Downscaling of future scenarios of temperature and precipitation across Europe based on quantile-quantile corrections of EURO-CORDEX projections

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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

Less cold weather

More hot weather

Increase in variance of temperature

More cold weather

More record cold weather

More hot weather

More record hot weather

Increase in mean and variance of temperature

Less change for cold weather

Much more hot weather

More record hot weather
Statistical downscaling of RCM outputs: Quantile-Quantile adjustment (Amengual et al. 2011)

\[ p_i = o_i + g\bar{\Delta} + f\Delta_i', \]

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

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

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

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

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

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

- Validation task

- Calibration task
  1. Compute changes in CDFs for periods including 1956-1980 and successive 21-year periods. Shifts are corrected and transferred to the observed CDFs for the control period.

<table>
<thead>
<tr>
<th>Driving GCM</th>
<th>RCM</th>
<th>Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPI-ESM-LR</td>
<td>CCLM4-8-17</td>
<td>CLMcom</td>
</tr>
<tr>
<td>HadGEM2-ES</td>
<td>CCLM4-8-17</td>
<td>CLMcom</td>
</tr>
<tr>
<td>CNRM-CM5-LR</td>
<td>CCLM4-8-17</td>
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<td>EC-EARTH</td>
<td>CCLM4-8-17</td>
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<tr>
<td>EC-EARTH</td>
<td>RACMO22E</td>
<td>KNMI</td>
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<td>HadGEM2-ES</td>
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<tr>
<td>EC-EARTH</td>
<td>HIRHAM5</td>
<td>DMI</td>
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<tr>
<td>NorESM1-M</td>
<td>HIRHAM5</td>
<td>DMI</td>
</tr>
<tr>
<td>CNRM-CM5</td>
<td>ALADIN53</td>
<td>CNRM</td>
</tr>
</tbody>
</table>
2. Database and methodology

- Validation task
  
  Perkins skill score (PSS) (*Perkins et al. 2007*)

  - Dataset and methodology
    - Minimum temperature (ºC)
      - OBS (1956-80)
        - PSS = 92.13%
      - Local (1956-80)
        - PSS = 94.07%
      - Global (1956-80)
        - PSS = 87.85%
      - Raw (1956-80)
        - PSS = 87.85%

  ![Graph showing minimum temperature distribution with PDF](image)

  - Graph title: PDF
  - X-axis: Minimum temperature (ºC)
  - Y-axis: Frequency
  - Legend:
    - OBS (1956-80)
    - Raw (1956-80)
3. Results

- PSS of the whole PDF for annual precipitation

HIRHAM5

Global: 85.54%
Raw: 85.60%
Local: 85.55%
3. Results

- PSS over $P_{99}$ for annual precipitation

HIRHAM5

52.63%

Global

70.79%

Local

74.03%
3. Results

- PSS of the whole PDF for annual precipitation

ENSEMBLE

- Raw 86.29 %
- Local 86.10 %
- Global 86.14 %
3. Results

- PSS over $P_{99}$ for annual precipitation

**ENSEMBLE**

- Raw: 63.99%
- Local: 74.29%
- Global: 71.87%
3. Results

- PSS under $P_5$ for minimum temperature in winter

**ENSEMBLE**

- Raw: 49.17%
- Local: 67.07%
- Global: 66.14%
3. Results

- PSS over $P_{95}$ for minimum temperature in winter

**ENSEMBLE**

- Raw
  - 46.64%
- Local
  - 71.20%
- Global
  - 70.23%
3. Results

- PSS under $P_1$ for maximum temperature in summer
3. Results

- PSS over $P_{99}$ for maximum temperature in summer

**ENSEMBLE**

- **Raw**: 24.03%
- **Local**: 52.67%
- **Global**: 51.27%
### Annual PSS (%) whole PDF

<table>
<thead>
<tr>
<th>Variable</th>
<th>Raw</th>
<th>Global</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr</td>
<td>86,29</td>
<td>86,14</td>
<td>86,10</td>
</tr>
</tbody>
</table>

### PSS(%) over P<sub>99</sub>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Raw</th>
<th>Global</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr</td>
<td>63,99</td>
<td>71,87</td>
<td>74,29</td>
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</tbody>
</table>

### Winter

<table>
<thead>
<tr>
<th>Variable</th>
<th>PSS (%) under P&lt;sub&gt;5&lt;/sub&gt;</th>
<th>PSS (%) over P&lt;sub&gt;95&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw</td>
<td>Global</td>
</tr>
<tr>
<td>Tmin</td>
<td>49,17</td>
<td>66,14</td>
</tr>
</tbody>
</table>

### Summer

<table>
<thead>
<tr>
<th>Variable</th>
<th>PSS(%) under P&lt;sub&gt;1&lt;/sub&gt;</th>
<th>PSS (%) over P&lt;sub&gt;99&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw</td>
<td>Global</td>
</tr>
<tr>
<td>Tmax</td>
<td>36,03</td>
<td>57,57</td>
</tr>
</tbody>
</table>
5. Future work

1. Build a better annual calibration from seasonal calibration
2. Validate the method picking up even years for the training period and odd years for the calibration period in order to avoid the effects of climate change
3. Calibration task
4. Obtain results on future annual and seasonal temperatures and precipitation changes (both means and extremes)
5. These future scenarios will be used to feed the different impact studies/models.