The risk of river flooding

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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,
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ABOUT THE AUTHORS

**Sir David King** is the UK Foreign Secretary’s Special Representative for Climate Change, and was formerly the UK Government’s Chief Scientific Adviser. He has authored over 500 papers on chemical physics and on science and policy, and his university positions have included Professor of Physical Chemistry at Cambridge University, and Founding Director of the Smith School of Enterprise and the Environment at Oxford University.

**Professor Daniel P. Schrag** is Director of the Harvard University Center for the Environment, and serves on the US President’s Council of Advisors on Science and Technology. He is the Sturgis Hooper Professor of Geology and Professor of Environmental Science and Engineering, and studies energy technology and policy as well as geochemistry and climatology. He has received several honors including a MacArthur Fellowship.

**Professor Zhou Dadi** is a member of the China National Expert Committee on Climate Change, and was formerly Director General of the Energy Research Institute of the National Development and Reform Commission of the Government of China. He is a specialist in energy economics and energy systems analysis, sustainable energy strategy, energy conservation, and climate change policy.

**Professor Qi Ye** is Director of the Brookings-Tsinghua Centre for Public Policy at the School of Public Policy and Management, Tsinghua University, and a Senior Fellow of the Brookings Institution. He is an expert on China’s policies on climate change, the environment, energy, natural resources, biodiversity, and on the theory and practice of sustainable development.

**Dr Arunabha Ghosh** is the CEO of the Council on Energy, Environment and Water (CEEW), one of India’s top-ranked climate think-tanks. He is an expert in climate, energy, water and environment policy, economics and governance, has presented to parliaments including those of India, Europe and Brazil, and to heads of state, and has previously worked at Princeton and Oxford Universities, United Nations Development Programme and World Trade Organization. He is a founding Board member of the Clean Energy Access Network and on the Board of the International Centre for Trade and Sustainable Development.


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.

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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. 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 localized. 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 and – on average – over 20 million of these were affected by floods with a return period of greater than once every 30 years.

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.

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.

- **Yangtze**: 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 2050, 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.

Endnotes
2. As defined in the UNISDR PREVIEW data base.
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.