Detection and sensitivity to global warming of disastrous-like storms in the complex alpine area

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WCRP CORDEX
FLAGSHIP PILOT STUDIES

ICTP The Abdus Salam International Centre for Theoretical Physics

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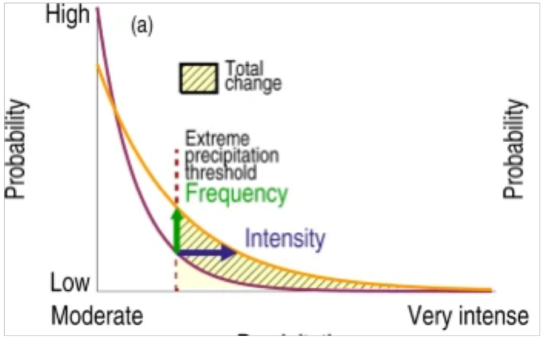
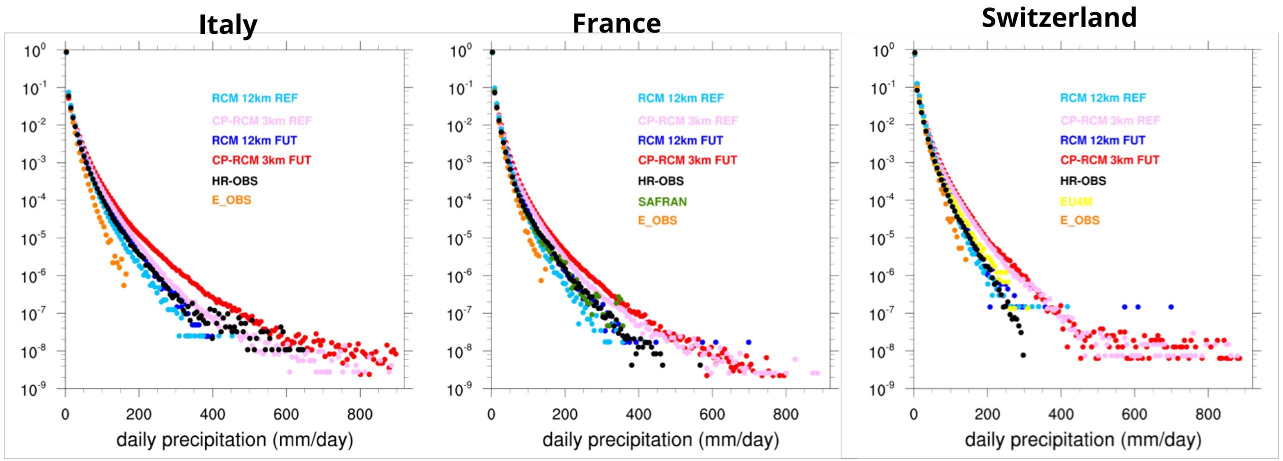
ICRC-CORDEX

Heavy to extreme precipitation: the km-scale to represent it

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



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).

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.

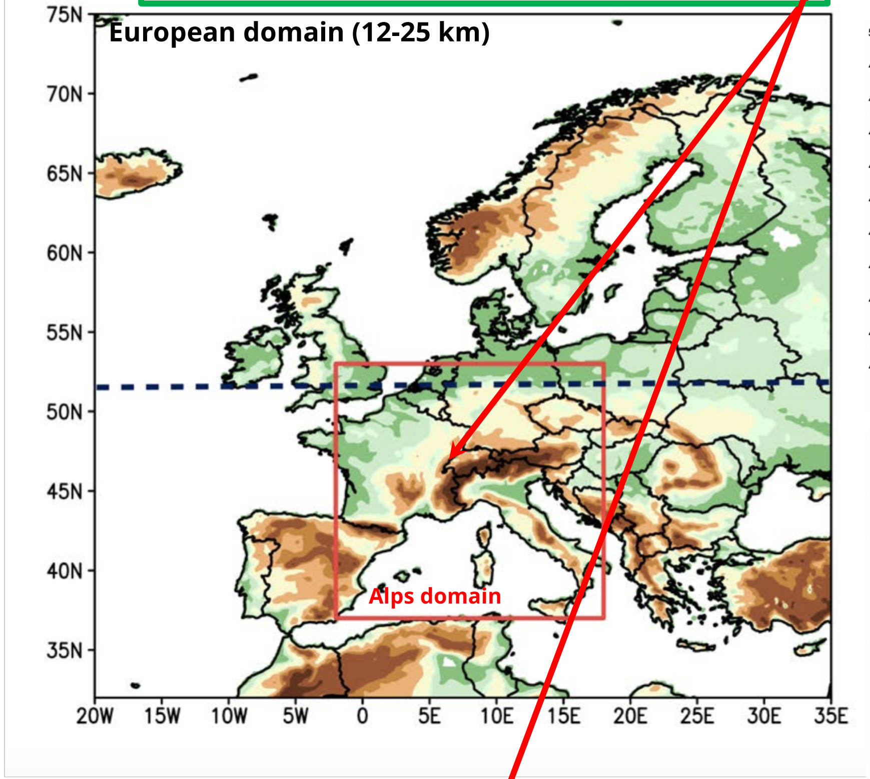
CORDEX-FPSCONV

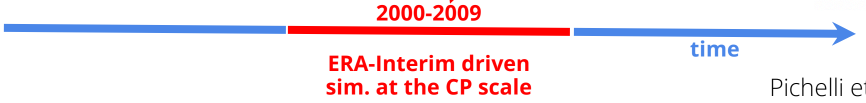
Coppola et al. (2020)

DOI: 10.1007/s00382- 018-4521-8

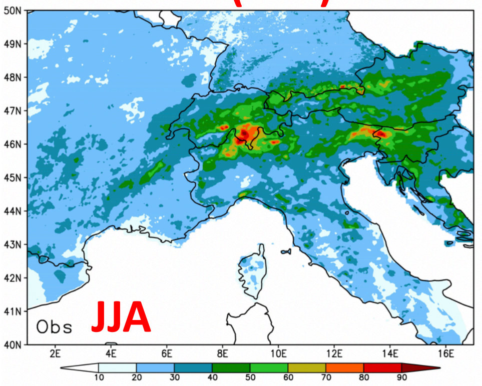
Spatio-temporal constraint

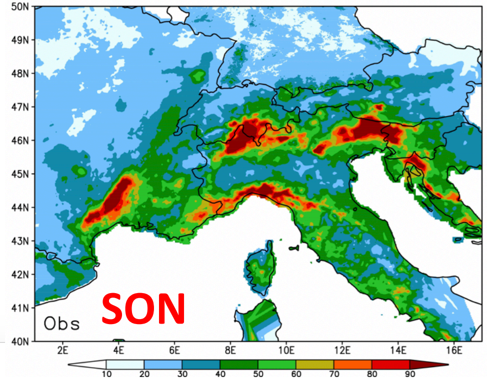
DT : the event occurs in the ALP3 domain area in the 2000-2009 decade





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

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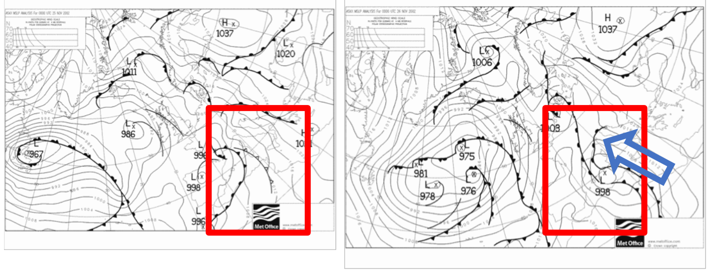
XAIDA

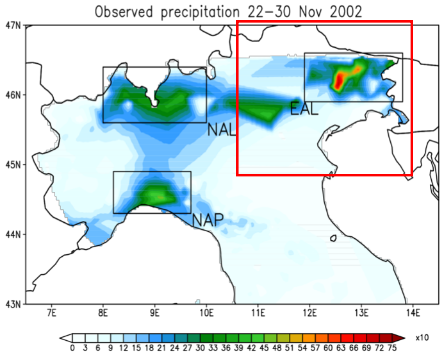
XAIDA	Date	Region	Description	Impact	Main area
1	**Jul. 2009** (23/07/07)	Austria Bavaria (South Germany)	Cold front inducing severe thunderstorms and hail; interaction between the convergence line and the foehn.	60 000 hectare arable lands devastated. Damages 15 Mln Euro.	South Germany 8-13.5E 47.5-50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

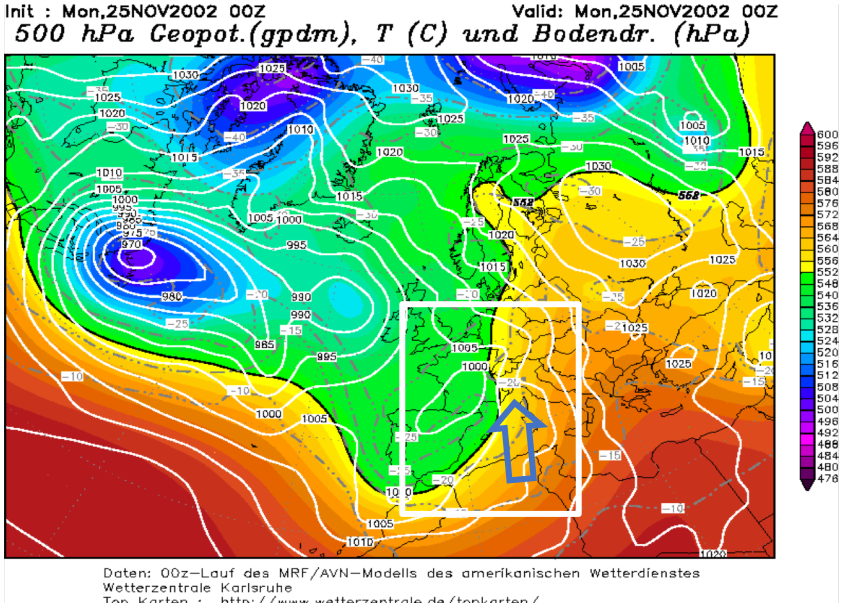
Satellite (MODIS Terra) picture of the Po river in Northern Italy

Surface fronts and MSLP



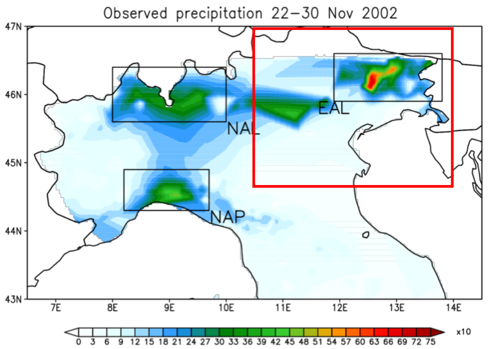


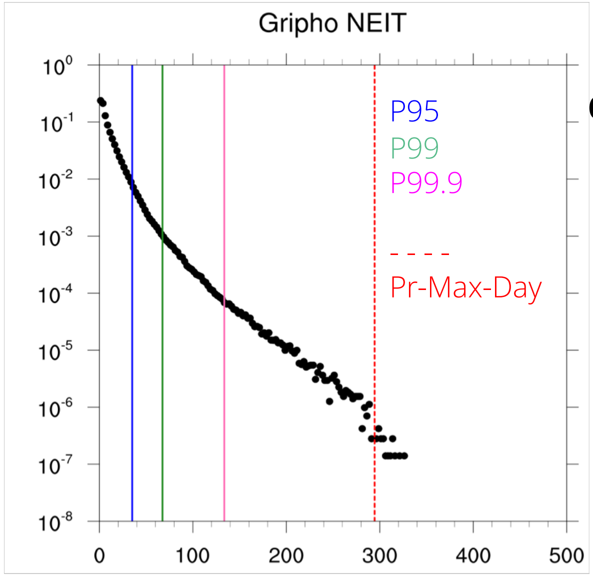
A North-Atlantic **upper-level trough entered the Western Mediterranean** inducing unstable humid south-westerly winds over Northern Italy (black arrows on pressure maps), slowly evolving eastward (finally leaving a cut-off low on the Eastern Mediterranean). Interaction with orography induced persistent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

The precipitation event in the CP-models world: evaluation run

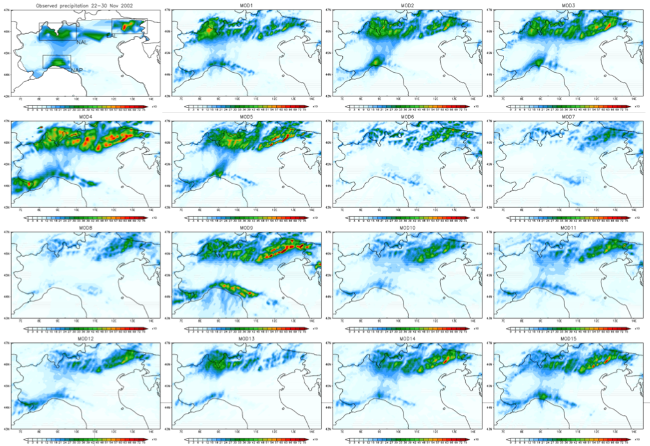
CORDEX-FPSCONV km-scale simulations

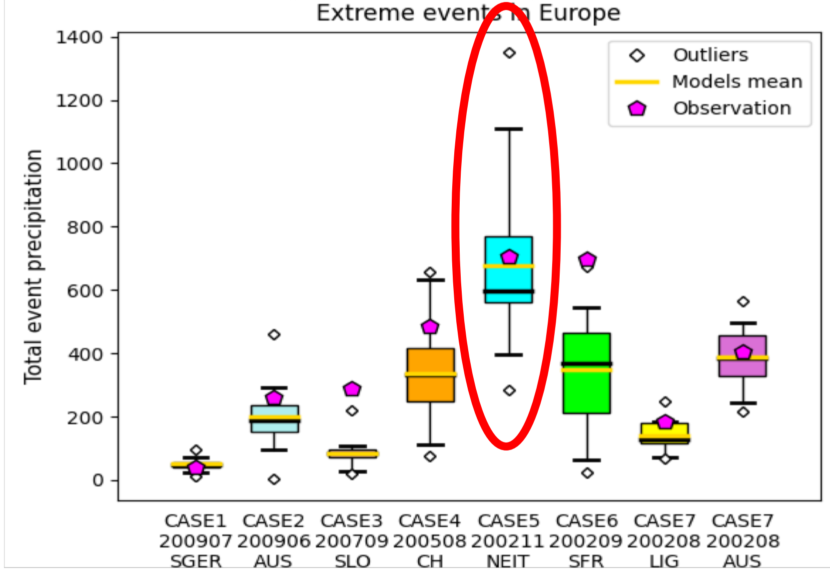
protocol Coppola et al. (2020) DOI: 10.1007/s00382- 018-4521-8

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

The precipitation event: observed and modeled





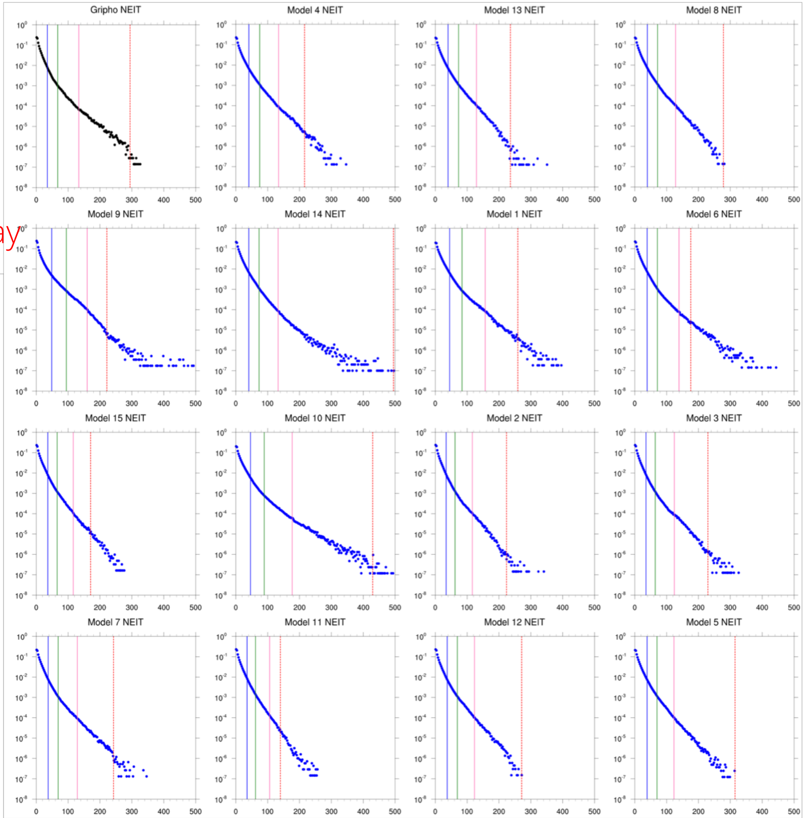
P95

P99

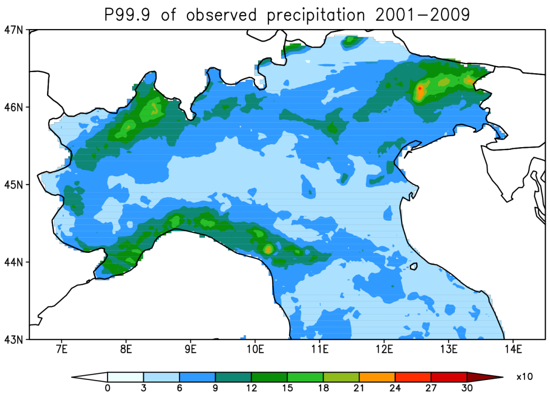
P99.9

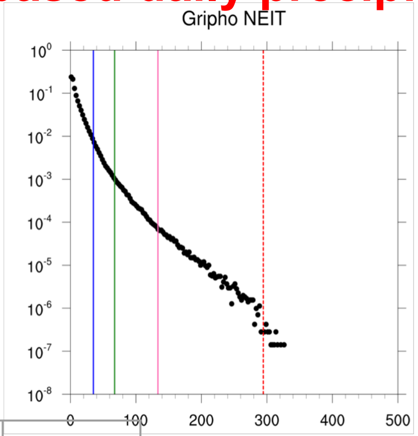
- - - -

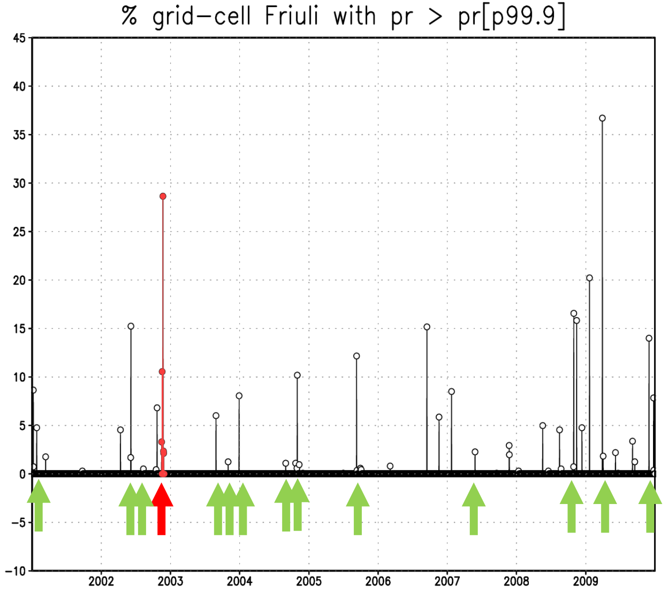
Pr-Max-Day



Method based daily precipitation extremes

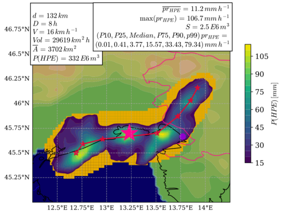






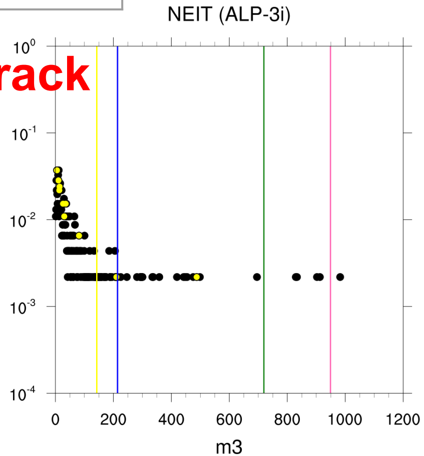
ex	SON	DJF	MAM	JJA
Obs	30	11	7	11

Method based on storm track



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

CORDEX-FPSCONV km-scale simulations

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

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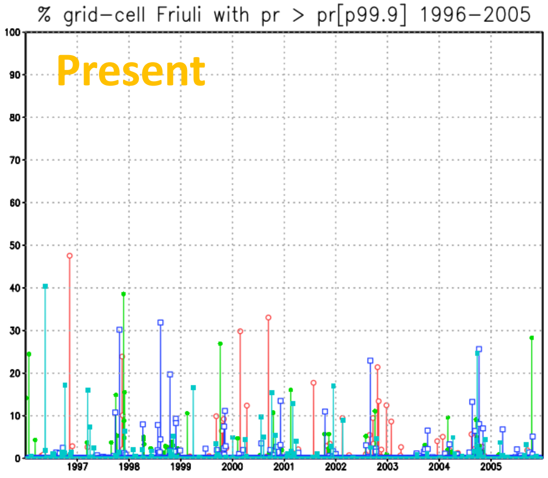
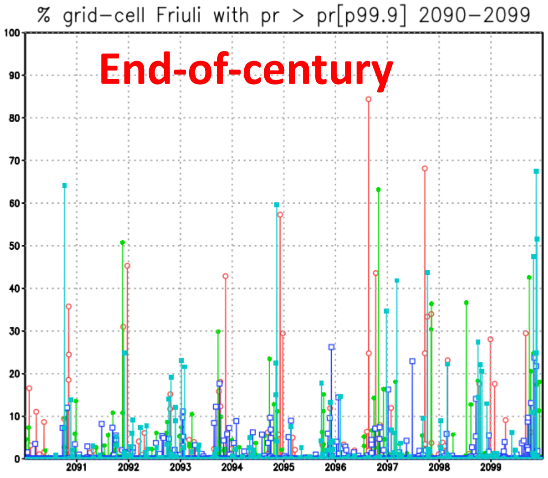
Institute	cpRCM	dx(cpRCM) [km]	RCM	dx(RCM) [km]	GCM
CMCC	CLMcom-CMCC-CCLM5-0-9 (E)	3	CCLM (E1)	12	ICHEC-EC-EARTH
CNRM	AROME41t1 (B)	2.5	ALADIN63 (B1)	12	CNRM-CERFACS-CNRM-CM5
DWD	CLMcom-DWD-CCLM5-0-15 (E)	3	CCLM4 (E1)	12	MOHC-HadGEM2-ES
ETHZ	COSMO-crCLIM (F)	2.2	COSMO-crCLIM (F)	12	MPI-M-MPI-ESM-LR
HCLIMcom	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

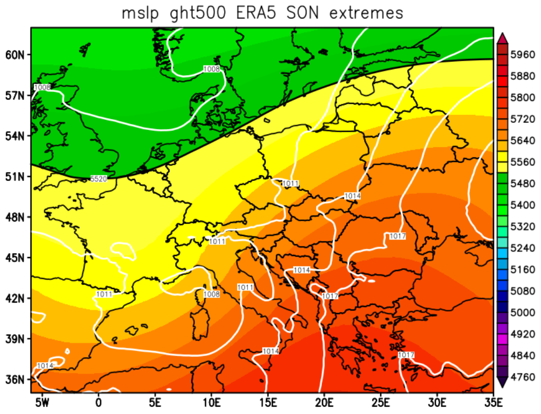




More HPEs hitting **larger areas**

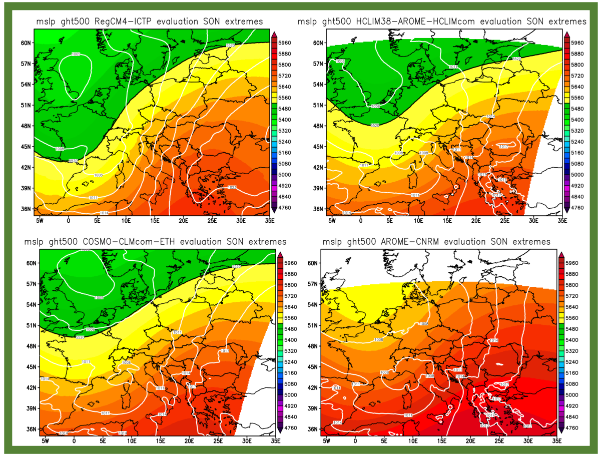
Driving conditions: mean large scale dynamical signature of the events

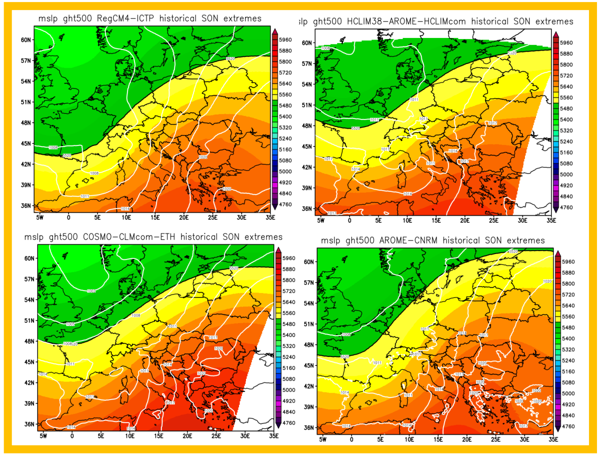
ERA5



Mean sea level pressure
(hPa, contours)
500 hPa geopotential height
(m, colors)

Evaluation run





Historical run

ICTP-RegCM4

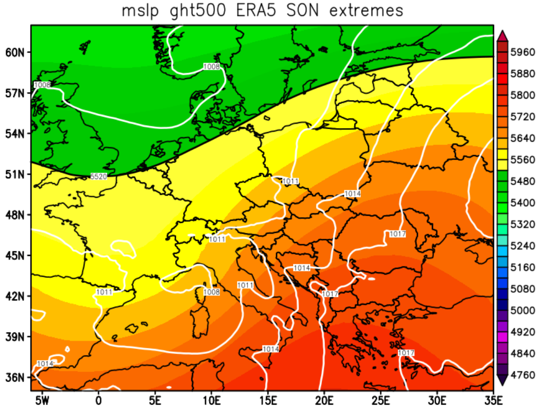
HCLIMcom-HCLIM38-AROME

ETHZ-COSMO

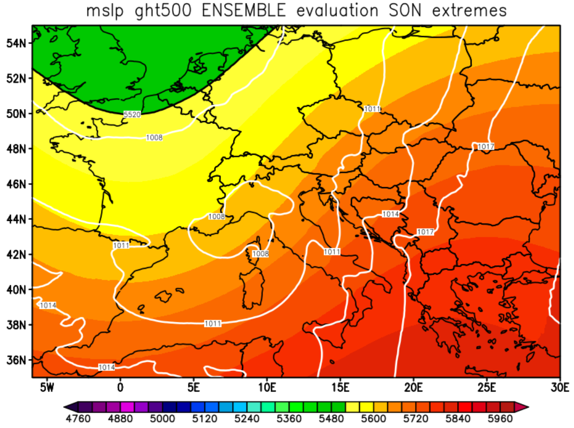
CNRM-AROME

Driving conditions: mean large scale dynamical signature of the events

ERA5



ENSEMBLE evaluation run

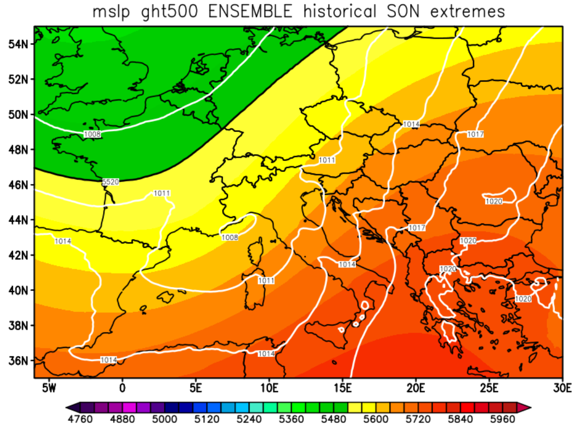


Mean sea level pressure

(hPa, contours)

500 hPa geopotential height

(m, colors)



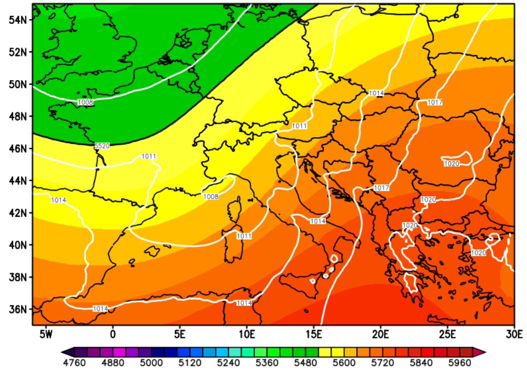
ENSEMBLE historical run

Driving conditions: mean large scale dynamical signature of the events

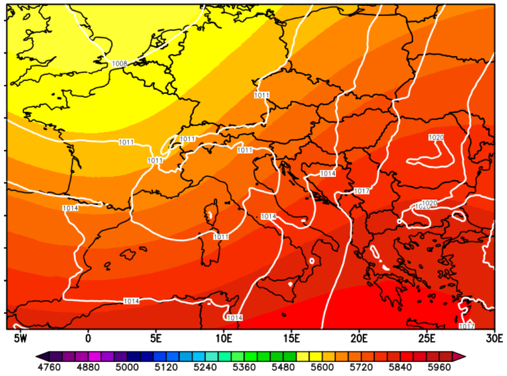
	Historical period	End of Century	Change

Mslp (hPa)
Ght (m)

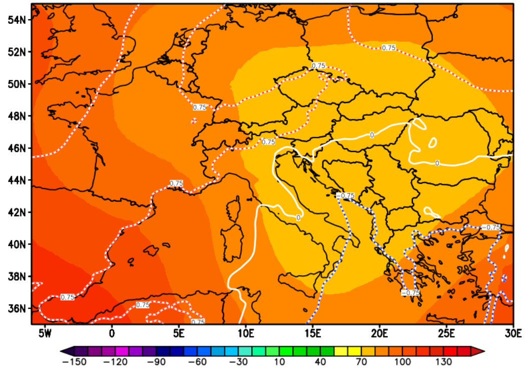
mslp ght500 ENSEMBLE historical SON extremes



mslp ght500 ENSEMBLE rcp85 SON extremes

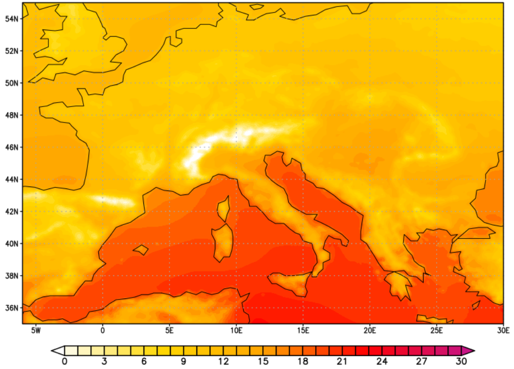


mslp ght500 ENSEMBLE CHANGE SON extremes

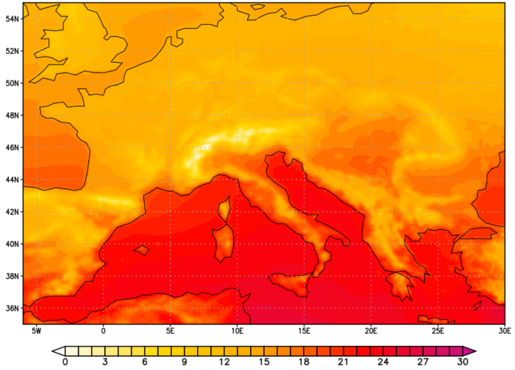


Tas (C)

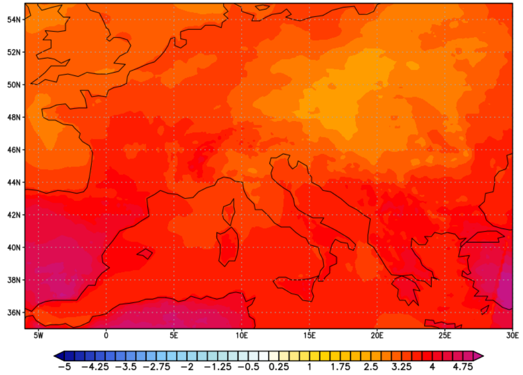
Tas ENSEMBLE historical SON extremes



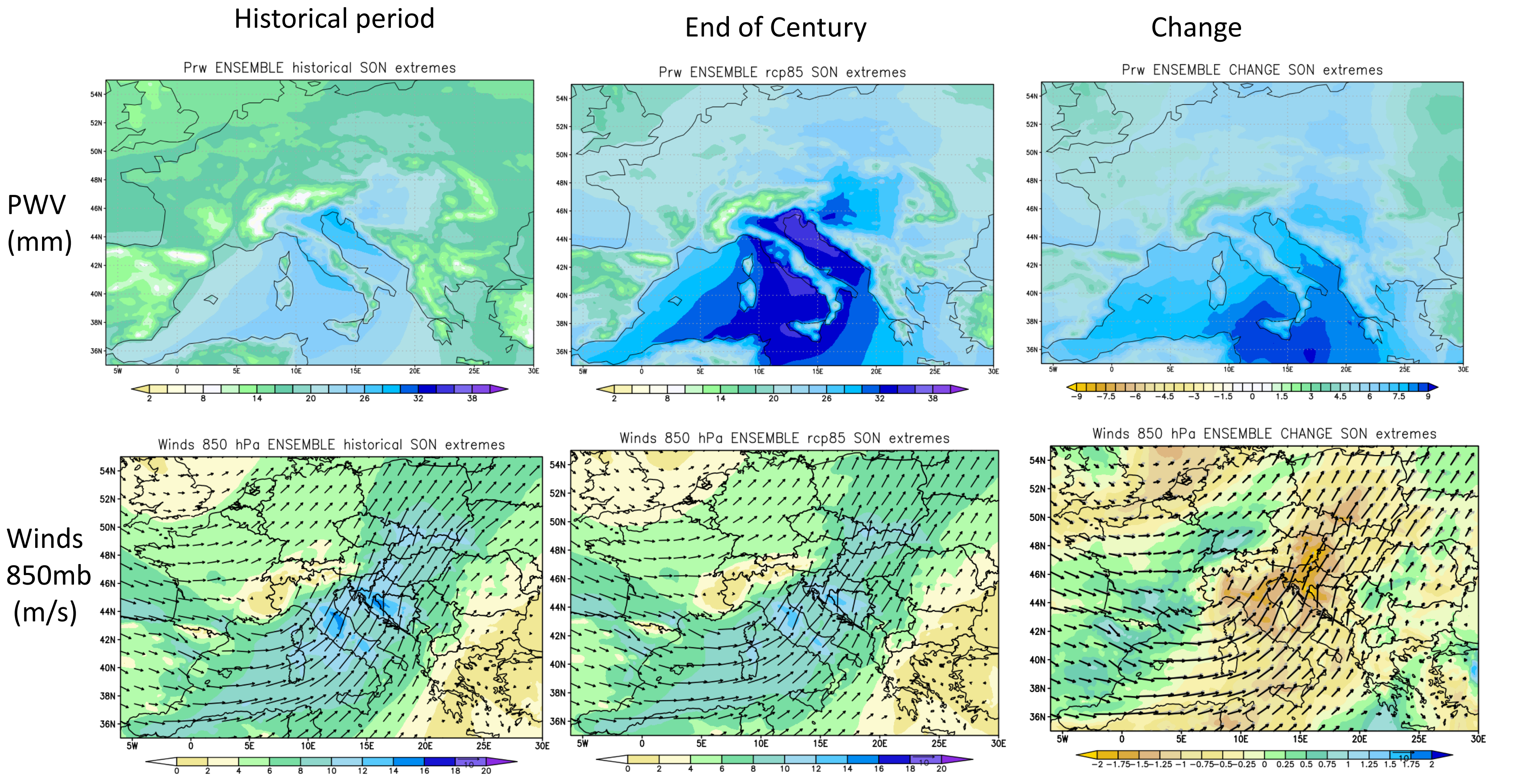
Tas ENSEMBLE rcp85 SON extremes



Tas ENSEMBLE CHANGE SON extremes



Driving conditions: mean large scale dynamical signature of the events



Summary

- We have built two detection methods (based on daily precip. P99.9 and on volume of HPE tracking) able to sample the most extreme events hitting the Mediterranean area (here North East of Italy as an example).
- The tendency shown under RCP8.5 scenario warming conditions is an increase of frequency, intensity and hit-area of the most extreme HPEs over the North East Italy.
- The large-scale patterns of these extreme “disastrous-like” events are shown to change in the future: on average, even with shallower unstable flows, blocking configurations are favoured to the East, which confine the perturbations on the West-Med. basin, larger availability of vapor across the flow feeding the NE-ALPS (and slower winds close to the surface).
- Results to be confirmed with more populated ensemble (CORDEX-FPSCONV)
- The model ensemble is shown to be able to represent those HPEs mainly driven by well set forcing (orographic and/or cold fronts), whereas most of the models tend to fail in representing the ones driven by more complex interactions (ex. pre-frontal flow, MCS formation).

Thank you for your attention