

Simulated Chain Flow between the Augusta and Columbia Metropolitan Areas

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The Urban Heat Island in Augusta

- Urban heat islands (UHIs) are enhanced temperatures in urban regions (Oke, 1982).
- UHIs are studied fairly well for larger cities, but there is a knowledge gap in the extent of UHI effects in smaller or moderately-sized cities such as Augusta, GA.
- Four different types of UHI:
 - Surface
 - Canopy Layer
 - Hydrological
 - **Boundary Layer**

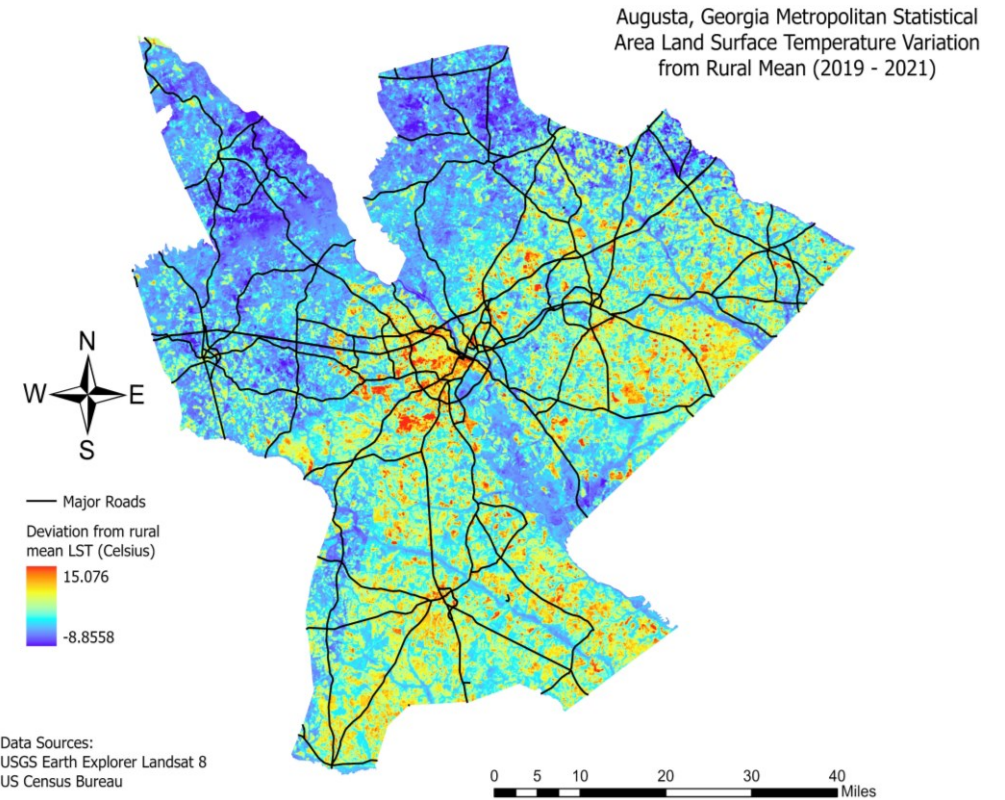
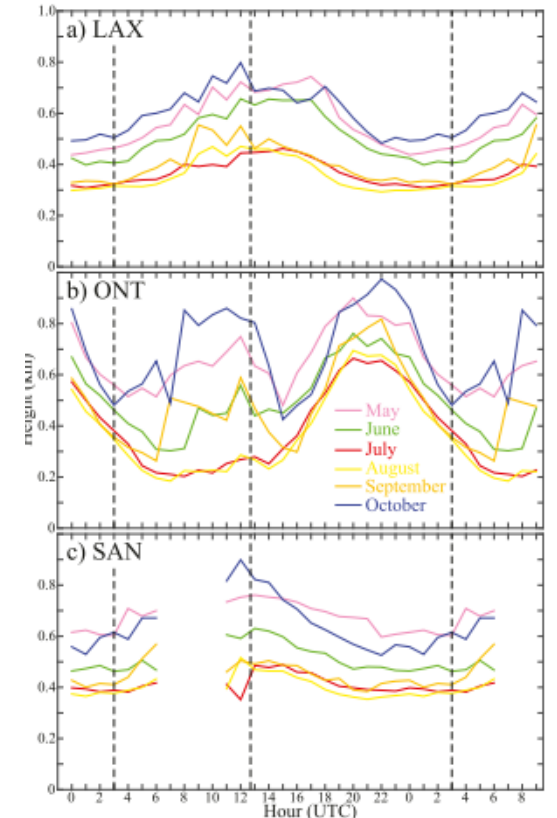
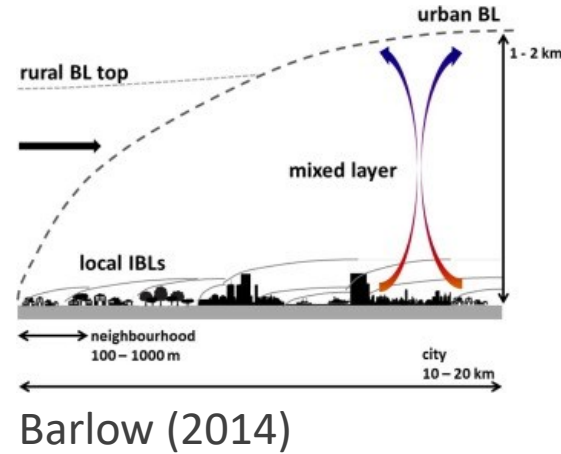


Figure prepared by Max Appelbaum from University of Georgia

The Urban Boundary Layer

- The Urban Boundary Layer (UBL; Barlow, 2014) describes enhanced mixed layer heights due to increased turbulence from the urban surface layer.
 - Increases in sensible heat fluxes increases turbulent mixing during the day.
 - At night, the increased heat storage fluxes continue surface driving of turbulent mixing in the “residual layer”, stalling or eliminating the formation of a nocturnal surface inversion.
 - Observations are traditionally limited, although can be studied in large urban areas with AMDAR soundings. (Rahn & Mitchell, 2016)

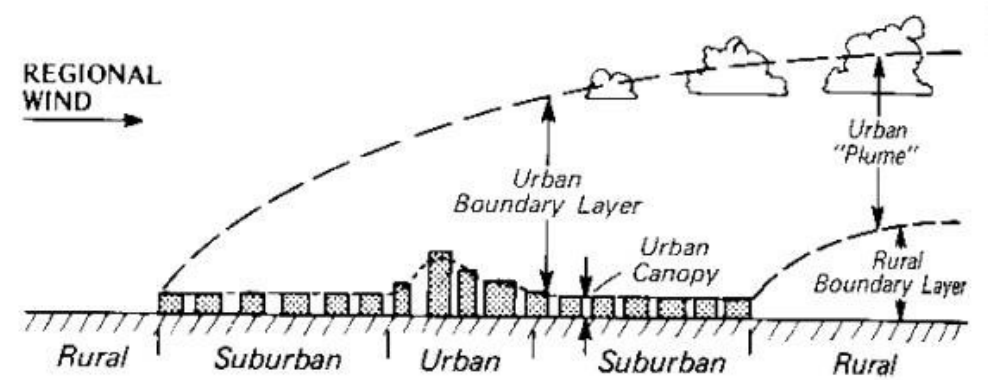


Rahn & Mitchell (2016)



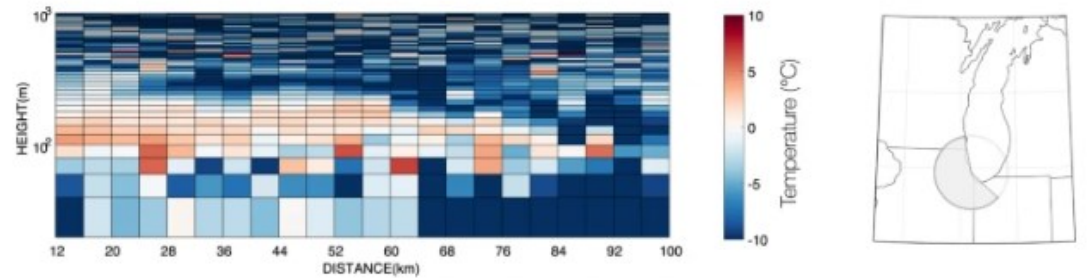
The Urban Boundary Layer

- UBLs can be advected downwind of the urban center in the form of “urban plumes” (Oke, 1987).
 - Plume has been simulated for large urban areas such as Chicago (Cosgrove and Berkelhammer, 2019).
 - These can aid in the fate and transport urban pollutants, especially nocturnally.
 - They allow for the formation of urban convection, or the urban rainfall effect (URE), urban convection effect (UCE), often occurring downwind of urban centers (McLeod et al & Shepherd, 2017).
 - Similar observation problem for urban plumes, but remote sensing can aid in seeing some of the effects of urban plumes, such as rainfall.



Oke (1987)

a. Heat movement over land - UL Site

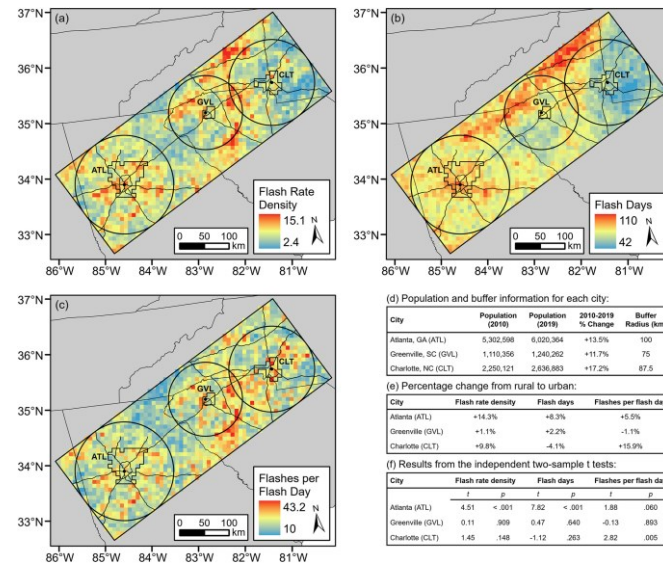


Cosgrove & Berkelhammer (2019)

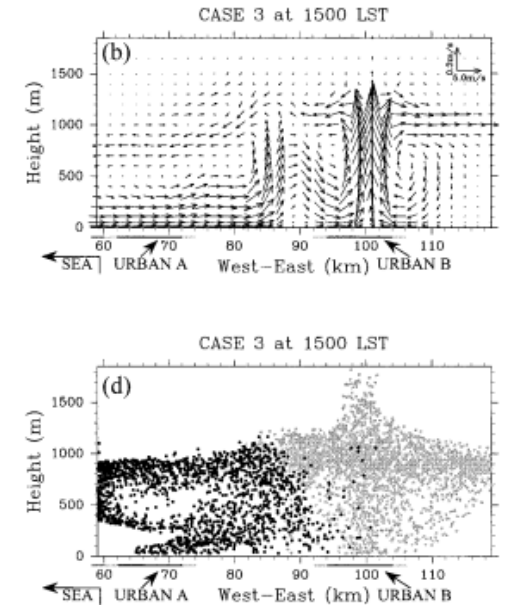


The “Urban Climate Archipelago” & Chain Flow

- UHI effects are often studied isolated from other cities, but large urban regions can demonstrate connective properties. (Shepherd, et al. 2013)
- “Chain flows” can allow exchanges of particles between UBLs (Ohashi & Kida, 2002).
- Other large scale UBL connections manifest such as enhanced lightning over connected urban regions such as along the “I-85 Corridor” (Burke & Shepherd, 2023).



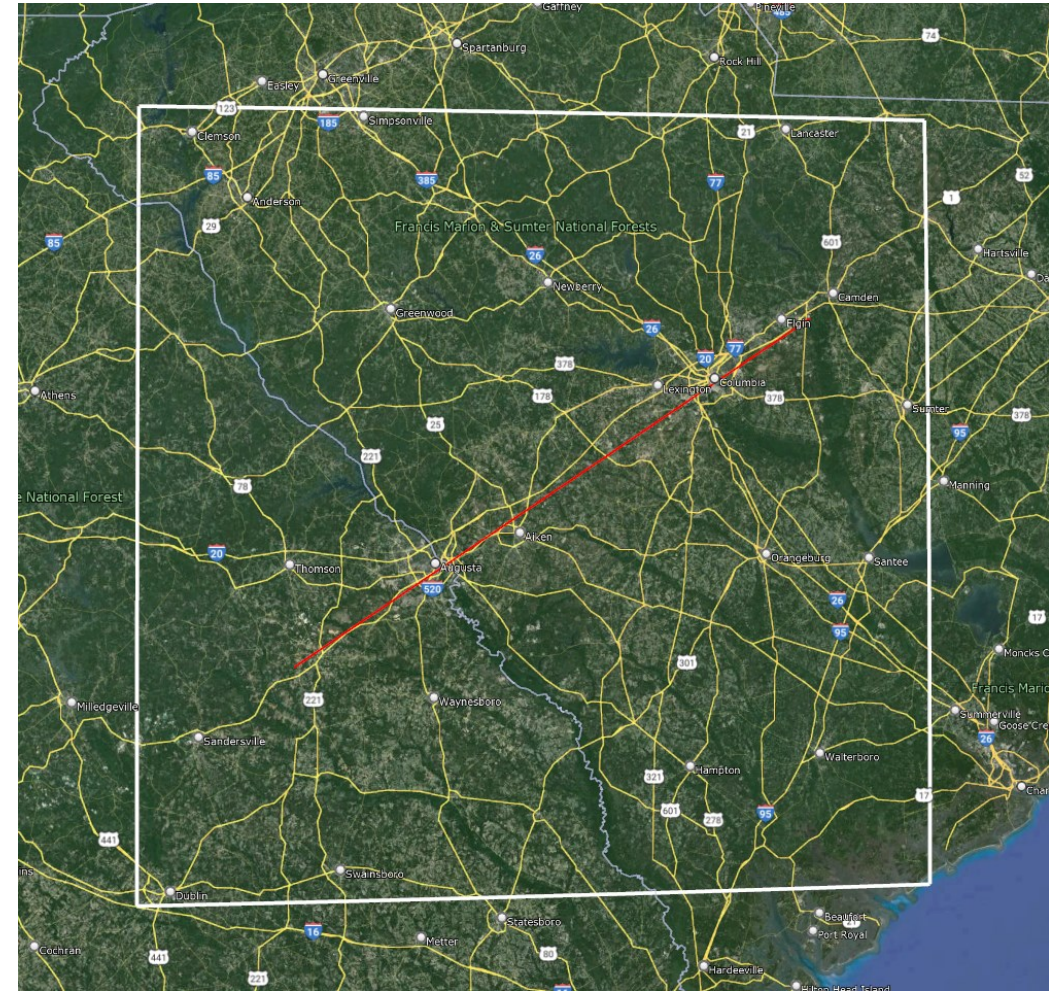
Burke & Shepherd (2023)



Ohashi & Kida (2002)

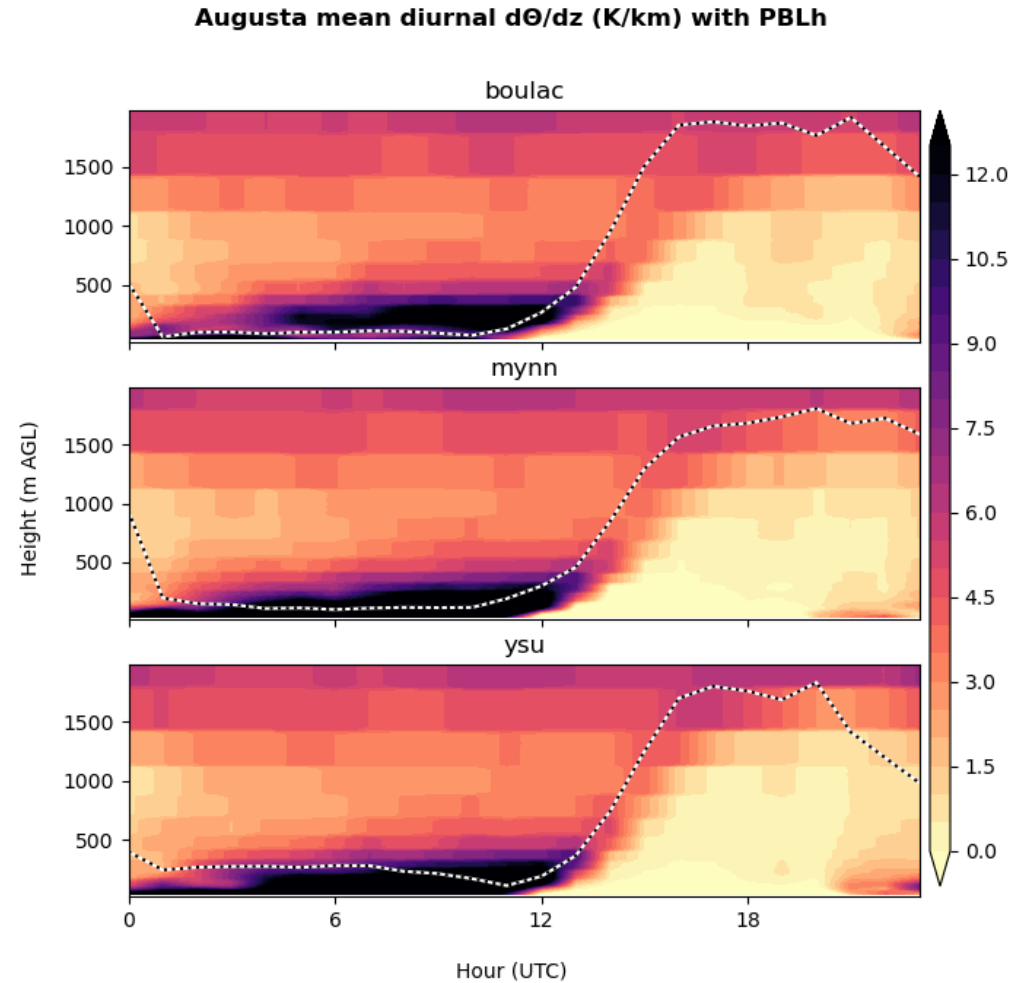
Urban Boundary Layer WRF Simulations

- Utilized the Weather Research and Forecasting (WRF) atmospheric model. (Version 4.4.2) (Skamarock, 2019)
 - Single domain of 250x250 grid points with 1km spacing.
 - Initial and boundary conditions provided by HRRR.
 - 40 eta layers up to 50hPa (20 beneath 850hPa).
 - Single-Layer Urban Canopy Model (SLUCM) using NLCD40 land categories.
- Analyzing sensitivity to PBL/turbulence parameterization
 - MYNN (used in SRS operational WRF forecasts)
 - Bougeault/Lacarrere (BouLac)
 - Yonsei University (YSU)
- Vertical gradients of potential temperature (θ) are analyzed along a transect.
 - Values ≤ 0 K/km are at the dry adiabatic lapse rate and represent the most unstable air.



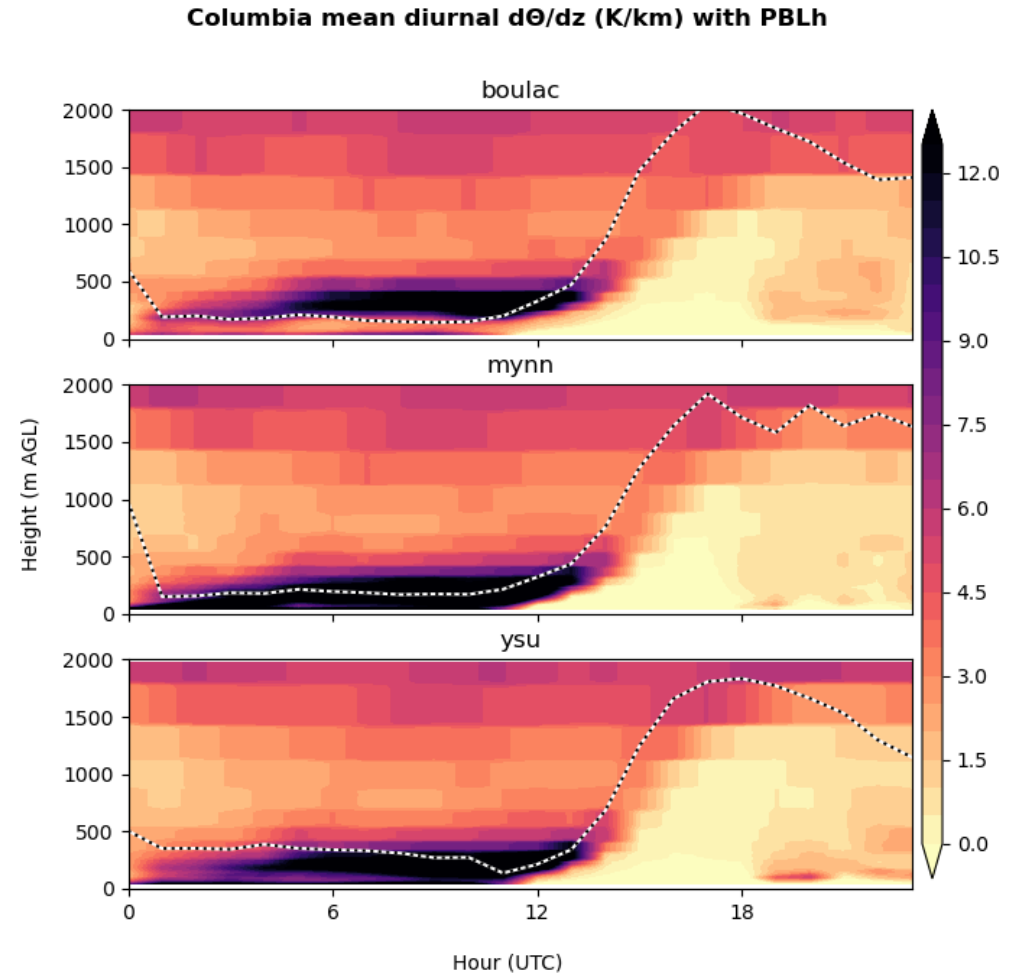
Diurnal PBL Evolution - Augusta

- Nocturnal residual layer picked up in BouLac and YSU simulations but is not nearly as strong in the MYNN.
- YSU has a steeper nocturnal decrease in PBLh, but delayed development of a surface inversion in Augusta.



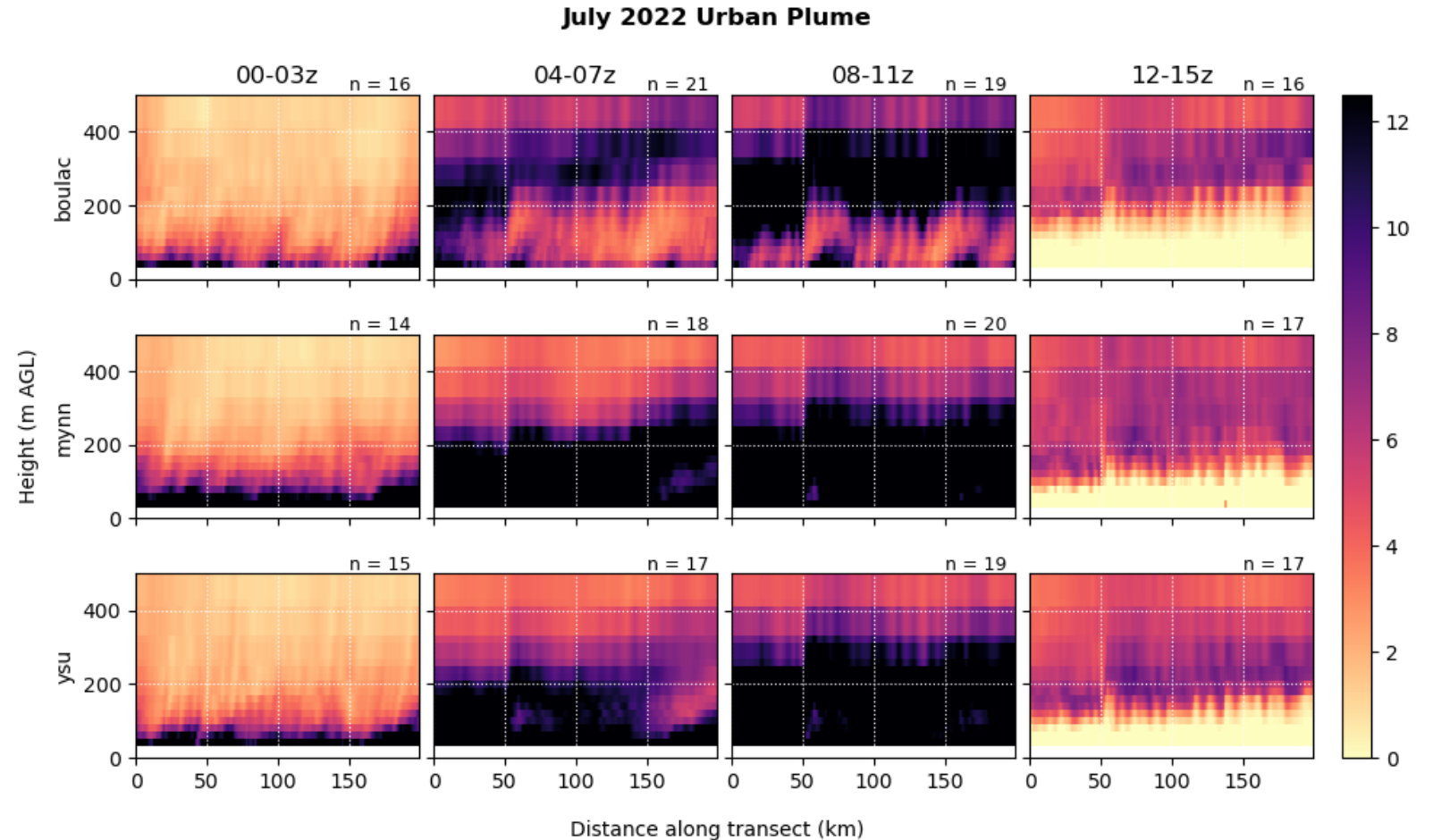
Diurnal PBL Evolution

- Compared to Augusta, Columbia has a much more defined residual layer in BouLac and YSU simulations.
- Additionally, deeper daytime PBLh is seen in all three simulations.



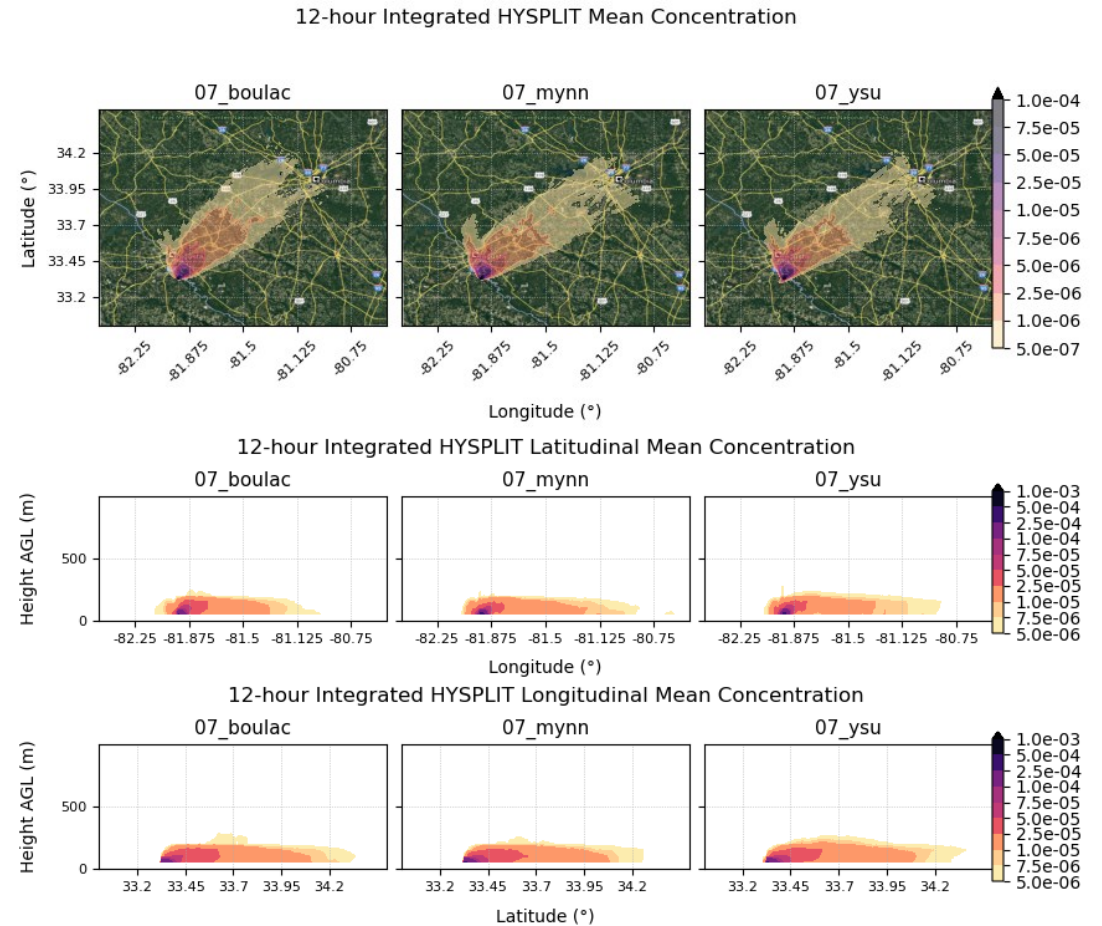
Streamwise UBL cross-sections

- Some indication of a connected UBL in the BouLac simulation, but any connective features are generally muted out in MYNN and YSU, at least along the transect.



HYSPLIT Simulations

- All three simulations show a general tendency for the transport to move from Augusta to Columbia.
- With BouLac, the plume tends to go west of Columbia, compared to the eastward motion of the MYNN and YSU simulations.
- All simulations show a coalescence of the plume near the Congaree river, showing a river/wetland valley effect in the early morning.



Conclusions

- Modest UBL signatures are picked up at the urban centers of Augusta and Columbia.
- BouLac seems to promote more mixing, with strong UBL and connective plume schemes.
- MYNN and YSU do not promote as much mixing, and the connective chain flows are not as strong.
- HYSPLIT simulations show that there is a decent exchange between the urban regions, with more of a westward bias seen in BouLac compared to MYNN and YSU.



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