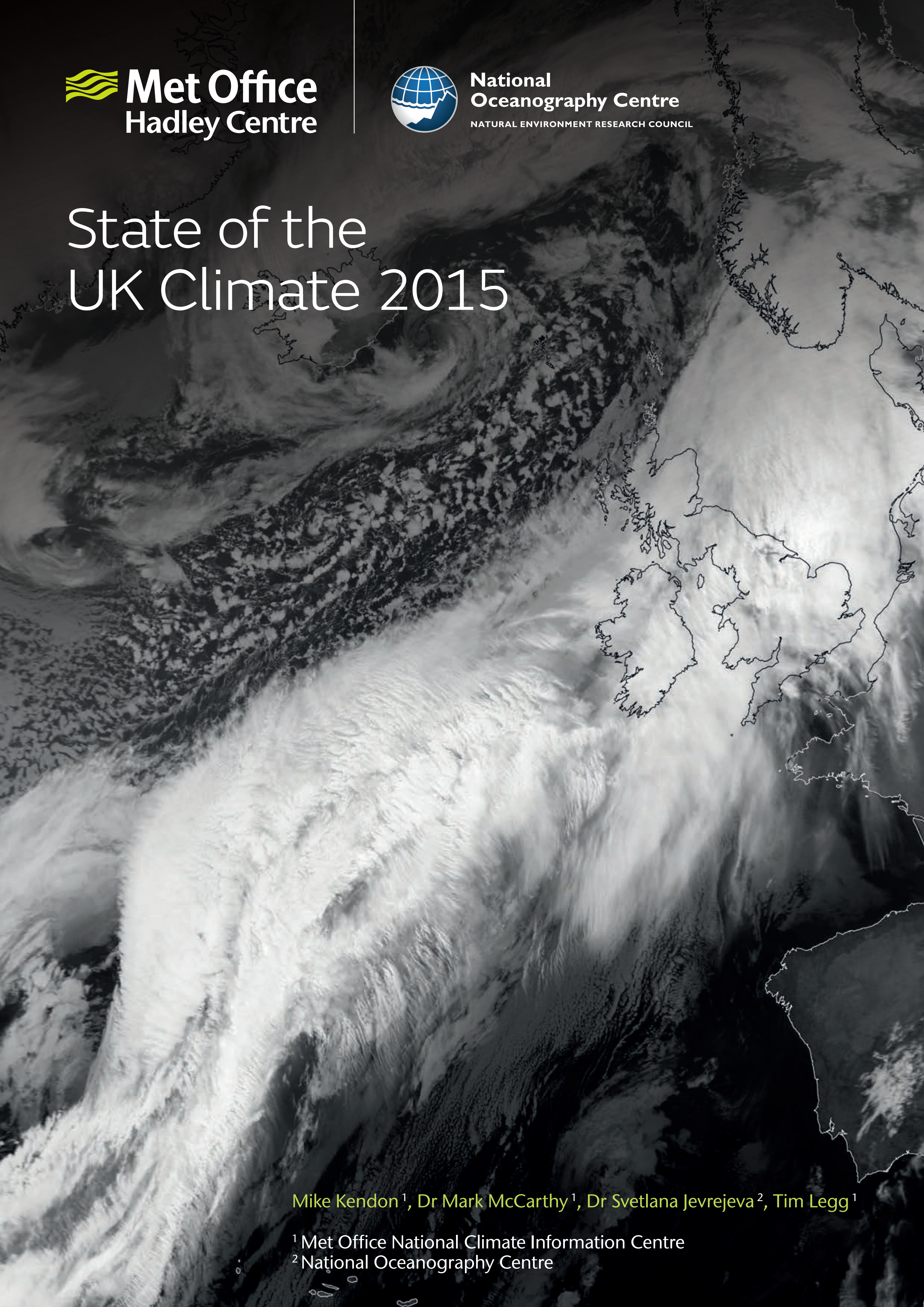

Met Office Hadley Centre

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

State of the UK Climate 2015

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Cover: Satellite image of storm Desmond on 5 December 2015. The low pressure centre is off south-east Iceland at 940 hPa with associated fronts draped across Britain and stretching south-west into the Atlantic. The Azores are at the bottom of the image. The UK was located in a moist south-westerly airstream with these fronts bringing exceptionally prolonged and heavy rainfall across high ground. A rain-gauge at Honister Pass, Cumbria, recorded 341.4mm in 24 hours to 1800 GMT on 5 December, a new UK record for any 24-hour period. This image is from the Advanced Very High Resolution Radiometer (AVHRR) satellite sensor channel 4 (thermal infra-red image) on the polar-orbiting NOAA-19 satellite at 0418 GMT showing night-time cloud and sea surface temperature. This image from the NERC Satellite Receiving Station, Dundee University http://www.sat.dundee.ac.uk/

Contents

Mean sea level pressure and relative humidity will be covered in next year's report.

Introduction

This report provides a summary of the UK weather and climate through the calendar year 2015, alongside the historical context for a number of essential climate variables. This is the second in a series of annual 'State of the UK climate' publications and an update to the 2014 report (Kendon et al, 2014). It provides an accessible, authoritative and up-to-date assessment of UK climate trends, variations and extremes based on the latest available climate quality observational datasets.

The majority of this report is based on observations of temperature, precipitation, sunshine and wind speed from the UK land weather station network as managed by the Met Office and a number of key partners and co-operating volunteers. The observations are carefully managed such that they conform to current best practice observational standards as defined by the World Meteorological Organization (WMO). The observations also pass through a range of quality assurance procedures at the Met Office before application for climate monitoring. In addition, time series of near-coast sea-surface temperature and sea-level rise are also presented.

FEEDBACK

We would welcome suggestions or recommendations for future publications of this report. Please send any feedback to the Met Office at socuk@metoffice.gov.uk

This report should be cited as:

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Executive Summary

Land temperature

- 2015 was the 16th warmest year for the UK in a series from 1910, and 25th warmest for Central England in a series from 1659.
- Eight of the ten warmest years for the UK have occurred since 2002 and all the top ten warmest years have occurred since 1990.
- The most recent decade (2006-2015) has been on average 0.3 °C warmer than the 1981-2010 average and 0.9 °C warmer than 1961-1990.
- December 2015 was the warmest December on record for the UK. It was also the warmest December on record for Central England with the highest anomaly of any month by a margin of over 1 °C.

Air and ground frost

- The numbers of air and ground frosts in 2015 were below average but not exceptionally so for the year overall. However frosts were notably absent in November and December.
- The most recent decade (2006-2015) has had 7% fewer days of air frost and 9% fewer days of ground frost compared to the 1981-2010 average, and 17% / 14% compared to 1961-1990.

Energy demand and Growing conditions

- Heating degree days in 2015 were slightly below average but not exceptionally so. Growing degree days were near average.
- The most recent decade (2006-2015) has had 3% fewer heating degree days per year on average compared to 1981-2010 and 9% fewer compared to 1961-1990.
- The most recent decade (2006-2015) has had 5% more growing degree days per year on average compared to 1981-2010 and 15% more compared to 1961-1990.

Near-coast sea-surface temperature

- 2015 was the 20th warmest year for UK near-coastal sea-surface temperature (SST) in a series from 1870.
- Nine of the ten warmest years for near-coast SST for the UK have occurred since 1989.

Precipitation

- 2015 was the seventh wettest year on record for the UK in a series from 1910.
- Seven of the ten wettest years for the UK have occurred since 1998.
- In the past few decades there has been an increase in annual average rainfall over the UK, particularly over Scotland. However, the trend is less clear from longer term records of rainfall over England and Wales since 1766.
- December 2015 was the wettest calendar month on record for the UK.
- UK rainfall records were set in December 2015 for the highest 24-hour total, the highest 2-day total (both during storm Desmond) and the highest monthly rainfall total.

Snow

- Although there were some snowfalls during 2015 this was not a particularly snowy year for the UK overall.
- With the notable exceptions of 2010 and 2013, widespread and substantial deep snow events have been relatively rare in recent decades.

Sunshine

- 2015 was sunnier than the 1981-2010 average for the UK overall.
- Winter 2015 and April 2015 were each the sunniest on record for the UK in series from 1929, whereas November was dullest on record.
- Hours of bright sunshine have increased in recent decades, particularly in winter.

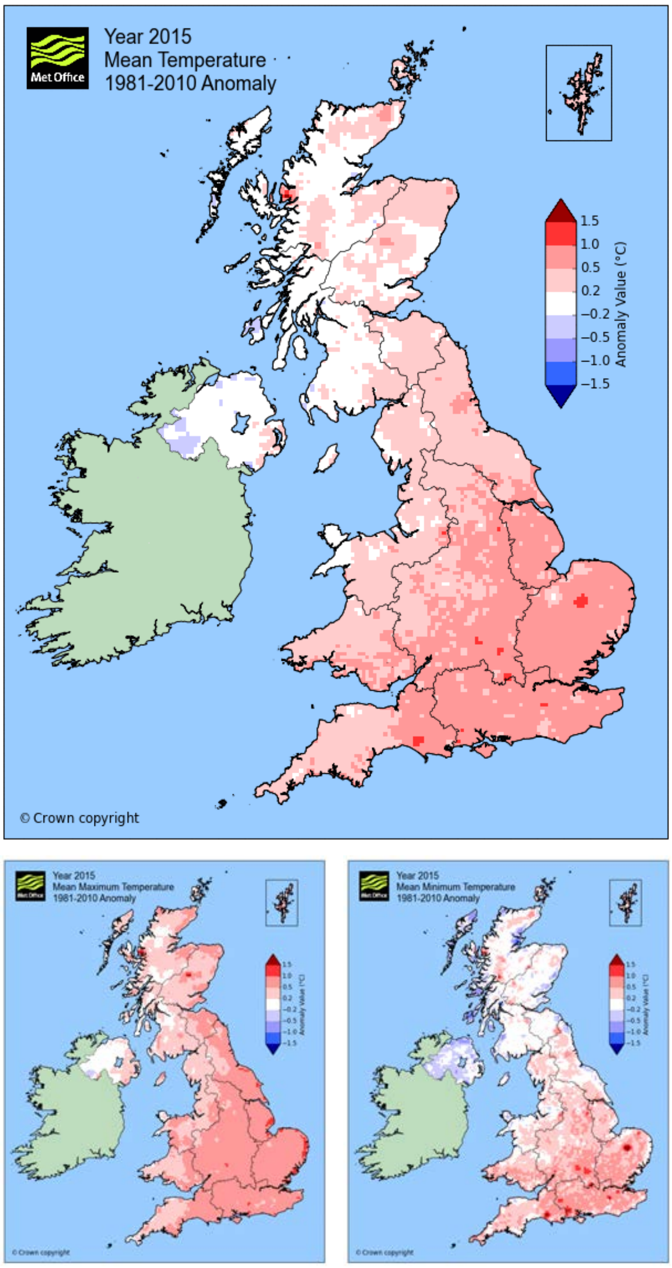
Wind

- 11 major Atlantic storms affected the UK in 2015, however this is not particularly unusual compared to recent decades.
- There are no compelling trends in storminess as determined by maximum gust speeds from the UK wind network over the last four decades.

Sea level rise

- Mean sea level around the UK rose by approximately 1.4mm/yr in the 20th century, when corrected for land movement.

Temperature



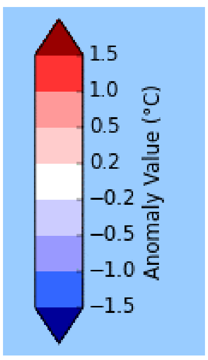


Figure 1: 2015 annual average temperature anomalies (°C) relative to 1981-2010 average for mean, maximum and minimum temperature.

The UK mean temperature (Tmean) for 2015 was 9.2 °C, 0.4 °C above the 1981-2010 long term average, and this was the 16th warmest year in the UK series from 1910, although not as warm as year 2014 (anomaly 1.1 °C and the warmest year in the series). 2015 was ranked 25th warmest in the Central England temperature (CET) series from 1659. Most of England, Wales and eastern Scotland were warmer than average with the highest anomalies across the south-east, whereas the annual mean temperature was near normal across most of central and western Scotland, and slightly below for Northern Ireland where it was the coolest year since 2010 (Figure 1, Table 1).

The UK annual mean maximum temperature (Tmax) for 2015 was 12.9 °C, 0.5 °C above average. The Tmax anomaly pattern was in general very similar to Tmean, but with slightly higher anomalies across Scotland and Wales. The UK annual mean minimum temperature (Tmin) for 2015 was 5.5 °C, 0.2 °C above average. Tmin anomalies were around 0.5 °C above average across the southern half of the UK, but near normal across the northern half and slightly below average for Northern Ireland (Figure 1).

The UK seasonal Tmean for winter and spring were each very close to the 1981-2010 average throughout the UK. However, it was a cool summer with mean summer temperatures which were below average, particularly in the west. The summer overall was cooler than the previous two summers of 2013 and 2014 and more comparable to those of 2011 and 2012. Despite record-breaking temperatures on the 1st, July was a particularly cool month with maximum temperatures notably suppressed in the west and north; Northern Ireland and western Scotland each had their coolest July since 1993. The UK seasonal Tmean for autumn was above average, with a cool September - the coldest for England and Wales since 1994 - offset by a notably warm November - third-warmest in the UK series behind Novembers 1994 and 2011 (Figures 2 and 3, Table 1).

December was an exceptional and record-breaking month and the warmest in the UK series by a margin of 1.0 °C. Monthly Tmean anomalies exceeded 5 °C across most of central and southern England, reaching 6 °C in a few locations. December was easily the warmest December in the CET series (margin of 1.6 °C) and had the highest temperature anomaly relative to the 1981-2010 average of any month in the CET series (margin of 1.3 °C). More details are provided in the significant weather section of this report, page 48).

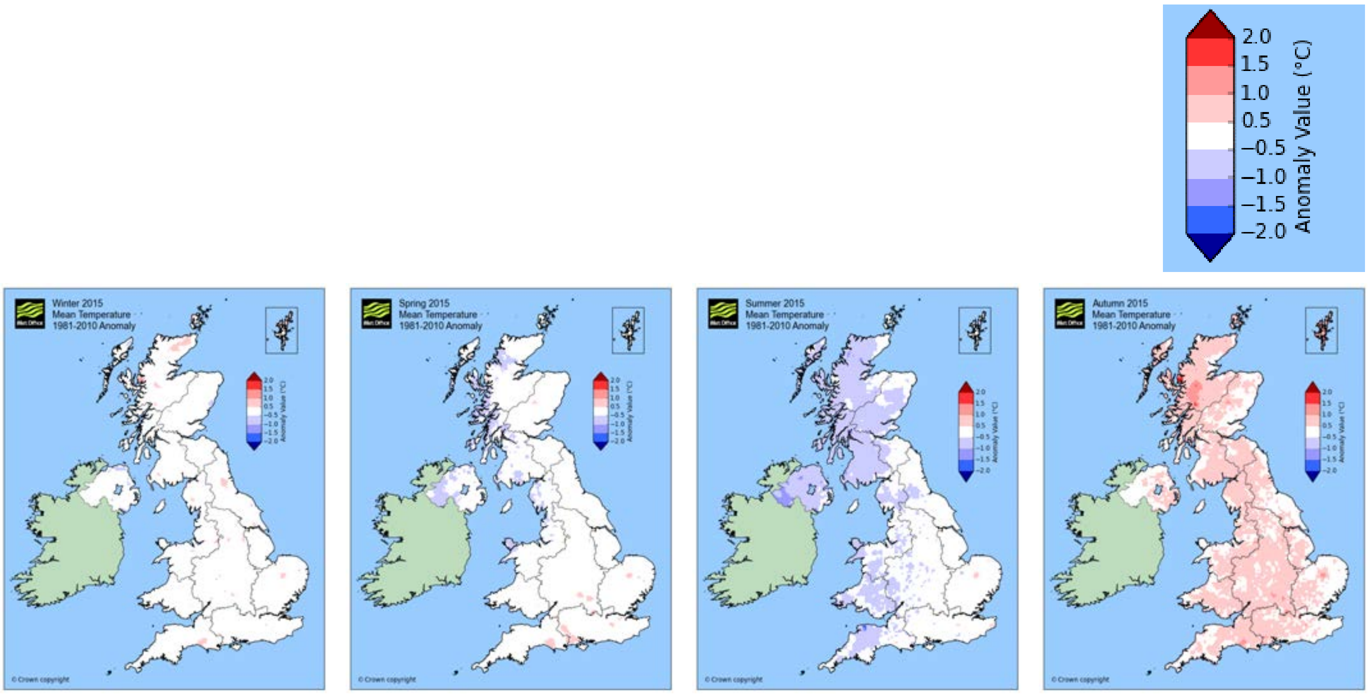


Figure 2: 2015 seasonal average temperature anomalies (°C) relative to 1981-2010 average. Winter refers to the period December 2014 to February 2015. Note that winter 2016 (December 2015 to February 2016) will appear in next year's publication.

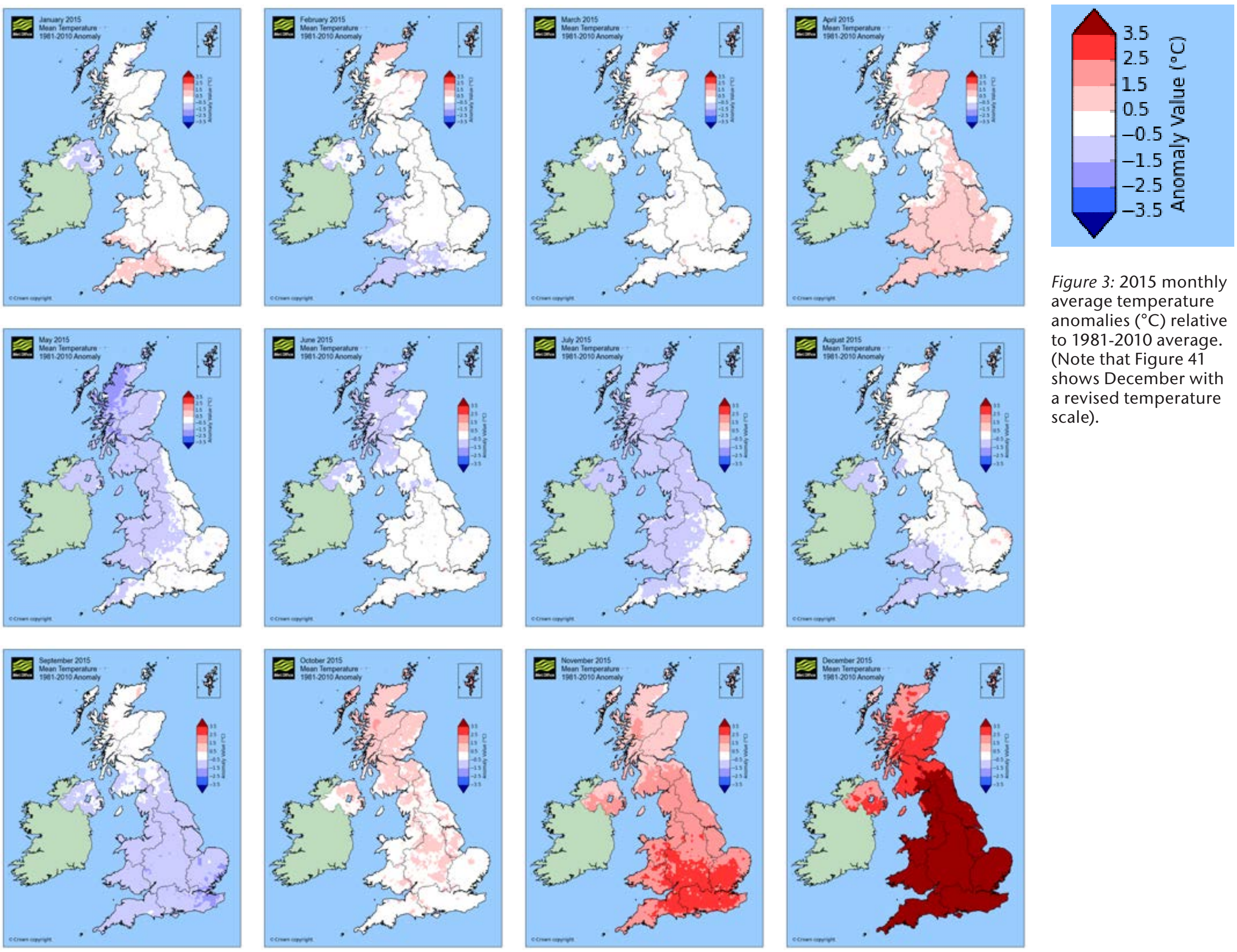


Figure 3: 2015 monthly average temperature anomalies (°C) relative to 1981-2010 average. (Note that Figure 41 shows December with a revised temperature scale).

Table 1: Monthly, seasonal and annual mean temperature and anomaly values (°C) relative to 1981-2010 average for the UK, countries and CET for year 2015. Colour coding relates to the relative ranking in the full series which spans 1910 - 2015 for all series except CET which is 1659 to 2015.

	UK		England		Wales		Scotland		N Ireland		CET	
	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom
Jan	3.7	0.1	4.3	0.2	4.5	0.3	2.5	-0.1	3.7	-0.5	4.4	0.0
Feb	3.5	-0.1	3.9	-0.2	3.5	-0.5	2.9	0.2	3.9	-0.4	4.0	-0.4
Mar	5.5	0.1	6.2	0.0	5.5	-0.2	4.4	0.2	5.6	-0.3	6.4	-0.2
Apr	7.9	0.5	8.9	0.8	8.4	0.8	6.3	0.2	7.7	0.1	9.0	0.5
May	9.6	-0.8	10.8	-0.4	9.8	-0.8	7.6	-1.2	9.1	-1.1	10.8	-0.9
Jun	12.7	-0.3	13.9	-0.1	13.0	-0.2	10.6	-0.7	12.3	-0.5	14.0	-0.5
Jul	14.4	-0.7	15.8	-0.5	14.4	-0.8	12.2	-1.0	13.3	-1.3	15.9	-0.8
Aug	14.7	-0.2	15.9	-0.2	14.4	-0.6	12.9	-0.1	13.6	-0.7	15.9	-0.5
Sep	11.9	-0.8	12.6	-1.1	11.8	-1.1	10.8	-0.1	11.8	-0.6	12.6	-1.4
Oct	10.0	0.5	10.7	0.4	10.1	0.3	8.7	0.8	9.8	0.4	11.0	0.3
Nov	8.2	2.0	9.2	2.4	9.1	2.4	6.2	1.2	7.9	1.5	9.5	2.4
Dec	7.9	4.1	9.4	5.0	9.2	4.7	5.4	2.6	6.9	2.4	9.7	5.1
Win	3.9	0.2	4.4	0.2	4.4	0.2	2.9	0.2	4.0	-0.3	4.5	0.0
Spr	7.7	-0.1	8.6	0.1	7.9	-0.1	6.1	-0.3	7.5	-0.4	8.7	-0.2
Sum	13.9	-0.4	15.2	-0.3	13.9	-0.5	11.9	-0.6	13.1	-0.8	15.3	-0.6
Aut	10.0	0.6	10.8	0.5	10.3	0.5	8.6	0.6	9.8	0.4	11.0	0.4
Ann	9.2	0.4	10.2	0.5	9.5	0.4	7.6	0.2	8.8	-0.1	10.3	0.3

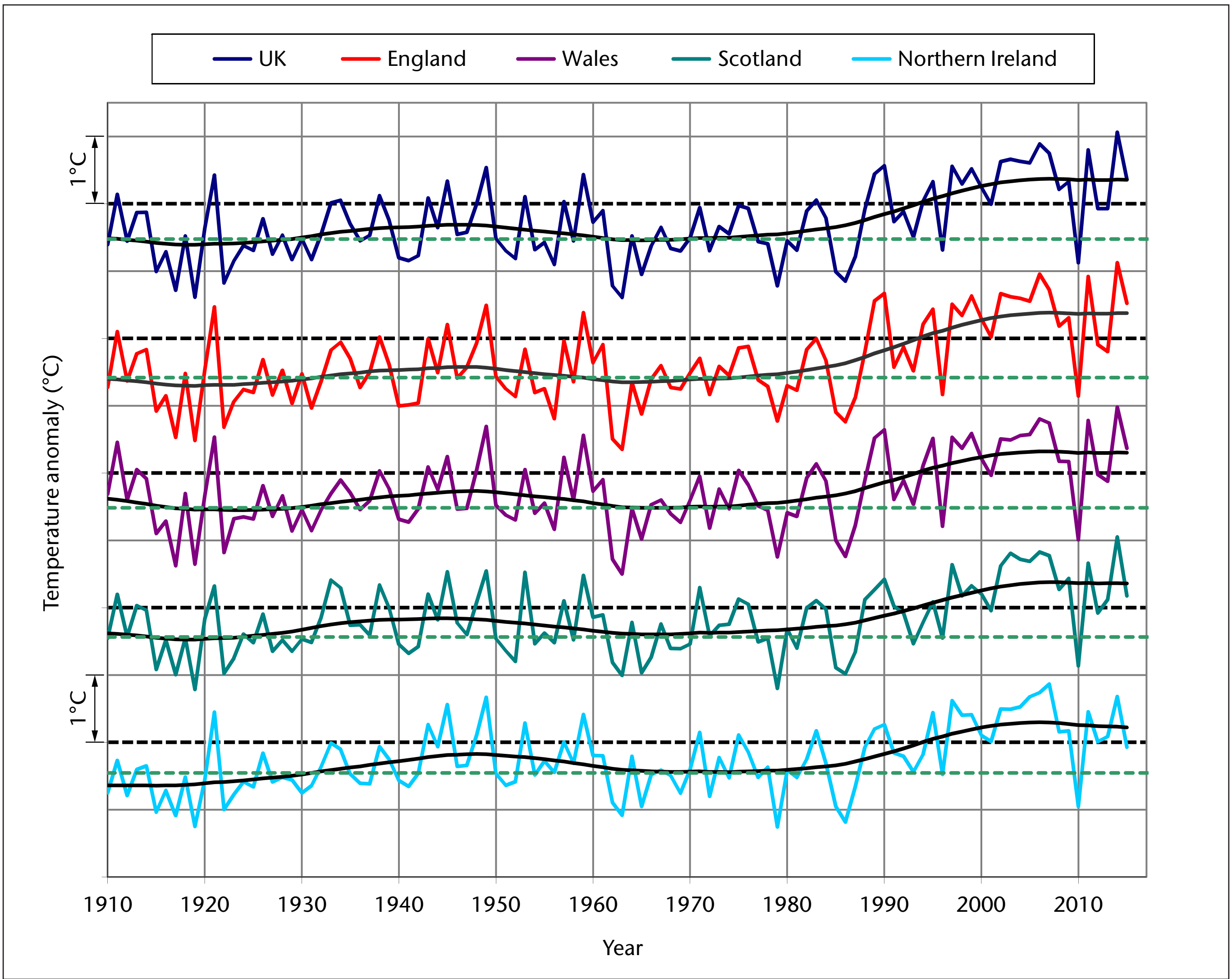
Key							
	Warmest on Record	Top ten warm	Warm: Ranked in upper third of all years	Mid: Ranked in middle third of all years	Cool: Ranked in lower third of all years	Top ten cold	Coldest on record

Figure 4 shows time series of annual Tmean anomalies for the UK and countries from 1910 to 2015 inclusive and Figure 5 the seasonal UK Tmean anomaly series. There is an increase in temperature from the 1970s to the 2000s with the most recent decade (2006–2015) being on average 0.9 °C warmer than the 1961–1990 average and 0.3 °C above 1981–2010.* All of the top ten warmest years in the UK Tmean series have occurred since 1990 and the eight warmest years have all occurred since 2002. Year 2015 is ranked 16th and for the UK overall lies directly on the smoothed trend-line (Figure 4). Nevertheless, while year 2015 might be considered near normal in comparison to the most recent decade, it would still be a notably warm year compared to the first eight decades of the series; from 1910 to 1990 only six other years were comparable to or warmer than 2015. Nevertheless, despite the warming trend, year 2010 (ranked 12th coldest in the UK series) demonstrates that it is still possible for a recent year to be notably cold.

The largest seasonal change has occurred in spring and autumn with 2006-2015 being 1.0 °C above 1961–1990, and the smallest change in winter with 2006–2015 being 0.6 °C above. Warming has been slightly greater for Tmax than Tmin (Figure 6) resulting in a small increase in the average daily temperature range but to levels similar to those observed in the first half of the 20th Century.

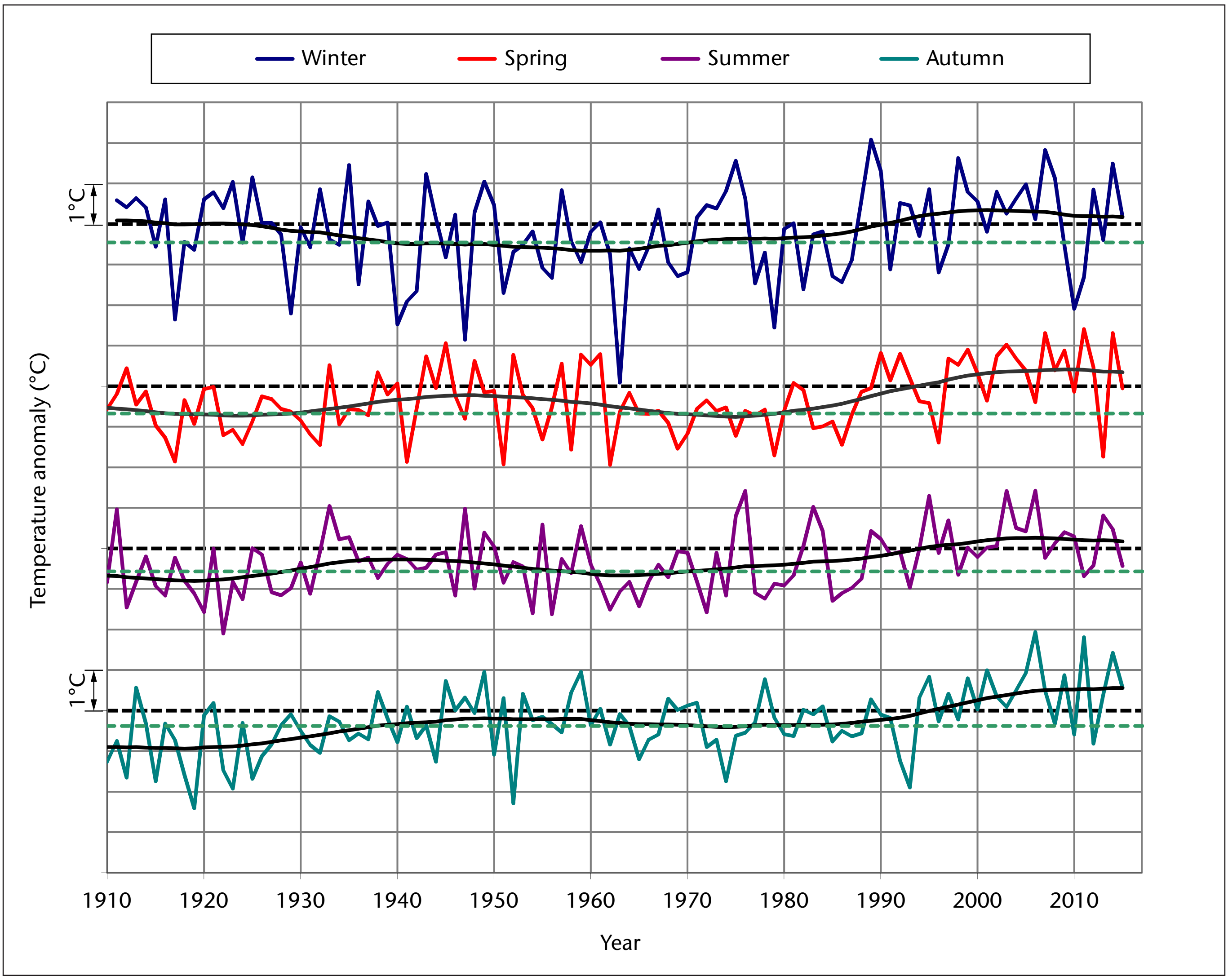
*Note that the UK values for 2006-2015 (9.18 °C) and 1981-2010 (8.84 °C) have been rounded to 9.2 °C and 8.8 °C respectively in the table below Figure 4, whereas their difference (0.34 °C) rounds to 0.3 °C. See also Annex 2 – rounding.

The uncertainty in these statistics is principally a function of the number and distribution of stations in the observing network which varies through time. For monthly, seasonal and annual averages this uncertainty is less than 0.1 °C and consequently much smaller than the year-to-year variability. For simplicity of presentation all the temperature data are presented in the tables to the nearest 0.1 °C. More information relating to the uncertainties and how they are estimated is provided in Annex 2.



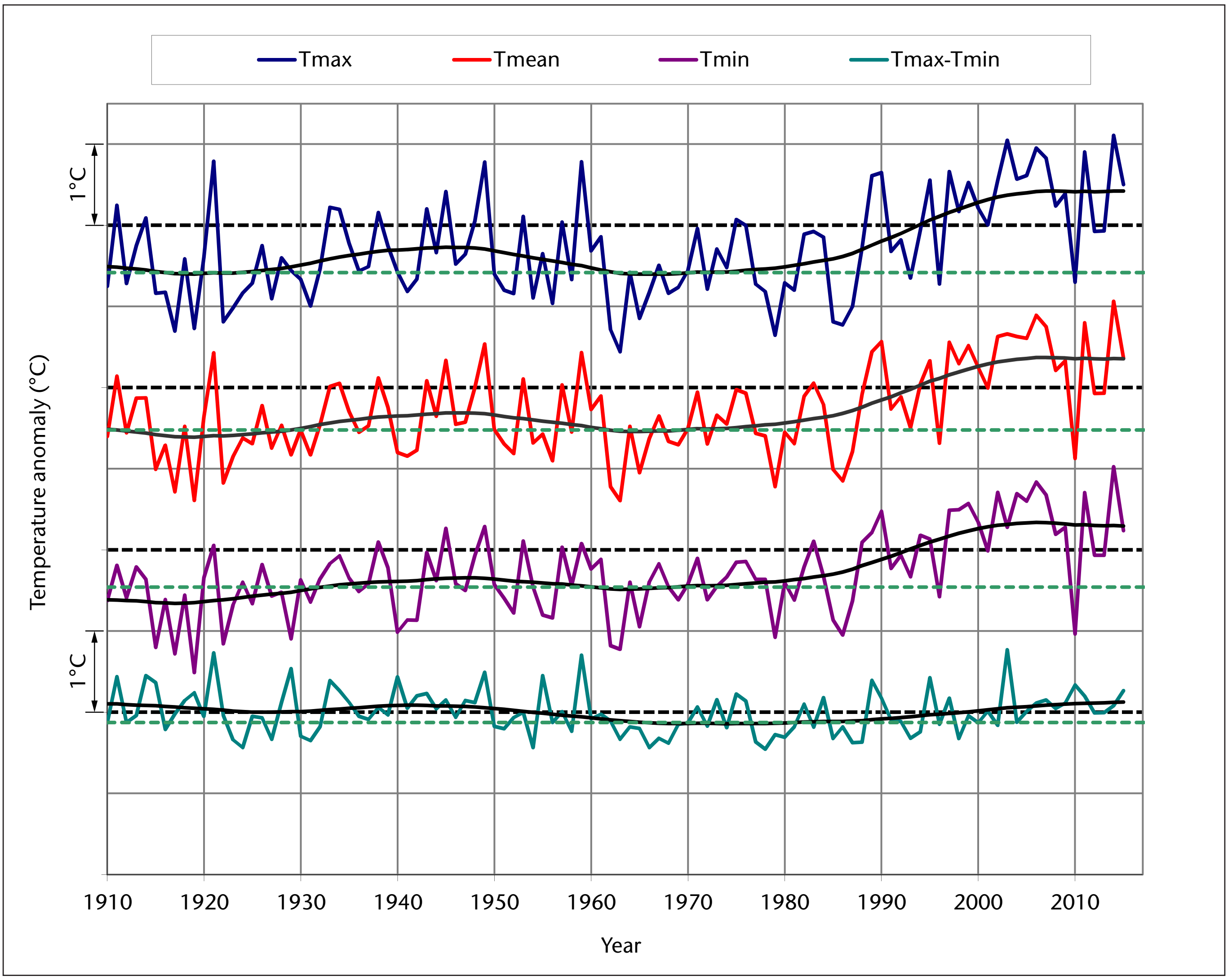
Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK	8.3	8.8	9.2	9.2
England	9.1	9.7	10.0	10.2
Wales	8.6	9.1	9.4	9.5
Scotland	7.0	7.4	7.7	7.6
Northern Ireland	8.4	8.9	9.1	8.8

Figure 4: Annual Tmean for the UK and countries, 1910 to 2015, expressed as anomalies relative to the 1981-2010 average. The hatched black line is the 1981-2010 long-term average. The lower hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 1 °C. The table provides average values (°C). Smoothed trend lines used here and throughout the report are described in Annex 2.



Season	1961-1990 average	1981-2010 average	2006-2015 average	2015
Winter	3.3	3.7	3.9	3.9
Spring	7.1	7.7	8.1	7.7
Summer	13.8	14.4	14.5	13.9
Autumn	9.1	9.4	10.0	10.0

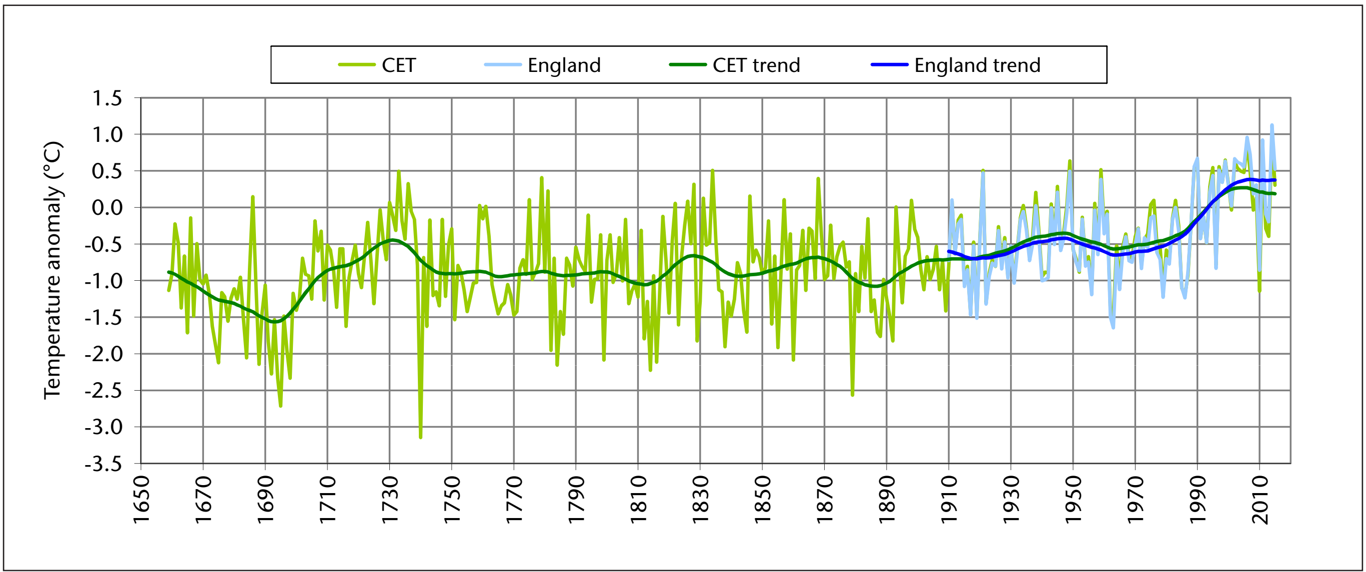
Figure 5: Seasonal Tmean for the UK, 1910 to 2015 (note winter from 1911 to 2015; year is that in which January and February fall. Winter 2016 – which includes December 2015 - will appear in next year's publication). Light grey grid-lines represent anomalies of +/- 1 °C. The table provides average values (°C).



Variable	1961-1990 average	1981-2010 average	2006-2015 average	2015
Tmax	11.8	12.4	12.8	12.9
Tmean	8.3	8.8	9.2	9.2
Tmin	4.8	5.3	5.6	5.5
Tmax minus Tmin	7.0	7.2	7.3	7.4

Figure 6: Annual Tmax, Tmean and Tmin for the UK, and Tmax minus Tmin, 1910 to 2015, expressed as anomalies relative to the 1981-2010 average. Light grey grid-lines represent anomalies of +/- 1 °C. The table provides average values (°C).

Figure 7 shows annual Tmean for England from 1910 to 2015 and CET series from 1659. The series are highly correlated (R^2 value 0.98) and have a root mean square difference of 0.09 °C which is comparable to the estimated series uncertainty as described in Annex 2. The CET series from 1659 could effectively be considered a proxy for an England series from 1659. The CET series provides evidence that the most recent decade is warmer than any decade in the previous three centuries, and that all seasons are also warmer (Figure 8).



Variable	1961-1990 average	1981-2010 average	2006-2015 average	2015
CET	9.5	10.0	10.2	10.3
England	9.1	9.7	10.0	10.2

Figure 7: Annual Tmean for CET series, 1659 to 2015, and England temperature series, 1910 to 2015, expressed as anomalies relative to the 1981-2010 average. The table provides average values (°C).

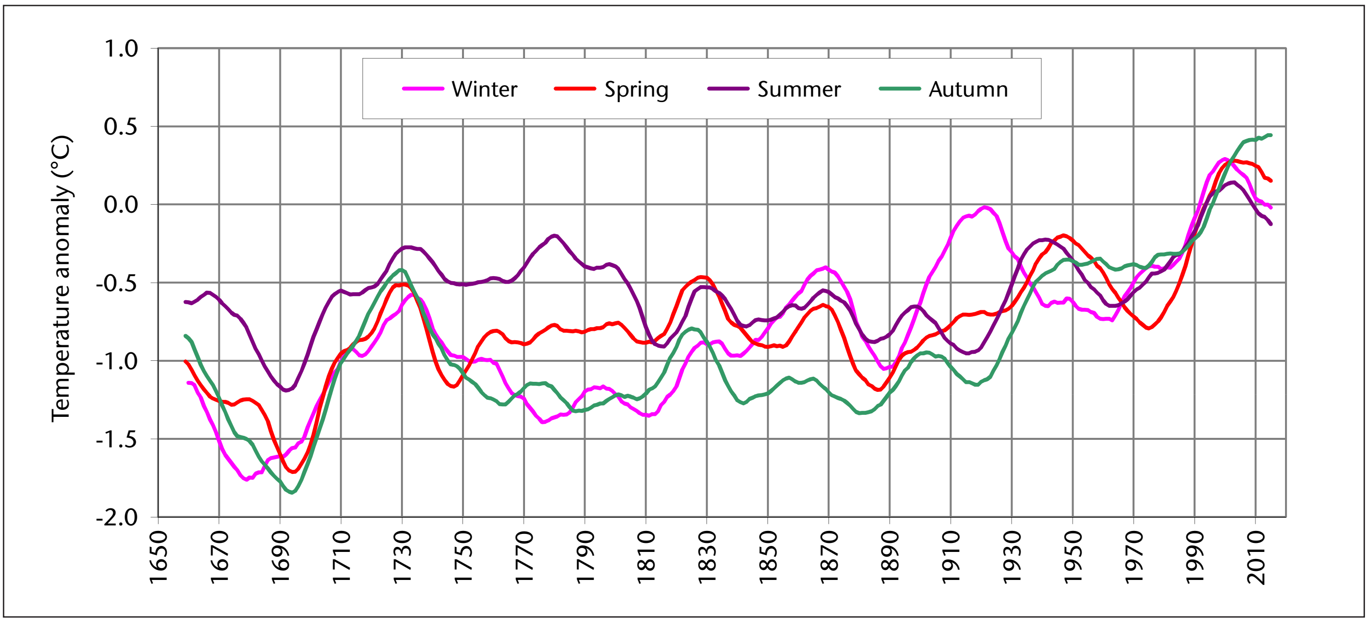


Figure 8: Seasonal CET series, 1659 to 2015, expressed as anomalies relative to 1981-2010 average.
The figure shows a smoothed trend for each series using a weighted filter described in Annex 2.

DAYS OF AIR AND GROUND FROST

The number of days of air frost for the UK for 2015 was 40 days, 14 days below the 1981-2010 average. This was typically between 10 and 20 days below the 1981-2010 average across most areas (for some locations this was over 20 days below), see figure 9. The lack of air frosts was largely due to the exceptionally mild conditions through December, when all but a handful of stations across Wales, central and southern England recorded no air frosts during the month, in comparison to between 10 and 15 days that might be expected based on the 1981-2010 average. November also saw around 3 fewer days of air frost than the 1981-2010 average, whereas the other months of the year were generally near normal.

The number of days of ground frost for 2015 was 89 days, 21 days below the 1981-2010 average. While some locations recorded between 10 and 20 days below the 1981-2010 average, others recorded more than 30 days below, and in general there was more spatial variability compared to air frost (with frost hollow effects at individual weather stations a strong influence) – see figure 9. As with air frost, most of the deficit in ground frost was accounted for by November (UK anomaly -7 days) and December (-12 days), with the other months of the year generally near normal. In contrast to other regions of the UK, Northern Ireland had near average days of air and ground frost during 2015.

The annual numbers of days of air and ground frost for the UK overall for 2015 were ranked equal-seventh lowest (air frost) and fourth lowest (ground frost) respectively in series from 1961 (Figure 10). 2014 was the lowest on record for both variables. There was a decline in both air and ground frosts through the 1980s and 1990s, resulting in the most recent decade, 2006–2015 having had an average of 17% fewer annual days of air frost and 14% fewer ground frosts per year than the average for 1961-1990

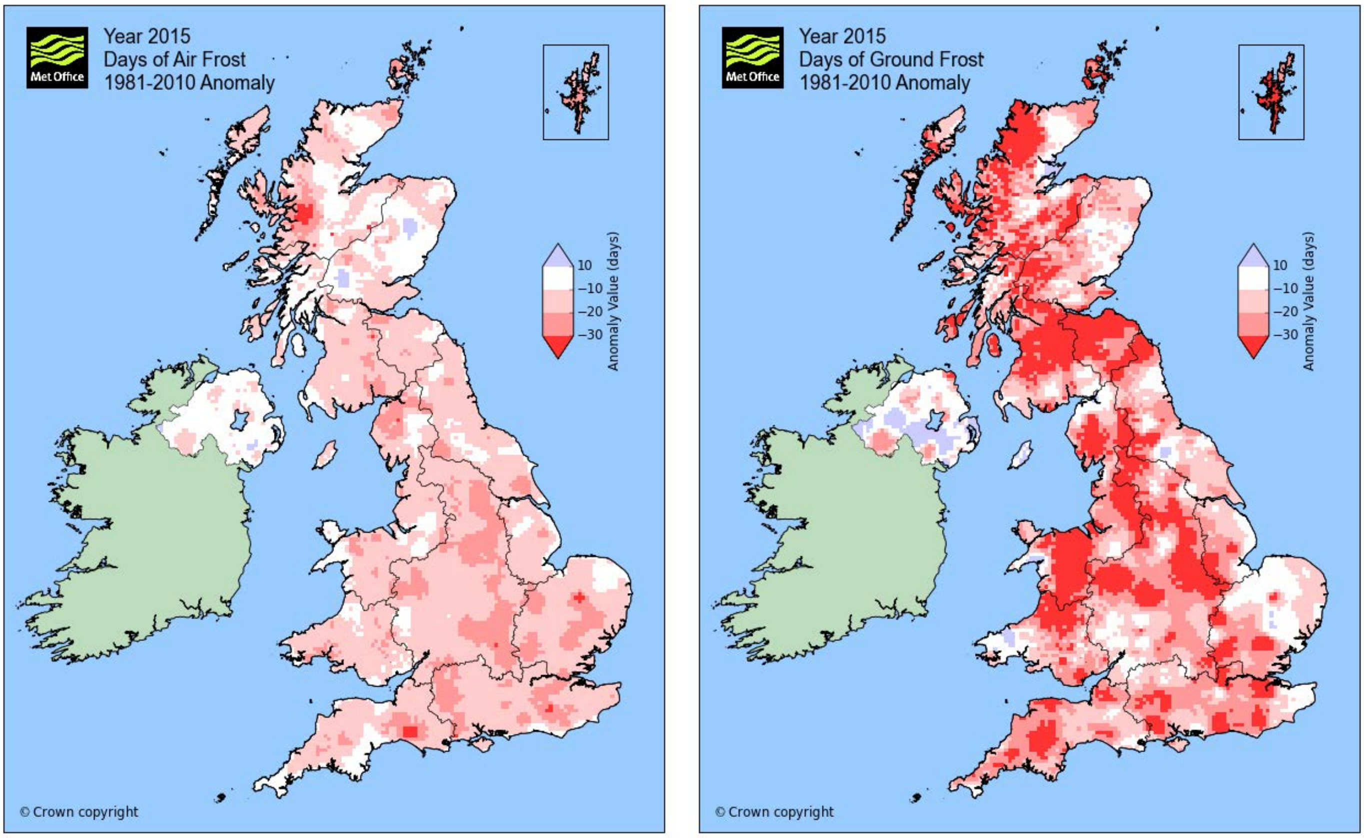
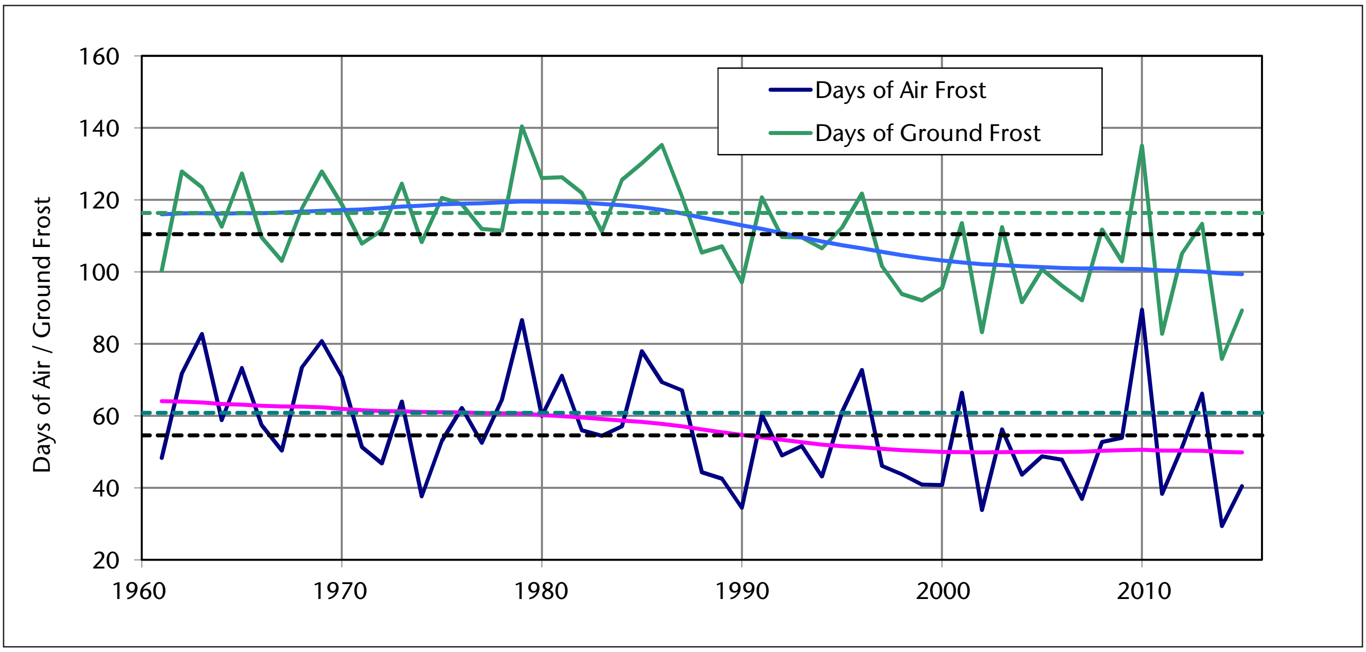


Figure 9: Days of air frost and days of ground frost anomaly for 2015 relative to 1981-2010. See Annex 1 for definitions. Bulls-eye features in these and the Tmin maps are likely to be due to localised factors such as frost hollow effects at individual weather stations which the gridding process is unable to fully represent, particularly for ground frost.



Variable	1961-1990 average	1981-2010 average	2006-2015 average	2015
Days of Air Frost	61	55	51	40
Days of Ground Frost	116	111	100	89

Figure 10: Annual number of days of air frost and ground frost for the UK, 1961 to 2015.
The hatched black lines are the 1981-2010 annual averages. The table provides average values (days).

DEGREE DAYS

A degree day is an integration of temperature over time and is commonly used to relate temperature to particular impacts. It is typically estimated as the sum of degrees above or below a defined threshold each day over a fixed period of time. The standard degree days monitored by the Met Office are heating, cooling and growing degree days which relate to the requirement for heating or cooling of buildings to maintain comfortable temperatures, or the conditions suitable for plant growth respectively. The definitions and thresholds used are described in Annex 1.

Heating degree days (HDD) for 2015 were around 90 to 95% of average across most of England and Wales but nearer average across Scotland and Northern Ireland (Figure 11). Averaged across the UK HDD for 2015 were 95% of the 1981-2010 average and ranked 13th lowest in the series from 1960. The lowest ten HDD years for the UK have all occurred since 1990, with the lowest seven since 2002. Overall HDD for 2015 were unremarkable compared with the most recent decade, and were higher than in 2014 (which was the lowest year on record for the UK (Figure 12)). For the UK, the most recent decade has had an annual average HDD 9% lower than 1961–1990 and 3% lower than 1981–2010. Nevertheless, year 2010 demonstrates that it is still possible for a recent year to have well above HDD values.

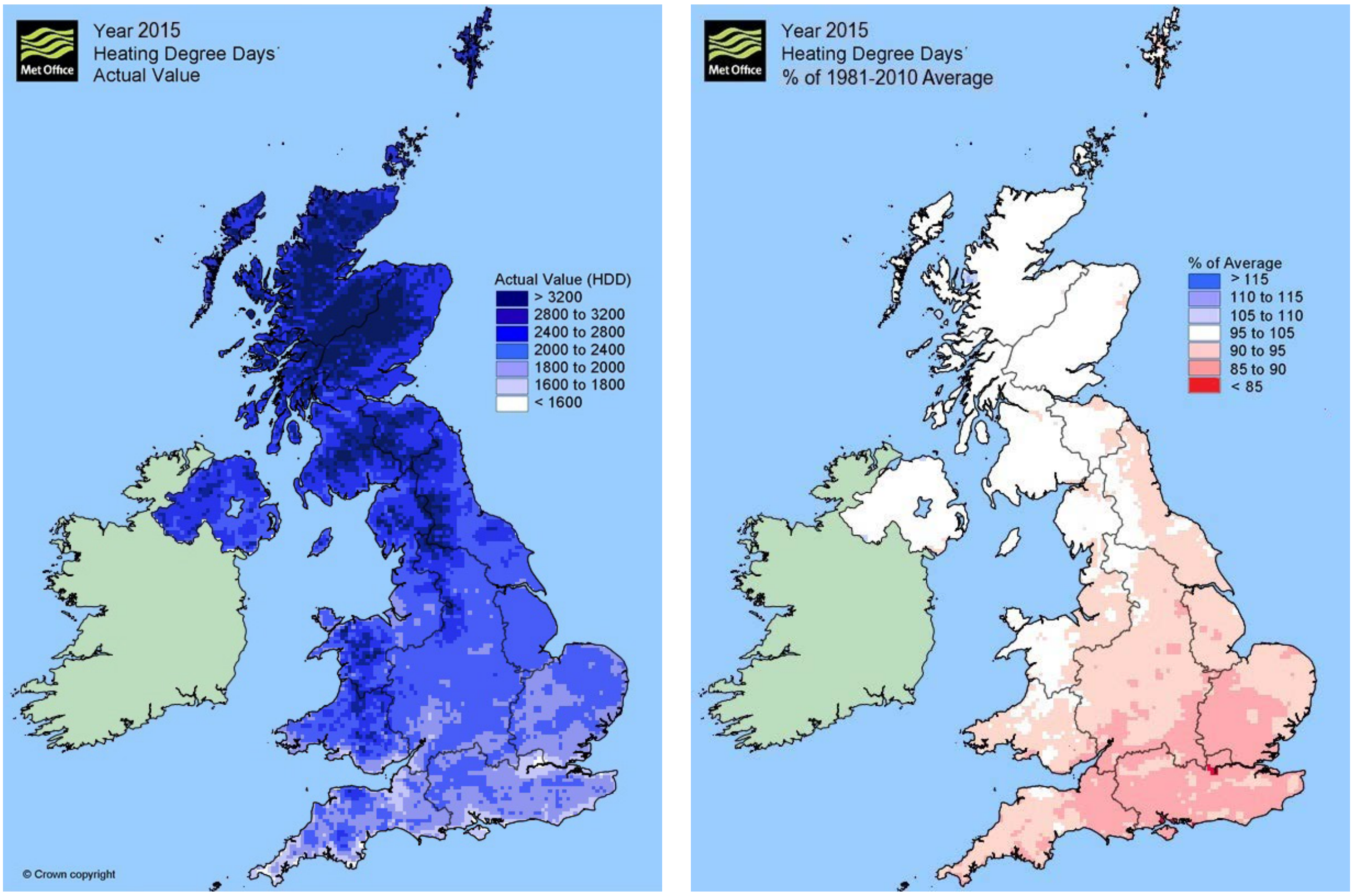
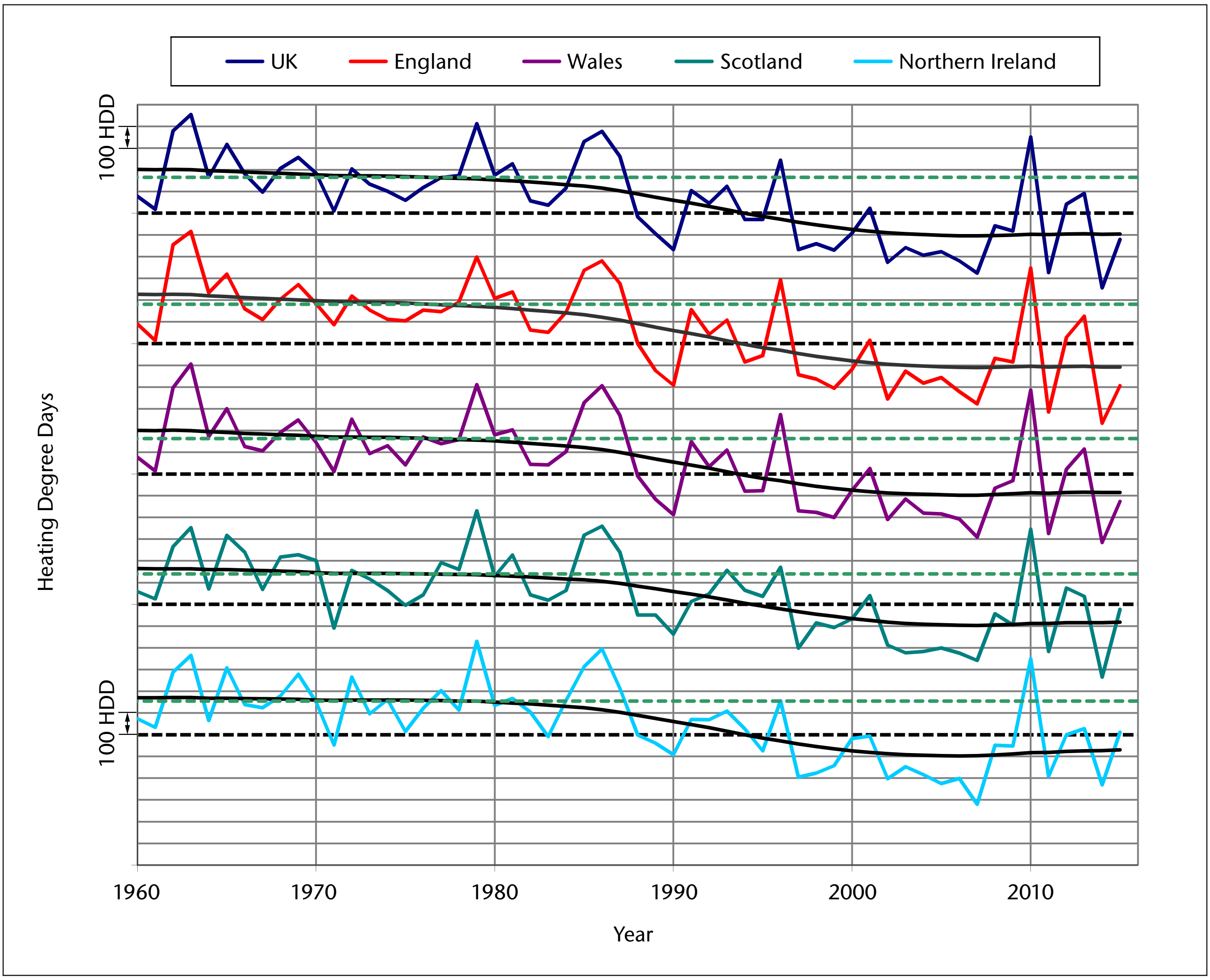


Figure 11: Heating degree days for 2015 (left) actual and (right) % of 1981-2010 average

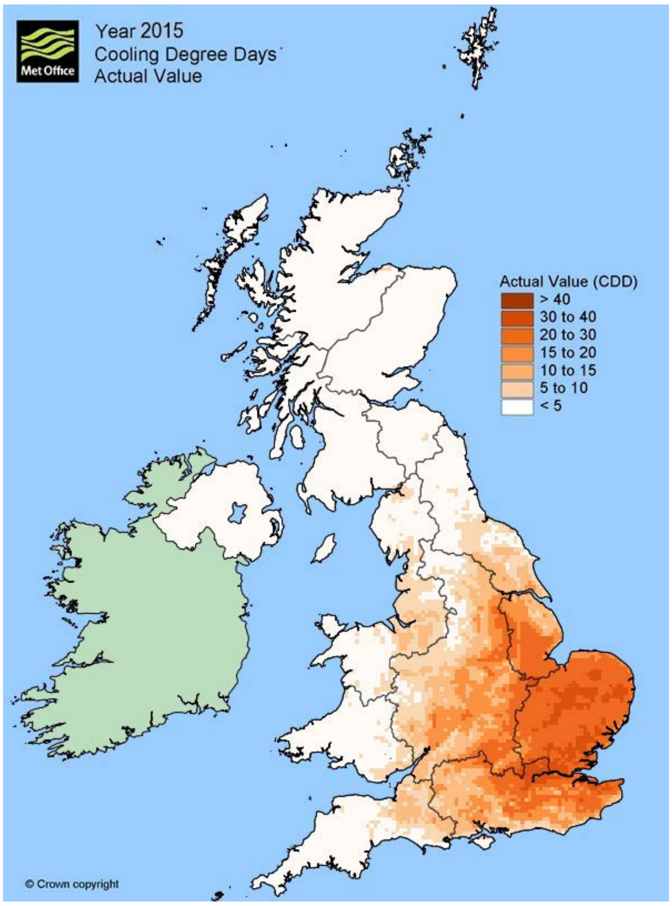


Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK	2731	2566	2477	2445
England	2514	2333	2231	2140
Wales	2609	2446	2368	2320
Scotland	3140	3000	2926	2976
Northern Ireland	2646	2491	2426	2503

Figure 12: Heating degree days for the UK and countries, 1960 to 2015, expressed as an anomaly relative to the 1981-2010 average. The hatched black line is the 1981-2010 long-term average. The hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 100 HDD. The table provides average values (HDD). Please also refer to page 54 correction to State of the Climate 2014 report.

In general, the highest cooling degree day (CDD) values are around Greater London due in part to the urban heat-island effect. Although 2015 was a warmer than average year, UK CDD (8) was well below the 1981-2010 average (13). CDD tend to occur during the warm summer months, but in 2015 the summer was cool. There was a brief heat-wave from the end of June to 1st July associated with a flow of hot, humid air from the near continent, and a further brief spell of warmth during the second half of August, but despite this temperatures for summer overall were below the 1981-2010 average. There were around 10 CDD fewer than average across much of southern England, with the exception of the far east of East Anglia (Figure 13).

The years with high CDD in the time-series across England and Wales (notably 1976, 1995, 2003 and 2006) are those when major heat-waves occurred. The cooler climate of Scotland and Northern Ireland means that CDD are much lower, each with long-term averages of less than 5 CDD. Although there has been a general increase in CDD across England (Figure 14) significant peaks are dependent on when major heat-waves happen to occur. The last year with above-average CDD was 2013, associated with a warm dry spell during July, but otherwise CDD have been notably low from 2007 onwards associated with a run of generally poor summers compared to previous decades.



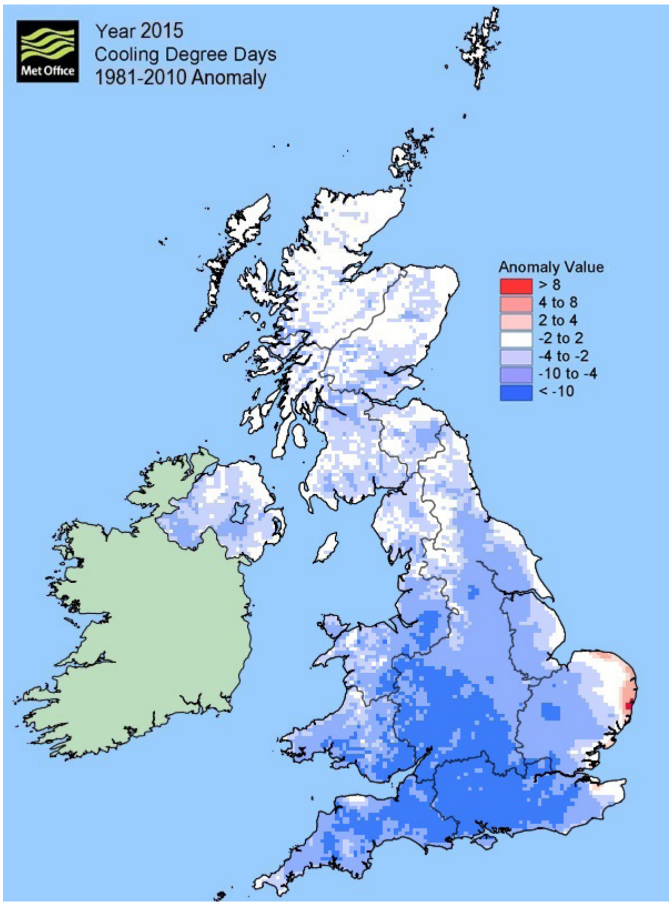
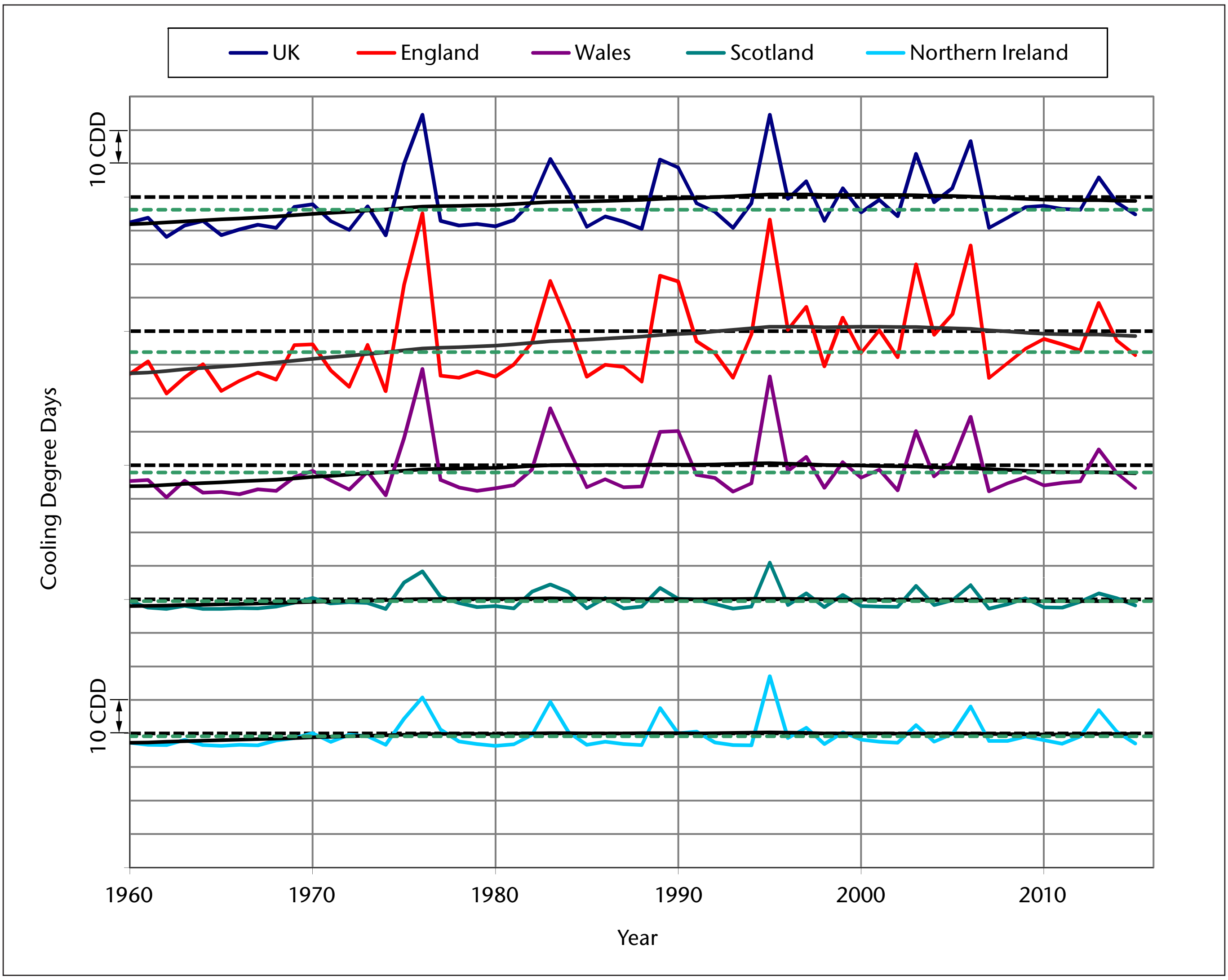


Figure 13: As Figure 11 for cooling degree days for 2015 but the anomaly is presented as a difference from, rather than percentage of, average. This is because 1981-2010 average CDD are close to zero over Highland Scotland.

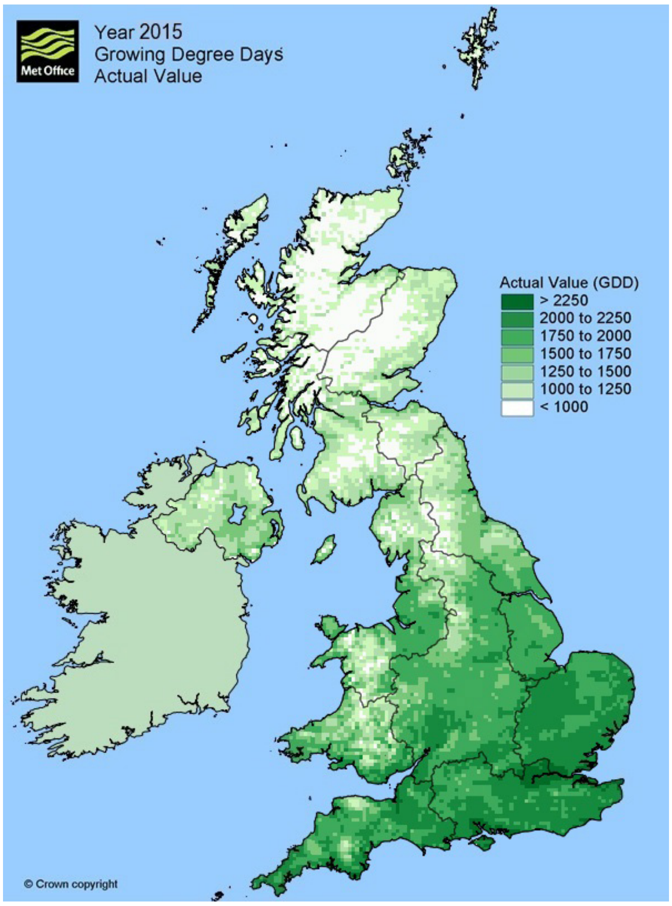


Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK	9	13	12	8
England	14	21	19	13
Wales	8	10	8	3
Scotland	3	3	3	1
Northern Ireland	3	4	4	1

Figure 14: Cooling degree days for the UK and countries, 1960 to 2015, expressed as anomalies relative to the 1981-2010 average. The hatched black line is the 1981-2010 long-term average. The hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 10 CDD. The table provides average values (CDD).

Growing degree days (GDD) for 2015 were within 5% of average across most of the UK, although slightly higher across the south-east and lower across Scotland, reflecting an often rather cool north-westerly influence to the weather during the growing season (Figure 15). UK GDD overall were 101% of the 1981-2010 average.

The most recent decade has had an annual GDD 15% higher than 1961-1990 and 5% higher than 1981-2010, and the similar (downward) trend in HDD and (upward) trend in GDD from 1960 to date each reflect the underlying warming of the UK's climate (Figure 16).



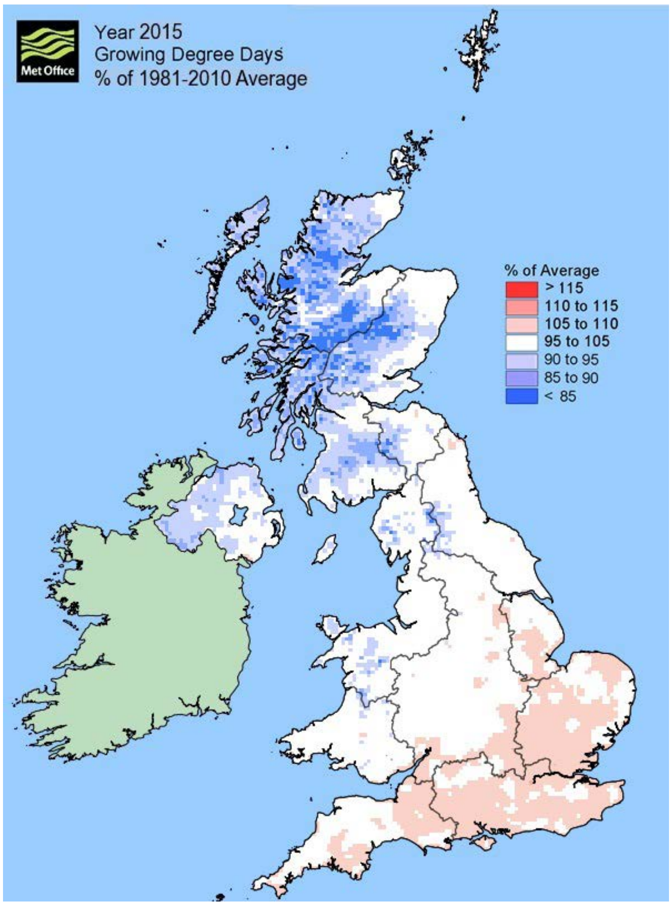
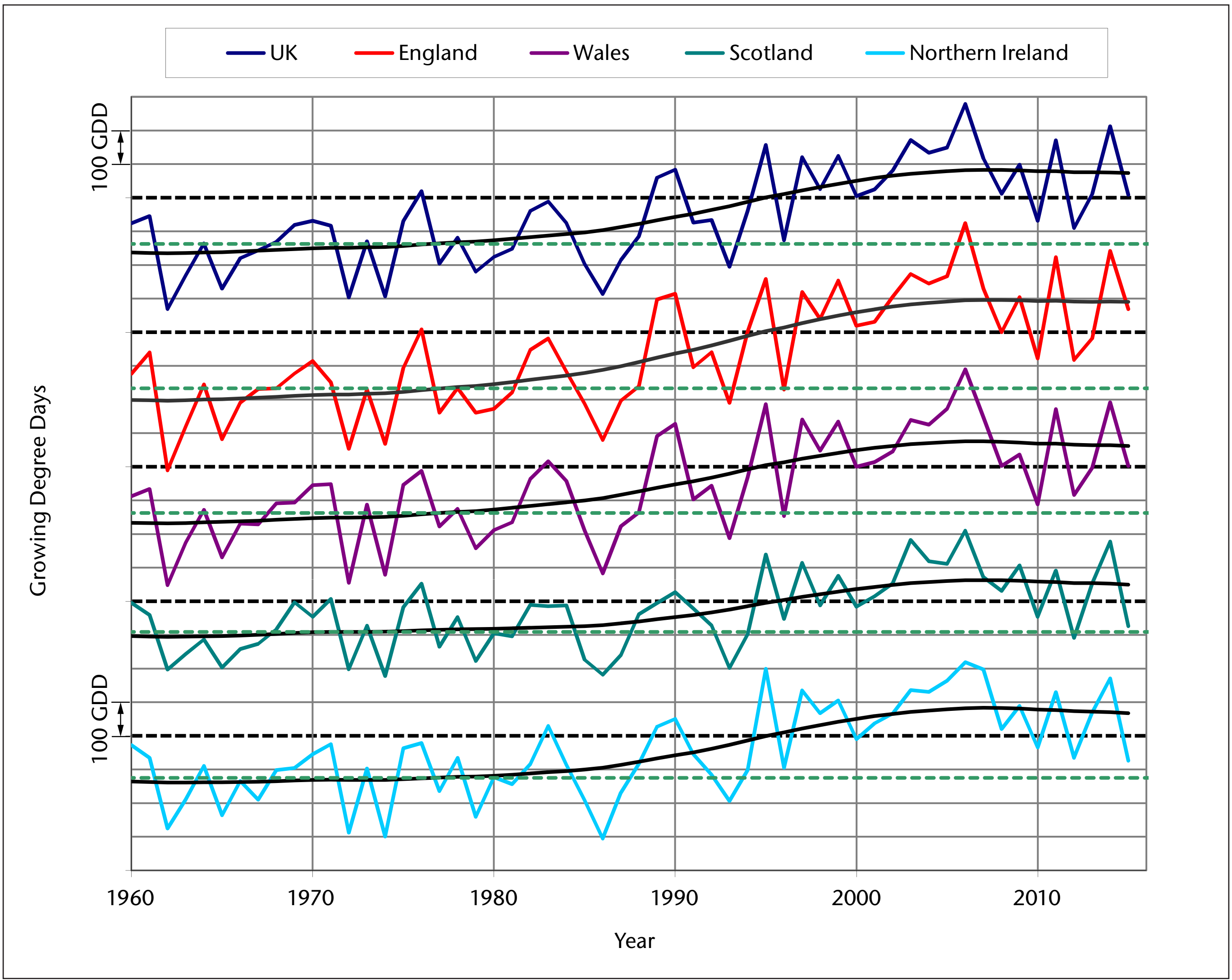


Figure 15: Growing degree days for 2015 (left) actual and (right) % of 1981-2010 average

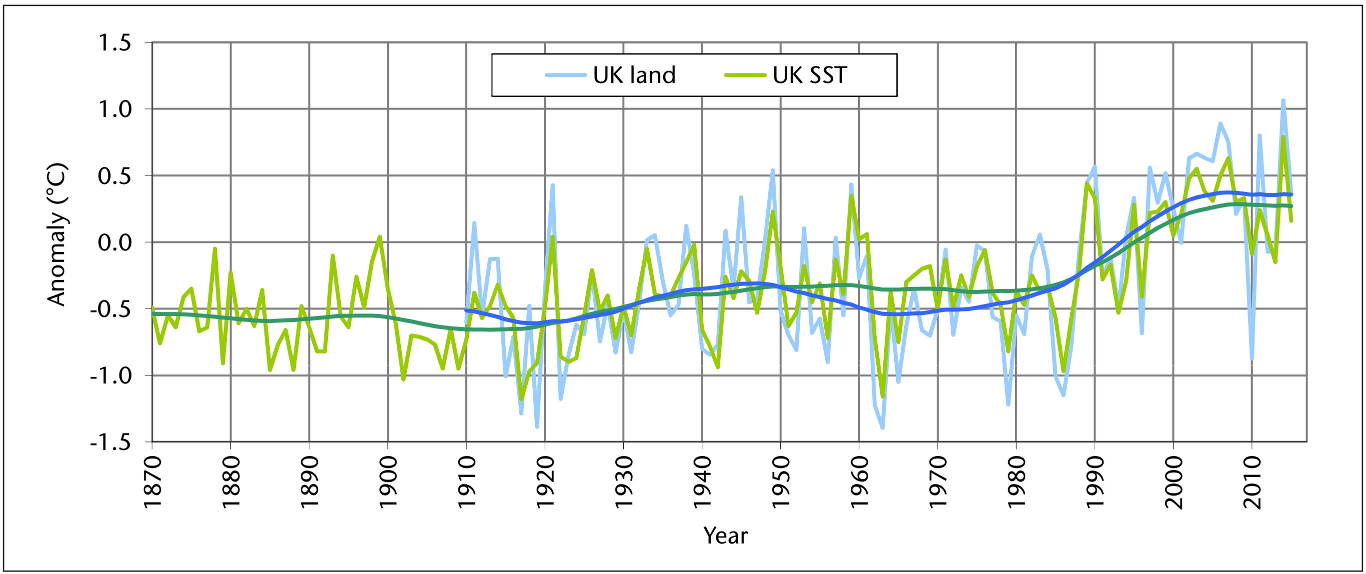


Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK	1403	1541	1616	1549
England	1611	1778	1869	1846
Wales	1457	1594	1658	1596
Scotland	1054	1145	1196	1070
Northern Ireland	1353	1478	1550	1403

Figure 16: Growing degree days for the UK and countries, 1960 to 2015, expressed as anomalies relative to the 1981-2010 average. The hatched black line is the 1981-2010 long-term average. The hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 100 GDD. The table provides average values (GDD).

The annual mean sea-surface temperature (SST) for 2015 for near-coast waters around the UK was 11.6 °C, 0.2 °C above the 1981-2010 long term average and ranked 20th in the series from 1870 (Figure 17).

Near-coast SST data is highly correlated with the land observations, the most recent decade, 2006–2015, is 0.6 °C higher than the 1961–1990 average and 0.3 °C above 1981–2010. As with the UK annual mean air temperature over land, the 2015 annual mean near-coast SST was near normal in comparison to the most recent decade, but would be considered a warm year compared to the first 12 decades of the series; from 1870 to 1990 only four other years were comparable to or warmer than 2015, including 1989 and 1990. Nine of the ten warmest years in the series have occurred since 1989, the other year being 1959 which is also ranked 14th in the UK land series.



Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK land	8.3	8.8	9.2	9.2
UK near-coast SST	11.1	11.5	11.7	11.6

Figure 17: UK annual mean temperature over land 1910 to 2015 and UK annual mean sea surface temperature across near-coastal waters around the UK 1870 to 2015, expressed as anomaly relative to the 1981-2010 long term average. The table provides average values (°C).

Precipitation

2015 was the seventh wettest year in the UK rainfall series from 1910, with 1272mm, 110% of the 1981-2010 average, but not as wet as the previous year 2014 (1301mm). The wettest parts of the country were across Scotland, Northern Ireland, much of northern England and parts of west Wales and the south-west, with many upland areas receiving 125% or more (Figure 18). The wettest observed location from the official network was a monthly raingauge at Styhead, Cumbria (335 masl) with 6056mm, 133% of the 1981-2010 average. However, the rainfall anomaly pattern during 2015 was markedly different to that for the previous year, and in contrast to 2014, much of 'lowland England' – i.e. central, southern and eastern areas, and parts of north-east Scotland, received below-average rainfall – typically around 85 to 95%, with some locations less. The driest locations in Lincolnshire received less than 450mm (around 74% of the 1981-2010 average).

Figures 19 and 20 and Table 2 show seasonal and monthly rainfall across the UK for 2015. April and June were dry months across most of England and Wales with less than half the average rainfall widely in these areas, and it was similarly dry in September and October in the north-west. September was equal-fifth driest for Scotland in the series, although not as dry as September 2014. In contrast, January and May were wet months in the north and north-west; January was a particularly wet month across Shetland with 200% of the 1981-2010 average, where it was the wettest January in a series from 1910. In May, it was the turn of Orkney which received 258% of average rainfall, again the wettest May in the series and part of a particularly cool wet early summer in this area (more details are provided in the significant weather section (p45 of this report). More than twice the average rain fell across parts of East Anglia and eastern Scotland in July, and across southern coastal counties in August, the latter unfortunately coinciding with the school summer holidays.

There was plenty of dry, settled weather through September and October and despite the onset of persistent wet weather during November, the UK rainfall total for January to November was still near normal at 1054mm, 102% of the 1981-2010 long term average. However from mid-November through December well over twice the average rainfall fell across northern and western areas from a succession of Atlantic storms. Six named storms brought persistent, heavy and in some cases record-breaking rainfall across these areas resulting in extensive severe flooding. More details are provided in the significant weather section (p48 of this report).

November was the second-wettest month in series from 1910 across north-west England and North Wales and western Scotland, with only November 2009 wetter. December saw up to four times the monthly average rainfall in some locations and was the wettest calendar month in the UK series from 1910. For north-west England and North Wales the December 2015 rainfall total was 33% higher than the previous December record in the series from 1910. The UK rainfall total increased from 1054mm for January to November (near-average) to 1272mm, 110% of average for the year overall, seventh-wettest year in the series, with December rainfall accounting for around one-sixth of the UK annual total; for the wettest areas, this proportion was closer to one-quarter.

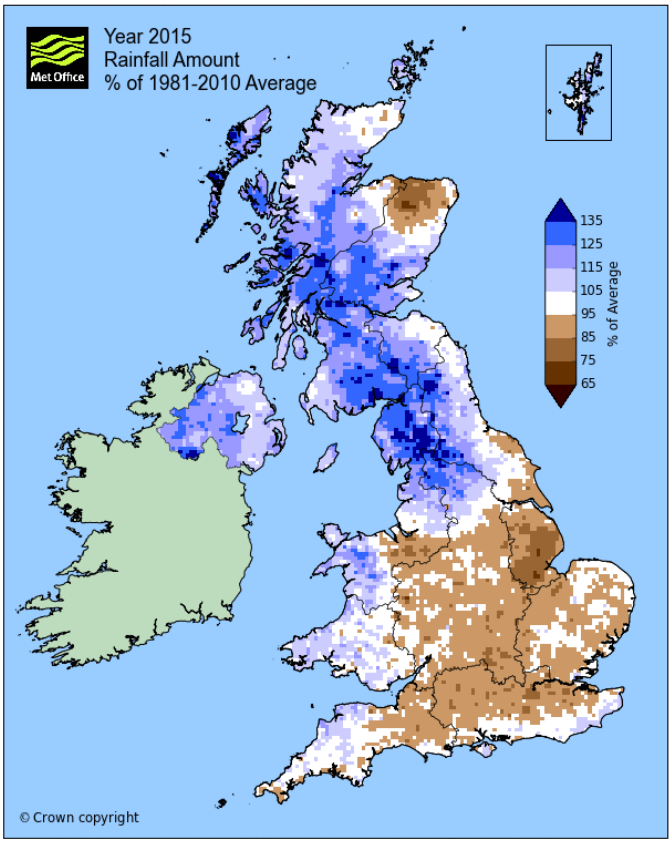


Figure 18: Rainfall anomalies (%) for year 2015

Seasonal rainfall patterns for winter and spring 2015 showed a marked north-west to south-east rainfall gradient with rainfall totals for the six month period December 2014 to May 2015 exceeding 2000mm across upland areas of Cumbria and western Scotland, compared to less than 200mm across parts of eastern England (such as the Vale of York). Summer 2015 overall was rather cool and wet, despite plenty of dry weather in June and for the UK wetter than summer 2013 or summer 2014. Autumn overall was relatively dry in the south and northern Scotland but wet across northern England, the area worst affected by the named storms. Winter 2016 (December 2015 to February 2016) will be described in next year's publication.

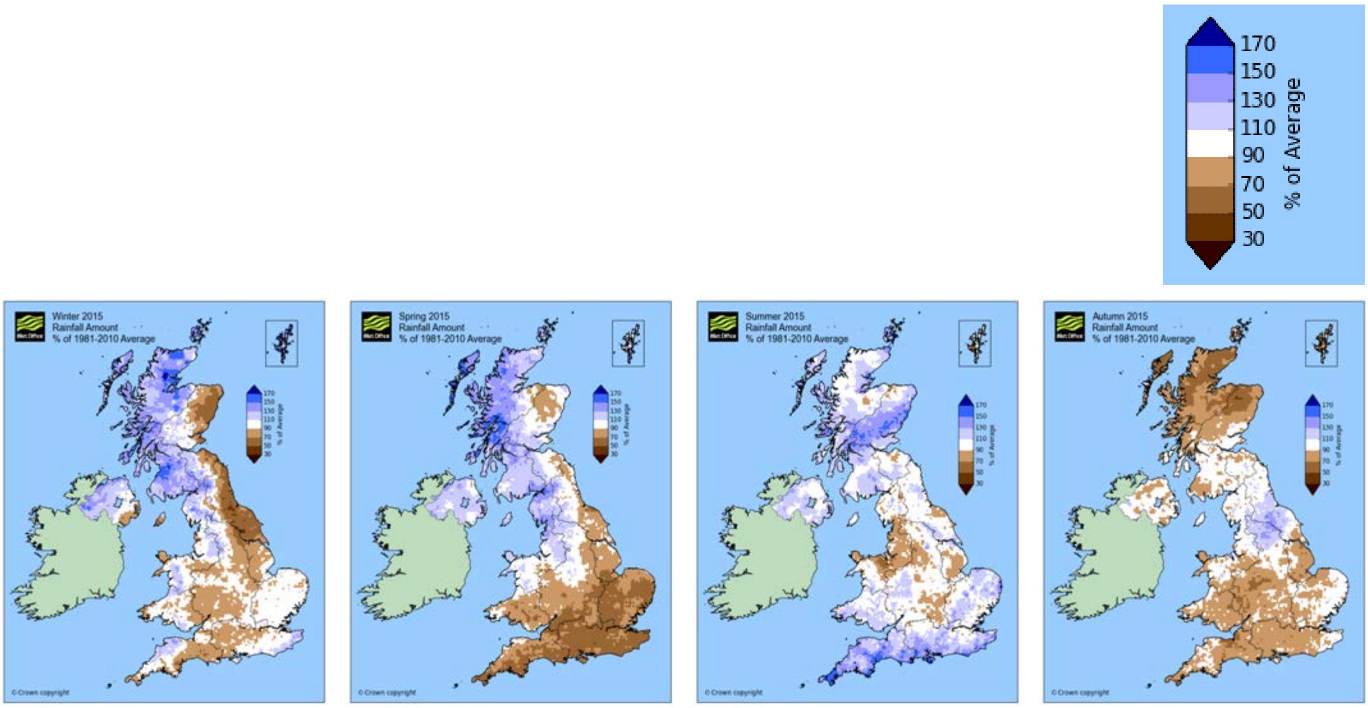
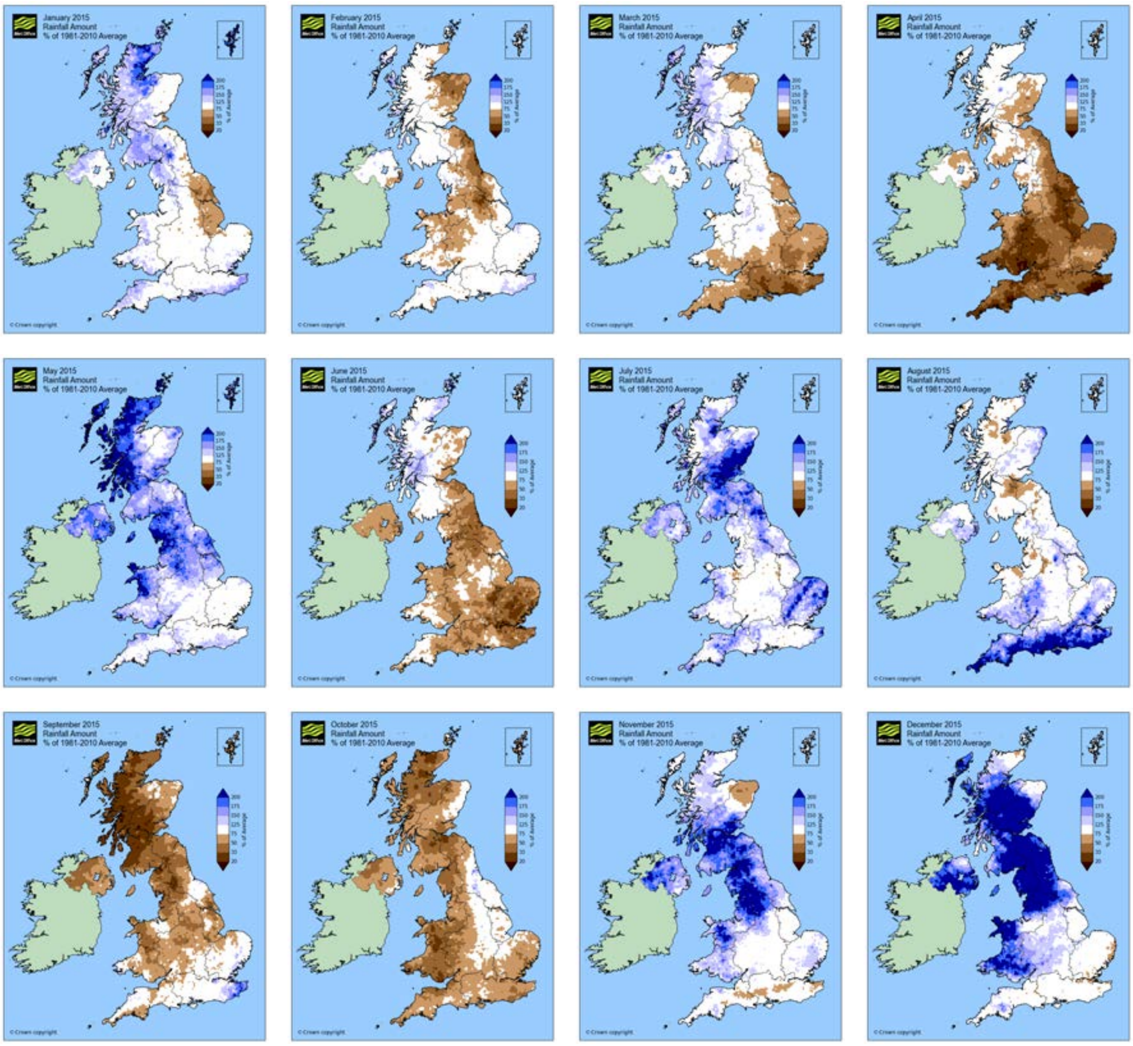


Figure 19: Rainfall anomalies (%) for seasons of 2015. Winter refers to the period December 2014 to February 2015. Note that winter 2016 (December 2015 to February 2016) will appear in next year's publication.



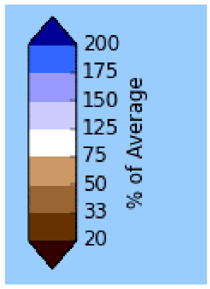


Figure 20: Rainfall anomalies (%) for months of 2015. (Note that Figure 41 shows December with a revised legend scale).

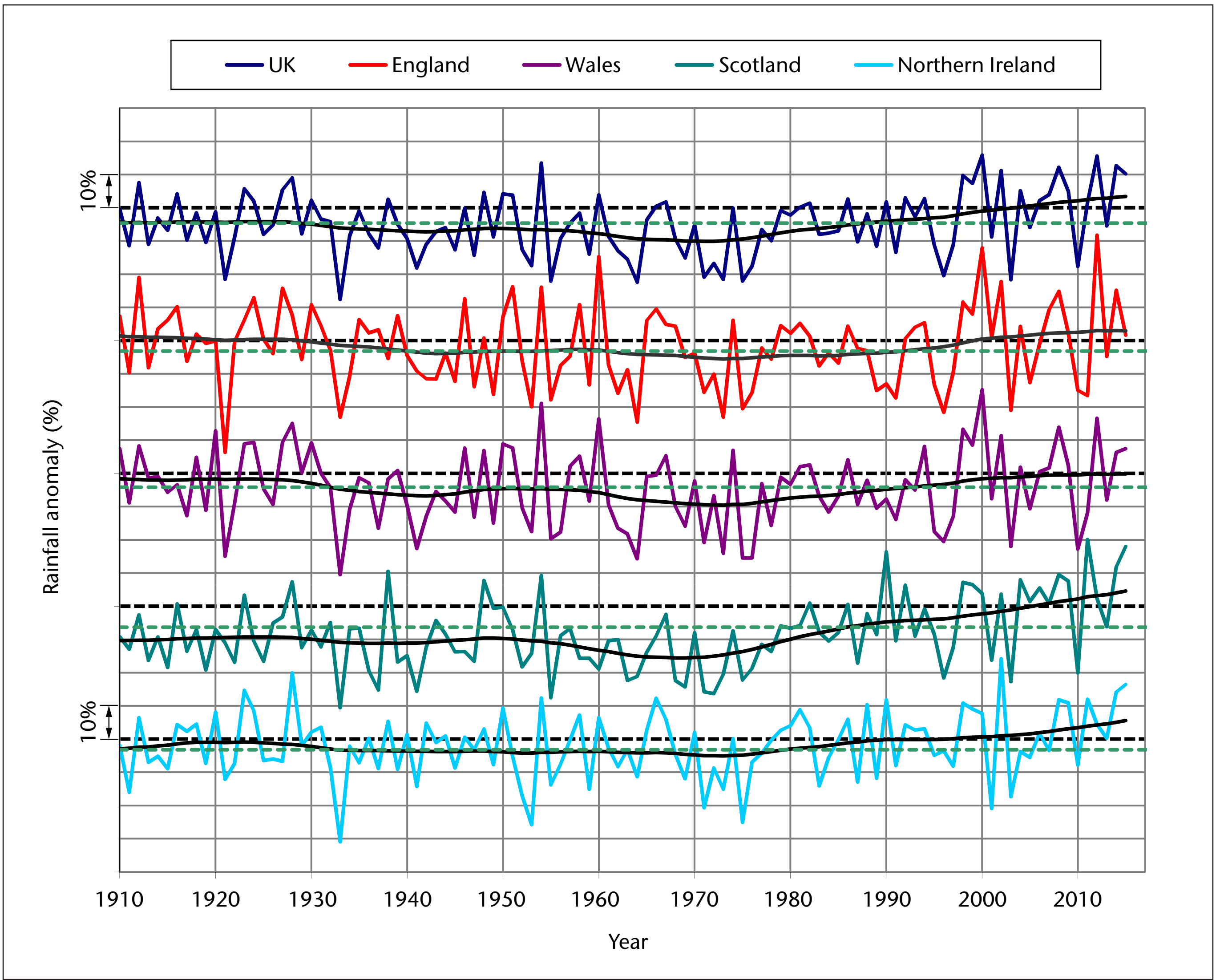
The storms from mid-November brought extensive flooding of national significance but otherwise flood incidents during the year were relatively localised. Persistent wet weather across western Scotland in early March, coinciding with snow-melt, caused some flooding problems and landslides. Lightning strikes and large hail-stones from thunderstorms associated with the brief heat-wave at the start of July caused some damage and disruption, and on 5th July two walkers were killed by lightning strikes in the Brecon Beacons. A vigorous depression in mid-July brought flooding across Perthshire with the town of Alyth particularly badly affected, and thunderstorms in mid-July also caused flash-flooding to parts of Hertfordshire, Cambridgeshire and Norfolk (the rainfall from these storms can clearly be seen on the July rainfall anomaly map figure 20). There was further localised flash-flooding from torrential downpours through mid to late August. Other flood incidents through the year were generally minor in nature until mid-November.

Table 2: Monthly, seasonal and annual rainfall actual (mm) and anomaly values (%) relative to 1981 – 2010 for the UK, countries and EWP for year 2015. Colour coding relates to the relative ranking in the full series which spans 1910 - 2015 for all series except EWP which is 1766 – 2015.

	UK		England		Wales		Scotland		N Ireland		EWP	
	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom
Jan	154	127	92	110	187	119	252	142	142	122	101	109
Feb	80	91	53	87	87	79	125	96	83	99	59	89
Mar	96	100	48	76	97	83	172	122	101	106	51	72
Apr	46	63	26	44	35	39	79	87	61	81	28	43
May	110	158	80	136	136	158	152	180	124	171	87	136
Jun	57	77	35	57	59	69	93	104	46	60	39	58
Jul	108	138	79	127	114	123	152	152	120	148	92	137
Aug	105	117	92	133	129	120	117	100	120	123	109	144
Sep	52	54	51	73	72	62	50	37	46	51	63	81
Oct	72	57	60	66	72	42	93	53	69	58	68	66
Nov	173	143	118	134	246	152	242	145	190	169	127	126
Dec	219	182	134	154	335	202	328	201	220	192	146	150
Win	367	111	219	95	434	100	596	127	370	118	238	92
Spr	252	106	154	85	268	92	403	127	286	118	166	83
Sum	270	112	207	107	302	106	361	118	286	112	240	115
Aut	298	86	229	92	390	87	384	80	306	95	258	92
Ann	1272	110	869	102	1569	107	1854	118	1323	116	970	102

Key							
	Wettest on record	Top ten wettest	Wet: Ranked in the upper third of all years	Mid: Ranked in middle third of all years	Dry: Ranked in lower third of all years	Top ten driest	Driest on Record

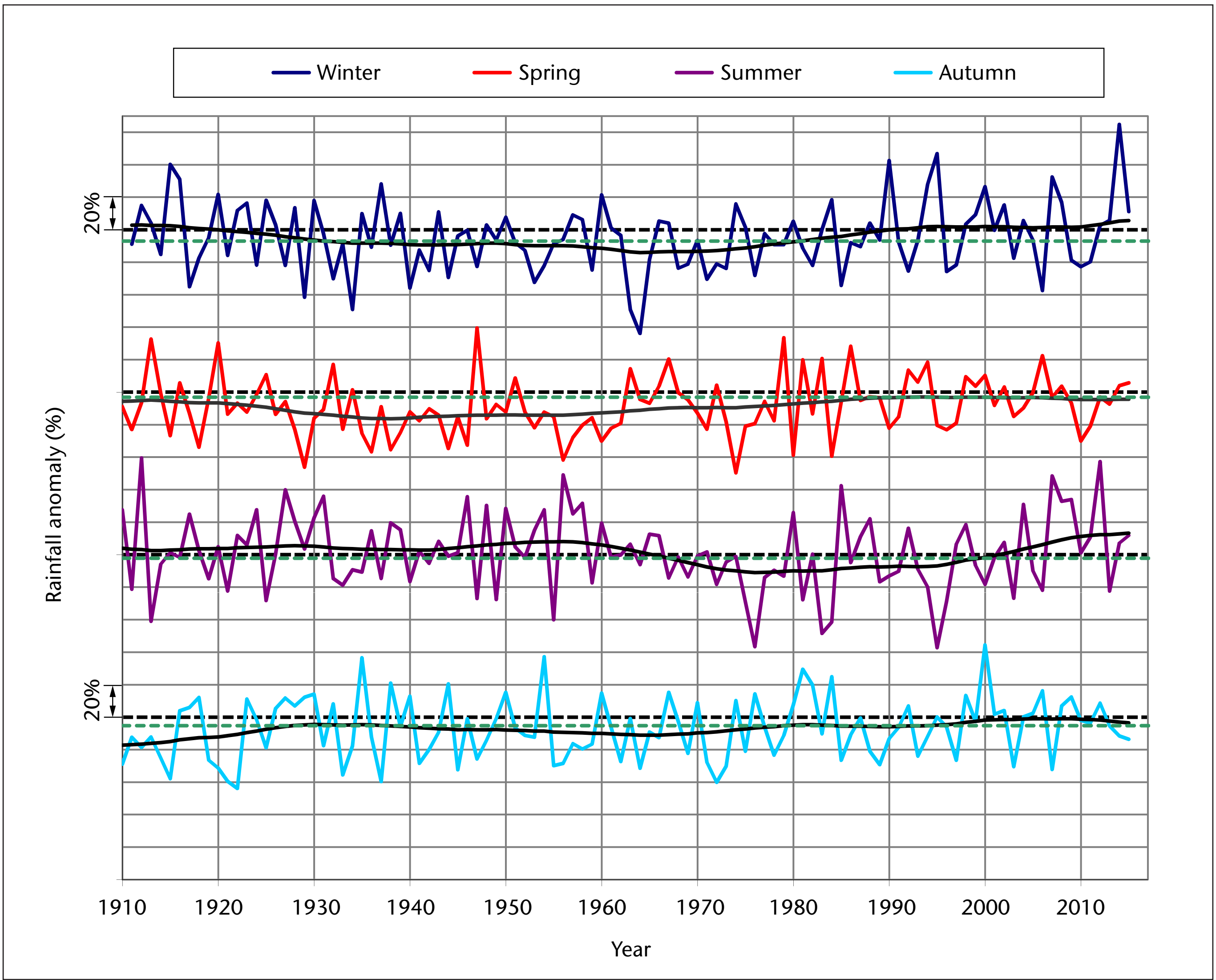
The precipitation data show a slight increasing trend from the 1970s onwards (Figure 21) that is most pronounced for Scotland for which the most recent decade (2006–2015) has been on average 12% wetter than 1961–1990 and 5% wetter than 1981-2010. The wettest years for the UK overall are 2000 and 2012 (both 116% of average) and the driest 1933 (72%). 2015 was the seventh-wettest year in the UK series from 1910, and six of the seven wettest years in the UK series have occurred since 2000.



Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK	1101	1154	1201	1272
England	828	855	887	869
Wales	1400	1460	1469	1569
Scotland	1472	1571	1649	1854
Northern Ireland	1099	1136	1205	1323

Figure 21: Annual rainfall, 1910 to 2015, expressed as a percentage of 1981-2010 average. The hatched black line is the 1981-2010 long-term average. The lower hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 10%. The table provides average values (mm).

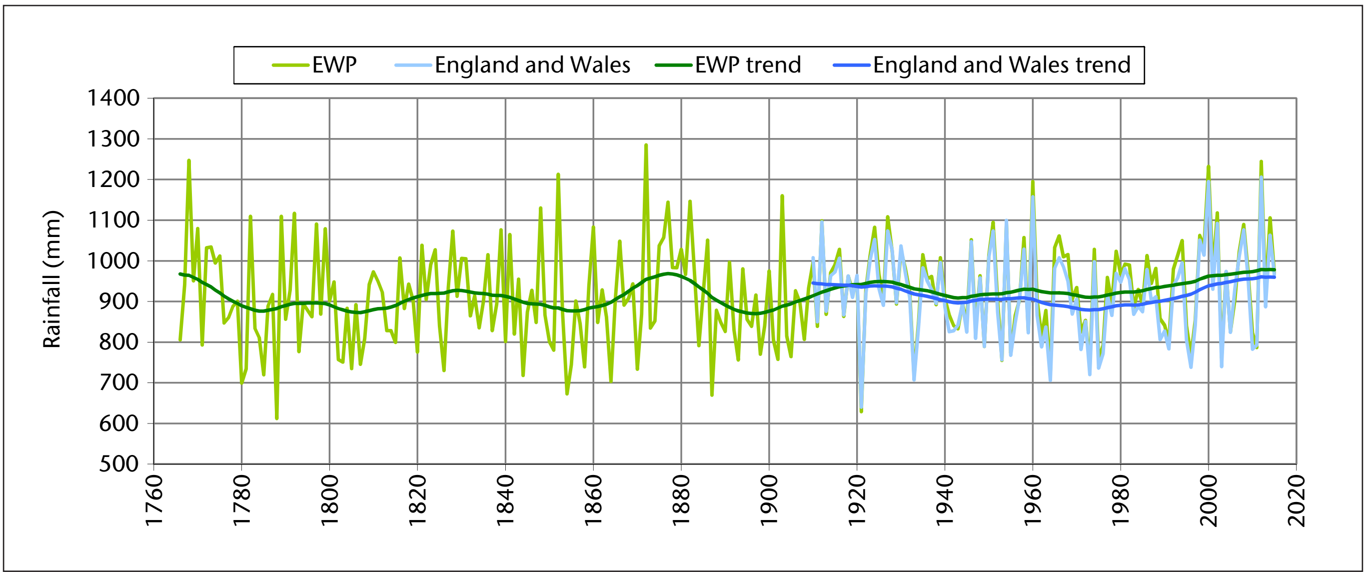
Figure 22 shows seasonal rainfall series for the UK from 1910 to 2015 (for winter 1911 to 2015). Of particular note is the sequence of recent wet summers from 2007, with only that of 2013 drier than average for the UK and four of these summers exceeding 130% of average for the UK overall.



Season	1961-1990 average	1981-2010 average	2006-2015 average	2015
Winter	308	330	342	367
Spring	231	238	229	252
Summer	236	241	279	270
Autumn	327	345	336	298

Figure 22: Seasonal rainfall for the UK, 1910 to 2015 (note winter from 1911 to 2015; year is that in which January and February fall. Winter 2016 – which includes December 2015 - will appear in next year's publication). Light grey grid-lines represent anomalies of +/- 20%. The table provides average values (mm).

The annual rainfall total for 2015 in the England and Wales precipitation (EWP) series from 1766 was 970mm, 102% of average with drier than average conditions across lowland England offsetting wetter conditions across upland areas of Wales and northern England. Overall this made 2015 a near-average year in the EWP series - contrasting with the UK overall where 2015 was a notably wet year – a consequence of the omission of Scotland and Northern Ireland from the EWP series. Figure 23 shows there are some notable decadal fluctuations in the series such as a wet period through the 1870s, and the 'Long Drought' from 1890 to 1910 (Marsh et al, 2007) highlighting the value of rainfall series before the 20th Century for understanding the full historical context of UK rainfall. The most recent decade is a relatively wet decade in this series. The England and Wales areal rainfall series based on 5km resolution gridded data is closely correlated to EWP, with an R^2 value of 0.97 and root mean square difference of 2.0%. Minor differences between the series are inevitable due to the more limited sampling of stations used for the EWP series and the gridding method used for the England and Wales areal series.



Variable	1961-1990 average	1981-2010 average	2006-2015 average	2015
EWP	915	948	984	970
England and Wales	907	938	968	965

Figure 23: Annual rainfall for EWP series, 1766 to 2015, and England and Wales areal series, 1910 to 2015 (mm). The table provides average values (mm).

Figure 24 shows trends in seasonal EWP rainfall amounts from 1766 to date. While there is little change in the long-term mean for the annual EWP series, this is not the case for the seasonal series. EWP shows a marked increase in winter rainfall. Before 1900, EWP winter rainfall was substantially lower than autumn rainfall, but the increase in winter rainfall has meant that during the 20th century autumn and winter rainfall were roughly equivalent. The increasing winter rainfall has been offset by a slightly smaller reduction in summer rainfall, although a recent run of wet summers demonstrates that these trends are very sensitive to the choice of start and end date. Spring / autumn rainfall have each remained fairly steady with only a slight increase / decrease respectively.

The rainfall statistics throughout are presented to the nearest whole mm, but the uncertainties of the areal statistics relating to changes in the observing network over time can approach 1 % to 4 % depending on region in early decades, but less than 1 % or 2 % for the comprehensive network of rain gauges in the years since 1960. The uncertainties are therefore much smaller than the year to year variability and more detail on this can be found in Annex 2. However it is non-trivial to determine the robustness or significance of observed trends in rainfall as they are quite sensitive to region, season and choice of start and end dates.

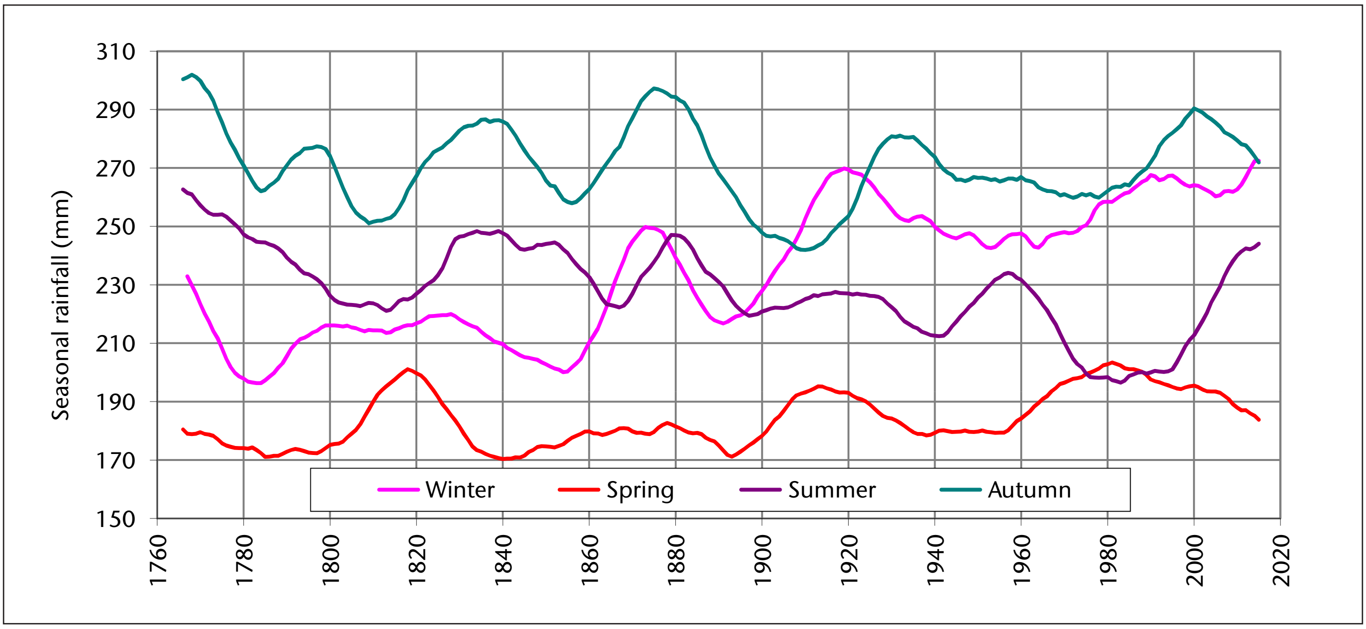


Figure 24: Seasonal rainfall totals for EWP series in mm, 1766 to 2014 (note winter from 1767).
The figure shows a smoothing trend for each series using a weighted filter (see Annex 2).

DAYS OF RAIN AND RAINFALL INTENSITY

The annual number of days of rain with greater than or equal to 1mm (Dr1) was well above average for 2015 by 10 to 20 days or more across much of the far south-west, Wales, northern England, Northern Ireland and Scotland. Elsewhere the number of days of rain was near average (Figure 25). A major contributing factor was the exceptionally wet December, but January, May, July, August and November also had more days than average. In contrast, April and June (in the south) and September and October (mainly in the west and north) saw prolonged dry spells and fewer days on average. The number of days of rain greater than or equal to 10mm (Dr10) was also well above average across upland areas of the west and north (Figure 25), with the storms of November and December again a major contributing factor in these areas; in the wettest parts of the Cumbrian Fells there were almost 40 Dr10 during November and December alone, approaching half the 1981-2010 annual average.

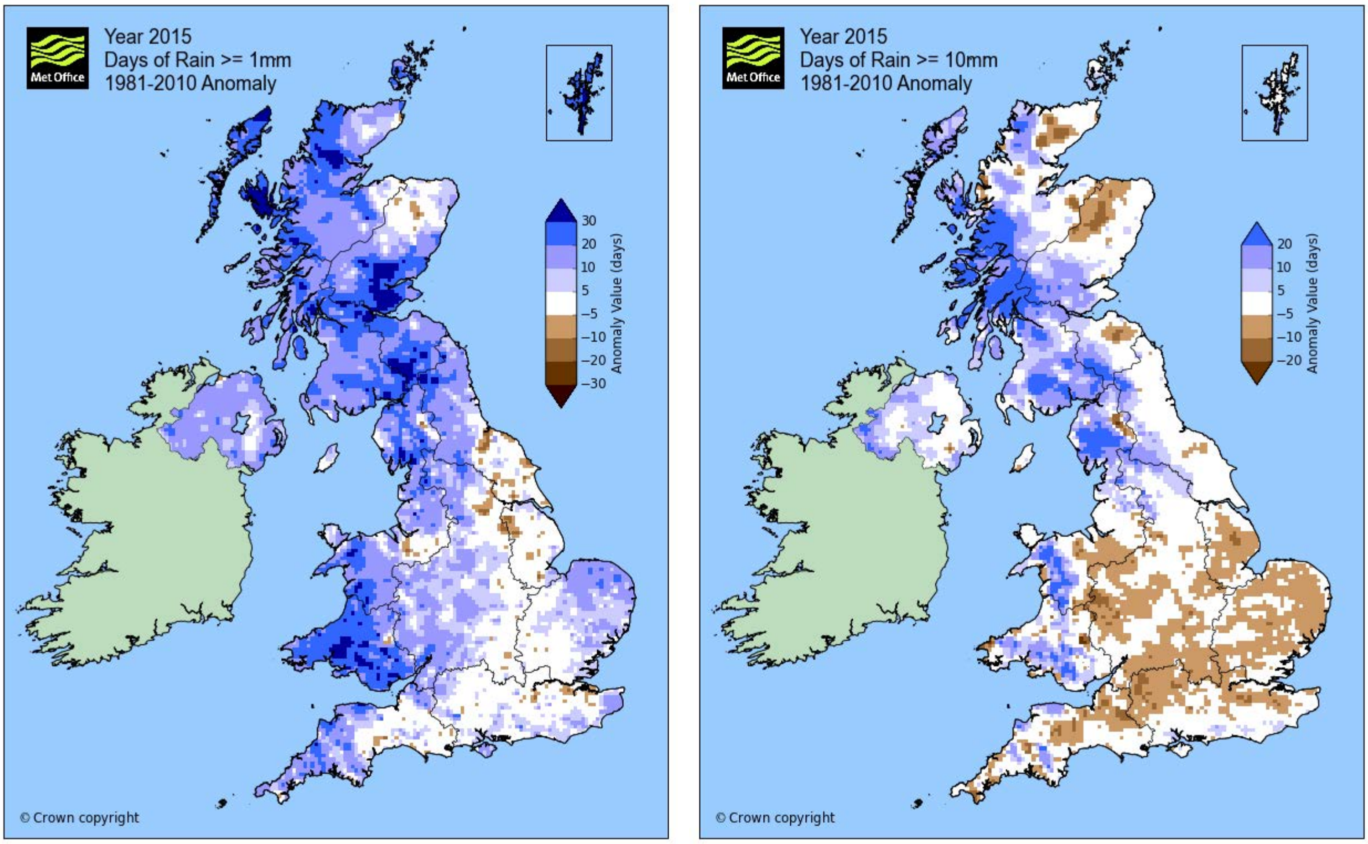
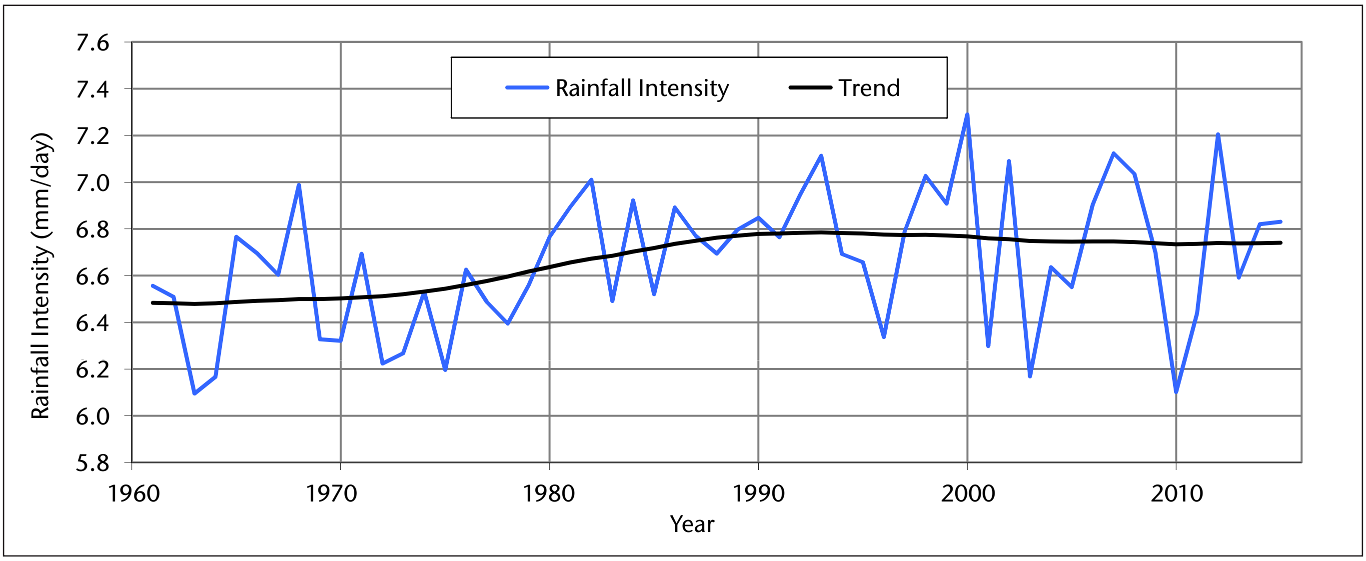


Figure 25: Days of rain >= 1mm (Dr1) and 10mm (Dr10) for 2015, difference from 1981-2010 average.

Figure 26 shows an estimate of the areal-average rainfall intensity (see Annex 1 for definition) across the UK for each year, based on Dr1, from 1961 to 2015 inclusive. Although the figure neither provides a seasonal break-down, nor distinguishes between upland and lowland areas, it is indicative of trends in rainfall intensity across the UK on wet days. Overall, 2015 was an unremarkable year for this metric. Although there is a slight upward increase of 0.2 mm (or 3 %), this is a short time-series dominated by year to year variability. The two years with highest rainfall intensity in the series (2000 and 2012) also correspond to the wettest years for the UK in the series from 1910.



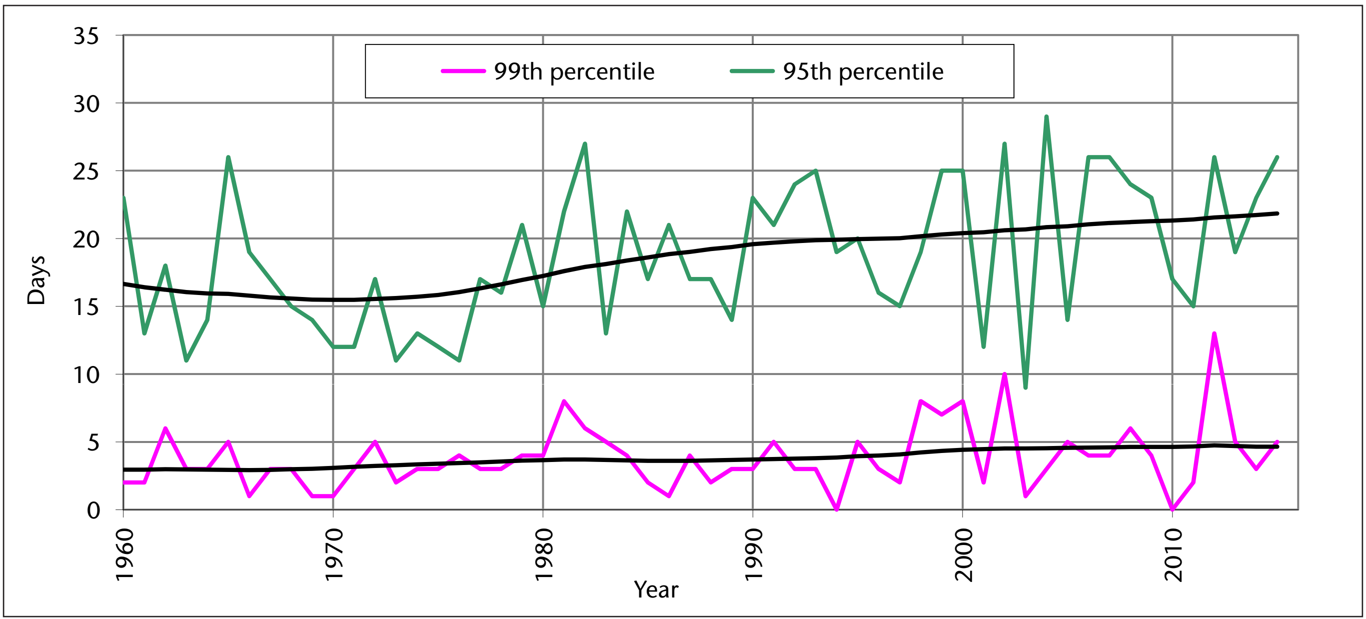
	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK rainfall intensity	6.6	6.8	6.8	6.8

Figure 26: Annual average rainfall intensity for the UK on days of rain >= 1mm, 1961 to 2015. The table provides average values (mm/day).

Alternative metrics for heavy rain are presented here. The ranking of individual years is quite sensitive to the choice of definition used and the series are relatively short given the variability of rainfall. However there are some consistent features across the different metrics -most notably, more heavy rain events have been recorded in the most recent decade than in earlier decades in the series.

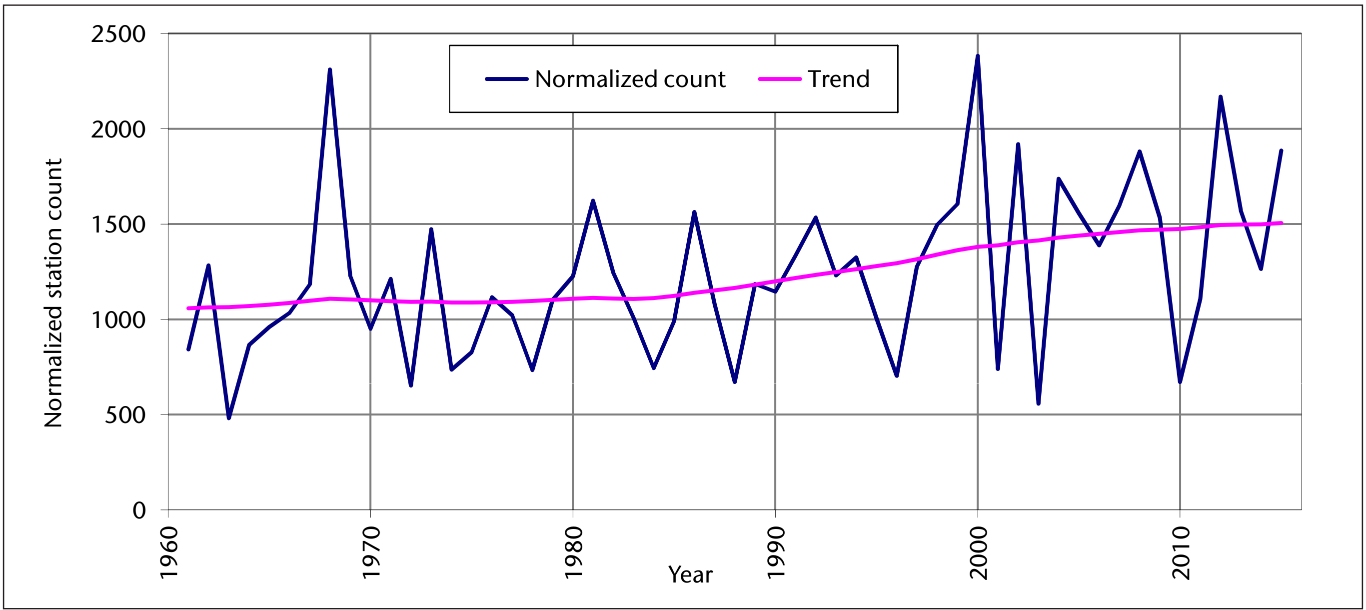
The 95th and 99th percentiles of UK daily areal-average rainfall based on the 50-year period 1961 to 2010 inclusive are 9.5mm and 13.9mm respectively. Figure 27 plots the number of days each year in the series when this percentile was exceeded (by definition we would expect on average 18 days and 3 to 4 days respectively). As with rainfall intensity, his neither includes a seasonal break-down, nor does it distinguish between orographically enhanced frontal rain and convective rain, but rainfall would need to be fairly widespread across the UK to exceed these percentiles, so this metric gives some indication of trends in widespread heavy rain events. 2015 is unremarkable in the 99th percentile series but there were 26 days exceeding the 95th percentile (12 of which were in November and December) making this among the top eight years in this series; six of these top eight years having occurred since 2002. Both series show some increase in the average number of heavy rain days, but with large variability.

Figure 28 provides a count of the number of times each year any rain gauge in the observing network below 500m elevation has recorded a daily rainfall total greater than or equal to 50mm. We refer to this type of metric as a count of station-days. This metric cannot therefore distinguish between a small number of widespread events recorded at many stations, or more frequent but localised events. This series has therefore been adjusted to take into account the changing size of the UK rain-gauge network which reached over 5100 gauges in the 1970s and has reduced to approximately 3000 or fewer in the 2010s. The dense network of several thousand rain gauges across the UK means that widespread heavy rain events will tend to be well captured, although highly localised convective events may still be missed. However, note that the adjustment does not take into account the fact that the relative proportion of rain-gauges within different parts of the UK also changes with time. Therefore we cannot rule out the possibility that the present day network, while having fewer stations overall, may provide better sampling of regions that experience higher frequency of heavy rain days such as western Scotland. 2015 had the sixth highest count by this metric, with six of the top seven years having occurred since 2000. The other year is 1968, during which there were three major heavy rain events in March, July and September, covering large areas (Bleasdale, 1969). This series shows an upward trend from around 1100 station-days in the 1960s to over 1400 station-days since 2000, although, again, this is a short series with high variability.



Percentile	1961-1990 average	1981-2010 average	2006-2015 average	2015
99th	3	4	5	5
95th	17	20	23	26

Figure 27: The number of days per year with UK areal-average daily rainfall exceeding 95th percentile (9.5mm) and 99th percentile (13.9mm) based on the 50-year period 1961-2010. The table provides average values (days).



	1961-1990 average	1981-2010 average	2006-2015 average	2015
Number of station-days	1083	1291	1506	1885

Figure 28: Annual count of the number of UK station-days which have recorded daily rainfall totals greater than or equal to 50mm from 1961 to 2015, adjusted for station network size and excluding stations above 500 metres above sea level. The table provides average values (station-days).

SNOW

Snowfalls across the UK in mid and late January and early February caused some disruption but in general were no more than might be expected at this time of year. Impacts were mostly limited, but on 29th January runways at Manchester Airport were closed for several hours, and snow and ice continued to cause some disruption during the first week of February. Snow depths of 5 to 10cm or more were generally confined to upland areas of the north and east, with up to 30cm recorded at Aviemore (Inverness-shire) and Tulloch Bridge (Highland) on 14th January. However, on 30th January lying snow was recorded as far south as Andrewsfield (Essex) and Mickleham (Surrey) and on 3rd February there was 3 to 5cm of lying snow recorded across parts of Oxfordshire, Hampshire and Berkshire. Wintry conditions continued through March across Scotland's mountains with extensive snow cover and blizzards at times at higher elevations, and a northerly incursion in late April brought some sharp frosts and further significant fresh falls of snow over Scottish mountains.

In November, Arctic air brought colder weather between the 21st and 23rd with some snow and ice occurring near west and east coasts, particularly high ground in the north of Scotland, but after this the weather was exceptionally mild with no further snow.

The last widespread falls of snow across lowland areas of the UK were in January and March 2013. 2010 was the snowiest year by far for the UK in the last two decades, and was comparable to several snowy years in the 1970s and 1980s. Figure 29 shows the count of station-days (not adjusted for network size) where snow depth sensors recorded greater than or equal to 10 cm or 20 cm of lying snow. Year 2015 had one of the lowest counts of station-days for both metrics in this series, broadly comparable with several other recent years such as 2007, 2008, 2011 and 2012 but there are also several comparable years earlier in the series such as 1974, 1975, 1988 and 1989. The station-days for both metrics were not quite as low as for the previous year, 2014 (the lowest in these series)

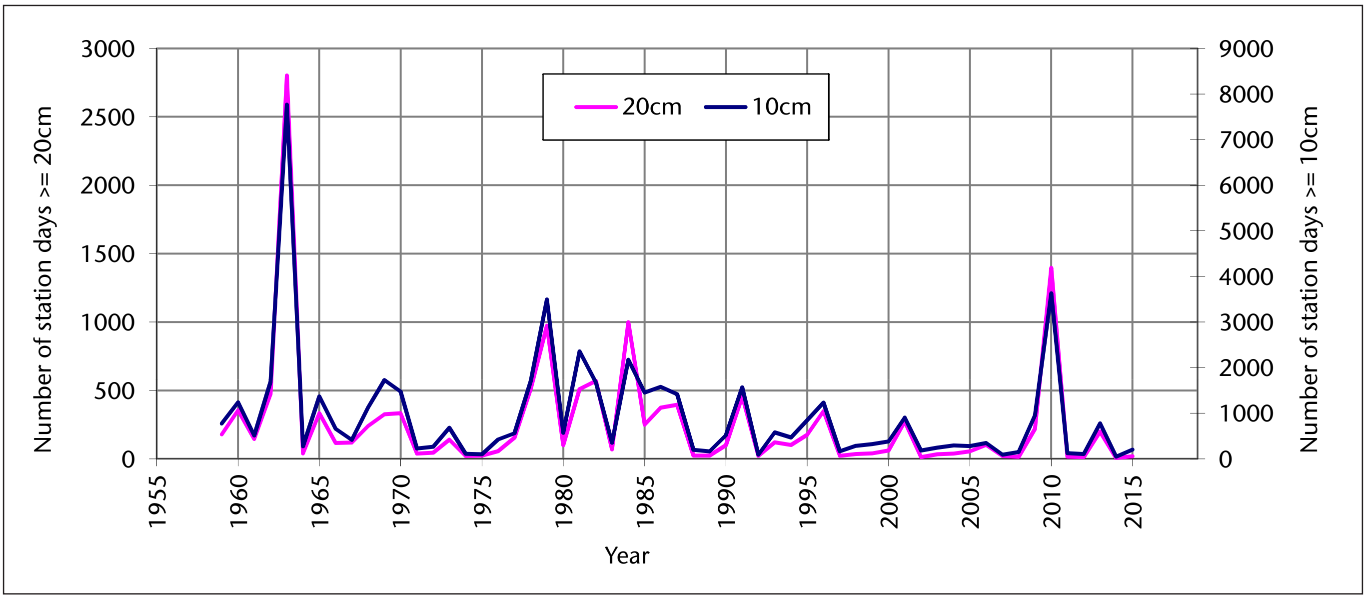


Figure 29: Count of number of station-days per year in the UK with recorded snow depths exceeding 10cm and 20cm, excluding stations above 500 metres above sea level. This series has not been adjusted for network size. The 2015 values are 199 (10cm) and 18 (20cm).

Sunshine

2015 was a sunnier than average year for the UK overall (106% of 1981-2010 average). It was a particularly sunny year across north-east England and eastern Scotland with more than 120% in some locations. However, limited areas were duller (Figure 30). Note however the possibility that imperfect exposure at individual stations and the relatively sparse density of stations may have had some influence on the detail in the sunshine anomaly pattern. UK sunshine totals for the year ranged from 1110 hours at Lerwick, Shetland (93% of average) to 1930 hours at Hastings (103%).

Winter 2015 was the sunniest winter in the UK series from 1929, with 121% of average sunshine. It was especially sunny in the north-east with Morpeth Cockle Park, Northumberland and Dyce, Aberdeenshire among the sunniest locations, each recording over 280 hours for the winter, around 150% of average sunshine; remarkable considering their northerly locations. In contrast, the Western and Northern Isles experienced a particularly dull winter. Spring was also a sunny season, in large part due to the sunniest April in the UK series when high pressure brought prolonged spells of fine, settled weather. Many stations had their sunniest April on record, including Morpeth with 265 hours, nearly 9 hours per day, this being the sunniest April here in a 106-year record and almost twice the long-term average.

Summer sunshine totals were fairly near average overall, but western Scotland was rather dull. September was another fine, settled and sunny month, whereas both November and December were particularly dull. With a succession of Atlantic low pressure systems, sunshine was particularly scarce across north-west Scotland with fewer than 30 hours recorded for November and December combined at Poolewe and Loch Glascarnoch (both Ross & Cromarty) – only half an hour per day on average (Figure 31 and 32). It was the dullest November in the UK series from 1929.

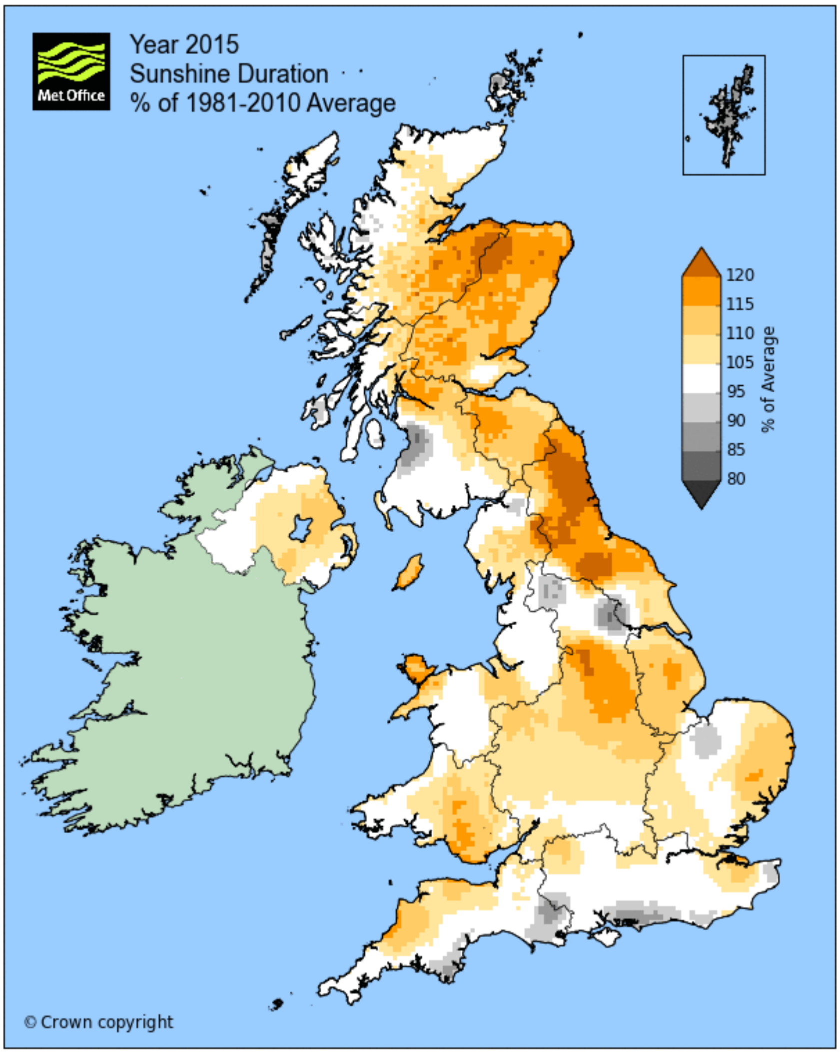


Figure 30: Sunshine anomalies (%) for year 2015 relative to 1981-2010

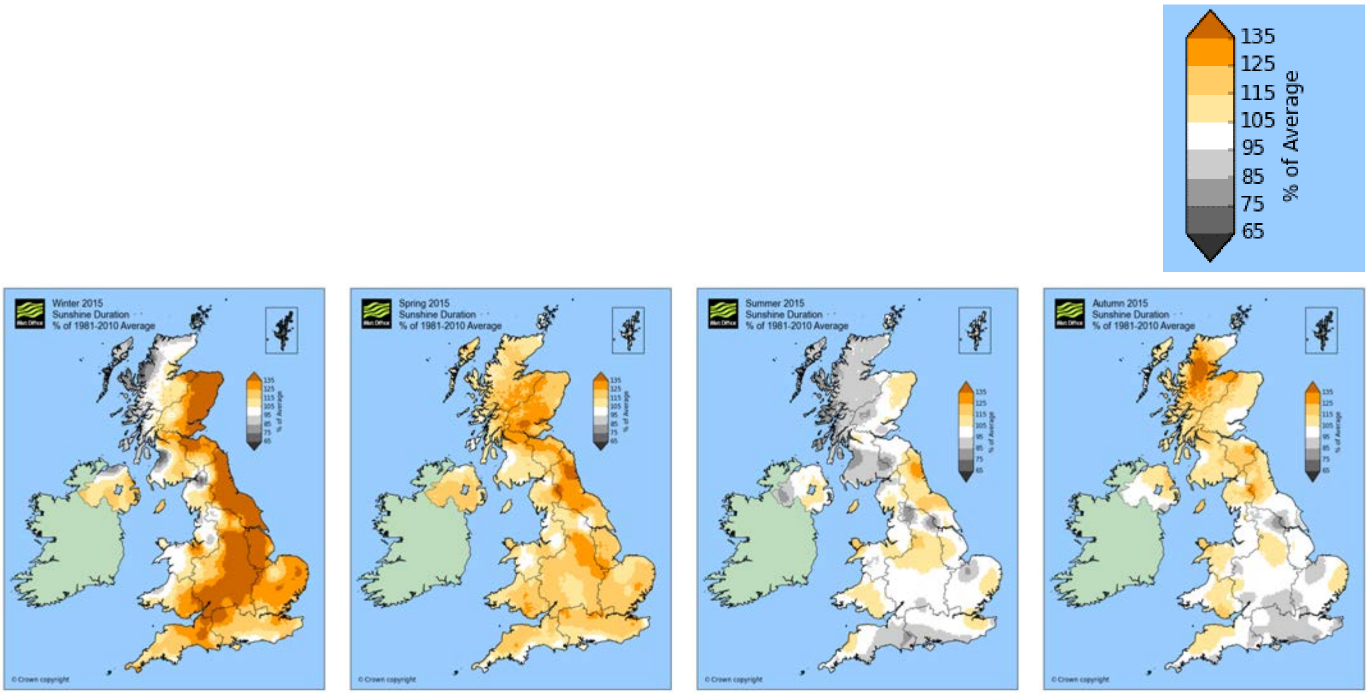
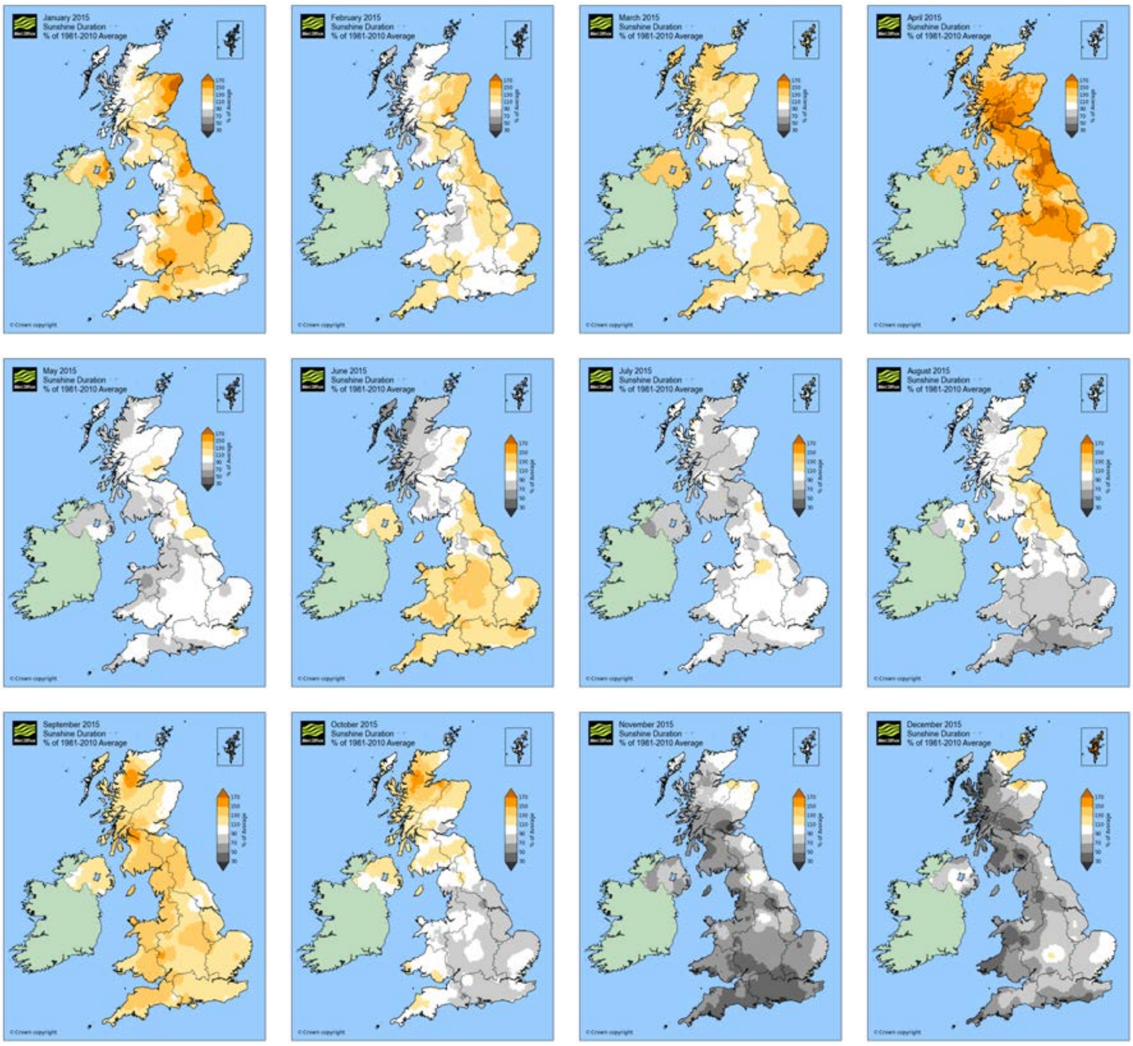


Figure 31: Sunshine anomalies (%) for seasons of 2015. Winter 2015 refers to the period December 2014 to February 2015.



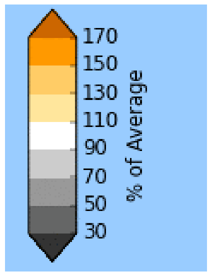
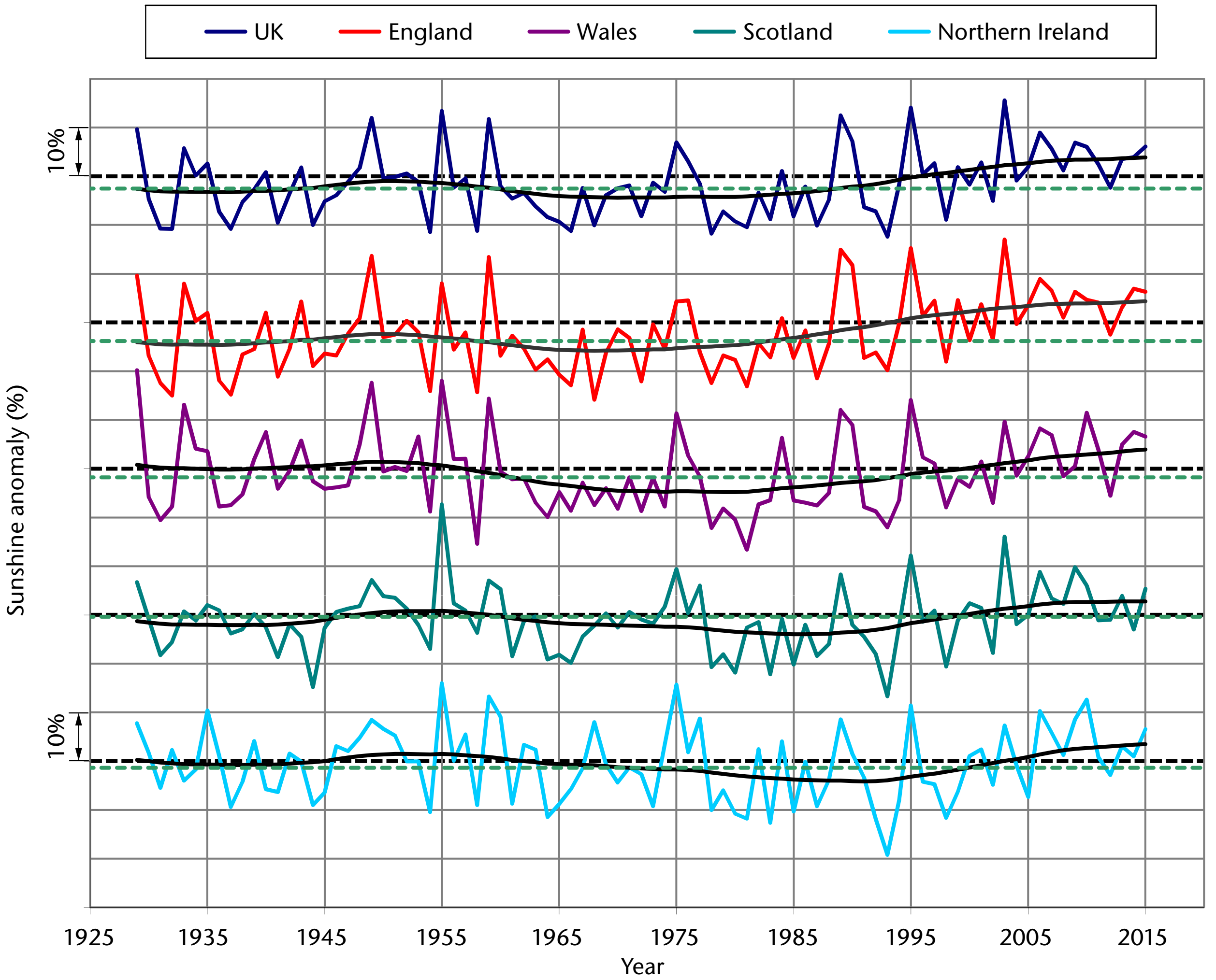


Figure 32:
Sunshine anomalies (%) for months of 2015

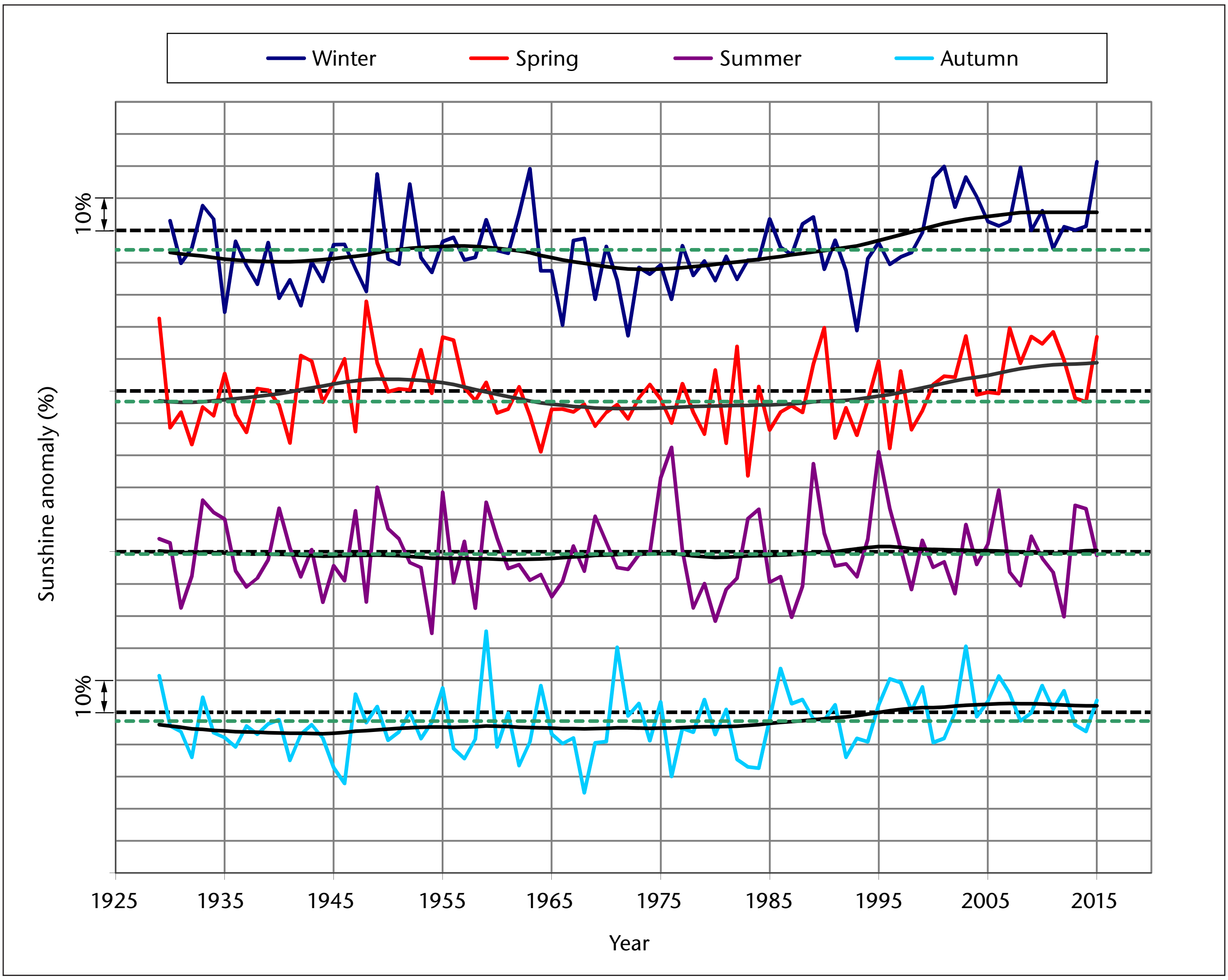
Figures 33 and 34 show annual sunshine anomalies for the UK and countries, and seasonal sunshine anomalies for the UK, from 1929 to 2015 inclusive. The smoothed trend shows a slight increase in sunshine from a low during the 1960s to 1980s to a sunnier period from 2000 onwards. The most recent decade (2006–2015) has had for the UK on average 7% more hours of bright sunshine than the 1961–1990 averages and 4% more than the 1981-2010 average. This trend is apparent across all countries but is most prominent during the winter and spring, where the most recent decade is 14% and 12% higher than 1961-1990 respectively.

The sunshine network is relatively sparse with corresponding large uncertainty in areal values. Stations may have exposure issues, particularly in the winter months when the sun is at a low elevation and topographic shading may be important.



Area	1961-1990 average	1981-2010 average	2006-2015 average	2015
UK	1338	1373	1431	1457
England	1436	1493	1560	1587
Wales	1376	1401	1461	1493
Scotland	1182	1187	1228	1250
Northern Ireland	1239	1256	1315	1339

Figure 33: Annual sunshine duration (hours) for UK and countries, 1929 to 2015, expressed as a percentage of 1981-2010 average. The hatched black line is the 1981-2010 long-term average. The lower hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 10%. The table provides average values (hours).



Season	1961-1990 average	1981-2010 average	2006-2015 average	2015
Winter	148	158	165	192
Spring	422	436	479	509
Summer	501	505	507	499
Autumn	267	274	281	285

Figure 34: Seasonal sunshine duration for the UK, 1929 to 2015 (note winter from 1930 to 2015; year is that in which January and February fall). Light grey grid-lines represent anomalies of +/- 10%. The table provides average values (hours).

Wind

The windiest days of year 2015 are listed in Table 3. There was a particularly windy spell of weather from 9th to 15th January during which four major Atlantic storms driven by a powerful jet stream brought very strong winds, with the north of Scotland bearing the brunt of the weather impacts. The strongest winds from the first storm on 9th January were across the Western Isles and far north of the Scottish mainland, gusting at over 80 Kt, with 98 Kt (113mph) at Stornoway Airport (Western Isles) and 96 Kt (111 mph) at Loch Glascarnoch (Ross & Cromarty). The second storm followed in rapid succession on the 10th, with the strongest winds across Shetland, Lerwick recording 88 Kt (101 mph). Even by the standards of the Western and Northern Isles these were unusually high gust speeds and close to record values. The third storm and fourth storms occurred on the 12th and overnight 14th to 15th. While gust speeds were not quite so high the focus of the strongest winds was further south. This spell of storms caused widespread disruption, there were reports of some fallen trees, minor structural damage and huge waves battered exposed coastlines of the north and west.

A further major storm affected the UK on 30th to 31st March with winds gusting at 50 to 60 Kt in exposed coastal locations. On 1st June a deep area of low pressure brought an unseasonably windy start to the UK's summer, with strong winds and heavy rain causing some disruption; Capel Curig (Conwy) recorded a gust of 68 Kt (78 mph).

From mid-November to New Year six named storms (Table 4) brought further strong wind accompanied by heavy rain. These storms were named as part of a new initiative between the Met Office and Met Eireann in which storms were named if they had the potential to cause medium or high impacts from wind on the UK and/or Ireland (storms are not named for rainfall). The strongest winds from Abigail (12th to 13th November) were across Scotland, while during both Barney (17th to 18th November) and Clodagh (29th November) the focus was further south across England and Wales. The remaining storms Desmond (4th to 6th December), Eva (24th December) and Frank (29th to 30th December) also brought strong winds but by this stage the worst impacts were from the exceptional rainfall. While the storms from mid-November to New Year were exceptional in terms of rainfall, in terms of wind both this spell and the mid-January storms were significant, but individually these storms would not be considered exceptional for the UK at this time of year. Comparable or more severe windy spells or individual storms have occurred in the last few years, notably the storms from December 2013 to February 2014 and from December 2011 to January 2012.

Table 3: The windiest days of year 2015. The table lists dates where 20 or more stations across the UK recorded a maximum wind gust greater than or equal to 50 Knots on that day. The table also gives a count of affected stations by country. The number of wind observing sites in 2015 for each country (based on data availability) is also given in brackets.

Date	England (105)	Wales (15)	Scotland (36)	N Ireland (11)	Total	Named storm
01-Jan-2015	8	3	8	2	21	
02-Jan-2015	7		18		25	
07-Jan-2015	5	4	9	2	20	
08-Jan-2015	6	5	20	5	36	
09-Jan-2015	21	6	35	6	68	
10-Jan-2015	32	7	30	5	74	
12-Jan-2015	15	7	27	3	52	
14-Jan-2015	18	9	13	2	42	
15-Jan-2015	38	9	24	8	79	
28-Jan-2015	18	7	6	3	34	
28-Feb-2015	5	2	11	5	23	
09-Mar-2015	1	1	25	4	31	
29-Mar-2015	14	6	1		21	
30-Mar-2015	11	6	5	3	25	
31-Mar-2015	47	6	10	7	70	
01-Jun-2015	10	7	8	2	27	
09-Nov-2015	8	4	13		25	
12-Nov-2015	6	4	19	3	32	Abigail
13-Nov-2015	7	6	11		24	Abigail
16-Nov-2015	12	4	13	3	32	
17-Nov-2015	33	12	3	1	49	Barney
21-Nov-2015	19	2		1	22	
29-Nov-2015	33	10	16	3	62	Clodagh
04-Dec-2015	11	8	18	4	41	Desmond
05-Dec-2015	26	12	11	1	50	Desmond
09-Dec-2015	9	5	22	3	39	
23-Dec-2015	1	9	15	2	27	Eva
24-Dec-2015	11	8	13	1	33	Eva
29-Dec-2015	3	6	18	6	33	Frank
30-Dec-2015	21	8	17	2	48	Frank

Table 4: UK Named storms of 2015. Subsequent named storms occurring in early 2016 included Gertrude (late January), Henry and Imogen (early February), Jake and Katie (early and late March).

Name	Date of impact on UK and/or Ireland
Abigail	12-13 November
Barney	17-18 November
Clodagh	29 November
Desmond	5-6 December
Eva	24 December
Frank	29-30 December

As a measure of storminess figure 35 counts the number of dates each year on which at least 20 stations recorded gusts exceeding 40 / 50 / 60 Kt. Most winter storms have widespread effects, so this metric will be relatively insensitive to minor variations in the wind network size which exceeds 150 sites, and will reasonably capture fairly widespread strong wind events. There are no compelling trends in max gust speeds recorded by the UK wind network in the last 4 decades, particularly bearing in mind the year-to-year and decadal variations and relatively short length of this time series.

2015 was a fairly windy year with around 11 major storms overall, and by the 40 and 50 Kt metrics, this was the windiest year since 2000. However, there were many comparable or windier years in the 1980s and 1990s. This earlier period also included among the most severe storms experienced in the UK in the observational records including the 'Burns' Day Storm' of 25 January 1990, the 'Boxing Day Storm' of 26 December 1998 and the 'Great Storm' of 16 October 1987 and none of the individual storms during 2015 compared with these for severity. However, the last two years have been relatively windy and contrast particularly with 2010, during which there was a notable absence of wind events. Changes in instrument type, station network size, station exposure, and choice of metric used mean that interpreting trends in storminess from UK wind speed data is not straightforward and results should be treated with caution.

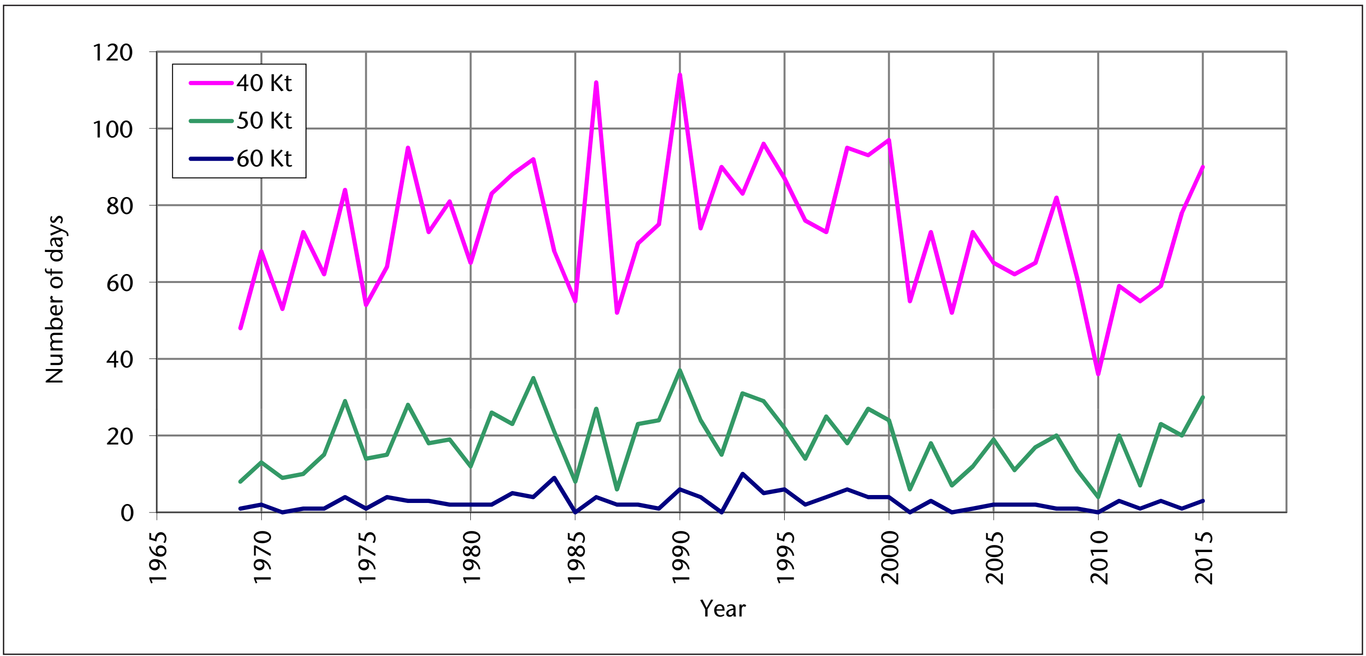


Figure 35: Count of the number of individual days each year during which a max gust speed >= 40, 50 and 60 Kt has been recorded by at least 20 or more UK stations, from 1969 to 2015. Stations above 500 metres above sea level are excluded.

Sea Level

A UK sea level index (Figure 36) for the period since 1901 provides a best estimate trend of 1.4 ± 0.2 mm/yr for sea level rise, corrected for land movement (Woodworth et al, 2009). This is close to the estimate of 1.7± 0.2 mm/yr estimated for the global sea level rise suggested by the Fifth Assessment Report of Intergovernmental Panel on Climate Change (Church et al, 2013). However, UK sea level change is not a simple linear increase, but also includes variations on annual and decadal timescales. Also, a number of large scale atmospheric and ocean processes contribute to non-uniform sea level rise around the coast of the UK. Unfortunately the uncertainties in the UK sea level index for recent years, especially 2015, are large as a result of missing data.

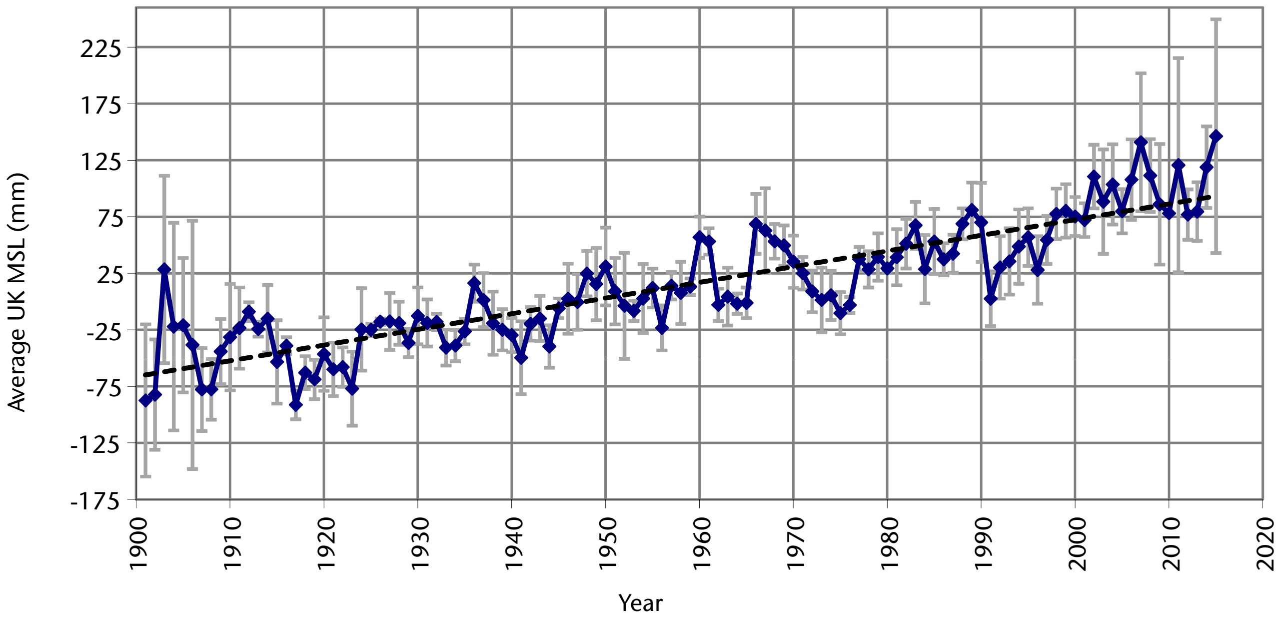


Figure 36: UK sea level index for the period since 1901 computed from sea level data from five stations (Aberdeen, North Shields, Sheerness, Newlyn and Liverpool) from Woodworth et al, 2009. The linear trend-line has a gradient of 1.4 mm/year. Error bars indicate uncertainty (one standard deviation) in values for individual years.

Figure 37 presents a 100-year record of sea level at Newlyn, Cornwall showing time-series of the annual 99th percentile water level and annual maximum water levels, relative to the long term mean for the 99th percentile. The 99th percentile is the level which is exceeded 1 percent of the time, or for about 88 hours in any given year. Any periods of high tides and storm surges in the year are likely to be in the 88 hours above the 99th percentile. The annual maximum water level shows greater annual variability than the 99th percentile series. Consequently the 99th percentile time-series is sometimes preferred because it provides a description of change in high and low water characteristics without the greater year-to-year variability inherent in the true extremes.

The 99th percentile annual water level and the highest maximum water level during year 2015 were unremarkable compared to recent decades but nonetheless notably high compared to earlier decades of these series (ranked 14th- and 11th- highest respectively). The long term trend in 99 percentile level is 2.0mm/year for the period 1916-2015, compared to the trend of 1.8 mm/year in median sea level at Newlyn (this being slightly greater than the UK overall). The trend for the highest maximum water level is 2.2mm/year, but with greater variability in the records.

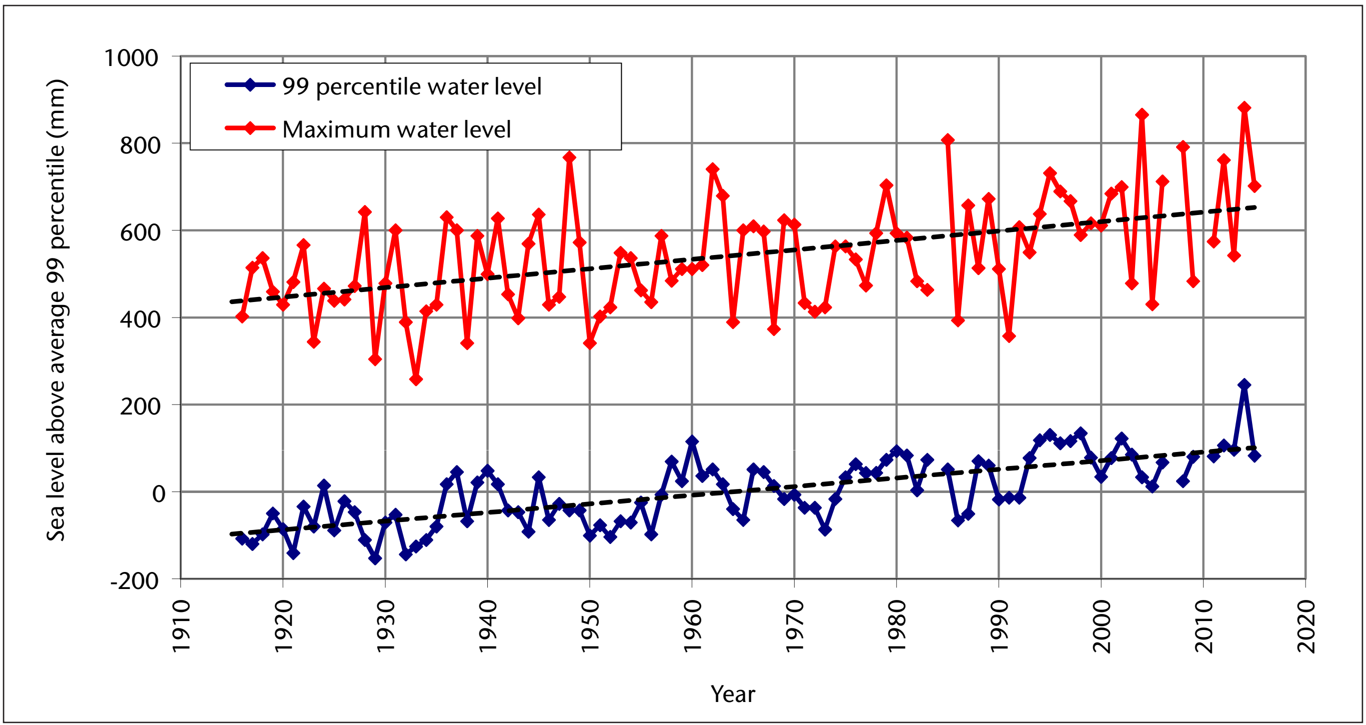


Figure 37: Extreme sea levels at Newlyn, Cornwall (1916-2015), in mm. The blue and red time-series are annual 99 percentiles and maximum water levels respectively. Levels are relative to the long-term average for the 99 percentile. The linear trend-lines for the 99th percentile and maximum water levels have gradients of 2.0 mm/year and 2.2mm/year respectively.

Extremes for year 2015

Table 5 shows the UK weather extremes for year 2015. The highest temperature of 36.7 °C set a new UK record for July and was the highest temperature recorded in the UK since the heatwave of August 2003. A new UK record for November was also set when Trawsgoed, Ceredigion recorded 22.4 °C, breaking the previous UK November record of 21.7 °C set at Prestatyn (Denbighshire) on 4 November 1946. The lowest Tmin of -13.7 °C occurred during a period of clear skies, light winds and lying snow cover across the north of the UK, but this value is fairly typical for the UK (see Figure 3 of Kendon et al, 2015).

The highest daily rainfall total (0900-0900 GMT) of 264.4mm at Thirlmere, Cumbria during storm Desmond on 5 December came close to the UK record for a standard 09-09GMT rain-day of 279mm at Martinstown, Dorset on 18 July 1955.

The highest gust speed of 98 Kt (113 mph) at Stornoway Airport on 9 January 2015 was the equal-highest gust on record at this long-running station, shared with 98 Kt on 12 February 1962, although not a record for the UK.

Table 5: Annual extremes for the UK for year 2015, excluding stations above 500 masl.

Extreme	Observation	Date	Station
Highest daily maximum temperature	36.7 °C	1 July	Heathrow, Greater London
Lowest daily minimum temperature	-13.7 °C	20 Jan	Loch Glascarnoch, Ross & Cromarty
Highest daily rainfall (09-09 GMT)	264.4 mm	5 Dec	Thirlmere, St Johns Beck, Cumbria
Highest gust speed	98 Kt	9 Jan	Stornoway Airport, Western Isles

Significant weather events of 2015

NORTHERN SCOTLAND COOL WET EARLY SUMMER

The far north of Scotland experienced a particularly cold, dull and wet early summer in 2015, with Orkney especially badly affected. Temperatures were below average during May (Orkney anomaly -1.2 °C), June (-0.6 °C) and July (-1.2 °C) while rainfall totals were well above average for all three months, May (Orkney anomaly 258%), June (168%) and July (131%). In addition to the cold and wet conditions, sunshine totals were below average during both May and June. This was the wettest May to July period in series from 1910 for both the Western Isles and Orkney (Figure 38). The ongoing bad weather in northern Scotland led to increasing concerns from the farming industry about poor growing conditions for grass for livestock.

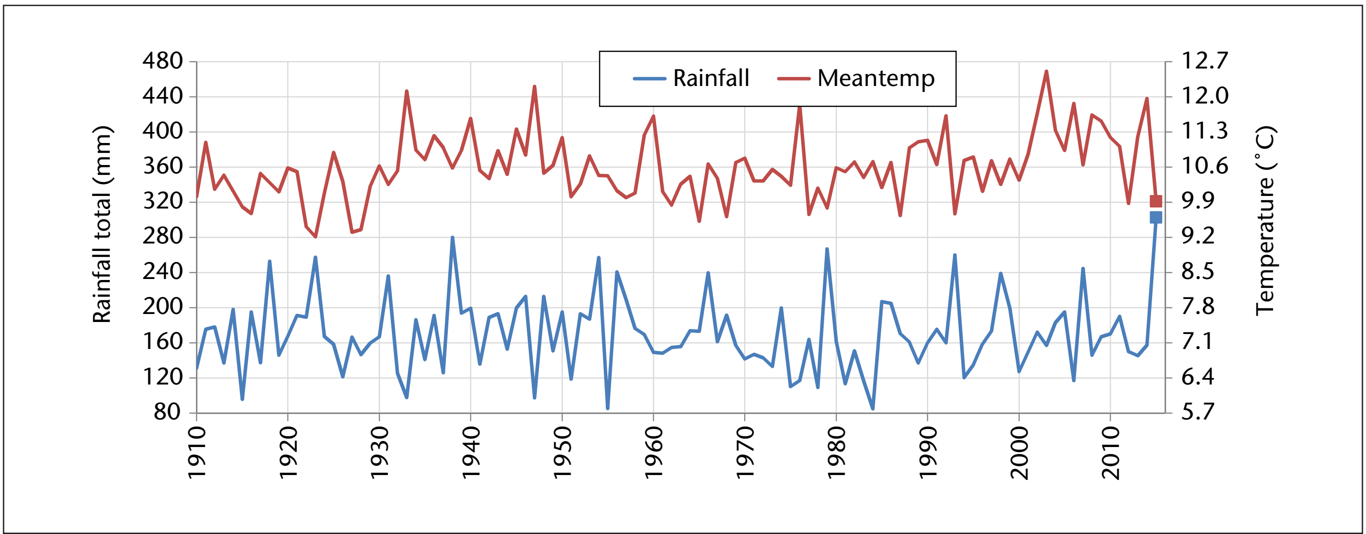


Figure 38: Rainfall totals and mean temperature for Orkney for the months of May-June-July series from 1910 to 2015 inclusive. The 2015 values were 303mm (182% of 1981-2010 average) and 9.9 °C (anomaly -1.2 °C) respectively.

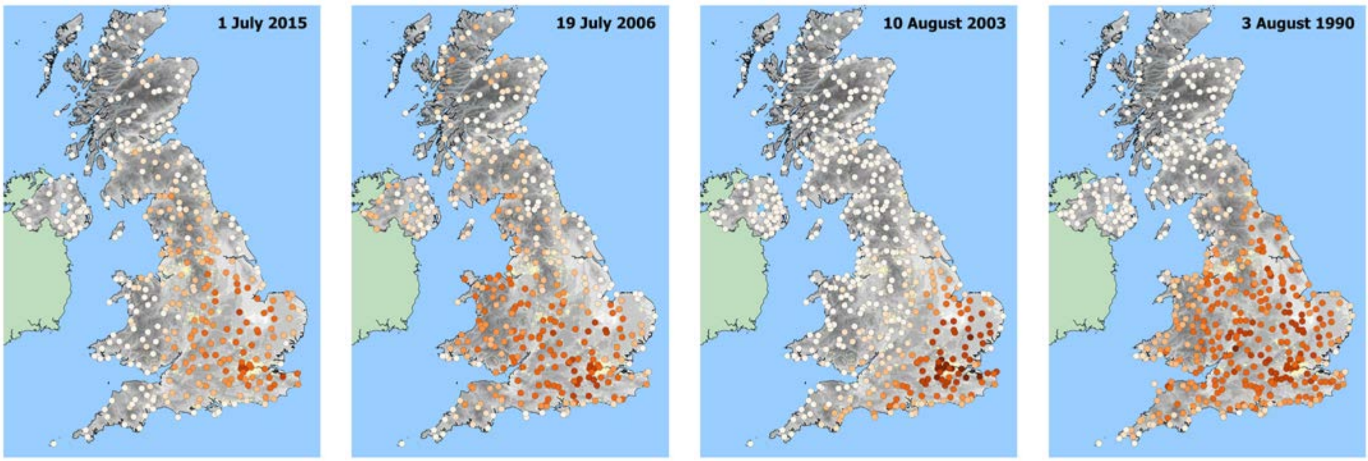
JULY HOT SPELL

The UK experienced a 1-day hot spell on 1 July 2015, linked to a significant heatwave affecting mainland Europe. Heathrow, Greater London recorded a maximum temperature of 36.7 °C, the highest July temperature on record for the UK, and just ahead of the previous July record 36.5 °C at Wisley, Surrey on 19 July 2006. This was the highest temperature recorded in the UK since the record-breaking heatwave of 10 August 2003. This was only the fourth time a temperature of 36.7 °C has been reached in the UK in observational records, the others being 9 August 1911 (36.7 °C at Raunds, Northamptonshire, Canterbury, Kent and Epsom, Surrey); this UK record stood for nearly 80 years until 3 August 1990 (37.1 °C at Cheltenham, Gloucestershire) which was broken again on 10 August 2003 (38.5 °C at Faversham, Kent). As this was a short duration heatwave, impacts for the UK were limited, but the heat may have contributed to a large fire which affected Thetford Forest, East Anglia. The heat also triggered thunderstorms and torrential downpours across parts of northern England and Scotland.

The heatwave was associated with hot air moving north from Spain. While this was only a brief heat-wave for the UK, severe and in some cases prolonged heat waves affected Europe, North Africa and the Middle East between May and September. Spain recorded an intense heat-wave of exceptional duration from 27th June to 22nd July, with 45.2 °C recorded at Cordoba in southern Spain on 6th July. In Germany, 40.3 °C was recorded on 5th July at Kitzingen, and in France 41.4 °C was recorded at Brive-la-Gaillarde on 16th July (see Useful Resources for a link to WMO Annual Bulletin on the Climate in region VI Europe and Middle East). However, other than on 1st July, the UK remained on the periphery of this heat on the near-continent

On 1 July the temperature also reached 35.7 °C at Kew Gardens and Northolt, Greater London, 35.3 °C at Wittering, Cambridgeshire and 35.2 °C at Faversham, Kent. The heat extended across the UK to the north of Scotland with 29.0 °C at Aviemore, Inverness-shire and 28.0 °C at Altnaharra, Sutherland. A notable feature of the heatwave was the high temperatures early in the day. At 0900 GMT the temperature was already 32.5 °C at Heathrow, resulting in the highest night-time maximum temperature (2100 to 0900 GMT) on record for the UK. (Increased automation of the UK's weather station network means that there are many more 12-hour observations of this type than in the past, since most manual stations only report 24-hour 0900 to 0900 GMT values.)

Figure 39 compares 1 July 2015 against three of the hottest days in the UK's observational records.* Although the all-time UK record of 38.5 °C was set on 10 August 2003 the extreme heat on this date was largely confined to the south-east. In contrast, on 3 August 1990 the hottest areas extended to south-west England, Wales and much of north-east England. On 19 July 2006 heat extended to Wales, north-west England and western Scotland. On 1 July 2015 the heat extended to northern England and Scotland but it was cooler across Wales.



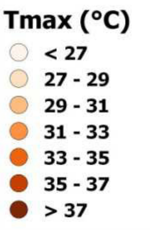


Figure 39: Daily maximum temperatures across the UK during four of the hottest days on record. The table shows the highest UK maximum on each date

Date	Highest UK maximum temperature	Station
1 July 2015	36.7 °C	Heathrow, Greater London
19 July 2006	36.5 °C	Wisley, Surrey
10 August 2003	38.5 °C	Faversham, Kent
3 August 1990	37.1 °C	Cheltenham, Gloucestershire

*Note that in summer 1976 (when England and Wales experienced a major drought) the heatwave was more notable for its duration rather than extreme temperatures on any individual date.

Durham, Sheffield and Bradford each recorded their warmest July day in over 100 years of records, and a number of other stations recorded their warmest July day on record (Table 6). Figure 40 shows long-running stations which broke their July Tmax records. These data show that record temperatures for July were not confined to London or other major urban centres but extended across northern England. Notably, Stonyhurst, Lancashire (a CET station) recorded its highest temperature on record for any month (in a 70+ year record-length) by a margin of nearly 1 °C.

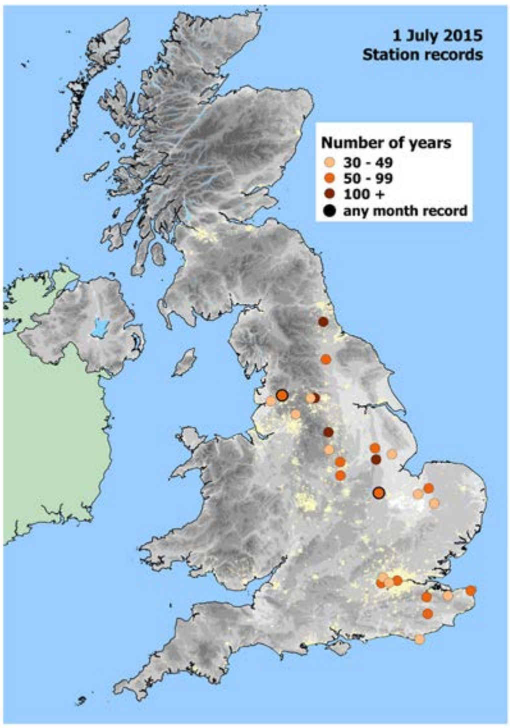


Figure 40: Stations which on 1 July 2015 recorded either their highest July temperature on record (30+ year record length) or their warmest July day for 30+ years. Bold circles indicate stations which recorded their highest temperature for any month.

Table 6: New July station records set on 1 July 2015 for long-running stations with 50+ year record-lengths. An asterisk denotes stations which recorded their highest temperature for any month.

Station	Tmax (°C)	Number of years	Previous record (°C)	Previous date
Durham, County Durham	31.0	136	30.6	31-07-1943
Sheffield, South Yorkshire	33.3	132	31.7	31-07-1943
Bradford, West Yorkshire	30.9	108	30.6	31-07-1943
Cranwell, Lincolnshire	34.3	100	32.6	22-07-1996
Sutton Bonington, Nottinghamshire	33.6	86	32.9	19-07-2006
Stonyhurst, Lancashire	32.6*	77	31.5	29-06-1976
Goudhurst, Kent	33.3	76	32.8	03-07-1976
Manston, Kent	33.6	76	31.4	15-07-1983
Waddington, Lincolnshire	33.1	69	32.2	12-07-1949
Heathrow, Greater London	36.7	68	35.5	19-07-2006
Nottingham, Watnall	33.9	67	32.4	30-07-1995
Marham, Norfolk	33.5	60	32.8	03-07-1976
Wittering, Cambridgeshire	35.3*	57	35.2	03-08-1990
London, St James's Park	34.7	54	34.4	05-07-1959

For more information on the 1 July heatwave see http://www.metoffice.gov.uk/climate/uk/interesting/july2015

EXCEPTIONALLY MILD AND WET DECEMBER

December was one of the most remarkable months in the UK's historical weather records. The month was dominated by a mild tropical maritime airstream, bringing unusually high temperatures, particularly across the southern half of the UK. Frontal systems associated with the mild, moist south-westerly airflow brought record-breaking rainfall across upland areas of the north and west, with significant orographic enhancement. Figure 41 shows temperature and rainfall anomaly patterns across the UK.

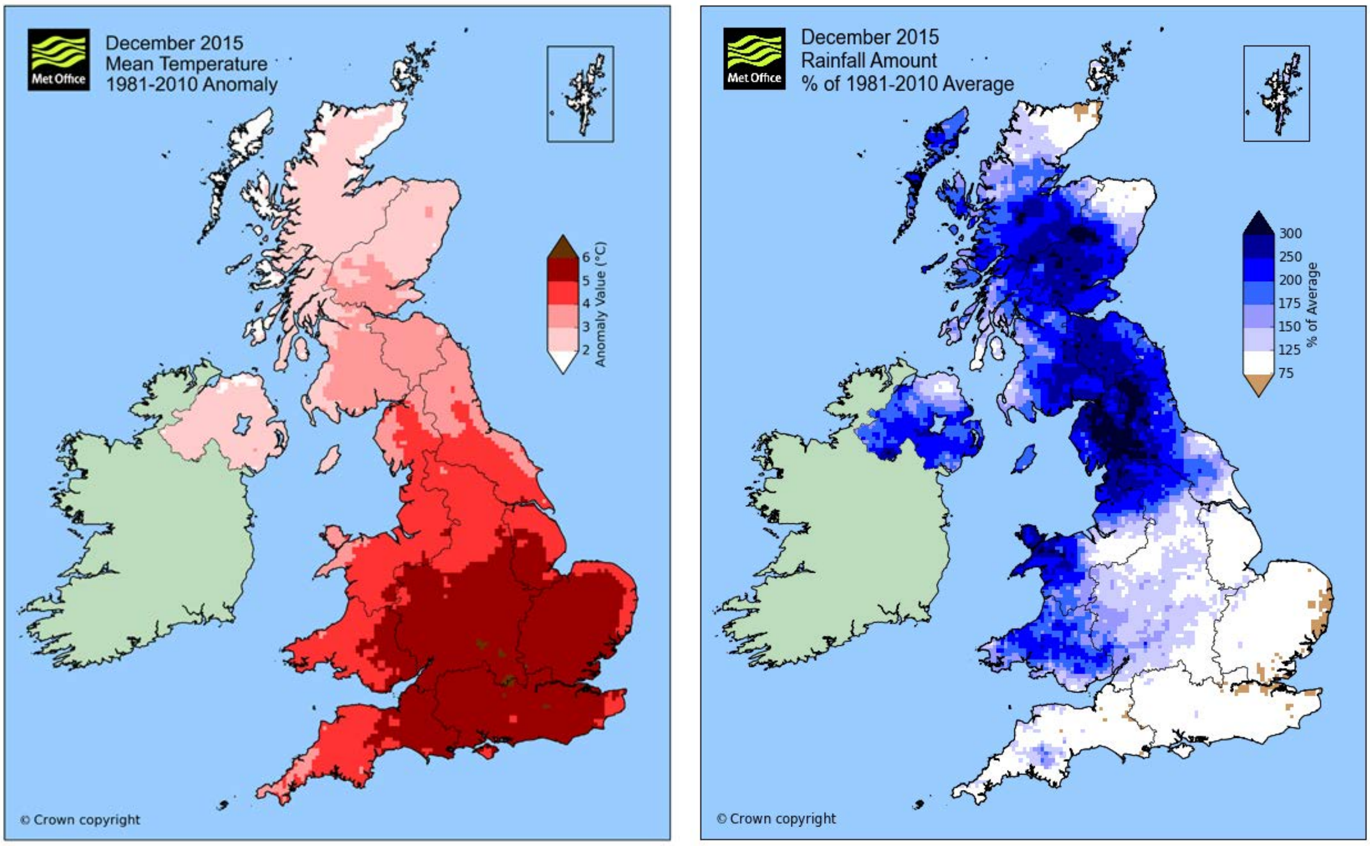


Figure 41: December 2015 monthly average temperature and rainfall total relative to 1981-2010 average.

Record-breaking rainfall

December was the wettest calendar month on record for the UK, with rainfall from storms Desmond (4th to 5th), Eva (23rd to 24th) and Frank (29th to 30th) resulting in severe flooding across parts of northern Britain. The flooding was exacerbated by saturated conditions in the affected areas due to previous wet weather in November, following storms Abigail (12th to 13th), Barney (17th to 18th) and Clodagh (29th). The resulting floods followed recent severe flooding affecting Cumbria in November 2009 and Carlisle in January 2005. Thousands of homes were flooded across northern Britain, with storm Desmond resulting in the inundation of parts of Carlisle. Storms Eva and Frank toward the end of the month brought subsequent severe flooding elsewhere, particularly across parts of north Manchester, West Yorkshire, Lancashire, southern and eastern Scotland but there were flooding problems elsewhere too.

Individually, the most extreme rainfall event was storm Desmond, when 200 to 300mm or more of rain fell across the Cumbrian fells in around 36 hours from the evening of 4 December to morning of 6 December. The hourly rainfall rate across the high ground was sustained at typically 10 to 15mm per hour, with the exceptional rainfall remarkable for its duration rather than intensity, and being very similar in character to the event of 18th to 19th November 2009.

For the rain-day of 5 December (24 hours to 0900GMT on 6th), three raingauges in the central and eastern Cumbrian fells recorded over 200mm, with 11 raingauges recording over 150mm. A raingauge at Thirlmere recorded 405.0mm over the two consecutive rain-days from 0900 GMT 4th to 0900 GMT 6th December 2015, a new UK record. A 24-hour total of 341.4mm to 1800 GMT on 5th December at Honister Pass during this same event also set a new record for any 24-hour period, exceeding 316mm at Seathwaite, Cumbria in November 2009. The highest monthly total for December 2015 was 1361.1mm at Birkside, Cumbria (a monthly raingauge located at 655 metres elevation on the western slopes of Helvellyn), again setting a new monthly record, exceeding 1349mm at Styhead, Cumbria in November 2009*. Two-month rainfall totals for November and December combined widely exceeded 1000mm across upland areas of Snowdonia, Cumbria, parts of the north Pennines and West Highlands, with between 1.5m and 2m recorded at a few of the wettest locations. As a result of the sustained wet weather this was the wettest December across north-west England and North Wales by a wide margin (Figure 42).

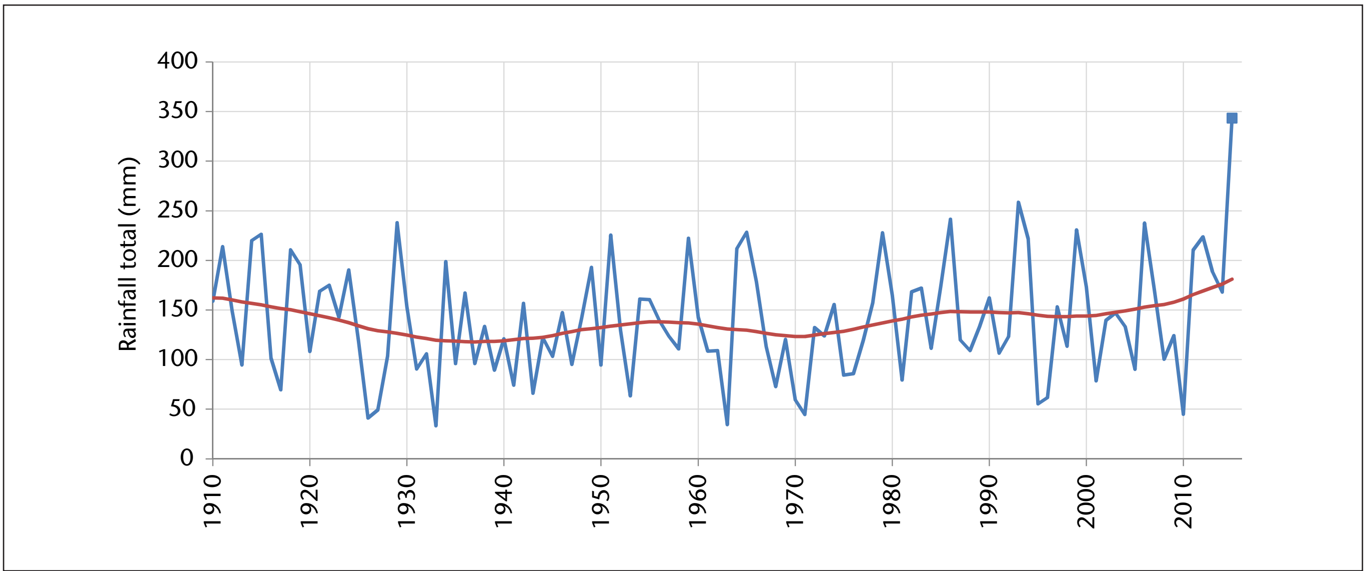


Figure 42: December rainfall totals from 1910 to 2015 for the climate district of north-west England and North Wales. The December 2015 rainfall total was 343mm, 237% of the 1981-2010 long-term average and exceeded the next wettest December by a margin of 85mm. This was also the wettest calendar month in the series, with November 2009 next wettest at 307mm.

*1349mm being a quality control estimated value adjusted to take into account the fact that the observation period did not exactly span the calendar month. A monthly total of 1396mm at Crib Goch (a monthly rain-gauge located at 713 metres elevation on Snowdon) in December 2015 is also likely to exceed this value subject to confirmation.

Figure 43 shows the number of historical observations by year with a daily rainfall total exceeding 150mm and 200mm respectively, representing the most extreme daily falls. This figure has not been adjusted for network size; the overall number of UK raingauges was over 5000 in the 1970s decreasing to 3000 or fewer in the 2010s, and it is possible that the figure may be affected by changes in the density of historical station network coverage across the wettest upland areas of the UK. Also, some extreme historical rainfall events may have been split across consecutive rain-days and are therefore not taken into account. Nevertheless, the figure provides some historical context for the extreme rainfall totals experienced during November and December, particularly from storm Desmond. 2015 had by far the largest number of counts of station-days exceeding 150mm and 200mm in the series. 11 stations recorded a daily total (09-09GMT) exceeding 150mm during storm Desmond, compared to eight stations for 19th November 2009, the next wettest.

Daily falls of over 200mm are extremely unusual for the UK, for example there were only 16 observations exceeding 200mm in over 100 years of British Rainfall publications from 1866 to 1968 (Rodda et al, 2009), with five on 18 July 1955 and four on 28 June 1917 (the former setting the UK record of 279mm at Martinstown, Dorset). However, in contrast to November 2009 and December 2015, these were from large-scale convective summer events rather than frontal rainfall during the winter half-year.

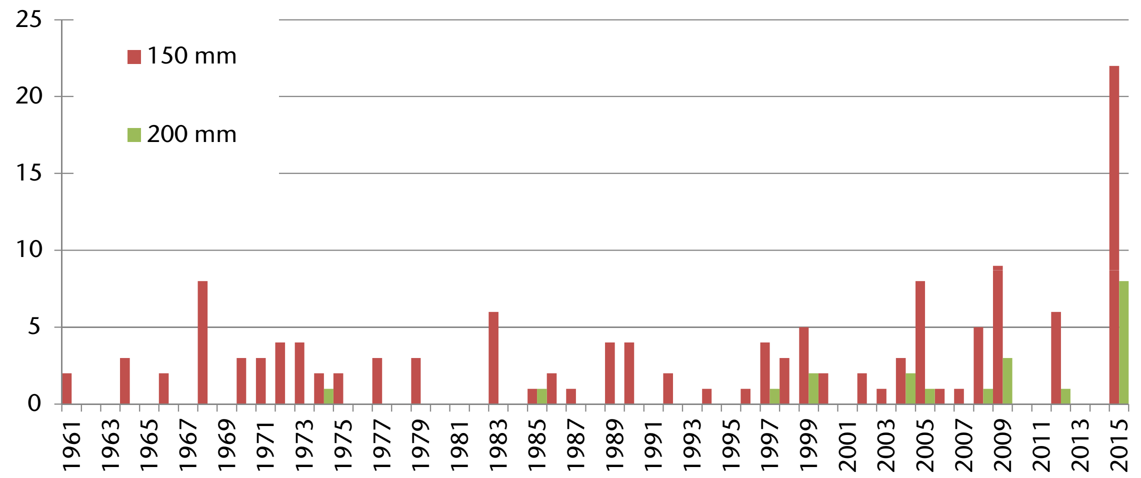


Figure 43: The number of UK daily rainfall station totals by year which have exceeded 150mm (in red) and 200mm (in green).

Figure 44 shows the number of historical observations by year where monthly rainfall totals exceeding 800mm and 1000mm were recorded respectively, representing the most extreme monthly falls. 2015 has the greatest count of station-months exceeding 800mm, also accounting for almost half of all station-months exceeding 1000mm. Other notably wet months with more than 10 stations exceeding 800mm include January 1974, March 1990, January 1993, December 2006 and November 2009. These months were typically characterized by wet and sometimes stormy weather brought by Atlantic depressions across the north and west of the UK. Nevertheless, far more stations exceeded 800mm or 1000mm in December 2015 than any other of these months (Table 7). As with the previous figure there may be some suspect data.

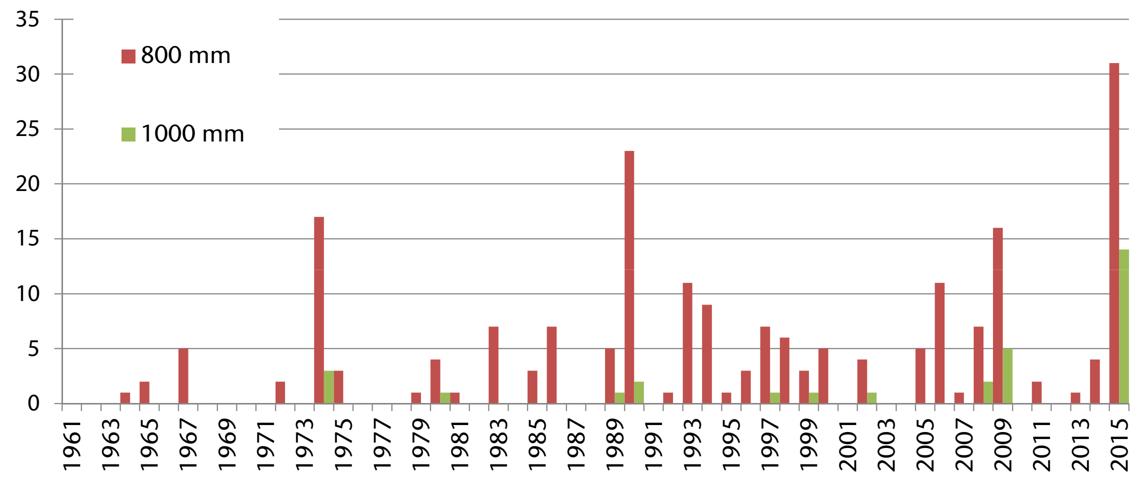


Figure 44: The number of UK monthly rainfall station totals by year which have exceeded 800mm (in red) and 1000mm (in green).

Table 7: The number of stations by month in the UK network with a rainfall total exceeding a) 800mm, 5 or more, and b) 1000mm, 2 or more

Month	Count
Dec-2015	25
Mar-1990	16
Nov-2009	15
Jan-1974	11
Jan-1993	11
Dec-2006	11
Dec-1974	6
Mar-1994	6
Feb-1997	6
Feb-1998	6
Oct-2008	6
Oct-1967	5
Jan-2005	5
Nov-2015	5

Table 7: (a)

Month	Count
Dec-2015	12
Nov-2009	5
Jan-1974	3
Oct-2008	2
Nov-2015	2

Table 7: (b)

Record-breaking temperatures

For prolonged periods during December temperatures were frequently closer to what might be expected in April or even May. Maximum temperatures at individual weather stations during the month reached 15 or 16 °C; several long running stations recorded their highest December temperature on record including Oxford (163 years), Durham (135 years), Bradford, West Yorkshire, Buxton, Derbyshire, Rothamsted, Hertfordshire, Balmoral, Aberdeenshire and Woburn, Bedfordshire (all 100+ years).

Monthly mean monthly temperature anomalies across southern England were typically 5 °C above average, reaching 6 °C in a few locations. This was the warmest December in the CET series by a margin of 1.6 °C and had the highest positive anomaly of any calendar month in the series by a margin of well over 1 °C (Figure 45 and 46). The CET December time-series emphasises the marked contrast in temperature between the Decembers of 2010 and 2015. Remarkably, all but a handful of stations across central and southern England and Wales recorded no air frosts during the month.

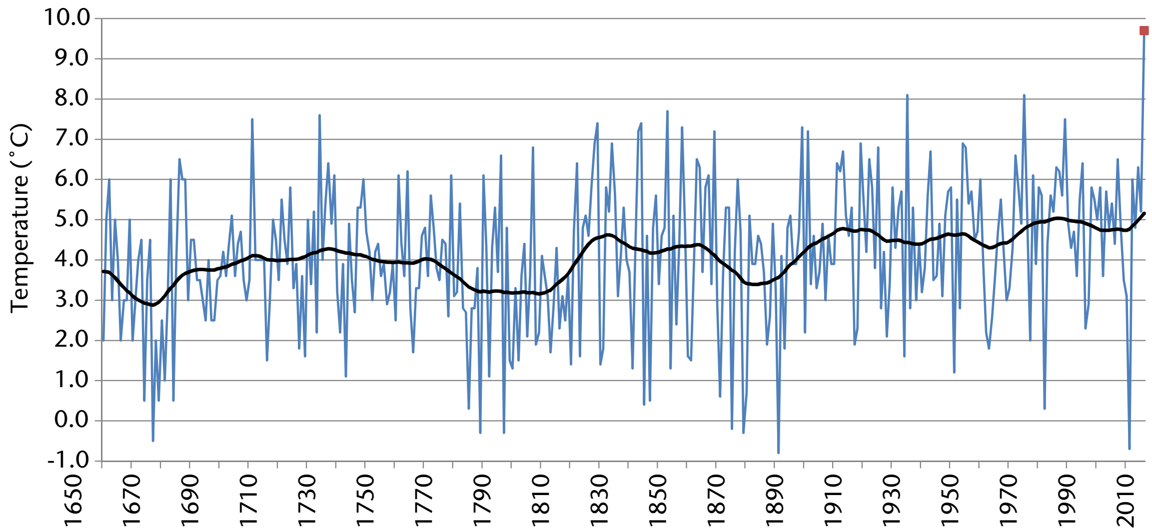


Figure 45: December CET series from 1659 to 2015. The values for December 2010 and December 2015 differ by over 10 °C.

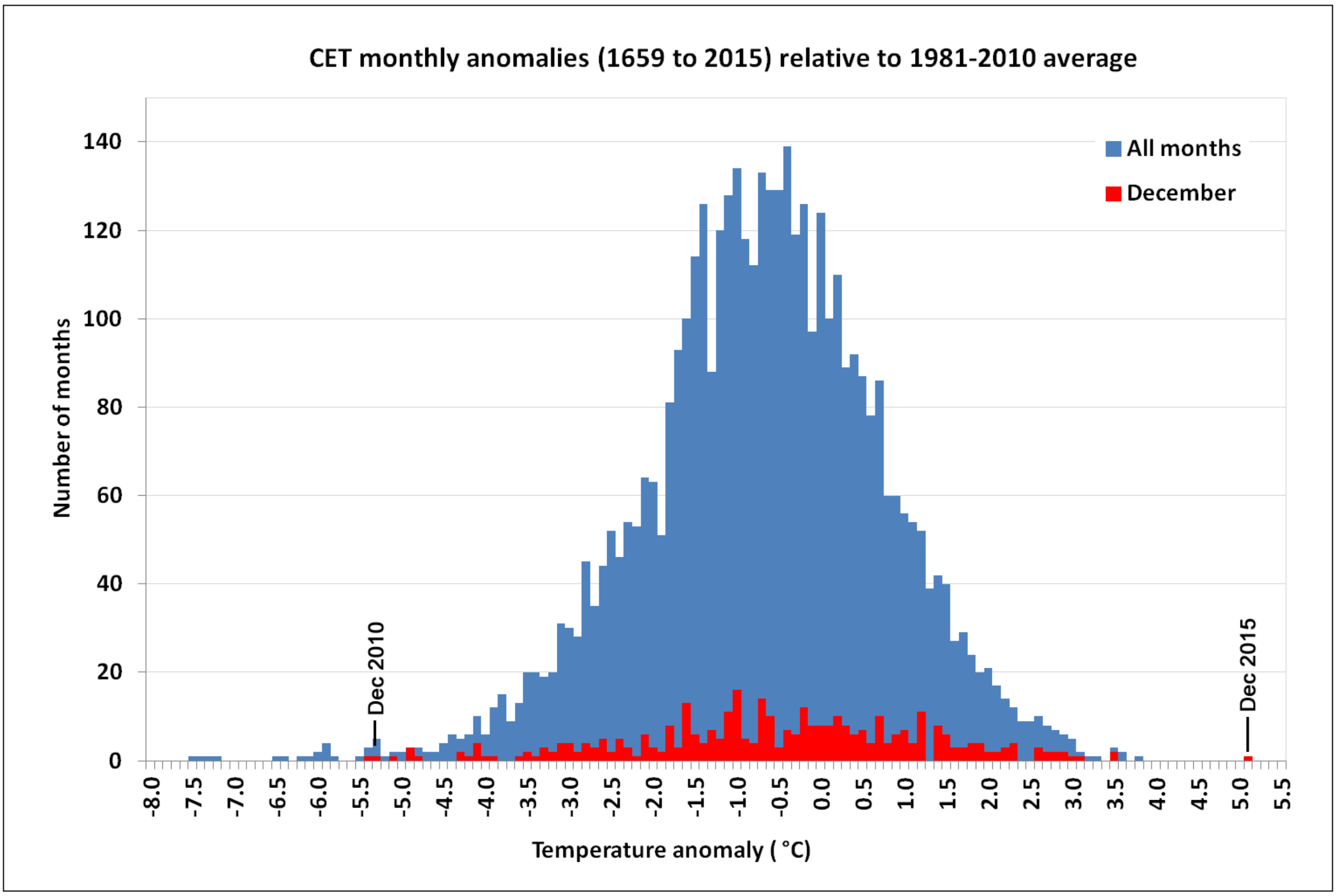


Figure 46: Histogram of monthly temperature anomalies for all months (blue) and Decembers (red) in CET series from 1659 to 2015 inclusive.

For more information on the December floods see
http://www.metoffice.gov.uk/climate/uk/interesting/december2015 and
http://www.metoffice.gov.uk/climate/uk/interesting/december2015_further

For more information on the December record-breaking temperatures see
http://www.metoffice.gov.uk/climate/uk/interesting/december2015_temperature

A special issue of Royal Meteorological Society Weather is planned for December 2016, covering the storms and record-breaking warmth of December 2015.

Correction to 2014 report

The heating degree days (HDD) table below Figure 12 in the State of the UK Climate 2014 report showed incorrect values for 2005 to 2014 averages. The corrected values are included in Table 8 third column with the incorrect (published) values in brackets. The other columns in this table were correct as published.

Table 8: Corrections to heating degree days (hdd) for 2014. Previous incorrect published values in brackets.

Area	1961-1990 average	1981-2010 average	2005-2014 average	2014
UK	2731	2566	2472 (2499)	2222
England	2514	2333	2235 (2265)	1967
Wales	2609	2446	2362 (2387)	2131
Scotland	3140	3000	2908 (2935)	2665
Northern Ireland	2646	2491	2402 (2418)	2261

Minor rounding issues affected three temperature values in the State of the Climate 2014 report.

Northern Ireland 1961-1990 annual Tmean, correct value 8.4 °C not 8.5 °C as published.

UK 1981-2010 autumn Tmean, correct value 9.4 °C not 9.5 °C as published.

UK 1961-1990 annual Tmax, correct value 11.8 °C not 11.9 °C as published.

The 1981-2010 number of station-days greater than or equal to 50mm has been changed from 1273 to 1291 (see Figures 28 in both State of the UK Climate 2014 and this report). This is due to minor methodological changes in data extraction.

Annex 1: Datasets

MONTHLY GRIDS

The principal sources of data in this report are monthly gridded datasets at 5 km resolution covering the UK (Perry and Hollis, 2005b). The grids are based on the GB national grid, extended to cover Northern Ireland and the Isle of Man, but excluding the Channel Islands. Table A1.1 shows the gridded data used for this report, including the year from which variables are available.

Table A1.1: List of variables presented in this report, gridded over the UK at 5km resolution

Climate Variable	Definition	First year available	Gridding time-scale
Max air temperature	Average of daily max air temperatures °C	1910	Monthly
Min air temperature	Average of daily min air temperatures °C	1910	Monthly
Mean air temperature	Average of mean daily max and mean daily min air temperatures °C	1910	Monthly
Days of air frost	Count of days when the air min temperature is below 0 °C	1961	Monthly
Days of ground frost	Count of days when the grass min air temperature is below 0 °C	1961	Monthly
Heating degree days	Day by day sum of number of degrees by which the mean temperature is less than 15.5 °C	1961	Annual
Cooling degree days	Day by day sum of number of degrees by which the mean temperature is more than 22 °C	1961	Annual
Growing degree days	Day by day sum of number of degrees by which the mean temperature is more than 5.5 °C	1961	Annual
Precipitation	Total monthly precipitation amount (mm)	1910	Monthly
Days of rain >= 1mm	Number of days with >= 1mm precipitation	1961	Monthly
Days of rain >= 10mm	Number of days with >= 10mm precipitation	1961	Monthly
Rainfall intensity^	Total precipitation on days with >= 1mm divided by the count of days with >= 1mm during the year	1961	Annual
Sunshine	Total hours of bright sunshine during the month based on the Campbell-Stokes recorder	1929	Monthly

^ Annual rainfall intensity grids have been derived from 5km daily precipitation grids which are gridded separately to monthly precipitation

The Met Office Integrated Data Archive System Land and Marine Surface Stations (MIDAS) Database is the source of UK station data for this gridded dataset. The network size for each variable changes each month and the gridding process is designed to remove the impact of these changes on climate monitoring statistics. Table A1.2 summarizes the approximate number of stations which have been used for each of the variables for gridding. Figure A1.1 shows the 2015 UK station network for the variables presented in this report.

Table A1.2: Typical number of stations used to create the gridded datasets.

Climate Variable	Before 1961	1961 onwards
Air temperature (max, min, mean)	320	550
Days of ground frost	n/a	420
Precipitation	650	4400
Days of rain >= 1mm, >= 10mm	n/a	4000
Sunshine	270	300

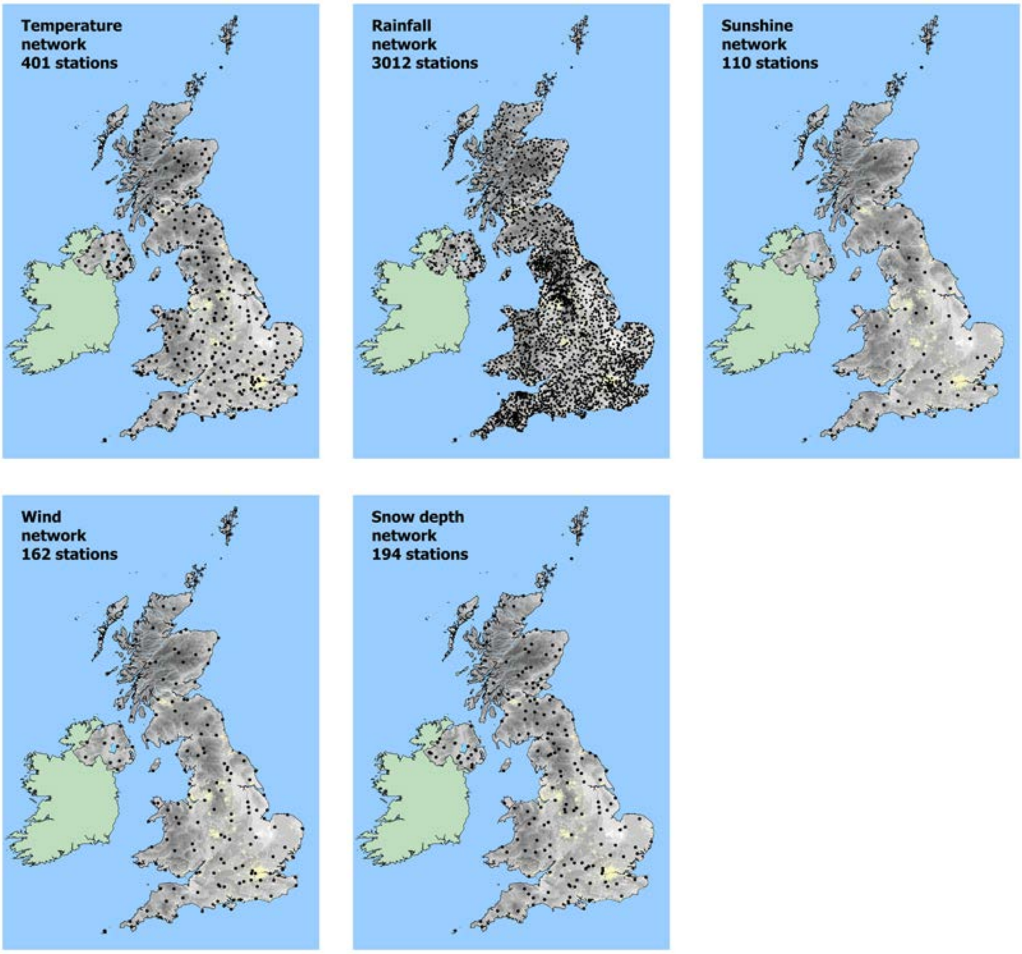


Figure A1.1: State of the UK observing network in 2015. The number of observations may vary on a daily basis due to data availability. The number of stations has reduced since the 1970s, partly because of station closures and partly because of delayed data yet to be received. The number of snow depth observations is typically much lower than that shown on the map – typically approximately 120 - because currently observers often do not record zero snow depths. This map shows all 194 stations which have returned at least one snow depth observation at 0900GMT during year 2015

A key aim of the gridding process is to remove the effects of the constantly varying pool of stations. This could be overcome by only using stations with a complete record, but the sparseness of such stations would introduce much greater uncertainty due to the spatial interpolation required. Instead, all stations believed to have a good record in any month are used, and every effort made to compensate for missing stations during the gridding process reducing uncertainty by maximising the number of observations used. A description of the gridding process is also given in Jenkins et al, (2008) and Prior and Perry (2014).

LONG TERM AVERAGE GRIDS

Areal-averages for the WMO standard 30-year climatological reference periods 1961-1990 and 1981-2010 presented in this report have been calculated from long-term average monthly gridded datasets at 1km resolution covering the UK (Perry and Hollis, 2005a). The process for producing these grids is outlined as follows: For the majority of variables, long-term averages for each station are calculated from monthly station data. Gaps in the monthly station data are filled with estimates obtained via regression relationships with a number of well-correlated neighbours, and long-term averages are then calculated for each site. Gridded datasets of long-term averages are created by regression against latitude, longitude, elevation, terrain shape, proximity to coast and urban extent, followed by inverse-distance weighted interpolation of residuals from the regressions. The estimation of missing values allows a dense network of stations to be used, and this along with the range of independent variables used in the regression, allows detailed and accurate long-term average datasets to be produced. These are then used to constrain the gridded analyses for individual years, seasons, months and days via the geographical interpolation of deviations from, or ratios of, the long-term average.

However, this method does not work well for a number of variables, including days of air frost and ground frost, and an alternative approach is used. Firstly, a 1 km resolution grid of values for each month is calculated from the available station data. Secondly, the gridded long-term average datasets are then obtained by averaging the monthly grids.

Because the long-term averages are calculated from 1km grids separately to the monthly 5km grids, the long-term averages are not exactly consistent with the monthly analyses. There are a number of reasons for this: for most variables the order of the calculation varies i.e. 'average-then-grid' versus 'grid-then-average'; the station network will be very much denser for the long-term average grids than the monthly grids; the grid resolution is 1km rather than 5km.

Table A1.3 compares 1981-2010 long-term average annual mean temperature and rainfall as derived from 1km long-term average, and 5km monthly grids. For temperature, the difference of 0.04 °C for the UK overall is less than 10% of the difference between 1961-1990 and 1981-2010 1km long-term averages. For rainfall, the difference of 2.5% is around half the difference between the 1961-1990 and 1981-2010 1km long-term averages. For both temperature and rainfall, the difference is greatest in Scotland, which contains the largest area of mountain topography in the UK and where the 1km resolution long-term average grid is likely to provide a greater level of detail.

Table A1.3: Comparison of 1981-2010 long-term average annual mean temperature and rainfall as derived from 1km long-term average grids.

Area	Temperature 5km	Temperature 1km	Difference (°C)	Rainfall 5km	Rainfall 1km	Difference (%)
UK	8.88	8.84	0.04	1126	1154	2.5
England	9.68	9.65	0.03	842	855	1.5
Wales	9.18	9.14	0.03	1414	1460	3.2
Scotland	7.47	7.40	0.07	1517	1571	3.6
Northern Ireland	8.92	8.91	0.01	1136	1136	0.0

DAILY GRIDS AND DEGREE DAYS

Daily Tmax, Tmin and Tmean grids of the UK at 5km resolution from 1960 have been generated using a similar method to that for the monthly grids (Perry et al, 2009). However, with daily data there is often a weaker link between the data and the geographical factors which shape the average over a longer time-scale.

Degree day datasets were generated from the daily temperature grids using formulae for calculating degree days above a threshold given in Table A1.4. The daily mean temperature Tmean is calculated from the daily maximum temperature Tmax and the daily minimum temperature Tmin as (Tmax + Tmin)/2. The degree day value is estimated differently depending on which of Tmin, Tmean or Tmax are below (for HDD) or above (for CDD and GDD) the defined degree day threshold.

Table A1.4: Formulae used for calculating cooling or growing degree days above thresholds of 22 °C and 5.5 °C, equivalent formulae used for heating degree days below a threshold of 15 °C.

Temperature	Day value (above threshold)
$T_{max} \leq T_{threshold}$	0
$T_{min} \geq T_{threshold}$	$T_{mean} - T_{threshold}$
$T_{mean} \geq T_{threshold}$ & $T_{min} < T_{threshold}$	$0.5\,(T_{max} - T_{threshold}) - 0.25\,(T_{threshold} - T_{min})$
$T_{mean} < T_{threshold}$ & $T_{max} > T_{threshold}$	$0.25\,(T_{max} - T_{threshold})$

CENTRAL ENGLAND TEMPERATURE

The Central England Temperature (CET) monthly series, beginning in 1659, is the longest continuous temperature record in the world (Manley, 1974). It comprises the mean of three observing stations covering a roughly triangular area of England from Bristol to London to Lancashire; the current stations used for this series are Pershore College (Worcestershire), Rothamsted (Hertfordshire) and Stonyhurst (Lancashire) although the stations used in this series have changed in the past. A CET daily series is also available from 1772 (Parker et al, 1992).

Following each station change the data are adjusted to ensure consistency with the historical series, and since 1960 the data have been adjusted to allow for any effects of warming due to the expansion of local built up areas. Work by Parker and Horton, 2005 and Parker, 2010 have investigated uncertainties in the CET series.

SEA SURFACE TEMPERATURE DATA

The Met Office Hadley Centre's sea ice and sea surface temperature (SST) data set, HadISST1 is a global dataset of monthly sea-surface temperature and sea ice concentration on a 1 degree latitude-longitude grid from 1870 to date (Rayner et al, 2003). The dataset is derived from a combination of fixed and drifting buoys, ship bucket and engine room intake thermometers and hull sensors; and satellite data.

The UK near-coast sea-surface temperature series in this report comprises the average of all 1 degree latitude-longitude grid points adjacent to the coast of Great Britain (approximately 50 grid points).

ENGLAND AND WALES PRECIPITATION SERIES

The England and Wales precipitation series (EWP) has monthly data back to 1766, and is the longest instrumental series of this kind in the world. The daily EWP series begins in 1931. The series incorporates a selection of long-running rainfall stations to provide a homogeneity-adjusted series of areal averaged precipitation. EWP totals are based on daily weighted totals from a network of stations within each of five England and Wales regions.

The extent to which seasonal trends apparent in the EWP series are influenced by homogeneity issues (for example: the number of stations used historically to compile the EWP series, how well the network has historically captured orographically enhanced rainfall across high ground; how well the network has historically captured precipitation which has fallen as snow) remains an area of investigation. Various papers detail the development of the EWP series (Wigley, 1984, Alexander and Jones, 2001, Simpson and Jones, 2012).

RAINGAUGE AND SNOW DEPTH DATA

Daily rainfall data presented in this report are from 0900-0900 GMT totals from either daily or tipping-bucket rain-gauges registered with the Met Office. The rain-gauge network has diminished from over 4000 rain-gauges across the UK in the 1960s, reaching over 5000 in the 1970s, to approximately 3000 or fewer in the 2010s. The gauges are owned and maintained by several organizations: the Met Office, the Environment Agency, Natural Resources Wales, SEPA and Northern Ireland Water. The spatial distribution of the network has changed with time but nevertheless the high network density ensures that all but the most localized convective events are captured at a daily time-scale.

Snow depth data are recorded at 0900 GMT. These are either spot observations from automatic snow depth sensors or manual observations of representative level depth in a location free from drifting or scour by wind; ideally the average of three measurements would be recorded. The network comprised over 400 stations from 1960 to 2000 but typically around 120 stations from 2013 to 2015 (based on data availability).

SUNSHINE DATA

The UK's sunshine network in 2015 comprises two instrument types. In 2015, just over half the network comprised Campbell-Stokes (CS) sunshine recorders which are read manually; just under half comprises Kipp & Zonen CSD-1 (KZ) automatic sunshine recorders. An upward adjustment of KZ totals is made to give a monthly 'CS equivalent sunshine'. This ensures that the full sunshine network (automatic and manual) is used while maintaining consistency between the two instrument types. Legg, 2014a and references therein provide further details.

SEA LEVEL DATA

Sea level changes around the British Isles are monitored by the UK national network of tide gauges. For more than 100 years tide gauges provide measurements of sea level change relative to the Earth's crust. However, tide gauges are attached to the land, which can move vertically thus creating an apparent sea level change. A UK sea level index for the period since 1901 computed from sea level data from five stations (Aberdeen, North Shields, Sheerness, Newlyn and Liverpool) provides the best estimate for UK sea level rise, corrected for land movement (Woodworth et al, 2009, Bradley et al, 2011). The 2015 Annual Report for the UK National Tide Gauge Network is available at https://www.bodc.ac.uk/data/online_delivery/ntslf/reports/documents/2015annualreport.pdf

Newlyn, Cornwall has a century of hourly (or, since 1993, 15 minute) sea level data from float and pressure tide gauges that have been maintained better than most around the UK. It also has a more open ocean location than stations around North or Irish Sea coasts (Araujo and Pugh, 2008).

Annex 2: Time-series, trends and uncertainty

TIME-SERIES AND TRENDS SHOWN IN THIS REPORT

The time-series in this report are plotted on either actual or anomaly scales. The plots with anomaly scales often show several different areas, seasons or variables which are offset for clarity and ease of comparison; the offsets do not reflect absolute differences between the time-series.

The time-series shown throughout are plotted showing the annual series and a smooth trend. This means that both annual variability and longer term trends (removing this short-term variability) can be viewed simultaneously. Importantly, we note that for some series there may be few individual years that fall close to this long-term trend; and many or even most years may fall well above or well below. Most time-series plots also include the 1981-2010 and 1961-1990 long-term averages.

The smooth trend-lines are constructed using a weighted kernel filter of triangular shape, with 14 terms either side of each target point. The kernel defines how much weighting the terms either side of a point in the series have in estimating the smoothed average at that point, in this case the triangular shape using 14 data points either side means that data points further away have less influence. The effect is to smooth out the year-to-year variations and estimate any longer term variations in the data. At the ends of the time series, only the 14 points to one side of the target point are used, increasing to the full 29 year bandwidth by the 15th point from each end. Similar smoothing filters were used for the earlier trend reports (Jenkins et al 2008, Prior and Perry 2014).

A table of summary statistics is provided below each time-series plot. This shows 1961-1990 averages, 1981-2010 averages, 2006-2015 averages (for the latest decade) and year 2015. While 2006-2015 is a non-standard reference period it provides a 10-year ‘snapshot’ of the most recent decade of observational data, since in a non-stationary climate 1981-2010 averages may already be partially out of date. Differences between the 2006-2015 averaging period and the baseline reference average can reflect both long term trend in the data or shorter term decadal variations. These data are presented to show what has happened in recent years not necessarily what is expected to happen in a changing climate.

Importantly we note that the 1961-1990 and 1981-2010 averages presented are based on 1km resolution gridded data and these are not exactly consistent with the average of the yearly data through the same period (see previous discussion on long term averages), although in practice any differences are small. Annex 1 Table A1.3 provides further details. We use the 1km resolution 1961-1990 and 1981-2010 averages because these datasets contain the greatest level of detail and most comprehensive set of stations, and thus represent our best estimate of these climatologies.

UNCERTAINTY ESTIMATES

Recent studies have considered uncertainties in the gridded data and areal-averages (Legg 2011, Legg 2014b). These have principally focussed on uncertainty associated with the density of the observing station network which is the dominant source of uncertainty, but they have been adjusted upward to acknowledge other sources of error, for example observational errors such as random errors in instrument readings, calibration errors or structural uncertainty (the latter implying that alternative methods of analysis may produce slightly different results). Legg, 2014b published uncertainty ranges for areal-averages of monthly mean temperature, rainfall and sunshine; these increase in the past as the network density reduces.

Table A2.1 lists 1σ uncertainty ranges for annual mean temperature, rainfall and sunshine for different periods in the gridded dataset. Indicative date periods are presented here, but more comprehensive tables can be found in Legg et al. (2014b). We have applied a conservative reduction factor of $\sqrt{2}$ to convert monthly uncertainty ranges to annual. Uncertainty associated with individual months of the year cannot be considered independent but it is reasonable to assume that winter half-year biases are likely to be different in nature from summer half-year biases (Parker, 2010). Uncertainties in the CET and EWP series have also been investigated elsewhere (Parker and Horton, 2005, Parker 2010, Simpson and Jones, 2012).

Table A2.1: 1σ Uncertainty ranges for annual Tmean, rainfall and sunshine.

Temperature (°C)

Year range	UK	England	Wales	Scotland	Northern Ireland
1910-1919	0.04	0.04	0.06	0.06	0.08
1961-1965	0.03	0.03	0.04	0.03	0.04
2006-2012	0.03	0.03	0.04	0.04	0.04

Rainfall (%)

Year range	UK	England	Wales	Scotland	Northern Ireland
1910-1919	1.2	1.2	3.0	2.8	3.7
1961-1965	0.3	0.3	0.6	0.5	0.8
2006-2012	0.4	0.4	0.9	0.7	1.6

Sunshine (%)

Year range	UK	England	Wales	Scotland	Northern Ireland
1929-1935	0.7	0.8	1.0	1.0	1.6
1959-1964	0.6	0.8	0.9	0.8	1.4
2005-2012	0.7	0.9	1.1	1.1	1.8

The summary rainfall statistics for the UK and countries presented in this report are based on an estimate of the total volume of rainfall across the country, rather than an areal-average of the rainfall anomaly field. This means that the climatologically wetter parts of the UK have a greater influence on the overall UK summary statistic than the lowest areas, rather than all equal-sized areas having equal influence. This introduces uncertainty because the rank of each year relative to the others may vary depending on which of these two metrics is chosen. A particular characteristic of the rainfall anomaly pattern for the UK for year 2015 was that the highest anomalies were across the climatologically wettest areas of the west and north, with the lowest anomalies being across the climatologically driest areas of the south and east, so this may have introduced a greater degree of uncertainty for 2015 compared to most other years in the series. A recent study has investigated the different choice of metrics on monthly rainfall data in the UK series (Kendon and Hollis, 2014).

A further source of uncertainty in the rainfall data is introduced by measurement of precipitation which has fallen as snow. At manually read raingauges the observer will measure precipitation equivalent of fresh snow fallen at 0900 GMT, whereas at automatic raingauges any snow collected will be recorded when it subsequently melts; quality control of these data may then re-apportion this precipitation to previous days. However, inevitably snow measurement can be problematic, for example if wind eddies may carry snow over or blow it into or out of the gauge, in many situations estimation of precipitation from snow may be underestimated.

ROUNDING

Values quoted in tables throughout this report are rounded, but where the difference between two such values is quoted in the text (for example comparing the most recent decade with 1981-2010), this difference is calculated from the original unrounded values.

Annex 3: Useful resources

Met Office:

UK climate information http://www.metoffice.gov.uk/climate

Annual State of the UK climate publications from 2014 http://www.metoffice.gov.uk/climate/uk/about/state-of-climate

The CET dataset is maintained by the Met Office Hadley Centre and can be downloaded at http://www.metoffice.gov.uk/hadobs/hadcet/

The EWP dataset is maintained by the Met Office Hadley Centre and can be downloaded at http://www.metoffice.gov.uk/hadobs/hadukp/

The HadISST1 dataset is maintained by the Met Office Hadley Centre and can be downloaded at http://www.metoffice.gov.uk/hadobs/hadisst/

The 5km monthly, annual, and daily temperature datasets used in this report may be downloaded at http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/
Data from the most recent years may be available on request by contacting the Met Office National Climate Information Centre ncic@metoffice.gov.uk

Further information about the daily gridded precipitation data may be obtained by contacting the Met Office Customer Centre http://www.metoffice.gov.uk/about-us/contact

Met Office UK Storm Centre Name our Storms project http://www.metoffice.gov.uk/uk-storm-centre

External links:

The Met Office is not responsible for the content of external internet sites

Access to a copy of the Met Office Midas database is available to researchers on registration at http://catalogue.ceda.ac.uk/uuid/220a65615218d5c9cc9e4785a3234bd0

Bulletin of the American Meteorological Society (BAMS) state of the Climate Report http://www.ncdc.noaa.gov/bams-state-of-the-climate/

Annual Bulletin on the Climate in region VI Europe and Middle East http://www.dwd.de/ravi

Centre for Ecology and Hydrology, National Hydrological Monitoring Programme, Monthly Hydrological Summaries for the UK http://nrfa.ceh.ac.uk/monthly-hydrological-summary-uk

Environment Agency Water Situation Reports for England https://www.gov.uk/government/collections/water-situation-reports-for-england

Natural Resources Wales Water Situation Reports for Wales https://naturalresources.wales/water/resources/water-situation-report/?lang=en

National Oceanography Centre information on sea level rise http://noc.ac.uk/science-technology/climate-sea-level/sea-level

Scottish Avalanche Information Service annual reports of the winter season http://www.sais.gov.uk/sais-annual-reports/

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