Atlanta Urban Heat Island and Air Quality Modeling Study
Overview

Dale Quattrochi (NASA), Bill Crosson (USRA), Maury Estes (USRA), Maudood Khan (EPD), Gordon Kenna (CC), Lucie Griggs (CC), USRA, Bill Lapenta (NASA), Steve French (Ga Tech).

October 27, 2005

Background: Project ATLANTA

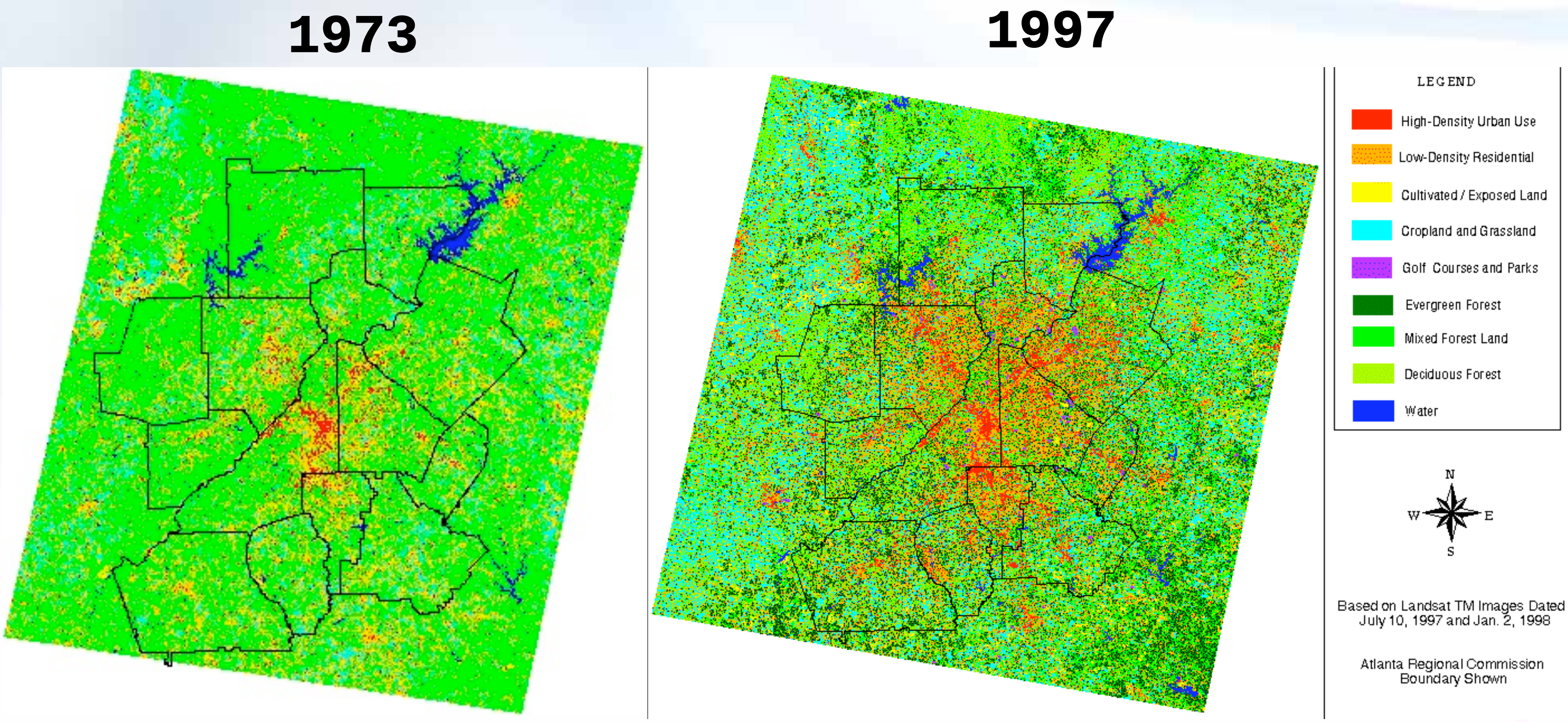
Urban Air Quality Modeling Project

- Spatial Growth Modeling
- Model Urbanization
- Results
- Lessons Learned

Objectives

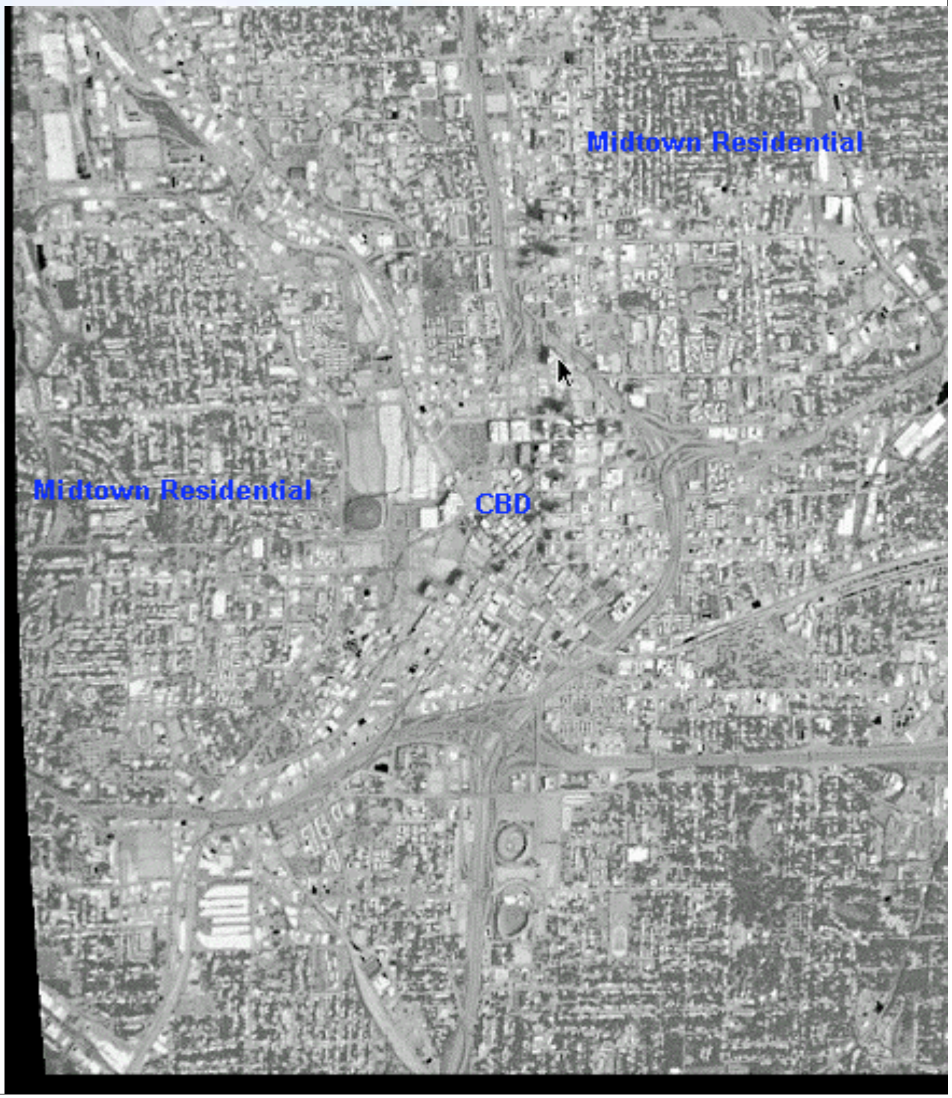
- Characterize Urbanization Extent and Rate of Change
- Describe the Urban Heat Island Effect
- Evaluate Urbanization Environmental Impacts with Remote Sensing Data
- Incorporate Urbanization in Meteorological and Air Quality Modeling
- Modeling Results

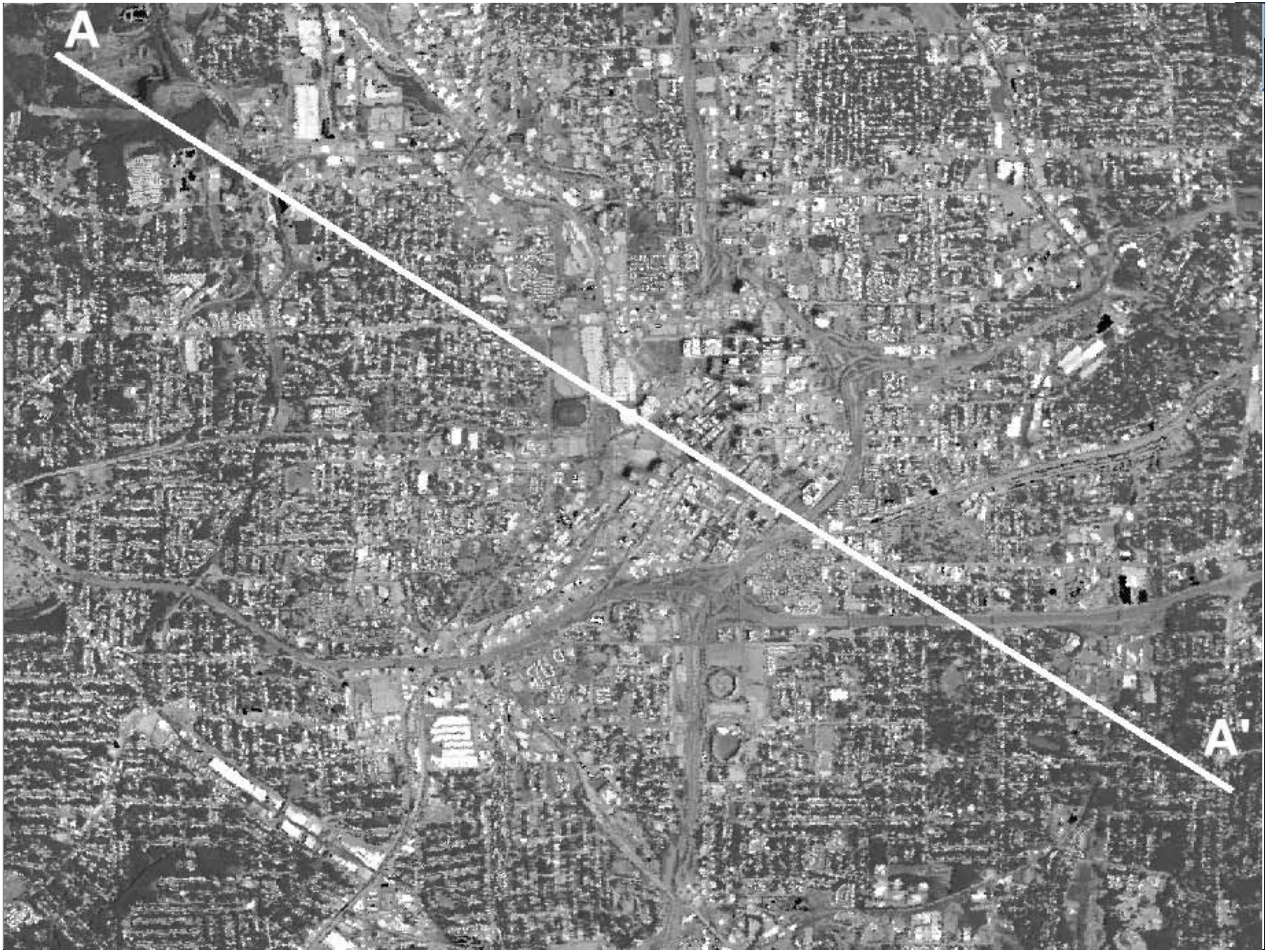
Historical Atlanta Land Use Change

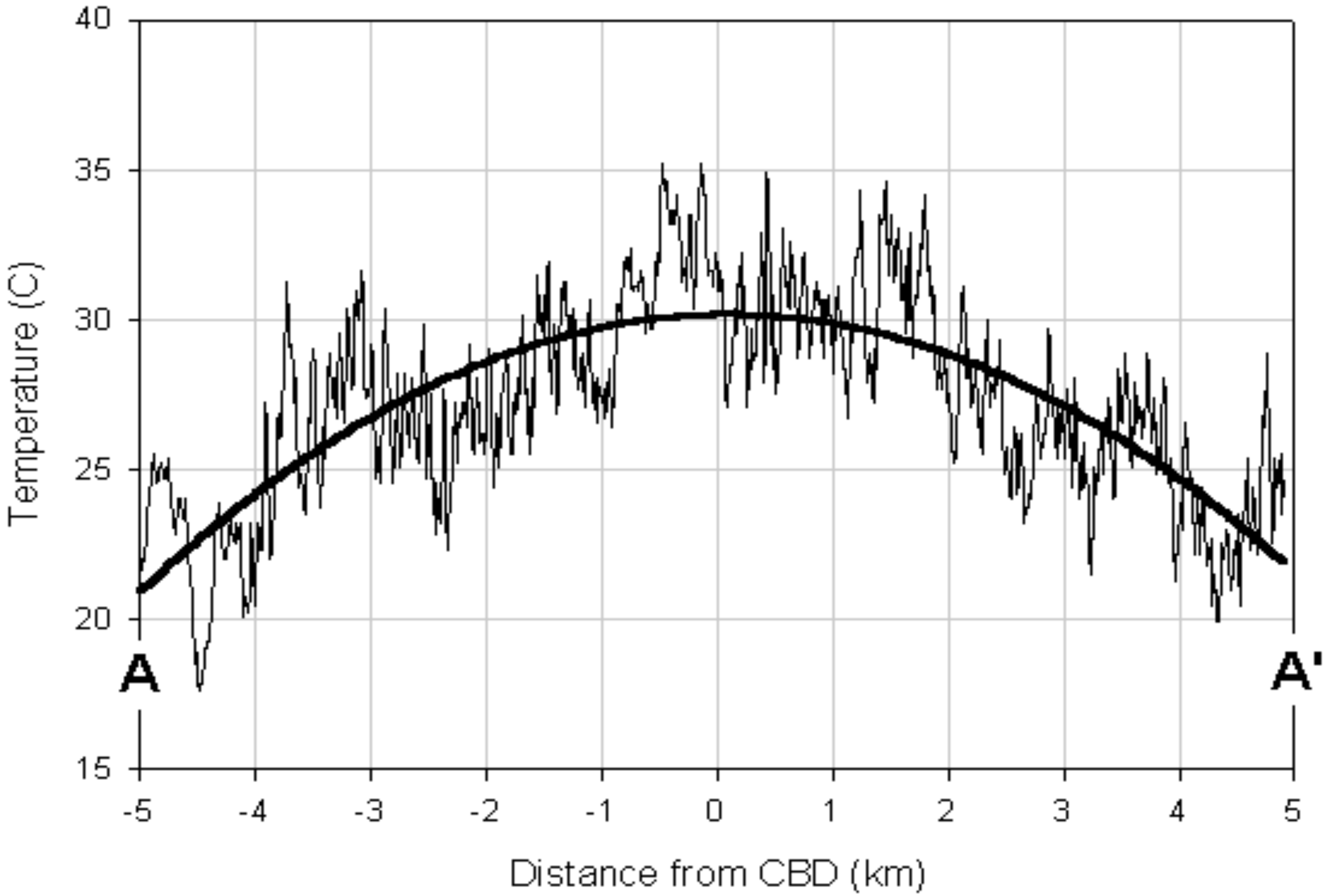


Atlanta Urban Heat Island and Air Quality Modeling Study

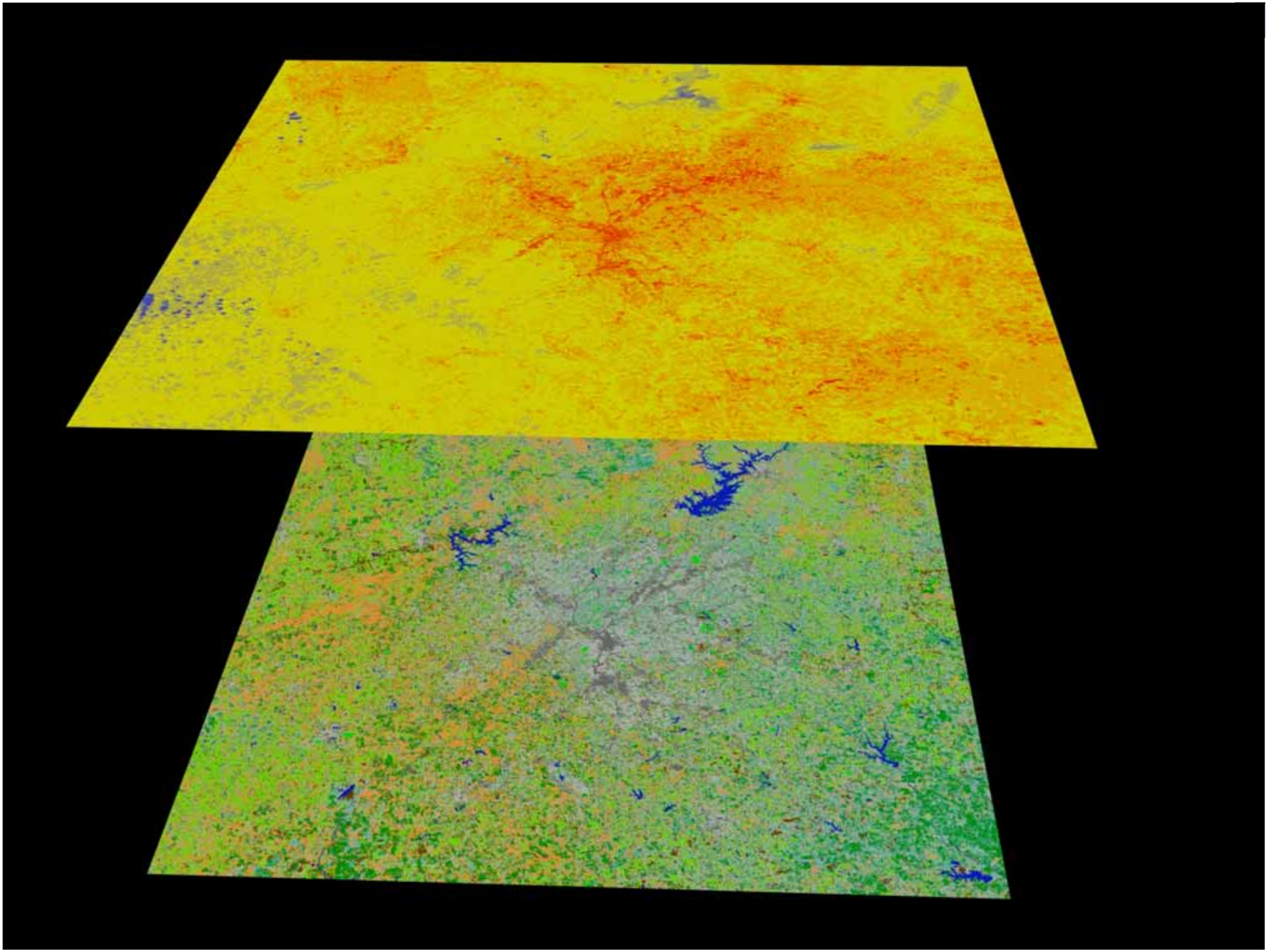
Using Remotely Sensed Data to Characterize the Urban Landscape

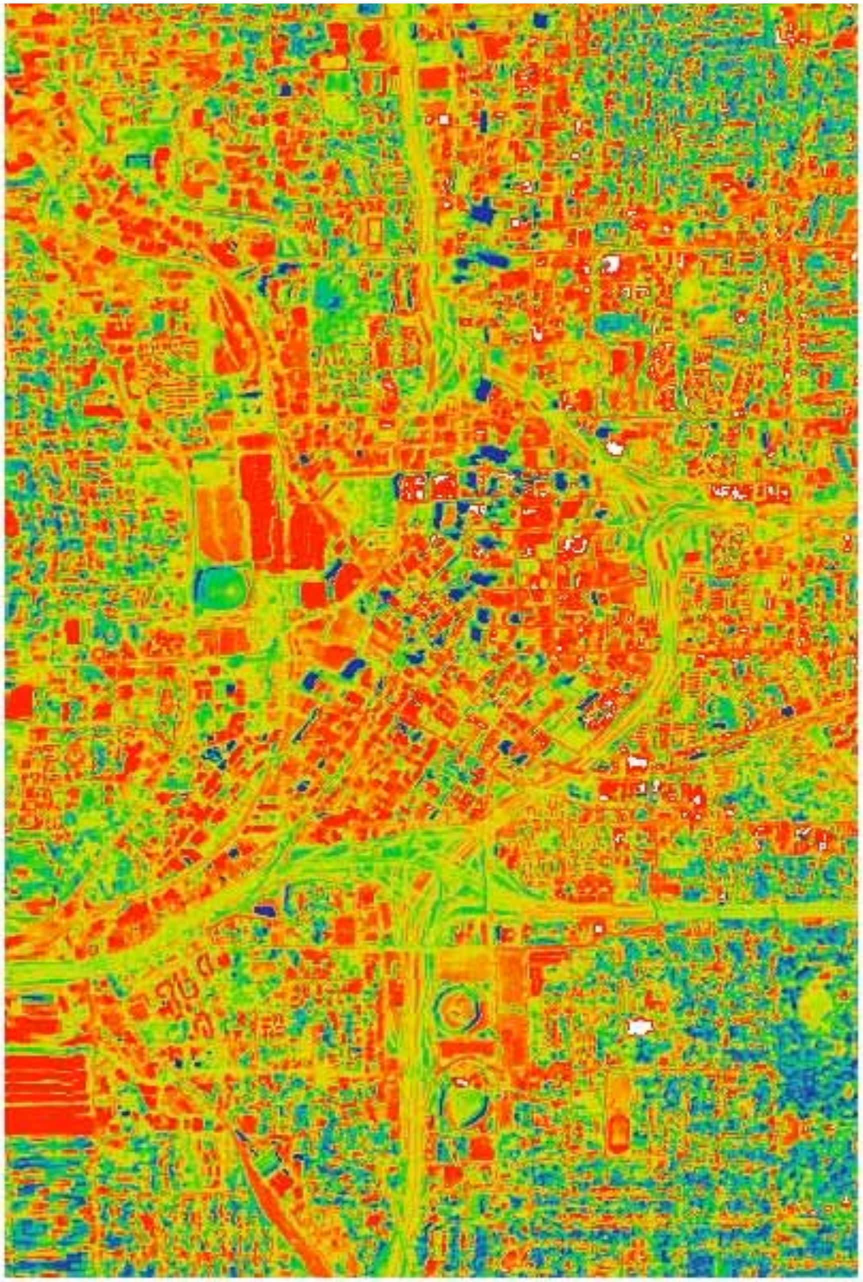



A
A'

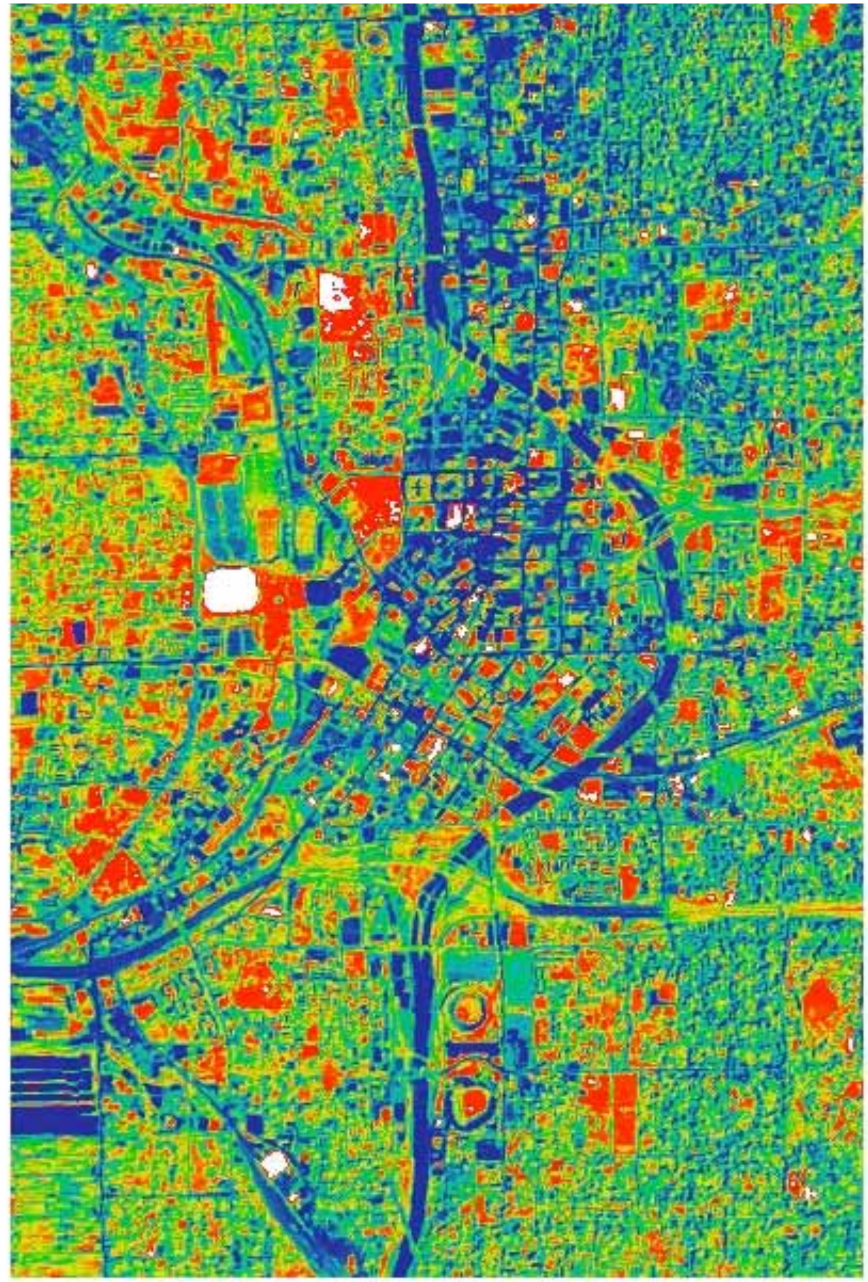


40
35
30
25
20
15
Temperature (C)
A
A'
-5
-4
-3
-2
-1
0
1
2
3
4
5
Distance from CBD (km)





Temperature

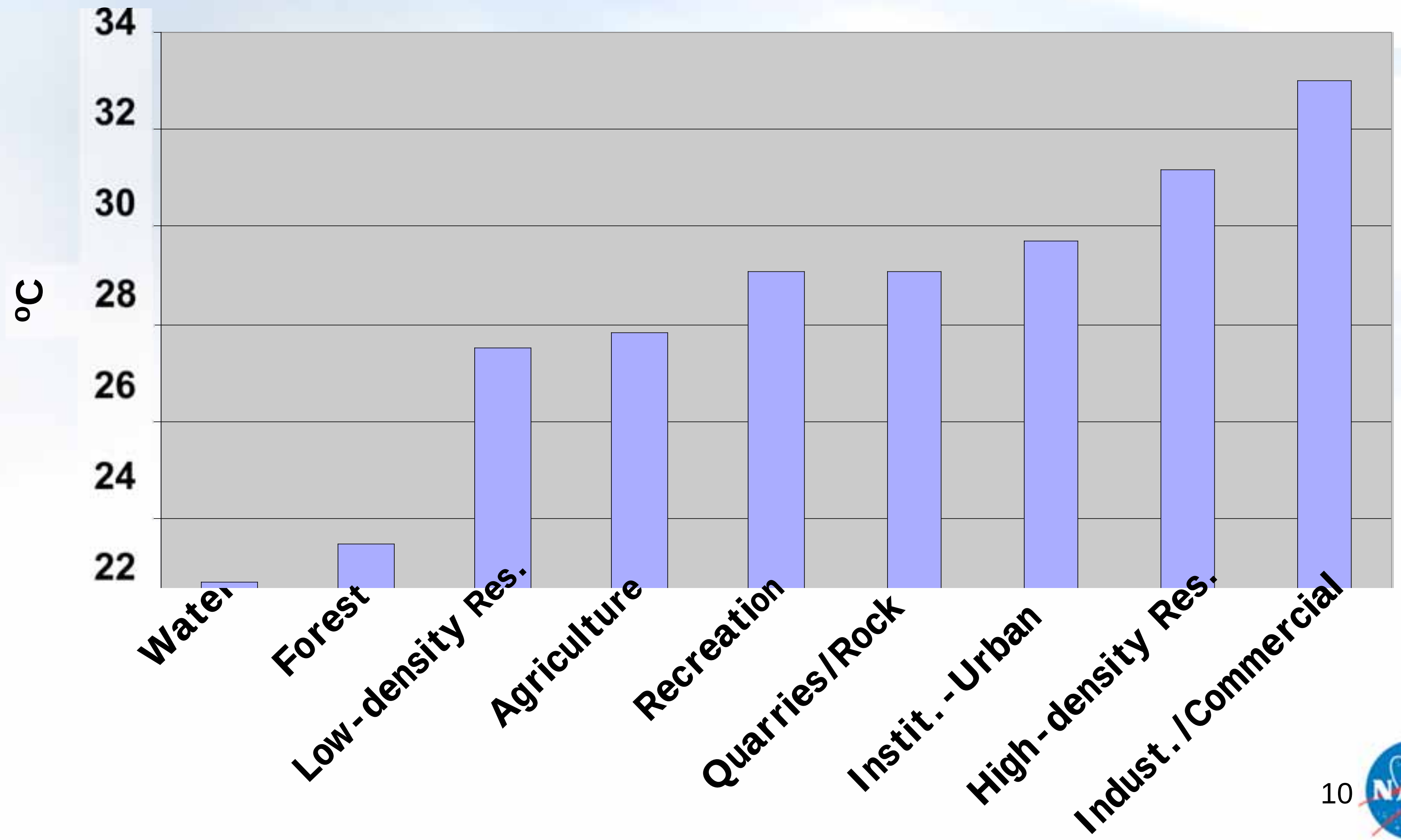


Albedo

Atlanta, GA - May 1997

Surface Temperature by Land Use Class

Based on ATLAS aircraft data, May 1997



Previous Air Quality Modeling Assumptions and Results

- **Albedo Increases of .30 residential roofs, .40 commercial roofs, .20 - .25 roads, parking lots and sidewalks.**
- **Vegetative Cover: 4 trees per residential or commercial unit, 6 trees per industrial unit, and mixed urban 4 trees.**
- **Result was a peak reduction in ozone of 7 ppb or 5 percent.**

Source: LBNL and EPA

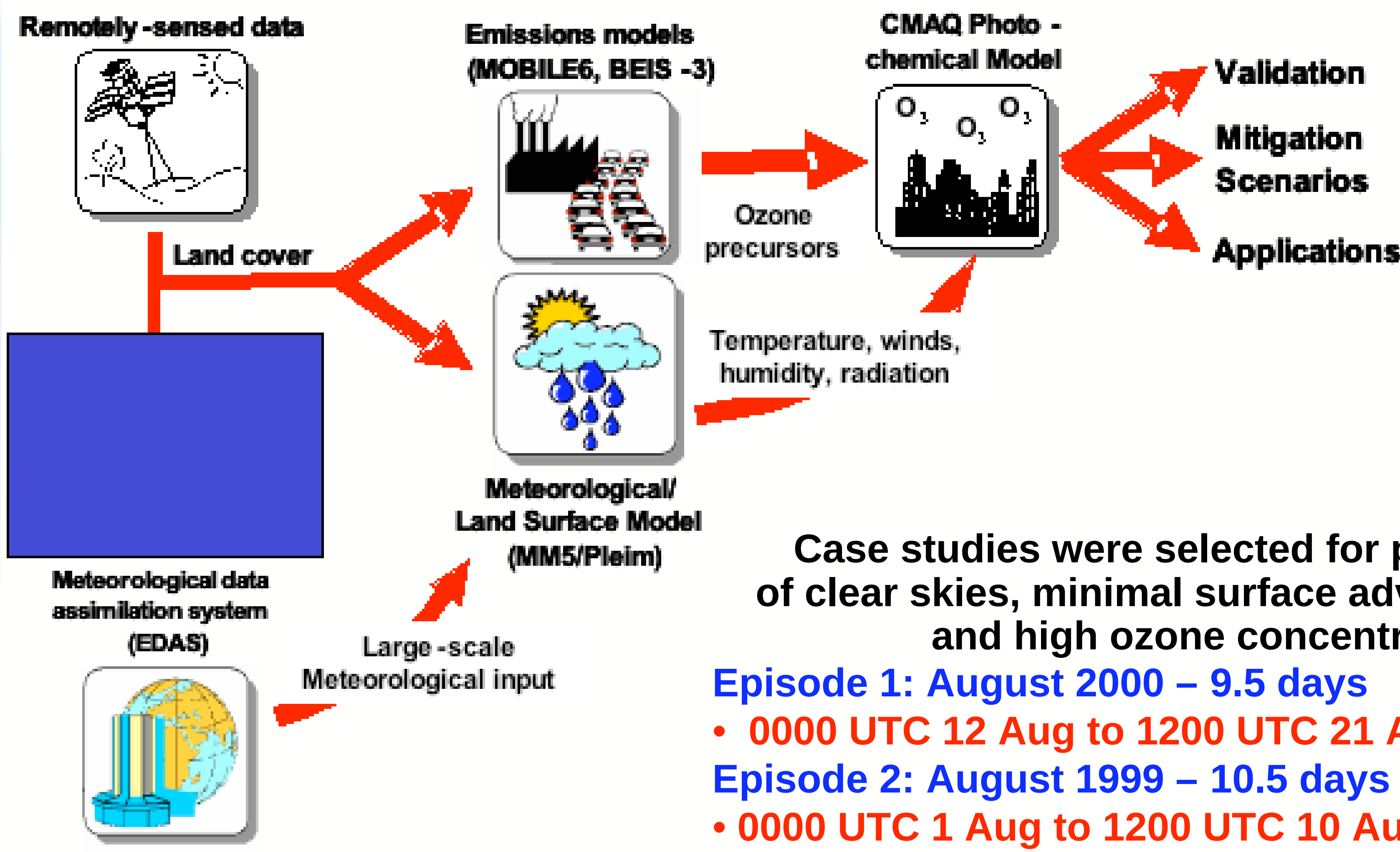
Urban Air Quality Modeling Project

1. How much can air quality model performance be improved with the application of remote sensing data?

2. What is the optimal scale to remotely sense urban land surface properties to improve the accuracy of air quality models in use today?

3. To what extent do various urban heat island mitigation strategies serve to reduce or alter the spatio-temporal distribution of ground level ozone?

Urban Air Quality Modeling System



Case studies were selected for periods of clear skies, minimal surface advection and high ozone concentrations.

Episode 1: August 2000 – 9.5 days

- **0000 UTC 12 Aug to 1200 UTC 21 August**

Episode 2: August 1999 – 10.5 days

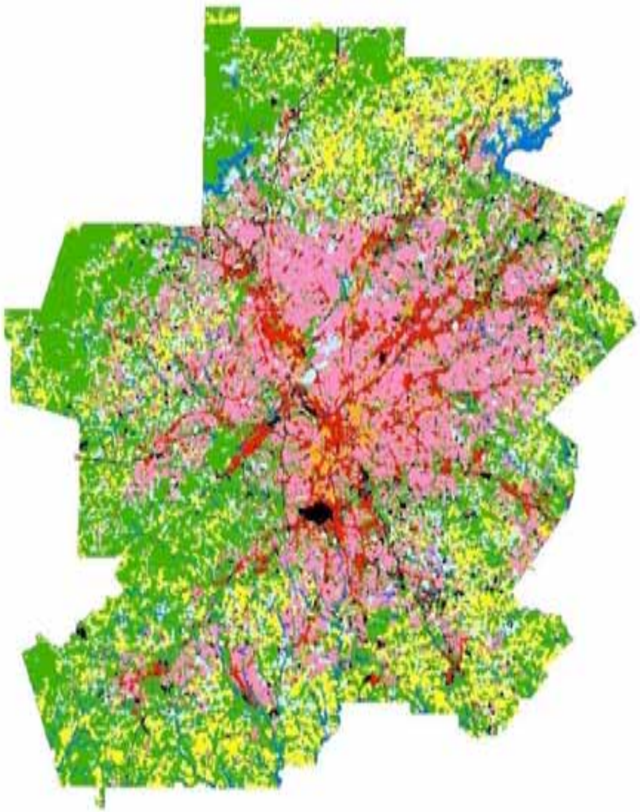
- **0000 UTC 1 Aug to 1200 UTC 10 August**

Spatial Growth Modeling in Collaboration with Prescott College

- **The Spatial Growth Model (SGM) was used to project land use/land cover for the area to 2010, 2020 and 2030.**
- **Inputs to the model are current land use and current and projected population, employment, and road networks.**
- **Current land use/land cover is defined by the LandPro99 data set created by the Atlanta Regional Commission (ARC).**

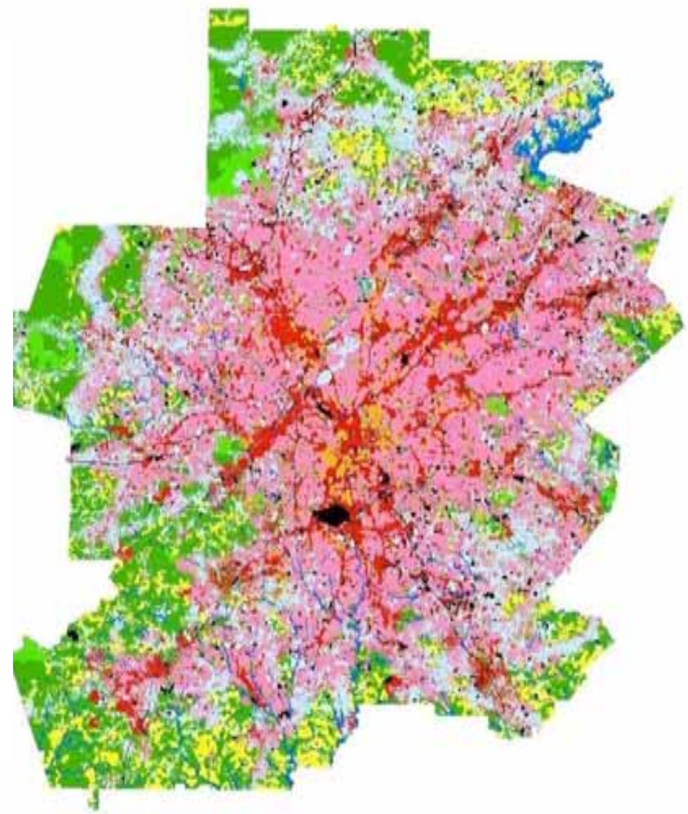
Current and Projected 2030 Land Use
13-county Atlanta Metro Area

Current (1999)

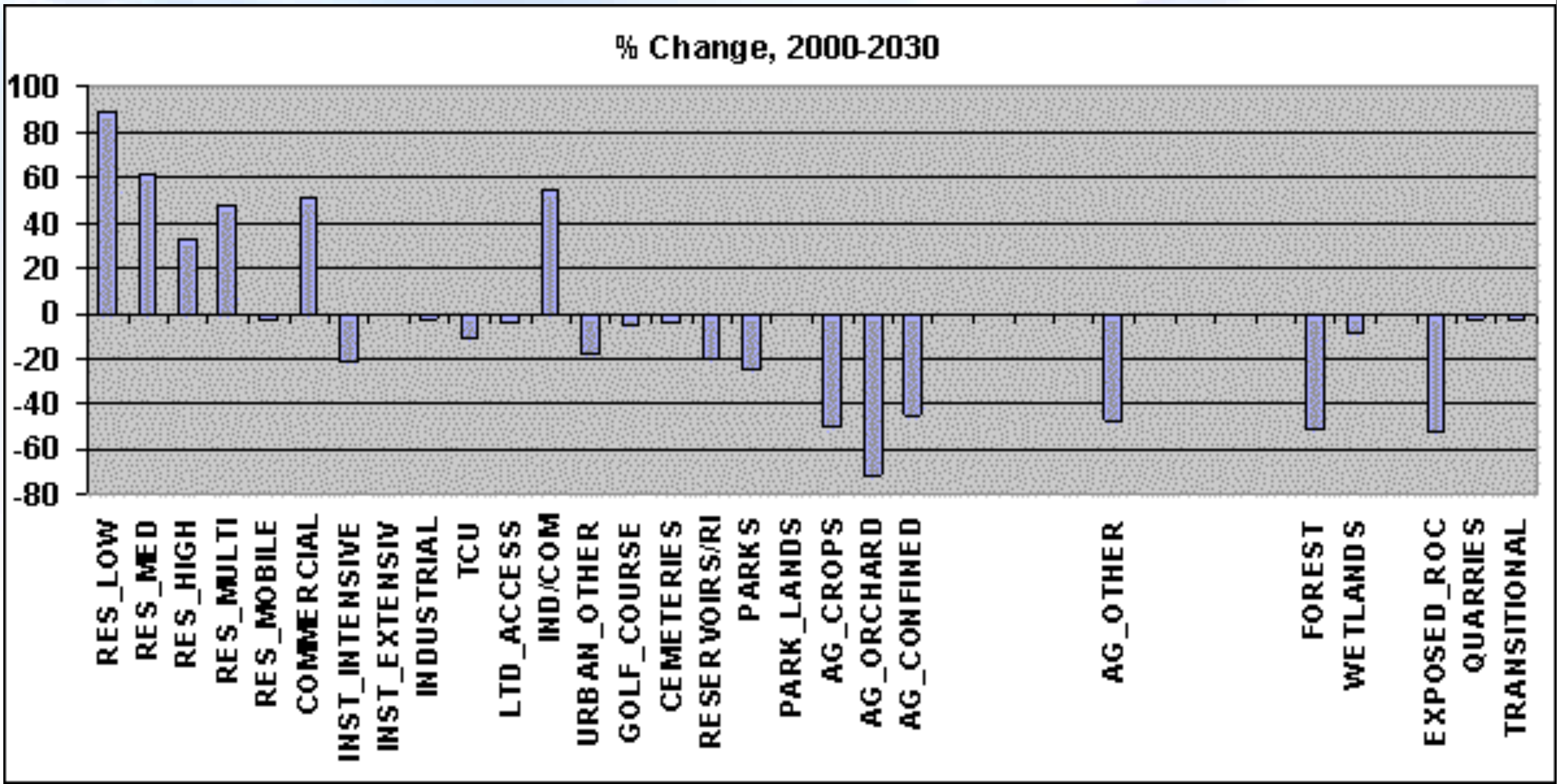


- Low Density Residential
- Med. Density Residential
- High Density Residential
- Commercial/Services
- Institutional
- TCU
- Industrial/Commercial
- Water
- Crops/Pasture
- Row Crops
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Woody Wetlands
- Quarries/Mines/Gravel Pits
- Transitional

Projected (2030)



Land Use Projections



Source: Prescott College Spatial Growth Model

Urban and Regional Land Use Impacts

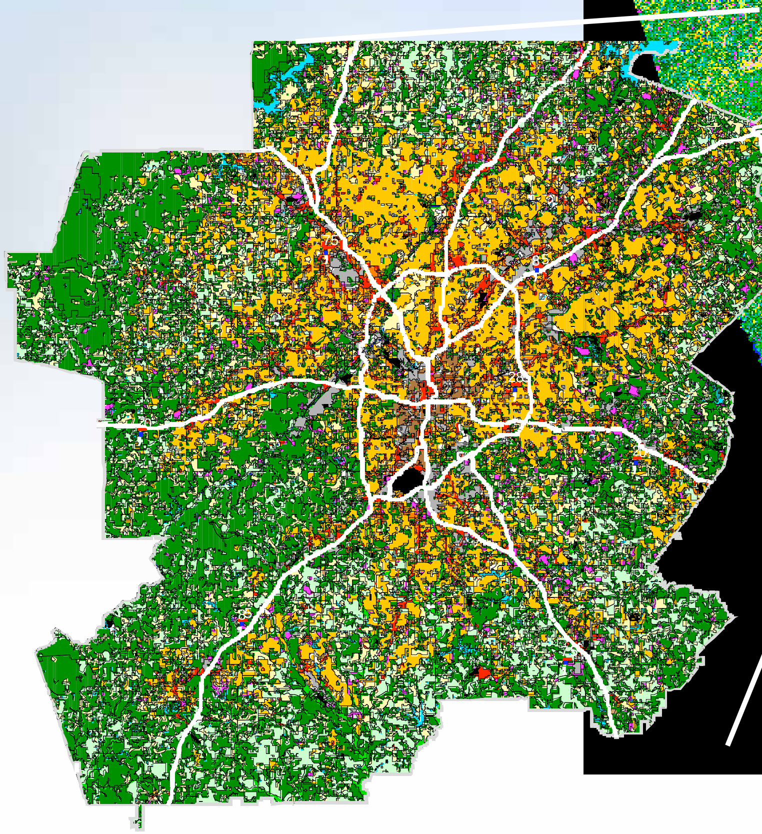
Aggregated Land Use	1999 5-county	2030 5-county	% change, 5-county	1999 13-county	2030 13-county	% change, 13-county
Commercial	10.62	11.94	+12.4	5.91	8.54	**+44.5**
Transportation/Utilities	2.02	1.98	-2.0	1.21	1.12	-7.4
Industrial/Institutional	2.33	2.50	+7.3	1.29	1.64	**+27.1**
Transitional/Extractive Lands	2.64	2.59	-1.9	2.14	2.03	-5.1
Multi Family Residential	3.06	3.40	+11.1	1.42	2.09	**+47.2**
High Density Residential	1.20	1.26	+5.0	0.60	0.73	+21.7
Medium Density Residential	33.77	39.96	+18.3	20.05	32.43	**+61.7**
Low Density Residential	8.29	12.53	**+51.1**	11.14	19.61	**+76.0**
Agriculture	5.98	2.60	**-56.5**	13.49	6.72	**-50.2**
Forest/Open Space	27.59	19.01	**-31.1**	38.86	21.71	**-44.1**
Water/Wetlands	2.49	2.23	-10.4	3.89	3.38	-13.1

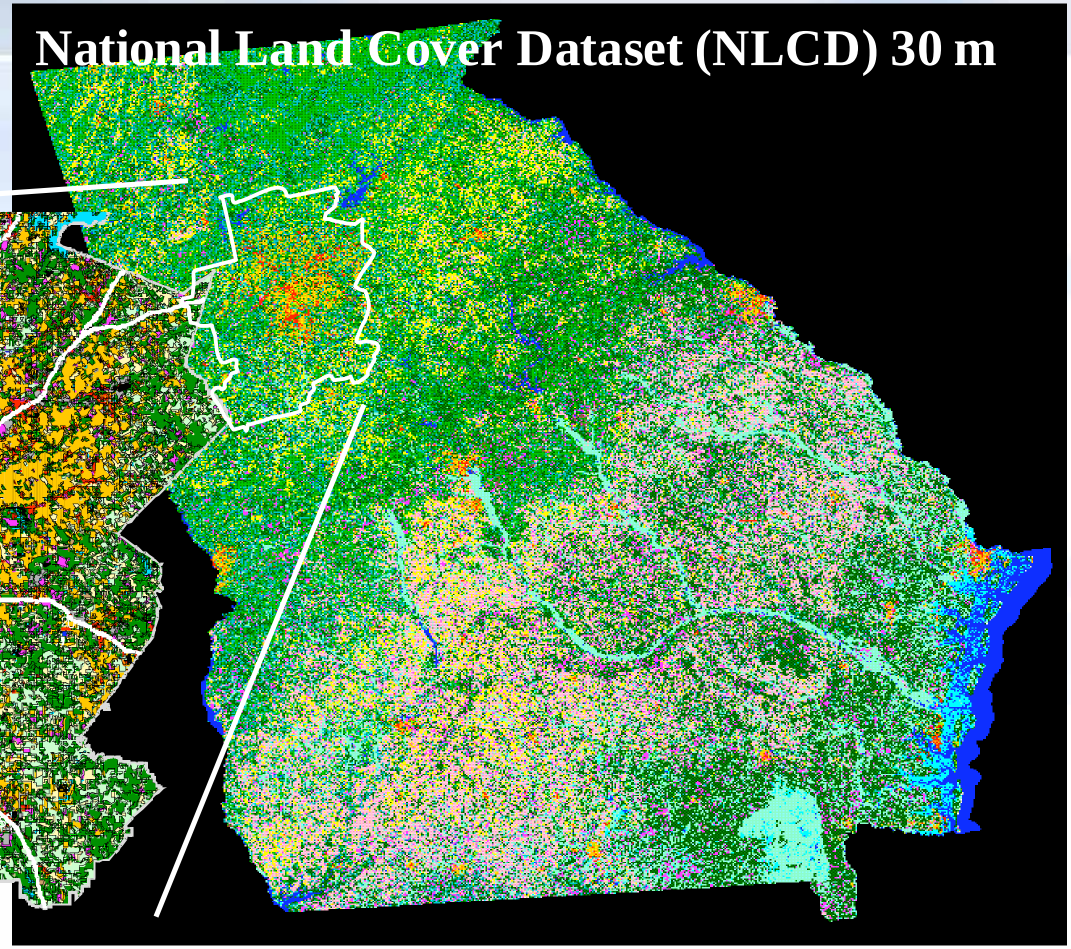
Definition of Physical Market for 21-county Study Area [GA Tech Center for GIS]

- Current & future estimates of impervious cover
- Asphalt = 2/3 of all impervious cover
- 45% increase in impervious by 2030
- >25% land area will be impervious for core counties by 2030
- Valuable study with regional implications

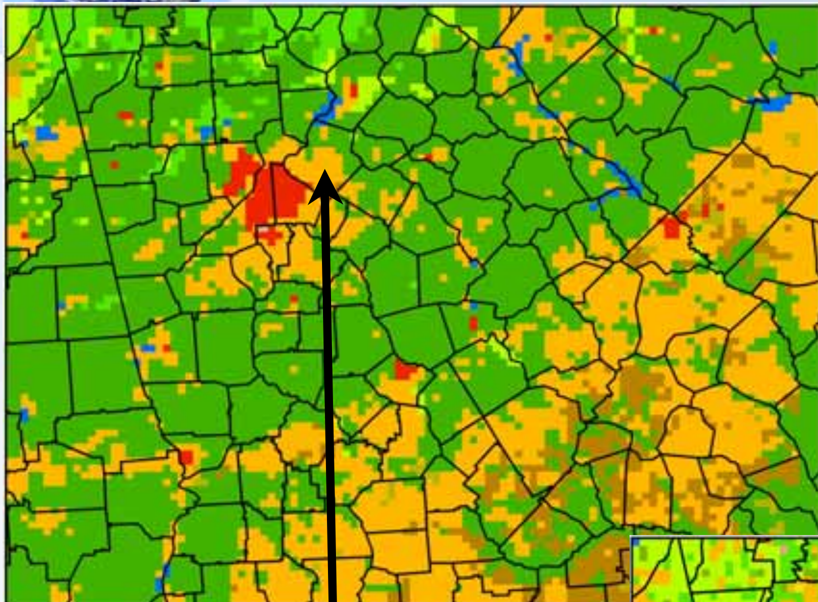
Advanced Land Use/Land Cover Classification

Atlanta Regional Council
LandPro '99 30 m





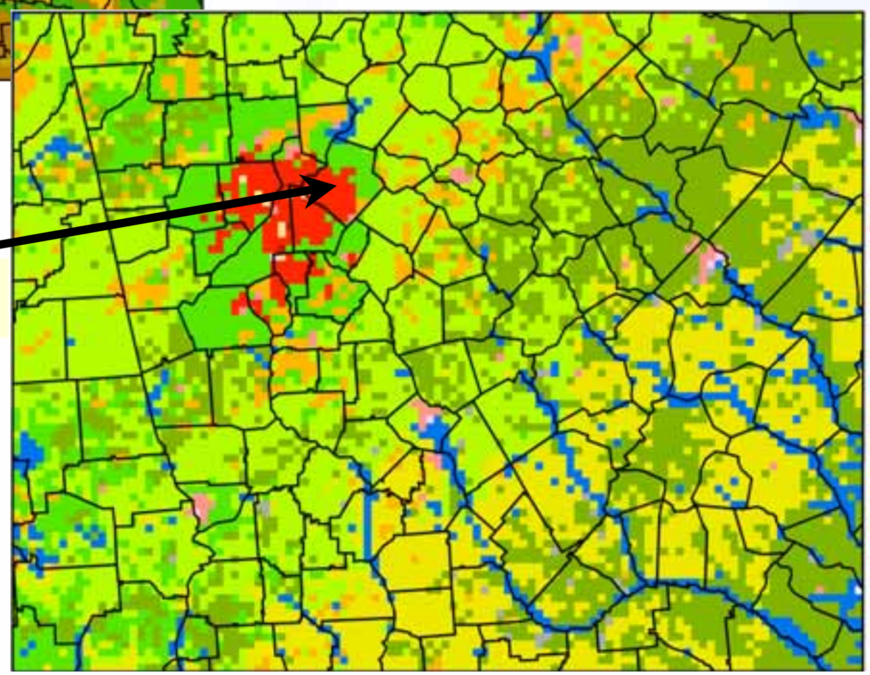
Comparison of Landuse Classifications



USGS 4 km Landuse

- Urban
- Crops/Pasture Mosaic
- Grass/Crops Mosaic
- Woodland/Crops Mosaic
- Shrubs
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Water

Combined NLCD/LandPro99 Landuse Aggregated to 4 km



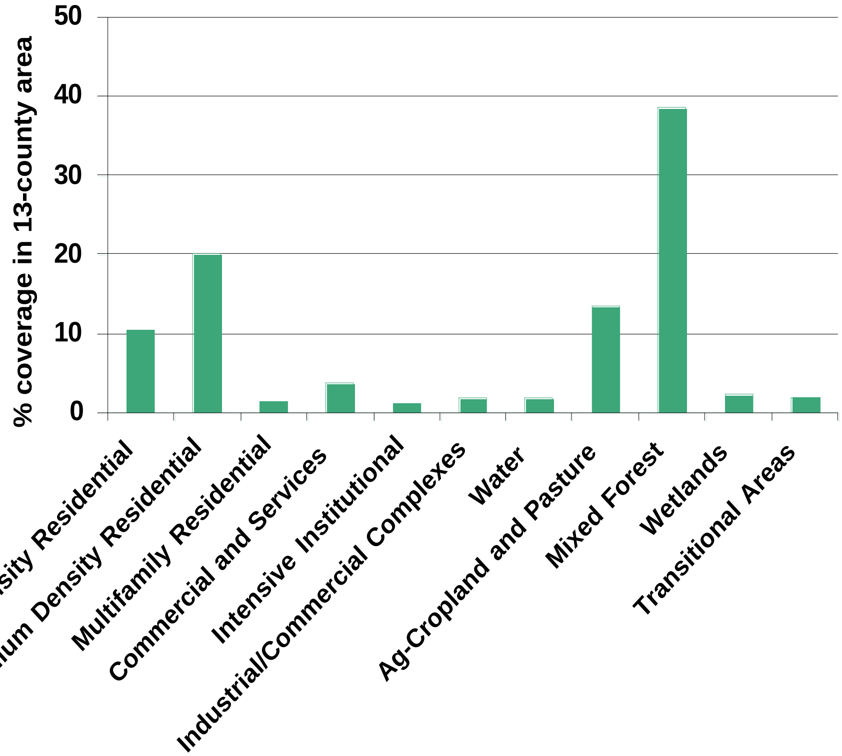
'Crops/Pasture Mosaic'

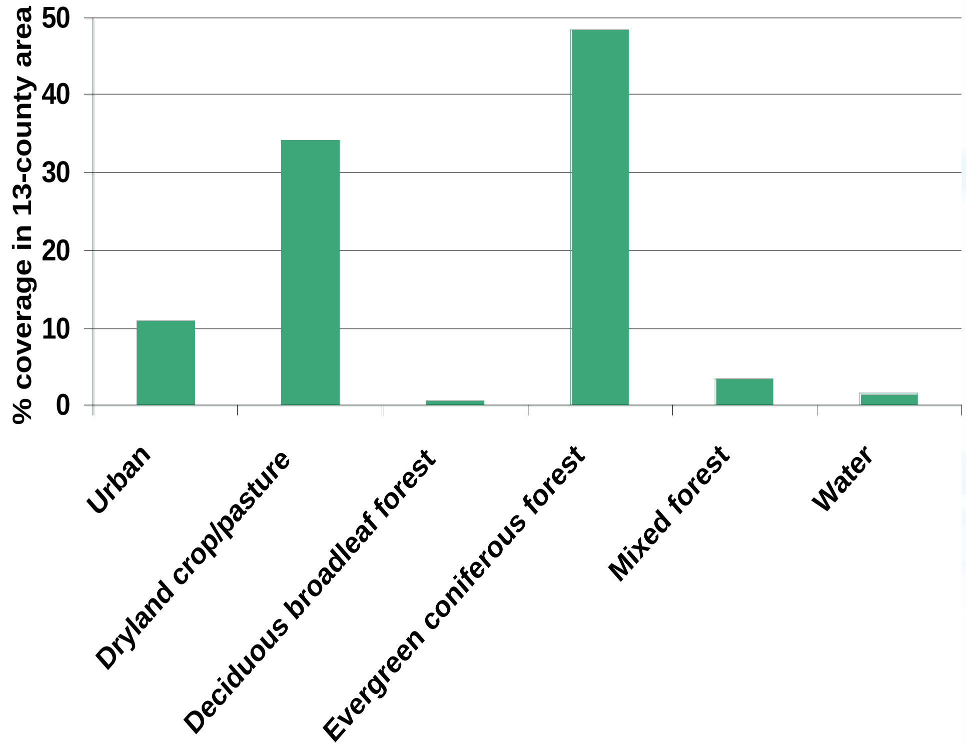
'Medium Density Residential'

- Low Density Residential
- Med. Density Residential
- High Density Residential
- Commercial/Services
- Institutional
- TCU
- Industrial/Commercial
- Water
- Crops/Pasture
- Row Crops
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Woody Wetlands
- Quarries/Mines/Gravel Pits
- Transitional

Comparison of Landuse Classifications

Landpro99 vs. USGS – 13 county area





LandPro99

Forest:	38%
Agriculture:	13%
Urban (excl. LD res):	28%

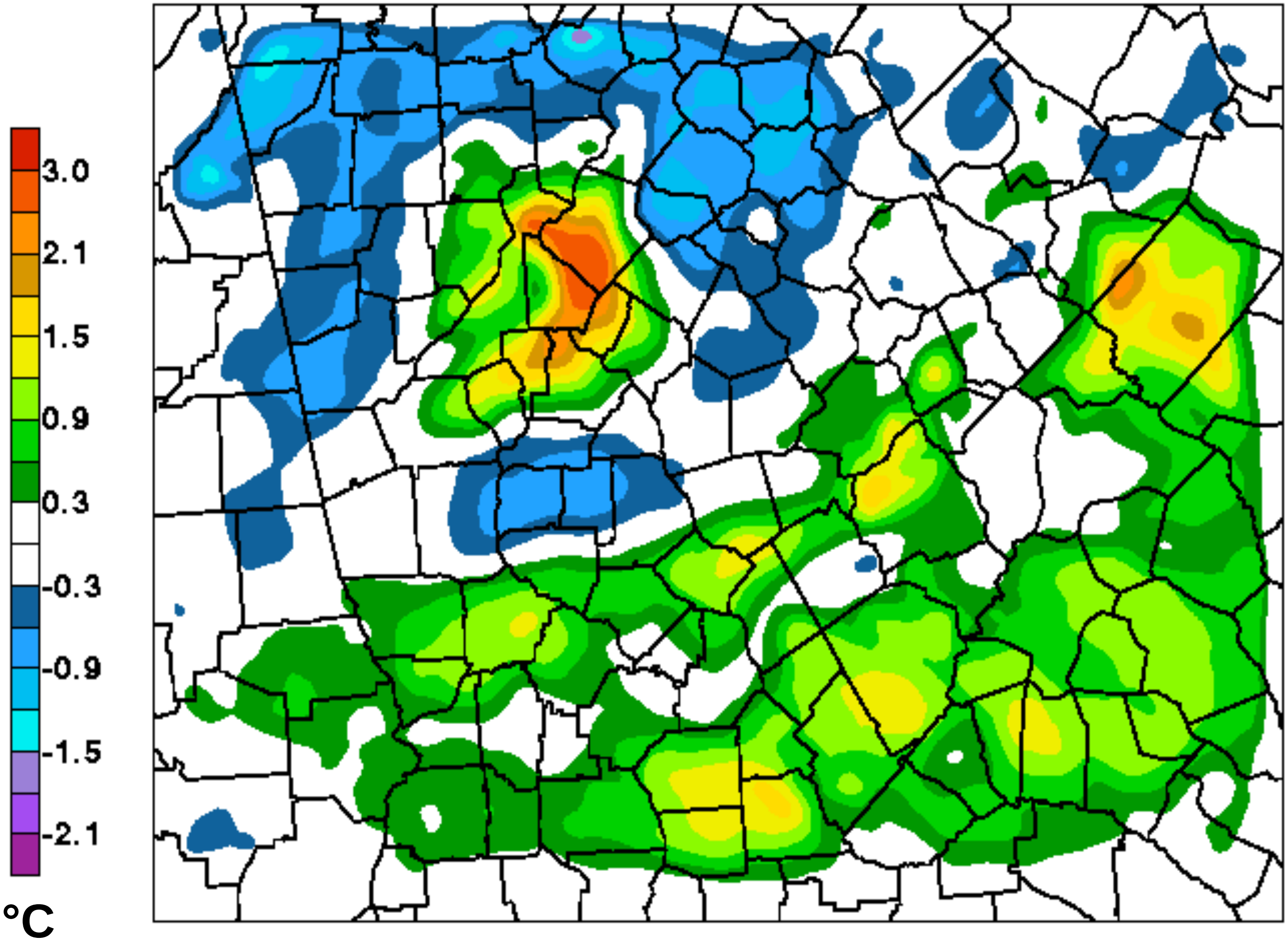
USGS

Forest:	53%
Agriculture:	35%
Urban:	11%

Impact of LC/LU data on 2 m Air Temperature

NLCD/LandPro – USGS

141 hour forecast valid 21 UTC 17 August 2000



Development of UHI Mitigation Strategies

- **3 Focus Groups on Paving, Roofing, Vegetation**
- **10-12 participants from various professional fields**
- **Considerations & Issues:**
  - Costs and Effectiveness
  - Timing
  - Market Penetration
  - Feasibility

Source: Georgia Cool Communities Program

Evaluating Potential Effects of UHI Mitigation Strategies

- **Urban Heat Island mitigation scenarios were developed using a great deal of input from local stakeholders through 'focus group' meetings.**

The impact of the mitigation scenarios on air temperature and air quality was evaluated using the Atlanta Air Quality Modeling System (AAQMS). Using a summer 2000 episode as a baseline, AAQMS was run using:

1. **Current land use**
2. **Future (2030) land use with no mitigation scenarios (BAU)**
3. **Future (2030) land use with high albedo (roofing and pavement) mitigation scenario**
4. **Future (2030) land use with increased tree canopy mitigation scenario**
5. **Future (2030) land use with combined (albedo and tree canopy) mitigation scenario**

Comparisons have been made between:

Runs (1) and (2) to illustrate effects of projected land use change

Runs (2) and (5) to show effects of the UHI mitigation strategies

UHI Mitigation Measures

- **Reflective roofing**

UHI Mitigation Measures

- **Green roofs**

UHI Mitigation Measures

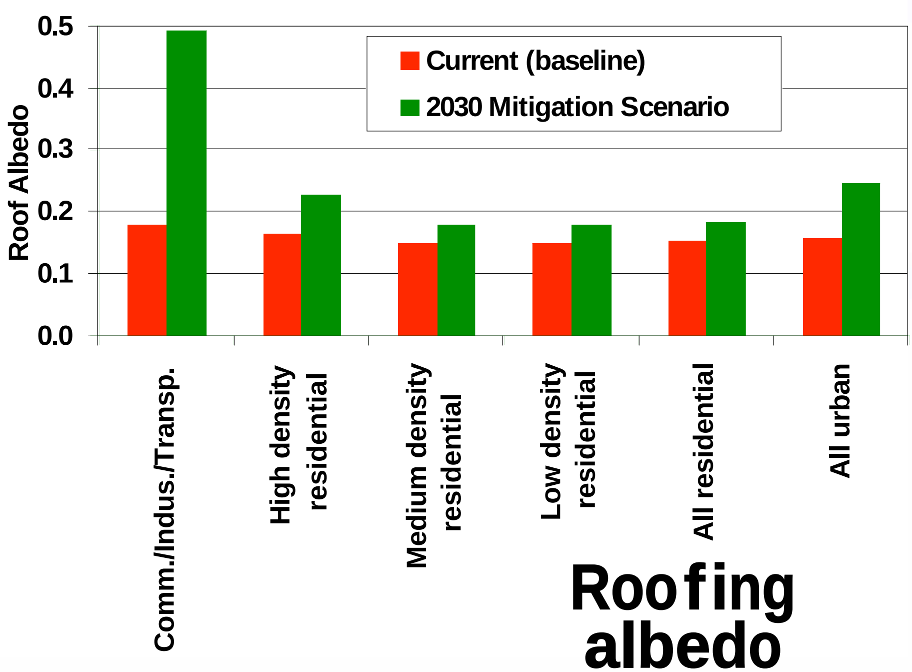
- **Shade trees**

Urban Heat Island Mitigation Scenarios

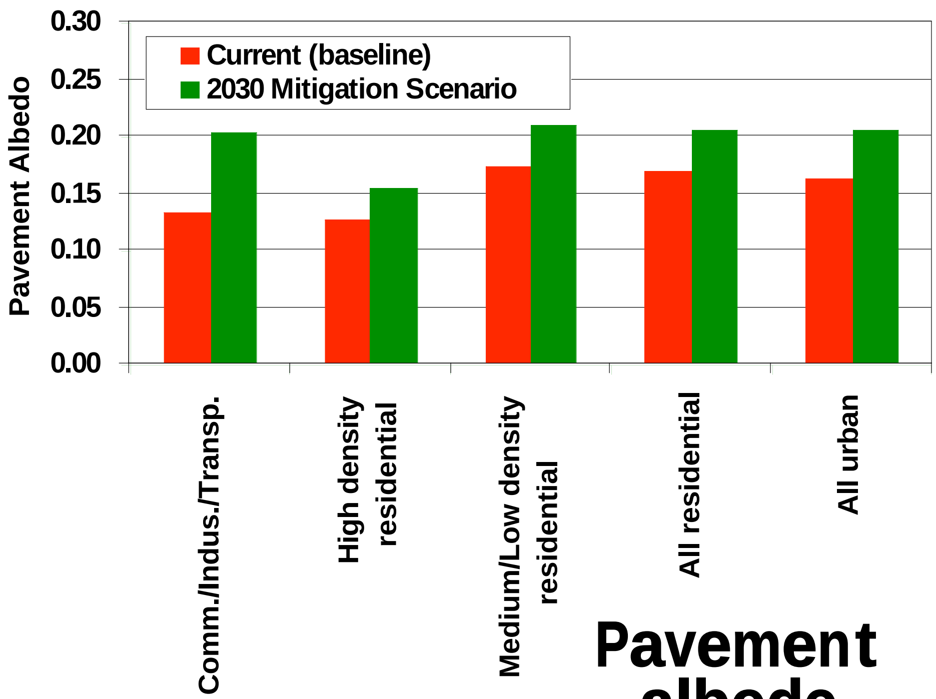
In conjunction with stakeholder focus groups coordinated by Georgia Cool Communities, we defined UHI mitigation scenarios to represent conditions attainable by 2030 given strong support from local governments.

Three strategies were considered:

- **Use of higher reflectivity roof materials**
- **Use of higher reflectivity paving materials**
- **Increasing vegetation cover through tree planting**



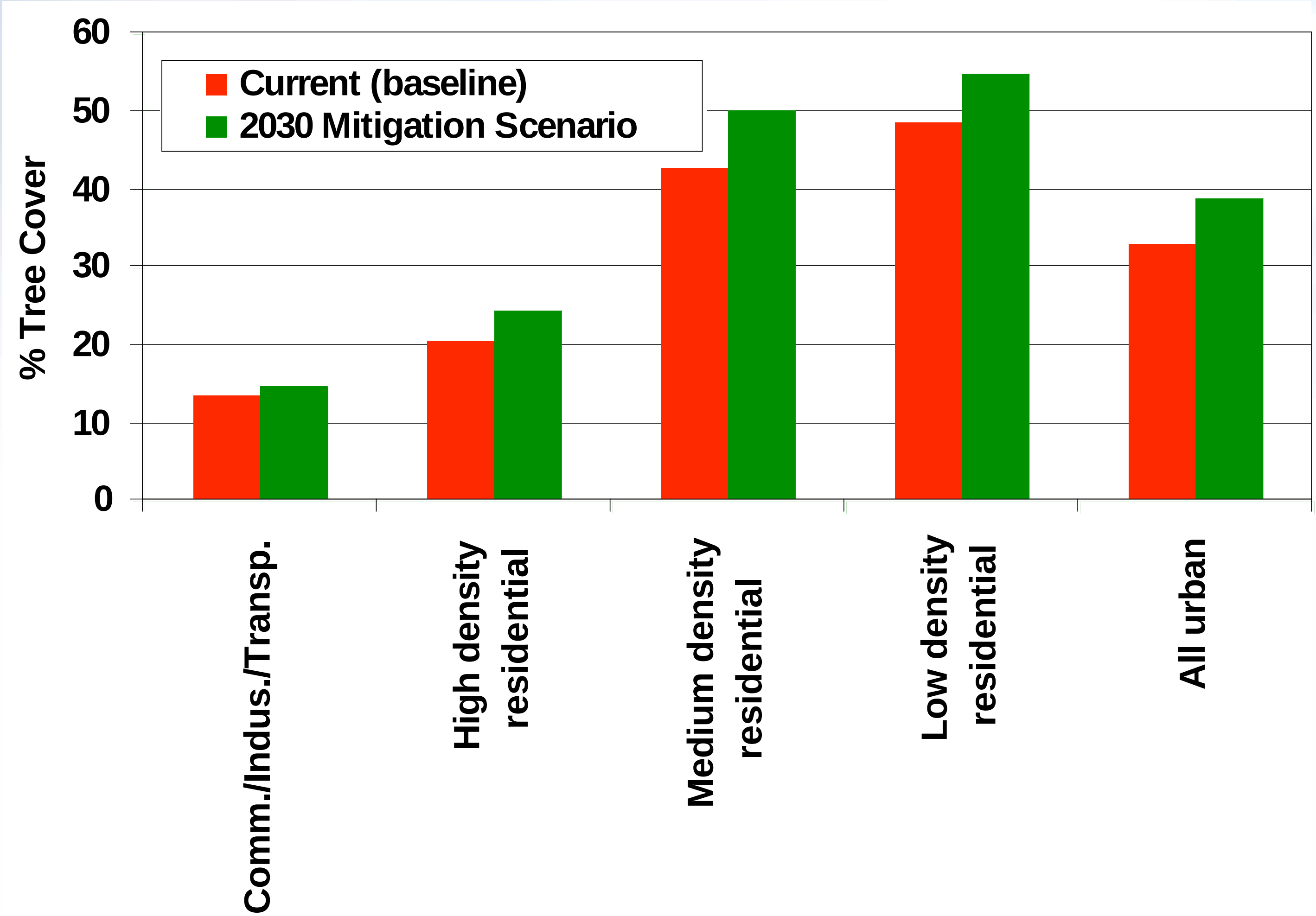
Roofing albedo



Pavement albedo

Current and 2030 Tree Cover - UHI Mitigation Scenarios

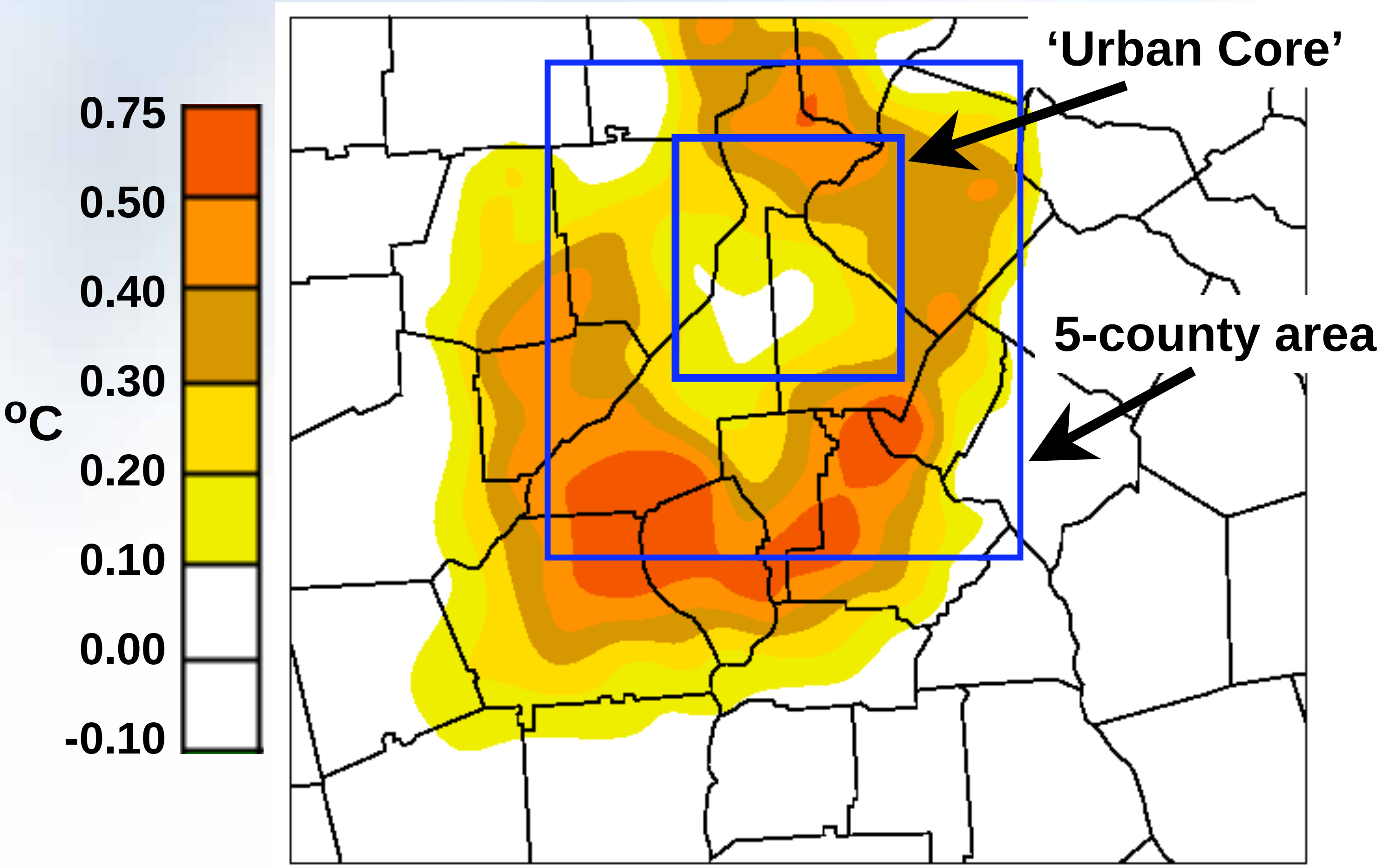
Due to changing land use distribution, the % tree cover in 2030 is projected to be significantly lower than in 2000. The additional trees assumed in the UHI mitigation scenarios *partially* offsets this net loss.



Regional Climate Change Results

Surface air temperature difference

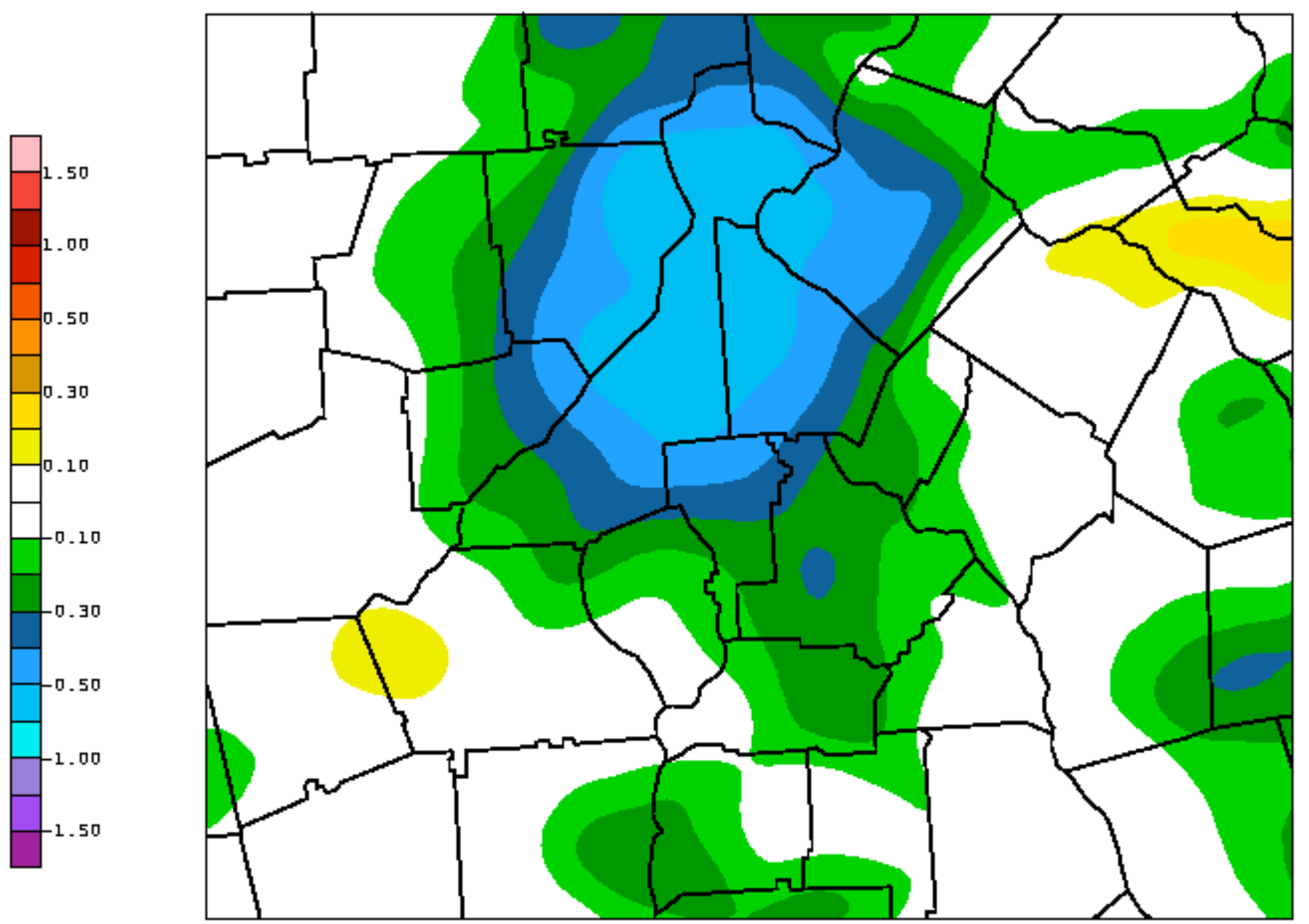
2030 Business as Usual – 2000 Baseline
3:00 PM EDT, Day 1 of Episode 1 simulation



2 Meter Air Temperature Difference

2030 Combined Mitigation – 2030 Baseline

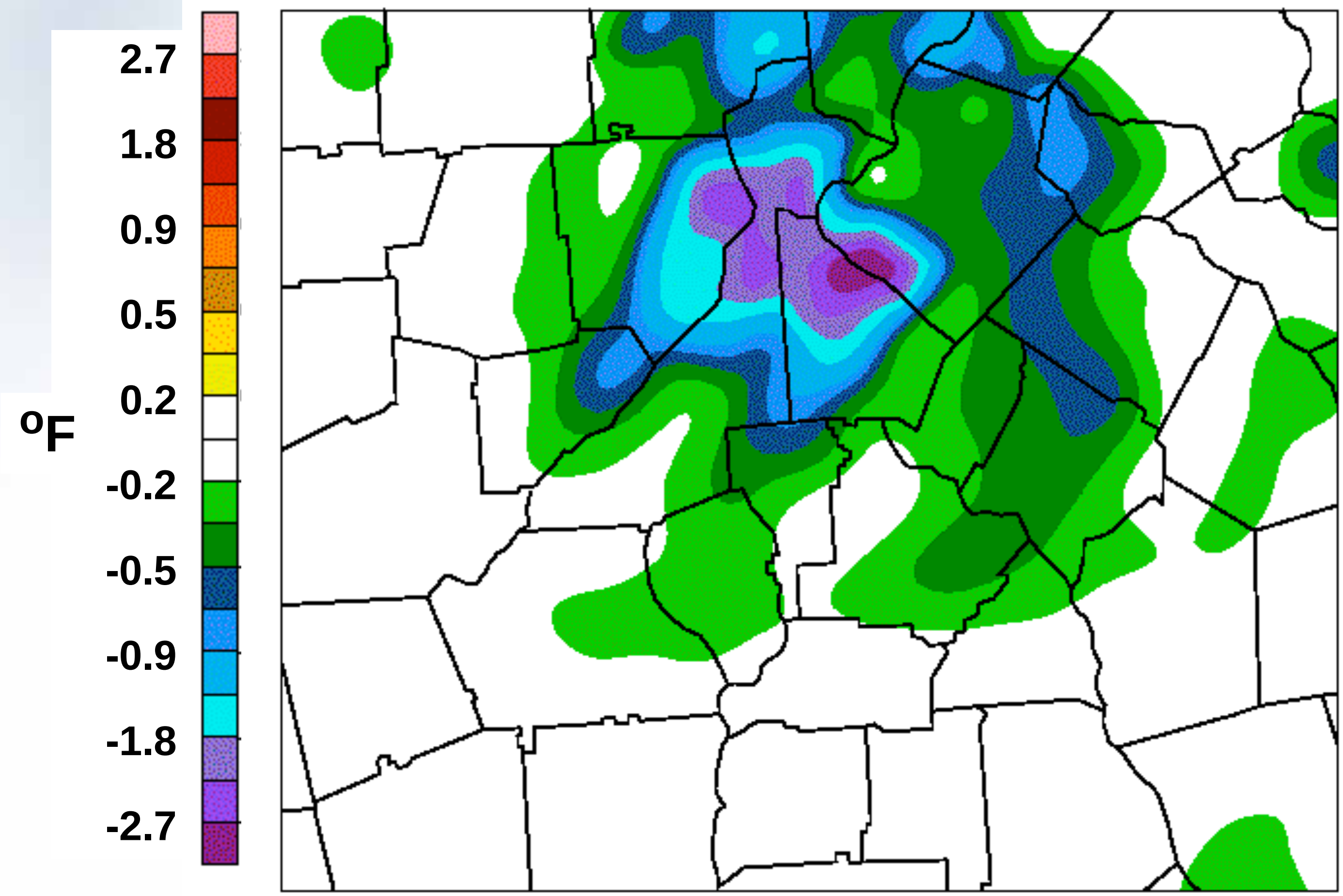
3:00 PM EDT Day 3



Air Temperature Difference

2030 Combined Mitigation – 2030 Baseline

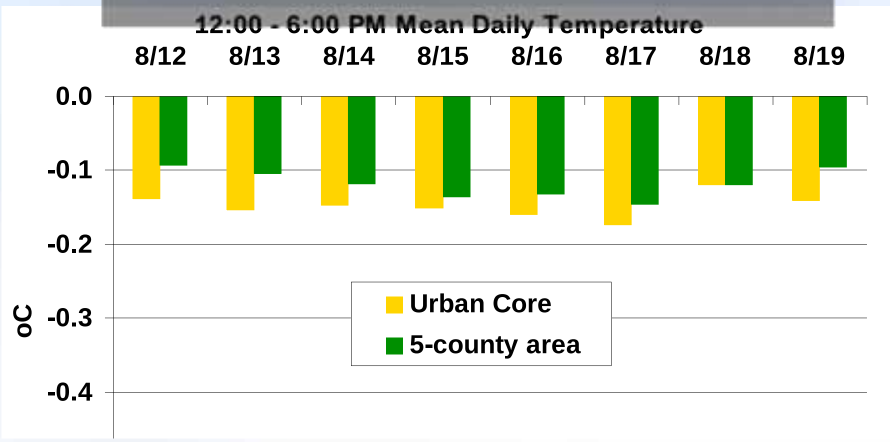
1:00 PM EDT Day 7



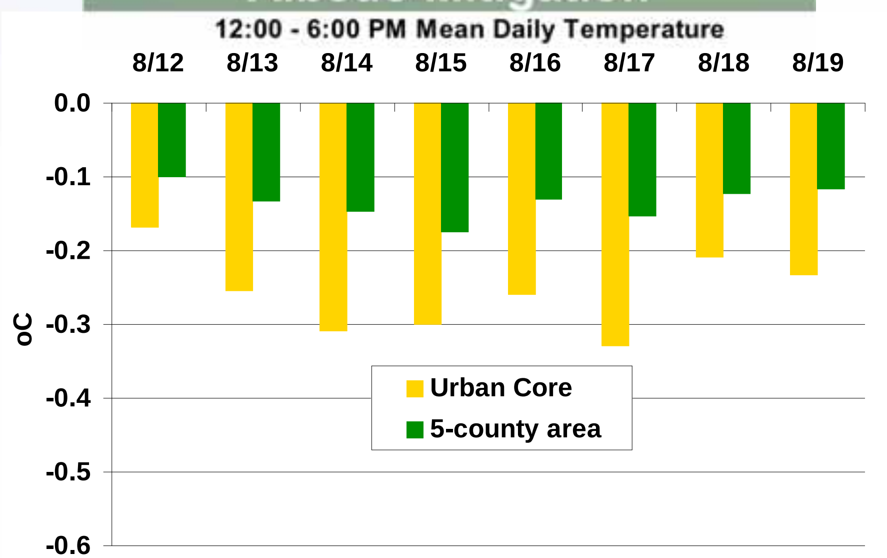
Impact of UHI Mitigation Scenarios on Air Temperature

Noon – 6PM Local Daylight Time daily

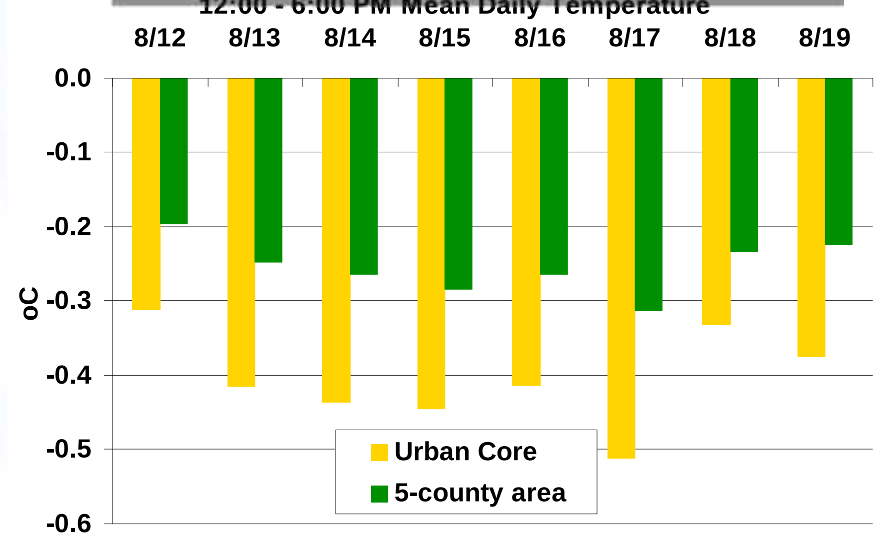
Vegetation Mitigation



Albedo Mitigation



Combined Mitigation



Summary of 2030 Mitigation Simulations

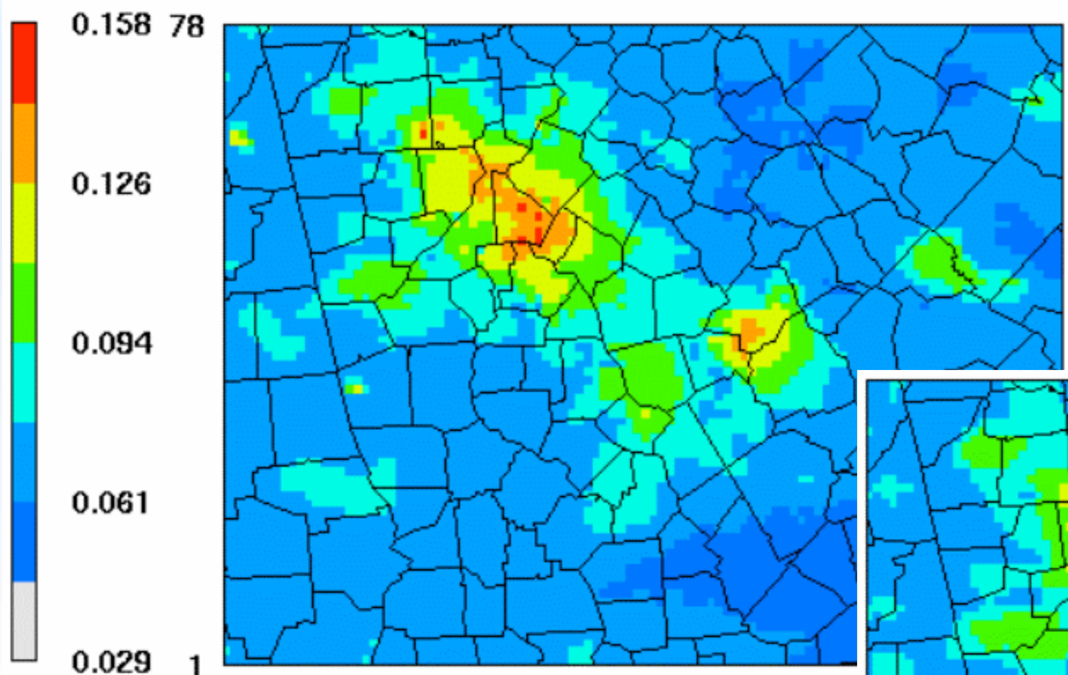
Air Temperature Changes
Based on Albedo and Vegetation Changes

	Urban core mean change	5-county mean change	13-county mean change
Noon – 6 PM	-0.41° C	-0.23° C	-0.14° C
2 PM	-0.53° C	-0.28° C	-0.17° C

Air Quality Results for Ozone

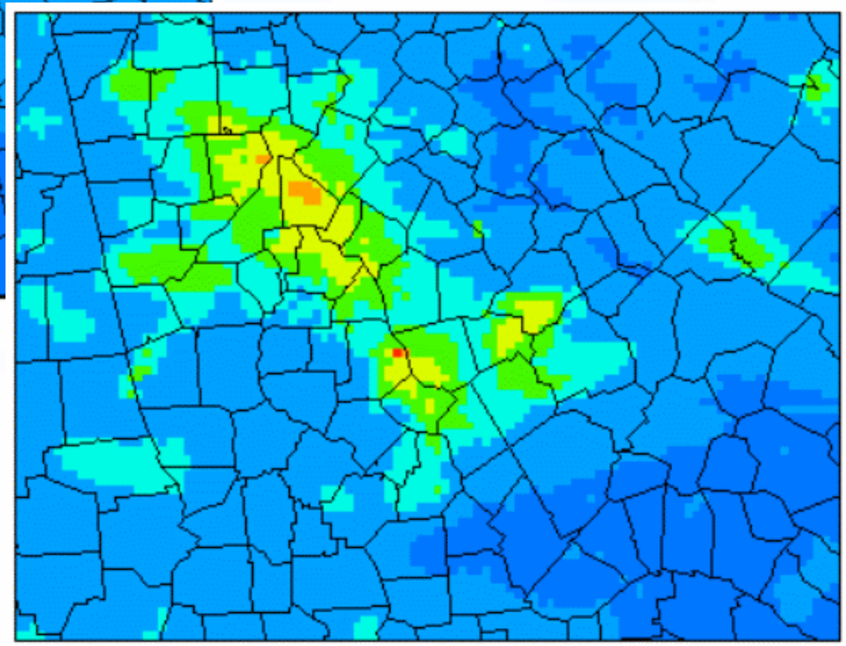
Impact of LC/LU data on Ozone Concentrations

Daily Maxima on August 16



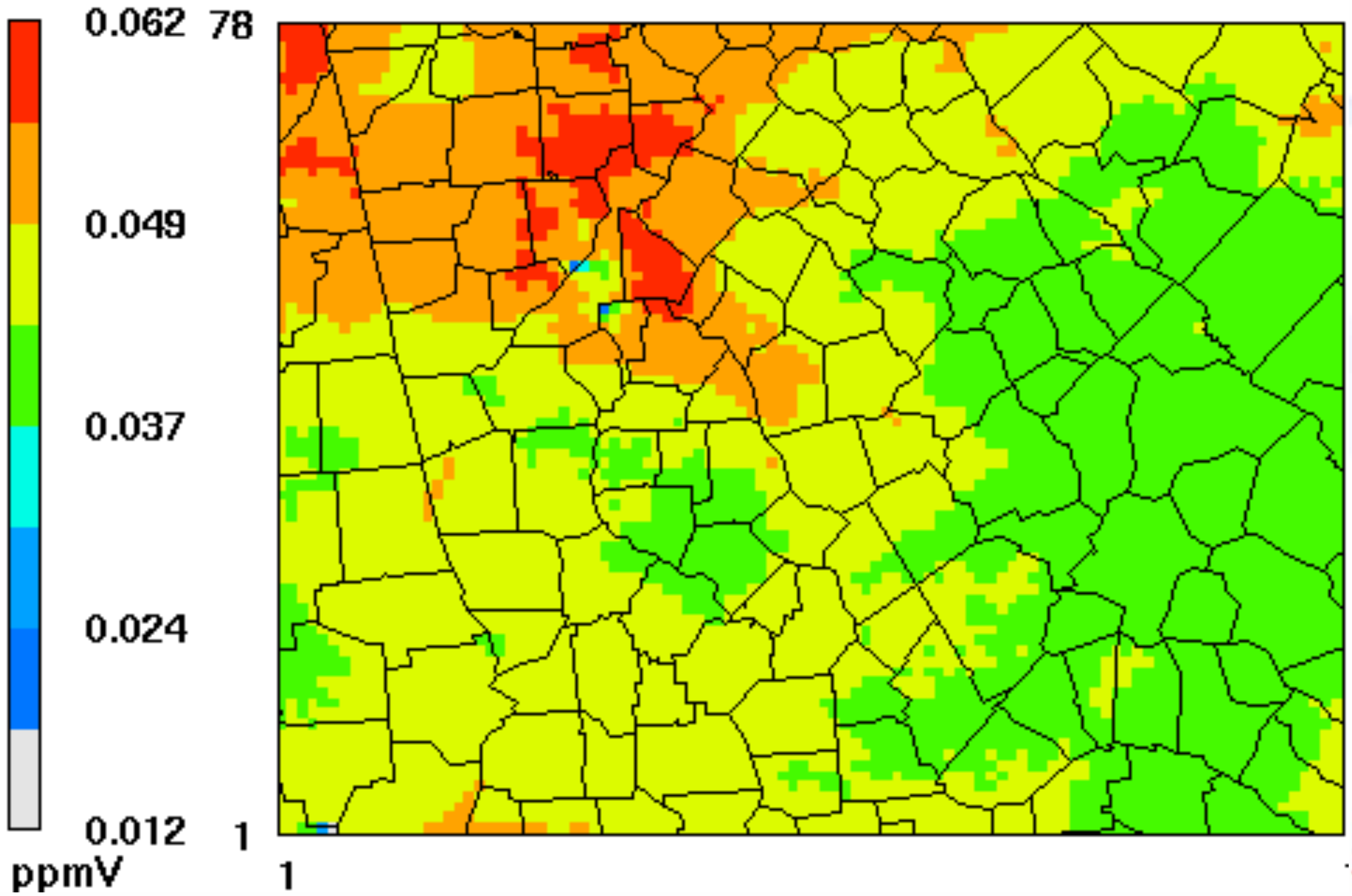
USGS LULC

NLCD/LandPro99 LULC



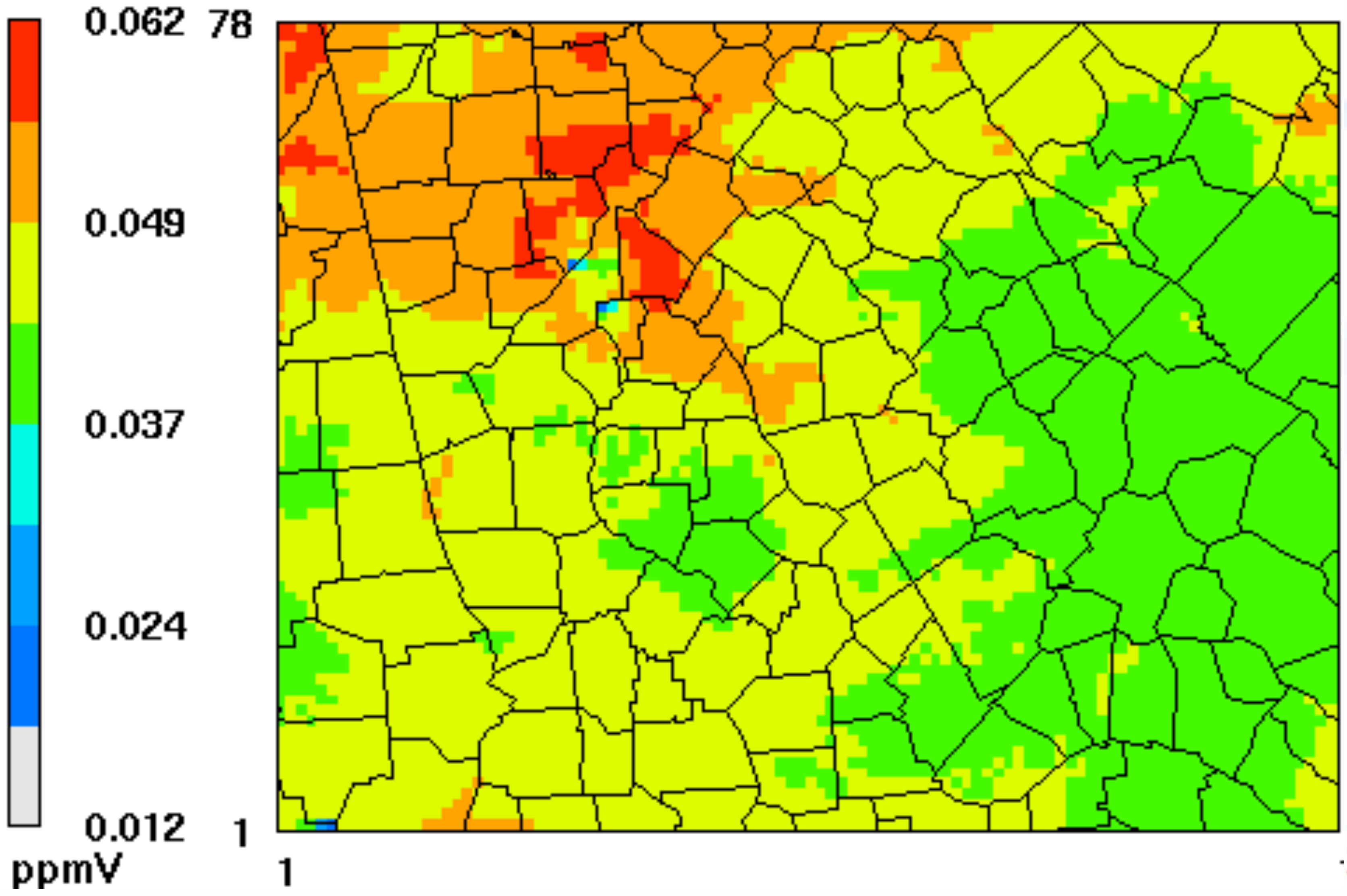
Impact of UHI Mitigation Strategies on Ozone Concentrations

2030 Business as Usual; Daily Means for August 16



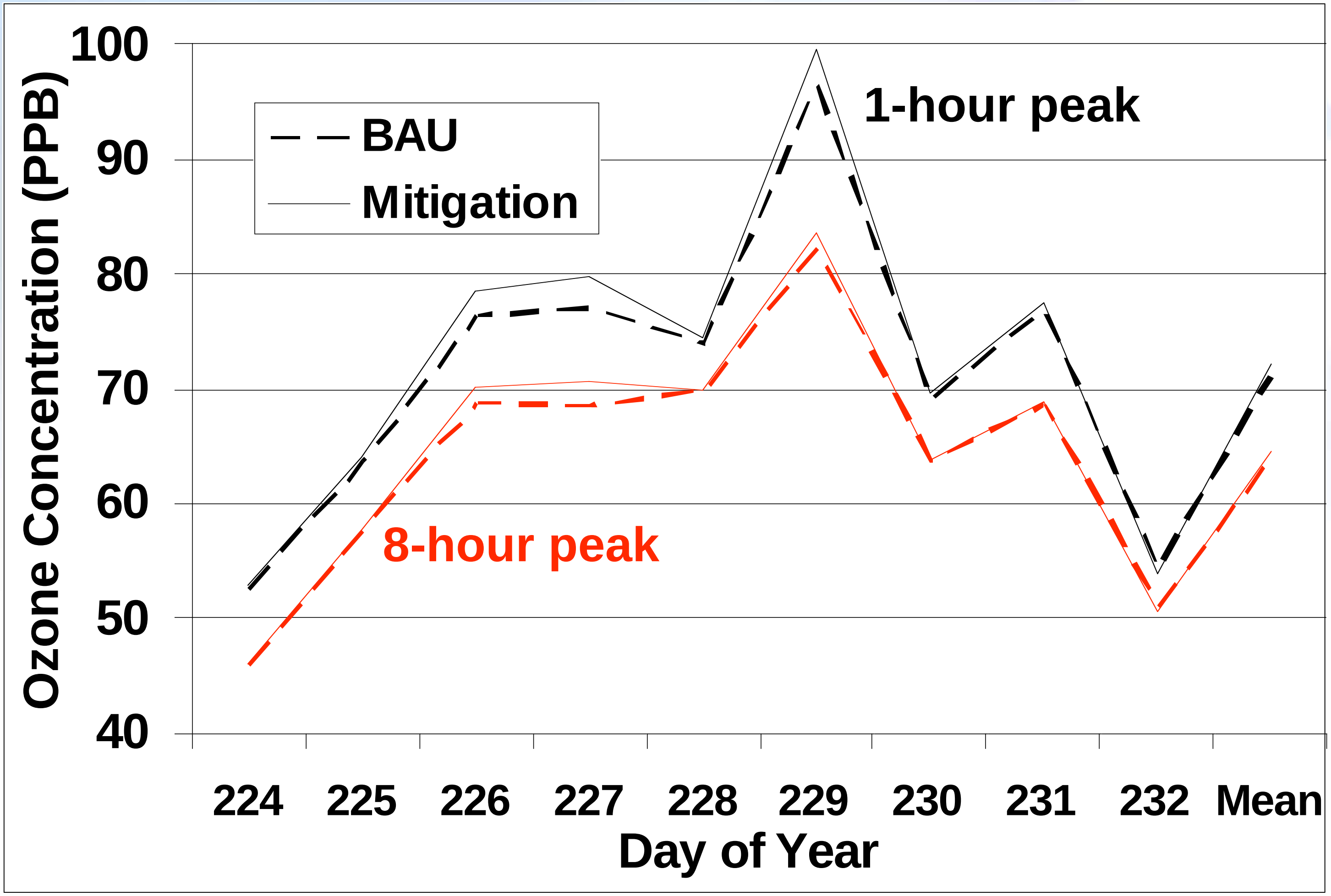
Impact of UHI Mitigation Strategies on Ozone Concentrations

2030 with Mitigation Strategies; Daily Means for August 16



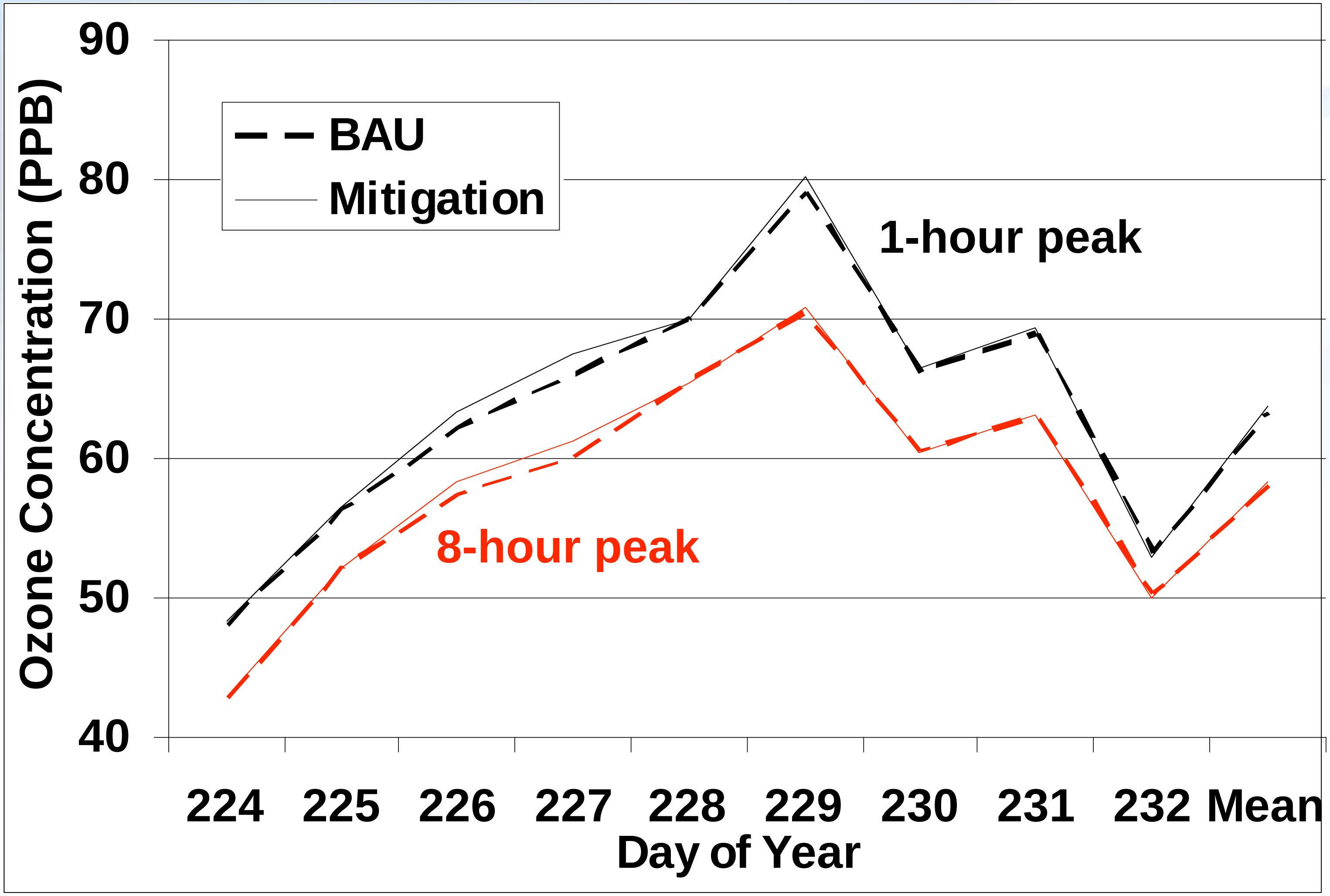
BAU vs. UHI Mitigation Simulations

5-County Area



BAU vs. UHI Mitigation Simulations

20-County Area



Summary and Lessons Learned

- The high-resolution LandPro99 data characterized land use in the metropolitan Atlanta area more accurately than the traditional USGS land use data set, particular in suburban areas.

- Use of LandPro99 landuse data improved the performance of the meteorological model, reducing the large daytime cold bias by 30%.

- Ozone estimated by CMAQ are not very sensitive to the choice of landuse data set.

- Use of LandPro99 landuse data facilitated the application of the Spatial Growth Model.

Summary and Lessons Learned (Continued)

- **Projected landuse changes over the next 30 years will lead to increases in summertime temperatures. Changes are most pronounced in the outlying counties.**
- **Application of UHI mitigation strategies will offset much of the projected warming, but will have marginal effects on ozone.**
- **UHI mitigation common themes for success are sustained commitment over time, comprehensive approach, high public awareness, and leadership and policy commitment. (Georgia Cool Communities Program)**