Controlling Factors for Smoke Emissions from Urban and Wildland Fuels

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NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

News Media Images
South Fork/Salt Fires Near Ruidoso, NM 2024 ~25K acres

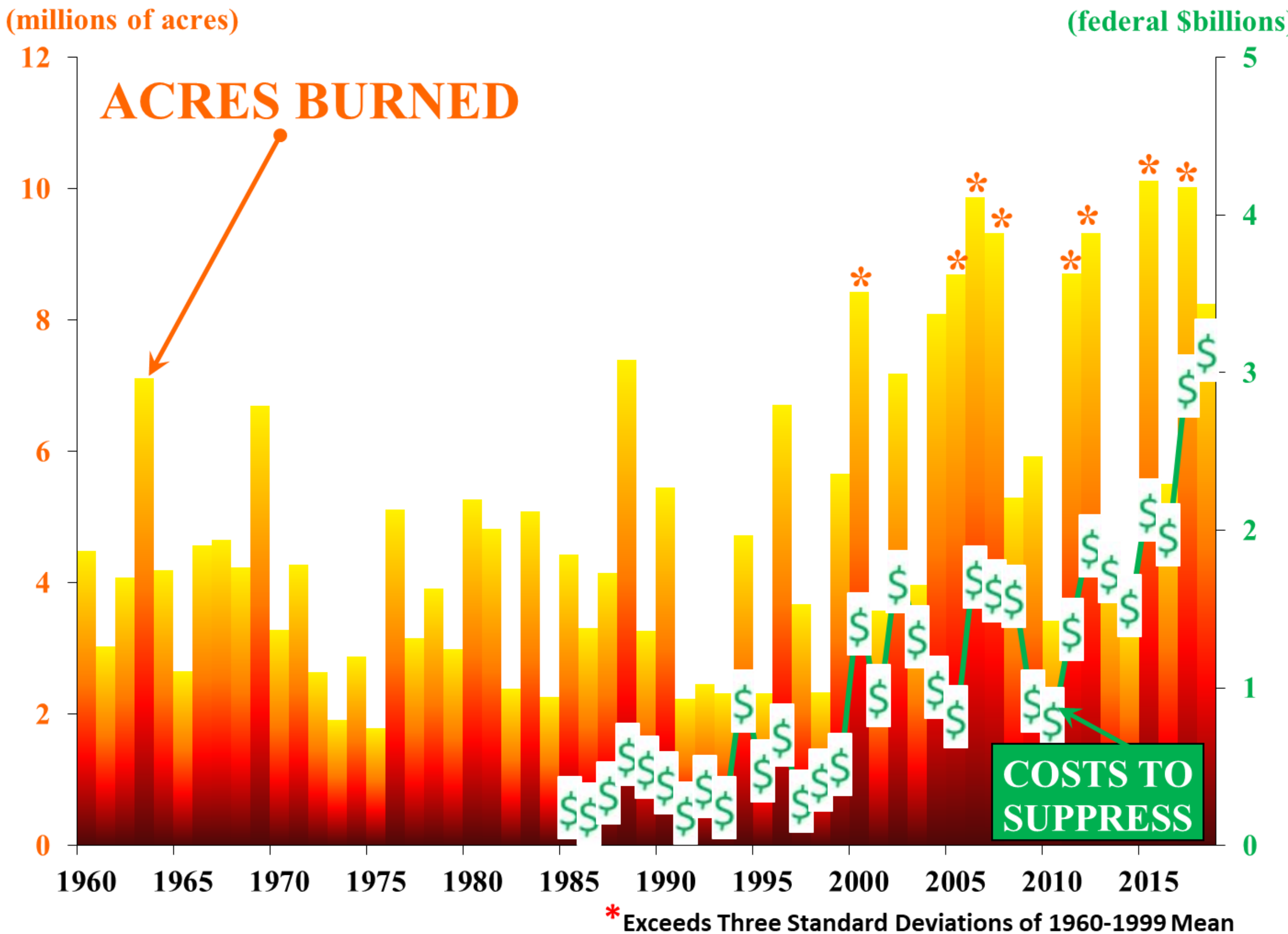
A. Aiken, K. Benedict, K. Gorkowski, J. Lee, A. Josephson, J. Reisner, M. Dubey

Los Alamos NATIONAL LABORATORY EST. 1943

IMPROVE 30 YEARS OF IMPROVING VISIBILITY 1985 - 2015

October 2024

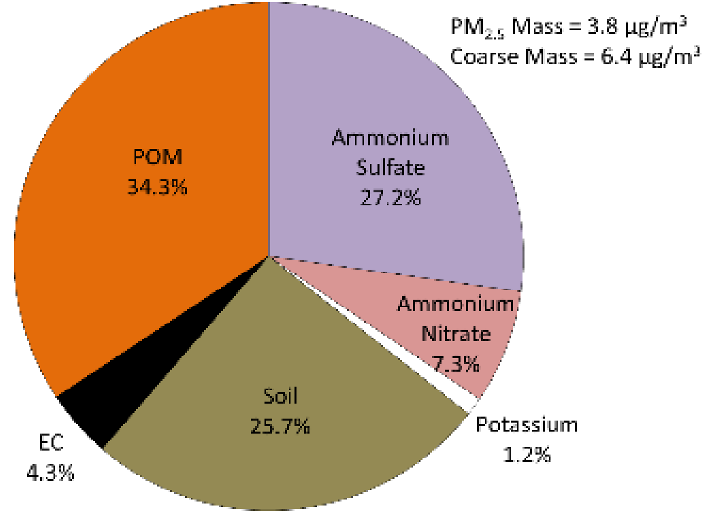
Overview

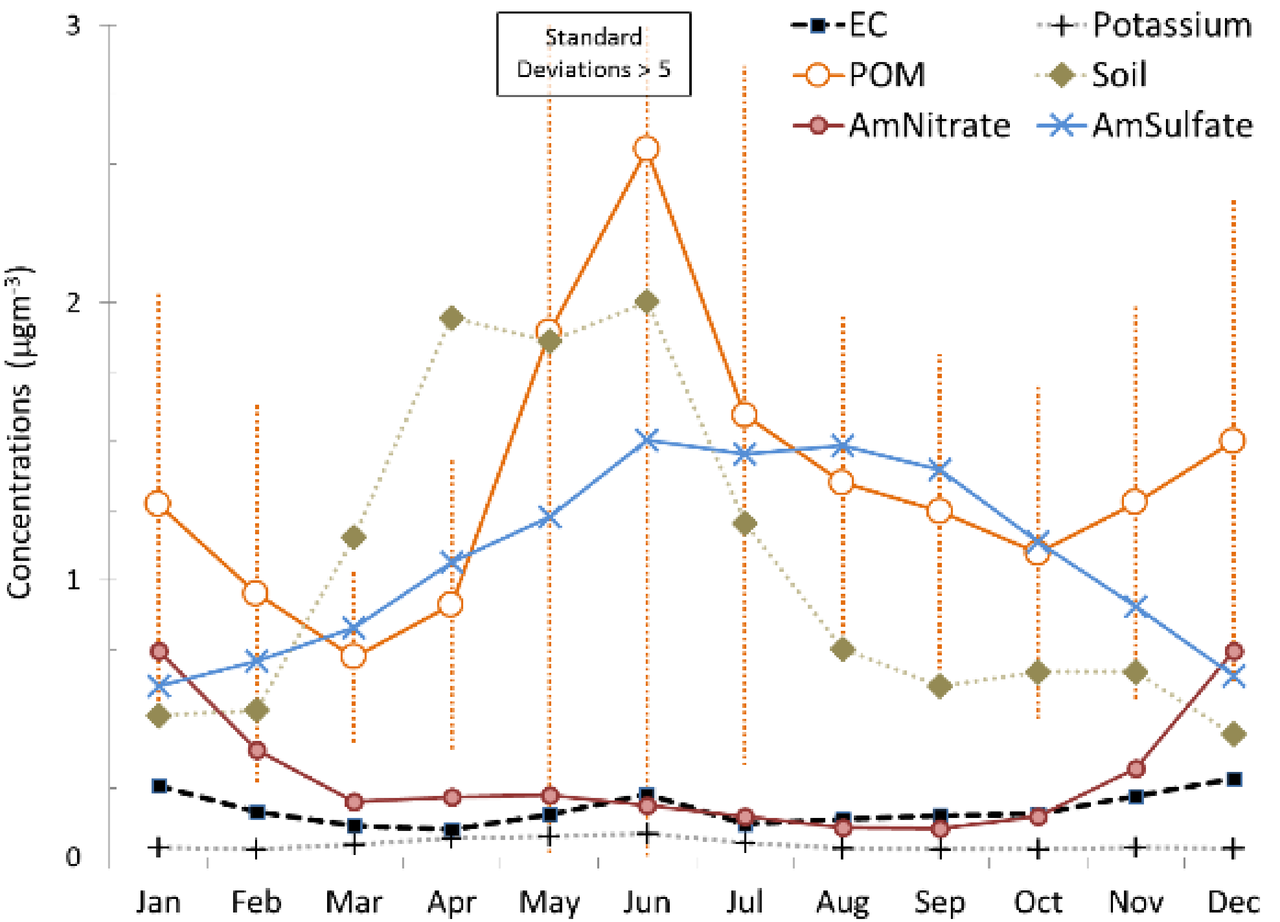


- USFS is now spending ~half its budget on fire suppression (to the detriment of forest management and prescribed burning)

Southwest US $PM_{2.5}$ Air Quality

$PM_{2.5}$ is typically mixture of organic carbon, elemental carbon, salt species, soil dust species

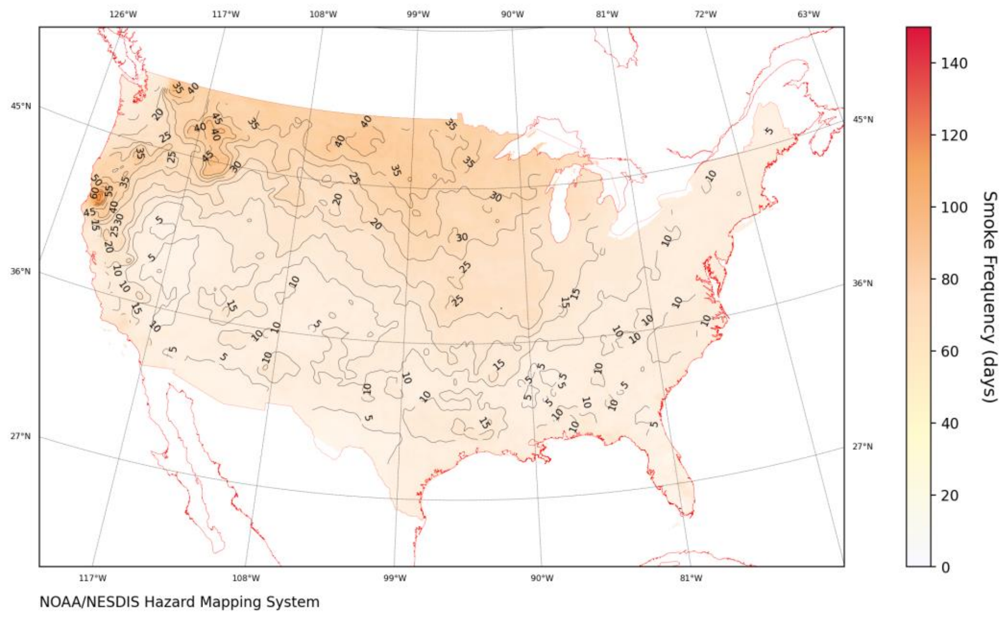




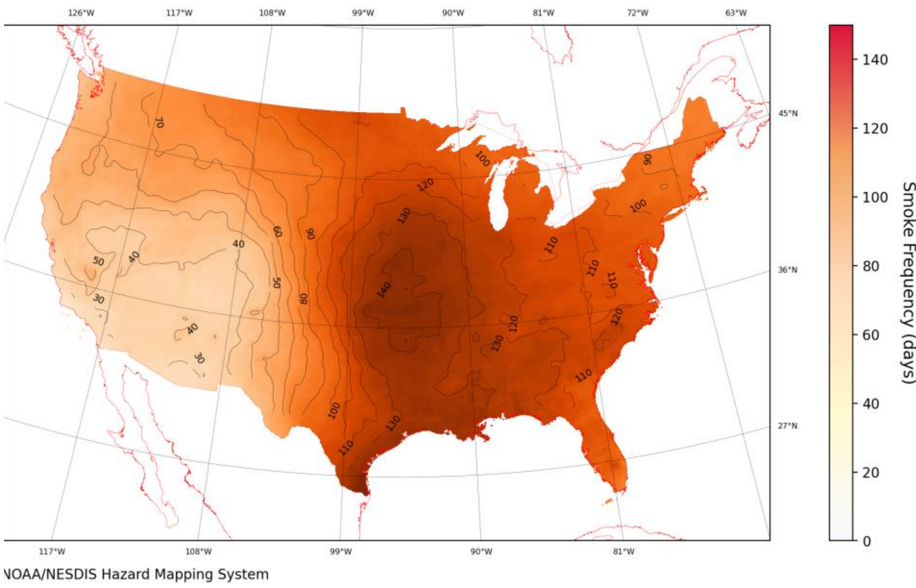
Bosque del Apache IMPROVE station (2000-2014 data)

- ❖ Peak in dust + smoke in April-July
- ❖ Winter secondary peak in POM, NH_4NO_3, EC
- ❖ Summer peak in $(NH_4)_2SO_4$

Biomass Smoke Exposure: Not just the West (NOAA)



Cumulative Smoke Distribution (CONUS) 2006



Cumulative Smoke Distribution (CONUS) 2024

Parameters of Interest

Parameter	Description	Units	Techniques	Notes & Relevance
σ_{abs}				
σ_{scat}				
Å, b	Ångtröm exponent, backscatter fraction	----------	Wavelength dependence and direction of	Determines radiation reflected to space
ω				
				, CCN,
σ_g	Geometric standard deviation	----------	Particle Sizer (eg SMPS)	Width of size distribution
f(RH) *gRH)*	Hygroscopic growth	----------	Controlled RH nephelometry, H-CAPS PMssa	Aerosols water uptake key to radiative effects
MCE	Combustion Efficiency	----------	CO & CO_2 Instruments	$\frac{\Delta CO_2}{\Delta CO_2 + \Delta CO}$

- These two integrated over the column give aerosol optical depth
- These are key variables that parameterize aerosol effects in climate & visibility models

Laboratory: Summary of κappa vs. Plant Phenotype

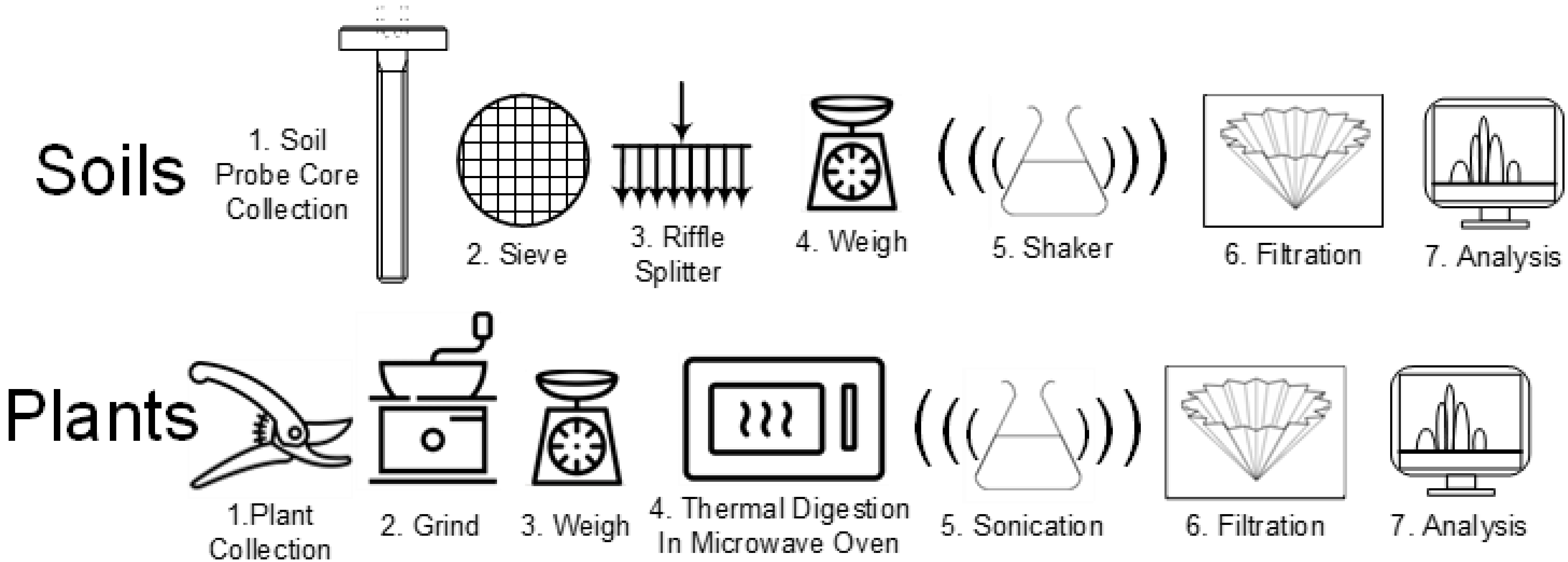
(Gomez et al., 2018, JGR)

Fuel Type	Lower Combustion Temperatures	Higher Combustion Temperatures
Evergreen Needles and Woods	Low Hygroscopicity Kappa$_{avg}$: 0.008 Kappa$_{nin}$: 0.003 Kappa$_{max}$: 0.012	Low Hygroscopicity Kappa$_{avg}$: 0.014 Kappa$_{nin}$: -0.008 Kappa$_{max}$: 0.040
Deciduous Woods	Low Hygroscopicity Kappa$_{avg}$: 0.008 Kappa$_{nin}$: -0.002 Kappa$_{max}$: 0.017	Low Hygroscopicity Kappa$_{avg}$: 0.014 Kappa$_{nin}$: -0.005 Kappa$_{max}$: 0.041
Deciduous Leaves	Low Hygroscopicity Kappa$_{avg}$: 0.007 Kappa$_{nin}$: -0.007 Kappa$_{max}$: 0.027	Moderate Hygroscopicity Kappa$_{avg}$: 0.032 Kappa$_{nin}$: -0.011 Kappa$_{max}$: 0.086
Grasses (Native and Invasive)	Moderate Hygroscopicity Kappa$_{avg}$: 0.025 Kappa$_{nin}$: 0.006 Kappa$_{max}$: 0.100	High Hygroscopicity Kappa$_{avg}$: 0.098 Kappa$_{nin}$: 0.004 Kappa$_{max}$: 0.234
Halophytic and Salt Tolerant	Moderate Hygroscopicity Kappa$_{avg}$: 0.036 Kappa$_{nin}$: -0.013 Kappa$_{max}$: 0.179	High Hygroscopicity Kappa$_{avg}$: 0.056 Kappa$_{nin}$: -0.004 Kappa$_{max}$: 0.266

Increasing Hygroscopic Response

Gomez et al. [2018]

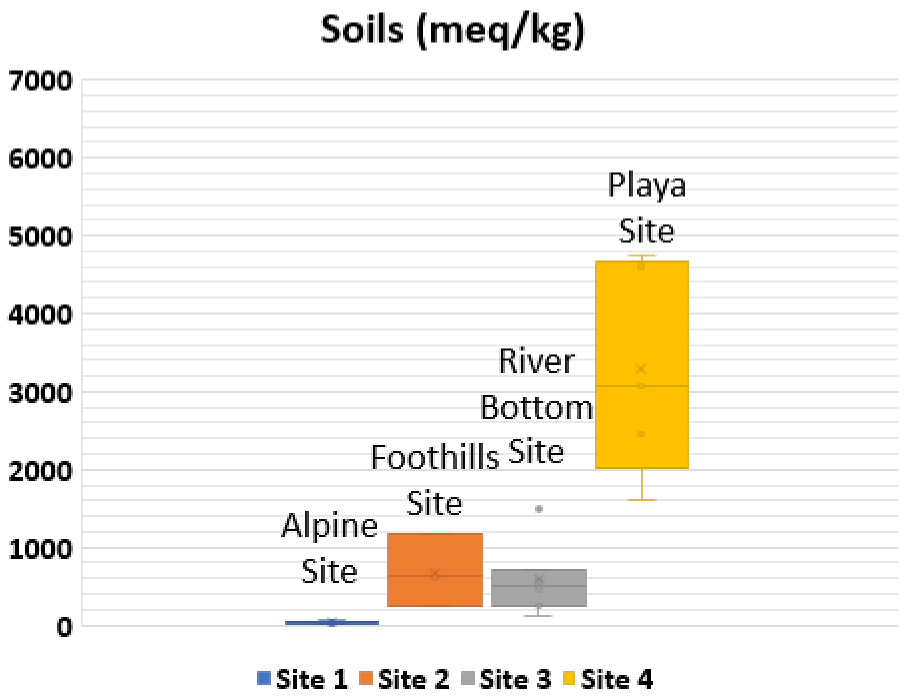
Plants & Soils Analyses

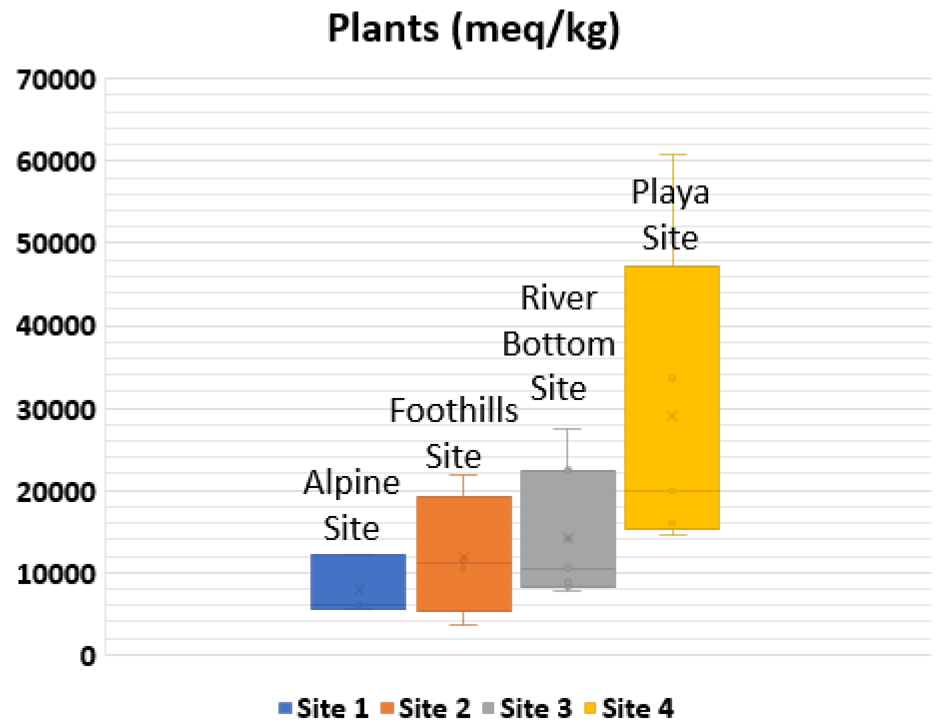


- Congruent sampling and analysis of soil and plant samples
- Used IMPROVE filter sample analysis protocols as starting point

Soil to Plant to Smoke Inorganics Relationship

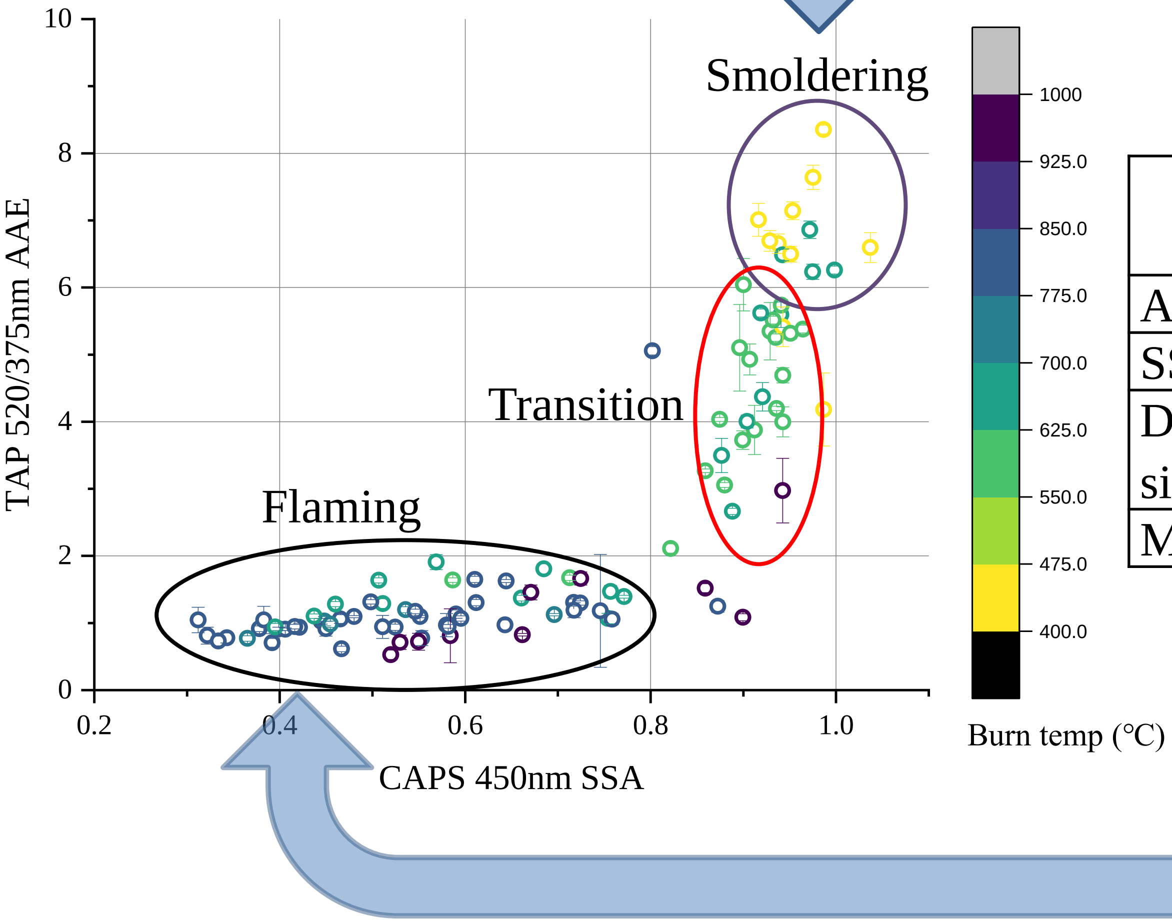
(Gulick et al., 2023, SciTotEnv)





- Soils & plants relationship to aerosol hygroscopicity showed some level of ecosystem level correlation

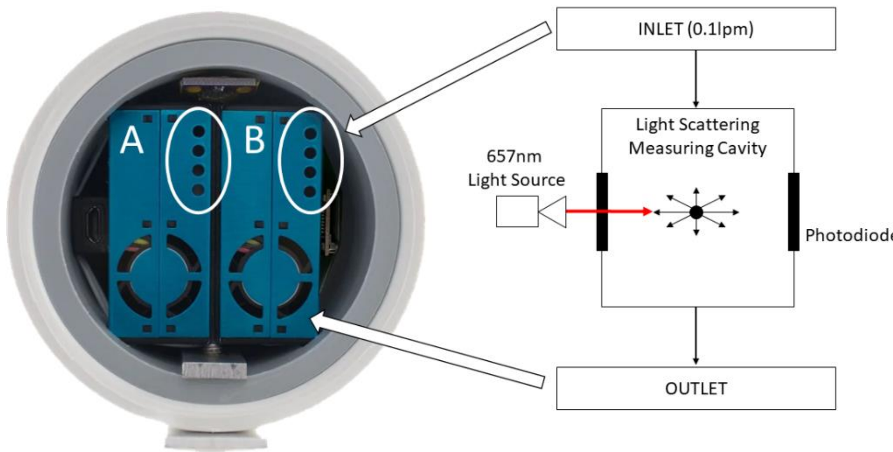
Burn temperature is a key driver on aerosol properties. Fuel less important to physical properties (Dungan, 2022 MS thesis).



	Low temp 400-550°C	High temp 650-1000°C
AAE	↑	↓
SSA	↑	↓
Diameter size	↑	↓
MCE	↓	↑

Purple Air Sensor and Microaethalemeter

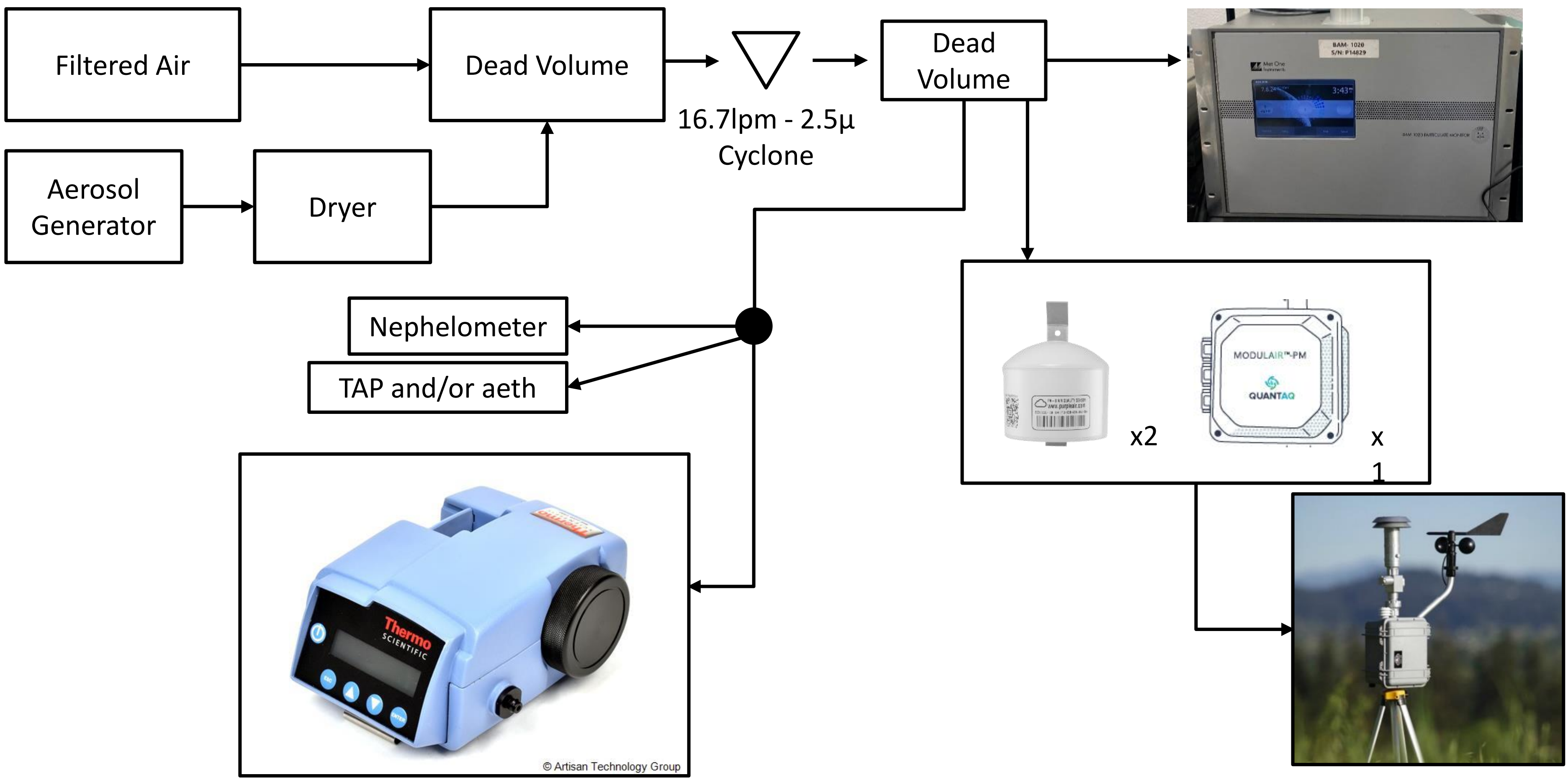
- Cost-effective sensor (~$300) and light weight (~1kg)
- Utilizes two, redundant PlanTower PMS5003 sensors
  - Measures PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ [$\mu g/m^3$]
  - Records T, P, and RH from other sensors
- Light scattering based sensor
  - 657nm light source
- Corrections for moderately aged smoke have been constructed (Holder et al., 2020)
  - Over measures low concentrations
  - Non-linear transition
  - Under measures high concentrations



- Multiwavelength UV-IR aerosol light absorption from BC concentrations
- Dual spot operation for minimization of non-idealities

Laboratory Experiments: Low-Cost Sensors vs. Benchtop (Himes et al., in prep)

FEM Beta Attenuation



ThermoScientifc PDR Combination Light Scattering and Backup Filter

Near FRM Filter Sampler

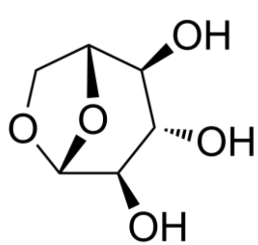
Lab Validation Experimental Iterations

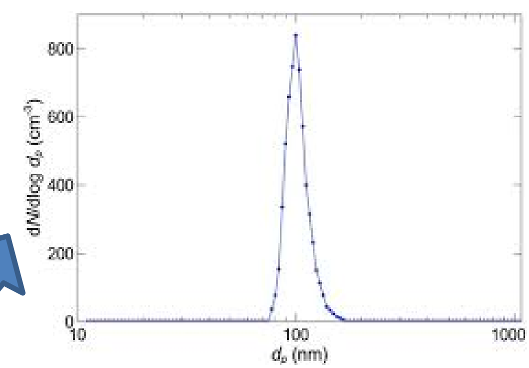
- Real Laboratory Generated Smoke: Too Variable for Day+ Experiments

- Liquid Aerosol and Semivolatile: Filter Discrepancies

- Step Back to Something Simple and Known: Ammonium Sulfate

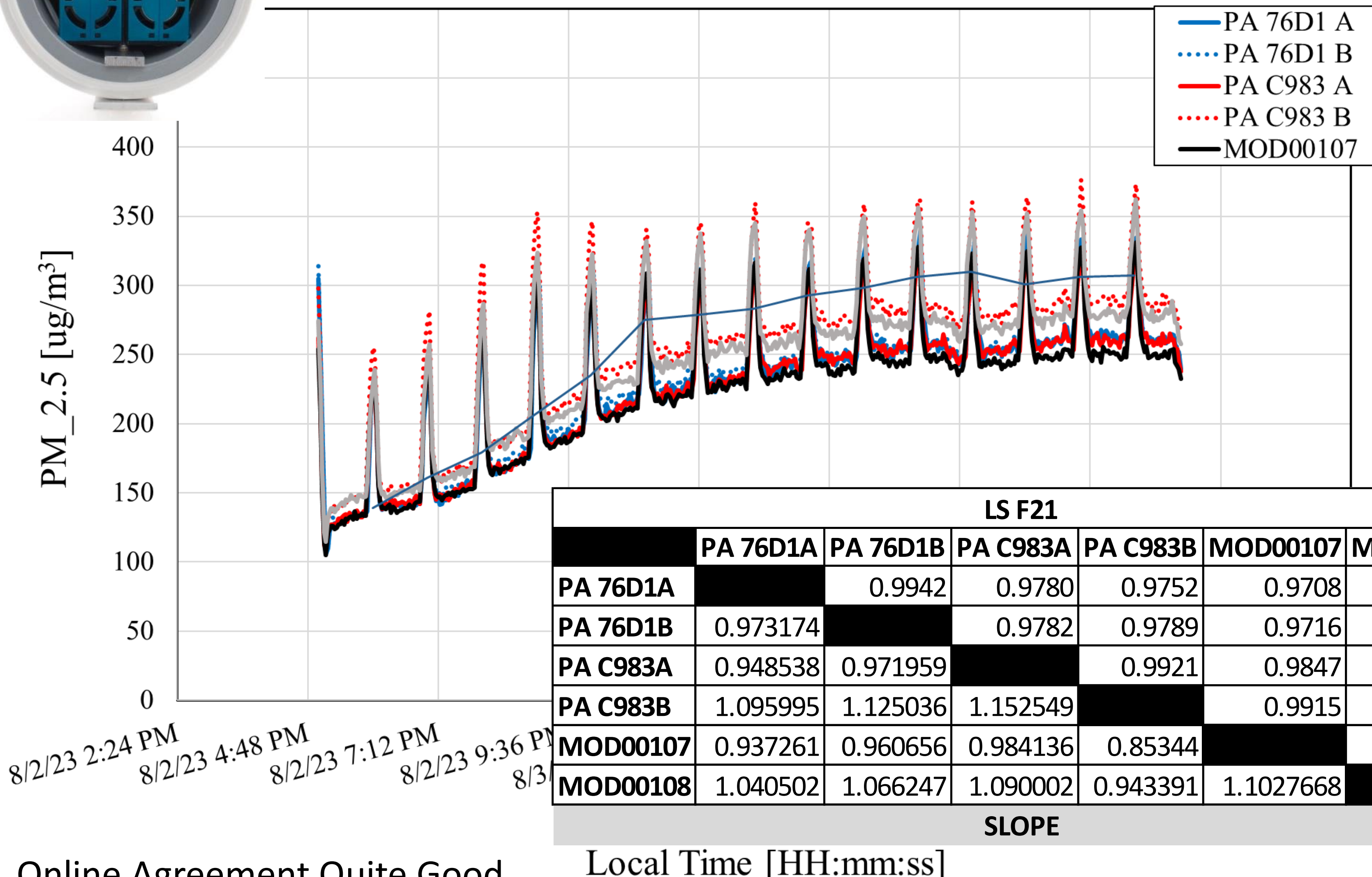
- Reintroduce More Complexity: Smoke Filter Extractions, Soot and biomass smoke proxies





- Explicitly probe the size dependence

Online Sensor Agreement in Laboratory (Artificial Smoke)



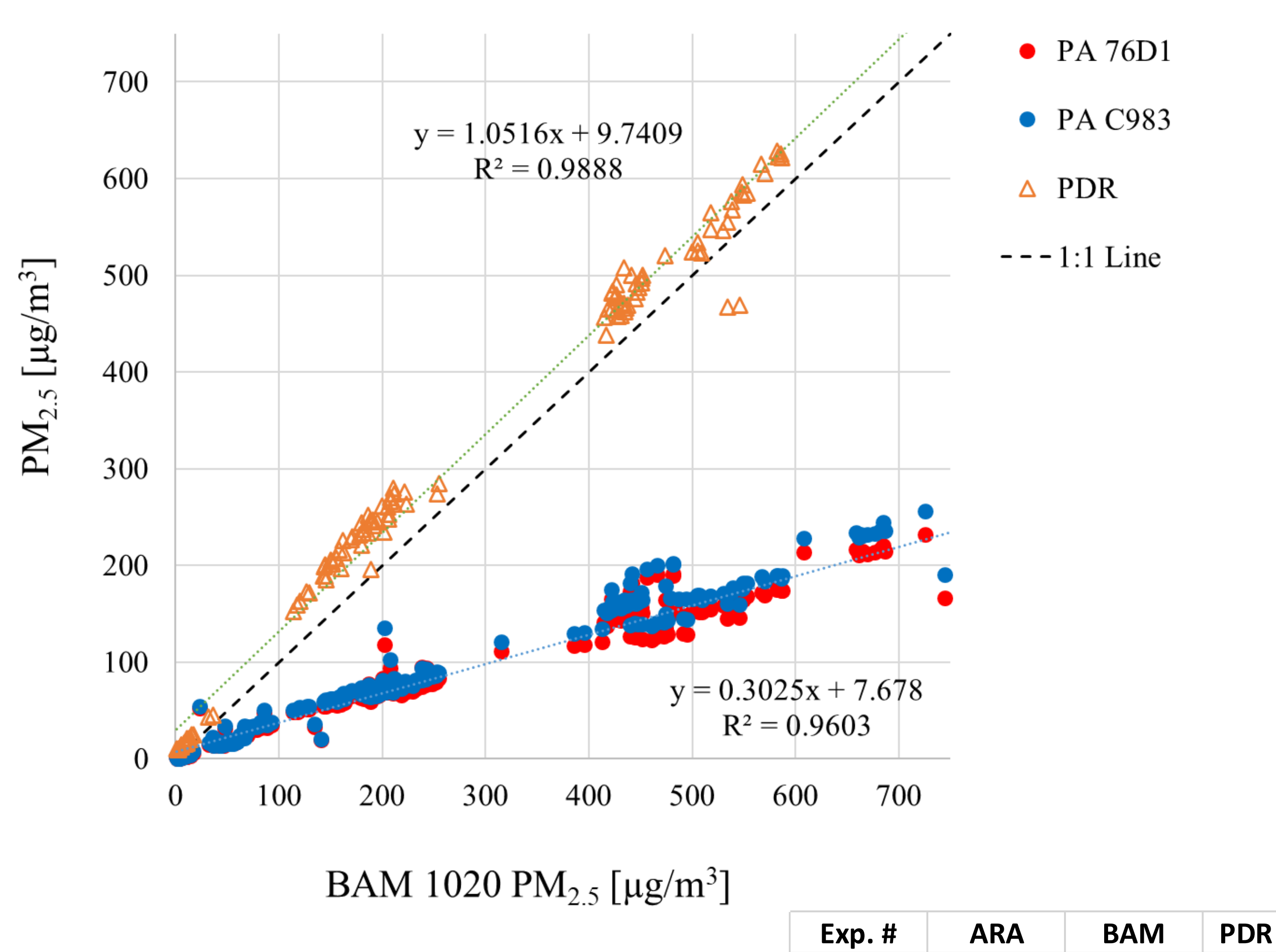
LS F21						
	PA 76D1A	PA 76D1B	PA C983A	PA C983B	MOD00107	MOD00108
PA 76D1A		0.9942	0.9780	0.9752	0.9708	0.9762
PA 76D1B	0.973174		0.9782	0.9789	0.9716	0.9765
PA C983A	0.948538	0.971959		0.9921	0.9847	0.9855
PA C983B	1.095995	1.125036	1.152549		0.9915	0.9884
MOD00107	0.937261	0.960656	0.984136	0.85344		0.9922
MOD00108	1.040502	1.066247	1.090002	0.943391	1.1027668	

R^2

SLOPE

- ➢ Online Agreement Quite Good
- ➢ Need More Effort to Compare to FEMs, FRMS with Non-volatile Aerosol

Can we take the raw data from the PurpleAir and get a reasonable $[PM_{2.5}]$?

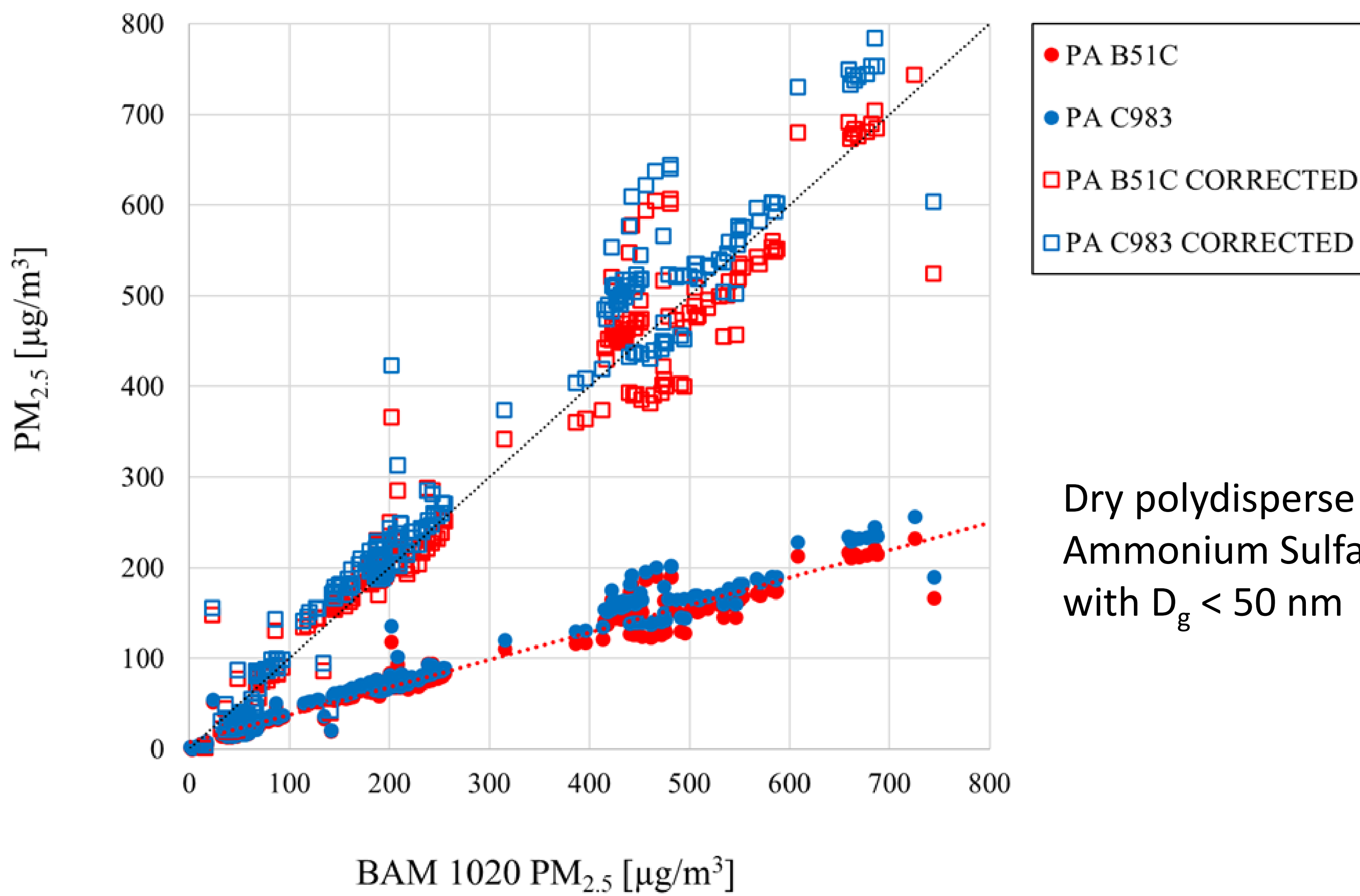


Dry polydisperse Ammonium Sulfate with D_g < 50 nm

Dry polydisperse Ammonium Sulfate with D_g ~ 40-50 nm

Exp. #	ARA	BAM	PDR Filt.	PDR Opt.	PA B51C AVG	PA C983 AVG
AS 500	410.84	434.5	614.81	468.7	146.52	160.25
082524 AS	27.03	11.25	12.35	19	4.23	5.08
082624 AS	156.73	155.39	207.73	266.73	93.84	102.26
082824 AS	191.63	208.12	271.11	256.66	73.09	78.15
090124 AS	476.73	552.05	728.96	587.35	167.53	180.9

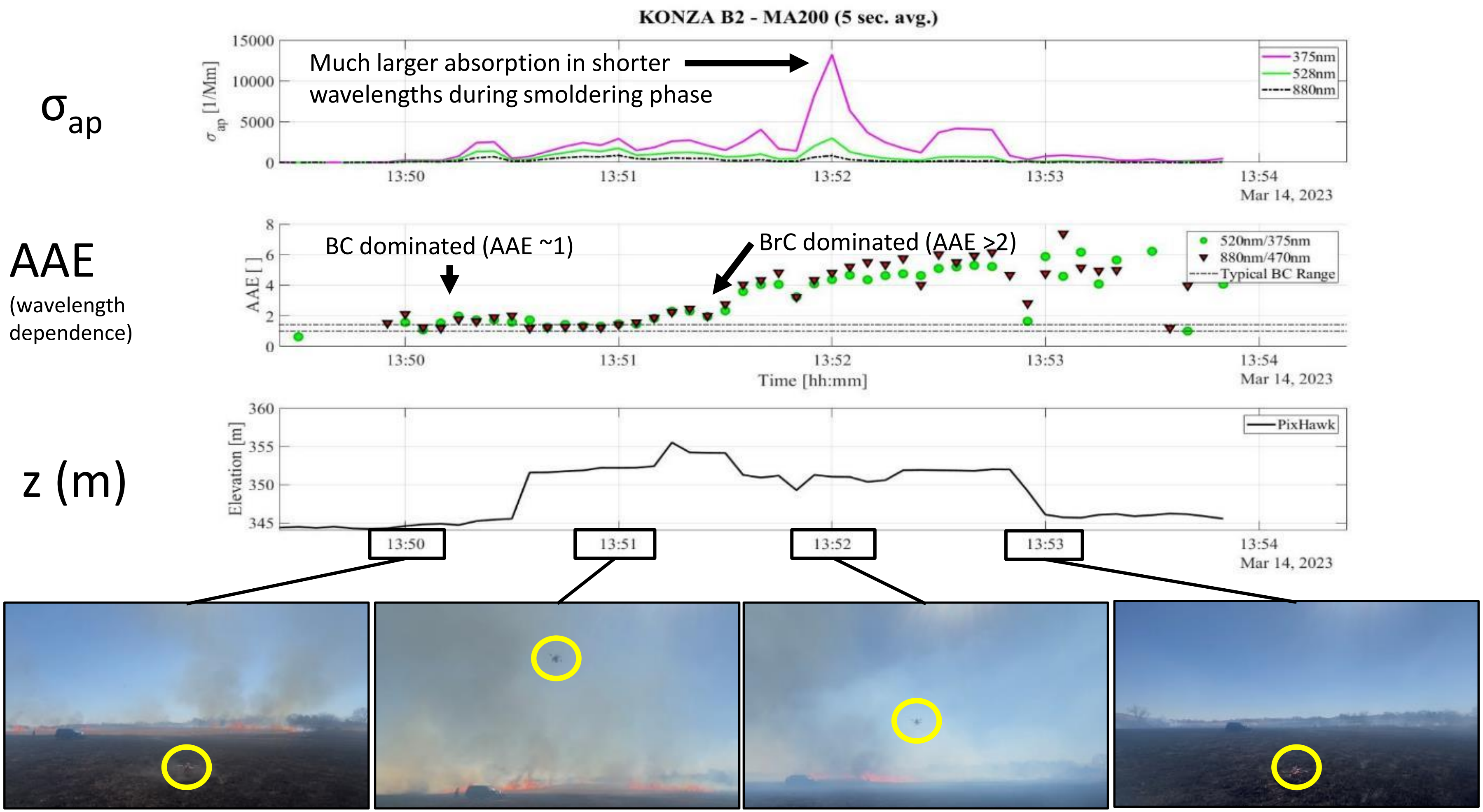
Can we take the raw data from the PurpleAir and get a reasonable [$PM_{2.5}$]?....



Dry polydisperse Ammonium Sulfate with D_g < 50 nm

- .....maybe if the aerosol of interest is calibrated to (size, refractive index)

Ambient Konza Prairie Fires Light Absorption (Manhattan, KS)



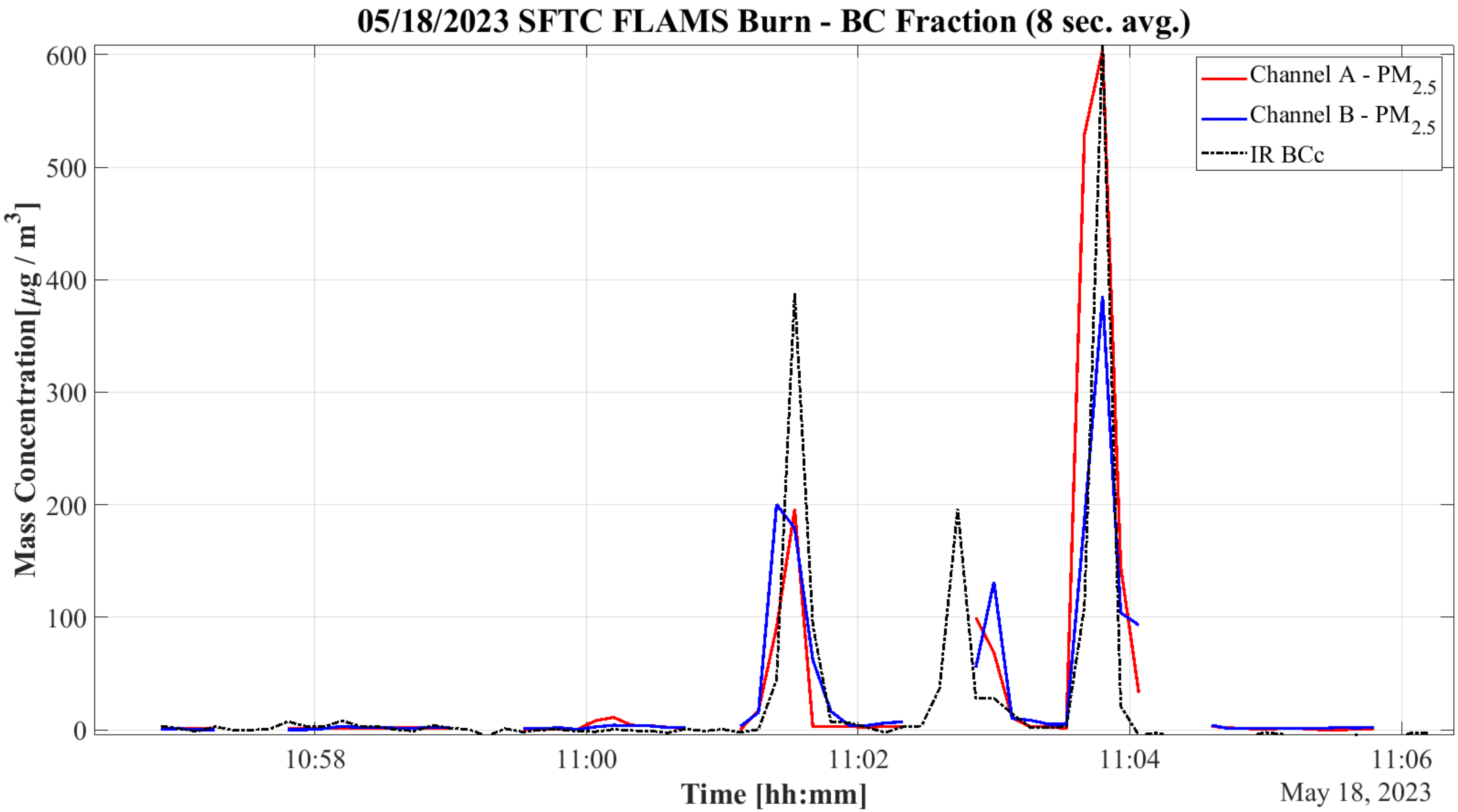
Take off

Black carbon dominated (Intense flaming)

Brown carbon sampling (Primarily smoldering)

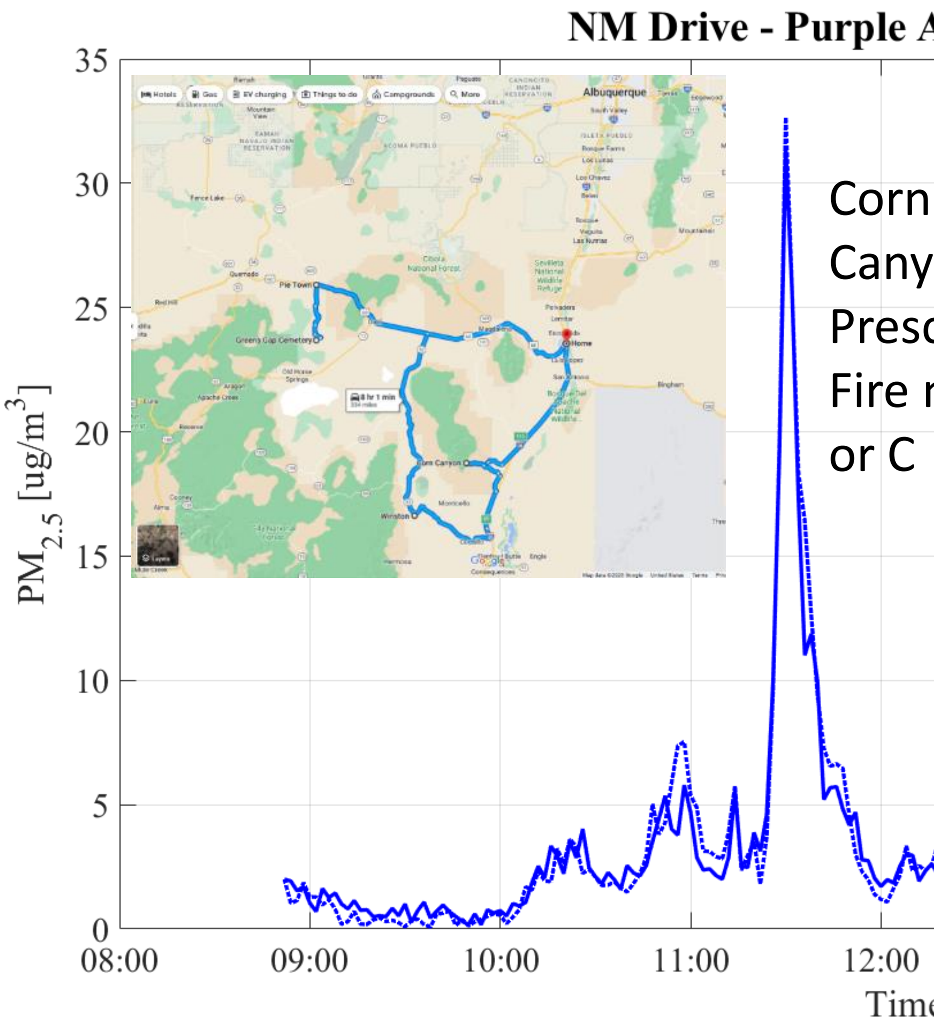
Landing (Smoldering remnants)

Drone Measurements of Fuel Spill Burn
New Mexico Fire Training Academy

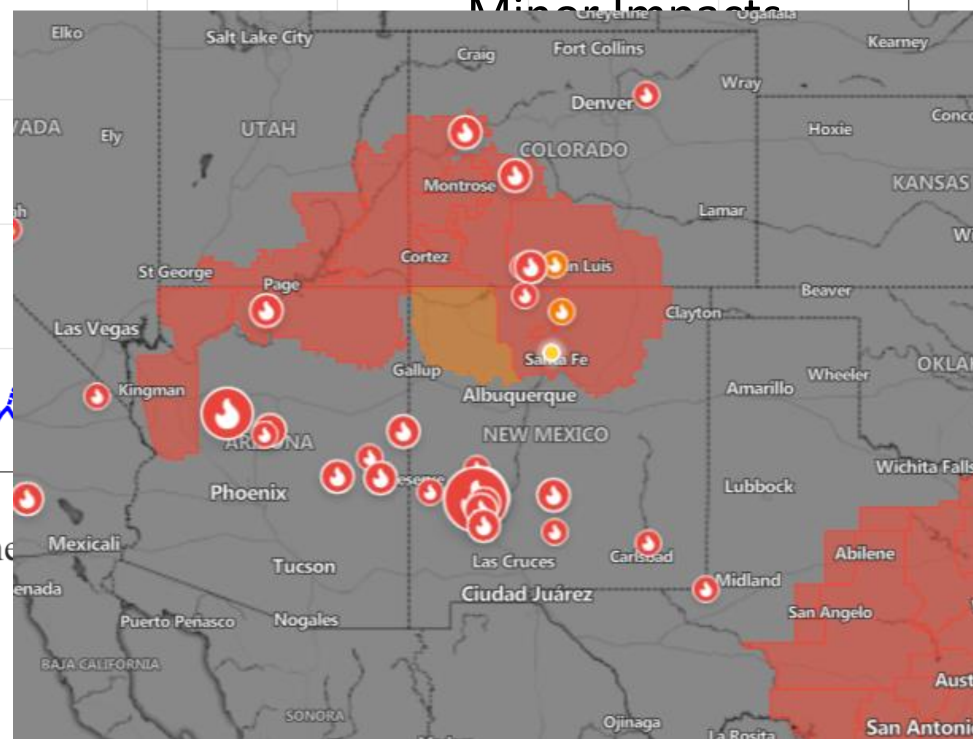


- For small (Dg,n <100nm) and very dark smoke emissions the PurpleAir sensors miss a significant fraction of the PM2.5 mass concentration

Mobile Sampling Gila Wilderness Corn Canyon Prescribed Burn and Pass Fire

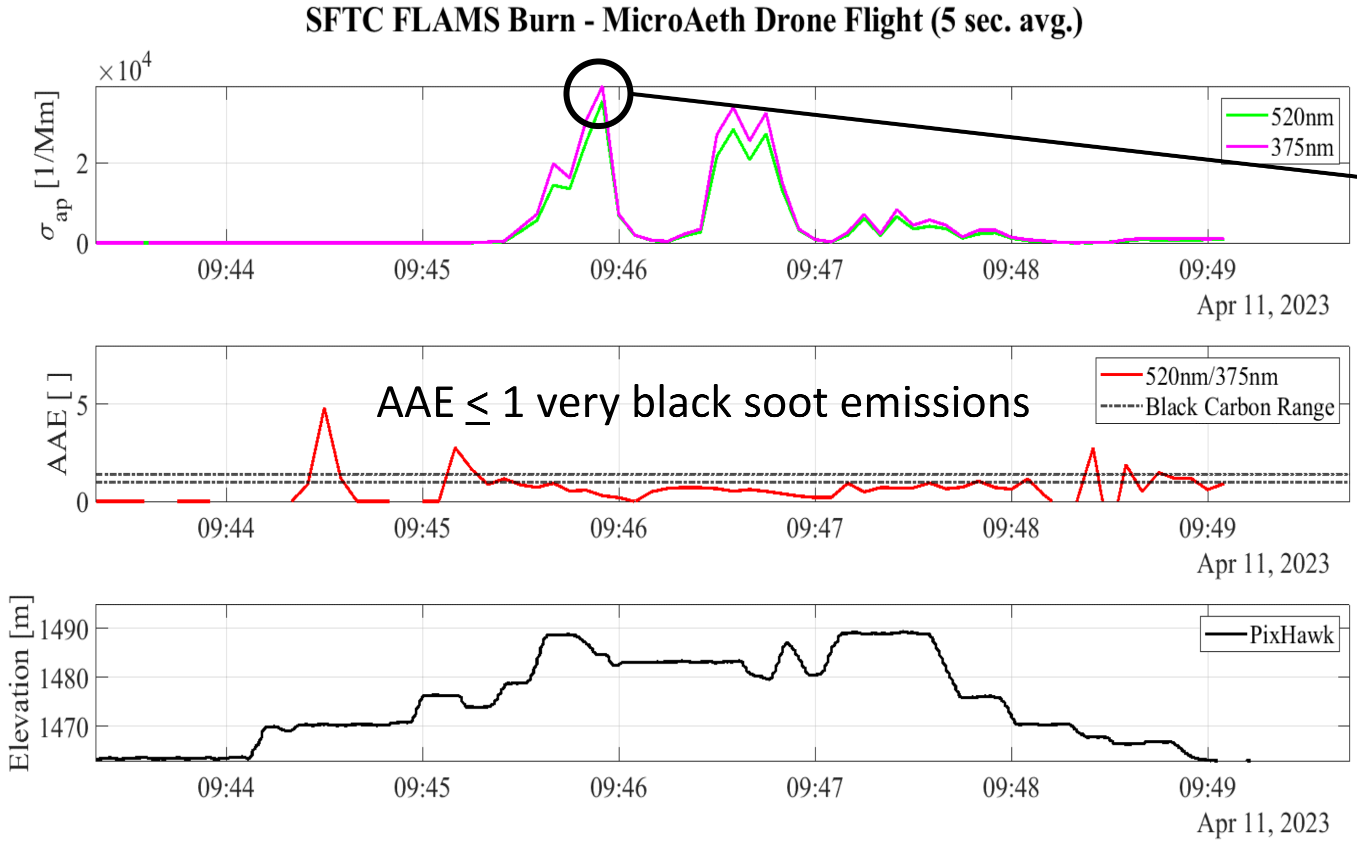


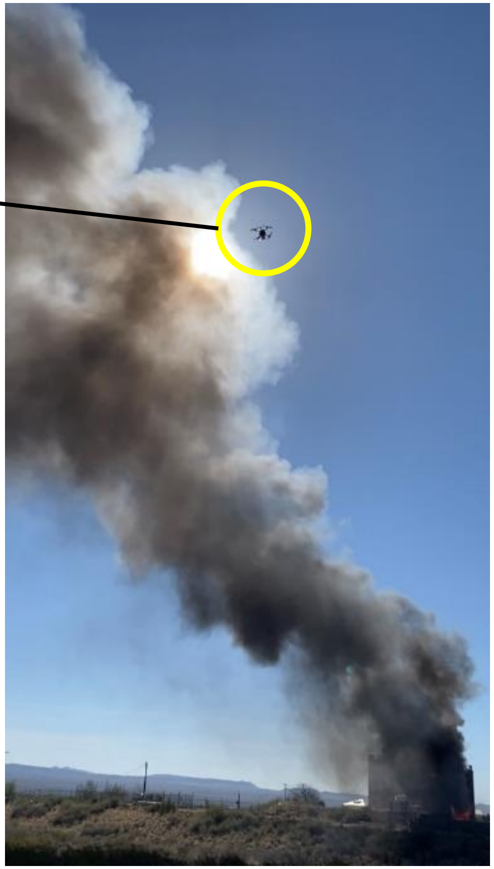
Corn Canyon Prescribed Fire near T or C



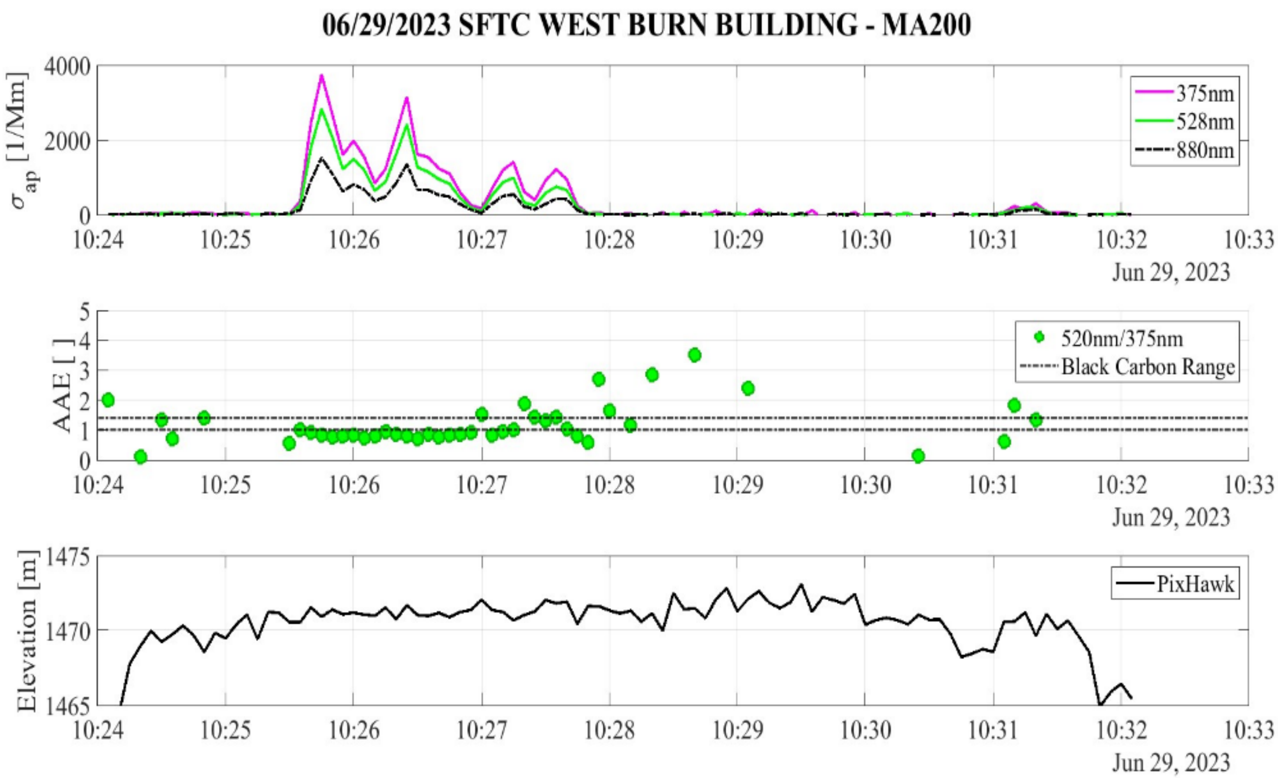
New Mexico State Fire Training Center

Diesel Fuel Spill Burn Light Absorption
New Mexico Fire Training Academy





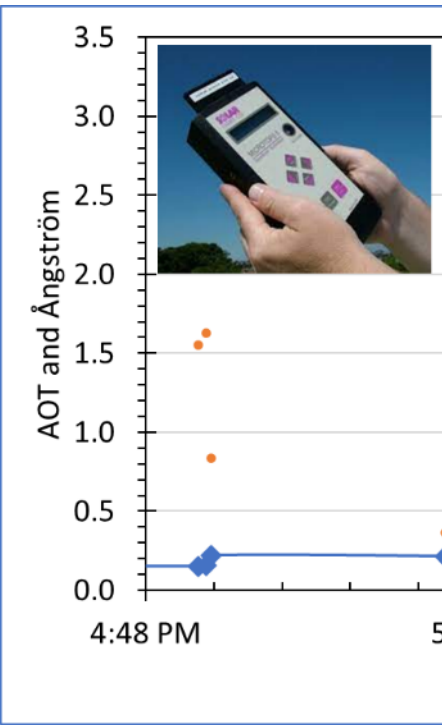
Building Burn Light Absorption
New Mexico Fire Training Academy

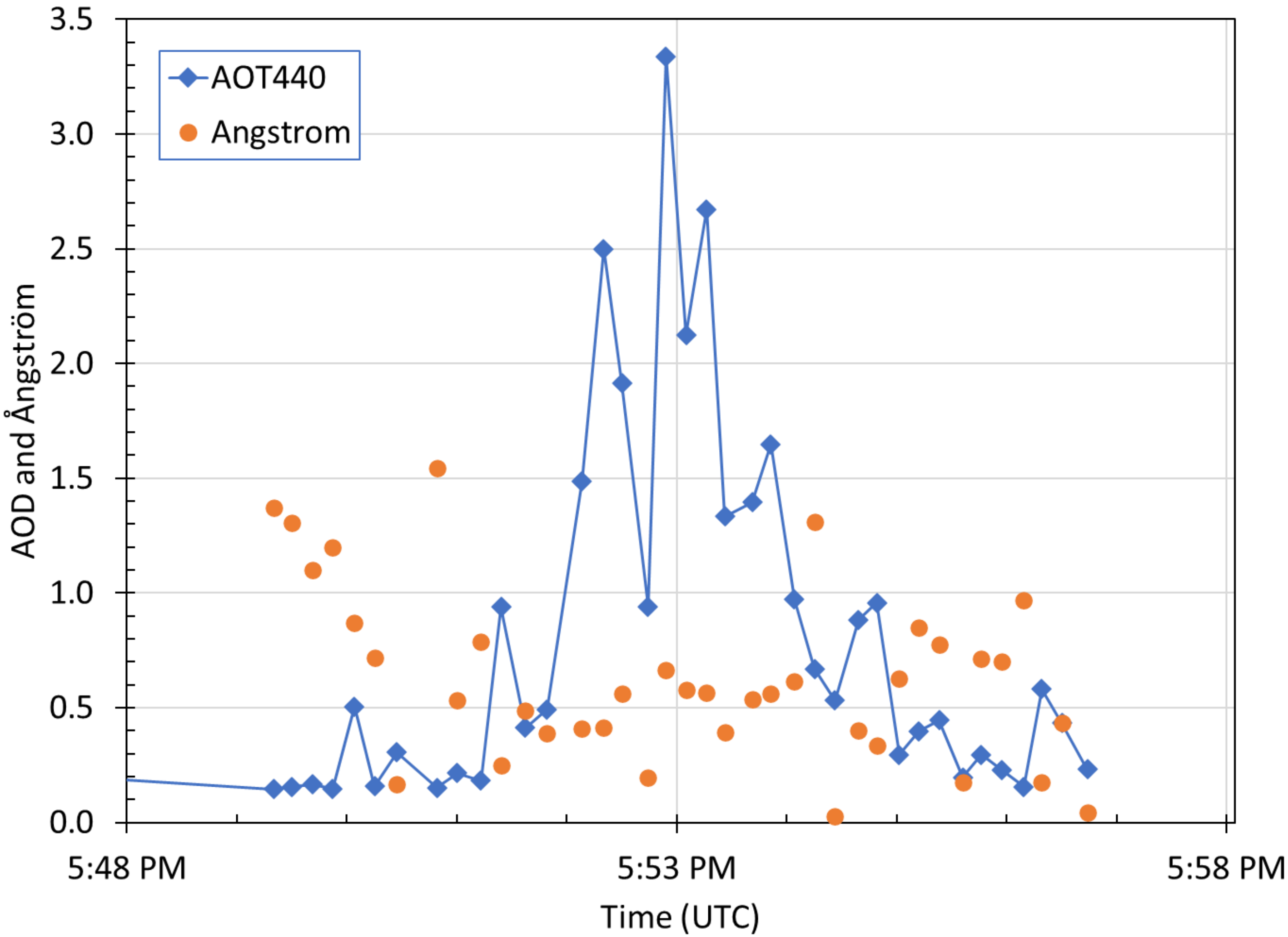


➤ Typical Fuel: Wood pallets on a pool of diesel fuel

NM Fire Training Academy AOD

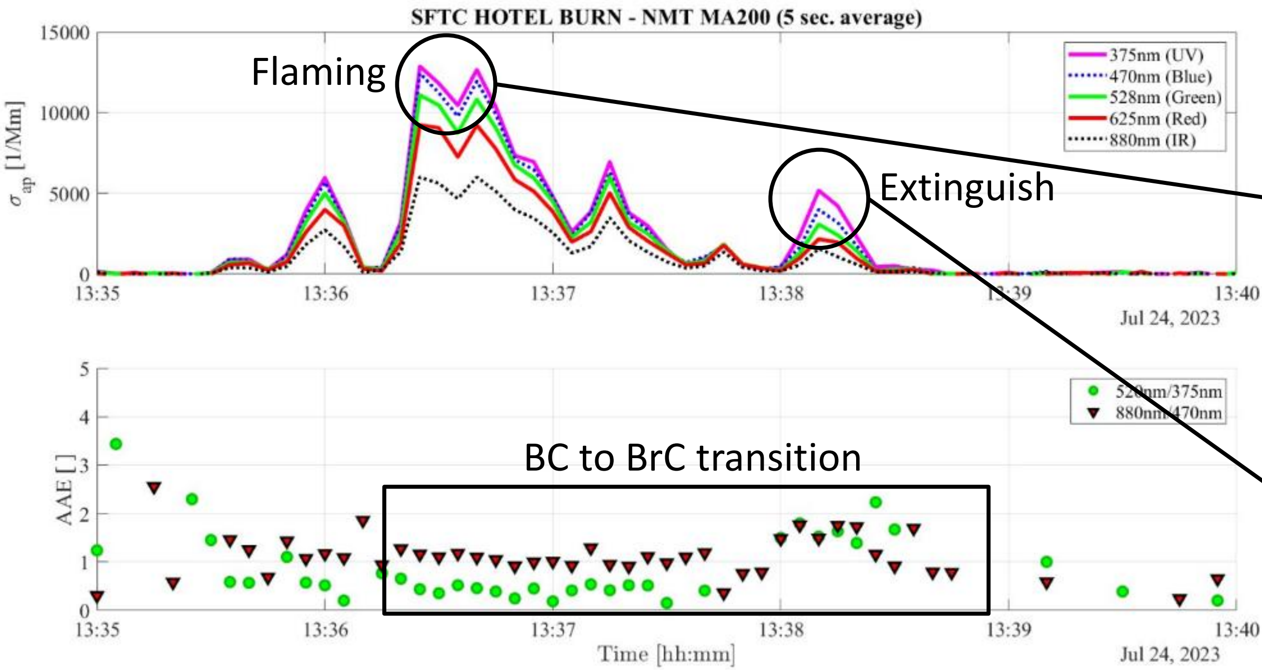
Colur





- Diesel Fuel Spill Burns Produce a Very Black Smoke

Hotel Room Burn Light Absorption
New Mexico Fire Training Academy



Conclusions

1) Field measurements are showing **consistency** with what we observed in the lab (Flaming/smoldering, BC vs. BrC)
2) Combustion **temperature/phase** plays a key role for aerosol physical properties
3) Biomass burning aerosol properties—an important climate component—are diverse, variable and **fuel/phase specific**
4) Sensors such as PA strongly benefit from an **aerosol-specific ground truth**
5) Pursuing further **field measurements** and **sensor validation studies** (urban & wildland fuels)


Acknowledgments

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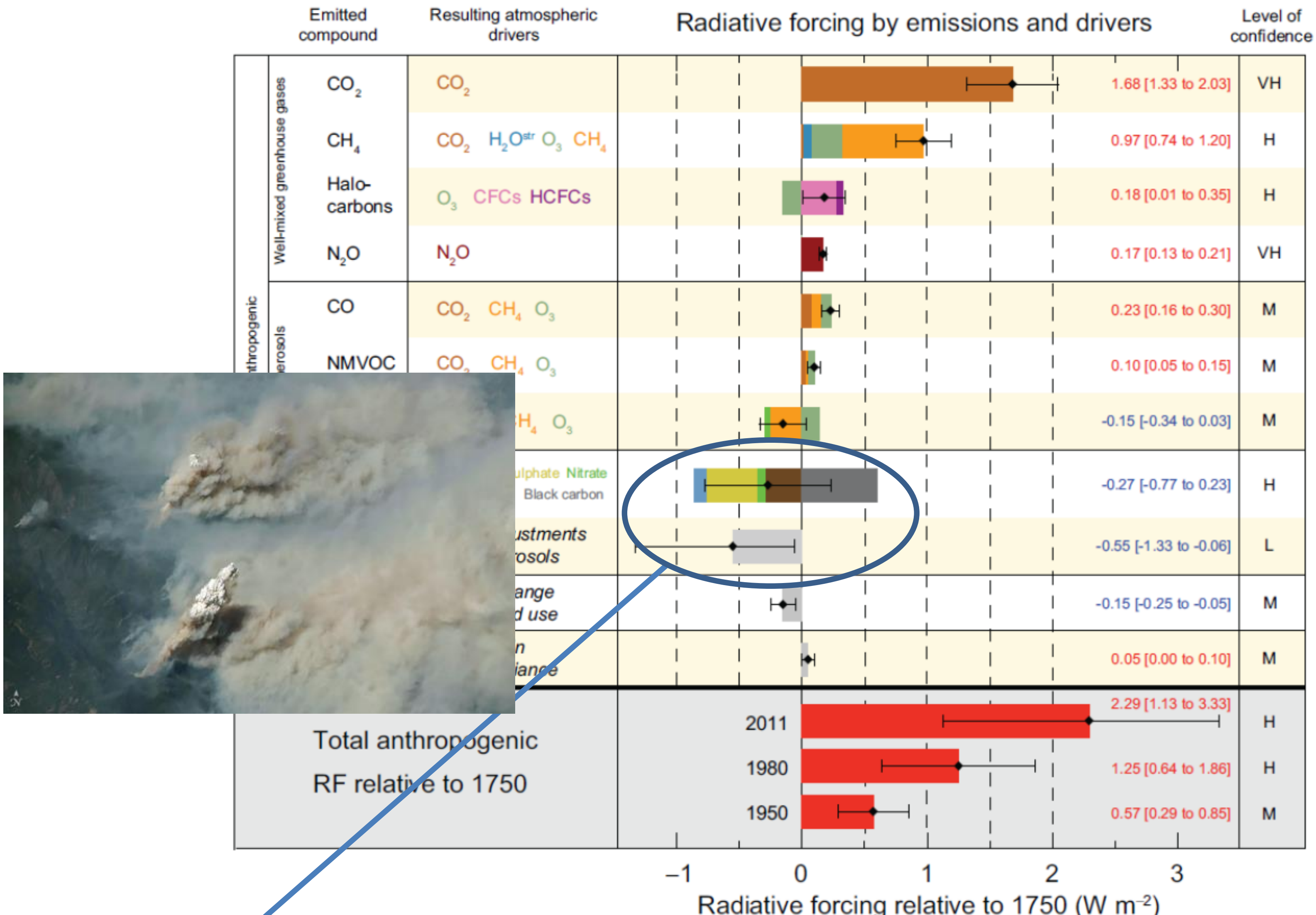
- The Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Visiting Faculty Program (VFP) supported this research. The New Mexico Consortium is gratefully acknowledged for financial support in this research. LANL support includes DOE Office of Science Biological and Environmental Research Atmospheric System Research Program.

END

Backup Slides

Climate Forcing and Aerosols (IPCC, 2013)



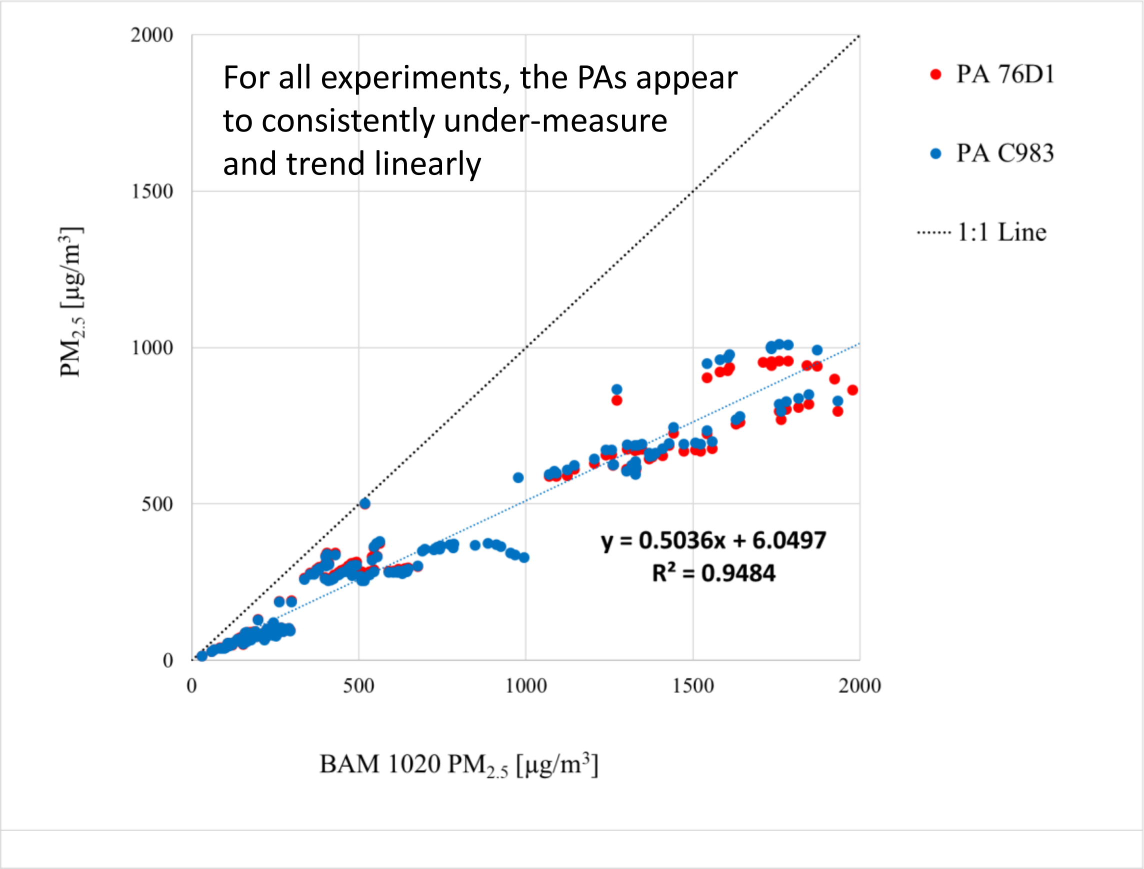
Long Lived GHG

Short Lived Gases

Aerosol Direct Indirect

- Aerosols have the largest climate forcing uncertainty range (IPCC, Bond et al., 2013)
- Large, variable, emissions light absorbing/scattering from biomass burning
- **Absorbing aerosols** and water uptake vital to climate, visibility and human health

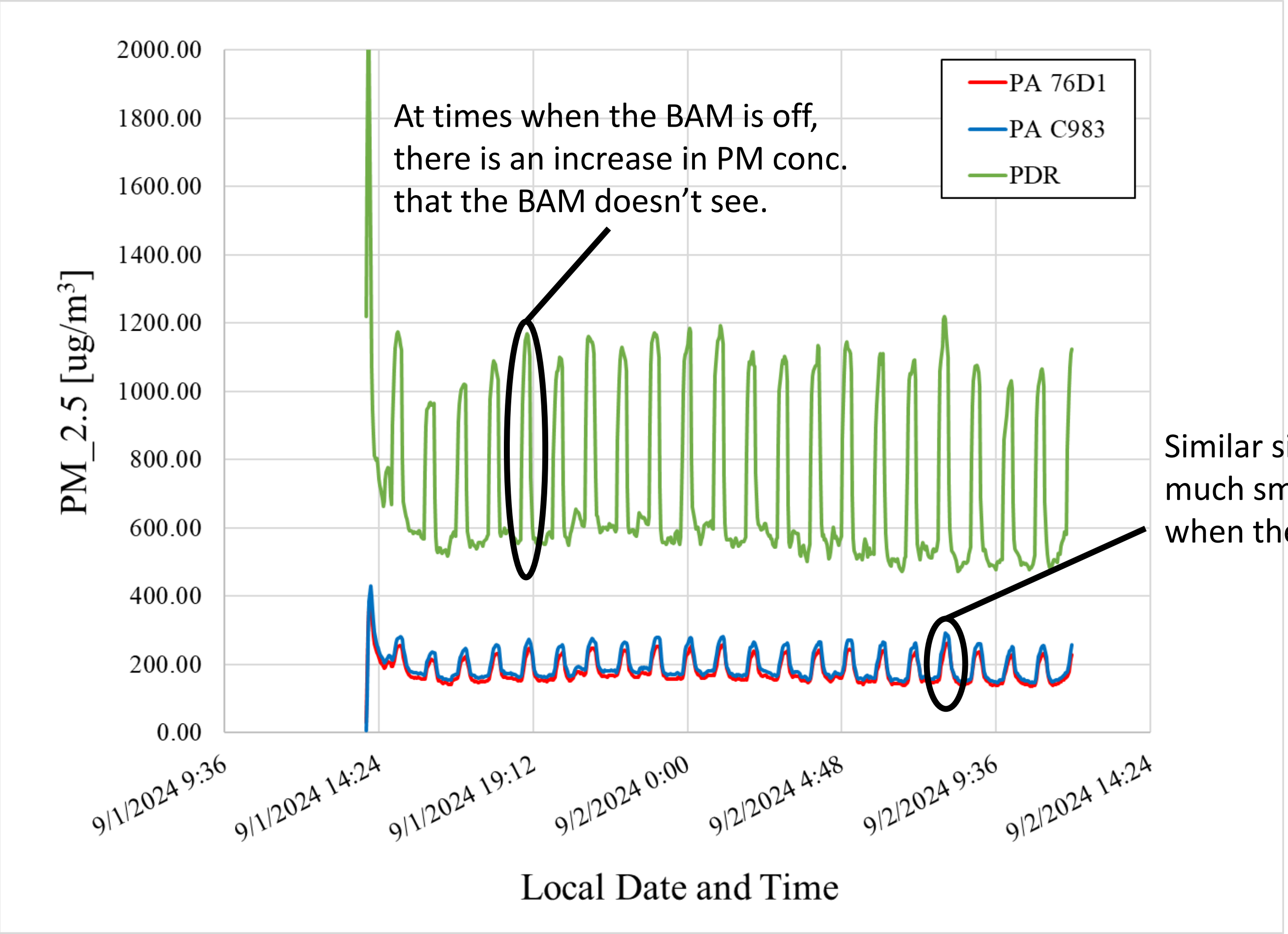
Measurements of Artificial Smoke (liquid and semivolatile)



ARA	BAM
140.57	1541.89
916.94	799.47
NA	477.79
110.44	339.18

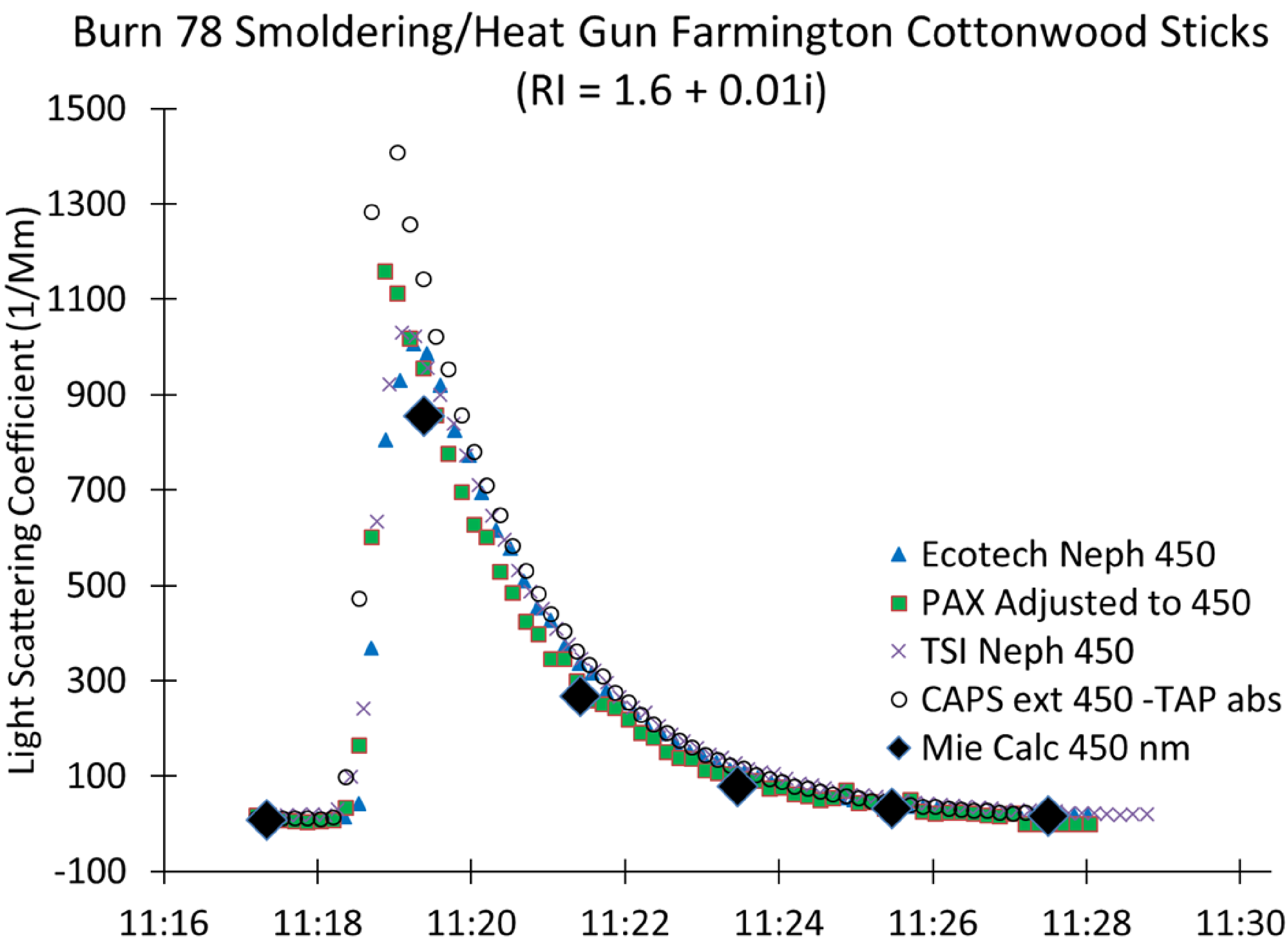
Disagreement between FRM and FEM possibly due to the volatility of liquid smoke.

BAM high flowrate and housekeeping time can be problematic



Similar situation here, but much smaller difference when the BAM is on or off.

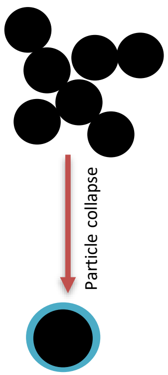
Smoke: Instrument Agreement and Modeled Light Scattering

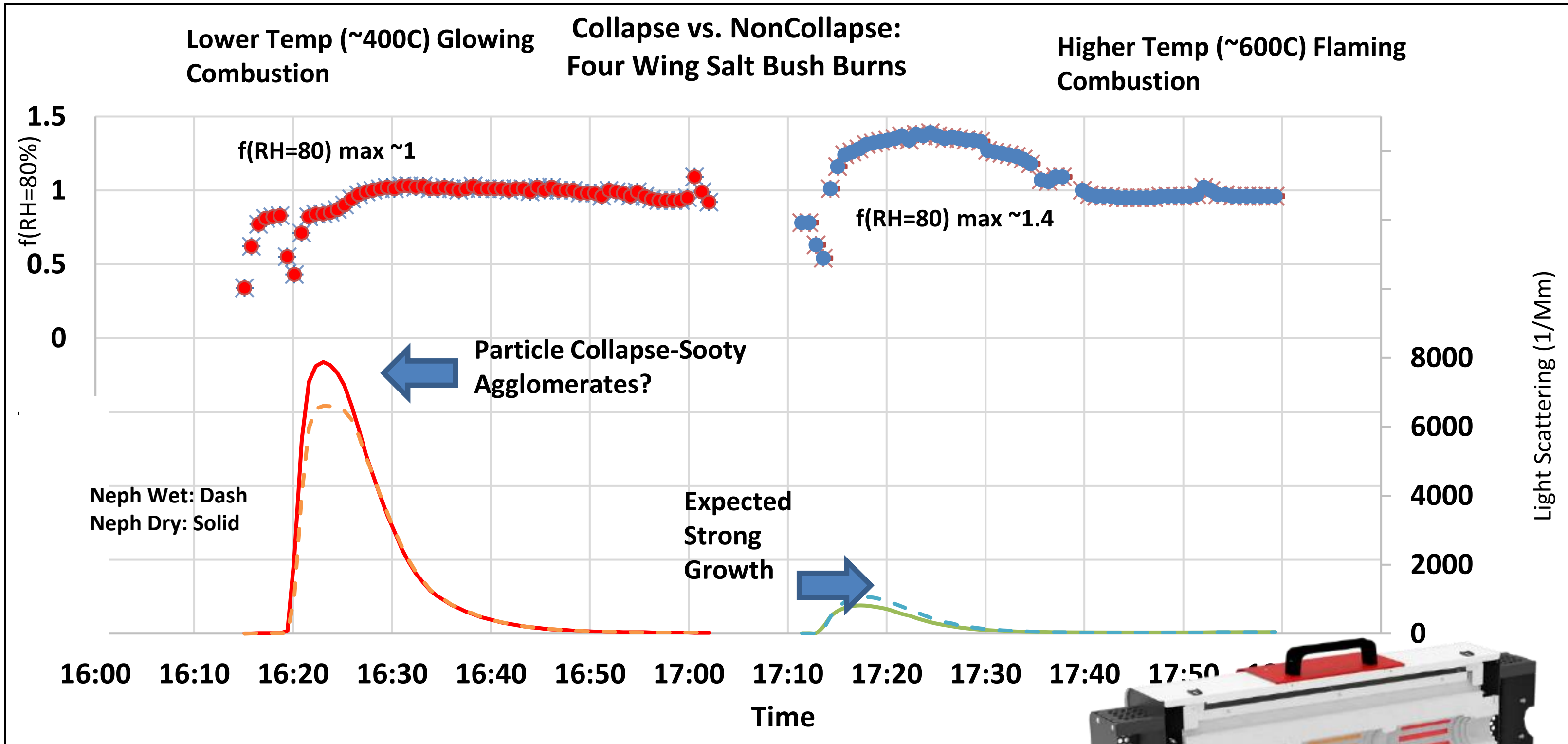


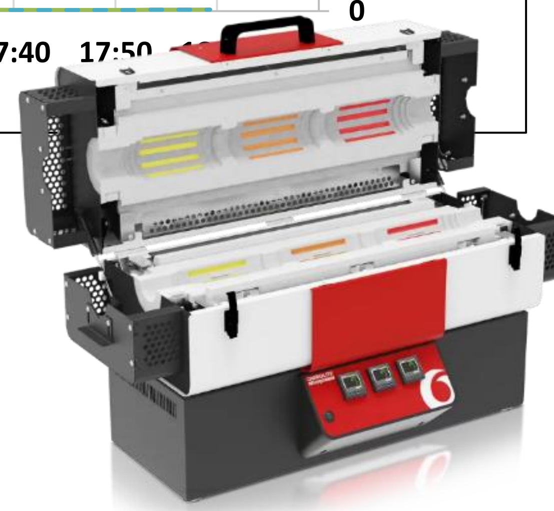
- Using Mie modelled, uniform spheres of uniform and measured SMPS size distribution R.I. typical of smoldering burn from FLAME

Laboratory Burns Four-Winged Salt Bush

Two laboratory burns were conducted using four wing salt bush (branch and leaf) as fuel.







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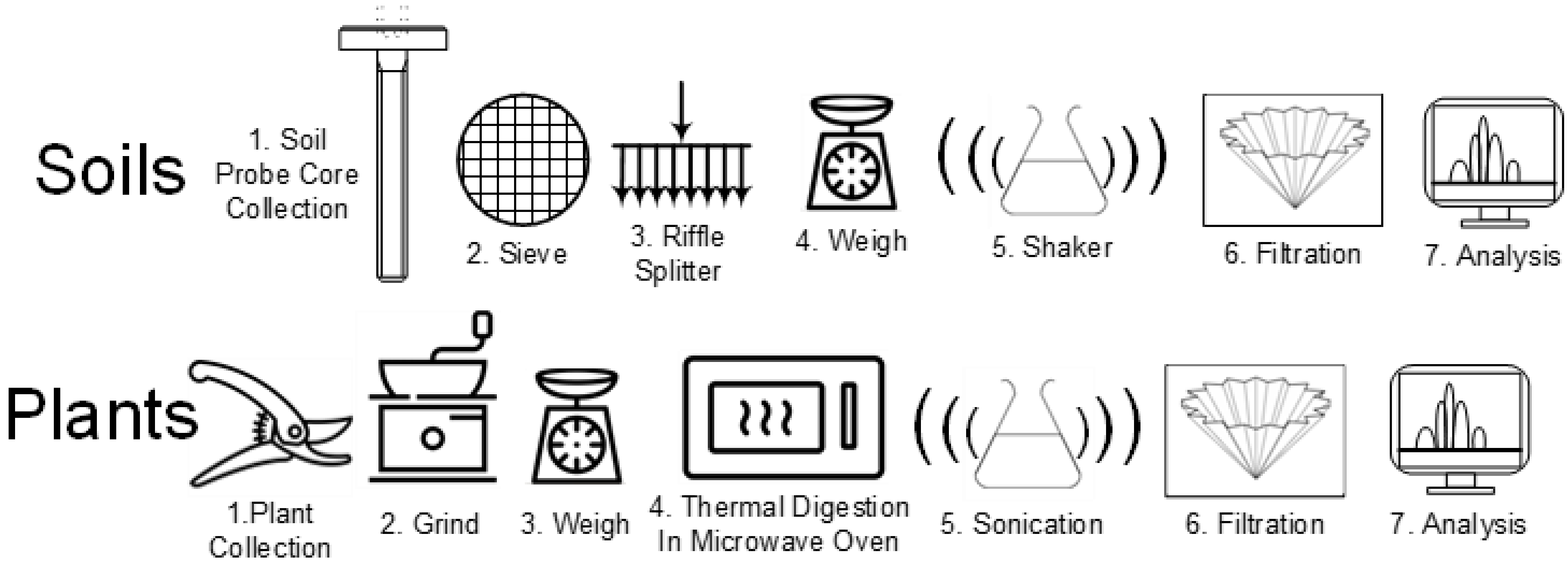
Plants & Soils Analyses



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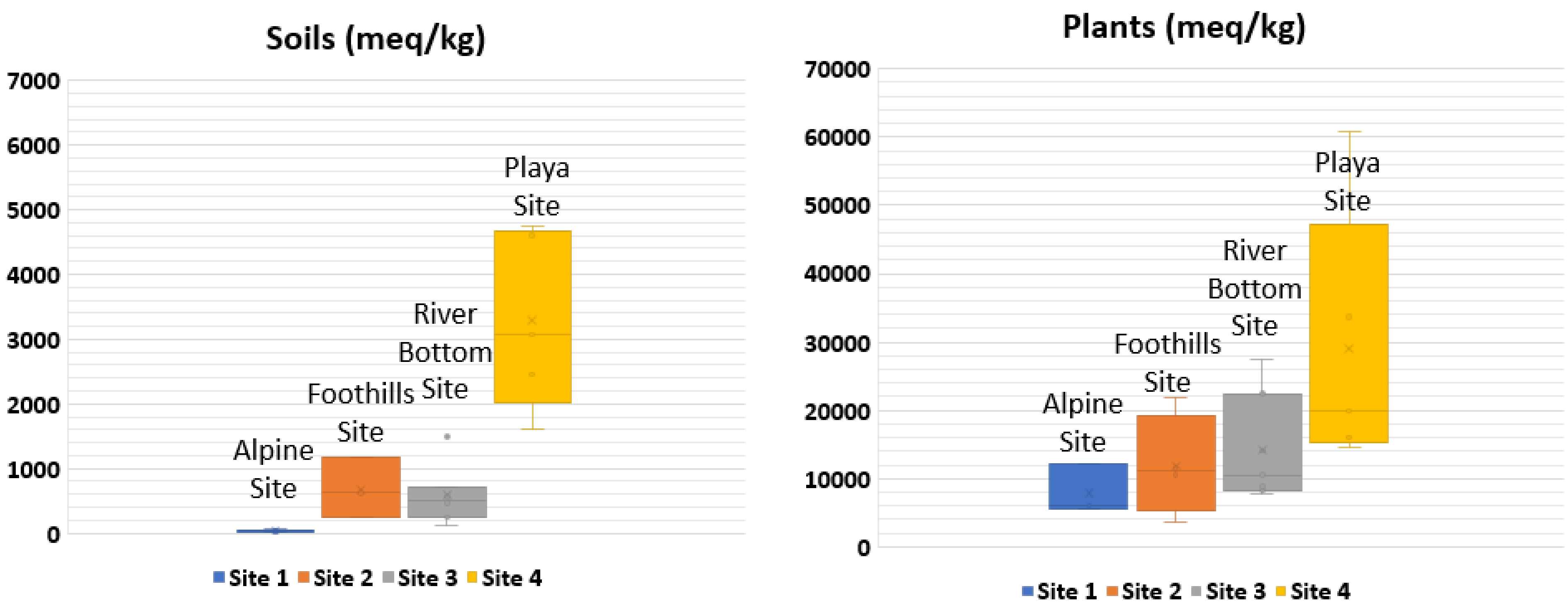
Soil to Plant to Smoke Inorganics Relationship
(Gulick et al., 2023)



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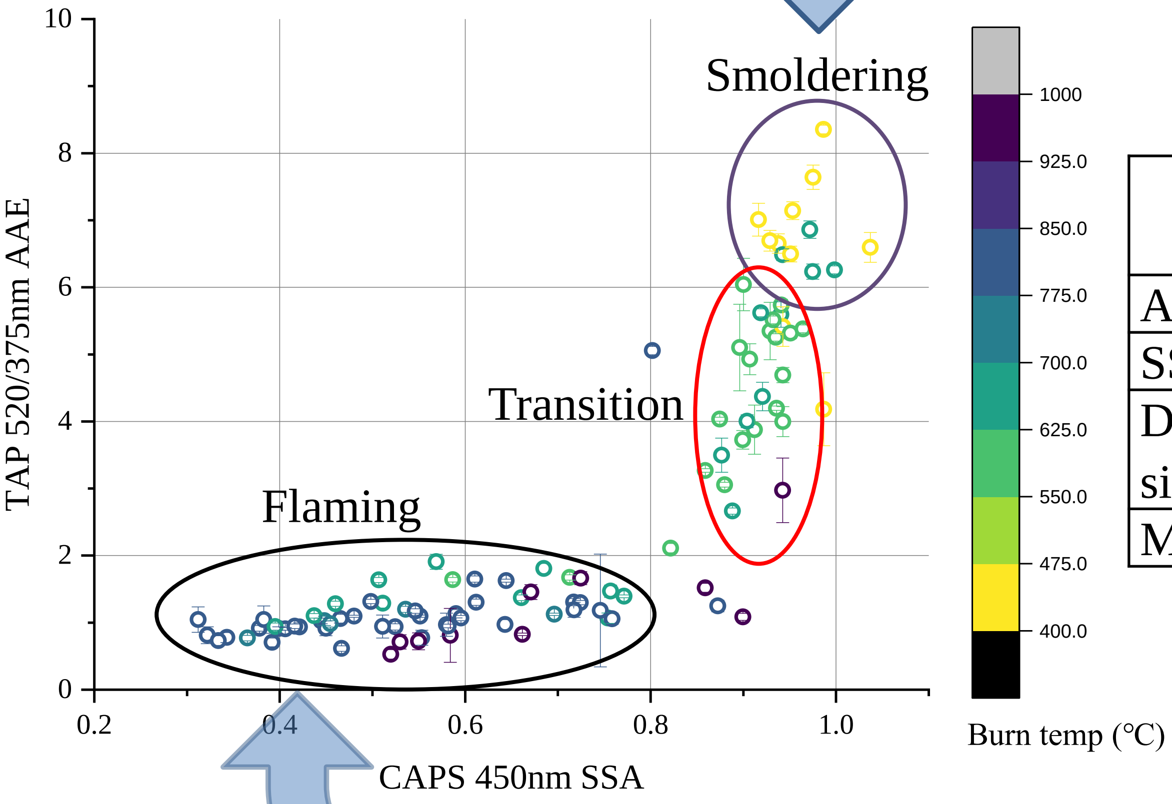
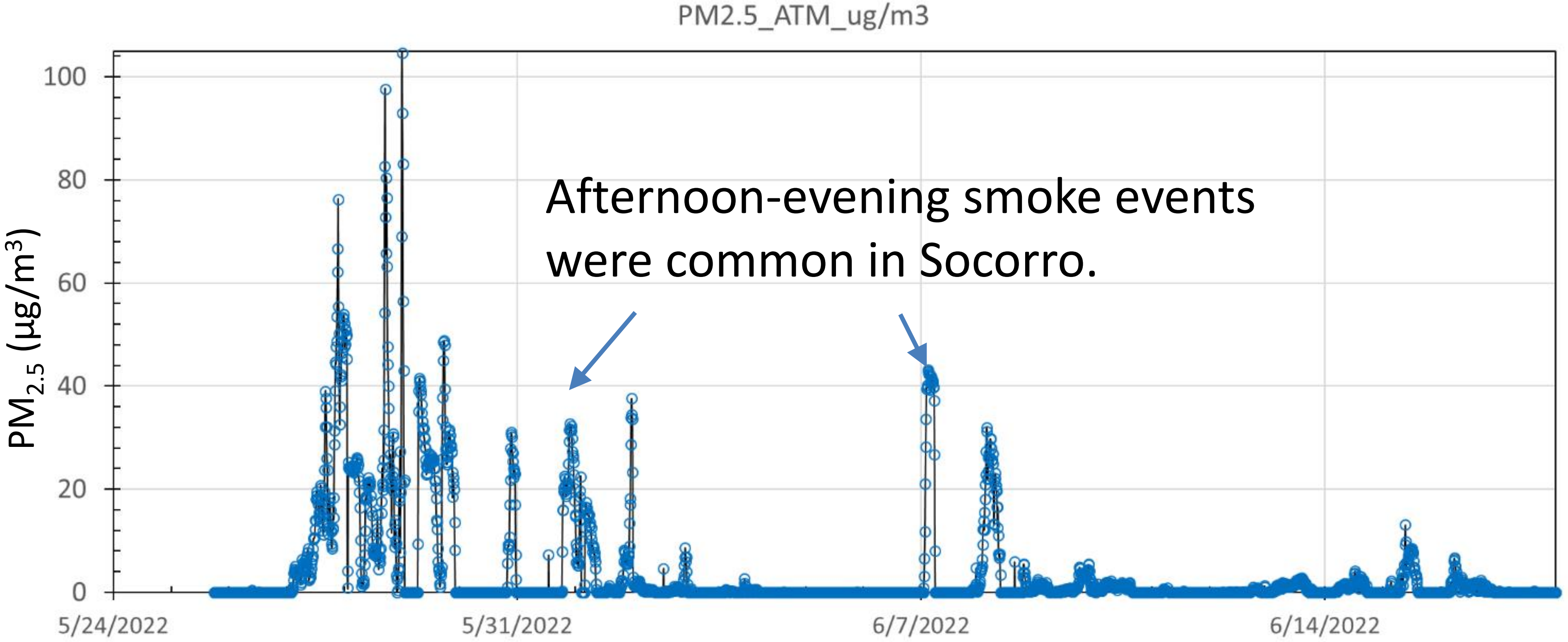


	Low temp 400-550°C	High temp 650-1000°C
AAE	↑	↓
SSA	↑	↓
Diameter size	↑	↓
MCE	↓	↑

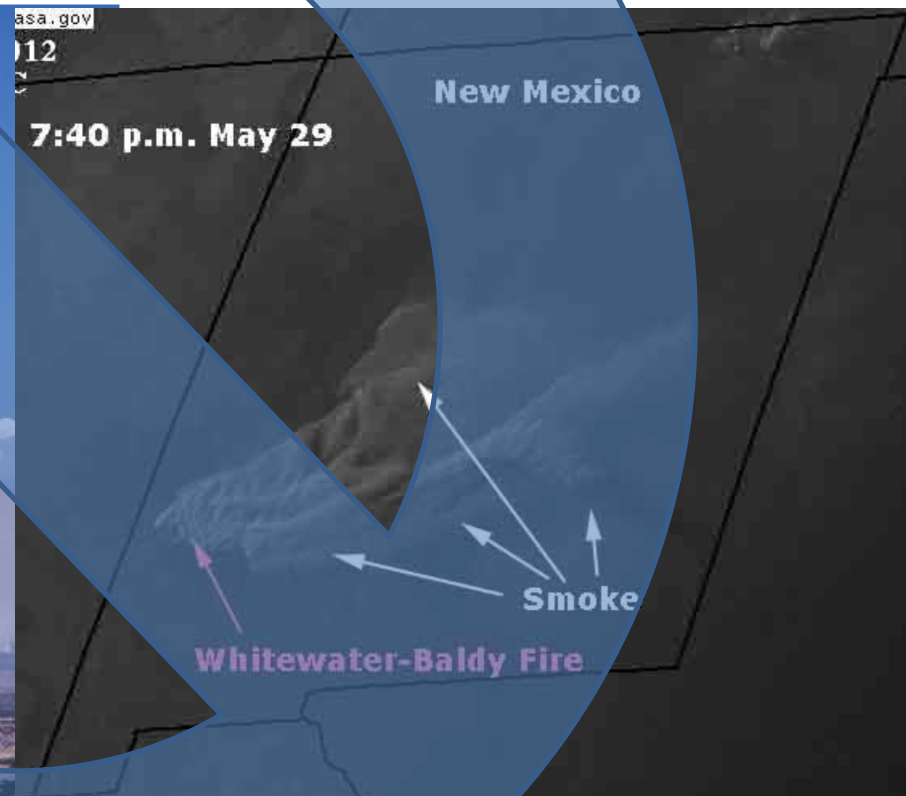
PurpleAir Measurements during BearTrap & Black Fires



1. Plume development in morning and early afternoon
2. Transport upriver during afternoon
3. Affected Rio Grande Valley until flow reversal overnight and downriver

Wildfires Affect New Mexico Air Quality

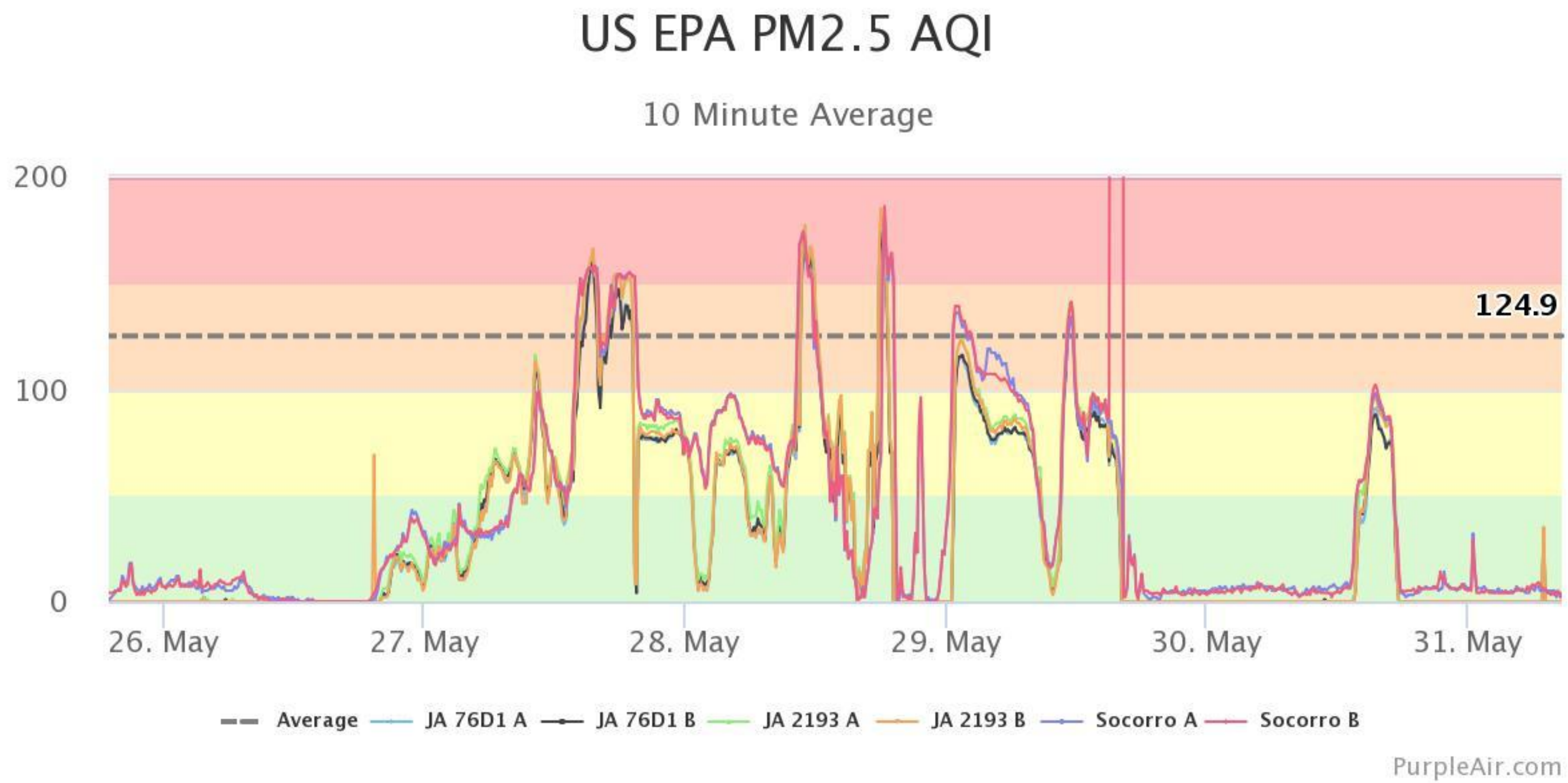
Cerro Grande Fire 48,000 Acres 2000
Ponil Complex Fire 92,000 Acres 2002
Dry Lakes Fire 93,000 Acres 2003
Las Conchas Fire 150,000 Acres 2011
Whitewater-Baldy Complex 297,845 Acres 2012



wikipedia, wildfiretoday.com, nasa

- Several satellite scale events in last 20 years

PurpleAir Measurements during BearTrap & Black Fires



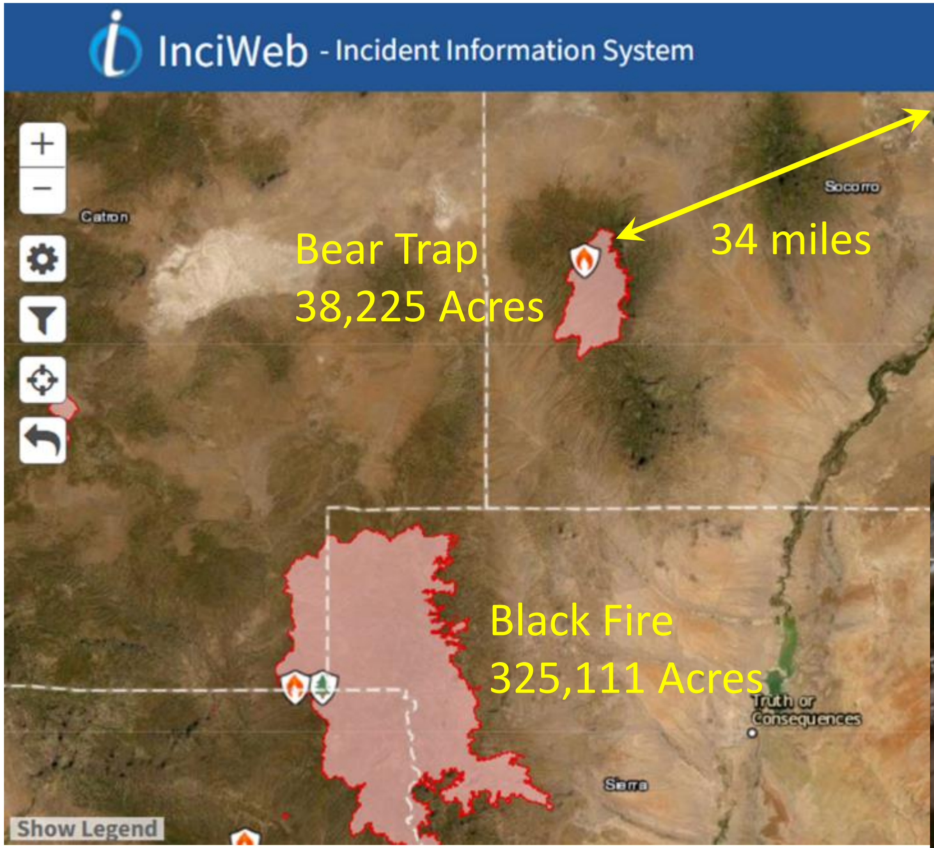
- ❖ Agreement is reasonable among 3 instruments (6 sensors)

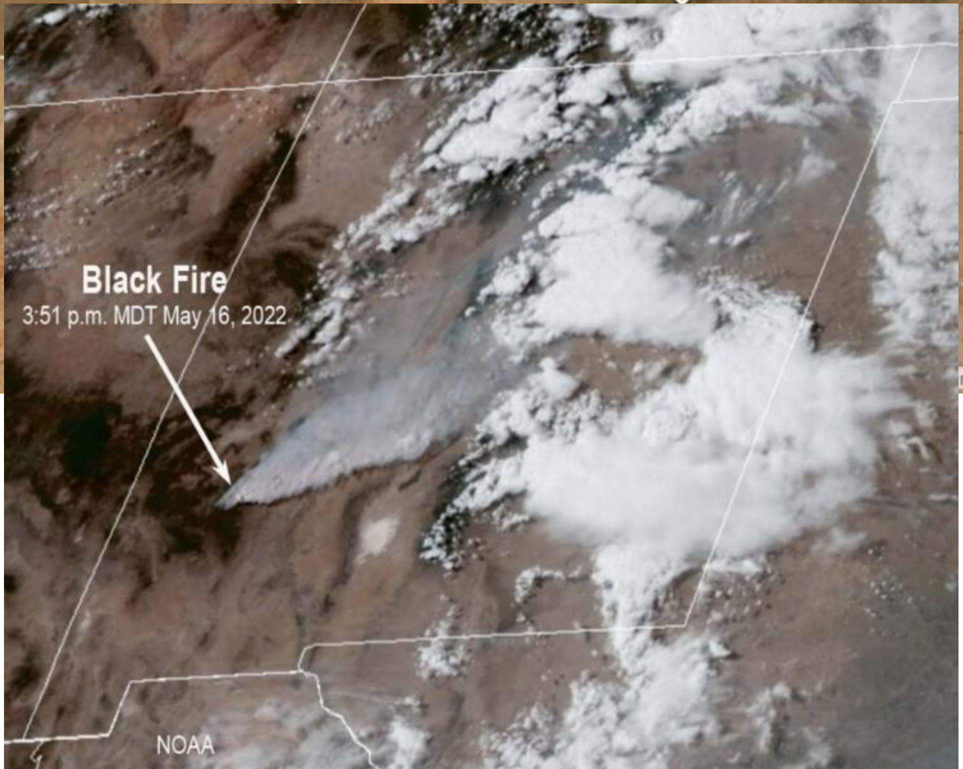
ns could produce a high Cl^-/Org ct fuels.

Soils-Plants-Smoke Connection
(Gulick et al., 2023)

- ❖ Taking a similar selection of species from very different ecosystems (Socorro Rio Grande River Bottom, Socorro Foothills Site, Los Alamos SUMO alpine site, Estancia Salt Lakes Region Playa site)
- ❖ Can soils properties predict the hygroscopic response of the smoke?

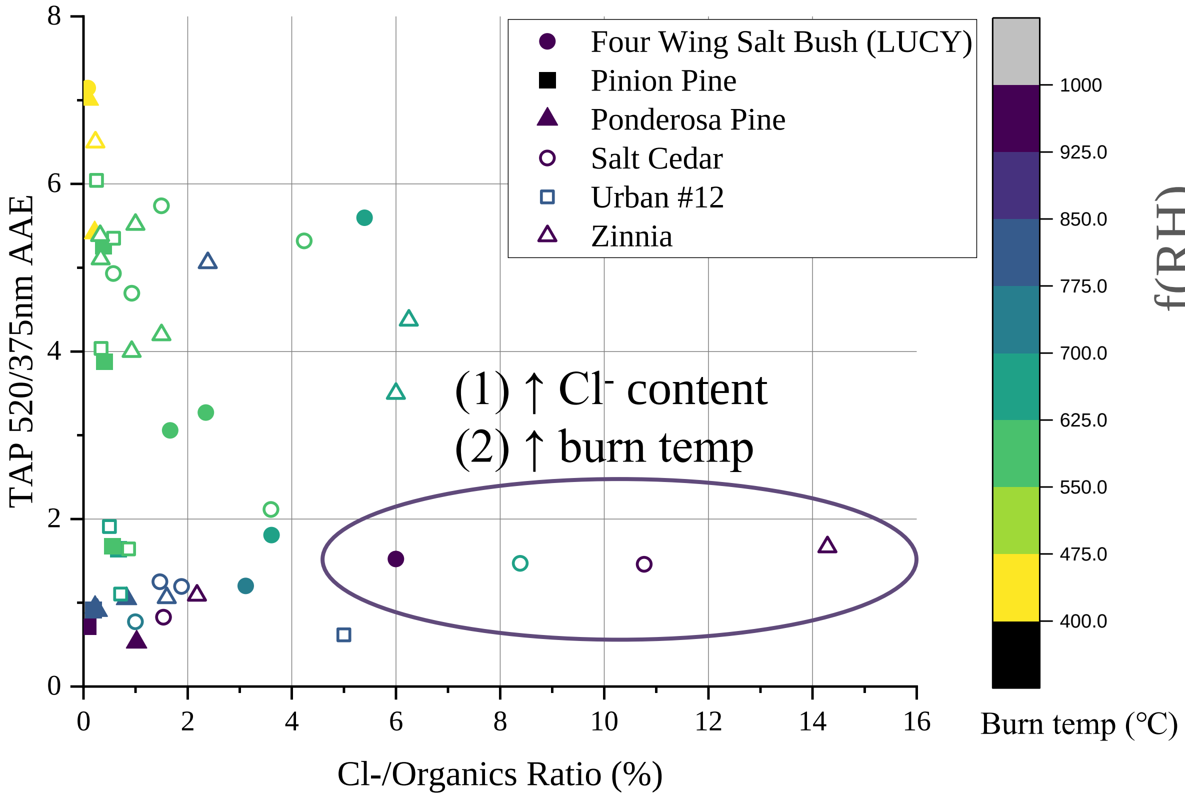
2022: Two Largest New Mexico Wildfires on Record

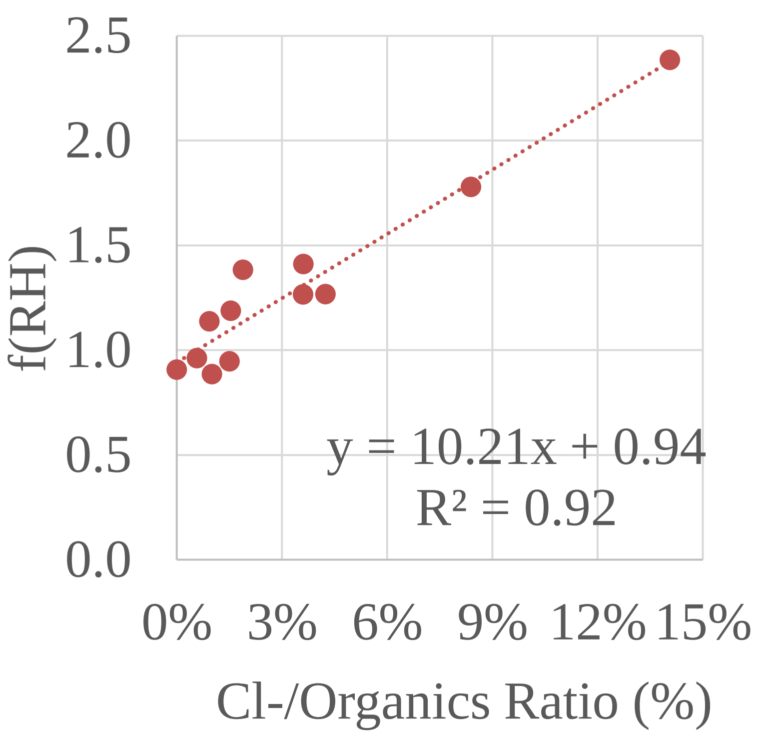




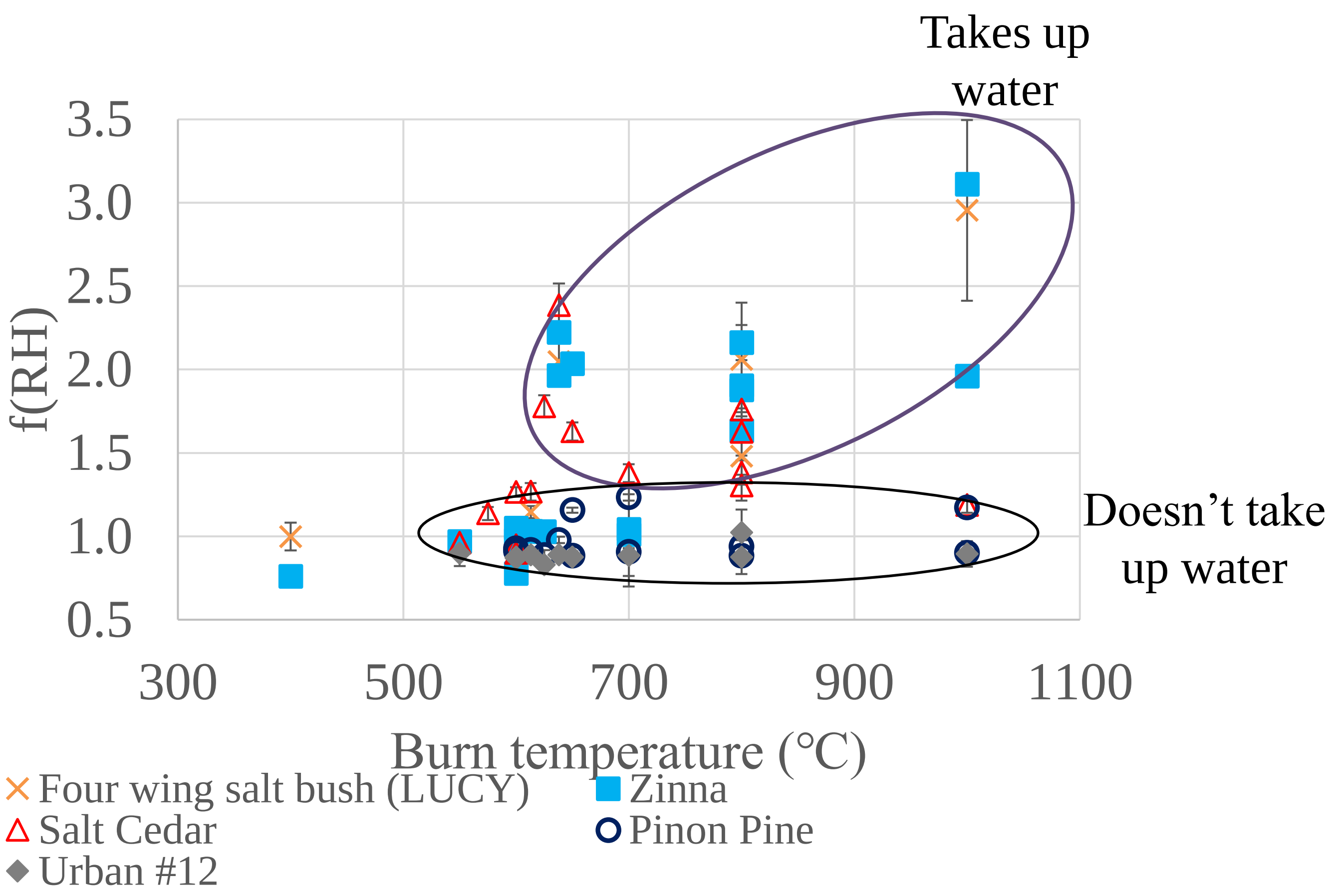
- Intermittent smoke impacts in Rio Grande Valley

Higher T burns could produce a high Cl^-/Org for select fuels. High Cl^-/Org generate highest *f*(RH) (Dungan, 2022).



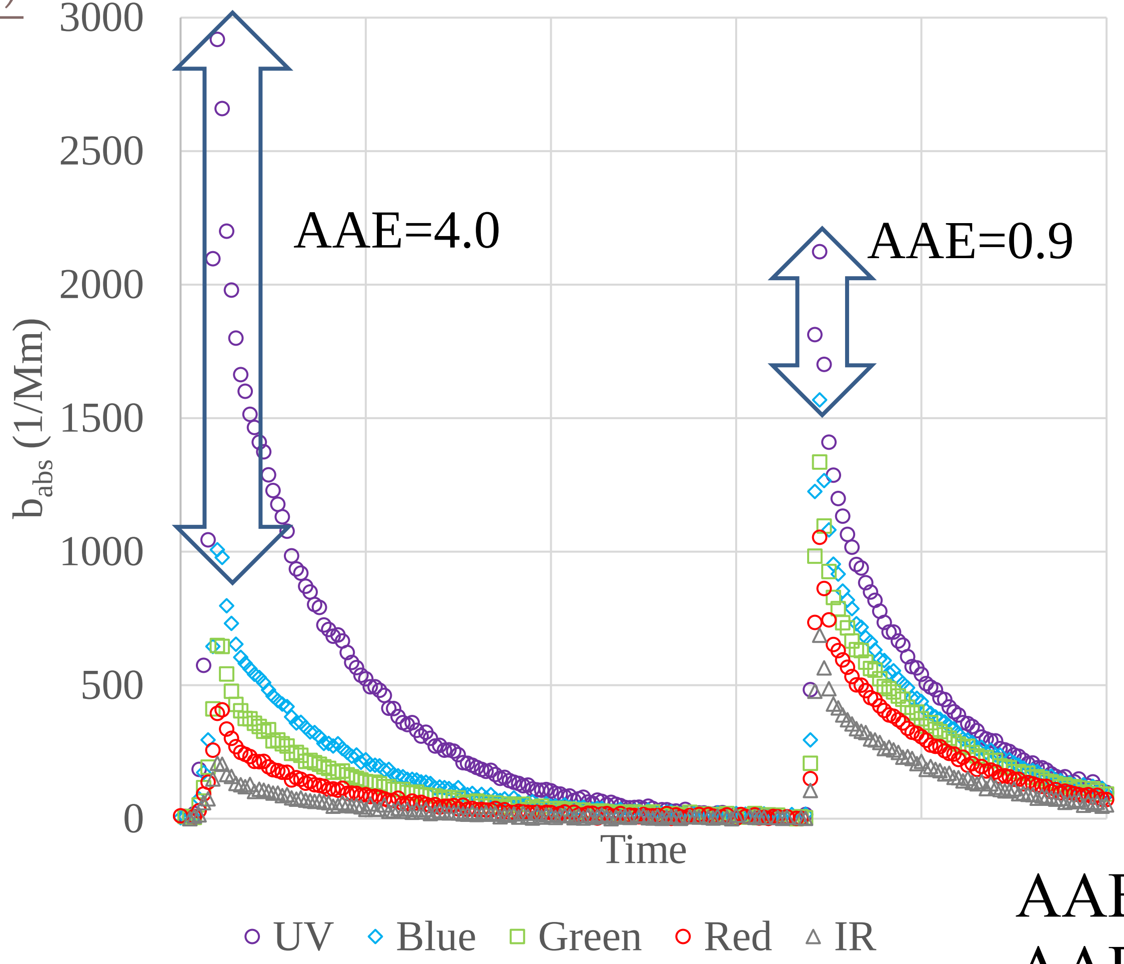


At high temperatures, certain fuels take up water as RH increases.



Absorption Ångström Exponent describe aerosol absorption properties.

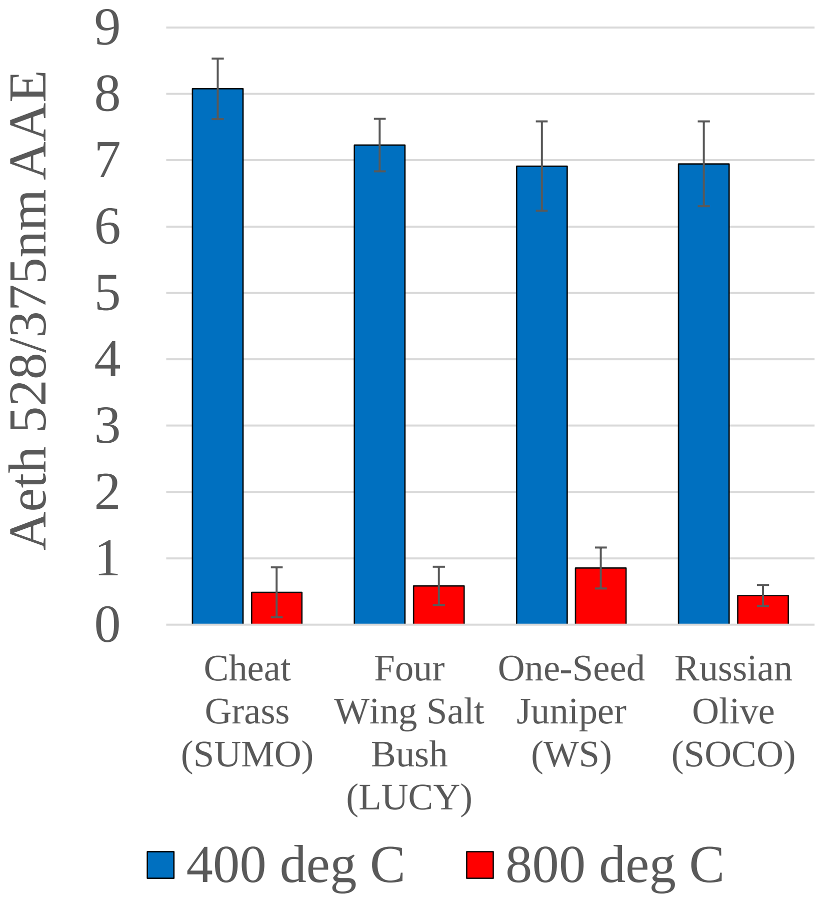
$$AAE = \frac{-\ln\left(\frac{b_{abs}(\lambda_1)}{b_{abs}(\lambda_2)}\right)}{\ln\left(\frac{\lambda_1}{\lambda_2}\right)}$$

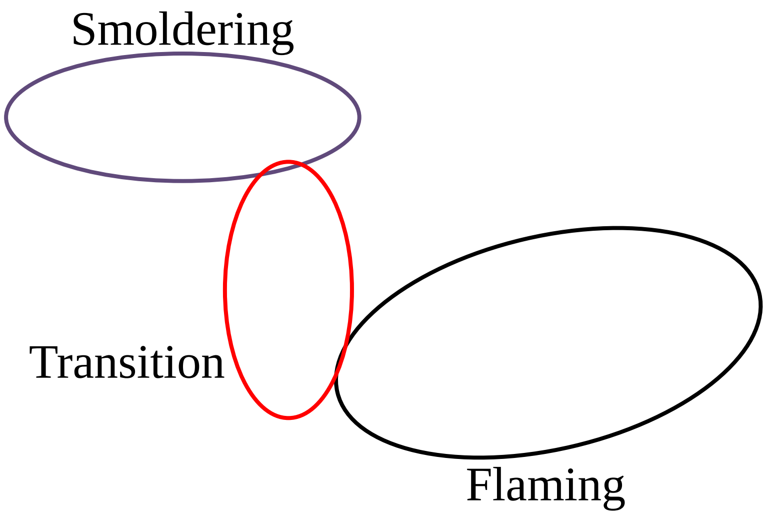


AAE~1 → BC

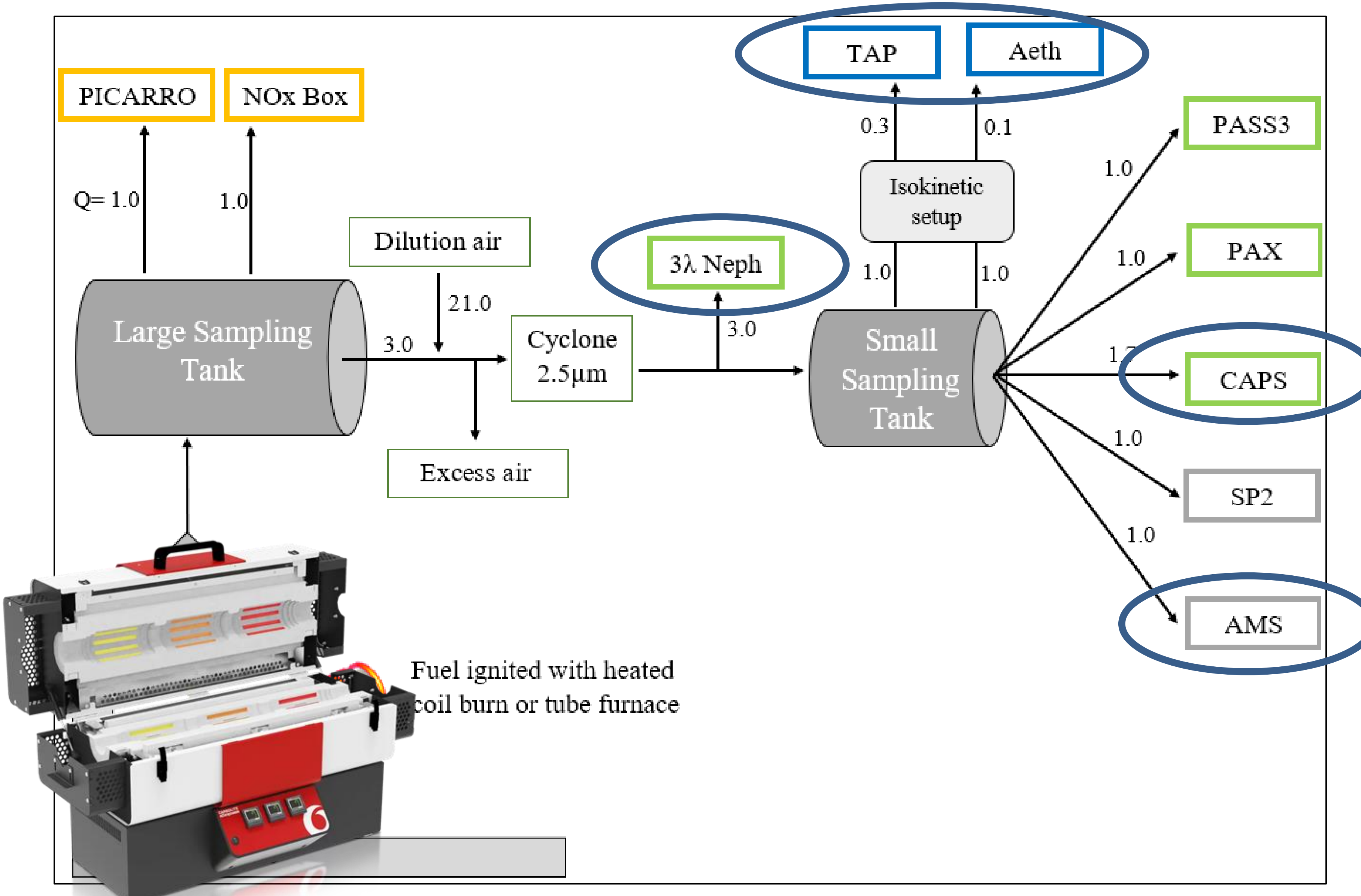
AAE>1.6 → BrC

Low and high temperature burns produced smoldering and flaming conditions, respectively.





Tube Furnace Controlled Temperature Combustion



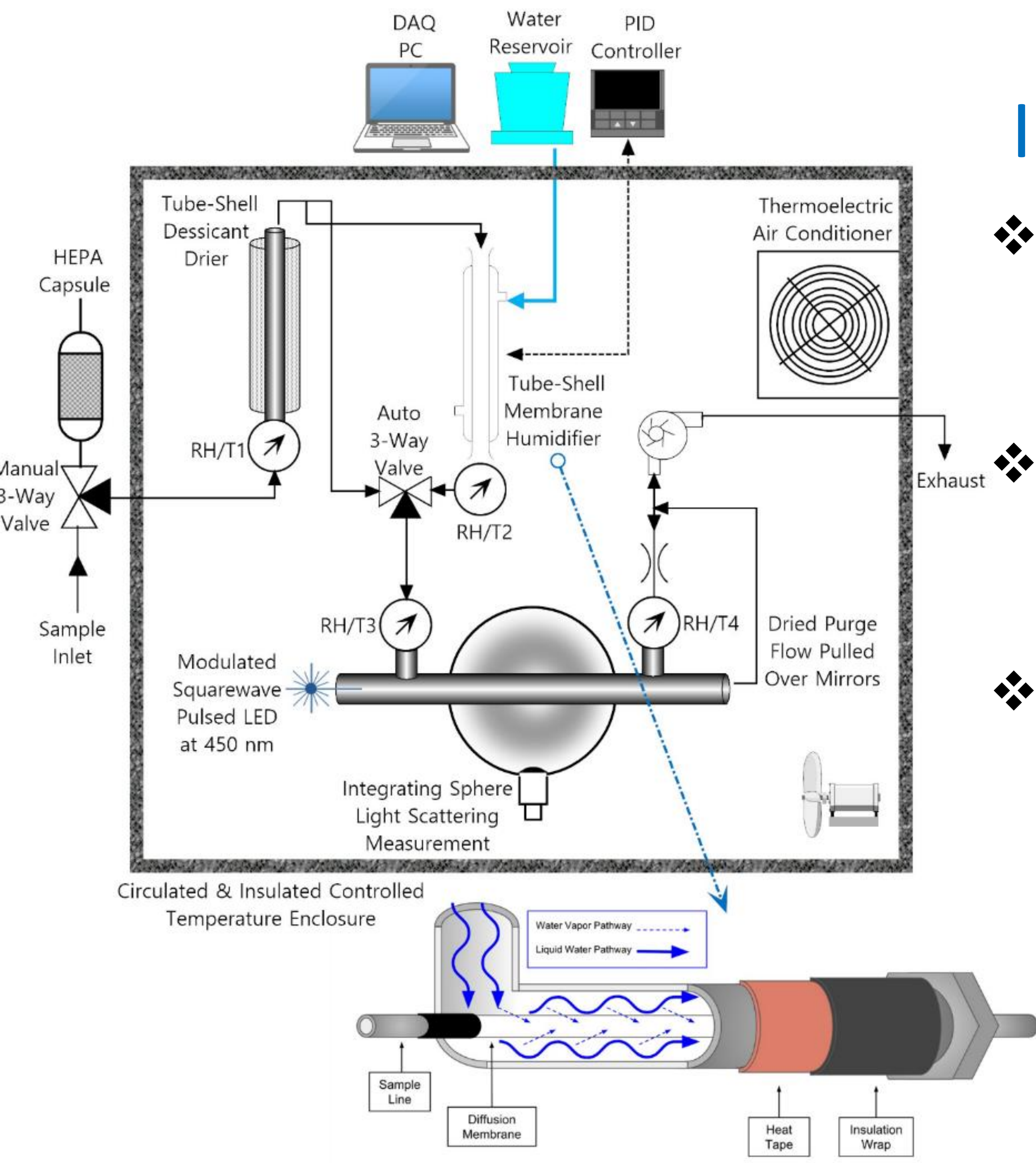
Laboratory: Summary of кappa vs. Plant Phenotype

Fuel Type	Lower Combustion Temperatures	Higher Combustion Temperatures
Evergreen Needles and Woods	Low Hygroscopicity $Kappa_{avg}$: 0.008 $Kappa_{min}$: 0.003 $Kappa_{max}$: 0.012	Low Hygroscopicity $Kappa_{avg}$: 0.014 $Kappa_{min}$: -0.008 $Kappa_{max}$: 0.040
Deciduous Woods	Low Hygroscopicity $Kappa_{avg}$: 0.008 $Kappa_{min}$: -0.002 $Kappa_{max}$: 0.017	Low Hygroscopicity $Kappa_{avg}$: 0.014 $Kappa_{min}$: -0.005 $Kappa_{max}$: 0.041
Deciduous Leaves	Low Hygroscopicity $Kappa_{avg}$: 0.007 $Kappa_{min}$: -0.007 $Kappa_{max}$: 0.027	Moderate Hygroscopicity $Kappa_{avg}$: 0.032 $Kappa_{min}$: 0.011 $Kappa_{max}$: 0.086
Grasses (Native and Invasive)	Moderate Hygroscopicity $Kappa_{avg}$: 0.025 $Kappa_{min}$: 0.006 $Kappa_{max}$: 0.100	High Hygroscopicity $Kappa_{avg}$: 0.098 $Kappa_{min}$: 0.004 $Kappa_{max}$: 0.234
Halophytic and Salt Tolerant	Moderate Hygroscopicity $Kappa_{avg}$: 0.036 $Kappa_{min}$: -0.013 $Kappa_{max}$: 0.179	High Hygroscopicity $Kappa_{avg}$: 0.056 $Kappa_{min}$: -0.004 $Kappa_{max}$: 0.266

Increasing Hygroscopic Response

Gomez et al. [2018]

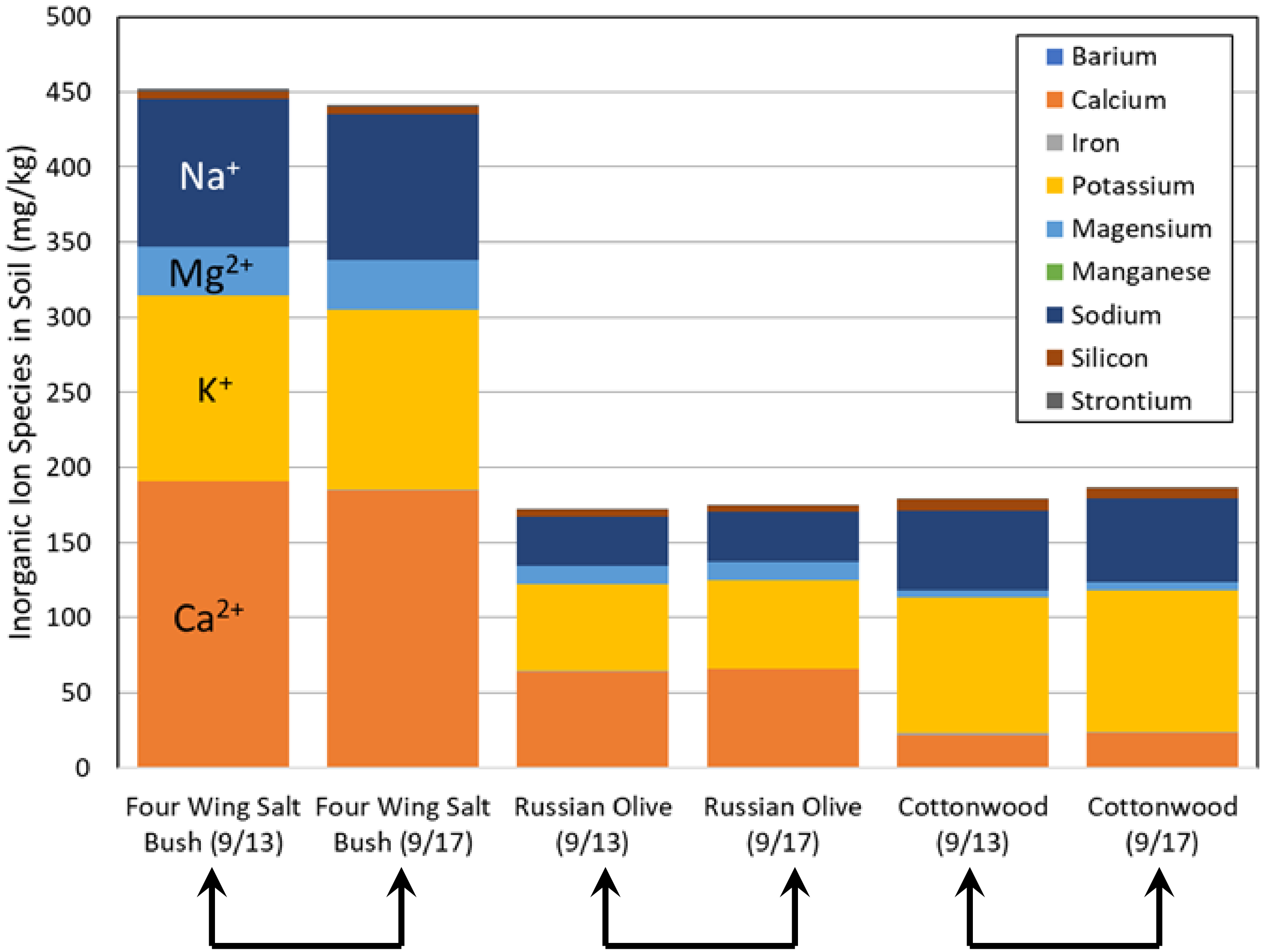
H-CAPS-PM$_{SSA}$ Instrument V1.0

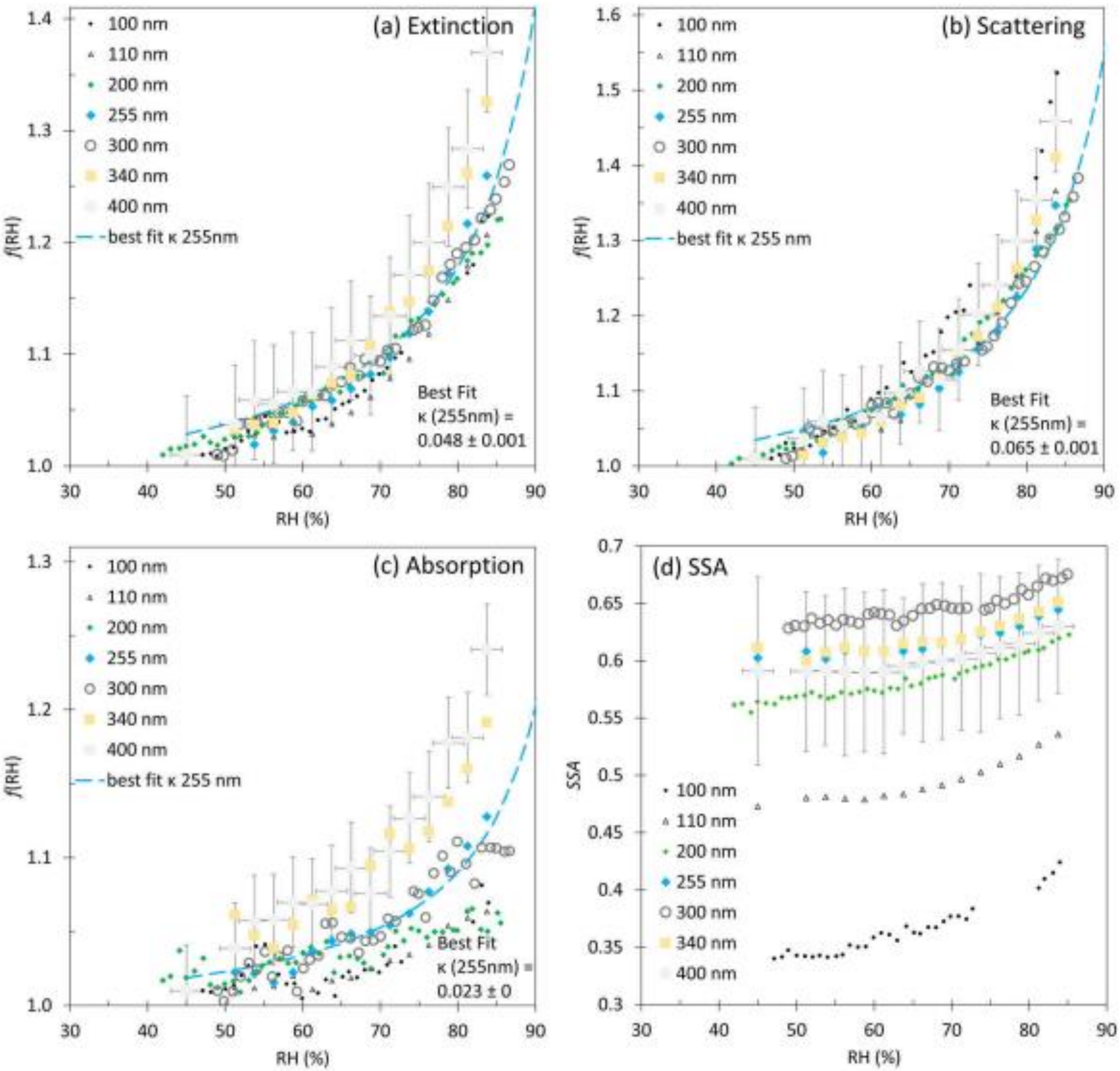


- Starting point was nephelometry f(RH) system (Gomez et al, 2018)
- Key pitfalls: Drying of Purge Flow & Temperature control of CAPS cell
- V2.0: 2 CAPS instruments to avoid the switching and improved RH/T control

Carrico et al (2021) AS&T

Plants & Soils Analysis Repeatability

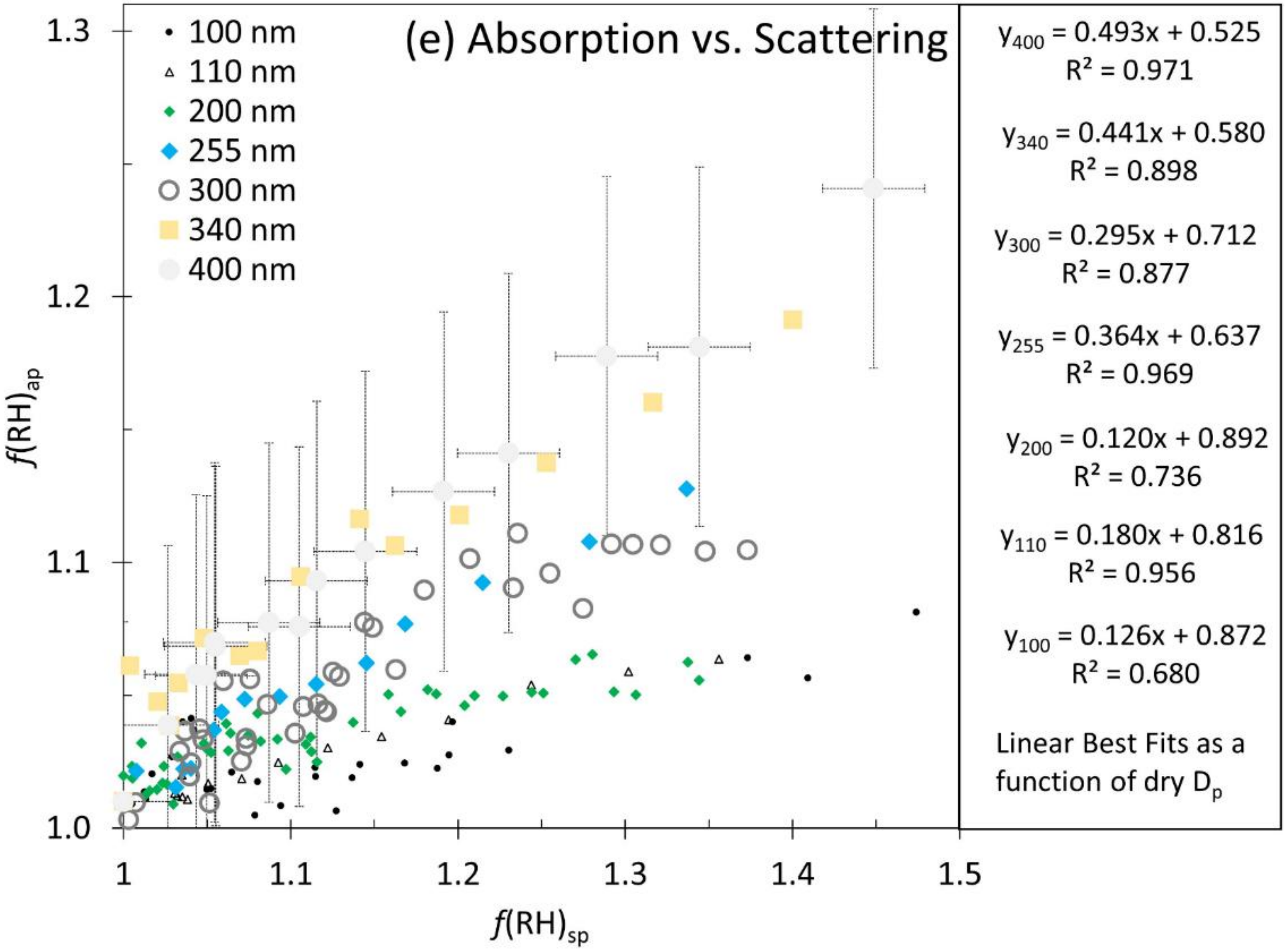




Size Selected Nigrosin (brown carbon mimic)

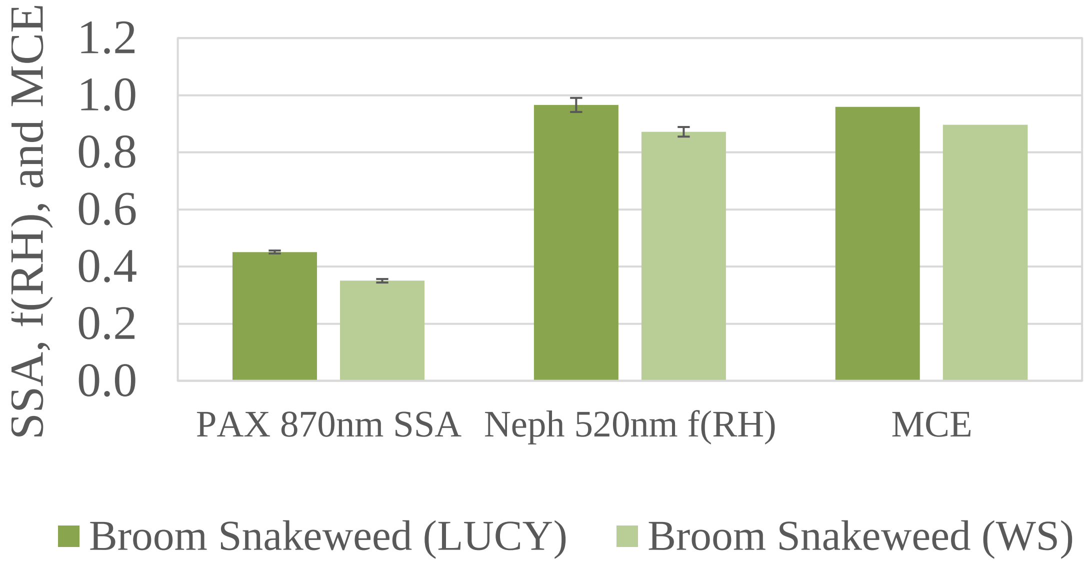
Scattering vs. Absorption *f*(RH) for Nigrosin

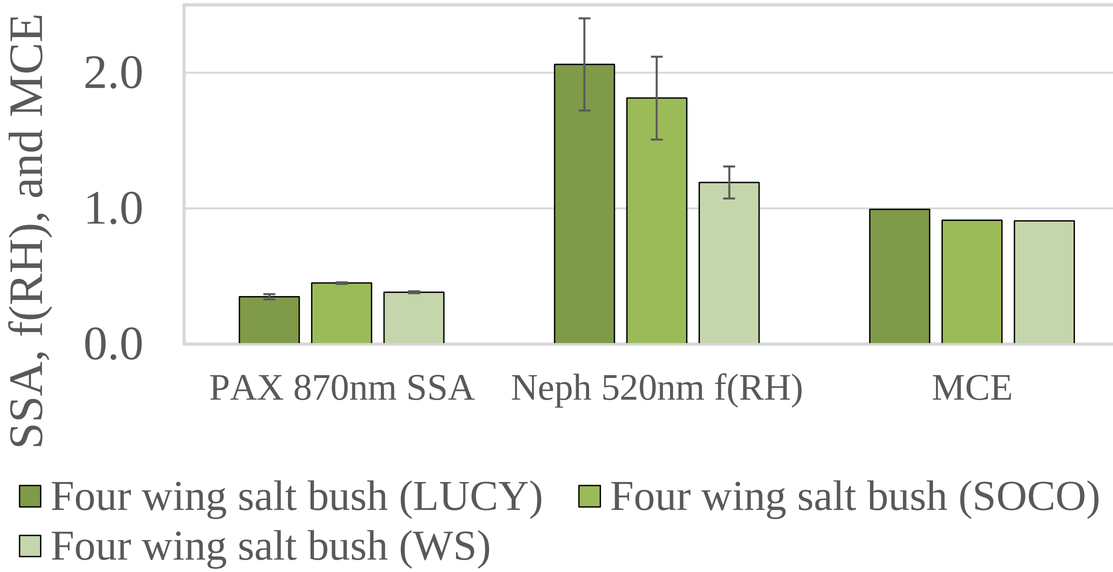
(Carrico et al, 2021 AS&T; Cappa AGU)



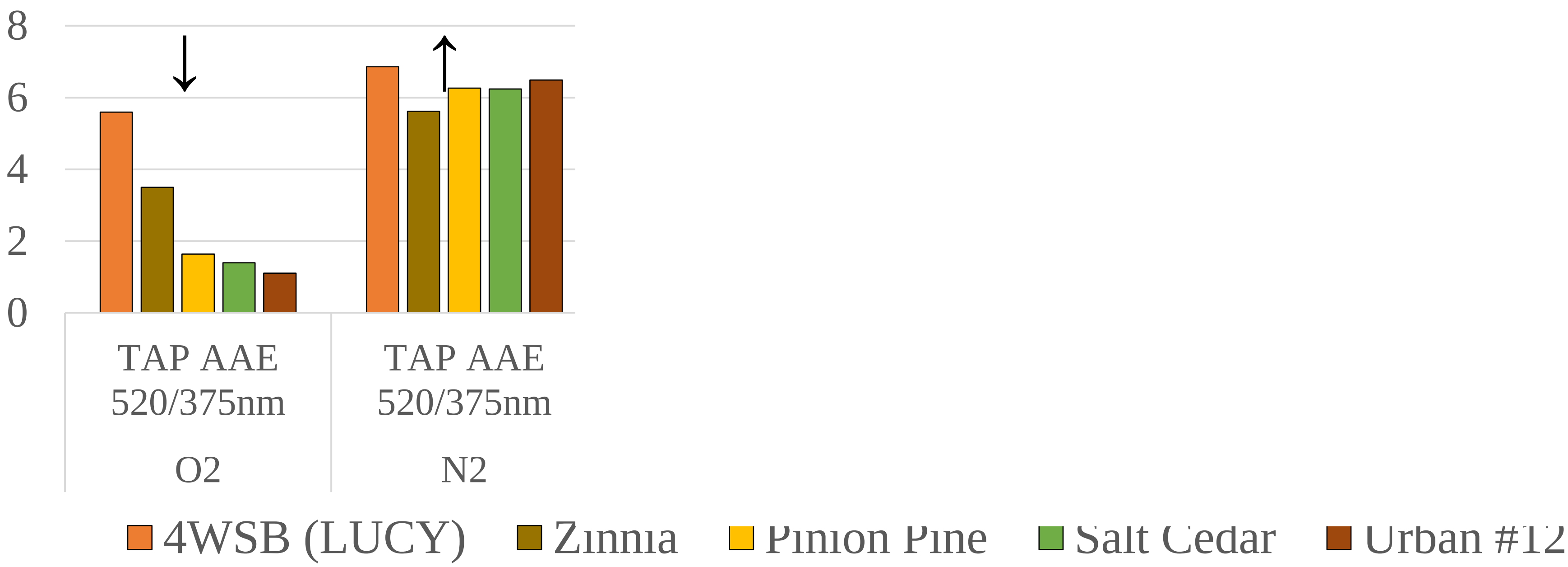
- Relatively linear relationship between light scattering and absorption *f*(RH)

Fuel moisture content and harvest ecosystem have minimal impact on aerosol properties (except f(RH)).

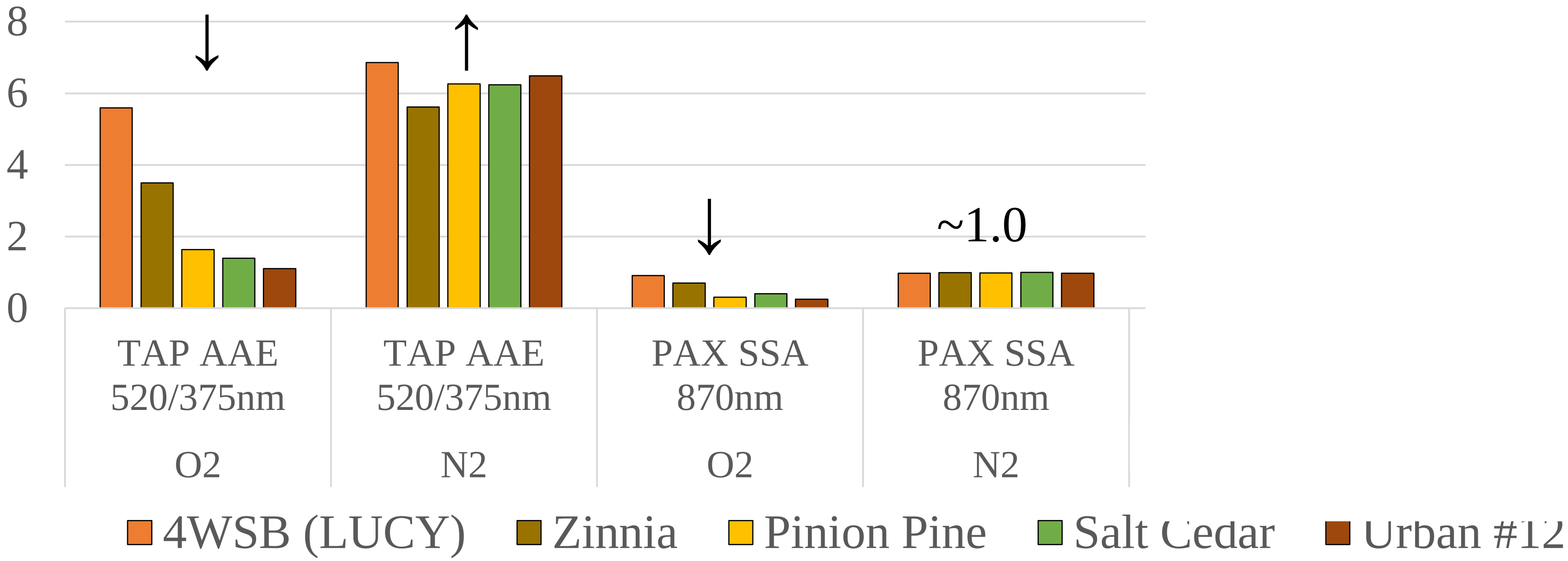




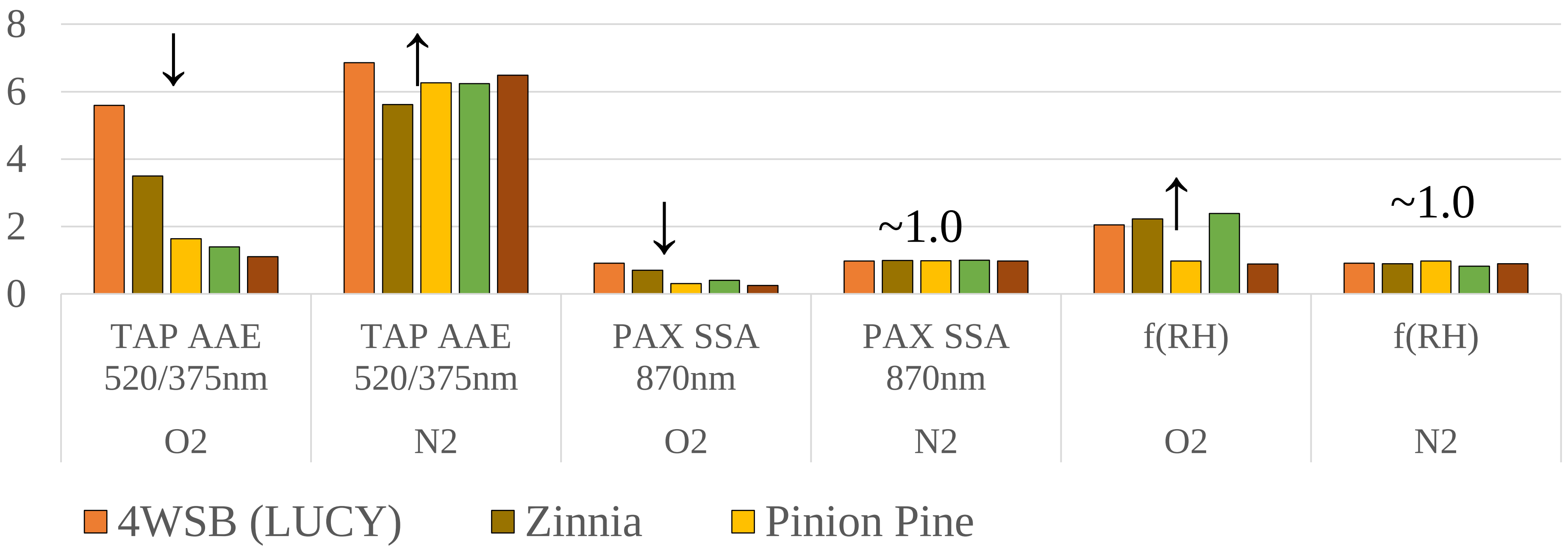
Pyrolysis conditions were similar to low temp smolder.



Pyrolysis conditions were similar to low temp smolder.



Pyrolysis conditions were similar to low temp smolder.



ABSTRACT

Biomass Smoke Hygroscopicity vs. In-Situ Aerosol Composition: The Roles of Plant Species, Soil Type, Combustion Temperature and Efficiency

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Allison C. Aiken, Katherine Benedict, Kyle Gorkowski, James Lee, Alex Josephson, Jon Reisner, Manvendra K. Dubey, Los Alamos National Laboratory, Los Alamos, NM

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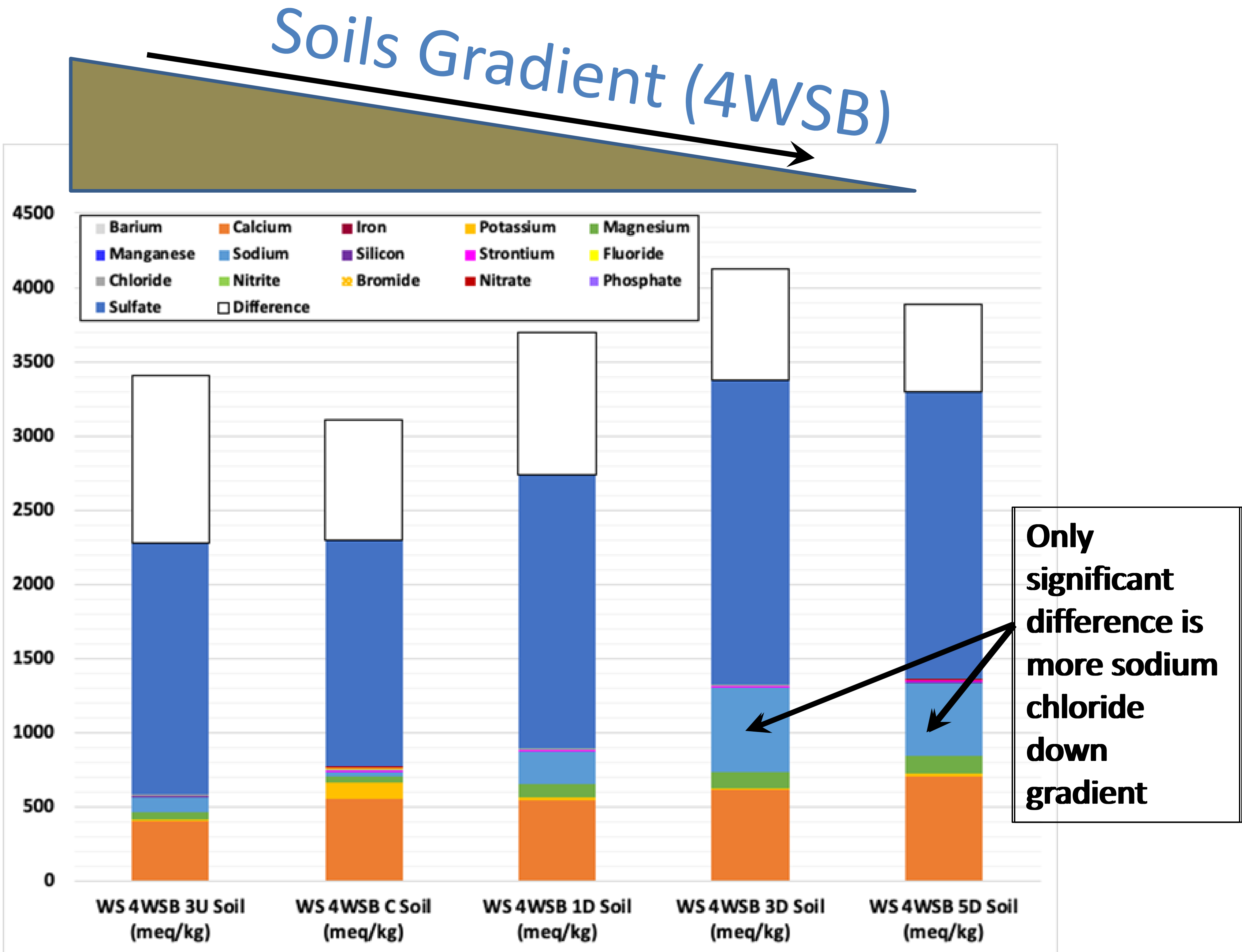
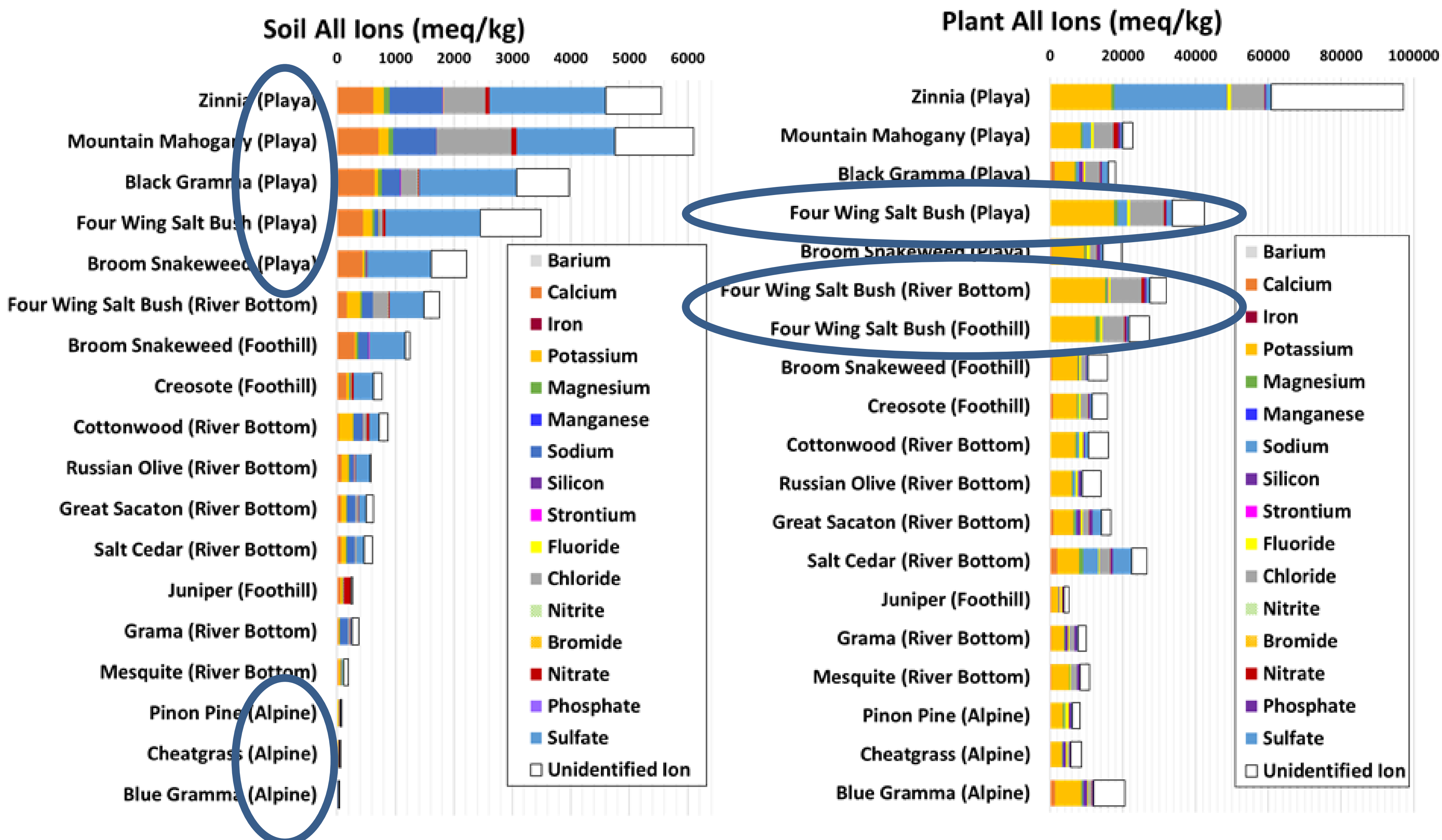
Air quality and climate change concerns drive an increased importance of aerosol emissions from wildland and urban fuels. Recent fires in grasslands and the wildland-urban interface (WUI) such as the Camp, Lahaina, Texas Panhandle, and Marshall fires, underscore the importance of fires in these transitional landscapes. Wildland fire studies here have focused upon U.S. native and invasive species as well as common urban fuels as controlling factors in smoke properties. This research focuses on key aerosol combustion sources including grassland fires at the Konza Prairie in Kansas and emissions from urban fuels measured at the New Mexico Firefighter Training Academy. Key measurements include laboratory, drone-based and ground-based techniques. Drone-based measurements include air quality sensors to measure PM2.5 properties including mass concentrations (PurpleAir and similar sensors) and light absorption and its wavelength dependence (micro-aethalometer). Complementary measurements from the ground include aerosol optical depth, filter-based PM2.5 measurements, CO and CO2, aerosol hygroscopicity, and meteorological data. Transitory wildfire nature and shifts in combustion phase as indicated by the Modified Combustion Efficiency (MCE) are clearly observed influencing the dominance of black versus brown carbon aerosols. The field measurements echo some of the key findings of laboratory studies of biomass burning emissions and provide some new insights into the evolving nature of fires in the WUI. Measurement highlights from the field sites as well as laboratory experiments with smoke and its proxies will be discussed..



Soils Gradient (4WSB)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Barium
Calcium
Iron
Potassium
Magnesium
Manganese
Sodium
Silicon
Strontium
Fluoride
Chloride
Nitrite
Bromide
Nitrate
Phosphate
Sulfate
Difference
WS 4WSB 3U Soil (meq/kg)
WS 4WSB C Soil (meq/kg)
WS 4WSB 1D Soil (meq/kg)
WS 4WSB 3D Soil (meq/kg)
WS 4WSB 5D Soil (meq/kg)
Only significant difference is more sodium chloride down gradient

Did the plants look like the soils?

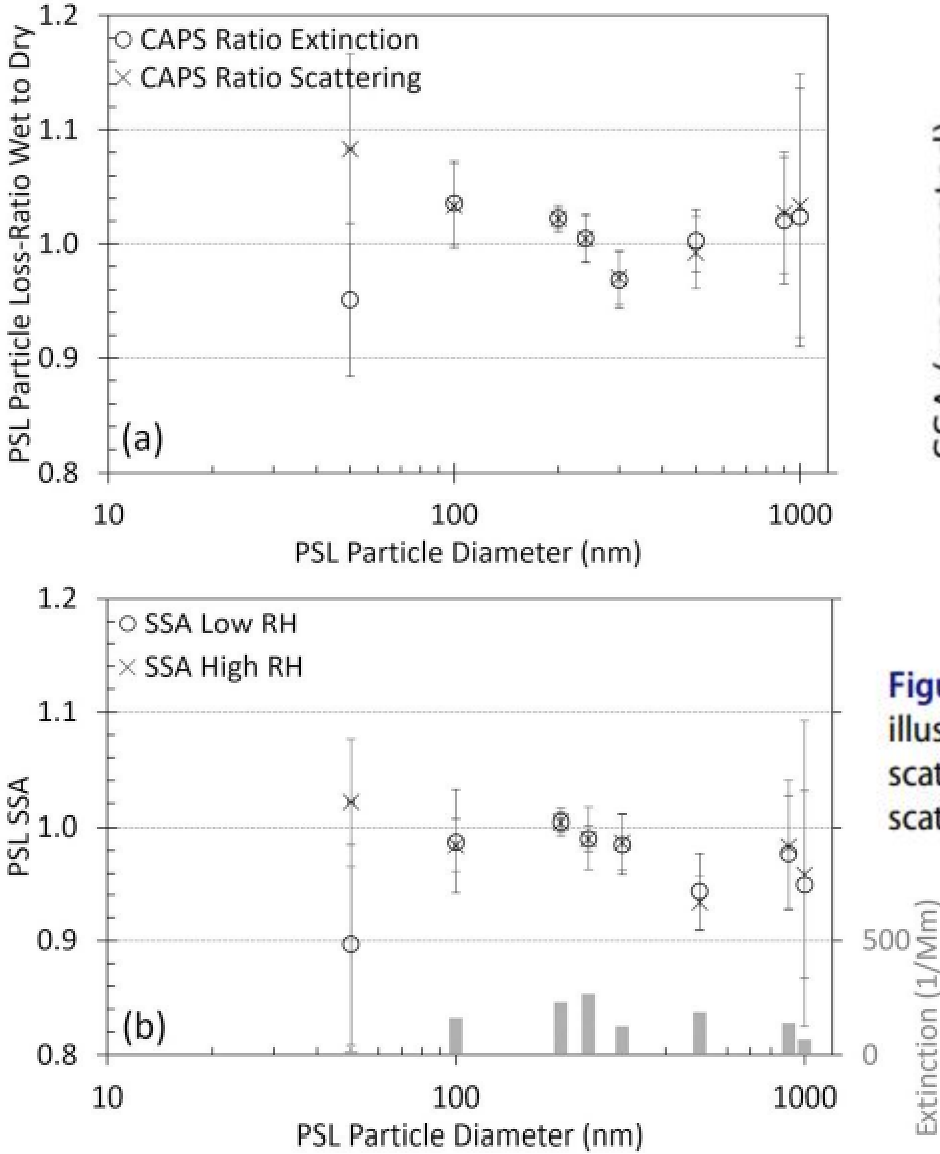


- Slightly similar profiles soils vs plants, but more a function of the plant species than where it grows
- (Calcium and sulfate in soils) (Postassium, Sodium, Sulfate and Chloride in Plants)

Biomass smoke hygroscopicity:

1) Fuel **inorganic content** of is key to hygroscopicity
2) Combustion T/phase **enhances** (High T/flaming) or **diminishes** (Low T/smoldering) hygroscopicity
3) General rules on smoke hygroscopicity:
   - Large Inorganic Fraction >> Little Inorganic
   - Flaming > Smoldering
   - Leaves > Woods and Barks
   - Deciduous > Evergreen
   - Invasives > Natives

Particle Loss and Truncation Correction-PSLs, Ammonium Sulfate



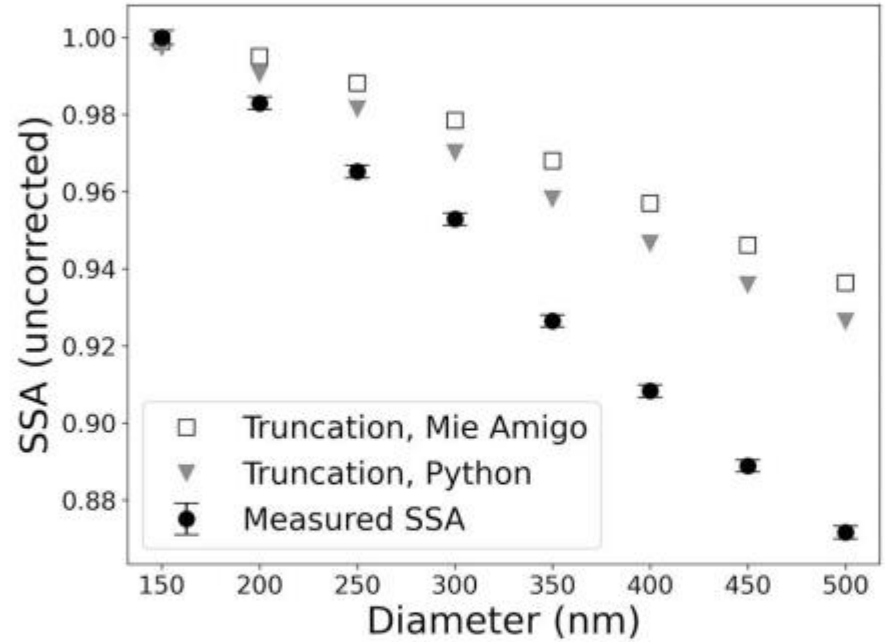


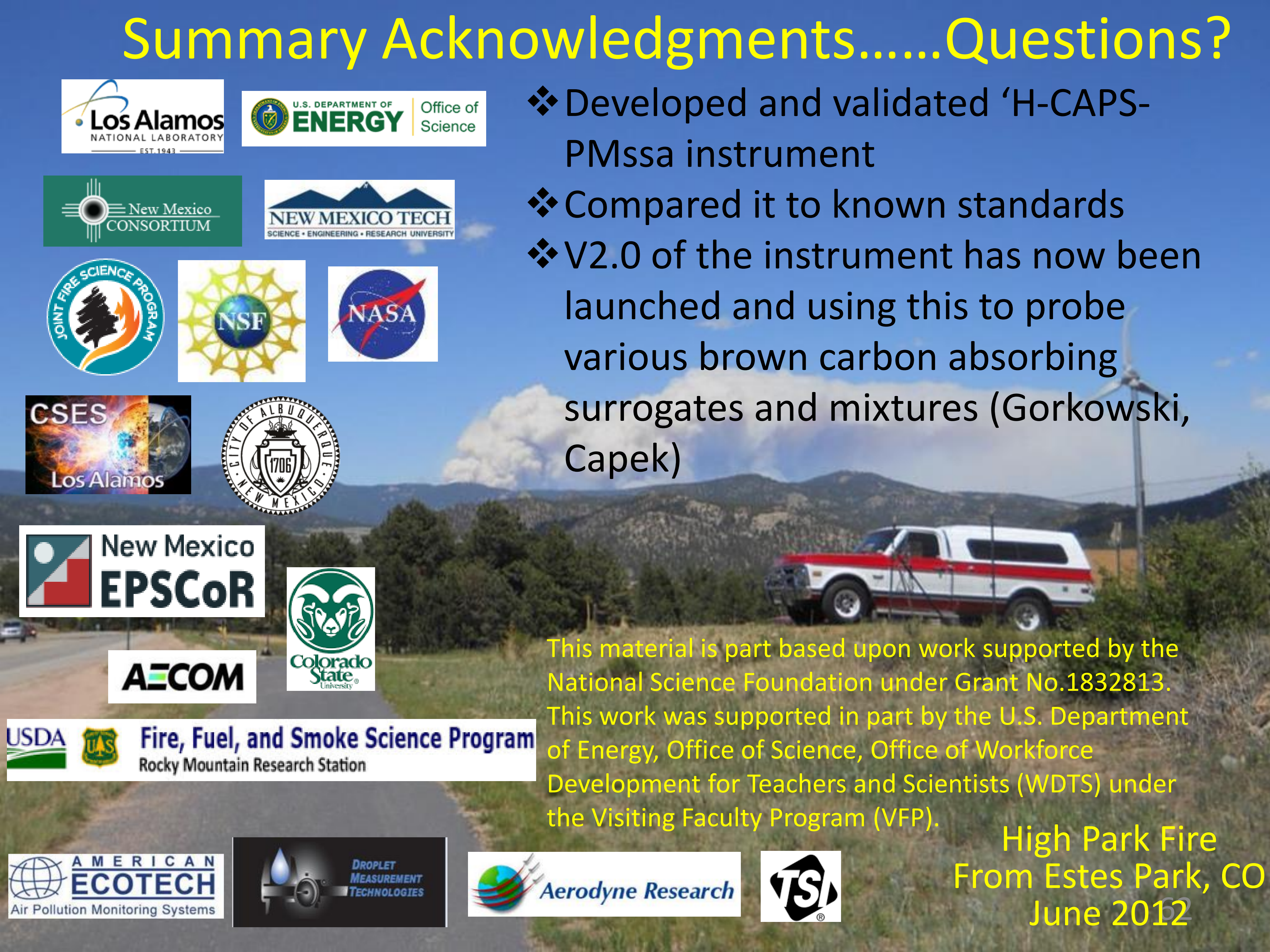
Figure 4. Truncation error effects for CAPS light scattering illustrated by the decrease in uncorrected measured single scattering albedo (SSA) with electrical mobility D_p for a purely scattering ammonium sulfate aerosol.

- ❖ Within 5% of expectations for D_p < ~400 nm
- ❖ For truncation used 2 models and known SSA=1 to calibrate

Summary Acknowledgments…..Questions?

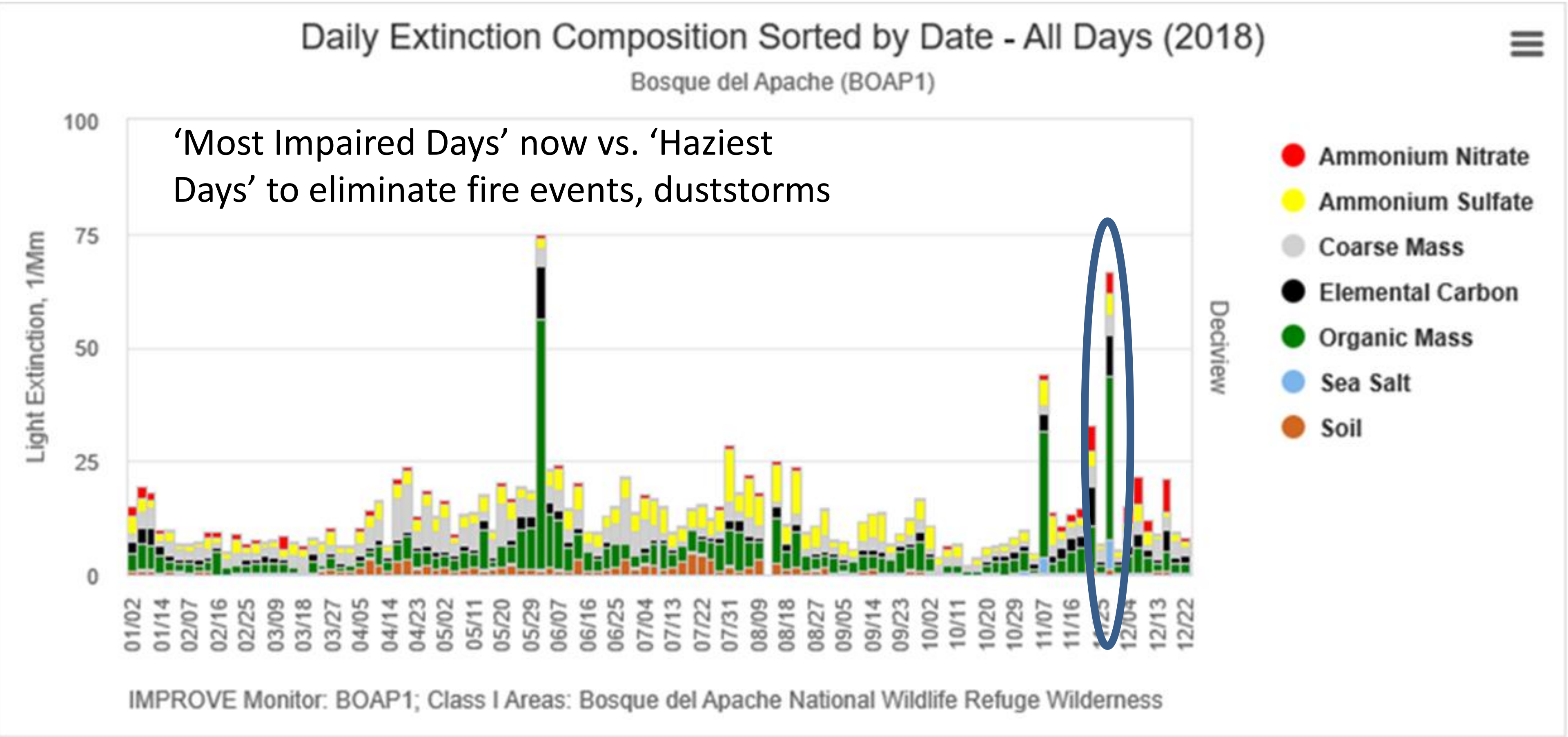
- ❖ Developed and validated 'H-CAPS-PMssa instrument
- ❖ Compared it to known standards
- ❖ V2.0 of the instrument has now been launched and using this to probe various brown carbon absorbing surrogates and mixtures (Gorkowski, Capek)

This material is part based upon work supported by the National Science Foundation under Grant No.1832813. This work was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Visiting Faculty Program (VFP).



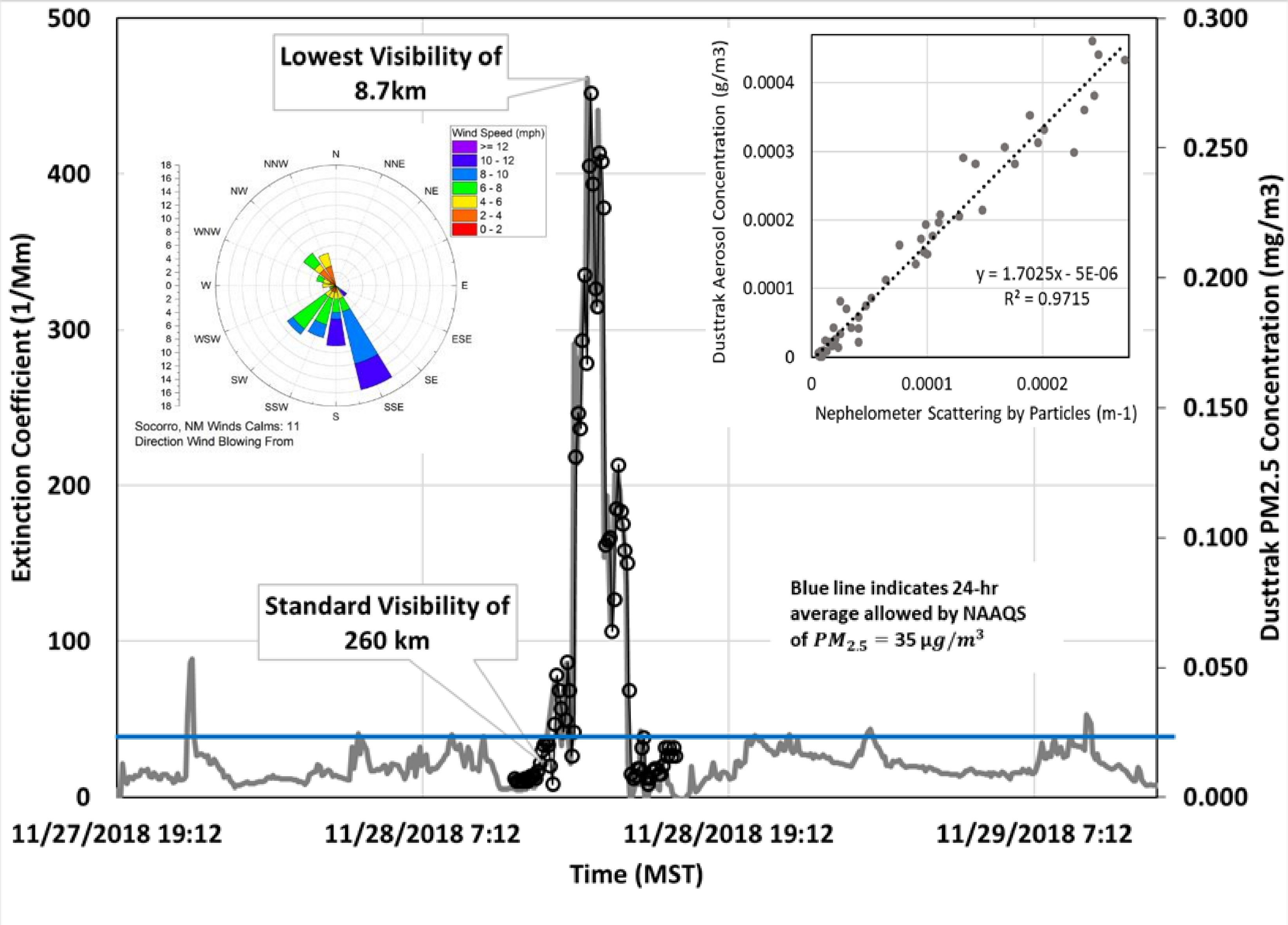
High Park Fire
From Estes Park, CO
June 2012

Bosque del Apache (IMPROVE TSS data)



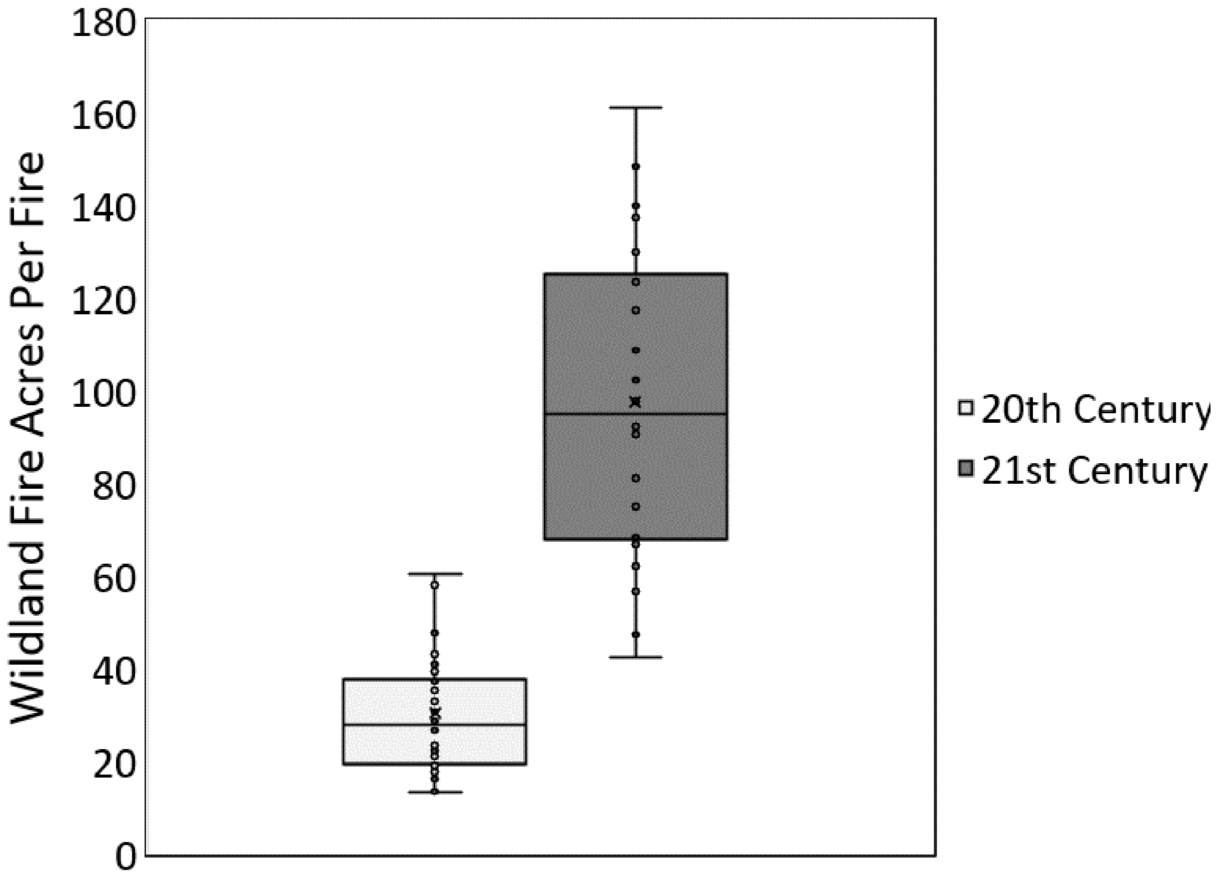
➢ Regional haze Rule will be complicated by fire emissions and coarse mode particle contributions in the southwest

Bosque del Apache Prescribed Fire Event (Socorro Measurements)



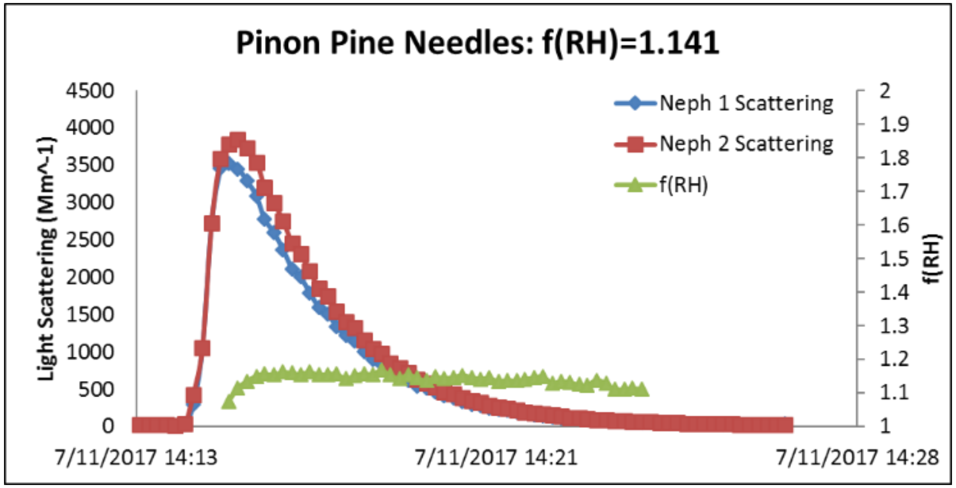
➢ Localized discrete event over a few hours in the Rio Grande Valley

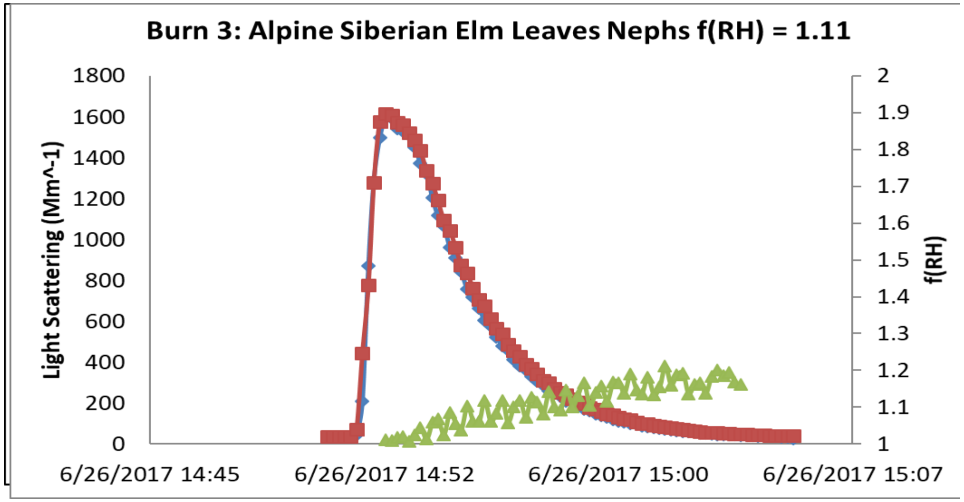
To Burn or Not to Burn



- Management of fire entirely necessary and at a much higher level to avoid the effects from megafires we are experience in the last 2 decades.

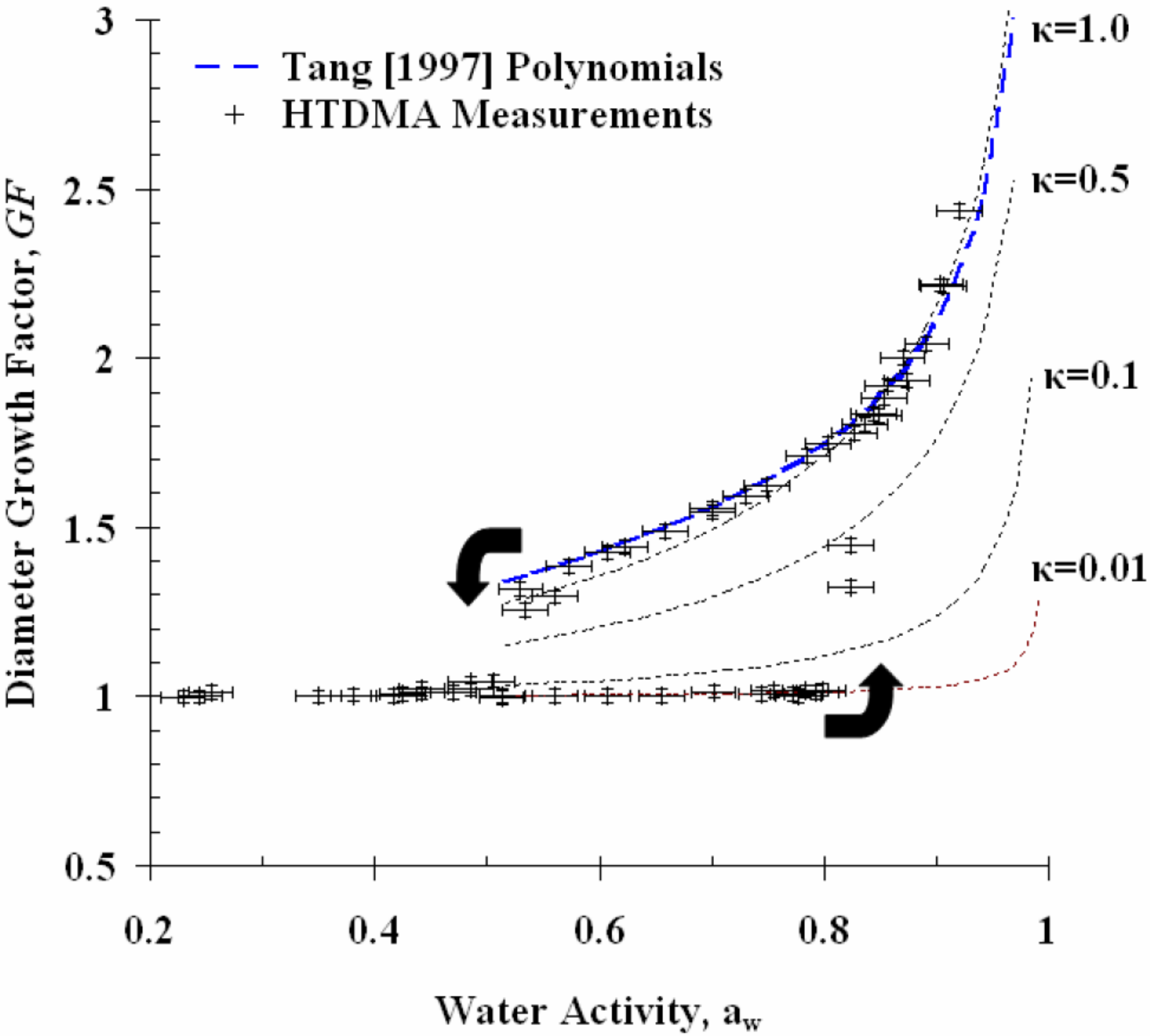
Plants from Different Locations and Soils





Could Phenotypic plasticity alter biomass smoke properties?

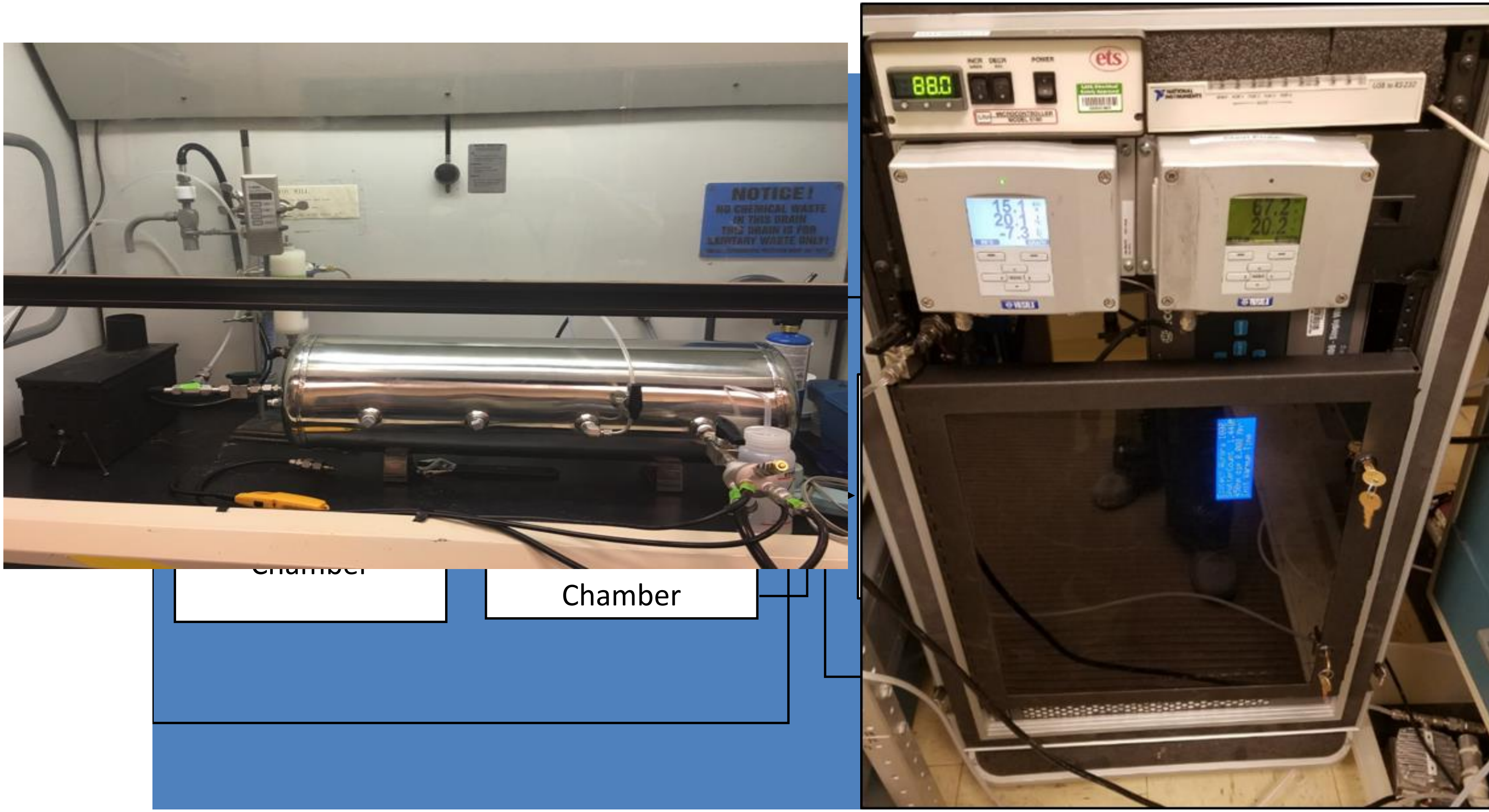
(Some) Aerosols Like Water (KCl)



- κ= 0, non-hygroscopic
- κ approaching 1, very hygroscopic salts

Carrico et al. (2010)

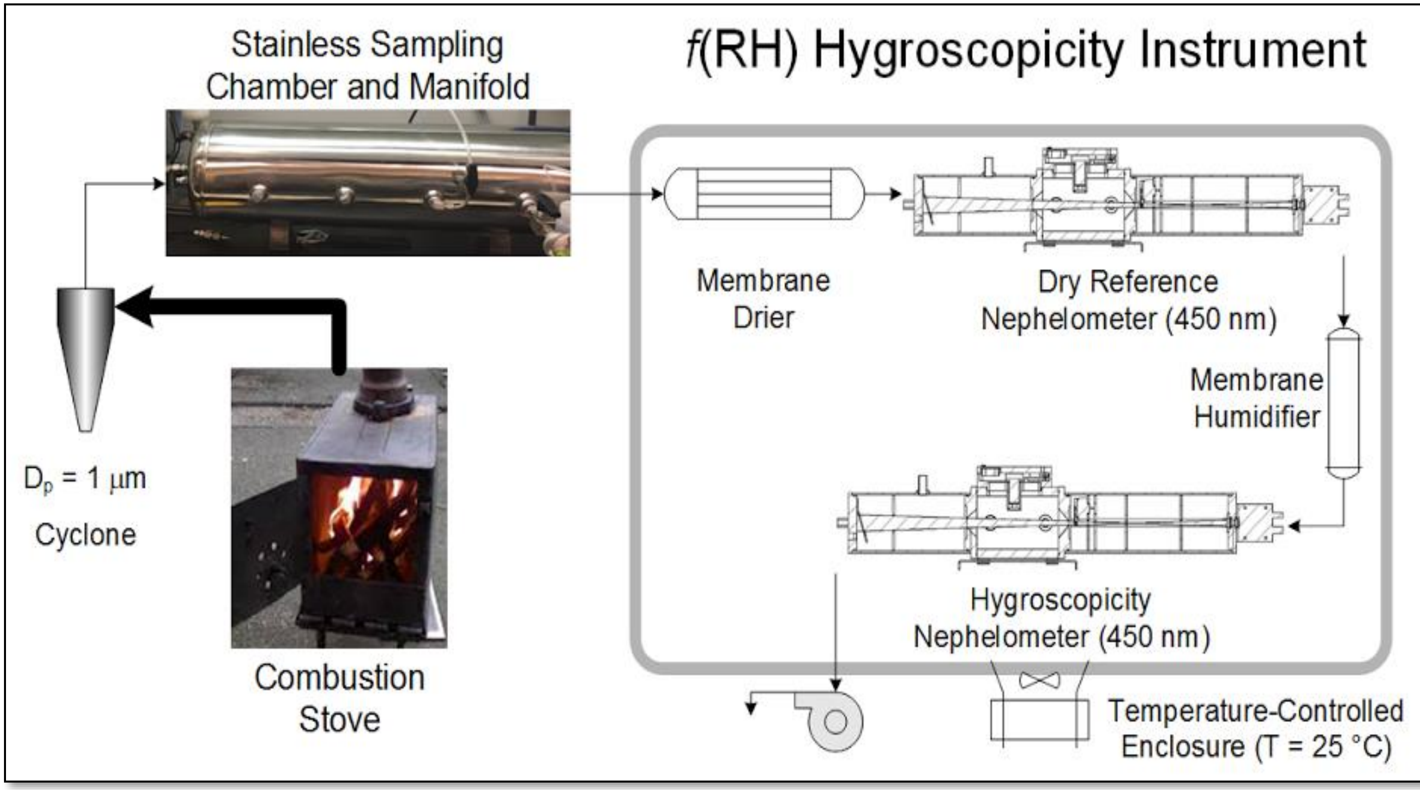
Biomass Burning Source Testing Measurements



- >300 burns with native and invasive species in the southwestern US

(Gomez et al., 2018 JGR; Carrico et al., 2018 Atmos. Environ.)

Hygroscopicity Measurement Systems



Gomez et al. (2018) JGR

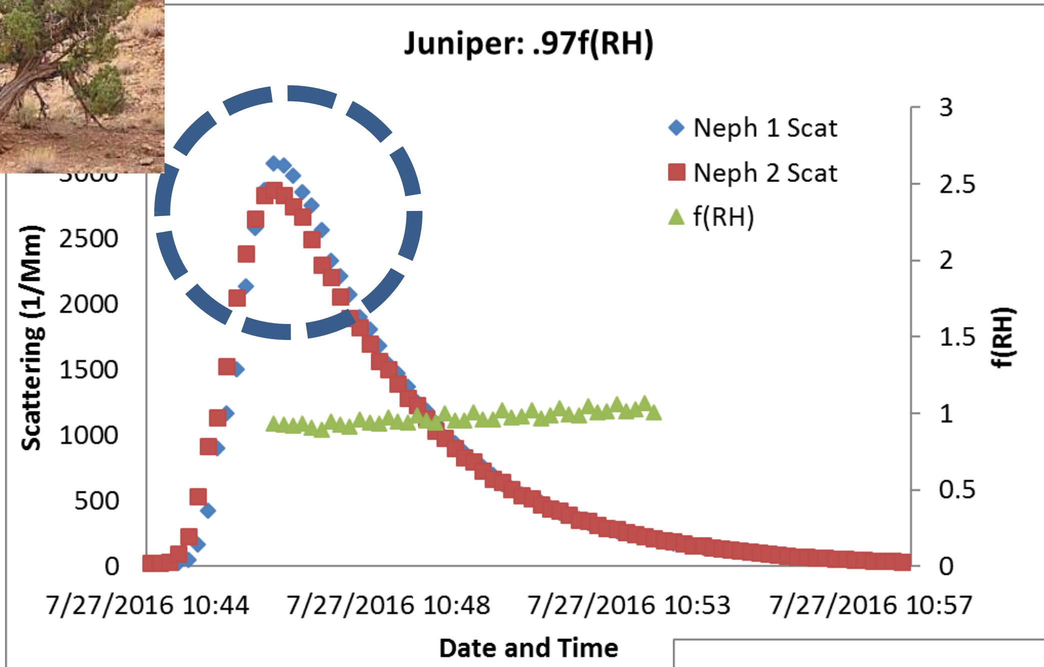
- Other optical techniques including PAX, TAP, CAPS, 3λ nephelometer measuring in parallel

$$f(RH) = \frac{Humidified\ Light\ Scattering\,(Mm^{-1})}{Dry\ Light\ Scattering\ (Mm^{-1})}$$

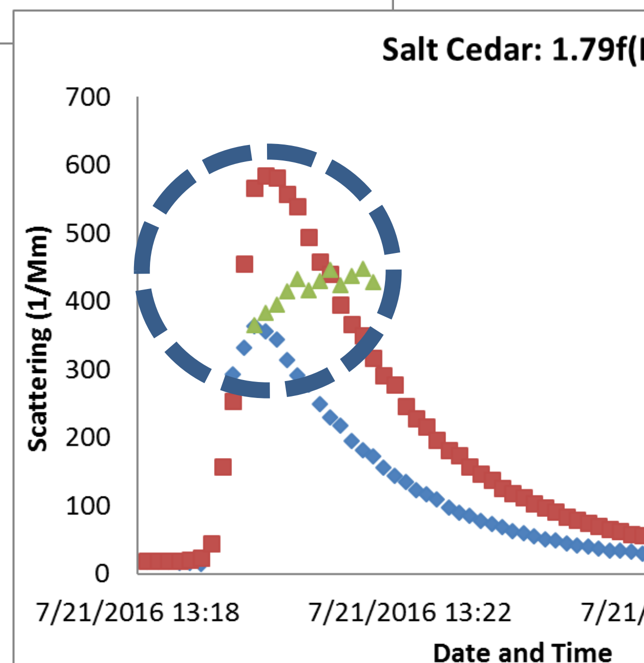
$$f\,(\mathrm{RH}) \cong 1 + \kappa_{\mathrm{ext}} \frac{\mathrm{RH}}{100 - \mathrm{RH}}$$

Brock et al. (2016)

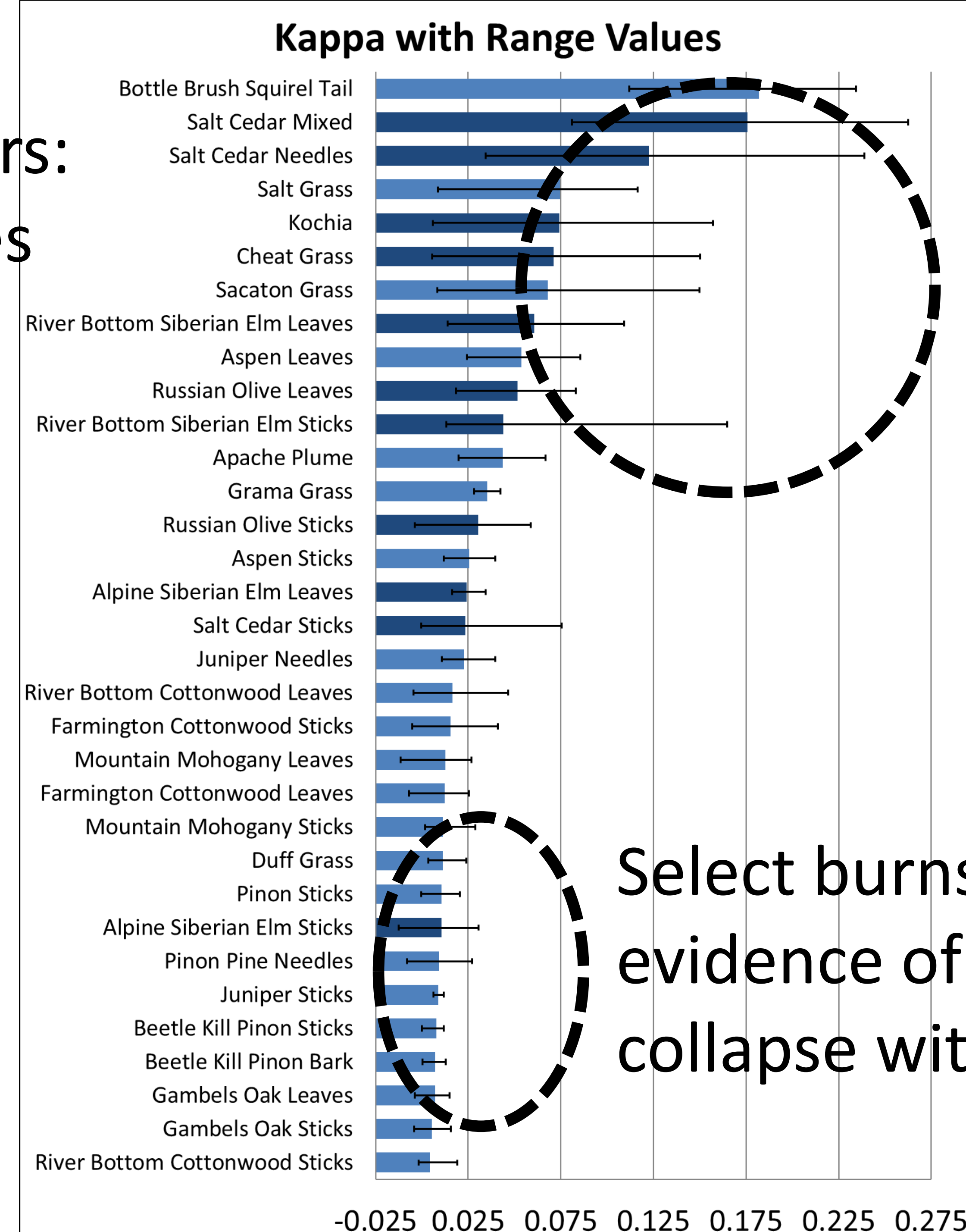
Fuel Species vs. *f*(RH)



Invasives (salt cedar, cheatgrass & Russian olive): pronounced hygroscopicity. Found in drainages thriving in saline soils



Dark Bars: Invasives



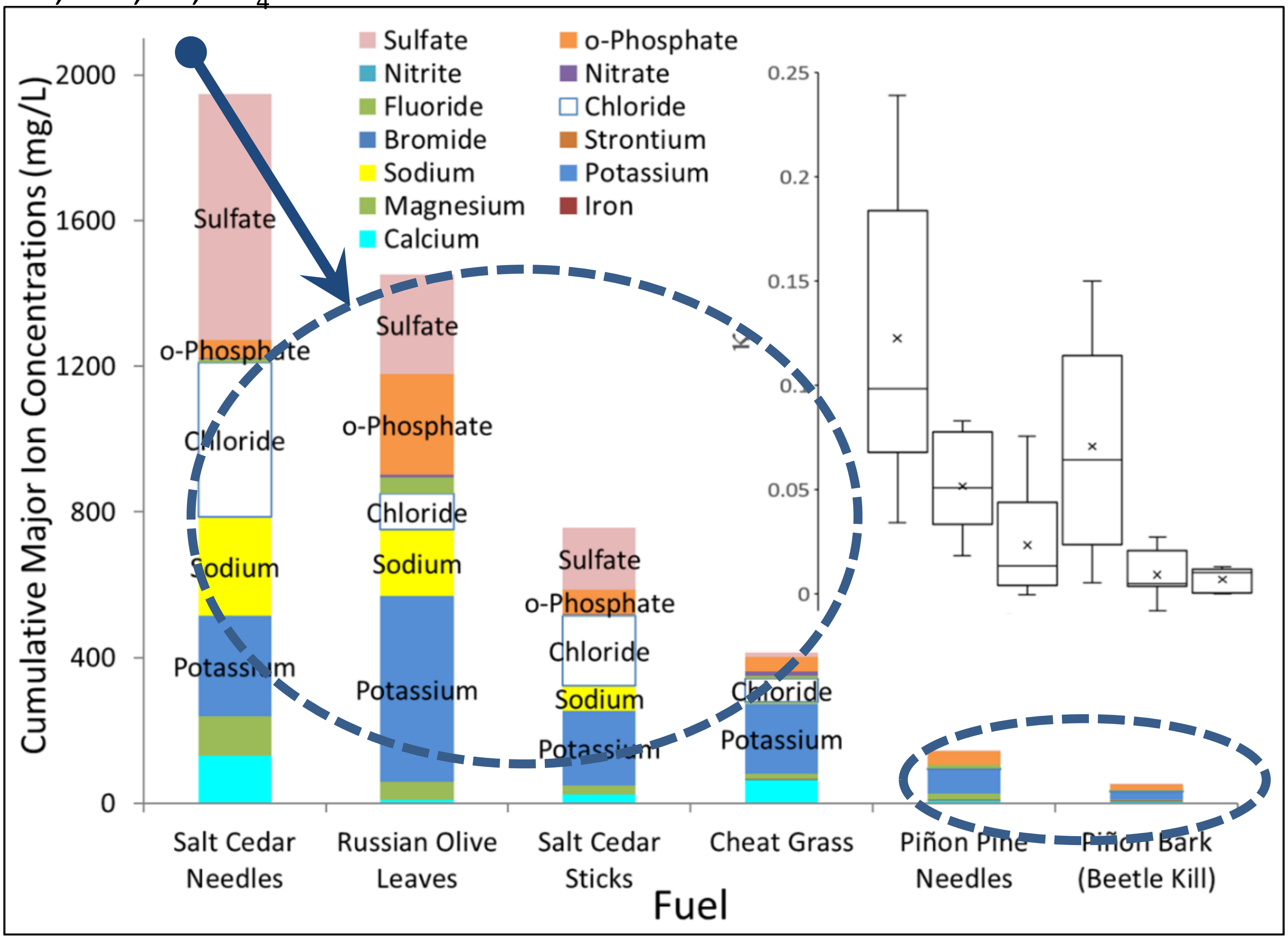
Fuel vs. Hygroscopicity (κ)

Some smokes as hygroscopic as pure salts.

Select burns: evidence of particle collapse with ↑RH

Hygroscopic smokes are driven by large inorganic content in fuels, notably K^+, Na^+, Cl^-, SO_4^{2-}

Fuel Composition vs. *f*(RH)



Bixler et al. (2018, JGR)

Weakly Hygroscopic: OC dominated

Prescribed Burning (SWFC)

- ❖ While acres restored by the Forest Service has improved in the southwest, the cost of treatment has been a major barrier to achieving a much broader area impacted.
- ❖ Included in the cost of treatment are the planning, preparation, administration, mechanical thinning and prescribed burning costs, which can total from **$1,321 to $3,195 (in 2015 dollars) per acre** (Selig et al. 2010, Huang et al. 2013).

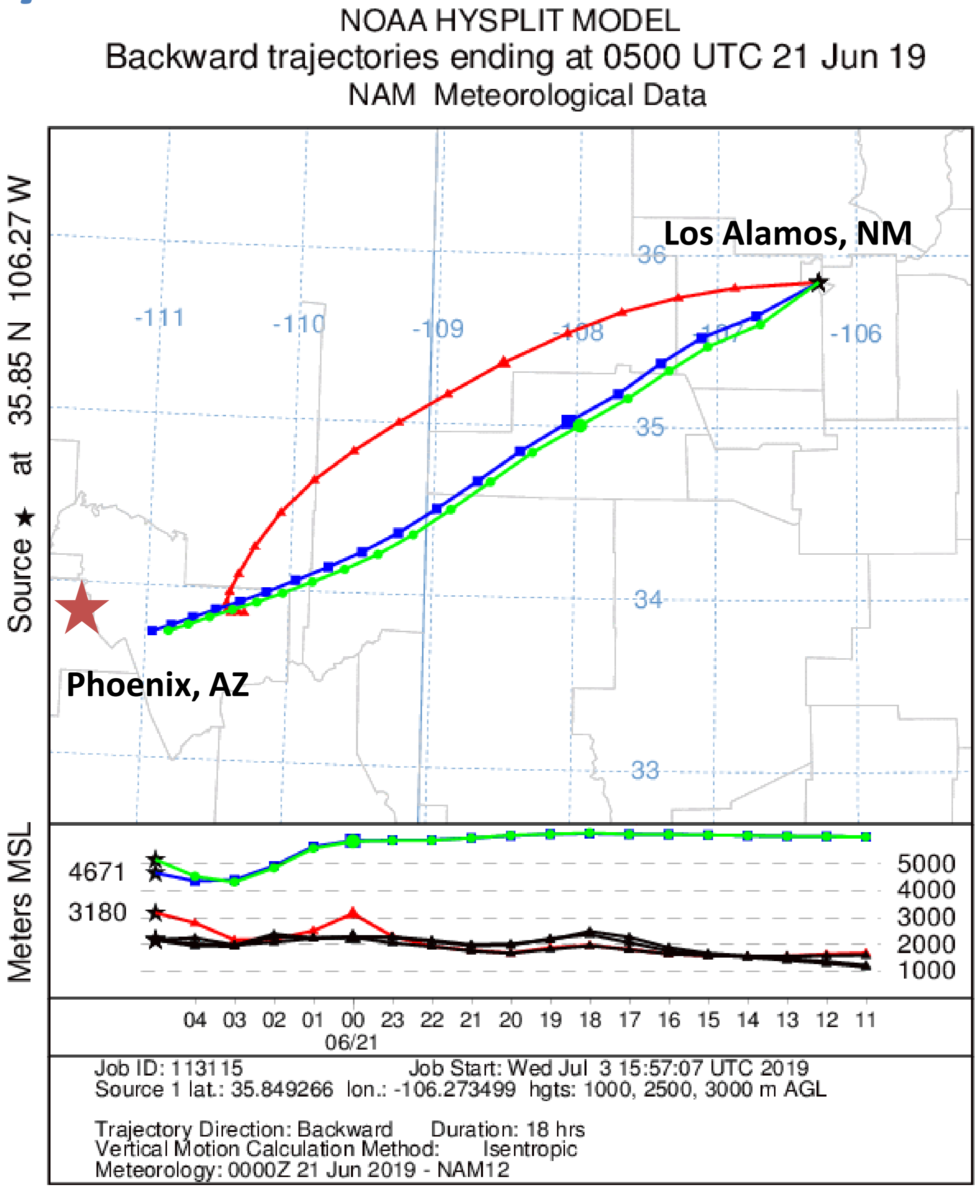
Costs to burn 10E6 acres/year (5% of USFS land): 10E6 acres/year * $1500/acre = $15 billion/year or 4 more USFS!!!!

Woodbury Fire 2019

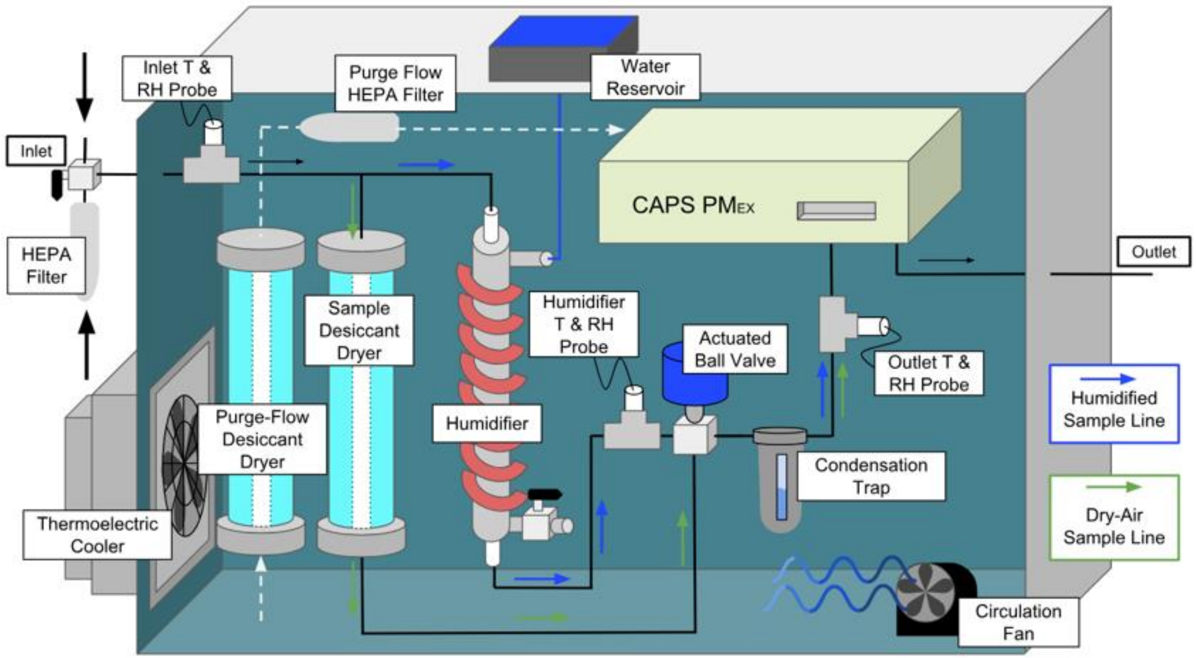
Woodbury Fire (east of Phoenix, AZ):

- 124,000 acres burned (as of 7-18-2019)
- 12-hour transport time to Los Alamos (~330 miles)
- Primary fuel: Ponderosa Pine (found to have very low f(RH) in lab)

Photos courtesy of abc15.com

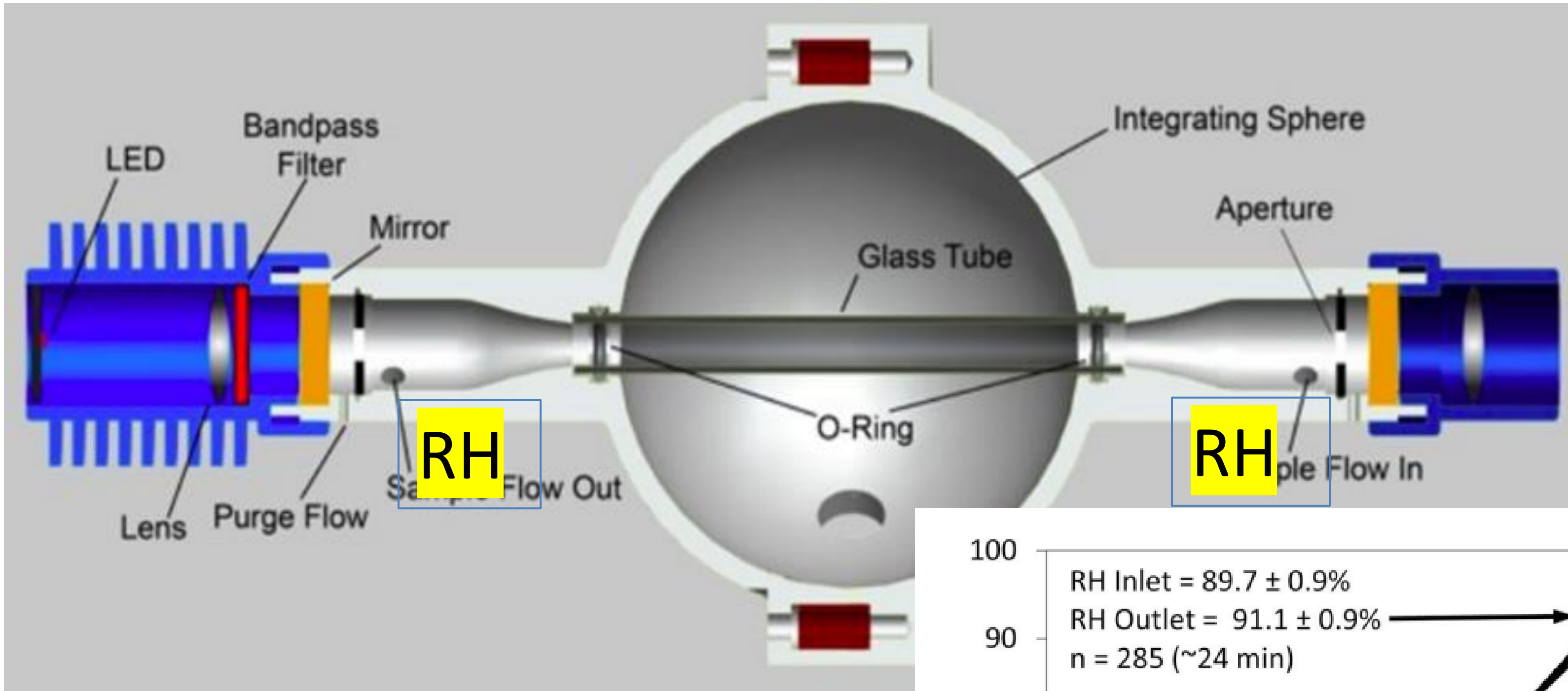


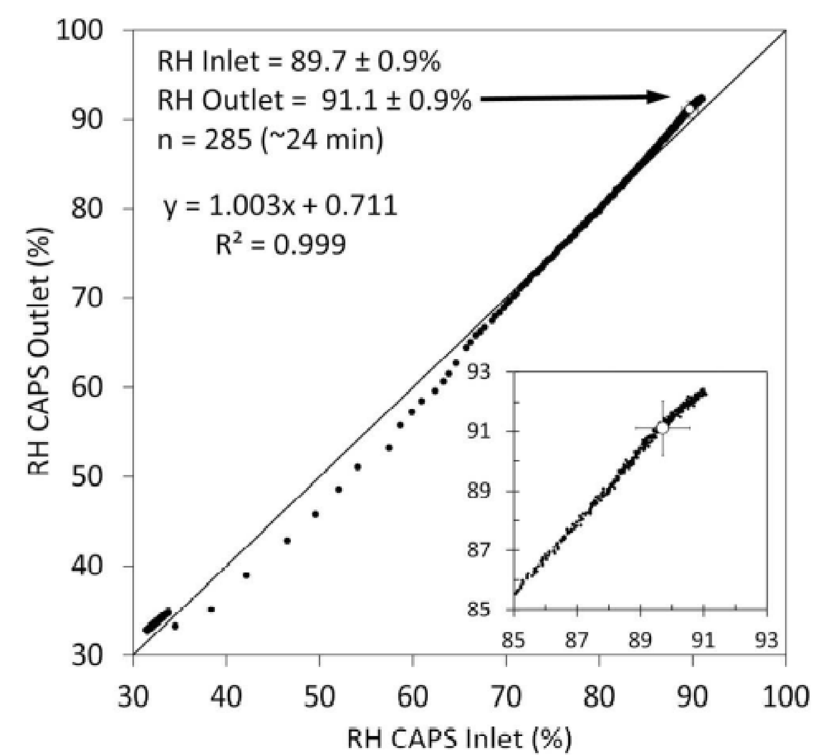
CAPS f(RH) System



- System designed to measure RH dependence of light extinction AND light scattering
- By difference: light absorption and SSA as function of RH
- Currently testing and characterizing its performance

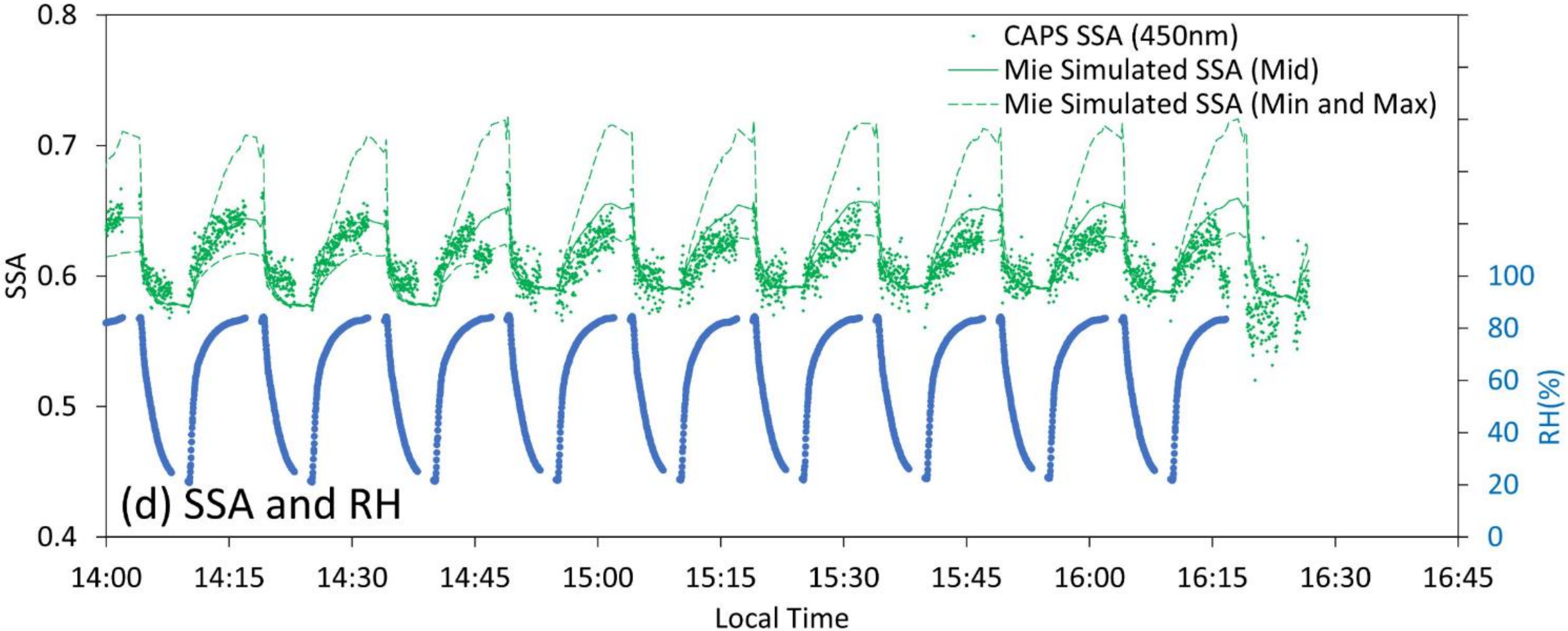
H-CAPS-PM$_{SSA}$ Instrument





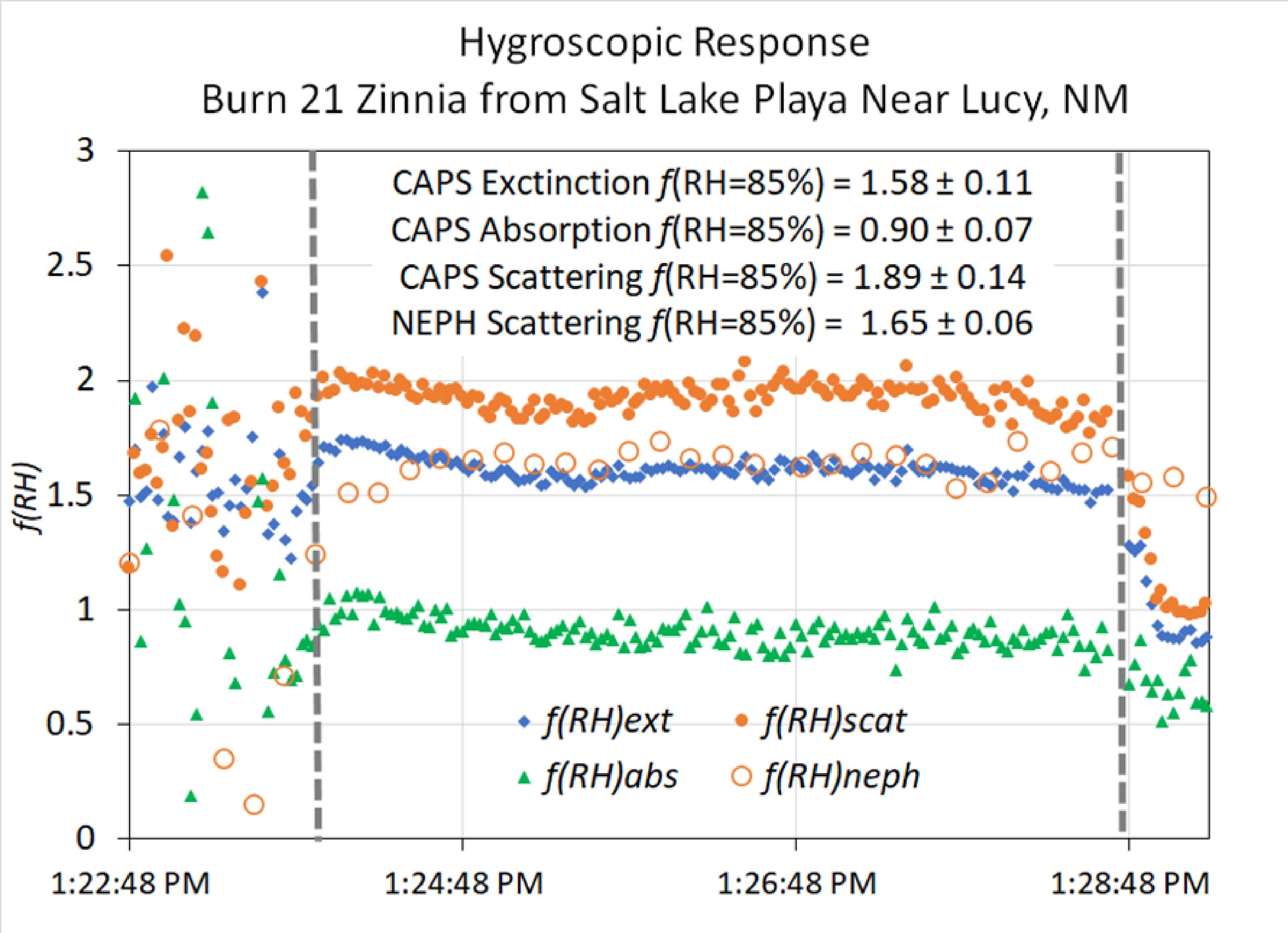
- ❖ CAPS-PM$_{SSA}$ instrument: Light scattering AND extinction (aerodyne, Inc.)
- ❖ By difference: light absorption & SSA (Onasch et al., 2016)
- ❖ Added upstream & downstream capacitive RH sensor (RH +/- 2%)

H-CAPS-PM_{SSA} Instrument



- ~10 RH Cycles showing the Single Scattering Albedo for nigrosin as a function of RH vs. Mie simulations for size selected nigrosin

Biomass Smoke: Measurements of *f*(RH) with Two Instruments



Ignition Flaming into Smoldering Combustion

- Both CAPS and Dual-Nephelometery systems showed strongest water uptake for this plant

Literature Comparison of Extinction, Scattering and Absorption for Nigrosin as a Function of RH

Table 7. Comparison of values of f(RH) for light absorption for nigrosin.

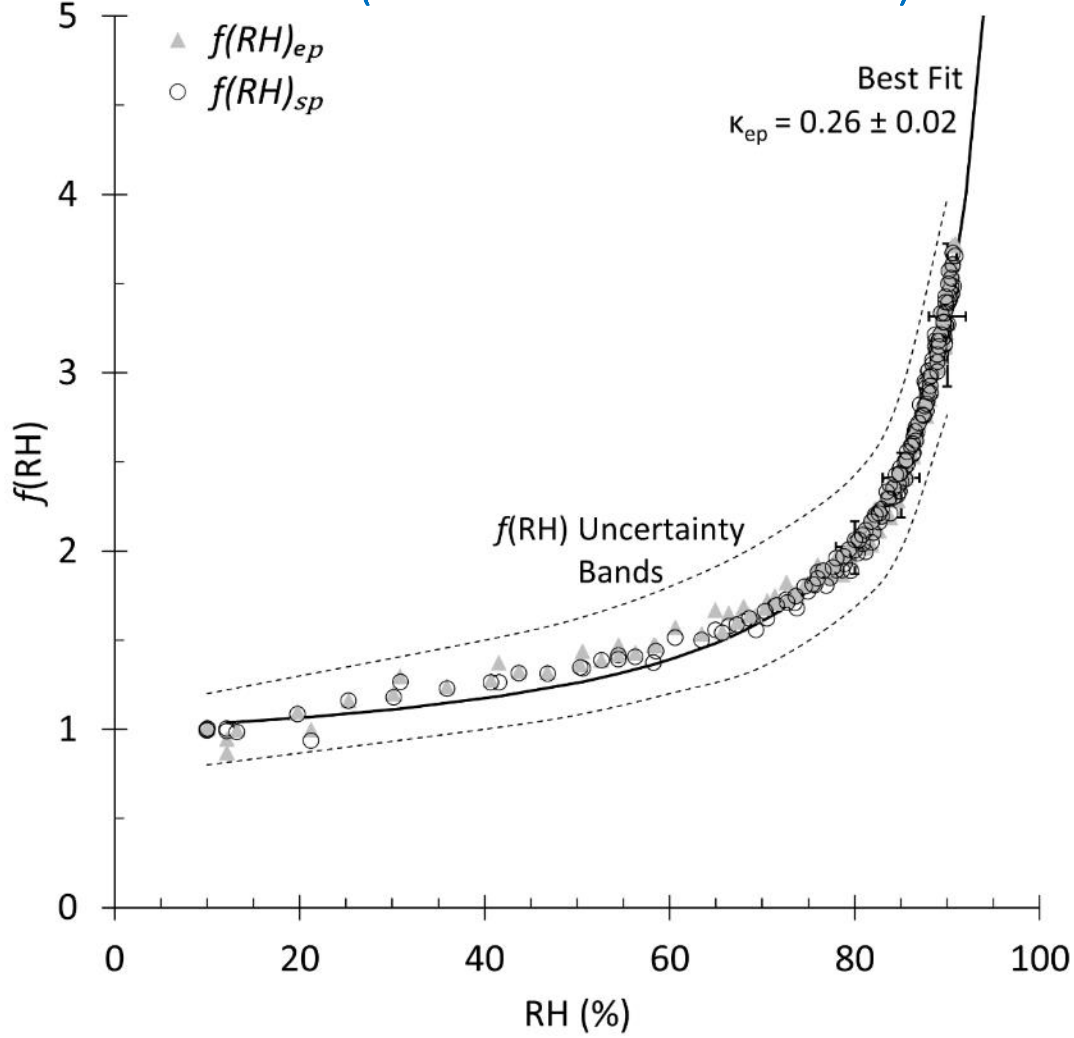
Nigrosin study	Technique	Dry size	f(RH = 80) extinction	f(RH = 80) scattering	f(RH = 80) absorption
Zhou et al. (2020)	Cavity Enhanced Aerosol Extinction Spectrometry 532 nm	200 nm	1.22 ± 0.00	1.34 ± 0.00	1.12 ± 0.01
		300 nm	1.26 ± 0.01	1.34 ± 0.02	1.18 ± 0.01
Brem et al. (2012)	CRDS & Nephelometer 467 nm	D_p < 500 nm polydisperse	~1.26	~1.33	~1.2
Michel Flores et al. (2012)	CRDS (σ_{ep} only) 532 nm	200	1.18 ± 0.06	NA	NA
		300	1.19 ± 0.04		
This study	Cavity Attenuated Phase Shift 450 nm	110	1.15 ± 0.02	1.27 ± 0.04	1.05 ± 0
		255	1.18 ± 0.03	1.25 ± 0.05	1.09 ± 0.01
		340	[illegible]	[illegible]	1.14 ± 0.02

Dry conditions are defined similarly in the studies as RH < 40%. Uncertainties shown [illegible] nd shown in Figure 9.

f(RH = 80) absorption
1.12 ± 0.01
1.18 ± 0.01
~1.2
NA
1.05 ± 0
1.09 ± 0.01
1.14 ± 0.02

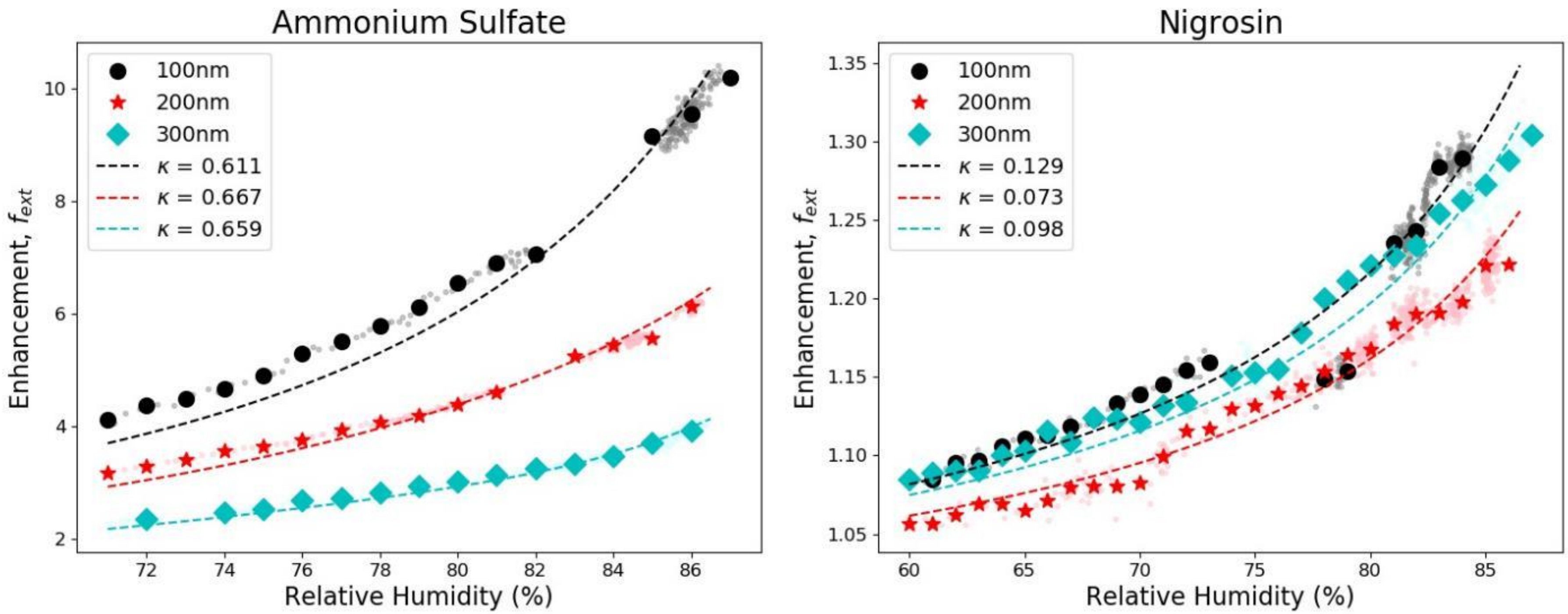
H-CAPS-PM_{SSA} Measurements: Levoglucosan Biomass Smoke Tracer

(Carrico et al. 2021 AS&T)

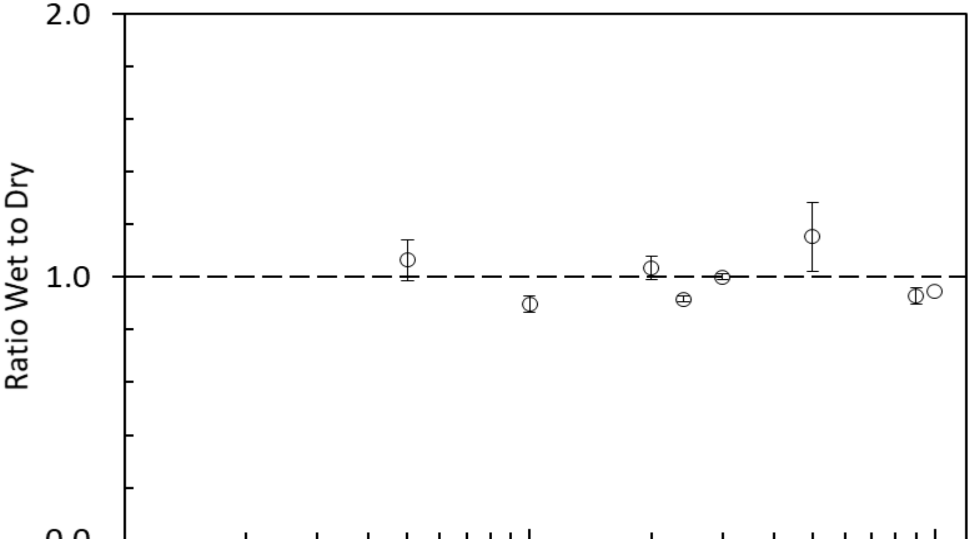


❖ H-CAPS-PM_{SSA} two independent measurements (σ_{sp} and σ_{ep}) in a single instrument

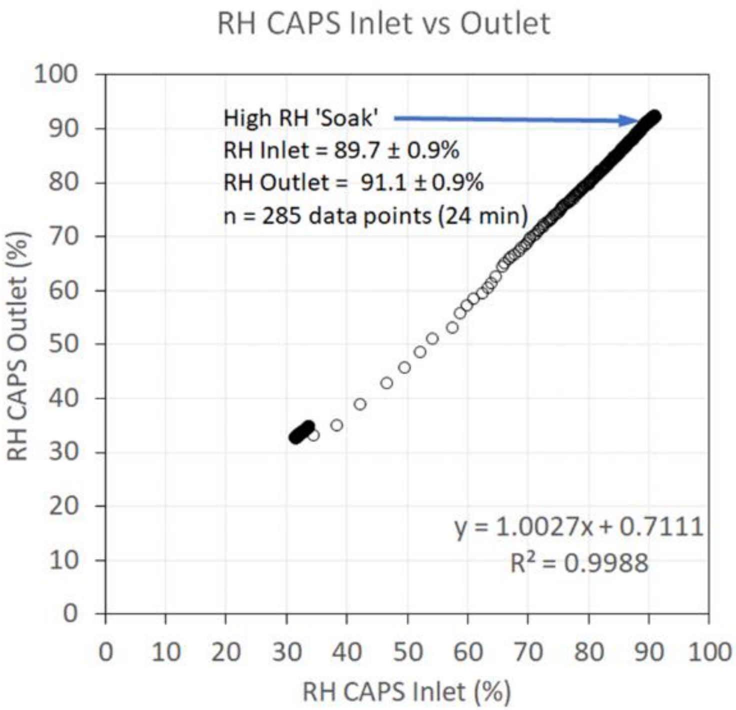
Light Extinction Ehancement-Scattering and Absorbing Aerosols



CAPS f(RH) System Characterization



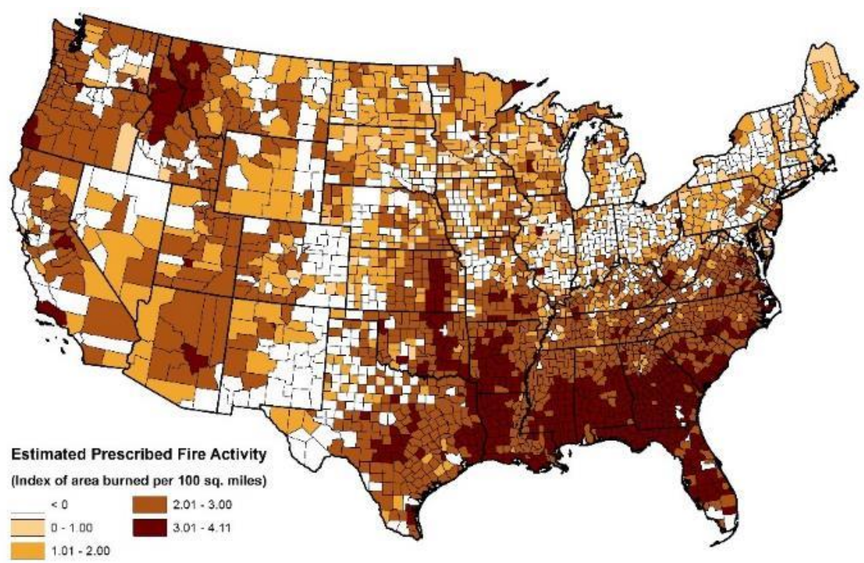
Particle loss measurements with PSLs show wet line to dry line ratio 0.99 +/- 0.09



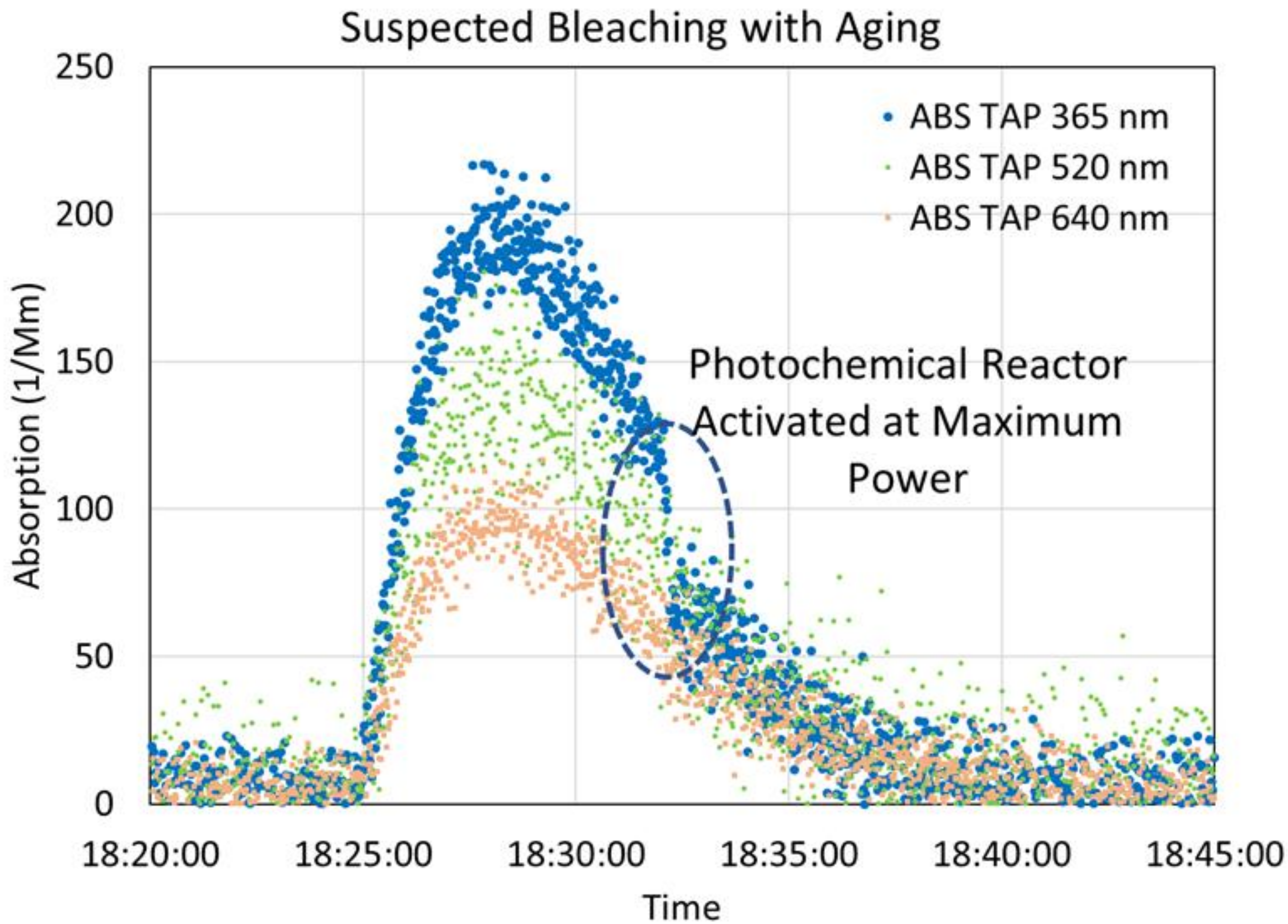
Characterized truncation losses: exceeds 2% for D_p > 300 nm

Open Questions & Future Work

- What drives production of sooty aggregates that collapse causing $f(\mathrm{RH}) < 1$?
- Flame temperature and hygroscopicity?
- Photochemical aging vs. hygroscopicity?
- Plant adaptations & smoke emissions?



Aging Experiments with Smoke



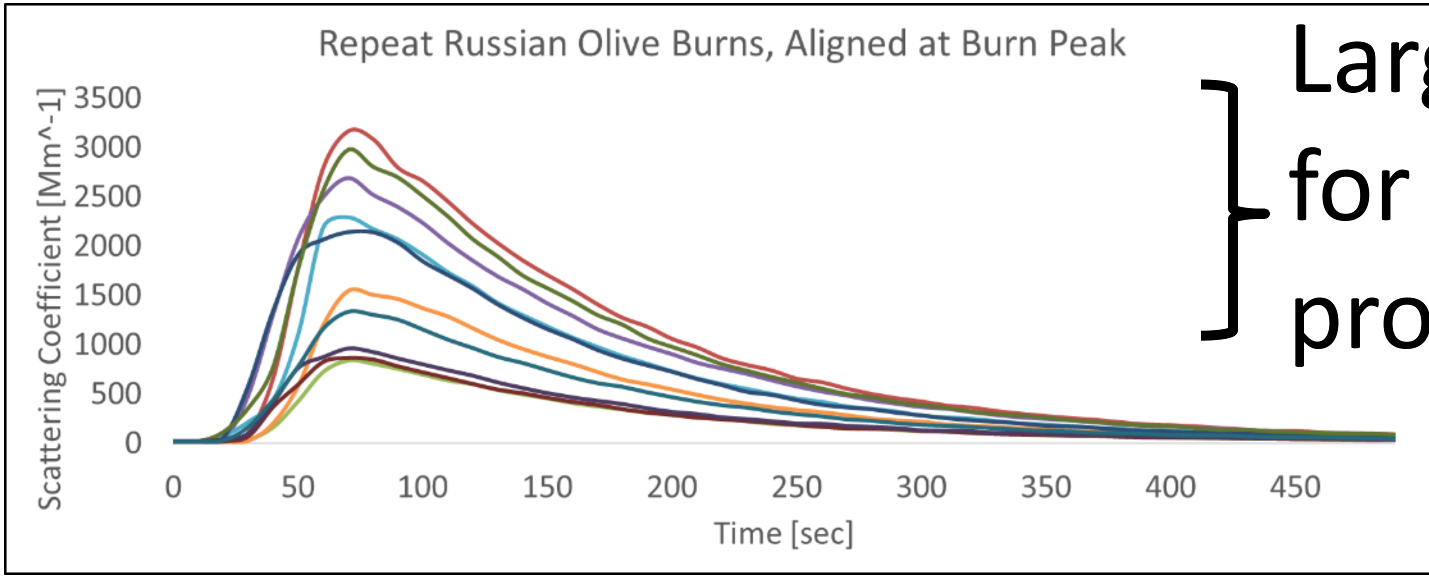
- As aerosols age photochemistry and other physicochemical processed alter there properties
- At LANL we have a flow through reactor that allows simulation of the aging process

NMT Student Involvement

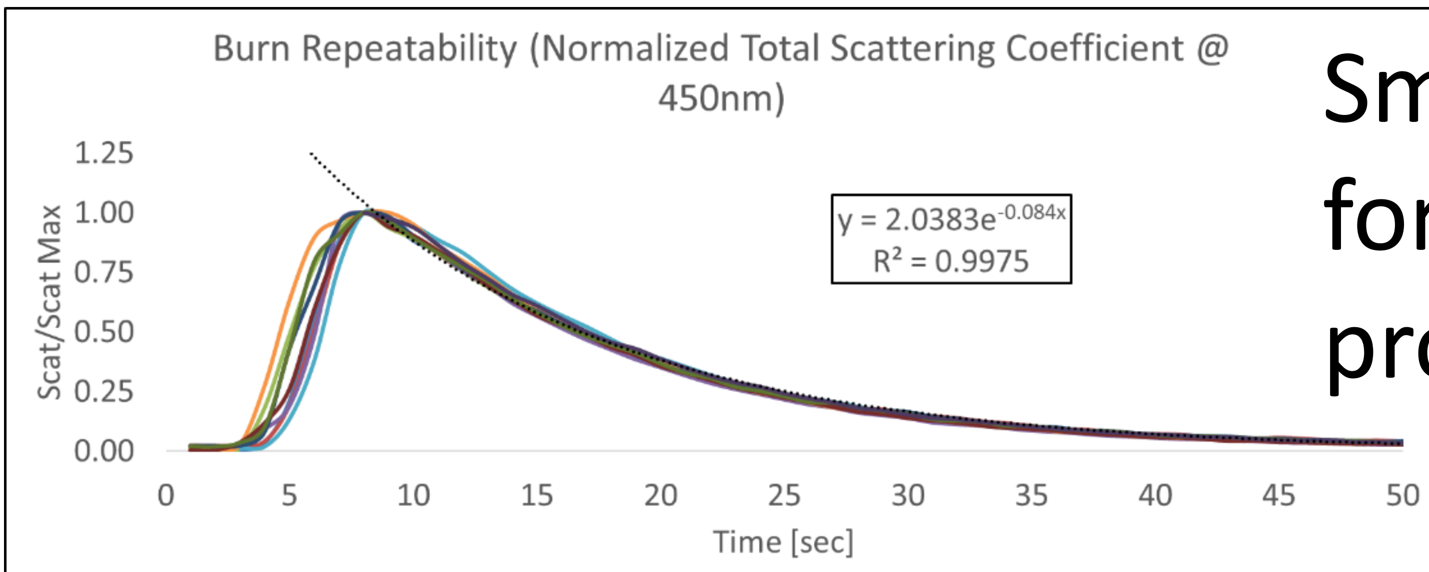
Activity	Number
Undergraduates	8 summers/8 students
MS theses	2 theses
Faculty support	4 summers
Publications	5 published (JGR, Atmos Environ, JA&WMA)
Publications in progress	4
Conference presentations	>dozen

- Outside support from DOE, NSF, NMC and others through multiple channels such that costs essentially covered externally

Burn Repeatability



Large spread for extensive properties



Small spread for intensive properties

Lam et al. (2017)

Biomass Smoke Aerosols, Climate & Air Quality

- Smoke a Substantial and Growing Contributor to Haze [Spracklen et al., 2007]
- Fires and Climate Connection [Westerling et al., 2003; 2006; Abatzoglou and Williams, 2016; Moritz et al. 2012; Marlon et al., 2016]
- Vital Importance of Smoke Aerosol Particle Properties to Impacts

2002 Yosemite Aerosol Characterization Study

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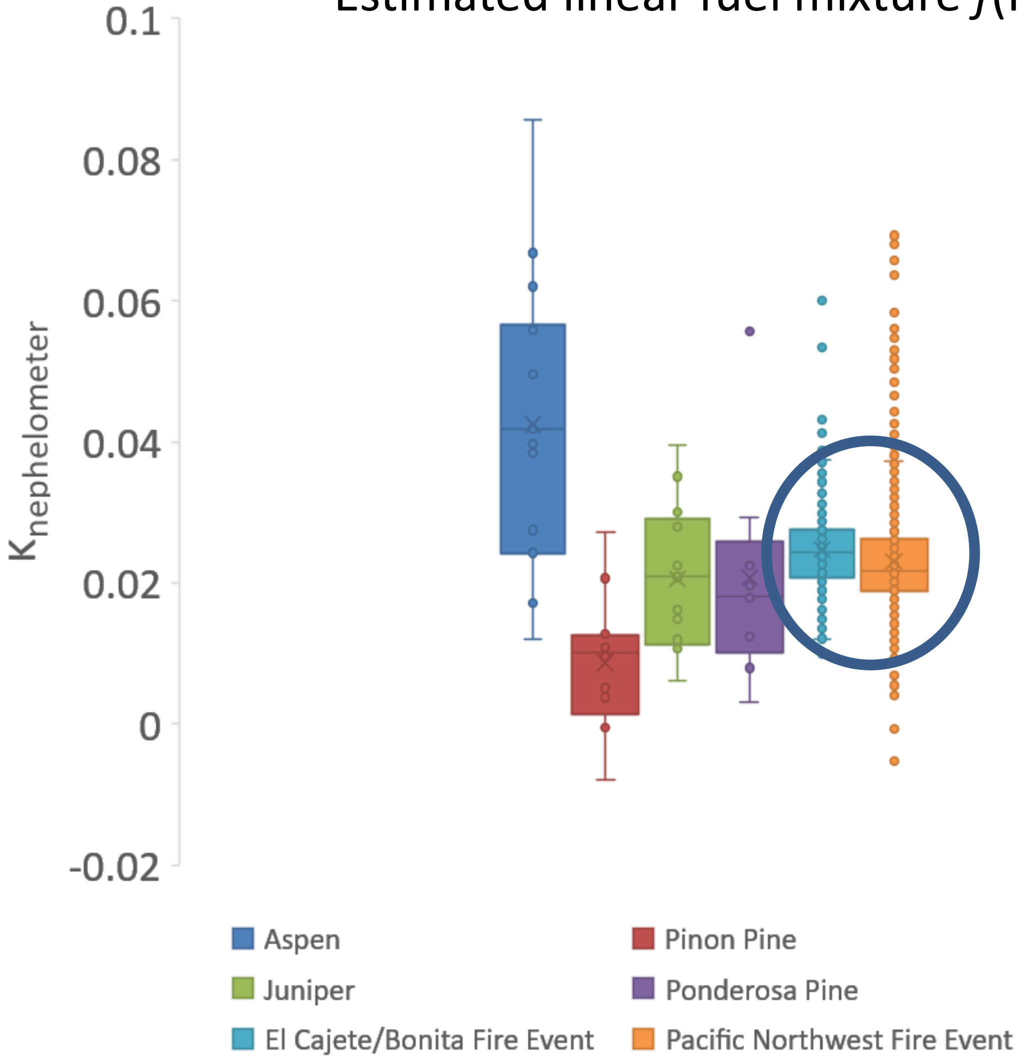
2002 Yosemite Aerosol Characterization Study

27 June 2017: Bonita/Cajete Fires near LANL

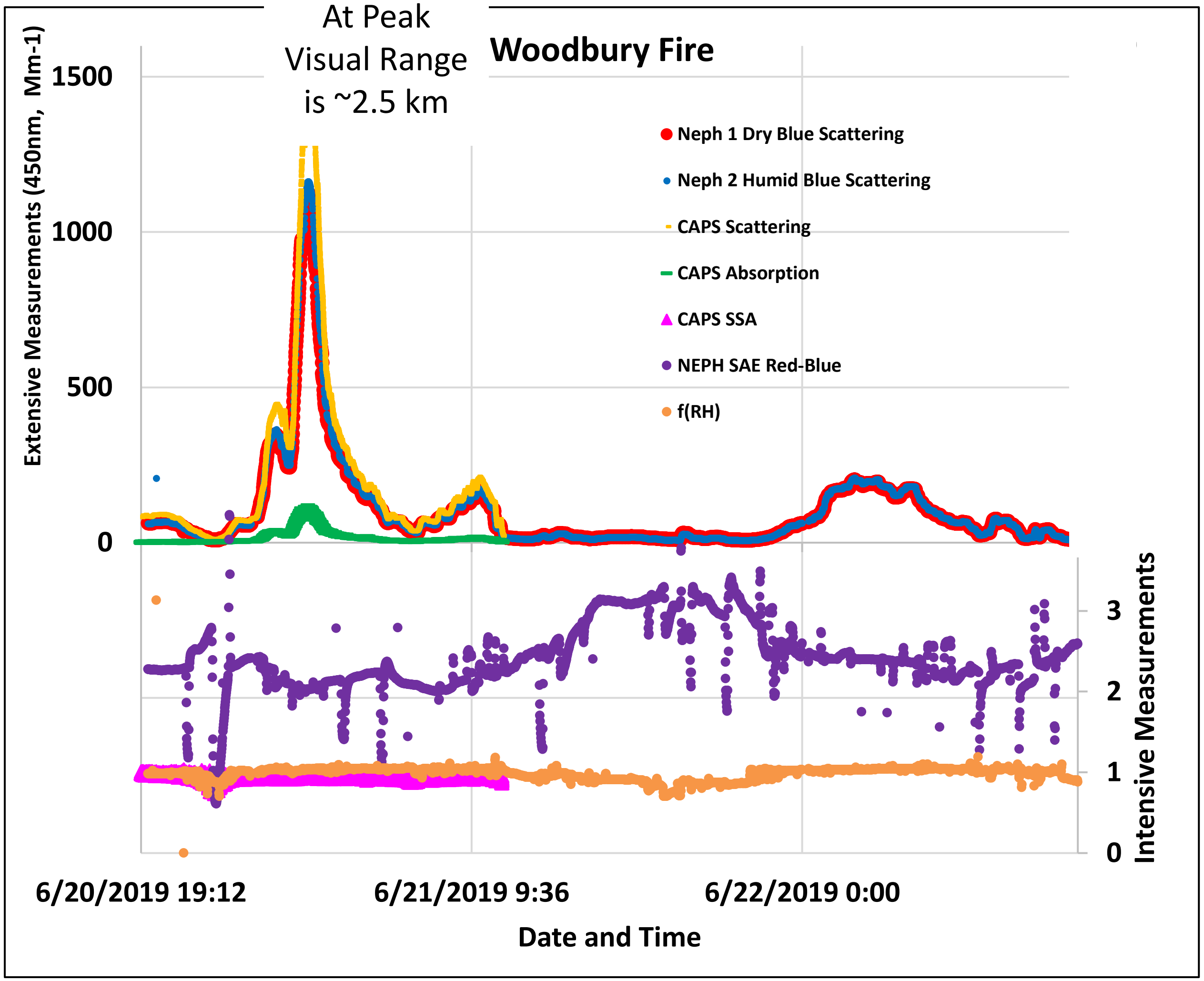
- Mixed Mountain Fuels: Juniper, Pine, Aspen, Duff
  - Ambient measured *f*(RH=85%)=1.145
  - Estimated linear fuel mixture *f*(RH=85%) 1.124



Woodbury Fire Plume

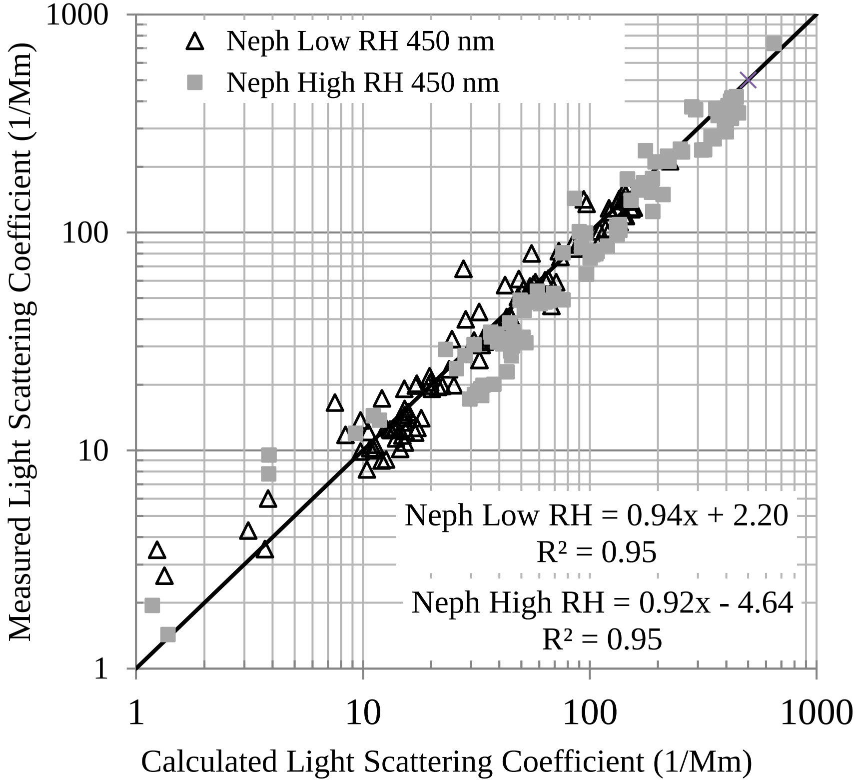
Smoke Optical Properties Observed:

- f(RH) of ~1 indicates organic dominated
- SSA nearly 1 indicates mostly scattering aerosol (net cooling effect)
- Also confirmed with low CAPS absorption calculation
- SAE shows shift in size distribution to larger mean size during smoke plume

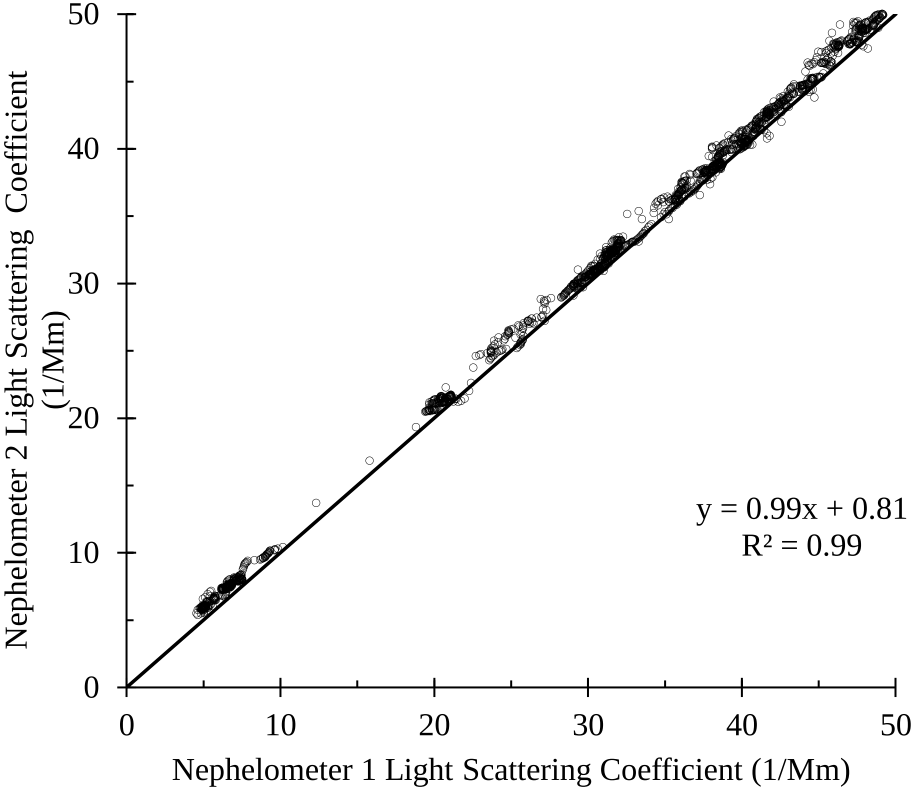


Nephelometer Agreement

Ammonium Sulfate Model vs. Measure



Dry Conditions-Ambient Smoke Event 2016



Gomez et al. (2018); Carrico et al. (2018)

New Mexico Regional Haze Rule Issues (IMPROVE TSS data)

CM

OMC

- Regional Haze Rule compliance will be complicated by coarse mode particle and by fire emissions contributions in the southwest