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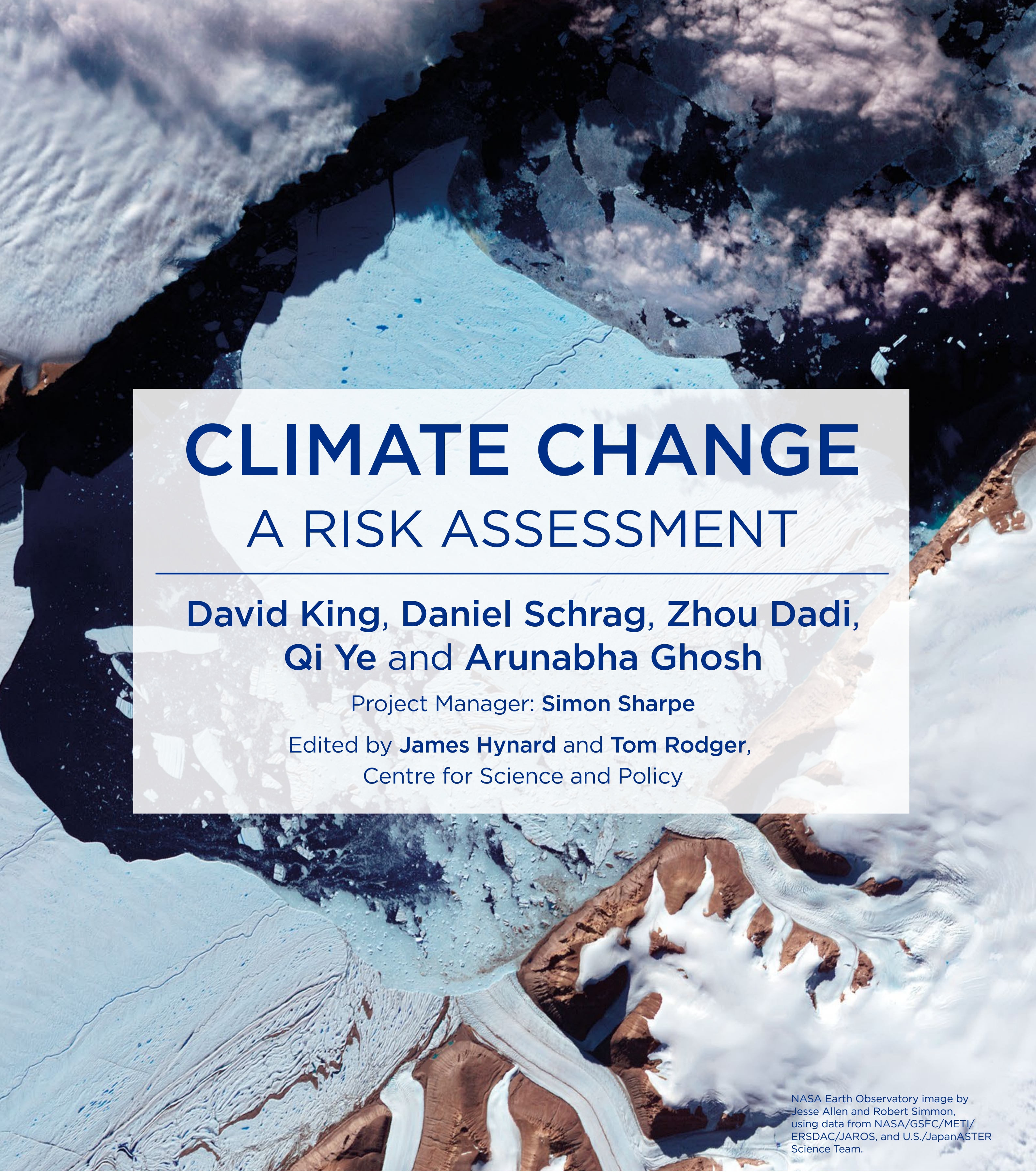
CLIMATE CHANGE
A RISK ASSESSMENT

David King, Daniel Schrag, Zhou Dadi, Qi Ye and **Arunabha Ghosh**

Project Manager: **Simon Sharpe**

Edited by **James Hynard** and **Tom Rodger**, Centre for Science and Policy



NASA Earth Observatory image by Jesse Allen and Robert Simmon, using data from NASA/GSFC/METI/ERSDAC/JAROS, and U.S./JapanASTER Science Team.

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This report was edited and produced by the Centre for Science and Policy (CSaP) at the University of Cambridge. CSaP's mission is to promote the use of expertise and evidence in public policy by convening its unique network of academics and policy makers.

STATUS OF THIS REPORT

Sir David King led this project in his official capacity as the UK Foreign Secretary's Special Representative for Climate Change. The Foreign and Commonwealth Office commissioned this report as an independent contribution to the climate change debate. Its contents represent the views of the authors, and should not be taken to represent the views of the UK Government.

ACKNOWLEDGMENTS

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14 THE RISK OF RIVER FLOODING

Professor Nigel Arnell, Director of the Walker Institute for Climate System Research

What do we want to avoid?

River flooding is the most serious and widespread weather hazard affecting the world. According to the Munich Re natural hazards catalogue, between 1980 and 2014 river floods accounted for 41% of all loss events, 27% of fatalities and 32% of losses.[1] By changing the timing and amount of precipitation, climate change has the potential to substantially alter flood regimes and therefore future flood losses.

River floods are generated through intense or prolonged rainfall or through snowmelt. There are three main scales of river flooding:

- Flash floods occur when the volume of water produced by intense heavy rainfall generates significant overland flow, and are typically localized and small-scale.
- Floods along major rivers with extensive floodplains typically occur following prolonged periods of heavy rainfall or snowmelt, and flood waters may persist for weeks.
- Between these two extremes are floods that are locally generated by rainfall and snowmelt within a catchment area.

The relative contribution of these three broad scales of flooding to the overall flood threat varies from country to country. At the global scale, there is little information on the numbers of people exposed to flash flooding, because the hazard is highly localised. Most information at the global scale therefore relates to flooding along major rivers and floodplains with catchments of several thousand square kilometres.

For the purposes of this assessment we shall take as our threshold floods of the magnitude of current 1 in 30 year flood events. In 2010 just over 700 million people were living in major floodplains[2] and – on average – over 20 million of these were affected by floods with a return period of greater than once every 30 years.[i] Almost half of these people live in South Asia. Some of the flood-prone populations are protected by flood defences so do not actually see their properties flooded, although they are likely to be indirectly affected through impacts on their communities and infrastructure.[3]

How could the impact of flooding change over time?

Population change alone will increase the numbers of people affected by flooding in the future. Climate change could increase the number further, in some regions. Figure F1 shows the numbers of people affected by floods greater than the current '30-year flood' globally and for four major world regions, for high (red) and low (green) emissions pathways, as a function of time.

i. The methods used here are summarised in the annex

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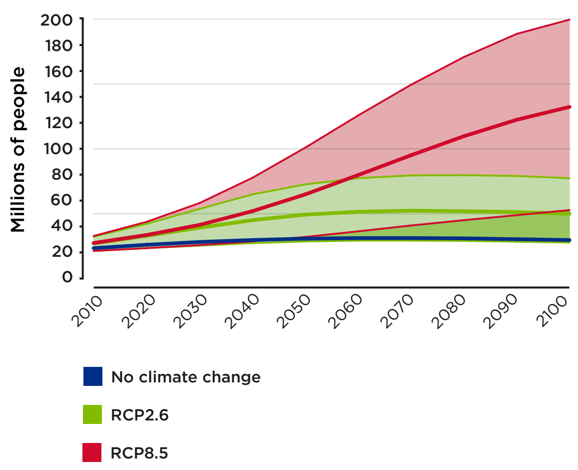
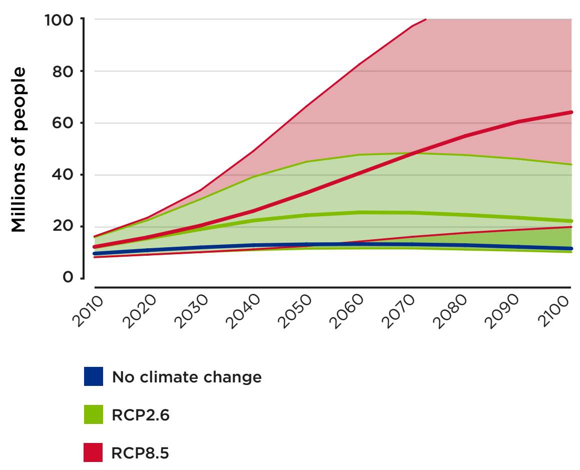
RISK ASSESSMENT PART 2: DIRECT RISKS

Figure F1: **The average annual number of people affected by river flooding with and without climate change.** The plots show two climate pathways (RCP2.6 and RCP8.5). The solid line represents the median estimate of impact for each pathway, and the shaded areas show the 10% to 90% range. A medium growth population projection is assumed.

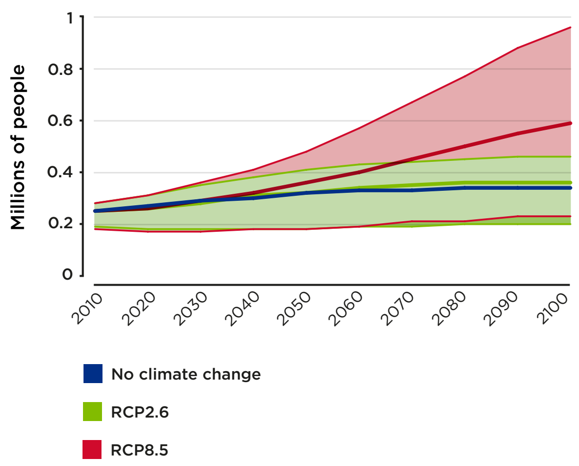
Global: flooded population



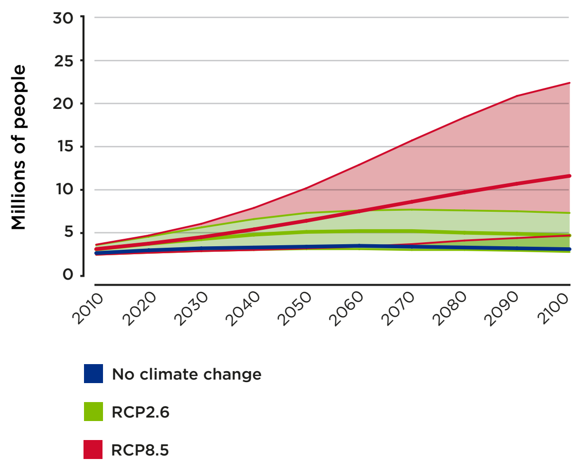
South Asia: flooded population



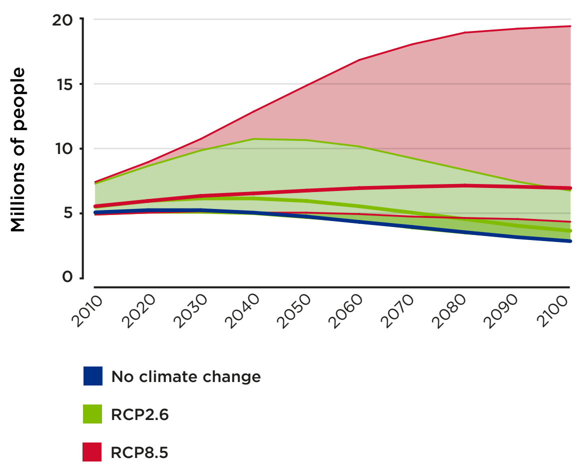
US: flooded population



South East Asia: flooded population



East Asia: flooded population

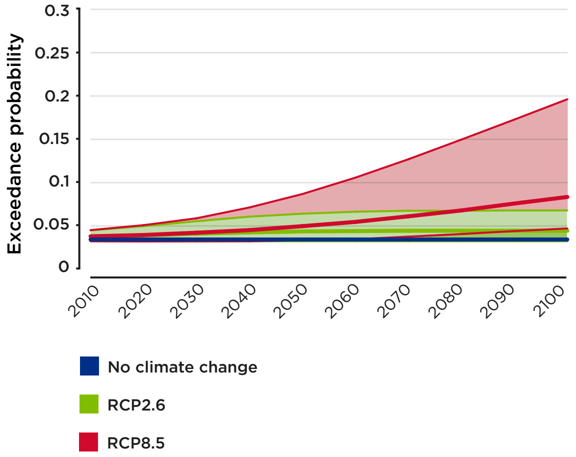


The global total increases very substantially – by around five or six times, over the course of the century for the high emissions pathway. This is largely due to increases in South, southeast and East Asia. There is a clear difference between the high and low emissions pathways, but there is also very high uncertainty in the numbers of people affected by flooding in the future due to uncertainty in changes in precipitation.

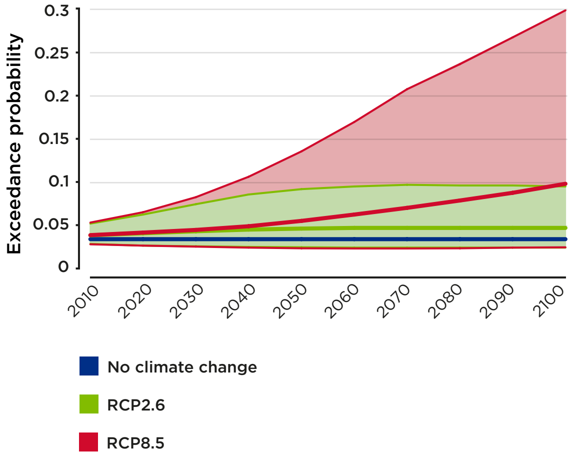
How could the likelihood of flooding change over time?

Figure F2: **The probability that flood magnitude in a given year exceeds the magnitude of the current 30-year return period flood in five illustrative catchments, under two climate pathways.**

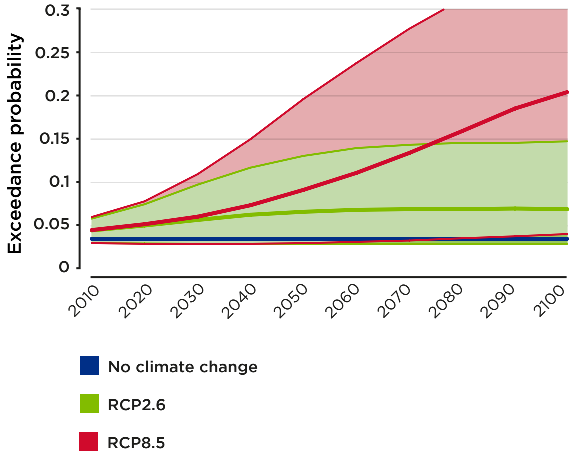
Yangtse: annual probability of exceeding current 30-year flood



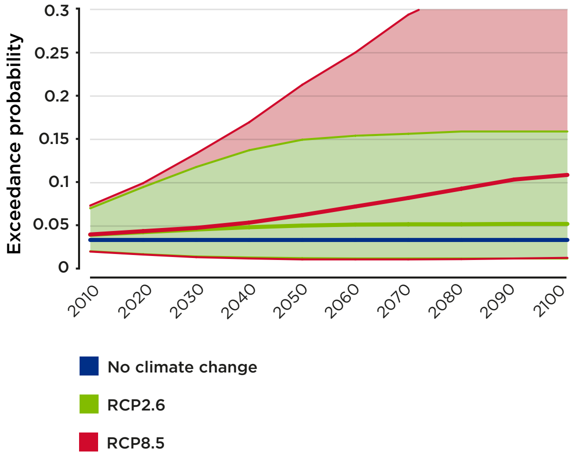
Huang Ho: annual probability of exceeding current 30-year flood



Ganges: annual probability of exceeding current 30-year flood



Indus: annual probability of exceeding current 30-year flood



Mississippi: annual probability of exceeding current 30-year flood

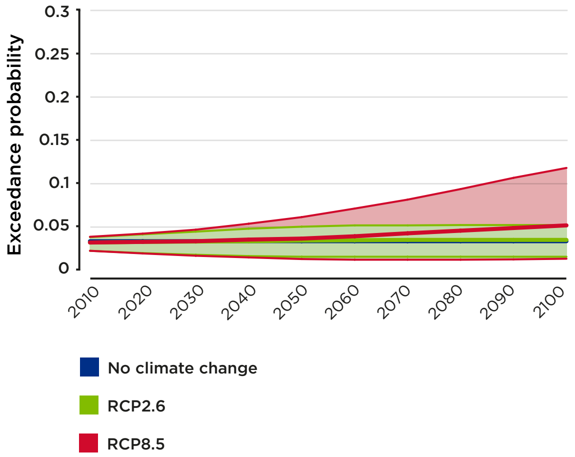
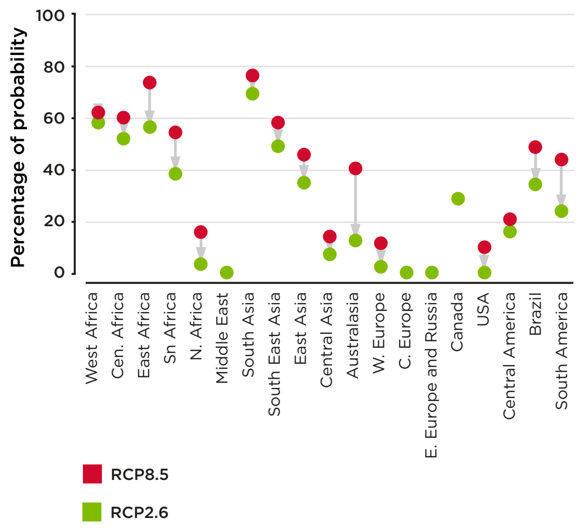


Figure F2 shows change through the 21st century in the probability of experiencing a flood greater than the baseline '30-year flood'. In the Asian examples, the probability of flooding increases very substantially under the high emissions pathway: tripling in the Huang He and Indus, and multiplying by six in the Ganges (becoming a 1 in 5 year event), over the course of the century, according to the central estimate. The increase in probability is considerably lower under the low emissions pathway. The figures show, however, that there

is very large uncertainty in the change in future flood probability. In the best case, some regions could see a small reduction in probability. In the worst case, flooding on the Ganges, Indus and Huang He could be in the region of ten times more frequent by the end of the century.

Figure F3: **The risk that climate change increases by more than 50% the numbers of people affected by the current 30-year flood, relative to the situation with no climate change, under the two climate pathways.** A medium growth population projection is assumed.

2050: probability of number of people affected by flooding increasing by >50%



2100: probability of number of people affected by flooding increasing by >50%

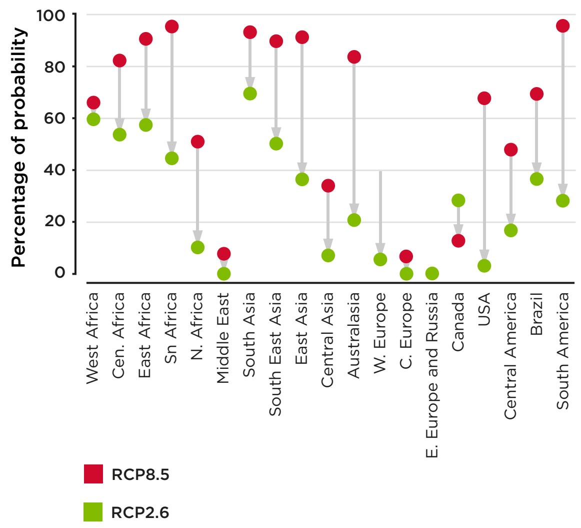


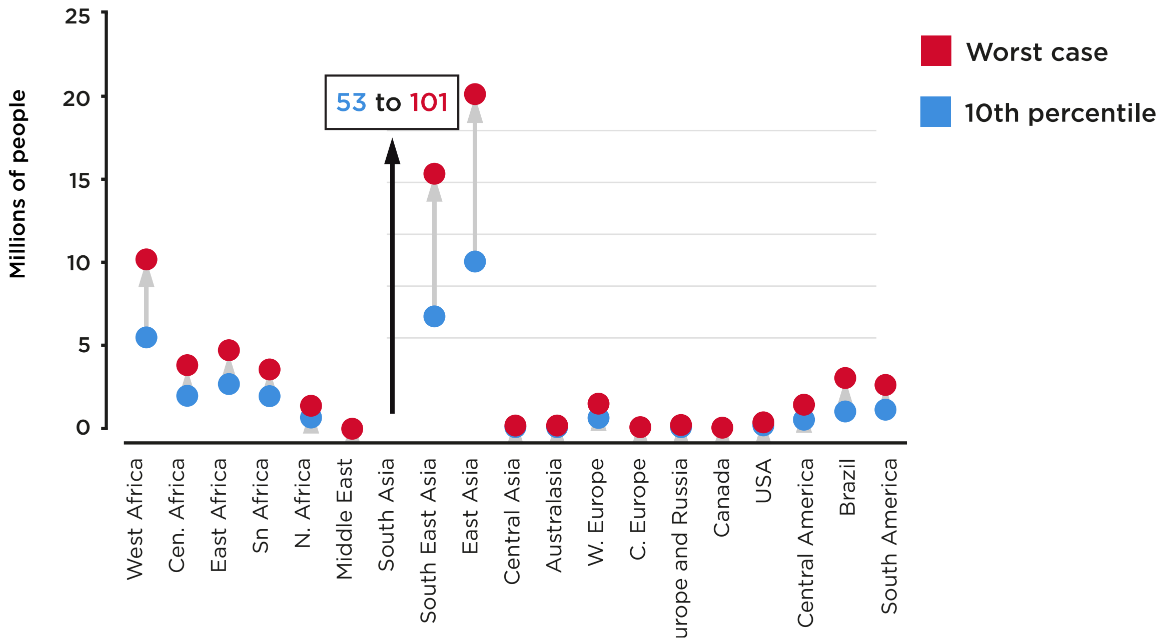
Figure F3 shows the risk by region that climate change increases by more than 50% the numbers of people affected by the current 30-year flood, relative to the situation without climate change. By the 2050s, there is at least a 50% chance that climate change alone would lead to a 50% increase in flooded people across sub-Saharan Africa, and a 30-70% chance that such an increase would be seen in Asia. By 2100 the risks are greater. Under the low emissions pathway the probabilities are lower in all regions than under the high emissions pathway, particularly in 2100.

What is a plausible worst case for changes in river flooding due to climate change?

It is clear from Figure F1 that there is considerable uncertainty in projected impacts of climate change. By 2050, under the 'worst case' climate scenario (the climate model pattern that projects the greatest increase in rainfall in the regions with the greatest flood-prone population), approximately 115 million extra people would be flooded in each year (relative to the situation with no climate change). Figure F4 shows the 'worst case' by region. In most regions the 'worst case' has approximately twice the impact of the 10th percentile impact. However, the worst cases shown in each region do not occur under the same plausible climate scenario: the global worst case is not the sum of the regional worst cases.

Figure F4 is based on the assumption that all the climate models used to estimate impacts are equally plausible and that they span the range of potential regional climate changes. This is not necessarily the case, so the numbers are to be regarded as indicative. Changes in south Asia (and therefore the global total) are strongly dependent on projected changes in the south Asian monsoon (see the previous chapter on water stress).

Figure F4: **Plausible ‘worst case’ impacts of climate change in 2050 on exposure to river flooding.** The graph shows the increase in numbers of people affected by flooding under the RCP8.5 climate pathway and the medium growth population assumption. There is a 10% probability that the impact is greater than that shown by the blue dots, and the red dots show the maximum calculated impact. Note that the impacts in south Asia are separately indicated, as they are far larger than those in other regions.



What do we know, what do we not know, and what do we think?

Estimates of how flood risk will change in the future are based on (i) projections of future regional climate change, (ii) projections of how these translate into changes in flood characteristics and (iii) projections of future exposed population and the implementation of flood defences.

Projections of future regional climate change depend partly on the assumed rate of growth in emissions, and partly on projected changes in regional and seasonal precipitation. From meteorological first principles, we would expect that – other things being equal – the frequency of high rainfall events would increase in a warmer world, simply because the hydrological cycle is enhanced and warmer air can hold more water. The frequency of flash flooding can therefore be expected to increase.

However, changes in atmospheric circulation patterns potentially have a greater impact on the magnitudes of persistent or prolonged heavy rainfall that have the greatest influence on flooding in most river basins, and these changes are currently uncertain. Wet regions are likely to get wetter, but the precise magnitude of change is uncertain, and the extent to which climate change alters the relative variability in rainfall from day to day and year to year is uncertain too. Higher temperatures would also in general mean that less precipitation would fall as snow during winter so there would be less snow to melt during the melt season – but this will vary from place to place depending on temperature regime, and may be offset or exaggerated by circulation changes generating more or less precipitation during winter.

The effects of changes in precipitation on river flood characteristics are typically estimated using a hydrological model, perhaps combined with a hydraulic model to simulate the routing of flood flows along the river network and through floodplains. Flood frequencies are estimated by fitting a statistical frequency distribution to time series of flood flows. All of these stages introduce uncertainty in the projected effect of a given change in precipitation regime.

Finally, the estimated future impacts on human society depend on changes in exposure to floods and vulnerability to their effects. This will depend not only on population and economic growth, but also on the extent to which physical flood defences are developed, buildings and infrastructure are sited to reduce exposure, and measures are implemented to help individuals and communities respond to and recover from floods and loss.

Production of this chapter was supported by the AVOID 2 programme (DECC) under contract reference 1104872.

Endnotes

1. MunichRe (2015) NatCatSERVICE: Loss events worldwide 1980-2014.
2. As defined in the UNISDR PREVIEW data base.
3. The UNDP estimates that around 50-60 million people are affected by river flooding each year, but this includes people affected by smaller magnitude floods. UNDP (2009) Risk and poverty in a changing climate: 2009 Global Assessment Report on Disaster Risk Reduction. UNDP: New York.

ERRATA – October 2015

Following publication of the report, errors have been identified, and corrections made to the online version as listed below. Thanks are due to those who pointed these out, and apologies to the contributing authors, whose mistakes these were not.

Printed versions of the report should be read with these corrections in mind.

1. Inside front cover, p.2: "Global Challenges Foundation" added to list of organisations thanked in the ACKNOWLEDGEMENTS section.

2. Page 89, Figure 1: the titles of the 'US' and 'South Asia' graphs of flooded populations were incorrectly labelled and have been switched. And the 'East Asia' and 'South East Asia' graphs of flooded populations were also incorrectly labelled and have been switched.

3. Page 94, Figure 1: There is a mislabelled graph has the vertical axis marked as 1 … 10 … 100 … 200. It is supposed to be a logarithmic scale, so the topmost line should be labelled as 1000, not 200.

4. Page 114, Figure 1: A key has been added to the map showing the proportion of total calories coming from the four main commodity crops.