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Substantial Errors Revealed When Calculating Heat Stress Using Grid Cell Averages as Compared to Sub-Grid Cell Environments

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We implement the Wet Bulb Globe Temperature (WBGT), a standardized heat stress metric, into the Community Land Model (CLM5), the land surface component of the Community Earth System Model (CESM2). This includes the notoriously difficult calculation related to measuring human heat stress: radiation. Following the International Organization for Standardization (ISO) 7243, physical representations of the instruments, a globe thermometer and natural wet bulb thermometer, simulate where humans work and live in non-urban environments. By using ISO 7243 within CLM5, we create a common framework within Earth system models to calculate the impact of radiation on temperature-moisture covariance.

We demonstrate the capabilities of the WBGT using a default configuration of CLM5. We output 4x daily temporal resolutions globally, showing the advantage of simulating the WBGT within each environment. The WBGT outdoor and indoor calibration is simulated in an averaged grid cell, above the vegetation canopy, below the vegetation canopy, and bare ground environments. We examine the 1995 Chicago Heatwave, specifically the rural regions impacted by the heatwave, and demonstrate that the grid cell average calculated at the CLM5 30-minute time step is a poor representation of human environments and can differ by multiple degrees. In high heat stress environments following ISO 7243, a 0.5C change in WBGT can lead to a >10% reduction in labor capacity. This difference in temperature and labor capacity shows that assumptions about calculating a non-linear algorithm — even utilizing high temporal frequency grid cell averages that drive non-linear labor capacity impact models — is a flawed approach that can grossly over or underestimate the impact of heat stress on future climate change projections. To accurately assess the direct exposure, risk, and damage of climate change on people, it is critical to implement diagnostics directly into Earth system models.