Analysis of Pollutant and Tracer Dispersion During a Prescribed Forest Burn

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Introduction

Background

Prescribed fires are often used to minimize the potential for catastrophic wildfires and to improve the health of forests, however, emissions of pollutants from prescribed fires contribute to local and regional air quality issues and health impacts. Emissions of particulate matter (PM2.5), volatile organic compounds and nitrogen oxides are important pollutants associated with prescribed fires. There remain large uncertainties in the actual emission rates of these pollutants from prescribed fires. The emission rate of any pollutant depends on the fire emission factors of the pollutant, fuel consumption per area burned. In this work, instrumented towers were deployed within and immediately next to a long-leaf pine forest burn unit to measure pollutant concentrations from prescribed fire. The objective was to investigate the dispersion of pollutants in the near field and to use the measurements to estimate emission rates for prescribed fire pollutants.

Image 1: Flames during a prescribed burn done to remove surface fuels and to help the sub-canopy grassland. The grass species that grow in this region require fire to propagate. Pohot courtesy of Kara Yedinak

Methods

Site

Located in The Nature Conservancy's Calloway Forest Preserve, the 89 acre burn area was outfitted with three instrumented towers—two 25 m towers and WSU's 32 m "Supertower." Positioned just outside of the burn area, the Supertower was placed to collect meteorological and trace gas data throughout the burn. Additionally, a sulfur hexafluoride (SF6) tracer dispersion test was conducted by releasing SF6 from a multiple points within the burn and measuring SF6 concentrations at the Supertower.

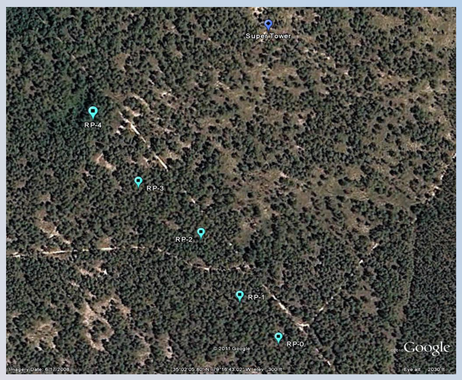


Image 2: Google Earth image of site and instruments

Image 2 displays the relative locations of release points and the supertower. Light blue dots represent the release points south/ southwest of the supertower, which is labeled with a dark blue dot.

Supertower Instrumentation

- Above canopy CO2/H2O fluxes with an open path Licor LI - 7500, CO/N2O, and CH4/CO2 concentrations with Los Gatos and Picarro instruments
- Trace Gas Automated Profiling System (TGAPS) connected to a CO2 closed path Licor LI-6262 and a SF6 detector (7 inlet locations)
- Cambell and ATI sonic anemometers at 4 levels
- Aspirated temperature profile (8 levels)
- NOx concentrations (tower base)
- Particulate black carbon (BC) Magee Scientific Aethelometer, AE-16 (tower base)

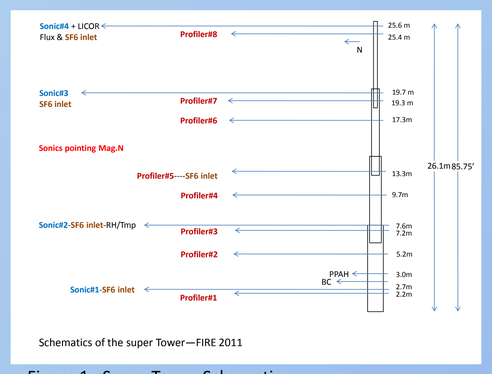


Figure 1: Super Tower Schematic

Data Analysis

Three types of data analysis were done:

1. Analysis of pollutant concentrations patterns
2. Emission factor estimates for some pollutants
3. Evaluation of a Gaussian plume model to simulate smoke dispersion

Modeling

A modified Gaussian Plume Equation for SF6 dispersion was used. Two scenarios were considered:

a) winds and turbulence from each level used to predict plume concentrations at each level (model A)

b) winds and turbulence averaged over 4 levels and the average set used to predict concentrations at each level (model B)

Results

Figure 2 shows shows the concentration of CO2 and NOx over time.

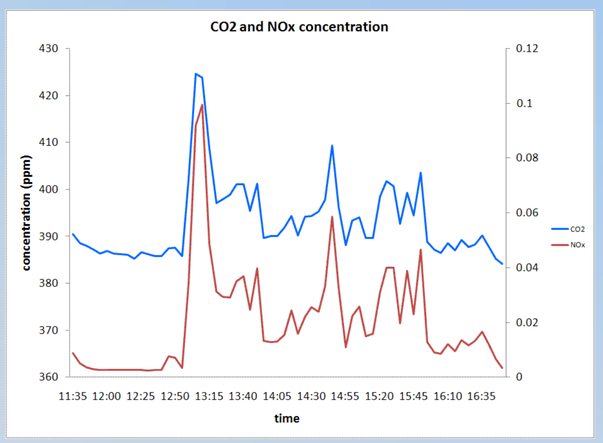
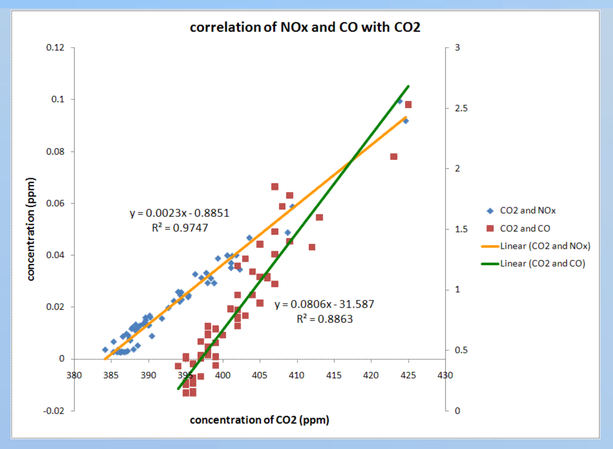


Figure 2

Since CO2 and NOx display almost identical patterns, we anticipated the concentration of them were highly correlated (R^2 = 0.97), as displayed in figure 3a. In comparison, CO2 shows a moderate correlation with black carbon (R^2 = 0.7, figure 3b).



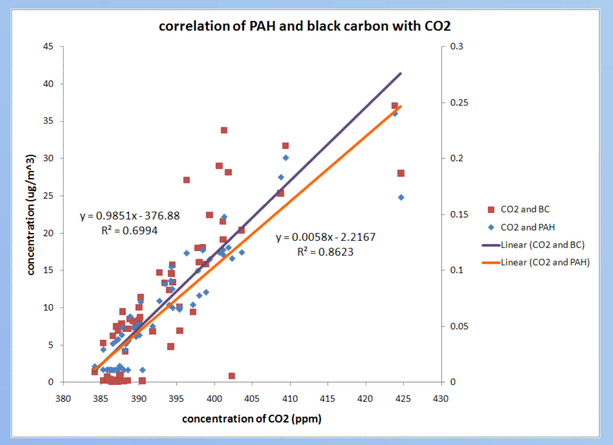


Figure 3a (top) and figure 3b (bottom)

Next, the emission factors were calculated and compared with that from peer-review journals. Table 1 compares emission factor of CO2 from our observation and those from Battye and Battye (2002).

Unit (g kg / fuel)				
	observation		Battye and Battye	
	active burn	post burn	active burn	post burn
CO2	1598.31	1639.66	1650	1393
CH4	3.21	1.30	3.8	9.9
CO	142.42	117.66	75	213
black carbon	0.65	1.42	7.3	17

Table 1

Our modeling consider two distinct conditions. Figure 4 shows the time series of SF6 concentrations between observations and model A. Figure 5 displays model B.

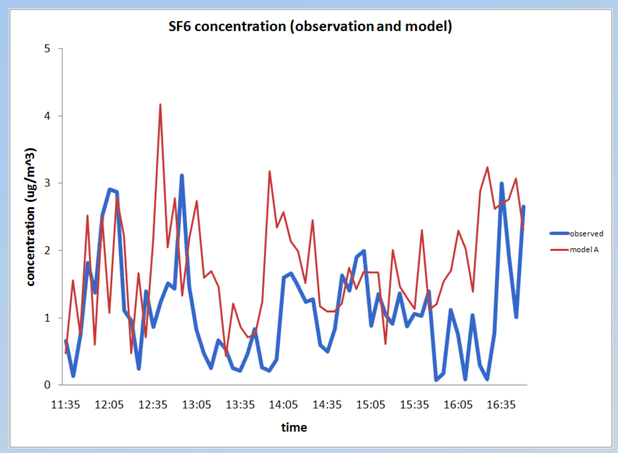


Figure 4, comparison of SF6 concentration between observation and model A

Acknowledgment

We thank the Missoula Technology and Development Center for assisting with tower deployment and instrumentation.

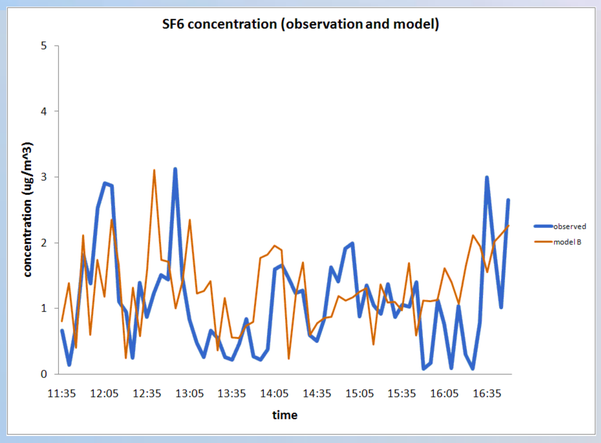


Figure 5

Statistics revealed that model B did a better job than model A for predicting SF6 concentrations, although model A showed a higher correlation with observation. Table 2 compares the prediction of SF6 concentration between observation, model A and model B. Figure 5 display the correlations between SF6 concentrations between observation and model A.

	observation	model A	model B
max	3.12	4.18	3.11
mean	1.11	1.77	1.30
stdev	0.76	0.80	0.59

Table 2
(Note: the above stats are based on the averages of all 4 levels and do NOT include the last two data points, where the observation SF6 sharply increased.)

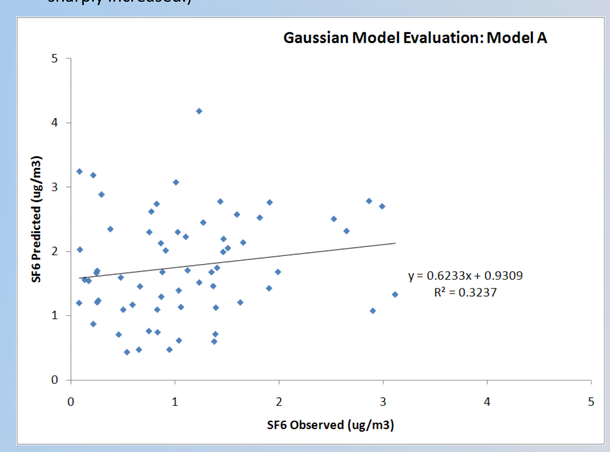


Figure 5

Summary

1. The pollutant concentration patterns were self-similar and in good correlation with CO2 as expected for the combustion source.

2. Estimated emission factors based on these data were in relatively good agreement with results from the literature, except for black carbon which seemed to be much less for this burn.

3. The Gaussian model results were in general agreement with observations, although the model results were slightly higher than observed.

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