Background

Global temperature has risen by about 0.6ºC over the last 100 years, and 1998 was the single warmest year in the 142-year global instrumental record. The Intergovernmental Panel on Climate Change has recently concluded that most of the warming observed over the last 50 years is likely to have been because of increasing concentrations of greenhouse gases due to human activities.

The UK climate has also changed over the last century, with central England temperature rising by almost 1ºC. The decade of the 1990s was the warmest in central England since records began in the 1660s, average sea level is rising by about 1 mm per year and winters across the UK have been getting wetter, with a larger proportion of the precipitation falling on heavy rainfall days.

It is likely that some degree of further climate change is inevitable. This is because much of the change in climate over the next 30 to 40 years is already determined by past and present emissions of greenhouse gases and by the inertia of the climate system. On the other hand, the climate of the second half of the twenty-first century and beyond will be increasingly influenced by the volume of greenhouse gases emitted over the next few decades.

This report presents a set of four alternative scenarios of how climate change may affect UK climate over the next hundred years. These scenarios are labelled **Low Emissions**, **Medium-Low Emissions**, **Medium-High Emissions** and **High Emissions** and relate to four scenarios of future global emissions of greenhouse gases. More information on the scenarios and how to use them is available in a separate scientific report and from the UK Climate Impacts Programme (see back cover).

Key results

- *UK climate will*[1] *become warmer.* By the 2080s, annual temperature averaged across the UK may[2] rise by between 2ºC for the **Low Emissions** scenario and by 3.5ºC for the **High Emissions** scenario. There will be greater warming in the south and east than in the north and west, and there may be greater warming in summer and autumn than in winter and spring. By the 2080s for the **High Emissions** scenario, parts of the southeast may be up to 5ºC warmer in summer. The temperature of UK coastal waters will also increase, although not as rapidly as over land.

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

- *Winters will become wetter and summers may become drier everywhere.* The relative changes will be largest for the **High Emissions** scenario and in the south and east of the UK, where summer precipitation may decrease by 50 per cent or more by the 2080s and winter precipitation may increase by up to 30 per cent. Summer soil moisture by the 2080s may be reduced by 40 per cent or more over large parts of England for the **High Emissions** scenario.

- *Snowfall amounts will decrease throughout the UK.* The reductions in average snowfall over Scotland might be between 60 and 90 per cent (depending on the region) by the 2080s for the **High Emissions** scenario.

- *Heavy winter precipitation (rain and snow) will become more frequent.* By the 2080s, winter daily precipitation intensities that are experienced once every two years on average may become between 5 per cent (**Low Emissions**) and 20 per cent (**High Emissions**) heavier.

- *Relative sea level will continue to rise around most of the UK's shoreline.* The rate of increase will depend on the natural vertical land movements in each region and on the scenario. By the 2080s, sea level may be between 2 cm below (**Low Emissions**) and 58 cm (**High Emissions**) above the current level in western Scotland, but between 26 and 86 cm above the current level in southeast England.

- *Extreme sea levels will be experienced more frequently.* For some east coast locations, extreme sea levels could occur between 10 and 20 times more frequently by the 2080s for the **Medium-High Emissions** scenario than they do now.

- *The Gulf Stream may weaken in future and the changes in climate described in this report reflect this.* It is unlikely that this weakening would lead to a cooling of UK climate within the next 100 years. We do not understand enough about the factors that control this ocean circulation, however, to be completely confident about this prediction, especially in the longer term.

(1) The word 'will' is used in this Briefing Report where we have High Confidence about an outcome (see Box on p.14).
(2) The word 'may' is used where we have less then High Confidence about an outcome.

Introduction

This Briefing Report provides a summary of how climate may change in the United Kingdom over the twenty-first century. It is based on the full UKCIP02 climate change scenarios report, *Climate Change Scenarios for the United Kingdom: the UKCIP02 Scientific Report*, prepared for the UK Climate Impacts Programme (UKCIP). UKCIP was established by the UK Government in 1997 to help organisations identify how they will be affected by climate change and prepare adaptation strategies. The UKCIP02 climate change scenarios are one of a series of products published by UKCIP that, together, provide a common starting point for assessing climate change vulnerability, impacts and adaptation in the UK. See the back cover for more details.

Our description of future UK climate is based on four different emissions scenarios recently published by the Intergovernmental Panel on Climate Change. These scenarios are based in turn on four different descriptions of how the world may develop in the decades to come. We make no statements of relative confidence about the underlying emissions scenarios – they simply reflect four alternative views of the future. It is impossible to assign objective likelihoods to these emissions scenarios, since they depend on choices made by society.

The scenarios have been designed to respond to the requests of users for more detailed information.

The implications of the four emissions scenarios for future global climate are calculated using the latest global climate model from the Hadley Centre, one of the most comprehensively validated climate models in the world. These changes in global climate are then used as input to a higher resolution regional model which simulates changes in UK climate on a grid with 50 km resolution. The resulting four UKCIP02 climate change scenarios are described by the emissions scenarios on which they are based: **Low Emissions**, **Medium-Low Emissions**, **Medium-High Emissions** and **High Emissions**.

The UKCIP02 and UKCIP98 scenarios

The UKCIP02 scenarios replace the climate scenarios published for the UK Climate Impacts Programme in 1998 (the UKCIP98 scenarios). The new scenarios have been designed to respond to the requests of users for more detailed information about geographical variations across the UK and for more information about changes in extremes of weather and sea level. Even though more detail is provided in the new scenarios compared to those from 1998, the two sets of scenarios are qualitatively similar in many respects. The main differences between them are highlighted on p.14 of this Briefing, and in more detail in the full scientific report.

Guidance on using scenarios of climate change

We recommend that all four UKCIP02 climate change scenarios be used in any impact assessment or adaptation study. For studies where the aim is simply to scope the size and nature of the problem, a minimum of two contrasting scenarios may be sufficient. The UKCIP02 scenarios have *not* been designed to formally or quantitatively reflect all of the uncertainty that surrounds our ability to predict future climate - to appreciate the full extent of this uncertainty it is necessary to read the scientific report and to use some of the supplementary data sources that are indicated. We therefore also recommend that when designing detailed climate change adaptation strategies, or making substantial investment decisions, this wider range of uncertainty should be explored. Adaptation strategies should also be flexible enough to cope with differences in successive generations of climate scenarios.

We recommend that this wider range of uncertainty should be explored.

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 on these small scales. Since the regional climate model is driven by a global model, any errors in the global model simulations (for example in wind flow) will be reflected in the regional model results.

There will be specific guidance available from UKCIP on using these scenarios for some key applications. For example, guidance about their application in flood management will be available later in 2002.

Is our climate changing?

Global climate

The most useful index describing the state of global climate is the average surface air temperature of the planet. Estimates of this index are compiled from millions of individual thermometer measurements taken around the world and date back to 1860. The records show that global temperature has risen by about 0.6ºC since the beginning of the twentieth century, with about 0.4ºC of this warming occurring since the 1970s (Figure 1). The year 1998 was the warmest in this 142-year record, and 2001 was the third warmest. The 1990s was, globally, the warmest decade in the last 100 years, and it is likely the last 100 years was the warmest century in the last millennium.

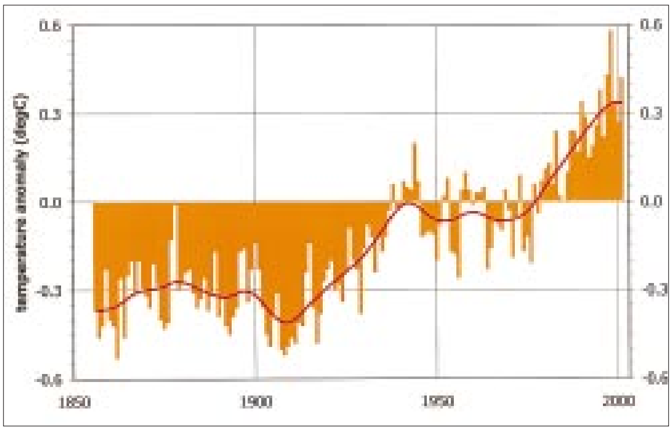


Figure 1: The observed increase in global-average surface air temperature. Anomalies are relative to 1961-1990 average.

Other evidence for changes in global climate include:

- an increase in night-time temperatures over many land areas at about twice the rate of day-time temperatures increases;
- an increase in the length of the freeze-free season in many Northern Hemisphere mid-to-high latitude regions and a lengthening of thermal growing seasons;
- more intense rainfall events over many Northern Hemisphere mid-to-high latitude land areas;
- a near worldwide decrease in mountain glacier extent and ice mass;
- a decrease in Northern Hemisphere sea-ice amounts and a substantial thinning of Arctic sea-ice in late summer.

UK climate

Changes have also been observed in the climate of the United Kingdom, for which we have some data extending back three and a half centuries. Central England temperature rose by almost 1ºC during the twentieth century and the 1990s was the warmest decade in central England since records began in the 1660s and this warming of climate over land has been accompanied by warming of UK coastal waters (Figure 2).

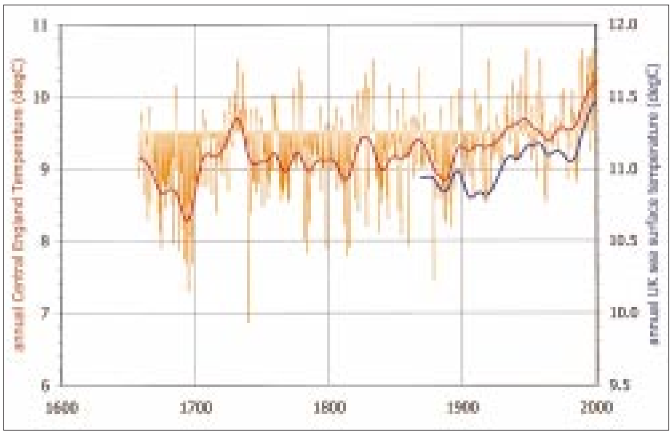


Figure 2: The warming of central England climate (red) and surrounding UK coastal waters (blue). Deviations are relative to 1961-1990 average. Note different scales.

Analysis of other climate data has revealed the following changes in UK climate:

- the thermal growing season for plants in central England has lengthened by about one month since 1900 (Figure 3);
- heatwaves have become more frequent in summer, while there are now fewer frosts and winter cold spells;
- winters over the last 200 years have become wetter relative to summers throughout the UK;
- a larger proportion of winter precipitation in all regions now falls on heavy rainfall days than was the case 50 years ago;
- after adjusting for natural land movements, average sea level around the UK is now about 10 cm higher than it was in 1900.

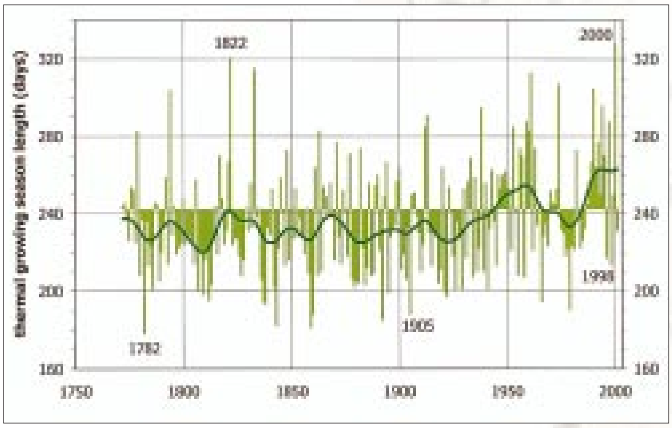


Figure 3: The length of the thermal growing season in central England has increased. Deviations are relative to 1961-1990 average.

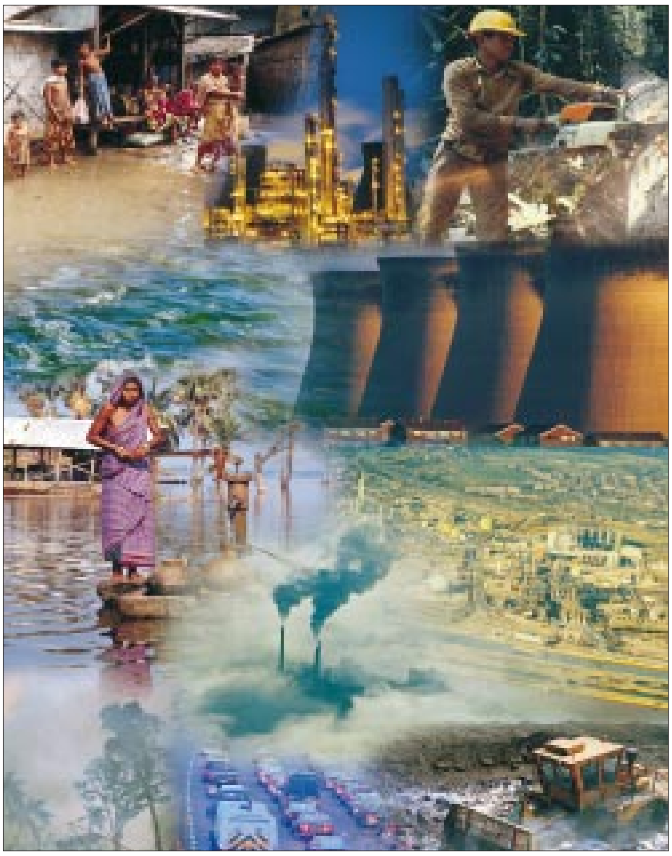
To assist with studies of the impacts of climate change, and with assessments of how to adapt to these changes, a new set of observed climate data has been prepared to accompany the new scenarios. These data are for a 5 km grid for the whole land area of the UK and contain monthly data for 26 surface climate variables for the period 1961 to 2000 (see back cover for web address).

Why is climate changing?

Factors affecting climate

The observed changes in global climate are likely to be due to a combination of both natural and human causes. The Earth's climate varies *naturally* as a result of interactions between the ocean and the atmosphere, changes in the Earth's orbit, fluctuations in energy received from the sun and volcanic eruptions. The main *human* influence on global climate is likely to be through increasing emissions of greenhouse gases such as carbon dioxide and methane. At present for example, about 6.5 billion tonnes of carbon is emitted globally into the atmosphere each year, mostly through the combustion of coal, oil and gas for energy. Changes in land use result in a further net annual emission of between 1 and 2 billion tonnes of carbon. Increasing concentrations of greenhouse gases in the atmosphere over the last 200 years (Figure 4) have trapped more energy in the lower atmosphere, thereby altering global climate. The picture is complicated, however, by other pollutants from human activities, for example sulphur dioxide which transforms into small particles (aerosols) which act to cool climate.

The main human influence on global climate is through increasing emissions of greenhouse gases.



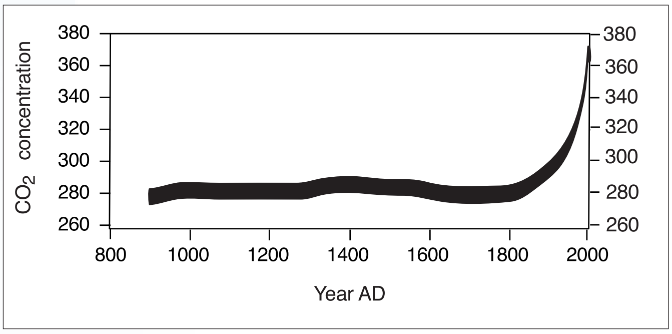


Figure 4: Increasing historic concentration (parts per million) of carbon dioxide in the global atmosphere. Line thickness indicates uncertainty in the concentrations. [Source: IPCC]

Attributing changes to different factors

In order to explain the cause of the recent changes in climate, the Hadley Centre climate model was used to simulate global climate from 1860 to 2000, considering natural factors, human factors (greenhouse gases and aerosols) and then both sets of factors combined. Model simulations which only took account of natural factors could explain the mid-twentieth century warming, but not the observed warming since the 1970s. When the experiment was repeated using just changes in human factors, the recent rise in temperature was well replicated, but not the earlier warming in the mid-twentieth century. Only when *both* natural and human factors were included (Figure 5) could the model provide an adequate simulation of the course of global-average temperature over the entire 140-year period, and especially the warming since the 1970s.

This analysis is one of several important pieces of evidence that point towards a substantial, and an increasing, human influence on global climate. Thus the Intergovernmental Panel on Climate Change concluded in their Third Assessment Report that, *" … most of the warming observed over the last 50 years is likely to have been due to increasing concentrations of greenhouse gases."*

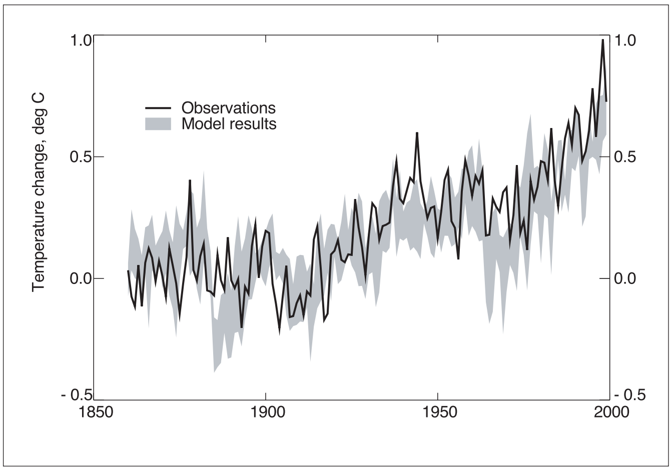


Figure 5: A good fit between observed and model-simulated global temperature is obtained only when both natural and human factors are included in the model simulation. Temperature change is relative to 1880-1920 average.

How were the UKCIP02 scenarios designed?

The emissions scenarios

How climate changes in the future depends on future emissions of greenhouse gases and other pollutants, which in turn depend upon how population, economies, energy technologies and societies develop. The Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (IPCC SRES) developed a range of projections of possible future emissions. We have chosen to use four of these (designated B1, B2, A2 and A1FI) which span nearly the full range. The amount of carbon emitted over the twenty-first century under each of these emissions scenarios is shown in Figure 6. Summed over the century, A1FI has the highest total emissions (2189 giga, or billion, tonnes of carbon; GtC), more than twice the mass of the lowest scenario, B1 (983 GtC). The atmospheric concentrations of carbon dioxide by the 2080s resulting from these emissions are shown in Table 1.

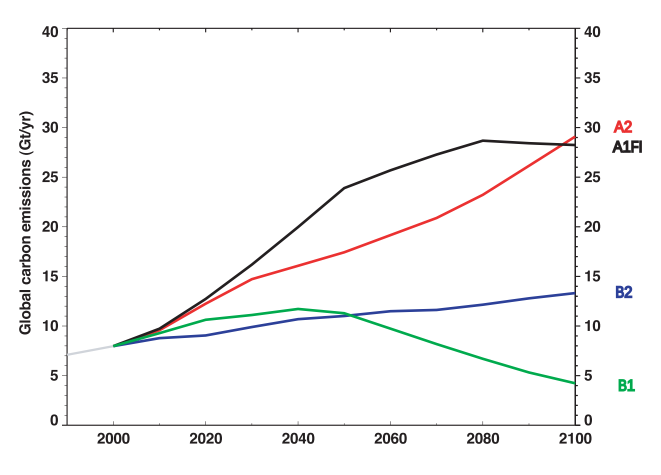


Figure 6: Global carbon emissions from 2000 to 2100 for the four chosen SRES emissions scenarios. Observed data to 2000.

The climate models

The Hadley Centre global climate model was used to simulate changes in climate due to each of these emissions scenarios. Results from the global model for the SRES A2 emissions were then used, via a further stage, to drive the regional version of the model, which has a resolution of 50 km over Europe. Results from these regional climate model experiments formed the UKCIP02 **Medium-High Emissions** climate change scenario. Three further climate change scenarios were generated from these same model results using pattern-scaling methods and are labelled **Low Emissions**, **Medium-Low Emissions**, and **High Emissions**, corresponding respectively to the B1, B2 and A1FI emissions scenarios. The Hadley Centre global model simulates warming for the A1FI emissions scenario that, by the 2080s, is about twice as great as for the B1 scenario (Table 1). No probabilities can be assigned to these four scenarios and they should all be regarded as plausible future climates.

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 would be about four times that experienced during the twentieth century. If the emissions rate increases to approximately four times today's level – as for the **High Emissions** scenario – the future warming rate would be about twice as rapid again.

The UKCIP02 scenarios are all based on results from the Hadley Centre models.

The UKCIP02 scenarios are all based on results from the Hadley Centre models. Different models, however, produce different patterns and magnitudes of climate change over the UK and it is important to appreciate the size of these differences. An illustration of the uncertainties involved is provided on p.13.

Stabilising climate

Carbon dioxide has an effective lifetime in the atmosphere of about 100 years, so it takes several decades for any reduction in global emissions to make a substantial change to the rate of rise of concentrations in the atmosphere. To *eventually* stabilise concentrations of carbon dioxide would require global emissions to fall by between 60 and 70 per cent relative to today. Even if concentrations of greenhouse gases *were* eventually stabilised, however, surface temperatures would keep on rising for several further decades, and sea level would continue to rise for several further centuries.

SRES Emissions Scenario	UKCIP02 Climate Change Scenario	Increase in Global Temperature (ºC)	Atmospheric CO_2 Concentration (ppm)
B1	**Low Emissions**	2.0	525
B2	**Medium-Low Emissions**	2.3	562
A2	**Medium-High Emissions**	3.3	715
A1FI	**High Emissions**	3.9	810

Table 1: Changes in global temperature (ºC) and atmospheric carbon dioxide concentration (parts per million) for the 2080s period (2071- 2100 average) for the four scenarios. Carbon dioxide concentration in 2001 was about 370 ppm.

How will UK climate be affected?

All aspects of the climate of the United Kingdom will be affected by changes in global climate. We show some examples of these effects for each of the four UKCIP02 scenarios, for different seasons, and for three future periods – 2011 to 2040 (labelled the 2020s), 2041 to 2070 (the 2050s) and 2071 to 2100 (the 2080s). The changes in climate for each of these periods reflect a change in the average statistics of weather over a 30-year period. Since all changes are calculated with respect to the average 1961-1990 climate, some part of these changes may already have been realised. We describe below only the changes in climate about which we have the greatest confidence (see p.14) and generally for the **Low Emissions** and **High Emissions** scenarios by the 2080s. Small changes, or changes which are highly uncertain, are not mentioned. On the maps we have shown as grey the regions of the UK where future changes are within 'natural' climate variability.

Temperature

By the 2080s, annual temperature averaged across the UK may rise by about 2ºC for the **Low Emissions** scenario and by about 3.5ºC for the **High Emissions** scenario. Annual rates of warming may vary across the UK from 0.1º to 0.3ºC per decade for the **Low Emissions** scenario, to 0.3º to 0.5ºC per decade for the **High Emissions** scenario. The temperature of UK coastal waters will also increase, although not as rapidly as over land. In general, there will be greater warming in the southeast than in the northwest of the UK (Figure 8), there may be greater warming in summer and autumn than in winter and spring, and there may be greater warming during the nights in winter and during the days in summer. As would be expected, increasing temperatures means that heating 'degree days' (an index used to calculate how much energy is needed to heat a building to a given temperature) will decrease, and cooling 'degree days' (a similar index, but used to indicate energy needed for cooling buildings) will increase.

Precipitation (rain and snow)

Winter precipitation will increase for all periods and for all scenarios.

Winter precipitation will increase for all periods and for all scenarios (Figure 9). By the 2080s, this increase ranges from between 10 and 20 per cent for the **Low Emissions** scenario (depending on region), to between 15 and 35 per cent for the **High Emissions** scenario. For summer, the pattern is reversed and almost the whole of the UK may become drier, with a decrease in rainfall for the **Low Emissions** scenario of up to 35 per cent, and for the **High Emissions** scenario of 50 per cent or more. The largest changes in precipitation in both winter and summer are experienced in eastern and southern parts of England, while the changes are smallest in northwest Scotland.

Snowfall

There will be less snow over the whole UK and for all scenarios, with the largest percentage reductions – perhaps up to 90 per cent or more by the 2080s for the **High Emissions** scenario - around the coast and in the English lowlands (Figure 7). In relative terms, the Scottish Highlands experience the smallest reductions, but even here total snowfall by the 2080s might decrease by 60 per cent or more relative to present-day totals. Some areas of the UK are increasingly likely to experience quite long runs of snowless winters.

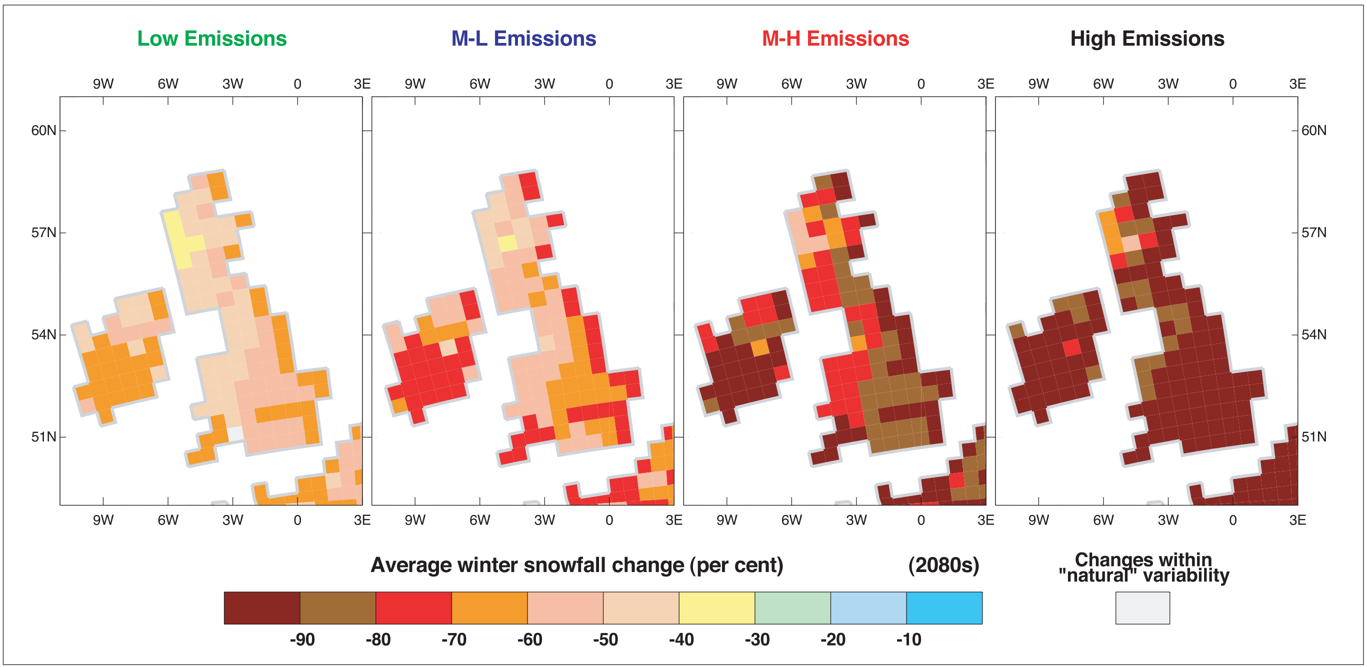


Figure 7: Per cent change in average winter snowfall amount for the 2080s.

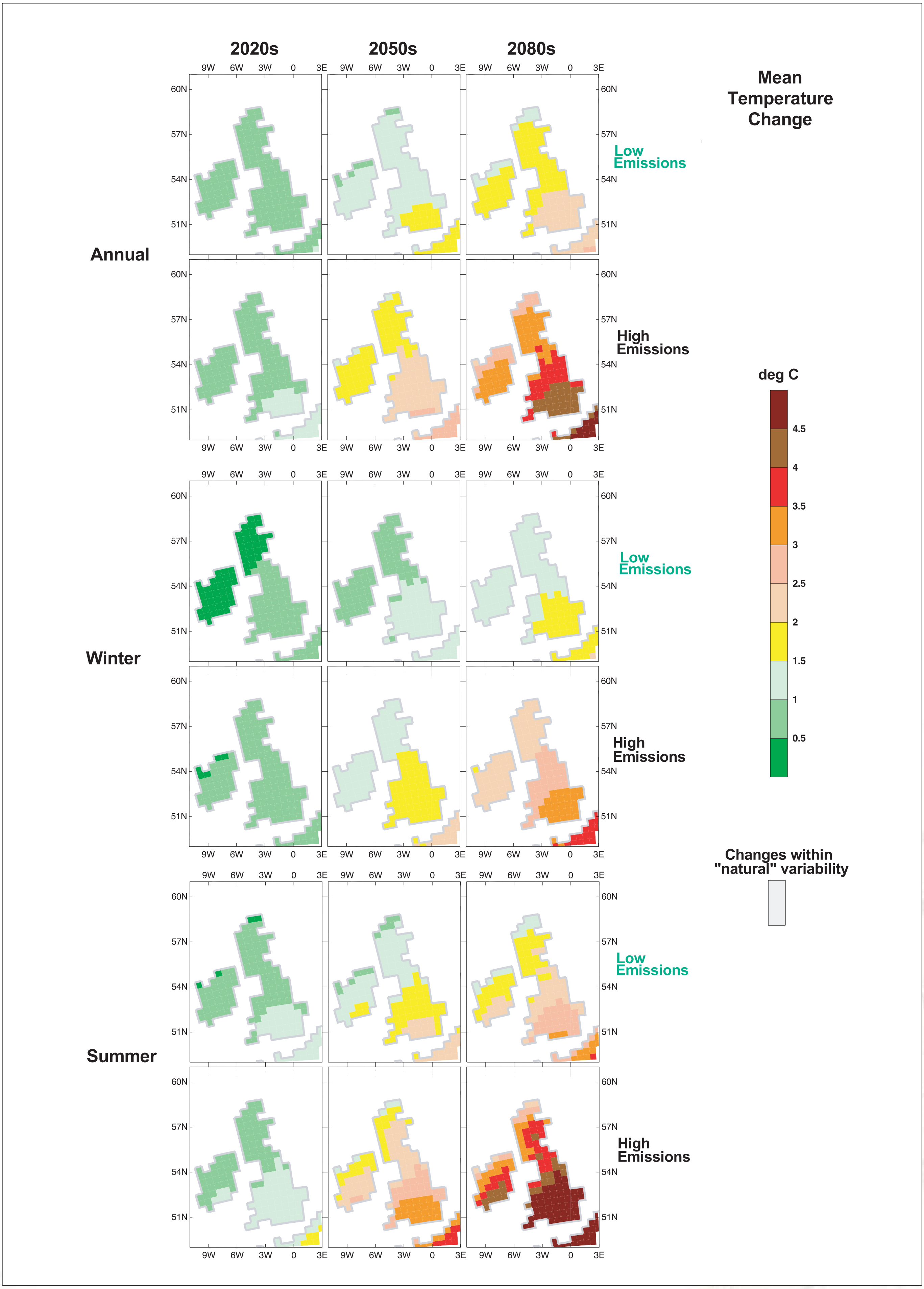


Figure 8: Change in average annual, winter and summer temperature for the 2020s, 2050s and 2080s for the Low Emissions and High Emissions scenarios.

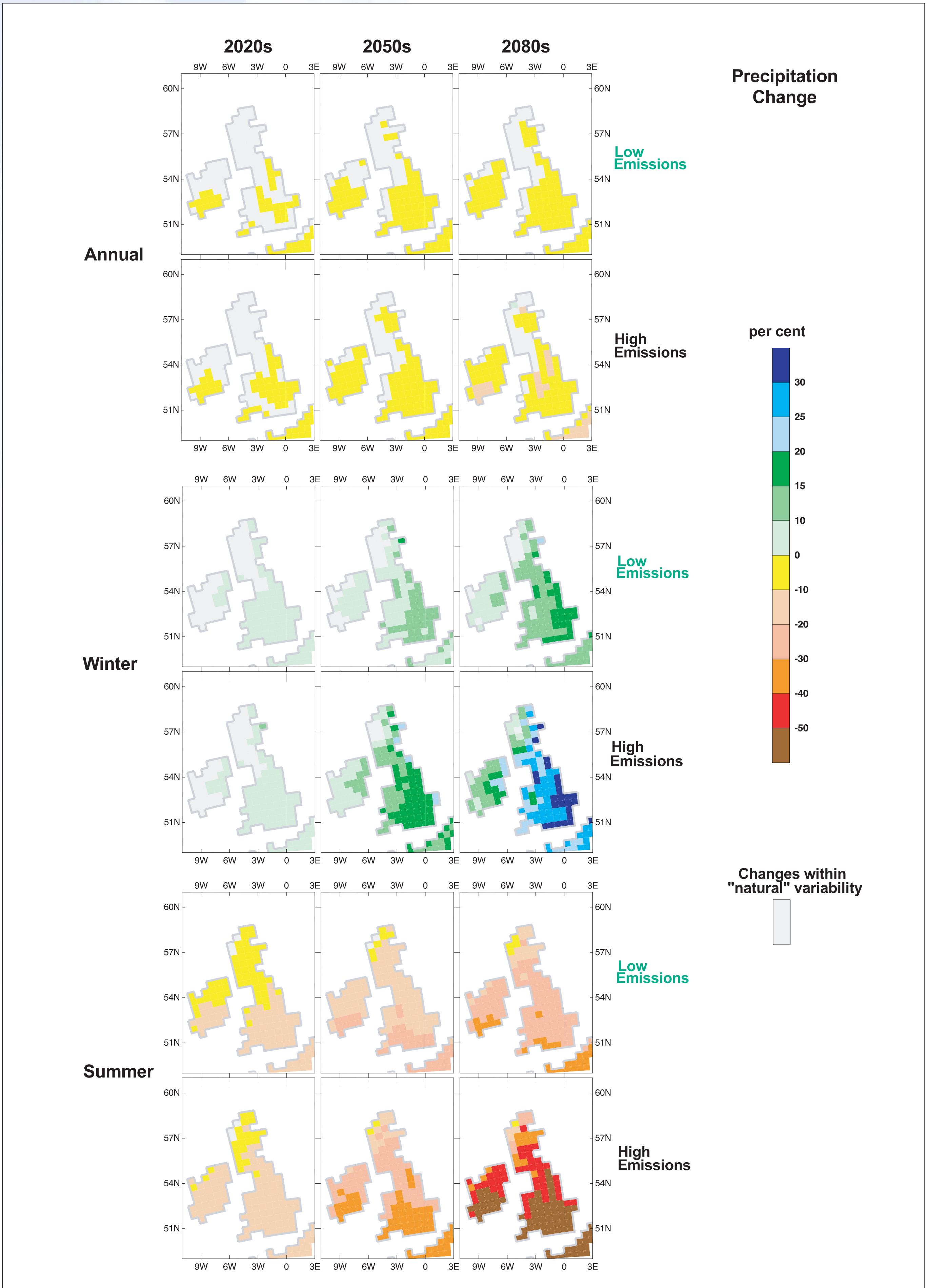


Figure 9: Per cent change in average annual, winter and summer precipitation for the 2020s, 2050s and 2080s for the Low Emissions and High Emissions scenarios.

Year-to-year variability

The weather experienced in the UK will continue to vary substantially from year-to-year, and from decade-to-decade, for entirely natural reasons. By the 2020s, these natural variations may, in some cases, still be greater than the changes in average climate due to increased greenhouse gas emissions. This is especially true for precipitation. By the 2050s however, and especially by the 2080s, most changes in average climate we describe as due to human activities are likely to greatly exceed the natural variability of UK climate.

Extreme seasons and years

Changes in the probabilities of selected seasonal climate extremes for central England and Wales are summarised in Table 2 for the **Medium-High Emissions** scenario. For this scenario, a hot August (such as in 1995 when we experienced 17 days with maximum temperatures above 25ºC and 4 days above 30ºC in central England) might be expected to occur one year out of five by the 2050s. By this period, the vast majority of years might be warmer than the record-breaking warm year of 1999. For precipitation, very dry summers such as 1995 might occur in 30 per cent of years by the 2050s, while very wet winters such as 1994/95 might occur on average once every three decades.

Very dry summers such as in 1995 might occur in 30 per cent of years by the 2050s.

Seasonality

The contrast between winter and summer climate will increase for all scenarios. Winters will become wetter and summers may become drier, continuing the trend observed over the last century. Temperatures will increase in all seasons. This warming may be more rapid in summer than in winter, increasing the seasonal temperature contrast. The thermal growing season for plants will lengthen across the UK, again continuing a trend observed in recent decades. Each degree of annual warming causes a lengthening of the thermal growing season of about three weeks in southern areas and of about one and a half weeks in northern areas.

Cloud cover and solar radiation

UK climate may become sunnier than at present in summer, with solar radiation increasing during this season, most notably over southern parts of the UK. Cloud cover may decrease in summer over the whole country, especially in the south where reductions by the 2080s may be around 10 per cent for the **Low Emissions** scenario and more than 20 per cent for the **High Emissions** scenario.

Relative humidity and fog

Relative humidity may decrease throughout the year for all scenarios in all but a few areas of northern Scotland. In summer, relative humidity reductions of 10 per cent or more may occur by the 2080s, especially in England and Wales for the **High Emissions** scenario. We estimate that some 20 per cent fewer fog days in winter might be expected across all areas of the UK for the **Medium-High Emissions** scenario by the 2080s, but these estimates are very uncertain.

Wind speeds

High winds can be very damaging and users of scenarios are keen to have good estimates of how these will change in the future. Climate models in general, however, do not yield consistent or robust estimates of wind speed changes and the models used to generate the UKCIP02 scenarios are no exception. The most significant change seen in the scenarios is that in winter - when most severe winds occur – more depressions cross the UK which leads to stronger winds in southern and central Britain. These results, however, are very uncertain.

Soil moisture

Changes in soil moisture depend on changes in precipitation, temperature, wind speed and radiation. In summer, the whole of the UK will experience a decrease in average soil moisture, with the largest reductions - 40 per cent or more by the 2080s - occurring in the **High Emissions** scenario in southeast England, compared with only 20 per cent for the **Low Emissions** scenario.

In summer, the whole of the UK will experience a decrease in average soil moisture.

	Anomaly	2020s	2050s	2080s
Mean Temperature				
A hot '1995-type' August	3.4ºC warmer	1	20	63
A warm '1999-type' year	1.2ºC warmer	28	73	100
Precipitation				
A dry '1995-type' summer	37 per cent drier	10	29	50
A wet '1994/95-type' winter	66 per cent wetter	1	3	7

Table 2: The percentage of years experiencing various extreme seasonal anomalies across central England and Wales for the Medium-High Emissions scenario. The anomalies shown are relative to the average 1961-1990 climate.

What will happen to extreme weather?

Changes in average climate only occur because of changes in the frequency and intensity of different types of weather experienced over much shorter periods of time. These include extremes of weather such as heavy rain, heatwaves and gales. In this section information is presented about changes in the distribution of daily weather, including extremes, simulated by the high resolution regional model.

Heavy precipitation

When physical structures are designed to withstand, say, a 'once in 100-year event', it is currently assumed that the magnitude of such an event is constant. For many aspects of climate this is unlikely to be true in the future. For example in winter, the intensity of the daily precipitation event that has a 50 per cent chance of occurring in a given year may increase all over the UK, apart perhaps from northwest Scotland. In some areas by the 2080s - southeast England and southeast Scotland - the increase in intensity may be more than 20 per cent for the **Medium-High Emissions** and **High Emissions** scenarios (Figure 10).

Heavy winter precipitation will become more frequent.

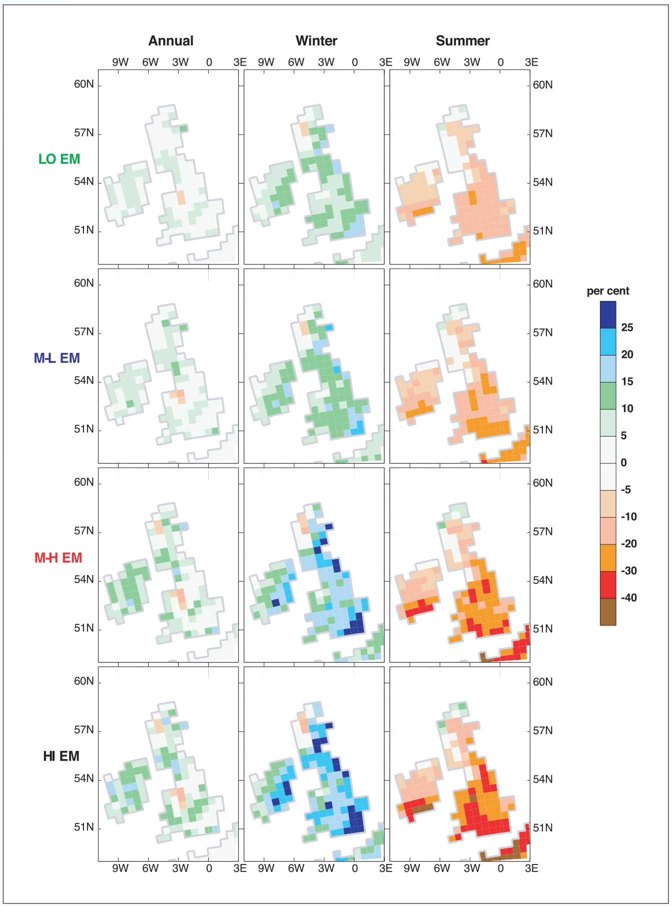


Figure 10: Per cent change by the 2080s in the maximum daily precipitation amount which has a 50 per cent chance of occurring in any given year.

Temperature extremes

We can also analyse changes in the likelihood of extreme weather using probability plots. These are shown in Figure 11 for daily maximum temperatures for four localities representing different climatic regions of the UK – central-south England (roughly equivalent to Berkshire), coastal Wales ('Pembrokeshire'), coastal Northern Ireland ('County Down'), and highland Scotland ('Inverness-shire'). The graphs show the probability that, on any given day, the daily maximum temperature will exceed a certain value.

For example, for the **Medium-High Emissions** scenario the probability of a given summer day in the Scottish Highlands experiencing a maximum temperature of 23ºC or more may increase from about 1 per cent at present to nearly 15 per cent by the 2080s. Alternatively, one might read the graphs to deduce that for coastal Wales the summer maximum temperature that has a 1 per cent chance of occurring on a given day may increase from about 28ºC to 36ºC. We have lower confidence in the results rarer than about 1 per cent probability, since these very low-frequency events are not simulated so well by the climate models. Note that the daily maximum temperatures shown are those simulated by the climate model for areas 50 km by 50 km in size; they are lower than temperatures that would actually be measured at specific sites.

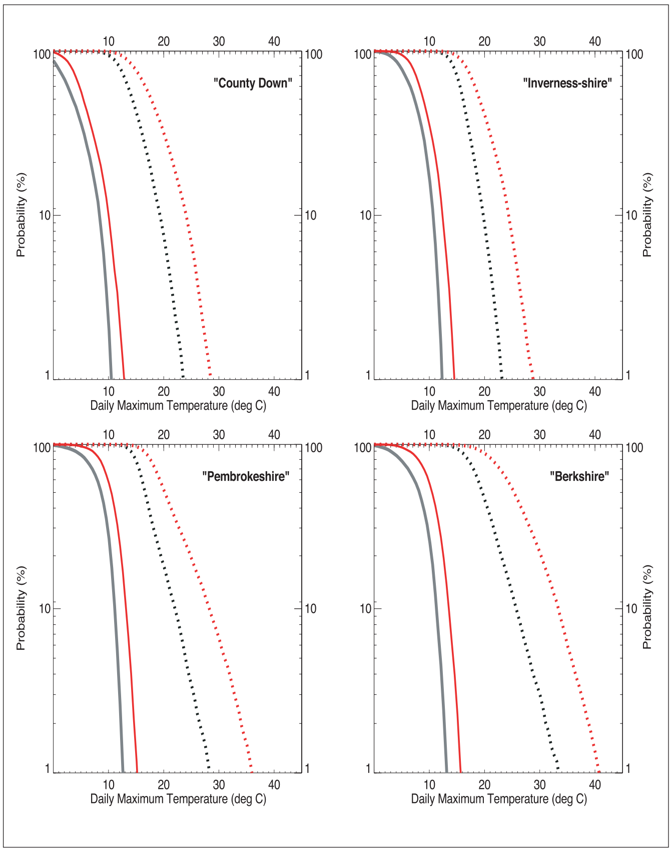


Figure 11: The probability of a given daily maximum temperature in summer (dashed) and winter (solid) being exceeded on any given day. Dark grey = present climate; Red = the Medium-High Emissions scenario for the 2080s.

What will happen to sea level?

Global sea level

As global climate warms, the world's oceans will expand in volume, causing a rise in the average level of the sea. Many land glaciers will continue to melt, adding to this rise in sea level. Changes will occur to the ice sheets of Greenland and Antarctica, although over the coming 100 years they are unlikely in combination to contribute much to changes in sea level. If climate continues to warm in the longer-term, however, both these ice sheets may contribute enough melt water over the next 1000 years to raise global sea level by several metres.

The range in global sea-level rise quoted by the Intergovernmental Panel on Climate Change for the 2080s for the **Low Emissions** scenario is from 9 to 48 cm and for the **High Emissions** scenario from 16 to 69 cm. These ranges arise because of differences between climate models, especially the ocean component, and uncertainty in the parameters governing the calculation of future ice melt.

The change in the level of the sea relative to the land will not be the same everywhere because of natural land movements.

Sea level around the UK

The change in the level of the sea relative to the land will not be the same everywhere because of natural land movements; much of southern Britain is sinking at between 1 and 1.5 mm per year, and much of northern Britain is rising at between 0.5 and 1 mm per year relative to the sea (Table 3).

Extreme sea levels

Extremes of sea level – as experienced during storm surges - cause most coastal damage. Changes in the height of these extremes have been modelled using the 35 km Proudman Oceanographic Laboratory model by including the effects of changes in storm regime, the rise in sea level and vertical land movements (Figure 12). The largest rise in extreme sea levels may occur around the southeast coast of England, a region which experiences both the largest changes in winds and storms and also the greatest fall in the height of the land. This result, however, depends very much on the particular model that is used and so there is less confidence in this result than in the numbers shown in Table 3.

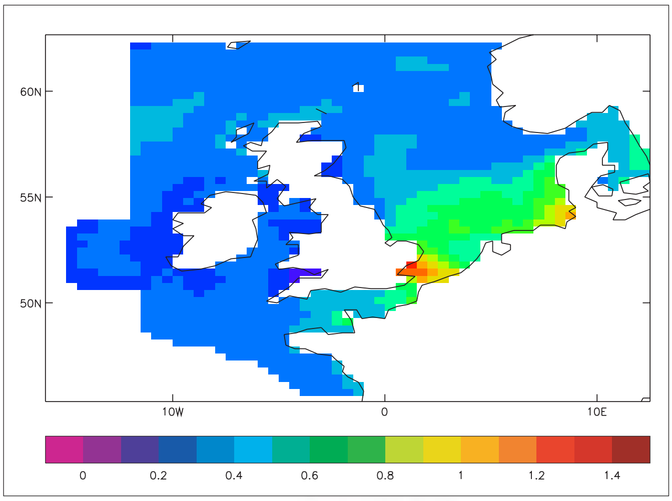


Figure 12: The change, by the 2080s, in the height (metres) of the extreme sea level that has a 2 per cent chance of occurring in any given year – Medium-High Emissions scenario, mid-range estimate of 30 cm global sea-level rise. Illustrative example only.

Changes in extreme sea levels associated with storm surges may also be expressed in other ways. For example, at the port of Immingham on the east coast of England, the high water level that has a 2 per cent chance of occurring in any given year may be approximately 60 cm higher by the 2080s for the **Medium-High Emissions** scenario. This is equivalent to increasing the probability of a present-day extreme sea level occurring in any given year from 2 per cent currently to about 33 per cent by the 2080s. For the upper end of the **High Emissions** scenario this probability increases to about 90 per cent.

	Vertical Land Change (mm/yr)	Sea-level Change 2080s (cm) Relative to 1961-1990	
		Low Emissions	**High Emissions**
NE Scotland	+0.7	1	61
SE Scotland	+0.8	0	60
NE England	+0.3	6	66
Yorkshire	-0.5	15	75
East Midlands	-1.0	20	80
Eastern England	-1.2	22	82
London	-1.5	26	86
SE England	-0.9	19	79
SW England	-0.6	16	76
Wales	-0.2	11	71
Northern Ireland	n/a	9*	69*
NW England	+0.2	7	67
SW Scotland	+1.0	-2	58
NW Scotland	+0.9	-1	59
Orkney & Shetland	n/a	9*	69*
Global-average	**n/a**	**9***	**69***

*Table 3: Historic rates of vertical land movement and the estimated net change in sea level by the 2080s using the low end of the Low Emissions scenario (9 cm global sea-level rise) and the high end of the **High Emissions** scenario (69 cm rise).*
** These estimates exclude vertical land changes.*

How confident are we?

There are a number of reasons why we cannot be completely confident in our descriptions of future climate.

Emissions uncertainties

Uncertainty about future emissions of greenhouse gases and other pollutants arises because we cannot be sure how population, economies, energy technologies, and other social factors that influence emissions will change in the future. The emissions used as the basis for the UKCIP02 scenarios cover almost the full range reported by the Intergovernmental Panel on Climate Change (IPCC), but we do not know which of the emissions scenarios will turn out to be closest to reality and the actual emissions might lie outside even these limits.

Scientific uncertainties

The response of climate to these emissions depends upon several factors: what proportion of the emitted greenhouse gases remains in the atmosphere to increase their concentration; how much additional heat is 'trapped' by these increased concentrations; how this additional heating changes climate; and how important is the cooling effect of aerosols and the warming effect of soot particles. The way in which climate responds to a given emissions scenario will differ from model-to-model, but at present we have no agreed way of attaching probabilities to the results from these different models. Our scenarios make use of the Hadley Centre regional climate model which resolves UK climate at a 50 km scale. This regional model is one way of adding detail to global model results at spatial scales which are more useful for impacts and adaptation assessments. Different regional models from other modelling centres will be used for this purpose in the future, together with a range of statistical methods. These different approaches yield different results at the local scale, but the uncertainties associated with downscaling have not yet been systematically assessed.

What do other climate models show?

The Hadley Centre global model used as the basis for the UKCIP02 scenarios has been developed over many years and is extensively validated. It is important, however, to appreciate the uncertainties involved in modelling global climate, because these also influence the confidence we have in higher resolution regional results, such as those used for the UKCIP02 scenarios. Currently, the only way to appreciate this uncertainty is to look at results from the full range of global models that have been presented in the recent IPCC assessment. Whilst comparing different model results is important to illustrate uncertainty, there is no easy way to attach higher or lower confidence to the results of one model over another. The Hadley Centre model, however, performs well in representing current climate.

There is no easy way to attach higher or lower confidence to the results of one model over another.

All models agree that, over the UK, winters will become wetter and warmer (Figure 13). There is not quite the same agreement about changes in summer. A majority of the models indicate less rain, but more consistently in the south of the country than in the north. The Hadley Centre global model simulates changes close to the middle of the model range for winter, but shows a greater decrease in summer rain than most models.

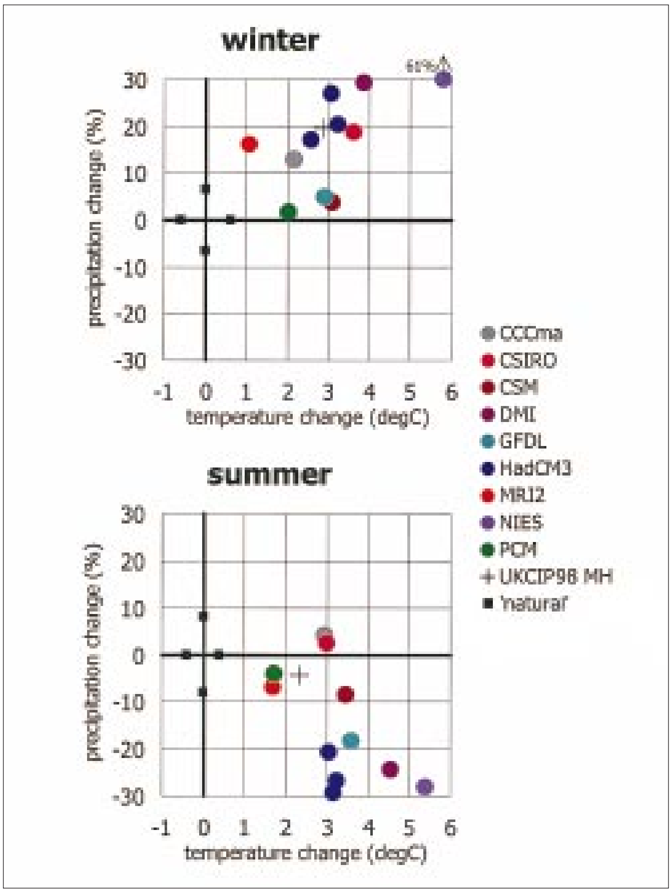


Figure 13: Changes in average winter and summer temperature and precipitation for the 2080s over the UK for the SRES A2 emissions scenario (the UKCIP02 Medium-High Emissions scenario). Each coloured circle represents the result from a different global climate model; the dark blue circles represent results from three experiments with the model used for the UKCIP02 scenarios. The black squares centred on the origin indicate "natural" climate variability as estimated by the model.

What will happen to the Gulf Stream?

One specific area of uncertainty concerns the response of the Gulf Stream, a current of warm water which keeps northwest Europe warmer than it would otherwise be. The Gulf Stream is part of a much larger ocean circulation, driven by differences in water density caused by temperature and salinity. Changes in the density of north Atlantic surface