Notes on the Meteorological Context of the UK Flooding in June and July 2007

Mike Blackburn, Brian Hoskins and Julia Slingo

NCAS-Climate and Department of Meteorology

Walker Institute for Climate System Research

University of Reading

Large-scale context

1. The two recent extreme rainfall events, over the S. Yorkshire region on 25 June and over southern and central England on 20 July, followed a period of above average rainfall which had increased soil moisture so that a smaller fraction of the rain could be absorbed, giving higher run-off. The persistence of an anomalous "wet" weather pattern was also a major factor in the Autumn 2000 UK flooding.

2. The large-scale weather pattern over the north Atlantic and Europe has persisted since early June. The jet-stream, which both generates and steers the weather systems, has been south of its normal position, particularly over the eastern Atlantic. There has also been a persistent train of waves in the jet-stream, from the north Pacific through to Europe, with a trough (low pressure) close to the UK. This means that Atlantic weather systems have been steered towards the UK, and have tended to slow and "park" over the country. This leads to more prolonged rainfall than in situations where the weather systems are more mobile, moving eastwards across the UK. In addition, the persistent trough just west of the UK has brought air from a more southerly track than normal, passing over warmer sea temperatures and therefore likely to carry more moisture.

3. We do not currently know the reason(s) for this anomalous weather pattern and why it has persisted over a month or more. Although aspects of the pattern over the Pacific have varied, the Atlantic features including the trough near the UK have been more persistent. It was only for a period in early July that the situation became more "mobile", with weather systems moving eastward over the UK, giving a brief respite of improved weather.

4. Elsewhere over the last month, there has been a strong anticyclone over the eastern Mediterranean with very high temperatures and wild fires, above-average rainfall in a very vigorous Indian/Asian Summer Monsoon and a weak La Niña in the equatorial East Pacific sea surface temperatures.

   Previous atmospheric modelling studies at Reading(*) suggest that the strong Indian/Asian Monsoon may be a factor for the eastern Mediterranean heat, but it is equally possible that the recent Mediterranean conditions could be an extension of the pattern affecting the UK and western Europe. Experiments with atmospheric models will help us to clarify these possible links.

The links with La Niña appear to be tenuous with no strong evidence, so far, that La Niña is responsible for a significant southward shift of the jet-stream or the persistent weather pattern that the UK has experienced this summer.

(*) Rodwell, M.J. and B.J. Hoskins (1996) QJRMS, 122 (534): 1385-1404. http://dx.doi.org/doi:10.1002/qj.49712253408

Synoptic Situation for July floods

1. A combination of the jet-stream anomaly south west of the UK (the upper level trough, associated with a region of high potential vorticity), together with low level temperature and moisture contrasts between western Europe and the Atlantic, appear to have provided the forcing and organisation for the intense and prolonged rainfall.

2. In the week preceding Friday's extreme rainfall, northerly flow over Iceland had brought cold air at low levels over the eastern Atlantic, which enhanced the contrast with warm air over south western Europe, providing energy (baroclinicity) for Friday's weather system. On that day, ahead of the low, very moist, warm air was transported over us that a few days earlier had been over the subtropical Atlantic. There was a very large temperature difference between the warmth of Southern Europe and the cool air streaming southwards to the west of the low. These were the ingredients required for the large-scale, very heavy and prolonged rainfall.

3. The air over the UK ahead of the system was warm and almost saturated over the depth of the troposphere, and was very unstable to daytime surface warming and/or lifting, providing a copious moisture supply. (*)
   (*) Hertmonceux radiosonde sounding 00Z, 20 July.
   See http://weather.uwyo.edu/upperair/sounding.html
   copy at http://www.met.rdg.ac.uk/~mike/cw/skewt_herstmonceaux.gif

4. The stationary nature of the jet stream-level anomaly contributed to the long duration of intense rainfall.

5. Ball-park estimation of column moisture and implications: approximate the maximum total column moisture by the surface qsat in 200hPa of the lower atmosphere. How much rain from condensing it all in-situ over a region? Ts=20degC → qsat=15g/kg → 30kg/m2 → 30mm rain. So 100mm, exceeded over Oxfordshire and W. Midlands, needs all the water vapour to condense from an area several times larger than the rainfall footprint. This requires convergence maintained over many hours, implying large-scale and mesoscale (frontal) organisation.

Climate Change aspects

1. Some simple basic physics can tell us much about what we can expect:
    - generally warmer temperatures imply more extreme high temperatures.
    - warmer air can hold more moisture (e.g. increasing temperature by 10degC roughly doubles the amount of water vapour the air can hold. This is the Clausius-Clapeyron relationship). This means we can expect higher peak rainfall rates and daily totals, locally and regionally, from both convection (thunderstorms) and larger-scale weather systems, where air is forced to rise and cool in clouds, condensing its water vapour and creating rain.
    - Globally averaged precipitation is NOT likely to change significantly, despite higher moisture amounts in the atmosphere, because it is ultimately the net radiative cooling of the atmosphere that drives and balances the latent heating associated with precipitation, and that cooling is not predicted to change significantly. There is a fundamental difference between storage (how much water the atmosphere can hold) and throughput (precipitation).
    - Possible changes in regional weather patterns will mean that an individual region may see substantially larger changes (both negative and positive) than those implied by the globally averaged change.
2. Whether the current floods have any climate change component is difficult to argue. Atlantic Ocean temperatures are currently cooler than normal south of and around the UK so simple arguments of warmer air holding more water may not apply.
3. Current climate change projections for the southern UK have suggested wetter winters. They have also suggested drier summers, associated with a poleward shift of the storm-track, the opposite of what has occurred this summer. Recent Hadley Centre work has also suggested that despite the decrease in summer mean rainfall, the wettest days in the summer are likely to become somewhat wetter. This increase is associated with enhanced rainfall from isolated convective storms in a warmer world with more moisture in the air. In contrast the recent floods were from rainfall, often of a convective nature, but organised by a mid-latitude cyclone.

    A crucial question is whether enhanced greenhouse gases imply a change in the probabilities of stationary patterns in the European region as seen in recent summers, e.g. 2003 with its widespread heat, and 2007 with its rain in the UK and heat in the Mediterranean. This question can only be tackled with better, higher resolution climate models and enhanced understanding of the climate system.