"Watch! Three folds left, two folds up, one fold down, two folds at a 57-degree angle ... I'm tellin' ya, it's beautiful! No one can ever refold it!"

Close to Home

Land Surface Process and Air Quality Research and Applications at MSFC

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NASA Applied Sciences Air Quality Applications Program Meeting

June 18-20, Bolger Center, Potomac, MD

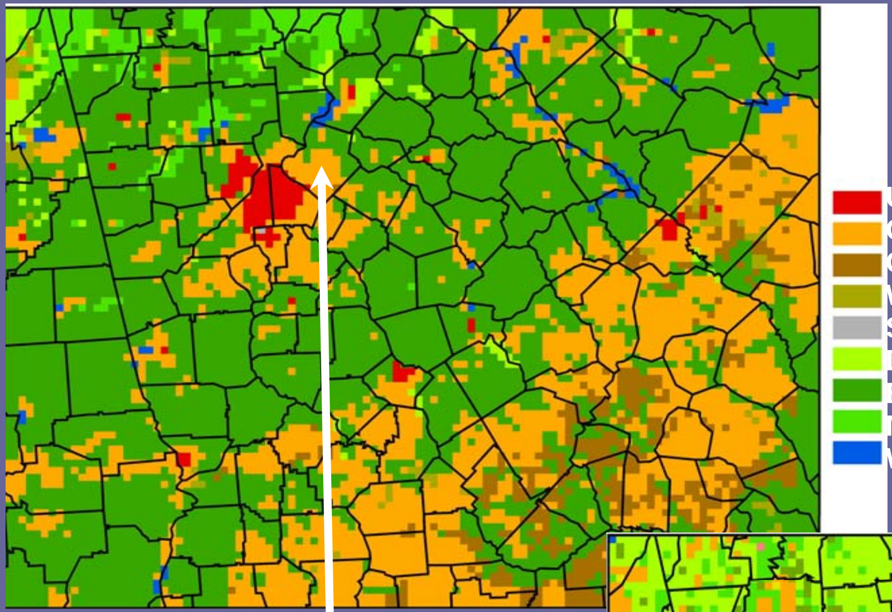
Outline

- Project overview:
  - "Development and Validation of Improved Air Quality Modeling system using High Resolution Remote sensing data"
- Report overview:
  - "Land Use and Land Cover Characterization within Air Quality Management Decision Support Systems: Limitations and Opportunities"
- Current work:
  - Creation of a modeling test bed:
    - Incorporate the 2001 NLCD LULC data within MM5 and ARW
    - Atmospheric modeling simulations for the 2006 calendar year using MM5 and ARW/CMAQ and SMOKE modeling system
  - Applications:
    - Exposure assessment at high spatial and temporal resolution
    - Evaluation of Urban Heat Island (UHI) mitigation strategies
    - Use of satellite derived meteorological products for model validation

Land surface characterization in atmospheric models

- Land surface characteristics (e.g., albedo, surface roughness, fractional vegetative cover) exert a significant influence on the surface energy budget
  - Most atmospheric models employ the 24-category USGS dataset
  - Seasonal or monthly values for these parameters are defined within meteorological models as a function of Land Use Land Cover (LULC) type via a lookup table
- Objective: Improve the Air Quality Management Decision Support System (AQMDSS) through use high resolution LULC data
  - Improvement in baseline model predictions
    - Process high resolution LULC data for the domain
    - Conduct meteorological and air quality modeling simulations and quantify the improvement in model predictions
  - Improved decision making
    - Predict future LULC change due to urbanization
    - Conduct meteorological and air quality modeling simulations and quantify the resulting changes in urban meteorology and air quality
    - Evaluate Urban Heat Island mitigation strategies

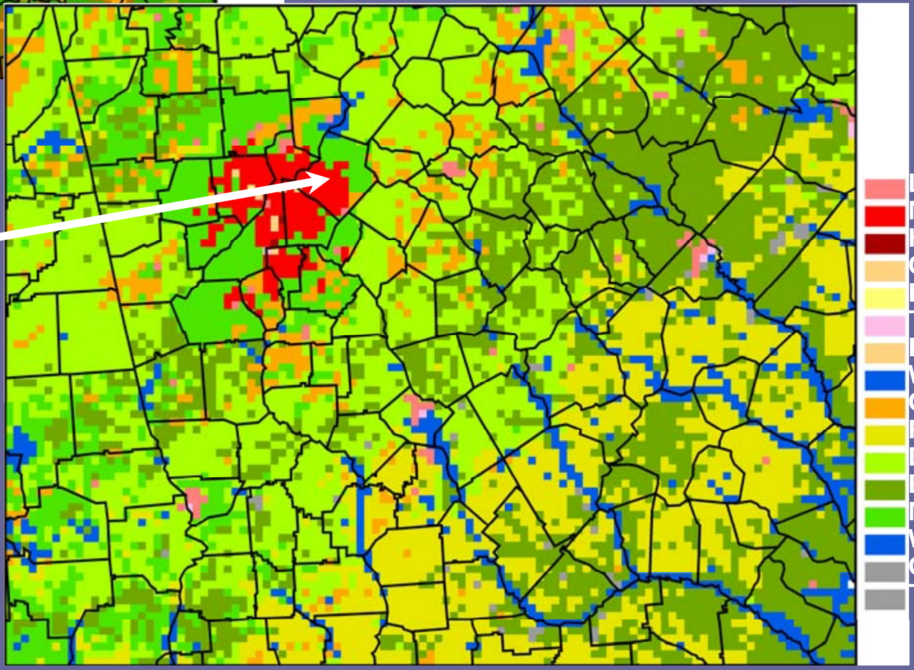
USGS LULC aggregated to 4 km



Combined NLCD and LandPro99 LULC aggregated to 4 km

‘Crops/Pasture Mosaic’

‘Medium Density Residential’



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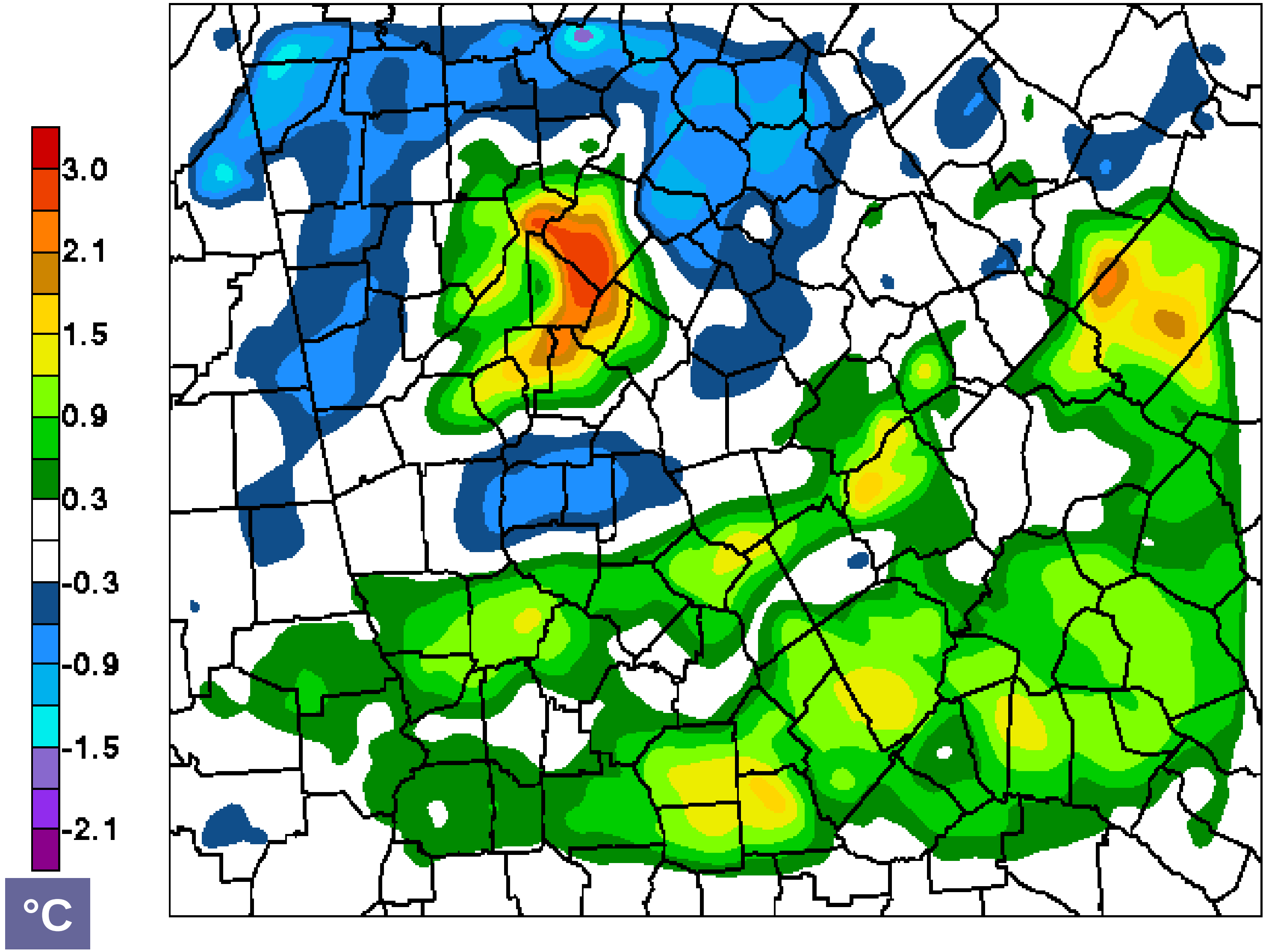
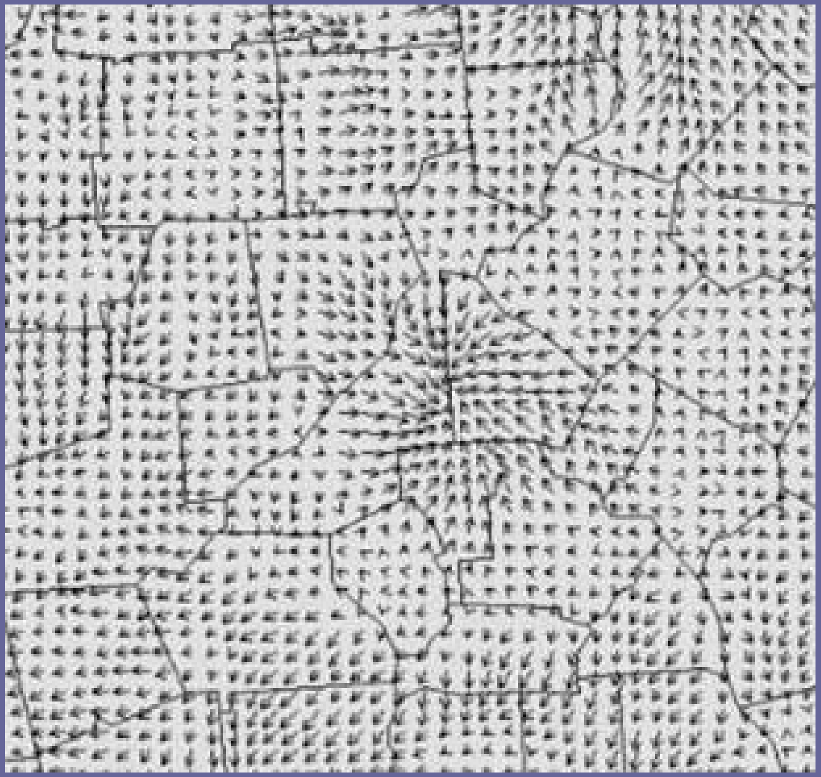
10m air temperature
17 August, 2000 @ 21 UTC

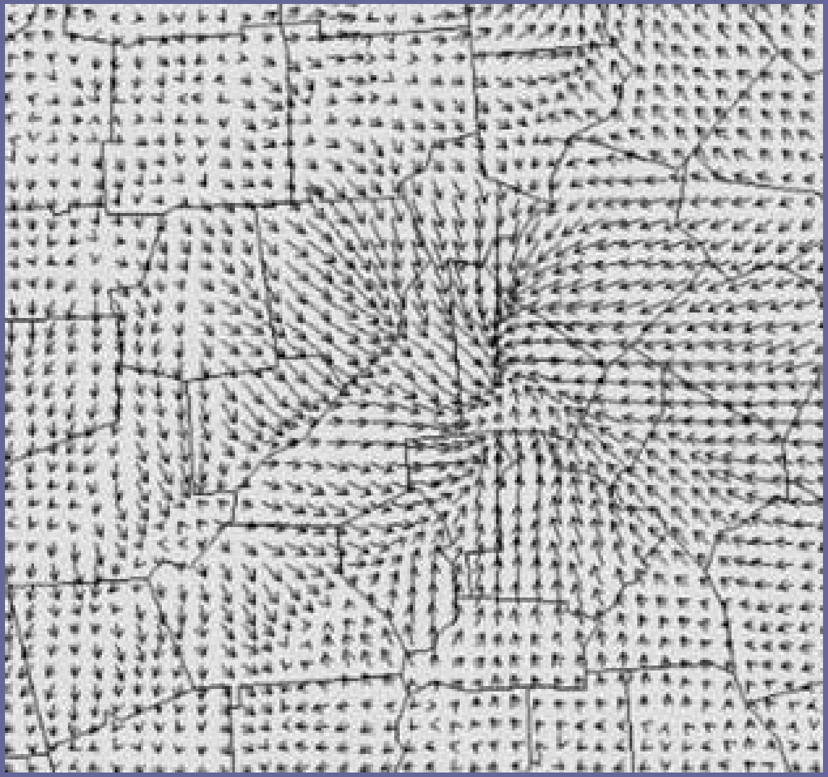


9-day mean surface winds at 7pm

USGS



NLCD/LandPro99



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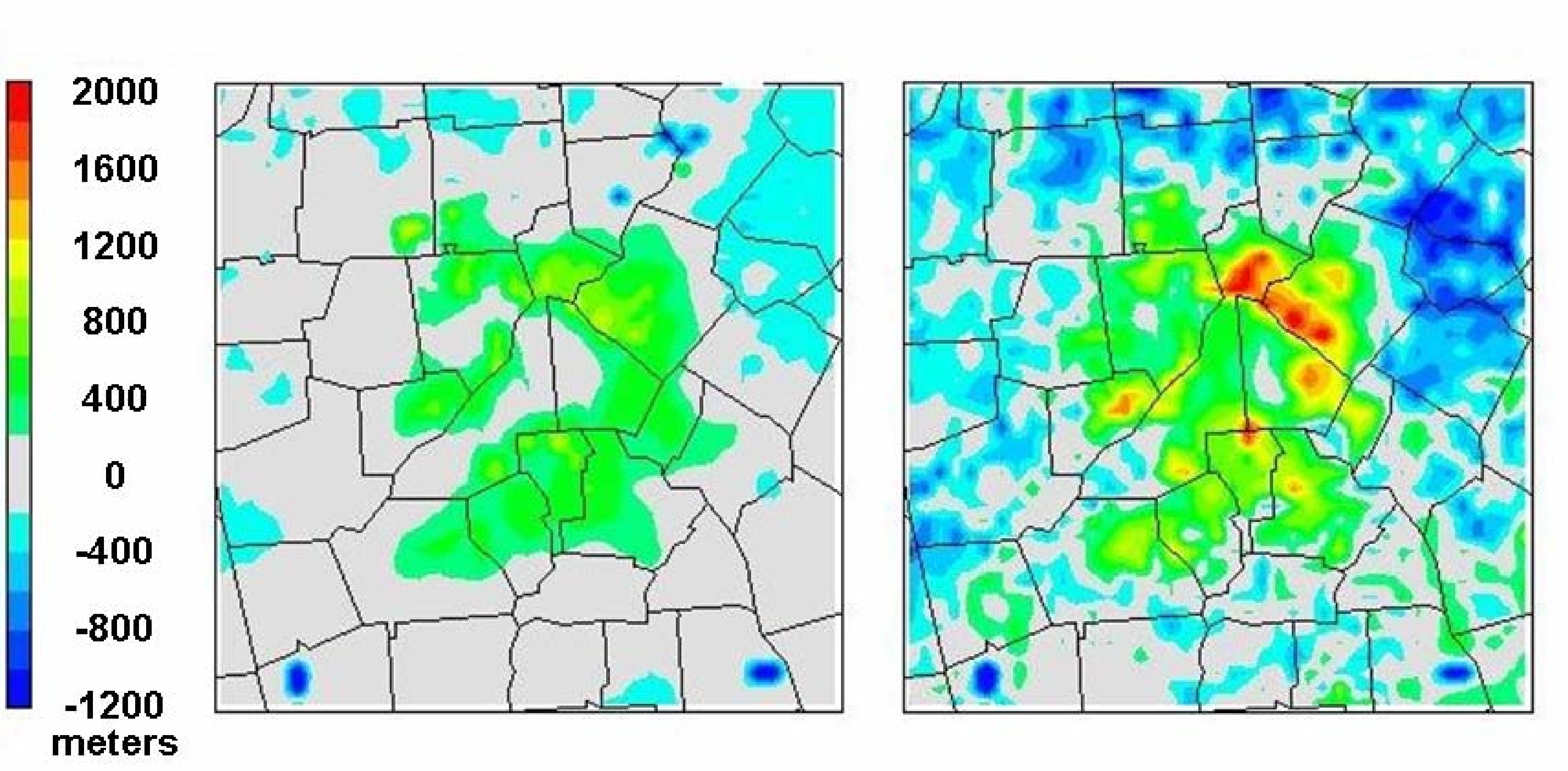
9 day mean difference in PBL heights
(NLCD/LandPro99 – USGS)

2:00 PM **7:00 PM**



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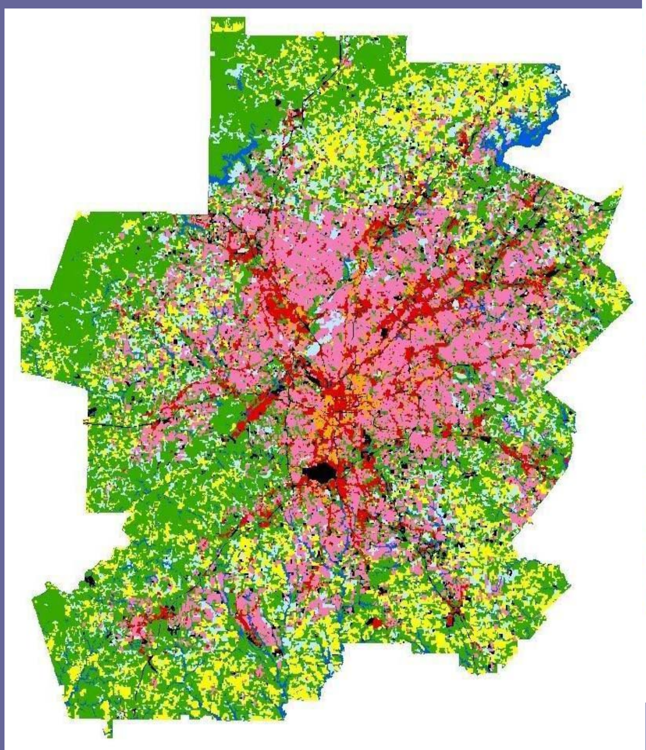
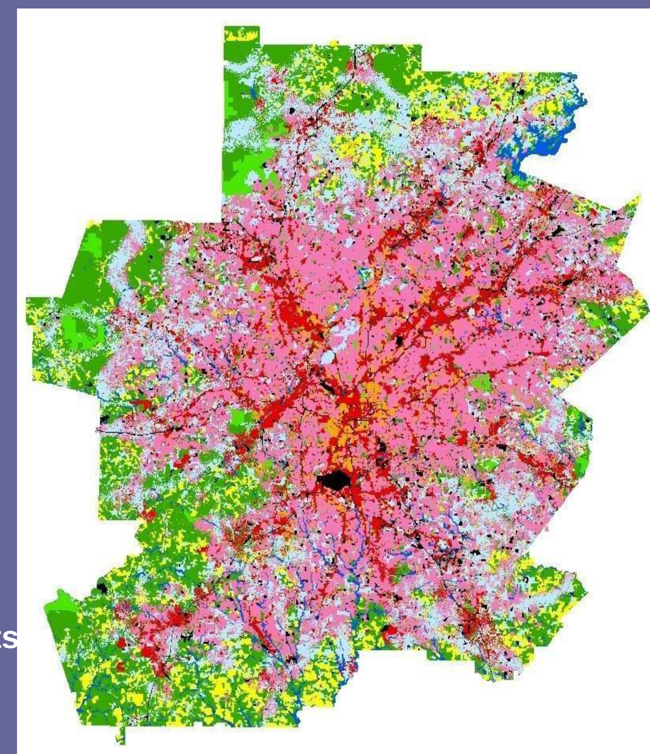
Modeling Land Use Land Cover change

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

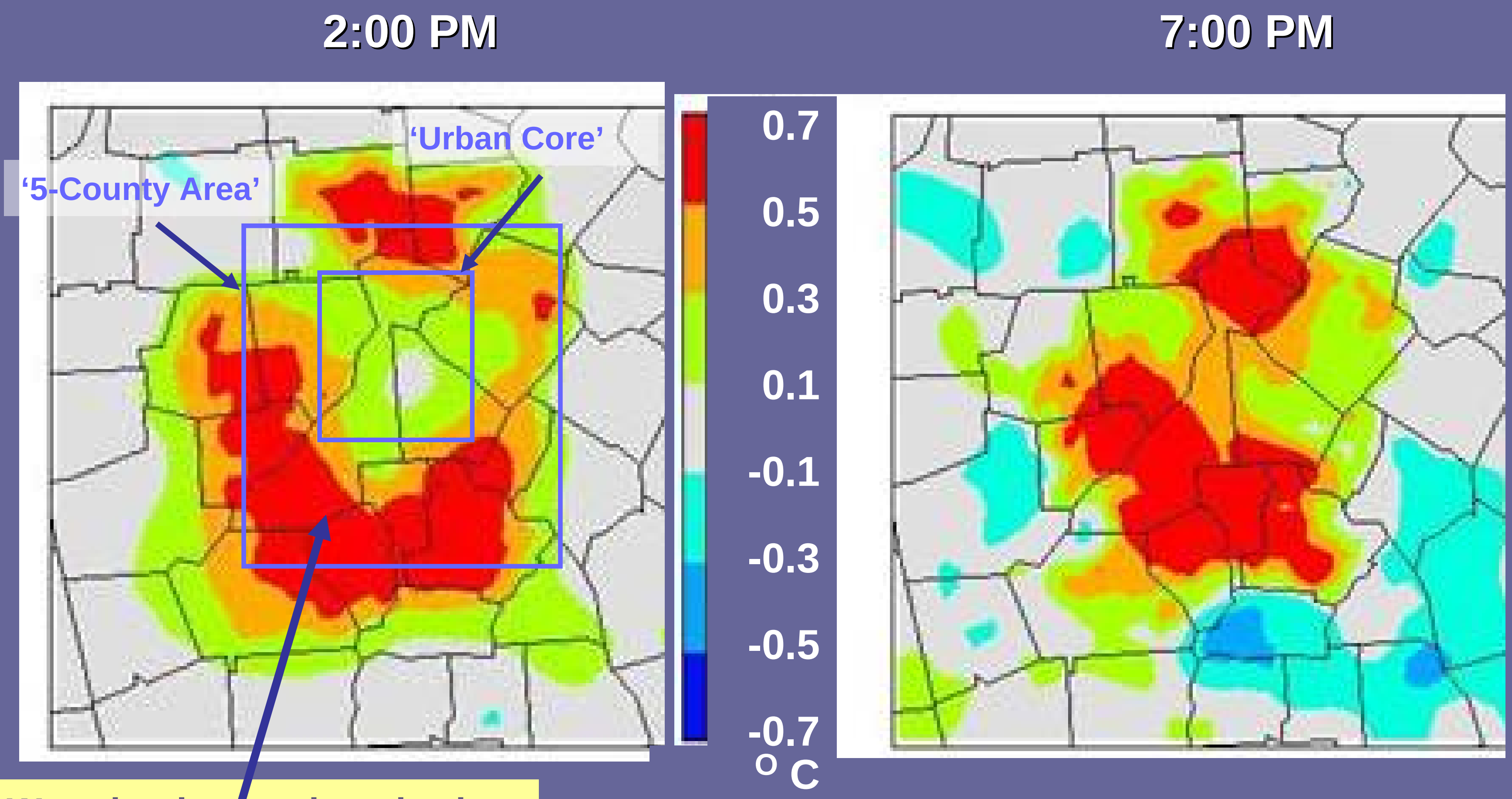
Projected (2030)



The Spatial Growth Model (SGM) was used to project land use/land cover for the area to 2030.
SGM inputs: current and projected population, employment, and road networks.

9 day mean difference in 10m air temperature

(2030 Business as Usual – 2000 Baseline)

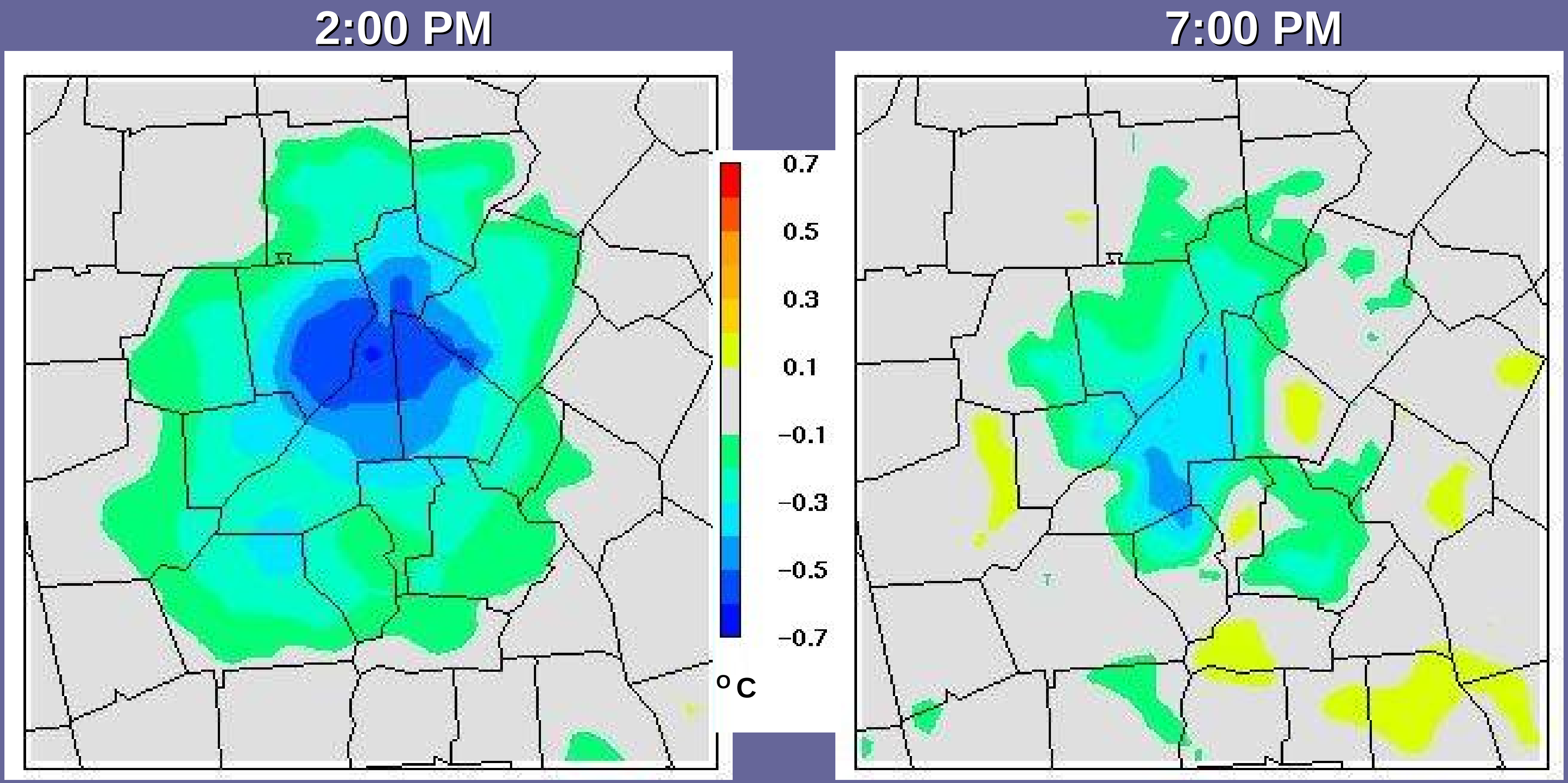


Warming largest in suburbs where development from 2000-2030 is greatest.

, NASA Marshall Space Flight Center, Huntsville, AL

9 day mean difference in 10m air temperature

(2030 Mitigation – 2030 Business as usual)



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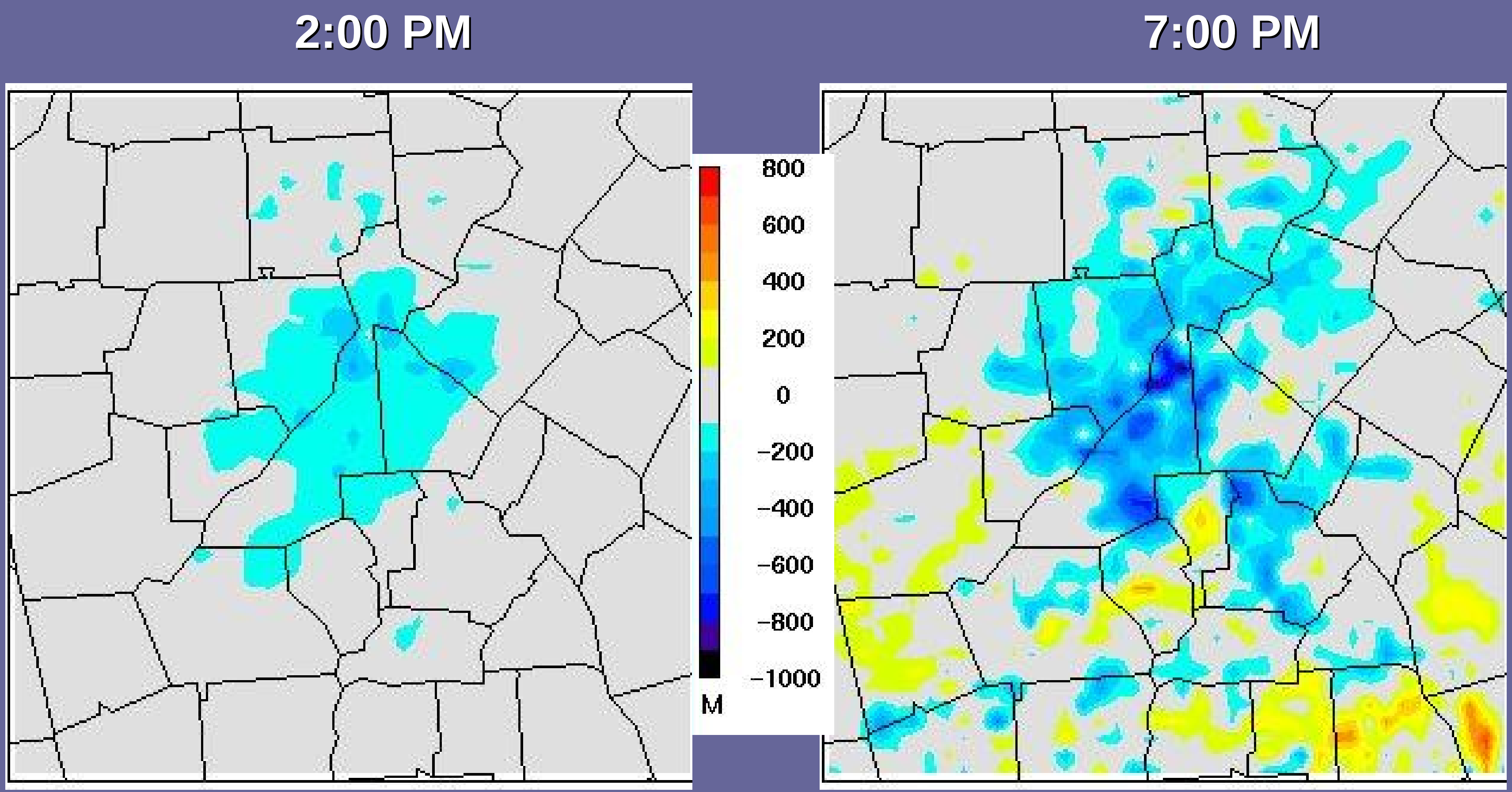
9 day mean difference in PBL height

(2030 Mitigation – 2030 Business as usual)



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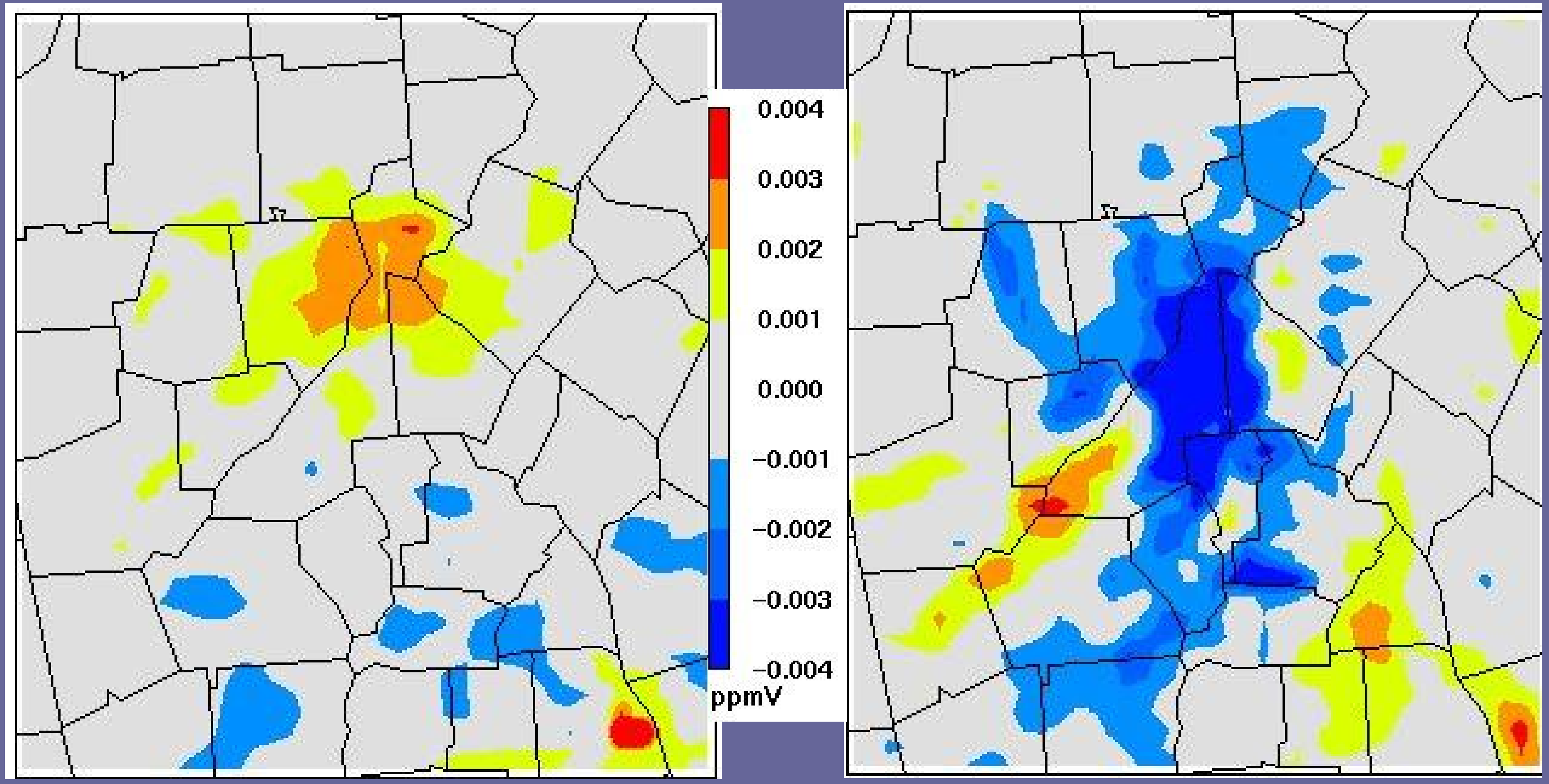
9 day mean difference in Ozone concentrations

(2030 Mitigation – 2030 Business as usual)

2:00 PM **7:00 PM**



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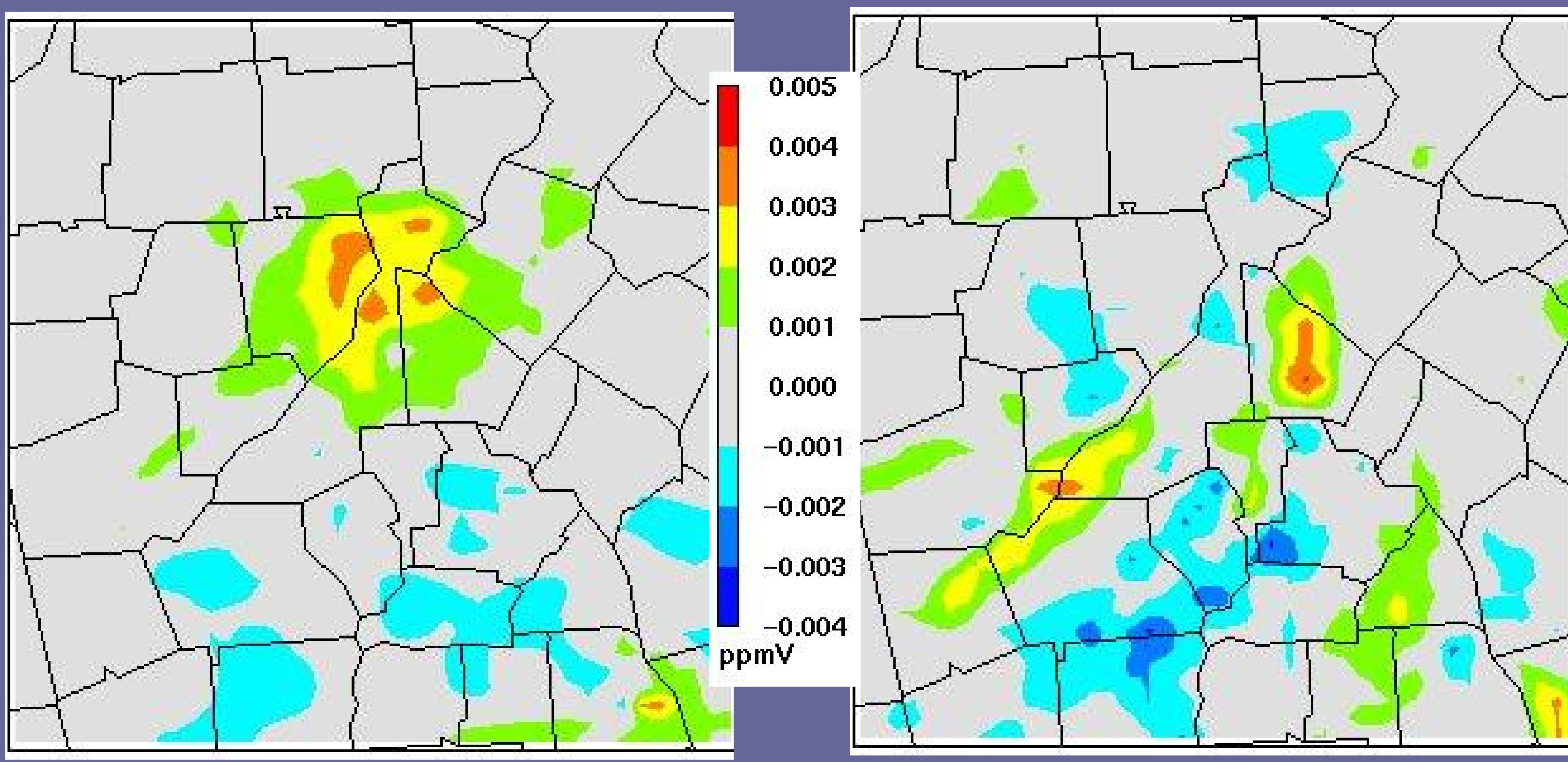
9 day mean difference in O3+NO2

(2030 Mitigation – 2030 Business as usual)

2:00 PM **7:00 PM**



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9 day mean difference in NOx
(2030 Mitigation – 2030 Business as usual)

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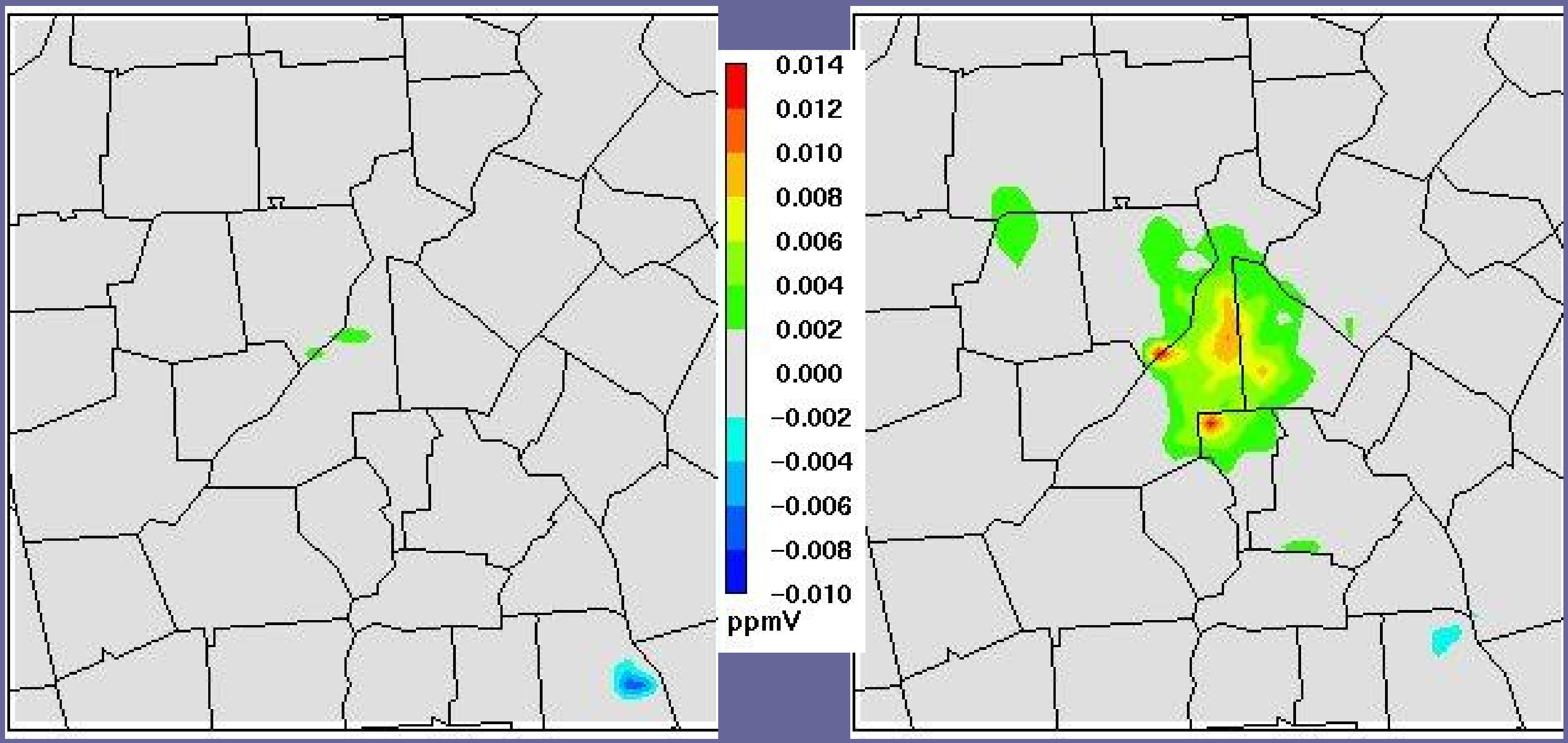

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Land Use and Land Cover Characterization within Air Quality Management Decision Support Systems: Limitations and Opportunities

- Use of satellite derived LULC data within 1) CALPUFF, 2) AERMOD, 3) MM5/WRF, and 4) CMAQ modeling systems
- Key findings:
  - LULC is an important input to dispersion and Eulerian models which play a critical role in AQMDSS established in response to provisions of the CAA, with implications for socio-economic development and public health
  - 24-category USGS data is widely used, and for certain applications lacks detailed characterization and/or temporal resolution for accurate description of certain atmospheric processes (e.g., behavior of boundary layer, dry deposition)
    - Meteorological and air quality forecast over populated areas
    - Retrospective analysis of heat and air pollution events and public exposure
    - Effect of changing LULC (e.g., urbanization) on climate and air quality
  - Limited software engineering is required to implement better LULC data products within most modeling systems
  - International applications of atmospheric models by U.S businesses, national and international organizations will greatly benefit from availability and regular updates to NASA's LULC data for use within atmospheric models

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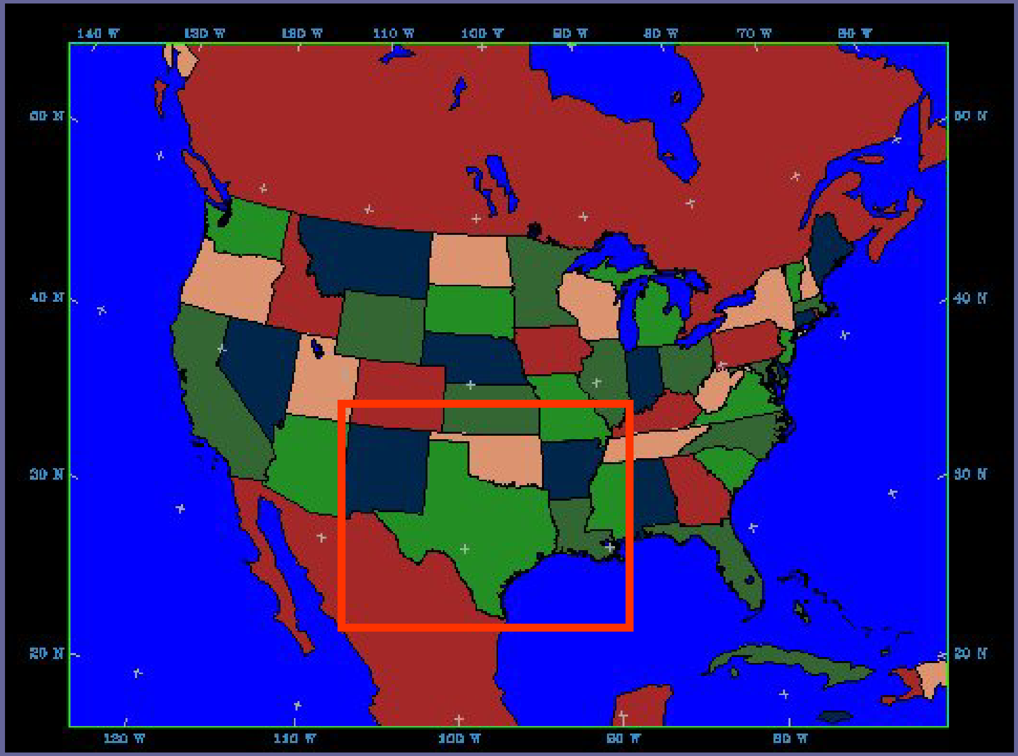
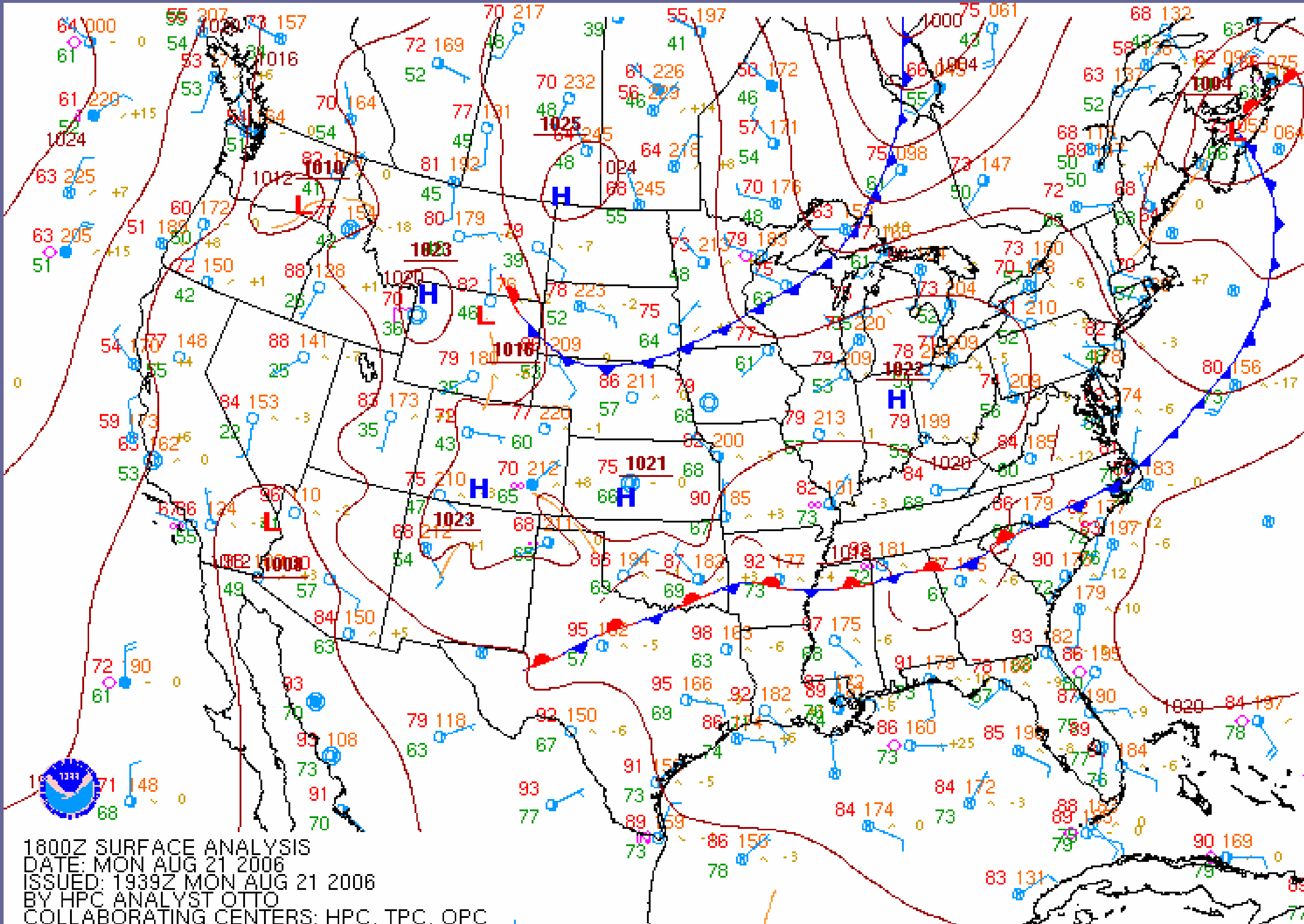
On-going work

- Goal: Modeling at spatiotemporal scales relevant to urban planning
- Objective/task: Undertake a more **comprehensive** spatiotemporal analysis of the effects of accurate land surface characterization on atmospheric modeling results
- Approach: Create a modeling test bed
  - Atmospheric modeling of the 2006 calendar year using MM5 and ARM/CMAQ/SMOKE modeling system
- Air Quality and public health applications
  - **Improve air pollution exposure assessment** through better characterization of the land surface and boundary layer processes, together with a more accurate assessment of the spatiotemporal distribution of population
  - **Quantify the effect of Urban Heat Island (UHI) mitigation strategies on aerosols** through use of dynamically coupled atmospheric models
  - Use of satellite derived meteorological products for model validation: **An investigation to support development of guidelines for regulatory applications**

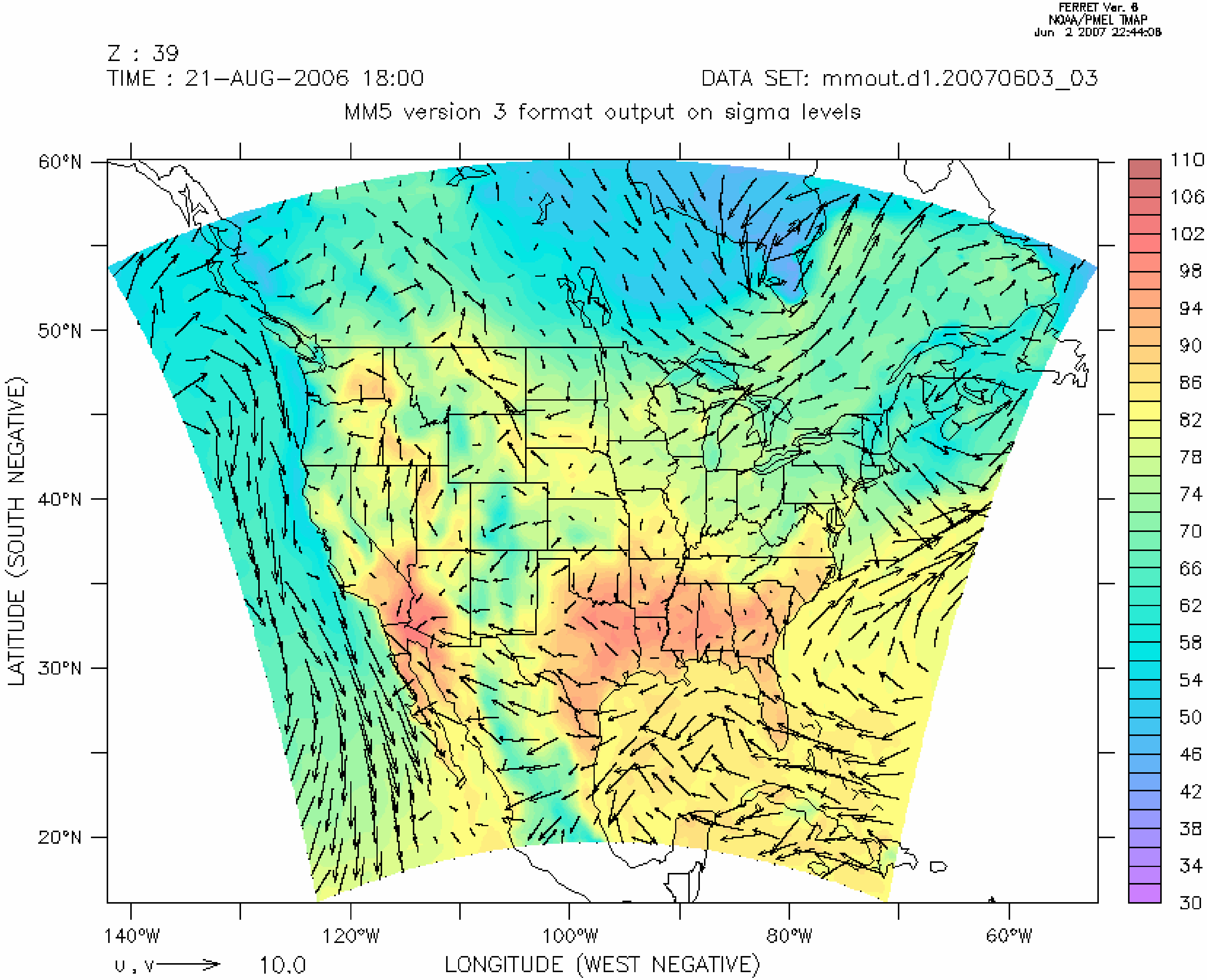
Meteorological modeling

- MM5 and ARW
- 36, 12 and 4-km resolution grids
- 40 vertical layers up to 10mb. Lowest layer is 9m thick
- Annual simulation for 2006 conducted in 5.5 day segments (12 hours for ramp-up)
- Analysis nudging at 36 and 12-km grid resolution using NAM
- Standardized performance evaluation using METSTAT and EPA's Atmospheric Modeling Evaluation Tool (AMET)
- Partners: Arastoo Biazar, Kevin Doty, Dick McNider





Courtesy: Arastoo Biazar



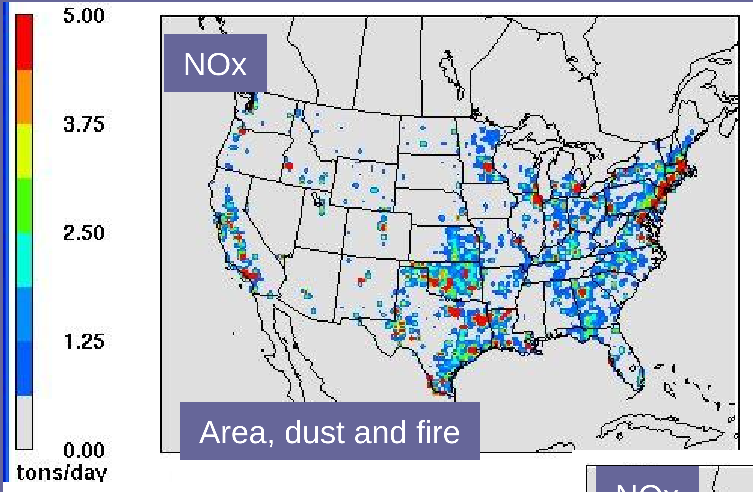
Temperature (F)

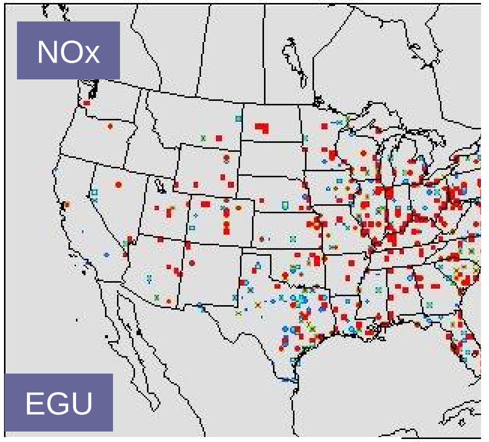
Courtesy: Arastoo Biazar

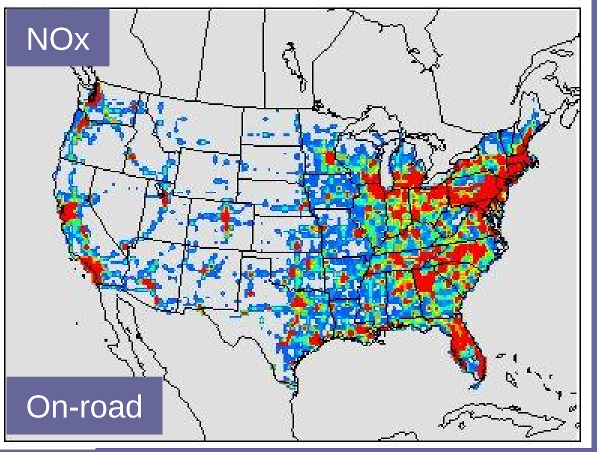
Emissions Modeling

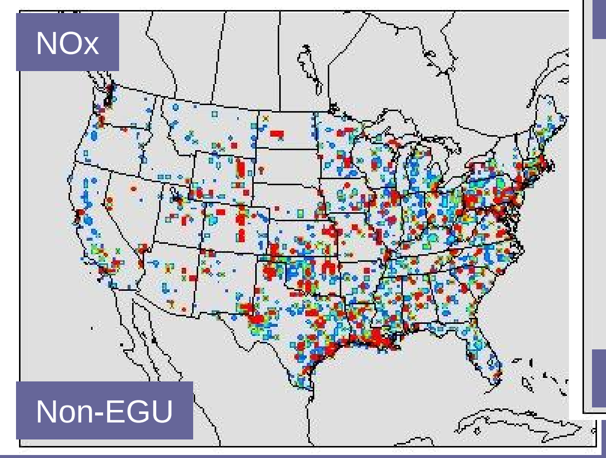
- Model: Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system
- Purpose: Generate spatially, temporally and chemically resolved emission fields for air quality models
- Inputs: Source specific emission inventories, speciation profiles, temporal profiles, spatial surrogates, etc
- Source categories
  - Area (e.g., gas stations, dry cleaners)
  - Non-Electricity Generating Units (NEGU)
  - Electricity Generating Units (EGU)
    - Continuous Emission Monitoring (CEM) Data
  - Dust (e.g., wind blown, road)
  - Fire (e.g., prescribed, wild)
  - On-road mobile
    - Activity: Highway Performance Management System (HPMS) and Travel Demand Model
    - Emission factors: MOBILE6
  - Off-road mobile (construction, shipping, aircraft and airport, etc)
  - Off-shore mining operations
  - Biogenics (BEIS, Biogenic Emissions Inventory System)

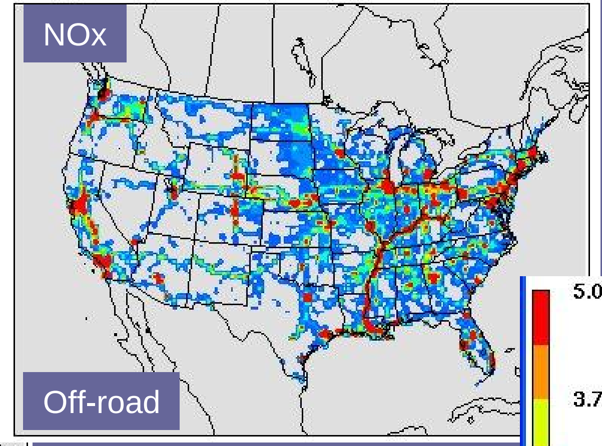
Gridded Emissions

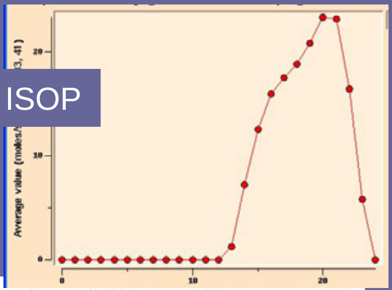


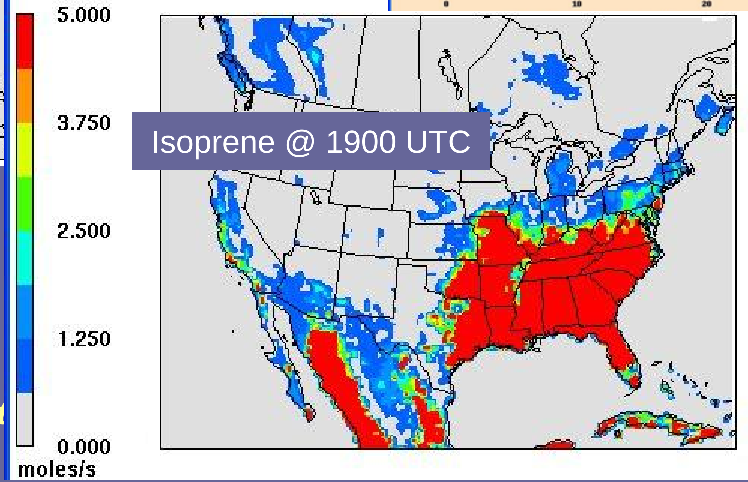












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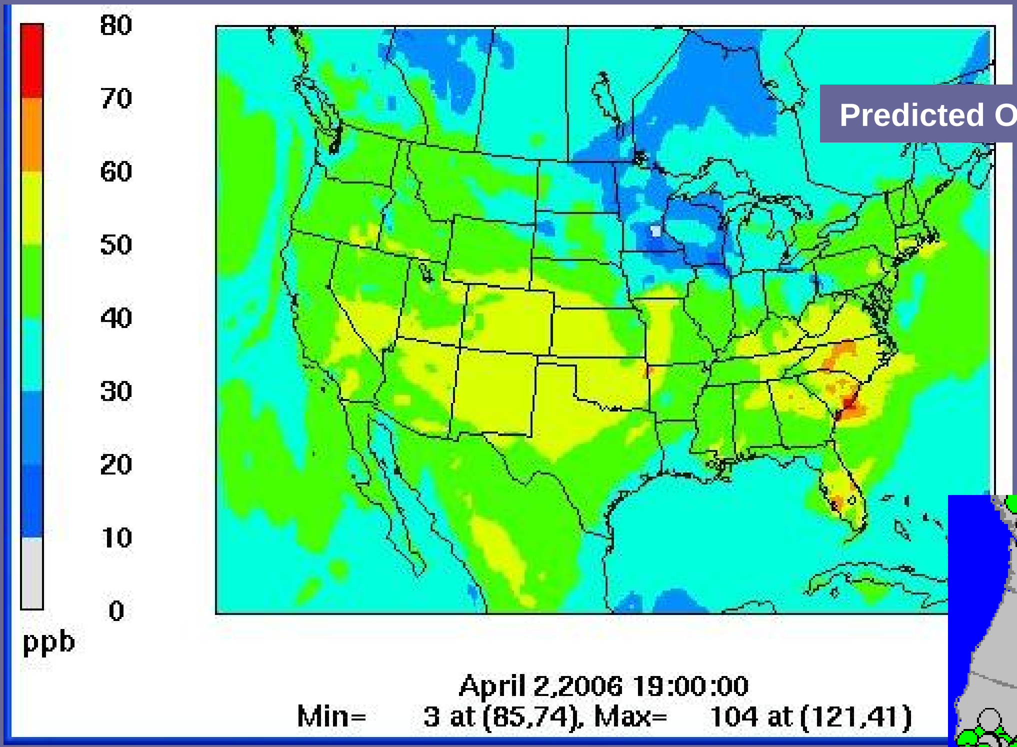
Criteria Air Pollutant (CAP) emission updates

- Texas2006 Emissions inventory
- 2006 CEM data for EGUs
- Emissions from off-shore mining developed by the Mineral Management Service (MMS)
- Lightning NOx
  - National Lightning Detection Network (NLDN) dataset
- Dust emissions inventory
- Fire emissions inventory
- MOVES (Motor Vehicles Emissions Simulator)
  - Models energy consumption using a “modal” emission rate approach and a broad array of advanced technology vehicles; uses second-by-second data to develop emission rates;
  - Includes well-to-pump energy emission estimates to enable life-cycle analysis.
  - Calculates total energy and emission inventories rather than simply calculating per-mile emission factors
- TRANSIMS
  - An agent-based simulation system capable of simulating the second-by-second movements of every person and every vehicle through the transportation network within any domain
  - Developed by Los Almos National Labs with funding from USDOT

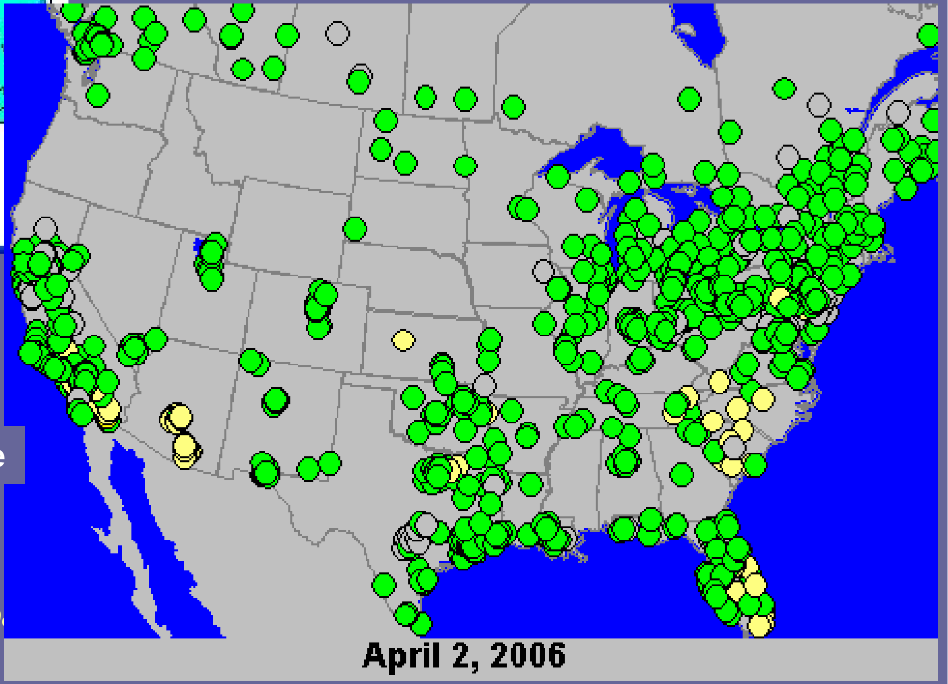
Air Quality Modeling

- CMAQ version 4.6 or later
- Input data:
  - BC/IC (EPA default vs. global model output, TES)
  - Photolysis rates (default vs. adjusted using satellite observations)
- Model evaluation
  - Standardized performance evaluation using EPA's observational network using Atmospheric Model Evaluation Tool (AMET)
  - Texas 2006 measurements
  - INTEX-B, IONS-06, AURA measurements

Daily Maximum hourly averaged O_3



Predicted Ozone



Observed Ozone

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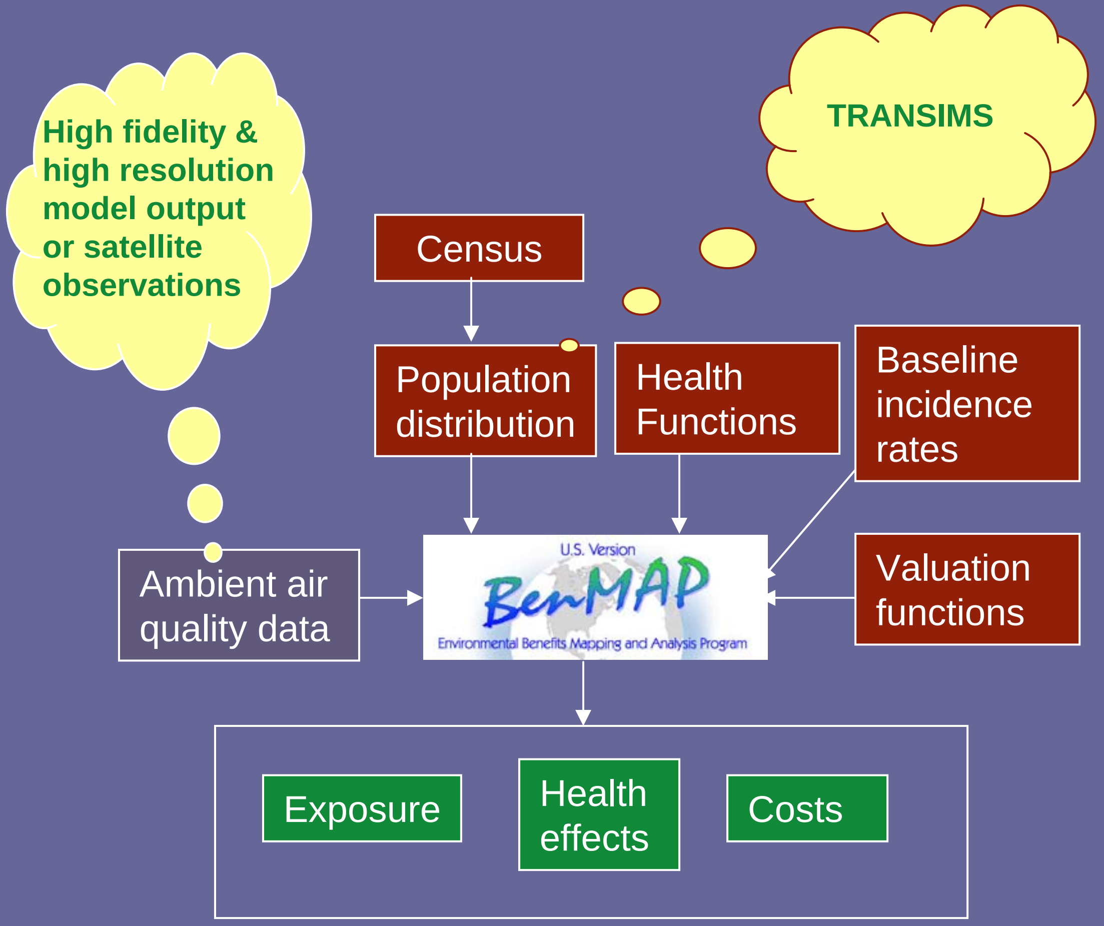
Health Effects of Air Pollution

- Model: Benefits Mapping and Analysis Program (BenMap)
- Purpose: Used to calculate health costs associated with air pollution
- Input:
  - Population distribution
  - C-R functions
  - Incidence rates
  - Valuation functions
  - Air quality data
  - Meteorological data



The value of partnerships

- "This is the next frontier of human productivity. We've had the agricultural era, the industrial era, the information age. The next era is the era of interoperability."
- The world is intuitively weaving itself into networks
- These are underpinned by collaboration
- Those who get better at collaboration will prosper

Michael O. Leavitt,
Former EPA Administrator
Secretary, Dept of Health & Human Services

Keynote Address to the 2005 Public Meeting of the Interagency Working Group On Earth Observations

Noha Gaber, Ph.D.,
(On behalf of Dr. Gary Foley)
Office of Research and Development
US Environmental Protection Agency

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- UNC
  - Adel Hanna and Aijun Xiu
- Georgia Environmental Protection Division
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- Georgia Regional Development Authority
  - Rob Goodwin
- Georgia Institute of Technology
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Thank You