Brief report

How will climate change affect UK heatwaves?

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What is a heatwave?

A heatwave is typically a period of unusually hot weather that persists for at least a few days. For the UK, the Met Office defines a heatwave over a location as when it records maximum temperatures higher than or equal to a temperature threshold for at least three consecutive days. This threshold varies from 25°C in Scotland, Northern Ireland and most of Wales to 28°C in Greater London, reflecting the regional variation in summer climate. Heatwaves can impact heat-related illnesses and deaths, disrupt transport systems, and damage crops and agriculture.

What causes a heatwave?

Heatwaves are often a result of high-pressure systems that 'block' weather systems travelling eastwards from the North Atlantic. These blocking patterns can result in cloud-free regions, allowing the Sun to bake the ground below and warm air to flow from lower-latitude regions, such as Southern Europe and North Africa. The most extreme UK heatwaves, many of which have occurred in the last two decades, have all featured persistent blocking patterns lasting one to two weeks. Other processes that drive heatwaves include sea surface temperature patterns and soil moisture feedback. The relative roles of these processes vary from heatwave to heatwave. For instance, the atmospheric circulation and, to a lesser degree, soil moisture deficit were drivers of the 2015 European heatwave (Wehrli *et al*., 2019), but the circulation and sea surface temperature patterns were the main drivers of the 2018 heatwave, at least over the UK (Petch *et al*., 2020).

How has climate change affected heatwaves?

While the processes above are all critical for the formation of heatwaves, their intensity and duration are being enhanced by the increase in global-mean temperature due to increasing levels of greenhouse gases in the atmosphere (McCarthy *et al*., 2019; Wehrli *et al*., 2019). Already, there has been a two- to three-fold increase in Central England heatwave activity since the late 1800s (Chapman *et al*., 2019), and at least a doubling in the risk of the infamous 2003 European heatwave due to human activity (Stott *et al*., 2004). The 2003 European heatwave is infamous for its impacts, notably its high mortality rate. In general, heatwaves since 2003 have been enhanced even more due to human-induced climate change, with the likelihood of many of them increasing ten- to fifty-fold (American Meteorological Society, n.d.).

How will heatwaves change in the future?

The Met Office's latest UK Climate Projections (UKCP18) indicate a trend towards hotter and drier summers in the twenty-first century, and thus higher magnitude heatwaves. For example, a summer as hot as that of 2018, which is the joint warmest summer in the UK since 1884, could occur every other year by mid-century in a warming climate (Lowe *et al*., 2019). This is principally due to the increase in background atmospheric temperatures, but the specific increase in heat extremes will be modified by future changes in the jet stream location and summer blocking patterns, which are highly uncertain in current climate models.

At present, the highest temperature recorded in the UK is 38.7°C (Cambridge Botanic Garden, 25 July 2019). In the future, under a medium greenhouse gas emissions scenario, climate models project that somewhere in the UK would reach the unprecedented high temperature of 40°C about once every 15 years by the end of the century (Christidis *et al*., 2020). Under a high emissions scenario, this likelihood is further increased to once every 3 to 4 years by the end of the century (Christidis *et al*., 2020). This represents a faster warming rate than the global average (Kennedy-Asser *et al*., 2021). On top of this warming trend, urbanisation can lead to even higher summer temperatures in cities due to factors such as heat storage and release by urban structures, a lack of vegetation and reduced average wind speeds (Lo *et al*., 2020).

Based on the existing definition of heatwaves, England and Wales are expected to experience at least one heatwave every year by mid-century, under the high emissions scenario (Arnell *et al*., 2021). In Scotland and Northern Ireland, the chances of a heatwave occurring in a year are expected to increase to over 50% by mid-century (Arnell *et al*., 2021). The extent to which extreme heat and heatwaves become common in the UK will largely depend on the concentrations of carbon dioxide and other greenhouse gases in the atmosphere, which in turn is dictated by the speed at which the world can achieve net zero emissions of greenhouse gases.

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