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High-resolution modelling of heat stress across Ireland using the Universal Thermal Climate Index

Aditya Rahul[1], Julie Clarke[1], Paul Nolan[2], Martin King[2], and Liam Heaphy[2]
[1]Trinity college Dublin, Department of civil, environment and structural engineering, Dublin 2, Ireland (rahula@tcd.ie)
[2]Irish Centre for High-End Computing, Dublin, Ireland

Heat stress is an emerging hazard in temperate regions, driven by rising temperatures and increasing urbanisation. Understanding its spatial distribution and future evolution is critical for informing effective climate adaptation strategies. This study investigates human thermal comfort across Ireland using the Universal Thermal Climate Index (UTCI), with particular emphasis on urban–rural contrasts and Local Climate Zone (LCZ) classifications. High-resolution (~4 km) regional climate projections are generated through Regional Climate Models (RCMs) that dynamically downscale Coupled Model Intercomparison Project Phase 6 (CMIP6) outputs. Both standard atmosphere-only and fully coupled atmosphere–ocean–wave RCM configurations are employed, providing a detailed representation of regional climate processes and extremes through to 2100. Human thermal response is simulated using the UTCI-Fiala multi-node thermoregulation model, integrated with an adaptive clothing model to account for physiological responses to thermal stress.

The study addresses four primary objectives. First, UTCI distributions are mapped nationwide to identify regions and periods most susceptible to heat stress. Second, variations in UTCI between LCZs are analysed to evaluate how urban form and land cover modulate thermal stress patterns. Third, projected changes in UTCI under multiple Shared Socioeconomic Pathway (SSP) scenarios are assessed to quantify future shifts in the intensity, frequency, and spatial extent of heat stress. Fourth, intra LCZ variation in UTCI is examined across varying spatial and temporal scales to capture differential sensitivities to climate change.

Preliminary results indicate strong spatial heterogeneity in thermal stress, with urban cores and densely built LCZs experiencing higher UTCI values than surrounding rural areas. Future projections suggest a marked increase in the duration and intensity of heat stress events, particularly under high-emission SSP scenarios, with implications for public health, urban planning, and climate adaptation policy. By integrating high-resolution climate projections with physiologically based thermal indices and urban morphology, this study provides a comprehensive assessment of both current and future human thermal comfort across Ireland. The findings offer an evidence base for guiding mitigation strategies, designing climate-resilient urban environments, and informing health-focused interventions in a warming climate.