UK Climate Projections science report: Climate change projections

James Murphy, David Sexton, Geoff Jenkins, Penny Boorman, Ben Booth, Kate Brown, Robin Clark, Mat Collins, Glen Harris, Lizzie Kendon, *Met Office Hadley Centre*

Annexes: Richard Betts, Simon Brown, Tim Hinton, Tom Howard, Ruth McDonald, Mark McCarthy, Richard Wood, *Met Office Hadley Centre,* Kathryn Humphrey, *Department for Environment, Food and Rural Affairs,* Ag Stephens, *British Atmospheric Data Centre,* Craig Wallace, *National Oceanography Centre,* Rachel Warren, *University of East Anglia,* Rob Wilby, *Loughborough University*

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Review comments from:

Dr Richard Betts, Met Office Hadley Centre, Exeter
Dr Rachel Capon, Arup, London
Dr Vic Crisp, Chartered Institution of Building Services Engineers, London
Dr Suraje Dessai, Tyndall Centre for Climate Change Research, Norwich
Dr Bill Donovan, Environment Agency, Bristol
Dr Stephen Dye, Centre for Environment, Fisheries and Aquaculture Science, Lowestoft
Dr Clare Goodess, Climatic Research Unit, University of East Anglia, Norwich
Karl Hardy, Flood and Coastal Erosion Research Management, Defra, London
Kathryn Humphrey, Adapting to Climate Change Programme, Defra, London
Kay Jenkinson, UK Climate Impacts Programme, Oxford
Kay Johnstone, UK Climate Impacts Programme, Oxford
Prof. Phil Jones, Climatic Research Unit, University of East Anglia, Norwich
Dr Richard Jones, Met Office Hadley Centre, Exeter
Richard Lamb, UK Climate Impacts Programme, Oxford
Gerry Metcalf, UK Climate Impacts Programme, Oxford
Prof. John Mitchell, Met Office Hadley Centre, Exeter
Laurie Newton, UK Climate Impacts Programme, Oxford
Maeve O'Donoghue, Welsh Assembly Government, Cardiff
Kathryn Packer, Adapting to Climate Change Programme, Defra, London
Dr Vicky Pope, Met Office Hadley Centre, Exeter
Peter Singleton, Scottish Environment Protection Agency, Stirling
Ag Stephens, British Atmospheric Data Centre, Abingdon
Anna Steynor, UK Climate Impacts Programme, Oxford
Roger Street, UK Climate Impacts Programme, Oxford
Prof. Rowan Sutton, University of Reading
Dr Stephen Wade, HR Wallingford, Wallingford
Dr Rachel Warren, Tyndall Centre for Climate Change Research, Norwich
Dr Glen Watts, Environment Agency, Bristol
Dr Olly Watts, Royal Society for the Protection of Birds, Sandy
Dr Chris West, UK Climate Impacts Programme, Oxford
Richard Westaway, UK Climate Impacts Programme, Oxford
Prof. Rob Wilby, Loughborough University
Guy Winter, Scottish Government, Edinburgh

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Prof. Myles Allen, University of Oxford
Prof. Nigel Arnell, Walker Institute for Climate System Research, University of Reading
Dr Clare Goodess, Climatic Research Unit, UEA, Norwich
Prof. Claudia Tebaldi, Climate Central, Princeton, USA
Prof. Francis Zwiers, Climate Research Division, Environment Canada, Toronto, Canada

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Discussions with Prof. Jonathan Rougier, University of Bristol, have encouraged us to adopt the methodology for the UKCP09 Probabilistic Projections.

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Summary

The UK Climate Projections (UKCP09) provide projections of climate change for the UK, giving greater spatial and temporal detail, and more information on uncertainty, than previous UK climate scenarios.

This report is designed for those who wish to find out more about the purpose and design of the UKCP09 methodology for producing the probabilistic projections of climate change, and is drafted to suit a range of levels of expertise. It shows some examples of projections; the full set of results is available through the User Interface and the pre-prepared maps and graphs, with key findings presented in the Briefing Report.

Purpose and design of UKCP09

- Over land, UKCP09 gives projections of changes for a number of climate variables, averaged over seven overlapping 30-yr time periods, at 25 km resolution and for administrative regions and river basins. Similar projections are given for a smaller number of variables averaged over marine regions around the UK (Chapter 1).

- UKCP09 is the first set of UKCIP projections to attach probabilities to different levels of future climate change. The probabilities given in UKCP09 represent the relative degree to which each climate outcome is supported by the evidence currently available, taking into account our understanding of climate science and observations, and using expert judgement (Chapter 1).

- The Met Office Hadley Centre has designed a methodology to provide probabilistic projections for UKCP09, based on ensembles of climate model projections consisting of multiple variants of the Met Office climate model, as well as climate models from other centres. These ensembles sample major known uncertainties in relevant climate system processes (Chapters 2 and 3).

- UKCP09 gives projections for each of three of the IPCC's Special Report on Emissions Scenarios (SRES) scenarios (A1FI (called High in UKCP09), A1B (Medium) and B1 (Low)) to show how different emissions pathways affect future climate (Chapter 2 and Annex 1). Each of the emissions scenarios suggests a different pathway of economic and social change over the course of the 21st Century; it is not possible to assign probabilities to each scenario. They do not include planned mitigation measures directly.

- For a given emissions scenario, the UKCP09 probabilistic projections account for uncertainties arising from the representation of climate processes, and the effects of natural internal variability of the climate system (Chapter 2).

- Changes to external factors such as solar activity and volcanic eruptions cannot be predicted, and are not considered (Chapter 2).

- UKCP09 projections explicitly include the climate carbon cycle feedback for the first time, and uncertainties in the feedback from the land carbon cycle. They also include the direct and first indirect effects of sulphate aerosol and uncertainties in these. Some feedbacks, such as those from the methane cycle, are not well enough understood to be included (Chapter 2).

- The UKCP09 methodology uses the Met Office regional climate model (RCM) to downscale global climate projections to a 25 km scale; uncertainties in this downscaling are also included in the probabilistic projections (Chapter 3).

- Continuous daily time series from 1950 to 2099 for 11 variants of the Met Office RCM are available via a separate project called LINK. These time series are spatially coherent between grid squares and are available over land and sea. However, being based only on Met Office models, they do not take as much uncertainty into account (Chapter 5)

- It has not been possible to produce probabilistic projections of changes in snowfall rate, and users are recommended to take these from the 11-member RCM ensemble (Chapter 4)

- The current observed strength of the Urban Heat Island effect is included in the projections of future climate, but possible changes in the strength of the Urban Heat Island in the future cannot yet be included (Annex 7).

- It is unlikely that an abrupt change in the Atlantic Ocean Circulation will occur this century. The effects of a gradual weakening of the circulation over time are included in the UKCP09 climate projections (Annex 5).

- Models will never be able to exactly reproduce the real climate system; nevertheless there is enough similarity between current climate models and the real world to give us confidence that they provide plausible projections of future changes in climate (Annex 3).

- There is a cascade of confidence in climate projections, with moderate confidence in those at continental scale; those at 25 km resolution are indicative to the extent that they reflect large-scale changes modified by local conditions such as mountains and coasts. The level of confidence is different for different variables.

- Errors in global climate model projections cannot be compensated by statistical procedures no matter how complex, and will be reflected in uncertainties at all scales.

Some examples of projected seasonal and annual changes

We summarise in the box below some changes by the 2080s with Medium emissions, but stress that projections can be very different for other time periods and other emissions scenarios. Users should look at the time period appropriate for their decisions, and examine projections for all three emissions scenarios, to gain a full appreciation of changes to which they might have to adapt.

Summer, winter and annual mean changes by the 2080s (relative to a 1961–1990 baseline) under the Medium emissions scenario. Central estimates of change (those at the 50% probability level) followed, in brackets, by changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively).

- All areas of the UK warm, more so in summer than in winter. Changes in summer **mean temperatures** are greatest in parts of southern England (up to 4.2°C (2.2 to 6.8°C)) and least in the Scottish islands (just over 2.5°C (1.2 to 4.1°C)).

- **Mean daily maximum temperatures** increase everywhere. Increases in the summer average are up to 5.4°C (2.2 to 9.5°C) in parts of southern England and 2.8°C (1 to 5°C) in parts of northern Britain. Increases in winter are 1.5°C (0.7 to 2.7°C) to 2.5°C (1.3 to 4.4°C) across the country.

- Changes in the **warmest day of summer** range from +2.4°C (–2.4 to +6.8°C) to +4.8°C (+0.2 to +12.3°C), depending on location, but with no simple geographical pattern.

- **Mean daily minimum temperature** increases on average in winter by about 2.1°C (0.6 to 3.7°C) to 3.5°C (1.5 to 5.9°C) depending on location. In summer it increases by 2.7°C (1.3 to 4.5°C) to 4.1°C (2.0 to 7.1°C), with the biggest increases in southern Britain and the smallest in northern Scotland.

- Central estimates of **annual precipitation** amounts show very little change everywhere at the 50% probability level. Changes range from –16% in some places at the 10% probability level, to +14% in some places at the 90% probability level, with no simple pattern.

- The biggest changes in **precipitation in winter**, increases up to +33% (+9 to +70%), are seen along the western side of the UK. Decreases of a few percent (–11 to +7%) are seen over parts of the Scottish highlands.

- The biggest changes in **precipitation in summer**, down to about –40% (–65 to –6%), are seen in parts of the far south of England. Changes close to zero (–8 to +10%) are seen over parts of northern Scotland.

- Changes in the **wettest day of the winter** range from zero (–12 to +13%) in parts of Scotland to +25% (+7 to +56%) in parts of England.
- Changes in the **wettest day of the summer** range from –12% (–38 to +9%) in parts of southern England to +12% (–1 to +51%) in parts of Scotland.
- **Relative humidity** decreases by around –9% (–20 to 0%) in summer in parts of southern England — by less elsewhere. In winter changes are a few percent or less everywhere.
- **Summer-mean cloud amount** decreases, by up to –18% (–33 to –2%) in parts of southern England (giving up to an extra +20 Wm^{-2} (–1% to +45 Wm^{-2}) of downward shortwave radiation) but increase by up to +5% (zero to +11%) in parts of northern Scotland. Changes in cloud amount are small (–10 to +10%) in winter.

- Projected changes in **storms** are very different in different climate models. Future changes in anticyclonic weather are equally unclear (Annex 6).
- We have been unable to provide probabilistic projections of changes in **snow**. The Met Office Hadley Centre regional climate model projects changes in winter mean snowfall of typically –65% to –80% over mountain areas and –80% to –95% elsewhere.
- We make no assessment of how the **Urban Heat Island** effect may change (Annex 7).
- It is very unlikely that an abrupt change to the Atlantic Ocean Circulation (**Gulf Stream**) will occur this century (Annex 5).

- UKCP09 provides a state-of-the-art basis for assessing the risk of different outcomes consistent with current climate modelling capability and understanding. As our understanding, and our modelling and statistical capabilities, improve in future, the projections are very likely to change (Chapter 3 and Annex 2).
- UKCP09 projections are appropriate for decisions on adapting to long-term climate change which need to be taken on the basis of current knowledge (Chapter 2).