Urban Greenery Project: Building a Park Using CFD and Satellite Imaging

Hayato Takai and Justin Walkup
Washington University in St. Louis and Howard Unversity, Columbia University

Introduction

New research has shown that temperatures on a scorching summer day can vary as much as 20 degrees across different parts of the same city, with marginalized neighborhoods often bearing the brunt of that heat. Recent studies have shown that marginalized US neighborhoods, which have seen a long history of disinvestment and are more likely to have Black or Hispanic residents, consistently heat up the most. Low-income neighborhoods feature fewer urban trees and parks that help cool the air and have more paved surfaces, such as asphalt lots or nearby highways, that absorb and radiate heat. Introducing green spaces in sweltering urban environments is without a doubt, one of the most effective strategies to mitigate the urban heat island effect because they block solar irradiation and cool air through evapotranspiration. The goal of this project is to quantify air and surface temperature reductions resulting from the introduction of green spaces in urban areas. Satellite measurements and numerical models are used as methods.

Satellite Mapping

NASA's Landsat 8 satellite measurements of the South Bronx region are adopted to evaluate the correlation between the normalized difference vegetation index (NDVI) and land surface temperature (LST). These measurements were used to quantify spatial variations of LST and NDVI. By mapping spatially distributed values for LST and NDVI, for selected NYC regions, we can shed light on the impact of urban greenery on the urban climate. Measurements were taken of the South Bronx region from August 8th to September 1st of 2021. Fig. 1 below shows a linear regression model that shows the negative correlation between NDVI and LST.

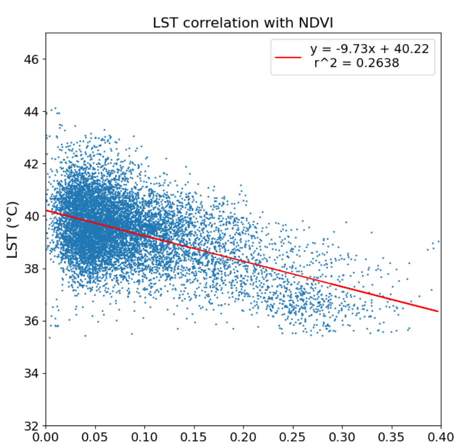

Figure 1: Linear Regression Model of NDVI and LST Spatial Variations

Numerical Simulation

Computational fluid dynamics simulations are conducted to quantify the impact of park geometry and vegetation density on air temperature. We consider a radially symmetric geometry with the forest at the center and an evenly spaced radial array of cuboids. The radially symmetric nature of the geometry allows us to observe a characteristic plane. The geometry is simplified to an open channel flow of air over an array of evenly spaced square buildings and a rectangular forest as shown in Fig. 2 below.

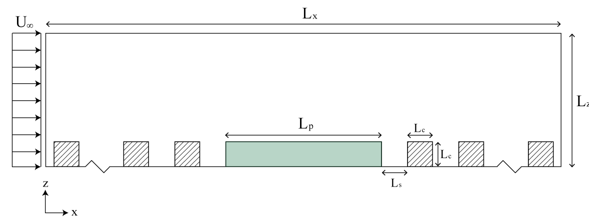

Figure 2: Domain of the Computational Domain for the Numerical Simulation

The length of the park (L_P), the height of the park (H_P), and the frontal area (λ) are varied. λ is directly proportional to L_P, representing short dense forests ($H_P = 5m : \lambda = 0.1m^2/m^3$) and tall sparse forests ($H_P = 20m : \lambda = 0.025m^2/m^3$). The setup will effectively contrast the capabilities of each configuration. The physical parameters of each product run are summarized in Table 1. below.

Table 1: Summary of CFD Parameters

#	$\lambda (m^2/m^3)$	$L_P(m)$	$H_P(m)$
L2p5_D0p4_H0p2	0.1	40	5
L2p5_D0p4_H0p2	0.025	40	20
L10_D0p8_H0p05	0.1	80	5
L2p5_D0p8_H0p2	0.025	80	20

Fig. 3 below shows the temperature plot for each parameter configuration.

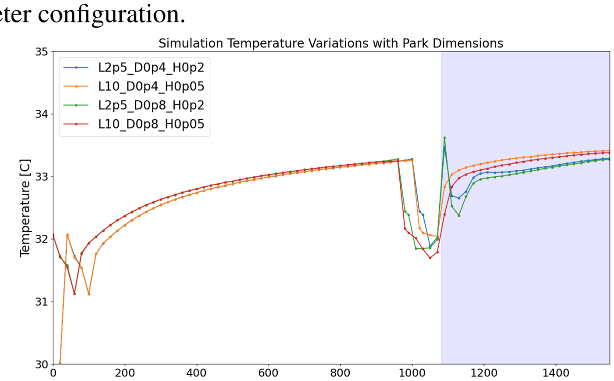

Figure 3: Temperature Plot of Park With Varied Dimensions

Results

The findings highlight that urban temperatures are negatively correlated to NDVI and, not surprisingly, that larger parks with taller trees are more effective than smaller ones with shorter trees in reducing air temperature in the downwind direction. An interesting and novel finding pertaining to the impact of park geometry on the airflow is that parks with tall trees can result in higher air temperatures in the street canyon adjacent to the park, mainly due to the presence of wake flow in the region downwind of the park, which is characterized by poor air ventilation and hence heat up more.

Conclusion

Findings from the numerical simulation and satellite measurements will support an ongoing field campaign whose goal is to measure the impact of green spaces on urban surfaces and air temperatures. We will continue working with NYC Department of Parks and Recreation officials to identify a specific location in the South Bronx and with Boomforest to plant an optimized forest with local community volunteer groups.

Acknowledgments

Columbia University and Amazon Summer Undergraduate Research Experience Program

United States Geological Survey

References

Giometto, M. G., Christen, A., Egli, P. E., Schmid, M. F., Tooke, R. T., Coops, N. C., & Parlange, M. B. (2017). Effects of trees on mean wind, turbulence and momentum exchange within and above a real urban environment. Advances in Water Resources, 106, 154–168. https://doi.org/10.1016/j.advwatres.2017.06.018

Grove, J. M., O'Neil-D., J., Pelletier, K., Nowak, D., & Walton, J. (2006). A report on New York City's present and possible urban tree canopy. Parks & Recreation.

Ramamurthy, P., & Bou-Zeid, E. (2017). Heatwaves and urban heat islands: A comparative analysis of multiple cities. Journal of Geophysical Research, 122, 168–178. https://doi.org/10.1002/2016JD025357

NYC Mayor's Office. (2017). Cool Neighborhoods NYC: A Comprehensive Approach to Keep Communities Safe in Extreme Heat. New York, NY. Retrieved from https://www1.nyc.gov/assets/orr/pdf/Cool_Neighborhoods_NYC_Report.pdf