Satellite-Derived High Resolution Land Use/Land Cover Data to Improve Urban Air Quality Model Forecasts and Decision-Making

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1. Motivation and Objectives

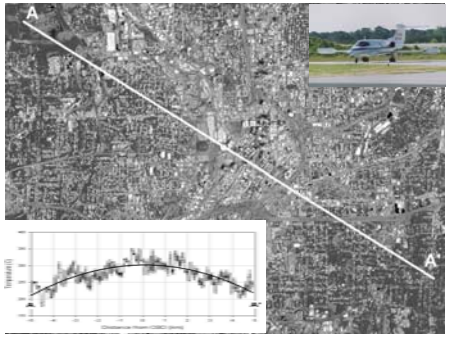
Elevated urban temperatures, referred to as the Urban Heat Island (UHI), affect human health, energy consumption, and air quality. In partnership with local and state stakeholders, we have developed realistic UHI mitigation strategies based on use of high-albedo roofing and paving materials and increased tree canopy. We performed meteorological and air quality modeling for Atlanta to examine the potential for the UHI mitigation strategies to reduce urban air temperatures and improve air quality. A spatial growth model was used to project land use/land cover for the area to 2030. Temperature changes from 2000 to 2030 and the effect of the mitigation strategies in 2030 are presented here.

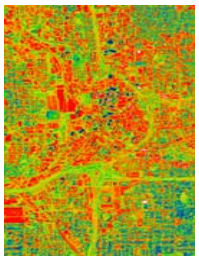
2. Remote Sensing of Atlanta's Surface Heating Characteristics

The Atlanta metropolitan area has been one of the fastest growing urban areas in the United States for many years. This rapid urbanization has contributed to problems with air quality, particularly ground-level ozone (O_3), along with significant land use and land cover changes (LULCC). LULCC has also enhanced the development of the UHI over the Atlanta metropolitan area.

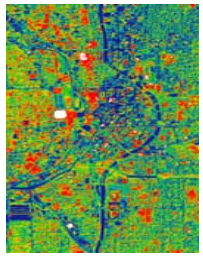
High resolution true-color remotely sensed image of the Atlanta area (Digitalglobe)

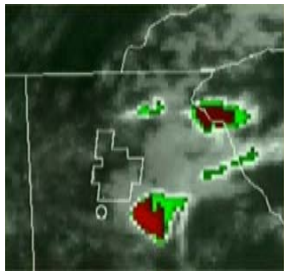
High spatial resolution (10m) thermal infrared (TIR) remote sensing data were collected over Atlanta during the daytime using a NASA aircraft to measure heating and patterns over the metropolitan area



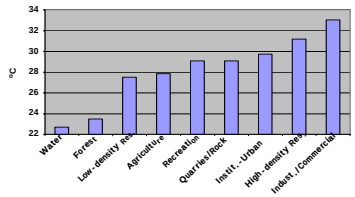


Surface Temperature and Albedo Comparison Atlanta, GA May 1997





Surface Temperature by Land Use Class
Based on ATLAS aircraft data, May 1997

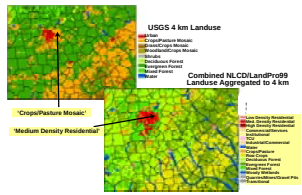


As a "serendipitous" finding from this study, Atlanta's UHI can affect local weather conditions. As shown in this GOES weather satellite image, Atlanta (outlined in the polygon) spawns rainfall (in red and green) east of the city as a result of the UHI effect "pumping" hot air into the lower atmosphere. This hot air rises and condenses, producing rainfall downwind of Atlanta.

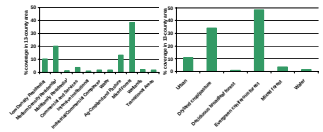
3. Comparison of Land Use Classifications

A high-resolution (30m) LULC data set was created by merging the National Land Cover Data (NLCD) data set with the LandPro99 data set for the metropolitan Atlanta area and used in model simulations. Results were compared with those obtained using the traditional U.S. Geological Survey (USGS) 4 km LULC data set.

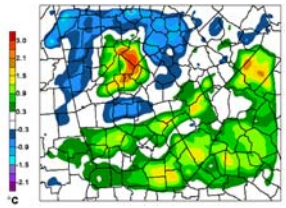
Comparison of Landuse Classifications



Comparison of Landuse Classifications
Landpro99 vs. USGS – 13 county area

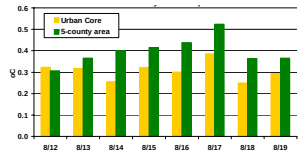


LandPro99		USGS	
Forest:	38%	Forest:	53%
Agriculture:	13%	Agriculture:	35%
Urban (excl. LD res):	28%	Urban:	11%

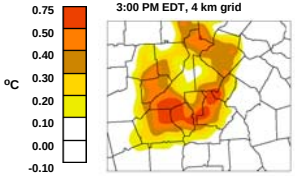


Air temperature difference between USGS and NLCD/LandPro99 LULC data sets at 5:00 local daylight time on day 6 of the model simulation

Mean surface air temperature differences
2030 Business as Usual – 2000 Baseline
12:00 – 6:00 PM EDT 4 km grid



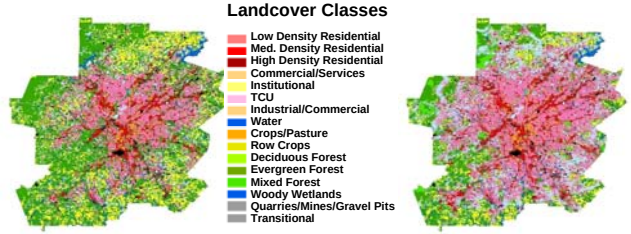
Surface air temperature difference
2030 Business as Usual – 2000 Baseline
3:00 PM EDT, 4 km grid



4. Spatial Growth Modeling

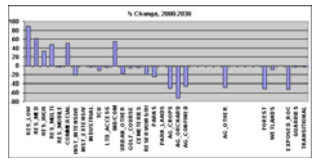
A Spatial Growth Model (SGM) was used to project land use/land cover for the 13 county Atlanta metropolitan area to 2030. Inputs to the model were current land use and projected population, employment, and road networks. Current land use/land cover were defined using the high-resolution (30m) LandPro99 data set created by the Atlanta Regional Commission.

Landcover Classes



1999 2030

Land Use Projections



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	11.34	+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	2.58	+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	3.09	3.38	+13.1

Source: Prescott College Spatial Growth Model

5. Impact of Urban Heat Island Mitigation Strategies on Regional Climate

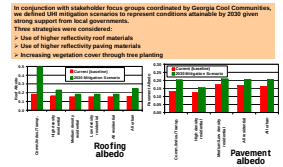
To evaluate the effectiveness of UHI mitigation strategies in reducing urban air temperatures, different mitigation strategies were modeled for the Atlanta metro area. The modeling of mitigation strategies was performed to illustrate what impacts they will have on air temperatures across the urban landscape out to 2030.

■ Reflective roofing

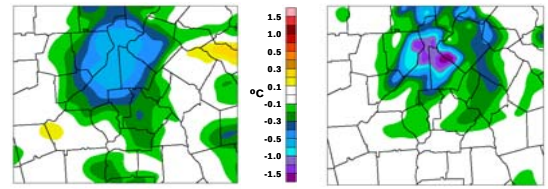
■ Green roofs

■ Shade trees

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



Air Temperature difference between 2030 UHI mitigation simulation and 2030 BAU simulation



3:00 PM local daylight time, day 3 of simulation

1:00 PM local daylight time, day 7 of simulation

The extent to which urban areas can benefit from heat island reduction strategies depends upon several factors. Some of these factors such as prevailing weather patterns, geography, and pollution transported from upwind regions, are largely beyond the influence of local policy. However, such factors as land use patterns, road and building construction materials, and area covered by urban trees and vegetation, can be directly affected by decision-makers who can initiate policies and programs to reduce the impacts of urban heat islands, and achieve related environmental and energy-saving goals. The UHI mitigation scenarios shown here were developed in conjunction with Georgia Cool Communities and local stakeholders to represent aggressive but attainable scenarios by 2030.

6. Conclusions

- Using an SGM in conjunction with high-resolution land cover data for 2000 and projected to 2030, daytime urban air temperature is shown to increase in the Atlanta area, most notably in the suburban areas that are projected to grow significantly. The mean amount of warming for the 5-county urban core Atlanta area is about 0.4 °C for the midday period.
- Applying realistic urban heat island mitigation strategies, based on higher roof and pavement albedos and increased tree canopy, is shown to have a cooling effect on daytime urban air temperatures.
- UHI mitigation common themes for success are sustained commitment over time, comprehensive approach, high public awareness and leadership and policy commitment.