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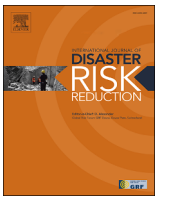

The implications of climate change for emergency planning

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ABSTRACT

Heatwaves, droughts and wildfires in 2022 raised questions about how prepared the UK is for extreme events and how they might become more frequent in the future. This paper reviews the implications of climate change for current emergency planning, and for emergency planning as an adaptation to climate change, using the UK as an example. There are seven key implications for current operational emergency planning: risk assessment needs to consider a broader range of events and changing likelihoods, a long-term perspective is necessary, response capabilities may need to be enhanced, some types of events will become less frequent but will not be eliminated, training and exercises need to consider novel events, public engagement and messaging needs to be revised to reflect increased severity of events, and improving resilience is necessary to reduce the need for emergency response. Many organisations include emergency planning as part of their climate change adaptation toolkit. However, relying on current or enhanced emergency planning procedures is unlikely to be a sufficient adaptation to a changing climate. Improved resilience in some sectors will reduce the need for emergency planning and response, but it will not be feasible to improve resilience everywhere: the focus for emergency planning is therefore likely to evolve to reflect diverging impacts of climate change in and between communities. Achieving a balance between measures to increase resilience and measures to manage events requires a discussion on appropriate standards for resilience and definitions of 'emergency'. Improving the coordination between emergency planning and climate change adaptation is essential to reduce current and future risks.

1. Introduction

In July 2022 the UK, along with other European countries, experienced an unprecedented heatwave. Temperatures broke records in many regions. The Met Office issued its highest 'red' warning, health services were put on the highest alert level, and the government declared a 'national emergency'. There were over 3000 excess deaths during the five periods with the most extreme heat [1]. Rail companies introduced speed restrictions and cancelled services, and the London Fire Brigade had its busiest day since the Second World War dealing with many wildfires: fire services in many other regions declared 'major incidents'. Two themes rapidly emerged in the media and in political discourse: how prepared is the UK for extreme events, and what effect is climate change having on risks and preparations?

Emergency planning [2] is the component of disaster risk reduction dealing specifically with preparing for events and immediate recovery from them. For some types of environmental hazards – for example floods, droughts and erosion – it is often possible to reduce the exposure and vulnerability of people and property through structural defence measures, spatial planning and building codes, but for others – heat, cold and storms – exposure and vulnerability can really only be reduced through codes, standards and measures

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to support recovery. The relative importance of emergency planning to overall disaster risk reduction therefore varies between hazards.

Climate change is increasingly cited as a driver increasing the chance of extreme events [3]. The European Union called in March 2022 for the further adaptation of civil protection systems to the consequences of climate change [4], but did not specify in detail how the systems should be adapted. Studies have identified governance challenges in incorporating climate change into emergency planning (e.g. Refs. [5–7], and Shaw & Maythorne [8] outlined how the concept of resilience provided an opportunity to link the two. Pescaroli [9] reported how emergency planners in London expected climate change to increase the frequency of cascading events. However, in practice emergency planning in the UK has so far rarely explicitly considered climate change, and climate change adaptation plans have rarely considered the role of emergency planning.

The UK's National Risk Register of Civil Emergencies [10] mentions climate change whilst describing long-term trends but explicitly focuses on risks that could occur in the next two years. In December 2021 the House of Lords Select Committee on Risk Assessment and Risk Planning [11] concluded that the current system in the UK was deficient at assessing and addressing future threats and hazards, and specifically highlighted the increasing risks posed by climate change. It concluded that 'risk assessment cannot be conducted without acknowledging this fact' (p13). Another parliamentary report in October 2022 concluded that insufficient attention was being paid in government to making critical national infrastructure resilient to increasing numbers of extreme events [12].

The Technical Report for the Third Climate Change Risk Assessment (CCRA3 [13]) for the UK assessed 61 risks to specific sectors or activities following extensive consultation with stakeholders – but the list does not specifically include risks to emergency planning. The current National Adaptation Programme (NAP2 [14]) for England has the objective of 'ensuring that emergency and local services are best prepared for extreme weather events', but neither of the two specific actions actually mentions climate change (one is on communicating risks and the other on developing community resilience policy). The Scottish adaptation programme [15] notes that flood forecasting 'will be increasingly important as climate changes' but has no specific policies to address how climate change might affect emergency planning.

This paper summarises the implications of climate change for the occurrence of emergency events in the United Kingdom, and implications for both emergency planning as an operational activity and as a component of adaptation to climate change. The focus is specifically on emergency planning for weather-related events. "Emergency planning" is here interpreted broadly to include planning to deal with exceptional events and operational plans dealing with more frequent adverse weather conditions. The paper does not consider the recovery phase of emergency management, or actions actually taken during an emergency. The paper is based on a review of published reports and papers, and informed by (unstructured) discussions with individual actors in many organisations involved in emergency planning and climate change adaptation. The focus is on the UK, but the implications of climate change for emergency planning are of more general relevance. First, it is necessary to review arrangements for emergency planning and climate change adaptation in the UK because the institutional context is important in understanding how emergency planning, disaster risk reduction and climate change adaptation are related.

2. The institutional context: emergency planning and climate change adaptation in the UK

2.1. Emergency planning

The overall structure of emergency planning and management in the UK is currently (October 2022) defined through the Civil Contingencies Act 2004 [16], which gave governments and local authorities powers and duties to prepare for civil emergencies (broadly defined as events or situations which threaten serious damage to human welfare or the environment somewhere in the UK). The Act established groups (termed Local Resilience Forums in England and Wales, Local and Regional Resilience Partnerships in Scotland and Emergency Preparedness Groups in Northern Ireland – called generically 'Resilience Partnerships' here) to coordinate action by organisations providing public services within an area. These are mostly based on police force boundaries, and whilst they have statutory responsibilities, they are not legal entities so rely on voluntary cooperation. The Act created Category 1 and Category 2 responders with duties to plan and prepare for emergencies. Category 1 responders are local authorities, emergency services and environment agencies, and Category 2 responders are providers and operators of services: most of these are private sector organisations. The institutional arrangements are slightly different in Northern Ireland, but the principles are the same. The Civil Contingencies Act embodies an 'all-hazards' approach to civil protection and the management of civil emergencies, which treats environmental hazards, accidents and malicious threats together.

Emergency planning and management operates at different institutional levels in the UK. High level *planning* – identifying national-scale risks and defining national capabilities and standards - is undertaken at the national level, and this high level planning informs assessments and plans made by Resilience Partnerships at the local scale. In contrast, the primary responsibility for *managing* lies at the local level with larger emergencies involve increasing levels of central government involvement. The central government Concept of Operations [17] defines three level of emergency involving central government involvement. Level 1 involves input from a specific lead government department (varying depending on the emergency), Level 2 involves central government coordination across departments, and Level 3 requires central government leadership and direction. Level 2 emergencies require the establishment of a COBR committee to coordinate departments and agencies. The 'national' emergency declared in July 2022 was the first time Level 3 was reached. Unlike in some other countries, the declaration of an 'emergency' does not give local or national governments any additional powers. Before, during and after an event public authorities have no legal powers of compulsion over people or organisations (apart from Category 1 and 2 responders), so cannot for example force people to evacuate.

Emergency planning and management in the UK follows the concept of Integrated Emergency Management (IEM), which has six steps in a cycle: anticipation, assessment, prevention, preparation [18], response and recovery [19]. 'Prevention' focuses on measures

taken to seek to prevent an emergency which is about to happen, and does not cover measures taken well in advance to reduce risks. A core principle of IEM is to plan for consequences rather than for events, recognising that whilst it is not feasible to identify all potential types of emergencies it is possible to identify a series of common consequences and therefore common actions or capabilities.

The assessment stage in IEM is therefore primarily designed to determine what capabilities are needed at the local and national scales to deal with all types of emergencies, rather than provide a comprehensive review of all potential types of hazard. The UK National Security Risk Assessment (NSRA) is the national-scale assessment of the likelihood and magnitude of hazards and the required capabilities, and is confidential within government. The public National Risk Register [10] lists key risks. Resilience Partnerships produce their own assessments and publish Community Risk Registers. These are typically based on the national assessment, but many include risks that are particularly relevant at the local scale (some Resilience Partnerships, for example, identify groundwater flooding as a risk). Scotland also produces a National Risk Assessment.

At the operational level, individual organisations have 'severe weather plans', under various names. These are required of Category 1 and 2 responders under the Civil Contingencies Act and are also required of infrastructure operators by regulators. The National Health Service in England, for example, has both a heatwave [20] and a cold weather plan [21]. Network Rail – the public body managing the railway network - has procedures in place to alter punctuality standards during 'adverse' or 'challenging' weather, and plans to reduce services and speeds during periods of extreme temperature. Water supply companies in England have Drought Management Plans, and gas and electricity distribution companies have plans to deal with extreme weather events. Public sector organisations often implement emergency plans by defining a 'critical incident'.

These severe weather or emergency plans are typically implemented once conditions are forecast to exceed some trigger threshold, so forecasting and warning services are central to emergency planning. The Meteorological Office (Met Office) National Severe Weather Warning Service (NSWWS [22]) produces forecasts up to seven days ahead for severe rain, thunderstorms, wind, snow, lightning, ice, fog and, since 2021, high temperature. Warnings are classified into yellow, amber and red based on both the likelihood of an event occurring and its potential magnitude. The magnitude categories are typically based on challenges posed to emergency responders. The Natural Hazards Partnership Daily Hazard Assessment [23] forecasts 12 hazards up to five days ahead, providing the forecasts to emergency responders. Since 2015 potentially severe storms have been given names in order to help in communications. River and coastal flood forecasting is undertaken in collaboration between the Met Office and the Environment Agency, Scottish Environmental Protection Agency and Natural Resources Wales, and again uses a risk-based categorisation based on likelihood and magnitude. The NHS heatwave and cold weather plans in England are based on tailored warnings of extreme high or low temperatures. The triggers for severe weather and emergency plans vary considerably between organisations. Some may be activated several times a year (for example plans to deal with adverse operating conditions on railways, roads and airports), whilst others may be activated only in exceptional circumstances. Experience during the summer of 2022 suggested that plans may not be adequate to deal with extreme circumstances. For example, the number of (concurrent) wildfires significantly stressed fire and rescue services, and several data centres were forced to close because temperatures exceeded design thresholds and no high temperature plans had been produced.

The details of these arrangements have evolved over time, largely in response to failings during individual events and often following formal reviews and investigations (e.g. Refs. [24–28]). Common themes from these reviews include the need to have plans in place before events and the capacity to deal with events and their consequences, the importance of coordination between different organisations, and the large effects of 'cascading' risks where impacts on one organisation impact upon another. The review of the effects of storms Arwen and Eunice in 2021 and 2022 pointed out that the events exceeded planning assumptions [28], and both the London Flood Review [27] and the overall review for the highway sector [26] noted that emergencies are likely to occur more frequently in the future. A review of heatwave planning in NHS England [29] concluded that the thresholds used to trigger levels of preparedness were too high, and that there was a lack of awareness of actions to take both in the health service and in the general public. It also concluded that heatwave planning was seen as an exercise in emergency preparedness rather than as a component of long-term strategic public health planning. A review of Multi-Agency Flood Plans [30] concluded that Local Resilience Forums were likely to be able to cope with small and moderate floods, but not with very large scale, widespread and enduring flood incidents.

A more wide-ranging review of emergency planning procedures in the UK was conducted by a House of Lords Select Committee in 2020–2021 [11], largely prompted by the COVID-19 crisis. This highlighted an over-reliance on a top-down approach to planning, a tendency to be reactive rather than proactive in identifying risks, a lack of communication and accountability (the full NSRA is confidential within government), increasing burdens on Resilience Partnerships, and a risk assessment process that did not provide an adequate basis for risk planning. As mentioned in the introduction, the review also noted that "many of the risks facing the UK are likely to increase both in magnitude and frequency as a result of climate change, and risk assessment cannot be conducted without acknowledging this fact". The National Preparedness Commission – a non-governmental organisation, not a government body – conducted an independent review of the 2004 Civil Contingencies Act in 2022, and amongst its recommendations [31] concluded that a revised act should better integrate risk reduction with emergency response and take a longer-term perspective.

There are other critiques too of emergency management, including of the effectiveness and resourcing of Resilience Partnerships, of the way that volunteer organisations are incorporated, of the disconnect between emergency planners (very influenced from the top down) and emergency managers, the lack of resources and priority given to preparing for emergencies, the lack of visibility of the National Risk Register [32] and of the lack of a regional scale to coordinate neighbouring Resilience Partnerships. Whilst these critiques do not affect the implications of climate change for emergency planning, they do affect how these implications are addressed.

2.2. Climate change adaptation

The Climate Change Act 2008 places a duty on government to adapt to climate change through developing National Adaptation Programmes for the four nations of the UK (adaptation is a devolved matter). These programmes set out specific government actions to support adaptation and follow a Climate Change Risk Assessment. The Third Climate Change Risk Assessment (CCRA3) was completed in 2022 [33,34] and the third round of National Adaptation Programmes are scheduled to follow in 2023.

The climate change adaptation actions in the second round NAPs focus on increasing resilience through structural defences, spatial planning measures, and building codes and infrastructure standards. In principle, adaptation to climate change is therefore embedded in disaster risk reduction as broadly defined, although in practice the extent to which climate change adaptation is incorporated varies considerably across sectors. In 2019, the Climate Change Committee [35] produced a critical assessment of the English National Adaptation Programme, concluding that it was not sufficiently ambitious, there were some key gaps, and that the priority given in government to adaptation had reduced over time. Emergency planning is mentioned in the second round English and Scottish National Adaptation Programmes – although without any specific actions – but is not discussed in the National Adaptation Programmes for Wales or Northern Ireland.

The Climate Change Act 2008 also gives the Secretary of State for the Environment powers to require organisations providing public services or infrastructure to produce reports describing how they plan to adapt to climate change. These are known as Adaptation Reporting Powers and apply to organisations providing services in England along with organisations providing some specific services in Scotland and Wales: there are no powers to require organisations operating in Northern Ireland to report. The reports provide a source of evidence on what organisations providing public services and infrastructure are actually doing to adapt to climate change.

Many of the organisations submitting their 3rd round adaptation reports highlight their emergency planning and some explicitly state that climate change has increased pressures on emergency planning. Some (e.g. Refs. [36–38] state that their emergency planning procedures are sufficient to deal with expected extremes in a changing climate. Others have specific plans to alter their emergency planning processes because of climate change. SP Energy Networks [39] and Cardiff Airport [40] are reviewing the capacity of their systems and emergency equipment, and the Forestry Commission [41] is developing emergency procedures to deal with wildfire. The Environment Agency [42] is reviewing and revising its Incident Management System and standardising its messaging around extreme events and climate change.

3. Implications of climate change for emergency events

As indicated above, several reports have indicated that climate change will increase the frequency of events above some defined threshold and the magnitude of events with a defined frequency, but climate change also may generate novel events that have not so far been experienced in the UK and, at the same time, reduce the frequency of some types of event.

Emergency planning is typically concerned with the near term, looking forward at most a few years. This is partly because it is largely an operational activity, and partly because plans are intended to be updated and reviewed frequently. From this perspective, the effects of climate change over the recent past and the near future are most relevant: they affect perceptions of the changing nature of emergencies and influence operational planning. However, a longer-term perspective is relevant when considering the longer-term development of capabilities to respond to events and assessing emergency planning as a component of adaptation to climate change.

This section concentrates on the potential effects of climate change on emergency events over the recent past and the next 20 years – to the 2040s – because the primary focus of the analysis is on emergency planning rather than climate change adaptation. Over this time scale, the increase in global average temperature will be largely determined by past emissions of greenhouse gases and the changes in weather and climate are therefore committed. Over the longer time scale, future changes in climate will depend on progress towards reducing emissions, so there is more difference between the 2 °C and 4 °C worlds increasingly recommended to be considered in adaptation planning [33]. At the risk of oversimplification, the impacts of climate change on emergency events will generally stabilise over time in a 2 °C world – with the notable exception of those generated by higher sea levels - but continue to increase in a 4 °C world [43]. Changes to extreme events become increasingly likely at higher levels of emissions.

Whilst there is clear evidence that average temperatures and average sea level around the UK have increased over the last few years [44], there is mixed evidence on whether the extremes that trigger emergencies have changed. It is not feasible to look for trends in the number of alerts, warnings or named storms, partly because records do not extend back more than a few years, and partly because procedures and criteria have changed over time. It is therefore necessary to infer trends in emergency events from meteorological and hydrological data, using where appropriate thresholds currently used in emergency planning.

The number of extreme daily rainfall events above specific totals has increased since the 1960s, there have been fewer days with temperatures below freezing [44], and the chance of experiencing high temperatures has increased [45–47]. However, there is very strong year-to-year variability, particularly for river floods [48] and windstorms [44] but also for heatwaves [49,50], related to variability in the atmospheric circulation patterns that typically generate extreme weather in the UK. Whilst individual events cannot be directly attributed to climate change, a number of studies have demonstrated that events similar to recent hot and wet extremes are much more likely now than they would have been with no increase in greenhouse gas concentrations (e.g. Refs. [51–53]). Zachariah et al. [54] concluded that, without climate change, the temperatures in excess of 40 °C seen in July 2022 would have been extremely unlikely.

Fig. 1 summarises a range of indicators of extreme events relevant to emergency planning between 1961 and 2021 by nation of the UK, using thresholds and criteria in place in 2020 (see Table 1) and calculating indicators using the HadUK-Grid data base [55]. It also plots projected 30-year mean values to 2040, based on UKCP18 [45] climate projections (see Refs. [43,50] for more details). The strong year to year variability in some of the indicators is clear, as is the strong variability across the UK: there is also,

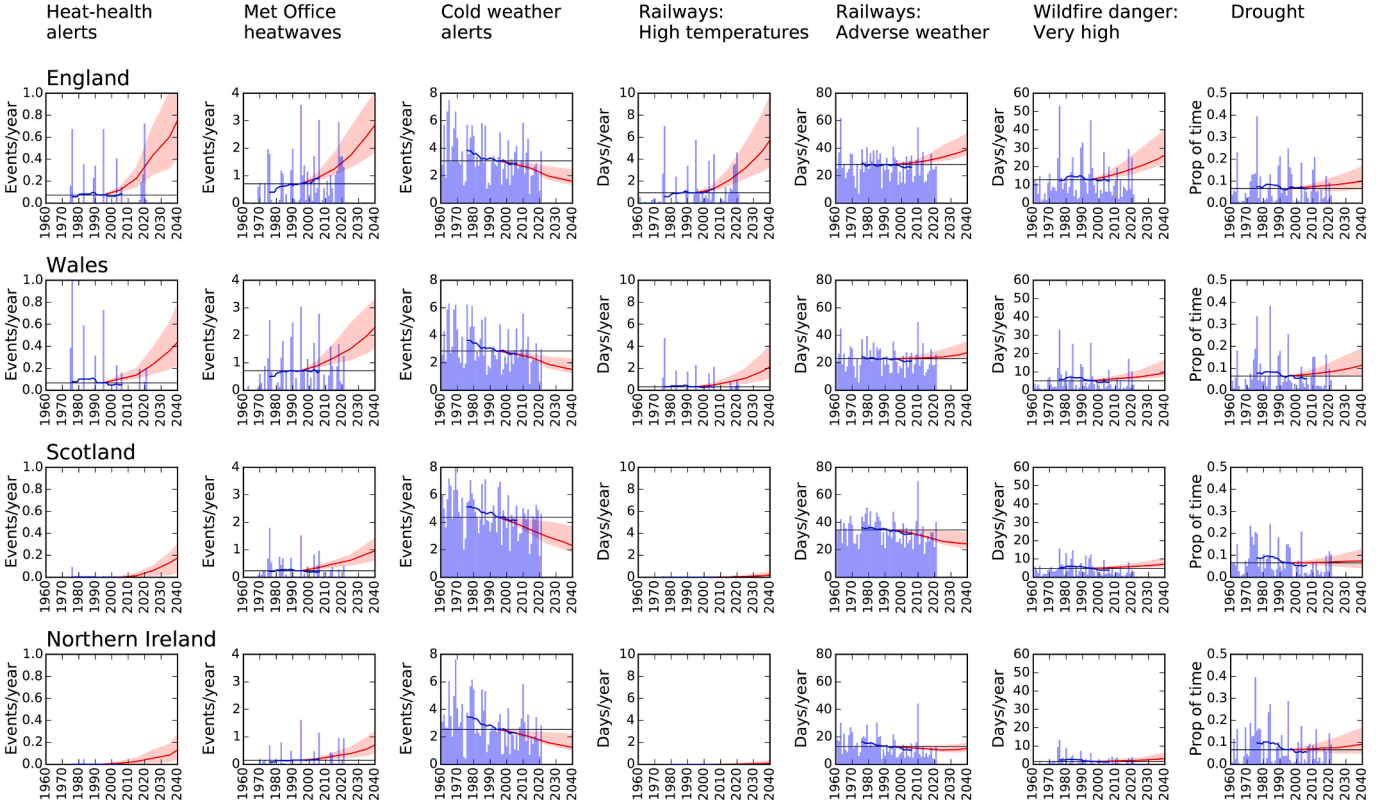

Fig. 1. Observed and projected extreme events by nation of the UK. The plots show observed values (as calculated from observed weather data [55]) between 1961 and 2021, running 30-year means, and projected 30-year means to 2040. The 30-year means are plotted at the middle year of the 30-year time period. The projected changes are based on the UKCP18 global strand HadGEM ensemble, with very high RCP8.5 emissions. See Table 1 and Arnell et al. [43] for details of indicators and methods.

Table 1
Summary of the indicators in Fig. 1. See arnell et al. [43] For details and references

Heat-health alerts	Number of events triggering National Health Service (NHS) heat-health alerts
Met Office heatwaves	Number of events exceeding Met Office heatwave thresholds
Cold weather alerts	Number of events triggering NHS cold weather alerts
Railways: high temperatures	Number of days with maximum temperatures greater than 30 °C: these lead to speed restrictions on railways
Railways: adverse weather	Number of days with 'adverse weather' on the railway network, when service standards are relaxed
Wildfire danger	Number of days with Met Office Fire Severity Index at 'very high'
Drought	Proportion of time when rainfall deficits, as represented by the Standardised Precipitation Index (SPI) are in 'severe drought'

See arnell et al. [43] For details and references

of course, considerable variability within each nation. The projections show large increases in the mean number of extreme events – with one exception discussed below – and of course in any one year the number of events could be considerably greater than the long-term mean. Whilst the observed trends are consistent with projections for some of the indicators – for example heatwaves – for others they are not. This reflects the high year-to-year variability, and also suggests that past trends are not necessarily a good guide to the frequency of events in the future.

The exception to the general trend in Fig. 1 is the frequency of cold weather alerts. These have shown a decreasing trend (although 2021 had a large number) and are projected to decrease into the future, but they are still highly likely to occur.

Fig. 1 does not show past and projected extreme rainfalls, floods or windstorms. The number of extreme short-duration rainfall events is highly likely to increase into the future [56], as is the frequency of river flooding exceeding specific levels, particularly in the north and west of the UK [57,58]. There is also evidence that storms bringing intense rain might move more slowly with climate change [59], increasing further the amount of rain which falls on a place. Higher sea levels increase the risk of coastal flooding, although actual changes in coastal flood frequency will be strongly determined by changes in the number and direction of storms. Such changes are currently uncertain, but it is likely that not only the number of intense windstorms but also the chance of clustering of storms will increase [60]. The chance of windstorms developing sting jets – areas of very high wind speeds – is also likely to increase in the future [61].

Fig. 1 also does not show changes in the magnitude and duration of events in the future: the indicators are based on specific absolute thresholds. Peak temperatures during heatwaves are likely to increase [62], and the duration above fixed thresholds will increase [50]. The magnitude of the 20-year flood may increase by up to 30% over the period 2010–2039 (relative to 1961–1990 [58]), and similar increases are plausible for the less frequent floods that are used as the basis for the design of flood defences.

Climate change can also plausibly lead to the occurrence of extreme events currently not experienced in the UK. A small proportion of the storms which affect the UK and northern Europe originate in Atlantic Tropical Cyclones, and these typically are the windiest and most intense storms [63]. These storms change character as they cross the Atlantic, so whilst they are powerful, they do not have the central eye characteristic of hurricanes. In the future, warmer seas may plausibly mean that tropical cyclones are more likely to reach western Europe, and they would arrive earlier in the year than more typical extra-tropical cyclones [64]. The UK typically has around 30 small tornadoes a year on average and on physical grounds it is possible to infer that more frequent convection could plausibly generate more intense tornadoes, but there have been no studies so far.

Compound events occur when more than one meteorological hazard occurs over a specific time period, when there is a sequence of events (perhaps because an initial event creates conditions that increase the risk of subsequent events), or when events occur at many places at the same time [65]. By altering all the drivers of meteorological hazards, climate change will alter the likelihood of experiencing challenging compound events. In many cases, this likelihood will increase – most obviously for the combination of drought, heatwave and wildfire, but also potentially for clusters of winter storms – but in other circumstances it is possible that the likelihood of challenging combinations may decrease [66]: this is seen for example in the change in number of adverse weather days on the railway network (Fig. 1). The key point is that climate change alters the likelihood of compound events, with the extent and significance of the change depending on how exposed an organisation or place is to compound events. An additional complication is that climate change is superimposed on other trends and types of hazard – such as epidemics – adding to the pressures of multi-hazard emergency planning and management.

4. Implications of climate change for emergency planning

Future climate is uncertain. The main points, however, are that climate change has altered the frequency and characteristics of some types of extreme weather events, that it will increase future frequency and magnitude of most, may potentially generate novel extreme and compound events, and cold extremes will continue to occur. This will increase pressures on incident and emergency management, and on the staff and resources involved: it increases the residual risks beyond current coping mechanisms. There are seven key implications for emergency planning (Table 2).

The national risk assessments in the UK informing an understanding of weather-related risks and the development of capabilities explicitly take a very short-term perspective – at most two to five years ahead – because they are intended to inform current operational capabilities. They are also rather static and there is a tendency to assume likelihoods have not changed. Climate change has made some events more likely than previously assumed, and more extreme (for example the July 2022 heatwave). It implies that past assessments need to be explicitly reviewed at each repetition of the assessment cycle: it is not appropriate to assume that previous assessments of magnitude or likelihood remain valid.

Table 2
Key implications of climate change for emergency planning.

Risk assessment	Review types of potential events and their estimated magnitudes or likelihoods: do not assume previous assessments remain valid
A long-term perspective	Changing conditions mean that methods and capabilities will need to evolve: long-lead times imply the need to take a long-term perspective
Response capabilities and planning for cascading consequences	Altered event characteristics and frequencies, and a greater potential for cascading consequences, imply changes to response capabilities
Cold events will continue to occur	Climate change reduces, but does not eliminate, the risk of cold weather events
Training and exercises	Plan for novel conditions through exercises
Public engagement and messaging	More frequent, and more challenging, events imply changes to messages in warnings
Improving resilience	Improve resilience to extreme events to reduce the need for emergency response

Climate change also means that risk assessment and emergency planning need to take a longer-term perspective (as recommended by the House of Lords [11]; for example). This would not be necessary if operational procedures and capabilities could be rapidly altered to suit changing circumstances, but this is not the case in practice. New procedures take time to develop and become embedded, and some capabilities take a long time to build.

Emergency planning is based around planning for consequences rather than events – with the important exception of flooding where there are specific capabilities – but climate change has the potential to alter the capabilities that are required. Greater capacity may be needed, for example, to cope with more frequent events (a point made in several adaptation plans), the 'alert period' might need to be extended, and capacity might be needed to deal with simultaneous events occurring in more places than currently envisaged. Greater redundancy might need to be built into systems used during emergencies, such as communications networks. New forecasting capabilities might be needed to deal with altered risks (will the UK need a tornado warning service, for example?). Emergency planning has typically concentrated on the direct rather than cascading consequences of an event (e.g. Refs. [9,67,68]). Cascading consequences are a characteristic of highly-interconnected systems and are a risk irrespective of climate change, but climate change increases the potential for cascading consequences because it affects many components of a system. Climate change therefore further increases the necessity for planning for cascading consequences.

Climate change reduces the frequency of cold weather events, but does not eliminate them. This means that plans, capabilities and resources need to be maintained to deal with cold weather events, even though they are likely to be used less frequently. Strong year-to-year variability means that a run of mild winters should not be interpreted as a sign to reduce stocks of cold weather equipment (snowploughs and salt) and let cold weather plans wither. This will be particularly challenging as pressures on resources increase.

Emergency events are by definition rare, so planning and preparations must be informed and tested by training and exercises. These need to be based on the types of events that may plausibly happen, including events that have not occurred previously. Meanwhile, improvements in seasonal weather forecasting and understanding of the drivers of extreme events may mean that exercises can be based on conditions that are likely to be expected in the coming few months.

Emergency planning and preparation involves not just government agencies and the operators of services and infrastructure: it needs active involvement and engagement with those exposed to extreme events, including the public and business. Since 2015, potentially severe storms have been given names by the UK and Irish Met Offices (subsequently joined by others), and this has helped enhance reporting in the media and raised awareness [69]. It has been suggested that heatwaves be given names [70] – this was started in summer 2022 Seville in Spain - but challenges in defining heatwaves may make this difficult in practice (in effect three definitions of 'heatwave' are currently used in the UK - heat-health alerts for England, Met Office heatwaves, and Met Office Severe Weather Warnings - and this has the potential for generating confusing messages). Message content is important too, and several studies have shown that it is important to include advice on actions to take in warnings [71,72,73]. A particular problem with heatwave warnings is that 'warm spells' are often seen as positive (often reinforced by media imagery). Bruine de Briun et al. [71] and Howarth et al. [72] both recommended emphasising negative consequences in warnings, and this strategy was widely used during the July 2022 heatwave.

Perhaps most importantly, however, an increasing frequency of challenging events implies a need to improve resilience and adapt services and infrastructure to a changing climate. It will not be sustainable, for example, to operate a heat-health plan all through summer, every summer, or to close the railway network for several days each year due to high temperatures. This means that emergency planning needs to be better integrated into other areas of disaster risk reduction such as resilience standards, building codes, spatial planning and structural defences. It will be more feasible in some sectors to raise resilience standards than in others, and the time for new standards to have an effect varies considerably. Where standards cannot readily be improved rapidly – for example if they involve retro-fitting large numbers of properties to deal with hotter summers, or involve replacing long lengths of railway – then warning and emergency services will be under increased pressure in the future. Improving resilience to reduce exposure to loss is a long-term activity.

5. Implications for emergency planning as an adaptation to climate change

In general terms, there are four key implications for emergency planning as an adaptation to climate change (Table 3).

First, relying on current or even improved emergency planning procedures on their own will not be a sufficient adaptation to climate change. It implies a reduction in the level of service as disruptive events become more frequent (for example in terms of disruption time) and it assumes that procedures will be able to cope with the new characteristics and types of events that might arise. Experience during the summer of 2022 also suggests that current plans are not necessarily sufficient to cope with current extremes.

Table 3
Implications for emergency planning as adaptation to climate change.

Relying on current emergency planning procedures is unlikely to be a sufficient adaptation to climate change in itself
Adaptation to increase resilience should reduce the need for emergency planning where buildings, services and infrastructure can adapt
Adaptation is not always feasible, and in such cases the need for emergency planning will be increased and needs to be adequately resourced
There is a need for discussion on resilience standards to define an acceptable level of 'emergency'

Second, many services, buildings and infrastructure networks are not adapted to the current climate as it has changed over the last few years, so adaptation measures which improve resilience and reduce risk should in principle *reduce* the overall need to rely on emergency planning and response to deal with weather extremes.

Third, however, in practice it may be very difficult to increase resilience in some sectors, and therefore the need for emergency planning and response for these will *increase*. It will be easier, for example, to improve resilience for new buildings and infrastructure and will it likely be difficult to retrofit existing buildings and infrastructure to new standards. It may continue to be physically difficult or economically prohibitive to increase resilience in some locations, particularly in rural environments. Climate change is therefore likely to exacerbate geographical inequalities within and between communities. As a consequence, the focus of emergency planning and response is likely to shift towards those communities and services that cannot benefit from improved resilience through climate change adaptation. Emergency planning therefore needs to be adequately resourced as an integral component of climate change adaptation.

Fourth, the increasing frequency and magnitude of extreme events highlights the importance of developing consistent and accepted resilience standards based on what is deemed to be acceptable as an 'emergency' or disruption to normal service. The National Infrastructure Commission [74] recommended that government set resilience standards for infrastructure, but these need to be developed in collaboration with service providers and users. The regulators of companies providing public services set standards of service. However, there is currently little discussion around levels of resilience at the community scale.

6. Conclusions

Climate change has altered the frequency of many types of extreme events, has generated novel events or events greater than experienced in the recent past, and will continue to lead to changes in the frequency and characteristics of extreme events. This paper has reviewed potential implications for current emergency planning in the UK, and for emergency planning as an adaptation to climate change. The focus is on the UK, but the conclusions about specific implications and on the links between emergency planning, disaster risk reduction and climate change adaptation are likely to also be relevant to other geographical and institutional settings. Similar assessments in other countries would test further the generality of the implications and the barriers and opportunities to better link emergency planning with climate change.

There are seven key implications for current operational emergency planning: risk assessment needs to consider a broader range of events and changing likelihoods, a long-term perspective is necessary to address changing conditions, response capabilities may need to be enhanced, some types of events will become less frequent but will not be eliminated with implications for prioritisation of resources, training and exercises need to consider novel events, public engagement and messaging needs to be revised to reflect increased severity of events, and – over the longer term – improving resilience is necessary to reduce the need for emergency response.

Many organisations include emergency planning as part of their climate change adaptation toolkit. However, relying on current or even enhanced emergency planning procedures is unlikely to be a sufficient adaptation to a changing climate. Improved resilience in some sectors will reduce the need for emergency planning and response, but it will not be feasible to improve resilience everywhere: the focus for emergency planning and response is therefore likely to evolve to reflect diverging impacts of climate change in and between communities. Finally, achieving a balance between measures to increase resilience and measures to manage events requires a discussion on appropriate standards for resilience and definitions of 'emergency'.

Taken together, these implications imply greater coordination is needed between the operational communities involved in emergency planning and response and the more strategic communities involved in longer-term risk reduction and adaptation planning. There are four barriers – in the UK and probably also more widely – to improved coordination, but there are also a number of opportunities.

The first barrier is the nature of the institutional arrangements for emergency planning and for climate change adaptation: in the UK these responsibilities are spread across departments and agencies, the legislative framework is different, and different organisations have different institutional cultures and priorities. There is little coordination [12], and the Resilience Partnerships do not have formal responsibilities for either risk reduction or climate change adaptation. The second barrier is the difference in time horizon and specifically the difference between a focus on short-term operational planning and on longer-term strategy and policy. Third, the two communities have very different interpretations of the term 'resilience' and this hinders communication and expectations in practice (despite Shaw & Newcombe's [8] suggestion that a focus on resilience is a way of linking the two). Fourth – and following from the previous two barriers - the two communities give very different priorities to measures to reduce risks before events occur.

The opportunities for better connections between the two in the UK arise from three activities currently under way or proposed. The Third National Adaptation Programme (NAP3) is scheduled for publication in 2023, and there is scope for specific actions relating to emergency planning and adaptation. Institutional arrangements within the UK government regarding emergency planning and risk assessment changed in summer 2022, and there is an opportunity to better integrate resilience with risk reduction. Third, it is

likely that the Civil Contingencies Act 2004 will be reviewed and, following the recommendations of the National Preparedness Commission, there is scope to introduce powers and duties for risk reduction as well as emergency planning.

Finally, it is possible to draw two more general conclusions about the relationship between emergency planning, disaster risk reduction and climate change adaptation. The review of adaptation plans highlighted two attitudes towards emergency planning and climate change: some organisations believe that their current emergency planning arrangements are sufficient to cope with climate change, whilst others believe that climate change requires a substantial revision to emergency planning. The evidence presented here suggests that the first view is untenable. More broadly, it has frequently been noted that there is a lack of coherence between disaster risk reduction and climate change adaptation (see for example [75–81]. The evidence in this review suggests that the disconnect is actually more nuanced. There are close links in the UK between many of the elements of the 'risk reduction' part of disaster risk reduction and climate change adaptation. The integration is not perfect (as concluded by the Climate Change Committee [35]) but in general the same institutions are responsible for both. For example, flood defence and spatial planning arrangements, and some aspects of building codes, currently incorporate climate change adaptation. Rather, the disconnect is between emergency planning and efforts to reduce risks, whether looked at through the lens of disaster risk reduction or of climate change adaptation. This is where greater effort is needed to improve both emergency response to extreme events and adaptation to climate change.

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.

Data availability

The link to the data is provided in the figure caption

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