Modeling New York City impacts on Energy Demand and Downwind Weather During the July 2010 Heat Wave

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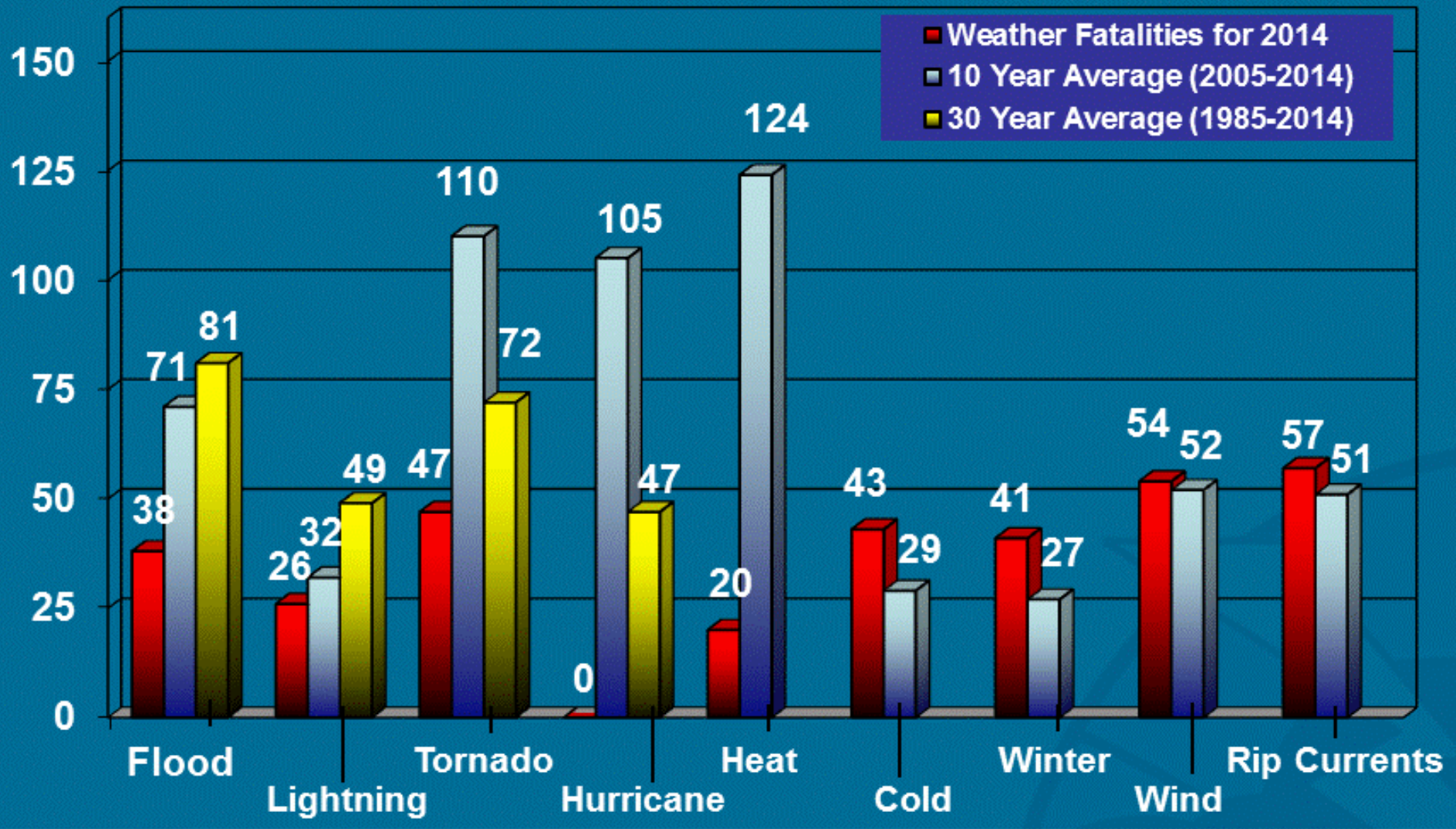
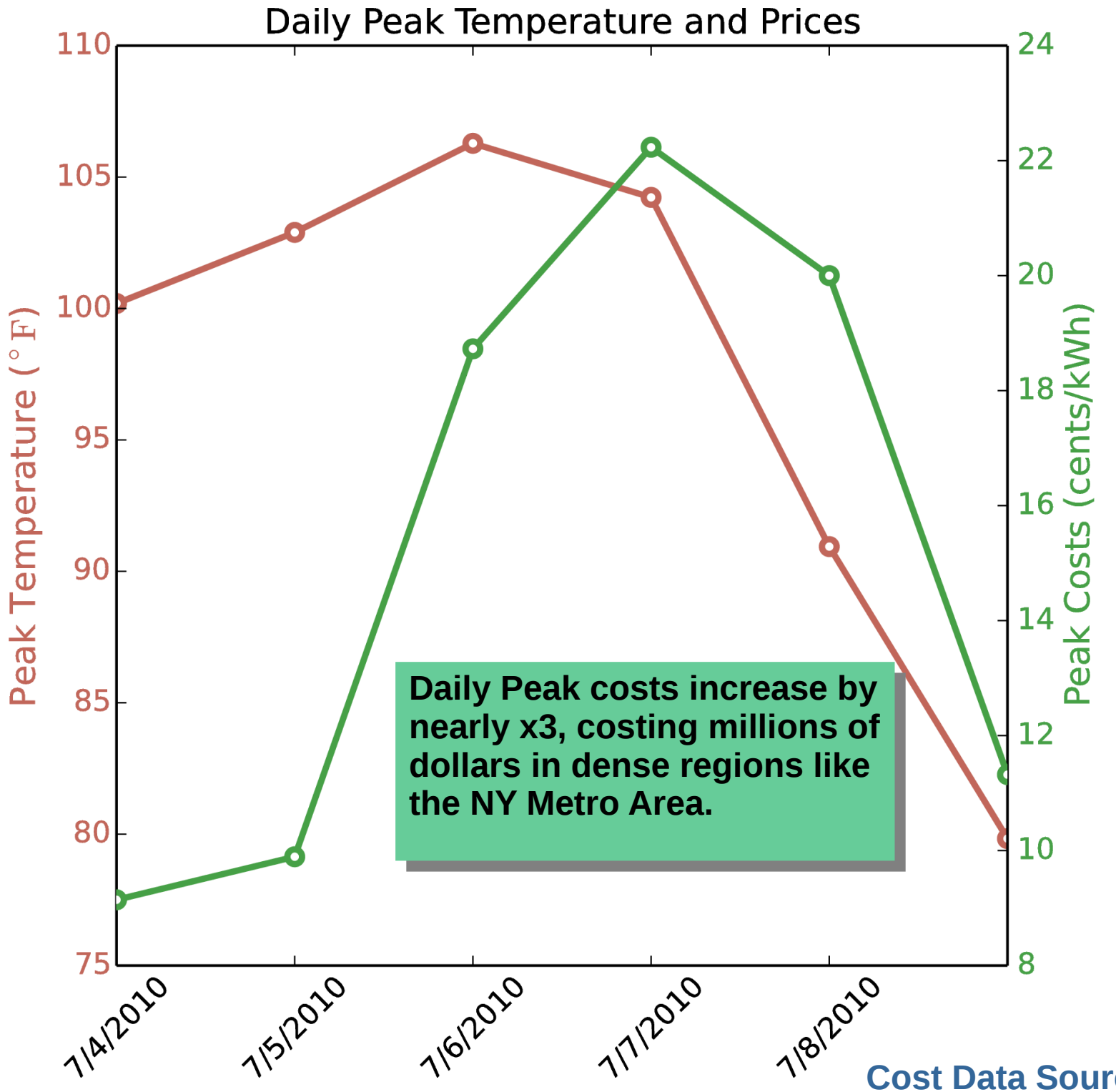
Weather Fatalities

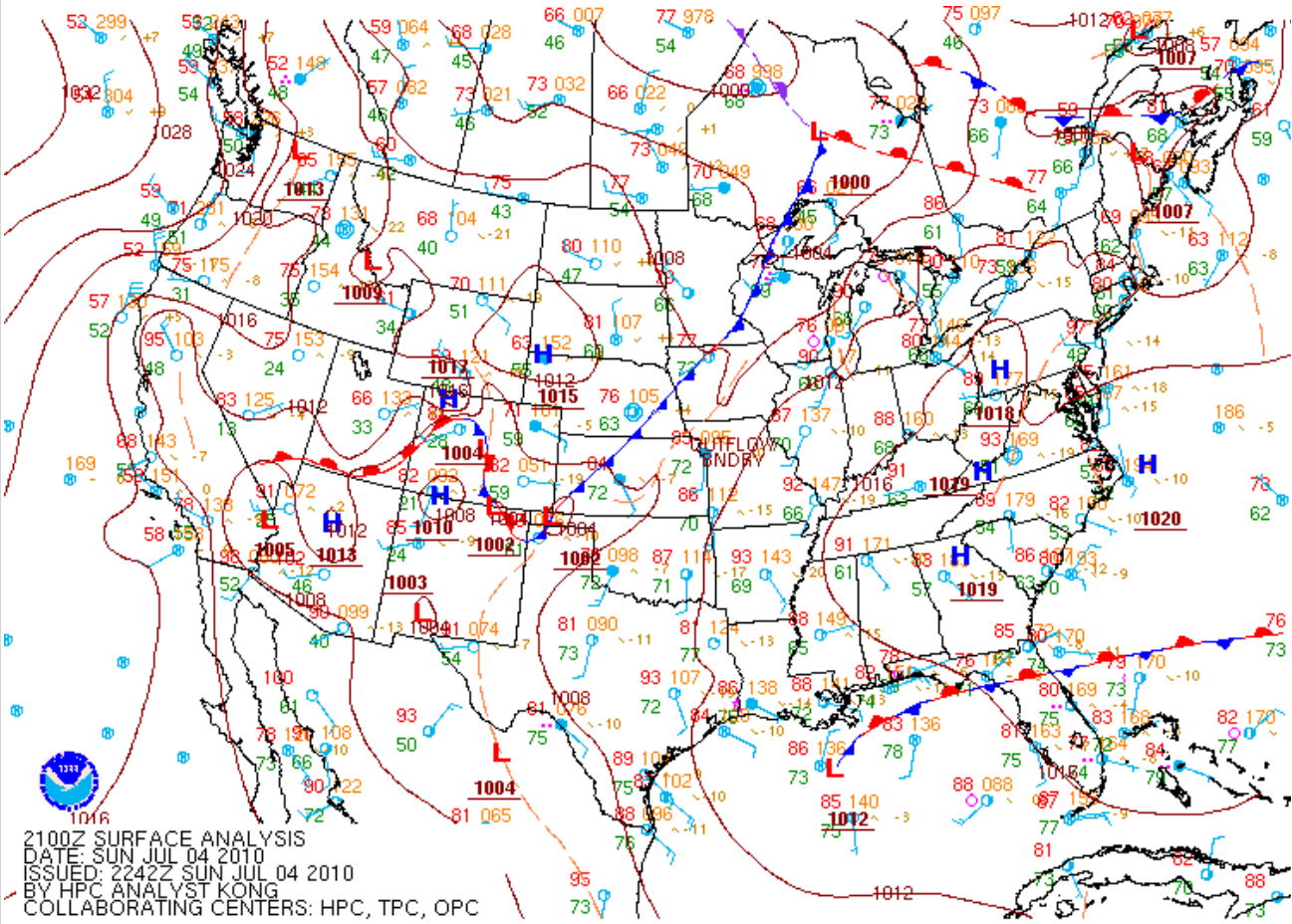




Cost Data Source: NYISO

July 2010 Heatwave

- A heat-wave event affected the Northeast United States in July 4-8, 2010.
- Temperatures reached **39.4˚C**, causing **2 casualties** and increasing hospitalizations.
- Power outages reported in NYC and Philadelphia, with **record peak demand**.



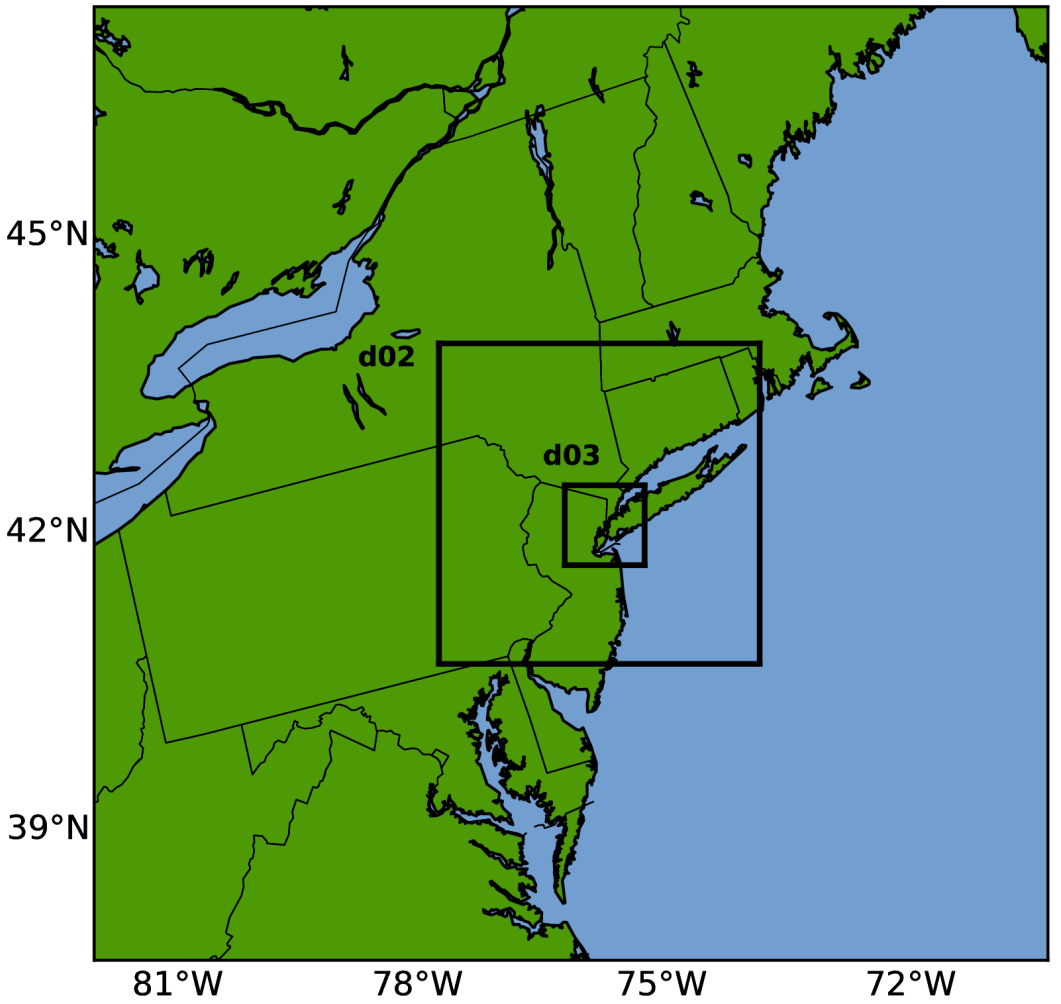
Research Questions

- Can we use dynamical downscaling to simulate the 2010 heat wave event?
- What are the regional impacts of urbanization, for example, **suburban/rural Long Island weather**?
- What impacts do heat wave events have on the city's energy demand?

Simulation Setup

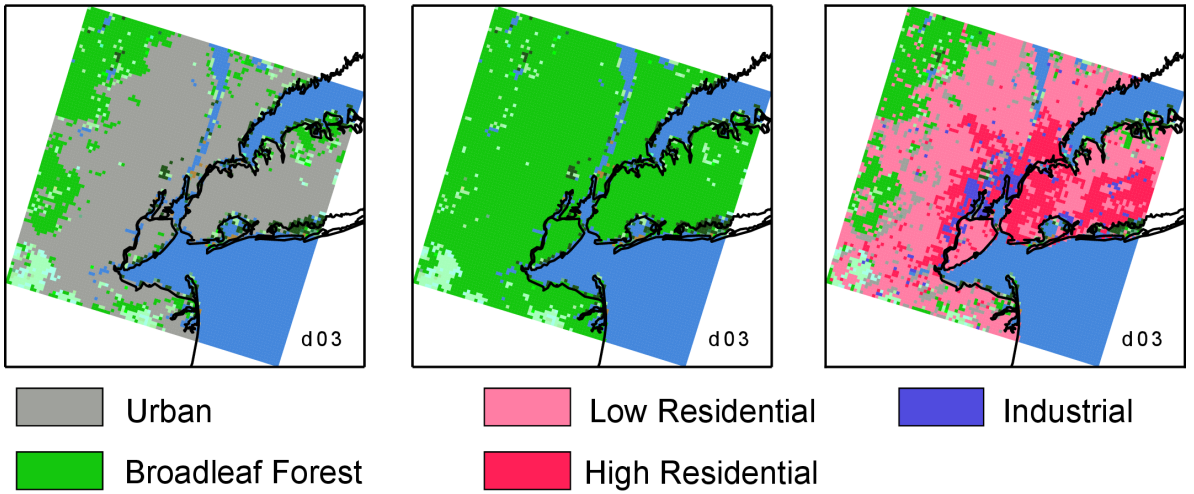
- WRF version 3.5.1
- **Three domains (2 nests)**
  - D01: **Δx: 9 km** (1071 x 1071 km)
  - D02: **Δx: 3 km** (360 x 360 km)
  - D03: **Δx: 1 km** (90 x 90 km)

- **Model Physics Options**
  - Kain-Fritsch Cumulus (off in D03)
  - WSM6 Microphysics
  - BouLac PBL
  - RRTM Longwave
  - Dudhia Shortwave



Simulation Cases

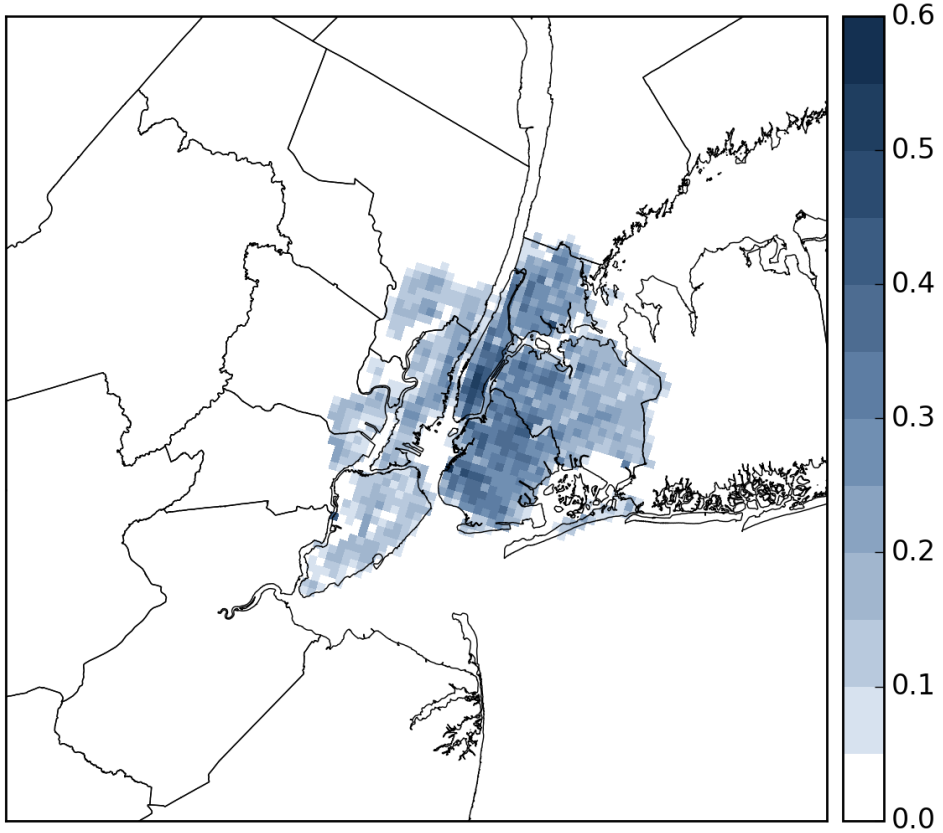
1. **CONTROL**: NOAH LSM
2. **FOREST**: Urban LC switched to forest
3. **URBAN**: BEP + BEM urban
4. **LATENT**: BEP + BEM + Hydro



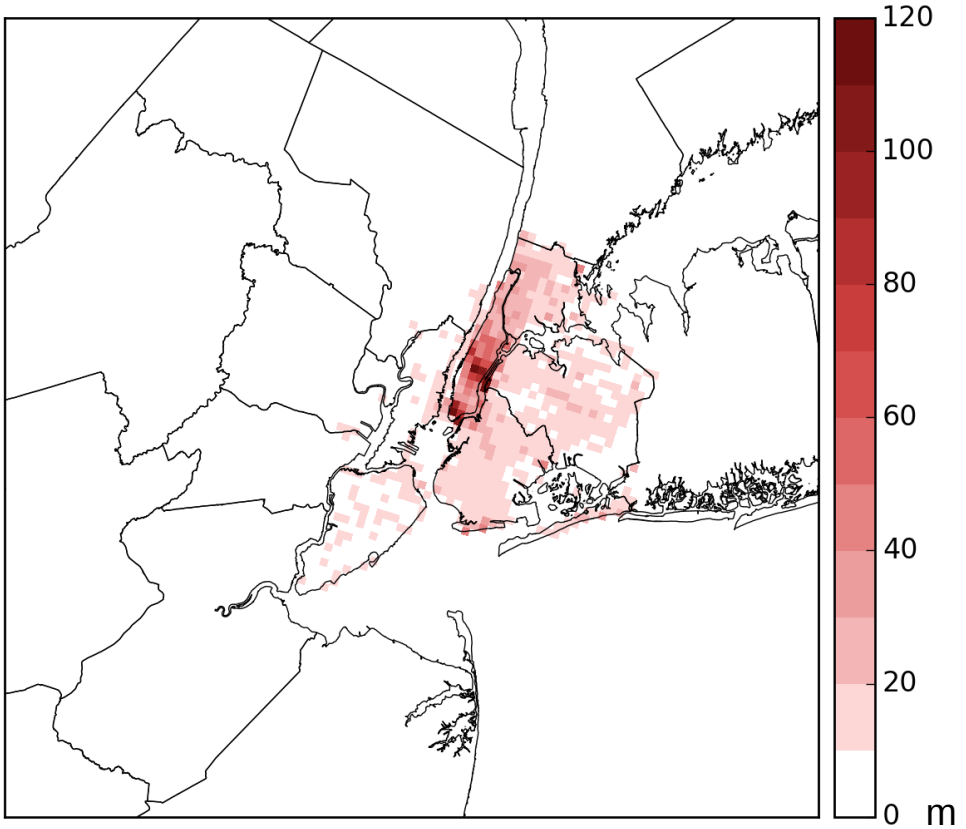
PLUTO – Land use urban parameters at the tax-lot level

Provided by New York City, it includes information such as building plan area fraction, building heights, and building use (residential/commercial). An urban classification has been created, which is assimilated into the model.

Building Area Fraction

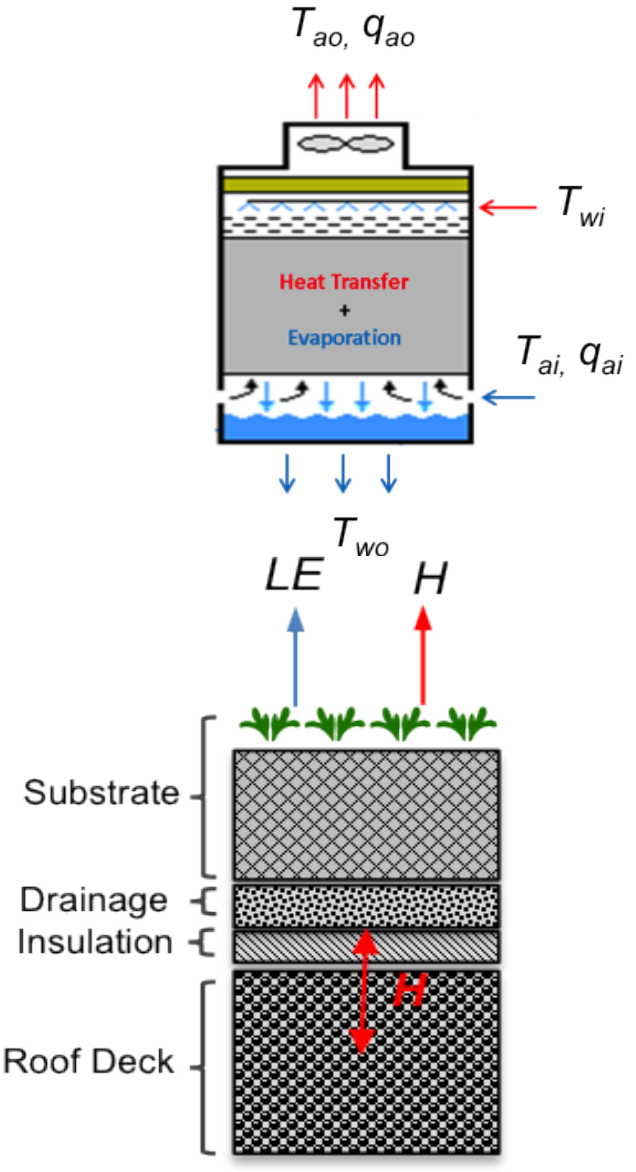


Building Height (m)



Urban Hydrology + Cooling Tower Param.
(Case 4, LATENT)

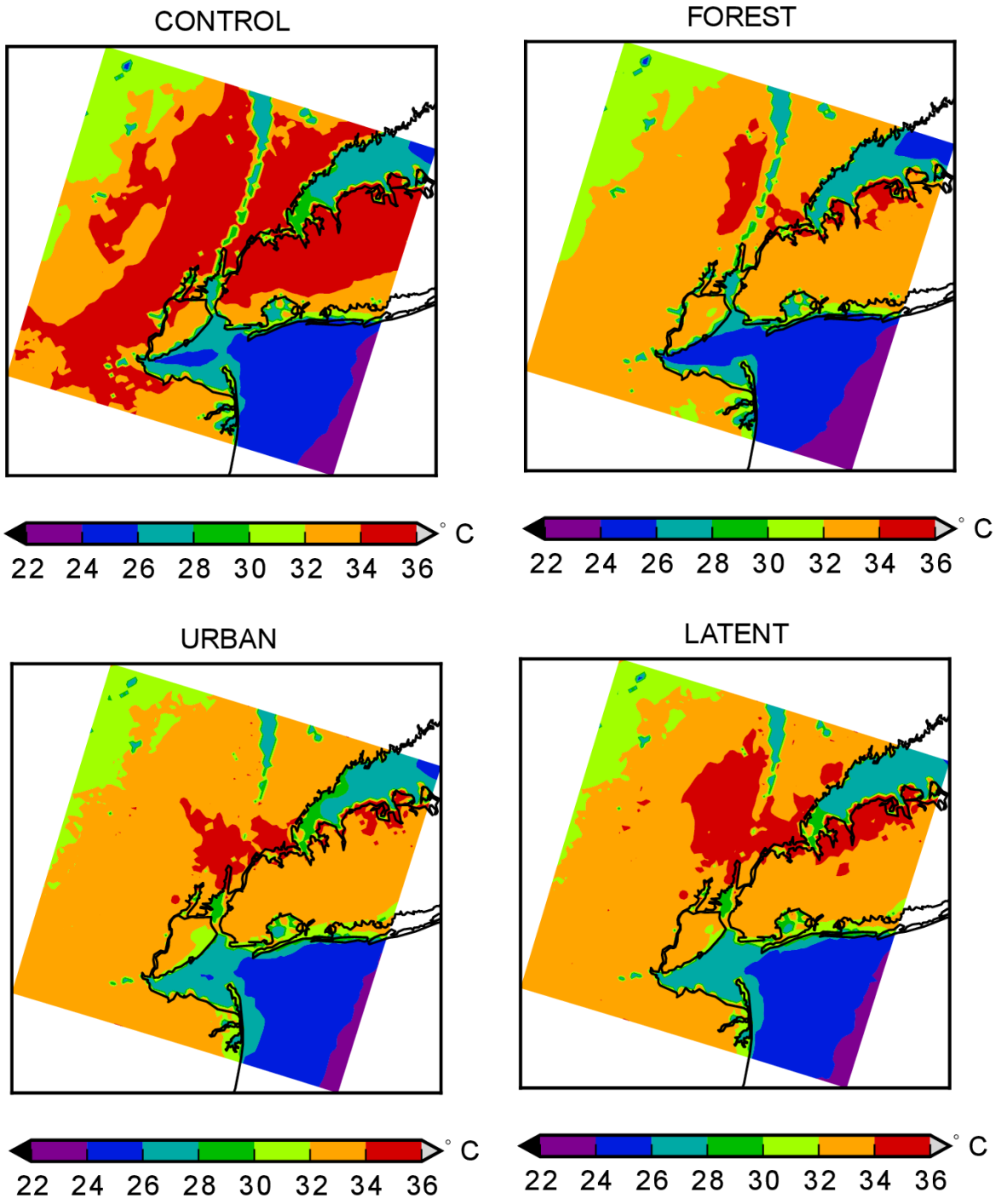
- Takes into account the effects of water in urban surfaces
- Adds the latent heat from cooling towers into the WRF BEM parameterization
  - Repartitions the anthropogenic heat balance in cities
  - Ability to forecast building energy demand

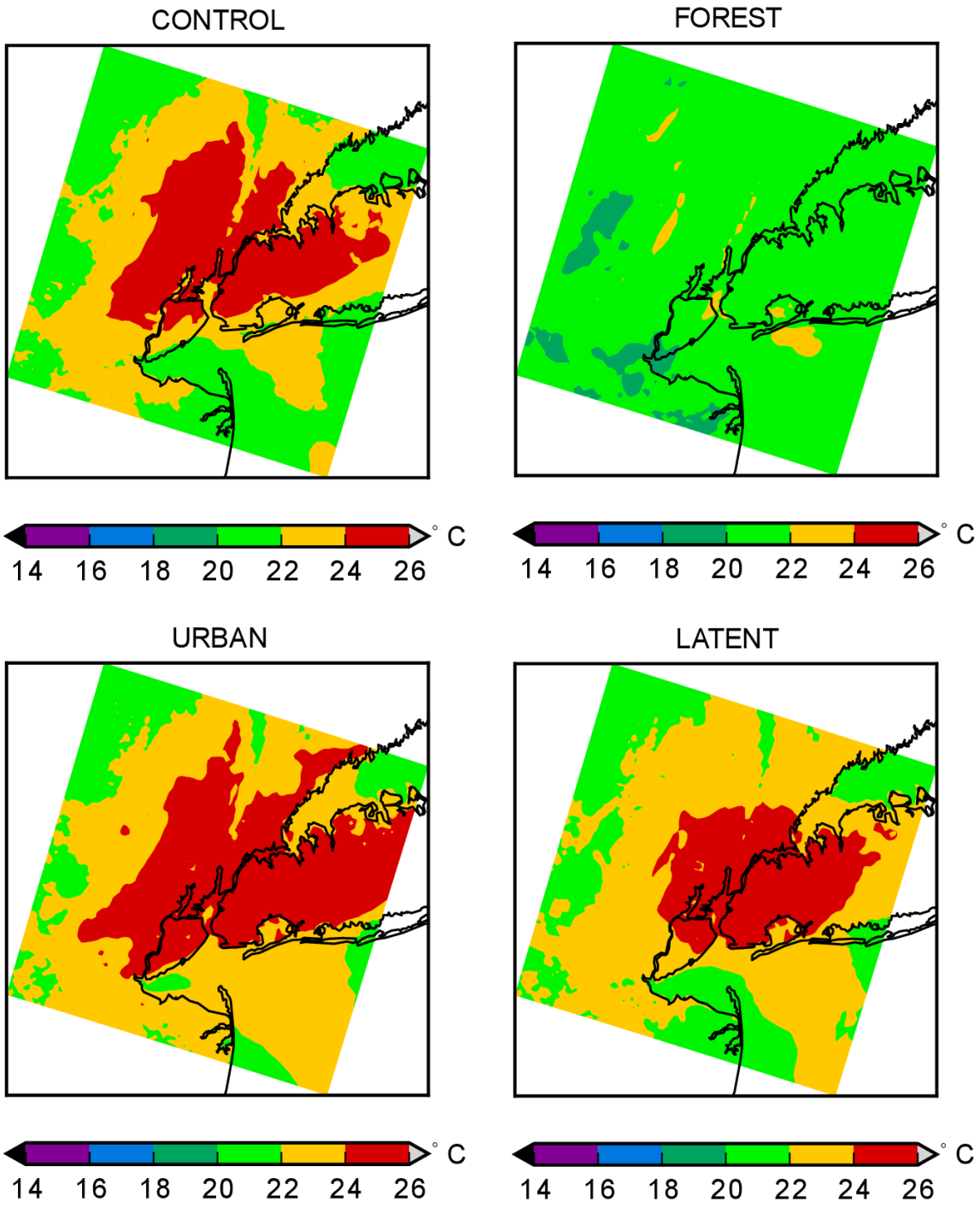


Gutiérrez et. al., 2015

Daily Tmax

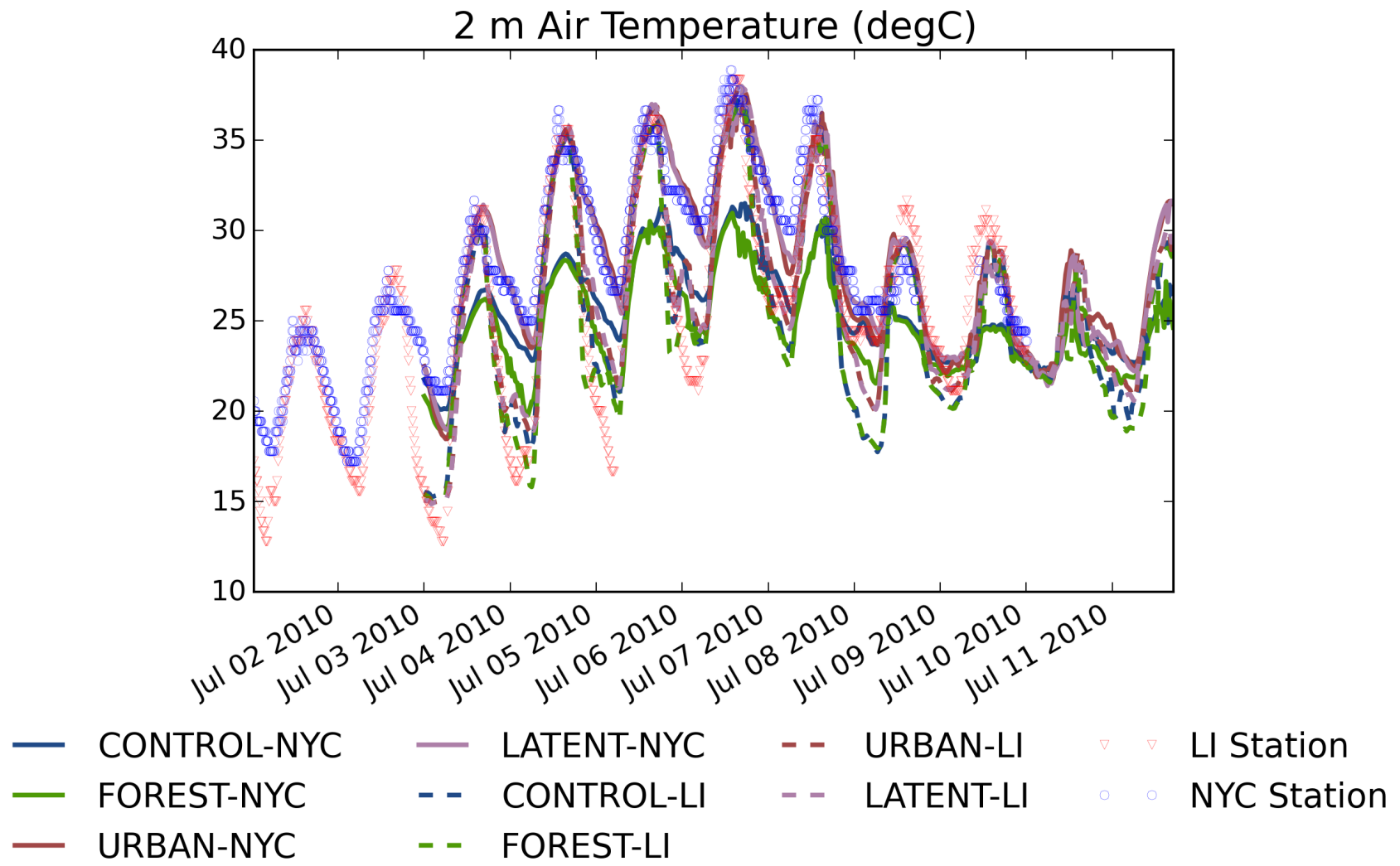
- The homogeneous treatment of the urban surface in **CONTROL** leads to an urban heat island (UHI) extending through the entire New York Metropolitan Area.
- The **FOREST** case leads to an almost disappearance, except west of the Hudson river.
- The **URBAN** and **LATENT** cases, due to the urban parameterization, change the UHI extent and magnitudes, with hot spots in Midtown Manhattan and the Bronx.



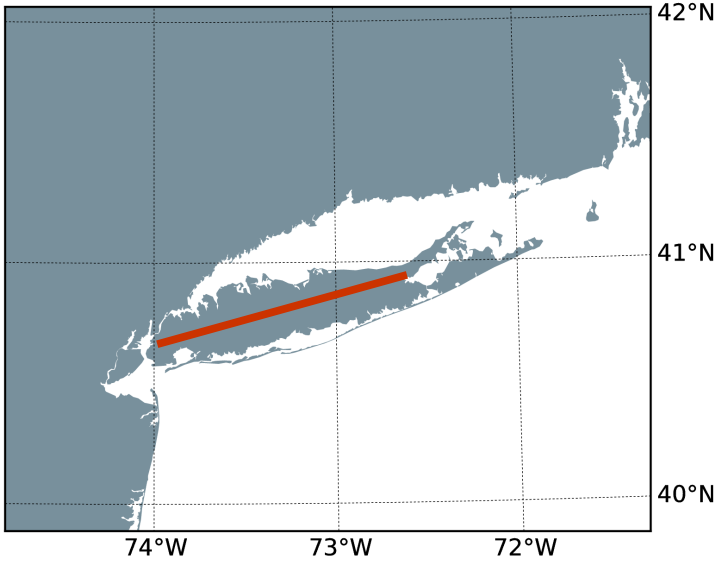


Daily Tmin

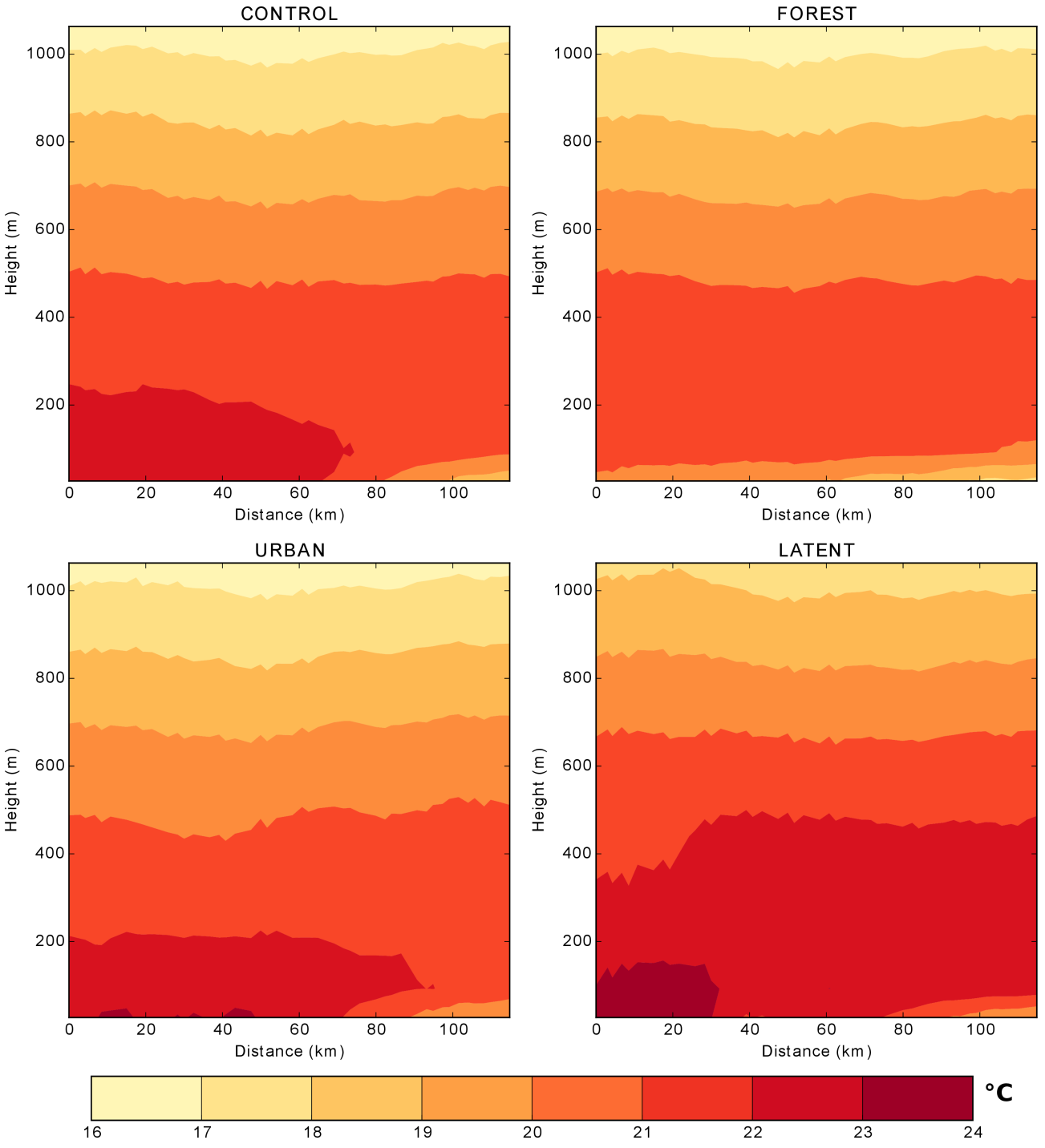
- Strong nighttime UHI
- In the **FOREST** case, UHI disappears completely.
- The **URBAN, CONTROL,** and **CONTROL** cases show an UHI magnitude of ~5 °C, 1 °C greater than avg. as reported by Gedzelman et. al., 2003.
- The extent of the UHI is again very sensitive to urban parameterization, with the **LATENT** simulation showing the smallest area.



- Timing of the heatwave event is captured, with several locations reaching **39°C**
- Maximum differences between the cases are in nighttime minimum temperatures.
- Long Island (Suffolk County) temperatures show differences with the urbanized simulations of up to 1 °C at night.

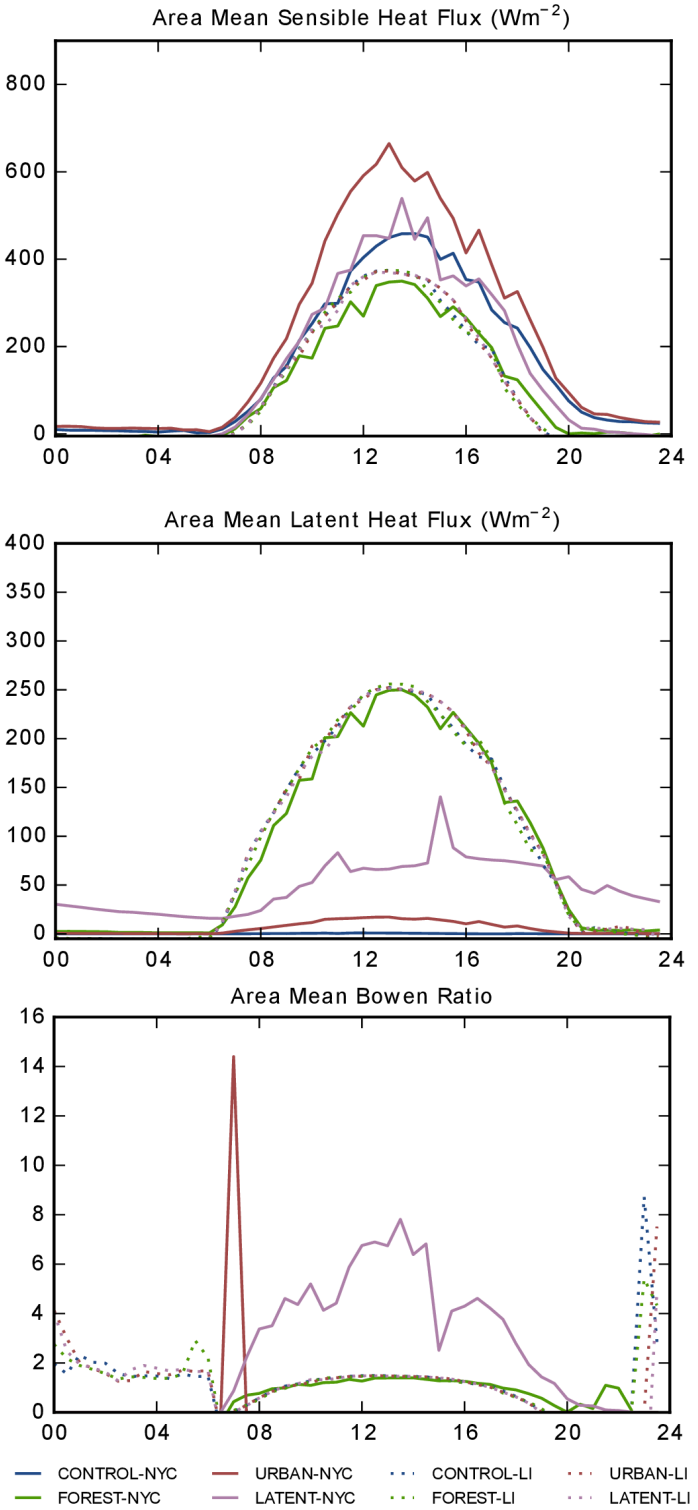


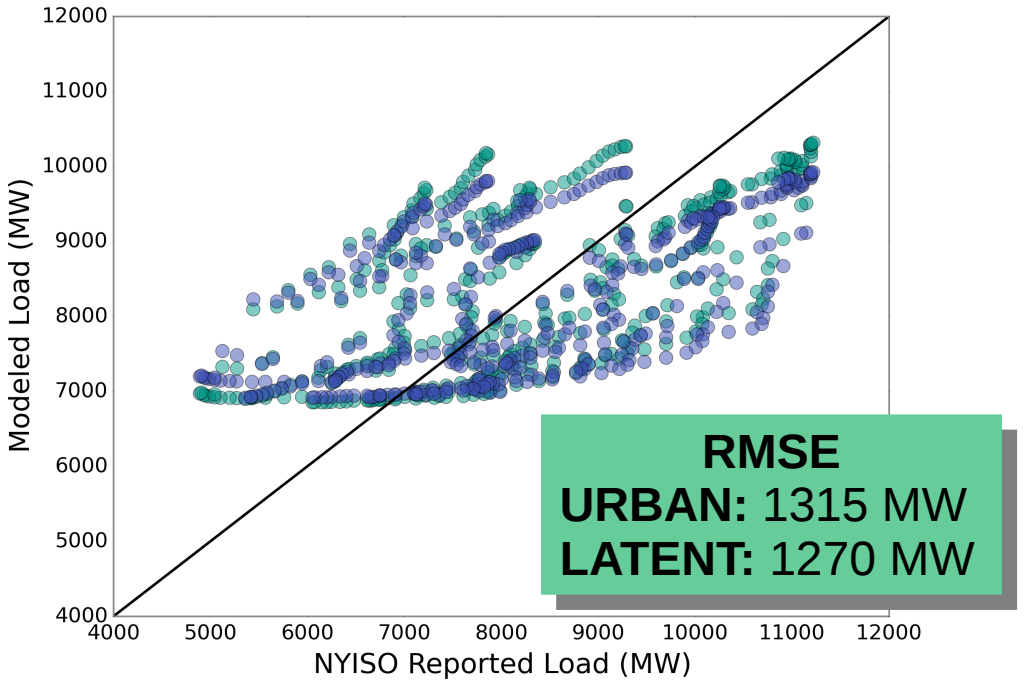
- Vertical cross-section of nighttime minimum temperature throughout NYC and Long Island.
- Urban plume disappear in FOREST case.
- LATENT case has very warm core in NYC, warm air extends throughout the cross-section.
- URBAN and CONTROL show warm mass, with small hotspots in urbanized land cover visible near surface of URBAN.

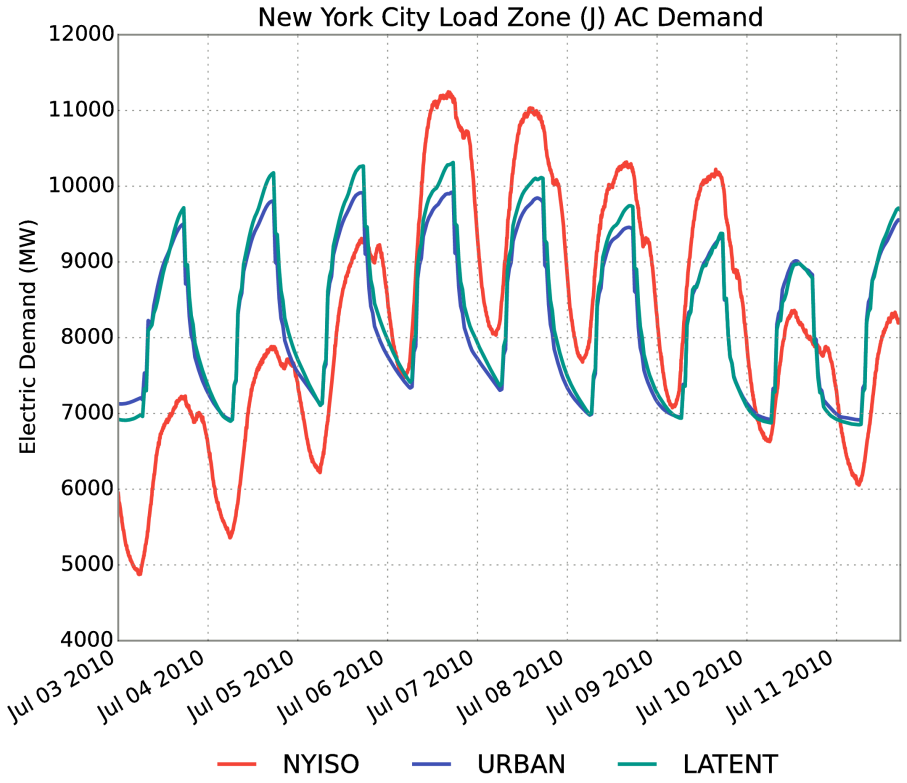


Surface Fluxes

- Two locations: **Midtown Manhattan (solid) and Upton, NY (dashed)**
- **URBAN** case exhibits largest sensible heat (675 W/m^2), with Upton and the **FOREST** case showing lower, similar peaks (375 W/m^2).
- **FOREST** and all all Upton cases have the highest latent heat fluxes (250 W/m^2 peak)
- Due to lower Latent Heat and higher Sensible heat flux, **URBAN** case Bowen Ratio is extremely high, growing unbounded.







Energy Impacts

- The Building Energy Model (BEM) in WRF (used in URBAN and LATENT) cases, can produce energy demand from buildings (AC consumption).
- An equipment electric load model is added to the model based on the urban land cover classification and work-hour schedules.
- The model is able to capture the timing and some of the variability from the heat wave event.
- Lack of non-building related energy components (e.g., NY subway) may account for part of the error.

Conclusions

- The model was able to capture the timing and magnitude of the heatwave event, as well as the NY UHI.
- A daytime UHI with a magnitude of 4 °C and a nighttime UHI of 5 °C were observed.
- A difference in rural/suburban Suffolk County, LI between the FOREST and other cases of up to 1 °C was observed.
- Vertical minimum temperature profiles show an urban plume in the CONTROL, URBAN, and LATENT cases, with the latter two showing larger extents both along the cross-section and vertically.
- The timing of the energy demand profile for NY was captured, with a RMSE of 1315 MW and 1270 MW for the URBAN and LATENT cases, respectively.

Future Work

- Expand study to United States Northeast.
- Climatology study
  - Urbanized climate simulation in the present

- Move into the future
  - Impacts of urbanization in the Northeast region during heatwaves and storms under the climate change signal

Acknowledgements

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