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Dynamic Management of Prescribed Burning for Better Air Quality

US EPA STAR Program
Dynamic Air Quality Management
Progress Review Webinar
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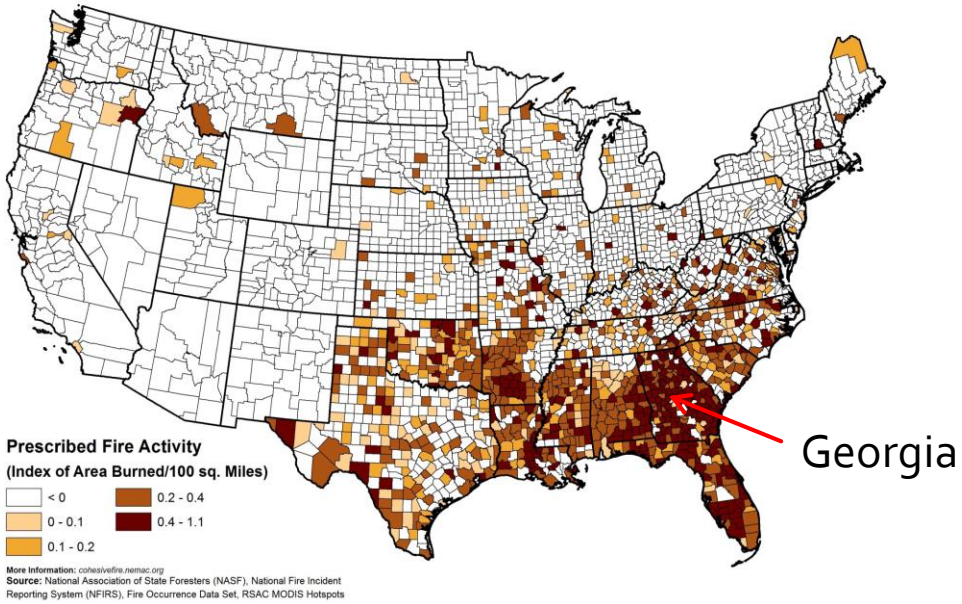
Prescribed burning, the preferred land management tool in the Southeast, is a large source of PM.

- Prescribed burning (**PB**) is practiced to improve native vegetation and wildlife habitat, control insects and disease, and reduce wildfire risk.

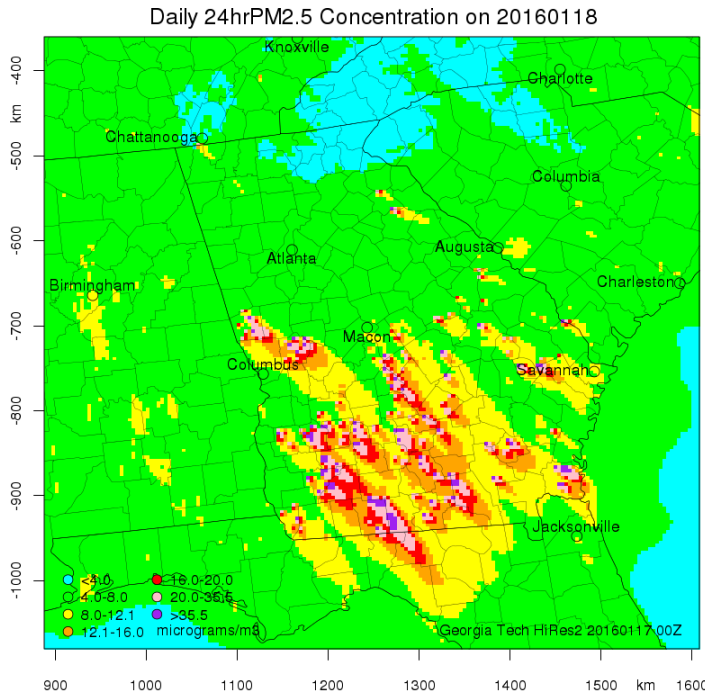


- According to 2011 National Emission Inventory, 15% of PM2.5 emissions in the US (820 Gg) are from PB, second largest source after wildfires (18% or 995 Gg)
- In the Southeast, PB is the largest source of PM2.5 emissions (20% or 210 Gg)

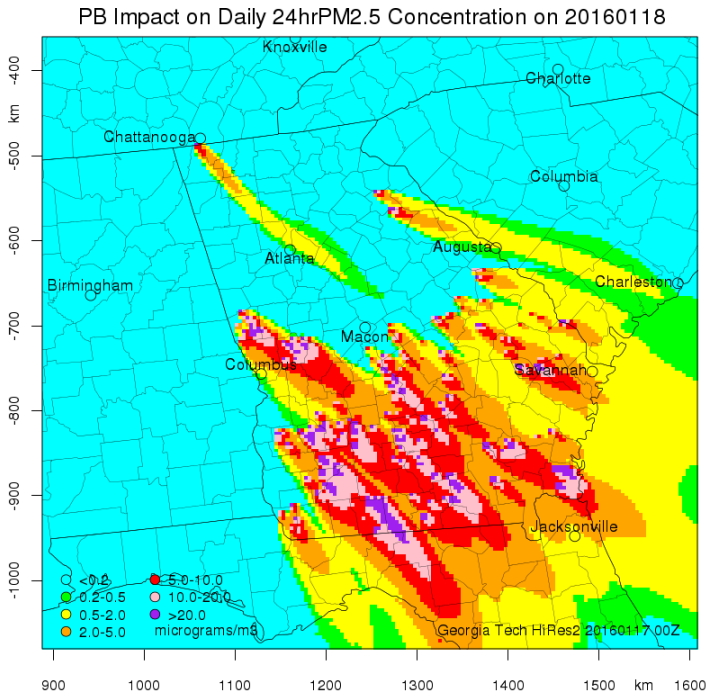
Dynamic management of PB is easy relative to other emission sources.

- Burn/no-burn decisions are made daily.
- PB impact forecasts can be used in decision making.

$PM_{2.5}$



PB Impact



Burn Area

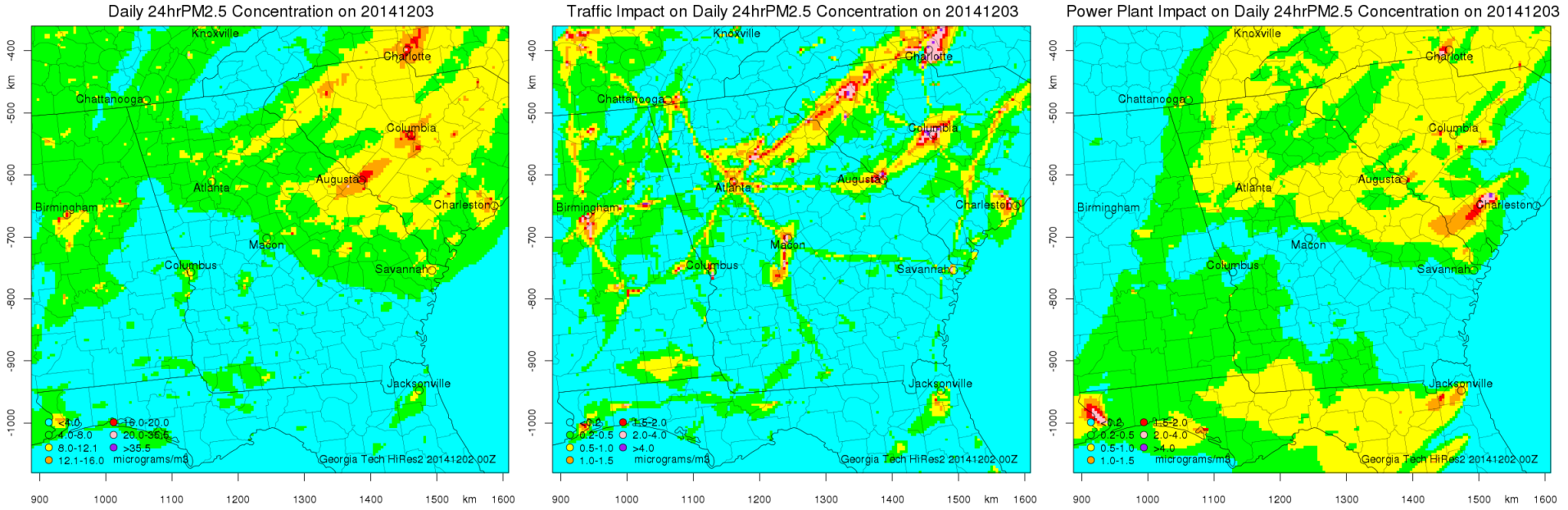
Thomas County	
PM2.5	75 μg/m³
PB Impact	70 μg/m³
Burn Area	1400 acres

https://forecast.ce.gatech.edu

Hi-Res2 Air Quality and Source Impact Forecasting System (https://forecast.ce.gatech.edu)

- Updated Hi-Res with 2011 NEI, WRF3.6.1 and CMAQv5.02
- 72-hour forecasts at 4-km resolution in/around Georgia
- Source impact forecasting using the Decoupled Direct Method, DDM-3D

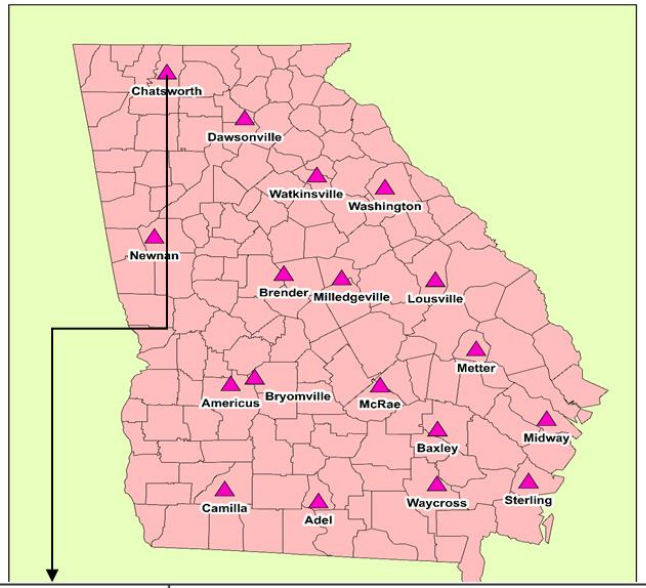
$PM_{2.5}$ | **Traffic Contribution** | **Power Plant Contribution**



(The scales for $PM_{2.5}$ and the contributions are different)

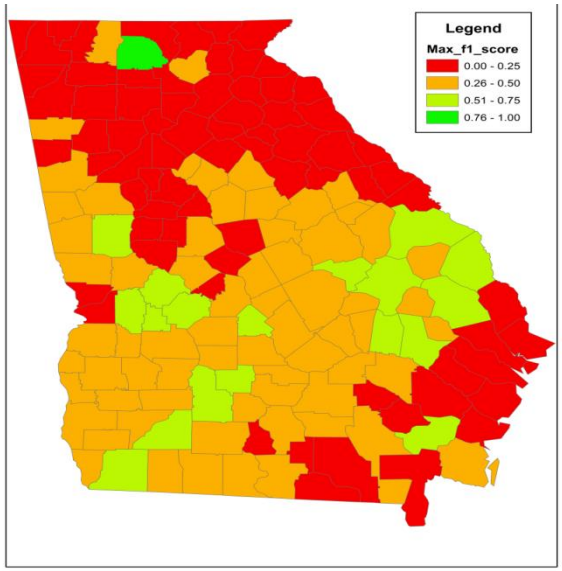
The burn forecasting tool is a decision tree model using fire weather and burn permit data.

- The model was trained with 2010-14 meteorological data at 18 fire weather stations in Georgia and burn permit data for each county.
- The weather forecast is used to predict if tomorrow will be a burn day in any county.



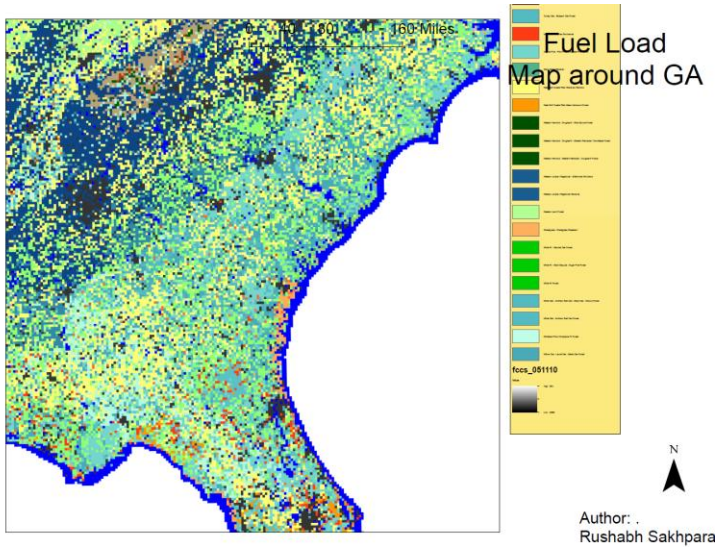
Chatsworth, Ga			Observed NFDRS-88 at 1300 EST Jul 20 2015					
RH (%)	IC	BI	Class Day	KBDI	Wind (mph)	Mx_Wind (mph)	Rn24 (inch)	Dur (Hr)
54	18	22	2 Moderate	359	S 2	S 9	0.29	2
Sow	Temp (°F)	Td (°F)	Tmax (°F)	Tmin (°F)	RHMax (%)	RHMin (%)	HrbGF	WdyGF
0	94	75	92	72	97	58	12	12

2015 Burn Forecast Evaluation: F1 Score



A bottom-up method for estimating prescribed burn (PB) emissions

- For each county, the average daily total burn area and typical burn sizes are calculated from permit records. The number of burns is determined and those burns are randomly distributed to managed lands.
- Burn emissions are estimated for forecasted burns using:
  - Fuel Characteristic Classification System (FCCS) fuelbed maps for fuel loads,
  - Fuel moisture forecasts for fuel consumption, and
  - Emission factors for Southeast USA fuels.

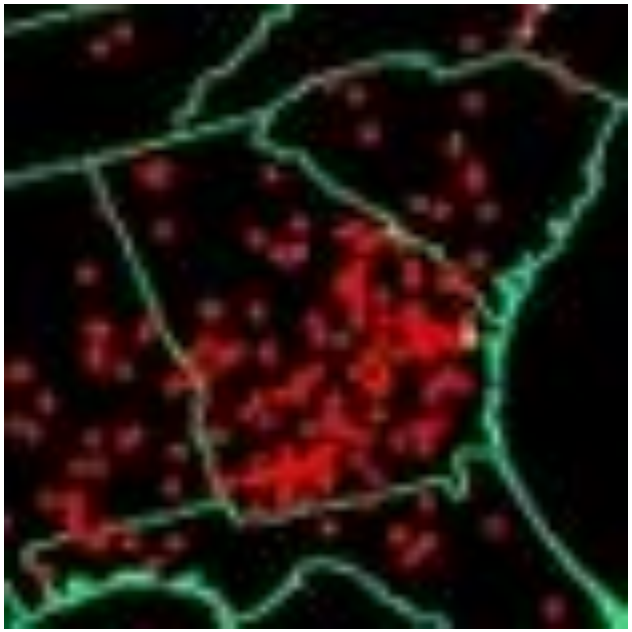


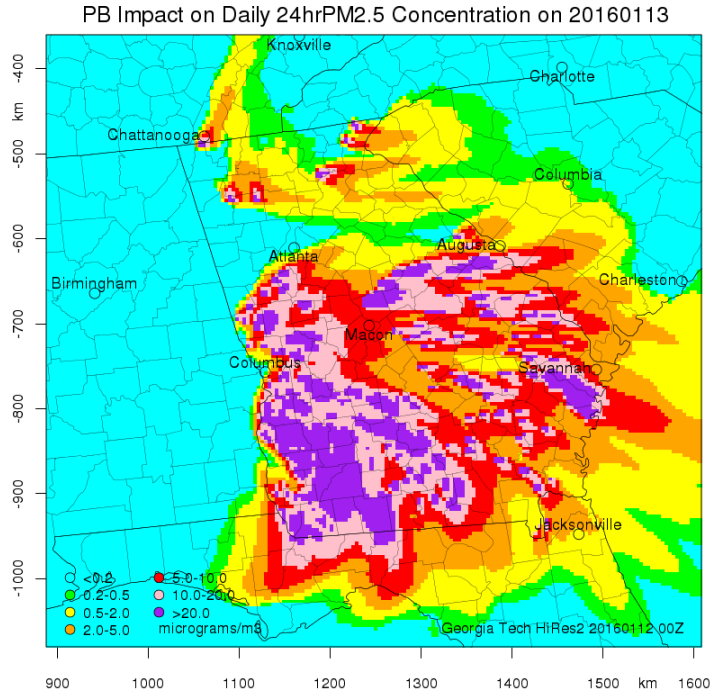
- Burn emissions are distributed to the vertical layers of the CMAQ model based on plume rise calculations.

Satellite fire & smoke analyses are used for evaluating the PB forecasts.

- We compare our forecast qualitatively to the Hazard Mapping System Fire and Smoke Analysis by NOAA.
- We give each day's forecast a rating based on the agreement in location and density of fires.

January 13, 2016: Rated very good

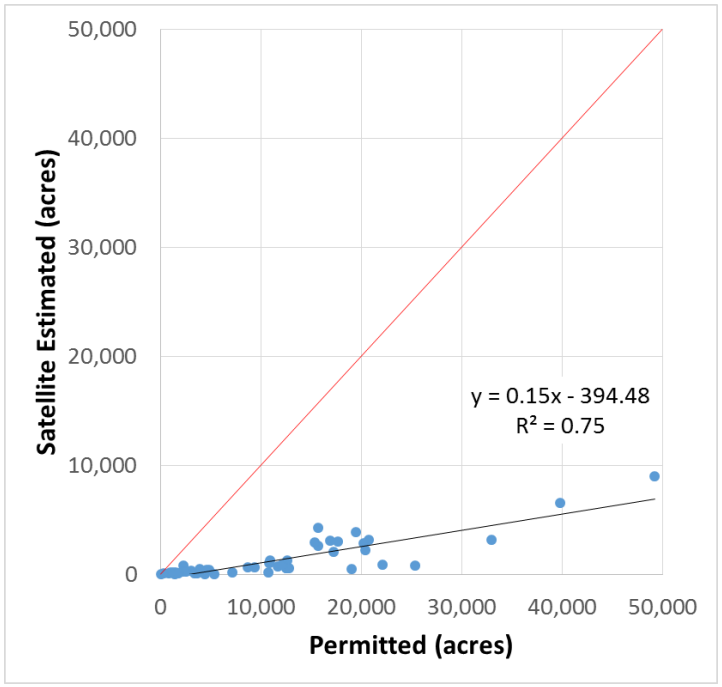




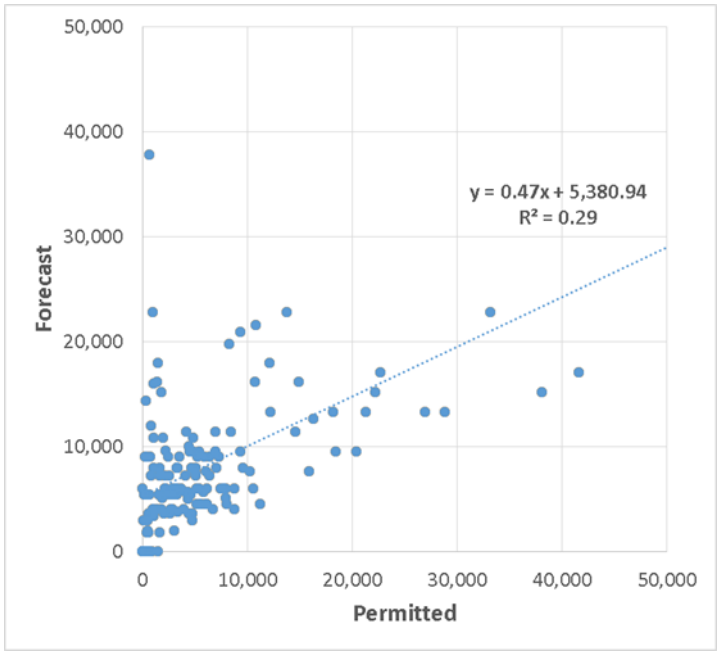
Burn areas from satellites and permit records are used for quantitative forecast evaluation.

- We compare our burn area forecasts to:
  - Burn areas provided by NOAA's Biomass Burning Emission Product for North America blended from GOES-E, GOES-W, MODIS, and AVHRR.
  - Burn areas permitted by the Georgia Forestry Commission

Satellite vs Permits



Forecast vs Permits



Complementary research: Why do satellites underestimate burn areas?

Deciduous forest

January
Slope = 0.33
R2 = 0.54

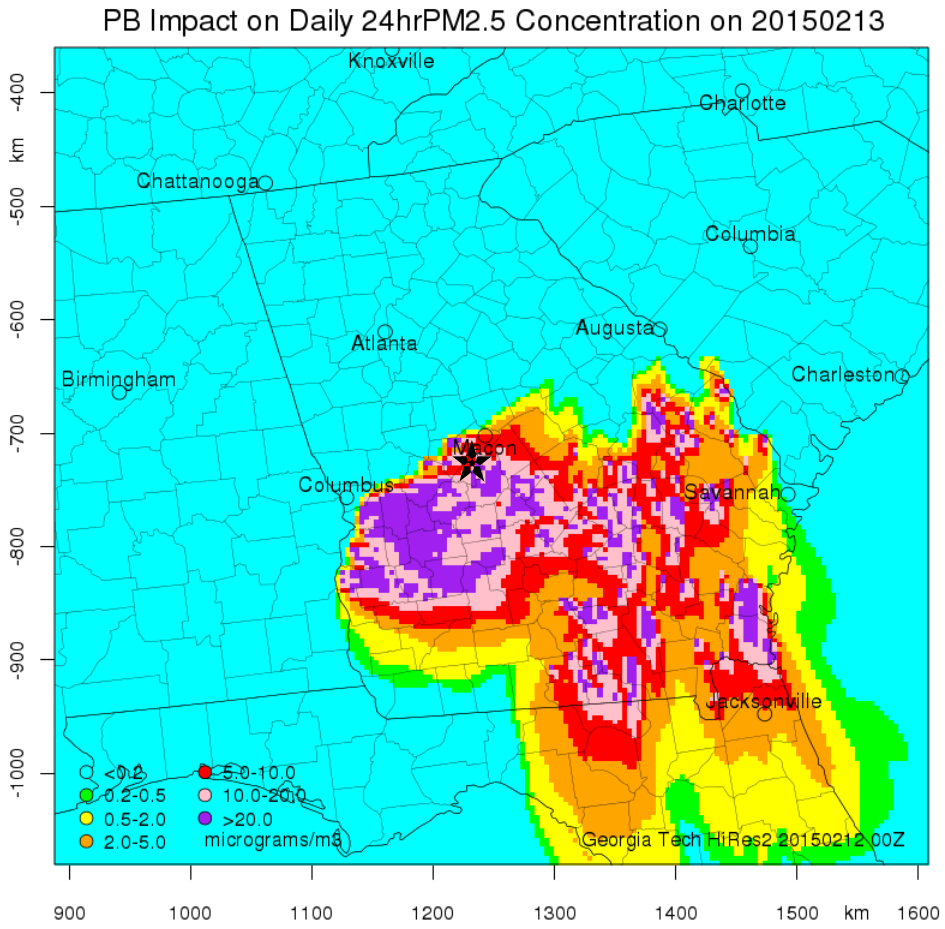
April
Slope = 0.02
R2 = 0.33

Coniferous forest

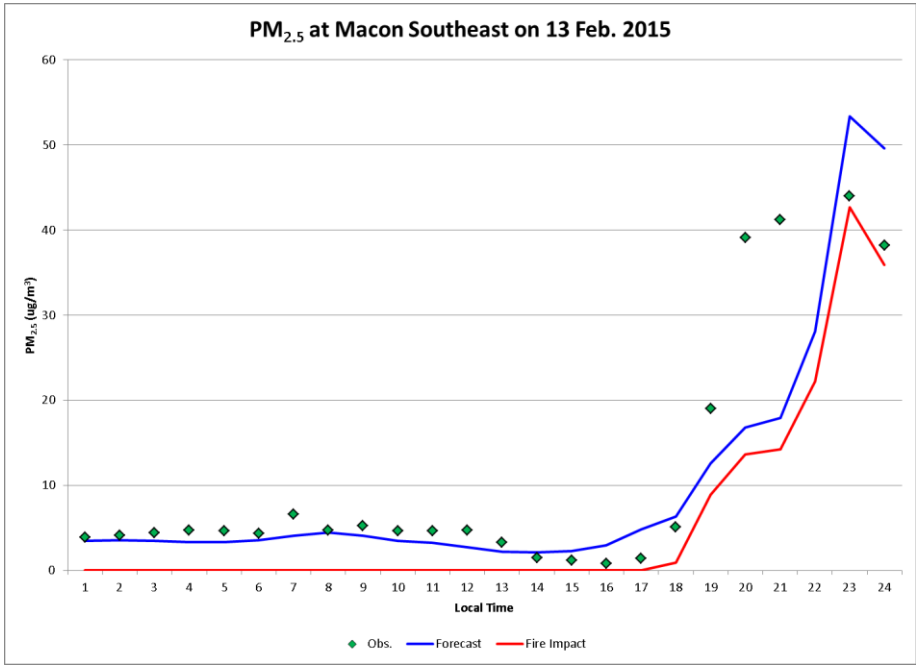
January
Slope = 0.17
R2 = 0.45

April
Slope = 0.21
R2 = 0.50

Ground-level $PM_{2.5}$ observations are used for evaluating the impact forecasts.

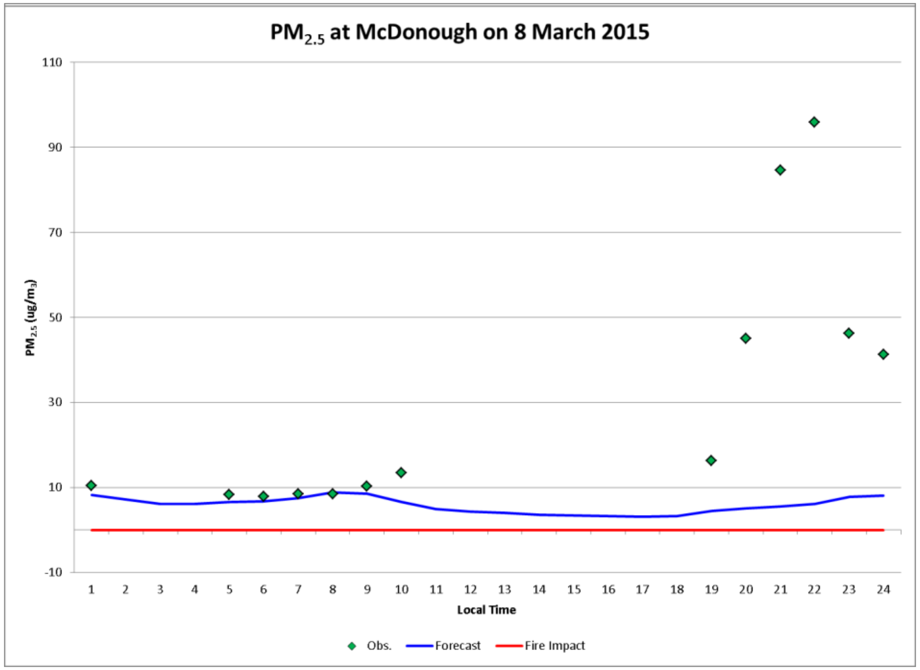


A perfect hit (true positive)

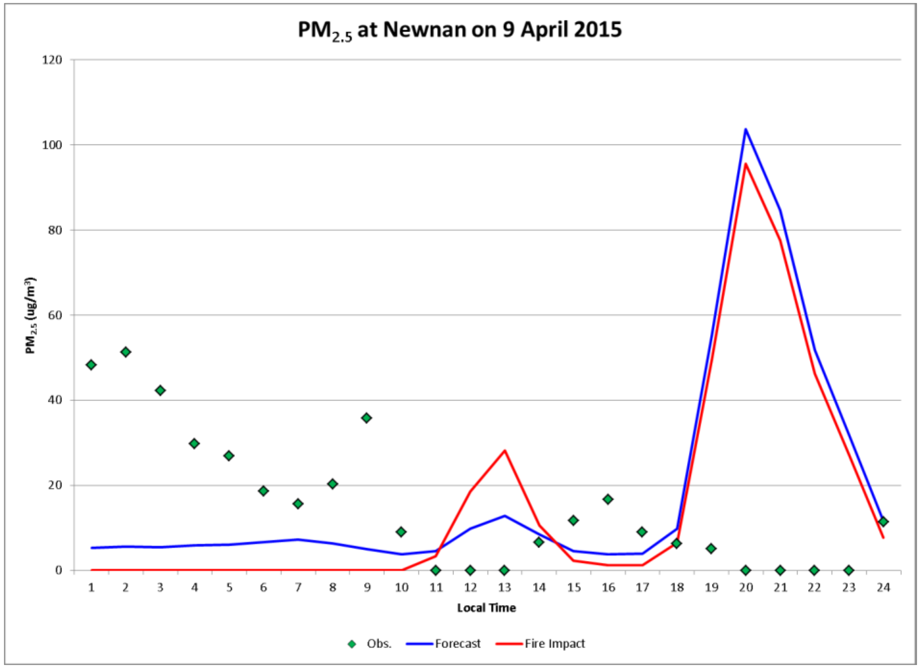


There is room for improvement.

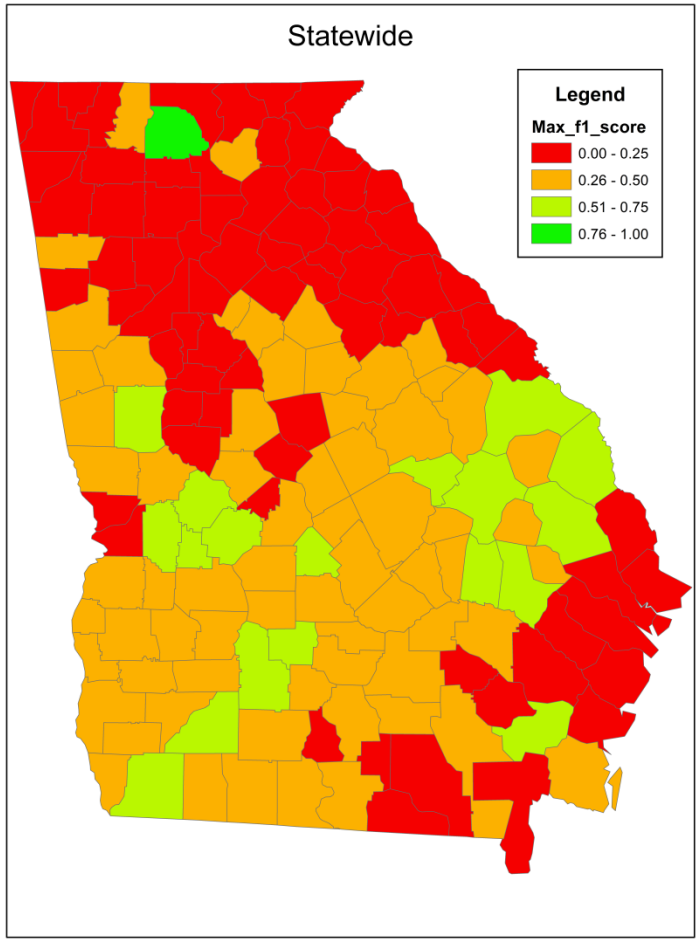
Another hit but underestimate
A miss (false negative)

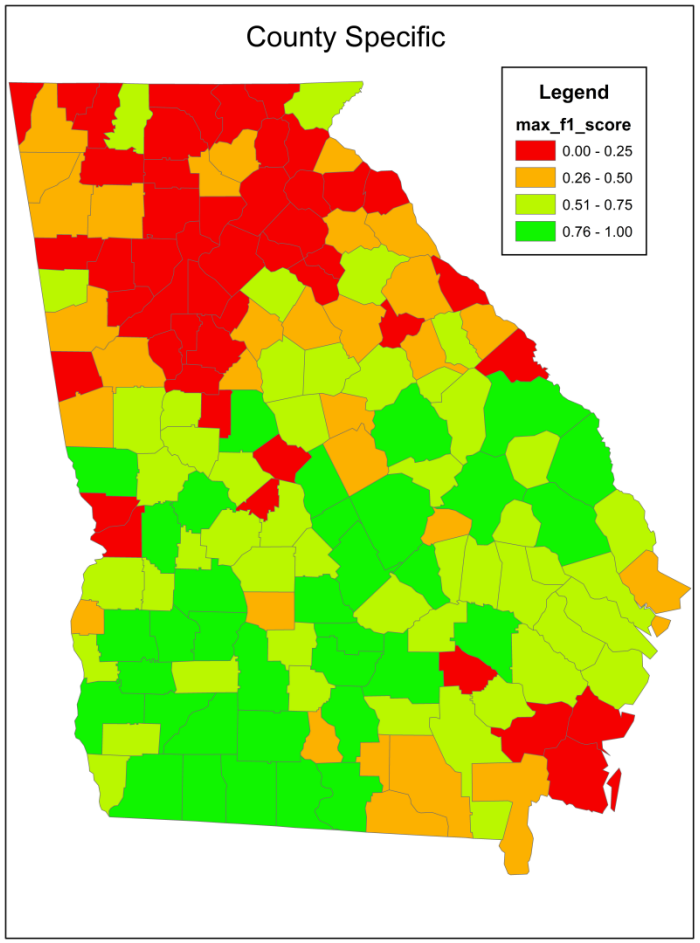


Another hit but overestimate
A false alarm (false positive)

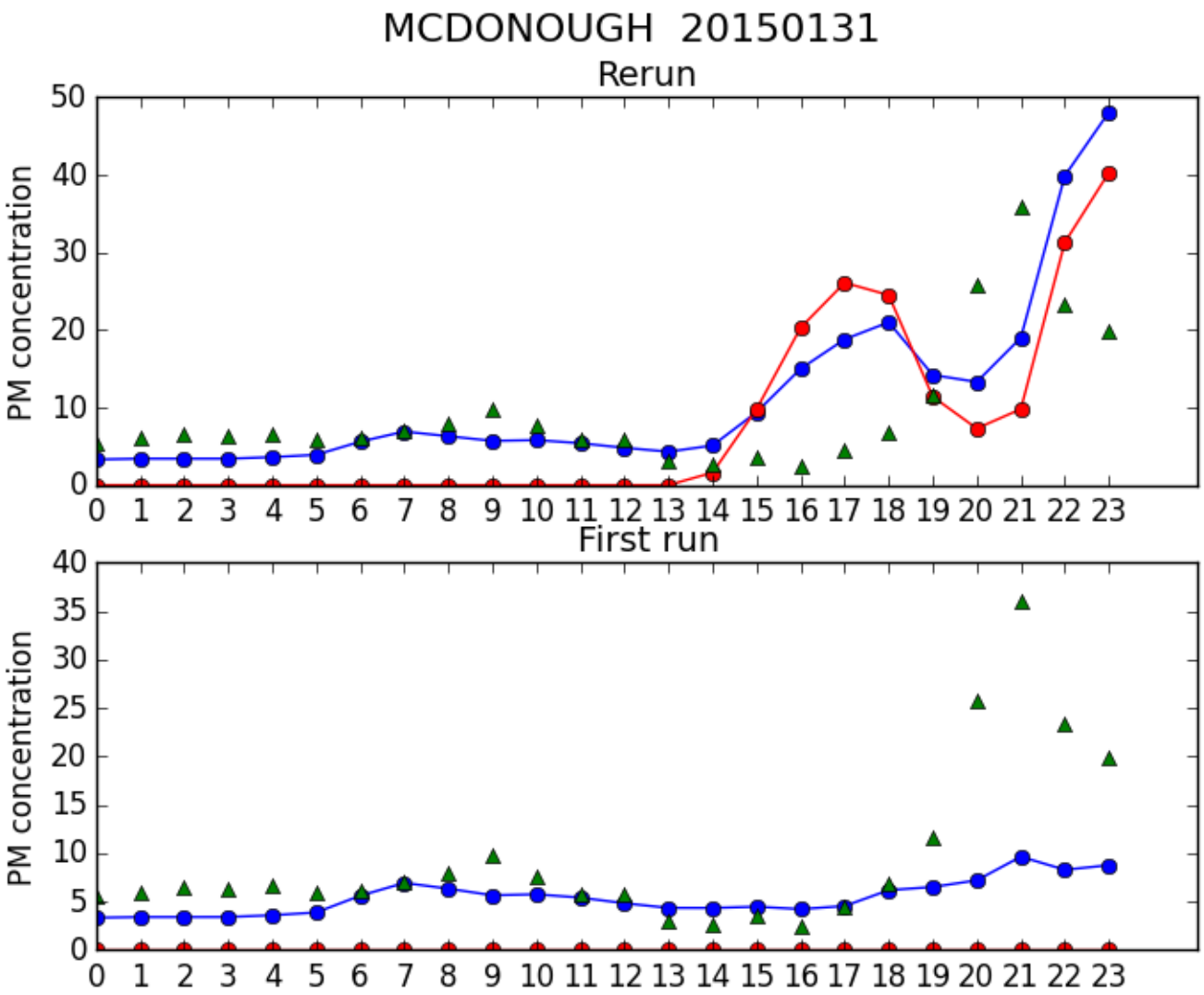


County-specific models perform much better than a single, statewide model.



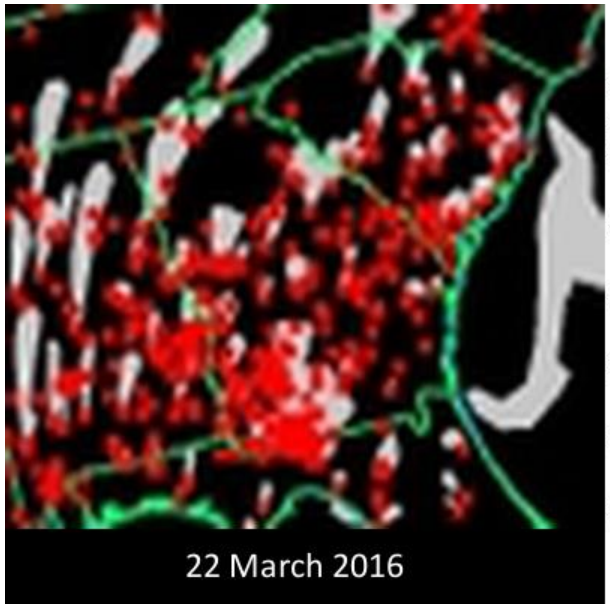


Improved burn forecasts lead to better burn impact forecasts.

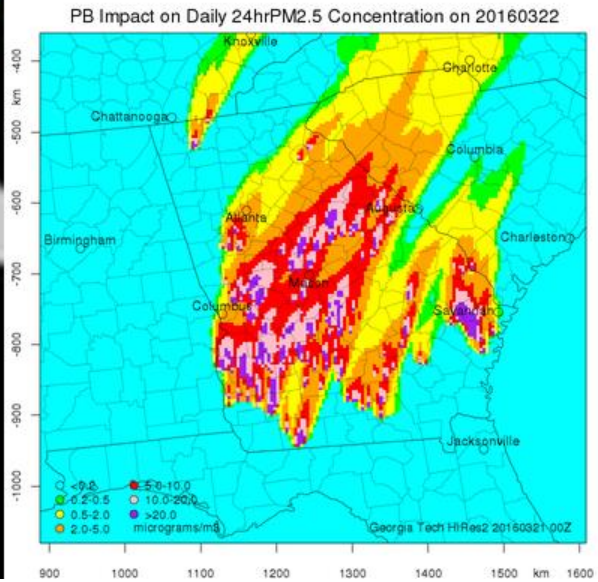


This year's burn forecasts are encouraging.

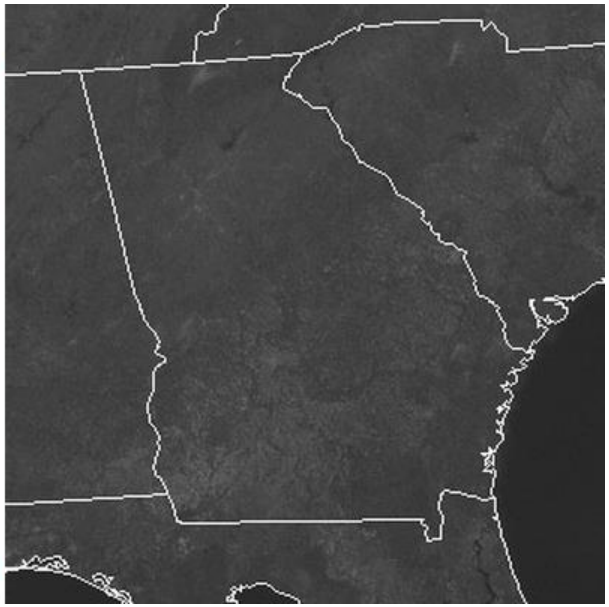
Fire & Smoke from Satellite



Our Burn Impact Forecast



Cloud Cover from Satellite



Summary & Conclusions

- We are forecasting source impacts using the Hi-Res2 air quality forecasting system (https://forecast.ce.gatech.edu).
- Forecasting PB impacts is beneficial not only for air quality management but for land/forest management as well.
- We are forecasting burn activity for accurate PB impact forecasts.
  - County-specific regression models yield much more accurate burn forecasts in 2016 than the statewide model used in 2015.
- Evaluation of the forecasted PB impacts is difficult.
  - Satellites do not always see the low-intensity prescribed burns.
  - Only a few cases of PB impacts are observed at the ground monitoring sites.

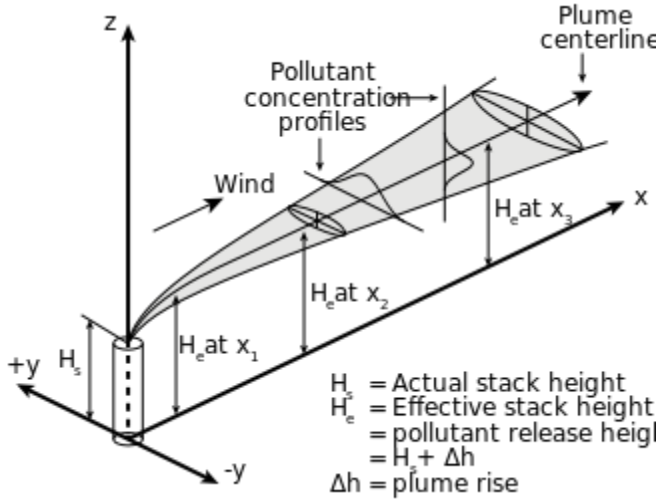
Future Research

- Evaluate performance for 2016 burn season
- Make burn impact forecast more useful for dynamic burn/air quality management
- Publications
  - Dynamic burn management concept
  - Burn impact forecasting and evaluation

- Expand the forecast to other states in the Southeast (FL, AL, SC)
- Use inexpensive sensor packs to detect burn impacts in unmonitored areas of the Southeast

How many acres to burn in each district/county without causing any air quality issues?

- We can compute the impact of burns in each district/county
  - Computationally too demanding
  - Currently we compute the impact of all burns statewide.
- Another approach is to partition the impact to burns upwind using another type of modeling (e.g., Gaussian plume)



$$C = \frac{Q}{u} \cdot \frac{f}{\sigma_y\sqrt{2\pi}} \cdot \frac{g_1 + g_2 + g_3}{\sigma_z\sqrt{2\pi}}$$

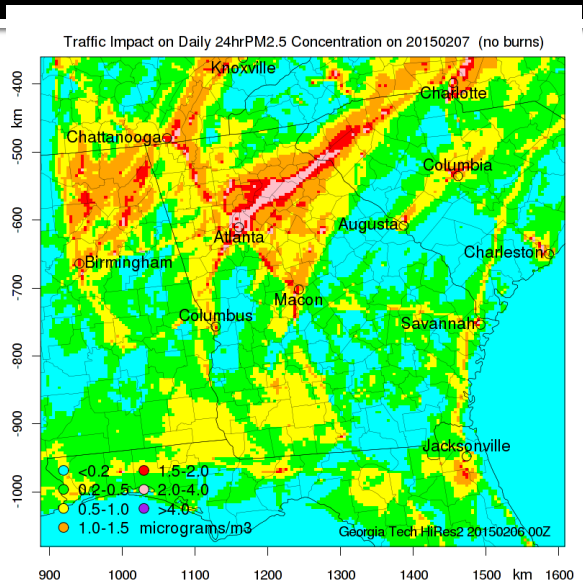
$$b_i = \frac{B}{\sum_{i=1}^{N} c_i} \times c_i$$ ← Total burn impact

$b_i \propto A_i$ ← Burn area

- Optimize A_i's for desired B

Potential collaboration: Source interactions (Impacts on $PM_{2.5}$)

Traffic Impacts w/o Burns



Traffic Impact on Daily 24hrPM2.5 Concentration on 20150207 (with burns)

Traffic Impacts with Burns

PB Impact on Daily 24hrPM2.5 Concentration on 20150207 (with burns)

Burn Impacts

Traffic Impact on Daily 24hrPM2.5 Concentration on 20150207 (with-no burns)

Traffic – Burn Interactions