

On Climate Change and Temperature Variance: A Discussion of the paper “Perception of Climate Change” by Hansen et al. [2012]

Zeke Hausfather
Berkeley Earth Surface Temperature Project

In their recent paper “Perception of Climate Change” [PNAS, 2012], James Hansen, Mikiko Sato, and Reto Ruedy show that global mean temperature increase over the last six decades and that this increase increases the frequency of extreme heat events. They do not specifically address the related issue of whether the variance of the temperature distribution changes with time, although they do present histograms that could be misinterpreted as showing that. The primary focus of this analysis will be on whether the variance is increasing as the globe warms.

We begin by attempting to replicate the Hansen et al.[2012] analysis of changing means and variance shown in Figure 4 of their paper. We use GHCN version 3.1 quality controlled adjusted mean temperature data, and retain all stations that span the 1950-2010 period with at least 600 months of data available. We next assign each station to a 5x5 lat/lon grid cell based on its coordinates, and retain only June, July, and August observations. Temperatures are converted into anomalies over a common baseline period, and anomalies are divided by the standard deviations over the baseline period. The results are averages across all stations within each grid cell. Figure 1 shows the frequency density plots for each decade of the resulting values using a baseline period of 1951-1980 side-by-side with Figure 4 from Hansen et al.

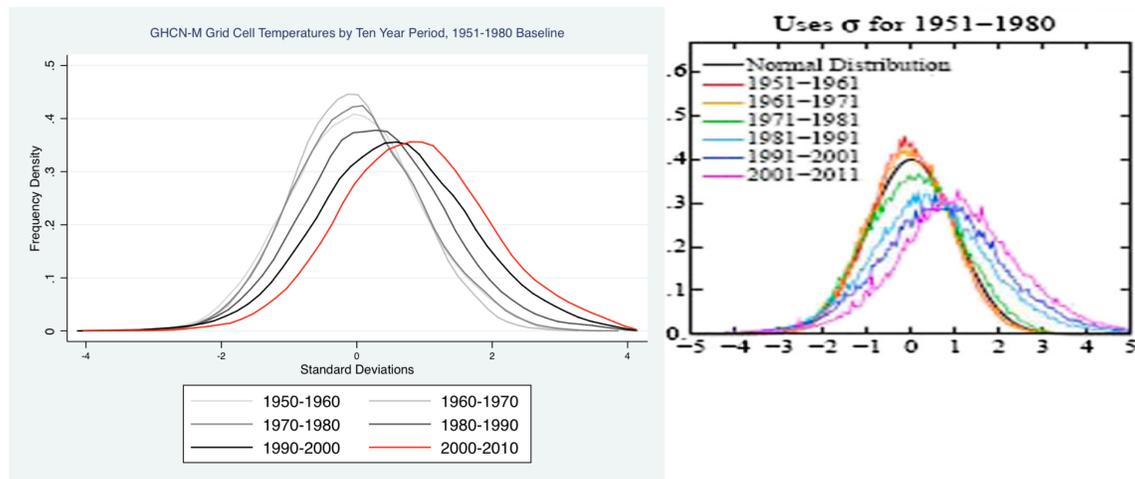


Fig. 1. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August temperature anomalies divided by local standard deviation relative to 1951-1980 (left side) and a global land value from Hansen et al. [2012] (right side). Area under each curve is unity. Differences in smoothness are due to the choice of bandwidth.

Similar to Hansen et al. [2012], when we use a 1951-1980 baseline we find both warming in the mean and a widening of the distribution (e.g. the variance in temperature) over time.

The results shown here are not necessarily due to dividing by standard deviations. If we simply take the grid-cell anomalies and plot a frequency density function, we obtain a similar result, as shown in Figure 2. Note that anomaly versions of all subsequent plots were also created, but are not shown for brevity.

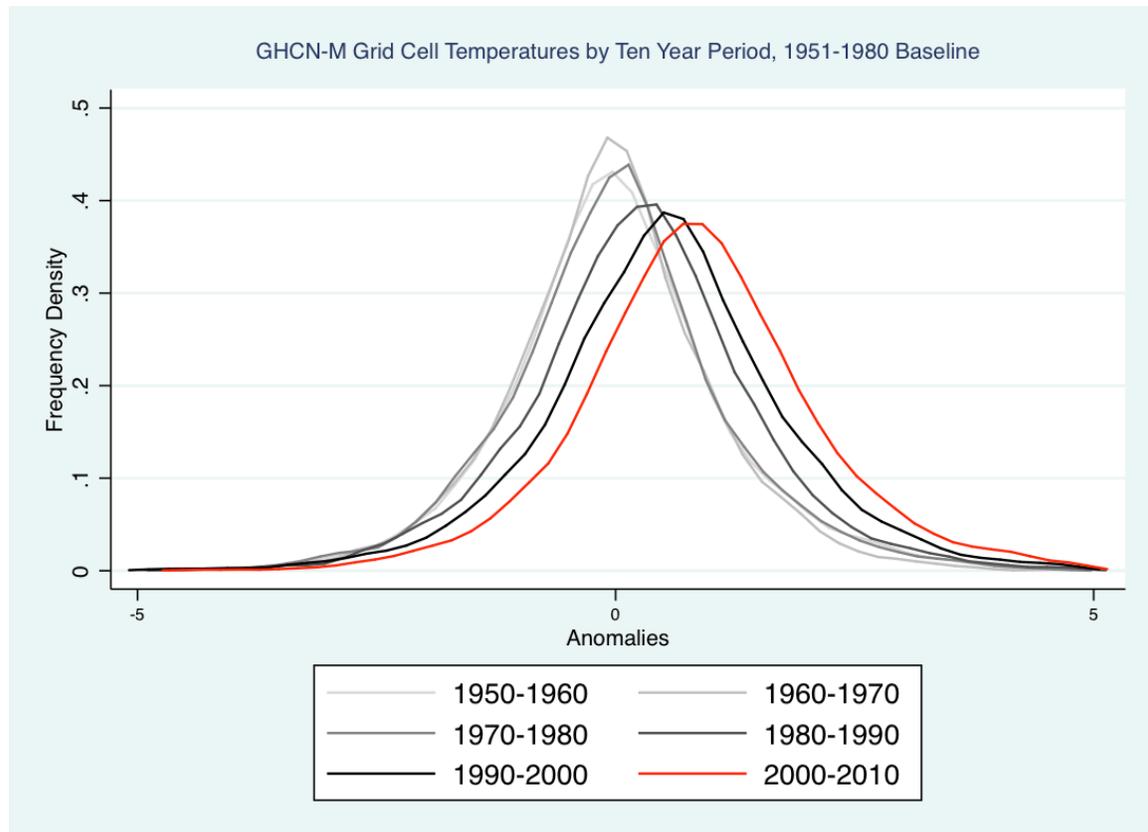


Fig. 2. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August temperature anomalies relative to 1951-1980. Area under each curve is unity.

However, the widening variance shown in Figures 1 and 2 is highly dependent on the baseline period chosen. If we select a baseline of 1981-2010, we get Figure 3, below.

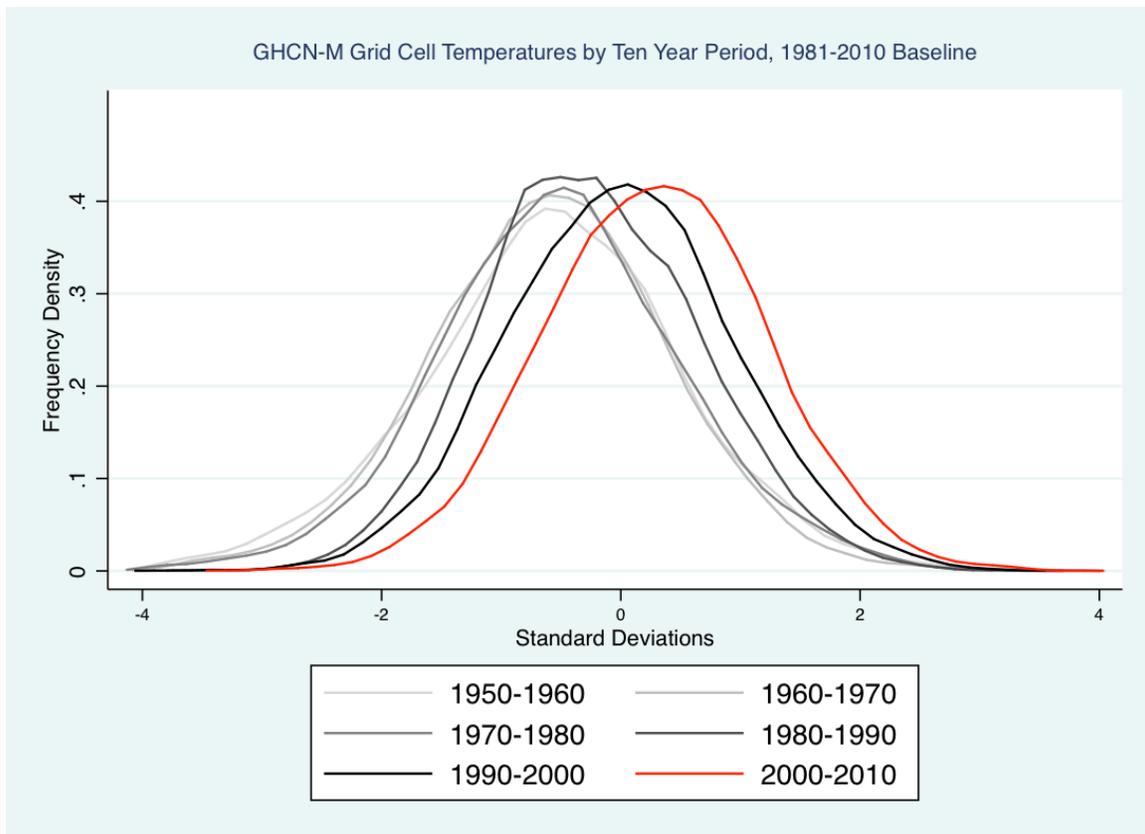


Fig. 3. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August temperature anomalies divided by local standard deviation relative to 1981-2010. Area under each curve is unity.

In this case the mean temperature is still increasing, but we no longer observe any change in variance over time. The anomalies plot even shows slightly less variance in the current decades than in prior decades. This is even more pronounced in Figure 4, below, which uses a 1991-2010 baseline.

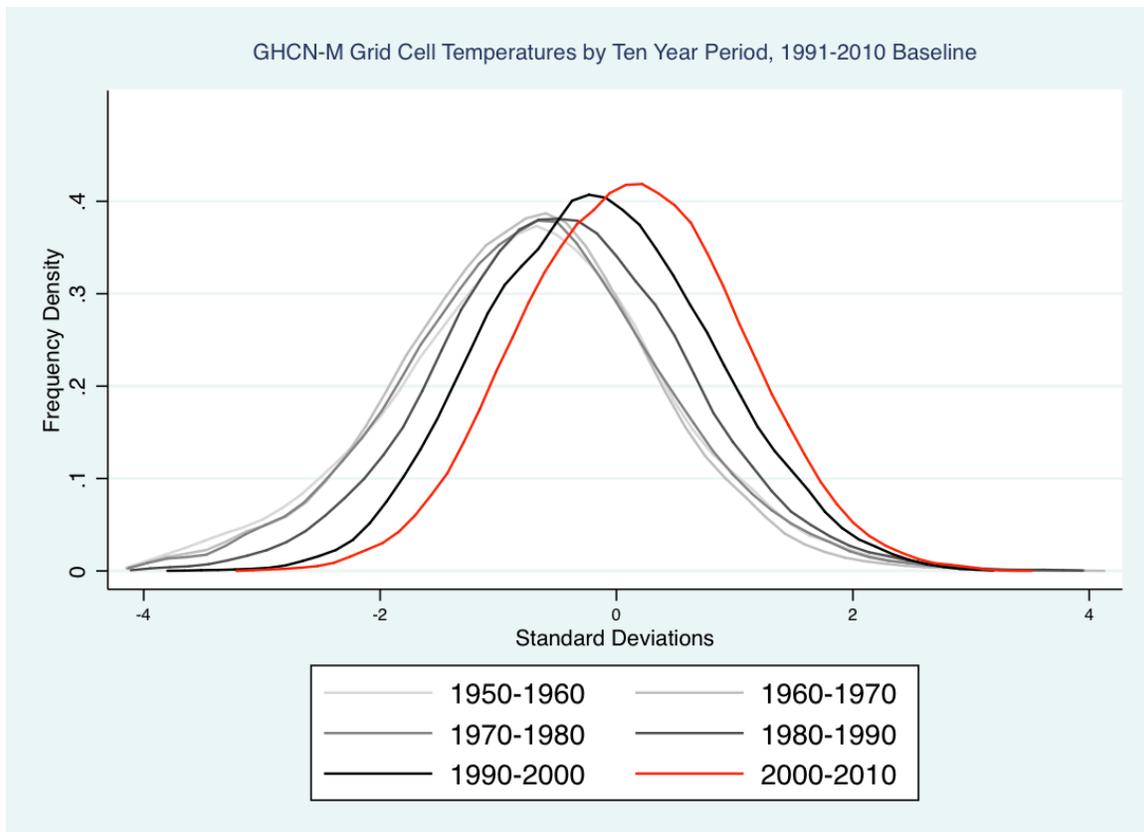


Fig. 4. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August temperature anomalies divided by local standard deviation relative to 1991-2010. Area under each curve is unity.

When we use a baseline of 1991-2010, we reach opposite conclusion: namely that variance was larger in the past and is smaller now! This suggests that the method used by Hansen et al might be inappropriate for detecting shifts in variance (for more technical discussion of this point, see [Tamino \[2012\]](#)). While Hansen et al acknowledge that their results depend on the baseline chosen, their justification that the 1951-1980 period was a more stable climate and lacked a warming trend is by itself not sufficient justification without additional tests.

Here we suggest two alternative approaches to address the question of variance over time that somewhat mitigate the effect of baseline period selection on the results: lowess-based detrending to remove low-frequency climate signals, and a variable baseline approach to calculate anomalies for each decade with a baseline spanning that decade.

Lowess-based Detrending

By using locally weighted scatterplot smoothing (lowess) with a bandwidth of 0.8 we can remove the long-term climate signal from each individual grid cell record while preserving monthly variability. Lowess has significant advantages over a simple linear detrending, as individual grid cell records tend not to be characterized

by the same long-term somewhat monotonic trends seen over larger areas of the globe. In this case we used a lowess smoother with a bandwidth of 0.8 on 60 years of grid cell data, which should remove variability above periods of 24 years.

By subtracting the resulting smoothed fits from the grid cell records we are left with detrended monthly annual, and intra-decadal variability while excluding any long-term secular trends. If we repeat our prior frequency density functions using this detrended data, we get the results shown in Figure 5.

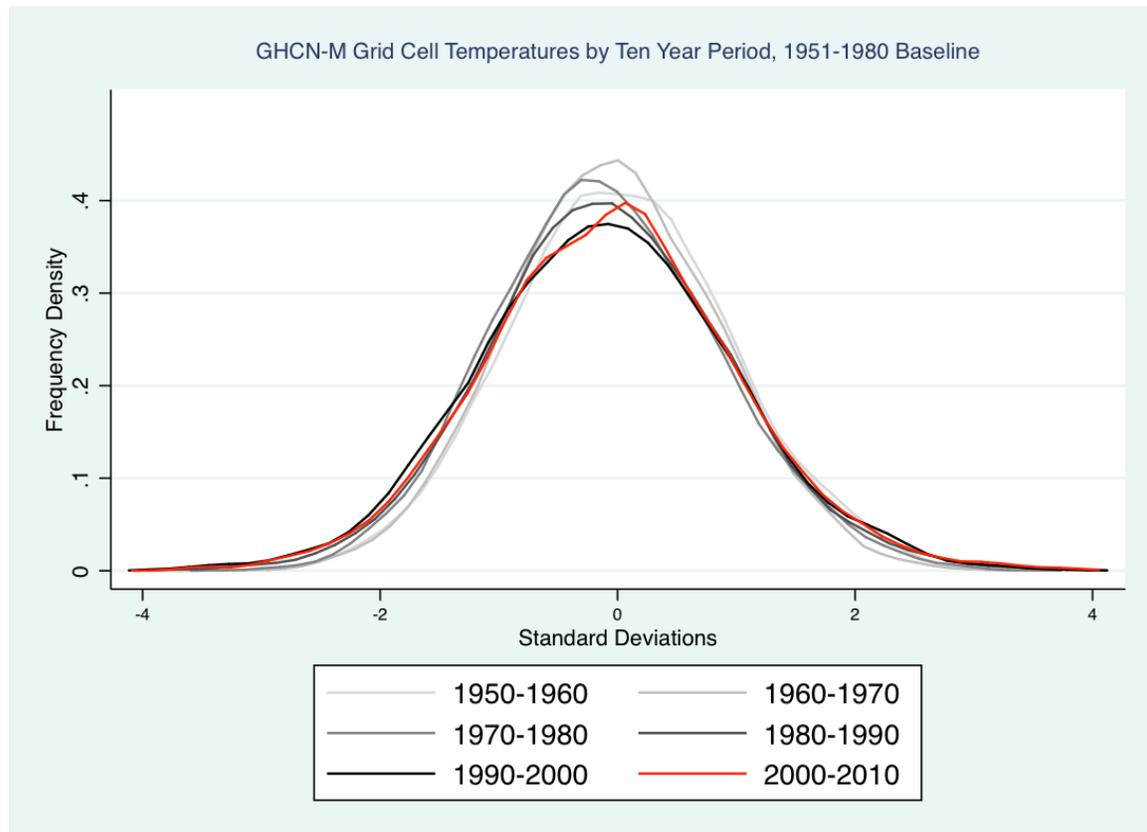


Fig. 5. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August lowess-detrended temperature anomalies divided by local standard deviation relative to 1951-1980. Area under each curve is unity.

In this case there is some broadening over time, but it less than half the magnitude seen in the non-detrended series. This result also turns out to be somewhat sensitive to the baseline chosen. If we use a 1981-2010 baseline (for anomaly calculation prior to lowess detrending), there is no significant change in variance over time as shown below in Figure 6.

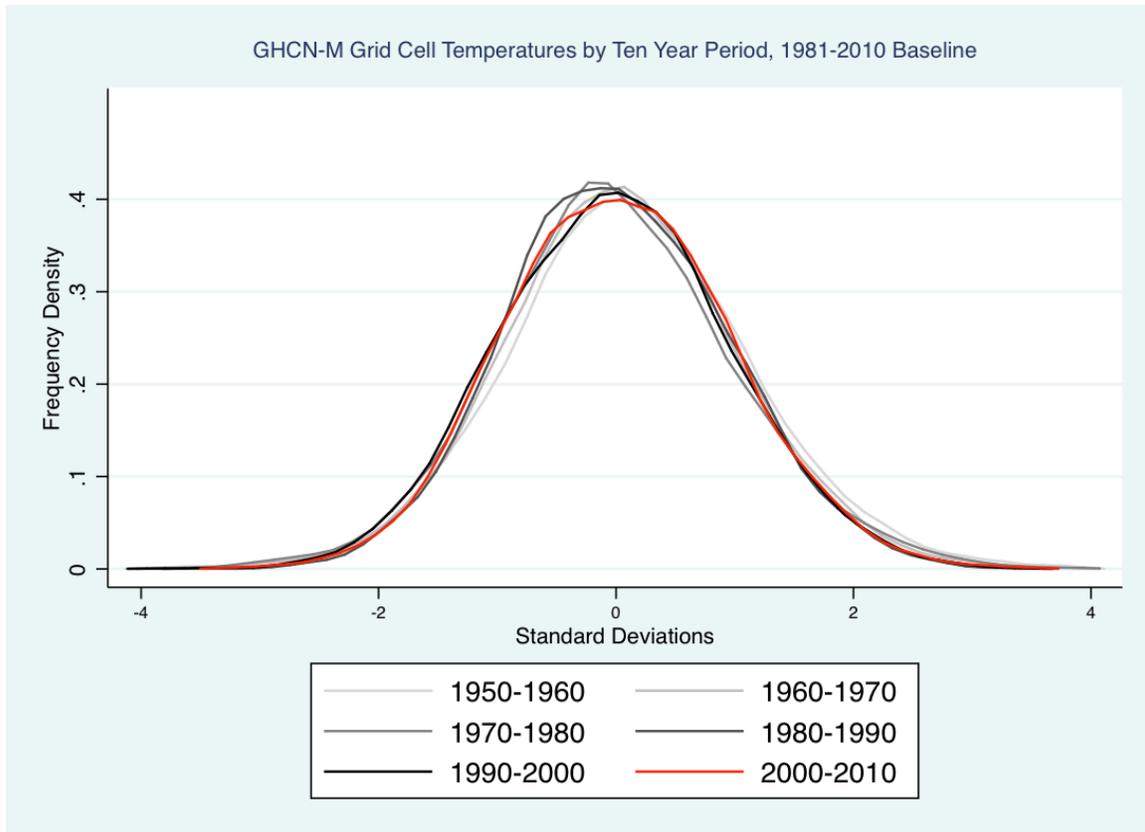


Fig. 6. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August lowess-detrended temperature anomalies divided by local standard deviation relative to 1981-2010. Area under each curve is unity.

Variable Baselines

Instead of dealing with fixed baselines for the analysis, we can calculate each decadal curve using a baseline of that decade. For example, the curve representing the 1951-1960 period would use that period for calculating anomalies. This approach precludes the use of anomalies divided by standard deviations, as standard deviations using variable baselines would be unable to discern changes in variance over time. However, as we saw earlier the frequency density plots of anomalies show much the same results as those using anomalies divided by standard deviations. If we take this approach for every decade, we get the frequency density plots shown below in Figure 7, which shows little change in variance over time.

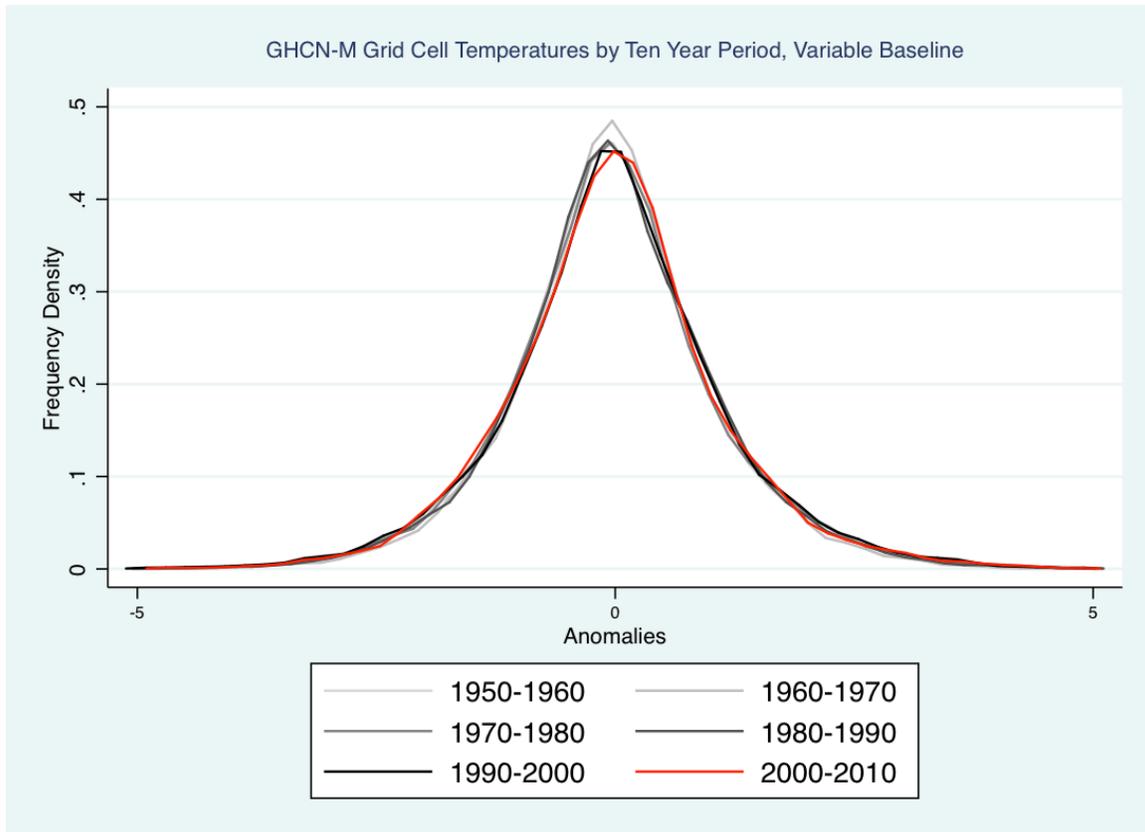


Fig. 7. Frequency of occurrence (y-axis) of 5x5 lat/lon grid cell land June, July, and August anomalies. Anomalies for each decade are calculated using the monthly mean values over that decade as a baseline. Area under each curve is unity.

One must be careful not to misinterpret the Hansen et al. [2012] paper as indicating a change (broadening) of the variance of the temperature distribution with time. According to the authors of that paper [private communication], it was not their intent to study that issue and their paper did not address it, although it has been misinterpreted to do so by some who did not closely examine their mathematical approach.

For further analysis and discussion of the Hansen et al method, see the memo by Sebastian Wickenburg.

REFERENCES (internet links)

Hansen et al. [2012]: http://www.columbia.edu/~jeh1/mailings/2012/20120105_PerceptionsAndDice.pdf

Tamino [2012]: <http://tamino.wordpress.com/2012/07/23/temperature-variability-part-2/>