Selecting regional climate scenarios for impact modelling studies

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Motivation

Climate model output data are applied within climate impact studies.
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Climate model output data are applied within climate impact studies

Common issue: Climate model ensemble is bigger than what can/want/will be used by impact modellers
Idea

See also poster of **Thomas Mendlik: Wednesday Y85, 17.30-19.00, Session CL5.5**
Ensemble reduction in five steps.

1. Identify user requirements (variables, seasons, regions).
2. Transform variables into uncorrelated (orthogonal) variables.
3. Calculate the optimum number of clusters.
4. Use hierarchical clustering to group the simulations.
5. Select the simulation closest to the group’s mean as representative.
Selection process – sketch

- Matrix A
- SVD
- Uncorrelated variables
- K for tree-cutting
- Silhouette values
- Hierarchical clustering
- Clusters
- Final selection

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Selection process – SVD

SVD

uncorrelated variables

k for tree-cutting

silhouette values

hierarchical clustering

clusters

final selection

matrix A

RCM

CORDEX

BCM

MIROC

GCM

HadGEM

RegCM

CCLM

WRF

EC-EARTH

ALADIN

HRES

MPI-ESM

beaufort days

precipitation

temperature

degree days

frost days

SON

seasons regions

DJF

wind speed

heat days

MAM

indices

JJA

day

wet days

relative humidity

precip

RCM
SVD

- Uncorrelate and reduce variables without loosing information.
- Transform to orthogonal vector space.

- Standardized data matrix $A = \{a_{ij}\}$ with $m$ models and $n$ variables.

$$a_{ij} = \text{CCS} \left( \langle \text{sim}_i(\phi_j) \rangle \right), \ i \in [1, m], \ j \in [1, n]$$

E.g. $a_{ij}$ can be the CCS of temperature from one simulation averaged over Austria and averaged over summer months.
Selection process – How many simulations to select?

matrix A

SVD

uncorrelated variables

silhouette values

hierarchical clustering

clusters

k for tree-cutting

final selection

cluster means

tree-cutting
Optimum size of subset

- Silhouettes (Rousseeuw, 1987): distance measure (point to all other points in different clusters).
- Testing for different number of clusters
- Quantity of interest: highest average silhouette value

Selection process – Hierarchical clustering

matrix A

uncorrelated variables

k for tree-cutting

silhouette values

hierarchical clustering

clusters

tree-cutting

final selection

SVD

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Hierarchical clustering

- Applied to euclidean distances between PCs
- Bottom-up, starting with $m$ clusters
- Clusters built by minimizing distances
- Distance representing similarity
Selection process – Selection

matrix A

SVD

uncorrelated variables

k for tree-cutting

silhouette values

hierarchical clustering

clusters

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cluster means

tree-cutting
**Selection from clusters**

- Cluster represents group distinct from the others.
- Multidimensional **means** represent clusters.
- Selection: Simulations closest to cluster means.
- Clusters with only 2 members: arbitrary choice.

![Diagram showing clustering of regional climate scenarios](image)
### Ingredients for variables

<table>
<thead>
<tr>
<th>( \phi )</th>
<th>seasons</th>
<th>regions</th>
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</thead>
<tbody>
<tr>
<td>mean temperature</td>
<td>winter</td>
<td>region 1</td>
</tr>
<tr>
<td>min temperature</td>
<td>spring</td>
<td>region 2</td>
</tr>
<tr>
<td>max temperature</td>
<td>summer</td>
<td>region 3</td>
</tr>
<tr>
<td>precipitation</td>
<td>autumn</td>
<td>region 4</td>
</tr>
<tr>
<td>rel. humidity</td>
<td>annual</td>
<td>region 5</td>
</tr>
<tr>
<td>wind speed</td>
<td></td>
<td>region 6</td>
</tr>
<tr>
<td>beetle degree day exceeding threshold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>frost days</td>
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<td></td>
</tr>
<tr>
<td>wet day frequency</td>
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<tr>
<td>Beaufort day</td>
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</tbody>
</table>
Example study

- CCS: 2069–2098 vs. 1971–2000,
- 6 regions Northern Europe,
- 4 seasons

Example 1:
- temperature (tas) & 2 indices,
- precipitation (pr) & 1 index

Example 2:
- relative humidity (hurs),
- precipitation (pr) & 1 index
Example study

Example 1 (tas, pr, ind)

Example 2 (hurs, pr, ind)

Average silhouette value vs. clusters for different principal components (PCs).

- **3 PCs (74%)** for Example 1.
- **4 PCs (74%)** for Example 2.

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Example study

Example 1 (tas, pr, ind)

Example 2 (hurs, pr, ind)

Selecting regional climate scenarios
Example study

Example 1 (tas, pr, ind)

Example 2 (hurs, pr, ind)

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Results

- Many combinations of variables analysed.
- 3 CCS periods analysed (separately).

- High sensitivity to choice of variable.
- CCS of temperature is dominating clustering.
- Temperature dominates NOT final selection.
- Experiments without temperature sensitive to indices.
- Influence of CCS of clim. indices stronger at end of century.
- Sensitivity to choice of period.
Effect of bias adjustment – outlook

- bias adjusted mean temperature (quantile mapping)
- 6 temperature threshold indices (degree days)
- Rockel boxes, CCS: 2069–2098
Summary

- Sensitivity to input information (variables, region, ...).
- Importance for application.
- Sensitivity to bias adjustment → relate to impact study?
- Method reduces an ensemble if needed.
- No statement about the quality of the simulations.

Outlook

- Ongoing: evaluation and application within different climate impact studies with bias adjusted data.
- Information about single periods (non CCS) will be included.
- Inter-variable relation: Use of multi-variate indices.
Set-up – simulations

Table: 11 GCM-RCM combinations from EURO-CORDEX RCP8.5 on 0.44° grid.

<table>
<thead>
<tr>
<th>GCM</th>
<th>RCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CanESM2</td>
<td>SMHI-RCA4</td>
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<tr>
<td>CERFACS CNRM CM5</td>
<td>SMHI-RCA4</td>
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<tr>
<td>IPSL CM5A MR</td>
<td>SMHI-RCA4</td>
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<tr>
<td>MIROC5</td>
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