

Reply to Stone et al.: Human-made role in local temperature extremes

Stone et al. (1) find that their analysis is unable to show a causal relation of local temperature anomalies, such as in Texas in 2011, with global warming. It was because of limitations in such local analyses that we reframed the problem in our report (2), separating the task of attribution of the causes of global warming from the task of quantifying changes in the likelihood of extreme local temperature anomalies.

The SD (σ) of summer mean temperature about the 30-y mean (Fig. 1, *Upper*) varies from less than 0.5 °C at low latitudes to more than 1 °C at high latitudes. The hemispheric average of σ is the same (0.71 °C) in the 30-y period 1981–2010 as in 1951–1980, provided that both the average warming is removed (by calculating σ relative to the mean of the current 30-y period) and warming within the current period is removed (by detrending; for example, subtracting the warming trend before calculating σ).

Of course, the warming did occur, and we would like to know how the warming altered the chances of having extreme summer heat relative to the climate of 1951–1980, which is an appropriate base period because the cli-

mate then was still within the range of the Holocene (2). It makes little difference if a longer base period, such as 1931–1980, is used (3). The average decadal mean temperature anomaly has increased decade by decade for the past three decades (Fig. 1, *Lower*). The warming is large, now exceeding 1σ on average, and ubiquitous.

The result is that the “bell curve” formed by all of the local summer mean temperature anomalies has shifted steadily to the right (2, 3) in the past three decades, such that anomalies exceeding $+3\sigma$ now cover about 10% of the land area in summer. This shift of the bell curve, which is a manifestation of global warming, has caused the chance of having a $+3\sigma$ or greater anomaly increase from 0.1% to 0.2% to an order of 10%.

We cannot reliably predict where the hot spots will occur next summer. However, regarding any place experiencing a $+3\sigma$, we can say with high confidence that it is a consequence of global warming. Independently, it has been concluded that the rapid warming of recent decades is primarily a result of increasing human-made greenhouse gases (4).

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1 Stone DA, et al. (2013) Inferring the anthropogenic contribution to local temperature extremes. *Proc Natl Acad Sci USA* 110: E1543.

2 Hansen J, Sato M, Ruedy R (2012) Perception of climate change. *Proc Natl Acad Sci USA* 109(37):E2415–E2423.

3 Hansen J, Sato M, Ruedy R (2012) Increasing climate extremes and the new climate dice. Available at http://www.columbia.edu/~jeh1/mailings/2012/20120811_DiceDataDiscussion.pdf. Accessed August 10, 2012.

4 Intergovernmental Panel on Climate Change; Solomon S, et al., eds. (2007) *Climate Change 2007: The Physical Science Basis* (Cambridge Univ Press, New York, NY).

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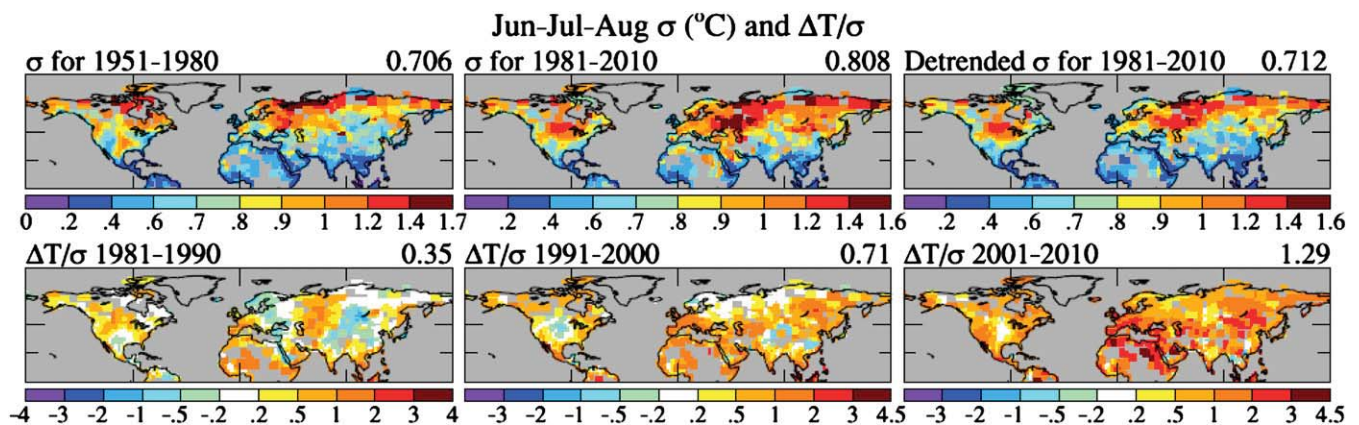


Fig. 1. Numbers in upper right corner of each map are means over Northern Hemisphere land, excluding Greenland.