Met Office
Hadley Centre

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

State of the UK Climate 2014

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Cover: Satellite image of the UK on 24 July 2014 showing low cloud over the North Sea which drifted inland bringing patchy mist and fog to parts of eastern England and Scotland. Thundery showers affected the far south-west, but otherwise it was a fine, hot summer's day with temperatures reaching the high 20s throughout the UK. This was the hottest day of the year for over 80 weather stations from the south of England to the west of Wales to the north of Scotland. This image from the NERC Satellite Receiving Station, Dundee University http://www.sat.dundee.ac.uk/

Contents

Introduction

This report provides a summary of the UK weather and climate through the calendar year 2014, alongside the historical context for a number of essential climate variables. The report is intended as an update to *The climate of the UK and recent trends* (Jenkins et al, 2008) and as the first in a series of annual 'State of the UK climate' publications. 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, wind speed, sea level pressure and humidity from the UK land weather station network as managed by the Met Office and a number of key partners or 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.

This report should be cited as:

Kendon, M., McCarthy, M., and S. Jevrejeva (2015): State of the UK Climate 2014, *Met Office, Exeter, UK.*

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Executive Summary

Land temperature

- 2014 was the warmest year on record for the UK, England, Wales and Scotland in a series from 1910, and for Central England in a series from 1659.
- 8 of the 10 warmest years for the UK have occurred since 2002 and all the top ten warmest years have occurred since 1990.
- The most recent decade (2005-2014) has been on average 0.4 °C warmer than the 1981-2010 climatology and 0.9 °C warmer than 1961-1990.

Air and ground frost

- 2014 had the fewest air and ground frosts on record for the UK in a series from 1961.
- The most recent decade (2005-2014) has had 5% fewer days of air frost and 8% fewer days of ground frost compared to the 1981-2010 average, and 15% / 12% fewer compared to 1961-1990.

Energy demand and Growing conditions

- 2014 had the lowest Heating degree day index and second highest Growing degree day index for the UK in series from 1960.
- The most recent decade (2005-2014) has had 3% fewer Heating degree days per year on average compared to 1981-2010, and 8% fewer compared to 1961-1990.
- The most recent decade (2005-2014) has had 6% more Growing degree days per year on average compared to 1981-2010, and 16% more than 1961-1990.

Near-coast sea-surface temperature

- 2014 was the warmest year on record for UK near-coastal sea-surface temperature (SST) in a series from 1870.
- 9 of the 10 warmest years for near-coast SST for the UK have occurred since 1989.

Sea level rise

- Mean sea level around the UK rose by approximately 1.4 mm/yr in the 20th century, when corrected for land movement.
- During 2014 Newlyn, Cornwall recorded its highest maximum water level in a 100 year record.

Precipitation

- 2014 was the fourth wettest year on record for the UK in a series from 1910.
- Winter 2013/14 was the wettest for England and Wales in a series from 1766.
- 7 of the 10 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.

Snow

- 2014 was not a 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.

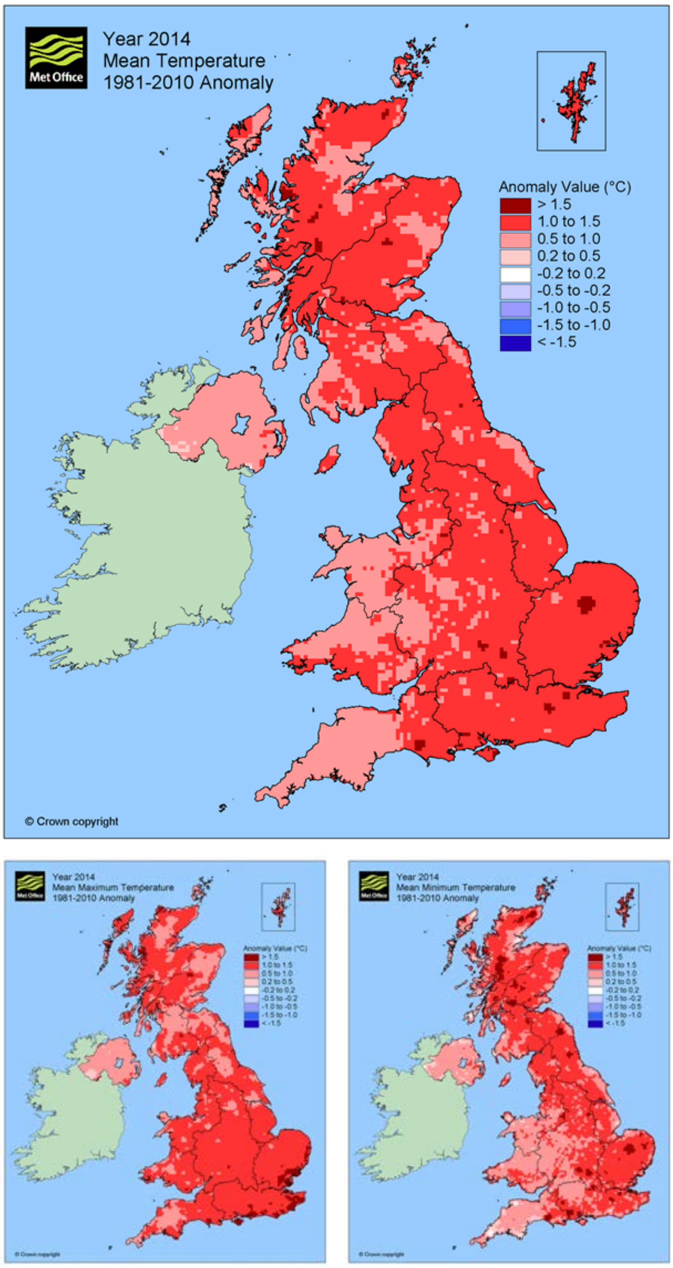
Sunshine

- 2014 was marginally sunnier than average for England and Wales, but duller for Scotland.
- Hours of bright sunshine have increased in recent decades, particularly in winter.

Wind

- There are no compelling trends in storminess as determined by maximum gust speeds from the UK wind network over the last four decades.

Temperature



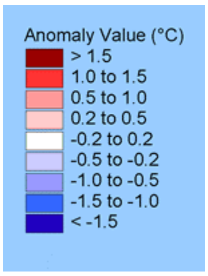


Figure 1: 2014 annual average temperature anomalies (°C) relative to 1981-2010 climatology for mean, maximum and minimum temperature.

Average mean (Tmean), daily maximum (Tmax), and daily minimum (Tmin) temperatures for 2014 were widely 1 to 1.5 °C above the 1981-2010 long term average (Figure 1, Table 1), although slightly lower across Northern Ireland, Wales and parts of south west England. 2014 was the warmest calendar year for Tmean for the UK, England, Scotland and Wales in series from 1910, and in the Central England temperature (CET) series from 1659. In all cases the previous warmest year was 2006. For Northern Ireland the years 2007 and 2006 were warmer.

2014 was the warmest year for Tmax for the UK, England and Wales, second warmest (behind 2003) for Scotland, and equal-third warmest (with 2003, behind 2006 and 2007) for Northern Ireland. It was also second warmest year (behind 2003) for the CET Tmax series from 1878. However, unlike 2003, there were no extreme heatwaves during 2014; instead it was characterized by consistent warmth throughout the year.

2014 was also the warmest year for Tmin for the UK, England, Wales and Scotland. A marked absence of hard frosts through the winter months resulted in Scotland breaking the previous Tmin record by a reasonable margin of 0.3 °C. For the CET Tmin series only 2006 was warmer while for Northern Ireland 2014 was ranked 9th warmest year for Tmin in the series from 1910.

The UK seasonal Tmean (Figure 2, Table 1) for winter (equal-fifth warmest), spring (equal-second warmest) and autumn (third warmest) were notable, and it was the warmest spring for Scotland in the series. As a result of a cool August, the summer Tmean was much nearer average. Tmean was above the 1981-2010 average for all months of the year except August (Figure 3, Table 1), although no individual months were record-breaking.

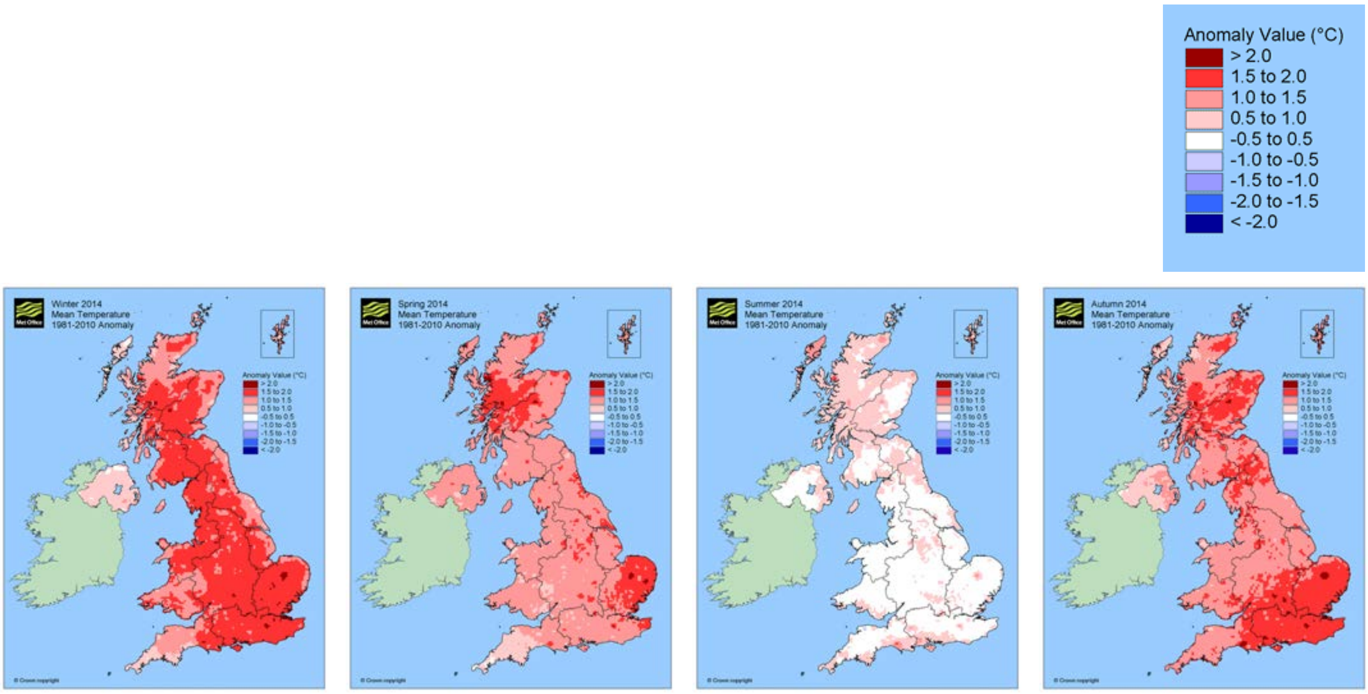
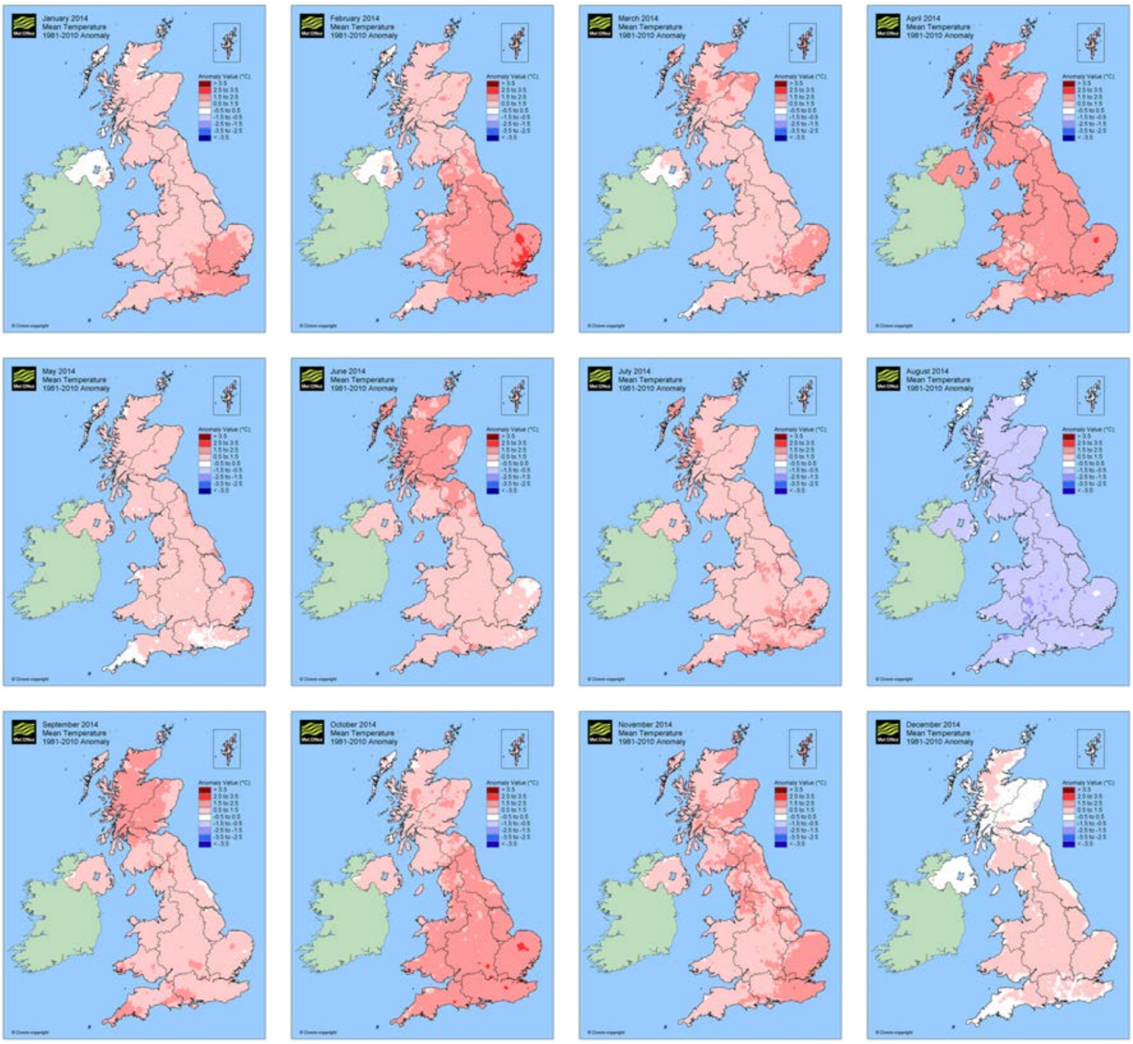


Figure 2: 2014 seasonal average temperature anomalies (°C) relative to 1981-2010 climatology. Winter 2014 refers to the period December 2013 to February 2014.



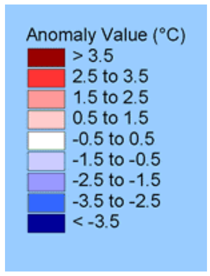


Figure 3: 2014 monthly average temperature anomalies (°C) relative to 1981-2010 climatology.

Table 1: Monthly, seasonal and annual mean temperature (°C) and anomaly values (°C) relative to 1981-2010 for the UK, countries and CET for year 2014. Colour coding relates to the relative ranking in the full series which spans 1910-2014 for all series except CET which is 1659-2014.

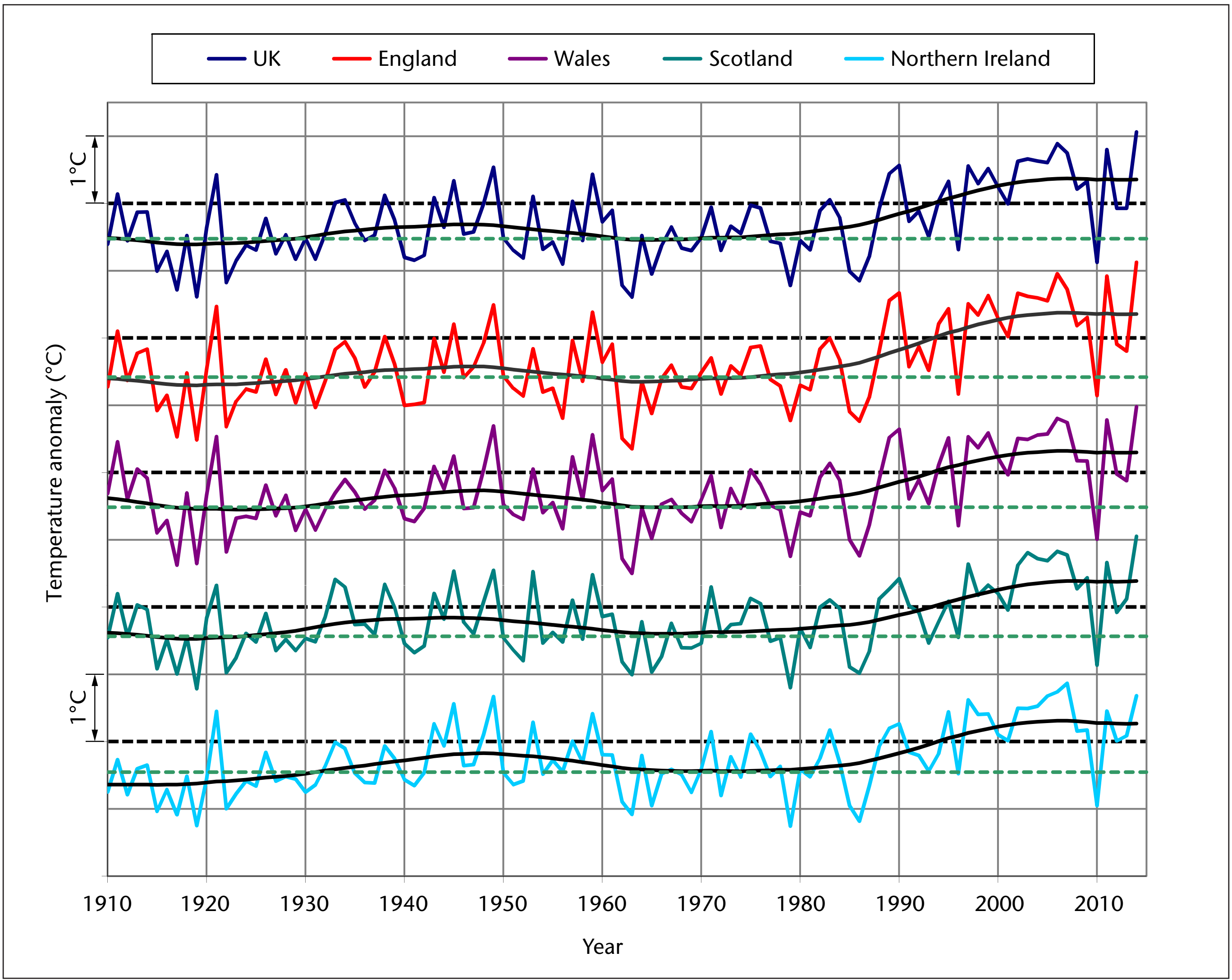
	UK		England		Wales		Scotland		N Ireland		CET	
	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom
Jan	4.8	1.1	5.4	1.3	5.4	1.2	3.5	0.9	4.5	0.3	5.7	1.3
Feb	5.2	1.5	6.0	1.9	5.5	1.5	3.8	1.1	4.7	0.4	6.2	1.8
Mar	6.7	1.2	7.5	1.3	6.8	1.1	5.5	1.3	6.3	0.5	7.6	1.0
Apr	9.2	1.8	10.0	1.8	9.2	1.6	7.9	1.8	9.6	2.0	10.2	1.7
May	11.2	0.9	12.1	0.9	11.3	0.7	9.8	1.0	11.3	1.1	12.2	0.5
Jun	14.2	1.2	15.0	1.0	14.1	1.0	12.9	1.6	13.8	1.0	15.1	0.6
Jul	16.3	1.2	17.6	1.3	16.2	1.0	14.5	1.2	15.7	1.1	17.7	1.0
Aug	13.9	-1.0	15.0	-1.1	14.0	-1.0	12.2	-0.8	13.4	-0.9	14.9	-1.5
Sep	13.9	1.3	14.9	1.2	14.1	1.2	12.5	1.6	13.3	0.9	15.1	1.1
Oct	11.1	1.6	12.3	1.9	11.5	1.7	9.1	1.2	10.3	0.9	12.5	1.8
Nov	7.6	1.4	8.3	1.5	7.8	1.0	6.4	1.4	7.2	0.8	8.6	1.5
Dec	4.4	0.5	5.1	0.7	5.2	0.7	3.1	0.3	4.5	0.1	5.2	0.6
Win	5.2	1.5	5.8	1.6	5.7	1.5	4.2	1.4	5.1	0.7	6.1	1.6
Spr	9.0	1.3	9.8	1.3	9.1	1.1	7.7	1.4	9.1	1.2	10.0	1.1
Sum	14.8	0.5	15.9	0.4	14.8	0.3	13.2	0.6	14.3	0.4	15.9	0.0
Aut	10.9	1.4	11.8	1.5	11.1	1.3	9.3	1.4	10.3	0.9	12.1	1.5
Ann	9.9	1.1	10.8	1.1	10.1	1.0	8.5	1.1	9.6	0.7	11.0	1.0

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 2014 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 (2005-2014) being on average 0.9 °C warmer than the 1961-1990 climatology and 0.4 °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.

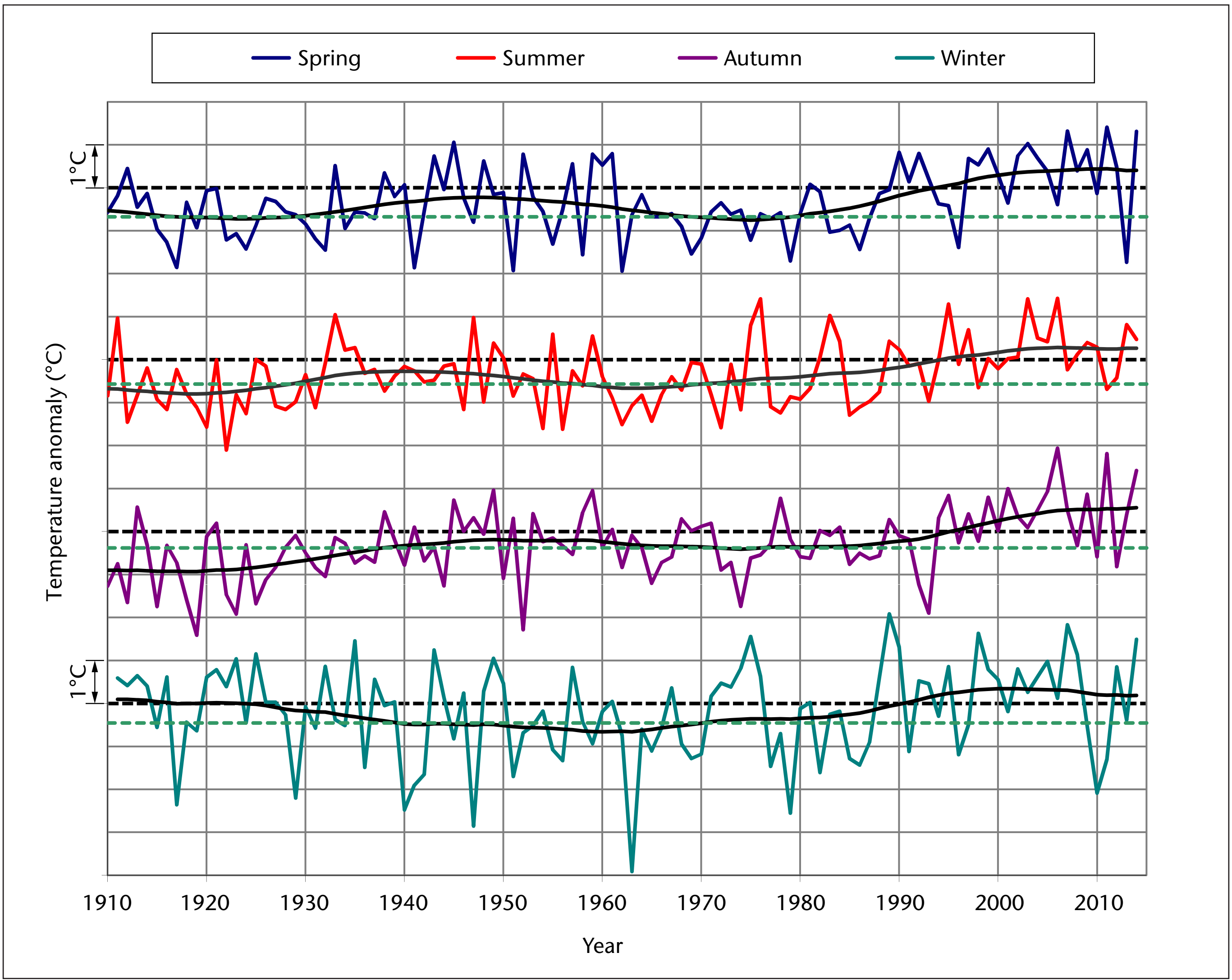
The largest change has occurred in Spring and Autumn with 2005-2014 being 1 °C above 1961-1990, and the smallest change in winter with 2005-2014 being 0.6 o°C above. Warming has been slightly greater for Tmax than Tmin (Figure 6) resulting in a small increase in the average daily temperature range but to levels similar to those observed in the first half of the 20th Century.

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 to the nearest 0.1 °C. More information relating to the uncertainties and how they are estimated is provided in Annex 2.



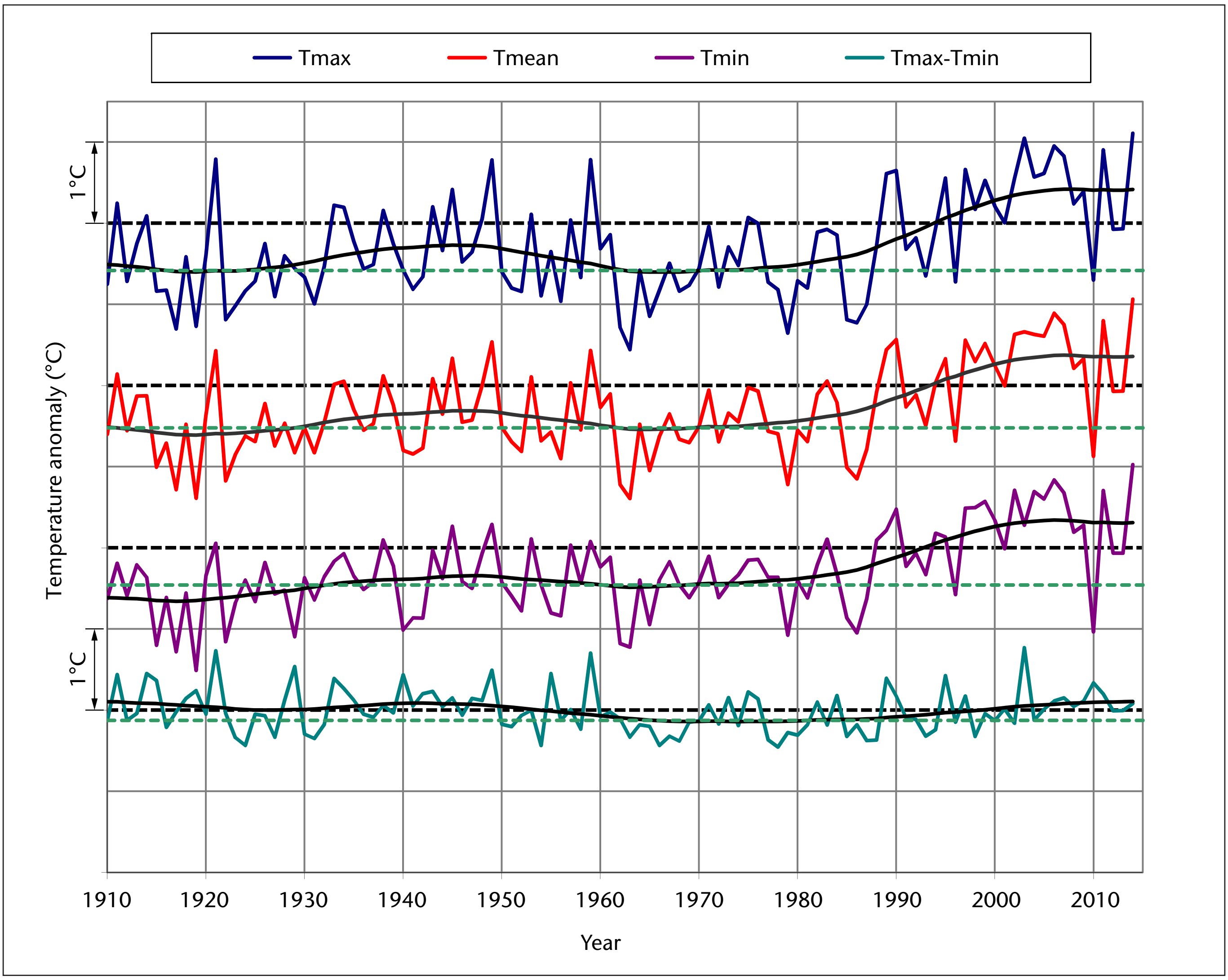
Area	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK	8.3	8.8	9.2	9.9
England	9.1	9.7	10.0	10.8
Wales	8.6	9.1	9.5	10.1
Scotland	7.0	7.4	7.8	8.5
Northern Ireland	8.5	8.9	9.2	9.6

Figure 4: Annual Tmean for the UK and countries, 1910 to 2014, 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 below provides average values. Smoothed trend lines used here and throughout the report are described in Annex 2.



Season	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Spring	7.1	7.7	8.1	9.1
Summer	13.8	14.4	14.6	14.8
Autumn	9.1	9.5	10.1	10.9
Winter	3.3	3.7	3.9	5.2

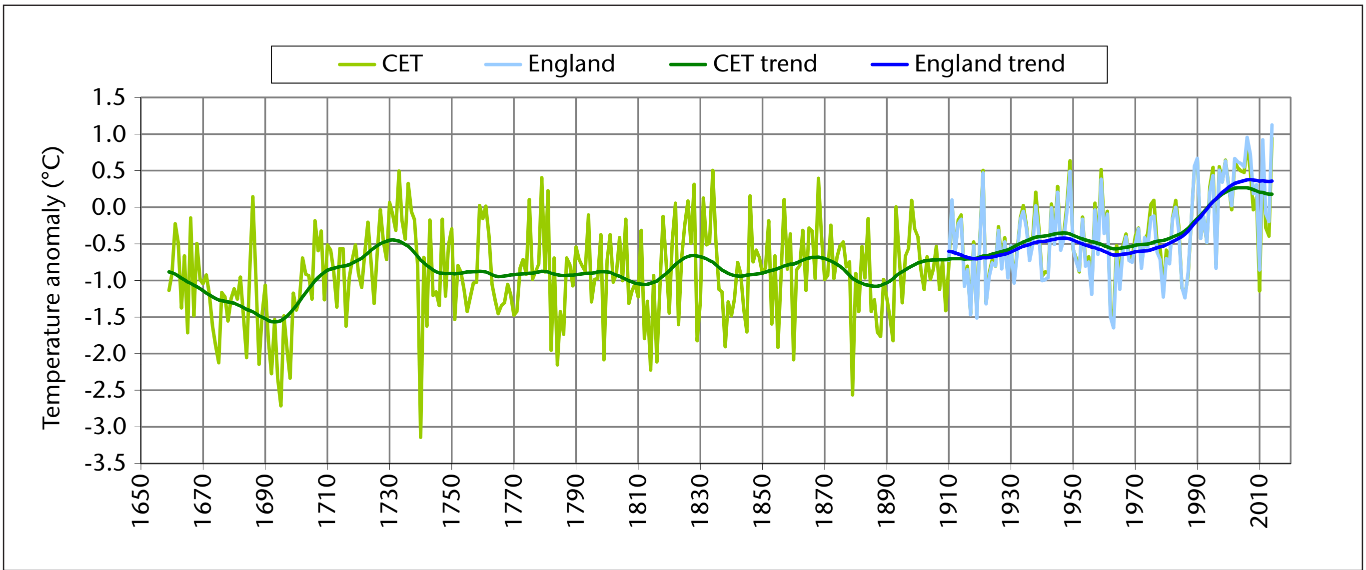
Figure 5: Seasonal Tmean for the UK, 1910 to 2014 (note winter from 1911 to 2014; year is that in which January and February fall). Light grey grid-lines represent anomalies of +/- 1 °C. The table below provides average values.



Variable	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Tmax	11.9	12.4	12.9	13.5
Tmean	8.3	8.8	9.2	9.9
Tmin	4.8	5.3	5.6	6.3
Tmax minus Tmin	7.0	7.2	7.3	7.2

Figure 6: Annual Tmax, Tmean and Tmin for the UK, and Tmax minus Tmin, 1910 to 2014, expressed as anomalies relative to the 1981-2010 average. Light grey grid-lines represent anomalies of +/- 1 °C. The table below provides average values.

Figure 7 shows annual Tmean for England from 1910 to 2014 and CET series from 1659. The series are highly correlated (R^2 value 0.98) and 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).



	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
CET	9.5	10.0	10.2	11.0
England	9.1	9.7	10.0	10.8

Figure 7: Annual Tmean for CET series, 1659 to 2014, and England temperature series, 1910 to 2014, expressed as anomalies relative to the 1981-2010 average. The table below provides average values.

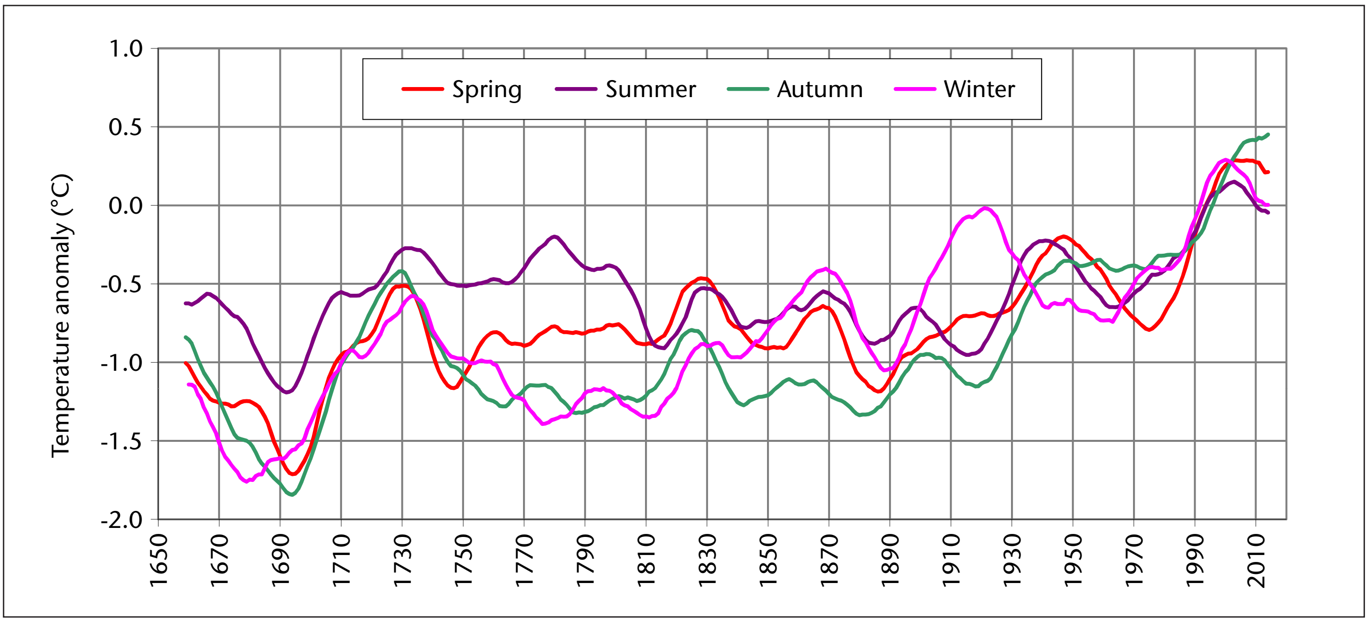


Figure 8: Seasonal CET series, 1659 to 2014, expressed as anomalies relative to 1981-2010 average (°C).
The figure shows a smoothed trend for each series using using a weighted kernel filter described in Annex 2.

Table 2 shows the highest UK Tmax and lowest UK Tmin recorded for the year 2014. The highest temperature of 32.3 °C was fairly typical for the UK. By contrast, the lowest Tmin of -9.0 °C at Cromdale (Moray) on 27th December was unusually mild; in the last 50 calendar years -10 °C has failed to have been recorded in the UK in only 2014 and 1990.

Temperatures below -10 °C usually occur with clear skies, light winds and snow cover, often in the Scottish Glens. However, during the winter months of 2014 a westerly Atlantic weather type was predominant, and such conditions were generally absent.

Table 2: Annual extremes for year 2014

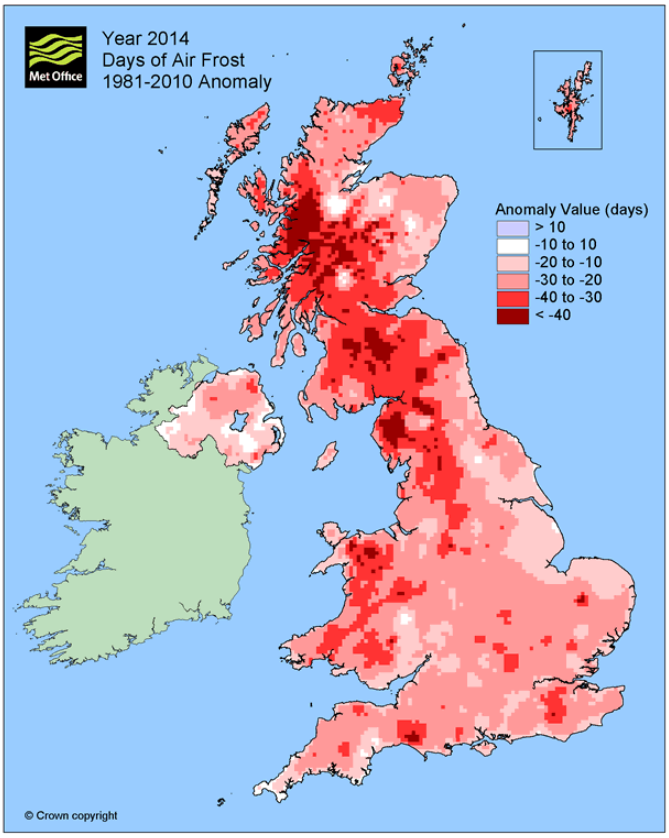
Highest UK daily maximum temperature	32.3 °C at Gravesend (Kent) on 18 July
Lowest UK daily minimum temperature	-9.0 °C at Cromdale (Moray) on 27 December
Highest daily rainfall (09-09 GMT)	148.6mm at Ennerdale, Black Sail (Cumbria) on 6 March
Highest gust speed*	95 Kt Needles Old Battery, Isle of Wight, on 14 February

* Excluding stations above 500 metres above sea level.

DAYS OF AIR AND GROUND FROST

As a consequence of the persistently mild conditions through 2014 the number of days of air frost (see Annex 1 for definition) was typically 20 to 30 days below the 1981-2010 average across much of England, and 30 to 40 days or more below across upland Wales, parts of Northern England and much of Highland Scotland. Similarly, the number of days of ground frost was more than 40 days below average across much of north Wales northern England and Scotland. However, localised parts of west Wales and Northern Ireland had nearer average ground frost (Figure 9). Notably, -1.9 °C at Katesbridge, County Down on 24th August 2014 was the lowest August temperature recorded in Northern Ireland in digitized records.

The annual number of days of air frost and ground frost for the UK overall for 2014 was lowest in both series from 1961 (Figure 10). There was a decline in both air and ground frosts through the 1980s and 1990s, resulting in the most recent decade, 2005-2014 having had an average of 15% fewer annual days of air frost and 12% fewer ground frosts per year than the average for 1961-1990.



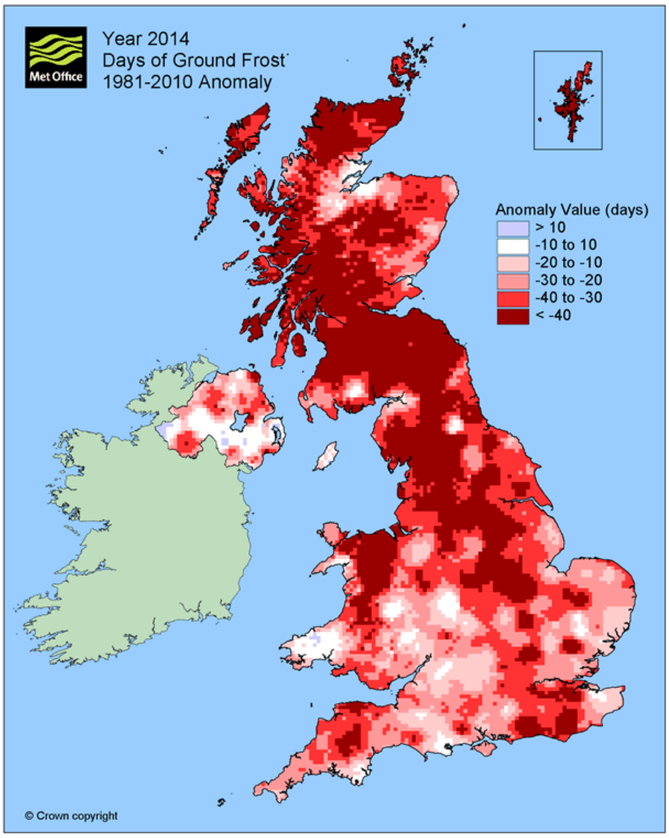
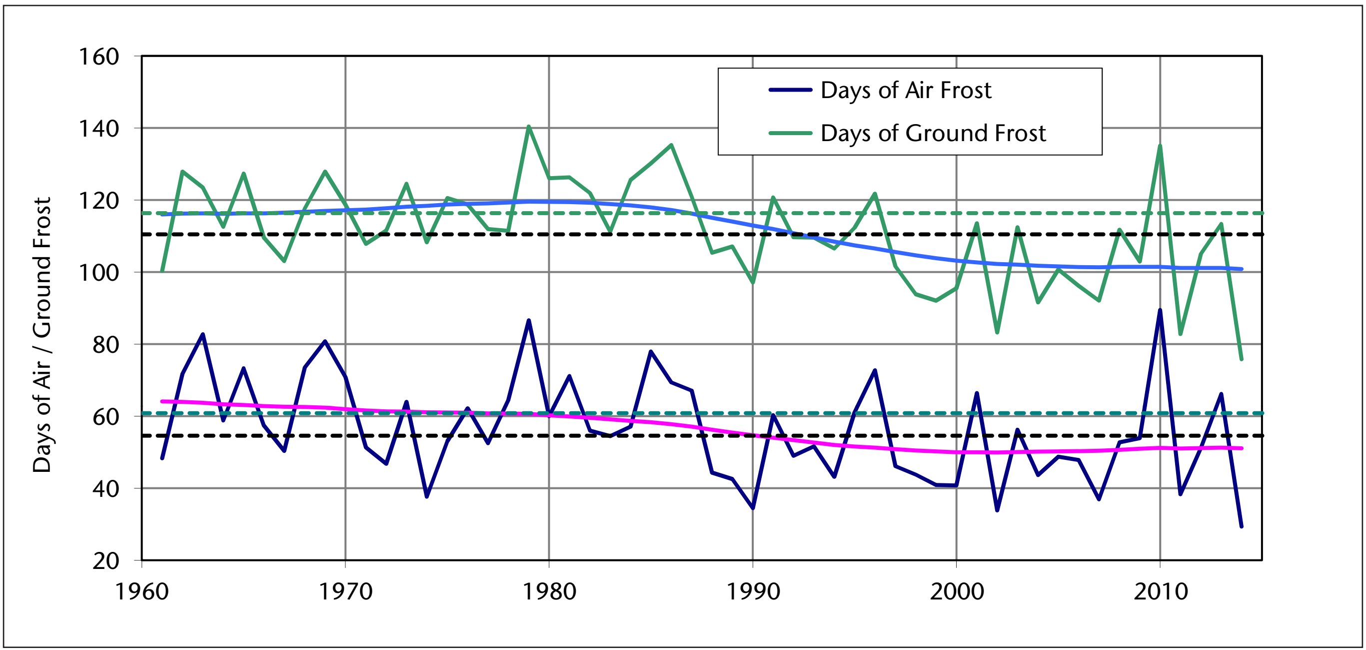


Figure 9: Days of air frost and days of ground frost anomaly for year 2014 relative to 1981-2010. Bulls eye features in these maps are likely to be due to localised factors such as frost hollow effects at individual weather stations which the gridding process is unable to fully represent, particularly for ground frost.



Variable	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Days of Air Frost	61	55	52	29
Days of Ground Frost	116	111	102	76

Figure 10: Annual number of days of air frost and ground frost for the UK, 1961 to 2014.
The hatched black lines are the 1981-2010 annual averages. The table below provides average values.

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) were the lowest on record for the UK in 2014, but most especially across south-east England (here typically 80 to 85% of 1981-2010 average (Figures 11 and 12). Only Northern Ireland has experienced lower HDD most notably in 2007. For the UK, the most recent decade has had an annual average HDD 8% lower than 1961-1990 and 3% lower than 1981-2010. Nevertheless, in year 2010 HDD was well above average (but not record-breaking) across all countries.

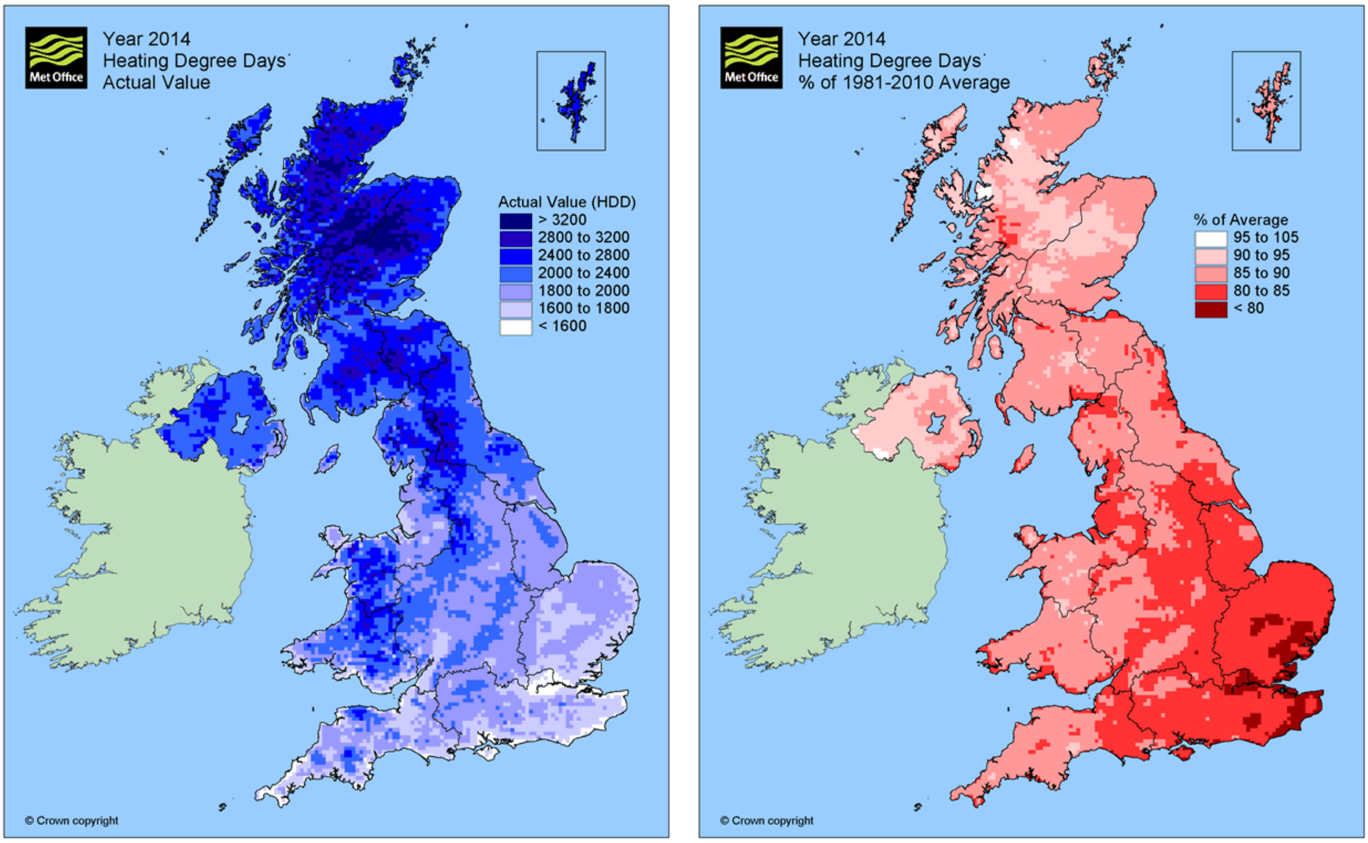
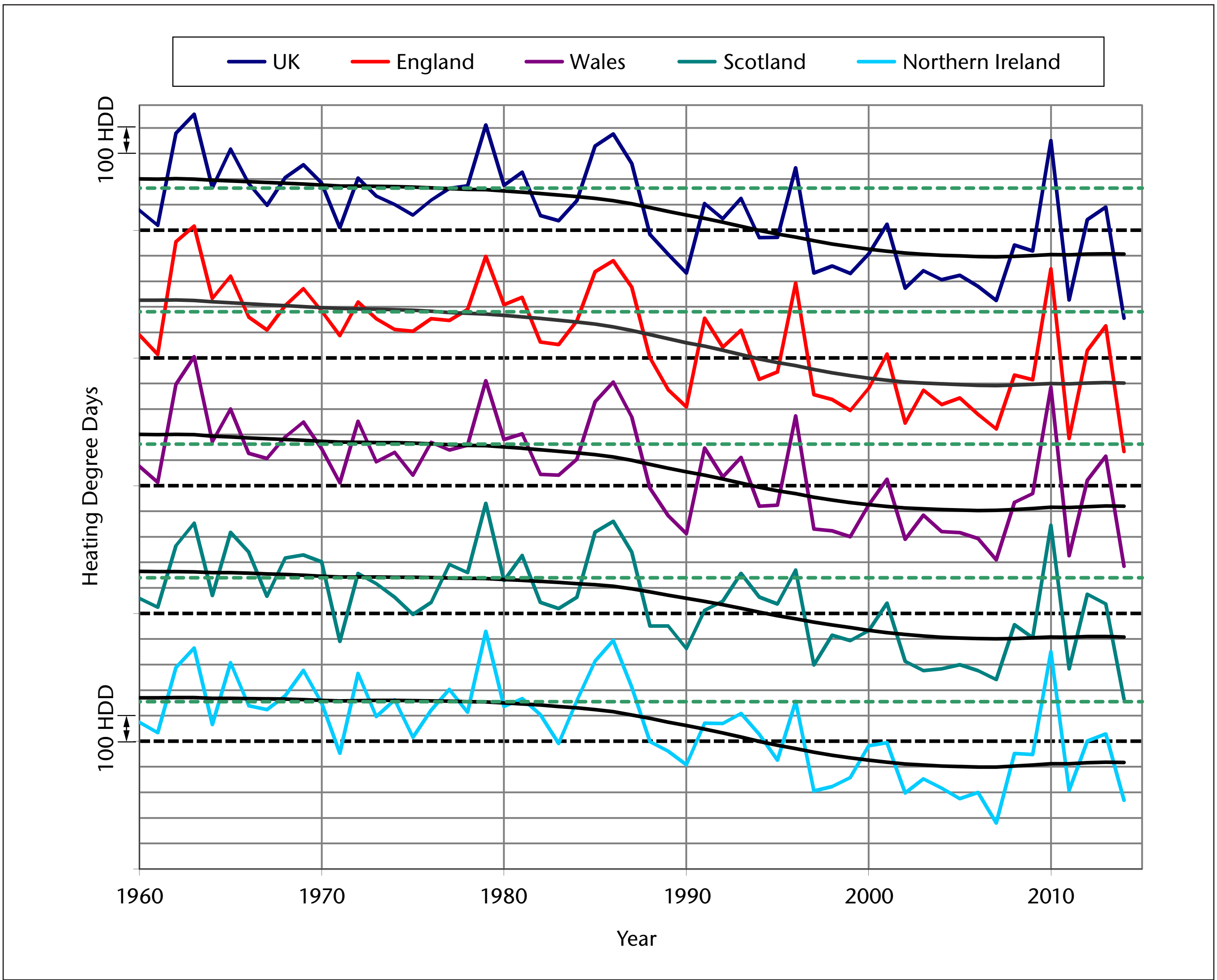


Figure 11: Heating degree days for 2014 (left) actual and (right) % of the 1981-2010 average.



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

Figure 12: Heating degree days for the UK and countries, 1960 to 2014, 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 below provides average values.

In general, the highest cooling degree day (CDD) values are around Greater London due in part to the urban heat-island effect. Despite 2014 being the warmest year in the UK series from 1910, cooling degree days were below average across much of central England by around 5 CDD compared to a 1981-2010 long-term average of around 15 to 20 CDD (Figure 13). There were no notable heat-waves during the summer, rather consistent above-average warmth through the year.

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.

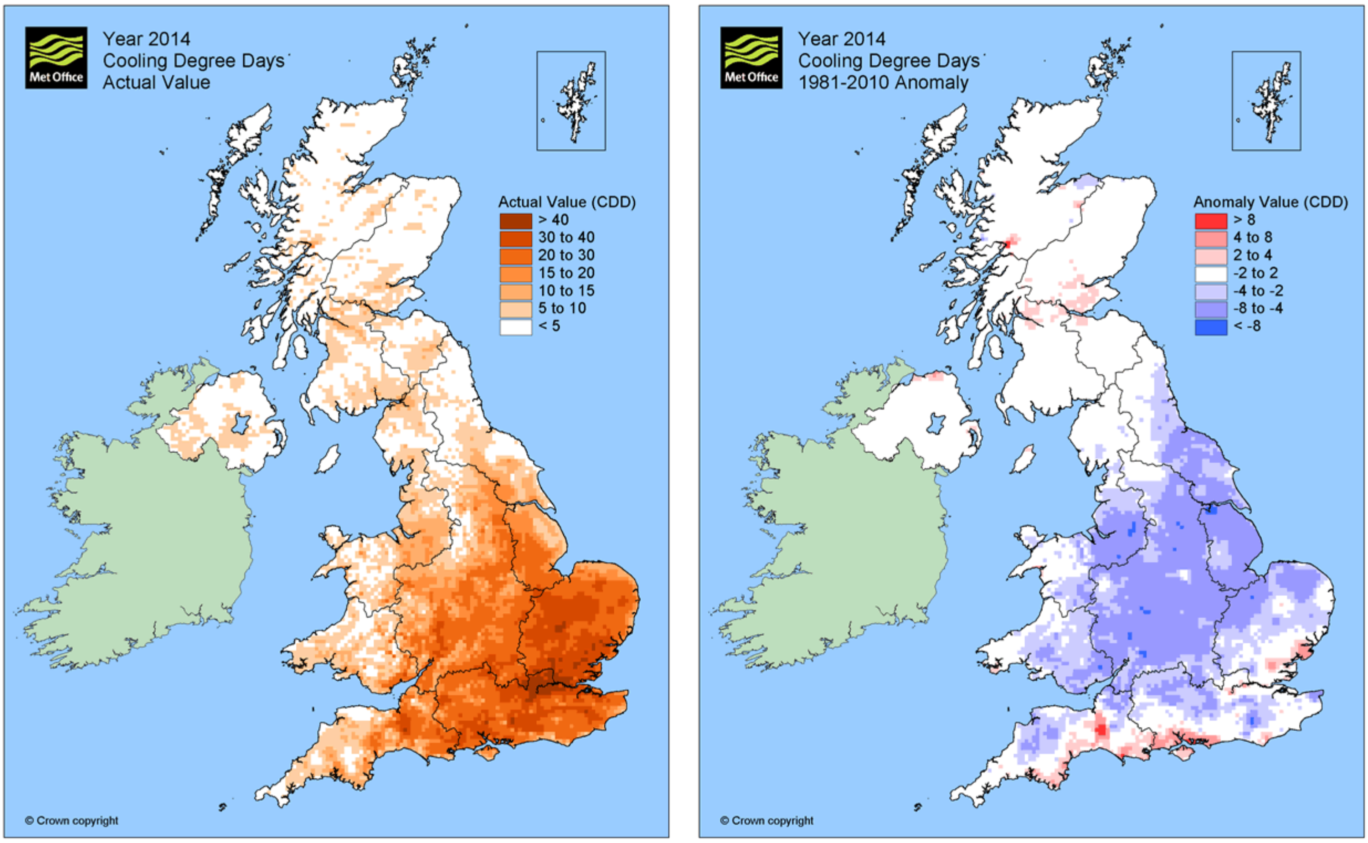
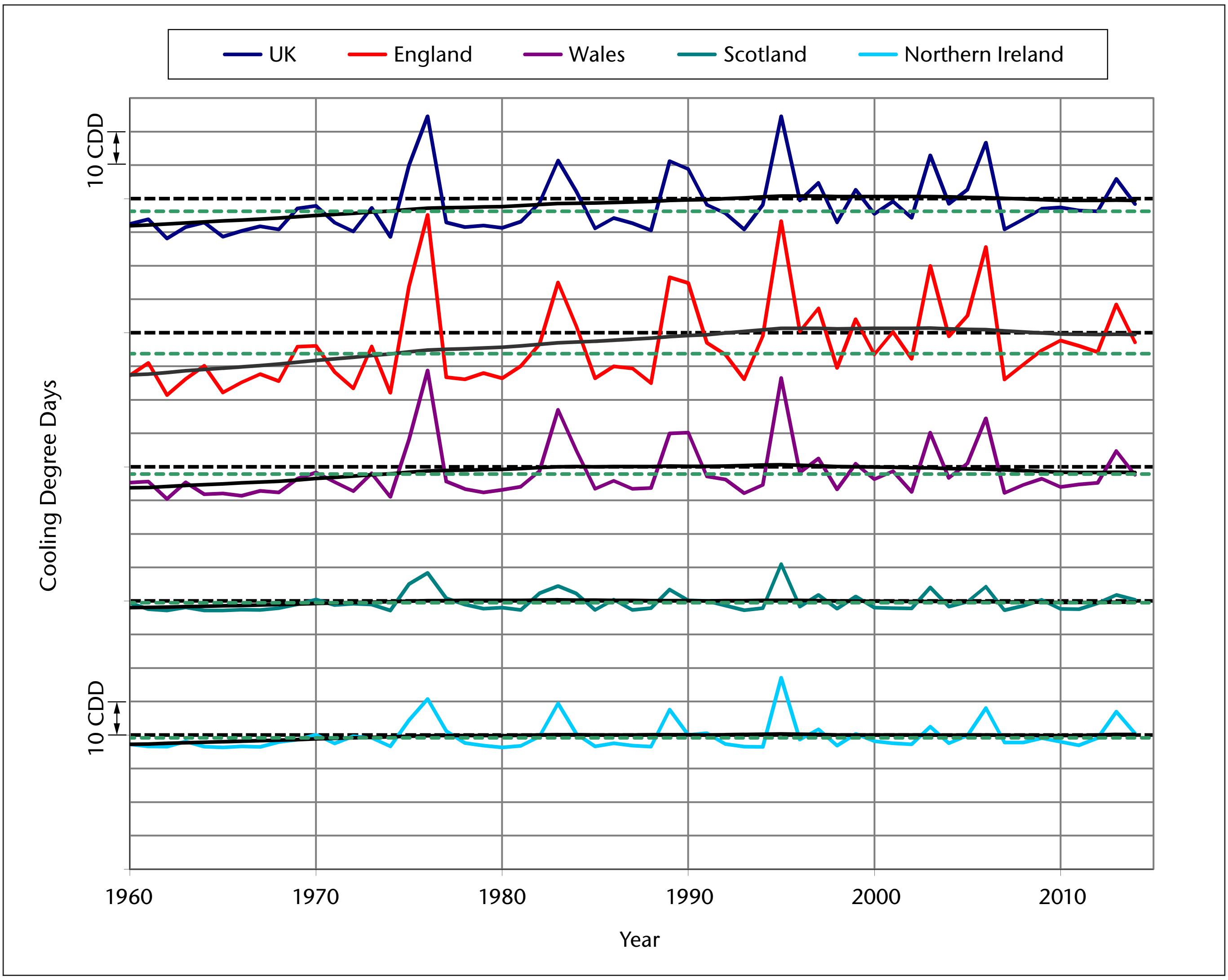


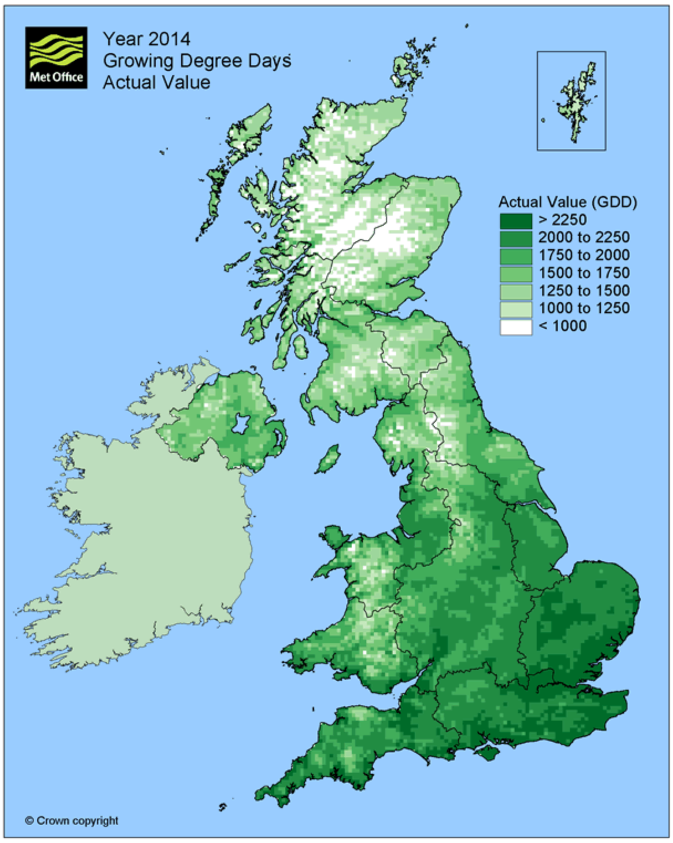
Figure 13: As Figure 11 for Cooling degree days for 2014 but the anomaly is presented as difference from, rather than percentage of, average. This is because CDD are close to zero over Highland Scotland.



Area	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK	9	13	13	11
England	14	21	20	18
Wales	8	10	8	8
Scotland	3	3	3	3
Northern Ireland	3	4	4	4

Figure 14: Cooling degree days for the UK and countries, 1960 to 2014, 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 below provides average values.

Growing degree days (GDD) were typically 110 to 120% of average across the UK in 2014 (Figure 15). 2014 had the second highest GDD in the series from 1960 for the UK overall, behind 2006 (Figure 16) which saw higher anomalies during the principal growing season. The most recent decade has had an annual GDD 16 % higher than 1961-1990 and 6% higher than 1981-2010.



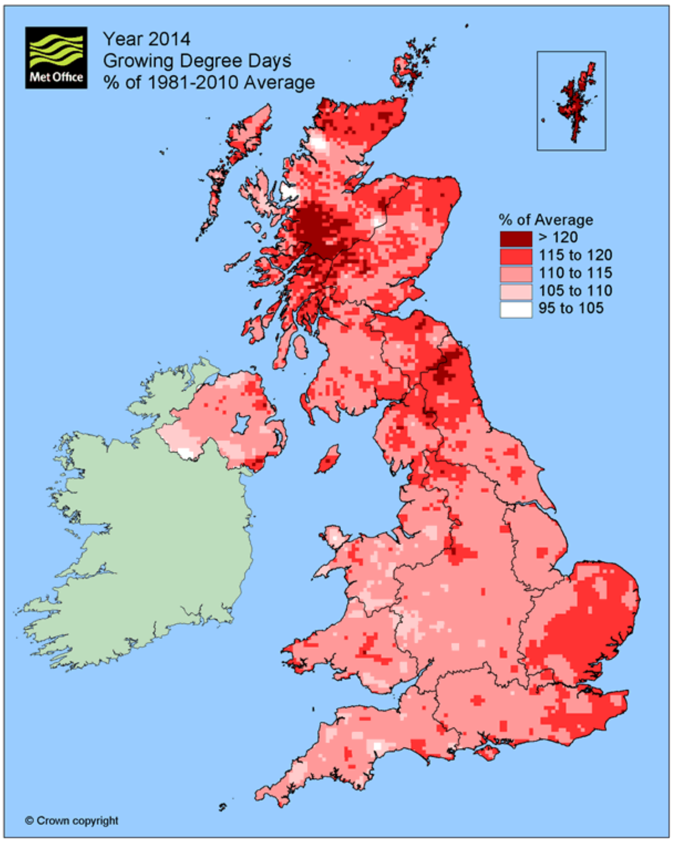
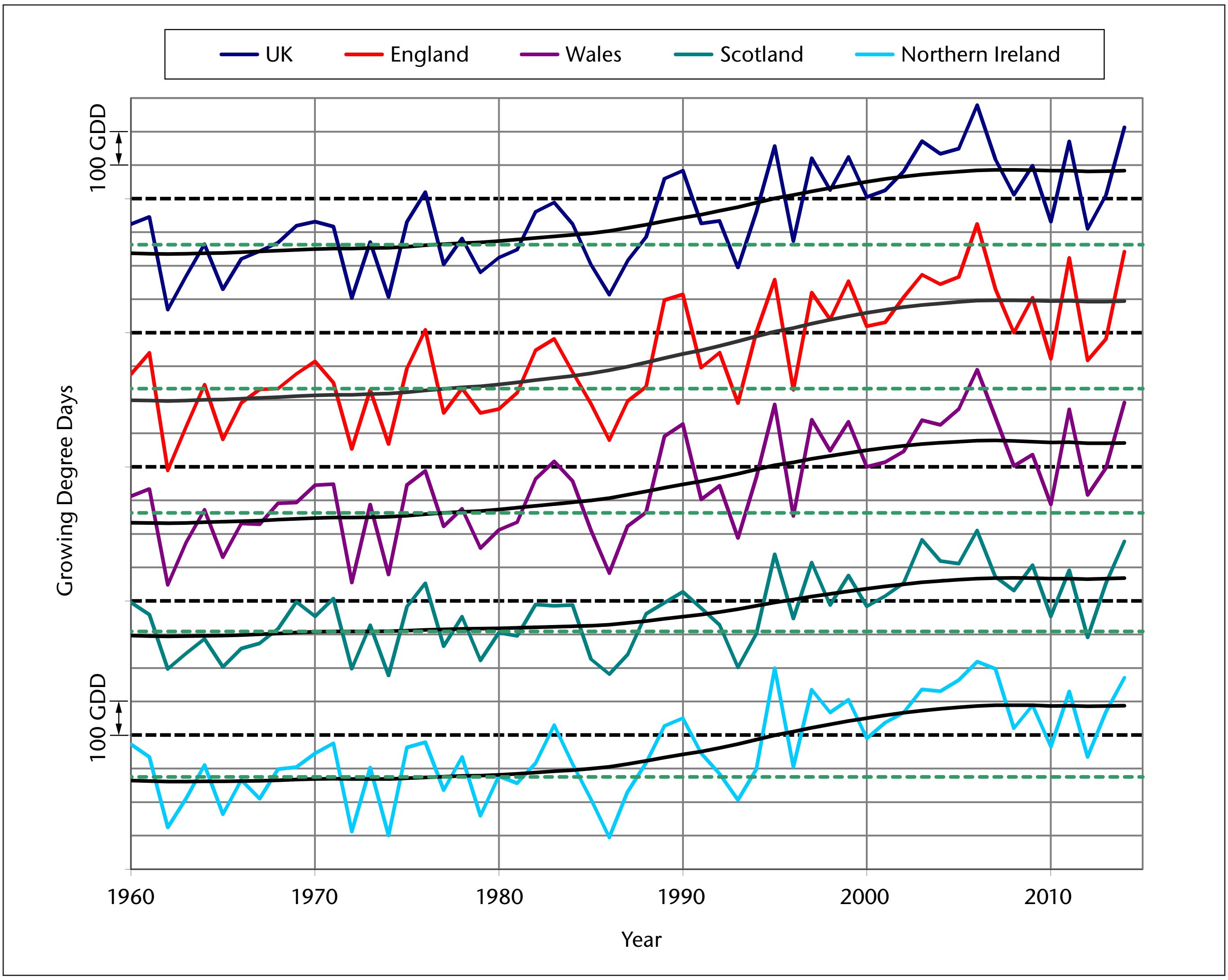


Figure 15: Growing degree days for 2014 (actual and % of 1981-2010 average).

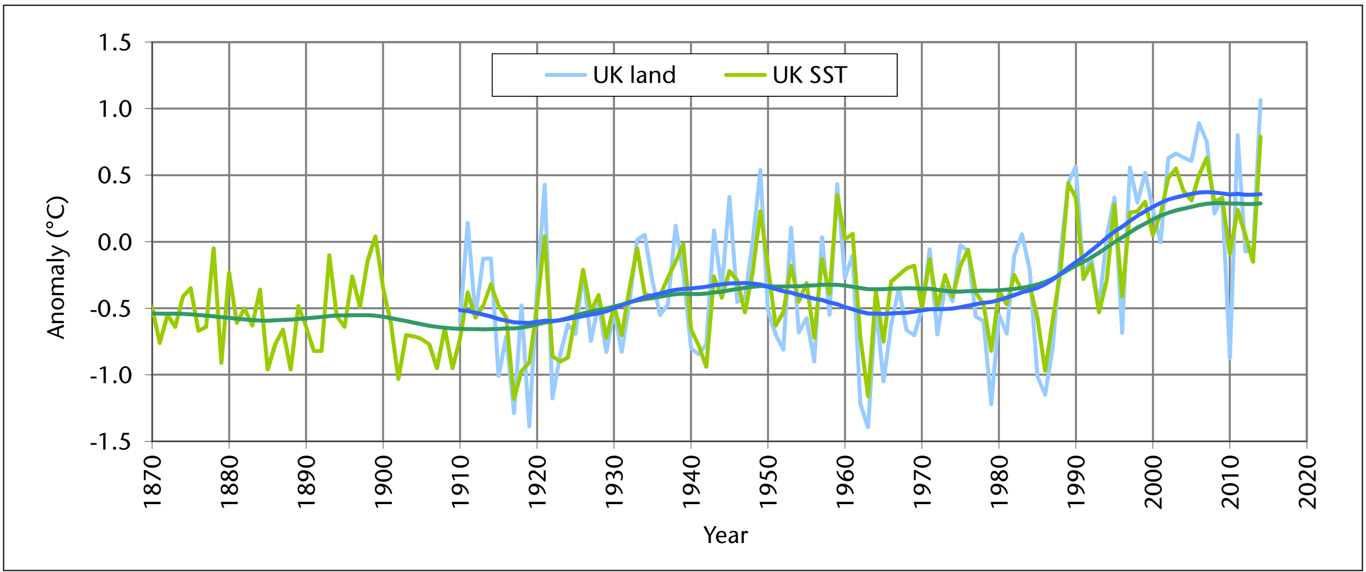


Area	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK	1403	1541	1630	1754
England	1611	1778	1879	2020
Wales	1457	1594	1675	1785
Scotland	1054	1145	1214	1322
Northern Ireland	1353	1478	1573	1649

Figure 16: Growing degree days for the UK and countries, 1960 to 2014, 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 below provides average values.

COASTAL WATERS

2014 was the warmest year on record for annual mean sea surface temperatures (SST) averaged across near-coastal waters around the UK, in a series from 1870 (Figure 17). Near-coast SST data is highly correlated with the land observations. The most recent decade, 2005-2014, is 0.6 °C higher than the 1961-1990 climatology and 0.2 °C above 1981-2010. Nine of the ten warmest years in the series have occurred since 1989, the other year being 1959 which is also ranked 14th warmest in the UK land series.



Variable	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK land	8.3	8.8	9.2	9.9
UK near-coast sst	11.1	11.5	11.7	12.2

Figure 17: UK annual mean temperature over land 1910 to 2014 and UK annual mean sea surface temperatures across near-coastal waters around the UK 1870 to 2014, expressed as anomaly relative to 1981-2010 long-term average. The table below provides average values.

Precipitation

2014 was the fourth wettest year in the UK rainfall series from 1910, behind 2012, 2000 and 1954. The wettest parts of the country relative to average were across south-east England and eastern Scotland with over 135% in some places, but most areas were wetter than average.

Figures 18-20 and Table 3 show annual, seasonal and monthly rainfall anomalies for the UK and countries from 1910 to 2014 inclusive. A large contribution to the annual rainfall total came from the very wet weather during winter storms in January and February. Winter 2013/14 was exceptionally wet and stormy and this was easily the wettest winter in both the UK series from 1910 and the longer running England and Wales Precipitation series from 1766. For much of Scotland and south-east England rainfall totals were double the long-term average, and some locations in the south-east received 75% of a years' rainfall in just 2 months. The winter storms brought the most significant flooding of the calendar year in January and February, with the Somerset Levels and Thames valley worst affected. In general it was the persistence of the storms rather than the intensity of any individual event which led to the prolonged flooding in these areas.

In comparison, with only a few notable exceptions the weather during the rest of the year was relatively benign. May, October and November were rather wetter than average and August especially so across Northern Scotland. It was the wettest August in Northern Scotland from 1910, largely as a result of rainfall from ex-hurricane Bertha which brought extensive flooding across parts of north-east Scotland from 10th to 12th August. Heavy thunderstorms at times during the summer also caused some localised flash-flooding, for example across East Anglia in July. However, in contrast high pressure dominated during most of September and large swathes of the country received less than 20% of the monthly average rainfall; it was the driest September in the UK series.

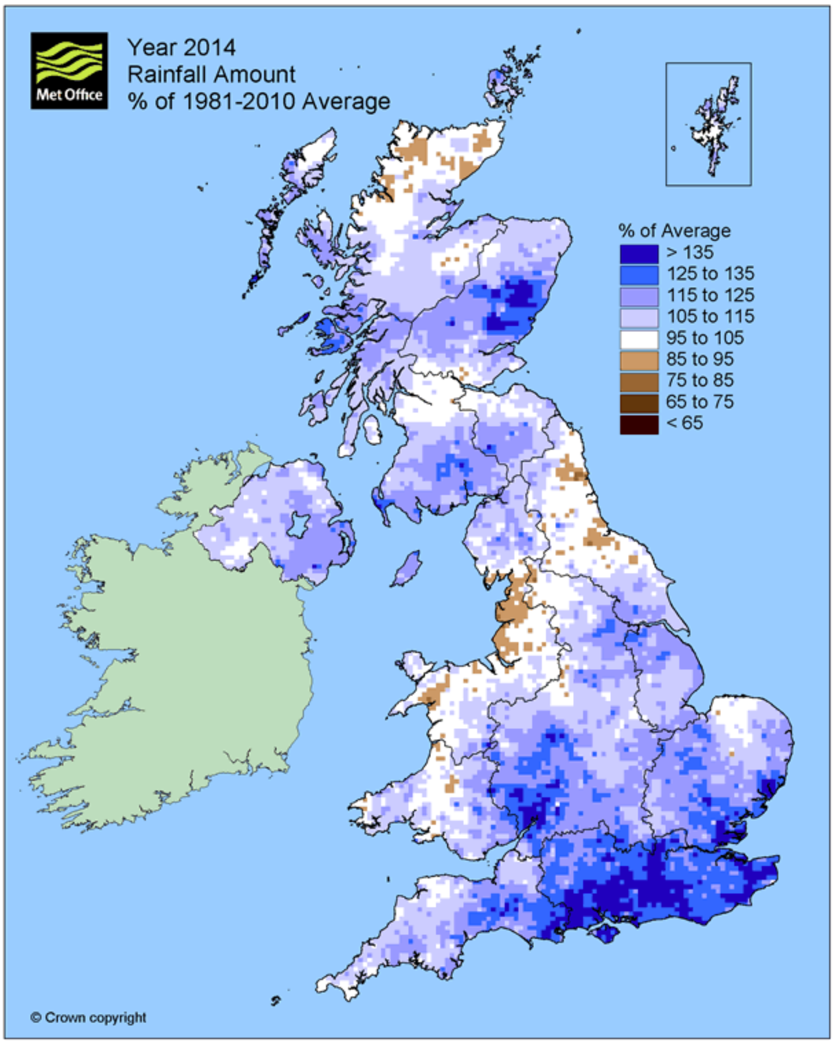


Figure 18: Rainfall anomalies (%) for year 2014.

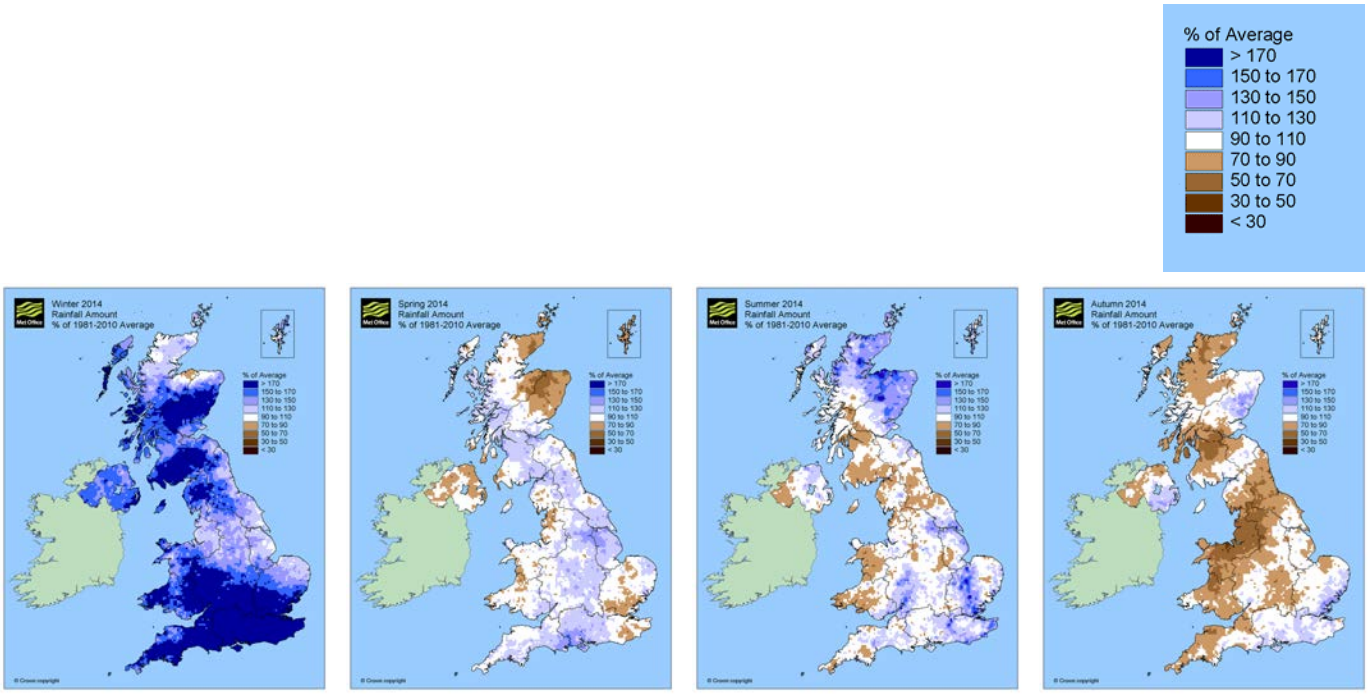


Figure 19: Rainfall anomalies (%) for seasons of 2014. Winter 2014 refers to the period December 2013 to February 2014.

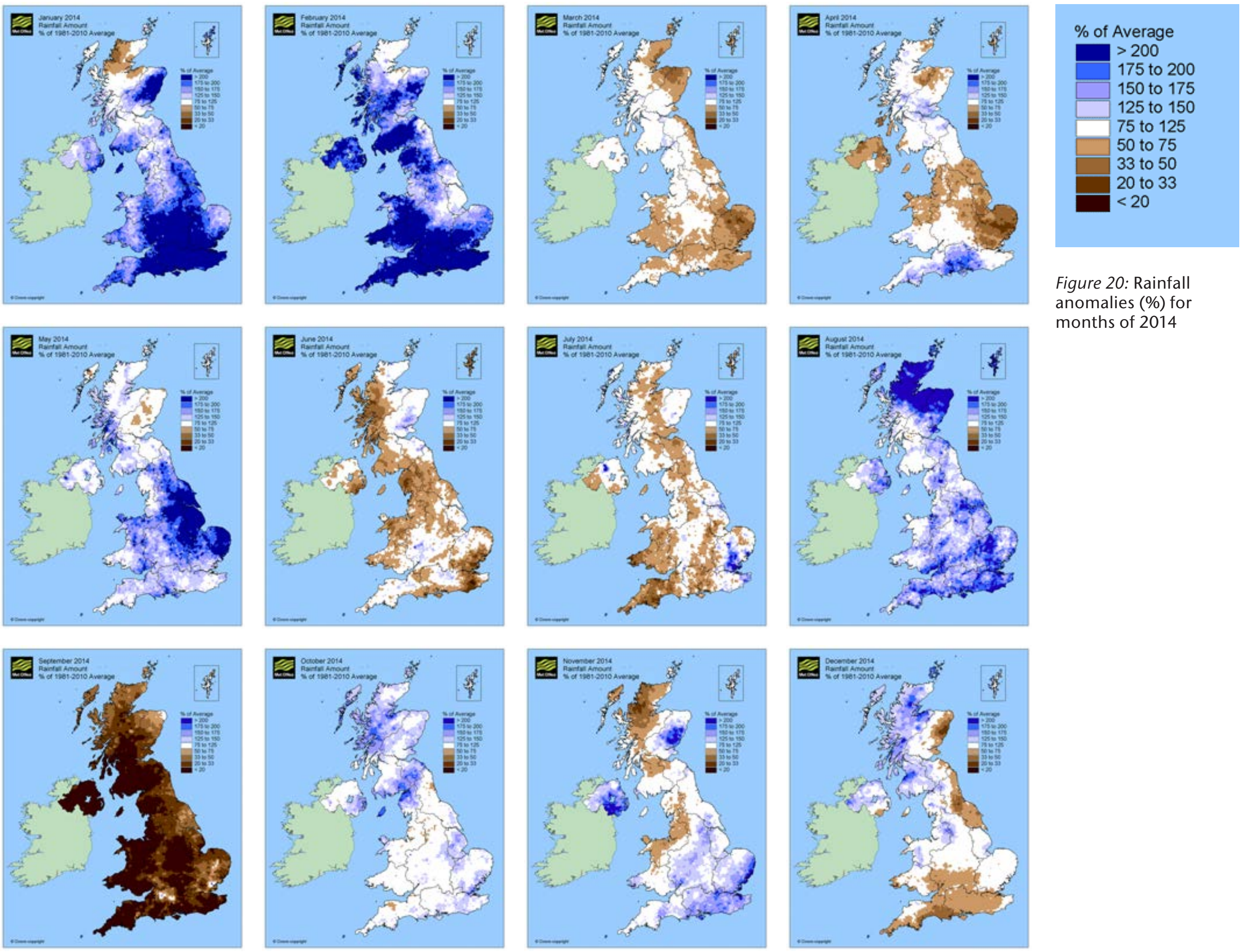


Figure 20: Rainfall anomalies (%) for months of 2014

Table 3: Monthly, seasonal and annual rainfall actual (mm) and anomaly values (%) relative to 1981-2010 for the UK, countries and EWP for year 2014. Colour coding relates to the relative ranking in the full series which spans 1910-2014 for all series except EWP which is 1766-2014.

	UK		England		Wales		Scotland		N Ireland		EWP	
	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom	Actual	Anom
Jan	188	155	160	193	258	164	218	123	173	149	185	198
Feb	169	191	124	205	242	218	225	173	171	205	137	206
Mar	80	84	49	77	80	68	130	92	86	90	56	78
Apr	68	93	53	90	79	88	94	103	44	58	64	98
May	100	142	96	164	130	152	100	118	91	125	103	162
Jun	55	75	46	75	58	68	68	76	57	74	50	75
Jul	65	83	52	83	57	62	87	87	73	89	55	81
Aug	139	155	108	155	143	133	190	163	136	139	119	157
Sep	23	24	15	22	16	14	39	29	10	11	16	21
Oct	159	125	103	112	178	105	249	142	134	112	118	114
Nov	124	102	105	119	151	93	138	83	178	158	127	126
Dec	133	110	75	86	159	96	219	134	145	127	77	79
Win	545	165	401	174	726	167	744	158	489	155	456	176
Spr	247	104	198	109	289	99	324	102	221	91	222	111
Sum	258	107	206	106	258	90	345	113	265	104	223	107
Aut	305	88	223	89	346	77	426	89	321	99	262	93
Ann	1300	113	985	115	1552	106	1757	112	1297	114	1106	117

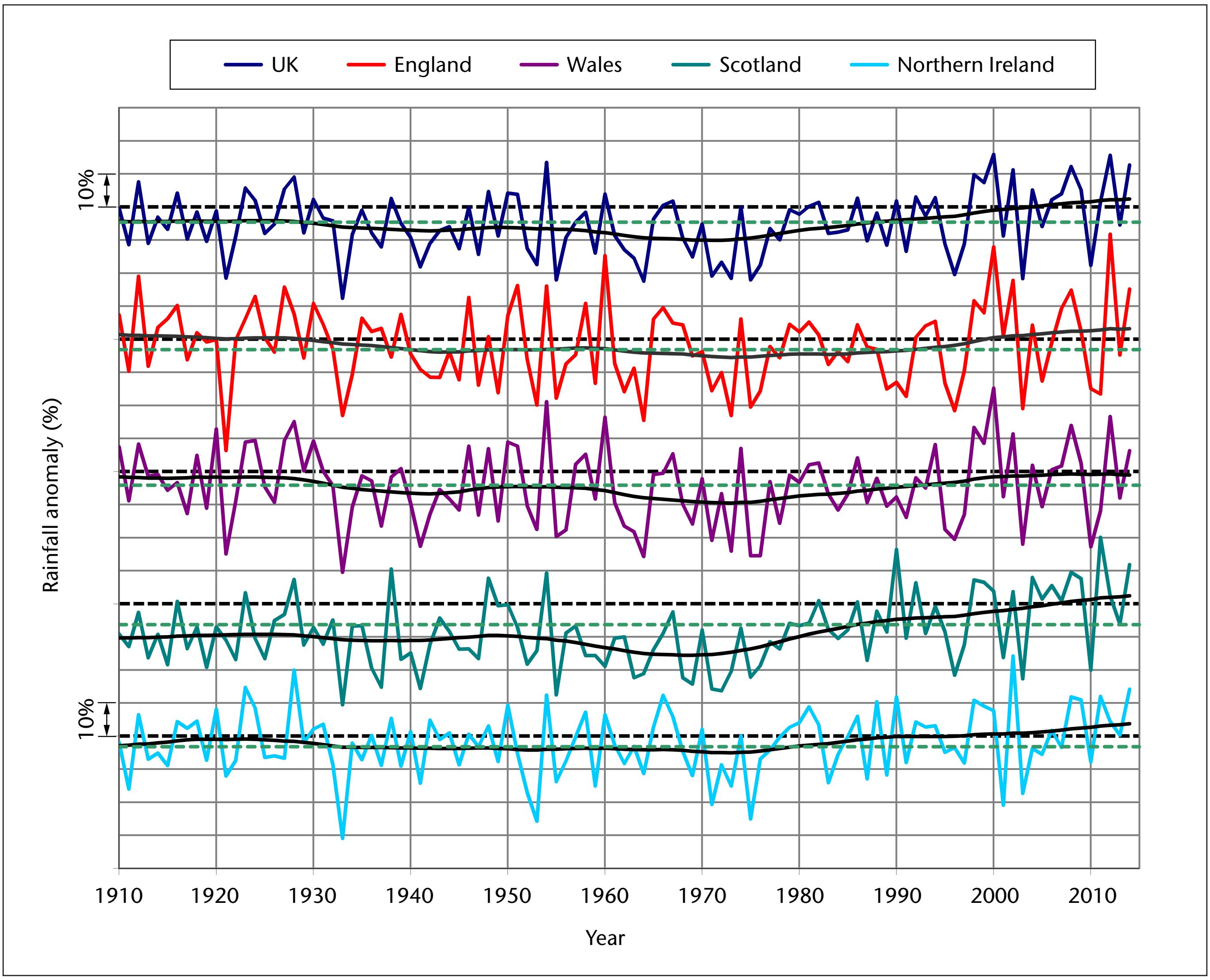
Key							
	Driest on Record	Top ten driest	Dry: Ranked in lower third of all years	Mid: Ranked in middle third of all years	Wet: Ranked in the upper third of all years	Top ten wettest	Wettest on record

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 (2005-2014) has been on average 10 % wetter than 1961-1990 and 3% wetter than 1981-2010. The wettest years for the UK overall are 2000 and 2012 (both 116% of average) and the driest 1933 (72%). 2014 was a wet year but more notably 7 of the 10 wettest years in the UK series have occurred since 1998. Figure 22 shows seasonal rainfall series for the UK from 1910 to 2014 (for winter 1911 to 2014). The UK seasonal rainfall total for winter 2013/2014 of 545 mm, or 165% of 1981-2010 average was the highest for any meteorological season (spring, summer, autumn or winter) in the series from 1910.

2014 was ranked 16th wettest year in the England and Wales precipitation (EWP) series from 1766. 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 in order to understand the full historical context of UK rainfall. However 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 2.1%. 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.

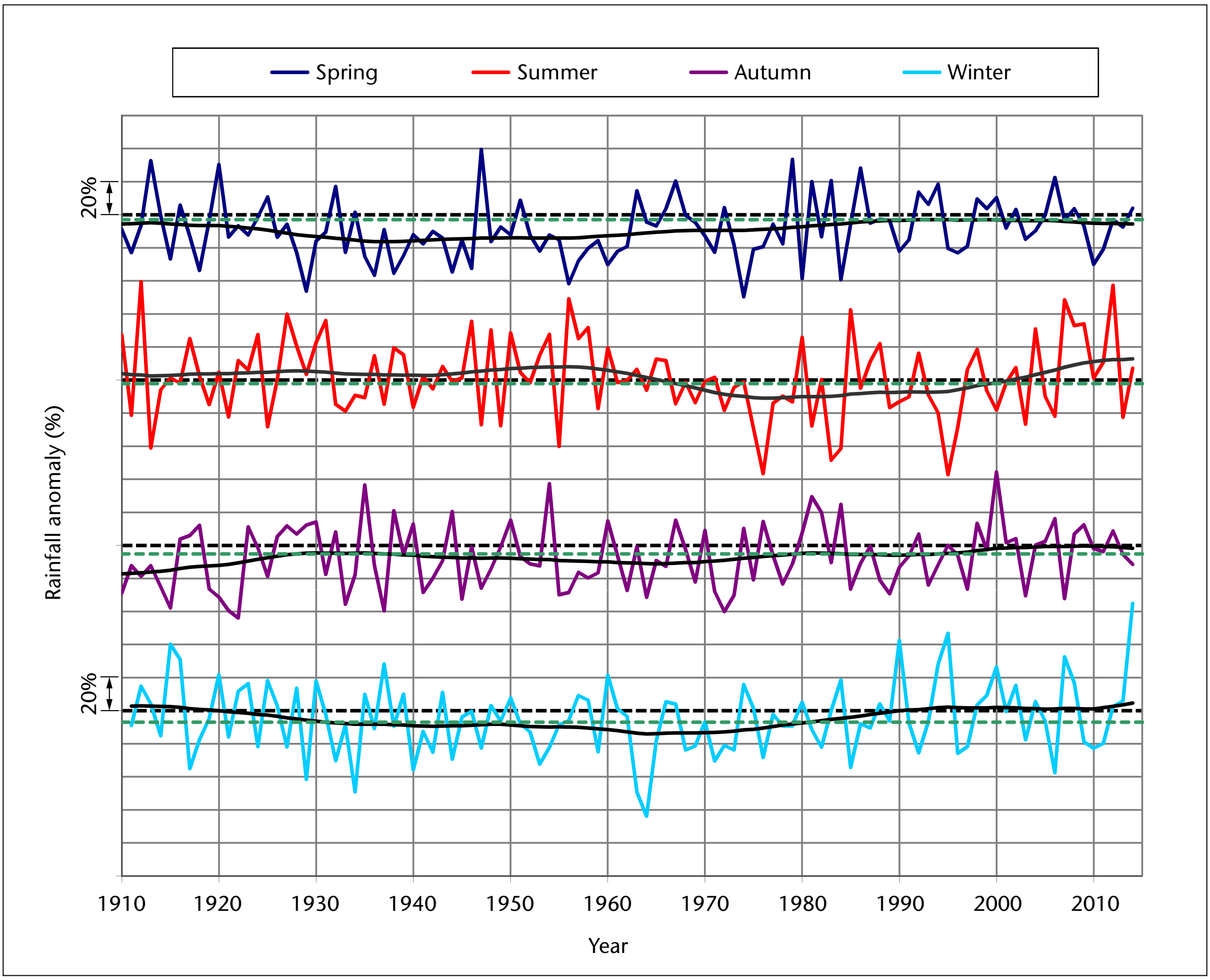
Figure 24 shows trends in seasonal EWP rainfall amounts from 1766 to date. While there is little change in the long-term mean for the annual EWP series, this is not the case for the seasonal series. EWP shows a marked increase in winter rainfall. Before 1900, EWP winter rainfall was substantially lower 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 precipitation 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 be approaching 1% to 4% depending on region in early decades, but then 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 not straightforward 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.



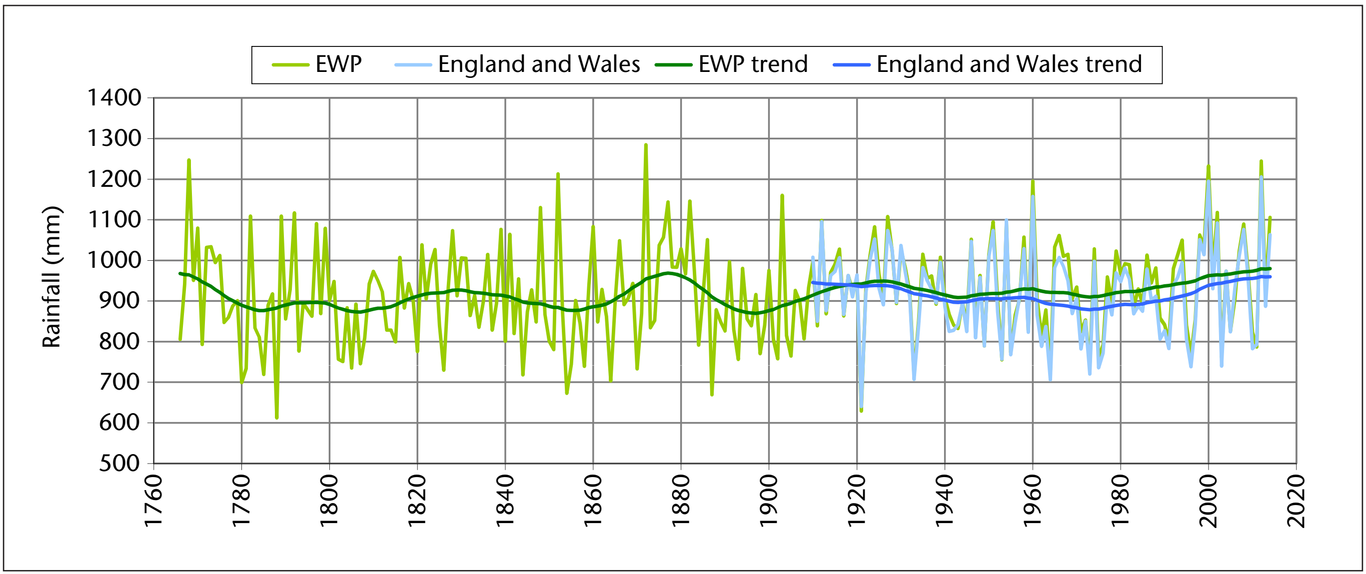
Area	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK	1101	1154	1182	1300
England	828	855	875	985
Wales	1400	1460	1443	1552
Scotland	1472	1571	1623	1757
Northern Ireland	1099	1136	1180	1297

Figure 21: Annual rainfall, 1910 to 2014, 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%.



Season	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Spring	231	238	228	247
Summer	236	241	274	258
Autumn	327	345	342	305
Winter	308	330	336	545

Figure 22: Seasonal rainfall for the UK, 1910 to 2014 (note winter from 1911 to 2014; year is that in which January and February fall). Light grey grid-lines represent anomalies of +/- 20%.



	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
EWP	915	948	970	1106
England and Wales	906	938	953	1063

Figure 23: Annual rainfall for EWP series, 1766 to 2014, and England and Wales areal series, 1910 to 2014 (mm).

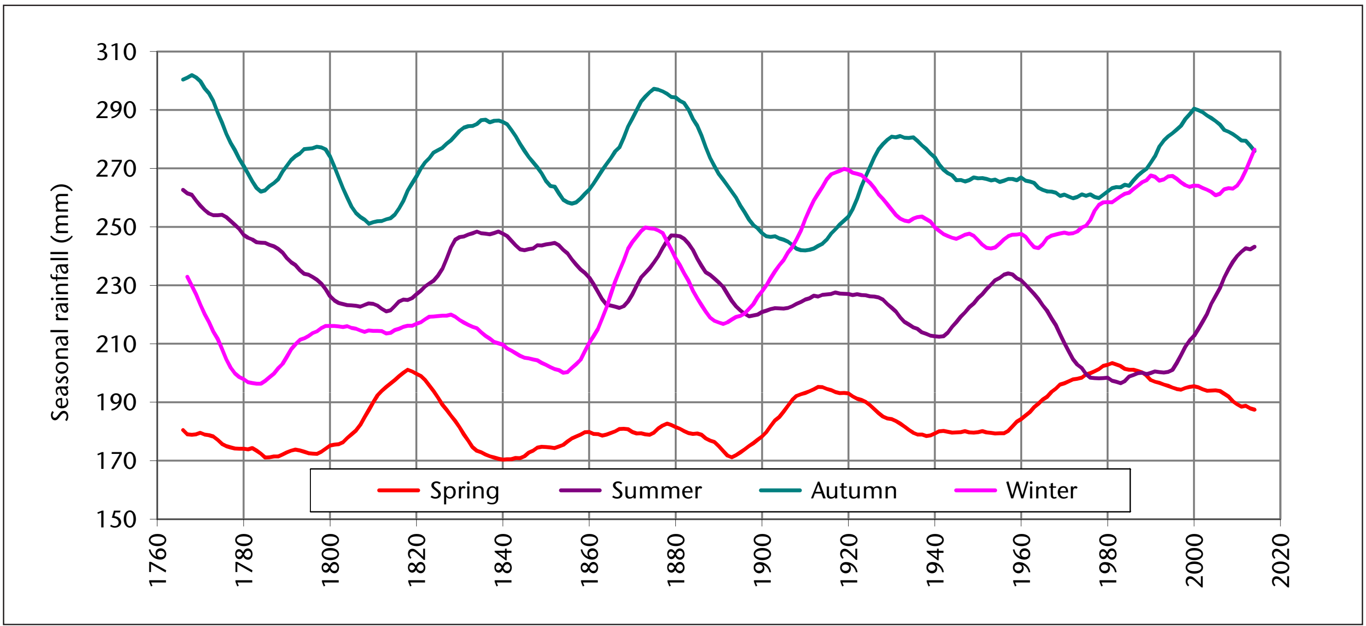


Figure 24: Seasonal rainfall totals for EWP series in mm, 1766 to 2014 (note winter from 1767).
The figure shows a smoothing trend for each series using a weighted filter (see Annex 2).

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 year 2014 across most of the UK, but especially in the south and west where there were more than 30 Dr1 above average in some areas. The persistent wet weather during winter 2013/2014 was a major contributing factor, especially across southern England. Similarly, the number of days of rain greater with than or equal to 10mm (Dr10) was also above average in some southern and western areas (Figure 25).

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 2014 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, despite the record-breaking wet winter, 2014 was an unremarkable year. 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.

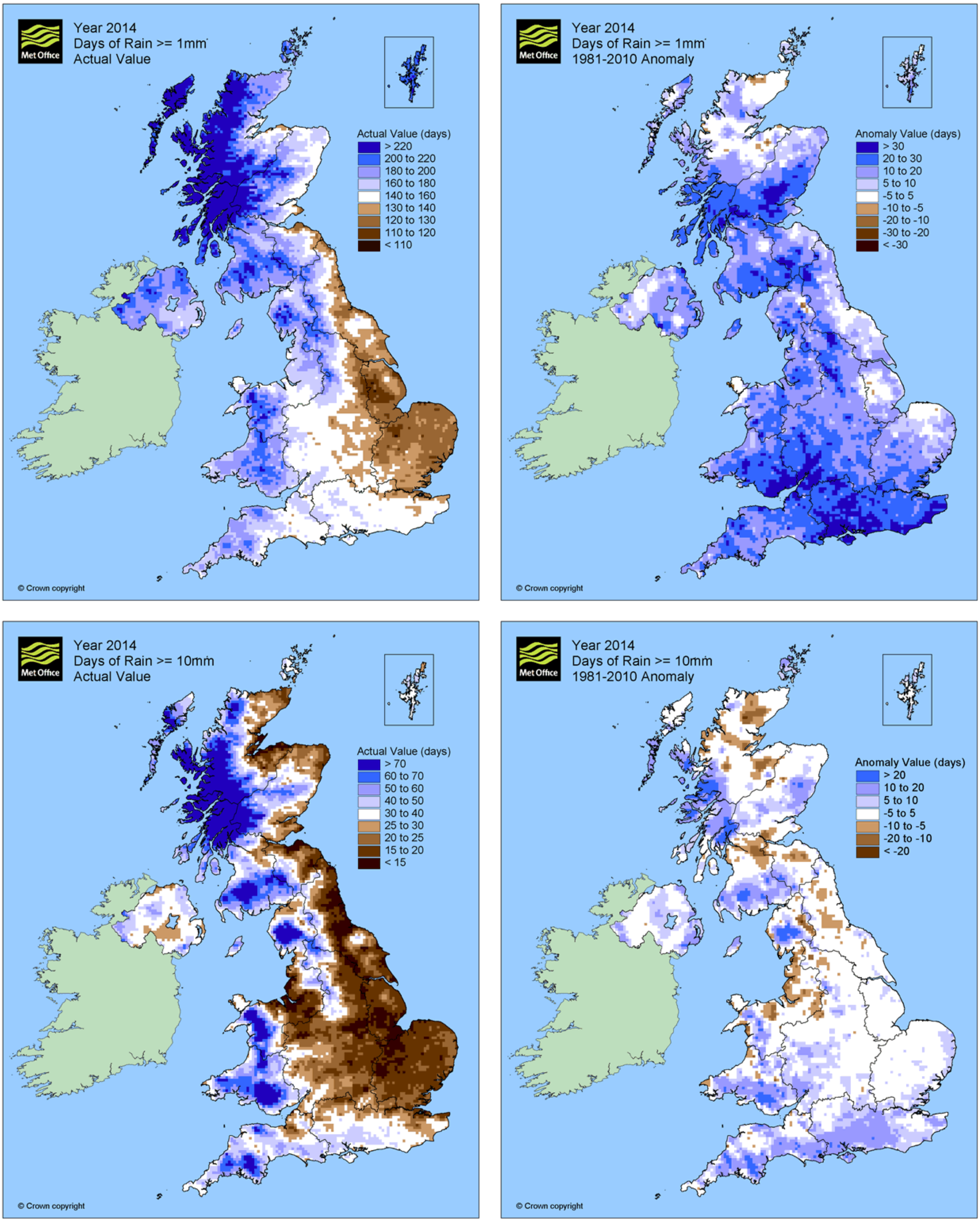
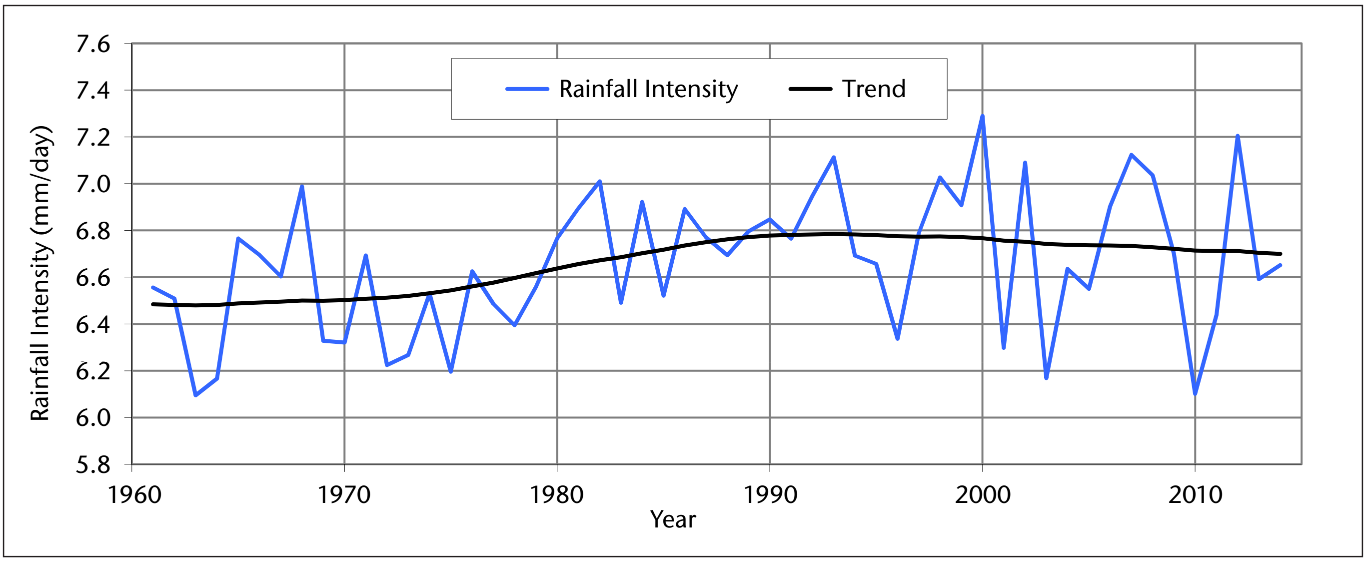


Figure 25: (Top) Days of rain >= 1mm (Dr1) and (Bottom) 10mm (Dr10) for 2014. Showing both the (left) actual value and (right) anomaly relative to 1981-2010.



	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK rainfall intensity	6.6	6.8	6.7	6.7

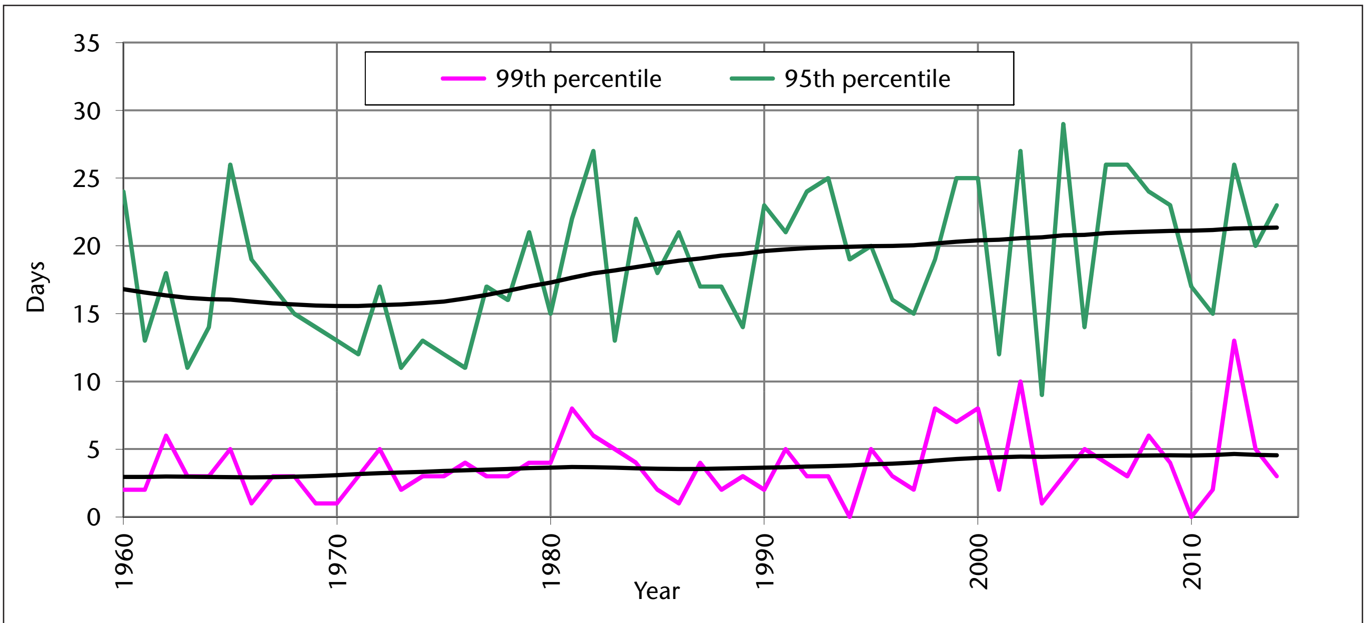
Figure 26: Annual average rainfall intensity for the UK on days of rain >= 1mm, 1961 to 2014.

HEAVY RAINFALL

Alternative metrics for heavy rain are presented. 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 apparent 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.

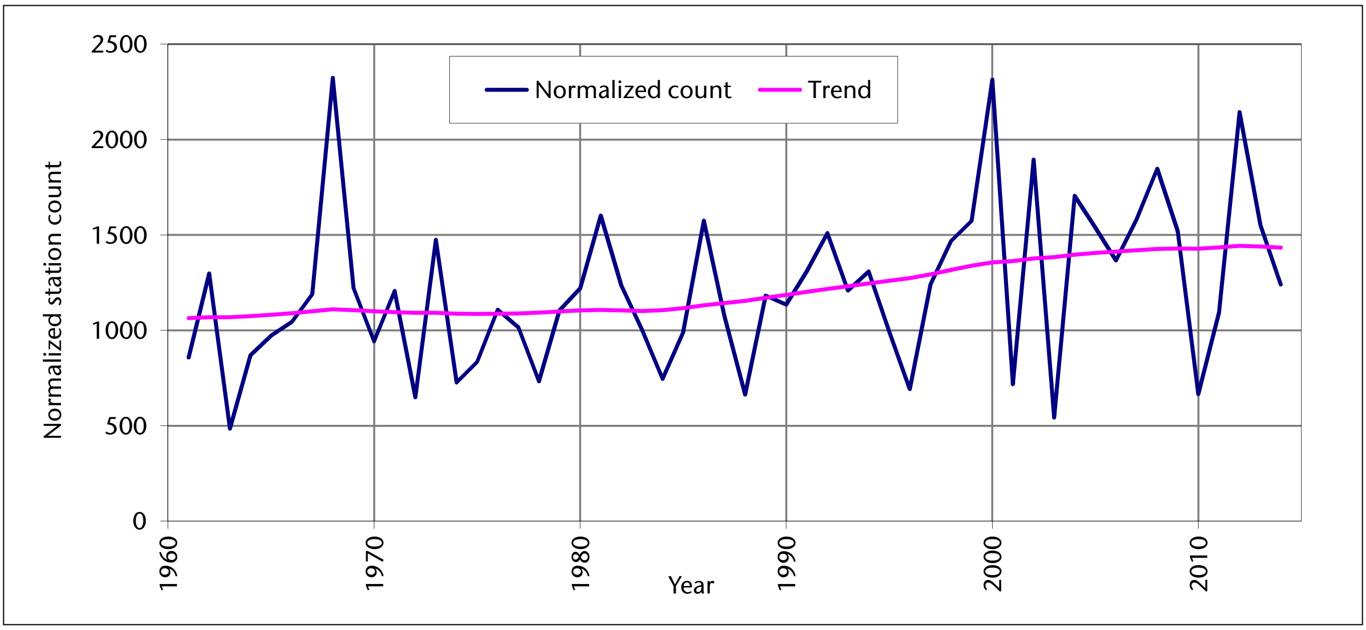
The 95th and 99th percentile of UK daily areal-average rainfall based on the period 1960 to 2014 inclusive are 9.5mm and 14.0mm respectively. Figure 27 plots the number of days each year in the series when this percentile was exceeded (by definition we would expect on average 18 days and 3 to 4 days respectively). As with rainfall intensity (figure 26), this does not include 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. 2014 is unremarkable in these series, both of which show a small 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 below 500 metres above sea level in the observing network 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 been adjusted to take into account the changing size of the overall UK rain-gauge network which reached 4900 gauges in the 1970s and has reduced to approximately 2600 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. 2014 was unremarkable with 2000 and 2012 again among the highest years in this series. However, the highest year is 1968, during which there were three major heavy rain events in March, July and September, covering large areas (Bleasdale, 1969).



	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
99th percentile	3	4	5	3
95th percentile	17	20	21	23

Figure 27: The number of days per year with UK areal-average daily rainfall exceeding 95th percentile (9.5mm) and 99th percentile (14.0mm) based on the period 1960 to 2014.



	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Number of station-days	1083	1273	1455	1240

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 2014, adjusted for station network size and excluding stations above 500 metres above sea level.

SNOW

The winter months of 2014 were mostly dominated by a mild Atlantic weather type and consequently there were no major snowfalls during the year across the UK. The most significant snowfall occurred on 26 December 2014 with lying snow across parts of North Wales, the north Midlands and Pennines. The Scottish mountains were the exception with unusually deep and prolonged cover at higher elevations, with persistent snowfalls at higher levels through the storms from mid-December 2013 to mid-February 2014 lying un-melted until late February or March.

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, although this 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 2014 had the lowest count of station-days for both metrics in this series, although this is broadly comparable with several other years such as 2007 and 2008.

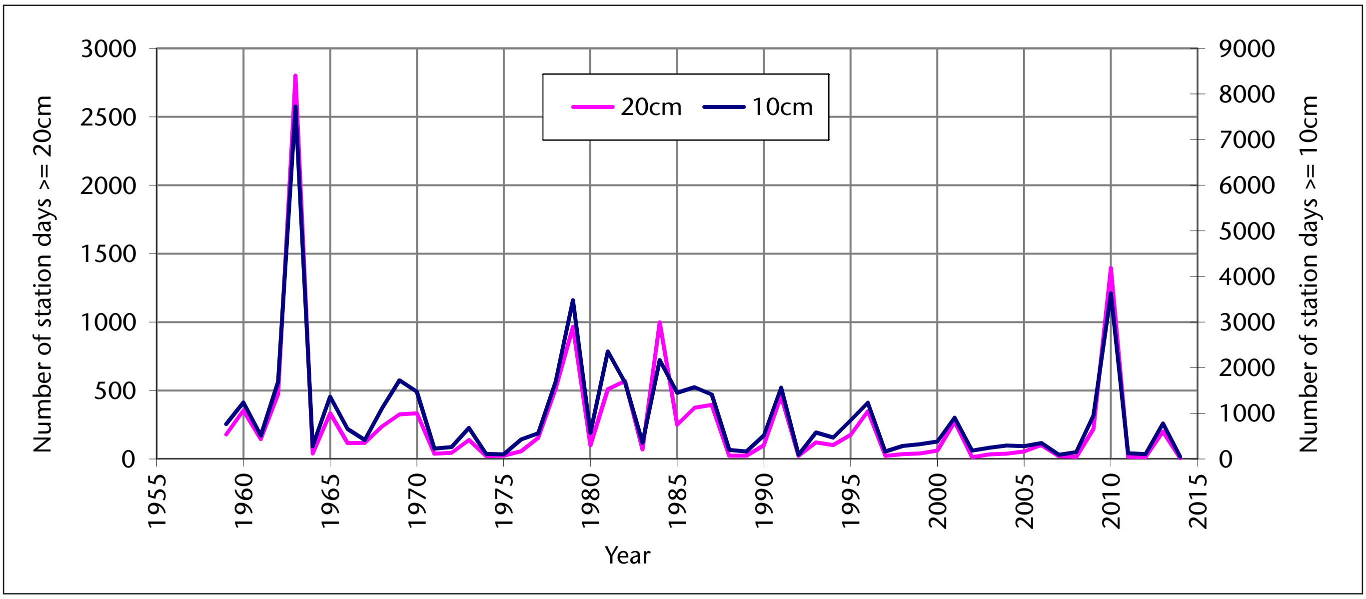


Figure 29: Count of number of station-days per year in the UK with recorded snow depths exceeding 10cm and 20cm, excluding stations above 500 metres above sea level. This series has not been adjusted for network size. The 2014 values are 48 (10cm) and 6 (20cm).

Sunshine

2014 was somewhat sunnier than average for the UK overall (104% of 1981-2010 average). It was sunnier across the southern half of the UK but duller further north, except for the Western Isles, Figures 30-32. Despite being exceptionally wet, much of southern, central and eastern England were sunnier than average during winter 2013/2014. Fast-moving frontal systems bringing the wet weather through the winter were interspersed with clear, sunny spells and there was an absence of overcast anti-cyclonic conditions. Summer 2014 was relatively sunny (particularly July) and comparable with summer 2013, whereas spring and autumn had near or slightly below average sunshine for most areas. However, for the UK overall December 2014 was the second-sunniest December in the series from 1929.

Figures 33 and 34 show annual and seasonal sunshine anomalies for the UK and countries from 1929 to 2014 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 (2005-2014) 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 it is 10% and 12% 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 effects may be important.

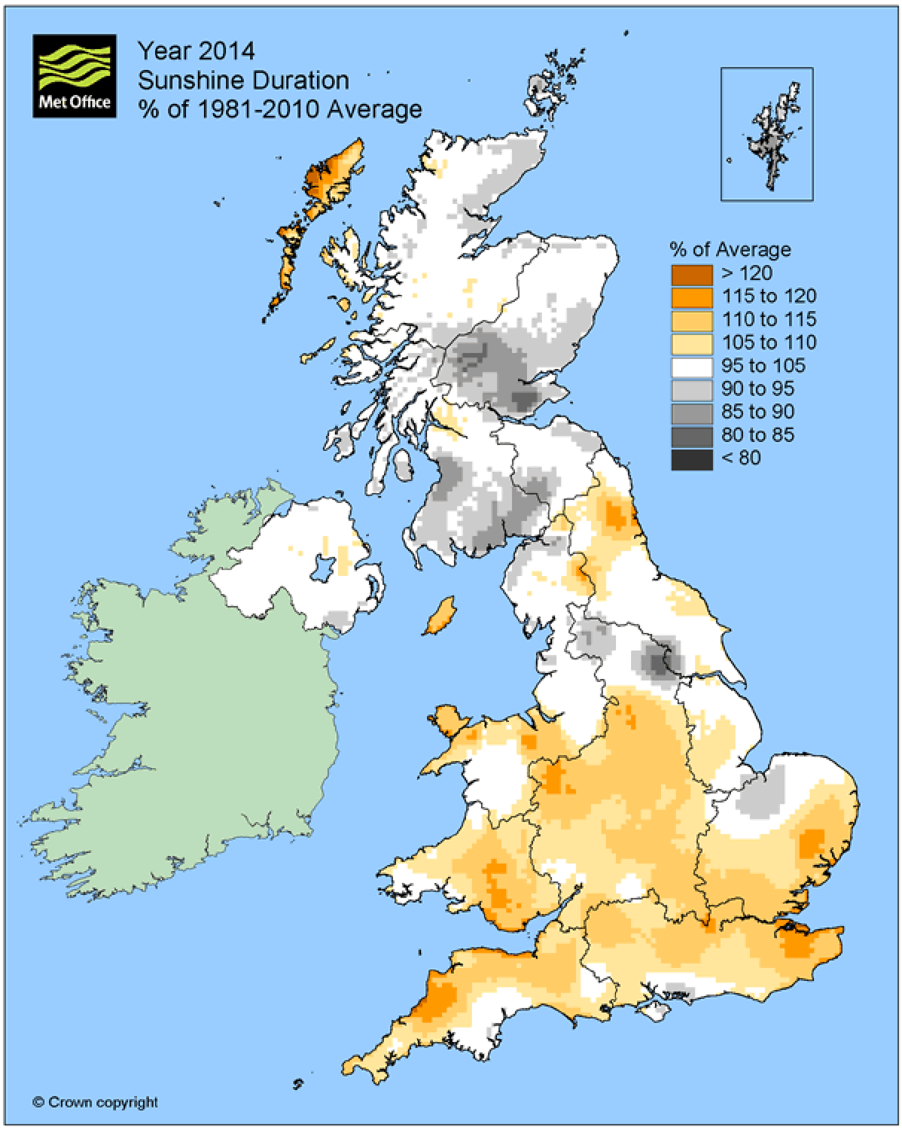


Figure 30: Sunshine anomalies (%) for year 2014 relative to 1981-2010.

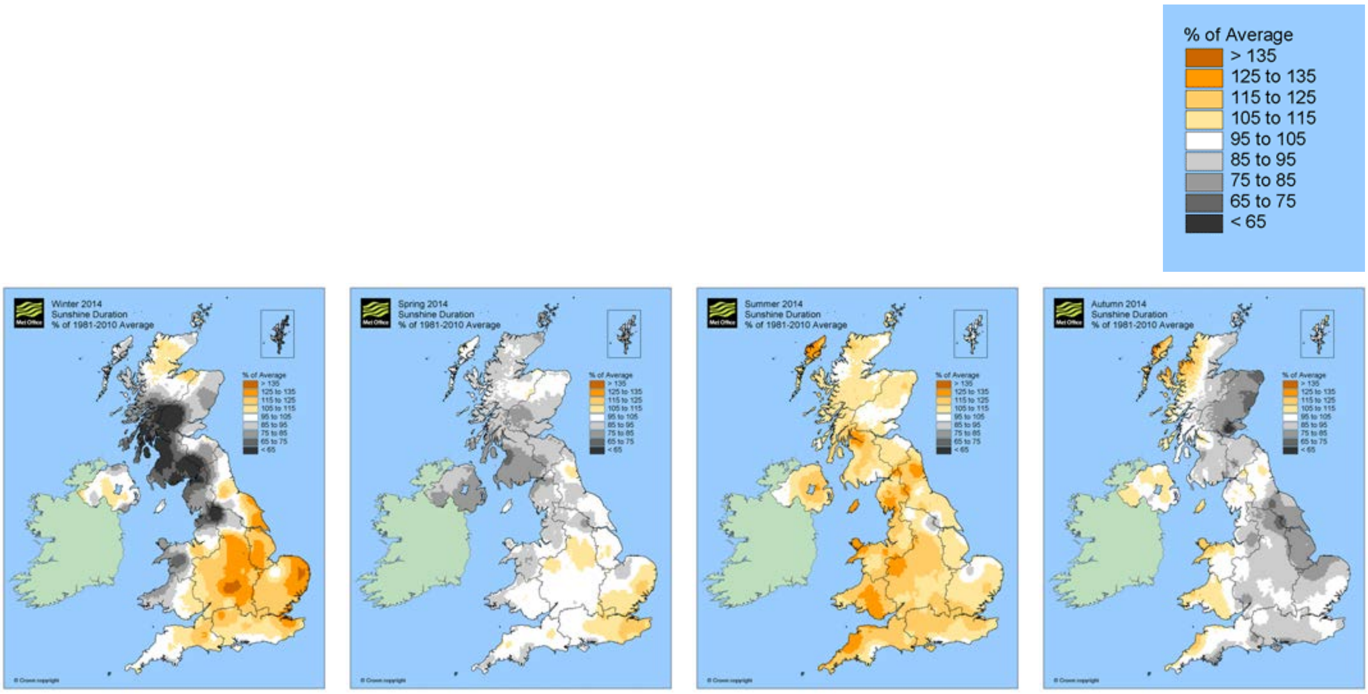
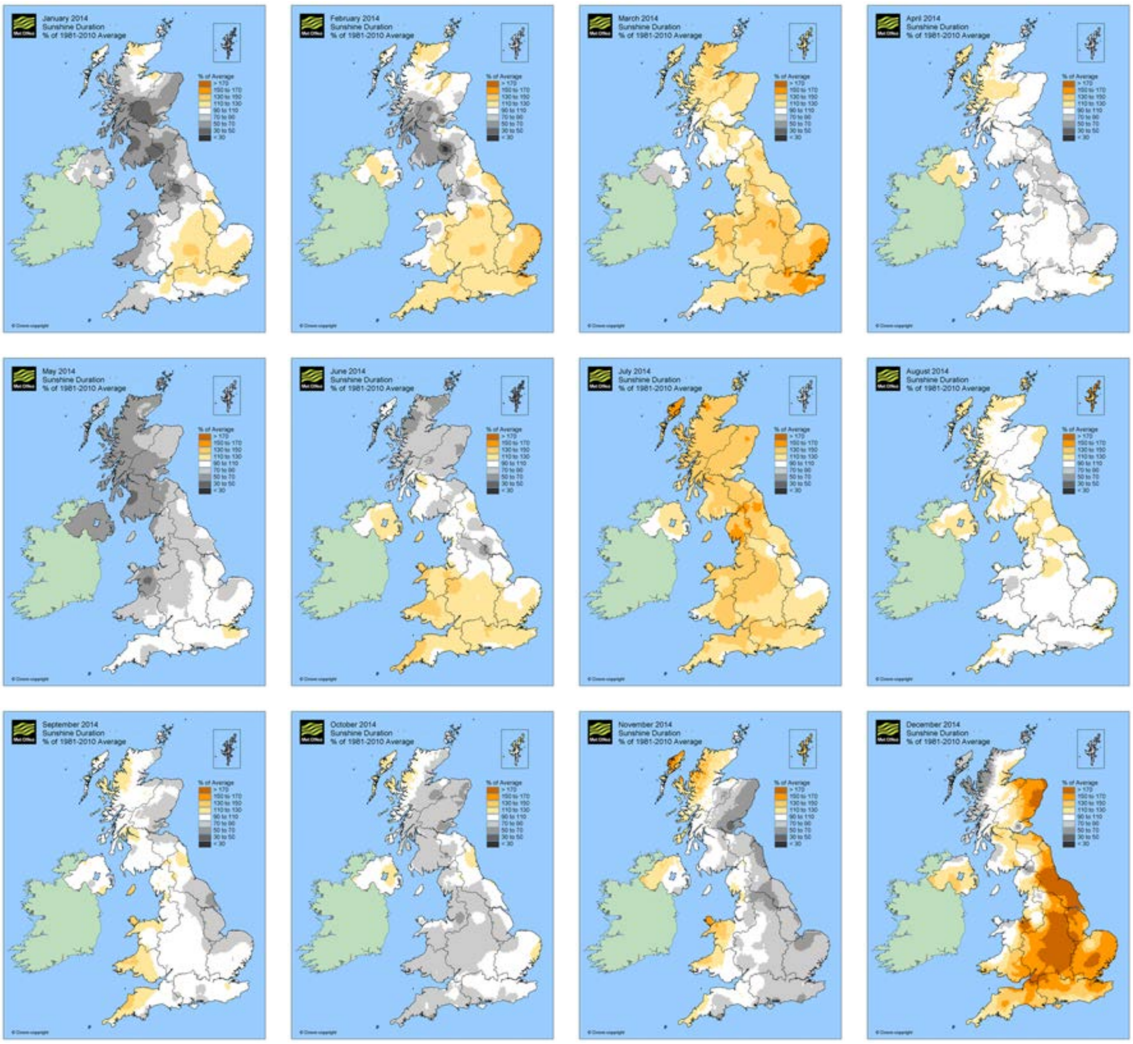


Figure 31: Sunshine anomalies (%) for seasons of 2014. Winter 2014 refers to the period December 2013 to February 2014.



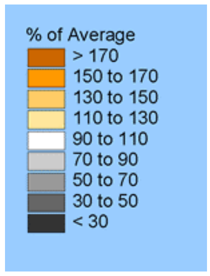
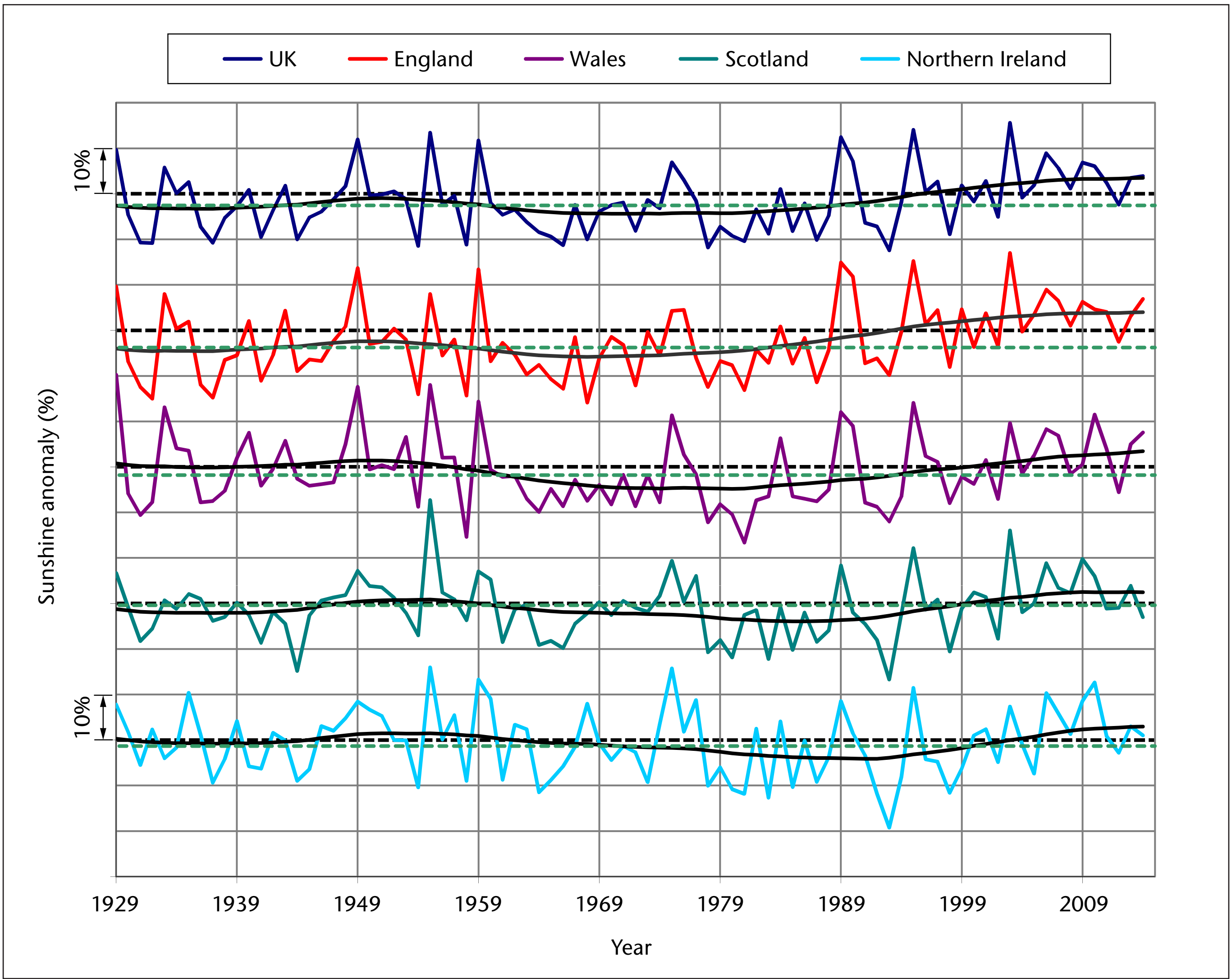
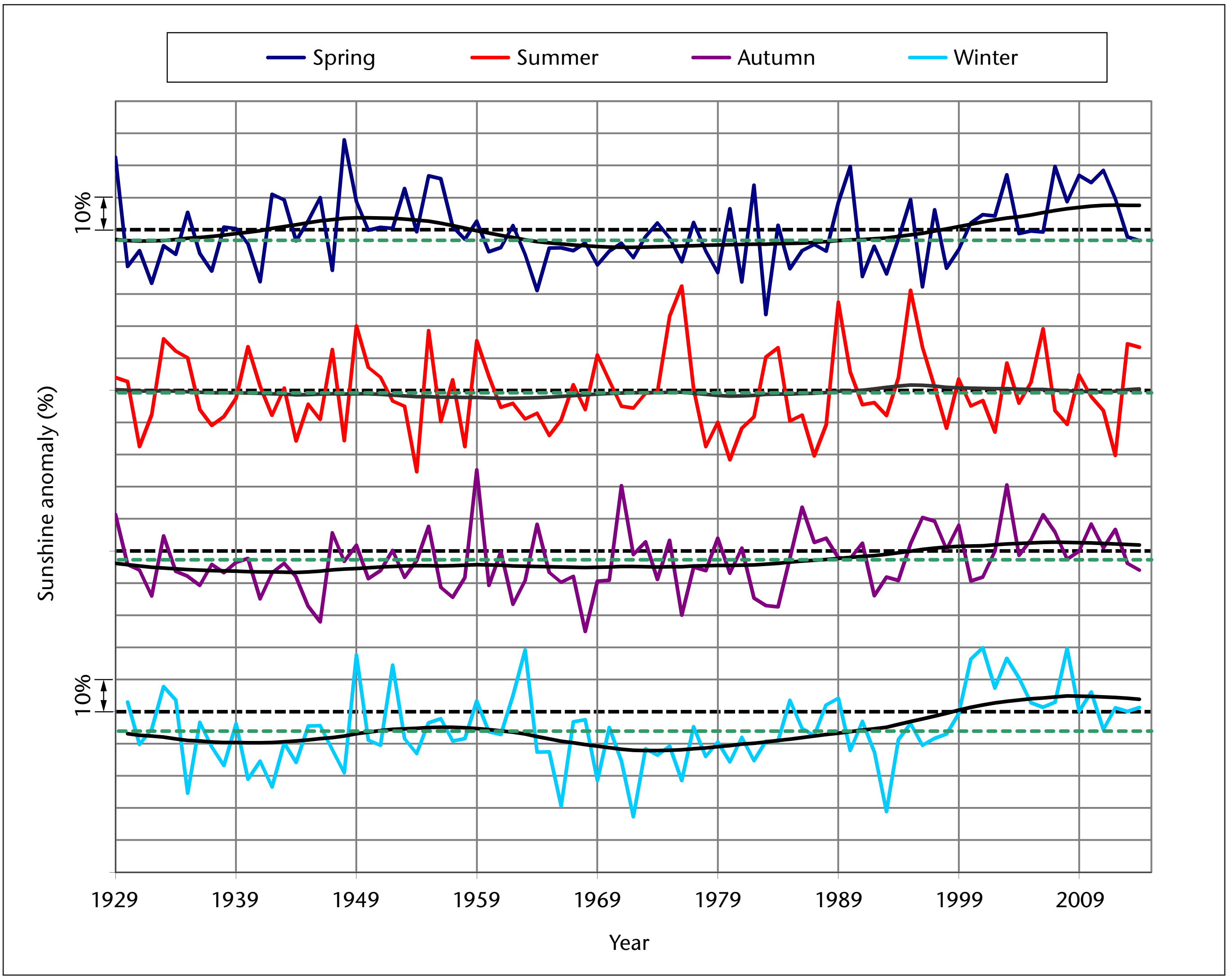


Figure 32:
Sunshine anomalies (%) for months of 2014



Area	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
UK	1338	1373	1425	1427
England	1436	1493	1556	1596
Wales	1376	1401	1456	1507
Scotland	1182	1187	1221	1151
Northern Ireland	1239	1256	1297	1268

Figure 33: Annual sunshine duration (hours) for UK and countries, 1929 to 2014, 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%.



Season	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Spring	422	436	471	421
Summer	501	505	509	572
Autumn	267	274	281	258
Winter	148	158	163	160

Figure 34: Seasonal sunshine duration for the UK, 1929 to 2014 (note winter from 1930 to 2014; year is that in which January and February fall). Light grey grid-lines represent anomalies of +/- 10%.

Wind

The windiest days of year 2014 are listed in table 4. Winter 2013/14 saw the stormiest period of weather experienced by the UK for at least 20 years (Kendon and McCarthy, 2015). The windiest day (in terms of number of stations which recorded a gust exceeding 50 Kt) was 12 February 2014. Every station in Wales and two-thirds of stations in England recorded a max gust exceeding 50 Kt, including many stations well inland. This was the only event of 2014 where the Met Office National Severe Weather Warning Service issued a red warning for wind, and the first such warning since January 2012. Over half the England network also recorded maximum gusts exceeding 50 Kt on 14 and 15 February, the last of the winter 2013/2014 storms. The list of dates is dominated by these storms in January and February with the relatively low-latitude track of the storms often affecting England and Wales. Other storms in March, October and December tended to be at higher latitudes, mainly affecting Scotland and these would not be considered unusual for the UK at this time of year.

Table 4: The windiest days of year 2014. 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 break-down by country. The number of wind observing sites in 2014 for each country is also given in brackets.

Date	England (99)	Wales (15)	Scotland (37)	N Ireland (11)	Total (162)
03-Jan-2014	22	13	15	1	51
06-Jan-2014	13	11	1		25
25-Jan-2014	24	8	3	2	37
26-Jan-2014	7	4	15	2	28
31-Jan-2014	4	4	11	2	21
01-Feb-2014	17	10	7	1	35
05-Feb-2014	23	8	2	1	34
08-Feb-2014	22	11	1	1	35
12-Feb-2014	65	15	7	4	91
14-Feb-2014	52	8		1	61
15-Feb-2014	50	8			58
23-Feb-2014	7	8	8		23
07-Mar-2014	1	1	18		20
20-Mar-2014	5	5	10		20
06-Oct-2014	4	5	16	4	29
21-Oct-2014	13	6	15	3	37
09-Dec-2014	7	3	17	1	28
10-Dec-2014	10	3	19	3	35
11-Dec-2014	8	6	9		23

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 the varying wind network size 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.

2014 was a fairly windy year but 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. Year 2014 also contrasts with 2010, during which there was a notable absence of wind events. However, 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.

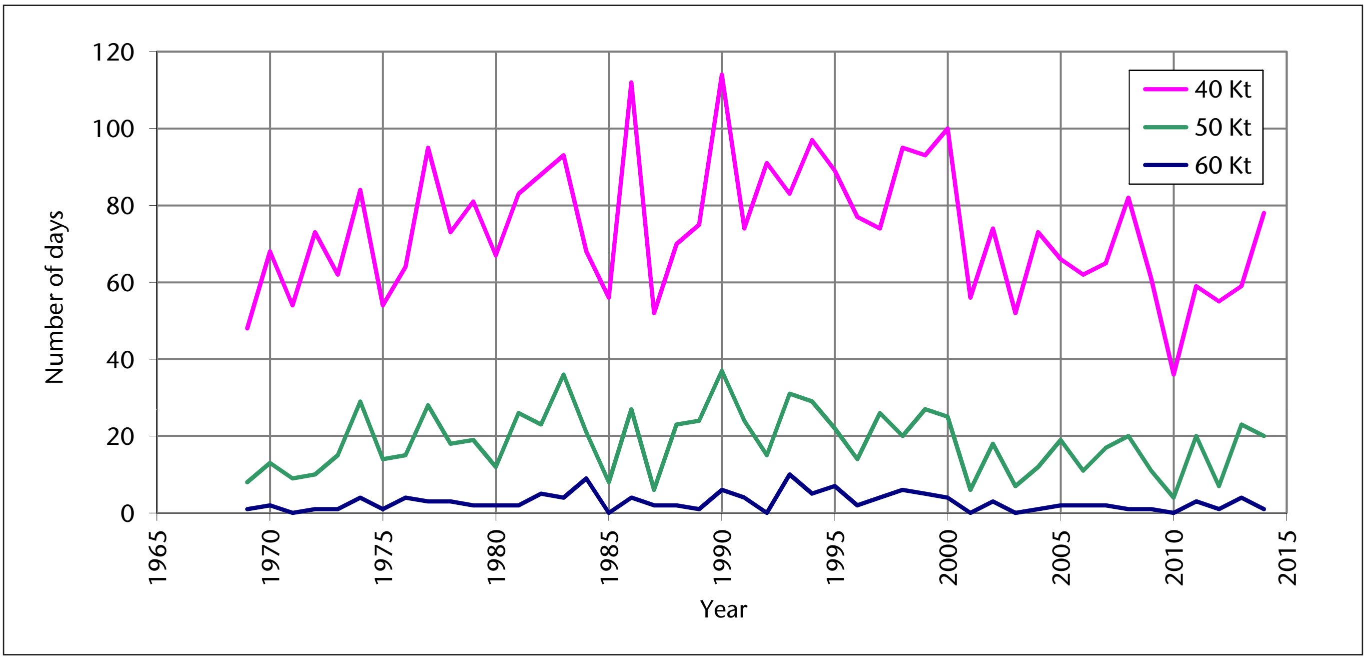


Figure 35: Count of the number of individual days each year during which a max gust speed >= 40, 50 and 60 Kt has been recorded by at least 20 or more UK stations, from 1969 to 2014. Stations above 500 metres above sea level are excluded.

Mean sea level pressure

The UK mean sea level pressure (MSLP) anomalies for January and February 2014 were -16 and -22 hectopascals (hPa) respectively. February 2014 had the lowest UK areal-average pressure for any calendar month in a series from 1961, while January 2014 was ranked 4th lowest. These are two of only 7 months in the 648-month series with a UK average monthly pressure below 1000 hPa. During the exceptionally stormy winter of 2013/2014, at least 12 major storms affected the UK in two spells from late-December 2013 to mid-February 2014, during which the central pressure of each low pressure system approached or fell below 950 hPa.

The relationship between UK monthly MSLP and rainfall over the last 5 years is shown in Figure 36. The series are well correlated (R^2 value 0.58 for the full series from 1961). In contrast to January and February 2014, the September 2014 pressure anomaly was +5.2 hPa with high pressure dominating for much of the month, while the UK rainfall anomaly that month was only 24% of the average, the driest September in the UK series from 1910.

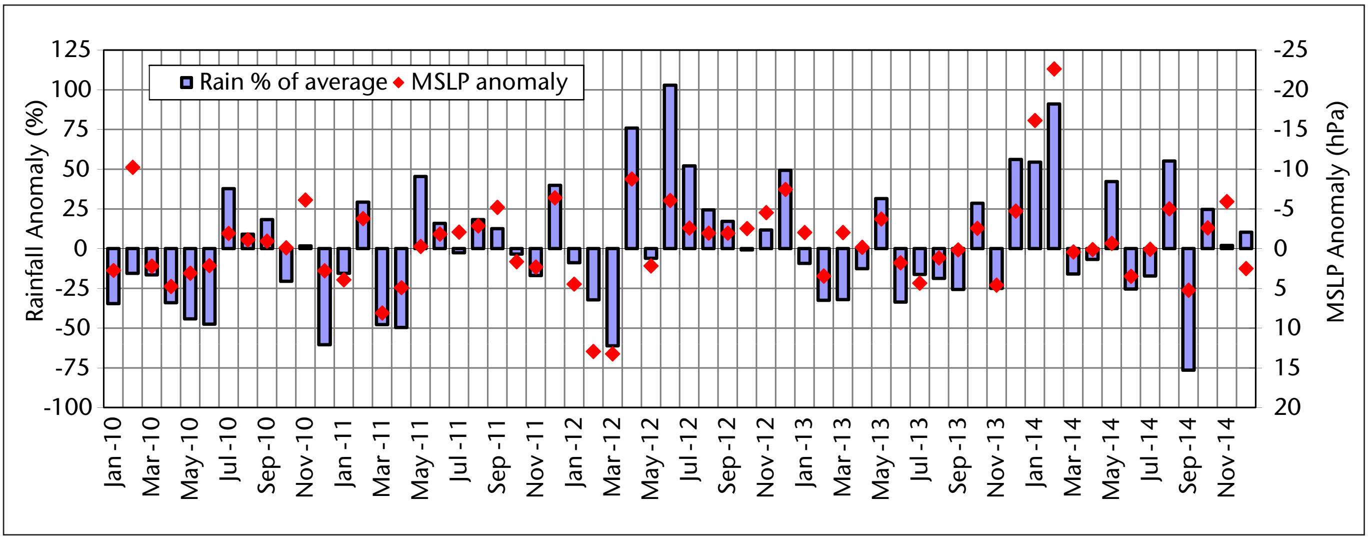
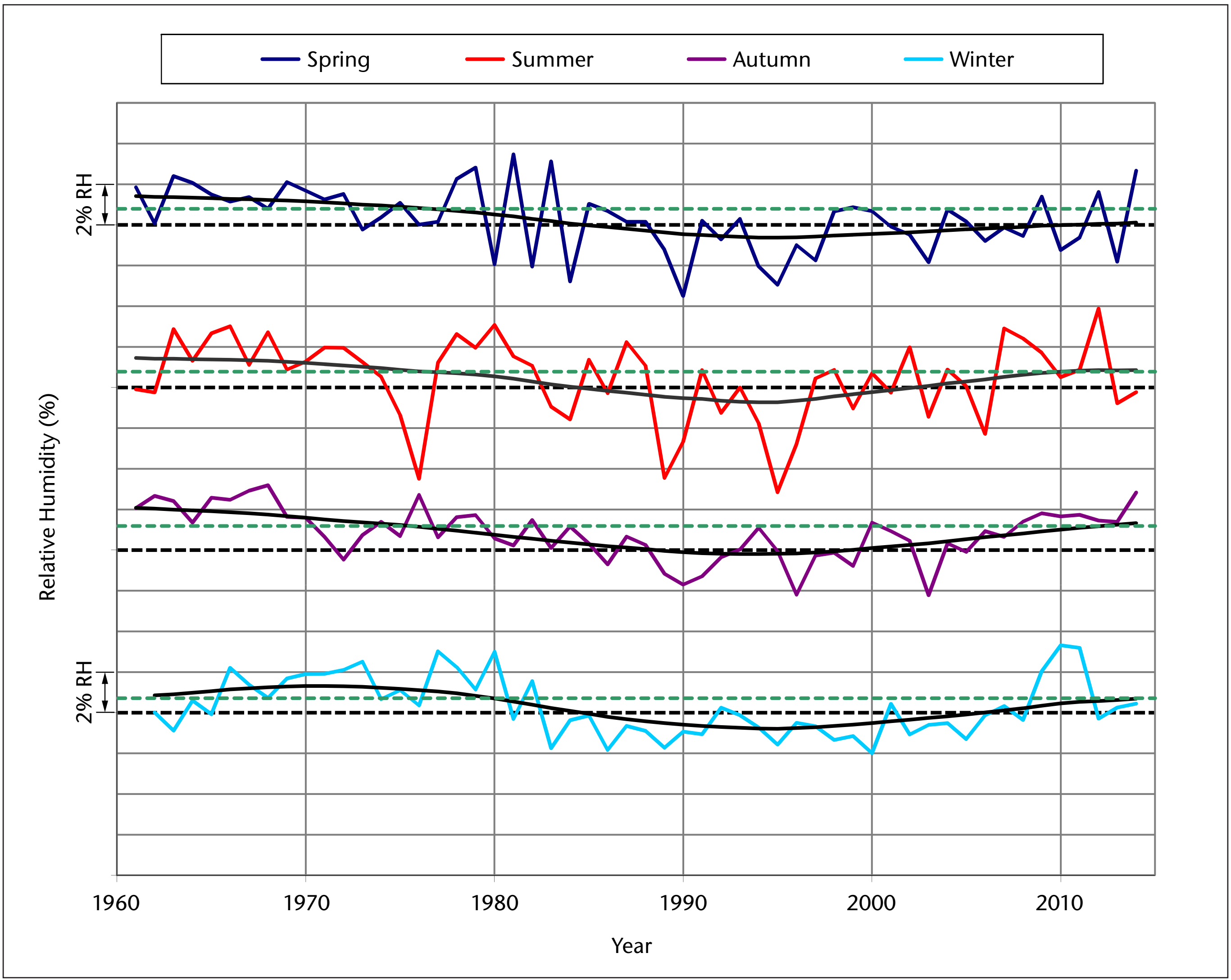


Figure 36: UK rainfall and mean sea level pressure anomalies for months from January 2010 to December 2014 inclusive. Note that the pressure scale is inverted for ease of comparison.

Relative Humidity

The 1981-2010 average relative humidity (RH) was slightly less than 1% below the 1961-1990 average. The most recent decade however has had an average RH much closer to the 1961-1990 value except in Spring. Some patterns are apparent, for example the warm, dry summers of 1976 and 1995 each had low relative humidity (< 75%), whereas the wet summer of 2012 saw high relative humidity (>83%). The high relative humidity of winter 2010 is associated with this being a cold winter (it was relatively dry for the UK overall in terms of precipitation). For the year 2014 relative humidity was fairly high in spring and autumn but otherwise unremarkable.



Season	1961-1990 average	1981-2010 average	2005-2014 average	Year 2014
Spring	79.7	79.0	79.0	81.6
Summer	80.0	79.2	80.1	79.0
Autumn	85.2	84.0	85.3	86.8
Winter	86.0	85.3	86.0	85.7

Figure 37: UK average relative humidity (%), 1961 to 2014, expressed as anomalies relative to the 1981-2010 average. The hatched black line is the 1981-2010 long-term average and the hatched green line is the 1961-1990 long-term average. Light grey grid-lines represent anomalies of +/- 2% relative humidity.

Sea Level

A UK sea level index (Figure 38) 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.

Figure 39 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.

During 2014 Newlyn recorded both the highest 99th percentile annual water level and the highest maximum water level. The latter occurred on 3 February 2014, associated with winter storms which brought major coastal impacts to south-west England. The long term trend in 99 percentile level is 2.0mm/year for the period 1916-2014, 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 2.1mm/year, but with greater variability in the records.

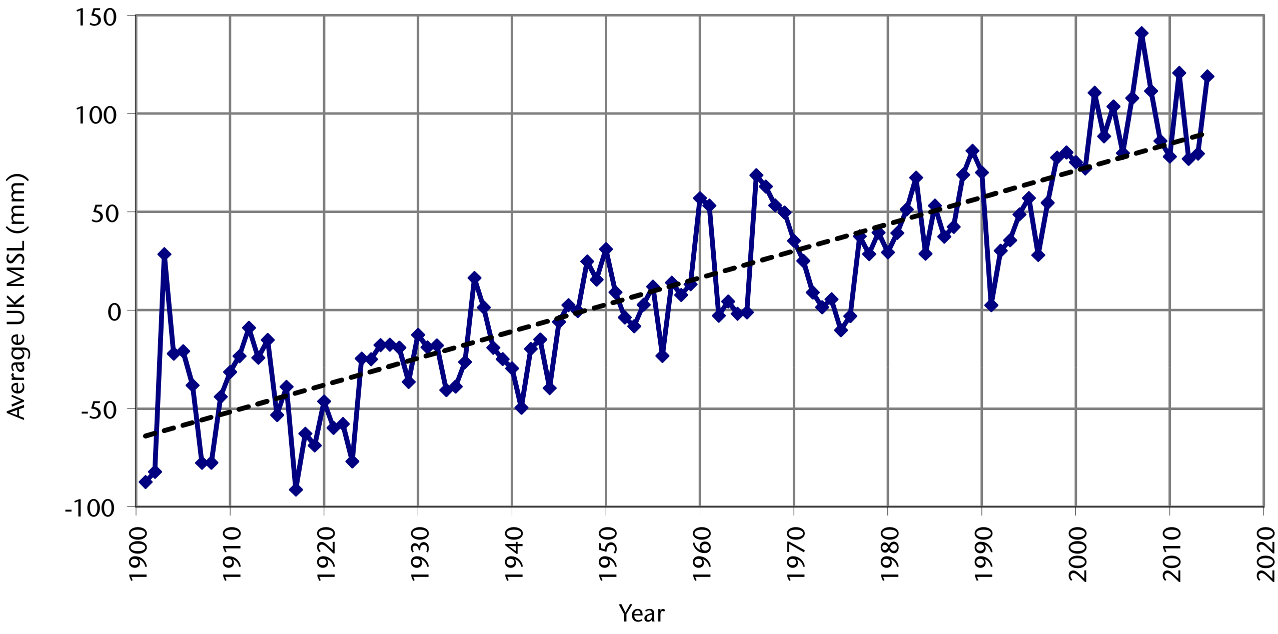


Figure 38: UK sea level index for the period since 1901 computed from sea level data from five stations (Aberdeen, North Shields, Sheerness, Newlyn and Liverpool) from Woodworth et al, 2009. The linear trend-line has a gradient of 1.4mm/year.

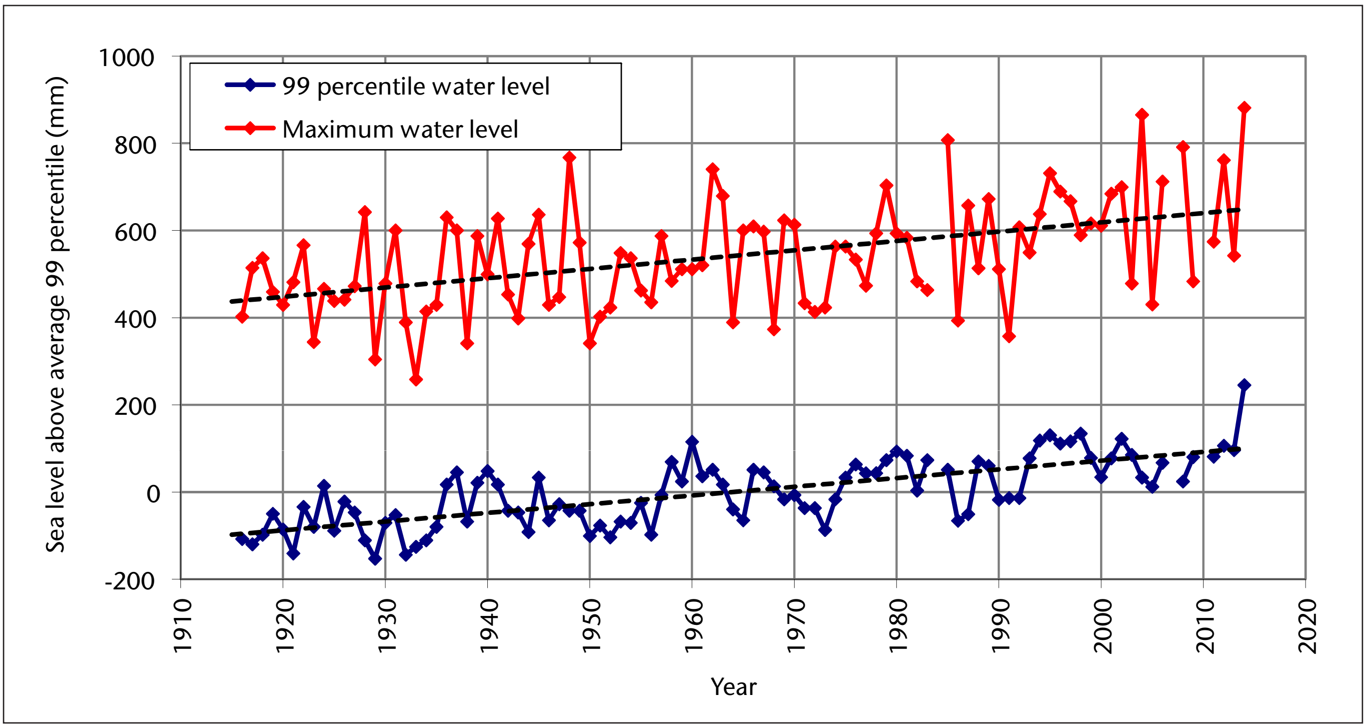


Figure 39: Extreme sea levels at Newlyn, Cornwall (1916-2014), in mm. The blue and red time-series are annual 99 percentiles and maximum water levels respectively. Levels are relative to the long-term average for the 99 percentile. The linear trend-lines for the 99th percentile and maximum water levels have gradients of 2.0 mm/year and 2.1mm/year respectively.

Significant Weather Events in 2014

This section provides a short summary of significant weather events during 2014.

WINTER STORMS 2013/14

Winter 2013/2014 was exceptionally wet and stormy as a succession of deep Atlantic low pressure systems, associated with a powerful jet stream, affected the UK. Following a major storm-surge event in early December 2013, there were two spells of major storms from mid-December to early January and late-January to mid-February; in total at least 12 major winter storms affecting the UK.

Initially, the storms brought strong winds mainly across Scotland but by early January the persistent wet weather led to flooding across the Somerset levels, while high spring tides and swell waves combined to cause coastal damage across south-west England and west Wales. It remained very unsettled and wet through January before the second succession of storms, this time with a much lower-latitude storm-track.

January 2014 was the wettest calendar month on record for climate regions of south-west and south-east England in a series from 1910, while much of southern and south-east England received between half and two-thirds of an average year's rainfall in just over two months. Flows in large river catchments such as the Thames and Severn responded and there was extensive and prolonged flooding in the Thames catchment, while the Somerset levels remained inundated. Substantial coastal flooding resulted from a combination of factors – high-energy swell waves, high spring tides and increased flows in rivers. The most damaging flooding affected the coasts of south-west and southern England, and huge waves overtopped coastal defences. A key event occurred during the storm of 4 to 5 February when the south-west mainline railway at Dawlish, Devon was severely damaged, severing a key transport link for many weeks. Although not the same magnitude as the floods of summer 2007, the storms of winter 2013/2014 resulted in several fatalities and over 7000 homes and businesses flooded.

Various papers document the storms of winter 2013/2014: weather events and climatological features (Kendon and McCarthy, 2015); hydrological response for river flows and groundwater (Muchan et al, 2015); coastal flooding (Sibley et al, 2015).

For more information about the winter storms see also
http://www.metoffice.gov.uk/climate/uk/interesting/2013-decwind
http://www.metoffice.gov.uk/climate/uk/interesting/2014-janwind

EX-HURRICANE BERTHA 10 TO 11 AUGUST 2014

From Sunday 10 to Monday 11 August 2014, the UK experienced some unseasonably windy and very wet weather from an active low pressure system containing the remnants of ex-hurricane Bertha. North-east Scotland experienced persistent heavy rain with a significant orographic component; for the Inverness area the north-easterly flow resulted in an effective reversal of the normal rain-shadow effect. This then shifted to a north-westerly flow bringing heavy rain to the North-West Highlands.

Over a 48 hour period some locations in each of these areas recorded 100 to 150 mm of rain. For the climatologically dry area around Inverness this was equivalent to 150 to 200% of the August whole-month long-term average rainfall, resulting in significant flooding. Impacts included disruption to rail travel, flooding and damage to roads and 200 homes being evacuated in Elgin. Ferry services were cancelled and there were reports of fallen trees across north-east Scotland and in eastern England.

The low pressure system remained centred near Shetland for several days before finally drifting east on 14 August. It contributed toward a cool and exceptionally wet month across Northern Scotland; the wettest in a series from 1910. The previous weather system to Bertha also brought some exceptionally wet weather to the Northern Isles: on 9 August around 100 mm fell across parts of Shetland and at Fair Isle 132.6 mm was recorded, easily the wettest day in a 40 year record. North-east Scotland was affected by flooding from a similar event in early September 2009.

For more information about ex-hurricane Bertha see http://www.metoffice.gov.uk/climate/uk/interesting/2014-bertha

WARMEST HALLOWEEN ON RECORD

31 October 2014 was the warmest Halloween on record for the UK. A maximum temperature of 23.6 °C was recorded at Kew Gardens (Greater London) and Gravesend (Kent). Temperatures were widely over 20 °C across England and Wales, 19 °C in Edinburgh and 17 °C in Inverness. These values are approaching 10 °C above normal at this time of year.

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.

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 2014 UK station network for the variables presented in this report.

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 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
Mean sea level pressure	Hourly (or 3-hourly) mean sea-level pressure (hPa) averaged over the month	1961	Monthly
Relative humidity	Hourly (or 3-hourly) relative humidity (%) averaged over the month	1961	Monthly

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

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

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
Humidity, pressure	n/a	100

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)

Temperature 375 stations

Rainfall 2837 stations

Snow Depth 118 stations

Sunshine 96 stations

Wind 152 stations

Pressure 132 stations

Humidity 126 stations

Figure A1.1: State of the UK observing network in 2014. Maps are based on stations reporting in June 2014, or for snow depth December 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 and 5km monthly 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.

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 to fewer than 3000 in the 2010s. The gauges are owned and maintained by several organizations: the Met Office, the Environment Agency, Natural Resouces 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 has subsequently declined to around 200 stations in 2010 and just over 100 stations during 2013 and 2014.

SUNSHINE DATA

The UK's sunshine network in 2014 comprises two instrument types. In 2014, 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 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).

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).

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, 2005-2014 averages (for the latest decade) and year 2014. While 2005-2014 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 2005-2014 averaging period and the baseline reference climatology 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); 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 √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

Annex 3: Useful resources

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

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

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/

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

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 UK 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://www.ceh.ac.uk/data/nrfa/nhmp/monthly_hs.html

Environment Agency Water Situation Reports for England
http://www.ceh.ac.uk/data/nrfa/nhmp/monthly_hs.html

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

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