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Understanding the impact of climate change on inland flood risk in the UK

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Are extremes a new normal?

Flooding is one of the biggest environmental risks facing the UK. Floods have the potential to cause devastating impacts on people's lives, the economy and natural ecosystems. Since the widespread floods in 2007, a number of high-profile events (Table 1) have repeatedly led to headlines about record breaking rainfall, the highest water levels on record and "unprecedented" floods.

Climate change is expected to lead to an increase in both the frequency and severity of flooding for some parts of the UK. In this briefing we explain these impacts and consider if we are already seeing evidence of this change.

How does climate change affect rainfall?

The Earth is getting warmer. Warmer air can hold more water and therefore has the potential to increase rainfall intensity and the associated risk of flooding. However, regional weather patterns are also likely to change, meaning while some places will be wetter others will see a reduction in rainfall.

Climate change projections over the UK for the 21st century show an increased chance of wetter winters. Summers are likely to be drier overall, but an increase in the frequency and intensity of convective rainfall (such as that from thunderstorms) is projected¹. The effects are projected to vary across the country, in the North and West, where rainfall is driven by the prevailing westerly winds from the Atlantic, the most significant change is the expected increase in winter precipitation. In the drier South and East there is more concern about the increased risk of summer droughts than flooding².

What does this mean for flood risk?

Scientists agree that flood risk across the UK is likely to increase due to climate change. As global or regional scale climate models predict results on large grids, one of the big difficulties for hydrologists is understanding the impact of these changes at the scale of individual catchments.

UK catchments are varied in terms of size and geology and some are more susceptible to increases in rainfall than others. More rain does not necessarily mean more flooding as changing weather patterns also change the ability of catchments to store water in soils or vegetation. As well as climate change, river flows are affected by changes to land use, farming practices, urbanisation, river engineering, reservoirs, and hydropower. Floods only cause significant impacts when people, property, infrastructure or vulnerable ecosystems are located in the path of the flood water. Development on floodplains has therefore played an important role in increasing flood risk regardless of the changing climate.

To account for some of these potential feedbacks, scientists use hydrological models that represent the interaction between changes in rainfall, evaporation and land use to predict river flow. These studies consistently show an increase in the chance of river flooding due to

climate change of up to 40% by 2100 from long duration winter rainfall events, particularly in western England, Wales and Scotland².

Flash floods occur in steep-sided catchments or urban areas (sometimes called surface water flooding) during intense storms where the rainfall rate is greater than the rate at which the ground or sewage system can drain it away (for example in Coverack in 2017). The fast-flowing flood water can be very dangerous. From a hydrological perspective any increase in intense rainfall has the potential to increase the frequency and severity of flash flooding, however predicting these changes is challenging. The type of storms that lead to flash floods are very localised and only last for short periods of time, as such, they are hard to represent in climate models. A new generation of 'convection-permitting' models, similar to those used for weather forecasting, are enabling scientists to understand more about how future changes to localised intense rainfall events will affect flood risk.

Is there any evidence that climate change has played a part in recent flood events?

Anecdotally it seems that we are experiencing more extreme and more frequent flood events. Observed changes in the rainfall and river flow records³ are broadly consistent with climate model projections indicating climate induced changes are already happening. However, these records can also show changes caused by natural climatic variability. Thus more years of data will be required before we can be completely confident that any upward trend is a signal of climate change.

Similarly, due to the number of factors involved it is difficult to say that any one individual flood event was caused by climate change. But by comparing the driving weather conditions with and without anthropogenic climate change influences on the atmosphere, research has shown that the type of rainfall events which led to widespread flooding in Southern England in 2013/14⁴, and from Storm *Desmond* in 2015⁵ and Storms *-Ciara* and *Dennis* in 2020⁶, are more likely to occur in the current climate.

Summary

Scientists are confident that climate change will alter the rainfall patterns and quantities in the UK. Therefore, there is an urgent need to increase resilience to flooding. Such plans need to be flexible enough to account for the varying risk across the country and the uncertainties around both predicting future rainfall and understanding the impact of climate change on flood risk in individual catchments.

Table 1 Examples of 'record breaking' flood events in the UK since 2007

Event	Why was it record breaking? ^{7,8}
Summer 2007	The May-July period was the wettest on record for the UK. In some regions the July rainfall was over four times the monthly average leading to widespread river and surface water flooding. 55000 properties were flooded.

Winter 2013-14	An exceptionally wet winter with unusual clustering and persistence of rainfall led to flooding in Somerset and the lower Thames which had an exceptional geographical extent and duration. 11,000 properties were flooded.
Winter 2015-2016 (Storms <i>Desmond</i> , <i>Eva</i> and <i>Frank</i>)	A long period of persistent Atlantic storms, particularly in northwest Britain, resulted in several highest daily rainfall totals and the highest peak river flows ever recorded in England. In Scotland 50 of SEPA's 400 river gauges recorded new peak flows. The magnitude, persistence and repetitive nature of the flooding was notable. 17,000 properties were flooded in England and over 1000 in Scotland.
Coverack 2017	Flash flooding in a small Cornish catchment from a (estimated) near record amount of rainfall over three hours. 50 properties were flooded.
February 2020 (Storms <i>Ciara</i> and <i>Dennis</i>)	Two named storms a week apart led to the UK's wettest February on record. River flows exceeded observed records in catchments across the UK. 4633 properties were flooded.

Note: Flooded properties numbers are from Environment Agency figures for England only unless otherwise stated. They do not take account of properties protected by flood defences.

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Further reading

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² Arnell, N. *et al.* (2021) Changing climate risk in the UK: A multi-sectoral analysis using policy-relevant indicators. *Climate Risk Management*. 31. <https://doi.org/10.1016/j.crm.2020.100265>.

³ Harrigan, S. *et al.* (2021) An updated national-scale assessment of trends in UK peak river flow data: how robust are observed increases in flooding?. *Hydrology Research*; 52 (3): 699–718. <https://doi.org/10.2166/nh.2021.156>

⁴ Schaller, N. *et al.* (2016) Human influence on climate in the 2014 southern England winter floods and their impacts. *Nature Clim Change* 6, 627–634, <https://doi.org/10.1038/nclimate2927>

⁵ Otto, F. *et al.* (2018) Climate change increases the probability of heavy rains in Northern England/Southern Scotland like those of storm Desmond—a real-time event attribution revisited. *Environ. Res. Lett.* 13 <https://iopscience.iop.org/article/10.1088/1748-9326/aa9663/pdf>

⁶ Davies, P.A. *et al.* (2021), The wet and stormy UK winter of 2019/2020. *Weather*. <https://doi.org/10.1002/wea.3955>

⁷ National Hydrological Monitoring Programme hydrological summaries available from <https://nrfa.ceh.ac.uk/monthly-hydrological-summary-uk>

⁸ Met Office past weather events available from <https://www.metoffice.gov.uk/weather/learn-about/past-uk-weather-events>