Hadley Centre Technical Note 106

Attribution of the 2018 summer heatwave in the UK

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Introduction

The summer of 2018 was the joint hottest in the UK, driven by persistent high-pressure conditions. The season was marked by sunny weather and soaring temperatures, particularly during June and July. Temperatures across parts of southern England were often well above average with 30°C exceeded fairly widely on 15 days during July and early August. The heat finally ebbed away as the season drew to its close. An attribution study of the event is presented in this report, which uses an ensemble of climate models to determine how anthropogenic climate change affects the likelihood of extremely hot summers in the UK. It is found that summers at least as warm as 2018 become 30 times more likely because of human influence.

Event Attribution

Attribution of weather and climate extremes is a research area that has seen major advances over the last decade (Stott et al., 2016). It aims to estimate in a quantitative manner the extent to which causal factors (most commonly human influence on the climate) alters characteristics of extreme events, like their likelihood, or magnitude. A series of annual reports has been published in the Bulletin of the American Meteorological Society (BAMS) since 2012 reviewing extreme events of the previous year in the context of variability and change (Herring et al., 2017). The BAMS reports have provided ample evidence of a detectable anthropogenic effect not only on temperature extremes, but also on an increasing number of other types of events like, for example, storms, droughts, tropical cyclones and hurricane-related inundations. The potential of this new scientific area has been acknowledged by the United States National Academies of Sciences, Engineering, and Medicine (NAS, 2016).

The attribution study of the UK summer heatwave follows the standard approach employed in risk-based analyses, whereby changes in characteristics of extreme events are derived by comparing their distribution in the real world against their distribution in a counterfactual “natural” world, without the effect of human influence (Stott et al., 2016). The concept was first introduced by Stott et al. (2004) in their study of the 2003 European summer heatwave. Methodological variants apply the same concept, but use different tools to construct the distributions. While all methods require data from large ensembles of simulations with all (both natural and anthropogenic) forcings (ALL) and without human influence (NAT), some employ atmospheric models (Pall et al., 2011; Christidis et al., 2013; Black et al., 2016), others use coupled atmosphere-ocean models (Christidis and Stott, 2016; Lewis and Karoly, 2015) or long observational records (Vautard et al., 2015; van Oldenborgh et al., 2015). These differences alter the framing of the attribution question: studies with atmospheric models estimate the changing likelihood of extremes given the observed state of the ocean at the time of the event, while coupled model studies consider a general case by sampling the entire range of variability. This broader class of events is considered here and summer heatwave events are simply identified when the summer (June to August) mean temperature anomaly exceeds the observed anomaly in summer 2018. Hence, the attribution question can be stated as "how have anthropogenic forcings changed the likelihood of summers in the UK warmer than 2018"?

The CMIP5 ensemble and model evaluation

The analysis uses multi-model ensembles from 20 models that contributed data to the phase 5 of the Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012). The same methodology with large CMIP5 ensembles was adopted by Christidis et al., 2018 in their study of the warm and wet winter of 2015/16 in the UK. The 20 models provided 56 simulations of the historical climate (experiment ALL), extended to the end of the 21st century with the RCP4.5 scenario, and 66 simulations of the natural climate (experiment NAT). Details of the models and the two experiments are given in Table 1. The models were evaluated against a gridded UK temperature dataset produced by the National Climate Information Centre (NCIC; Perry and Hollis, 2005). The model data were re-gridded on the NCIC grid and masked to include the same coverage (i.e. land areas only over the UK). Summer mean temperature anomalies (relative to 1901-1930) were then computed for each simulated year and the resulting timeseries are plotted together with the NCIC observations in Figure 1. Anomalies as high as 2018 appear to become common by the middle of the century and move into the colder half of the distribution by 2100. To increase confidence in the attribution results, the models were evaluated against the observations using standard evaluation tests (Christidis et al., 2013) to ensure they reproduce well-observed trends and variability. Results from these assessments are shown in Figure 2. Temperature trends since 1900 are shown in Fig. 2a. Uncertainties were estimated based on the standard deviation of the slope calculated with least square fits. Almost all simulations have trends consistent with the observations marked by the grey area. One of the CSIRO simulations is found to lie outside the observational range, but as the remaining nine ensemble members of this model are in agreement with the observations, all the CSIRO simulations were retained. Power spectra analyses (Fig. 2b) reveal that the simulated variability is also realistic and the observed spectrum is well within the range of the modelled spectra. Finally, a standard Q-Q plot (Fig. 2c) provides a simple comparison between the CMIP5 and NCIC temperature distributions. Although a small number of models seem to generate more intense cold summers, the ensemble as a whole is found provide an adequate representation of the UK summer temperature, at least as far as warm events are concerned.

Results and conclusions

The ALL and NAT distributions of UK summer temperatures are constructed from anomalies over 15 years extracted from each model simulation. The period 2011-2025 (i.e. a 15-year period centred on 2018) is used to construct the ALL distribution and the last 15 years of the NAT simulations are used for the distribution without human influence. 840 ALL and 990 NAT summers are used in total. The probability of exceeding the observed 2018 anomaly and the return time (inverse probability) are calculated next from the two distributions. As in previous work (Christidis et al., 2013), extreme probabilities are computed with the generalised Pareto distribution and their associated uncertainties with a Monte Carlo bootstrap procedure. Results are reported in Table 2.

It should be noted that this study focuses solely on the effect of anthropogenic forcings. The summer of 2018 was also characterised by persistent anticyclonic circulation patterns that favour warm summer extremes in the UK. Here the likelihood of hot summers is estimated in the general case, i.e. under any possible atmospheric circulation pattern. The role of the 2018 circulation is currently being investigated in detail in a separate study.

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Table 1 The CMIP5 models used in the analysis and the number of simulations for each experiment. The ALL simulations were extended to 2100 with the RCP4.5 scenario.

Model	ALL Ensemble Size	NAT Ensemble Size
ACCESS1-3	1	3
bcc-csm1-1	1	1
BNU-ESM	1	1
CCSM4	6	4
CESM1-CAM5	3	3
CNRM-CM5	1	6
CSIRO-Mk3-6-0	10	10
CanESM2	5	5
FGOALS-g2	1	3
GFDL-CM3	3	3
GFDL-ESM2M	1	1
GISS-E2-H	5	5
GISS-E2-R	5	5
HadGEM2-ES	4	4
IPSL-CM5A-LR	4	3
IPSL-CM5A-MR	1	3
MIROC-ESM	1	3
MIROC-ESM-CHEM	1	1
MRI-CGCM3	1	1
NorESM1-M	1	1
Total No of Simulations	**56**	**66**

Table 2 Results from the attribution study. Estimates of the return time of summers at least as warm as 2018, with and without the anthropogenic effect. Best estimates are reported (50th percentile) and the 5-95% uncertainty is given in parenthesis. The risk ratio indicates the increase in the likelihood of warm summers under the effect of anthropogenic forcings.

ATTRIBUTION RESULTS		
Return Time ALL	**Return Time NAT**	**Risk Ratio**
8.15 (7.23 to 9.28) years	244.78 (144.27 to 1169.3) years	30.16 (17.26 to 142.31)

Figure 1 Timeseries of the UK summer mean temperature (shown as anomalies relative to 1901-1930) from the ALL (red) and NAT (blue) model simulations and the NCIC data (black). The 2018 anomaly is marked by the asterisk and the horizontal dotted line.

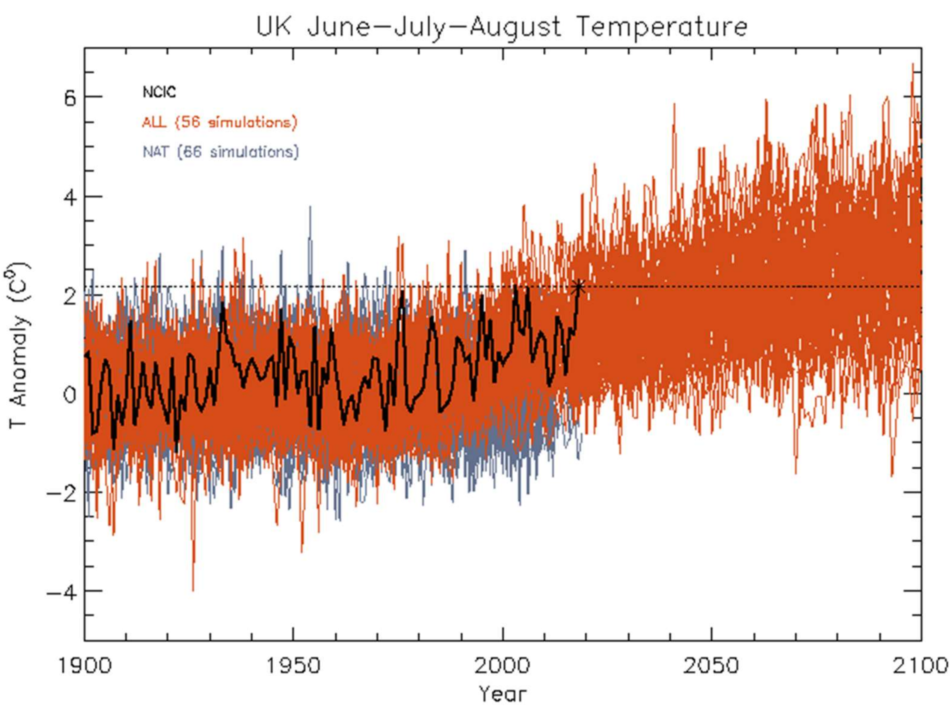
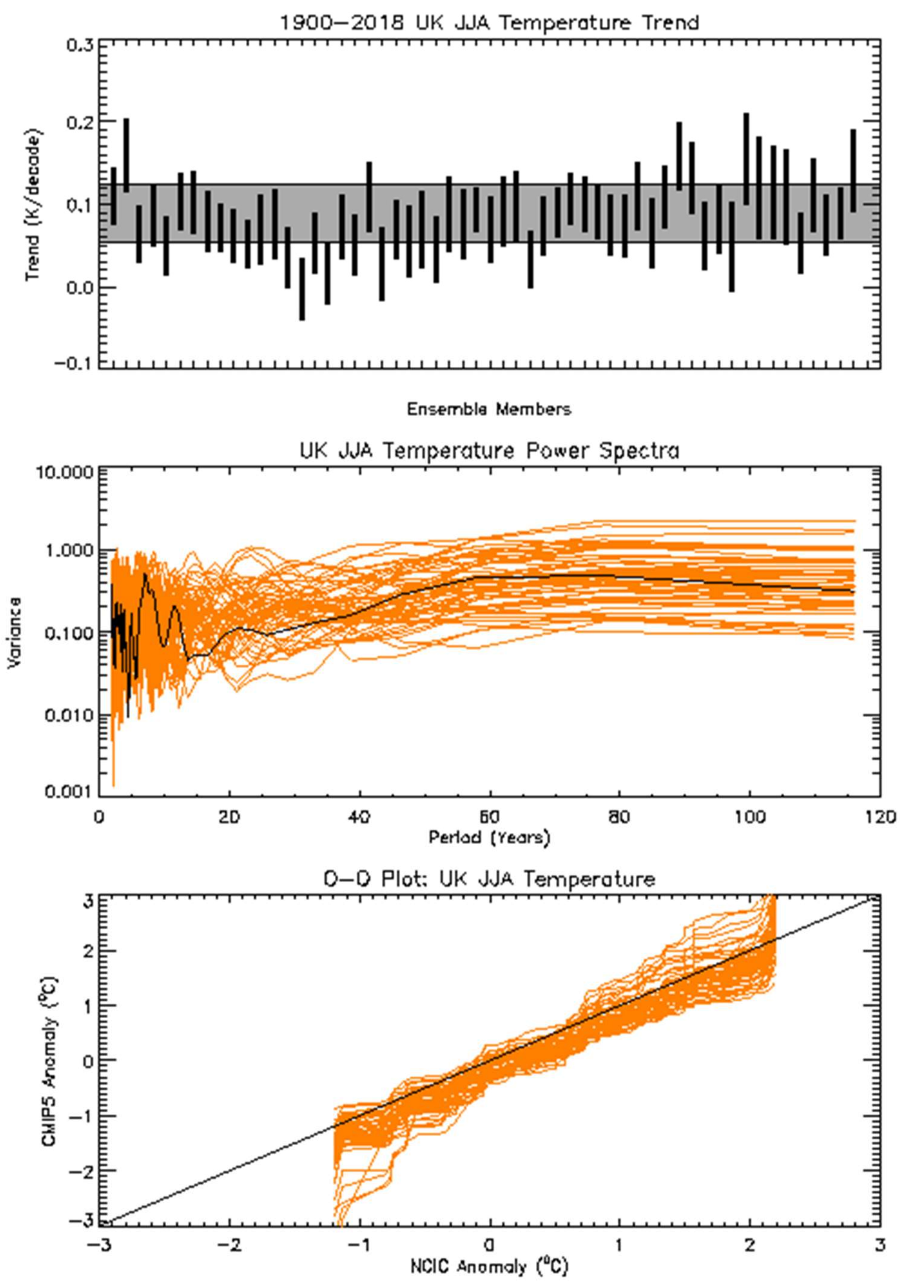


Figure 2 Evaluation of the CMIP5 models (ALL experiment) against NCIC observations. Top panel: summer temperature trends (1900-2018) estimated with observations (grey area) and individual model runs (vertical bars). The standard deviation of the slope computed with least square fits gives the plotted uncertainty range. Middle panel: Power spectra for the summer mean temperature estimated from observations (black line) and CMIP5 simulations (orange lines). Bottom panel: Q-Q plots of summer temperature anomalies. Each line corresponds to a different CMIP5 simulation.



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