

A collaborative hackathon to investigate climate change and extreme weather impacts in justice and insurance settings

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Introduction

To better manage and prepare for the impacts of a changing climate, it is vital to have a thorough understanding of how it may affect society. The UK has already felt some of the impacts of climate change, with the chance of recording days above 40°C significantly increasing (Christidis *et al.*, 2020) and some of the wettest days recorded in history occurring in recent years (Christidis *et al.*, 2021).

Most studies linking climate change, crime, and justice are international (e.g. Ranson, 2014) and there is a notable gap in the literature for the UK. Furthermore, with the increased likelihood of extreme weather events due to climate change (e.g. Thiery *et al.*, 2021) and the observed increasing trend in sudden, heavy rainfall events over the UK (Cotterill *et al.*, 2021; Kendon *et al.*, 2022), it is vital that the insurance industry considers how more unpredictable weather events could influence the time window for assessing and managing the projected losses leading up to an event. For the first time, the UK Met Office collaborated with the UK Ministry of Justice (MoJ) and reinsurance broker Aon, using UK climate projections datasets (UKCP18) (Met Office, n.d.), to explore these themes on a UK domain, facilitating more relevant research for UK institutions.

In addition to traditional scientific research and development, novel approaches can be helpful to explore climate data in new and exciting ways (Thomas *et al.*, 2022). One such approach is through the concept of 'hackathons'; events where a range of collaborators come together and spend a dedicated, short period of time to approach and solve questions of particular interest (Crook *et al.*, 2022; Fallon *et al.*, 2022; Mitchell *et al.*, 2022; Thomas *et al.*, 2022).

In May 2022, the Met Office, the MoJ and Aon, collaborated with academics from the Met Office Academic Partnership universities to explore four themes:

- How climate change could impact crime and justice in the UK.
- The effect of changing temperatures on thermal discomfort in hearing rooms.
- How uncertainty regarding the exposure of extreme weather hazards affect insurance risk modelling.
- Providing historical context to an extreme event in real time.

By bringing together a diverse set of skills and backgrounds, participants were able to utilise each other's expertise to overcome challenges and achieve tangible outputs in 2 days. Some participants focused on the technical analysis and methods for analysing the data while others conducted literature reviews to gain a good understanding of previous progress in the field. This style of event also facilitated the development of broad professional networks and transferable skills.

It is important to note that, rather than working individually, the idea of a hackathon is to work collaboratively to progress more effectively towards answering a research question. The reader can relate this concept to a famous quote attributed to Aristotle: 'The whole is greater than the sum of its parts'. The expectation is that outputs from hackathons do not need to be publishable; instead, they aim to provide a platform for ideas and concepts to be taken further.

There was a total of seven teams within the event, each containing 3–10 participants. These teams were split into two groups focusing on themes defined by the MoJ and Aon. This article presents four of the teams' outputs (two from each theme), along with a discussion of how further work and new research has followed on from the initial exploration as part of the hackathon event.

How climate change could impact crime and justice in the UK

Research shows that particular weather conditions correlate with certain crimes, (e.g. Towers *et al.*, 2018), and therefore as the climate changes, it is likely that rates and types of crime will also alter (Ranson, 2014).

The published studies around this topic are largely international; the MoJ and Met Office want to understand if similar results are applicable to the UK.

Unfortunately, crime statistics for the UK are typically aggregated every financial quarter (e.g. ONS, 2022) which makes it difficult to compare directly to meteorological data for extreme weather events, given that these can occur on specific days and times of day.

While not at a high enough temporal resolution to compare with extreme weather events, the Metropolitan Police provide monthly aggregated crime statistics (Metropolitan Police Service, 2022) which enabled the group to analyse how seasonality may affect different crime rates in London Boroughs and consider how climate change may affect these trends.

Figure 1 suggests seasonality in both public order offences¹ and burglary; these results agree with the consensus from existing literature. While not published at the time of the hackathon, (Shiode *et al.*, 2023) offer a more in-depth analysis of the seasonality of crimes across London. They suggest that the longer summer days mean offenders spend more time outdoors, resulting in a greater number of public order offences and the darker days of winter allow for less on-street witnesses, providing more opportunity for burglary.

Relating back to extreme weather events and climate change, the group conducted a brief literature review and found international studies suggesting a positive correlation between temperature (specifically dry, hot weather) and violent crime (Baryshnikova *et al.*, 2022; Potgieter *et al.*, 2022), and for precipitation, a negative correlation with assault and criminal damage (Towers *et al.*, 2018). Therefore hotter, drier summers due to climate change could result in more social and violent crime, while warmer, wetter winters could result in less crime in general. However, more domestic violence offences could occur due to the ‘cabin-fever’ effect (Donaldson James, 2014), and because natural disasters such as widespread floods tend to increase incidences of domestic abuse (Parkinson and Zara, 2013).

There are likely nuances within the trends worth consideration; for example, Horrocks and Menclova (2011) found a curvilinear relationship between temperature and violent crime in New Zealand, with a direct positive correlation up to 27°C and a slight negative correlation for temperatures above this threshold. For a more comprehensive understanding of how climate change may

¹A public order offence is defined to be offences such as public alarm/distress, violent disorder or racially/religiously aggravated public fear (Metropolitan Police Service, 2022).

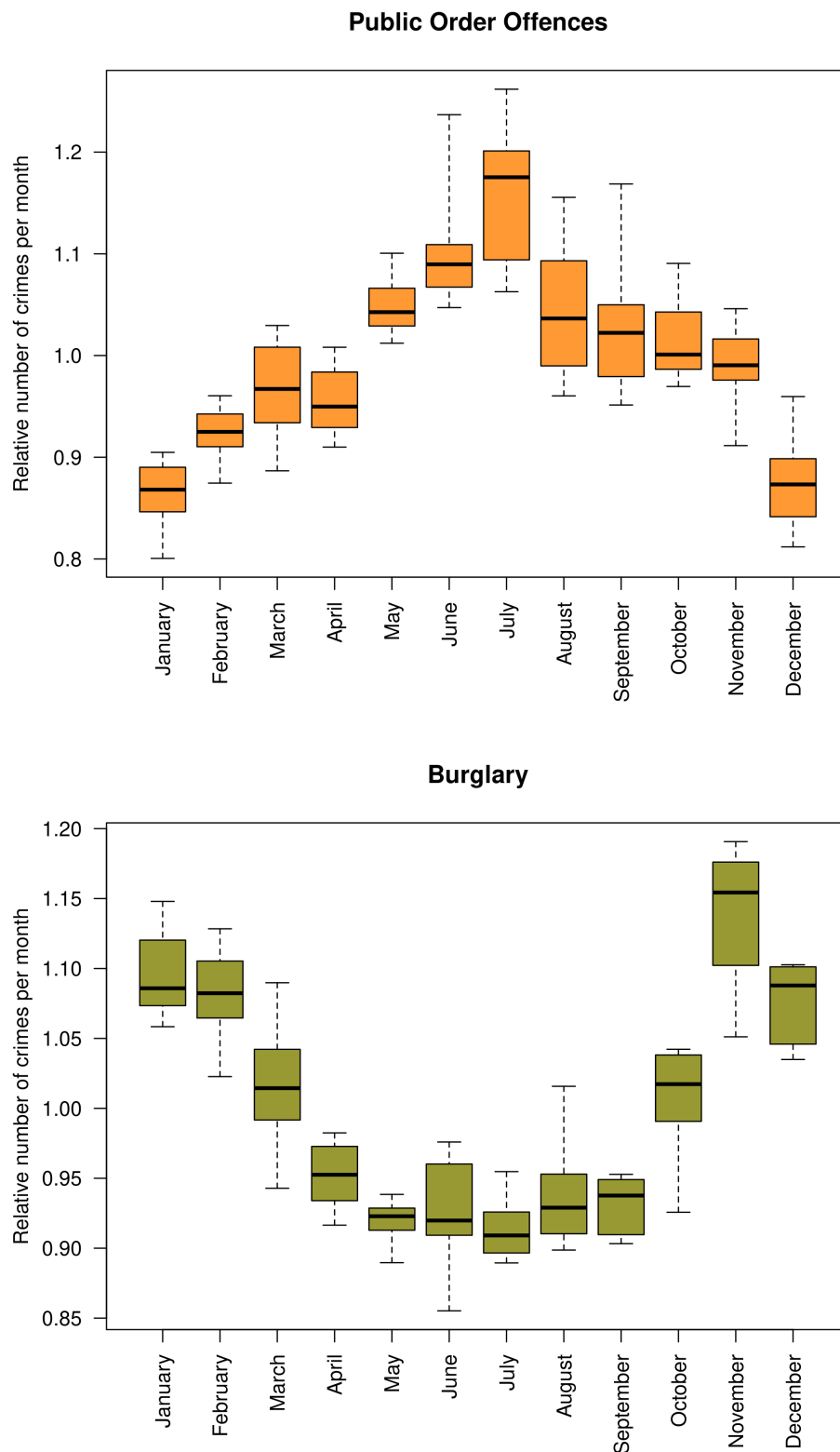


Figure 1. Seasonal cycles of public order offences (orange) and burglaries (green) averaged across all London boroughs between 2011 and 2019 (Metropolitan Police, 2022). Values are expressed as the relative number of crimes per month and are calculated as the monthly total divided by the 12-month moving average. Analysis conducted using the decompose function in the R ‘stats’ package, R Core Team (2020).

affect crime, it would be necessary to understand whether it is the weather *per se*, or the *anomaly* in the weather (i.e. extreme events) that is important in triggering differences in crime rates. Crime statistics of greater spatial and temporal detail must be made available for such analyses.

Besides the low temporal resolution of crime data, there are many other factors that make this analysis challenging. Crime rates are influenced by many socio-economic, political and demographic factors and as such, it is important that any predictions of how future crime rates may change

under climate change must not be solely relied upon for accurate decision-making. Furthermore, crime statistics must be made available more frequently for robust causation to be established with weather or climate data. Ongoing discussions seek to understand how this may be achieved and the MoJ continue to work on this subject with other partners as part of their climate change adaptation programme (MoJ, 2020).

The effect of changing temperatures on thermal discomfort in hearing rooms

The second team's output also approached themes presented by the MoJ, this time focusing on the effect of heat and discomfort on the proceedings of the UK justice system.

An increase in ambient temperature has been found to reduce the number of decisions favourable to the applicant in immigration tribunals and parole hearings (Heyes and Saberian, 2018) – possibly through affecting mood and cognition (Gockel *et al.*, 2014; Drápal and Pina-Sánchez, 2019; Evans and Siminski, 2021). The size and significance of this effect vary between studies, and thus far no such research has been conducted in the UK, creating a knowledge gap that forms the focus of this group's hackathon output.

HM Courts and Tribunals Service is committed to achieving net-zero by 2050 or earlier; their net-zero strategy includes improving insulation and energy efficiency in Court and Tribunal buildings (UK Government, 2022a). However, so far this has not taken into consideration how climate change may impact the effectiveness of processes in hearing rooms by creating potentially more uncomfortable conditions.

The main Hackathon output of this group was a proposal for a research project seeking to answer:

1. How applicable are existing literature findings to the UK?
2. How will changes to weather patterns affect the temperature and humidity within courtrooms?
3. How will any potential impacts project into the future, in a warmer, less predictable climate?
4. What are the implications of increasing remote participation in trials and hearings?
5. What costs and savings (financial and CO₂) would be associated with retrofitting UK court buildings to a standard that minimises unwanted effects on decision-making?

Collating resources to answer these questions highlighted several limitations: UK hearing room statistics are aggregated and

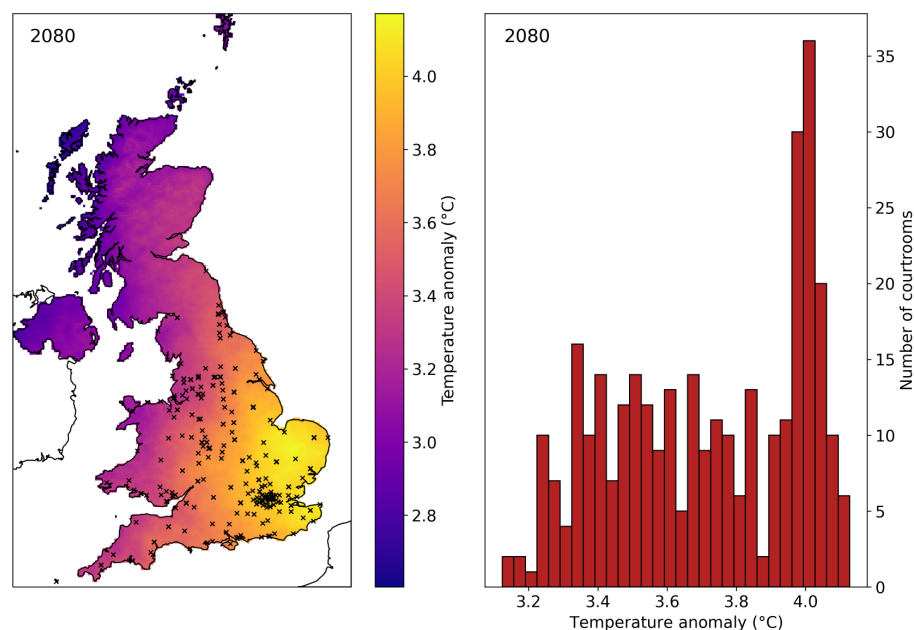


Figure 2. (Left) projected average annual 1.5m air temperature anomaly relative to 1981–2000 inclusive (UKCP18 Local Projections) (Met Office, *n.d.*) with locations of hearing rooms in England and Wales shown as black crosses. The locations of hearing rooms (last updated September 2019) were taken from National Audit Office (2019). (Right) histogram with bins approximately 0.033 degC wide showing the number of courtrooms located in regions with various projected 2080 temperature anomalies.

reported quarterly, rather than by individual cases (MoJ, 2022; UK Government, 2022b), and where individual case data exist, it is difficult to interpret because exact dates and locations of each case were difficult to obtain (UK Government, 2022c). Therefore, for a comprehensive future study to be performed, more granular data on hearing room locations and dates of trials must be made available for an accurate comparison with climatological data. Furthermore, the measurement of building comfort in hearing rooms has so far been unsystematic and therefore these data would also need to be collected to perform accurate studies on how meteorological conditions affect the inside environment.

Given these limitations, the team used the hackathon to define the resources needed to support further research into this topic. Figure 2 provides motivation for this research, given that in a scenario where the emission of greenhouse gases continues to increase unmitigated, temperatures in England and Wales where hearing rooms are located could be over 3 degC hotter by 2080 compared to the 1981–2000 average, with 25% of hearing rooms in regions with over 4 degC warming.

Following the event, discussions are underway to collate and analyse further data. This may involve measuring temperature and humidity in courtrooms; regression analyses of indoor building comfort metrics and keeping a clear record of different weather conditions for judicial processes; and projecting any correlations found onto future climate scenarios.

The research proposed has the potential to strengthen the case for adaptation measures in HM Court and Tribunal Service buildings. If an adverse impact on the decision-making ability of the judiciary and the physical comfort of participants in legal processes within hearing rooms can be confidently quantified, it would heavily justify the expenditure on retrofitting. This would also help to reduce CO₂ emissions. If no link is found, it should provide reassurance that judicial processes in the UK would not be unduly affected by climate change. Even if this was the case, decarbonising the Court and Tribunal Service's estate and operations and respecting human comfort and health remain crucial.

How uncertainty to exposure of extreme weather hazards affect insurance risk modelling

The third hackathon team focused on the challenges and themes proposed by Aon, specifically looking at how exposure is modelled by the insurance industry when considering the impacts of future extreme weather events.

Global mean annual temperature has risen to more than 1.2 degC above pre-industrial levels (Copernicus Climate Change Service, 2022) and this has already resulted in changes in the frequency and magnitude of extreme weather events (Christidis *et al.*, 2020). These events will continue to become more hazardous and unpredictable as anthropogenic warming increases (Pachauri *et al.*, 2014; Thiery *et al.*, 2021).

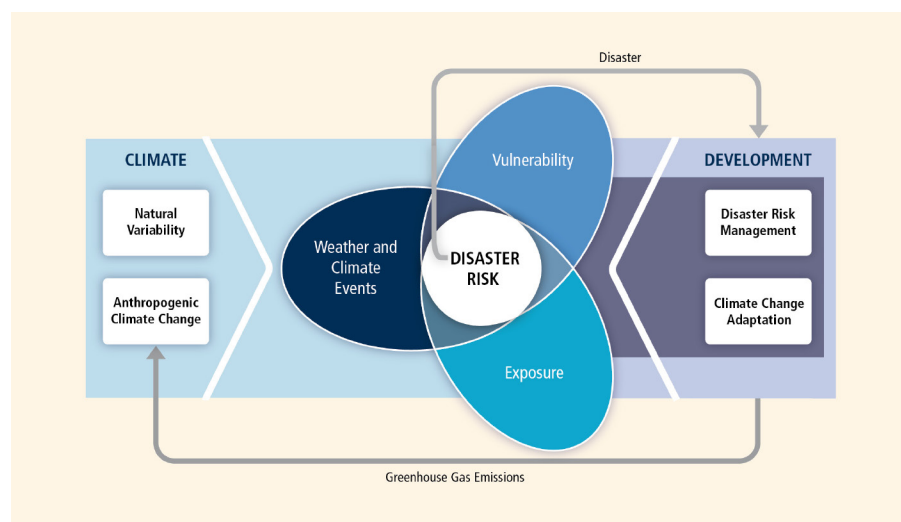


Figure 3. The concept of risk defined by the IPCC.

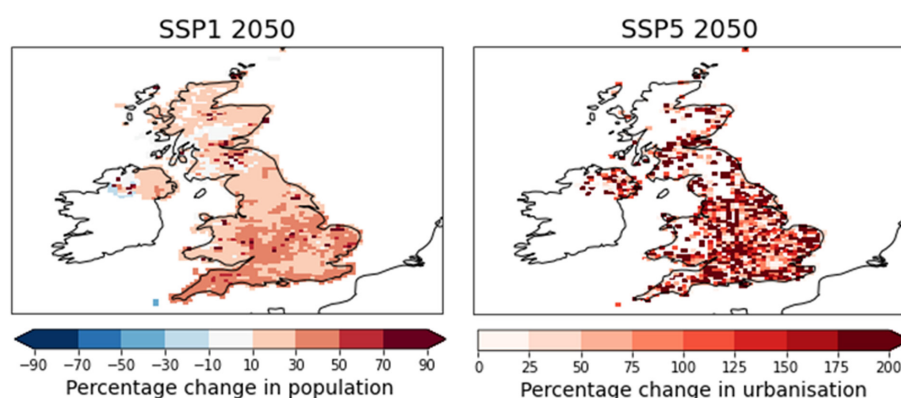


Figure 4. Projected changes in UK population and urbanisation for 2050 compared to 2020, used for depicting the future exposure component of risk under the SSP1 and SSP5 scenarios. Data from UK SSP quantitative projections (Stenning *et al.*, 2021).

The societal risk associated with extreme weather and climate events can be thought of as a combination of hazard, exposure and vulnerability (Figure 3). Hazard is the frequency and magnitude of extreme weather events, exposure corresponds to the location and value of exposed assets, and vulnerability is the likelihood that those assets will be affected when exposed to such hazards, based on each asset's individual physical characteristics.

Reinsurance is often described as 'insurance for insurance companies' (Swiss Re, 2010). As a reinsurance broker, Aon brokers the relationship and agreements between the primary insurer and the reinsurer, using catastrophe risk models (cat models) to model the potential losses to their clients' portfolios; these models are also used by the primary insurers and reinsurers in their own assessment of risk. Crucially, the hazard component of the risk is typically the only uncertainty considered (e.g. Jewson *et al.*, 2021) and vulnerability cannot be examined using climate models. Therefore, the aim of the team was to

investigate how future exposure to climate hazards could impact cat modelling.

The Shared Socioeconomic Pathways (SSPs) framework conceptualises plausible societal futures (O'Neill *et al.*, 2014). Future scenarios, and corresponding societal changes, differ by the strength and implementation of climate policies and mitigation. The two most opposing scenarios are SSP1 and SSP5. SSP1 has a narrative of sustainability, where climate change mitigation and adaptation are central, the use of available resources is maximised, and environmental pressures are minimised. SSP5 has a narrative of expanding fossil fuel use with a focus on adaptation rather than climate change mitigation. This results in increasing urbanisation and a lack of public support for sustainable development.

Within the UK Climate Resilience Programme,² the global SSPs have been used to develop a consistent set of SSPs specifically for the UK, quantifying the relevant exposure metrics at 12km spatial

²<https://www.ukclimatesresilience.org/>

resolution (Stenning *et al.*, 2021). During the hackathon, the UK population and urbanisation projections for 2050 were used to create exposure metrics, as shown in Figure 4. It was assumed that the projected population increases would be accommodated by an increase in population density for SSP1 and by an increase in urban area for SSP5. The gridded percentage changes from each grid point are used as scaling factors for the building replacement costs in the database of UK infrastructure provided by Aon, to represent the relative uplift of costs for the present-day building stock associated with changing exposure.

Following the hackathon, the parties have continued to collaborate, with a wider focus on understanding uncertainties in European windstorm modelling. Results of further study on the relative roles of hazard versus exposure uncertainty are intended to be published, aiming to answer the important remaining research questions:

- How does climate change impact the largest European windstorms and their associated risk to society based on changes in hazard and exposure?
- How is this influenced by climate model, land use and exposure dataset choices? (Luu *et al.*, 2023).

A key outcome of this ongoing collaboration will be to quantify if changes in future climate or future exposure have the largest impact on total risk to the insurance industry, indicating whether current cat modelling without changing the exposure component is adequate for risk analyses of the future.

Providing historical context to an extreme event in real time

The final team focused on providing context for ongoing extreme weather events in real time. As extreme events occur, Aon estimate their severity, to guide clients on what financial losses they may expect.

To give Aon a better understanding of how certain extreme events may evolve, and hence better predict their future severity, this team developed a tool to visualise the return periods (i.e. how often rainfall events have occurred in the past), using ensemble forecasts to also illustrate their associated uncertainty.

Reinsurance is a mechanism by which multiple insurance companies share risk, to ensure that no one company has too much exposure to a particular hazard. In the lead-up to a major event, insurance companies may also choose to buy emergency catastrophe reinsurance if they are concerned about large losses from a single event. To decide whether to buy catastrophe reinsurance, insurance companies need to assess the severity of the event by linking the fore-

cast hazard (e.g. rainfall) with their potential insured losses. Being able to assess the expected return period in real time allows Aon to assess the potential impact the event may have on their clients' portfolios and support them in managing that impact. The further in advance extreme weather events can be modelled and quantified, the more time Aon has to help their clients assess and manage the projected losses. As such, there is a need to identify and calculate the return periods of severe weather events from forecast data at longer lead times to compare to the expected losses calculated from cat models for similar events.

The proposed approach drew on recent applications of impact-based forecasts (IbF) (Merz *et al.*, 2020) that link outputs from complex offline models, with current forecasts in real time. These Hazard Impact Models support decision-making, using a look-up approach, for example the development of surface water flood forecasts in the UK (e.g. Speight *et al.*, 2021). In this case, the return period of the forecast rainfall was calculated using ERA5 reanalysis data (Hersbach *et al.*, 2020). The spatially varying estimated return period can then be utilised to produce an estimated event return period (Figure 5). High-resolution reanalysis data has previously been used to estimate return periods for extreme weather events (Della-Marta *et al.*, 2009; Fox-Hughes *et al.*, 2022). However, the calculation of rainfall return period is non-trivial, requiring consideration of data resolution, record length and climate change (Buishand *et al.*, 2008; Milly *et al.*, 2008; Griffin *et al.*, 2019; Poschod *et al.*, 2021; Slater *et al.*, 2021).

The forecast return period can provide more contextual detail to insurers than is available in public-facing weather forecasts and warnings. For example, the footprint of exceedance of a 75-year rainfall return period could be considered against the location of insured assets to indicate potential exposure and estimate losses. At this proof-of-concept stage, only rainfall is considered; no consideration of hydrology or inundation, or link to damages and loss were made. Figure 5 illustrates how the methodology could be expanded to include these aspects.

To illustrate the concept and build a prototype tool, an archived MOGREPS-UK Legacy forecast for a past event was used. MOGREPS-UK Legacy is the Met Office ensemble forecasting system which produces 12 ensemble members with a 54h lead time, on a 2km grid (Porson *et al.*, 2020). In ensemble forecast systems, all members are considered equally likely to occur. During the hackathon the focus was to calculate and display a grid-based forecast return period estimate, for each ensemble member. This ensemble-based

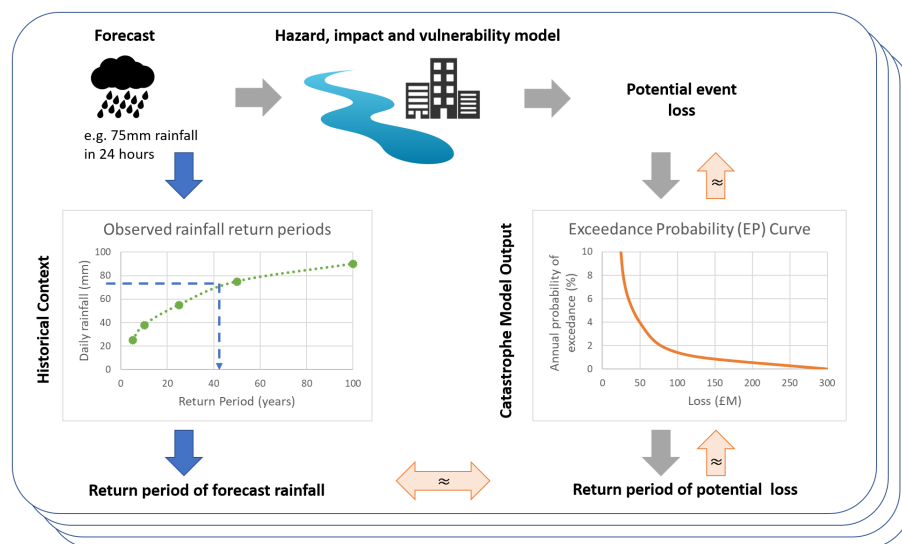


Figure 5. Proposed approach to link forecast rainfall with insured loss to provide historical context for extreme events. The blue arrows illustrate the process followed during the hackathon to produce spatially varying rainfall return periods for each ensemble member and grid cell. The grey arrows describe the additional steps required to calculate the return period of insured loss. The light orange arrows show how potential event loss can be approximated with historic rainfall, assuming that the return period of event loss can be considered approximately equal to the return period of event rainfall. The process is repeated for each ensemble member.

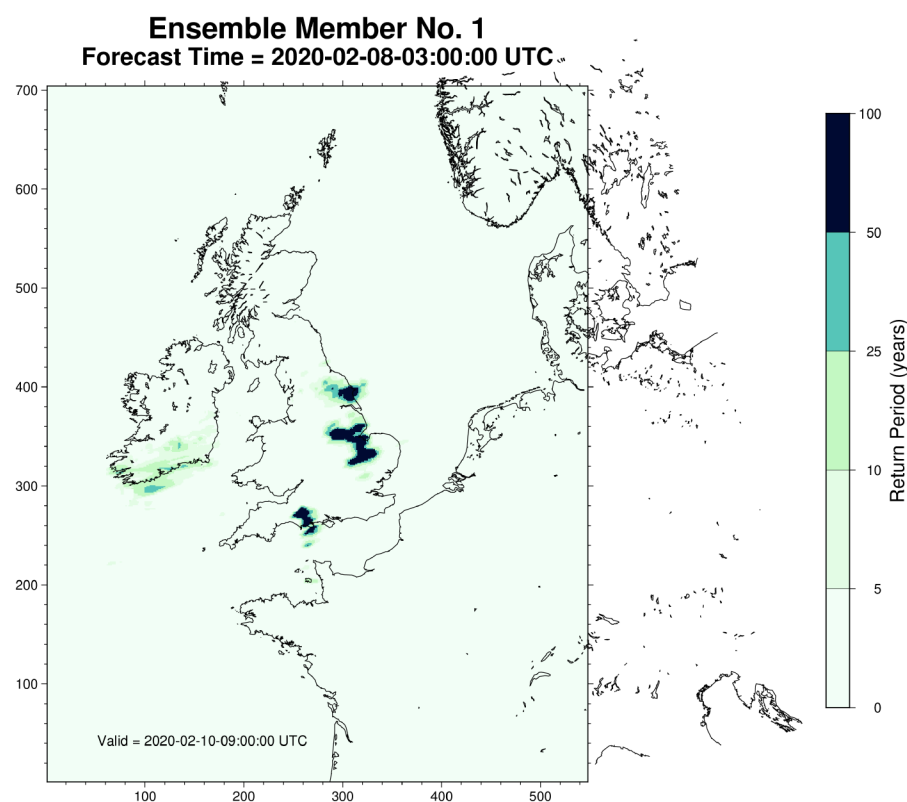


Figure 6. Dynamic output from the proof-of-concept tool to visualise the historical return period estimate of a forecast event in real time.

approach showed the potential to support risk-based decision-making through visualising forecast uncertainty. Rainfall return periods were calculated using cumulative 24h rainfall totals. To best capture extreme events, the team chose to calculate 24h

accumulated rainfall totals using a sliding window approach across the 54h of the forecast lead time. The maximum cumulative 24h rainfall total was then selected for each ensemble member. These outputs were then compared to the values for the

5, 10, 25, 50 and 100 year return periods, calculated using ERA5 reanalysis data and observations from 1989 to 2018 (Hersbach *et al.*, 2020; Mercogliano *et al.*, 2021).

Using Storm *Ciara* as a pilot case study (a fluvial flood event from February 2020 which impacted North Wales, Yorkshire and Cumbria in the UK), the team produced a dynamic ‘proof of concept’ notebook developed in Julia using the Pluto package (Van der Plas *et al.*, 2022), which calculates the return periods and visualises the result in real time. A snapshot of the notebook showing the spatial return periods for the first forecast ensemble member is shown in Figure 6.

Following the hackathon, the team has continued to work with Aon to explore the concepts presented here. Further development of the visualisation tool will seek to demonstrate additional case studies, including comparison against observed losses. The team endeavour to expand the calculation of return periods using different data sources, for example the NASA Global Precipitation Measurement dataset (Skofronick-Jackson *et al.*, 2017), and hope to assess the sensitivity of return period calculations given different data and modelling assumptions.

Additionally, there are plans to address several related research questions. First, an exploration of the relationship between the return period of rainfall and insured losses to establish if the inclusion of hazard, impact, and vulnerability models would add significant value to insurers (as illustrated in Figure 6). Second, exploring how best to synthesise multiple ensemble members into relevant scenarios that are informed by the type of decisions made by insurers will hopefully offer promising results. Furthermore, investigating the use of nonstationary return periods under climate change is an exciting avenue for future work (Salas and Obeysekera, 2014).

Conclusions and feedback

This event enabled participants to develop their skillsets across exciting areas of research as well as expanding their professional networks. By bringing together a wide range of participants with diverse skillsets, the event has facilitated the beginning of new collaborative research with the MoJ and Aon. In addition to the positive feedback below, it is particularly encouraging that all teams presented in this article are continuing their collaboration with the MoJ and Aon, seeking to develop research papers and grant proposals.

‘This hackathon has enabled the Ministry of Justice to understand how applied climate science can provide insight on the social

angle of climate change adaptation. The research outputs have furthered the MoJ’s understanding of the connections between climate change, crime, and justice, and will better inform decisions on how best to research, manage and formulate responses’.

– **Charlotte Davenport, Climate Change Adaptation Manager, MoJ and HMPPS Climate Change and Sustainability Unit.**

‘The method and tool developed provided Aon a unique insight as to how return period estimations could be calculated and visualised, which will allow Aon to provide better estimations as to the severity of a natural hazard event as it is forecast. The climate projections-based population and urbanisation maps give Aon an invaluable opportunity to understand how future risk of European windstorms varies depending on changes in the hazard or changes in the exposure. Both challenges have provided Aon with a set of tools, data and methods that will help Aon and clients make better decisions’. – **Adrian Champion, Climate Research Lead UK & EMEA, Reinsurance Solutions, Aon.**

Author contributions

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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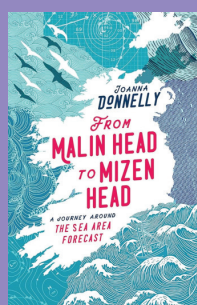
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Book review



From Malin Head to Mizen Head: A Journey Around the Sea Area Forecast

Joanna Donnelly
Gill Books, 2023
Hardback £21-99
244 pp.
ISBN 978-0-71-719736-1

The author of this interesting book (Joanna Donnelly) is a physical scientist who became a weather forecaster at Met Éireann. However, accurate weather forecasting is not just about the science but the art of communicating the message and she honed that skill whilst working as a broadcaster for Raidió Teilifís Éireann (RTÉ), Ireland's national broadcaster.

The Sea Area Forecast for the Island of Ireland is broadcast on RTÉ at 0600h and midnight and like the Shipping Forecast broadcast by the BBC it has become a favourite for listeners, with its strict but consistent

format, almost poetic in its unique language. It was established in 1859 following the sinking of The Royal Charter passenger ship in a dangerous storm off Anglesey. Donnelly uses The Sea Area Forecast as the basis of the book along with the complex topography of the most remote parts of the Irish coastline. The author explains its purpose best on the back cover when she writes '*Journey with me around our island's wildest and most remote headlands as I decode the mysterious language and patterns of the Sea Area Forecast*'. Each chapter is both a travel diary and a lesson in the weather as Donnelly explains the science behind weather forecasts in laymen's language. This is a unique skill, as I know from a career of nearly 40 years in the Met office, for it is difficult to keep it simple whilst maintaining the integrity of the meteorology. This she does well, along with naming and explaining some of the most notorious storms and weather events to affect the Island of Ireland; from the Spanish Armada sinking to the horrific Fastnet race of August 1979, she recalls maritime disasters and emphasises the potential perils of weather at sea to mariners. She describes how forecasts have improved greatly in accuracy from the early simple 'cone' storm warnings of Admiral Fitzroy to current methods using highly technical methods, no doubt saving many lives.

However, in her tour, she paints a clear and sometimes romantic picture of the

geography and topography of the headlands and lighthouses she sees along her route, as well as recalling the many tales (the local Irish lore) that often become folklore on this Emerald Isle. The main title of the book is *From Malin Head to Mizen Head* but in fact that is the way the crow would fly as it battles the strong prevailing southwesterly winds. However, she takes her tour in 5 chapters, clockwise (or anticlockwise) from Loop Head to the famous observing site of Valentia, via the equally vital Belmullet observing post, historically important as the oldest weather observation place in the country and the last observation on the Sea Area Forecast.

It is a well-written book and as the author says, probably most suited to amateur and professional weather forecasters. However, it may also be of interest to travellers with its insight into the history, scenery and in some cases life on the Island of Ireland. I certainly found it a very enjoyable and informative read. I would recommend it to those who may want to understand what is 'behind' a Sea Area Forecast whether for Ireland, or indeed other maritime parts of Northwest Europe.

Ewen McCallum

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