Revealing a systematic bias in temperature extremes and its implications

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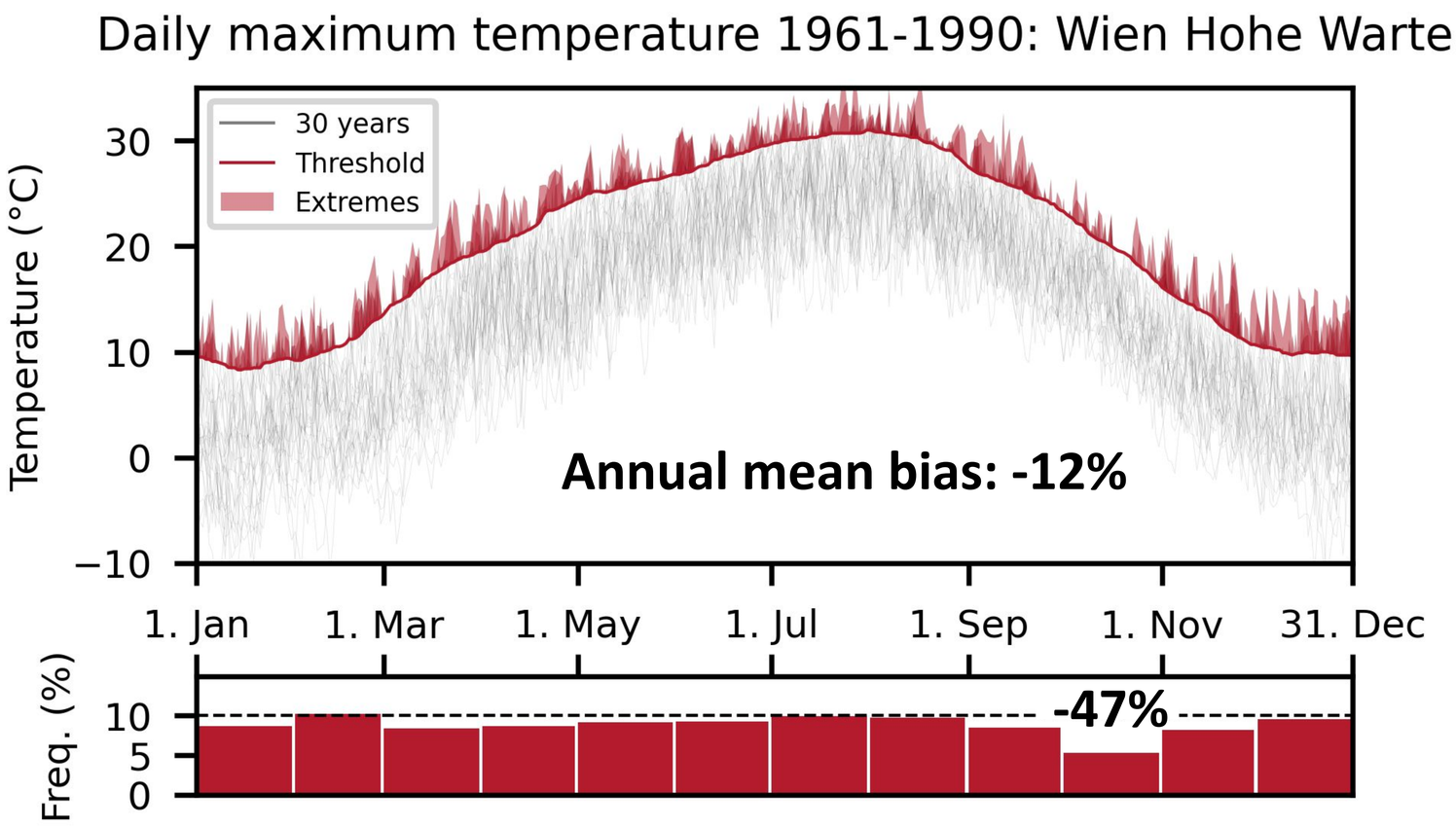


Running seasonal windows in the percentile calculation can lead to an underestimation of temperature extremes.

Brunner and Voigt (2024): Pitfalls in diagnosing temperature extremes. *Nature Communications* https://doi.org/10.1038/s41467-024-46349-x

Properties of relative temperature extremes

Temperature extremes are often defined relative to the local temperature distribution and following the seasonal cycle. This allows for extremes that can occur everywhere on Earth and during the entire year.

A common threshold is the 90th percentile of daily maximum temperature in the period 1961-1990 (following the ETCCDI). By definition **we expect 10% extremes** on average (in sample)...

- …independent of the location
- …independent of the season
- …independent of the dataset

Effect of the bias on temperature extreme properties

To increase the sample size in the percentile calculation, often running seasonal windows are used. The ETCCDI recommends a 5-day window, but many studies use longer windows of 15- or even 31-days.

An interaction between the running window and the seasonal cycle leads to a strong bias in the frequency of temperature extremes, which **violates generally accepted properties of relative extremes** as it leads to…

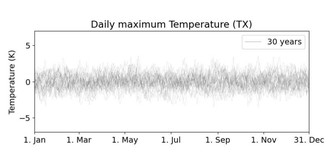
- …extreme frequencies changing with location
- …extreme frequencies changing across the seasonal cycle
- …extreme frequencies changing between datasets

Mixing the seasonal cycle into the extreme threshold leads to the bias

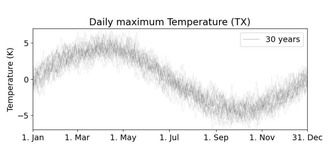
Calculation of the threshold for day of the year 170 (June 19th) using a 31 day window

1. From the 30-year period select all days in a +/-15 day window around June 19th
2. This is a total of 30 years x 31 days = 930 values, used to calculate the 90 percentile
3. The seasonal gradient between summer and winter distorts the threshold
4. Less than the theoretically expected 10% of June 19ths exceed the threshold due to the bias

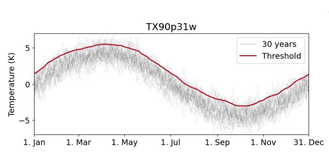
Figures: Demonstrating the effect based on synthetically produced data



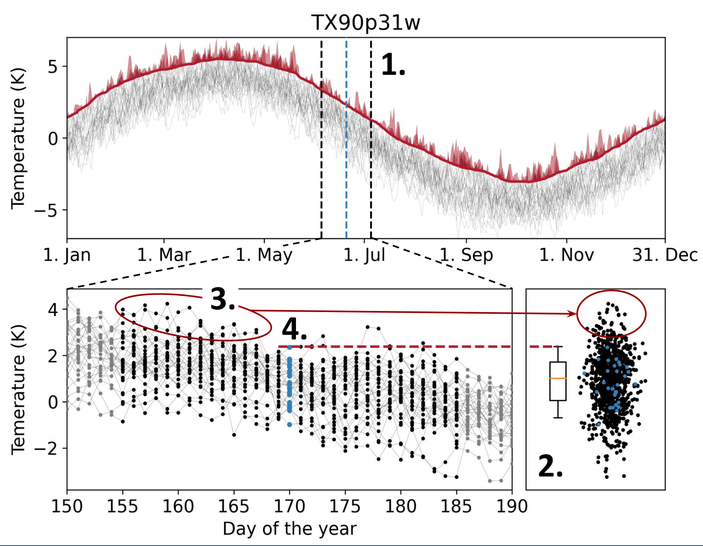
White noise with lag 1-day auto-correlation of 0.8



Sine function with amplitude 3 to emulate the seasonal cycle



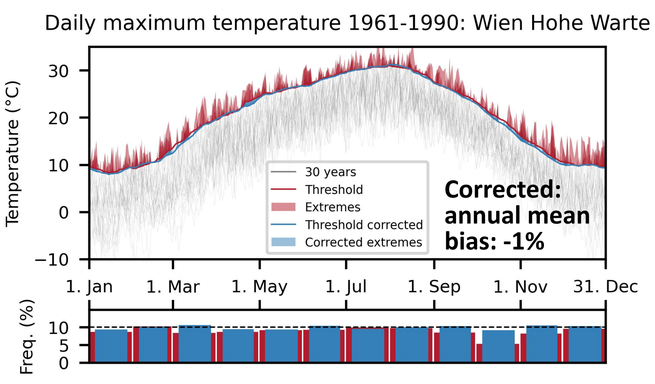
Threshold calculated as 90th percentile using a 31-day window

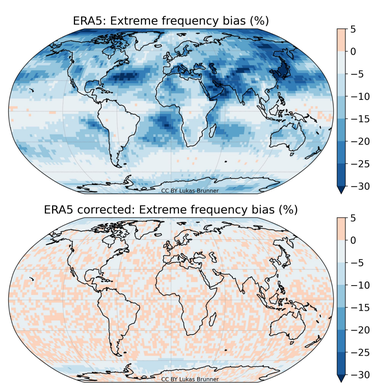


Eliminating the bias

Since the bias originates in an interaction between too long running windows and the seasonal cycle one needs to either

- Use shorter windows
  → this can cause problems due to the limited sample size (Zhang et al. 2005)
- **Remove the seasonal cycle before calculating the threshold**





Conclusions and outlook

We strongly warn against the use of long-running windows without correction *when calculating extreme thresholds [...] even though the impacts on derived metrics might not always be strong or immediately apparent. [...] Crucially, the same biased method may have a negligible effect in one setting and a large impact in another.* (Brunner and Voigt 2024)

So far we have only shown the **potential for biased results**, in a next step cases where the bias might manifest and distort results will be investigated.

References

Expert Team on Climate Change Detection and Indices (ETCCDI): http://etccdi.pacificclimate.org/list_27_indices.shtml

Zhang, X., Hegerl, G., Zwiers, F.W., Kenyon, J. (2005): Avoiding Inhomogeneity in Percentile-Based Indices of Temperature Extremes. https://doi.org/10.1175/JCLI3366.1