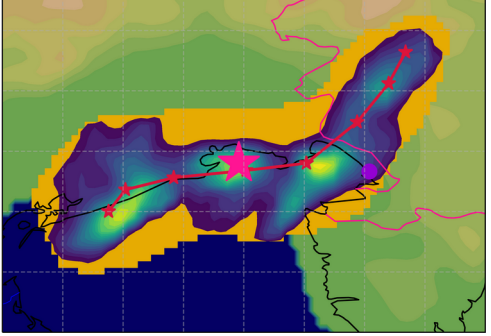
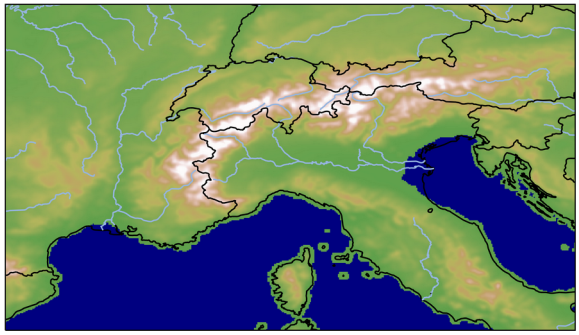


The Climate Change Response of Heavy Precipitation Events over the Alps and in the Mediterranean



at EGU22 by Sebastian K. Müller[1]

[smueller@ictp.it]

Sharing is encouraged

EUCP European Climate Prediction system

ICTP The Abdus Salam International Centre for Theoretical Physics

WCRP CORDEX FLAGSHIP PILOT STUDIES

with Emanuela Pichelli[1], Erika Coppola[1], Segolene Berthou[2], Susanne Brienen[3], Cécile Caillaud[4], Marie-Estelle Demory[5], Andreas Dobler[6], Hendrik Feldmann[7], Paola Mercogliano[8], Merja Tölle[9], Hylke de Vries[10]

1:=The Abdus Salam International Centre for Theoretical Physics - Earth System Physics Section (ICTP-ESP), Trieste, Italy; 2:=Met Office Hadley Centre, Exeter, United-Kingdom; 3:=Deutscher Wetterdienst (DWD), Offenbach, Germany; 4:=CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France; 5:=Norwegian Meteorological Institute, Oslo, Norway; 6:=Center for Environmental Systems Research (CESR), University of Kassel, Germany; 7:=Eidgenössische Technische Hochschule Zürich (ETHZ); 8:= Euro-Mediterranean Center on Climate Change, Lecce, Italy; 9:= University of Giessen, Germany; 10:=Koninklijk Nederlands Meteorologisch Instituut, KNMI, De Bilt, Netherlands

MOTIVATION

Projected changes in mean and extreme precipitation over the Mediterranean region from a high resolution double nested RCM simulation

Xuejie Gao,[1,2] Jeremy S. Pal,[1] and Filippo Giorgi

Heavy precipitation in a changing climate: Does short-term summer precipitation increase faster?

Nikolina Ban[1], Juerg Schmidli[1], and Christoph Schär[1]

Enhanced summer convective rainfall at Alpine high elevations in response to climate warming

Filippo Giorgi[1]*, Csaba Torma[1], Erika Coppola[1], Nikolina Ban[2], Christoph Schär[2] and Samuel Somot[3]

Many studies show:

Under climate warming,
the Alpine-Mediterranean climate is drying,
but heavy&convective precipitation is intensifying.

Flooding in Southern France in 09/2003

We want to know:

How, where and when will the **properties** of heavy precipitation events (HPEs) [Scale, Intensity, Severity, Occurrence Frequency, Propagation…] change in response to warming climate?

MODELS: convection-permitting regional climate models

METHOD: Tracking Algorithm → Lagrangian frame of reference

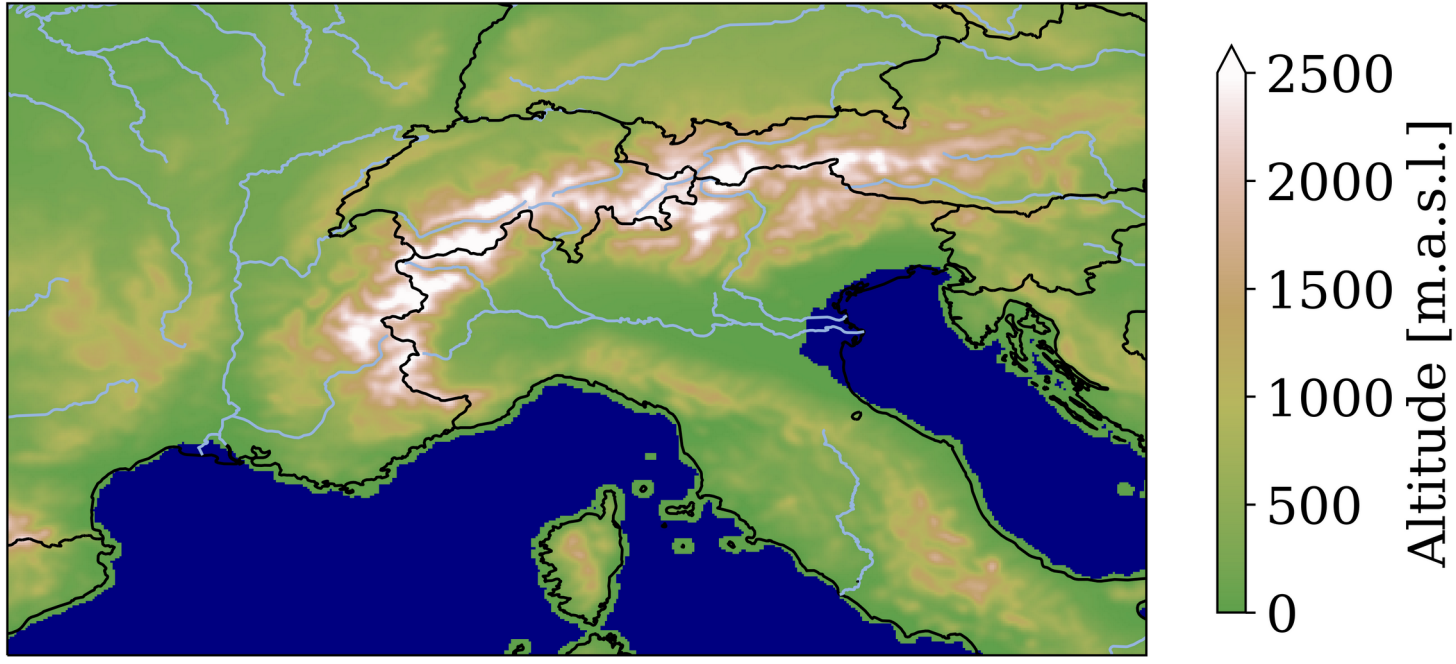
MODELS: Convection-permitting regional climate models

WCRP CORDEX FLAGSHIP PILOT STUDIES

Coppola, et al. (2020) "A first-of-its-kind multi-model convection-permitting ensemble for investigating convective phenomena over Europe and the Mediterranean."

- driven by CMIP5-GCMs under RCP85
- 10-member ensemble
- grid spacings < 3 km

- 3 simulation periods:
  - +historical [2000-2009]
  - +nearfuture [2040-2049]
  - +farfuture [2090-2099]



Analysis domain and model terrain

METHOD:

Tracking Algorithm

→ Investigation of HPEs in the Lagrangian frame of reference

Setup:
- smoothing radius 8 cells
- smoothing in time +-1 step
- pr-threshold = 5 mm h^{-1}
- minimum volume TH = 100 cells

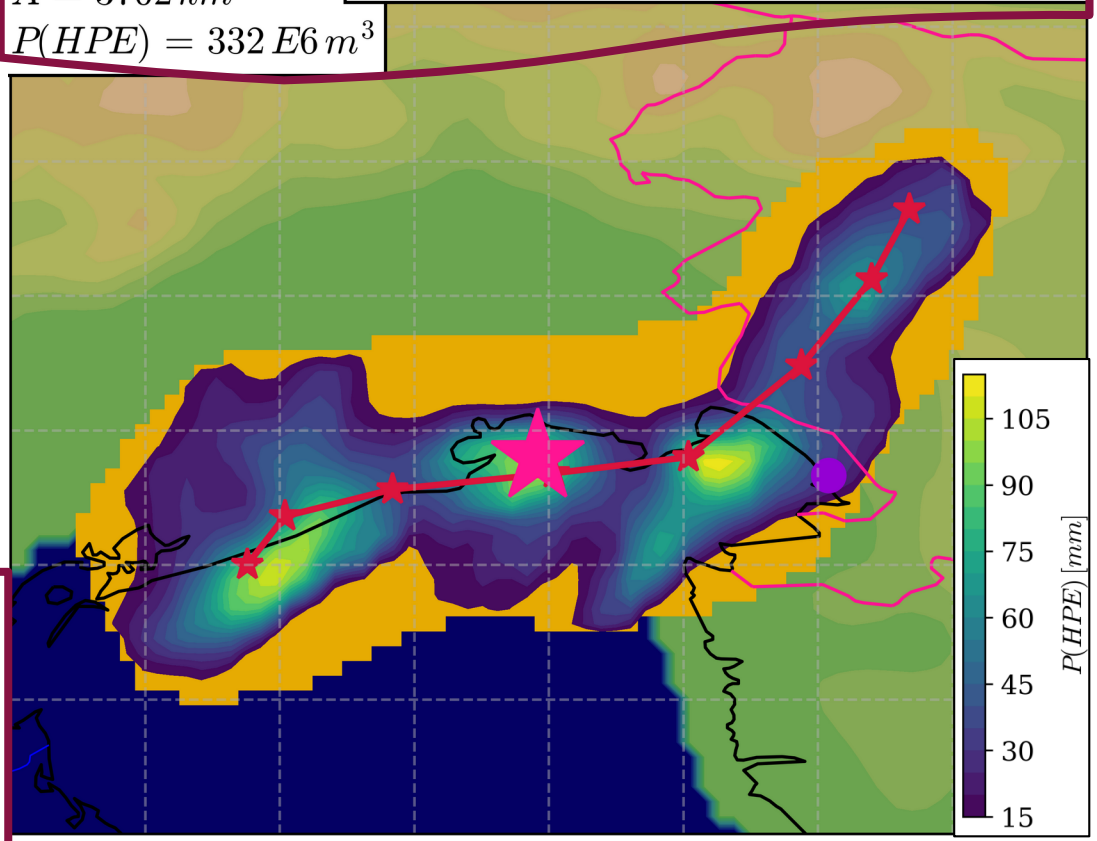
DTC/MET-MTD

Documentation

→ characteristic HPE-properties, describing scale, intensity, propagation and severity

$d = 132\,km$
$D = 8\,h$
$V = 16\,km\,h^{-1}$
$Vol = 29619\,km^2\,h$
$\overline{A} = 3702\,km^2$
$P(HPE) = 332\,E6\,m^3$

$\overline{pr_{HPE}} = 11.2\,mm\,h^{-1}$
$\max(pr_{HPE}) = 106.7\,mm\,h^{-1}$
$S = 2.5\,E6\,m^3$
$(P10, P25, Median, P75, P90, p99)\,pr_{HPE} =$
$(0.01, 0.41, 3.77, 15.57, 33.43, 79.34)\,mm\,h^{-1}$

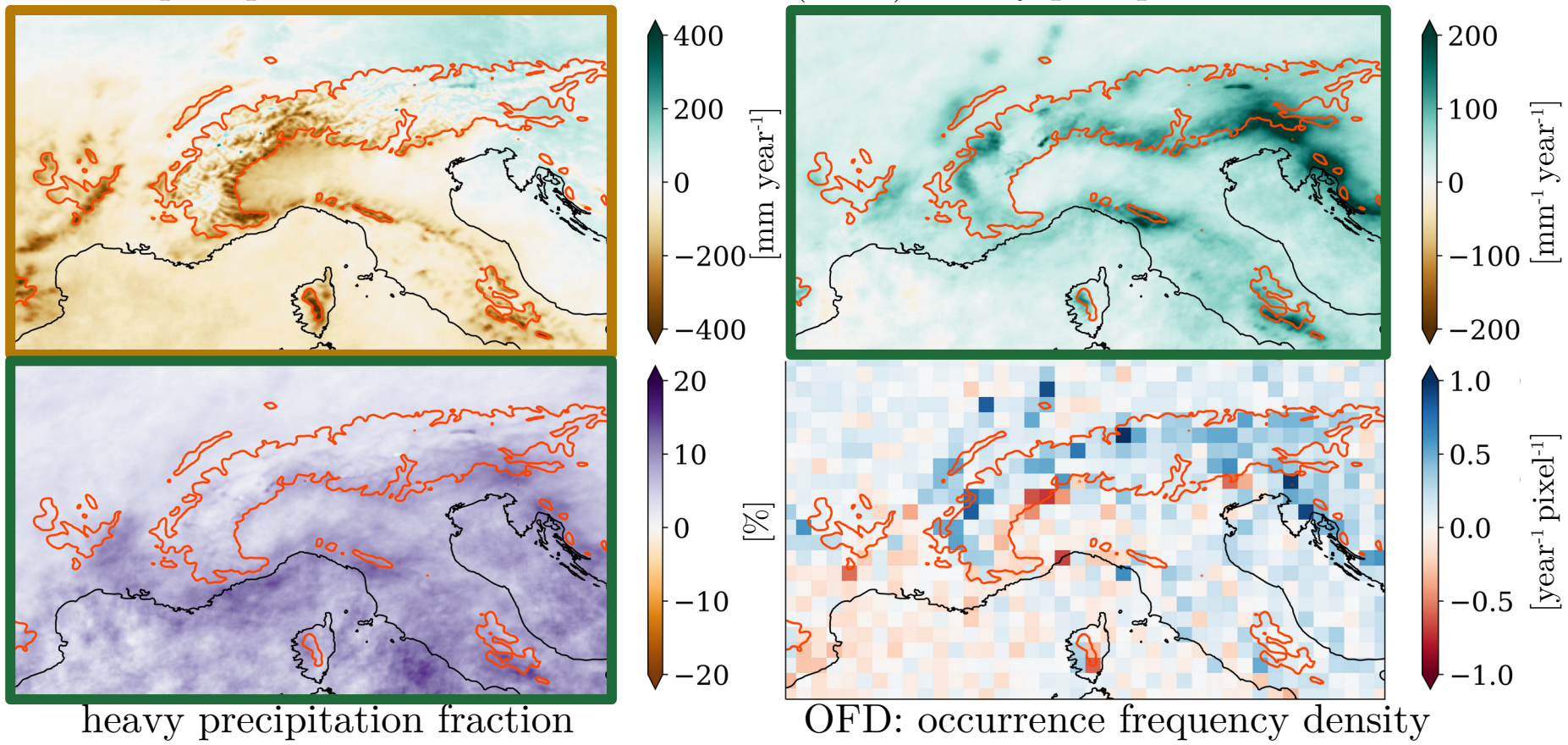


HPE-Track in the Gulf of Trieste, 09/2098

RESULTS: A) *The classic Eulerian view & proof of assumption*

➜ **Altough climate is drying, heavy precipitation is increasing.**

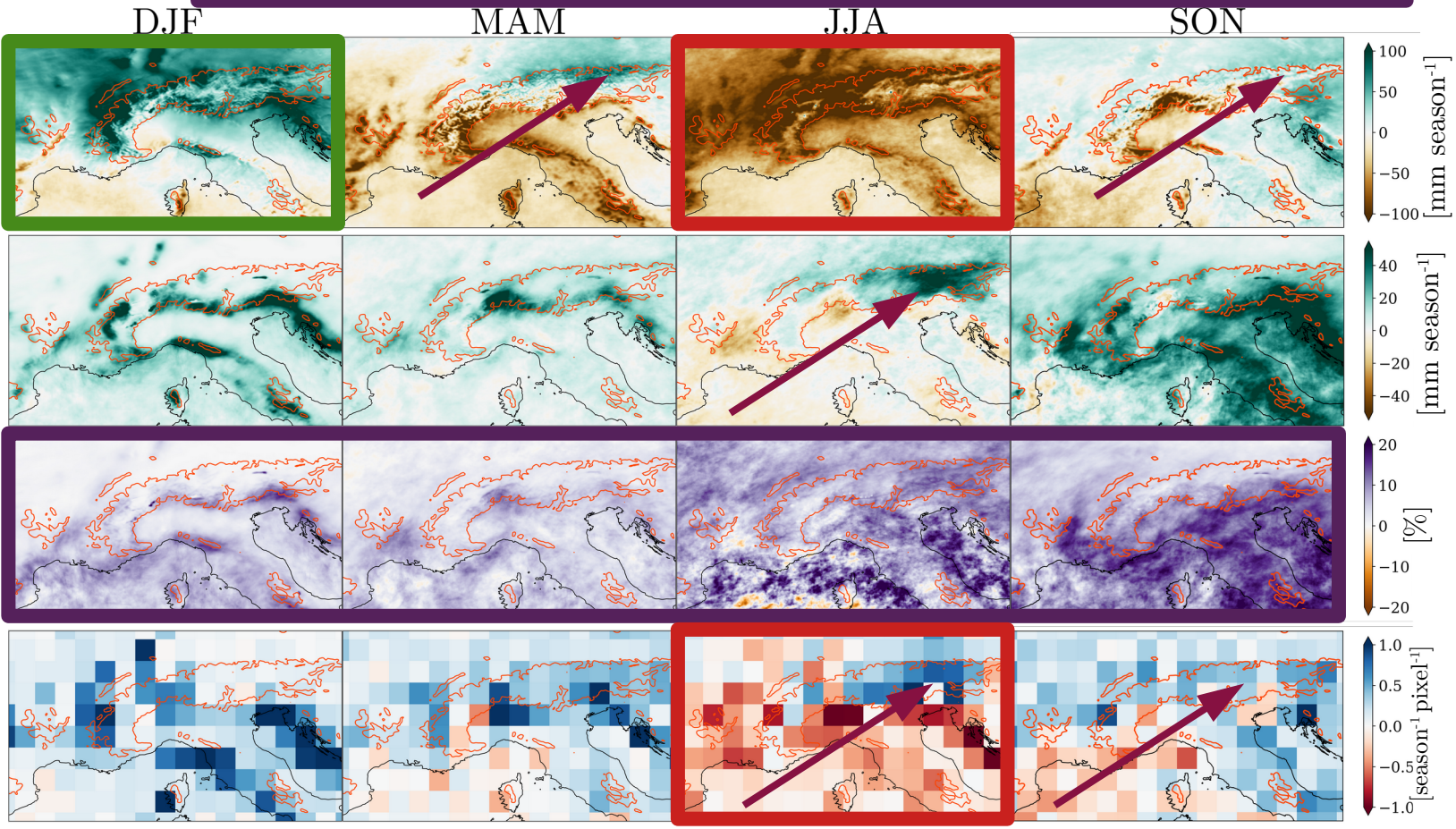
Climate Change Response := farfuture – historical



RESULTS: A) *But the seasonal and regional CCR is complex!*

- **summer-drying** vs. **winter-moistening** & **SW-NE gradient in spring & autumn**

But: heavy precipitation fraction increasing allover



total precipitation amount

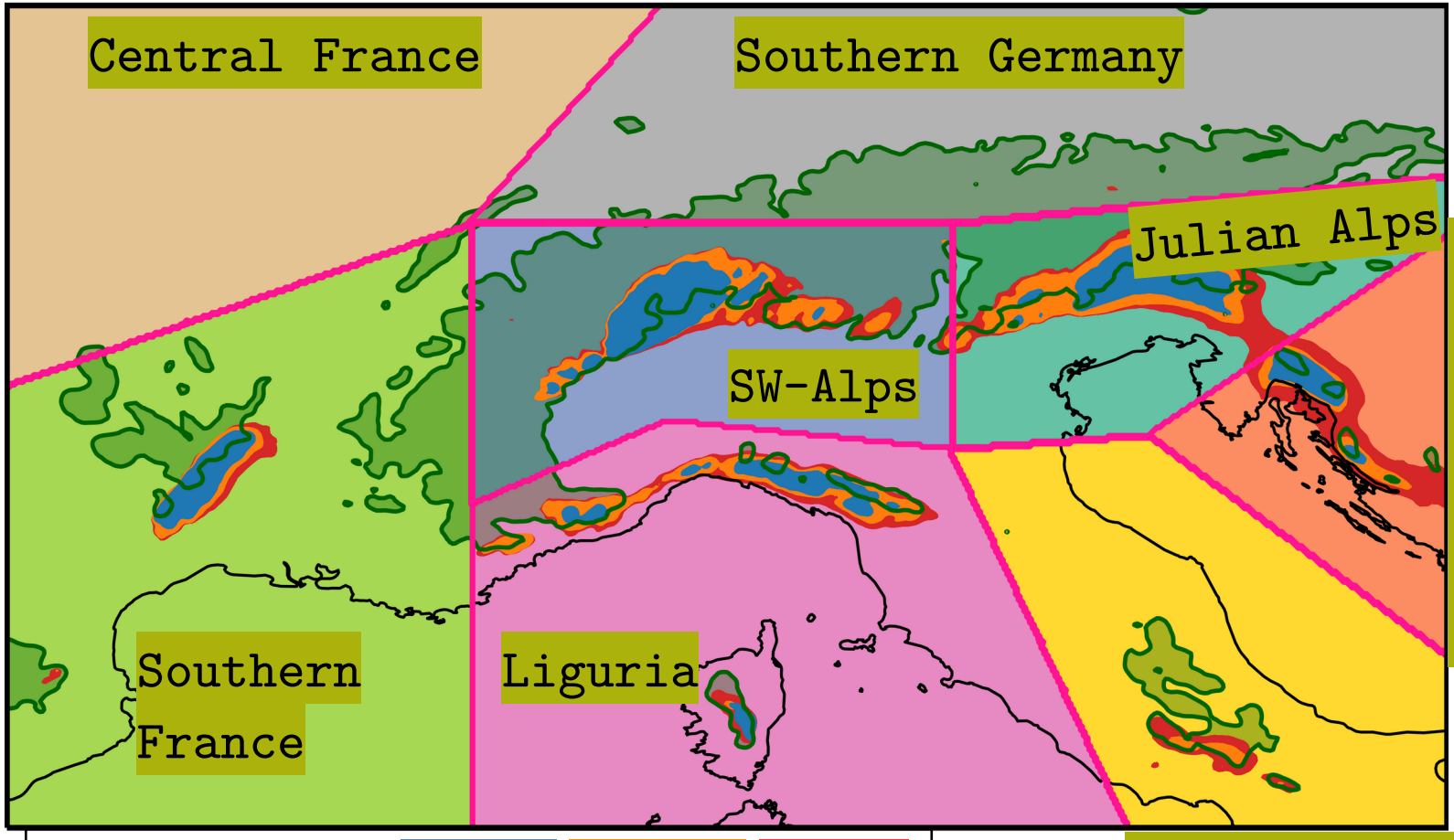
P(HPE): heavy precipitation amount

heavy precipitation fraction

OFD: occurrence frequency density

RESULTS: Introduction of characteristic HPE categories and regions:

- Orographic / Plain: HPE migrating across more/less than 1000m of elevation
- Sea / Land: HPE occurring only over sea/land
- Hybrid: HPE crossing the coastline

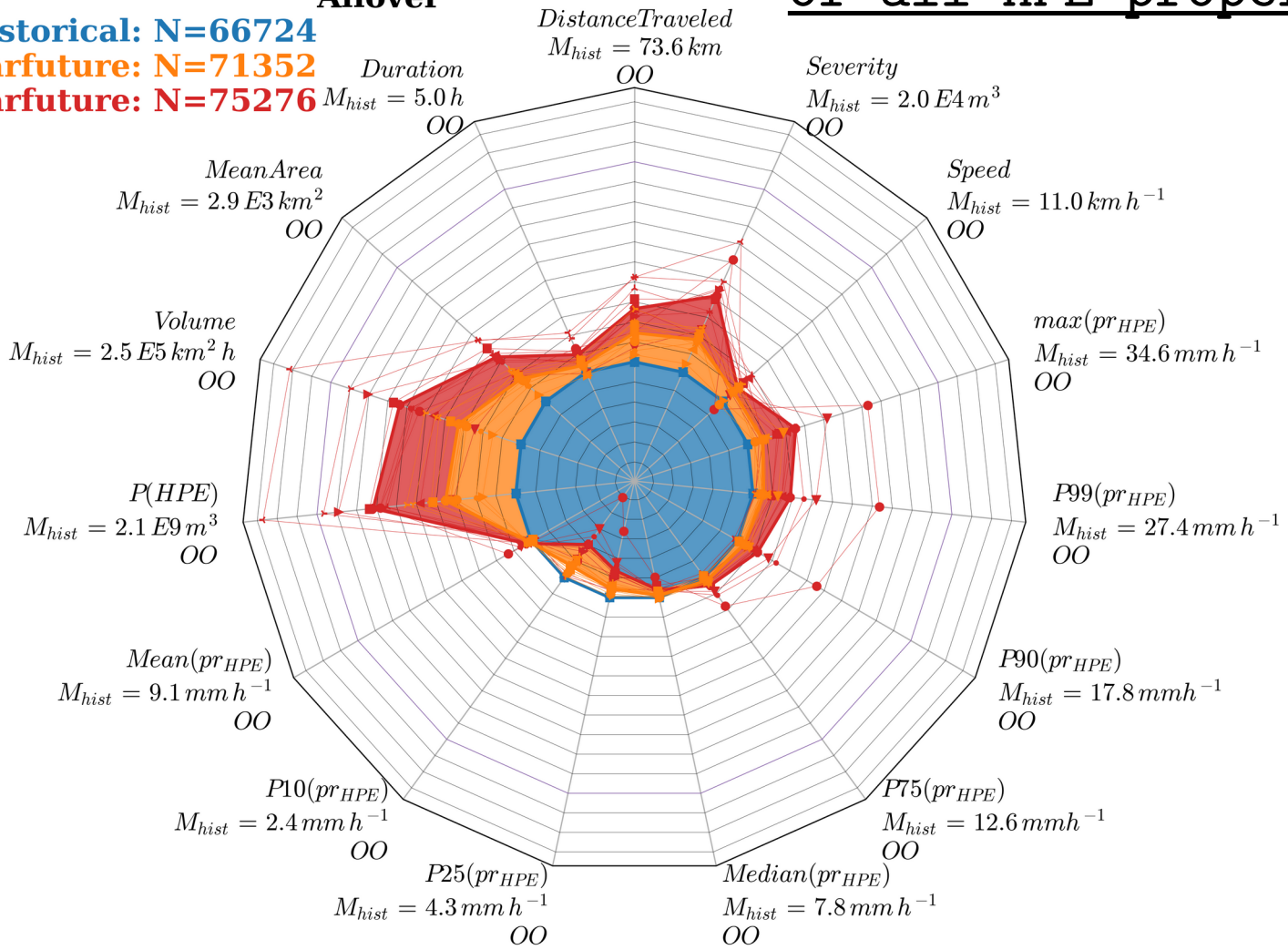


RESULTS: B) The Climate Change Response w.r.t. historical

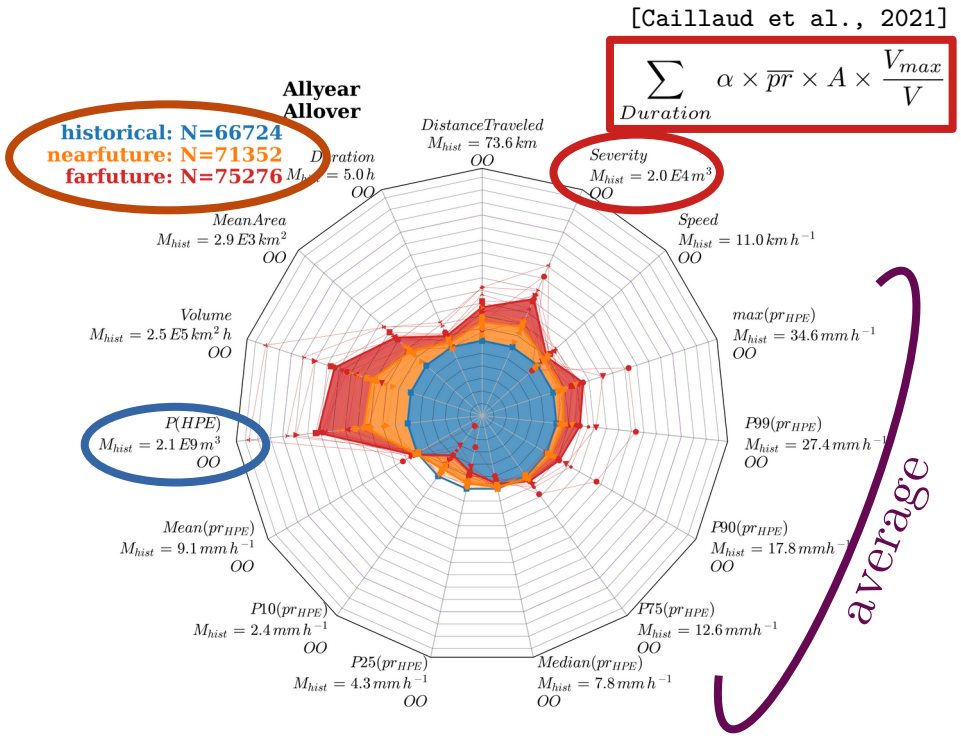
of all HPE-properties [%]

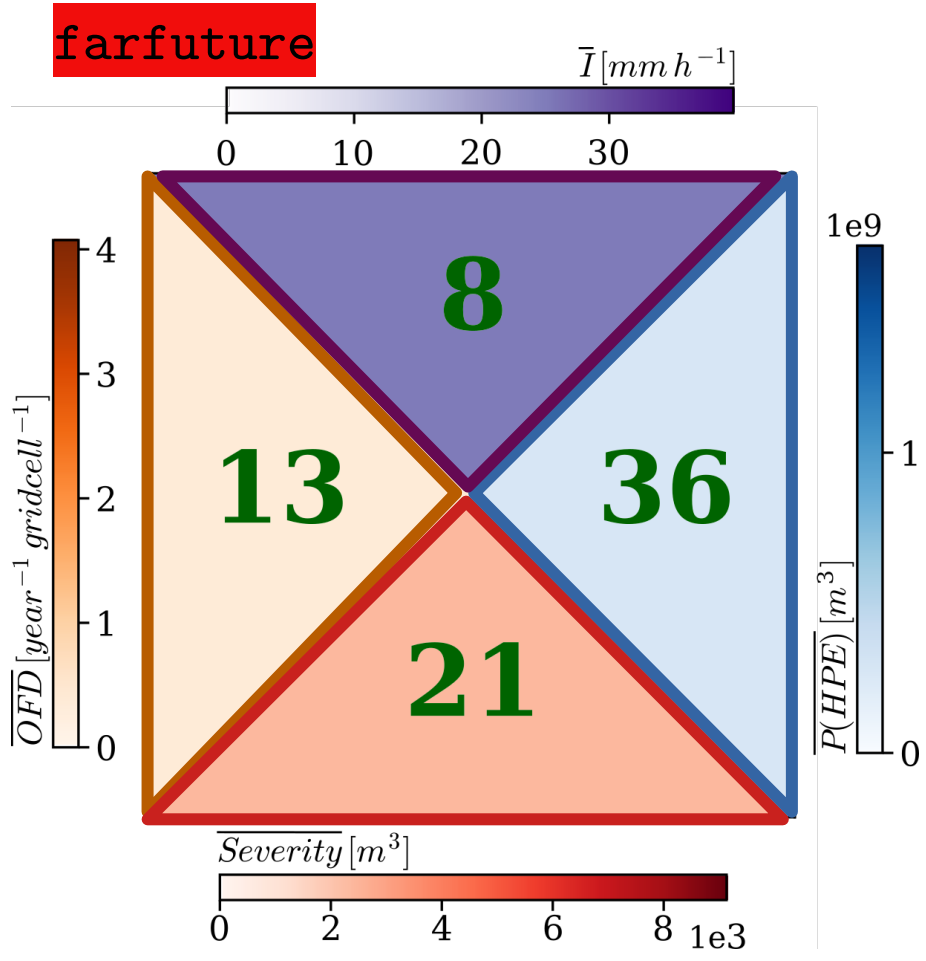
Allyear
Allover

historical: N=66724
nearfuture: N=71352
farfuture: N=75276



RESULTS: B) *Distillation!* → into only 4 HPE-properties





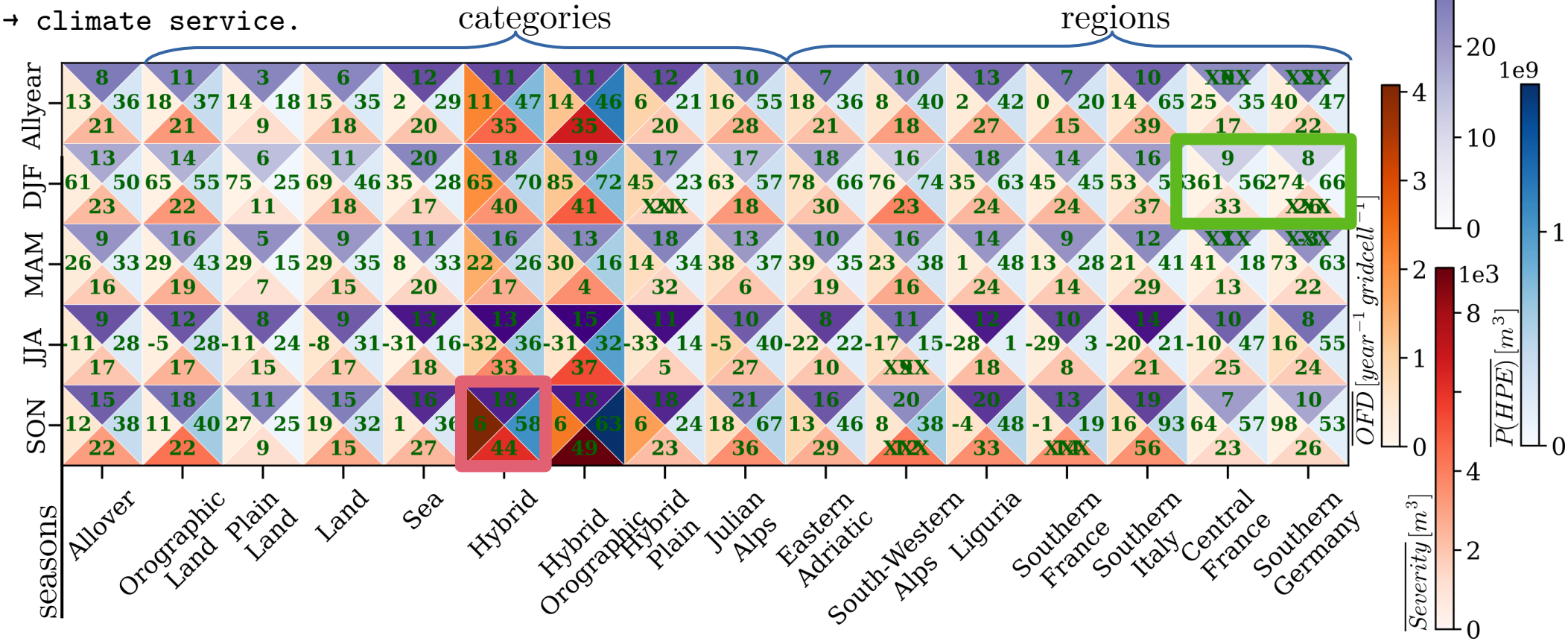
Shading shows magnitude, numbers denote changes w.r.t. historical [%]

RESULTS: B) The HPE-CCR [%] (seasons, categories, regions)

→ a: hybrid events in autumn are most frequent, severe, intense and heavy, but also show a greater-than-domain-average climate change response.

→ b: regions north of the alps show a strong increase in HPE frequency, along with increases of rainfall volume of 56 and 66%.

→ climate service.



DISCUSSION:

- nearfuture surface warming = 1.1K
- farfuture surface warming = 4.0K w.r.t. historical

- all 4 HPE-properties scale and intensify with climate warming, but at rates **less than** the Clausius-Clapeyron scaling suggests

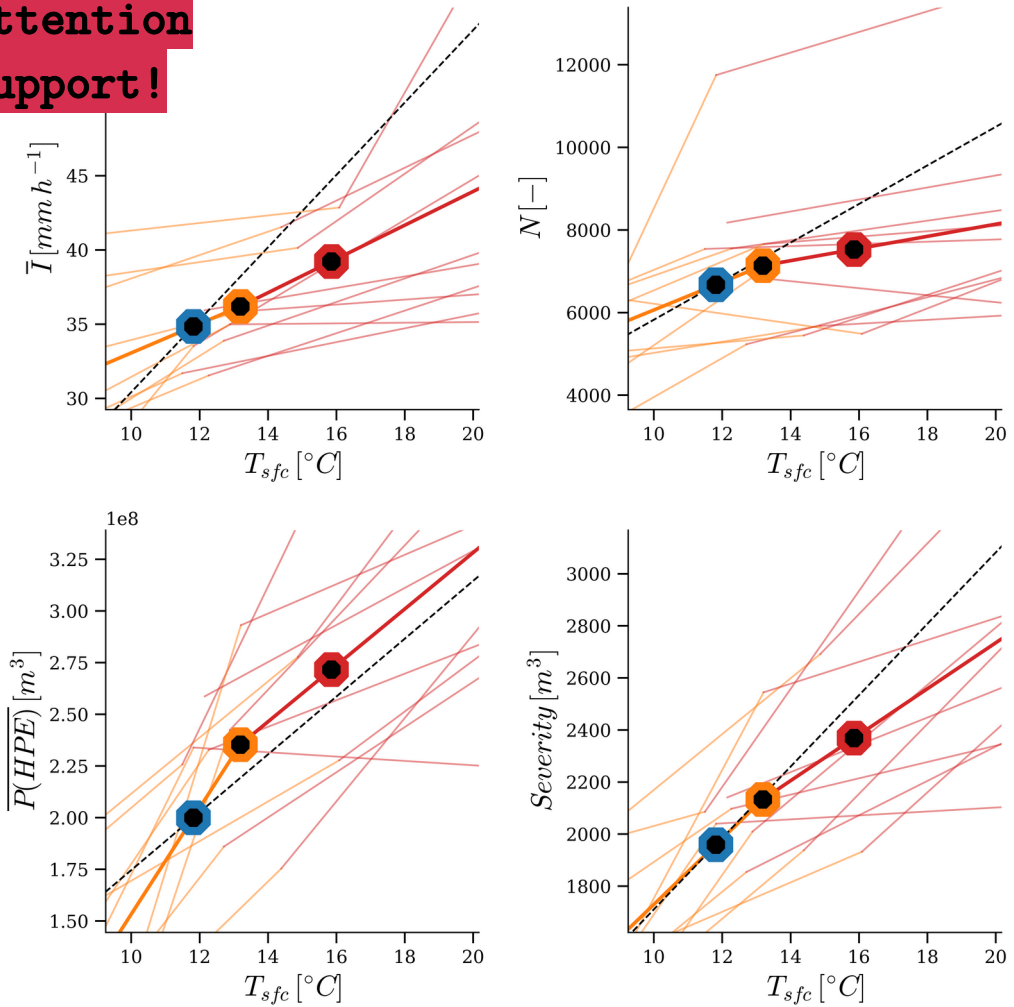
TAKE HOME MESSAGE:

- within a complex domain, local and seasonal differences must be considered
- leave me a question and find out more! At →

smueller@ictp.it

Thank you for your attention and support!

Correlation of HPE-properties with surface temperature



The black dashed line denote Clausius-Clapeyron Scaling of 7%/1K. Thin lines are single models, thick line is the model ensemble mean.

Project and Tracking Algorithm:

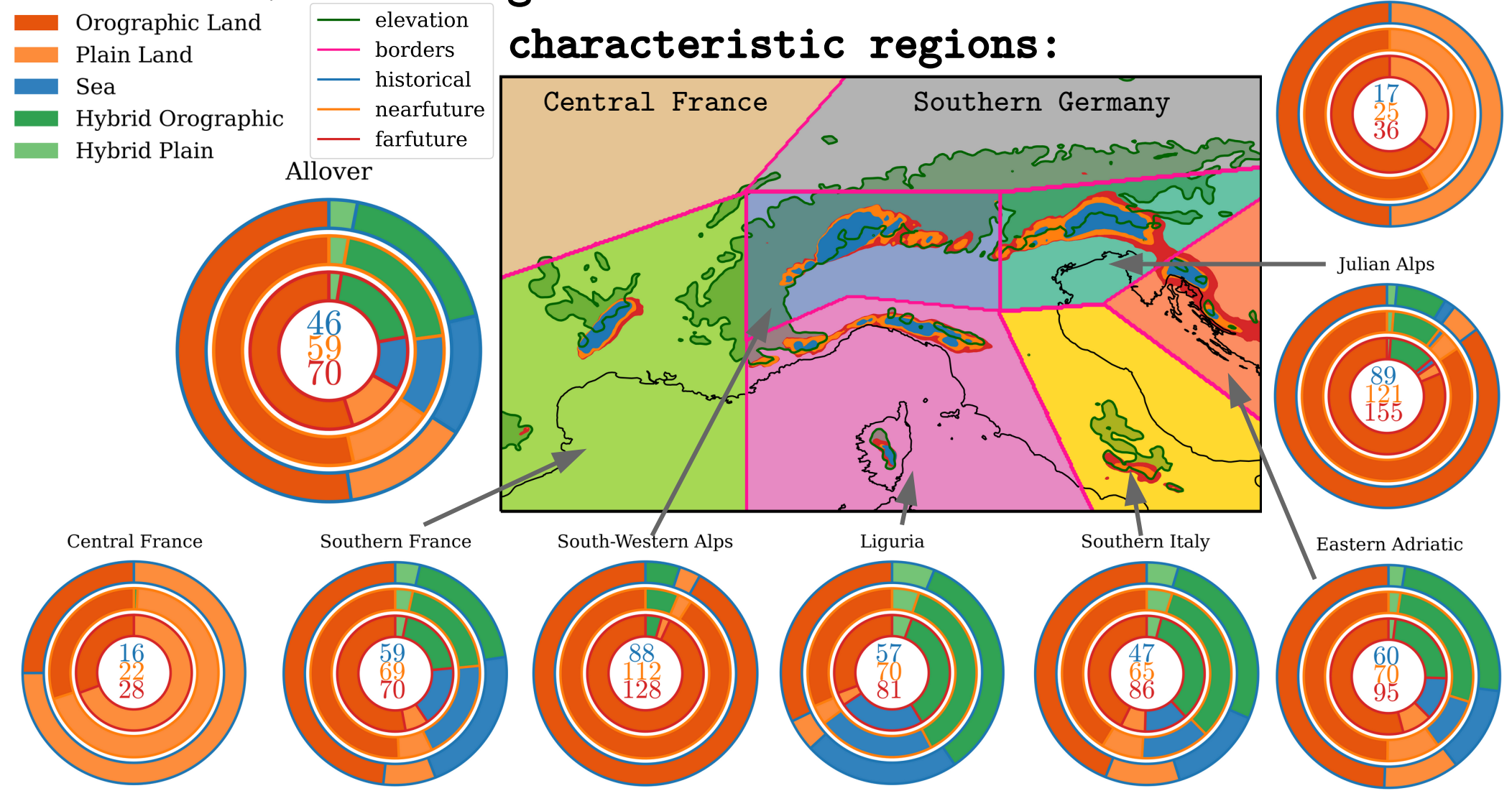
https://www.hymex.org/cordexfps-convection/wiki/doku.php

https://github.com/dtcenter/MET/blob/main_v9.1/met/docs/Users_Guide/mode-td.rst

List of References:

- Gao, Xuejie, Jeremy S. Pal, and Filippo Giorgi. "Projected changes in mean and extreme precipitation over the Mediterranean region from a high resolution double nested RCM simulation." Geophysical Research Letters 33.3 (2006).
- Ban, Nikolina, Juerg Schmidli, and Christoph Schär. "Heavy precipitation in a changing climate: Does short-term summer precipitation increase faster?." Geophysical Research Letters 42.4 (2015): 1165-1172.
- Giorgi, Filippo, et al. "Enhanced summer convective rainfall at Alpine high elevations in response to climate warming." Nature Geoscience 9.8 (2016): 584-589.
- Coppola, Erika, et al. "A first-of-its-kind multi-model convection permitting ensemble for investigating convective phenomena over Europe and the Mediterranean." Climate Dynamics 55.1 (2020): 3-34.
- Caillaud, Cécile, et al. "Modelling Mediterranean heavy precipitation events at climate scale: an object-oriented evaluation of the CNRM-AROME convection-permitting regional climate model." Climate Dynamics 56.5 (2021): 1717-1752.

RESULTS: B2) HPE categories and characteristic regions:

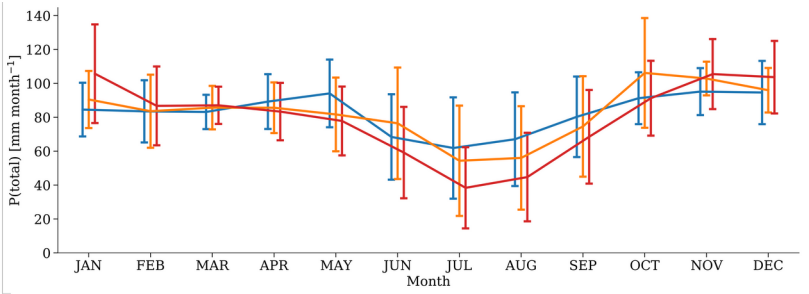


RESULTS: Annual cycle

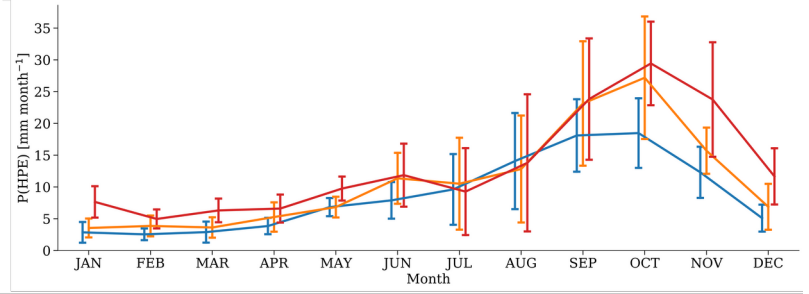
- Summer drying + winter-moistening

  corresponds to

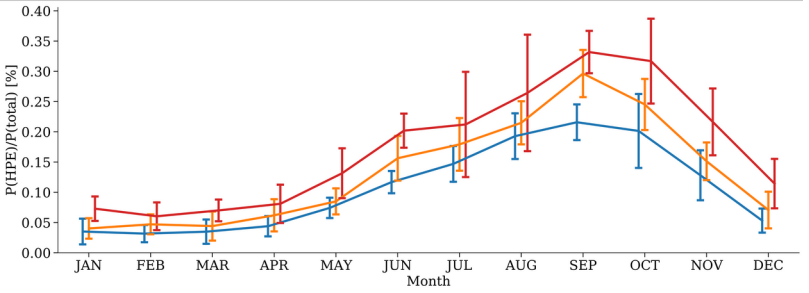
- fewer events in summer + more events in winter



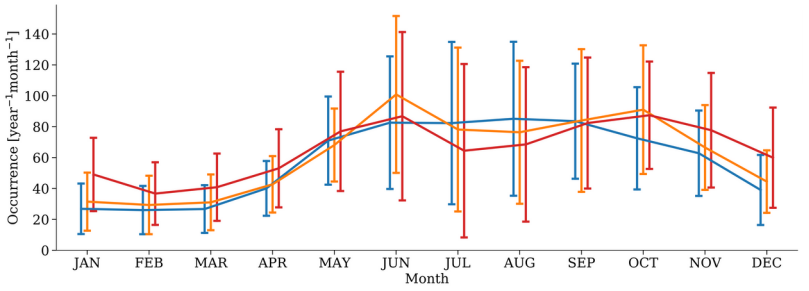
total precipitation amount



P(HPE): heavy precipitation amount



heavy precipitation fraction



OFD: occurrence frequency density

RESULTS: B1) Distill and resolve seasons of the CCR of HPE-properties [%]