Modeling New York City Impacts on Long Island Weather

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Motivation and Goals

Extreme events such as heat waves are known to stress infrastructure, ecosystems, and human health. In large urban centers such as those found in the U.S. Northeast (e.g., New York City), these stresses can be exacerbated (Gutierrez et al, 2015). What is less known are the effects of the urban land cover at the regional scale. With this in mind, a case study was designed using the heatwave that affected the Northeast Corridor in July 4-9, 2010, focusing on the New York City and neighboring Long Island area. Our goal is assessing the sensitivity of Long Island temperatures to NYC urban land cover during this event as a stepping stone to a fuller analysis of the entire Northeast Corridor in the past and future.

Model Setup

- WRF version 3.5.1
- 3 domains with 9 km, 3 km, and 1 km spatial resolution via two-way nesting.
- 50 vertical levels
- Simulation period: 2010-07-03 to 2010-07-11
- NARR Initial and Boundary Conditions
- Explicitly solved convection in highest resolution domain (d03).
- 4 simulation cases
  - CONTROL: MODIS 20-category land use index, no urban parameterization
  - FOREST: Urban land use changed to deciduous broadleaf, soil moisture mod.
  - URBAN: BEP + BEM (Salamanca et al, 2010) parameterizations active. Tax-lot derived urban parameters
  - LATENT: Same as URBAN, but with a Cooling tower and water balance component added (Gutierrez et al, 2015).

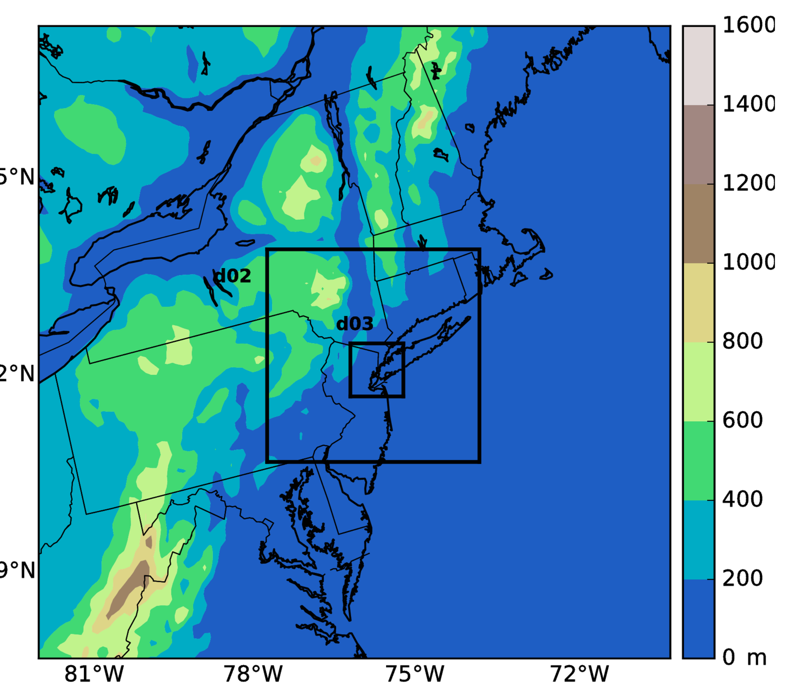

Figure 1. Simulation outer and nested (d02, d03) domains. Shaded contours represent terrain height in meters.

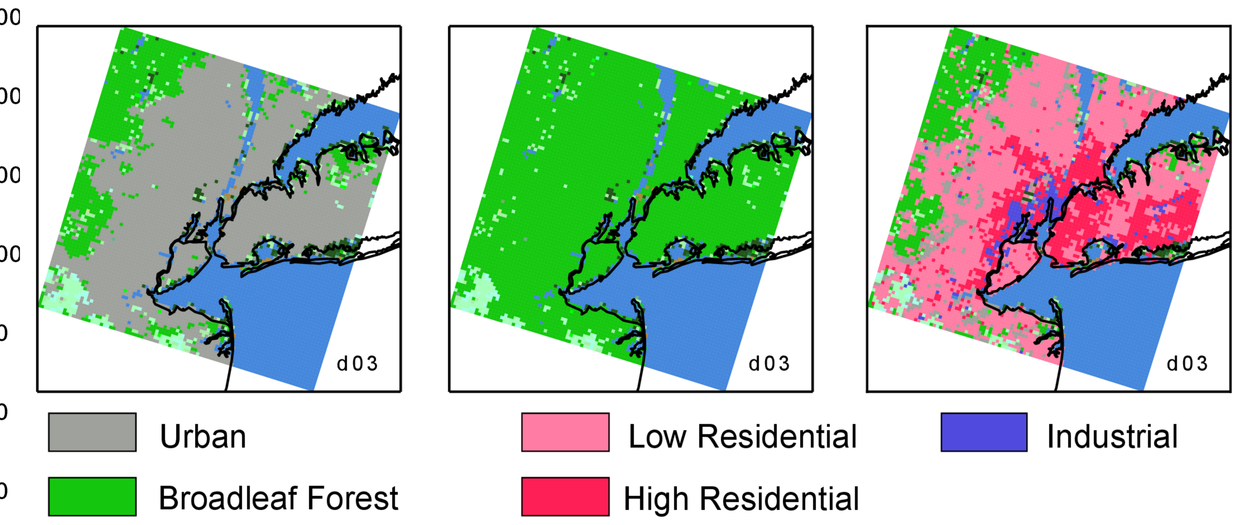

Figure 2. Land use index used in the CONTROL case (left), FOREST case (center), and the URBAN/LATENT cases (right). The URBAN case uses the default MODIS land use classification, while the FOREST modifies this dataset to convert the urban land cover to deciduous broadleaf. Finally, the URBAN and LATENT cases use a disaggregated 3-category urban land cover derived from tax-lot data developed by the city of New York.

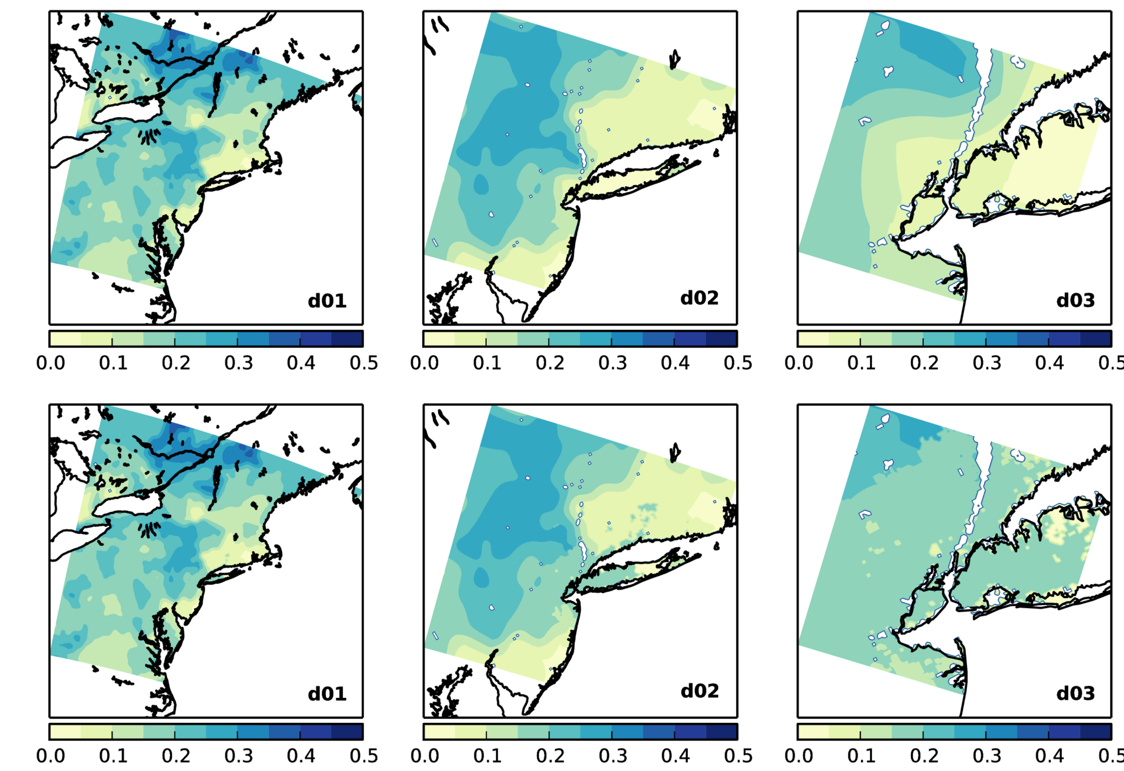

Figure 3. NARR soil moisture for the topmost soil layer (top row). Bottom row shows the modifications used in the FOREST case. Contours are soil moisture in kg/kg units.

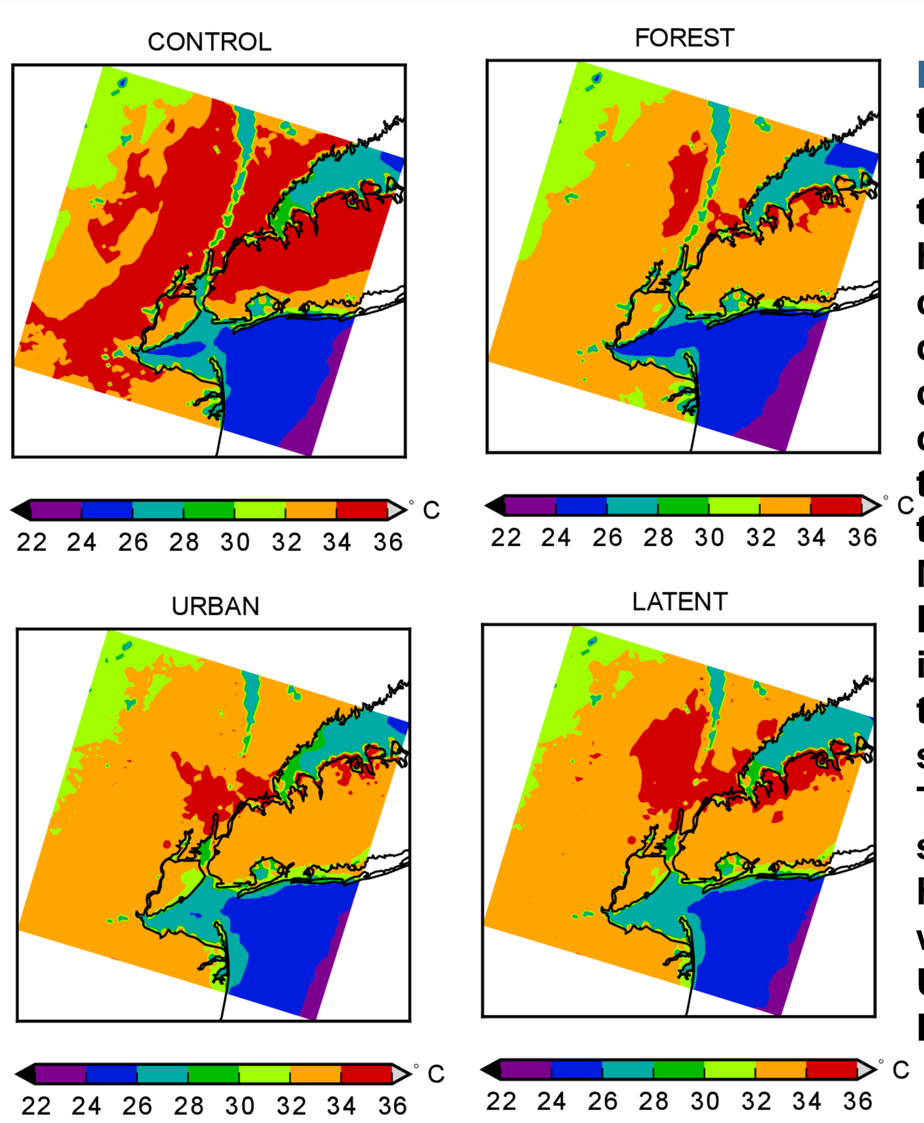

Figure 4. Spatial distribution of the daily maximum temperature from July 4-9, 2010 for each of the simulation cases. Due to the homogeneity of the urban land cover in the CONTROL case, derived from MODIS 20-category land use index classification, the high temperature core extends throughout the entire New York Metropolitan region. In the FOREST case, the urban heat island all but disappears, even though there are still "hot spots" east of the Hudson river. The URBAN and LATENT simulations show a more heterogeneous distribution, with warmer temperatures in Upper Manhattan and the Bronx.

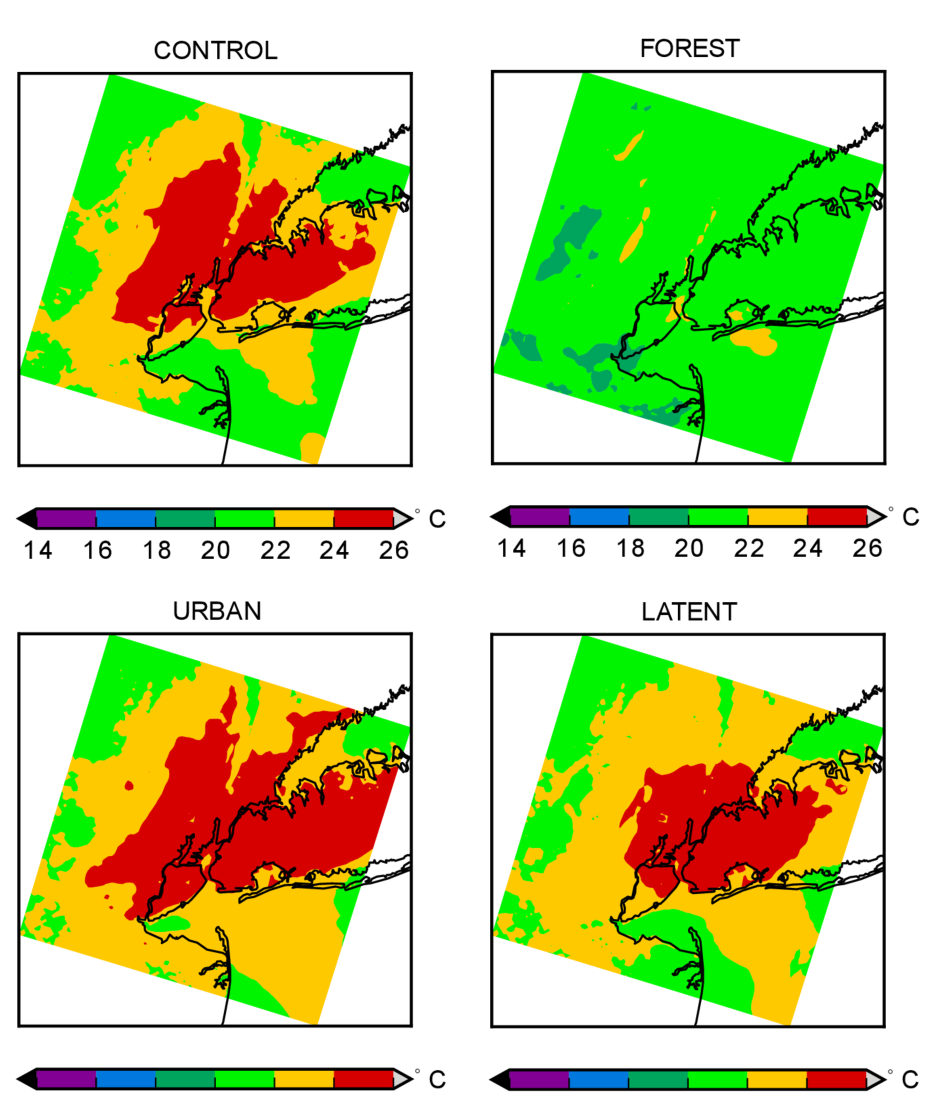

Figure 5. Same as Figure 4, but for daily minimum temperatures. The urban heat island effect is clearly visible in the CONTROL, URBAN, and LATENT simulation cases. In the FOREST case, the high temperature signal all but vanishes due to evaporative cooling from the added retained moisture. The URBAN case exhibits a larger extent of the high temperature core, mainly due to the modified partition of the anthropogenic heat performed in by the cooling tower/urban hydrology performed in the LATENT simulation.

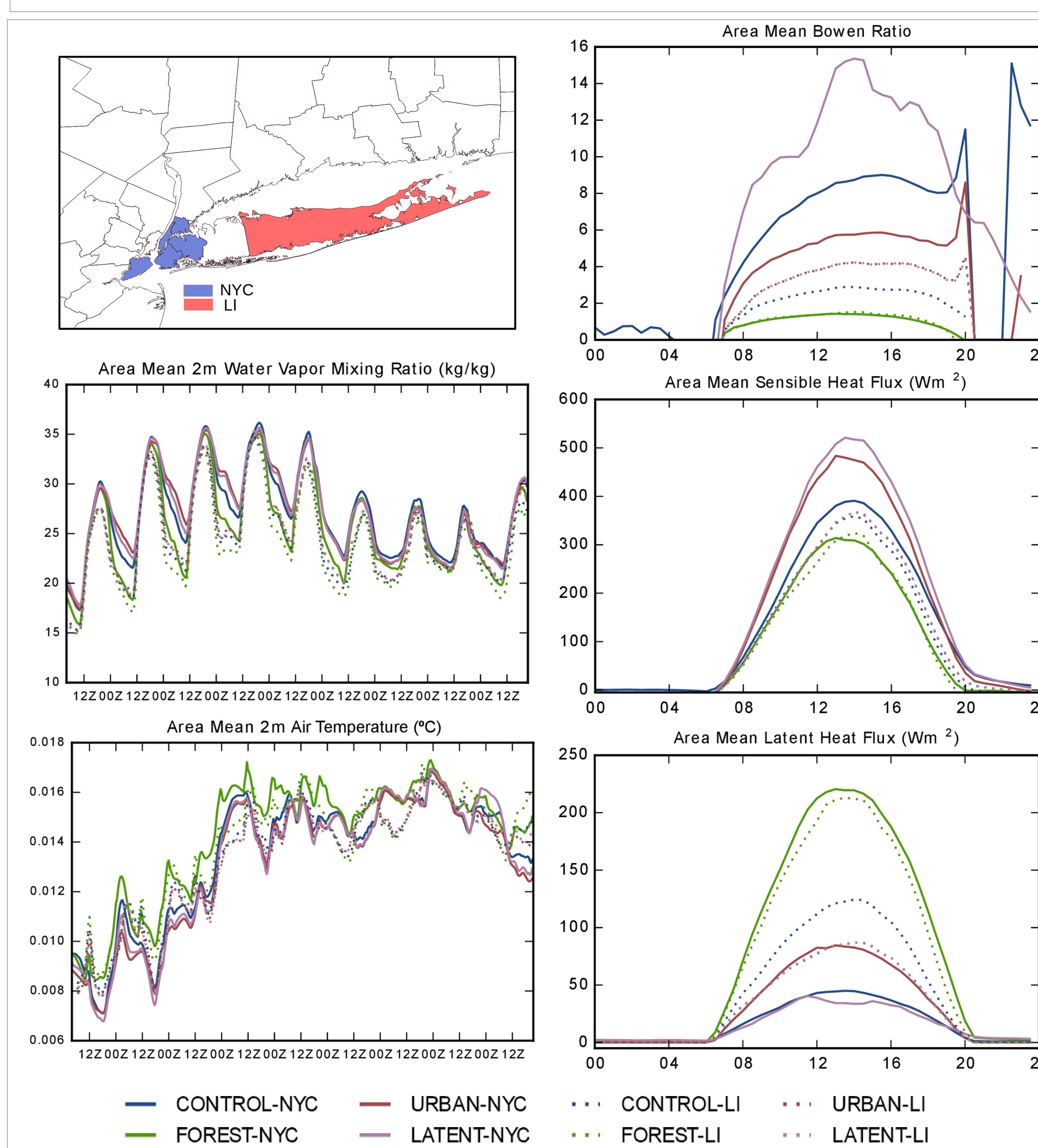

Figure 6. The domain is partitioned into two sections: NYC and suburban Long Island (LI). The progression of the 2m air temperature and water vapor mixing ratio are presented (left column). Daily maximum temperatures do not seem to vary much as they are dominated by the synoptic heat wave conditions. However, nighttime minima show a wider gap, with the FOREST simulation over LI showing a 1-2°C difference over the other cases. The right column presents the climatology of the surface fluxes during the heatwave event, with the urban cases showing both increased sensible and decreased latent heat fluxes.

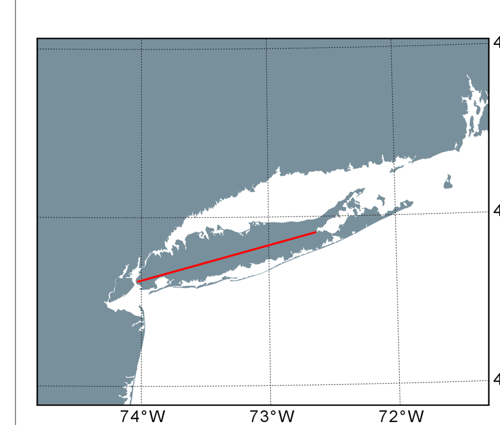

Figure 7. The red line follows the path of a vertical cross-section that traverses Long Island, starting at the highly urbanized boroughs of Queens and Brooklyn, to the end of the suburban/rural Suffolk county.

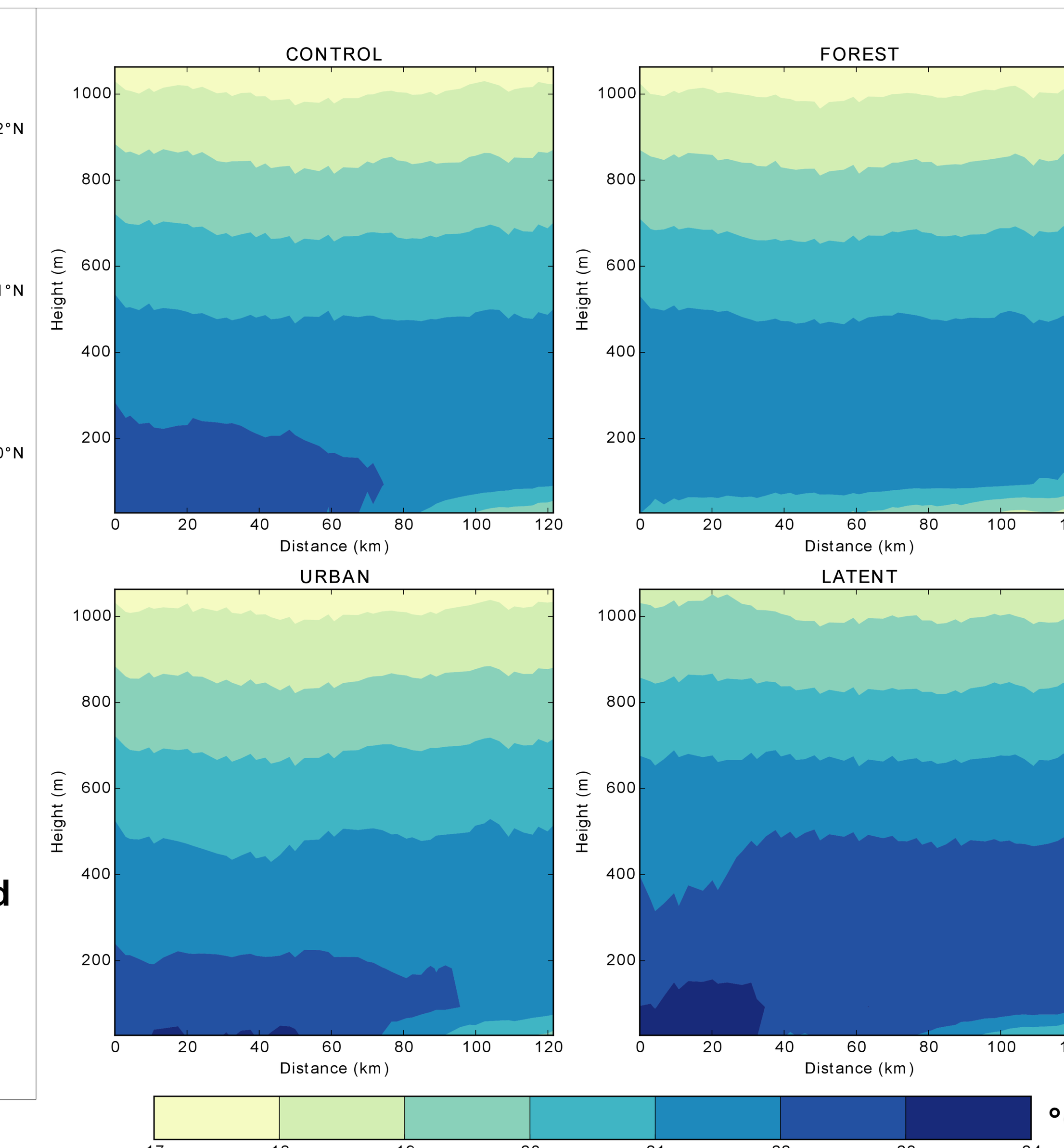

Figure 8. Vertical distribution of the mean daily minimum temperature for the four simulation cases during the heat wave. A slab of warm air extends over the urbanized regions in the CONTROL, URBAN, and LATENT cases, with warmer cores in Brooklyn and Queens. Consistent with other results, LATENT simulation temperatures are warmer, with this difference extending all the way to 300m. The LATENT simulation also exhibits a dip from 0-20 km in the cross-section. The FOREST case shows an inversion layer, which is inhibited with the presence of urban land cover in the other cases.

Summary

The heat wave event appears well represented, with the daily maximum temperatures reaching 39°C as reported by the National Weather Service. The sensitivity of the Long Island region to land cover over NYC is more notable in the nighttime minima, with differences between 1 and 2 °C observed between the FOREST and URBAN/LATENT cases over Long Island. These differences might be due to warm air being advected from the city into the suburban and rural areas in LI, which is in part supported by the vertical temperature cross-section presented in Figure 8. The CONTROL run exhibits slightly higher maximum temperatures over the entire domain than the URBAN run due to the uniform treatment of the land cover, which also affects the extent of the warm temperature heat island to cover the entire New York Metropolitan Area. The URBAN and LATENT simulations show a less spread out nighttime urban heat island, due to both the heterogeneous treatment of the urban land cover with tax-lot derived urban morphology, as well as the addition of cooling tower parameterization.

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