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Findings of the African Combustion Aerosol Collaborative Intercomparison Analysis (ACACIA) Pilot Project to Understand the Optical Properties of Biomass Burning Smoke

Marc N. Fiddler et al.

Correspondence to: Manvendra K. Dubey (dubey@lanl.gov) and Solomon Bililign (bililign@ncat.edu)

Section S1. African and New Mexican Biomass Fuels

Fuels in this work are described in Negash (2021), GBIF Secretariat (2023), and Orwa et al. (2009).

Acacia: Acacia abyssinica, also known as Ethiopian acacia, flat-top acacia, or red thorn, is a tree species belonging to the *Fabaceae* family (Kyalangalilwa et al., 2013). It is native to East-South Africa (Fig. S1), particularly in countries such as Ethiopia, Somalia, Kenya, Tanzania, Uganda, Zambia, Zimbabwe, Malawi, Mozambique, and South Africa. It typically grows in savannas, grasslands, and woodland ecosystems at altitudes ranging from sea level up to 2,400 meters, and is well-adapted to regions with semi-arid to sub-humid climates. *Acacia abyssinica* wood is known for its durability and resistance to termites, making it suitable for various applications, including construction, fence posts, and furniture. The wood is known to produce good quality firewood due to its relatively high calorific value (high amount of energy per volume), which means it generates a good amount of heat when burned. Moreover, it tends to burn slowly, thus providing sustained heat for an extended period. It is a relatively common tree in its native regions, making it readily available as a source of firewood.

Mopane: Colophospermum mopane, commonly known as the Mopane tree, mopani, butterfly or balsam tree, is a species of tree belonging to the *Fabaceae* family (Timberlake, 1995; Orwa et al., 2009). It is native to Southern Africa, mainly found in countries such as Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe (Fig. S1). The tree typically grows in hot, dry regions, often dominating the woodland vegetation in these areas. Mopane wood is dense, heavy, and durable, making it suitable for various uses, including construction, furniture, and fencing. When it comes to using Mopane as a fuel, its properties allow it to burn slowly and produce intense heat, making it an excellent choice for firewood, particularly for low and slow indirect (traditional) cooking, high-heat direct cooking, and charcoal production. In regions where Mopane trees are abundant, local communities rely on them for cooking and heating purposes. Mopane trees are also host to *Gonimbrasia belina* or Mopane worms, which primarily feed on mopane leaves and are an important source of protein.

Wanza: Cordia africana, also known as Wanza, the African Cordia, or African cherry, is a tree species that belongs to the *Boraginaceae* family (Bekele-Tesemma and Tengnäs, 2007; Orwa et al., 2009). It is native to various regions in Africa, particularly in the eastern and southern parts, including Ethiopia, Kenya, Tanzania, Malawi, Mozambique, Zambia, and Zimbabwe, and can also be found in South Sudan and Uganda (Fig. S1). The tree is often found in montane forests, wooded grasslands, and riverine areas, and it is well-adapted to a range of environmental conditions. It is valued for its many uses, such as timber, fodder, medicine, and ornamental purposes. As a fuel source, *cordia africana* has a moderate calorific value and can be used for firewood/charcoal production. The wood is known for its hard and durable properties, making it a good choice for producing heat/energy. In rural areas of Africa, firewood and charcoal from *cordia africana* are used for cooking/heating.

Eucalyptus: Eucalyptus camaldulensis, commonly known as the River Red Gum or Bahir Zaf in Amharic, is a tree species belonging to the *Myrtaceae* family (Orwa et al., 2009; Brooker and Kleinig, 1999). It is native to Australia but has been introduced to many other parts of the world, including Africa, Asia, Europe, and the Americas. In its native range, *Eucalyptus camaldulensis* typically grows along watercourses, floodplains, and wetlands, as it has a high tolerance for waterlogged soils. *Eucalyptus camaldulensis* wood is known for its durability and resistance to termites, making it suitable for various applications such as construction, fence posts, and furniture. The wood is relatively dense and has a high calorific value, meaning it generates a good amount of heat when burned. It also burns relatively slowly, providing sustained heat for an extended period. In some regions, *eucalyptus* species are grown and managed as a source of firewood and biomass energy.

Traditional fuel sources in sub-Saharan Africa: In addition to wood, other traditional fuel sources include cow-dung and tree branches or leaves (Sola et al., 2016; World Bank, 2011). Cow-dung, formed into cakes or patties after drying, is an economical, readily available, and renewable resource, particularly in rural areas where cattle farming is common. It produces a moderate amount of heat suitable for daily household needs. Tree branches and leaves, common fuel sources in many African regions, have been traditionally used for cooking, heating, and boiling water. While leaves burn faster and generate less heat compared to branches or logs, they remain a significant energy source.

Savanna grass: The fuel used in this work was sourced from Palapye, Botswana. There are extensive grasslands in Botswana, which is partially used to support the cattle that are raised in the country. While it is not used for cooking purposes, it certainly can be used to start fires, and this fuel would undoubtedly be consumed in wildfires.

Blue Grama: *Bouteloua gracilis* is a native warm-season perennial grass found throughout the United States and Canada (USDA Natural Resources Conservation Service, 2025a). It grows in short bunches reaching 10-20 inches in height. It is often grazed by livestock during the growing season and dormant season.

Ponderosa Pine: *Pinus ponderosa* is a native coniferous forest tree found throughout the western United States (USDA Natural Resources Conservation Service, 2025b). The bottom half of trees typically do not have branches, and the crown of the tree is conical to round-shaped. These long-lived trees can live 300-600 years and reach heights of 30-50 meters tall and 0.6 to 1.3 m in diameter. These trees are susceptible to fungal diseases transmitted by pine beetles and to damage by pine beetle larva which consume their phloem and the ponderosa pine budworm which eats new needles.

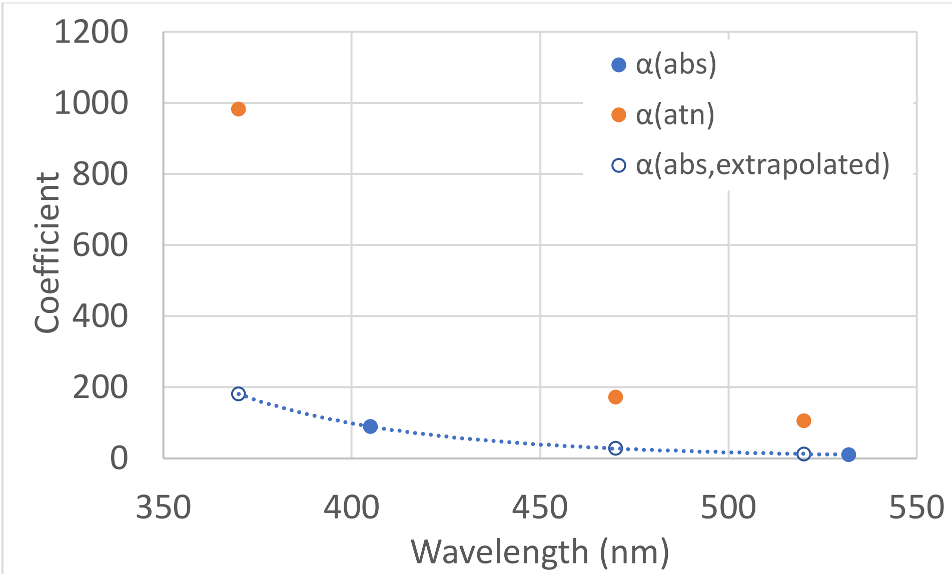

Figure S1. Absorption coefficients extrapolated from measured wavelengths of the PASS (532 and 405 nm) to wavelengths used by the Aethalometer. This was then used to calculate correction factors for the Aethalometer. Average coefficients for burn 17 (Mopane) were used for demonstration purposes.

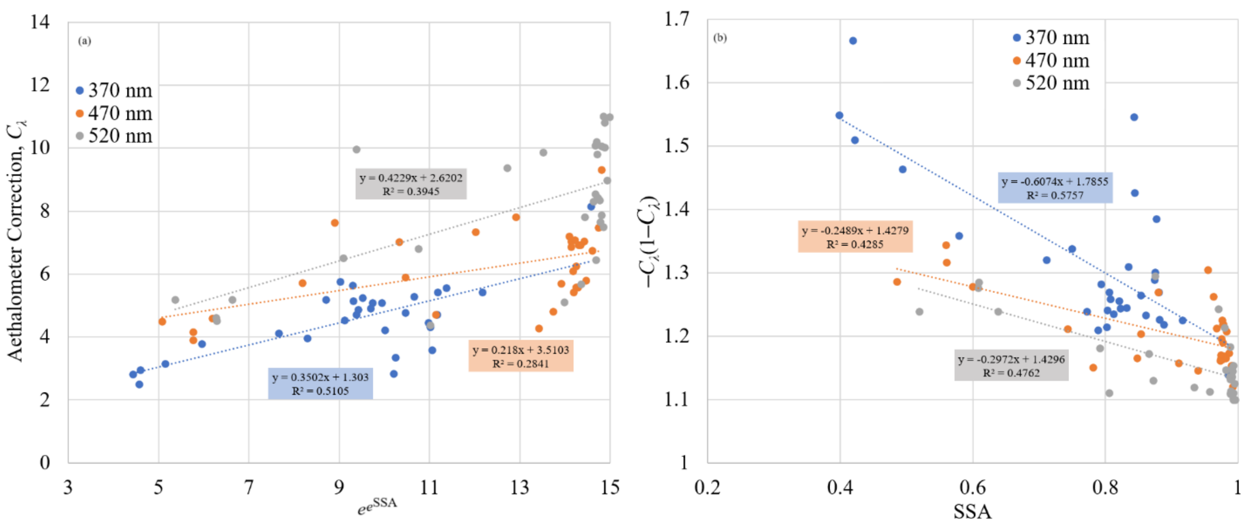

Figure S2. Results of the best fit functions of C_λ to SSA for all fuels in this study: (a) the nested exponential of SSA vs. C_λ and (b) SSA vs. $-C_\lambda(1-C_\lambda)$.

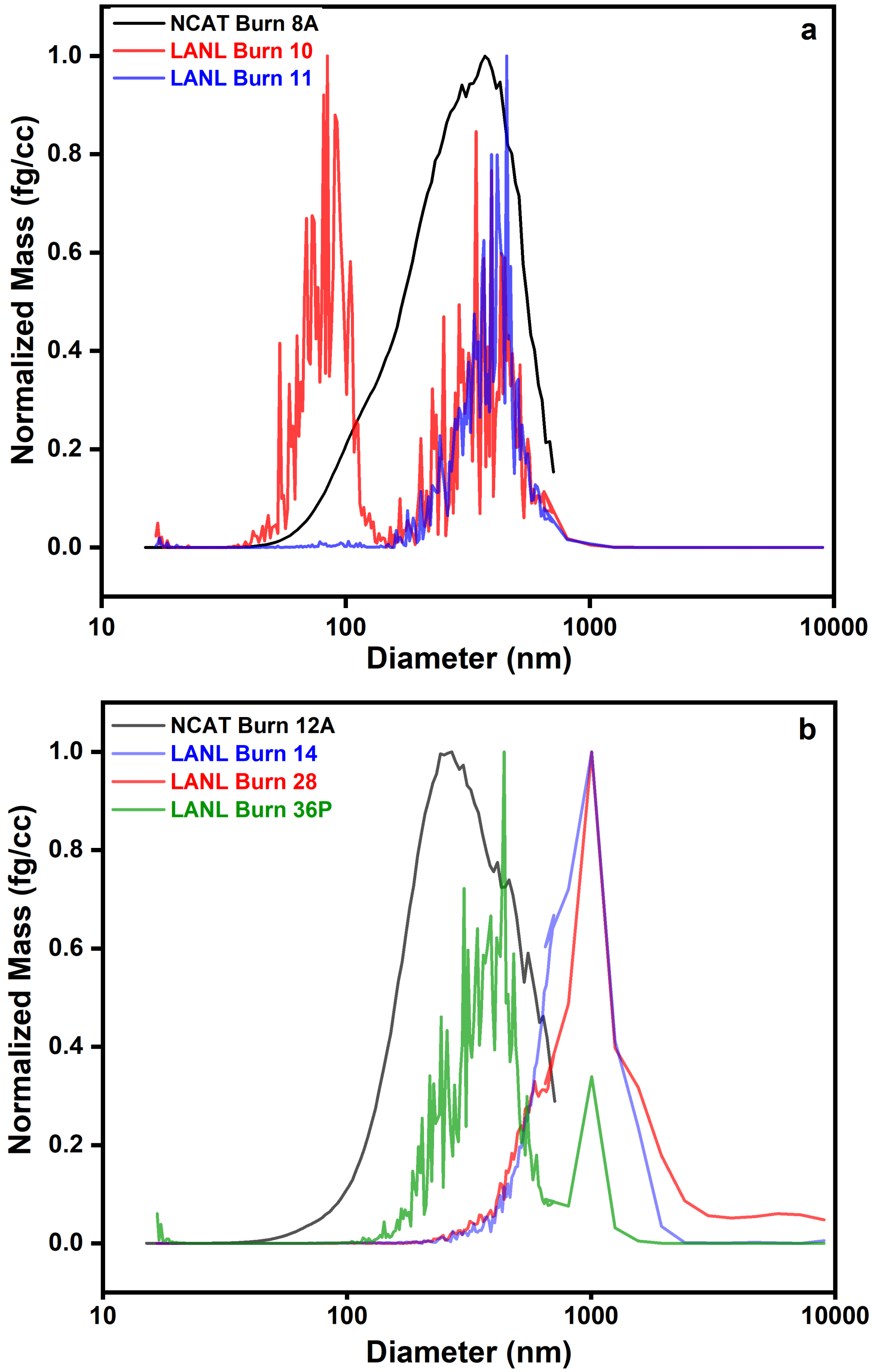

Figure S3. The normalized mass distributions (dM/dlogD_P) measured at LANL and NCAT for (a) wanza and (b) mopane.

Table S1. Burn experiments, showing the burn number, fuel, temperature of the tube furnace, MCE, AAE, ASE, and AEE from 405 to 532 nm using aethalometer correction factors (C_λ) at three wavelengths, and extrapolated SSA values at these wavelengths. Directly measured mass extinction and SSA at 532 nm are included. Value marked with * was not included in parametrization fits. P. Pine, S. grass, and B. Gama are short for Ponderosa Gama.

				Ångström Exponents						Avg Aethalometer Correction, C_λ						Avg Extrapolated SSA						Cross Secti	
				AAE		ASE		AEE		370		470		520		370		470		520		MEC_{532}	
Burn #	Fuel	Temp.	MCE	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD
7	Eucalyptus	450	-	8.82	0.21	-0.41	0.03	-0.10	0.03	4.71	0.25	5.58	0.47	7.65	0.80	0.81	0.01	0.98	0	0.99	0	4.10	0.17
8	Eucalyptus	450	-	10.18	0.12	-0.46	0.03	-0.10	0.03	3.95	0.14	6.92	0.14	11.01	0.29	0.75	0	0.98	0	0.99	0	3.65	0.05
9	Acacia	450	-	9.34	0.16	-0.78	0.05	-0.50	0.04	4.86	0.11	7.04	0.21	10.03	0.49	0.81	0.01	0.98	0	0.99	0	4.85	0.45
10	Wanza	450	-	8.47	0.28	-0.36	0.15	-0.04	0.14	5.65	0.35	7.05	0.17	9.81	0.48	0.80	0.01	0.97	0	0.99	0	4.39	0.19
11	Wanza	450	-	8.33	0.15	-0.22	0.07	0.10	0.06	5.15	0.20	0.93*	0.06	8.54	0.52	0.80	0	0.97	0	0.99	0	4.52	0.14
12	Dung	450	0.87	8.29	0.48	-0.22	0.03	-0.02	0.03	4.45	0.35	5.81	0.32	7.49	0.71	0.87	0.01	0.98	0	0.99	0	5.59	0.04
13	S. grass	450	0.71	9.32	1.08	0.30	0.04	0.42	0.04	5.43	0.52	7.48	1.31	10.99	3.05	0.92	0.01	0.99	0	1.00	0	5.48	0.16
14	Mopane	450	0.81	9.37	0.22	-0.32	0.03	0.00	0.03	4.54	0.11	5.58	0.19	7.88	0.49	0.79	0	0.98	0	0.99	0	5.08	0.74
15	Mopane	600	0.92	2.30	0.10	0.64	0.07	1.32	0.08	3.16	0.05	4.59	0.08	5.18	0.13	0.49	0	0.60	0	0.64	0	18.90	1.61
17	Mopane	550	0.93	7.77	0.24	1.04	0.05	1.25	0.05	5.42	0.22	6.09	0.21	8.30	0.56	0.88	0.01	0.98	0	0.99	0	19.27	1.51
18	Wanza	575	0.91	7.09	0.32	1.17	0.07	1.40	0.07	4.32	0.25	5.70	0.35	7.81	0.88	0.88	0.01	0.97	0	0.98	0	21.89	2.60
19	Wanza	600	0.92	5.15	0.29	1.92	0.11	2.23	0.10	4.9	0.33	7.34	0.22	9.37	0.53	0.82	0.01	0.91	0	0.93	0	19.09	0.94
20	Dung	600	0.75	8.39	0.07	0	0.04	0.27	0.03	4.22	0.20	7.09	0.12	8.43	0.21	0.83	0	0.98	0	0.99	0	6.74	0.13
24	Eucalyptus	650	0.91	4.28	0.44	2.27	0.13	2.59	0.10	5.18	0.39	7.02	0.52	8.67	0.98	0.77	0.01	0.85	0.01	0.87	0.01	17.56	3.07
25	Acacia	650	0.89	4.38	0.54	2.88	0.11	3.21	0.17	4.12	0.35	7.63	0.48	9.97	1.11	0.71	0.02	0.78	0.01	0.81	0.02	10.56	1.24
27	Dung	700	0.97	4.68	0.67	2.40	0.07	2.42	0.07	8.15	0.54	9.30	1.34	10.81	2.41	0.99	0	0.99	0	0.99	0	18.71	2.16
28	Mopane	700	0.82	1.50	0.02	-0.58	0.02	0.36	0.02	2.96	0.17	4.16	0.26	4.62	0.28	0.42	0	0.56	0	0.61	0	4.80	0.08
29	Acacia	700	0.93	2.29	0.05	0.17	0.06	1.12	0.05	2.50	0.15	3.90	0.20	4.51	0.22	0.42	0	0.56	0	0.61	0	6.25	0.08
33	Acacia	800	0.97	2.65	0.05	1.29	0.06	2.00	0.05	2.82	0.06	4.49	0.13	5.18	0.17	0.40	0	0.49	0	0.52	0	6.28	0.22
35P	Acacia	450	0.75	9.20	0.15	0.15	0.03	0.41	0.03	5.08	0.15	6.92	0.20	10.06	0.67	0.83	0.01	0.98	0	0.99	0	4.72	0.26
35O	Acacia	450	0.75	8.60	0.37	0.81	0.04	1.08	0.05	2.83	0.17	6.87	0.26	10.09	0.76	0.84	0.01	0.97	0	0.99	0	5.40	0.16
36P	Mopane	450	0.76	9	0.17	0.05	0.03	0.39	0.04	5.76	0.31	7.19	0.28	10.21	0.69	0.79	0	0.97	0	0.99	0	2.01	0.03
36O	Mopane	450	0.76	5.48	0.09	1.10	0.16	1.32	0.15	3.59	0.20	4.28	0.25	5.11	0.33	0.88	0	0.95	0	0.97	0	4.02	0.20
37	B. Grama	450	0.79	9.24	0.15	0	0.04	0.18	0.04	4.71	0.34	6.75	0.35	8.97	0.53	0.88	0.01	0.99	0	0.99	0	3.81	0.15
38	B. Grama	650	0.87	2.66	0.03	-0.17	0.06	0.59	0.04	3.79	0.07	5.71	0.08	6.51	0.08	0.58	0.01	0.74	0	0.79	0	9.65	0.24
39P	Dung	450	0.83	7.37	0.12	-0.35	0.02	-0.11	0.02	4.78	0.40	5.42	0.18	6.44	0.13	0.85	0.01	0.98	0	0.99	0	3.19	0.17

39O	Dung	450	0.83	6.43	0.11	0.13	0.06	0.41	0.06	3.34	0.17	4.80	0.10	5.67	0.13	0.84	0	0.96	0	0.98	0	3.63	0.18
40	P. Pine	450	0.70	8.99	0.08	-0.10	0.05	0.20	0.04	5.24	0.3	6.25	0.43	8.35	0.55	0.81	0	0.98	0	0.99	0	2.61	0.20
41	P. Pine	600	0.92	2.76	0.07	1.81	0.12	1.95	0.11	5.09	0.19	5.89	0.32	6.80	0.35	0.82	0	0.85	0	0.87	0	8.72	0.52
42P	Acacia	650	0.87	5.80	0.42	2.11	0.09	2.35	0.09	5.29	0.35	7.82	0.41	9.87	0.92	0.86	0.01	0.94	0	0.96	0	6.41	0.19
42O	Acacia	650	0.87	2.33	0.74	2.72	0.19	2.67	0.21	5.56	0.90	4.71	0.31	4.38	0.63	0.89	0.02	0.88	0.01	0.87	0.01	4.06	0.13

Table S2. Fit functions applied to the plot of C_λ against SSA for African wood fuels (see Table 1) and the resulting R^2 and the Chi squared (X^2) values

		R^2			X^2		
Function	Form	370	470	520	370	470	520
Linear	$C_\lambda = A\omega+B$	0.467	0.311	0.393	4.12	5.21	9.73
Polynomial	$C_\lambda = A\omega^2+B\omega+D$	0.491	0.322	0.396	3.99	5.10	9.71
Log	$C_\lambda = A\cdot\ln(\omega)+B$	0.446	0.318	0.386	4.33	5.14	9.88
Exponential	$C_\lambda = Ae^{B\omega}$	0.485	0.305	0.396	4.11	5.39	10.04
Power Law	$C_\lambda = A\omega^B$	0.463	0.314	0.394	4.30	5.29	10.06
Schmid/Yus-Díez	$C_\lambda = A\omega/(1-\omega)+B$	0.433	0.329	0.379	5.06	5.53	11.08
	$C_\lambda = -A/\ln(\omega)+B$	0.434	0.330	0.379	5.06	5.53	11.07
Arctangent	$C_\lambda = A\cdot\arctan(\omega)+B$	0.453	0.317	0.389	4.26	5.15	9.81
	$C_\lambda = A\cdot e^{(\omega-1)}/(1-\omega)+B$	0.430	0.329	0.379	5.09	5.54	11.08
Nested Exp.	$C_\lambda = A\cdot e^{e^{\omega}}+B$	0.511	0.284	0.395	3.85	5.51	9.85
	$-C_\lambda/(1-C_\lambda) = A\omega+B$	0.576	0.429	0.476	0.14	0.04	0.05
	$1/\ln(C_\lambda) = A\omega+B$	0.574	0.417	0.470	0.37	0.16	0.20
	$\arctan(C_\lambda) = A\omega+B$	0.562	0.408	0.469	0.03	0.02	0.02

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