BERAC FALL MEETING
OCTOBER 24–25, 2024

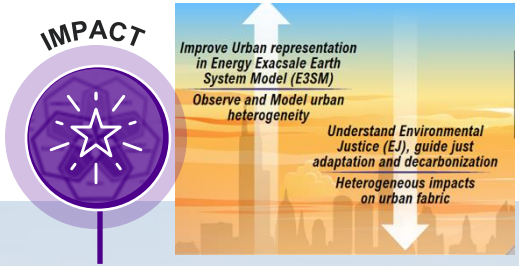
CROCUS
Community Research on Climate & Urban Science

CROCUS PROGRESS

COMMUNITY RESEARCH ON CLIMATE AND URBAN SCIENCE

CRISTINA NEGRI
Lead PI
Director,
Environmental Science Division
On behalf of the CROCUS team
negri@anl.gov

CROCUS SYNOPSIS



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

Provide data in data-poor environments

SCENARIOS

Translate community needs into actionable queries

Model potential resilience and mitigation solutions

OBSERVE

MODEL

EXISTING DATA

COMMUNITY VISION

EDUCATION AND WFD

SOLUTIONS

Provide better physics to represent urban canopy, determine what resolution captures specific processes

Inform how to observe a heterogeneous urban environment

OBSERVATIONS AND DATA

for equitable and inclusive science

OBSERVATIC
LOCATIOI

TEMI

VEGE

CROCUS Community Research on Climate & Urban Science

Nodes Data Docs Help

Sensors

AQT530	latest time	last day	value
Temperature	19.8 secs ago		12.7°C
Humidity	19.8 secs ago		87.9RH
Pressure	19.8 secs ago		996.5hPa
co	19.8 secs ago		0.171PPM
no	19.8 secs ago		0PPM
no2	19.8 secs ago		0.029PPM
ozone	19.8 secs ago		0.001PPM
pm1	19.8 secs ago		1.8µg/m³
pm2.5	19.8 secs ago		5.8µg/m³
pm10	19.8 secs ago		11.8µg/m³

Sap Flow Meter SX61NA0D	latest time	last day	value
Uncorrected Inner/Outer	5.1 min ago		1.236

Sap Flow Meter SX61NA08	latest time	last day	value
Uncorrected Inner/Outer	13.4 days ago		2.271

WXT536	latest time	last hour	value
Temperature	2.7 secs ago		12.4°C
Humidity	2.7 secs ago		89.5%
Pressure	2.7 secs ago		995.9hPa
Rain Accum.	2.7 secs ago		73.11mm
Hail Accum.	-		n/a
Wind Direction	2.7 secs ago		299°
Wind Speed	2.7 secs ago		2.1m/s

RG-15	latest time	last day	value
Rainfall	23.6 secs ago		7.4mm

MFR node MNLA4O103	latest time	last day	value
Air Temp	5.9 min ago		12.69
Water Conductivity	3.5 days ago		3399
Water Depth	3.5 days ago		1247
Water Temp	3.5 days ago		15.5

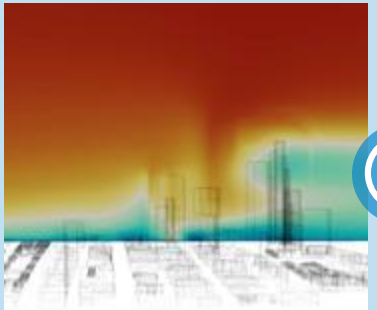
HIGH FIDELITY SIMULATION INFORMS BETTER STREET-CITY SCALE MODELING

MODEL

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

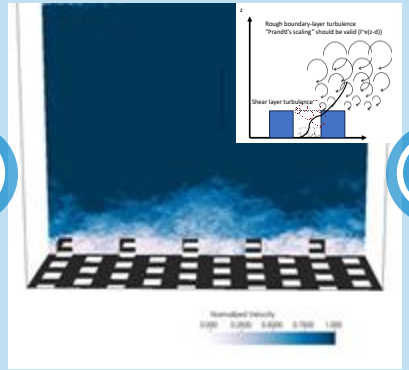
The results of these simulations were used to derive an improved parameterization for street-scale/street-level dynamics, which was then implemented into our regional meso-scale model (WRF) to better capture urban impacts.

HIGH-FIDELITY SIMULATIONS:
Street resolving simulations

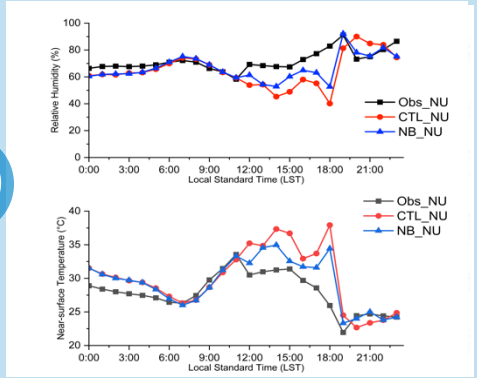


nekRS/OpenFOAM

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



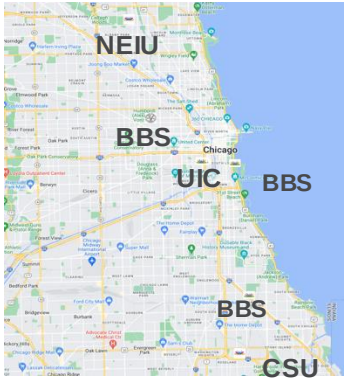
Mesoscale: 2-m Temperature

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

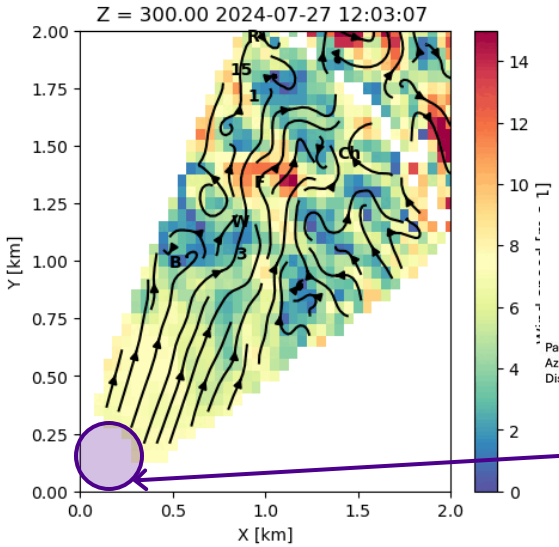
- Guiding instrument placement.
- Interact with Measurement Strategy Team (MST) to decide the measurement locations (ModEx)
- **Inputs from community and research partners was essential**
  - 9 Organizations
  - 2 IOPs (4 days)
  - 42 balloon launches
  - 400+ hand-held measurements

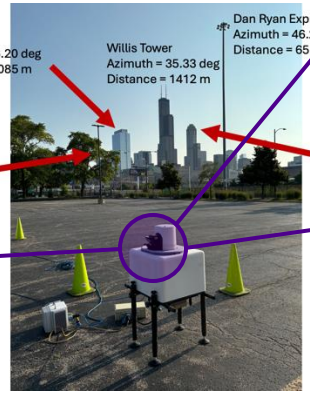
Collis et al 2024 “The Community Research On Climate and Urban Science (CROCUS) Urban Canyons Field Campaign” BAMS *in prep*.

URBAN CANYONS CAMPAIGN: CITY WAKE VORTICITY

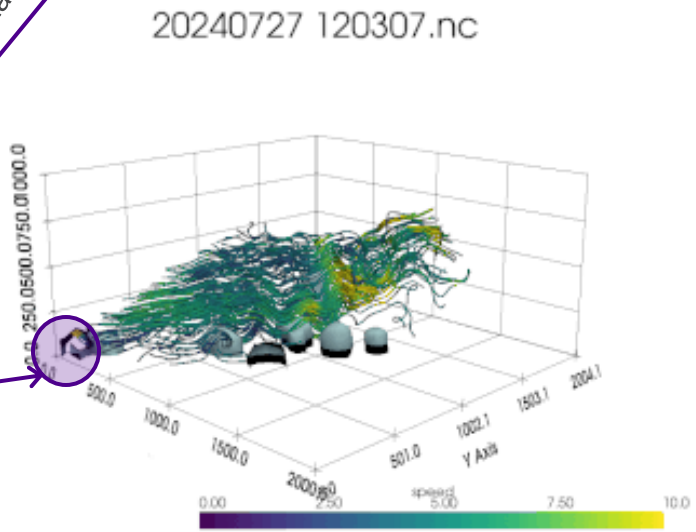
Providing models with unique datasets

OBSERVE





1.6 mi from lake

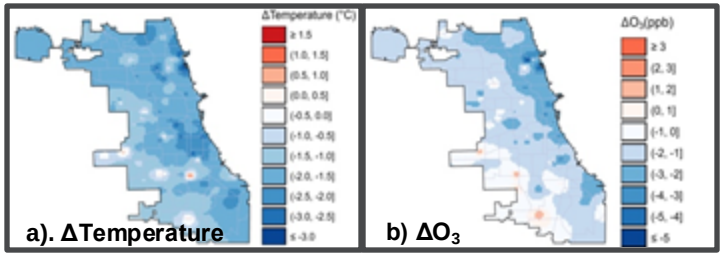


Bobby Jackson, Tim Wagner, Paytsar Muradyan, others?

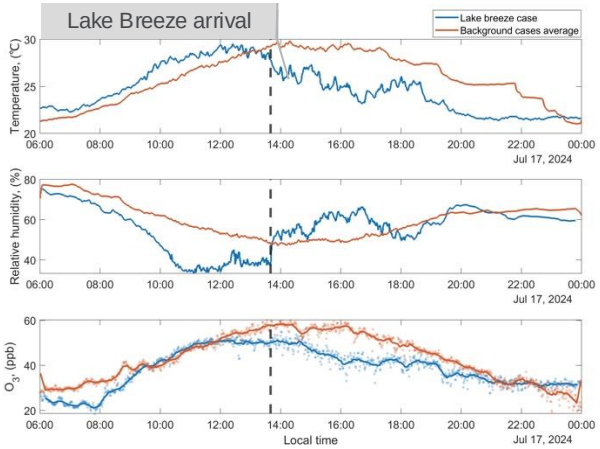
URBAN CANYONS CAMPAIGN: LAKE BREEZE AIR QUALITY EFFECTS

- 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

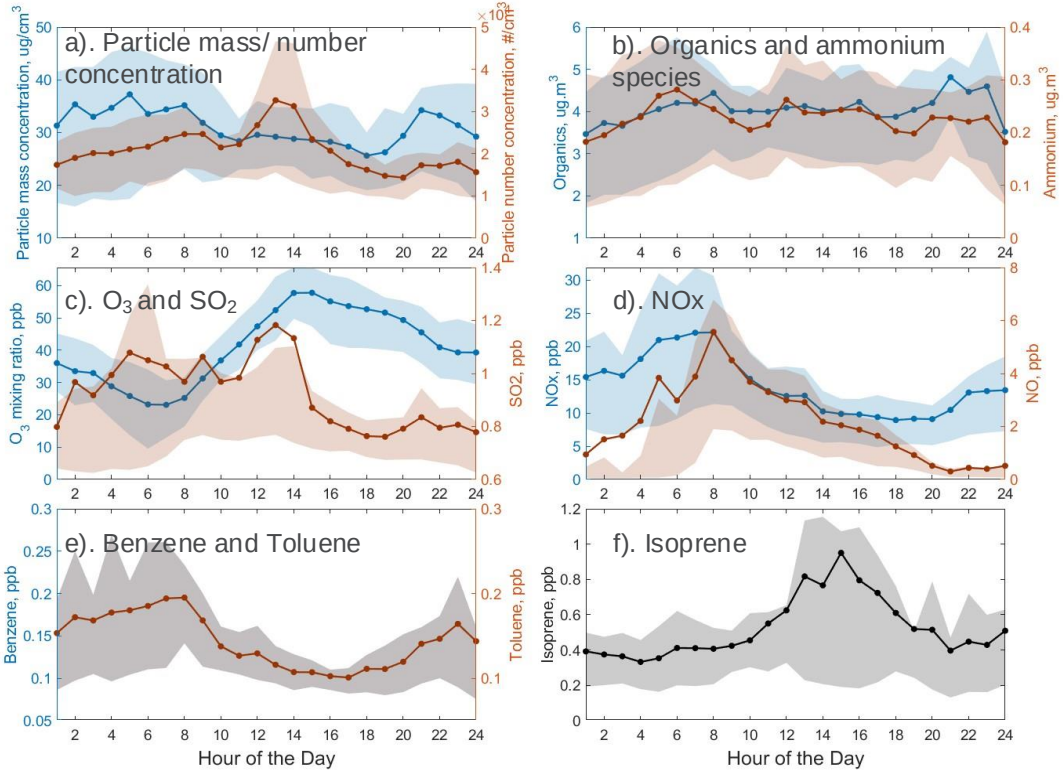
DIURNAL VARIATIONS

NOX
Peaks during morning rush hour, linked to traffic emissions.

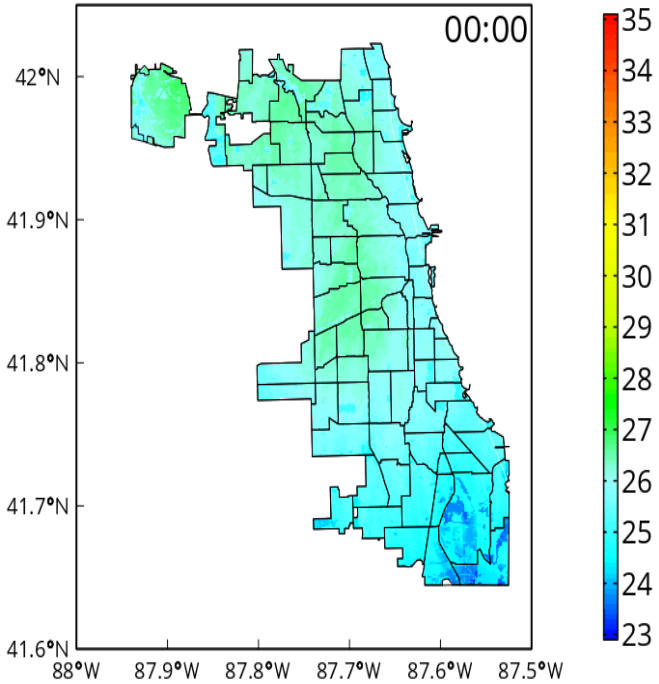
O_3
Peaks at 3 pm (~60 ppb), driven by photochemical reactions.

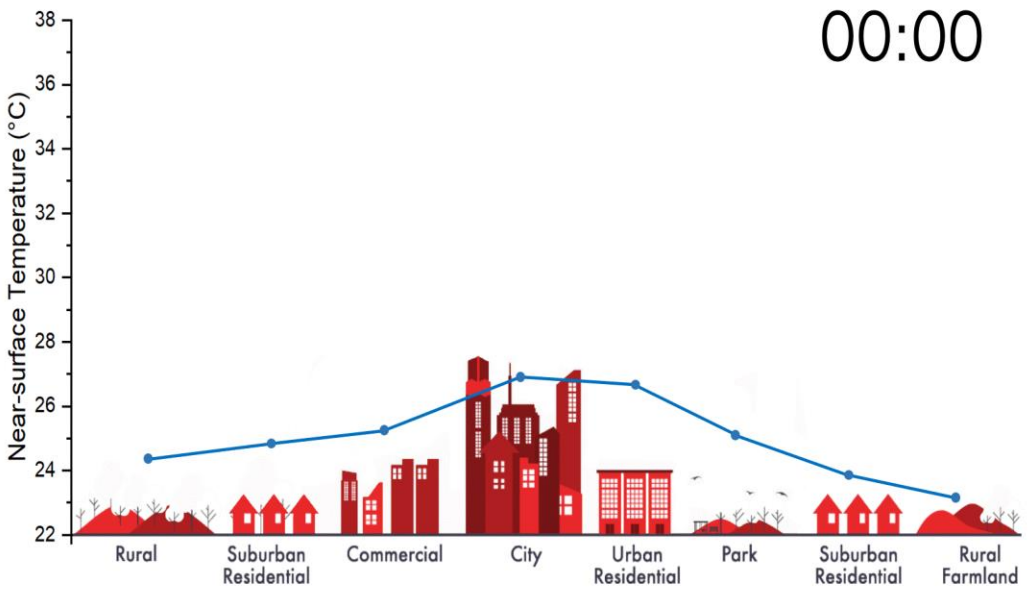
ISOPRENE
Peaks at 3 pm, likely due to enhanced emission from vegetation.

BENZENE & TOLUENE
Higher concentrations at night



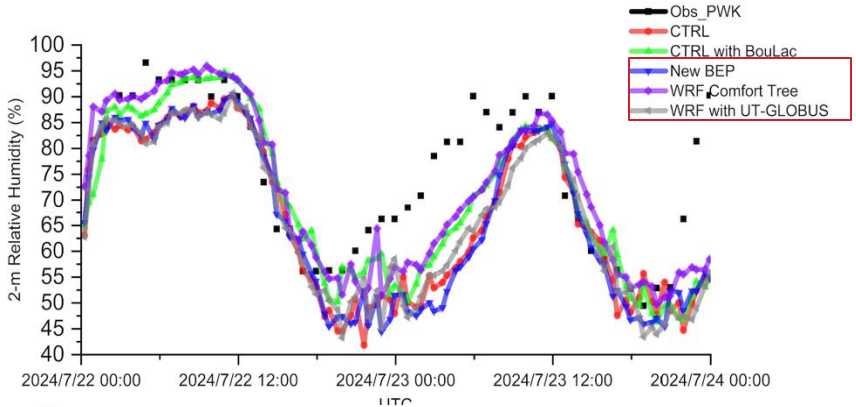
CITY SCALE SIMULATION OF TEMPERATURES

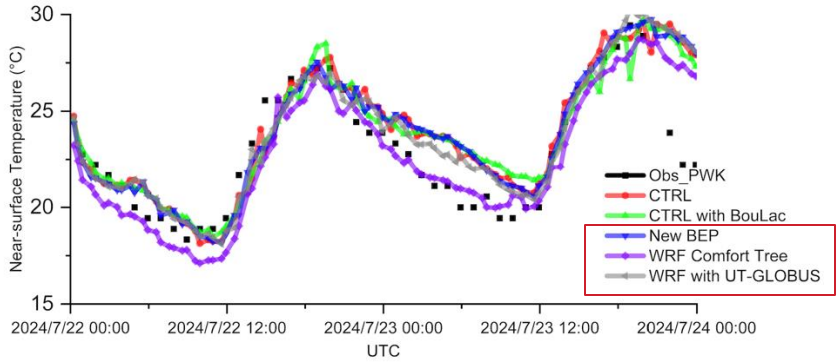




Source: Haochen Tan, Argonne National Laboratory

ADVANCING MODEL CAPABILITY





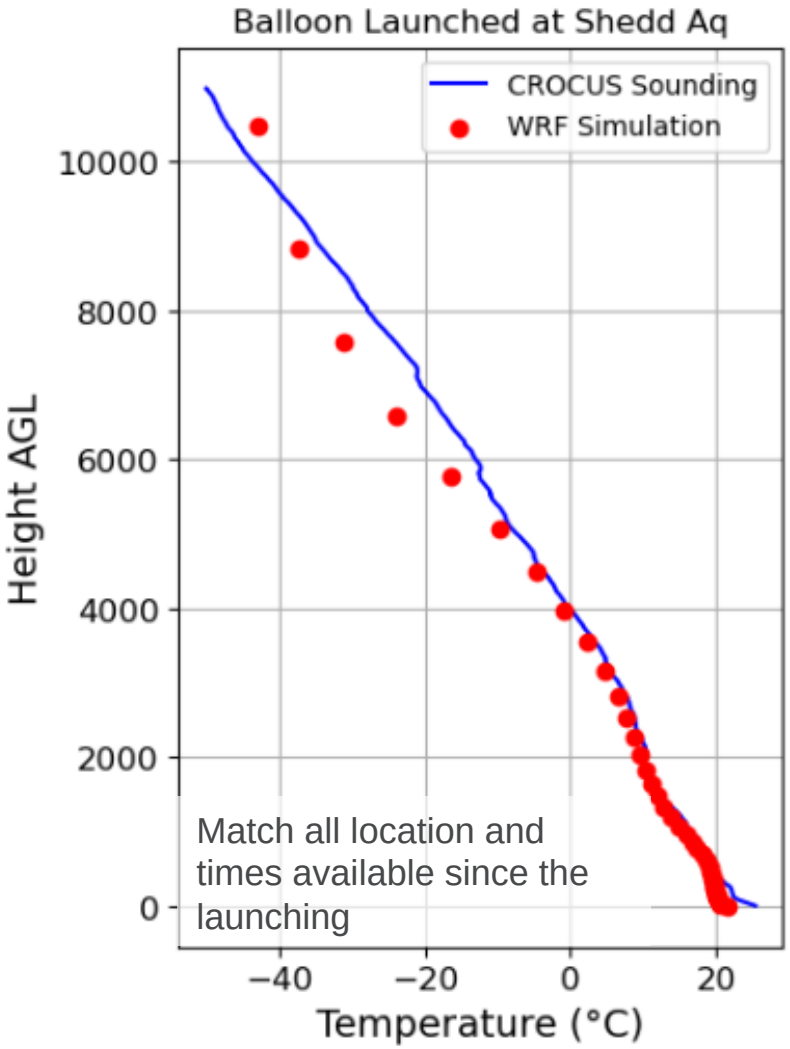
PWK

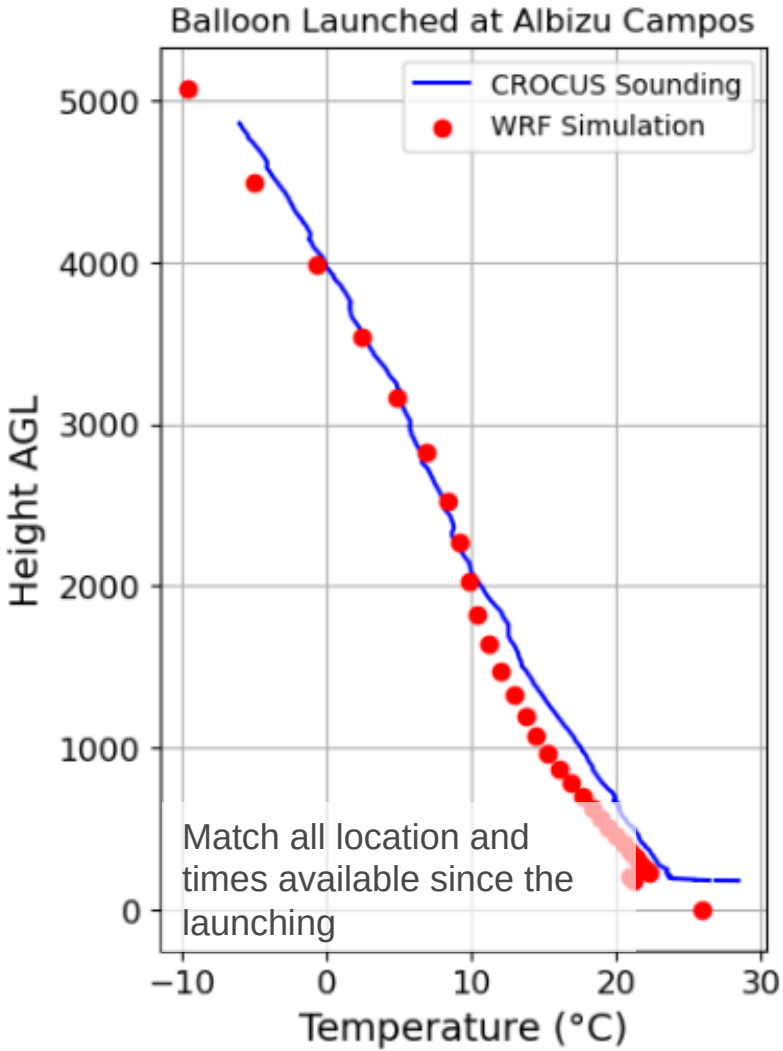
- If the model sees a different land use than reality, the simulation will be different too!
- Spatial resolution matters (the model does a good job in some locations but not others).

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

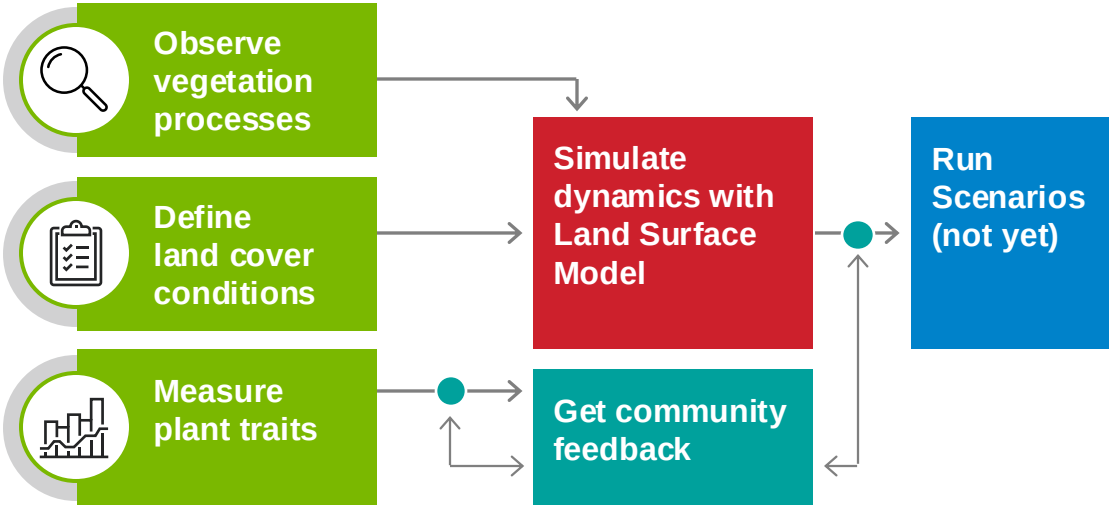
D. K. Fytanidis, H. Tan, A. Martilli, J. Wang, R. Kotamarti, 2024. ***An Improved BEP-BEM-based Urban Canopy Parameterization Scheme: Model Development from High-Fidelity Simulations and Applications***, in preparation.


Balloon Launched at Shedd Aq
CROCUS Sounding
WRF Simulation
Height AGL
10000
8000
6000
4000
2000
0
−40
−20
0
20
Temperature (°C)
Match all location and times available since the launching


Balloon Launched at Albizu Campos
CROCUS Sounding
WRF Simulation
Height AGL
5000
4000
3000
2000
1000
0
−10
0
10
20
30
Temperature (°C)
Match all location and times available since the launching

NATURE BASED SOLUTIONS

Understanding the function of green spaces in Chicago



SQ6
How do microclimate (e.g., heat and precipitation patterns), soil legacy, and species assemblage produce emergent ecosystem properties in urban systems?

SQ7
How do feedbacks between plant water demand, groundwater, and hydraulic systems influence local scale flood risks?

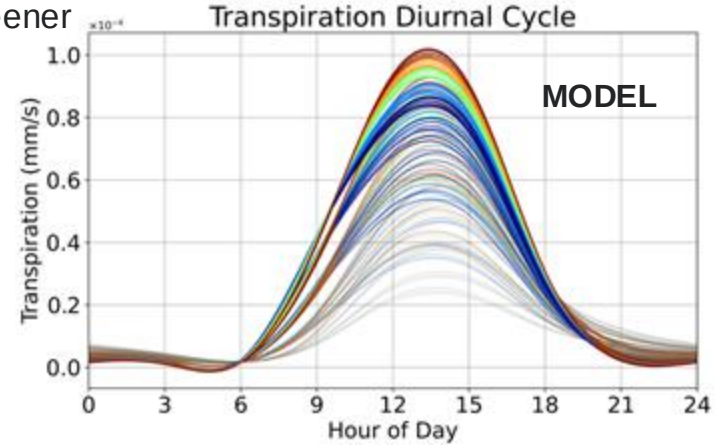
SQ8
What determines the spatial- and temporal-scale dependence between green coverage and reductions in heat and flood risks?

SQ9
How do NBS and other interventions address local UHI, flooding, and other community concerns and how can interventions achieve the most beneficial tradeoffs for diverse communities?

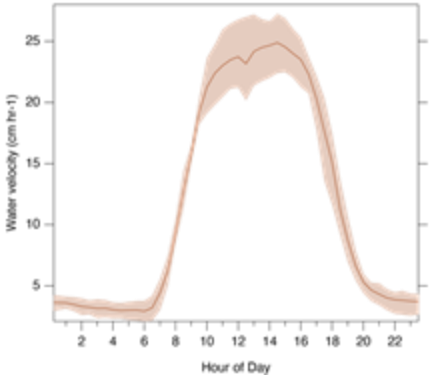
SIMULATING THE SERVICES AND EFFECTS OF TREES

requires traits that are correctly defined in models

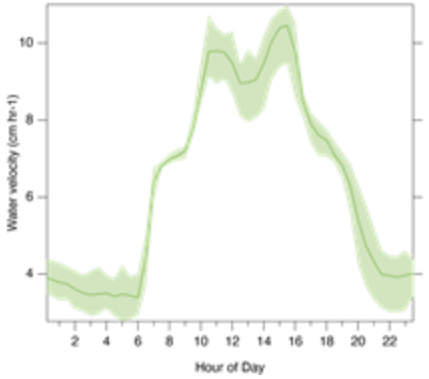
Greener



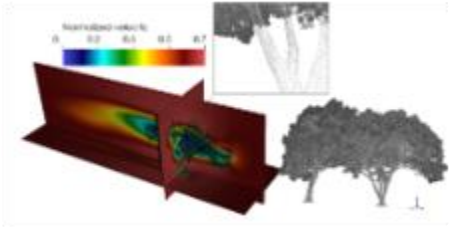
OBSERVED MAPLE



OBSERVED OAK



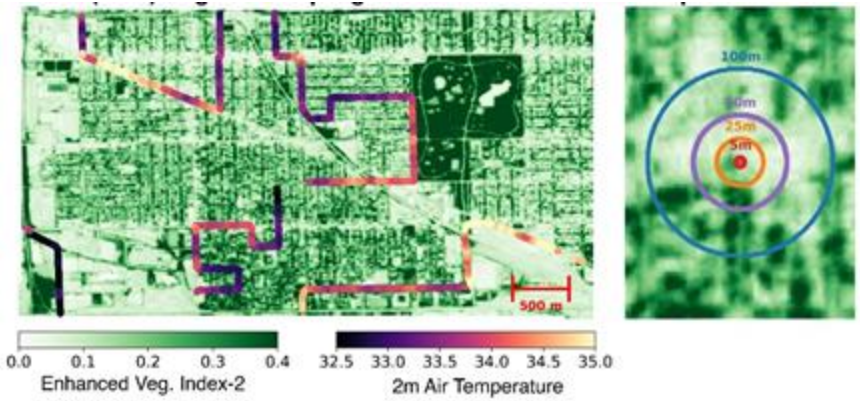
An example of simulated water use by trees in Chicago based on 125 different simulations with unique land covers. Red lines mean more trees and blue mean more grass. Transparency of the line represents higher urban percentage in the gridcell.



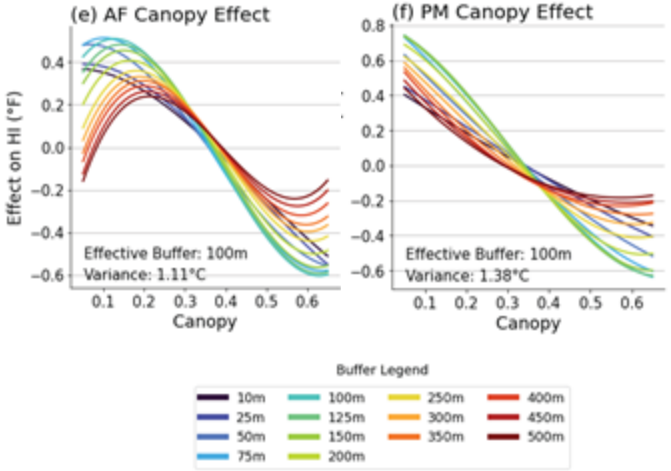
CUMULATIVE SERVICES FROM THE CANOPY

reflect the diverse behavior of trees, soils and land cover

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

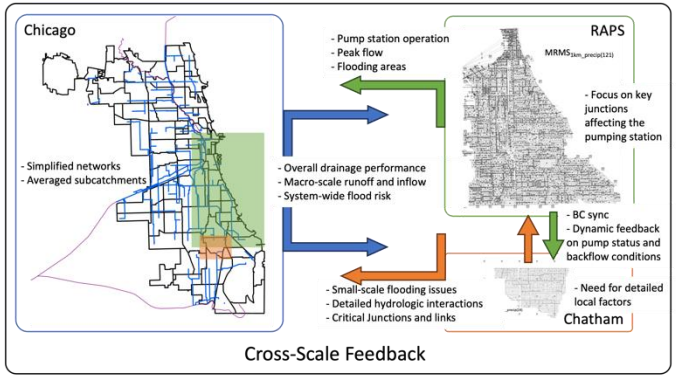


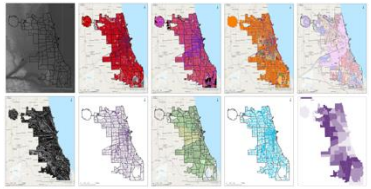
Observed change Heat Index in afternoon (left) and evening (right) depending on local canopy cover



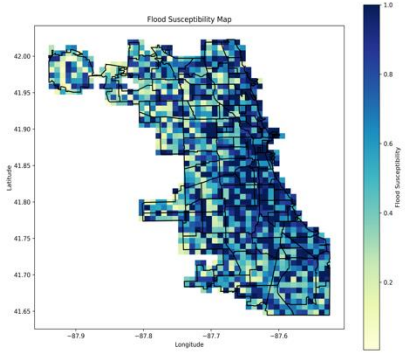
Lee and Berkelhammer (2024) Observational constraints on the spatial effect of greenness and canopy cover on urban heat in a major midlatitude city. Geophysical Research Letters, in press.

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

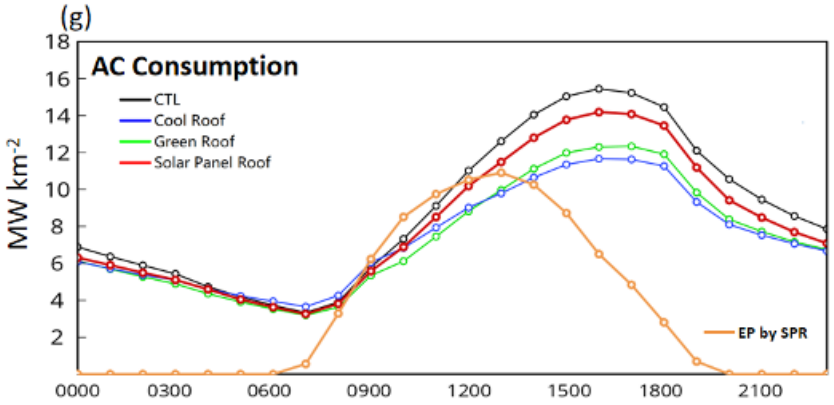
- High impervious areas (downtown Chicago) are more flood-prone due to limited infiltration and overwhelmed sewers.
- Low-lying areas with poor drainage have higher flood risk during heavy rainfall.
- The map highlights areas needing infrastructure upgrades, like better drainage or more green space to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

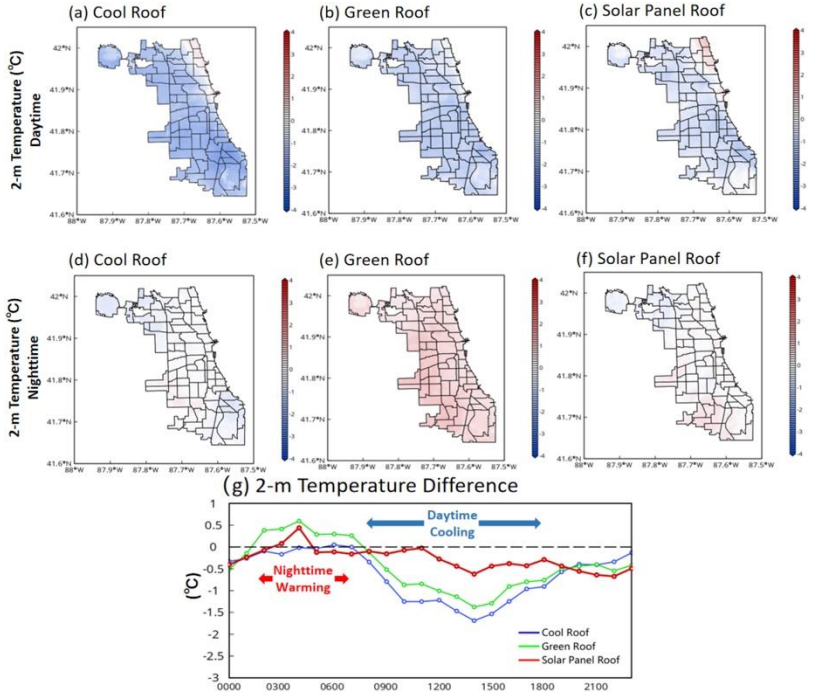
Park, S., D. Hence, S. Nesbitt, and M. Garcia, 2024: Composite Flood Susceptibility Mapping for Chicago: Integrating Atmospheric and Hydrologic Uncertainties. Urban Climate, in preparation.

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**

CITY COLLEGES OF CHICAGO

CHICAGO STATE UNIVERSITY

Argonne NATIONAL LABORATORY

UIC UNIVERSITY OF ILLINOIS CHICAGO

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

CROCUS
Community Research on Climate & Urban Science

COMMUNITY ENGAGED RESEARCH AND MENTORING WORKSHOP REPORT

Akilah Easter, Olive Harvey College
Daniel R Block, Chicago State University
Miquel A Gonzalez-Meler, University of Illinois Chicago

Workshop: Inclusive Mentoring

- Maintaining Effective Communication
- Aligning Expectations
- Assessing Understanding
- Reflecting on Diversity and Addressing Inclusion
- Fostering Independence
- Promoting Professional Development
- Adopting Work-Life Integration

TEN SIMPLE* RULES FOR BUILDING AN ANTI-RACIST LAB

V. Bala Chaudhary (@BalaChaudhary) and Asmeret Asefaw Berhe (@aaberhe)

FULL TEXT HERE: https://ecoevorxiv.org/4a9p8/

Rule 1: Lead informed discussions about anti-racism in your lab regularly.

Rule 2. Address racism in your lab and field safety guidelines.

Rule 3: Publish papers and write grants with BIPOC colleagues.

Rule 4: Evaluate your lab's mentoring practices.

Rule 5: Amplify voices of BIPOC scientists in your field.

Rule 6: Support POC in their efforts to organize.

Rule 7: Intentionally recruit BIPOC students and staff.

Rule 8: Adopt a dynamic research agenda.

Created by Phạm Thanh Lộc from Noun Project

Rule 9: Advocate for racially diverse leadership in science.

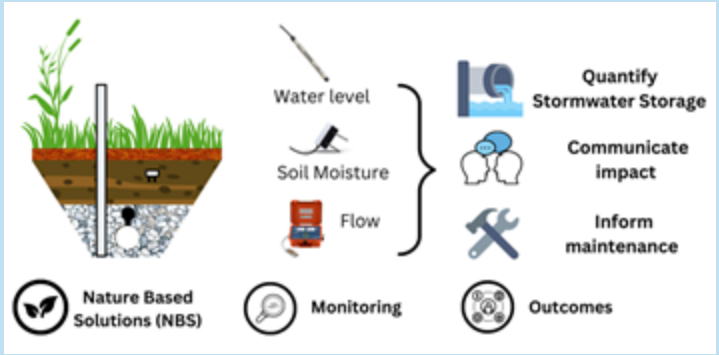
Rule 10: Hold the powerful accountable and don't expect gratitude.

*the authors adhered to this format recognizing that 10 rules is far from exhaustive and that fostering an anti-racist lab won't always be simple.

Chaudhary, Bala, and Asmeret A. Berhe. 2020. Ten Simple Rules for Building an Anti-racist Lab. EcoEvoRxiv. June 18. doi:10.32942/osf.io/4a9p8.

COMMUNITY NBS EVALUATION AND SCIENCE PLANNING

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

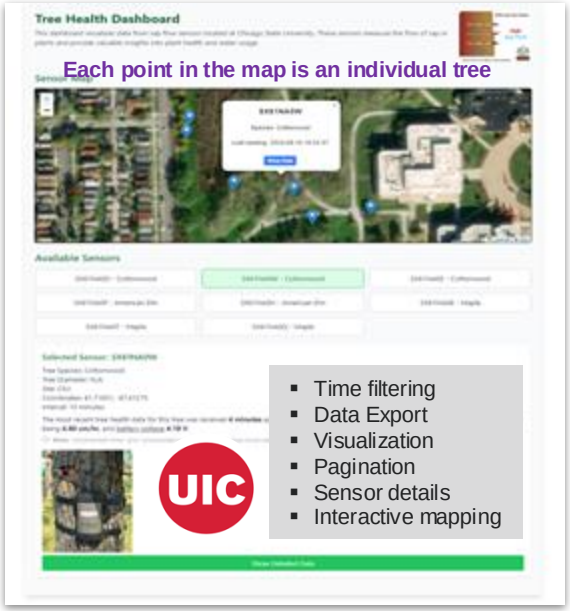


https://ess.science.energy.gov/urban-ifls/highlight/strategies-for-measuring-urban-green-spaces-impact-on-stormwater-management/

Woodlawn site visit & instrumentation plan

EDUCATION AND WORKFORCE DEVELOPMENT

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



CHICAGO STATE UNIVERSITY

CHICAGO STATE UNIVERSITY

Renaming and reshaping the Program: Environmental Studies Concentration

CITY COLLEGES OF CHICAGO

Olive-Harvey College

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

Northeastern ILLINOIS UNIVERSITY

NORTHEASTERN ILLINOIS UNIVERSITY

Data science course using CROCUS observational data

UIC UNIVERSITY OF ILLINOIS CHICAGO

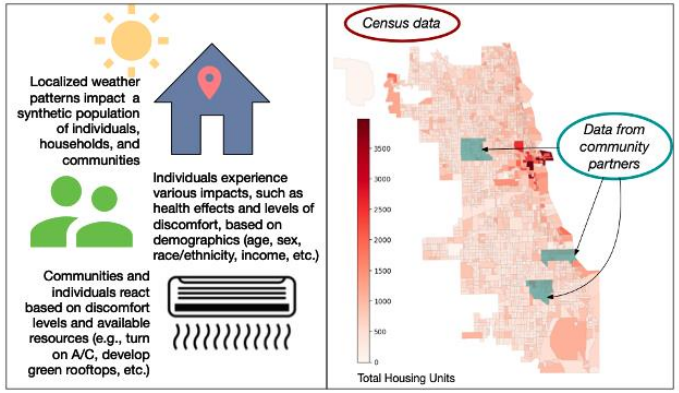
UNIVERSITY OF ILLINOIS AT CHICAGO

The UIC Data Dashboards CROCUS-Focused Curriculum

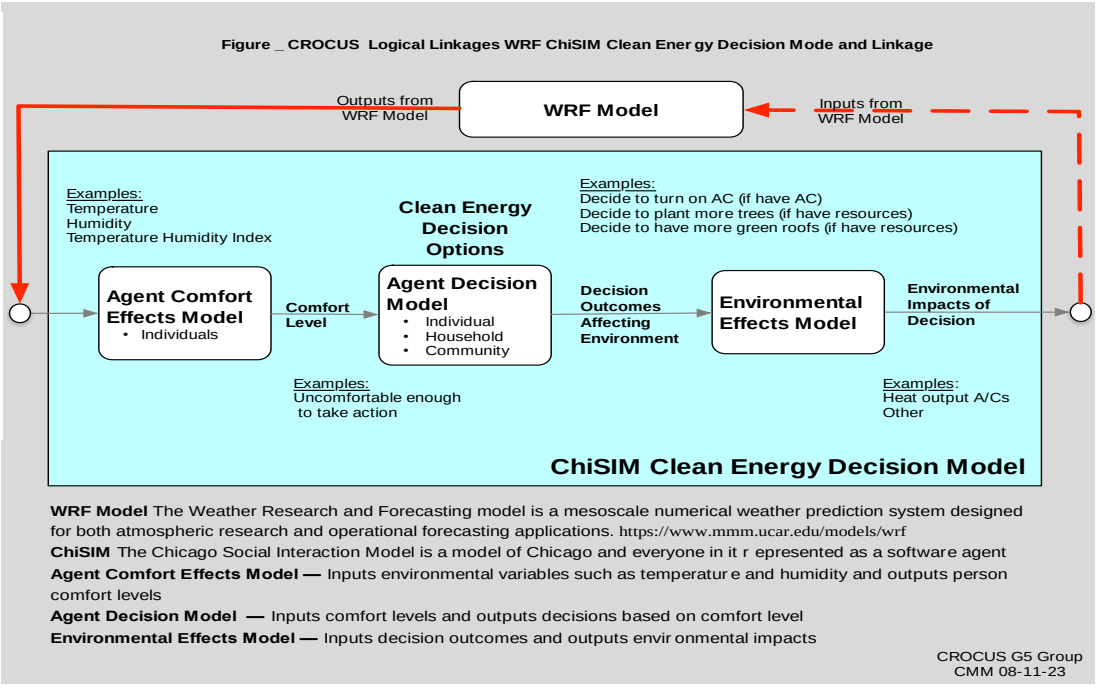
StormAlytics

MODELING THE IMPACT OF DECISIONS

Linking physical models and decision inputs with Decision Model



- Incorporate equity and inclusion
- Support decisions towards capital expenditures



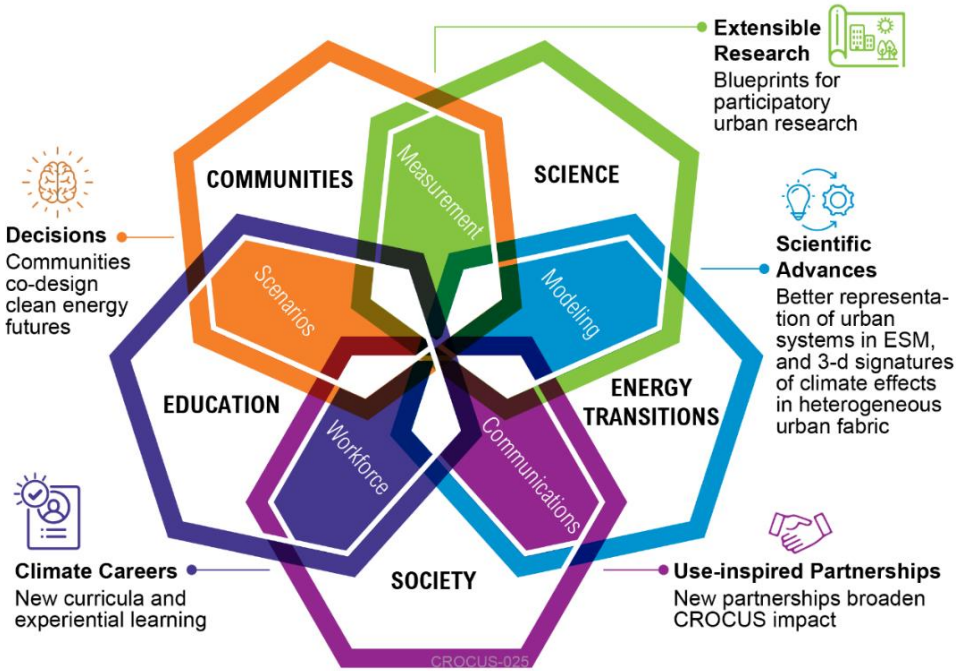
NEXT STEPS FOR IMPACT

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

NEXT CAMPAIGN: FOCUS ON HYDROLOGY & BIOGEOCHEMISTRY

~April 1st to May 15th 2025

- Community named the campaign
- Model results to guide the field campaign
- We will set up a sounding array again and heavily instrument (including ADM + SPARC, Radar system) the area around Chatham – where flooding concerns are the highest.
- Students, citizens, documenting plant status, flooding depth, soil moisture.
- Most comprehensive urban hydrology and plant response experiment.

CROCUS

Community Research on Climate & Urban Science

www.crocus-urban

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research's Urban Integrated Field Laboratories research activity under contract number DE-AC02- 06CH11357