A Novel Workflow for Detailed Mapping of Urban Microclimates and Outdoor Thermal Comfort

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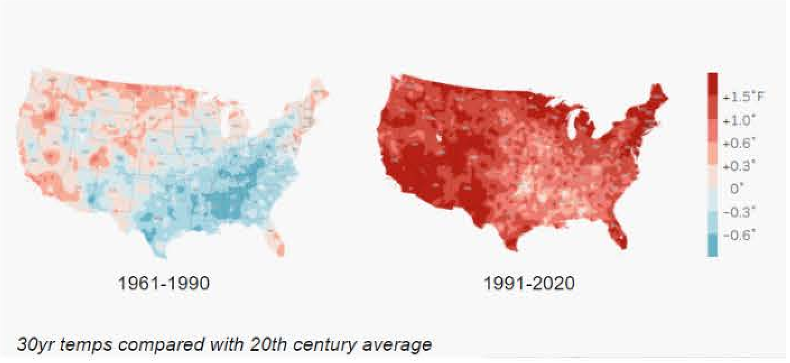
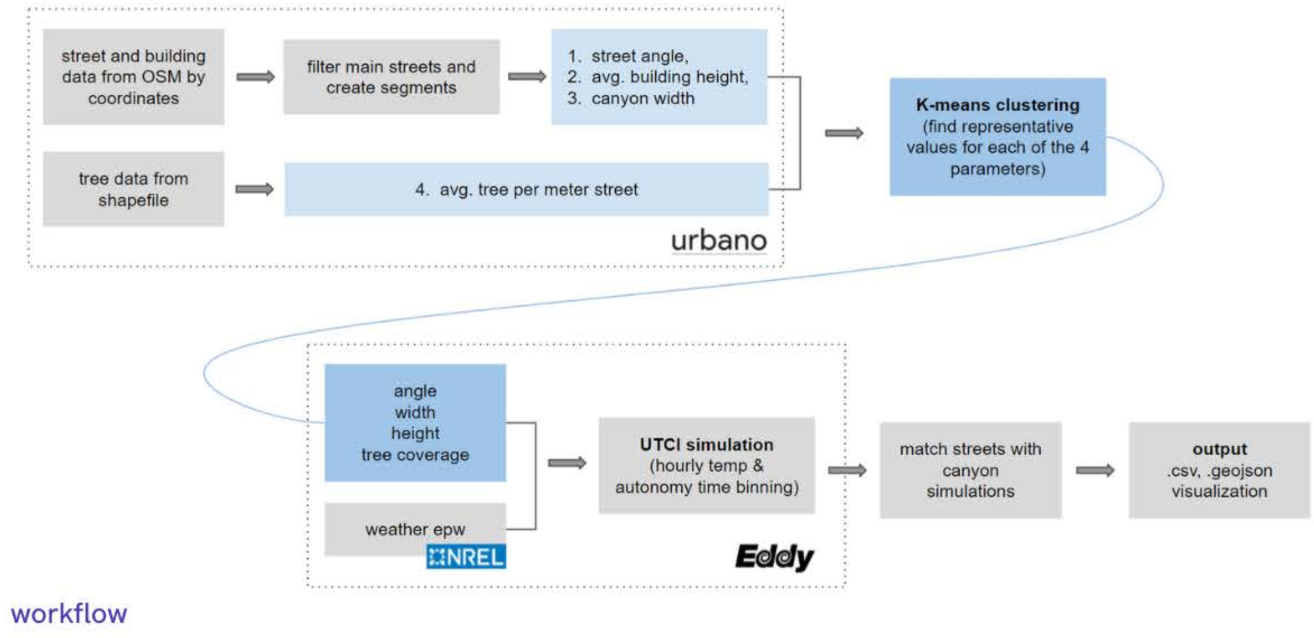
INTRODUCTION

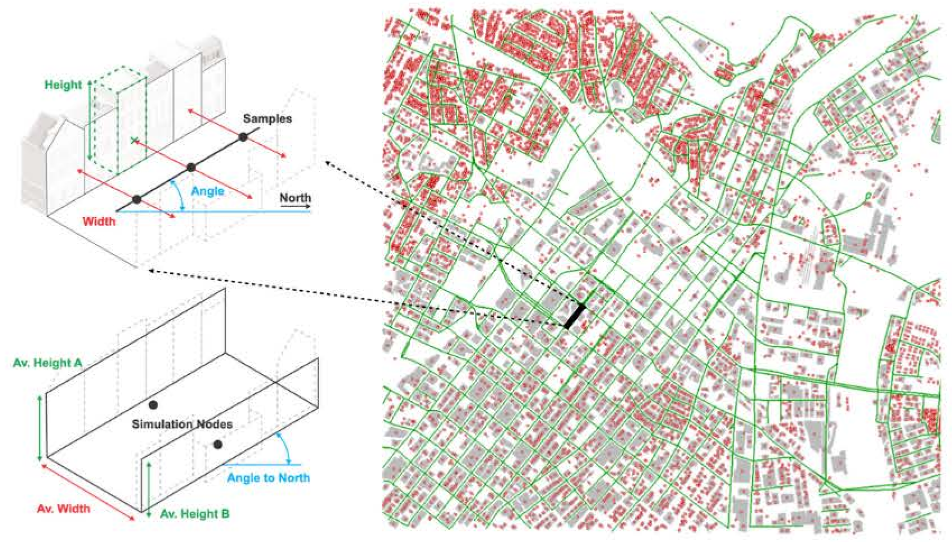
Sunshine, and the heat that comes with it, has become a growing global crisis. Cities such as Los Angeles, which was once known for its sunny skies, now worries about the lack of shade and the associated inequality (Arango & Mollenkof, 2019). The increase of extremely hot days burdens the poor disproportionally, as access to vegetation and the resulting shade directly correlates to wealth (Locke et al., 2021; Schwarz et al., 2015) They also have fewer social and material resources to deal with problems resulting from extreme heat. For example, the low-income population—many of whom don't have access to private transportation—are left no option but to walk or wait for public transportation in uncomfortably hot outdoor spaces. Further, the lack of trees in a community has also been shown to correlate with higher asthma rates, more heat-related hospital stays and mental health problems.

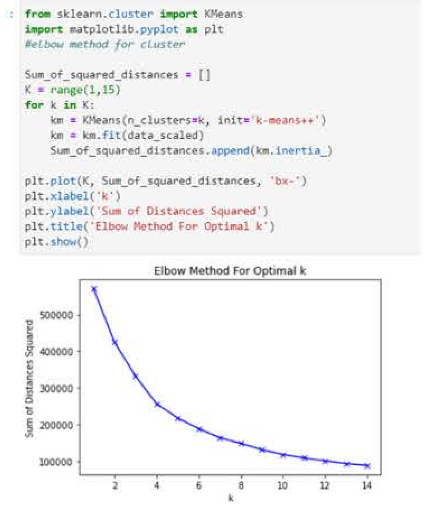


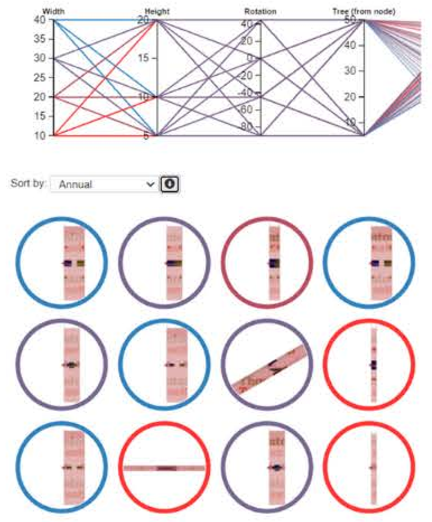
METHODOLOGY

This research develops a novel and scalable workflow to generate detailed street-level outdoor thermal comfort maps using the popular Universal Thermal Climate Index (UTCI) metric. Available street, building, and vegetation data are clustered using unsupervised machine learning. Cluster centroids (representative street canyons) are then used to compute detailed urban microclimate using Radiance and EnergyPlus, and results are matched back to actual streets. The workflow is accurate, scalable, fast, and allows annual hourly UTCI values to be computed and mapped for entire cities.









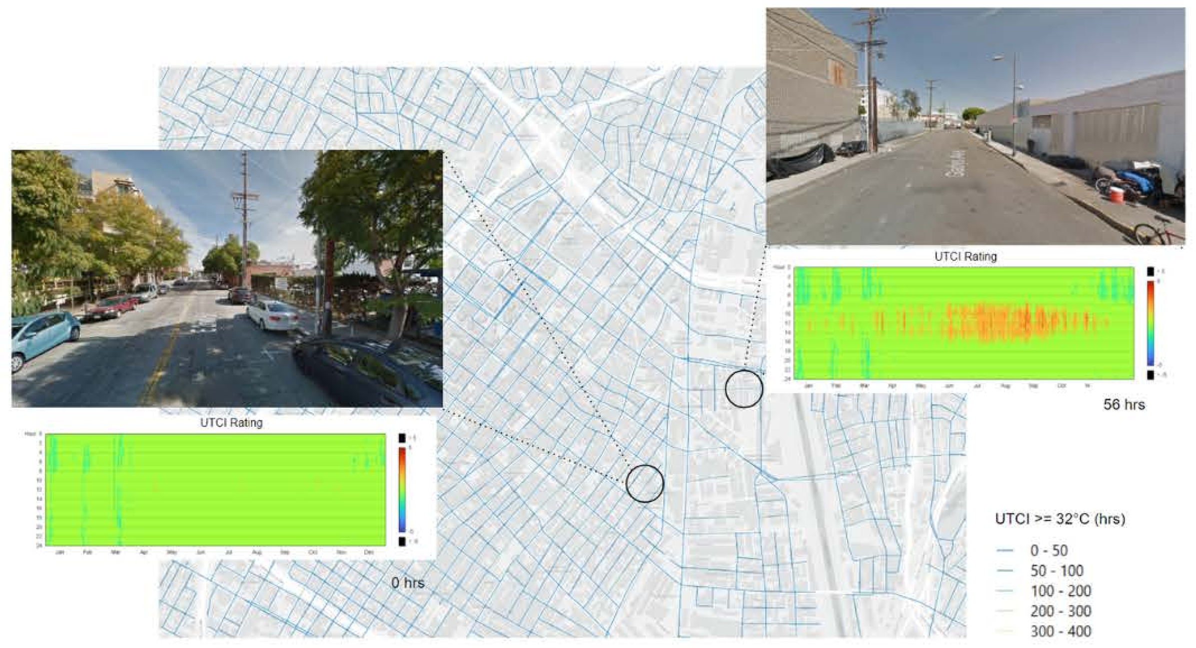
RESULTS & ANALYSIS

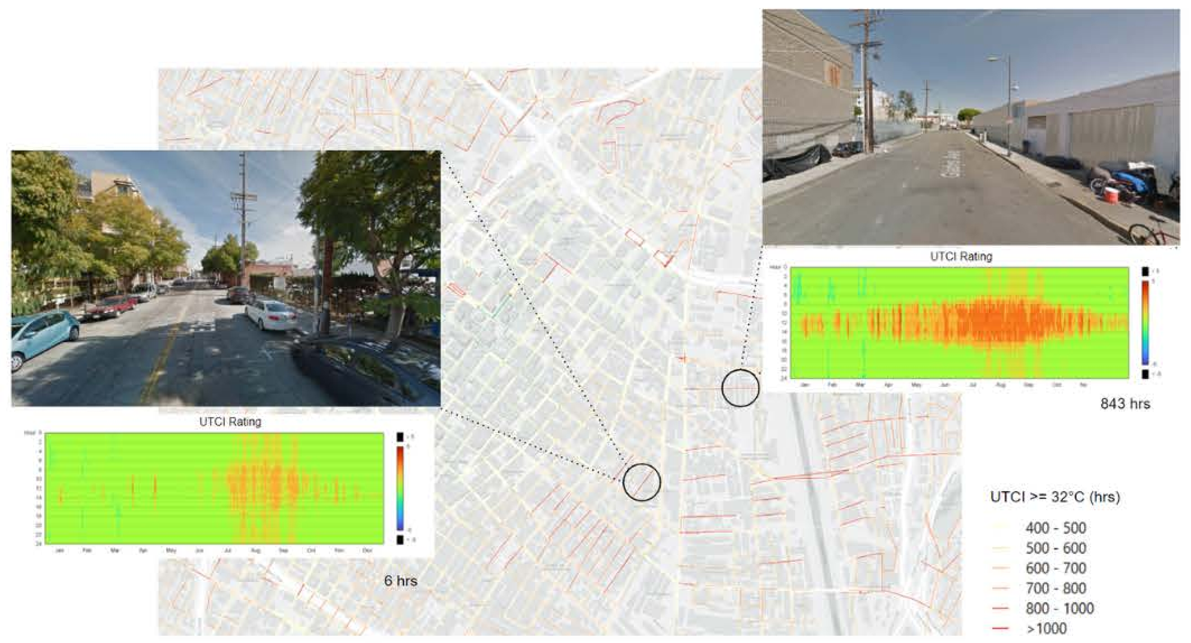
Using Los Angeles as a case study, annual hourly UTCI was calculated using TMY3 weather data (representative of current weather) and morphed climate data for year 2080.
The results show that given the same air temperature, UTCI fluctuates greatly depending on tree coverage, street design and surrounding site conditions.

The comparison on the right shows two canyons that are similar except for tree coverage. Although they experience similar hours of heat stress in the present (0 with tree coverage and 56hrs without), the difference becomes clearly distinguishable in the future (1 with tree coverage and 418hrs without).

For LA as a whole, the city center experiences the least amount of heat stress. Tall buildings are effective at blocking the sun, and prevent canyons from extreme heat. The suburban areas experience the most amount of heat stress, because street canyons are often wide and unshaded.

In the future, this workflow can be refined by considering more specific inputs such as building and pavement materials, precipitation, and tree height and canopy size.





Two streets with similar geometry have drastically different comfort ratings due to shade availability.

CONCLUSION

With that said, outdoor comfort is significantly impacted by street designs. Street orientation, canyon width, average surrounding building height and the presence of trees all influence microclimates and human heat/cold perception. Thus, it is imperative to study the impact of these factors (and more, such as façade materials and precipitation) on a city scale and leverage findings to design more comfortable urban spaces.