

# Georgia Wildland Fire Emissions and Their Air Quality Impacts

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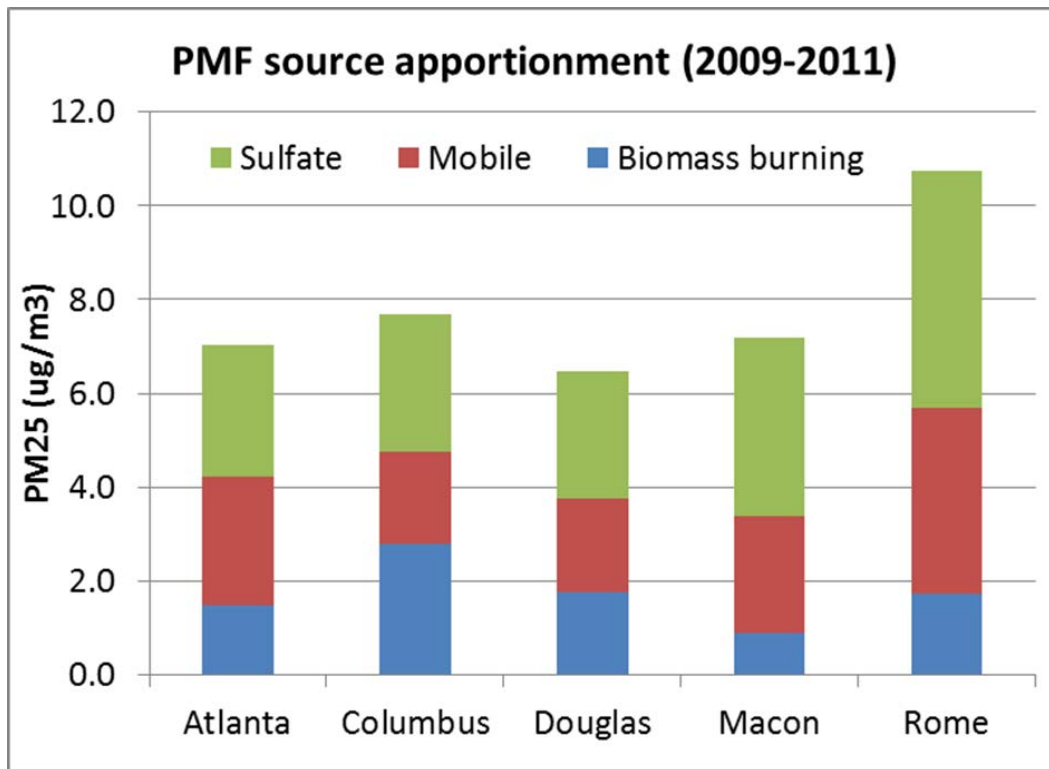
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- Summary - Suggestions for NEI2014 fire emission inventory development

# Wildland Fires in Georgia

- Wildland fires emit large amounts of air pollutants
  - e.g. PM, VOC, NOX, NH3, etc
- Biomass burning has large contribution on PM<sub>2.5</sub>
  - Prescribed fires, wildfires, agriculture burning, land clearing and RWC
  - Mostly prescribed fires (more than 1 million acres of forest land a year in GA)



- Positive Matrix Factorization (PMF) - Multivariate factor analysis tool
- Three years of speciated PM<sub>2.5</sub> observations at CSN sites in Georgia(2009-2011)
- Three major sources: Biomass burning, Sulfate, and Mobile

# Quantifying Emissions from Wildland Fires

$$E = A \times F_a \times E_f$$

A: burned area (acres)

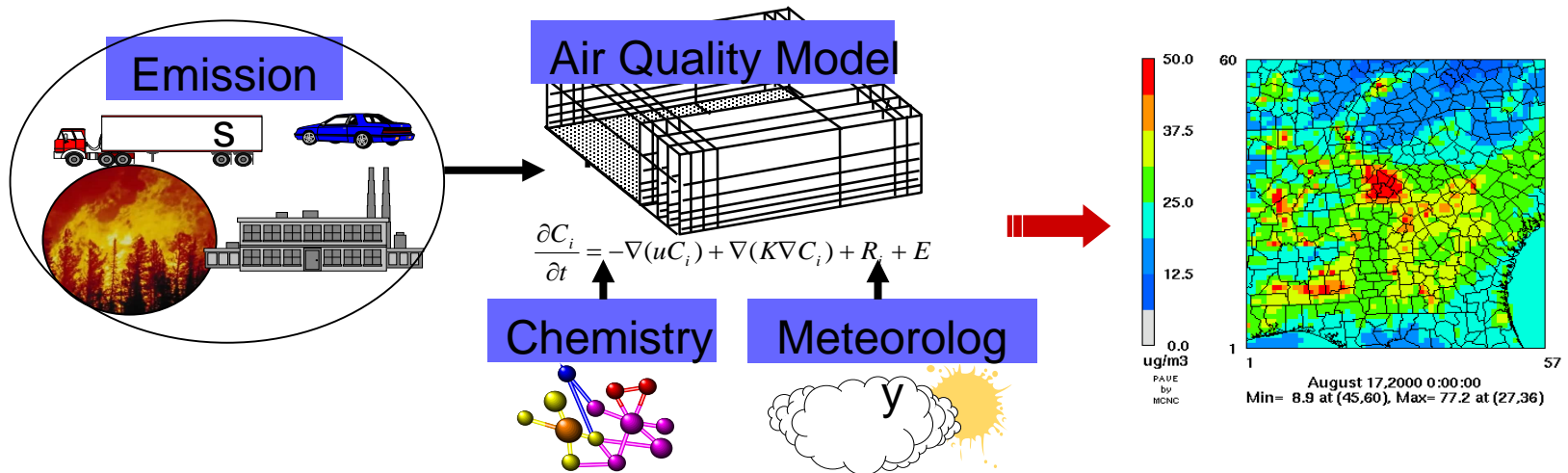
F<sub>a</sub>: fuel consumption (tons/acre)

E<sub>f</sub>: emission factor (lbs/ton)

- Georgia Fire emissions inventory
  - Three NEI inventories: 2005, 2008 and 2011 fire emissions developed by GA EPD and submitted to U.S. EPA to include as part of NEI
  - Two SIP fire inventories: VISTAS2002 and SEMAP2007, collaborative efforts in the southeast
- Georgia fire emissions in NEI2011
  - 2011 burned records: by events
    - Georgia Forestry Commission (GFC), military bases, USFS, and FWS (daily burned area for the Okefenokee area fire)
  - Shared these burning records with U.S. EPA and USFS
  - Reviewed SMARTFIRE estimates
  - Developed GA estimates using the same method as used in the SEMAP2007 fire inventory development, no satellite data are used in the GA estimates
    - AMEC, 2012. *Development of the 2007 Base Year and Typical Year Fire Emission Inventory for the Southeastern States Air Resource Managers, Inc.*

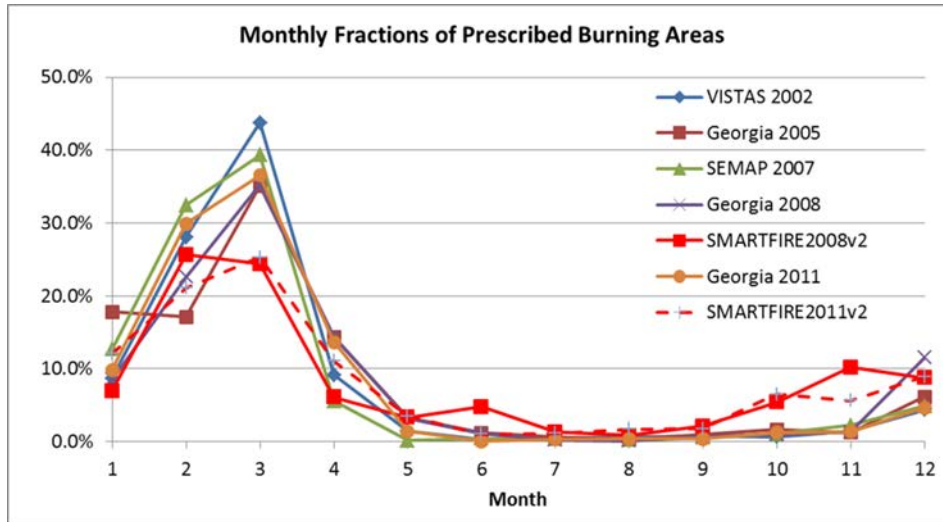
# Photochemical Air Quality Modeling

- Meteorological conditions, emissions by hour and modeling grids, physical and chemical processes in the atmosphere (WRF/SMOKE/CMAQ)
- How air pollutant concentrations change with source emissions
- Wildland fire emissions have large impacts on air quality modeling performance
  - Tian, 2009; Garcia-Menendez, 2014
- Quantifying control efficiency to inform control strategy development
- Attainment demonstration
- Forecasting air quality to inform burning permit issuing

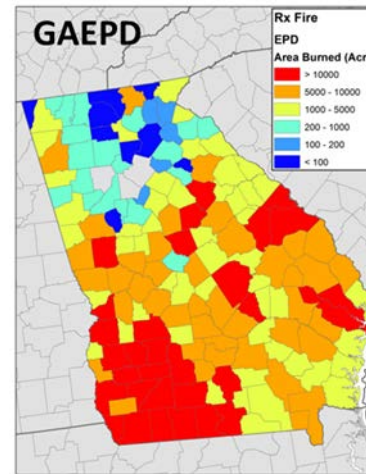


# Fire Emissions Have large Impacts on AQM Performance

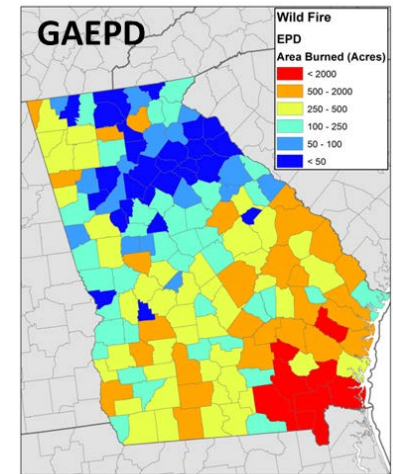
Fire emissions have large temporal and spatial variation



Prescribed Fires



Wildfires



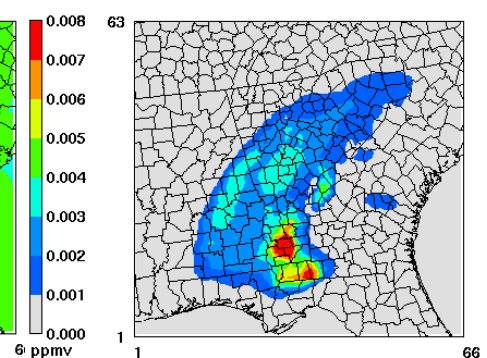
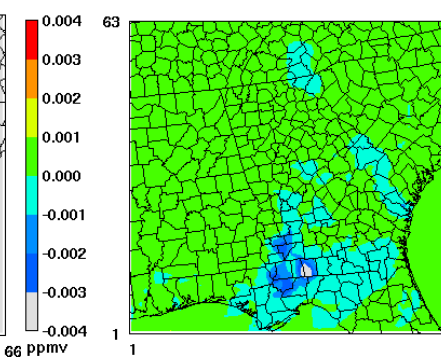
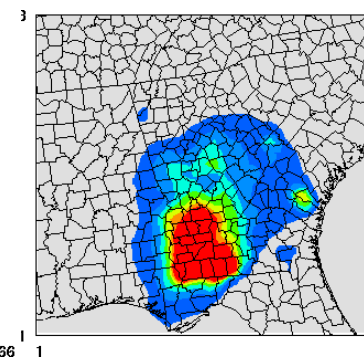
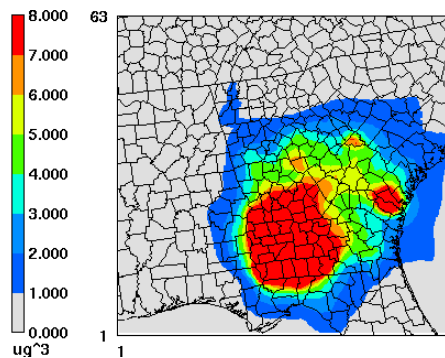
The same fire emissions emitted during different months have different impacts on  $PM_{2.5}$  and  $O_3$  (Peaks of daily maximum 8-hr ozone)

$PM_{2.5}$  Jan:  $7.3 \mu g/m^3$

$PM_{2.5}$  May:  $3.4 \mu g/m^3$

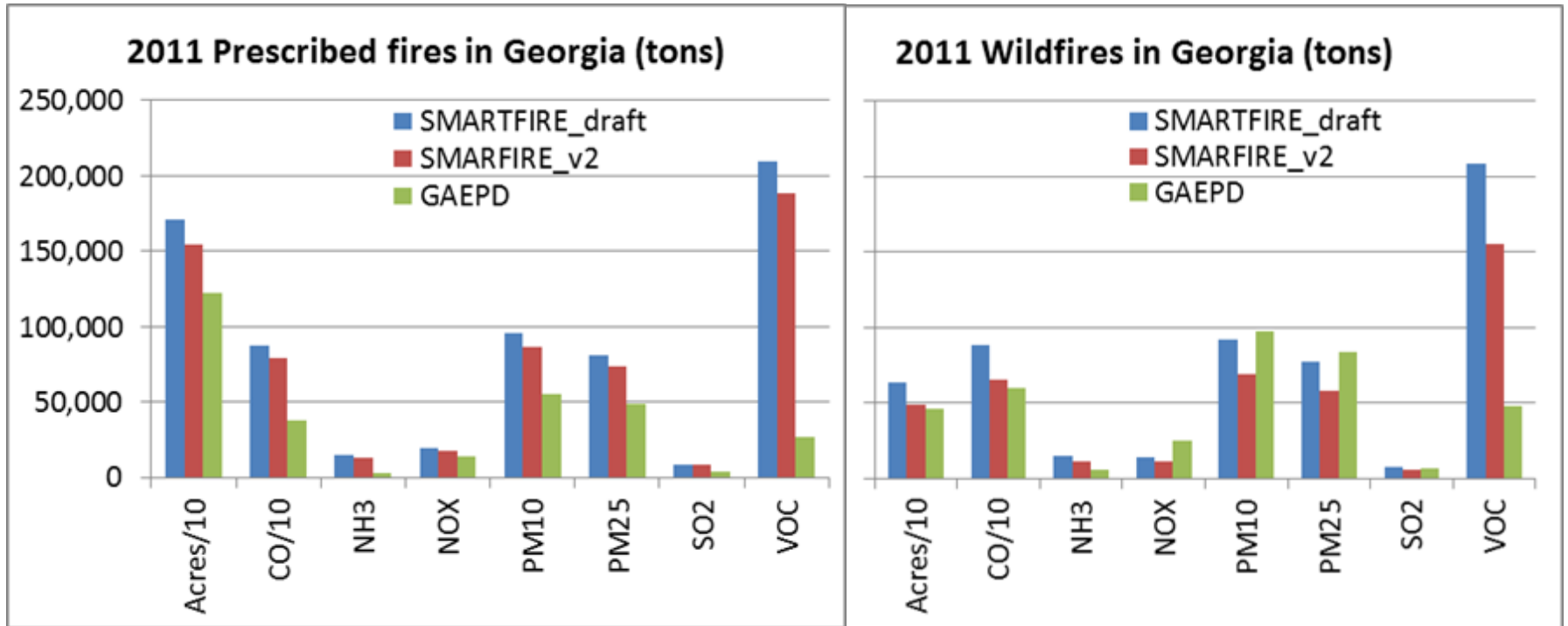
Ozone Jan: 0.18 ppbv

Ozone May: 2.4 ppbv



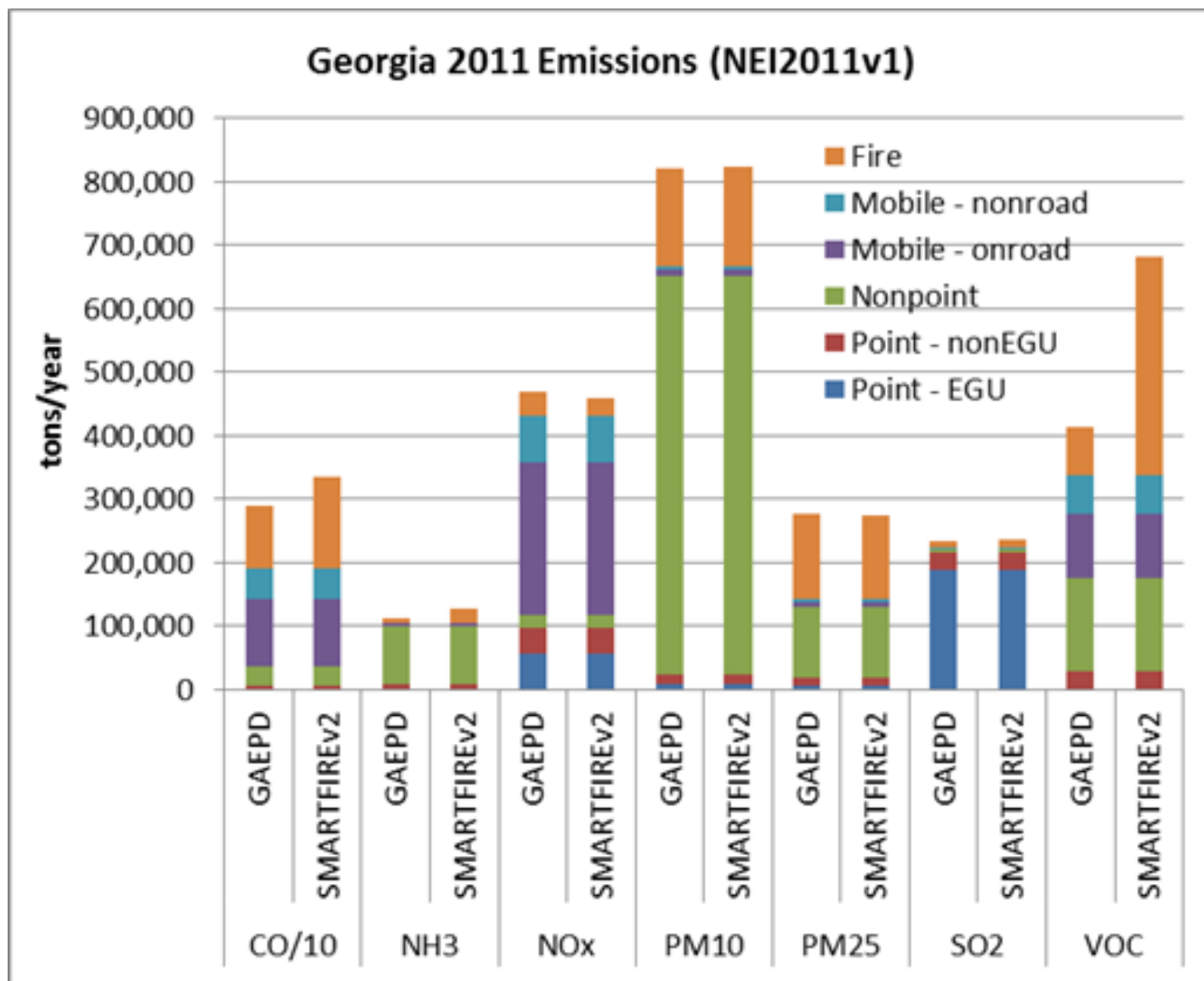
\*  $PM_{2.5}$  Values are monthly averages for Georgia, and ozone values are averages for Atlanta metropolitan area.

# Comparison of SMARTFIRE Estimates and GA EPD Estimates



	Emissions (tons/year)			Difference (%)	
	SMARTFIRE_draft	SMARTFIRE_v2	GA EPD	SMARTFIRE_draft	SMARTFIRE_v2
<b>Acres</b>	2,349,116	2,034,861	1,686,655	39%	21%
<b>CO</b>	1,761,852	1,450,815	981,215	80%	48%
<b>NH3</b>	29,102	23,981	8,154	257%	194%
<b>NOX</b>	33,575	28,530	38,888	-14%	-27%
<b>PM10</b>	187,746	155,390	152,840	23%	2%
<b>PM25</b>	159,107	131,686	132,861	20%	-1%
<b>SO2</b>	16,156	13,574	10,663	52%	27%
<b>VOC</b>	418,337	344,731	74,976	458%	360%

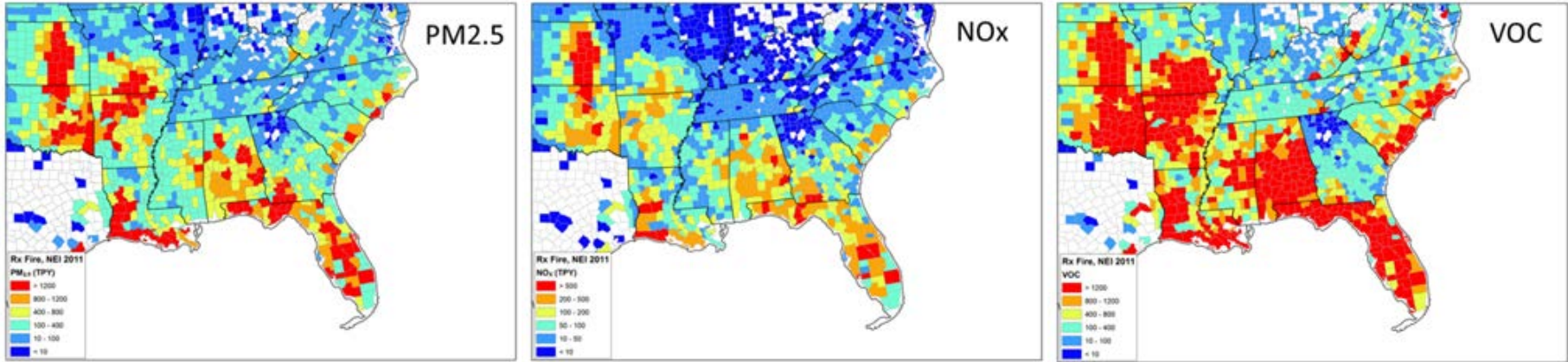
# Emissions by Source Categories in Georgia during 2011



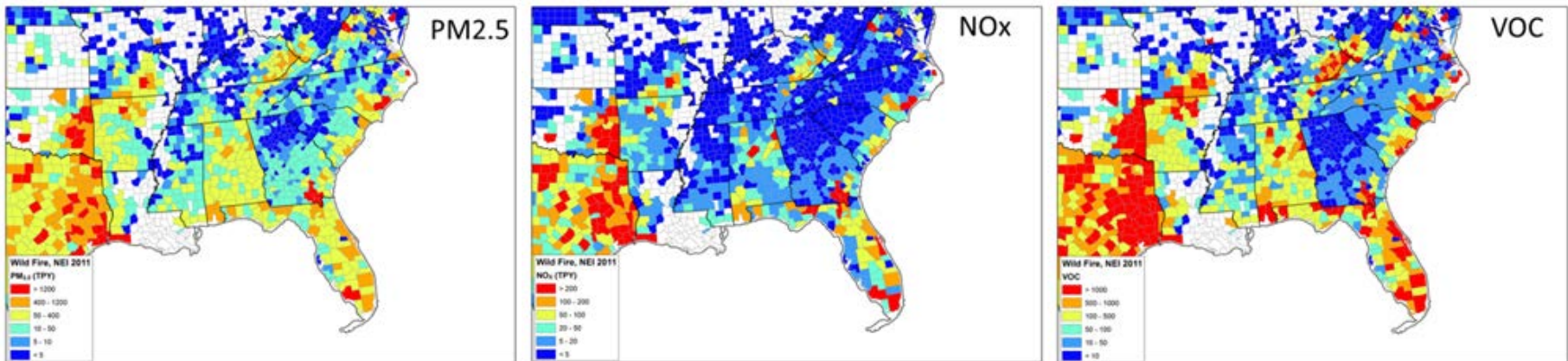


# Spatial Distribution of Wildland Fire Emissions in NEI2011v1

## Prescribed fires



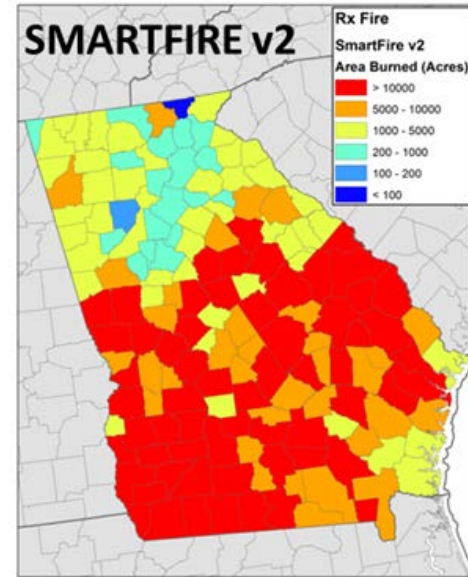
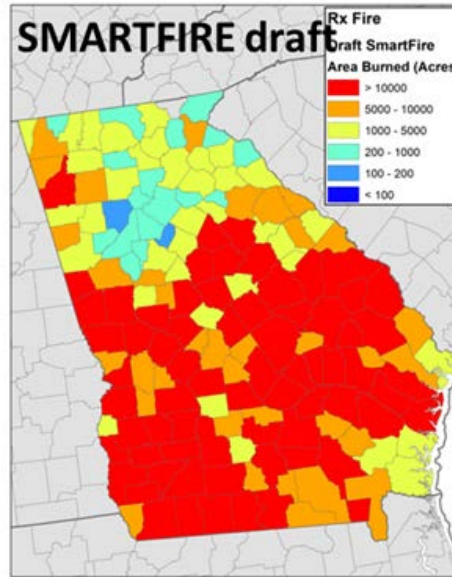
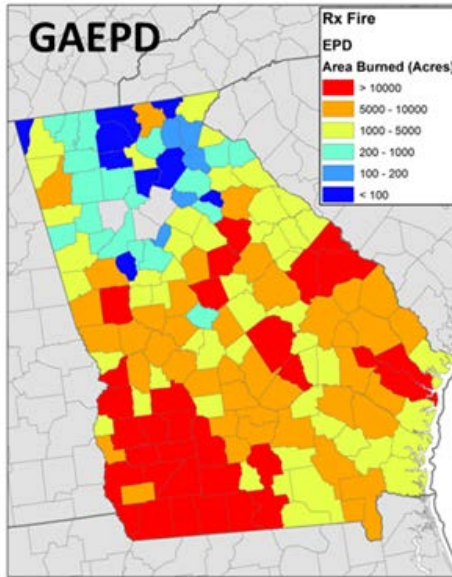
## Wildfires



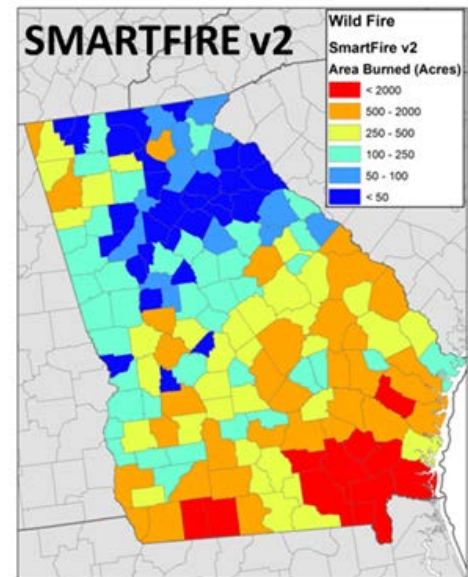
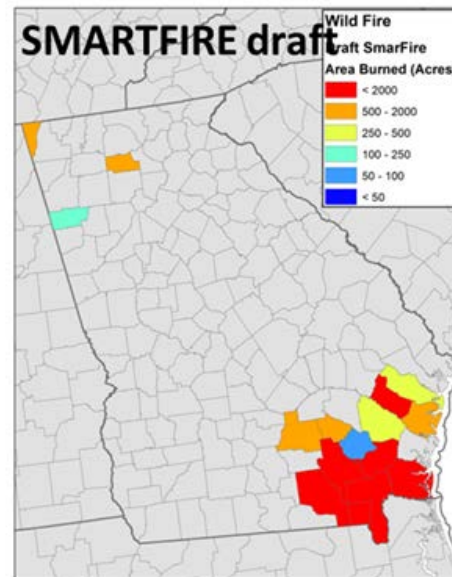
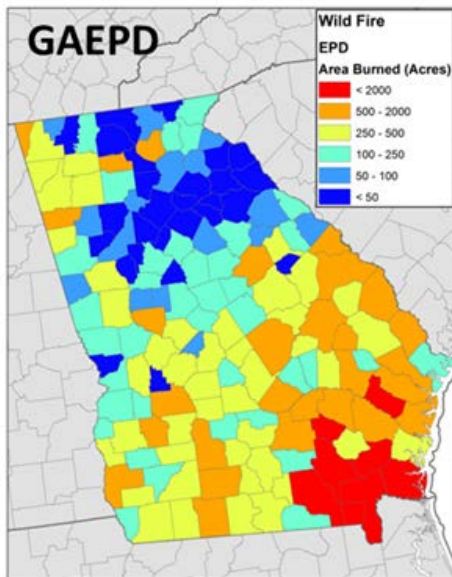
- VOC emissions in NEI2011 look high in all states except Georgia
- Large difference in PM2.5 and NOx emissions between GA and AL/FL
- Low prescribed fire emissions in TX and low wildfire emissions in LA

# Spatial Distribution of Burned Area in Georgia during 2011

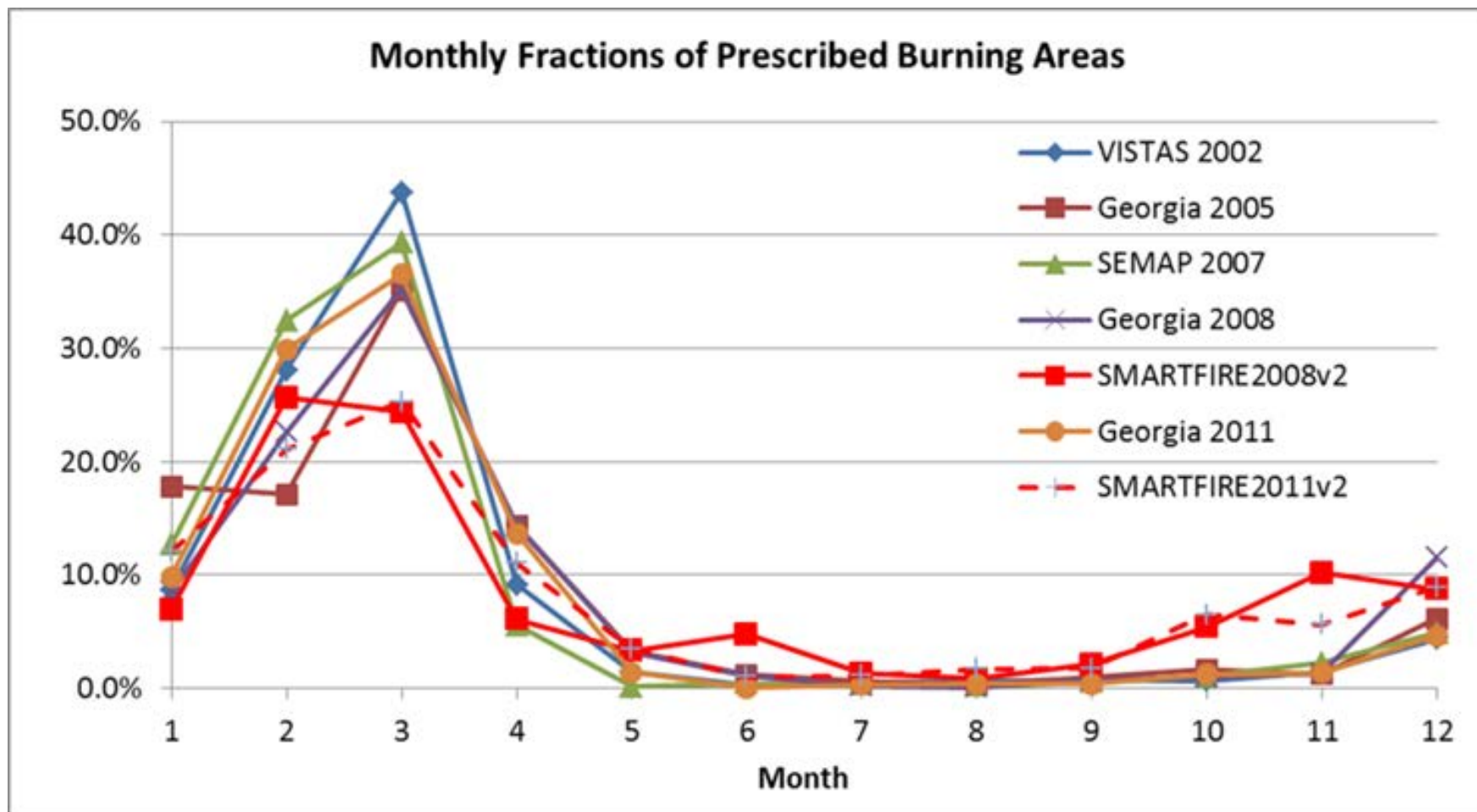
Prescribed fires



Wildfires



# Monthly Fractions of Prescribed Burning Areas



SMARTFIRE\_v2 has overestimated prescribed fire activities during October and November and underestimated such activity during March

# Fire Counts and Acres Distribution by Fire Size



Southeastern wildland fires are usually small and under canopy prescribed fires with short duration

# Fuel Consumption Comparison (1)

## Fuel consumption calculation methods in SMARTFIREv2 and GAEPD fire inventory

	Fuel Map	Fuel loading	Fuel moisture	Percent of fuel consumption
SMARTFIREv2	FCCS	FCCS fuel bed	Nearby monitors	CONSUME
GAEPD/SEMAP	NFDRS	NFDRS fuel bed	Typical fuel moisture levels for prescribed fires and wildfires. Drier conditions for wildfires.	FEPS and Expert judgments Percent duff consumption for prescribed fires: 0 Percent duff consumption for wildfires: 10% Percent shrub and wood fuel combustion is reduced

## Fuel consumption calculation values in SMARTFIREv2 and GAEPD fire inventory

	Prescribed fires	Wildfires
SMARTFIREv2	26 FCCS fuel types (0.9 -23.66) tons/acre	27 FCCS fuel types (2.43-196.38) tons/acre
GAEPD	8 NFDRS fuel types (0.6 – 8.1) tons/acre	12 NFDRS fuel types (0.7 – 25) ton/acre

## Fuel Consumption Comparison (2)

- Large uncertainties in fuel consumption values due to scarce of data
  - Prescribed fires are usually conducted every 2~5 years in the southeast
  - Typical prescribed fire fuel consumption is about 4 tons/acre
- Improve fuel type assignment
  - Fuel consumption values vary greatly with fuel type
  - Quality of location information in fire records (e.g. “Urban” in SMARTFIREv2)
  - Reviewing assigned fuel type using local knowledge in GAEPD fire inventory
- More representative fuel loading information
  - Collect information such as whether fire is applied to log slash and number of years since last burn for areas under high burning frequency
- Improve fuel consumption estimation
  - Fuel consumption values are sensitive to fuel moisture levels. Should typical fuel moisture level be used in SMARTFIREv2 for prescribed fires?
  - High Duff consumption for some fuel types for prescribed fires
  - Should set maximum fuel consumption value by fuel types with local knowledge

# High VOC Emissions from Wildland Fires

- High CO, NH<sub>3</sub> and VOC emissions in SMARTFIREv2 than GAEPD fire inventory
  - Separate EFs by combustion phases in SMARTFIREv2 are not available
  - Likely caused by more fuel consumption during smoldering phase
- Comparing EFs in GAEPD Fire Inventory with EFs for Prescribed fire southeast conifer forest in Urbanski 2014
  - CO – Similar, NH<sub>3</sub> – lower, VOC – higher
  - VOC: 52 lbs/ton, 32 lbs/ton (without unidentified species), 13-15 lbs/ton (GAEPD/SEMAP). Should VOC for unidentified species in Urbanski 2014 be used in the emission calculation??
  - Much higher emission factors for Stumps and logs or temperate forest duff/organic soil, need to identify such fires
- Investigate impacts of high VOC emissions from fires on AQM
  - Need to update VOC Speciation profiles for wildland fires

# Emissions by Flaming and Smoldering (1)

- EPA requires states to submit wildland fire emissions by flaming and smoldering for NEI2014
- Separate fuel combustion and emission factors values by combustion phases
- Percent of fuel consumption values by combustion phases vary with fuel types in SMARTFIREv2
  - Prescribed fires: flaming (36.7%-93.2%), smoldering (6.7%-25.2%), residual smoldering (0.2%-38.1%)
  - Few emissions during residual smoldering for prescribed fires in the southeast
- Lumped emission factors in Urbanski 2014 for both flaming and smoldering phases



## Emissions by Flaming and Smoldering (2)

- Using such emissions in AQM depends on the definition of flaming and smoldering (???)
  - Different plume rise
  - Residual smoldering: after strong fire flames
  - Flaming and smoldering: simultaneously occur, often mixed together
- AQM is not sensitive to vertical distribution, but sensitive to emission injection altitude relative to PBL height (Garcia-Menendez, 2014)
  - Prescribed fires usually are not very hot with few emissions during residual smoldering
  - Small wildfires: similar like prescribed fires
  - Large wildfires: very complicated, large uncertainties in emissions

# Developing Typical Fire Emissions (1)

- Future year air quality projection and control strategy development using AQMs need fire emissions representing the typical emission and air quality conditions
  - Large year-to-year variation in wildland fire activity, unlike other anthropogenic sources
  - Year-specific inventory might not be representative
- Air quality modeling projections
  - $DV_F = DV_C * RRF$
  - $RRF = \text{Model}_{\text{future}} / \text{Model}_{\text{base}}$
  - If the fire emissions inventory includes large wildfires near a monitor that last for weeks or months, the relative response factors (RRFs) become unresponsive to anthropogenic emission controls because the base year and future year modeled concentrations are dominated by fire emissions.
  - Air quality responses to emission reductions can't be properly simulated by the AQM.

# Developing Typical Fire Emissions (2)

- Consistent with Design Value (DV) calculations
  - Ozone and PM2.5 DVs for attainment with NAAQS
    - Average of 3 years of measurements (e.g., DV2011 based on 2009-2011)
  - Ozone and PM2.5 DVs for model attainment demonstrations
    - Average of 3 DVs (e.g., DV2011, DV2012, DV2013 for base year 2011)
    - $(2009 + 2010*2 + 2011*3 + 2012*2 + 2013)/9$
  - Regional haze projections for 20% best and 20% worst days
    - 5-year straight average (e.g., 2009-2013 for base year 2011)
- Typical fire emissions should be representative of either 3 years or 5 years for ozone and PM2.5, and 5 years for regional haze
  - Remove fires classified as exceptional events by U.S. EPA
  - Scale county-by-county base year actual emissions by the ratios of multi-year average of acreage burned and base year acreage burned
- Future fire emissions can either be kept constant with the base year typical fire emissions or adjusted for projected growth

# SEMAP Example

- Two SEMAP 2007 emission inventories: 2007actual and 2007typical
- SEMAP 2007actual: best estimates for emissions during 2007
  - Used for model performance evaluations
- SEMAP 2007typical: same as 2007 actual emissions, except fires
  - Removed exceptional events and average fire activity during 2006-2008
- Two CMAQ runs were performed with 2007actual or 2007typical fire emissions with emissions from other anthropogenic and natural sources

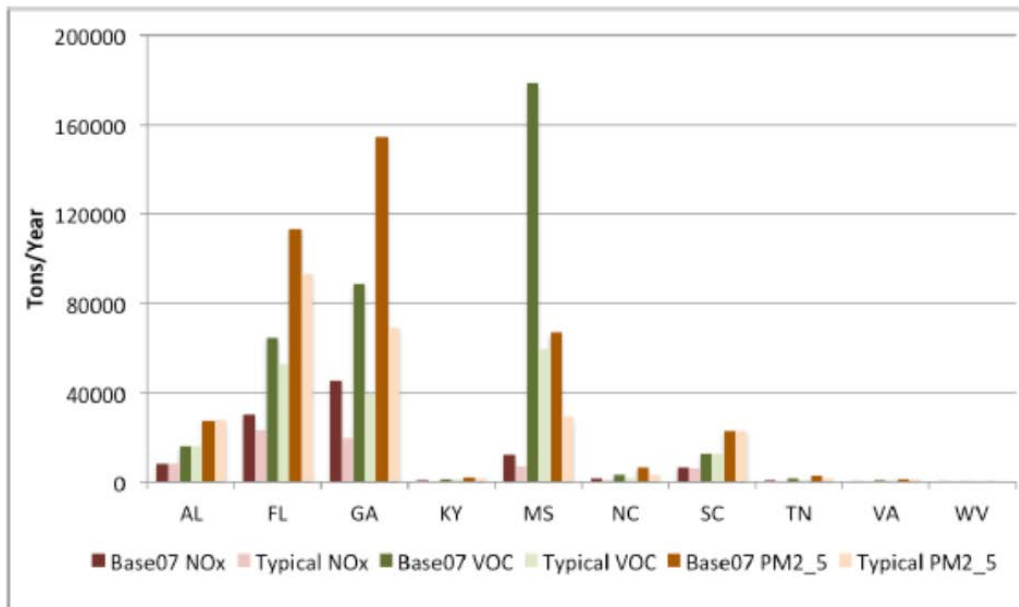
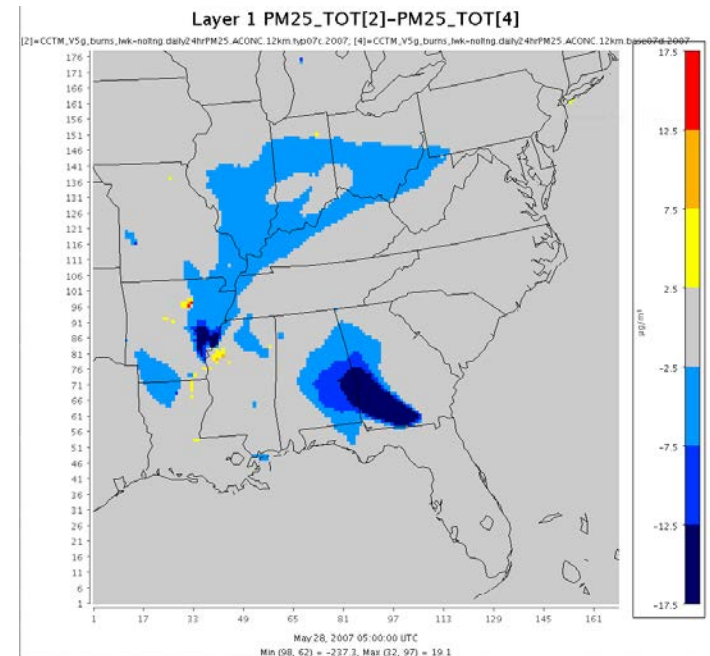


Figure 2-37. SESARM base 2007 and typical annual total fire emissions of NO<sub>x</sub>, VOC, and PM<sub>2.5</sub>



# Summary

- Reviewed 2011 SMARTFIREv2 and GAEPD fire inventory
- Suggestions for NEI2014 fire emission inventory development
  - Burned area: Satellite data should not be used for the southeast if detailed local fire records are provided in NEI2014
  - Fuel consumption: Local knowledge about fuel consumption should be used in addition to the fuel consumption model results.
  - Emission factors: Updated values in Urbanski 2014 work should be used.
  - Investigate impacts of high VOC emissions on air quality modeling and how to adjust VOC speciation profiles accordingly.
  - Separate emissions by flaming and smoldering: How important to have separate emissions? How to match fuel consumption with emission factors by combustion phases? how to use them in AQM.
  - Need more discussion on how to develop typical fire inventory for AQM.