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

E. Pichelli, E. Coppola
and CORDEX-FPSCONV team
Heavy to extreme precipitation: the km-scale to represent it

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

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.
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

HPE (P99)

Ecosystem damages
Human casualties/injuries
Economical losses

Severe Impact
North East Italy affected area (Di BERNARDO et al. 2003)
https://www.monzatoday.it/cronaca/monza-alluvione-2002-brianza.html

Pichelli et al. (2021) DOI: 10.1007/s00382-021-05657-4
<table>
<thead>
<tr>
<th>Date</th>
<th>Region</th>
<th>Description</th>
<th>Impact</th>
<th>Main area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul. 2009</td>
<td>Austria Bavaria (South Germany)</td>
<td>Cold front inducing severe thunderstorms and hail; interaction between the convergence line and the foehn.</td>
<td>60 000 hectare arable lands devastated. Damages 15 Mln Euro.</td>
<td>South Germany 8-13.5E 47.5-50</td>
</tr>
<tr>
<td>23/07/07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Jun. 2009  | 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: 70 mm/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. | 13.1-16E 47.4-48.5/6N |
| 22-26/06/09|                                 |                                                                                                                                                                                                             |                                                                                                                                                  |                         |
| Sept. 2007 | 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 | 6 casualties. 60 over 210 municipalities were reporting flood, damages for 200 Mln Euro                                                                 | 13.8-14.5E 46-46.7N    |
| 18/09/07   |                                 |                                                                                                                                                                                                             |                                                                                                                                                  |                         |
| Aug. 2005  | 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-epression), 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           |
| 14-23/08/05|                                 |                                                                                                                                                                                                             |                                                                                                                                                  |                         |
| Nov. 2002  | 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    |
| 23-27/11/02|                                 |                                                                                                                                                                                                             |                                                                                                                                                  |                         |
| Sept. 2002 | 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         |
| 8-9/09/02  |                                 |                                                                                                                                                                                                             |                                                                                                                                                  |                         |
| Aug. 2002  | Southern and Eastern Europe Italy 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          |
| 5-13/08/02 |                                 |                                                                                                                                                                                                             |                                                                                                                                                  |                         |
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

![Map of flood event](image1)

![Graph of daily precipitation distribution](image2)

<table>
<thead>
<tr>
<th>Year</th>
<th>22NOV</th>
<th>23NOV</th>
<th>24NOV</th>
<th>25NOV</th>
<th>26NOV</th>
<th>27NOV</th>
<th>28NOV</th>
<th>29NOV</th>
<th>30NOV</th>
<th>MAX EVENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBS max</td>
<td>214.5</td>
<td>14.4</td>
<td>75.9</td>
<td>294.5</td>
<td>261.3</td>
<td>26.1</td>
<td>1.7</td>
<td>101.7</td>
<td>7.7</td>
<td>46.1-46.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.5-13.3</td>
</tr>
</tbody>
</table>

> 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

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

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

<table>
<thead>
<tr>
<th>ex</th>
<th>SON</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs</td>
<td>30</td>
<td>11</td>
<td>7</td>
<td>11</td>
</tr>
</tbody>
</table>

Method based on storm track

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

Mueller et al. (2023, their Table 1) https://doi.org/10.1007/s00382-023-06901-9
Driving conditions: mean large scale dynamical signature of the events

**ERAS5**

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

**Evaluation run**

- ICTP-RegCM4
- HCLIMcom-HCLIM38-AROME
- ETHZ-COSMO
- CNRM-AROME

**Historical run**
Driving conditions: mean large scale dynamical signature of the events

- **ERAS5**
  - mslp, ght500, ERA5 SON extremes

- **ENSEMBLE evaluation run**
  - mslp, ght500, ENSEMBLE evaluation SON extremes

- **ENSEMBLE historical run**
  - mslp, ght500, ENSEMBLE historical SON extremes

**Mean sea level pressure**
- hPa, contours

**500 hPa geopotential height**
- m, colors
Driving conditions: mean large scale dynamical signature of the events

Historical period

End of Century

Change

Mslp (hPa)
Ght (m)

Tas (C)
Driving conditions: mean large scale dynamical signature of the events

Historical period

End of Century

Change

PWV (mm)

Winds 850mb (m/s)
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