Projecting Wildfire Impacts on Southeastern U.S. Air Quality

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Background

The increasing frequency and intensity of wildfires over the past few decades has greatly concerned land and air quality managers, due to the environmental and health impacts, as well as the potential impacts on the radiation budget due to the short-lived climate forcing pollutants produced in these fires, and climate change is increasingly seen as a driver. The U.S. Forest Service (USFS), in its current projections of the condition of rangeland and forests required by the Resources Planning Act (RPA) of 1974, has included the impacts of climate change on wildfires in its current assessment. USFS has developed statistical models of annual areas burned (AAB) over the Southeast at the county level, to project their trends from 2010-2060. These projections account not only for changes in regional meteorology, downscaled from an ensemble of nine climate simulations, but also changes in land use, population and economic growth patterns over the region, consistent with the greenhouse gas (GHG) emission scenarios used in those simulations. This study used these AAB projections in a stochastic model of fire generation that disaggregates them into daily areas burned, to estimate fire emissions needed to drive air quality simulations in the present (2010), and in selected future years, and analyzed the regional air quality impacts for the 2010 baseline and future years. *This work is supported by USFS Joint Venture Agreement # 11-JV-11330143-080.*

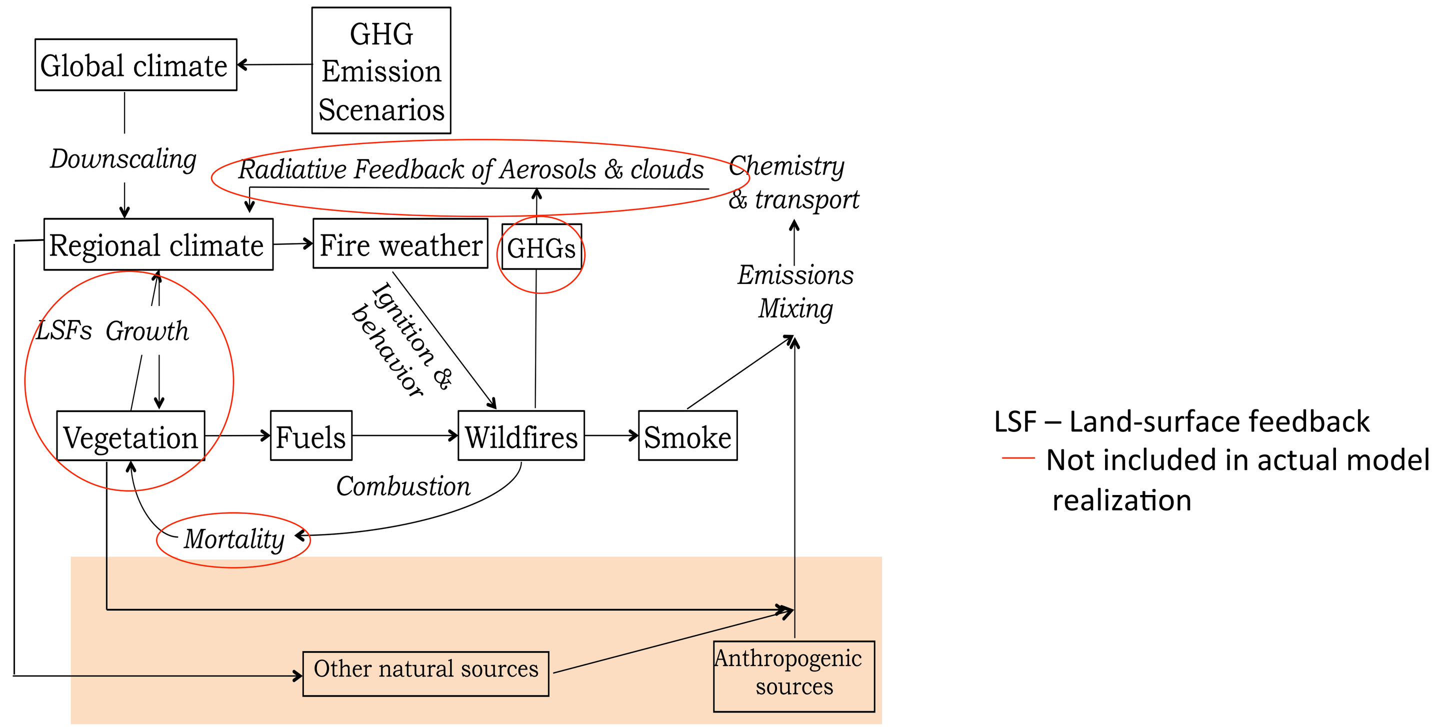
Project Goal and Objectives

Goal: To assess the impact of climate change on wildfire activity, emissions and air quality in the Southeast.

Objectives

- Examine the impacts of changes in climate and socioeconomic variables relevant for fire activity on annual areas burned in the next five decades over the Southeast.
- Use the downscaled meteorology to project daily fire activity, and estimate fire emissions in selected years.
- Examine the trends in fire emissions and air quality over the Southeastern U.S. in modeled years.

Conceptual Modeling System



Climate Model Ensemble

Statistical models of AAB projections are built on original models of Mercer and Prestemon (2005) and related work. Statistically downscaled meteorological inputs to these models come from a nine-member ensemble of 3 climate models, each run with 3 GHG emission scenarios from the PRISM (Daly et al., 2002) database at 8'x8' resolution.

General Circulation Models:

Canadian General Circulation Model Version 3.1 (CGCM31)

Commonwealth Scientific and Industrial Research Organization Mark 3.5 (CSIRO MK35) model

Model for Interdisciplinary Research on Climate Version 3.2 (MIROC32)

Emission Scenarios (from IPCC AR4):

A1B: Moderate population growth, high economic growth

A2: Moderate economic growth, high population growth

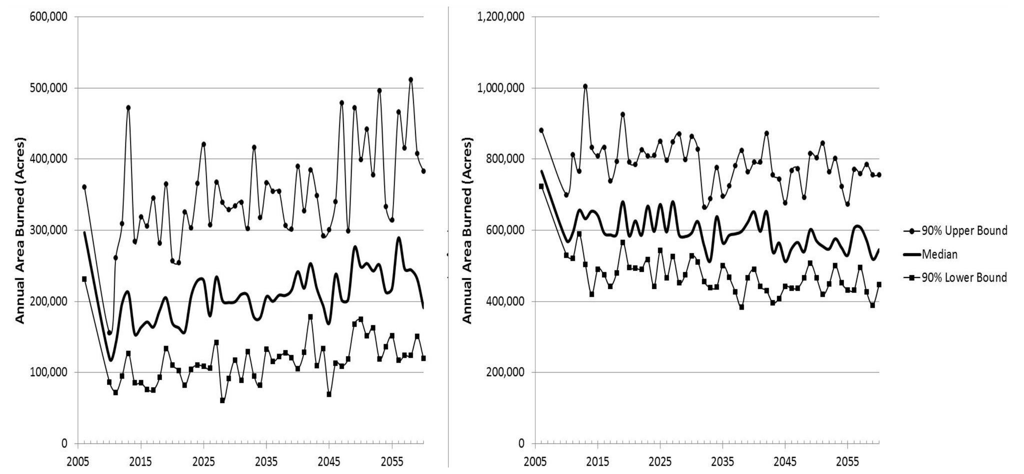
B2: Moderate economic growth, low population growth

Model Setup

- **Regional climate**: Dynamically downscaled from CGCM3 A2 scenario, the only ensemble member available in the North American Regional Climate Change Assessment Program (NARCCAP) archive, using the Weather Research and Forecasting (WRF) model at 12-km resolution over the Southeastern U.S. for selected years*: 2010, 2043, 2048, 2053 and 2058*
- **Fuel Loads**: Static, from Fuel Characteristic Classification System (FCCS)
- **Fire activity:** Fire Scenario Builder (McKenzie et al., 2006), adapted for the Southeast; disaggregated three ways to examine emission sensitivities, from:
  - AABs estimated using statistically downscaled meteorological inputs in all years 2010 - 2060 (labeled ST)
  - AABs estimated using WRF model inputs to replace statistically downscaled inputs in the selected years (labeled DY)
  - actual historical mean (1992-2010) AABs (labeled HIS)
- **Smoke emissions**: BlueSky (USFS); dynamic plume rise in CMAQ
- **Chemistry-transport**: CMAQ v5.0.2; Carbon Bond 2005 (gas phase) and AERO6 (aerosol) mechanisms; lateral boundary inputs from an existing 2010 Continental U.S. simulation at 36-km resolution for the same mechanisms.

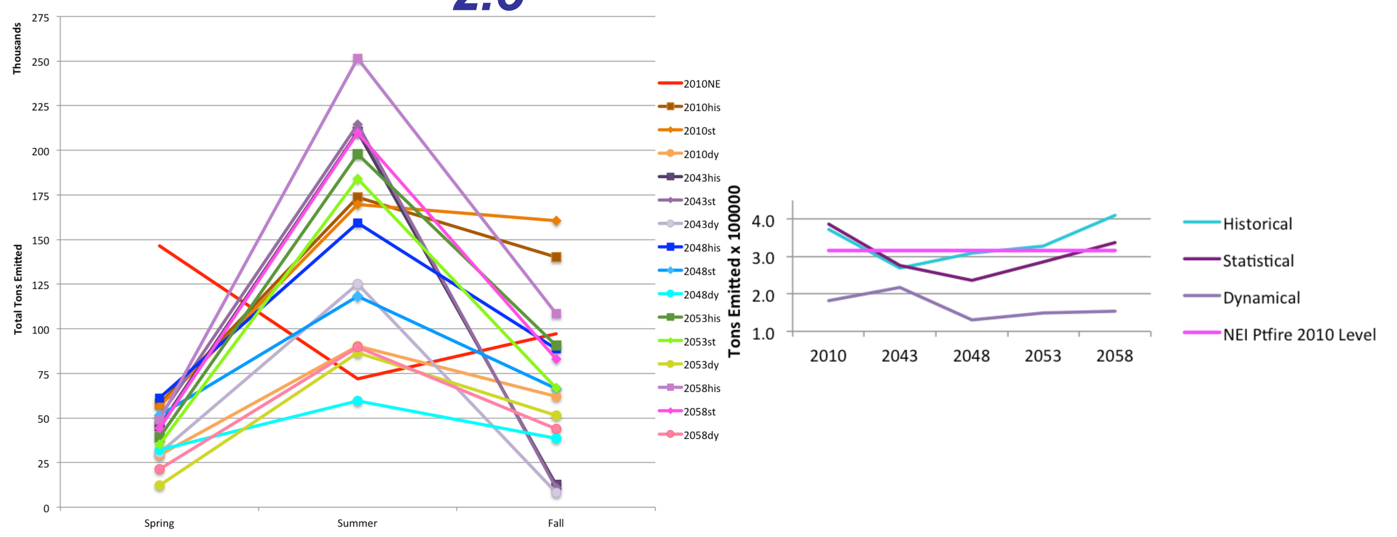
AAB Projections 2010-2060

Lightning-caused Human-caused



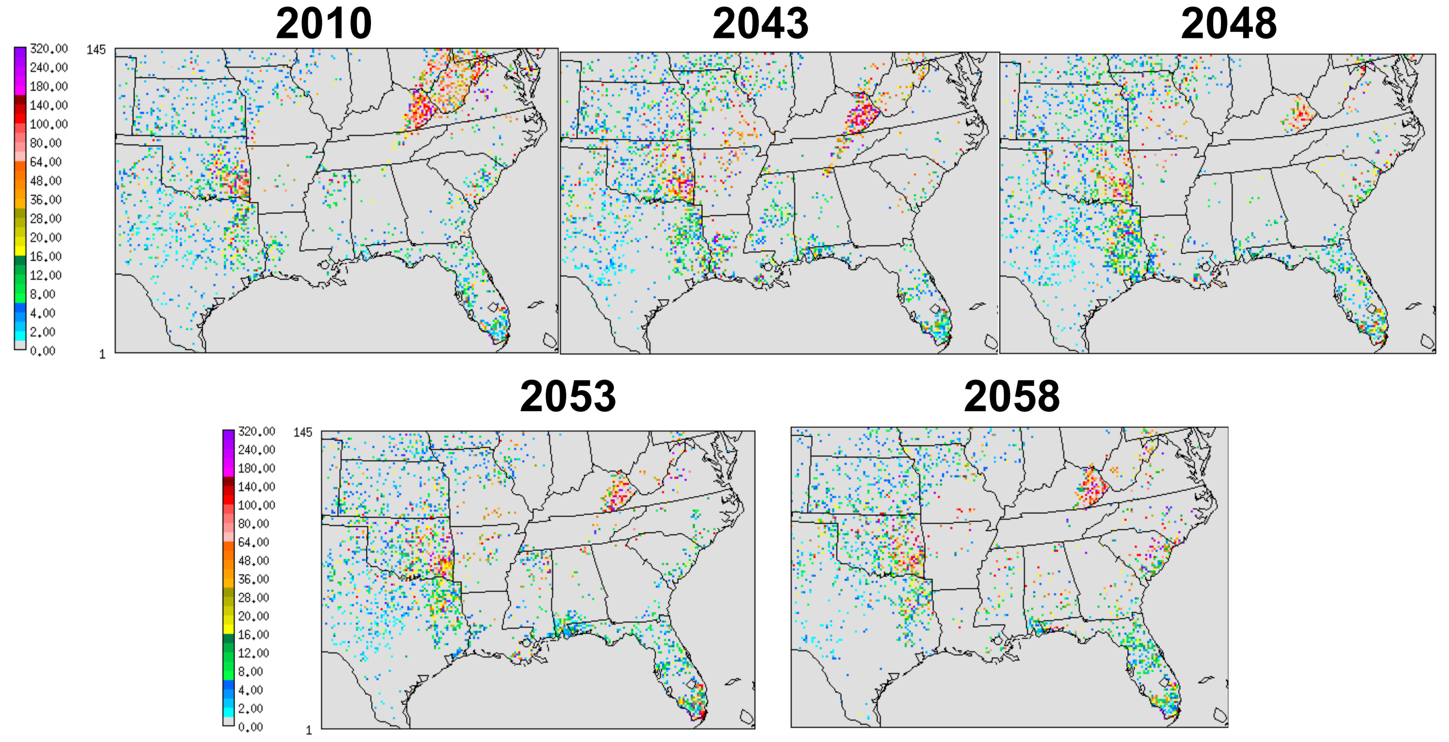
AABs in the Southeast from human-caused fires seen to be ~ 3 times those from lightning-caused fires, and decreasing in the future

Wildfire $PM_{2.5}$ Emission Trends



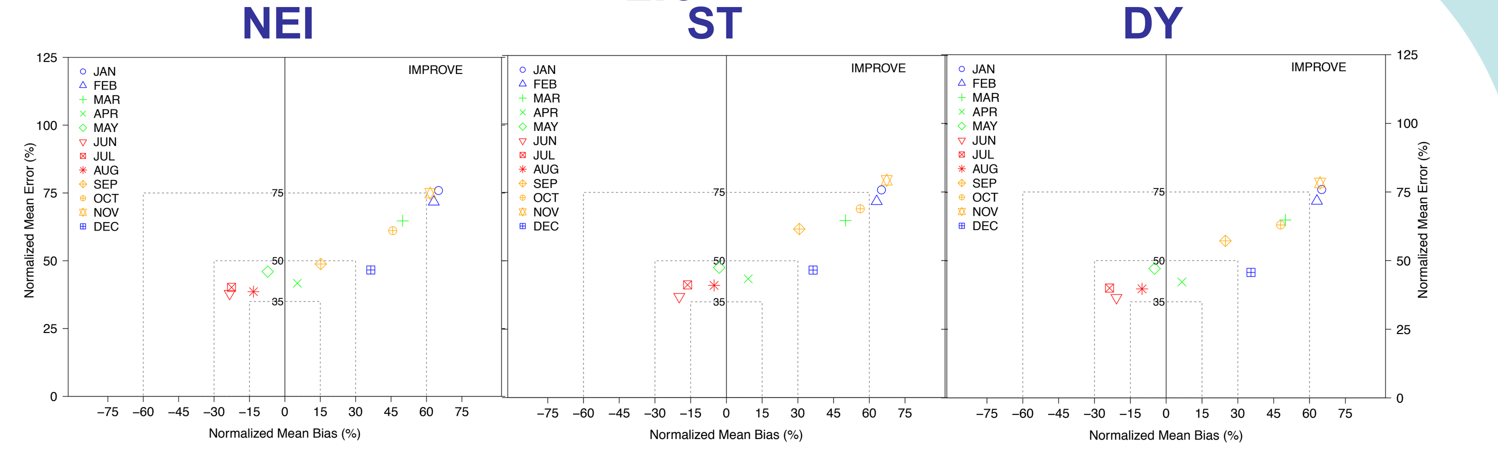
NEI emissions are much higher in spring, and much lower in summer for almost all years than for HIS, ST and DY cases. DY meteorology-based AAB estimates yield the lowest emission values in all years simulated.

Summer DY Wildfire $PM_{2.5}$ Emissions (T)



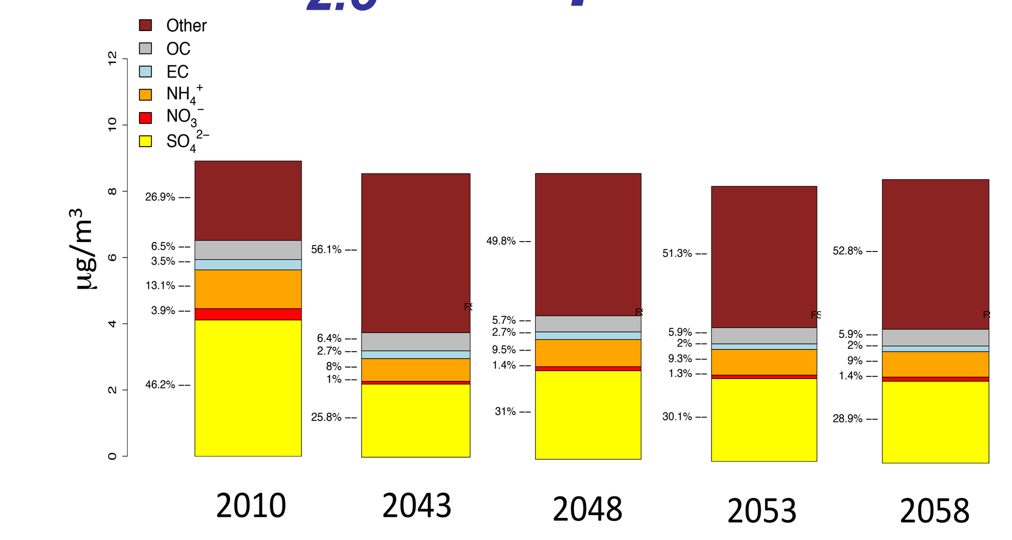
Future DY-based summertime emissions are seen to decrease slightly relative to 2010 in Southeastern coastal areas and in West Virginia, although the trend is not uniform, consistent with AAB trends in these years.

2010 Annual $PM_{2.5}$ Performance



$PM_{2.5}$ model performance against IMPROVE is nearly identical for the ST- and DY-based fire emissions relative to simulations with the NEI wildfire inventory, with slightly better summertime performance, and slightly worse performance in the fall. Wintertime performance (when there are no fires) is identical.

Annual $PM_{2.5}$ Composition Trends (DY)



Total $PM_{2.5}$ shows a slight decrease in the 2040-2060 period relative to 2010. The decrease in SO_4 is mainly from reductions in the energy sector.

Conclusions

- Socioeconomic factors play a major role in decreasing future wildfires
- Projected $PM_{2.5}$ emissions track AAB trends well, showing a slight decrease in future for all three methods of calculating daily fires
- Projected emissions significantly differ from 2010 NEI in all seasons
- DY estimates of daily AB produce lower fire emissions in all seasons and years compared to the other methods
- 2010 $PM_{2.5}$ performance is very similar for all methods, implying that the fire emissions projection methodology is reasonably robust; however, more in-depth evaluation is needed for all pollutants

References

Daly, C., W. P. Gibson, G.H. Taylor, G. L. Johnson, and P. Pasteris, 2002, *Climate Research 22*, 99-113.

McKenzie, D., S. M. O'Neill, N. A. Larkin, and R. A. Norheim, 2006, *Ecol. Modell.*, *199*, 278–288.

Mercer, D. E., and J. P. Prestemon, 2005, *Forest Policy and Economics* **7**, 782–795.

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