Studying heat waves with the extended heat index

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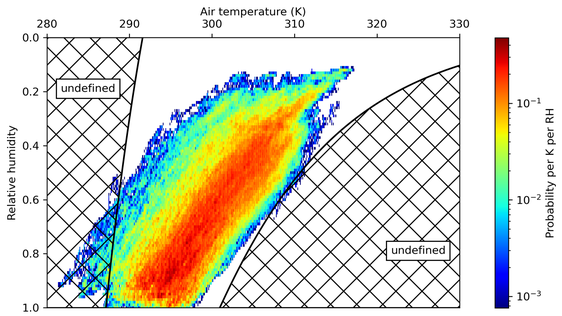
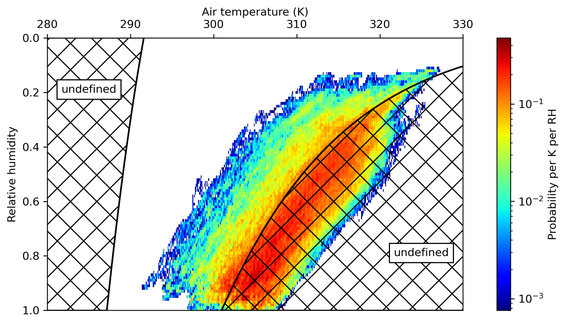
Undefined heat index at SGP

The existing heat index is well-defined for most combinations of high temperature and humidity experienced on Earth in the preindustrial climate, but the heat index is already undefined for the most severe heat waves on Earth today.

The plot below shows the joint probability distribution of near-surface one-minute air temperature and relative humidity at the ARM SGP site during June, July, and August from 2012 to 2021. The hatched regions show where the heat index is undefined. Even at SGP, there are times when the heat index is undefined.



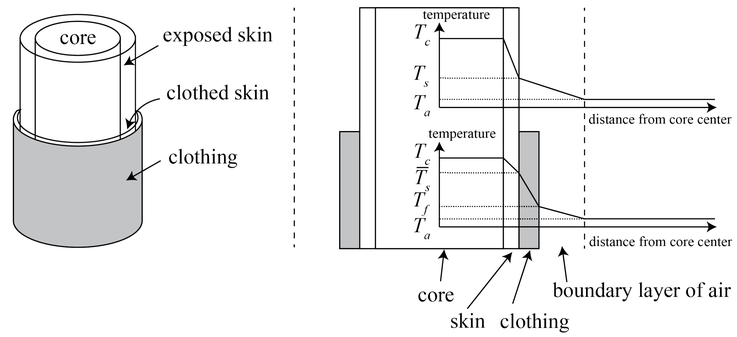
Global warming is increasingly generating conditions for which the heat index is undefined. In an extreme global-warming scenario (e.g., burning on the order of 5 TtC of fossil fuels), the Earth's global-mean surface temperature would be expected to rise about 10 K. Shifting the existing PDF of SGP temperature and humidity by +10 K while holding relative humidity fixed puts the majority of times during summer into the region where the heat index is undefined.



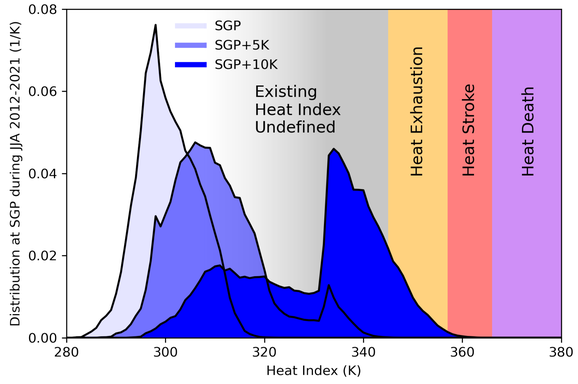
Even with modest warming, Earth will increasingly probe conditions with an undefined heat index. Therefore, an extension of the original heat index is needed.

Extending the heat index

To extend the heat index, we use the same physiological model as in the original work of Robert Steadman to ensure backwards compatibility. The heat index is based on a model of human thermoregulation for a partially clothed human walking in the shade with unlimited access to drinking water, accounting for sensible, latent, and radiative fluxes of energy.



The original heat index becomes undefined when the skin's vapor pressure equals and then exceeds the saturation vapor pressure; at this critical threshold, the model breaks. To extend the heat index, the key is to recognize that this critical threshold is when sweat begins to drip off the skin.



This insight allows the heat index to be extended in a straightforward and natural way, defining it for all combinations of temperature and humidity. Like the original, the extended heat index maps onto unique physiological states, so we can now assess the health outcomes during severe heat.

References

Lu and Romps, 2022: Extending the heat index, *Journal of Applied Meteorology and Climatology*, vol. 61, no. 10, 1367-1383.

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Acknowledgments

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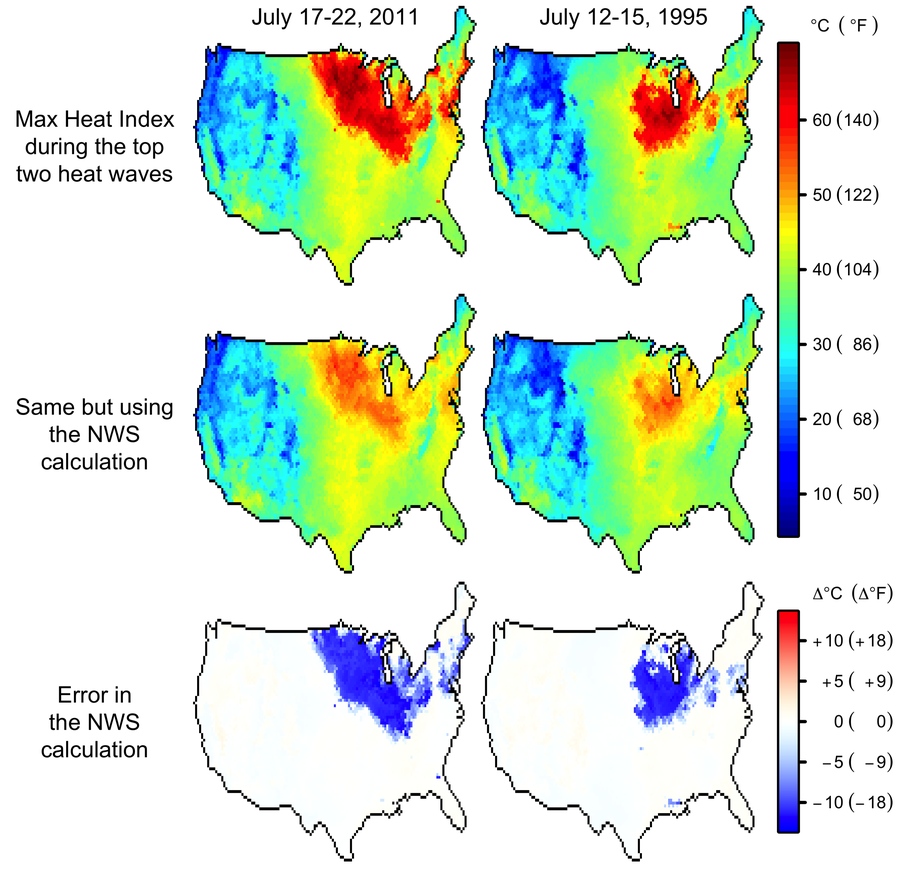
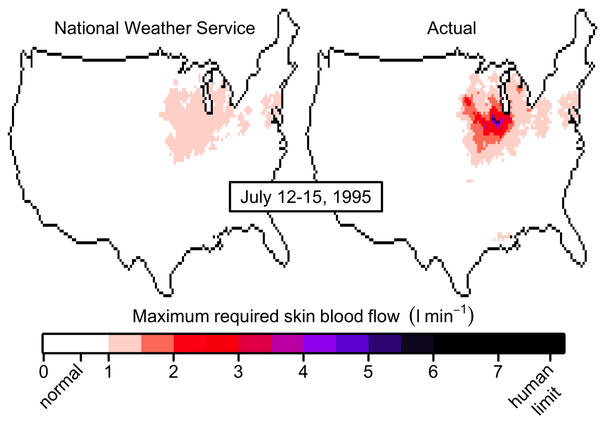
Error revealed in NOAA's heat index

NOAA's National Weather Service has been using a polynomial approximation to extrapolate the heat index to combinations of temperature and humidity for which it is undefined. The extended heat index reveals major errors in that approximation.



During the severe Midwest heat waves of July 2011 and July 1995, the National Weather Service underreported the heat index by as much as 20 °F.



This figure shows the skin blood flow required during the July 1995 heat wave using (left) NOAA's approximation and (right) the actual heat index. The required skin blood flow was severalfold higher than usual, approaching the physiological limit.