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Revealing a systematic bias in percentile-based temperature extremes

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Worsening temperature extremes are among the most severe impacts of human-induced climate change. To quantify such extremes and their changes various methods have been applied over the years. One frequently used approach is to define extremes relative to the local temperature distribution as exceedances of a given percentile threshold.

For hot extremes, the Expert Team on Climate Change Detection and Indices (ETCCDI) defines TX90p relative to the 90th percentile of maximum temperature on each calendar day in the 30-year period 1961-1990. To increase the number of samples available for the percentile calculation a 5-day running window is recommended leading to a total of 30x5=150 samples for each calendar day. However, this still limited number of samples can lead to internal variability being mixed into the percentile and cause a strongly varying extreme threshold, which is undesirable. Therefore, many studies do not follow the ETCCDI recommendation and use longer seasonal windows of 15- or even 31-days to increase the number of samples available for the percentile calculation.

We show that the use of such long seasonal windows introduces a systematic bias that leads to a striking underestimation of the expected extreme frequency. This expected exceedance frequency is 10% for the 90th percentile when evaluating the extreme frequency in the same period as the threshold is calculated (in-base). For ERA5 the 1961-1990 average, global average temperature extreme frequency is only 9% – a relative bias of -10%. In individual regions and seasons, the bias can be considerably larger, exceeding -75%.

We develop a simple bias correction and use it to show that the bias generally decreases in a warming climate in CMIP6. It, therefore, also affects estimates of future temperature and related heatwave changes. The decrease of the bias can lead to an overestimation of changes in the heatwave frequency by as much as 30%. Based on these results, we strongly warn against the use of long seasonal windows without correction when calculating extreme frequencies and their changes.