HAVE THE ODDS OF WARM NOVEMBER TEMPERATURES AND OF COLD DECEMBER TEMPERATURES IN CENTRAL ENGLAND CHANGED?

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The Central England Temperature (CET) data set is the oldest continuously running temperature dataset in the world (Manley 1974) and records temperatures over a central area of England stretching between Lancashire, Bristol, and London. The decade of 2002–11 has been a particularly interesting one for CETs, with a number of warm autumns (2009, 2011), along with a number of cold winters (2009/10, 2010/11).

The emergent science of probabilistic event attribution is becoming an increasingly important method of evaluating the extent of how this human-influenced climate change is affecting localized weather events. Studies into the European heat wave of 2003 (Stott et al. 2004), the England and Wales floods of 2000 (Pall et al. 2011), and the Russian heat wave of 2010 (Dole et al. 2011; Rahmstorf and Coumou 2011; Otto et al. 2012) have sought to determine to what extent the risks of these events occurring have increased because of anthropogenic global warming.

We follow a similar methodology to Pall et al. (2011), which uses very large ensembles of global climate models (GCMs) to assess the change in risk of autumn flooding in the United Kingdom under two

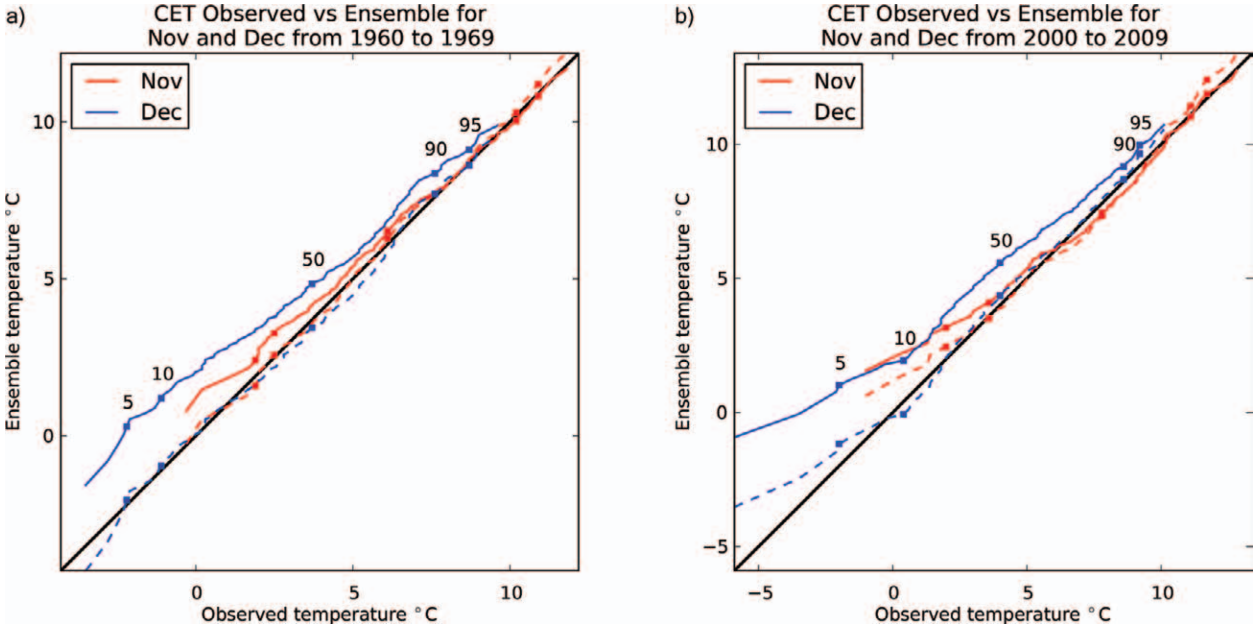

FIG. 12. (a) Quantile-quantile plot for November and December of the 1960–1969 decade. Uncorrected ensemble data are shown with a solid line, whereas the same ensemble data corrected for bias in the mean and standard deviation are shown with a dashed line. The squares denote the 5th, 10th, 50th, 90th, and 95th percentiles. (b) As in (a), but for the 2000–2009 decade.

different climate scenarios: observed autumn 2000 and a natural-only forcing autumn 2000. However, our two climate scenarios are based both on observations, one scenario for the 1960s decade and one for the 2000s. The method of Pall et al. (2011) decouples the anthropogenic signal from the natural variability by ensuring that the natural variability is the same in both scenarios. Although our method does not permit decoupling, using decadal long scenarios reduces some of the effects of natural variability and allows both scenarios to be validated against observed data. We have also expanded the method to use a regional climate model (RCM) embedded within a GCM. The increased resolution of the RCM results in a more realistic simulation of localized weather events, including cold and warm temperatures (Jones et al. 2004).

In this section we use large ensembles of the two climate scenarios to evaluate whether the frequency of warm Novembers and cold Decembers occurring has altered between the 1960s and 2000s, this being the period during which there has been a significant anthropogenic influence on climate.

Method. Weatherathome is a volunteer-distributed computing project that uses idle computing time from a network of "citizen scientists" home computers to run an RCM embedded within a GCM. The models used are HadAM3P, an atmosphere only, medium-resolution (1.875° × 1.25°, 19 levels, 15-min time step) GCM and HadRM3P, a high-resolution (0.44° × 0.44°, 19 levels, 5-min time step) RCM. Both models have been developed by the UK Met Office and are based upon the atmospheric component of HadCM3 (Pope et al. 2000; Gordon et al. 2000) with some improvements to the sulfur cycle and cloud parameterizations (Jones et al. 2004). The coupling between the models is performed every 6 h when the lateral boundary conditions of the RCM are relaxed to the GCM across four perimeter grid boxes (Jones et al. 2004)

Each volunteer's computer runs both models for a model year at a time, with initial conditions being provided by model runs previously completed by other volunteers. In this way, very large ensembles of RCMs can be computed, on the order of thousands, which in turn allows greater confidence when examining the tails of the distribution of climate variables.

The results examine the changing frequency of warm Novembers and cold Decembers since the 1960s. Two periods are analyzed, the 2000s and the 1960s which both use sea surface temperatures (SST) and sea ice fractions (SIF) from the HadISST observational dataset (Rayner et al. 2003). Atmospheric gas concentrations, including CO_2, N_2O, CH_4, O_3, and the halocarbons, are taken from observations and Special Report on Emissions Scenarios (SRES) scenario A1B (Nakicenovic and Swart 2000). Natural

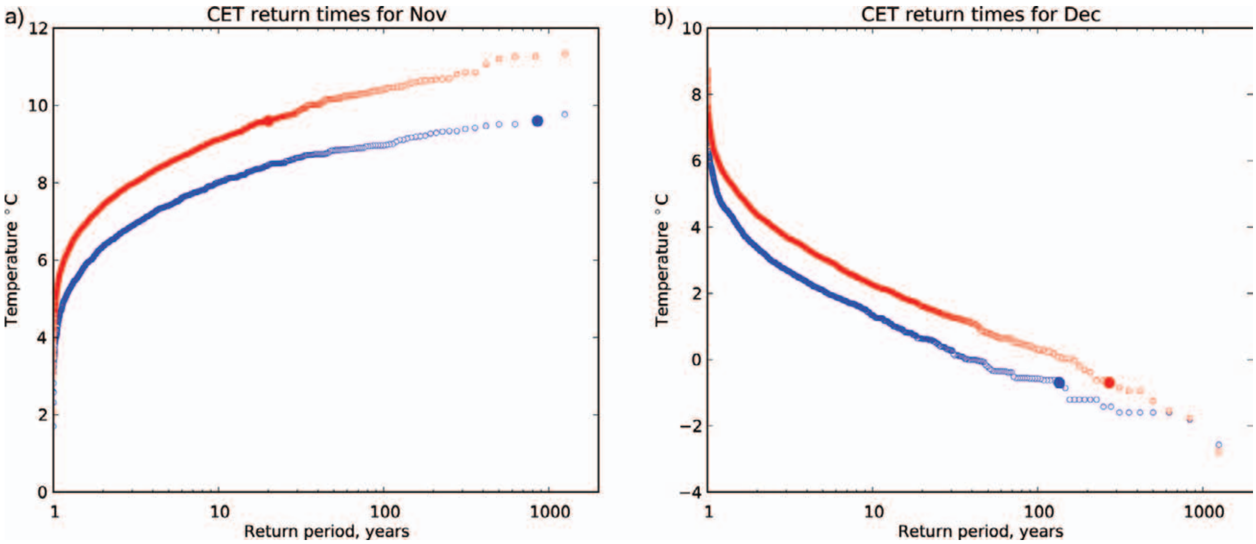

Fig. 13. (a) Return times of temperatures for November in the 1960–1969 decade (blue curve) and the 2000–2009 decade (red curve). The observed value for the warm November 2011 of 9.6°C is shown on both curves as a solid, larger circle, with a return period in 1960–1969 of 1250 years and in 2000–2009 of 20 years. (b) Return times of temperatures for December in the 1960–1969 decade (blue curve) and the 2000–2009 decade (red curve). The observed value for the cold December 2010 of –0.7°C is again shown as a solid, large circle, with a return period in 1960–1969 of 139 years and in 2000–2009 of 278 years.

volcanic emissions are assigned values from Sato et al. (2011). Finally, a modification to the model allows a variable solar forcing, which is taken from Krivova et al. (2007) and Lockwood et al. (2011). The topography and land use remain unchanged between scenarios.

Validation and bias correction. To analyze the results from the regional modeling experiment, four separate ensembles are formed from the data. Each data point in each ensemble is the mean of 27 grid boxes from the regional model, corresponding to 9 grid boxes centered over London, 9 over Bristol, and 9 over Manchester, which replicates the spatial distribution of the CET. The four ensembles are: all the Novembers occurring in the 1960s, all Decembers in the 1960s, all Novembers in the 2000s, and all Decembers in the 2000s. To ensure that the distribution of temperatures in these ensembles are representative of the distribution of the observed Central England Temperature, a validation exercise is performed.

Figure 12a shows quantiles of temperatures in the ensembles of 1960s Novembers and Decembers against the corresponding quantiles in the CET dataset. Figure 12b shows the same for the 2000s ensembles. The solid lines are the raw ensemble data, whereas the dashed lines are the result of applying a simple bias correction to ensure the means and standard deviations of the ensembles match the means and standard deviations of the observed CET dataset. The same bias correction is applied to both the 1960s and 2000s.

After the bias correction, there is good agreement between the ensembles and observations, giving confidence that any change in return time is representative of the change in return time in the observations.

Results and conclusions. Figure 13a shows the return times of warm temperatures in November in both the 1960s ensemble (blue) and 2000s ensemble (red). The temperature of a 100-yr event in Novembers in the 2000s has increased to 10.42°C from 8.97°C. The warm November of 2011, which is the second warmest in the CET, has a monthly mean temperature of 9.6°C. This corresponds to a return period of 20 years in the 2000s, but a return period of 1250 years in the 1960s, an approximately 62 times increase in occurrence.

Figure 13b shows the return times of cold temperatures in December in both the 1960s and 2000s. Although the occurrence of a cold December in the 2000s has decreased from the 1960s, the difference in temperature of the 100-yr event is 0.87°C. The cold December of 2010, which is the second coldest December and coldest since 1890, has a monthly mean temperature of –0.7°C, which has a return period of 139 years in the 1960s and a return period of 278 in the 2000s. Therefore, a cold December of –0.7°C is half as likely to occur in the 2000s when compared to the 1960s.

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