4 Probabilistic projections of seasonal climate changes

This chapter has three purposes. Firstly, it gives some key findings of seasonal changes to climate, at national level and for each of the administrative regions, for the most widely used variables.

Secondly, it shows examples of the probabilistic projections of change which can be obtained from the User Interface. For many users, the maps and diagrams in the UKCIP02 Science Report acted as their main access to the scenarios, and provided them with all they needed. In UKCP09 the amount of information available, and its complexity, is substantially greater. For this reason, a comprehensive set of *prepared* maps and graphs can be seen on the UKCP09 website, which provides many more illustrations of UKCP09 results than can be shown in a report — for example, maps for other future time periods and emissions scenarios. However, because pre-prepared graphics are not always sufficient, a User Interface has been developed which will create additional graphics and data to user specifications. This chapter will show some examples of the various maps which can be generated by the User Interface, focussing mainly on projected changes in seasonal means of some temperature and precipitation variables.

Thirdly, it compares various PDFs of change to show how they differ for different future time periods, emissions scenarios, and spatial and temporal averaging choices, using temperature and precipitation variables as examples. These comparisons, which are listed in Table 4.3, are designed to help users in deciding which choices to make from the possibilities that the User Interface presents. Understanding them is fundamental to their proper use.

As discussed in Chapter 3, it has not been possible to derive probabilistic projections of changes in latent heat flux, snowfall rate and soil moisture; these variables are discussed at the end of this chapter.

4.1 Probabilistic projections as PDFs and CDFs

In Chapter 1 we discussed the presentation of the probabilistic projections in two ways: the probability density function (PDF) and the cumulative distribution function (CDF), using hypothetical cases. In Figure 4.1, we illustrate changes using UKCP09 projections for a 25 km square over the East of England. The information contained in the two plots is identical, and hence we present only the PDF form later in this chapter. The PDF form is useful to get an appreciation of the uncertainties in the change, but the CDF may be the form used in assessments

and impacts studies, particularly when thresholds are important; this is discussed in the UKCP09 User Guidance.

As explained in Annex 4, the UKCP09 User Interface allows the user to download probabilistic data and create PDF plots of their own offline. The User Interface dataset stores probability values down to very low levels, but when it creates plots the curves are trimmed at both ends to suppress long *tails* where the probability is changing only very slowly.

In UKCP09, following IPCC, we use the descriptors *very likely to be less than* or *very unlikely to be greater than* to describe projections with a cumulative probability of 90%. We use *very likely to be greater than* or *very unlikely to be less than* for a cumulative probability of 10%. We use the term *central estimate* to describe the projections having 50% cumulative probability (properly known as the median of the distribution). For convenience, we use the term *probability* rather than *cumulative probability* in the rest of the chapter.

Hence, the CDF in the example in Figure 4.1 tells us that, for the particular location, time period, emissions scenario:

- The projected warming is very unlikely to be less than (or, alternatively, very likely to be more than) about 3.7°C (red lines)
- The central estimate for the warming is about 7°C (green lines)
- The projected warming is very likely to be less than (or, alternatively, very unlikely to be more than) 11°C (blue lines).

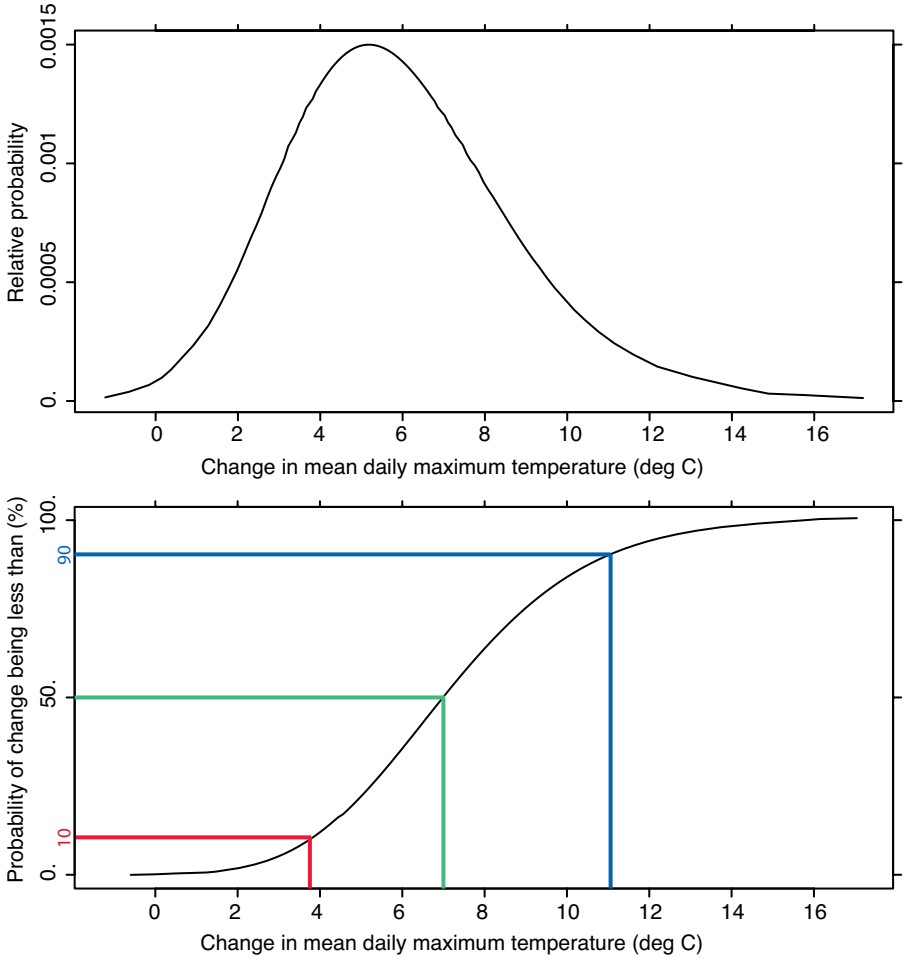


Figure 4.1: PDF (top) and CDF (bottom) of change in summer mean daily maximum temperature (°C) over a particular 25 km square by the 2080s under the High emissions scenario. Both these figures are from the User Interface, but the coloured lines on the CDF have been added later; they cannot be added by the User Interface.

Note that, as with all climate change projections (for example those in IPCC AR4), probabilities given are conditional on the methodology used. So when we say a particular projected change is *very likely* to be less than a given value of temperature change, we mean *very likely according to probabilities derived using the UKCP09 methodology*.

4.1.1 The credibility of changes at extremes of the probability distributions

The UKCP09 probabilistic projections allow us in principle to look at changes near the upper and lower extremes of the projected probability distributions; we advise against this. Probabilistic projections, although they are designed to quantify uncertainty, require us to make a number of assumptions in their development, and hence they are themselves uncertain. Annex 2 describes some of the sensitivities of the projections to choices and assumptions in our methodology. This uncertainty applies to the whole of the PDF or CDF, but increases as we go towards the extremes (tails) of the distribution, and for this reason the confidence in our results is much smaller here. We have different levels of confidence in different variables so, for example, data at a given probability level (say 95%) may be relatively robust for one variable (for example, seasonal mean temperature) but less robust in the case of another (for example, the wettest day of the season). In addition, what may be an unacceptable uncertainty for one user may be quite acceptable for another application. However, as a general guideline we suggest that users should be able to use the distribution from the 10% to the 90% probability levels, but not outside this range, although data covering the full range is available. For some variables the limits may be more stringent than this.

4.1.2 Consequences of having the baseline climate as 1961–1990

User consultations and surveys carried out by UKCIP showed support for retaining the same baseline (or reference) period as was used in UKCIP02, namely 1961–1990 (strictly Dec 1960–Nov 1990). Hence all changes shown or described in this report are changes with respect to that baseline. Users will recognise, however, that the current climate has already changed significantly since the baseline period, and so changes should not be described as "compared to today's climate". This is obviously more important for the earliest projected time period of the 2020s (2010–2039) and less important, but certainly not negligible, for the most distant one. For example, the central year of the baseline time period is 1975–1976; that of the first future time period is 2024–2025, 49 yr later. However, this report is published in 2009, 33 yr after the central year of the baseline period and hence already about two-thirds of the way to the central year of the first time period of the projections. Similarly, we are already about 40% of the way to the central year of the 2050s time period (2040–2069), and even about 30% of the way towards the last projected period of 2070–2099. If users wish to estimate the change in any variable relative to today's climate, the UKCP09 report *The climate of the UK and recent trends* and data sources quoted in this, may help. However, users should note that (a) recent change may not be linear, and (b) due to natural variability, the actual climate change over the last 33 yr, based on observations, may not be the same as that simulated by models. For users who may wish to relate future changes to a pre-industrial baseline, some data (for example, the Central England Temperature) on longer term trends is available from the MOHC website (http://hadobs.metoffice.com/hadcet/).

4.2 Key findings

In this section we present key findings from the probabilistic projections at a national level and for each of the 16 administrative regions.

4.2.1 National key findings

National key findings are given in the form of tables (4.1 to 4.3) of the winter and summer seasonal average changes in a number of variables (plus the change in the annual average in the case of precipitation). The tables contain the values of change (relative to 1961–1990) in the 25 km grid squares which show both the highest and lowest changes anywhere in the UK, for each UKCP09 emissions scenario, for the 2080s time period and for the 10, 50 and 90% probability levels. To explain this further, we take the example, in Table 4.1, of the *highest change* of winter mean temperature shown in the *10% probability* box, by the 2080s, under the High emissions scenario — the top right box. This has a value of 2.2°C. This means that, for the grid square in the UK showing the highest change (for that time period, emissions scenario and probability level), the UKCP09 methodology estimates that it is very unlikely (10% probability) that the winter mean temperature change will be less than 2.2°C or, in other words, the warming is very likely to be greater than 2.2°C. The three probability levels shown in the tables (10, 50 and 90%) have been chosen to show the widest range which we consider to be robust within the methodology (see 4.1.1). The definitions of *highest* and *lowest* take into account the sign of change; for example a change of –10% is considered to be lower than one of +5%. Note that for a given emissions

Table 4.1: Highest and lowest changes in mean daily temperature, mean daily maximum temperature and mean daily minimum temperature (°C) in winter and summer, by the 2080s, relative to 1961–1990.

Variable		Mean temperature, winter			Mean temperature, summer			Mean daily maximum temperature, winter			Mean daily maximum temperature, summer			Mean daily minimum temperature, winter			Mean daily minimum temperature, summer		
Probability level		10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
High emissions	Highest change in UK	2.2	3.8	5.8	2.9	5.3	8.4	1.6	3.4	6.1	3.0	6.8	11.7	2.0	4.2	7.0	2.8	5.3	8.8
	Lowest change in UK	1.0	2.1	3.5	1.6	3.1	5.0	1.1	2.3	3.9	1.2	3.5	6.3	0.8	2.4	4.3	1.7	3.3	5.6
Medium emissions	Highest change in UK	1.7	3.1	4.8	2.2	4.2	6.8	1.3	2.9	5.1	2.2	5.4	9.5	1.5	3.5	5.9	2.0	4.1	7.1
	Lowest change in UK	0.8	1.8	3.1	1.2	2.5	4.1	0.8	2.0	3.4	1.1	2.8	5.0	0.6	2.1	3.7	1.3	2.7	4.5
Low emissions	Highest change in UK	1.5	2.7	4.1	1.4	3.1	5.3	1.3	2.6	4.3	1.4	4.1	7.5	1.4	2.9	4.8	1.4	3.2	5.6
	Lowest change in UK	0.8	1.7	2.7	0.8	1.9	3.2	0.9	1.8	3.0	0.7	2.1	3.9	0.7	2.0	3.3	0.9	2.1	3.5

Variable		Mean precipitation, annual			Mean precipitation, winter			Mean precipitation, summer			Precipitation on wettest day of the winter			Precipitation on wettest day of the summer		
Probability level		10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
High emissions	Highest change in UK	–3	+3	+20	+18	+47	+97	–8	0	+10	+11	+35	+77	–1	+14	+64
	Lowest change in UK	–21	+6	+3	–12	–3	+6	–74	–49	–10	–12	0	+13	–46	–18	+6
Medium emissions	Highest change in UK	–3	+2	+14	+9	+33	+70	–8	+1	+10	+7	+25	+56	–1	+12	+51
	Lowest change in UK	–16	–3	+3	–11	–2	+7	–65	–40	–6	–12	0	+13	–38	–12	+9
Low emissions	Highest change in UK	–2	+3	+14	+8	+30	+59	–8	+1	+16	+4	+22	+47	–2	+10	+49
	Lowest change in UK	–12	–1	+3	–11	–2	+7	–55	–30	+1	–12	0	+13	–29	–7	+10

Table 4.2: Highest and lowest changes in annual-, winter- and summer-mean daily precipitation, and in precipitation on the wettest day of the season (%) in winter and summer, by the 2080s, relative to 1961–1990.

Variable		Total cloud, winter			Total cloud, summer			Relative humidity, winter			Relative humidity, summer		
Probability level		10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
High emissions	Highest change in UK	–1	+2	+8	+1	+7	13	+2	+4	+6	+1	+2	+4
	Lowest change in UK	–10	–4	+1	–39	–23	–4	–3	0	0	–24	–11	0
Medium emissions	Highest change in UK	–1	+1	+6	0	+5	+11	+1	+3	+5	+1	+2	+3
	Lowest change in UK	–9	–4	+1	–33	–18	–2	–3	0	0	–20	–9	0
Low emissions	Highest change in UK	–1	+1	+5	–1	+3	+7	0	+2	+4	0	+1	+3
	Lowest change in UK	–8	–3	+1	–26	–12	0	–2	0	0	–16	–6	0

Table 4.3 Highest and lowest changes in cloud amount (%) and mean relative humidity (% of %) in winter and summer, relative to 1961–1990.

scenario, the grid square with the highest change at the 10% probability level may not be the same grid square that shows the highest change at the 50 or 90% probability levels.

4.2.2 Regional key findings

Regional key findings are based on changes averaged over administrative regions (shown as Figure 4.2), given in Tables 4.4 and 4.5. They show summer- and winter-mean changes for a number of key variables, at the 10, 50 and 90% probability level, by the 2050s under the Medium emissions scenario. In addition, the tables show a *wider range of uncertainty* for the 2050s, defined here as the lowest and the highest values seen in all three emissions scenarios and all three (10, 50 and 90%) probability levels. In the case of precipitation, change in the annual mean is also shown.

Variable	Mean temperature, winter °C					Mean temperature, summer °C					Mean daily maximum temperature, summer °C					Mean daily minimum temperature, summer °C				
Probability level	10%	50%	90%	Wider range		10%	50%	90%	Wider range		10%	50%	90%	Wider range		10%	50%	90%	Wider range	
North Scotland	0.6	1.7	2.8	0.6	3.0	0.9	2.0	3.4	0.9	3.9	0.8	2.5	4.5	0.9	5.3	0.9	2.3	3.9	0.9	4.4
East Scotland	0.7	1.7	2.9	0.6	3.1	1.1	2.3	3.9	1.0	4.5	1.0	3.0	5.4	1.0	6.3	1.1	2.5	4.3	1.0	4.9
West Scotland	1.0	1.9	3.0	0.8	3.3	1.1	2.4	3.8	1.0	4.4	0.9	3.0	5.2	0.9	5.9	0.9	2.4	4.2	0.9	4.7
N Ireland	0.9	1.7	2.7	0.6	2.9	1.0	2.2	3.5	0.8	4.0	0.9	2.7	4.8	0.8	5.4	1.0	2.4	4.2	0.9	4.6
Isle of Man	0.9	1.8	2.7	0.7	3.0	1.1	2.3	3.7	1.0	4.2	0.9	2.9	5.1	0.8	5.7	0.9	2.2	3.9	0.8	4.4
NE England	1.0	2.0	3.1	0.8	3.4	1.2	2.5	4.1	1.1	4.7	1.0	3.2	5.7	0.9	6.4	1.0	2.5	4.4	0.9	4.9
NW England	1.0	2.0	3.0	0.8	3.3	1.2	2.6	4.1	1.1	4.7	1.0	3.3	5.8	1.0	6.5	1.0	2.5	4.4	0.9	4.9
Yorkshire & Humber	1.1	2.1	3.3	0.9	3.7	1.1	2.3	3.9	0.9	4.4	1.2	3.1	5.4	1.0	6.1	1.1	2.6	4.4	1.0	5.0
East Midlands	1.1	2.2	3.4	0.9	3.8	1.2	2.5	4.2	1.0	4.7	1.3	3.3	5.9	1.1	6.6	1.2	2.7	4.6	1.1	5.2
West Midlands	1.2	2.1	3.2	0.9	3.5	1.2	2.6	4.4	1.0	4.8	1.3	3.6	6.5	1.1	7.2	1.1	2.7	4.8	1.0	5.3
Wales	1.1	2.0	3.1	0.8	3.4	1.2	2.5	4.1	1.0	4.6	1.3	3.4	6.1	1.0	6.8	1.1	2.6	4.6	0.9	5.1
East England	1.1	2.2	3.4	0.9	3.8	1.2	2.5	4.3	1.0	4.8	1.3	3.4	6.0	1.1	6.8	1.2	2.7	4.7	1.1	5.3
London	1.2	2.2	3.5	0.9	3.8	1.3	2.7	4.6	1.1	5.2	1.4	3.7	6.5	1.2	7.3	1.3	2.9	5.0	1.2	5.6
SE England	1.1	2.2	3.4	0.9	3.8	1.3	2.7	4.6	1.1	5.2	1.4	3.7	6.5	1.2	7.3	1.3	2.9	5.1	1.2	5.7
SW England	1.1	2.1	3.2	0.8	3.5	1.3	2.7	4.6	1.1	5.1	1.4	3.8	6.8	1.2	7.6	1.2	2.9	5.0	1.0	5.5
Channel Isles	1.1	2.0	3.1	0.8	3.4	1.2	2.5	4.2	1.0	4.7	1.3	3.4	6.2	1.0	6.9	1.1	2.8	4.8	0.9	5.3

Table 4.4: Changes in daily mean (summer and winter averages), and summer-mean daily maximum and minimum temperatures, averaged over administrative regions, by the 2050s under the Medium emissions scenario. *Wider range* is defined as the range from the lowest to highest value of change for all emissions scenarios and all three (10, 50 and 90%) probability levels by the 2050s. Note that values from the User Interface may differ by a percent from those above due to rounding.

These tabular findings can also be presented as written statements, using the term *very unlikely to be less than* to refer to the 10% probability level, *very unlikely to be greater than* to refer to the 90% probability level and *central estimate* to refer to the 50% probability level. We give below written key regional findings for Wales for some temperature and precipitation quantities as examples; statements for other administrative regions can be generated from Tables 4.4 and 4.5. On the UKCP09 website, users will be able to view pre-prepared maps and graphs and written key findings for all regions.

Figure 4.2: Administrative regions over which changes are averaged in the regional key findings.

Variable	Annual mean precipitation %					Winter mean precipitation %					Summer mean precipitation %				
Probability level	10%	50%	90%	Wider range		10%	50%	90%	Wider range		10%	50%	90%	Wider range	
North Scotland	–6	0	+5	–7	+6	+3	+13	+24	0	+26	–23	–10	+2	–23	+6
East Scotland	–4	0	+5	–5	+6	+2	+10	+20	–1	+21	–26	–12	+1	–27	+6
West Scotland	–6	0	+5	–7	+6	+5	+15	+28	0	+30	–26	–12	+1	–27	+6
Northern Ireland	–3	0	+3	–3	+3	+2	+9	+19	0	+19	–26	–12	+3	–27	+8
Isle of Man	–5	0	+4	–6	+5	+2	+16	+35	–1	+36	–31	–15	+1	–32	+8
North East England	–4	0	+5	–5	+5	+1	+11	+24	0	+26	–29	–14	+1	–30	+7
North West England	–5	0	+6	–6	+7	+3	+13	+26	0	+27	–34	–17	+1	–36	+8
Yorkshire & Humber	–3	0	+4	–4	+5	+2	+11	+24	0	+27	–35	–17	+1	–37	+9
East Midlands	–4	0	+6	–5	+6	+2	+14	+29	+1	+33	–35	–15	+6	–37	+13
West Midland	–4	0	+6	–5	+6	+2	+13	+28	+1	+31	–36	–16	+6	–38	+13
Wales	–4	0	+5	–5	+6	+2	+14	+30	0	+31	–36	–16	+6	–38	+13
East England	–4	0	+5	–4	+6	+3	+14	+31	+1	+35	–37	–16	+6	–39	+14
London	–4	0	+5	–4	+5	+2	+15	+33	0	+37	–39	–18	+7	–41	+16
South East England	–4	0	+6	–5	+6	+2	+16	+36	+1	+40	–40	–18	+7	–42	+16
South West England	–4	0	+6	–5	+6	+4	+17	+38	0	+41	–41	–19	+7	–43	+16
Channel Islands	–4	0	+3	–4	+4	+2	+15	+34	0	+38	–47	–22	+9	–49	+20

Table 4.5: Changes in annual-, winter- and summer-mean precipitation, averaged over administrative regions, by the 2050s under the Medium emissions scenario. *Wider range* is defined as the lowest and the highest values of change seen in all three emissions scenarios and all three (10, 50 and 90%) probability levels. Note that values from the User Interface may differ by a percent from those above due to rounding.

Key findings for Wales, changes by the 2050s

- Under Medium emissions, the central estimate of increase in winter mean temperature is 2.0°C; it is very unlikely to be less than 1.1°C and is very unlikely to be more than 3.1°C. A wider range of uncertainty is from 0.8 to 3.4°C.

- Under Medium emissions, the central estimate of increase in summer mean temperature is 2.5°C; it is very unlikely to be less than 1.2°C and is very unlikely to be more than 4.2°C. A wider range of uncertainty is from 1.0 to 4.6°C.

- Under Medium emissions, the central estimate of increase in summer mean daily maximum temperature is 3.4°C; it is very unlikely to be less than 1.3°C and is very unlikely to be more than 6.1°C. A wider range of uncertainty is from 1.0 to 6.8°C.

- Under Medium emissions, the central estimate of increase in summer mean daily minimum temperature is 2.6°C; it is very unlikely to be less than 1.1°C and is very unlikely to be more than 4.6°C. A wider range of uncertainty is from 0.9 to 5.1°C.

- Under Medium emissions, the central estimate of change in annual mean precipitation is 0%; it is very unlikely to be less than –4% and is very unlikely to be more than +5%. A wider range of uncertainty is from –5% to +6%.

- Under Medium emissions, the central estimate of change in winter mean precipitation is +14%; it is very unlikely to be less than +2% and is very unlikely to be more than +30%. A wider range of uncertainty is from 0% to +31%.

- Under Medium emissions, the central estimate of change in summer mean precipitation is –16%; it is very unlikely to be less than –36% and is very unlikely to be more than +6%. A wider range of uncertainty is from –38% to +13%.

4.2.3 Key findings for marine regions

Variable	Mean temp winter °C					Mean temp summer °C					Precipitation winter %					Precipitation summer %				
Probability level	10%	50%	90%	Wider range		10%	50%	90%	Wider range		10%	50%	90%	Wider range		10%	50%	90%	Wider range	
Scottish Continental shelf	0.3	1.2	2.2	0.3	2.5	0.1	1.1	2.3	0.1	2.6	–5	0	+4	–8	+5	–8	–1	+6	–8	+8
Northwest approaches	–0.2	0.9	2.1	–0.2	2.3	–0.3	0.8	2.2	–0.3	2.5	–4	+4	+15	–4	+15	–7	–1	+6	–7	+6
West Scotland	0.3	1.1	2.2	0.3	2.5	0.1	1.2	2.5	0.1	2.8	–4	+1	+6	–9	+7	–8	–1	+7	–8	+8
Irish Atlantic approaches	0.7	1.4	2.4	0.6	2.7	0.6	1.5	2.5	0.6	2.8	–5	+5	+19	–5	+19	–18	–9	+1	–18	+3
Northern North Sea	1.0	1.8	2.9	0.9	3.1	0.9	1.8	2.8	0.9	3.1	+1	+9	+18	–2	+19	–9	–2	+6	–9	+7
Southern North Sea	1.4	2.2	3.3	1.2	3.7	1.2	2.1	3.2	1.2	3.6	+3	+11	+21	+1	+24	–32	–17	0	–33	+6
Irish Sea	0.6	1.4	2.3	0.6	2.6	0.3	1.5	2.9	0.3	3.3	–1	+6	+14	–2	+15	–25	–12	0	–25	+4
Southwest approaches	1.2	1.9	2.9	1.0	3.1	1.3	2.2	3.2	1.2	3.5	0	+11	+28	–3	+30	–43	–23	–2	–44	+7
Eastern English Channel	1.2	2.1	3.3	1.0	3.6	1.4	2.3	3.4	1.2	3.9	+1	+14	+31	–2	+34	–49	–27	0	–50	+10

Table 4.6: Changes in winter- and summer-mean temperature and precipitation, averaged over marine regions, by the 2050s under the Medium emissions scenario. *Wider range* is defined as the lowest and the highest values of change seen in all three emissions scenarios and all three (10, 50 and 90%) probability levels.

4.3 Maps of changes in seasonal climate

The purpose of this section is to display a number of maps (mainly of projected summer- and winter-mean changes by the 2080s under the Medium emissions scenario) of some of the more frequently used temperature and precipitation variables. We show in each case changes at 10, 50 and 90% probability levels. Most maps are at 25 km resolution but we also show a single set of maps of change averaged over administrative regions, river basins and marine regions.

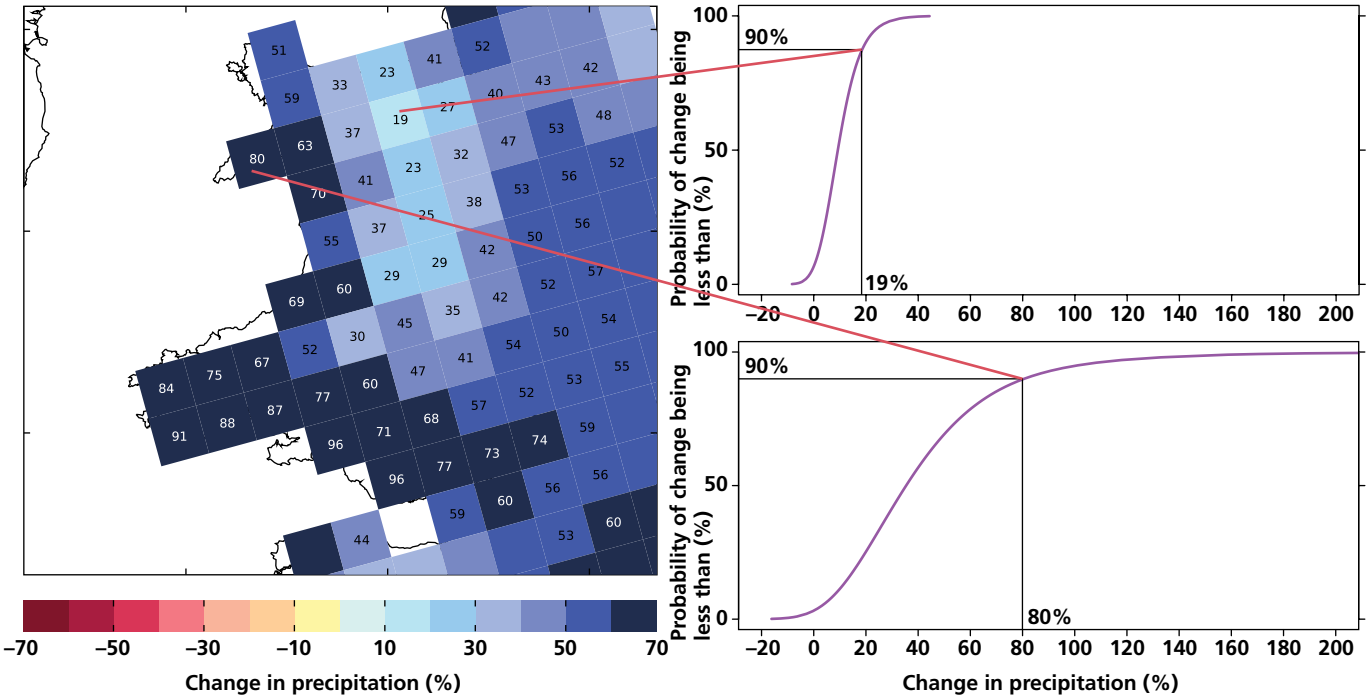
As mentioned earlier, this is not meant to be a comprehensive source of information, but simply to show examples of some of the likely most-requested products available from UKCP09. In the pdf and html versions of this report, users can click on a map of interest to be taken to the same map within the User Interface; they can then use the accompanying control panel to create similar maps for a different variable, future time period, temporal averaging period or emissions scenario.

Geographical patterns can be most easily seen from the maps. Nevertheless a short summary of any significant pattern is given for changes at the 50% probability level by the 2080s under the Medium emissions scenario. Other time periods and emissions scenarios, and particularly probability levels, may have very different patterns.

4.3.1 Interpreting maps of probabilistic climate change

Many users of the UKCIP02 projections will have become used to looking at maps which show a *snapshot* of the distribution of changes in climate over the UK, for example those showing change in summer precipitation by the 2080s, for a High emissions scenario, at a resolution of 50 km. The UKCP09 maps which are shown in this chapter have the same sort of appearance as those in UKCIP02, apart from the increased resolution of 25 km, but the nature of their content is quite different.

Figure 4.3: Relating a map of changes, at 90% probability level, to mean winter precipitation over Wales by the 2080s under High emissions, to the CDFs of change at two of the 25 km squares.



The maps in this section show changes at the 10, 50 and 90% probability level, taken from the cumulative distribution functions, CDF, at each 25 km square. Figure 4.3 shows a map generated by the User Interface, of projected changes in mean winter precipitation at the 90% probability level, over Wales. Values of percentage change are overprinted on each 25 km square; there is a 90% probability of the precipitation change being below this value. Shown alongside are the CDFs for two of the individual squares in that region, showing correspondence between the 90% probability level on the CDF and the value given on the map. So, for example, the upper CDF for an inland square shows that the projected change is very unlikely to be greater than 19% or, alternatively, very likely to be less than 19%. The lower CDF shows the very different change, 80%, at the same probability level, at a coastal grid square. The same principle will, of course, apply to maps showing projected changes at 10 and 50% probability levels.

The values of change at a particular probability level (for example, 90%) for a number of grid squares cannot be averaged together; for this reason projections in UKCP09 are also given over two sets of larger areas (administrative regions and river basins). In addition, values of change at a particular probability level (for example, 90%) for two different variables (for example, mean temperature and precipitation) at a particular grid square, cannot be combined; this is the reason that joint probability values are made available (see Section 4.6).

The maps shown in this chapter have been produced directly by the User Interface, although they have been grouped together offline. In addition, the User Interface allows users to zoom in on particular regions of the UK (as in Figure 4.3 above) where each 25 km square can be overprinted with the value of change for that square.

4.3.2 Projected changes to winter and summer seasonal mean temperature

Figure 4.4 shows that, in winter, the central estimates of change are projected to be generally between 2 and 3°C across most of the country, with slightly larger changes in the south east, and slightly smaller in the north west, of Britain. In summer a south to north gradient exists with changes in some parts of southern England being just over 4°C and in parts of northern Scotland about 2.5°C. This general north–south spatial gradient of change was also seen in UKCIP02, reflects the large scale difference between areas closer to continents (where warming is projected to be relatively more rapid) and those more influenced by oceans (where it is slower).

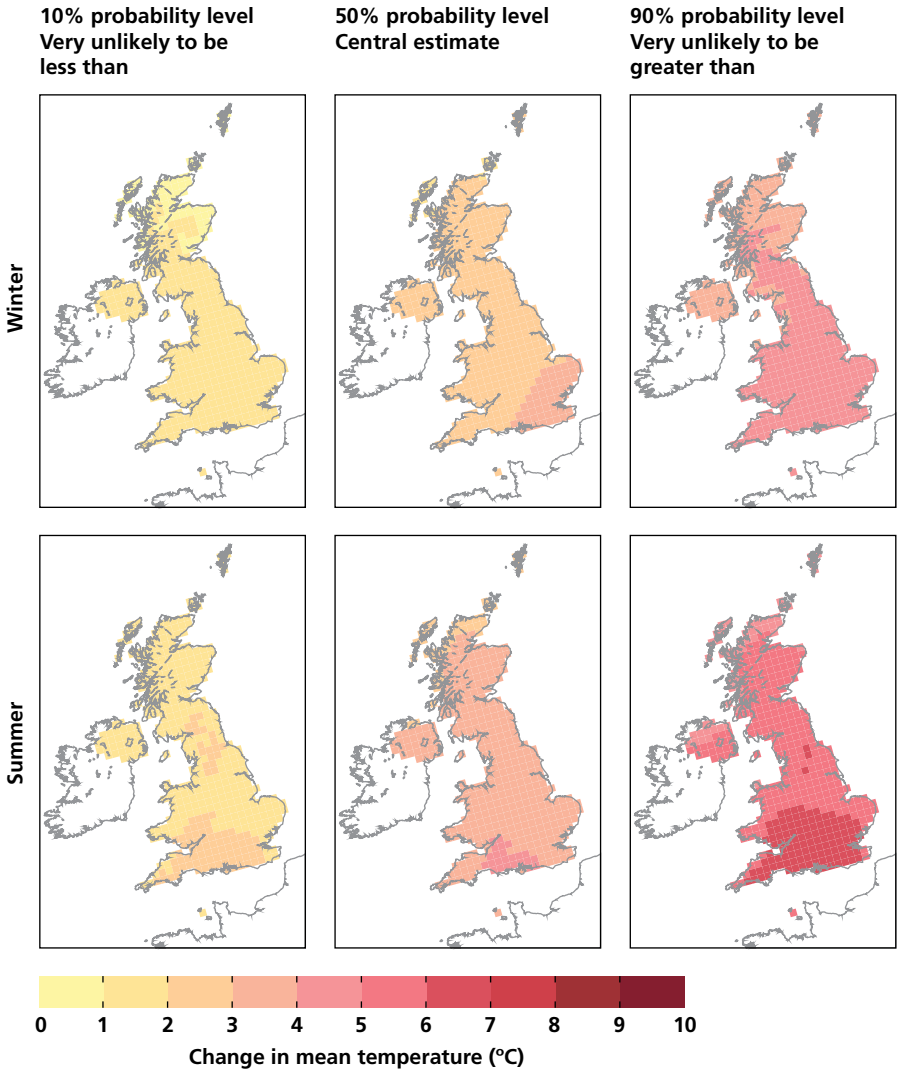


Figure 4.4: 10, 50 and 90% probability levels of changes to the average daily mean temperature (°C) of the winter (upper) and summer (lower) by the 2080s, under Medium emissions scenario. (Note that individual maps are from the User Interface, but this does not allow maps to be grouped as shown here).

4.3.3 Projections of future winter and summer seasonal mean temperature

In addition to maps of climate change, the User Interface will also supply maps of projected future climate over land regions, for a few of the variables (see Chapter 1, paragraph 1.3.1). These are generated by applying the projections of climate change applied to the 1961–1990 baseline observed climate. An example, for summer and winter mean temperature, is shown in Figure 4.5, where the projections of change shown in Figure 4.4 have been added to observations. For variables (such as precipitation) where change is expressed as percentages, the future climate is generated by increasing (or decreasing) the 1961–1990 baseline observations by the percentage change factor.

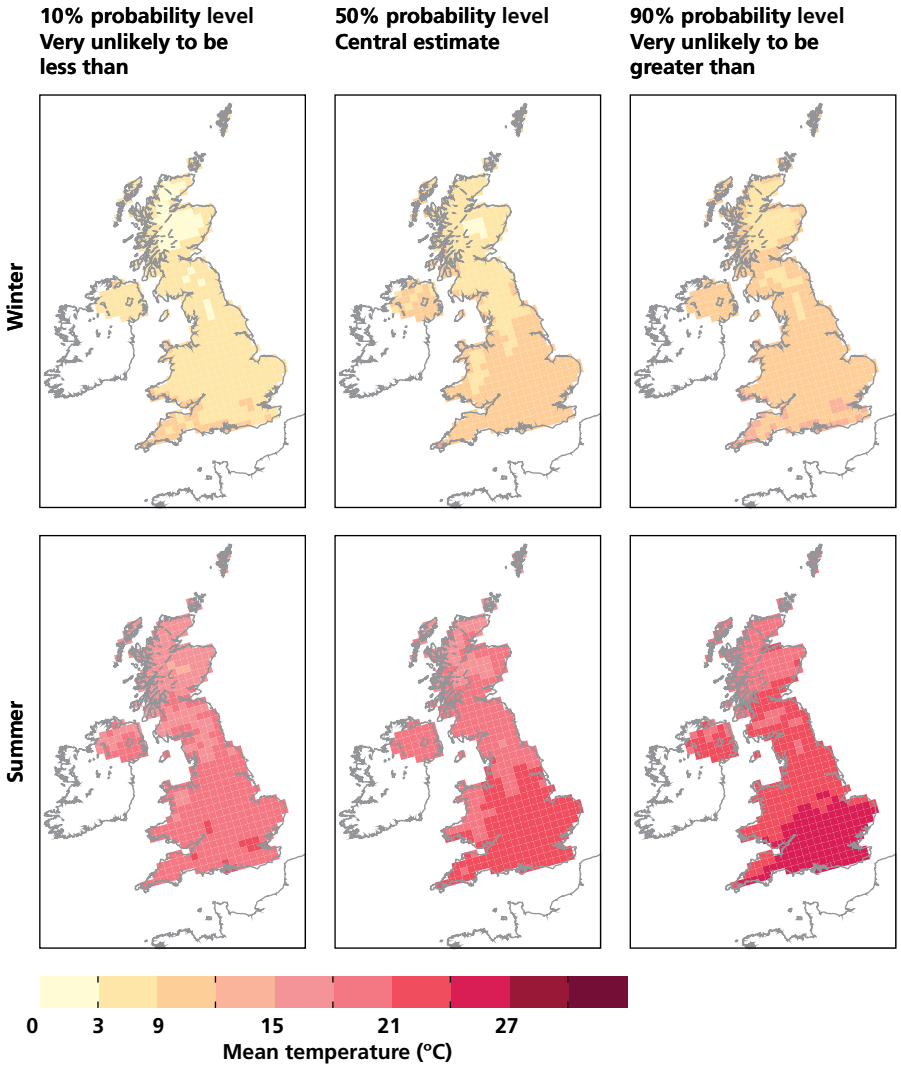


Figure 4.5: As Figure 4.4, but showing projected summer and winter seasonal mean temperature by the period of the 2080s under the Medium emissions scenario.

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.

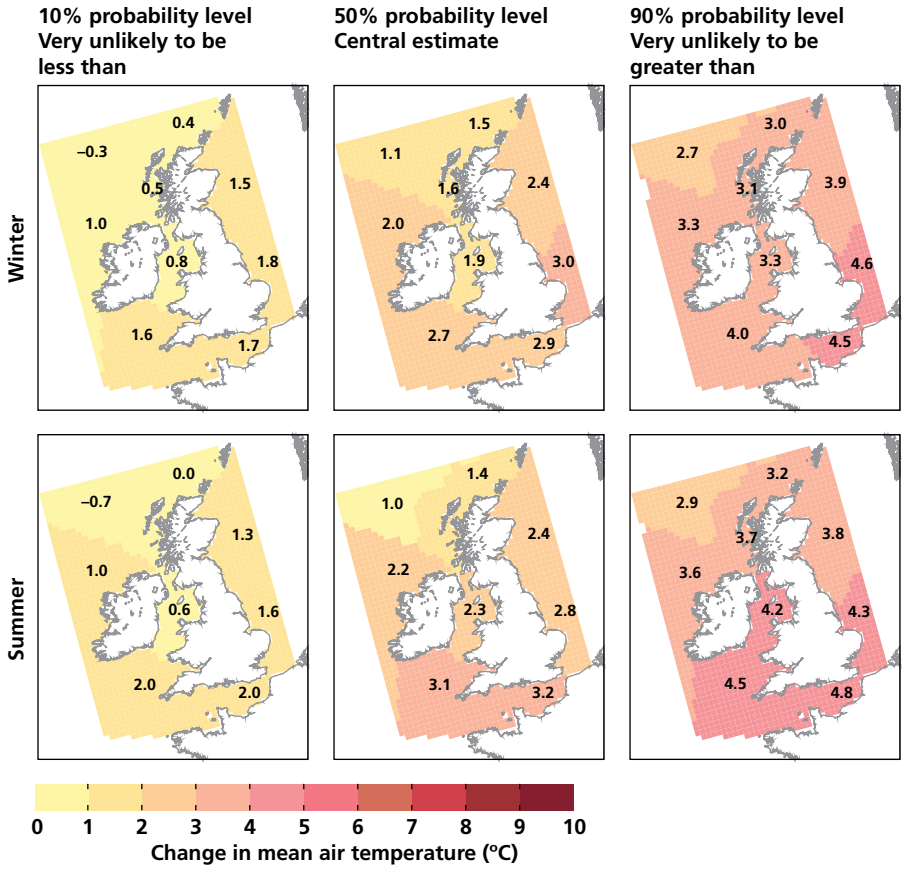


Figure 4.6: 10, 50 and 90% probability levels of changes to winter-mean (top) and summer-mean (bottom) mean air temperature under Medium emissions by the 2080s.

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.

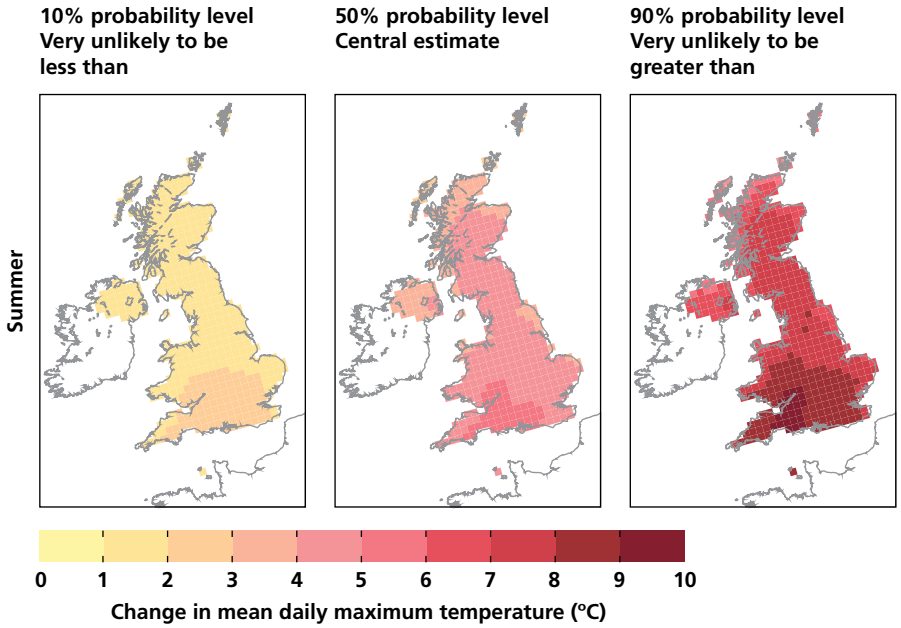


Figure 4.7: 10, 50 and 90% probability levels of changes to mean daily maximum temperature (°C) in summer, by the 2080s, under the Medium emissions scenario.

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.

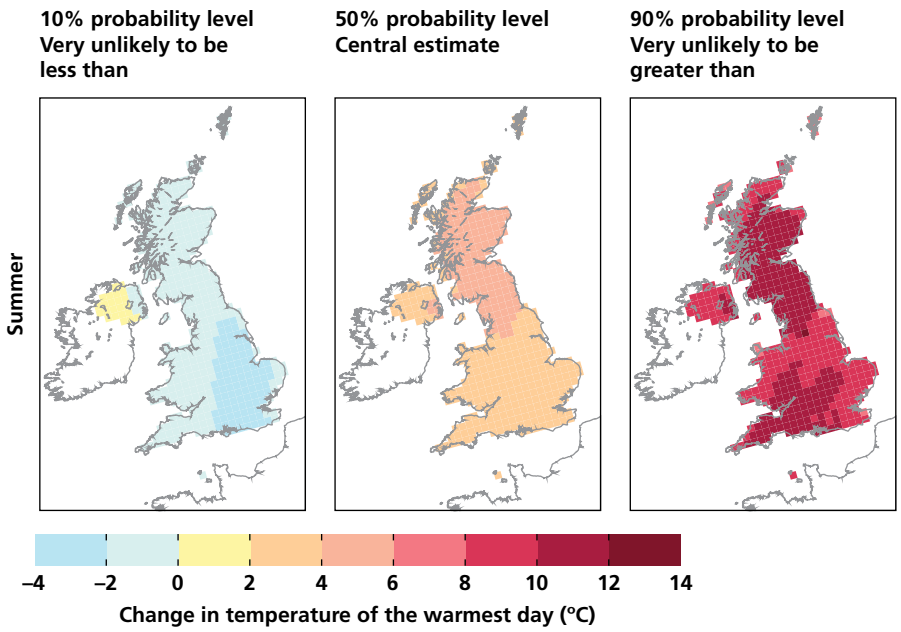


Figure 4.8: 10, 50 and 90% probability levels of changes to the temperature of the warmest day of the summer, by the 2080s, under the Medium emissions scenarios.

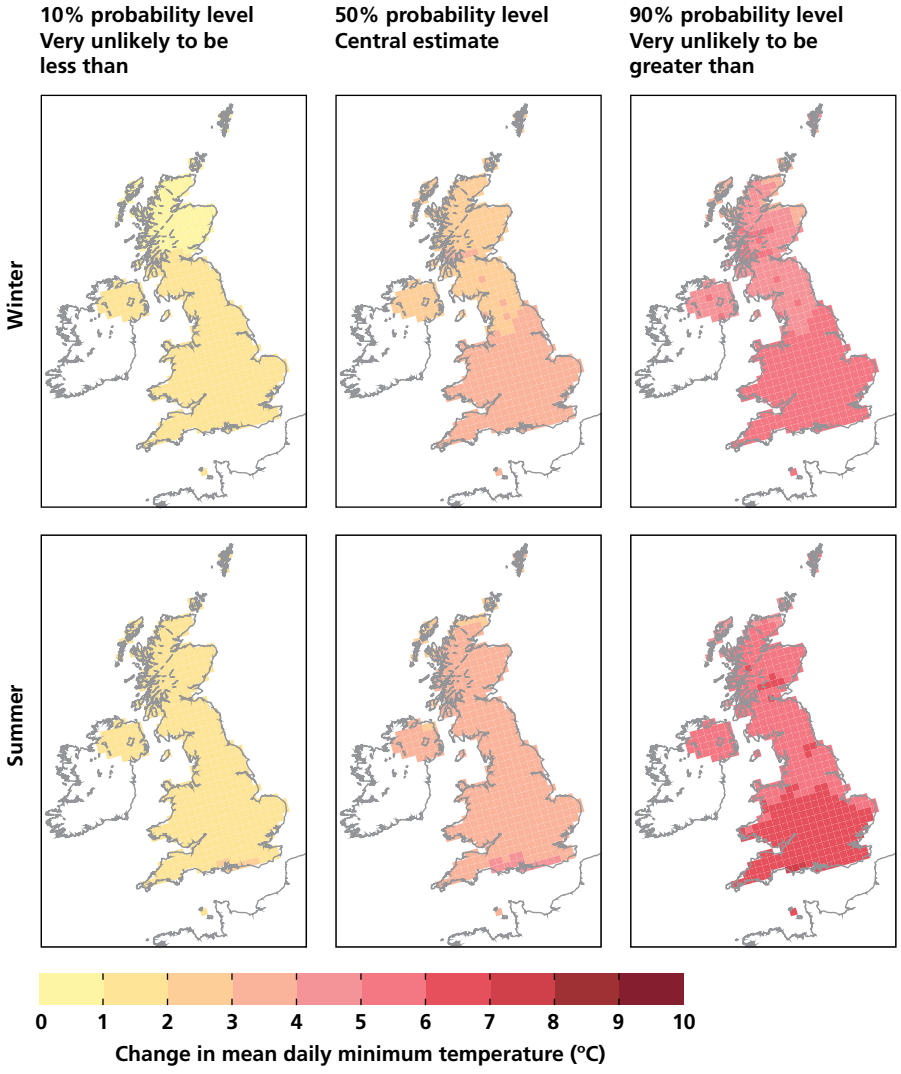


Figure 4.9: 10, 50 and 90% probability levels of changes to the mean daily minimum temperature in winter (top) and summer (bottom), by the 2080s, under the Medium emissions scenario.

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.

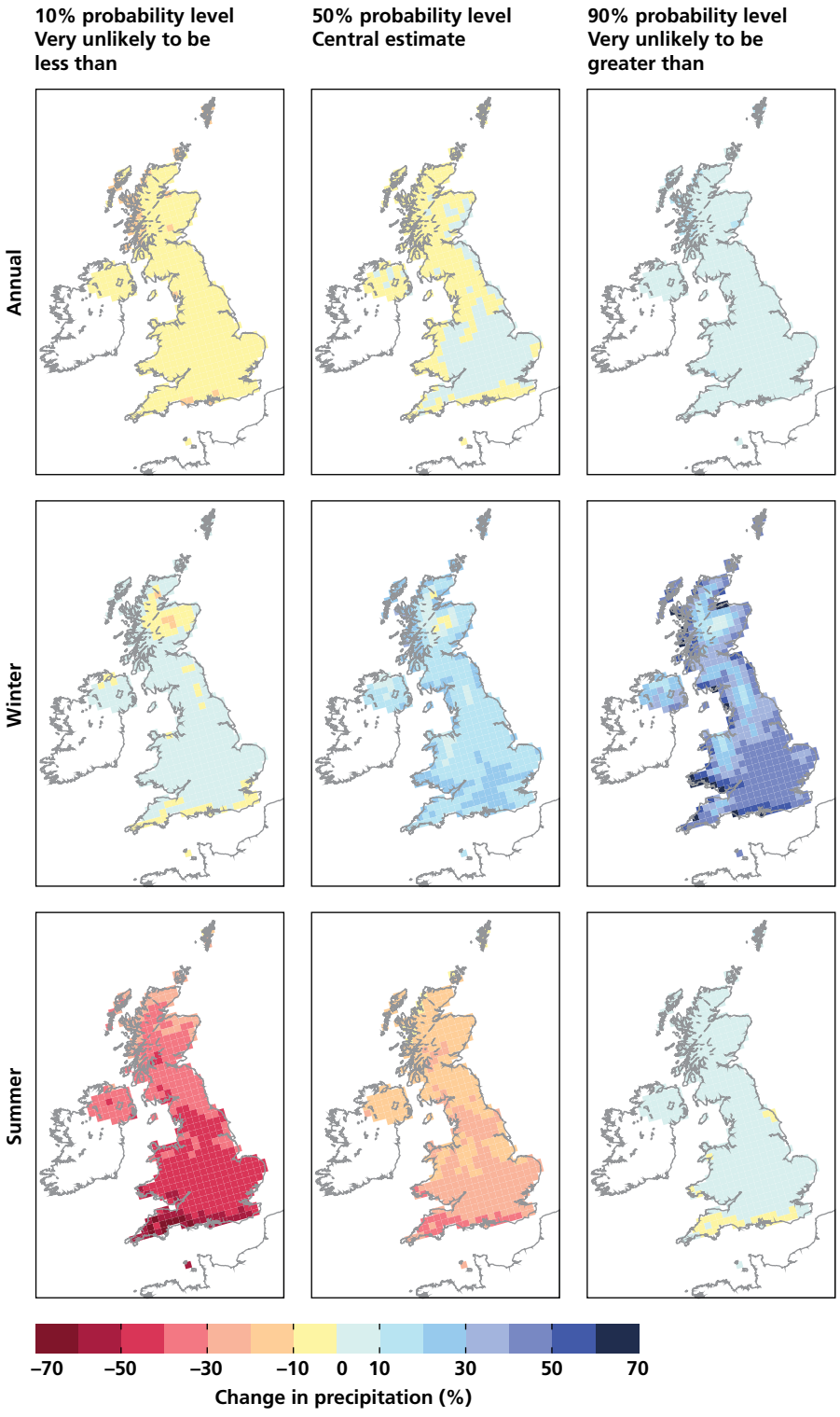


Figure 4.10: Changes in annual (top), winter (middle) and summer (bottom) mean precipitation (%) at the 10, 50 and 90% probability levels, for the 2080s under the Medium emissions scenario.