Aerial and Ground Measurements of Emissions from Prescribed and Laboratory Forest Burns

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Objective and Motivation

The objective of this work was to sample and compare emissions from prescribed and laboratory forest burns using both aerial- and ground-based sampling.

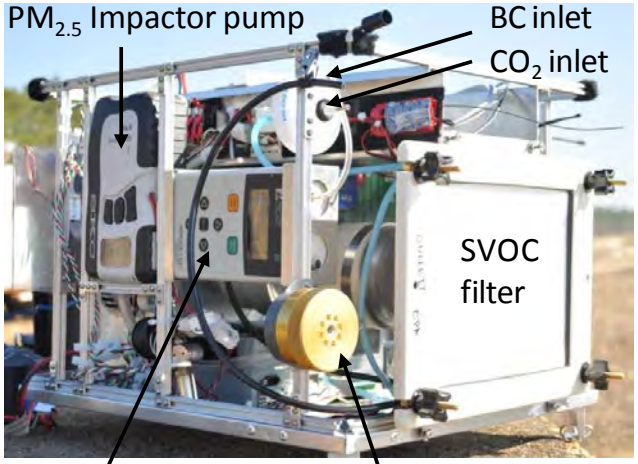
Aerial sampling

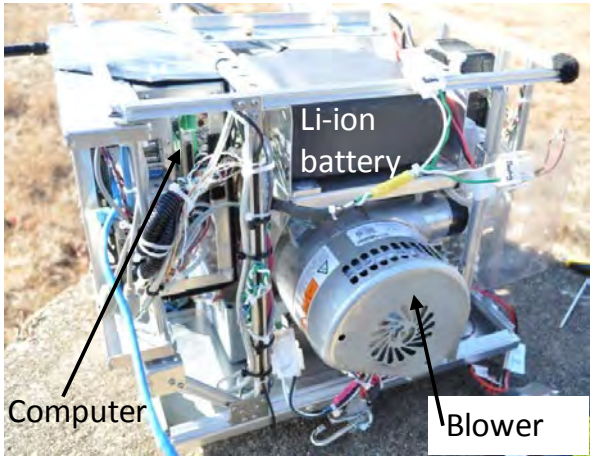
Ground sampling

Open Burn Test Facility

OBTF sampling

Instrument Platform
The "Flyer"





- Total weight ~ 21 kg (46 lb)
- Flight time 4 h
- SVOC sampling time 60 min
- Onboard computer with control software
- Transmission of data from Flyer to the ground
- Every millisecond data logging
- User-set CO_2 triggering of samplers
- GPS

- CO_2
- CO
- Semi-Volatile Organic Compounds (SVOCs)
- Volatile Organic Compounds (VOCs)
- Black carbon (BC)
- PM by filter ($PM_{2.5}$, PM_{10})
- Continuous $PM_{2.5}$, PM_{10}
- 3D-anemometer

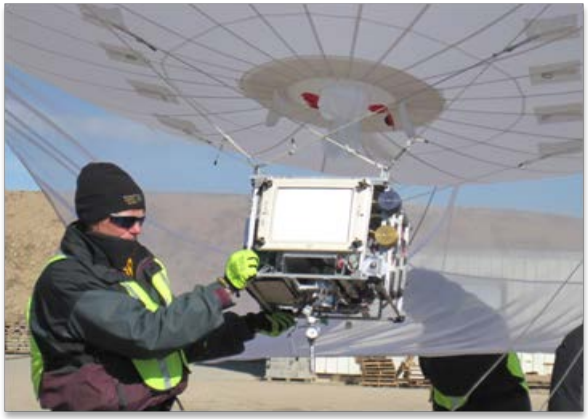
Sampling Analytes and Instrumentation

Analytes	Instrument	Mode	Sampling period/rate	Analyses
Black carbon	AE51	Continuous	every second	IR 880 nm
Black carbon	AE52	Continuous	every 10 second	IR 880 nm
Brown carbon	AE52	Continuous	every 10 second	UV 370 nm
PM_1, $PM_{2.5}$, PM_7, PM_{10} and TSP	Aerocet 531	Continuous	every 2 min	Light-scattering laser photometer
$PM_{2.5}$	DustTrak 8520	Continuous	every second	Light-scattering laser photometer
$PM_{2.5}$	SKC impactor, teflon filter	Batch	10 L/min	Gravimetric
PCDD/PCDF	Quartz filter/PUF	Batch	850 L/min	HRGC/HRMS
VOC	Summa Canister	Batch	~ 2 min	GC/LRMS
CO, CO2	Summa Canister	Batch	~ 2 min	GC
CO_2	LICOR-820	Continuous	every second	non-dispersive infrared (NDIR)
Ambient pressure, Elevation, and Location	MTi-G	continuous	every second	Global position system, attitude and heading referNCe system (AHRS), static pressure sensor

Aerostat and the Flyer

Aerostat

- 4.9 × 4.0 m (16 × 13 foot) in diameter
- Two layer
  - Polyurethane inner layer
  - Rip-stop nylon as outer layer
- Helium filled



Payload

- 21 kg (46 lb) at an elevation of 1500 m
- ~30 kg (70 lb) at sea level

Spectra lines

- 300-600 m (1,000-2,000 feet) long
- 2.5 mm in diameter

Prescribed Forest Burns

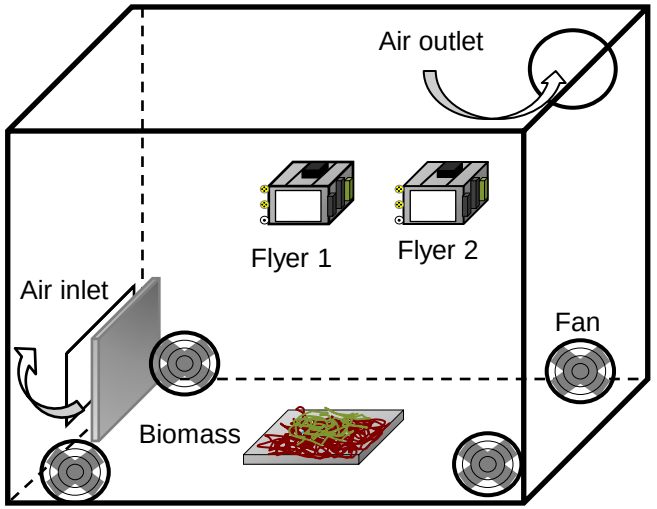
Three different locations

- Camp Lejeune – North Carolina
  - Two prescribed burns
  - Aerostat based sampling
- Eglin Air Force Base – Florida
  - Three prescribed burns
  - Aerostat based sampling
- Fort Jackson – South Carolina
  - Three prescribed burns
  - Ground based sampling

Emission factors used to supplement ambient monitoring, and to calculate total emission inventories.

Burn Hut Sampling

Parallel field and laboratory testing (of gathered biomass) to compare emission factors.



United States Environmental Protection Agency

Biomass

	Biomass source		
	Florida	**North Carolina**	**South Carolina**
Loss on drying (%)	14	22	19
Carbon, F_c (%)	52	55	51
Chlorine (ppm)	645	194	111
Oxygen (%)	36	36	40
Hydrogen (%)	5.8	5.9	5.8
Nitrogen (%)	<0.5	<0.5	0.65
Sulfur (%)	0.06	<0.5	0.056

- A higher chlorine content in the Florida biomass compared to NC and SC biomass

Emission factor calculation

Emission factor is a measure of the average amount of a pollutant to the atmosphere from a specific source, expressed as e.g. gram pollutant per kg biomass burned.

The carbon mass balance method was used to calculate emission factors.

Assumes:

- that all of the carbon from the material burned is emitted to the atmosphere as CO_2, CO, CH4, THC and Particulate Matter-bound carbon.
- complete mixing of the plume, i.e. the pollutants and the carbon emitted are assumed to be proportionally distributed throughout the plume.

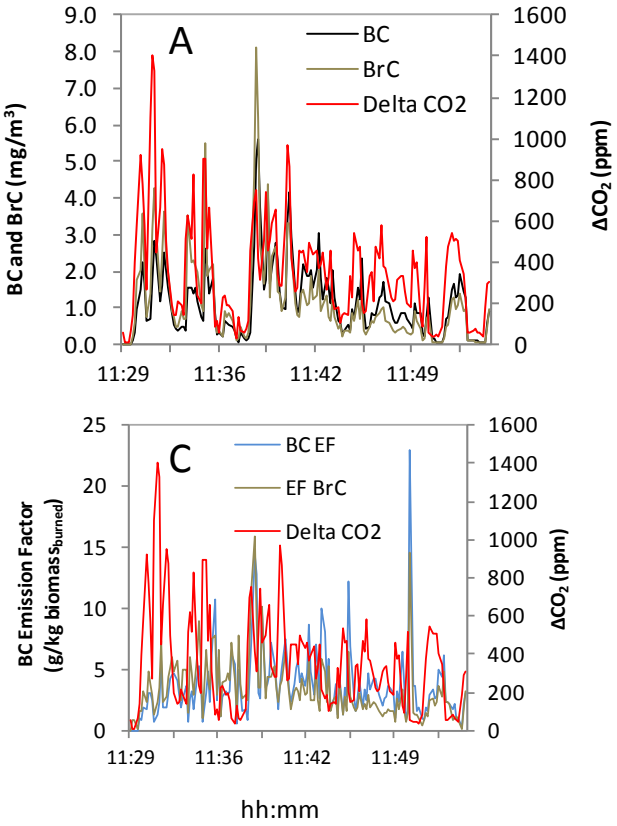
The black carbon data were corrected for particle loading on the filters using Kirchstetter and Novakov's formula[1].

1. Kirchstetter, T. W.; Novakov, T. Controlled generation of black carbon particles from a diffusion flame and applications in evaluating black carbon measurement methods. *Atmospheric Environment.* **2007,** *41* (9), 1874-1888.

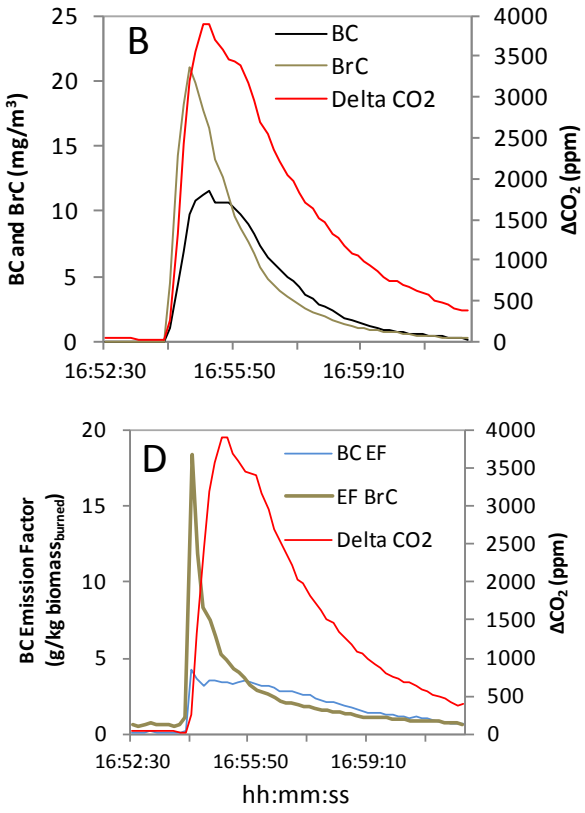
United States Environmental Protection Agency

Black carbon and CO_2 - traces and emission factors

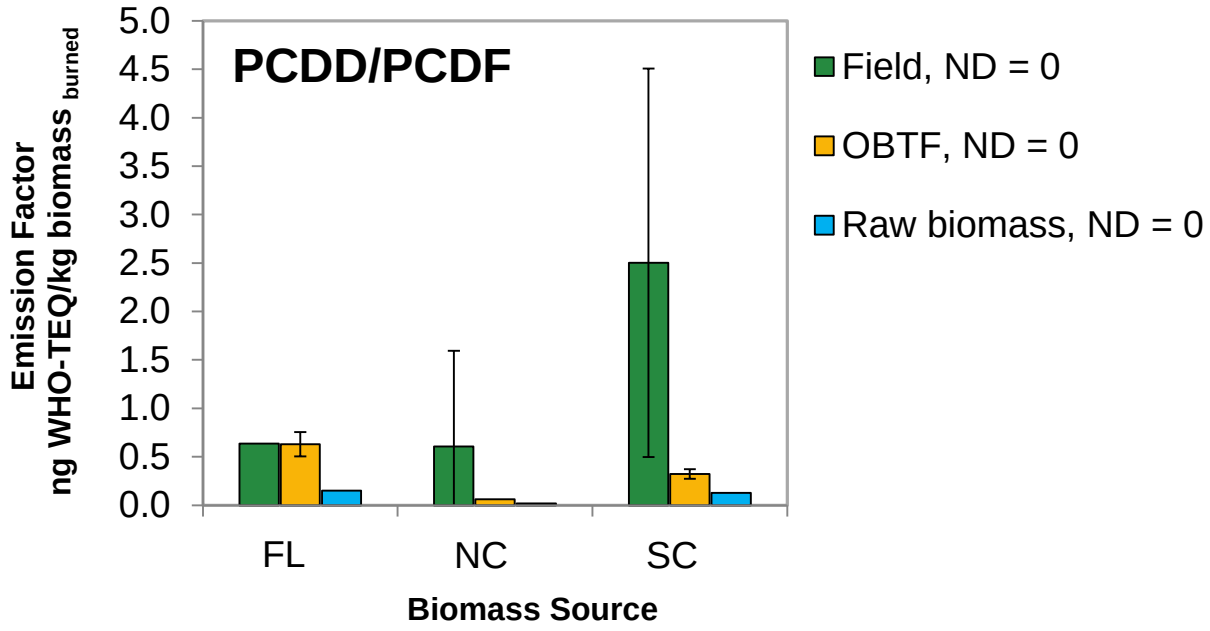
Field



OBTF



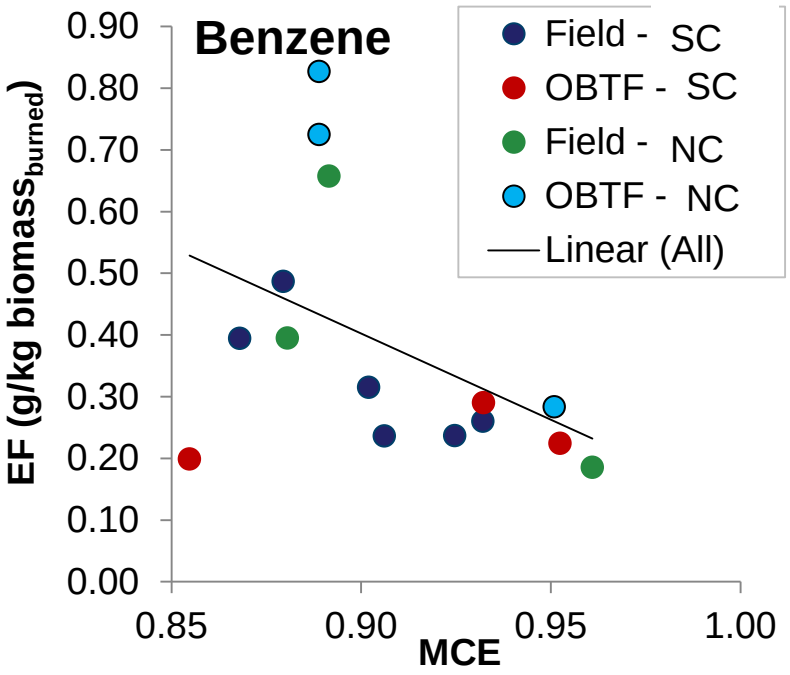
Results PCDD/PCDF

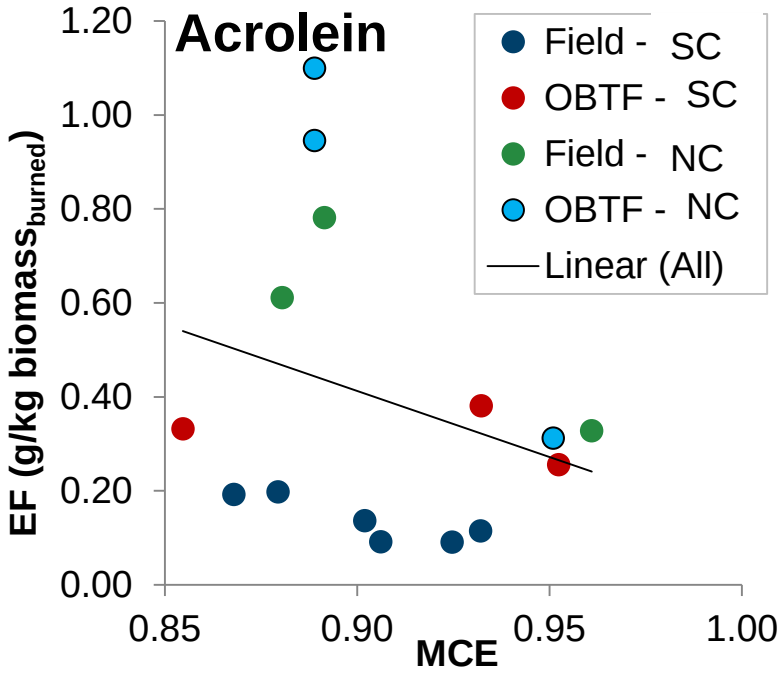


- Raw biomass contains minor amounts of PCDD/PCDF.
- Main source is reactive formation during combustion.
- Given the trace nature of PCDD/PCDF, reasonable agreement between field and lab testing.

EF for raw biomass in ng WHO-TEQ/kg raw biomass.

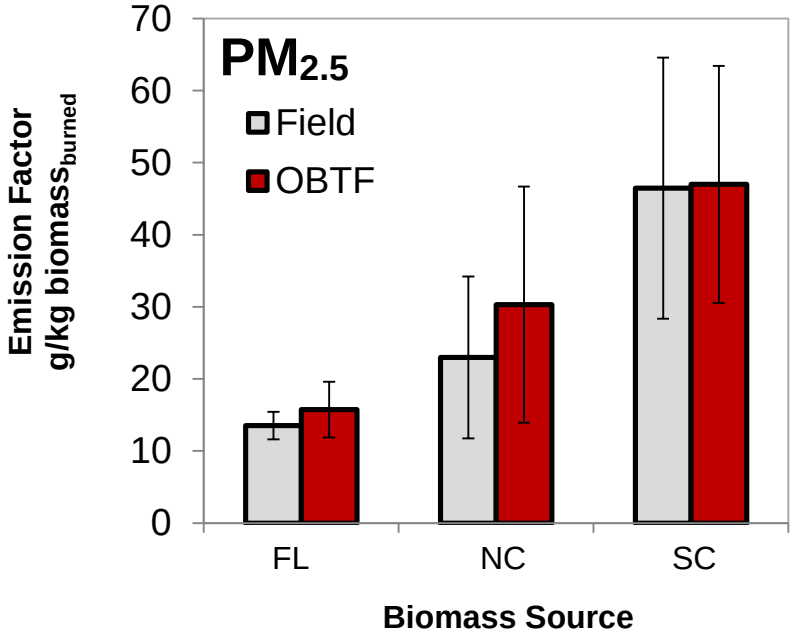
Results VOCs

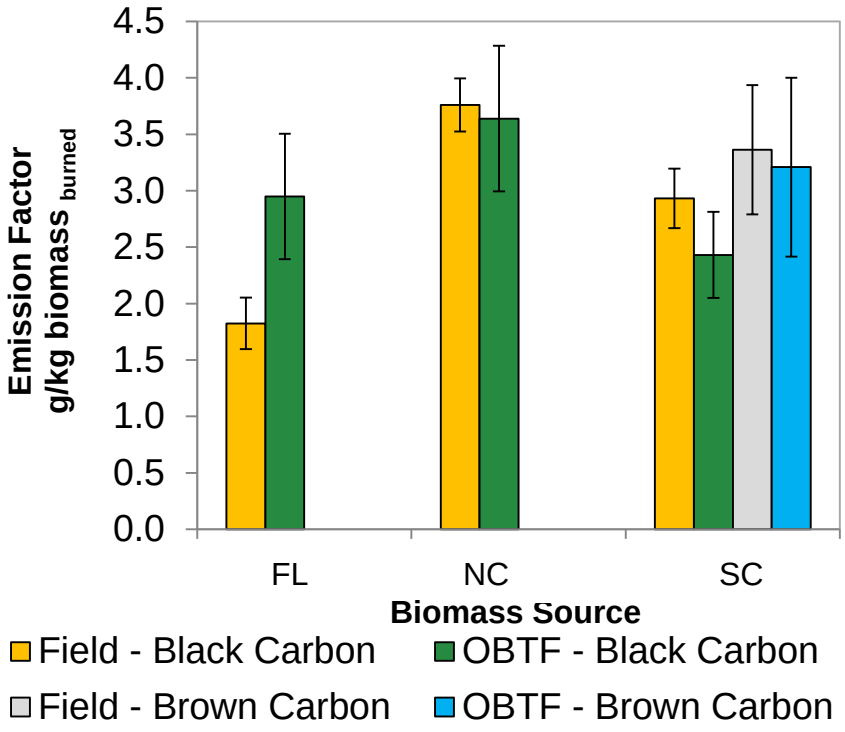




- Consistency between sites, and lab vs. field.
- Higher emissions when MCE is low.

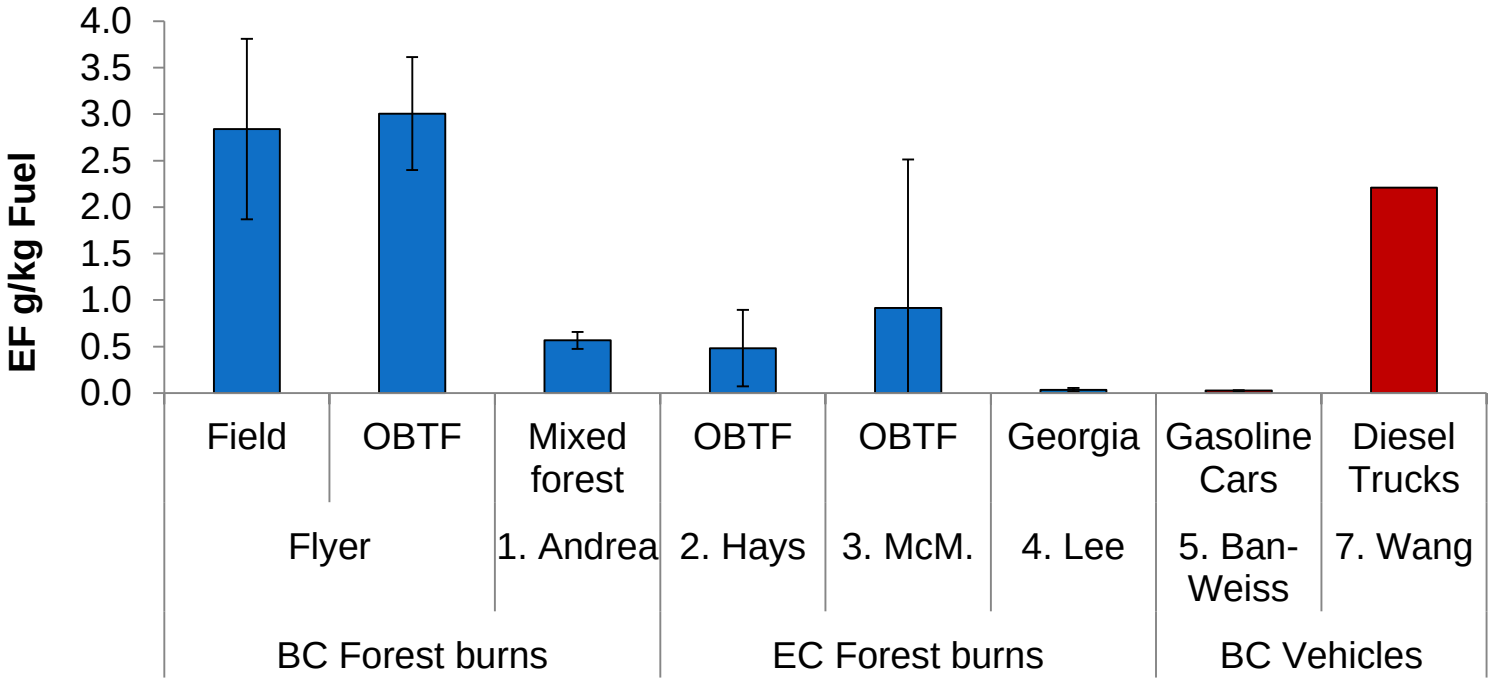
Results $PM_{2.5}$ and BC, BrC





- Results show similarity between field and lab (OBTF) testing, differences between sites.

Black Carbon Emission Factors Comparison



1) Andreae, M. O. and Merlet, P. *Global Biogeochemical Cycles.* **2001,** *15* (4), 955-966.2) Hays, M. D. et al. *EST* **2002,** *36* (11), 2281-2295. 3) McMeeking, G. R. et al. *Journal of Geophysical Research-Atmospheres.* **2009,** *114*. 4) Lee, S. et al. EST. **2005,** *39* (23), 9049-9056 5) Ban-Weiss, G. A. et al. *Atmospheric Environment.* **2008,** *42* (2), 220-232. 6) Wang et al. Atmospheric Environment 45, 503-513, **2011**

Conclusion

Methodology

An aerial sampling method and apparatus was developed

- The method is flexible and sampling instruments can be added or removed to match the source pollutants or measurements of interest

Science

- Forest burns: Laboratory OBTF ~ Field
- VOCs concentrations a function of modified combustion efficiency
- Black Carbon emission factors higher than known Elemental Carbon values

Thank you!

- Projects supported by SERDP (Dr. John Hall) and EPA/ORD
- Marine Corps Base Camp Lejeune (NC): Susan Cohen and Danny Becker
- Eglin Air Force Base (FL): Kevin Hiers and Brett Williams
- Fort Jackson (SC)
- Roger Ottmar and David Weiss (US Forest Service),
- Karsten Baumann (Atmospheric Research and Analysis, Inc.)
- Tim Johnson (PNNL)
- Chris Pressley, Dennis Tabor, Bill Squier, Bill Mitchell, Amara Holder, Tiffany Yelverton, Gayle Hagler (EPA)
- Dahman Touati, Steve Terll, Barbara Wyrzykowska-Ceradini, Mike Tufts (Arcadis-US, Inc.)
- Will Stevens (ORISE)
- Rob Gribble (ISSI)