Simulating spatially coherent widespread flood events for risk modelling in the UK

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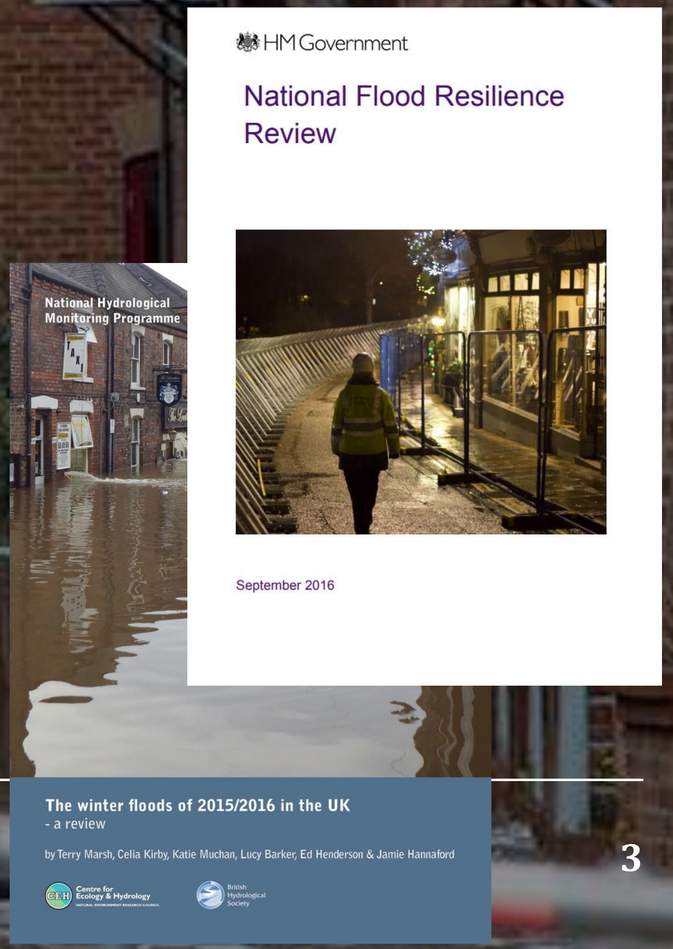
Outline of Presentation

- Widespread flooding in the UK
- The AquaCAT Project
- Hydrological modelling using UKCP18 data and the G2G model
- Bias Correction Analysis
- Rare event simulation using Heffernan-Tawn and Empirical Copulas
- Key initial findings

Widespread Flood Events

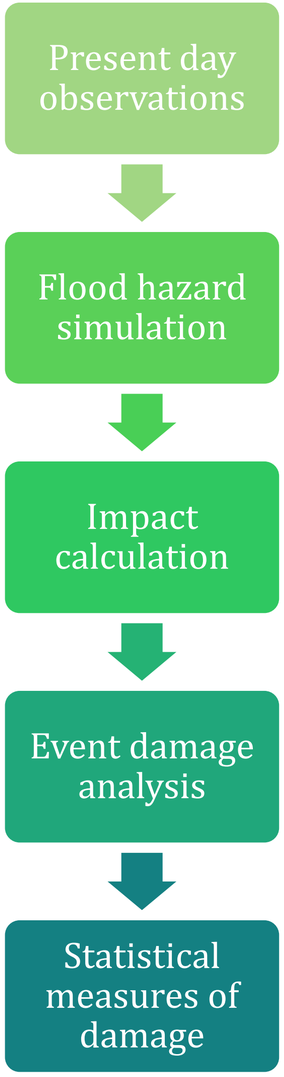
Real floods are spatially coherent. An event-based understanding is commonplace within the insurance and financial sectors to understand risks, but public sector understanding of risk often ignores spatial correlations despite research on present day widespread events (Lamb *et al.*, 2017).

Flood events often cover a wide spatial area, yet some methods of flood risk quantification use at-site flood descriptions, rather than spatial characteristics. This project investigates the characteristics of widespread rare flood events.

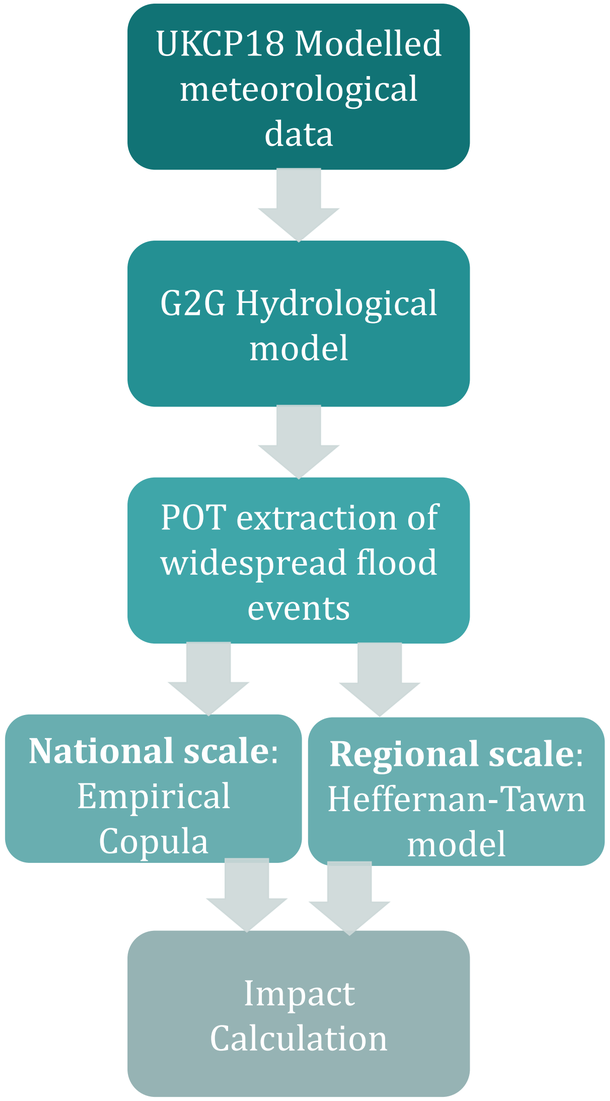


AquaCAT

One aim of this project was to understand the spatial coherence of flood events and how it may change in the future. This led to improving on standard catastrophe modelling (CAT modelling) frameworks for national risk assessment, making use of the Future Flood Explorer (Sayers et al., 2015) as an efficient UK-scale risk analysis.
UKCP18 climate data was used within a gridded hydrological model (Grid-to-Grid) to model likely flood patterns in the present and the future.
Multivariate statistical methods were used to simulate a wider spread of possible events from the same conditions.



Typical CAT modelling framework



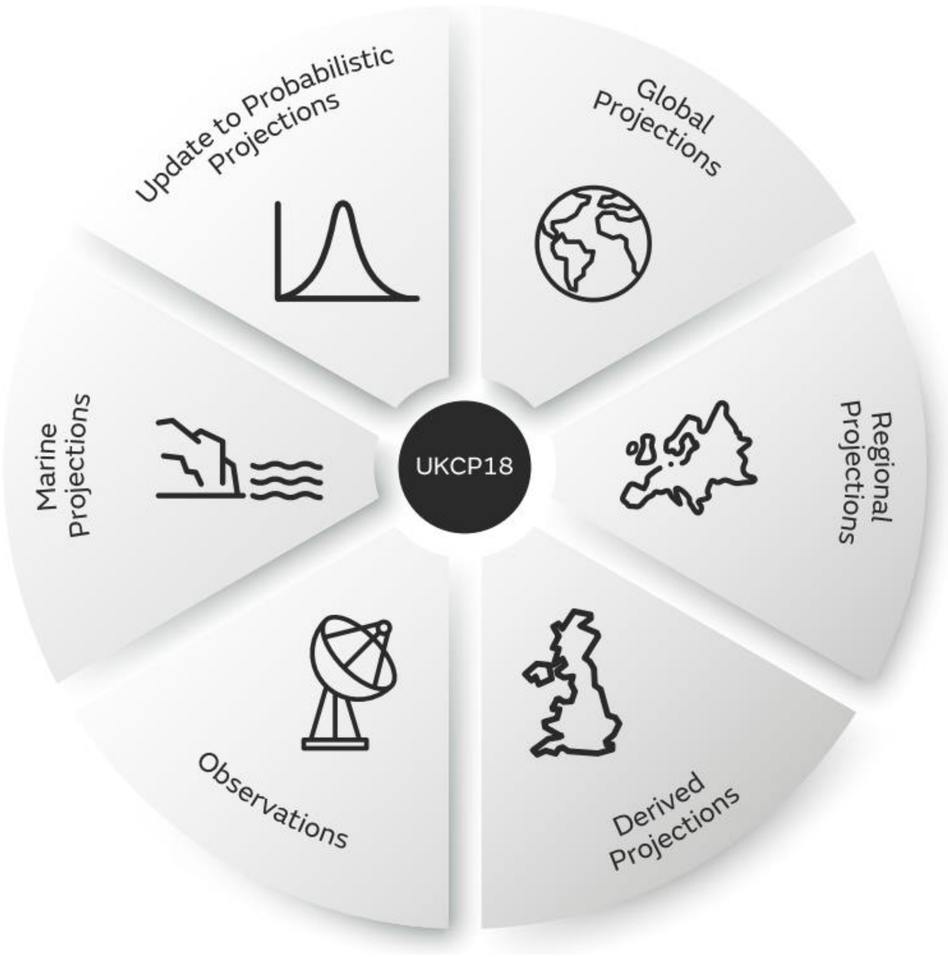
Widespread future event simulation pipeline

UKCP18

A hydrological model was driven by data from the UKCP18 Regional projections, which use the Met Office Hadley Centre RCM (Lowe *et al.*, 2018).

- 12km daily-timestep data modelled for 12 ensemble members.
- Present and future time slices (1980-2010, 2050-2080)
- Each ensemble member uses a unique set of perturbed parameters.
- Based on RCP8.5 projections.
- Gives spatially consistent driving data, balances performance for mean flows, floods and droughts.

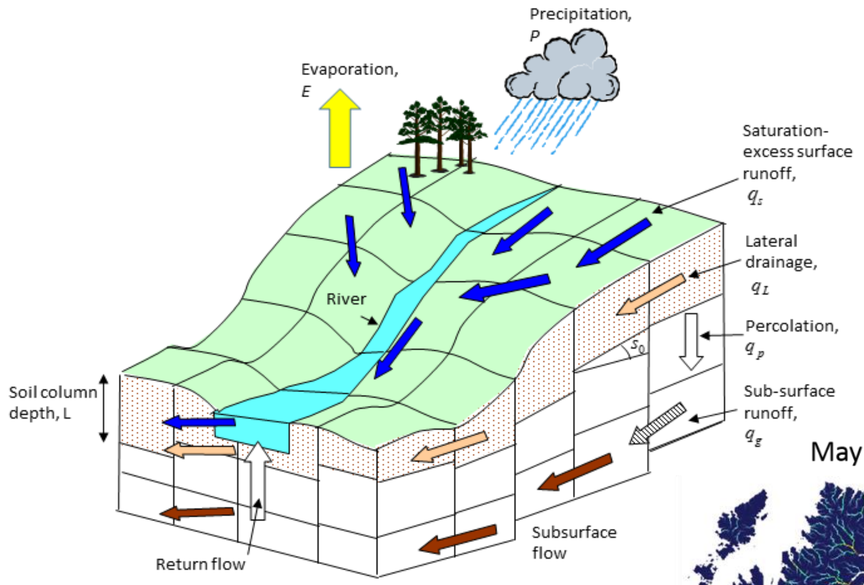
Used to analyse changes in multiple hazards in the UK (Kay *et al.*, 2021).

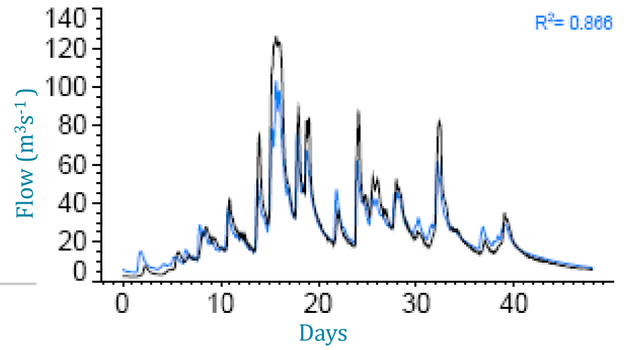


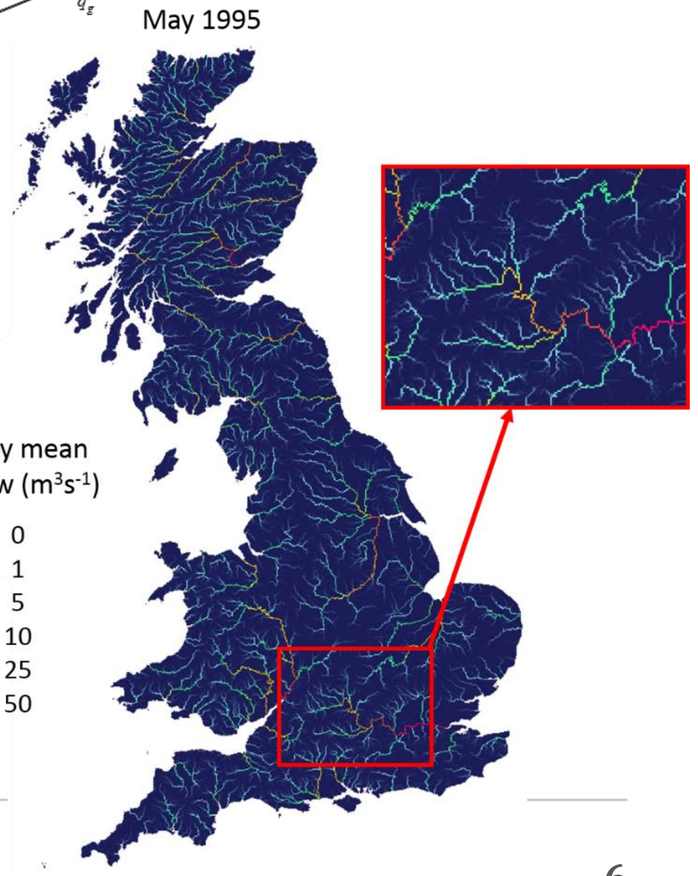
Grid-to-Grid

River flow was modelled using the Grid-to-Grid Hydrological Model (Bell *et al*., 2009).

- Estimates natural river flows
- Uses a 15-min time-step
- 1km^2 grid across Great Britain
- Calibration: national not catchment-specific







Extracting Events

At each gridcell, high flows were identified using a simple threshold with a daily exceedance of 2 days per year.
Events were determined by identifying consecutive days where the number of gridcells exceeding threshold was greater than 0.1% of the river network (~20km^2).
Due to the possibility of capturing multiple near-simultaneous events, duration was capped at 14 days.
Return periods were determined for each cell using a mixed empirical-GLO distribution on events, and converted to annual probabilities of exceedance.

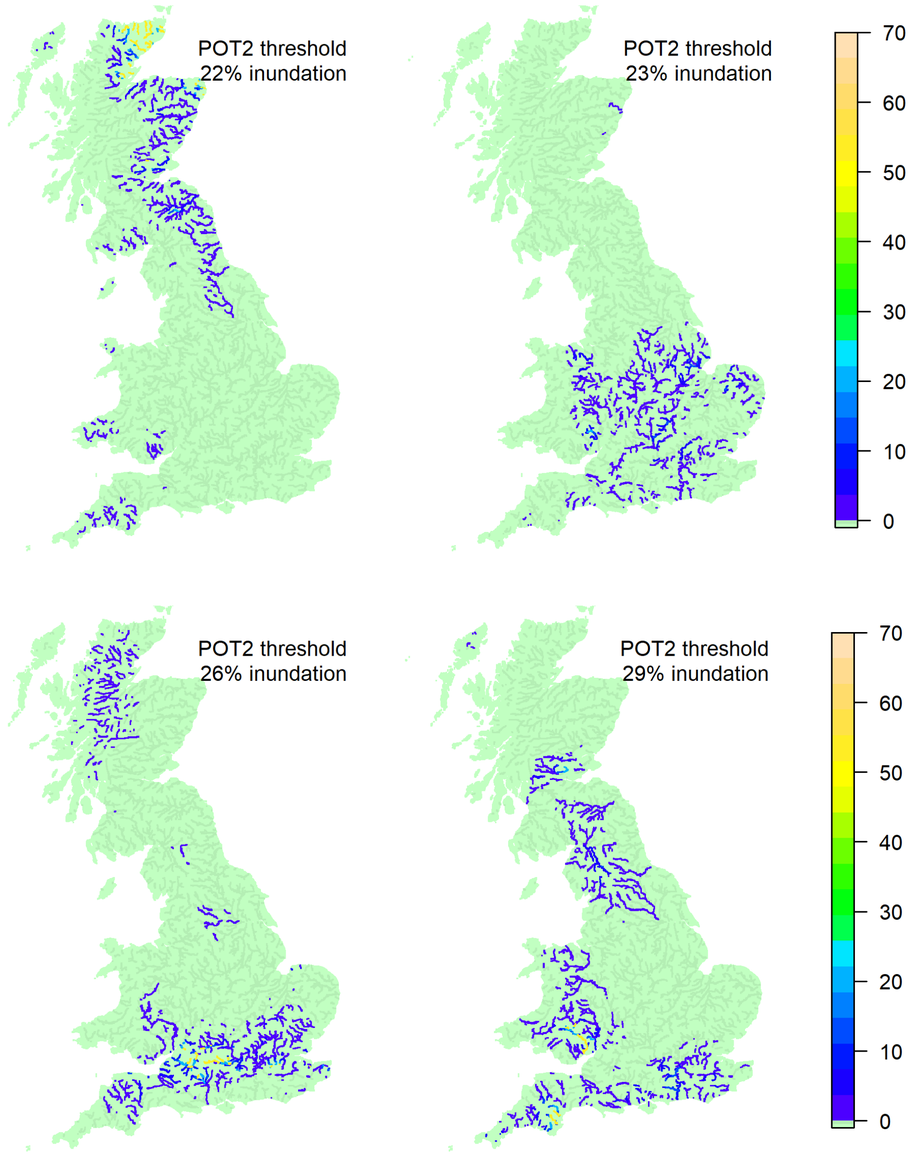
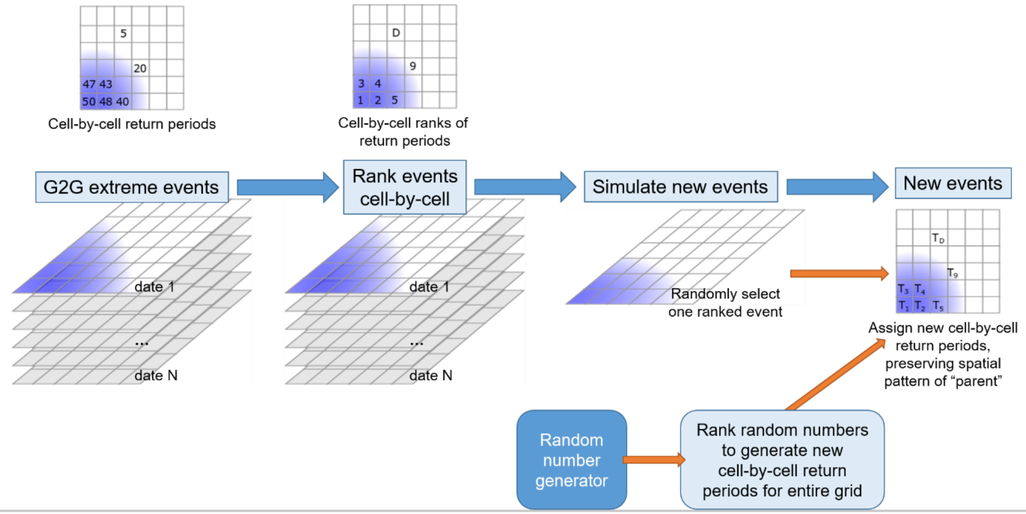


Figure: Example events from 1981-2010 period from a single RCM, showing return period in years.

Spatial Coherence

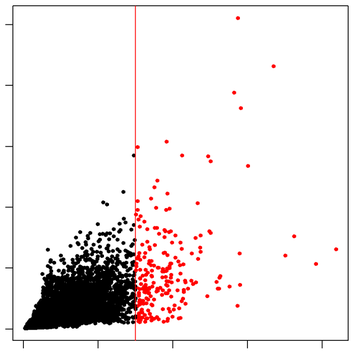
National events simulated using an empirical copula approach (Rüschendorf, 2009), which preserved the spatial patterns in the observed data, and assign new return periods based on an empirical distribution of observed return periods.

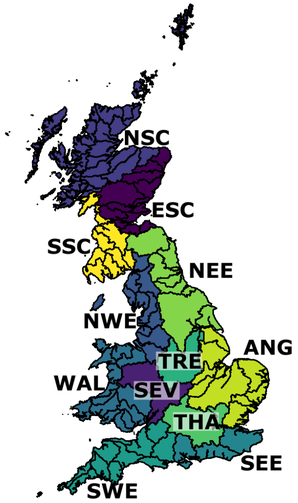
5000 events simulated per RCM per time horizon = 120,000 events.



Regional events were simulated using a Heffernan-Tawn model (Heffernan and Tawn, 2004) using Laplace-transformed margins conditioning on a maximal value occurring at a specific point and that value being above threshold.

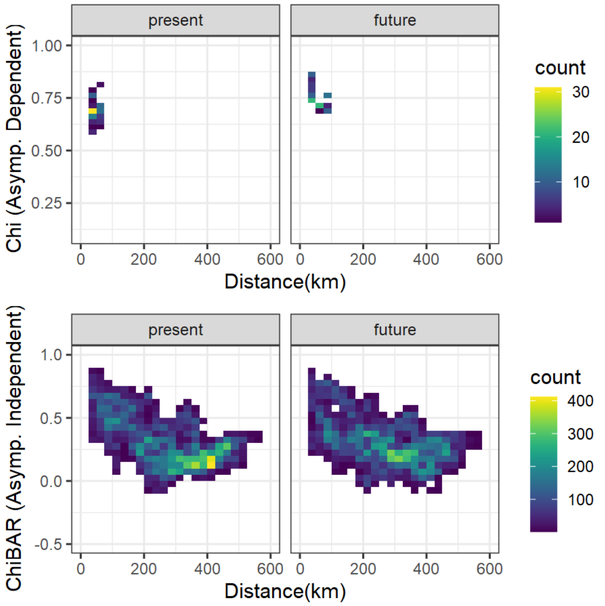
200 events simulated per RCM per time horizon = 4800 events.

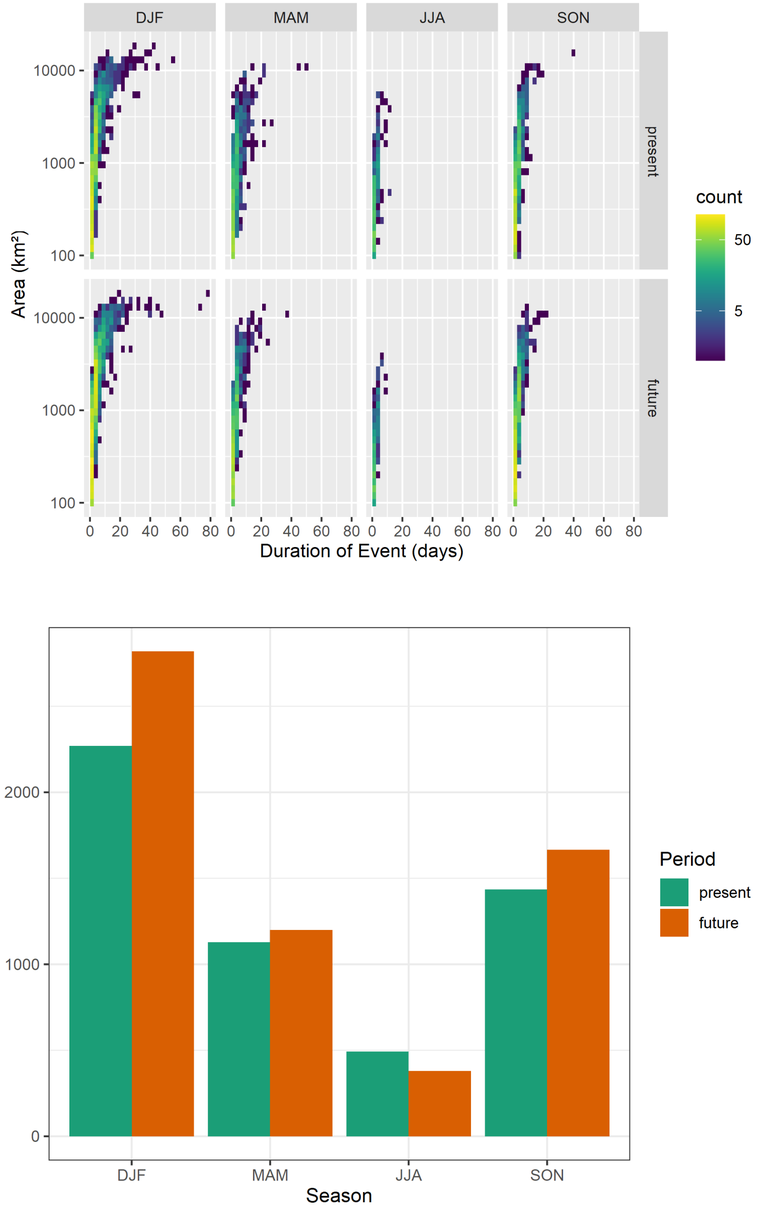




Key initial results

- Heffernan-Tawn model struggled to fit conditional exceedance models on the largest regions, but simulated events which agreed well with those observed.
- Empirical Copula model worked efficiently and broadly matched the observed dataset. Estimation of very long return periods was challenging due to short duration of observed data (30 years).
- Within the UKCP18-G2G dataset, future events seem to show fewer events in summer, but more widespread events overall.
- The size and duration of events during wetter months may be higher in the future.
- Initial findings suggest that spatial dependence is strong out to a radius of around 50km, outside which locations are asymptotically independent, but dependence is similar in present and future.





Conclusions

- Both the Empirical Copula and Heffernan-Tawn models show promise in applying modelled data to enhance risk estimation in the UK and wider by simulating plausible high return-period events.
- Trade-off between complexity and tractability
- Sample simulated data set to be published on EIDC.
- Could this lead to a standardised event set for comparing risk quantification approaches?

References

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