Update of IMPROVE Carbon Analysis

Judith C. Chow (judith.chow@dri.edu)
John G. Watson
Xiaoliang Wang
Dana L. Trimble
Steven D. Kohl

Desert Research Institute, Reno, NV

Presented at:
2015 IMPROVE Steering Committee Meeting
Grand Canyon, AZ

November 3, 2015

Objectives

- Report status of IMPROVE carbon analyses
- Update on Model 2001 hardware improvements
- Discuss plans for transition to DRI Model 2015

Carbon Laboratory Operations
(July 2014 to June 2015 samples)

- Received ~1,700 samples per month (varied from 1,200 to 2,000 for samples received each month)
- Maintained 24 hours per day/5-7 days per week operation with 6 staff
- Analyzed ~21,600 IMPROVE samples (869 to 3,000 per month)
- Averaged ~4,247 samples per month in the queue (2,290 to 7,400)

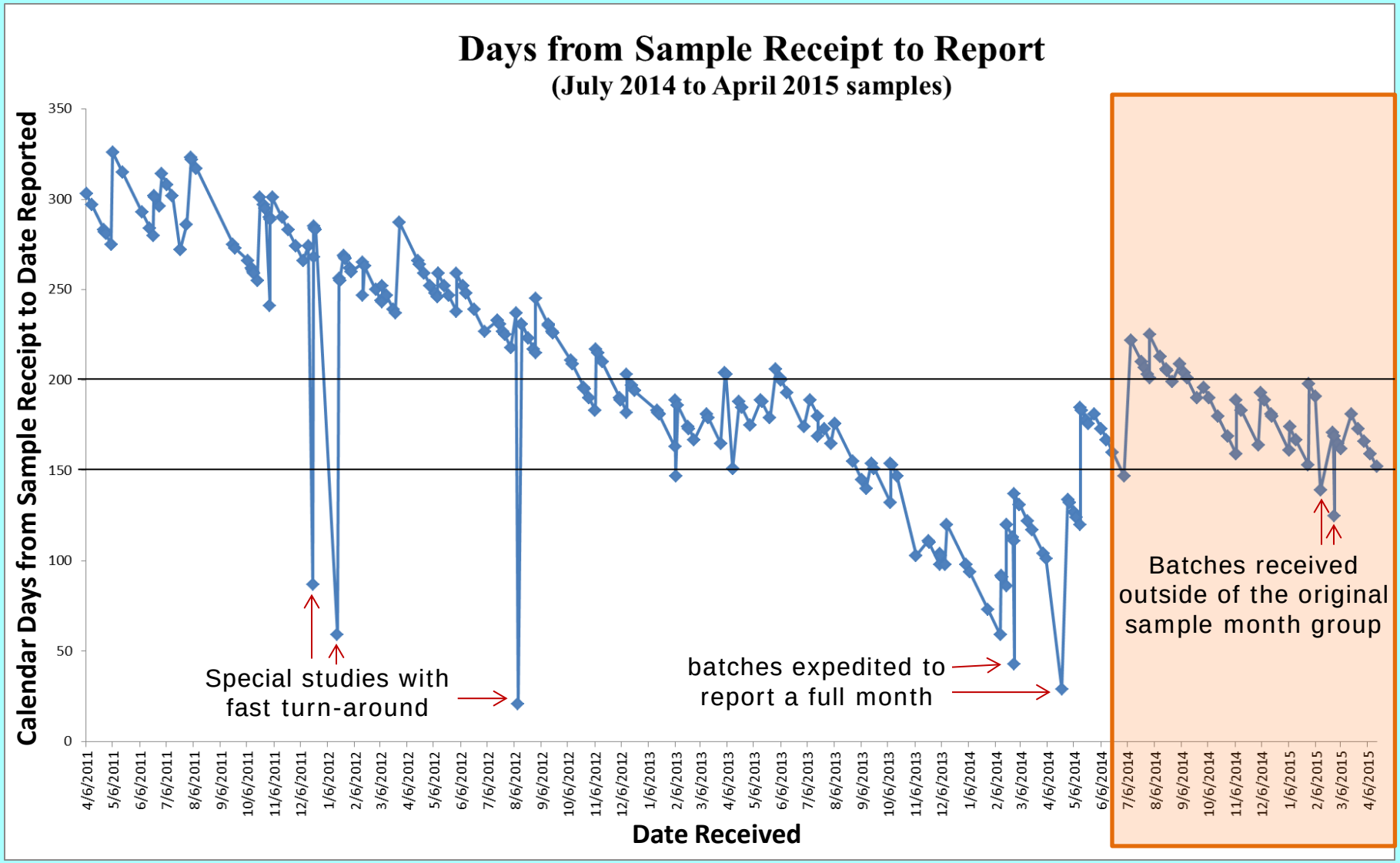
IMPROVE_A Carbon Analyses

(July 2014 to June 2015 samples)

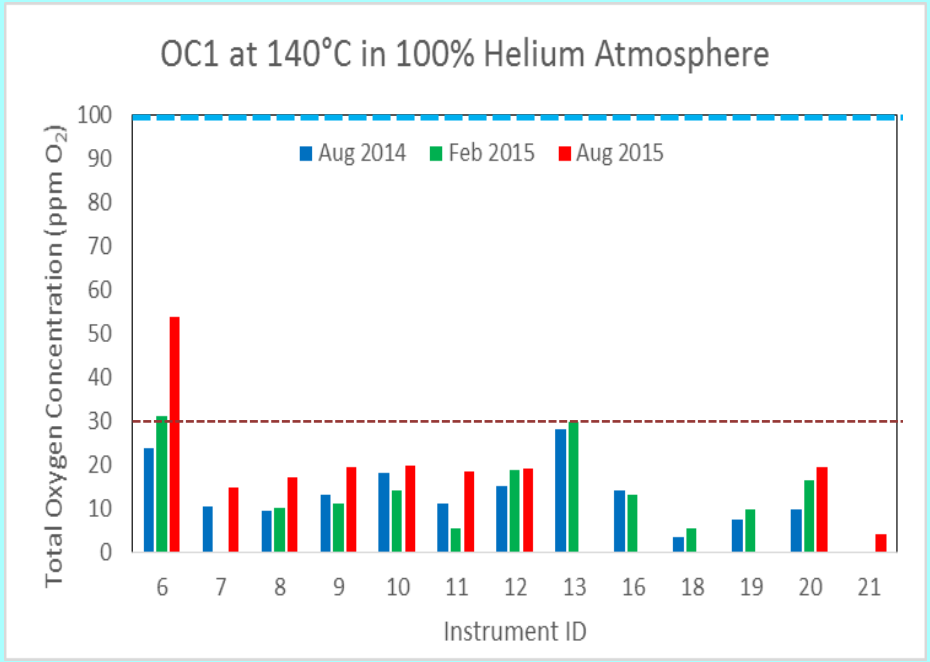
Sampling Period	Samples Received	Analysis Completion Date
7/1/14-12/31/14	9,966	May 2015
1/1/15-6/30/15	10,400	Est. November 2015

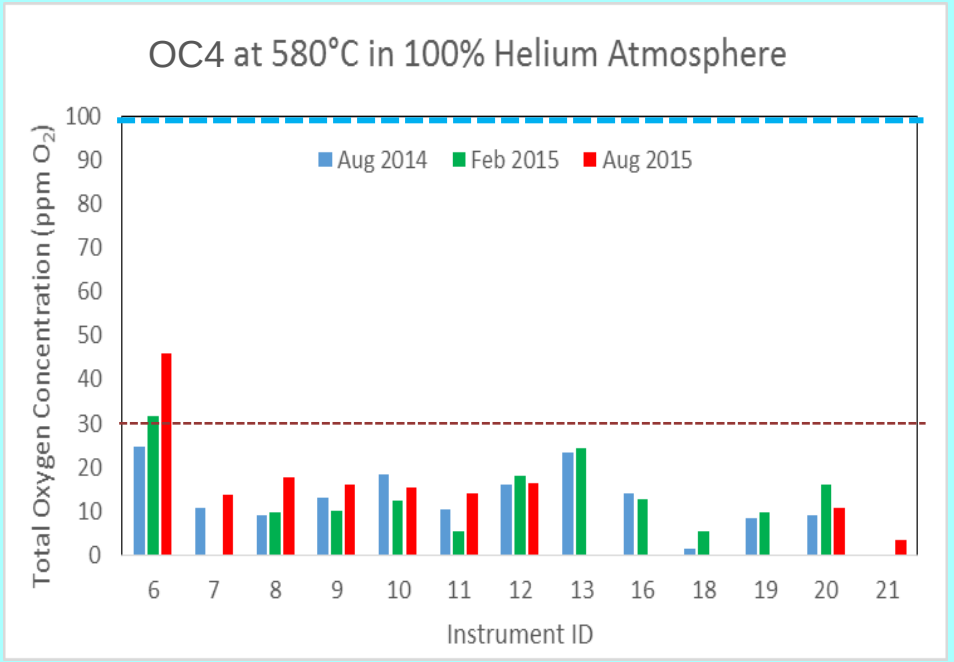
[a] Chow et al. (2007) *JAWMA*

IMPROVE carbon reporting time fluctuates between 150 and 200 days (increased frequency of instrument failures)



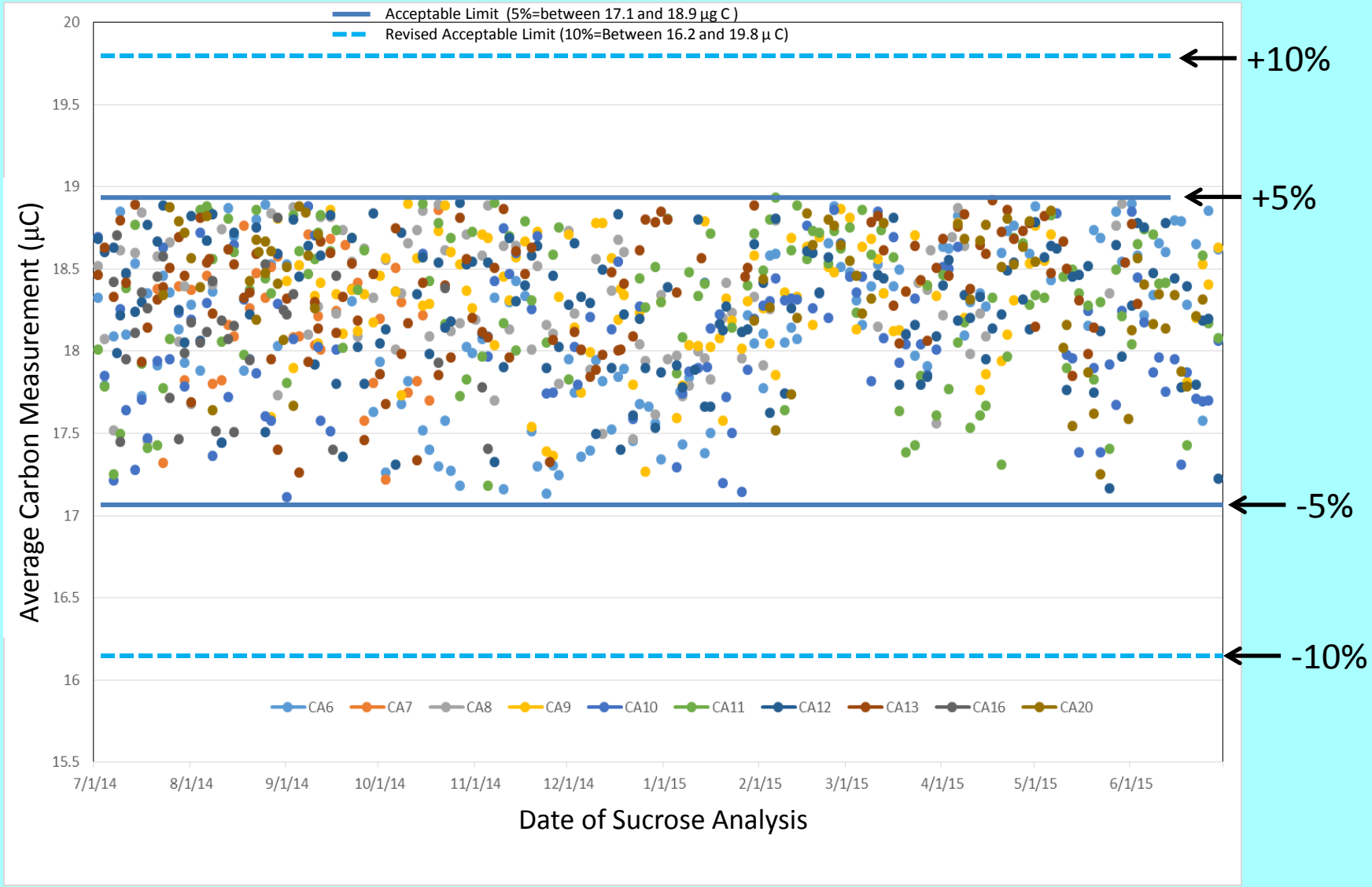
Traceable O_2 in pure He remains below 30 ppm (O_2 performance test limit is 100 ppm)





Thrice per week sucrose performance tests are within 5% tolerance

(Between 7/1/2014 and 6/30/2015, acceptance testing limits are ± 10%)



Current boards in Model 2001 became obsolete (working with Chinese firm to reverse engineer the boards)

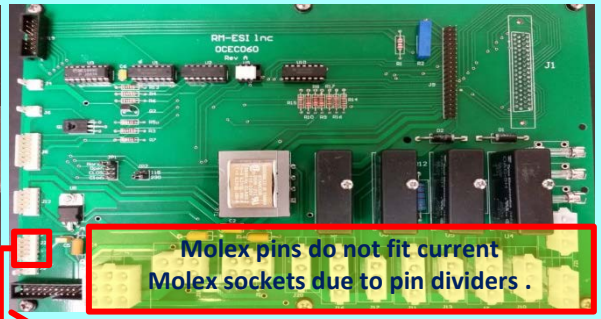
- Stepper Drive Control
- Signal Control
- Optical Shutter (Chopper) (Working after DRI modifications)

- Power Distribution (needs modification)

Original Power Board

J2 contains 4 pins

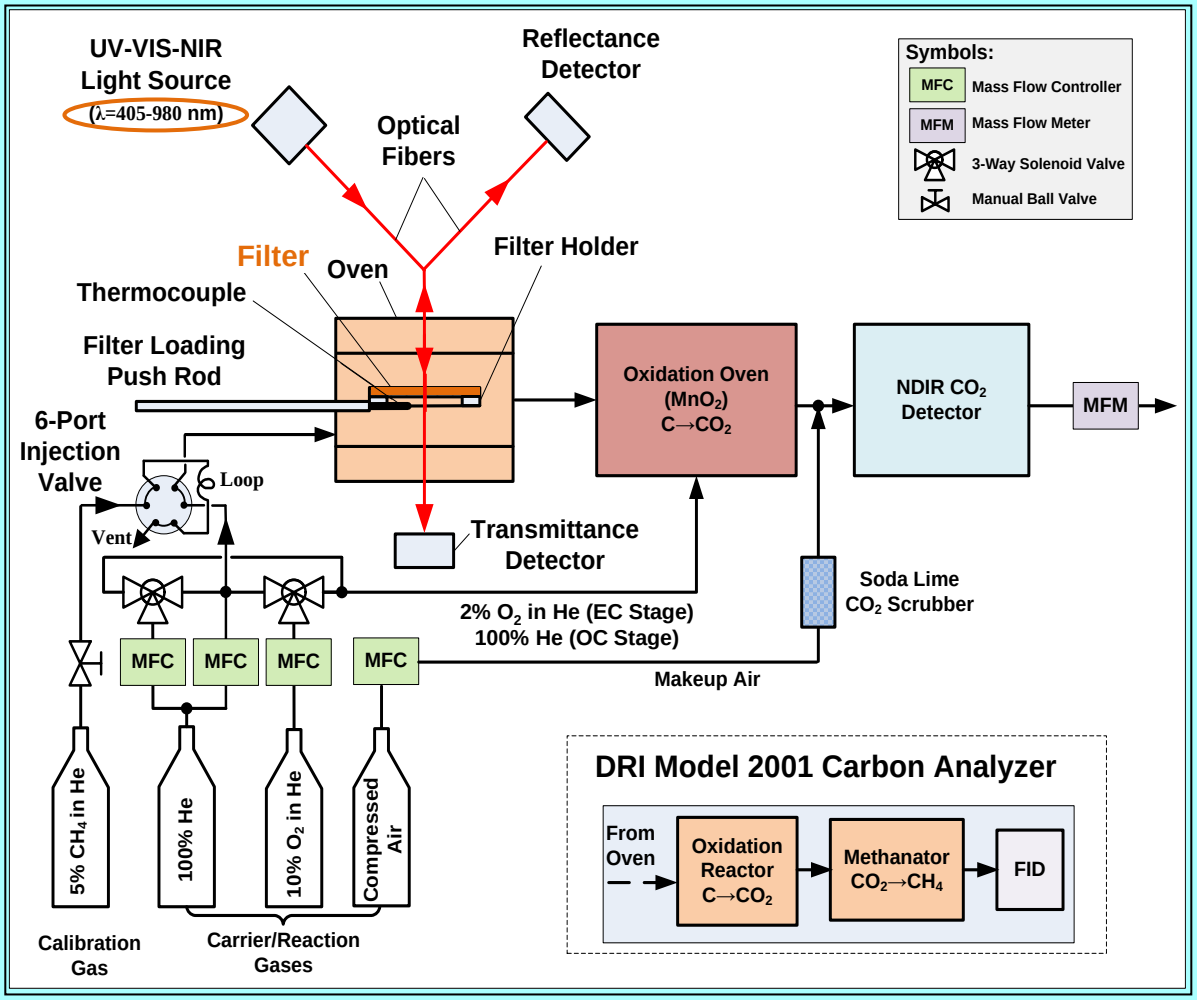
New Power Board



J2 contains 6 pins instead of 4

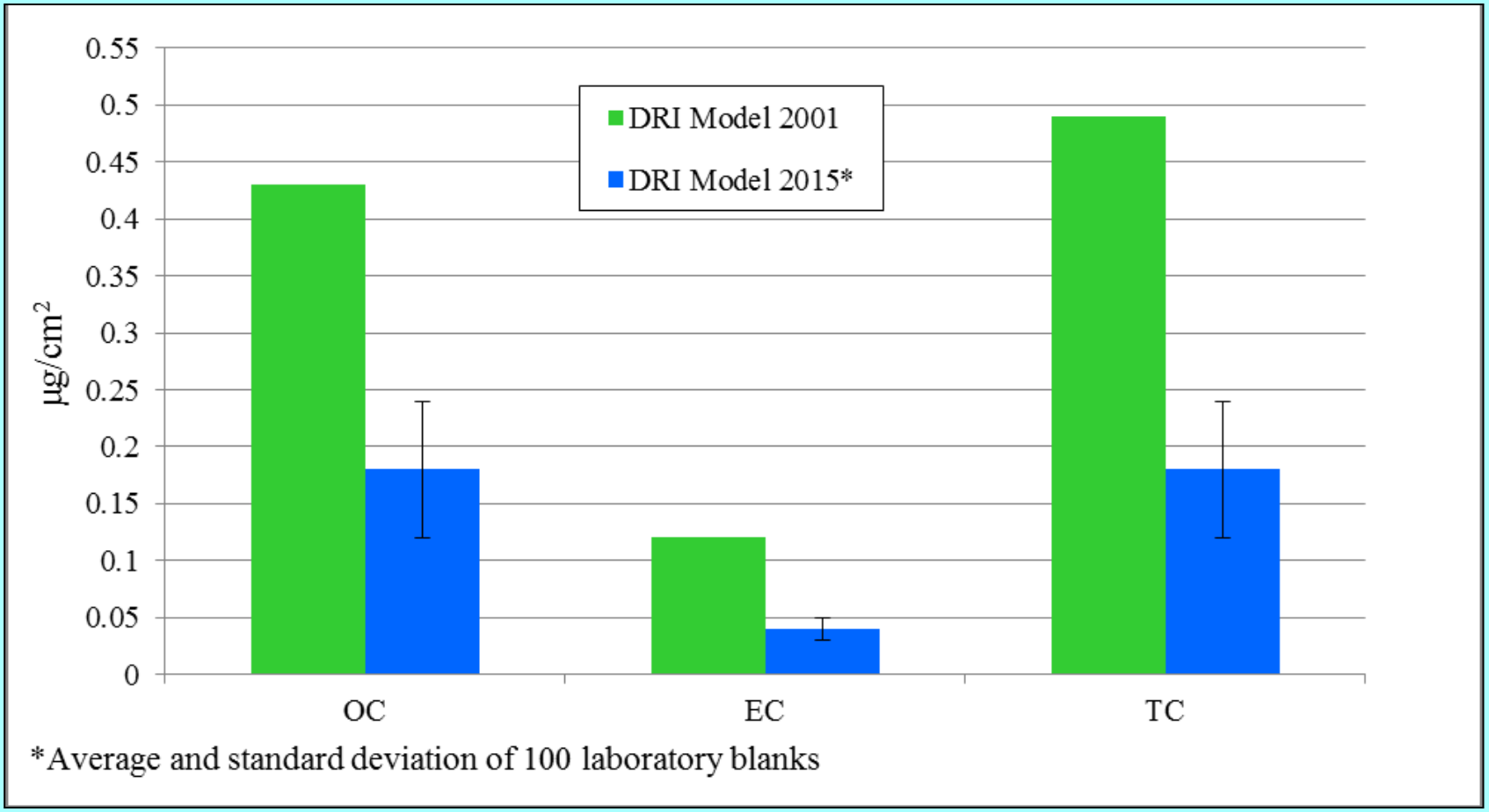
DRI Model 2015 has been designed, tested, and commercialized

(Magee Scientific, Berkeley, CA, USA)



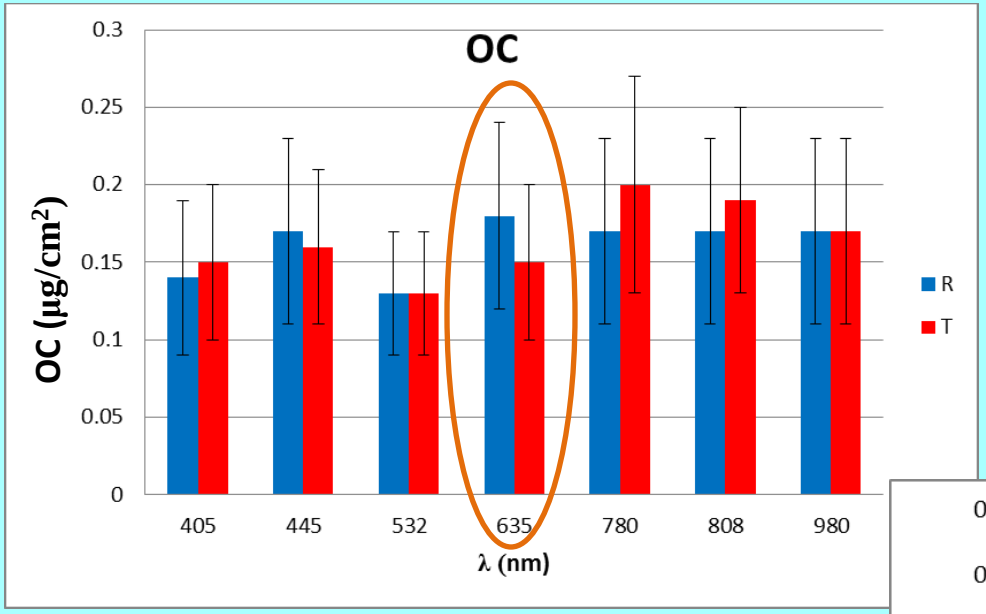
DRI Model 2015 configuration

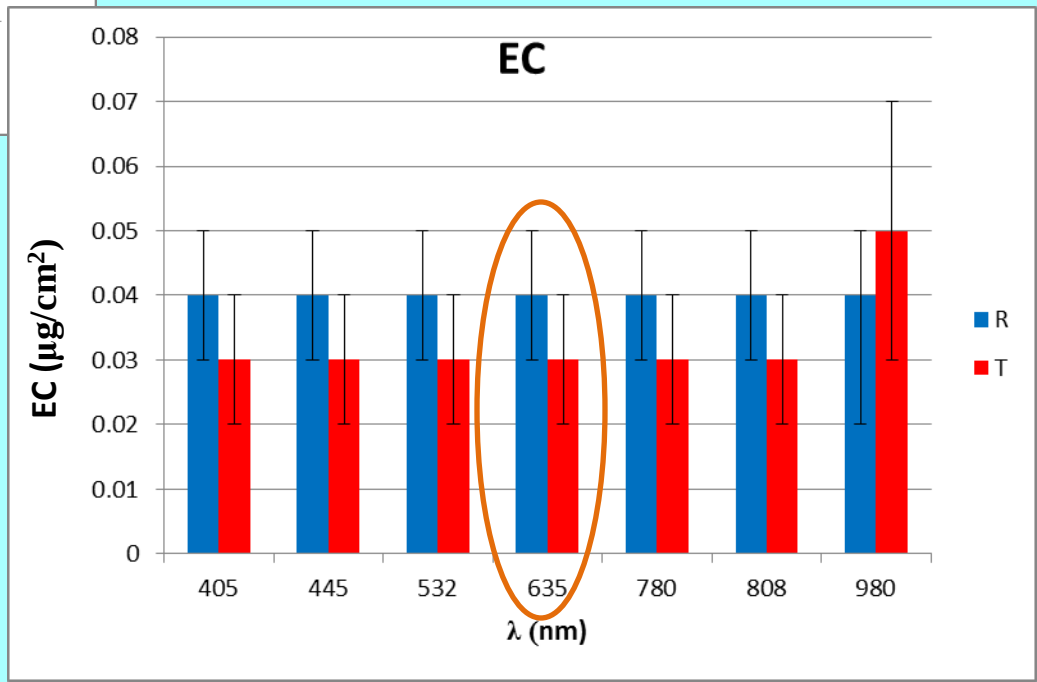
60-70% lower MDLs† are achieved



† Minimum Detectable Limits

MDLs are similar among the 7 wavelengths

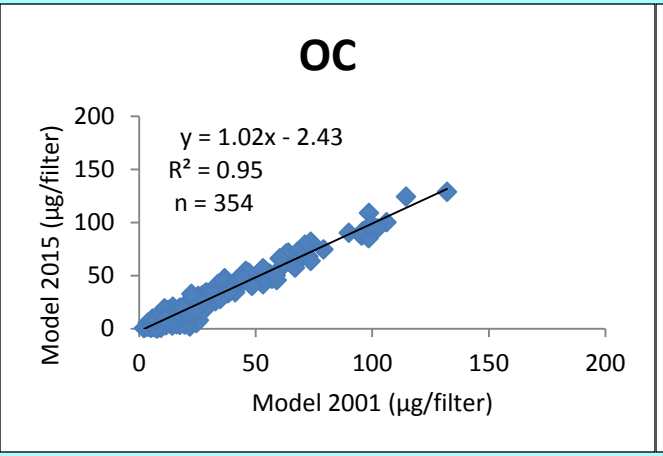


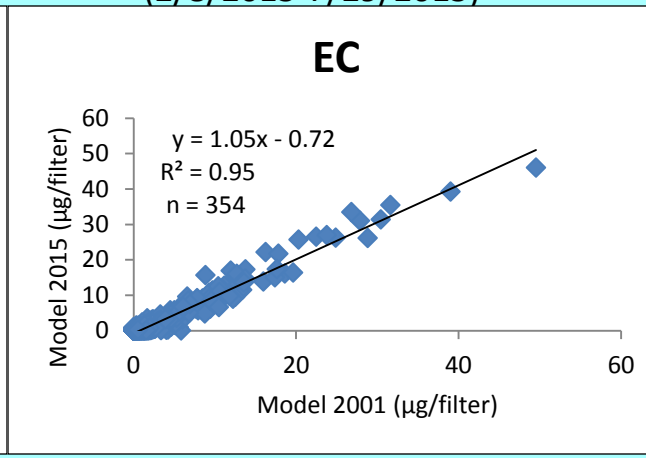


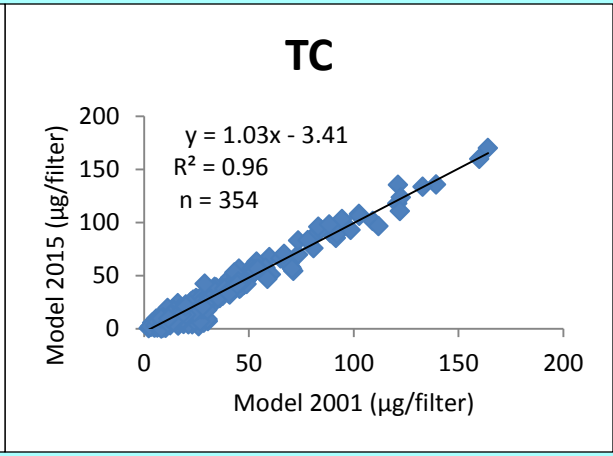
Began replicate analysis between Models 2001 and 2015 during Fall 2014 (equivalence in carbon found for >350 samples)

Model 2015 vs. Model 2001

(2/8/2015-7/29/2015)

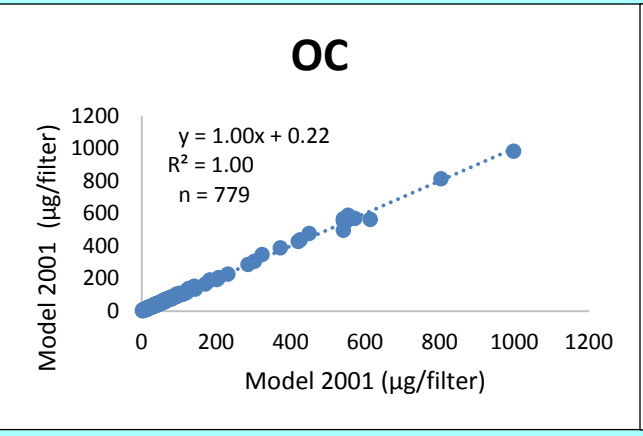


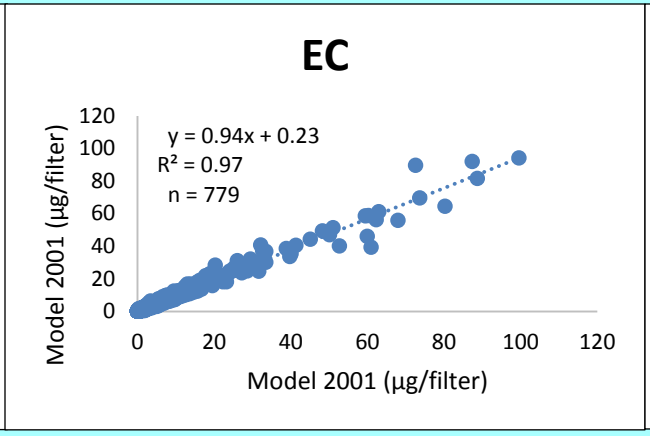


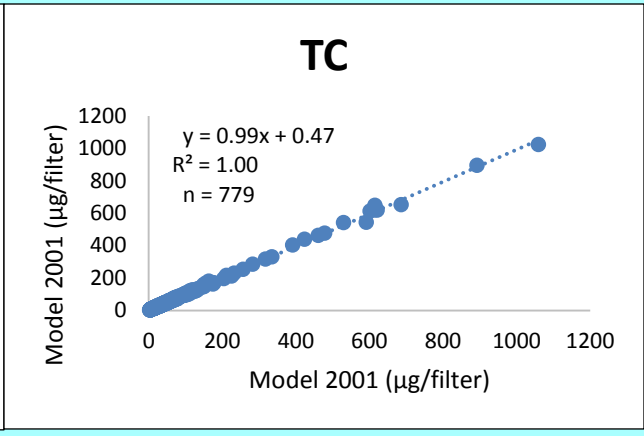


Model 2001 vs. Model 2001

(2/8/2015-7/29/2015)





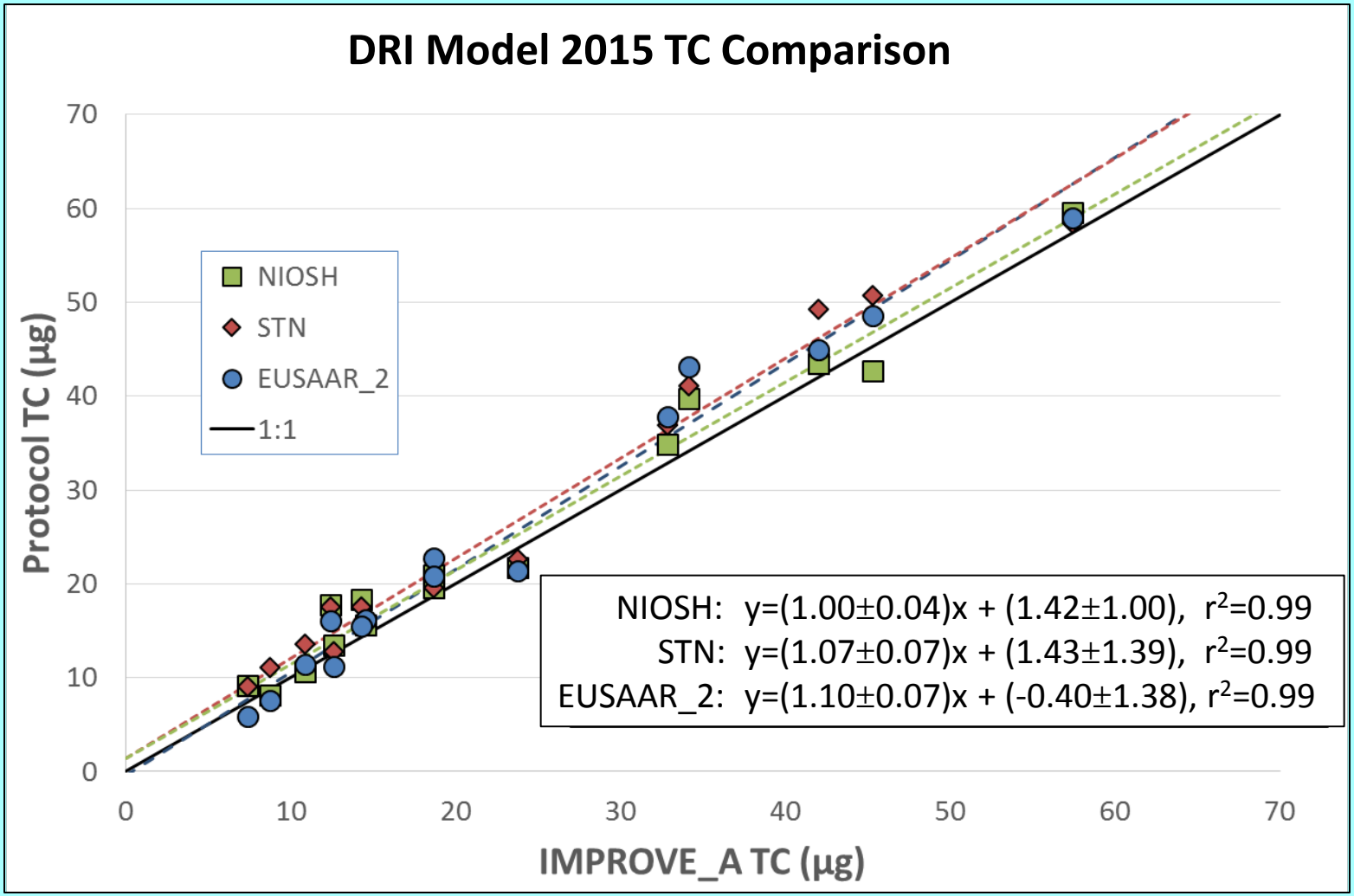


All temperature and optical (R or T) protocols can be implemented

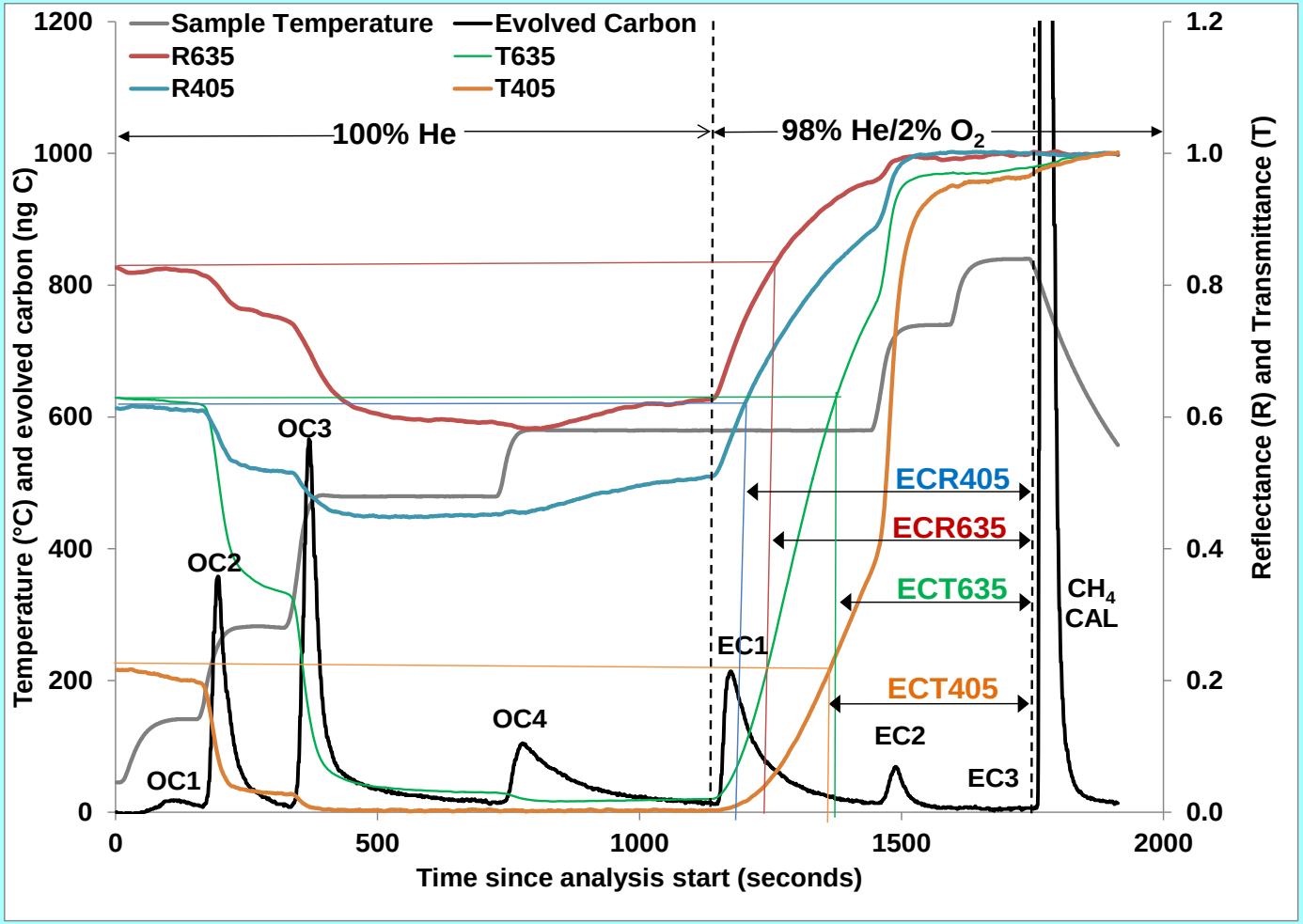
Common analysis protocols are pre-programmed

		IMPROVE_A		NIOSH		STN		EUSAAR_2	
	Atmosphere	Temp (°C)	Residence Time (t_r, sec)	Temp (°C)	Residence Time (t_r, sec)	Temp (°C)	Residence Time (t_r, sec)	Temp (°C)	Residence Time (t_r, sec)
OC1	Inert (He)	140	80-580	250	150	310	60	200	120
OC2	Inert	280	80-580	500	150	480	60	300	150
OC3	Inert	480	80-580	650	150	615	60	450	180
OC4	Inert	580	80-580	850	160	900	90	650	180
Cooling			N/A		45		45		45
EC1	Oxidizing (2% O_2 in He)	580	80-580	650	150	600	45	500	120
EC2	Oxidizing	740	80-580	750	150	675	45	550	120
EC3	Oxidizing	840	80-580	850	150	750	45	700	70
EC4	Oxidizing		N/A		N/A	825	45	850	80
EC5	Oxidizing		N/A		N/A	920	120		N/A

Comparable TC is found using different thermal/optical protocols, but OC and EC are different



For wood smoke dominated samples[a] EC_{405} (i.e., ECR and ECT at 405 nm) exceeds EC_{635}



[a] IMPROVE samples from Buffalo Pass, CO, USA, using multiwavelength IMPROVE_A protocol

Introduction of BrC in DRI Model 2015 requires redefinition of LAC_λ

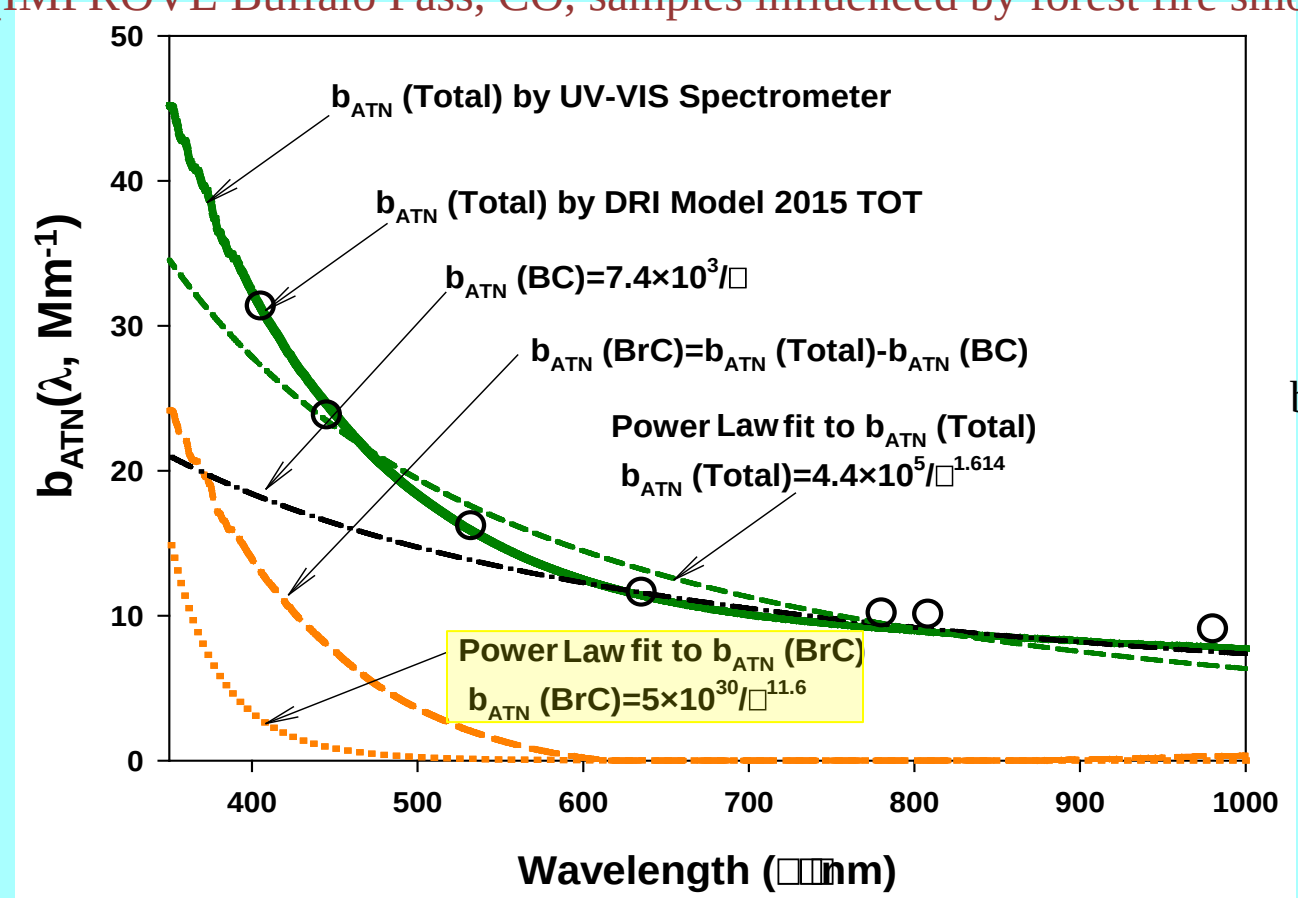
($LAC_\lambda = BC_\lambda + BrC_\lambda$)

- $EC_{633} = LAC_{633}$ (IMPROVE_A protocol in Model 2001)

- $EC_{405} = BrC_{405} + BC_{405}$ (For each wavelength in DRI Model 2015)
  $EC_{445} = BrC_{445} + BC_{445}$
  $EC_{532} = BrC_{532} + BC_{532}$
  $EC_{635} = BrC_{635} + BC_{635}$
  $EC_{780} = BrC_{780} + BC_{780}$
  $EC_{808} = BrC_{808} + BC_{808}$
  $EC_{980} = BrC_{980} + BC_{980}$

Continue software development to separate brown from black carbon (λ^{-AAE*} assumption does not necessarily provide a good fit to the measurements)

(IMPROVE Buffalo Pass, CO, samples influenced by forest fire smoke)



$$ATN_T(\lambda) = \ln\left(\frac{FT_{\lambda,F}}{FT_{\lambda,I}}\right)$$

$$b_{ATN}(\lambda, Mm^{-1}) = ATN(\lambda) \times \frac{\text{Area}}{\text{Volume}}$$

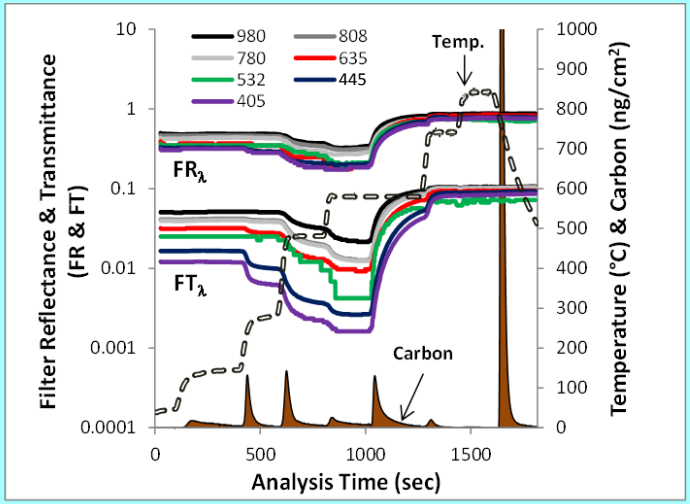
$$b_{ATN}(\lambda) \propto \lambda^{-AAE}$$

* AAE = Absorption Ångström Exponent

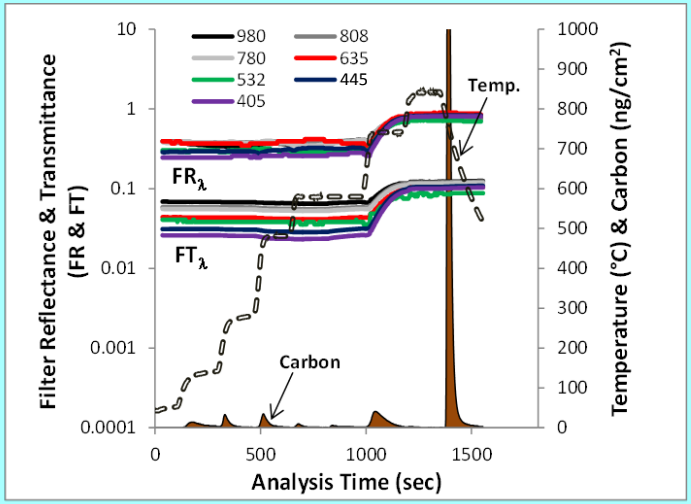
Transition Plan

- Start replicates on available Model 2015 units (3 units by December 2015 – total of 6-8 units by Spring 2016)
- Working with U.C. Davis team to begin 7 λ data reporting for samples collected after January 1, 2016 (~May 2016)

After Optical Calibration



Fresno Ambient Sample



Diesel Exhaust

DRI publications and reports using the IMPROVE protocol (2014 and 2015, n=17)

- Blanchard, C.L., Chow, J.C., Edgerton, E.S., Watson, J.G., Hidy, G.M., Shaw, S., 2014. Organic aerosols in the southeastern United States: Speciated particulate carbon measurements from the SEARCH network, 2006 to 2010. Atmos. Environ 95, 327-333.
- Chakrabarty, R.K., Pervez, S., Chow, J.C., Dewangan, S., Robles, J.A., Tian, G.X., Watson, J.G., 2014. Funeral pyres in south Asia: Large-scale brown carbon emissions and associated warming. Environmental Science & Technology Letters 1, 44-48.
- Chen, L.-W.A., Chow, J.C., Wang, X.L., Robles, J.A., Sumlin, B.J., Lowenthal, D.H., Watson, J.G., 2015a. Multi-wavelength optical measurement to enhance thermal/optical analysis for carbonaceous aerosol. Atmos. Meas. Tech 8, 451-461.
- Chen, L.-W.A., Han, Y.M., Chow, J.C., Watson, J.G., Cao, J.J., 2015b. Black carbon in urban dust and surface soil particles: Refining optical measurement for environmental pollution survey. J. Aerosol Sci, submitted.
- Cheng, Y., Lee, S.C., Gu, Z.L., Ho, K.F., Zhang, Y.W., Huang, Y., Chow, J.C., Watson, J.G., Cao, J.J., Zhang, R.J., 2015. PM2.5 and PM10-2.5 chemical composition and source apportionment near a Hong Kong roadway. Particuology 18, 96-104.
- Cheng, Z., Wang, S.X., Fu, X., Watson, J.G., Jiang, J.K., Fu, Q.Y., Chen, C.H., Xu, B.Y., Yu, J.S., Chow, J.C., Hao, J.M., 2014. Impact of biomass burning on haze pollution in the Yangtze River Delta, China: A case study of summer in 2011. Atmos. Chem. Phys 14, 4573-4585.
- Chow, J.C., Wang, X.L., Sumlin, B.J., Gronstal, S.B., Chen, L.-W.A., Trimble, D.L., Kohl, S.D., Mayorgal, S.R., Riggio, G.M., Hurbain, P.R., Johnson, M., Zimmermann, R., Watson, J.G., 2015a. Optical calibration and equivalence of a multiwavelength thermal/optical carbon analyzer. AAQR 15, 1145-1159.
- Chow, J.C., Yang, X.F., Wang, X.L., Kohl, S.D., Watson, J.G., 2015b. Characterization of ambient PM_{10} bioaerosols in a California agricultural town. AAQR 15, 1433-1447.
- Diab, J., Streibel, T., Cavalli, F., Lee.S.C., Saathoff, H., Mamakos, T., Chow, J.C., Chen, L.-W.A., Watson, J.G., Sippula, O., Zimmermann, R., 2015. Hyphenation of a EC/OC thermal-optical carbon analyzer to photo ionization time-of-flight mass spectrometry: A new off-line aerosol mass spectrometric approach for characterization of primary and secondary particulate matter. Atmos. Meas. Tech, 3337-3353.
- Eklund, A.G., Chow, J.C., Greenbaum, D.S., Hidy, G.M., Kleinman, M.T., Watson, J.G., Wyzga, R.E., 2014. Public health and components of particulate matter: The changing assessment of black carbon-Critical review discussion. JAWMA 64, 1221-1231.
- Gargava, P., Chow, J.C., Watson, J.G., Lowenthal, D.H., 2014. Speciated PM10 emission inventory for Delhi, India. AAQR 14, 1515-1526.
- Hand, J.L., Schichtel, B.A., Malm, W.C., Copeland, S., Molenar, J.V., Frank, N.H., Pitchford, M.L., 2014a. Widespread reductions in haze across the United States from the early 1990s through 2011. Atmos. Environ 94, 671-679.

DRI publications and reports using the IMPROVE protocol
(2014 and 2015, continued)

- Hand, J.L., Schichtel, B.A., Malm, W.C., Pitchford, M.L., Frank, N.H., 2014b. Spatial and seasonal patterns in urban influence on regional concentrations of speciated aerosols across the United States. J. Geophys. Res. Atmos 119, 12832-12849.
- Lowenthal, D.H., Zielinska, B., Samburova, V., Collins, D., Taylor, N., Kumar, N., 2015. Evaluation of assumptions for estimating chemical light extinction at US national parks. JAWMA 65, 249-260.
- Orasche, J., Seidel, T., Hartmann, H., Schnelle-Kreis, J., Chow, J.C., Ruppert, H., Zimmermann, R., 2012. Comparison of emissions from wood combustion. Part 1: Emission factors and characteristics from different small-scale residential heating appliances considering particulate matter and polycyclic aromatic hydrocarbon (PAH)-related toxicological potential of particle-bound organic species. Energy & Fuels 26, 6695-6704.
- Pervez, S., Chakrabarty, R.K., Dewangan, S., Watson, J.G., Chow, J.C., Matawle, J.L., Pervez, Y., 2015. Cultural and ritual burning emission factors and activity levels in India. AAQR 15, 72-80.
- Schwander, S., Okello, C.D., Freers, J., Chow, J.C., Watson, J.G., M., C., Q.Y., M., 2014. Particulate matter air pollution in Mpererwe District, Kampala, Uganda - A pilot study. Journal of Environmental and Public Health 2014, 1-7.
- Tang, D.L., Li, T.Y., Chow, J.C., Kulkarni, S.U., Watson, J.G., Ho, S.S.H., Quan, Z.Y., Qu, L.R., Perera, F., 2014. Air pollution effects on fetal and child development: A cohort comparison in China. Environ. Poll 185, 90-96.