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Blending machine-learning and mesoscale numerical weather prediction models to quantify city-scale heat mitigation

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Urban warming in cities is increasingly exacerbated by the escalation of more frequent and severe heat extremes. Effectively mitigating overheating necessitates the adoption of a comprehensive, whole-system approach that integrates various heat mitigation measures to generate rapid and sustained efficacy in mitigation efforts. However, there remains a significant gap in the exploration of how to quantify the efficacy of mitigation strategies at the city-scale.

We address this research question by leveraging mesoscale Weather Research Forecasting (WRF) models alongside machine-learning (ML) techniques. As a showcase, ML models have been established for Zurich and Basel, Switzerland, utilizing seven WRF-output-based features, including shortwave downward radiation (SWDNB), hour of the day (HOUR), zenith angle (COSZEN), rain mix ratio (QRAIN), longwave downward radiation (LWDNB), canopy water content (CANWAT), and planetary boundary layer height (PBLH). Impressively, the resultant median R^2 values for T2 (2m temperature) predictions during heatwave and non-heatwave periods are notably high at 0.94 and 0.91 respectively.

Within the perspective of the whole-system approach, we quantify the impacts of reducing shortwave radiation absorption at ground surfaces, a potential result of a combination of both shading and reflective coating-based mitigation measures, through the utilization of ML models. Remarkably, a 5% reduction in the absorption of radiation at ground surfaces in Zurich could lead to a reduction in T2 by as much as 3.5 °C in the city center. During a heatwave in Basel, the potential for cooling is even more pronounced, with temperature decreases of up to 5 °C. These case studies in Zurich and Basel underscore the efficacy of utilizing WRF feature-trained ML models to quantify heat mitigation strategies at the city-scale.