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Reflections on delivering place-based climate risk data in support of local adaptation decisions

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ABSTRACT

Strengthening the adaptive capacity of the UK, via national plans and local-scale interventions, requires easy access to climate risk information and adaptation scenarios. Stakeholder engagement can ensure the right balance between top-down prescriptive modelling, and bottom-up, solution-focussed and lived experience approaches. National-scale, spatially-explicit, integrated climate risk frameworks can help inform the needs of localised climate risk assessments, but there are barriers to local actors accessing the information.

1. Where we are

The first UK national assessment of climate change impacts was in 1991 (UK Climate Change Impacts Review Group, 1991). In 2008 the Climate Change Act established the requirement for a UK Climate Change Risk Assessment (CCRA) to be published by the Government every five years. The first UK CCRA (DEFRA, 2012) informed the National Adaptation Programme (NAP) in England (DEFRA, 2013) and equivalents for Scotland, Wales, and Northern Ireland. Another aspect of the Climate Change Act is the Adaptation Reporting Power (ARP) that requires statutory and infrastructure organisations to identify current and/or future climate risks and report the steps and actions they have in place to manage and adapt to these risks (DEFRA, 2011). Beneath these national level assessments, adaptation actions frequently need to be place-based rather than high-level and generic, and specific to the local conditions that set the context for local vulnerability (Dessai et al., 2024).

There is a disconnect between the national focus of past CCRAs and the need for evidence to inform place-based climate adaptation that addresses local vulnerabilities. Whilst the risk assessment method used for past CCRAs can successfully inform sub-national regions and cities, as demonstrated by the Climate Ready Clyde initiative (Climate Ready Clyde, 2019), to inform sub-national to local place-based action requires additional effort and resources.

Our perspectives are drawn from experience with the Open CLimate Impacts Modelling Framework (OpenCLIM), which was developed to demonstrate the benefits of integrated, consistent and spatially-explicit assessments of national-scale climate risks in advance of CCRA4, NAP4 and its equivalent for the devolved administrations. CCRA4 has since issued two calls for evidence and will draw widely from a variety of national and local sources. The benefits of presenting sets of risk indicators are that they can be

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meaningful to different end-users, provide information in understandable forms, and are often interpreted at a variety of scales (Bernie et al., 2024). Through our stakeholder engagement, we have found that, alongside complementary datasets such as (e.g. population data from the Office for National Statistics, ONS), the results are also wanted for evaluation of place-based climate risks to inform local adaptation planning, which is the scale at which the majority of adaptation needs are governed and implemented. In addition, OpenCLIM analyses have been coupled with other data to investigate climate change risks in rural Northern Ireland (Kennedy-Asser et al., 2024), across the Fens, (Jenkins et al., 2024), and in Norwich (Girling, 2022), illustrating the potential to underpin a more general local approach.

1.1. Stakeholder engagement

The process of engaging stakeholders in climate risk research enables better understanding of their questions, their data needs including preferred format and how they will use the data, and their technical, social and local contexts (André et al., 2023). Stakeholder engagement processes seek to balance institution-oriented (top-down, model-led) and community-oriented (bottom-up, experience-led) approaches. Analysis has revealed that where the right balance is found, co-produced projects with strong community involvement have increased effectiveness, efficiency, equity, flexibility, legitimacy, sustainability, and replicability (Sherman and Ford, 2014). This also requires a balance of influence and power dynamics between researchers and stakeholders (Bamzai-Dodson et al., 2024; Carney et al., 2009). However, this is often a challenge from a number of perspectives, including being able to engage the right people, and maintain engagement throughout what are often long-running projects (Perks et al., 2024). Through well crafted and implemented processes, research plans can be refined to ensure that outputs are appropriate for potential decision makers and other users. Key to support this will be early engagement to help co-develop strategies for data provision and ensure stakeholder needs are embedded from the outset (Harcourt and Hopkins-Bond, 2024; Jenkins, 2017). Although where diverse stakeholders (e.g. geographically, sectorally) have different information or data needs, some compromise, trade-off, or multiple data sharing formats, may be required (André et al., 2023).

1.2. Data sharing

Previous UK national climate risk assessments (CCRA 1–3) have not been spatially explicit, with hazards and risks synthesised from literature and tabulated. CCRA4 will be the first to include evaluation of climate risk maps and other spatial data. OpenCLIM was conceived as a pilot study for CCRA4 to develop a method to produce consistent spatially-explicit, national climate risk maps, representing different scenarios of climate hazard, socioeconomic vulnerability, and exposure (Fig. 1). The target audience for these results included the Climate Change Committee (CCC), devolved administrations, government departments, infrastructure operators, academics, researchers, and consultants. These users were anticipated to be familiar with climate risk information, including using spatial data files. On this basis, the Data and Analytics Facility for National Infrastructure (DAFNI), which is a computational platform for systems research (Matthews et al., 2023), was chosen to host OpenCLIM in order to (i) facilitate consistency among different models; (ii) enable easier expansion and scalability of models and sectors for future model development, e.g. during CCRA4; and (iii) provide an accessible legacy where results would be available, avoiding maintenance of a bespoke database or data sharing tool after the project funding expired.

However, numerous local stakeholders showed interest in using OpenCLIM results in regional climate change risk assessments, alongside comparable projects, complementary data and local evidence, including lived experience. Despite being national in scale, the results can offer suitable spatial resolution (the majority are 1 km grids) to support local actors to assess climate risks in a consistent manner, and at a resolution appropriate for local adaptation (England et al., 2024).

In contrast to national-scale climate risk modellers, many local users lack some capacity to access or utilise spatial data files hosted on a technical database (e.g. DAFNI or the Centre for Environmental Data Analysis, CEDA). Results need to be intuitive and shareable without requiring technical understanding of data formats, or use of complex, bespoke software tools. Some local authorities have expressed a preference for standard desktop formats, such as powerpoint slides, PDF reports or web-hosted maps. To address some of the barriers local users faced accessing results, the project has now developed GIS-based risk reports, and visualisations (Fig. 2) to share results tailored to regional and place-based organisations and make them available online. Work continues with knowledge exchange and capacity building planned via the Maximising UK Adaptation to Climate Change (MACC) Hub.[1]

Done well and rigorously user-tested, data visualisation tools and dashboards are powerful methods of communicating climate services to broad audiences (Kause et al., 2020; Lu et al., 2022; Morelli et al., 2021; Neset et al., 2020; Opach et al., 2020; Perks et al., 2024) and for making data available to be re-applied by users to their locations and contexts. These tools must leverage nuance and understanding from disciplines including psychology, cognition, communication, sociology, geography, politics, and others, in order to effectively communicate with publics and decision makers (Harold et al., 2016; Howarth et al., 2020). The relative merits of decision support tools and systems were only minimally evaluated in CCRA3 (Betts et al., 2021) and could be explored in greater detail in CCRA4 to support stakeholder use in adaptation planning (Watkiss et al., 2015), among other functions, as a research literature exists (Jenkins, 2017).

Table 1 lists some representative examples where climate risk or impact information has been shared previously to meet varying

[1] The Maximising UK Adaptation to Climate Change Hub is a 3 year program funded by the UK Research & Innovation (UKRI) and the Department for Environment, Food and Rural Affairs (DEFRA), led by King's College London.

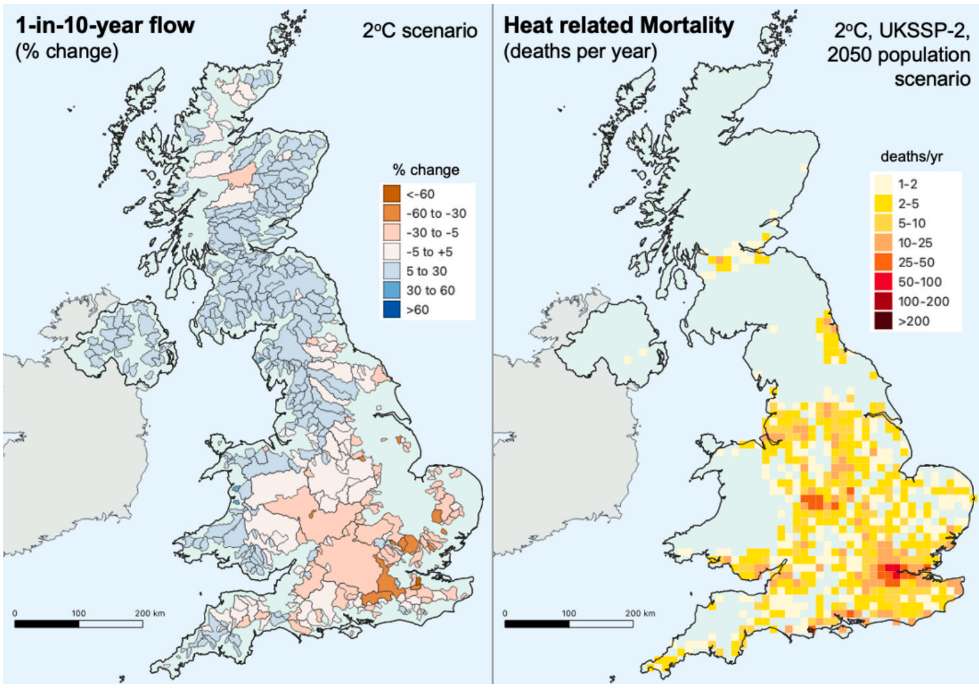

Fig. 1. Example national-scale climate risk map for (left) projected heat-related mortality (deaths per year), scenario shown is 2°C warming with UK Shared Socioeconomic Pathway 2 (UKSSP2) and 2050 population; and (right) projected % change from baseline in catchment river flows for the 1-in-10-year return-period flow (an event with a 10% annual probability) for 2°C warming scenario. Unshaded areas represent zero heat related mortality, or areas where river catchment is not modelled, respectively.

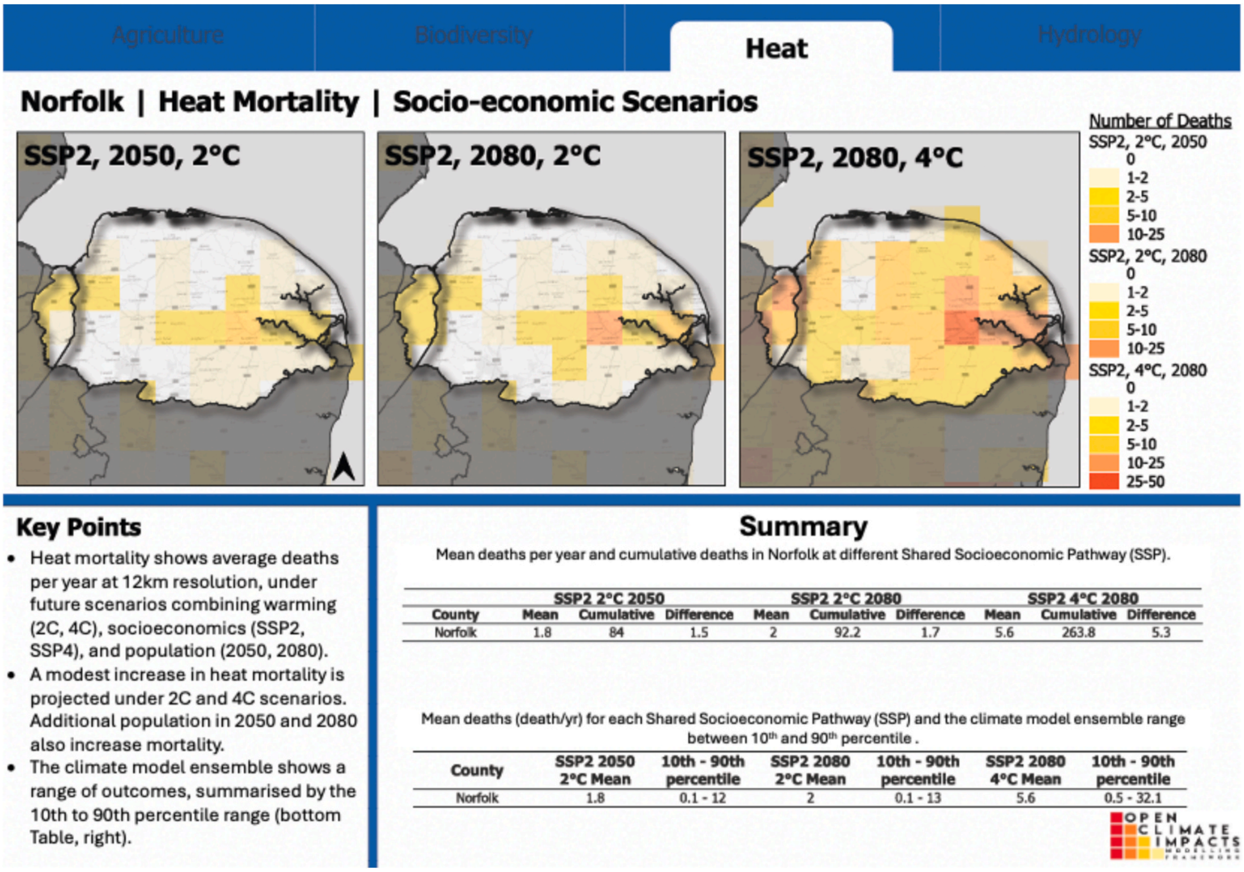

Fig. 2. Exemplar local-scale climate risk report for heat mortality in Norfolk, showing UK Shared Socioeconomic Pathway 2 (UK-SSP2) scenarios of warming and population change. Further examples can accessed at openclim.science.

Table 1
Illustrative examples of existing climate risk assessments, data sharing tools, dashboards and decision support systems, sorted alphabetically. Table is indicative and not exhaustive.

Name	Function, context	Active
CLIMADA	Global weather and climate risk assessment platform (Riedel et al., 2024). https://wcr.ethz.ch/research/climada.html.	Yes
Climate Change Impacts Tool	River flood peaks in Great Britain data dashboard (Kay et al., 2021). https://eip.ceh.ac.uk/hydrology/cc-impacts/.	Yes
Climate Impact Explorer	Global climate change impacts over time in continents, countries and provinces, at different levels of warming. https://climate-impact-explorer.climateanalytics.org/.	Yes
Climate Just Maps	Neighbourhood-scale climate vulnerability and disadvantage dashboard (Kennedy-Asser et al., 2022; Lindley et al., 2011). https://www.climatejust.org.uk/map.html.	Yes
CLIMSAVE	European Integrated Assessment Platform (Harrison et al., 2015). https://oppla.eu/product/1915.	No
IMPACT2C	European climate change impacts dashboard at + 2C warming. https://www.atlas.impact2c.eu/en/	No
IMPRESSIONS	European Impacts of high-end climate change scenarios (Harrison et al., 2019). http://impressions-project.eu/.	No
London Climate Risk Maps	Local climate and socioeconomic risk dashboard. https://cityhall.maps.arcgis.com/apps/instant/media/index.html?appid=59236d2e842c4a3ba6480d9dac585d1e.	Yes
Met Office Climate Data Portal	Access to UK climate observations & projections, UK Shared Socioeconomic Pathways (SSP). https://climatedataportal.metoffice.gov.uk/.	Yes
National Trust Climate Hazards	UK climate hazard dashboard & data portal. https://experience.arcgis.com/experience/0295557a52b5446595fc4ba6a97161bb.	Yes
PROVIDE	Global dashboard to explore future climate change impacts and (un)avoidable risks from cities to the global scale. https://climate-risk-dashboard.climateanalytics.org/.	Yes
Regional Impact Simulator (RegIS) and (RegIS2).	Impact Assessment of climate and socio-economic change in two case study areas in England (Holman et al., 2005, 2008; Holman and Harman, 2008).	No
UK Climate Risk Indicator (CRI)	UK climate risk indicator dashboard (Arnell et al., 2021). https://uk-cri.org/.	Yes

objectives. Some examples assume a level of prior understanding of technical language and scenario names, or utilise different input data, or focus on different sectors and vary in geographic or temporal extent. This can be confusing for stakeholders, increase the time to access all relevant data, increase the chance that a certain data portal is not identified in the evidence gathering stage, or prove a barrier to use altogether. Further examples focus on climate change projections (e.g. mean surface temperature) rather than climate risk metrics (e.g. heat-related mortality), or may lack vulnerability assessment. Others provide a limited number of risk sectors, such as flood and heat only. Additional examples were published after the funding call for national, spatially explicit climate risk assessment was released, meaning at that time, there was a research gap. Consequently, it isuncertain how easily these climate services projects are used by stakeholders to facilitate high-quality decision making (Dilling and Lemos, 2011; Findlater et al., 2021; Lemos et al., 2012). An earlier review of projects providing data and visualisation tools on adaptation to changes in the built environment and infrastructure, found that a key barrier to uptake was the way in which data and tools had been presented by researchers (Jenkins, 2017). This hindered the accessibility for stakeholders and the potential for stakeholders to easily use tools and outputs within their own reports.

Support for a national, integrated and intuitive digital portal that can host complementary datasets and research outputs from across the climate risk community, including present and future exposure and vulnerability data, will facilitate a more informed evaluation of future risk, to support stakeholder knowledge needs (Bernie et al., 2024).

2. Further development

The OpenCLIM project has enabled consistent climate and socioeconomic scenarios to be applied to different climate risk sectors to quantify spatially explicit impacts throughout the UK. The high spatial resolution of climate hazards and downscaling of UK Shared Socioeconomic Pathways (UK-SSPs) to local authority district scale (LAD), allows additional local information to be integrated by a range of local stakeholders, e.g. local authorities, water resource zone managers, or infrastructure operators.

Further development and improvement of tools for providing information to non-climate modelling audiences remains vital to ensure the information can be optimally used by organisations planning climate adaptation interventions. This includes iterative co-production with and testing by stakeholders (Dilling and Lemos, 2011) to ensure a balance between top-down modelling and bottom-up impact assessment capturing local knowledge and lived experience (Sherman and Ford, 2014). This would ensure the design of the tool is demand-driven, intuitive for end-users and the information within supports high quality decision making (Findlater et al., 2021; Hewitt et al., 2017; WMO, 2018), and builds stakeholder buy-in to use the evidence generated through the project, which is vital in both local and national climate initiatives (Howarth et al., 2021). Interdisciplinarity, defined here as working across sectoral boundaries, has increased the quality of climate research (Jenkins, 2017). Embracing interdisciplinarity in the design and development of tools for data delivery and sharing will further enhance the potential impact and utilisation of research outputs.

Maps delivered via digital platforms allow a coherent and dynamic evidence base to evolve, progressing away from the cyclical production of written evidence reports. National and sub-national assessments based on shared evidence potentially optimise efficiency, reduce duplication of effort and ensure that the best available evidence is freely accessible for all. Future approaches to developing the UK CCRA should consider the needs of sub-national, place-based stakeholders across scales. The responsibility for addressing many ‘national risks’ spans national, devolved, regional and local scales and the data each CCRA develops can greatly facilitate place-based action if made available.

The growing demand for climate services to translate technical information into actionable science (Beier et al., 2017; Sun, 2023) is at the heart of the call for co-produced and professionally developed web-based data visualisation tools (Reiter et al., 2019). Minimising usability gaps relating to the validity, readability, and interactivity of a climate service or tool, is also key (Raaphorst et al., 2020). Beyond this, capacity building support, knowledge exchange and information brokering are key elements that will assist local decision makers (Dilling and Lemos, 2011). From our experience, groups such as the climate change charity Verture (formerly Sniffer), and Sustainability West Midlands, can facilitate co-design processes, helping form multidisciplinary groups of researchers, policy makers and practitioners to ensure climate risk assessments are decision relevant. The sustained presence of such organisations to provide this support is vital to advancing more effective adaptation, as individual projects are often unable to support stakeholders after the funding period ends (Reiter et al., 2019). The MACC Hub can assist in the provision of this role, but mechanisms to ensure this role is sustained are required beyond the life of this one project.

The continual development of new data portals and web-based interactive tools may be misplaced. It is timely for the climate risk community and funding agencies to consider whether a nationally coordinated and maintained data visualisation infrastructure would be more cost effective. The curation of data through an authoritative organisation, where data could be hosted or imported as updates are made to an openly accessible platform would be a valuable community resource (Bernie et al., 2024). While within the UK data archiving and sharing is facilitated by systems such as DAFNI or CEDA, the visualisation of these data is not fulfilled currently. Public-private sector partnerships could unlock additional skills and technologies in support and nurture a new generation of users. For example, leveraging existing GIS technologies can aid data visualisation of maps and other spatial data. Data visualisation would be an extremely valuable function to include within the scope of the new UK National Data Library, proposed prior to the 2024 general election, and included in a recent Government Policy Paper (UK Government, 2025).

Future research projects could call on these resources to add elements of their research to an existing digital interface, hosting a suite of legacy results. This could be supported by a sustained and suitably resourced Adaptation Hub for instance, under the mandate of facilitating national and local transformational climate adaptation.

3. Conclusions

National climate risk assessments made available in an accessible, spatially explicit form, can also support a myriad of sub-national, place-based adaptation decisions. Our experience with national assessment via the OpenCLIM project highlights the importance of making available climate risk maps of suitable scale, resolution and format to be both useful to, and re-usable by, local place-based stakeholders, in their work. For example, LAD-scale maps are particularly useful for visualising local context and community perspectives. These steps begin to address the challenge that the capacity to model climate risks, impacts, and adaptation responses outstrips capacity to communicate and share this information in a decision relevant, usable format (Hewitt et al., 2017). Applying science communication research into climate risk mapping and other cognitive insights further contributes to usability (Fairbairn and Hepburn, 2023).

Whilst OpenCLIM is the latest project to demonstrate the potential to provide a coherent multi-scale (national to local) evidence base to inform adaptation, barriers to use were identified through regional case studies via consultation with stakeholders. Feedback focused on the challenges of using complex data sharing databases to access sub-national information at useful scales.

Stakeholder co-production and user testing are vital steps in achieving a balance between top-down and bottom-up approaches that ensure results are demand-driven and continue to be used. Adaptation requires local implementation, which must be sensitive to specific contexts, which national-scale cannot. Care must be taken to support local solutions via consultation and co-production, which is not simply downscaling a national scenario to a local fit. However, national scenarios are the appropriate baseline from which local analysis can be derived and modified.

A nationally maintained, coordinated, and updated, web-based data visualisation facility will aid in the delivery of research results to inform place-based adaptation needs, as well as collect examples of implemented adaptation. This could be a beneficial addition to the UK National Data Library, under development by the Government. As adaptation becomes ever more essential to the UK economy, infrastructure, and wellbeing, we recommend from our pilot project the considerable need for co-produced and user-tested climate risk datasets, risk assessments, and decision support tools, in line with open science principles. These lessons are probably applicable more widely than the UK.

CRediT authorship contribution statement

Adam J.P. Smith: Writing – review & editing, Writing – original draft, Conceptualization. **Asher Minns:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Robert J. Nicholls:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Anna Beswick:** Writing – original draft, Conceptualization. **Katie Jenkins:** Writing – review & editing, Funding acquisition. **Sandy Avrutin:** Writing – original draft. **Craig Robson:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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