Increasing chance of previously record-breaking UK average June temperatures

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Introduction

Following methodology developed to study the hot summer of 2018 and the 20˚C day in the UK February 2019 (McCarthy et al, 2019, Kendon et al, 2020), this note documents a study using the UK Climate Projections (UKCP) to assess the changing chance of observing the previously record-breaking June temperature recorded in 1940 and 1976. This study was triggered by the record-breaking June 2023 temperatures, which were anticipated several days before the end of the month. The 1940/1976 record of 14.9˚C was studied, rather than the new record (provisionally 15.8˚C) for two reasons. Firstly, it was notable that this record had held for such a long period of time even within a changing climate, so studying the previous chance of this record being exceeded provided useful context to the present-day record. Secondly, because of the rapid nature of the study a method that could be quickly produced was favoured. The method used was to count the number of exceedances of thresholds rather than use extreme value analysis. This meant that the study was limited to studying less extreme temperatures due to limited sample sizes. These methods were assessed to be sufficient for the purpose, which was to estimate the changing risk of extreme June temperatures due to climate change for communication immediately following the end of the month. Future studies could extend the number of models used, and deploy extreme value analysis to more precisely assess the probability of extreme June temperatures, and to assess the relative role of natural variability in the June 2023 record.

Specifically, this aims of this study are to:

a) identify the approximate probability that any June would reach or exceed the UK average June average 1940 record (14.9˚C) during a period centred on 1940 (1925-1955),

b) compare this to the chance of a June reaching or exceeding this value over a recent 30-year period (1991-2020),

c) quantify how this index for extreme heat is projected to change in the future by the end of the 21st century under different climate change scenarios. In particular RCP2.6 and RCP8.5 for the periods 2050-2060 and 2080-2090.

Data

This study uses the land component of the UK Climate Projections (Murphy et al, 2019) probabilistic sample realisations and the global projections averaged over the UK to compare the chance of June average temperatures in the UK exceeding the previous 1940/1976 record of 14.9˚C. These two products were chosen for this study for the following reasons:

- The global projections are available for all of the periods, and two emissions scenarios of relevance for this study (historic and future, and high and low emission futures) and provide the ability to study structural model uncertainty due to including simulations for several global modelling centres alongside an ensemble of variants of a Hadley Centre model, HadGEM3. At approximately 60km resolution the ability to simulate the climate of June in the UK is expected to be acceptable (further validation was also performed, and used to correct for biases in variability).
- The probabilistic projections are only available for the recent past and future periods, but are available for several alternative future scenarios including the high and low emission futures. They provide a comprehensive sampling of uncertainty, and are expected to well represent the climate of UK June temperature.

Observed temperatures for the study come from the monthly average of the daily mean temperatures from HadUK-Grid (Hollis et al., 2019) averaged over the UK. This dataset covers the period from 1884 to close to the present day. Taking the period up to June 2023 the record value is 14.9˚C which was equalled in both 1940 and then 1976. In this study we use an anomaly relative to the period 1991-2020 for the analysis. This anomaly is 1.6˚C.

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Model evaluation

The UKCP global and probabilistic products have been subject to extensive evaluation and use and deemed suitable for use for statistics such as UK and monthly means values. This study builds on this validation and focuses on identifying model biases and processing to remove their impact on the results.

By using anomaly values the impact of any mean bias in the model simulation of the UK mean is removed. There is however a remaining mismatch in variability between some ensemble members of the global and probabilistic models compared to the observations (compare Figure 1 to Figures 2 and 3).

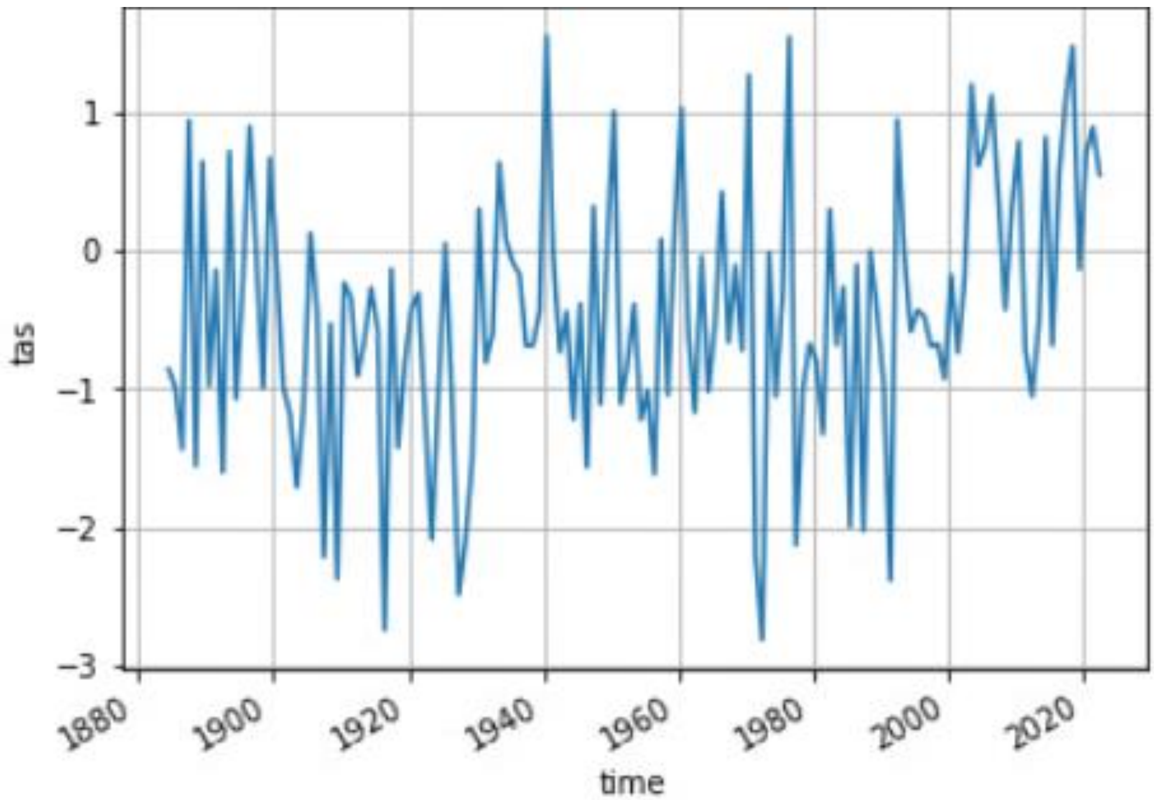

Figure 1: Observed UK June average temperature anomaly from HadUK-Grid relative to 1991-2020 period.

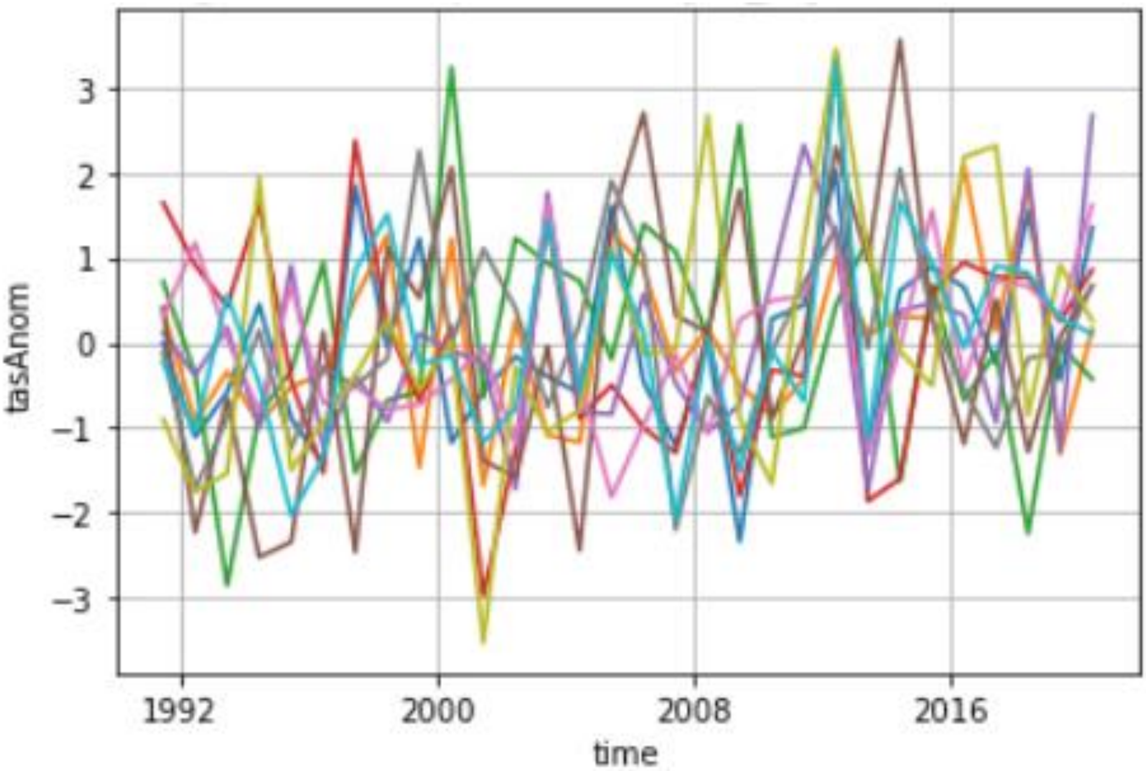

Figure 1: Random sample of trajectories of UK average June temperature anomalies from probabilistic projections covering the period 1991-2020 as an anomaly relative to this period, using RCP8.5 (similar results, not shown, can be obtained from RCP2.6).

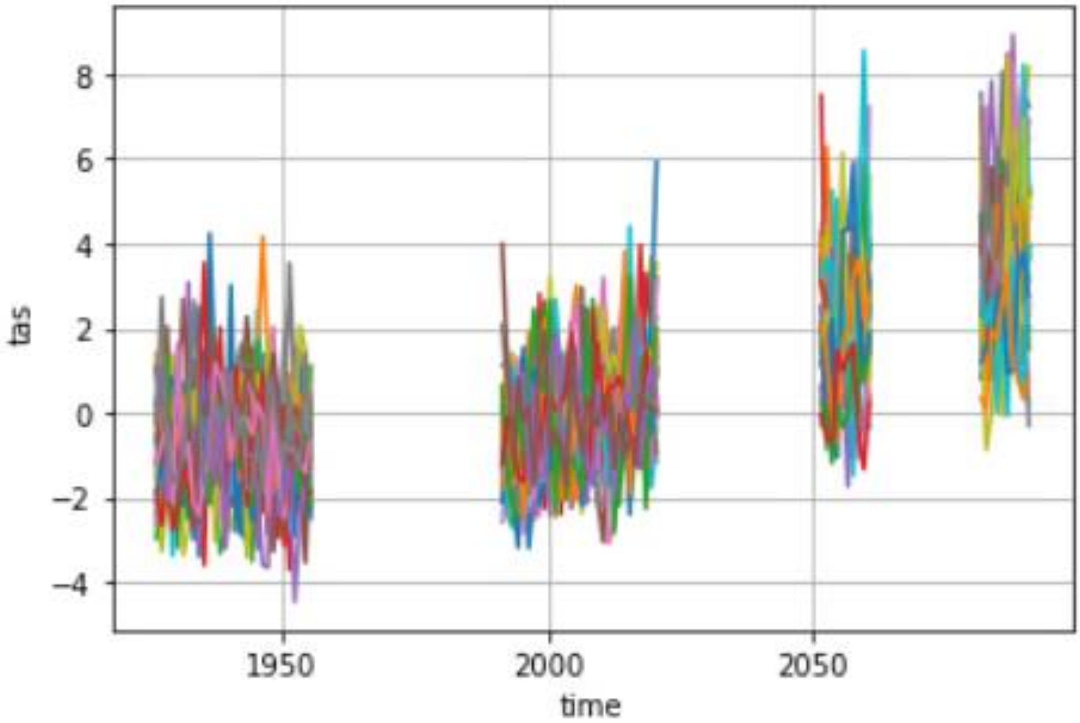

Figure 2: Trajectories of UK average June temperature anomaly from global projections using RCP8.5 covering time slices 1925-1955, 1991-2020, 2050-2060 and 2080-2090, all as anomalies relative to 1991-2020.

The over-variance in the models is more clearly seen by comparing frequency distributions of the standard deviations of UK June temperatures in the global and probabilistic models over the period 1991-2020. The observation falls within the distributions of the two sets of projections, but is in the lower tails of both distributions. This provides additional confidence that the models represent relevant processes responsible for year-to-year variability in June temperatures. The (on average) greater variance may be a result of sampling of different patterns of internal variability, or could be as a result of a bias in variability in the models.

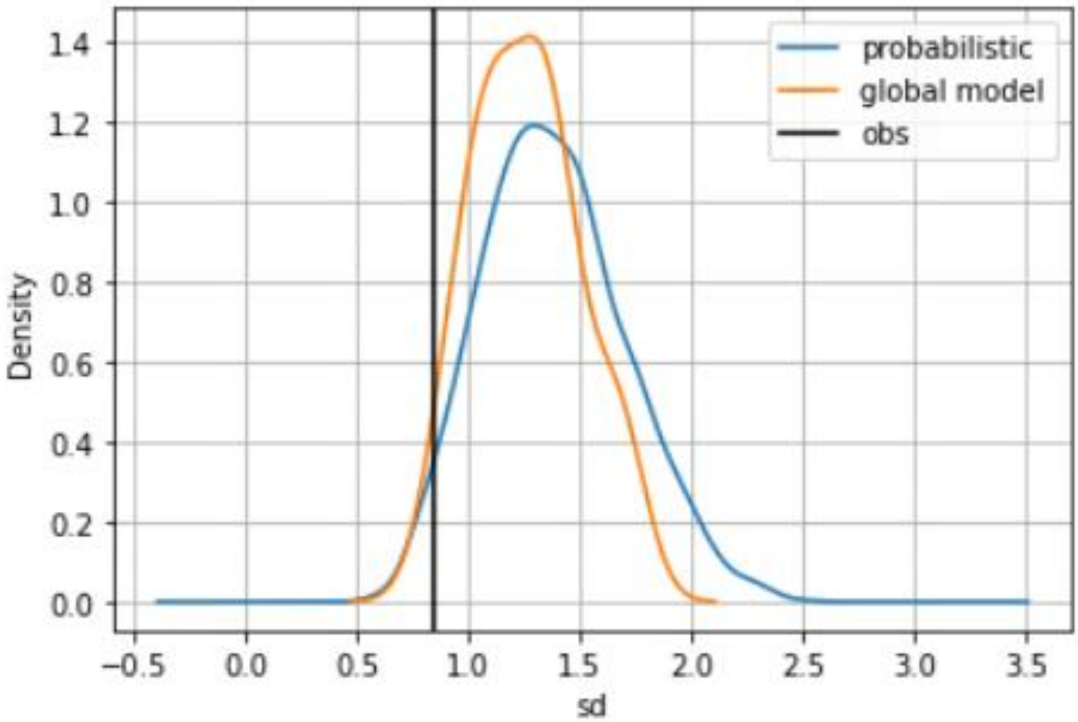

Figure 3: Frequency distribution (smoothed using a kernel density approach) of standard deviations from global and probabilistic models for June average UK temperatures over the period 1991-2020, with standard deviation of the corresponding observations (vertical black line).

Method

To take account of the difference of anomaly variation within the observations compared to the two sets of projections two approaches were used in this analysis. Since we cannot be sure which approach is better aligned to the reality of the earth system, the communicated results of the study are based only on those for which the two approaches agree.

Approach 1 (hereafter, All): For each of the two sets of projections (global and probabilistic), each time period, and each RCP, the number of times that the simulations exceed the anomaly value of 1.6˚C (the 1940/1976 anomaly relative to the baseline of 1991-2020) was counted and divide by the number of model years. This approximates the probability of exceedance according to that sample.

Approach 2 (hereafter, Filered): For each of the two sets of projections (global and probabilistic), each time period, and each RCP, the sample is filtered to only include those ensemble members whose standard deviation during the 1991-2020 period is within ±10% of the observed standard deviation during this period. The number of model years exceeding the anomaly value of 1.6˚C is divided by the total number of model years (as for All).

Results

The results of this method are as follows:

Year range	RCP2.6				RCP8.5			
	Global (All)	Global (Filtered)	Prob (All)	Prob (Filtered)	Global (All)	Global (Filtered)	Prob (All)	Prob (Filtered)
1925-1955		Not enough data	Not included in projections		3.3	1.7	Not included in projections	
1991-2020			13.0	3.5	9.8	3.3	13.1	3.7
2050-2060	31.7		30.5	30.4	55.7	55.0	51.1	52.4
2080-2090	35.0		36.7	34..3	88.2	75.0	78.2	78.5

The filtered global and probabilistic projections for both of the RCPs in the baseline period (1991-2020) are all a little over 3%. This is in line with the return period estimate on observed UK average June anomaly of 1.6˚C relative to 1991-2020 using a generalised extreme value distribution (not shown). Unfiltered estimates are all significantly higher, as would be expected due to the larger variance of the projections. Whilst there is disagreement between the methods on this statistic, there is strong indication of a positive change between the recent period compared to the period centred on 1940. Here there is agreement between the All and Filtered approach, with both approximately doubling or increasing further (more than doubling for All approach).

Into the future filtered and unfiltered estimates are more similar since the climate change signal becomes more significant compared to the natural variability. Here by 2050s the RCP8.5 indicates that June temperatures as hot as the previously record-breaking 1940/1976 June of 14.9 ˚C could be occurring around every other year, assuming RCP2.6 means they would be approximately once every 3 years. Beyond that the chance of summers this hot is strongly governed by emission pathway – increasing significantly under RCP8.5 but levelling off under RCP2.6.

These results are in line with existing attribution studies showing that the chance of hot summer temperatures has increased significantly over the 20th century in Europe (for example Christidis, 2015, McCarthy et al, 2019).

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