2012 Air & Waste Management Association Annual Conference:

Sensitivity Analysis of Model-Related Inputs in Wildland Fire Simulations using CMAQ

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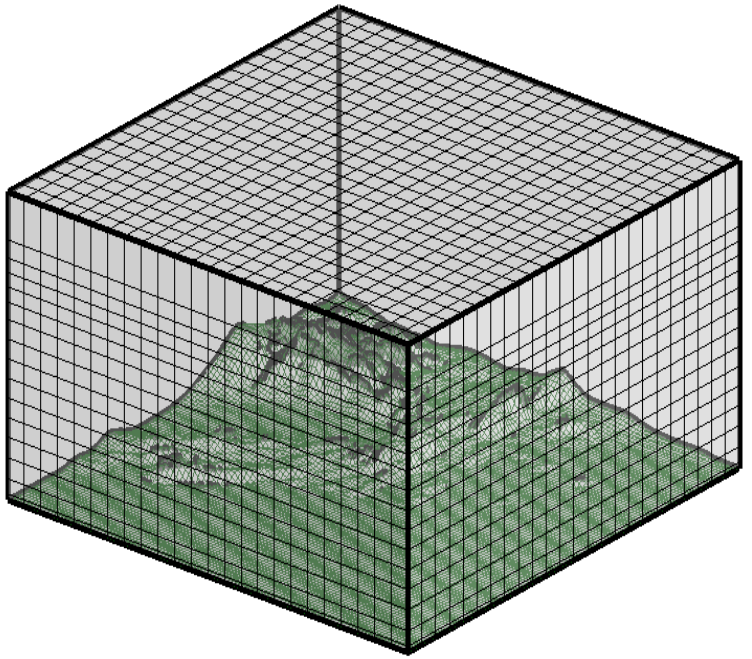
Impacts of Wildland Fires on Air Quality

- Fires may have detrimental impacts on air quality, health & visibility.
- Fires can account for a substantial fraction of $PM_{2.5}$ pollution.
- Air quality forecasts produced with numerical models can provide valuable information to environmental regulators and land-managers.
- Modeling the impacts on air quality requires understanding the model's capabilities & uncertainties.

Air Quality Simulations with Eulerian Models

Advantages:

- State-of-the-science representations of complex physical and chemical processes
- Comprehensive emissions inventories
- Detailed 3-dimensonal meteorological fields

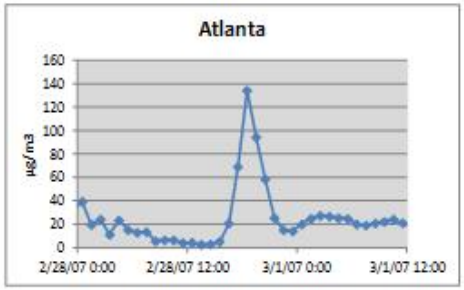


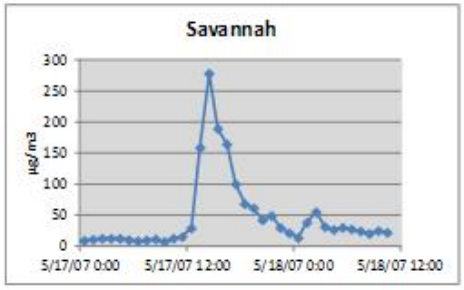
Multiscale capabilities :

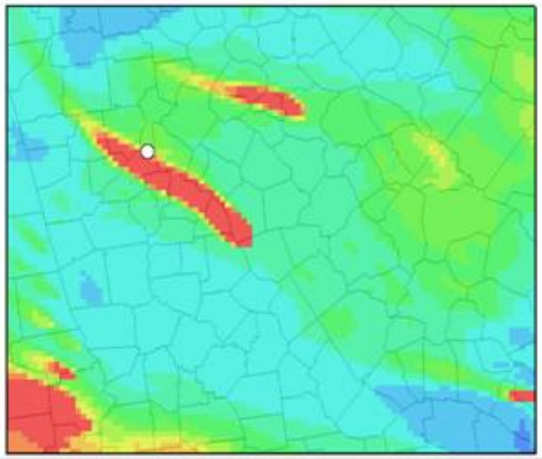
- Initial transformations and dispersion
  → local scales
- Long-range transport and air quality impact
  → regional scales

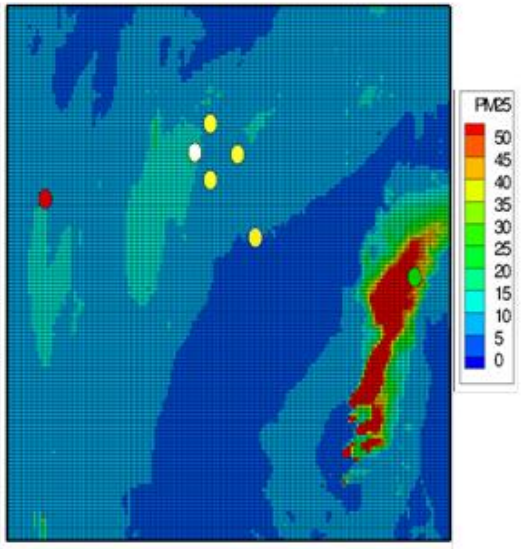
Air Quality Modeling Framework

- Community Multiscale Air Quality modeling system (CMAQ)
- Sparse Matrix Operator Kernel Emissions (SMOKE)
- Weather Research & Forecasting model (WRF)
- BlueSky modeling framework
- Fire Emissions Production Simulator (FEPS)

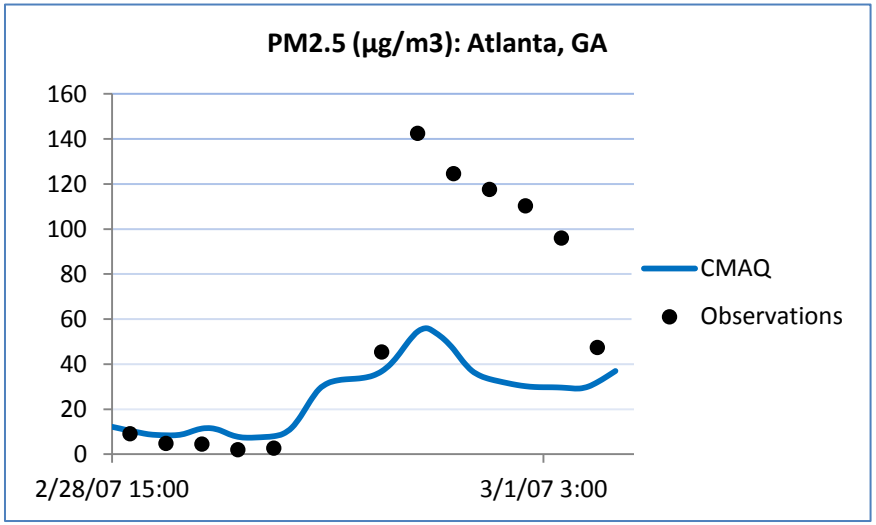


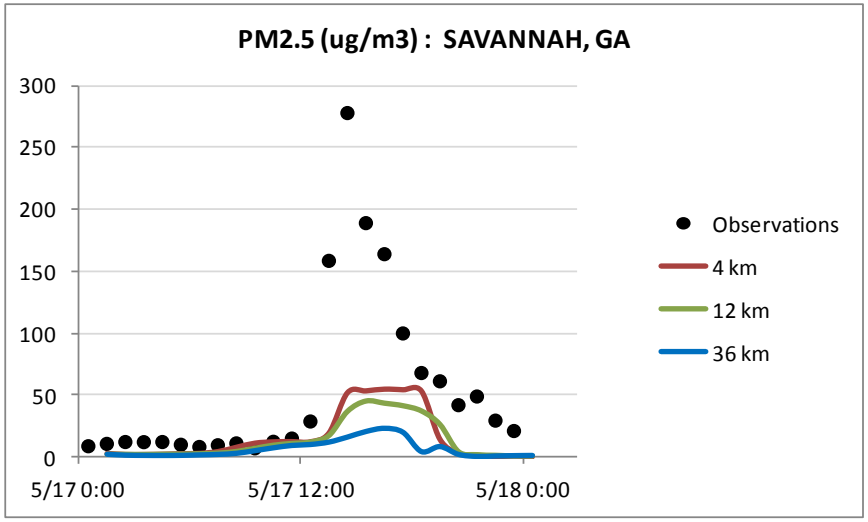






Model Performance

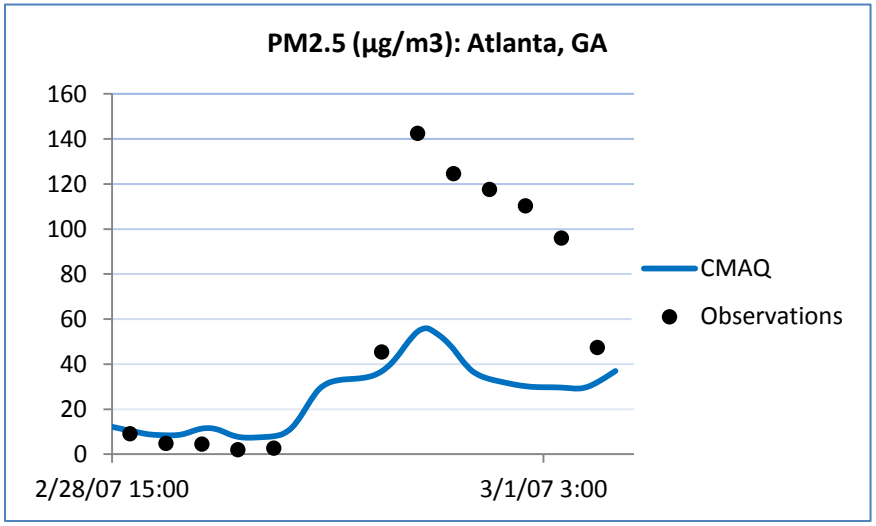


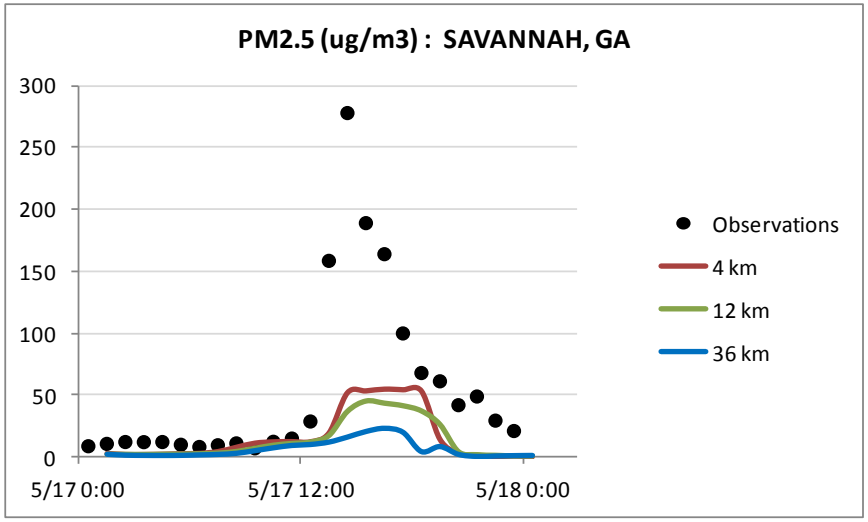


Conclusions from atmospheric plume simulations:

- CMAQ (and other gridded air quality models) can be ineffective as a AQ prediction tool for fire impacts
- Model can severely underpredict AQ impacts

Model Performance

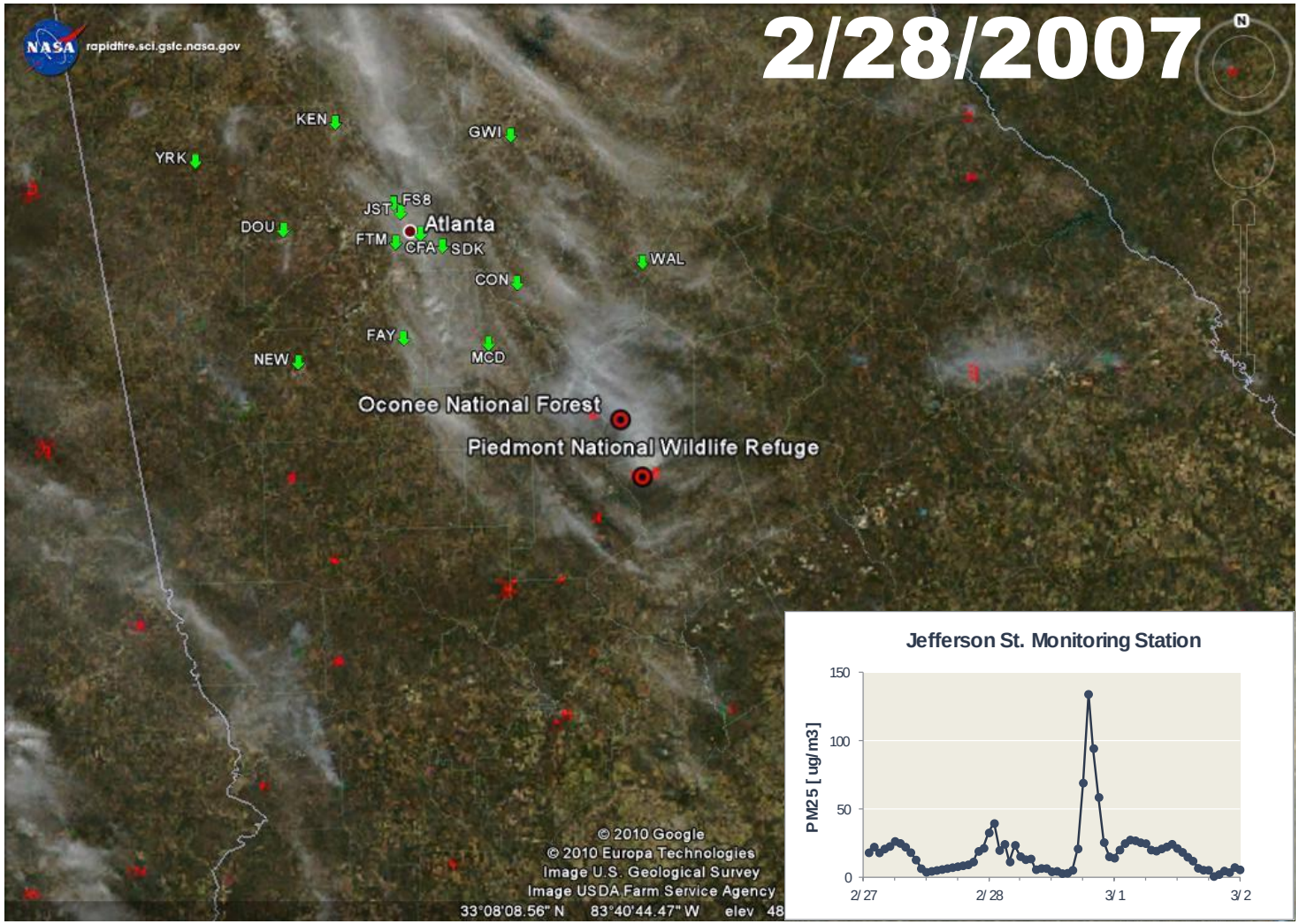




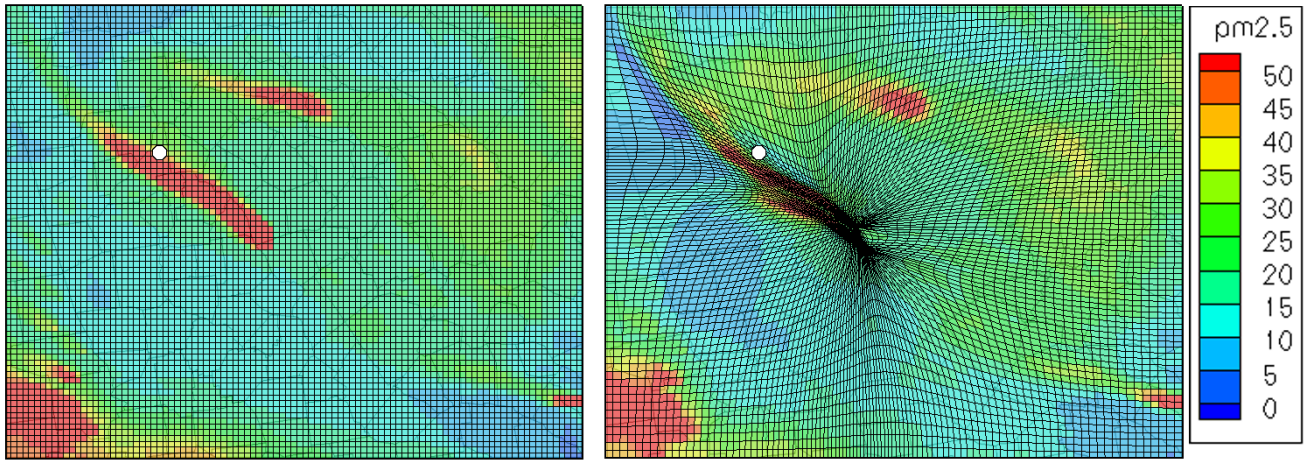
Objective: *Evaluate the uncertainties in modeling the air quality impacts of fires with gridded photochemical models through sensitivity analyses*

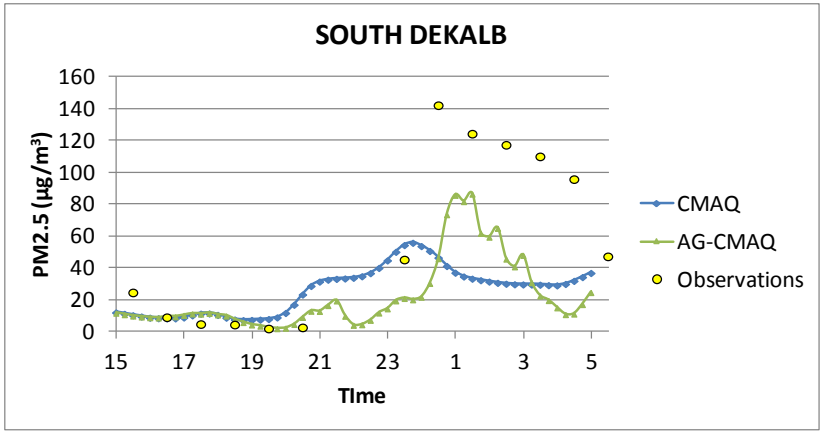
- Fire-related emissions and emission factors
- Spatiotemporal allocation of fire emissions on gridded domains
- Grid resolution
- Meteorology

Case Study: Atlanta, GA



Adaptive Grid CMAQ

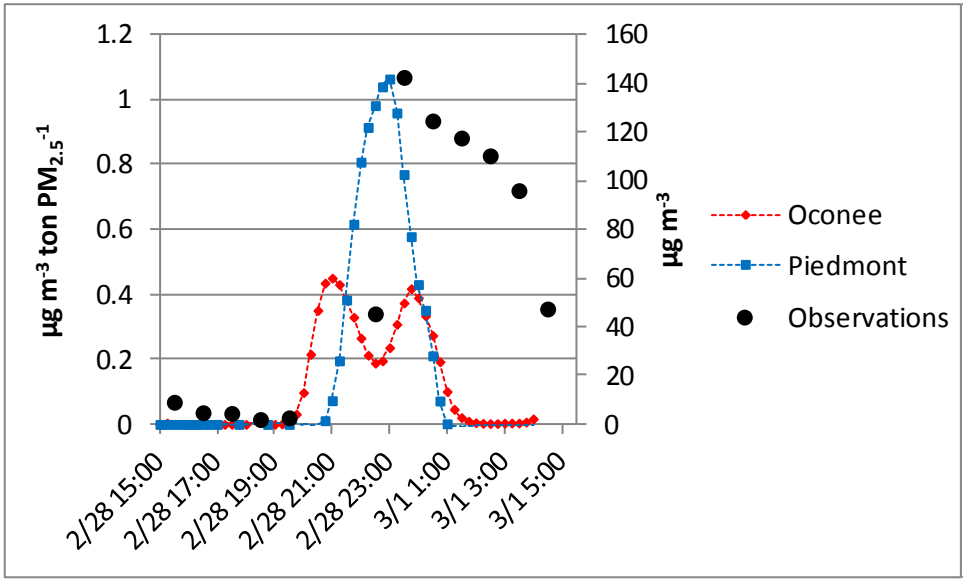


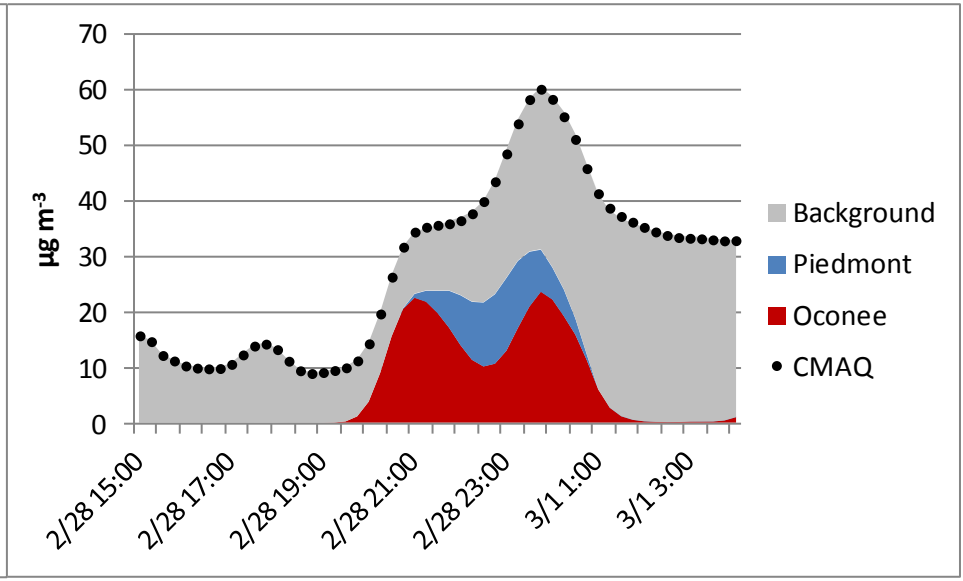


Sensitivity Analyses

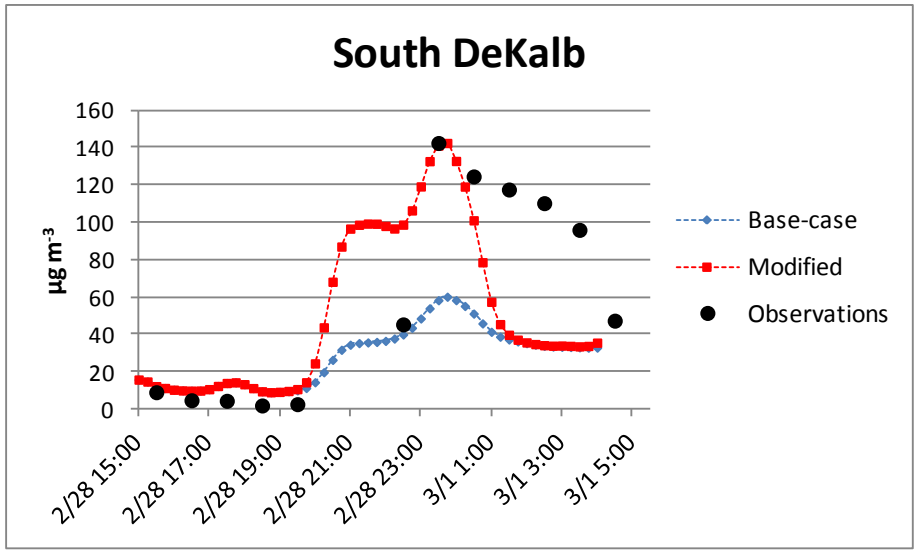
"Brute-force" first-order sensitivity coefficients:

$$\frac{\partial C}{\partial x} = \frac{C_{x+\Delta x} - C_{x-\Delta x}}{2\Delta x} \qquad O(\Delta x^2)$$

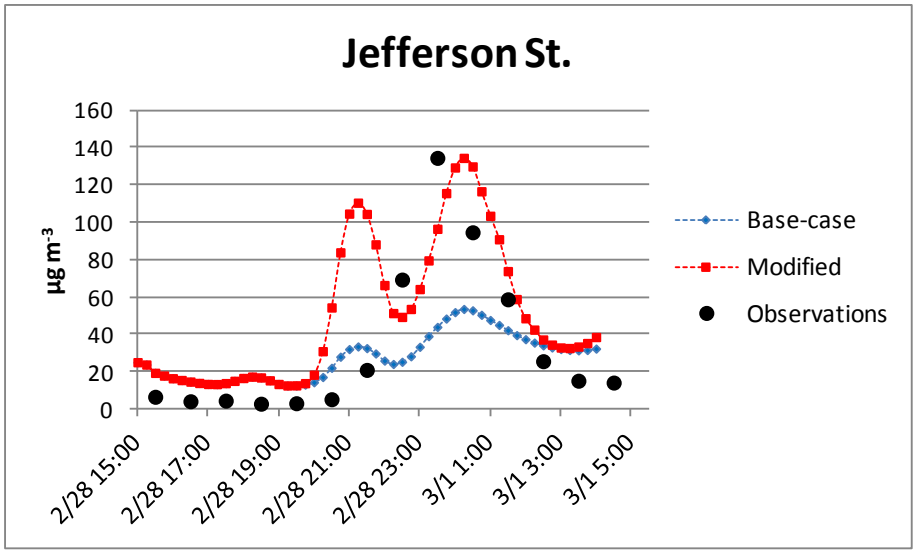




Fire Emissions Magnitude



Fire emissions x 3.7



Fire emissions x 5.1

Horizontal Allocation of Fire Emissions

Changes relative to base-case at Jefferson St. after relocating Oconee fire emissions:

Total contribution to PM2.5

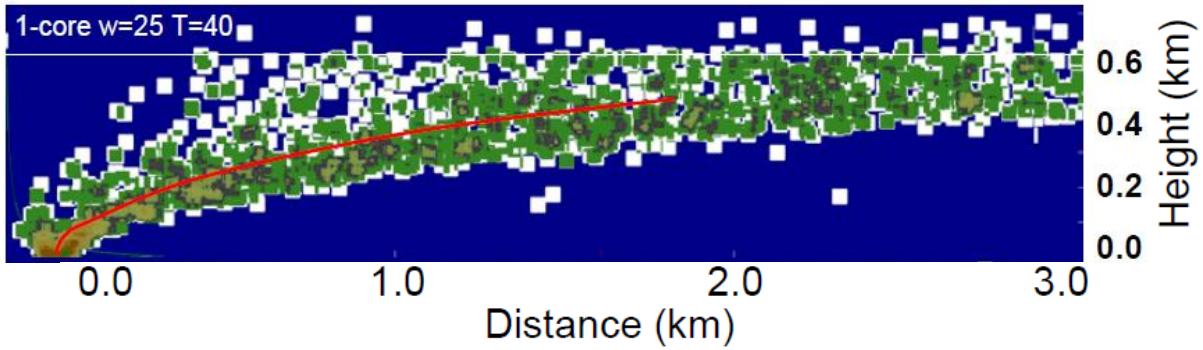
-0.6%	-2.7%	-1.8%
8.0%	0.0%	-5.4%
27.8%	17.7%	8.2%

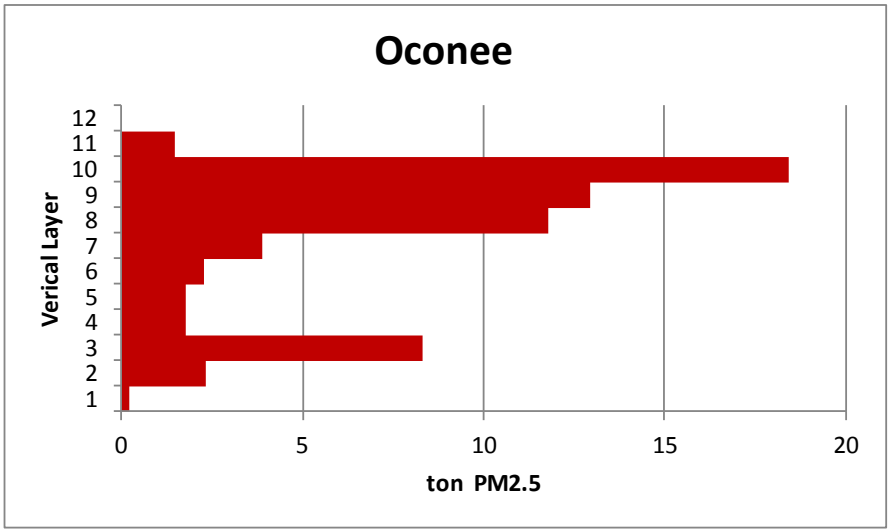
Maximum simulated concentration

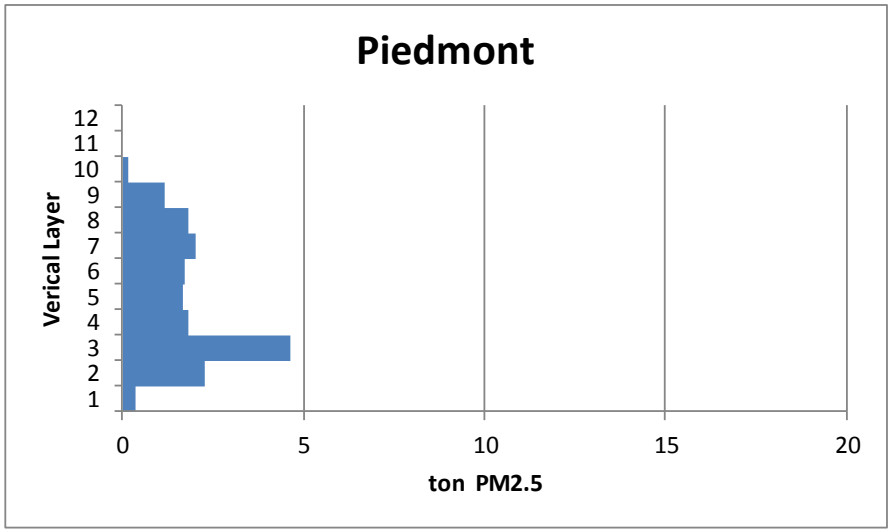
-6.7%	-11.9%	-13.6%
7.1%	0.0%	-7.7%
19.9%	15.3%	7.9%

Vertical Allocation of Fire Emissions

Subgrid scale plume model, Daysmoke:

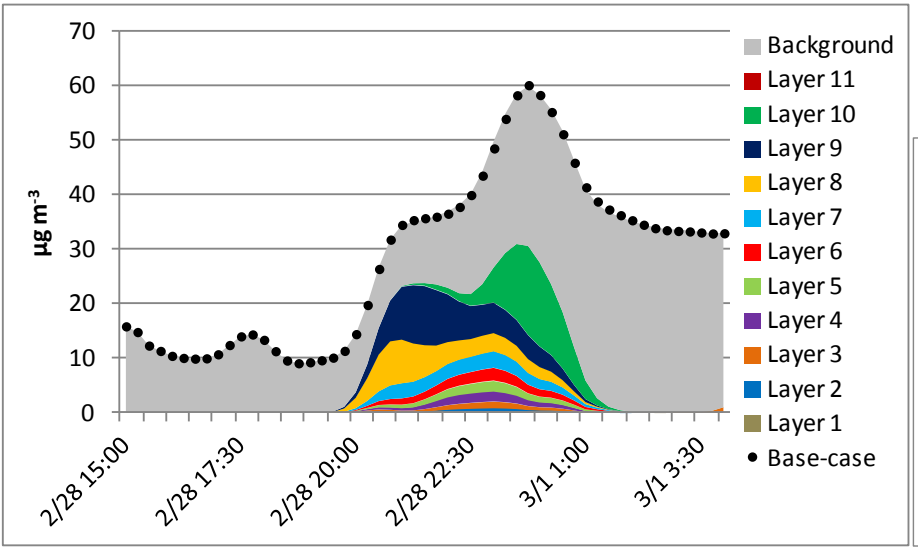


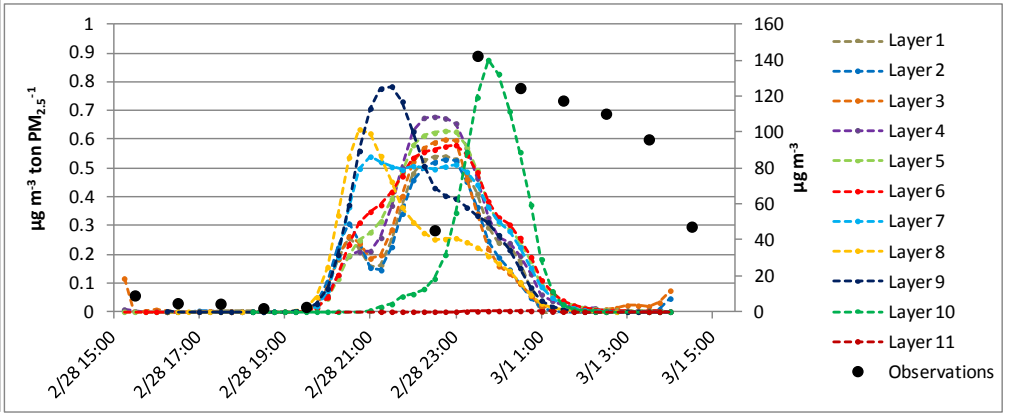




Vertical Allocation of Fire Emissions

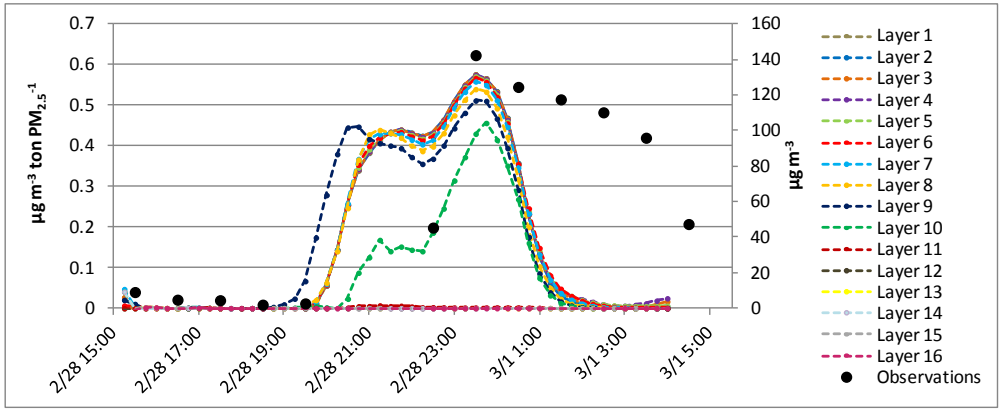
Fire contributions to modeled PM2.5 and first-order sensitivity coefficients for PM2.5 concentration response to fire emissions at South DeKalb:

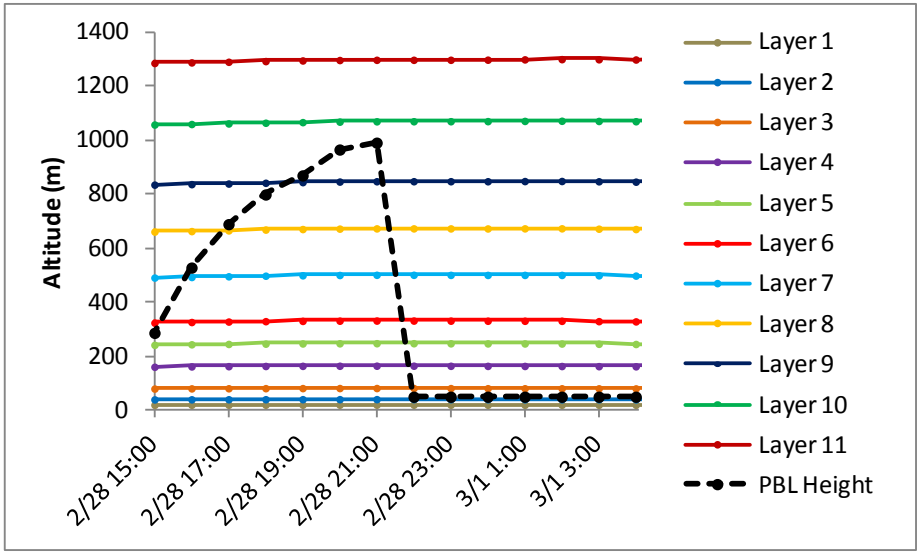




Vertical Allocation of Fire Emissions

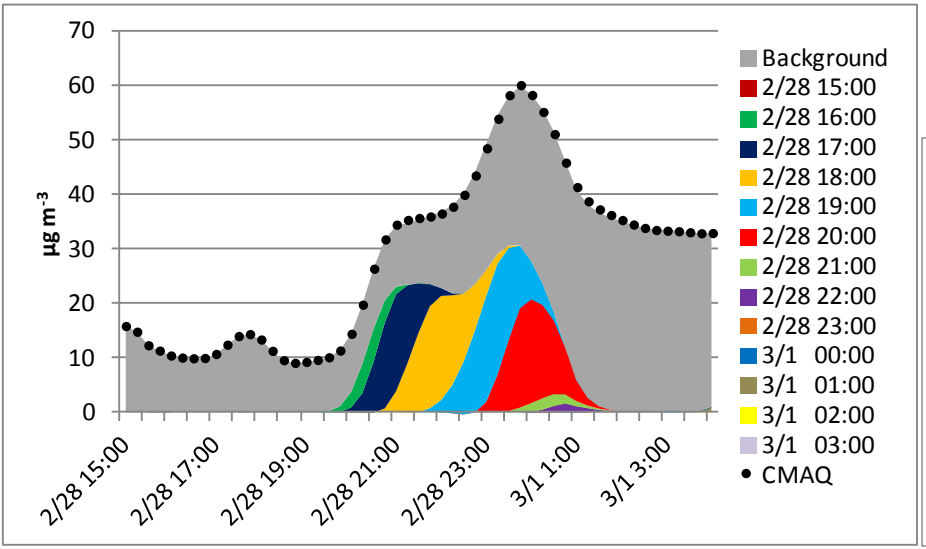
Brute-force first-order sensitivity coefficients for PM2.5 concentration response to fire emissions at South DeKalb, **for uniform-by-layer distribution into 16 lowest layers** :

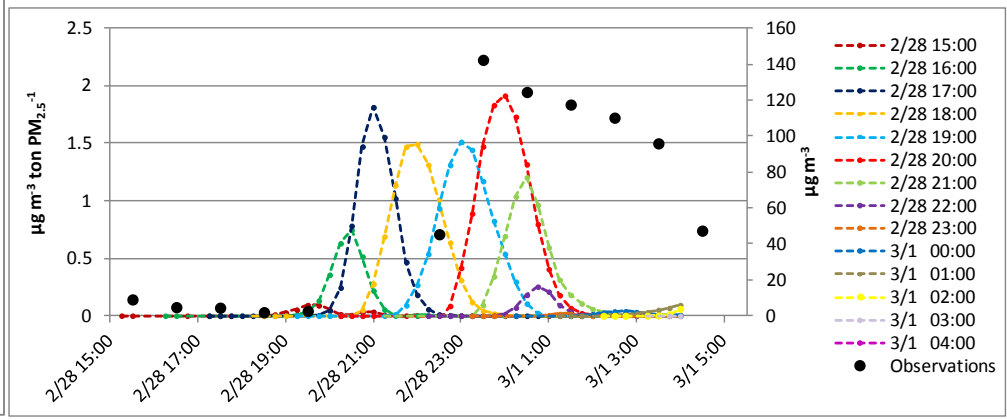




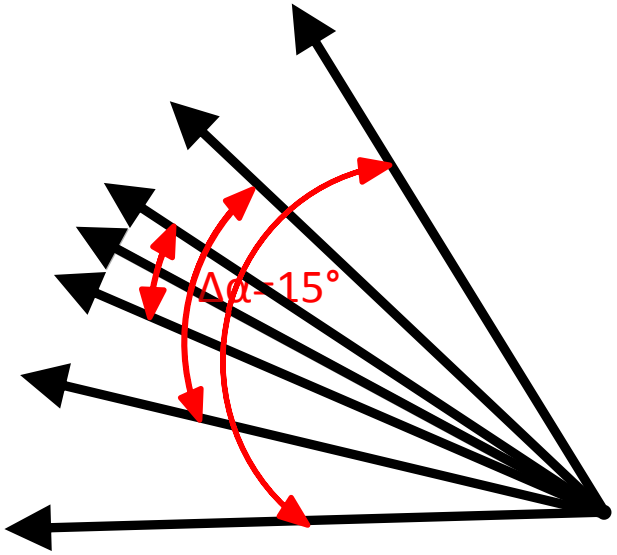
Temporal Allocation of Fire Emissions

Fire contributions to modeled PM2.5, and first-order sensitivity coefficients for PM2.5 concentration response to fire emissions at South DeKalb for uniform-by-layer distribution into 16 lowest layers :





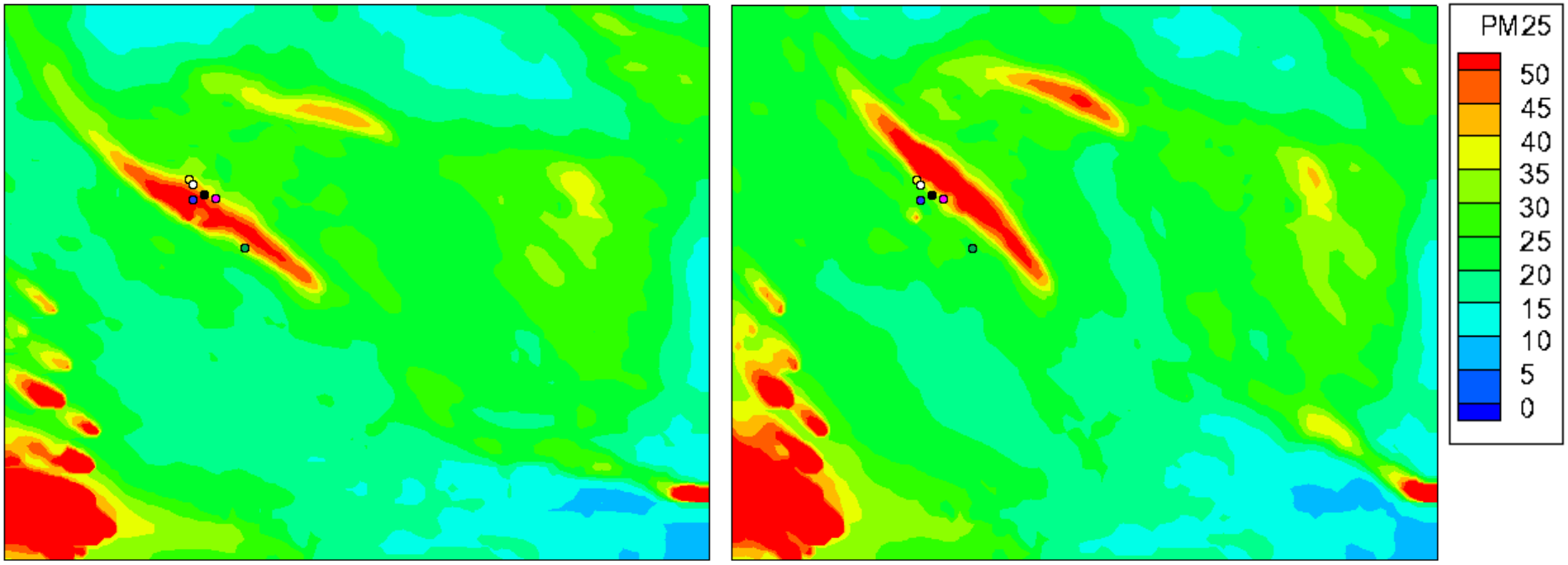
$PM_{2.5}$ Concentration Sensitivity to Wind Direction



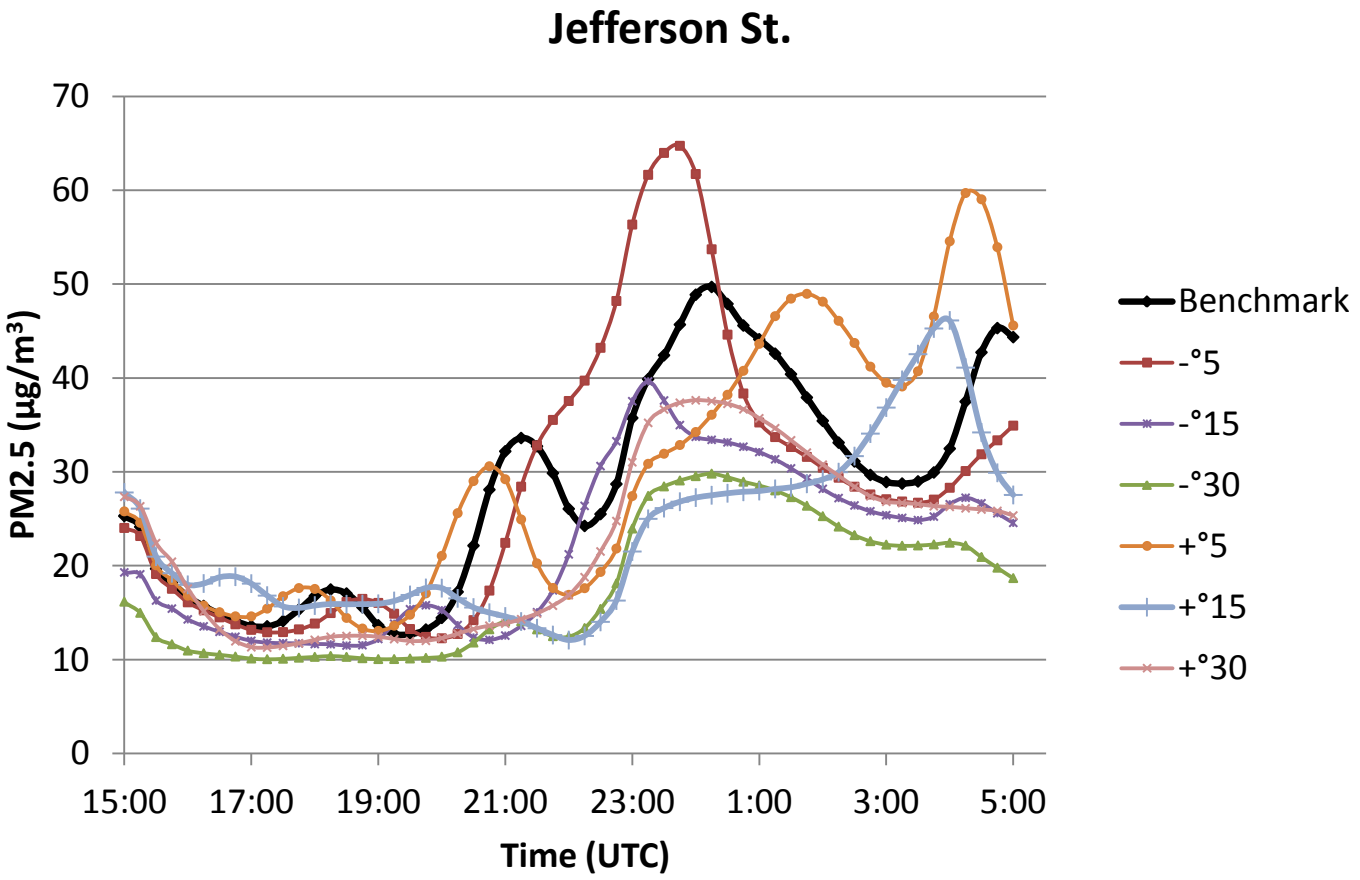
Δα = ±5°, ±15°, ±30°

$PM_{2.5}$ Concentration Sensitivity to Wind Direction

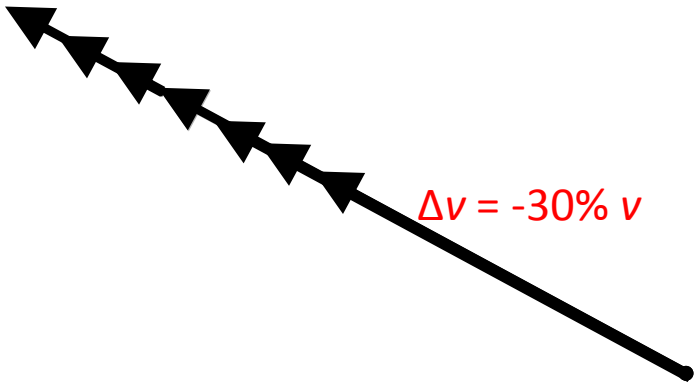
$\Delta\alpha = +15°$



$PM_{2.5}$ Concentration Sensitivity to Wind Direction

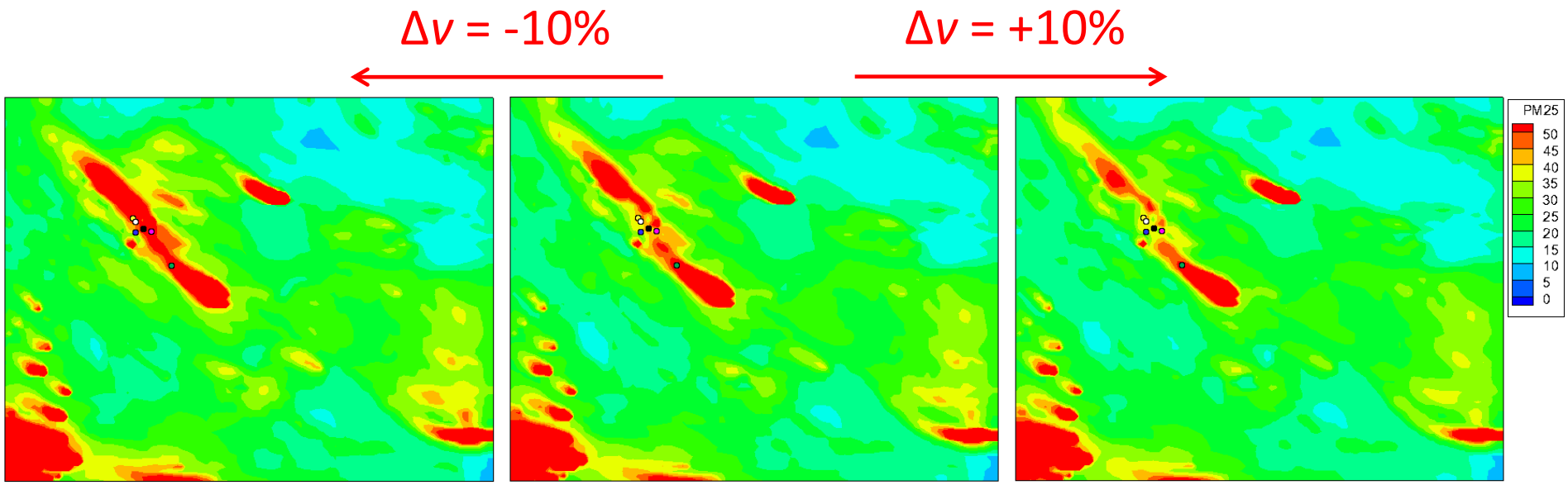


$PM_{2.5}$ Concentration Sensitivity to Wind Speed

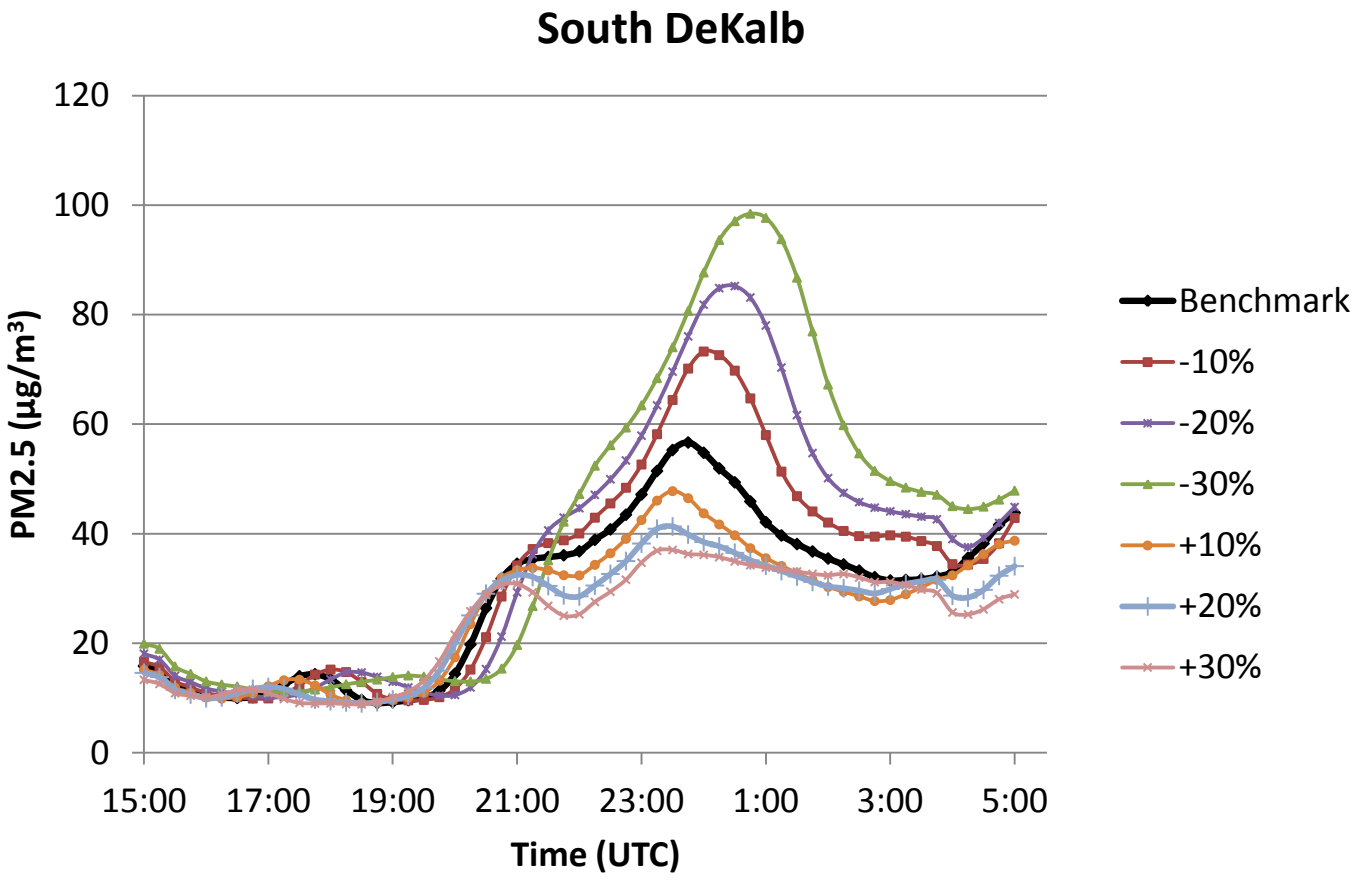


Δ*v* = ±10%, ±20%, ±30%

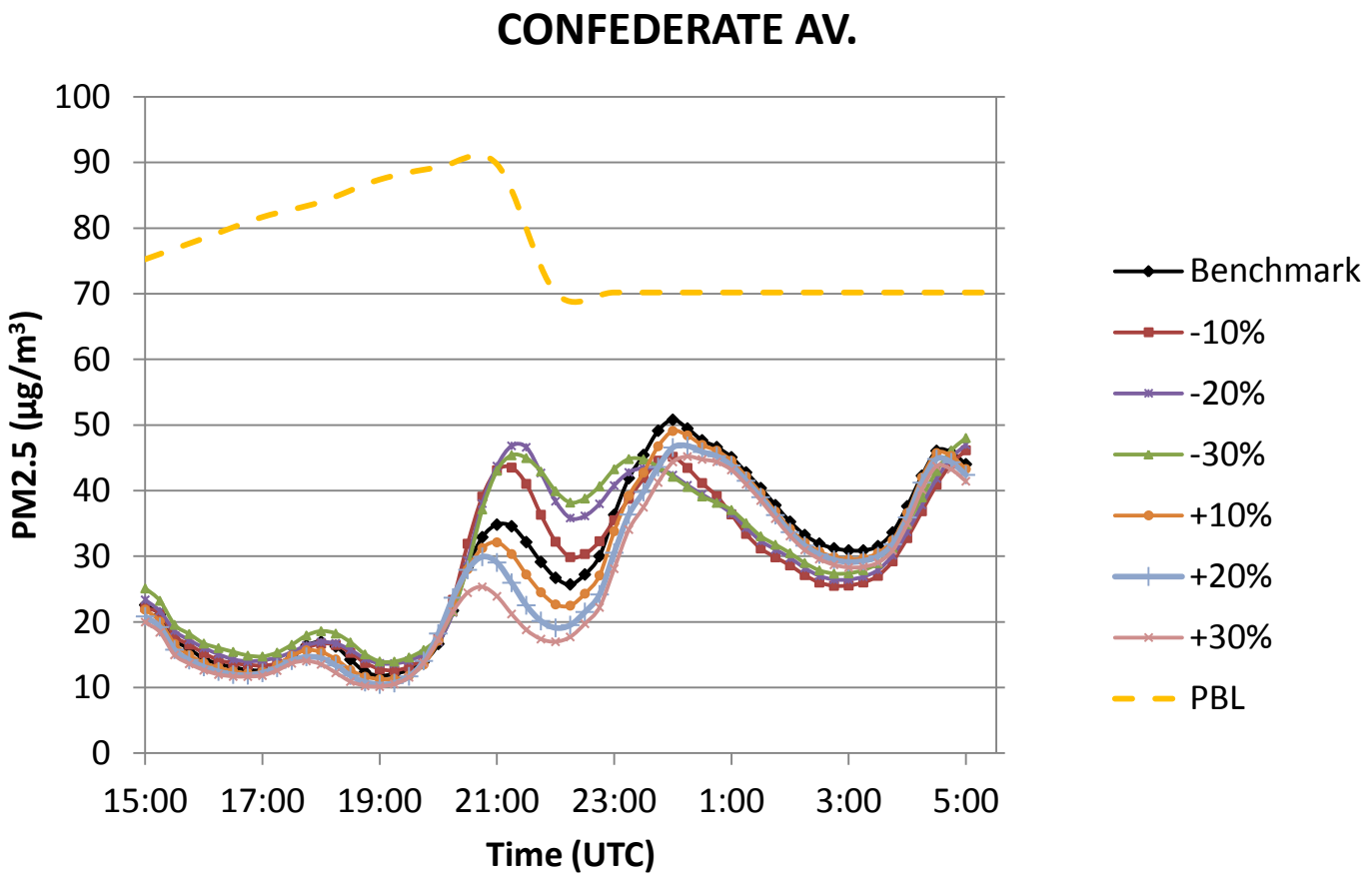
$PM_{2.5}$ Concentration Sensitivity to Wind Speed



$PM_{2.5}$ Concentration Sensitivity to Wind Speed



$PM_{2.5}$ Concentration Sensitivity to PBL Height



Conclusions from Sensitivity Analyses

- Modeled PM2.5 concentrations at downwind receptors are significantly sensitive to horizontal grid resolution.
- Predicted concentrations are sensitive to the horizontal allocation of emissions and whether fires are treated as point or area sources.
- In relation to plume rise, PM2.5 concentrations are mostly sensitive to the fraction of emissions injected into the PBL.
- Predicted concentrations are sensitive to the temporal distribution of fire-related emissions; better approximating the timing and progression of pollutant releases is a practical approach to improve model performance.
- Significant sensitivity to wind speed, direction, and boundary layer height should be expected in fire AQ simulations at receptors downwind.
- Uncertainty in meteorological inputs to gridded models can significantly affect simulated concentrations and limit their ability to predict impacts from fires.

THANK YOU!

Strategic Environmental Research and Development Program

Joint Fire Science Program

Georgia Department of Natural Resources, Environmental Protection Division

US Forest Service, Southern Research Station