Climate Change Scenarios for the United Kingdom

The UKCIP02 Scientific Report

April 2002
Climate Change Scenarios for the United Kingdom:
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On-line sources of UKCIP02 scenario data and related climate change information

- **UKCIP02 Climate Scenario Data:**
  
  www.ukcip.org.uk/scenarios/
  
  Observed (5km), Climate change scenarios (50km) and climate scenarios (5km).

- **The Climate Impacts LINK Project:**
  
  www.cru.uea.ac.uk/link/
  
  Supplying model output from the full range of Hadley Centre climate model experiments.

- **Climatic Research Unit, University of East Anglia:**
  
  www.cru.uea.ac.uk/
  
  Supplying global/hemispheric temperatures and gridded climate data sets.

- **The British Atmospheric Data Centre (BADC):**
  
  tornado.badc.rl.ac.uk/
  
  Supplying observed daily weather data for the UK.

- **UK Marine Environmental Data Network:**
  
  www.oceannet.org/
  
  Co-ordinating available information and data for the UK marine environment.

- **Solar Radiation Database for Environment (SoDa):**
  
  soda.jrc.it/
  
  Project for integration and exploitation of international solar radiation databases.

- **European Solar radiation Atlas (ESRA):**
  
  www.helioclim.net/esra/radiation.html
  
  Links to information on obtaining solar radiation data for Europe.

- **The Hadley Centre for Climate Prediction and Research, Met Office:**
  
  www.metoffice.com/research/hadleycentre/index.html
  
  Supplying Central England Temperature, England and Wales Precipitation and air flow indices.

- **The Inter-governmental Panel on Climate Change (IPCC):**
  
  www.ipcc.ch/
  
  Information about IPCC activities, assessment reports and other publications.

- **The IPCC Data Distribution Centre (DDC):**
  
  http://ipcc-ddc.cru.uea.ac.uk/
  
  Supplying results from worldwide global climate model experiments and other scenario-related information.

- **The IPCC Special Report on Emissions Scenarios (SRES):**
  
  sres.ciesin.org/index.html
  
  Detailed information about the IPCC emissions scenarios and related non-climate scenario information.

- **The Statistical DownScaling Model:**
  
  co-public.lboro.ac.uk/co/model/SDSM/IDLogin.html
  
  A public-domain weather generator.

- **The LARS Weather Generator:**
  
  www.iacr.bbsrc.ac.uk/mas-models/larSWG.html
  
  A public-domain weather generator, designed for UK climate.
The Tyndall Centre is the national UK centre for trans-disciplinary research on climate change. Its purpose is to research, assess and communicate from a distinct trans-disciplinary perspective the options to mitigate, and the necessities to adapt to, climate change, and to integrate these into the global, national and local contexts of sustainable development. It is dedicated to advancing the science of integration, to seeking, evaluating and facilitating sustainable solutions to climate change and to motivate society through promoting informed and effective dialogue. The Centre was constituted in October 2000 and is the result of a unique collaboration between nine UK research institutions and three of the UK Research Councils - NERC, EPSRC and ESRC. It draws additional support from the UK Government's Department of Trade and Industry. The Centre has its Headquarters in the School of Environmental Sciences at the University of East Anglia in Norwich, but it also has regional offices at UMIST in Manchester and at the University of Southampton.

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The Hadley Centre is the UK government centre for research into the science of climate change. It is a branch of the Met Office with about 100 staff, currently situated at Bracknell, but due to move to Exeter in 2003. It was opened in 1990, building on 20 years’ previous research into climate. Its main roles are:

- To understand processes in the climate system and develop climate models which represent them
- To use the models to simulate change and variability in the past, and predict change in the future
- To monitor global and UK climate trends
- To attribute recent climate change to a number of possible causes, including human activities
- To advise government, industry and the media

The Hadley Centre is funded under contracts from DEFRA and the Government Meteorological Research Programme.

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The UK Climate Impacts Programme helps organisations identify how they will be affected by climate change so they can plan to adapt. The Programme was established by the Government in 1997, with the aim of providing a framework for an integrated assessment of climate change impacts. Since then it has coordinated stakeholder-led studies for most of the regions in England, as well as Scotland, Wales and Northern Ireland. A number of sectoral studies have also been undertaken, including research on health and nature conservation.

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EXECUTIVE SUMMARY

What is this report for and what does it contain?

1. This report presents a set of four scenarios of future climate change for the UK based on our current understanding of the science of climate change. They have been commissioned and funded by the Department for Environment, Food and Rural Affairs for the UK Climate Impacts Programme (UKCIP). The climate change scenarios (known as UKCIP02) provide a common starting point for assessing climate change vulnerability, impacts and adaptation in the UK. The scenarios are designed to be used in conjunction with other UKCIP reports and products.

2. The UKCIP02 report contains the following information:

- it summarises the changes that are already occurring in global and UK climate;
- it presents four alternative climate change scenarios for the UK, including information about changes in average climate, in some selected daily weather extremes, and in average and extreme sea levels around the coast;
- it discusses the main uncertainties that influence our confidence in these descriptions, and illustrates the importance of some of them;
- it directs users to further sources of information, both quantitative and qualitative, that will assist them in using the UKCIP02, and other, climate change scenarios when conducting scoping, impacts or adaptation studies in the UK.

3. The UKCIP02 scenarios represent an advance in our description of future UK climates compared to the scenarios published for UKCIP in 1998. This is because they are based on new global emissions scenarios published in 2000 by the Intergovernmental Panel on Climate Change (IPCC) in their Special Report on Emissions Scenarios, and because they are based on a series of climate modelling experiments completed by the Hadley Centre using their most recently developed models. The scenarios describe four alternative future climates for the UK labelled, respectively, Low Emissions, Medium-Low Emissions, Medium-High Emissions and High Emissions. A new 5 km observed monthly climate data set for the UK for the period 1961 to 2000 has also been prepared.

4. No probabilities can be attached to these four climate futures - in line with the IPCC, we do not suggest that one is more likely than another. While they represent a wide range of possible future climates, the UKCIP02 scenarios do not capture the entire range of future possibilities.

How has climate changed?

5. Global temperature has risen by about 0.6°C over the last 100 years, and 1998 was the single warmest year in the 142-year global instrumental record. A large part of the warming over the latter part of this period is likely to be due to human activities and cannot be explained solely by our understanding of the natural variability of the climate system.

6. The UK climate has also changed over the same period, and many of these changes are consistent with the warming of global climate. Central England temperature rose by almost 1°C through the twentieth century. The decade of the 1990s was the warmest in central England since records began in the 1660s. The warming over land has been accompanied by a warming of UK coastal waters. Hot summer days with daytime temperature in central England exceeding 25°C have become more common - almost twice as many on average during the 1990s compared to the first half of the twentieth century - while days with air frosts have been declining in frequency. The UK’s thermal growing season for plants is now longer than at any time since the start of the record in 1772.

7. Winters across the UK have been getting wetter, with a larger proportion of the precipitation falling in the heaviest downpours, while summers have been getting slightly drier. The average rate of sea-level rise during the last century around the UK coastline, after adjustment for natural land movements, has been approximately 1 mm per year. Although the last decade has seen an increase in gale frequency in the UK, this increase is not unprecedented in the historic record.

How will future emissions affect future climate?

8. Much of the change in climate over the next 30 to 40 years has already been determined by historic emissions and because of the inertia in the climate system. We are likely, therefore, to have to adapt to some degree of climate change however much future emissions are reduced. The climate of the second half of the twenty-first century, and beyond, will be increasingly influenced, however, by the volume of greenhouse gases emitted by human society over the coming decades.

9. By the 2080s, the UKCIP02 scenarios suggest that atmospheric carbon dioxide concentrations may be between 525 parts per million (Low Emissions scenario) and 810 parts per million (High Emissions). This represents an increase from the average 1961-1990 concentration of 334 parts per million of between 57 and 143 per cent, and is between almost two and three times the pre-industrial concentration of 280 parts per million. The atmospheric carbon dioxide concentration in 2002 is about 370 parts per million.

10. Even if global emissions of carbon dioxide eventually fall below today’s level, as assumed in the UKCIP02 Low Emissions scenario, the future rate of global warming over the
present century may be about four times that experienced during the twentieth century. If the emissions rate increases to approximately four times today’s level – the **High Emissions** scenario – the future warming rate may be about eight times that experienced during the twentieth century.

**How will UK climate change?**

**Annual changes**

11. Average annual temperatures across the UK may rise by between 2ºC and 3.5ºC by the 2080s, depending on the scenario. In general, there will be greater warming in the south east than in the northwest of the UK, and there may be more warming in summer and autumn than in winter and spring. Under a **High Emissions** scenario, the southeast may be up to 5ºC warmer in summer by the 2080s.

12. The temperature of UK coastal waters will increase, although not as rapidly as over land, with again the greatest warming in the south. Offshore waters in the English Channel may warm in summer by between 2ºC and 4ºC by the 2080s.

13. Annual average precipitation across the UK may decrease slightly, by between 0 and 15 per cent by the 2080s depending on scenario, although there are likely to be large regional and seasonal differences.

14. Snowfall amounts will decrease significantly throughout the UK, perhaps by between 30 and 90 per cent by the 2080s.

**Seasonal changes**

15. By the 2050s, typical spring temperatures may occur between one and three weeks earlier than at present and the onset of present winter temperatures may be delayed by between one and three weeks. This is likely to lead to a lengthening of the thermal growing season for plants. The amount of heating and cooling required in buildings will also change.

16. The seasonal distribution of precipitation will change, with winters becoming wetter and summers perhaps drier across the UK and with the biggest relative changes in the south and east. Precipitation in the **High Emissions** scenario may decrease in summer by 50 per cent by the 2080s in the southeast and increase in winter by up to 30 per cent.

17. Summer soil moisture by the 2050s may be reduced by about 30 per cent over large parts of England for the **High Emissions** scenario, and by 40 per cent or more by the 2080s.

**Changes in weather extremes**

18. High summer temperatures will become more frequent and very cold winters will become increasingly rare. A very hot August, such as experienced in 1995 with average temperature 3.4ºC above normal, may occur as often as one year in five by the 2050s, and three years in five by the 2080s, for the **Medium-High Emissions** scenario. Even for the **Low Emissions** scenario, about two summers in three may be as hot as, or hotter than, the summer of 1995 by the 2080s.

19. Extreme winter precipitation will become more frequent. By the 2080s, winter daily precipitation intensities that are experienced once every two years on average, may become up to 20 per cent heavier. Very dry summers - like 1995 – may occur in half the years by the 2080s, while very wet winters like 1994/95 may occur on average almost once a decade for the **Medium-High Emissions** scenario.

20. A combination of high temperatures and dry conditions in summer will also become more common. By the 2080s, virtually every summer over England and Wales – whether for the **Low Emissions** or **High Emissions** scenario - may be warmer and drier than the summer of 2001.

**Other effects on climate**

21. As climate warms, specific humidity – the absolute amount of moisture in the atmosphere - will increase through the year, although relative humidity may decrease, especially in summer. Cloud cover in summer and autumn may decrease, especially in the south. Summer sunshine and solar radiation may correspondingly increase.

22. There is much greater uncertainty about future changes in wind speed and direction and we have little confidence about the regional changes in average or extreme wind speeds. It is possible that there will be fewer days of fog in winter, although again this conclusion is not robust.

**How will sea level change?**

23. As global temperature warms, global-average sea level may rise by between 7 and 36 cm by the 2050s, and by between 9 and 69 cm by the 2080s. The majority of this change will occur due to the expansion of warmer ocean water. It appears unlikely that the West Antarctic ice-sheet will contribute much to sea-level rise during the twenty-first century.

24. Relative sea level (including the effect of land movements) will continue to rise around most of the UK shoreline, the rate depending on region and scenario. By the 2080s, and depending on scenario, sea level may be between 2 cm below and 58 cm above the current level in western Scotland, and between 26 and 86 cm above the current level in southeast England.

25. Extreme sea levels, occurring through combinations of high tides, sea-level rise and changes in winds, will be experienced more frequently in many coastal locations. For some east coast locations, for example, a water level that at present has a 2 per cent probability of occurring in any given year, may have an annual occurrence probability of 33 per cent by the 2080s for the **Medium-High Emissions** scenario. Sea-level rise may also lead to deeper water in the near-shore
zone allowing waves with greater energy to reach the shoreline.

26. Even if concentrations of greenhouse gases in the atmosphere are stabilised, there remains an inescapable commitment to further substantial increases in sea level over many centuries due to the extremely slow response of the oceans to changes in air temperature.

What will happen to the Gulf Stream?

27. The Gulf Stream will continue to exert a very important influence on UK climate. Although its strength may weaken in future, perhaps by as much as 25 per cent by 2100, it is unlikely that this would lead to a cooling of UK climate within the next 100 years since the warming from greenhouse gases will more than offset any cooling from a weakening of the Gulf Stream. (All of the changes in climate described in this report reflect this weakening of the Gulf Stream). Nevertheless, we do not understand enough about the factors that control this ocean circulation to be completely confident about this prediction, especially in the longer-term.

What are the new features of the UKCIP02 scenarios?

28. Users of the UKCIP98 scenarios suggested a number of improvements that would make future scenarios more useful for impacts and adaptation studies in the UK. We have taken these suggestions into account in designing the new scenarios. In particular, we have addressed the four most prominent concerns:

- the need for greater regional detail - by basing the UKCIP02 scenarios on a higher resolution (50 km grid) model than was used in 1998 (300 km grid);
- the need for estimates of changes to extremes of weather and sea-level - by using the regional model and by providing a larger set of analyses examining changes in such extreme events;
- advice on the possibility of rapid climate change, in particular a significant change in the Gulf Stream - by drawing upon new work completed at the Hadley Centre and elsewhere;
- guidance on how to handle uncertainty - by explaining and illustrating the relative importance of different sources of uncertainty such as future greenhouse gas emissions, inter-model differences and the representation of feedbacks in models. We have also assigned a relative confidence scale, based on the expert judgement of the authors, to summary statements at the end of relevant chapters.

29. There are two main sources of uncertainty that influence descriptions of potential future climates - uncertainties in future emissions of greenhouse gases (which depend on society's choices), and uncertainties in how the climate system will respond to these emissions (scientific uncertainty). The UKCIP02 climate change scenarios illustrate the range of uncertainty arising from future emissions, but do not illustrate the scientific uncertainty. However, results from other global climate models, albeit at a coarser resolution, are used to reveal and estimate the importance of scientific uncertainty for future UK climate change scenarios.

What are the main differences compared to the UKCIP98 scenarios?

30. The two sets of scenarios are largely consistent, although there are a number of differences. The four UKCIP02 scenarios show slightly larger warming rates over the UK than the four 1998 scenarios, especially for the Low Emissions scenario. This is partly because we use a model with a higher effective sensitivity and partly because we now consider the effects of changing sulphate aerosol concentrations. The UKCIP02 scenarios show a higher atmospheric concentration of carbon dioxide for the Medium-High Emissions and High Emissions scenarios than the 1998 scenarios. This is mainly because the new scenarios assume higher global emissions of carbon dioxide during the twenty-first century. The UKCIP02 scenarios show slightly smaller rates of sea-level rise than the 1998 scenarios, especially for the High Emissions scenario. This is because improvements in the way the thermal expansion of ocean waters and the dynamics of land glaciers are modelled suggest that sea-level rise is slightly less sensitive to global warming than was understood to be the case four years ago.

31. The UKCIP02 scenarios suggest that summers may become drier across the whole of the UK - not just in England and Wales - and by a larger amount than was the case in the 1998 scenarios. In the 1998 scenarios, spring and autumn became wetter, but the UKCIP02 scenarios suggest these seasons may become slightly drier. For Scotland, the UKCIP02 scenarios show significantly different changes in precipitation patterns compared to earlier scenarios. The new 2002 scenarios suggest different patterns of change in average wind speed compared to the 1998 scenarios. These changes in wind speed are still relatively small, however, and it remains the case that we have little confidence in the simulated changes in the UK wind regime. The UKCIP02 scenarios include a more comprehensive analysis of changes in some aspects of extreme weather and extreme sea levels than was the case with the 1998 scenarios. Since these changes derive from a higher resolution model that simulates extreme weather better than the global model used for this purpose in 1998, in general we have more confidence in the results reported here than those in 1998.

How should the scenarios be used?

32. An examination of all four UKCIP02 climate change scenarios is desirable in any impact assessment or adaptation study. This is especially true for detailed studies relating to major investment decisions, which should also ideally include...
an examination of the results from other climate models. For studies where the aim is to scope out the size of the problem, a minimum of two contrasting scenarios should be examined. The UKCIP02 scenarios provide greater detail than was reported in UKCIP98, and many - but not all - of the qualitative results are consistent with the earlier scenarios. Adaptation strategies should be flexible enough to cope with differences between climate model results and between successive generations of climate scenarios.

33. Although the UKCIP02 scenarios are derived from a high-resolution model and the results presented at a resolution of 50 km, users should be wary of over-interpreting the significance of geographical differences over these small scales.

**How will climate change research help in the future?**

34. Research is currently in progress on several fronts to improve understanding of climate change and our ability to make predictions. This includes work on still higher resolution models, improved representation of important small-scale physical processes and large-scale biogeochemical feedbacks, and new techniques for assigning probabilities of occurrence to different global and regional climate scenarios. Nevertheless, uncertainties about what climate we will experience in the decades ahead will remain considerable for some time to come, not least because of the intractable uncertainty about future global emissions of greenhouse gases and other climate-altering pollutants.