2017 Winter Conference

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Seminar 55 – Urban-Scale Energy Modeling, Part 4

Urban Microclimate for Building Energy Models

Learning Objectives

1. Understand optimization by climate zone for energy efficiency of neighborhood building morphology
2. Describe how UBEM can be used to make well-informed utility planning decisions
3. Recognize significance of analytical problems that can be addressed at urban scale that cannot be well addressed at the individual building level
4. Recognize key structural and operating requirements for an urban-scale energy modeling platform

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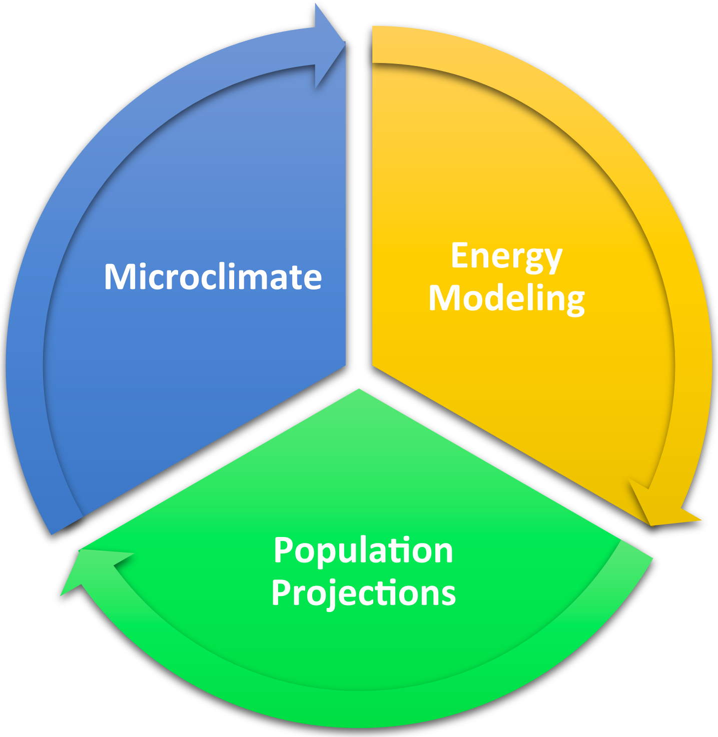
Outline/Agenda

- Urban-MET: Urban Microclimate and Energy Tool
- Modeling Urban Micrometeorological Processes
- Microclimate Projections for Future Energy Use
- Urbanization Projections for Future Energy Use
- Energy-efficient Urban Morphological Development
- Analysis and Visualization

Urban-MET: Urban Microclimate and Energy Tool

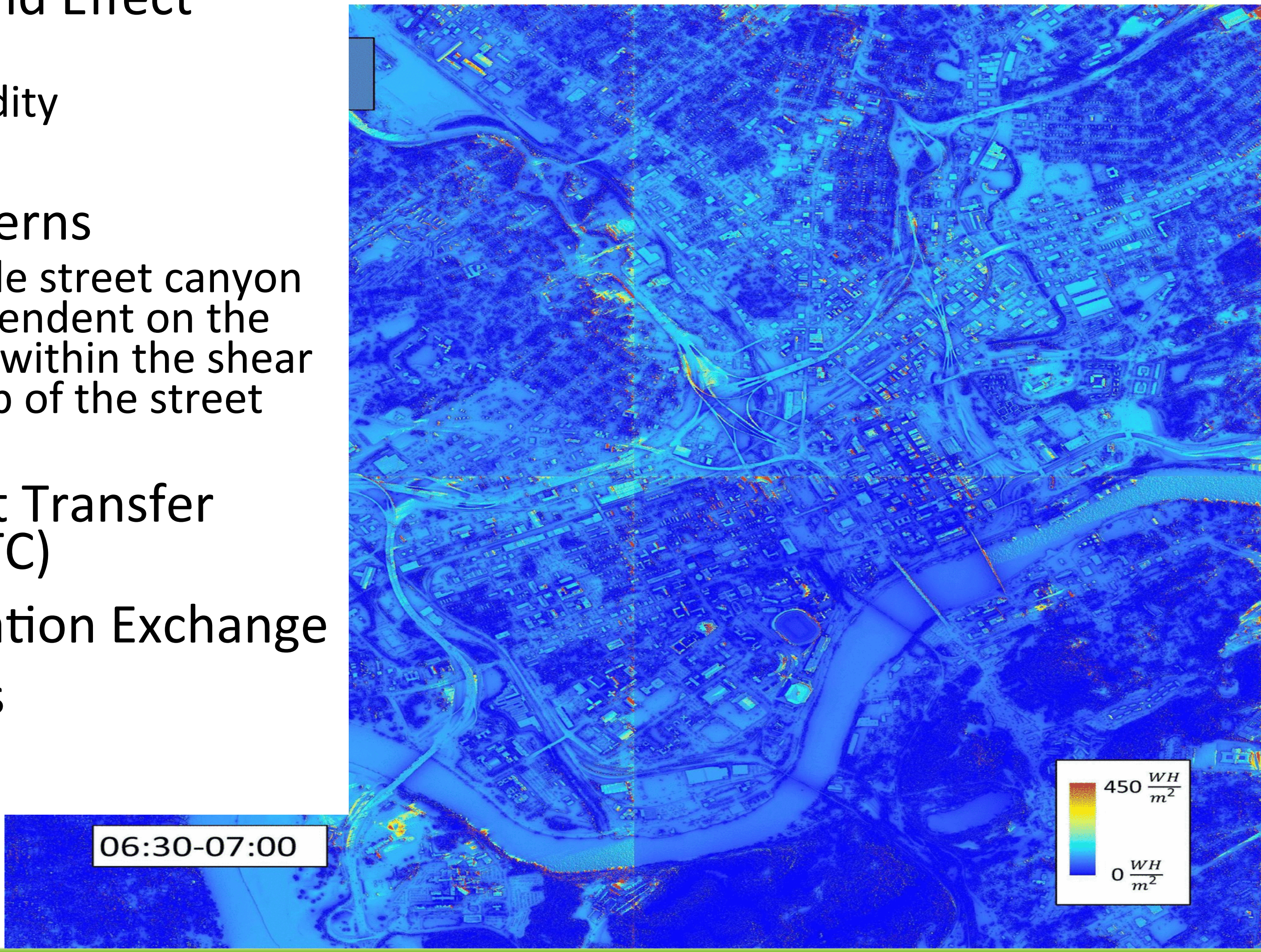
Microclimate, Morphology and Energy Tool for City Planning

Integrated Approach



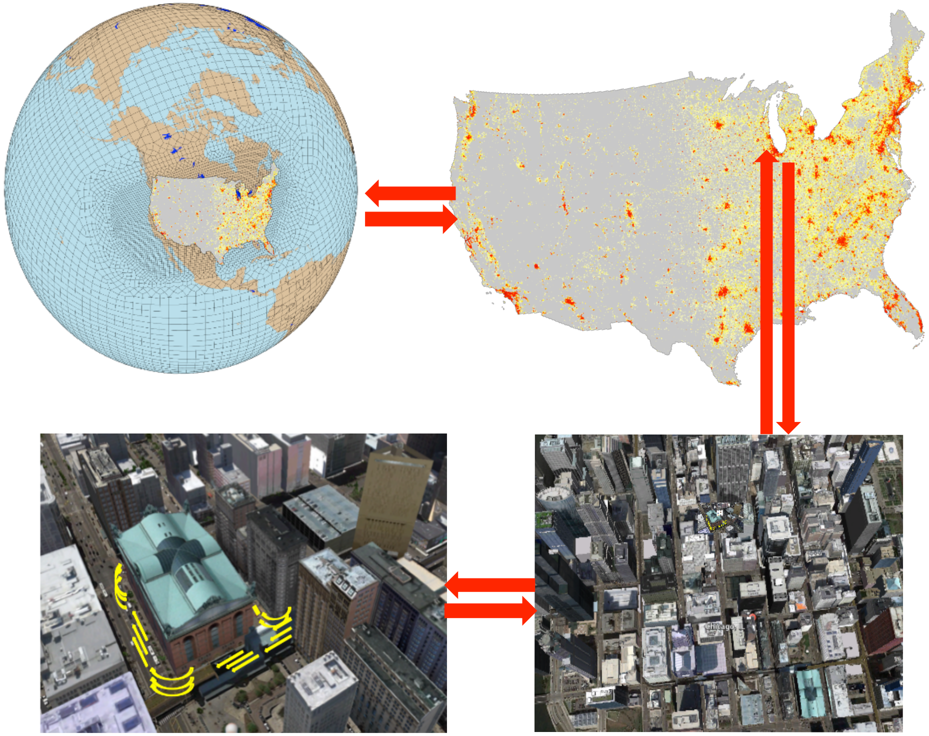
Modeling Urban Micrometeorological Processes: Key Variables

- Urban Heat Island Effect
  - Temperature
  - Relative Humidity
  - Land Cover
- Local Wind Patterns
  - Flow field inside street canyon is strongly dependent on the flow structure within the shear layer at the top of the street canyon.
- Convective Heat Transfer Coefficient (CHTC)
- Longwave Radiation Exchange
- SkyView Factors



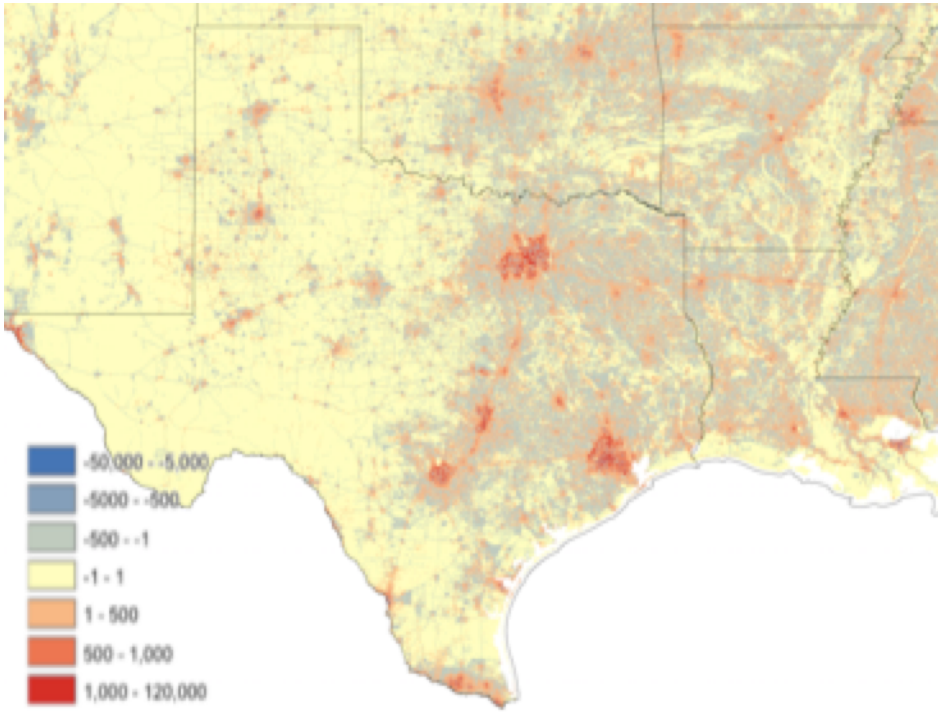
Microclimate Projections for Future Energy Use

- Global Climate Models as boundary conditions
  - CMIP5 Ensemble Members
- Regional model with embedded CFD
  - Downscale to meso and micro



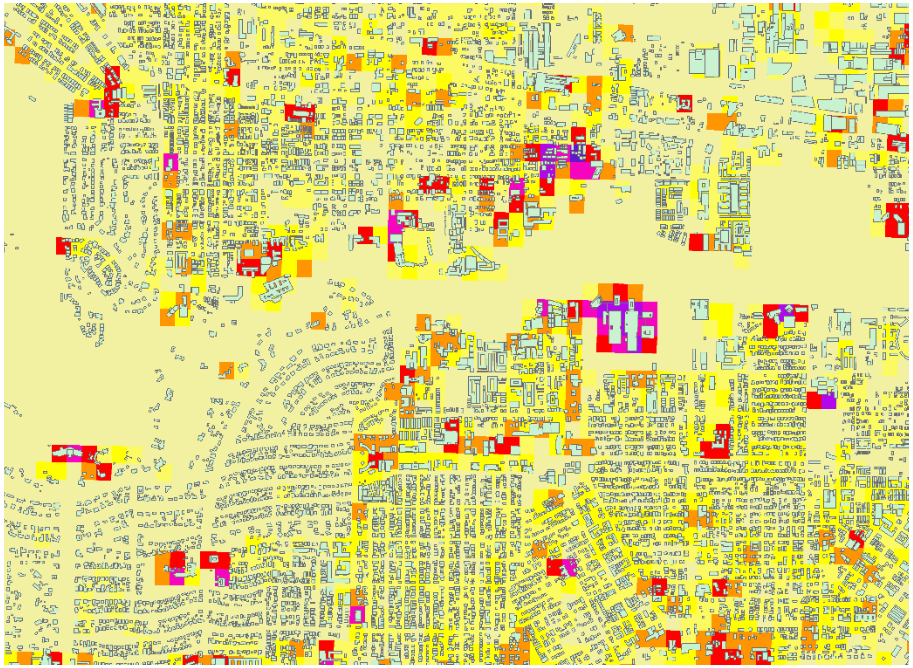
Urbanization Projections for Future Energy Use

- Population, demographics, etc.
  - Dense settlement can afford energy efficiencies by encouraging multi-dwelling living
  - In New York City the average carbon footprint is approximately 6.5 tons per capita in buildings holding the highest concentration of billionaires in the world and those of homeless individuals living less than a mile away
- LandCast
  - Locally adaptive, spatially explicit population predictions

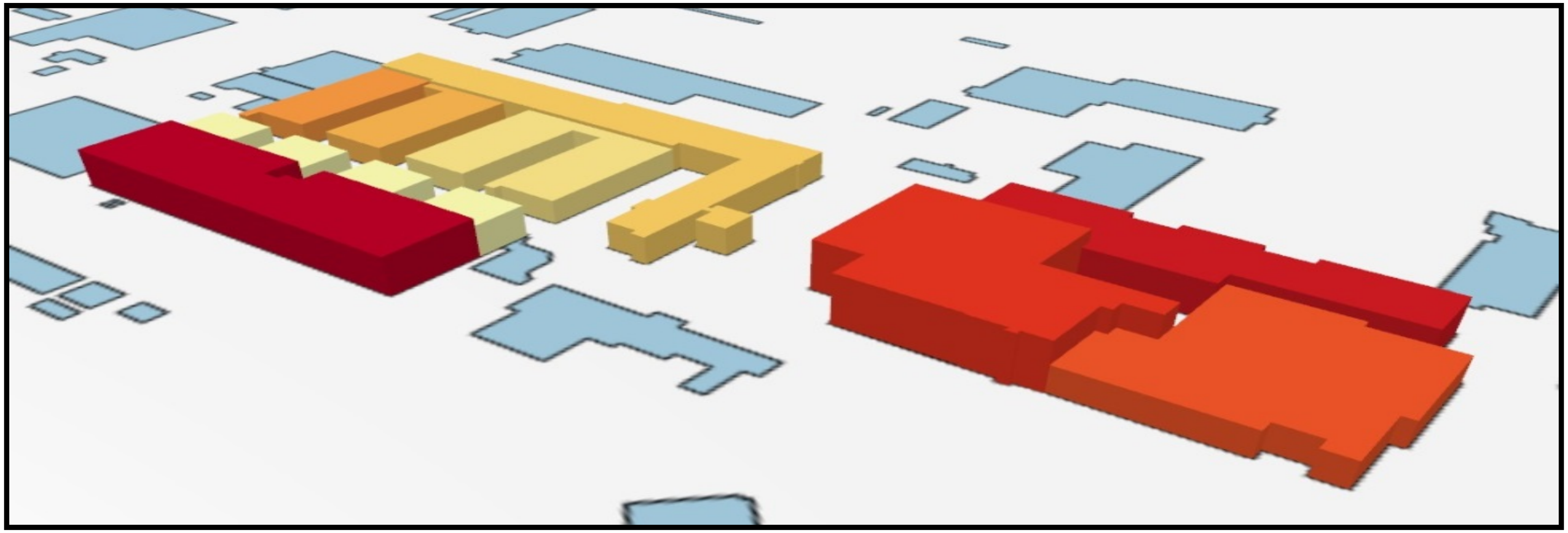


Energy-efficient Urban Morphological Development

- GIS Shapefiles/LiDAR
  - Provide city morphology to microclimate simulation platform
- Cold climates
  - Reduced winter energy demand in buildings due to urban heat island effects
- Warm climates
  - Building Geometry has a large impact on CHTC correlations

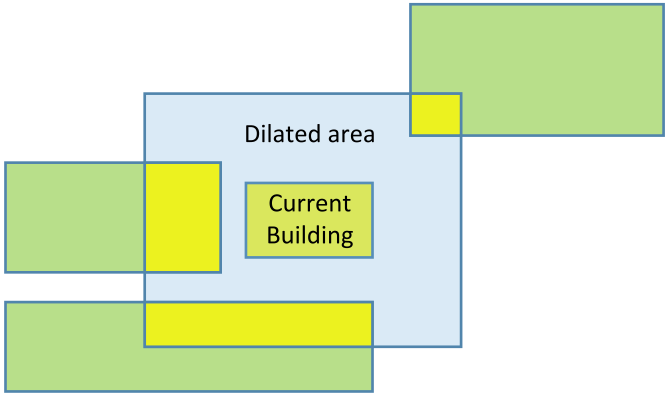


Real and Idealized Morphologies for WRF



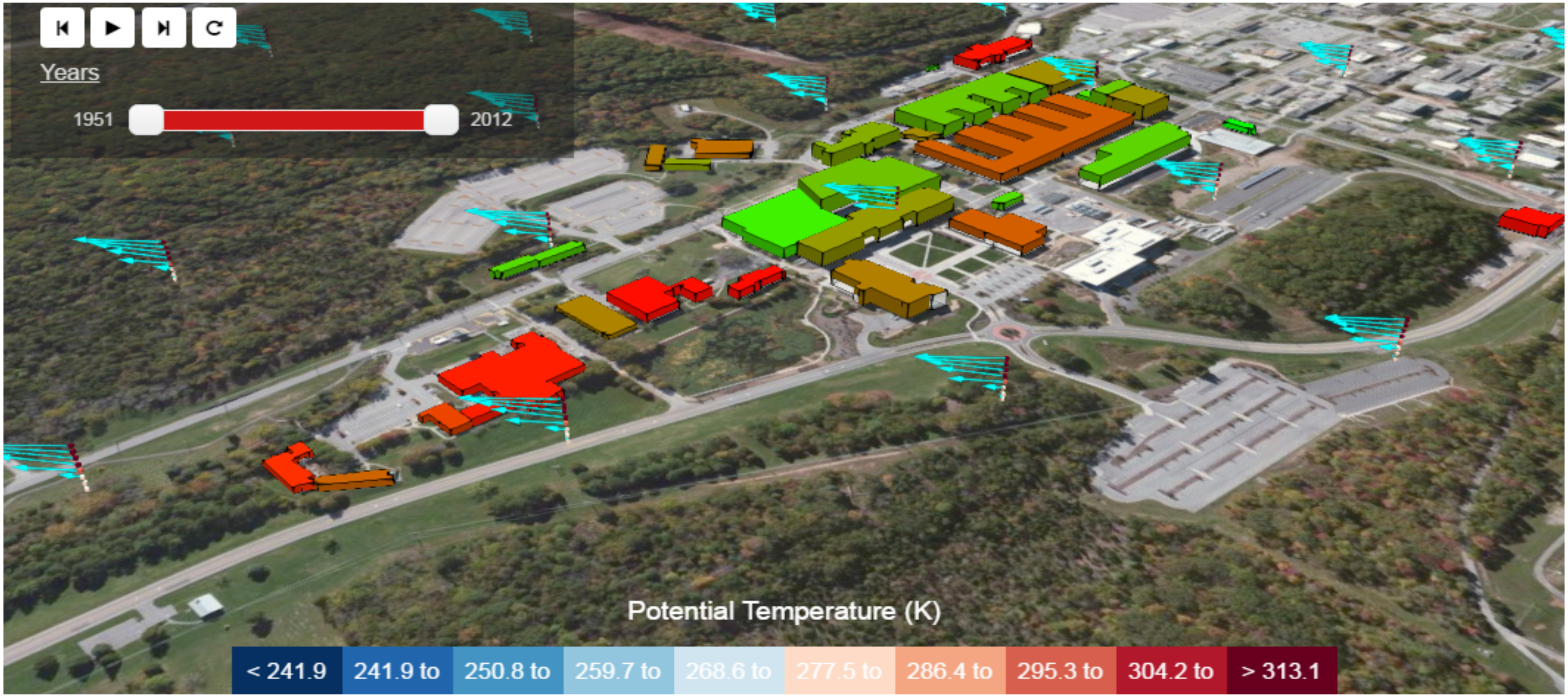
Key Parameters:

- Plan Area Density – Ratio of the plan area to the dilated area
    - Plan area - sum of the building surface areas within the dilated area
- Frontal Area Index – Ratio of the wall area to the average distance between the building centroids from North to South multiplied by the average from East to West
- Height to Width Ratio – ratio of the building height to the average distance between each building



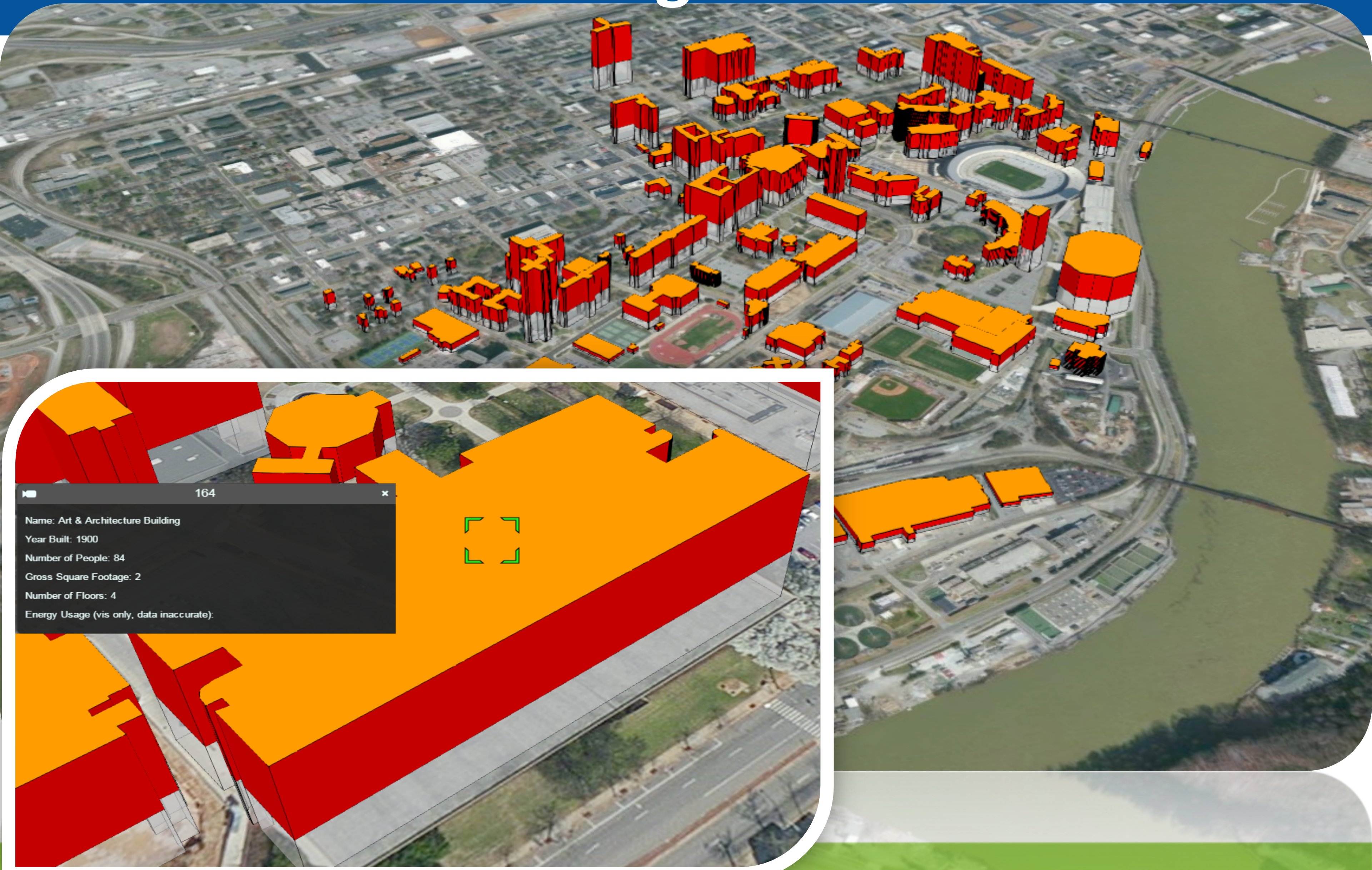
Plan area is highlighted in yellow

Visualization: ORNL Campus as Test for Validity



12 Meteorological Variables Considered
132 "Urban" Parameters Considered
Buildings colored by energy use
(Potential Temperature shown is for December 31, 2014, 1:00am, EST.
Min and Max in Fahrenheit are 32.5 and 45.9, respectively.)

Extending the Results to locations in Knoxville and Chicago



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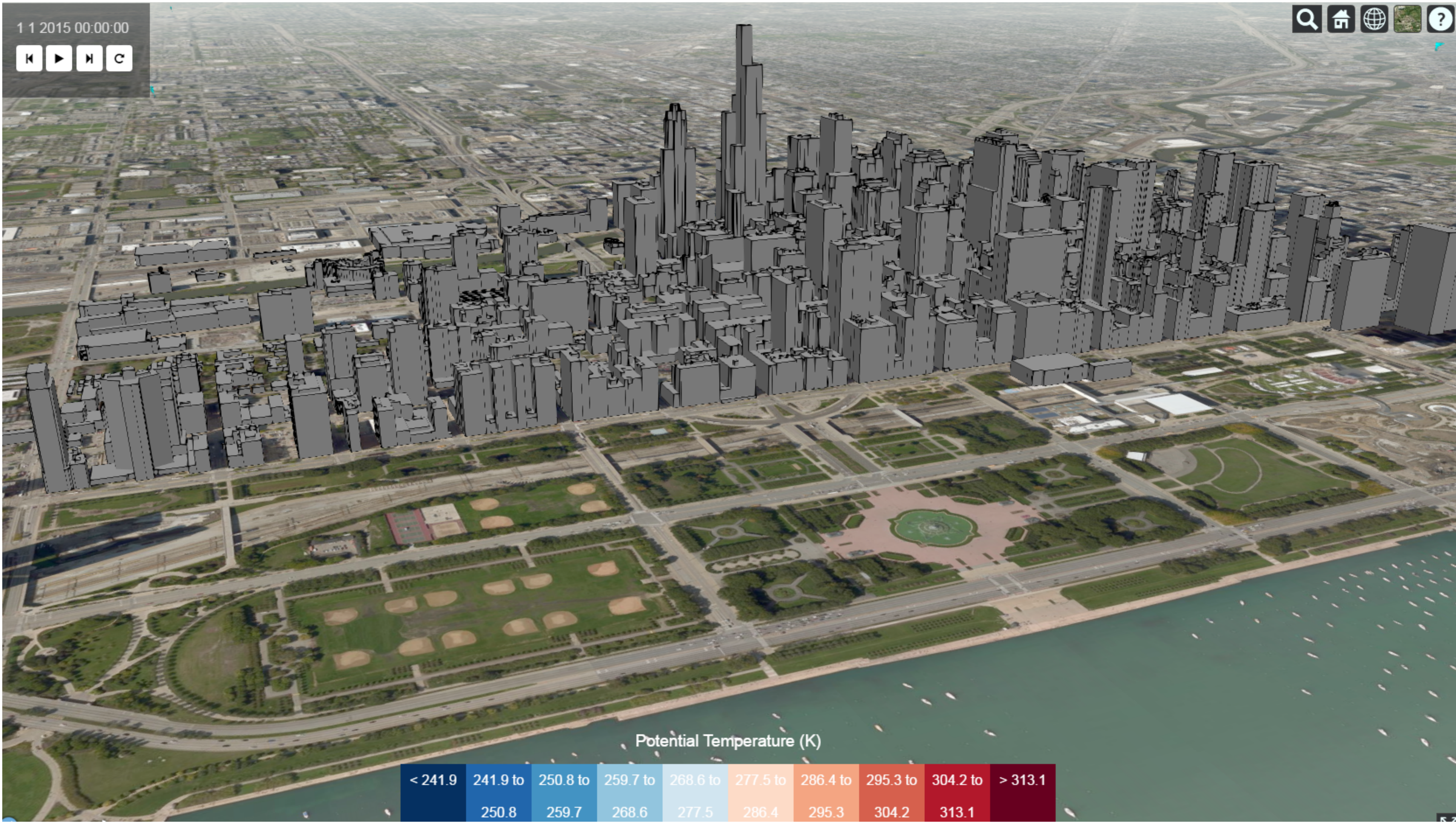

Conclusions

- We can quantify, at neighborhood resolution, the effect of various microclimate effects and urban morphologies on energy usage for building heating and cooling for cities.
- Using historical data and and projected climate and urban morphology, we can calculate energy savings based on the interaction of these components.
- We can generate recommendations for optimal morphology and expected energy savings under various scenarios.

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QUESTIONS?

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