Update to UKCP18 probabilistic projections:

Maps of projected changes in surface temperature and precipitation

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1. Introduction

The UKCP18 probabilistic projections consist of 3000 individual realizations of time-dependent climate change, plus a set of probability distributions derived from the realizations. The results are derived from 360 climate model simulations. The probabilistic projections have been updated to incorporate five developments, outlined below and described in detail by Harris et al. (2022) https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports. The developments improve consistency between the probabilistic projections and the underlying climate model data and make the results easier to use.

The probabilistic projections are provided for five scenarios of future greenhouse gas emissions: The Representative Concentration Pathway (RCP) scenarios RCP2.6, 4.5, 6.0 and 8.5 of Moss et al. (2010), and the SRES A1B scenario (Nakicenovic and Swart, 2000). The results in Harris et al. (2022) consist mainly of projected changes for 2070-2089 relative to 1981-2000 under RCP85 emissions. This scenario and time period is selected because it contains some of the largest changes available in the probabilistic projections data, and therefore provides clear illustrations of the scientific impacts of the developments. The report provides several tables of statistics and a limited selection of maps to illustrate the impact of the developments on spatial patterns of change.

This document provides more information for users, comparing the UKCP18 results (referred to as the "original" probabilistic projections) against the updated results, referred to as the "new" projections. The maps presented here cover all four seasons, whereas those in Harris et al (2022) were mainly restricted to winter and summer. Here, we show projected changes for the RCP4.5 scenario during 2040-2059 as well as covering RCP8.5 responses for 2070-2089. Adding the RCP4.5 time-slice provides an example of a mid-range emissions scenario for a mid-century period, characterised by smaller levels of future warming compared to RCP85 at the end of the century (see Fig. 1 in Section 2).

Results are presented for future changes projected at the 10th (low, P10), 50th (median, P50) and 90th (high, P90) percentiles of the probability distributions[1]. We focus on changes in daily mean surface temperature (Tmean) and precipitation, two primary climate variables analysed in many user applications.

General advice for users of the probabilistic data is available from the accompanying Frequently Asked Questions (Fung et al, 2022) at https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports.

[1] The distributions are expressed in the data as probability density functions (pdfs) and cumulative distribution functions (cdfs).

Recap of the developments included in the new probabilistic projections.

1) A software error in the downscaling section of the probabilistic calculations has been corrected, strengthening and tightening relationships between global and regional climate model simulations used to add spatial detail to the projected changes.
2) A software error affecting daily maximum (Tmax) and minimum (Tmin) surface temperature has been corrected, improving physical consistency between projected changes in Tmax, Tmin and Tmean.
3) The statistical treatment of extreme changes in precipitation has been improved, increasing the credibility of projected changes that are either extremely dry or extremely wet.
4) Minor biases in the centring of projected climate anomalies relative to the baseline period of 1981-2000 have been removed.
5) The representation of climate variability has been improved in the annual probability distributions, leading to smoother temporal evolution in the climate changes associated with specific percentiles of the pdfs.

This update does not affect other UKCP18 projection products.

2. Results

Each map shows P10, P50 and P90 changes from the new and original projections, plus the differences between them. Maps are provided for two of the four sets of UKCP18 region definitions for which pdfs are provided (Fung et al., 2018). These consist of the British National Grid (OSGB) at 25km spatial resolution, and a set of UK administrative regions. The OSGB pdfs provide local information, while the administrative-region pdfs express changes in climate variables spatially averaged over each region. Therefore, sixteen figures are provided for each of the two scenarios featured (RCP4.5 during 2040-2059, and RCP8.5 for 2070-2089). The maps show 20-year average responses. For convenience, we refer to these below as "RCP85 in 2080" and "RCP45 in 2050". In each scenario, eight figures are provided for Tmean (four seasons and two region definitions, changes expressed in °C) and eight for precipitation (changes expressed in %). Changes are presented relative to the UKCP18 1981-2000 baseline period.

Figure 1 places the two scenario choices in context, showing pdfs of projected change in annual Tmean for the UK aggregated region. Results are shown for each of the RCP scenarios during the time slices featured in this document. The SRES A1B scenario (not shown) gives similar results to RCP6.0. During 2040-2059 the distributions for RCP2.6, 4.5 and 6.0 are almost indistinguishable, with the distribution for RCP8.5 shifted towards warmer responses. By 2070-2089 the differences between the four scenarios are more pronounced. A warming exceeding 5°C cannot be ruled out under the RCP8.5 scenario, which assumes relatively high greenhouse gas emissions. On the other hand, a relatively small warming below 0.5°C cannot be ruled out under the RCP2.6 scenario, which assumes strong mitigation measures.

The green RCP4.5 curve in Fig. 1a, and the red RCP8.5 curve in Fig. 1b, show the pdfs of UK average warming that lie behind the regional changes featured in this document. For scenarios and time periods in which pdfs of projected UK warming lie between these two distributions in their ranges of response, the corresponding regional changes are likely to lie between those shown in the following maps and Tables.

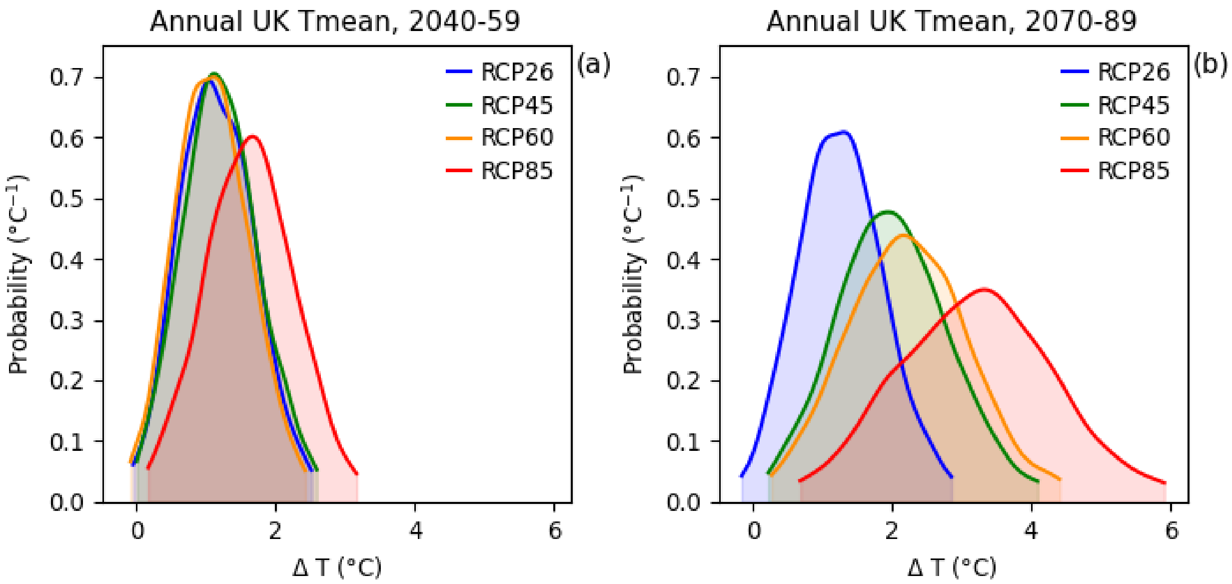

Figure 1. *Changes in annual Tmean (°C) for the UK aggregated region for (a) 2040-2059 and (b) 2070-2089, relative to 1981-2000. Probability distributions are shown for each of the four RCP scenarios provided in the UKCP probabilistic projections. The distributions are clipped at the 1st and 99th percentiles, to omit extreme values that may be sensitive to methodological assumptions and therefore less credible than data lying between these limits. See* [*https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/science/technical-notes*](https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/science/technical-notes).

2.1 Tables

The four Tables in this section provided spatially averaged summaries of the local and regional changes shown in the accompanying figures of Section 2.2. The rows labelled “Original” and “New” show spatial averages over the UK of the relevant P10, P50 and P90 response. The grey rows labelled “Mean Absolute Difference” show spatial averages of the regional magnitudes of difference between the new and original projections[2]. We provide brief overview comments on the differences, with more detailed scientific analysis of their causes available in Harris et al. (2022).

In this document, the new and original projections are compared using simple differences expressed in °C or as percentage precipitation anomalies. In some user applications, quantifying the differences in these *absolute* terms may be sufficient to understand their implications for existing impacts studies carried out using the original pdfs. In other cases, it may also be helpful to assess the differences in *relative* terms. Harris et al. (2022) suggest one method of doing so, by dividing differences between the new and original projections for specific percentiles by the spread in the new pdfs (defined as their P90 – P10 range). However, criteria for assessing the decision-relevance of the differences will often be application-specific. Users are encouraged to study the new projections for their specific variables and regions of interest.

Table 1 provides UK averages of the mapped 25km-scale changes in Tmean, shown in Figures 2-9. The panels on the right of the figures show local differences between the New and Original projections, which vary with region.

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[2] For example, if <> denotes a spatial average over all i UK grid points or administrative regions on a given map, and P90(i) denotes the high-end projected change at a specific location, then the Mean Absolute Difference (MAD) for the high-end response is given by $MAD = <Abs(P90(i)_{new} – P90(i)_{original})>$, where Abs() denotes the absolute value of a local difference. Similar equations apply for MAD calculated for P10 and P50 responses.

The local P10, P50 and P90 changes are considerably larger for RCP85 in 2080, compared to the values for RCP45 in 2050. This is consistent with the differences between the respective pdfs in national warming (Fig. 1). The average magnitudes of difference between the new and original projections are also larger for the warmer scenario (maximum value ~0.4°C cf ~0.2°C for RCP45 in 2050). The average spread in the new pdfs is smaller than the original spread in all cases, indicating reductions in uncertainty.

In absolute terms, larger reductions in spread occur for RCP85 in 2080 than for RCP45 in 2050. In relative terms, RCP45 in 2050 provides both the largest average reduction (19% in autumn) and the smallest (5% in winter). As a general guide, Harris et al. (2022) suggest that differences in spread smaller than 10% are unlikely to affect the conclusions of impacts studies while differences in the range 10-20% may affect the conclusions, dependent on the specific application.

Table 1. *Projected P10, P50 and P90 changes in daily mean surface air temperature (Tmean) from the original and new probabilistic projections. The numbers are UK averages of local seasonal values calculated at all 25km locations in the British National Grid (Figures 2-9). The grey boxes show the UK average of regional absolute differences between the new and original projections, showing two decimal places as some values are small.*

Season	Version	RCP45 2040-2059			RCP85 2070-2089		
		P10	P50	P90	P10	P50	P90
Winter	Original	0.2	1.2	2.3	1.0	2.9	4.8
	New	0.1	1.1	2.1	0.8	2.6	4.4
	Mean Absolute Difference	0.06	0.11	0.21	0.19	0.30	0.37
Spring	Original	0.1	0.9	1.7	0.7	2.2	3.8
	New	0.2	0.9	1.7	1.1	2.5	3.9
	Mean Absolute Difference	0.12	0.08	0.09	0.38	0.24	0.18
Summer	Original	0.3	1.5	2.7	1.4	3.8	6.5
	New	0.4	1.4	2.5	1.7	3.9	6.2
	Mean Absolute Difference	0.13	0.04	0.14	0.37	0.14	0.32
Autumn	Original	0.1	1.2	2.4	1.3	3.2	5.3
	New	0.3	1.2	2.2	1.6	3.3	5.1
	Mean Absolute Difference	0.18	0.01	0.17	0.28	0.08	0.22

Corresponding Tmean results for administrative regions are shown in Figures 10-17, with national averages of the regional changes provided in Table 2. The average spread in the new and original projections is essentially identical in summer and autumn, in contrast to the reductions seen in the 25km-scale pdfs (Table 2 cf Table 1). The new projections for RCP85 in 2080 show an average reduction of 0.3°C in the P50 response for winter and an increase of 0.3°C in spring, in common with the 25km-scale results.

Table 2. *Projected P10, P50 and P90 changes in seasonal daily mean surface air temperature (Tmean) from the original and new probabilistic projections. The numbers are UK averages of regional seasonal values calculated for each of sixteen UK administrative regions (Figures 10-17). The grey boxes show the UK average of regional absolute differences between the new and original projections, showing two decimal places as some values are small.*

Season	Version	RCP45 2040-2059			RCP85 2070-2089		
		P10	P50	P90	P10	P50	P90
Winter	Original	0.2	1.2	2.2	1.1	2.9	4.8
	New	0.1	1.1	2.1	0.9	2.6	4.5
	Mean Absolute Difference	0.09	0.09	0.09	0.21	0.24	0.29
Spring	Original	0.1	0.9	1.7	0.8	2.2	3.7
	New	0.3	1.0	1.7	1.1	2.5	3.9
	Mean Absolute Difference	0.12	0.08	0.09	0.30	0.30	0.25
Summer	Original	0.5	1.5	2.6	1.8	4.0	6.3
	New	0.5	1.5	2.6	1.9	4.1	6.4
	Mean Absolute Difference	0.02	0.02	0.03	0.09	0.08	0.05
Autumn	Original	0.3	1.2	2.2	1.6	3.3	5.2
	New	0.3	1.2	2.2	1.6	3.3	5.2
	Mean Absolute Difference	0.02	0.02	0.01	0.08	0.07	0.04

Projected changes in precipitation are shown in Figures 18-25 for the 25km-scale pdfs and Figures 26-33 for the administrative regions. UK averages of the 25km and administrative region results are provided in Tables 3 and 4. The most notable differences between the new and original precipitation projections occur in the 25km-scale pdfs.

In winter, spring and autumn, RCP85 results for 2080 show notable increases in the average P90 (wet-end) response in the new 25km-scale projections. In autumn, for example, the original average value of 24.7% increases to 32.0% in the new results (Table 3). The average P10 (dry-end) response also intensifies in the new projections, from -4.8% to a stronger drying of -10.8%. In winter, the average P90 response increases from 40.5% to 46.6% in the new projections, but the average P10 response shows little change. The average P50 responses in the new autumn and winter pdfs show relatively small differences between the new and original projections (average regional magnitudes are ~2%), continuing to show a high probability of an increase in winter precipitation in most parts of the UK (Figure 22). The average P50 response is higher in winter (20.1%) than in autumn (9.2%).

Table 3. *Projected P10, P50 and P90 changes in seasonal precipitation from the original and new probabilistic projections. The numbers are UK averages of local values calculated at all 25km locations in the British National Grid (Figures 18-25). The grey boxes show the UK average of regional absolute differences between the new and original projections.*

Season	Version	RCP45 2040-2059			RCP85 2070-2089		
		P10	P50	P90	P10	P50	P90
Winter	Original	-4.9	7.7	21.1	-0.5	18.7	40.5
	New	-5.2	7.8	22.3	-1.7	20.1	46.6
	Mean Absolute Difference	1.1	1.2	2.4	1.8	1.9	6.1
Spring	Original	-11.0	0.2	12.2	-9.4	1.8	13.7
	New	-12.0	1.6	15.7	-20.0	-0.5	21.3
	Mean Absolute Difference	1.2	1.5	3.5	10.7	2.3	7.6
Summer	Original	-30.2	-13.1	5.2	-49.6	-25.5	-0.4
	New	-28.2	-9.4	9.7	-50.6	-25.8	2.3
	Mean Absolute Difference	2.3	3.7	4.5	4.0	2.2	3.1
Autumn	Original	-7.0	4.6	17.0	-4.8	9.4	24.7
	New	-9.2	4.4	19.0	-10.4	9.2	32.0
	Mean Absolute Difference	2.3	0.8	2.4	5.6	2.0	8.5

In spring, the new 25km-scale pdfs for RCP85 in 2080 (Figure 23) are typically characterised by a relatively small median response (-0.5% on average in the new projections), with broad uncertainty ranges that encompass significant drying at P10 (average value -20.0%) and significant wet-end increases at P90 (average value 21.3%). The P90 – P10 spread increases substantially in the new projections, amounting on average to 41.3% in the new projections compared to 23.1% originally. The average spread also increases significantly in autumn (from 29.5% originally to 42.4% in the new results), and to a lesser degree in winter. These differences are caused mainly by correction of the software error in the original downscaling calculations (Harris et al., 2022).

For RCP85 in 2080, summer P10 and P50 responses in the new projections generally become drier in Scotland, Northern Ireland and parts of northern England (Figure 24), while increasing over most areas in Wales and southern and central England. Responses at P90 become slightly wetter in the new projections in most regions, with an average regional absolute difference of 3.1%. The average spread increases in summer, but the changes are smaller compared to other seasons.

Projected changes for RCP45 in 2050 are qualitatively similar, but of smaller magnitude. The average P50 responses in the new projections show an increase of 7.8% in winter, with smaller increases in spring and autumn. A 9.5% drying is projected for P50 in summer, compared with a 25.8% drying for RC85 in 2080.

For the administrative regions, average magnitudes of difference in P50 between the new and original projections are generally similar to those found at 25km scale (Table 3 cf Table 4). The average spread across administrative regions changes by less than 5% in all cases. For spring and autumn this contrasts markedly with the 25km-scale results, in which average spread increases substantially (Table 3, discussed above). In existing applications where assessments of impacts are sensitive to the spread in spring or autumn precipitation changes, the conclusions are likely to be affected if they used the 25km-scale pdfs, but not if they used the aggregated-region pdfs.

Table 4. *Projected P10, P50 and P90 changes in seasonal precipitation from the original and new probabilistic projections. The numbers are UK averages of regional values calculated for each of sixteen UK administrative regions (see Figures 26-33). The grey boxes show the UK average of regional absolute differences between the new and original projections.*

Season	Version	RCP45 2040-2059			RCP85 2070-2089		
		P10	P50	P90	P10	P50	P90
Winter	Original	-5.7	7.0	20.9	1.4	20.4	46.4
	New	-4.5	7.7	21.3	-0.6	20.3	45.5
	Mean Absolute Difference	1.5	1.4	1.8	1.4	2.7	4.7
Spring	Original	-12.5	0.0	13.3	-19.3	-0.8	19.0
	New	-12.5	0.8	14.3	-20.7	-1.3	20.1
	Mean Absolute Difference	0.8	0.9	1.3	2.1	0.6	1.7
Summer	Original	-31.2	-13.6	4.6	-55.2	-28.4	-2.0
	New	-29.5	-10.4	9.1	-52.7	-27.2	1.8
	Mean Absolute Difference	1.9	3.2	5.0	4.8	2.4	4.8
Autumn	Original	-10.9	2.6	16.8	-12.4	8.0	30.2
	New	-9.1	3.7	17.4	-10.6	8.3	30.3
	Mean Absolute Difference	1.9	1.1	0.9	1.9	1.2	3.1

In winter, the RCP85 results for 2080 show a relative increase of 18% in average spread for the 25km-scale pdfs, indicating that some applications may be affected. However, average spread changes little for the administrative regions. These larger impacts in the 25km-scale results occur because the local pdfs are (in general, with some regional exceptions) affected more strongly by correction of the downscaling software error (Harris et al., 2022).

In summer, the improved treatment of precipitation extremes influences the results, tending to offset the impacts of correcting the downscaling error. The net result is a relative increase in average spread of 7% in the 25km-scale pdfs and 2% in the administrative-region pdfs.

Correction of the downscaling error also results in improved consistency between the 25km-scale and aggregated-region pdfs in the new projections (Harris et al., 2022). This applies to all variables supplied in the probabilistic projections dataset. Taking precipitation in spring as an example, the average P90 value for RCP85 in 2080 was originally 13.7% for the 25km-scale pdfs, cf 19.0% for the administrative regions. In the new projections, the corresponding values are 21.3% and 20.1%, differing by only 1.2%. Note that these values are not expected to be identical, partly because the characteristics of natural climate variability (which contribute to the range of projected changes) vary with spatial scale.

2.2 Figures

The figures show spatial patterns and are presented in groups of four, showing seasonal progressions from winter to autumn for each variable, region definition and scenario. Each figure contains nine panels, showing P10, P50 and P90 changes for the original (left) and new (centre) projections, with new minus original differences on the right. The numbers above each map show UK averages of the P10, P50 and P90 changes (left and centre), and the UK average of regional absolute differences for the panels on the right. These numbers are reproduced in tabular form in Section 2.1. For administrative regions, the projected changes for each region are printed as numbers as well as being shown as colours. For each variable, common colour scales are used in all maps.

The maps are presented without further commentary, as a gallery for readers to use in comparing the new probabilistic projections against the original UKCP18 results for regions and seasons relevant to specific user applications. Data is available for download from the UKCP User Interface, at https://ukclimateprojections-ui.metoffice.gov.uk/ui/home. Table 5 below summarises the grouping of figures.

Table 5. *Grouping of map figures comparing the new and original probabilistic projections. The maps show 20-year average responses for 2040-2059 under RCP4.5 emissions and 2070-2089 under RCP8.5 emissions, relative to a 1981-2000 baseline. For convenience, we refer to these as "RCP85 in 2080" and "RCP45 in 2050".*

Figures	Variable	Region Definition
2-5	Tmean for RCP45 in 2050	25km boxes
6-9	Tmean for RCP85 in 2080	25km boxes
10-13	Tmean for RCP45 in 2050	Administrative regions
14-17	Tmean for RCP85 in 2080	Administrative regions
18-21	Precipitation for RCP45 in 2050	25km boxes
22-25	Precipitation for RCP85 in 2080	25km boxes
26-29	Precipitation for RCP45 in 2050	Administrative regions
30-33	Precipitation for RCP85 in 2080	Administrative regions

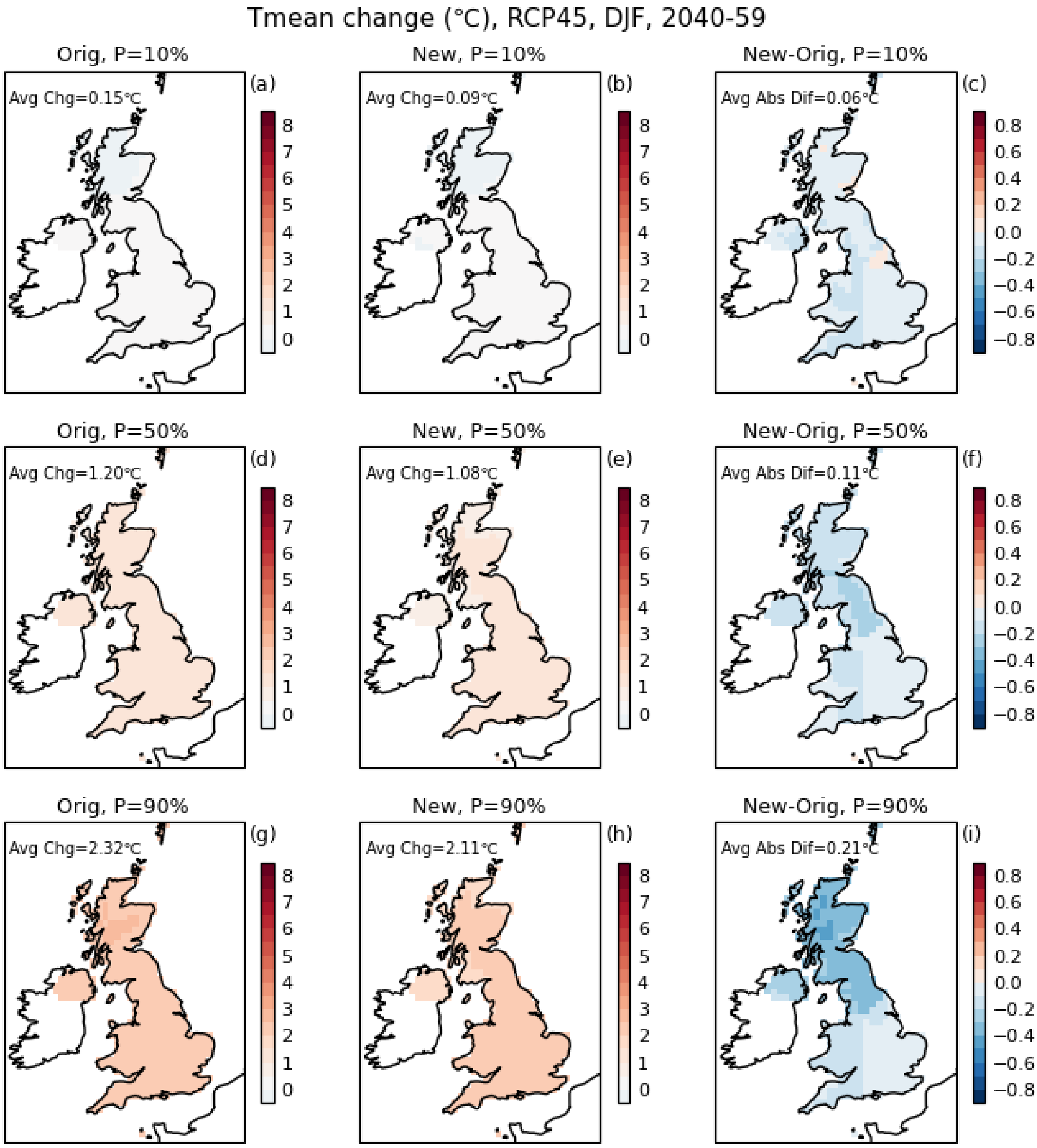

Figure 2. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in winter for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

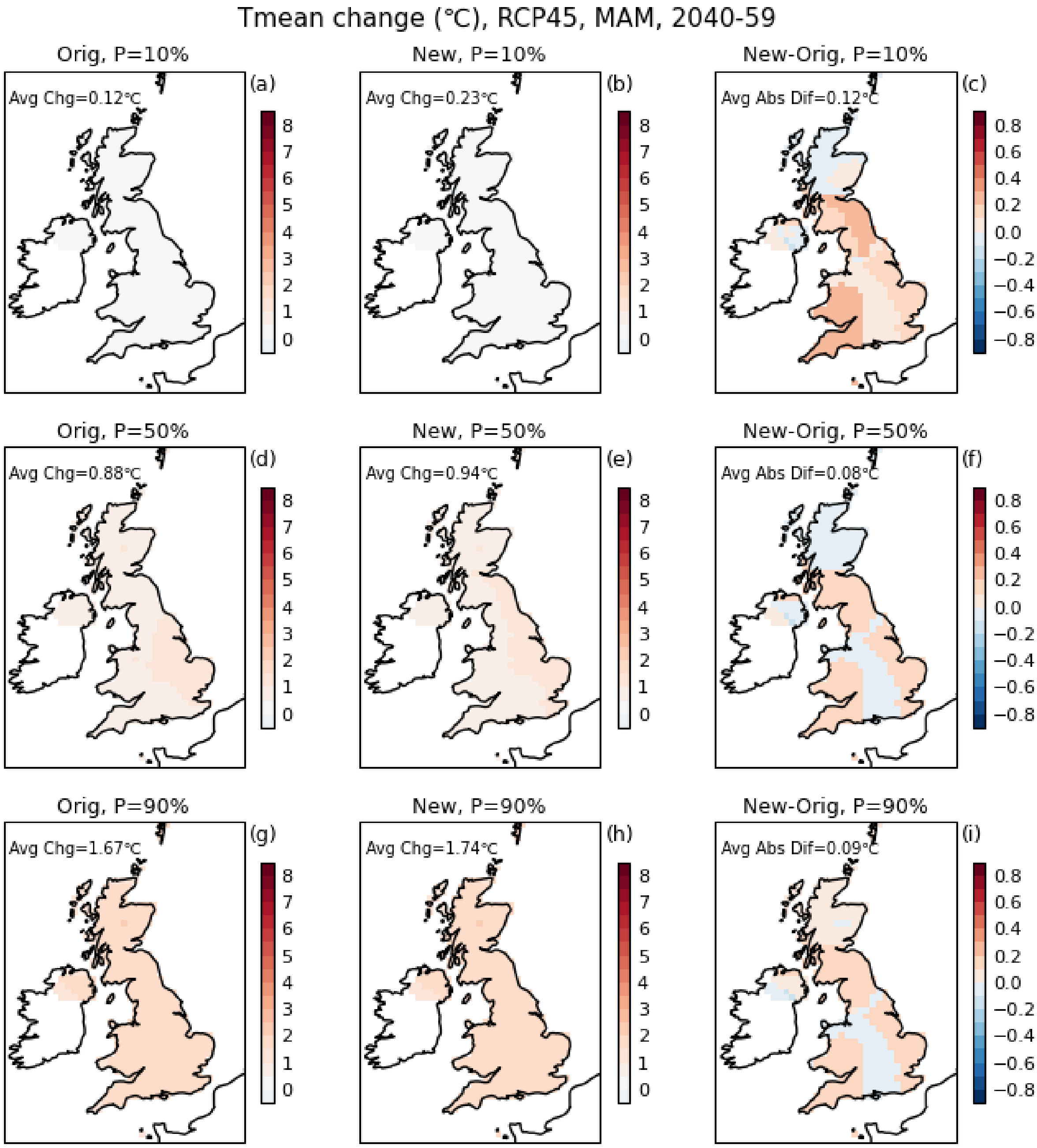

Figure 3. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in spring for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

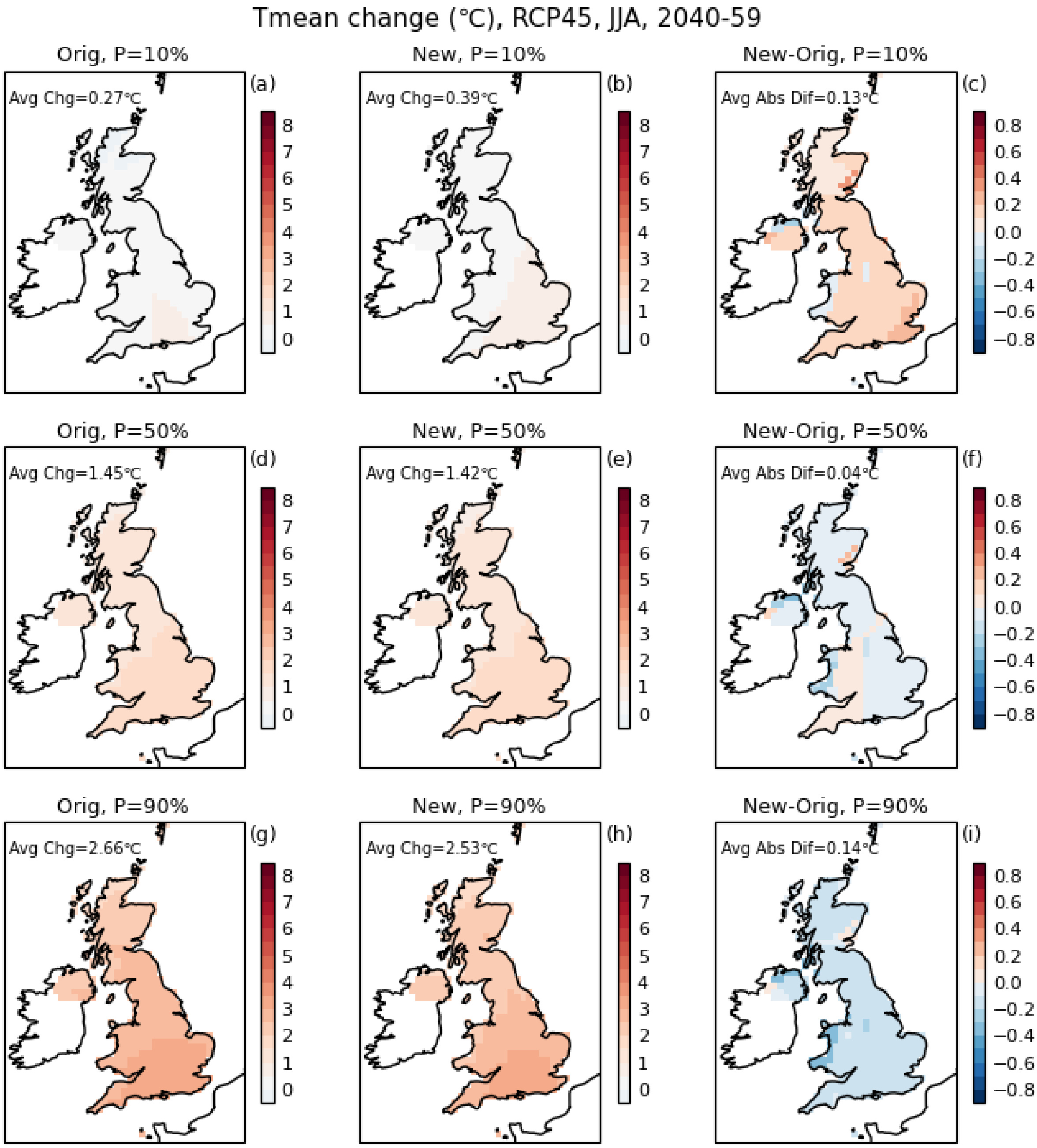

Figure 4. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in summer for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

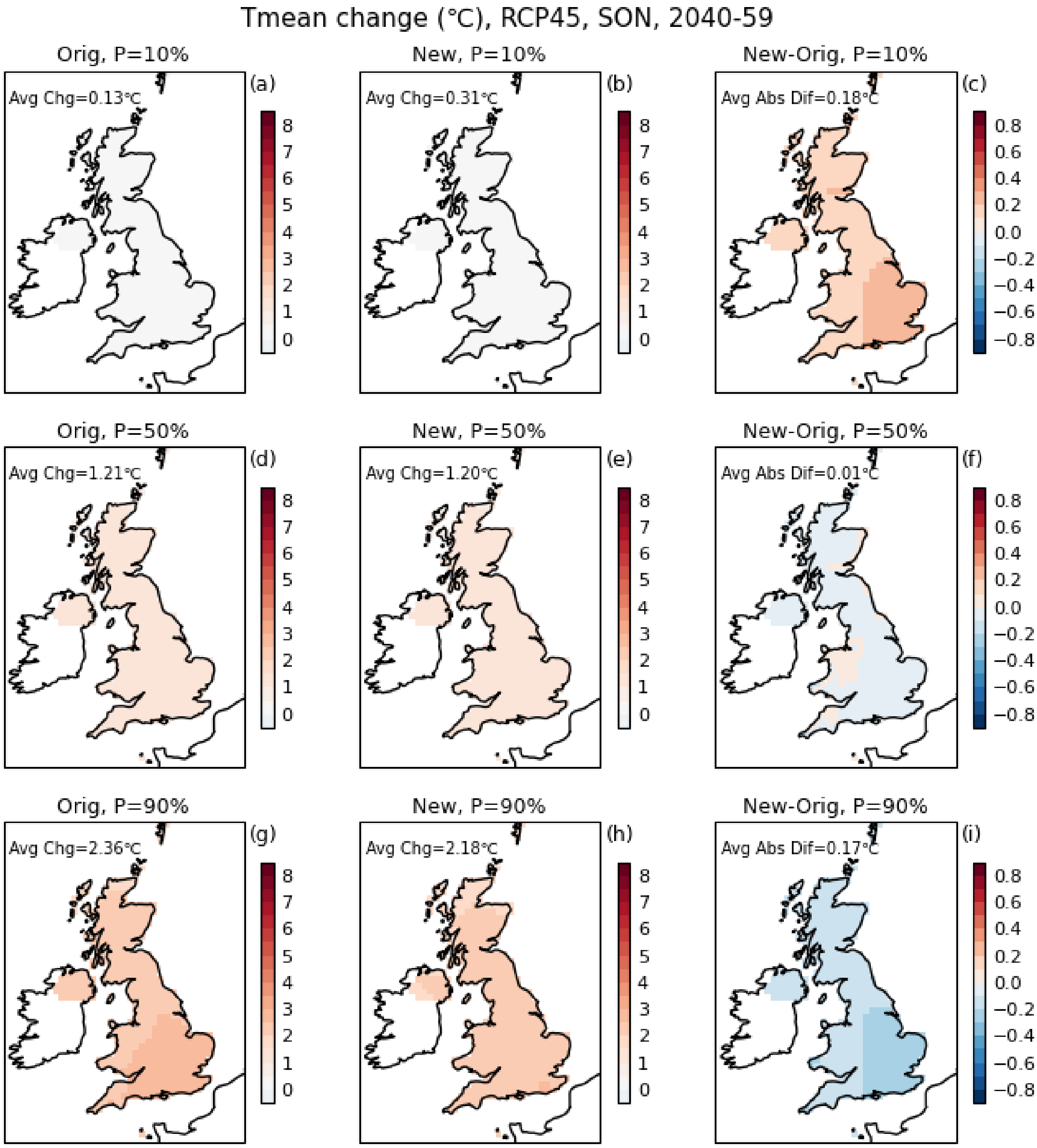

Figure 5. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in autumn for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

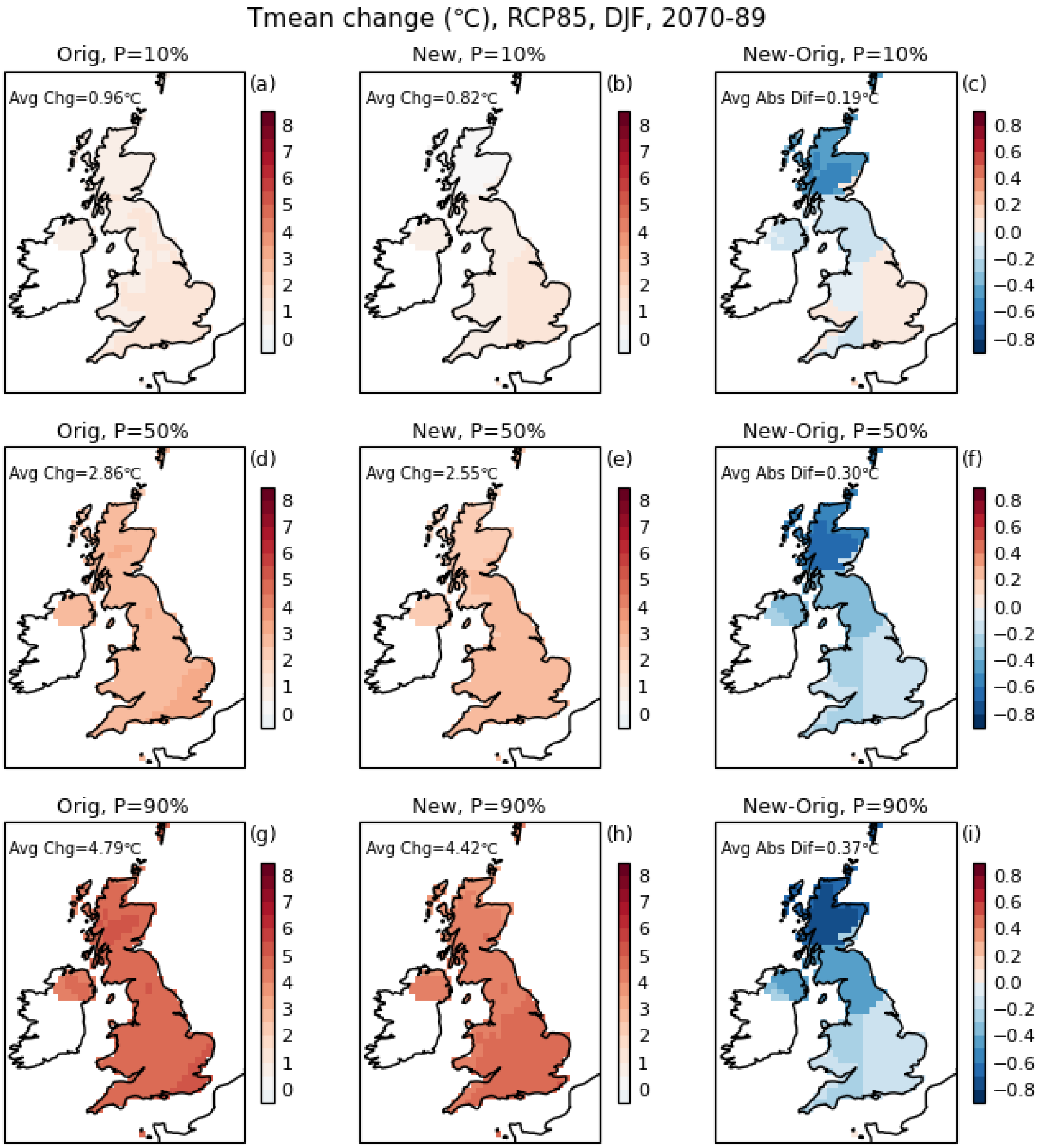

Figure 6. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in winter for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

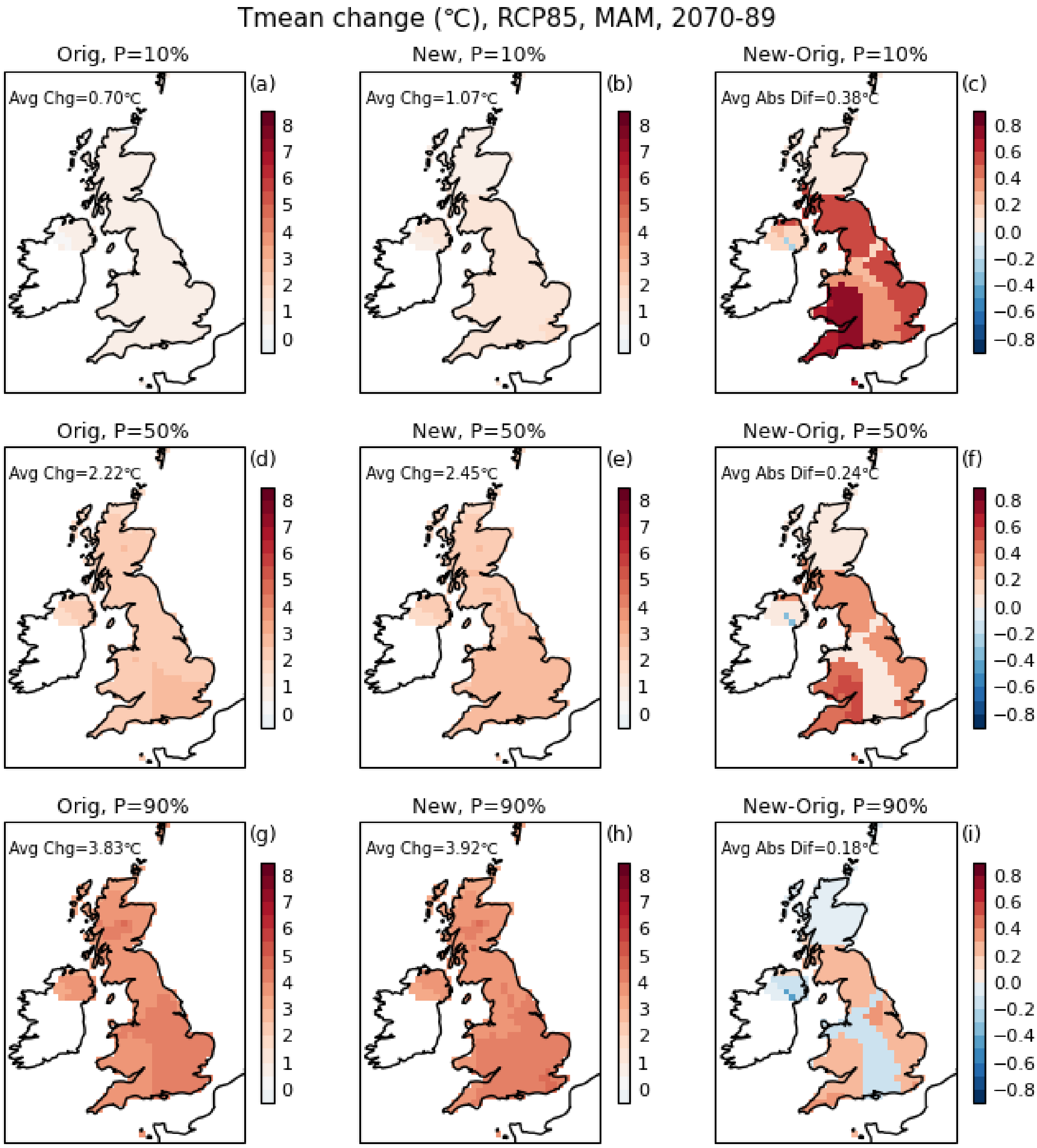

Figure 7. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in spring for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

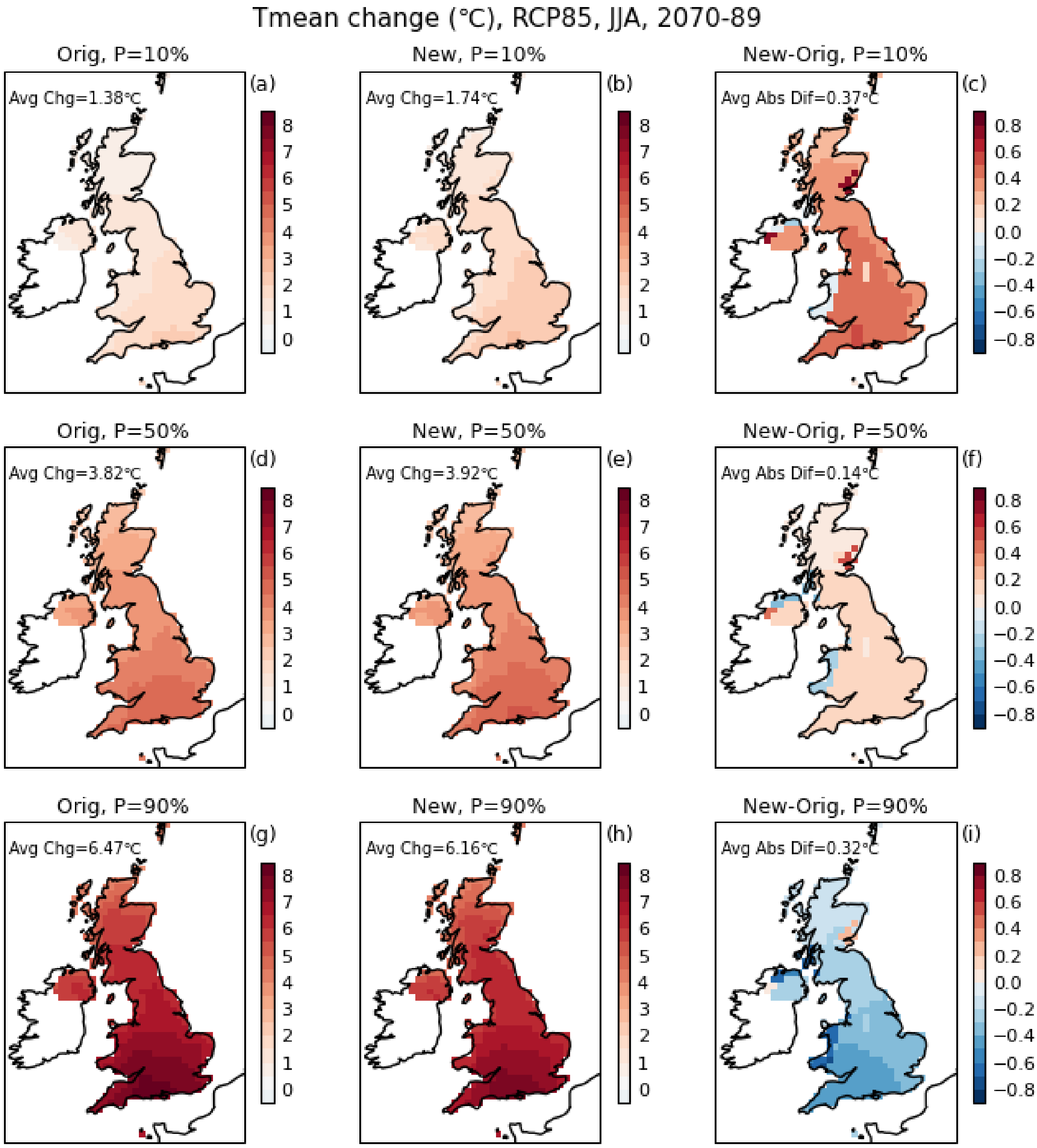

Figure 8. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in summer for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

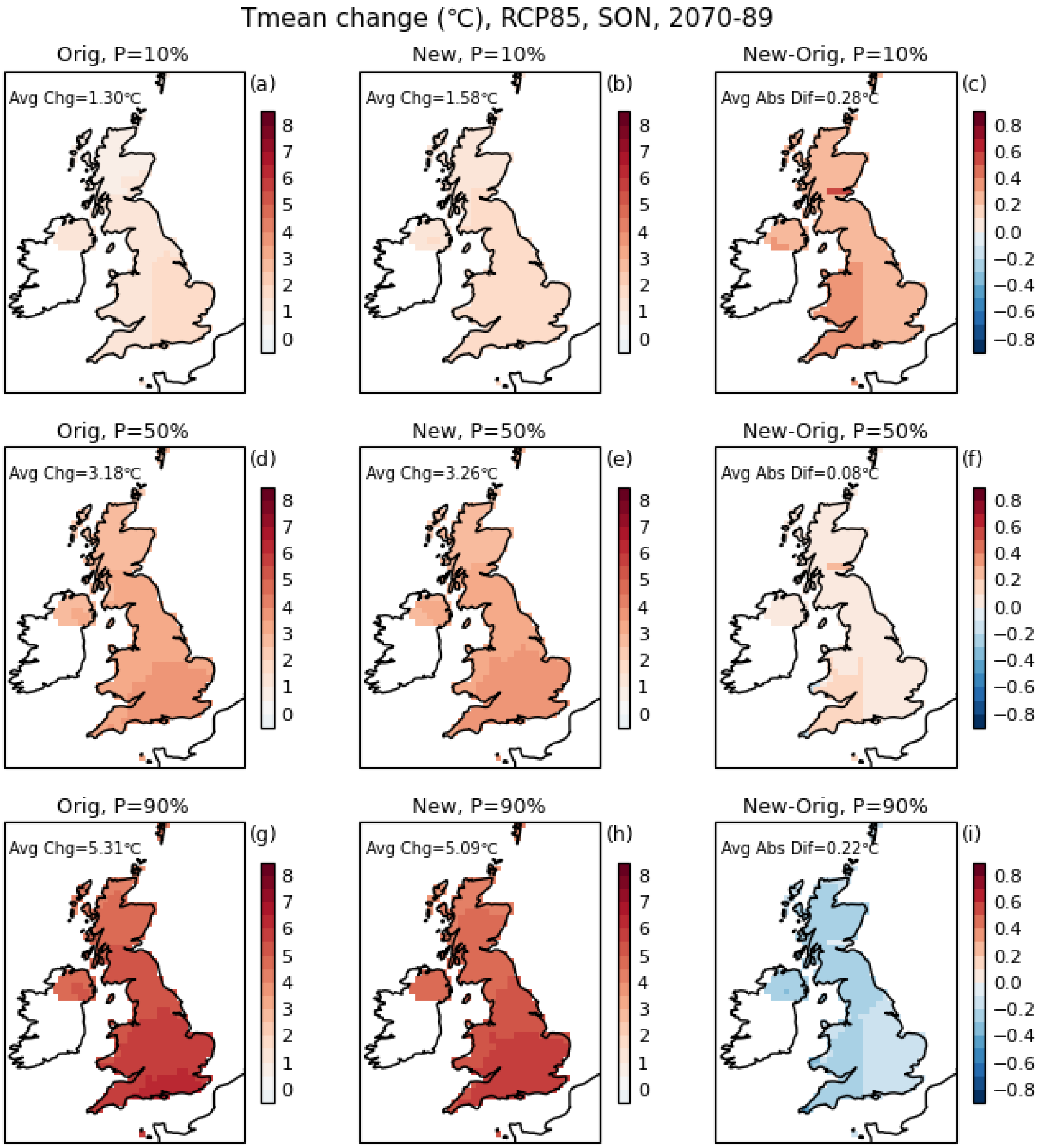

Figure 9. *Projected changes for 25km OSGB boxes in daily mean surface air temperature (Tmean, °C) in autumn for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

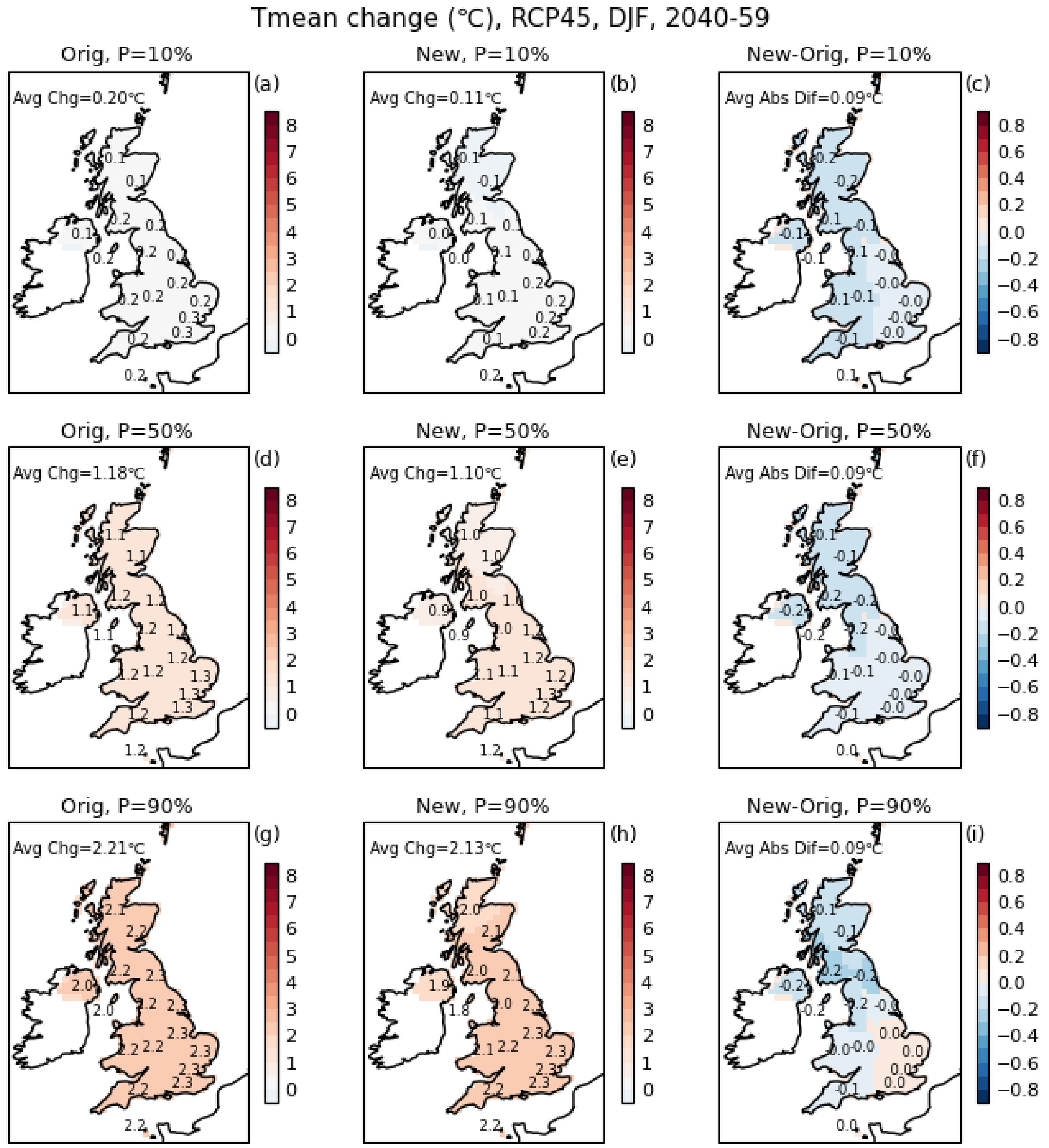

Figure 10. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in winter for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

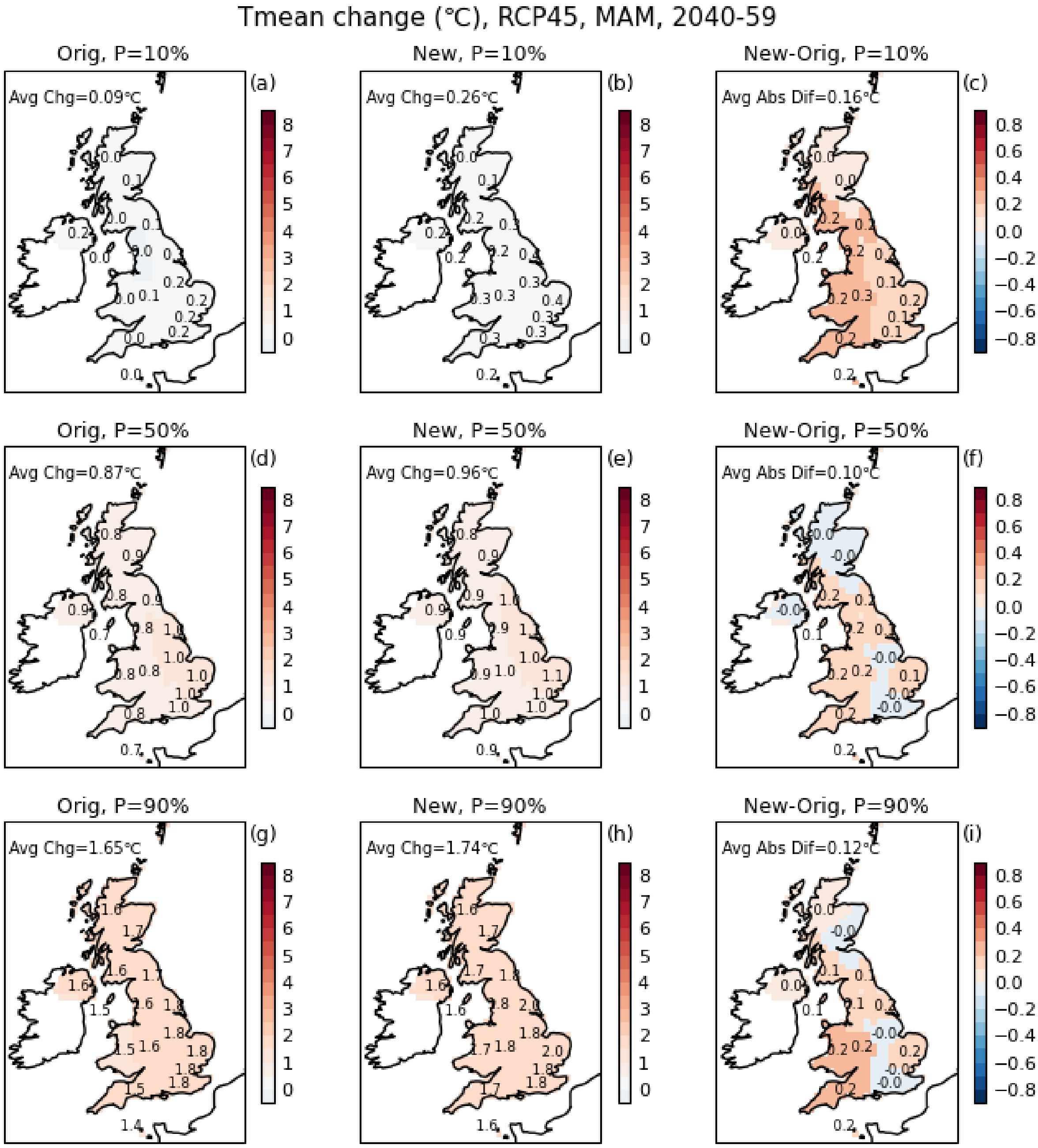

Figure 11. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in spring for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

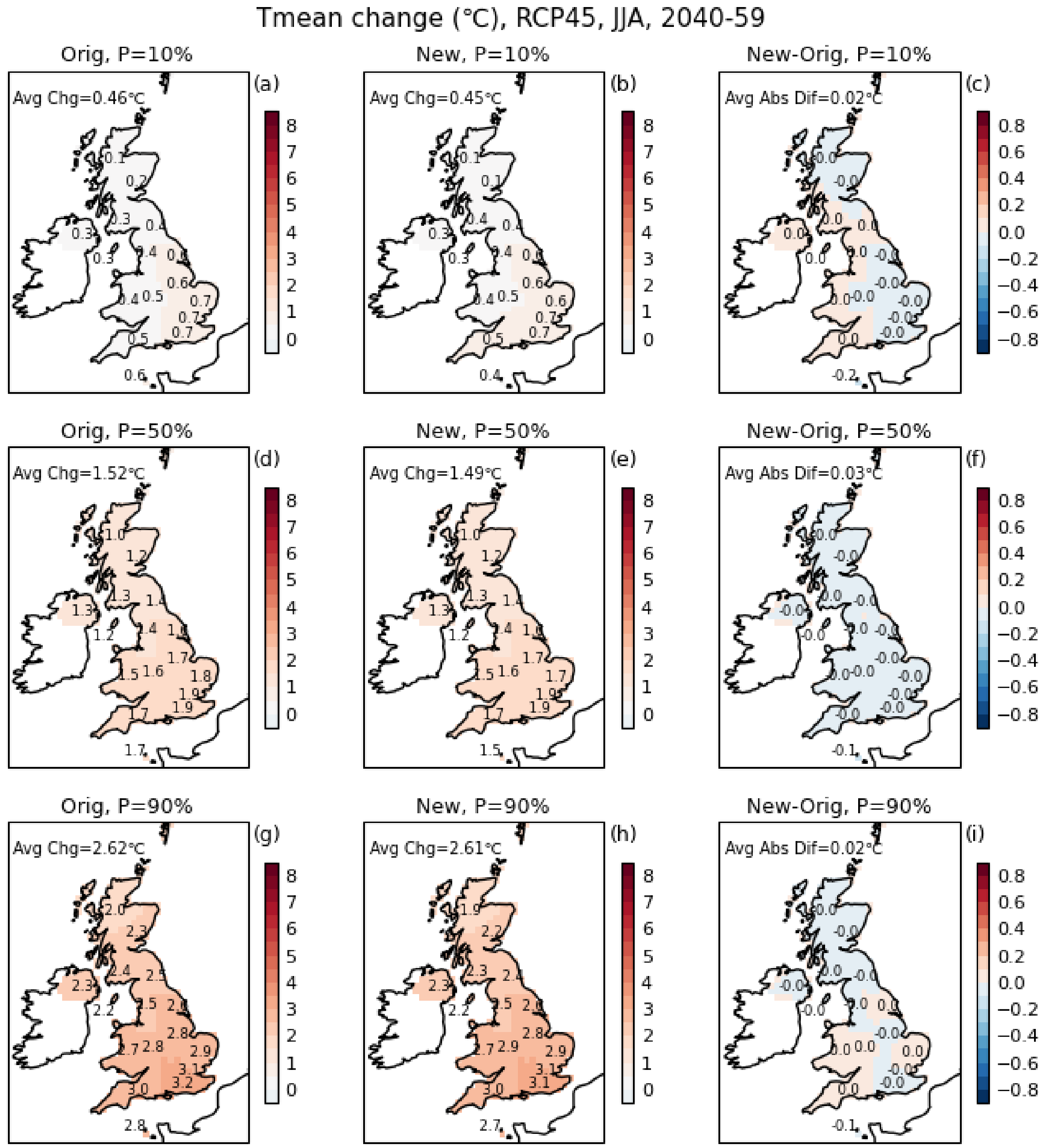

Figure 12. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in summer for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

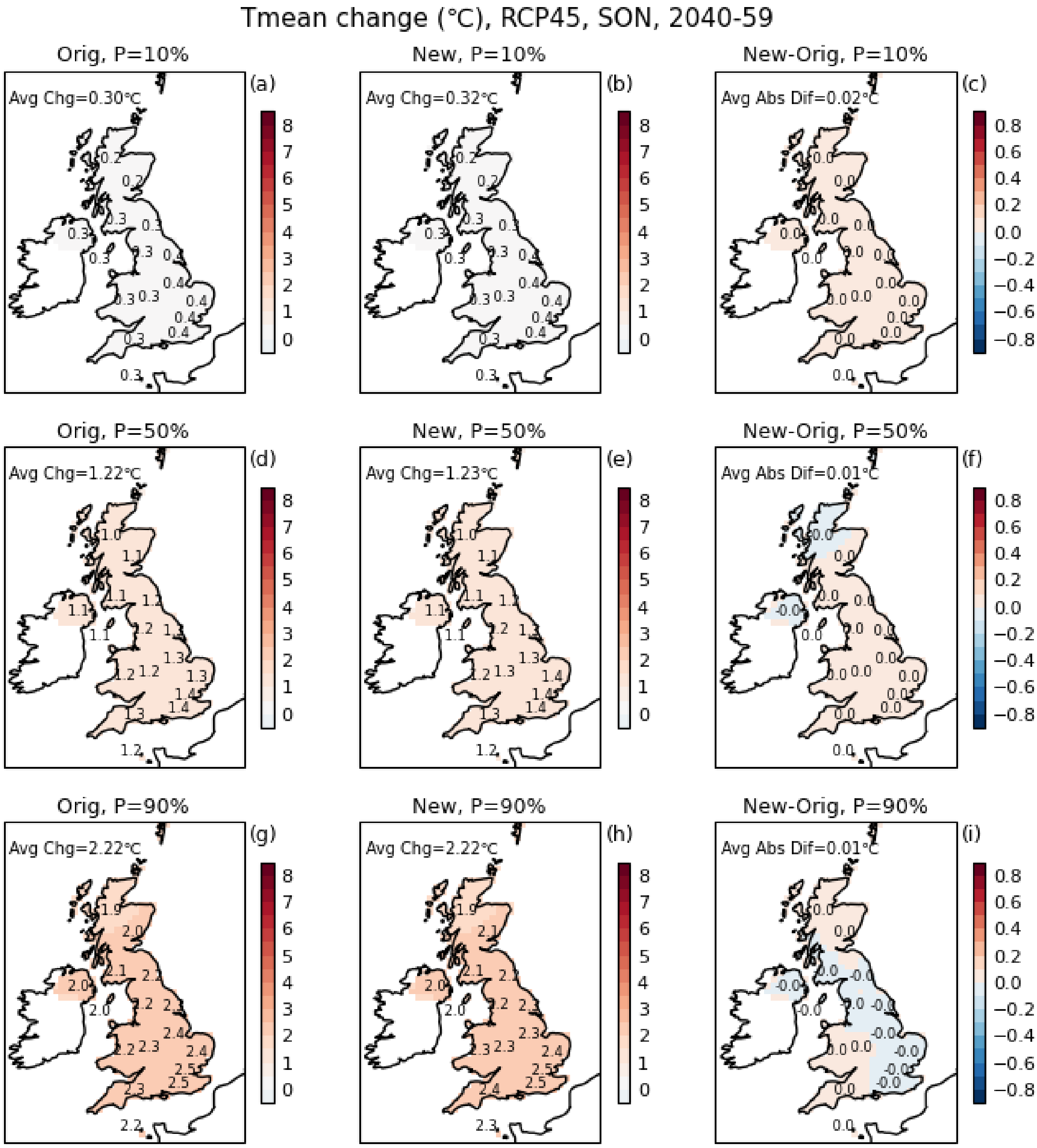

Figure 13. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in autumn for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

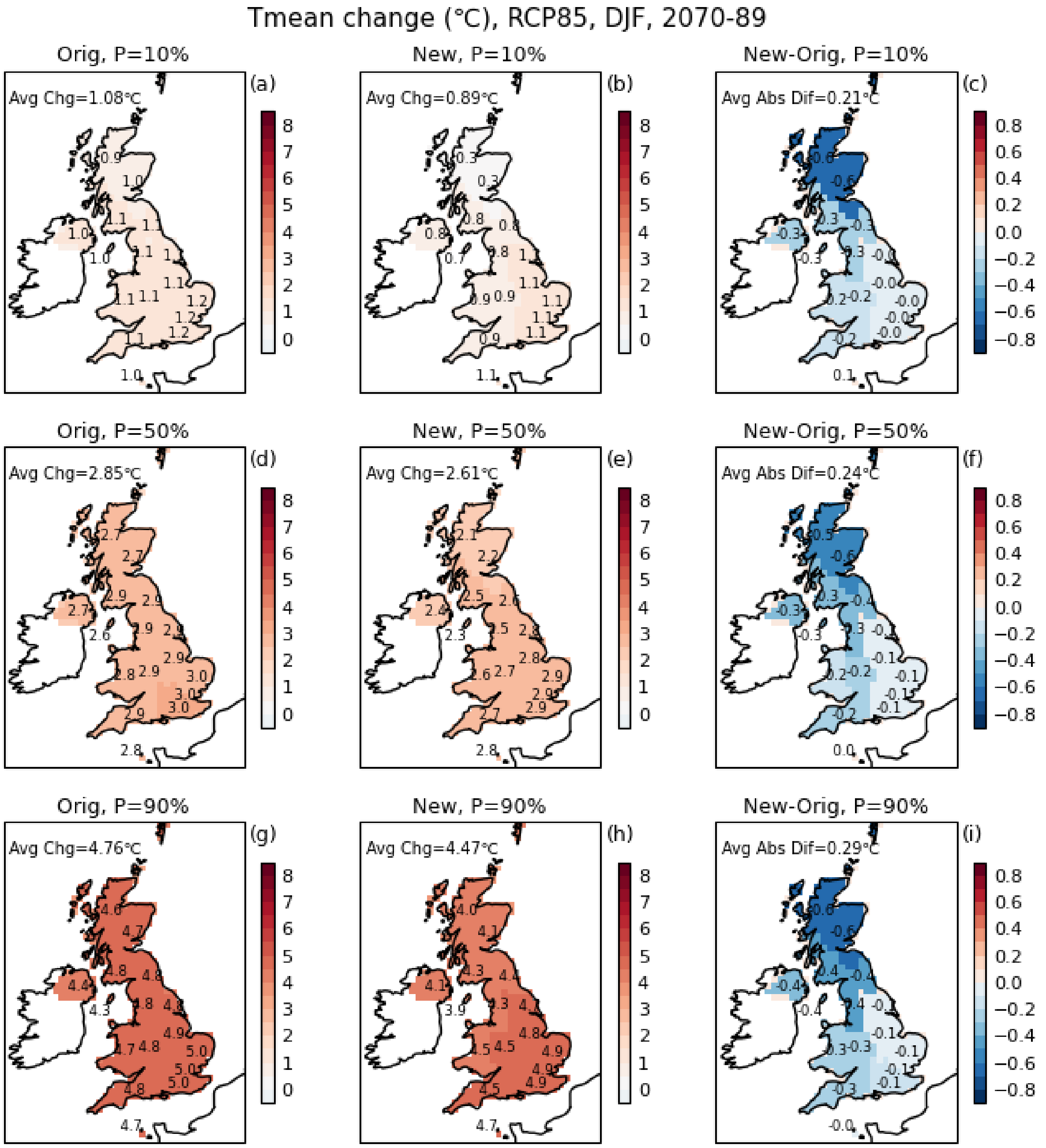

Figure 14. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in winter for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

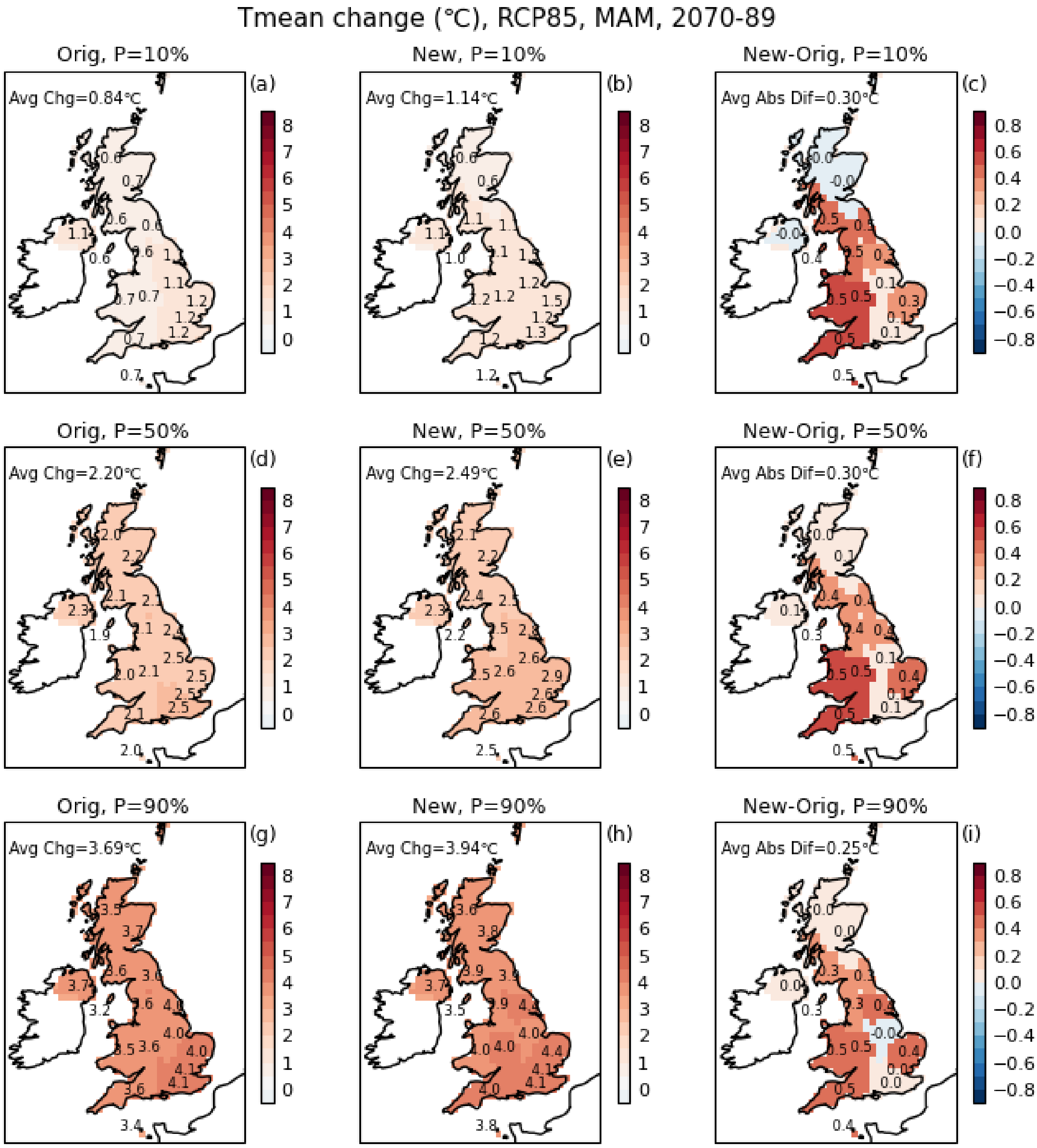

Figure 15. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in spring for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

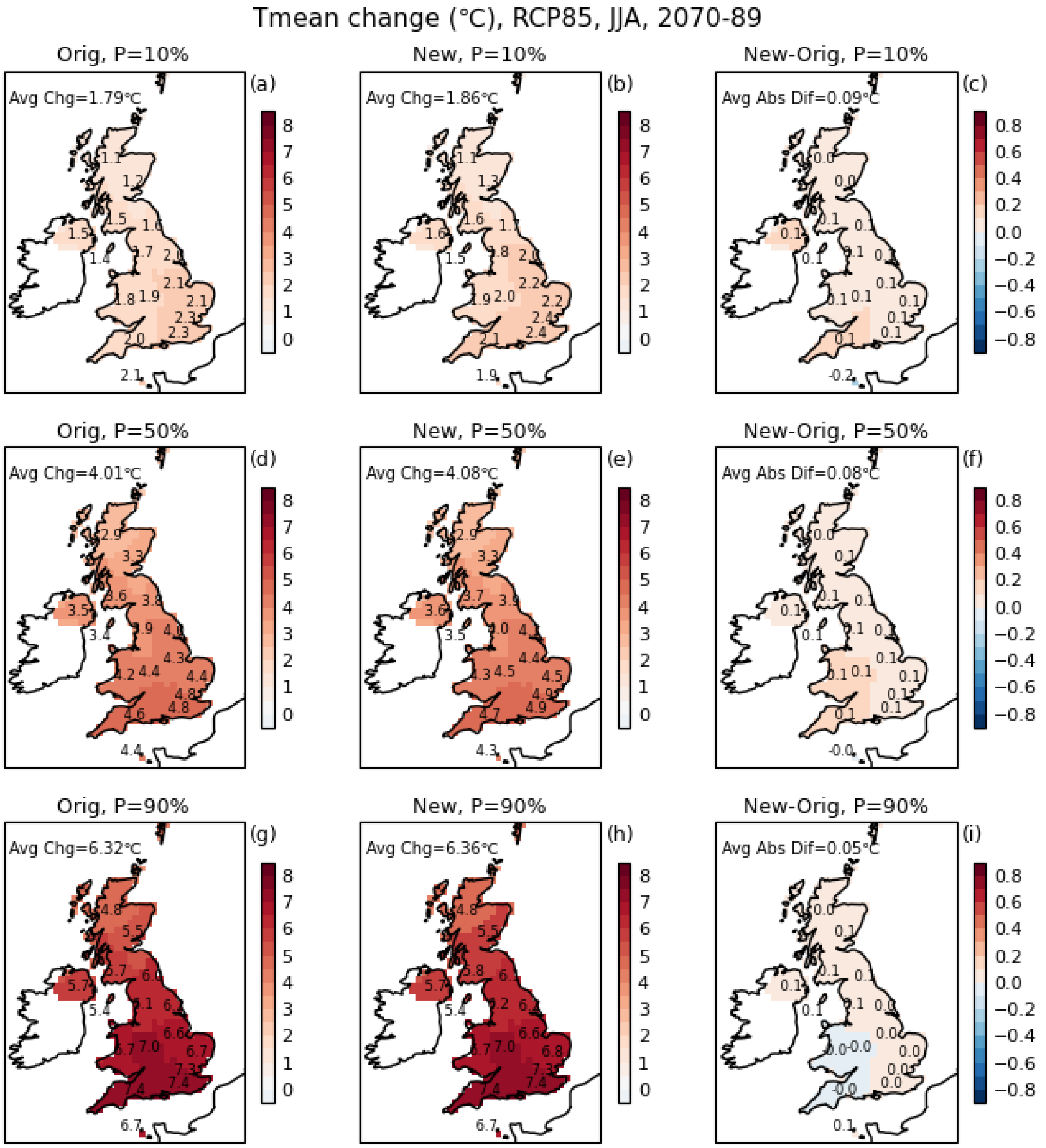

Figure 16. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in summer for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

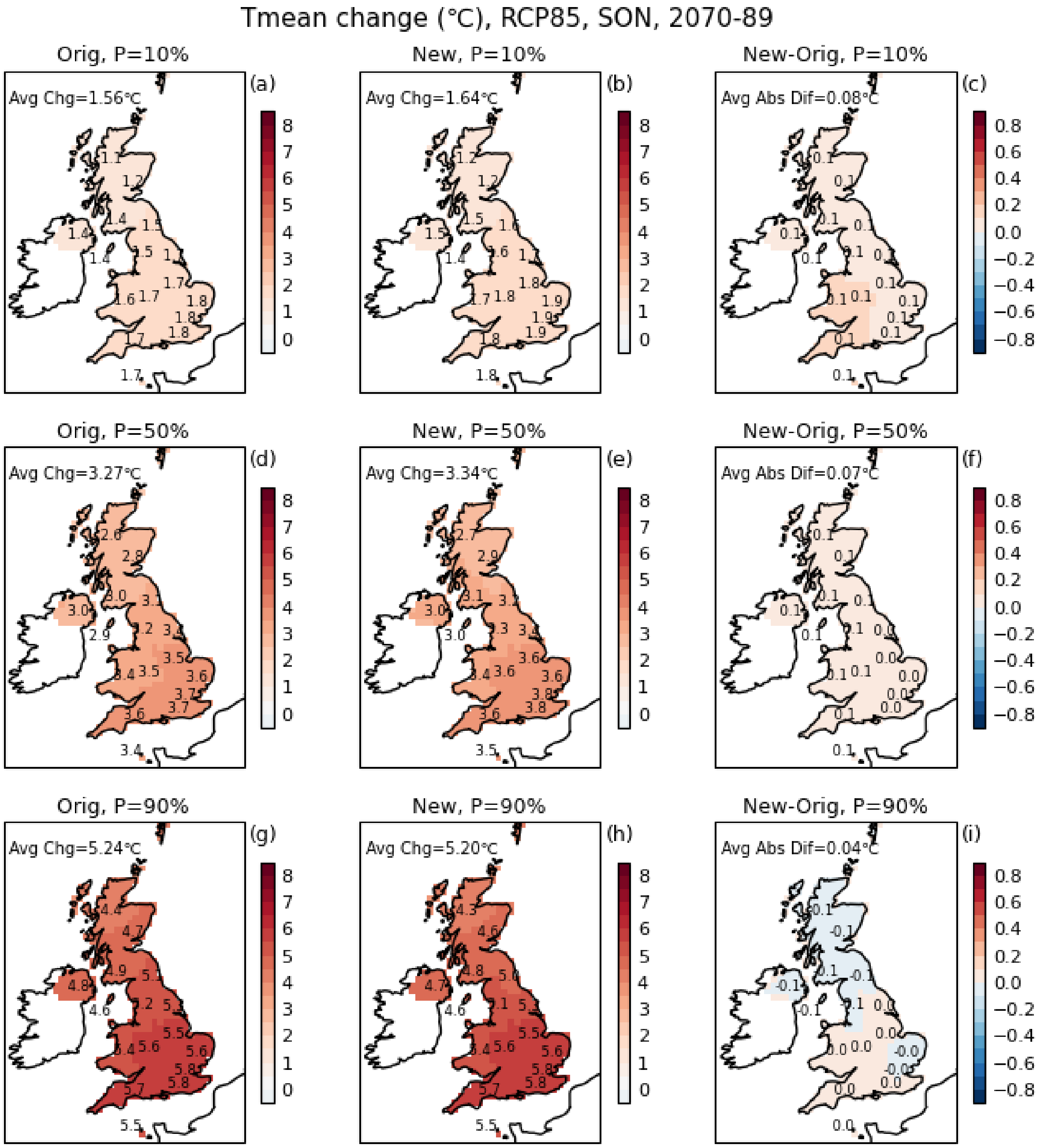

Figure 17. *Projected changes for administrative regions in daily mean surface air temperature (Tmean, °C) in autumn for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

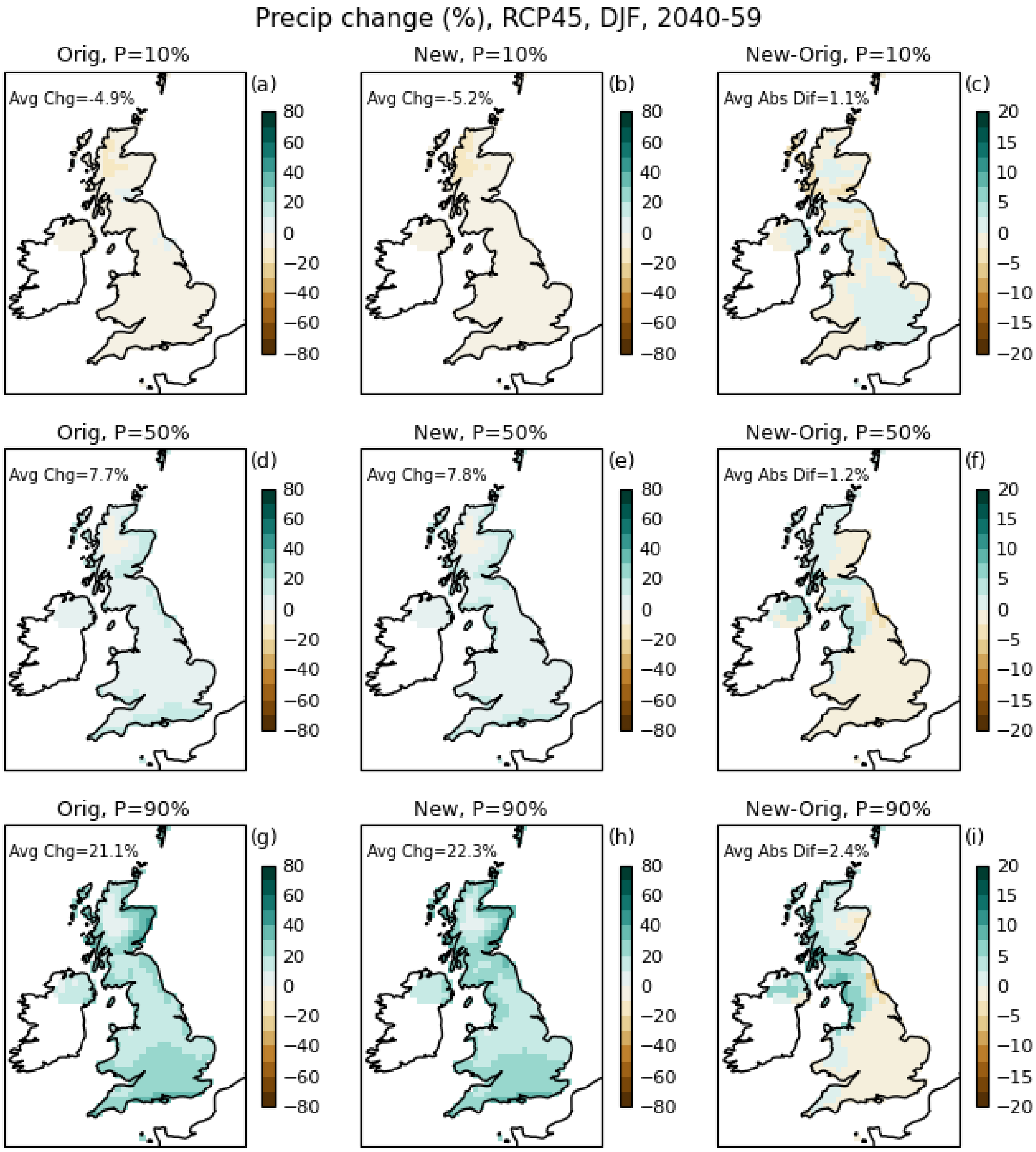

Figure 18. *Projected changes for 25km OSGB boxes in precipitation (%) in winter for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

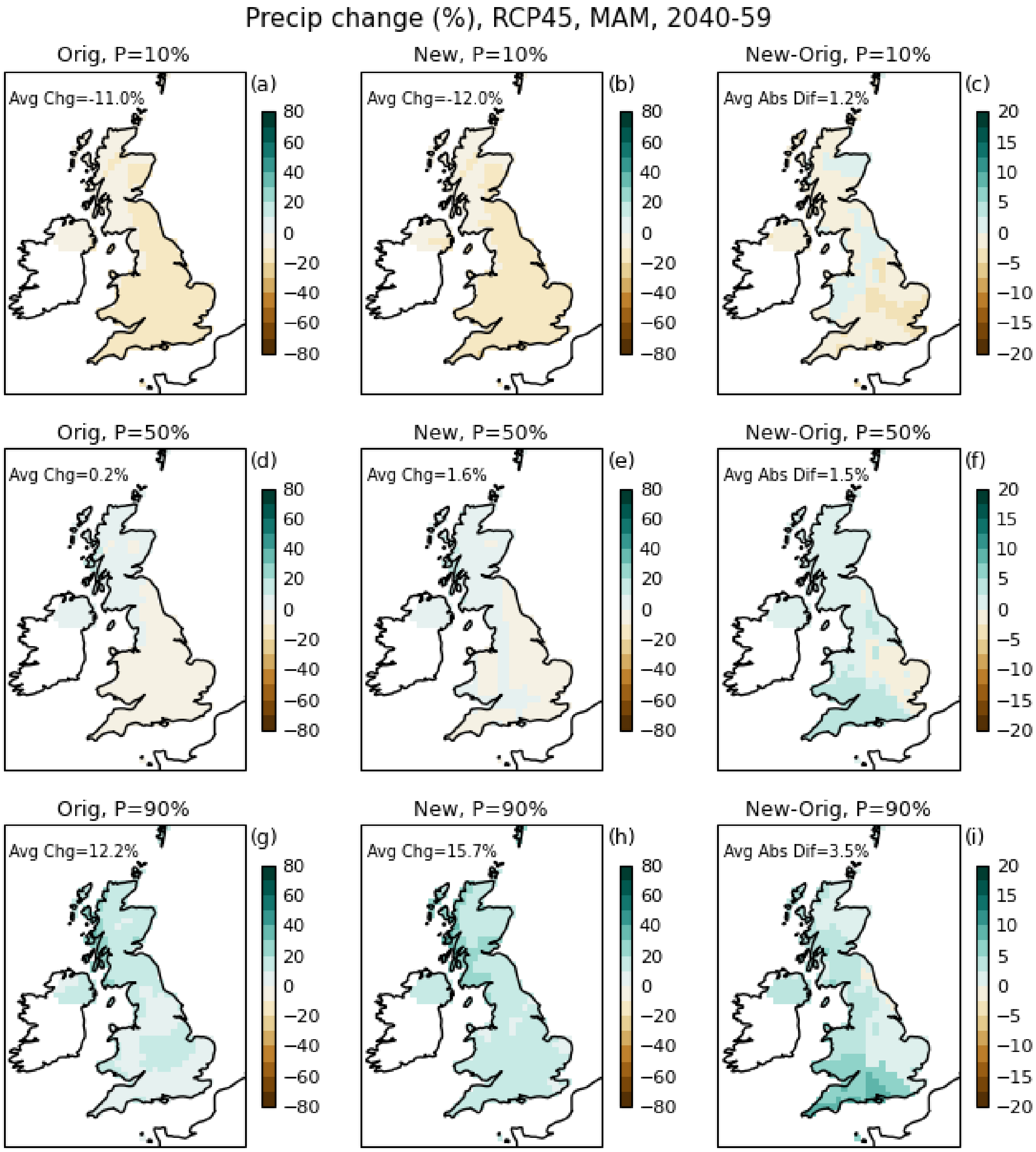

Figure 19. *Projected changes for 25km OSGB boxes in precipitation (%) in spring for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

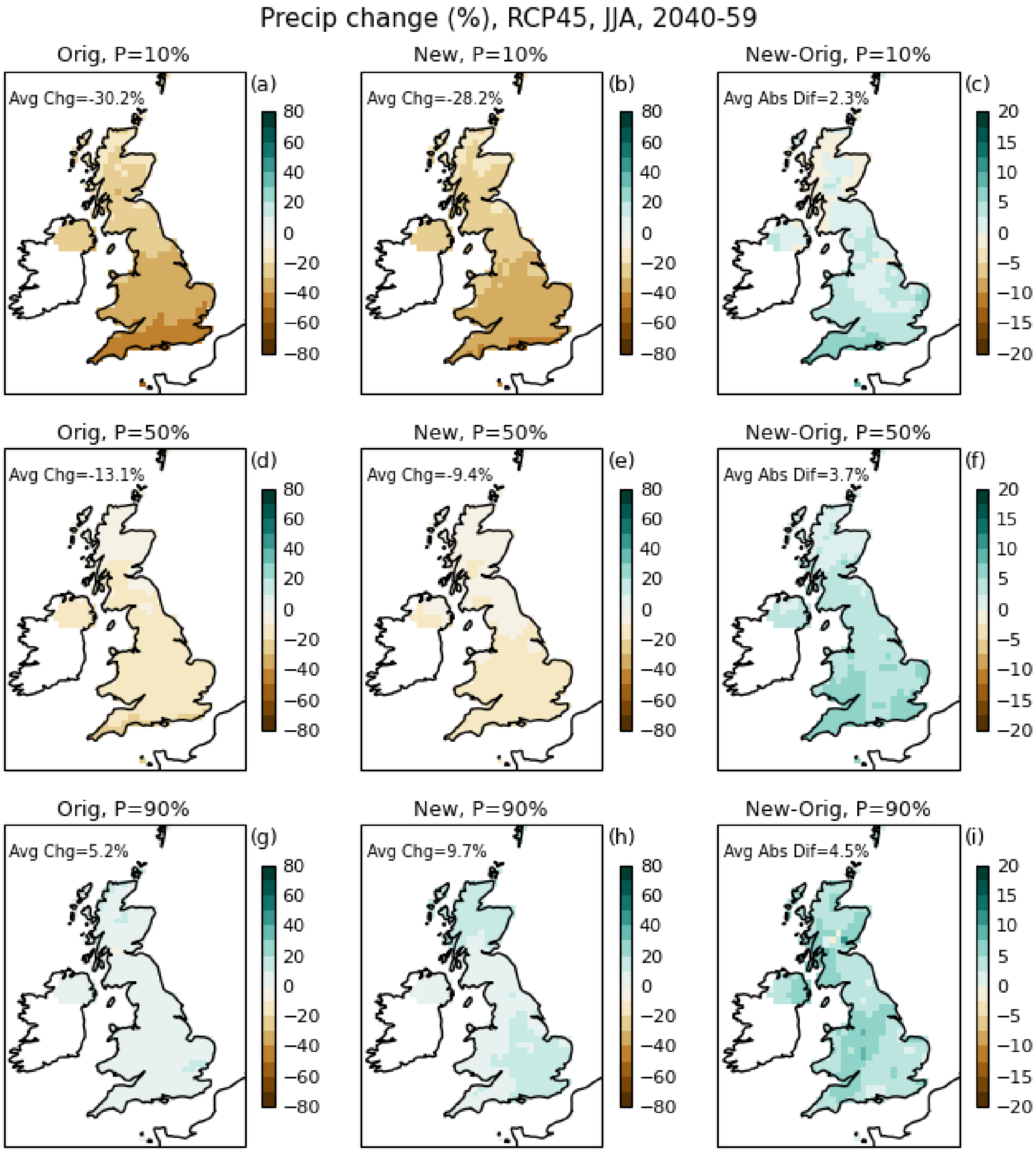

Figure 20. *Projected changes for 25km OSGB boxes in precipitation (%) in summer for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

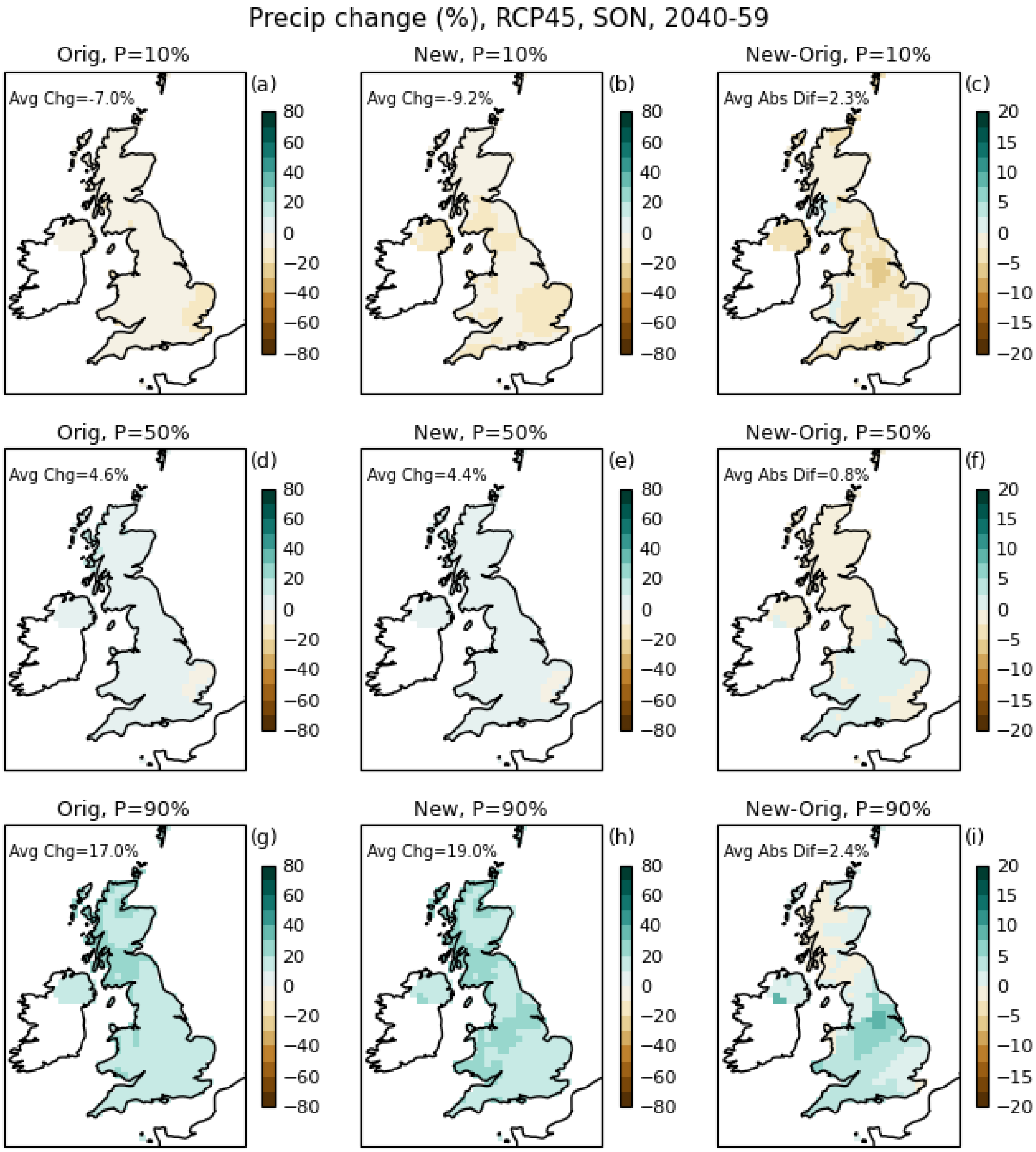

Figure 21. *Projected changes for 25km OSGB boxes in precipitation (%) in autumn for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

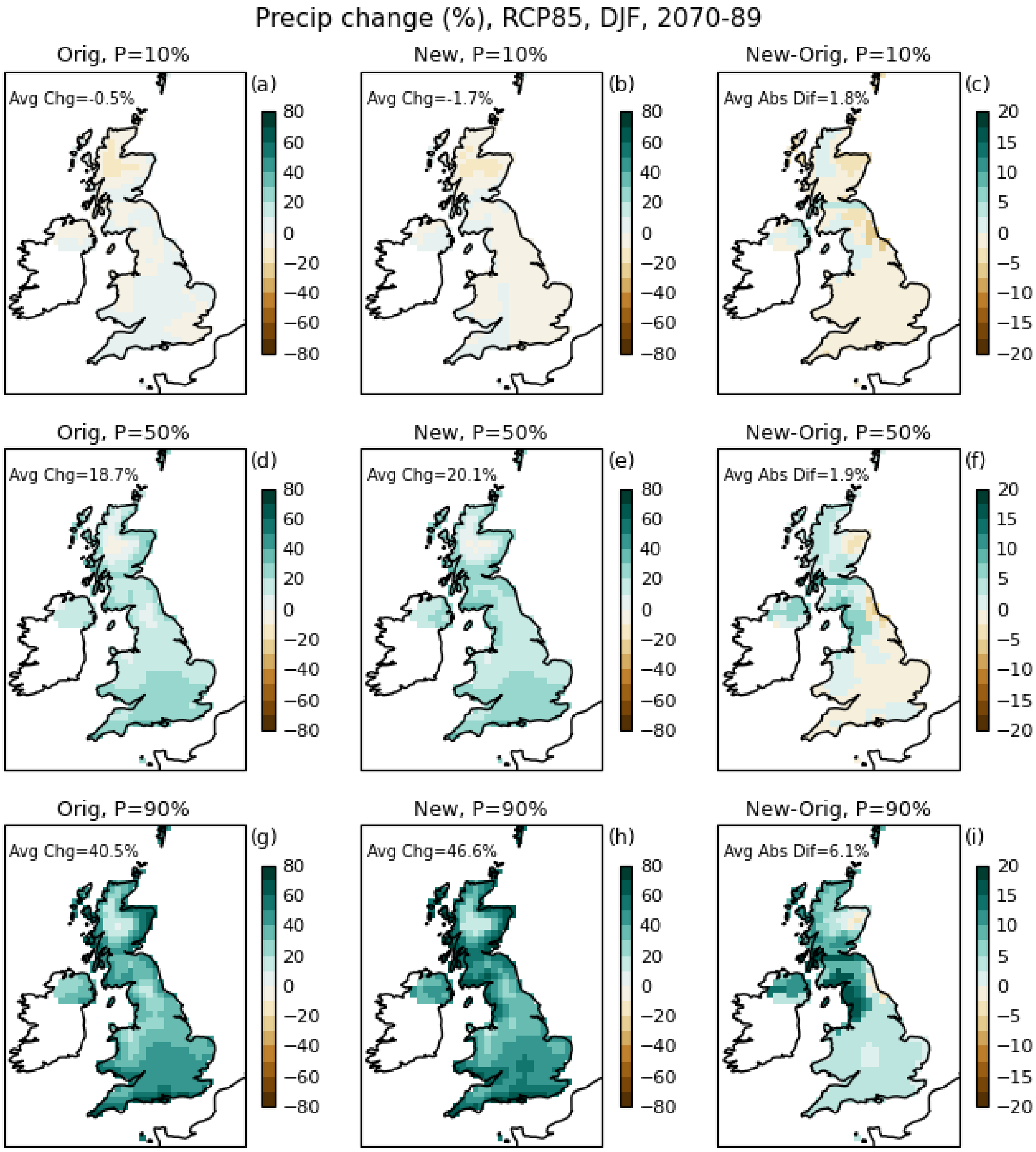

Figure 22. *Projected changes for 25km OSGB boxes in precipitation (%) in winter for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

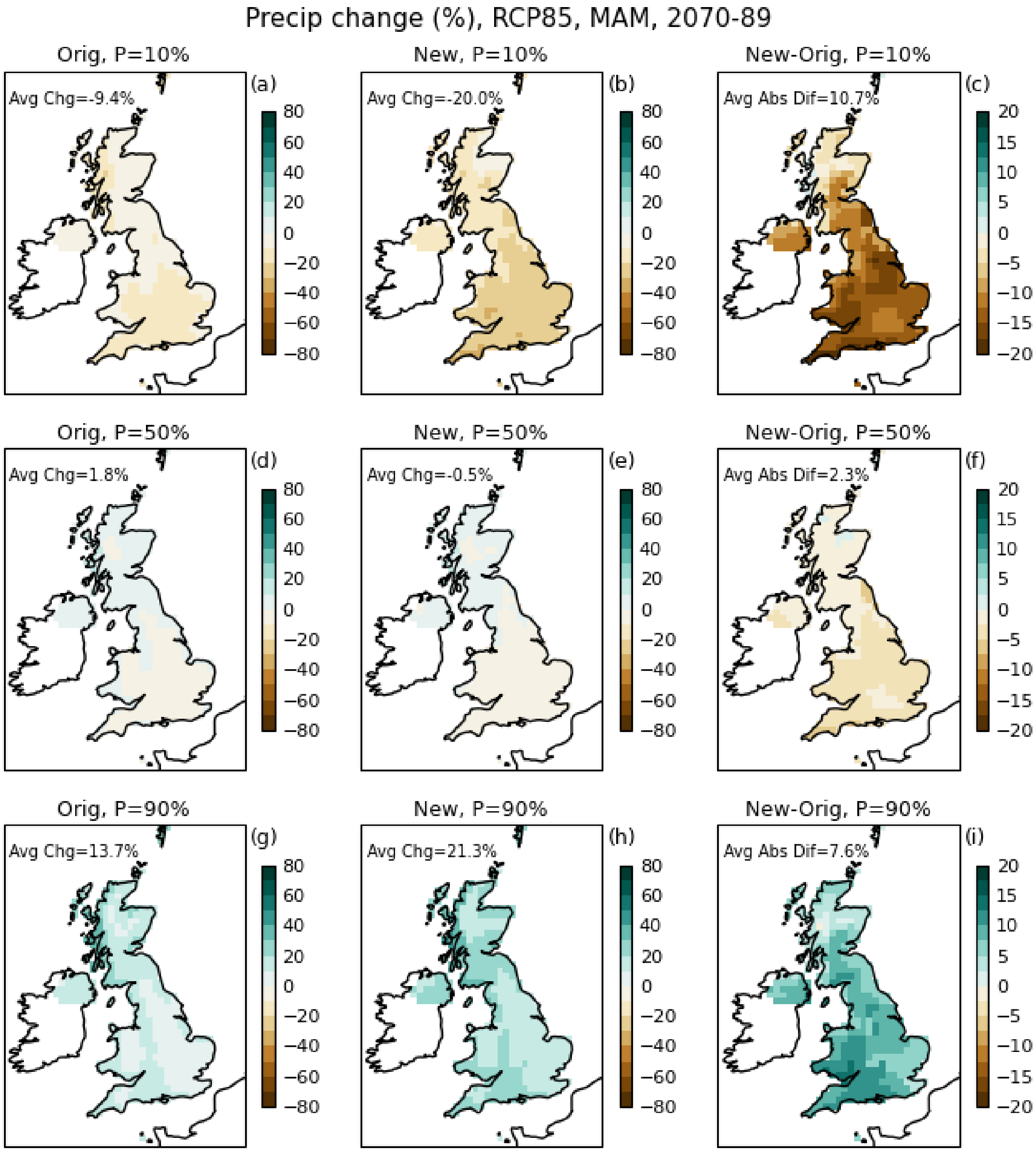

Figure 23. *Projected changes for 25km OSGB boxes in precipitation (%) in spring for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

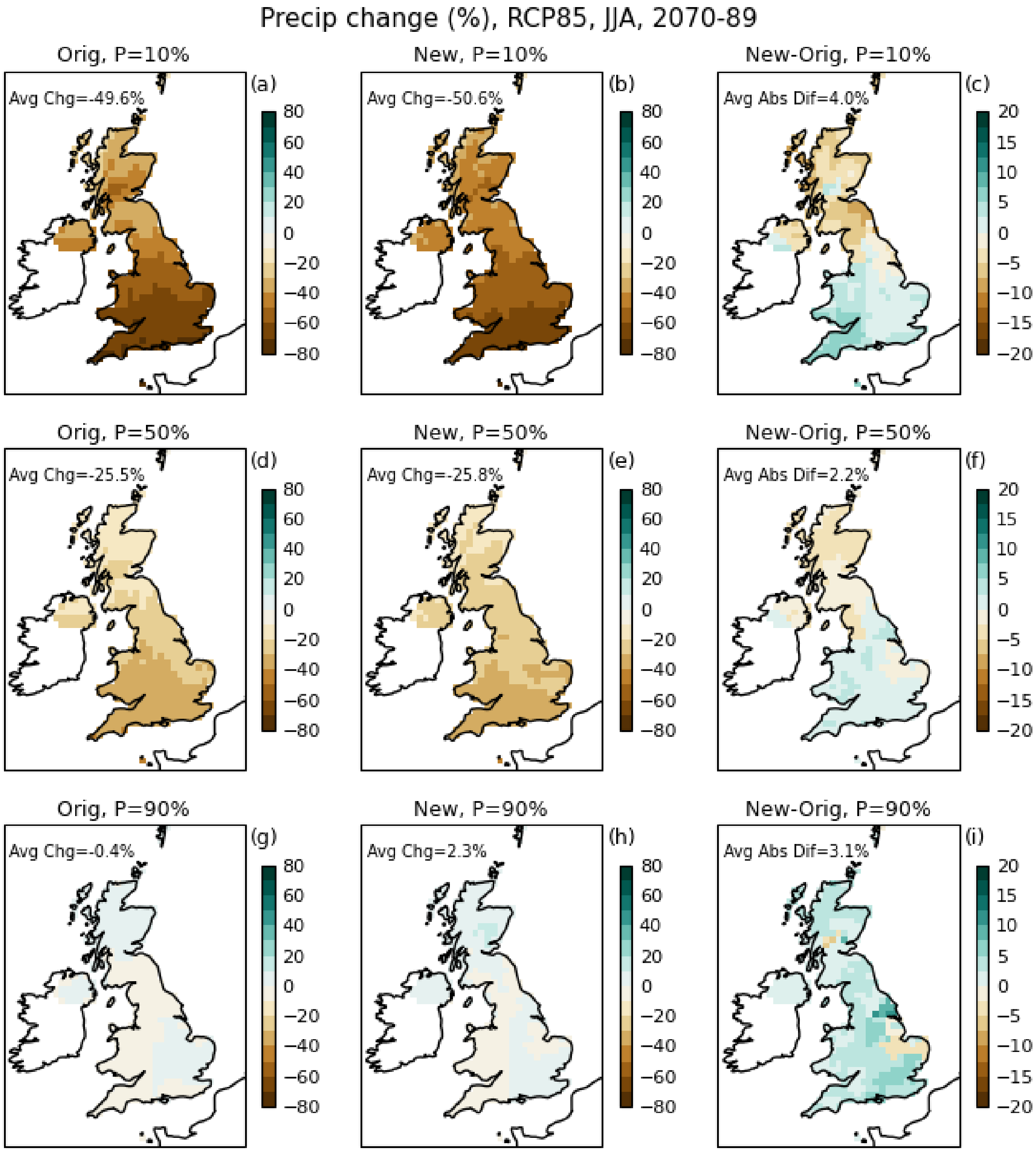

Figure 24. *Projected changes for 25km OSGB boxes in precipitation (%) in summer for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

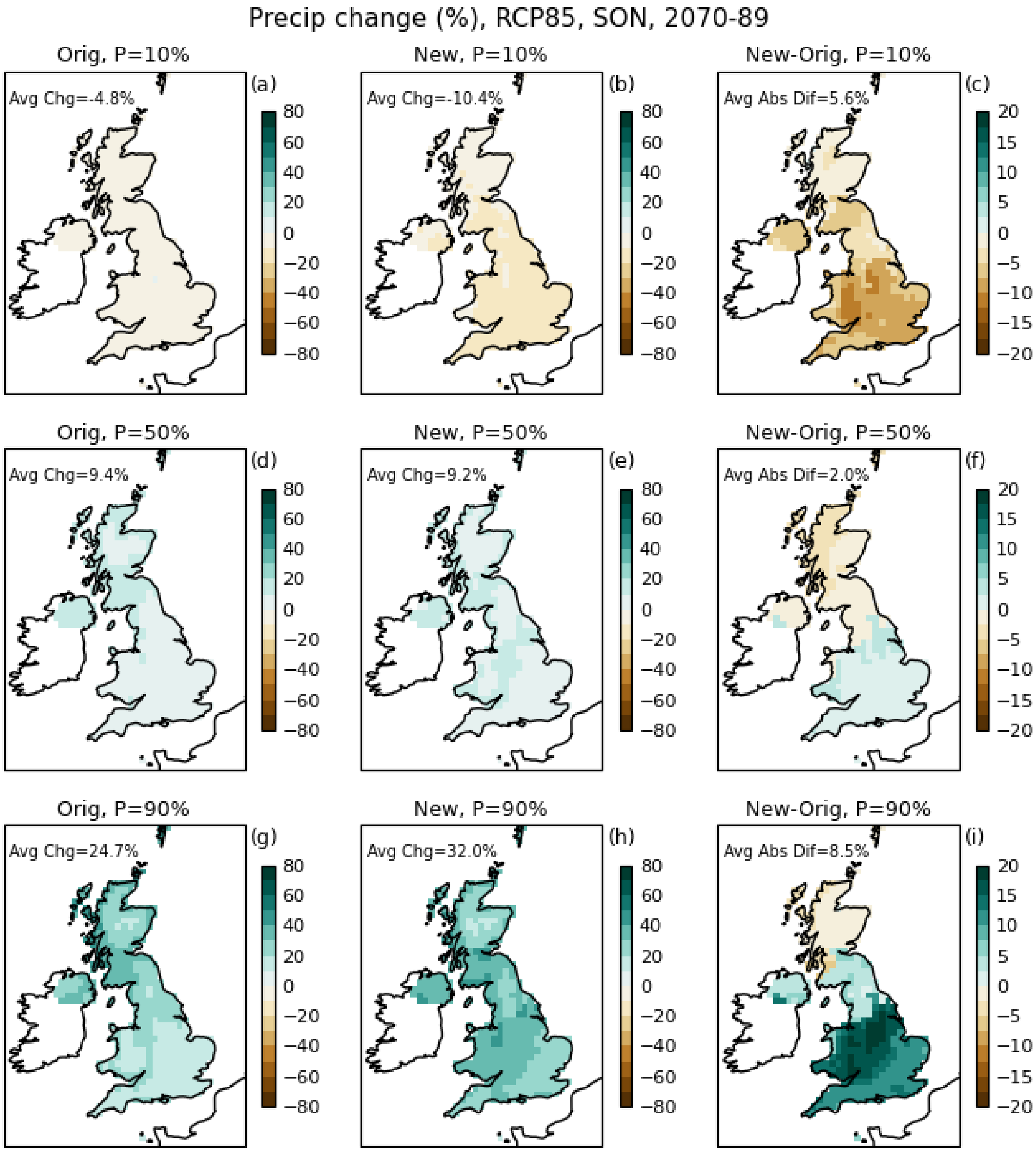

Figure 25. *Projected changes for 25km OSGB boxes in precipitation (%) in autumn for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

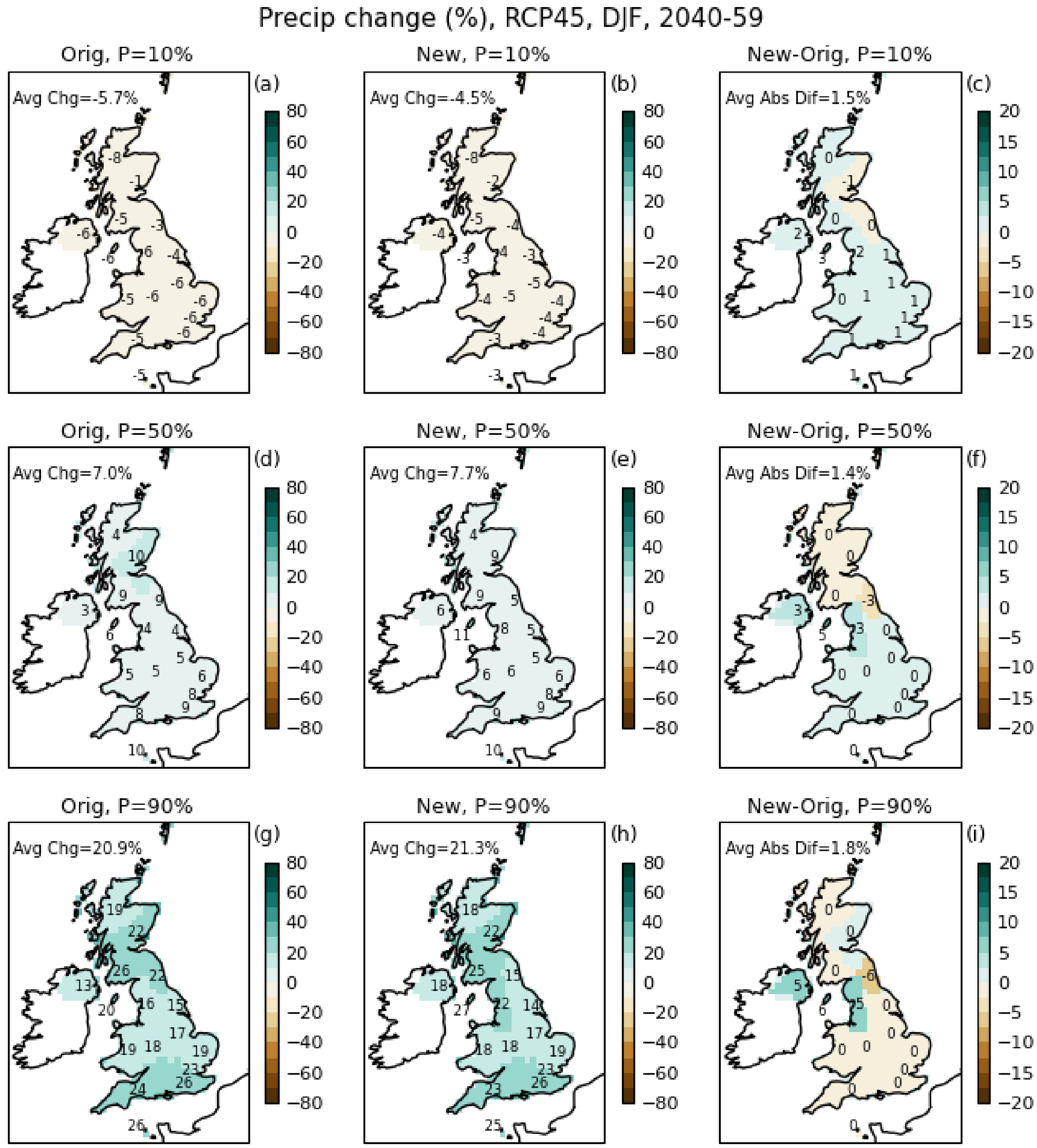

Figure 26. *Projected changes for administrative regions in precipitation (%) in winter for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

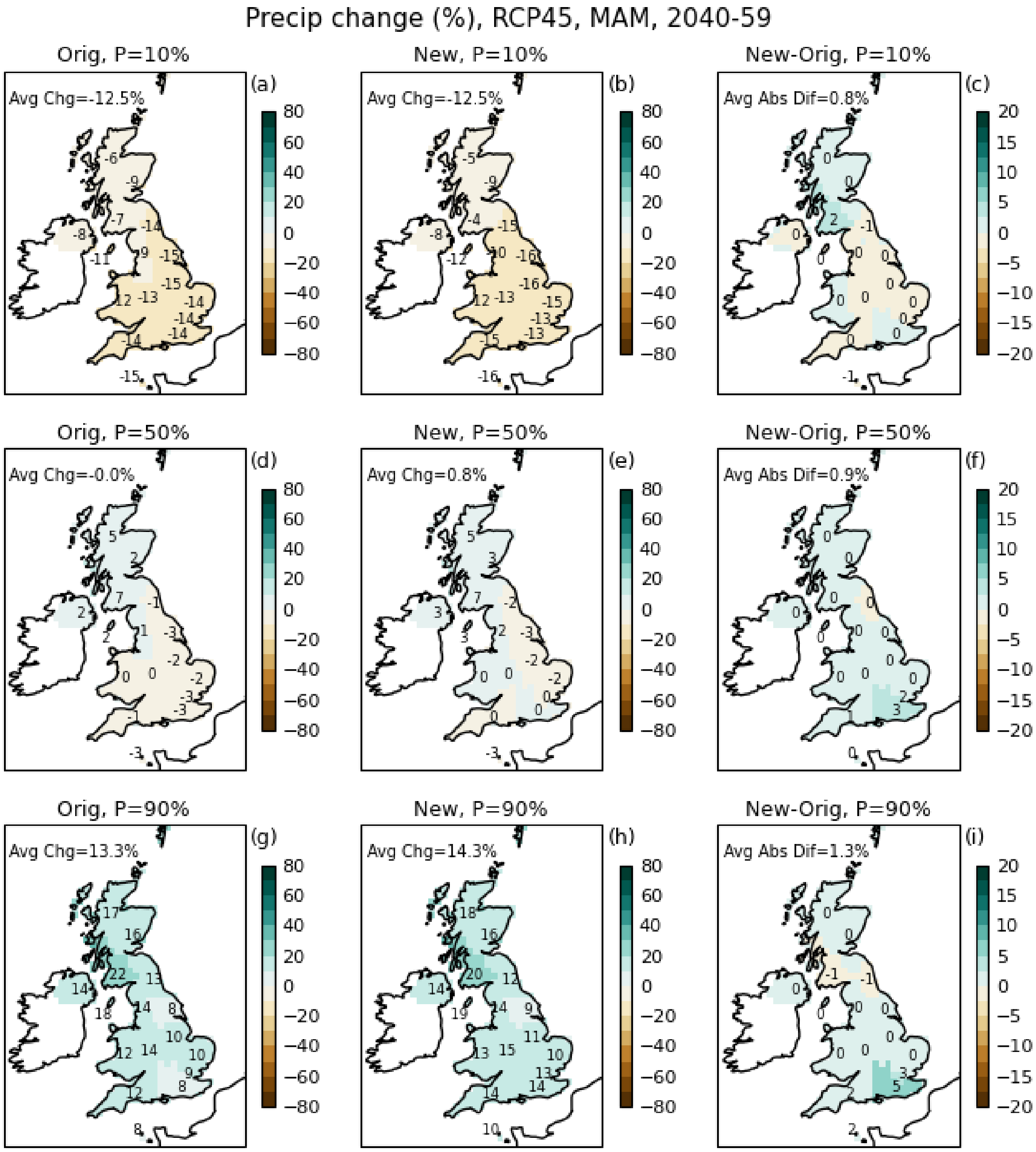

Figure 27. *Projected changes for administrative regions in precipitation (%) in spring for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

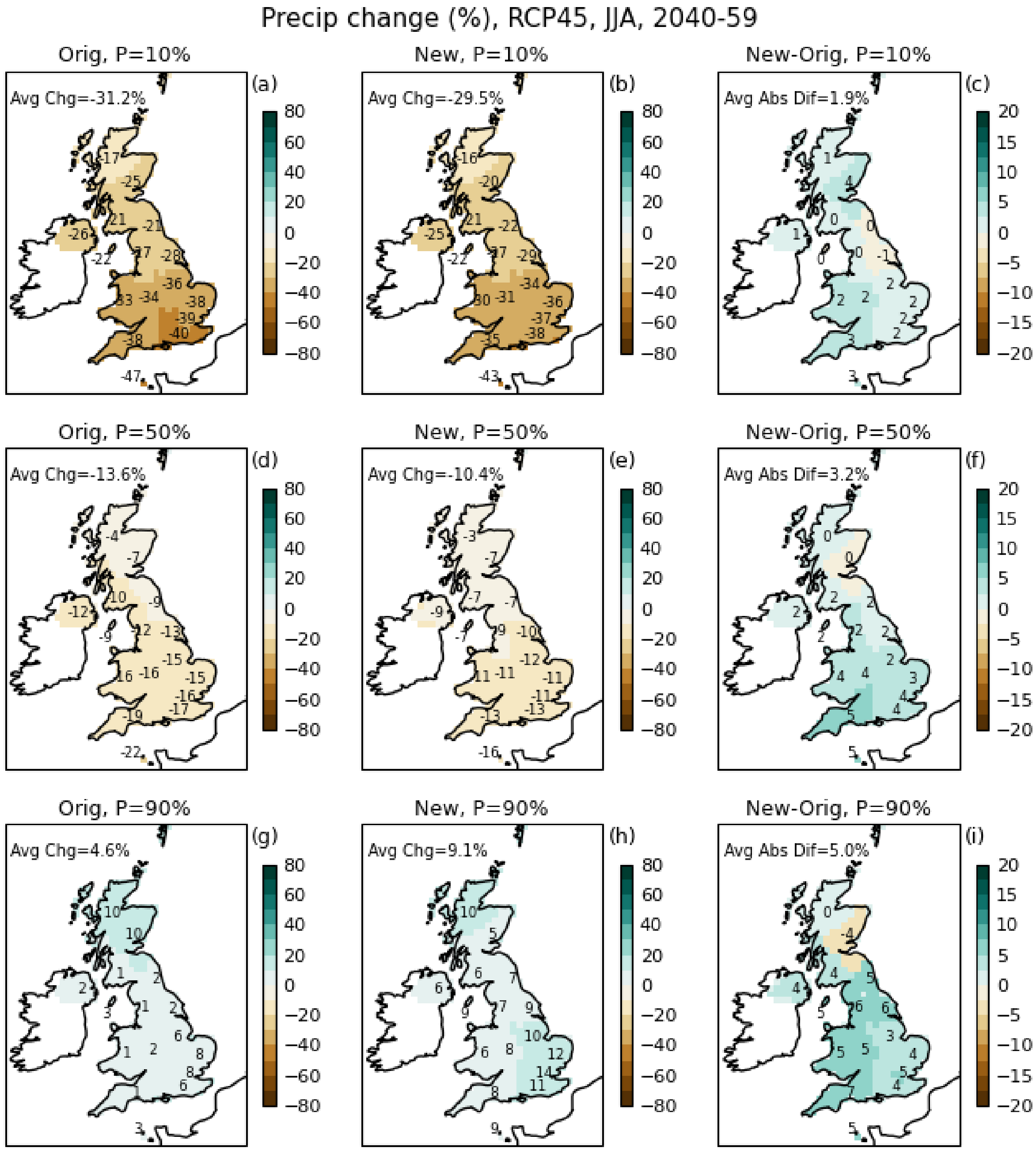

Figure 28. *Projected changes for administrative regions in precipitation (%) in summer for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

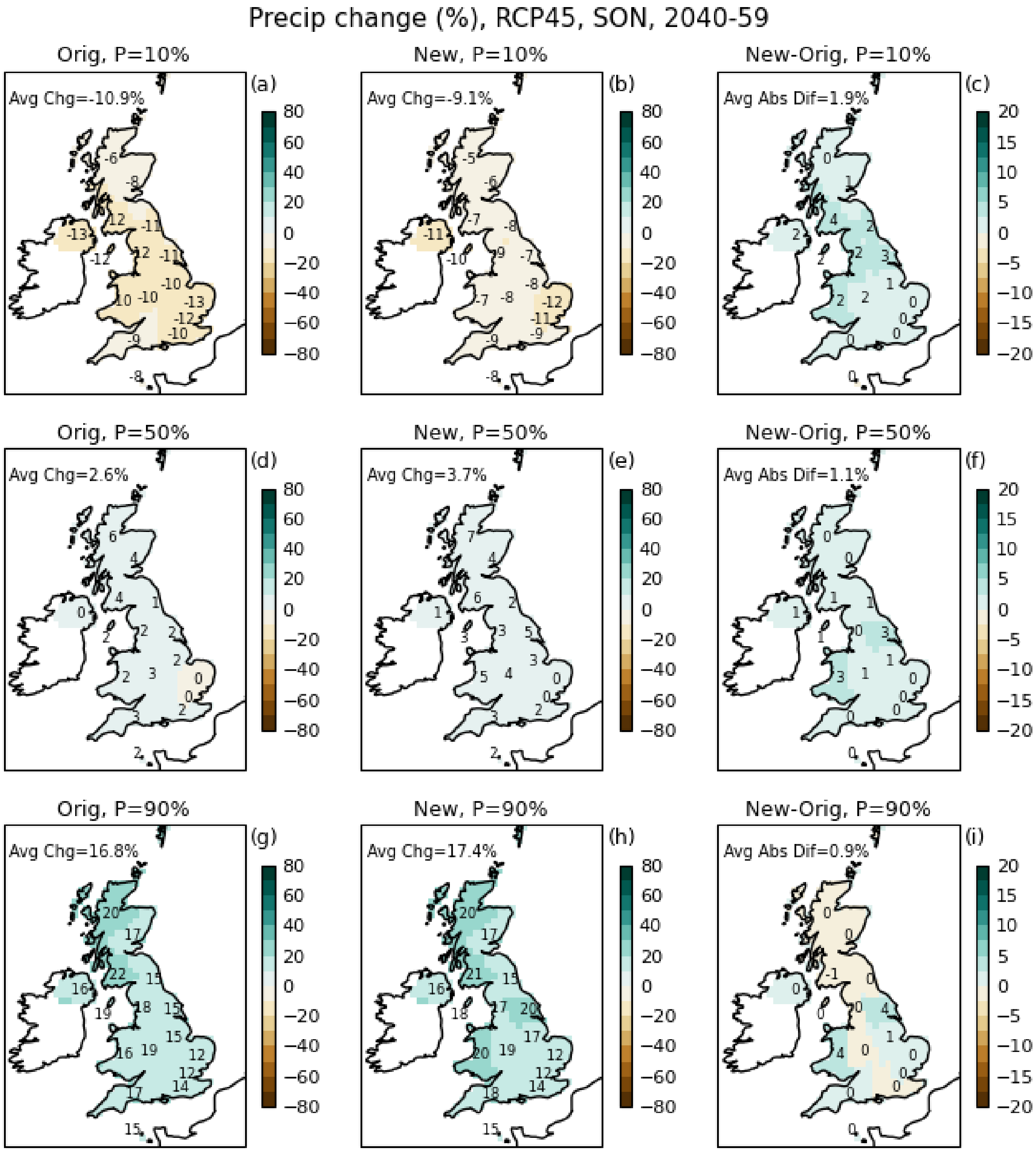

Figure 29. *Projected changes for administrative regions in precipitation (%) in autumn for 2040-2059 relative to 1981-2000 under RCP45. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

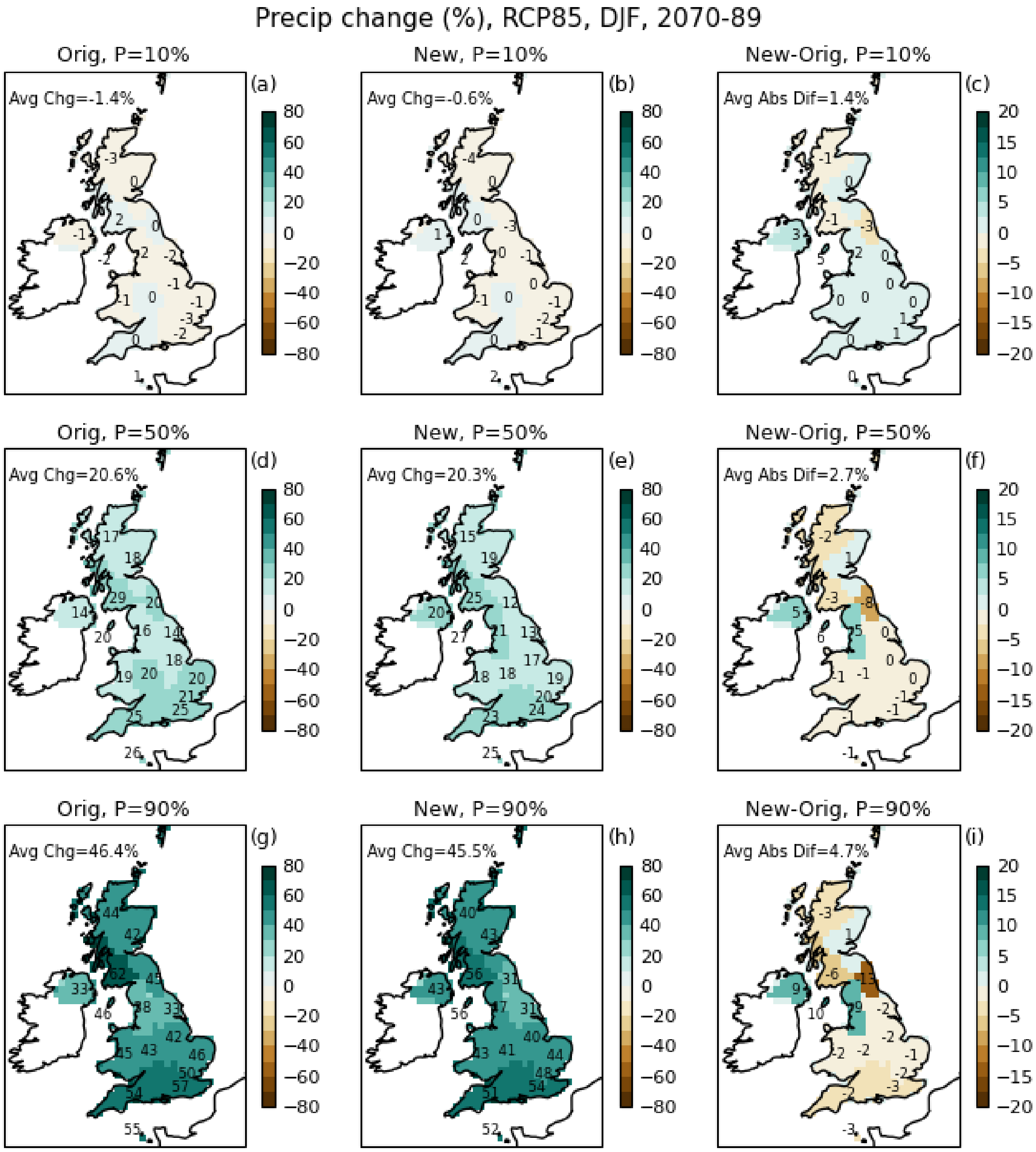

Figure 30. *Projected changes for administrative regions in precipitation (%) in winter for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

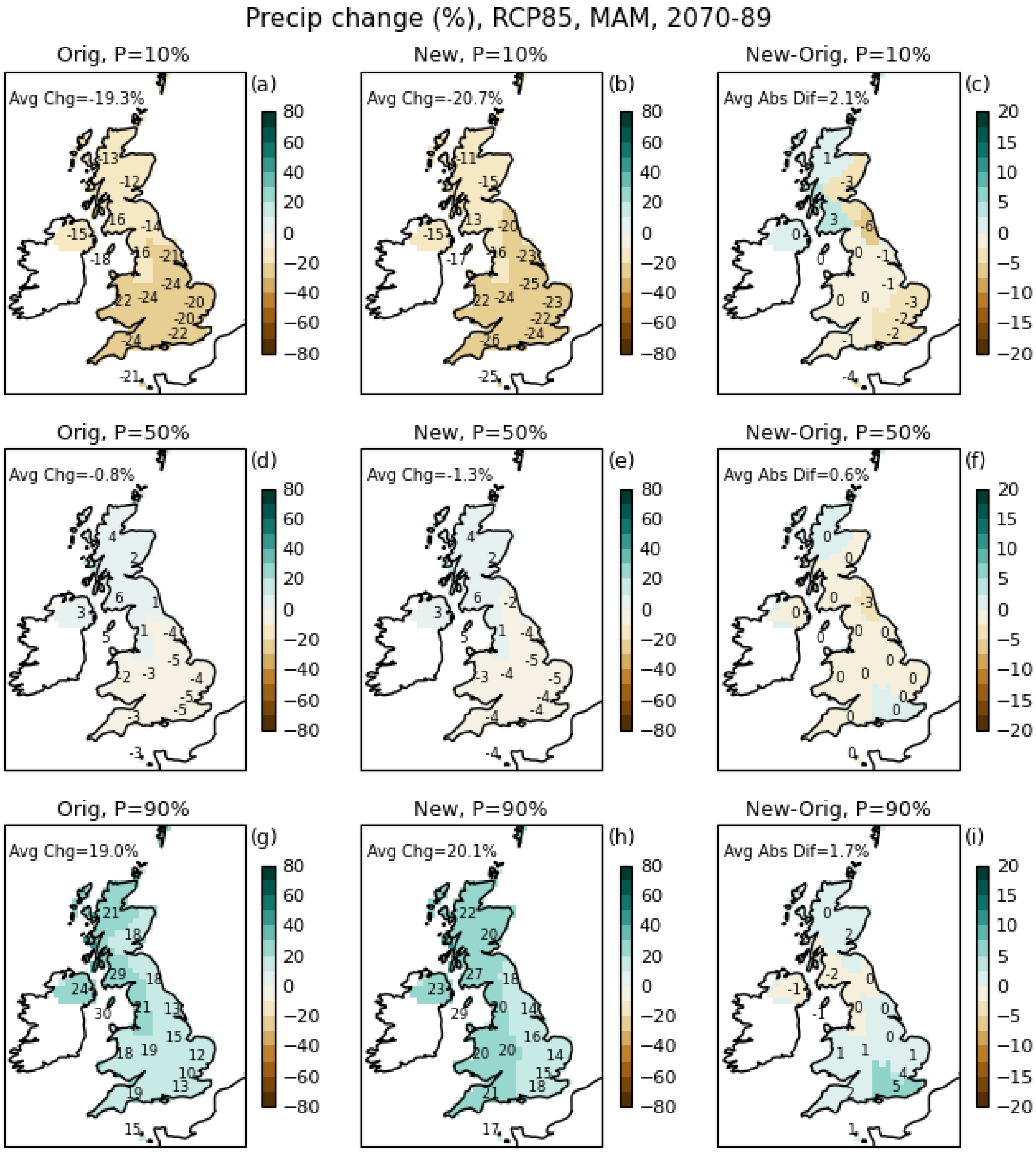

Figure 31. *Projected changes for administrative regions in precipitation (%) in spring for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

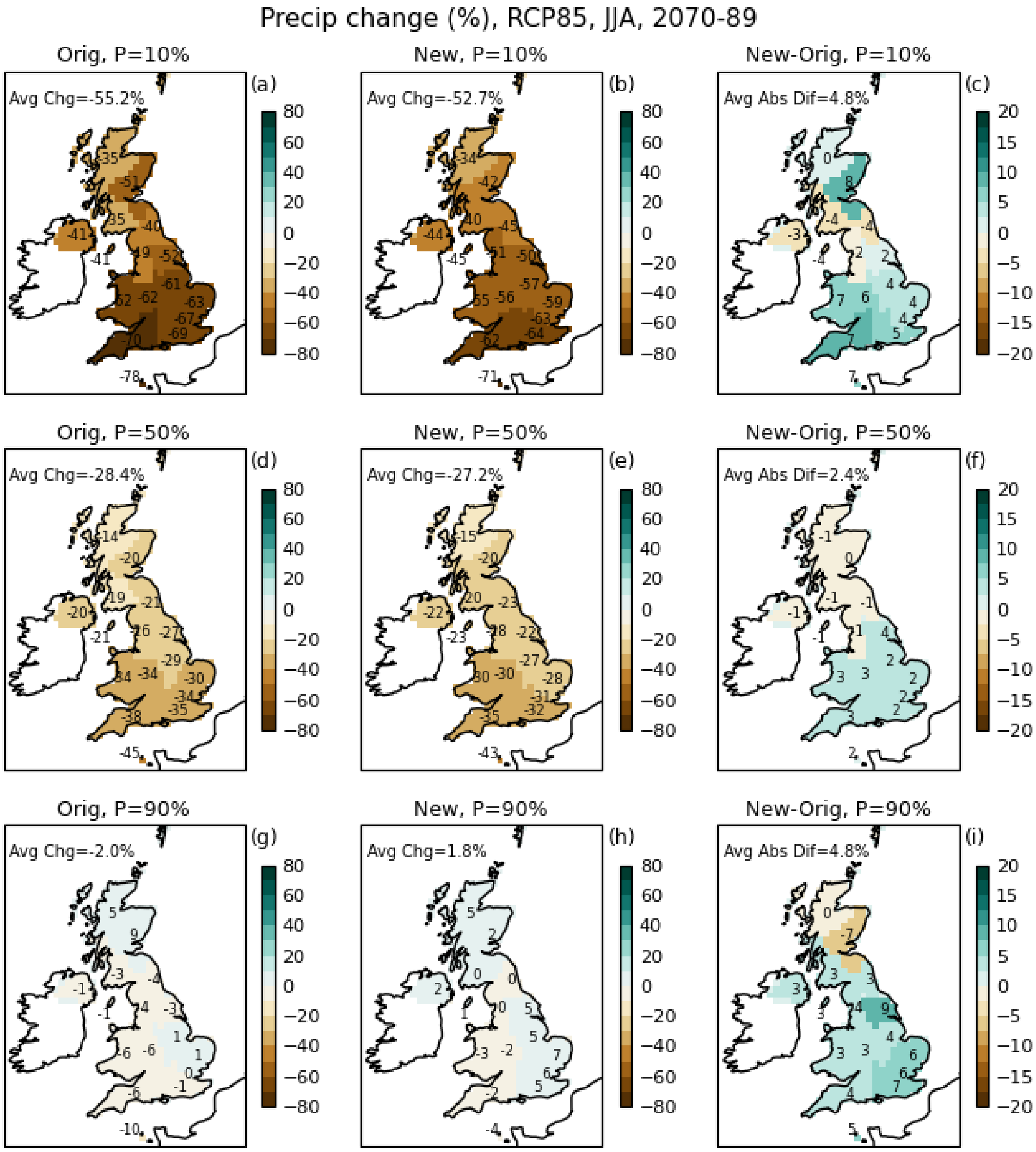

Figure 32. *Projected changes for administrative regions in precipitation (%) in summer for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

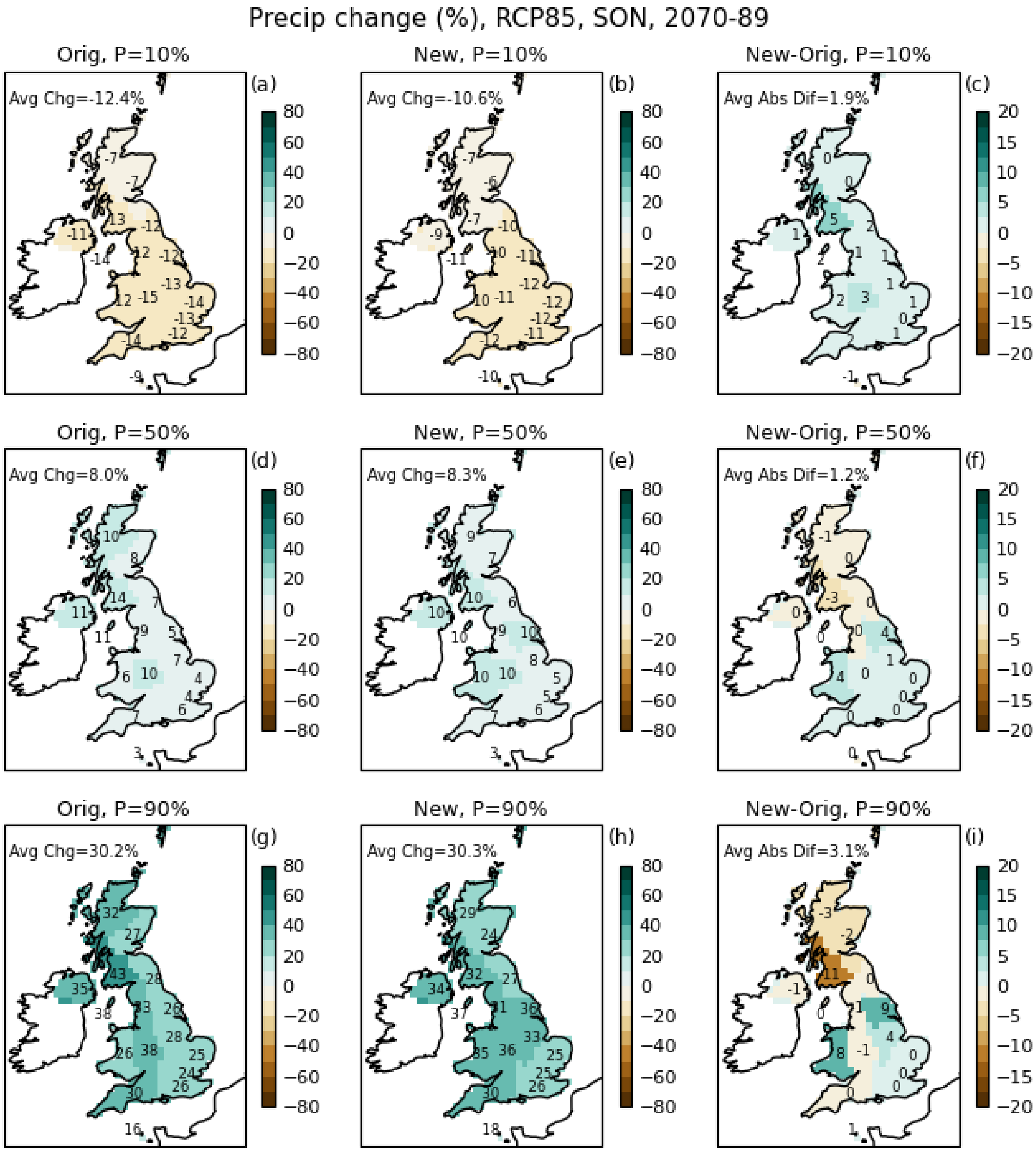

Figure 33. *Projected changes for administrative regions in precipitation (%) in autumn for 2070-2089 relative to 1981-2000 under RCP85. The panels show P10 (top), P50 (middle) and P90 (bottom) for the original UKCP18 probabilistic projections (left) and the new projections (centre). Differences between the new and original responses are shown on the right.*

References

Fung F, Stephens A, Wilson A (2018), **UKCP18 Guidance: Data availability, access and formats**, Available from https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/download-data (updated July 2021).

Fung F, Pirret JSR, Fuller EA, Harris GR, Murphy JM, Sexton DMH (2022), **Probabilistic Projections Update – FAQs**, Met Office. Available from https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports.

Harris GR, Murphy JM, Pirret JSR, Sexton DMH (2022), **Update to UKCP18 probabilistic projections**, Met Office. Available from https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports.

Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, van Vuuren DP, Carter TR, Emori S, Kainuma M, Kram T, Meehl GA, Mitchell JFB, Nakicenovic N, Riahi K, Smith SJ, Stouffer RJ, Thomson AM, Weyant JP, Wilbanks TJ (2010), **The next generation of scenarios for climate change research and assessment**, *Nature* 463: 747-756.

Nakicenovic N, Swart R (2000), **Special Report on Emissions Scenarios**, Cambridge University Press.