



Impacts of Surface Radiative Properties on the Urban Microclimate and Outdoor Thermal Comfort in a High-Density Urban Area

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This study investigates the impact of changes in the radiative properties of building façades and ground surfaces on the urban thermal environment in a high-density urban district characterized by diverse building heights and surface covers. To this end, surface temperatures were calculated using CitySim Pro—which simulates detailed thermal properties and inter-building radiative exchange—and were subsequently integrated as boundary conditions for a high-resolution CFD model. After validating the CitySim Pro–CFD coupling method against in situ observation data in a control experiment (CNTL), sensitivity experiments were conducted across various scenarios involving the application of cool coatings to building façades and ground surfaces.

The results indicate that while increased reflectance from cool coatings led to reduced daytime surface temperatures, the cooling intensity was spatially non-uniform due to multiple reflections and radiation trapping between building façades and ground surfaces. Under certain conditions, this was accompanied by localized nighttime warming. Applying cool coatings solely to ground surfaces resulted in a moderate decrease in average air temperature at pedestrian height during both day and night, suggesting the potential for mitigating heatwaves and tropical nights. In contrast, applications to building façades only, or to both building façades and ground surfaces, led to localized nighttime air-temperature increases due to enhanced longwave radiative coupling; however, a daytime air-temperature reduction of up to approximately 2.0 °C was confirmed.

In terms of outdoor thermal comfort accounting for solar radiation, ground-surface-only application maintained Universal Thermal Climate Index (UTCI) levels similar to the control while reducing air temperatures. Conversely, façade application showed a distinct trend of increasing daytime UTCI due to increased exposure to reflected shortwave radiation. These findings imply that air-temperature reduction does not always directly translate into improved thermal comfort and that the effectiveness of cool coatings can vary spatiotemporally due to multiple reflections and radiation trapping. Therefore, effective application strategies must be optimized according to site usage and pedestrian exposure, balancing the benefits of surface cooling against the potential negative impacts of increased radiative loads.

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