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Enabling Urban Climate Model Validation with Meter-Scale Heat Stress Observations

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Amidst the warming climate, it is crucial for urban planners and policymakers to identify which adaptation strategies effectively reduce outdoor urban heat stress. To address this need, high-resolution meter-scale observations alongside numerical models are essential. However, such detailed heat stress observations are scarce, creating a gap in our ability to explore the micro-environmental effects of adaptation on heat stress and to validate the high-resolution heat stress models. This gap is addressed by conducting a dense meter-scale measurement campaign in the urban fringe of Ghent (Belgium) during a heat wave. The campaign evaluates consumer-grade portable AT-HTS01 devices against advanced Campbell meteorological stations, which measure all components of heat stress explored with wet bulb globe temperature (WBGT). Additionally, thermal infrared imaging was employed to correlate these measurements with surface temperatures. The findings demonstrate that the consumer-grade sensors closely match the accuracy of sophisticated research-grade equipment in assessing WBGT, affirming their utility in urban heat studies. The analysis highlights that building and tree shade can significantly reduce daytime WBGT by up to 5 °C, while at night, WBGT values are 0.8 °C lower over unpaved surfaces compared to paved surfaces. These insights emphasize the effectiveness of strategic urban design, such as optimized tree placement and reduced paving, in lowering heat stress and enhancing climate resilience. Besides the insights in the micro-environmental heat stress variations, the meter-scale in-situ observational data from this campaign serve as a crucial resource for validating high-resolution numerical heat stress models, such as the UrbClim-HiREx model exemplified in this study. UrbClim is a fast urban boundary layer model for long-term urban climate simulations at 100-meter resolution with a downscaling HiREx heat stress module calculating WBGT at meter-scale resolution considering individual building and tree shades.