LETTER

Frequent summer temperature extremes reflect changes in the mean, not the variance

Hansen et al. (1) demonstrated that the probability of extremely hot summers has markedly increased because the mean of the distribution of seasonally averaged temperatures has increased. However, the authors also implied that the variance of the distribution has increased, a result that differs from regional studies that show changes in the extremes are consistent with a simple shift in the mean (2, 3). Here we extend the spatially aggregated distribution analysis of Hansen et al. to show that once issues related to normalizations, trends, and reductions in surface-station density are accounted for, there is no indication that variability about the mean has increased, at least using these methods and data.

Hansen et al. reported that the variance of summer surface temperature between 1981 and 2010 is greater than that in the 1951–1980 period (see figures 4 and 9 in ref. 1). Variance was calculated by first normalizing each temperature time series to have zero mean and unit variance during the 1951–1980 reference period, and then by computing the variance of average summer temperature across all time series and all years within a given period. Using this method and the same data, we find that variance increases from 1 in 1951–1980 (as required by the local normalization) to 1.88 in 1981–2010. However, using only the earlier period to normalize each time series imparts a positive bias to the variance in the later period (4). This bias is because the mean temperature of individual time series generally differs from zero during the later period, and differences in the mean across time series contribute to the aggregated variance estimate. Removing the sample means independently from each period yields a variance for 1981–2010 that is only 1.49 times that of 1951–1980.

Temperature trends also increase the sample variance of any given time series and, insomuch as trends differ between time series, they also increase the spatial variance. Such trends represent a shifting mean, and we suggest that they ought to be removed when focusing on variability about the mean. Detrending each time series independently for each period reduces the variance ratio to a value of 1.24. Although trends in the data increase variance during both periods, the reduction in the variance ratio results from the trends in the later period being larger.

Finally, a correction is needed to account for the 35% decrease in the number of surface stations providing monthly temperature estimates between the first and second period. The average temperature in a given grid cell is estimated by computing a weighted average across individual stations within a fixed distance of the cell, and thus a reduction in the number of stations implies an increase in noise variance. To estimate the effect that this has on the variance ratio, we assume an error variance of 1 °C for each grid cell during the earlier period (5) and that the underlying station errors are independent, normal, and homogeneous. The error variance associated with each grid cell during the later period is then estimated as 1 °C times the ratio of the number of stations available between the earlier and later period. Reductions in station density are estimated to cause a 26% increase in overall variance between 1981 and 2010. Correcting for this effect along with the previously discussed biases gives a variance ratio between the earlier and later period of 0.98, which is indistinguishable from 1, given the uncertainties.

The main conclusion of Hansen et al. (1) was that recent extremes would be highly unlikely without a warming climate, and this finding withstands our additional analysis. However, the second-order change in variance cannot be detected given the issues associated with normalization, trends, and variable data density. Finally, we emphasize that this analysis pertains only to summer averages and that other analyses based on, for example, shorter-term heat waves or droughts, may yield different results.

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