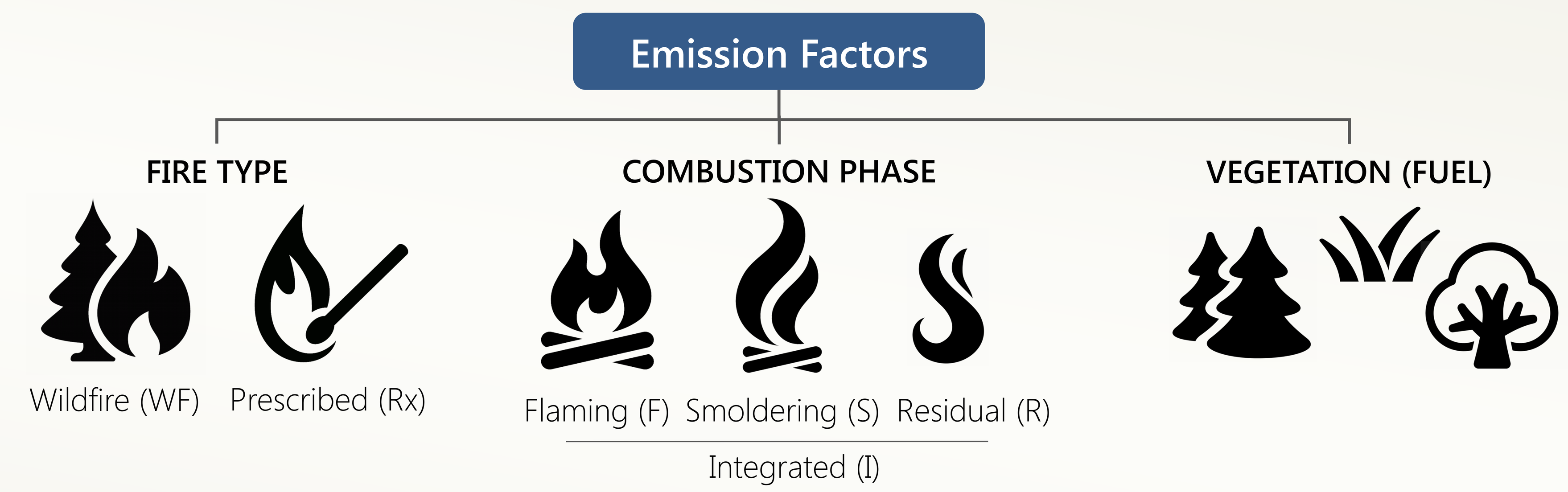
A Comparison Between Model- and Literature-Based Emission Factors for Wildland Fires

Annie F. Seagram[1], ShihMing Huang[1], and Venkatesh Rao[2]
[1]Sonoma Technology, Inc., Petaluma, CA; [2]U.S. Environmental Protection Agency, Durham, NC

Sonoma Technology, Inc.
Innovative Environmental Solutions

Why Are Accurate EFs Important?

Emission factors (EFs) are used to estimate emissions of pollutants from wildland fires. These emissions are used in atmospheric transport models to assess retrospective and real-time smoke impacts and evaluate management strategies, and can be used to create emissions inventories, such as the National Emissions Inventory (NEI). Thus, the accuracy of these emissions, in part, depends on accurate EFs.



Background

- EFs are typically expressed in mass of a chemical species emitted per mass of vegetation (fuel) burned (lbs/ton).
- EFs for wildland fires are empirically derived, either in a laboratory setting or by *in situ* measurements of fire plumes.
- EFs are incorporated into fire emissions models, such as the Fire Emission Production Simulator (FEPS) and the CONSUME model, both of which are available in the BlueSky Framework (BSF). Emissions directly depend on EFs:

$$Emission_i = A \times B \times CE \times EF_i$$

A = area burned
B = biomass available
CE = combustion/consumption efficiency
EF_i = emission factor for pollutant/group i

We compiled EFs by fire type, combustion phase, vegetation type, region, and measurement method (where available) from emission models and selected literature for

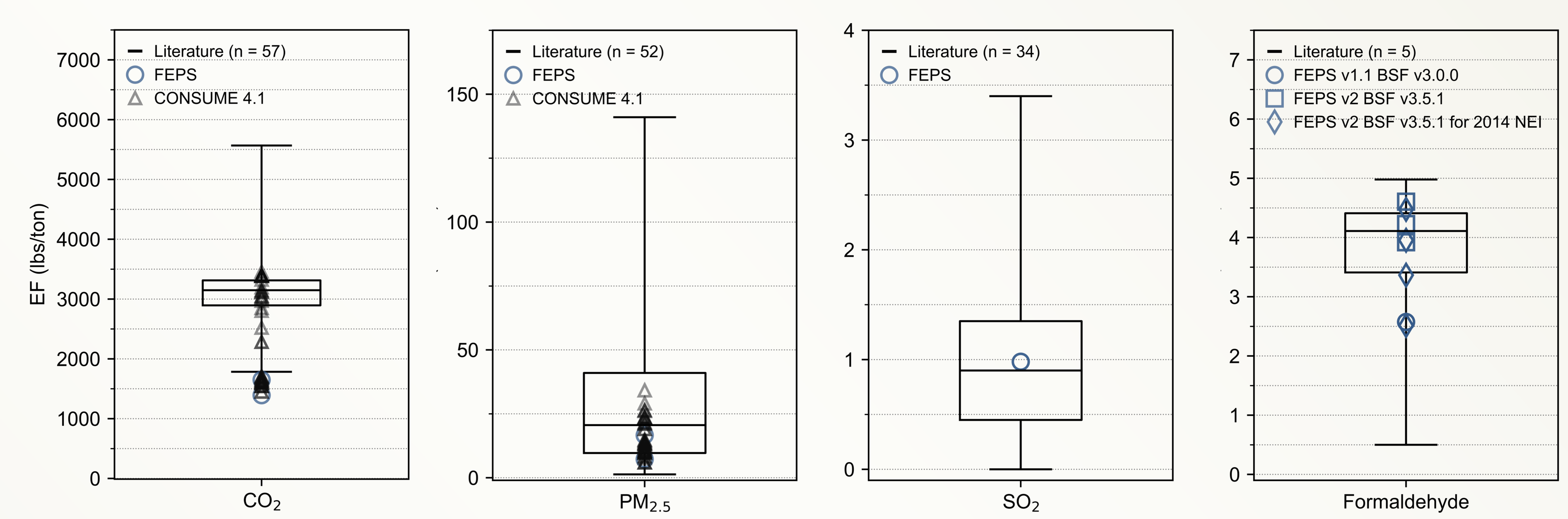
9 air pollutants (APs):
CO, CO_2, CH_4, NO_x, NH_3, SO_2, $PM_{2.5}$, PM_{10}, VOCs
34 hazardous air pollutants (HAPs)

Source	AP	HAP	EF Availability by		
			Fire Type	Combustion Phase	Region/ Vegetation
FEPS v1.1 BSF v3.0.0	✓	✓[a]		APs only	
FEPS v2 BSF v3.5.1	✓	✓[a,b]	HAPs only	✓	
FEPS v2 BSF v3.5.1 for 2014 NEI	✓	✓[a,c]	HAPs only	APs only	Region - HAPs only[d]
CONSUME 4.1	✓			✓	Vegetation[e]
Literature (selected)	✓	✓	WF, Rx, Lab	F, S, I	✓

[a]FEPS as implemented in BSF
[b]HAP EFs provided by EPA
[c]HAP EFs based on Urbanski (2014)
[d]Regions 1-3 are grouped by state and by fire type
[e]Fuelbed determined by Fuel Characteristic Classification System (FCCS)

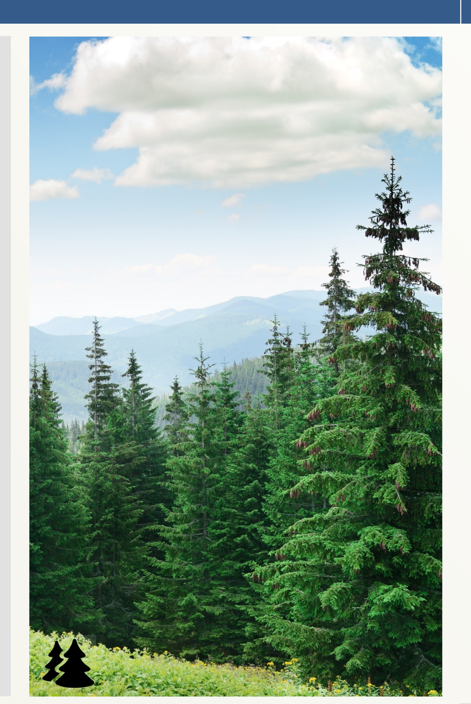
Sample Wildland Fire EFs

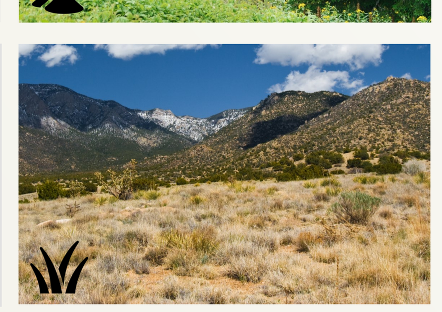
- Wildland fire EFs exhibit a wide range of values by pollutant
- FEPS and CONSUME EFs are comparable
- FEPS and CONSUME EFs are usually within the range of EFs reported in selected literature



EFs for all parameters. Whiskers indicate minimum and maximum values. FEPS EFs are based on reasonable coefficients for F and S phases.

$PM_{2.5}$ EFs (lbs/ton)	F	S	R	I	Fire Type	Vegetation	Source
Pine	16.632	7.28			WF, Rx	(All)	FEPS[a]
	14.6	3	3		WF, Rx	Ponderosa/lodgepole	CONSUME v4.1
	9.6	23.6	23.6		WF, Rx	Mixed conifer	CONSUME v4.1
	2	3.8	3.8		WF, Rx	Southern pine	CONSUME v4.1
				11.67	Rx	Pine-dominated forest	Akagi *et al.* (2013)
	4.07	4.29		5.36	Rx	Pine-dominated forest	Akagi *et al.* (2014)
	4.64	6.96			Rx	Pine-dominated forest	Balachandran *et al.* (2013)
	3.26	12.98			Rx	Pine-dominated forest	Lee *et al.* (2005)
				8.4	Lab	Lodgepole pine	McMeeking *et al.* (2009)
				6.4	Lab	Ponderosa pine	McMeeking *et al.* (2009)
				4.2	Lab	Longleaf pine	McMeeking *et al.* (2009)
				2.8	Lab	Boreal forest	McMeeking *et al.* (2009)
Chaparral	16.632	7.28			WF, Rx	(All)	FEPS[a]
	3.4	9	9		WF, Rx	Chaparral	CONSUME v4.1
				10.92	Lab	Chaparral	Hosseini *et al.* (2013)
				8.2	Lab	Maritime chaparral	Hosseini *et al.* (2013)
				23.2	Lab	Chaparral	McMeeking *et al.* (2009)

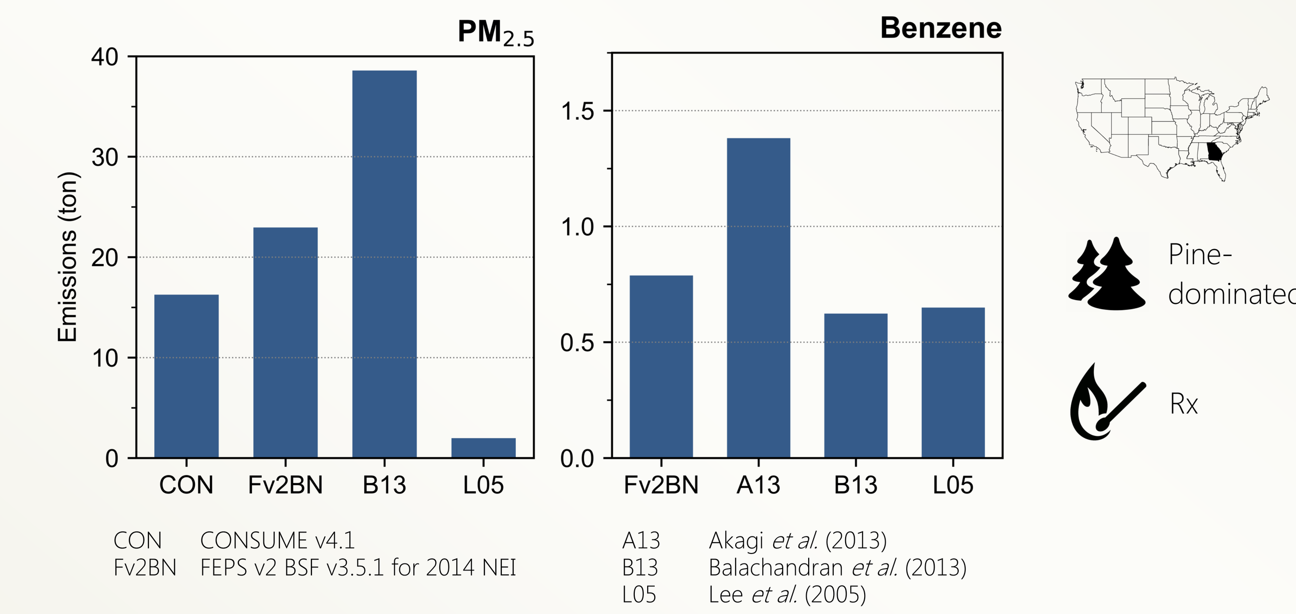




[a]FEPS EFs are based on reasonable combustion coefficients for F and S phases.

Emission Estimates

We modeled the emissions from a single Rx fire in Georgia for 38 hours using EFs from FEPS and CONSUME model defaults and from literature.



For this modeled fire, total $PM_{2.5}$ emissions varied by up to a factor of 20, and total benzene emissions varied by up to a factor of 2.

Implications

- EFs depend on many parameters; current models (e.g., FEPS and CONSUME) do not resolve all parameters
- A wide range in EFs by pollutant indicates potential large uncertainties in emission estimates if EFs are not chosen carefully for a specific project
- Selecting appropriate EFs to include in models could have policy and research implications (e.g., affecting management decisions and biasing trend analysis)

Future Work

Determining EFs for wildland fire is an active area of research given advancing technologies and changing environmental conditions and vegetation. EFs vary considerably by pollutant and require refinement in models. The impact of EF choice on emission estimates will be evaluated in the next NEI cycle for wildland fires. EPA's Office of Air Quality Planning and Standards is working with EPA's Office of Research and Development to measure updated EFs of fires by combustion phase and fuel type.

Contact Us

707.665.9900 | sonomatech.com

Poster presented by Annie Seagram (aseagram@sonomatech.com) at the 2017 International Emissions Inventory Conference, August 14-18, 2017, in Baltimore, Maryland (STI-6728).

Akagi S.K. *et al.* (2013) Measurements of reactive trace gases and variable O_3 formation rates in some South Carolina biomass burning plumes. *Atmos. Chem. and Phys.*, 13, 1141-1165, February 1.
Balachandran S. *et al.* (2013) Particulate and gas sampling of prescribed fires in South Georgia, USA. *Atmos. Environ.*, 81, 125-135, December.
Hosseini S. *et al.* (2013) Laboratory characterization of PM emissions from combustion of wildland biomass fuels. *J. of Geophys. Res.: Atmos.*, 118(17), 9914-9929, September 9.
Lee S. *et al.* (2005) Gaseous and particulate emissions from prescribed burning in Georgia. *Environ. Sci. Technol.*, 39(23), 9049-9056, December 1.
McMeeking G.R. *et al.* (2009) Emissions of trace gases and aerosols during the open combustion of biomass in the laboratory. *J. of Geophysical Research*, 114, October 14.
Urbanski S.P. (2014) Wildland fire emissions, carbon, and climate: emissions factors. *Forest Ecology and Management*, 317, 51-60.