Urban Greenery Project

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COLUMBIA | ENGINEERING
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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. 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 as shown in Fig 1. The goal of this project is to quantify air and surface temperature reductions resulting from the introduction of green spaces in urban areas by using satellite measurements and numerical models as methods. Specifically, Landsat 8 measurements are adopted to evaluate the correlation between the normalized difference vegetation index (NDVI) and land surface temperature (LST), and computational fluid dynamics simulations are conducted to quantify the impact of park geometry and vegetation density on air temperature. Findings from this project will support an ongoing field campaign whose goal is to measure the impact of green spaces on urban surfaces and air temperatures.

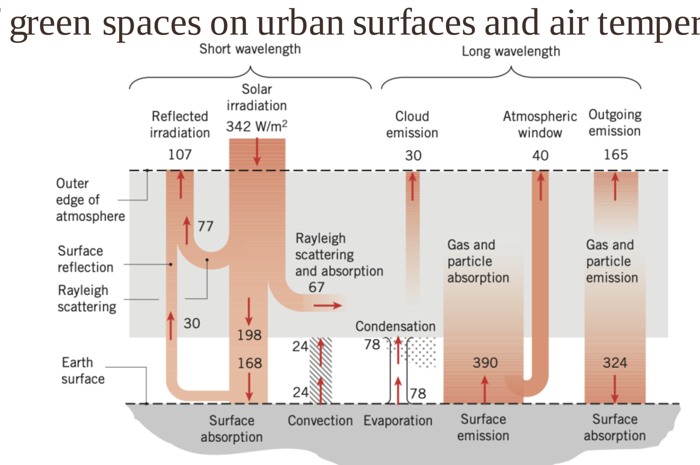
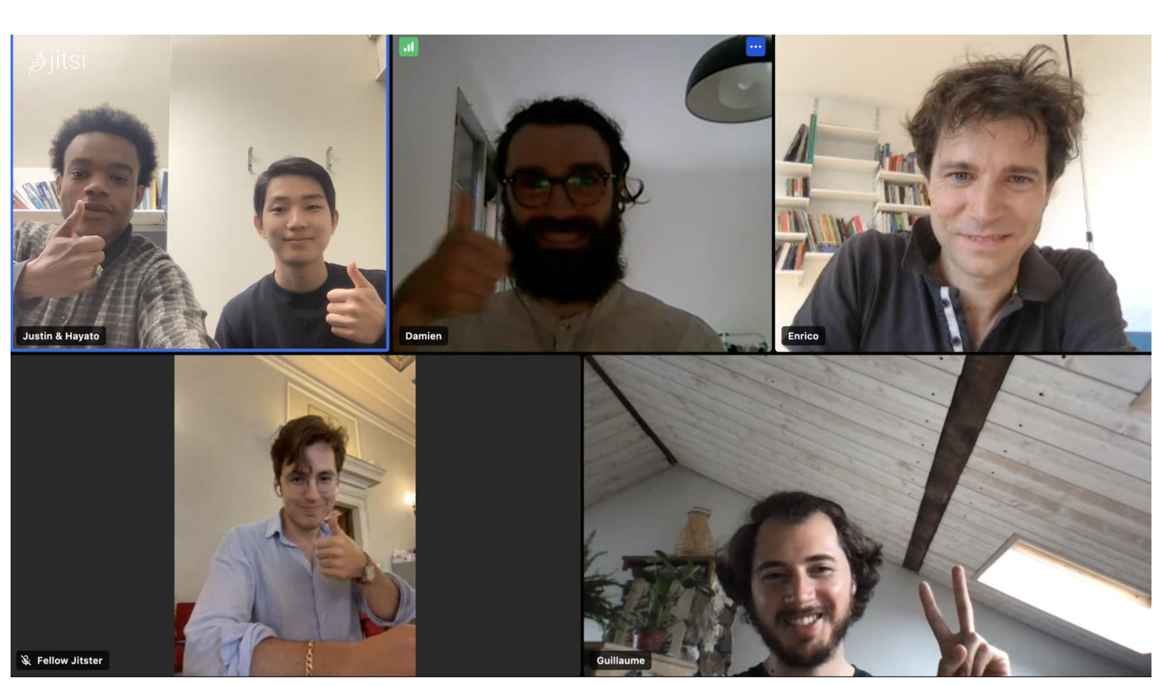


Figure 1. Breakdown of Atmospherical Energy Balance for Moderate Temperature and Cloudy Conditions

NGO AND GOVERNMENTAL PARTNERSHIP

boomforest   NYC Parks

Boomforest is an NGO based in Paris that will be working with us to build our forest. They specialize in a reforestation process called the Miyawaki plantation method, which grows dense trees from local species very quickly. This work will be supervised and conducted alongside the NYC Department of Parks and Recreation.



www.boomforest.org

SATELLITE MAPPING

Methods

NASA's Landsat 8 satellite measurements of the South Bronx region were acquired as a part of this project. 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. The NDVI was calculated from Eq. 1. below.

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}} \qquad (1)$$

Background. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 400 to 700 nm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared (NIR) light (from 700 to 1100 nm). The more leaves a plant has, the more these wavelengths of light are affected. These differences in plant reflectance determine their spatial distribution in these satellite images.

Results

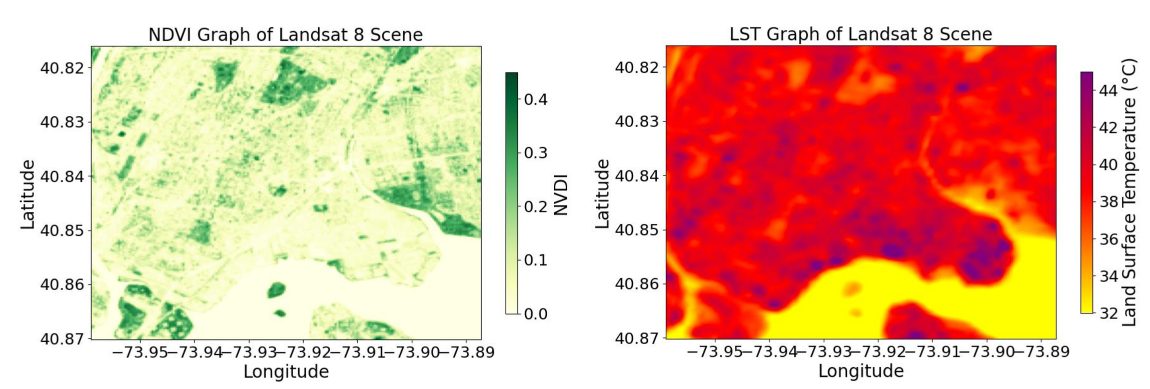


Figure 2. 08/26 - 09/01, 2021 Map of South Bronx Region: NDVI (left), LST (Right)

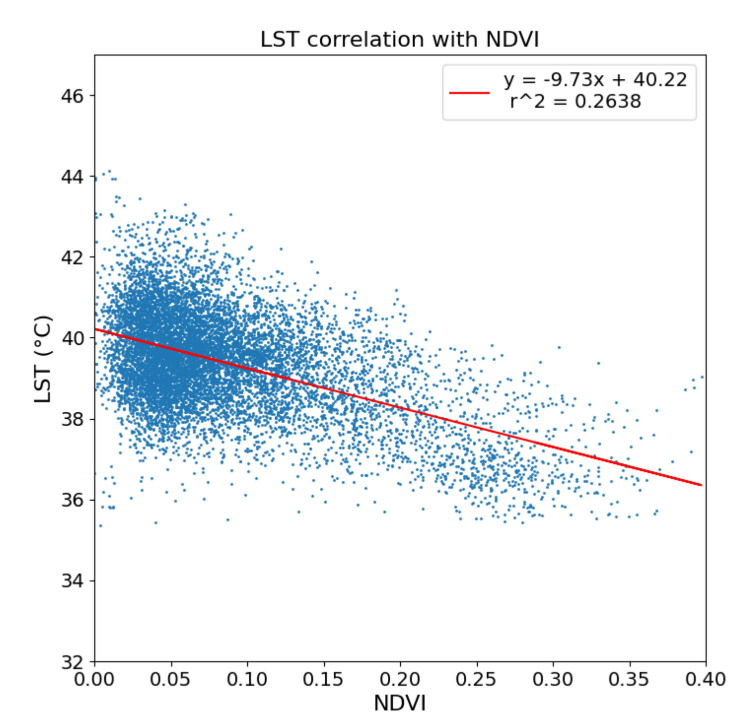


Figure 3. Linear Regression Model of NDVI and LST Spatial Variations

- Spatial variations of NDVI span 0 to 0.4
- Spatial variations of LST span 34 to 44 °C
- Linear regression model predicts $\mathrm{T} = -9.73\ \mathrm{NDVI} + 40.22$ with a coefficient of determination of $\mathrm{R}^2 = 0.2638$

Visiting the South Bronx area of interest

NUMERICAL SIMULATION

Methods

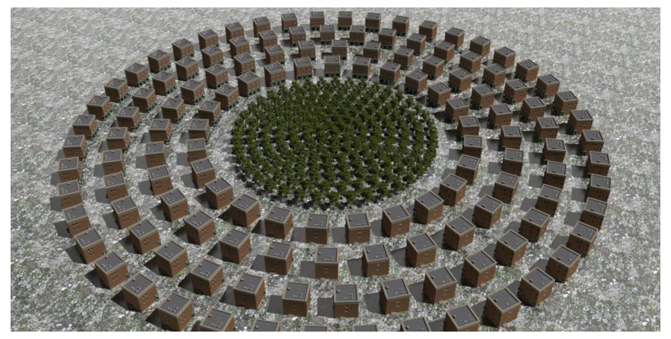


Figure 4. Render of the Computational Domain

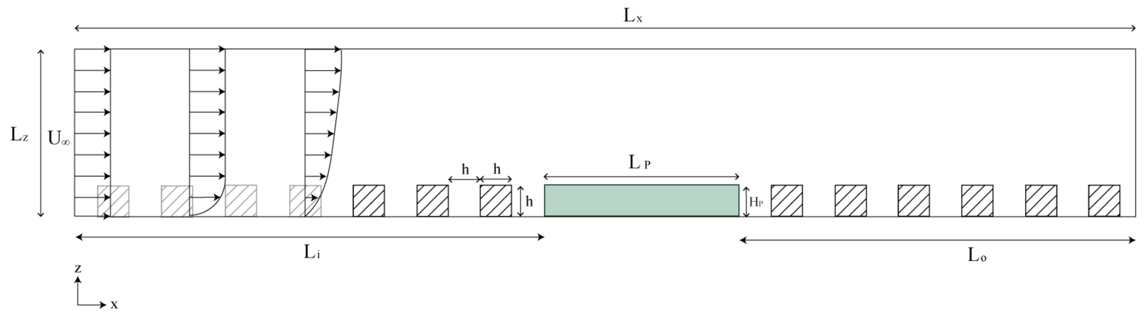


Figure 5. Diagram of the Computational Domain

Table 1. Summary of CFD Runs

#	$\lambda(m^2/m^3)$	$L_P(m)$	$H_P(m)$
L10_D0p4_H0p05	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

A range of L_P and H_P were evaluated to quantify the impact of park geometry and foliage density on the ambient temperature. To study heat transfer for the considered idealized park, we solve the mass, momentum, and thermal energy equations:

$$\frac{\partial \bar{u}_i}{\partial x_i} = 0 \qquad (2)$$

$$\rho \bar{u}_j \frac{\partial \bar{u}_i}{\partial x_j} = \rho \bar{f}_i + \frac{\partial}{\partial x_j}\left[-\bar{p}\delta_{ij} + 2\mu \bar{S}_{ij} - \rho \overline{u_i' u_j'}\right] + F_{d,i} \qquad (3)$$

$$\rho c_p \left(\bar{u}_j \frac{\partial \bar{T}}{\partial x_j}\right) = \frac{\partial}{\partial x_j}\left(k \frac{\partial \bar{T}}{\partial x_j} - \partial c_p \overline{u_j' T'}\right) + S_v \qquad (4)$$

Results

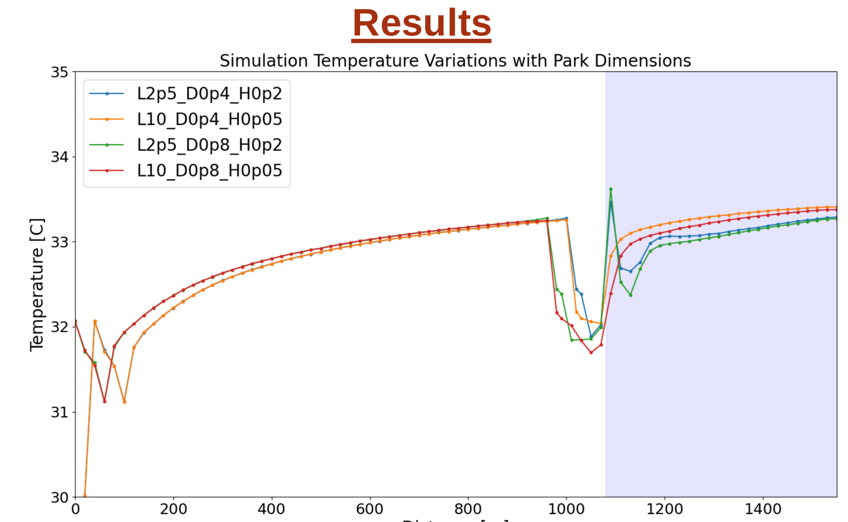


Figure 6. Plot of Parks with Varied Dimensions

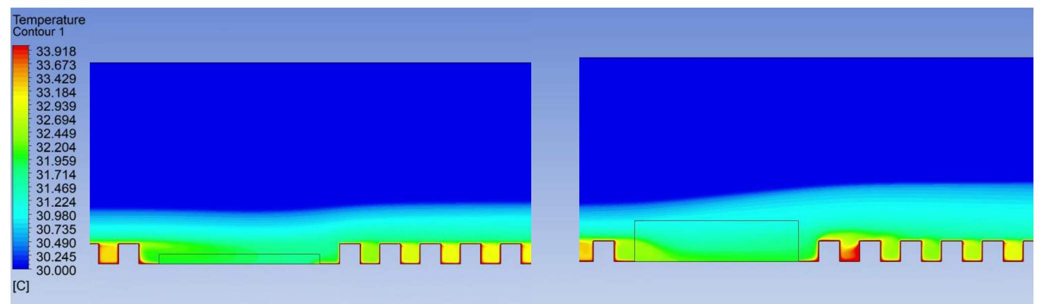


Figure 7. Temperature Contour plots of L10_D0p8_H0p05 (left) and L2p5_D0p8_H0p2 (right)

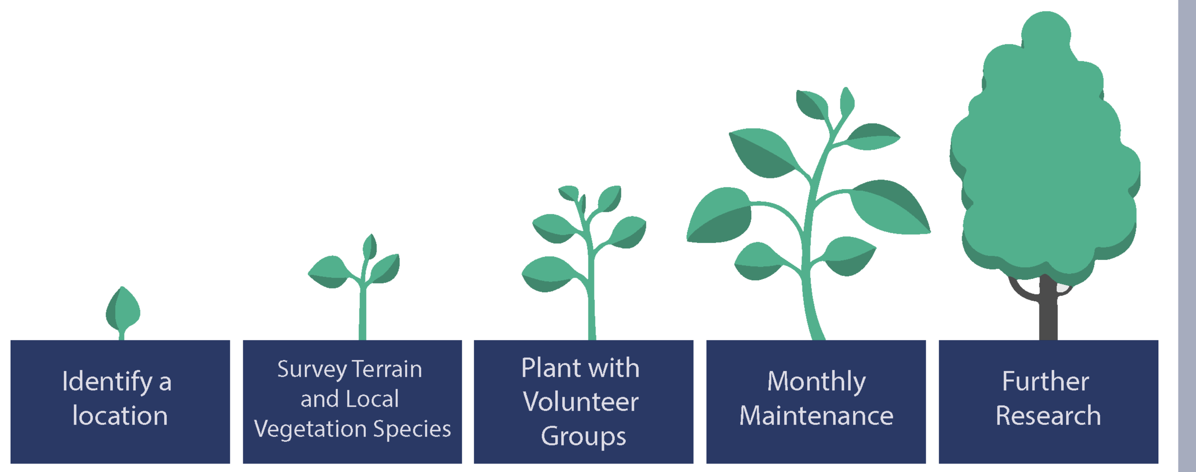
- Parks with tall trees can result in higher air temperatures in the street canyon adjacent to the park, mainly due to the presence of wake flow in the region downwind of the park.
- Larger parks with taller trees are more effective than smaller ones with shorter trees in reducing air temperature in the downwind direction.

SUMMARY AND CONCLUSION

- Numerical simulation and satellite measurements were used to characterize the impact of vegetation on the temperature in an urban environment.
- Satellite measurements have revealed a linear dependency of LST on NDVI.
- Numerical simulations have shown that the geometry of a city park can have a profound impact on the air temperature distribution in the vicinity of a park.

PATH FORWARD

In upcoming months, the field campaign will include working with the NYC Department of Parks and Recreation officials to identify a specific location in the South Bronx and with Boomforest to plant the optimized forest with local community volunteer groups in early November.



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