ExSamples: generating samples of extreme winters to support climate adaptation

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Thank you to Myles Allen for help setting up the project.
To Alex Chamberlain-Clay and Kathryn Lock for putting the data on JASMIN and updating the data web page.
To Zorica Jones for her good advice, and to Jason Lowe for helpful comments. And of course, all the volunteers!!!
What’s this talk about?

I. Design
II. Results
III. Conclusion

- Very large single-winter ensembles
- Sample uncertainty of extremes
- Provide multi-variable spatio-temporally & physically coherent extreme samples
Study design

- UKCP18 future (2061-2080)
- 3 extreme winters
- SST / sea ice conditions for AGCM
- CPDN distributed computing
- Target ~1500 members
- + AGCM present-day baseline
<table>
<thead>
<tr>
<th>Models</th>
<th>ExSamples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>UKCP18 Global (land strand 2)</td>
</tr>
<tr>
<td>Name</td>
<td>HadGEM-GC3.05</td>
</tr>
<tr>
<td>Horizontal resolution</td>
<td>N216 (5/6° zonal and 5/9° meridional) 60 km</td>
</tr>
<tr>
<td>Vertical levels</td>
<td>85</td>
</tr>
<tr>
<td>Ocean</td>
<td>NEMO3.6 @ ORCA025Z75</td>
</tr>
<tr>
<td>Ensemble</td>
<td>15 members x 200 years (1899-2099)</td>
</tr>
<tr>
<td>Computation</td>
<td>Supercomputer</td>
</tr>
</tbody>
</table>


Design motivation

- Uncertainties surrounding sampling of extreme in UKCP18

- Extremes arise from:
  - Anthropogenic forced trend
  - Internal variability
    - Ocean
    - Atmosphere

- We select extreme deviations
- Sample atmospheric internal variability
<table>
<thead>
<tr>
<th>Boundary condition (study winter) info</th>
<th>Abbreviation used</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKCP18 member</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td></td>
</tr>
<tr>
<td>Extreme type</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Future projections</td>
<td></td>
</tr>
<tr>
<td>02868</td>
<td>HOT1</td>
</tr>
<tr>
<td>Year 2066</td>
<td>HOT</td>
</tr>
<tr>
<td>01554</td>
<td>HOT2</td>
</tr>
<tr>
<td>Year 2072</td>
<td>HOT</td>
</tr>
<tr>
<td>02242</td>
<td>WET1</td>
</tr>
<tr>
<td>Year 2068</td>
<td>WET</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>Baseline ensembles</td>
<td></td>
</tr>
<tr>
<td>02868</td>
<td>HOT1-B</td>
</tr>
<tr>
<td>Year 2007-2016</td>
<td>-</td>
</tr>
<tr>
<td>01554</td>
<td>HOT2-B</td>
</tr>
<tr>
<td>Year 2007-2016</td>
<td>-</td>
</tr>
<tr>
<td>02242</td>
<td>WET1-B</td>
</tr>
<tr>
<td>Year 2007-2016</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table 1: Summary of experiments performed for ExSamples project.*
Selecting three extreme winters: synoptics
HOT1 winter

- Step-by-step through figure
- Mainly internal variability
  - Dark orange line panel C
HOT2 winter

- Strongly conditioned
WET winter

- Strongly conditioned

RESULTS
<table>
<thead>
<tr>
<th>Study winter</th>
<th>Variable</th>
<th>UKCP18 quantile (return period)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.9 (1-in-10 year)</td>
</tr>
<tr>
<td>HOT1</td>
<td>TXm</td>
<td>0.9 [0.86 , 0.96]</td>
</tr>
<tr>
<td></td>
<td>PRm</td>
<td>1.02 [0.95 , 1.08]</td>
</tr>
<tr>
<td>HOT2</td>
<td>TXm</td>
<td>4.25 [3.95 , 4.64]</td>
</tr>
<tr>
<td>WET1</td>
<td>TXm</td>
<td>3.75 [3.61 , 4.06]</td>
</tr>
</tbody>
</table>

*Table 2*: Relative risk of three extreme thresholds in ExSamples future ensembles compared to UKCP18 PPE 2061-2080 deviations. Square brackets indicate a 90% CI.
“Record-shattering” scenarios

- Sample exceptional weather events also
- Considerably higher than anything in UKCP
- February 2019 link
- Use case: **High Impact Low Likelihood**
Summary

- Proof-of-concept using **distributed computing**
- Generated **3x ~1250 member ensembles** sampling internal variability about UKCP extremes
- 2 SST conditioned, 1 not
- Many samples of **physically coherent extremes**
- Return periods of beyond 1000 years, some ~10,000 years
  - ~500 member UKCP18 PPE
Discussion & future work

● Use cases:
  ○ **Impact** studies
  ○ **H++ / HILL** scenarios
  ○ **Validation** of other approaches

● Future work:
  ○ **Which SSTs?**
  ○ **Downscaling**
    ▪ Statistical
    ▪ Dynamical

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Thanks very much listening!

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more info here...
How to access the data

- Papers:
  - Science paper Leach et al (in revision)
  - Data paper Sparrow et al (in preparation)
- Data and guidance (see https://www.ukclimateresilience.org/resources/data/) available at
  - /gws/pw/j05/climateresilience/data/final_outputs/exsamples/full
    - ~1200-1300 members
    - UK and North Atlantic sectors
  - /gws/pw/j05/climateresilience/data/final_outputs/exsamples/published
    - ~1000 members per winter as used in Leach et al.
    - UK only
  - Plan to place this on CEDA
- Guidance
  - Useful advice on making anomalies
  - Different number of members per variable due to quality checking
- Data can be used but until either of papers has been published, any analysis using the data should be seen as exploratory.
User guidance and feedback

- Large number of physically, spatially, temporally, multi-variable examples of future extreme winters.
- So useful for impacts that hit multiple sectors as well as single impact studies.
- Some examples of very high return levels. Note conditioning on the ocean state means cannot be used in isolation to quantify risk.
- It is not 2.2km resolution so ExSamples does not capture the detail like UKCP Local projections. We used percentage precipitation change in this study.
- It would be helpful to have any user feedback on the value of this proof-of-concept product.
Appendix 1: baseline comparison

- negligible mean bias
- prm mean bias of ~ 20 % (0.6 mm day\(^{-1}\))
- negligible prx mean bias
Appendix 2: dynamical comparison

- very similar EOF distributions
- prm bias likely NOT due to large scale dynamical differences...
- ... which is a good thing
Appendix 3: winter analog frequency

- baseline = black line
- increased analog frequency for HOT2 & WET, reduced for HOT1
- consistent with canonical ENSO / NAO teleconnection?