BERAC FALL MEETING
OCTOBER 24–25, 2024

CROCUS
Community Research on Climate & Urban Science

CROCUS PROGRESS

COMMUNITY RESEARCH ON CLIMATE AND URBAN SCIENCE

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On behalf of the CROCUS team
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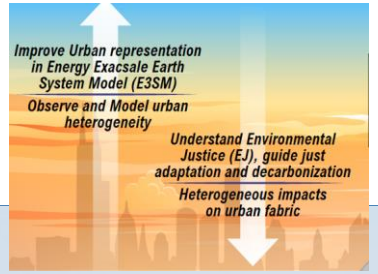
U.S. DEPARTMENT OF ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Argonne NATIONAL LABORATORY

CROCUS SYNOPSIS



IMPACT

VISUALIZE AND COMMUNICATE

Integrated ABM decision-making model ChiSIM, Scientific publications

UNDERSTAND

Heterogeneity, processes and dynamics
Heat and flooding
Mitigation approaches and feedbacks to urban systems

SCENARIOS

Translate community needs into actionable queries

OBSERVE

Provide data in data-poor environments

MODEL

EXISTING DATA

Provide better physics to represent urban canopy, determine what resolution captures processes
Inform how to observe a heterogeneous urban environment

COMMUNITY VISION

EDUCATION AND WFD

SOLUTIONS

Model potential resilience and mitigation solutions

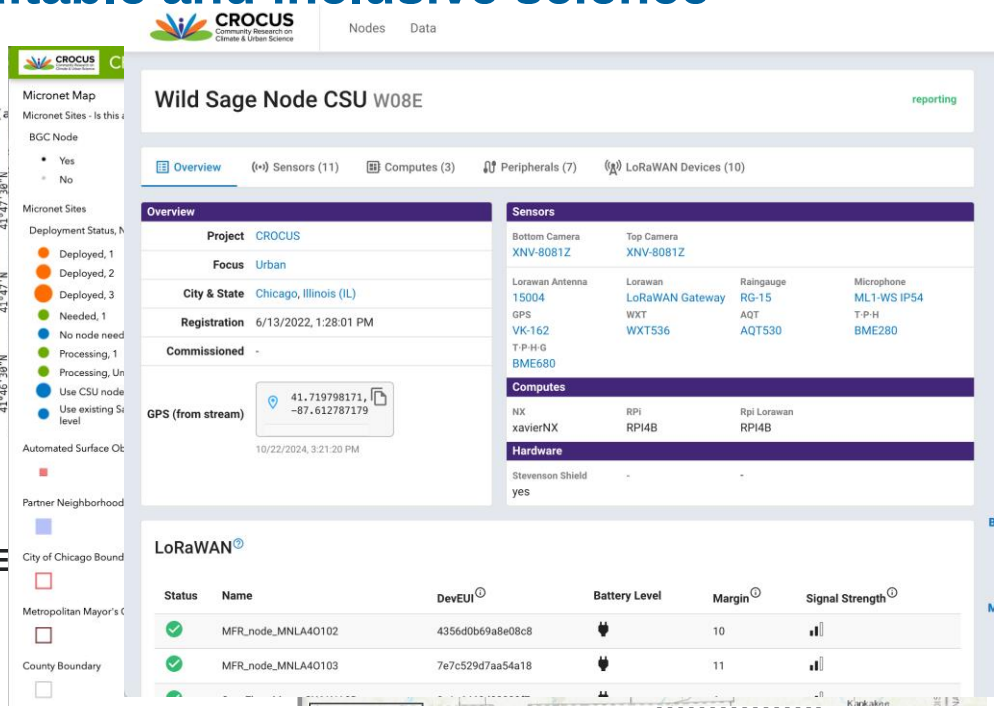
OBSERVATIONS AND DATA

for equitable and inclusive science

OBSERVATIC
LOCATION

TEMP

VEGE



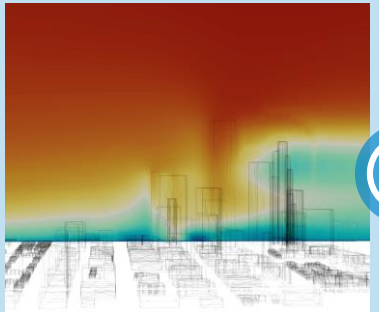
HIGH FIDELITY SIMULATION INFORMS BETTER STREET-CITY SCALE MODELING

MODEL

Focusing on improving urban physics parameterization at the street level (2 meters), we performed high-fidelity Large Eddy Simulations in nekRS.

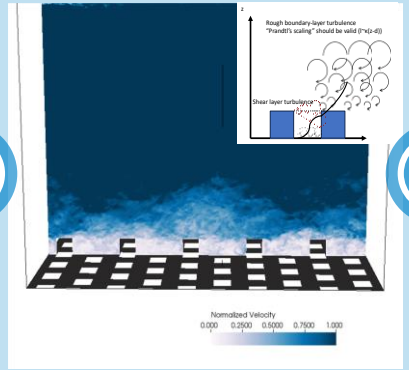
The results of these simulations were used to derive an improved parameterization for street-scale/street-level dynamics, which was then implemented into our regional meso-scale model (WRF) to better capture urban impacts.

HIGH-FIDELITY SIMULATIONS:
Street resolving simulations

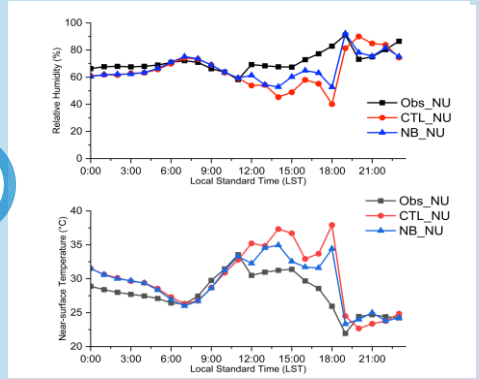


nekRS/OpenFOAM

IMPROVED PARAMETERIZATION:
Use high-fidelity simulations to derive improved parameterization within the Urban Canopy at the street level/comfort level (2-m)



MESOSCALE MODELING:
Improved predictions at the street level



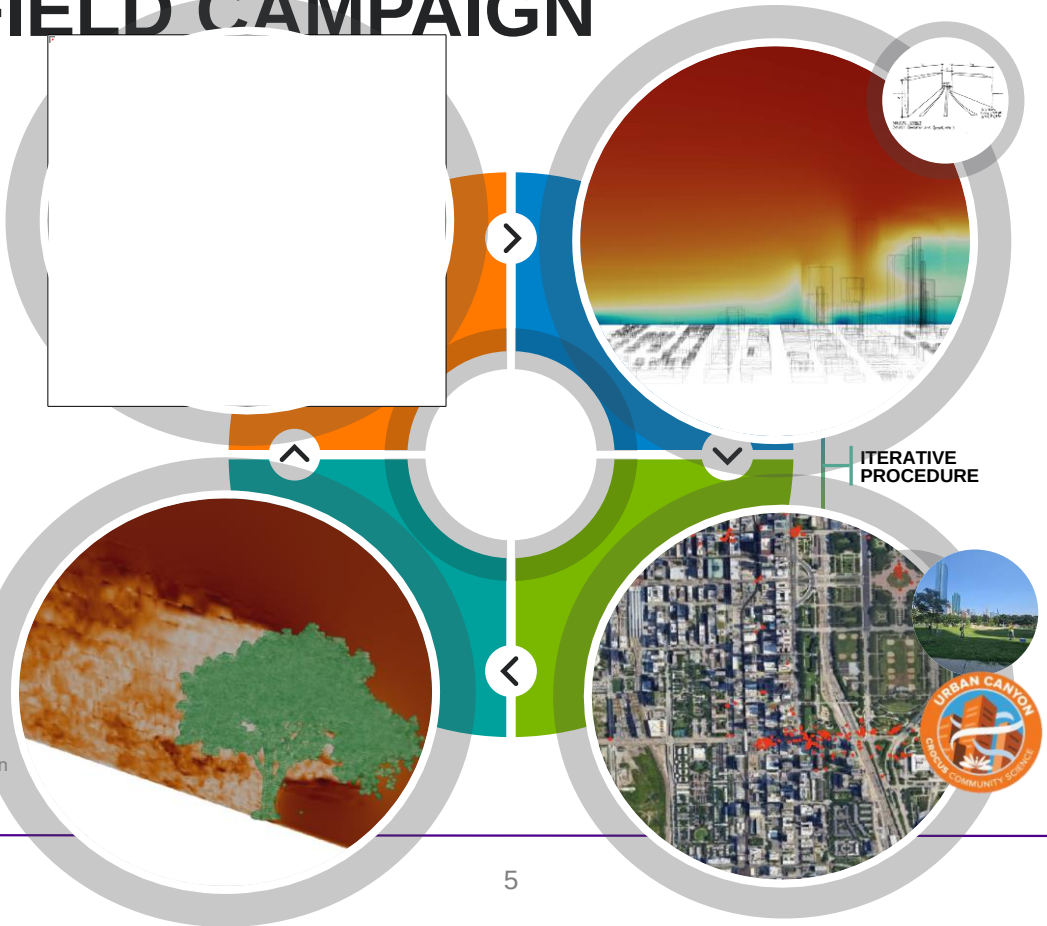
Mesoscale: 2-m Temperature

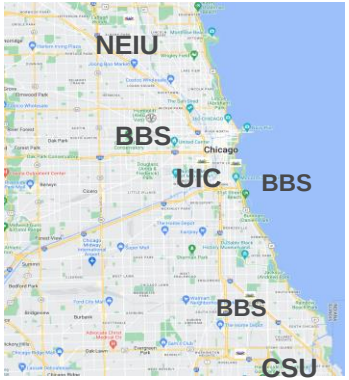
D. K. Fytanidis, H. Tan, A. Martilli, J. Wang, R. Kotamarti, 2024. *An Improved BEP-BEM-based Urban Canopy Parameterization Scheme: Model Development from High-Fidelity Simulations and Applications,* in preparation.

MODEL-INFORMED URBAN CANYON FIELD CAMPAIGN

DATA FROM THE URBAN CANYON CAMPAIGN:

- Improve understanding of land-atmosphere processes
- Validate models and test model hypothesis
- Refine boundary and initial conditions and improve models.





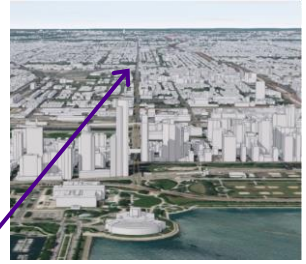
HIGH-FIDELITY SIMULATIONS

- Guiding instrument placement.
- Interact with Measurement Strategy Team (MST) to decide the measurement locations (ModEx)
- **Inputs from community and research partners was essential**
  - 9 Organizations
  - 2 IOPs (4 days)
  - 42 balloon launches
  - 400+ hand-held measurements

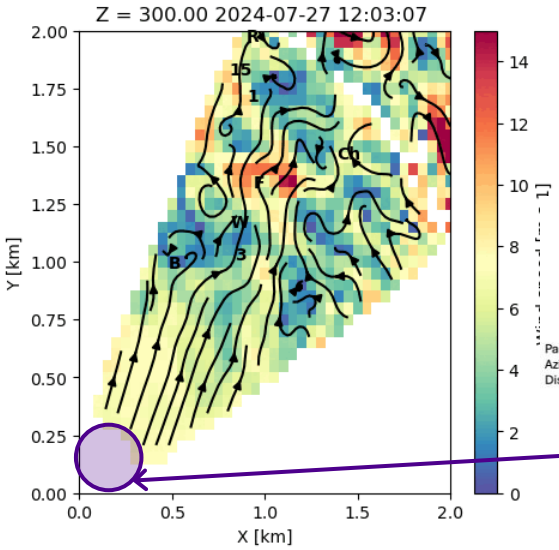
Collis et al 2024 “The Community Research On Climate and Urban Science (CROCUS) Urban Canyons Field Campaign” BAMS *in prep.*

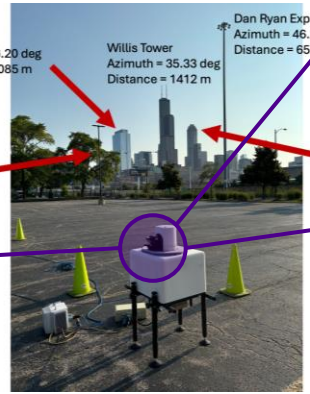
URBAN CANYONS CAMPAIGN: CITY WAKE VORTICITY

Providing models with unique datasets

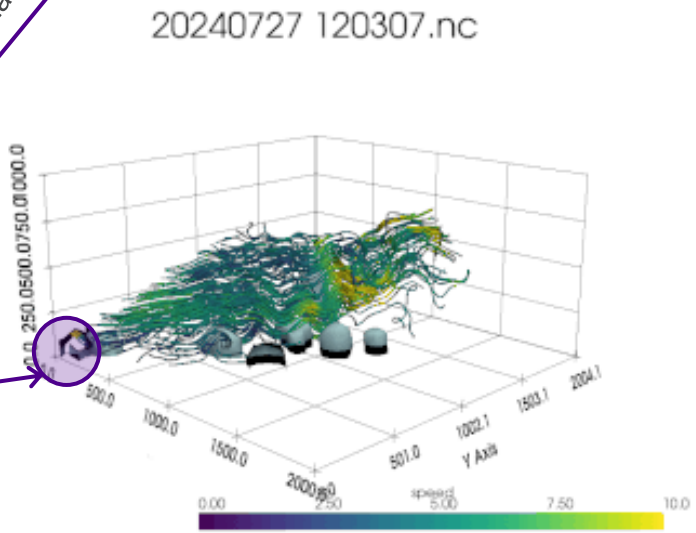


OBSERVE





1.6 mi from lake

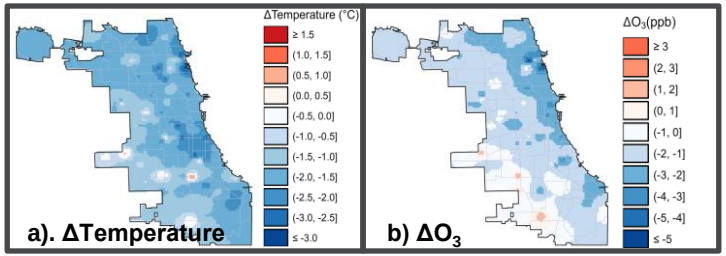


Bobby Jackson, Tim Wagner, Paytsar Muradyan, others?

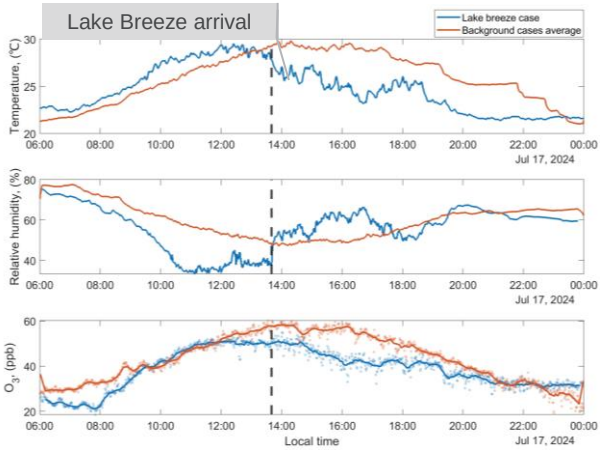
URBAN CANYONS CAMPAIGN: LAKE BREEZE AIR QUALITY EFFECTS

- The lake breeze appeared to significantly mitigate heat stress and decrease O_3 in Chicago across the city (Eclypse Data)
- More precise measurements confirmed these trends, and registered an increase in RH at the UIC observing station during the July 17, 2024 IOP.

Chen, X., Wang, J., et al. High-Resolution Spatiotemporal Analysis of Air Quality and Urban Heat Island in Chicago Using the Microsoft Eclipse Network. In prep for Atmospheric Chemistry and Physics



Eclypse: Low-cost sensor network-detected change of
a) temperature
b) ozone 3 hours after the arrival of lake breezes

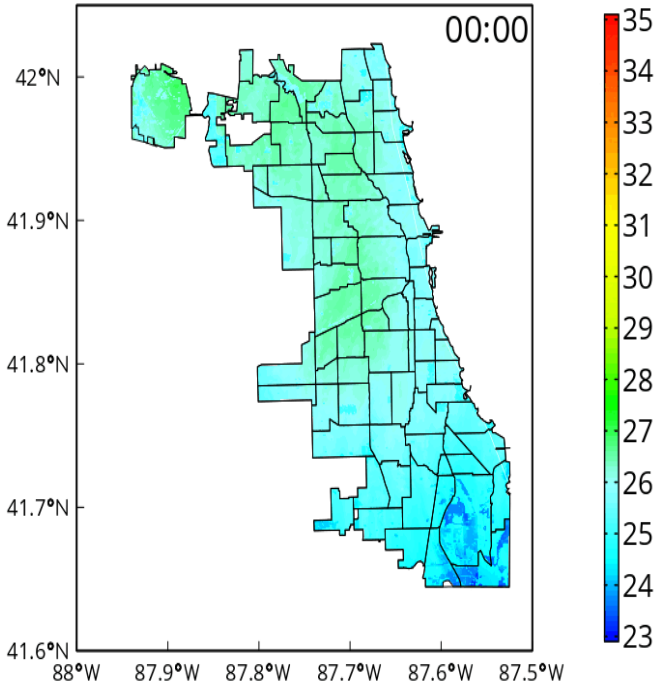


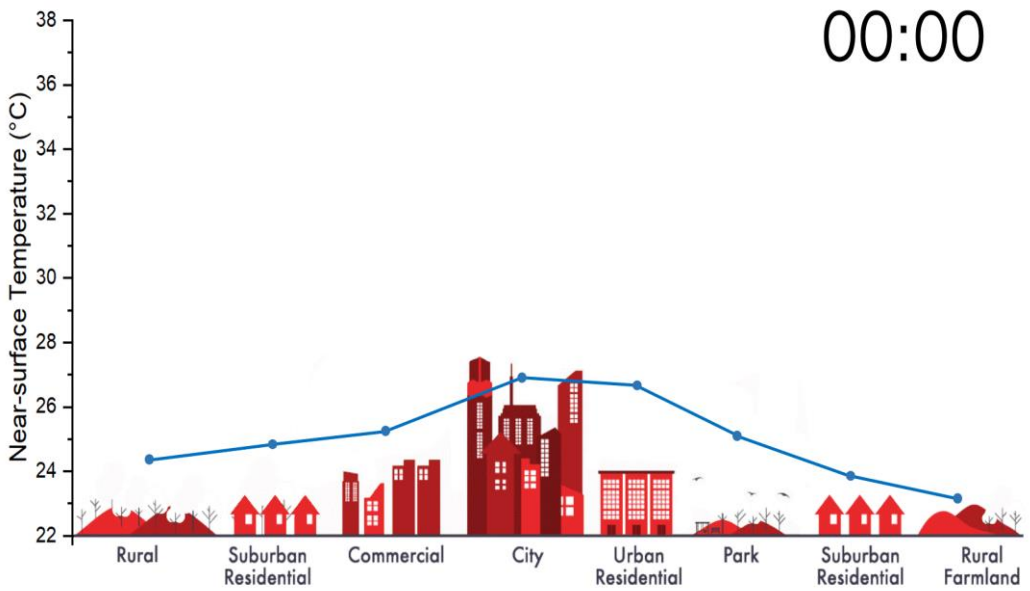
Decreasing Temperature

Increasing RH

Decreasing Ozone mixing ratio

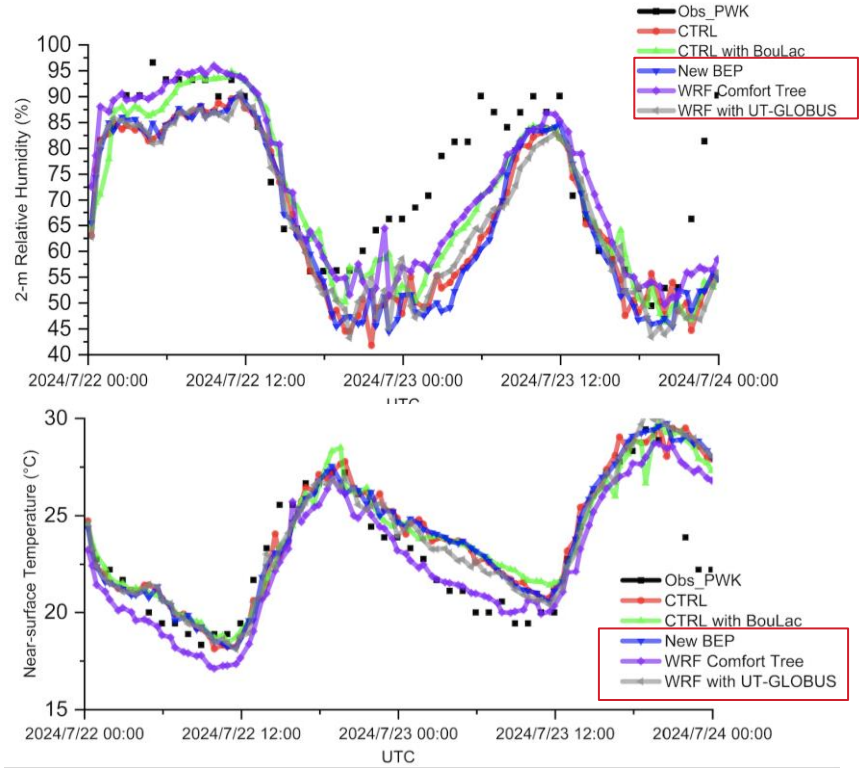
CITY SCALE SIMULATION OF TEMPERATURES





Source: Haochen Tan, Argonne National Laboratory

ADVANCING MODEL CAPABILITY



PWK

- If the model sees a different land use than reality, the simulation will be different too!
- Spatial resolution matters (the model does a good job in some locations but not others).

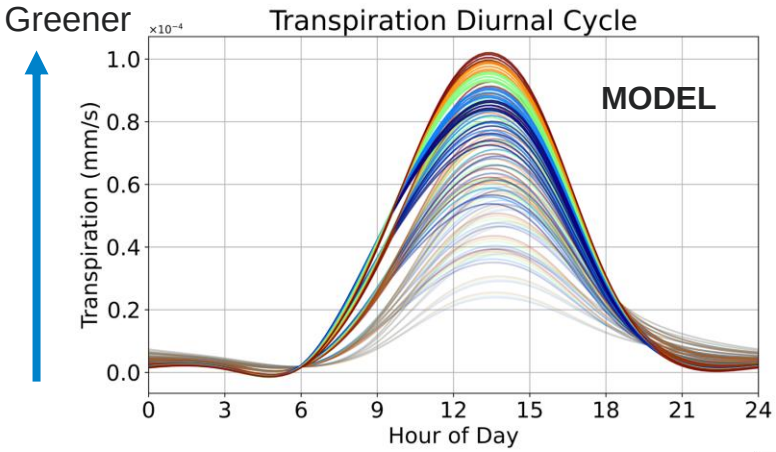
Martilli, A., Nazarian, N., Krayenhoff, E. S., Lachapelle, J., Lu, J., Rivas, E., Rodriguez-Sanchez, A., Sanchez, B., and Santiago, J. L.: **WRF-Comfort: simulating microscale variability in outdoor heat stress at the city scale with a mesoscale model**, Geosci. Model Dev., 17, 5023–5039, https://doi.org/10.5194/gmd-17-5023-2024, 2024.

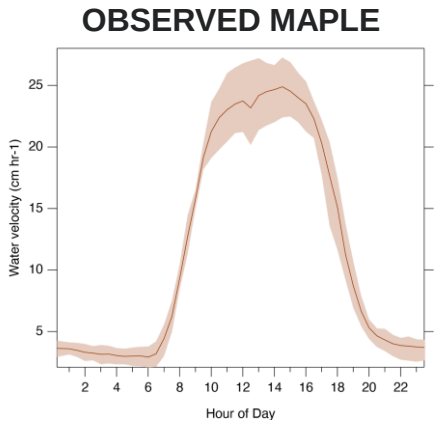
H. Kamath, M. Singh, N. Malviya, A. Martilli, L. He, D. Aliaga, C. He, F. Chen, L. A. Magruder, Z. Yang & D. Niyogi. **GLObal Building heights for Urban Studies (UT-GLOBUS) for city- and street- scale urban simulations: Development and first applications.** Scientific Data, August 15, 2024. DOI: 10.1038/s41597-024-03719-w

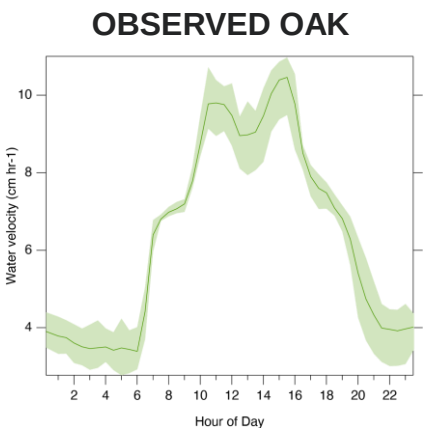
D. K. Fytanidis, H. Tan, A. Martilli, J. Wang, R. Kotamarti, 2024. ***An Improved BEP-BEM-based Urban Canopy Parameterization Scheme: Model Development from High-Fidelity Simulations and Applications***, in preparation.

SIMULATING THE SERVICES AND EFFECTS OF TREES

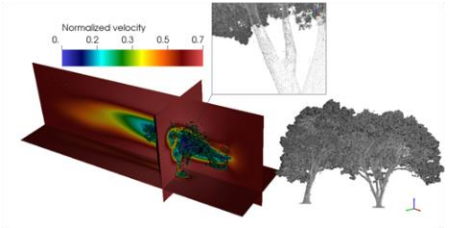
requires traits that are correctly defined in models







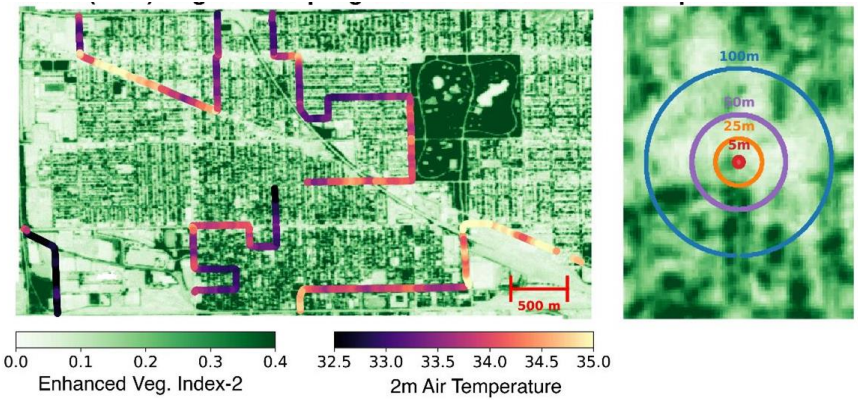
An example of simulated water use by trees in Chicago based on 125 different simulations with unique land covers. Red lines mean more trees and blue mean more grass. Transparency of the line represents higher urban percentage in the gridcell.



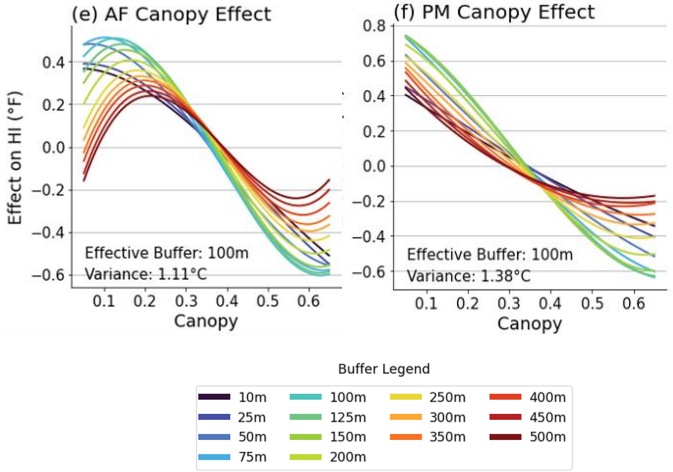
CUMULATIVE SERVICES FROM THE CANOPY

reflect the diverse behavior of trees, soils and land cover

Example image showing temperature measurements, greenness and radii of influence around each measurement.



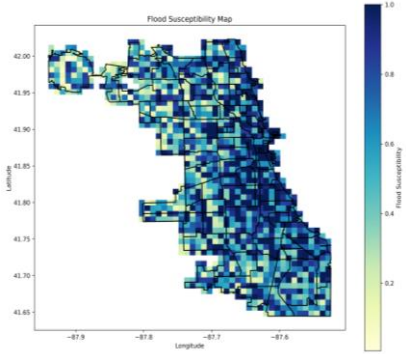
Observed change Heat Index in afternoon (left) and evening (right) depending on local canopy cover



Lee and Berkelhammer (2024) Observational constraints on the spatial effect of greenness and canopy cover on urban heat in a major midlatitude city. Geophysical Research Letters, in press.

COMPOSITE FLOOD SUSCEPTIBILITY MAPPING WITH HIGH-RESOLUTION DATA

- DEMs
- Imperviousness
- LULC
- Soil types and infiltration capacity
- Waterways and drainage pipe networks
- Historical flood reports
- Hydrological-Hydraulic Modeling (SWMM)
  - 10, 25, and 100 year storms with IDF curves
  - Integration of multi-scale models with
  - strategic simplification and cross-scale feedback
  - Junction and link performance assessment



Composite flood susceptibility

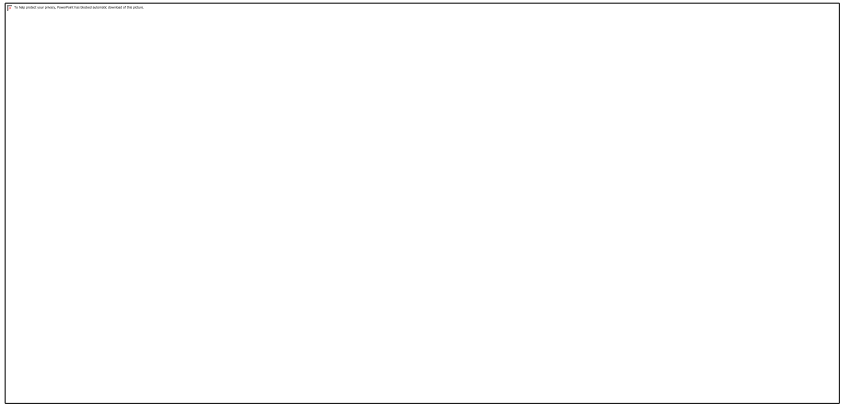
- High impervious areas (downtown Chicago) are more flood-prone due to limited infiltration and overwhelmed sewers.
- Low-lying areas with poor drainage have higher flood risk during heavy rainfall.
- The map highlights areas needing infrastructure upgrades, like better drainage or more green space to reduce runoff.

- **Strategically simplifies the Chicago (city-scale) model** by focusing on major interceptors in the sewer system, ensuring computational efficiency while maintaining accuracy.
- Uses **high-resolution data** (DEMs, land use, soil types) for more precise flood risk predictions, identifying areas that simpler models might miss.
- **Integrates multi-scale** hydrological and hydraulic modeling with **cross-scale feedback** by combining system-wide drainage performance with infrastructure operation and localized small-scale issues
- Utilizes **a probabilistic framework to quantify flood uncertainty at different scales**, addressing both localized storm impacts and city-wide vulnerabilities.

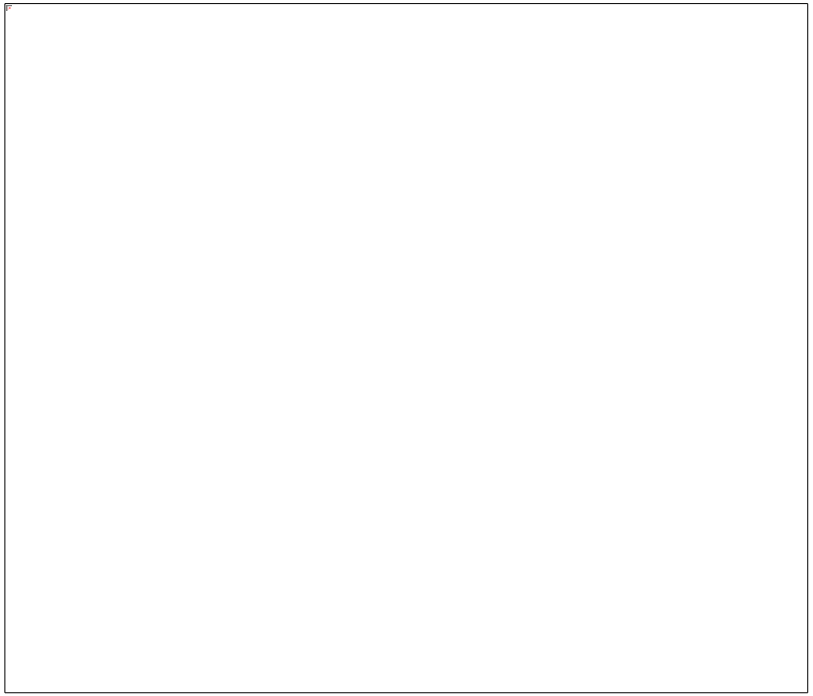
Park, S., D. Hence, S. Nesbitt, and M. Garcia, 2024: Composite Flood Susceptibility Mapping for Chicago: Integrating Atmospheric and Hydrologic Uncertainties. Urban Climate, in preparation.

TEMPERATURE MITIGATION AND ENERGY CONSUMPTION

Decision-making elements



Diurnal cycle of simulated air-conditioning electricity consumption for control simulation (black), Cool Roof (blue), Green Roof (green), and Solar Panel Roof (red) and the electricity production generated by Solar Panel Roof (orange).



Tan et al. DOI: 10.1016/j.scitotenv.2022.160508.

COMMUNITY BASED PARTICIPATORY RESEARCH PRINCIPLES

- **Level setting: communication, history, demographics, power dynamics, social structure**
- **Integrate a broad spectrum of different ways of knowing, experiences, and expertise**
- **Empathy and community knowledge**
- **Equitable decision-making procedures and transparency**

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A decision-making framework under development that is inclusive of the varying interests and perspectives of the diverse group of CROCUS stakeholders, including the communities of focus

Suggested Core Principles for a community-based research framework (National Opinion Research Center, NORC, 2024):

- Shared Power and Equity
- Transparency and Open Communication
- Accountability and Respect
- Accessibility and Demonstrated Value
- Capacity Bridging and Co-Learning
- Avoidance of Harm

Building Partnerships

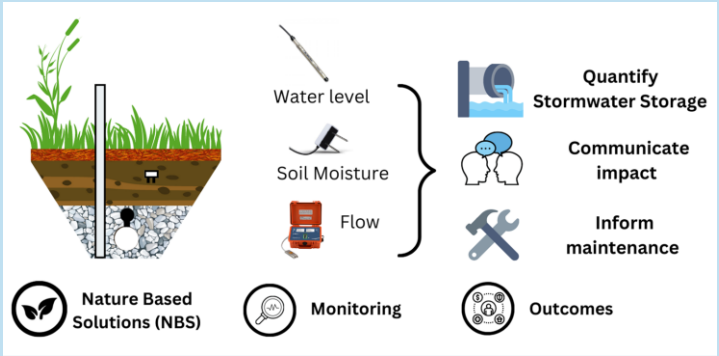
Establish agreements and expectations

Intentional collaborations and codesign

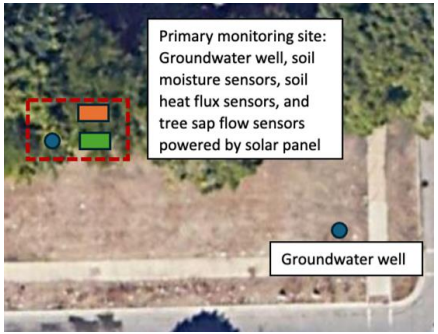
Shared commitment to agreements, processes, and outcomes

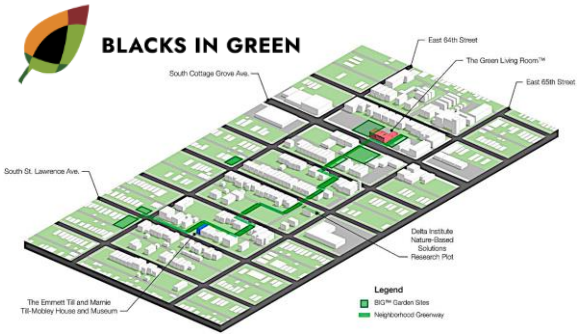
COMMUNITY NBS EVALUATION AND SCIENCE PLANNING

Link observation and modeling for urban hydrologic science, NBS evaluation, and community-based design.



https://ess.science.energy.gov/urban-ifls/highlight/strategies-for-measuring-urban-green-spaces-impact-on-stormwater-management/

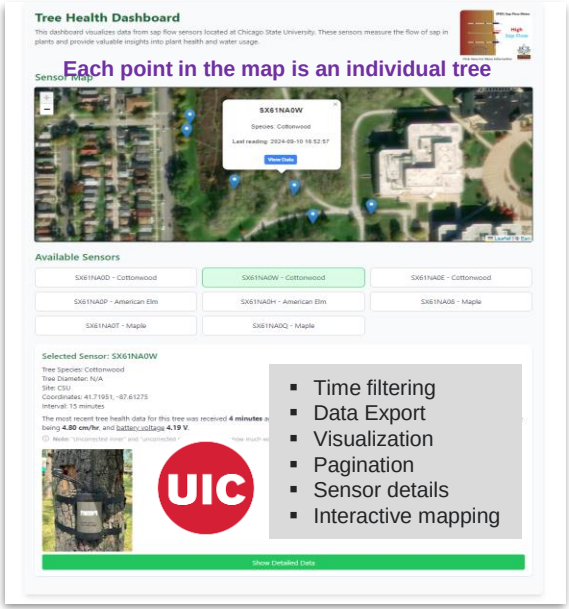




Woodlawn site visit & instrumentation plan

EDUCATION AND WORKFORCE DEVELOPMENT

Using CROCUS science to train, educate, and develop new programs at MSIs



CHICAGO STATE UNIVERSITY

Renaming and reshaping the Program: Environmental Studies Concentration

Olive-Harvey College

Curriculum development and Student Research in Community in Urban Science and Urban Agriculture

NORTHEASTERN ILLINOIS UNIVERSITY

Data science course using CROCUS observational data

UNIVERSITY OF ILLINOIS AT CHICAGO

The UIC Data Dashboards CROCUS-Focused Curriculum
StormAlytics

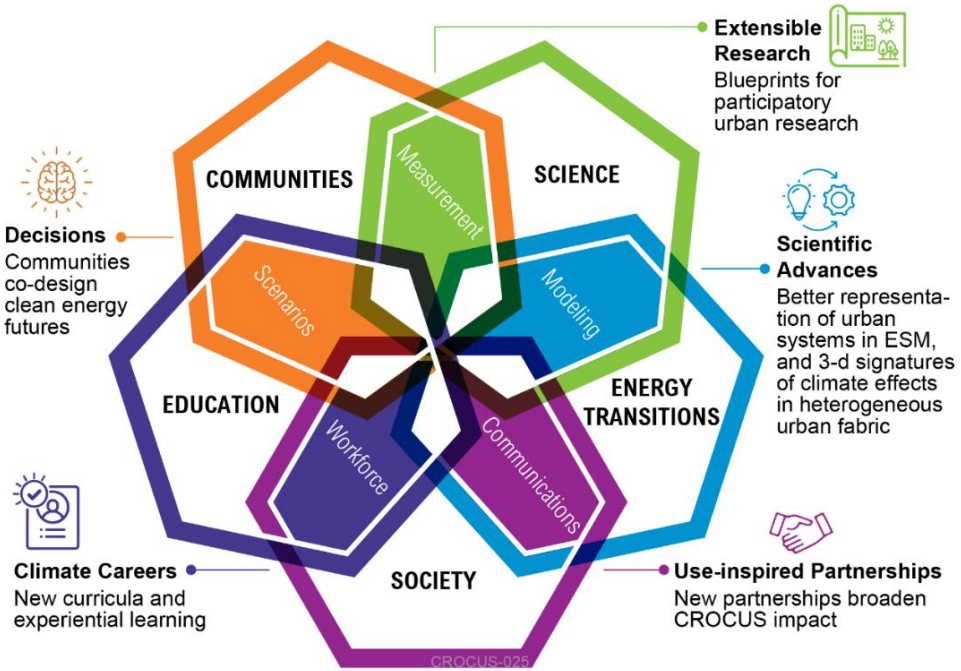
NEXT STEPS FOR IMPACT

Develop authentic scenarios for clean energy and resilience decisions

Incorporate scenarios in Agent-based decision model CROCUS-CHiSIM

Continue experiential learning and engage with students in multiple ways

Sponsor Careers of the Future workshop



Vet our framework for community engaged research
Continue community engagement

Complete the Observation system and conduct Flooding field campaign

Continue model refinement

Understand processes

Include energy transition elements in models

Publish

City of Chicago, Park District, MWRD, Museums, EPA, NOAA

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Community Research on Climate & Urban Science

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