Improved Heterogeneity in Urban Climate Simulations from HRLDAS

Allison Cullen

Wayne State University, SIParCS

Mentor: Steve Sain

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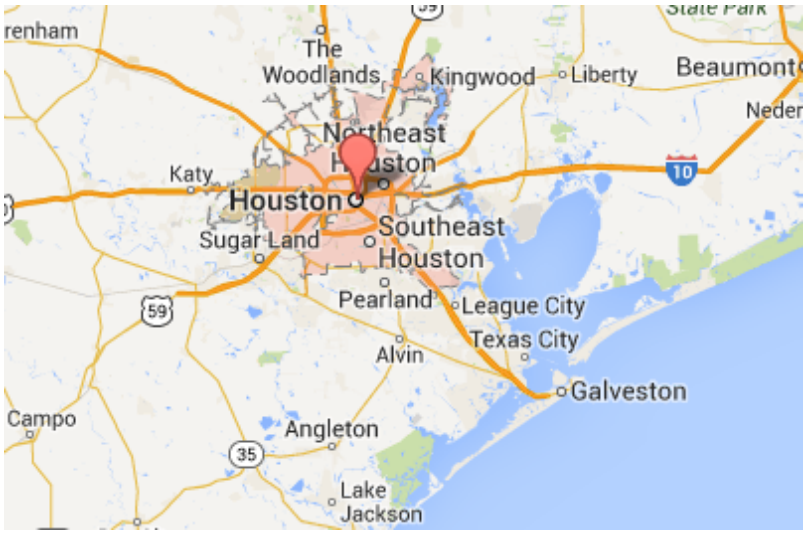
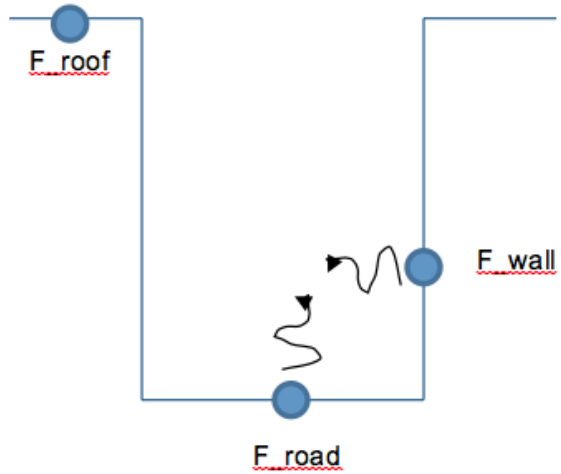
Motivation: The SIMMER Project

- Extreme heat and climate change are serious public health concerns
- The System for Integrated Modeling of Metropolitan Extreme Heat Risk (SIMMER) studies the impact of heat stress and urban heat islands on public health
  - Simmer Website: http://www.rap.ucar.edu/projects/simmer/
- One objective of the SIMMER Project is to improve the representation of urban land cover and its accompanying radiative and thermal characteristics at local and regional scales
- Our focus is on Houston, where we see urban heat island effects



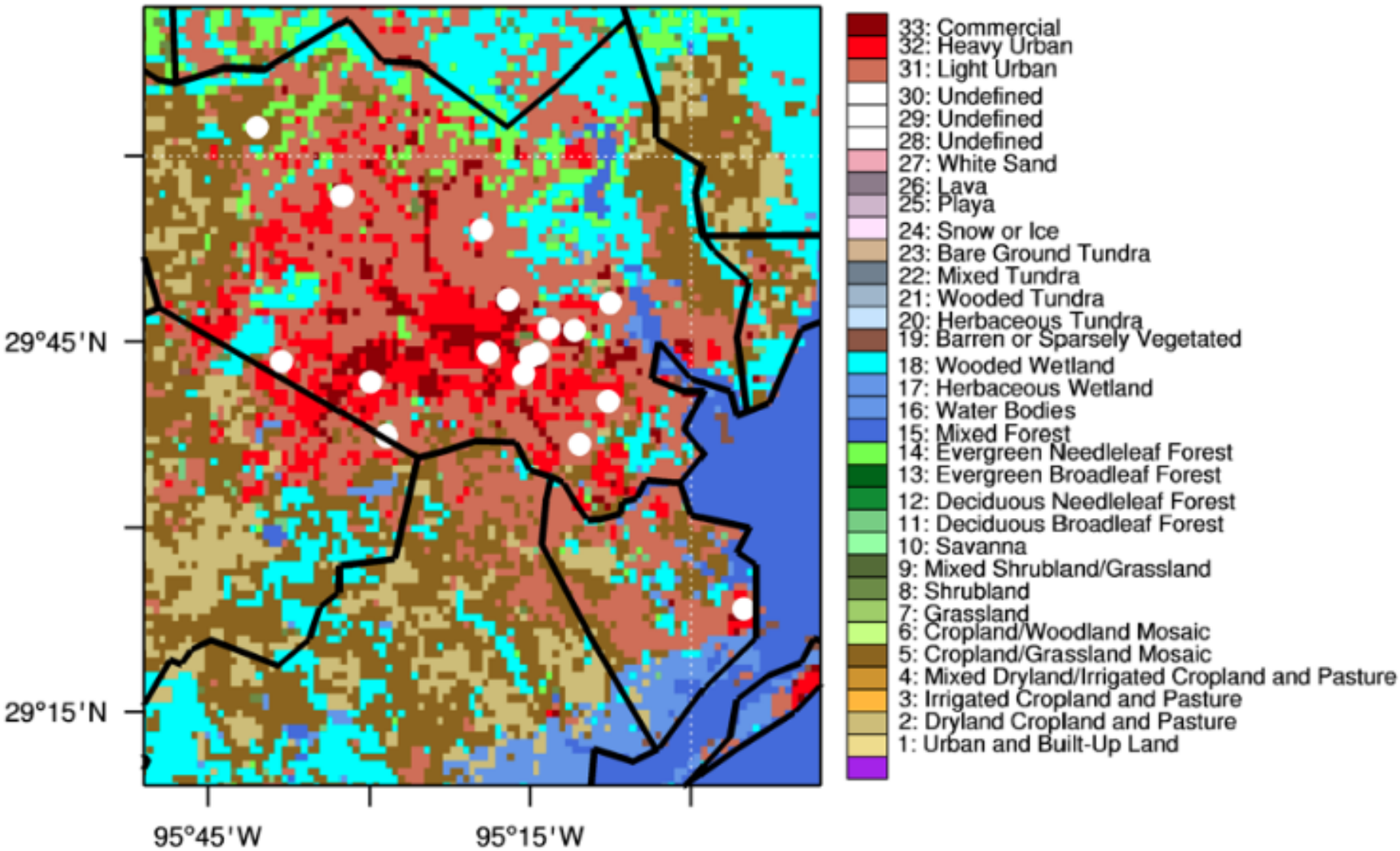
HRLDAS

- The High Resolution Land Data Assimilation System (HRLDAS) simulates temperature in urban environments
  - Part of the offline version of the Noah LSM
  - Driven by the NLDAS-II forcing fields (coming from the NARR reanalysis) and also by small scale land cover data
  - 1-layer UCM
  - Hourly simulations at 1-km resolution
  - We focus on the temperature in the summer months (June through August)
  - Also focus on midnight and noon (to compare to MODIS)

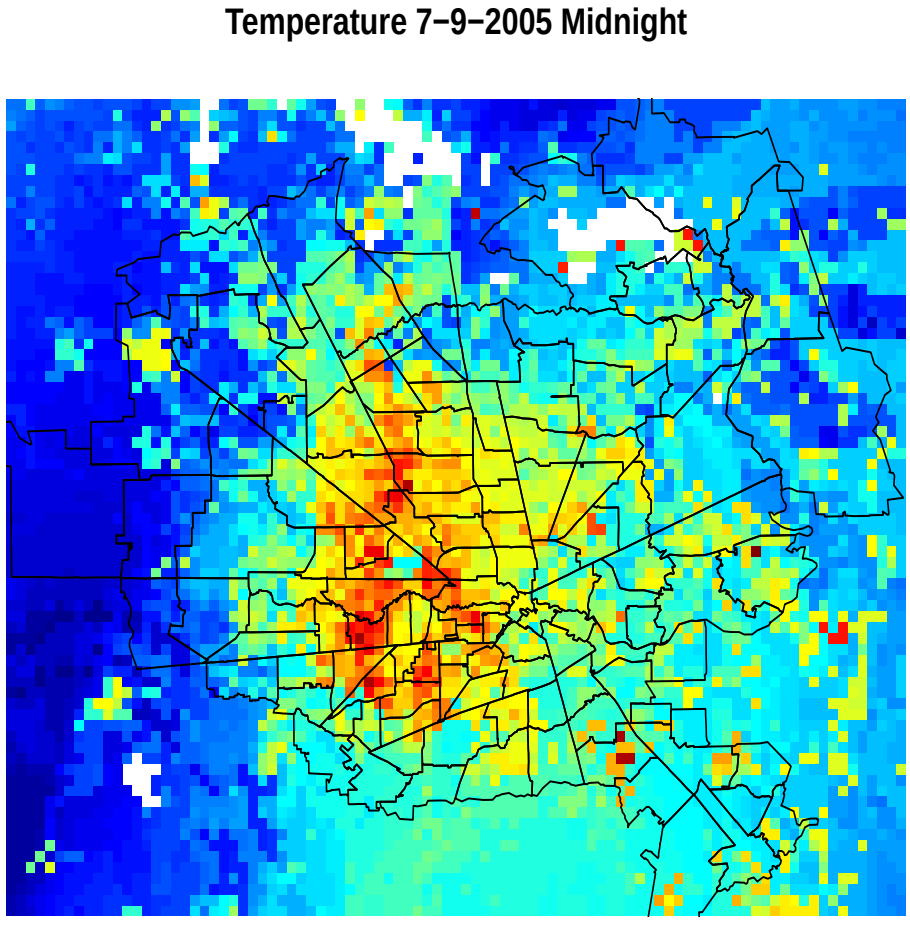


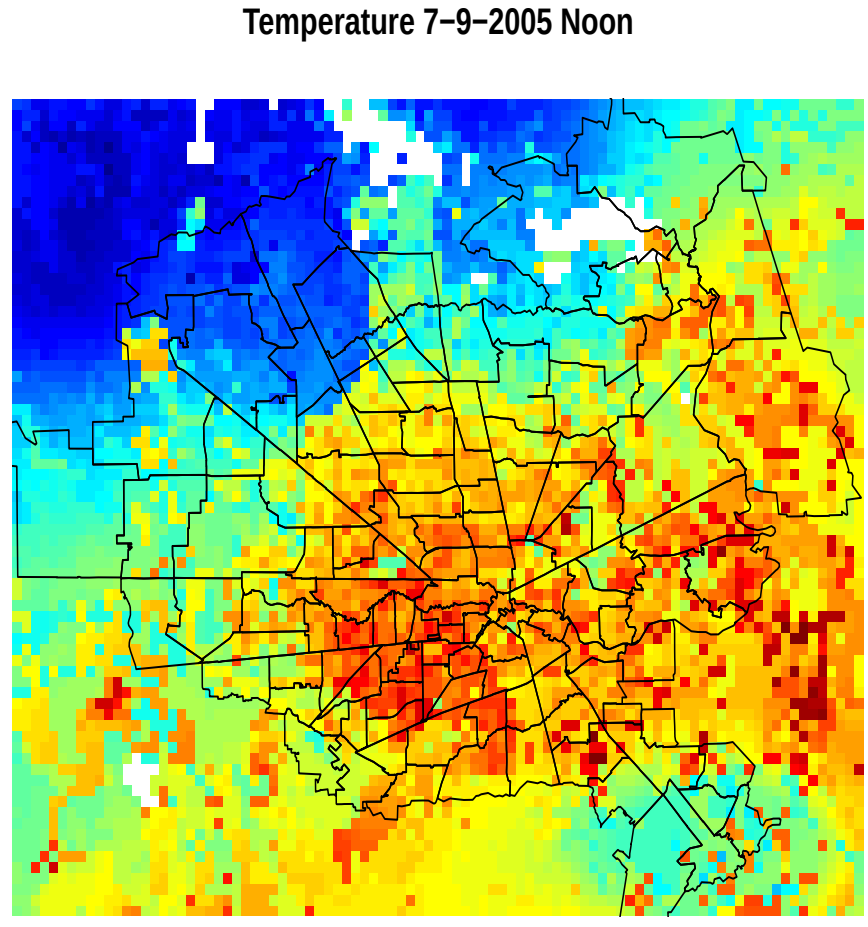
Land Use Types

Land use types come from a 30-m National Land Cover Database and are determined based on characteristics of the buildings in each grid cell



Example of HRLDAS Output



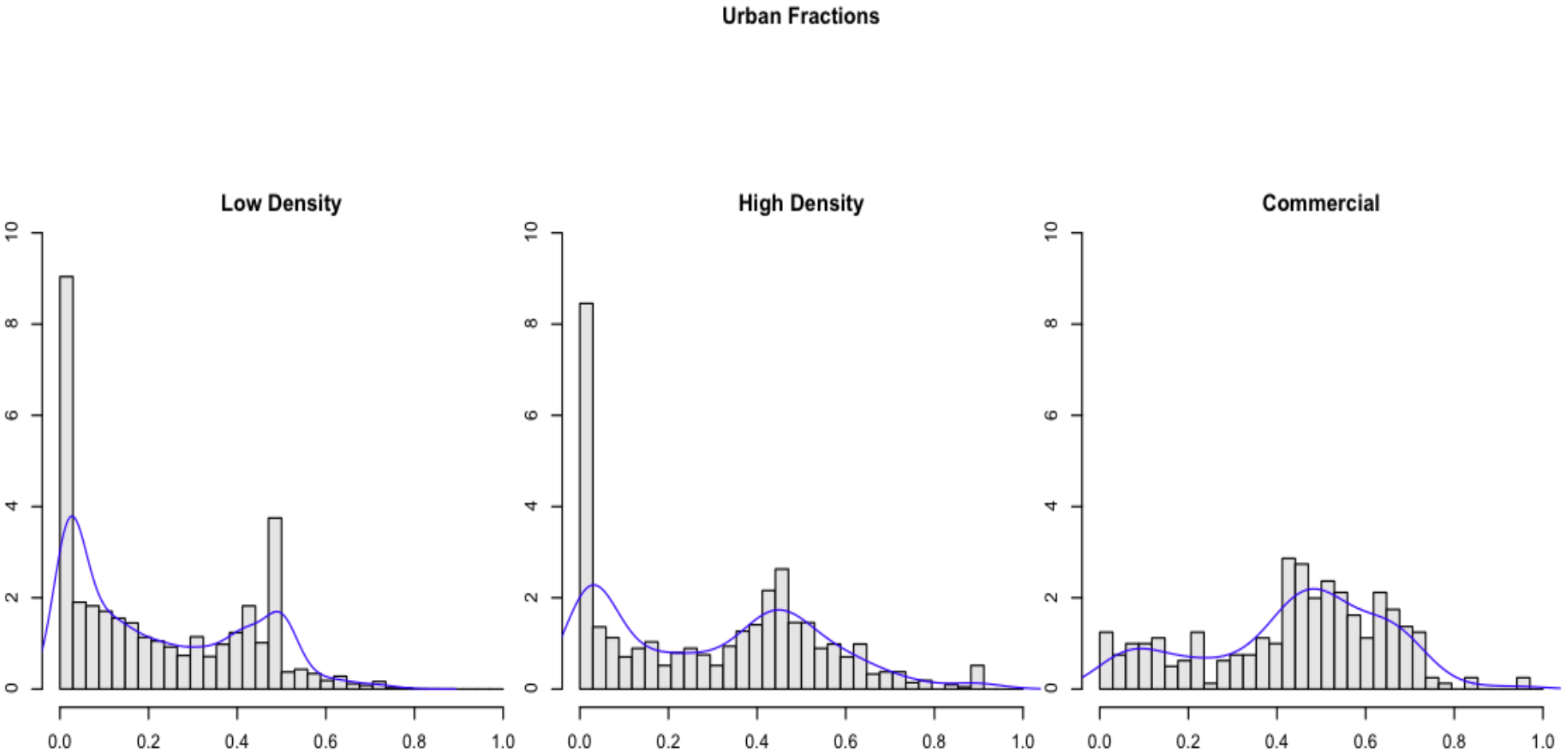


Adding Urban Fraction Heterogeneity

- Inlcuded in the characteristics of each grid cell is a fraction of the land that is urban, vegetated, water, etc.
- We focus on the three urban land use types: low density, high density and commercial
- Previously, the urban fraction was fixed based on the land use type
  - 50% for low density
  - 90% for high density
  - 95% for commercial
- Instead, the National Urban Database with Access Portal Tool (NUDAPT) was used to define the urban fraction for each grid cell
  - This allowed cells to have more varying urban fraction percentages
  - More realistic spatial depiction of the urban heat island

Heterogeneous Urban Fractions

We see different distributions of urban fraction for the different land use types and many small urban fractions

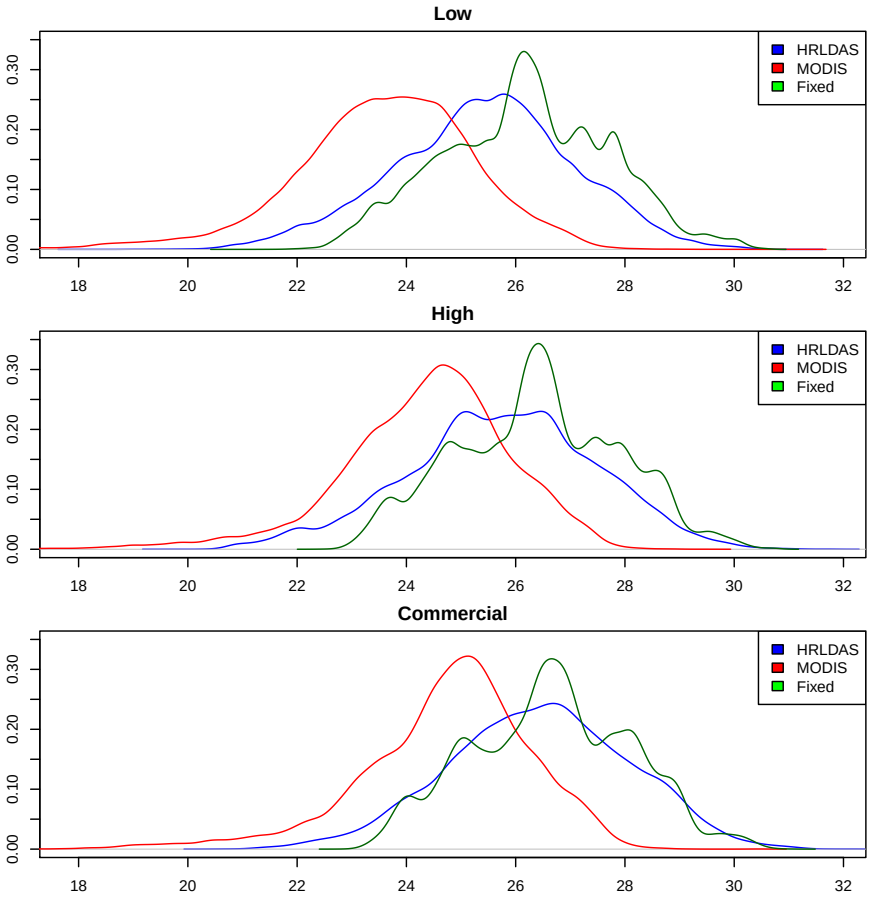


Comparison to Other Outputs

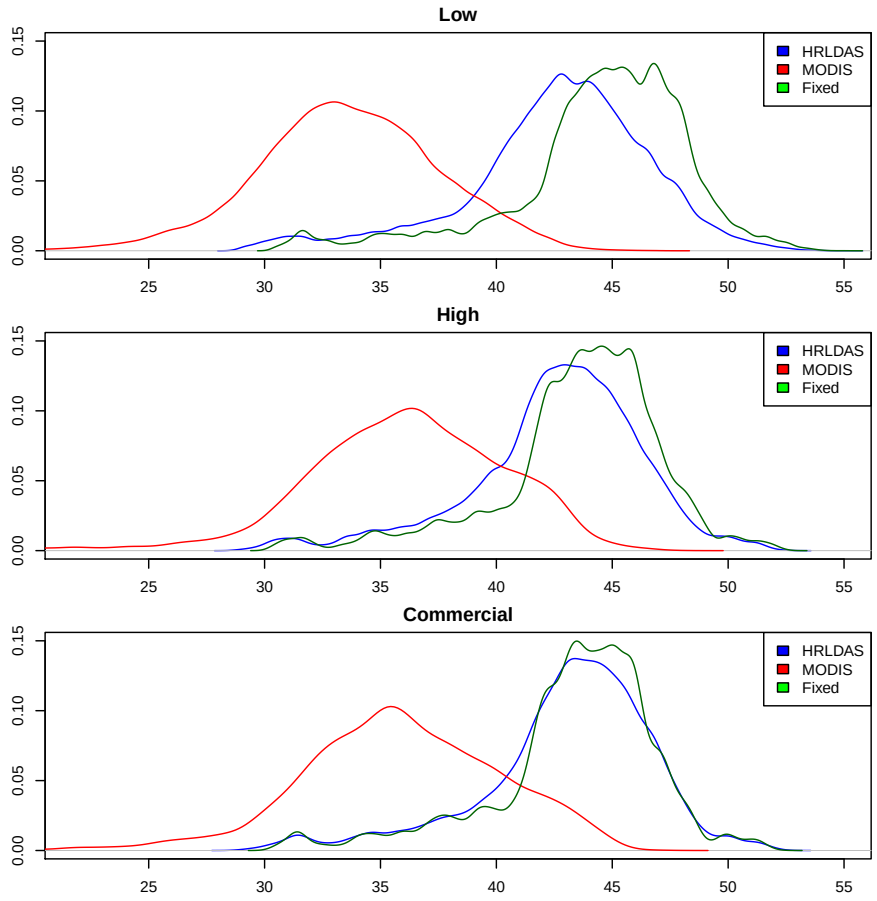
- We want to evaluate improvements in the model from this added heterogeneity
- We compared the HRLDAS output (including NUDAPT data) to the temperatures using a fixed urban fraction and the satellite data from MODIS

2005 Temperature Distributions

Midnight



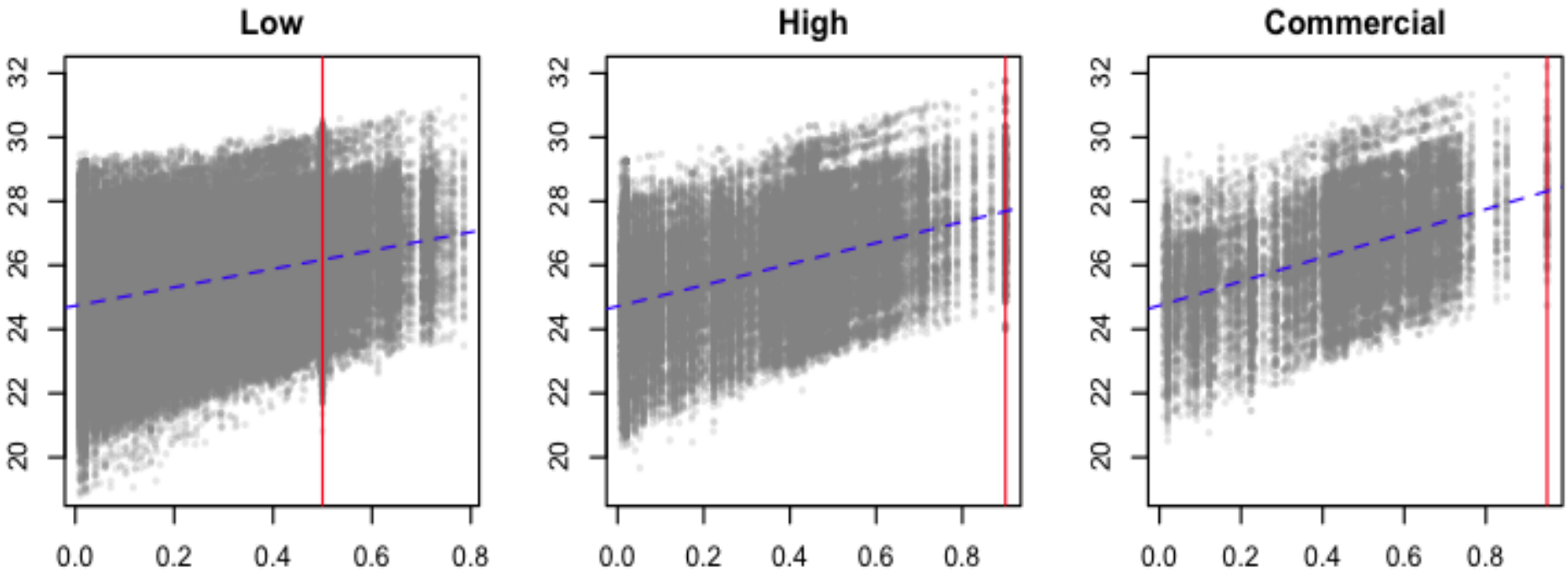
Noon



We see that there is a strong warm bias in the model output compared to MODIS

Land Use Types and Urban Fraction

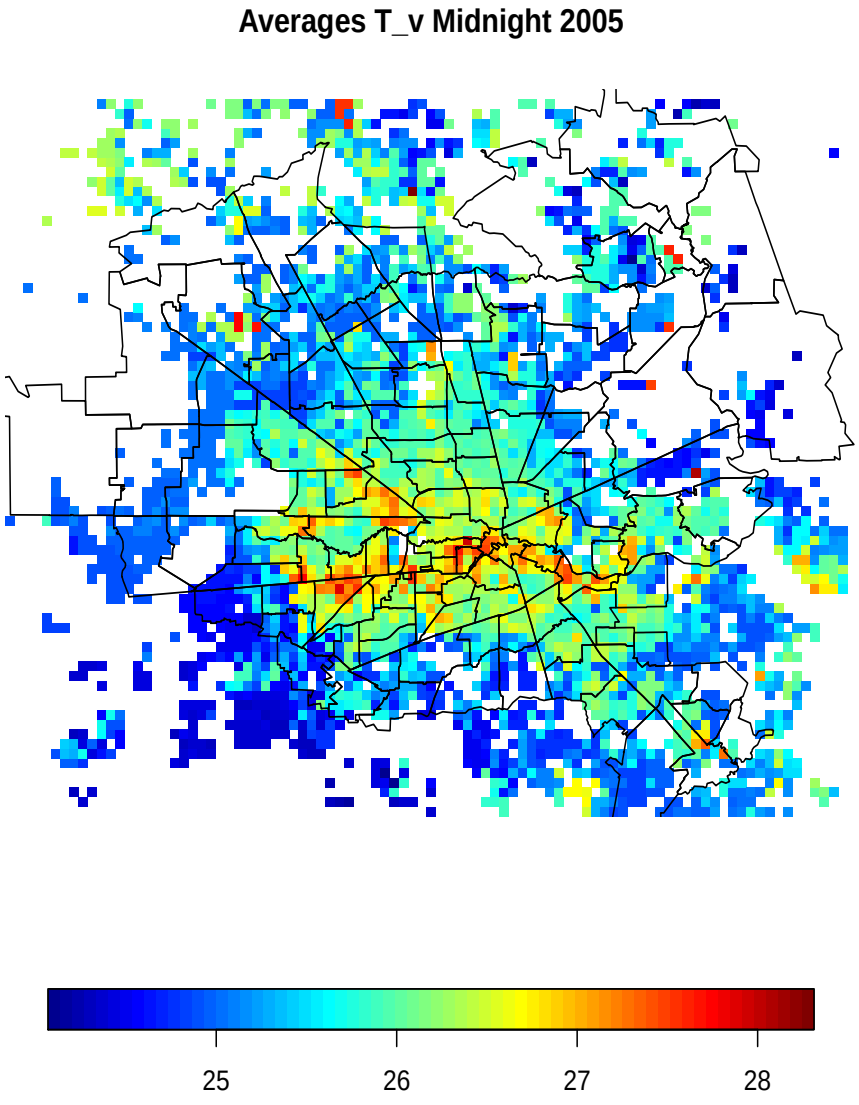
- We see different slopes for the land use types
- We get more heterogeneity in the temperatures
  - From approximately 19 to 32
  - Smaller ranges of temperature with fixed fractions
- High density and commercial have few cells with urban fractions as high as the fixed fractions defined

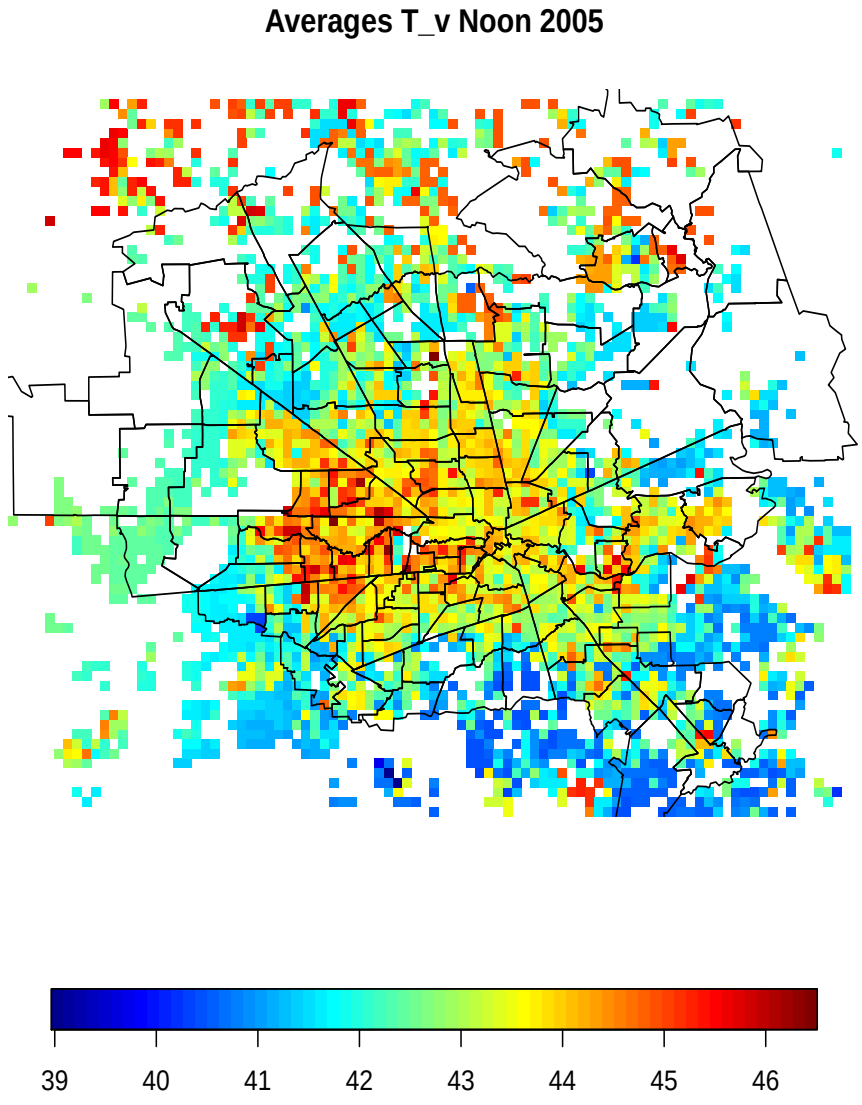


- The NUDAPT HRLDAS output shows an improvement in heterogeneity over the fixed urban fractions from a look-up table

Approach

We take the average of the summer (JJA) temperatures for each grid cell to limit the effect of day-to-day changes based on the weather





Modeling the Temperatures

- For the temperatures using a fixed urban fraction,

$$T_f = \text{ land use} + \text{forcing}$$

  - Heuristic arguments show that this fixed fraction temperature does not include any variability due to urban fraction
- The temperatures from HRLDAS would also depend on the variable urban fraction

$$T_v = \text{ land use} + \text{urban fraction} + \text{land use} : \text{urban fraction} + \text{forcing}$$

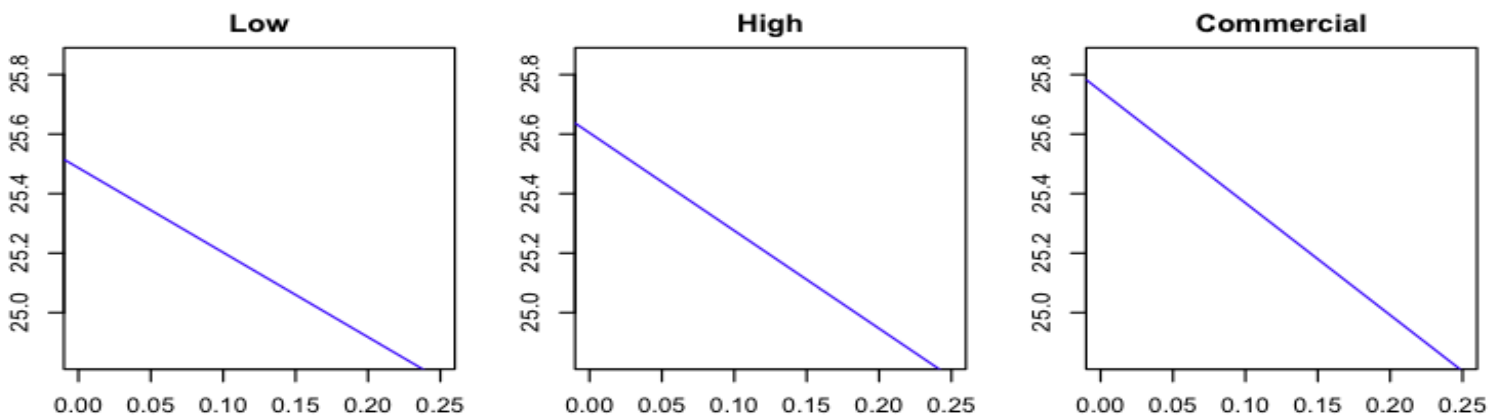
  - Here urban fraction and land use are not the same and an interaction is present

Regression

- We fit this regression for T_v using R and got the following estimates for the regression coefficients

Coefficient	**Estimate**	**Std. Error**	**T value**	**p-value**
Intercept	25.487	0.004	76584.3	<2e-16
land use High	0.118	0.008	14.306	<2e-16
land use Commercial	0.259	0.016	16.277	<2e-16
alpha	-2.844	0.020	-143.616	<2e-16
land use high : alpha	-0.443	0.035	-12.504	<2e-16
land use commercial : alpha	-0.924	0.060	-15.349	<2e-16
longitude	0.017	0.017	1.031	0.302
latitude	-0.289	0.018	16.103	<2e-16

- The estimates show not only different intercepts for the land use types but also different slopes (the interactions)



Linear Model Comparisons

- Using ANOVA, we can compare this full model to a model not including the urban fraction
  - Full Model: T_v =land use + urban fraction + land use : urban fraction + forcing
  - Reduced Model: T_v =land use + forcing

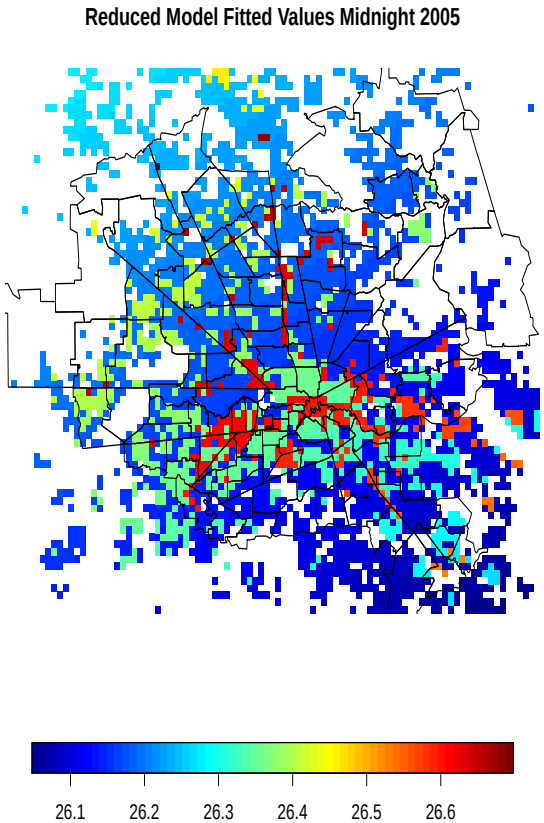
Model	**SSE**
Reduced	1364.86
Full	110.57

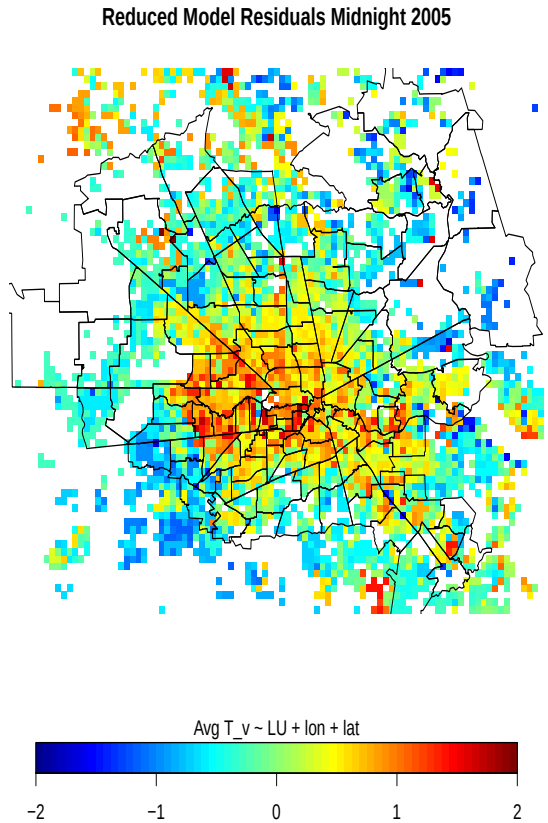
- We calculate the coefficient of partial determination

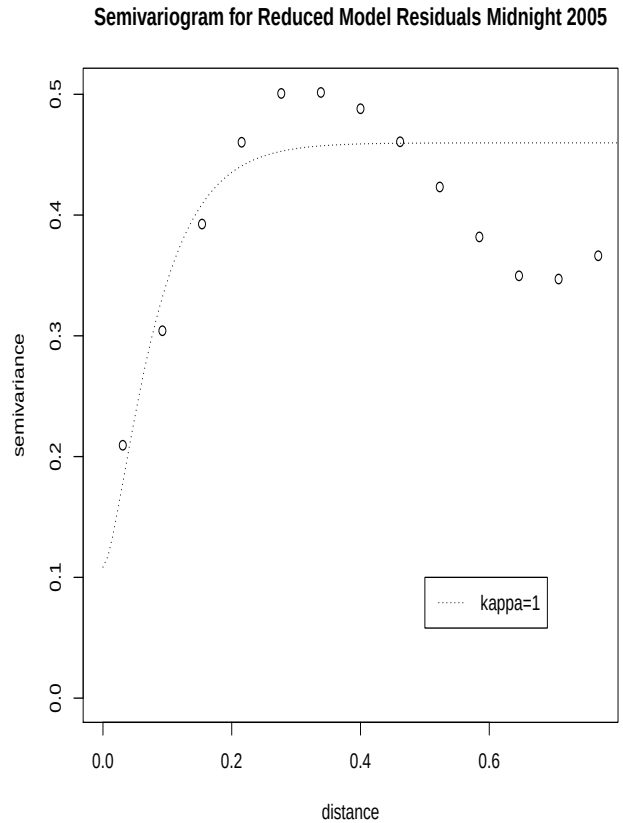
$$\frac{SSE_{reduced} - SSE_{full}}{SSE_{reduced}}$$

and we see that the added variability from including urban fraction when already accounting for land use is about 91.9%

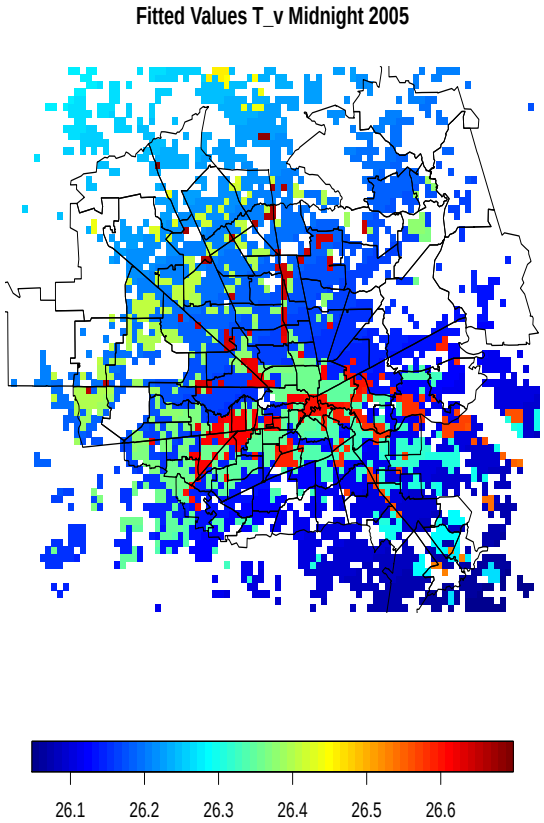
Regression Plots: Reduced Model

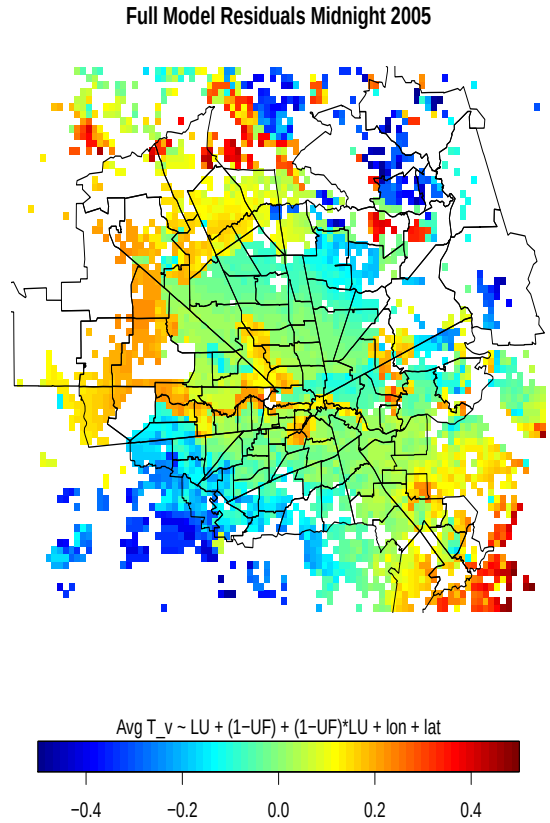


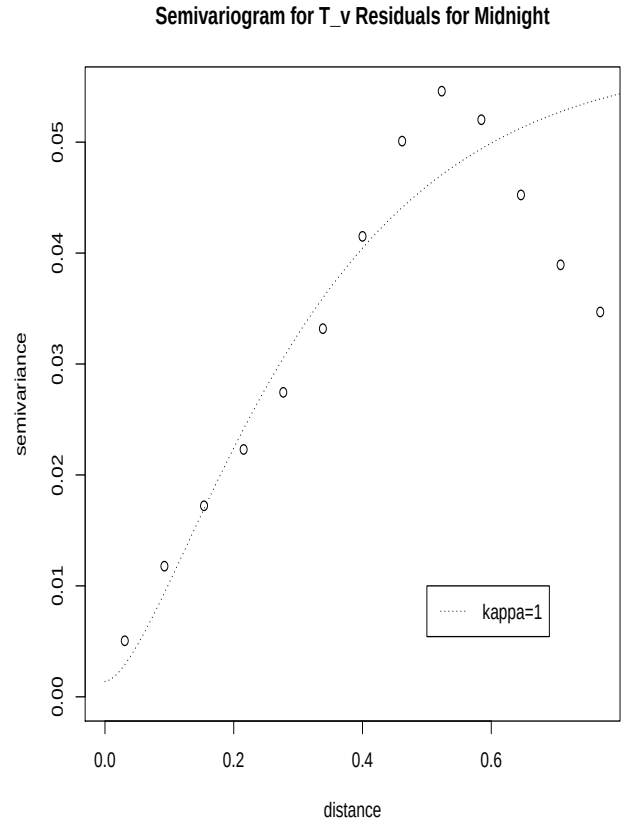




Regression Plots: Full Model







- The fitted values are very similar to the reduced model
- But we have reduced the size of the residuals
  - Range reduced from ≈ 3.8 to ≈ 1.2
- The semivariance has also been reduced
  - Sill reduced from ≈ 0.45 to ≈ 0.057

Future Work

- Examine the added variability in models for noon
- Do this analysis for other years (data for 2002-2010)
- Compare results for multiple years

Acknowledgments

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Thank you

Questions?