Development of a Quantitative Accounting Framework for Black Carbon and Brown Carbon from Emissions Inventory to Impacts

Jamie Schauer, UW-Madison (PI)

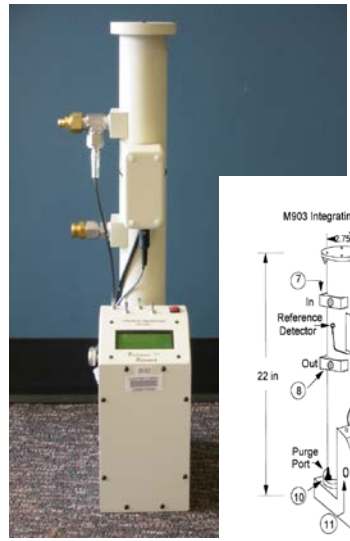
Mike Bergin, Georgia Teach/Duke (Co-PI)

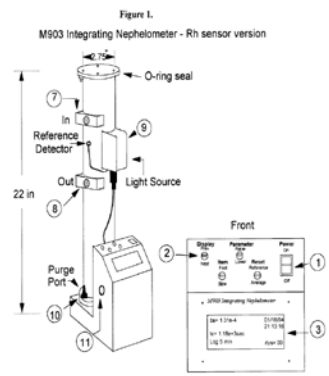
Mike Olson (UW-Madison)

Project Thrust Areas

- Brown Carbon (BrC) and Black Carbon (BC) Measurement Developments
- Source Emissions Characterization
- BrC and BC Atmospheric Abundance and Associated Impacts
- Source Apportionment of BrC

Methods

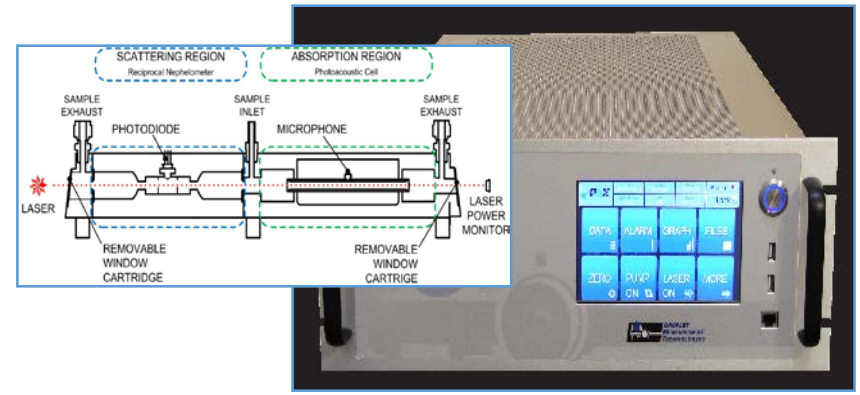




Radiance Research Nephelometer

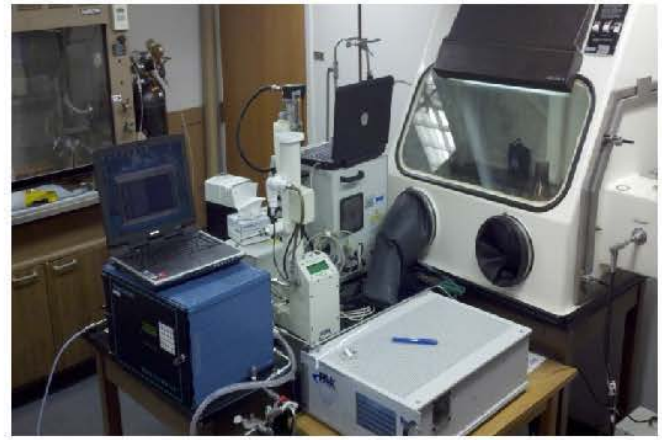
Magee Scientific AE31 7-channel Aethalometer

TSI Scanning Mobility Particle Sizer/ Electrostatic classifier

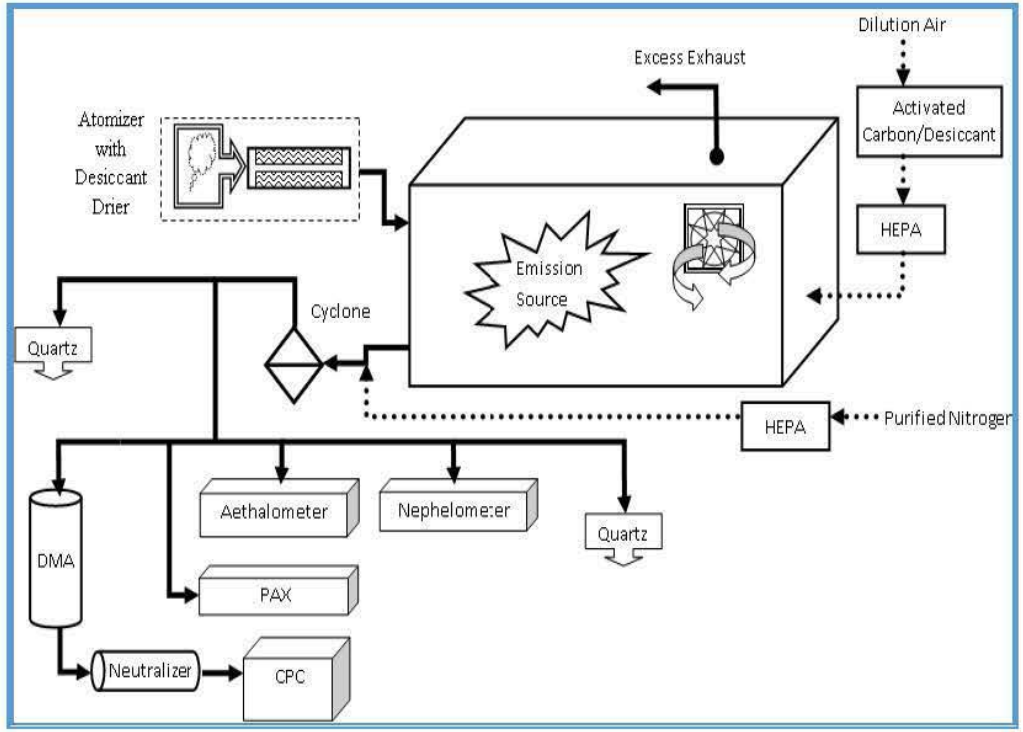


DMT PAX 532: Photoacoustic Extictionometer

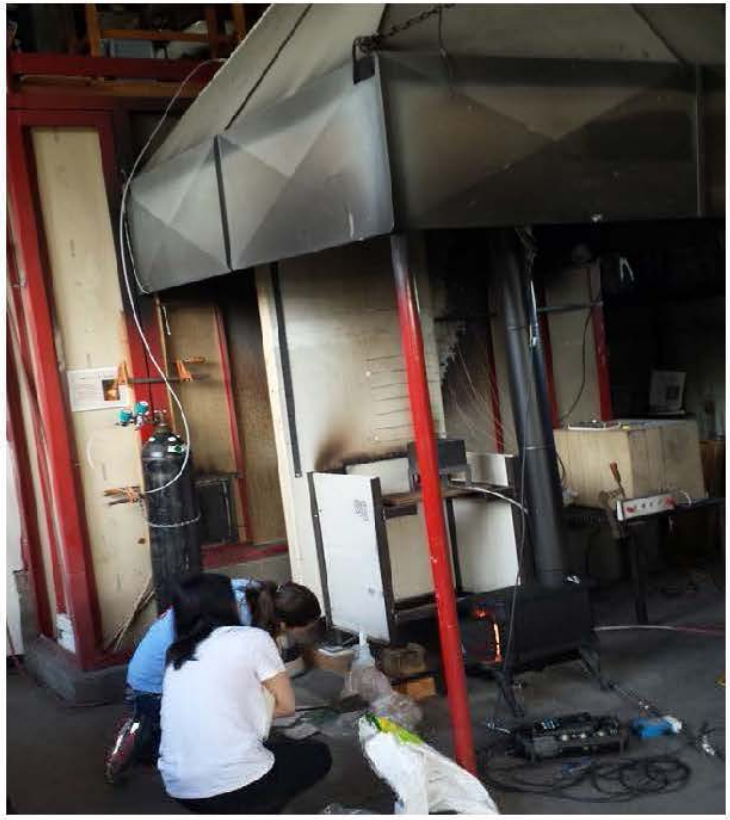
Methods




UV


Dilution Air
Excess Exhaust
Activated Carbon/Desiccant
HEPA
Atomizer with Desiccant Drier
Emission Source
Cyclone
Quartz
HEPA
Purified Nitrogen
Aethalometer
Nephelometer
Quartz
DMA
PAX
Neutralizer
CPC

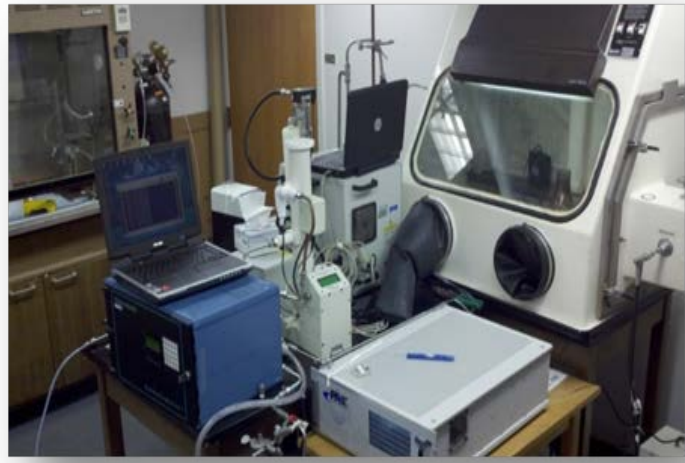
Methods

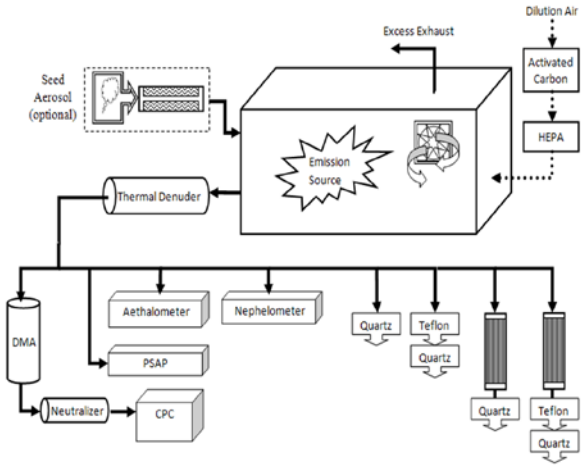


BrC and BC Measurement Developments

- Re-aerosolization of solvent extractable organics from particulate matter samples
- UV-Vis analysis of extracts of particulate matter samples using organic solvents and water
- Color Space analysis of OC and EC

BrC – Determined by physical removal of BC

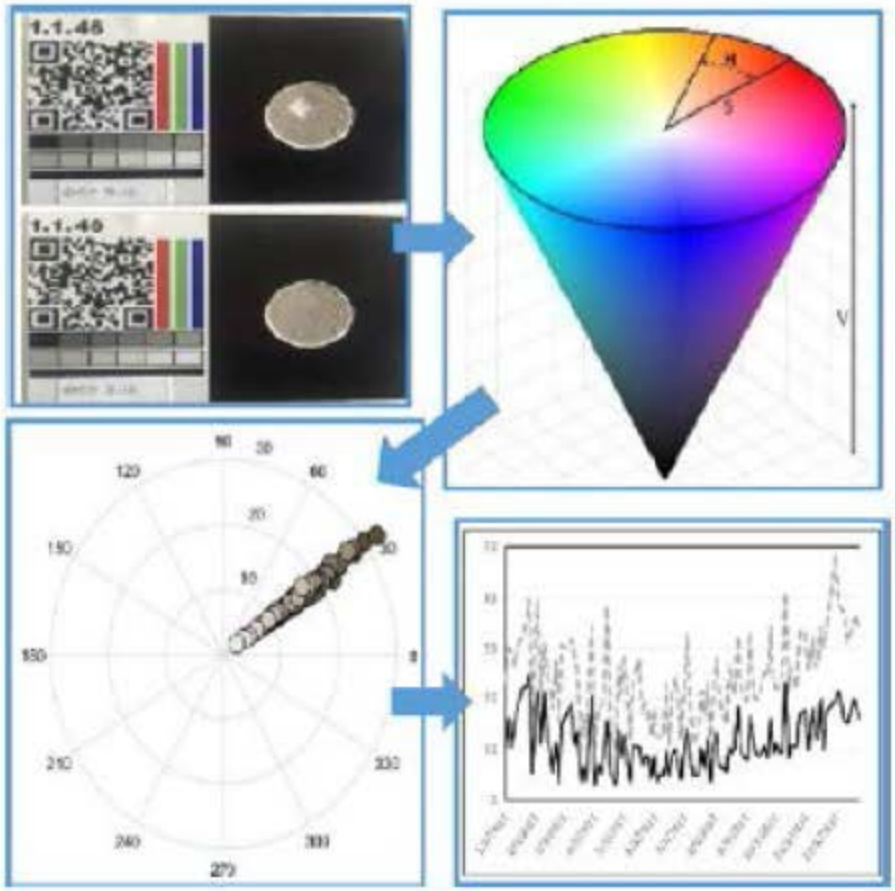


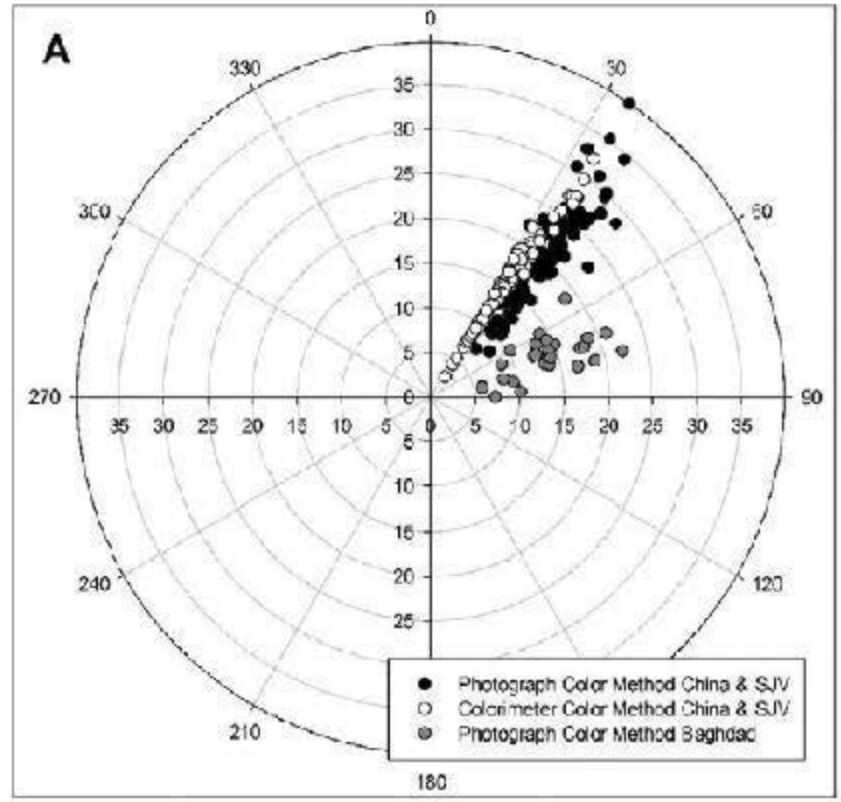


Quantification of elemental and organic carbon in atmospheric particulate matter using color space sensing—hue, saturation, and value (HSV) coordinates

Michael R. Olson [a], Eric Graham [b,c], Samera Hamad [a], Pajean Uchupalanun [a], Nithya Ramanathan [b], James J. Schauer [a,*]

Science of the Total Environment 548–549 (2016) 252–259





Color Space EC/OC analysis

$$EC = \alpha_{EC} + \beta_{EC}H + \gamma_{EC}S + \delta_{EC}V + \varepsilon_{EC}V^2$$
$$OC = \alpha_{OC} + \beta_{OC}H + \gamma_{OC}S + \delta_{OC}V + \varepsilon_{OC}S^2$$

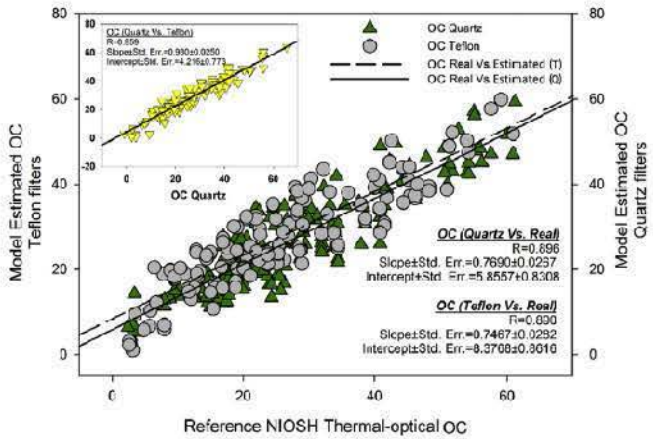
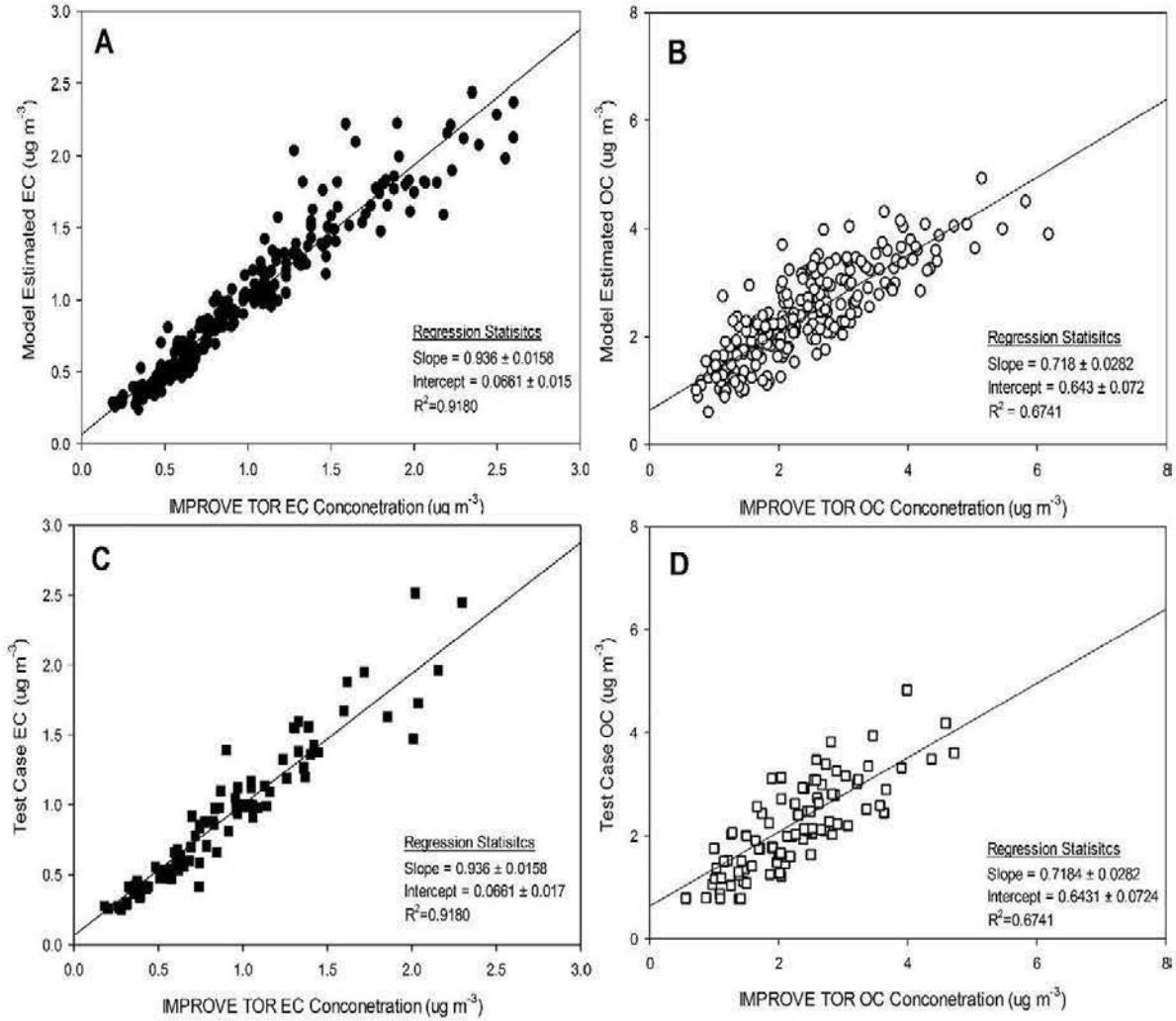


Fig. 5. Cross-validation between model developed OC on Teflon filters, Quartz filters and the NIOSH thermal-optical method.



Atmospheric Environment 149 (2017) 84–94

A non-destructive optical color space sensing system to quantify elemental and organic carbon in atmospheric particulate matter on Teflon and quartz filters

Reza Bashiri Khuzestani [a, b], James J. Schauer [c], Yongjie Wei [d], Yang Zhang [a, e], Yuanxun Zhang [a, b, c, f, *]

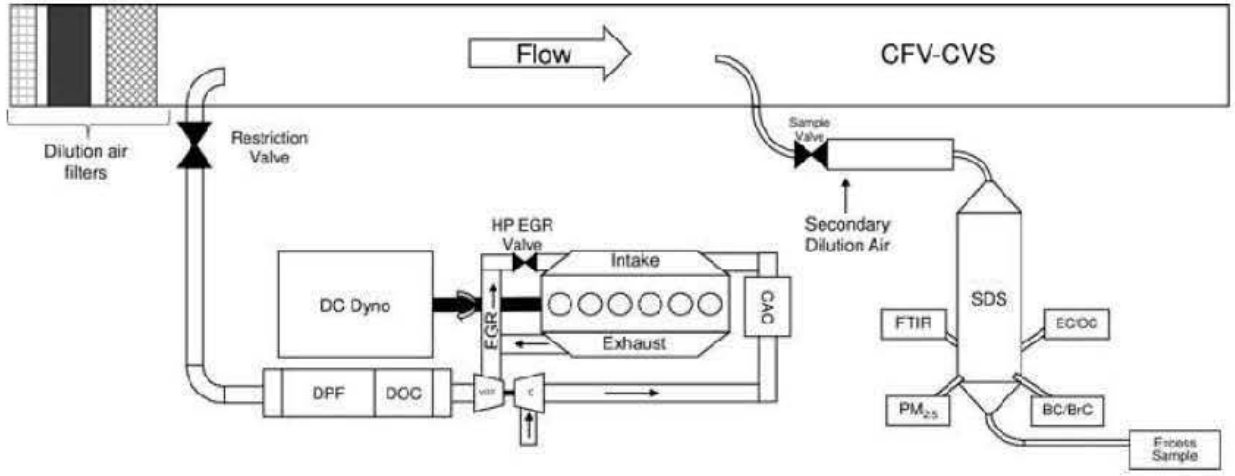
Source Characterization

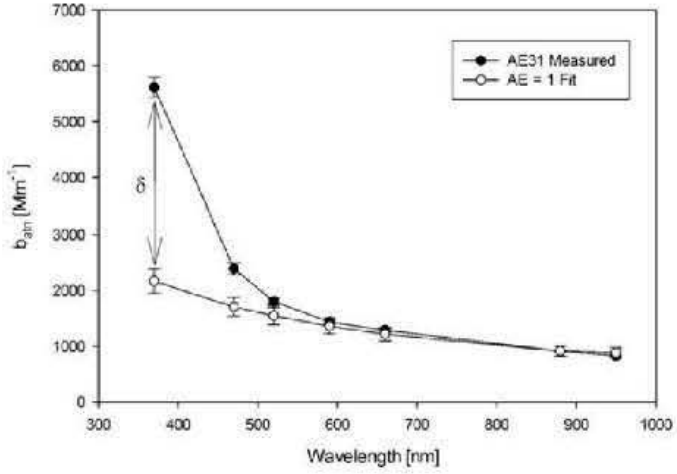
- Diesel Engine Emissions – With modern controls and before controls
- Biomass and Fossil Fuel Burning
- Trash Burning

The effects of emission control strategies on light-absorbing carbon emissions from a modern heavy-duty diesel engine

Michael A. Robinson,[1,*] Michael R. Olson,[2] Z. Gerald Liu,[1] and James J. Schauer[2]

Journal of the Air & Waste Management Association 65 (2015) 759–766





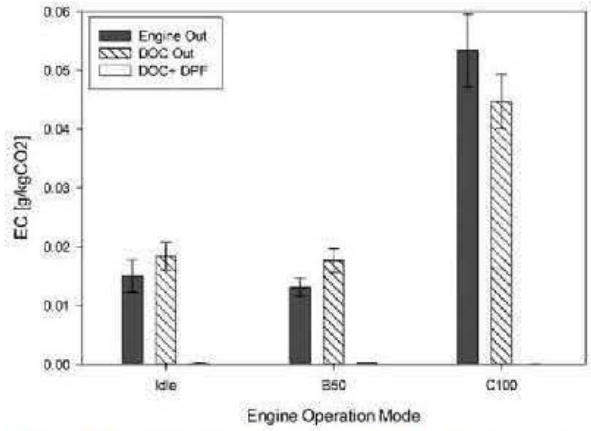


Figure 4. Effect of AT on EC emissions rates as a function of engine operation.

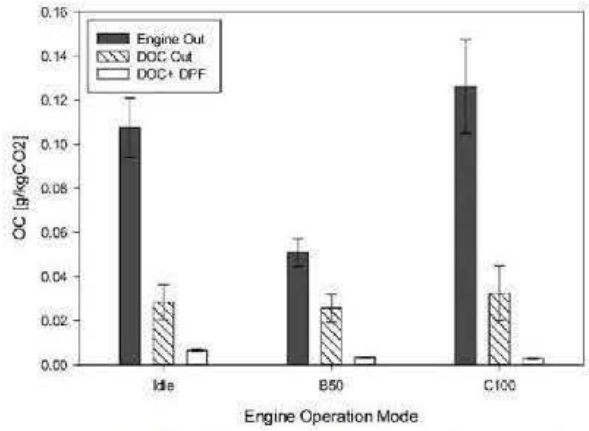


Figure 5. Effect of AT on OC emission rates as a function of engine operation.

Engine Out EC, OC, BC, and BrC

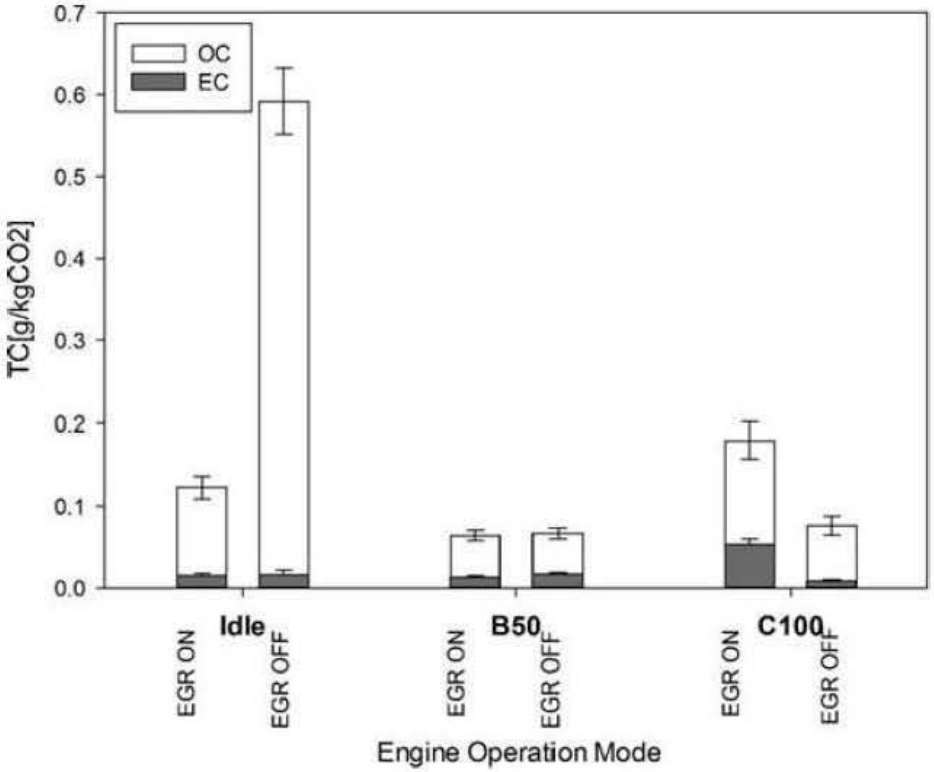


Figure 7. Effect of EGR on EC/OC emission rates.

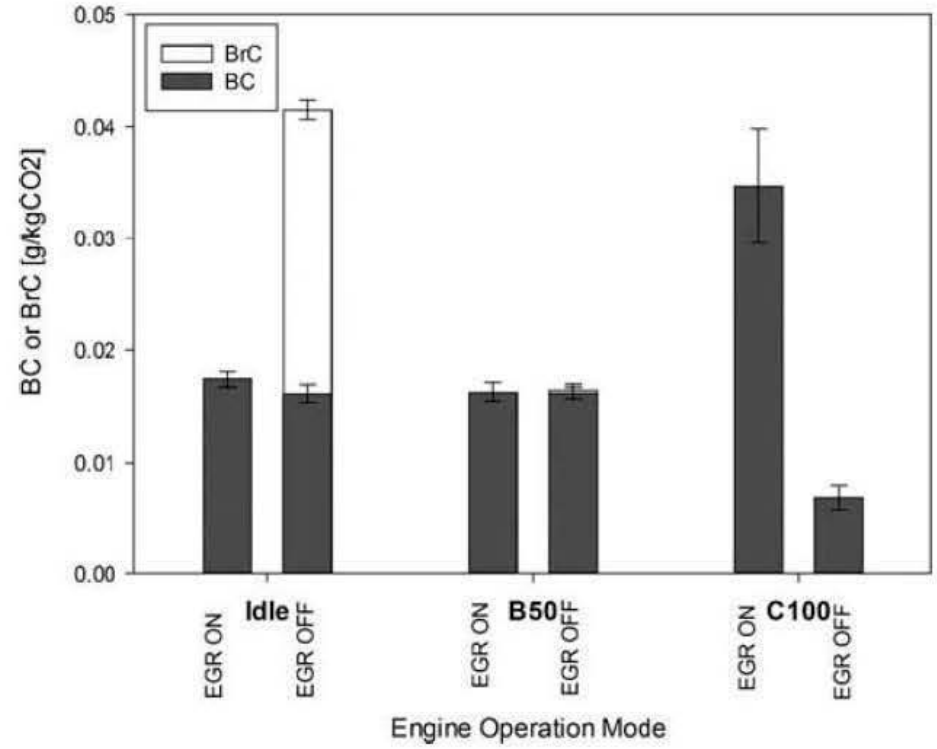


Figure 8. Effect of EGR on BC and BrC emission rates.

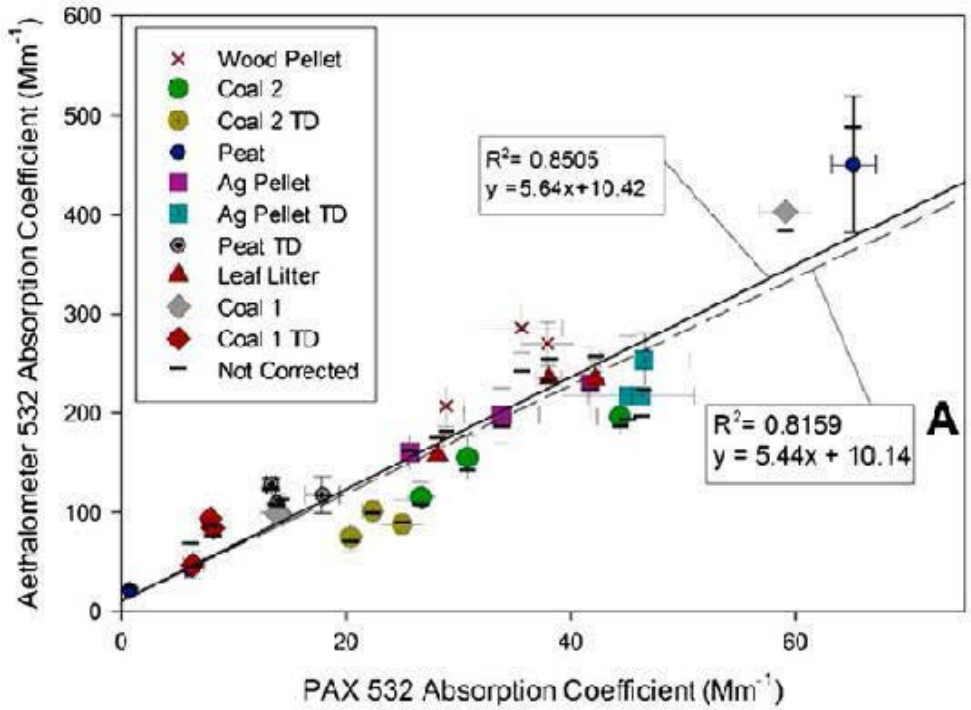
Table 1. Engine operation modes

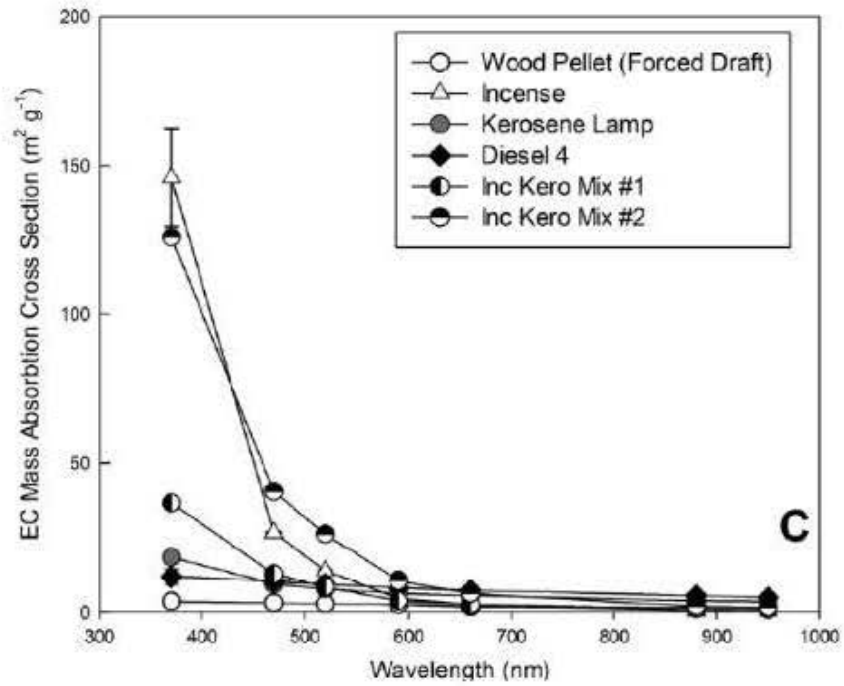
	Idle	B50	C100
Speed	650 rpm	1555 rpm	1912 rpm
Load	10%	50%	100%
EGT	128°C	341°C	424°C

Investigation of black and brown carbon multiple-wavelength-dependent light absorption from biomass and fossil fuel combustion source emissions

Michael R. Olson[1], Mercedes Victoria Garcia[1], Michael A. Robinson[2], Paul Van Rooy[1], Mark A. Dietenberger[3], Michael Bergin[4], and James Jay Schauer[1]

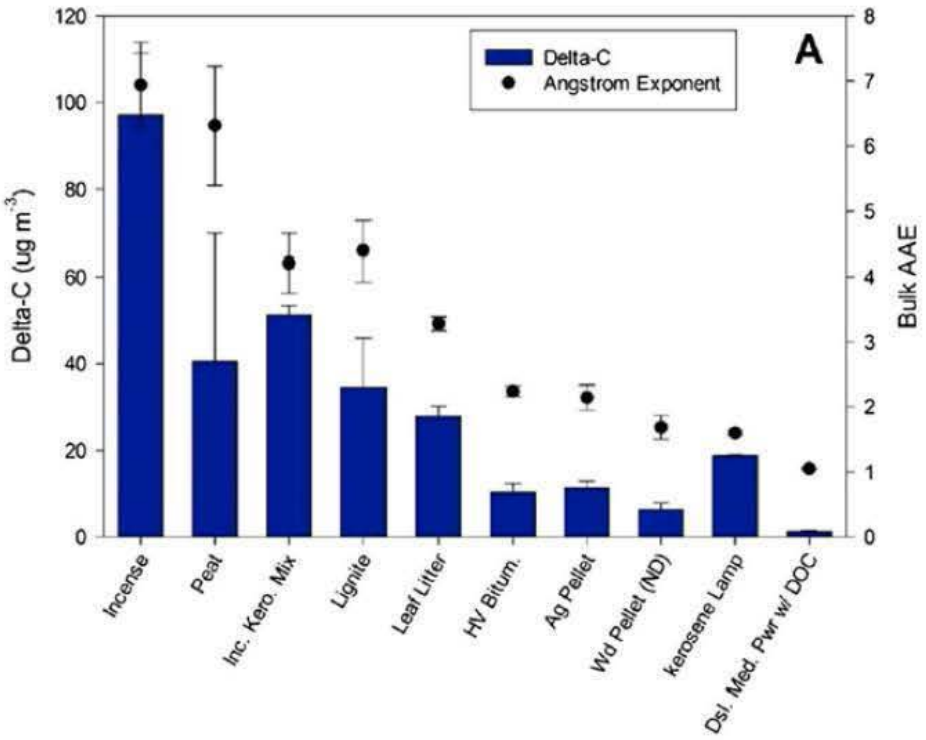
Journal of Geophysical Research: Atmospheres

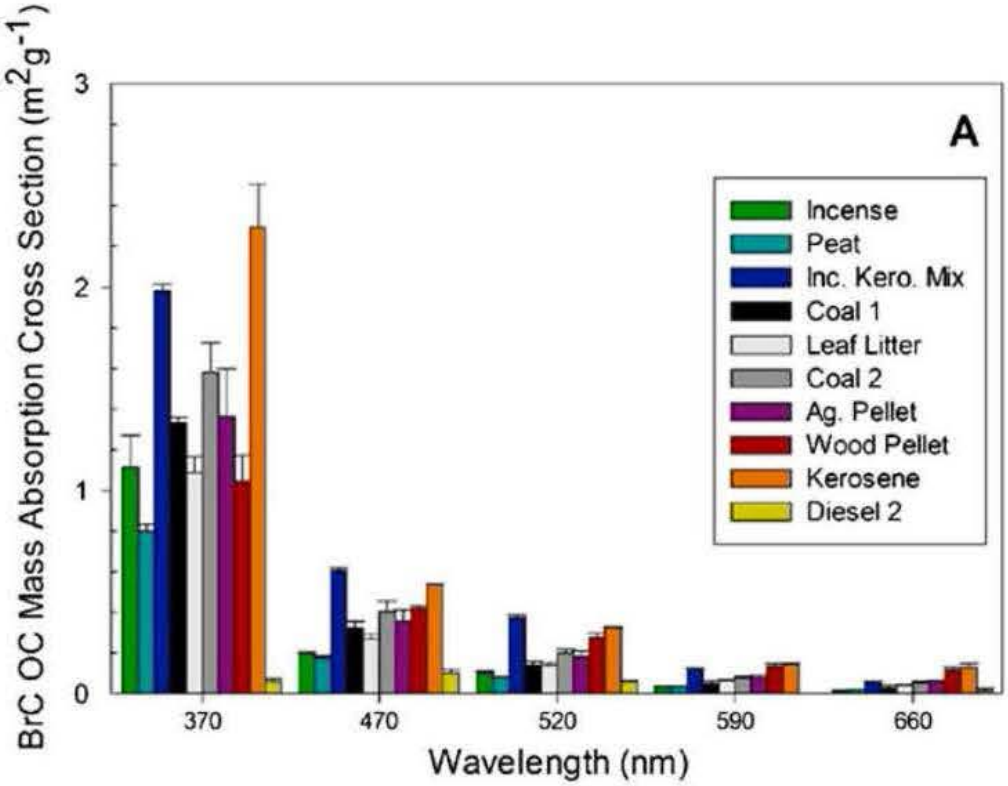




Investigation of black and brown carbon multiple-wavelength-dependent light absorption from biomass and fossil fuel combustion source emissions

Michael R. Olson[1], Mercedes Victoria Garcia[1], Michael A. Robinson[2], Paul Van Rooy[1], Mark A. Dietenberger[3], Michael Bergin[4], and James Jay Schauer[1]



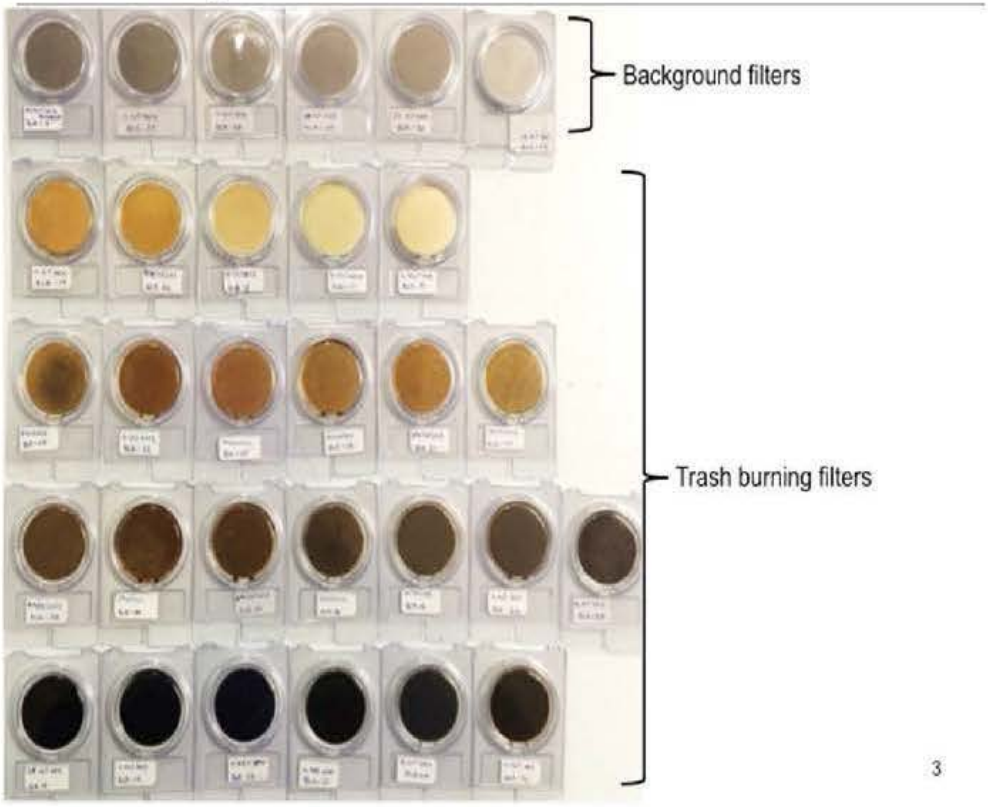


Atmospheric Environment
Volume 147, December 2016, Pages 22–30

Chemical characterization and toxicity of particulate matter emissions from roadside trash combustion in urban India

Heidi Vreeland[a], James J. Schauer[b], Armistead G. Russell[c], Julian D. Marshall[d], Akihiro Fushimi[b, e], Grishma Jain[f], Karthik Sethuraman[f], Vishal Verma[g, 1], Sachi N. Tripathi[h], Michael H. Bergin[a]

Visual Comparison



3

Sampling Roadside Burning

2

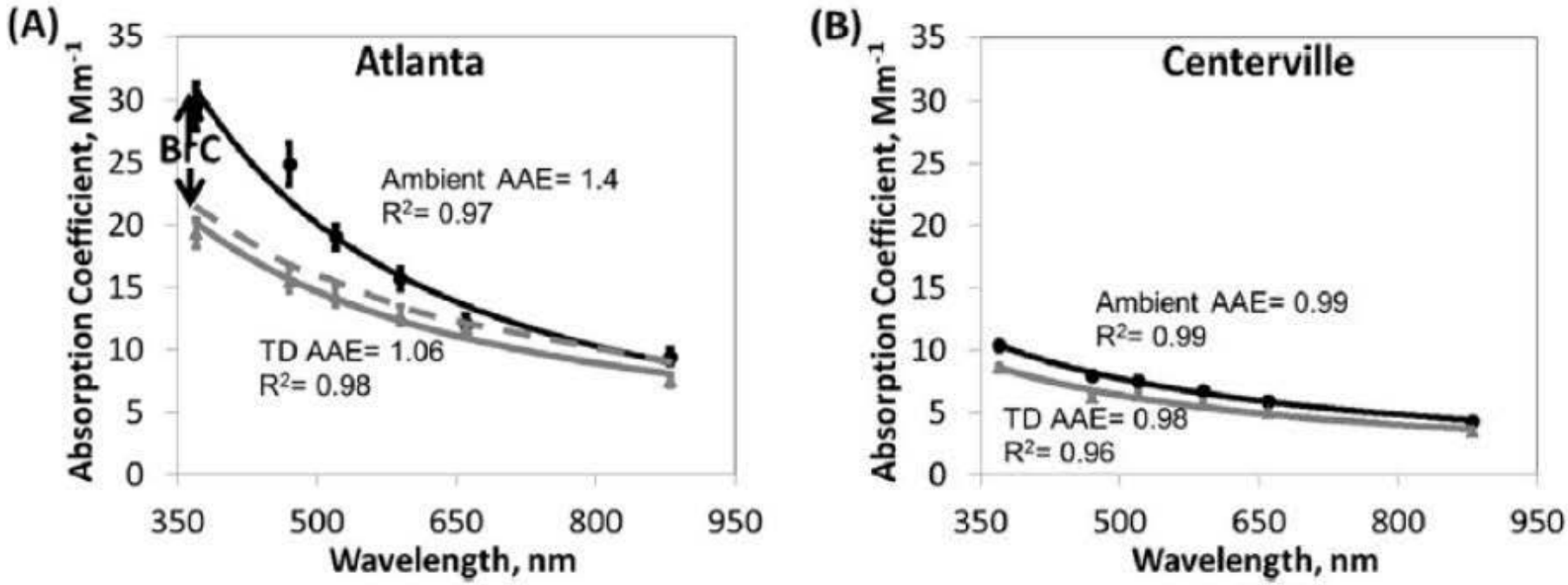
Atmospheric BC and BrC and Impacts

- Southeast US – Urban and Rural BrC
- Contribution of BrC to radiative forcing in Indo-Gangetic Plains
- Deposition of PM and Discoloration of the Taj Mahal

Contribution of particulate brown carbon to light absorption in the rural and urban Southeast US

J. Jai Devi [a, 1], Michael H. Bergin [a, *], Michael Mckenzie [a], James J. Schauer [b], Rodney J. Weber [c]

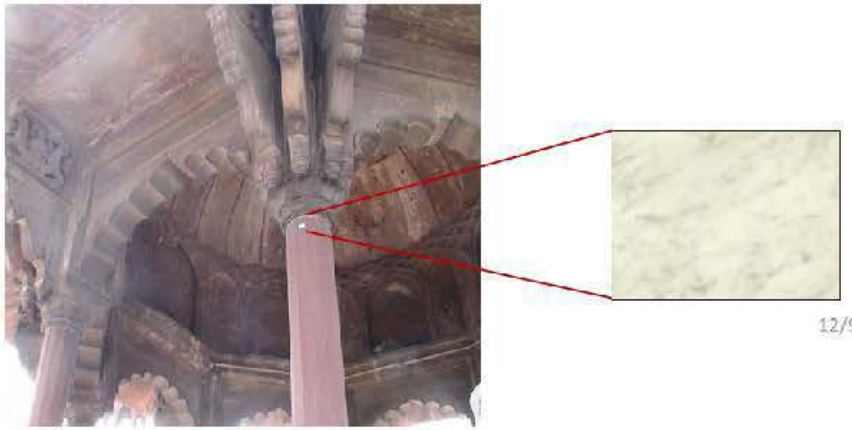
Atmospheric Environment 136 (2016) 95–104

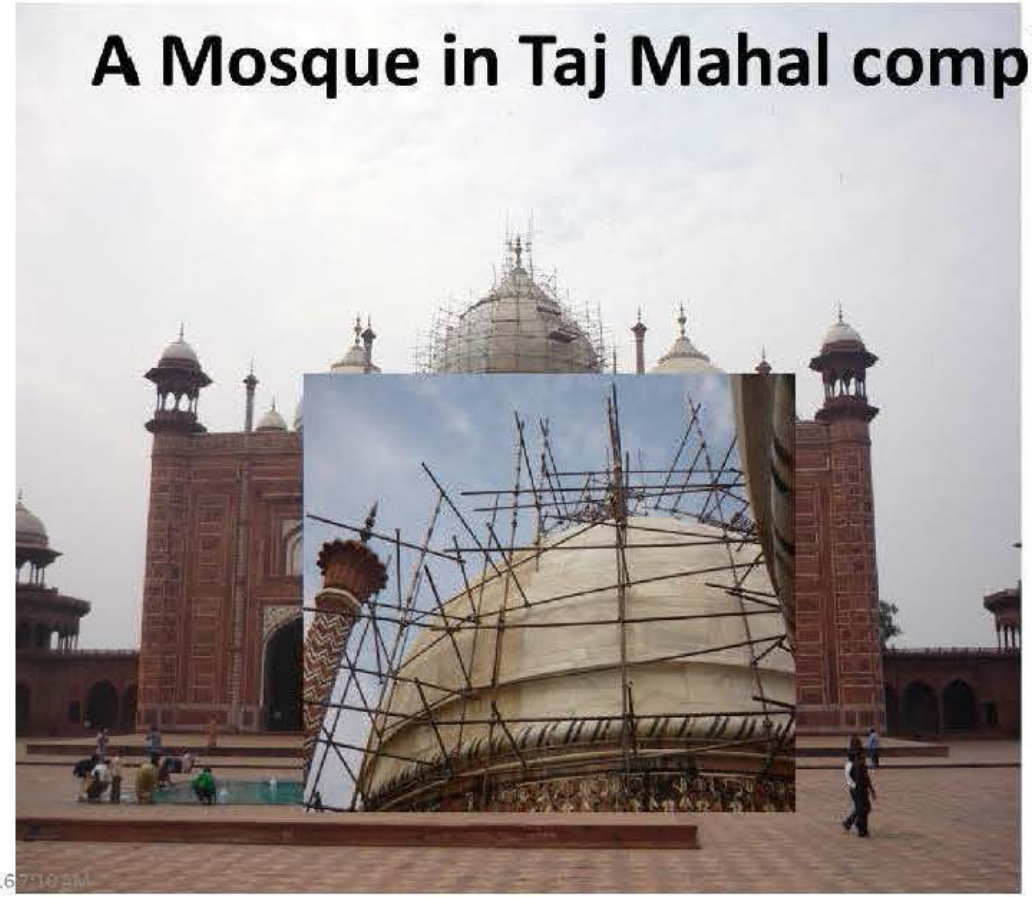


The Discoloration of the Taj Mahal due to Particulate Carbon and Dust Deposition

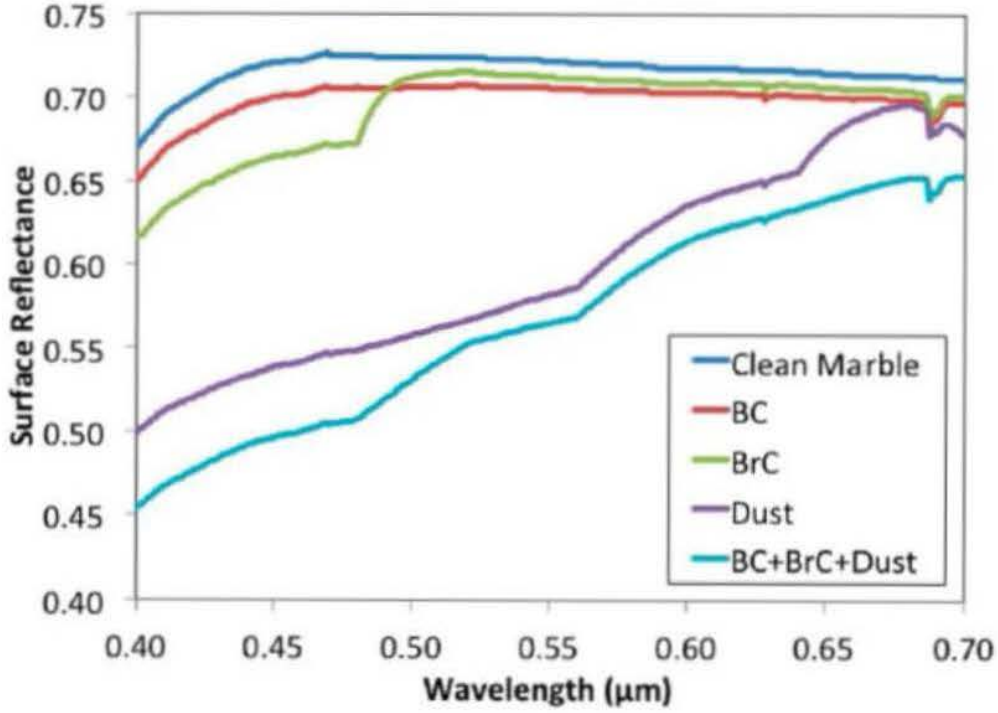
M. H. Bergin,[*,†,‡] S. N. Tripathi,[*,§] J. Jai Devi,[†,‡] T. Gupta,[§] M. Mckenzie,[‡] K. S. Rana,[∥] M. M. Shafer,[⊥] Ana M. Villalobos,[⊥] and J. J. Schauer[⊥]

dx.doi.org/10.1021/es504005q | *Environ. Sci. Technol.* 2015, 49, 808−812

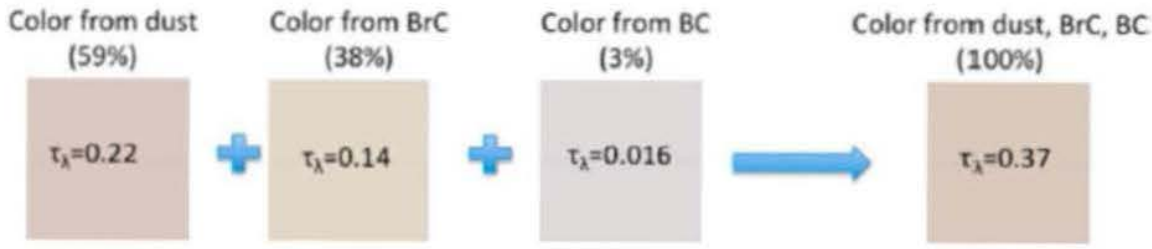


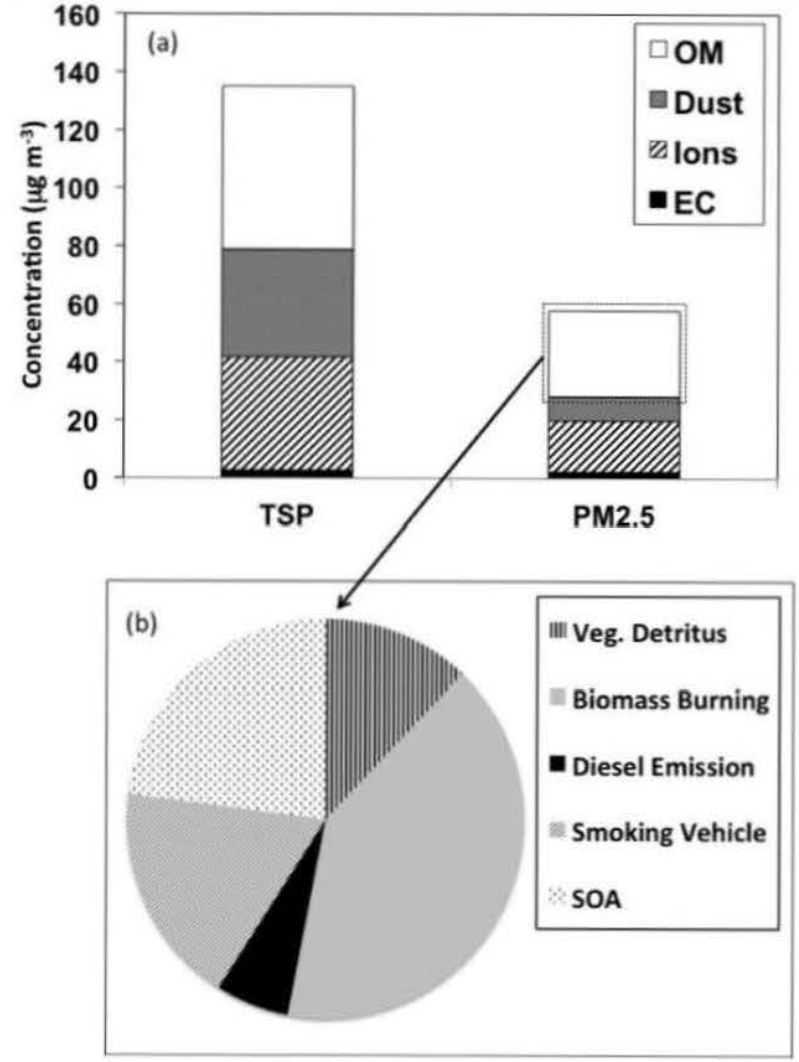


(a)


0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
Surface Reflectance
0.40
0.45
0.50
0.55
0.60
0.65
0.70
Wavelength (μm)
Clean Marble
BC
BrC
Dust
BC+BrC+Dust

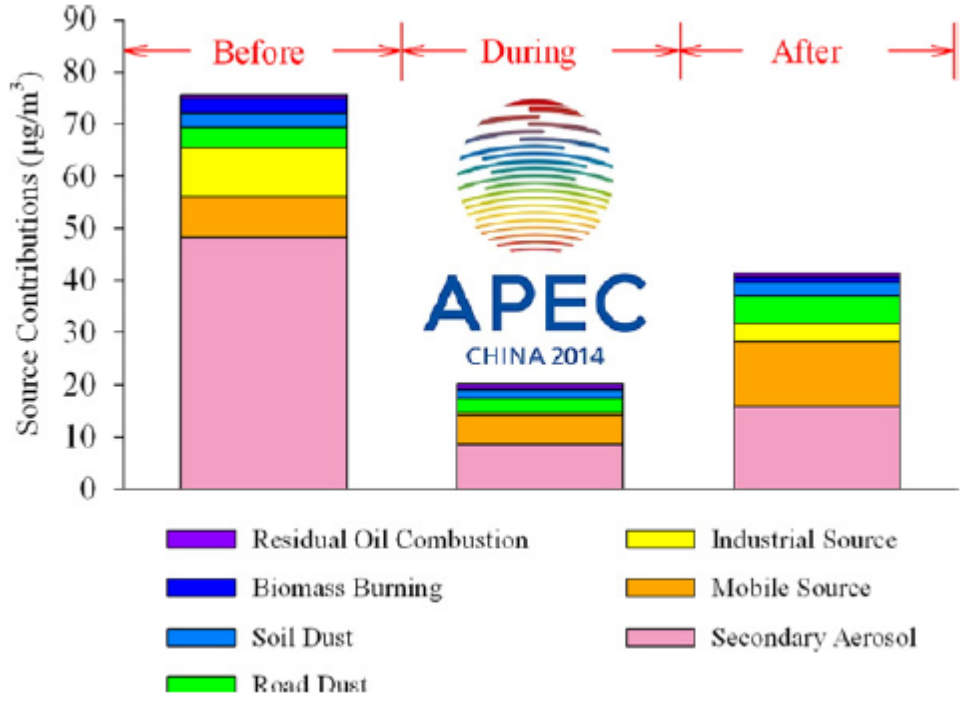
(b)


Color from dust (59%)
Color from BrC (38%)
Color from BC (3%)
Color from dust, BrC, BC (100%)
τλ=0.22
τλ=0.14
τλ=0.016
τλ=0.37


(a)
160
140
120
100
80
60
40
20
0
Concentration (μg m-3)
OM
Dust
Ions
EC
TSP
PM2.5
(b)
Veg. Detritus
Biomass Burning
Diesel Emission
Smoking Vehicle
SOA

Source Apportionment of BrC

- Asian Pacific Economic Study (APEC) Blue Skies Controls



Relative impact of emissions controls and meteorology on air pollution mitigation associated with the Asia-Pacific Economic Cooperation (APEC) conference in Beijing, China

Yuqin Wang [a], Yang Zhang [a], James Jay Schauer [b,c], Benjamin de Foy [d], Bo Guo [e], Yuanxun Zhang [a,f,g,*]

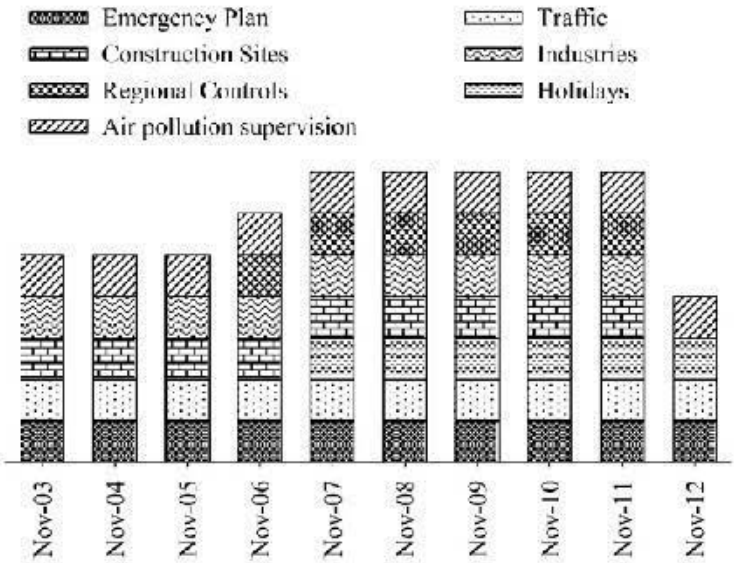


Fig. 1. Control measures were taken for the APEC conference from November 3rd to 12th, 2014. Y-axis means the accumulated control measures. For example, at November 3rd, five kinds of control measures were taken including air pollution supervision, emergency plan, traffic restriction, contraction sites and industrial restriction.

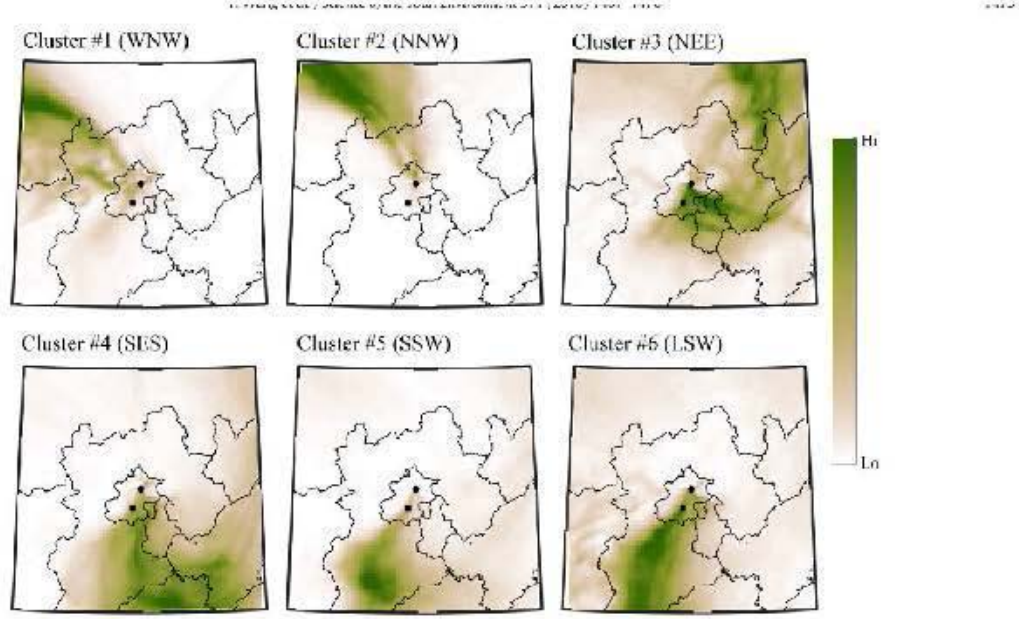


Fig. 4. Average RTA grids for each cluster. The diamond represents the sampling site on each map and the square points to the center of Beijing. Dark areas show dominant pollutant transport to the measurement site, whereas light areas show transport directions with low impacts.

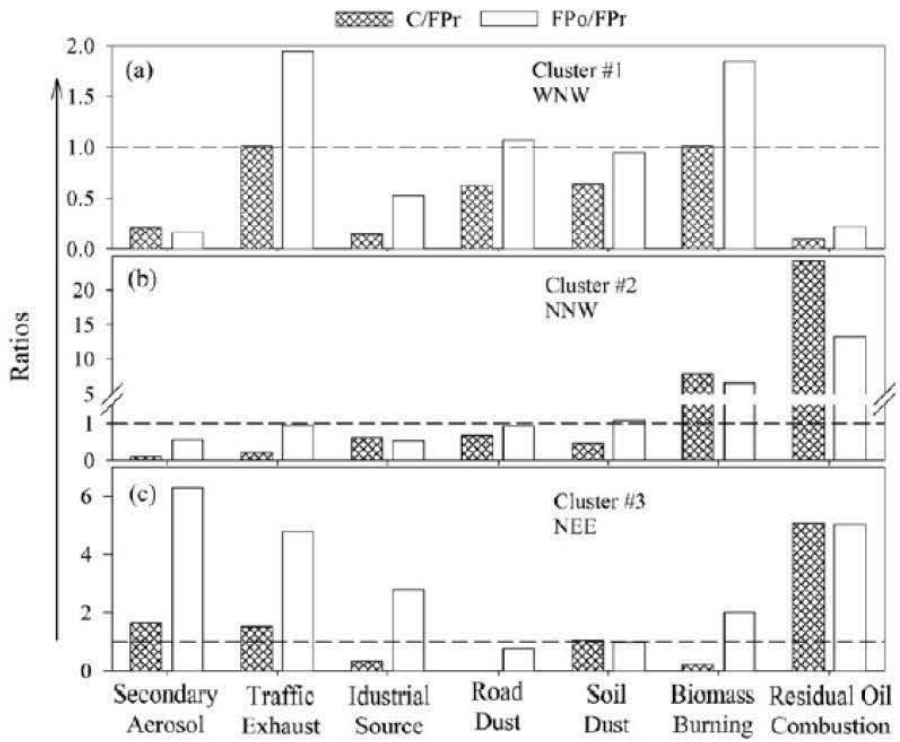
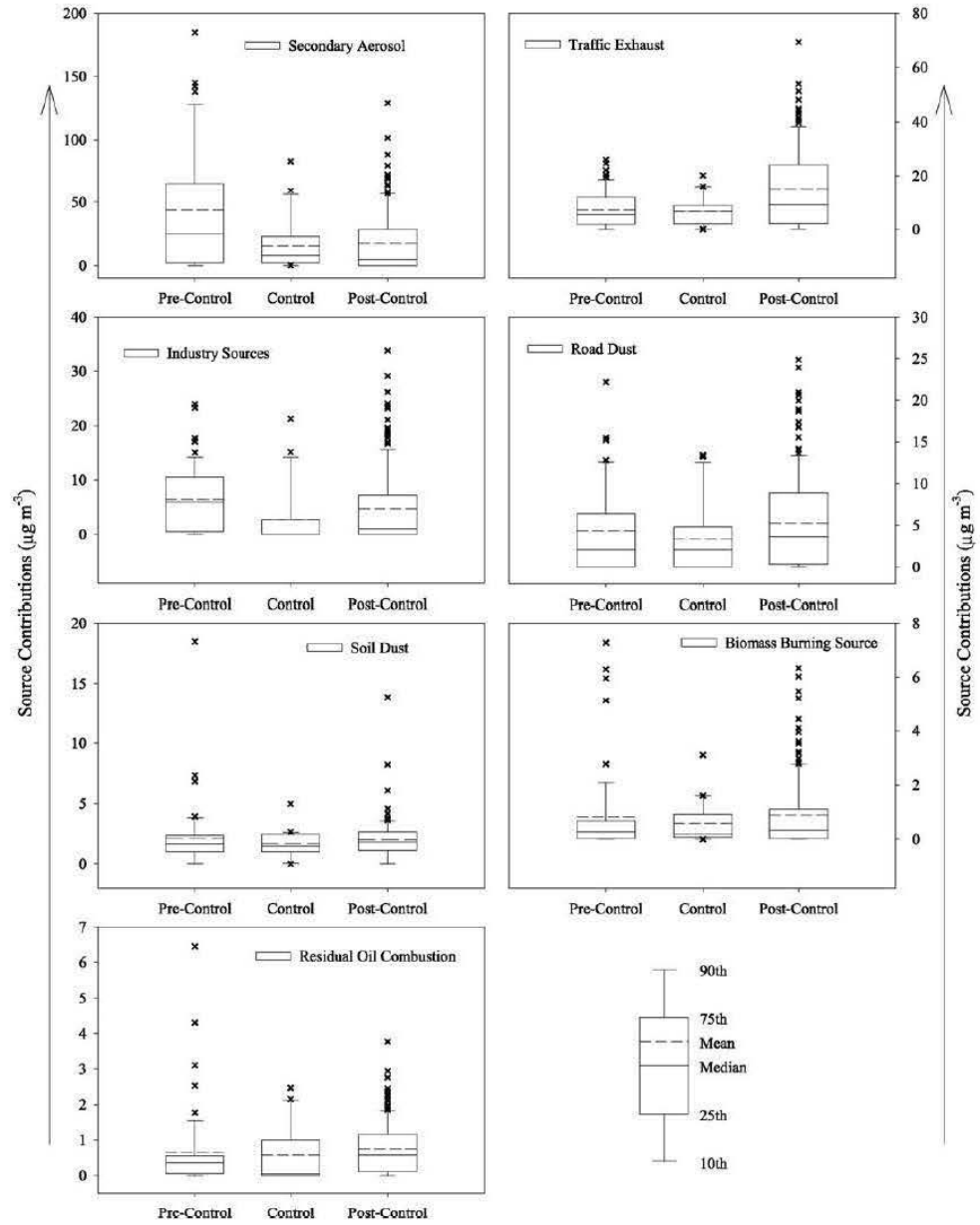


Fig. 5. Ratios of source contributions for full post-control/full pre-control (FPo/FPr) and control/full pre-control (C/FPr). Short-dash lines equal the value "1". WNW: west northwest; NNW: north northwest; and NEE: northeast via east.



Publications (1/3)

1) Impacts of regional transport on Black Carbon in Huairou, Beijing, China. 2016. Y. Wang, B. de Foy, J. J. Schauer, M. R. Olson, Y. Zhang,, Z. Li, Y. Zhang, Environmental Pollution, http://dx.doi.org/10.1016/j.envpol.2016.11.006.
2) Chemical characterization and toxicity of particulate matter from roadside trash combustion in urban India. 2016. H. Vreeland, M. H. Bergin, A. G. Russell, J. J. Schauer, J. Marshall, F. Akihiro, G. Jain, S. Karthik, A. Villalobos, and S. N. Tripathi. Atmos. Environ., 147, 22-30, 2016.
3) Quantification of Elemental and Organic Carbon in Atmospheric Particulate Matter Using Color Space Sensing - Hue, Saturation, and Value (HSV) Coordinates. 2016. M. R. Olson, E. Graham, S. Hamad, P. Uchupalanun, N. Ramanathan, and J. J. Schauer. Science of the Total Environment, 548, 252-259.
4) The Contribution of Particulate Brown Carbon to Light Absorption in the Rural and Urban South Eastern US: A Volatility Based Approach. 2016. J. Jaidevi, M. H. Bergin, M. McKenzie, J. J Schauer, and R. J. Weber. Atmospheric Environment. 136, 95-104.
5) Contribution of Brown Carbon to Direct Radiative Forcing over the Indo-Gangetic Plain. 2015. P. M. Shamjad, S. N. Tripathi, R. Pathak, M. Hallquist, A. Arola, and M. H. Bergin. Environmental Science & Technology. 49, 17, 10474-10481.

Publications (2/3)

6) Brown carbon aerosol in the North American continental troposphere: sources, abundance, and radiative forcing. 2015. J. Liu, E. Scheuer, J. Dibb, G. S. Diskin, L. D. Ziemba, K. L. Thornhill, B. E. Anderson, A. Wisthaler, T. Mikoviny, J. J. Devi, M. Bergin, A. E. Perring, M. Z. Markovic, J. P. Schwarz, P. Campuzano-Jost, D. A. Day, J. L. Jimenez, and R. J. Weber. Atmospheric Chemistry and Physics, 15, 14, 7841-7858.
7) The Effects of Emission Control Strategies on Light Absorbing Carbon Emissions from a Modern Heavy Duty Diesel Engine. 2015. M. A. Robinson, M. R. Olson, Z. G. Liu, and J. J. Schauer. JAWMA, 65 (6), 759-766.
8) Comparison of Measurement Strategies for Light Absorbing Aerosols from Modern Diesel Engines. 2014. M. A. Robinson, M. R. Olson, Z. G. Liu, and J. J. Schauer. SAE International Journal of Fuels and Lubricants 7 (2014-01-1570), 543-550.
9) Investigation of Black and Brown Carbon Multiple Wavelength Dependent Light Absorption from Biomass and Fossil Fuel Combustion Source Emissions. 2015. M. R. Olson, M. V. Garcia, M. A. Robinson, P. Van Rooy, M. A. Dietenberger, M. H. Bergin, and J. J. Schauer. JGR-Atmospheres. 120 (13), 6682-6697.
10) The Discoloration of the Taj Mahal Due to Particulate Carbon and Dust Deposition. 2014. M. H. Bergin, S. N. Tripathi, J. JaiDevi, T. Gupta, M. Mckenzie, K. S. Rana, M. M. Shafer, A. M. Villalobos, and J. J. Schauer. Environmental Science and Technology. 49, 2, 808-812.

Publications (3/3)

Publications in Preparation:

9) Multiple Wavelength Light Absorption Characterization of Water, DCM, and Methanol Soluble Organic Carbon from Sources and Ambient Particulate Matter.

10) Regional Impacts to Black and Brown Carbon Particulate Matter in Beijing, China during the 2014 APEC Control Period

Acknowledgments

- Cummins Emission Solutions, Stoughton, WI
- The USFS Forest Products Laboratory, Madison, WI
- California Air Resources Board
- The University of Chinese Academy of Science (UCAS)
- NEXLEAF
- The Wisconsin State Laboratory of Hygiene, Madison, WI
- Benjamin de Foy, Saint Louis University
- Mark Dietenberger and Charles Boardman, USFS
- Nithya Ramanathan and Eric Graham at NEXLEAF
- Yuanxun Zhang and Yuqin Wang at the UCAS
- Jerry Z. Liu and Mike Robinson, Cummins Inc.