NONROAD Emissions Model Uncertainty Analysis for the State of Georgia

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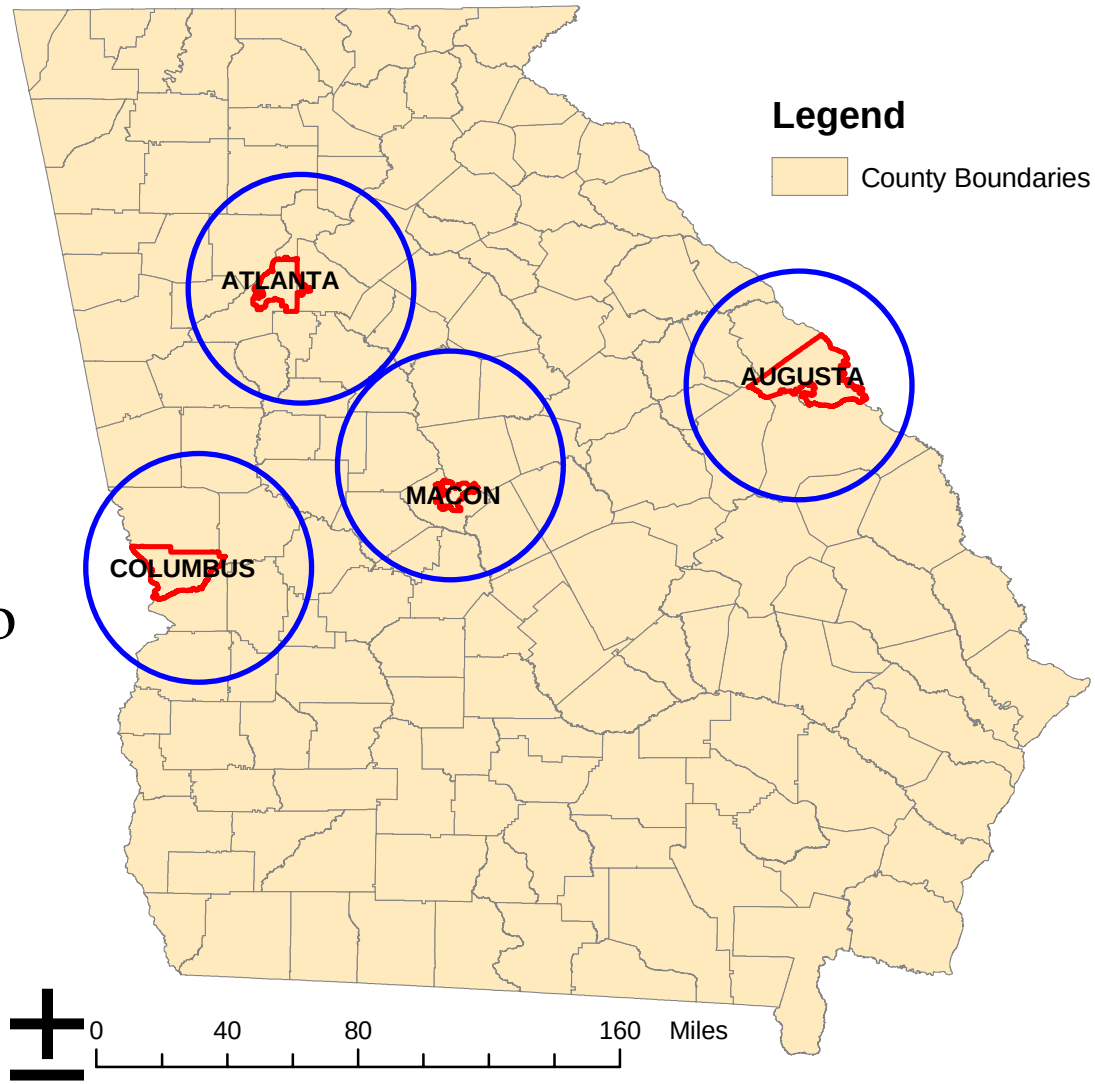
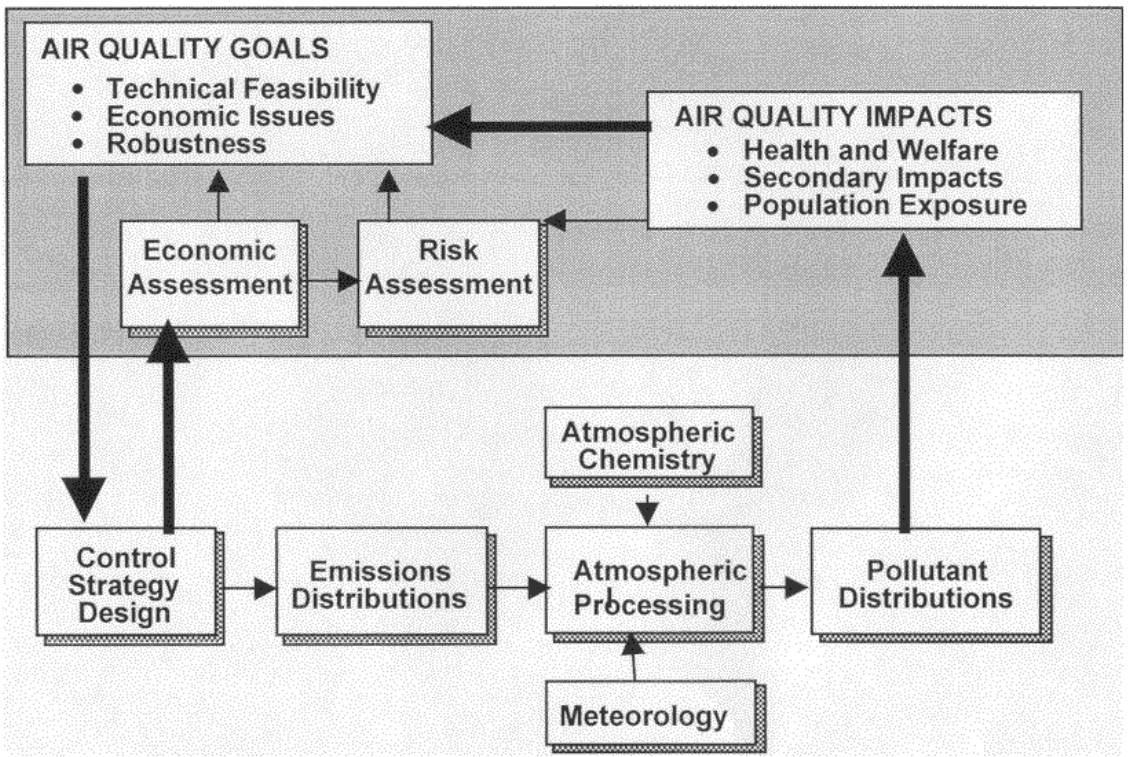
Motivation

- Areas at or near non-attainment means Air Quality Modeling!!
- Understanding emissions uncertainty leads to better understanding of AQM limitations, errors, uncertainties…



Fall line Air Quality Study

- Assess urban and regional air pollution, identify the sources of pollutants and pollutant precursors, and recommend solutions to the Augusta, Macon, and Columbus metropolitan areas of Georgia.

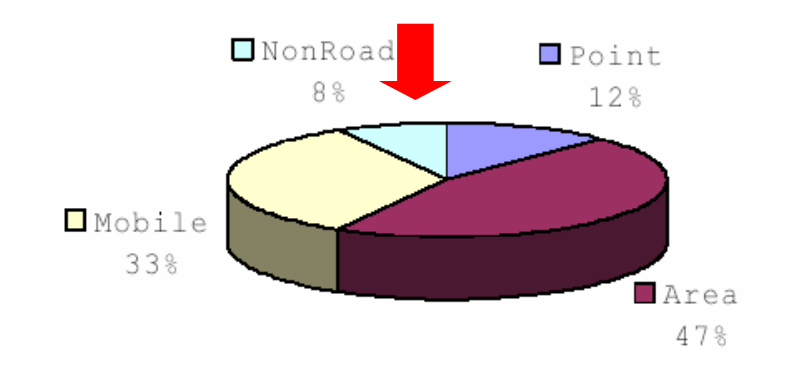


Why Nonroad?

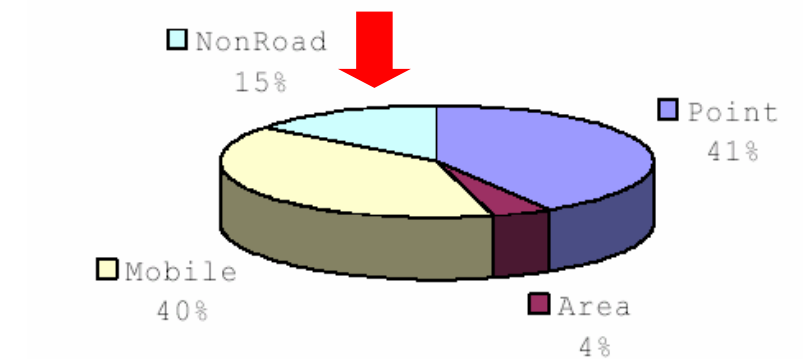
- Significant source of emissions in polluted areas

- EPA NONROAD model is user-friendly, easy to manipulate → good for uncertainty analysis!!

VOC Emissions



NOx Emissions



Source: Fall-line Air Quality Study August 2000 Inventory for 11 counties

Objective

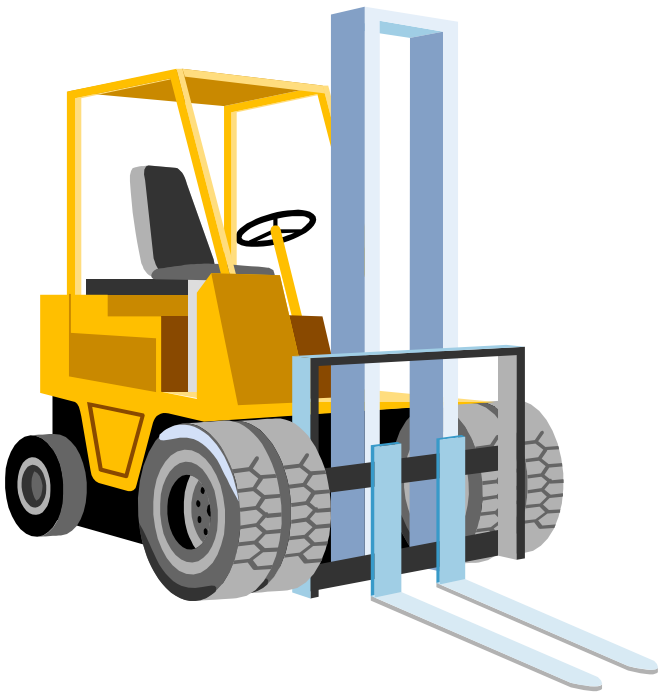
- Quantify uncertainty of emissions from the NONROAD model using a bottom-up, emissions-based approach for the state of Georgia

EPA NONROAD Emissions Model

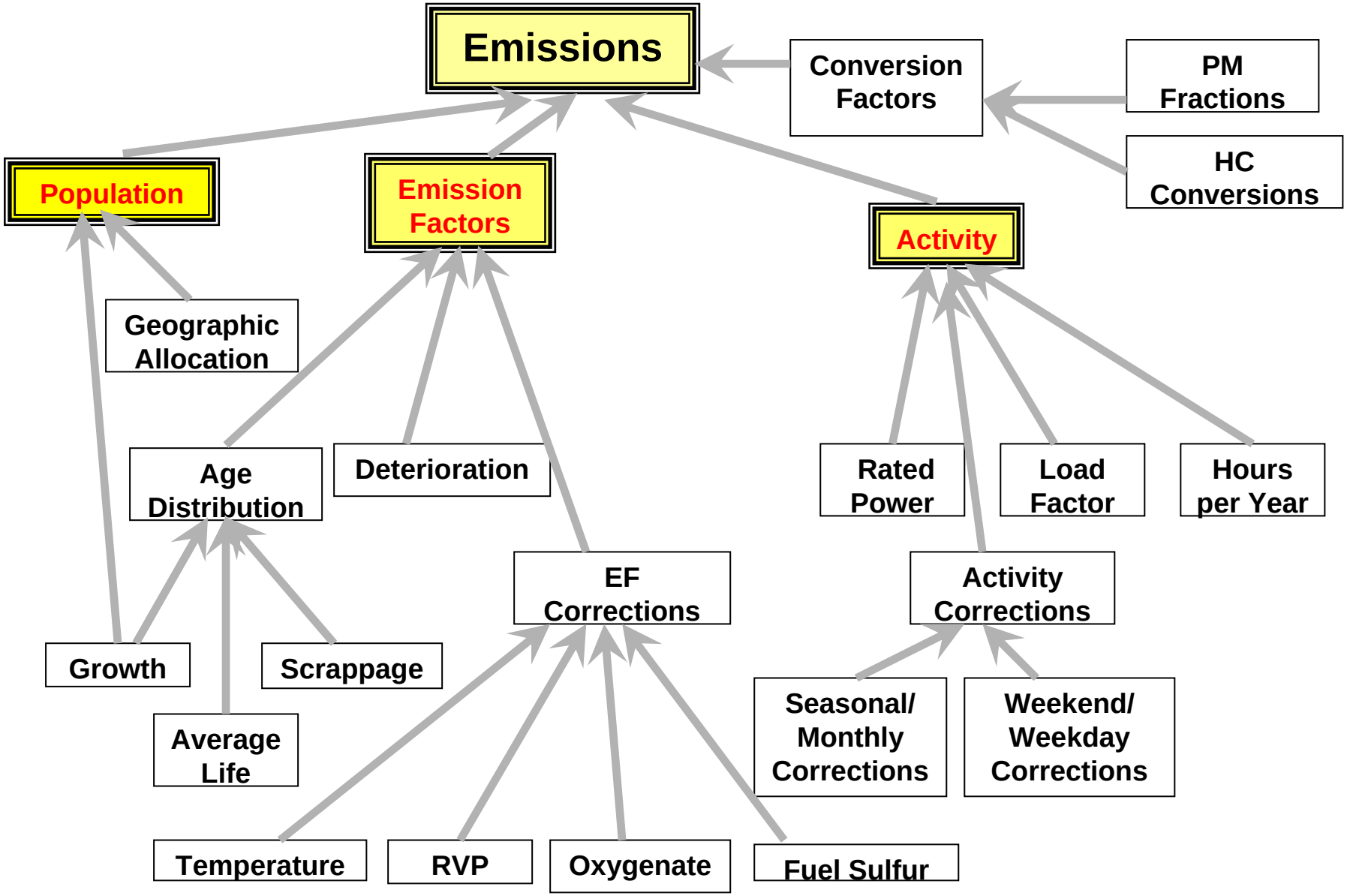
- Includes over 260 off-road equipment type in source categories: Construction, Lawn & Garden, Industrial, Agricultural, etc.
- Does NOT include: Aircraft, Locomotives, Commercial Marine

Photos from www.freefoto.com

NONROAD Emissions Calculations



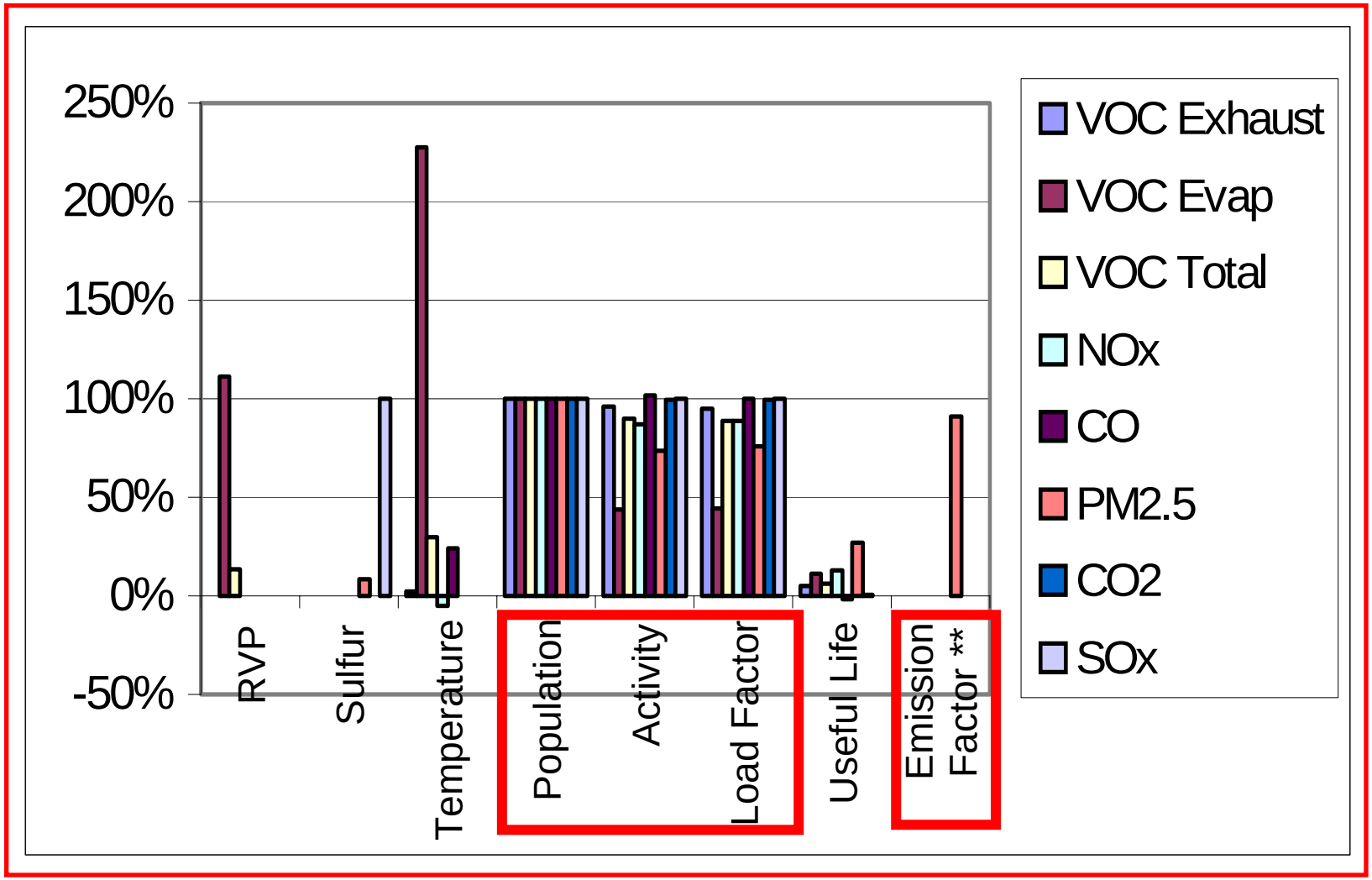
- EMISSIONS = (Population) x (Rated Power) x (Load Factor) x (Activity) x (Emission Factor)
- Complications:
  - Geographic allocations
  - Age distribution
  - Deterioration
  - Growth
  - Scrappage


Emissions
Conversion Factors
PM Fractions
HC Conversions
Population
Emission Factors
Activity
Geographic Allocation
Age Distribution
Deterioration
Rated Power
Load Factor
Hours per Year
EF Corrections
Activity Corrections
Growth
Scrappage
Average Life
Seasonal/ Monthly Corrections
Weekend/ Weekday Corrections
Temperature
RVP
Oxygenate
Fuel Sulfur

Methods

- Use 1999 average summer day scenario for Georgia
- Sensitivity analysis of NONROAD
- Expert elicitation of uncertainty of major NONROAD input parameters
- Monte Carlo uncertainty analysis of NONROAD emissions output uncertainty

Sensitivity Analysis



Emission Factor Bootstrap Analysis

- Diesel engine emission test certification data available in NONROAD documentation for model years 1996 +
- AuvTool (Frey, Zheng; NC State) empirical distribution fits and bootstrap analysis
- Shows uncertainties due to random sampling errors, but not errors of representativeness

Model Year	HP 95% Confidence Interval		HC 95% Confidence Interval		NOx 95% Confidence Interval		CO 95% Confidence Interval		PM 95% Confidence Interval	
Average	-5%	5%	-21%	21%	-4%	3%	-16%	16%	-10%	10%
Maximum	-7%	7%	-49%	46%	-6%	5%	-20%	23%	-18%	17%
Minimum	-2%	2%	-4%	4%	-2%	2%	-8%	8%	-4%	4%

Expert Elicitation

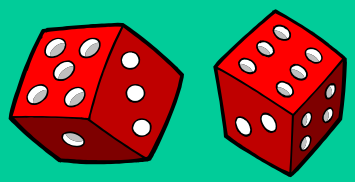
- Focus on experts in nonroad emissions modeling, not air quality modeling
- Experts self-rate based on experience
- Experts give opinions of uncertainties of NONROAD input parameters
- Expert opinions aggregated as average of answers weighted by self-rating

Expert Elicitation

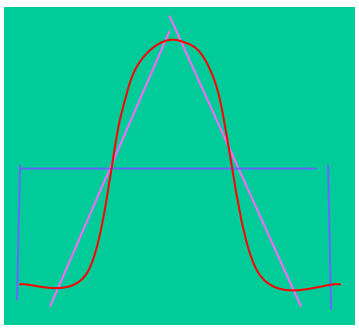
Input Category	Most Uncertain 95% Confidence Interval	Least Uncertain 95% Confidence Interval
Population	+68%, -25%	+29%, -23%
Geographic Allocation	+194%, -50%	+10%, -10%
Activity	+65%, -38%	+22%, -22%
Load Factor	+37%, -41%	+23%, -21%
Emission Factor	+96%, -29%	+16%, -14%

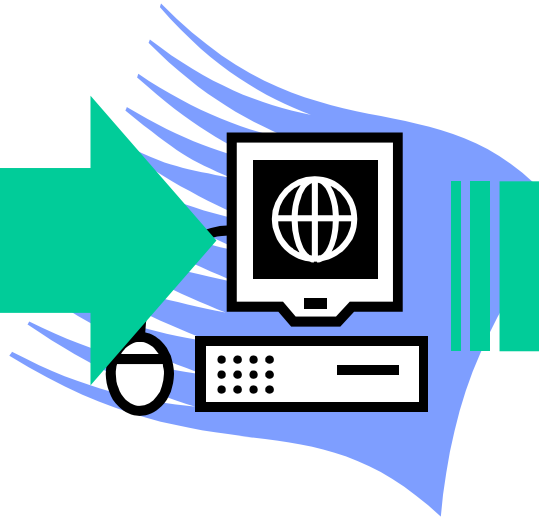
Monte Carlo Simulation

Generate random inputs



Population
Activity
Load Factor
Emission Factor
Geographic Allocation



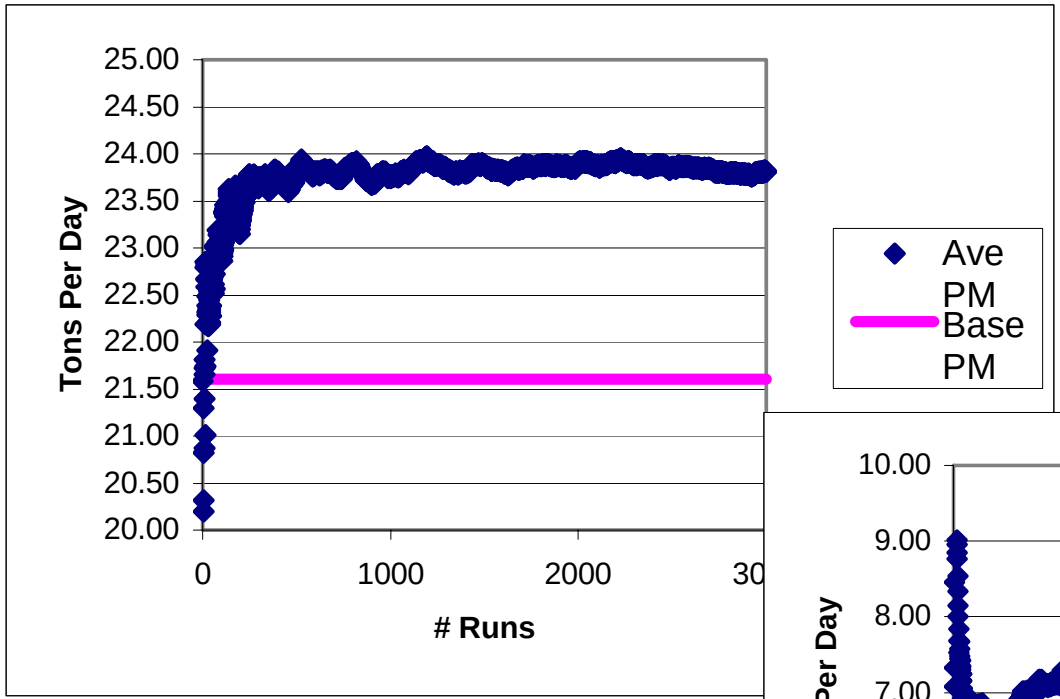


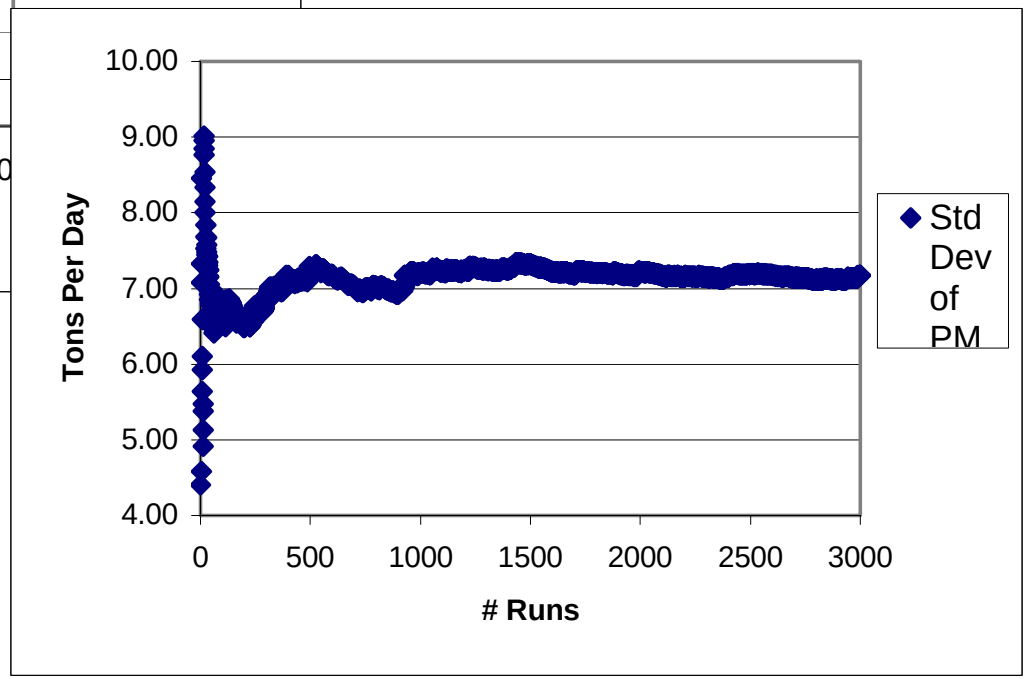
Run NONROAD **n** times

Calculate statistics on outputs

Average
Standard Deviation
Skew

Monte Carlo Simulation





Monte Carlo Simulation

Georgia 1999 Summer Day Statewide NONROAD Output Results

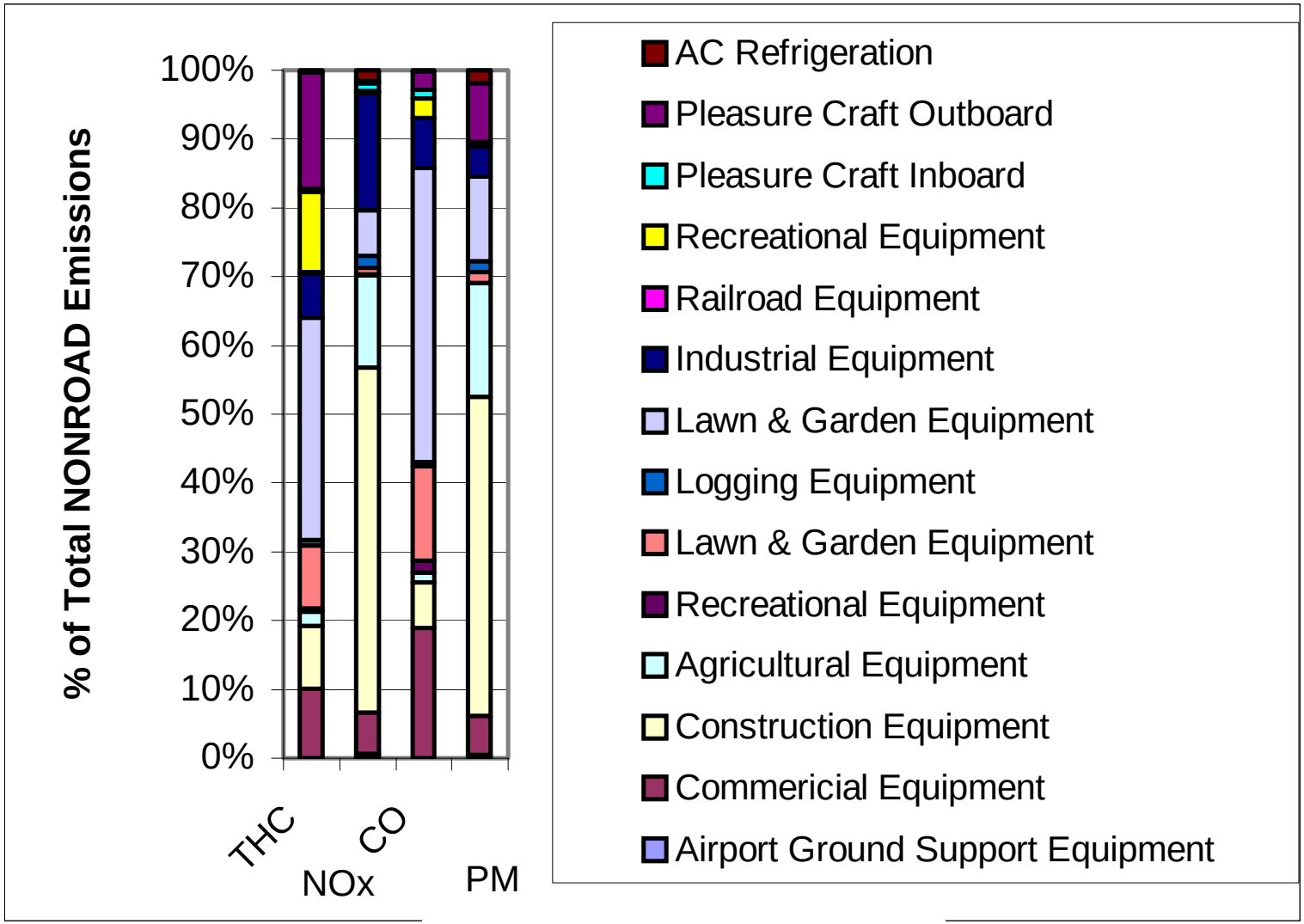
Input Distribution	**Average (Tons Per Day)**			
	THC	NOx	CO	PM
Normal	204	205	2581	24
Triangle	220	214	2804	26
Uniform	227	222	2931	28
Input Distribution	**Standard Deviation as % of Average (%)**			
	THC	NOx	CO	PM
Normal	24	29	29	30
Triangle	23	27	28	28
Uniform	26	33	32	33

Monte Carlo Simulation

Uncertainty of NONROAD Output Results for State and Counties

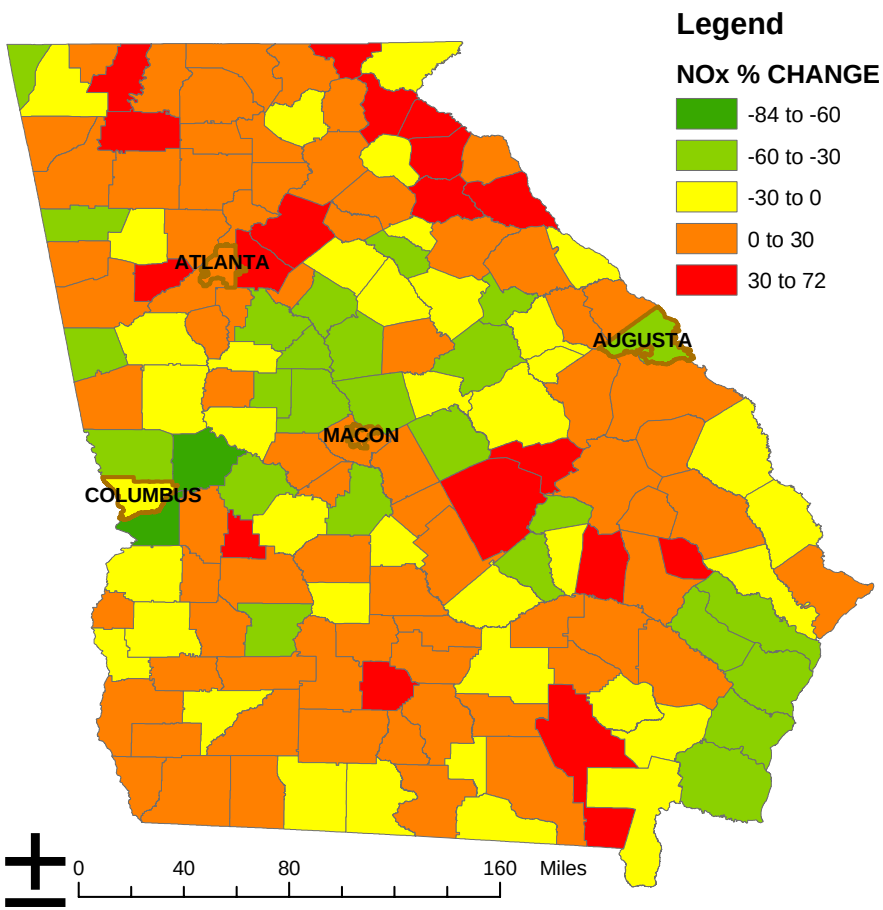
	Standard Deviation for Emissions as % of Average			
	County Emissions			State Emissions
	Maximum	Minimum	Average	
THC	35	19	23	24
NOx	33	20	29	29
CO	38	19	28	29
PM	37	22	31	30

Monte Carlo Simulation

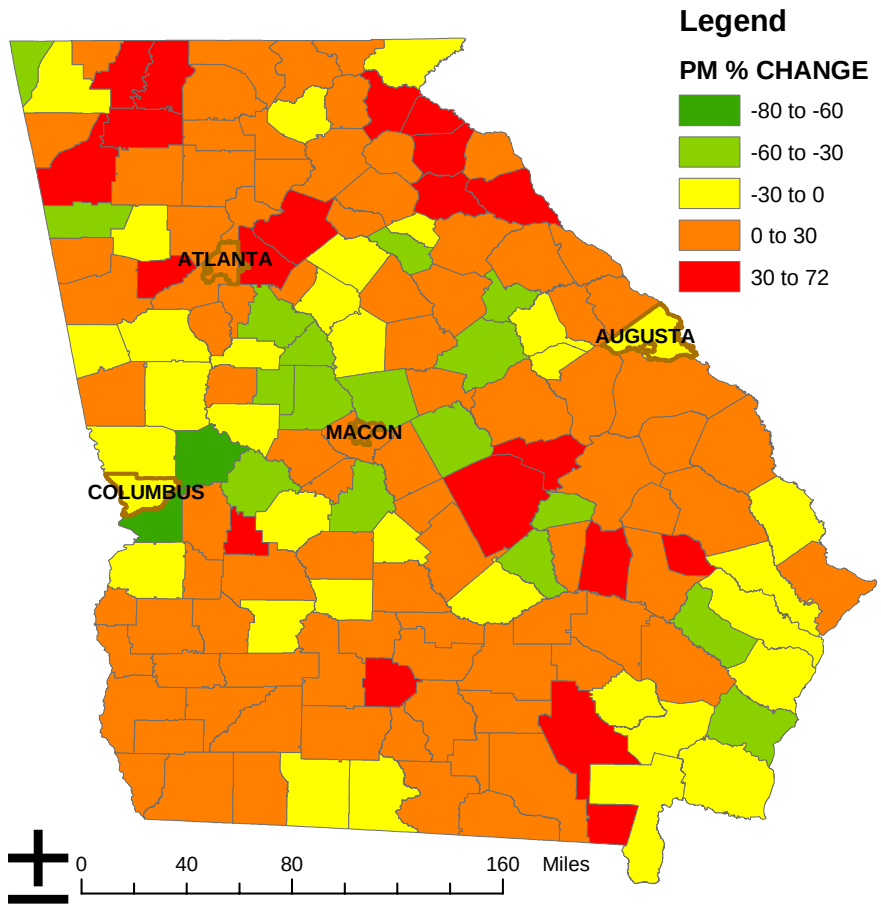


Monte Carlo Simulation

NOx % Change From Base Case

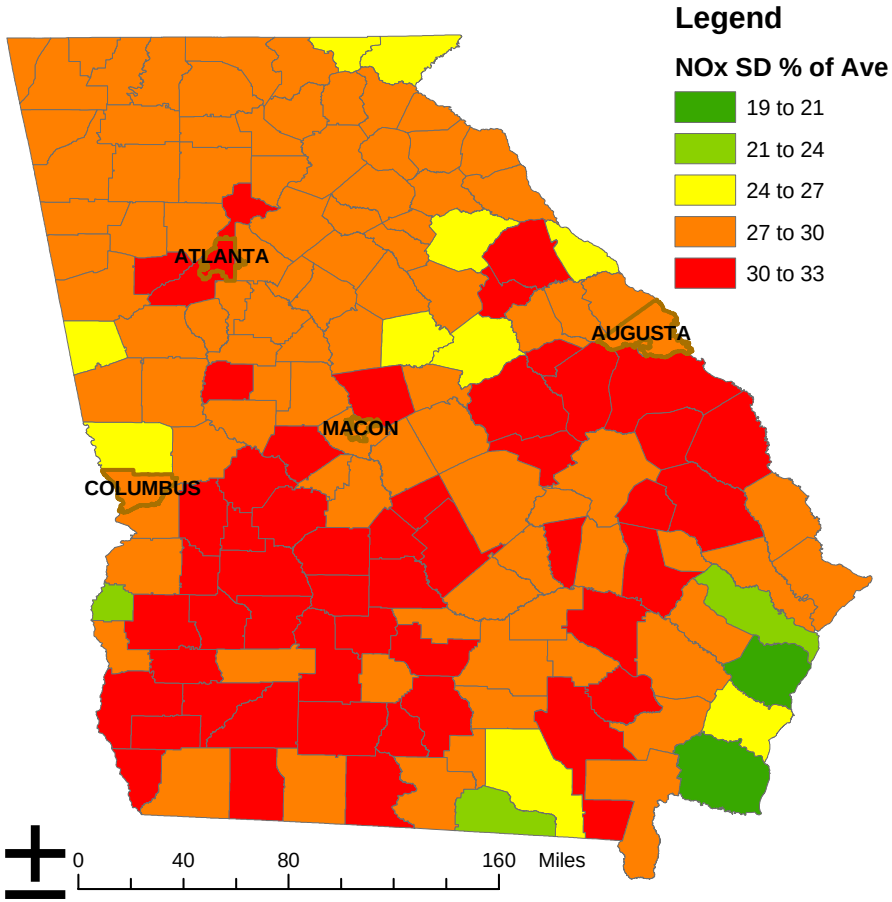


PM % Change From Base Case

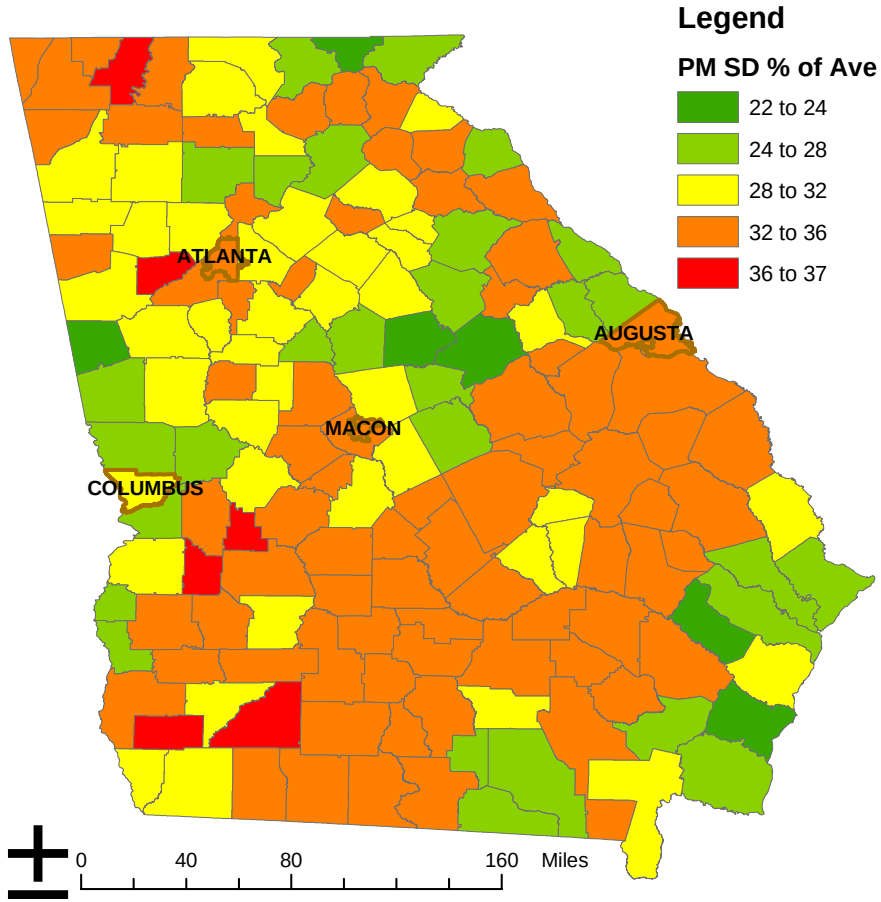


Monte Carlo Simulation

1999 NONROAD NOx Uncertainty



1999 NONROAD PM Uncertainty



Conclusions

- Uncertainties of NONROAD emissions as calculated in this study were between 24% and 30% (standard deviation as % of mean) for the state of Georgia for THC, NOx, CO, and PM
- Uncertainties of input parameters were often positively skewed → uncertainties of output emissions also positively skewed
- Using the Monte Carlo approach in this study resulted in approximately 10% increase of calculated emissions for all studied pollutants.
- Uncertainty analysis of NONROAD model does NOT account for all possible uncertainties → underestimation?

On-going and Future Work

- Improvement of distributions of NONROAD input parameters and sampling methods
- Sensitivity analysis of CMAQ model to NONROAD emissions uncertainties in Georgia
- Uncertainty of aircraft, locomotive, commercial marine emissions → rest of emissions inventory
- Uncertainty analysis of CMAQ model results

Acknowledgements

Much thanks to…

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