Town+Gown's **Water In and Water Out—Innovative Water Research (IWR)**

February 16, 2024

CHICAGO'S URBAN INTEGRATED FIELD LABORATORY

AN UPDATE

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CROCUS
Community Research on Climate & Urban Science

US Department of Energy Office of Science's vision for urban integrated field laboratories

SCIENCE GOALS

Understand the natural and human drivers and effects of environmental change in an urban area

SOCIETAL BENEFITS

Sustainable, resilient, and equitable solutions, with special attention to underserved communities

LOCATIONS

Austin – U of Texas at Austin
Baltimore – Johns Hopkins U
Chicago – Argonne
SW Corridor – AZ State U

CHICAGO’S URBAN INTEGRATED FIELD LABORATORY

SCIENCE GOALS

Understand the natural and human drivers and effects of environmental change in an urban area

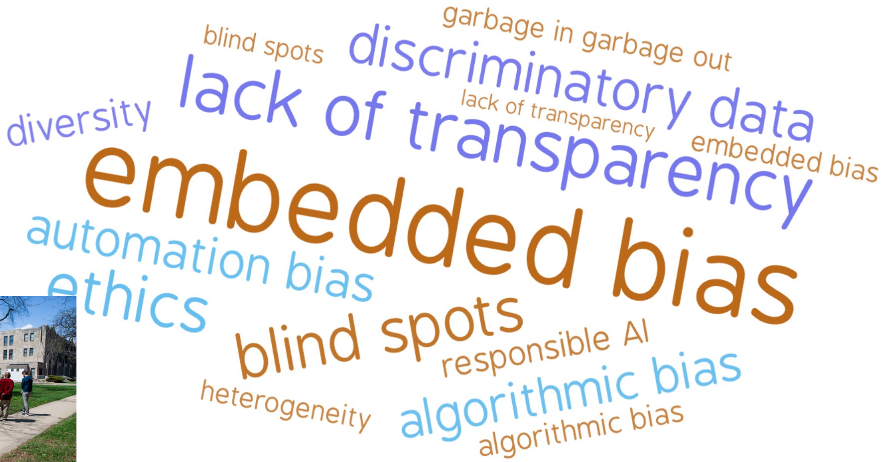
URBAN DIGITAL TWIN FOR CLIMATE SERVICES

Scientifically advanced tools for decision making and stakeholder capacity building

SOCIETAL BENEFITS

Sustainable, resilient, and equitable solutions, with special attention to underserved communities

PRODUCE FAIR, EQUITABLE AND INCLUSIVE SCIENCE



Fair, equitable and inclusive science begins with data that represent all ways of life in the studied environment, and models that account for inclusive baselines, and scenario settings, community vision and interests that are co-designed with all stakeholders

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1- MERGE SCIENTIFIC AND COMMUNITY VISION

Develop science that is not extractive but provides useful information to inform action

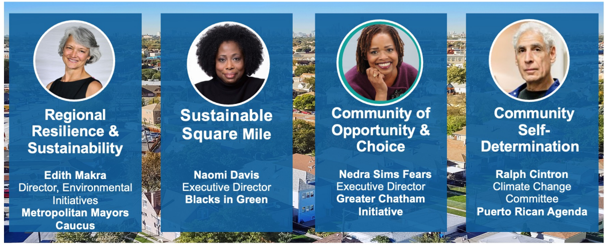
Maintain a scientific discourse that is understandable to non-scientists and across scientific disciplines

Seek community participation to help shape science questions, define/perform the ‘experiment’ to test hypotheses, locate observation sites

Foster ongoing, respectful and in good faith discourse.

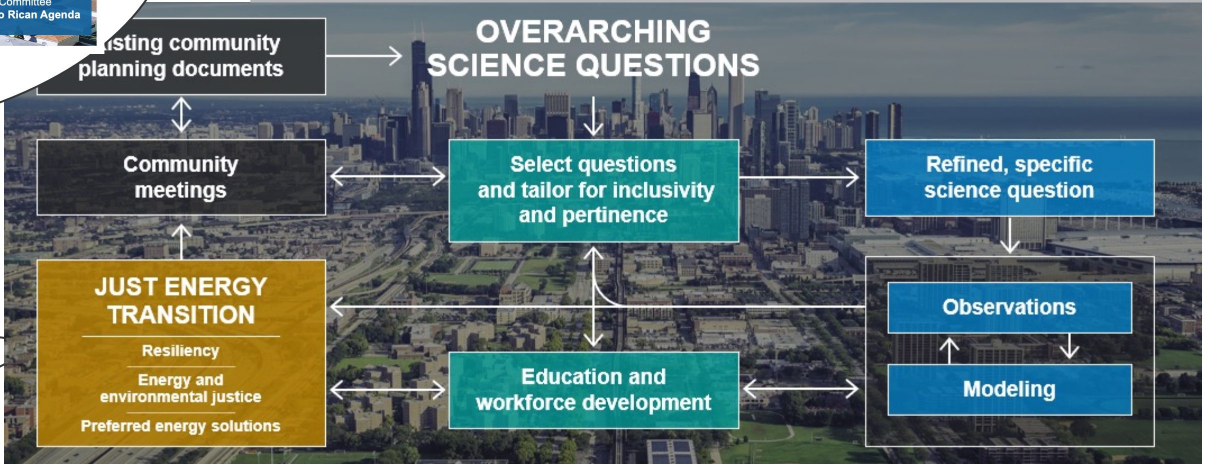
COMMUNITY VISION

Climate Science Through the Lens of Community



COMMUNITY-DRIVEN SOLUTIONS
TO BENEFIT LOCAL AND LARGER URBAN ECOSYSTEMS

Putting a mix of technological, engineered, and ecological urban solutions to the test



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MOTIVATION AND CONTEXT

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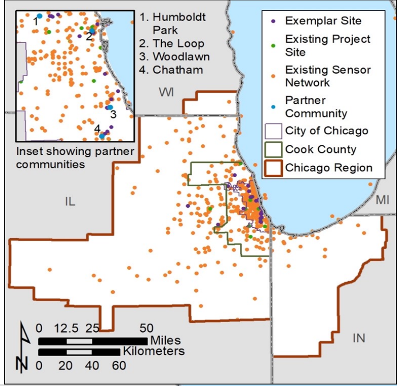
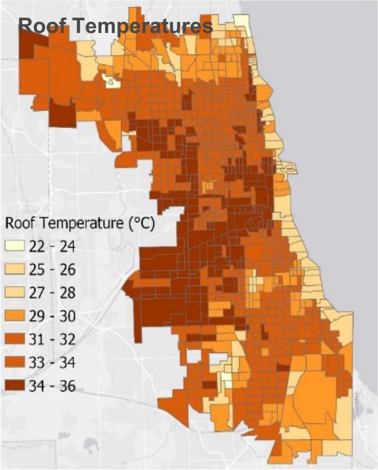
Urban climate science needs an integrated approach to evaluate physical and social drivers and community impacts of climate change

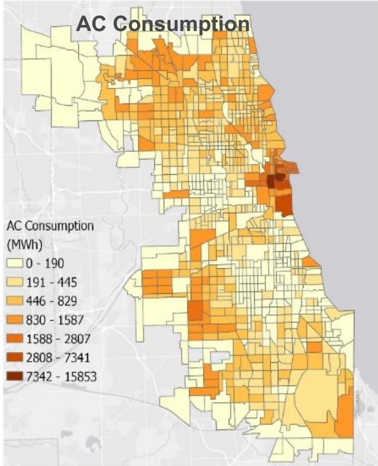
Chicago is 8th in income inequality among the Nation's largest cities.

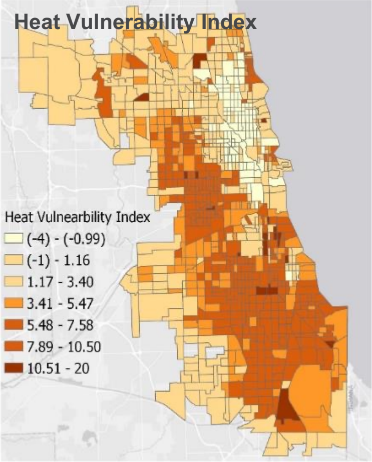
Today's inequalities in the region have old roots. These have pushed underrepresented communities into the most physically challenging areas with lower quality infrastructure.



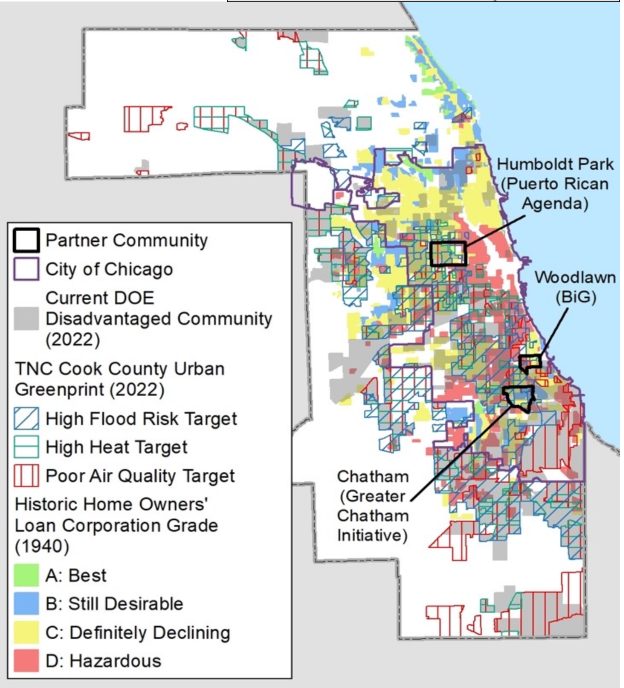
Flooding Heat Housing Marginalization Health Stress Food security Extremes Tornadoes Gentrification Jobs Green spaces Deterioration Variability





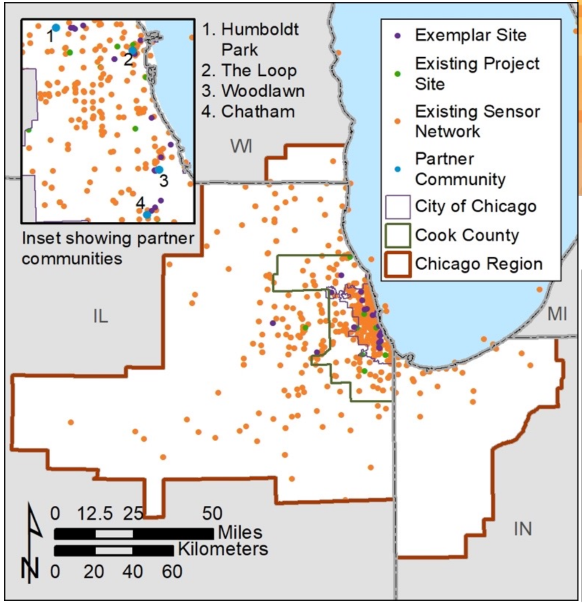


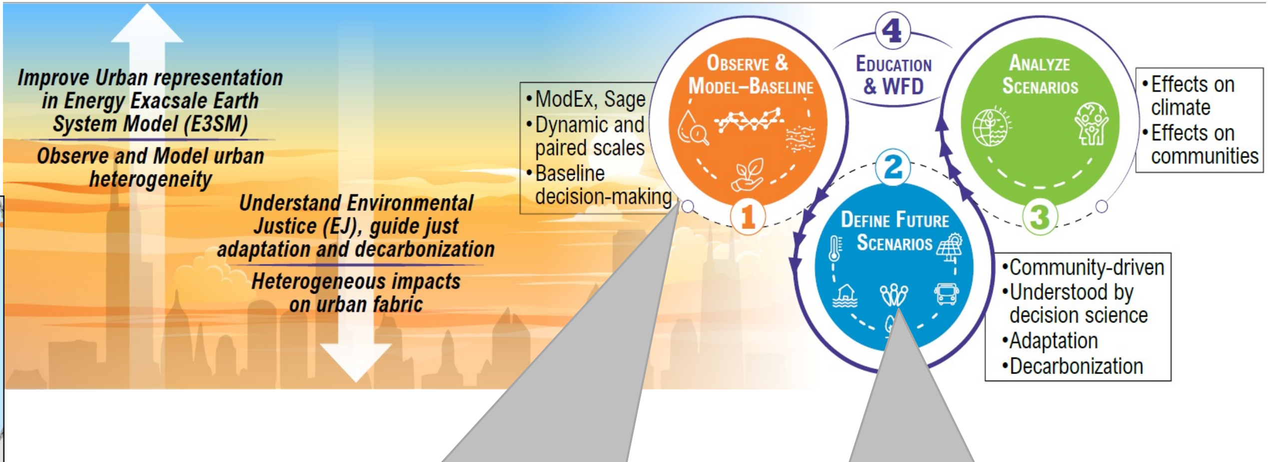
Sharma *et al.* (2018) *Env. Res. Lett.*

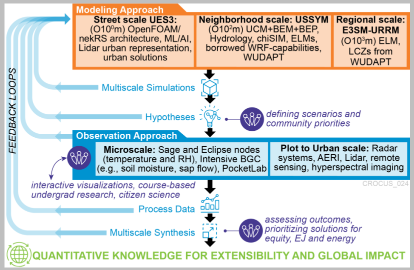


SENSING AND MODELING INTEGRATED

The Chicago region provides an excellent test bed to understand urban to regional climate processes and how to implement solutions that are equitable to communities.







JUST ENERGY TRANSITION

Putting a mix of technological, engineered, and ecological urban solutions to the test

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Addressing scales in modeling and observations

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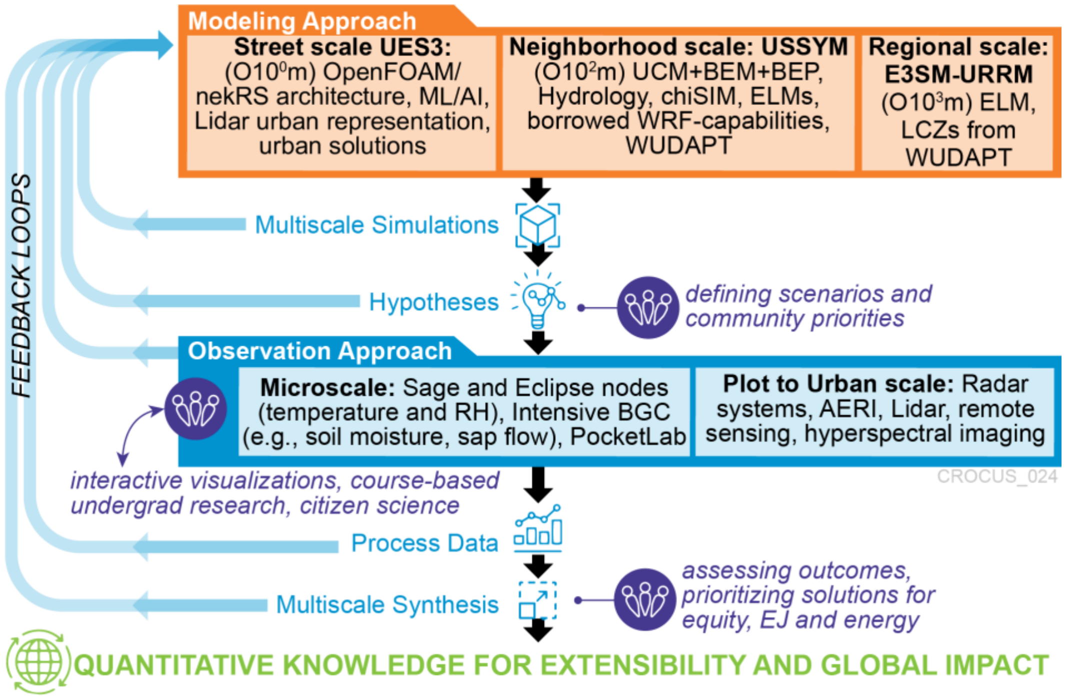

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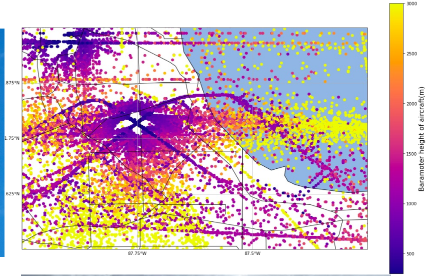

OBSERVATIONS GENERATE THE RELEVANT DATA AT THE RIGHT SCALE

Four observational components:

- **CROCUS Micronet,**
- **Field campaigns,**
- **Public data**
- **Community science.**

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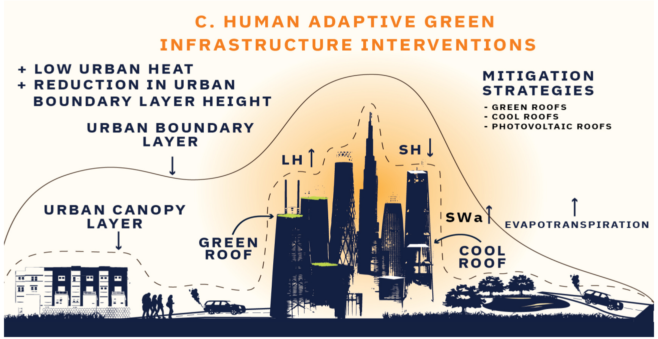
COMMUNITY-DRIVEN SOLUTIONS
TO BENEFIT LOCAL AND LARGER URBAN ECOSYSTEMS



Green rooftops

Photovoltaic rooftops

Nature based solutions

Permeable pavements

Cool rooftops

Electric transport

Putting a mix of technological, engineered, and ecological urban solutions to the test

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CROCUS is on track to deliver a blueprint that can be applied to other urban areas

Greater Chatham Initiative's Flood Fair

Systems-based approach for integrating physical, biological, and human dimensions of climate change

Framework to simulate, evaluate, and project impacts and feedbacks between climate and urban systems

Integrated approach to localizing observation and modeling

Advanced tools for making decisions and building stakeholder capacity

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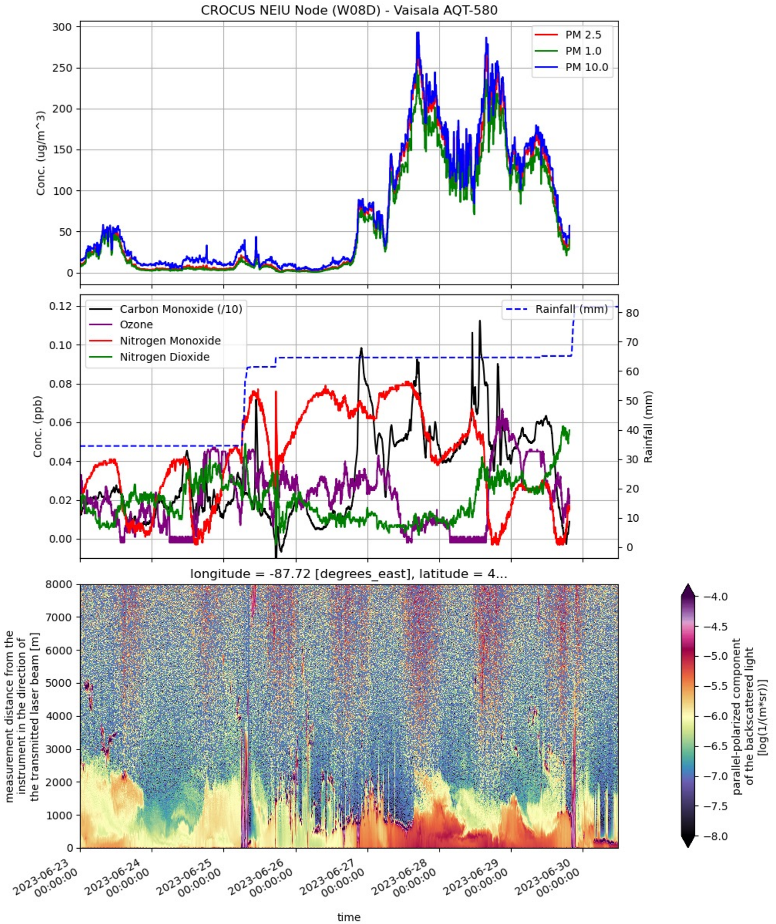
What can CROCUS sensors see?



Data collected June 23-30 at Northeastern Illinois U, showing Canadian wildfire smoke in Chicago's air

PARTICULATE MATTER
Top: Concentration at the node, micrograms per cubic meter – levels >35 are unhealthy

GASSES
Middle: Concentration at the node, parts per billion – carbon monoxide levels indicate wildfire smoke

SMOKE LOCATION
Bottom: Smoke density in the area surrounding the node, from ground level to 8,000 meters altitude

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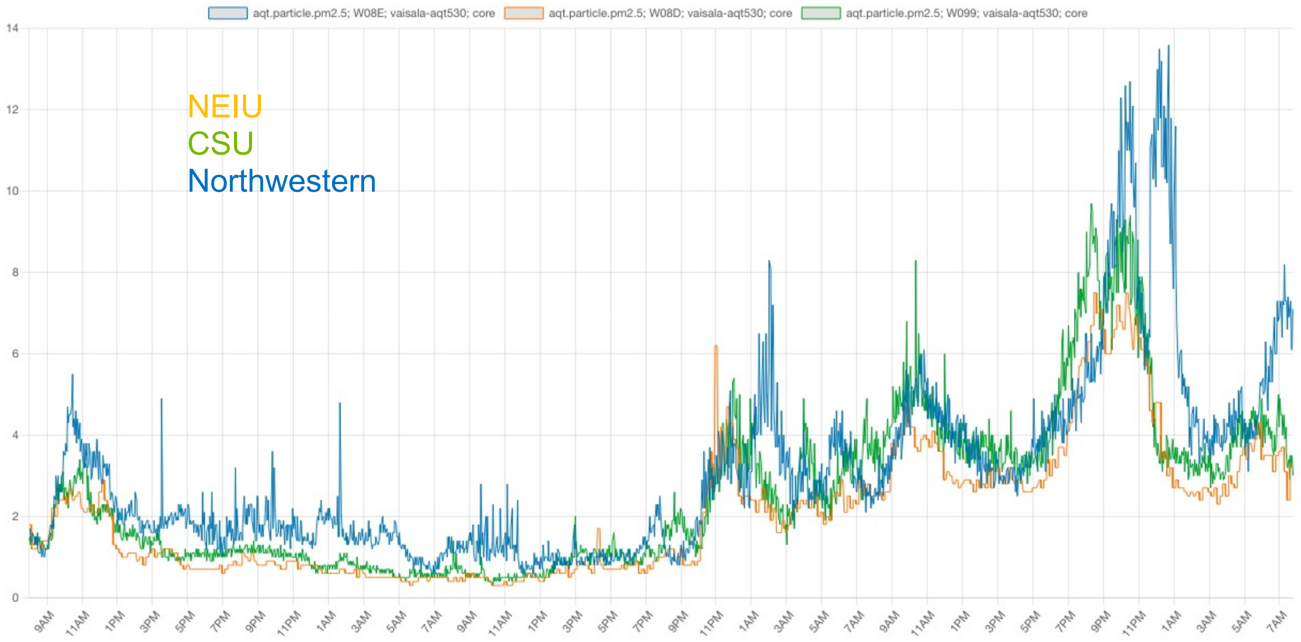
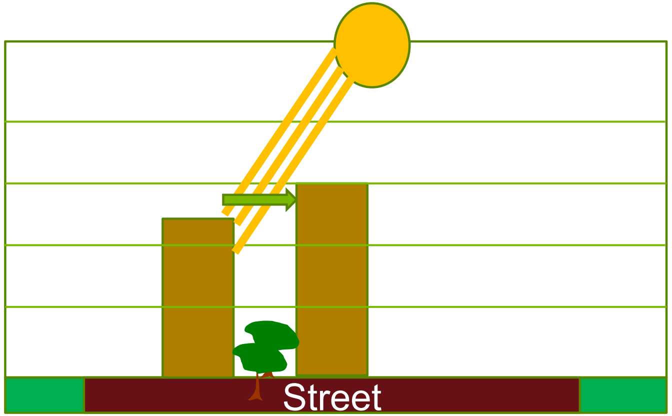
MEASUREMENT STRATEGY UPDATES

- Successful deployments to CSU and Northwestern. Data is flowing and available using engineering interface.
- Planning started for first field campaign.



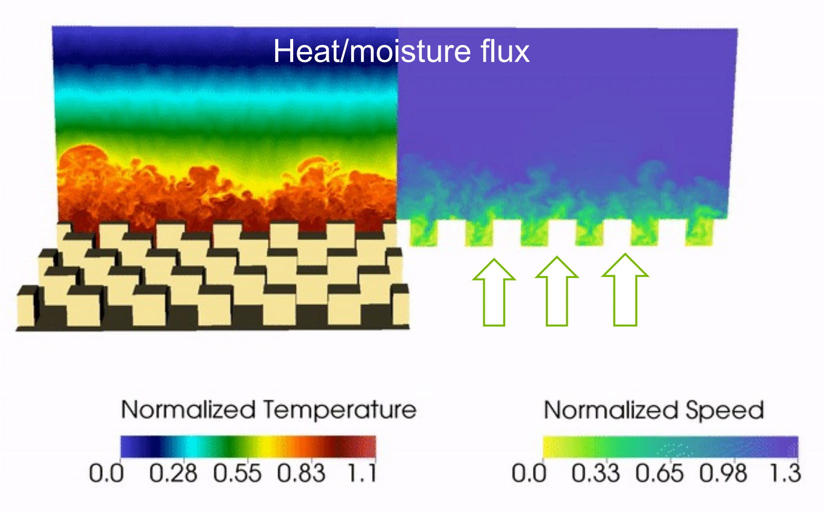
Particulate matter from Chicago State, NEIU and Northwestern. Showing advection across the city. Source: Collis et al, Argonne National Laboratory.

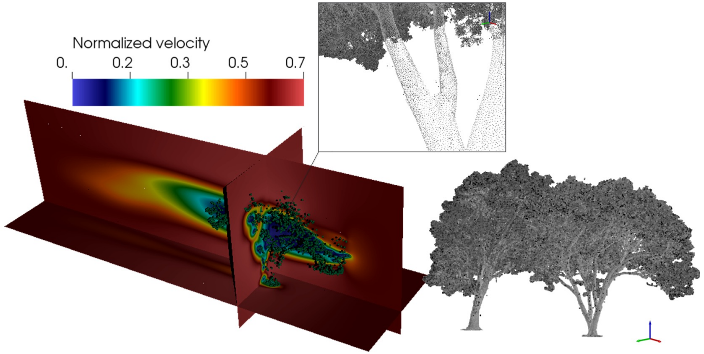
STREET-SCALE MODELING



Source: Martilli, CIEMAT

Micro-scale modeling to enhance the Building Effect Parameterization (BEP) schemes currently used in mesoscale models like WRF

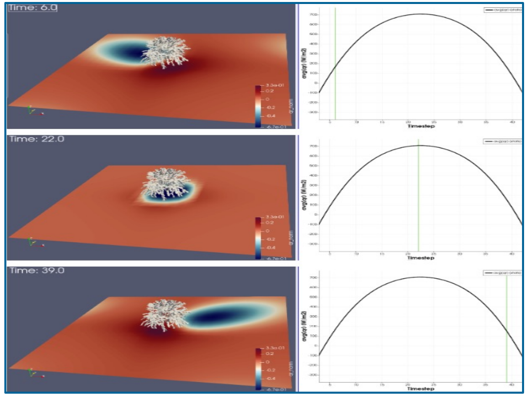


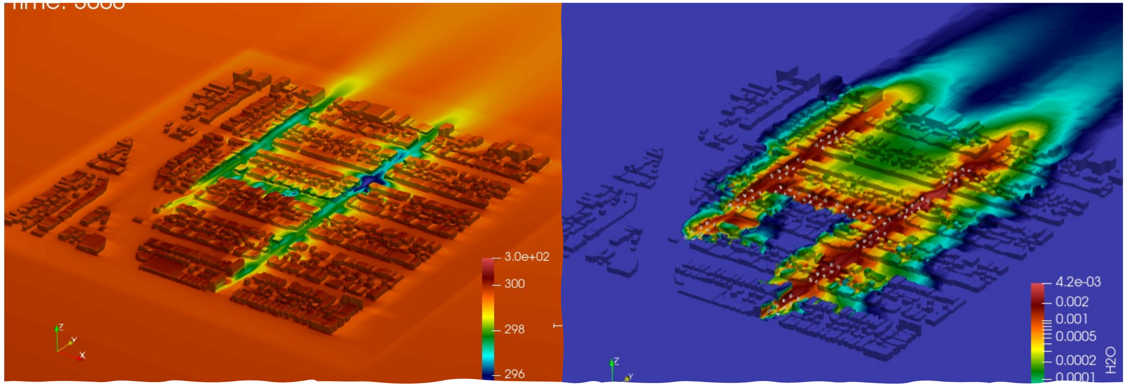


Source: D. Fytanidis, Argonne

MODELING VEGETATION IN URBAN STREETS

A: estimation of surface radiative flux under solar radiation accounting for canopy shading. The right pane is the time evolution of the radiative flux averaged over the model domain including the tree, green line marks the time corresponding to the shading shown on the left. **B** and **C**: a simulation over the Humbolt park with southerly wind using a RANS model developed from OpenFOAM. Trees are included for test in the three streets (two N-S and one E-W). Simulation results after 1 hour simulation time, 3D view of the temperature (**B**) and water vapor (**C**) mixing ratio distribution at the surface (Wang and Fernando, manuscript in prep).

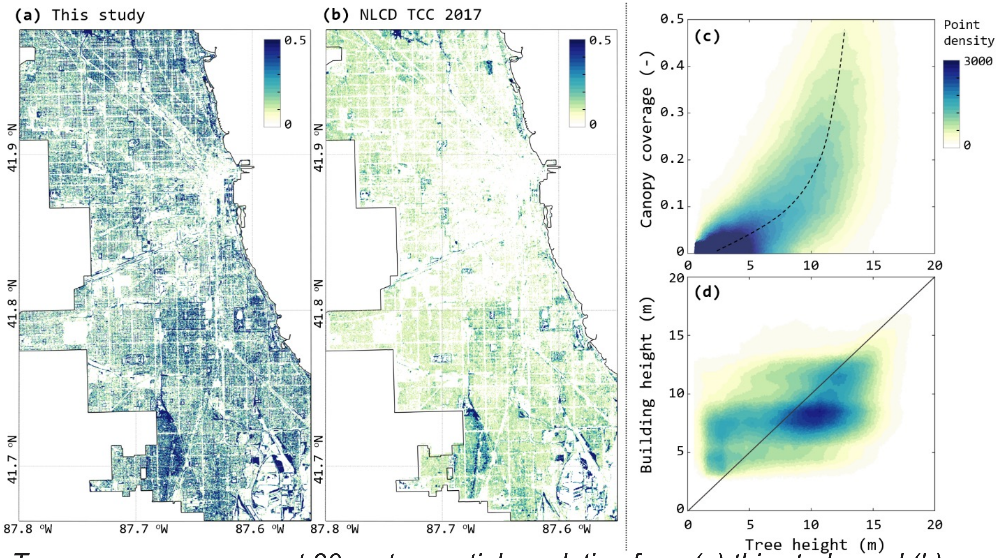




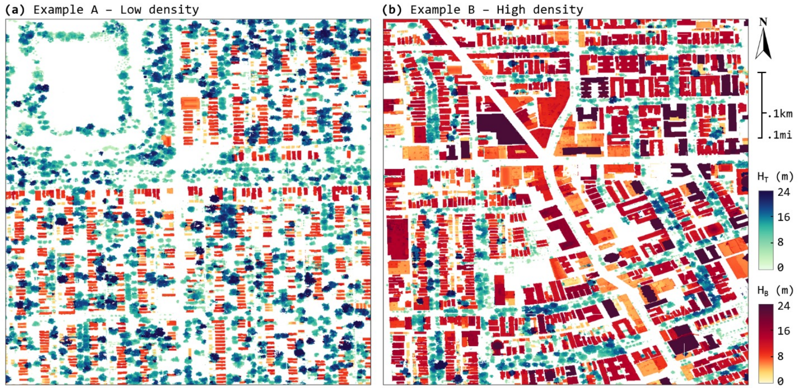
Source: Sen and Fernando, University of Notre Dame

MODELING PROGRESS

HiTAB-Chicago: HeIght map of Trees And Buildings for the city of Chicago



Tree canopy coverage at 30-meter spatial resolution from (a) this study; and (b) NLCD 2017. Relationships between tree height and (c) tree canopy coverage; and (d) building height at the same street block. The dashed line indicates the superliner trend between the averaged tree height and canopy coverage. The solid line shows the 1:1 ratio.



Height maps over two exemplary street blocks with (a) low development intensity (41.7952oN, 87.6562oW), and (b) high development intensity (41.9329oN, 87.6449oW).

Open source data available at:
https://doi.org/10.5281/zenodo.10463648

Li and Sharma (in review; ERL)

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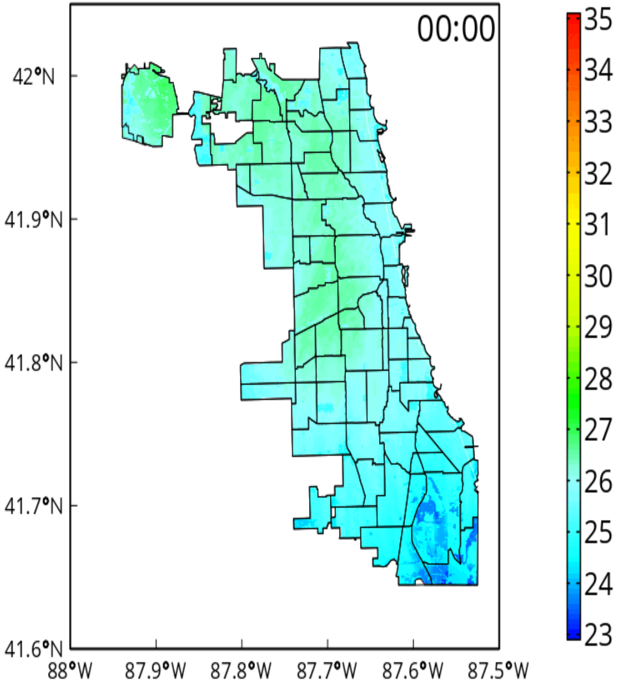
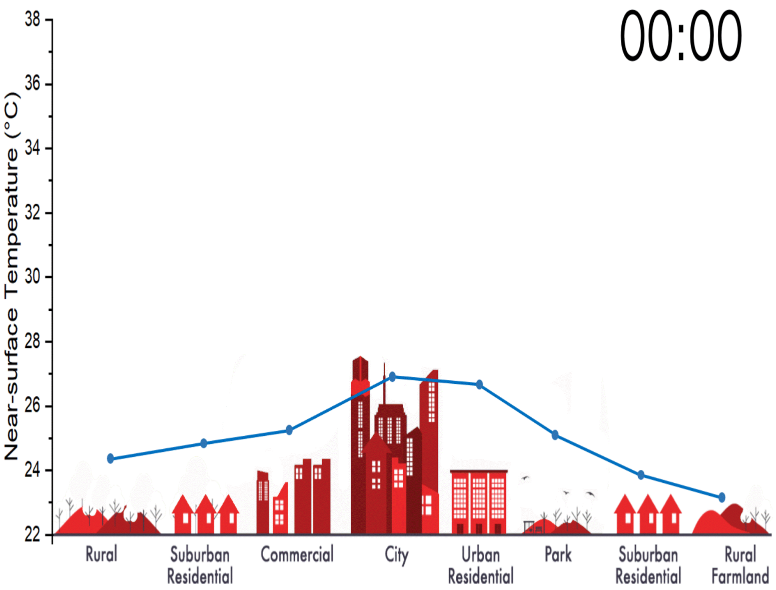
CITY SCALE SIMULATION OF TEMPERATURES





Source: Haochen Tan, Argonne National Laboratory

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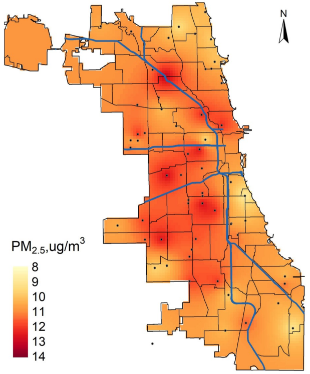
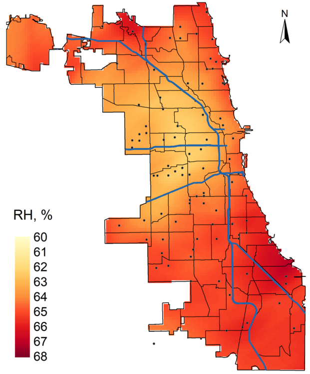
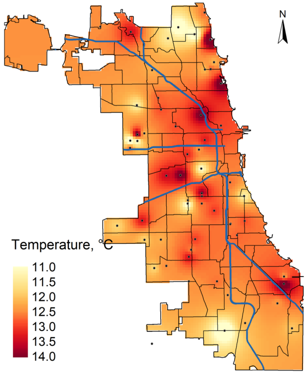
LEVERAGING EXISTING DATA AND ADDING TO IT







Spatial distribution of annual average for $PM_{2.5}$, RH and temperature during 2021/07-2022/02, Spatial resolution: 300 m (Source: J. Wang, WUSTL team)

Digital elevation of Chicago from Light Detection and Ranging (LiDAR) data at 3m resolution. (Source: Li and Sharma, DOI: 10.22541/essoar.168121520.07415257/v1.)

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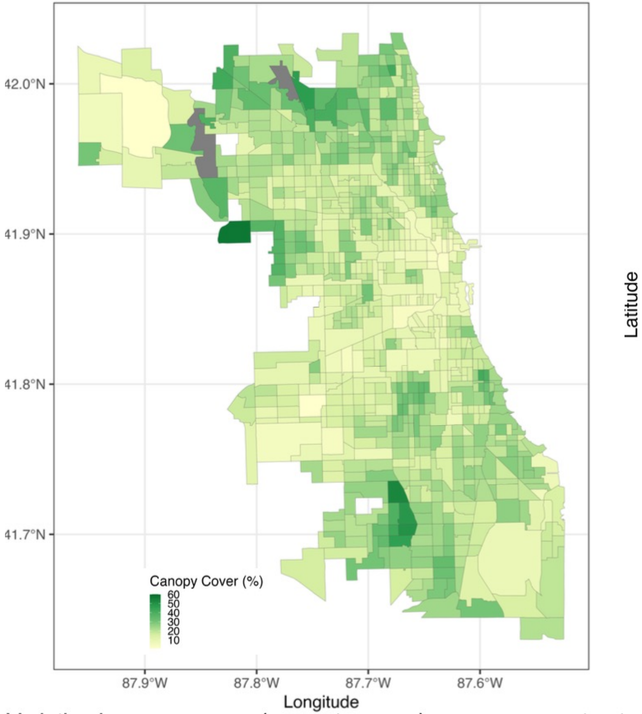
MAPPING TREE CANOPY AND ITS HEALTH

- Used Sentinel-2 data (10m) to calculate annual enhanced vegetation indices (EVI) across the city of Chicago during the peak growing season (June to August) between 2017 and 2023. EVI metrics were masked to the European Space Agency's WorldCover v200 tree cover class to include only pixels classified as tree cover in the analyses.
- Assessed spatial variation in EVI by summarizing current EVI and interannual summer EVI variance (2017-2023), a preliminary proxy for resilience, at the census-tract level
- Assessed preliminary income-based inequality with linear models using 2021 median household income data from the American Community Survey. We controlled for percent canopy cover in all analyses.
- All analyses were performed in Google Earth Engine and R



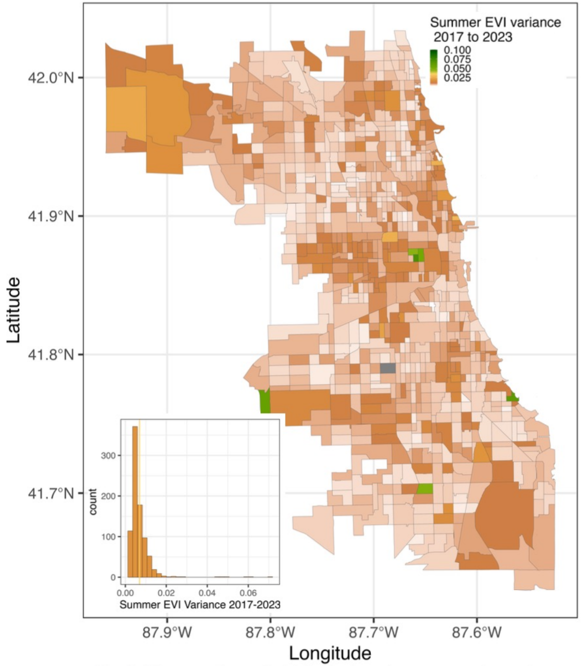


Fig 5. Mean variance in EVI of urban tree canopy in each census tract during summer 2017-2023. Histogram depicts the distribution of EVI variance values among tracts.

Source: Love, N., et al., (2023), UIC

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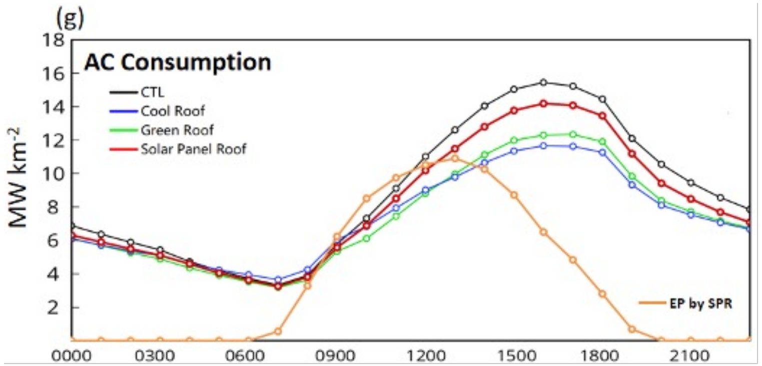
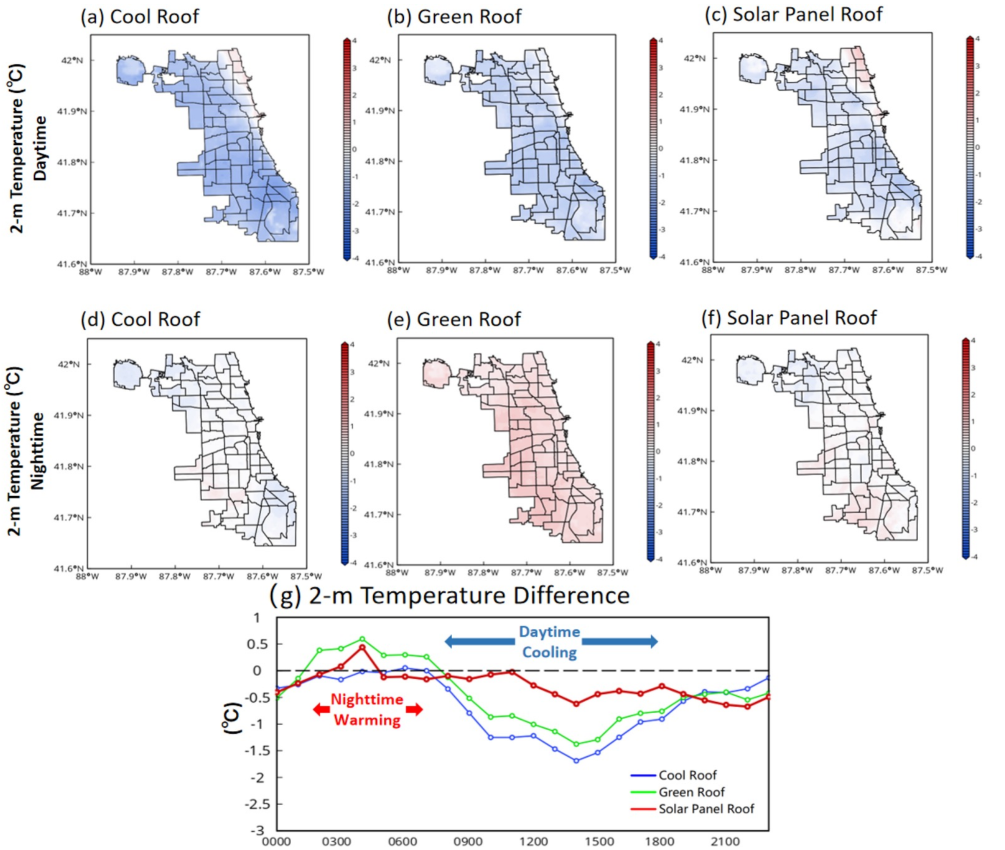
TEMPERATURE MITIGATION AND AC CONSUMPTION



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).

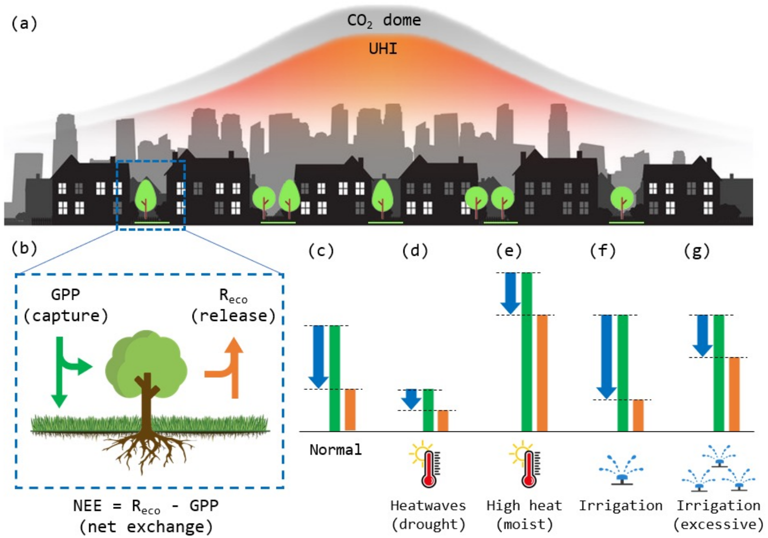


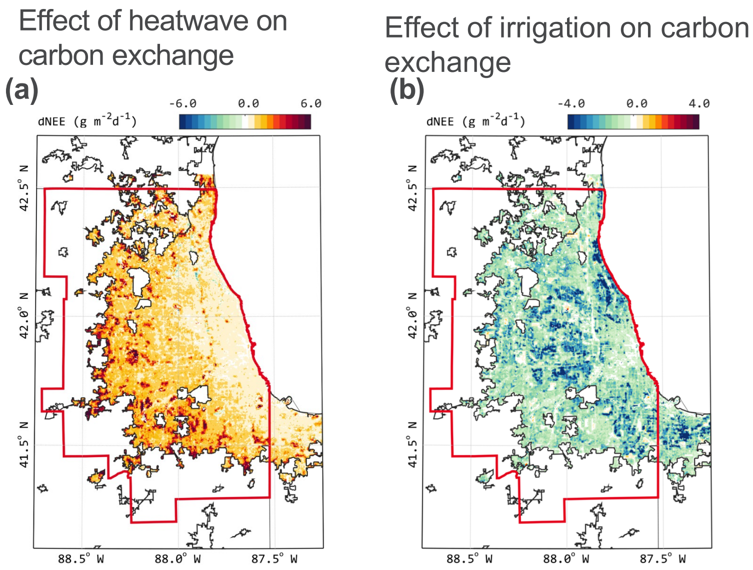
Source: Tan et al. DOI: 10.1016/j.scitotenv.2022.160508.

URBAN VEGETATION AND SOIL

Changes in CO_2 due to urban vegetation

Passive impacts from UHI and elevated background CO_2 level alter the growth of plants





Li *et al.* (in review)

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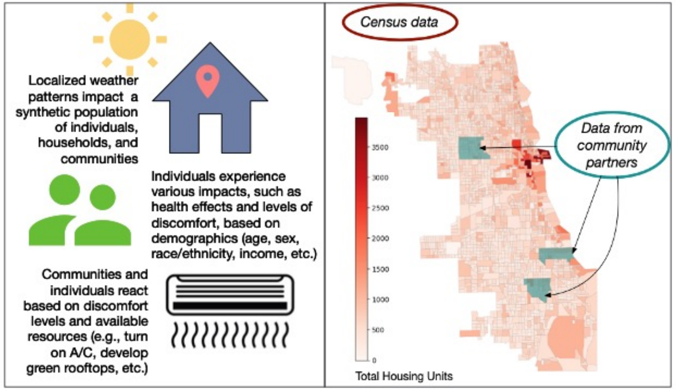
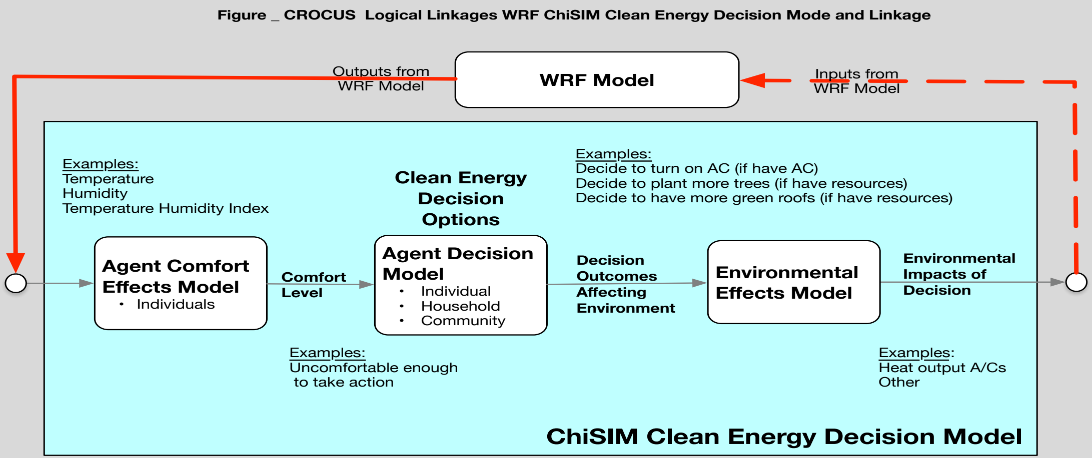
MODELING THE IMPACT OF DECISIONS

Linking physical models with Agent-based Decision Model (Macal and Ozik)



- Incorporate equity and inclusion
- Support decisions towards capital expenditures



WRF Model The Weather Research and Forecasting model is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. https://www.mmm.ucar.edu/models/wrf

ChiSIM The Chicago Social Interaction Model is a model of Chicago and everyone in it represented as a software agent

Agent Comfort Effects Model — Inputs environmental variables such as temperature and humidity and outputs person comfort levels

Agent Decision Model — Inputs comfort levels and outputs decisions based on comfort level

Environmental Effects Model — Inputs decision outcomes and outputs environmental impacts

CROCUS G5 Group
CMM 08-11-23

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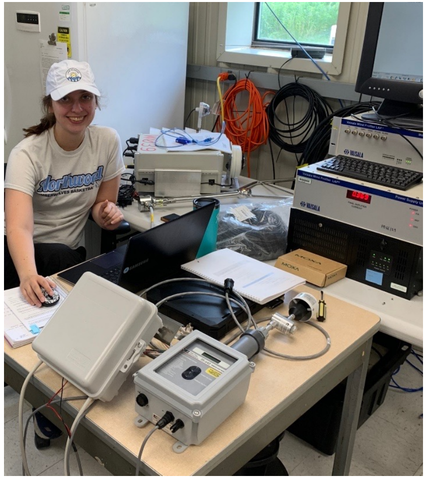
Student participation:
Climate learning in action this summer

30+ graduate, undergrad, and high school students involved in CROCUS research



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