An Attribution Study of the UK annual mean temperature of 2025

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Executive Summary

- 2025 was the warmest year on record for the UK with an annual mean temperature of 10.09°C replacing 2022 (10.03°C) as the hottest year on record.
- In the current climate, UK annual mean temperatures exceeding those observed in 2025 are expected to occur with a best-estimate return time of approximately 3 years (5% to 95% range 2.9 to 3.2 years).
- Human influence has increased the probability of occurrence by around 260 times.
- In a pre-industrial climate reaching the 2025 annual mean temperature is highly unlikely with a return time estimate of just above 780 years (5% to 95%, range 600 to 1100 years).
- This new annual record is not extreme in the current climate, and considerably higher annual mean temperatures are already possible.

1. Introduction

2025 was the hottest year on record for the UK, with a mean annual temperature of 10.09°C, replacing 2022 (10.03°C) as the hottest year on record. This was driven by persistent above-average temperature through the year as shown in Figure 1. January and September were the only monthly means to record below average temperature (relative to a 1991-2020 average), while both spring and summer of 2025 were the hottest on record. During spring and summer seasons the UK experienced periods dominated by high-pressure systems resulting in high temperatures, clear-skies, and extended dry conditions. This contributed to 2025 also being the sunniest year on record for the UK. The period from March to August (meteorological spring and summer combined), saw less than 50% of average rainfall fairly widely across southern and central England, but wetter conditions in September, November and December alleviated the rainfall deficit somewhat, resulting in a drier-than average year, but not exceptional.

A rapid attribution analysis was conducted to quantify the human-influence on the likelihood of reaching or exceeding the record-breaking 2025 annual mean temperature. The approach provides estimates of the exceedance probability of similar events in the climate of a 'natural' world, the climate of the present day, and that of the end of the 21st Century. A timeseries of UK annual mean temperature in Figure 2 also shows 2025 in the context of the observed warming in the UK climate. 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 (Kendon et al., 2025).

The analysis was conducted using a system developed by the Met Office for rapid studies and described in Christidis (2021). This uses climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6, Eyring et al., 2016).

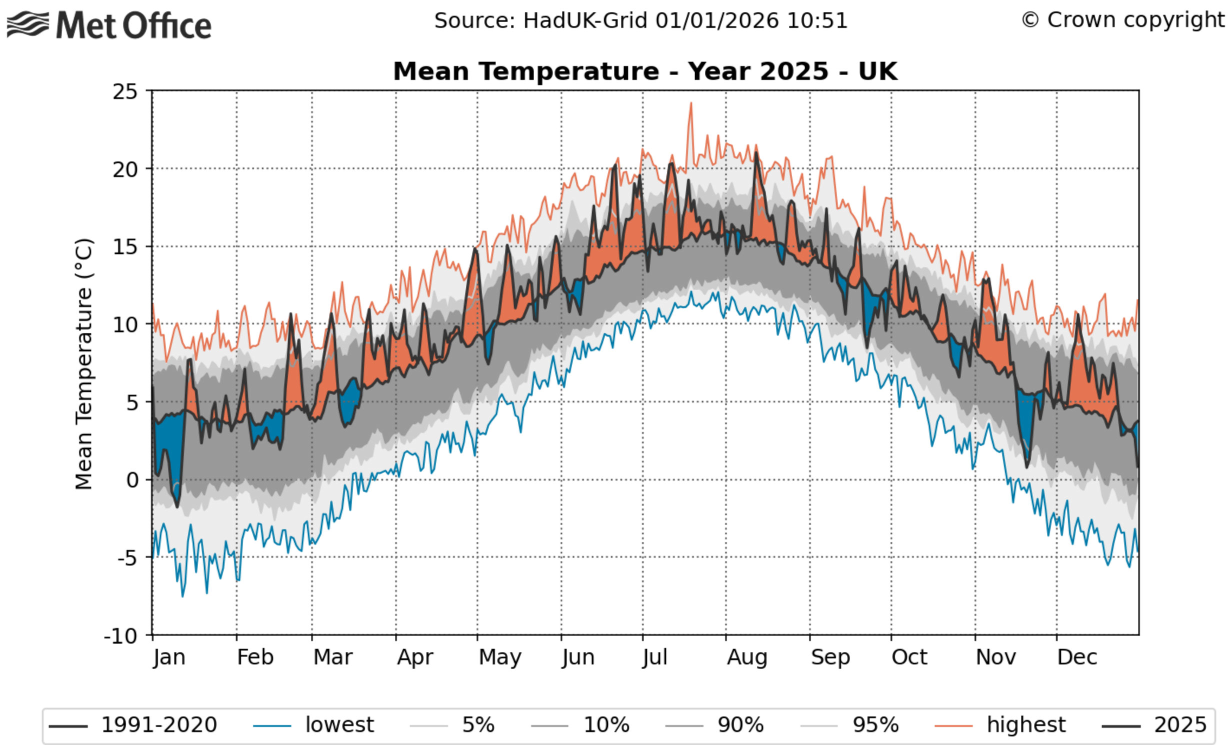

Figure 1: UK daily mean temperature for 2025. Periods of above average temperature are highlighted orange, and periods below average are blue. The 1991-2020 average temperature is shown in black. The (light) grey shaded regions show the (5%-95%) 10%-90% of all years, and the thin orange and blue outer lines show the daily record temperatures.

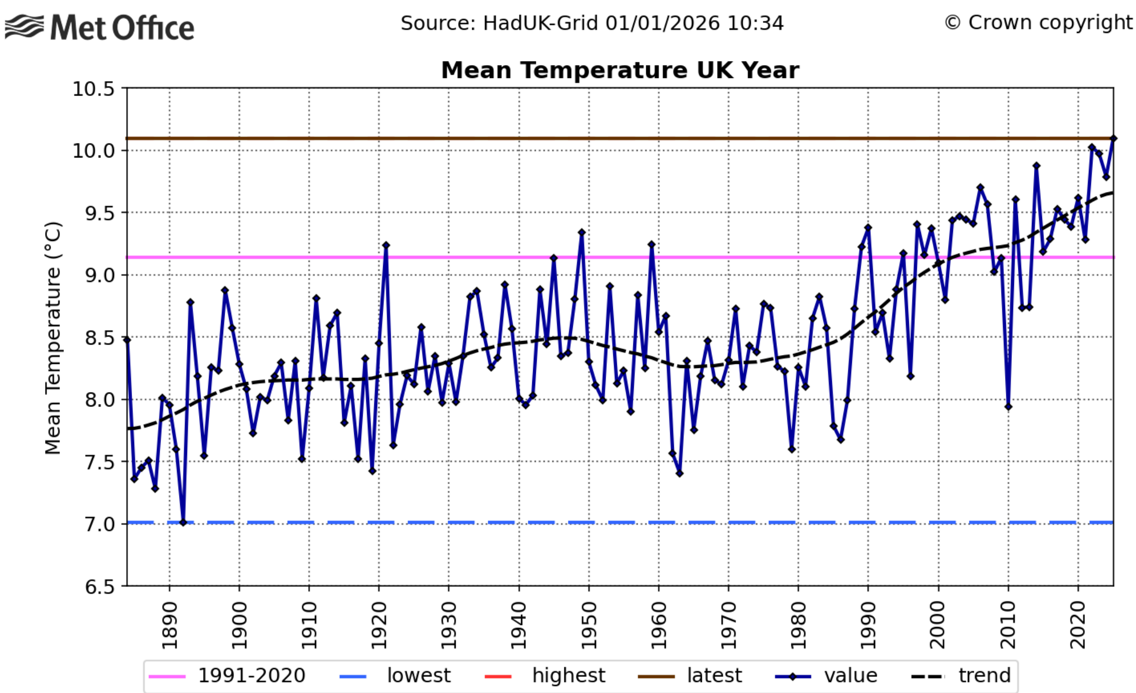

Figure 2: UK annual mean temperature from 1884 to 2025. The smoothed trend is shown as a black dashed curve. The 1991-2020 average is shown as a pink line.

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2. Data

Observed values of the UK annual mean temperature are obtained from the HadUK-Grid dataset v1.3.1.0 (Hollis et al., 2019; Met Office, 2025). The time series contains UK monthly means spanning January 1884 – December 2025. Annual mean values are obtained by averaging monthly data over all months of each calendar year, appropriately weighted by the number of days in each month.

Model data is taken from 14 CMIP6 models that provide ensemble members for each of the natural (hist-nat) and historical (historical) climate experiments as well as projections driven by greenhouse gas and aerosol concentrations and land-use change from the SSP2-4.5 scenario (ssp245, Riahi et al., 2017). The hist-nat experiment provides simulations of the pre-industrial climate and the historical experiment provides simulations of the changing climate under observed climate forcings. The SSP2-4.5 projections are valid from 2015 onwards and are chosen as a “middle of the road” scenario for mitigation and adaptation to climate change. The names of models and the number of ensemble members used from each are shown in Table 1.

Table 1: CMIP6 models and corresponding number of ensemble members used from each experiment in the attribution analysis.

Model Name	historical	ssp245	hist-nat
ACCESS-CM2	3	3	3
ACCESS-ESM1-5	18	18	3
BCC-CSM2-MR	3	1	3
CESM2	11	6	3
CNRM-CM6-1	30	6	10
CanESM5	25	25	15
FGOALS-g3	4	4	3
GFDL-ESM4	3	3	3
GISS-E2-1-G	6	3	5
HadGEM3-GC31-LL	5	5	5
IPSL-CM6A-LR	32	11	10
MIROC6	10	3	10
MRI-ESM2-0	5	1	5
NorESM2-LM	3	3	3
Total	**158**	**92**	**81**

Time series of the observed and modelled UK annual mean temperature anomalies, relative to a baseline period of 1901 – 1930, are shown in Figure 3. Increasing temperatures are shown in both observations and the historical and ssp245 simulations, with further increases projected through the rest of the 21st Century. This shows a steadily increasing likelihood of higher-than-average annual temperatures being experienced in the UK. The historical and hist-nat ensembles start to diverge from around the 1980s suggesting that climate forcings arising from human influence are the dominant factor in the observed warming trend.

The value of the UK annual mean temperature for 2026 was 10.09°C, 0.067°C above the record set in 2022 of 10.03°C. The value of the UK annual mean temperature anomaly for 2026, relative to a baseline period of 1901 – 1930, was 1.95°C, compared to 2022's anomaly of 1.88°C. It is clear just from the time series in Figure 3 that this new annual record is not extreme in the current climate, and that considerably higher annual mean temperatures are already possible.

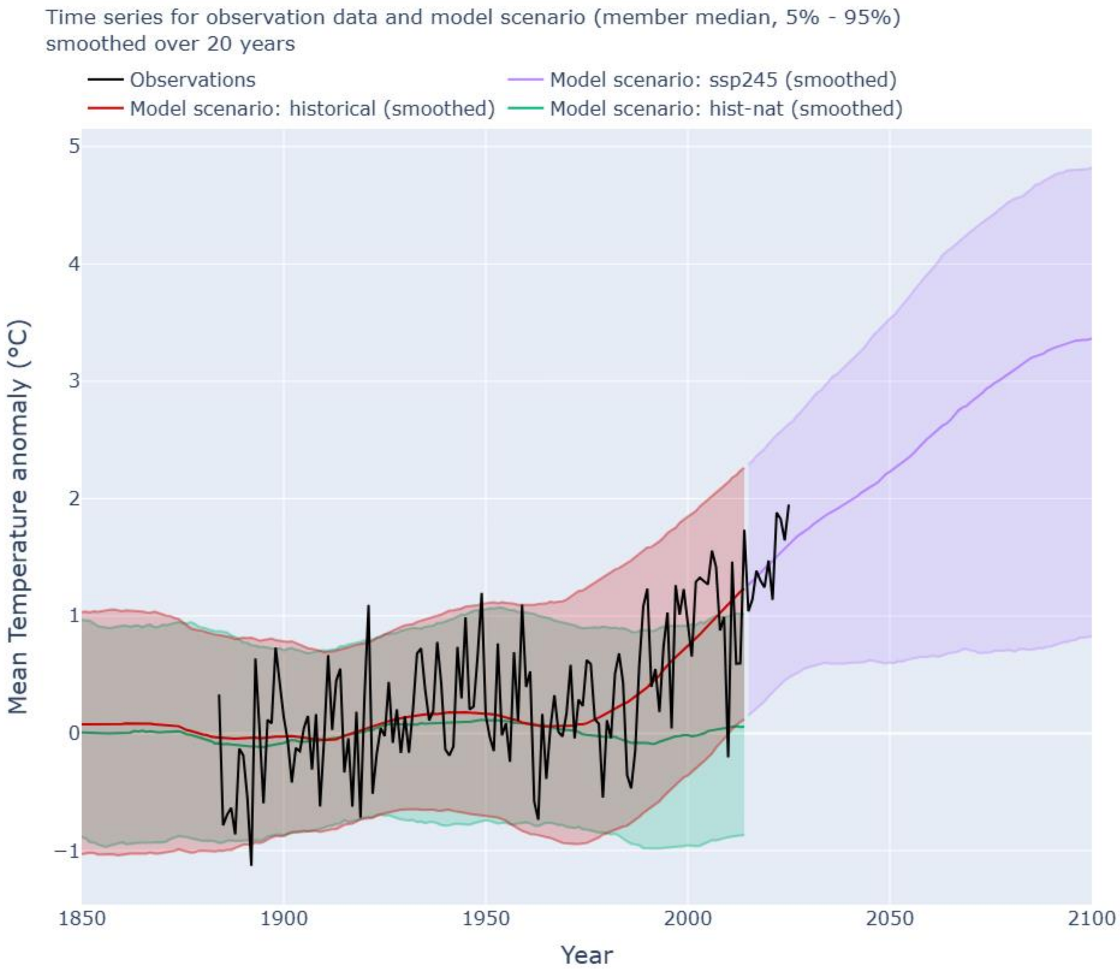

Figure 3: Time series of the UK annual mean temperature anomaly (w.r.t. 1901 – 1930). Observational data from HadUK-Grid (black). Simulations from the CMIP6 historical (red), ssp245 (purple) and hist-nat (green) experiments. Simulation data is represented as median values and filled 5th – 95th percentile ranges explored by members of the multi-model ensemble. Percentiles of simulation data are smoothed with a rolling window of 20 years, with historical and ssp245 combined into one continuous series. Observed data runs from 1884 – 2025.

3. Method

The method employed is to find exceedance probabilities of the 2025 UK annual mean temperature in the natural world climate without human influence (nat), the current day climate (now) and that of the end of the century (end). The nat climate is represented by collating all available years from the hist-nat simulations (1850 - 2020). The now climate is represented by taking all data from the 20-year period 2015 – 2034 that is centred on 2025, from the historical simulations up to 2014 and continued by ssp245. The end climate is represented by all data taken from the final 20 years of the ssp245 experiment (2081 - 2100).

Time series of both observations and model members are produced for the UK regional mean of anomalies of gridded annual mean temperatures. In all cases the anomalies are calculated relative to a 1901 – 1930 baseline. Land fraction masks are applied for each model individually to obtain land-only temperatures comparable to the HadUK-Grid observations. All available members from the 14 CMIP6 models are combined into a single multi-model ensemble and samples taken from the appropriate time periods, from which distributions may be estimated.

Exceedance probabilities are then calculated in one of two ways.
If the observed value of the UK annual mean temperature anomaly is not an extreme value (i.e. it does not sit within the tail of the distribution), then the exceedance probability is the empirical fraction of model values lying above the observed threshold.
If the observed value of the UK annual mean temperature anomaly can be treated as an extreme value, then a Generalised Pareto Distribution (GPD) is fit to the model tail data and an exceedance probability is found from the continuous approximation of the tail of the model distribution.

Probability ratios are used to express changes in probability between the current climate and that of the natural world, and between the climate of the end of the century and the natural world. The probability ratio in each case is the exceedance probability in the climate of interest divided by that in the pre-industrial climate.

Uncertainty ranges are calculated by performing a 10,000-member bootstrap (90% with replacement) from which the 5% and 95% values of the exceedance probabilities, return times and probability ratios are found. For each bootstrap resampling of the data, we re-count or re-fit the GPD to find the new exceedance probability.

4. Model Evaluation

The models were evaluated against the HadUK-Grid observations, as presented in Figure 4. Several evaluation tests commonly employed in event attribution studies (Christidis et al., 2013, Christidis, 2021) are conducted on the full multi-model ensemble of historical simulations over the evaluation period 1884 – 2014, which is the overlap of the historical experiment with availability of the observations. This provides over 20,000 years of model data.

The observed temperature trend for the evaluated historical period is well within the range of the simulations and close to the ensemble mean (Figure 4, top panel, observed trend in black is 0.084°C per decade and model mean trend in red is 0.070°C per decade). A small number of simulations exhibit a negative trend over the evaluation period, but we do not exclude these members. Examining each model separately, all models have a positive trend over the evaluation period. When extended further into the 21st Century with the SSP2-4.5 scenario, all models retain positive anomalies with respect to the start of the 20th century.

Estimates of the power spectra as seen in the periodogram (Figure 4, middle panel) also indicate good consistency of the variability in annual mean temperature between the model ensemble and HadUK-Grid, both at short and long periods.

The Quantile-Quantile plot (Figure 4, lower panel) produced for each simulation separately shows curves that mostly lie close to the 1:1 line, indicating that the shapes of member distributions compare well with that observed. Persistent deviations of individual members above (below) observed values are expected for members exploring cool (warm) variations during the anomaly period 1901 – 1930 (Figure 3). Model members examined separately exhibit consistent variability at multi-decadal time scales (see the periodograms, Figure 4, middle panel). As the observed quantiles remain within the range of members over these values, and both trend and periodogram show consistency, we accept the multi-model ensemble representation of the shape of the distribution of anomalies.

We do not exclude any members or models based on these assessments. The ensemble is deemed suitable for an attribution analysis of extreme UK annual mean temperatures. However, it should be noted that users requiring more comprehensive assessment of future projections than are provided through this particular model ensemble and emission scenario choice should use the UK Climate Projections (UKCP).

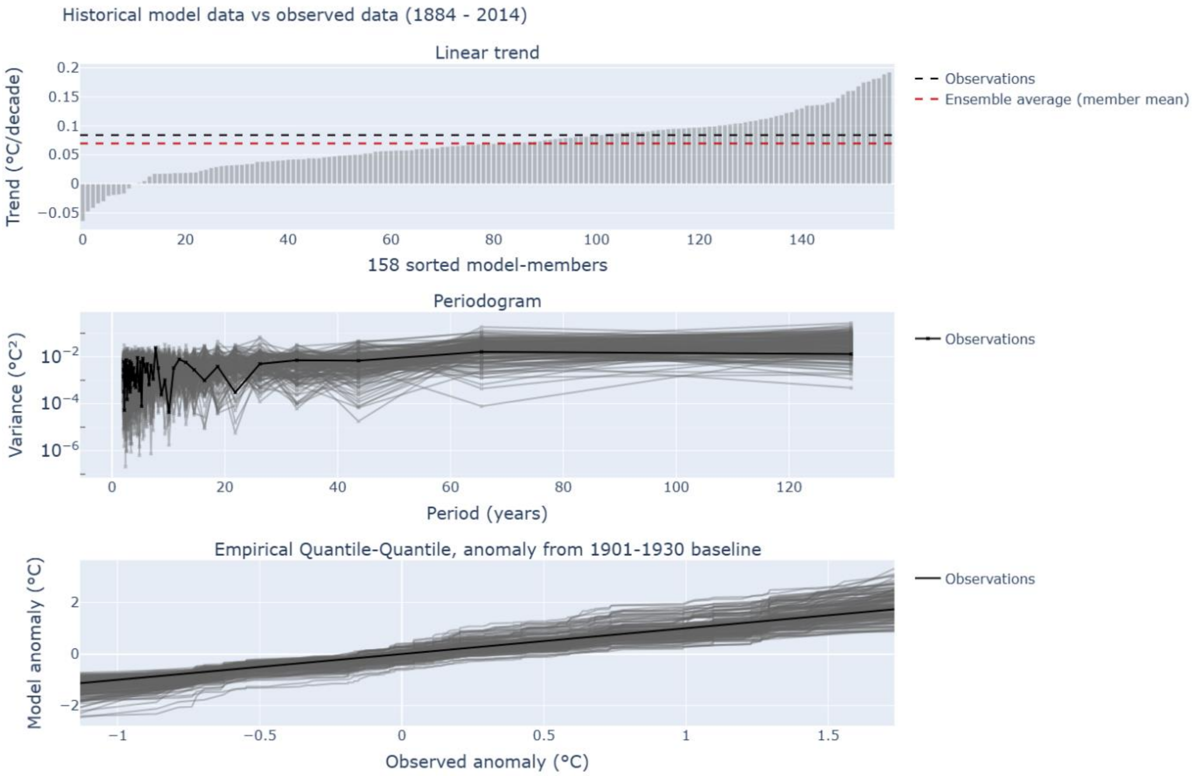

Figure 4: Evaluation of CMIP6 multi-model ensemble used in the attribution analysis, for the historical experiment, evaluated over 1884 – 2014 by comparison with observational HadUK-Grid data.
Top panel: temperature trends over the evaluation period.
Middle panel: power spectra estimates (periodogram) from the HadUK-Grid data and historical simulations.
Bottom panel: quantile-quantile plot for each of the historical simulations.

5. Climate Attribution

The results of the analysis are presented as the probability and equivalent return period of exceeding the 2025 observed annual mean temperature anomaly, along with associated probability ratios in Table 2. UK annual mean temperatures exceeding those observed in 2025 are expected to occur with a best estimate return time of approximately 3 years (5% to 95% range 2.9 to 3.2 years) in the current climate, human influence having increased the probability of occurrence by around 260 times from an equivalent return time estimate of just above 780 years (5% to 95% range 600 to 1100 years) in the climate of the pre-industrial period.

Individual model projections (not shown) diverge by the end of the century (apparent from Figure 3) but further warming to the end of the century could see the annual temperatures of 2025 being exceeded more frequently than the best estimate. The multi-model best estimate return time is approximately 1.3 years at the end of the century for the ssp245 scenario, but this includes a range of responses and is shorter in some individual model projections and longer in others.

Table 2: Exceedance probabilities and risk ratio estimates for exceeding the observed 2025 UK annual mean temperature anomaly (w.r.t. 1901 - 1930). 5-95% uncertainty ranges found by a 10,000-member bootstrap.

Experiment	Exceedance Probability (5%, 95%)	Return time / years (5%, 95)	Probability Ratio (5%, 95%)
nat: hist-nat all data	0.00128 (0.0009, 0.0017)	783 (600, 1100)	N/A
now: historical and ssp245 2015-2034	0.329 (0.31, 0.35)	3.04 (2.9, 3.2)	257 (200, 370)
end: ssp245 2081-2100	0.772 (0.75, 0.79)	1.296 (1.3, 1.3)	604 (460, 870)

Other attribution studies have evaluated UK annual mean temperature extremes using essentially the same method as used here. Christidis et al. (2023) conducted an attribution study of the, at the time, record-breaking 2022 annual temperature. This study estimated a return time of reaching or exceeding 2022 annual mean temperature of 3.4 years, for a climate centred on 2022. Ciavarella et al. (2024) also conducted a study of the near-record breaking 2023, estimating a return time of reaching or exceeding 2023 annual mean temperature of 3.3 years, for a climate centred on 2023.

UK annual mean temperatures are warming rapidly. The change between 2022 and 2025 in the CMIP6 ensemble mean is 0.069°C in 3 years (equivalent to 0.23°C in 10 years). Consequently, as the 2022 record was broken by 0.067°C, this difference could be explained numerically by the rapid background warming in the UK arising from human-induced climate change.

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