PRECIPITATION, DELUGE AND FLOOD

Observational evidence and computer modelling

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The Global Warming Policy Foundation

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1 Introduction

Demands for policy responses to global warming are often based in part on claims that rainfall will increase and become more intense and that flooding will therefore be an ever-increasing problem. Serious events such as the Bocastle flood of 2004, the floods in Kashmir, the wet summer of 2007 and the winter floods of 2014 are always followed by insinuations that they are linked to climate change together with explicit claims that more such floods can be expected in the future.

However, the link between a warming world and increased flooding is far from clear, particularly in the British Isles. So although flooding is said to be the 'number one natural risk in the UK',[1] it remains far from clear whether rainfall or flooding have in fact become more prevalent than previously, at least in any meaningful way.

This briefing examines recent changes in heavy rainfall and flood in the UK and worldwide, the tools that are used to assess them for evidence of climate change and the way in which they are used to predict how these factors might change in the future.

2 Observations of precipitation and flood

Global

In its latest report on global warming, the UN Intergovernmental Panel on Climate Change (IPCC) makes no strong claims about changes in rainfall. The Fifth Assessment Report declares that over the second half of the 20th century, when carbon dioxide emissions have been most significant, and over the whole of the 20th century, trends in precipitation are inconclusive, to the extent that it is unclear whether there has been an increase or decrease.[2]

However, floods are not only caused by extended periods of rainfall; they can also be caused by short intense cloudbursts. So increases in the *intensity* of rainfall are just as important as changes to overall totals. Here the IPCC brings a message that is of more concern, but only slightly so, noting that there are likely to be more land areas that have experienced increases in intense rainfall than decreases.[2]

[1] HM Government. The National Adaptation Programme: Making the country resilient to a changing climate.

[2] Hartmann, DL et al. Observations: atmosphere and surface. In: Stocker TF et al. (eds) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2013

Similarly, the Fifth Assessment says that there is low confidence about the trends in frequency and magnitude of floods worldwide.[2]

UK

There are similar problems when analysing the UK. If anything the situation is more problematic still because of Britain's geographical location on the edge of the continent of Europe, where either continental and maritime climates can be in the ascendancy, leading to highly variable weather.

Osborn and Maraun, two researchers working at the Climatic Research Unit at the University of East Anglia, found that overall UK rainfall has increased marginally in recent years, with increased variability from year to year. However, they said that it was unclear if this represented anything other than natural variability.[3] Other papers have found a difference between the seasons. Jones et al. found that longer-duration rainfall events had increased in 1961–2009 in both winter and summer, but short-duration summer events had decreased.[4] It is perhaps noteworthy that the authors have not attempted to ascribe these changes to any particular factor, noting only the fact of the change. However, Britain's weather is also affected by long-term natural cycles such as the Atlantic Multidecadal Oscillation. It is therefore plausible that the results may be affected by the starting date, since the 1960s were a relatively dry period. An unpublished analysis of longer term data suggests little trend over the period since 1930.[5]

Trends in flooding are notoriously difficult to determine, with many factors affecting the amount of property damaged, in particular the tendency to build new homes on floodplains. However, one recent paper about the UK failed to find any trend in flooding once changes in exposure had been corrected for.[6]

3 Climate models and precipitation

The poor performance of global climate models with regard to temperature changes has been widely noted. However, rainfall is more problematic still for

[3] Osborn T and Maraun D. Changing intensity of rainfall over Britain. http://www.cru.uea.ac.uk/documents/421974/1295957/Info+sheet+%2315.pdf. The authors say 'the changes may not be outside the range of variation that could occur naturally'.

[4] Jones MR et al. An assessment of changes in seasonal and annual extreme rainfall in the UK between 1961 and 2009. *International Journal of Climatology* 2013; 33.5: 1178–1194.

[5] Homewood P. Heavy rainfall claims not borne out by the data. http://notalotofpeopleknowthat.wordpress.com/2014/01/24/corinne.

[6] Stevens AJ et al. Trends in reported flooding in the UK: 1884–2013. *Hydrological Sciences Journal* 2014; DOI: 10.1080/02626667.2014.950581.

climate modellers. Precipitation comes in many different varieties, for example rainfall, drizzle, dew, snow and hail, as well as more exotic types like fog drip and rime. It is highly variable: in space, in intensity and in quantity. So while relatively simple physics can describe the movement of water from the tropical oceans into the atmosphere, computer simulation of water vapour condensing into clouds and then emerging as precipitation of some kind has proved almost impossible, with much of the physics taking place at too small a scale to be modelled properly and scientists having to use somewhat arbitrary approximations.[7] To make it worse, tiny changes in the starting assumptions produce vastly different results, making the results of limited use in the policy world.[8] Little work has been done on sub-daily rainfall levels.[9]

Climate modellers themselves admit the performance of their models is poor and has scarcely improved over the last decade. In its Fifth Assessment Report, the IPCC said that:

> …simulation of large-scale patterns of precipitation has improved somewhat since the AR4, although models continue to perform less well for precipitation than for surface temperature. The spatial pattern correlation between modelled and observed annual mean precipitation has increased…At regional scales, precipitation is not simulated as well, and the assessment remains difficult owing to observational uncertainties… The broad-scale features of precipitation as simulated by the CMIP5 models are in modest agreement with observations, but there are systematic errors in the Tropics.[10]

The IPCC is routinely accused of overstating the abilities of computer climate simulations, so to see the match between observations and simulations described as 'modest' suggests just how poor global climate models are when it comes to precipitation.

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[7] 'Paramaterisations' in the jargon. Roy Spencer describes the parameterisations of the physics of cloud conversion into precipitation as 'arbitary', adding '…we do not understand how precipitation efficiency changes with warming, and so the physics cannot currently be included in climate models for the purpose of predicting climate change.' See Spencer R. Water vapor feedback and the global warming pause. Dr Roy Spencer blog, 10 September 2014. http://www.drroyspencer.com/2014/09/water-vapor-feedback-and-the-global-warming-pause/.

[8] Koutsoyiannis D and Langousis A. Precipitation. In P. Wilderer and S. Uhlenbrook (eds), *A Treatise on Water Science*. Academic Press, Oxford, 2011.

[9] Sanderson M. Changes in the frequency of extreme rainfall events for selected towns and cities. Met Office, 2010.

[10] Flato, G et al. Evaluation of climate models. In: Stocker TF et al. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2013.

This impression is confirmed by a paper by hydrologist Demetris Koutsoyiannis and colleagues, who assessed a group of climate models by comparing their output to observations at a selection of different locations around the globe.[11] They found that, on annual and climate-relevant timescales, climate simulations were less than useless, performing worse than a naïve forecast based on projecting a simple average for that location. As he put it in his paper, 'future climate projections at the examined locations [are] not credible'. When, in a later paper, the analysis was extended to the continental scale, the performance of the GCMs was worse still.[12]

Similarly, an international team of authors led by Graeme Stevens of Colorado State University described what they saw as the 'dreary state of precipitation in global models'.[13] Other authors have expressed similar concerns over the performance of GCMs, noting in particular their inability to predict extremes.[14]

4 Attribution of precipitation and flood

Global

It is notoriously difficult to attribute changes in rainfall to climate change because to do so relies largely on climate models, which as described cannot create valid simulations of rainfall. Empirical evidence for significant changes in rainfall are very limited. One exception is a paper by Karl and Trenberth, who analysed a small network of climate monitoring stations with approximately equal annual rainfall totals and observed that those in hot places experienced more intense rainfall than those in cold ones.[15] Whether this truly tells us any-

[11] Koutsoyiannis D et al. On the credibility of climate predictions. *Hydrological Sciences Journal* 2008; 53: 671–684.

[12] G. G. Anagnostopoulos et al. A comparison of local and aggregated climate model outputs with observed data. *Hydrological Sciences Journal* 2010; 55: 1094–1110.

[13] As the authors explain: 'The differences between observed and modeled precipitation are larger than can be explained by observational retrieval errors or by the inherent sampling differences between observations and models. We show that the time integrated accumulations of precipitation produced by models closely match observations when globally composited. However, these models produce precipitation approximately twice as often as that observed and make rainfall far too lightly.' Stevens G et al. Dreary state of precipitation in global models. *Geophysical Research Letters* 2010; 115: D24211.

[14] For example, Gadgil et al, writing about GCM predictions of the Indian monsoon state that '…the skill of atmospheric and coupled models in predicting the Indian monsoon rainfall is…not satisfactory, and the problem is particularly acute as these models fail to predict the extremes, i.e. droughts and excess rainfall seasons.' Gadgil S et al. Monsoon prediction – Why yet another failure? *Current Science* 2005; 88: 1389–1400.

[15] Karl TR and Trenberth KE. Modern global climate change. *Science* 2003; 302: 1719–1723.

thing about what manmade global warming would do to rainfall patterns is debatable.

Similarly, there is little evidence of a link between floods and carbon dioxide levels. For example, a study of flood levels in the USA found that no strong evidence of a link and indeed noted that in some places there was a negative relationship.[16]

Despite this lack of any strong evidential base, the IPCC says that there is medium confidence that changes in extreme rainfall can be attributed to manmade global warming. Such confidence seems at odds with their observation that the models have systematic biases in the tropics, the ultimate source of most of the world's rain.

UK

As noted above, the UK climate is highly variable, making attribution of any changes highly problematic. One recent paper found that most changes to UK precipitation could be explained without reference to climate change. As the authors noted, '[m]any of the observed changes in seasonal precipitation totals are most likely associated with changes in the North Atlantic Oscillation',[17] in other words natural variability.

Attempts have been made to connect specific weather events to global warming, particularly those that have achieved prominence in the media, but many authors have steered clear of such speculative efforts. For example, the winter storms of early 2014 led to extensive flooding of the Somerset levels and days of news reports. These events were later the subject of an official report, published jointly by the Met Office and the Centre for Ecology and Hydrology.[18] This adopted a cautious approach, noting that:

> As yet, there is no definitive answer on the possible contribution of climate change to the recent storminess, rainfall amounts and the consequent flooding. This is in part due to the highly variable nature of UK weather and climate.

However, the authors did allude to the possibility of a climate link.

> There is an increasing body of evidence that extreme daily rainfall rates are becoming more intense, and that the rate of increase is consistent

[16] Hirsch RM and Ryberg KR. Has the magnitude of floods across the USA changed with global CO2 levels? *Hydrological Sciences Journal* 2012; 57: 1–9.

[17] Simpson IR and Jones PD. Analysis of UK precipitation extremes derived from Met Office gridded data. *International Journal of Climatology* 2014; 34: 2438–2449.

[18] Slingo J et al. The Recent Storms and Floods in the UK. Met Office/CEH, 2014. http://www.metoffice.gov.uk/media/pdf/n/i/Recent_Storms_Briefing_Final_07023.pdf.

> with what is expected from fundamental physics. Although formal attribution is still challenging, it is possible to identify a contribution from climate change for some major flooding events, as the recent paper by Peterson et al. (2013) on the attribution of extremes showed. It is worth emphasizing that there is no evidence to counter the basic premise that a warmer world will lead to more intense daily and hourly heavy rain events.

In fact, Peterson et al, a collection of studies about attribution of extreme weather events, relies entirely on climate models. If these are, in Koutsoyiannis's words, 'not credible' for projections into the future, it is hard to believe that they can plausibly be used to attribute extreme events in the way described. It is perhaps also worthy of note that the Peterson collection only included only one contribution about the UK. This concerned the wet summer of 2012 and concluded that 'any anthropogenic influence…was minimal'.

The authors of the Met Office report did, however, suggest that changes seen in UK rainfall were 'consistent with' what would be expected with man-made global warming, citing a paper by Allan and Soden.[19] The words 'consistent with' are regularly used by those seeking to make the link between some weather event and global warming, but they are words that are calibrated to give an impression of scientific rigour while actually meaning little or nothing: almost all weather events are consistent with global warming, global cooling or indeed with climate stasis.

Moreover, once again the underlying science is shaky indeed. Allan and Soden, in common with other authors making such claims,[20] attempted to demonstrate a link between increased sea surface temperatures and extreme rainfall by tweaking the parameters on a climate simulation. A similarity in the pattern of rainfall between a greenhouse-gas-influenced climate model and the observed record of very heavy rainfall was said to demonstrate a link. Of course a computer simulation does not represent 'evidence', and particularly so given the difficulties with computer modelling.

5 Predictions of precipitation and flood

The difficulties of creating realistic computer simulations of rainfall and the IPCC's recognition of climate models' 'modest' agreement with reality have been described above. However, this has surprisingly done very little to dent

[19] Allan R and Soden B. Atmospheric warming and the amplification of precipitation extremes. Science, 321, 1481–1484

[20] See eg Zhang X-B et al. Attributing intensification of precipitation extremes to human influence. *Geophysical Research Letters* 2013; 40: 5252–5257.

confidence in their precipitation predictions. As hydrologists Demetris Koutsoyiannis and Andreas Langousis note:

> Amazingly…there is little disbelief in some climate modellers' prophecies…of the precipitation regimes over the globe in the next 100 years or more.[8]

Global

On the subject of precipitation, the IPCC's Fifth Assessment report mirrored the findings of its earlier SREX report on extreme weather. It declared that:

- For the next few decades, it was 'likely' that there would be an increase in extreme rainfall over many land areas.
- At the end of the 21st century, it was 'very likely' that there would be an increase over the tropics, and mid-latitudes as well.

Again, one has to ask how they can be so confident at the same time as recognising the climate models' systematic errors in the tropics.

It is frequently claimed – again on the basis of climate models – that wet areas will get wetter, while dry areas will get dryer.[21,22] However, observational evidence to support these claims is thin on the ground. For example, one recent paper that examined the observational evidence found precisely the opposite trend: dry regions were becoming wetter and wet regions drier.[23] Another paper found that nearly as much land area was bucking the expected trend as was following it.[24]

UK

Predictions for the UK are even more difficult because of this country's highly variable weather. Nevertheless, the Met Office has issued confident predictions to its commercial clients about future rainfall in the UK. For example, Ofwat were informed that winter rain will become more frequent, while summer rain could become more or less frequent.[25] On the subject of extreme

[21] Durack PJ et al. Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *Science* 2012; 336: 455–458.

[22] Liu C-L and Allan RP. Observed and simulated precipitation responses in wet and dry regions 1850–2100. *Environmental Research Letters* 2013; 8: 034002.

[23] Sun F-B et al. Changes in the variability of global land precipitation. *Geophysical Research Letters* 2013; 39: L19402.

[24] Greve P et al. Global assessment of trends in wetting and drying over land. *Nature Geoscience* 2014; doi:10.1038/ngeo2247.

[25] See footnote 9.

rainfall, however, the report advised considerable caution, because different models gave very different answers.

Underlying this advice are the UK's official climate predictions, known as UKCP09. The official summary of the predictions[26] opens by declaring that there will be 'increased frequency and intensity of extreme weather for the UK'. Surprisingly, however, the rest of the report gives no details of any such changes.

The use of the UKCP09 dataset is unfortunate, since a significant flaw in the prediction has recently been uncovered: the underlying climate model is incapable of generating virtual climates that resemble the real one in certain key features. What is more, the Met Office has acknowledged this inability.[27] So regarding the official UK predictions of future precipitation, not only do we have to take into account the inability of typical climate models to simulate rainfall, but we have a model that is known to contain a major problem as well. It would therefore be foolish of anyone to place reliance on any of the UKCP09 predictions.

Nevertheless, UKCP09 informs many areas of public policy. For example, The Environment Agency recently raised the annual likelihood of flooding expected in each of the rivers it monitors using data from UKCP09.[28] Elsewhere, Network Rail is preparing climate change adaptation plans for each of its main routes.[29] It is hard to credit the idea that global climate models are providing input into this process.

[26] Defra. Adapting to climate change. UK Climate Projections 2009. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69487/pb13698-climate-risk-assessment.pdf.

[27] Although worryingly they refuse to be drawn on whether an inability to generate realistic climates is a problem or not. Full details of the problem are set out in Montford A. The climate model and the public purse. GWPF Briefing paper No 8, 2013. http://www.thegwpf.org/content/uploads/2013/09/Montford-Climate-Model.pdf.

[28] Cited in Adaptation Subcommittee progress report 2014, Managing climate risks to well-being and the economy.

[29] http://archive.defra.gov.uk/environment/climate/documents/adapt-reports/06road-rail/network-rail.pdf.

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