



University of Utah, Dept. of Geography
Invited Lecture

Urban Sustainability and Public Health: Throwing the Bath Water Out and Not the Baby

Dale A. Quattrochi

NASA

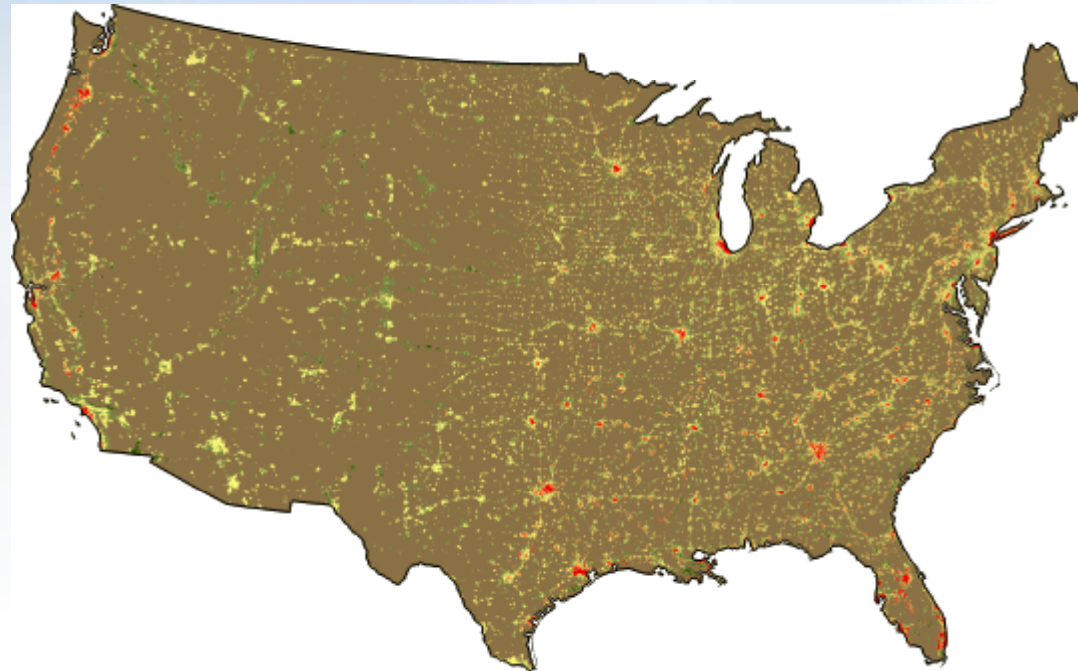
Earth Science Office

Marshall Space Flight Center

Huntsville, Alabama



U.S. Urbanization



Change in NPP due to Urbanization (gC/m² year)



- Total Impervious Surface Area of Continental U.S. is 112,610 km² (Slightly smaller than the state of Ohio)

Source: EOS, June 2004

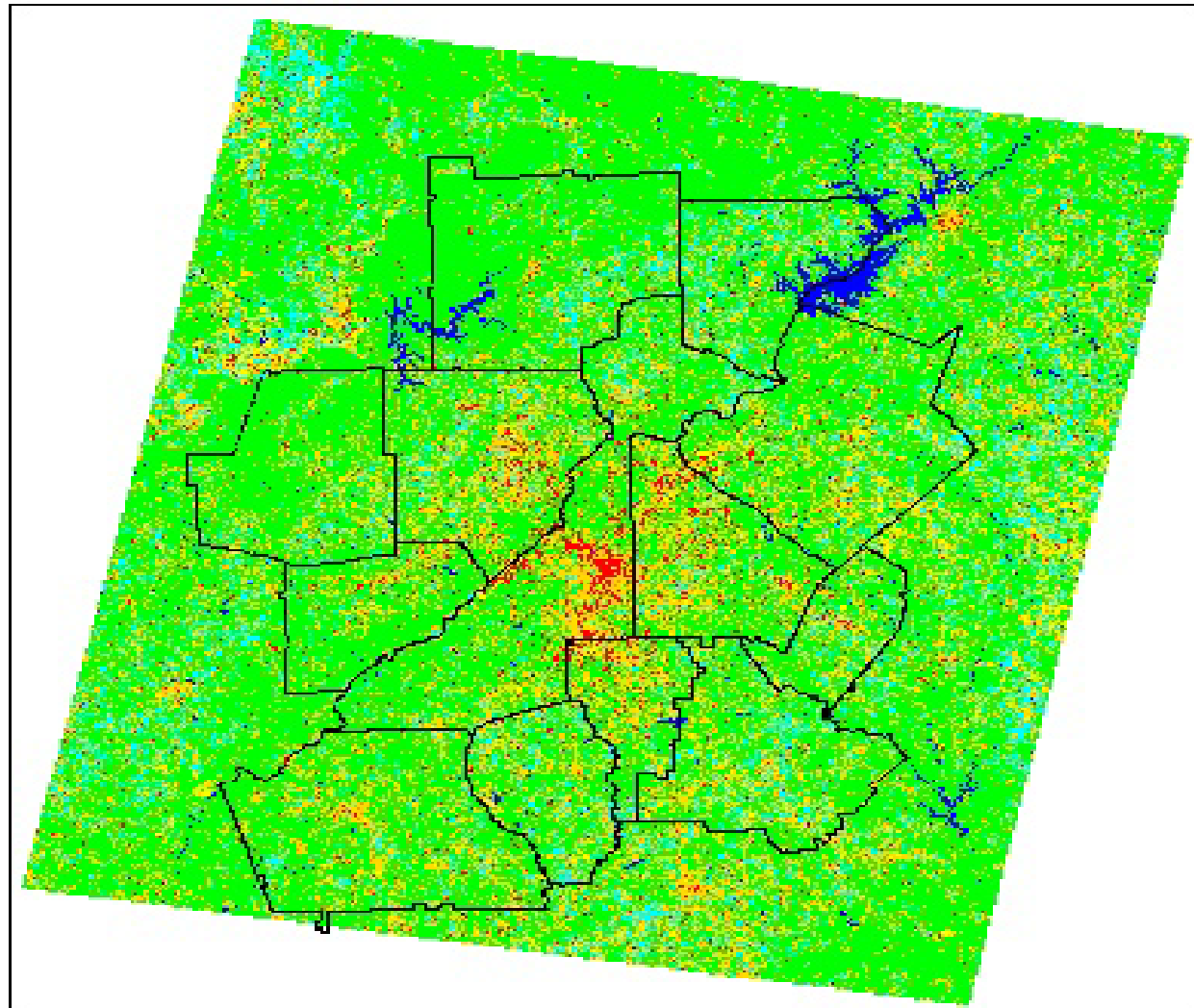


Urbanization Impacts







- Increases Surface Runoff
- Reduces Carbon Sequestration
- Alters Energy Balance

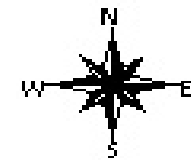


LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1973



LEGEND

-  High-Density Urban Use
-  Low-Density Residential
-  Cultivated / Exposed Land
-  Cropland and Grassland
-  Forest Land
-  Water

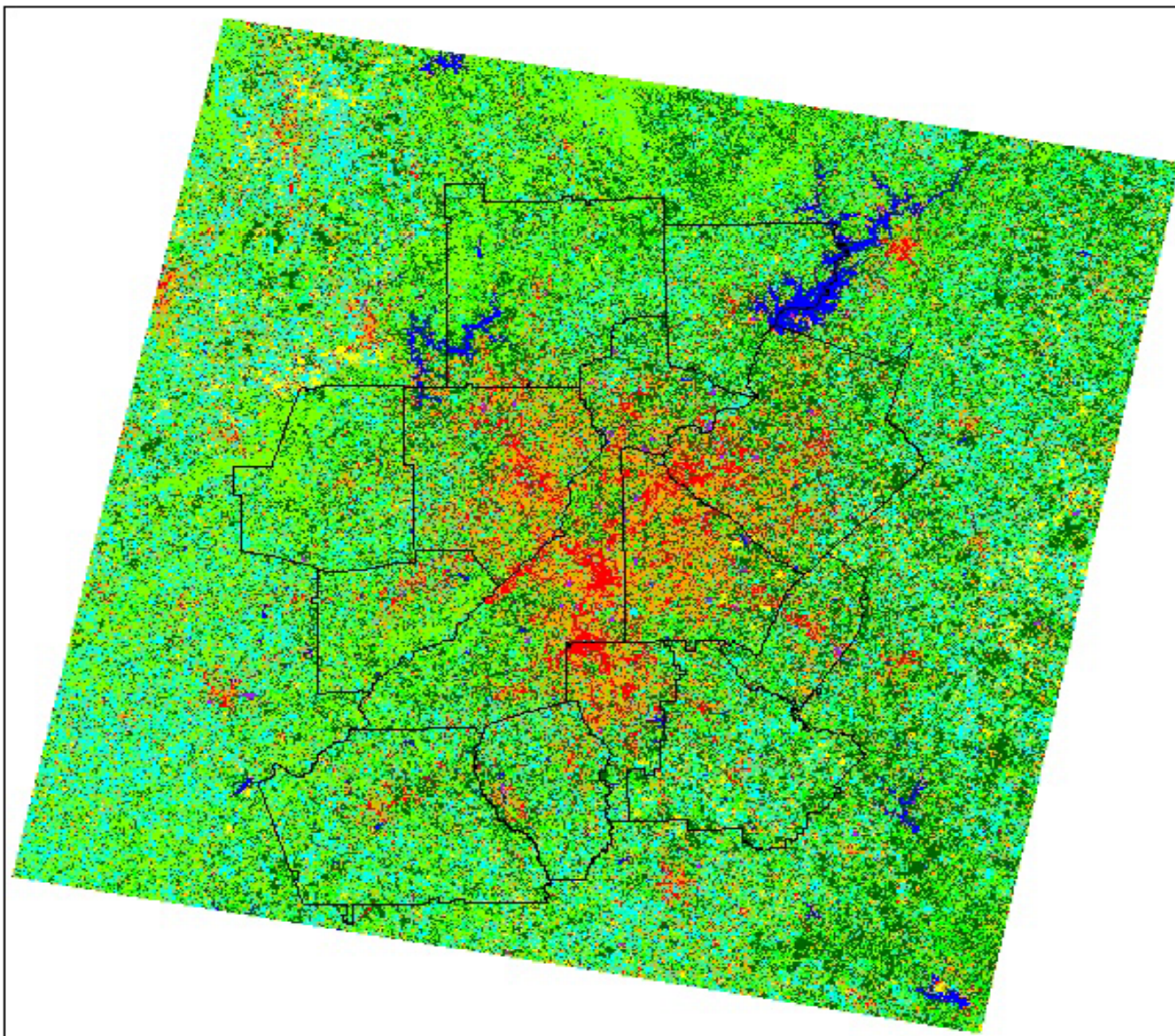


Based on Landsat MSS
Image Dated April 13, 1973

Atlanta Regional Commission
Boundary Shown

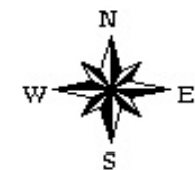


LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1987



LEGEND


-  High-Density Urban Use
-  Low-Density Residential
-  Cultivated / Exposed Land
-  Cropland and Grassland
-  Golf Courses and Parks
-  Evergreen Forest
-  Mixed Forest Land
-  Deciduous Forest
-  Water



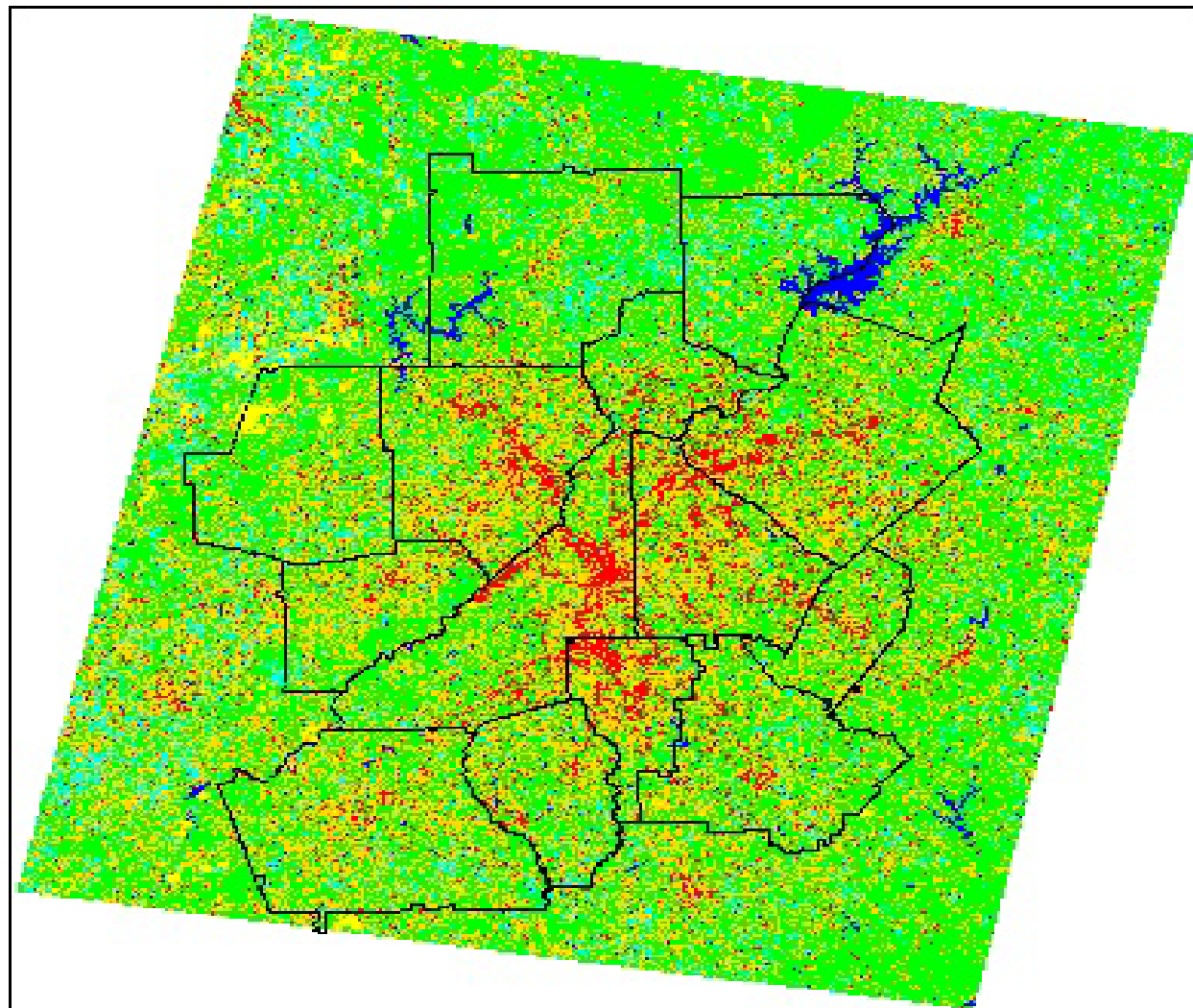
Based on Landsat TM Images
Dated June 29 , 1987

Atlanta Regional Commission
Boundary Shown







15 0 15 30 45 60 75 90 Kilometers

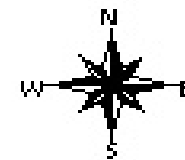


LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1992



LEGEND

-  High-Density Urban Use
-  Low-Density Residential
-  Cultivated / Exposed Land
-  Cropland and Grassland
-  Forest Land
-  Water

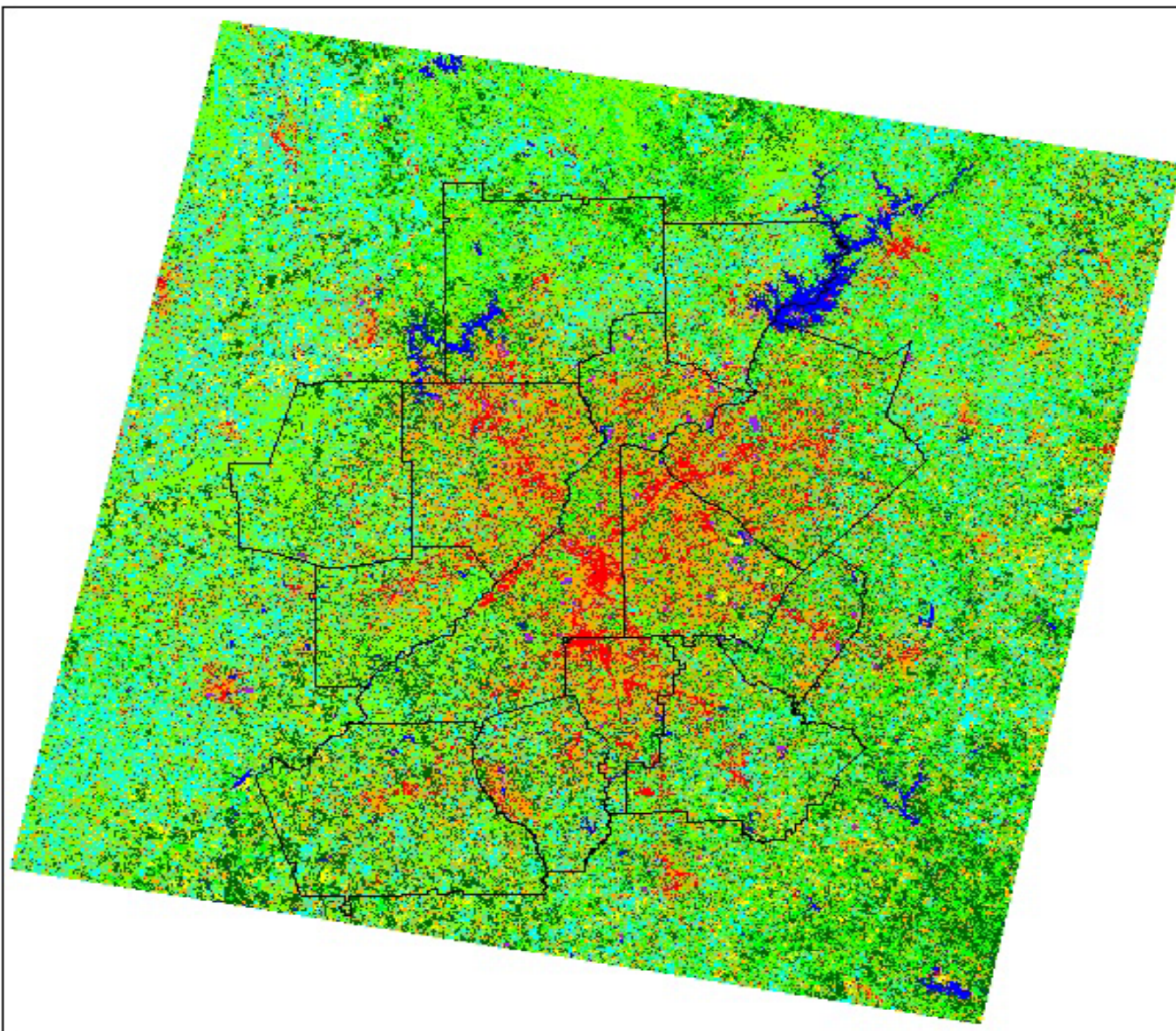


Based on Landsat MSS
Image Dated April 23, 1992

Atlanta Regional Commission
Boundary Shown

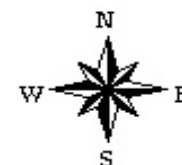


LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1997-1998



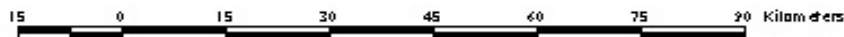
LEGEND

-  High-Density Urban Use
-  Low-Density Residential
-  Cultivated / Exposed Land
-  Cropland and Grassland
-  Golf Courses and Parks
-  Evergreen Forest
-  Mixed Forest Land
-  Deciduous Forest
-  Water



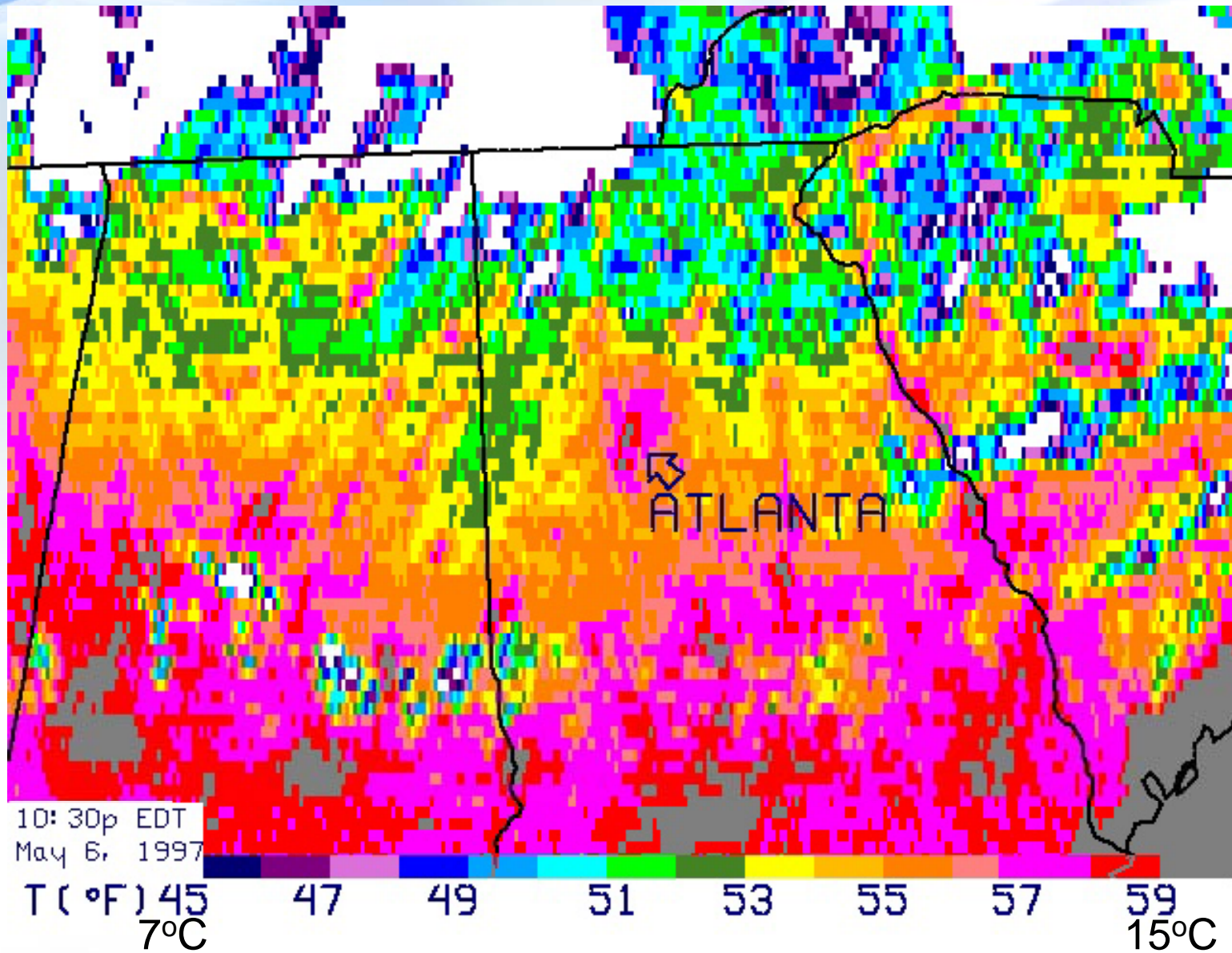
Based on Landsat TM Images Dated
July 10, 1997 and Jan. 2, 1998

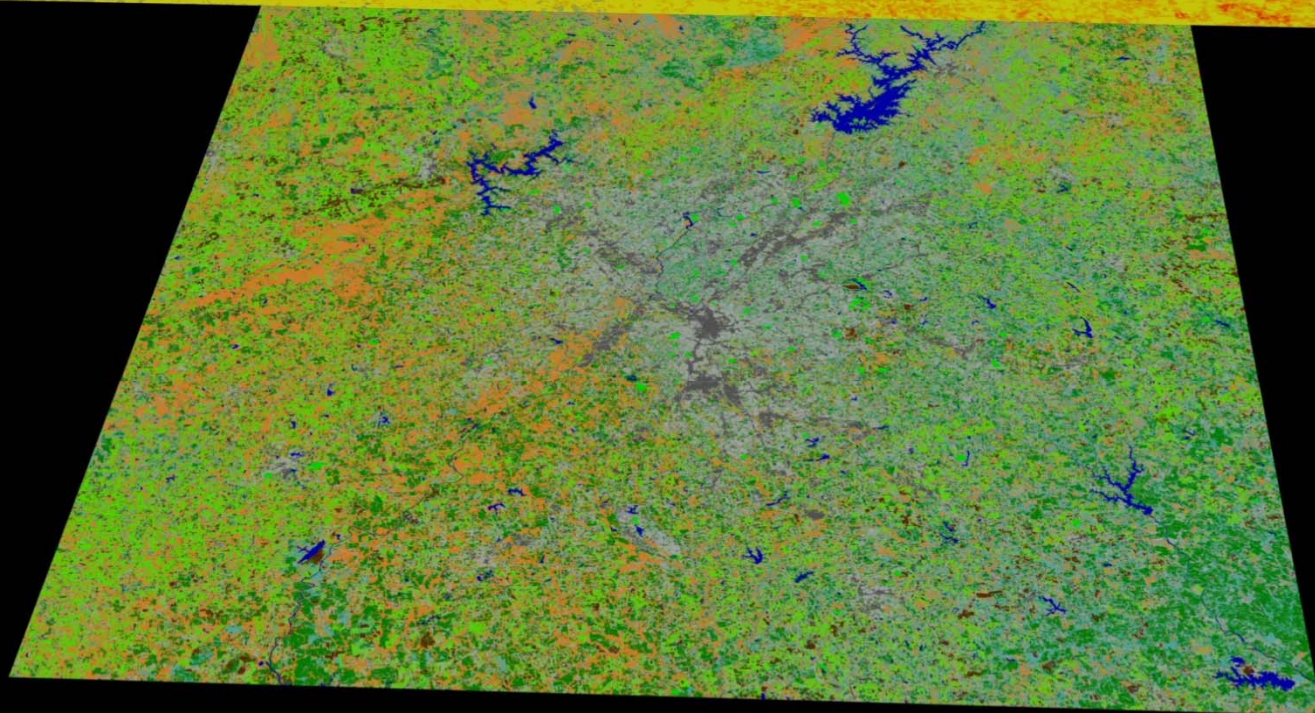
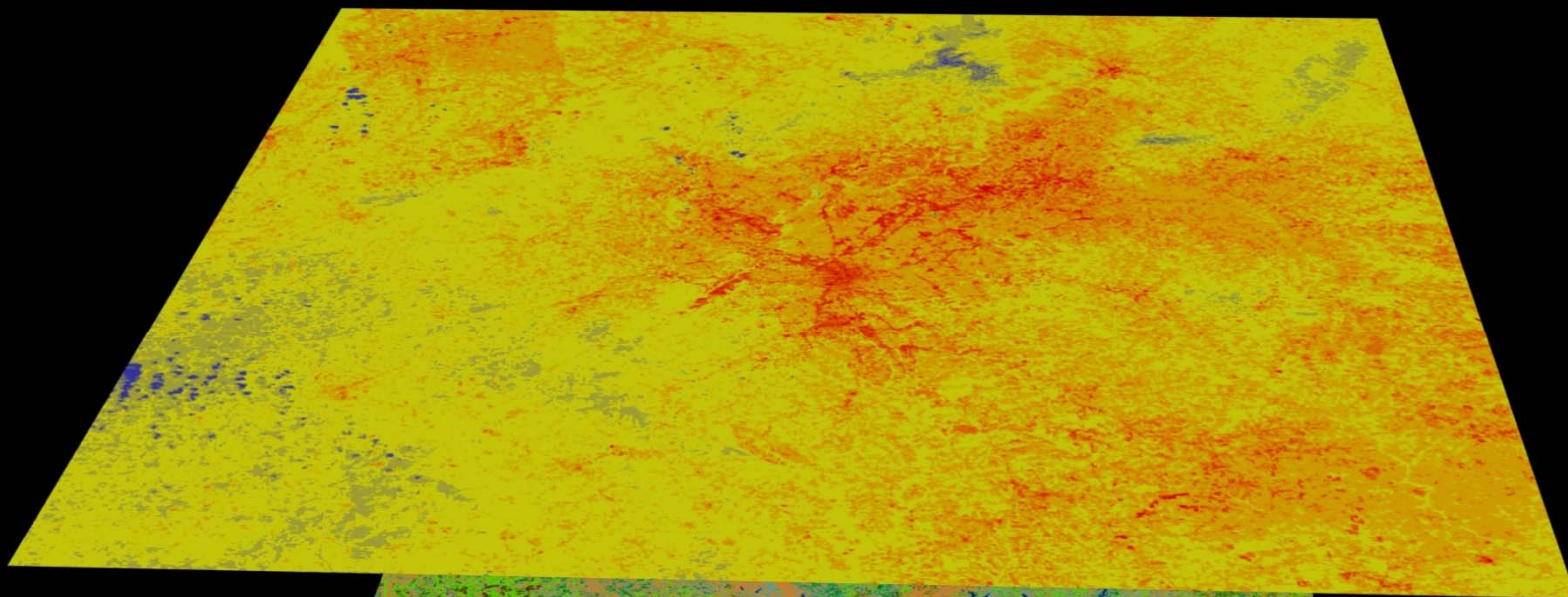
Atlanta Regional Commission
Boundary Shown





NAS Sustainable Urban Systems Forum

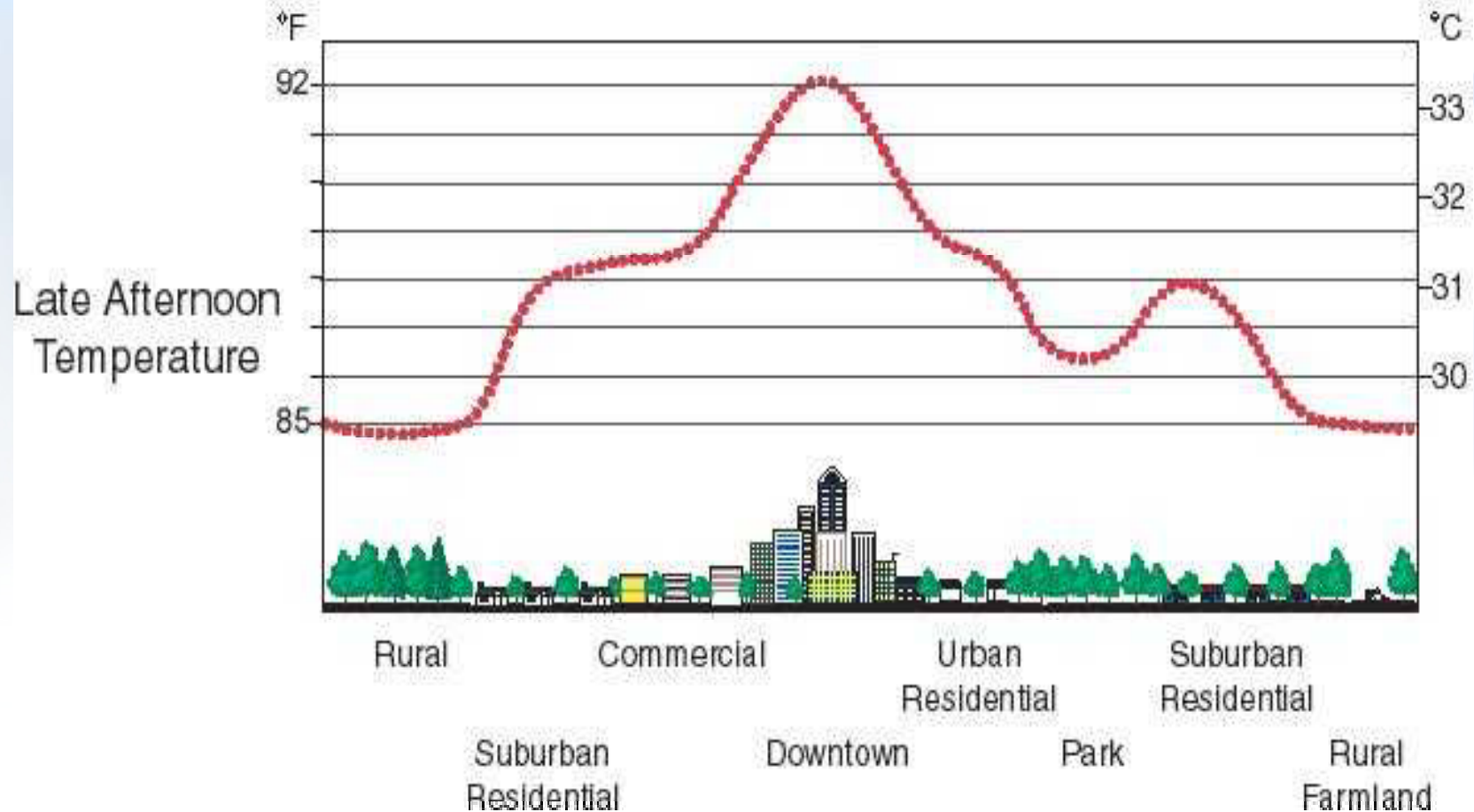






NAS Sustainable Urban Systems Forum

Sketch of an Urban Heat-Island Profile





NAS Sustainable Urban Systems Forum

Mission to Planet Earth
National Aeronautics and Space Administration



Urban Remote Sensing and Air Quality Models

Volatile Organic Compounds
+ Nitrogen Oxides
+ Sunlight
→ Ozone



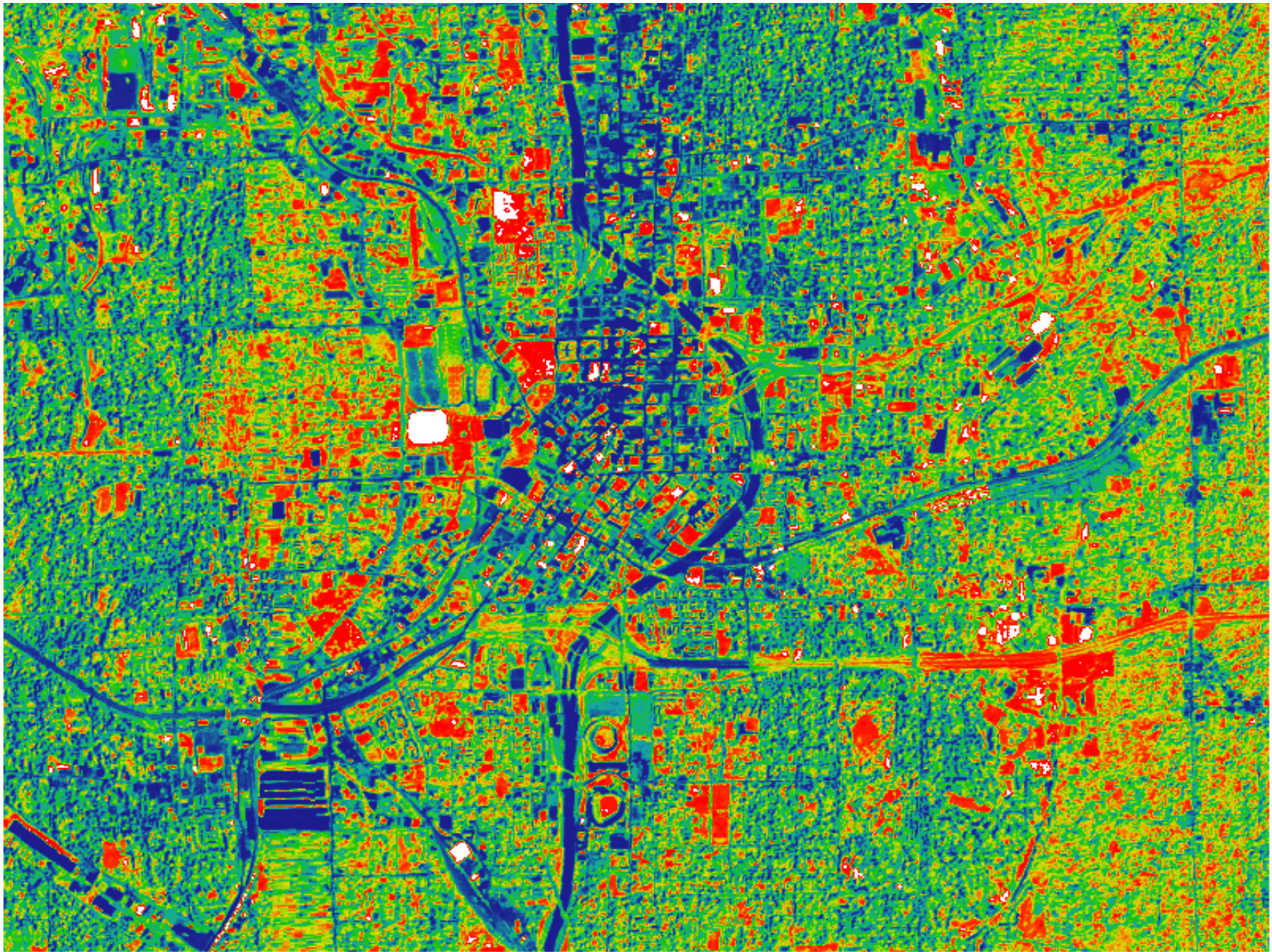
- Air pollution remains a National issue.
- Temperature increases the ozone levels.
- Urban heat island has major effect on temperature and height of mixing layer.
- Measurement program is defining land use patterns and relationship to heat production.
- Remote sensing data are being used to improve air quality modeling.



NAS Sustainable Urban Systems Forum

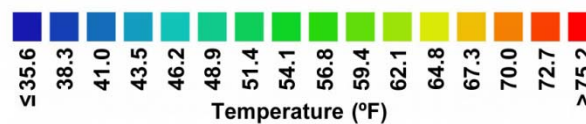
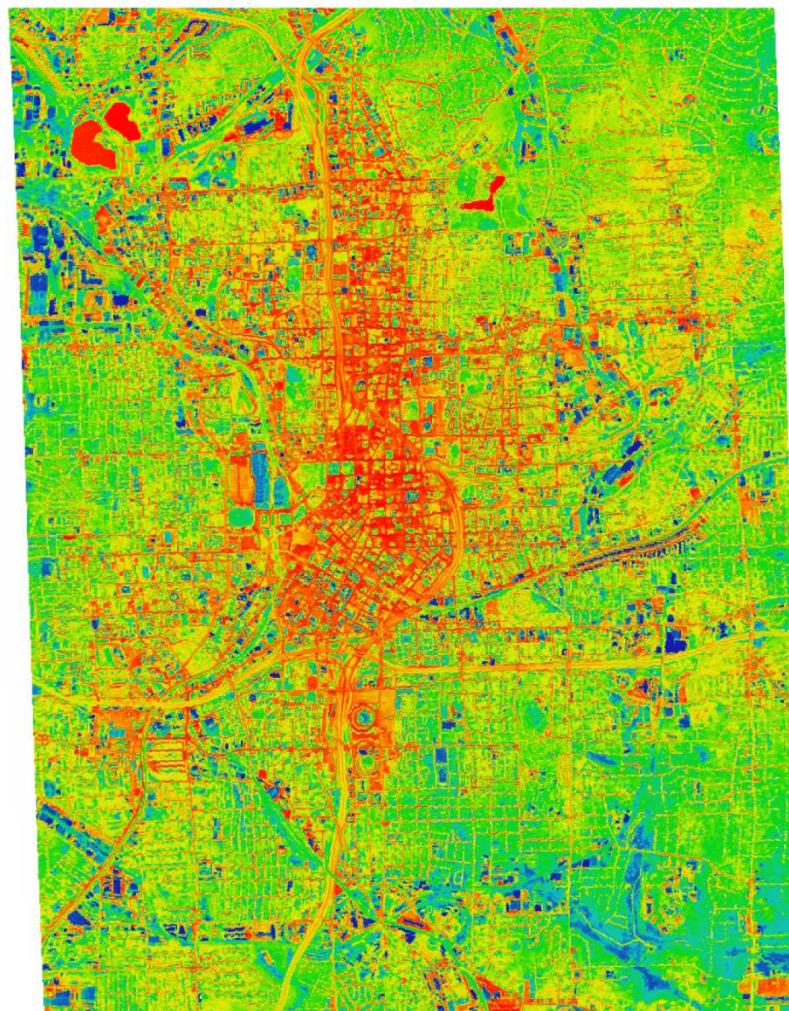








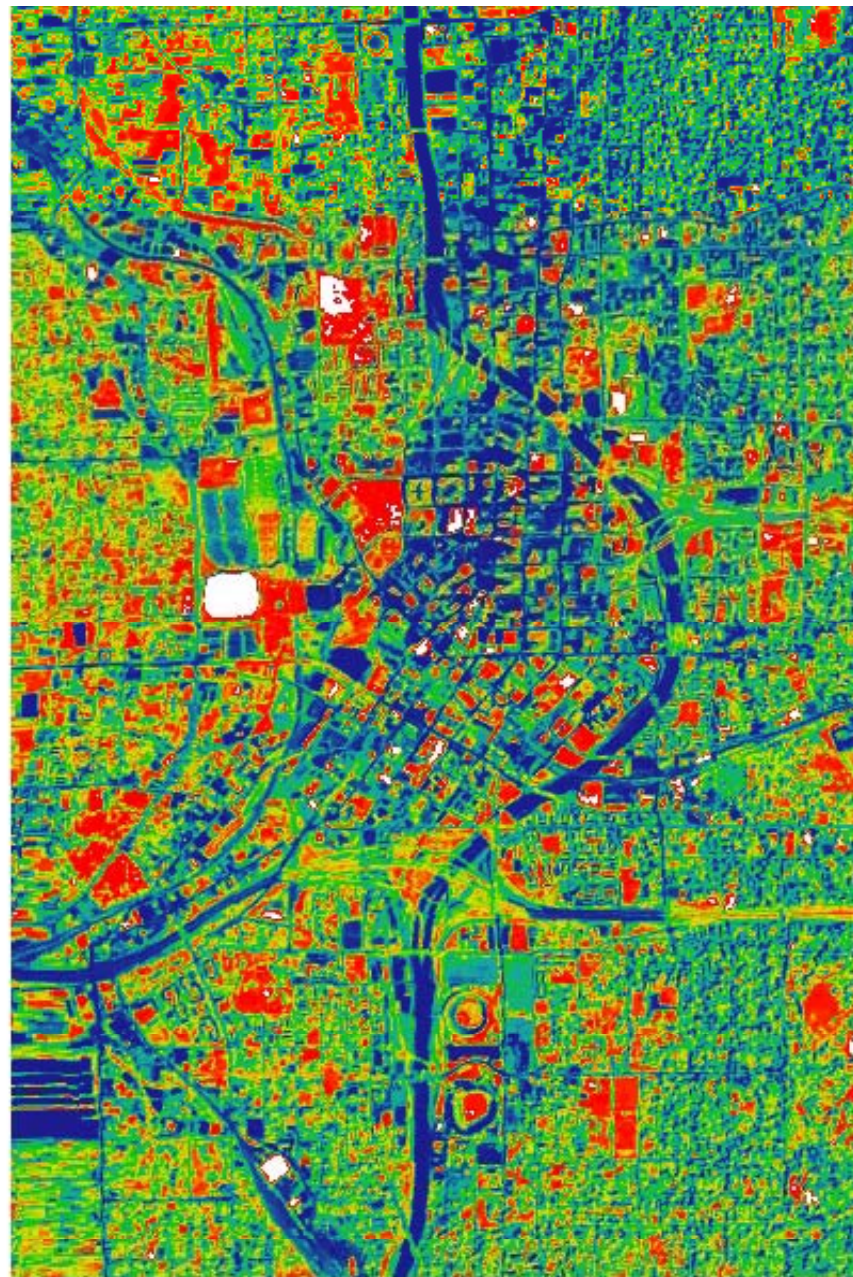
Atlanta Central Business District Night Data – May 1997



Source: NASA / EPA



Temperature



Albedo

Atlanta. GA - May 1997



Impervious Surfaces





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NAS Sustainable Urban Systems Forum





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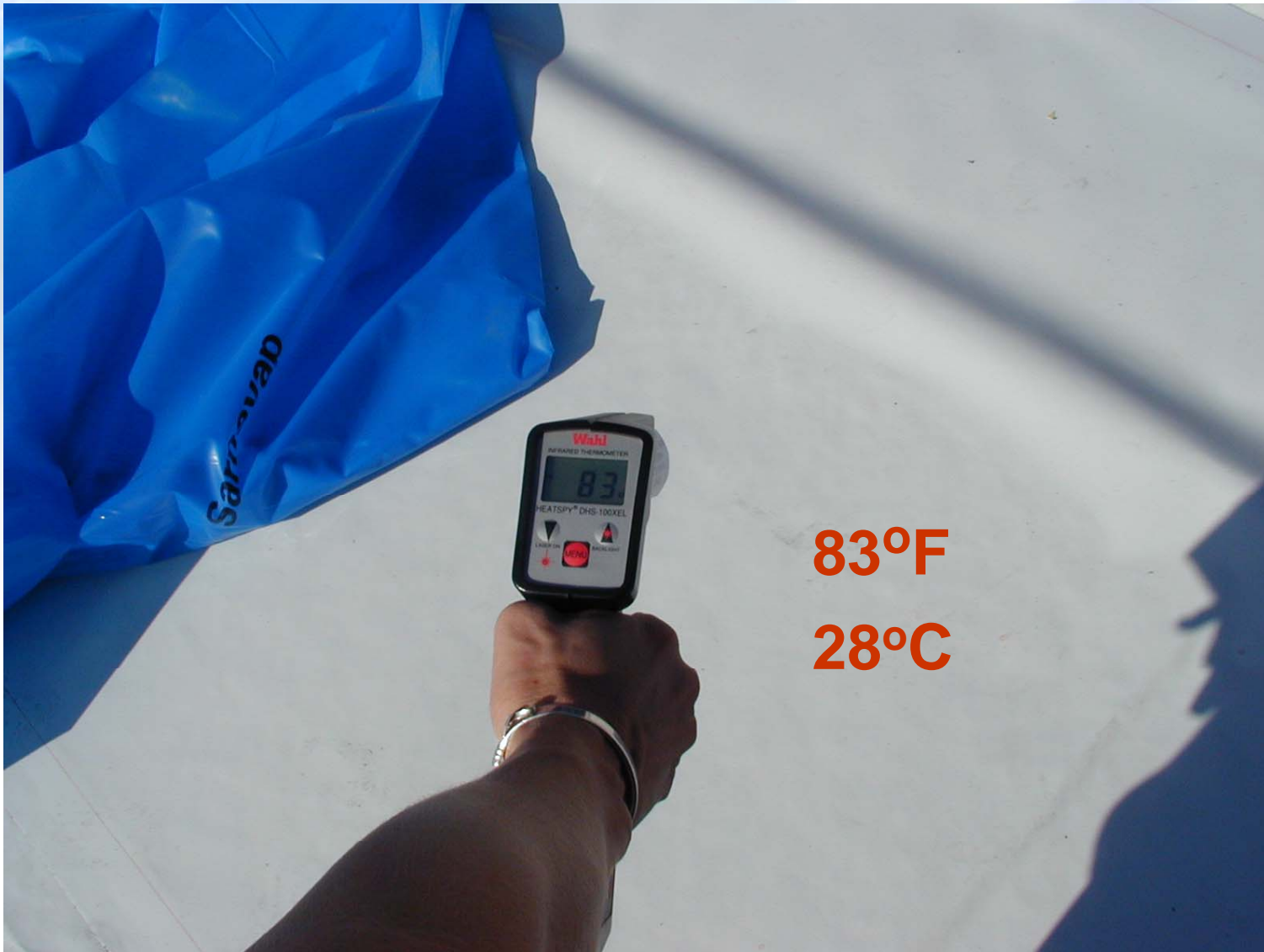
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120°F
49°C



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83°F
28°C



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Mitigation Measures

- Green roofs





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Mitigation Measures

- **Less impervious land cover**





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Mitigation Measures

- **Shade trees**





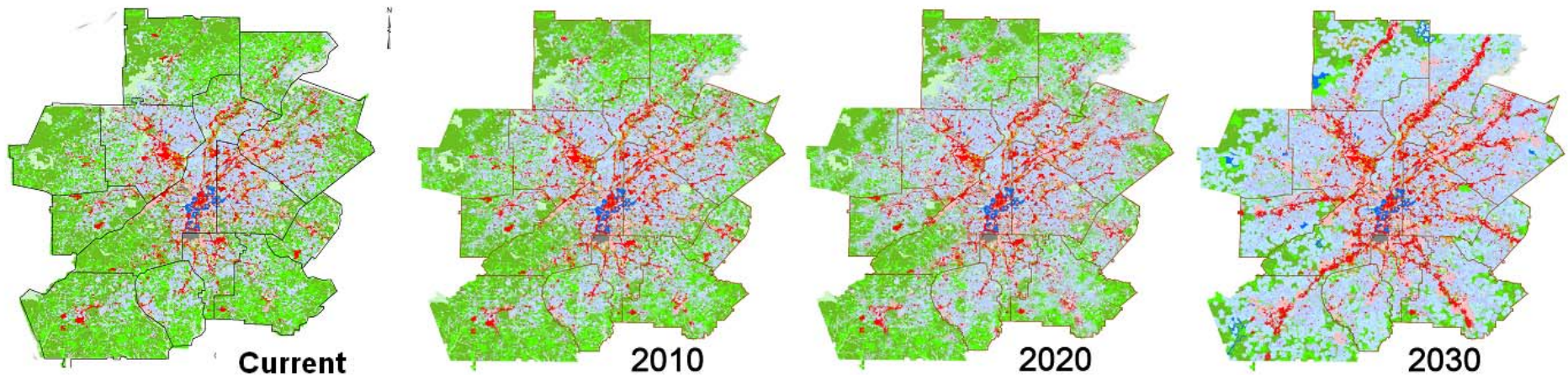
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Mitigation Strategies


























Spatial Growth Modeling Results



Legend

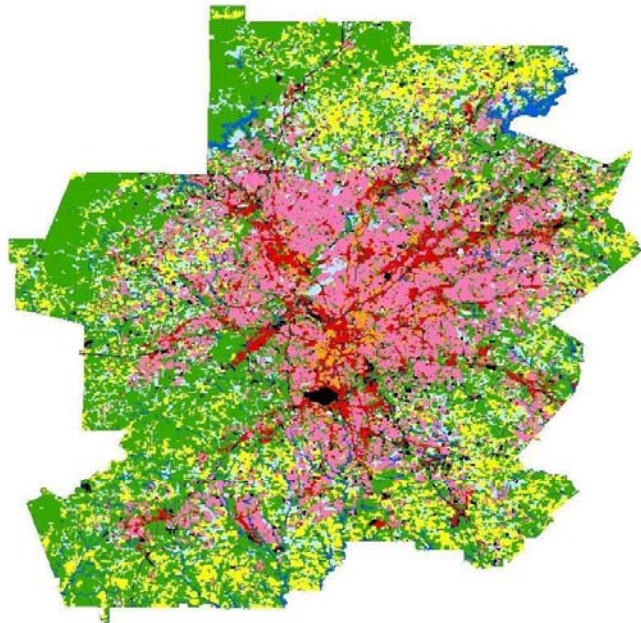
 AG_CONFINED	 COMMERCIAL	 LTD_ACCESS	 RES_MOBILE
 AG_CROPS	 FOREST	 PARKS	 RES_MULTI
 AG_ORCHARD	 IND/COM	 RESERVOIRS	 RIVERS
	 INDUSTRIAL	 RES_HIGH	 TCU
	 INST_EXTENSIVE	 RES_LOW	 TRANSITIONAL
	 INST_INTENSIVE	 RES_MED	 URBAN_OTHER





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

Current (1999)



Projected (2030)



The Spatial Growth Model (SGM) was used to project land use/land cover for the area to 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).

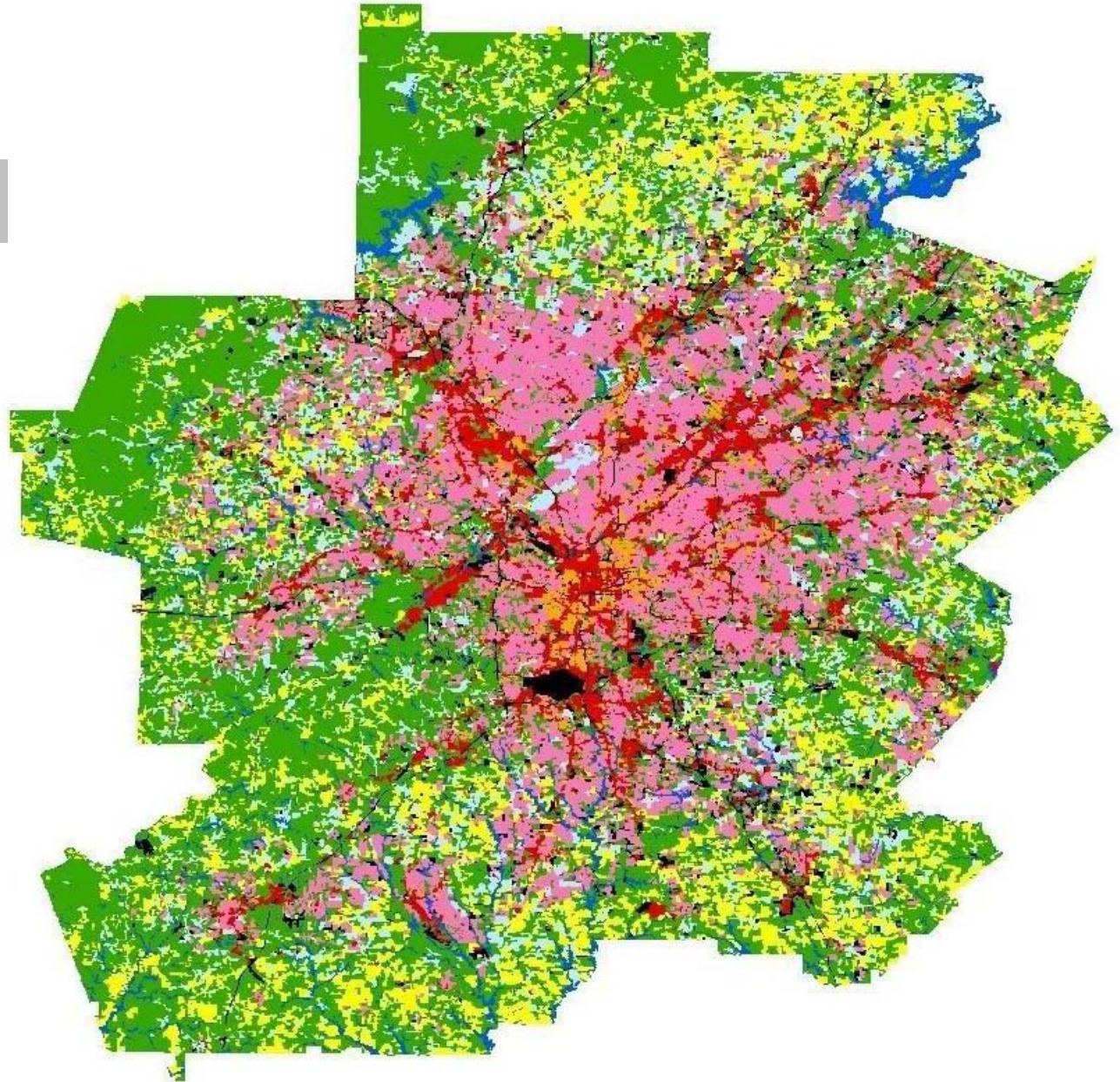




Atlanta Urban Heat Island and Air Quality Modeling Study

Land Use in 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

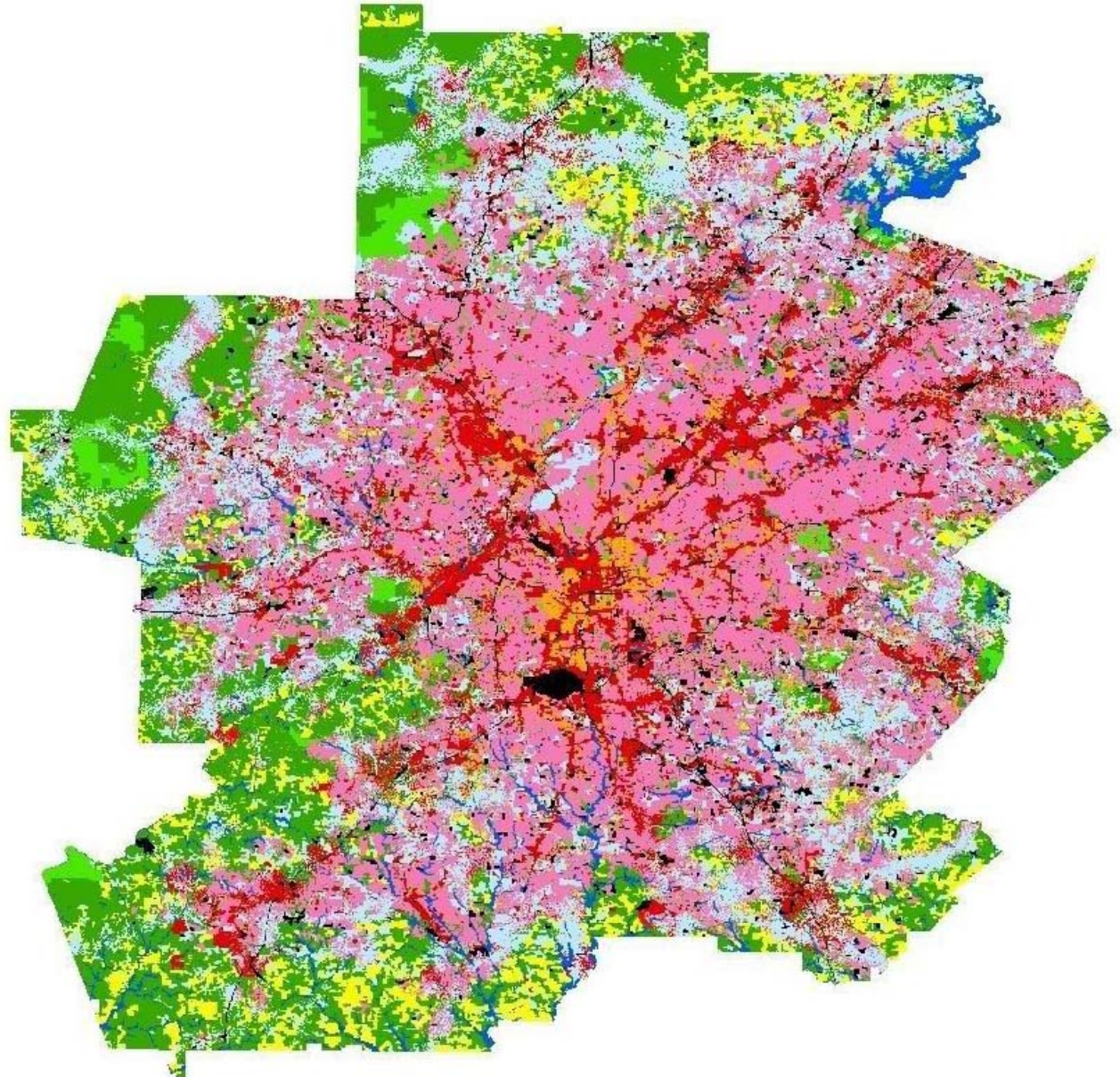




Atlanta Urban Heat Island and Air Quality Modeling Study

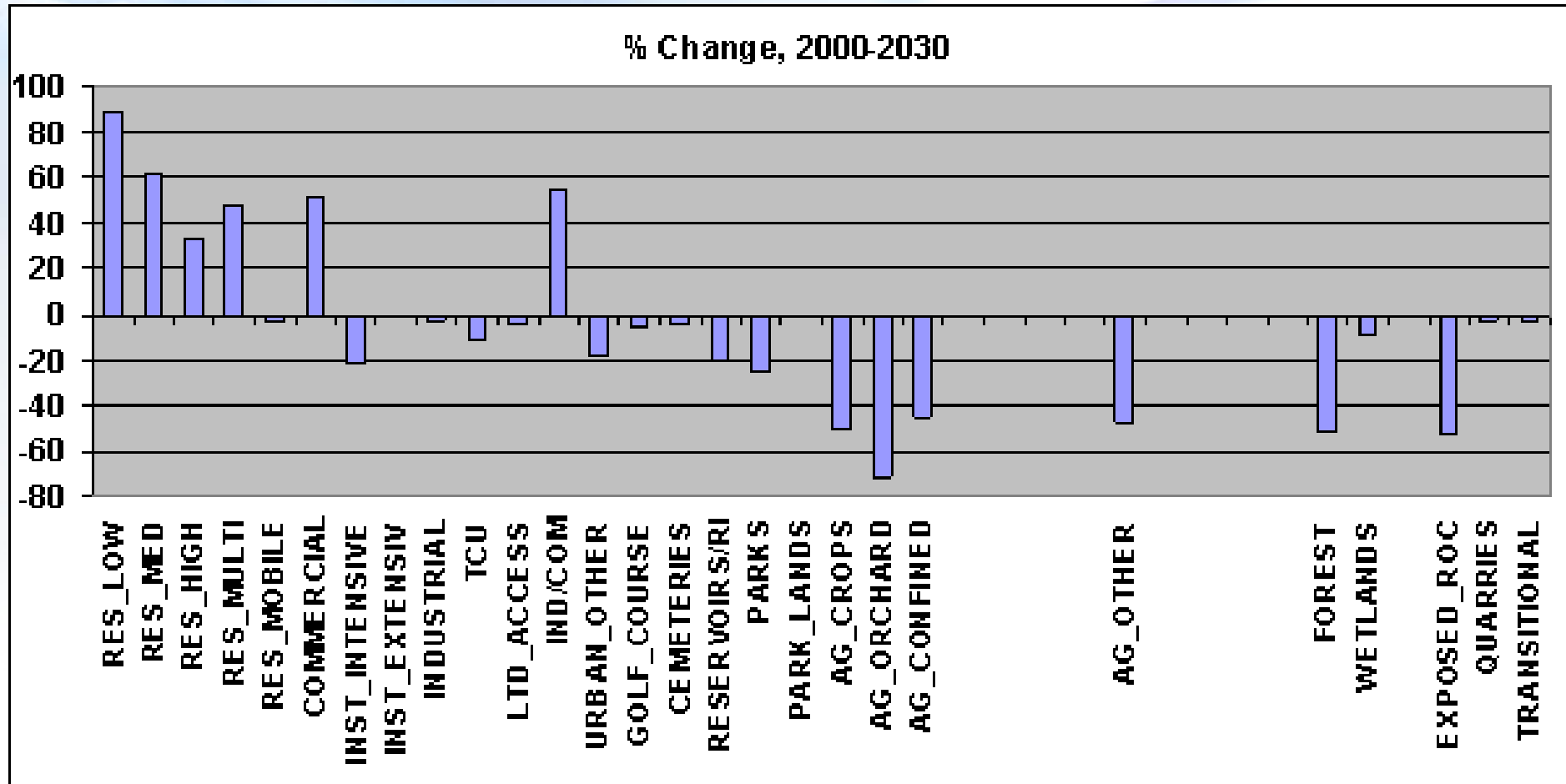
Projected Land Use in 2030

-  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





Land Use Projections



Source: Prescott College Spatial Growth Model





Basics of Public Health

Public Health Approach

Problem

- Surveillance:
 - What is the problem?

- Risk Factor
- Identification:
 - What is the cause?

- Intervention
- Evaluation:
 - What works?

- Implementation:
 - How do you do it?

Response





□ HELIX-Atlanta Overview

□ Public Health Surveillance

- Ongoing systematic collection, analysis, and interpretation of outcome-specific data used to plan, implement, and evaluate public health practice.





□ HELIX-Atlanta Overview

□ Surveillance Information Uses

- Monitor & detect changes in the magnitude & distribution of selected events
- Develop hypotheses for research
- Evaluate interventions
- Facilitate public health decision-making





□ HELIX-Atlanta Overview

- The U.S. Center for Disease Control and Prevention's (CDC) National Environmental Public Health Tracking (EPHT) Program was initiated in 2002
- Congressional funding for *development and implementation of a nationwide environmental health tracking network and capacity development in environmental health at State and local health Departments*”



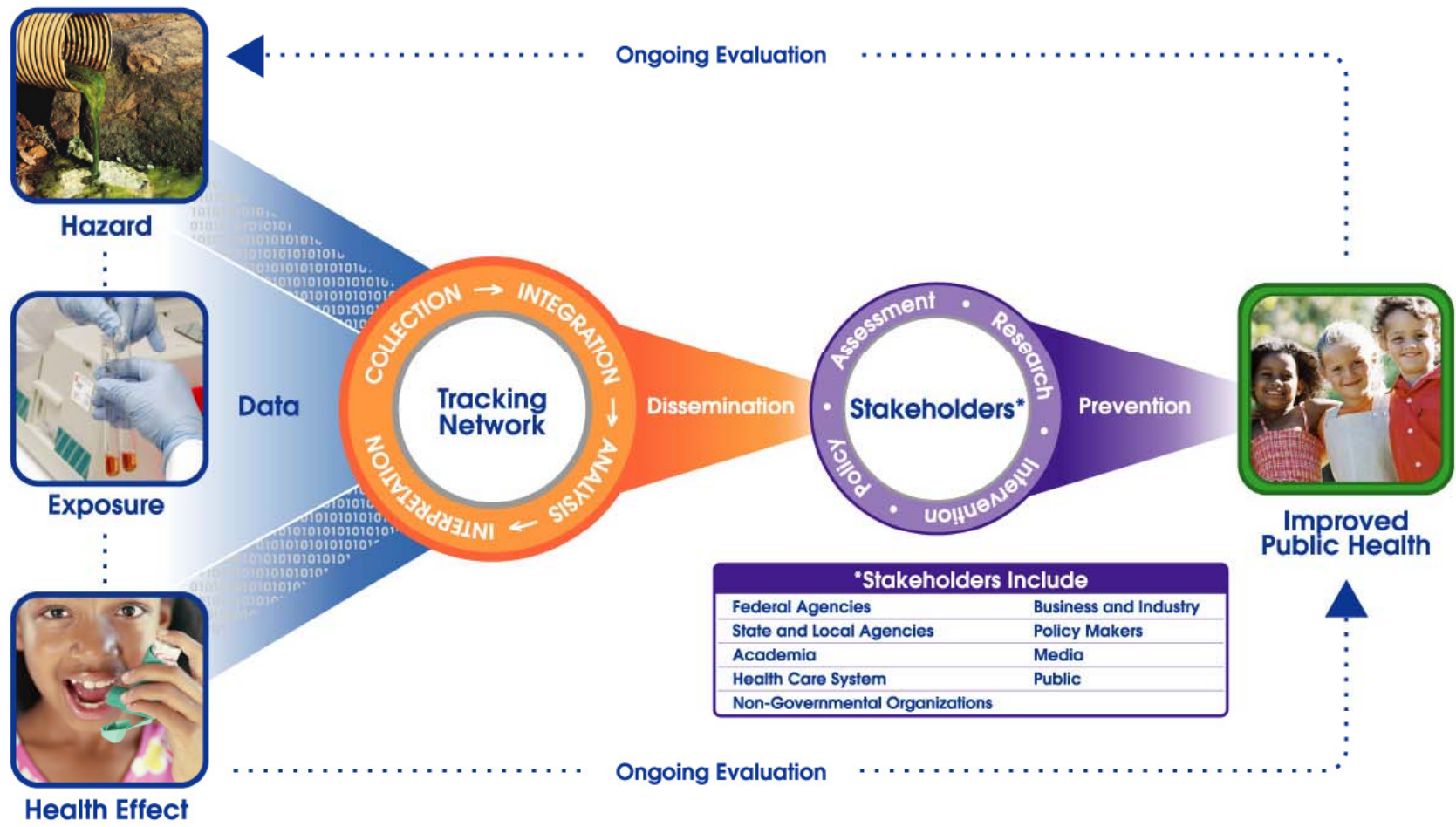


□ Tracking = Public Health Surveillance

- Environmental public health tracking is the ongoing, systematic collection, integration, analysis, and interpretation of data about the following factors:
 - environmental hazards
 - human exposure to environmental hazards
 - health effects potentially related to exposure to environmental hazards
- Data must be disseminated to plan, implement, and evaluate environmental public health action



ENVIRONMENTAL PUBLIC HEALTH TRACKING



***Stakeholders Include**

Federal Agencies	Business and Industry
State and Local Agencies	Policy Makers
Academia	Media
Health Care System	Public
Non-Governmental Organizations	



**DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION
SAFER • HEALTHIER • PEOPLE**





□ PUBLIC HEALTH, AIR QUALITY, AND REMOTE SENSING

□ THE INTEGRATION OF PUBLIC HEALTH SURVEILLANCE, AIR QUALITY ASSESSMENT, AND REMOTE SENSING:

□ AN ATLANTA, GEORGIA CASE STUDY





Health and Environment Linked for Information Exchange (HELIX)-Atlanta

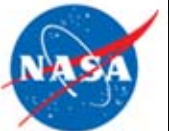
- Provide information regarding the 5-county Metro-Atlanta Area
 - Clayton, Cobb, DeKalb, Fulton, & Gwinnett
- Integrate environment & public health data into a local network that is part of a national network
- Take action to prevent & control environmentally related health effects





□ HELIX-Atlanta Overview

- HELIX-Atlanta was developed to support current and future state and local EPHT programs to implement data linking demonstration projects which could be part of the EPHT Network.
- HELIX-Atlanta is a pilot linking project in Atlanta for CDC to learn about the challenges the states will encounter.
- NASA/MSFC and the CDC are partners in linking environmental and health data to enhance public health surveillance.
- The use of NASA technology creates value – added geospatial products from existing environmental data sources to facilitate public health linkages.
- Proving the feasibility of the approach is the main objective





□ HELIX-Atlanta Challenges

- **Sharing data between agencies with different missions and mindsets**
- **Protecting confidentiality of information**
- **Ensuring high quality geocoded data**
- **Ensuring appropriate spatial and temporal resolutions of environmental data**
- **Developing sound resources and methods for conducting data linkages and data analysis**





□ HELIX-Atlanta Respiratory Health Team

- **RH Team Pilot Data Linkage Project:**
- **Link environmental data related to ground-level PM_{2.5} (NASA+EPA)**
- **with health data related to asthma**

Goals:

- 1. Produce and share information on methods useful for integrating and analyzing data on asthma and PM_{2.5} for environmental public health surveillance.**
- 2. Generate information and recommendations valuable to sustaining surveillance of asthma with PM_{2.5} in the Metro-Atlanta area.**

Environmental Hazard Measure: Daily PM_{2.5}

Asthma Measure: Daily acute asthma office visits to KP-GA Medical Facilities

Time period: 2001-2003

Linkage Domain: 5-county metropolitan Atlanta



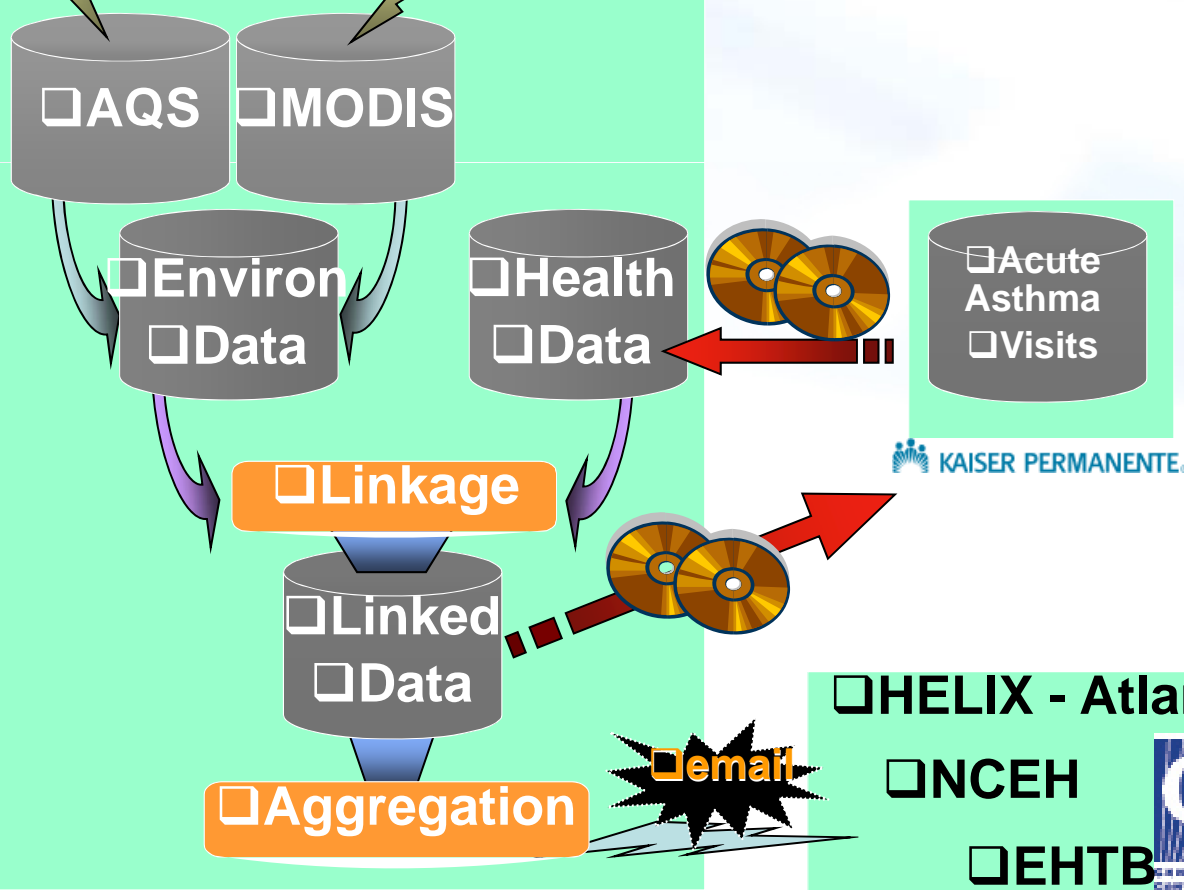
Data Linkage



EPA



NASA



- HELIX - Atlanta Team
- NCEH
- EHTB





Sources of PM_{2.5} data: EPA AQS

EPA Air Quality System (AQS) ground measurements

- National network of air pollution monitors
- Concentrated in urban areas, fewer monitors in rural areas

➤ Time intervals range from 1 hr to 6 days (daily meas. every 6th day)

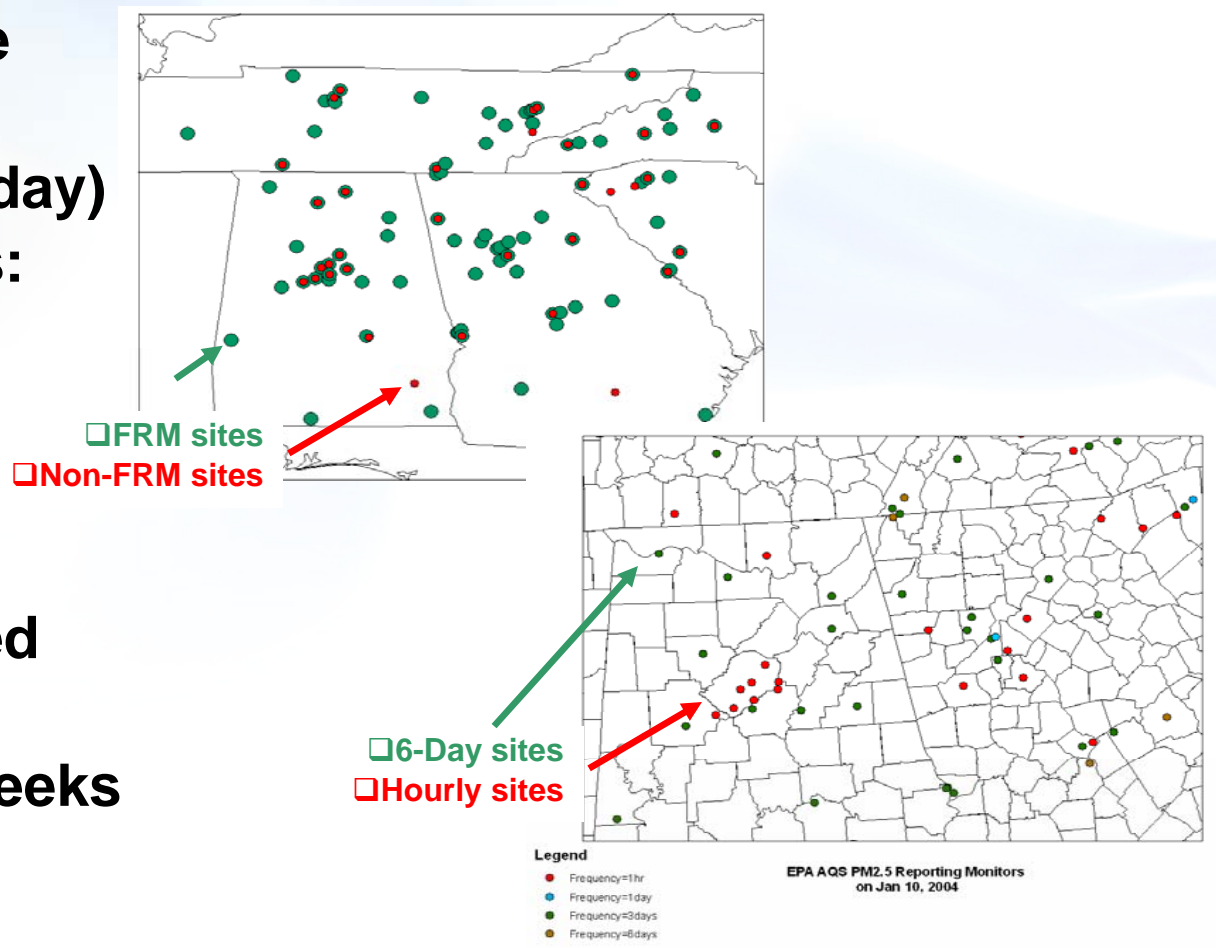
➤ Three monitor types:

- Federal Reference

Method (FRM)

- Continuous
- Speciation

➤ FRM is EPA-accepted standard method; processing time 4-6 weeks

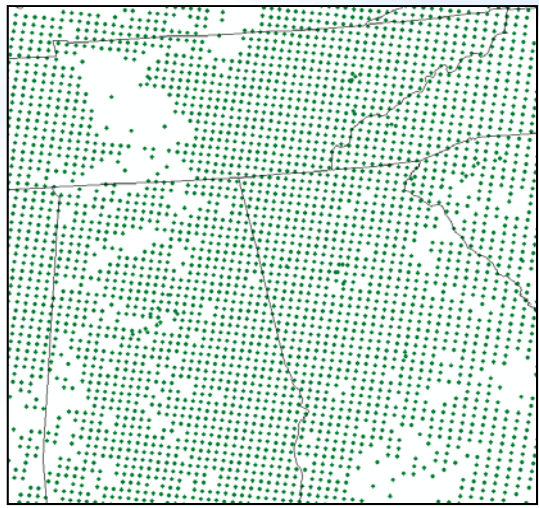




□ Sources of PM_{2.5} data: MODIS

□ MODIS Aerosol Optical Depth (AOD)

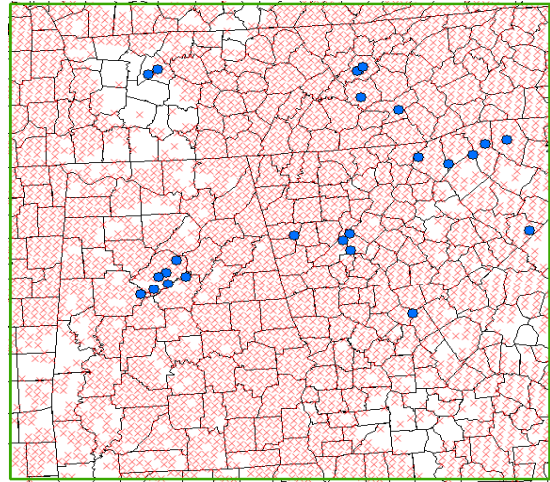
- AOD is a measure of the total particulate in the atmosphere
- If atmosphere is well mixed, AOD is a good indicator of surface PM_{2.5}
- Enhanced Spatial Coverage
- Provided on a 10x10 km grid
- Available twice per day
(Terra ~10:30 AM, Aqua ~1:30 PM)
- Clear-sky coverage only
- Available since spring 2000



□ MODIS



□ June 25, 2003



□ AQS





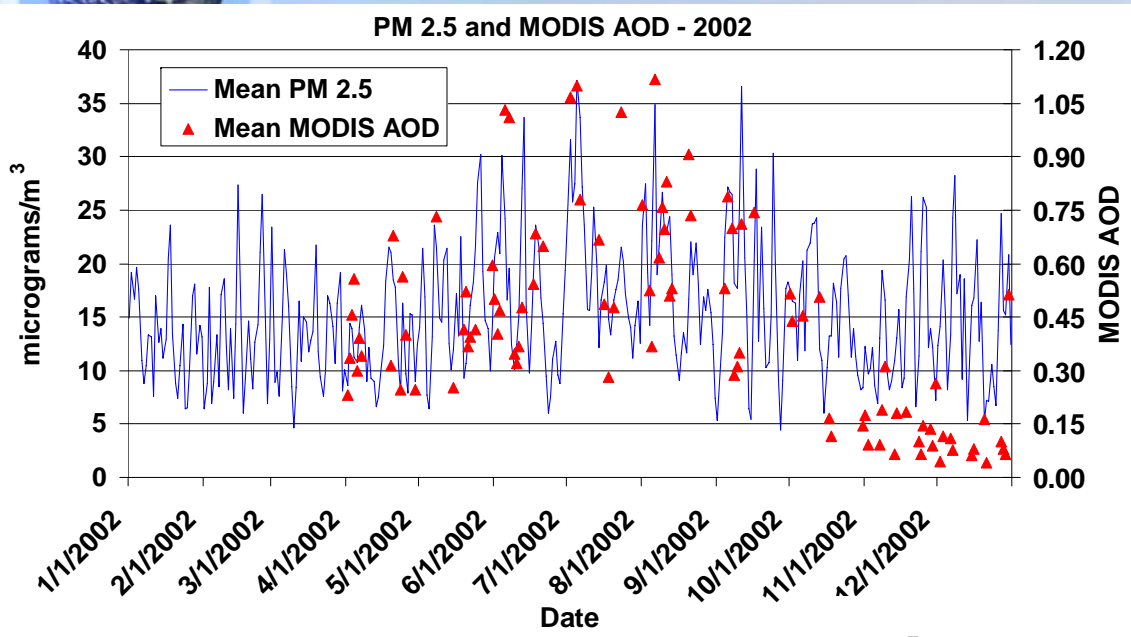
□ Estimating $PM_{2.5}$ from MODIS data

- For 2002-2003, obtain MODIS AOD and EPA AQS $PM_{2.5}$ data
- Extract AOD data for 5 AQS site locations
- Calculate daily averages from hourly AQS $PM_{2.5}$ data
- Using daily $PM_{2.5}$ averages from all 5 Atlanta AQS sites, determine statistical regression equations between $PM_{2.5}$ and MODIS AOD
- Apply regression equations to estimate $PM_{2.5}$ for each 10 km grid cell across region





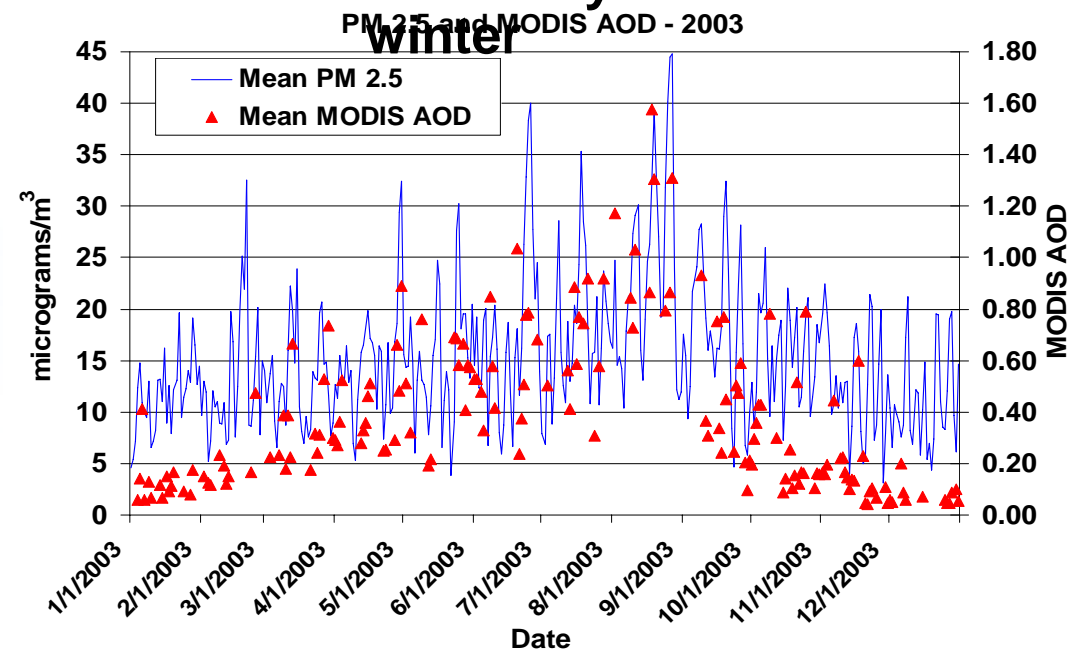
MODIS AOD - PM_{2.5} Relationship



- Daily 5-site means of observed PM_{2.5} and MODIS AOD
- MODIS data not available every day due to cloud cover
- MODIS AOD follows seasonal patterns of PM_{2.5} but not the day-to-day variability in fall and winter

□ 20
02

□ 20
03





□ PM 2.5 – MODIS AOD Correlations

□ April - September

MODIS-Terra MODIS-Aqua

2000 -->	0.579	
2001 -->	0.643	
2002 -->	0.559	0.401
2003 -->	0.661	0.727

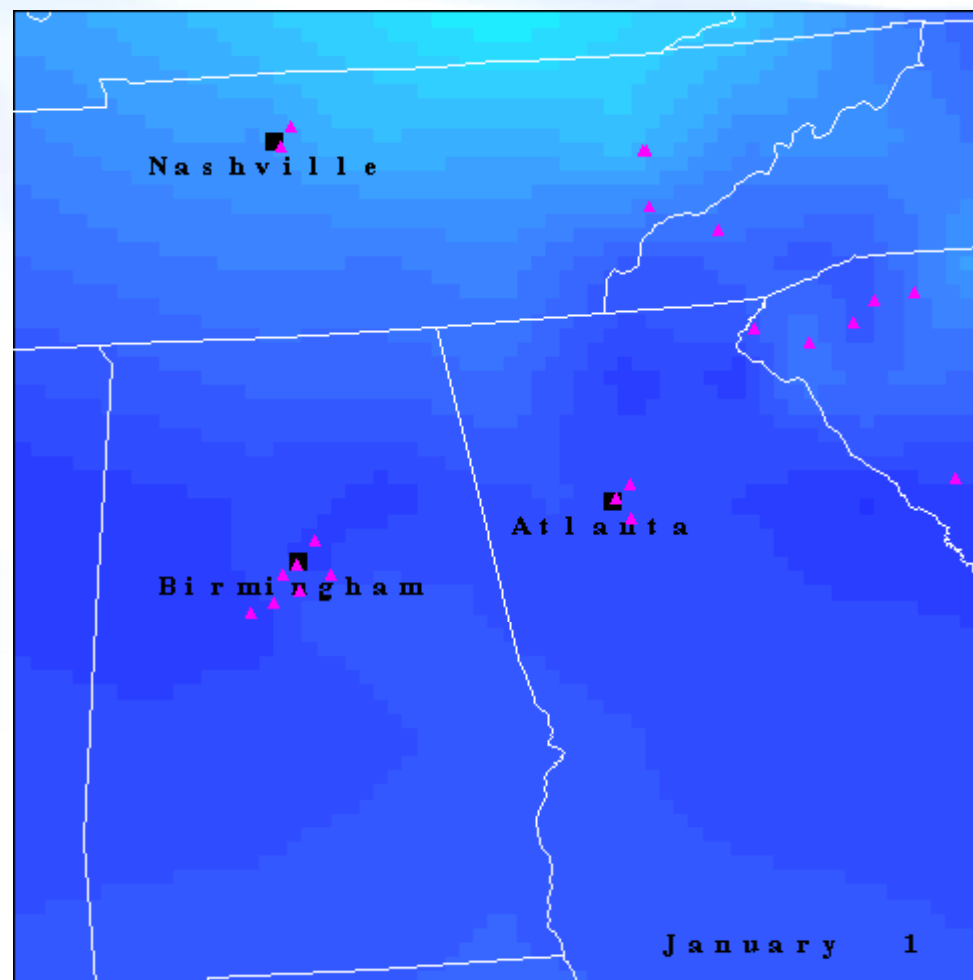
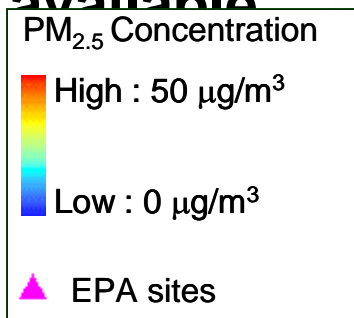
- Correlations between PM_{2.5} and MODIS AOD are generally high (> 0.55) for the warm season.
- The lower correlation for MODIS-Aqua in 2002 is for July-September only.





□ PM_{2.5} Exposure Assessment- Spatial Surfacing

- 1st degree recursive B-spline in x- and y-directions
- Inverse Distance Weighted (IDW)
- Daily surfaces created on a 10x10 km grid
- Variable number of measurements available each day



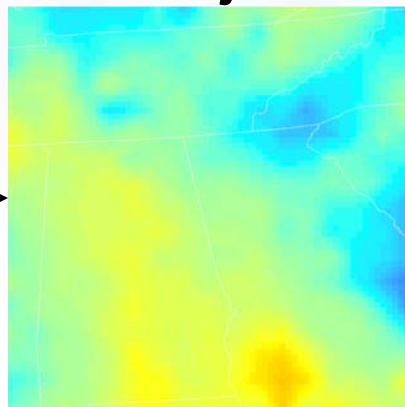
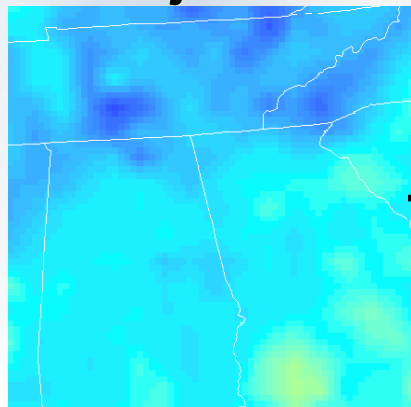


□ Merging MODIS and AQS PM_{2.5} Data

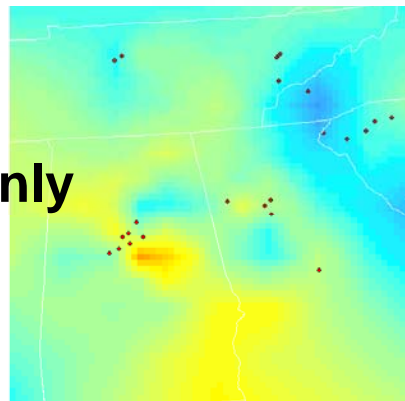
- MODIS and AQS data have been merged to produce final PM_{2.5} surfaces.

□ B-Spline Surfacing

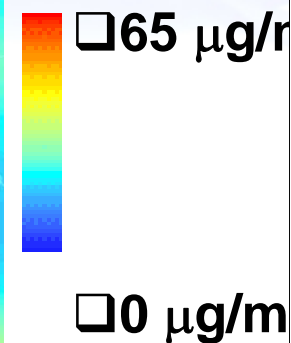
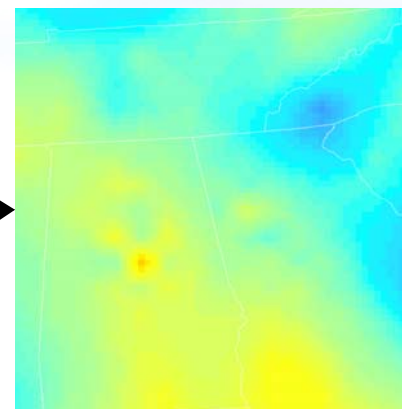
□ Unadjusted MODIS □ Bias-adjusted MODIS



□ AQS only



□ Merged

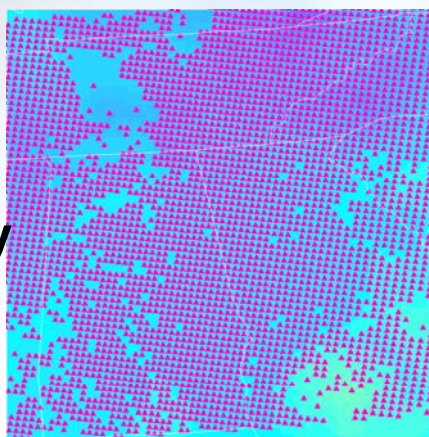




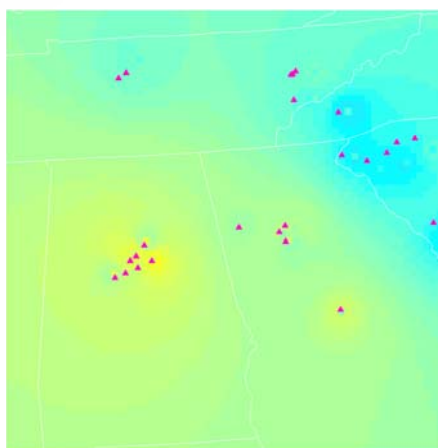
☐ Merging MODIS and AQS PM_{2.5} Data

☐ IDW Surfacing

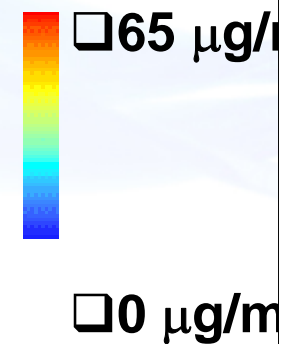
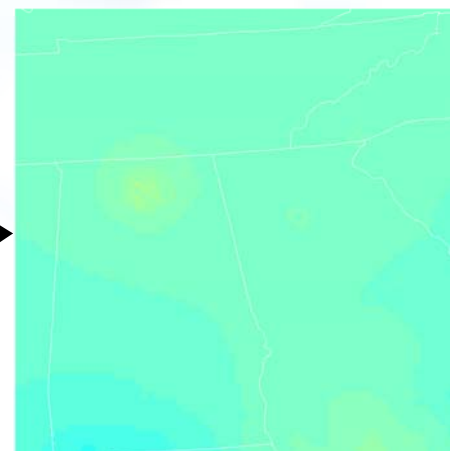
☐ MODIS Only



☐ AQS only



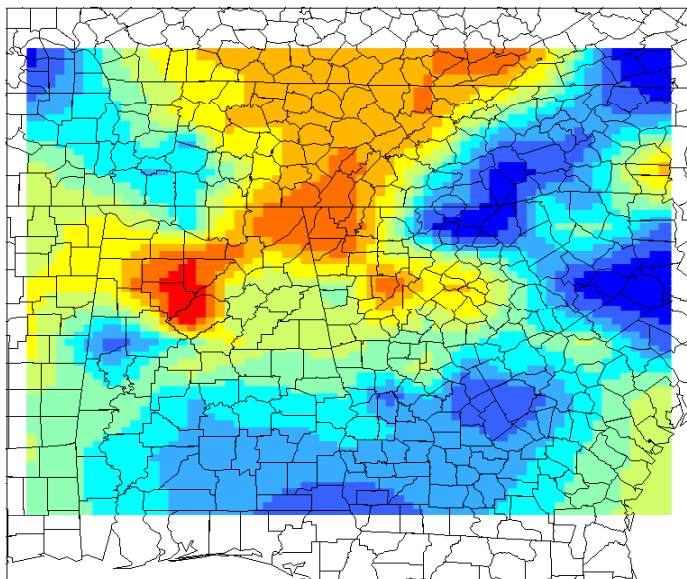
☐ Merged





Annual Composite Surfaces

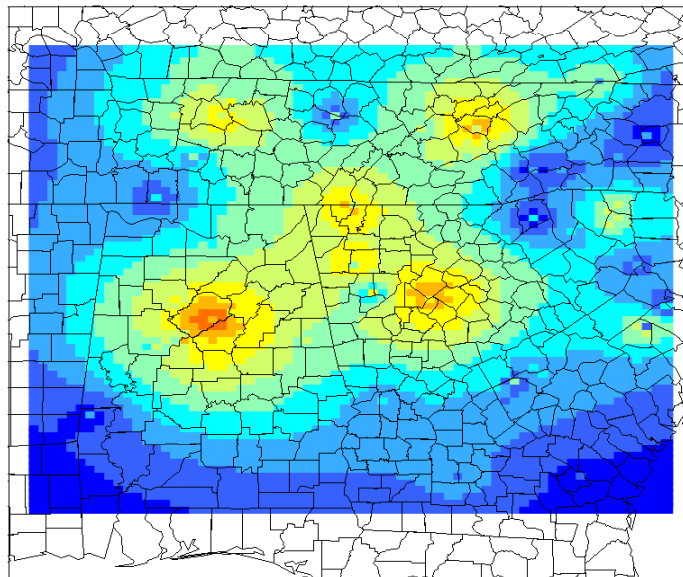
PM2.5 B-Spline Surfaces Year 2003 Composite



- PM2.5 (ug/m³)⁹⁷
- 11.98 - 12.57
 - 12.58 - 12.97
 - 12.98 - 13.35
 - 13.36 - 13.74
 - 13.75 - 14.23
 - 14.24 - 14.85
 - 14.86 - 15.54
 - 15.55 - 16.50
 - 16.51 - 18.36

B-Spline

PM2.5 IDW Surfaces Year 2003 Composite



- PM2.5 (ug/m³)⁹⁷
- 11.98 - 12.57
 - 12.58 - 12.97
 - 12.98 - 13.35
 - 13.36 - 13.74
 - 13.75 - 14.23
 - 14.24 - 14.85
 - 14.86 - 15.54
 - 15.55 - 16.50
 - 16.51 - 18.36

IDW





Linkage of Environmental and Health Data

Health Data Set

Members

LON	LATID	AGE	GENDER	YEAR/MO
-84.207	99.200	1	ChildM	200301
-84.802	99.359	2	AdultM	200301
-83.798	99.993	4	ChildF	200301

Acute asthma office visits

ID	AGE	LON	LAT	GENDER	DATE
1811	Child	-84.179	99.118	F	1/1/2003
54767	Adult	-84.625	99.802	F	1/1/2003
84580	Adult	-84.679	99.691	F	1/1/2003

*Simulated Data Set. F=female, M=male, A=adult, C=child.





Linkage of Environmental and Health Data

Data Linkage Outputs

Visit counts by grid cell

Date	Cell	PM2.5	FC	MC	FA	MA
200301	1	21.74	1	0	2	0
200301	2	12.79	0	0	0	0
200301	3	12.21	0	1	0	1

PM_{2.5} for each visit

Date	ID	Member	Lat/Lon	Cell	Cell Lat/Lon	County	State	Gender	Age	P
1	1811	99.572	-84.251	1944	99.552 -84.284	Coweta	GA	F	Child	2
2	15299	99.063	-83.860	1608	99.104 -83.806	Upson	GA	F	Child	1
2	15879	99.727	-84.369	2079	99.731 -84.403	Fulton	GA	M	Child	1

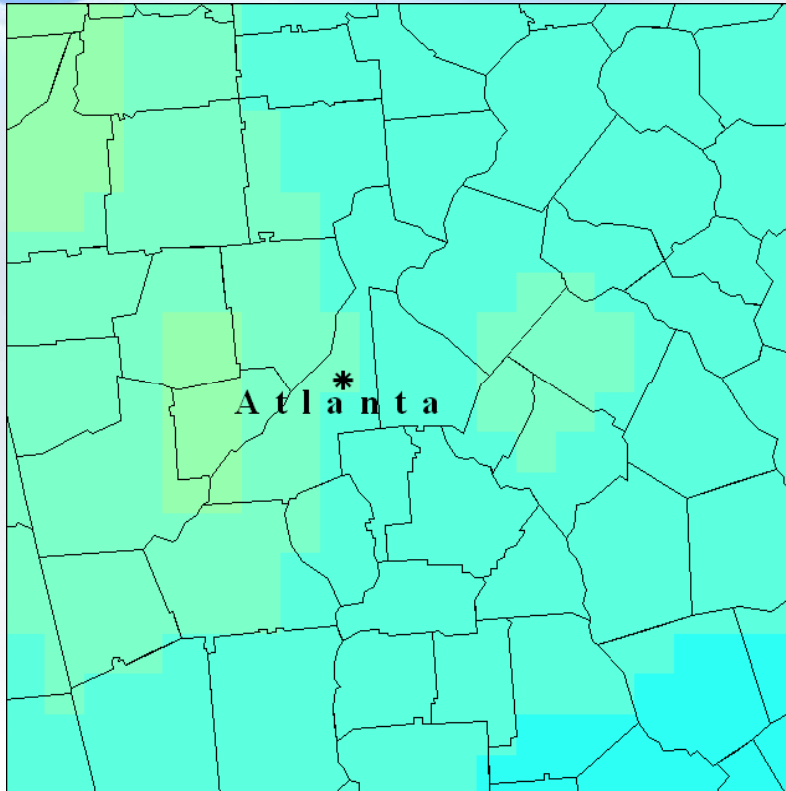
*Simulated Data Set. F=female, M=male, A=adult, C=child.



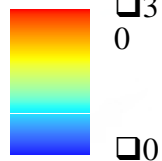
Linkage of Environmental and Health

Data

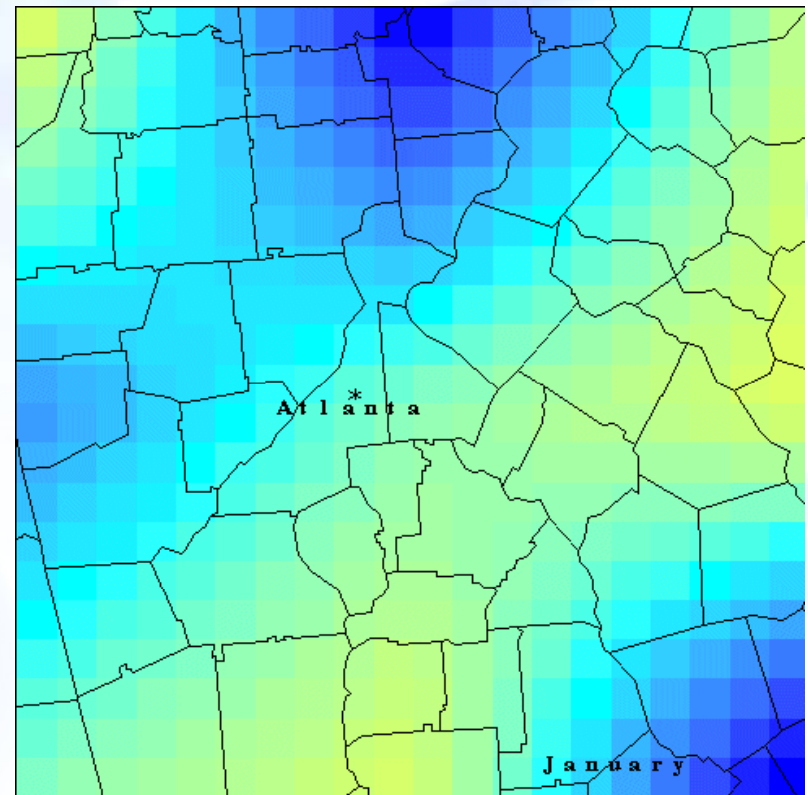
2002



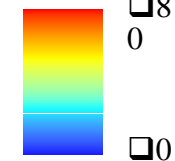
Monthly Mean PM_{2.5}
(ug/m³)



January



Monthly Asthma Visits Rate (Per
10,000)



Year
2002

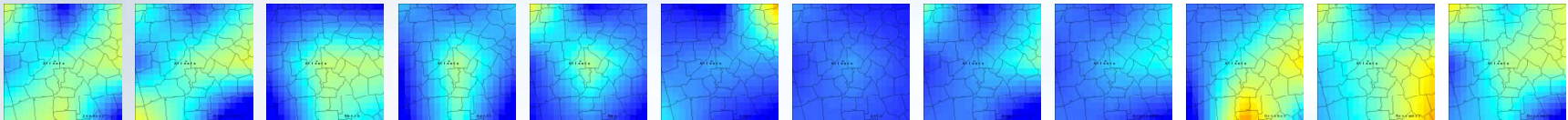




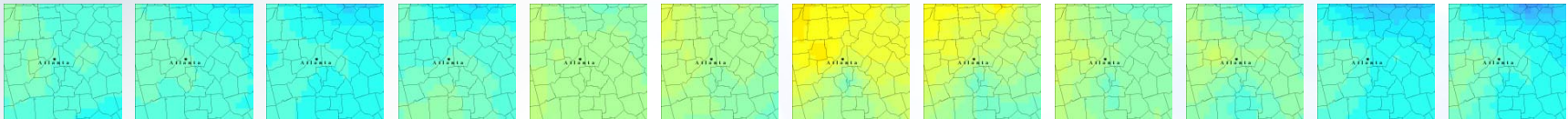
Linkage of Environmental and Health Data

Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.

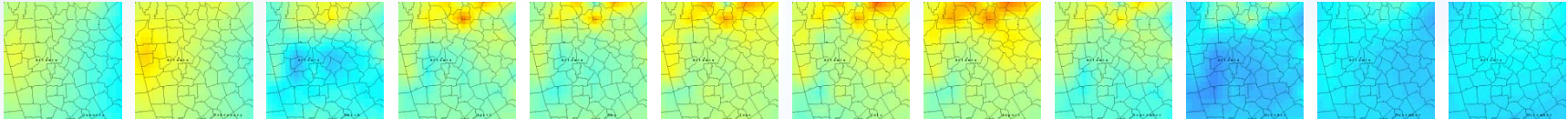
Rates



PM2.5



Ozone



Year 2002



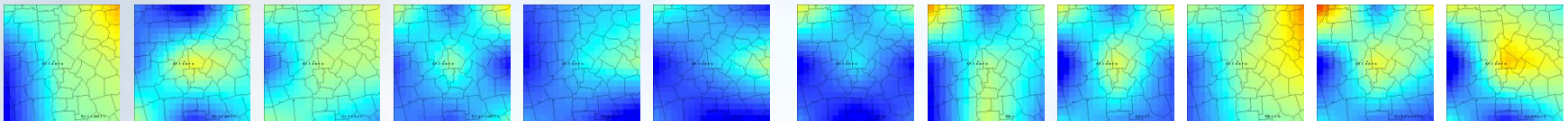


Linkage of Environmental and Health Data

Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.

Rates

2001



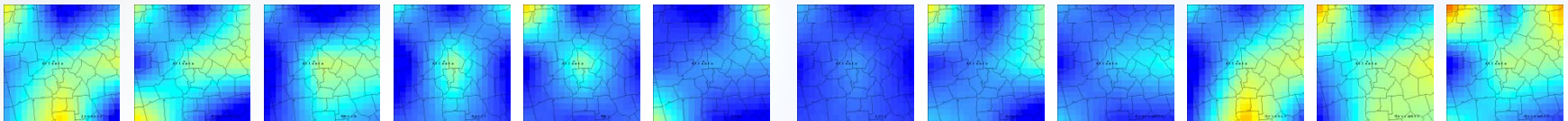
PM2.5

2001



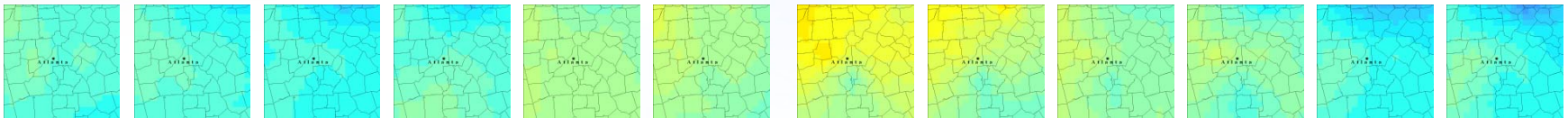
Rates

2002



PM2.5

2002

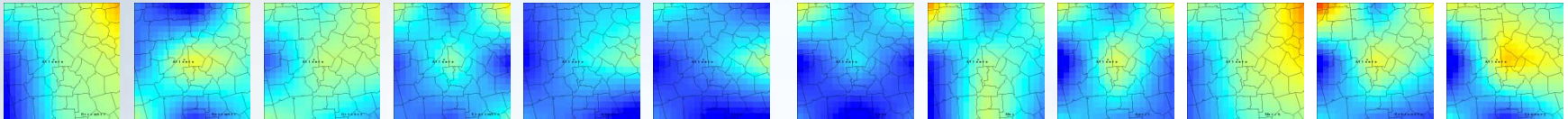




Linkage of Environmental and Health Data

Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.

Rates
2001



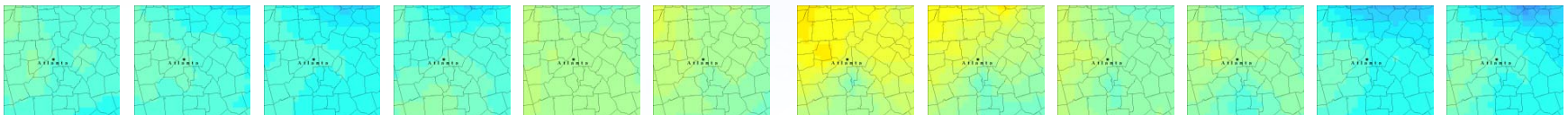
Rates
2002



PM2.5
2001



PM2.5
2002





□ Successes

- **Proven the feasibility of linking environmental data (MODIS PM_{2.5} estimates and AQS) with health data (asthma)**
- **Developed algorithms for QC, bias removal, merging MODIS and AQS PM_{2.5} data, and others...**
- **Developed spatial maps of exposure rates to PM_{2.5} based on MODIS and AQS data**
- **Negotiated a Business Associate Agreement with a health care provider to enable sharing of Protected Health Information**





□ Team Members and Acknowledgements

□ Member's Name, Affiliation

- John Haynes, Program Manager, Public Health, NASA Headquarters
- (Co-Chair) Kafayat Adeniyi, Centers for Disease Control and Prevention,
- (Co-Chair) Solomon Pollard, Environmental Protection Agency (EPA), Region 4
- Mohammad Z. Al-Hamdan, Universities Space Research Association/NSSTC
- Rob Blake, DeKalb County Board of Health
- David Blaney, Georgia Division of Public Health
- Bill Crosson, Universities Space Research Association/NSSTC
- Maury Estes, Universities Space Research Association/NSSTC
- Kristen Mertz, Georgia Division of Public Health
- Amanda Sue Niskar, Centers for Disease Control and Prevention
- Dale Quattrochi, National Aeronautics and Space Administration
- Amber Sinclair, Kaiser Permanente
- Allison Stock, Centers for Disease Control and Prevention
- Denis Tolsma, Kaiser Permanente
- Linda Thomas, Environmental Protection Agency, Region 4
- Ntale Kajumba, Environmental Protection Agency, Region 4
- Carolyn Williams, Georgia Division of Public Health

□ Acknowledgments

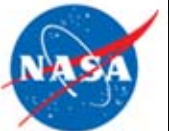
- Leslie Fierro, Centers for Disease Control and Prevention
- Gabriel Rainisch, Centers for Disease Control and Prevention
- Emily Hansen
- HELIX-Atlanta Partners





□ Continued Work

- Proposal Submitted to ROSES '08
- “Decision Support through Earth Science Research Results” (A18)
 - in Conjunction with the CDC and others
 - *“Enhancing Environmental Public Health Tracking with Satellite-Driven Particle Exposure Modeling and Epidemiology”*
- Dr. Yang Liu, PI. Harvard University School of Public Health
- Co-I's from the Centers for Disease Control and Prevention





☐ www.cdc.gov/nceh/tracking

