UNIVERSITY OF OXFORD

DEPARTMENT OF ENGINEERING SCIENCE

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!!!

climateprediction.net

Met Office

University of BRISTOL

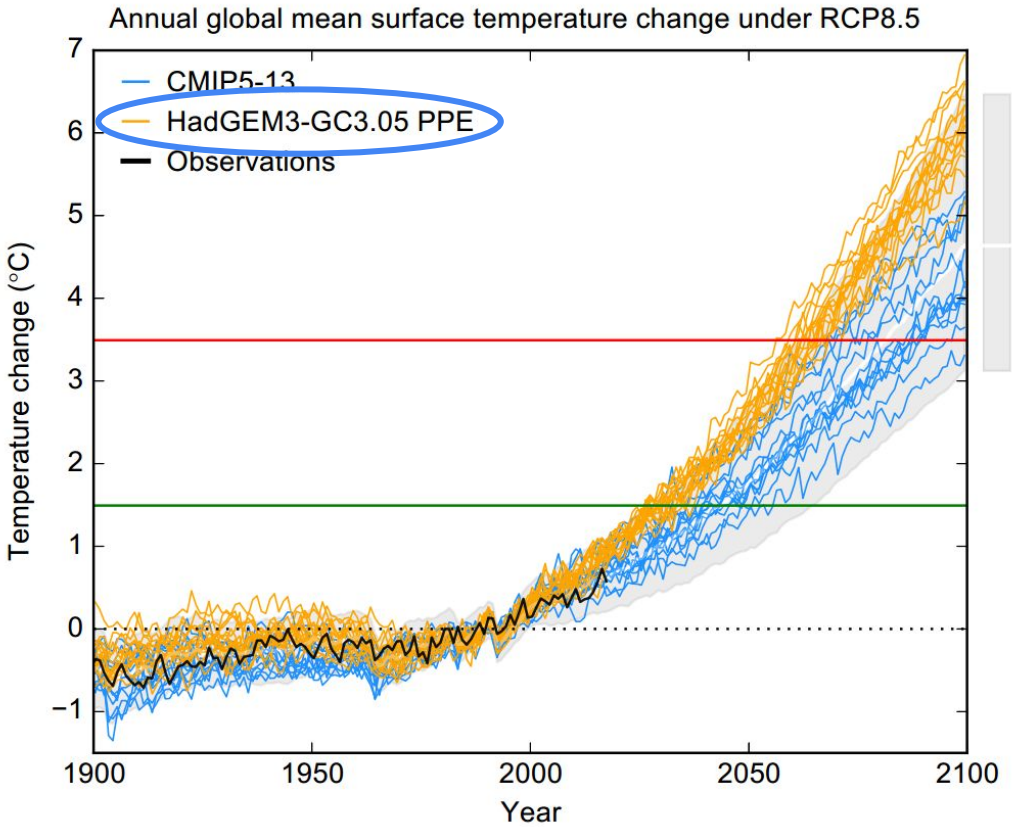
What’s this talk about?

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



Lowe, J. A., Bernie, D., Bett, P., Bricheno, L., Brown, S., Calvert, D., Clark, R., Eagle, K., Edwards, T., Fosser, G., Fung, F., Gohar, L., Good, P., Gregory, J., Harris, G., Howard, T., Kaye, N., Kendon, E., Krijnen, J., … Belcher, S. (2018). UKCP18 Science Overview Report. Met Office Hadley Centre. https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf

Models

Project	UKCP18 Global (land strand 2)	ExSamples
Name	HadGEM-GC3.05	HadAM4
Horizontal resolution	**N216** (5/6° zonal and 5/9° meridional) 60 km	**N216**
Vertical levels	85	38
Ocean	NEMO3.6 @ ORCA025Z75	Prescribed SST
Ensemble	15 members x 200 years (1899-2099)	~1500 members x 3 future winters ~500 members x 3 baseline winters
Computation	Supercomputer	CPDN **distributed**

Bevacqua, E., Shepherd, T. G., Watson, P. A. G., Sparrow, S., Wallom, D., & Mitchell, D. (2021). Larger Spatial Footprint of Wintertime Total Precipitation Extremes in a Warmer Climate. Geophysical Research Letters, 48(8), e2020GL091990. https://doi.org/10.1029/2020GL091990
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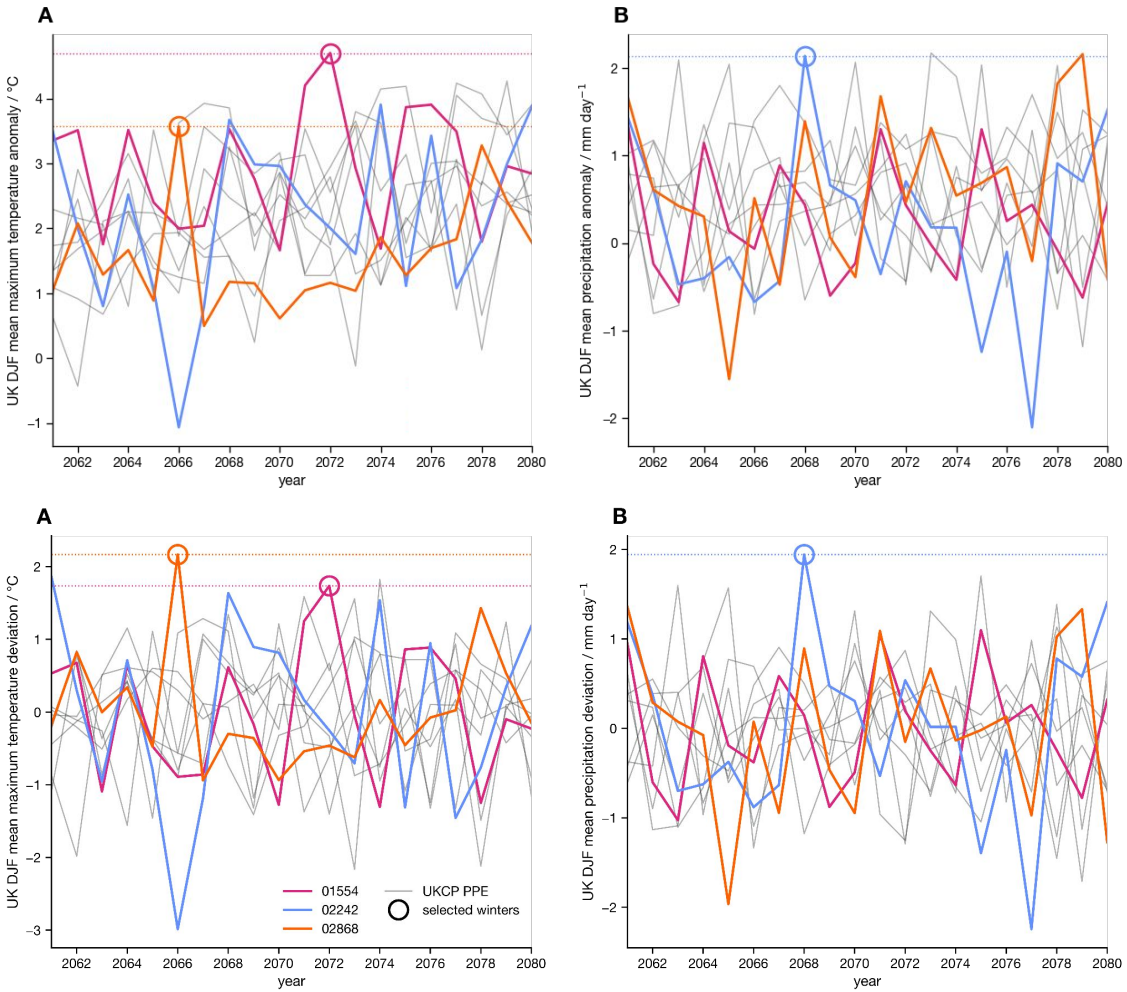
Williams, K. D., Copsey, D., Blockley, E. W., Bodas-Salcedo, A., Calvert, D., Comer, R., Davis, P., Graham, T., Hewitt, H. T., Hill, R., Hyder, P., Ineson, S., Johns, T. C., Keen, A. B., Lee, R. W., Megann, A., Milton, S. F., Rae, J. G. L., Roberts, M. J., … Xavier, P. K. (2018). The Met Office Global Coupled Model 3.0 and 3.1 (GC3.0 and GC3.1) Configurations. Journal of Advances in Modeling Earth Systems, 10(2), 357–380. https://doi.org/10.1002/2017MS001115

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**

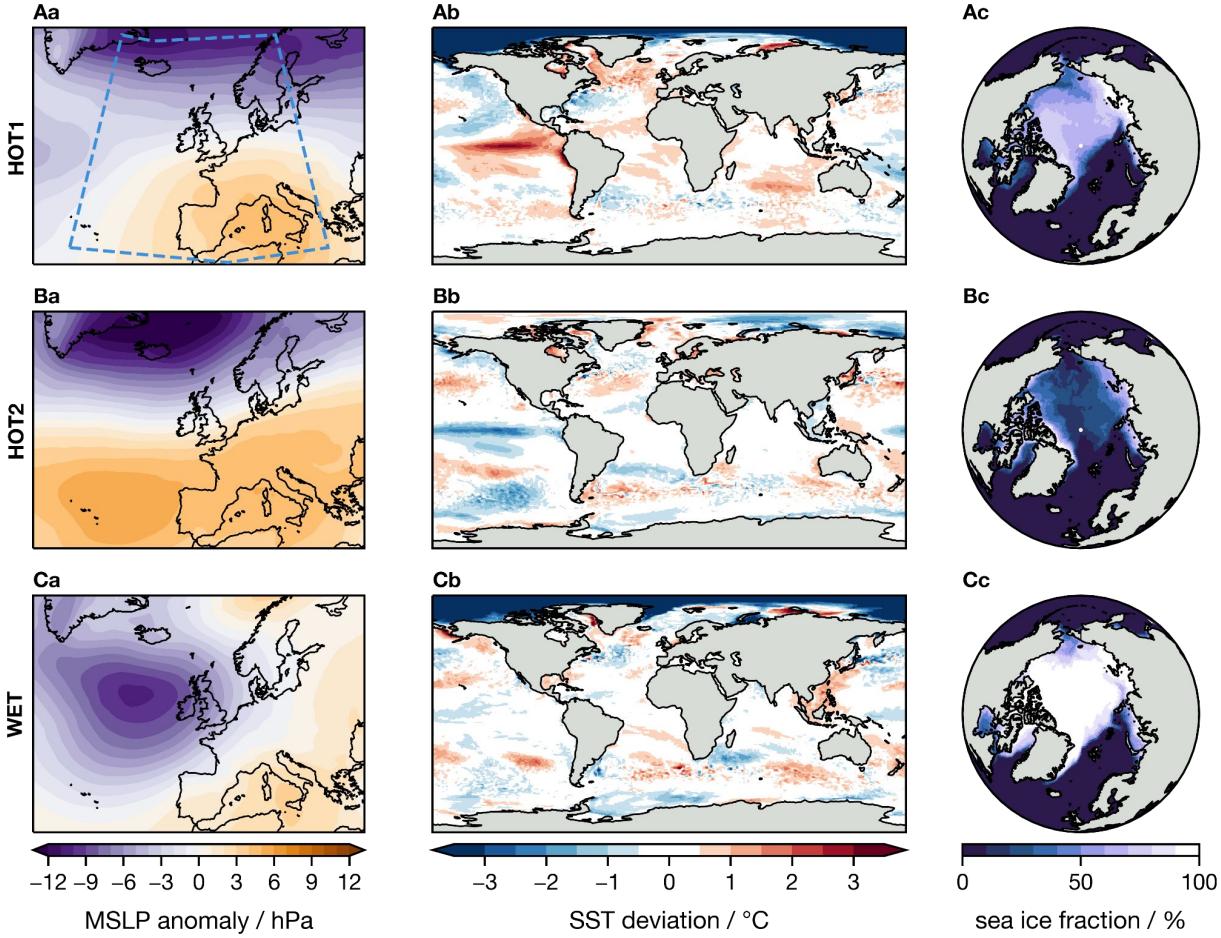


Ensembles overview

	Boundary condition (study winter) info			Abbreviation used
	UKCP18 member	Year	Extreme type	
Future projections	02868	2066	HOT	HOT1
	01554	2072	HOT	HOT2
	02242	2068	WET	WET1
Baseline ensembles	02868	2007-2016	-	HOT1-B
	01554	2007-2016	-	HOT2-B
	02242	2007-2016	-	WET1-B

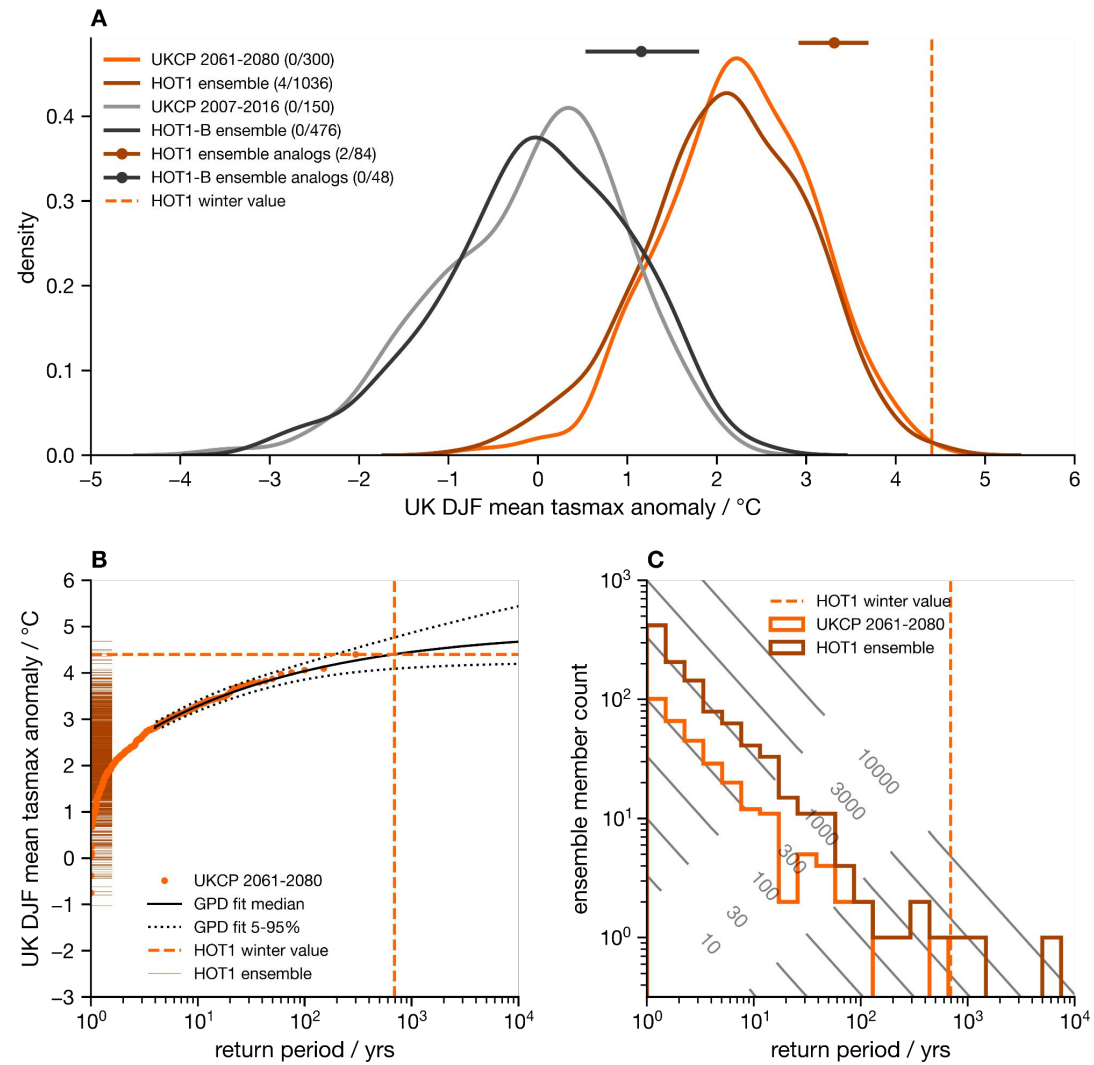
Table 1: Summary of experiments performed for ExSamples project.

Selecting three extreme winters: synoptics



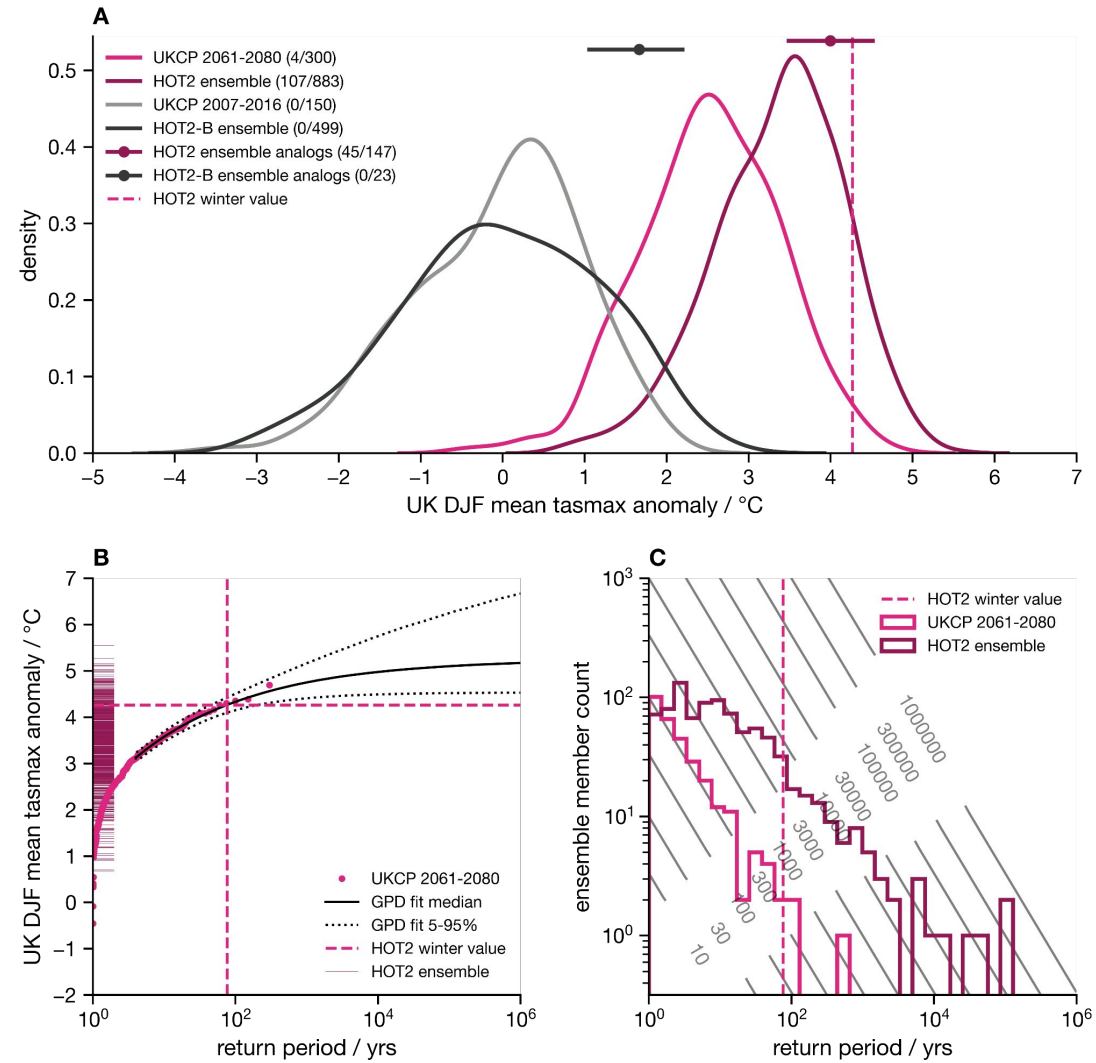
HOT1 winter

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



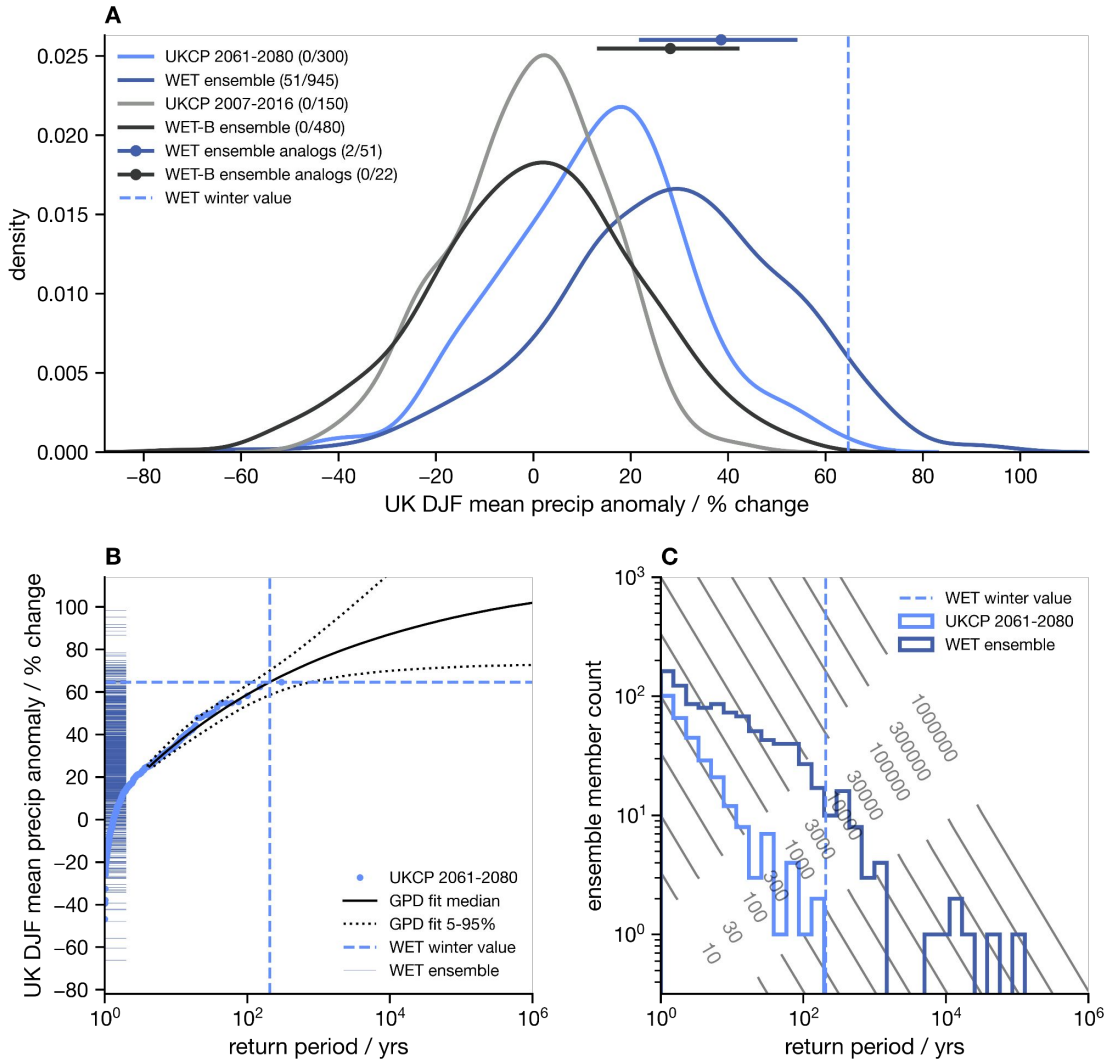
HOT2 winter

- **Strongly conditioned**



WET winter

- **Strongly conditioned**



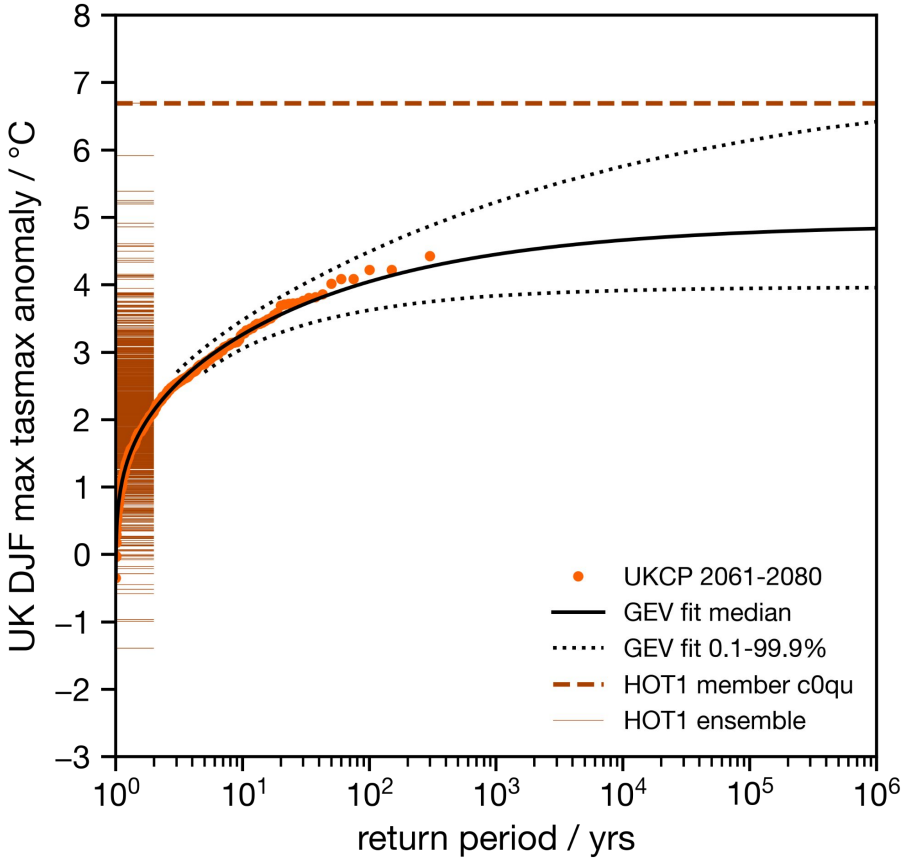
Results: quantitative

		UKCP18 quantile (return period)		
Study winter	**Variable**	0.9 (1-in-10 year)	0.95 (1-in-20)	0.99 (1-in-100)
HOT1	TXm	0.9 [0.86 , 0.96]	0.84 [0.77 , 0.97]	0.97 [0.75 , 2.32]
	PRm	1.02 [0.95 , 1.08]	0.98 [0.85 , 1.03]	2.03 [1.0 , 3.78]
HOT2	TXm	4.25 [3.95 , 4.64]	5.71 [4.97 , 6.05]	9.97 [7.34 , 24.8]
	PRm	2.93 [2.5 , 3.22]	3.6 [3.17 , 3.81]	10.08 [4.5 , 16.19]
WET1	TXm	3.75 [3.61 , 4.06]	4.3 [3.67 , 4.7]	5.02 [3.53 , 10.14]
	PRm	3.96 [3.42 , 4.22]	4.7 [4.22 , 4.94]	11.75 [6.17 , 17.14]

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**

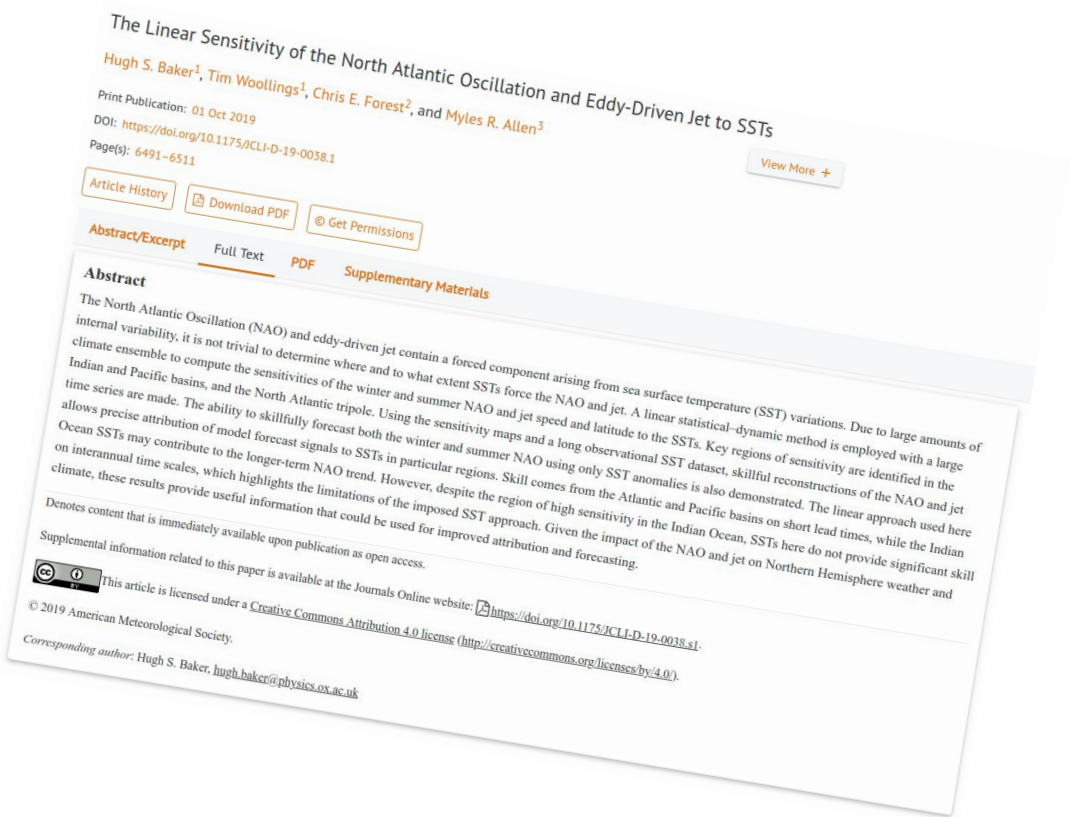


Summary

- 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



The Linear Sensitivity of the North Atlantic Oscillation and Eddy-Driven Jet to SSTs

Hugh S. Baker[1], Tim Woollings[1], Chris E. Forest[2], and Myles R. Allen[3]

Print Publication: 01 Oct 2019

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Page(s): 6491–6511

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Abstract

The North Atlantic Oscillation (NAO) and eddy-driven jet contain a forced component arising from sea surface temperature (SST) variations. Due to large amounts of internal variability, it is not trivial to determine where and to what extent SSTs force the NAO and jet. A linear statistical–dynamic method is employed with a large climate ensemble to compute the sensitivities of the winter and summer NAO and jet speed and latitude to the SSTs. Key regions of sensitivity are identified in the Indian and Pacific basins, and the North Atlantic tripole. Using the sensitivity maps and a long observational SST dataset, skillful reconstructions of the NAO and jet time series are made. The ability to skillfully forecast both the winter and summer NAO using only SST anomalies is also demonstrated. The linear approach used here allows precise attribution of model forecast signals to SSTs in particular regions. Skill comes from the Atlantic and Pacific basins on short lead times, while the Indian Ocean SSTs may contribute to the longer-term NAO trend. However, despite the region of high sensitivity in the Indian Ocean, SSTs here do not provide significant skill on interannual time scales, which highlights the limitations of the imposed SST approach. Given the impact of the NAO and jet on Northern Hemisphere weather and climate, these results provide useful information that could be used for improved attribution and forecasting.

Denotes content that is immediately available upon publication as open access.

Supplemental information related to this paper is available at the Journals Online website: https://doi.org/10.1175/JCLI-D-19-0038.s1.

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Baker, H. S., Woollings, T., Forest, C. E., & Allen, M. R. (2019). The Linear Sensitivity of the North Atlantic Oscillation and Eddy-Driven Jet to SSTs. Journal of Climate, 32(19), 6491–6511. https://doi.org/10.1175/JCLI-D-19-0038.1

Thanks very much listening!

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more info here...

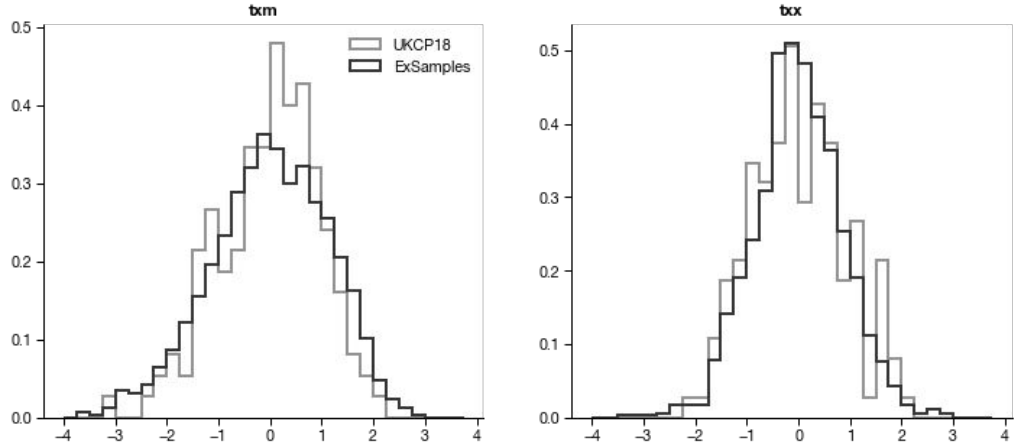
How to access the data

- 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

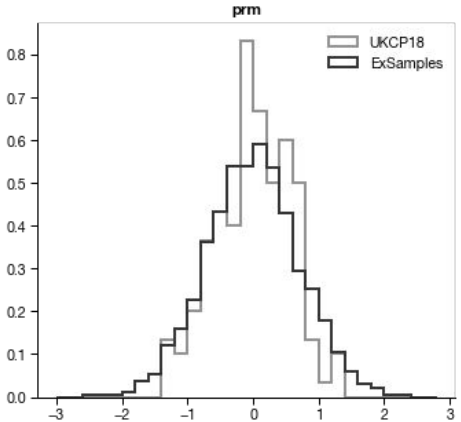
- Large number of physically, spatially, temporally, multi-variable examples of future extreme winters.
- So useful for impacts that hit multiple sectors as well as single impact studies.
- Some examples of very high return levels. Note conditioning on the ocean state means cannot be used in isolation 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.

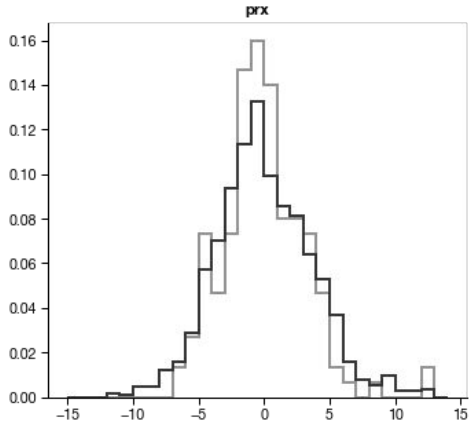
Appendix 1: baseline comparison



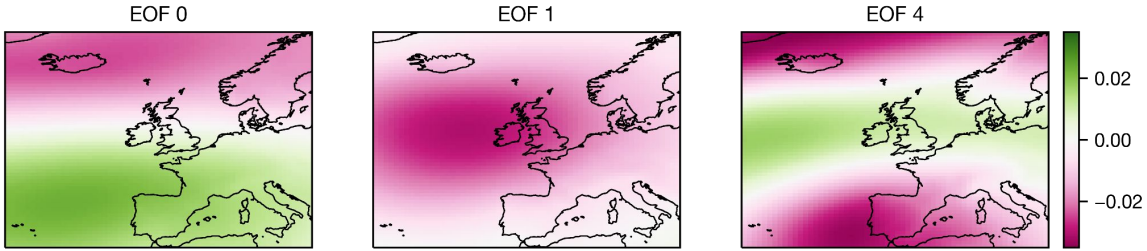
- negligible mean bias

- prm mean bias of ~ 20 % (0.6 mm day^{-1})
- negligible prx mean bias



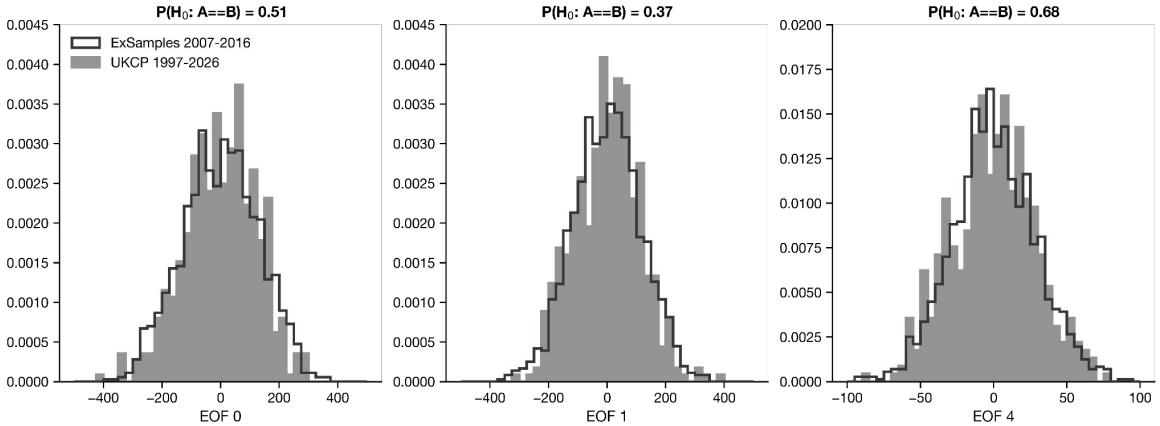


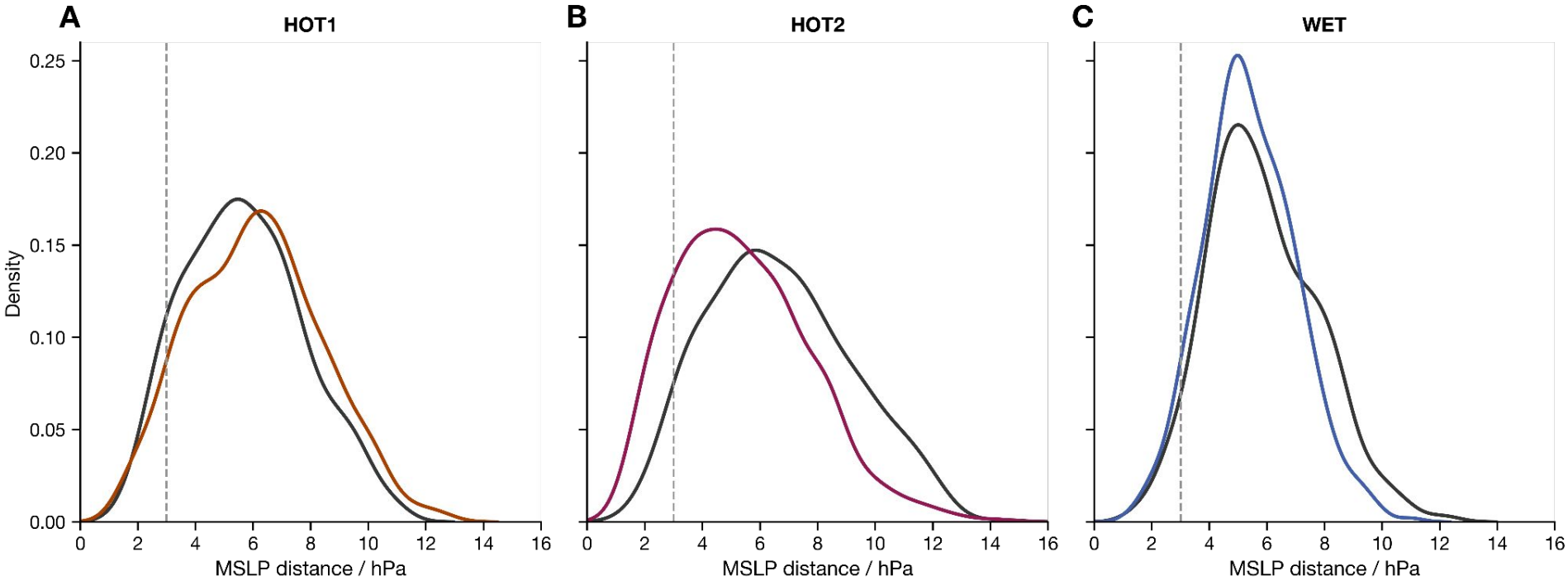
Appendix 2: dynamical comparison



- key mslp EOFs
- 43 / 33 / 2.3 % explained
- 71 % prm explained

- 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?