HPEvol	+17%
HPE p75/p90/p99	<+5%
Severity	+10%

End-Century	% bias
Mean Area bias	+25%
Distance traveled	+15
Duration	+5%
Geometric volume	+30%
Mean(pr-HPE)	+3%
HPEvol	+35%
HPE p75/p90/p99	+5-10%
Severity	+21%

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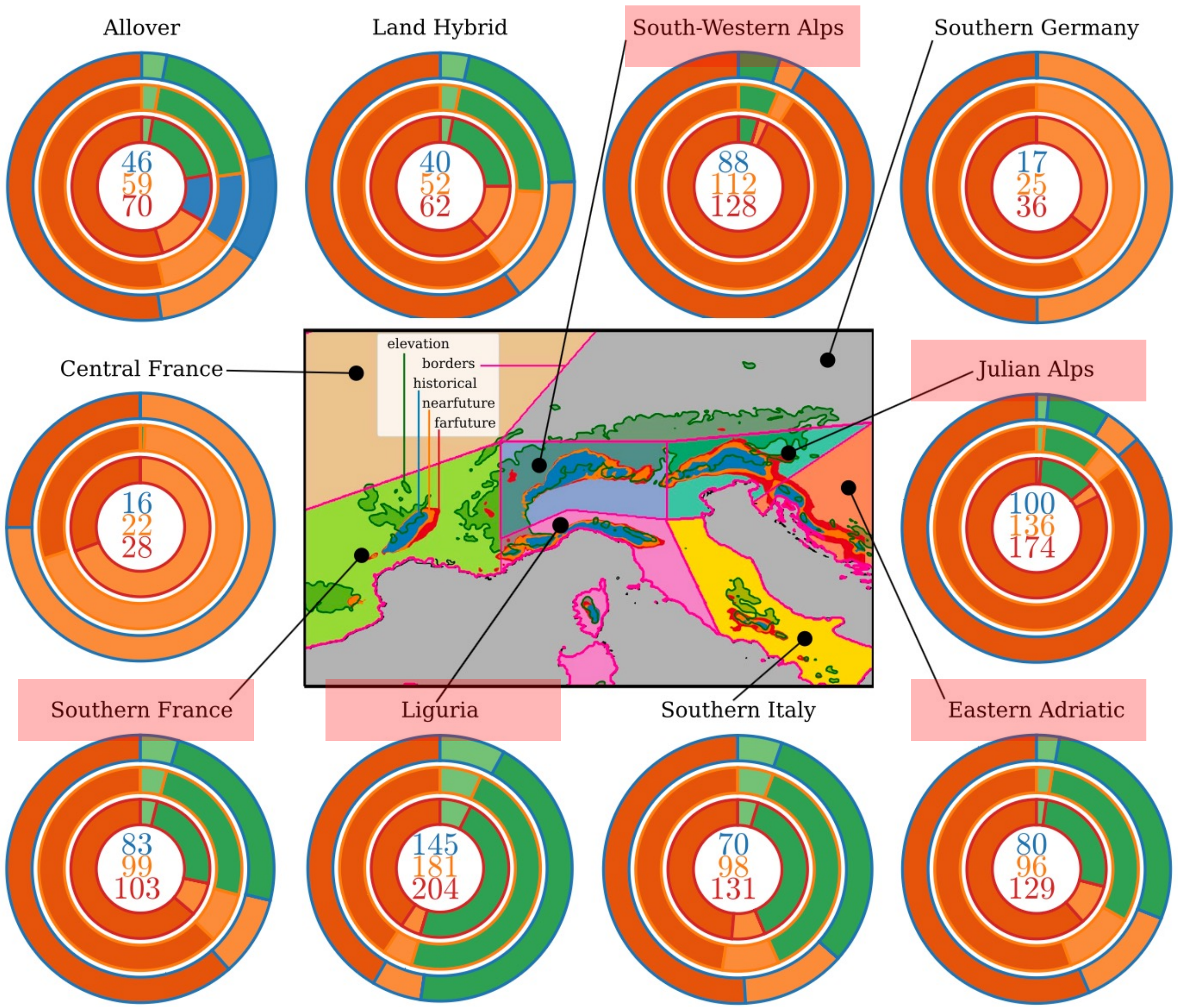
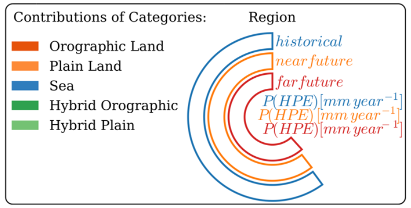


Hotspot sub-regions

HPE category	Definition
Sea	over sea surface
Land	over land surface
Orographic	over 1000 m
Plain	below 1000 m



HPE category	Definition
Plain Land	Land ∩ Plain
Orographic Land	Land ∩ Orographic
Hybrid	both over land and sea
Hybrid Orographic	Hybrid ∩ Orographic
Land Hybrid	Land ∪ Hybrid
Hybrid Plain	Hybrid ∩ Plain

- Regions around Mediterranean coast and South of the Alps have larger (area av.) HPE pr → > 80mm/yr
- Prevailing HPE of these regions are Orographic-Land and Hybrid-Orographic (>80%). Orographic forcing is key ingredient in the region, as well as their interaction with sea surface (hybrid!).
- The Julian Alps show the greatest increase of P(HPE) from 100 to 174 mm/yr
- HPE north-flank of Alps will double their pr at end of Century.

The CPMs to study storms response to warming climate

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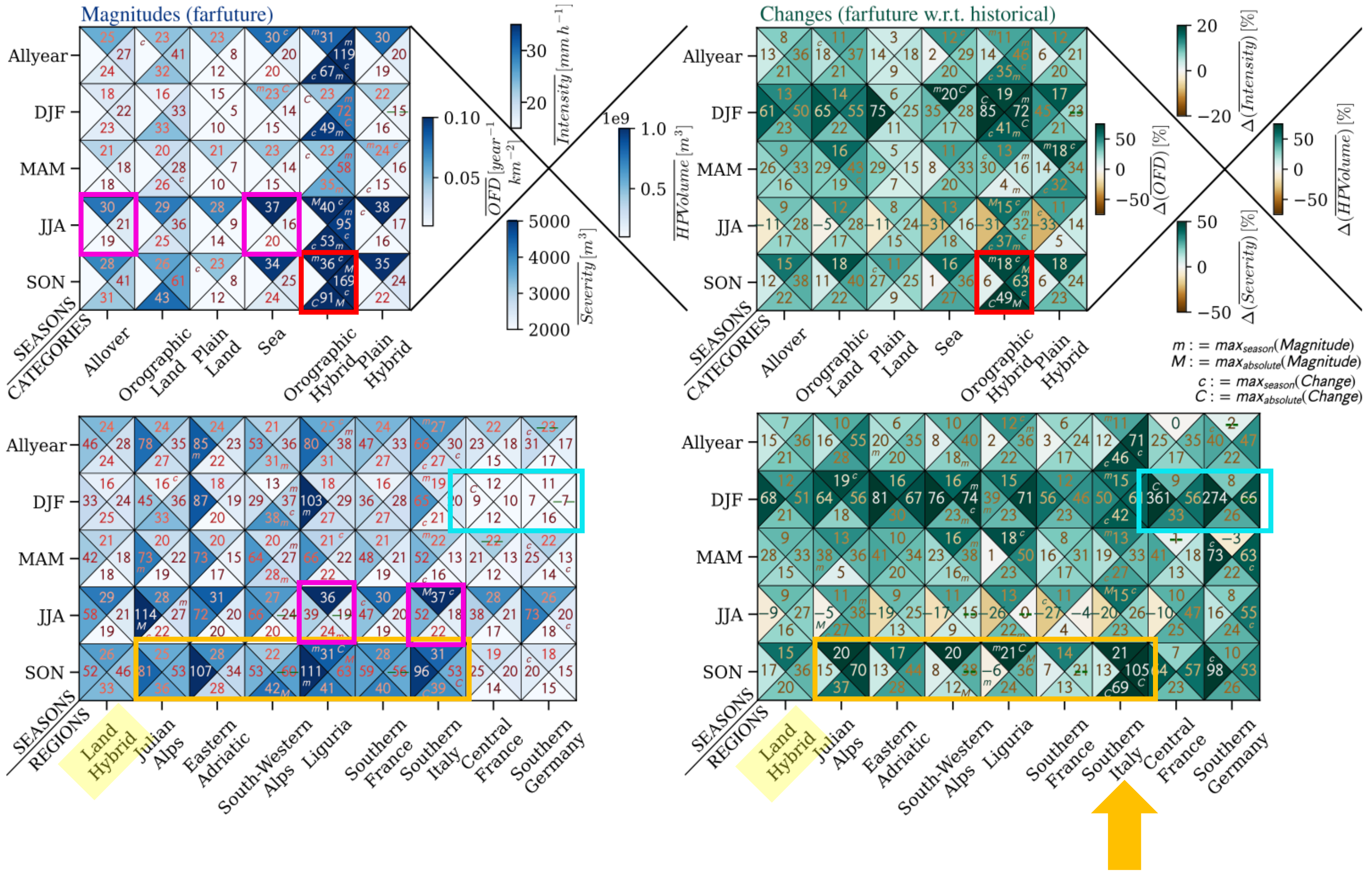
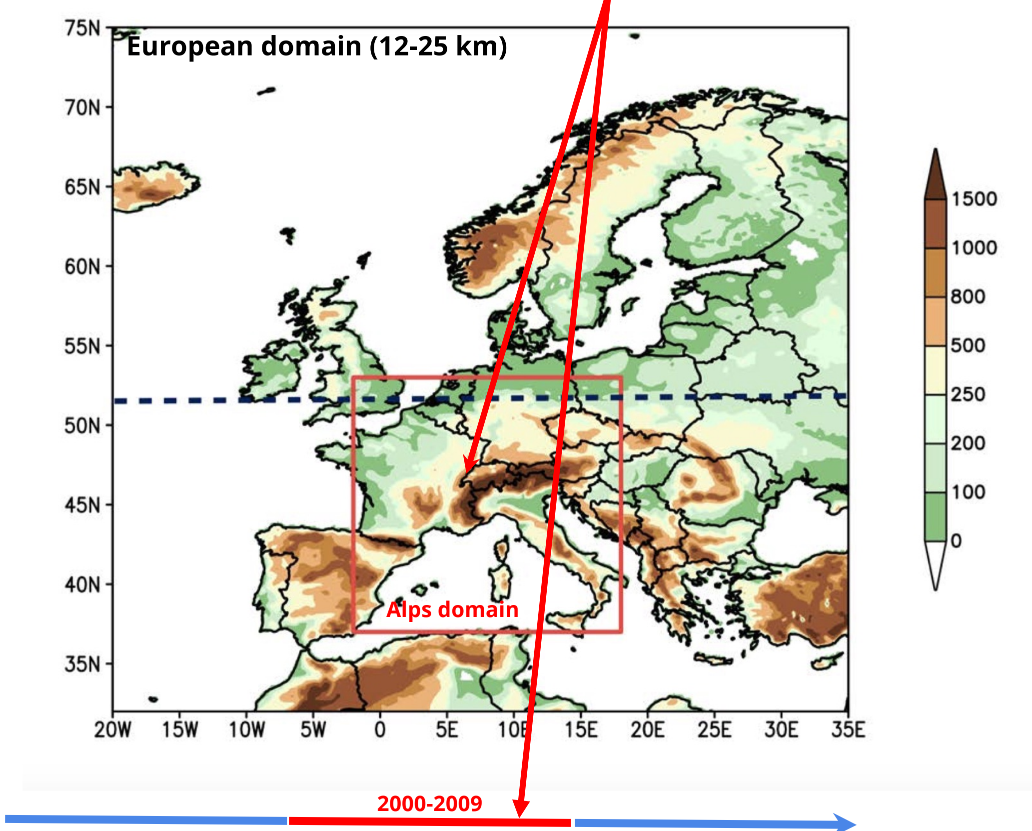


- **Hybrid-Orographic HPEs** are the heaviest and most severe in fall (SON), with increases in HPVolume by 63% and in Severity by 49%.
- **Hotspot regions** and **South Italy** (SI) have the most intense, severe and heavy HPEs, and the greatest changes; **SI** having HPEs 21% more intense, 105% more heavy, 69% more severe and 13% more frequent.
- Across the whole domain (**Allover**) HPEs are most intense **JJA** (30 mm/h), especially over the **SEA**. Hybrid max over Liguria and SI.
- **HPE occurrence frequency** increases in regions **north of the Alps** by 361% and 274% (but less than for the hotspot-regions in term of intensity and severity).

Detection of disastrous storms

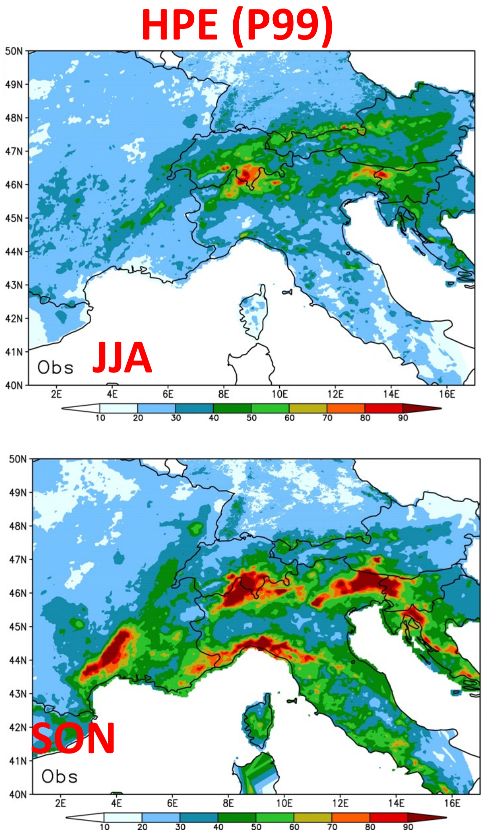
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

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



CORDEX-FPSCONV

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



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

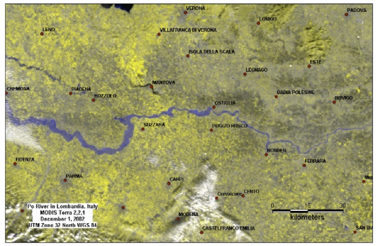
XAIDA	Date	Region	Description	Impact	Main area
1	**Jul. 2009** (23/07/07)	Austria Bavaria (South Germany)	Cold front inducing severe thunderstorms and hail; interaction between the convergence line and the foehn.	60 000 hectare arable lands devastated. Damages 15 Mln Euro.	South Germany 8-13.5E 47.5-50
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

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

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

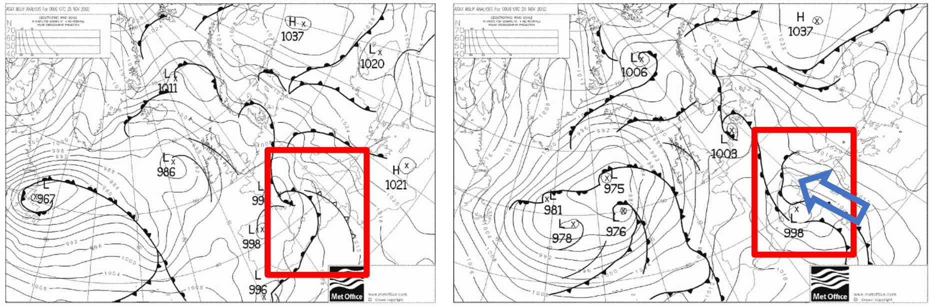
(Po/ Adda/ and tributary rivers, NWI; Friuli VG area, NEI)

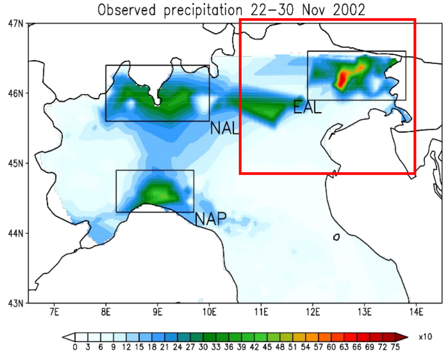
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196



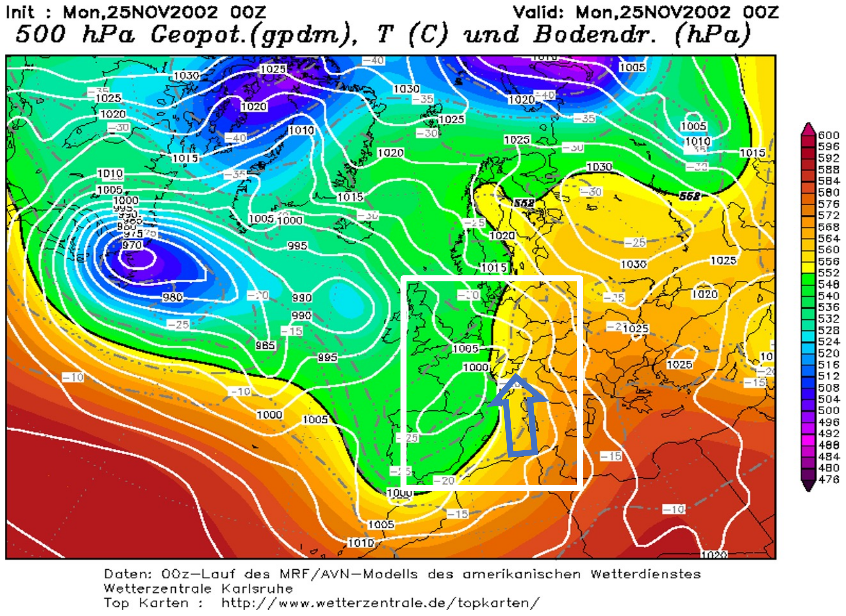
Satellite (MODIS Terra) picture of the Po river in Northern Italy

Surface fronts and MSLP



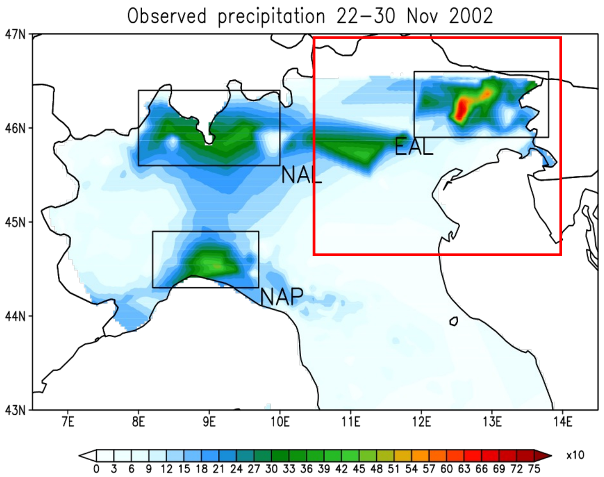


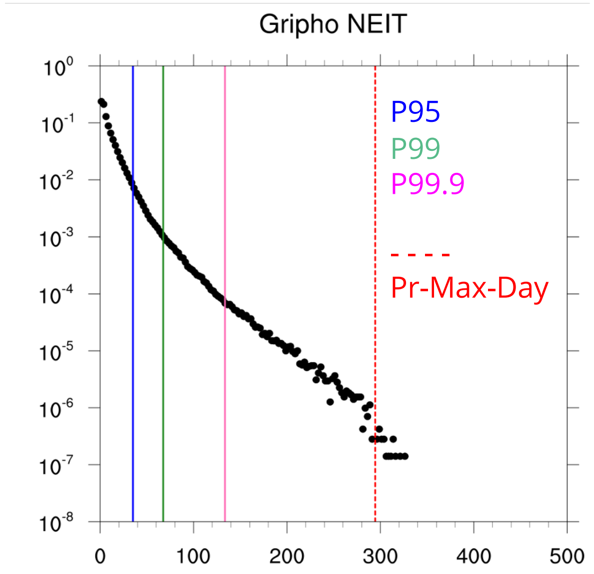
A North-Atlantic **upper-level trough entered the Western Mediterranean** inducing unstable humid south-westerly winds over Northern Italy (black arrows on pressure maps), slowly evolving eastward (finally leaving a cut-off low on the Eastern Mediterranean). Interaction with orography induced persistent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

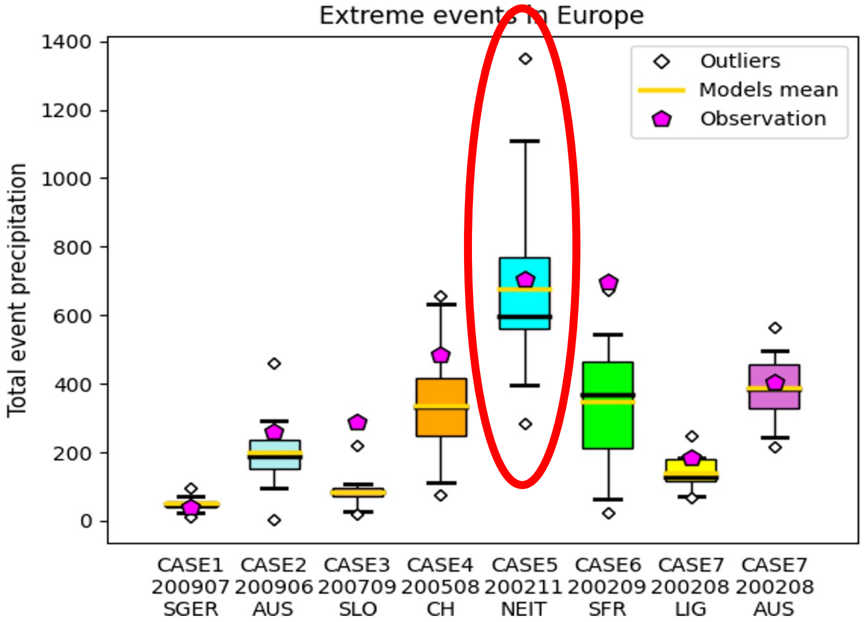
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

The precipitation event: observed and modeled

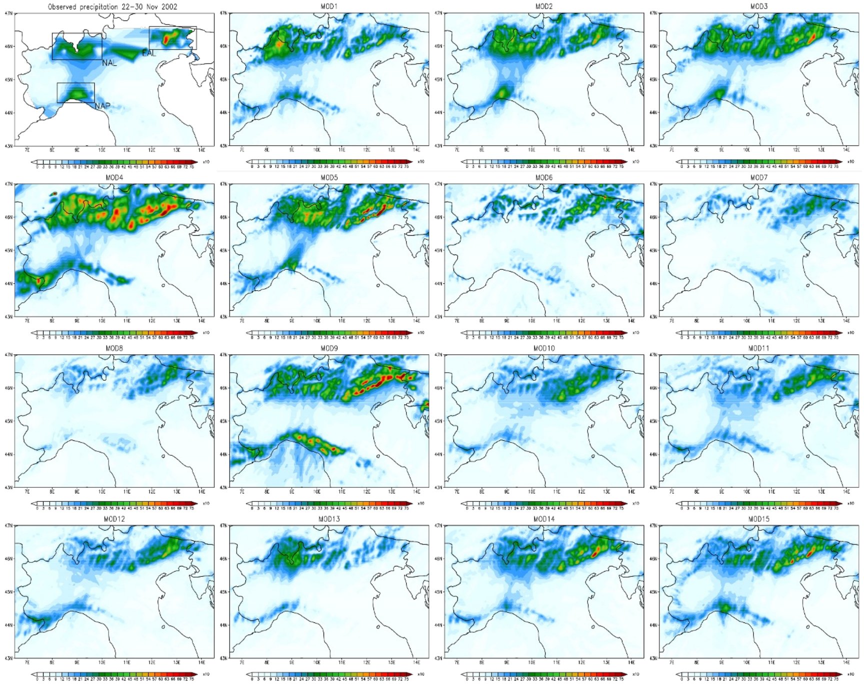
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

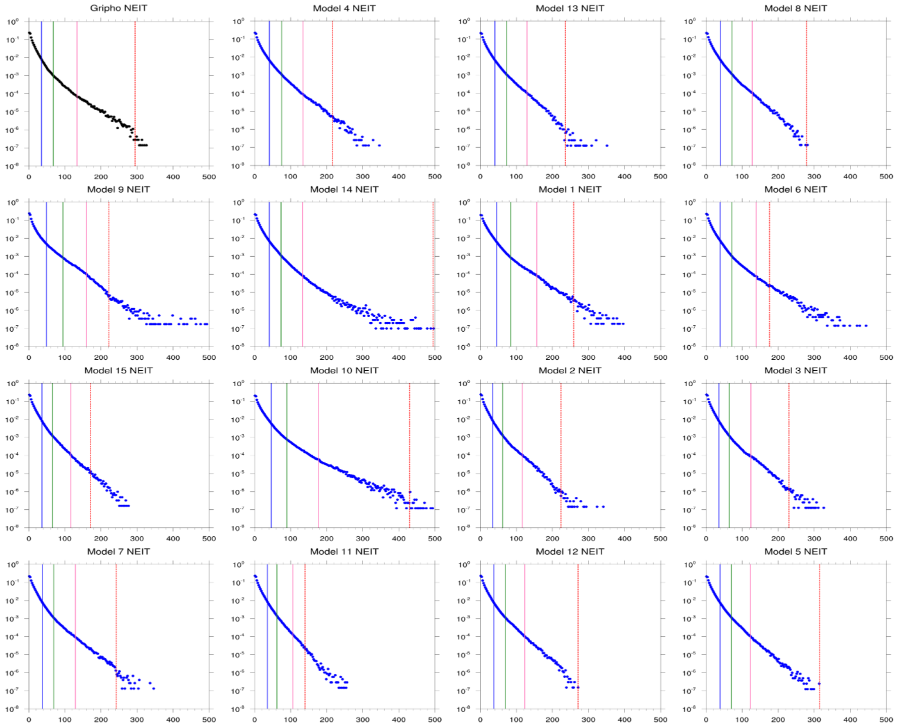
Institute	cpRCM	dx(cpRCM)[km]	Driving RCM	dx(RCM)[km]	RCM domain
AUTH	WRF381BJ (A)	3	WRF	15	EURO-CORDEX
FZJ	WRF381BB	3	WRF	15	EURO-CORDEX
IPSL	WRF381BE (A)	3	WRF	15	EURO-CORDEX
UHOH	WRF381BD	3	WRF	15	EURO-CORDEX
BTU	COSMO-CLM (B)	3	COSMO-CLM	12	EURO-CORDEX
CMCC	COSMO-CLM (B)	3	COSMO-CLM	12	EURO-CORDEX
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



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).





P95
P99
P99.9

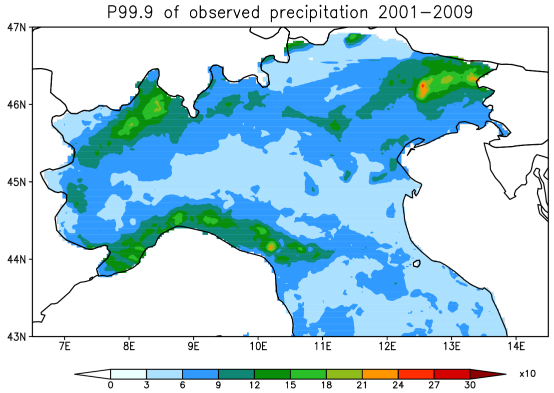
- - - -
Pr-Max-Day

Detection of disastrous-like storms

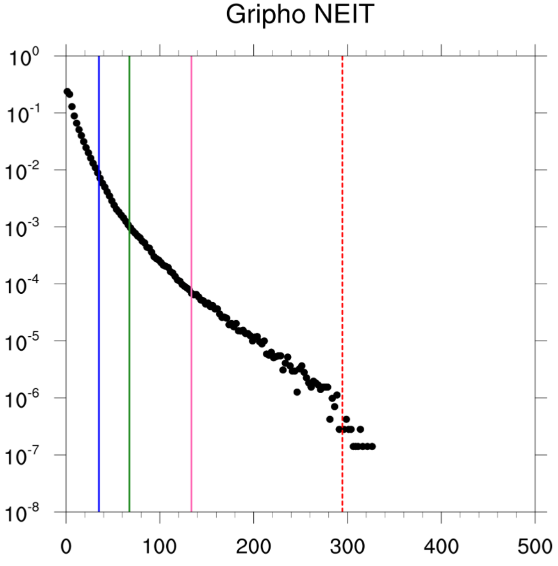
Method 1 based daily precipitation extremes

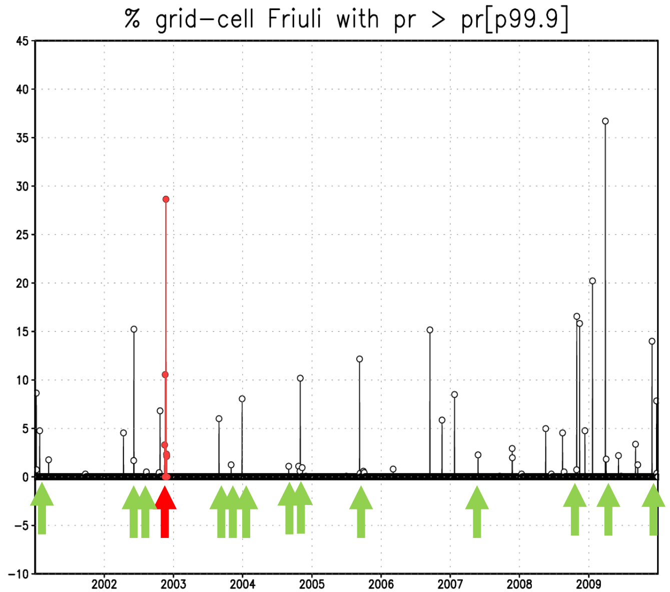
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

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

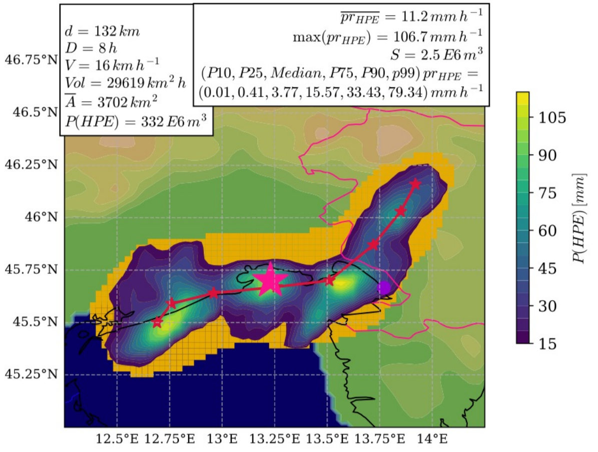


ex	SON	DJF	MA M	JJA
Obs	30	11	7	11

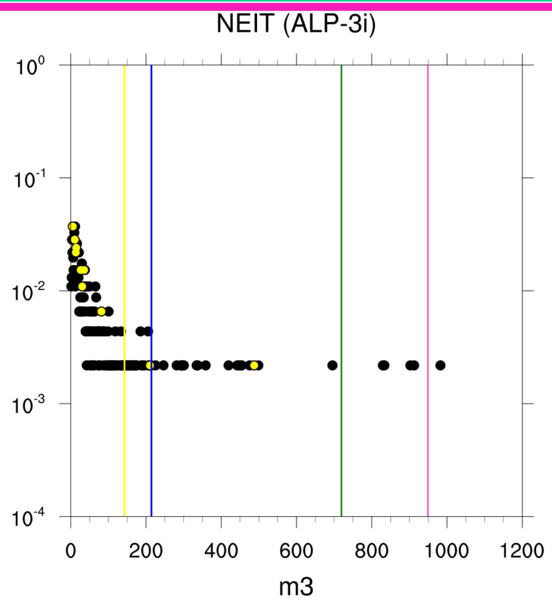




Method 2 based on storm tracks



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

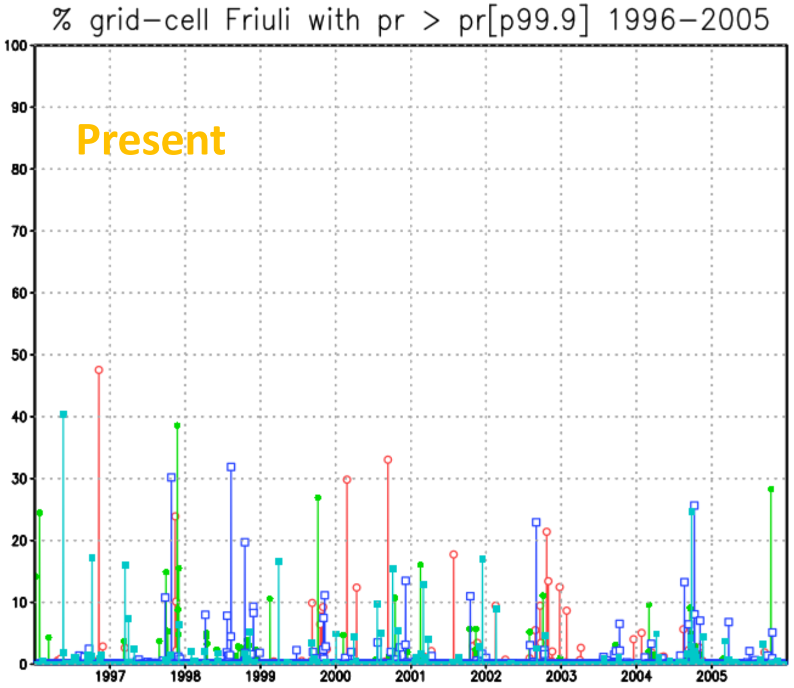
Pichelli et al., 2023 https://doi.org/10.5194/egusphere-egu23-11196

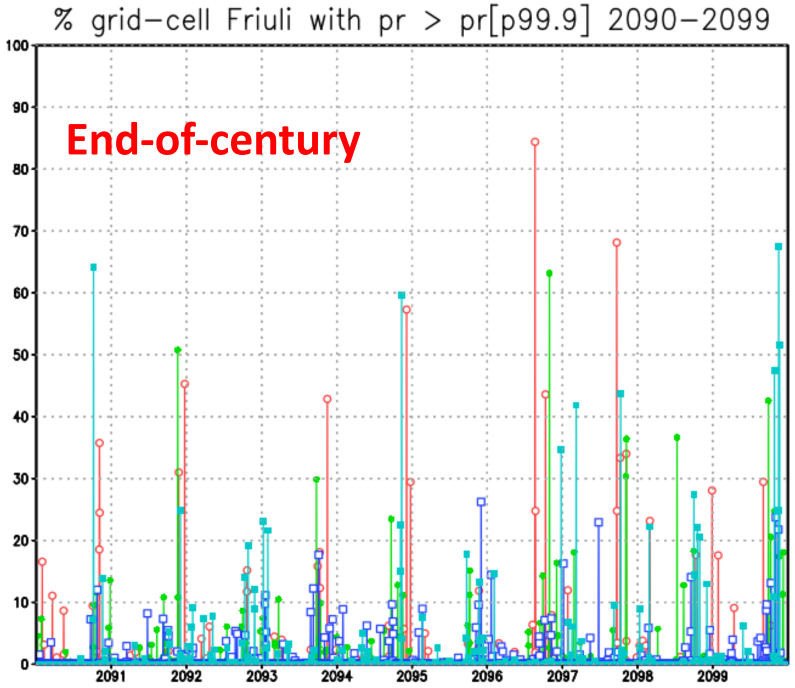
Chen et al., 2024 https://doi.org/10.5194/egusphere-egu24-2525

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**

WCRP CORDEX FLAGSHIP PILOT STUDIES

Driving conditions: mean large scale dynamical signature of the events

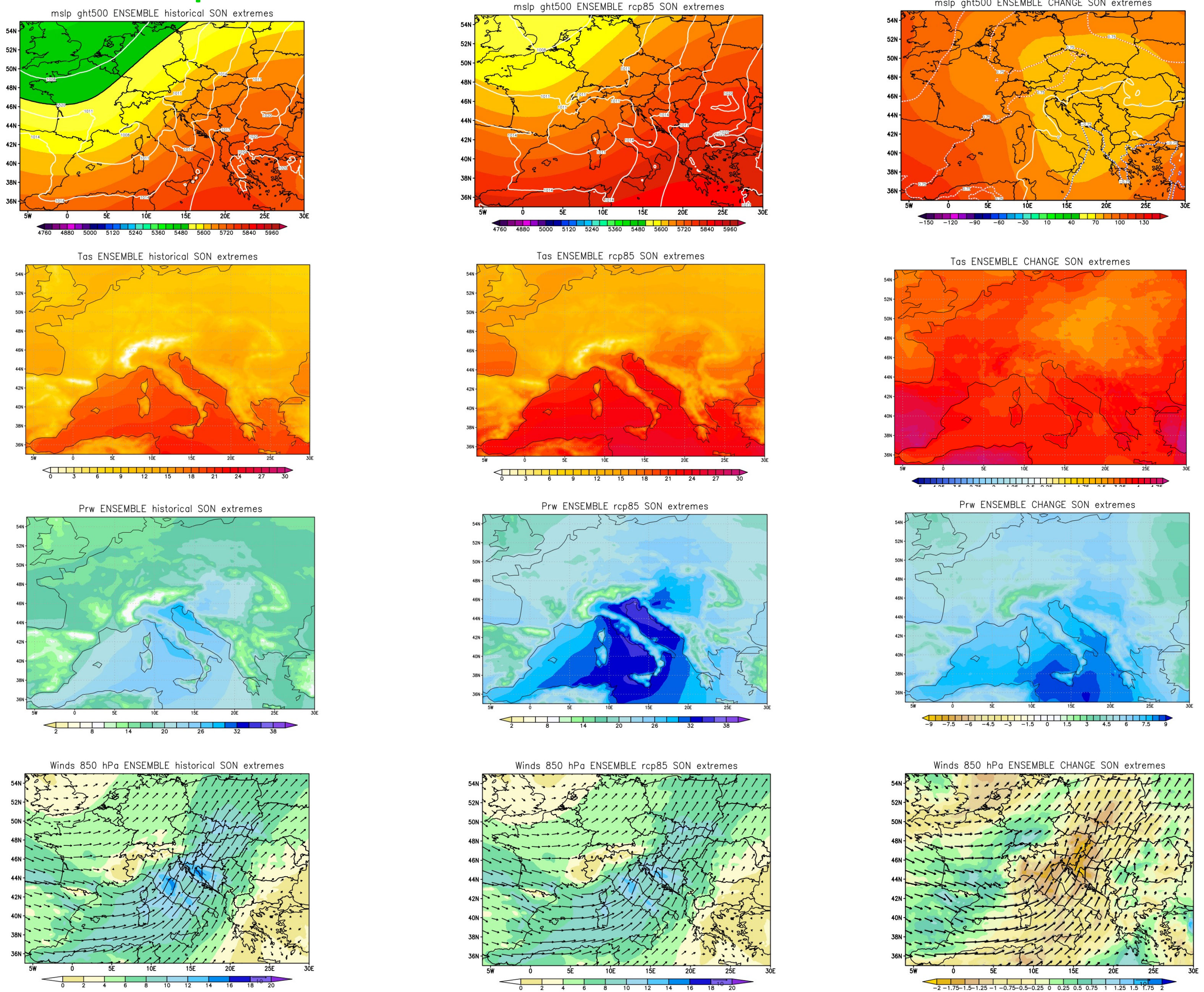
Historical period | **End of Century** | **Change**

Mslp (hPa)
Ght (m)

Tas (C)

PWV (mm)

Winds
850mb (m/s)



In the warmer climate at the end of the Century, slower W/SW-winds across the Mediterranean will favor an overload of moist over the sea; wetter flows will be impinging the basin and particularly Italian and Balkan orography's

Take Home message

- CPMs are useful tools for having better insight on climatology of **complex** morphology **regions**, especially in terms of **extremes**. CPMs can be useful when interested to **impacts**
- Improvements are only matter of km-scale? NO! Single-model studies already demonstrated that also **domain-size** is key-factor for storms representation
- **RCMs** are still **welcome** not only for building BC but also for studies about aspects where their performances are fair
- Multi-model approach is warmly suggested to build robustness in terms of precipitation extremes.