

IMPROVE Carbon Analysis

Judith C. Chow (judith.chow@dri.edu)

Xiaoliang Wang

Dana L. Trimble

L.-W. Antony Chen

John G. Watson

Desert Research Institute, Reno, NV

Presented at

the IMPROVE Steering Committee Meeting

Incline Village, NV

October 23, 2012

Objectives

- Report status and improvements of IMPROVE carbon analyses
- Update progress on next-generation carbon analyzer (DRI Model 20XX)

Carbon Laboratory Operations

(July 2011 to June 2012)

- Received ~1,900 samples per month (between 800 – 3292)
- Maintained 24 hours per day/6-7 days per week operation with seven staff
- Analyzed ~21,000 IMPROVE samples per year (800 to 3,394 per month)
- Averaged ~3,000 samples per month in the queue (1,000 to 4,455)
- Participated in UC Davis Artifact Study (~560 samples for December 2011, January and August 2012)

IMPROVE Carbon Analysis following the IMPROVE_A^a Protocol

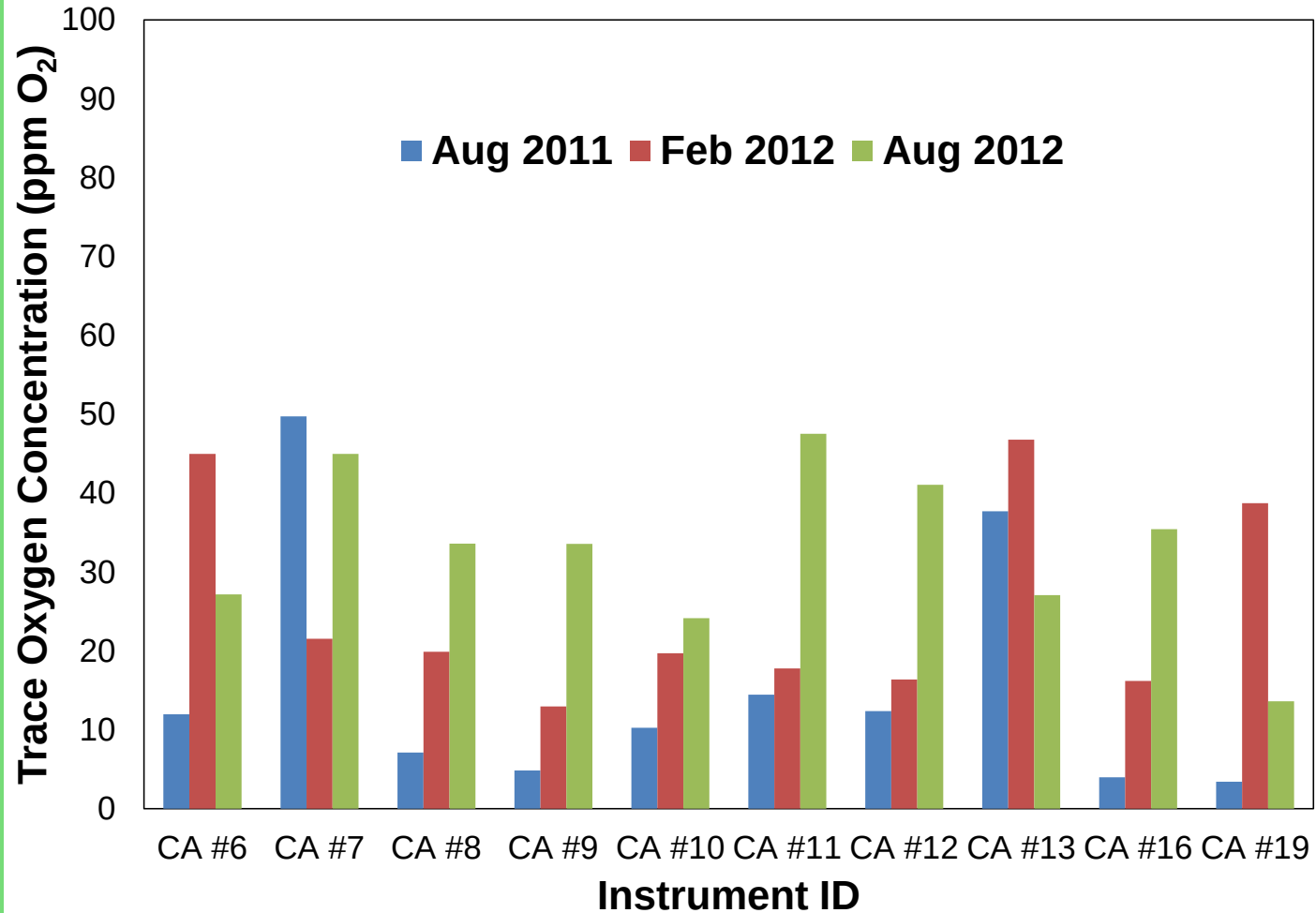
(July 2011 to June 2012)

Sampling Period	Samples Received	Analysis Completion Date
7/1/11-12/31/11	12,794	April 2012
1/1/12-6/30/12	10,850	October 2012

^a Chow et al. (2007) JAWMA

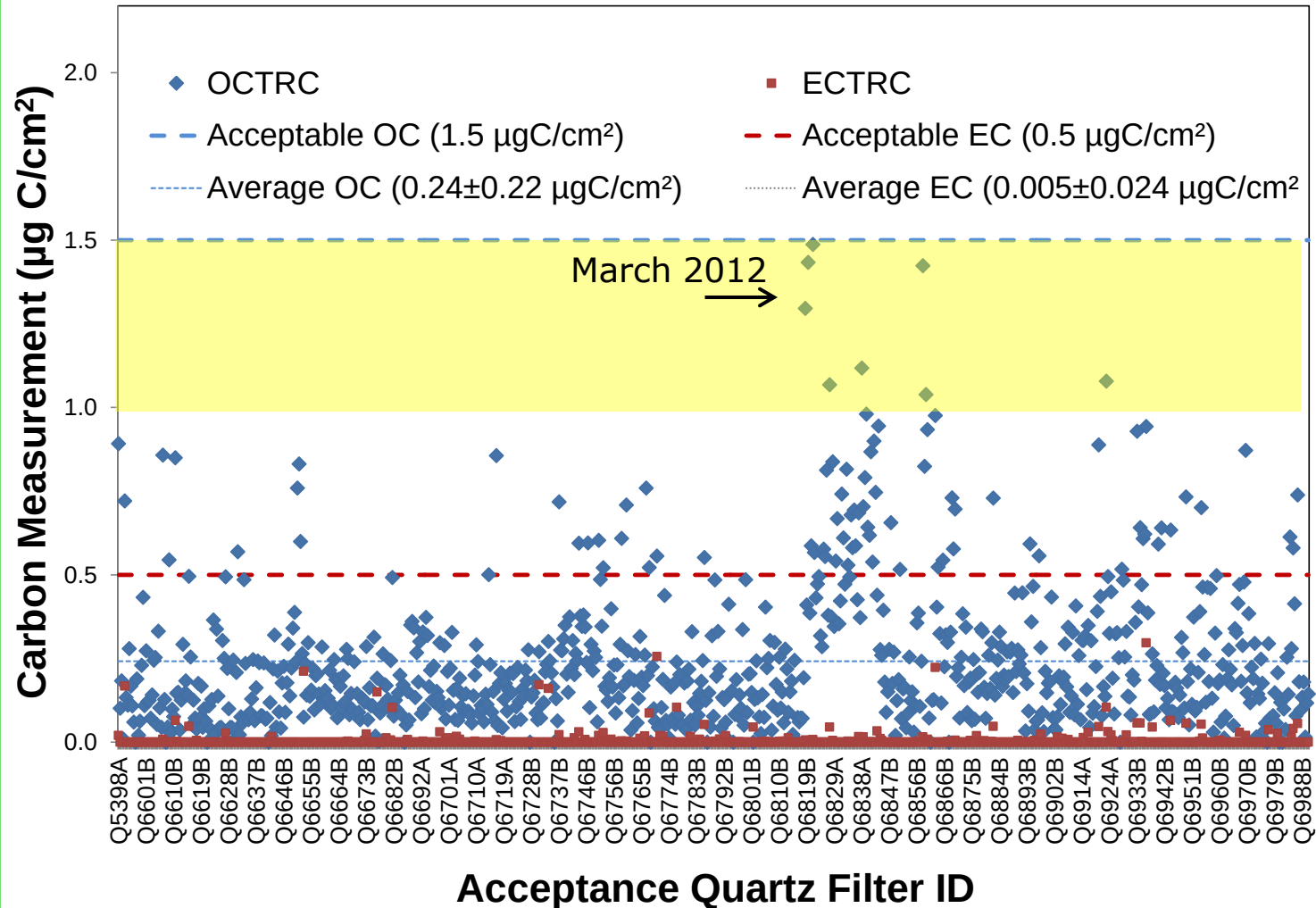
Regular oxygen performance tests show values within the 100 ppm tolerance

(Tested every six months)

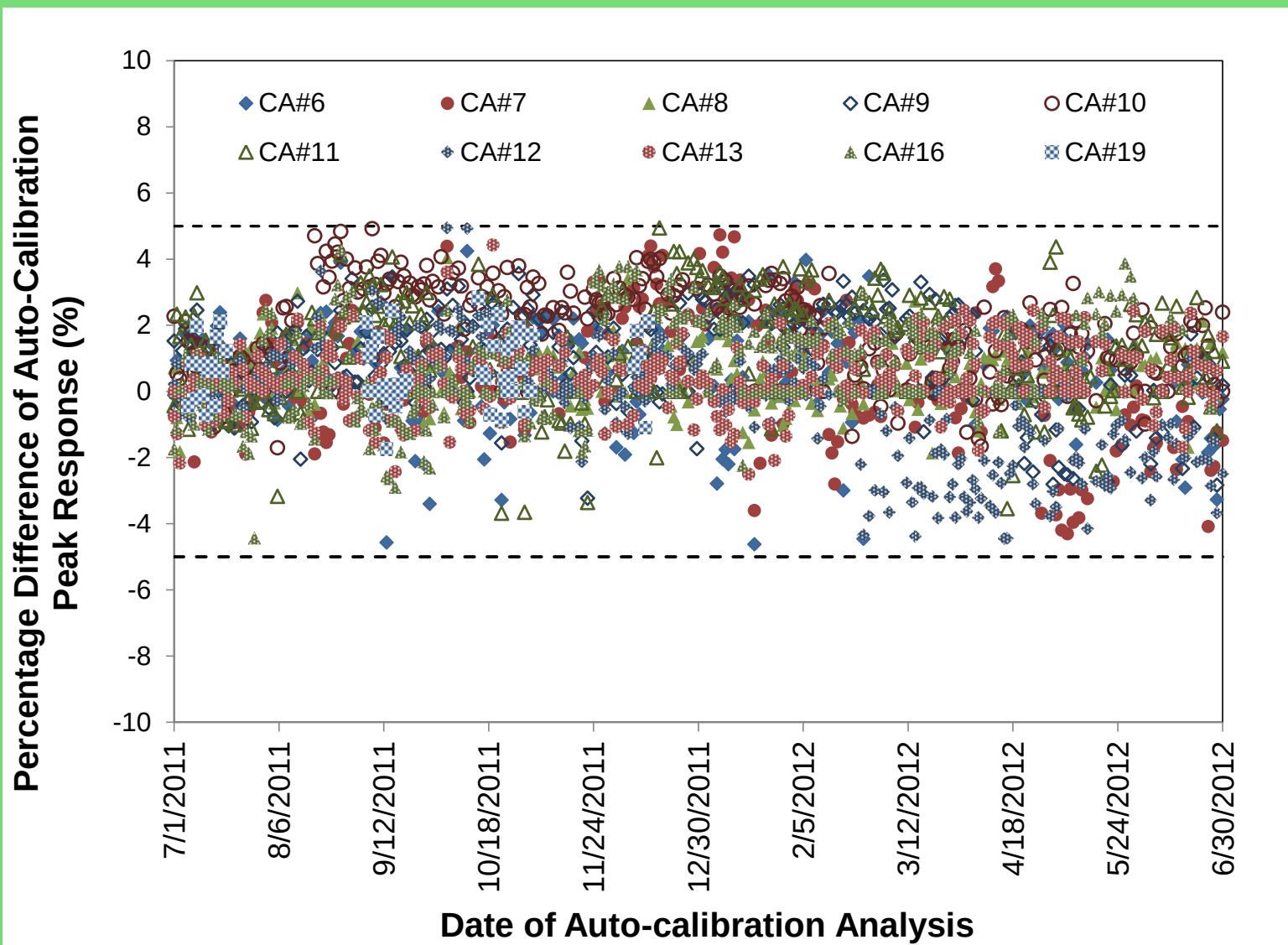


Low OC and EC levels found on pre-fired quartz-fiber filters

(Acceptance testing, August 2011-July 2012)



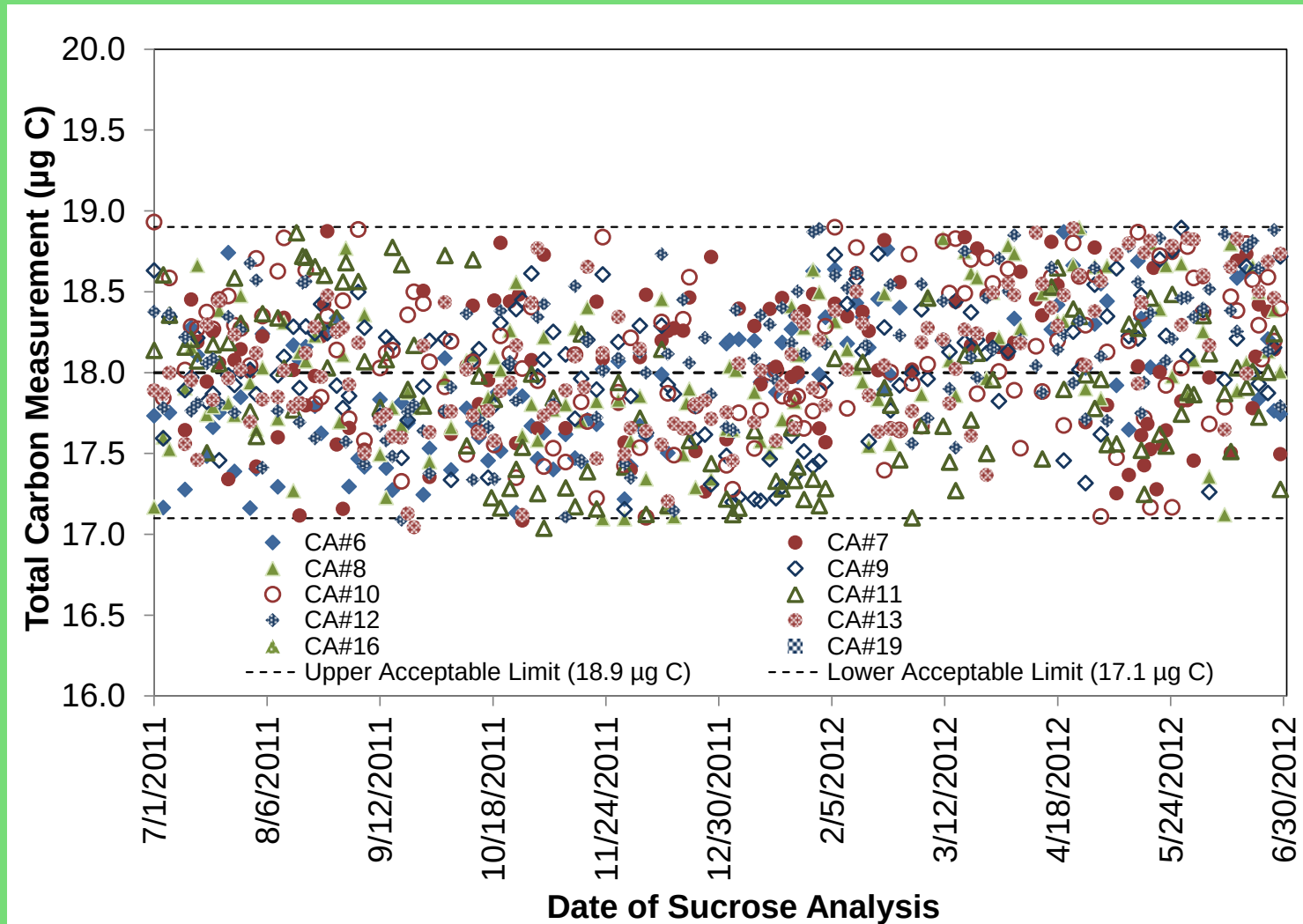
Daily instrument auto-calibration^a is within $\pm 5\%$ tolerance



^a With He, He/O₂ and CH₄

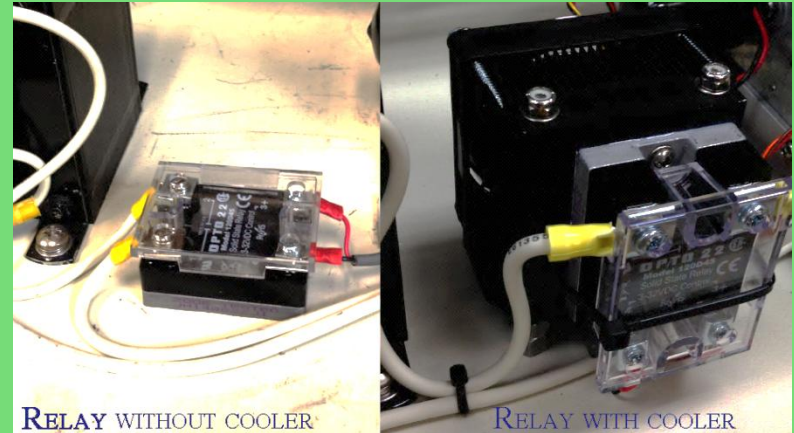
Quarterly standard calibration is within $\pm 5\%$ tolerance

(Sucrose; thrice per week)

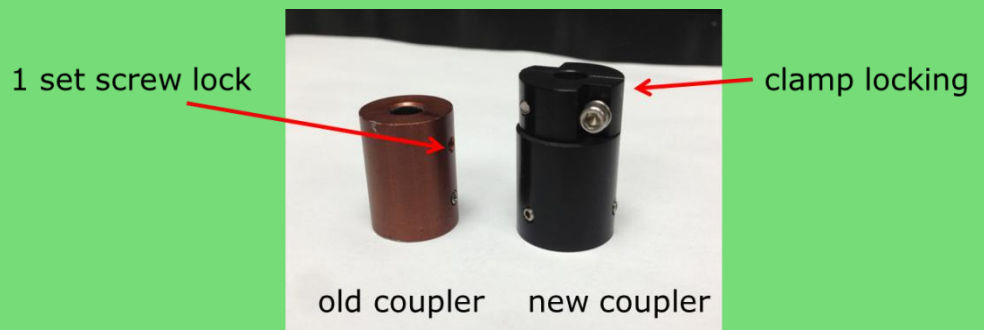


Improvements in Carbon Analyzer (DRI Model 2001)

- Updated oven relay (with active air cooling) to reduce electrical resistance, ensure sufficient heat dissipation, and minimize outages



- Installed a new coupler (between light pipe to optical fiber) to ensure stability and reduce laser drift ($<1.5\%$)



Worldwide Helium Shortage Mitigation Strategy

- Current helium (He) consumption is 2,500 L/day with an annual cost exceeding \$10,000
- Plans to reduce He consumption by 50% (Add new circuit board with valves)
 - Stop He-3 venting through methanator during analysis (50 mL/min)
 - Toggle make-up He valves (i.e., He-3, He-2, and CH_4)
- Eventually replace He with another non-oxidizing gas (e.g., nitrogen or argon)



Helium Tanks

Gas Regulator



Implement EUSAAR-II^a Protocol in DRI Model 2001

	Temperature		Residence Time ^b
<i>OC in 100% He</i>	IMPROVE_A	EUSAAR-II	EUSAAR-II
OC1	140 °C	200 °C	120 sec
OC2	280 °C	300 °C	150 sec
OC3	480 °C	450 °C	180 sec
OC4	580 °C	650 °C	180 sec
<i>EC in 98% He/2% O₂</i>			
EC0	--	500 °C	120 sec
EC1	580 °C	550 °C	120 sec
EC2	740 °C	700 °C	70 sec
EC3	840 °C	850 °C	80 sec

^a European Supersites for Atmospheric Aerosol Research protocol

^b IMPROVE_A residence times are predicated on peak and return-to-baseline and range from 120 to 580 seconds.

Revised carbon analysis SOP to reflect improvements

(Number 2-216r3, October 22, 2012)

- Revised daily calibration schedule

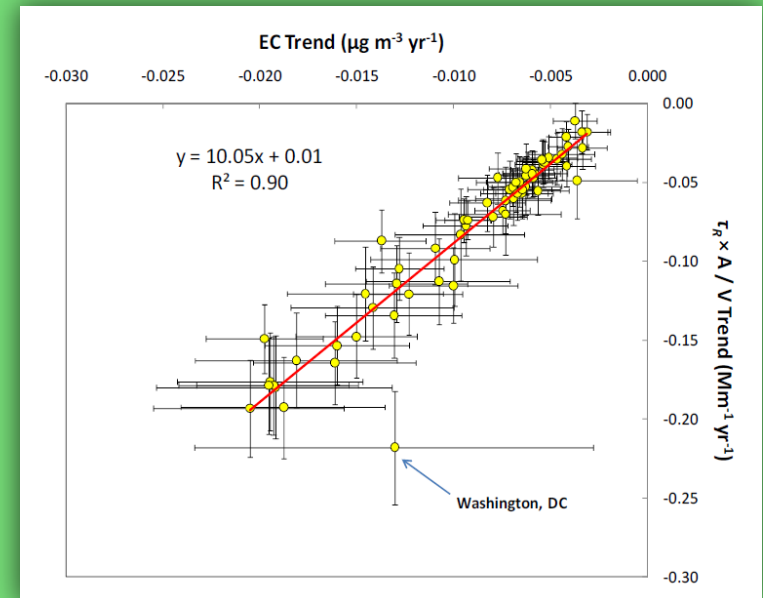
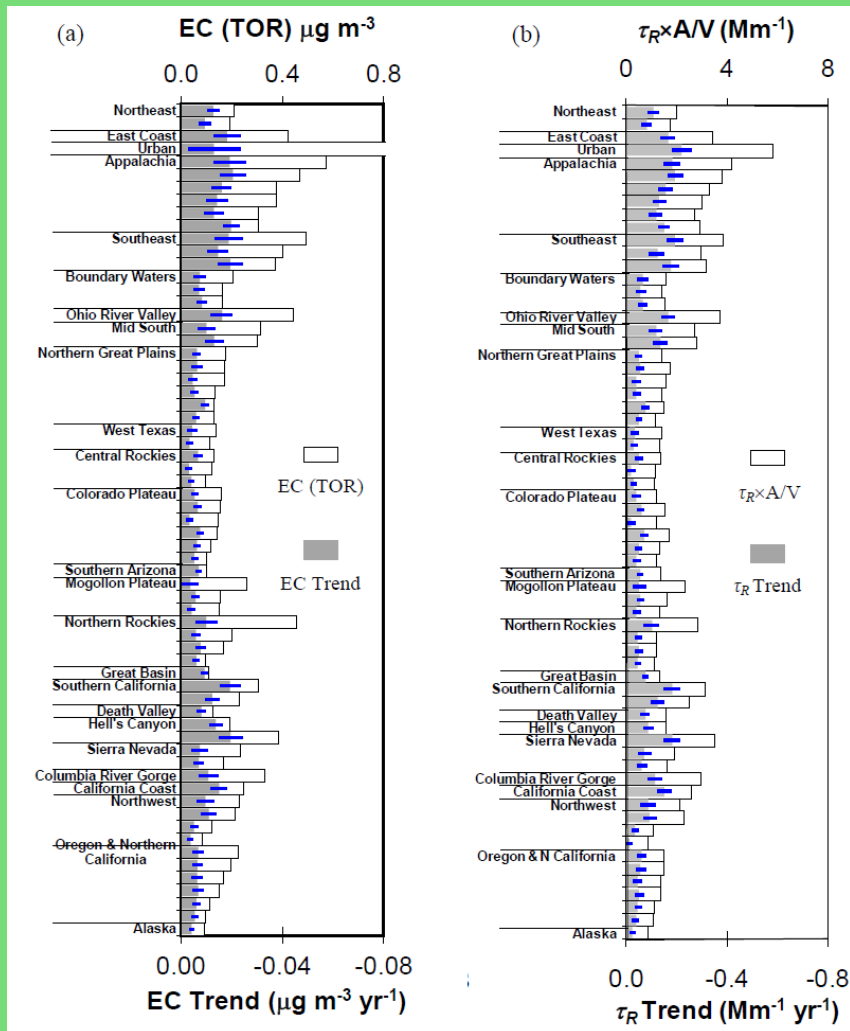
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Morning (Startup; 7 a.m.)	System blank, lab blank, Autocalib	Lab blank, sucrose	Lab blank, Autocalib, KHP	Lab blank, sucrose	Lab blank, Autocalib, KHP	Lab blank, sucrose	Lab blank, Autocalib
Evening (7 p.m.)	CO ₂ injection	Autocalib	CO ₂ injection	Autocalib	CO ₂ injection	Autocalib	CO ₂ injection

- Updated QA/QC activities
- Enhanced troubleshooting guide

Efforts in Carbon Research

- Examined data trends^a between EC and filter reflectance ($EC-\tau_R$) to resolve questions about consistency after instrument upgrade (2005) with IMPROVE_A protocol^a
- **Obtained NSF grant** (\$390,000 from Environmental Chemical Science Program) **to characterize source and chemical structures of brown carbon and compounds in thermal fractions** (integrates Model 2001 with soft photoionization TOF-MS)
- Conducted feasibility experiments for next generation DRI Model 20XX (Enhanced optical [$\lambda=400-900$ nm] and elemental detection [C, H, N, S, O, and m/z spectra])
- **Found changes in filter mass that may be related to organic vapor adsorption**

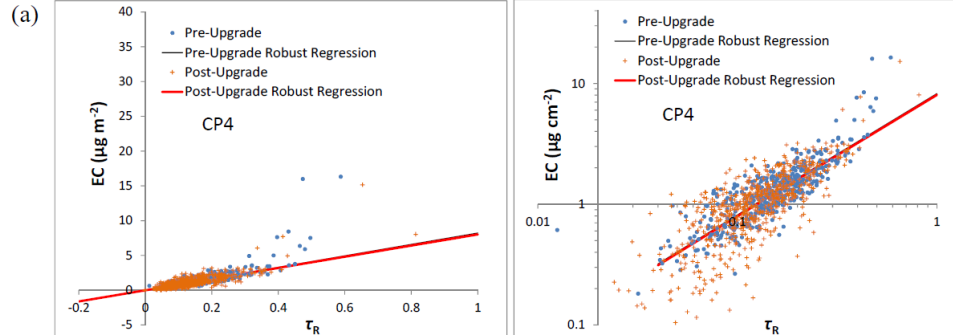
Consistent Decreasing Trends in EC and Reflectance (2000–2009)



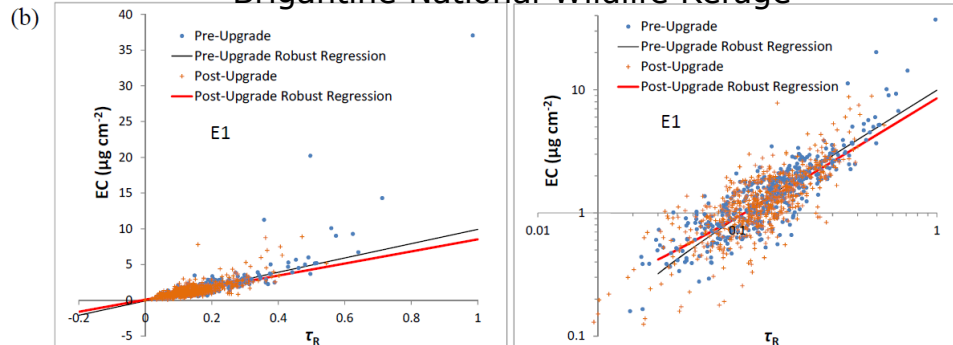
Similar downward trends at 65 sites with average rates (relative to the 2000–2004 baseline medians) of 4.5%/yr for EC and 4.1%/yr for τ_R .

EC- τ_R Relationship shows minor changes for most IMPROVE sites

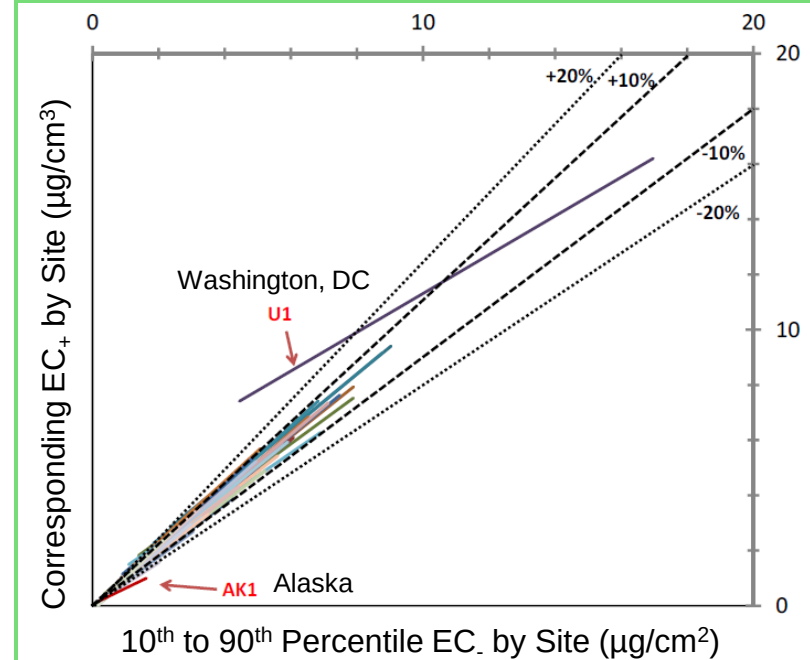
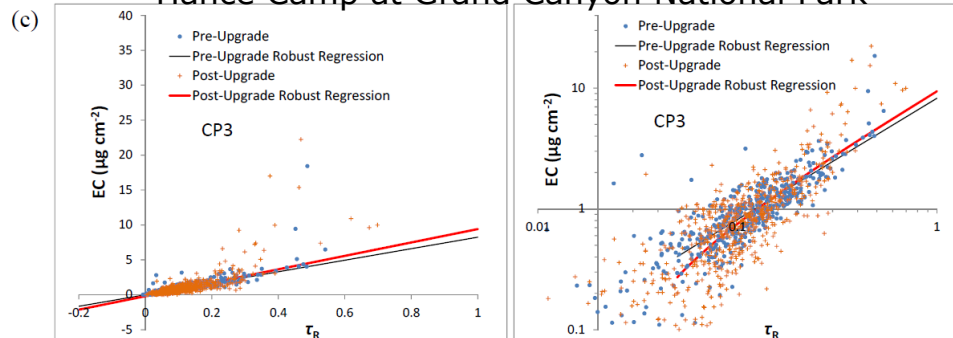
Wemianche Wilderness



Brigantine National Wildlife Refuge



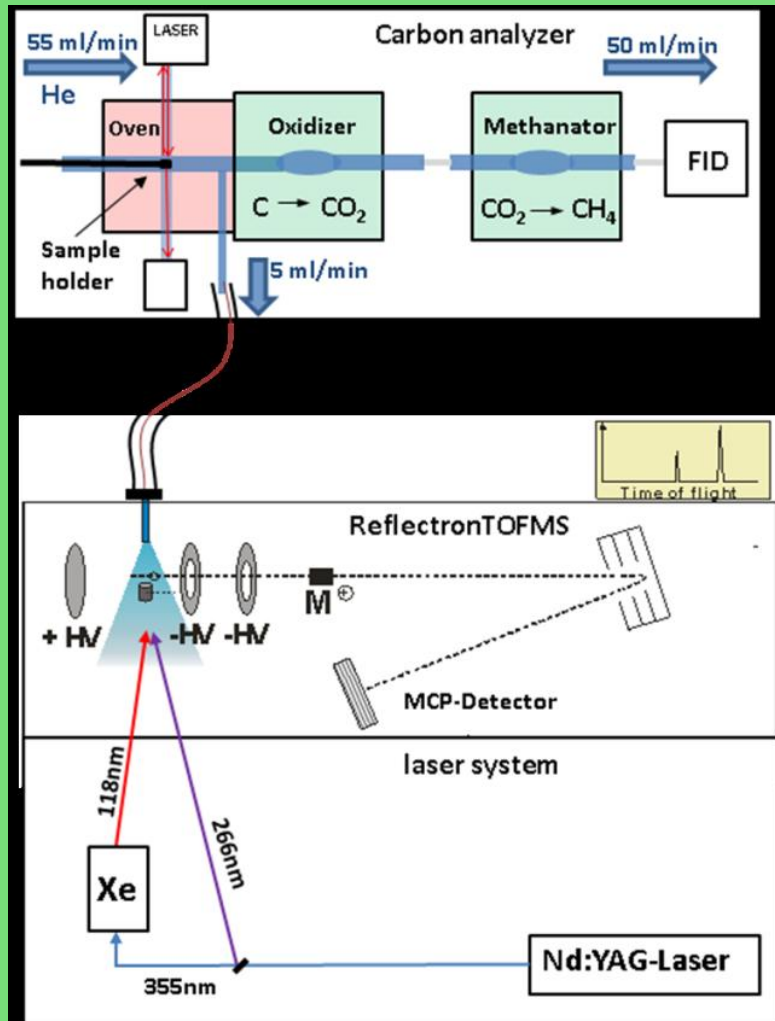
Hance Camp at Grand Canyon National Park



EC_+ (after 2005) vs. EC_- (before 2005) relationships derived from robust regression analysis through τ_R measurements show changes within 10% except for low-loading samples (> 20%).

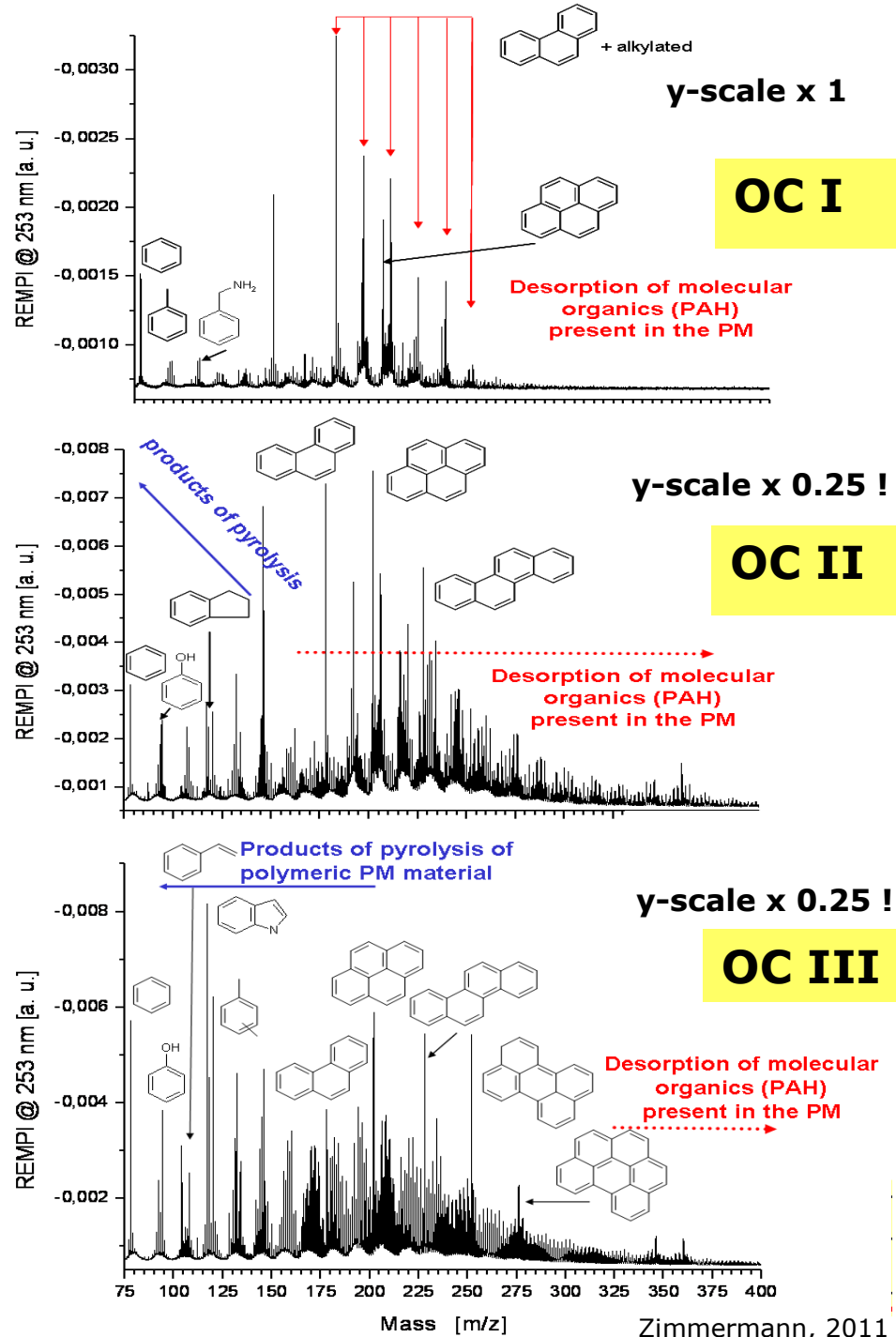
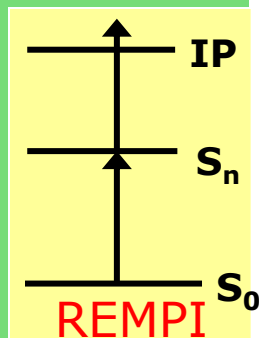
Integrated Model 2001 DRI carbon analyzer with Photoionization Time-of-Flight/Mass Spectrometer

(PI-TOF/MS; U. of Rostock, Germany)

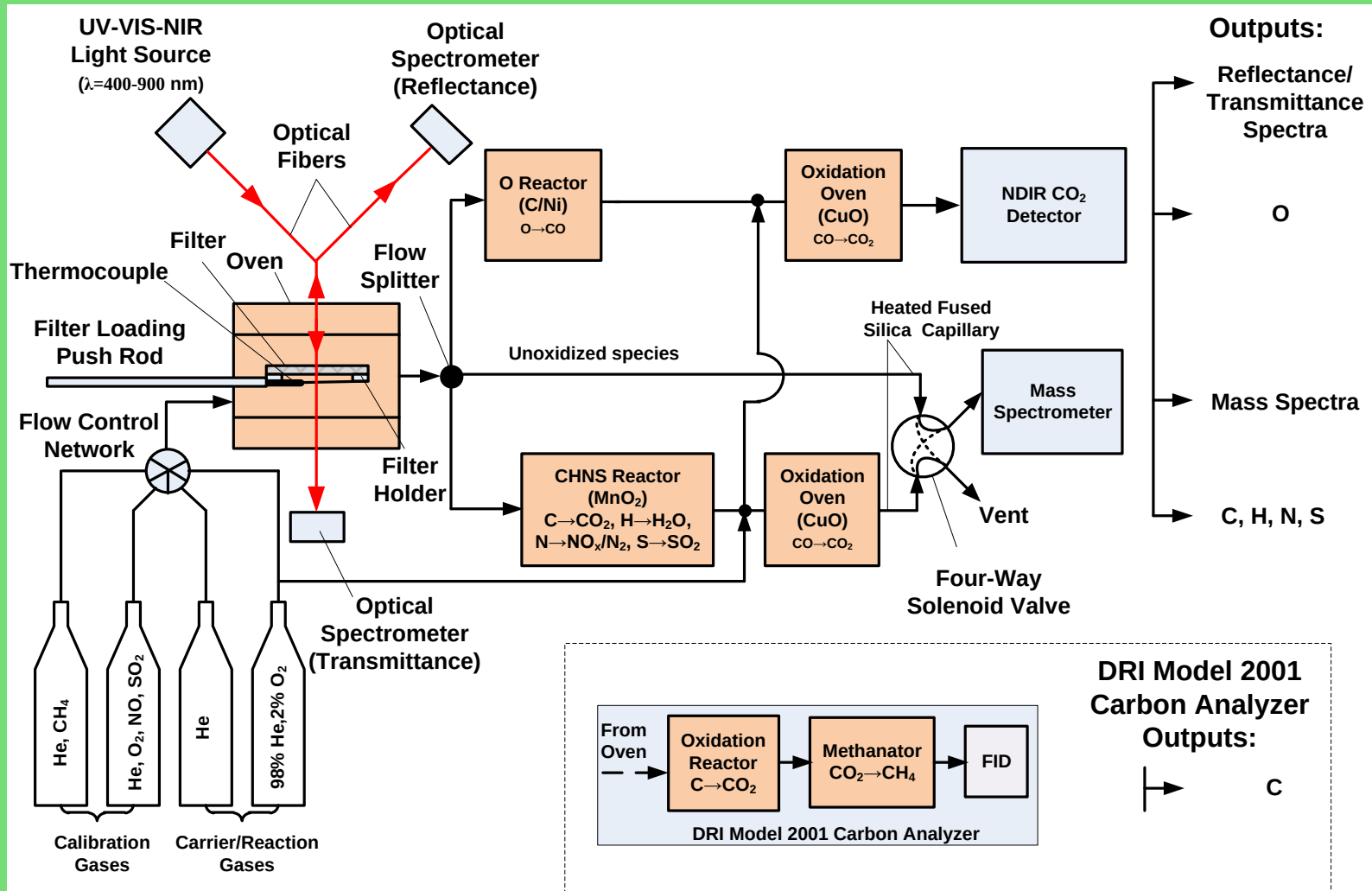


Pure Helium		Helium / 2 % O ₂	
OC1	120°C	EC1	550°C
OC2	250°C	EC2	700°C
OC3	450°C	EC3	800°C
OC4	550°C		

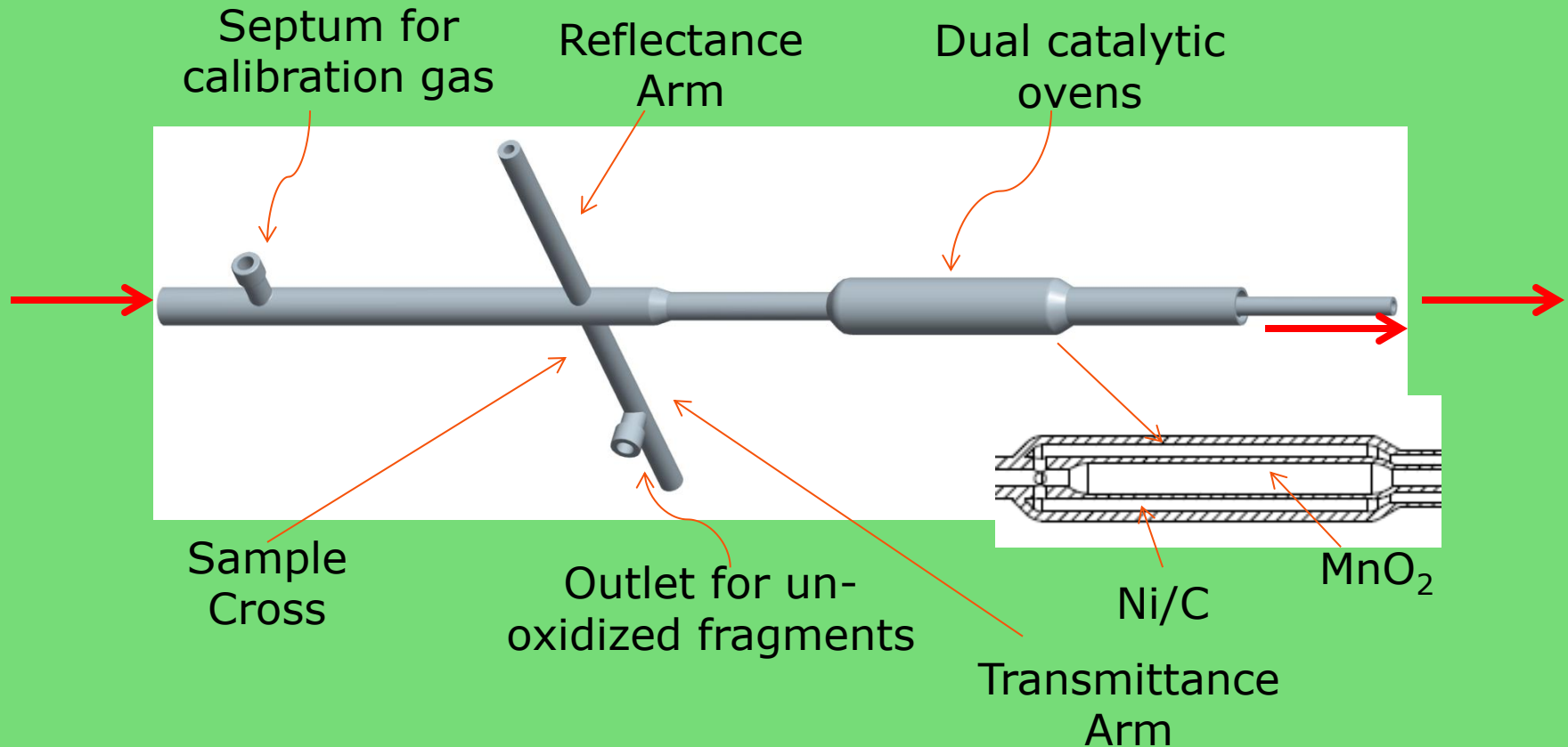
Mass spectra of thermal carbon fractions from Model 2001 with Resonance Enhanced Multi-Photon Ionization-Time-of-Flight/Mass Spectrometry (REMPI-TOF/MS)



Potential configuration for next generation thermal/optical carbon analyzer (DRI Model 20XX)

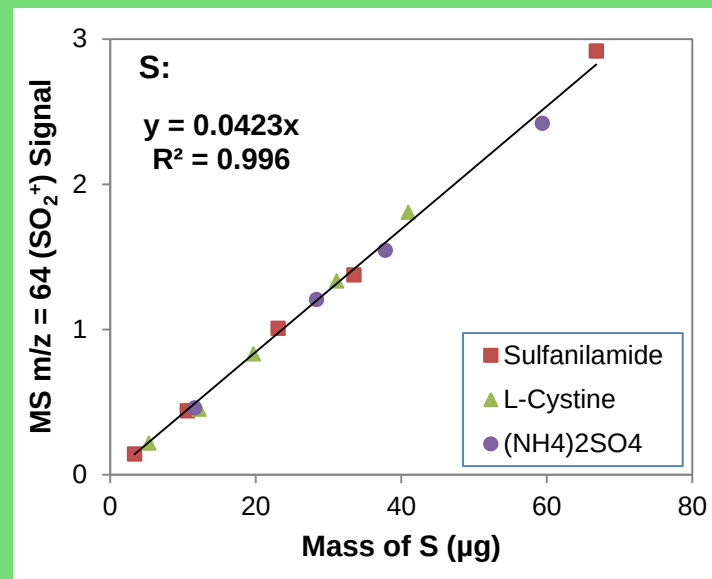
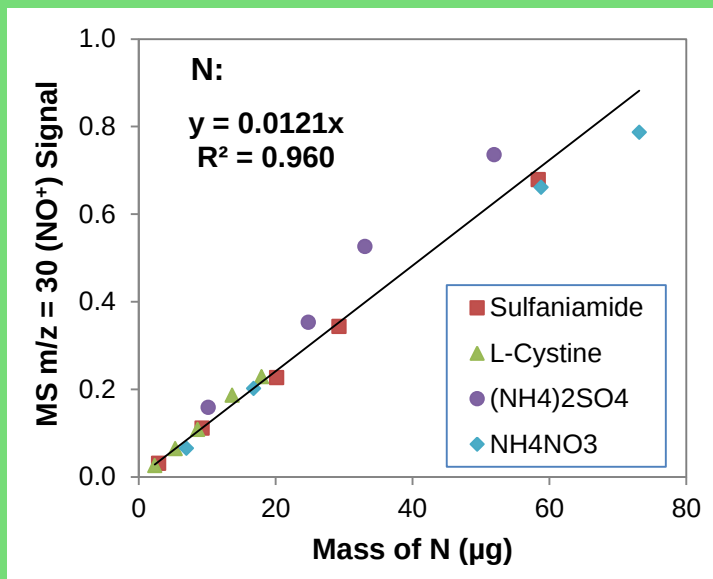
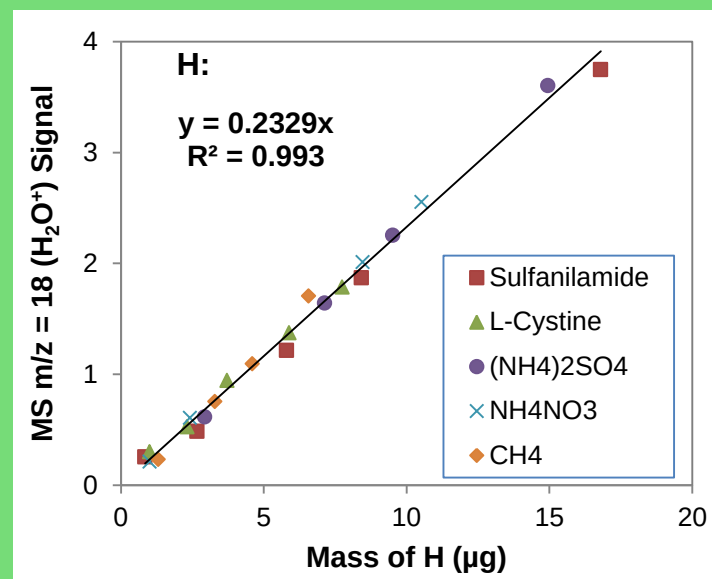
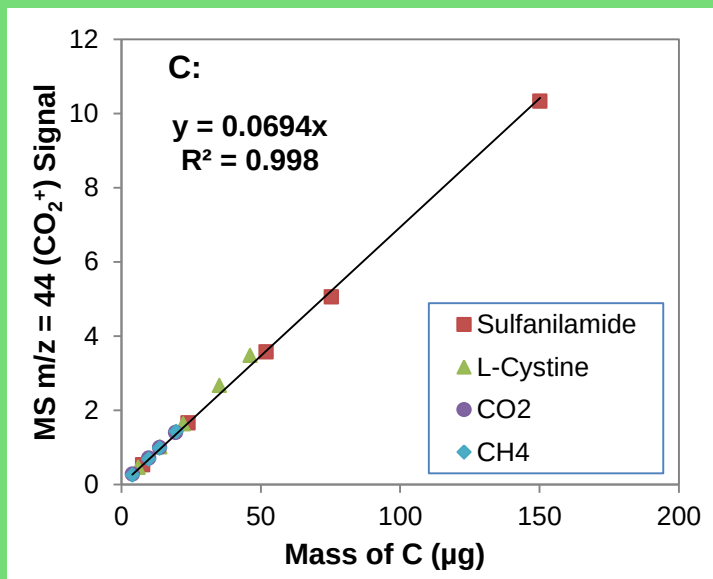


Use **annular oven** to measure key elements and mass spectra



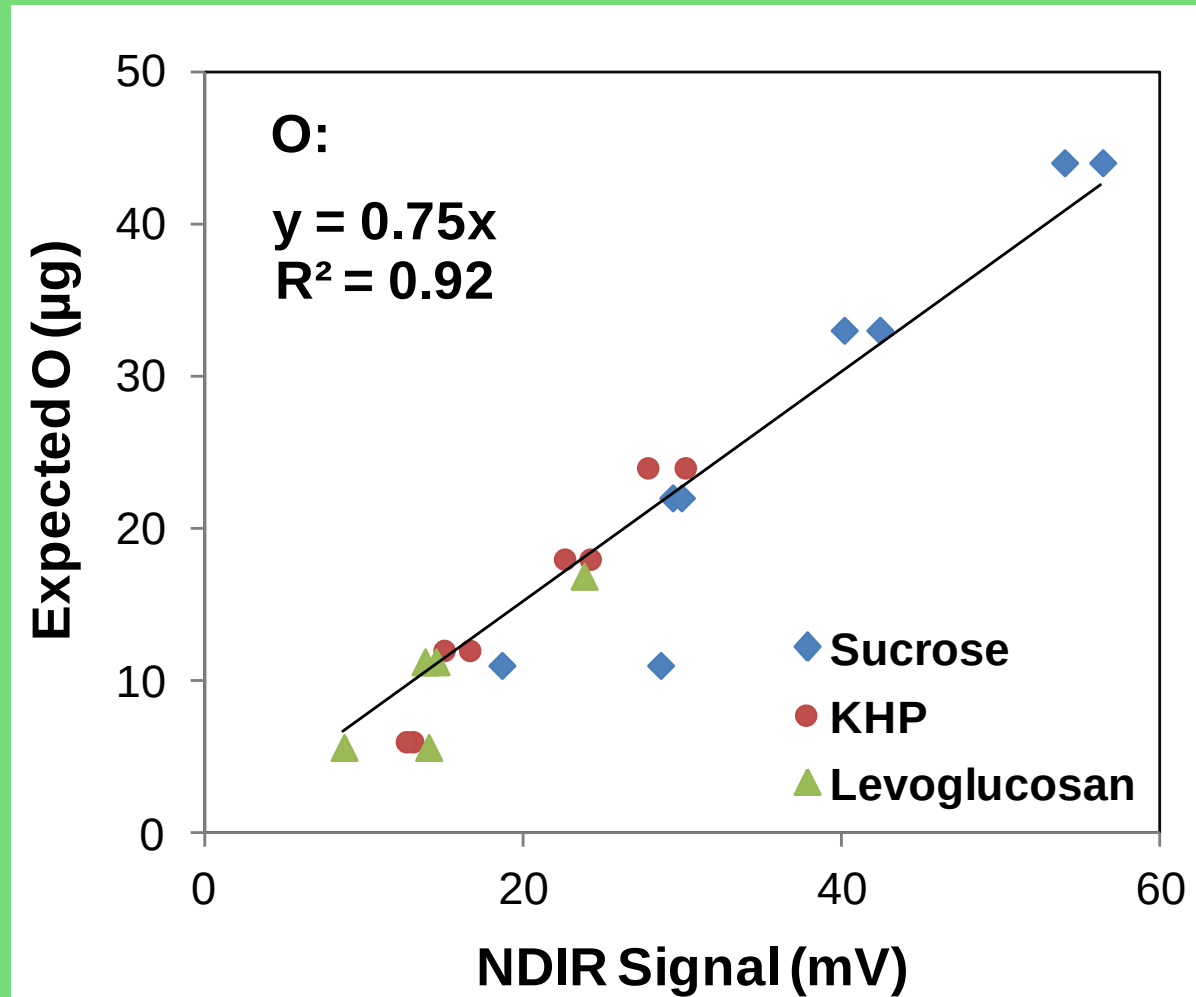
- Allow the evolved gases to be analyzed with or without pre-catalytic conversion.
- Two ovens contain MnO₂ or Ni/C catalyst for C, H, N, S, or O analysis

MS signals are linear with C, H, N, and S quantities in various calibration chemicals



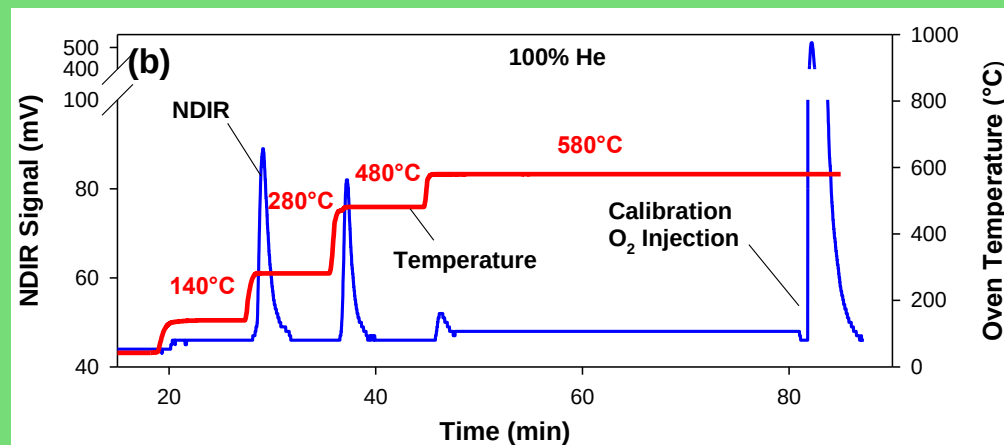
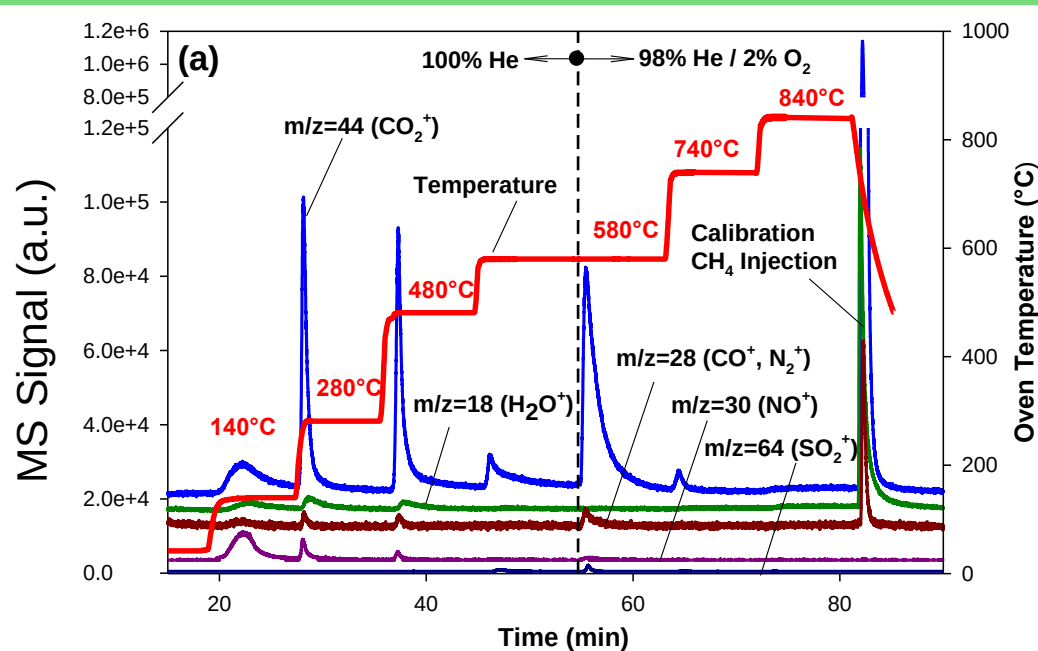
Sulfanilamide: $\text{C}_6\text{H}_8\text{N}_2\text{O}_2\text{S}$; L-Cystine: $\text{C}_6\text{H}_{12}\text{N}_2\text{O}_4\text{S}_2$

Use reverse flow for O analysis to minimize baseline drift (Reduce holding times by 45 minutes)

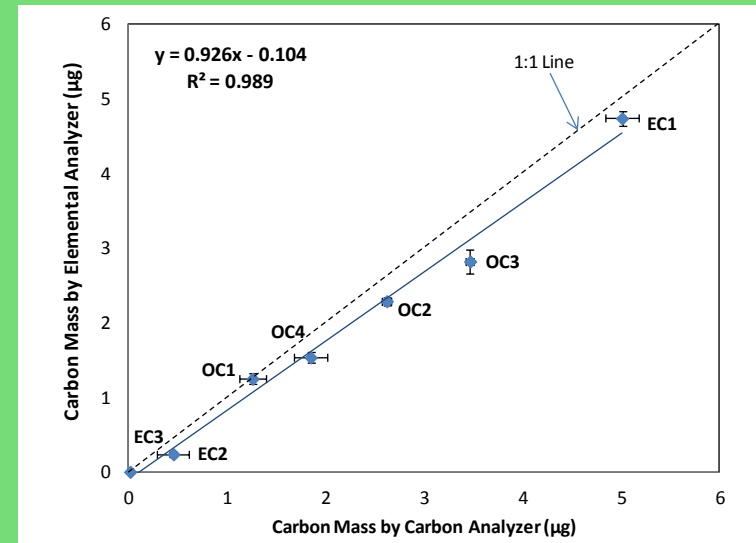


Non-dispersive infrared detector

Quantify C, H, N, S, and O using the IMPROVE_A protocol



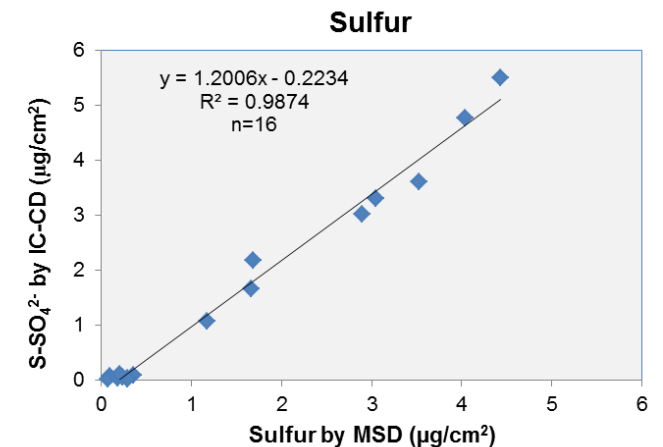
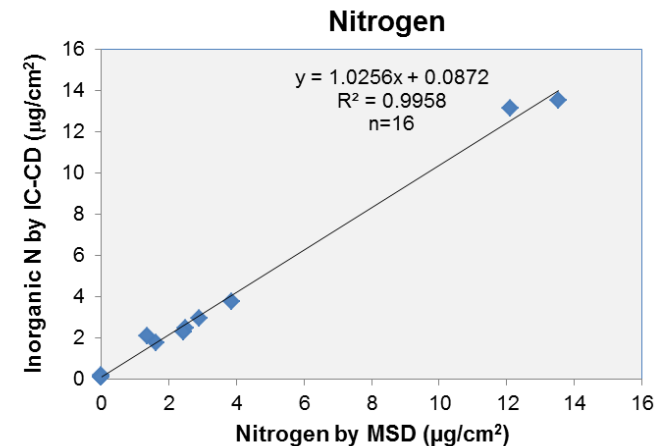
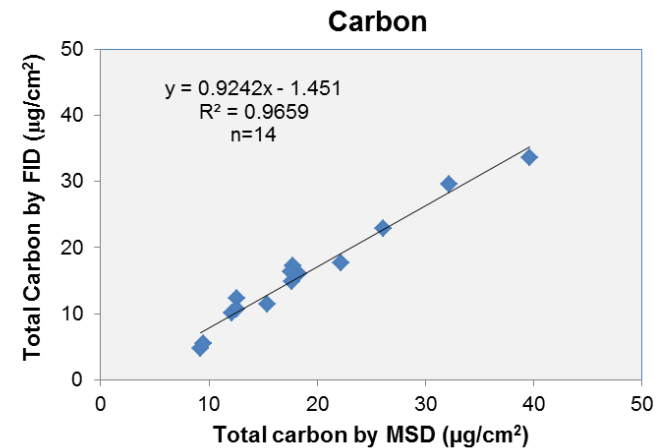
Thermogram of Fresno ambient aerosol sample for (a) CHNS, and (b) O following the IMPROVE_A protocol.



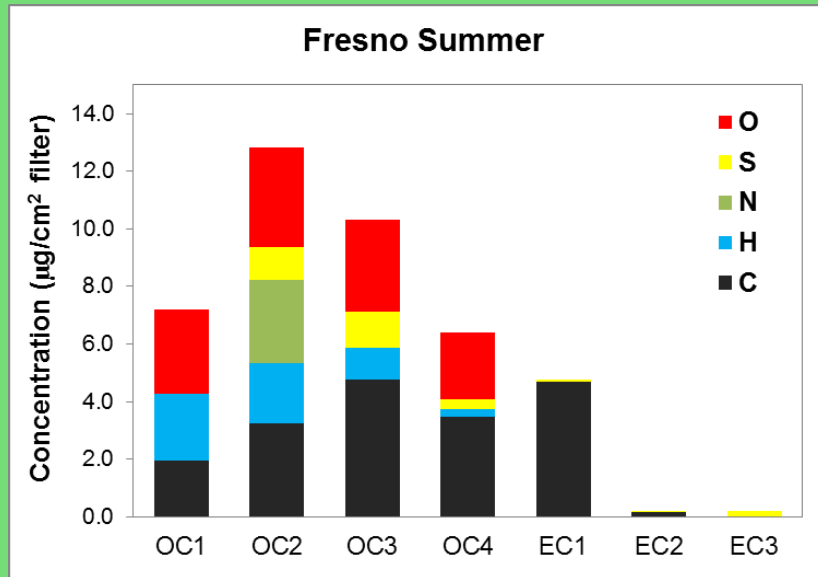
Comparison of carbon fractions measured by elemental analyzer and DRI Model 2001

Mass spectrometry produced elemental concentrations comparable with other detectors

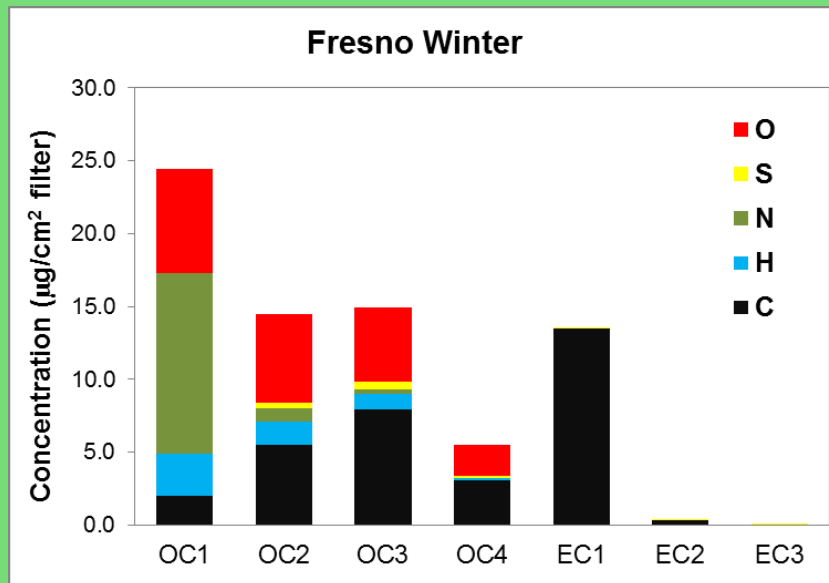
IC-CD: Ion chromatography with conductivity detector
FID: Flame ionization detector



Elemental composition varies between summer and winter (Fresno, California)



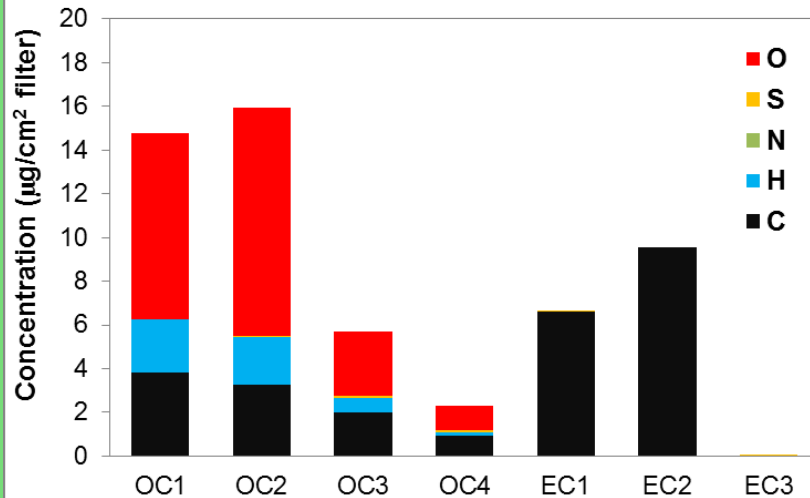
Abundant $(\text{NH}_4)_2\text{SO}_4$ in summer
(Decompose at 200–400 °C; OC2 at 280 °C in 100% Helium)
(EC/TC=0.23)



Abundant NH_4NO_3 in winter
(Dissociation starts at room temperature; OC1 at 140 °C in 100% Helium)
(EC/TC=0.28)

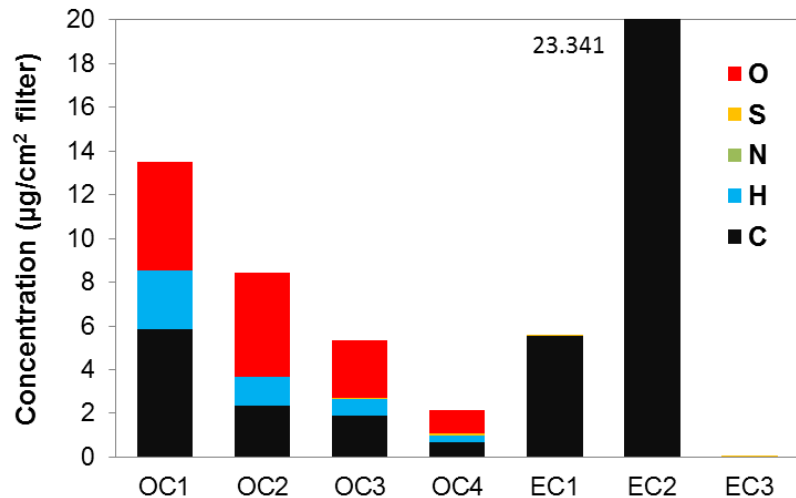
Source profiles vary between gasoline and diesel samples for carbon fractions

Gasoline (SIFQ003)



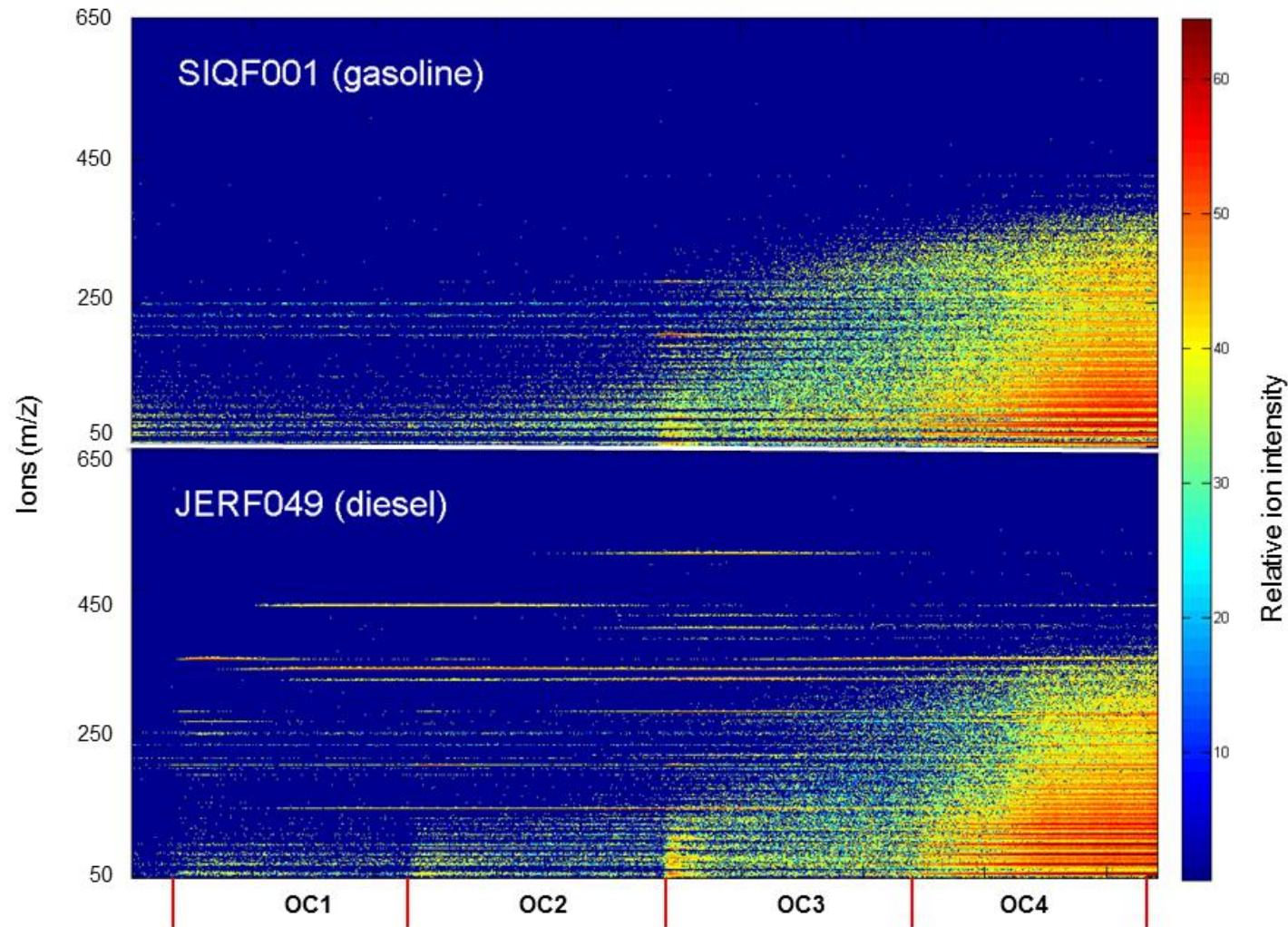
Increased C in OC and EC1 compared to diesel soot.
(EC/TC=0.73)

Diesel (JERF046)

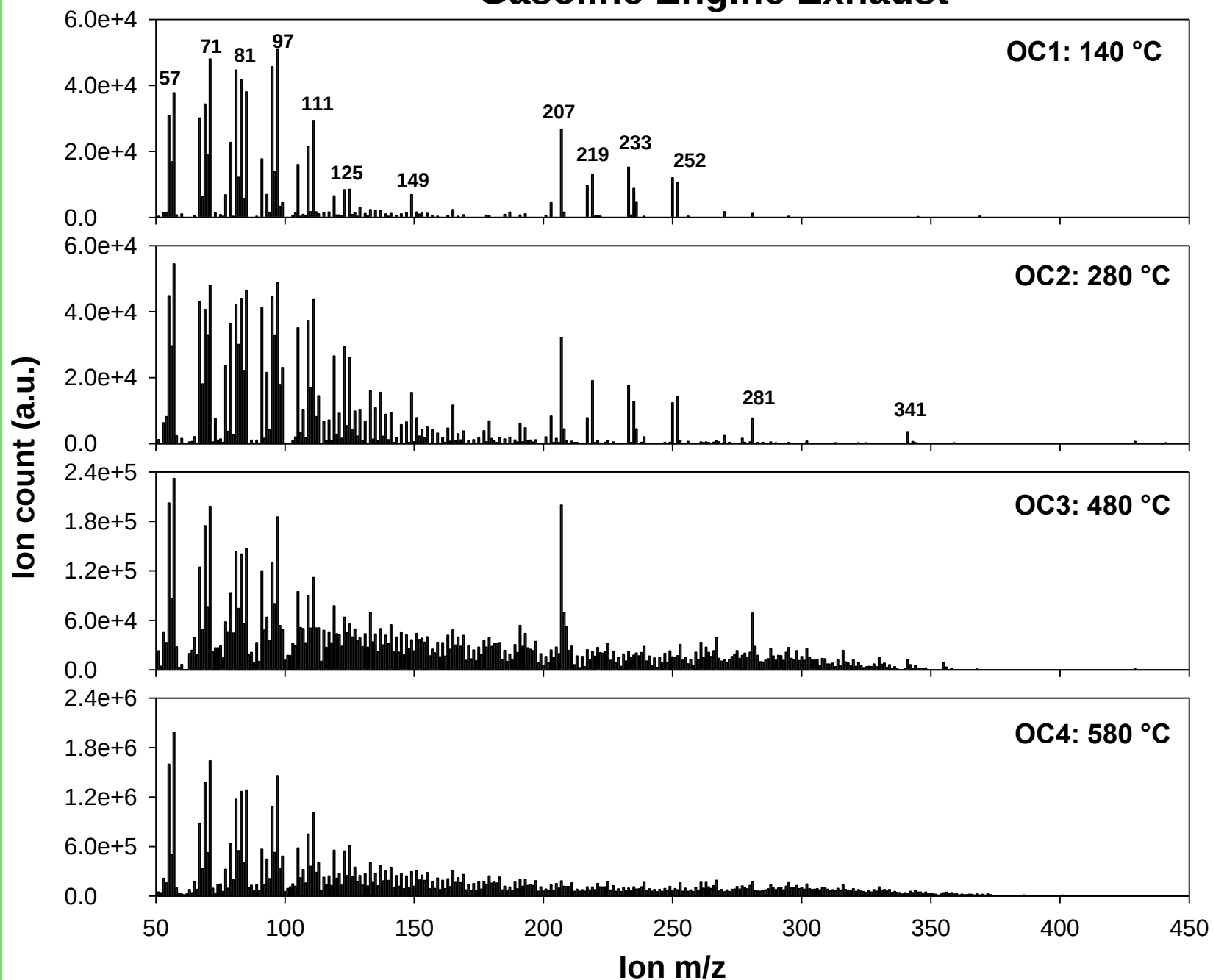


Most carbon is in EC2;
S is low due to low-S fuel.
(EC/TC=0.62)

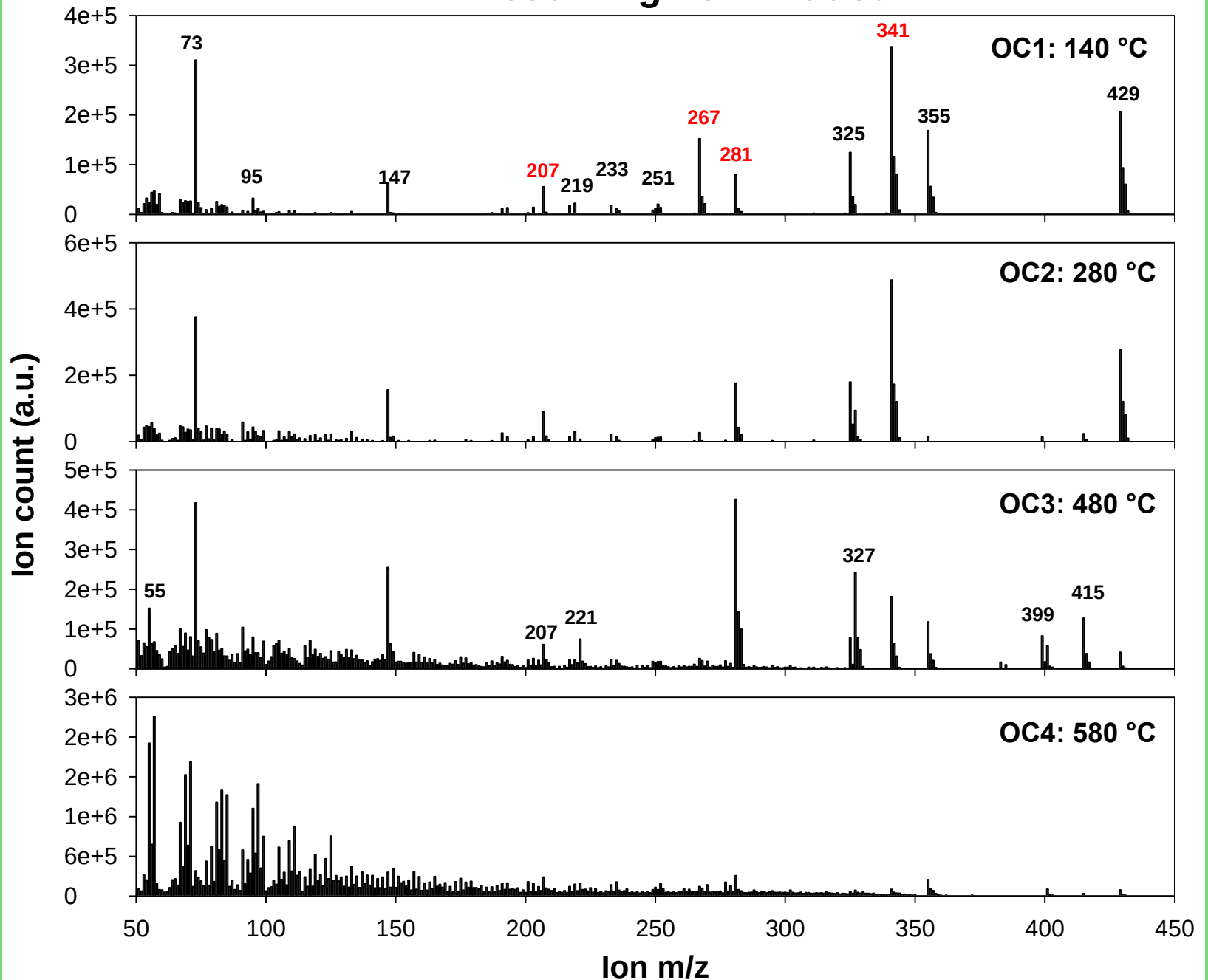
Unoxidized mass spectra show different patterns between gasoline and diesel exhaust samples



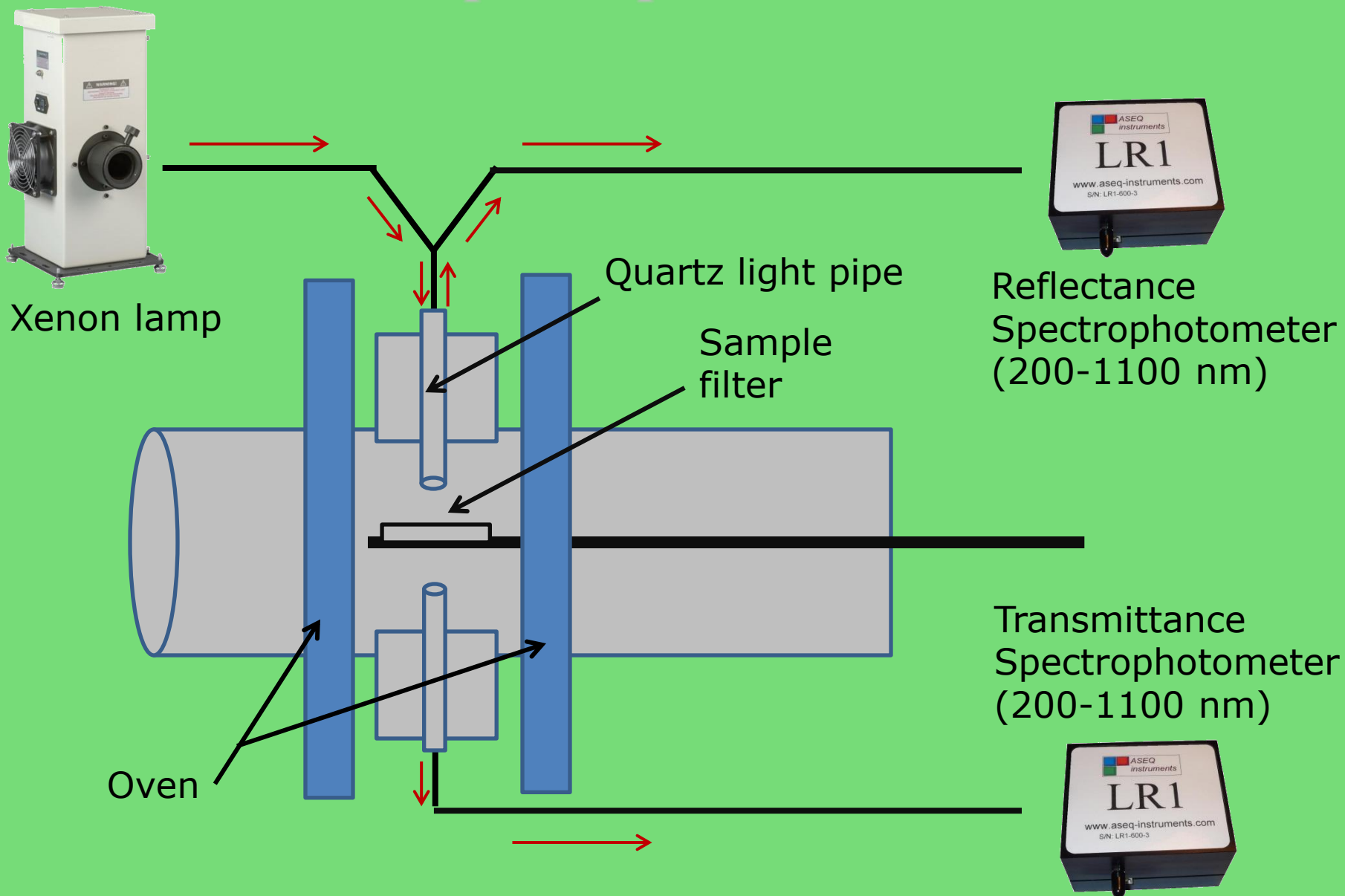
Gasoline Engine Exhaust



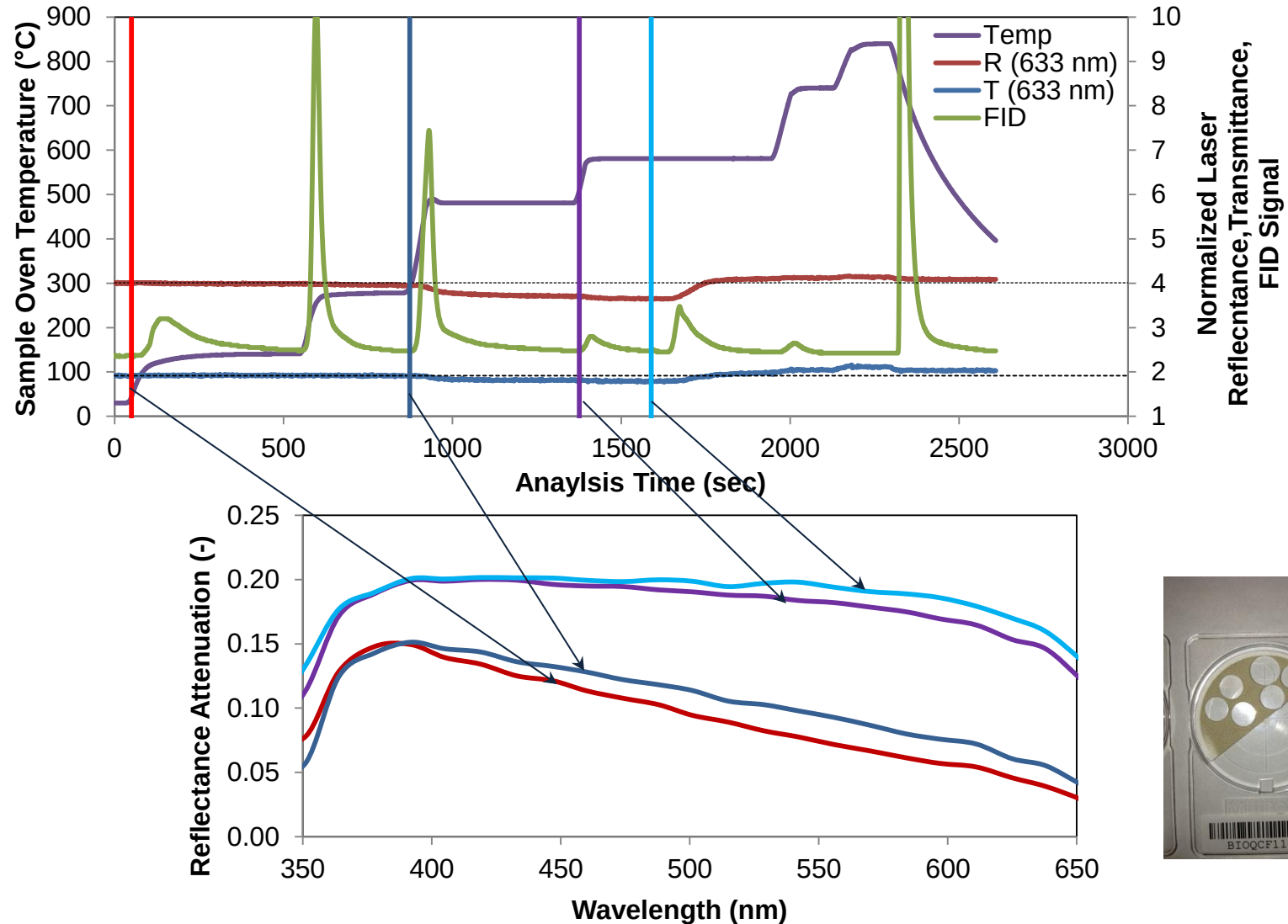
Diesel Engine Exhaust



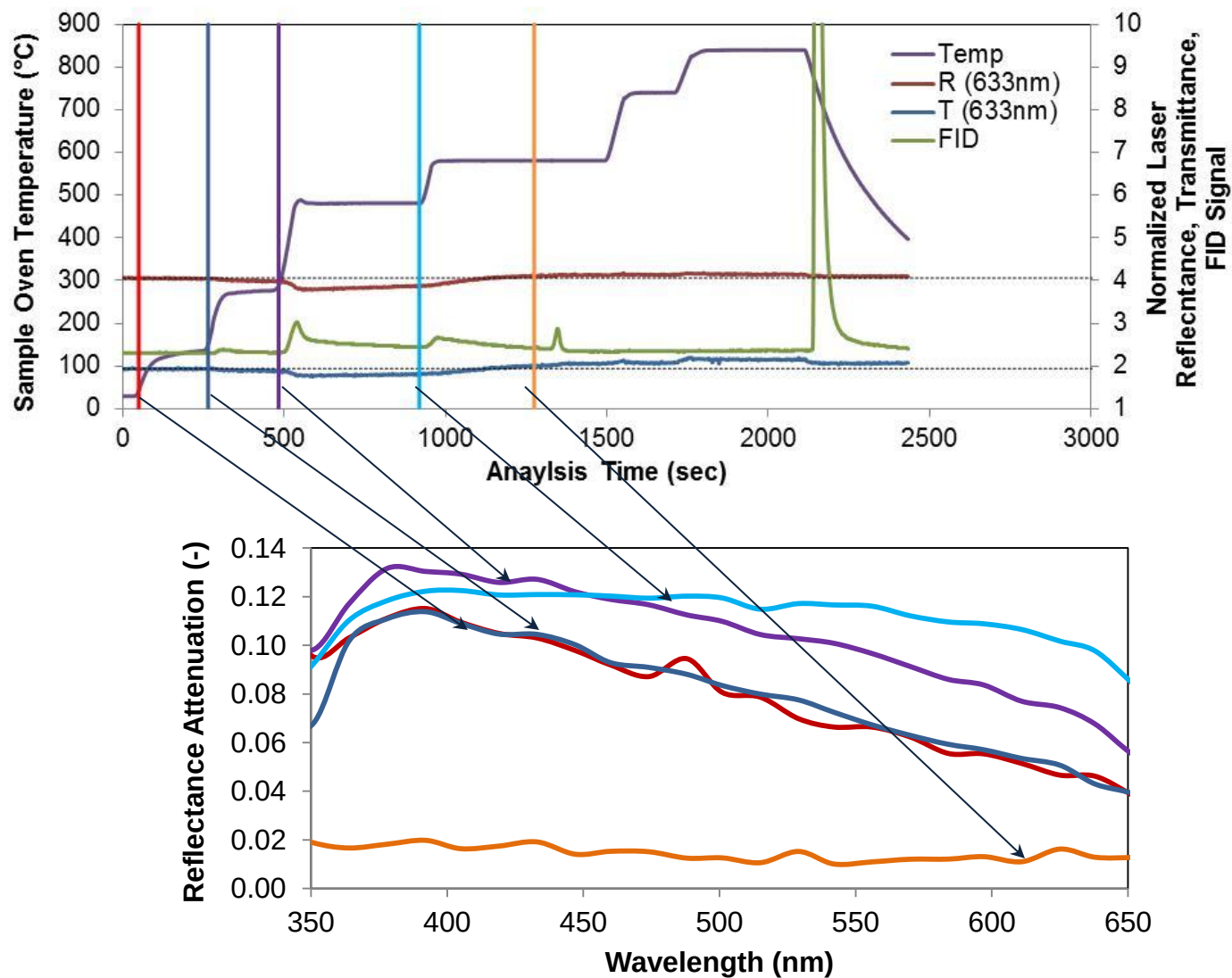
Experimental Configuration Using Xenon Lamp and Spectrophotometers



Spectral reflectance distinguishes native and charred light-absorbing carbon in wood smoke



Spectral reflectance reveals brown carbon absorption for humic acid



33 DRI publications using IMPROVE protocol since 2011 meeting

Anal Bioanal Chem
DOI 10.1007/s00216-011-5425-1

ORIGINAL PAPER

Hyphenation of a carbon analyzer to photo-ionization mass spectrometry to unravel the organic composition of particulate matter on a molecular level

Jana Grabowsky · Thorsten Streibel · Martin Sklorz ·
Judith C. Chow · John G. Watson ·
Athanasios Mamakos · Ralf Zimmermann

Received: 31 July 2011 / Revised: 15 September 2011 / Accepted: 15 September 2011
© Springer-Verlag 2011

Atmos. Meas. Tech., 5, 2329–2338, 2012
www.atmos-meas-tech.net/5/2329/2012/
doi:10.5194/amt-5-2329-2012
© Author(s) 2012. CC Attribution 3.0 License.



Consistency of long-term elemental carbon trends from thermal and optical measurements in the IMPROVE network

L.-W. A. Chen^{1,2}, J. C. Chow^{1,2}, J. G. Watson^{1,2}, and B. A. Schichtel³

¹Division of Atmospheric Sciences, Desert Research Institute, 2215 Raggio Parkway, Reno, Nevada 89512, USA

²State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, 10 Fenghui South Road, Xi'an 710075, China

³Cooperative Institute for Research in the Atmosphere, Colorado State University, 1375 Campus Delivery, Fort Collins, Colorado 80523, USA

Correspondence to: L.-W. A. Chen (antony@dri.edu)

Received: 14 April 2012 – Published in Atmos. Meas. Tech. Discuss.: 31 May 2012
Revised: 27 August 2012 – Accepted: 28 August 2012 – Published: 1 October 2012

- Bell, S.W.; Hansell, R.A.; Chow, J.C.; Tsay, S.C.; Wang, S.H.; Ji, Q.; Li, C.; Watson, J.G.; Khlystov, A. (2012). Constraining aerosol optical models using ground-based, collocated particle size and mass measurements in variable air mass regimes during the 7-SEAS/Dongsha experiment. *Atmos. Environ.*, online.
- Cao, J.J.; Li, H.; Chow, J.C.; Watson, J.G.; Lee, S.C.; Rong, B.; Dong, J.G.; Ho, K.F. (2011). Chemical composition of indoor and outdoor atmospheric particles at Emperor Qin's terra-cotta museum, Xi'an, China. *AAQR*, **11**(1):70-79. http://aaqr.org/VOL11_No1_February2011/8_AAQR-10-10-OA-0088_70-79.pdf.
- Cao, J.J.; Chow, J.C.; Tao, J.; Lee, S.C.; Watson, J.G.; Ho, K.F.; Wang, G.H.; Zhu, C.S.; Han, Y.M. (2011). Stable carbon isotopes in aerosols from Chinese cities: Influence of fossil fuels. *Atmos. Environ.*, **45**(6):1359-1363.
- Cao, J.J.; Shen, Z.X.; Chow, J.C.; Lee, S.C.; Watson, J.G.; Tie, X.X.; Ho, K.F.; Wang, G.H.; Han, Y.M. (2012). Winter and summer PM_{2.5} chemical compositions in 14 Chinese cities. *J. Air Waste Manage. Assoc.*, **62**(10):1214-1226. **DOI:** 10.1080/10962247.2012.701193. <http://www.tandfonline.com/doi/pdf/10.1080/10962247.2012.7011933>.

33 DRI publications using IMPROVE protocol since 2011 meeting (continued)

- Cao, J.J.; Wang, Q.Y.; Chow, J.C.; Watson, J.G.; Tie, X.X.; Shen, Z.X.; An, Z.S. (2012). Impacts of aerosol compositions on visibility impairment in Xi'an, China. *Atmos. Environ.*, **59**:559-566.
- Cao, J.J.; Huang, H.; Lee, S.C.; Chow, J.C.; Zou, C.W.; Ho, K.F.; Watson, J.G. (2012). Indoor/outdoor relationships for organic and elemental carbon in PM_{2.5} at residential homes in Guangzhou, China. *AAQR*, **12**(5):902-910. http://aaqr.org/VOL12_No5_October2012/18_AAQR-12-02-OA-0026_902-910.pdf.
- Chen, L.-W.A.; Watson, J.G.; Chow, J.C.; DuBois, D.W.; Herschberger, L. (2011). PM_{2.5} source apportionment: Reconciling receptor models for U.S. non-urban and urban long-term networks. *J. Air Waste Manage. Assoc.*, **61**(11):1204-1217.
- Chen, L.-W.A.; Robles, J.A.; Wang, X.; Chow, J.C.; Watson, J.G. (2011). Thermal pretreatment for online measurement of black carbon. Presented at 10th International Conference on Carbonaceous Particles in the Atmosphere (ICCPA), Vienna, Austria, 6/26-29/2011.
- Chen, L.-W.A.; Chow, J.C.; Watson, J.G.; Schichtel, B.A. (2012). Consistency of long-term elemental carbon trends from thermal and optical measurements in the IMPROVE network. *Atmospheric Measurement Techniques Discussion*, **5**:2329-2338. <http://www.atmos-meas-tech.net/5/2329/2012/amt-5-2329-2012.pdf>.
- Chen, L.-W.A.; Watson, J.G.; Chow, J.C.; Green, M.C.; Inouye, D.; Dick, K. (2012). Wintertime particulate pollution episodes in an urban valley of the western U.S.: A case study. *Atmos. Chem. Phys. Discuss.*, **12**(1):36. <http://www.atmos-chem-phys-discuss.net/12/15801/2012/acpd-12-15801-2012.pdf>.
- Chen, L.-W.A.; Tropp, R.J.; Li, W.-W.; Zhu, D.Z.; Chow, J.C.; Watson, J.G.; Zielinska, B. (2012). Aerosol and air toxics exposure in El Paso, Texas: A pilot study. *AAQR*, **12**(2):169-189. http://aaqr.org/VOL12_No2_April2012/3_AAQR-11-10-OA-0169_169-179.pdf.
- Cheng, Y.; Zou, S.C.; Lee, S.C.; Chow, J.C.; Ho, K.F.; Watson, J.G.; Han, Y.M.; Zhang, R.J.; Zhang F.; Yau, P.S.; Huang, Y.; Bai, Y.; Wu, W.J. (2011). Characteristics and source apportionment of PM₁ emissions at a roadside station. *J. Hazard. Mat.*, **195**:82-91.

33 DRI publications using IMPROVE protocol since 2011 meeting (continued)

- Chow, J.C.; Watson, J.G.; Robles, J.; Wang, X.L.; Chen, L.-W.A.; Trimble, D.L.; Kohl, S.D.; Tropp, R.J.; Fung, K.K. (2011). Quality assurance and quality control for thermal/optical analysis of aerosol samples for organic and elemental carbon. *Anal. Bioanal. Chem.*, **401**(10):3141-3152. DOI 10.1007/s00216-011-5103-3.
- Chow, J.C.; Watson, J.G.; Chen, L.-W.A.; Lowenthal, D.H.; Motallebi, N. (2011). PM_{2.5} source profiles for black and organic carbon emission inventories. *Atmos. Environ.*, **45**(31):5407-5414.
- Chow, J.C.; Watson, J.G. (2012). Chemical analyses of particle filter deposits. In *Aerosols Handbook : Measurement, Dosimetry, and Health Effects*, 2; Ruzer, L., Harley, N. H., Eds.; CRC Press/Taylor & Francis: New York, NY, 179-204.
- Cortez-Lugo, M.; Escamilla-Nunez, C.; Barraza-Villarreal, A.; Texcalc-Sangrador, J.L.; Chow, J.C.; Watson, J.G.; Hernandez-Cadena, L.; Romieu, I. (2012). Association between light absorption measurements of PM_{2.5} and distance from heavy traffic roads in the Mexico City metropolitan area. *Salud publica de Mexico*, **submitted**
- Grabowsky, J.; Streibel, T.; Sklorz, M.; Chow, J.C.; Mamakos, A.; Zimmermann, R. (2011). Hyphenation of a carbon analyzer to photo-1 ionization mass spectrometry to unravel the organic composition of particulate matter on a molecular level. *Anal. Bioanal. Chem.*, **401**(10):3153-3164.
- Green, M.C.; Chow, J.C.; Chang, M.C.O.; Chen, L.W.A.; Kuhns, H.D.; Etyemezian, V.R. (2012). Source apportionment of atmospheric particulate carbon in Las Vegas, Nevada, USA. *Particuology*, in press.
- Gyawali, M.; Arnott, W.P.; Zaveri, R.A.; Song, C.; Moosmüller, H.; Liu, L.; Mischchenko, M.L.; Chen, L.-W.A.; Green, M.C.; Watson, J.G.; Chow, J.C. (2012). Photoacoustic optical properties at UV, VIS, and near IR wavelengths for laboratory generated and winter time ambient urban aerosols. *Atmos. Chem. Phys.*, **12**:2587-2601. <http://www.atmos-chem-phys.net/12/2587/2012/acp-12-2587-2012.pdf>.
- Han, Y.M.; Cao, J.J.; Yan, B.Z.; Kenna, T.C.; Jin, Z.D.; Cheng, Y.; Chow, J.C.; An, Z.S. (2011). Comparison of elemental carbon in lake sediments measured by three different methods and 150-year pollution history in eastern China. *Environ. Sci. Technol.*, **45**(12):5287-5293.

33 DRI publications using IMPROVE protocol since 2011 meeting (continued)

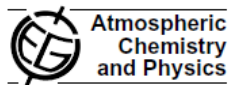
- Ho, S.S.H.; Chow, J.C.; Watson, J.G.; Ng, L.P.T.; Kwok, Y.; Ho, K.F.; Cao, J.J. (2011). Precautions for in-injection port thermal desorption-gas chromatography/mass spectrometry (TD-GC/MS) applied to aerosol filter samples. *Atmos. Environ.*, **45**(7):1491-1496.
- Hu, T.F.; Cao, J.J.; Ho, K.F.; An, Z.S.; Lee, S.; Chow, J.C.; Watson, J.G.; Li, H. (2011). Winter and summer characteristics of airborne particles Inside Emperor Qin's Terra-Cotta Museum, China: A study by scanning electron microscopy-energy dispersive x-ray spectrometry. *J. Air Waste Manage. Assoc.*, **61**(9):914-922.
- McDonald, J.D.; White, R.K.; Holmes, T.; Mauderly, J.L.; Zielinska, B.; Chow, J.C. (2012). Simulated downwind coal combustion emissions for laboratory inhalation exposure atmospheres. *Inhal. Toxicol.*, **24**(5):310-319.
- Pope, C.A., III; Ayala, A.; Bailer, J.C.; Bell, M.; Boyle, K.J.; Brandt, S.; Bui, L.; Corbett, J.J.; Fernandez, I.J.; Frey, H.C.; Fuglestvedt, J.; Gerking, S.; Helble, J.J.; Jacobson, M.Z.; Levy, J.; Menon, S.; Poirot, R.L.; Russell, A.G.; Walsh, M.; Watson, J.G. (2011). Review of the draft report to Congress on black carbon. prepared by U.S. Environmental Protection Agency, Washington,DC, [http://yosemite.epa.gov/sab/sabproduct.nsf/fedrgstr_activites/38059D3EA6FE3A19852578EA004A7469/\\$File/EPA-COUNCIL-11-002-unsigned.pdf](http://yosemite.epa.gov/sab/sabproduct.nsf/fedrgstr_activites/38059D3EA6FE3A19852578EA004A7469/$File/EPA-COUNCIL-11-002-unsigned.pdf).
- Sahu, M.; Hu, S.; Ryan, P.H.; LeMasters, G.; Grinshpun, S.A.; Chow, J.C.; Biswas, P. (2011). Chemical compositions and source identification of PM_{2.5} aerosols for estimation of a diesel source surrogate. *Sci. Total Environ.*, **409**(13):2642-2651.
<http://www.sciencedirect.com/science/article/pii/S0048969711002853>.
- Soto-Garcia, L.L.; Andreae, M.O.; Andreae, T.W.; Artaxo, P.; Maenhaut, W.; Kirchstetter, T.; Novakov, T.; Chow, J.C.; Mayol-Bracero, O.L. (2011). Evaluation of the carbon content of aerosols from the burning of biomass in the Brazilian Amazon using thermal, optical and thermal-optical analysis methods. *Atmos. Chem. Phys.*, **11**(9):4425-4444.

33 DRI publications using IMPROVE protocol since 2011 meeting (continued)

- Wang, X.L.; Watson, J.G.; Chow, J.C.; Kohl, S.D.; Chen, L.-W.A.; Sodeman, D.A.; Legge, A.H.; Percy, K.E. (2012). Measurement of real-world stack emissions with a dilution sampling system. In *Alberta Oil Sands: Energy, Industry, and the Environment*, Percy, K. E., Ed.; Elsevier Press: Amsterdam, The Netherlands, in press.
- Wang, X.L.; Watson, J.G.; Chow, J.C.; Gronstal, S.; Kohl, S.D. (2012). An efficient multipollutant system for measuring real-world emissions from stationary and mobile sources. *AAQR*, **12**(1):145-160. http://aaqr.org/VOL12_No2_April2012/1_AAQR-11-11-OA-0187_145-160.pdf.
- Watson, J.G.; Chow, J.C. (2011). Ambient aerosol sampling. In *Aerosol Measurement: Principles, Techniques and Applications, Third Edition*, 3; Kulkarni, P., Baron, P. A., Willeke, K., Eds.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 591-614.
- Watson, J.G.; Chow, J.C.; Wang, X.L.; Lowenthal, D.H.; Kohl, S.D.; Gronstal, S. (2011). Real-world emissions from non-road mining trucks. Report Number 010109-123109; prepared by Desert Research Institute, Reno, NV, for Ft. McMurray, AB, Canada, Wood Buffalo Environmental Association.
- Watson, J.G.; Chow, J.C.; Wang, X.L.; Kohl, S.D.; Gronstal, S. (2011). Winter stack emissions measured with a dilution sampling system. prepared by Desert Research Institute, Reno, NV, for Ft. McMurray, AB, Canada, Wood Buffalo Environmental Association.
- Watson, J.G.; Chow, J.C.; Lowenthal, D.H.; Chen, L.; Wang, X.L. (2012). Reformulation of PM_{2.5} mass reconstruction assumptions for the San Joaquin Valley. prepared by Desert Research Institute, Reno, NV, for San Joaquin Valley Unified Air Pollution Control District, Fresno, CA.
- Zhou, J.M.; Cao, J.J.; Zhang, R.J.; Chow, J.C.; Watson, J.G. (2012). Carbonaceous and ionic components of atmospheric fine particles in Beijing and their impact on atmospheric visibility. *AAQR*, **12**(4):492-502. http://aaqr.org/VOL12_No4_August2012/4_AAQR-11-11-OA-0218_492-502.pdf.

Canada and China have adopted IMPROVE_A for their long-term networks

Atmos. Chem. Phys., 12, 779–799, 2012
www.atmos-chem-phys.net/12/779/2012/
doi:10.5194/acp-12-779-2012
© Author(s) 2012. CC Attribution 3.0 License.



Atmospheric aerosol compositions in China: spatial/temporal variability, chemical signature, regional haze distribution and comparisons with global aerosols

X. Y. Zhang¹, Y. Q. Wang¹, T. Ni¹, X. C. Zhang¹, S. L. Gong², Y. M. Zhang¹, and J. Y. Sun¹

¹Key Laboratory for Atmospheric Chemistry, Chinese Academy of Meteorological Sciences, CMA, 46 Zhong Guan Cun S. Ave., Beijing 100081, China

²Air Quality Research Division, Science and Technology Branch, Environment Canada, 4905 Dufferin Street, Toronto, Ontario M3H 5T4, Canada

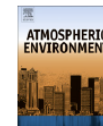
Correspondence to: X. Y. Zhang (xiaoye@cma.cma.gov.cn)



Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv



Canadian National Air Pollution Surveillance (NAPS) PM_{2.5} speciation program: Methodology and PM_{2.5} chemical composition for the years 2003–2008

Ewa Dabek-Zlotorzynska^{a,*}, Tom F. Dann^a, P. Kalyani Martinelango^{a,1}, Valbona Celo^a, Jeffrey R. Brook^b, David Mathieu^a, Luyi Ding^a, Claire C. Austin^a

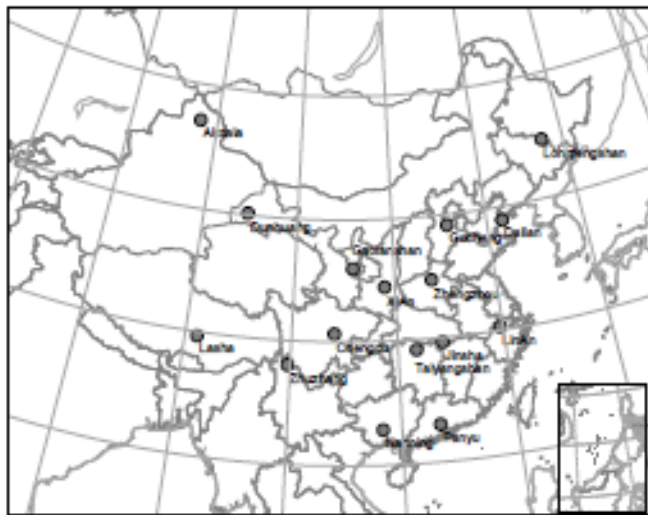


Fig. 1. Locations of sixteen CAWNET stations.

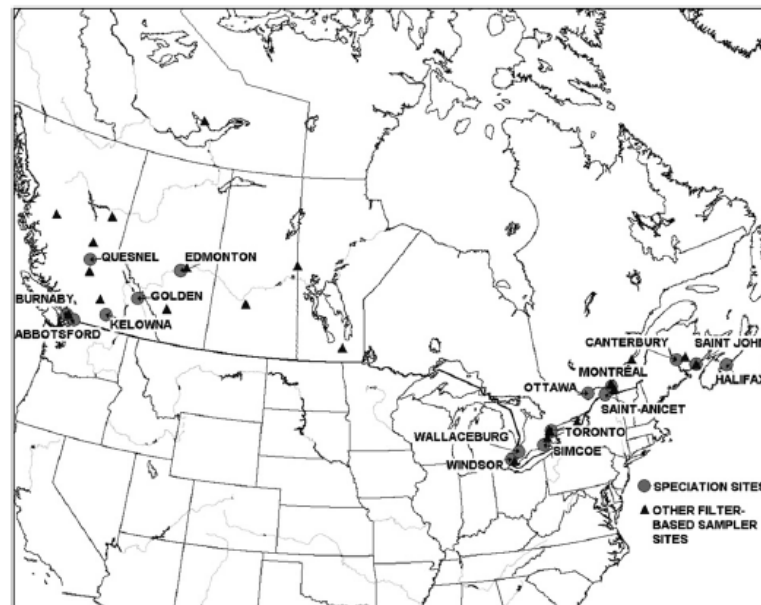


Fig. 1. Locations of the Canadian NAPS PM_{2.5} speciation sites and other PM_{2.5} monitoring sites.

Future Activities

- Retrofit new valves and circuit boards to reduce helium consumption on carbon analyzers.
- Evaluate comparability and differences between IMPROVE_A and EUSAAR-II protocols.
- Participate in European efforts for round-robin carbon intercomparison and standard reference material (SRM) development.
- Develop algorithm to convert reflectance/transmission signal to absorption and compare Angstrom Absorption Exponent to quantify OC, brown carbon, and EC.
- Integrate C, H, N, S, with O analysis.