Monitoring CO, $PM_{2.5}$, CO_2 from low-intensity fires for the development of modeling tools for predicting smoke dispersion

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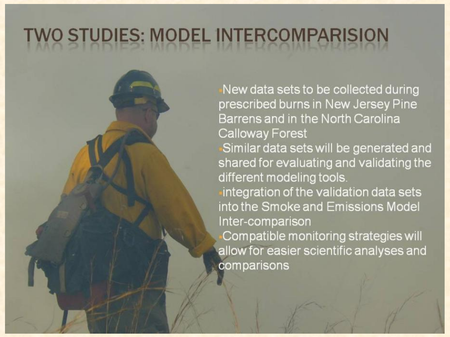
Introduction

This field study provides validation and support for the development of modeling tools for predicting smoke dispersion from low-intensity fires (Joint Fire Science Program grant # 09-1-04-1 and #09-1-04-2). Smoke models rely on measurements of $PM_{2.5}$, carbon monoxide (CO), and CO_2 as analogs for smoke.
The approach is a three year modeling and field validation study using tall towers (10m, 20m, 30m), and short towers (3m) inside and outside of fire perimeter equipped with smoke sensors, temperature, RH sensors and sonic anemometers.
We will give results from field tests, comparing the performance of low cost CO monitors, modified smoke monitors, and CO_2 analyzers against reference $PM_{2.5}$ monitors at prescribed fires in the New Jersey Pine Barrens and North Carolina.

Joint Fire Sciences Program Task D. Smoke dispersion from low intensity fires.

Data and smoke model comparisons will be done in cooperation with Tara Strand, PI, JFSP grant #09-1-04-2. Joint Fire Sciences Program. Warren Heilman, PI, JFSP grant # 09-1-04-1.



Objective

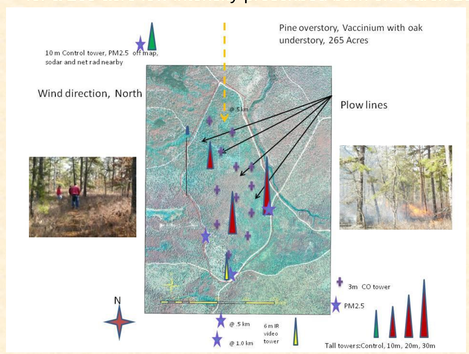
The purpose of this study is to monitor low level smoke from prescribed burn: wind turbulence, temperature profile, $PM_{2.5}$ for validation of smoke transport models.

Field Site Requirements

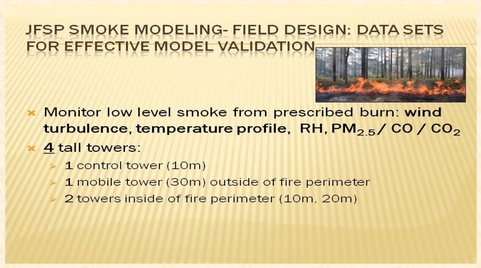
- Three year study, 1 burn per year, 3 burns - 2009-2012
- 50-250 acre low level prescribed burns, producing smoke.
- Tall towers downwind from burn.
- Accessible: to install control and tall tower outside of perimeter, i.e. along road.
- Interior towers (20m and 10 m) in the fire will need to be accessible to assemble tower and maintain battery power.
- Back perimeter with the reference $PM_{2.5}$ monitors downwind

Field Study Experimental Design, NJ Pine Barrens at Butler Place, 265 acres

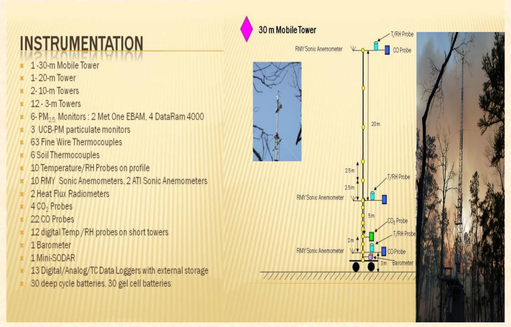
We will present the atmospheric monitoring results from the grid of four tall towers (10m, 20m, 30m, 10 m control) and twelve short towers (3m) placed inside and outside the fire perimeter for a 265 acre low intensity prescribed burn on March 20, 2011



Pitch Pine overstory, Vaccinium and shrub oak understory

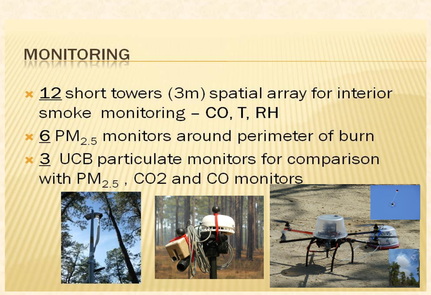


Burn site was part of NJ prescribed burn management plan. Controlled burn season in NJ is typically mid-Oct to mid-March. Burn site was inaccessible until first week of March due to record setting regional snowfall. Despite the conditions, all towers and instrumentation were put up and operational within 2 weeks of access into site.

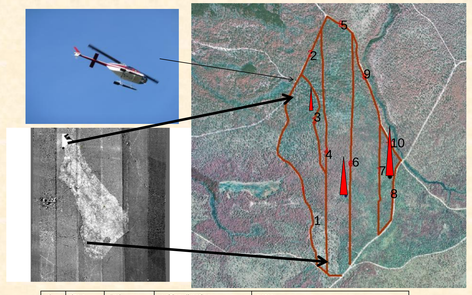


Smoke monitoring

Smoke models rely on measurements such as carbon monoxide (CO), $PM_{2.5}$, and CO_2 as analogs for smoke. A spatial grid of tall and short towers was designed in cooperation with NJ fire managers and researchers.
Typically $PM_{2.5}$ monitors are used to monitor smoke and particulates. Placing air quality PM2.5 monitors within the fire would be risky and prohibitively expensive. An array of inexpensive, expendable, fast response and low power CO sensors, based on carbon monoxide transducers from residential alarms was designed and built to provide a spatial grid over the wide range of CO concentrations (up to 1000 ppm) expected within the fire. The CO sensors, based on the Figaro TGS5042 transducer, was designed and built with a signal conditioning amplifier board (Data Design Group, La Jolla) Each is individually calibrated using CO reference gas (Scott Gas).



Particulate monitors based on smoke detector technology (UCB sensor, EME Systems) have been shown to have good correlation with $PM_{2.5}$. Inexpensive CO_2 monitors, based on a passive design by DCS model 305E were also incorporated in the equipment . A UCB particulate monitor was flown downwind with a RC helicopter (see above) up to 150 m in altitude (University of Maryland, Baltimore County).



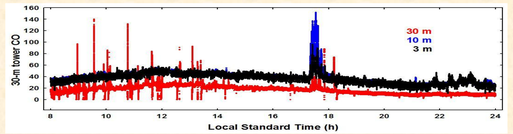
Id	Start	End	Ignition direction	Notes
1	955	1500	South to North	Slow going here. Wind shift at ca. 1350
2	1500	1630	North to South	Started S-N but had crowning.
4	1700	1715	North to South	Same time as 3
3	1630	1700	North to South	
5	1720	1740	West to East	
6	1730	1745	North to South	
7	1700	1730	South to North	
8	1745	1800	West to East	
9	1800	1900	South to North	
10	1830	1900	West to East	

The burn was complicated with the wind coming from the opposite direction, shifting from N to SE, instead of normally WNW. Burn was initiated at 9:55 Mar. 20, 2010 starting in the western perimeter instead of east ern perimeter as planned, going S to N. The lidar map showed only a small area burned by 1515 ET, 5.5 hours after start of burn, due to wind shifts and lookouts for spotting in the NW. See log time table and ignition direction.

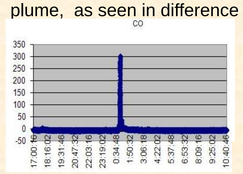
$PM_{2.5}$, CO and UCB particulate monitors co-located at NC and NJ smoke studies to correlate $PM_{2.5}$ with less expensive sensors that can be placed inside the burn.

Results

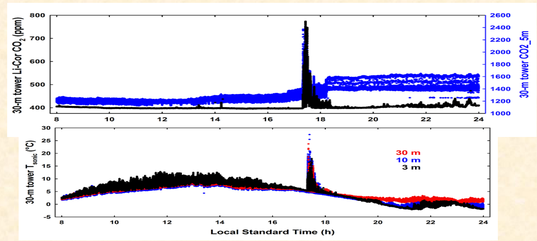
: The results are from the 30 m tower, the 3 m towers inside the burn, and $PM_{2.5}$ monitors on the outside perimeter and downwind.



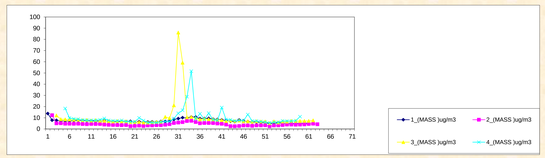
Inexpensive Figaro CO sensors (above) show good response and a wide range. As passive monitors, they must be in close proximity to the smoke plume, as seen in difference in response with position on 30 m tower.



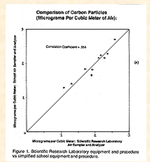
In the 3m towers (left), there was a wide response with peak readings of 150 ppm to 800 ppm, over a period of 13 hours due to the complex burn pattern with shifting wind direction for the 265 acre burn. The burn reached this 3m tower (#8) 13 hrs after prescribed burn started.

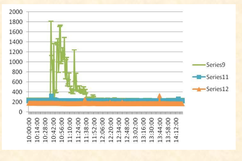


The Li-cor 840 CO_2 analyzer (black) with active (pump) sampling corresponded well with CO and temperature peaks . The inexpensive DCS CO_2 monitors (blue) had an embedded auto calibration function which complicated observations, as seen in the changing baseline after the fire.



DataRam 4 $PM_{2.5}$ monitors on perimeter show good sensitivity farther away from plume (ug/m3), with similar response as the inexpensive CO sensors





UCB monitor (EME Systems) modified smoke alarm photocell (mv) shows broad response, similar to CO_2 monitor. It has been well correlated with other CO and with $PM_{2.5}$ monitors in the literature.

Overall, results from the array of inexpensive CO and PM sensors within the burn yielded good results compared to the more expensive reference air quality $PM_{2.5}$ monitors, with the ability to show the spatial and temporal dynamics within the burn.

Acknowledgements

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