LETTER

Reply to Rhines and Huybers: Changes in the frequency of extreme summer heat

Rhines and Huybers (1) are correct that the decreasing number of measurement stations in recent years contributed slightly to our calculated increase of extreme summer mean temperature anomalies (2). However, the increased frequency of extreme heat anomalies is accounted for mainly by (*i*) higher mean temperature of recent decades relative to the base period 1951–1980, and (*ii*) the continuing upward temperature trend during recent decades.

The effect of decreasing stations is shown by comparing our prior analysis (2) with results using only stations with data records in both the base period and recent years (Fig. 1). The distribution is noisier, and the area with temperature anomaly exceeding three SDs during 2001–2011 decreases from 9.6 to 9.3% for the reduced number of stations (1,886 rather than 6,147), but our conclusions are not changed qualitatively.

The temperature anomaly distribution shifts to the right and broadens because it is defined relative to a fixed (1951–1980) base period, during which global temperatures were within the Holocene range (3). We argue on the basis of accelerating ice loss from Greenland and Antarctica and rapidly rising sea level (now exceeding 3 mm/y or 3 m per millennium) that temperatures in the early 21st century are already above the Holocene range (2), and thus use of a base period preceding the rapid warming of the past three decades has merit.

The distribution of temperature anomalies in the past decade (right graphs in Fig. 1) reveals a substantial loading of the climate dice, relative to the period 1951–1980, with the "warm" (red, including brownish-red subcategory) category having increased from 33% in the base period to about 75%. Extreme warm anomalies (more than three SDs warmer than the base-period mean) have increased from a few tenths of 1% to about 10%. The result is little changed if we use base period 1931–1980 (4), which includes the unusual 1930s anomalies in the United States Midwest.

The progressive shift of summer temperature anomalies, especially the growing hot tail of the distribution, is a representation of global warming that provides insight relevant to human civilization, the biosphere, and physical systems, such as the ice sheets, which are all adapted to or were in near-equilibrium with Holocene climate. We suggest that the increasing frequency and extremity of hot anomalies relative to a Holocene baseline will have important consequences for the Greenland ice sheet, agricultural regions, and the natural biosphere.

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The authors declare no conflict of interest.

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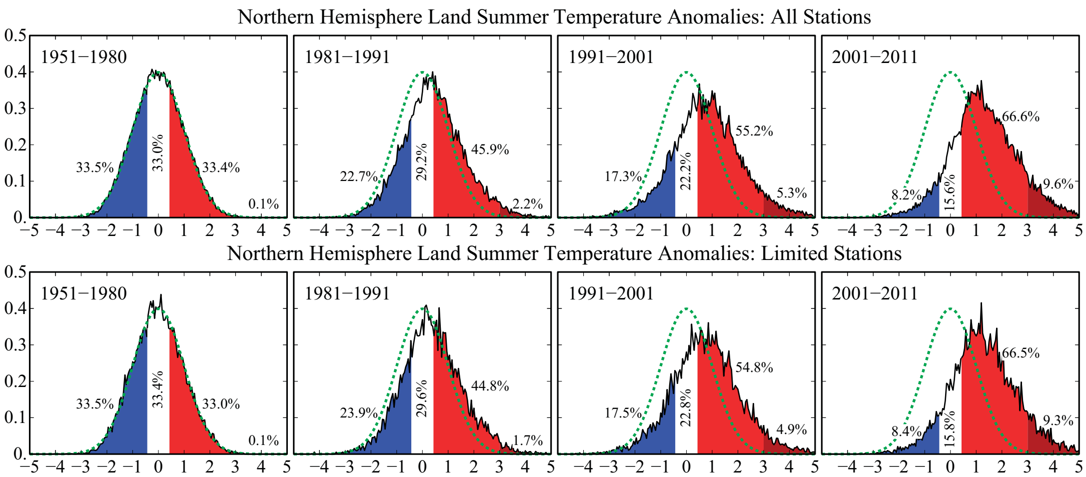

Fig. 1. Frequency of occurrence of local June-July-August temperature anomalies (relative to 1951–1980 mean) for Northern Hemisphere land in units of local SD (horizontal axis). Temperature anomalies in 1951–1980 match closely the normal distribution (green curve), which is used to define cold (blue), typical (white), and hot (red) seasons, each with probability 33.3%. Lower graphs use only a subset of stations (1,886 of 6,147) that were present in recent decades as well as in the base period.