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Cover Images:
(Left) Visible satellite image of snow cover across Wales and the West Midlands on 11 December 2017 following heavy snowfalls the previous day. Image copyright Met Office / NASA / NOAA.

(Right) A view north from Cadair Idris towards the Rhinog mountains of Snowdonia on the morning of Saturday 8 April 2017. High pressure was established over the UK with the mountains projecting above a layer of haze at around 600 masl. Image courtesy Mike Kendon, Met Office.
INTRODUCTION

This report provides a summary of the UK weather and climate through the calendar year 2017, alongside the historical context for a number of essential climate variables. This is the fourth in a series of annual “State of the UK climate” publications and an update to the 2016 report (Kendon et al., 2017). It provides an accessible, authoritative and up-to-date assessment of UK climate trends, variations and extremes based on the most up to date observational datasets of climate quality.

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.

The report presents summary statistics for year 2017 and the most recent decade (2008–2017) against 1961–1990 and 1981–2010 averages. 2008–2017 is a non-standard reference period, but it provides a 10-year “snapshot” of the most recent experience of the UK’s climate and how that compares to historical records. This means differences between 2008–2017 and the baseline reference averages may reflect shorter-term decadal variations as well as long-term trends. These data are presented to show what has happened in recent years, not necessarily what is expected to happen in a changing climate.

The majority of maps in this report show year 2017 against the 1981–2010 baseline reference averaging period—i.e., they are anomaly maps which show the spatial variation in this difference from average. Maps of actual values are not displayed because these are dominated by the underlying climatology, which for this report is of a lesser interest than the year-to-year variability.

Throughout the report’s text the terms “above normal” and “above average” etc. refer to the 1981–2010 baseline reference averaging period unless otherwise stated. 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.
EXECUTIVE SUMMARY

Land temperature
- 2017 was the fifth warmest year for the UK in a series from 1910, and eighth warmest for Central England in a series from 1659.
- Nine of the 10 warmest years for the UK have occurred since 2002 and all the top 10 warmest years have occurred since 1990.
- The most recent decade (2008–2017) has been on average 0.3 °C warmer than the 1981–2010 average and 0.8 °C warmer than 1961–1990.
- The Central England Temperature series provides evidence that the 21st century so far has overall been warmer than the previous three centuries.

Air and ground frost
- The number of air frosts in 2017 was well below average for the year overall, and the number of ground frosts was fourth lowest in a series from 1961.
- The most recent decade (2008–2017) has had 5% fewer days of air frost and 9% fewer days of ground frost compared to the 1981–2010 average, and 15%/14% fewer compared to 1961–1990.

Energy demand and growing conditions
- Heating degree days in 2017 were fifth lowest and growing degree days equal-fifth highest in series from 1960.
- The most recent decade (2008–2017) 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 (2008–2017) has had 4% more growing degree days per year on average compared to 1981–2010 and 14% more compared to 1961–1990.

Near-coast sea-surface temperature
- 2017 was the equal-fifth warmest year for UK near-coastal sea-surface temperature (SST) in a series from 1870.
- The most recent decade (2008–2017) has been on average 0.3 °C warmer than the 1981–2010 average and 0.6 °C warmer than 1961–1990.
- Eight of the 10 warmest years for near-coastal SST for the UK have occurred since 2002.

Precipitation
- 2017 rainfall for the UK overall was 97% of the 1981–2010 average and 102% of the 1961–1990 average.
- Seven 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 for which the most recent decade (2008–2017) has been on average 4% wetter than 1981–2010 and 11% wetter than 1961–1990.

- June 2017 was the second wettest June for Scotland in a series from 1910.
- UK summers for the most recent decade (2008–2017) have been on average 17% wetter than 1981–2010 and 20% wetter than 1961–1990, with only summer 2013 drier than average.

Snow
- On 10 December 2017 Wales and lowland England experienced, at the time, the most significant widespread snow since March 2013.
- In a long-term context 2017 was not a particularly snowy year for the UK overall.
- With the notable exceptions of 2009, 2010 and 2013, widespread and substantial deep snow events have been relatively rare in recent decades.

Sunshine
- 2017 sunshine for the UK overall was exactly 100% of the 1981–2010 average and 103% of the 1961–1990 average.
- The most recent decade (2008–2017) has had for the UK on average 3% more hours of bright sunshine than the 1981–2010 average and 6% more than the 1961–1990 average. These trends are particularly evident in winter and spring with 4%/10% more sunshine than the 1981–2010 average and 10%/14% more than 1961–1990.

Wind
- Seven named storms affected the UK in year 2017 (including ex-hurricane Ophelia and storm Ewan which mainly affected Ireland). The number and severity of these storms were not 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 has risen by approximately 1.4 mm/year from the start of the 20th century, when corrected for land movement.
- The 99th percentile water level (exceeded 1% of the time) at Newlyn, Cornwall for year 2017 was close to the long-term trend. Year 2014 was highest in this 100 year record.

1 | SYNOPTIC SITUATION

Figure 1 shows seasonal mean sea level pressure anomalies for the four seasons of 2017 relative to the 1981–2010 average, using the NCEP/NCAR reanalysis (Kalnay et al., 1996). This provides an indication of atmospheric circulation patterns for each season overall, although since each season comprises a mixture of weather types any
interpretation cannot fully take into account this complexity. For both winter and spring, the seasonal pressure was above normal, with the main contribution to these positive pressure anomalies over the UK being December 2016, January and April 2017. The position of the winter anomaly to the east of the UK resulted in a milder southerly flow overall. In contrast, the summer was characterized by a low pressure anomaly over the north of the UK bringing frequent Atlantic weather systems resulting in rather cooler and wetter conditions. The autumn pressure overall was near normal, but with an anomalous north-westerly flow resulting in rather cooler and wetter conditions across the north-west of the UK, particularly during September and November. Overall this resulted in a year in which the character of the first half—often relatively settled with warmer and drier than average conditions—contrasted with the second—more unsettled, cooler and wetter than average—although with exceptions.

1.1 | NAO index

Figure 2 shows the winter North Atlantic Oscillation (WNAO) index from 1870 to 2017 inclusive. (Note here and throughout the report winter refers to the year in which January and February fall.) This index is a measure of the large-scale surface pressure gradient in the North Atlantic between the Azores and Iceland, which determines the strength of westerly winds across the Atlantic. When the pressure difference is large, the WNAO is positive and westerly winds are strong with stronger and more frequent storms. When the pressure difference is small, the WNAO is negative and with an increased tendency for blocked weather pattern reducing the influence of these Atlantic weather systems. For the UK, a positive WNAO index tends to be associated with higher temperatures and higher rainfall ($R^2$ values of 0.47 for winter mean temperature and 0.23 for winter rainfall based on years 1911–2017, see Annex 2). This means that approximately half of the annual variability for
UK winter mean temperature and a quarter for rainfall may be associated with the WNAO. Importantly, however, it also implies that the WNAO is unable to fully explain the variability of UK winters because the complexity of weather types and associated temperature and rainfall patterns through the season cannot be fully accounted for by this single index. The influence of WNAO may also differ regionally across the UK, for example for rainfall across the northwest compared to the south-east, which overall UK rainfall statistics will tend to smooth out (West et al., 2018).

The WNAO index for 2017 was positive, although not exceptionally so. The winter was warmer and drier than average, with the sign of the anomalies being consistent with the WNAO index for temperature, although not for rainfall. Overall, the WNAO index shows a large annual variability but also decadal variability with periods of mainly positive phase (e.g., 1910s to 1920s and 1990s) and negative phases (e.g., 1960s). Hanna et al. (2015) discusses recent changes in the NAO index and notes a striking increase in variability of WNAO within the last two decades. The most positive winter in the index is 2015 and the most negative 2010—the latter being characterized by prolonged periods of blocked weather patterns and this was the UK’s coldest winter since 1979.

Figure 3 shows summer North Atlantic Oscillation (SNAO) index from 1870 to 2017 inclusive. Similar to the WNAO index, this is a measure of large-scale climate variability in the North Atlantic based on the surface pressure gradient, but based on a more northerly location and smaller spatial scale than the winter counterpart, reflecting the more northerly location of the Atlantic storm track. For the UK, a positive SNAO tends to be associated with higher temperatures and, of strongest influence, lower rainfall ($R^2$ values of 0.24 for summer mean temperature and 0.56 for summer rainfall based on years 1910–2017). The SNAO index for 2017 was negative, and while the UK summer mean temperature was near-normal for temperature it was wetter than average, with the sign of the anomaly being consistent with the SNAO index for rainfall. As with its winter counterpart, the SNAO shows periods of mainly positive phase (e.g., 1970s to 1990s) and negative phase (e.g., 1880s and
1890s), with Hanna et al. noting a striking recent decrease in SNAO since the 1990s.

2 | TEMPERATURE

The UK mean temperature ($T_{\text{mean}}$) for 2017 was 9.6 °C, which is 0.7 °C above the 1981–2010 long term average, making this the fifth warmest year in the UK series from 1910. 2017 was ranked eighth warmest in the Central England temperature (CET) series from 1659. The annual mean temperature was around 0.6–0.8 °C above normal across most of the UK (Figure 4, Table 1).

The UK annual mean maximum temperature ($T_{\text{max}}$) for 2017 was 13.1 °C, which is 0.7 °C above average. The highest $T_{\text{max}}$ anomalies were near North Sea coasts whereas

![Figure 4](image)

**FIGURE 4** 2017 annual average temperature anomalies (°C) relative to 1981–2010 average for mean, maximum and minimum temperature. Bulls-eye features present in the $T_{\text{min}}$ map are due to localized micro-climate features, such as frost hollow effects, at individual weather stations which the gridding process is unable to fully represent.

| 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 2017 |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UK      | England | Wales | Scotland | Northern Ireland | CET |
|         | Actual  | Anomaly | Actual  | Anomaly | Actual  | Anomaly | Actual  | Anomaly | Actual  | Anomaly | Actual  | Anomaly |
| January | 3.9     | 0.2     | 3.8     | -0.3    | 4.5     | 0.4     | 3.6     | 1.0     | 5.2     | 1.0     | 4.0     | -0.4   |
| February| 5.3     | 1.6     | 5.9     | 1.8     | 5.7     | 1.7     | 4.0     | 1.3     | 5.3     | 1.0     | 6.1     | 1.7    |
| March   | 7.3     | 1.8     | 8.4     | 2.2     | 7.6     | 1.8     | 5.4     | 1.3     | 7.2     | 1.4     | 8.7     | 2.1    |
| April   | 8.0     | 0.6     | 8.8     | 0.7     | 8.2     | 0.6     | 6.7     | 0.6     | 8.2     | 0.6     | 8.9     | 0.4    |
| May     | 12.1    | 1.8     | 12.9    | 1.7     | 12.4    | 1.8     | 10.6    | 1.8     | 12.1    | 1.9     | 13.2    | 1.5    |
| June    | 14.5    | 1.5     | 15.9    | 1.9     | 14.7    | 1.5     | 12.1    | 0.8     | 13.8    | 1.0     | 16.0    | 1.5    |
| July    | 15.1    | 0.0     | 16.6    | 0.3     | 15.3    | 0.1     | 12.9    | -0.4    | 14.4    | -0.2    | 16.8    | 0.1    |
| August  | 14.5    | -0.4    | 15.6    | -0.5    | 14.5    | -0.4    | 12.8    | -0.2    | 13.9    | -0.4    | 15.6    | -0.8   |
| September| 12.6   | -0.1    | 13.4    | -0.3    | 12.6    | -0.2    | 11.2    | 0.3     | 11.9    | -0.4    | 13.5    | -0.5   |
| October | 11.2    | 1.8     | 12.2    | 1.8     | 11.6    | 1.7     | 9.7     | 1.8     | 10.8    | 1.4     | 12.4    | 1.7    |
| November| 5.8     | -0.4    | 6.6     | -0.2    | 6.7     | 0.0     | 4.1     | -0.9    | 5.8     | -0.7    | 6.8     | -0.3   |
| December| 4.1     | 0.2     | 4.7     | 0.3     | 5.0     | 0.5     | 2.9     | 0.1     | 4.7     | 0.2     | 4.8     | 0.2    |
| Winter  | 5.0     | 1.3     | 5.2     | 1.0     | 5.5     | 1.3     | 4.4     | 1.7     | 5.6     | 1.3     | 5.4     | 0.9    |
| Spring  | 9.1     | 1.4     | 10.0    | 1.5     | 9.4     | 1.4     | 7.6     | 1.2     | 9.2     | 1.3     | 10.3    | 1.4    |
| Summer  | 14.7    | 0.4     | 16.0    | 0.5     | 14.8    | 0.4     | 12.6    | 0.1     | 14.0    | 0.1     | 16.1    | 0.2    |
| Autumn  | 9.9     | 0.4     | 10.8    | 0.5     | 10.3    | 0.5     | 8.4     | 0.4     | 9.5     | 0.1     | 10.9    | 0.3    |
| Annual  | 9.6     | 0.7     | 10.4    | 0.8     | 9.9     | 0.8     | 8.0     | 0.6     | 9.5     | 0.6     | 10.6    | 0.6    |

**Key**

- **Warmest on record**
- **Top ten warm**
- **Warm: ranked in upper third of all years**
- **Middle: ranked in middle third of all years**
- **Cool: ranked in lower third of all years**
- **Top ten cold**
- **Coldest on record**

Colour coding relates to the relative ranking in the full series which spans 1910–2017 for all series except CET which is 1659–2017.
FIGURE 5  2017 seasonal average temperature anomalies (°C relative to 1981–2010 average). Winter refers to the period December 2016 to February 2017. Note that winter 2018 (December 2017 to February 2018) will appear in State of the UK Climate 2018.

FIGURE 6  2017 monthly average temperature anomalies (°C) relative to 1981–2010 average.
anomalies were slightly lower in the west. The UK annual mean minimum temperature ($T_{\text{min}}$) for 2017 was 6.0 °C, which is 0.8 °C above average. $T_{\text{min}}$ anomalies were slightly lower around some coastal fringes of the North Sea and south coast but with considerable local variation (Figure 4, Table 1). The months from February to June were all warmer than average, whereas the second half of the year saw temperatures nearer to average with the exception of a warm October. February, March, May, June and October all had UK-average anomalies well in excess of 1 °C. The coolest months relative to average were August and November.

The UK seasonal $T_{\text{mean}}$ for winter 2017 (December 2016 to February 2017) was 5.0 °C, which is 1.3 °C above the 1981–2010 average and this was ninth warmest winter in the UK series from 1911. (Note here and throughout the report winter refers to the year in which January and February fall.) Temperature anomalies exceeded 2.0 °C across parts of Highland Scotland and it was the fourth/sixth warmest winter for Scotland/Northern Ireland in national series, and for both the warmest winter since 1998 (Figure 5). This was largely due a very mild December 2016 (not shown). January temperatures were overall fairly near-normal although high pressure brought cold continental air into south-east and central parts of England at times. February was a mild month and the temperature reached 18 °C in the London area on the 20th (Figure 6, Table 1).

The UK seasonal $T_{\text{mean}}$ for spring was 9.1 °C, which is 1.4 °C above the 1981–2010 average. This was the equal-warmest spring (with 2011) in the UK series from 1910, and for Wales and Northern Ireland the warmest spring in the series. It was also the warmest spring in the CET series from 1659 (just ahead of 2011). All three months were warmer than average, especially March and May (equal-fifth and second warmest for the UK in series from 1910 respectively). The second half of April was cooler with some cold nights and numerous late frosts. In contrast, the temperature reached 29.4 °C at Lossiemouth (Moray) on 26th May, the highest UK temperature for May 2017 and Scotland’s highest temperature of the year.

The UK seasonal $T_{\text{mean}}$ for both summer and autumn were 0.4 °C above normal. Overall June was a warm month with a spell of fine weather coinciding with the summer solstice; 30°C was exceeded every day from the 17th to the 21st and this was the equal-fifth warmest June in the UK series from 1910 (for more details see the significant weather events section). However, during July and August an often unsettled westerly regime brought mostly cooler weather with anomalies near or slightly below normal, $T_{\text{max}}$ anomalies were widely 0.5–1.0 °C below normal in August. September continued the mainly cool and unsettled theme with maximum temperatures suppressed under often cloudy conditions. However, October was mostly warmer than average, particularly for minimum temperatures which were 2.0 °C above normal for the UK overall—again cloudy conditions being a contributory factor. November was slightly colder than average, particularly in the north, mainly due to a cold final week. December saw a fairly typical mixture of weather types with temperatures near normal overall.

Figure 7 shows time series of annual $T_{\text{mean}}$ anomalies for the UK and countries from 1910 to 2017 inclusive and Figure 8 the seasonal UK $T_{\text{mean}}$ anomaly series. There is an increase in temperature from the 1970s to the 2000s with the most recent decade (2008–2017) being on average 0.8 °C warmer than the 1961–1990 average and 0.3 °C above 1981–2010. All the top 10 warmest years in the UK $T_{\text{mean}}$ series have occurred since 1990, and all but 1990 (ranked tenth) since 2002; year 2017 is ranked fifth (Figure 7). 2017 was warmer than any year in the series from 1910 to 2005. 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 cold.

All four seasons have seen 2008–2017 warmer than 1961–1990, with the largest change for spring at 1.1 °C (Figure 8). Warming has been slightly greater for $T_{\text{max}}$ than $T_{\text{min}}$ (Figure 9) 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 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.

Figure 10 shows annual $T_{\text{mean}}$ for England from 1910 to 2017 and CET series from 1659. The series are highly correlated for the period of overlap ($R^2$ value 0.98) and have a
root mean square difference of 0.1 °C which is comparable to the estimated series uncertainty as described in Annex 2. The CET series could effectively be considered a proxy for an England series from 1659, although because these are different dataset produced in a different ways, some differences are inevitable. The CET series provides evidence that the 21st century so far has overall been warmer than any period of equivalent length in the previous three centuries, and that all seasons are also warmer (Figures 10 and 11). When comparing the early 21st century (2001–2017) to previous centennial averages, the difference is typically 0.5–1.0 °C compared to 1901–2000 and 0.5 to 1.5 °C compared to 1801–1900 and 1701–1800 with the greatest difference in autumn and the least in summer (Table 2).

2.1 | Days of air and ground frost

The average number of days of air frost for the UK for 2017 was 45 days, which is 9 days below the 1981–2010 average (Figure 12). This was largely due to fewer frosts than normal in February and March. In contrast, most of south-east England had at least 15 days of frost in January alone, more than 5 days above normal for the month.

The number of days of ground frost for 2017 was 87 days, 23 days below the 1981–2010 average and fourth lowest in a series from 1961. Some locations, mainly in the west and north, recorded at least 30 fewer days of ground frost for the year overall compared to normal (Figure 12). As with air frost the greatest contributions to this deficit were during February and March, but ground frosts were also well below normal in October.

| Variable                      | 1961–1990 average | 1981–2010 average | 2008–2017 average | 2017 |
|-------------------------------|-------------------|-------------------|-------------------|------|
| Days of Air Frost             | 61                | 55                | 52                | 45   |
| Days of Ground Frost          | 116               | 111               | 100               | 87   |
the requirement for heating or cooling of buildings to maintain comfortable temperatures, or the conditions suitable for plant growth respectively. These indices are useful metrics, but as they are derived from temperature only, so users should be aware that other relevant factors such as solar gain, day length, wind and rain will also influence the actual responses of for example plant growth. The definitions and thresholds used are described in Annex 1.

Heating degree days (HDD) for 2017 were around 90% of average across most of England and Wales but closer to 95% of average across Scotland and Northern Ireland (Figure 14). Averaged across the UK HDD for 2017 were 91% of the 1981–2010 average and ranked fifth lowest in the series from 1960. The lowest 10 HDD years for the UK have all occurred since 1990, with the lowest eight since 2002. Overall HDD for 2017 were also well below the average for the most recent decade (Figure 15). For the UK, the most recent decade has had an annual average HDD 9% lower than 1961–1990 and 3% lower than 1981–2010. The most recent decade, including years 2010 and 2013 demonstrates that it is still possible for UK climate to experience well above average HDD values.

In general, the highest cooling degree day (CDD) values are around Greater London due in part to the urban heat-island effect. CDD for 2017 for the UK (12) and England (20) were each close to the 1981–2010 average (13 and 21). However, CDD were below normal across parts of East Anglia and the East Midlands. This is despite the year being on average the fifth warmest on record. Mild conditions in late winter and spring contributed to the warm year overall (Figure 6, Table 1) and below average HDD (Figure 15), but are not warm enough to contribute to CDD. The most significant spell of warmth contributing to CDD occurred from 17th to 21st June, when maximum temperatures exceeded 28 °C widely across much of England and minimum temperatures remained above 16 °C across southern England (Figure 16).

| Area          | 1961-1990 average | 1981-2010 average | 2008-2017 average | 2017  |
|---------------|-------------------|-------------------|-------------------|-------|
| UK            | 2731              | 2566              | 2492              | 2341  |
| England       | 2514              | 2333              | 2243              | 2086  |
| Wales         | 2609              | 2446              | 2378              | 2197  |
| Scotland      | 3140              | 3000              | 2944              | 2812  |
| Northern Ireland | 2646          | 2491              | 2446              | 2289  |

The years with high CDD in the time-series across England and Wales (notably 1976, 1995, 2003 and 2006) are those when major summer 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 17) significant peaks are dependent on when major heat-waves happen to occur. The most recent major summer heatwave for the UK affecting CDD was in July 2006 (Figure 17), so CDD for the most recent decade 2008–2017 are lower than the 1981–2010 averages, particularly across England and Wales. The latest year with well above-average CDD was 2013, associated with a warm dry spell during July. This contrasts with a run of notably low CDD from 2007 to 2012 associated with a run of generally cool summers compared to previous decades.

Growing degree days (GDD) for 2017 were around 10% above average across most of the UK, with the exception of parts of Scotland (Figure 18). UK GDD overall were 110% of the 1981–2010 average, the equal-fifth highest in a series from 1960 and also above the average for the most recent decade across all regions.

The most recent decade has had an annual GDD 14% higher than 1961–1990 and 4% 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 19). The recent cold years of 2010 and 2013 still recorded GDD well above the 1961–1990 average.

### Coastal waters

The annual mean sea-surface temperature (SST) for 2017 for near-coast waters around the UK was 11.9, 0.5 °C above the 1981–2010 long term average and ranked equal-fifth warmest in the series from 1870 (Figure 20).

Near-coast SST data is highly correlated with the land observations. The series are well correlated for the period of overlap ($R^2$ value 0.81, see Annex 2) with a root mean
The most recent decade, 2008–2017, is 0.6°C higher than the 1961–1990 average and 0.3°C above 1981–2010. Although the 2017 annual mean near-coast SST was above average in comparison to the most recent decade, the temperature anomaly was less than for the UK annual mean air temperature over land. Eight of the ten warmest years in the series have occurred since 2002.

### Precipitation

The UK rainfall total for 2017 was 1124 mm, 97% of the 1981–2010 average. The rainfall anomaly pattern showed considerable spatial variation with much of Highland Scotland and lowland England drier than average; for example only 75% was recorded across parts of Perthshire. The wettest areas relative to average were across west Wales, north-west England and parts of south-west and north-east Scotland. Parts of Lancashire, Cumbria and west Wales recorded over 125% of average and it was a wet year too across the Northern Isles (Figure 21).

The wettest locations and driest observed locations for the year generally reflected the long-term climatology. Several rain-gauges across the south-western fells of the Lake District recorded 4000 to 4,500 mm for the year (around 125% of the 1981–2010 average), and elsewhere parts of the West Highlands and Snowdonia also received 3,000–4,000 mm. In contrast, the driest locations were across Kent and parts of Essex with less than 500 mm (around 85% or less). Overall this represents a fairly typical range for the UK.

Inevitably, as is always the case, the annual map conceals the detail behind significant monthly and seasonal variations which occurred in rainfall patterns over the course of the year.

Winter 2017 (December 2016 to February 2017) was relatively dry across all areas, with 75% of average rainfall for the UK making this the driest winter since 2006. December
FIGURE 22  Rainfall anomalies (%) for seasons of 2017. Winter refers to the period December 2016 to February 2017. Note that winter 2018 (December 2017 to February 2018) will appear in State of the UK Climate 2018.

FIGURE 23  Rainfall anomalies (%) for months of 2017.
2016 was a dry month, particularly in the south with less than 20% of average rainfall across parts of the south-east, although totals were near normal across central and northern Scotland (not shown). In January, Scotland and Northern Ireland were relatively dry with less than 50% of average widely, whereas rainfall was nearer average across the Midlands and most of southern England. February rainfall was closer to average generally.

Spring 2017 was also a dry season across most of the UK, with 79% of average rainfall. This was largely as a result of a very dry April with high pressure established across the UK; it was the ninth driest April for the UK in a series from 1910. Monthly totals were less than a third of average widely and some locations in south-east England and around Lothian and Fife recorded less than 5 mm of rain. May was also quite dry in the north.

Following two dry seasons, all three months of the summer were wetter than average. This was the 13th wettest summer for the UK overall in a series from 1910, broadly comparable to summers 2008 and 2009 but not as wet as 2007 or 2012. In June, numerous places exceeded twice their average rainfall, most notably across southern and eastern Scotland and it was the UK’s eighth wettest June in a series from 1910. With 172% of average rainfall, Scotland recorded its second wettest June in the series. From mid-July onwards the weather was often cool with an unsettled westerly regime bringing rain at times: as a result, July overall was wetter than average in most areas, with more than double the average rainfall across parts of southern England, and just a few parts of northern Scotland below average. Rainfall was also above average in August.

Autumn rainfall was 95% of average for the UK. It was notably dry across the south-east with less than half the average rainfall across parts of Kent and Essex—although not as dry here as autumn 2011. September was generally wetter than average, with regular spells of rain throughout the month. October was a drier month, with below half the average rainfall over central and south-eastern areas of England. November was also slightly drier than average for most central and south-eastern areas, but wetter in parts of the north and west, especially Caithness and Sutherland. December rainfall totals were above average across East Anglia but below average across much of north-east England and eastern Scotland.

Various flood events occurred during 2017 although the number and severity was unexceptional compared to other years such as 2015, 2013–2014, 2012, 2009, 2007 and 2005, and impacts were generally localized.

Localized flooding affected rail services in Ayrshire and Fife on 6th February. Thunderstorms broke out between 27th and 29th May following a spell of warm weather, with flooding reported in North Yorkshire, south-east Scotland and south-east England accompanied by a number of incidents resulting from lightning strikes. Unseasonably wet and windy weather from a low pressure system on 5th to 6th June led to some flooding, first affecting much of south-west

| TABLE 3 Monthly, seasonal and annual rainfall actual (mm) and anomaly values (%) relative to 1981–2010 for the UK, countries and EWP for year 2017 |
|---|---|---|---|---|---|---|---|
| | UK | England | Wales | Scotland | Northern Ireland | EWP |
| | Actual | Anomaly | Actual | Anomaly | Actual | Anomaly | Actual | Anomaly |
| January | 76 | 63 | 63 | 76 | 83 | 53 | 101 | 57 | 55 | 47 | 80 | 86 |
| February | 94 | 106 | 62 | 102 | 119 | 107 | 143 | 110 | 75 | 89 | 72 | 108 |
| March | 98 | 103 | 70 | 109 | 154 | 132 | 128 | 91 | 107 | 113 | 81 | 113 |
| April | 134 | 45 | 18 | 30 | 25 | 20 | 64 | 70 | 25 | 34 | 20 | 31 |
| May | 57 | 82 | 57 | 98 | 72 | 84 | 54 | 54 | 63 | 56 | 78 | 65 | 102 |
| June | 111 | 151 | 82 | 133 | 131 | 153 | 153 | 172 | 103 | 135 | 94 | 141 |
| July | 102 | 130 | 91 | 145 | 122 | 131 | 110 | 112 | 122 | 151 | 106 | 157 |
| August | 103 | 115 | 72 | 105 | 111 | 104 | 147 | 126 | 124 | 127 | 84 | 111 |
| September | 118 | 122 | 91 | 131 | 172 | 147 | 142 | 104 | 147 | 160 | 106 | 138 |
| October | 103 | 81 | 54 | 59 | 110 | 65 | 180 | 102 | 106 | 88 | 52 | 49 |
| November | 108 | 89 | 68 | 77 | 146 | 90 | 164 | 99 | 113 | 100 | 81 | 81 |
| December | 122 | 101 | 98 | 113 | 171 | 103 | 148 | 90 | 116 | 101 | 114 | 117 |
| Winter | 248 | 75 | 160 | 70 | 284 | 65 | 391 | 83 | 208 | 66 | 193 | 75 |
| Spring | 189 | 79 | 145 | 80 | 251 | 86 | 245 | 78 | 189 | 78 | 166 | 83 |
| Summer | 315 | 131 | 246 | 127 | 364 | 128 | 411 | 135 | 350 | 137 | 283 | 135 |
| Autumn | 329 | 95 | 213 | 85 | 427 | 95 | 496 | 102 | 365 | 113 | 239 | 85 |
| Annual | 1124 | 97 | 827 | 97 | 1416 | 97 | 1534 | 98 | 1150 | 101 | 953 | 101 |

Colour coding relates to the relative ranking in the full series which spans 1910–2017 for all series except EWP which is 1766–2017.
England, Wales and Cumbria (where 30–50 mm or more fell widely), followed by north-east England and north-east Scotland (50–100 mm fell across near Edinburgh, the Moray coast, Caithness and Orkney). This system also brought significant impacts from strong winds. Localized flooding occurred in north-east England following the hot spell from 17th to 21st June and there was further flooding across parts of southern and eastern England on 27–28th June. Thundery showers caused flooding once again across parts of England following a brief warm spell on 18th and 19th July. Intense rainfall led to flash-flooding at Coverack, Cornwall on the afternoon of the 18th (for more details see the significant weather events section). Late July continued very unsettled with further flood incidents; most flights for Scotland’s National Air Show in East Lothian on 22nd July were cancelled. Heavy thundery showers caused localized flooding in early August; on the 8th and 9th there was flooding on the M20 and flash-flooding in parts of Yorkshire and Lincolnshire.

The 22nd to 25th August saw heavy rain over Northern Ireland and much of northern Scotland; on the 22nd 30–50 mm fell across counties Londonderry, Fermanagh and Tyrone with 70 mm locally. This brought widespread flooding with damage to properties and infrastructure, and over a hundred people were rescued after becoming trapped in homes and cars by overnight flooding. Derry Airport was closed due to flooding as well as many roads across the region. Landslides also closed roads; combined with swollen rivers, various bridges were damaged, some bridges collapsing and cutting off communities. The Western Isles also suffered from heavy flooding with rain falling on Barra and South Uist resulting in disruption to travel. Northern Ireland again experienced some flooding on 20th September from persistent heavy rain.

There were further localized flood events through the autumn but the main impacts from storms Aileen, Ophelia and Brian were due to wind. Over 150 mm fell across parts of the Cumbrian Fells on 10th October, resulting in some road closures and rail cancellations. A landslip closed the Inverness to Wick railway line on 21st November and there was further localized flooding across parts of Pembrokeshire and north-west England; with the long running station at Hazelrigg, Lancaster recording 73.6 mm on 22 November becoming the record highest 24 hr rainfall total for this site. Flooding also occurred in parts of Wales due to overnight rain on 26th/27th November. On 24 December the south-western fells of the Lake District received 150–200 mm with a daily total of 212.6 mm recorded at Ennerdale, Black Sail.

The precipitation data show a slight increase from the 1970s onwards (Figure 24). The most recent decade (2008–2017) has been on average 8% wetter than 1961–1990 and 3% wetter than 1981–2010; this increase is most pronounced for Scotland. The wettest years for the UK overall are 2000 and 2012 (both 116% of average) and the driest 1933 (72%). 2017 was ranked in the middle third of the UK series from 1910. Seven of the ten wettest years in the UK series have occurred since 1998, including 2015, 2014, 2012 and 2008.

Figure 25 shows seasonal rainfall series for the UK from 1910 to 2017 (for winter 1911–2017). The two recent winters of 2013–2014 and 2015–2016 stand out, each with over 150% of the 1981–2010 average UK rainfall overall. Also of note is the run of recent wet summers; of the last 10 summers from 2008 to 2017, only summer 2013 has seen a UK rainfall total below the 1981–2010 average and four of these summers have had around a third or more rainfall than normal (with summer 2007 also exceptionally wet). The run of wet summers from 2007 to 2012 coincide with a run of years of negative SNAO index as shown in Figure 3.

The annual rainfall total for 2017 in the long running England and Wales precipitation (EWP) series was 953 mm (Figure 26), which is 99% of the 1981–2010 average, making this an unremarkable year in the EWP series overall. Figure 26 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
The most recent decade is a relatively wet decade in this series being 4% wetter than 1981–2010 and 7% wetter than 1961–1990. The England and Wales areal rainfall series based on 5 km resolution gridded data is highly correlated to EWP for the period of overlap, 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.

Figure 27 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 (winter 2014 is the wettest winter in this series and 2016 ranked eighth wettest). 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 the 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 1–4% 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 nontrivial 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.

### 3.1 Days of rain and rainfall intensity

The number of days of rain greater than or equal to 1 mm (Dr1) during 2017 was above average across much of the west and north, with over 30 days more than normal across parts of Wales, north-west England and western Scotland. There were locally fewer days than normal elsewhere, most notably parts of the far south-east (Figure 28). In general, the monthly variation was comparable to the rainfall anomaly pattern (Figure 23) with fewer days of rain than average in January and April but more in July, August and September—other months mostly having smaller anomalies.
The number of days of rain greater than or equal to 10 mm (Dr10) was near-normal across much of the UK, above normal across some upland areas in the west but below across parts of south-west England, the West Midlands and central Scotland (Figure 28). One explanation for the apparent difference between the Dr1 and Dr10 anomaly patterns may be the unsettled westerly weather regimes in July, August and September bringing frequent frontal systems but, with the exception of these western upland locations, much of this rain not necessarily exceeding 10 mm per day.

Figure 29 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 2017 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, 2017 was well below average for this metric and the equal-third lowest year in the series from 1961, which is consistent with the discrepancy between Dr1 and Dr10 anomaly maps. 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.

### 3.2 Heavy rainfall

Alternative metrics for heavy rain are presented here. Heavy rainfall is a complex variable to monitor due to its potential to be highly localized. These metrics adopt two different methods: a percentile approach (which varies spatially across the UK depending on climatology) and an absolute threshold. 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 these 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 9.5 and 13.9 mm respectively. Figure 30 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 3–4 days respectively). As with rainfall intensity, 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. Eight days in 2017 exceeded the 95th percentile, this being the lowest such number of days in the series from 1960. Only one day exceeded the 99th percentile which was also well below average. Both series show some increase in the average number of heavy rain days, but with large annual variability.

The only day in 2017 when the 99th percentile was exceeded was on 5th June, due to a low pressure system centred over the UK; 20–30 mm fell widely across western England, Wales and southern Scotland, with 30–50 mm or more across many upland areas. The UK areal-average rainfall on this day was 17.0 mm, making this the wettest June day overall for the UK in a daily series from 1960.
system brought heavy continuing rainfall to northern and eastern areas on the 6th and the UK total for these two days combined was 29.7 mm, the highest 2-day total for a summer month since August 9–10, 2004.

Figure 31 provides a count of the number of times each year any rain gauge in the observing network below 500 m elevation has recorded a daily rainfall total greater than or equal to 50 mm. We refer to this type of metric as a count of station-days. This metric cannot distinguish between a small number of widespread events recorded at many stations, or more frequent but localized events, but is a useful gauge of the occurrence of extreme heavy rainfall overall. This series has been adjusted to take into account the changing size of the UK rain-gauge network which reached over 5,100 gauges in the 1970s and has reduced to fewer than 3000 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 localized convective events may still be missed. The adjustment is made by applying a scaling factor to the station-day counts for each year, so that earlier years are scaled down and later years scaled up and the apparent number of stations in the network remains constant throughout. However, note that this 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.

3.3 Snow

2017 was not a snowy year overall; while there were several snow events these were not unusual for the time of year when they fell. In mid-January a flow of Arctic Maritime air brought 10–20 cm across parts of north-east Scotland. Snow from this event also caused some transport disruption across Northern Ireland, north-west and south-east England. There was also some disruption due to snow across parts of central Scotland as storm Doris tracked further south across the UK on 23 February. Late November saw some snowfalls across parts of Scotland and north-east England with transport disruption across County Durham, North Yorkshire and Aberdeenshire and there was some early season snow in the West Highlands for skiers in Glencoe.

The most significant snow event of the year occurred on 10 December, as a low pressure system in the south-west pushed into cold air, bringing significant falls of snow across Wales and central England. 10 to 15 cm fell widely across the West Midlands but some parts of mid-Wales and Shropshire recorded depths of over 30 cm. Snow depths at 0900 UTC on 11 December included 40 cm at Llanarmon Dyffryn Ceiriog, Shropshire, 38 cm at Edge, Shropshire, 31 cm at Sennybridge, Powys, 18 cm at Hereford, 15 cm at Cirencester, Gloucestershire, 14 cm at High Wycombe, Buckinghamshire and 12 cm at Coleshill, Warwickshire (see cover image). This snow lay for several days before melting and caused significant disruption to road, rail and air travel, power outages occurred due to damaged railway lines in the West Midlands and schools were closed across many areas. This event was judged at the time to be the most significant widespread snow event (in terms of depth and extent) across Wales and lowland England since March 2013—for more details see the weather events section. There was further disruption from snow across parts of England between 27 and 29 December.

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. It is worth noting that year 2013 too would be regarded as relatively snowy in the context of the last two decades, but near-average for the first half of the series. Figure 32 shows the count of station-days where snow depth sensors recorded greater than or equal to 10 cm or 20 cm of lying snow. The series has not been adjusted for network size, consequently it is indicative but not homogenous. Despite the snow event in December, overall year 2017 had a low count of station-days for both metrics being broadly comparable with many other years with limited snowfalls since the mid-1990s.
2017 was a sunnier year than normal across parts of Scotland and north-east England, with some locations recording 110% or more of the 1981–2010 average hours of bright sunshine, for example Leeming, North Yorkshire and Morpeth, Northumberland. Faversham and East Malling, both in Kent, also recorded over 110% of average. In contrast, some locations in west Wales, south-west England and the west of Northern Ireland recorded less than 90%, for example Camborne, Cornwall and Aberporth, Ceredigion. Sunshine totals were near normal across most of southern and central England and the UK overall recorded exactly 100% (Figure 33). Note however the possibility that imperfect exposure at individual stations and the relatively sparse density of stations are likely to have had some influence on the detail in the sunshine anomaly pattern.

The UK’s highest annual sunshine total was 1,945 hr (116% of the 1981–2010 average) at Faverham, Kent, while sunshine totals in the Channel Islands were 1,948 and 1,903 hr on Jersey and Guernsey respectively (near average in these locations). In contrast, some western parts of Highland Scotland recorded just over 1,000 hr—this being near or for some locations slightly below normal.

Winter 2017 (December 2016 to February 2017), summer 2017 and autumn 2017 were all characterized by a broadly west (dull)—east (bright) sunshine anomaly pattern—although sunshine totals for winter were well above average across much of northern Scotland. The UK had its dullest autumn since 2001. In contrast, the spring was sunny with most of the UK recording over 110% of the 1981–2010 average. The months of January, March, May, November and December were sunnier than average whereas February and October, which were mild months, were both dull (Figures 34 and 35).

Figures 36 and 37 show annual sunshine anomalies for the UK and countries, and seasonal sunshine anomalies for the UK, from 1929 to 2017 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.
most recent decade (2008–2017) has had for the UK on average 6% more hours of bright sunshine than the 1961–1990 average and 3% 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 10% and 14% higher than 1961–1990 respectively. Eight of the last 10 springs have had around 110% or more of the 1981–2010 average sunshine.

The sunshine network is relatively sparse, with the 2017 network comprising typically just over 110 stations (Figure A1.1). This means that some parts of the UK such as Highland Scotland and central Wales have few observations. Sunshine stations may be affected by exposure issues, particularly in the winter months when the sun is at a low elevation and topographic shading may be important. The sunshine statistics throughout are presented to the nearest whole hour, but the uncertainties of the areal statistics relating to changes in the observing network over time can approach 2%. More details can be found in Annex 2.

5 | WIND

The windiest days of 2017 are listed in Table 4. Storms are named as part of an initiative between the Met Office and Met Eireann. The naming of storms was aimed at improving the communication of approaching severe weather through the media and government agencies by using a single authoritative system. This scheme was introduced in autumn 2015 with storms named if they had the potential to cause medium or high impacts from wind on the UK and/or Ireland. The naming system was subsequently adjusted to take into
account other weather types, so storms could be named on the basis of impacts from wind but also include impacts of rain and snow. The change in convention means that the number of named storms from year-to-year should not be used as a climate index in its own right.

The last named storms of the 2016–2017 season were Doris and Ewan in late February 2017—following Angus (November 2016), Barbara and Conor (in the run up to and around Christmas 2016). Storm Doris had a relatively southerly track across Northern Ireland and northern England on 23 February; this was the most severe storm of 2017. The strongest winds were across northern England and North Wales, with gusts of 60–70 Kt (69–81 mph) in these areas. Maximum gust speeds reached 82 Kt (94 mph) at Capel Curig (Conwy), 76 Kt (87 mph) at High Bradfield (West Yorkshire), 72 Kt (83 mph) at Lake Vyrnwy (Powys), 71 Kt (82 mph) at both Valley (Anglesey) and Aberdaron (Gwynedd) and 70 Kt (81 mph) at Weybourne (Norfolk). Across much of England and Wales wind gusts reached 50–60 Kt (58–69 mph)—even across the English Midlands. In terms of the spatial extent of 50 Kt gusts this was the most significant storm across England since mid-February 2014. Doris brought widespread disruption; there were two reported deaths and numerous injuries from windblown debris and fallen trees, trees fell on properties in London and Birmingham and there was widespread structural damage. The M48 Severn bridge and Dartford crossing were closed, flights were cancelled at Heathrow, ferries were cancelled and rail services were disrupted due to fallen trees; thousands of properties experienced power cuts. Storm Ewan was named by Met Eireann and brought strong winds across Ireland, particularly to the south on 27 February, but in contrast to Doris, there were no significant impacts across the UK.

Storm Aileen on 12–13 September brought the strongest winds across southern England and Wales, particularly south Wales; a number of trees were blown over. Brian on 21 October was a fairly typical autumnal Atlantic storm—again with the strongest winds across England and Wales, and large waves affected exposed coastlines. Caroline was a deepening area of low pressure to the north of Scotland, the Western and Northern Isles bore the brunt of this storm with gusts of 81 Kt/74 Kt (93 mph/85 mph) at Fair Isle and Balsasound (Shetland) respectively. Storm Dylan brought further strong winds to the UK on New Year’s Eve. However, the most significant storm of the autumn was ex-hurricane Ophelia on 16 October—this being the 30th anniversary of the “Great Storm” of 1987. This storm had previously been the most easterly Atlantic major hurricane on record (Klotzbach et al., 1987). Ophelia moved on a northerly track...
along the west coast of Ireland before sweeping north-eastwards across Scotland. Ahead of the storm, the southerly airflow drew a combination of Saharan dust and smoke from Portuguese wildfires across southern England giving the sun an orange appearance—accompanied by some very mild temperatures with an airflow from Iberia. The strongest winds of 60–70 Kt (69–81 mph) were around Irish Sea coasts, particularly west Wales with gusts of 78 Kt (90 mph) at Capel Curig and Aberdaron. Flights to Northern Ireland were cancelled and there was significant transport disruption in the west of the UK. However, the worst impacts from Ophelia were across the Republic of Ireland where there were three fatalities from falling trees (still mostly in leaf at this time of year).

As a measure of storminess Figure 38 counts the number of days each year on which at least 20 stations recorded gusts exceeding 40/50/60 Kt (46/58/69 mph). 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. The metric will consider large-scale storm systems rather than localized convective gusts. 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.

2017 was a fairly typical year compared to the most recent decade and does not stand out in terms of the 40, 50 or 60 Kt metrics; in fact there were no days where 60 Kt (69 mph) or more was recorded by at least 10 stations in the network, although both storms Doris and Ophelia came close. There were many windier years than 2017, particularly in the 1980s and 1990s. Note that the 40 Kt counts as shown in Figure 35 broadly track the positive phase of the winter NAO as shown in Figure 2. This earlier period also included among the most severe storms experienced in the UK in the observational records including the “Burns’ Day Storm” of January 25, 1990, the “Boxing Day Storm” of December 26, 1998 and the “Great Storm” of October 16, 1987. None of the individual storms of 2017 compared with these for severity over the UK. 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.
6 | SEA LEVEL

A UK sea level index (Figure 39) for the period since 1901 provides a best estimate trend of 1.4 ± 0.2 mm/year for sea level rise, corrected for land movement (Woodworth et al., 2009). This is close to the estimate of 1.7 ± 0.2 mm/year 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. A number of large scale atmospheric and ocean processes contribute to non-uniform sea level rise around the coast of the UK. The UK sea level index for 2017 was close to the long-term trend, as was also the case in 2016.

Figure 40 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 hr in any given year. Any periods of high tides and storm surges in the year are likely to be in the 88 hr 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 water level at Newlyn for year 2017 was close to the long-term trend, with year 2014 highest in the series. In contrast, the highest maximum water level during 2017 was the lowest since 1991; this is likely to have been because no major storm surges coincided with a high tide at this site in 2017. The long term trends in 99 percentile level and highest maximum water levels are both 2.0 mm/year for the period 1916–2017, slightly greater than for the UK overall.

7 | EXTREMES FOR YEAR 2017

Table 6 shows the UK weather extremes for year 2017. The highest temperature of the year, 34.5 °C at Heathrow Airport on 21st June was the UK’s highest temperature reading in June since 1976; many other stations recorded their highest June temperature since the heat-wave of 1976. The UK’s highest minimum temperature of the year also occurred during this heat-wave event. The lowest maximum, minimum and grass minimum temperatures followed the 10 December snow event (during which the greatest snow depth was also recorded); lowest temperatures tend to occur during a period of clear skies, light winds and lying snow cover. The highest rainfall total on 24 December was as a result of significant orographic
enhancement of rainfall in a moist south-westerly flow, however, totals of over 100 mm were confined to the highest fells of the western Lake District. The highest gust speed at a low-level station occurred during storm Doris on 23 February. Overall, the various UK annual weather extremes presented in Table 6 are fairly typical for the UK.

### Table 6

| Extreme                                      | Observation | Date       | Station                                      |
|----------------------------------------------|-------------|------------|----------------------------------------------|
| Highest daily maximum temperature (0900–0900 GMT) | 34.5 °C     | 21 June    | Heathrow, Greater London 25 masl              |
| Lowest daily minimum temperature (0900–0900 GMT) | -13.0 °C    | 11 December| Dalwhinnie, Inverness-shire 351 masl         |
| Lowest daily maximum temperature (0900–0900 GMT) | -4.5 °C     | 10 December| Dawyck Botanic Garden, Borders 183 masl      |
| Highest daily minimum temperature (0900–0900 GMT) | 20.0 °C     | 19 June    | Ventnor Park, Isle of Wight 60 masl          |
| Lowest grass minimum temperature (0900–0900 GMT) | -17.9 °C    | 12 December| Velindre, Powys 152 masl                      |
| Highest daily rainfall (0900–0900 GMT)         | 212.6 mm    | 24 December| Ennerdale, Black Sali, Cumbria 300 masl      |
| Greatest snow depth (0900 GMT)                 | 40 cm       | 11 December| Llanarmon Dyffryn Ceiriog, Wrexham 265 masl  |
| Highest daily sunshine                         | 16.2 hr     | 17 June    | Whitby, North Yorkshire 41 masl              |
|                                               |             | 18 June    | Hastings, East Sussex 45 masl                |
|                                               |             | 18 June    | Morecambe, Lancashire 7 masl                 |
| Highest gust speed                             | 82 Kt 94 mph| 23 February| Capel Curig, Conwy 216 masl                  |
| Highest gust speed (mountain)                  | 119 Kt 137 mph| 23 December| Cairngorm Summit, Inverness-shire 1,237 masl|

Stations above 500 masl are considered as mountain stations and therefore not representative of low-level areas. Channel Island values are also quoted if these exceed UK values.

8 | **SIGNIFICANT WEATHER EVENTS OF 2017**

This section describes notable weather events which occurred during 2017. The choice of event is determined by the National Climate Information Centre based on our experience of monitoring the UK’s climate through the year, broadly taking into account a combination of spatial extent, severity and duration and any associated impacts. It does not represent a comprehensive list of all impactful weather affecting the UK during the year. A discussion of notable and named storms for 2017 is also included in the wind section of this report.

8.1 | **Unseasonably wet and windy weather, early June**

An area of low pressure brought some very wet and windy weather in early June, with significant weather impacts (Figure 41). Upland areas of Wales, Cumbria, the North York...
Moors and northern and eastern Scotland and Northern Isles received over 50 mm of rain, with some locations near Edinburgh, Moray, Caithness and Orkney approaching 100 mm, around the whole-month long-term average (Figure 42). The rain was accompanied by some very strong winds, with gusts of 40–50 Kt (46–68 mph) around the coast of England and Wales and gusts exceeding 50 Kt in some parts of south-west England. Even many inland locations recorded gusts exceeding 40 Kt, for example 43 Kt (49 mph) at Heathrow and Northolt (Greater London) (Figure 43).

This storm resulted in several fatalities; on the 6th three men died in Plymouth when their van overturned, and there were two deaths due to trees falling on cars, one in Hampshire and the other in Perthshire. Fallen trees were reported across a wide area, bringing down overhead power lines, while floods also blocked some major roads. Localized flooding also affected eastern Scotland, including Edinburgh’s trams and the Inverness to Aberdeen rail line.

Although this system brought some unseasonably bad weather, there have been several other recent examples of similar storms in early June, examples including June 1–2, 2015 and June 7–8, 2012.

8.2 June heat-wave

The UK experienced a spell of hot, sunny weather in June 2017 associated with high pressure drawing warm air from the near-continent. From 17 to 21 June temperatures exceeded 28 °C widely across parts of England, with some locations reaching 30–32 °C. On 21 June Heathrow (Greater London) recorded 34.5 °C, the UK’s highest June temperature since 1976. While many enjoyed the fine, sunny weather, the heat resulted in some speed restrictions on rail lines to avoid buckling, and there was an increased risk of high air pollution to areas such as the East Midlands. There were also several accidents associated with swimming. The hot weather also led to increased vulnerability from heat stress particularly to the elderly and frail.

The panel of maps shows the extent and duration of hot weather across England (Figure 44). Initially the hottest areas were across eastern England, with the heat becoming more widespread by 19 June and peaking at over 32 °C across central southern England on 21 June. The hottest locations were to the west of London but 30 °C was also recorded in Devon and west Wales.

Summer temperatures usually peak in July or August and this was not a particularly hot spell in the context of summer overall—comparable or higher temperatures were recorded in September 2016 and July 2015, for example. However, it is relatively unusual to have spells of weather as hot as this in June; on the 21st many stations across central southern England recorded their warmest June day since 1976.

Figure 45 provides a count of the number of station-days in June of each year from 1959 to 2017 for the UK overall,
where the daily maximum/minimum temperature exceeded 28 °C/16 °C. This hot spell was broadly comparable with June heat-waves in June 2005, 2000 and 1995, but by far the most significant heat-wave in this series was from June 25–30, 1976. 32 °C was recorded very widely across southern England from June 26–28, 1976, with 35.6 °C at Southampton, Mayflower Park on June 28, 1976 the equal-highest June temperature on record for the UK. The June 1976 heat-wave coincided with the major 1975/1976 drought, with these high temperatures likely to have been significantly influenced by dry ground conditions.

8.3 | July flash-flooding at Coverack, Cornwall

Warm and very humid air pushing up from the south resulted in severe thunderstorms developing across southern England during the afternoon of July 18, 2017 and overnight into the 19th. These resulted in some localized intense downpours with large hail, frequent lightning and flash-flooding with rainfall totals in places exceeded 30 mm/hr. The worst of the thunderstorms affected parts of south-west England during the afternoon of 18 July with further storms affecting areas further east across southern coastal counties and East Anglia overnight and into 19 July.

The worst affected location was the village of Coverack on the eastern side of the Lizard peninsula, Cornwall, where flash flooding damaged about 50 properties and roads became impassable. Across the far east of the Lizard peninsula, rainfall rates exceeded 30 mm/hr for around 2.5 hr from 1400 to 1630 UTC (Figure 46). Fortunately most of the rainfall occurred just offshore with only the eastern fringe of coastline affected; it is probable that the interaction between the topography of the Lizard peninsula and the southerly airflow influenced the relatively stationary nature of the storm in this highly localized location for such a sustained period.

A manual rain-gauge located at St Keverne (around 3 km north of Coverack) recorded 105 mm, which would have
fallen within less than 3 hr, approximately 150% of the whole-month long-term average rainfall in this area, while an unofficial estimate of rainfall at Coverack itself (based on a builder’s bucket) was 170 mm (for more details see https://www.coverack.org.uk/pages/Flood_Archive.html). The precipitation included large hail which affects the reliability of rain-radar accumulations. An estimated radar-based accumulation over land for the Coverack storm, taking into account an adjustment for this hail, was 170–200 mm in the vicinity of Coverack and 200–220 mm just offshore to the east (Met Office radar products team, observations R&D). The highly localized nature of this event meant that in contrast, locations a few kilometre to the west, such as Culdrose, recorded no rainfall.

Previous examples of serious flash-flooding across the south-west have included Boscastle in August 2004 and Lynmouth in August 1952. Most of the rain from the Coverack event fell over the sea, where the totals were broadly comparable to the Boscastle event (which was also highly localized in nature). In this context, although the impacts were severe for the village, the Coverack storm could perhaps be regarded as a “near miss.”

8.4 | Widespread snow 10 December

A low pressure system pushing into cold air during 10 December caused significant falls of snow across Wales and central England, making this at the time the most significant snow event in terms of depths and extent across Wales and lowland England since March 2013 (Figure 47). Snow depths across central England and Wales widely exceeded 10 cm, with depths of 25–40 cm at five stations across Wales, Shropshire and the West Midlands (Figure 48). Much of this snow lay largely unmelted until 13 December (Figure 49).

The snow brought widespread travel disruption to air, road and rail transport. Hundreds of schools were closed on Monday 11th across England and Wales, and power cuts affected several thousand homes. Treacherous driving conditions led to a number of accidents. A cross-channel ferry ran aground at Calais due to strong winds in the English Channel.

CORRECTIONS TO 2016 REPORT

The temperature network map for 2016 (Figure A1.1) showed 393 stations, this should have been 435 stations.
The snow network map for 2016 (Figure A1.1) showed 184 stations, this should have been 218 stations.

ACKNOWLEDGEMENTS
This work was supported by the Met Office Hadley Centre Climate Programme funded by BEIS and Defra. Thanks to John Kennedy (Met Office) for providing UK near-coast SST data, and Adam Scaife (Met Office) for NAO index data. Thanks to four reviewers: Peter Bissolli (DWD), Ian Jolliffe (University of Exeter), Gerard van der Schrier (KNMI) and Robert Wilby (Loughborough University) for providing helpful comments and feedback.

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FEEDBACK
We would welcome suggestions or recommendations for future publications of this report. Please send any feedback to the Met Office at ncic@metoffice.gov.uk
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How to cite this article: Kendon M, McCarthy M, Jevrejeva S, Matthews A, Legg T. State of the UK climate 2017. *Int J Climatol*. 2018;38 (Suppl. 2):1–35.  
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ANNEX 1: DATASETS

**NAO index**

The Met Office Hadley Centre’s sea level pressure dataset, HadSLP2 is a global dataset of monthly mean sea level pressure on a 5 degree latitude–longitude grid from 1850 to date (Allan and Ansell, 2006). The dataset is derived from a combination of marine observations from ICOADS (International Comprehensive Ocean-Atmosphere Data Set) and land (terrestrial and island) observations from over 2,000 stations around the globe. The NAO index was calculated from HadSLP2 as the difference in seasonal mean sea level pressure between grid-point pairs for each year from 1870 to 2017 inclusive. For winter, these grid-point pairs were 40N, 25W and 65N, 25W—corresponding to the pressure difference between the Azores and Iceland (Scaife et al., 2014). For summer the grid-point pairs were 60N, 5E and 80N, 50W—corresponding to locations to the east of the Shetland Islands and in north-west Greenland. The summer NAO (SNAO) grid-points therefore reflect a smaller spatial scale and a more northerly location of the Atlantic storm track (Folland et al., 2009). Winter is defined as December, January and February and summer as June, July and August to provide consistency with seasonal statistics presented
elsewhere in the report. Note this SNAO definition differs from Folland et al., 2009 which uses July and August only.

### Monthly and annual 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 2017 UK station network for the variables presented in this report.

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 maximizing the number of observations used. A description of the gridding process is also given in Jenkins et al. (2008) and Prior and Perry (2014).

The number of observations is indicative as these may vary on a daily basis due to data availability. See also corrections to 2016 report.

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### Table A1.1

| 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 | 1960                 | Annual              |
| Cooling degree days    | Day-by-day sum of number of degrees by which the mean temperature is more than 22 °C | 1960                 | Annual              |
| Growing degree days    | Day-by-day sum of number of degrees by which the mean temperature is more than 5.5 °C | 1960                 | Annual              |
| Precipitation          | Total monthly precipitation amount (mm)                                    | 1910                 | Monthly             |
| Days of rain ≥1 mm     | Number of days with ≥1 mm precipitation                                   | 1961                 | Monthly             |
| Days of rain ≥10 mm    | Number of days with ≥10 mm precipitation                                   | 1961                 | Monthly             |
| Rainfall intensitya    | Total precipitation on days with ≥1 mm divided by the count of days with ≥1 mm 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 5 km daily precipitation grids which are generated separately to monthly precipitation.

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### Table A1.2

| Climate variable          | Before 1961 | 1961 onwards |
|---------------------------|-------------|--------------|
| Air temperature (max, min, mean) | 320         | 550          |
| Days of ground frost      | n/a         | 420          |
| Precipitation             | 650         | 4,400        |
| Days of rain ≥1 mm, ≥10 mm| n/a         | 4,000        |
| Sunshine                  | 270         | 300          |

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**FIGURE A1.1** State of the UK observing network in 2017. The number of observations is indicative as these may vary on a daily basis due to data availability. See also corrections to 2016 report.
During autumn 2017 all mercury-containing observing instruments were removed from UK observing sites in the network, in accordance with the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulations as jointly enforced by the Health & Safety Executive and the Environment Agency. This implemented the UK’s commitment to the 2013 Minamata Convention on Mercury, for which the overarching objective is to “protect human health and the environment from the release of mercury and its compounds and instigate a reduction in overall mercury levels in the environment over time.” This resulted in a replacement of all maximum temperature thermometers at manual climate stations with a non-mercury alternative. Alcohol-in-glass minimum temperature thermometers were unaffected.

The replacement of maximum temperature thermometry at manual climate stations resulted in a reduction in the overall network size from September to December 2017. The greatest reduction in network size of around 100 stations occurred in October 2017, representing approximately a quarter of the full network. Replacement thermometry was in place at the majority of these stations by the end of the year. The mercury replacement resulted in data gaps in the daily maximum temperature record, typically of 1 to 2 months, at individual climate stations. Data gaps in climate records, particularly for long running stations, are undesirable. The overall impact of this temporary reduction in network size has not yet been evaluated, but parallel measurements have been undertaken at some locations to provide data to ensure that the homogeneity and integrity of the climate network can be maintained. It is unlikely to have severe implications for the large-scale area-average statistics presented in this report.

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 1 km 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. First, a 1 km resolution grid of values for each month is calculated from the available station data. Second, the gridded long-term average datasets are then obtained by averaging the monthly grids.

Because the long-term averages are calculated from 1 km grids separately to the monthly 5 km 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 1 km rather than 5 km.

Table A1.3 compares 1981–2010 long-term average annual mean temperature and rainfall as derived from 1 km long-term average, and 5 km monthly grids. For temperature, the difference of 0.04 °C for the UK overall is much smaller than of the difference of 0.5 °C between 1961–1990 and 1981–2010 1 km long-term averages. For rainfall, the difference of 2.5% is around half the difference between the 1961–1990 and 1981–2010 1 km long-term averages. For both temperature and rainfall, the difference in annual average is greatest in Scotland, which contains the largest area of mountain topography in the UK and where the 1 km resolution long-term average grid is likely to provide a greater level of detail. The difference between 1 and 5 km long-term averages varies both by season and regionally across the UK.

### TABLE A1.3

| Area          | Temperature 5 km | Temperature 1 km | Difference (degC) | Rainfall 5 km | Rainfall 1 km | Difference (%) |
|---------------|------------------|------------------|-------------------|--------------|--------------|----------------|
| UK            | 8.88             | 8.84             | 0.04              | 1,126        | 1,154        | 2.5            |
| England       | 9.68             | 9.65             | 0.03              | 842          | 855          | 1.5            |
| Wales         | 9.18             | 9.14             | 0.03              | 1,414        | 1,460        | 3.2            |
| Scotland      | 7.47             | 7.40             | 0.07              | 1,517        | 1,571        | 3.6            |
| Northern Ireland | 8.92          | 8.91             | 0.01              | 1,136        | 1,136        | 0.0            |

Daily grids and degree days

Daily $T_{\text{max}}$, $T_{\text{min}}$, and $T_{\text{mean}}$ grids of the UK at 5 km resolution from 1960 have been generated using a similar method.
TABLE A1.4  Formulae used for calculating cooling or growing degree days above thresholds of 22 and 5.5°C, equivalent formulae used for heating degree days below a threshold of 15°C

| Condition: daily $T_{\text{max}}$, $T_{\text{min}}$, $T_{\text{mean}}$ above or below $T_{\text{threshold}}$ | Degree day value |
|----------------------------------------------------------|------------------|
| $T_{\text{max}} \leq T_{\text{threshold}}$ | 0 |
| $T_{\text{min}} \geq T_{\text{threshold}}$ | $T_{\text{mean}} - T_{\text{threshold}}$ |
| $T_{\text{mean}} \geq T_{\text{threshold}}$ and $T_{\text{min}} < T_{\text{threshold}}$ | $0.5 \left( T_{\text{max}} - T_{\text{threshold}} \right) - 0.25 \left( T_{\text{threshold}} - T_{\text{min}} \right)$ |
| $T_{\text{mean}} < T_{\text{threshold}}$ and $T_{\text{max}} > T_{\text{threshold}}$ | $0.25 \left( T_{\text{max}} - T_{\text{threshold}} \right)$ |

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 $T_{\text{mean}}$ is calculated from the daily maximum temperature $T_{\text{max}}$ and the daily minimum temperature $T_{\text{min}}$ as $(T_{\text{max}} + T_{\text{min}})/2$. The degree day value is estimated differently depending on which of $T_{\text{max}}$, $T_{\text{mean}}$ or $T_{\text{min}}$ are above (for CDD and GDD) or below (for HDD) the defined degree day threshold.

The daily temperature grids from which degree day datasets are generated are based on provisional data from December 2008 onwards, principally from the network of automated stations. This means that the number of stations used for gridding and the number of manual quality control steps are reduced; although this will not significantly affect degree day metrics at country-scale.

Areal series

The monthly series for the UK and countries are calculated as area-averages derived from the 5 km monthly gridded datasets. Each monthly value is an average of all the individual 5 km grid point values which fall within the UK or country. The seasonal and annual series in turn are calculated from the monthly areal series. This approach enables a single statistic to be produced for each area (UK or country) from each grid, despite the fact that the UK’s climate has a very high degree of spatial variation (for example with elevation). These statistics are self-consistent through time. In the same way, long-term averages are calculated as an average of all the individual 1 km grid points which fall within the UK or country.

Statistics for the UK and countries are useful for monitoring annual variability, trends and extremes but inevitably may mask considerable spatial variation across the area as shown in the anomaly maps.

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 by analysing periods of overlap between stations, 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 cells adjacent to the coast of Great Britain (approximately 50 grid cells). These grid cells were selected to ensure that all the main UK landmass fell within this area (Figure A1.2).

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 et al., 1984; Alexander and Jones, 2001; Simpson and Jones, 2012).

Rain gauge and snow depth data

Daily rainfall data presented in this report are from 0900 to 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 approximately 3,000 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 has subsequently reduced to around 200 stations in 2017.

Sunshine data
The UK’s sunshine network in 2017 comprises two instrument types, just under half the network comprised Campbell-Stokes (CS) sunshine recorders which are read manually; the remainder comprising 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 2017 this network comprises 44 sites. 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 of these sites (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).

As mentioned in Woodworth et al. (2009), the network of 44 sites falls under the responsibility of the Environment Agency (although it is no longer operated by the Proudman Oceanographic Laboratory), but only five date back to the beginning of the 20th century: the other sites did not begin until the 1950s. In creating the long term index, we follow Woodworth’s approach, which only uses data from the long term series.

Woodworth et al. (2009), which is based on data from up to 2006, notes that throughout the course of the record, at least three of the five stations are present for all years apart from three, the last of which was 1915. Unfortunately, from 2007 onward, there have been more gaps in observations for the five stations. More information about reasons for the issues can be found in the UK Coastal Monitoring and Forecasting annual reports, which are available from https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/reports/

Newlyn, Cornwall has a century of hourly (or, since 1993, 15 min) 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

FIGURE A1.2 One degree grid cells from HadISST1 used to calculate UK near-coast sea-surface temperature

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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).

Climate records at individual stations may be influenced by a variety of non-climatic factors such as changes in station exposure, instrumentation and observing practices. Issues of changing instrumentation and observing practices will tend to be of greater importance early in the series, particularly before the 20th Century. In contrast, station exposure issues related to urbanisation, which may for example affect temperature-related variables, may be of greater importance in the late part of the series from the mid-20th Century. Identifying and correcting for such factors in climate monitoring is referred to as homogenisation. Some homogenisation has been undertaken for some series presented in this report, such as the Central England Temperature record, and the adjustment of sunshine records described in Annex 1. For most variables however the individual station data in this report have not been explicitly homogenized to account for these non-climatic factors.

We note that the 1961–1990 and 1981–2010 averages presented are based on 1 km 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 1 km 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, 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. These correspond to: the earliest years of each dataset where the availability of station data is generally lowest and uncertainty highest; a period in the dataset around the 1960s which for rainfall corresponds to a step increase in availability of station data and corresponding decrease in uncertainty; and a recent period in the the dataset indicating current uncertainty. More comprehensive tables covering the full date range can be found in Legg (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).

The summary rainfall statistics for the UK and countries presented in this report are based on an areal-average of the rainfall total in mm, rather than an area-average of the rainfall anomaly field. This introduces uncertainty because the rank of each year relative to the others may vary depending on which of these two metrics is chosen (Kendon and Hollis, 2014). It may also influence any trend in overall UK rainfall if this varies spatially between climatologically wetter and drier parts of the UK.

A further source of uncertainty in the rainfall data is introduced by measurement of precipitation which has fallen as snow. At manually read rain gauges the observer will measure precipitation equivalent of fresh snow fallen at 0900 GMT, whereas at automatic rain gauges 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

| Year range | UK      | England | Wales | Scotland | Northern Ireland |
|------------|---------|---------|-------|----------|-----------------|
| Temperature (°C) |        |         |       |          |                 |
| 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 (%) |        |         |       |          |                 |
| 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 (%) |        |         |       |          |                 |
| 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             |
situations estimation of precipitation from snow may be either underestimated or overestimated. However, this now tends to be usually less of a problem than during cooler, snowier years of earlier decades.

**Coefficient of determination**

The coefficient of determination, $R^2$, is the square of the correlation coefficient, $r$, between an independent and a dependent variable based on linear least-squares regression. The $R^2$ value is a statistical measure of how closely the dependent variable can be predicted from the independent variable. An $R^2$ value of 1 would indicate a perfect correlation, in which the dependent variable can be predicted without error from the independent variable. An $R^2$ value of 0 would mean the dependent variable cannot be predicted from the independent variable. An $R^2$ value of 0.5 would mean that half of the variance in the dependent variable is predictable from the independent variable. For example, in this report $R^2$ values which exceed 0.9 would indicate time-series are very highly correlated.

**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 5 km monthly, annual, and daily temperature data-sets 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
  https://www.ncdc.noaa.gov/bams
- Annual Bulletin on the Climate in region VI Europe and Middle East
  https://www.dwd.de/EN/ourservices/ravibulletinjahr/ravibulletinjahr.html
- 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
- National Tidal and Sea Level Facility UK National Tide Gauge Network (owned and operated by the Environment Agency)
  http://www.ntslf.org/data/uk-network-real-time
- Natural Resources Wales Water Situation Reports for Wales
  https://naturalresources.wales/guidance-and-advice/environmental-topics/water-management-and-quality/resources/water-situation-report-2017/?lang=en
- Scottish Avalanche Information Service annual reports of the winter season
  http://www.sais.gov.uk/sais-annual-reports/