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State of the UK Climate in 2024

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The Royal Meteorological Society Journal of Climate Science

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- Projections of the future state of the climate system
- Interplay between climate variability and change
- Implications of regional studies for the greater knowledge of the climate system
- Relationships from larger and longer climate scales to localised scales

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Left: Sledging by local children in Exeter on the morning of Thursday 21 November 2024 – a rare opportunity not to be missed! There was significant disruption and many schools were closed. The UK had its most significant November snow since 2010. Image: Mike Kendon, Met Office.

Right: The rain gauge at Oxford Radcliffe Observatory. From 22 to 23 September 2024, this recorded a two-day total of 118.9mm, the wettest 2-day period at this weather station in a near 200-year daily record from 1827, exceeding the previous record by a margin of over 20%. Image: Alice Jardine, University of Oxford.

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SPECIAL ISSUE ARTICLE OPEN ACCESS

State of the UK Climate in 2024

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"Metric Units. – The Meteorological Office, under the direction of Sir Napier Shaw, has introduced a new system of units for the official records of British Meteorology based on absolute measures and the metric system. … I should not have felt justified this year undertaking the expense of converting over 5000 values from inches to millimetres (an operation which had to be done twice over to ensure accuracy), and of altering the format of the volume by widening the page to admit the additional column; but on explaining the position to Sir Napier Shaw I had the satisfaction of finding that the Meteorological Office was prepared to assist by bearing the cost of the change, which amounted to £30."

Commentary on the change to metric units introduced in the Met Office over a century ago, by Hugh Robert Mill, director of the British Rainfall Organization, British Rainfall 1914 (British Rainfall Organization 1915)

Introduction

This report provides a summary of the state of the UK's climate in 2024. It is one of a series of annual reports published in the *International Journal of Climatology* (IJC) since 2017. It provides the latest assessment of UK climate trends, variations and extremes based on the most up to date observations, and shows what has already happened to our climate.

The majority of observations presented are from the UK's network of weather stations, managed by both the Met Office and a number of key partners and co-operating volunteers. These observations represent 'ground truth'. They conform to current best-practice observational standards as defined by the World Meteorological Organization (WMO). They also pass through a range of quality assurance procedures at the Met Office before application for climate monitoring. The report also includes time series of near-coast sea-surface temperature and sea-level, and a short section on phenology.

This report and the UK's climate monitoring capability would not be possible without these observations, emphasizing the vital importance of maintaining observation networks, particularly the UK's land weather station network, into the future as our climate changes. Observations cannot be made retrospectively. The UK's extensive observational records back to the 19th Century provide evidence that scientists from previous generations clearly recognised the importance of maintaining this capability.

National, regional and county statistics are from the HadUK-Grid dataset which is the principal data source (Hollis et al. 2019). Monthly temperature and rainfall series from the HadUK-Grid dataset extend back to 1884 and 1836 respectively. Daily temperature has been extended back to 1931 (formerly 1960) in the latest version. The appendices provide details of the datasets used and how the series presented are derived.

This report presents summary statistics for the most recent year (2024) and decade (2015–2024). In comparison with previous reports, we have placed less emphasis on the most recent year and more on the most recent decade, representing a 10-year 'snapshot' of the UK's current climate from a climate change perspective. This period's relatively short length means that statistics for the latest decade may reflect shorter-term decadal variations as well as longer term trends. Even so, our climate is changing sufficiently fast that the climate of 2024 may be considered different to that of 2015, and this 10-year 'snapshot' is a compromise between these two competing factors. When considering the variability in the UK's climate, it is perhaps helpful to consider the observational series presented in this report as one realization of an ensemble of possible outcomes which, taken together, represent the UK's climate overall. While documenting the year 2024 is still important, this variability means that any individual year is less informative for providing overall climate change context.

We compare the most recent year and decade against the 30-year standard climate averaging period 1991–2020 and the baseline period 1961–1990, following World Meteorological Organization climatological best practice (WMO 2017). 1961–1990 is widely used for historical comparison, climate change monitoring, and climate modelling. We also include in several places statistics for 1931–1960 (for temperature, temperature indices, e.g., days of air frost and sunshine) and 1901–1930 and 1931–1960 (for rainfall), to better encompass the UK's climate of the 20th Century. The full series provides longer-term context, while a comparison is also made to centennial averages for the Central England Temperature (CET) series from 1659.

Throughout the report's text the term 'above/below average' refers to the 1991–2020 reference period unless otherwise stated. 'Average' can sometimes be used synonymously with 'normal', for example, by the WMO—although for temperature and rainfall recent observations suggest this period can no longer be considered as 'normal' for the UK's current climate, and indeed it may be argued that the whole concept of 'average' or 'normal' is awkward in a non-stationary climate.

Perhaps the greatest implication of the UK's changing climate is how this affects extremes. Monitoring changes in averages alone (e.g., annual mean temperature or rainfall) does not provide a complete picture of the state of the UK's climate. This report includes new analyses of daily temperature and monthly rainfall extremes, but a challenge of a summary report such as this, which aims to cover all main climate variables, is that it must be relatively brief, so these sections still present only summary statistics. The HadUK-Grid dataset is freely available for others to carry out more detailed analyses; the appendices provide details.

Maps of actual values of climate variables tend to be dominated by the underlying climatology, which is strongly influenced by elevation and distance from the coast. For this report, this is of a lesser interest than the year-to-year variability. The majority of maps are therefore anomaly maps for the year 2024 which show the spatial variation in difference from average.

The report does not cover climate model projections into the future, apart from a single figure showing projected change in annual mean temperature to 2100 from UK Climate Projections (UKCP) for future context.

Notes and Definitions

Seasons and half-years: The four meteorological seasons are defined as DJF, MAM, JJA, SON. Winter and summer half-years are defined as ONDJFM and AMJJAS. Winter 2024 is defined as December 2023 to February 2024; the 2024 winter half-year is defined as October 2023 to March 2024, and so forth.

Rounding: Values quoted in tables throughout this report are rounded, but any differences between two such values are calculated from the original unrounded values. The precision of values quoted (number of decimal places) depends on the variable and period.

Corrections to State of UK Climate 2023

The following minor numerical errors are noted.

In the table below Figure 32, the CET anomaly for 1991–2020 relative to 1961–1990 of 0.76°C was incorrect. This should be 0.81°C.

In Table 13, 'the windiest days of year 2023', the network size in brackets for Wales (11) and Northern Ireland (17) were incorrect. These should be Wales (17) and Northern Ireland (11).

Feedback

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

This State of the UK Climate report was supported by the Met Office Hadley Centre Climate Programme funded by DSIT.

Executive Summary

Observations show the UK's climate continuing to change. Recent decades have been warmer, wetter and sunnier than the 20th Century. The UK's warming is at a rate consistent with the observed change in global near-surface air temperature over land.

Temperature

The UK's climate has warmed steadily from the 1980s onwards. The greatest implications are for the frequency and intensity of daily temperature extremes.

- The last 3 years have been in the UK's top-five warmest on record. 2024 was the fourth warmest year in the series from 1884.
- Since the 1980s, the UK has been warming at a rate of approximately 0.25°C per decade. The most recent decade 2015–2024 has been 0.41°C warmer than 1991–2020 and 1.24°C warmer than 1961–1990.

- The Central England Temperature series shows that recent warmth has far exceeded any observed temperatures in at least 300 years.
- 2024 included the UK's second warmest February, warmest May, fifth warmest December, fifth warmest winter and warmest spring on record. Statistics like this are typical of recent years in the UK's climate records.
- The number of days with temperature anomalies exceeding the 1961–1990 average by 5°C has doubled for the most recent decade 2015–2024 compared to 1961–1990. For 8°C, it has trebled, and for 10°C, it has quadrupled.
- When comparing the most recent decade 2015–2024 to 1961–1990, the hottest summer days and coldest winter nights have warmed around twice as much as average summer days and winter nights for some parts of the UK.

Air and ground frost

Air and ground frosts have steadily declined from the 1980s onwards, reducing by around a quarter.

- The most recent decade 2015–2024 has had almost a week fewer air frosts per year than the 1991–2020 average and over a fortnight fewer than 1961–1990 and 1931–1960.
- The most recent decade 2015–2024 has had 1½ weeks fewer ground frosts per year than the 1991–2020 average and 4 weeks fewer than 1961–1990.
- In 2024, days of air frost were the second lowest in the UK series from 1931. Days of ground frost were the lowest in the UK series from 1961.

Indices for energy demand (heating and cooling) and plant growth

Heating degree days have steadily reduced from the 1980s onwards, and growing degree days have steadily increased. Cooling degree days are more variable, but these too have increased from a low in the 1960s.

- The most recent decade 2015–2024 has had 5% fewer heating degree days than 1991–2020, 14% fewer than 1961–1990 and 13% fewer than 1931–1960.
- The most recent decade 2015–2024 has had 6% more growing degree days than 1991–2020, 21% more than 1961–1990, and 18% more than 1931–1960.
- Cooling degree days have approximately doubled for the most recent decade 2015–2024 compared to 1931–1960 and 1961–1990.
- In 2024, heating degree days were fourth lowest, and growing degree days fifth highest, in the UK series from 1931.

Near-coast sea-surface temperature (SST)

UK near coastal waters have warmed steadily from the 1980s onwards at a rate slightly lower than the warming rate over UK land.

- The most recent decade (2015–2024) has been on average 0.3°C warmer than the 1991–2020 average and 0.9°C warmer than 1961–1990 for UK near-coast SST.
- Five of the 10 warmest years for UK near-coast SST have occurred in the most recent decade 2015–2024, with 2024 ranked sixth warmest.

Rainfall

The UK's climate has become steadily wetter since the 1980s, due to an increase in winter 'half-year' rainfall.

- The most recent decade 2015–2024 has been 2% wetter than 1991–2020 and 10% wetter than 1961–1990.
- Winter half-year (October to March) rainfall for the most recent decade 2015–2024 has been 6% wetter than 1991–2020 and 16% wetter than 1961–1990, compared to little change for the summer half-year.
- In the 250+ year England and Wales precipitation series, six of the 10 wettest winter half-years have occurred in the 21st Century so far, with October 2023 to March 2024 the wettest winter half-year on record.
- 2024 was the UK's 13th wettest year in the series from 1836 and included the sixth wettest winter (December to February) and sixth wettest spring.
- For the most recent decade 2015–2024, the number of county-months recording monthly rainfall totals of at least twice the 1991–2020 monthly average has increased by over 50% compared to 1961–1990.
- Observations suggest a slight increase in heavy rainfall across the UK in recent decades, although more digitization of daily rainfall before 1961 is needed.

Snow

The number and severity of snow events in the UK have declined since the 1960s.

- Widespread and substantial snow events have occurred in 2009, 2010, 2013, 2018 and 2021, but overall they are less frequent or severe than they were in the 1960s, 1970s or 1980s.
- From 19 to 23 November 2024, the UK had its most notable November snow event since 2010.

Sunshine

The UK's climate has become sunnier since the 1980s, primarily driven by increases in winter and spring sunshine.

- The most recent decade 2015–2024 has been 3% sunnier than 1991–2020 and 8% sunnier than 1961–1990.
- For the most recent decade 2015–2024, UK winters have been 4% sunnier than 1991–2020 and 14% sunnier than 1961–1990. UK springs have been 6%/15% sunnier.

- 2024 was UK's dullest year since 1998 with only 91% of the 1991–2020 average sunshine hours, bucking the increasing sunshine trend.

Wind

Observations do not currently suggest that the UK's climate is becoming windier or stormier.

- The UK annual mean wind speed from 1969 to 2024 shows a downward trend, consistent with that observed globally.
- There have been fewer occurrences of maximum gust speeds exceeding 40/50/60 Kt in the last two decades compared to the 1980s and 1990s.
- Nine named storms hit the UK in the calendar year 2024. Red warnings were issued for *Isha* in January and *Darragh* in December.

Extremes and significant weather

Observations show that extreme weather events are to be expected each year as an integral part of the UK's climate. As has been fairly typical in recent years, floods and storms brought the worst impacts in 2024.

- Within the most recent decade 2015–2024, the UK has recorded its all-time highest maximum temperature, at any station, in five of the 12 months of the year: January 2024 (19.9°C), February 2019 (21.2°C), July 2022 (40.3°C), November 2015 (22.4°C) and December 2019 (18.7°C).
- The six-month period October 2023 to March 2024 widely saw over 150% of the 1991–2020 average rainfall, resulting in widespread flooding with significant impacts on several occasions.
- Locally extreme rainfall in late-September 2024 resulted in the Oxford Radcliffe Observatory recording its wettest 2-day period in a near 200-year daily record and wettest calendar month for 250 years.
- Parts of South Wales experienced severe flooding from storm *Bert* in late November 2024, with 100 to 150 mm or more of rain falling across high ground.
- The prolonged duration and unusual north-westerly to northerly direction of the strongest winds from storm *Darragh* in December 2024 are likely to have contributed to the severity of wind impacts, including large mature trees brought down by the wind in the worst affected areas.

Sea-level rise

Sea level rise around the UK is accelerating.

- Since 1901, the sea level around the UK has risen by about 19.5 cm, with two-thirds of this rise happening in just over the last three decades.
- The last 3 years were the three highest on record for UK annual mean sea level in a series from 1901, with the 21st Century so far (2001–2024) including the 17 highest years.
- Over the past 32 years (1993–2024) UK sea level has risen by 13.4 cm. This is higher than the global estimate of 10.6 cm calculated from satellite altimetry over the same period, suggesting that UK sea level is rising faster than the global average. However, there are large uncertainties in estimates of sea level rise around the UK.
- The most extreme sea levels in 2024 were associated with Storm *Kathleen/Pierrick*, which coincided with spring tides and was influenced by high background mean sea levels.
- In 2024, the Thames Barrier had 11 operational flood defence closures, seven of which were on spring high tides and unrelated to named storm events.

Phenology

Earlier springs are likely to be one of the most obvious responses of Nature to the changing climate. However, such responses can be complex, and short observational records can make detecting trends difficult.

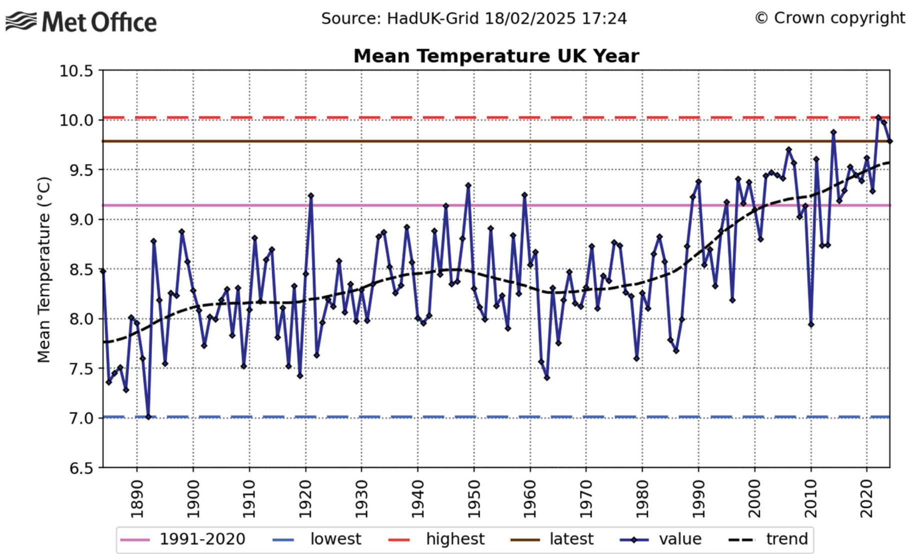
- Indicators for spring 2024 were mostly earlier compared to the 1999–2023 baseline due to the very warm February.
- Bare tree dates were a few days earlier than the 1999–2023 baseline due to a slightly cooler than average summer and early autumn.
- Overall, the 2024 leaf-on season and the 2024 lawn cutting season were longer than the 1999–2023 baseline, mainly due to the earlier spring.

1 | Temperature

1.1 | Annual, Seasonal and Monthly Temperature

2024 was the fourth warmest year on record for the UK in the series from 1884, with an annual mean temperature of 9.79°C, 0.65°C above the 1991–2020 average (Figure 1). Anomalies were slightly higher across England and Wales than Scotland and Northern Ireland (Figure 2a). The year was ranked equal-warmest on record (with 2023) for UK average minimum temperatures (T_{min}), but only eighth warmest for average maximum temperatures (T_{max}). England had its warmest year on record for average minimum temperatures, as did many counties in the eastern half of the country (Figure 2b).

Eight of the 12 months of the year were warmer than average, including the UK's second warmest February, warmest May and fifth warmest December, all with anomalies of 2.0°C or more above the 1991–2020 average (Table 1). May and December in particular saw prolonged spells of above average daily minimum temperatures (Figure 3) and the UK recorded its warmest May for average minimum temperatures by 1.2°C—a very wide margin (Figure 4). Largely as a result of this, the UK had its warmest spring on record in the series from 1884, and the fifth warmest winter. Statistics like this are typical of recent years in the UK's climate records; every year since 2020 has had at least one top-ten warmest season. In contrast, temperatures were generally fairly suppressed during the summer months (Table 1, Figure 3) with the UK having its coldest summer since 2015. There were



	1931-1960	1961-1990	1991-2020	2015-2024	2024
UK	8.48	8.31	9.14	9.55	9.79
England	9.17	9.04	9.96	10.45	10.73
Wales	8.80	8.60	9.41	9.85	9.99
Scotland	7.21	6.99	7.69	7.99	8.19
Northern Ireland	8.67	8.44	9.13	9.46	9.66

FIGURE 1 | Annual mean temperature for the UK, 1884 to 2024. The table shows actual values for the UK and countries (°C). While the series extends back to 1884, averages are shown back to 1931–1960 since network coverage before this reduces (see Figure A1). Charts for individual months and seasons are available at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-temperature-rainfall-and-sunshine-time-series.

no months in 2024 for countries of the UK falling in the coldest third of their respective series. Again, this is a typical characteristic of recent years. UK mean maximum and minimum temperatures for each calendar day of 2024 approached the high extremes of their historical range on a number of occasions through the year, compared to very few days approaching the low extremes (red and blue lines in Figure 3).

Further details for each month of the year and each day of the month are provided within the Met Office Monthly Climate Summaries and Daily Weather Summaries available from the Met Office Digital Library and Archive.

The UK's climate is on a clear upward trajectory with continuous warming from the 1980s onward at a rate of approximately 0.25°C per decade (1°C in 40 years). The last 3 years have been within the top five warmest in the series and all top 10 warmest years have occurred in the 21st Century (Figure 1). For the UK overall, average maximum temperatures have warmed slightly more than average minimum temperatures (Figure 5).

Table 2 shows seasonal and annual T_{mean}, T_{max}, and T_{min} anomaly values for the UK and countries for the most recent decade 2015–2024 against both 1961–1990 and 1991–2020. For the UK overall for T_{mean}, the most recent decade 2015–2024 has been 0.41°C warmer than 1991–2020 and 1.24°C warmer than 1961–1990, with more warming across England and Wales than Scotland and Northern Ireland. When comparing 2015–2024 against 1961–1990, the greatest warming has been for T_{max} across England in winter and spring by 1.8°C. These statistics will reflect some annual and decadal variability in the UK's climate in addition to the ongoing warming due to climate change.

This report provides an overview of climate change that has *already* been observed in the UK, and its scope does not extend to future projections. However, Figure 6 provides future context for the UK annual mean temperature series from 1884 to 2024 alongside UK climate projections (UKCP) from 1961 to 2100. These are probabilistic projections of the latest set of national climate projections for the UK under different scenarios RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 representing a range of possible outcomes (Murphy et al. 2018; Harris et al. 2022). The green line and grey shading shows the RCP 4.5 intermediate pathway scenario and how T_{mean} would be projected to evolve through the 21st Century based on this scenario. The spread accounts for both annual variability in UK climate and uncertainty in the magnitude of future change.

Thus far, the observed upward trajectory of observed UK annual mean temperature is consistent with projections, with the clear potential for the UK's climate to be pushed well outside the envelope of the current and historical range. Under the RCP 4.5 scenario, years 2022, 2023, and 2024 would likely be considered average by the 2050s and cool by around 2100.

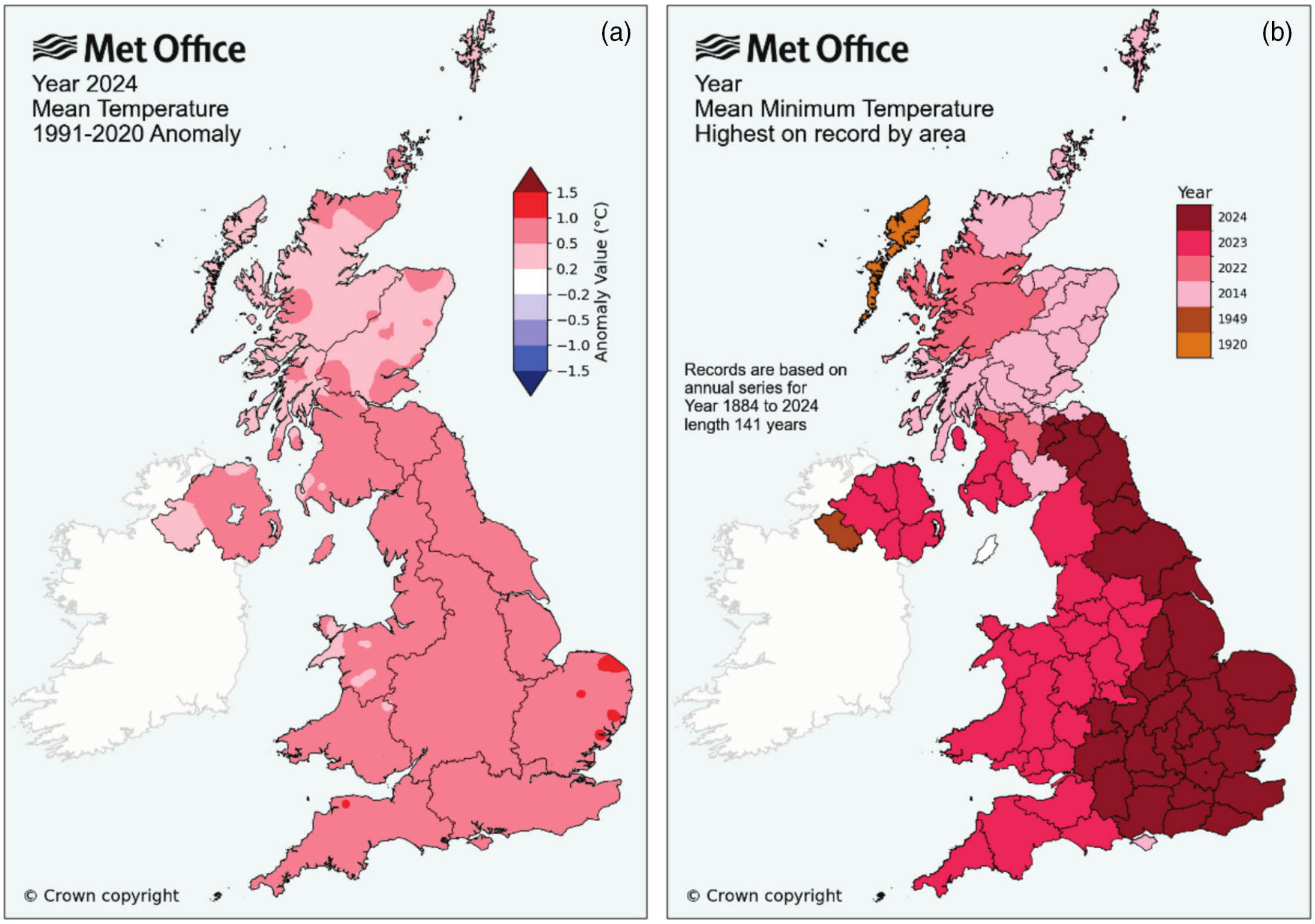


FIGURE 2 | (a) Mean temperature anomaly relative to 1991–2020 for year 2024. Maps for individual months and seasons are available at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-actual-and-anomaly-maps. (b) The warmest year on record for mean minimum temperature for county areas of the UK, based on county series from 1884 to 2024. Appendix A: Areal Series describes these county areas.

Figure 7 plots annual T_{mean} for the UK from 1884 to 2024 from HadUK-Grid alongside global mean surface temperature (near-surface air temperature over land and sea surface temperature) based on the 'best estimate' time-series from the HadCRUT5 dataset (Morice et al. 2021) and the global land surface only from the CRUTEM5 dataset (Osborn et al. 2021). All three series are plotted as anomalies relative to the baseline reference period 1961–1990. Globally, 2024 was the warmest year on record in the HadCRUT data series from 1850 and the first year that was likely more than 1.5°C above the pre-industrial average (1850–1900). 2023 was previously the warmest year on record and the last eleven years have all equalled or exceeded 1.0°C above the 1850–1900 average.

Globally, warming is greater across high latitudes compared to the equator, and over land compared to the ocean (IPCC 2021; Blunden and Boyer 2022). The most recent decade 2015–2024 has been 1.24°C warmer than 1961–1990 for the UK, compared to 0.90°C for global mean surface temperature and 1.23°C for global land only. The annual variability in UK T_{mean} is very much larger than in HadCRUT5 and CRUTEM5 because the UK covers only a small fraction (approximately 1/2000) of the Earth's surface. Overall, the warming observed for the UK is slightly greater than that observed globally over land and ocean combined, but is comparable with observed warming globally over land only. It is worth noting that the choice of 1961–1990 as the baseline will also affect this comparison.

1.2 | Central England Temperature

The monthly Central England Temperature (CET) series is the world's longest continuous instrumental temperature record, providing long-term context for recent changes in the UK's climate based on over 350 years of observations. Figure 8 compares the annual T_{mean} CET series from 1659 to 2024 with the HadUK-Grid England series from 1884 to 2024. 2024 was the fourth warmest year in the CET series, with the last 3 years within the top five warmest. It was the warmest year on record in the CET T_{min} series from 1878, but only 12th warmest in the CET T_{max} series.

The CET series provides evidence that the 21st Century so far has overall been warmer than any period of equivalent length within the previous three centuries; 2001 to 2024 has been 1.0°C warmer than 1901–2000 and 1.3°C warmer than 1801–1900 and 1701–1800 (Table 3). The recent warming in the annual series has far exceeded any fluctuations in temperature through these

TABLE 1 | Monthly, seasonal, and annual mean temperature actual and anomaly values (°C) relative to 1991–2020 for the UK and countries for the **year 2024**. Colour coding corresponds to the rank as given in the key below. The series lengths are 1884–2024 (141 years) except winter, which is 1885 to 2024 (140 years).

	UK		England		Wales		Scotland		Northern Ireland	
	Actual	Anomaly	Actual	Anomaly	Actual	Anomaly	Actual	Anomaly	Actual	Anomaly
January	3.8	−0.1	4.4	0.1	4.3	−0.1	2.5	−0.4	4.2	−0.3
February	6.3	2.2	7.5	2.9	6.9	2.5	4.2	1.1	6.4	1.7
March	6.7	1.1	7.8	1.4	7.0	1.1	5.0	0.6	6.6	0.7
April	8.3	0.4	9.3	0.6	8.5	0.4	6.6	0.1	8.3	0.3
May	13.1	2.4	13.6	2.0	12.7	1.9	12.3	3.2	12.9	2.4
June	12.9	−0.4	14.0	−0.3	12.8	−0.7	11.2	−0.5	12.4	−0.6
July	14.8	−0.5	16.1	−0.4	14.7	−0.6	12.8	−0.6	14.0	−0.7
August	15.4	0.3	16.8	0.5	15.4	0.3	13.2	−0.1	14.4	−0.1
September	12.6	−0.3	13.8	−0.1	12.8	−0.3	10.7	−0.6	12.1	−0.4
October	10.5	0.7	11.3	0.7	10.7	0.6	9.0	0.8	10.5	0.9
November	6.6	0.2	7.2	0.1	7.3	0.3	5.4	0.2	7.5	0.8
December	6.2	2.0	6.8	2.0	6.6	1.8	5.1	2.0	6.5	1.8
Winter	5.3	1.2	6.2	1.7	6.1	1.5	3.4	0.4	5.7	1.1
Spring	9.4	1.3	10.2	1.3	9.4	1.1	8.0	1.3	9.3	1.1
Summer	14.4	−0.2	15.7	−0.1	14.3	−0.4	12.4	−0.4	13.6	−0.5
Autumn	9.9	0.2	10.8	0.2	10.3	0.2	8.4	0.1	10.0	0.4
Year	9.79	0.65	10.73	0.77	9.99	0.58	8.19	0.49	9.66	0.52
Key	Coldest on record	Top ten coldest	Cool: Ranked in lower third of all years		Middle: Ranked in middle third of all years		Warm: Ranked in upper third of all years		Top ten warmest	Warmest on record

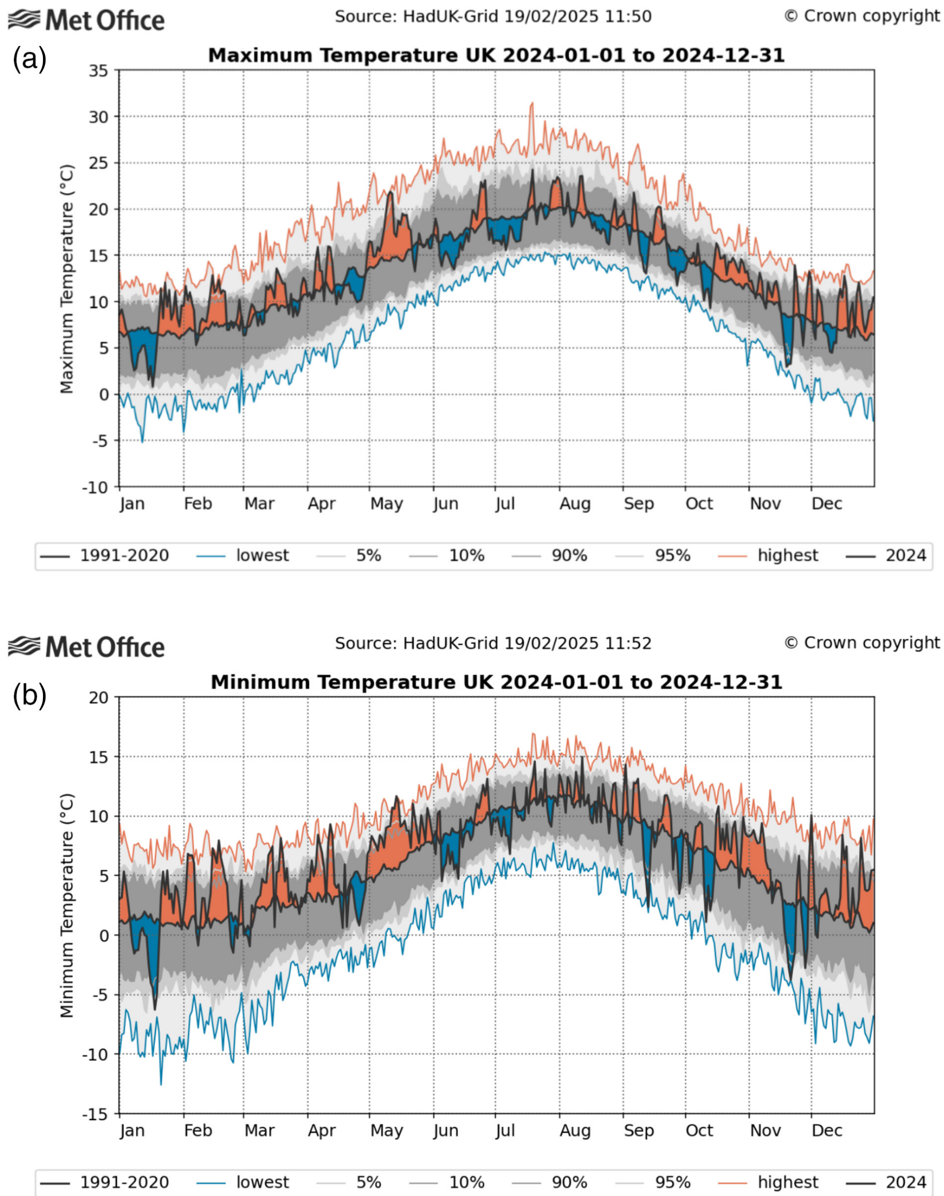


FIGURE 3 | Daily anomalies for (a) **UK mean maximum** and (b) **UK mean minimum temperature** for each calendar day of the year 2024. The central black line shows the 1991–2020 average for each calendar day; the outermost red and blue lines the highest and lowest values and the grey shading the percentile values for each calendar day of the year based on the period 1931 to 2024 inclusive.

centuries which have generally been within 0.5°C of the long term mean. All seasons of the 21st Century so far have also been warmer—although there are some seasonal variations with summer warming slightly less than the other seasons (Figure 9, Table 3).

1.3 | Daily Temperature Extremes

This section presents four different approaches to examine the question of how extremes of daily temperature have been affected by the changing climate, examining the *frequency* and *intensity* of daily temperature extremes, the frequency of the hottest days, and statistics for UK area-average daily T_{max} and T_{min}. The extension of the HadUK-Grid daily temperature grids back to 1931 (formerly 1960) has enabled a significant improvement in the analysis because it allows the period 1931–1960 to be used in addition to 1961–1990, and these two non-overlapping periods provide a longer term context for comparison with the 20th Century. Station data coverage for the period 1931–1960 is described in Appendix A: HadUK-Grid dataset and this has been significantly improved by recent and ongoing data digitization efforts. Temperature is a relatively smoothly varying field, so an analysis of extremes for this variable is much less likely to be affected by a reduction in station network density than for rainfall (where the high spatial variability makes it a critical factor).

To analyse **frequency** of daily temperature extremes—Figure 10 counts the average number of days per year for the periods 1931–1960, 1961–1990, 1991–2020 and 2015–2024 in which daily T_{max} area-average statistics for county areas of the UK (as shown in Figure A8) have exceeded their respective 1961–1990

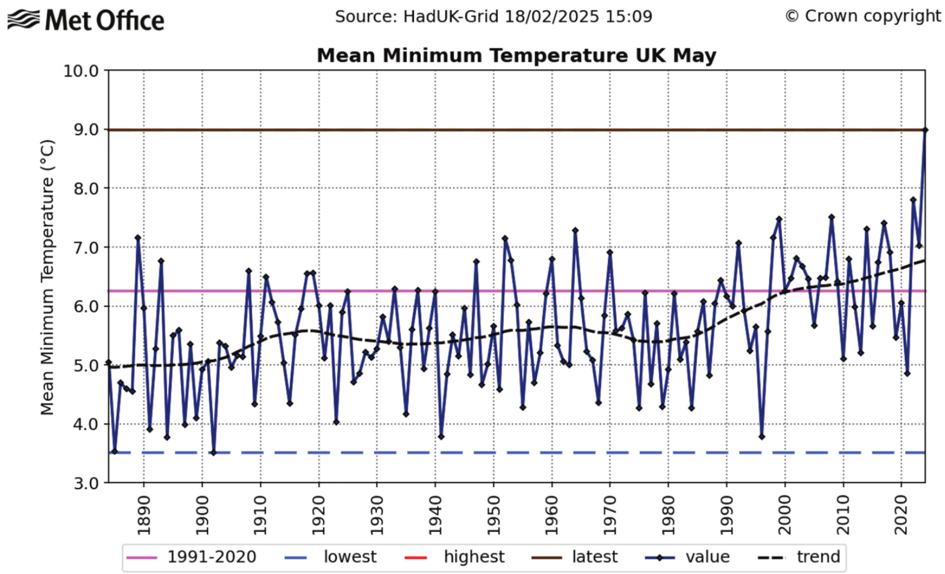
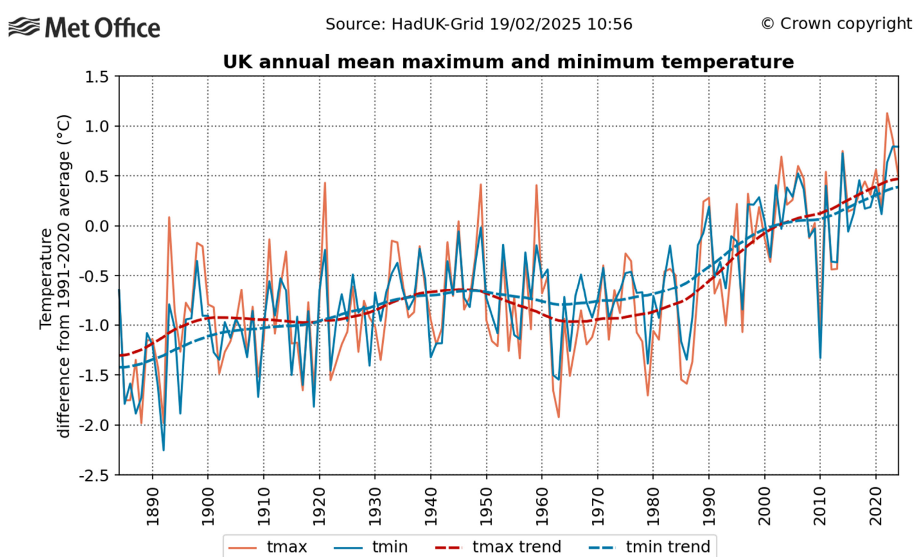


FIGURE 4 | May mean minimum temperature for the UK, 1884 to 2024.



	1931-1960	1961-1990	1991-2020	2015-2024	2024
Tmax	12.13	11.87	12.79	13.25	13.29
Tmin	4.87	4.80	5.53	5.89	6.32

FIGURE 5 | Annual mean maximum and minimum temperature for the UK, 1884 to 2024 as anomalies relative to 1991–2020. The table shows actual values for the UK (°C).

monthly average by the anomalies shown (+0°C, +1°C, +2°C, etc.). The numbers provide the absolute counts—which reduce as the anomalies increase—and the bar heights show the relative numbers comparing these four periods. (All four periods are analysed separately but note that 1991–2020 and 2015–2024 are overlapping, i.e., 1991–2020 and 2015–2024 should not be considered together otherwise the overlapping years 2015–2020 would be double-counted).

On average, 176 days per year for the period 1961–1990 exceeded the 1961–1990 monthly average—i.e., approximately half a calendar year as expected. This is broadly comparable with 1931–1960 (187 days) but significantly less than 1991–2020 (223 days) and 2015–2024 (242 days). If we examine an anomaly of +4°C, 36 days per year for the period 1961–1990 had an anomaly more than this, compared to 42 days for 1931–1960, 54 days for 1991–2020 and 67 days for 2015–2024. For a higher anomaly again, +8°C, 3 days per year for the period 1961–1990 had an anomaly more than this, compared to 4.3 days for 1931–1960, 5.8 days for 1991–2020 and 9.1 days for 2015–2014.

The greatest proportional changes—that is, the relative heights of the bars—are for the highest anomalies. Comparing the most recent decade 2015–2024 to 1961–1990, the average number of

TABLE 2 | Seasonal and annual temperature anomaly values (°C) relative to 1961–1990 and 1991–2020 for the UK and countries for the **decade 2015–2024** for (a) mean (b) mean maximum and (c) mean minimum temperature. Colour coding corresponds to the anomaly values as given in the key below.

	1961–1990					1991–2020				
(a)	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**
Winter	1.4	1.6	1.5	1.0	1.1	0.6	0.7	0.7	0.3	0.4
Spring	1.3	1.4	1.3	1.1	1.1	0.3	0.3	0.3	0.2	0.2
Summer	1.2	1.4	1.1	1.0	1.0	0.4	0.5	0.4	0.3	0.3
Autumn	1.0	1.2	1.0	0.9	0.9	0.4	0.5	0.4	0.3	0.3
Year	1.24	1.41	1.25	1.00	1.02	0.41	0.49	0.44	0.30	0.33

	1961–1990					1991–2020				
(b)	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**
Winter	1.5	1.8	1.6	1.1	1.1	0.6	0.7	0.7	0.3	0.3
Spring	1.6	1.8	1.6	1.3	1.3	0.4	0.4	0.4	0.3	0.3
Summer	1.3	1.5	1.1	1.0	1.0	0.4	0.5	0.4	0.3	0.3
Autumn	1.1	1.2	1.1	1.0	0.9	0.4	0.5	0.4	0.3	0.3
Year	1.38	1.58	1.37	1.11	1.08	0.46	0.55	0.47	0.34	0.32

	1961–1990					1991–2020				
(c)	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**
Winter	1.2	1.4	1.4	0.9	1.1	0.5	0.6	0.7	0.3	0.5
Spring	1.0	1.1	1.0	0.8	0.9	0.1	0.2	0.1	0.1	0.1
Summer	1.1	1.2	1.1	1.0	1.0	0.3	0.4	0.4	0.3	0.3
Autumn	1.0	1.1	0.9	0.8	0.9	0.4	0.4	0.4	0.3	0.3
Year	1.10	1.22	1.12	0.90	0.98	0.36	0.42	0.41	0.26	0.33

Key					
	< 0.25°C	0.25°C to 0.45°C	0.45°C to 0.95°C	0.95°C to 1.45°C	> 1.45°C

days per year for anomalies exceeding +0°C has increased by 38% and for anomalies exceeding +2°C by 58%. It has doubled for +5°C, trebled for +8°C, and quadrupled for +10°C. The bar heights for 1931–1960 are similar to 1961–1990 (indicating a broadly comparable temperature climate for these two periods), whereas there is a notable increase for 1991–2020, with by far the greatest increase for 2015–2024. An important limitation when interpreting these results is that the higher anomalies will be associated with a smaller sample size, and therefore the uncertainty in the statistics will be larger.

The analysis is repeated for daily T_{min} anomalies below 0°C, −1°C, −2°C, and so forth, and shows essentially the same effect in reverse (Figure 11). Comparing the most recent decade 2015–2024 to 1961–1990, the average number of days per year has decreased by 28% for anomalies below 0°C, it has halved for anomalies below −5°C and reduced by 10 times for anomalies below −10°C.

To analyse **intensity** of daily temperature extremes, Figure 12 shows the increase in temperature for the 98th percentile warmest summer days (daily T_{max}) and nights (daily T_{min}) (top), compared to mean summer days and nights (bottom) for county areas of the UK, for the most recent decade 2015–2024 against 1961–1990. The 98th percentile would correspond to around 2 days per summer, on average—although for this analysis, the percentiles are calculated from the full 10- or 30-year blocks, rather than for each individual year and then averaged.

Mean summer T_{max} has warmed slightly more than mean summer T_{min}, with the greatest warming across England consistent with Table 2. Warming for mean summer T_{max} has been greatest at 1.5°C to 2°C for central and eastern England, but this is much less than the warmest summer days (98th percentile T_{max}) which have seen 2°C to 3°C or more of warming in this area. In contrast, warming for mean and warmest summer nights (98th percentile T_{min}) shows relatively little difference.

The analysis is repeated for the coldest (2nd percentile) winter days and nights (Figure 13). Again, warming in mean winter T_{max} has been greatest for central and eastern England and greater for mean T_{max} than mean T_{min}. However the coldest winter days have warmed much more than this in the southern half of England and Wales—by 2°C to 3°C and there has been a very

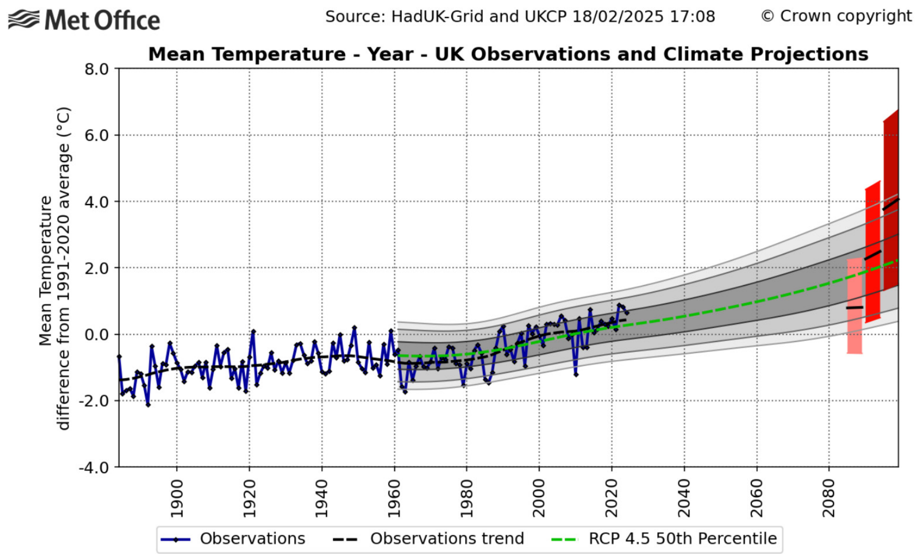
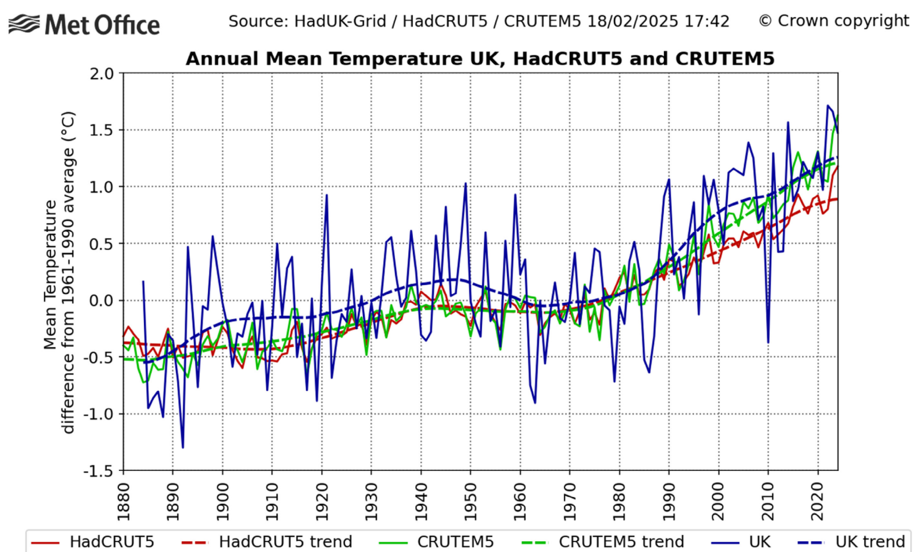


FIGURE 6 | Annual mean temperature for the UK, 1884 to 2024 and UK Climate Projections plume plot 1961 to 2100 as anomalies relative to 1991–2020 showing Representative Concentration Pathway (RCP) 4.5. The grey shading shows the 5 to 95 percentile, 10 to 90 percentile, and 25 to 75 percentile ranges. Other scenarios RCP 2.6 (light red), 6.0 (mid red) and 8.5 (dark red) are included in the 2080s showing the 50th percentile and 5 to 95 percentile ranges.



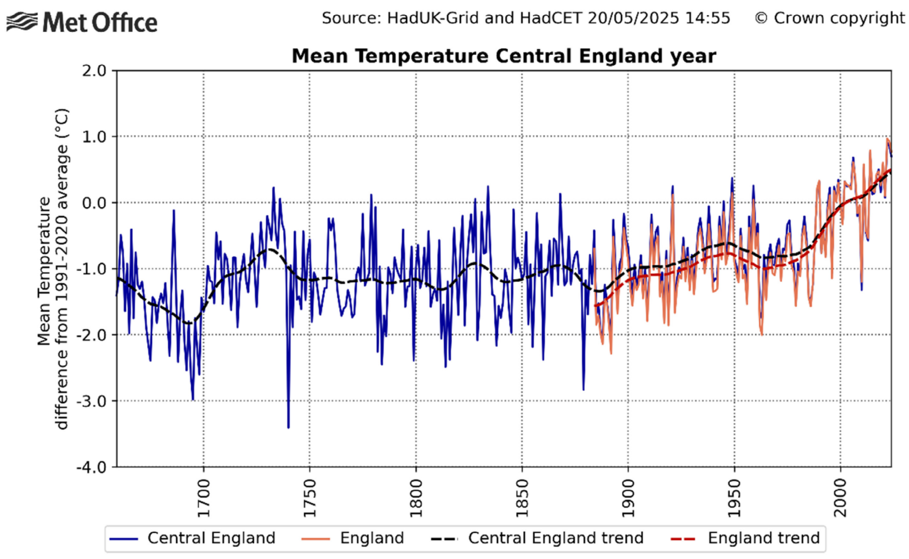
	1991-2020	2015-2024	2024
UK	0.83	1.24	1.48
HadCRUT5	0.54	0.90	1.18
CRUTEM5	0.74	1.23	1.63

FIGURE 7 | Annual mean temperature for the UK from HadUK-Grid, 1884 to 2024, plotted alongside global annual mean temperature based on the HadCRUT5 dataset and global land only based on the CRUTEM5 dataset as anomalies relative to **1961–1990**. The table shows anomaly values relative to 1961–1990 (°C).

pronounced warming of the coldest winter nights, by 2.5°C to 3.5°C or more, very widely.

Table 4 counts the average number of days per year for county areas of the UK in which the **highest** daily T_{max} within that county (i.e., the highest grid point value) has exceeded 20°C, 25°C, 28°C, 30°C and 32°C for the periods 1931–1960, 1961–1990, 1991–2020 and 2015–2024; Figure 14 shows maps for these periods for 28°C. This repeats and updates the analysis in last year's report (Kendon et al. 2024).

The *highest* maximum is defined as *anywhere* within that county level reaching that threshold at 1 km grid-point resolution. The *highest* maximum is chosen, rather than the *average* maximum because the latter metric would be much more influenced by elevation and proximity to the coast. Since the majority of the UK's



	1931-1960	1961-1990	1991-2020	2015-2024	2024
Central England	9.63	9.46	10.27	10.71	10.96
England	9.17	9.04	9.96	10.45	10.73

FIGURE 8 | Annual mean temperature for Central England (CET), 1659 to 2024, and England, 1884 to 2024, as anomalies relative to 1991–2020. The table shows actual values (°C).

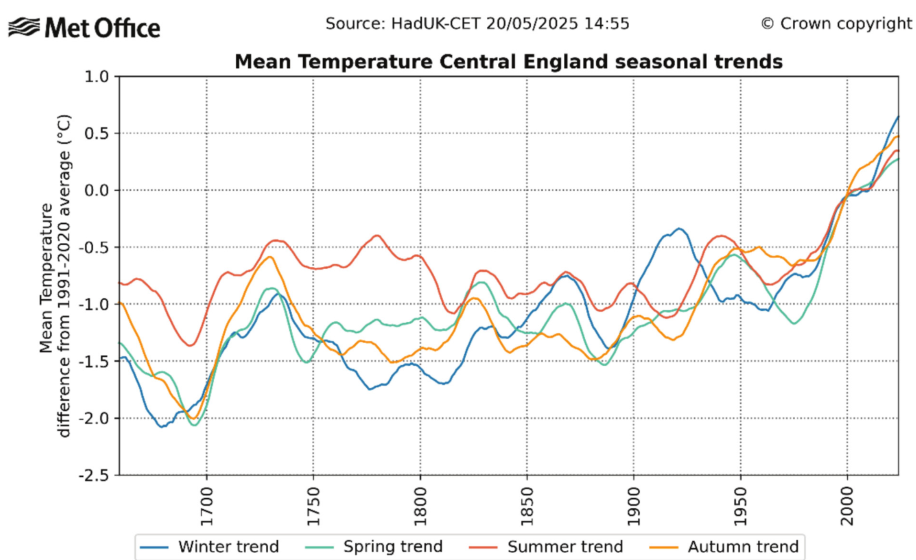


FIGURE 9 | Seasonal mean CET trends 1659 to 2024 (°C, winter 1660 to 2024), as anomalies relative to 1991–2020, showing the smoothed trends for each series using a weighted kernel filter described in Appendix B: Time-Series and Trends Shown in This Report.

TABLE 3 | Averages for each century of the CET series (°C) 1659 to 2024 (winter from 1660 to 2024).

Season	1659–1700 (42 years)	1701–1800 (100 years)	1801–1900 (100 years)	1901–2000 (100 years)	2001–2024 (24 years)
Winter	3.0	3.5	3.7	4.2	5.1
Spring	7.5	8.1	8.1	8.4	9.4
Summer	14.9	15.5	15.2	15.3	16.2
Autumn	9.1	9.6	9.5	10.0	11.1
Year	8.7	9.2	9.1	9.5	10.5

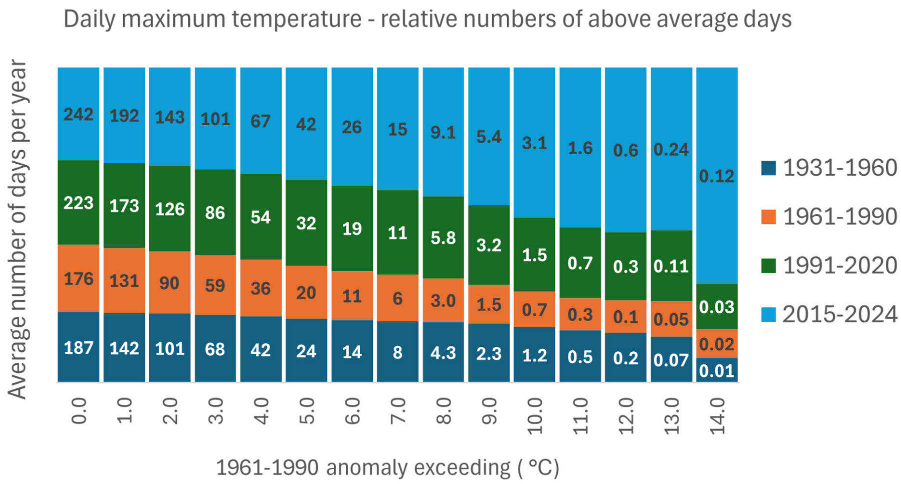


FIGURE 10 | The average number of days per year for county areas of the UK with **positive daily maximum temperature anomalies** as stated, compared to the monthly 1961–1990 average, for the periods 1931–1960, 1961–1990, 1991–2020 and 2015–2024.

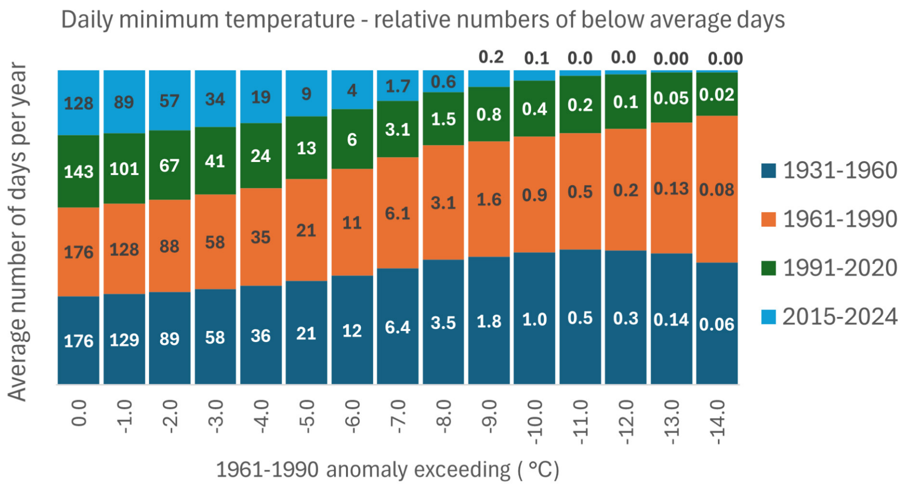


FIGURE 11 | The average number of days per year for county areas of the UK with **negative daily minimum temperature anomalies** as stated, compared to the monthly 1961–1990 average, for the periods 1931–1960, 1961–1990, 1991–2020, and 2015–2024.

population tends to live at lower elevations, the highest maximum is arguably judged as being more population-relevant. In Scotland, for example, a relatively high proportion of land area is at high elevation (above 500 masl) and mostly uninhabited.

The highest counts occur across the climatologically warmest parts of the south-east, with the darker colours expanding across the map from 1961–1990 to 1991–2020 to 2015–2024. The maps show the period 1931–1960 having slightly more days exceeding this threshold than 1961–1990. The table presents summary statistics for these thresholds for the count for 2015–2024 as a percentage of 1931–1960, 1961–1990 and 1991–2020. For the most recent decade, compared to 1961–1990, while exceedances of 20°C have increased by 39% and of 25°C by 62%, exceedances of 28°C have more than doubled and of 30°C and 32°C more than trebled. As was demonstrated in last year's report, this illustrates how the warming climate has the greatest implications for extremes of temperature, rather than average temperature, and this is particularly noteworthy because it is the extremes of temperature that tend to have the greatest impacts (e.g., on human health).

Finally, Table 5 (a and b) show highest, lowest and percentiles of the annual distribution of UK mean daily T_{max} and T_{min} as averages for 1931–1960, 1961–1990, 1991–2020 and 2015–2024, indicating how these distributions have changed over time. For the most recent decade, the median T_{max} has warmed by 1.2°C whereas the 99th percentile T_{max} has warmed by 1.9°C and the UK's warmest T_{max} day of the year by 2.7°C, when compared to 1961–1990. In the same way for the same periods the median T_{min} has warmed by 0.9°C but the 1st percentile T_{min} by 1.5°C and the UK's coldest T_{min} day of the year by 1.9°C. As with the previous three analyses, this again suggests that climate change has a much greater effect on the extremes of temperature than the mean.

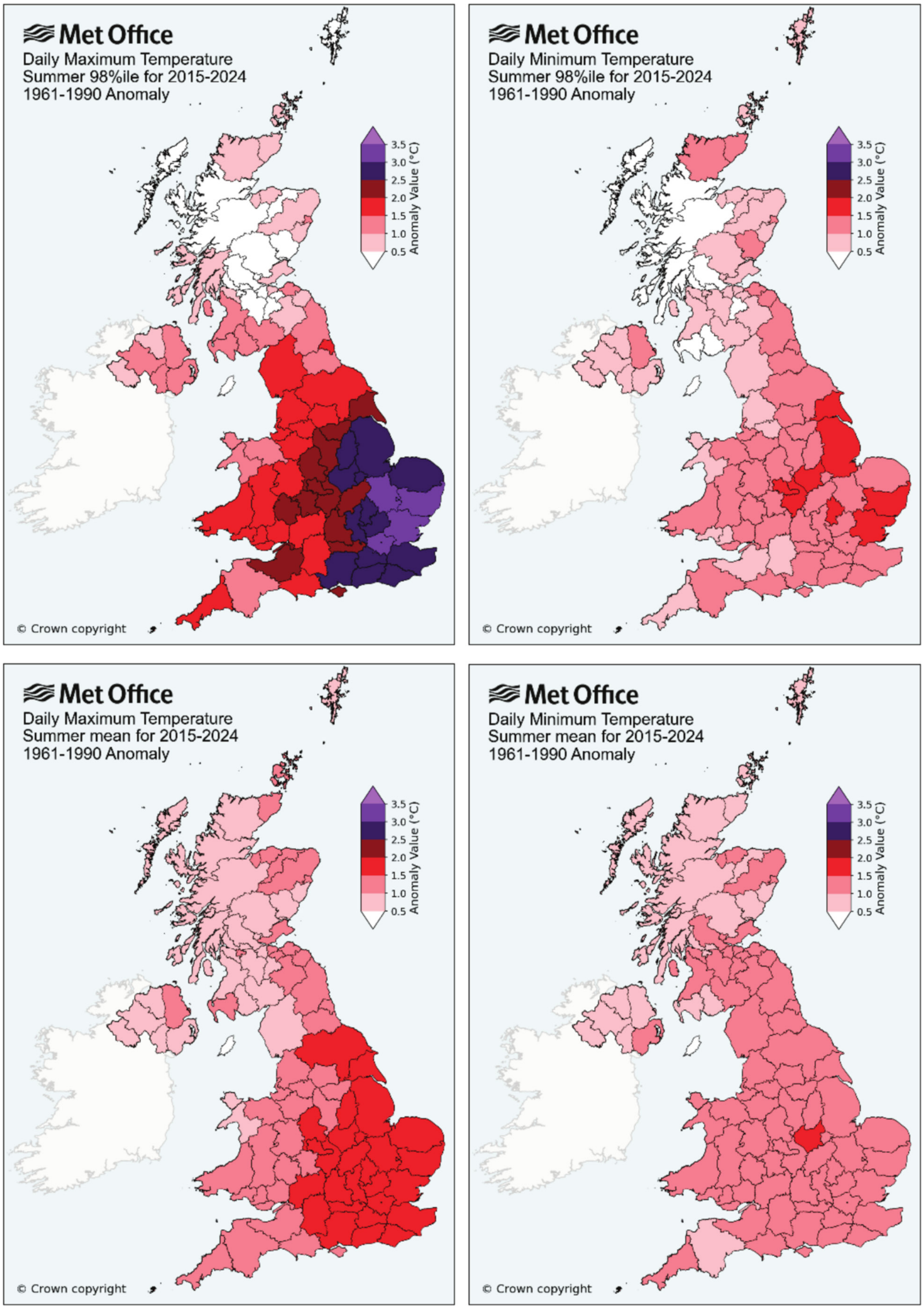


FIGURE 12 | Top: Increase in the **warmest (98th percentile)** daily maximum and minimum temperature (°C) in **summer** for 2015–2024 compared to 1961–1990 for county areas of the UK. Bottom: Difference in the mean for the same period, for comparison. Percentiles are calculated for the full 30 or 10-year periods, not for each individual year and then averaged.

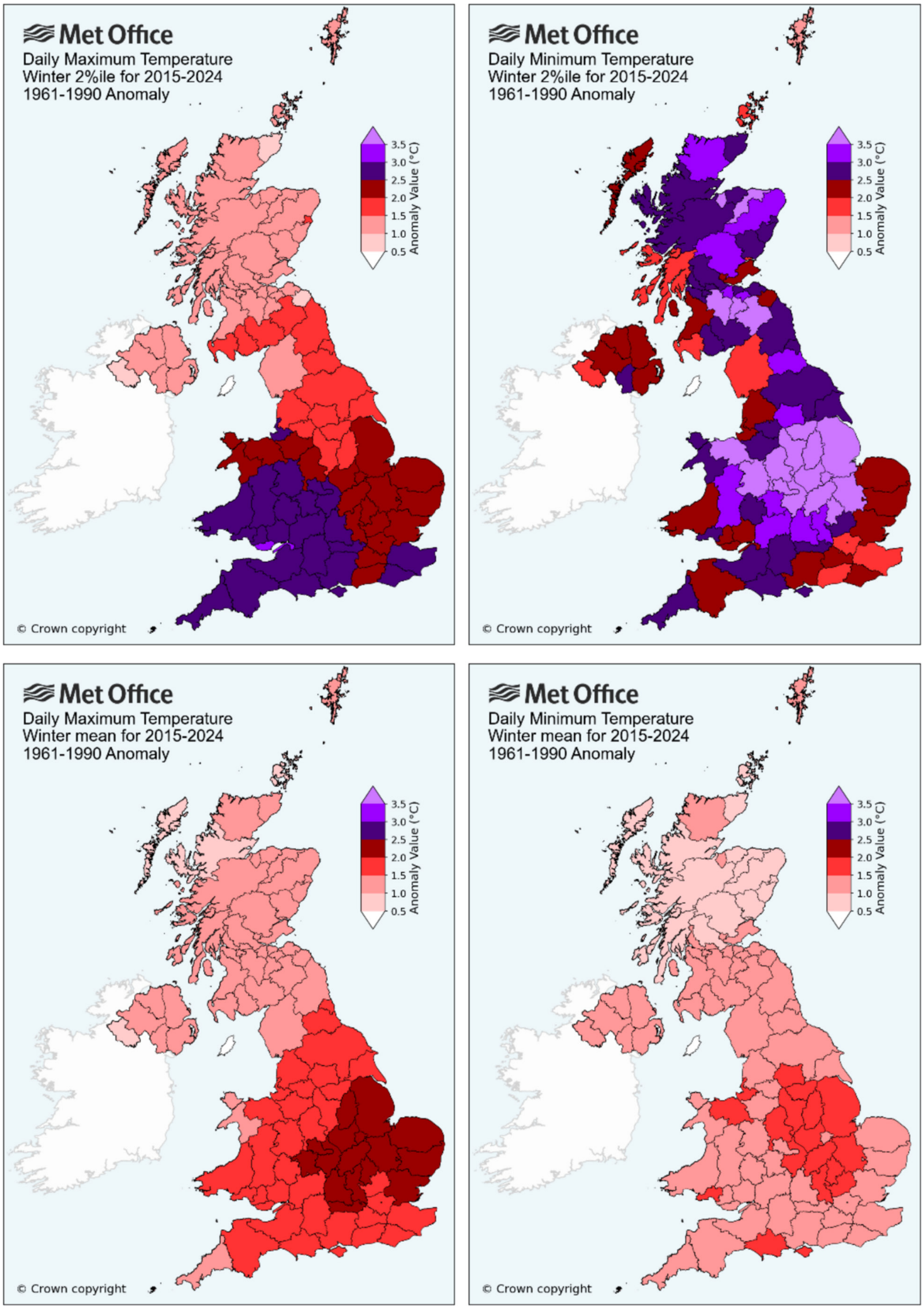


FIGURE 13 | Top: Increase in the **coldest (2nd percentile)** daily maximum and minimum temperature (°C) in **winter** for 2015–2024 compared to 1961–1990 for county areas of the UK. Bottom: Difference in the mean for the same period, for comparison. Percentiles are calculated for the full 30 or 10 year periods, not for each individual year and then averaged.

TABLE 4 | Average count of the number of days per year in which the **highest maximum temperature** for each county of the UK has exceeded 20°C, 25°C, 28°C, 30°C and 32°C, for the periods 1931–1960, 1961–1990, 1991–2020 and 2015–2024. (0.17 days would correspond to 1 day every 6 years on average).

	1931–1960	1961–1990	1991–2020	2015–2024	2015–2024 percentage of 1931–1960	2015–2024 percentage of 1961–1990	2015–2024 percentage of 1991–2020
20°C	60	57	73	79	133	139	108
25°C	11	10	14	17	156	162	117
28°C	2.8	2.3	4.1	5.8	211	254	144
30°C	0.8	0.7	1.5	2.5	310	340	171
32°C	0.17	0.25	0.40	0.91	540	370	227

1.4 | Days of Air and Ground Frost

Air frost statistics are derived from daily T_{min} grids extending back to 1931 (formerly 1960), whereas ground frost statistics are derived from monthly days of ground frost grids from 1961. Both variables have a very large spatial variation in climatology across the UK. For example, the 1991–2020 annual average days of air frost ranges from more than 100 days across much of the high ground of Scotland to fewer than 10 days across parts of west Cornwall. Appendix A: Areal Series explains how these areal-series are calculated.

The annual average days of air frost trend has been stable at around 65 days from the 1930s to the 1970s, followed by a steady decline from the 1980s (Figure 15). This trend is consistent with annual mean minimum temperature (Figure 5). The most recent decade 2015–2024 has had almost a week fewer air frosts compared to 1991–2020 and over 2 weeks fewer compared to 1961–1990 and 1931–1960 (the latter a reduction of around a quarter). For England and Northern Ireland, this reduction has been as much as a third.

The UK typically has around twice as many days of ground frost as air frost, that is, reflecting the large number of marginal days in the UK's climate where the surface temperatures over grass are below freezing but air temperatures recorded within the Stevenson Screen, typically around 1°C to 3°C higher, are not. The shorter ground frost series shows a similar trend but therefore with larger absolute reductions; the most recent decade 2015–2024 having 1½ weeks fewer ground frosts compared to 1991–2020 and 4 weeks fewer compared to 1961–1990. Again, the latter is a reduction of around a quarter.

The number of air frosts in 2024 was the second lowest for the UK in the series from 1931, with ground frosts the lowest in the UK series (Figure 15). For England, air frosts in 2024 were also the lowest in the series (not shown). February, March, and December all saw a marked absence of frosts—in December 2024, for example, the majority of stations in England recorded only a single day of air frost for the entire month. Nevertheless, despite the changing climate, exceptionally frosty years are still possible. 2010 has the most air frosts of any year in the series from 1931—despite this earlier period including several severe winters, most notably the exceptional winter of 1963.

1.5 | Degree Days

Heating, cooling and growing degree days (HDD, CDD, GDD) statistics are derived from daily temperature grids extending back to 1931 (formerly 1960). These relate to the requirement for heating or cooling of buildings to maintain comfortable temperatures (i.e., relating to energy demand), and the conditions suitable for plant growth. The thresholds used are 15.5°C for HDD, 22°C for CDD and 5.5°C for GDD (see Appendix A: Annual Degree Days for details).

The HDD[1] time-series trend shows remarkably stable HDD from the 1930s to the 1970s followed by a steady and continuing reduction over the last four and a half decades from the 1980s (Figure 16). The most recent decade 2015–2024 has had 5% fewer HDD than 1991–2020, 14% fewer than 1961–1990 and 13% fewer than 1931–1960, with the 10 fewest HDD years all occurring in the 21st Century. While comparatively recent years such as 2010, 2012 and 2013 show that above average HDD years are still possible, the latter 2 years would actually have been considered as below average compared to much of the 20th Century. All 10 years of the most recent decade have been below the 1991–2020 average, with HDD for 2024 fourth lowest in the series.

CDD have a larger annual variability than HDD, with significant peaks coinciding with summer heat-waves. Despite the warming climate, 1976 and 1995 still have by a wide margin the highest CDD values in the UK series. Nevertheless, there is still clear evidence of a rising trend in CDD from a low in the 1960s. CDD for the latest decade are 5DD more than 1991–2020, 10CDD more than 1961–1990 and 8CDD more than 1931–1960[2], representing an approximate doubling in CDD (the energy requirement for cooling buildings) compared to the 20th Century. The most recent year had the fewest CDD since 2015 (marginally below 2017), consistent with an absence of notable summer warmth (Figure 17).

The GDD time-series trend largely resembles the opposite of the HDD trend, with stable GDD from the 1930s to the 1970s, followed by a steady and continuing increase from the 1980s (Figure 18). The most recent decade 2015–2024 has had 6% more GDD than 1991–2020, 21% more than 1961–1990, and 18% more than 1931–1960, with the 10 highest GDD years all occurring

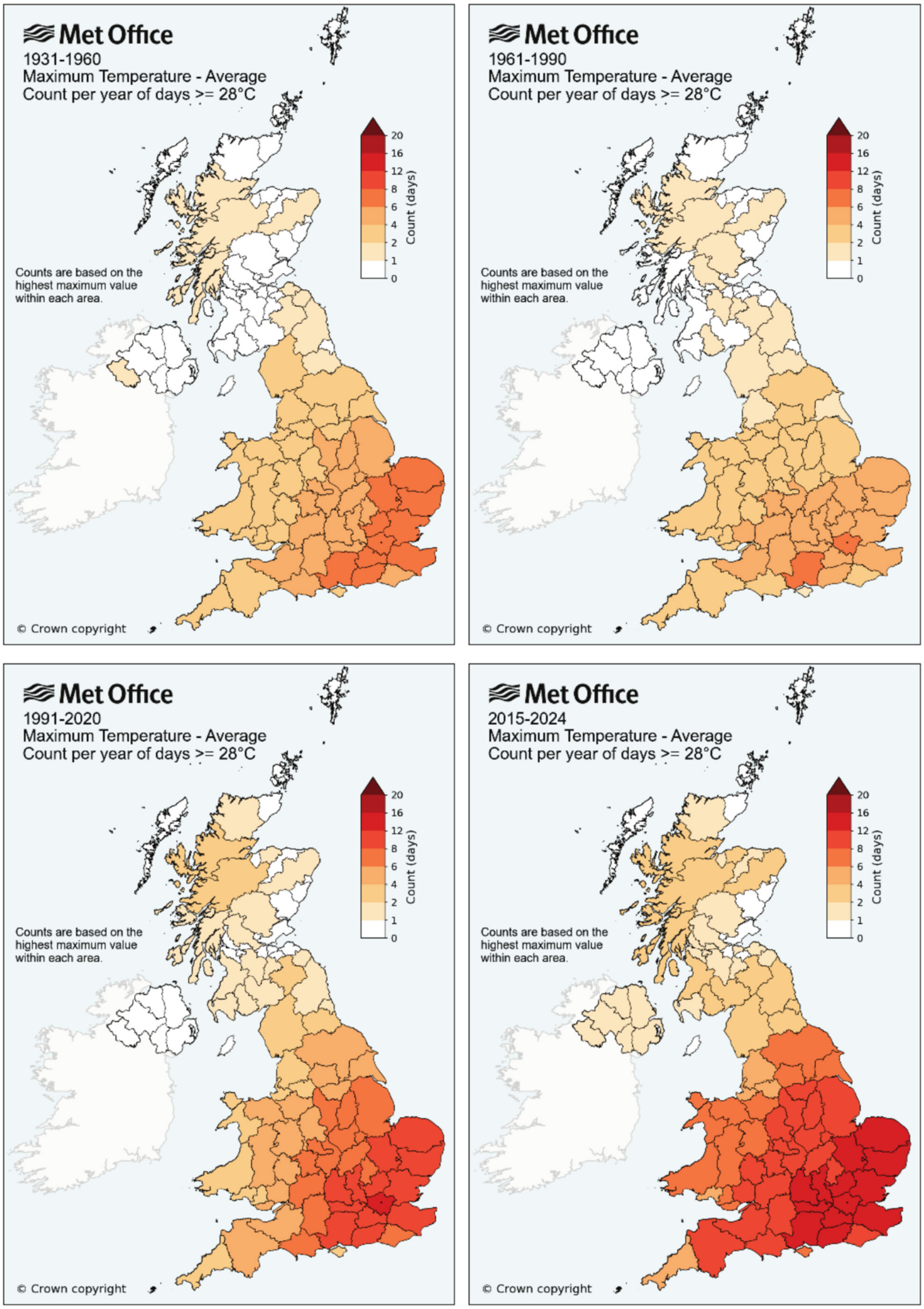


FIGURE 14 | Average count of the number of days per year in which the highest maximum temperature for each count of the UK has exceeded 28°C for the periods 1931–1960, 1961–1990, 1991–2020 and 2015–2024 for county areas of the UK.

TABLE 5 | Highest, lowest and percentiles of annual distributions of (a) **UK mean daily maximum temperature** (°C) and (b) **UK mean daily minimum temperature**, averaged for 1931–1960, 1961–1990, 1991–2020 and 2015–2024. The key colours are the same as for Table 2.

(a)	1931–1960	1961–1990	1991–2020	2015–2024	2015–2024 diff from 1931–1960	2015–2024 diff from 1961–1990	2015–2024 diff from 1991–2020
Min	−0.1	0.1	1.1	1.3	1.3	1.2	0.1
1%	1.4	1.5	2.3	2.5	1.1	1.0	0.2
5%	3.4	3.4	4.4	5.0	1.7	1.7	0.6
10%	4.8	4.7	6.0	6.6	1.8	1.8	0.6
25%	7.8	7.6	8.6	9.0	1.2	1.5	0.4
50%	12.0	11.8	12.6	13.0	1.0	1.2	0.4
75%	16.5	16.2	17.1	17.5	1.0	1.3	0.4
90%	19.2	18.9	19.7	20.0	0.8	1.1	0.3
95%	20.6	20.3	21.3	21.7	1.0	1.4	0.4
99%	23.2	22.8	23.7	24.7	1.5	1.9	1.0
Max	25.3	24.7	25.6	27.4	2.1	2.7	1.8
(b)	**1931–1960**	**1961–1990**	**1991–2020**	**2015–2024**	**2015–2024 diff from 1931–1960**	**2015–2024 diff from 1961–1990**	**2015–2024 diff from 1991–2020**
Min	−6.8	−7.0	−5.4	−5.1	1.7	1.9	0.2
1%	−5.0	−4.9	−3.7	−3.4	1.6	1.5	0.3
5%	−2.6	−2.5	−1.6	−1.2	1.4	1.3	0.4
10%	−1.1	−1.1	−0.4	0.1	1.2	1.2	0.5
25%	1.4	1.4	2.1	2.5	1.0	1.1	0.4
50%	4.9	4.9	5.5	5.8	0.9	0.9	0.3
75%	8.5	8.5	9.1	9.5	1.0	1.0	0.3
90%	10.9	10.6	11.3	11.7	0.8	1.1	0.3
95%	11.8	11.5	12.3	12.7	1.0	1.2	0.4
99%	13.1	13.0	13.9	14.2	1.1	1.2	0.3
Max	14.2	14.0	15.0	15.6	1.4	1.6	0.6

Key					
	< 0.25°C	0.25°C to 0.45°C	0.45°C to 0.95°C	0.95°C to 1.45°C	> 1.45°C

in the 21st Century. GDD for 2024 was the fifth highest in the series.

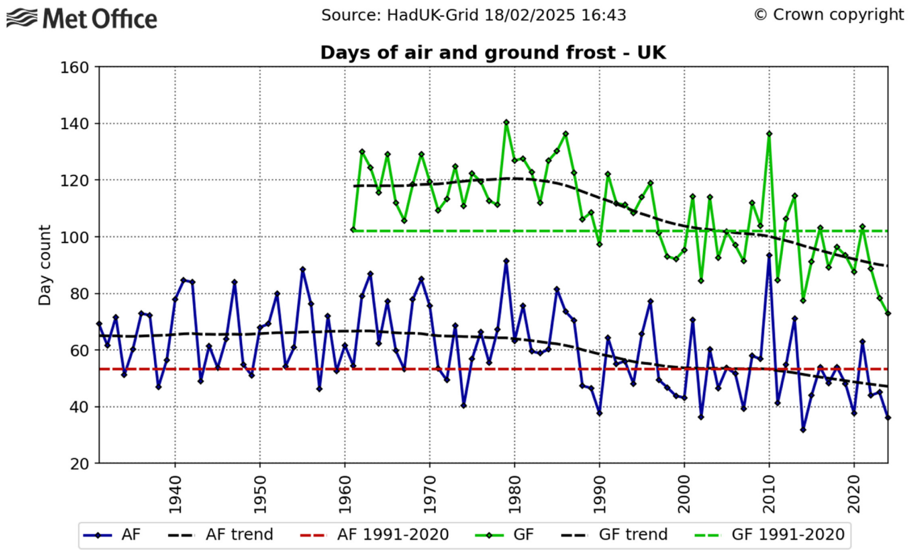
1.6 | Near-Coast Sea Surface Temperature

2024 was the sixth warmest year for UK near-coast sea surface temperature (SST) in a series from 1870 (Figure 19). See Appendix A: Sea-Surface Temperature Data for details of this series. The most recent decade 2015–2024 has been 0.3°C warmer than the 1991–2020 long term average and 0.9°C warmer than 1961–1990, this warming being slightly less than that over UK land (0.41°C and 1.24°C relative to 1991–2020 and 1961–1990 respectively). However, this is consistent with global observations which also show greater warming over land than sea (IPCC 2021). Five of the 10 warmest years for UK near-coast SST from 1870 have occurred in the most recent decade 2015–2024.

2 | Precipitation

2.1 | Annual, Seasonal and Monthly Rainfall

2024 was slightly less wet than the previous year but even so still the 13th wettest year in the UK series from 1836 with 109% of average rainfall. In the UK series from 1836, only 6 years were wetter than 2024 up until and including 2000. Since 2001, this same number of years have been wetter still. While Northern Ireland and some parts of Scotland were slightly drier than average, the year was particularly wet across central southern England with



Air Frost	1931-1960	1961-1990	1991-2020	2015-2024	2024	2015-2024 anom wrt 1931-1960	2015-2024 anom wrt 1961-1990	2015-2024 anom wrt 1991-2020
UK	65	65	53	47	36	-18	-17	-6
England	60	56	45	38	24	-22	-19	-7
Wales	51	54	45	38	28	-13	-16	-7
Scotland	80	83	72	68	59	-12	-15	-4
Northern Ireland	55	54	41	37	30	-18	-17	-5

Ground Frost	1961-1990	1991-2020	2015-2024	2024	2015-2024 anom wrt 1961-1990	2015-2024 anom wrt 1991-2020
UK	119	102	90	73	-28	-12
England	111	96	85	65	-26	-11
Wales	110	92	78	63	-32	-14
Scotland	136	116	104	89	-32	-12
Northern Ireland	111	93	82	69	-29	-11

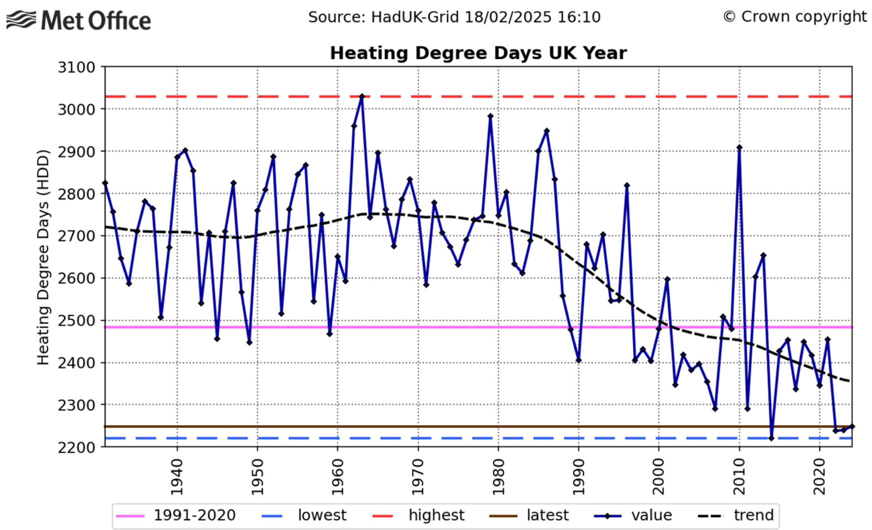
FIGURE 15 | Annual days of air and ground frosts for the UK, 1931 to 2024 and 1961 to 2024 respectively. The tables show actual values for the UK and countries (days), with anomaly values for 2015–2024 (days).

over a third more rain than average quite widely. It was a top-five wettest year for several county areas including the wettest year on record for Bedfordshire (Figure 20a,b, Table 6). The UK had its sixth wettest winter (134% of average) and sixth wettest spring (132%). Summer and autumn saw opposite north–south contrasts in rainfall patterns (Figure 21).

Figure 22 shows the large spatial variation in monthly rainfall typical of the UK's climate over the course of the year. February was particularly wet across much of England with over twice the average monthly rainfall. Southern England (south of a line from the Wash to North Wales, not shown) had its wettest February on record, and March too was wet. These months followed a wet October and December 2023 with significant flooding problems from a succession of named storms—culminating in *Gerrit* at the end of December 2023, *Henk* in early January 2024, and *Isha* and *Jocelyn* in late January. The period October 2023 to March 2024 was the second-wettest on record for the UK, behind only 2000–2001, and the wettest for England and Wales combined. This is described in more detail in Section 7.1. September also saw more than twice the average rainfall for much of England and was the wettest September for this same area (southern England) since 1918. Section 7.2 describes the extreme rainfall in late September.

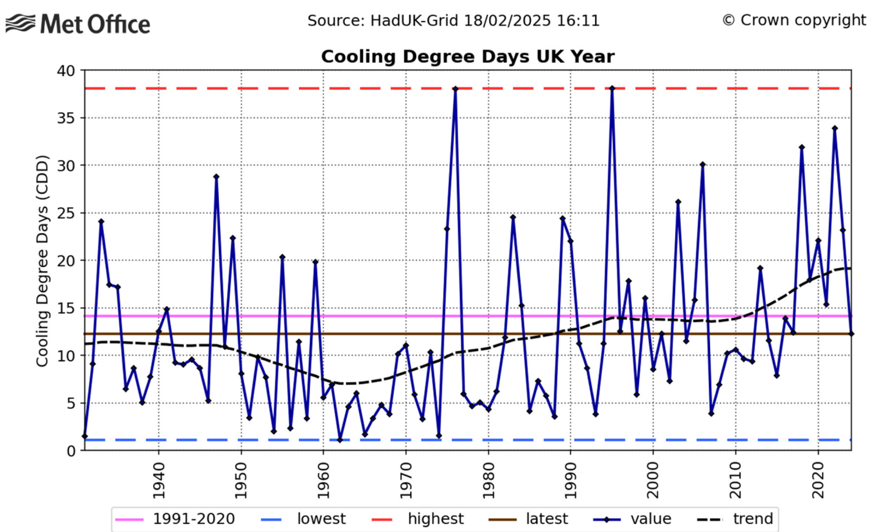
Capturing the patterns of observed rainfall across the UK as shown in Figures 20–22 is only possible if the rain gauge network across the UK is adequate. This report emphasizes the importance of halting and, preferably, reversing the ongoing steady decline in this network since the 1970s. This is especially important for daily rainfall extremes where spatial variation can be extremely large. If this decline continues, we will put at risk our ability to reliably monitor observed changes in rainfall in future years. More details are given in Appendix A: HadUK-Grid Dataset.

The UK annual precipitation time-series from 1836 to 2024 shows large annual variability but with an upward and ongoing increase from the 1970s (Figure 23). The 21st Century so far has seen a cluster of wet years—including 2024—compared to the 19th and 20th Centuries. The most recent decade 2015–2024 has been 2% wetter than 1991–2020 and 10% wetter than 1961–1990,



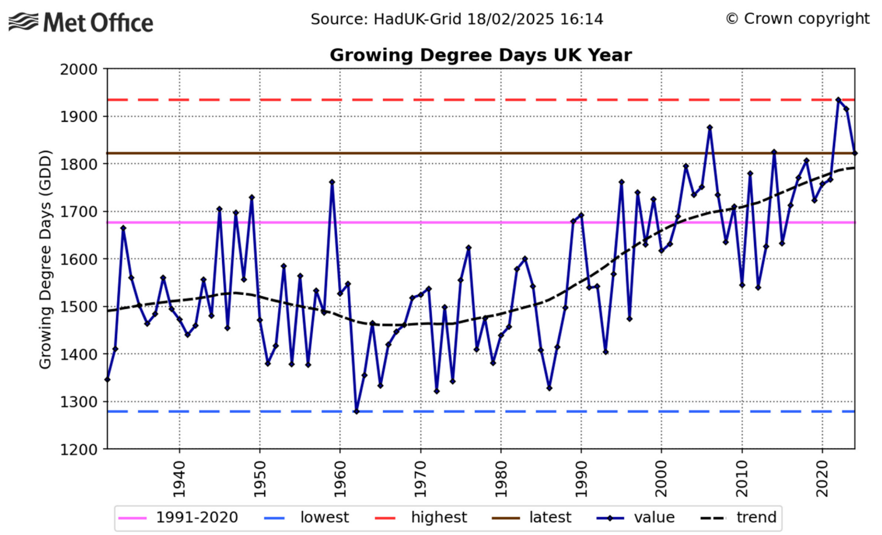
	1931-1960	1961-1990	1991-2020	2015-2024	2024	2015-2024 % of 1931-1960	2015-2024 % of 1961-1990	2015-2024 % of 1991-2020
UK	2700	2739	2484	2361	2249	87	86	95
England	2511	2522	2247	2108	1974	84	84	94
Wales	2565	2621	2363	2229	2142	87	85	94
Scotland	3068	3149	2923	2826	2742	92	90	97
Northern Ireland	2616	2655	2425	2322	2230	89	87	96

FIGURE 16 | Annual heating degree days for the UK, 1931 to 2024. The table shows actual values for the UK and countries (HDD) with percentage of average values for 2015–2024.



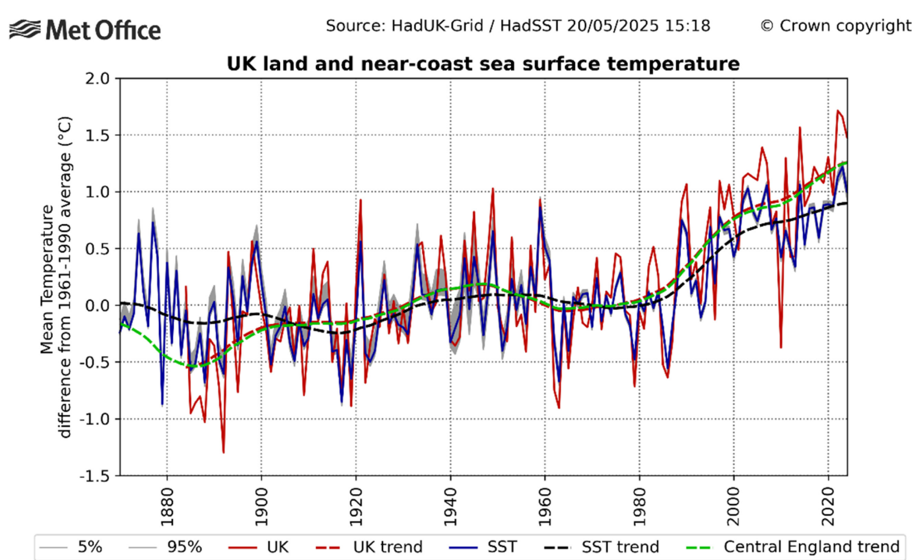
	1931-1960	1961-1990	1991-2020	2015-2024	2024	2015-2024 anom wrt 1931-1960	2015-2024 anom wrt 1961-1990	2015-2024 anom wrt 1991-2020
UK	11	9	14	19	12	8	10	5
England	16	14	22	30	21	14	16	8
Wales	9	8	10	14	6	5	6	4
Scotland	3	3	3	4	1	1	1	1
Northern Ireland	4	3	4	6	1	1	3	2

FIGURE 17 | Annual cooling degree days for the UK, 1931 to 2024. The table shows actual values for the UK and countries (CDD) with anomaly values for 2015–2024. Anomalies are presented as a difference from average (i.e., also CDD).



	1931-1960	1961-1990	1991-2020	2015-2024	2024	2015-2024 % of 1931-1960	2015-2024 % of 1961-1990	2015-2024 % of 1991-2020
UK	1517	1471	1676	1784	1822	118	121	106
England	1710	1677	1920	2048	2095	120	122	107
Wales	1568	1517	1723	1835	1841	117	121	107
Scotland	1191	1124	1269	1346	1378	113	120	106
Northern Ireland	1472	1423	1606	1694	1732	115	119	105

FIGURE 18 | Annual growing degree days for the UK, 1931 to 2024. The table shows actual values for the UK and countries (GDD) with percentage of average values for 2015–2024.



Area	1991-2020	2015-2024	2024
SST	0.6	0.9	1.0
UK	0.83	1.24	1.48
CET	0.81	1.25	1.50

FIGURE 19 | UK annual mean temperature over land 1884 to 2024, Central England temperature trend and annual mean sea surface temperature across near-coastal waters around the UK 1870 to 2024 as anomalies relative to **1961–1990**. The figure shows the SST uncertainty range (5%–95%). The table shows anomaly values relative to 1961–1990 (°C).

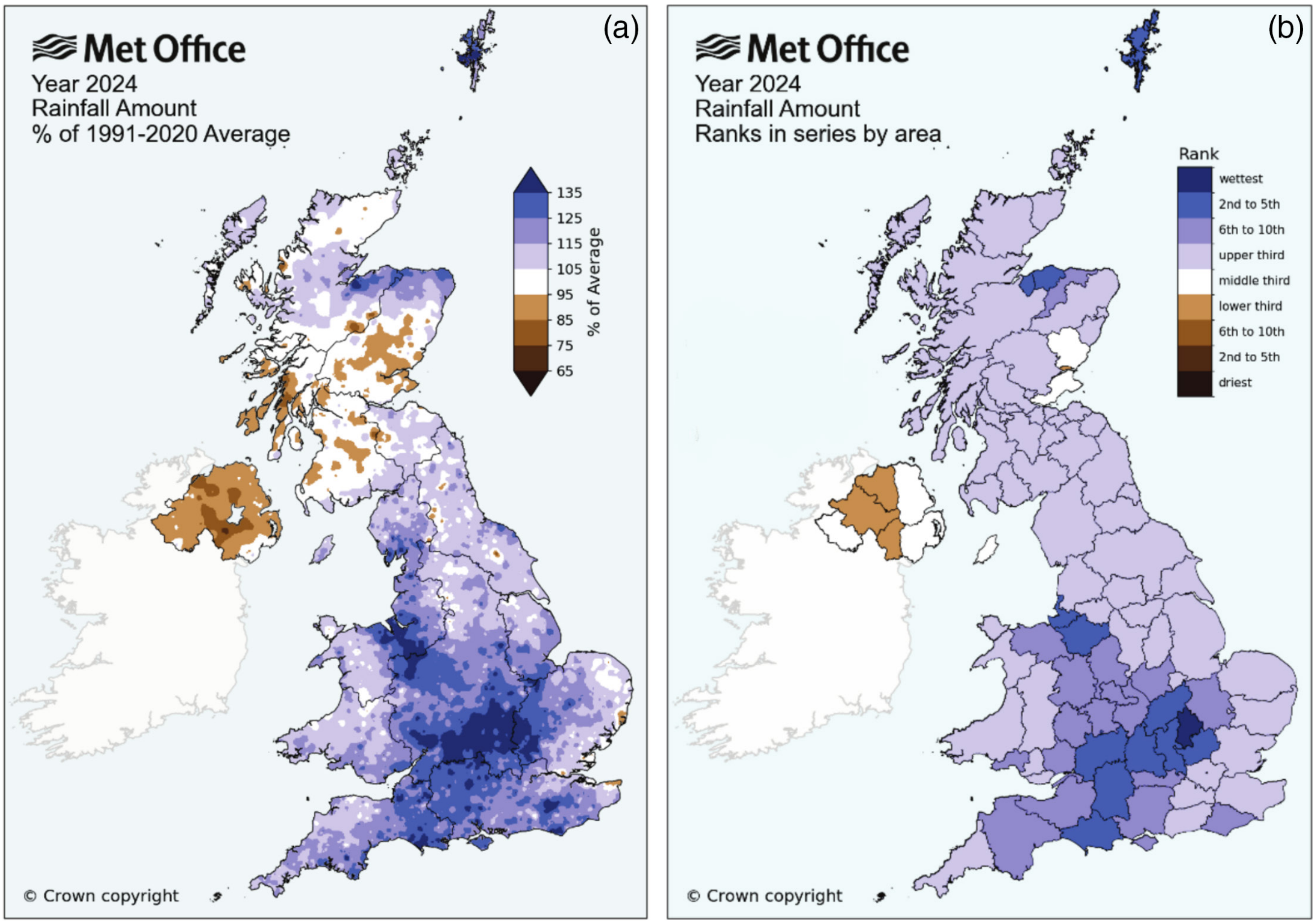


FIGURE 20 | (a): Rainfall anomalies (%) relative to 1991–2020 for year 2024. (b) The rank of 2024 annual rainfall for all counties of the UK based on monthly series from 1836.

with the largest increase in winter (Table 7). However, if the analysis is restricted to meteorological seasons only, it may fail to reveal the most significant trends. Splitting rainfall into the winter and summer 'half years' (October to March and April to September), shows that the increase in UK annual rainfall is entirely due to an upward trend in the winter half-year (Figure 24a), with no trend in summer half-year (Figure 24b). Winter half-year rainfall for the most recent decade 2015–2024 has increased by 6% compared to 1991–2020 and 16% compared to 1961–1990. (Note that winter rainfall accounts for approximately 60% of the annual total, that is, splitting the year in half does not mean splitting the rainfall amount in half.) Importantly, we note that while there is no increase in summer half-year rainfall, there is no decrease either. While the UK's climate is getting wetter overall, the large annual and decadal variability means that some caution is needed when interpreting these trends over relatively short time periods, since averages may be strongly influenced by extreme years.

2.2 | England and Wales Precipitation

The most recent decade 2015–2024 has been 4% wetter than 1991–2020 and 11% wetter than 1961–1990 in the long running England and Wales precipitation series (EWP) from 1766 (Figure 25). The trend in this series is consistent with the HadUK-Grid series for England and Wales combined from 1836. In both series, the 30-year annual averages for 1901–1930, 1931–1960 and 1961–1990 are all broadly comparable and substantially lower than both 1991 and 2020 and the most recent decade 2015–2024. Decadal fluctuations including the wet period in the 1870s and 'Long Drought' from 1890 to 1910 (Marsh et al. 2007) are present in both series and emphasize the value of extending observational climate series back to the early 19th Century, or earlier for capturing long term context. 2024 was the ninth wettest year in the EWP series, although not as wet as 2023 (ranked seventh).

Previous State of UK Climate reports have shown trends in rainfall for the four meteorological seasons. Instead, Figure 26 separates rainfall into the winter and summer 'half years' (October to March and April to September) in the same way as for the UK in Figure 24. This repeats the earlier finding that the overall increase in EWP annual rainfall is due to the trend in the winter half-year, with no increase in the summer half-year. There has been an extremely pronounced increase in EWP winter half-year rainfall for the most recent decade 2015–2024, which in this series has been 17% wetter than 1991–2020 and 10% wetter than 1961–1990; comparable with increases in the UK series (Table 7). Four of the 10 wettest winter half-years in this 250+ year series have occurred in the most recent decade, six have been in the 21st Century so far and seven since 1995, with 2024 and 2001 the wettest by a margin of over 60 mm (Table 8).

TABLE 6 | Monthly, seasonal and annual rainfall actual values (mm) and percentage of average values relative to 1991–2020 for the UK and countries for the **year 2024**. Colour coding corresponds to the rank as given in the key below. The series lengths are 1836–2024 (189 years) except winter, which is 1837 to 2024 (188 years).

	UK		England		Wales		Scotland		Northern Ireland	
	Actual	**%**	**Actual**	**%**	**Actual**	**%**	**Actual**	**%**	**Actual**	**%**
January	123	101	88	106	167	108	175	98	89	77
February	144	150	132	199	215	179	156	111	87	96
March	108	127	95	163	162	156	113	91	119	137
April	110	153	86	153	139	158	143	154	101	137
May	83	117	85	149	97	111	82	92	48	65
June	55	71	34	52	50	54	91	98	60	73
July	85	103	81	121	93	94	91	88	76	86
August	105	112	47	62	103	92	197	164	128	129
September	117	128	137	200	161	144	79	64	66	75
October	105	86	93	103	131	82	124	74	84	73
November	94	76	77	83	144	89	111	67	85	70
December	145	114	83	90	196	112	247	142	88	73
Winter	461	134	368	152	649	144	586	119	355	108
Spring	301	132	266	155	397	142	339	110	269	114
Summer	245	96	161	78	246	81	380	120	264	98
Autumn	316	94	307	122	436	101	314	69	234	72
Year	1273	109	1036	119	1657	113	1609	102	1032	89

Key						
	Driest on record	Top 10 driest	Dry: Ranked in lower third of all years	Middle: Ranked in middle third of all years	Wet: Ranked in upper third of all years	Top 10 wettest	Wettest on record

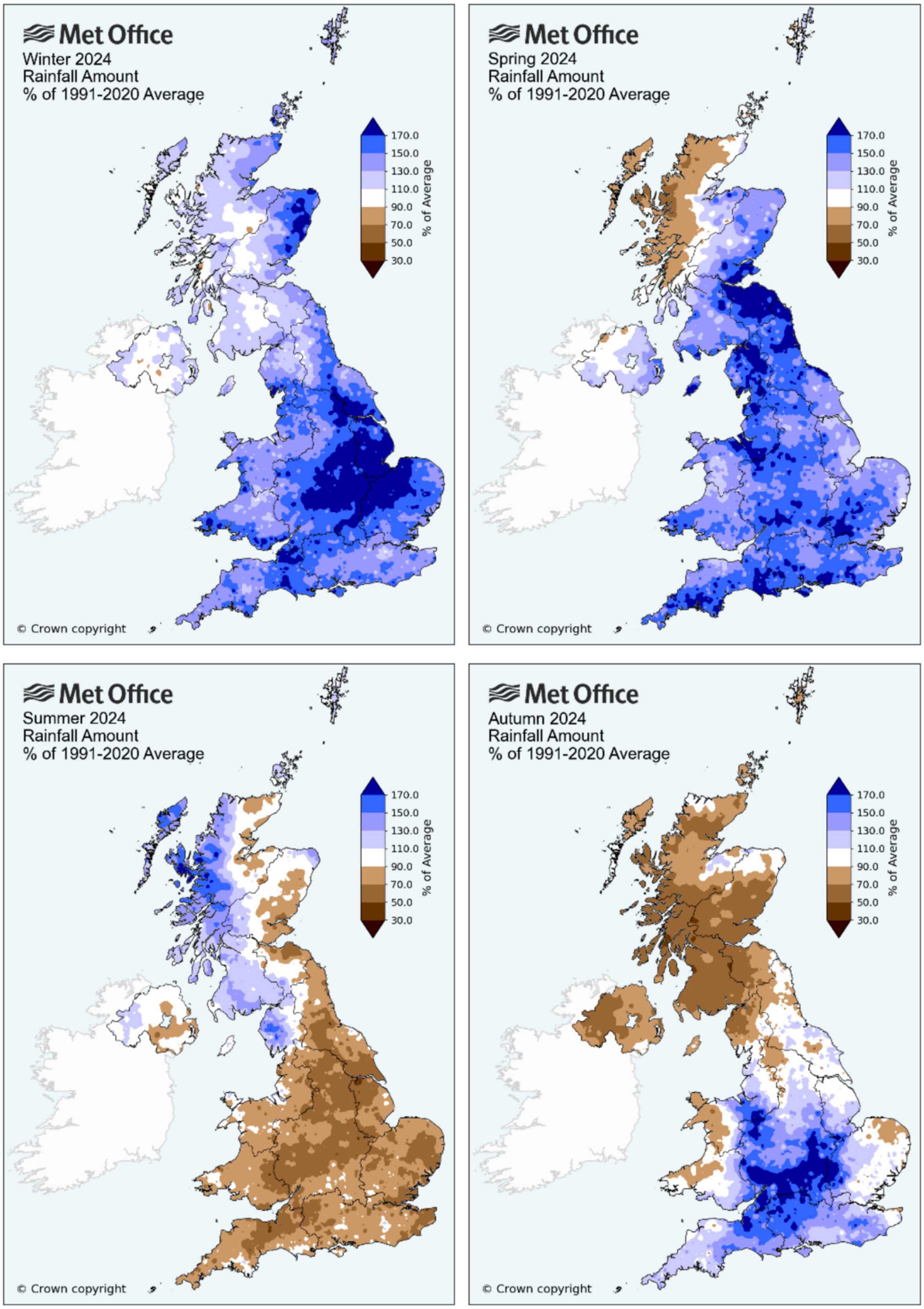


FIGURE 21 | 2024 seasonal rainfall anomalies (%) relative to 1991–2020. Winter refers to the period December 2023 to February 2024.

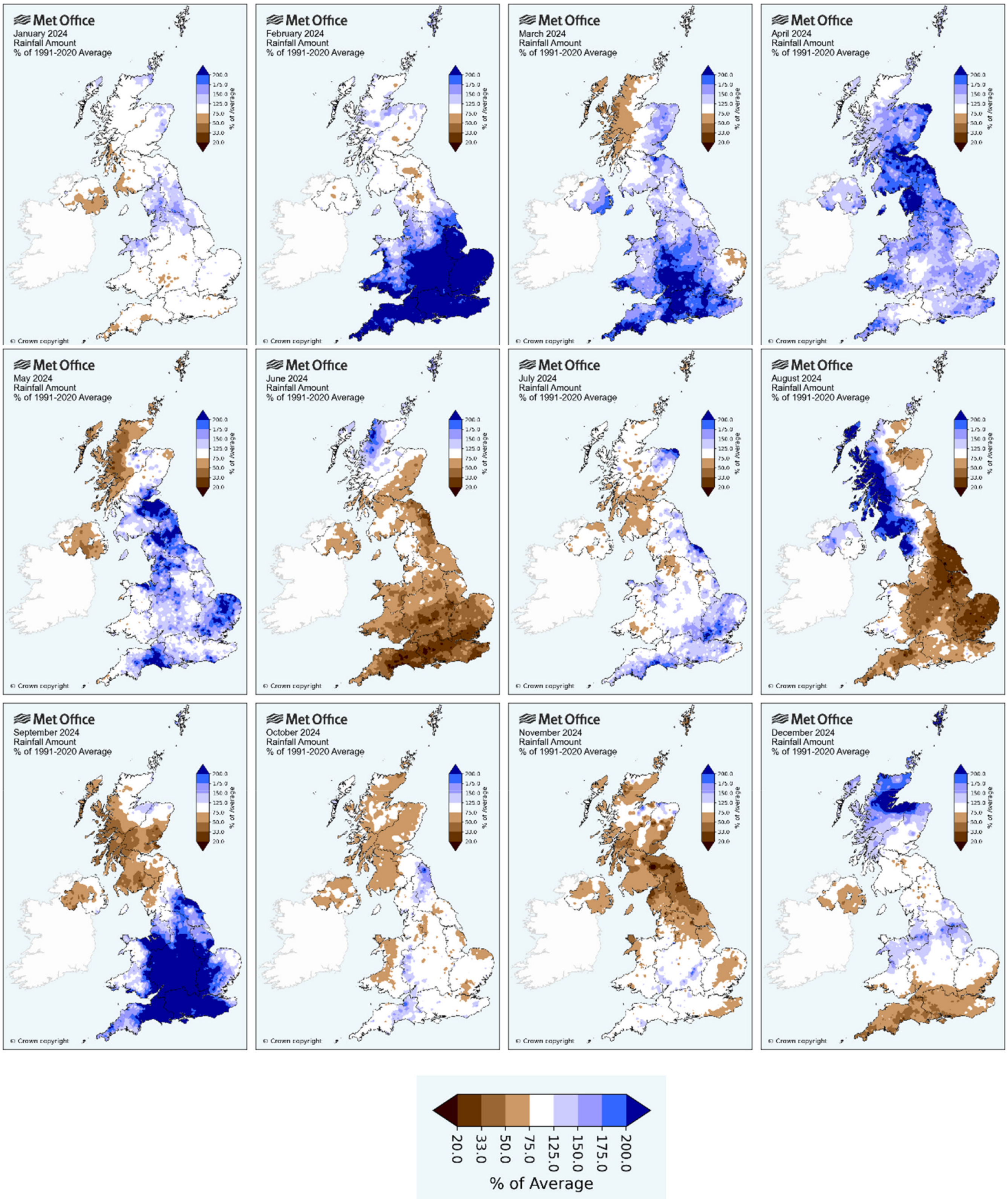
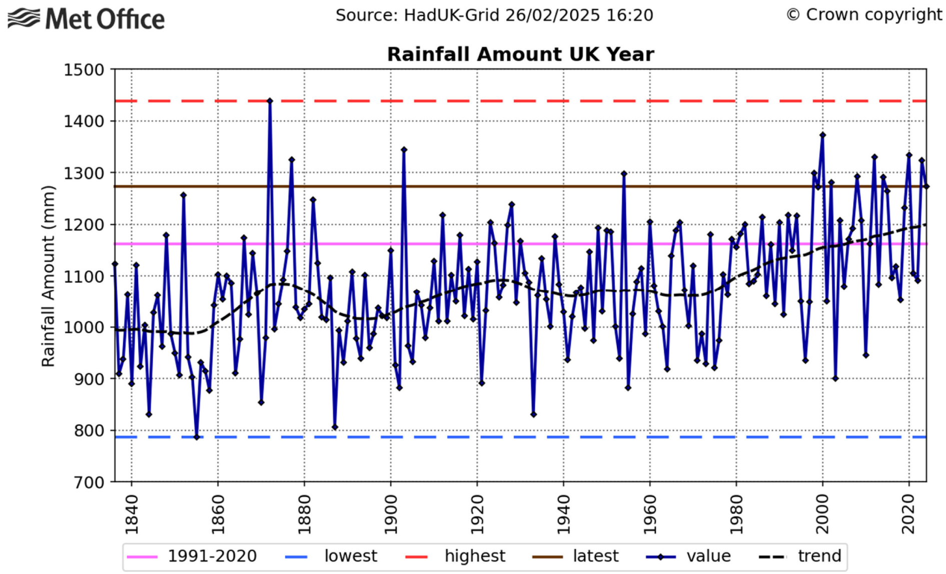


FIGURE 22 | 2024 monthly rainfall anomalies (%) relative to 1991–2020. For a detailed map of September see Figure 43.

There are potential issues with the estimation of winter rainfall early in this series relating to the treatment of snow, before systematic meteorological observing networks were established, which could be associated with an underestimation (Murphy et al. 2020). The lower number of rain-gauges earlier in the series used to construct EWP and how well they represent the wetter upland parts of western Britain (where winter rainfall is likely to be higher) could also be a factor. Summer rainfall trends in the 18th and early 19th century are also subject to some uncertainty and possibly overestimated (Murphy et al. 2020).



	1901-1930	1931-1960	1961-1990	1991-2020	2015-2024	2024
UK	1075	1064	1084	1163	1189	1273
England	832	825	820	870	904	1036
Wales	1380	1365	1380	1465	1525	1657
Scotland	1395	1380	1444	1573	1579	1609
Northern Ireland	1097	1084	1090	1156	1169	1032

FIGURE 23 | Annual rainfall (mm) for the UK, 1836 to 2024. The table shows actual values for the UK and countries. While the series extends back to 1836, averages are shown back to 1901–1930 since network coverage before this reduces (see Figure A3). Charts for individual months and seasons are available at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-temperature-rainfall-and-sunshine-time-series.

TABLE 7 | Seasonal, annual, and winter and summer half-year rainfall percentage of average values relative to 1961–1990 and 1991–2020 for the UK and countries for the **decade 2015–2024**. Oct-Mar 2015–2024 first winter half-year is October 2014 to March 2015, last winter half-year is October 2023 to March 2024, that is, in the same way as winter. Colour coding corresponds to the percentage of average values as given in the key below.

	1961–1990					1991–2020				
	UK	**England**	**Wales**	**Scotland**	**N Ireland**	**UK**	**England**	**Wales**	**Scotland**	**N Ireland**
Winter	121	117	121	125	112	106	108	111	104	104
Spring	98	97	100	99	100	98	103	101	93	97
Summer	110	105	108	114	120	101	96	97	105	106
Autumn	107	117	108	98	100	102	107	103	97	99
Year	110	110	111	109	107	102	104	104	100	101
Oct-Mar	116	119	116	115	110	106	110	108	102	104
Apr-Sep	103	101	103	104	107	99	98	98	100	101

Key: < 80% | 80% to 90% | 90% to 95% | 95% to 105% | 105% to 110% | 110% to 120% | > 120%

2.3 | Extreme Monthly Rainfall

The extent to which extreme monthly rainfall is changing as the UK's climate warms has major implications for flood risk. To analyse this, we count the total number of county-months for each year for the 97 county areas of the UK (shown in Figure A8) where the rainfall total has exceeded 100%, 125%, 150% etc. of the 1991–2020 monthly average. The monthly rainfall maps shown in Figure 22 provide an indication of the spatial variation and range of monthly rainfall anomalies that would typically

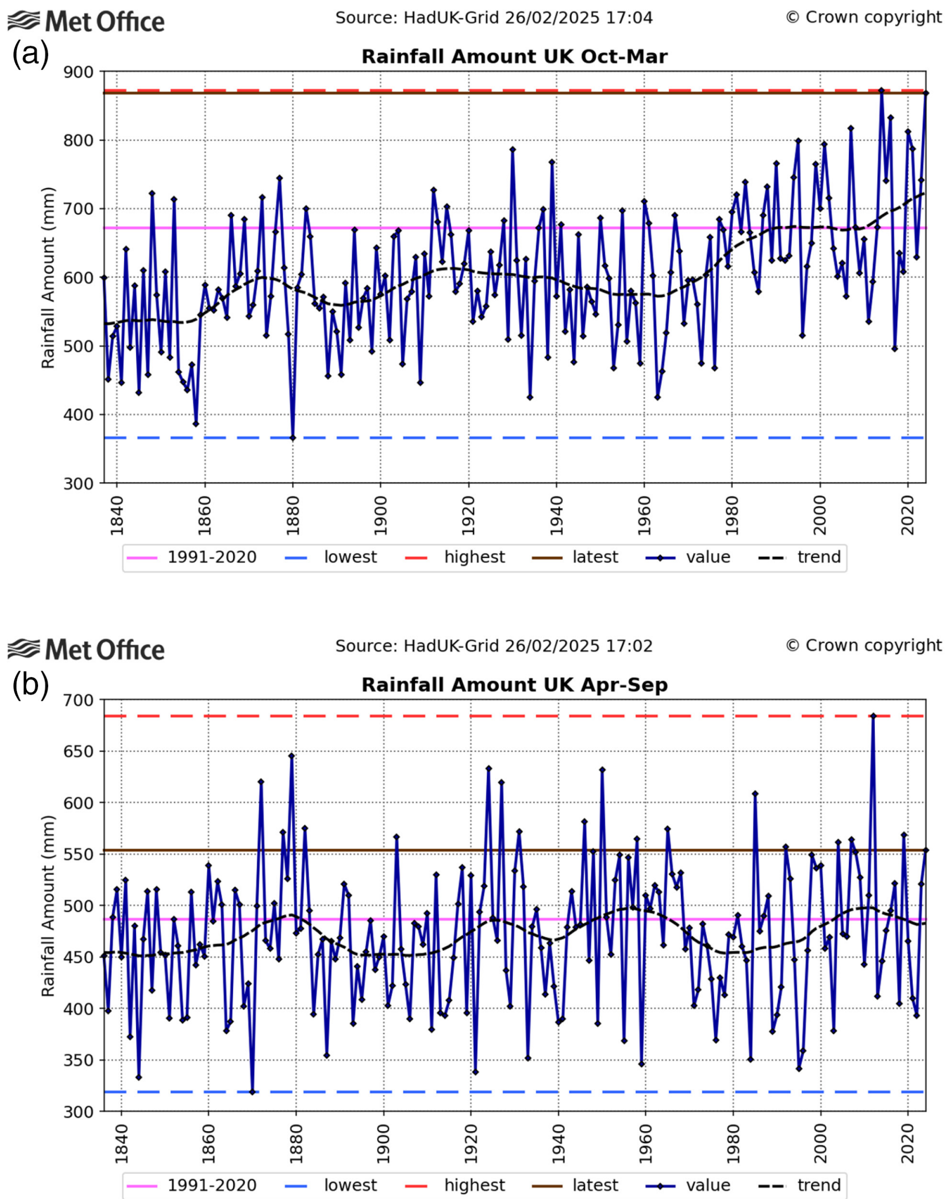
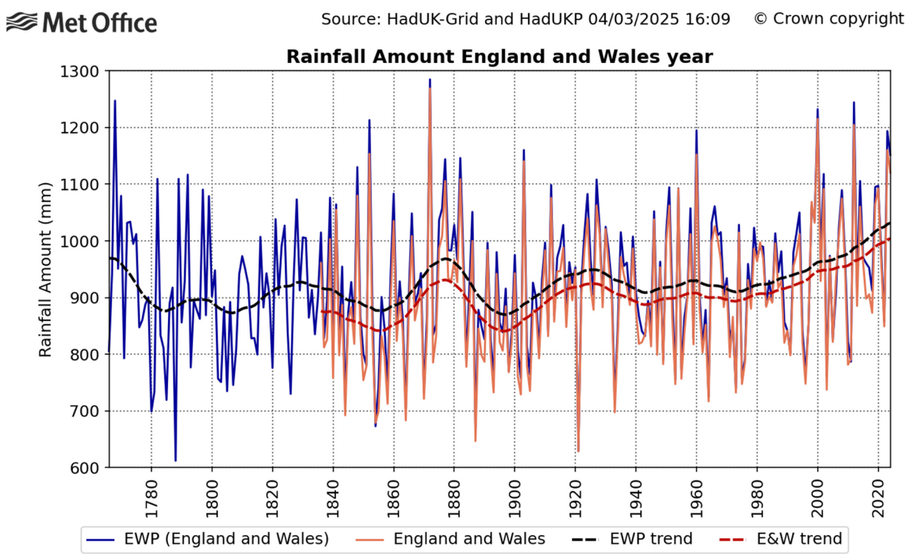


FIGURE 24 | UK half-year rainfall (mm) for (a) October to March 1837 to 2024, (b) April to September 1836 to 2024. Note the y-axis gridline spacing differs between the figures; the winter half-year is wetter on average than the summer half-year.

be expected based on a single year of the UK's climate records; maps for other years are available at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-actual-and-anomaly-maps. Figure 27 shows counts per year of county-months exceeding 150% and 200% of average from 1836 to 2024.

Table 9 presents summary results for the non-overlapping 30-year periods 1901–1930, 1931–1960, 1961–1990, 1991–2020 and the most recent decade 2015–2024. The total number of stations in the network for 1901–1930 is higher than for 2015–2024 (Appendix A: HadUK-Grid Dataset), so even with some clustering of stations in this earlier period, county-level statistics should be reasonably captured. Recently available monthly rainfall data from the Rainfall Rescue Project (Hawkins 2023, Hawkins et al. 2022) have vastly improved station network coverage in the HadUK-Grid dataset before 1961 and, hence, associated confidence in area-average statistics such as presented here. It is probable that the vast majority of historical monthly rainfall data have now been included, with further significant additions to HadUK-Grid monthly rainfall unlikely (this is ***not*** true for daily rainfall).

Although there is large annual variability, both time-series show an upward trend from around the 1980s. Table 9 confirms the greatest proportional changes are for the highest anomalies. Comparing the most recent decade 2015–2024 to 1961–1990, the average number of county-months per year with above average rainfall has increased by 15%, whereas the number with at least 1.5× average has increased by 30%, the number with at least 2× has increased by over 50%, and the number with at least 2.5× has doubled. The counts for 1901–1930, 1931–1960 and 1961–1990 are all broadly similar, suggesting that the 30-year period 1961–1990 is reasonably representative of the majority of the 20th Century.



	1901-1930	1931-1960	1961-1990	1991-2020	2015-2024	2024
EWP (England and Wales)	931	920	915	971	1017	1152
England and Wales	906	898	897	951	989	1120

FIGURE 25 | Annual rainfall for England & Wales (EWP) 1766 to 2024, and England and Wales from HadUK-Grid dataset, 1836 to 2024. The table shows actual values (mm).

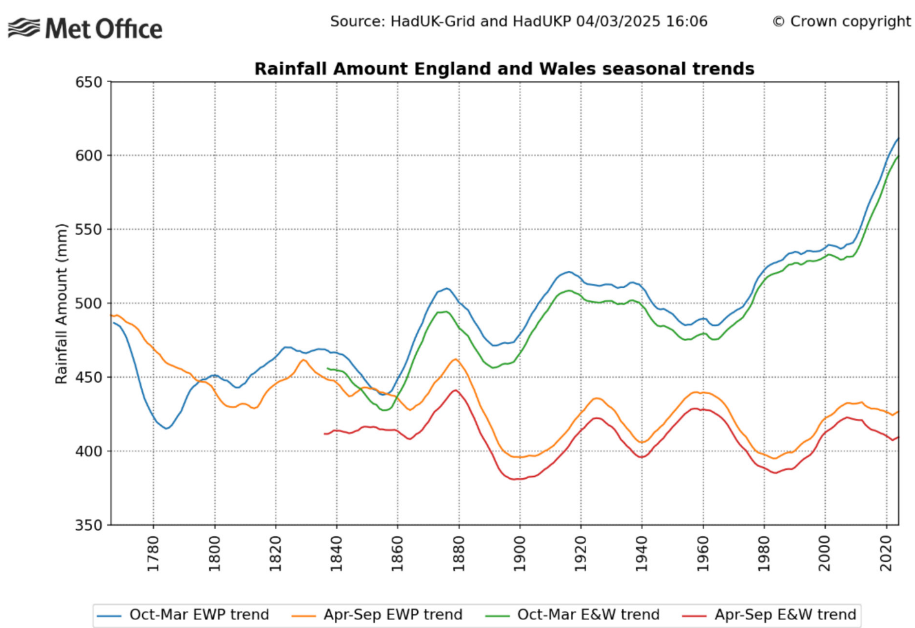


FIGURE 26 | Trends in the EWP series (mm) for the winter and summer half-years from 1766 to 2024 (winter and October–March 1767 to 2024) showing the smoothed trends for each series using a weighted kernel filter described in Appendix B: Time-Series and Trends Shown in This Report. The equivalent England and Wales series (E&W) from the HadUK-Grid dataset are also shown.

2.4 | Days of Rain and Rainfall Intensity

Figure 28a–c shows the UK area-average annual number of days of rain greater than or equal to 1 mm (RR1), 10 mm (RR10) and rainfall intensity on wet days (the annual total precipitation on days with ≥ 1 mm divided by the annual count of days with ≥ 1 mm). Due to the large step down in station network density going back in time from 1961 to 1960, these series are shown from 1961, even though daily rainfall grids in the HadUK-Grid dataset extend back to 1891 (see Appendix A: HadUK-Grid Dataset). The table compares UK values for 1961–1990, 1991–2020 and the most recent decade 2015–2024.

These are relatively short series with large annual variability, but nevertheless they all suggest an increase in the number of days of widespread heavy rain in the last few decades. The rainfall intensity series is fairly well correlated with the RR10 series (positive correlation, R^2 value 0.73) as would be expected because in

TABLE 8 | The 10 wettest winter 'half-years' in the EWP series from 1767. 'Half-year' refers to October to March. 2024 refers to October 2023 to March 2024 and so forth.

Year	Total (mm)
2024	827
2001	810
2014	748
2020	718
1930	716
1995	678
1877	677
1912	668
2021	667
2016	666

years with a large number of very wet days (≥ 10 mm) the average rainfall intensity on wet days (≥ 1 mm) is higher. These series do not distinguish between upland and lowland parts of the UK, nor do they take into account seasonal variations. However, in common with the UK annual rainfall series, the upward trends in UK days of rain RR1 and RR10 are both due to the winter half-year (October to March), with no trend in the summer half-year (April to September)—for brevity not included in this report. In 2024, the number of days of rain RR1, RR10 and the rainfall intensity were all well above the 1991–2020 average.

2.5 | Extreme Daily Rainfall

Any analysis of extreme daily rainfall is constrained by the limitations of data available. Because heavy rainfall can be highly localised, a network of several thousand rain gauges is required across the UK to reasonably capture the spatial variation, and even then rainfall events may fall between gauges. Figure 29a,b shows the number of days each year from 1961 onwards where the rainfall total has exceeded the 95th and 99th percentiles for wet days (≥ 1 mm). As for days of rain and rainfall intensity, years before 1961 have been excluded because of the large step down in station network density from 1961 to 1960.

The limitation of the length of these series emphasizes the importance of future digitisation work before 1961. Earlier years will include a number of extreme daily rainfall events (such as the Norfolk rain storm of August 1912) which have been captured by observations but are yet to be digitized and fully included in the HadUK-Grid dataset (British Rainfall Organization 1913). Events such as this from over a century ago are a reminder that extreme rainfall has occurred in the UK prior to any influence from the warming climate. They demonstrate the importance of a long-term perspective on the variability of UK rainfall extremes in order to fully quantify the climate change signal.

These percentiles are calculated at each grid point based on rainfall totals over the period 1961–1990 on wet days—days exceeding 1 mm of rain; the UK value is the areal average of the number of days calculated at each grid point. The 95th percentile series is highly correlated with the RR10 series (positive correlation, R^2 value 0.81). In common with the RR1, RR10, and rainfall intensity series, these rainfall percentile series are relatively short with large annual variability. However, despite the caveat noted above, they do show a rising trend, from 7.7/1.6 days for 1961–1990 to 9.3/2.0 days for the most recent decade 2015–2024—although statistics for 1901–1930 and 1931–1960 would increase confidence in this result. 2024 was the third highest year in both series.

2.6 | Snow

Table 10 counts the number of stations across England, Wales, Scotland and Northern Ireland recording snow depths ≥ 5 cm by day through 2024. This provides an indication of the most notable spells of snow through the course of the year.

The two main events were in the second half of both January and November. The January event mainly affected northern Scotland, with a northerly flow bringing an Arctic Maritime air mass. There were significant accumulations in areas exposed to snow showers from the north, with 20 cm in Shetland and 10 to 30 cm or more across Caithness and Sutherland. However, little snow reached as far south as Scotland's Central Belt and the cold air was eventually swept away by storm *Isha*. In November a northerly airflow brought another cold spell with more significant snowfalls across the UK—including fairly widespread lying snow across England and Wales. Depths reached 10 to 20 cm in parts of the Peak District and a low pressure system running through the English Channel brought lying snow to parts of south-west England (see cover image). This was the UK's most significant November snow event since 2010.

Figure 30 shows the count of station-days where snow depth sensors in the UK recorded greater than or equal to 10 or 20 cm of lying snow. These data have not been adjusted for network size; consequently they are indicative but not homogeneous– the 2024 network is less than half that of the 1960s to 1990s. These data clearly show the decline in the number and severity of snow events since the 1960s. 2024 saw more snow than several other recent years—2016, 2019, 2020 and 2022 but was less snowy than others, notably 2021, 2018, 2013, 2010 and 2009.

Since the start of the 20th Century, the UK's most severe spells of wintry weather (and the coldest UK months) occurred in January 1963 and February 1947. The 1960s had a greater frequency of snowfalls and blizzards than any decade since the 1860s and 1870s (Wild et al. 2000) and there were also some very substantial snow events with very low temperatures through the 1970s and 1980s (see, e.g., Sholl 2020). 2010 was the snowiest year by far for the UK in the last two decades, comparable to several snowy years in the 1970s and 1980s.

3 | Sunshine

2024 was not a sunny year. The UK annual total was 1281 h, only 91% of the 1991–2020 average and equivalent to a deficit

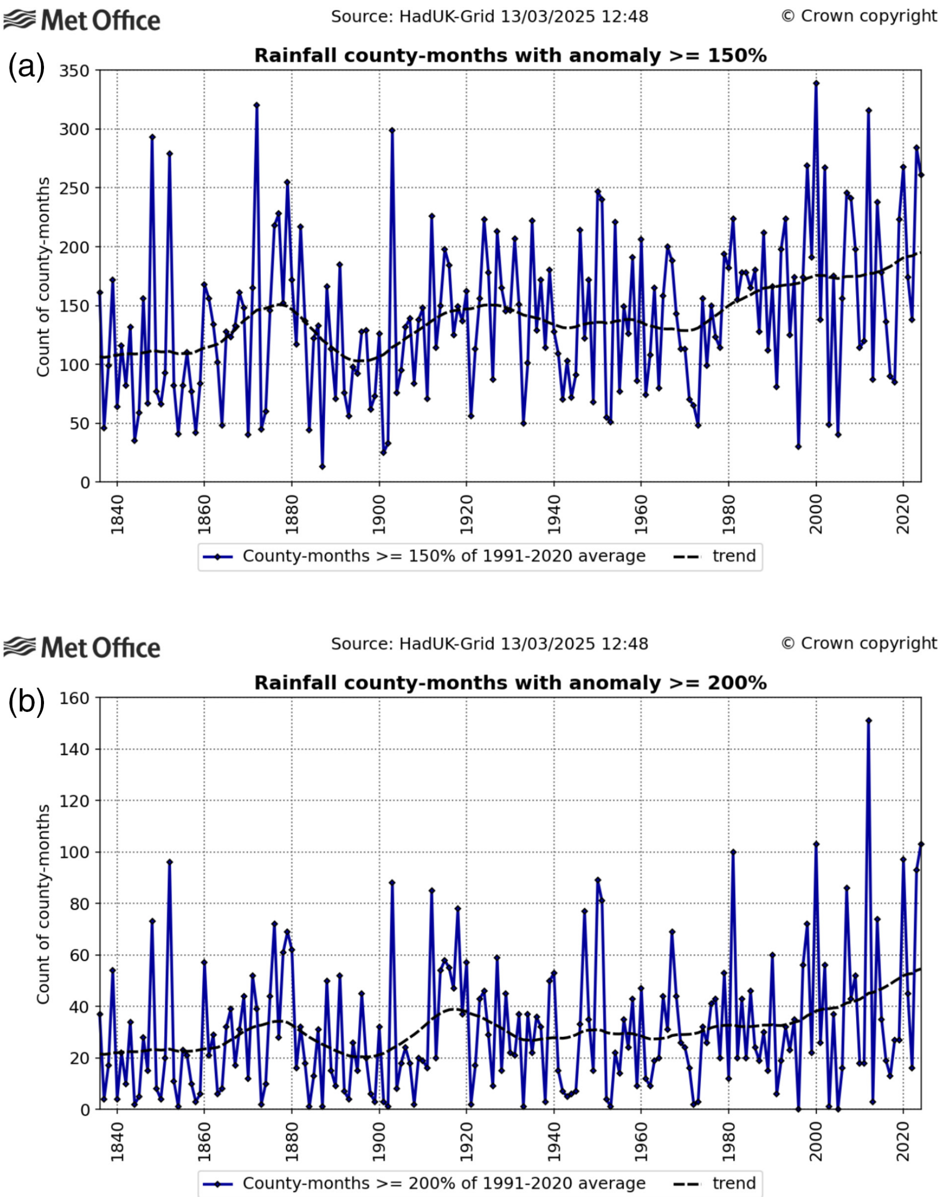
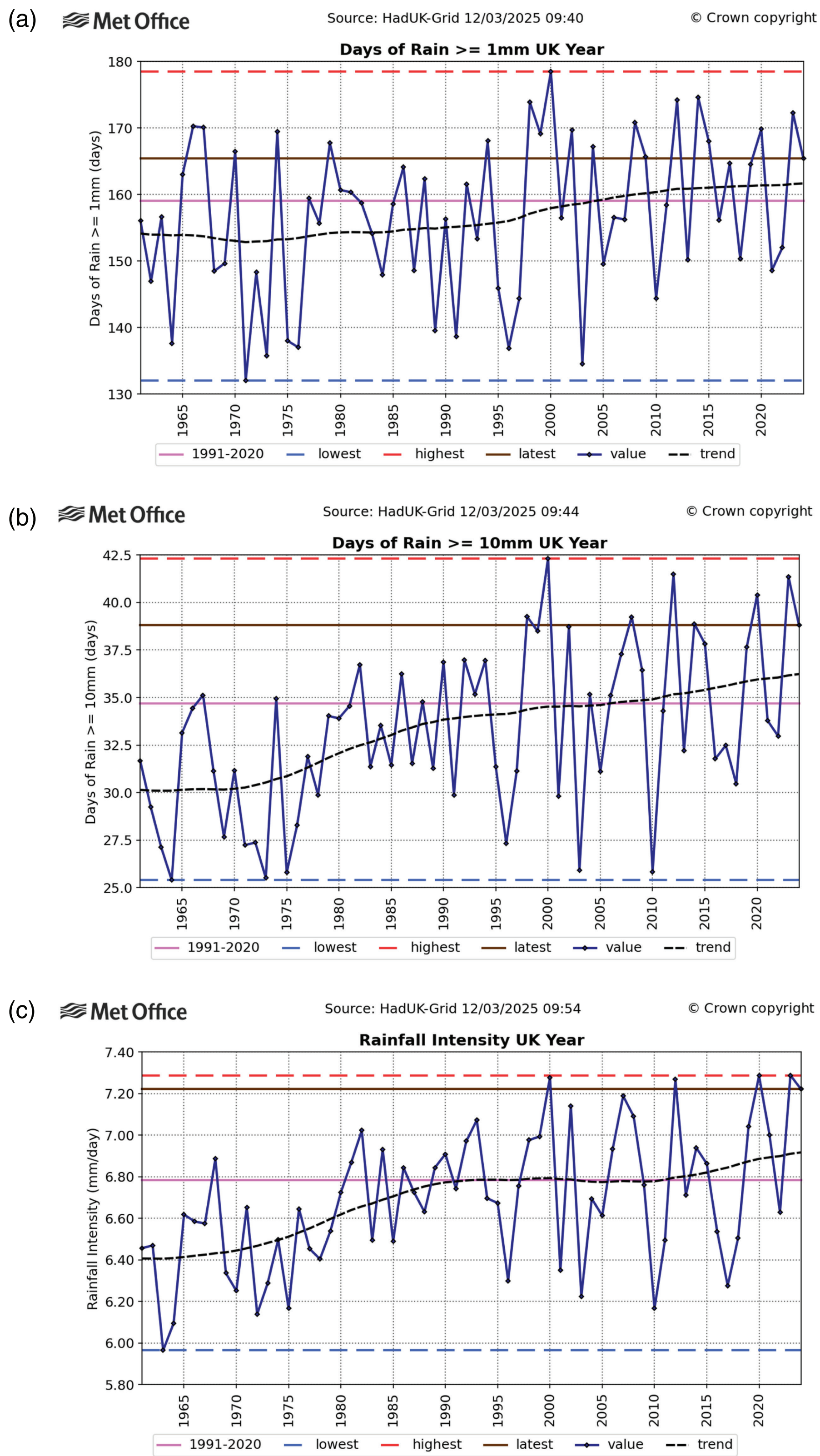


FIGURE 27 | Number of county-months per year for all UK county areas in which monthly rainfall anomalies for that county are at least (a) 150% and (b) 200% of the 1991–2020 monthly average.

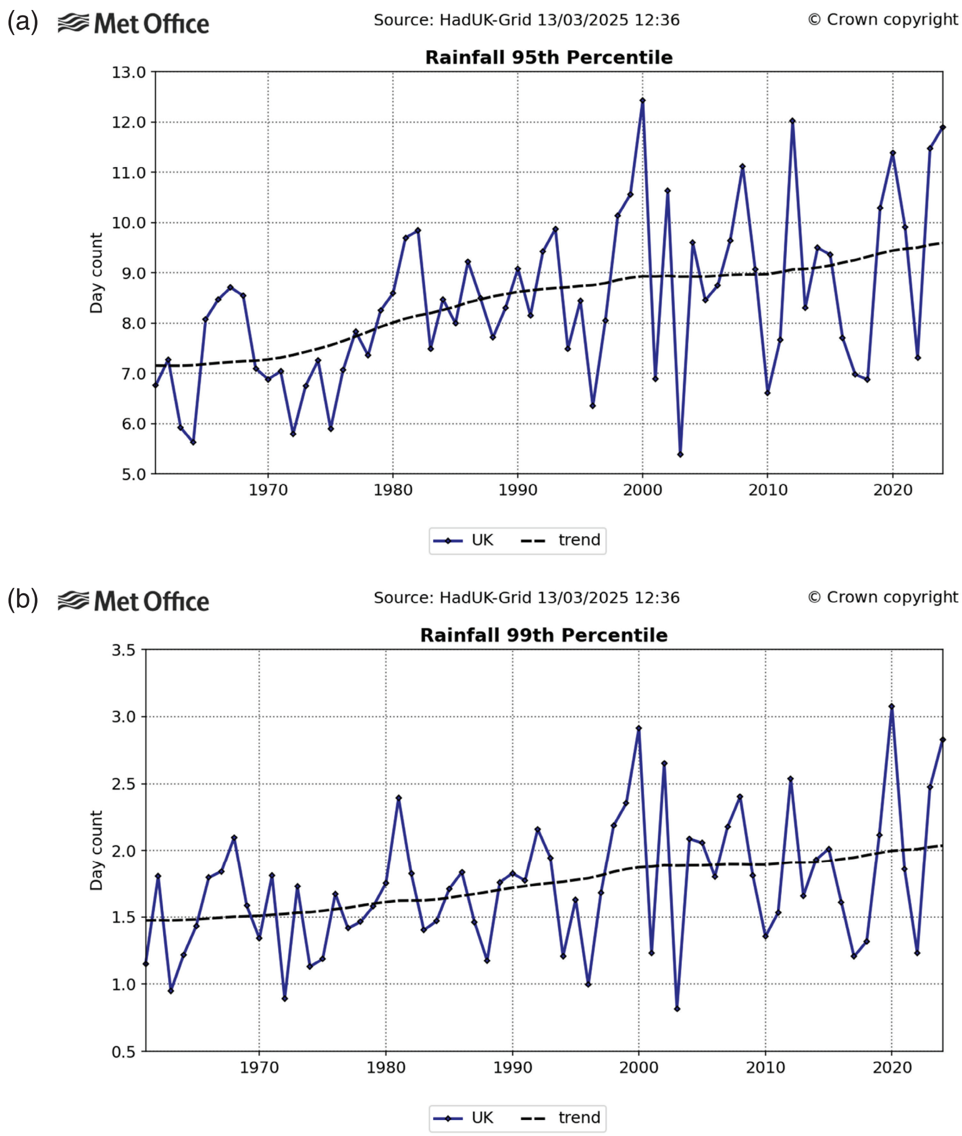
TABLE 9 | Average count of the number of county-months per year in which the monthly rainfall for each county of the UK is at least 100%, 125%, 150%, and so forth, of the 1991–2020 average, for the periods 1901–1930, 1931–1960, 1961–1990, 1991–2020 and 2015–2024.

	1901–1930	1931–1960	1961–1990	1991–2020	2015–2024	2015–2024 percentage of 1961–1990	2015–2024 percentage of 1991–2020
100	470	478	481	527	554	115	105
125	267	272	273	320	331	122	103
150	139	137	141	172	184	130	107
175	71	64	68	84	97	142	115
200	33	29	31	39	48	154	122
225	15	11	13	18	25	190	143
250	5.6	4.4	5.3	7.6	11.4	216	151



	1961-1990	1991-2020	2015-2024	2024	2015-2024 anom wrt 1961-1990	2015-2024 anom wrt 1991-2020
Raindays >= 1mm (days)	154	159	161	165	7	2
Raindays >= 10mm (days)	31	35	36	39	4	1
Rainfall intensity (mm/day)	6.6	6.8	6.9	7.2	0.3	0.1

FIGURE 28 | Annual days of rain (a) ≥ 1 mm and (b) ≥ 10 mm and (c) rainfall intensity (mm/day) for the UK, 1961 to 2024. The table shows actual values for the UK, with anomaly values for 2015–2024.



	1961-1990	1991-2020	2015-2024	2024
95% (days)	7.7	8.9	9.3	11.9
99% (days)	1.6	1.9	2.0	2.8

FIGURE 29 | UK mean number of days each year where rainfall totals have exceeded (a) the 95th percentile and (b) the 99th percentile. The table shows values for the UK.

of 10 h per month, on average. The sunshine pattern was variable but it was generally dullest in the west with less than 90% fairly widely (Figure 31). The UK had its dullest year since 1998, bucking a trend of increasing sunshine in recent decades (Figure 32). Wales had its dullest year since 1981 with only 86% of the average.

The year began on a promising start with a sunny January, the seventh sunniest in the UK series from 1910 (the Januarys of 2022 and 2023 were ranked third and fourth sunniest respectively). This was followed by a succession of dull months, with less than 90% in February to May, July and November to December (Table 11). September was sunny in north-western parts of the UK, coinciding with a marked north (dry) to south (wet) contrast in rainfall patterns and exceptional rainfall across England (Figure 43). This north-west to south-east contrast in both rainfall and sunshine in September 2024 is a fairly frequent pattern seen in the UK's climate observations. The UK received only 24 h of sunshine in December 2024, less than 1 h/day on average making this the UK's gloomiest calendar month since January 1996. Several stations in northern Scotland, Cumbria and North Wales recorded around 10 h, or less, for the whole month.

Annual sunshine totals for the UK have increased from the 1980s onward, with the most recent decade 2015–2024 3% sunnier than 1991–2020 and 8% sunnier than 1961–1990. The annual trend is primarily due to increases in winter and spring, particularly across England (Table 12). There is currently no trend in summer sunshine for the UK overall.

These decadal statistics will reflect annual and decadal variability in the UK's climate in addition to the overall increasing

TABLE 10 | The snowiest days of the year 2024. The table lists dates where 10 or more stations across the UK recorded a snow depth at 0900UTC ≥ 5 cm on that day. The indicative number of snow observing sites in 2024 for each country (based on data availability) is also given in brackets.

Date	England (89)	Wales (17)	Scotland (53)	Northern Ireland (13)	Total (172)
16/01/2024		1	15	1	17
17/01/2024	1	1	20		22
18/01/2024	1	1	25	1	28
19/01/2024	1	1	24	2	28
19/11/2024	8	3	3		14
20/11/2024	5	1	8	1	15
21/11/2024	5	1	13	1	20
22/11/2024	6	1	12	1	20
23/11/2024	7		10	1	18
Key					
Stations	1-9	10-19	20-29	30-39	40+

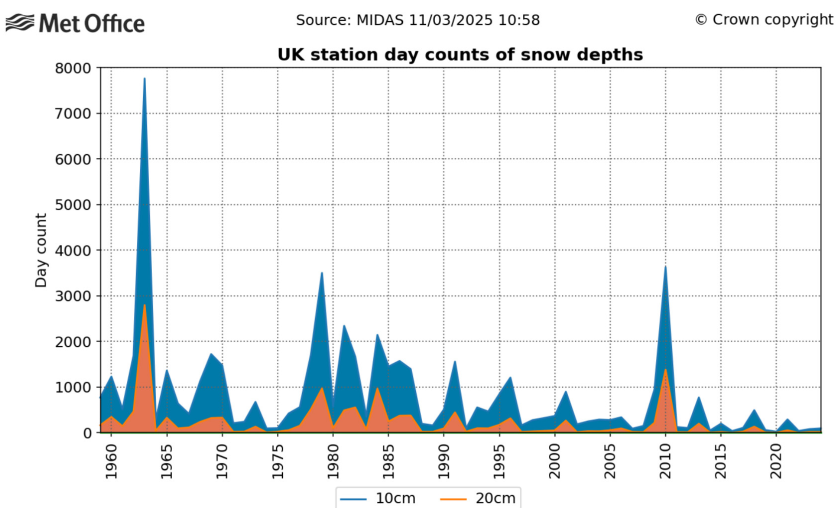


FIGURE 30 | Count of number of station-days per year in the UK with recorded snow depths ≥ 10 and 20 cm, excluding stations above 500 m above sea level. This series has not been adjusted for network size. The 2024 values are 95 (10 cm) and 18 (20 cm).

sunshine trend. They will be influenced by a combination of natural variability and circulation changes, as well as other regional and global drivers such as those contributing to global dimming and brightening trends including direct and indirect response to aerosols (Wild 2009). Christidis et al. (2016) found evidence of human influence on winter sunshine extremes in the UK with the increase in winter sunshine most likely to be explained by reduced aerosol emissions.

The sunshine network is relatively sparse (Appendix A: The Observing Network in 2024). Areas such as Highland Scotland and central Wales have relatively few observations, and 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.

4 | Wind

4.1 | Mean Wind Speed

The UK's annual mean wind speed based on the HadUK-Grid dataset shows a downward trend through the 1980s and 1990s (Figure 33). This series from 1969 to 2024 is unfortunately relatively short and must be interpreted with some caution as it has not been rigorously assessed for long term homogeneity. Observations of annual mean wind speed may be significantly affected by changes in the observing network and in the exposure of sites over time.

The UK trend is broadly consistent with that documented globally. The 2021 BAMS state of the global climate report

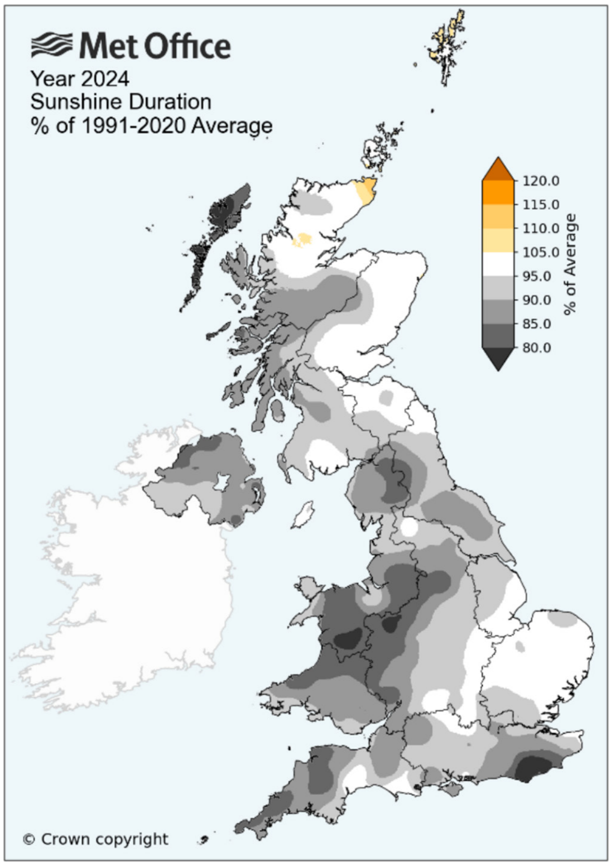


FIGURE 31 | Sunshine anomaly relative to 1991–2020 for year 2024. Maps for individual months and seasons are available at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-actual-and-anomaly-maps.

(Blunden and Boyer 2022) shows that on a continental and global scale prior to around 2010 there was a widespread and general slowdown of near-surface winds termed 'global stilling'. More recently there are some indications of a reversal of this trend (Zeng et al. 2019), although the reversal may be lower due to errors in encoding of calm periods in near-surface wind speeds for many stations in Europe and Asia (Dunn et al. 2022).

4.2 | Extreme Wind Speed

The western European storm naming group, an initiative between the Met Office, Met Éireann and KNMI (the Irish and Dutch national weather services) has been naming storms affecting the UK since autumn 2015. Storm naming improves the communication of severe weather warnings through the media and government agencies by using a single authoritative system. Storms are named based on a combination of both their impact, and the likelihood of those impacts occurring, taking into account wind, rain or snow. The number of named storms from year-to-year should not be used as a climate index in its own right because the system has been in place for only a relatively short time, and the criteria for naming storms have changed since the scheme was first introduced.

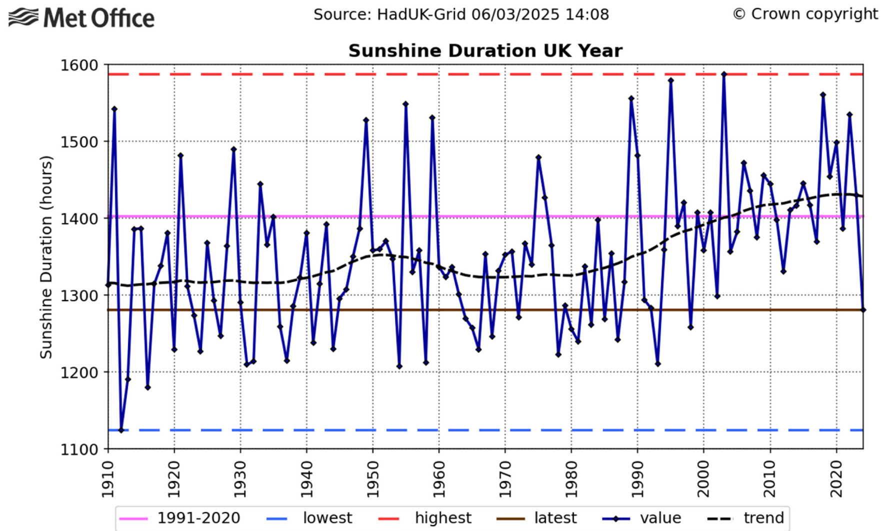
Named storms of year 2024 are listed in Table 13, the windiest days in Table 14. Overall there were nine named storms in 2024; five for the 2023–2024 season and four for the 2024–2025 season. In August, the 12th and last storm of the 2023–2024 season, *Lilian*, was the first time 'L' has been reached since storm naming was introduced in autumn 2015. The most severe of these storms were *Isha* and *Darragh*, each of which saw red warnings issued. *Darragh* is described in Section 7.4.

Henk brought damaging winds to south Wales and southern counties of England, with a gust of 70 Kt (81 mph) at Exeter Airport. However, the worst impacts were from flooding as the storm came soon after *Gerrit* in late December 2023, with major river catchments such as the Severn and Trent affected. See Section 7.1 for the exceptionally wet winter half-year October to March. *Isha* was the UK's most powerful wind storm since *Eunice* on 18 February 2022 (see Figure 52 for a chart of this storm). As typically occurs with severe storms it was influenced by a particularly strong jet stream intensified by a large temperature contrast across the North American continent as a pool of cold air over Canada moved south. Winds gusted widely at 60 to 70 Kt or more across the northern half of the UK with the red warning area covering north-east Scotland. *Jocelyn* followed rapidly behind *Isha*. Overall it was less severe but hampered clean-up efforts and brought some extremely strong winds across upland areas with gusts well over 100 Kt (115 mph) including the UK's highest recorded mountain gust of the year. While *Bert* brought significant wind impacts, this storm also saw the worst impacts from flooding, see Section 7.3.

Major storms are to be expected as a normal part of the UK's climate due to the country's geographical position relative to the jet stream and associated Atlantic storm track. Any storm analysis is complex because it depends on severity, spatial extent and duration. However, most Atlantic storms are large-scale systems having widespread impacts. Figure 34 counts the number of days each year on which at least 20 stations recorded gusts exceeding 40/50/60 Kt (46/58/69 mph). This is a useful measure of storminess although these series are relatively short; nonetheless, it does illustrate the year-to-year and decadal variations. Localised convective gusts will not contribute, nor will storms where the strongest winds are confined to a relatively small region of the UK.

The most recent two decades have seen fewer occurrences of maximum gust speeds above these thresholds than during the previous decades, particularly comparing the period before and after 2000. For the UK overall there are no storms in recent years which compare in severity with exceptional storms in the observations such as the 'Burns' Day Storm' of 25 January 1990, the 'Boxing Day Storm' of 26 December 1998 and the 'Great Storm' of 16th October 1987. The number of named storms affecting the UK each year and these earlier storms from the historical record demonstrate the ongoing risk of exceptionally severe wind storms hitting the UK.

The limitations of these data associated with changes in instrument type, station network size and station exposure for wind measurements mean that Figure 34 should be interpreted with caution. The development of an improved gridded wind gust monitoring product is an area for potential further work. The wind network on which Figure 34 is based comprises around 120 to 130 stations in the 1970s, increasing to 180 stations in the



	1931-1960	1961-1990	1991-2020	2015-2024	2015-2024 % of 1931-1960	2015-2024 % of 1961-1990	2015-2024 % of 1991-2020
UK	1337	1328	1403	1438	108	108	103
England	1437	1430	1538	1580	110	111	103
Wales	1388	1352	1407	1417	102	105	101
Scotland	1169	1165	1200	1234	106	106	103
Northern Ireland	1252	1233	1256	1263	101	102	101

FIGURE 32 | Annual sunshine for the UK, 1910 to 2024. The table shows actual values for the UK and countries (hours) with percentage of average values for 2015–2024. While the series extends back to 1910, averages are shown back to 1931–1960 since network coverage before this reduces (see Figure A4). Charts for individual months and seasons are available at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-temperature-rainfall-and-sunshine-time-series.

1990s before falling back to around 150 stations. The time series in this figure have not been adjusted to take into account this changing network, and this may partially account for the higher station counts in 40Kt gusts through the 1980s and 1990s.

5 | NAO Index

5.1 | Winter NAO

Figure 35 shows the winter (DJF) North Atlantic Oscillation (WNAO) index from 1850 to 2024 inclusive (Appendix A: NAO Index provides details of the WNAO index). This index is a measure of the large-scale surface pressure gradient in the North Atlantic between Gibraltar and Iceland, which determines the strength of westerly winds across the Atlantic, and is the principal mode of spatial variability of atmospheric patterns in this region. When the pressure difference is large, the WNAO is positive and westerly winds dominate with stronger and more frequent storms. When the pressure difference is small, the WNAO is negative with an increased tendency for blocked weather patterns, reducing the influence of Atlantic weather systems.

The WNAO index is therefore associated with winters which are either mild and wet or cold and dry. Detrended UK winter mean temperature (1885 to 2024) is fairly well correlated with WNAO (positive correlation, R^2 value 0.56) indicating that over half the variability can be explained by this index. Very cold winters such as 1963, 1979 and 2010 and mild winters such as 1989 and 2007 correspond to negative and positive WNAO values respectively. This index is therefore an indicator of likely weather types and impacts to affect the UK—winter often being the time when the most impactful weather is experienced (e.g., from severe cold and snow or from strong winds and flooding).

The WNAO index shows a large annual variability but also decadal variability with periods of mainly positive phase (e.g., the 1910s–1920s, 1990s and 2010s onwards) and negative phase (e.g., the 1960s) which are represented by the smoothed trend line. The WNAO index appears currently in a positive phase associated with a run of mostly mild and wet winters since the 2010s. Winter 2024 was WNAO positive, mild and wet overall.

5.2 | Summer NAO

Figure 36 shows the summer North Atlantic Oscillation (SNAO) index from 1850 to 2024 inclusive (Appendix A: NAO Index also provides details of the SNAO index). 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 in summer.

TABLE 11 | Monthly, seasonal and annual sunshine actual values (hours) and percentage of average values relative to 1991–2020 for the UK and countries for **year 2024**. Colour coding corresponds to the rank as given in the key below. The series lengths are 1910–2024 (115 years) except winter which is 1911 to 2024 (114 years).

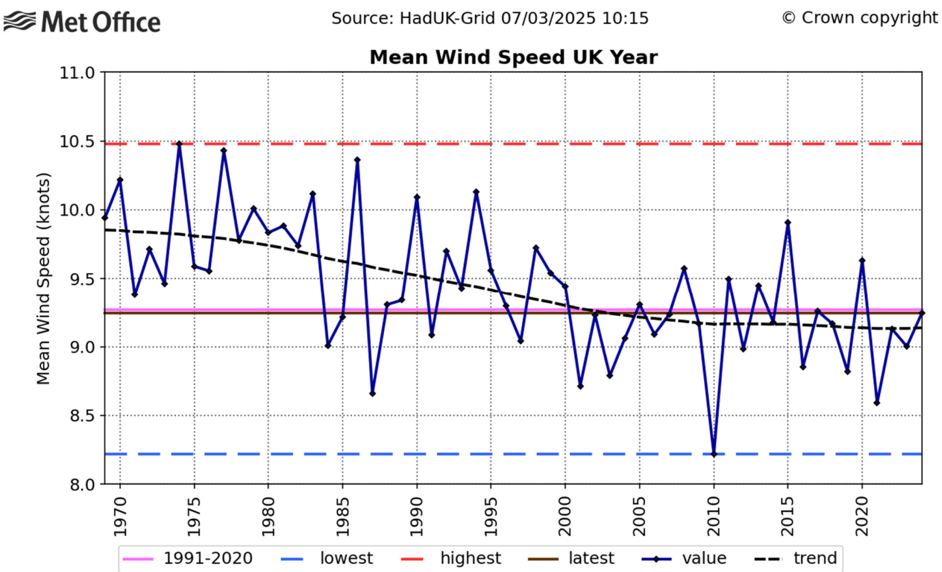
	UK		England		Wales		Scotland		Northern Ireland	
	Actual	**%**	**Actual**	**%**	**Actual**	**%**	**Actual**	**%**	**Actual**	**%**
January	60	126	69	125	58	122	46	131	56	132
February	57	80	53	68	43	63	67	106	64	96
March	97	89	96	82	91	82	102	105	87	86
April	125	80	129	79	115	73	121	86	123	83
May	160	83	171	86	162	85	145	80	139	76
June	178	104	208	111	175	98	140	96	116	77
July	155	89	181	92	152	86	120	85	110	81
August	161	100	185	102	150	94	130	97	131	96
September	123	96	122	87	105	81	126	118	134	119
October	89	97	100	97	97	106	70	94	88	103
November	51	88	56	87	44	79	46	97	37	68
December	24	57	28	54	23	56	19	62	24	62
Winter	144	89	150	82	124	78	139	109	146	99
Spring	382	84	395	82	367	80	369	88	349	81
Summer	495	98	574	102	477	93	390	93	357	84
Autumn	263	95	278	90	246	89	242	106	259	102
Year	1281	91	1397	91	1214	86	1132	94	1108	88

Key						
	Dullest on record	Top 10 dullest	Dull: Ranked in lower third of all years	Middle: Ranked in middle third of all years	Sunny: Ranked in upper third of all years	Top 10 sunniest	Sunniest on record

TABLE 12 | Seasonal and annual percentage of average values relative to 1961–1990 and 1991–2020 for the UK and countries for the **decade 2015–2024**. Colour coding corresponds to the percentage of average values as given in the key below.

	1961–1990					1991–2020				
	UK	England	Wales	Scotland	N Ireland	UK	England	Wales	Scotland	N Ireland
Winter	114	121	103	107	103	104	104	96	104	100
Spring	115	117	113	113	109	106	106	106	106	104
Summer	103	106	101	99	96	101	102	100	101	98
Autumn	105	105	100	107	103	100	100	97	100	100
Year	108	111	105	106	102	103	103	101	103	101

Key							
	< 80%	80% to 90%	90% to 95%	95% to 105%	105% to 110%	110% to 115%	> 115%



	1991-2020	2015-2024	2024
UK	9.3	9.2	9.2
England	8.3	8.2	8.2
Wales	9.8	9.7	9.5
Scotland	10.8	10.7	11.0
Northern Ireland	8.6	8.6	8.6

FIGURE 33 | Annual mean windspeed for the UK, 1969 to 2024. The table shows actual values for the UK and countries (Kt).

The SNAO index tends to be associated with summers which are either cool and wet (negative) or warm and dry (positive). Detrended UK summer rainfall (1850 to 2024) is fairly well correlated with SNAO (negative correlation, R^2 value 0.47). As with its winter counterpart, the SNAO shows periods of mainly positive phase (e.g., the 1970s to 1990s) and negative phase (e.g., the 1880s and 1890s, and recently, the run of wet SNAO negative summers from 2007 to 2012). (Rainfall has been reversed in the figure, that is, dry summers are shown with positive rainfall, wet summers with negative rainfall, for ease of comparison). Recent years have seen some large fluctuations in the SNAO index indicating some markedly contrasting summers.

Importantly, neither the WNAO nor SNAO can fully explain the variability of UK winters or summers because of the complexity of weather types and associated temperature and rainfall patterns through the season across the UK's relatively small spatial scale. The UK winter mean temperature and rainfall series have been detrended in Figures 35 and 36 because the focus here is on how their annual variability relates to that of the WNAO and SNAO when removing the additional effect of climate change.

TABLE 13 | Named storms of 2024, for storms in the 2023–2024 storm season ending August and 2024–2025 season starting September, as named by the western European storm naming group comprising the Met Office, Met Éireann, and KNMI.

Name	Date of impact on UK
Henk	2 January
Isha	21–22 January
Jocelyn	23–24 January
Kathleen	6–7 April
Lilian	22–23 August
Ashley	20–21 October
Bert	22–25 November
Conall	27 November
Darragh	6–7 December

6 | Extremes

6.1 | Annual Extremes

Table 15 documents station extremes for year 2024. Overall, these values are fairly typical for the UK. The wettest day at Glenfinnan occurred during a prolonged spell of extremely wet, windy and disruptive weather across Scotland; several severe flood warnings were issued and Edinburgh's Hogmanay celebrations were cancelled (the last times this happened were in 2003 and 2006). The highest gust speeds at Brizlee Wood and Cairngorm summit occurred during storms *Isha* and *Jocelyn* respectively, the latter in particular indicating the ferocity of conditions that can be experienced across Scotland's mountain summits. The UK's all-time gust record is 150 Kt (173 mph) at this station on 20 March 1986.

Figure 37a,b show the UK's highest maximum and lowest minimum temperatures, by year, across all stations, from 1900. The UK's average highest maximum temperature over the most recent decade 2015–2024, 35.9°C, was 2.3°C higher than 1991–2020 and 4.5°C higher than 1961–1990, much higher than equivalent changes for UK annual mean temperature (0.41°C and 1.24°C) (Table 2)—another illustration of how climate changes has impacted extremes more than mean values. Eight of the 10 years of the most recent decade have seen 34°C reached, whereas this was a comparatively unusual occurrence during the 20th Century.

The UK's average lowest minimum temperature over the most recent decade 2015–2024 was 0.4°C higher than 1991–2020 and 3.9°C higher than 1961–1990. The period 1961–1990 included some particularly extreme cold spells with temperatures falling to −20°C or lower in over half of these 30 years. For comparison, in the 21st Century −20°C has been recorded in just 3 years: 2001, 2010 and 2021.

6.2 | Daily Temperature Extremes for Each Month of the Year

A daily maximum temperature of 19.9°C was recorded at Achfary, Sutherland on 28 January 2024, setting a new January

TABLE 14 | The windiest days of the year 2024. The table lists dates where 20 or more stations across the UK recorded a maximum wind gust greater than or equal to 50 knots (58 mph) on that day. The indicative number of wind observing sites in 2024 for each country (based on data availability) is also given in brackets.

Date	England (96)	Wales (15)	Scotland (35)	Northern Ireland (11)	Total (157)	Named Storm
02/01/2024	30	2	2		34	*Henk*
21/01/2024	45	12	22	11	90	*Isha*
22/01/2024	25	4	29	2	60	*Isha*
23/01/2024	19	5	10	3	37	*Jocelyn*
24/01/2024	18	5	25	2	50	*Jocelyn*
31/01/2024	3	2	20	1	26	
06/04/2024	9	4	11	6	30	*Kathleen*
07/04/2024	6	4	11		21	*Kathleen*
20/10/2024	12	6	21	7	46	*Ashley*
23/11/2024	10	4	8	3	25	*Bert*
24/11/2024	22	6	5		33	*Bert*
07/12/2024	42	11	6	7	66	*Darragh*
21/12/2024	7	3	17	2	29	
22/12/2024	11	4	16	5	36	
Key						
Stations	1–9	10–19	20–29	30–39	40+	

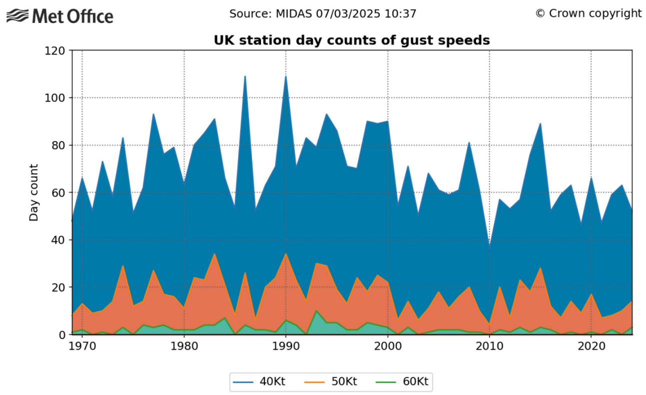


FIGURE 34 | Count of the number of individual days each year during which maximum gust speeds ≥ 40, 50 and 60 Kt (46, 58, 69 mph; 74, 93, 111 kph) have been recorded by at least 20 or more UK stations, from 1969 to 2024. Stations above 500 m above sea level are excluded. The counts for 2024 are 52 (40 Kt), 14 (50 Kt) and 3 (60 Kt). The 14 days in 2024 in which at least 20 stations recorded gusts ≥ 50 Kt are listed in Table 14. The 3 days in 2024 in which at least 20 stations recorded gusts ≥ 60 Kt were 21 and 22 January (storm *Isha*) and 7 December (storm *Darragh*).

record and exceeding the previous record (18.3°C) by a wide margin. Silkstone (2025) describes the foehn mechanisms and detailed meteorology of this event. It is not covered in this report, but we note that high temperature records such as this are to be expected as the UK's climate continues to warm, as supported by evidence from observations in recent years. The UK has recorded its all-time highest maximum temperature (i.e., at any station) for five of the 12 months of the year—January (2024), February (2019), July (2022), November (2015), December (2019) in the most recent decade 2015–2024—and seven of the 12 months since the start of the 21st Century. None of the UK's lowest minimum temperatures on record for the 12 months of the year have occurred in the 21st Century so far.

Table 16 lists the UK's highest recorded station values for each month of the year. All official UK station records are available on the Met Office website at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-extremes. The extremes from February to October listed in the table have occurred in England (most frequently in the south-east). However, those of November, December and January are in Scotland and Wales, where the influence of topography and the foehn effect mechanism can be very pronounced, especially in the winter months. For more details of the verification process for these records, see Appendix A: Quality Control of Record Values.

7 | Significant Weather Events

This section describes notable weather events which occurred during 2024. The choice of event is determined by the National Climate Information Centre, 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, which may be mentioned elsewhere in the report. See Section 4.2 for named storms in 2024.

7.1 | Record Wet October 2023 to March 2024 for England and Wales

Most of central, southern, and eastern England and eastern Scotland recorded over 150% of average rainfall for the six-month period October 2023 to March 2024 (the winter half-year) with over 175% fairly widely and a few locations around 200% (Figure 38). This was in large part due to the sequence of named storms: *Babet, Ciarán, Debi, Elin, Fergus, Gerrit, Henk, Isha*, and *Jocelyn*, with areas affected by flooding including eastern Scotland, Derbyshire, Nottinghamshire, and the West Midlands. Overall, hundreds of properties were flooded, including in major river catchments such as the Trent and Severn, some on several occasions.

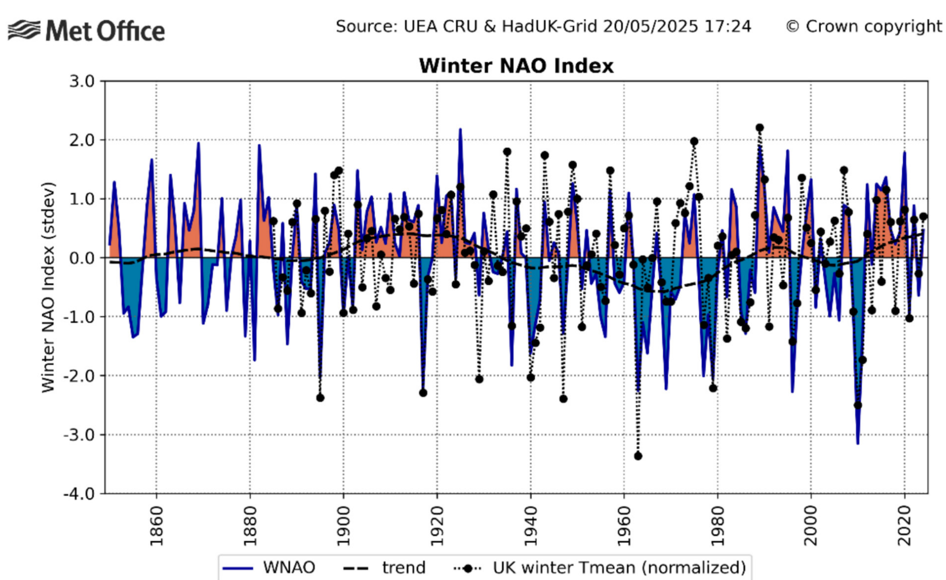


FIGURE 35 | Winter NAO index, 1850 to 2024 based on the standardised monthly mean pressure difference between stations in Gibraltar and south-west Iceland. Winter 2024 refers to the period December 2023 to February 2024. Also shown is normalised detrended UK winter mean temperature from 1885 to 2024.

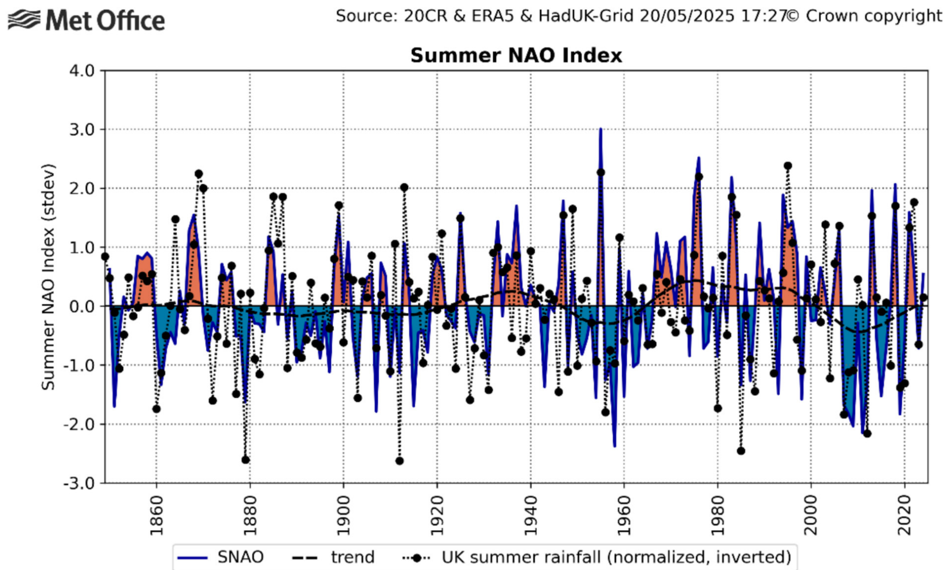


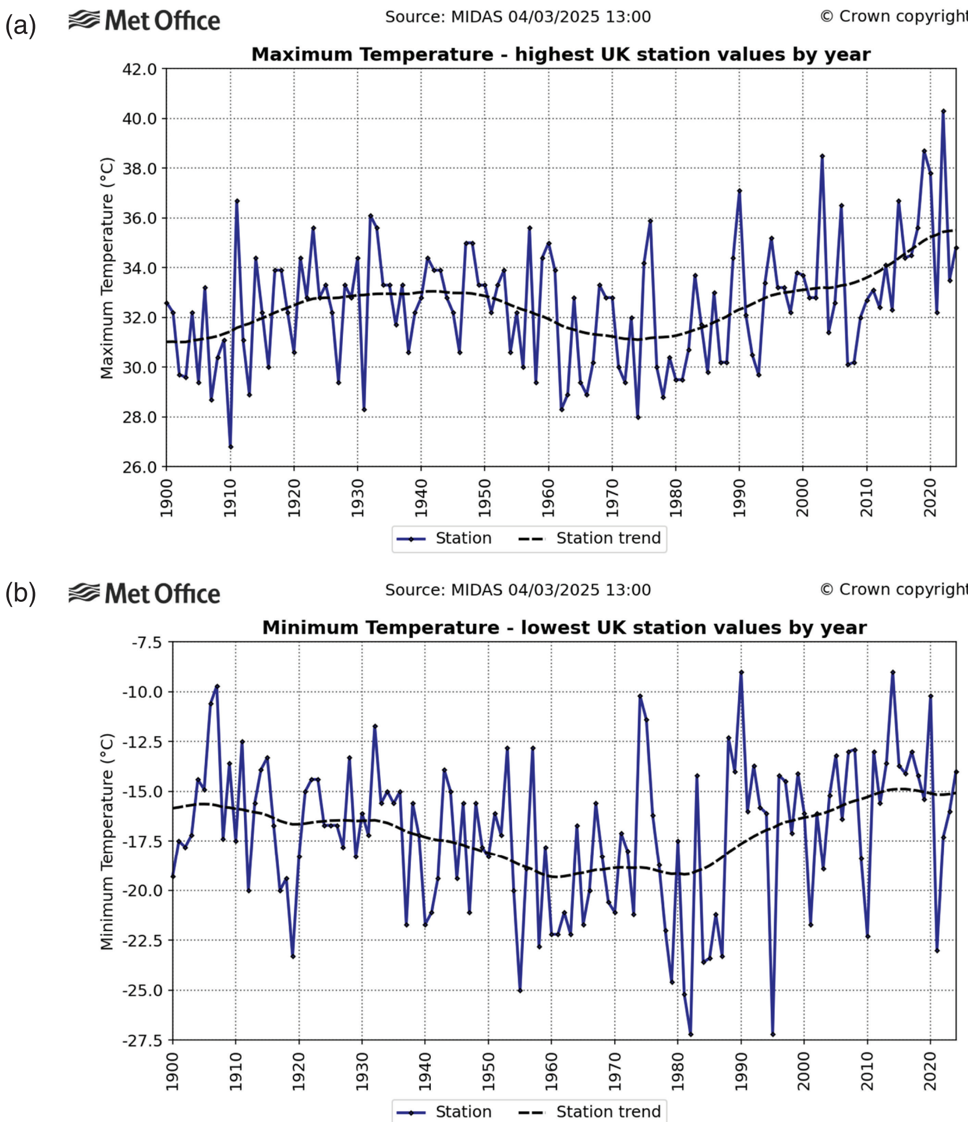
FIGURE 36 | Summer NAO index, 1850 to 2024 based on the standardised monthly mean pressure difference using the 20th Century Reanalysis (Slivinski et al. 2019) and extended to the present day using the ERA5 reanalysis (Hersbach et al. 2020). Summer refers to the period June to August. Also shown is normalised detrended UK summer rainfall, inverted so that negative values correspond to wet summers and positive values correspond to dry summers.

TABLE 15 | Annual extremes for the UK for year 2024. Stations above 500 m above mean sea level (masl) are considered as mountain stations and therefore not representative of low-level areas. They are excluded from the table with the exception of the highest mountain gust. Channel Islands stations are excluded.

Extreme	Value	Date	Station
Highest daily maximum temperature	34.8°C	12 August	Cambridge, NIAB, 26 masl
Lowest daily minimum temperature	−14.0°C	17 January	Dalwhinnie, Inverness-shire, 351 masl
Lowest daily maximum temperature	−4.3°C	10 December	Balmoral, Aberdeenshire, 283 masl
Highest daily minimum temperature	20.9°C	12 August	Gogerddan, Ceredigion, 31 masl, Gosport Fleetlands, Hampshire, 1 masl, Yeovilton, Somerset, 20 masl
Lowest grass minimum temperature	−18.2°C	15 January	Tulloch Bridge, Inverness-shire, 249 masl
Highest daily rainfall (09–09 UTC)	169.2 mm	29 December	Glenfinnan, Inverness-shire, 6 masl
Greatest snow depth (09 UTC)	37 cm	19 January	Altnaharra, Sutherland, 81 masl
Highest daily sunshine	16.1 h	24 June	Dyce, Aberdeenshire, 65 masl
Highest gust speed	86 Kt 99 mph	21 January	Brizlee Wood, Northumberland, 250 masl
Highest gust speed (mountain)	122 Kt 140 mph	24 January	Cairngorm Summit, Inverness-shire 1237 masl

Figure 39 shows the steady accumulation of surplus rainfall above the 1991–2010 average from October 2023 to March 2024, for England and Wales combined, with twice the monthly average falling fairly widely in the months of October, December, February, and March. This combined area of England and Wales had its wettest October to March half-year on record (Figure 40), exceeding October 2000 to March 2001; this also being true for the EWP series from 1767 (Table 8). The six-month total for this area was 149% of the 1991–2020 average, over 250 mm more than average and equivalent to 83% of annual average rainfall for this area.

Figure 38 also shows October 2000 to March 2001 for comparison. The focus of the wettest weather in 2000–2001 was south-east England. The autumn and winter of 2000 saw at that time the UK's most severe and widespread flooding since March 1947 (Marsh and Dale 2002). Autumn 2000 is the wettest autumn in



	1931-1960	1961-1990	1991-2020	2015-2024
Tmax	32.9	31.3	33.5	35.9
Tmin	-17.6	-19.0	-15.5	-15.1

FIGURE 37 | (a and b): UK highest maximum and lowest minimum daily temperature station observations for each year 1900 to 2024. The table shows average values (°C) of the highest maximum and lowest minimum temperature each year for the periods shown. For highest maximum, the figure shows the evolution of the UK national maximum temperature record through time—in 1911 (36.7°C), 1990 (37.1°C), 2003 (38.5°C), 2019 (38.7°C) then 2022 (40.3°C). For lowest minimum, the figure shows the national record in 1982 and 1995 (−27.2°)—which also occurred in 1895. The trends shown in these station series may be affected by station data availability, particularly prior to the 1960s, since a lower station network density will be less able to capture extremes. Not all historical values have been manually checked and some suspect values may be present in earlier years. Values may change as further data are digitized.

the UK series from 1836, with Lewes, East Sussex among locations affected by severe flooding.

7.2 | Exceptional Rainfall for Parts of Central England—September

The last 10 days of September 2024 brought extreme rainfall across central parts of England from three successive areas of low pressure on 22nd to 23rd, 25th to 26th and 29th to 30th. Of these, the first system brought the most extreme rainfall, with occluded fronts across England and Wales bringing thunderstorms and torrential rainfall in an unstable south-easterly flow (Figure 41). Rainfall rates exceeded 32 mm/h at times and two-day totals from 22nd to 23rd exceeded 100 mm across an area centred on Oxfordshire (Figure 42a). For context, the September whole-month 1991–2020 average rainfall for this county is only just over 50 mm. Oxford Radcliffe Observatory recorded 118.9 mm, making this the wettest 2-day period at this station in a near 200-year daily record from 1827, smashing the previous record of 98.1 mm on 9 to 10 July 1968. A number of other stations recorded even higher 2-day totals, with half a dozen

TABLE 16 | the UK's highest temperature station values for each month of the year. Dates in the latest decade 2015–2024 are in bold.

Month	Temperature (°C)	Date	Station
January	19.9	**28 January 2024**	Achfary, Sutherland
February	21.2	**26 February 2019**	Kew Gardens, London
March	25.6	29 March 1968	Mepal, Cambridgeshire
April	29.4	16 April 1949	Camden Square, London
May	32.8	22 May 1922 29 May 1944 29 May 1944 29 May 1944	Camden Square, London Horsham, West Sussex Tunbridge Wells, Kent Regent's Park, London
June	35.6	29 June 1957 28 June 1976	Camden Square, London Southampton Mayflower Park
July	40.3	**19 July 2022**	Coningsby, Lincolnshire
August	38.5	10 August 2003	Faversham, Kent
September	35.6	2 September 1906	Bawtry, Hesley Hall, South Yorkshire
October	29.9	1 October 2011	Gravesend, Kent
November	22.4	**1 November 2015**	Trawsgoed, Ceredigion
December	18.7	**28 December 2019**	Achfary, Sutherland

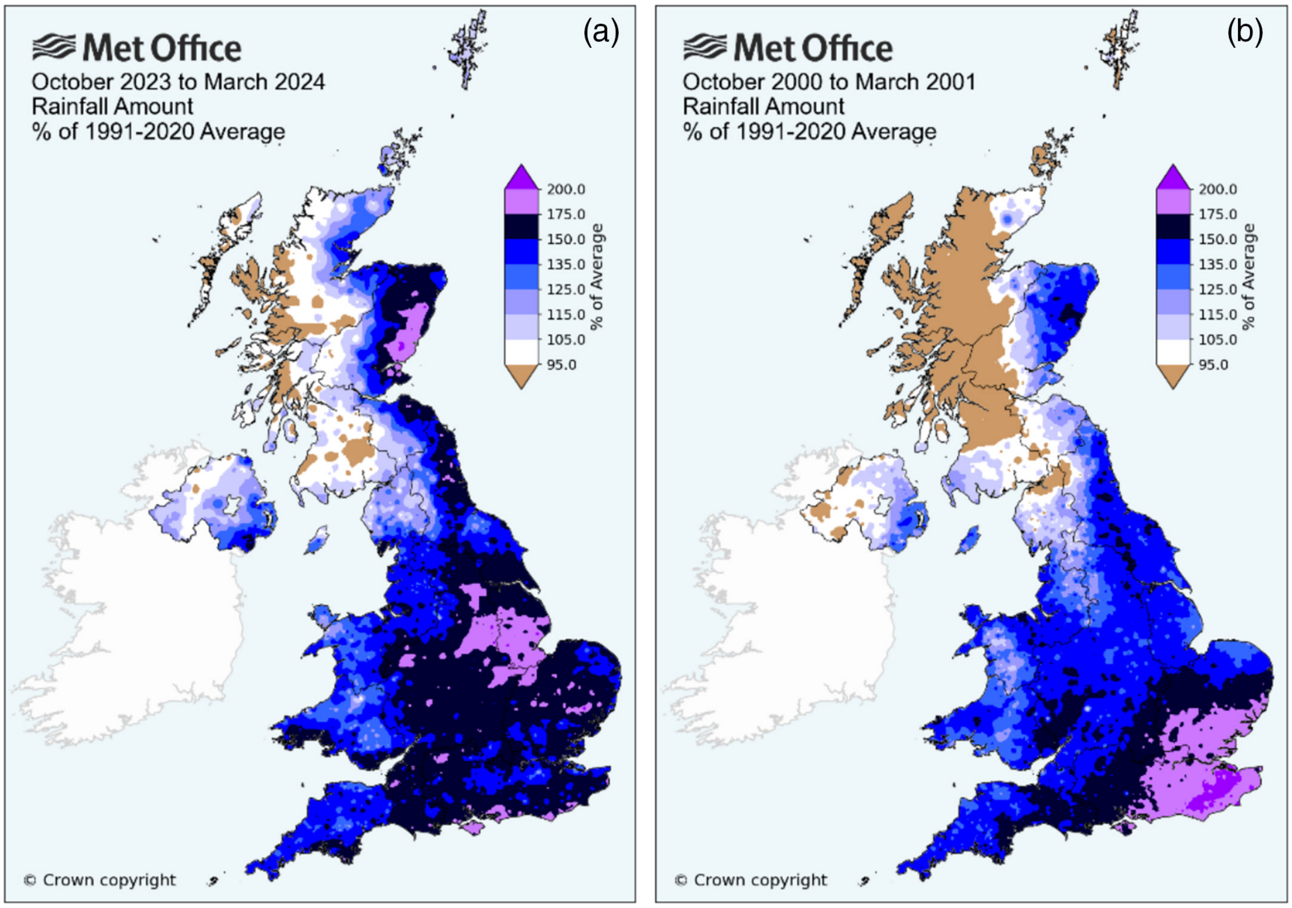


FIGURE 38 | UK rainfall totals for the winter half-years October 2023 to March 2024 (a) and October 2000 to March 2001 (b) as a percentage of the 1991–2020 average.

rain gauges in Oxfordshire and Northamptonshire exceeding 125 mm—well over twice the whole-month average rainfall in just 2 days.

The rainfall of 25th to 26th and 29th to 30th was less extreme, but these two events still each saw 30 to 50 mm falling very widely across parts of England and Wales, and locally 50 to 75 mm or more in parts of north-east England and the south Pennines respectively. Overall, over 100 mm of rain fell very widely across England in the last 10 days of the month, with 150 to 175 mm or more in the wettest area (Figure 42b). Totals for 21 to 30 September 2024 included 204.4 mm at South Newington, Oxfordshire (341% of the September 1991–2010 average), 216.2 mm at Woburn, Bedfordshire (391%) and 217.5 mm at Bozeat, Northamptonshire (405%). While most of central England recorded over 200% of the monthly average rainfall for September overall, a very wide central area received 300 to 350% (Figure 43).

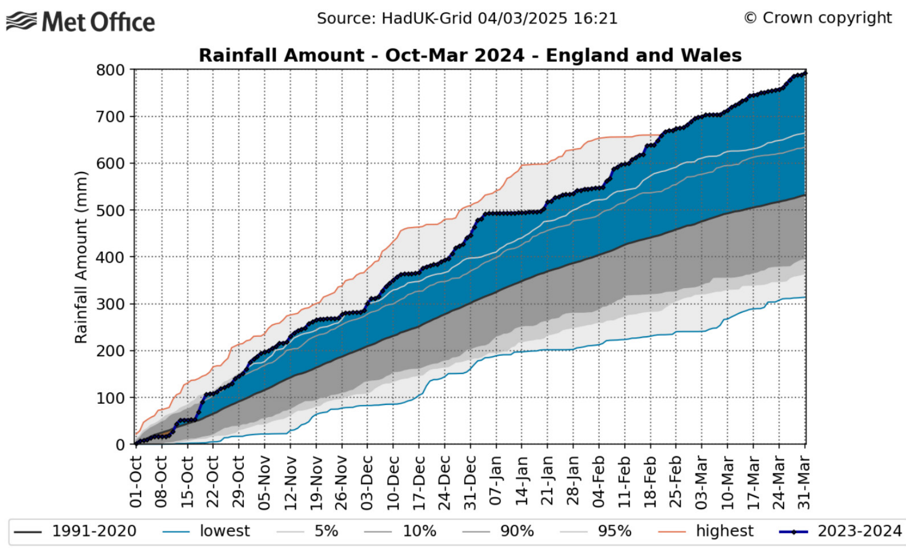
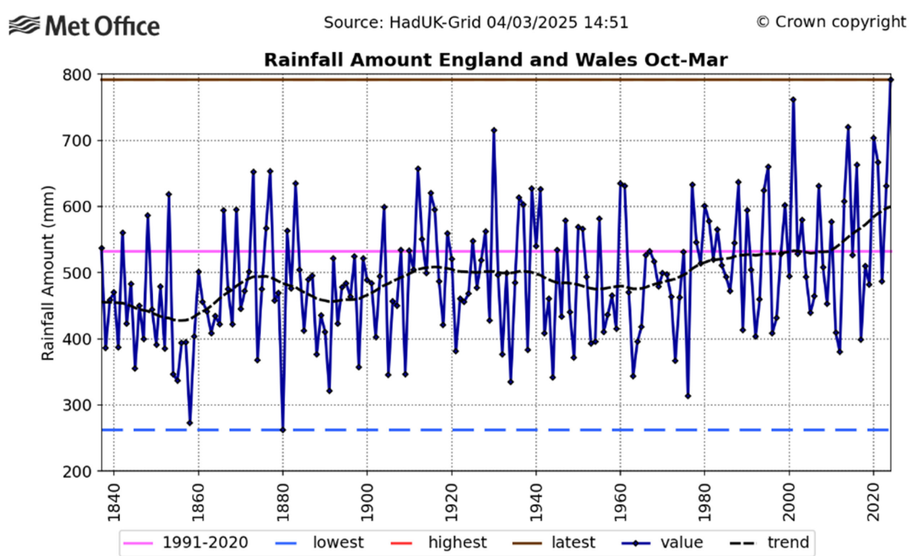


FIGURE 39 | **England and Wales mean daily rainfall** accumulation from October 2023 to March 2024. The black line shows the 1991–2020 average accumulation for each calendar day; the red and blue lines the highest and lowest values and the grey shading the percentile values for each calendar day of the period October to March based on the period 1891 to 2024 inclusive. The blue shaded area shows the accumulated rainfall above the 1991–2020 average from the start of October.



	1901-1930	1931-1960	1961-1990	1991-2020	2015-2024	2024
England and Wales	502	484	502	532	586	792

FIGURE 40 | England and Wales rainfall totals for the winter half-year October to March, 1836–1837 to 2023–2024. The table provides actual values (mm).

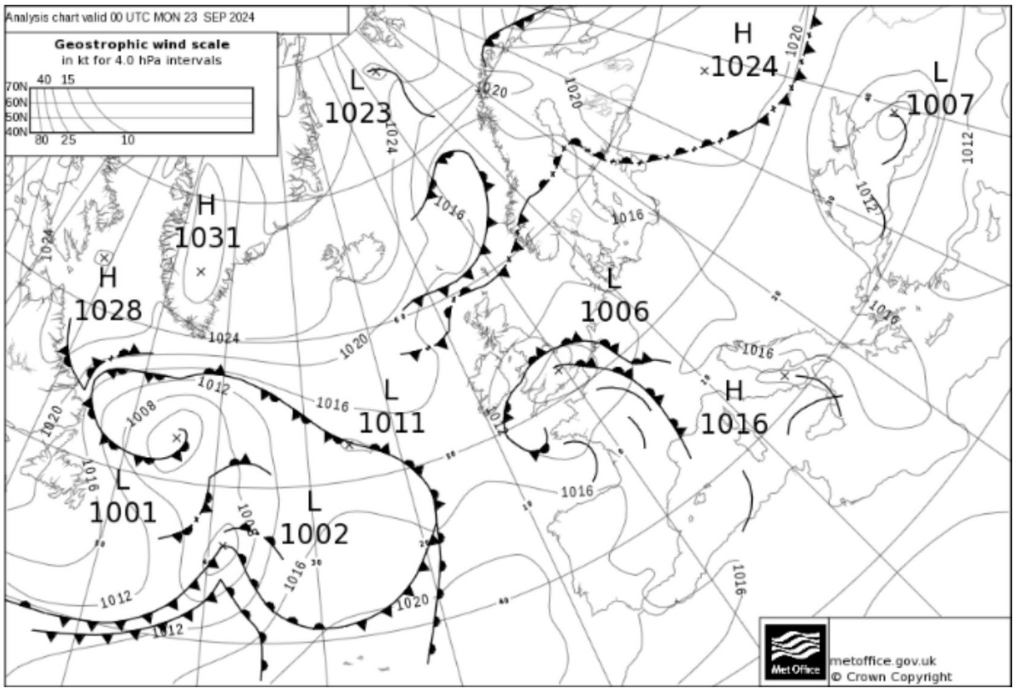


FIGURE 41 | Analysis chart at 0000UTC 23 September 2024.

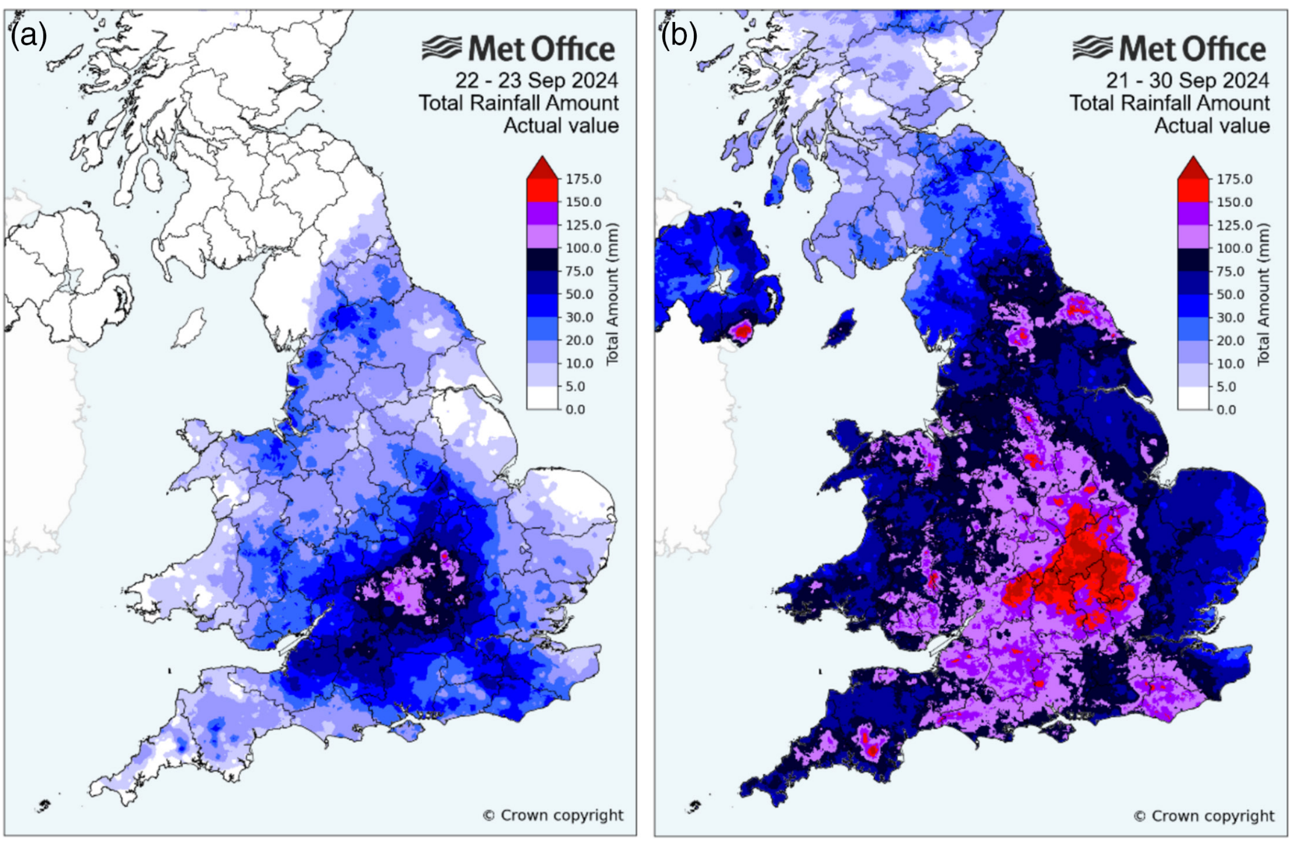


FIGURE 42 | Rainfall totals (mm) for (a) the 2-day period 22 to 23 September and (b) the 10-day period 21 to 30 September 2024. Both maps use the same legend scale.

Around a dozen counties recorded their wettest September on record, while for Oxfordshire, Bedfordshire, Buckinghamshire and Northamptonshire, September 2024 was the wettest calendar month on record in series from 1836 (September is normally not the wettest month of the year for these counties). Figure 44a shows rainfall for Oxfordshire from 1836, with September 2024 the wettest by a remarkable margin of 45 mm.

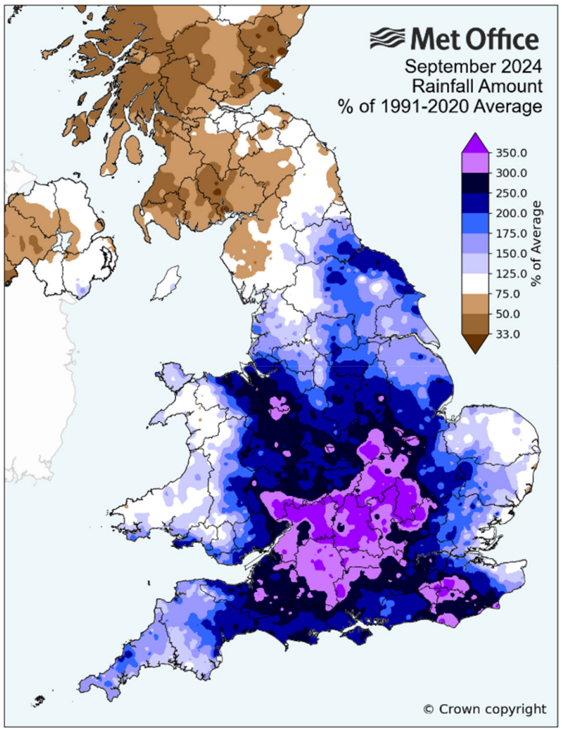


FIGURE 43 | September 2024 rainfall anomalies relative to 1991–2020 (%).

An important limitation of a chart such as this is 'event selection bias' which is a common difficulty of analysing extreme events. From this figure we might conclude that this rainfall event was unprecedented. However this chart has been deliberately selected only after pre-examination of the data in order to find the county (Oxfordshire) and month (September) of interest. Extreme spikes in the observations such as this are not unprecedented, nor are they confined to the most recent decades. For example, if we plot August rainfall for Norfolk (Figure 44b) there is a similarly extreme spike in the observations from the Norfolk rainstorm of 1912 (British Rainfall Organization 1913). Figure 44c shows the September rainfall series for 1767 onwards at the Oxford Radcliffe Observatory. At this station, September 2024 was the wettest calendar month for 250 years—since 1774—showing that September 2024 *had* been previously exceeded provided we go back far enough. Without the benefit of additional data for Oxford from 1767 to 1835 (before the start of the HadUK-Grid monthly rainfall series for Oxfordshire which starts in 1836), we would have no knowledge of this earlier event. This emphasizes the vital importance of long-term context and value of ongoing digitization of historical observations to capture as many extremes as possible in climate records.

As would be expected, the extreme rainfall brought damage and disruption, with roads and schools closed and a section of carriageway of the A421 in Bedfordshire submerged.

7.3 | Storm *Bert*—November

Storm *Bert* was a deep Atlantic low pressure system bringing heavy rain and strong winds to the UK in late November. This storm swept away cold air in place over the UK over the preceding days, and introduced a mild south-westerly flow from the Atlantic—temperatures on the 23rd increased by 15°C widely over the course of the day. Figure 45 shows the slow-moving fronts from *Bert* extending from south-west England to north-east Scotland. These brought persistent heavy rain—with some snow on the leading edge in areas such as the Peak District—and included lines of intense embedded convection (Figure 46).

Bert was a multi-hazard storm with heavy rain, strong winds and some snow, and tragically, several deaths reported. The worst impacts were felt across South Wales with severe flooding in Pontypridd from the River Taff and several hundred properties affected. At Cwmtillery, Blaenau Gwent, a landslide brought deep sludge and mud into a local street. Flooding also affected other areas including Tenbury Wells, Worcestershire, Chippenham and Bradford-on-Avon, and a major incident was declared in Northamptonshire when a holiday park was inundated. The UK overall recorded an area-average of 23.0 mm on 23 November 2024 making this the UK's wettest day overall since 3 October 2020.

Figure 47 shows 3-day accumulations from 22nd to 24th. Most of south-west England and Wales received 50 mm or more from this event, but the wettest areas were across the high ground of Dartmoor and in particular the hills of South Wales, with a fairly extensive area seeing over 150 mm. This was due to pronounced orographic enhancement, which is typical for an event of this type.

The 23rd was one of the wettest days on record in parts of South Wales. Figure 48 shows area-average rainfall for the county area of Mid Glamorgan for each day of the calendar year 2024. The red lines show the wettest days on record for each calendar day of the year based on the daily series for this county from 1891 to 2024. The 23rd was the only day in the series for this county area with a total exceeding 100 mm, although there are several other dates with 80 to 90 mm or more. Daily rainfall maps and analysis charts from Met Office daily weather summaries for two of these dates (3 December 1960 and 3 November 1931) show a similar rainfall pattern and synoptic situation to 2024 (Figures 49 and 50). Long-term records from a rain gauge at Treherbert, Tyn-y-Waun in the Rhondda Valley include several days in the historical record with higher totals than the 127.8 mm observed on 23 November 2024. These are 150.6 mm on 3 December 1960, 143.8 mm on 23 November 1946, 135.4 mm on 3 November 1931 and 133.3 mm on 11 November 1929 (this station has moved slightly in the 1980s). So while, locally, this rainfall was extreme, neither the rainfall totals nor the impacts were unprecedented (3 December 1960 for example saw severe flooding in Bridgend from the River Ogmore).

7.4 | Storm *Darragh*—December

Storm *Darragh* brought damaging winds to western parts of England and Wales in early December, with a red warning issued for west Wales and both coasts of the Bristol Channel (Figure 51). The UK Government sent an emergency alert to mobile phones of several million residents within the red warning

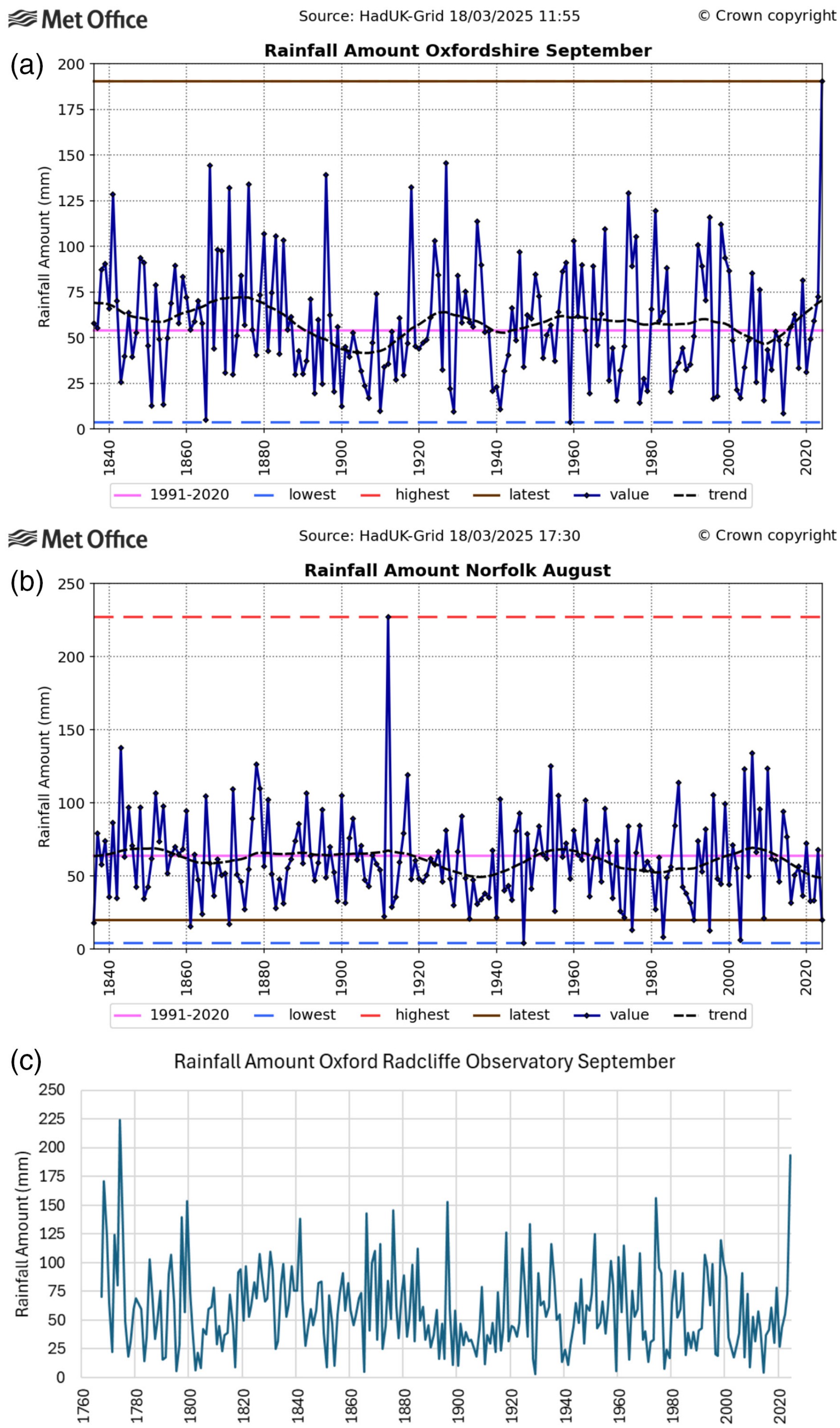


FIGURE 44 | September rainfall (a) 1836 to 2024 from the HadUK-Grid dataset for the county of Oxfordshire (b) similarly August rainfall for the county of Norfolk and (c) September rainfall from 1767 from the Oxford Radcliffe Observatory available at https://www.geog.ox.ac.uk/research/climate/rms/monthly-annual.html.

area and beyond, the first time this system has been used for a weather warning. Winds gusted at 60 to 70 Kt (69 to 81 mph) in the worst affected areas, with the highest gusts of 83 Kt (96 mph) at Berry Head, Devon, 81 Kt (93 mph) at Capel Curig, Conwy, 80 Kt (92 mph) at Aberdaron, Gwynedd and 74 Kt (85 mph) at Aberporth, Ceredigion (Figure 53). These gust speeds are indicative of a major Atlantic winter storm—that is, severe but not exceptional—although Darragh also saw some unusually high

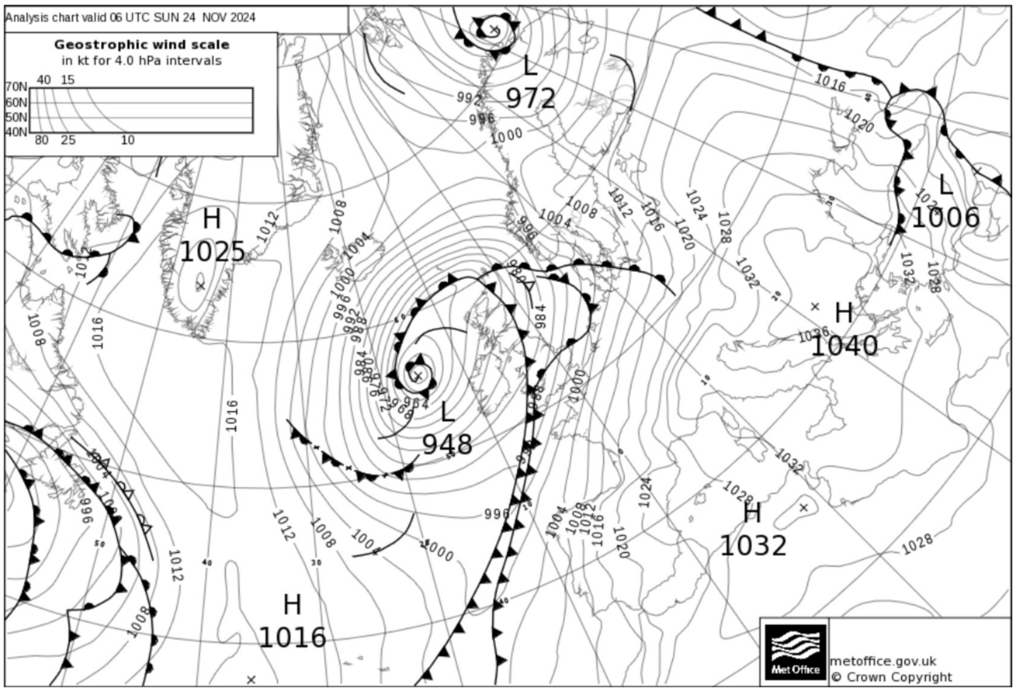


FIGURE 45 | Analysis chart at 0600UTC 24 November 2024.

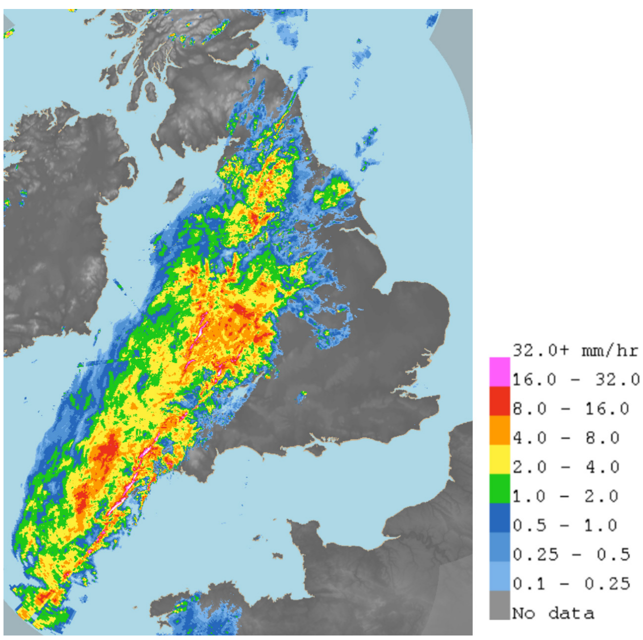


FIGURE 46 | UK rain-radar image (mm/h) at 0600UTC 24 November 2024.

gusts at inland stations in the south-west, such as 62 Kt (71 mph) at Cardinham, Bodmin, Cornwall and Yeovilton, Somerset.

In comparison with other recent major winter storms, *Darragh* was broadly comparable to storm *Isha* on 21 January 2024, although *Isha* had much stronger gusts across the northern half of the UK; storm *Eunice* on 18 February 2022 saw higher gust speeds across South Wales and south-west England than *Darragh*, whereas 12 February 2014 was a more severe event

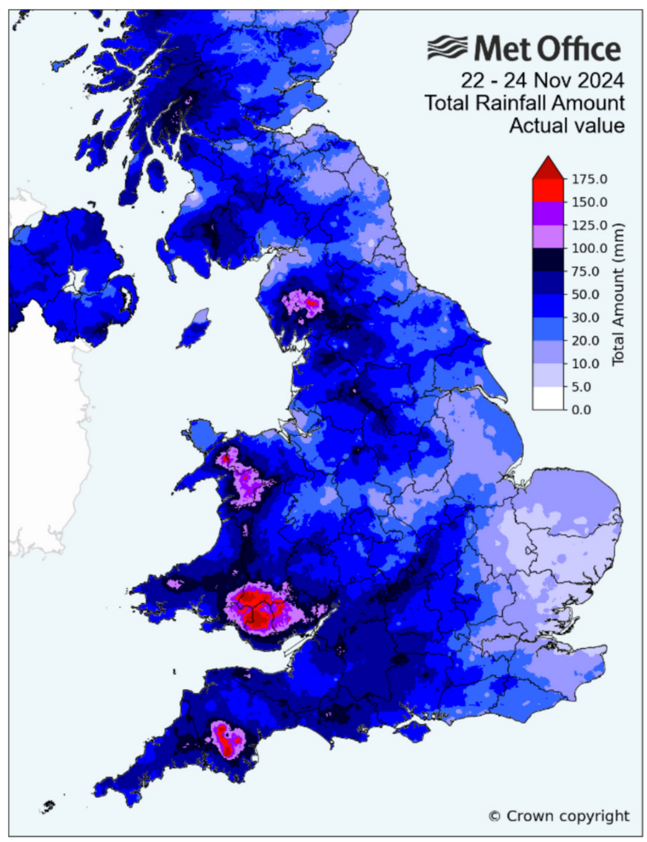


FIGURE 47 | Rainfall totals (mm) for the 3-day period 22 to 24 November 2024.

across western parts of the UK generally with a much larger area of gusts exceeding 70 Kt (81 mph)—(this was part of the sequence of storms in February 2014 that breached the sea wall

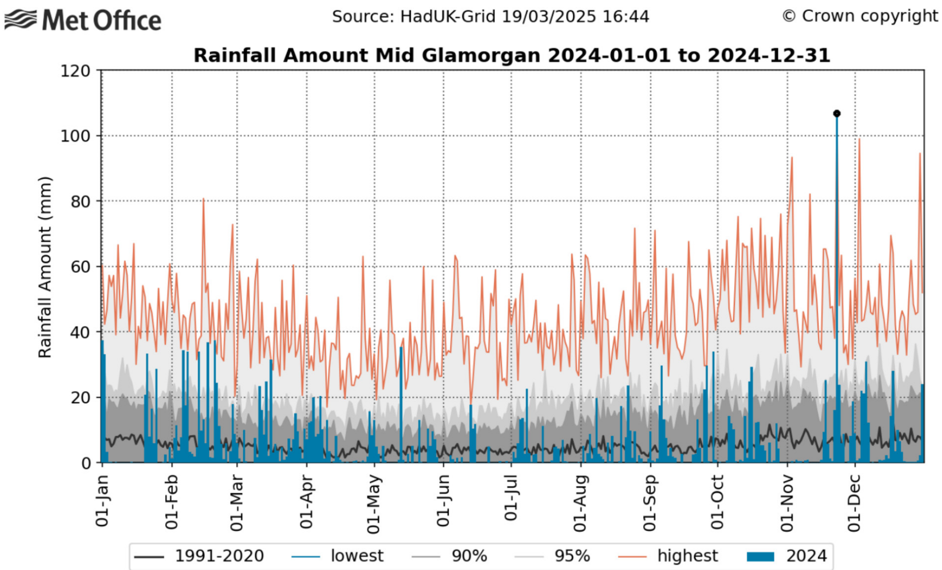


FIGURE 48 | Daily rainfall totals (mm) for the county area of Mid-Glamorgan for 2024. The grey shaded areas and red lines show extremes and percentiles for each calendar day of the year from 1891 to 2024, although this is based on a much reduced rain gauge network before 1961 (Appendix A: HadUK-Grid Dataset). The extreme total is 106.5 mm on 23 November during storm *Bert*.

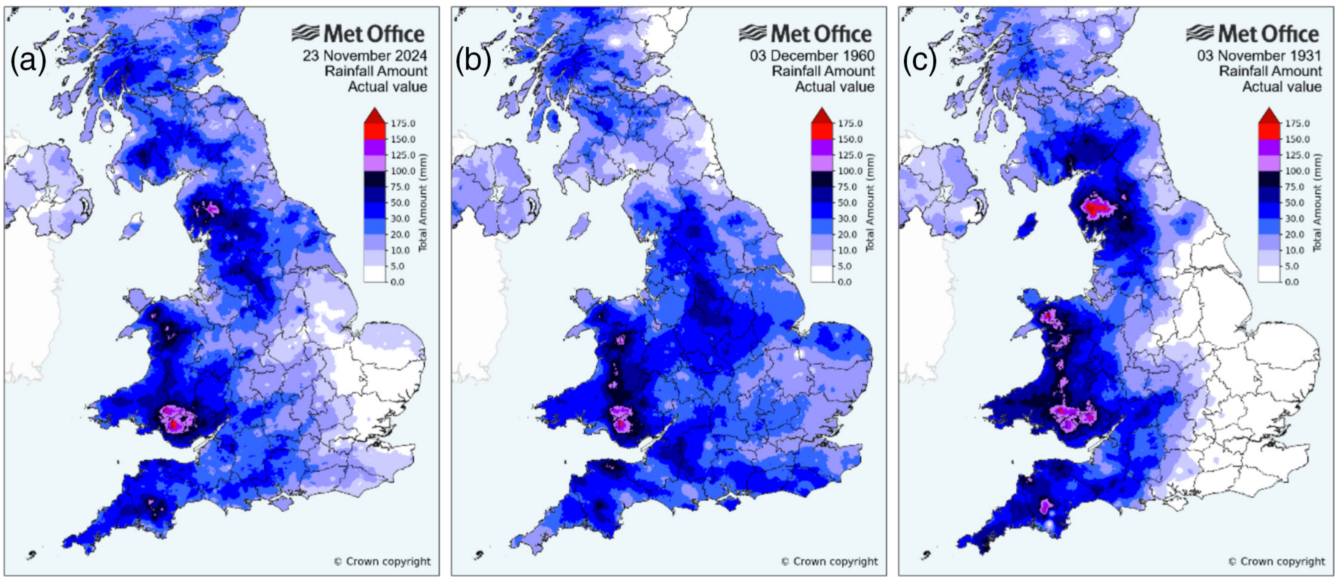


FIGURE 49 | Examples of three wet days in South Wales and more widely across western England and Wales: (a) 23 November 2024, (b) 3 December 1960 and (c) 3 November 1931. The maps for 1960 and 1931 are based on a reduced network size (Appendix A: HadUK-Grid Dataset); more data digitization of daily rainfall observations prior to 1961 is needed to adequately capture the detail of extreme events such as these.

carrying the south-west main line railway at Dawlish, Devon). Figure 52 compares charts for these events.

An unusual feature of *Darragh* was the intense area of high pressure in mid-Atlantic (1044 hPa). Although the storm's central pressure was not particularly deep, this caused a large pressure gradient and prolonged period of very strong winds from an unusual northerly direction. Figure 54 shows hourly maximum gust and mean wind direction at four example stations. At Aberporth, Ceredigion, hourly maximum gust speeds exceeded 50 Kt (59 mph) from 2300UTC on 6th to 0400UTC on 8th—a period of 30 h, with the winds veering from westerly (270°) to north-westerly (315°) and then northerly (360°); data from other stations are similar. The northerly direction and duration of the strongest winds are likely to have contributed to the severity of wind impacts from this event, with several deaths reported, over 2 million properties affected by loss of power, and major incidents declared in worst affected areas. In some areas large mature trees were brought down by the storm, for example at Bodnant Garden in the Conwy Valley, North Wales. The widespread wind-felling of mature trees in a northerly wind was also a feature of storm Arwen in November 2021.

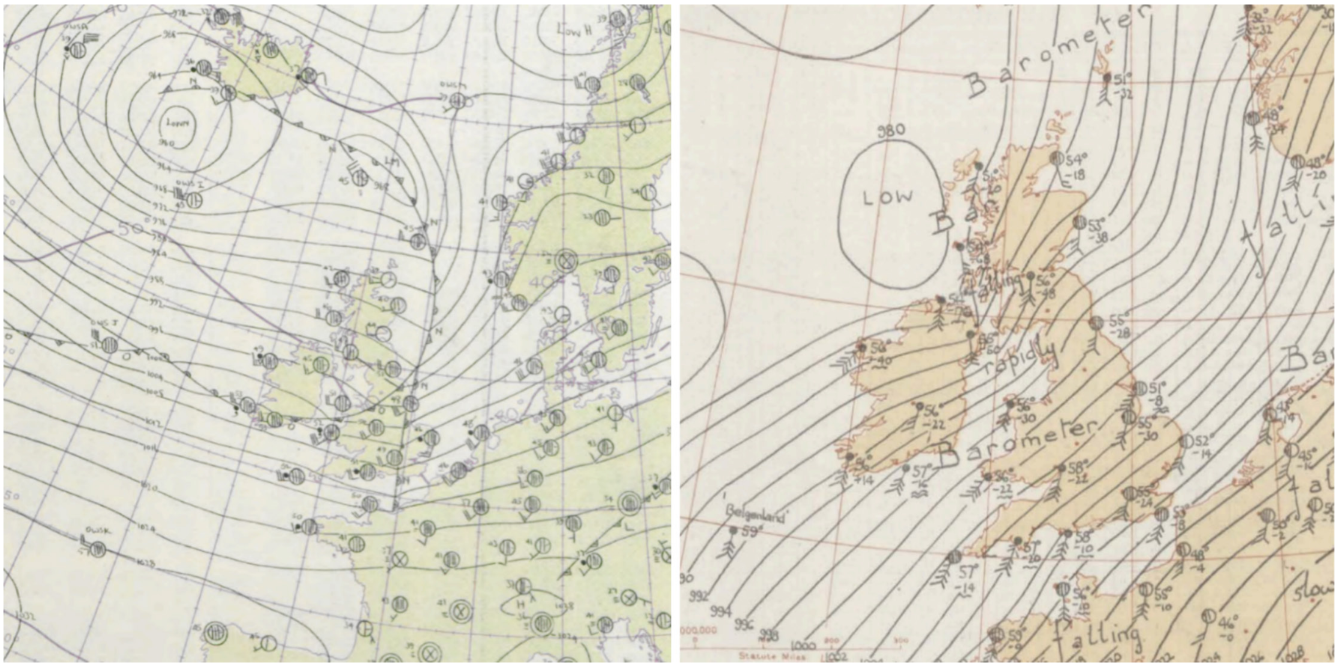


FIGURE 50 | Analysis charts for 3 December 1960 and 3 November 1931. The text on the latter states 'Bar. falling rapidly'.

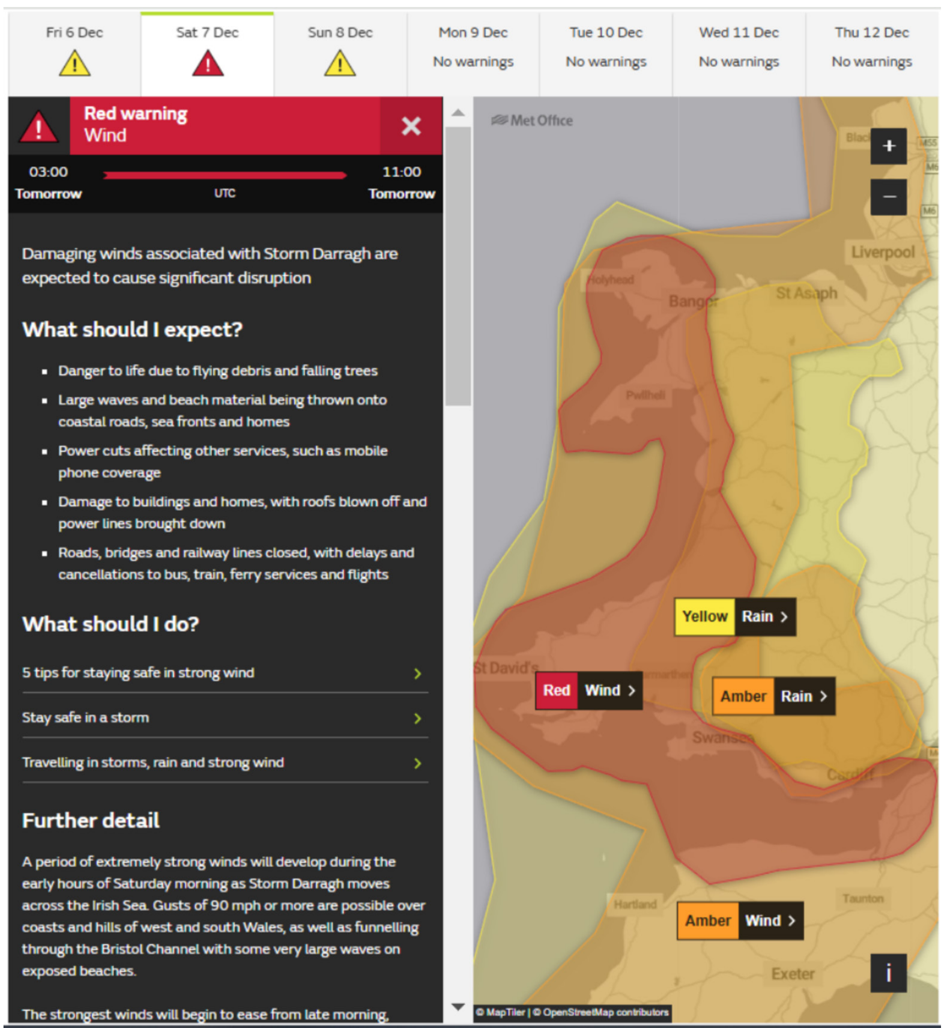


FIGURE 51 | The extent of the Met Office red warning area from 0300UTC to 1100UTC 7 December from storm *Darragh*. A red warning means dangerous weather is expected and there is very likely to be a risk to life.

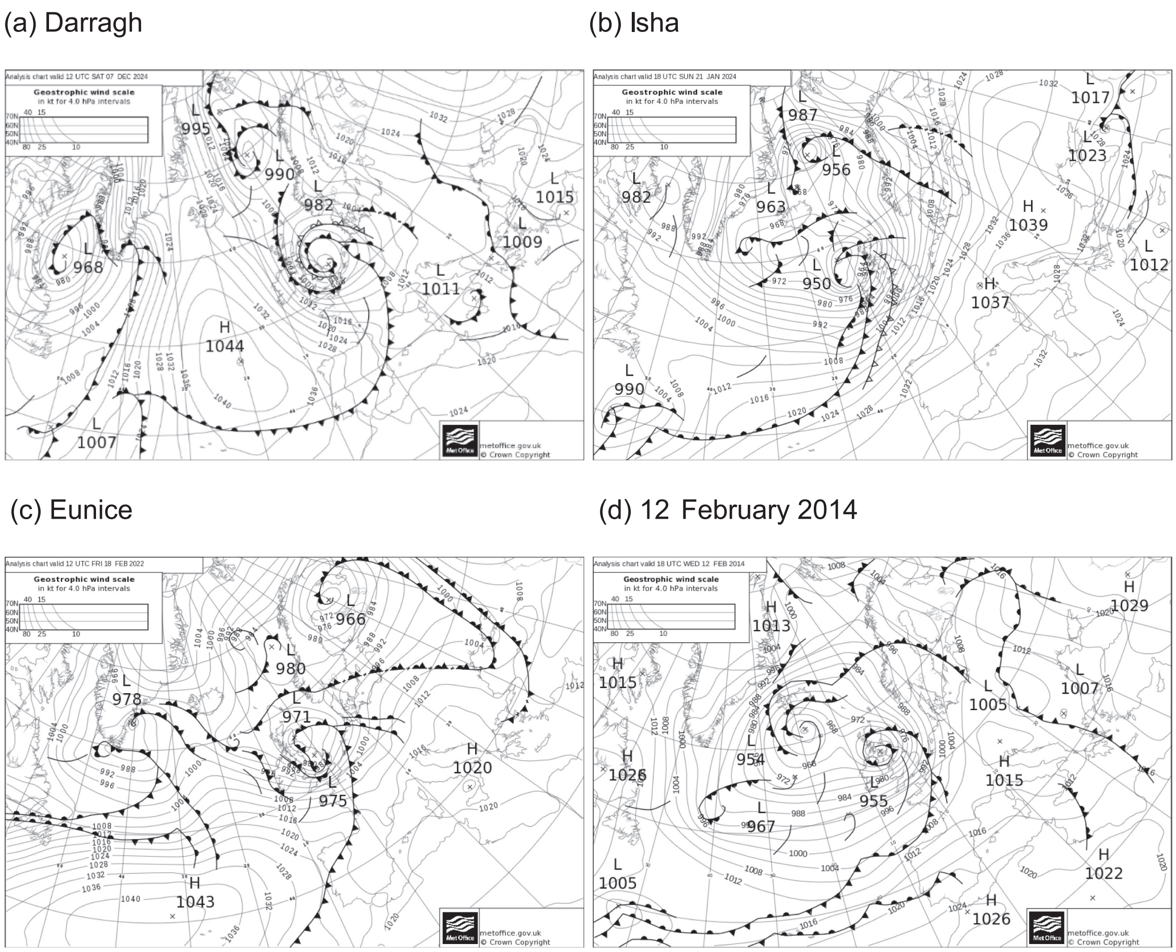


FIGURE 52 | Analysis chart for storm *Darragh* (a) on 7 December 2024 compared to examples of other recent notable wind storms—*Isha* (b) on 21 January 2024, *Eunice* (c) on 18 February 2022 and the storm of 12 February 2014 (d) (before storm naming was introduced).

8 | Sea Level

8.1 | Mean Sea Level

Since the beginning of the 20th Century, sea level in the UK has risen by about 19.5 cm [16.3–23.0 cm, 95% confidence interval], when excluding the effect of vertical land movement. This is based on an update of the UK index introduced in Woodworth et al. (2009), see Figure 55. The UK index in 2024 is derived from two of the original five long-term climate-quality tide gauge records. Long-term UK sea level rise is in good agreement with the global sea level rise estimate of 20 cm (likely range 15–25 cm) for the period 1901–2018 by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Fox-Kemper et al. 2021), and attributed to contribution from ice mass loss from glaciers and ice sheets in Greenland and Antarctica; and warming of the ocean.

There is observational evidence that sea-level rise is accelerating. Over the past 32 years (1993–2024) the UK sea level has risen by 13.4 cm, slightly higher than the global estimate of 10.6 cm (Thompson et al. 2024). There are larger uncertainties in estimates of sea level rise in the UK, using a limited number of tide gauge records, than in the global sea level rise values calculated from satellite altimetry data (Cipollini et al. 2017).

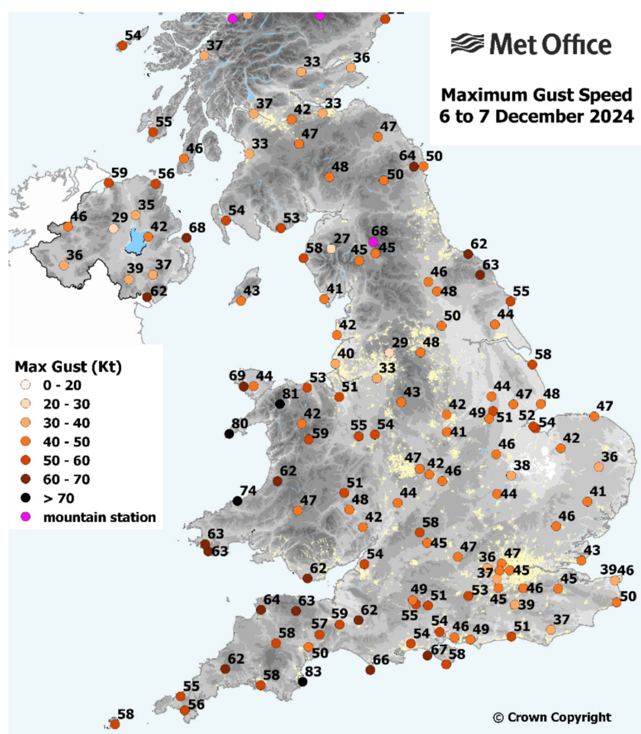


FIGURE 53 | Maximum gust speeds (Kt) from storm *Darragh* 6 to 7 December.

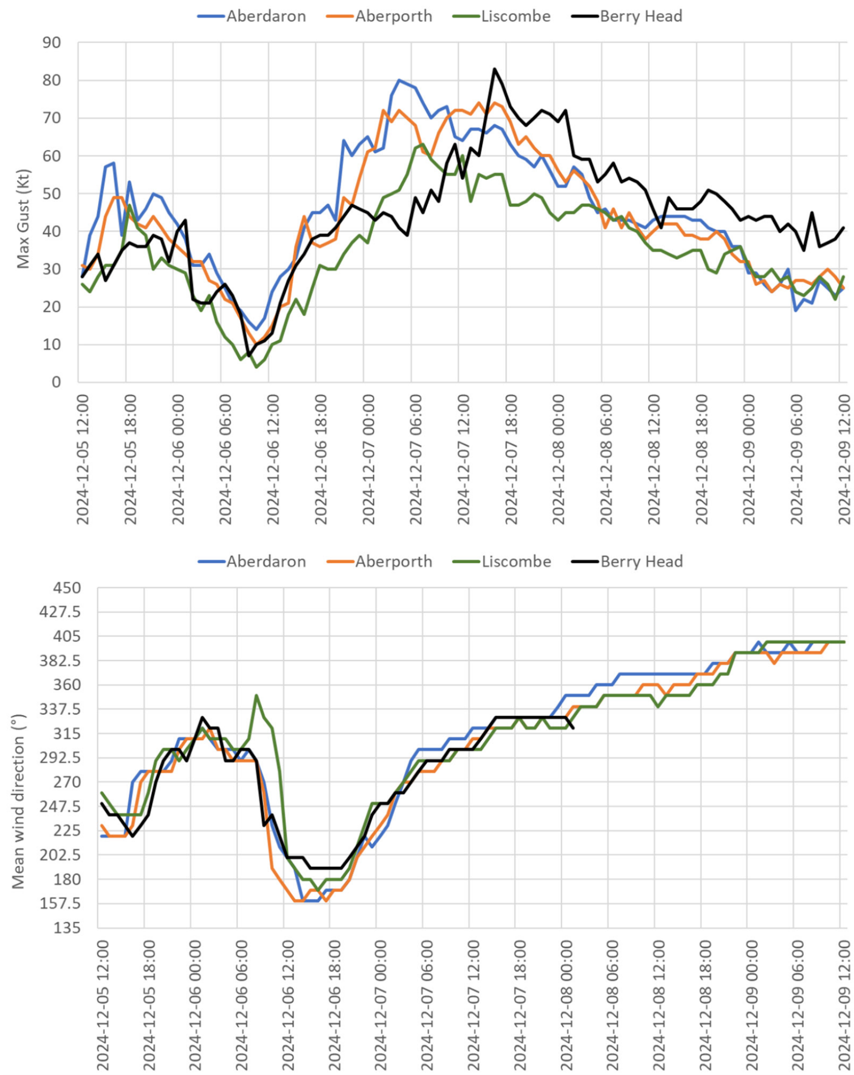


FIGURE 54 | Hourly maximum gust speed (Kt) and mean wind speed direction (°) at Aberdaron (Gwynedd), Aberporth (Ceredigion), Liscombe (Somerset) and Berry Head (Devon) during storm *Darragh*. The y-axis labels correspond to points of the compass clockwise from SE (135°) to E (90°, plotted as 450°).

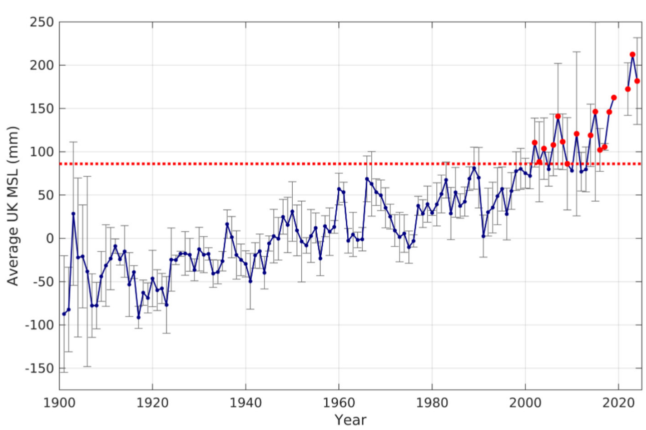


FIGURE 55 | UK sea level index, 1901–2024 (mm). Heights are above the average between 1921 and 1990. The red points represent the highest 17 values in the record, all occurring since 2001, with the red dotted line marking the 17th highest value. Bars behind represent the estimate of uncertainty (1 standard deviation)—where they are missing, data was only available from one of the five stations used to create the index, so no estimate of uncertainty could be calculated.

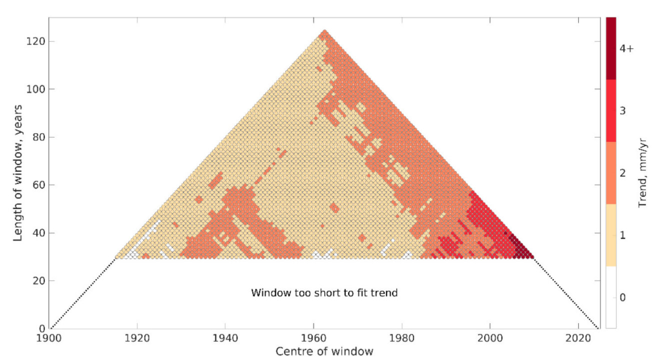


FIGURE 56 | Trends in the UK sea level index (mm/year) fitted over all possible windows at least 30 years long between 1901 and 2024. Each point represents one window, with the value on the horizontal axis representing the centre of the window, the value on the vertical axis representing the length of the window, and the colour of the point encoding the value of the trend. So, for example, the point at (1960, 61) represents the 1 mm/year trend over the period 1930–1990. The blank section at the bottom represents periods of under 30 years, too short to reasonably estimate a trend; the most recent window is always 15 years old.

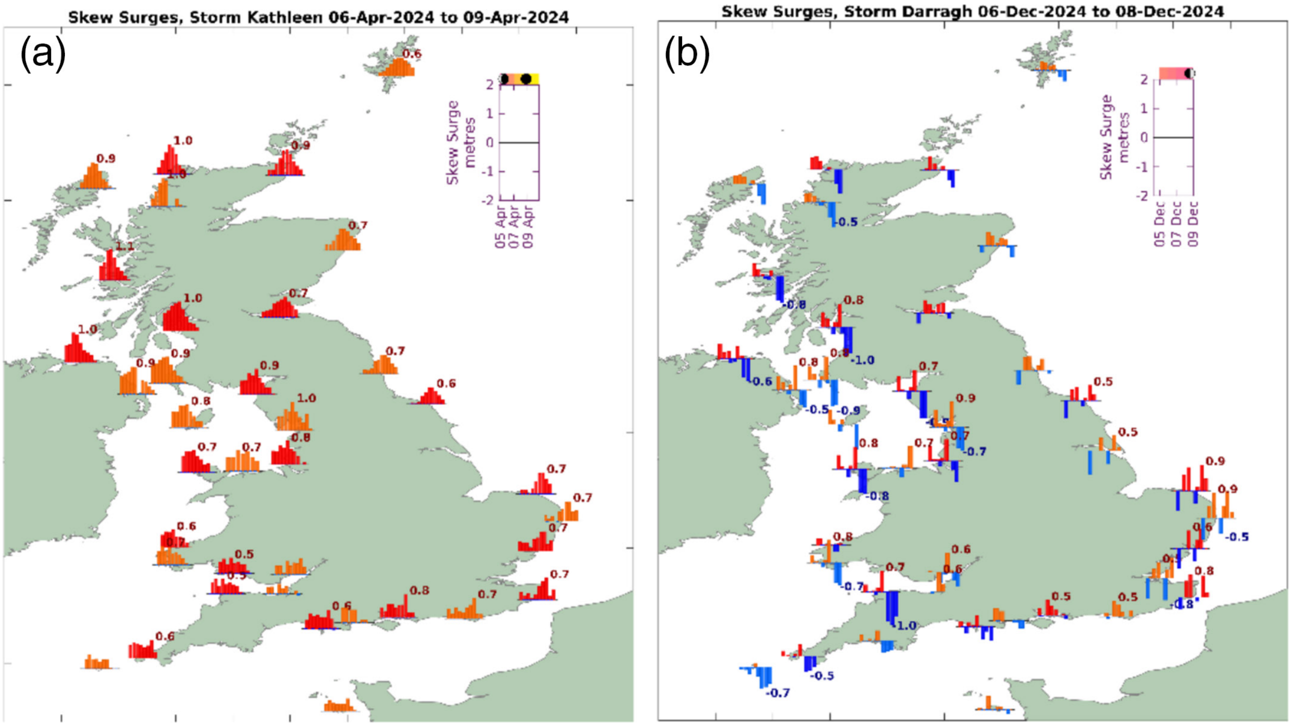


FIGURE 57 | Observations of storms *Kathleen/Pierrick* (a) and *Darragh* (b). *Kathleen* caused high skew surges everywhere, but especially on the west coast of Scotland, Northern Ireland, and the Irish Sea. It was followed immediately by *Pierrick* just before the April spring tide, leading to the highest total water levels in many places. Storm *Darragh* was notable for the extreme positive and negative surges in quick succession. Please see the online version of these figures to view at a larger scale.

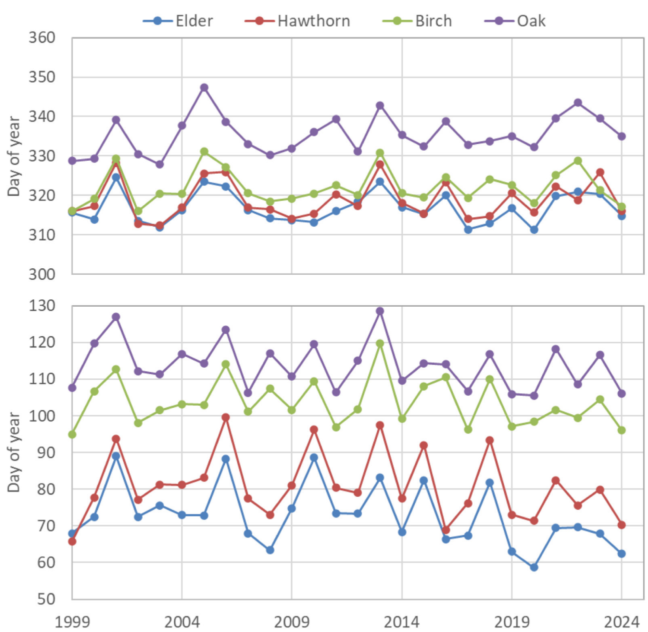


FIGURE 58 | Mean day of year of first leaf and bare tree for four common shrub or tree species: Elder, Hawthorn, Silver Birch and Oak, derived from UK observations contributed to Nature's Calendar from 1999 to 2024.

UK sea level change is not a linear increase or smooth acceleration but varies on seasonal to decadal timescales as has been demonstrated in Kendon et al. (2021) and Kendon et al. (2024). Despite this, the 17 highest annual sea levels on the UK record (1900–2024) all occurred since 2001, and the most recent 3 years are the three highest on record (Figure 55).

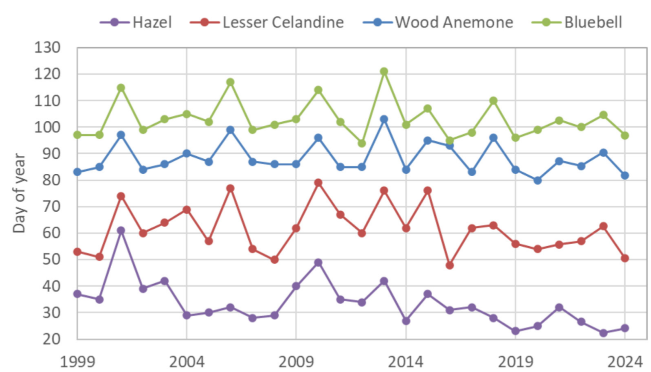


FIGURE 59 | Mean day of year of first flowering for four flower species: Hazel, Lesser Celandine, Wood Anemone and Bluebell, derived from UK observations contributed to Nature's Calendar from 1999 to 2024.

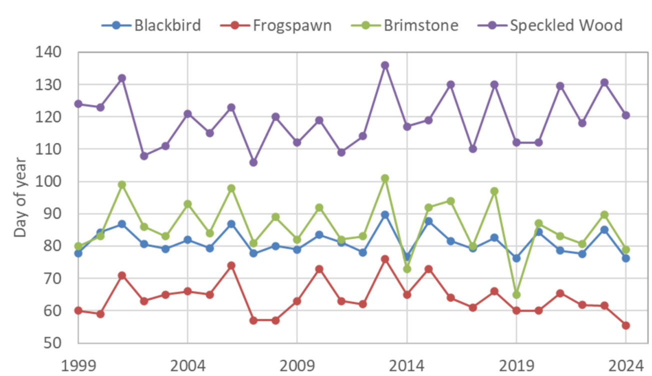


FIGURE 60 | Mean day of year of first nest building of Blackbird, first appearance of Common Frog spawn, Brimstone butterfly and Speckled Wood butterfly, derived from UK observations contributed to Nature's Calendar from 1999 to 2024.

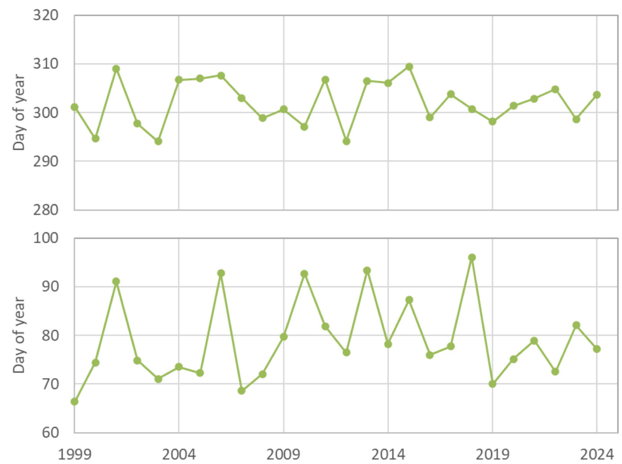


FIGURE 61 | Mean day of year of first and last lawn cut, derived from UK observations contributed to Nature's Calendar from 1999 to 2024.

Sea level changes have become more pronounced in recent years. Figure 56 shows trends fitted to moving windows between 1901 and 2024, from 30-years windows at the bottom of the plot to a 124-years long window at the top. The trends become more consistent as the length of the window increases. The darker tones on the right show that sea level is rising faster over windows covering the most recent decades.

The trends shown on Figure 56 are supported by previously published estimates, for example, since 1993 the rate of UK sea level rise is up to $4.2 \pm 1.0\,\mathrm{mm{\cdot}year^{-1}}$, compared to $2.4 \pm 0.3\,\mathrm{mm{\cdot}year^{-1}}$ since the 1960s (Hogarth et al. 2020) and to the long-term estimate of $1.5 \pm 0.1\,\mathrm{mm{\cdot}year^{-1}}$ since the 1900s (Kendon et al. 2021). The evolution of the trends on Figure 56 indicates that two-thirds of the sea level rise since the beginning of the last century has occurred in the past 32 years.

8.2 | Extreme Sea Level

Extreme sea level events on the UK coast occur due to the combination of several factors that vary over different timescales. The total water level during individual events is caused by the combined effect of waves, storm surges, tides, seasonal cycles, large-scale fluctuations in sea level and the underlying long-term relative sea level. As sea-level rise accelerates, the frequency of high sea-level events and hence coastal flood risk will increase.

Storm surges around the UK coast are associated primarily with Atlantic low pressure weather systems, caused by wind stress at the sea surface and the horizontal gradient of atmospheric pressure. The local magnitude of a particular storm surge depends on the intensity and track of the weather system, bathymetry and the shape of the UK coastline (Williams et al. 2016). There were eight storms in 2024 which caused surges of over 1 m (skew surge, see Appendix A: Sea Level Data) in the UK. All were assigned names by European storm naming groups except that on 22 December.

The timing of storm surge events relative to spring-neap tidal cycles is critical. Storm *Isha* in January had the highest skew

TABLE 17 | Highest total water levels in 2024, where tide-gauge data is available to climate standard and near-complete. Tide-gauges are ordered anticlockwise around the UK starting at Whitby, plus Port Erin (Isle of Man) and Jersey (Channel Islands). Return periods are based on median levels in the CFBC Report 2018. Heights are relative to the land, given in metres to the Ordnance Datum Newlyn or local island datum.

Tide gauge	Highest water level, metres	Date	Estimated return period (years)	Storm or other event
Whitby	3.59	2024-Apr-08	5–10	*Kathleen/Pierrick*[a]
North Shields	3.43	2024-Apr-08	5–10	*Kathleen/Pierrick*[a]
Leith	3.63	2024-Apr-08	10	*Kathleen/Pierrick*[a]
Lerwick	1.62	2024-Oct-21	5–10	*Ashley*
Kinlochbervie	3.48	2024-Oct-20	5–10	*Ashley*
Stornoway	3.20	2024-Oct-18	10–20	*Ashley*
Millport	2.89	2024-Oct-21	2–5	*Ashley*
Portpatrick	3.05	2024-Oct-21	2–5	*Ashley*
Port Erin	3.43	2024-Mar-13	2–5	Vernal Spring tide
Workington	5.21	2024-Aug-22	2	*Lilian*
Newlyn	3.28	2024-Feb-12	5–10	*Karlotta*[a]
Plymouth	3.05	2024-Feb-12	2–5	*Karlotta*[a]
Portsmouth	3.01	2024-Apr-08	50–75	*Kathleen/Pierrick*[a]
Newhaven	4.24	2024-Apr-08	25–50	*Kathleen/Pierrick*[a]
Jersey	6.42	2024-Mar-12	5–10	Vernal Spring tide

[a] Karlotta was named by the Spanish Met Service; Pierrick was named by MeteoFrance. Only 15 gauges had substantially complete, calibrated data for 2024. Others were not calibrated to climate standard so cannot be used for comparison between years, or had data gaps so the highest level is unknown.

surges of 2024 (up to 1.3 m) but *Kathleen/Pierrick* in April and *Ashley* in September occurred close to spring tides so brought the highest total water levels in many places (Table 17).

A sea level extreme as high as that caused by *Pierrick* at Portsmouth was only expected once every 50–75 years (Coastal Flood Boundary Report 2018, (Environment Agency, 2019)). In 2024, the monthly mean sea level at Portsmouth was unusually high in April, around 23 cm higher than the average for that month (1961–2023). Without this additional 23 cm contribution, the total water level from storm *Pierrick* would have been only around a 5-year return period event, even with the coincident high tides.

Storm *Darragh* was notable for an unusual surge profile, with a brief positive surge followed by a prolonged negative. Fortunately, *Darragh* occurred during neap tides. Figure 57 shows skew surges from storms *Kathleen/Pierrick* and *Darragh*.

Equinoctial spring tides in February, March and October also caused high total water levels, regardless of storms. The highest total water levels at 16 sites were due to high tides and background sea levels alone. In 2024, the Thames Barrier had 11 operational flood defence closures, seven of which were on spring high tides and unrelated to named storm events. Most closures also related to high river levels. Together with those in autumn 2023, this makes the season 2023–2024 the 4th highest year for Thames Barrier closures since operations began in 1982—see https://www.gov.uk/guidance/the-thames-barrier#thames-barrier-closures.

TABLE 18 | Mean dates of example events for woody plant species, flowers, invertebrates and vertebrates, and lawn first and last cut derived from UK observations contributed to Nature's Calendar from 1999 to 2024. Columns show the mean dates for the baseline period (1999–2023), the anomaly in days for 2024 relative to this period, the temperature response (days change/°C: −ve earlier, +ve later) and months of maximum temperature sensitivity. The final column shows the proportion of the variance in the mean first date explained by the temperature variables (R^2).

Group	Event	Species	Mean first date 1999–2023	2024 mean first relative to 1999–2023	Mean response to a 1°C increase in < month(s) right >	Month(s)	R^2 (%)
Woody plants	First Leaf	Elder	14-Mar	−10.9	−7.0	JFM	71
		Hawthorn	22-Mar	−11.1	−7.7	JFM	69
		Silver Birch	13-Apr	−7.9	−5.8	FMA	80
		Oak	24-Apr	−7.9	−5.8	FMA	78
Woody plants	Bare	Elder	12-Nov	−2.1	2.1	O	44
		Hawthorn	14-Nov	−2.9	2.6	O	44
		Silver Birch	18-Nov	−5.1	2.3	O	42
		Oak	1-Dec	−0.5	3.0	O	57
Flowers	First Flower	Hazel	2-Feb	−9.7	−5.1	DJF	39
		Lesser Celandine	2-Mar	−11.5	−6.7	JFM	55
		Wood Anemone	29-Mar	−7.0	−5.1	JFM	74
		Bluebell	13-Apr	−6.4	−5.1	FMA	50
Animals	First seen nest building	Blackbird	22-Mar	−5.2	−2.3	M	73
	First Seen	Frogspawn	5-Mar	−8.9	−4.7	JFM	59
		Brimstone butterfly	27-Mar	−7.3	−5.3	M	68
		Speckled Wood butterfly	29-Apr	+1.2	−6.9	MA	67
Grass	First in spring	Lawn cutting	20-Mar	−1.8	−6.6	JFM	62
	Last in autumn		29-Oct	+1.7	2.8	O	57

9 | Phenology

Phenology is the study of recurring biological events in relation to climate, typically of the dates of first and last events as they occur each year. It provides clear indicators of nature's response to weather and climate. In the UK, phenology data are collected by a citizen science project called Nature's Calendar which relies exclusively on volunteer observers. A summary of phenological recording in the UK was given in Sparks and Collinson (2008).

In this section, we summarise average UK changes in four species of woody plants (Figure 58), four flower species (Figure 59), and four animals, two vertebrates and two invertebrates (Figure 60). We also show first and last lawn cutting dates which integrate both grass responses to temperature and human behaviour (Figure 61). For the woody species, we summarise both first leaf and bare tree dates. Mean leafing of the four woody species, ranges from mid-March (Elder) to late April (Pedunculate Oak). In autumn, bare tree dates only span 2–3 weeks. The four flower species range from early February (Hazel) to mid-April (Bluebell). Indicators for the two vertebrates are evidence of nest building in the Blackbird and breeding (frogspawn) in the cold-blooded Common Frog. Of the two butterflies, the Brimstone overwinters as an adult and can be active on warm days early in the spring. Table 18 provides a summary of these data.

Spring 2024 was earlier than average for 12 of the 13 spring events reported here, and the earliest in the series for frogspawn and Blackbird nesting. Warm weather, particularly in February, will have contributed to this general state of earliness (Figure 3, Table 1). Hazel flowering has shown a significant advance over the 1999–2024 period. The four woody species had earlier-than-average autumn dates although the leaf-on season (the difference between first leaf and bare dates) was 7 days longer than the baseline, largely due to the early spring. The lawn cutting season was 3 days longer than the baseline. Spring responses to temperature varied from around 2–8 days earlier for every 1°C increase in mean temperature of the 1–3 months prior to the month of mean date. In contrast, tree bare dates in autumn typically showed a response of around 2–3 days later for every 1°C increase in October temperature.

Author Contributions

Mike Kendon: writing – review and editing. **Amy Doherty:** writing – review and editing. **Dan Hollis:** writing – review and editing. **Emily Carlisle:** writing – review and editing. **Stephen Packman:** writing – review and editing. **Svetlana Jevrejeva:** writing – review and editing. **Andrew Matthews:** writing – review and editing. **Joanne Williams:** writing – review and editing. **Judith Garforth:** writing – review and editing. **Tim Sparks:** writing – review and editing.

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Data Availability Statement

The data that support the findings of this study are openly available in Centre for Environmental Data Analysis at https://catalogue.ceda.ac.uk/uuid/f02cc6ddd92f45b18b9ab6ab544df7d9/.

Endnotes

[1] HDD statistics presented in this report are for the calendar year. These tend to be greatest in the winter half-year.

[2] CDD anomalies in the table are presented as a difference from average. This is because CDD average values for Scotland and Northern Ireland are very small and there is a very large annual variability in these series, with many years having near-zero CDD values for these regions.

[3] The alternative approach which we refer to as 'average-then-grid', is to calculate station averages and then grid these data which produces a slightly different result.

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State of the UK Climate 2024—Appendices

These appendices provide information about the underlying datasets used in this report. Much of the content is repeated from previous reports, with only minor updates, but they are included here in full for reference.

Appendix A: Datasets

HadUK-Grid Dataset

The principal source of data in this report is the HadUK-Grid dataset, comprising monthly and daily gridded data covering the UK (Hollis et al. 2019). The primary purpose of these data are to facilitate monitoring of UK climate and research into climate change, impacts and adaptation. All gridded data are at 1 km resolution. The grids are based on the GB national grid, extended to cover Northern Ireland and the Isle of Man, but excluding the Channel Islands.

This dataset is updated annually. This report uses version 1.3.1.0, ending 2024 (Met Office; Hollis et al. 2025). The previous version 1.3.0.0 ending in 2023 was used for the State of the UK Climate 2023 report (Kendon et al. 2024). In addition to the extra year, 2024, the main change from v1.3.0.0 to v1.3.1.0 has been extending the daily maximum, minimum and mean temperature grids back a further 29 years, from 1960 to 1931. Evaluating and improving the HadUK-Grid dataset and associated underlying station data for UK climate monitoring is an active and ongoing task.

The underlying source of UK station data used to produce the gridded dataset is the Met Office Integrated Data Archive System (MIDAS) Land and Marine Surface Stations Database. This has been supplemented by further digitised historical data from multiple sources including Met Office Monthly and Daily Weather Reports and monthly rainfall totals from both British Rainfall and the ‘Rainfall Rescue’ project, comprising digitised data contained within the ‘Ten year rainfall’ collection (Met Office Digital Library and Archive 2020). This collection of transcribed data went through an extensive process of consolidation, quality control and verification of metadata, described in detail by Hawkins et al. (2022). This version of HadUK-Grid uses the second version of this rainfall rescue collection (v2.0.0, Hawkins 2023), which was also used for the previous two versions of HadUK-Grid v1.3.0.0 and v1.2.0.0.

The HadUK-Grid dataset uses open-source ancillary files for terrain elevation, proximity to coast and urban land use within the interpolation scheme, which provides traceability. The gridding method used within HadUK-Grid involves interpolation of the station data to a regular grid of point locations using inverse-distance weighted (IDW) averaging. Hollis et al. (2019) provides further details.

Table A1 shows the monthly and daily grids from HadUK-Grid used for this report, including the year from which variables are available. Derived annual grids are also included. Several of the monthly climate variables (days of air frost, days of rain ≥ 1 mm and days of rain ≥ 10 mm) have been derived from the daily grids (daily T_{min} and daily rainfall, respectively) rather than gridded from monthly station values directly. This approach has the advantage of ensuring that they are consistent with the daily grids on which they are based (which would not be the case if they were gridded from station data). Because the gridding is at a daily timescale, we also anticipate that there will be a better overall representation of spatial variation in these monthly variables. Annual degree-day and rainfall intensity grids have also been derived from daily temperature and daily rainfall grids respectively. Monthly temperature and rainfall grids are gridded from monthly station data, rather than being derived from daily temperature and rainfall grids. This means that they are not exactly consistent (indeed observations from monthly rain-gauges, or digitised monthly rainfall data from Rainfall Rescue, can only be used for the monthly rainfall grids)—but in general differences are small.

The approximate total number of station values used to generate the grids for each variable is given in Table A2. In total well over 100 million stations, values have been used to generate the HadUK-Grid dataset, of which around three quarters are accounted for by daily rainfall. For monthly variables (e.g., monthly mean maximum temperature), the majority of the monthly station values will have themselves been derived from daily station values (e.g., daily maximum temperature). Therefore, in practice the number of *station values* used to generate the grids will differ from the number of *station observations* extracted from the MIDAS database or the other digitized data sources.

Figures A1–A4 show the number of stations used for creating monthly and daily grids for each year and variable. For monthly temperature, the number of stations starts at fewer than 100 for the period 1884 to

TABLE A1 | Monthly and daily variables presented in this report, gridded over the UK at 1 km resolution. The table also includes monthly and annual grids derived from daily grids.

Climate Variable	Definition	First year available	Gridding time-scale
Max air temperature	Monthly average of daily max air temperatures (°C)	1884	Monthly
Min air temperature	Monthly average of daily min air temperatures (°C)	1884	Monthly
Mean air temperature	Monthly average of mean daily max and mean daily min air temperatures (°C)	1884	Monthly
Days of air frost	Count of days when the min air temperature is below 0°C	1931	Monthly[a]
Days of ground frost	Count of days when the grass min temperature is below 0°C	1961	Monthly
Heating degree days	Day-by-day sum of number of degrees by which the mean temperature is less than 15.5°C	1931	Annual[b]
Cooling degree days	Day-by-day sum of number of degrees by which the mean temperature is more than 22°C	1931	Annual[b]
Growing degree days	Day-by-day sum of number of degrees by which the mean temperature is more than 5.5°C	1931	Annual[b]
Precipitation	Total monthly precipitation amount (mm)	1836	Monthly
Days of rain ≥ 1 mm	Number of days with ≥ 1 mm precipitation	1891	Monthly[a]
Days of rain ≥ 10 mm	Number of days with ≥ 10 mm precipitation	1891	Monthly[a]
Rainfall intensity	Total precipitation on days with ≥ 1 mm divided by the count of days with ≥ 1 mm during the year	1891	Annual[b]
Sunshine	Total hours of bright sunshine during the month consistent with the Campbell-Stokes recorder	1910	Monthly
Windspeed	Monthly mean wind speed Kt	1969	Monthly
Max air temperature	Daily max air temperatures (°C)	1931	Daily
Min air temperature	Daily min air temperatures (°C)	1931	Daily
Precipitation	Daily precipitation amount (mm)	1891	Daily

[a]Denotes monthly grids derived from daily grids.
[b]Denotes annual grids derived from daily grids.

TABLE A2 | Approximate total number of observations used for each variable in v1.3.1.0.

Climate variable	Number of years	Number of grids	Average number of stations values per grid	Total number of station values
Monthly T_{max}	141	1692	359	610,000
Monthly rainfall	189	2268	3402	7,700,000
Monthly ground frost	64	768	317	240,000
Monthly sunshine	115	1380	234	320,000
Monthly windspeed	56	672	126	85,000
Daily T_{max}	94	34,334	390	13,000,000
Daily rainfall	134	48,943	1902	93,000,000

1900, increasing steadily to a peak of over 600 stations in the 1990s, followed by a subsequent decline to below 400 stations in the most recent decade. Daily temperature has been gridded back to 1931, with around 100 stations through the 1930s, 1940s and 1950s, associated with recent data digitization work in the Met Office to improve station network coverage. Temperature has relatively smooth spatial variability, so this is a much less critical factor than for rainfall. Figure A5 shows an example of spatial coverage in 1941. Some areas of the UK, such as central England, are well covered in this year, but other areas are sparse, with only two stations in Northern Ireland and none at all in inland Wales, despite there being around 10 on the coast. The gap between the daily and monthly lines from 1931 to 1960 in Figure A2 reflects the potential for further daily temperature data to be digitized.

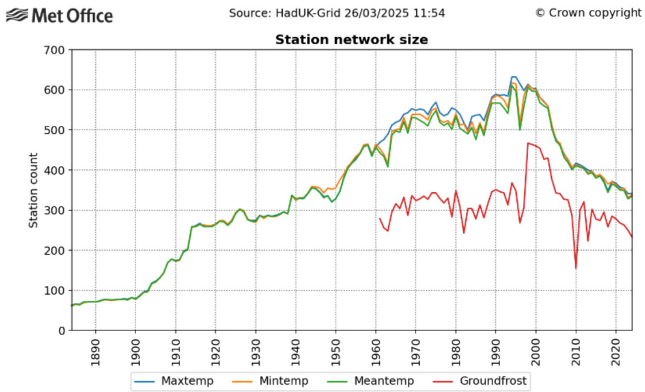

FIGURE A1 | Indicative numbers of stations used for gridding in this report—monthly T_{max}, T_{min}, T_{mean} (1884 to 2024), monthly days of ground frost (1961 to 2024) based on the actual numbers of stations used in January for each year.

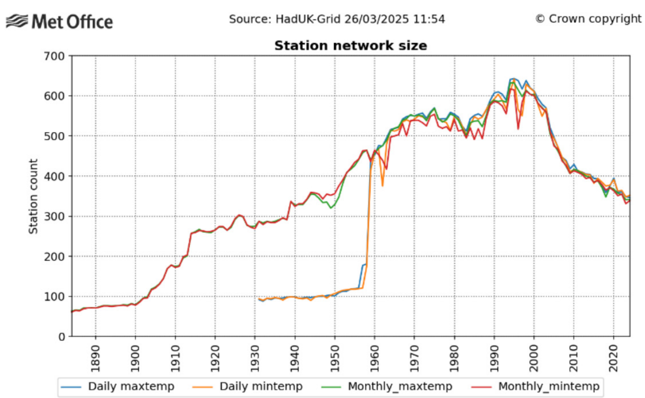

FIGURE A2 | Indicative numbers of stations used for gridding in this report—monthly T_{max}, T_{min} (1884 to 2024), daily T_{max}, T_{min} (1931–2024) based on the actual numbers of stations used in January/1 January of each year.

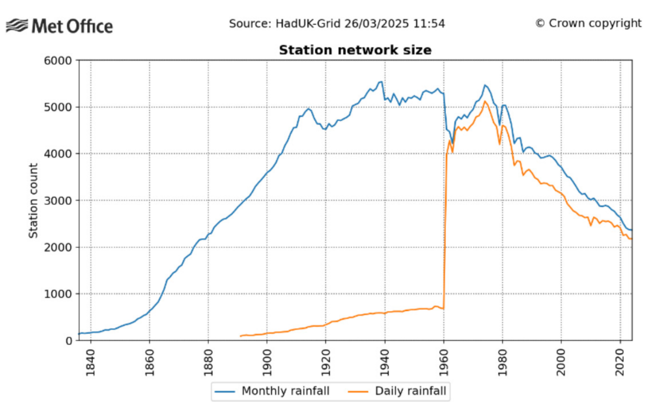

FIGURE A3 | Indicative numbers of stations used for gridding in this report—monthly rainfall (1836 to 2024), daily rainfall (1891–2024) based on the actual numbers of stations used in January/1 January of each year.

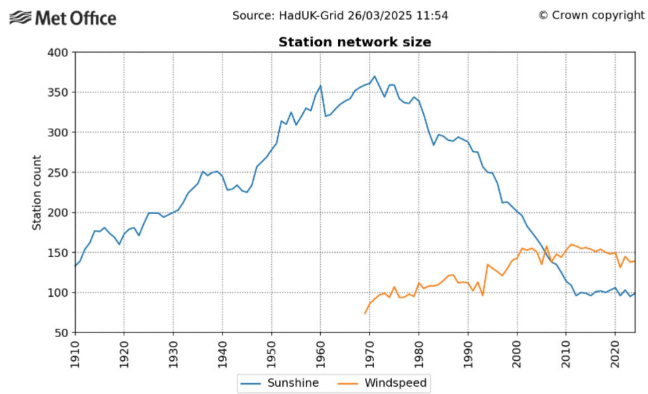

FIGURE A4 | Indicative numbers of stations used for gridding in this report—monthly sunshine (1910 to 2024) and monthly mean windspeed (1969 to 2024) based on the actual numbers of stations used in January of each year.

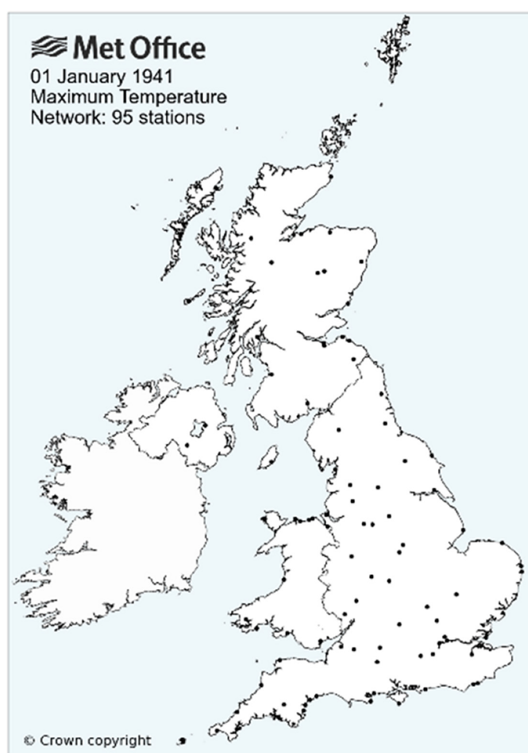

FIGURE A5 | Station network coverage for daily maximum temperature on 1 January 1941.

The number of stations used for monthly rainfall has increased from fewer than 100 stations in 1840 to 4000 or more stations from around 1900 to 2000, followed by a subsequent decline to fewer than 2500 in the 2020s. The approximate halving of station numbers in the last 40 years is cause for concern and discussed in Section 2.1. The inclusion of digitized monthly rainfall data sources prior to 1961, in particular Rainfall Rescue data, has eliminated a previous step change in station numbers before 1960 and transformed the quality of this dataset. The number of stations in the dataset in the 2020s is now approximately equivalent to that in the 1880s, although network coverage in the latter is more uneven with some clustering.

The step change in station numbers prior to 1961 is still present for daily rainfall. Metrics in this report based on the daily rainfall grids are therefore mostly presented from 1961, even though these grids extend back to 1891. Further work is needed to determine the extent to which any trends in metrics in earlier years are influenced by the relatively low station network density.

The gap between daily and monthly rainfall prior to 1961 shown in Figure A3 emphasizes the potential volume of historical daily rainfall data to go into future versions of HadUK-Grid and be made available more generally. An average of 3000 stations each day for 100 years would be equivalent to over 100 million observations, approximately doubling the number of observations in the HadUK-Grid dataset. Figure A6a shows as an example box files held within the Met Office library and archive containing paper records of daily rainfall returns for England, Scotland and Wales. These have been scanned with an example shown for Longwood House, Hampshire for year 1928 in Figure A6b. Daily rainfall has very high spatial variability, and these approximate 400,000 sheets are likely to contain a number of major extreme rainfall events yet to be fully captured. Any complete analysis of extreme rainfall in the UK must necessarily wait until these sheets are digitized if they are to exploit the full potential of the observations. Investigating the efficacy of different digitization approaches is an ongoing active area of research both in the Met Office and elsewhere, possibly requiring a new approach (e.g., the application of 'artificial intelligence' or 'machine learning' (AI/ML) techniques).

The number of monthly sunshine stations rises from around 150 in the 1910s to over 300 from the 1950s to 1980s, followed by a steady decline to around 100 stations in 2010, thereafter being stable. The number of monthly windspeed stations rises from 100 to 120 in the 1970s and 1980s to over 150 stations in the 2010s, followed by a slight fall. The number of stations recording monthly days of ground frost (i.e., with a grass minimum thermometer) is typically around 100 fewer than air temperature from the 1960s onwards.

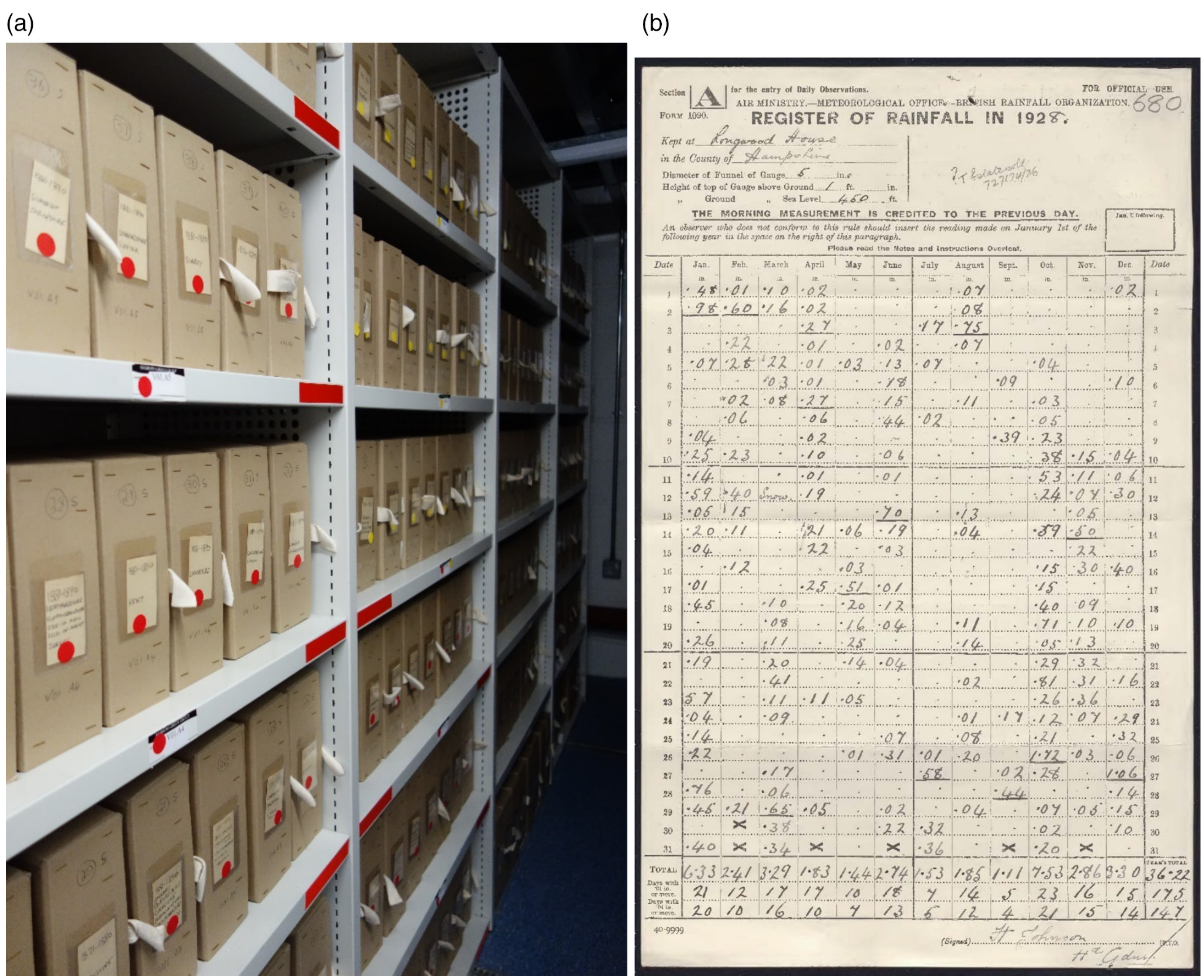

FIGURE A6 | (a): Box files of observations of historical daily rainfall data for the UK held by the Met Office library and archive in Exeter (b) an example of contents: daily rainfall observations in inches for Longwood House, Hampshire for each day of the year 1928. The annual total at this station for 1928 was 36.22 in. (920 mm).

The Observing Network in 2024

Figure A7 shows the state of the UK's observing network in 2024 based on data availability from stations that have actively returned data during the year. The networks are designed and maintained to achieve a good spatial coverage with stations representative of all areas of the UK. The rainfall network is much denser compared to other variables, due to its very high spatial variability. This network has been steadily declining as discussed in Section 2.1 and Appendix A: HadUK-Grid Dataset. At present, most rainfall events will be reasonably well captured although inevitably highly localised convective events may still be missed.

While the majority of the UK is reasonably well covered, some areas, notably western Scotland, are more data-sparse than others, but these also tend to correspond to areas with a lower population. Coverage for some variables (notably sunshine) may considerably reduce if data for an individual station is missing, and where surrounding stations struggle to cover the gap—that is, there is limited redundancy in the network. Overall however, even though the current number of stations may be fewer than in earlier decades (e.g., the 1970s), the spatial distribution of stations is more even, and so there is an improvement in the overall network's ability to capture the spatial characteristics of the weather on any given day.

Long Term Average Grids

The long term averages for the WMO standard 30-year climatological reference periods 1961–1990 and 1991–2020 and other periods 1901–1930 and 1931–1960 presented in this report have been calculated from long term average monthly gridded datasets at 1 km. These gridded long term averages have been derived as simple averages of the individual monthly grids spanning each 30 year period. We refer to this as 'grid-then-average' (i.e., grid the monthly data, then average the grids).[3] The long term averages for nations and regions quoted in this report are therefore consistent with the long term averages calculated from

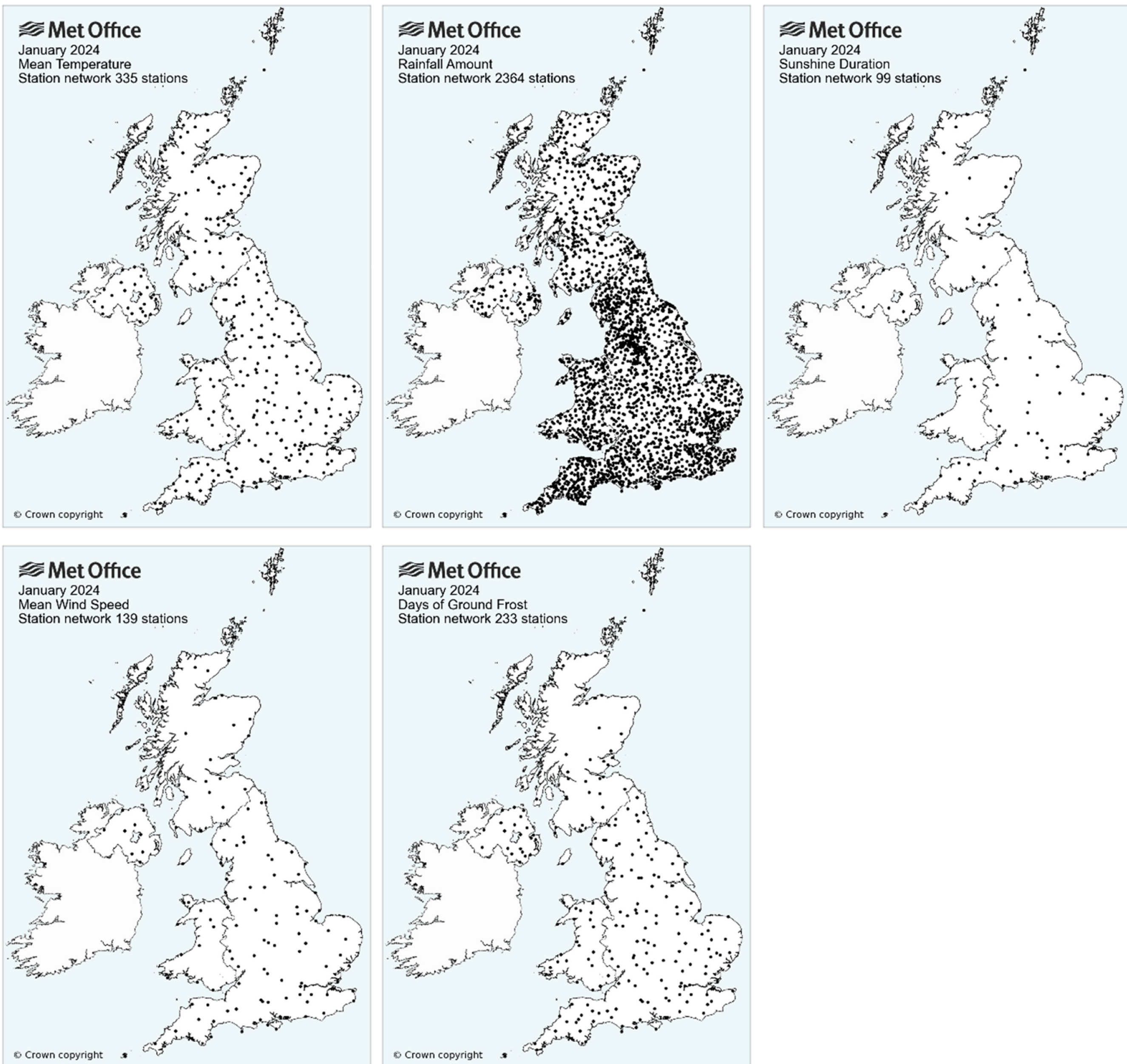

FIGURE A7 | State of the UK observing network in 2024. The maps show the actual number of stations used for the monthly grids for each variable for January 2024. The precise number of stations each day and month will vary depending on data availability, data completeness (for the month) and the amount of suspect data removed.

monthly, seasonal and annual series in the report, although we note this is not exactly true for winter, or the winter 'half-year' October to March, since, for example, 30 individual winters in the period will include the previous December (e.g., December 1990 for the period 1991–2020) and omit the last December (December 2020). In practice, however any difference will usually be small.

The introduction section explains the choice of average periods used in this report. Hulme (2020) provides more background and discussion regarding averaging periods.

Annual Degree Days

A degree day is an integration of temperature over time and is commonly used to relate temperature to particular impacts. It is typically estimated as the sum of degrees above or below a defined threshold each day over a fixed period of time. Degree days are useful metrics, but as they are derived from temperature only, users should be aware that other relevant factors may also be important depending on the application—for example, rain, wind and sun will also influence the growth of plants.

The thresholds used for heating degree days (HDD), cooling degree days (CDD) and growing degree days (GDD) are 15.5°C, 22°C and 5.5°C respectively, and the formulae used are described in Tables A3 and A4. The daily mean temperature T_{mean} is calculated from the daily maximum temperature T_{max} and the daily minimum temperature T_{min} as $(T_{max} + T_{min})/2$. The degree-day value is calculated differently depending on which of T_{max}, T_{mean}, or T_{min} is above (for Cooling Degree Days and Growing Degree Days) or below (for Heating Degree Days) the defined threshold.

Quality Control

The quality of this report can only be as good as the quality of the observations on which it is based. Quality control is therefore critically important for UK climate monitoring.

The HadUK-Grid dataset is mainly based on observations from the Met Office's national network of climate stations and rain-gauges registered with the Met Office. These observational data are held within the MIDAS database, which is the formal national archive. They undergo a range of Quality Control Processes as outlined in World Meteorological Organization guidelines WMO-No. 1269 (WMO 2021).

Other data sources which HadUK-Grid uses, such as data rescued from historical archives, have also had their quality checked. For example, tables of monthly rainfall published in British Rainfall also include annual totals, enabling a closure check on the monthly totals. Finally, the gridding process going from station to gridded data includes its own automated and manual QC steps depending on the variable and period. Further details are beyond the scope of this report, but this remains an ongoing active area of research and development.

The quality control process aims to remove as much bad data as possible ('hits'), minimise data errors ('misses') and avoid removing good data ('false alarms') which might, for example, result in over-smoothing. This is an area of potential future application of 'artificial intelligence' or 'machine learning' (AI/ML) techniques—that is, replicating the QC decisions a human would make based on judgement and experience, although clearly such techniques can only be as good as the data on which they are trained.

TABLE A3 | Formulae used for calculating cooling or growing degree days above thresholds of 22°C and 5.5°C.

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

TABLE A4 | Formulae used for calculating heating degree days below a threshold of 15.5°C.

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

Quality Control of Record Values

Quality control of station observations is particularly important for potential new record values. All possible records must be carefully checked, and this is especially the case for high profile records such as the UK highest maximum temperature record of 40.3°C at Coningsby, Lincolnshire on 19 July 2022 (Burt 2025). The monthly temperature records in Section 6.2 are examples of record values; 'official' records are published on the Met Office website at https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-extremes.

The Met Office has an established process for verifying potential new records, managed by the Site Weather Assessment Team (SWAT). Whenever a potential new record occurs, this team undertakes a detailed manual assessment prior to the new record's acceptance. This assessment includes: a site assessment to take into account any potential issues affecting exposure; checking instrument calibration dates; and a detailed check of the observations (at an automated site this would typically comprise minute-resolution data), including checks with neighbouring stations. At a manual station, verification may also involve a discussion with the observer. Supplementary evidence or observations would be used where possible (e.g., rain-radar).

The SWAT team makes a final decision based on collective expert judgement using all available evidence, based on the general premise that an observation should be assumed valid unless there is clear supporting evidence to the contrary. The record's acceptance or rejection is confirmed in as timely a manner as possible, typically within a week.

While SWAT reports are official Met Office documents primarily for internal use, publicly available versions of these documents are available as Weather Event Verification Reports from the Met Office digital library and archive at https://digital.nmla.metoffice.gov.uk/SO_cb95d84f-d807-4818-897c-687c2cdfc80b/.

Areal Series

The monthly series for the UK and countries are calculated as area averages derived from the 1 km monthly gridded datasets. Each monthly value is an average of all the individual 1 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 (e.g., with elevation). These statistics are self-consistent through time, without any gaps. Daily area averages have similarly been calculated from the 1 km daily gridded datasets.

In the same way, long term averages are calculated as an average of all the individual 1 km long term average grid points which fall within the UK or country. Long term average statistics are consistent with the monthly statistics (although as noted in the Appendix A: Long Term Average Grids winter is an exception to this).

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 illustrated by the anomaly maps.

Some of the analyses and maps within this report are based on a set of county areas for the UK. These comprise ceremonial counties in England, Scottish lieutenancy areas in Scotland, and preserved counties in Wales, defined in 1997. Northern Ireland is divided into six counties. These county areas provide a pragmatic and stable set of areas for long-term monitoring, avoiding potential problems with boundary changes for other possible choices of areas which might be routinely updated (e.g., as a result of administrative changes). Area average statistics would otherwise need continual updating to keep in step.

There are 97 county areas in total (Figure A8). These are particularly useful for climate monitoring because they are generally similar in size, although inevitably some areas are much smaller than others. At this size, these counties provide area average statistics that usually cover much of the spatial variation across the UK. Rainfall has such a large spatial variability that even at this scale, the county areas may struggle to capture the detail. Statistics for county areas will also be much more sensitive to station network density (see Figures A1–A4). More work is required to evaluate the relationship between area size and uncertainty in the area average statistics. Appendix A: Time-Series, Trends and Uncertainty discusses uncertainties further.

Global Surface Temperature

HadCRUT.5.0.2.0 is a gridded dataset of global historical surface temperature anomalies relative to a 1961–1990 reference period. Data are available for each month from January 1850 (Morice et al. 2021). The HadCRUT5 dataset of global surface temperature is produced from the station series of the CRUTEM5 land-surface air temperature dataset (Osborn et al. 2021) and the HadSST4 sea-surface temperature dataset (Kennedy et al. 2019).

The CRUTEM5 station series comprises monthly-mean temperature records from a global network of several thousand weather stations, from which CRUTEM5 anomaly fields are calculated. HadSST is produced by taking in situ measurements of SST from ships, moored, and drifting buoys.

The HadCRUT5 global average values are calculated as the 'best estimate' mean of 200 ensemble member dataset realisations that sample the distribution of uncertainty. HadCRUT5 is one of several global surface temperature datasets, with other examples produced by NOAA,

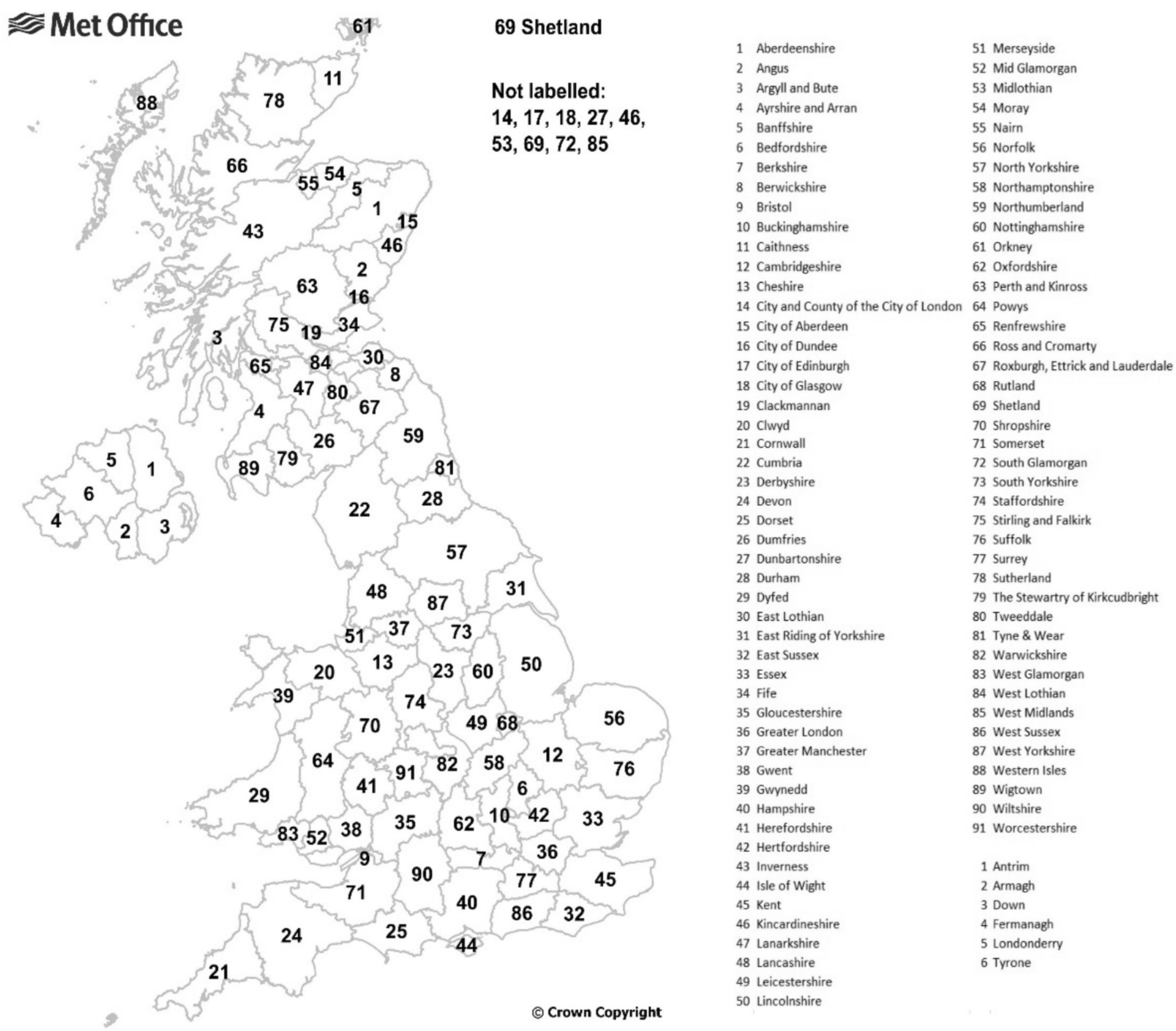

FIGURE A8 | County areas for the UK used in this report. The Isle of Man is excluded.

NASA, Berkeley Earth and the German Climate Computing Centre DKRZ. Global temperature series based on reanalysis are also produced by ECMWF (ERA5) and Japan (JRA-55).

Central England Temperature

The Central England Temperature (CET) monthly series, beginning in 1659, is the longest continuous instrumental 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 1974, the data have been adjusted to allow for any artificial warming effects due to the expansion of local built-up areas. Parker and Horton (2005) and Parker (2010) have investigated uncertainties in the CET series.

The CET and HadUK-Grid England series are very highly correlated (Figure 8). The CET series could effectively be considered a proxy for an England series from 1659, although because these are different datasets produced in different ways, some differences are inevitable. The England series has warmed slightly more than the CET series, which warrants further investigation since the cause of this difference cannot be confidently attributed at present. However, this difference is small compared to the overall warming trend common to both series.

The version control process for CET has recently been changed. Previously, CET was updated on a periodic basis, but this has now been changed to annual releases in the same way as the HadUK-Grid dataset. Detailed release notes are at https://www.metoffice.gov.uk/hadobs/hadcet/releases/cet_releases.html. This report uses v2.1.0.0. Previous updates have included substantial structural improvements to the underlying software and addressing some historical issues. The major update to version 2 of this dataset is described in Legg et al. 2025. Overall, these changes have had negligible impact on the CET series overall (e.g., the rank of individual years).

Sea-Surface Temperature Data

The Met Office Hadley Centre's sea surface temperature (SST) data set, HadSST.4.1.0.0, is a monthly global field of SST on a 5° latitude by 5° longitude grid from 1850 to date. This is derived from a combination of fixed and drifting buoys, ship bucket and engine room intake thermometers, and hull sensors. The data have been adjusted to minimise the effects of changes in instrumentation throughout the record. The data set is presented as a set of interchangeable realisations that capture the temporal and spatial characteristics of the estimated uncertainties in the biases (Kennedy et al. 2019).

The UK near-coast sea-surface temperature series in this report comprises the average of the 5° latitude-longitude grid-cells adjacent to the coast of Great Britain, which at this spatial resolution comprises four grid-cells. Although this is much lower than the 1° latitude-longitude resolution of HadISST1 (Rayner et al. 2003), HadSST.4.1.0.0 has a more up to date homogenization so should be better for identifying long term trends, and it also has uncertainty information as shown in Figure 19.

The UK near-coast sea-surface temperature series is entirely independent from observations from the UK land network, but is nevertheless well correlated with the UK land series (R^2 value 0.86, see Appendix B: Coefficient of Determination). Some differences between historical trends in these series are apparent, notably in the period pre-1900. However, these differences are also apparent in the Central England temperature series, also shown in Figure 19, which closely follows the UK series. Uncertainties in the SST dataset will generally be larger at smaller scales (such as UK near-coast) and can include uncertainty in the bias adjustments applied to minimize the effect of instrumentation changes.

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, and trends in the series should be treated with caution (Murphy et al. 2020). Various papers detail the development of the EWP series (Wigley et al. 1984; Alexander and Jones 2000; Simpson and Jones 2012).

The EWP series is very highly correlated to the England and Wales areal rainfall series from 1836 from the HadUK-Grid dataset, although it is a different dataset produced in a different way. Minor differences between these 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. Overall, the EWP series is around 2% to 3% wetter as shown by the offset between the series in Figure 25.

Rain Gauge and Snow Depth Data

Daily rainfall data presented in this report are 0900–0900 UTC totals from either daily or tipping-bucket rain-gauges registered with the Met Office. The majority of these gauges are owned and maintained by the Met Office, the Environment Agency, Natural Resources Wales, SEPA and Northern Ireland Water. Station network coverage is described in Appendix A: HadUK-Grid Dataset.

Snow depth data are recorded at 0900 UTC. 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, reaching a peak of over 500 stations in the 1990s. It subsequently reduced to around 200 stations in 2010 and has remained fairly steady thereafter.

Sunshine Data

The UK's sunshine network comprises two instrument types. The majority are Kipp & Zonen CSD-1 (KZ) automatic sunshine recorders from automated stations, with the remainder Campbell-Stokes (CS) sunshine recorders at manual stations. On average, KZ sensors record slightly lower values than co-located CS instruments, so an upward adjustment 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. The adjustment is made KZ to CS, not the other way round, because although KZ outnumbers CS for the current network, the majority of total historical sunshine observations, by far, are CS. Legg (2014a) and references therein provide further details.

Wind Data

Wind speeds are measured by cup anemometers located on a standard 10 m height mast. The rate of rotation is proportional to the speed of the wind. These were introduced by the Met Office for wind measurement at surface stations during the 1950s (Sloan and Clark 2012). At mountain stations, wind speeds are measured by heated sonic anemometers which have no moving parts and reduce potential problems with icing. Due to data availability, the wind analyses within this report are based on data from 1969.

NAO Index

The Winter North Atlantic Oscillation (WNAO) index is traditionally defined as the normalized pressure difference between the Azores and Iceland. This represents the principal mode of spatial variability of atmospheric pressure patterns in the North Atlantic. The WNAO index presented in this report is an extended version of this index based on a series maintained by the University of East Anglia Climatic Research Unit, using data from stations in Gibraltar (instead of the Azores but at a similar latitude) and south-west Iceland (updated from Jones et al. 1997). These two sites are located close to the centres of action that comprise the WNAO. Data from these stations have been used to create homogeneous pressure series at the two locations which extend back to 1821. Winter for the WNAO index is defined as December to February for consistency.

For the UK, a positive WNAO index tends to be associated with higher temperatures and higher rainfall. However, 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 correlation with rainfall in particular being fairly weak. The influence of WNAO may differ regionally across the UK, for example for rainfall across the north-west compared to the south-east, which overall UK rainfall statistics will tend to smooth out (West et al. 2018). Other modes of spatial variability in atmospheric pressure patterns also affect the UK's weather. For example, the East Atlantic (EA) and Scandinavian (SCA) patterns—the second and third modes of spatial variability represented in their positive phases by low pressure to the west of Ireland and high pressure over Scandinavia respectively—also exert an influence (Hall and Hanna 2018).

The centres of action that define the summer NAO (SNAO) correspond to grid-point pairs 60 N, 5 E and 80 N, 50 W—located to the east of the Shetland Islands and in north-west Greenland respectively These reflect the smaller spatial scale and a more northerly track of summer Atlantic low pressure systems (Folland et al. 2009). Due to their location, a station-based SNAO series cannot be used. Instead, the SNAO index has been calculated from the 20th Century Reanalysis (Slivinski et al. 2019) and extended to the present day using the ERA5 reanalysis (Hersbach et al. 2020).

The SNAO index is calculated as the difference in seasonal mean sea-level pressure between these grid-point pairs for each year from 1850. Summer is defined as June, July and August to provide consistency with summer statistics presented elsewhere in the report. Note this SNAO definition differs from Folland et al. (2009) which uses July and August only. For the UK, a positive SNAO tends to be associated with higher temperatures and lower rainfall. However, in contrast to winter, where the correlation between WNAO and winter mean temperature is clearer, in summer it is the correlation between SNAO and summer mean rainfall that is clearer. As with the WNAO, this index is unable to fully explain the variability of UK summers. The efficacy of the 20th Century Reanalysis to calculate the SNAO index prior to 1880 is likely to be limited by data availability, so uncertainties are likely to be larger early in the series.

Sea Level Data

Sea level changes around the British Isles are monitored by the UK national network of 42 tide gauges, which falls under the authority of the Environment Agency. For more than 100 years tide gauges have provided 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.

In recent years, the State of the UK Climate report has included a UK sea level index for the period since 1901 computed from sea level data from five of the longest operating stations (Aberdeen, North Shields, Sheerness, Newlyn and Liverpool), which provides a reliable estimate for UK sea level rise, excluding the effect of this vertical land movement. The records from each station are combined after removing the long-term trend from each to account for varying vertical land movement rates across the country. After aggregating the records, the calculated country-wide average rate of 1.4 mm·year^{-1} is reintroduced (Woodworth et al. 2009; Bradley et al. 2011).

However, creating this index relies on tide gauges following international best practice on operation and quality control to ensure reliability of the data, and long-term stability of the vertical reference frame (UNESCO/IOC 2020). Unfortunately, from 2007 onward, there have been more gaps in observations throughout the network, including for the five long-running stations. The update to the index for 2024 is only based on two sites, as only Newlyn and North Shields provided enough data to generate an annual mean. A UK national report in 2019 for the Global Sea Level Observing System (GLOSS) provides more information about issues with the network, available at https://goosocean.org/document/24144.

The tide gauge data used in this study is distributed by the British Oceanographic Data Centre (BODC, https://www.bodc.ac.uk) having undergone full quality control, and is funded by the Environment Agency. Trends in the index have been calculated by fitting linear trends using the CATS (Create and Analyse Time Series) package described in Williams (2008) which produces realistic estimates of uncertainty by accounting for autocorrelation in the series.

The data for the storm surge analysis is also supplied by BODC and processed for the National Tidal and Sea Level Facility (https://ntslf.org) specifically for short-term surge analysis. For Surge Quality Control, sites with possible datum shifts and levelling uncertainties not suitable for long term trend analyses are included. This provides a larger dataset to analyse the storm surge, but as a result, levels may not be comparable between sites or year-to-year.

Skew surge is the difference between the peak observed tide and peak astronomical tide, which is the part that can be predicted months in advance (Figure A9). It is usually slightly smaller than the 'non-tidal residual' that is sometimes reported, but is a more robust measure of peak impact, being independent of timing (Williams et al. 2016).

Phenology Data

The Woodland Trust's Nature's Calendar has been collating citizen science phenological observations across the UK for 26 years. Here we show UK mean dates, without geographic adjustment, for the first unfolded leaf ('first leaf') in spring and first bare tree ('bare tree') in autumn for four common woody species: Elder (*Sambucus nigra*), Hawthorn (*Crataegus monogyna*), Pedunculate Oak (*Quercus robur*) and Silver Birch (*Betula pendula*). We also show first and last lawn cutting dates in spring and autumn respectively. We report further spring events as follows: first flowering dates for Hazel (*Corylus avellana*), Lesser Celandine (*Ficaria verna*), Wood Anemone (*Anemone nemorosa*) and Bluebell (*Hyacinthoides non-scripta*); first appearance dates for the Brimstone butterfly (*Gonepteryx rhamni*), Speckled Wood butterfly (*Pararge aegeria*), first nest building by the Blackbird (*Turdus merula*) and the appearance of Common Frog (*Rana temporaria*) spawn. Dates are converted to day of the year (days from 1 January) before data analysis. Figure A10 shows some examples of these indicators.

Dates for the baseline period (1999 to 2023), derived from annual means, are compared with those for 2024. To assess the relationships with temperature for each spring plant event, we have regressed the 1999–2024 annual mean dates on a 3 month mean Central England Temperature (CET) for the month incorporating the mean date and the preceding 2 months. Past experience suggests that a 3-month block of temperatures is broadly appropriate for plants. For the animal events, we have used the mean of those months that appear most influential. We report the response to a 1°C increase in the selected months. We also compare 1999–2024 annual means of bare dates, and last lawn cutting,

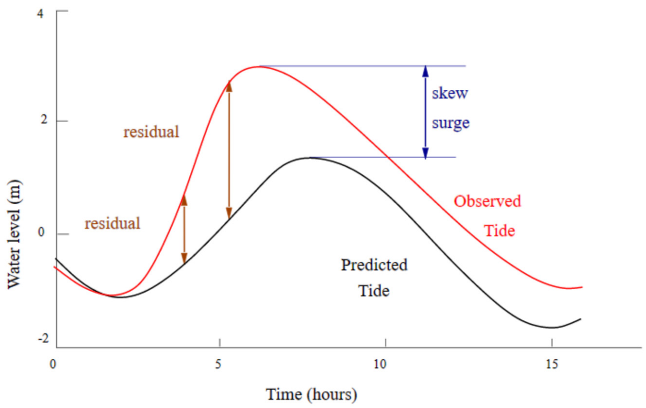

FIGURE A9 | Diagram of skew surge showing the difference between predicted tide and observed tide.

to October mean CET, since experience has shown that the influential window for autumn events is much shorter. CET provides a reasonable representation of the inter-annual temperature variations across the UK, for the UK-wide means. By necessity, the phenology data considered here are slightly shorter than the 30-year period used elsewhere in this report, and will be less able to detect trends.

Appendix B: 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 and include a smooth trend. This means that both annual variability and the longer-term trend (removing short-term variability) can be viewed simultaneously. 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.

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. The kernel is reflected at the ends of the time series to enable the trend lines to cover the full length of the series. However, this process of reflection will tend to damp any trends at the ends of the time series, so the trend line for the first and last decade of each series should be interpreted cautiously. The method of creating smoothed trend-lines using a 'non-parametric regression' is described in Mudelsee (2019), who describes the advantages and disadvantages of various possible statistical approaches in trend analysis of climate time-series. Further discussion is provided in de Valk (2020).

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 urbanization, 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, although this is likely to vary on a station by station basis—for example, whether a station is located in the centre of a large city or nearer the periphery, the latter being more likely to have changed over time. Identifying and correcting for such factors in climate monitoring is referred to as homogenization. This aims to ensure any biases introduced into the observations caused by these non-climatic factors are removed and the climate series are

FIGURE A10 | Examples of phenology indicators: (a) Pedunculate Oak (*Quercus robur*) 'first leaf'; (b) Wood Anemone (*Anemone nemorosa*) first flowering (c) Brimstone butterfly (*Gonepteryx rhamni*) first appearance, (d) Common Frog (*Rana temporaria*) spawn first appearance.

self-consistent through time. Homogenization may be considered as distinct from quality control—which is the identification and removal of errors in the observations (described in Appendix A: Quality Control). Some homogenization 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 Appendix A: Sunshine Data. For most variables, however the individual station data in this report have not been explicitly homogenized to account for these non-climatic factors.

Uncertainty Estimates

Earlier studies have considered uncertainties in the gridded data and areal-averages based on a 5 km 'legacy' gridded dataset previously used for UK climate monitoring (Legg 2011; Legg 2014b). Although the HadUK-Grid dataset is at a different resolution, it uses the same method of interpolation. The earlier uncertainty estimates will therefore still be broadly representative, although they will not reflect recent additions to the dataset (particularly the recent addition of Rainfall Rescue data).

The most important source of uncertainty in the dataset is spatial sampling—that is, how the number and distribution of stations in the observing network changes over time. Table A5 lists 1σ uncertainty (standard error) ranges for annual mean temperature, rainfall and sunshine for different periods in the legacy 5 km gridded dataset for the UK and countries. These correspond to: the earliest years in the 5 km dataset where the availability of station data was generally lowest and uncertainty highest; a period in the dataset around the 1960s which for rainfall corresponded to a step increase in availability of station data and decrease in uncertainty (for monthly rainfall this step has been eliminated) and a comparatively recent period in the dataset. 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). Seasonal uncertainty ranges are likely to be similar to monthly uncertainty ranges presented in Legg (2014b). The uncertainty estimates in these earlier studies 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).

In general, uncertainty ranges for areal-averages of monthly mean temperature, rainfall and sunshine increase in the past as the network density reduces. For monthly, seasonal and annual temperature for the UK and countries, the standard error is less than 0.1°C and consequently the uncertainty is much smaller than the year-to-year variability. For rainfall, the standard error is around 1% or less when the network comprises several thousand rain gauges but approaches 4% in early decades where this number reduces. For sunshine, the standard error can approach 2% (equivalent to approximately 5 min per day, on average).

Uncertainties will be larger for small (county-sized) areas earlier in the series as the number of stations reduces, depending on the spatial distribution, with rainfall affected to a much greater extent than temperature due to the much greater spatial variability. As noted in Appendix A: HadUK-Grid Dataset, the addition of monthly Rainfall Rescue data has transformed the quality of the monthly dataset, and a systematic reappraisal of uncertainty estimates in the 1 km HadUK-Grid dataset, taking into account both this and other recent additions of historical data, is required.

Uncertainties in the CET and EWP series have been investigated separately in Parker and Horton (2005), Parker (2010) and Simpson and Jones (2012).

Other Sources of Uncertainty

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 areal average of the rainfall anomaly field as a percentage. This is judged to be the simpler and more readily comprehensible statistic for the majority of users and is directly proportional to the total volume of rainfall across the country. However, it means that climatologically wetter areas of the UK have a greater influence on the overall UK summary statistic than the drier areas, rather than all equal-sized areas having equal influence (as would be the case using an areal 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.

TABLE A5 | 1σ Uncertainty (standard error) ranges for annual T_{mean}, rainfall and sunshine for 5 km resolution 'legacy' gridded dataset.

Temperature (°C)					
Year range	**UK**	**England**	**Wales**	**Scotland**	**Northern Ireland**
1910–1919	0.04	0.04	0.06	0.06	0.08
1961–1965	0.03	0.03	0.04	0.03	0.04
2006–2012	0.03	0.03	0.04	0.04	0.04
Rainfall (%)					
Year range	**UK**	**England**	**Wales**	**Scotland**	**Northern Ireland**
1910–1919	1.2	1.2	3.0	2.8	3.7
1961–1965	0.3	0.3	0.6	0.5	0.8
2006–2012	0.4	0.4	0.9	0.7	1.6
Sunshine (%)					
Year range	**UK**	**England**	**Wales**	**Scotland**	**Northern Ireland**
1929–1935	0.7	0.8	1.0	1.0	1.6
1959–1964	0.6	0.8	0.9	0.8	1.4
2005–2012	0.7	0.9	1.1	1.1	1.8

A further source of uncertainty in the rainfall data is introduced by the measurement of precipitation that has fallen as snow. At manually read rain gauges, the observer will measure the precipitation equivalent of fresh snow fallen at 0900 UTC, 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 situations, estimation of precipitation from snow may be either underestimated or overestimated. This important limitation, as noted for Figure 26, is acknowledged and investigated by Murphy et al. (2020). However, this now tends to be usually less of a problem than during the colder, snowier years of earlier decades.

Coefficient of Determination

The coefficient of determination, R^2, as presented in this report is a measure of the strength of the linear relationship between a predictor variable and a dependent variable, where R is the correlation coefficient, based on a linear least-squares regression. The R^2 value is a statistical measure of how closely the dependent variable can be predicted from the predictor variable. An R^2 value of 1 would indicate a perfect correlation, in which the dependent variable can be predicted without error from the predictor variable. An R^2 value of 0 would mean the predictor variable has no predictive value for the dependent variable. An R^2 value of 0.5 would mean that half of the variance in the dependent variable can be explained by variations in the predictor variable. R^2 values exceeding 0.9 for time-series in this report would indicate that they are very highly correlated. R^2 may also be expressed as a percentage.

Rounding

Values quoted throughout this report are rounded, but where the difference between two such values is quoted (for example comparing the most recent decade with 1991–2020), this difference is calculated from the original unrounded values. For internal processing purposes, unrounded values of area average statistics generated from the HadUK-Grid dataset are stored with a five decimal place precision for all variables and areas.

Appendix C: Useful Resources

Met Office

Annual State of the UK climate publications from 2014 https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate.

UK climate information https://www.metoffice.gov.uk/research/climate/maps-and-data.

HadUK-Grid information https://www.metoffice.gov.uk/climate/uk/data/haduk-grid/haduk-grid.

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

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

The HadSST4 dataset is maintained by the Met Office Hadley Centre and can be downloaded at https://www.metoffice.gov.uk/hadobs/hadsst4/.

The HadCRUT5 dataset is maintained by the Met Office Hadley Centre and can be downloaded at https://www.metoffice.gov.uk/hadobs/hadcrut5/.

Met Office UK Storm Centre for named storms https://www.metoffice.gov.uk/weather/warnings-and-advice/uk-storm-centre/index.

Met Office digital library and archive (for scanned copies of Daily Weather Summaries, Monthly Weather Reports, British Rainfall, etc.) https://digital.nmla.metoffice.gov.uk/.

Further information on data products available from the Met Office may be obtained by contacting the Customer Centre https://www.metoffice.gov.uk/about-us/contact.

External Links

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

Access to HadUK-Grid dataset (open access) https://catalogue.ceda.ac.uk/uuid/4dc8450d889a491ebb20e724debe2dfb/.

Access to HadCET dataset (open access) https://catalogue.ceda.ac.uk/uuid/f1e8696c6d5746e694fde4d6022e5a36/.

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

An open access version of the Met Office Midas database is available at https://catalogue.ceda.ac.uk/uuid/dbd451271eb04662beade68da43546e1.

Bulletin of the American Meteorological Society (BAMS) State of the Climate Report https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/.

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

Centre for Ecology and Hydrology, reports for major hydrological events https://nrfa.ceh.ac.uk/nhmp/occasional-reports.

ECMWF Copernicus Climate Data Store https://cds.climate.copernicus.eu/.

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

Lamb weather types and UK Jenkinson Gale Index maintained by the University of East Anglia Climatic Research Unit https://crudata.uea.ac.uk/cru/data/lwt/.

North Atlantic Oscillation (NAO) data maintained by the University of East Anglia Climatic Research Unit https://crudata.uea.ac.uk/cru/data/nao/.

National Tidal and Sea Level Facility UK National Tide Gauge Network (owned and operated by the Environment Agency) https://ntslf.org/data/uk-network-real-time.

National Oceanography Centre report of the UK Storm Surges of 2024 https://nora.nerc.ac.uk/id/eprint/539236/.

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

UK Health Security Agency heat mortality monitoring reports https://www.gov.uk/government/publications/heat-mortality-monitoring-reports.

Weather at Oxford Radcliffe Meteorological Station monthly and annual reports https://www.geog.ox.ac.uk/research/climate/rms/reports.html.

WMO Annual Bulletin on the Climate in region VI (Europe and Middle East) https://www.dwd.de/EN/ourservices/ravibulletinjahr/ravibulletinjahr.html.

WMO guide to climatological practices https://library.wmo.int/index.php?lvl=notice_display&id=5668.