Interactions of ecosystems, fires, air quality and climate change in the Southeast

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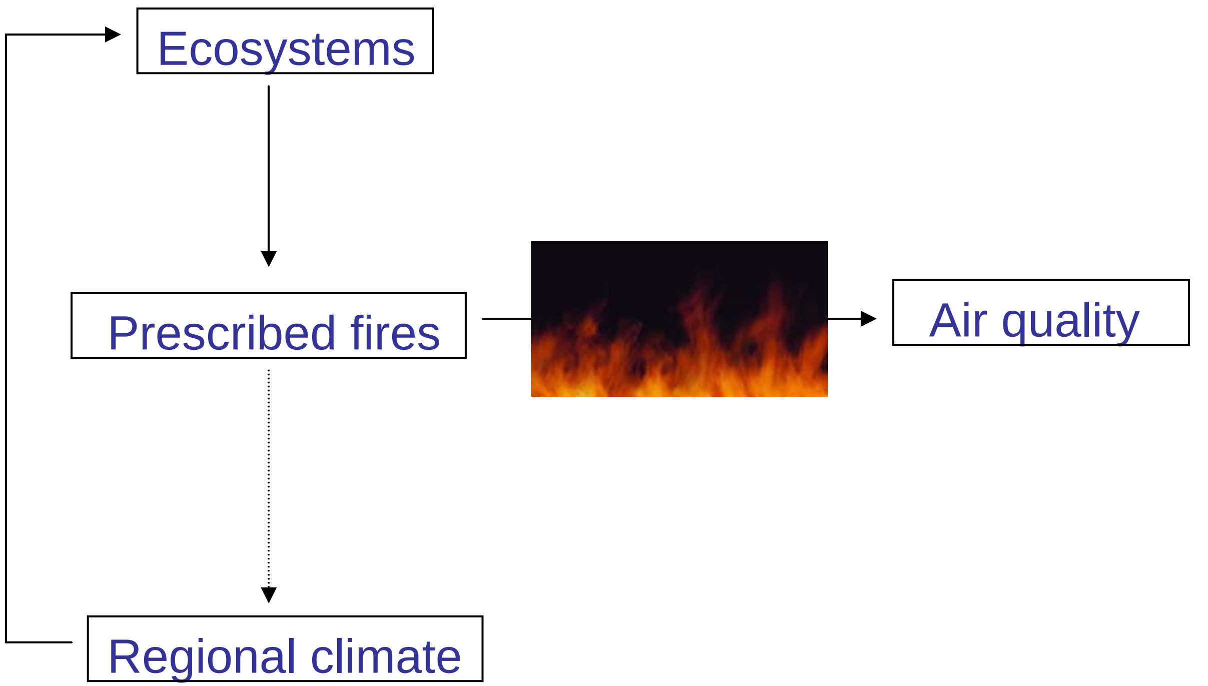


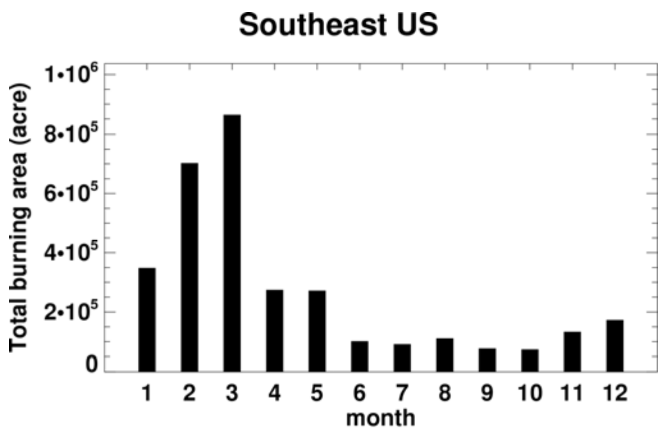
Two scientific questions

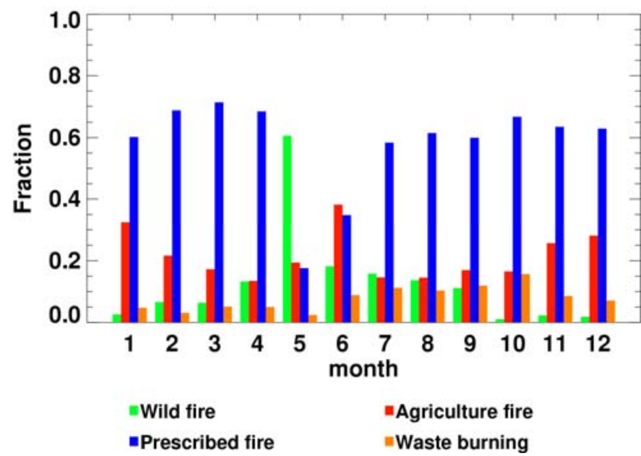
- How does prescribed fire emissions affect regional air quality in the Southeast at present?

- How does climate change affect fire emissions and their air quality impacts?

What are prescribed fires?

- The Southeast supplies 60% of US timber production
- Prescribed burning:
  - Reduce hazardous fuels
  - Manage competing vegetation
  - Improve wildlife habitat
  - Control insects and disease
- 8 million acres are burned annually
- Mostly under-story burning
- Only in recent years, their air quality impacts.are investigated





(VISTAS 2002)

1. Assessment of fire impacts in March

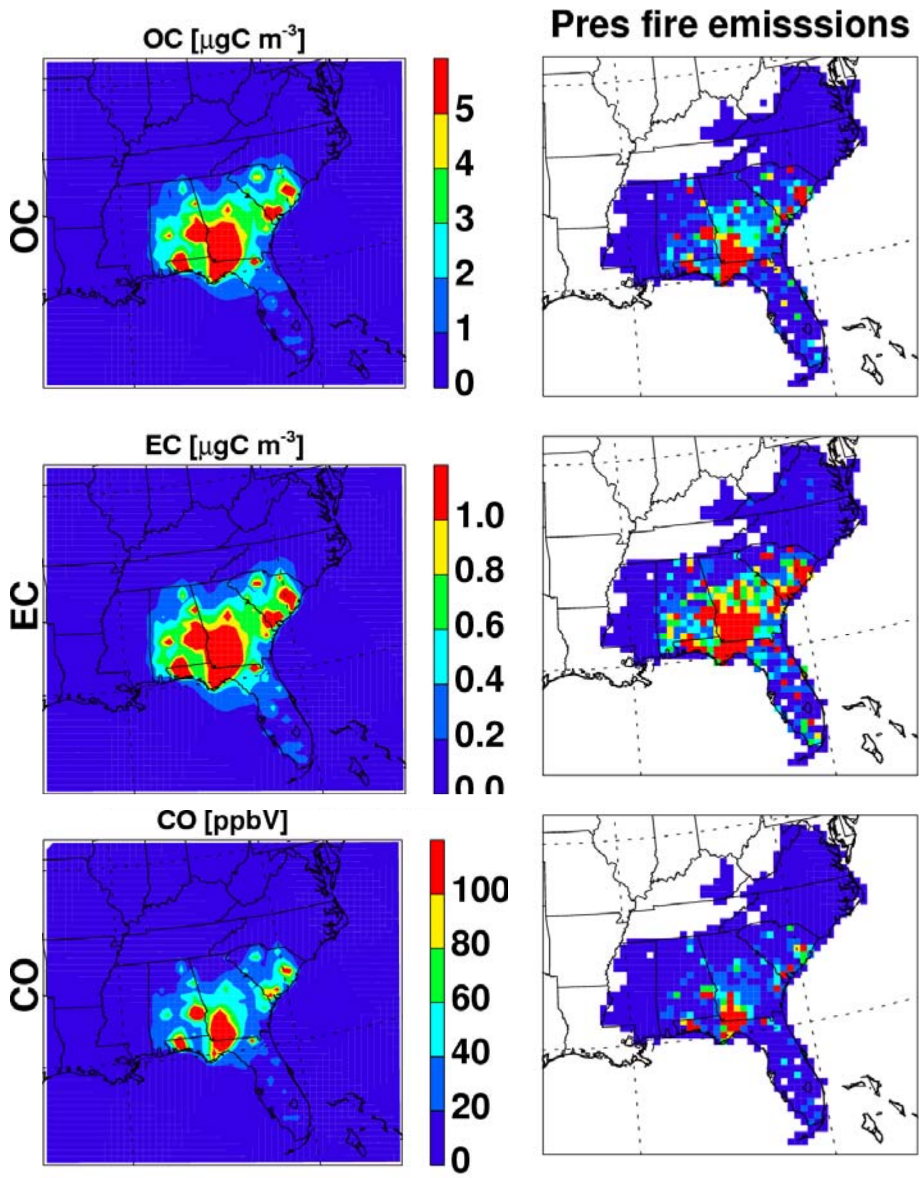
Model simulations & evaluations

Simulation

- SMOKE
- VISTAS emissions including fires
- CMAQ version 4.5
- SAPRC99_AE4_aq including SOA productions
- MM5
- March, 36x36 km^2

Measurements

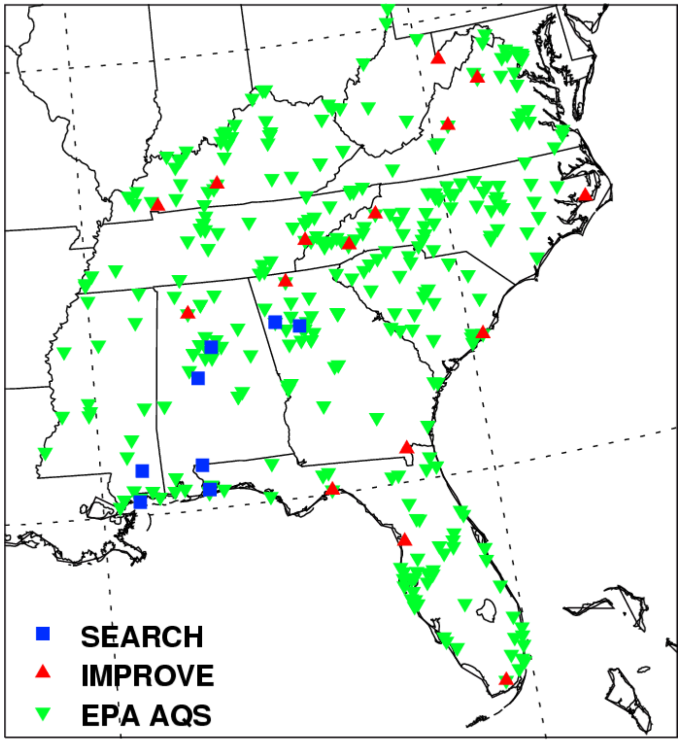
- Surface measurements of OC, EC, and CO
- Satellites: MOPITT CO and MODIS fire counts



Evaluation with surface observations

Statistics of model performance evaluation for ozone and CO.

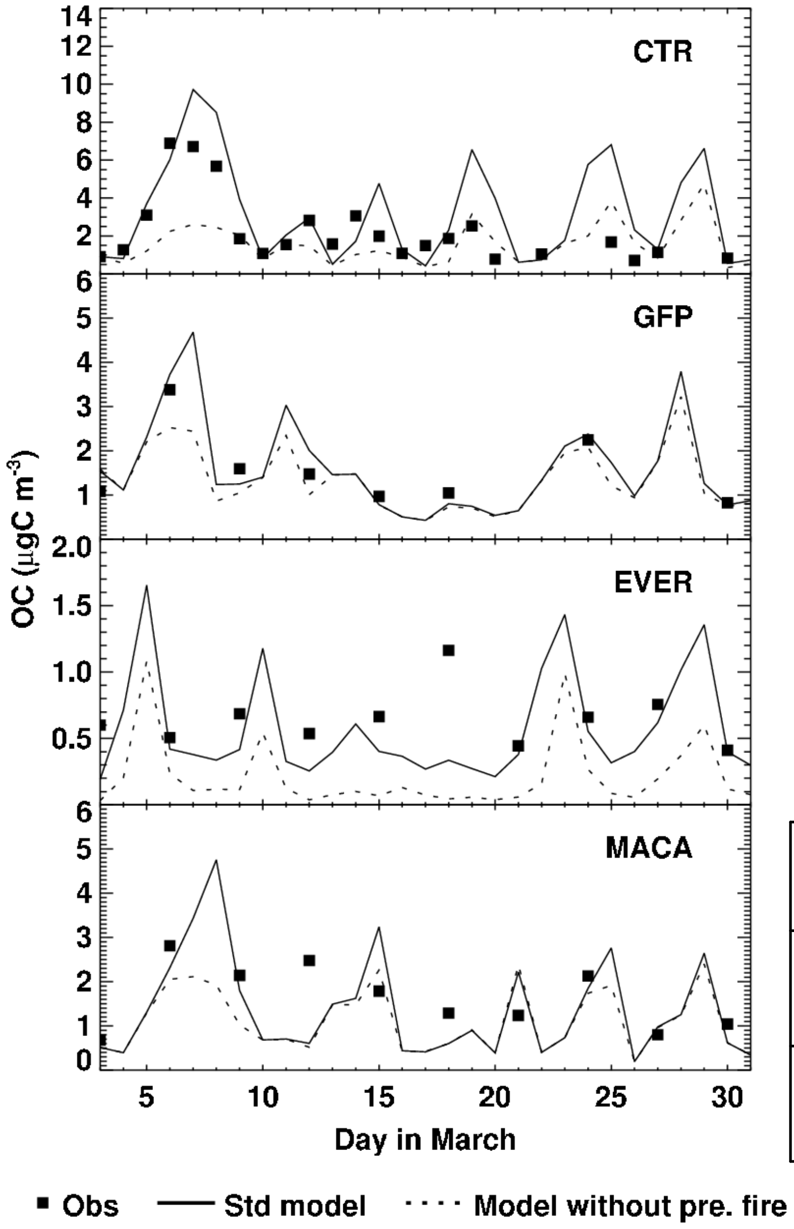
Species	O_Mean (ppbv)	S_Mean (ppbv)	Mean Bias (ppbv)	Mean Error (ppbv)	MNB (%)	MNGE (%)	APPA (%)
1-hr O_3	47.9	49.9	2.0	8.2	6.1	23.8	23.6
8-hr O_3	47.4	49.0	1.7	7.0	5.0	20.9	7.7
CO	279.0	250.1	-28.8	134.7	15.9	1.7	-15.4

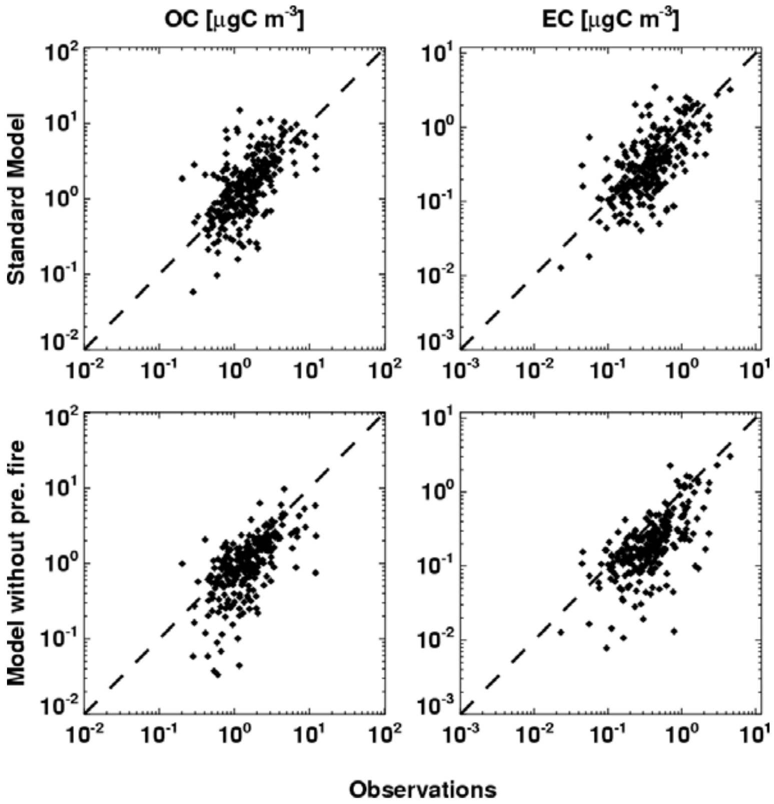


Statistics of model performance evaluation for OM, EC, and PM2.5

Species	Obs_Mean ($\mu g/m^3$)	Sim_Mean ($\mu g/m^3$)	Mean Bias ($\mu g/m^3$)	Mean Error ($\mu g/m^3$)	MFB (%)	MFE (%)
OM	2.69	3.13	0.44	1.61	5.3	35.0
EC	0.51	0.49	-0.02	0.28	-5.7	35.7
PM2.5	9.71	9.83	0.12	4.16	-2.4	30.0

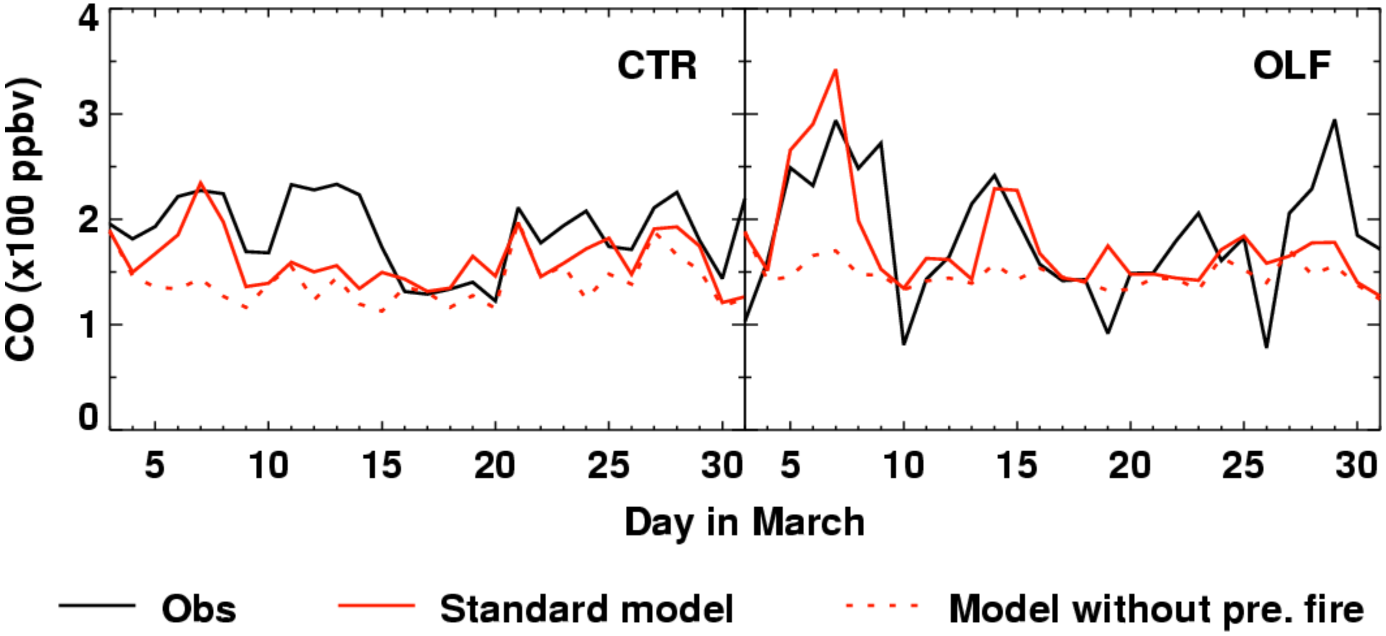
Impacts of prescribed fires on OC and EC





		Observation (μgC m^{-3})	Model w/ fire (μgC m^{-3})	Model w/o fire (μgC m^{-3})
OC	Mean	1.92	2.24	1.33
	Median	1.49	1.54	1.00
EC	Mean	0.51	0.49	0.29
	Median	0.37	0.30	0.18

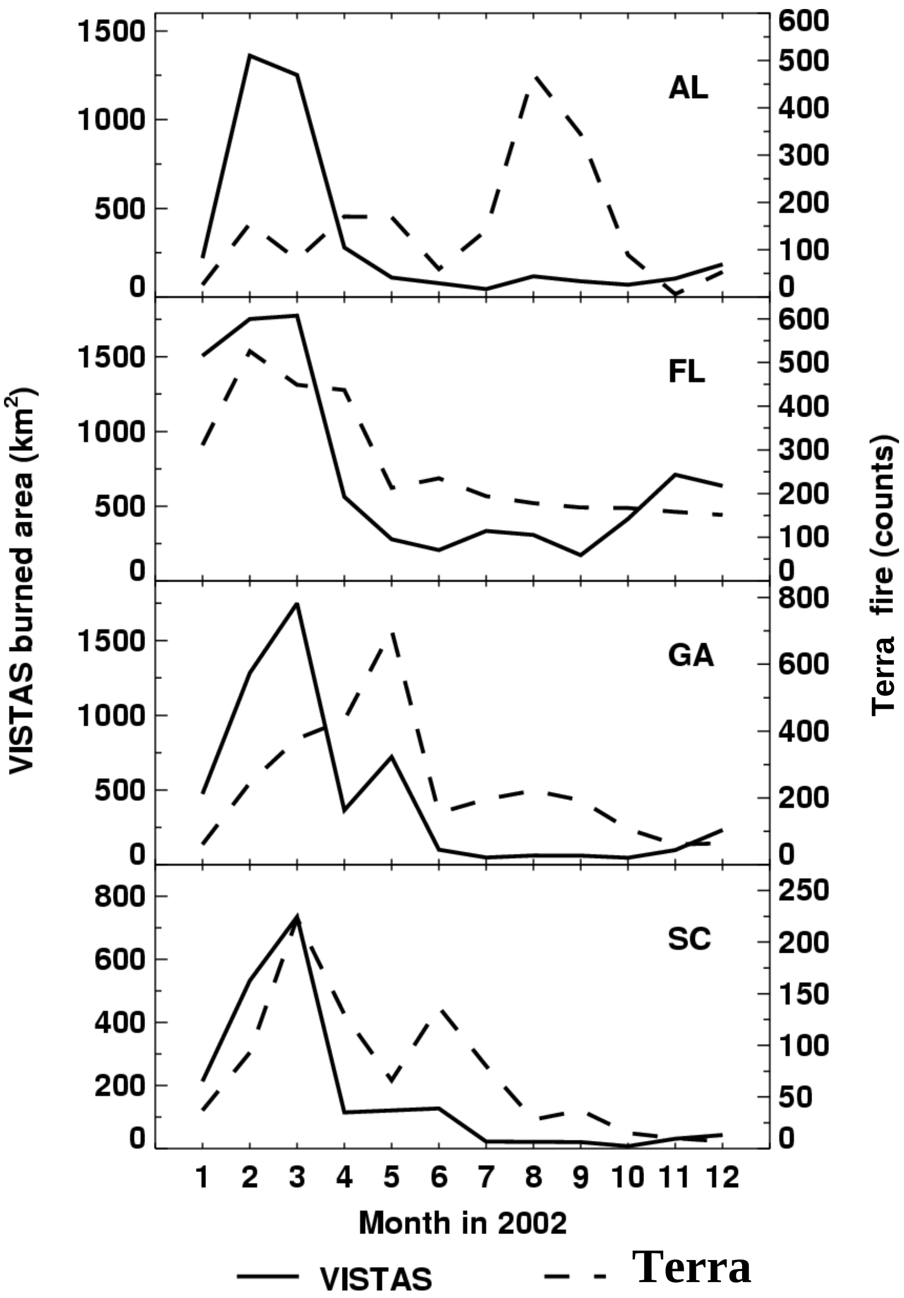
Impacts of prescribed fires on CO



2. Can satellite fire detections improve the emission inventories from forest fires in the southeastern United States?

• Combustion condition is different from wildfires: lower fire temperature (~440K); Canopy effects

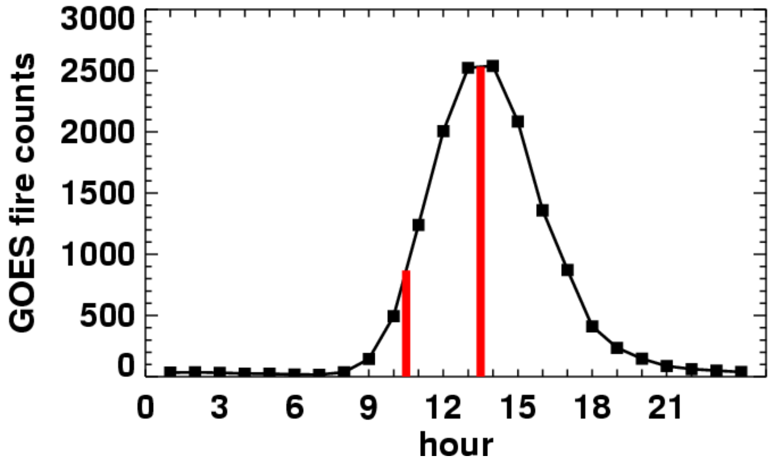
• A direct comparison between VISTAS emissions and Terra MODIS measurements suggest significant discrepancies in the summer but also in spring.



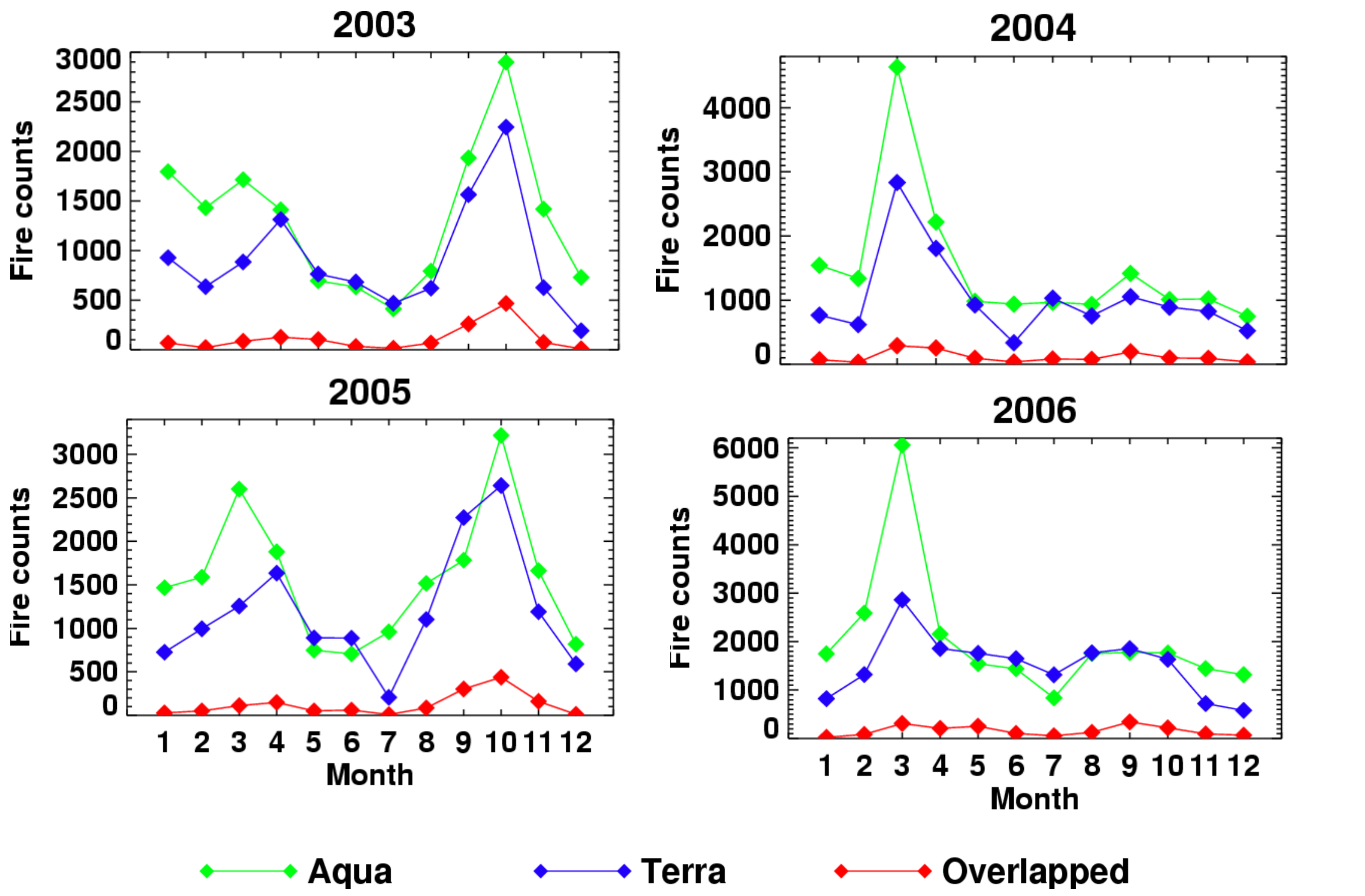
Terra vs. Aqua MODIS

- Aqua MODIS fire data are available after July, 2002
- According to the diurnal fire patterns from GOES, fire counts between 10-11 am (Terra MODIS) is about 30% of that between 1-2 pm (Aqua MODIS) over the SE US, although GEOS's resolution is coarse and could miss some fire activities.

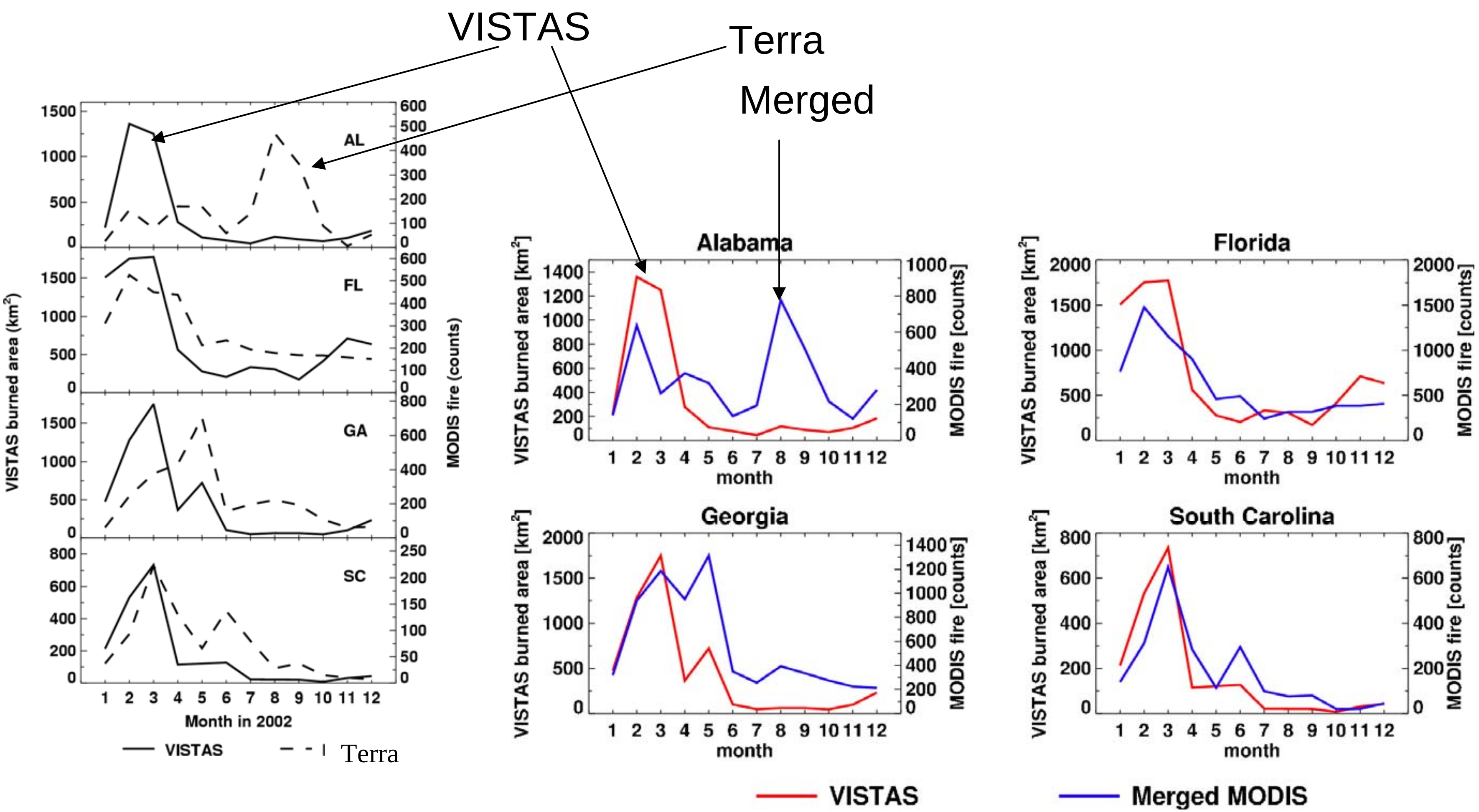
Instrument	*Satellite*	*Spectrum (μm)*	*Fire product Resolution*	*Local Crossing Time*
MODIS	Terra	4, 11	1x1 km^2	10:30 am/pm
MODIS	Aqua	4, 11	1x1 km^2	1:30 pm/am
VAS	GEOS	3.9, 10.7	4x4 km^2	15-min interval



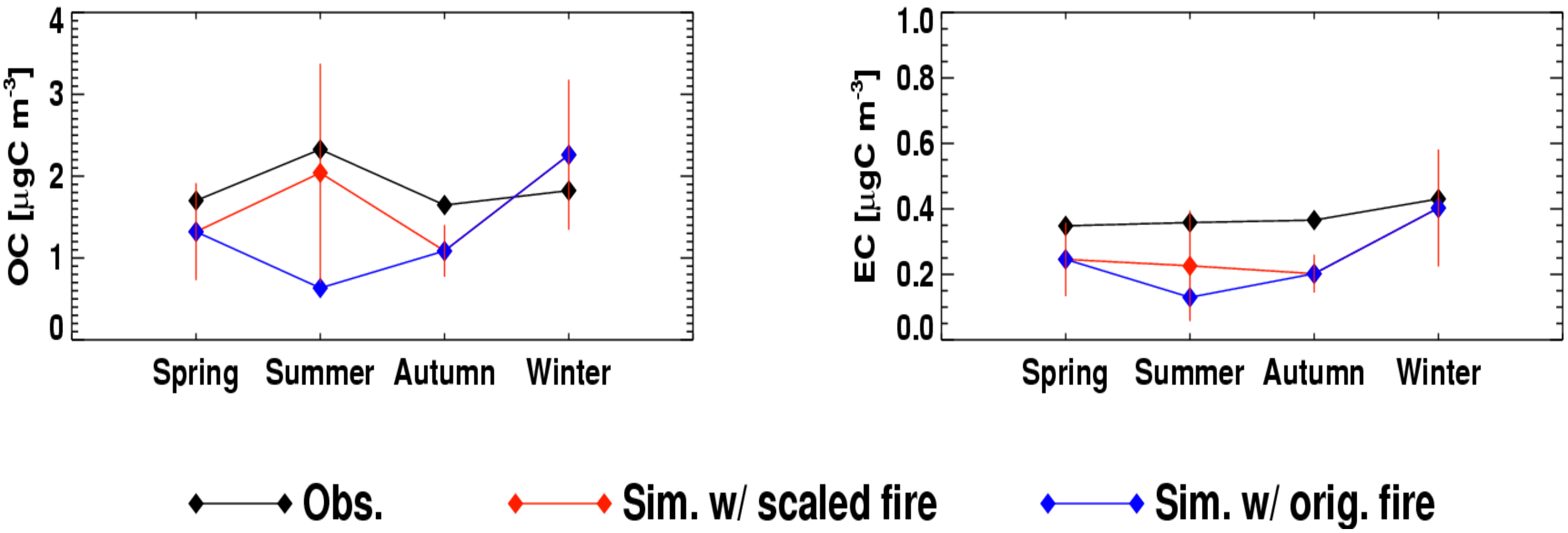
Aqua observes more fires than Terra in spring. We project 2002 Aqua MODIS fire counts based on 2003-2006 relationship and then merge the two datasets of Terra and projected Aqua.



Merged MODIS products show better agreement with VISTAS emissions. However, the large summer difference remains



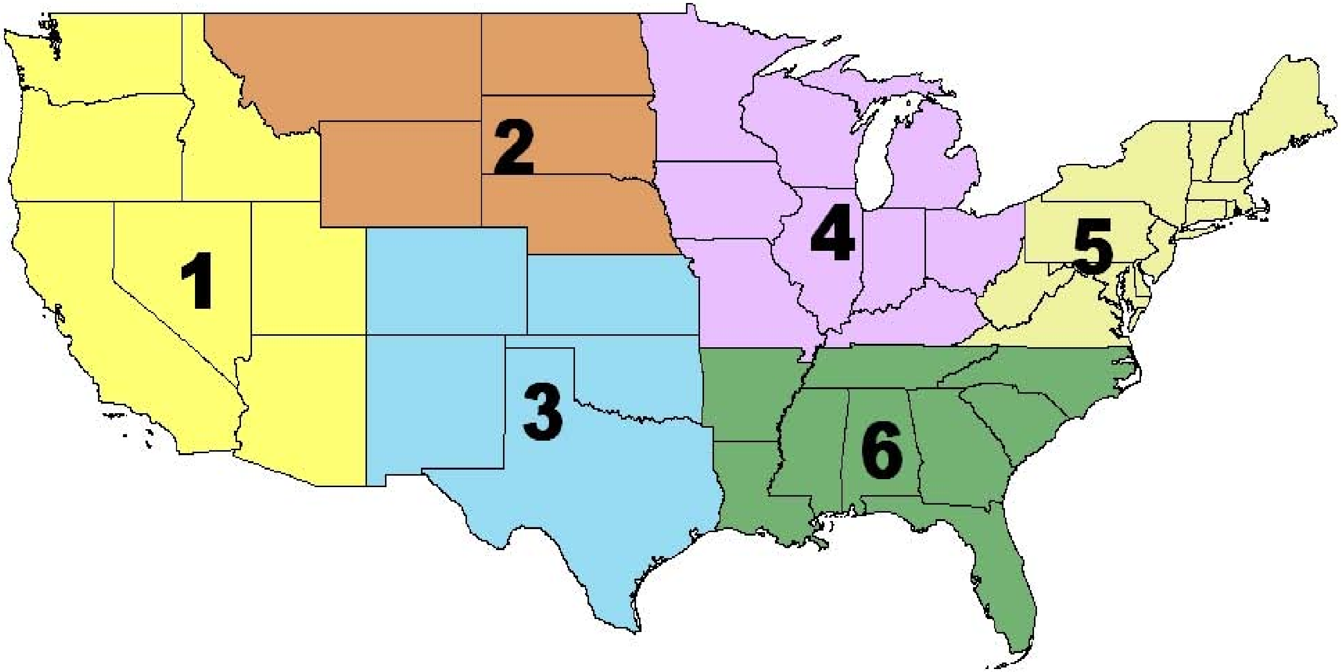
Scaling fire emissions with MODIS measurements, the model predicts large increases in simulated OC and EC, in better agreement with the observations



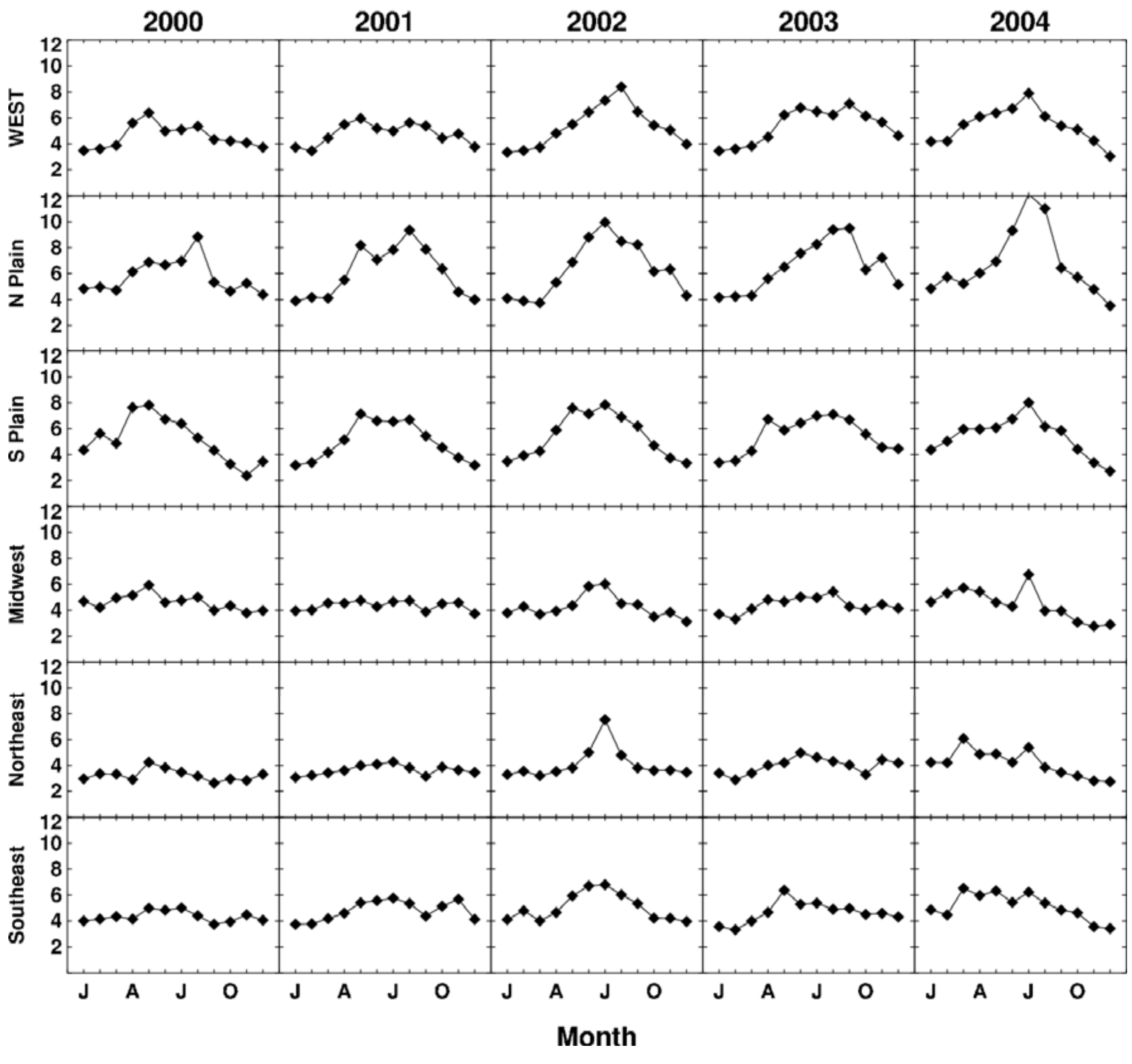
3. Does fire emissions in other regions affect the Southeast?

Analysis of IMPROVE OC/EC measurements between 2000-2004

- ~170 sites
- Continental US is examined by dividing into 6 regions, 1. West, 2. Northern Plain, 3. Southern Plain, 4. Midwest, 5. Northeast, and 6. Southeast.



Monthly OC/EC ratios from 2000 to 2004



Possible reasons

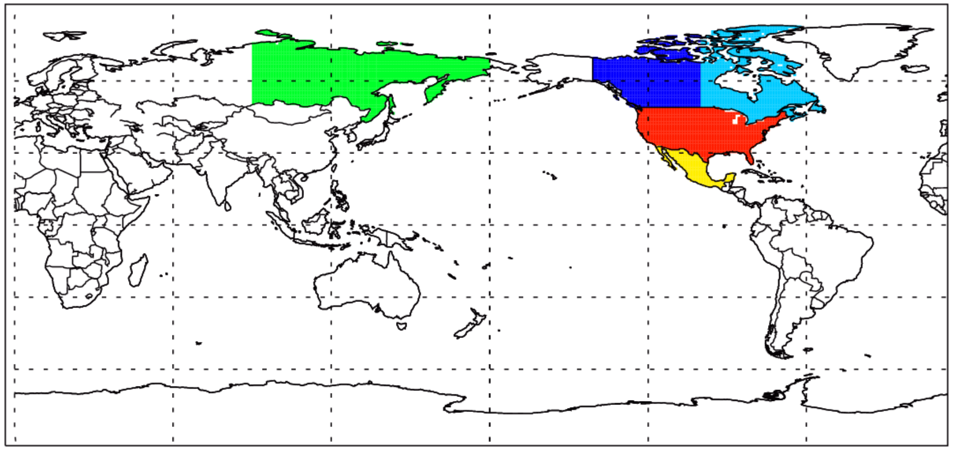
- Large-scale biomass burning

- Secondary organic aerosol
  - Biogenic SOA formation
  - In-cloud SOA production

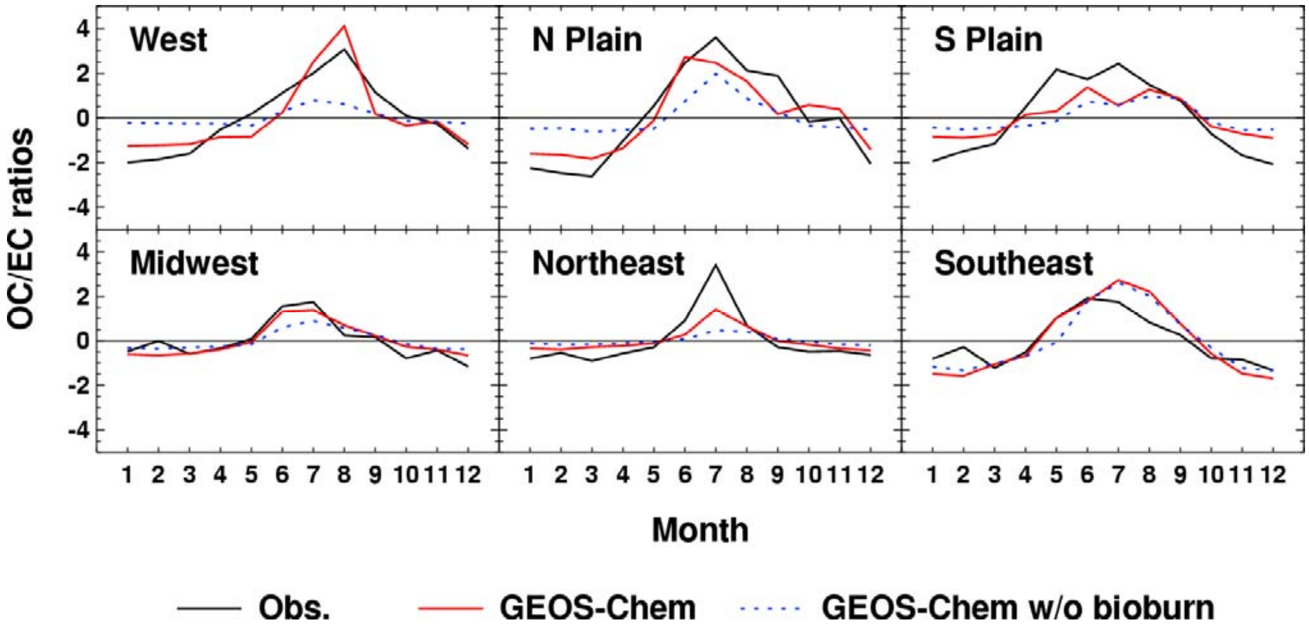
- Transpacific transport

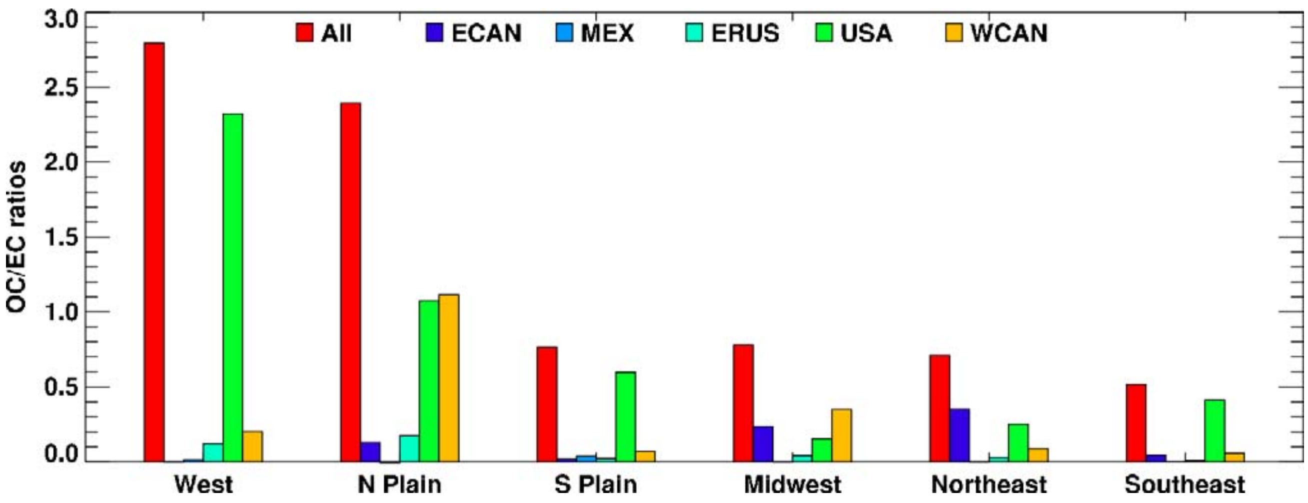
GEOS-Chem simulations

- GEOS-Chem v7-03-06 [*Bey et al., 2001*]
- Biomass burning emissions of OC and EC from Global Fire Emissions Database (GFED) version 2 [*van der Werf et al., 2006*].
- SOA from terpenes
- Sensitivity simulations to identify the regional source contributions



Regional contributions





4. Impacts of climate change on ecosystem, fire emissions, and air quality

Estimating fire emissions in 2050

- **Fire Emission = Burned Area** x **Fuel loading** x **Emission Factor**

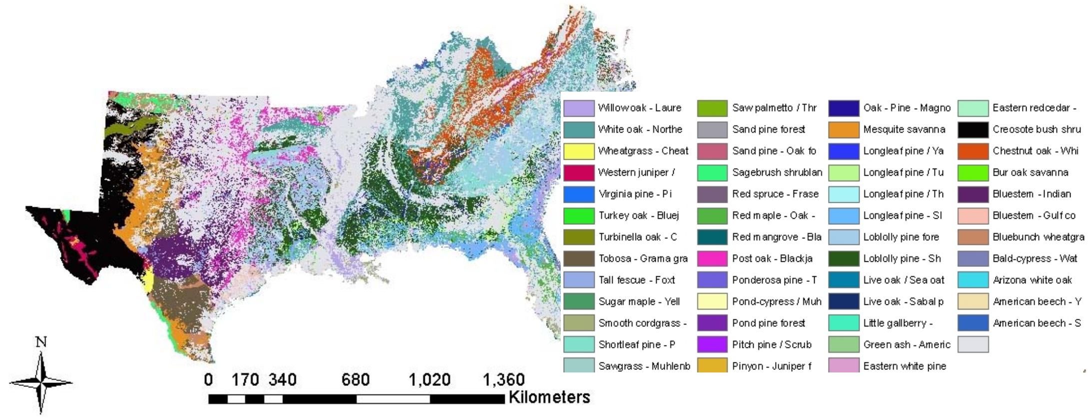
- **Fuel loading projection**
  The base fuel loading condition is provided by Fuel Characteristic Classification System (FCCS) map developed by USDA Forest Service (Roger Ottmar). The Dynamic Land Ecosystem Model (DLEM) at Auburn University is used to estimate the temporal and spatial patterns of fuel loading driven by the meteorological simulations in 2002 and 2050.

- **Future climate**
  Future climate in 2050 is simulated based on IPCC A1B scenario. GISS GCM is used for the climate simulation (Mickley, et al., 2004). The global outputs were downscaled to 36-km North America model domain using the MM5 (Leung et al., 2005).

- **Emission prediction in 2050**
  The future emission up to 2020 was developed by following the Clean Air Interstate Rule (CAIR) controls. From 2020 to 2050, the emissions were predicted based on IPCC A1B scenario by the Integrated Model to Assess the Global Environment (IMAGE) model (www.mnp.nl/image) [Woo et al., 2008].

Fuel loading estimate in 2050

Fuel Characteristic Classification System (FCCS, Ottmar et al.) → Current annual mean fuel loading



Current annual mean fuel loading ↓

Fuel Loading in 2002 and 2050

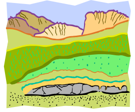
↑ Spatial and temporal distributions of biomasses

Dynamic Land Ecosystem Model (Auburn U.) → Spatial and temporal distributions of biomasses

Climate (TEMP,PPT)

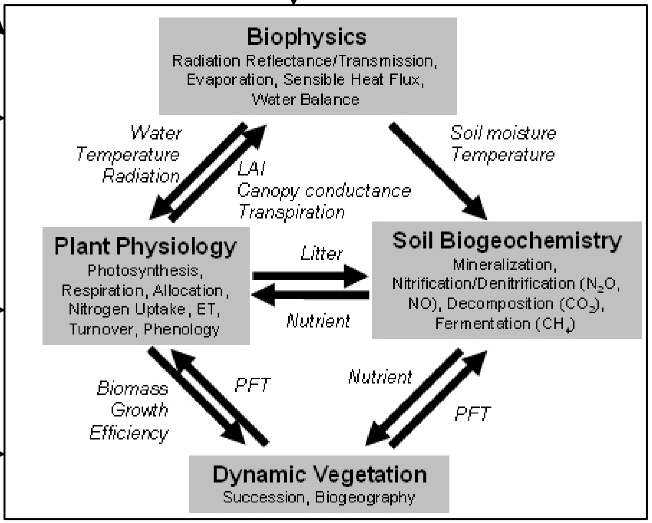
Atmospheric CO2

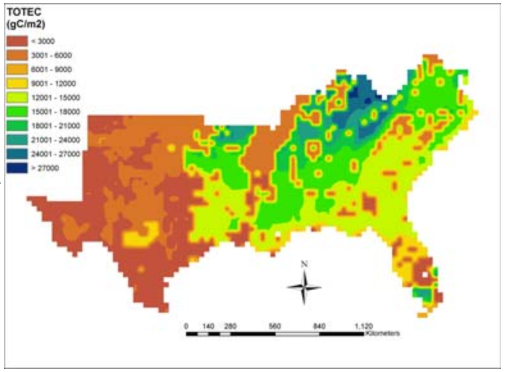
Soil (BD, PH, DEPTH, SILT, CLAY)



Topography (ELEV, SLOPE, ASPECT)

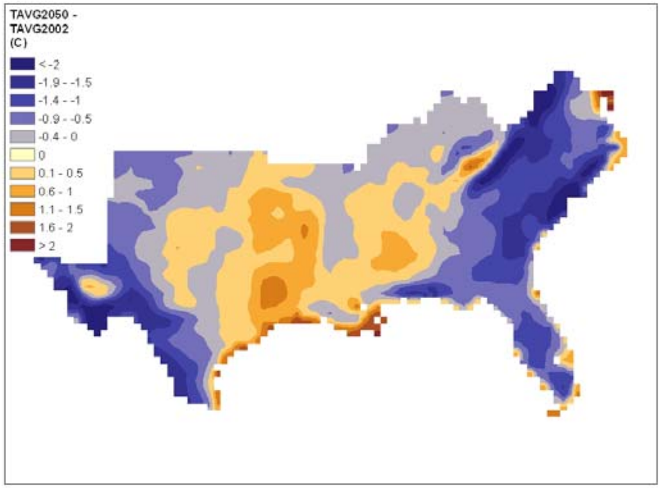
VEGETATION

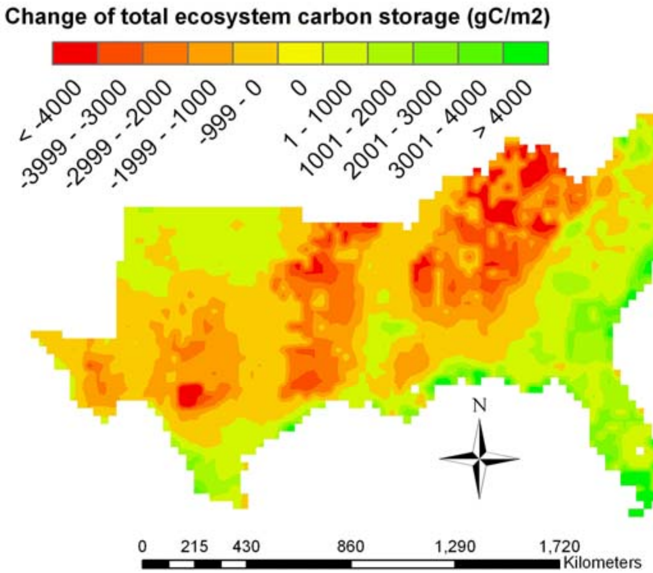




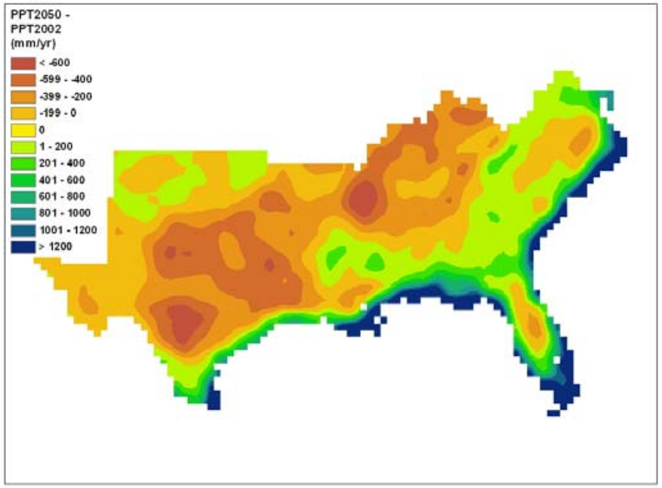
Fuel loading in 2050

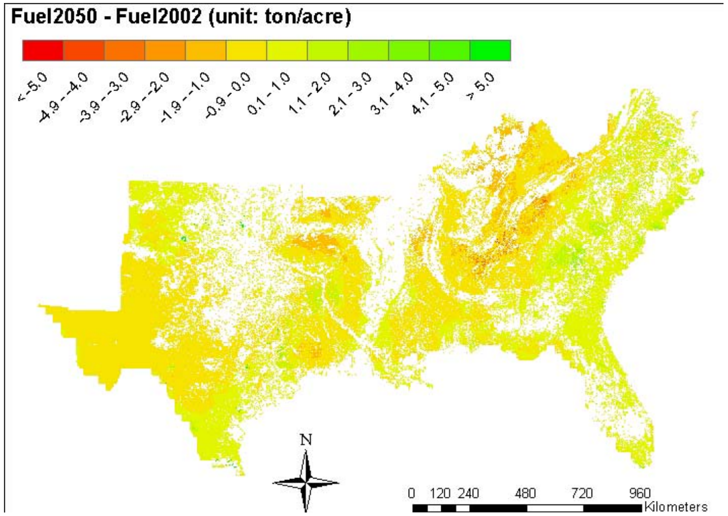
Temperature changes (2002 vs. 2050)



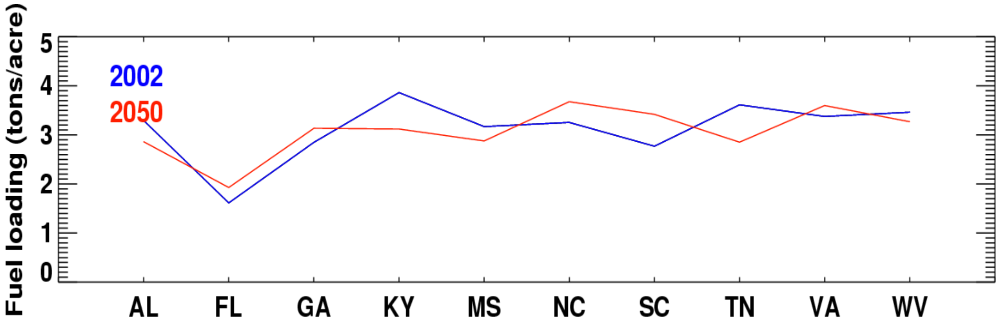


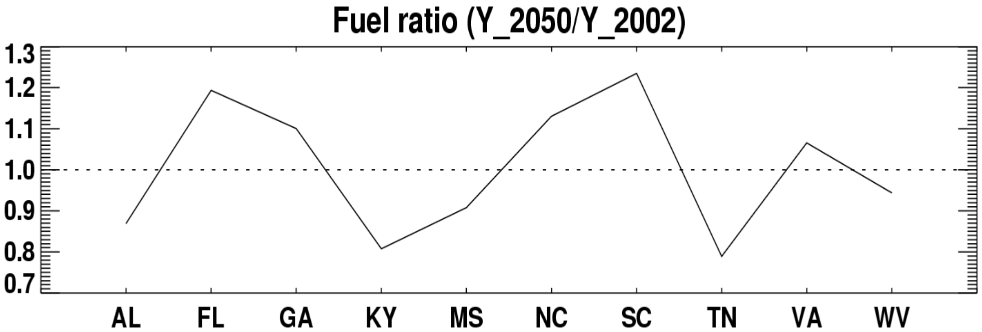
Precipitation changes (2002 vs. 2050)



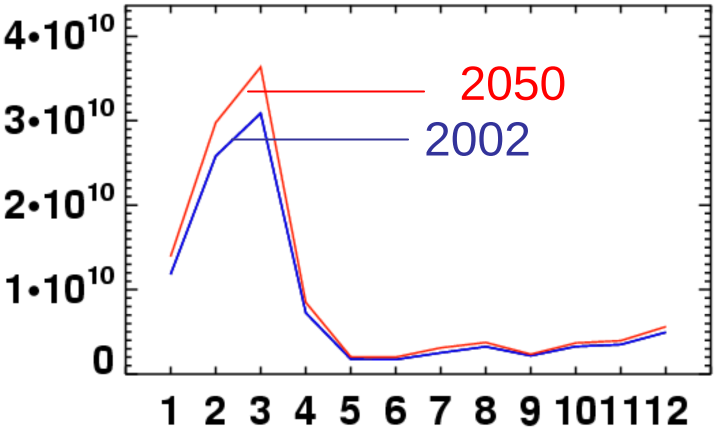


Projected fuel loading and fire emissions

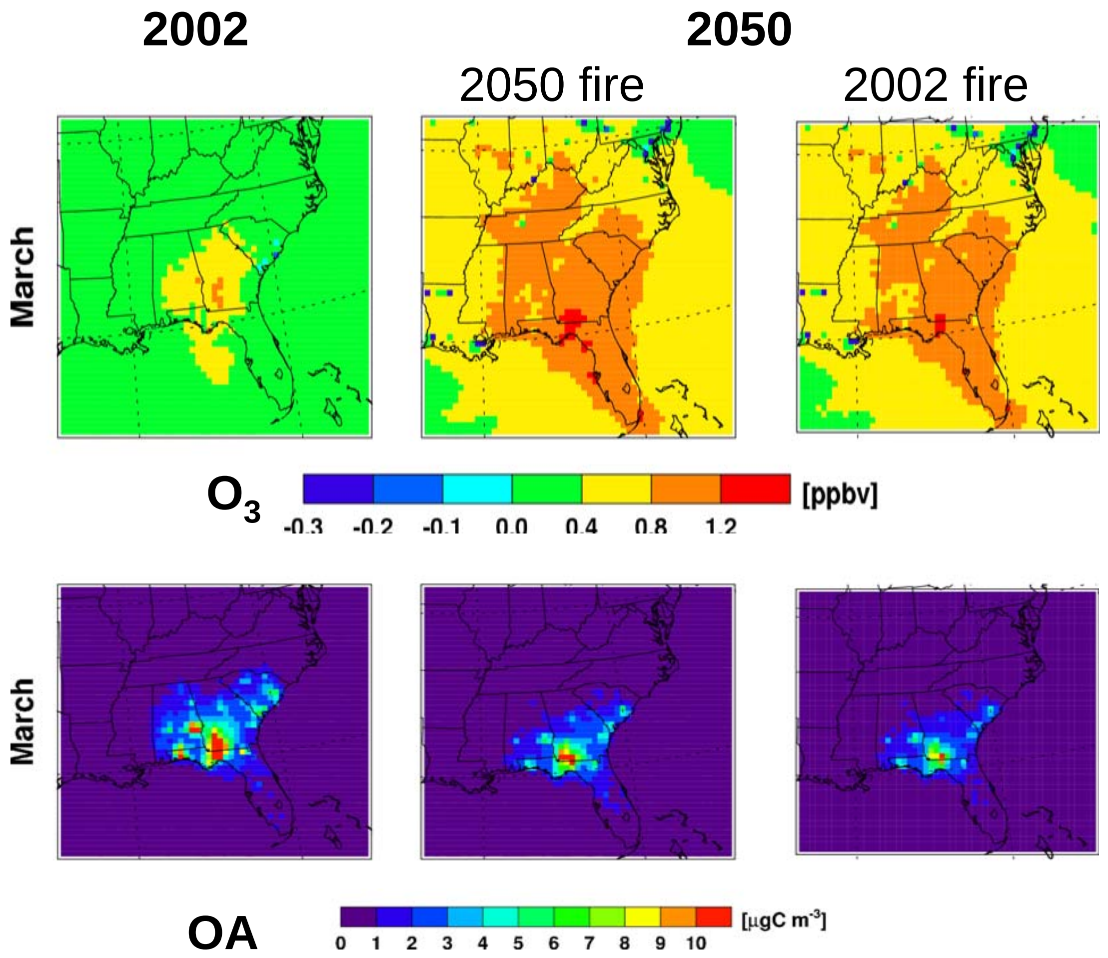


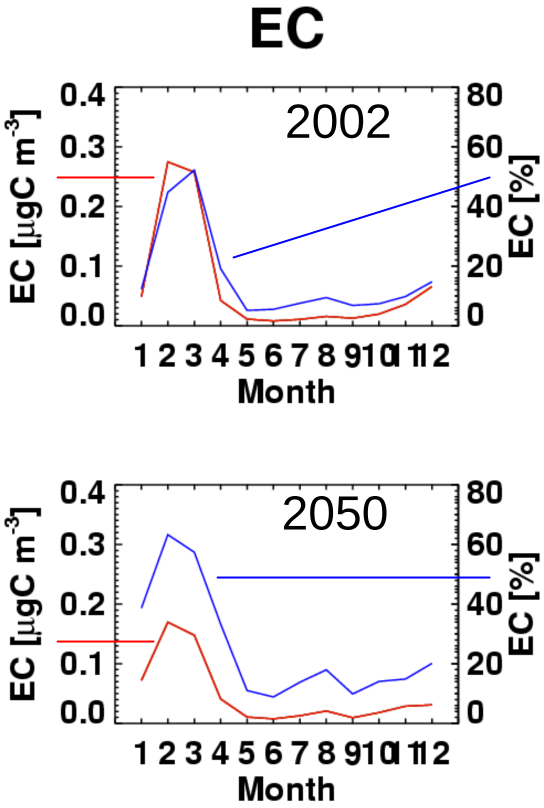


OA from fire emissions



Impacts of fire emissions





Conclusions

- In March 2002, estimated prescribed fire emissions lead to ~50% enhancements of mean OC and EC concentrations in the Southeast and a daily increase of PM2.5 up to 25 $\mu g\ m^{-3}$.
- Merged MODIS products and the VISTAS fire inventory both show large spring fire activities driven by prescribed burning. However, the MODIS products indicate more burning in summer than in VISTAS. Model simulations of OC and EC provide additional support.
- Fire emissions in the US and Canada result in nationwide consistent OC/EC peaks in summer 2002. Biogenic SOA also make important contributions in the South.
- Ecosystem modeling in 2050 suggests more biofuel and hence more fire emissions in coastal states but less in inland states. Meteorological impacts appear to be more significant than emission changes. NOx emissions from fires are more efficient in ozone production.
- There are still significant gaps in our knowledge of fire emissions and their impacts in the SE (e.g., large burning in other seasons in the SE, SOA, and ozone production). Higher temporal/spatial and key chemical marker measurements are critically important. Changing the CO reporting limit of 0.5 ppmv can be quickly implemented to help constrain fire impacts.