Using techniques from catastrophe modelling to assess climate risk

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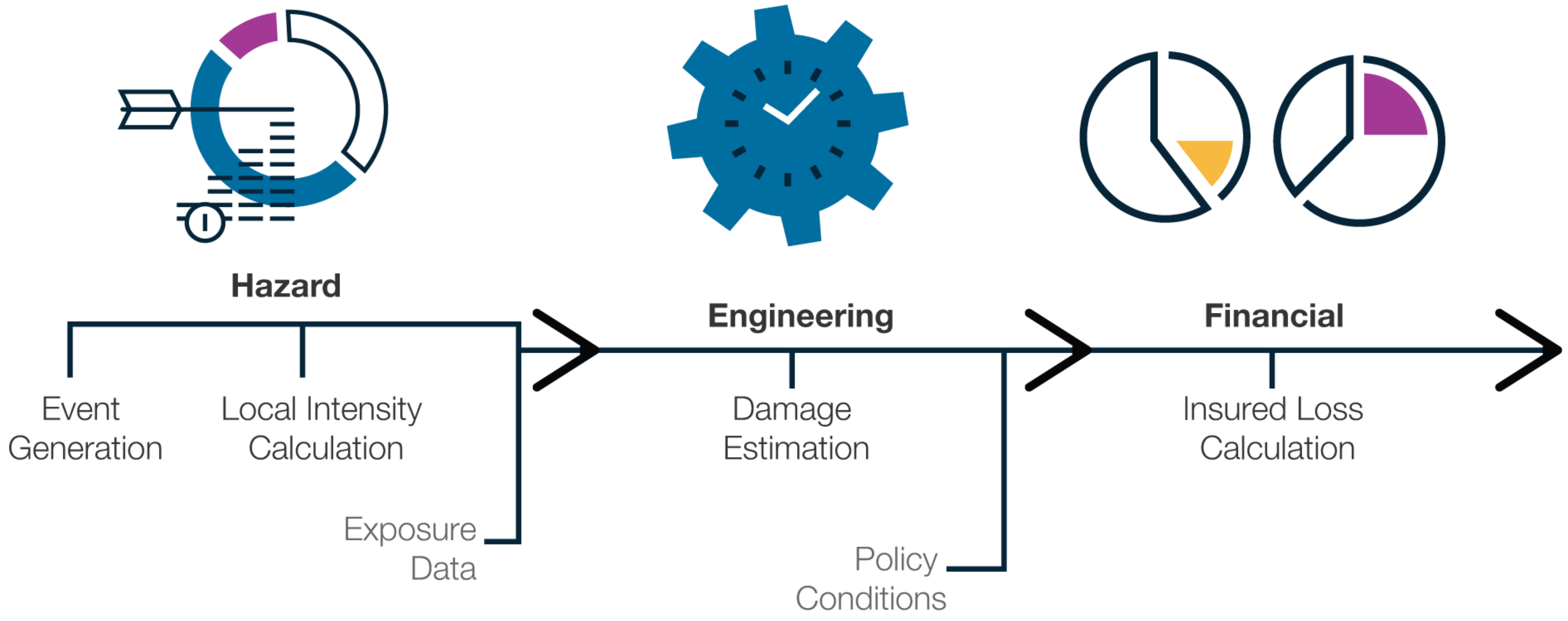
What is a typical Catastrophe (CAT) Model?

A tool for **spatially consistent**, **event-based**, **quantitative** risk estimation



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AquaCAT

Using techniques from catastrophe modelling to improve the assessment of flood risk across the UK

Lead: Sayers and Partners
With: UKCEH and Met Office

Limitations of other approaches:

- Local-dependence framework – estimates Expected Annual Damage **assuming full dependence** in the hazard across a region and uses **local climate change 'uplifts'**
- This assumption **underpins** the National Flood Risk Assessment in England and the flood projections with the Third UK Climate Change Risk Assessment **(CCRA3)**

Benefits of catastrophe modelling approach:

- **Spatially consistent hazard information** - more realistically captures spatial variability and how it might change
- **Event-based** provides greater **flexibility** in how risk can be quantified
- Help **decision makers prioritise** alternative courses of action in a **structured** and **coherent** way

Learning:

- The **spatial structure of flood events** is expected to **change in future**
- Not accounting for this leads to an **underestimation of the change in future risk** at a **national scale**

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AquaCAT: Event-based framework

Assessment of risk derived from a spatially coherent event set

UKCP18 Region Climate Model data: **spatially consistent driving data**

"Observations"
(UKCP18 RCM)

Socio-economic change
(e.g. Cambridge Econometrics)

Flood hazard simulation
(Grid-to-Grid)

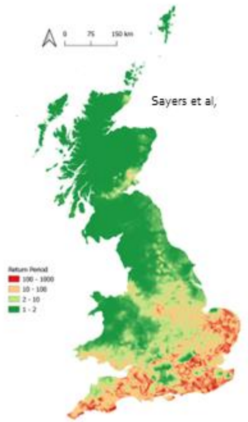
Event extraction
(PoT and footprint)

Stochastic event set
(Empirical Copula and Heffernan and Tawn)

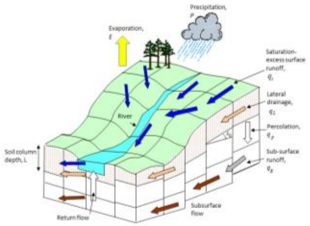
Impact
(Future Flood Explorer)

Statistical measures of damage

Adaptation (FFE)



Sayers et al, 2021



Bell *et al*

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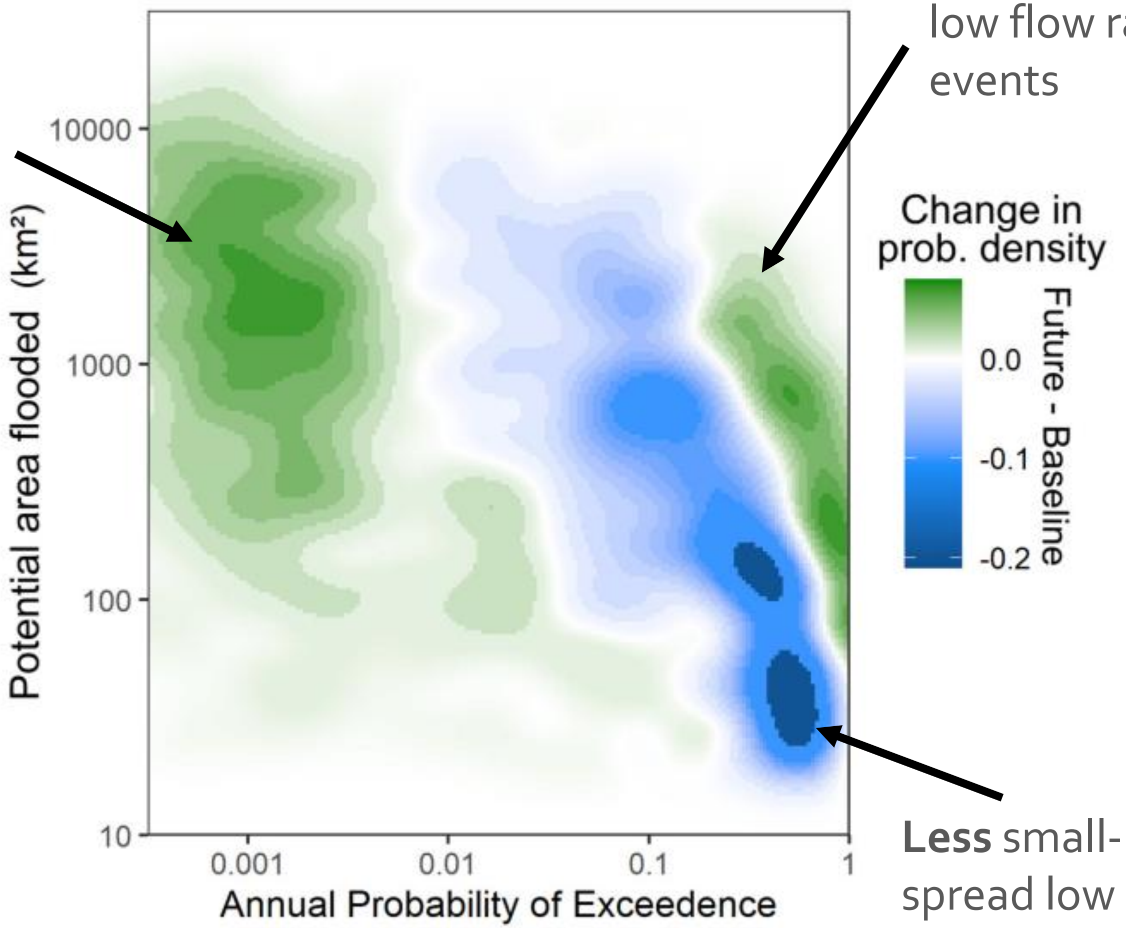
AquaCAT: Event-based framework

Assessment of risk derived from a spatially coherent event set

More large-spread events with very extreme/ rare flows

Griffin et al



(of flow rate)

More large-spread low flow rate events

Less small-spread low flow rate events

- Plot shows: **Difference** (future – baseline) in the **probability of flood events** with different spatial scales and flow rates
- Future = 2080s, 4°C rise in GMST
- Climate change is driving a **change in the structure of widespread flood events**
- This may have **important implications** for the extreme distribution of **damage** associated with an event

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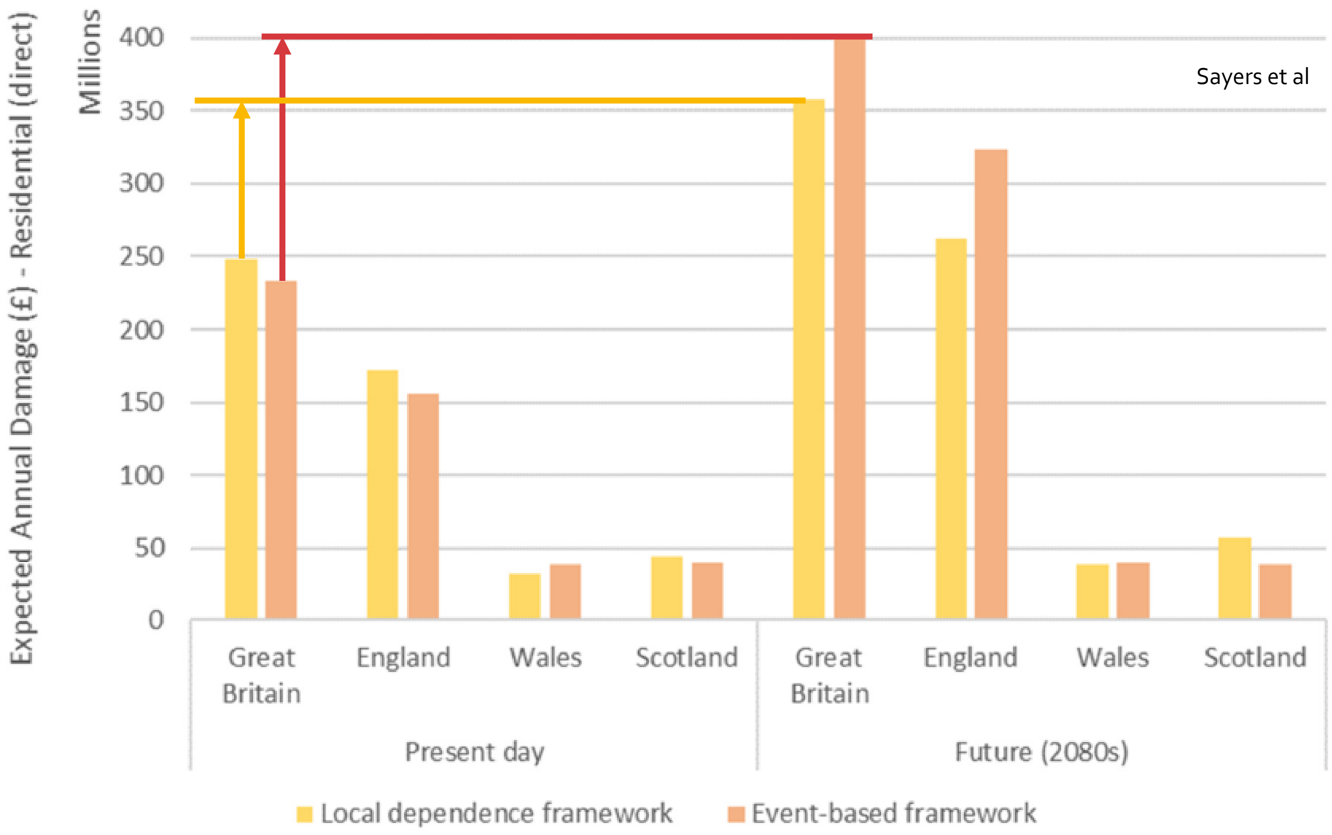
AquaCAT: Event-based framework

Assessment of risk derived from a spatially coherent event set



- Plot shows: A **comparison of the Expected Annual Impact** calculated using the local-dependence framework and the event-based framework (both assuming no change in population, a continuation of current levels of adaptation)
- **Non-trivial difference** between the two approaches in the **change in risk** (present day to future)
- Highlights the **need to use event-based modelling,** spatially coherent approaches in **national scale risk assessments** (e.g. CCRA4)

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Publications:

- Sayers, P.B, Griffin A, Carr, S, Stewart, E, Kay, A, Lowe J, Bernie, D (in review) **Beyond the local climate change uplift – The importance of changes in spatial structure on future fluvial flood risk in Great Britain** *In review*
- Griffin, A., A Kay, P Sayers, V Bell, E Stewart, S Carr (2022). **Widespread flooding dynamics changing under climate change: characterising floods using UKCP18**. Journal of Hydrology and Earth System Sciences Discussions, 1-18
- Griffin, A., A Kay, E Stewart, P Sayers (2022) **Spatially coherent statistical simulation of widespread flooding events under climate change** Hydrology Research 53 (11), 1428-1440
- Griffin, A.; Kay, A.; Bell, V.; Stewart, E.J.; Sayers, P.; Carr, S. (2022). **Peak flow and probability of exceedance data for Grid-to-Grid modelled widespread flooding events across mainland GB from 1980-2010 and 2050-2080**. NERC EDS Environmental Information Data Centre. (Dataset). https://doi.org/10.5285/26ce15dd-f994-40e0-8a09-5f257cc1f2ab
- Sayers, P.B, Griffin A, Carr, S, Stewart, E, Kay, A, Bell, V, Baruah, N (2021). **AquaCAT: Risk estimates using techniques from catastrophe modelling: UK Flood. Final Report**. Published by Sayers and Partners in association with UKCEH Wallingford and the Vivid Economics.

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Spatial Climate Risk Modelling

Using techniques from catastrophe modelling to assess risk and explore uncertainty and sensitivity

Lead: Met Office
With: UCL and DfE

Limitations of other approaches:

- Many examples of assessing climate risk use a **limited set of input information**
- Limited assessment of **uncertainty and sensitivity** – important for robust adaptation decision making

Benefits of catastrophe modelling approach:

- Growing number of **open-source software platforms** for implementing CAT modelling techniques (including non-financial impacts)
- Spatially coherent **assessment of risk** and its associated **uncertainty and sensitivity**

Learning:

- Able to '**unpick' the uncertainty budget of risk**
- **A major UKCR legacy capability** – allowing for a consistent risk assessment across many different use cases

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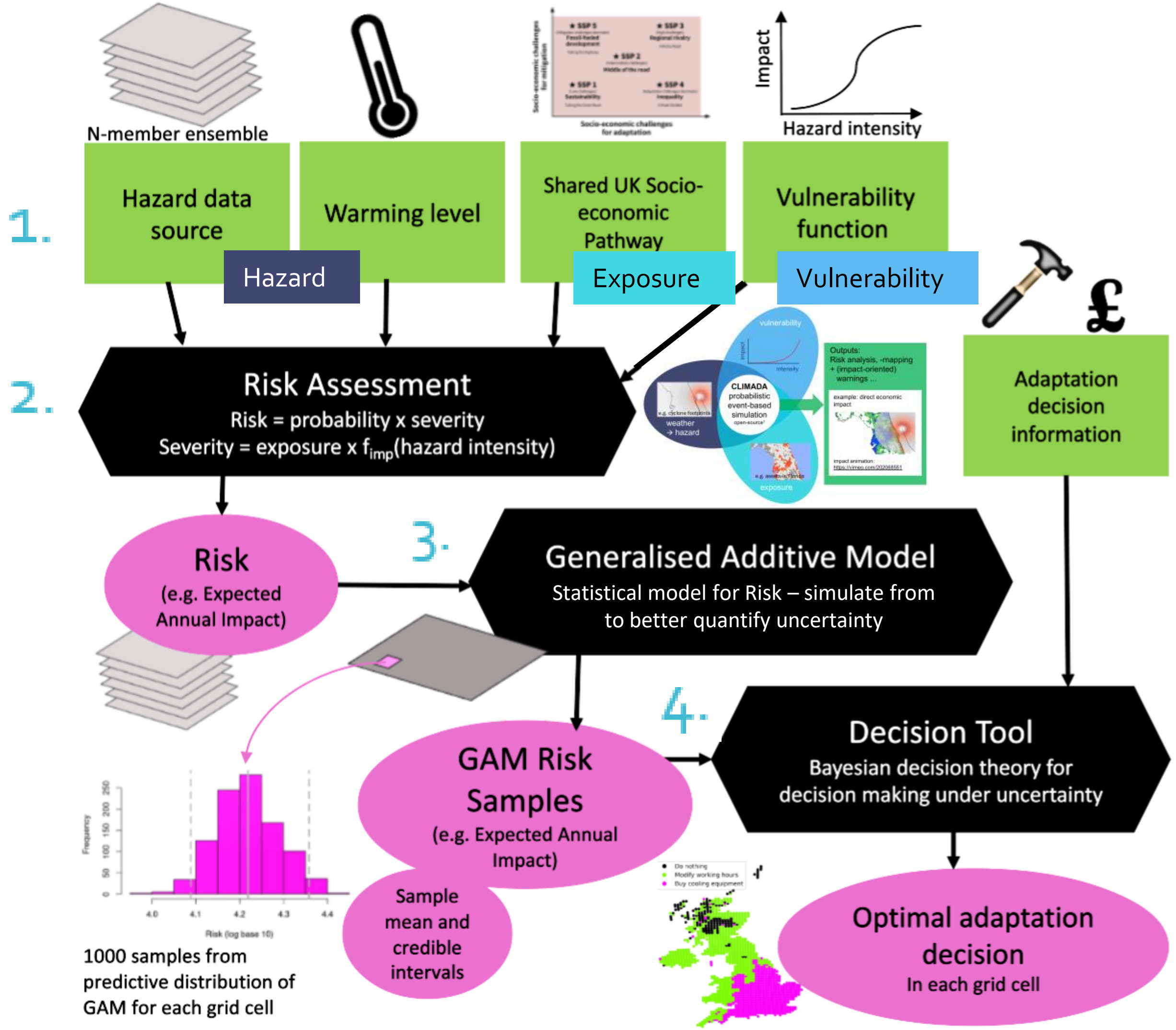
Spatial Climate Risk Modelling

An open-source capability for assessing risk and its uncertainty and sensitivity

Aim: develop the **capability** to use **multiple climate data sources** within an open-source quantitative **spatial risk assessment framework**

1. Input **spatially consistent** hazard, exposure and vulnerability information
2. Apply **open-source CLIMADA risk assessment platform** to assess risk based on each climate model ensemble member
3. **Statistically model** and stochastically simulate **risk** – richer quantification of climate model ensemble uncertainty
4. Use within a **decision tool** to identify optimal adaptation approach in each location



Spatial Climate Risk Modelling

An open-source capability for assessing risk and its uncertainty and sensitivity

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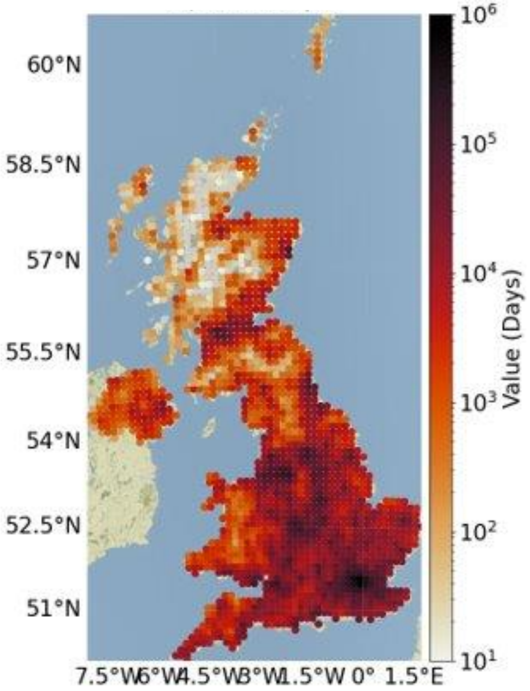
Idealised implementation – outdoor labour productivity

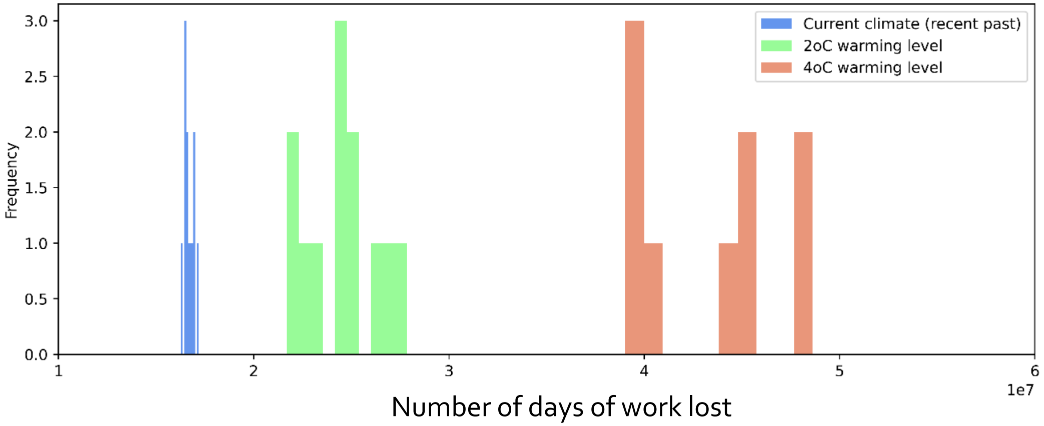
- **Risk: Expected annual total number of days of work lost due to heat-stress**
- **Hazard:** temperature and humidity (Humidex)
- **Exposure:** number of people working in outdoor jobs taken from the UK Shared Socio-Economic Pathways
- **Vulnerability:** function relating humidex to the impact on working capacity

Spatial map of Risk

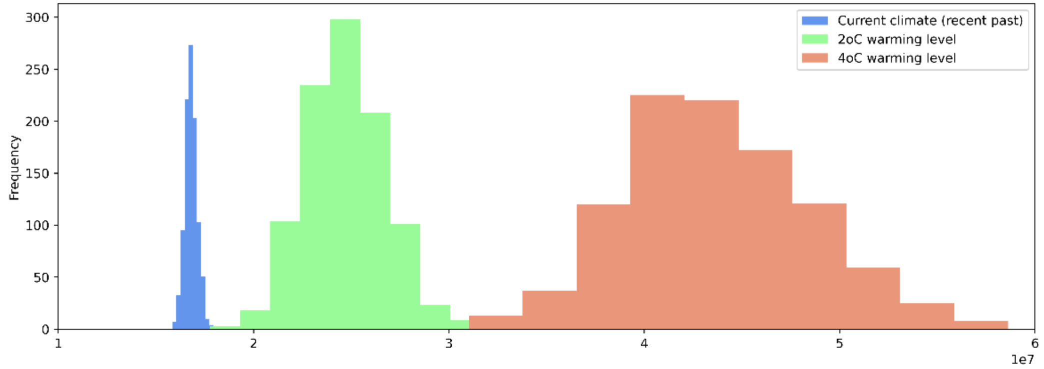


- UKCP18 Region Climate Model (bias corrected)
- Ensemble member 1 (of 12)
- **2°C warming level**

Spatially Aggregated Risk from 12 UKCP18 Regional Climate Model ensembles



Spatially Aggregated Risk from statistical model simulations (representing 1000 ensemble members)



Spatial Climate Risk Modelling

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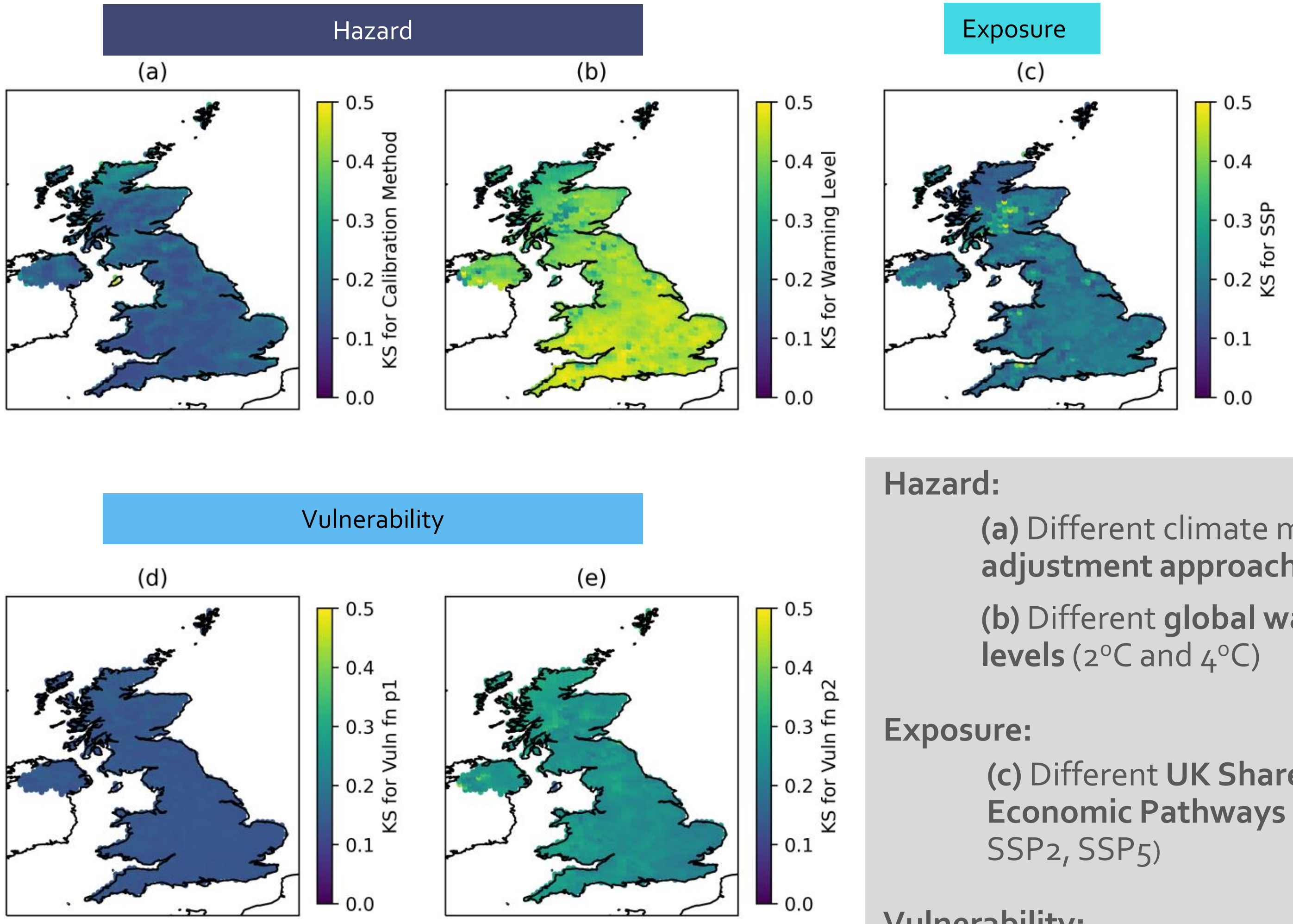
Sensitivity Analysis

- **Vary the inputs** and explore the **sensitivity of risk** – global all-at-once approach
- Quantify sensitivity using the Kolmogorov–Smirnov (KS) Statistic – **higher value means risk is more sensitive to this input**
- Generally highest sensitivity to **warming level**
- Highest sensitivity to **SSP in some parts of the UK**



Hazard:

(a) Different climate model **bias-adjustment approaches**

(b) Different **global warming levels** (2°C and 4°C)

Exposure:

(c) Different **UK Shared Socio-Economic Pathways** (SSP1, SSP2, SSP5)

Vulnerability:

(d) and **(e)** Different **parameters of vulnerability function**

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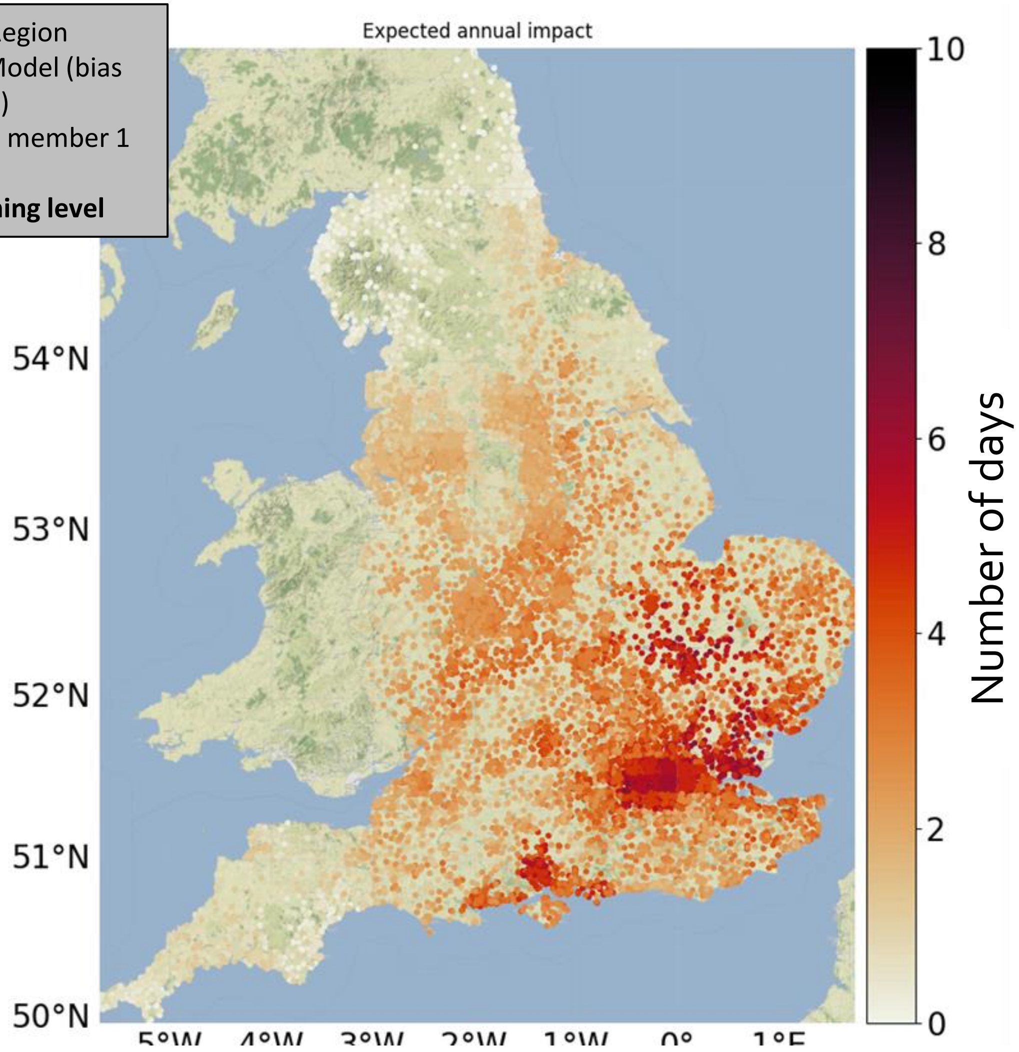
Real-world application: Overheating in Schools

- **Opportunistic application**, building on data and analysis commissioned to look at net-zero adaptation options (ARID project UCL & DfE)
- **Risk: expected total annual number of days each school overheats (internal temperature exceeds 35°C)**
- Working with the Department for Education and schools to aid **climate resilience planning**

- UKCP18 Region Climate Model (bias corrected)
- Ensemble member 1 (of 12)
- **2°C warming level**



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- Dawkins, L. C., Bernie, D. J., Lowe, J. A., and Economou, T. (2023). **Assessing climate risk using ensembles: A novel framework for applying and extending open-source climate risk assessment platforms**. *In review in Climate Risk Management*
- Dawkins, L. C., Bernie, D. J., Lowe, J. A., Economou, T. and Pianosi, F. (2023): **Quantifying uncertainty and sensitivity in climate risk assessments: varying hazard, exposure and vulnerability modelling choices**. *In review in Climate Risk Management*
- Dawkins, L. C., Bernie, D. J., Lowe, J. A., and Economou, T. (2023). **Quantifying future climate risk of overheating in UK schools using Catastrophe modelling techniques**. *In preparation*

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Summary

Limitations of other approaches:

- Not capturing the **spatial variability** in the hazard
- Limited assessment of **uncertainty and sensitivity**

Benefit of catastrophe modelling approach:

- Spatially consistent event-based approaches provide **greater flexibility** and **accuracy** in how risk can be quantified
- Open-source tools allow for **spatially coherent assessment of risk** and its associated **uncertainty and sensitivity**

Learning:

- Accounting for the **spatial structure of hazards**, and how this may change, is **important** for quantifying the **change in future risk**
- **Developed major UKCR legacy capabilities** – allowing for a consistent risk assessment across many different use cases

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