Fire-Atmosphere Interactions During Low-Intensity Prescribed Fires in the New Jersey Pine Barrens

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Study Objectives

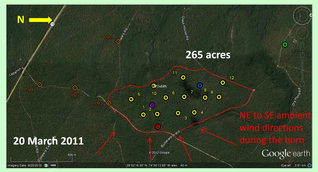
- **Develop a comprehensive monitoring network within and in the vicinity of prescribed burn blocks in the New Jersey Pine Barrens to measure fire-atmosphere interactions and local air quality during low-intensity fires.**
- **Examine the impacts of forest overstory vegetation on atmospheric circulations, thermal fields, and the transport and dispersion of smoke in forested environments during low-intensity fires.**
- **Use the observational data to evaluate meteorological and atmospheric dispersion modeling systems applied to low-intensity fires in forested environments.**

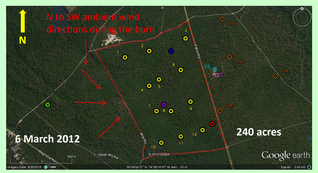
Study Locations

Monitoring networks were established within and near two relatively flat burn blocks located in the Brendan T. Byrne State Forest in central New Jersey. Burn experiments (surface fires) were conducted on 20 March 2011 and 6 March 2012. Vegetation in each block consisted of ~15-18 m pitch-pine/mixed-oak overstory and Vaccinium/scrub-oak understory.

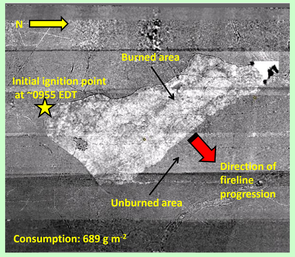
Surface Fuel Loading
Experiment E1: 1478 g m^{-2}
Experiment E2: 1104 g m^{-2}

Monitoring Networks and Prescribed Burn Patterns

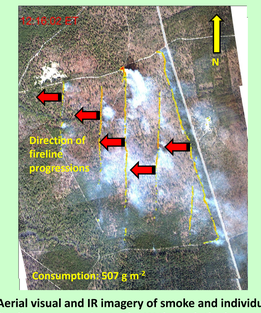




Location of towers and surface monitoring stations in each burn block for the E1 (20 March 2011) and E2 (6 March 2012) prescribed burn experiments. 3 m towers: yellow circles; 10 m towers: blue circles; 20 m towers: purple circles; 30 m towers: red circles; 10 m control towers: green circles; $PM_{2.5}$ monitors: brown diamonds; ceilometer: blue star; remote helicopter: pink square.



Aerial LIDAR imagery of forest floor elevation differences between burned and unburned areas at 1715 EDT on 20 March 2011. Image shows the general backing fire line progression to the NE through the burn block, starting with an initial fire line ignition along the western border of the burn block (~0955- EDT).



Aerial visual and IR imagery of smoke and individual fire lines progressing to the W through the burn block at 1210 EST on 6 March 2012. Initial fire line was ignited along the eastern border of burn block between ~0930-1030 EST.

A series of 3 m, 10 m, 20 m, and 30 m towers and surface stations were set up within and outside each burn block and instrumented with a variety of monitoring equipment to measure high frequency (0.5-10 Hz) wind speeds, wind directions, temperatures, relative humidity, radiative heat fluxes, pressure, turbulent heat and momentum fluxes, net radiation, and CO, CO_2, and $PM_{2.5}$ concentrations during backing prescribed fires that burned through each burn block.

Additional measurements included fuel loading, fuel moisture, ceilometer-based plume heights, LIDAR-based vegetation structure, and aerial IR imagery of the burns.

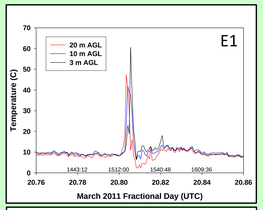
Tower	Instrument	Variable	Measurement Height (m AGL)	Sampling Frequency
3 m	Thermocouples (Omega XC-24-K-12 @ 0 m) (Omega SSRTC-GG-K-36-36)	Temperature	0, 1, 3	0.5 Hz
	CO Sensors (Figaro TGS5042)	CO conc.	3	0.5 Hz
	Anemometers (E2 only) (Davis Instruments DV6410)	Mean wind speed and direction	3	0.5 Hz
	Temperature/RH probes (EME Systems SHT75PG)	Mean temperature and RH	2	0.5 Hz
10 m	3D sonic anemometers (R.M. Young 81000V)	u, v, w, t	3, 10	10 Hz
	Temperature/RH probes (Vaisala HMP50)	Mean temperature and RH	3, 10	10 HZ
	Thermocouples (Omega SSRTC-GG-K-36-36)	Temperature	0, 1, 2, 3, … 10	10 Hz
	CO Sensors (Figaro TGS5042)	CO conc.	3, 10	10 Hz
	CO_2 Sensor (Vaisala GMM222E)	CO_2 conc.	5	10 Hz
	Radiative Heat Flux Sensor (Medtherm 64-20-20)	Radiative heat flux	4.5	10 Hz
	Barometer (Viasala PTB 110)	Pressure	7	10 Hz
	Soil thermocouples (Omega XC-24-K-12: Litter) (Omega KMQLX-032-6)	Temperature	Litter, -0.10, -0.20	10 Hz
20 m	3D sonic anemometers (R.M. Young 81000V)	u, v, w, t	3, 10, 20	10 Hz
	Temperature/RH probes (Vaisala HMP50)	Mean temperature and RH	3, 10, 20	10 HZ
	Thermocouples (Omega SSRTC-GG-K-36-36)	Temperature	0, 1, 2, 3, … 10, 12.5, 15, 17.5, 20	10 Hz
	CO Sensors (Figaro TGS5042)	CO conc.	3, 10, 20	10 Hz
	CO_2 Sensor (Vaisala GMM222E)	CO_2 conc.	5	10 Hz
	Radiative Heat Flux Sensor (Medtherm 64-20-20)	Radiative heat flux	4.5	10 Hz
	Barometer (Vaisala PTB110)	Pressure	11	10 Hz
	Soil thermocouples (Omega XC-24-K-12: Litter) (Omega KMQLX-032-6)	Temperature	Litter, -0.10, -0.20	10 Hz
30 m	3D sonic anemometers (R.M. Young 81000V)	u, v, w, t	3, 10, 30	10 Hz
	Temperature/RH probes (Vaisala HMP50)	Mean temperature and RH	3, 10, 30	10 HZ
	Thermocouples (Omega SSC-TT-T-36-36)	Temperature	0, 1, 2, 3, … 10, 12, 16, 20, 25, 30	10 Hz
	CO Sensors (Figaro TGS5042)	CO conc.	3, 10, 30	10 Hz
	CO_2 Sensor (LI-COR 820)	CO_2 conc.	5	10 Hz
	Net radiometer (Kipp and Zonen NR-Lite)	Net radiation	30	10 Hz
	Barometer (Vaisala PTB110)	Pressure	2.1	10 Hz
	Soil thermocouples (Omega KMQLX-032-6)	Temperature	-0.02, -0.20	10 Hz
10 m Control	3D sonic anemometers (R.M. Young 81000V)	u, v, w, t	3, 10	10 Hz
	Temperature/RH probes (Vaisala HMP50)	Mean temperature and RH	3, 10	10 HZ
	Thermocouples (Omega SSC-TT-T-36-36)	Temperature	0, 1, 2, 3, … 10	10 Hz
	CO Sensors (Figaro TGS5042)	CO conc.	3, 10	10 Hz
	CO_2 Sensor (LI-Cor 820)	CO_2 conc.	5	10 Hz
	Net radiometer (Kipp and Zonen NR-Lite)	Net radiation	2	10 Hz
	Barometer (Viasala PTB110)	Pressure	1.5	10 Hz
	Soil thermocouples (Omega TMQSS-032U-6)	Temperature	-0.02, -0.20	10 Hz

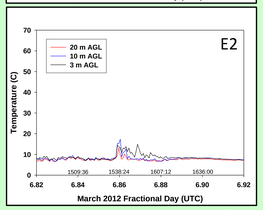
Summary of the instrumentation and monitoring protocols used at the 3 m, 10 m control, 10 m, 20 m, and 30 m towers for the E1 (20 March 2011) and E2 (6 March 2012) prescribed burn experiments.

Photographs

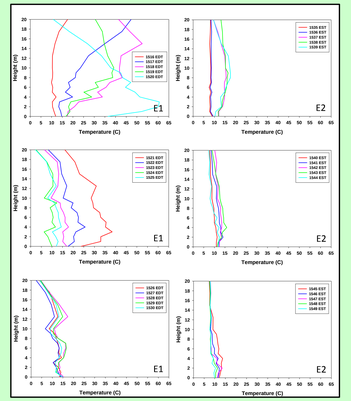
Example fire line and smoke conditions during the E1 (20 March 2011) and E2 (6 March 2012) burn experiments.

Temperatures at 20 m Tower



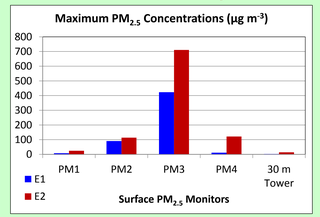


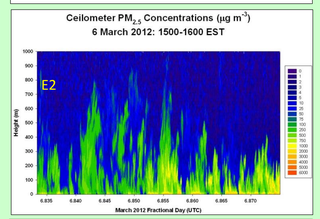
Observed temperature time series during fire front passage for the E1 and E2 experiments. EDT (E1) and EST (E2) times shown above x-axis.

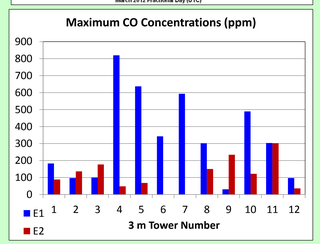


Observed temperature profiles during fire front passage for the E1 and E2 experiments.

Air Quality

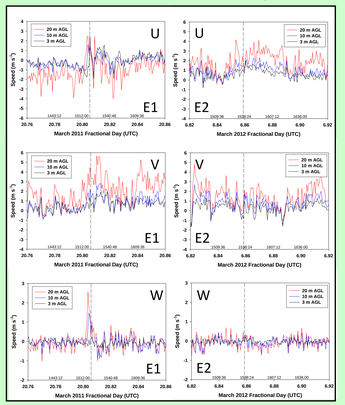




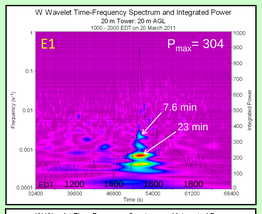


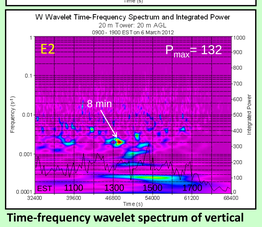
Observed $PM_{2.5}$ and CO concentrations within and in the vicinity of the E1 and E2 burn blocks.

Wind Speeds and Turbulence at 20 m Tower

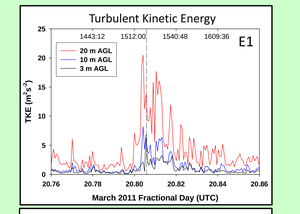


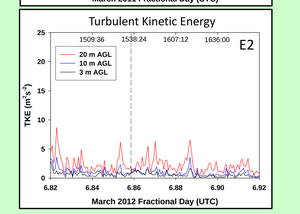
Observed east-west (U), north-south (V), and vertical (W) wind speed time series during fire front passage for the E1 and E2 experiments. EDT (E1) and EST (E2) times shown above x-axis. Dashed line indicates time of fire front passage.





Time-frequency wavelet spectrum of vertical wind speeds for the E1 and E2 experiments indicate prominent modes of variability before, during, and after fire front passage.





Observed turbulent kinetic energy during fire front passage for the E1 and E2 experiments. EDT (E1) and EST (E2) times shown below top axis.

Key Conclusions and Next Steps

- **Turbulent circulations in the vicinity of surface fires and the resulting horizontal and vertical dispersion of heat and smoke from those fires are not only affected by fire intensity, but also by the presence of forest overstory vegetation.**
- **Turbulent kinetic energy is most pronounced just above the canopy top, regardless of the presence of surface fires.**
- **Overstory vegetation affects turbulence anisotropy and the directional mixing of heat, moisture, and smoke.**
- **Meteorological and air-quality data from these experiments are being used to evaluate the ARPS-CANOPY/FLEXPART and RAFLES modeling systems applied to low-intensity wildland fires in forested environments (JFSP Project 09-1-04-1).**
- **Observational data will be uploaded to the Smoke Emissions Model Intercomparsion Project (SEMIP) data warehouse for future model evaluation efforts.**