Statistical Downscaling of EURO-CORDEX climate change scenarios: Projections of droughts, heavy precipitation, heat waves and cold spells

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1. Motivations and objectives

Climate change: current evidences

- Global mean surface air temperature has risen by about 0.74°C (1906-2005)
- 11 of the 12 warmest years on record have occurred in the past 12 years
- Important regional variations
- Redistribution of rainfall and other variables

Extreme weather events

Summary for Policymakers (IPCC)
- cold days and nights (99%)
- hot days and nights (99%)
- frequent and/or intense heavy rainfall events (90%)
- Longer and/or more intense droughts (66%)
- hurricane activity (50%)
  (western north pacific and north atlantic)
Tools for exploring climate change impacts

- **GCMs → RCMs**

  - **Regional scales:** Dynamical downscaling. Regional Climate Models (RCMs)
  - **Local scales:** Statistical downscaling and model calibration from RCMs
Statistical downscaling of RCM outputs

OBS 1981-2005 → RCM calibrated 2025-2099

climate change signal

RCM 1981-2005 (control) ↔ changes ↔ RCM 2025-2099

Increase in mean temperature

Increase in variance of temperature

Increase in mean and variance of temperature

Probabilities of occurrence

Previous climate vs. New climate

Less change for cold weather

More record hot weather

Much more hot weather

More record cold weather

More hot weather

More cold weather
Statistical downscaling of RCM outputs: Quantile-Quantile adjustment (Amengual et al. 2012)

\[ p_i = o_i + g\Delta + f\Delta', \]

\[ \Delta_i = s_{fi} - s_{ci} \]

\[ \bar{\Delta} = \frac{\sum_{i=1}^{N} \Delta_i}{N} = \frac{\sum_{i=1}^{N} (s_{fi} - s_{ci})}{N} = \frac{S_f}{N} - \frac{S_c}{N} \]

\[ \Delta' = \Delta_i - \bar{\Delta} \]

\[ g = \frac{\left( \sum_{i=1}^{N} o_i \right) / N}{\left( \sum_{i=1}^{N} s_{ci} \right) / N} = \frac{O}{S_c} \]

\[ f = \frac{\sigma_O}{\sigma_{S_c}} = \frac{\text{IQR}_O}{\text{IQR}_{S_c}}. \]

\[ f = \frac{\sigma_{O'_{ci}}}{\sigma_{S_c'_{ci}}} \]
2. Database and methodology

**E-OBS gridded dataset (25 km)**

Validation task


**EURO-CORDEX (12,5 km)**

Future regional scenarios **rcp4.5** and **rcp8.5**
Climate change projections

Compute changes in calibrated CDFs between a 25-year past (i.e. control/observed; 1981-2005) and successive 25-year RCM time-slices (2021-2045; 2046-2070; 2071-2095)

Future regional scenario rcp4.5 and rcp8.5

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<tr>
<th>Driving GCM</th>
<th>RCM</th>
<th>Institute</th>
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Extreme weather events

1. Heat Waves
2. Cold Spells
3. Heavy precipitation
4. Droughts

We characterize their attributes with the following parameters:

• **Number of extreme events** that occur in a given time interval

• **Frequency**: the number of days under extreme conditions in a given time interval

• **Duration exceedance**: the total number of consecutive days exceeding the duration threshold for all events in a given time interval. It accounts for the whole amount of excess days.

• **Amplitude exceedance**: the accumulated stress exceedance for all the days under extreme conditions in a given time interval.
3. Results

3.1 Heat waves

- A spell lasting $d_{th} = 3$ or more consecutive days with *daily maximum temperature* above 95th percentile of observed daily maximum temperature in summer.

$$HWA = HWT - T_{th} \quad HWF$$

*Fig. 1. Graphical sketch of heat wave duration (HWD) and amplitude (HWA, gray shading) exceedances. $T_{th}$ and $d_{th}$ denote the thermal stress and duration thresholds, respectively.*
Events over P95 of daily maximum temperature

FUTURE CHANGE

SPRING

SUMMER

AUTUMN
HEAT WAVE AMPLITUDE

SUMMER

Future change (multi-model mean)

Std (future change multi-model)
Future change (multi-model mean)

SPRING

AUTUMN

Std (future change multi-model)

SPRING

AUTUMN
3. Results

3.2 Cold spells

- A spell lasting $d th = 3$ or more consecutive days with *daily minimum temperature* under 5$^{th}$ percentile of observed daily minimum temperature in winter.

- Future events under P5 of daily observed minimum temperature in winter.

- Cold Spell Amplitude (CSA)

$$CSA = T_{th} \cdot CSF - CST$$

$T_{th}$: thermal stress

CSF: cold spell frequency

CST: integral of the minimum daily temperatures over the duration of each individual cold spell, and accumulated for all cold spells in a given time interval.
P5 of daily minimum temperature (WINTER)

OBSERVED

EVENTS UNDER P5: Future change (multi-model mean)
COLD SPELL AMPLITUDE

WINTER

Future change (multi-model mean)

Std (future change multi-model)
3. Results

3.3 Heavy precipitation

- A spell lasting $dth = 2$ or more consecutive days with daily precipitation above 95th percentile of observed annual daily precipitation

- Future change in seasonal precipitation days.
- Future events over P95 of daily annual observed precipitation.
- Heavy Precipitation Amplitude (HPA)

$$HPA = HPT - Tth \ HPF$$
Seasonal precipitation days

FUTURE CHANGE (multi-model mean)
P95 of daily precipitation (ANNUAL)

EVENTS OVER P95: Future change (multi-model mean)

OBSERVED
HEAVY PRECIPITATION AMPLITUDE

ANNUAL

Future change (multi-model mean)

Std (future change multi-model)
3. Results

3.4 Droughts

- A spell lasting \( dth = 3 \) or more consecutive days with daily precipitation \( \leq 0.1 \) mm

- P95 of observed annual drought duration

- Number of future events with a duration over P95 of observed drought duration
NUMBER OF DROUGHTS

ANNUAL

Future change (multi-model mean)

Std (future change multi-model)
Aknowledgments:

EXTREMO
CGL2014-52199-R (AEI/FEDER, UE) MINECO (Spain)
FPI-CAIB (Conselleria d’Innovació, Recerca i Turisme del Govern de les Illes Balears and the Fons Social Europeu)
