EuroTempest

Climate Change and Flash Flooding: How will the frequency and intensity of extreme precipitation events change?

Abstract

Flash flooding events are typically caused by summer showers and thunderstorms with rainfall rates greater than ~30 mm/hr (Met Office and Environment Agency Flood Forecasting Centre). As the climate warms, more heat and moisture become available for the formation of these systems, resulting in an increase in both the frequency and intensity of extreme precipitation events. For example, the latest UK Climate Change Risk Assessment found an increase in peak precipitation intensity of up to 50% for short-duration summer rainfall events (Sayers et al. 2017). The resultant shift in the rainfall intensity distribution towards more extreme rates is expected to increase the frequency of events exceeding this ~30 mm/hr threshold almost fivefold by the end of the century (Fowler 2017). As the number of these events increases, there is a greater chance that any individual shower could fall over a densely populated area, resulting in an increased risk of flash flooding. Summers similar to 2016, in which ~6,500 flood claims were made in June alone, could become the norm, or even a lower bound if enhanced adaptation measures are not put in place. Under current levels of adaptation, the annual damages caused by the impact of flash flooding on residential properties are expected to more than double by the 2080s.

Introduction

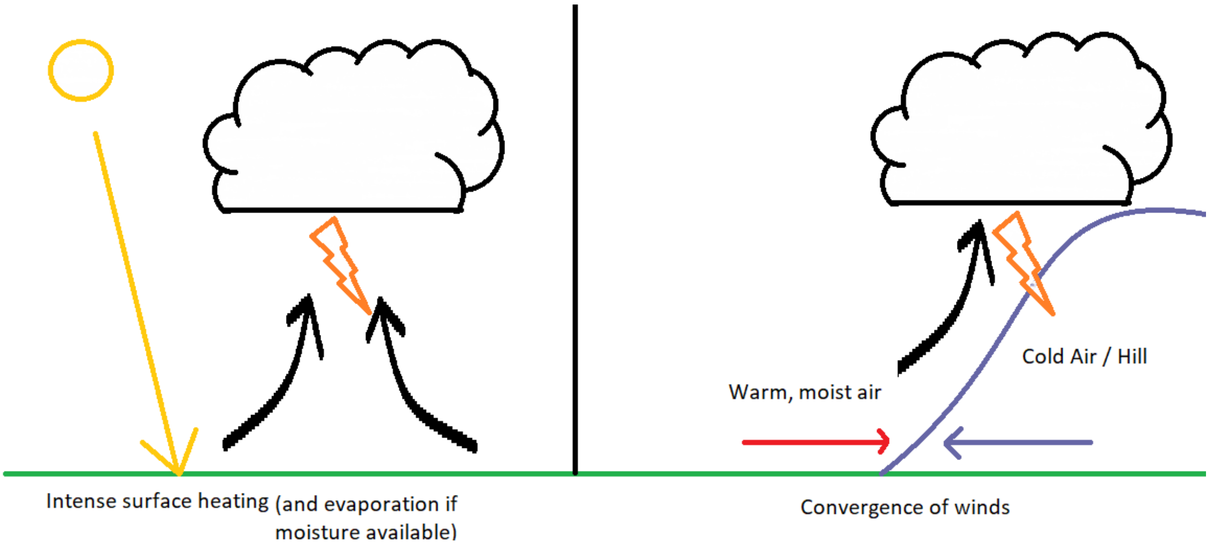
Flooding represents one of the greatest natural hazards experienced in the UK, with expected annual damages totalling ~£1.4 billion. While a small proportion of these damages are linked to coastal flooding, the majority, around 60%, are associated with excessive rainfall leading to river-based (fluvial) and surface water (pluvial) flooding (Sayers et al 2017). Flash flooding - defined by EuroTempest as flooding caused by precipitation events with a duration between 3 and 6 hours - can have both pluvial and fluvial elements, as short bursts of intense precipitation can overwhelm narrow or steep rivers as well as drainage systems and urban surfaces. Climate change is expected to result in an increase in both the frequency and intensity of extreme summer precipitation events across much of the UK, resulting in a greater risk of flash flooding (Sayers et al 2017). In addition, in order to keep up with a growing population, developments on floodplains are rapidly expanding, resulting in an increase in the number of properties exposed to flooding.

As the climate changes, it is important to understand the impact of rising temperatures on the hydrological cycle in the UK and the associated cost of more frequent and intense precipitation events. It is possible that much of the cost associated with an increase in these types of events could be offset by enhanced adaptation measures, but only if, as discussed in the recent speech by the chair of the Environment Agency, the UK 'prepares for the worst' (Environment Agency 2019).

What causes flash flooding?

As we get closer to summer, the pattern of airflow influencing the weather of the UK changes, with a reduction in the strength and dominance of westerly flow and an increase in the influence of airmasses from the south and east. In turn, the likelihood of sustained periods of heavy rain associated with weather systems moving in from the Atlantic decreases, while the risk of heavy bursts of precipitation, associated with summer showers and thunderstorms, increases.

Intense summer showers and thunderstorms are more common in summer due to the need for both **heat** and **moisture** in the formation process. The third ingredient required is atmospheric **instability** – the atmosphere is said to be unstable if the air at the surface is warmer than that higher up in the atmosphere. In an unstable environment, parcels of air at the surface are able to rise through the colder layers and as they do so they cool. This rising motion is part of a process known as convection. If moisture is also present, condensation occurs, and shower-producing clouds are formed. When conditions are favourable for strong convective motions, large cumulonimbus clouds capable of intense precipitation can be formed. These conditions often occur when the layer of air at the surface is stable while above is unstable, allowing lots of energy (convective available potential energy (CAPE)) to build up. If a parcel of air is lifted above this stable layer – for example if it were forced up by intense surface heating, a large hill or by the convergence of winds – it would again be able to rise, cool and condense resulting in severe thunderstorms (figure 1). In the UK, conditions conducive for instability often occur during what are known as 'Spanish plume events' which predominantly impact southern regions of the UK (Met Office). However, instability is also common in the UK near coasts and areas of complex terrain.



The rainfall associated with summer showers and thunderstorms is typically very intense, often resulting in a months-worth, or more, of rain falling in just a few hours. Due to the rate of rainfall, water cannot be drained away fast enough either by manmade drainage systems or through natural run-off, rivers and percolation into the soil, resulting in rapid flooding. Due to the speed at which flash floods can occur, there is often very little advanced warning as it is difficult to predict precisely where these systems will form. During unstable periods, where thunderstorm activity persists over the same area for a number of days, the soil can become saturated, exacerbating flash flooding by further reducing the ability of rain to be absorbed into the ground. Urban surfaces behave in a similar way to saturated soils, preventing absorption and increasing run-off. Therefore, expansion on floodplains not only increases exposure to flooding but also the chance of flooding. At the other end of the spectrum, very dry surfaces can also contribute to the flash flooding process as dry, hard soils are less able to absorb the rainfall at the rate it falls during extreme precipitation events, again increasing the chance of a flash flood event.

Case Study: Summer 2018

During the summer of 2018, EuroTempest estimates that over 4,000 flood claims were made nationwide. Of these claims, ~50% were made over a period of just a few days between the late May Bank Holiday weekend and the beginning of June. Prior to this period, warm moist air had been transported across the UK setting up favourable conditions for the formation of thunderstorms, which were then triggered by a weekend of warm and sunny weather resulting in the development of very isolated but intense thundery showers. Due to the sporadic distribution of these showers, some regions received more than a month’s worth of precipitation in just a couple of hours, while areas only a short distance away received very little or even no rain at all (Met Office). Many of these showers did not result in any major impacts due to their location over areas of relatively low population, however, due to the large number of showers, some inevitably hit more populated areas and hence had greater impacts. For example, parts of both Birmingham and London were affected by periods of prolonged thunderstorm activity a few days apart. Individually, these events resulted in fairly small uplifts in flood claims, but when aggregated together over the whole period resulted in a moderate cumulative impact. This is a common pattern observed over prolonged periods of thunderstorm activity, as a large number of very localised flash flood events can result in a sizeable ‘event’ when considered cumulatively. Another example is the summer of 2016 during which ~6,500 flood claims were made in June alone due to the accumulation of localised impacts from isolated thunderstorms across many regions.

An increase in frequency and intensity of heavy summer precipitation events, however isolated these events may be, would increase the chance of highly populated regions being affected, resulting in summers characterised by flood claims volumes similar to, or potentially greater than, those of 2016 and 2018 becoming more common.

Climate Change and precipitation

In general, climate projections suggest that the UK is likely to see a decrease in precipitation in the summer months as the climate warms. However, this decrease predominantly occurs for rainfall events at the lower end (< 85th percentile) of the intensity distribution, while at the upper end, an increase in both frequency and intensity is observed in climate models (Trenberth 2011). The observational record supports these findings, with extreme rainfall events contributing an additional 17% to total UK rainfall between 2007-2017 compared to the long-term average (Met Office).

As heat is a key ingredient for the formation of intense showers and thunderstorms, it is easy to appreciate how increased temperatures may result in a greater occurrence of these systems, for example by increasing surface heating and therefore the potential for triggering convective events. However, heating alone is insufficient for increasing the intensity of precipitation events, as moisture availability is often the limiting factor. The mechanism behind increasing precipitation events lies in the relationship between temperature and moisture in the atmosphere, as higher temperatures favour enhanced evaporation, increasing the availability of both energy and moisture in the atmosphere. In addition, according to scientific principles, as the climate warms the ability of the atmosphere to hold water increases at roughly 7% per degree of warming (Trenberth 2011).

Research using high-resolution climate models has found that the intensity of extreme (return periods of greater than 1 in 30 years), short-lived (<6 hours) rainfall events indeed increases at a similar (or greater) rate to the change in water-holding capacity of the atmosphere (Berg et al. 2013, Kendon et al. 2014, Sayers et al. 2017). For example, a change in temperature of 2°C by the end of this century has been found to increase the intensity of extreme precipitation by 10% over the next 30 years and by 20% by the 2080s. Under a 'business as usual' scenario, the increase in intensity could be as much as 50% by the 2080s (Sayers et al. 2017). Due to the growing evidence for the relationship between climate change and increasing precipitation intensity, the Environment Agency suggests incorporating between a **20%** and **40%** increase in **peak rainfall intensity** for flood risk assessments aimed at the 2080s based on a central and upper end scenario respectively (Environment Agency).

As peak rainfall intensity increases, the frequency of events at the upper end of the intensity distribution also increases resulting in a greater occurrence of extreme precipitation events. For example, experiments have found that due to this shift in intensity distribution, precipitation events with intensities exceeding **28mm/hr** could become almost **five times more frequent** by the end of the century (Fowler 2017).

What does this mean for flash flood risk?

Precipitation rates of between 25-30 mm/hr are typically associated with severe flash flood risk, therefore an increase in the frequency of events exceeding this threshold will in turn result in an increase in the frequency of flash flood events. This is reflected in the decreasing return periods of extreme surface water run-off events found by Sayers and Partners in the Climate Change Risk Assessment (2017).

For example, an increase in precipitation intensity of 20% has been found to result in a decrease in return period of a '100-year' event by 37 years in an urban environment by 2100, while the expected return periods for what are currently '30-year' events almost halve (Sayers et al. 2017). As discussed in a previous article on climate change and storm surge events, shifting return periods question the utility of planning for '1 in x year' events, as the severity of flooding associated with these labels changes with the climate. Instead, as advocated by the Chair of the Environment Agency in a recent speech, the UK needs to 'prepare for the worst' in order to manage the impact of increasingly frequent and severe flood events (Environment Agency 2019).

However, as the population grows, the number of properties being built on floodplains is expected to double, increasing exposure to river flooding as well as increasing the ratio of urban to rural surfaces, further inhibiting the absorption of water into the soil. As a result, the expected number of properties at risk from a flood more severe than what is today considered to be a 1 in 75 year event is expected to increase by more than 300,000 (900,000) by 2080 under 2°C (4°C) of warming (Sayers et al. 2017). In addition to an increase in the development of urban surfaces, due to the decrease in lower intensity rainfall over the summer months in general, normally permeable surfaces are likely to be drier and therefore less able to absorb moisture quickly, further increasing the risk of flash flood events.

Owing to both the increase in severity of the hazard (increased frequency and intensity of extreme precipitation events) and the increase in exposure (population growth), the cost of flash flooding is expected to more than double by the 2080s (The Committee on Climate Change). Much of the additional cost may be avoided through enhanced adaptation efforts if warming is limited to 2°C by the end of the century. However, beyond 2°C, it is likely that, in some regions, the impacts of increased flash flooding will be felt regardless of adaptation measures, with some areas at risk of becoming uninsurable and uninhabitable.

Concluding Remarks

Scientific principles, the observational record and the results of model-based studies suggest that the distribution of precipitation events is shifting towards more intense rainfall rates during the summer, while at the other end, lower intensity precipitation is expected to become less frequent. As a result, precipitation events with intensities exceeding the 25-30 mm/hr rate associated with flash flooding are likely to occur more frequently, increasing the probability of any one of these events being located over a densely populated area. In addition, as the population grows, and more properties are built in flood-prone areas, the exposure to flash flooding increases, further increasing flood risk.

Owing to the increase in severity of the hazard in combination with increasing exposure, expected annual damages caused by the impact of flash flooding on residential properties are expected to more than double by the 2080s. Some of the additional losses forecast may be mitigated against via investment in traditional flood defences proposed by the Environment Agency. However, away from rivers and coasts, the, often overlooked, risk of flash flooding from overwhelmed drainage systems and urban surfaces will continue to increase despite these adaptation efforts. Therefore, it is likely that the impacts of increased flash flooding will be felt over the coming decades, regardless of an increase in traditional flood defences.

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