Modeling and Analysis to Support Attainment Planning

Data & Modeling Unit (Planning & Support Program)

Georgia Air Policy Symposium
December 19, 2005

Outline

- NAAQS Attainment SIP Modeling
  - Ozone and PM2.5
- Regional Haze SIP Modeling
- Mercury Modeling for CAMR
- Observational Based Analyses
- Health Benefits Modeling

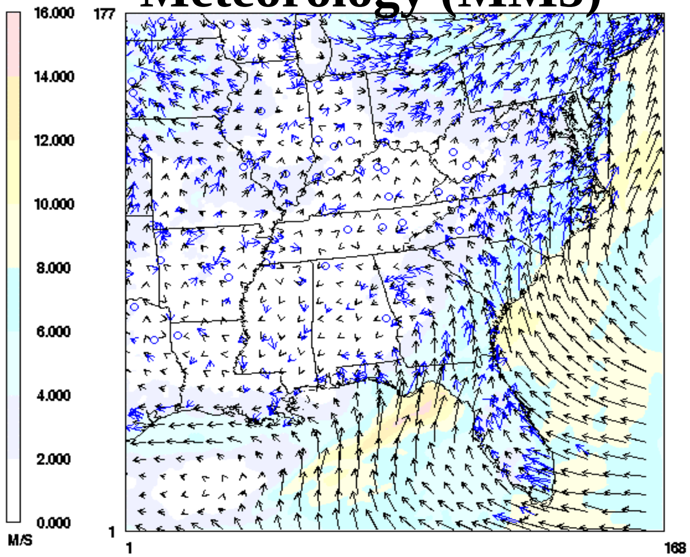
Modeling Resources

- Personnel
  - Jim Boylan (PhD), Maudood Khan (PhD), Amit Marmur (PhD candidate), Dan Cohan (PhD), one vacant position
- Computers
  - Seven Dell workstations with REDHAT 9.0 OS
    - 3.2 GHz Dual Processors and 4 GB RAM
    - 500 GB Internal SCSI hard drive
  - EMC CX500 SAN array
    - 19 TB of storage space
  - ADIC Scalar i2000 backup storage library
    - 28 TB of storage capacity

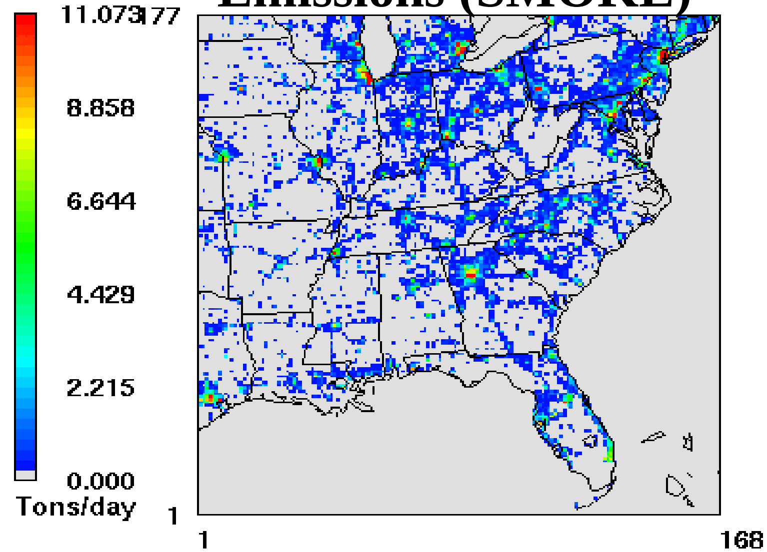
NAAQS Attainment SIP Modeling

Atmospheric Modeling System

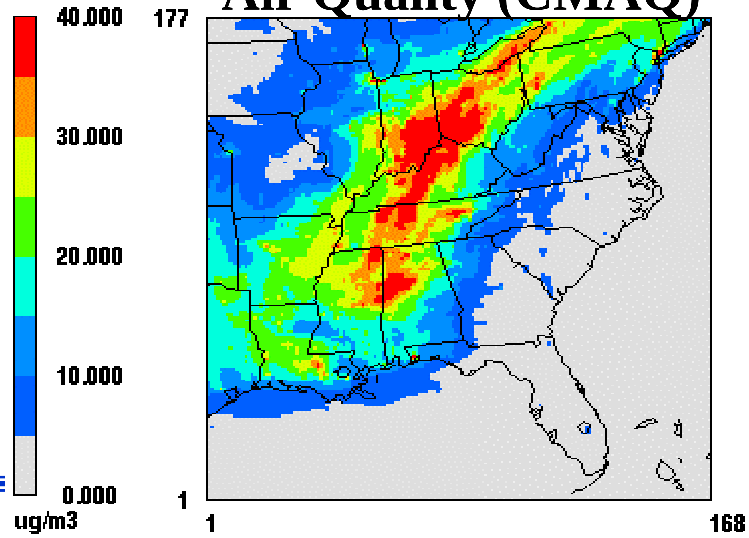
Meteorology (MM5)



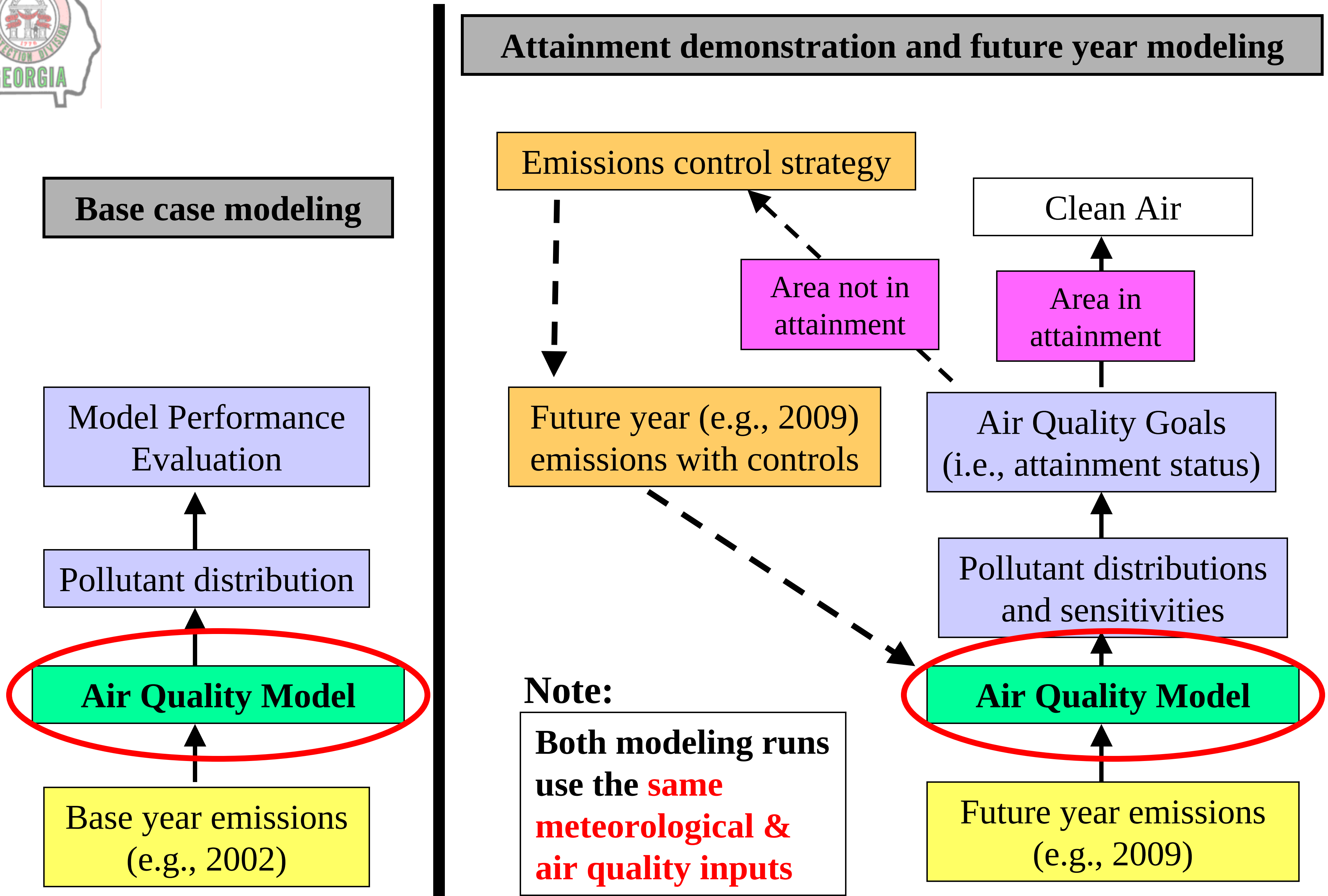
Emissions (SMOKE)

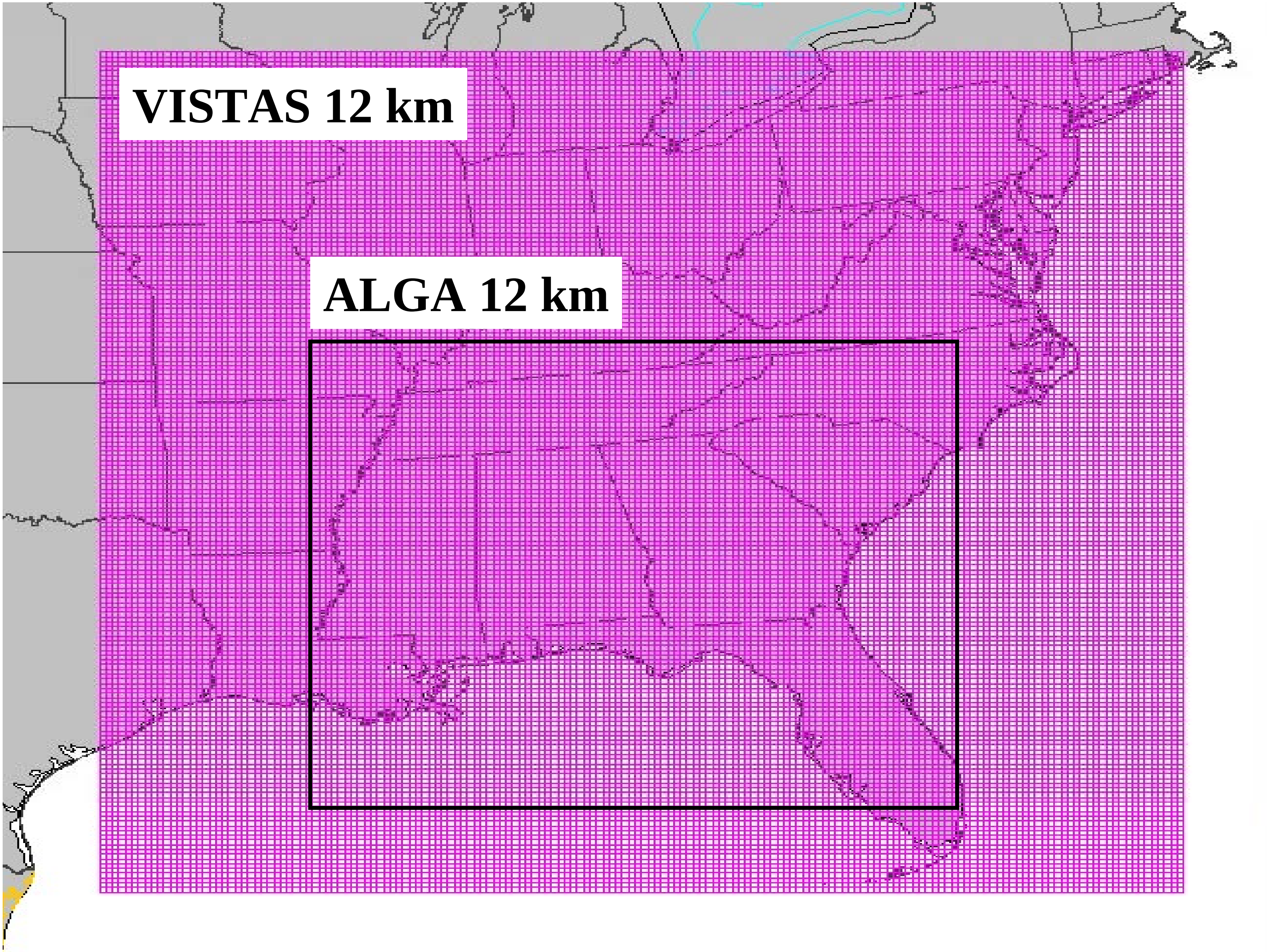


Air Quality (CMAQ)

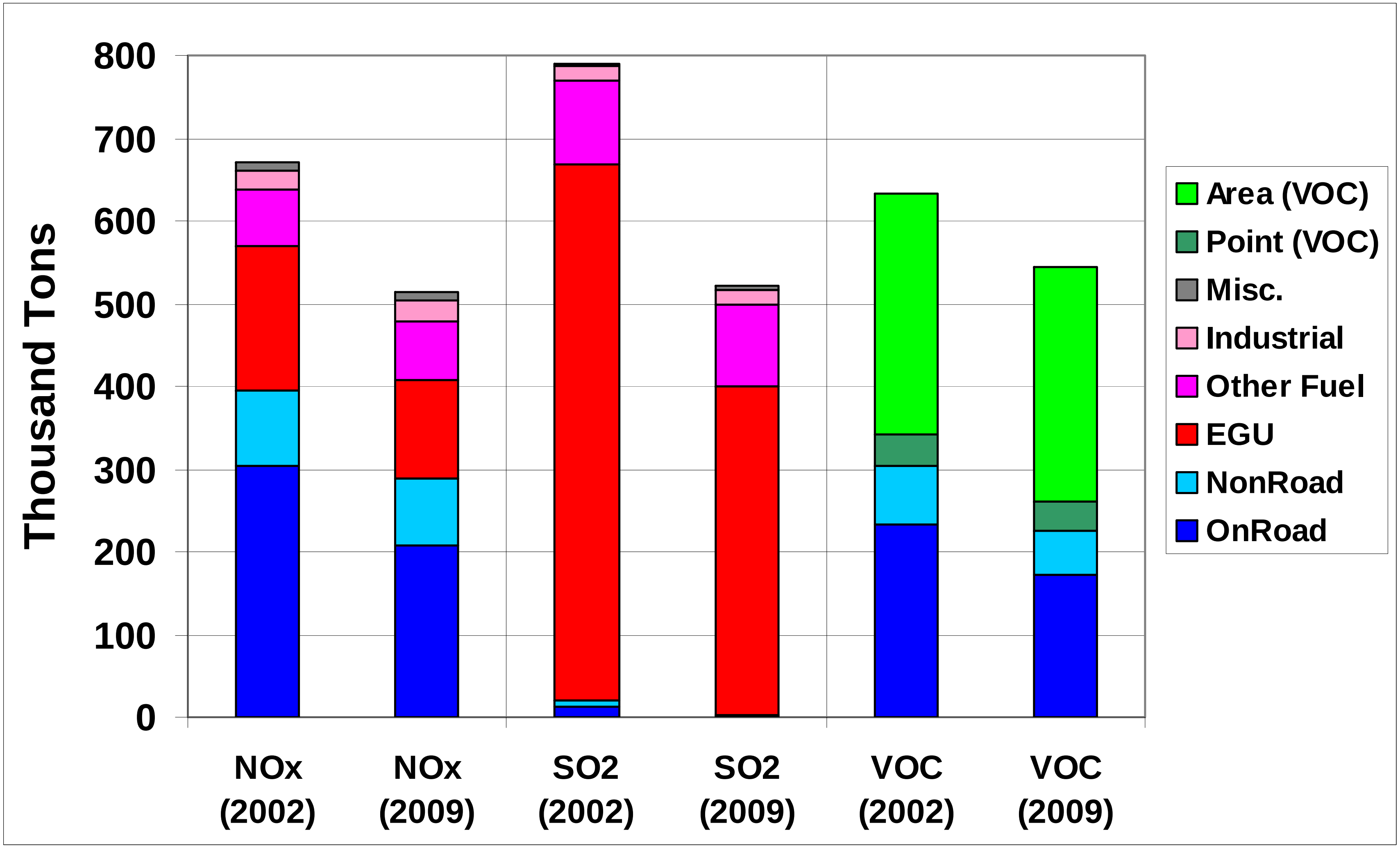


Demonstrating attainment using AQ models



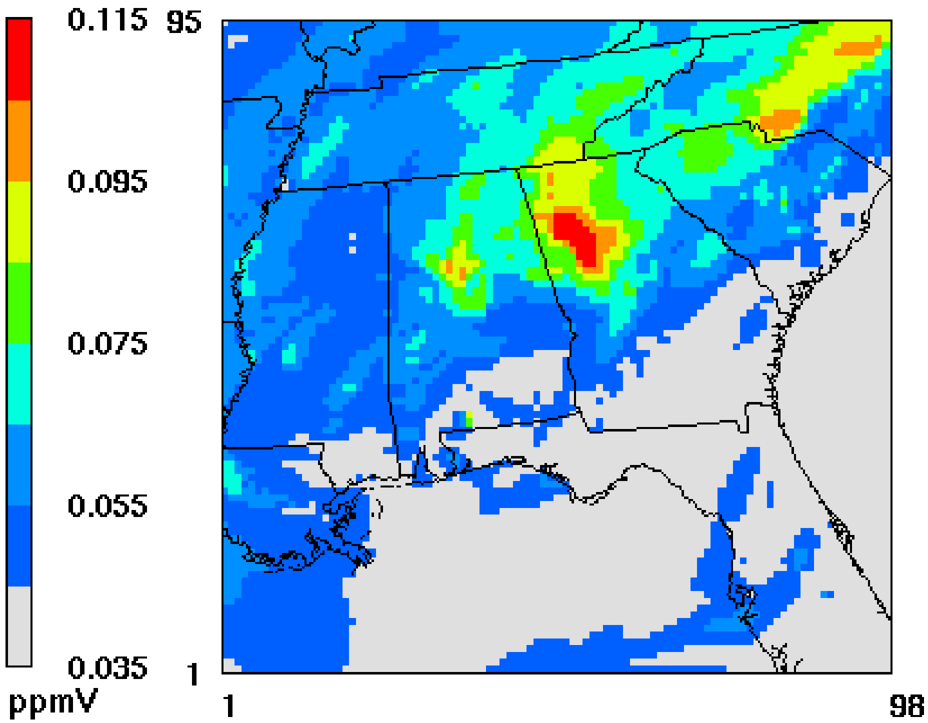

VISTAS 12 km
ALGA 12 km

Future Emissions in Georgia

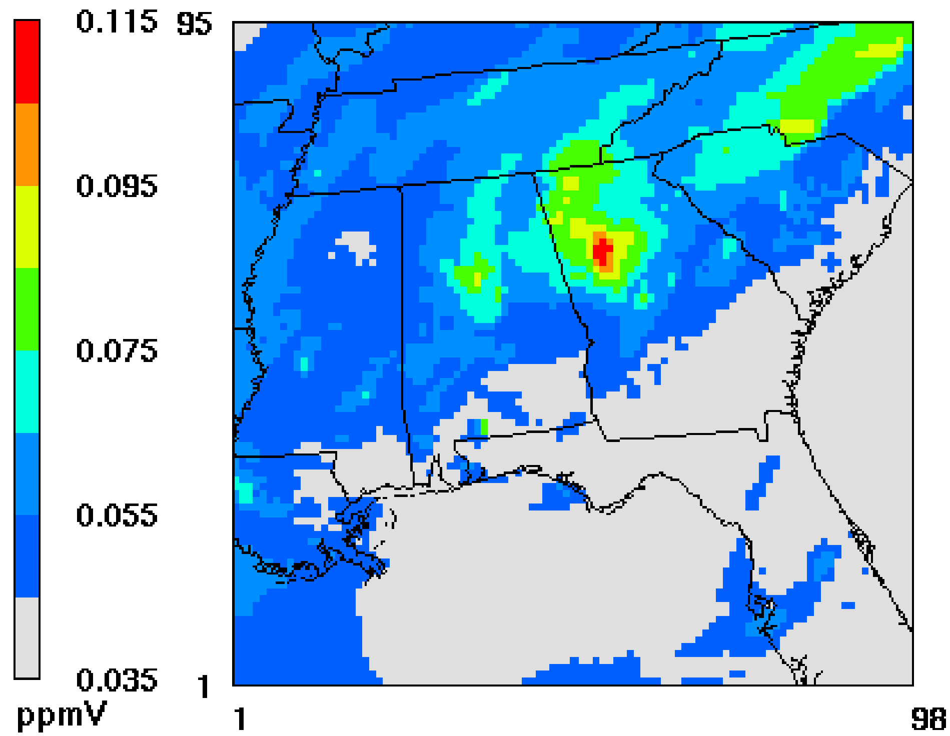


Reductions in Ozone (2002 → 2009)

Max 8-hour O3 on June 12, 2002
2002 Emissions

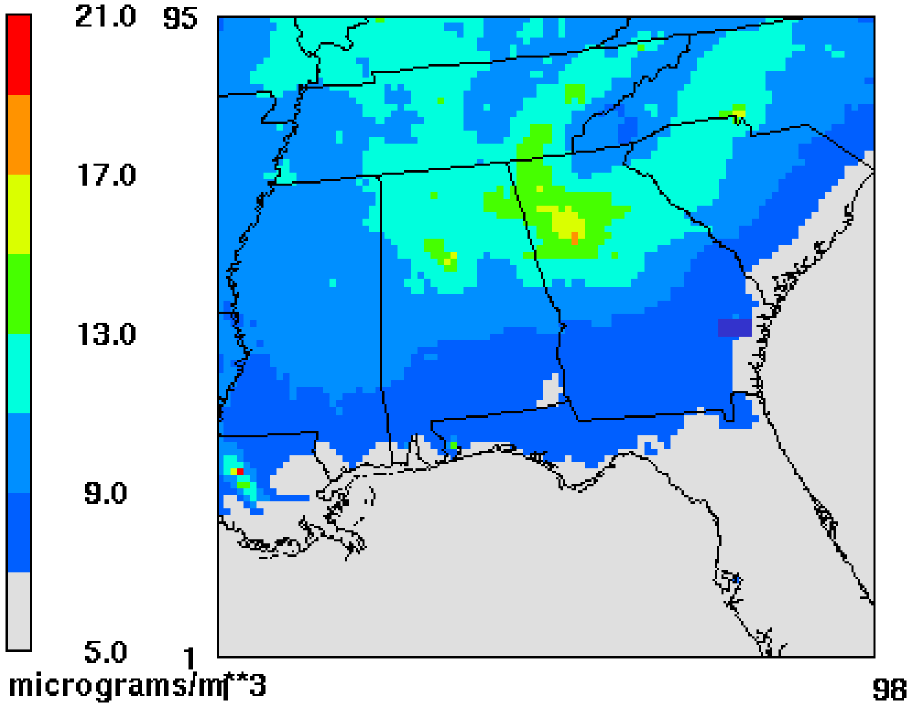


Max 8-hour O3 on June 12, 2002
2009 Emissions

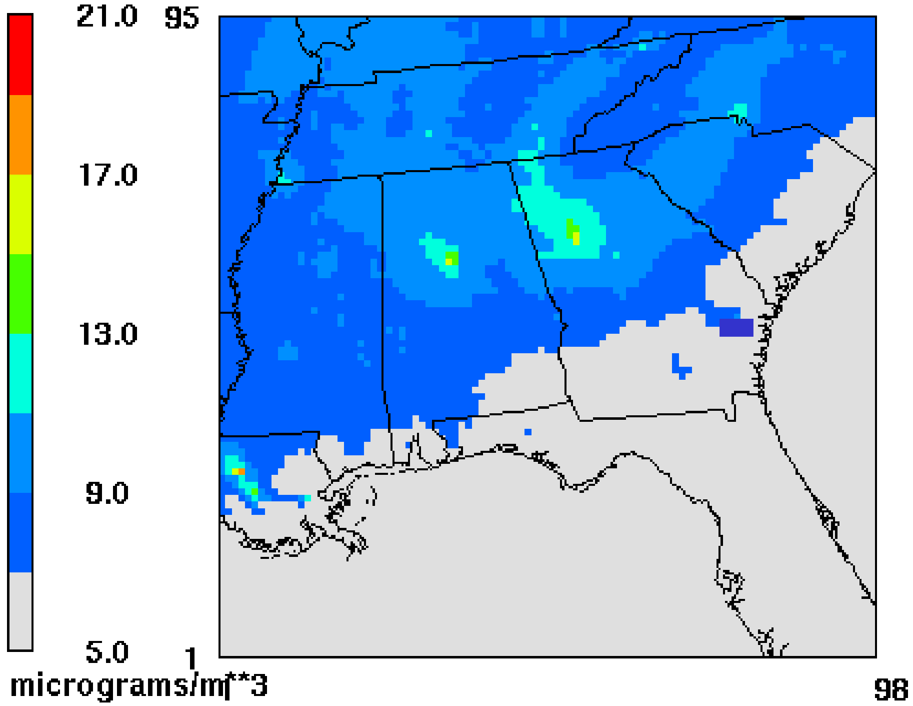


Reductions in PM2.5 (2002 → 2009)

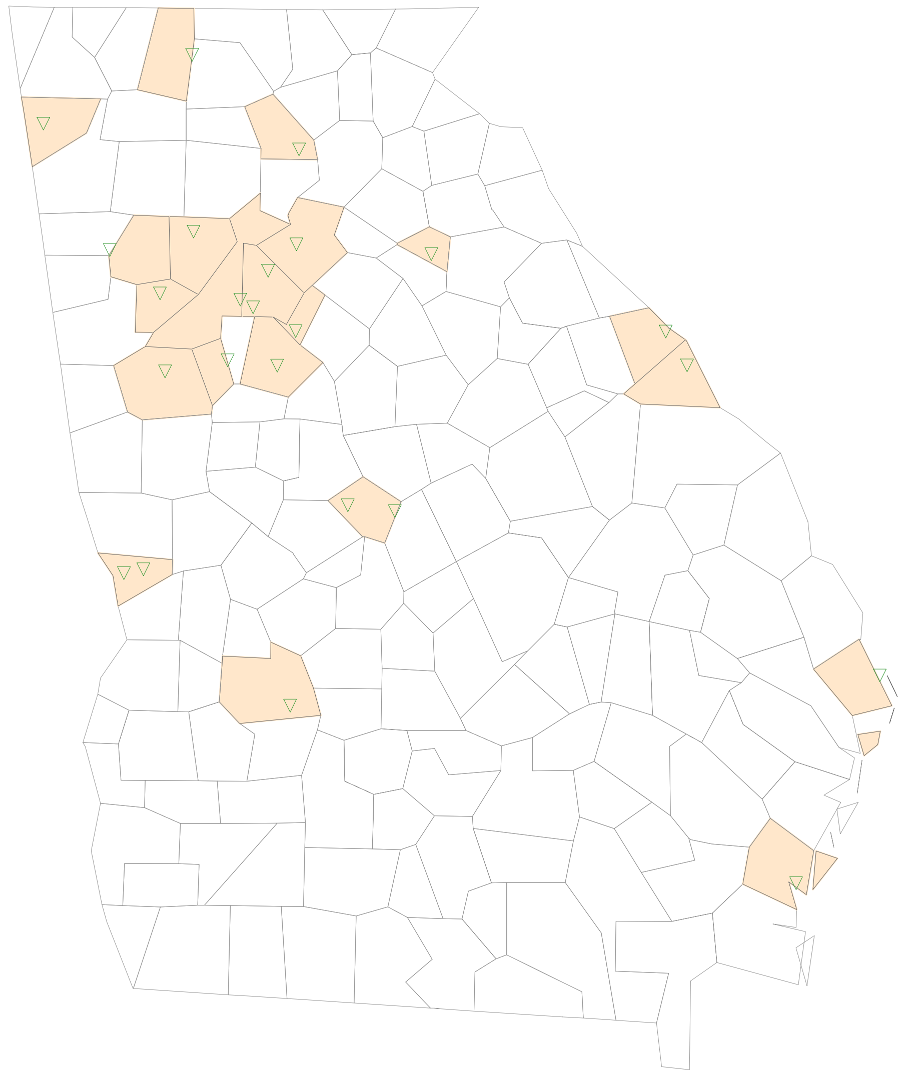
Summer $PM_{2.5}$ concentration
2002 Emissions



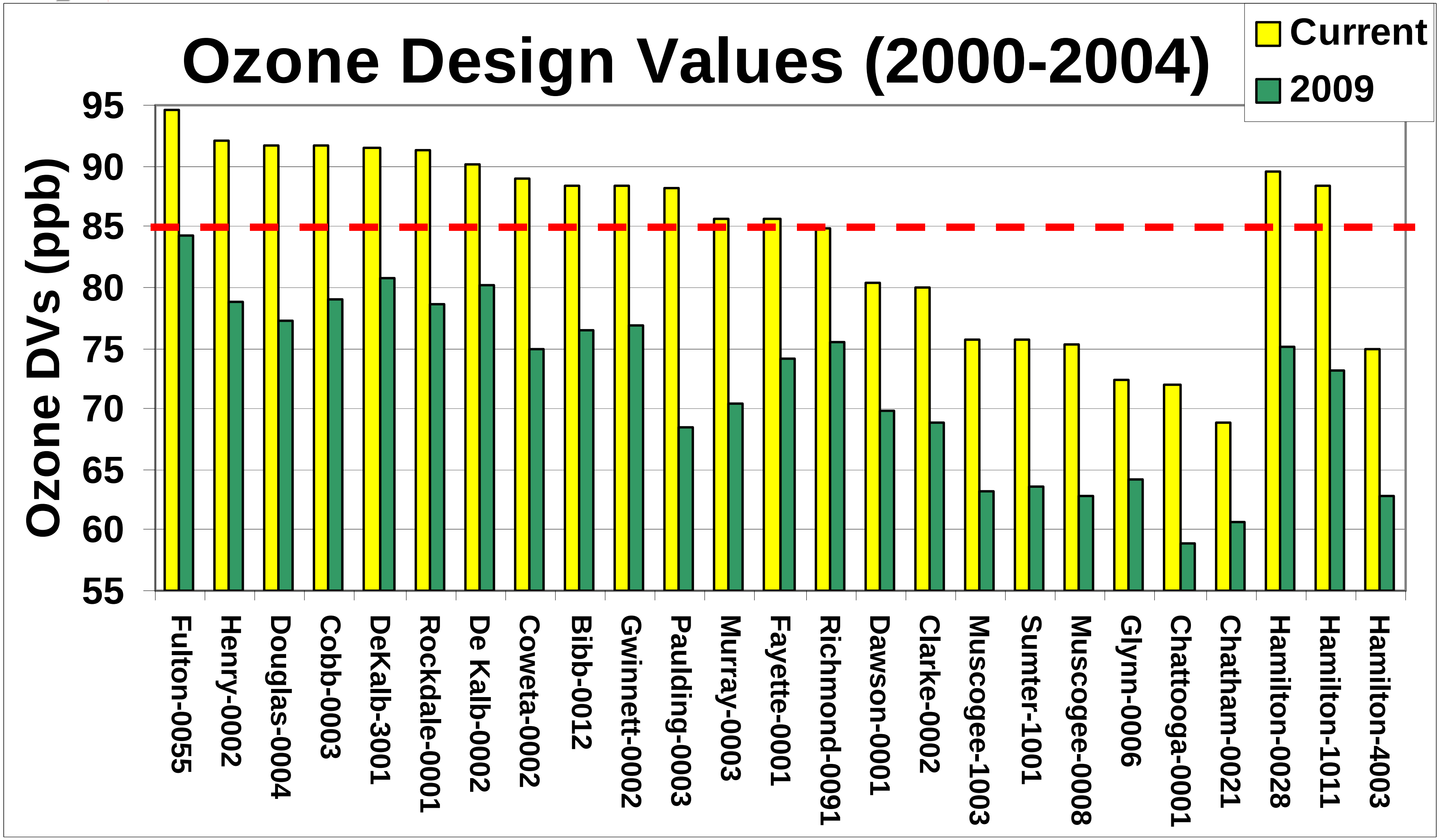
Summer $PM_{2.5}$ concentration
2009 Emissions



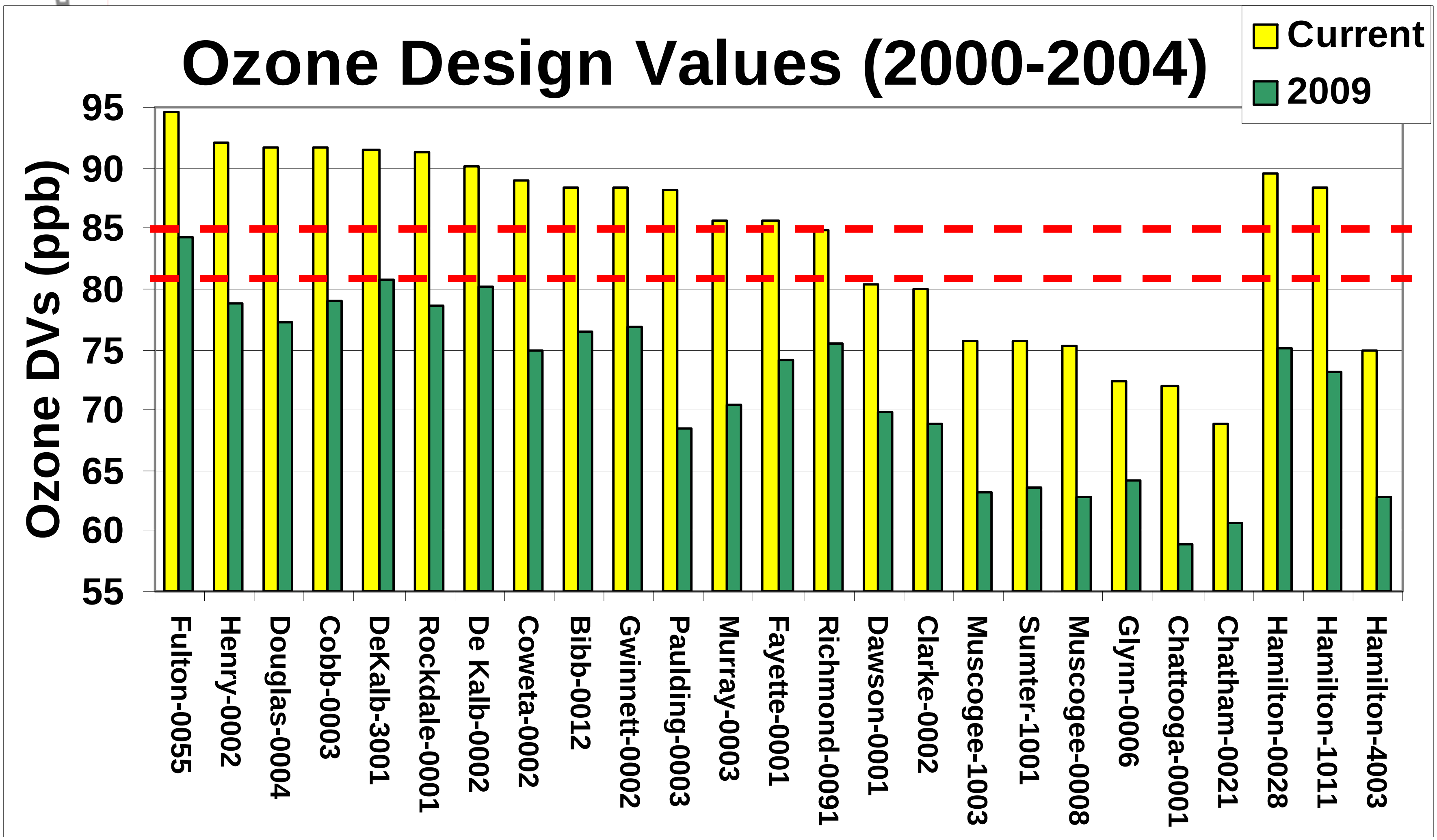
Ozone Monitors in GA



Future Ozone Concentrations

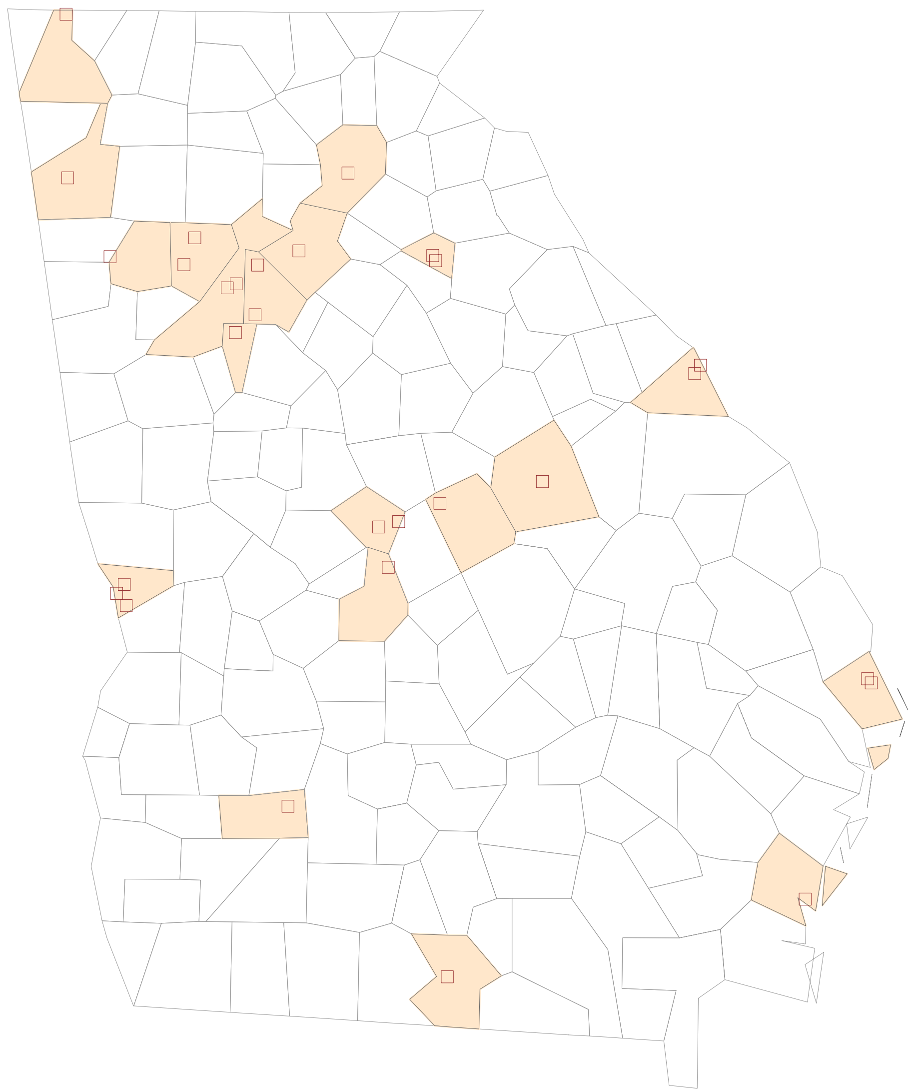


Future Ozone Concentrations

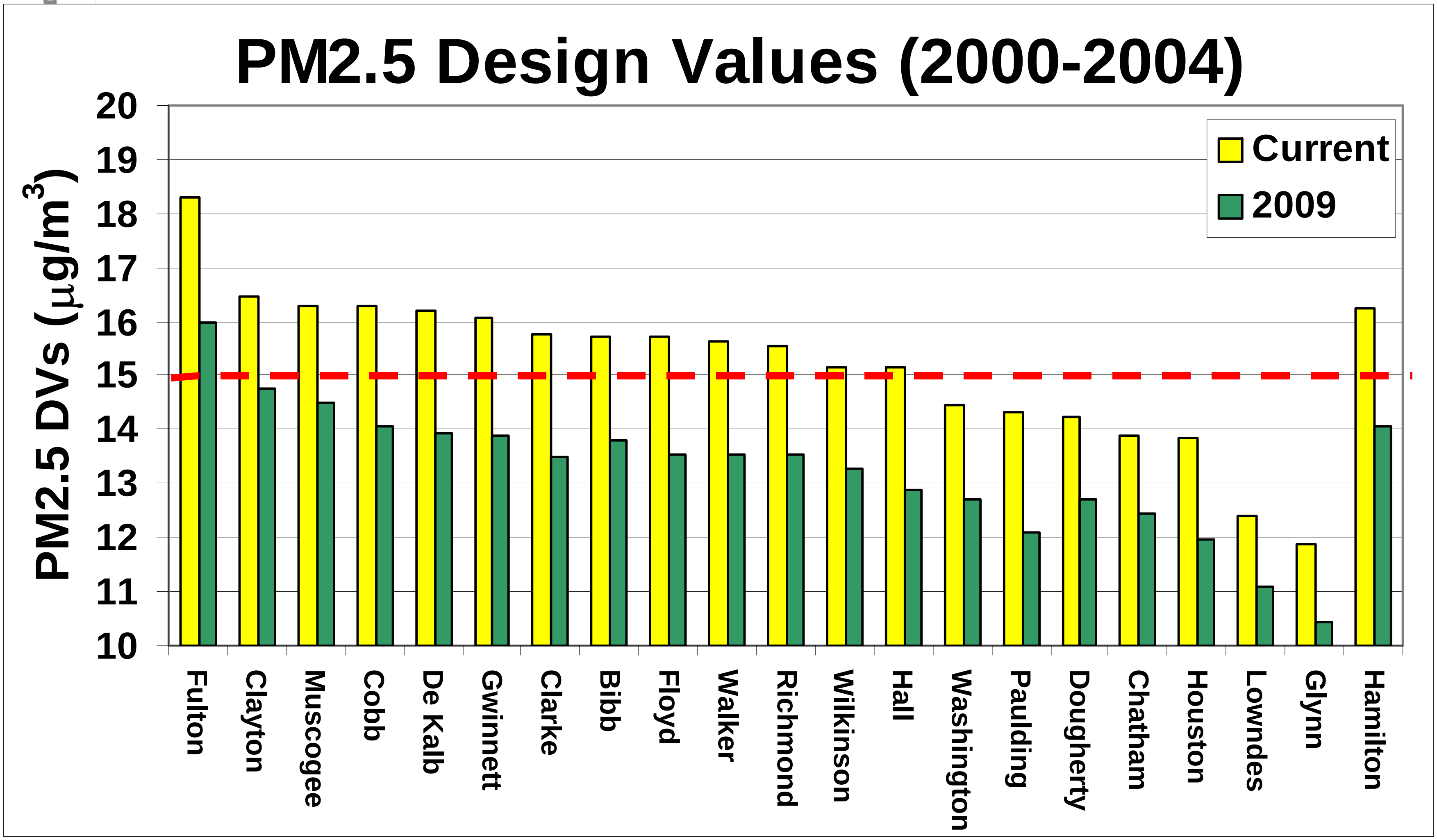


***Need ozone "buffer" below 85 ppb (e.g., 4 ppb in Atlanta)**

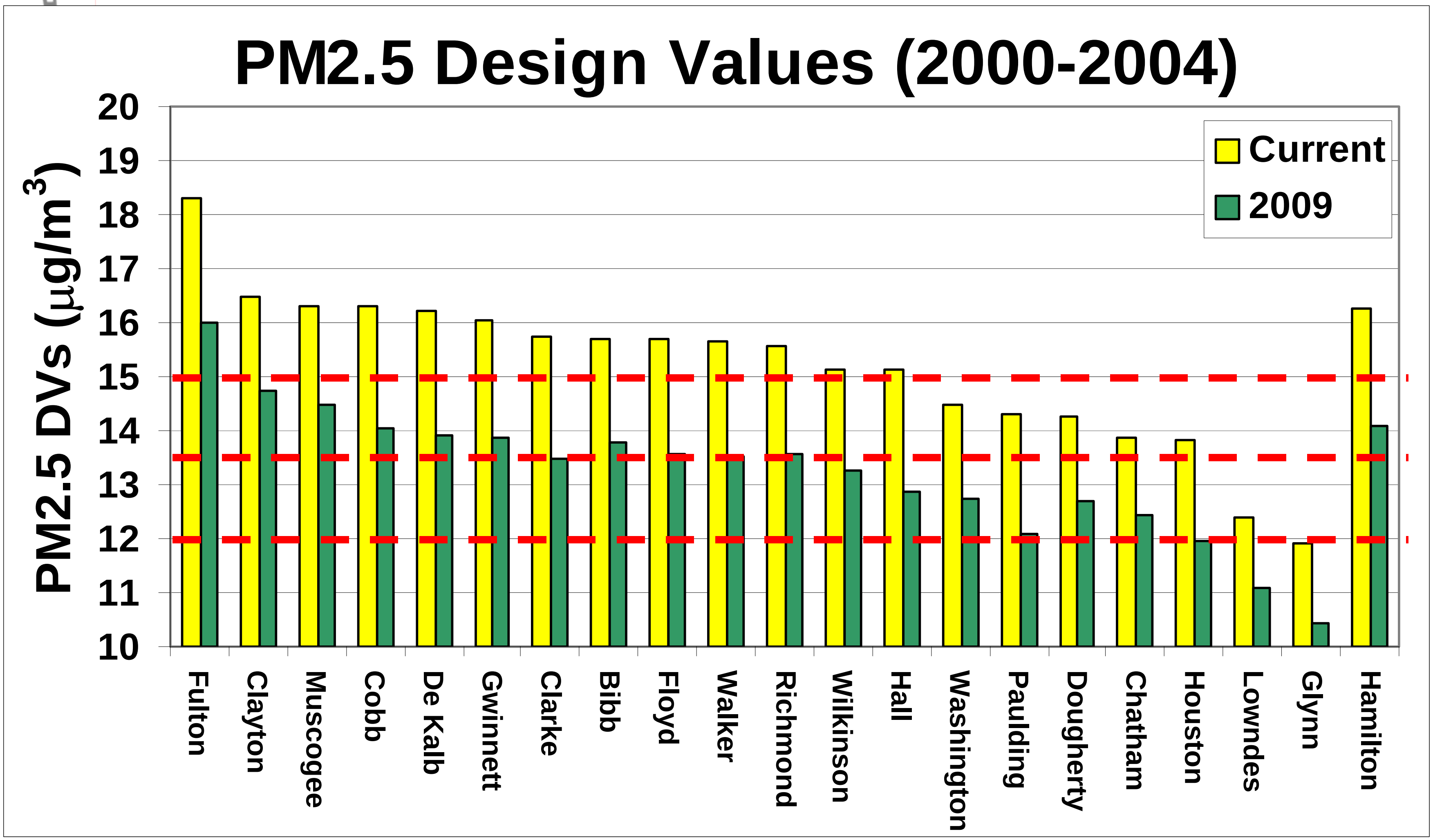
PM2.5 Monitors in GA



Future PM2.5 Concentrations



Future PM2.5 Concentrations



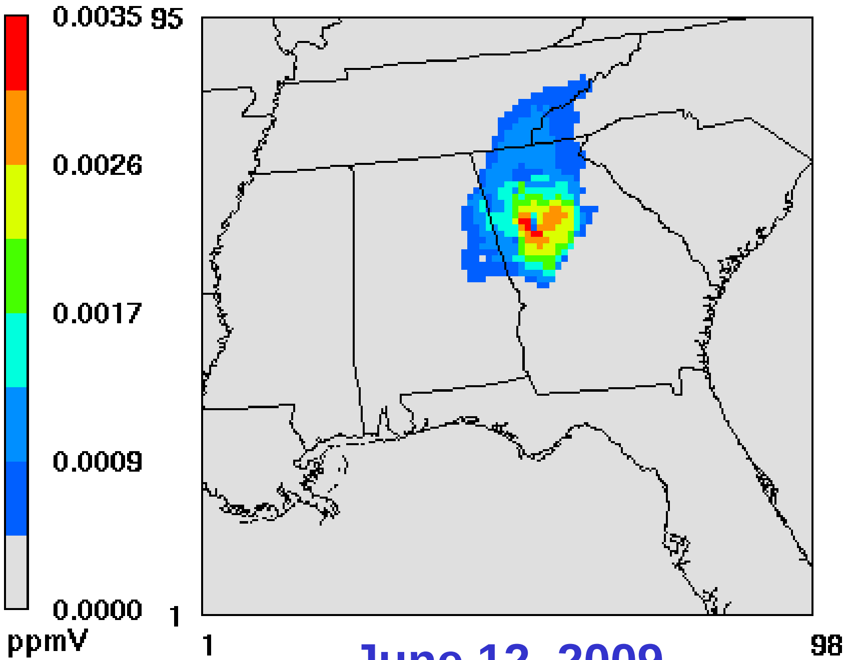
*EPA is considering lowering the PM2.5 NAAQS in the future (e.g., 13.5 μg/m³)

Emission Sensitivities

- Sensitivity of ozone (ppb) and $PM_{2.5}$ ($\mu g/m^3$)
  - Summer Episode: **May 25 - June 25, 2002 (2009)**
  - Winter Episode: **Nov 19 - Dec 19, 2002 (2009)**
- Regional 10% Emission Reductions
  - NOx, VOCs, SO_2, NH_3, and primary carbon (PC)
  - Atlanta (full & sub), Macon (full & sub), Chattanooga (full & sub), Floyd County
- Point Emission Reductions
  - SCR (NO_x) and Scrubber (SO_2) at 7 largest Power Plants in Georgia

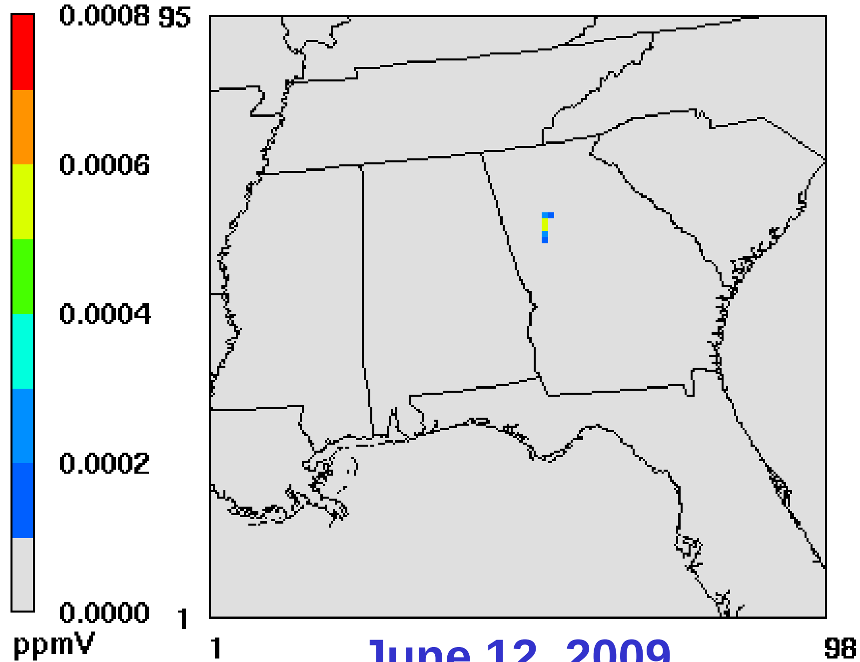
NOx & VOCs in Atlanta (Ozone)

10% NO_x (38 TPD)



June 12, 2009

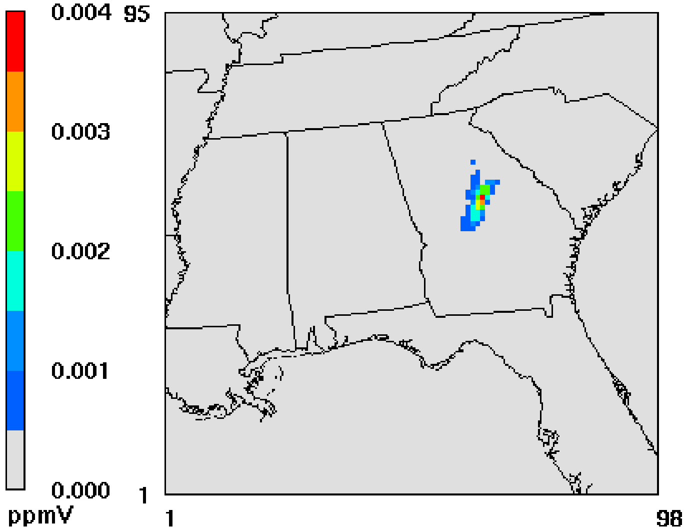
10% VOCs (49 TPD)



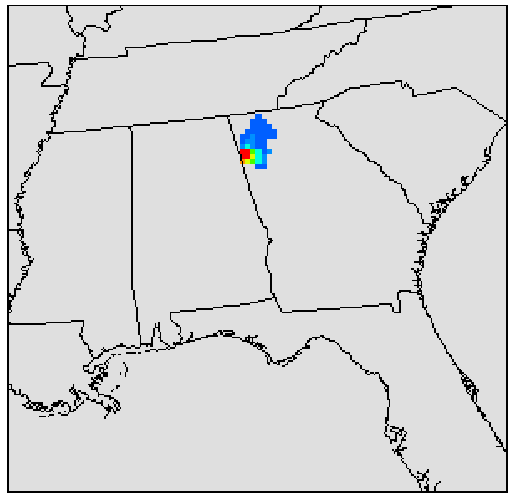
June 12, 2009

SCR NO_x Controls (Ozone)

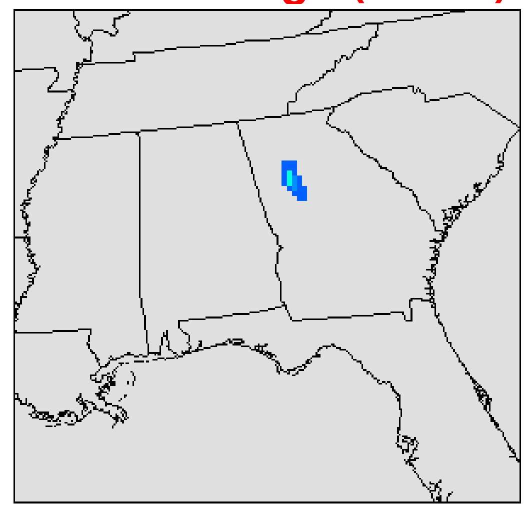
Branch (2 SCRs)



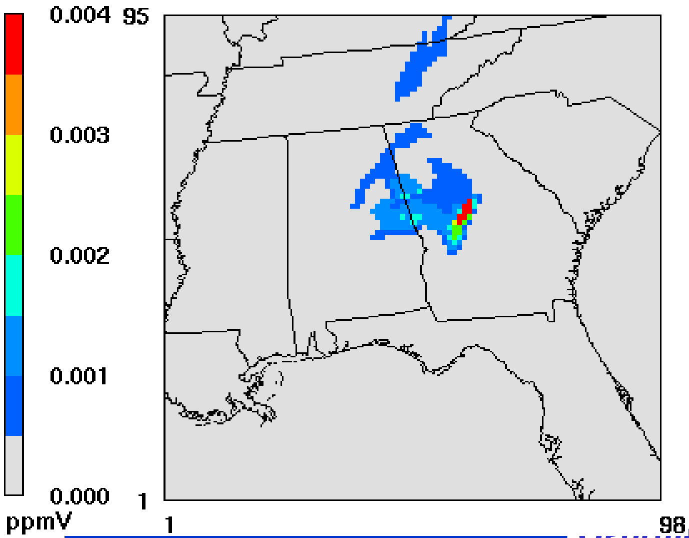
Hammond (3 SCRs)



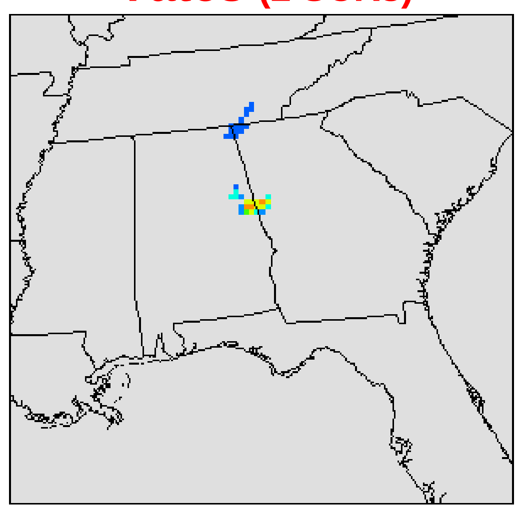
McDonough (2 SCRs)



Scherer (4 SCRs)



Yates (2 SCRs)

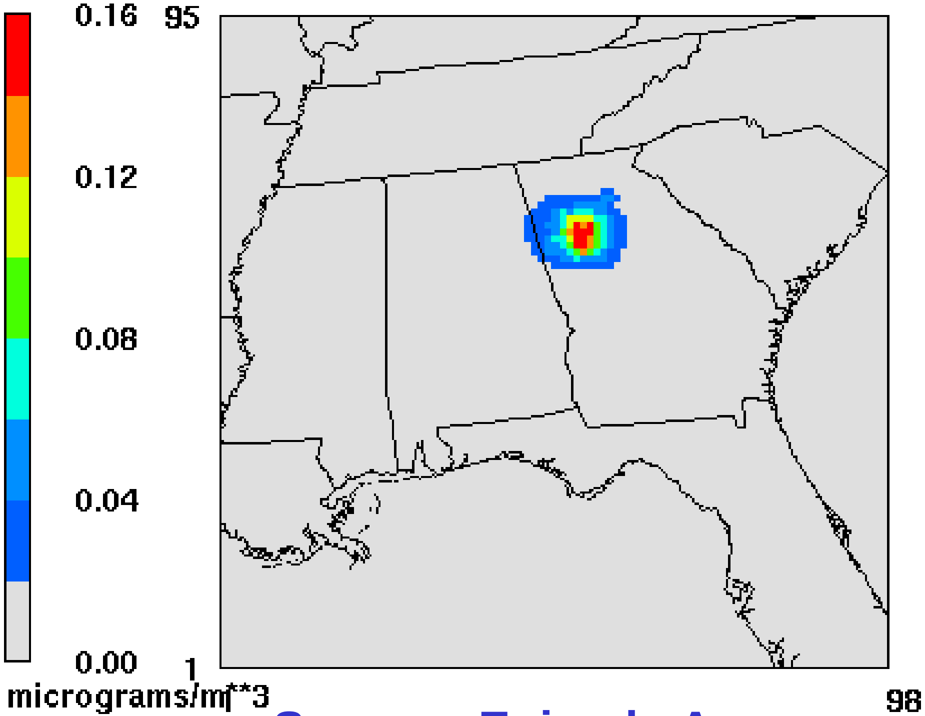


Ozone at Confederate Avenue

Sensitivity	Avg response (ppb)	ppt/TPD reduction
10% Atlanta NO_x (20 counties)	**1.36**	**35.7**
10% Atlanta NO_x (5 counties)	**0.95**	**41.1**
10% Atlanta VOC (20 counties)	0.08	1.5
10% Atlanta VOC (5 counties)	0.07	2.2
SCRs at Plant McDonough	**0.42**	**60.4**
SCRs at Plant Scherer	**0.41**	13.7
SCRs at Plant Branch	0.07	4.6
SCRs at Plant Hammond	0.03	2.2
SCRs at Plant Yates	0.11	9.9

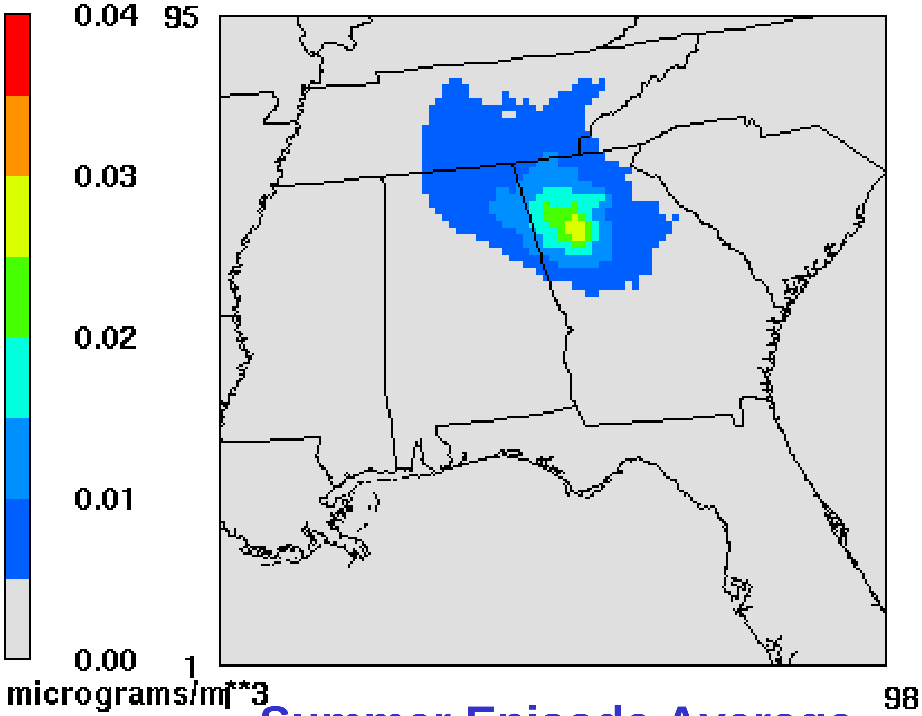
PC and SO_2 in Atlanta ($PM_{2.5}$)

10% Carbon (2 TPD)



Summer Episode Average

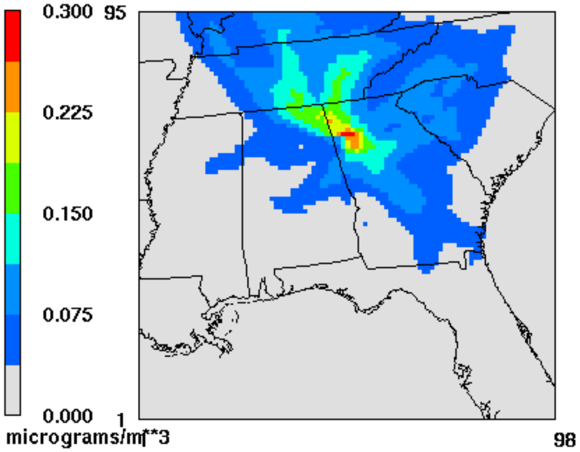
10% SO_2 (8 TPD)



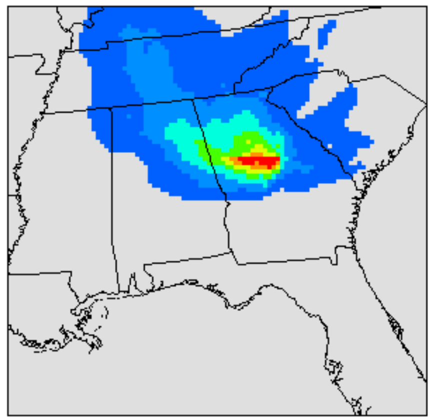
Summer Episode Average

Scrubber SO_2 Controls ($PM_{2.5}$)

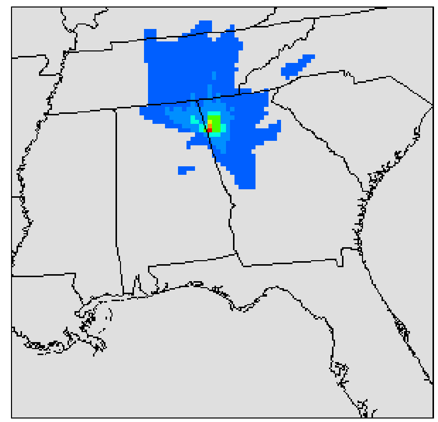
Bowen
(2 Scrubbers)



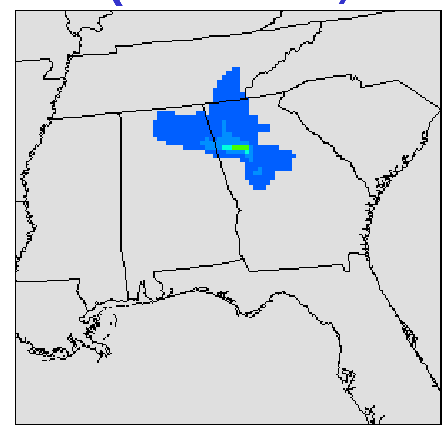
Branch
(4 Scrubbers)



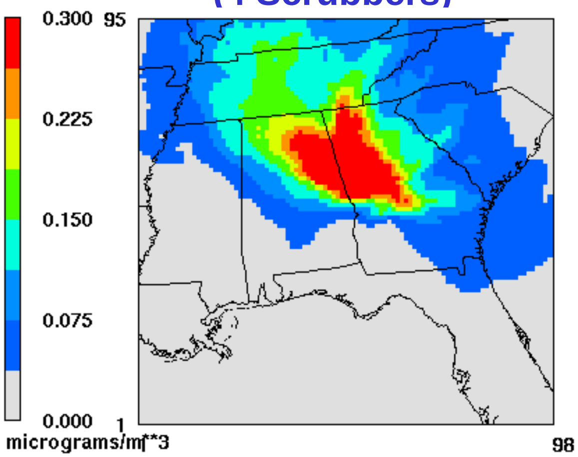
Hammond
(4 Scrubbers)



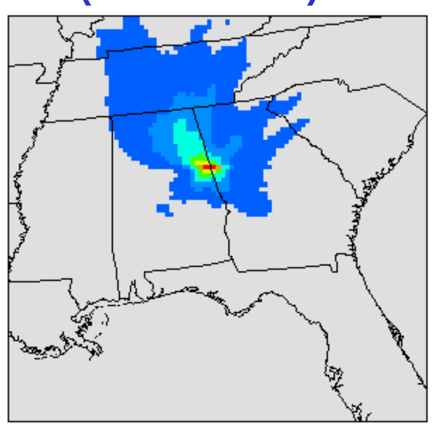
McDonough
(2 Scrubbers)



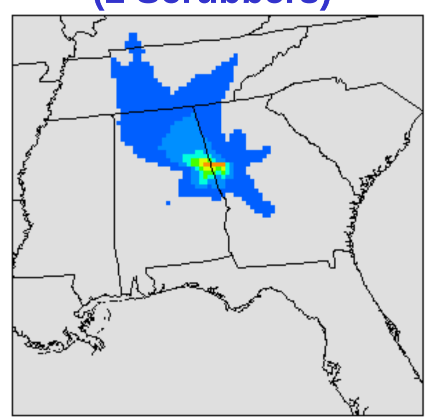
Scherer
(4 Scrubbers)



Wansley
(1 Scrubbers)



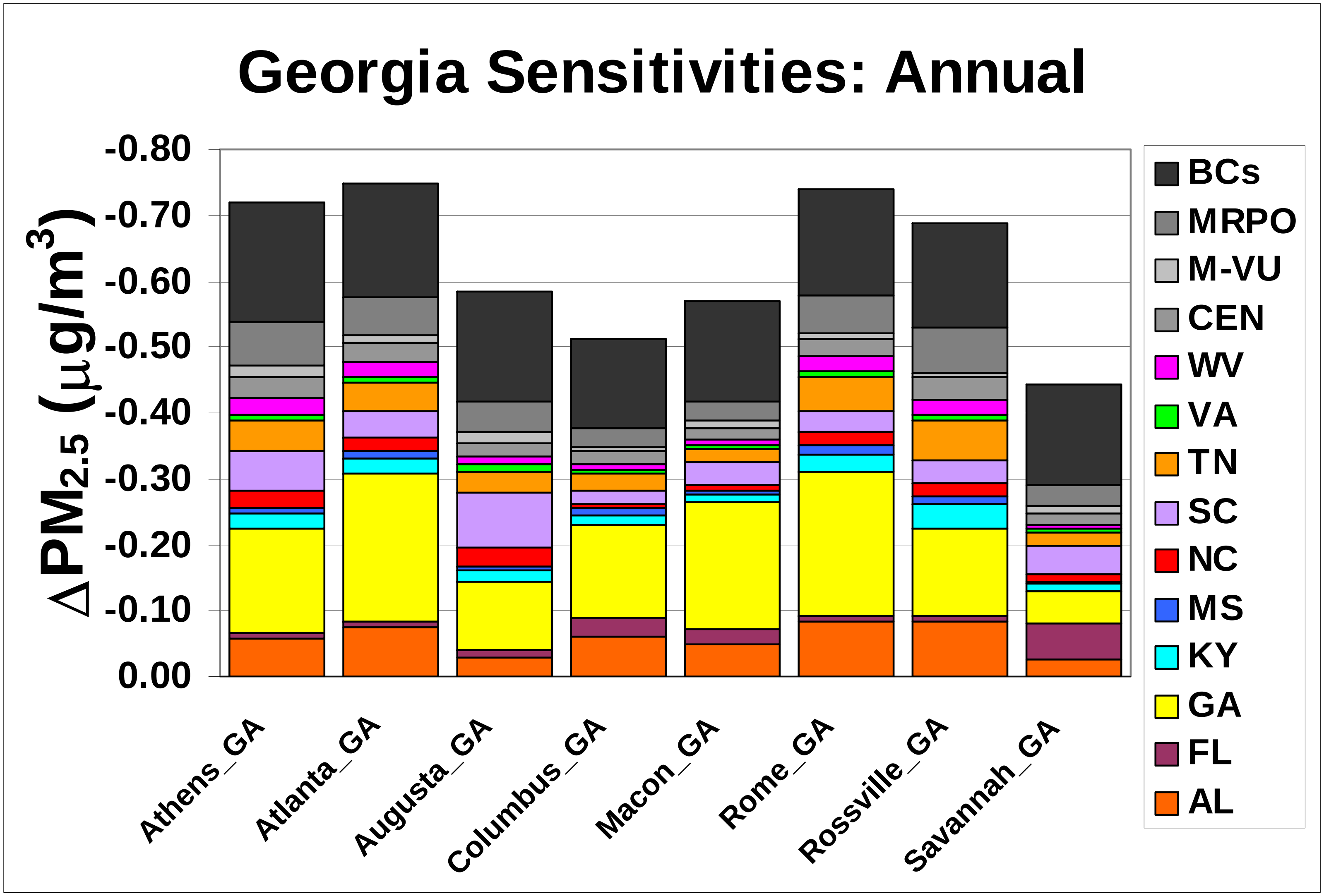
Yates
(2 Scrubbers)



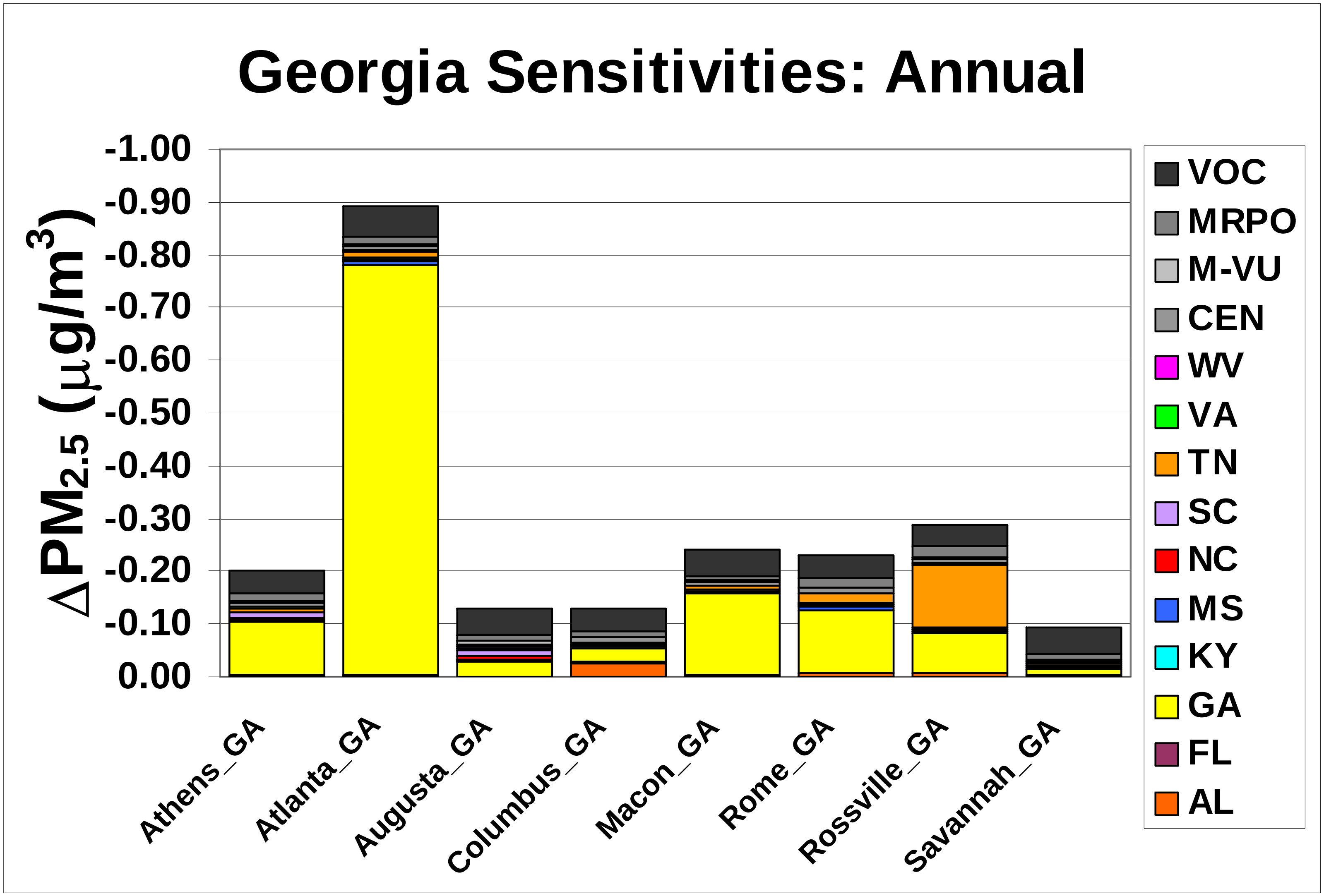
PM2.5 at Fire Station #8

Sensitivity	Summer ($\mu g/m^3$)	Winter ($\mu g/m^3$)	Annual ($\mu g/m^3$)	Annual ($\mu g/m^3$/TPD)
Atlanta (20) Pri. Carbon	0.19	0.36	**0.25**	85.7
Atlanta (5) Pri. Carbon	0.17	0.32	**0.23**	126
Scrubbers at Bowen (2)	0.19	0.07	**0.091**	0.50
Scrubbers at Branch (4)	0.15	0.03	**0.098**	0.63
Scrubbers at Hammond (4)	0.05	0.04	0.030	0.42
Scrubbers at McDonough(2)	0.11	0.07	0.070	1.39
Scrubbers at Scherer (4)	0.38	0.04	**0.150**	0.56
Scrubbers at Wansley (1)	0.09	0.06	0.044	0.44
Scrubbers at Yates (2)	0.05	0.06	0.037	0.71

30% EGU SO_2 in Georgia



30% Ground PC in Georgia

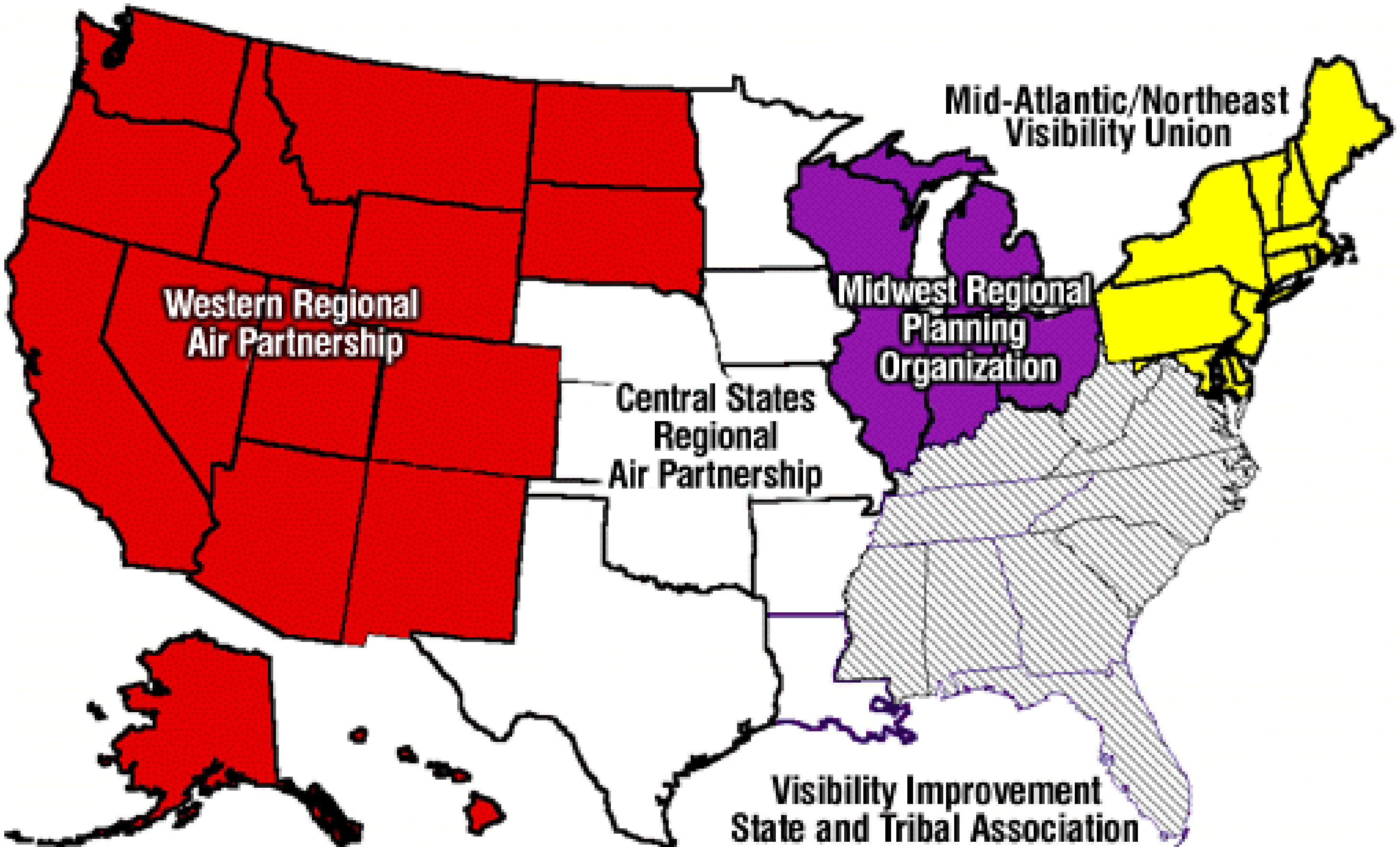


Next Steps

- Additional emission sensitivities to help develop control strategies
- Improvements to emission inventory
  - e.g., updated mobile source emissions
- Annual PM2.5 control strategy simulations to demonstrate attainment on ALGA 12 km domain
- Seasonal ozone control strategy simulations to demonstrate attainment on 4 km domain

Regional Haze SIP Modeling

Regional Planning Organizations



RPOs: created by EPA to initiate and coordinate activities associated with the management of regional haze at federally mandated Class I areas.

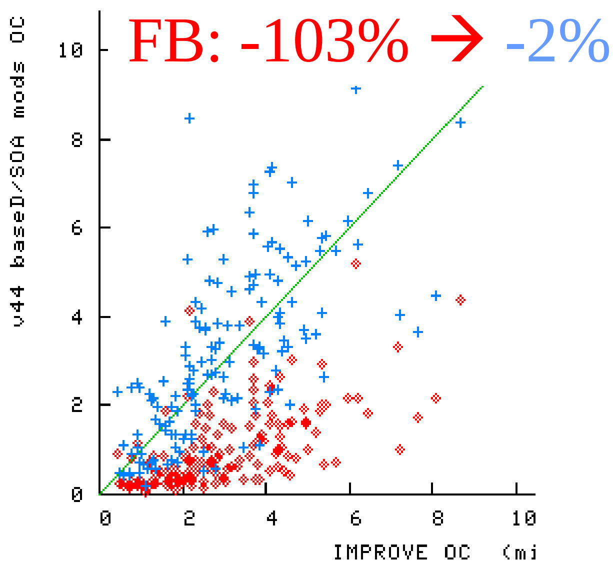
VISTAS

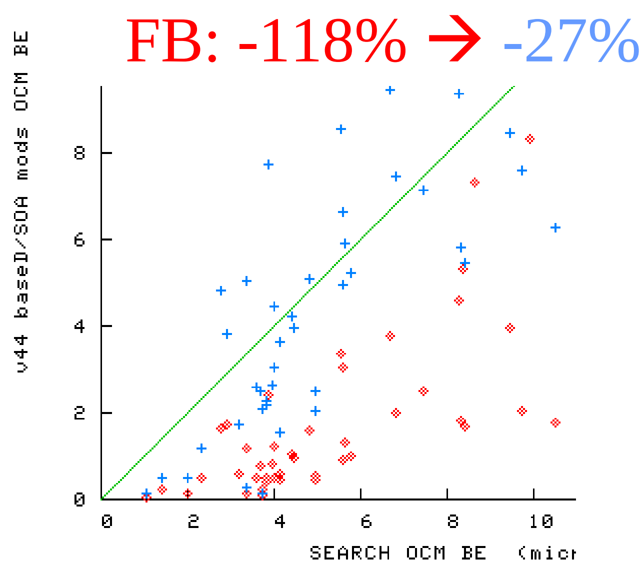
- Modeling Approach
  - 2002, 2009, and 2018 annual simulations at 36 and 12 km
  - MM5 Meteorology and SMOKE Emissions
  - CMAQ (primary model) and CAMx (corroborative model)
- Modeling Contractors
  - Baron Advanced Meteorological Systems (MM5)
  - Environ (CMAQ, CAMx)
  - Alpine Geophysics (SMOKE, CMAQ, CAMx)
  - University of California - Riverside (CMAQ)

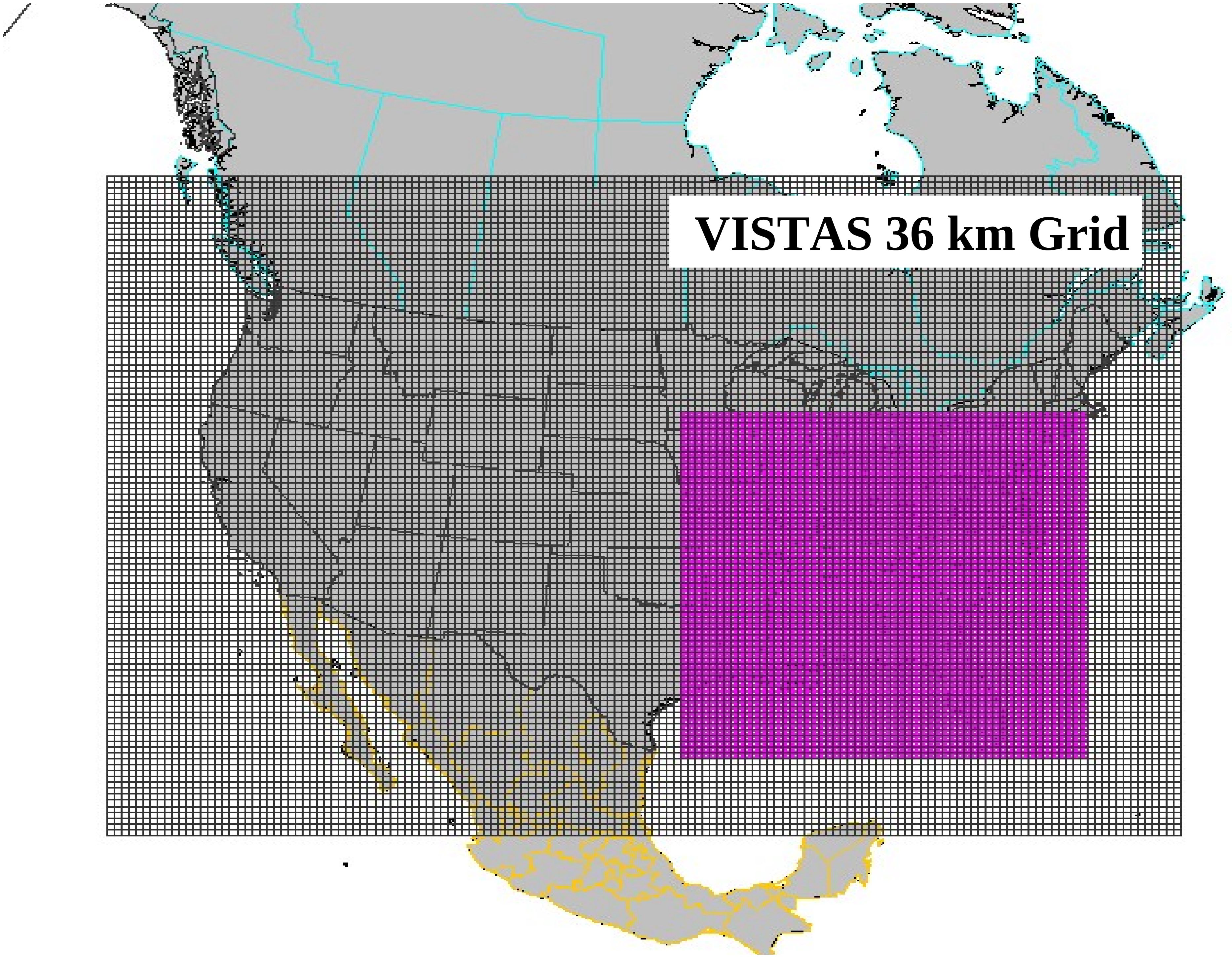
  (Annual Modeling (36/12 km) — applies to the four contractors above)
  - Georgia Tech (episodic emission sensitivities with CMAQ)
- Technical aspects of VISTAS modeling contracts being managed by GA EPD.

CMAQ SOA Updates

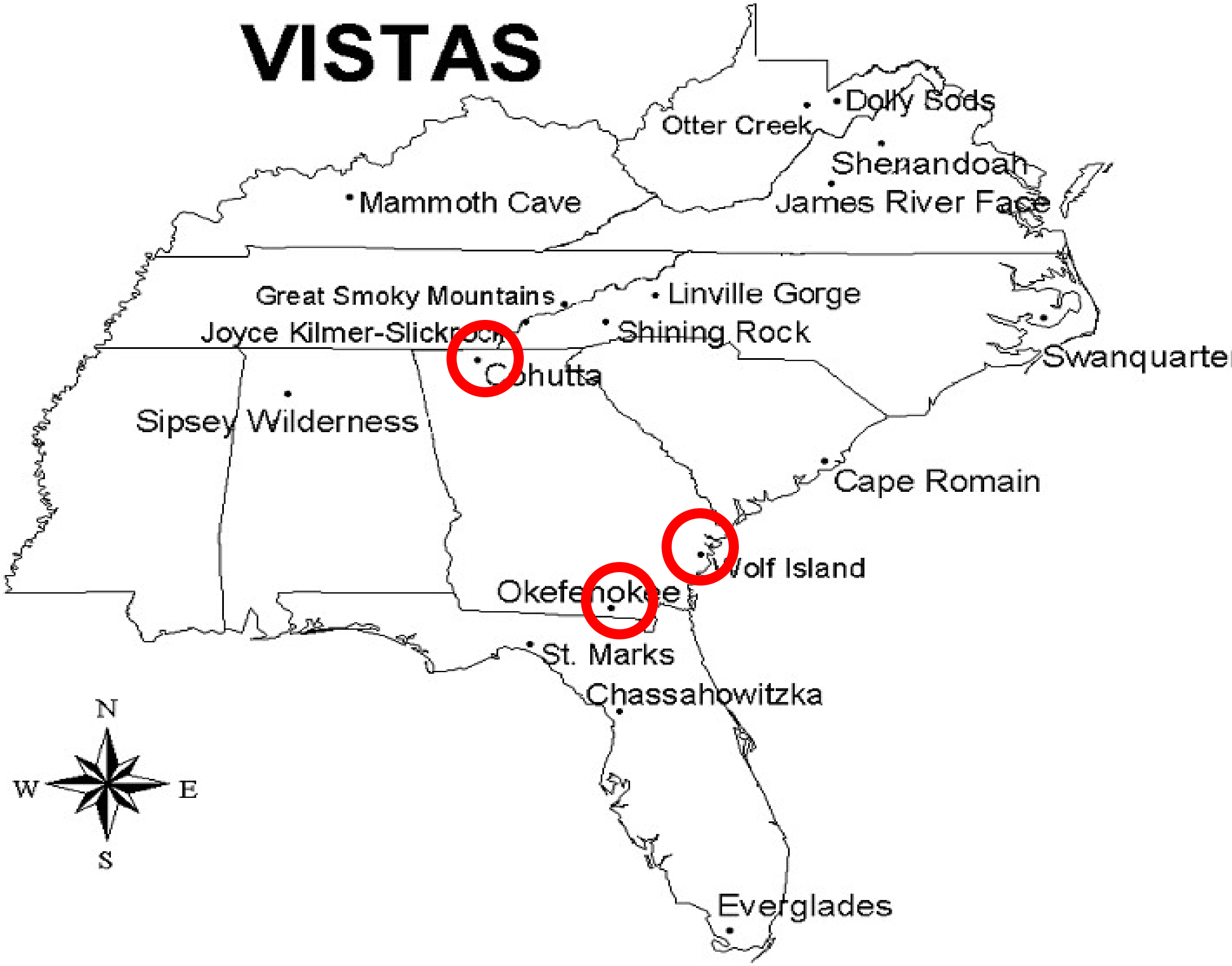
- VISTAS updated the CMAQ SOA module to include missing processes:
  - Added polymerization of SOA into non-volatile particles
  - Added SOA from sesquiterpenes, isoprene, and other monoterpenes
  - <u>Significant</u> Improvement in Model Performance



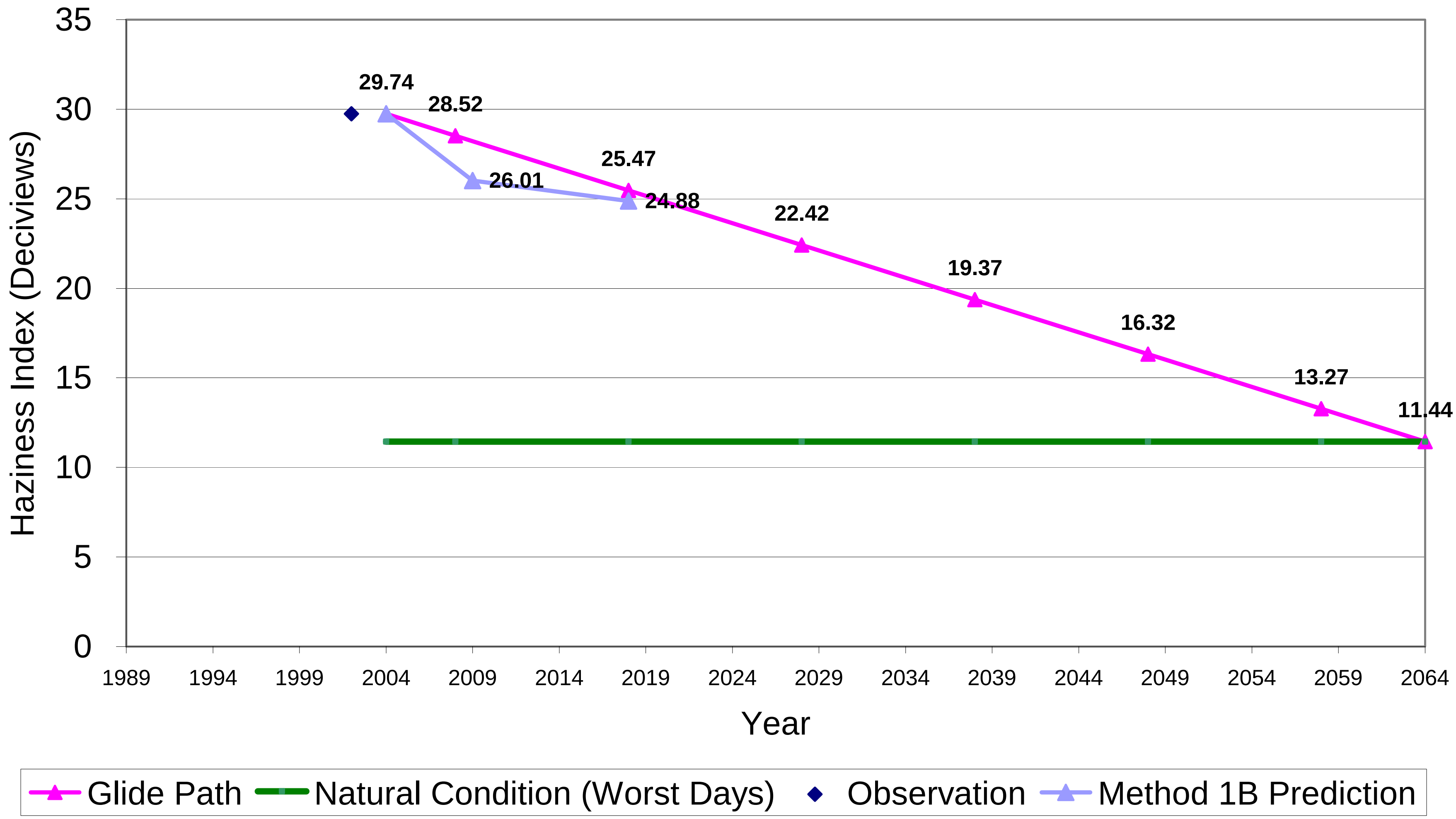



VISTAS 36 km Grid

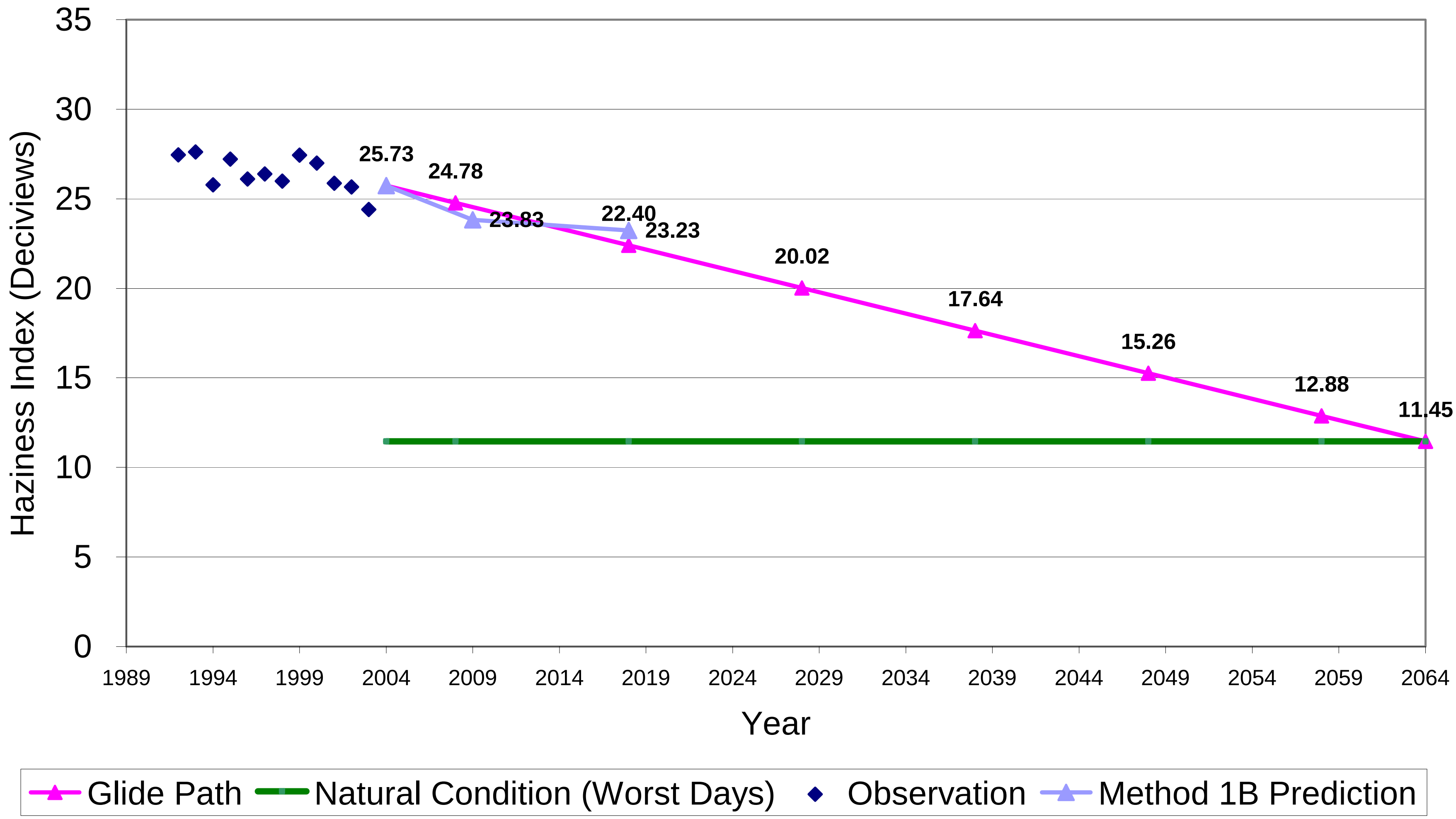
Class I Areas in Georgia



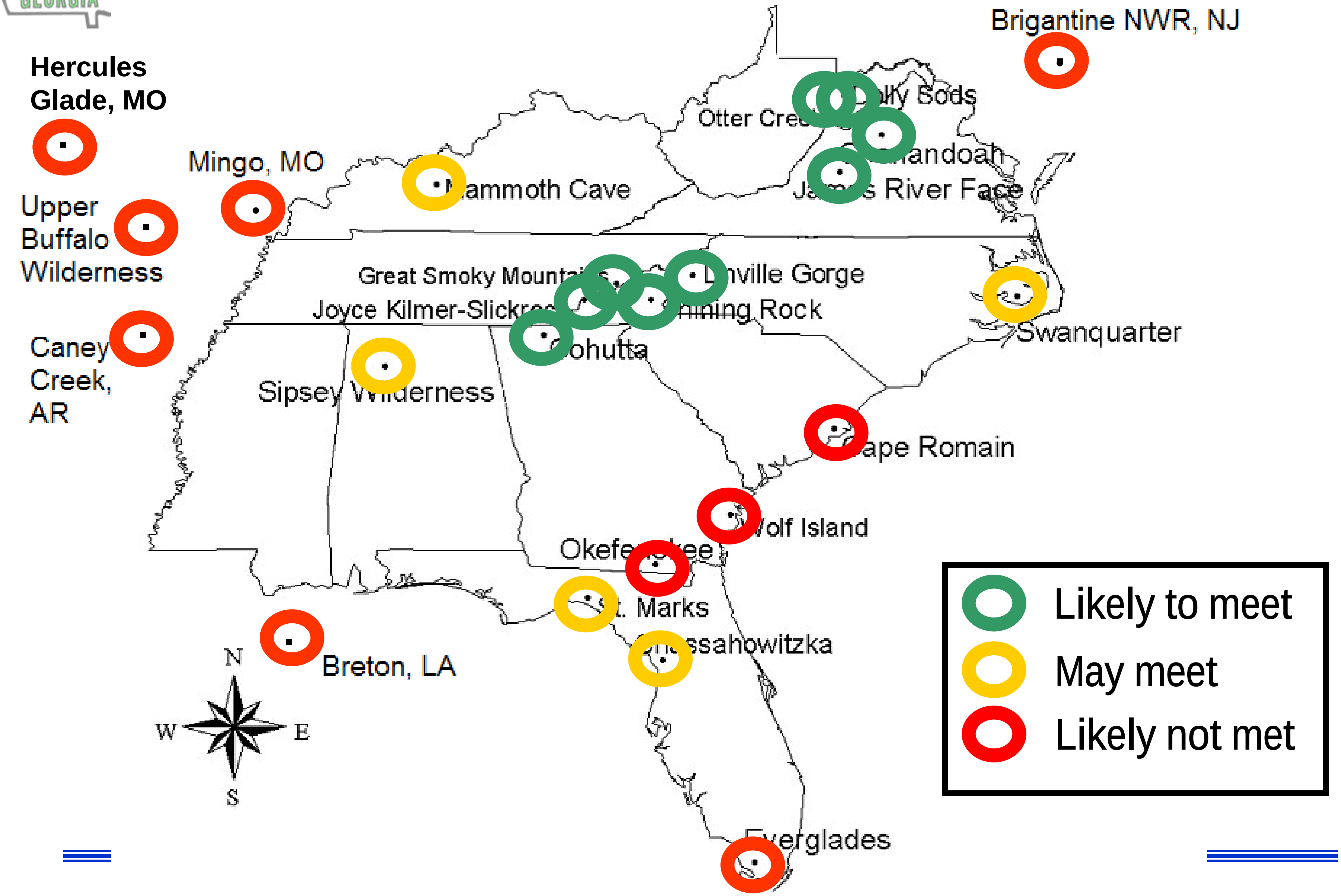
Uniform Rate of Reasonable Progress Glide Path
Cohutta Wilderness (GA) - 20% Worst Days



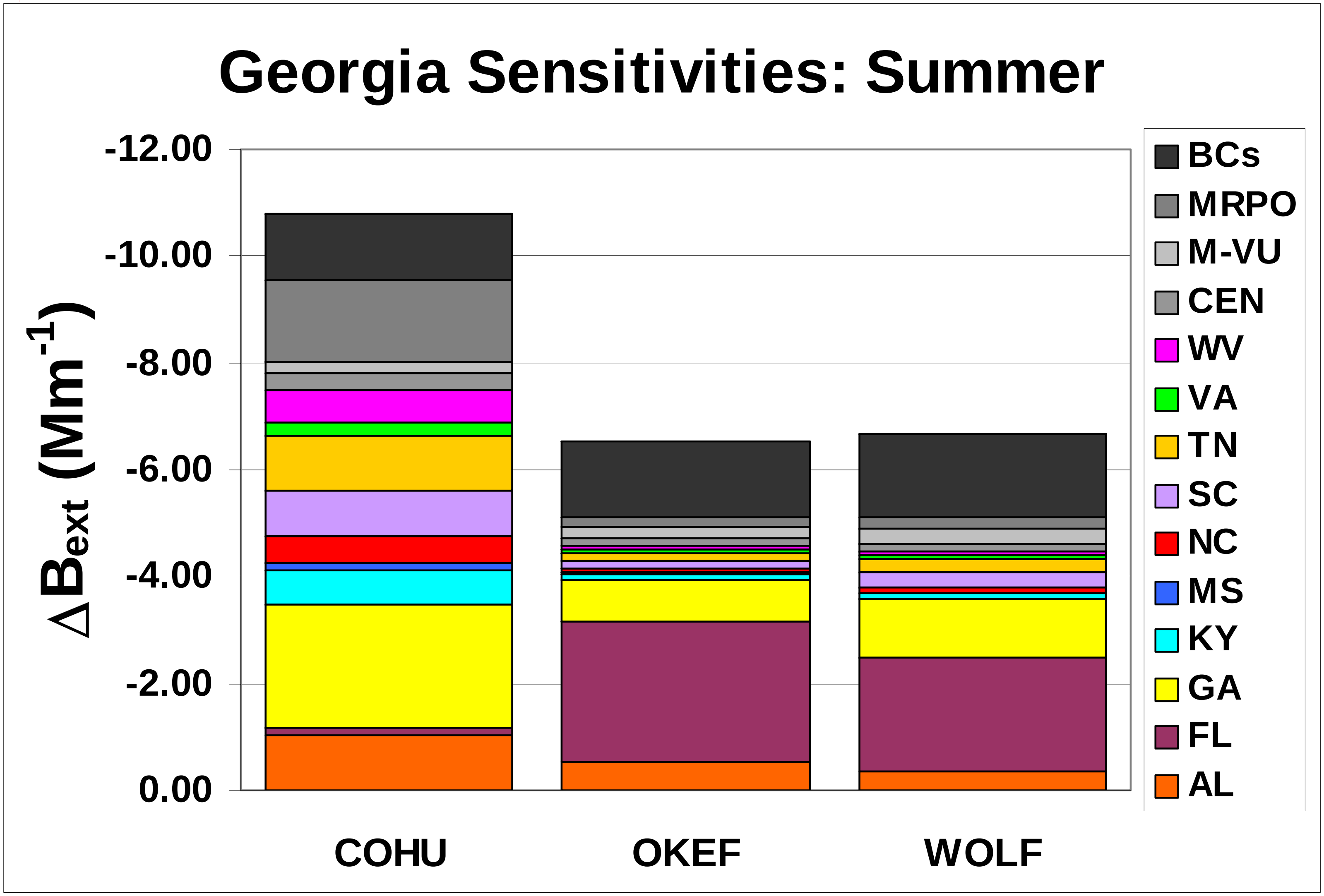
Uniform Rate of Reasonable Progress Glide Path
Okefenokee (GA) - 20% Worst Days



Reasonable Progress (2018)



30% EGU SO_2 (Summer)



Next Steps

- Develop emission control strategies to meet the reasonable progress goals
  - GT emission sensitivity results
  - Source specific emission sensitivities
    - GA EPD
  - Observational analyses
    - VISTAS and GA EPD
- Evaluate visibility impacts of BART and other "reasonable" controls using CMAQ annual simulations

Mercury Modeling for CAMR

Modeling in Support of CAMR

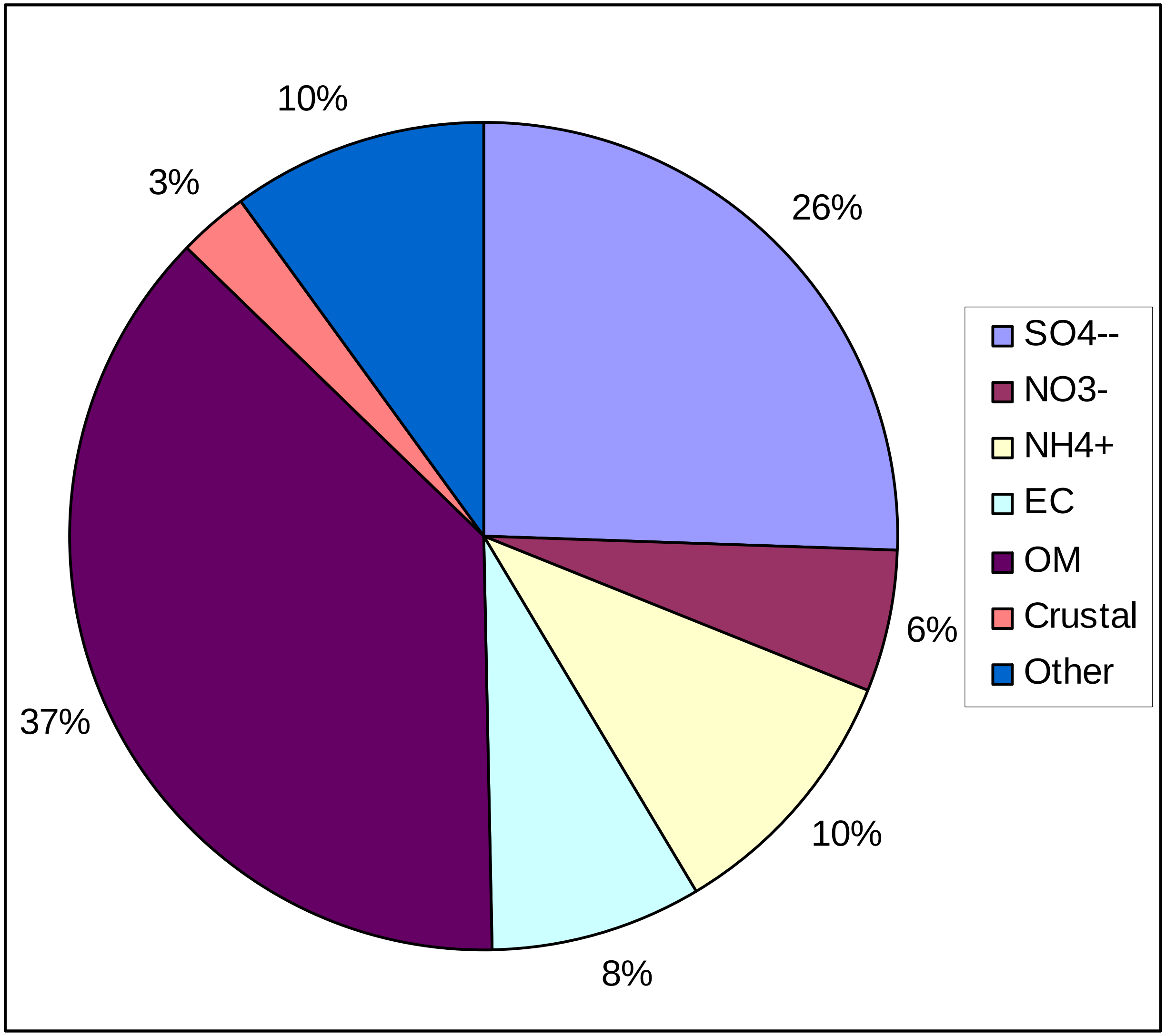
- EPA Mercury Modeling
  - 2001 annual simulation with MM5 and CMAQv4.3 (Hg) on a continental US 36-km grid
- EPD Mercury Modeling
  - 2002 annual simulation with MM5 and CMAQv4.3 (Hg) on our ALGA 12-km grid
  - Mercury Emissions processed for 7 EGUs in Georgia
    - Multiplied 2003 Hg/SO_2 annual emission totals by the modeled hourly SO_2 emissions to obtain hourly Hg emissions
    - Split the total mercury emissions for each facility into Elemental, Reactive Gaseous and Particulate Mercury
  - Modeling is currently underway

Observational Based Analyses

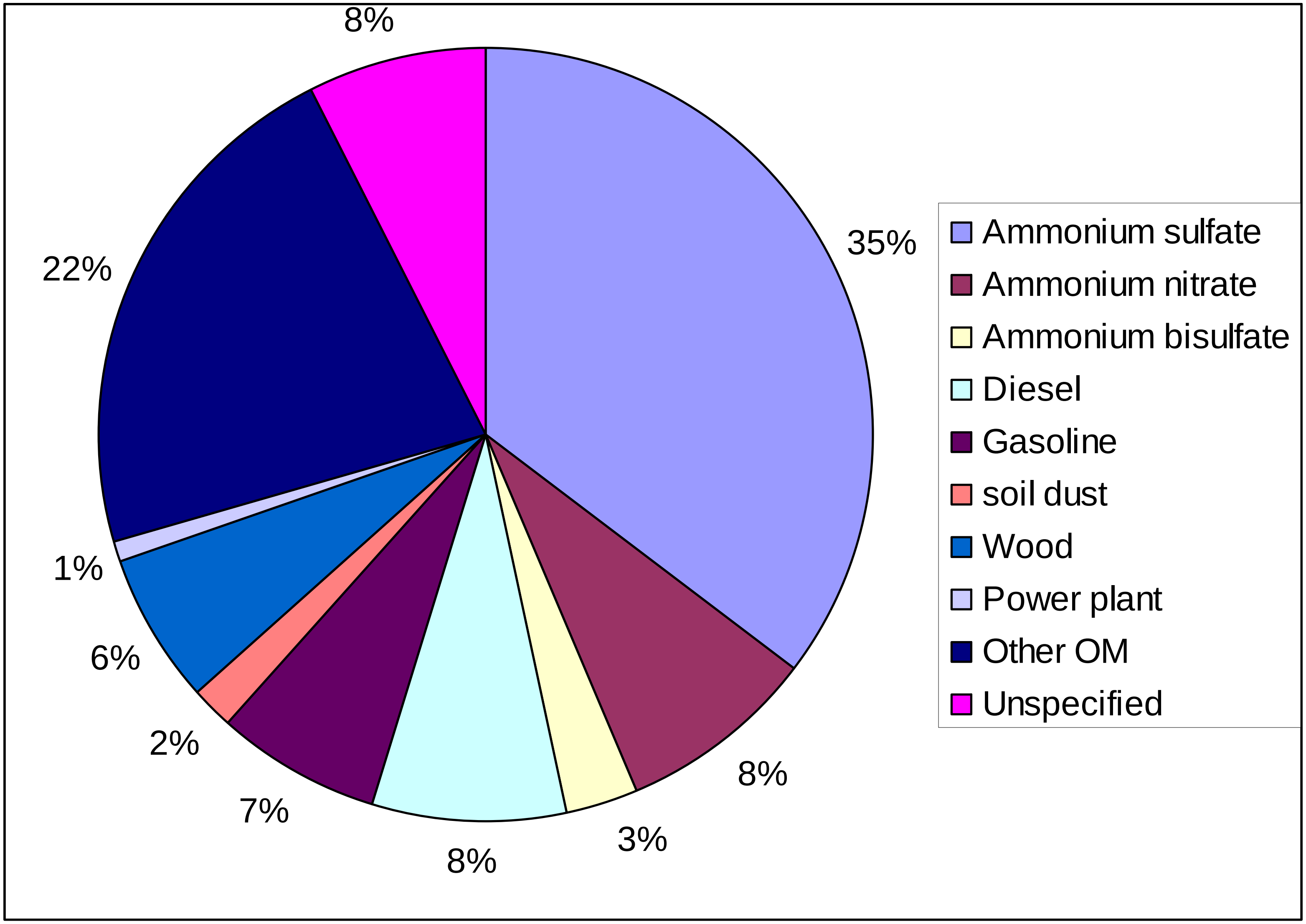
Observational Based Analyses

- Source Apportionment
  - Calculate the contribution of source categories to measured concentrations (statistical process)
  - CMB ➔ Chemical Mass Balance
  - PMF ➔ Positive Matrix Factorization
    - Currently being performed for various IMPROVE and STN sites in Georgia
- CART ➔ Classification and Regression Tree
  - Performed for VOCs from PAMS network
- Trends analyses in ozone and PM2.5
  - Cox and Chu for "buffer" calculations

$PM_{2.5}$ composition, JST 2001-2003

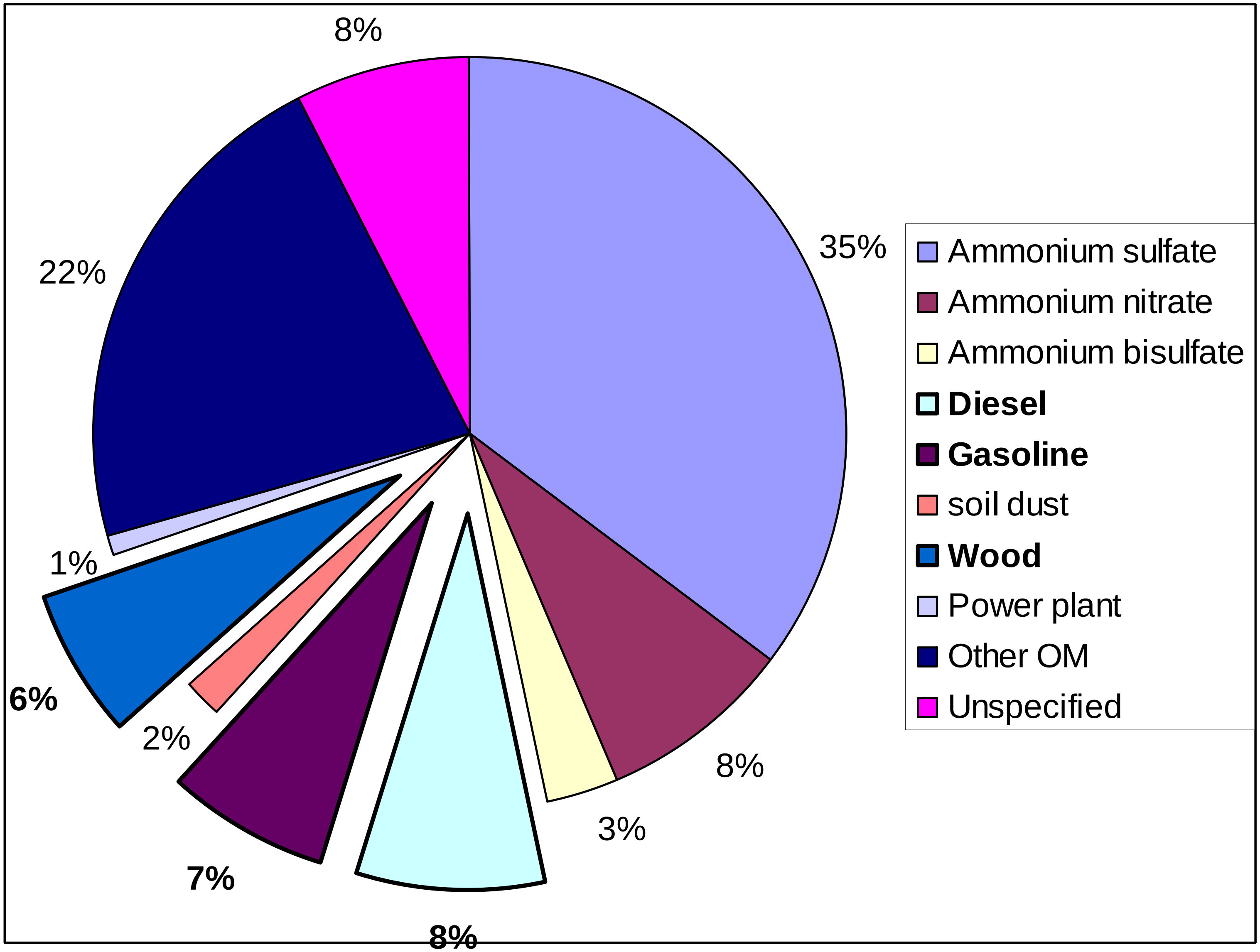


$PM_{2.5}$ sources*, JST 2001-2002

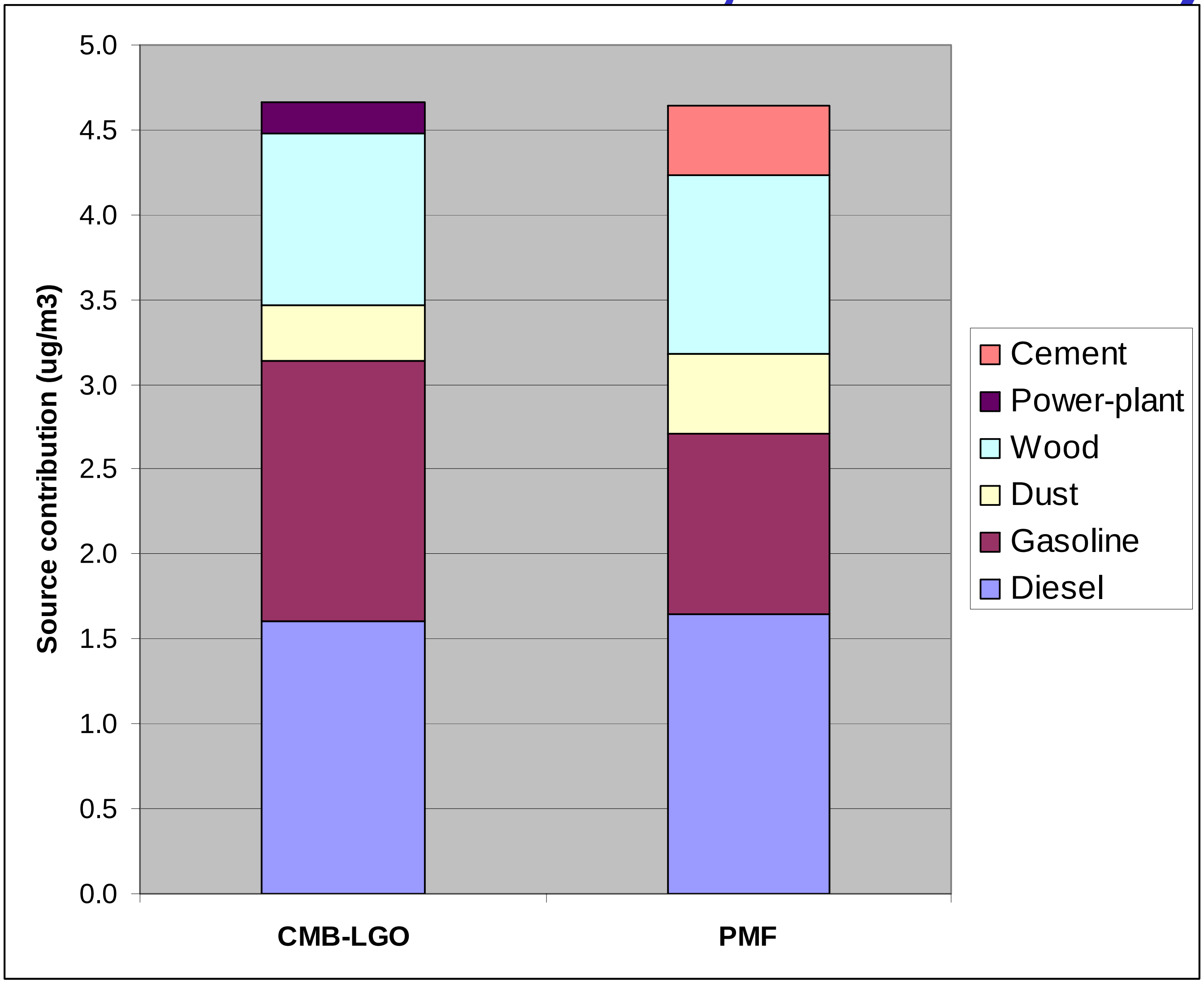


* - CMB-LGO, Marmur et al., 2005 (part of PhD research at GA Tech)

$PM_{2.5}$ sources, JST 2001-2002

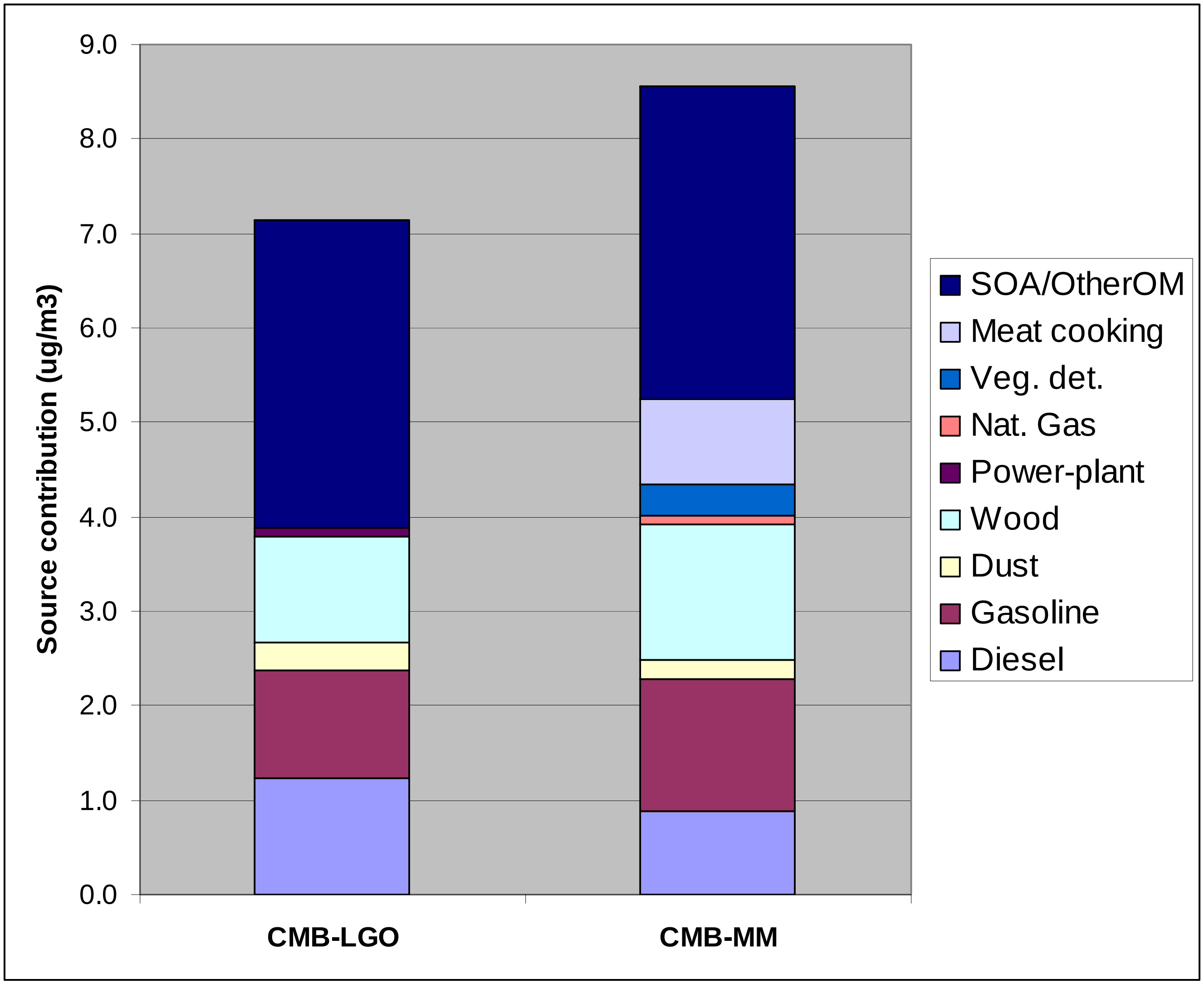


Other source-apportionment studies JST: PMF, 11/98-8/00)



* - PMF based on Kim and Hopke, 2004

Other source-apportionment studies JST: CMB-MM (7/01,1/02)

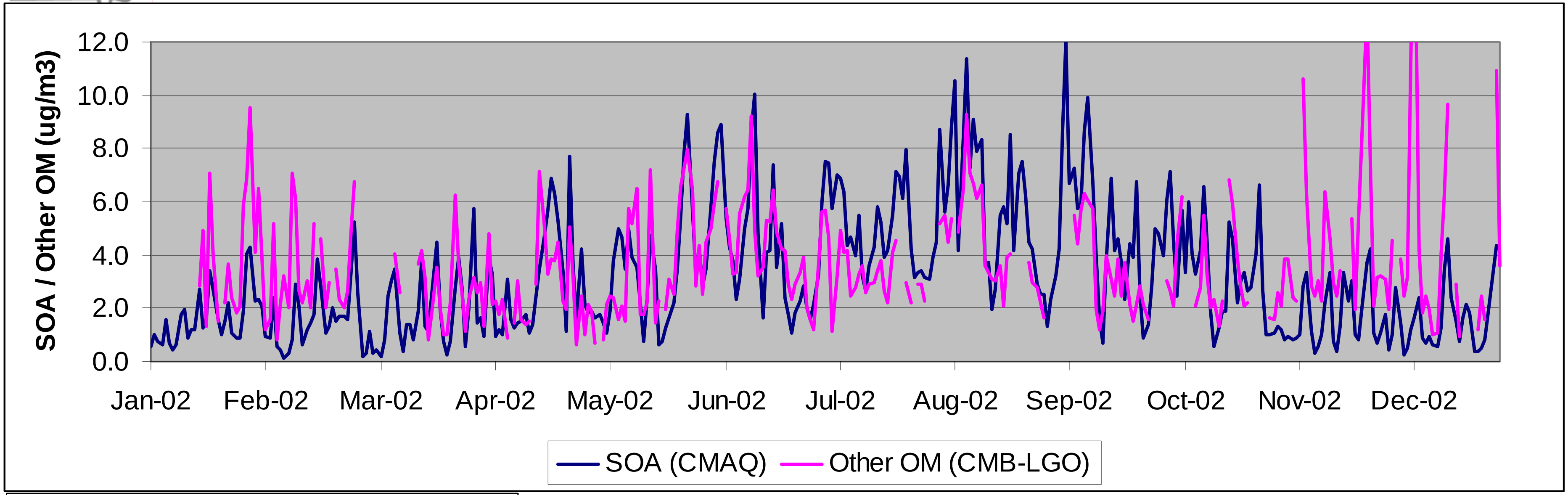


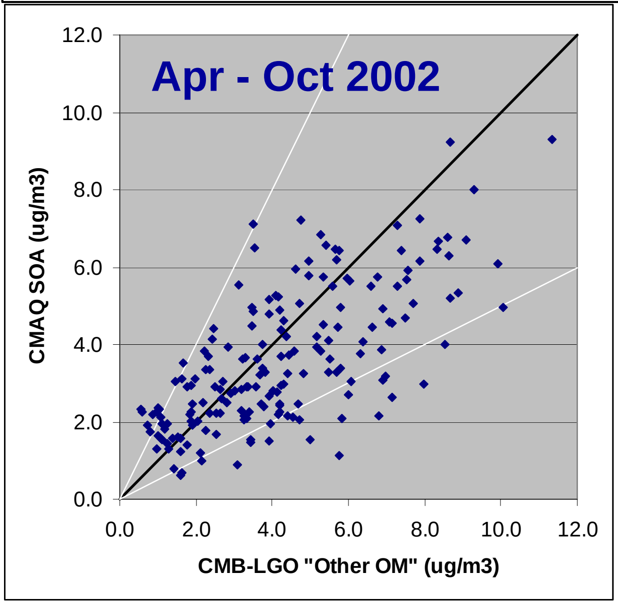
* - CMB-MM based on Zheng et al.

$PM_{2.5}$ controls – what about SOA?

- SO_2 controls for lowering sulfate levels
- Controls for reducing primary carbon levels (diesel and gasoline vehicles,wood/vegetative burning, meat charbroiling)
- **What can be done about Secondary Organic Aerosol (SOA)???**
  - Depends on whether the precursors are **biogenic** or **anthropogenic**
  - This issue is currently the center of much scientific research and debate…
    - CMAQ modeling (basis for GA-EPD sensitivity analysis) suggests **more than 90% of SOA is of biogenic origin**

Comparison between CMAQ SOA and CMB-LGO "Other OM"

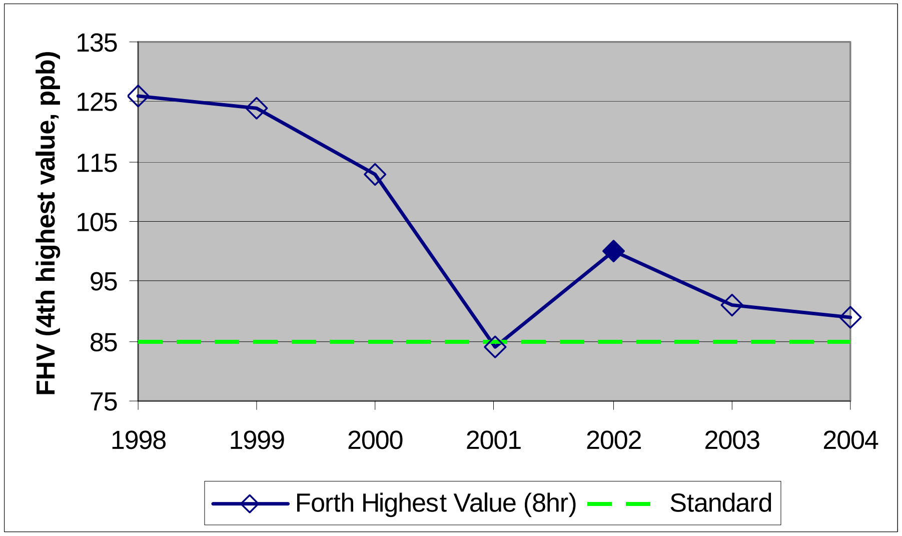




- This is not an apples-to-apples comparison
- **Winter**: poor agreement, unresolved outliers in CMB-LGO (and observations)
- **Summer**: good agreement (R^2=0.49, MNE=48%), as good as other species
- **Could this be interpreted as an indirect indication that most SOA is of biogenic origin?** If so, "complicates" control strategy

Atlanta Ozone “buffer”

- Significant variations in ozone FHVs (Forth Highest Values), which are the basis for the DV (Design Value)

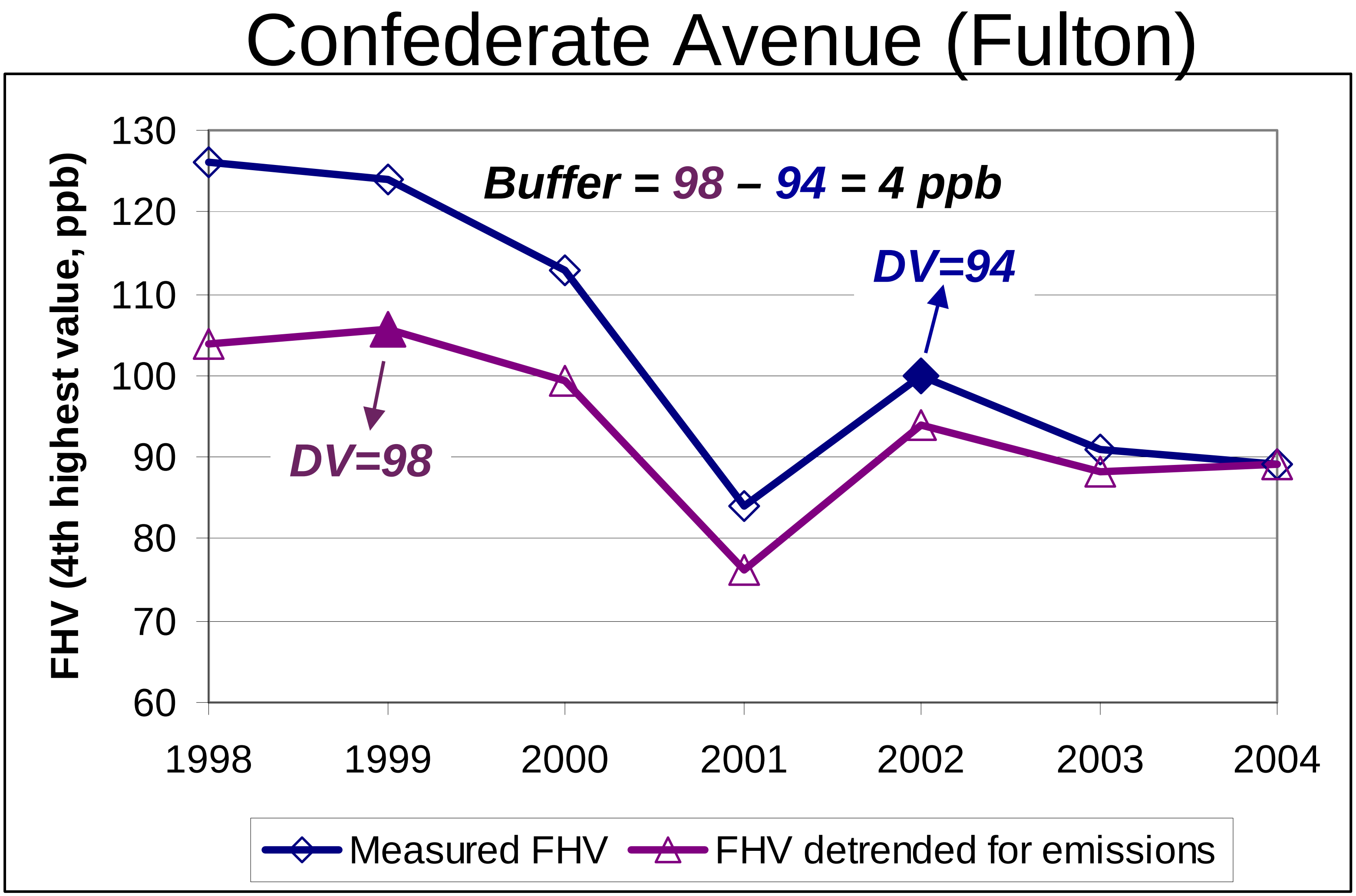


- Attainment demonstration is done based on an observed DV, *e.g.:*
  – DV for 2002 multiplied by a “reduction factor” based on air quality modeling
- But, how representative is a specific DV of long term meteorology?
  - Is the attainment demonstration “starting point” to low/high? (is a “buffer” needed?)

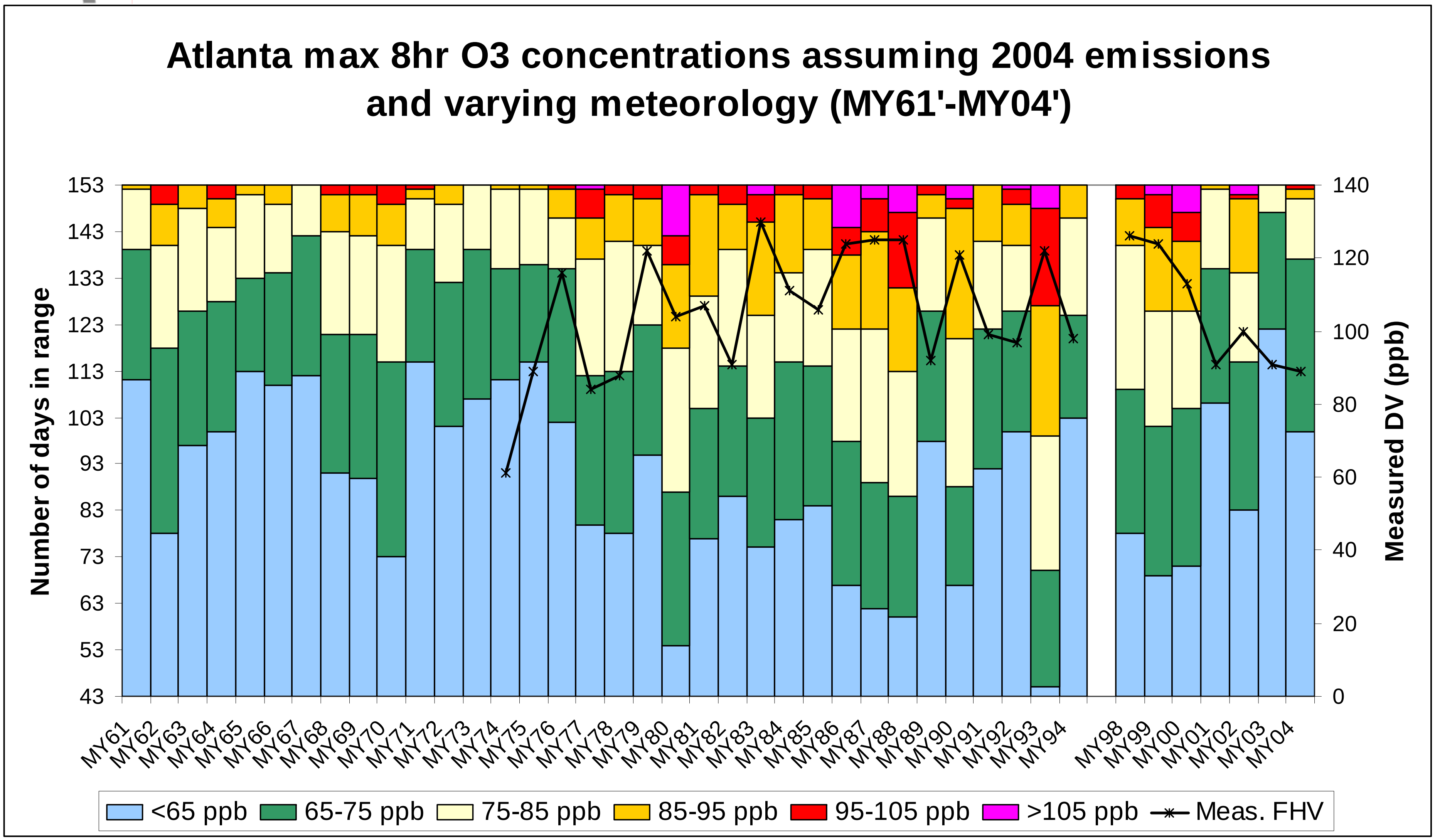
Atlanta Ozone “buffer”

- Buffer calculation based on the **Cox & Chu** method for exploring the effect of **short-term** (meteorological) and **long-term** (emissions) trends on ozone DVs, using a Weibull fit
- An **empirical formula** for maximum 8hr ozone is generated based on daily meteorology (T, RH, WS, SC etc.) and calendar year (as a surrogate for emissions)
- The formula can then be used to detrend ozone DVs and perform “buffer” calculations
  - What would have been the DV in 1999 with current (lower) emissions? (e.g., 1999 meteorology & 2004 emissions)

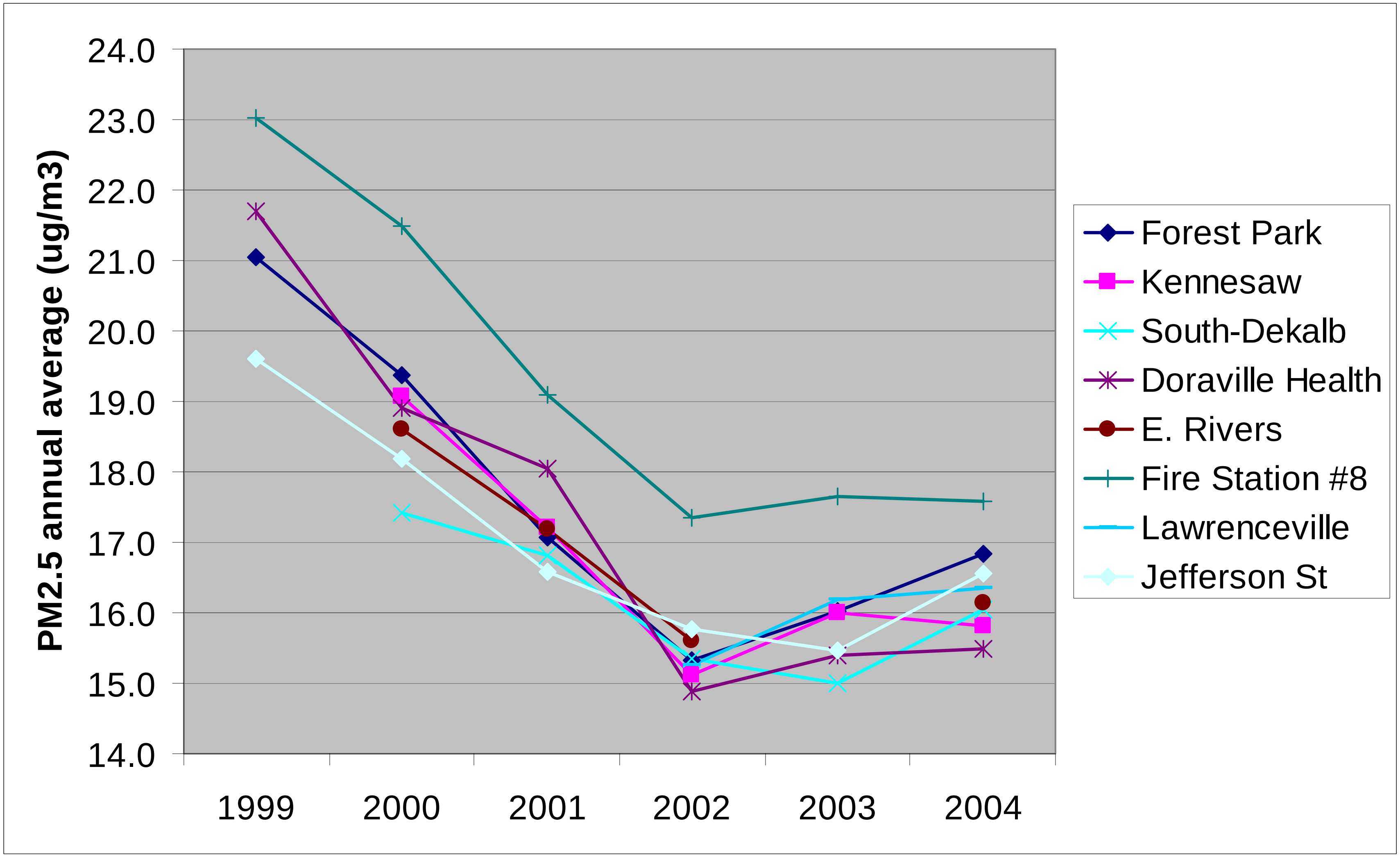
Ozone Detrended for Emissions



Long Term Trends



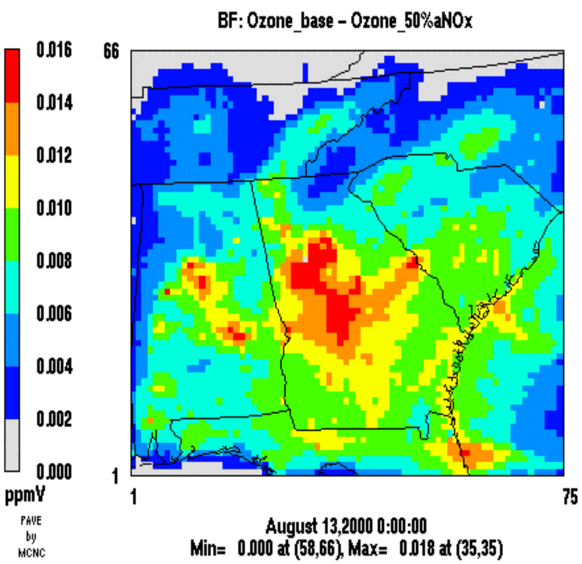
Do we need a PM2.5 "buffer"?



Health Benefits Modeling

Benefits analysis with BenMAP

Modeled (or measured) reductions in pollutant levels



U.S. Version
BenMAP
Environmental Benefits Mapping and Analysis Program

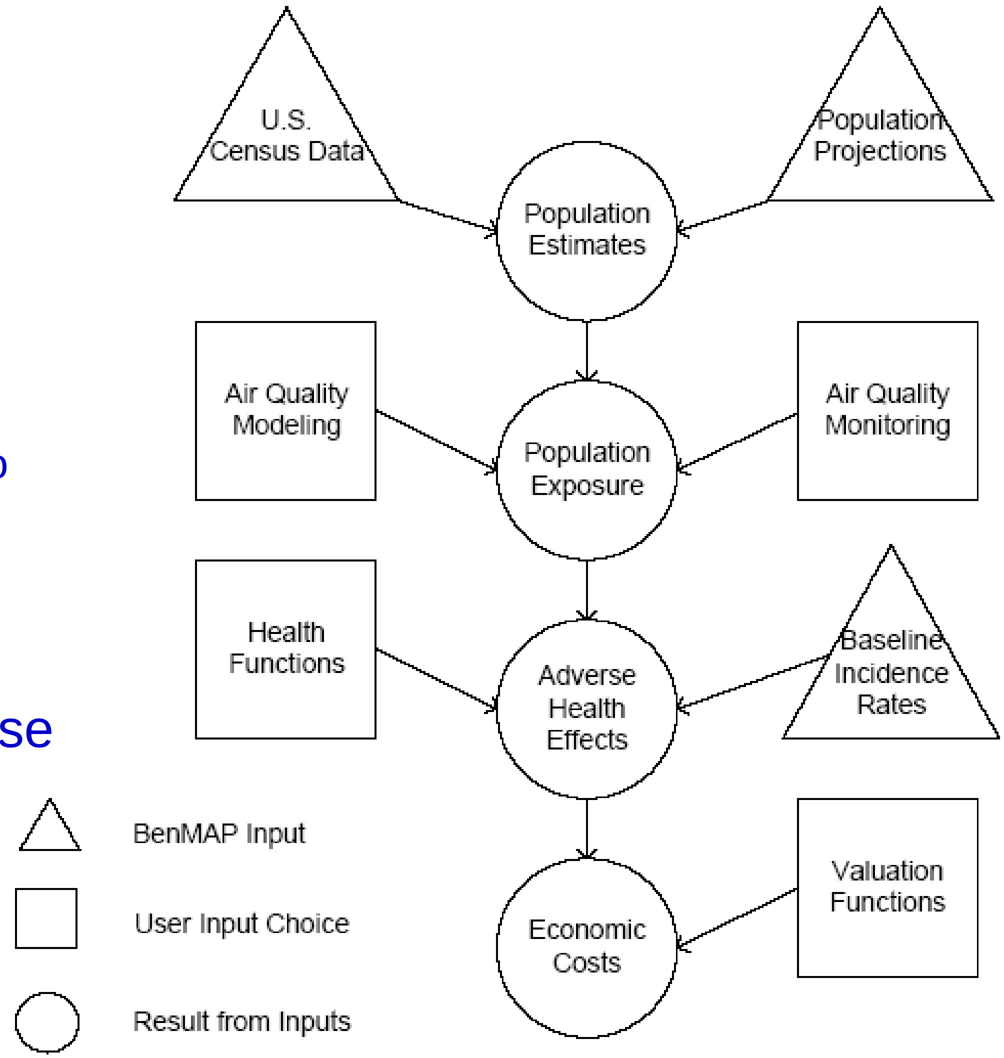
Reduced morbidity, mortality, health costs

What is BenMAP?

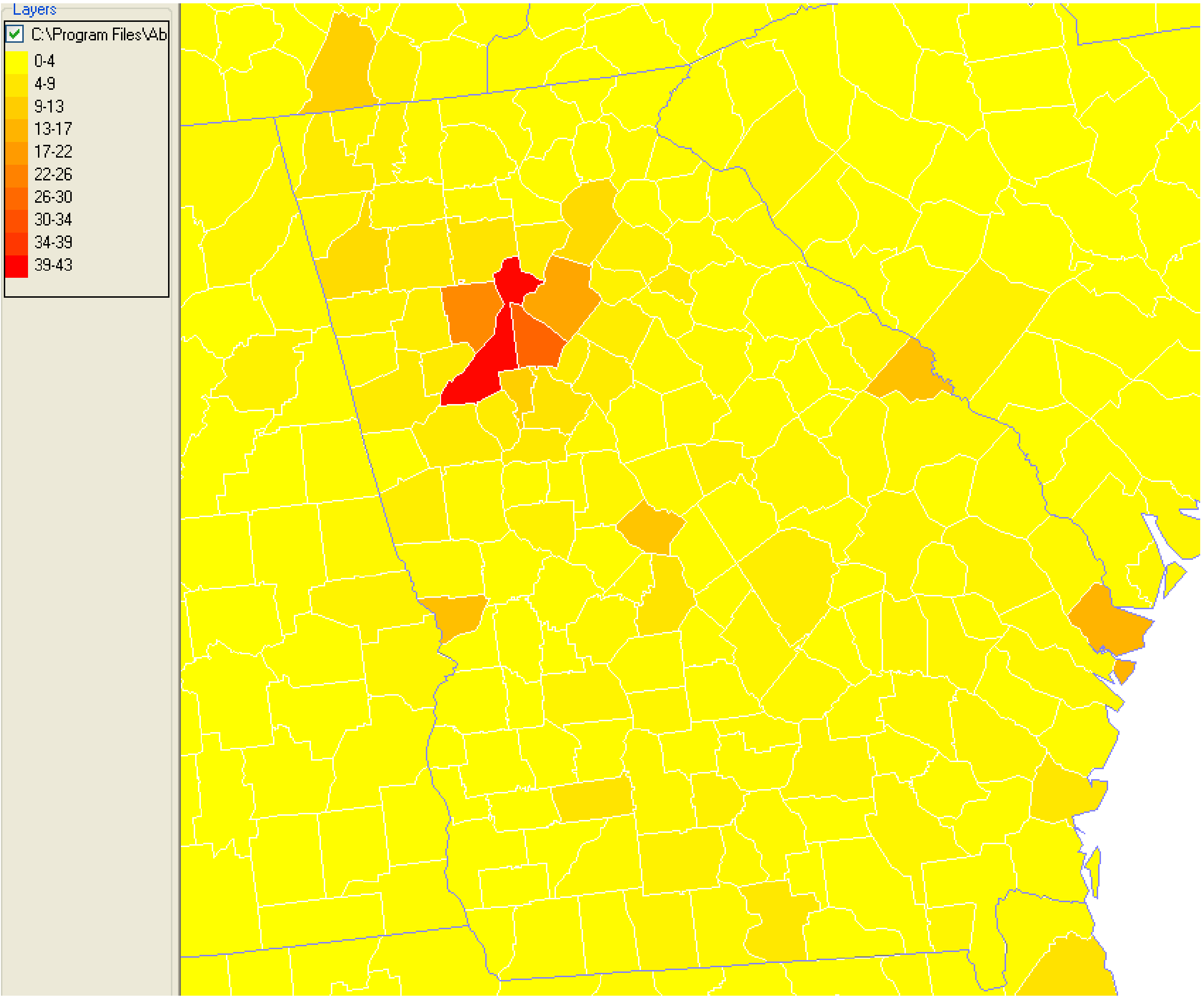
- A US-EPA Environmental **Ben**efits **M**apping and **A**nalysis **P**rogram that incorporates:
  - A population based geographic information system
  - Air quality data (monitor or model based) as inputs
  - Concentration-response functions and valuation estimates to estimate changes in health endpoints and the value of those changes
  - Can produce estimates at the population grid scale, county, state, or national level

BenMAP flow diagram

- Accepts measured or modeled AQ data
  - examine benefits of various control strategies using AQ modeling
  - examine benefits of reducing measured ambient concentrations to specific levels
- User choice of which health outcomes and C-R functions to use
- Output in either tabular or map form



Example: Avoided mortality by a state-wide 1μg/m^3 reduction in $PM_{2.5}$



Health benefits of reductions in $PM_{2.5}$ and O_3: Case study for Atlanta (core five counties)

(preliminary results)

Health Endpoint	$1\mu g/m^3$ reduction in $PM_{2.5}$		10 ppb reduction in O_3	
	cases prevented	million $	cases prevented	million $
Acute Bronchitis	243	0.02		
Acute Myocard. Infarct.	216	73.8		
Acute Resp. Symptoms	116,890	8.6	44,331	3.0
Chronic Bronchitis	90	23.4		
ER Visits, Resp.	145	0.04	24	0.01
Hospital Adm., Cardiov.	34	1.4		
Hospital Adm., Resp.	52	0.8	250	2.5
Lower Resp. Symptoms	2,790	0.1		
Mortality	114	700	34	198
Work/School Loss Days	20,232	2.8	52,683	4.1
Total		**811**		**207**
Total w/o mortality		**111**		**10**

Questions?

Reasons to assess health benefits

- Evaluate and prioritize various attainment strategy options
- Consider air quality management across multiple pollutants and regions
- Improve the net benefits of attainment efforts
- Communicate impacts to decision-makers, stakeholders and public