4.3.4 Projected changes to seasonal mean temperature over marine regions

Probabilistic projections of changes to winter- and summer-mean air temperature over the seas surrounding the UK, averaged over the nine marine regions, are shown in Figure 4.6.

Changes in air temperature in all cases are larger in the south and smaller in the north; this reflects the degree to which the marine regions are affected by proximity to continents or open oceans. As climate changes, land is projected to warm faster than oceans. Hence the marine regions closer to continental regions (for example, the Eastern English Channel) will warm faster because they are influenced by the nearby continent. More northern marine regions (for example, the Atlantic NW Approaches) will warm at a slower rate because they are influenced more by nearby ocean regions.

Note that, even by the 2080s, the 10% probability level shows small reductions in surface air temperature in the Atlantic NW Approaches in both seasons. This reflects the effect on temperatures of the large natural internal variability of climate. At the 10% probability level, this natural variability can more than offset the rather modest warming from human activities in these regions.

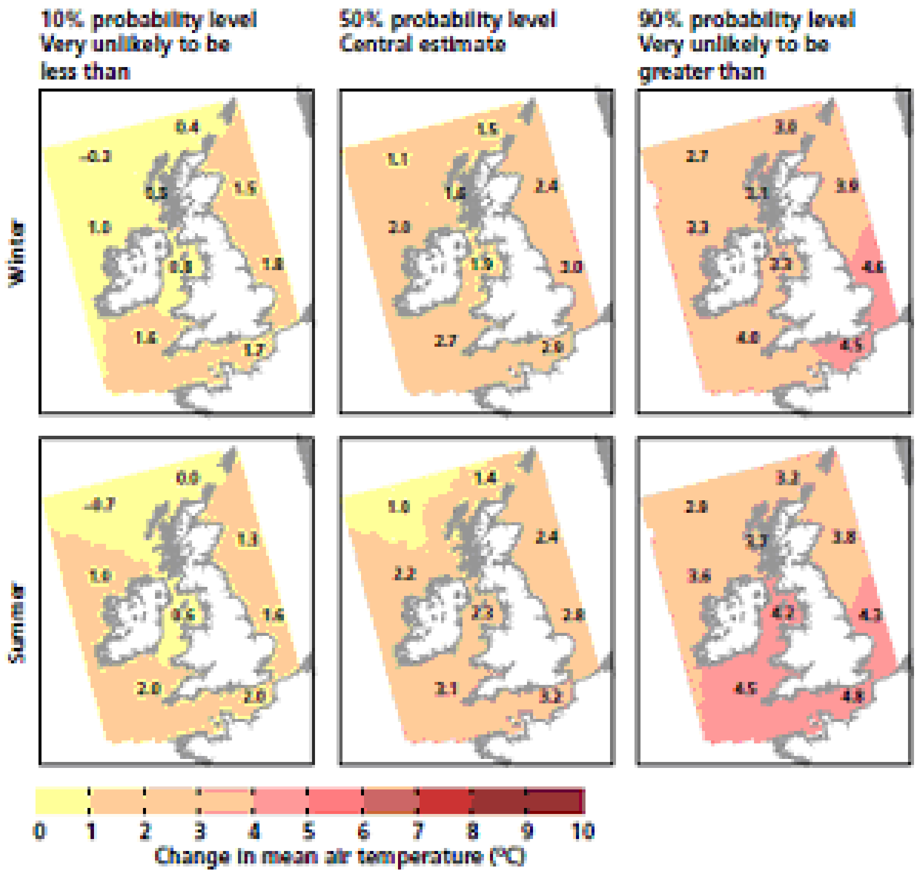


Figure 4.6: 10, 50 and 90% probability levels of changes to winter-mean (top) and summer-mean (bottom) mean air temperature under Medium emissions by the 2080s.

4.3.5 Projected changes to mean daily maximum temperature in summer

Figure 4.7 shows that, in summer, central estimates of changes to mean daily maximum temperature show a gradient between parts of southern England, where they can be 5°C or more, and northern Scotland, where they can be somewhat less than 3°C. Although not shown here, in winter the change is between 2 and 3°C across the whole of the UK.

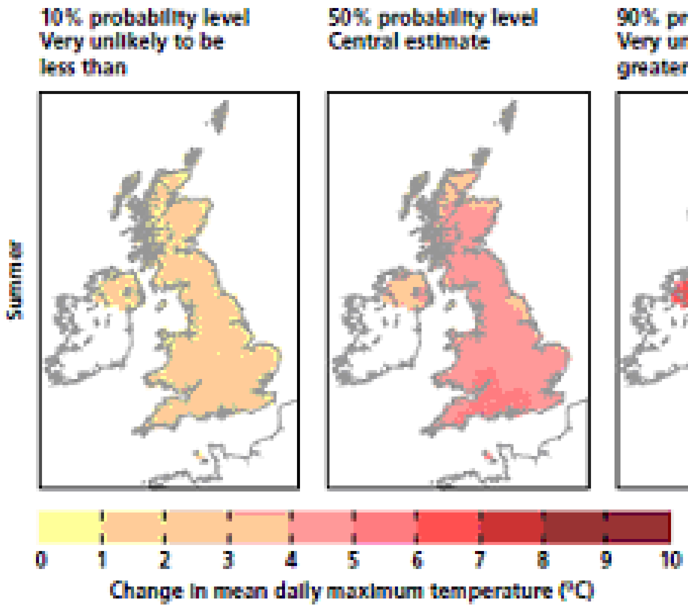


Figure 4.7: 10, 50 and 90% probability levels of changes to mean daily maximum temperature (°C) in summer, by the 2080s, under the Medium emissions scenario.

4.3.6 Projected changes to the warmest day of the summer.

Changes in extremes of temperatures are also available in UKCP09, and we illustrate one such change, that in the 99th percentile of daily maximum temperature, for the summer season, in Figure 4.8 (overleaf). This variable is calculated by taking the 99th percentile of the daily distribution of daily maximum temperature, over a complete 30-yr period (that is, about 2700 days). However, because a season has roughly 100 days, changes in the 99th percentile of the distribution can be thought of as roughly equivalent to changes in the extreme value of the season, giving a more user-friendly (albeit less accurate) name. Thus the change in the 99th percentile of the daily maximum temperature of the summer season can be thought of as the change in temperature of the *warmest day of the summer* and is referred to as such in this report. Change in this variable is projected to be between 2.5 and 4°C in the southern half of the UK, and between 4 and 5°C over most of the northern half.

4.3.7 Projected changes to the winter and summer mean daily minimum temperature

As can be seen from Figure 4.9 (overleaf), central estimates of change in mean daily minimum temperature in winter are 3–3.5°C in the south of the UK and 2–3°C in the north. In summer, changes are between 3 and 4°C across the vast majority of the UK; slightly lower in the far north and slightly higher in some southern parts.

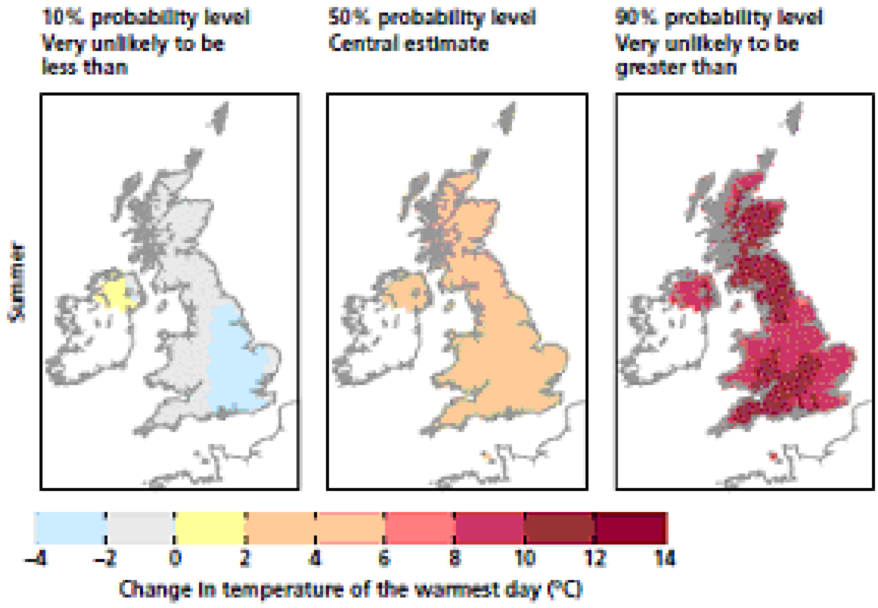


Figure 4.8: 10, 50 and 90% probability levels of changes to the temperature of the warmest day of the summer, by the 2080s, under the Medium emissions scenarios.

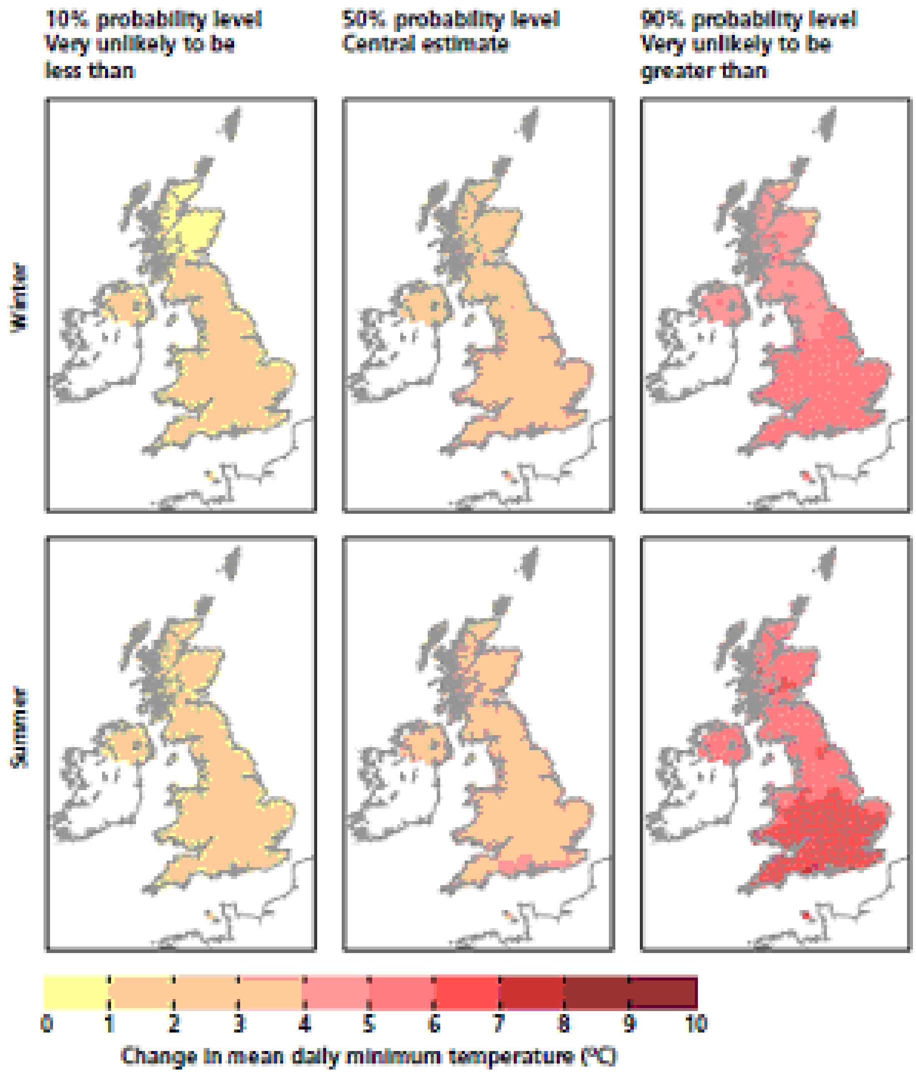


Figure 4.9: 10, 50 and 90% probability levels of changes to the mean daily minimum temperature in winter (top) and summer (bottom), by the 2080s, under the Medium emissions scenario.

4.3.8 Projected changes to annual-, winter- and summer-mean precipitation

The central estimate of changes in annual mean precipitation (Figure 4.10) are within a few percent of zero everywhere. In winter, precipitation increases are in the range +10 to +30% over the majority of the country. Increases are smaller than this in some parts of the country, generally on higher ground, where there can even be slight decreases. In summer, there is a general south to north gradient, from decreases of almost –40% in SW England to almost no change in Shetland.

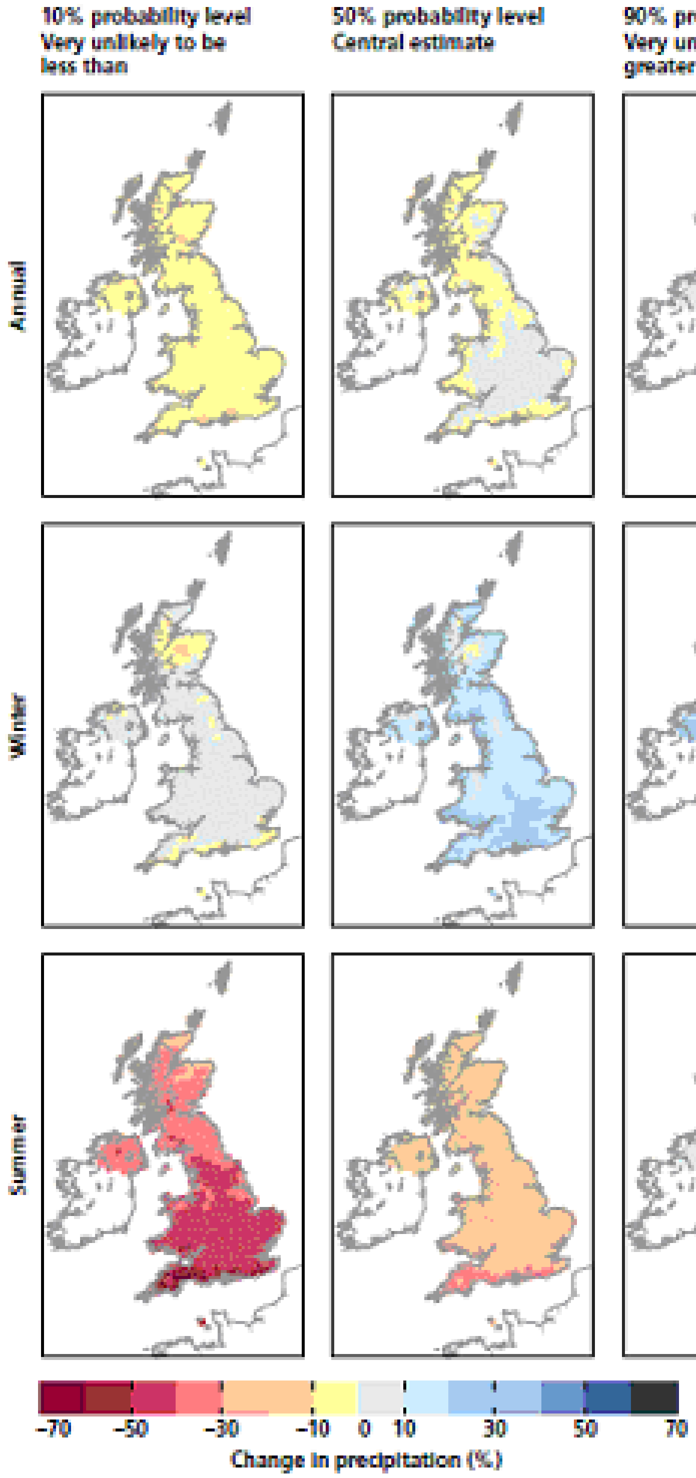


Figure 4.10: Changes in annual (top), winter (middle) and summer (bottom) mean precipitation (%) at the 10, 50 and 90% probability levels, for the 2080s under the Medium emissions scenario.

Note that the changes at 10, 50 and 90% probability levels not only have different magnitudes, but can also be in different directions (that is, can become wetter or drier). Thus summer precipitation (the lowest three maps in Figure 4.10) is projected to decrease almost everywhere in the UK at the 10 and 50% probability levels, but increase almost everywhere at the 90% probability level. In other words, using a specific area as an example, it is very unlikely that Northern Ireland in summer will dry by more than 30–40%, and very unlikely that it will be more than 0–10% wetter, with a central estimate of 10–20% drier.

The maps in Figure 4.11 show changes in precipitation for each administrative region, and those in Figure 4.12 show changes for river basins. The calculation of the change for the administrative region uses fractions of 25 km grid squares to approximate as closely as possible the true value for the administrative region;

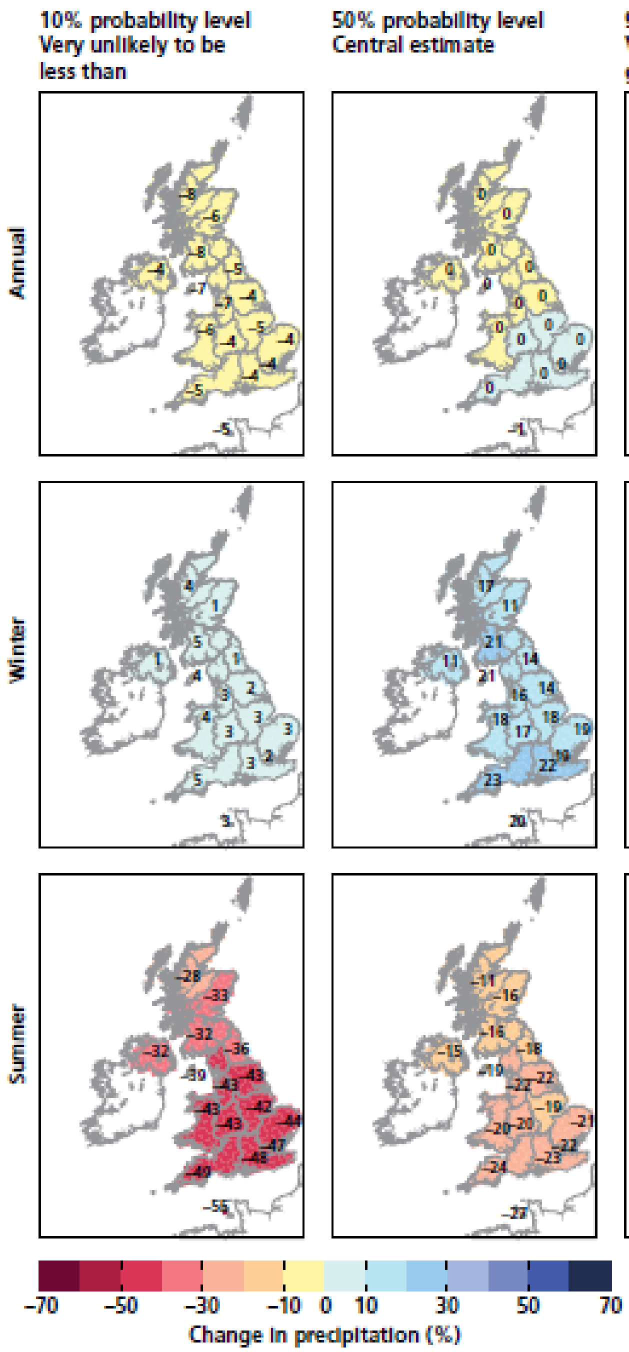


Figure 4.11: Changes to annual (upper panels), winter (middle) and summer (lower) seasonal mean precipitation (%) at the 10, 50 and 90% probability levels, by the 2080s under Medium emissions, for administrative regions. Values of change are shown over each region.

these are the values given in Table 4.5. The User Interface plots the same colour for the whole administrative region, of course, but the resolution in this case is that of the 25 km squares. Hence some small parts of administrative regions will appear from the User Interface map to be plotted in the *wrong* administrative region, but the value calculated, and shown on the region, is correct. The same comment applies also to river basins in Figure 4.12.

Figure 4.13 shows changes to seasonal mean precipitation over marine regions. Winter-mean precipitation at the 50% probability level by the 2080s under Medium emissions is projected to change by +17% over the Eastern English

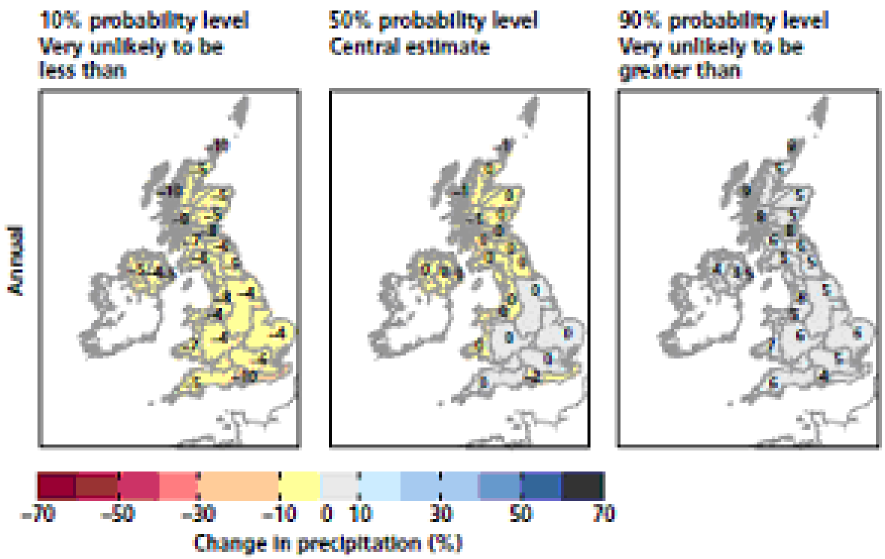


Figure 4.12: Changes to annual mean precipitation (%) at the 10, 50 and 90% probability levels, by the 2080s under Medium emissions, for river basins. Values of change are shown over each region.

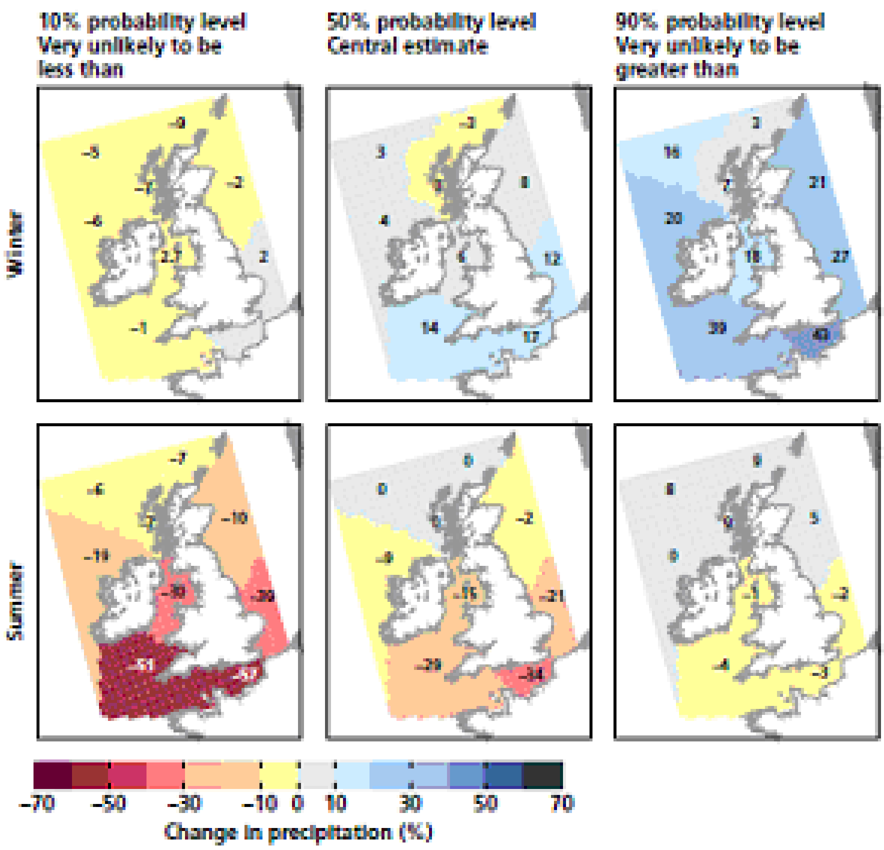


Figure 4.13: Change in winter-mean (top) and summer-mean (bottom) precipitation for marine regions by the 2080s under Medium emissions.

Channel to –3% over the Scottish Continental Shelf. There is also a south–north gradient in summertime, with changes ranging from –34% over the Eastern English Channel to essentially no change over the most northerly marine regions. Changes in the annual mean (not shown) at the 50% probability level are only a few percent everywhere.

4.3.9 Projected changes to the wettest day of the winter/summer by the 2080s

The change in the 99th percentile of daily precipitation in a season is roughly equivalent to change in the wettest day in that season. At the 50% probability level, Figure 4.14 shows increases in precipitation falling on the wettest day of winter of up to 25% in a few small areas of southern England, with a shallow gradient to zero change in the parts of the highlands of Scotland. In summer, there are reductions of 10% or so over parts of southern England, grading gradually to increases of around 10% in parts of north west Scotland.

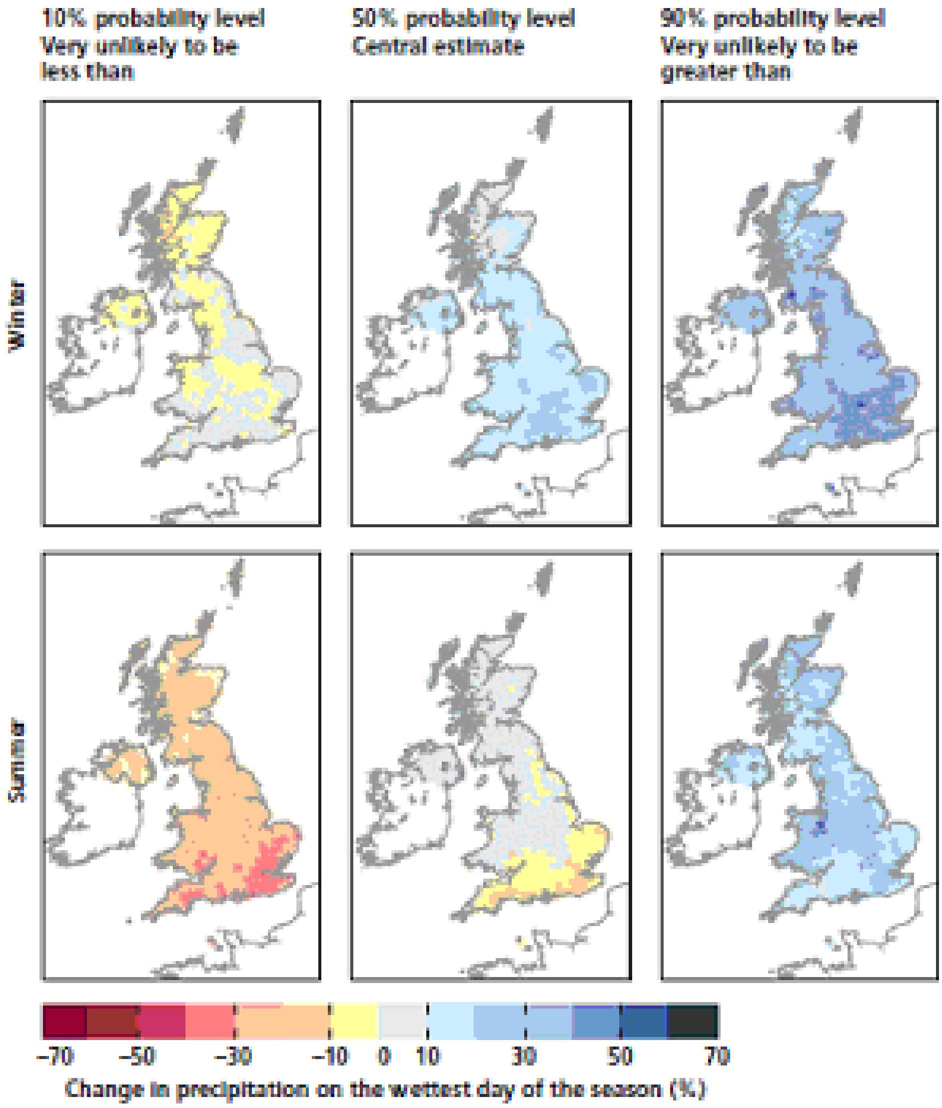


Figure 4.14: Changes to precipitation on the wettest day of the winter (top) and of the summer (bottom) at the 10, 50 and 90% probability levels, for the 2080s under the Medium emissions scenario.

4.3.10 Other variables

In addition to the temperature and precipitation variables discussed above, UKCP09 gives changes in a number of other variables. We summarise here changes in four of the most commonly used of these, by the 2080s under Medium emissions; projections are for the 50% probability level, followed in brackets by changes at the 10 and 90% probability levels.

- **Downward shortwave radiation** at the surface shows changes of only a few percent in winter. In summer it increases by up to 20 Wm^{-2} (0 to 45 Wm^{-2}) in parts of southwest England and Wales, but changes by only a few percent (0 to –25Wm^{-2}) in parts of northern Scotland.

- **Total cloud amount** changes by only a few percent (–9% to +6%) in winter. It decreases, by up to –18% (–33% to –2%), in parts of southern England, with smaller changes further north.

- **Relative humidity** decreases in summer in southern England, by up to about –10% (–20% to zero); changes are smaller further north. In winter, changes are ± a few percent only across the UK.

Note that, for cloud and relative humidity, the results refer to percentage changes relative to baseline values which are themselves expressed in units of percentages. Thus if the baseline value of relative humidity is (say) 80%, and the projected change is 10%, this implies a future value of 88%, not 90%.

4.3.11 Comparisons with UKCIP02

It is instructive to compare the UKCP09 projections with corresponding ones in UKCIP02. Figure 4.15 shows an example of a UKCP09 CDF of projected change in temperature, together with the single projection (for the same time period and emissions scenario, and at the closest location) from UKCIP02. It can be seen that, in this example, the UKCIP02 projection represents a probability of about 56%, that is, in the UKCP09 projections it is 56% probable that the change in temperature will not exceed the UKCIP02 value. This sort of comparison may be useful to those who have previously used UKCIP02 in research and to inform policy, as they can see where within the new distribution the previous value lies. The graph also shows that the change projected by UKCIP02 lies within the wide range of possible outcomes projected by UKCP09, illustrating the need to account for uncertainties in planning and decision-making. This comparison may give very different results for other locations, variables, time periods, etc.

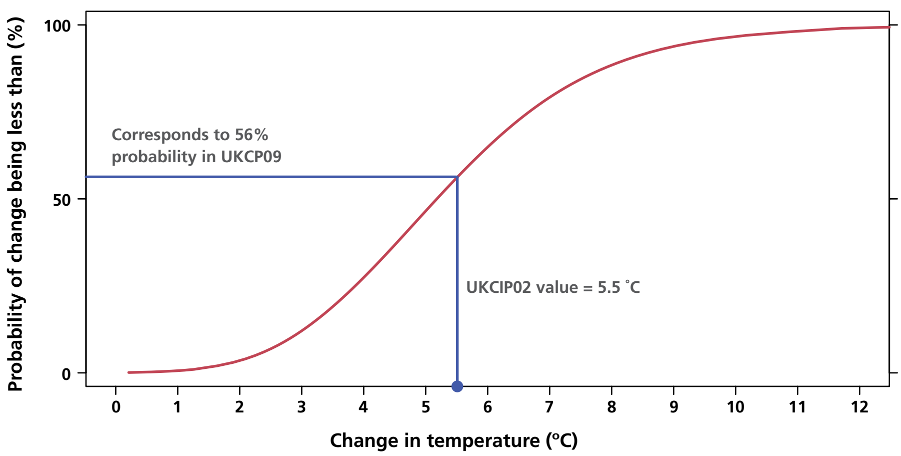


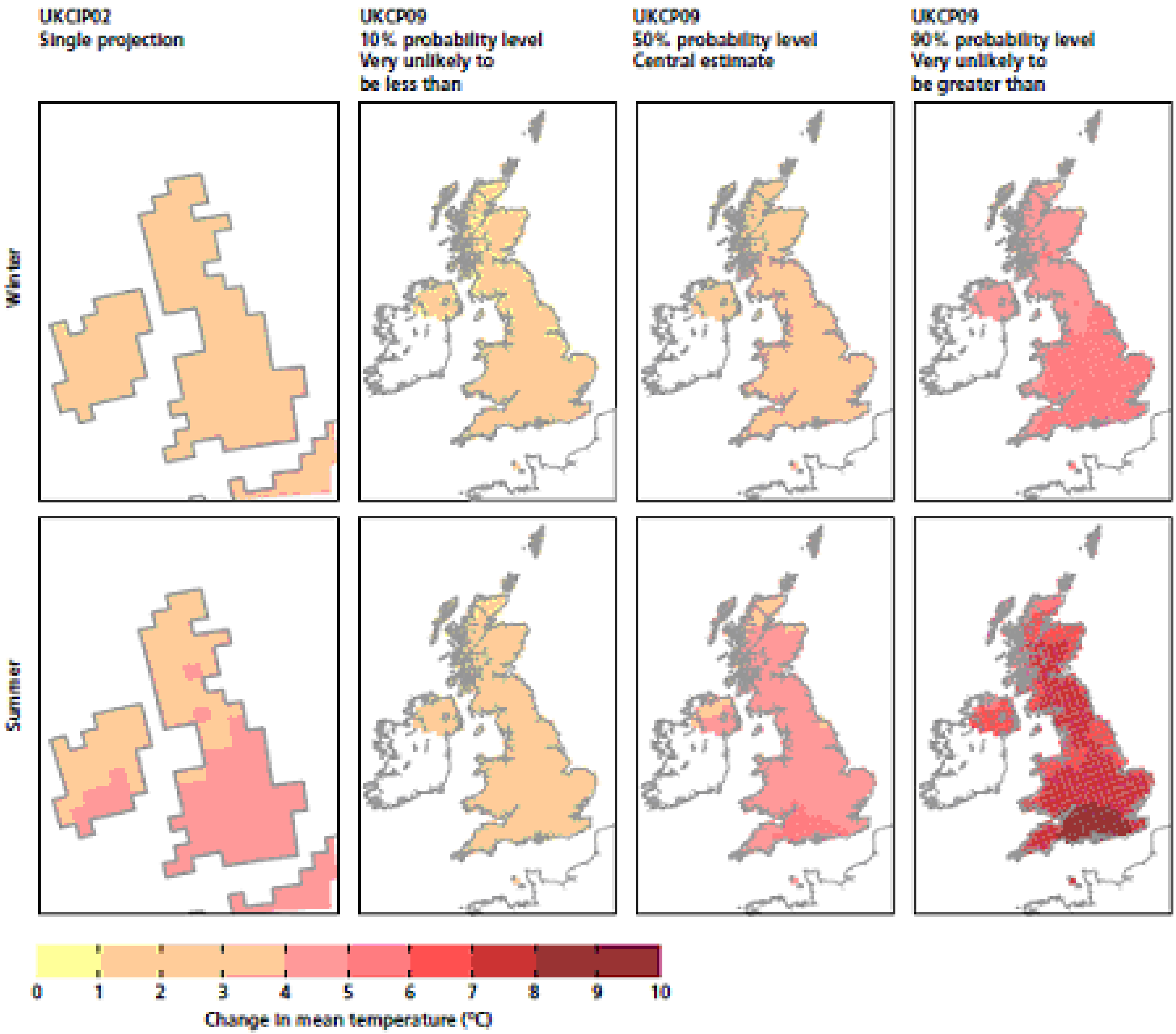
Figure 4.15: The CDF of temperature change for a 25 km square in Dorset, by the 2080s under High emissions. The blue dot shows the corresponding value from the nearest 50 km square in the UKCIP02 scenarios, and the blue lines show that this represents a probability in UKCP09 of about 56%.

Comparisons between the two sets of projections can also be illustrated using maps of changes; those below are in seasonal mean temperature (Figure 4.16) and precipitation (Figure 4.17), for summer and winter, for the 2080s under the High emissions scenario (which is identically the same scenario in the two sets of projections). We show the single result from UKCIP02 alongside the 10, 50 and 90% probability levels in UKCP09.

Having stressed the need for users to consider the full range of uncertainty given in UKCP09, it is nonetheless instructive to compare the central estimate (50% probability level) of the projected changes with the single projections (for the same, High, emissions scenario) in UKCIP02. This allows us to make the following qualitative comments:

- In the case of mean temperature, projected changes in UKCP09 are generally somewhat greater than those in UKCIP02.

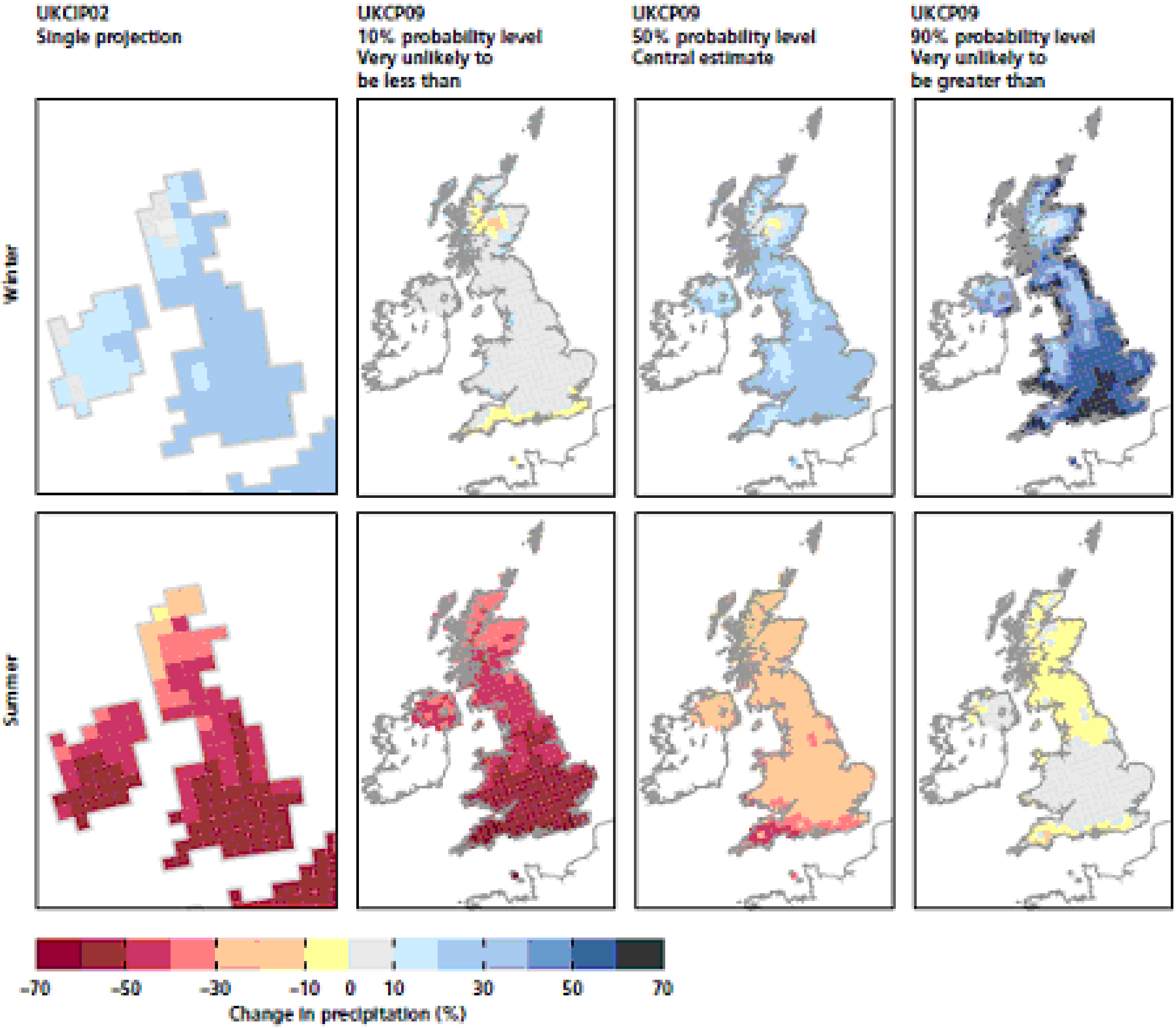
Figure 4.16: Comparison of changes in seasonal mean temperature, summer and winter, by the 2080s under High emissions scenarios, from the UKCIP02 report (far left panels) and as projected in UKCP09 (10, 50 and 90% probability level).



- The summer reduction in rainfall in UKCP09 is not as great as that projected in UKCIP02.
- The range of increases in rainfall in winter seen in UKCP09 are very broadly similar to those in UKCIP02, although with a different geographical pattern. A few grid squares UK are projected to dry in winter in UKCP09; in UKCIP02 all areas were projected to be wetter.
- Small changes in cloud (not shown here) are projected in winter, as in UKCIP02. Projections of summer decreases in cloud are similar to those in UKCIP02.

For brevity, comparisons above are made only with the central estimate in UKCP09; however, users are advised to use the projections over the full robust range (that is, 10–90%) of probabilities in adaptation decisions or when considering the need to update previous decisions based on UKCIP02.

Figure 4.17: As Figure 4.13 but for seasonal mean precipitation.



The reasons for the differences between the two sets of projections lie in the completely different model results and methodologies which were used to derive them. UKCP09 projections include:

- the explicit effects of land and ocean carbon cycle feedbacks, and the uncertainty in land carbon cycle feedback;
- uncertainty due to natural variability;
- modelling uncertainty: UKCIP02 was derived using one variant of one (Met Office) model, whereas UKCP09 is derived from ensembles of variants of Met Office models, together with smaller ensembles of other international models;
- uncertainties associated with the statistical processing required to convert results from model ensembles into probabilistic projections;

None of these factors were able to be included in the UKCIP02 projections.

Hence specific differences between changes in a particular variable in UKCIP02 and those (at a particular probability level) in UKCP09 will generally have a number of contributory reasons; identifying these would be a major undertaking. UKCIP02 projections should not be seen as some benchmark against which all successive projections must be compared and differences explained. The advent of new methodologies (allowing us to quantify uncertainty) and the inclusion of more recent knowledge (for example, carbon cycle feedbacks) give the UKCP09 projections many advantages over those in UKCIP02, and it is strongly recommended that users no longer employ UKCIP02 in isolation.

4.4 What effect do user choices have on the probabilistic projections?

In this section we show some probabilistic projections, generally in the form of PDFs of changes in climate. In the User Interface, the user can make choices using the following selection criteria:

- emissions scenario (Low, Medium and High);
- future time period (7 overlapping 30-yr periods from 2010–2039 to 2070–2099);
- spatial averaging (25 km grid square, administrative region, river basin or marine region);
- temporal averaging (generally month, season, annual);
- geographical location;
- variable; and
- change in climate, or future climate.

We compare below the PDFs which result from a number of these choices; Table 4.7 lists these and the figures that illustrate them. In general, the comparisons hold other choices fixed at a setting which maximises the differences between the choices being compared, in most cases this is for the 2080s under the High emissions scenario. We illustrate these comparisons using temperature and precipitation quantities.

Note that, with the exception of those for the three different emission scenarios (as shown in Figures 4.18 and 4.19), the User Interface cannot combine different PDFs on the same plot. We have combined them in this section to highlight differences.

Figure	Sensitivity explored	Variable used as example	Emission Scenario	Time periods	Spatial average	Temporal average	Location
4.18 4.19	Emissions scenario	Maximum temperature	L, M, H	2020s 2080s	Administrative region	Summer	SE England
4.20	Time period	Minimum temperature	H	2020s 2050s 2080s	Administrative region	Winter	W Scotland
4.21	Spatial average	Wettest day of the season	H	2080s	Administrative region, 25 km	Winter	N Scotland
4.22	Temporal average	Precipitation	H	2080s	Administrative region	January, Winter	NW England
4.23	Location (Administrative region)	Mean temperature	H	2080s	Administrative region	Summer	SW England Wales N Scotland N Ireland
4.24	Location (25 km)	Mean temperature	H	2080s	25 km	Summer	In Dorset Gwynedd Shetland Co Antrim
4.25	Variable	Mean temperature, Maximum temperature, Warmest day of the season	H	2080s	Administrative region	Summer	SW England
4.26	Climate change or future climate	Maximum temperature	H	2080s	25 km	Summer	In East Anglia

Table 4.7: Comparisons shown in this chapter which explore the sensitivity of PDFs to various user choices of emissions scenario, future time period, spatial average, temporal average and location. Locations have been chosen to give a wide geographical spread, but are not aimed to be comprehensive or representative.

4.4.1 How are PDFs affected by choice of emissions scenario?

Figure 4.18 shows that, for the first future time period (2020s), the PDFs are very similar for each of the three emissions scenarios. In part this is due to the long effective lifetime of CO_2 and the inertia of the climate system and in part due to the offsetting effects of increases in greenhouse gases and in sulphur dioxide emissions (which produce sulphate aerosols that cool climate) in the three emissions scenarios.

Unlike Figure 4.18, Figure 4.19 shows that, by the time period of the 2080s, the differences in the PDFs of summer mean daily maximum temperature between the three emissions scenarios are well marked. They still overlap substantially, showing that uncertainties associated with emissions, whilst important, do not dominate those associated with projecting climate response. Differences may be more or less pronounced in other variables.

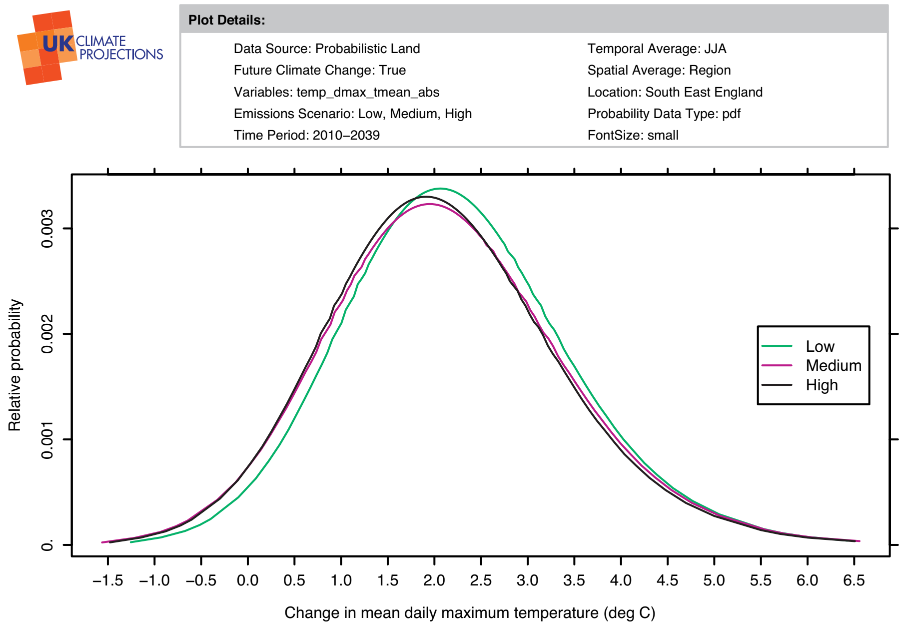


Figure 4.18 : PDFs of change in summer-mean daily maximum temperature in SE England for the Low (green), Medium (purple) and High (black) emissions scenarios, for the 2020s. (Note that this is an example graphic taken directly from the User Interface, showing the plot details in a box above the plot.)

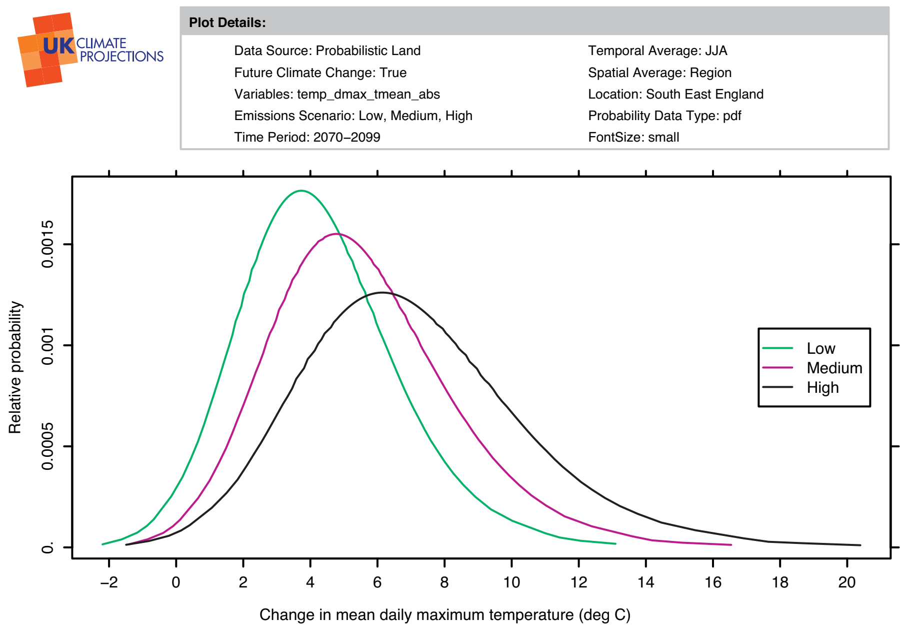


Figure 4.19: As Figure 4.16a but for the period of the 2080s.

4.4.2 How are PDFs affected by choice of future time period?

As might be expected, Figure 4.20 shows that the distribution moves to higher temperature changes with time, and becomes wider, reflecting the growth in uncertainty.

4.4.3 How are PDFs affected by choice of spatial averaging?

PDFs are available for each individual 25 km square, and also for two types of aggregated land areas: administrative regions and river basins. The change over an administrative region (for example, N Scotland) will, by definition, smooth out the variation from square to square seen in the 25 km resolution map. The PDFs for administrative regions are provided because it is not possible for users to create these for themselves by simply averaging the PDFs of changes for constituent 25km squares.

Figure 4.21 shows the PDF for the administrative regional average and, in contrast, the PDFs for two grid squares within in having particularly high and low changes compared to the mean. The variability from square to square will be mainly due to factors such as mountain and coastal effects but also, as explained earlier, reflect the varying relative influences of different causes of uncertainty at different locations.

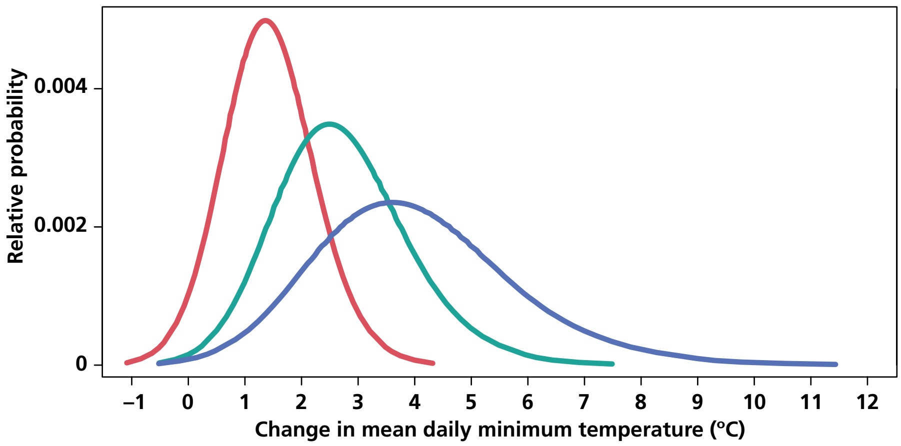


Figure 4.20: PDFs of change in winter mean daily minimum temperature averaged over W Scotland for the High emissions scenario, by the 2020s (red), 2050s (green) and 2080s (blue).

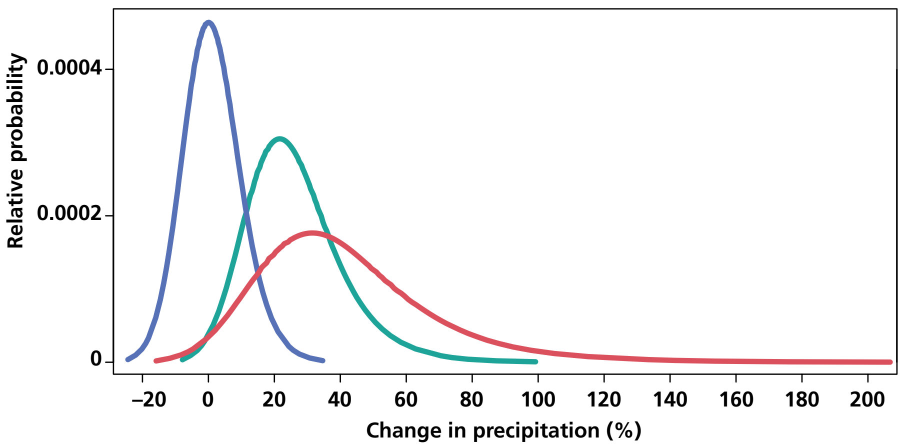


Figure 4.21: Change in winter-mean precipitation (%) by the 2080s under the High emissions scenario. PDF for the North Scotland administrative region (green) compared with PDFs for the 25 km squares in the region projected to experience a relatively high (red) and low (blue) change at 90% probability.

4.4.4 How are PDFs affected by choice of temporal averaging?

Figure 4.22 shows, as expected, that the uncertainty of a monthly average change is greater than that of the seasonal average change, largely due to the natural variability being greater at the shorter temporal scale. It also shows that changes in the central estimate for a particular month can be quite different from that in the corresponding seasonal mean.

4.4.5 How are PDFs affected by choice of geographic location?

Here we show some examples of PDFs of change in mean summer temperature for four administrative regions (Figure 4.23), together with single 25 km squares within these regions (Figure 4.24).

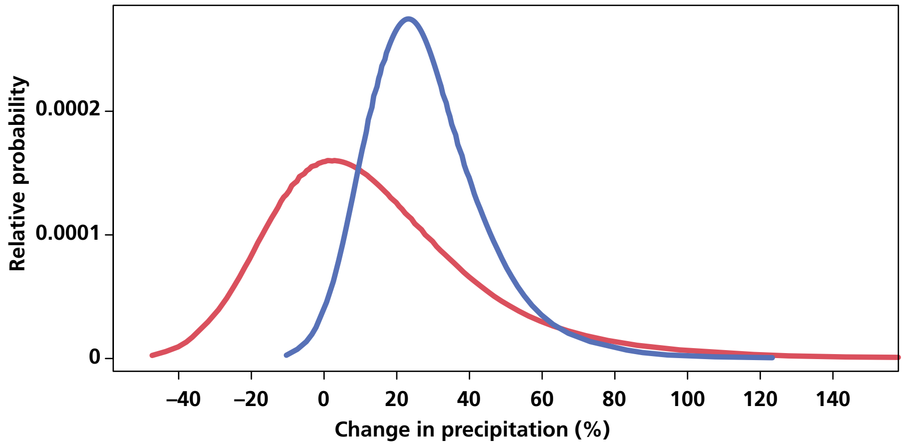


Figure 4.22: PDFs of change in precipitation for NW England by the 2080s under the High emissions scenario, showing means for winter (blue) and for the month of January (red).

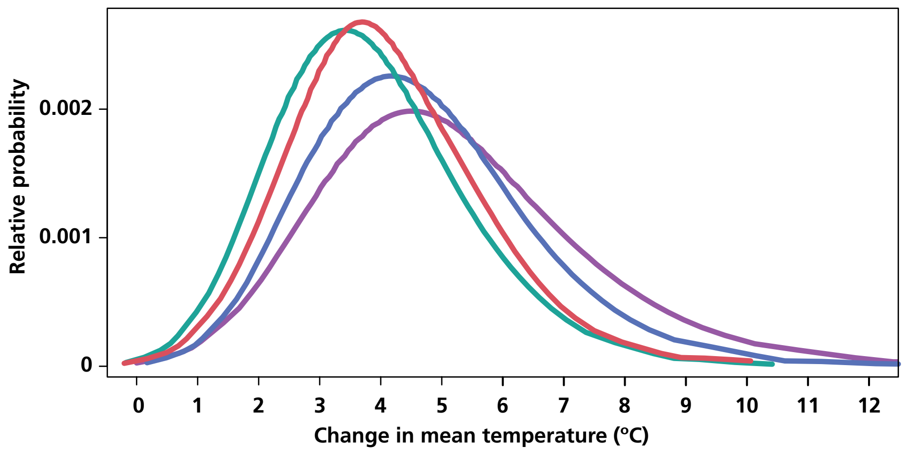


Figure 4.23: The projected change in mean summer temperature by the 2080s under the High emissions scenario for the four administrative regions of N Scotland (green), Northern Ireland (red), Wales (blue) and SW England (purple).