Update of IMPROVE Carbon Analysis

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Presented at:

2021 IMPROVE Technical Steering Committee Meeting

Virtual Meeting

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Objectives

- Report status of IMPROVE carbon analyses

- **Review internal quality control (QC) checks**

- Discuss operational challenges and improvements

DRI's Environmental Analysis Facility (EAF) continuously operates 10-13 Model 2015 Multiwavelength Carbon Analyzers

(2016-Present, analyzed over ~225,000 samples with ~100,000 for IMPROVE)

EAF Carbon Laboratory (Magee Scientific, Berkeley, CA and Aerosol, d.o.o., Ljubljana, Slovenia)

Carbon Laboratory Operations

(July 2020 – June 2021 samples, n= ~12,000)

- **Received ~1,660 IMPROVE samples per month** (varies from 0 to 4,800 samples per month)

- **Operated ~13 hours per day, 5 days per week, increased to ~18 hours per day, 7 days per week since August.**

- **Vinay Amin moved to the Financial Services Office and is pursuing his MBA degree. Matt Claassen has assumed responsibility since June 2021.**

Vinay

Matt

Completed analyses of 2020 samples in August 2021 and currently analyzing May 2021 samples
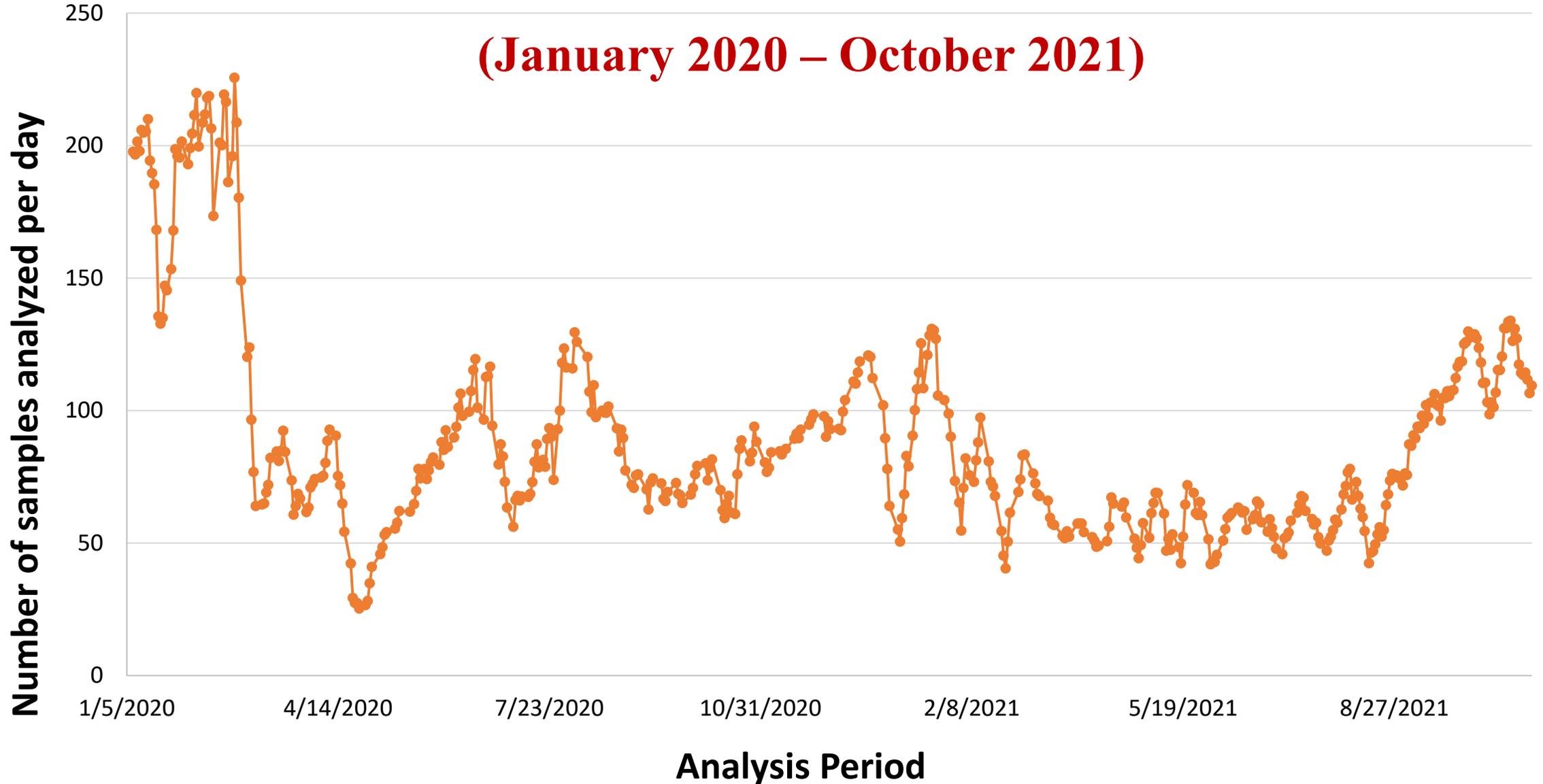
(July 2020 to June 2021 samples)

Sampling Period	Sample Receive Dates	Number of Samples Received	Analysis Completion Date
7/1/20 – 12/31/20	8/25/20 – 4/14/21	10,016	August 2021
1/1/21 – 6/30/21	4/30/21 – 9/30/21*	9,961*	December 2021 (est.)

*as of 11/08/21

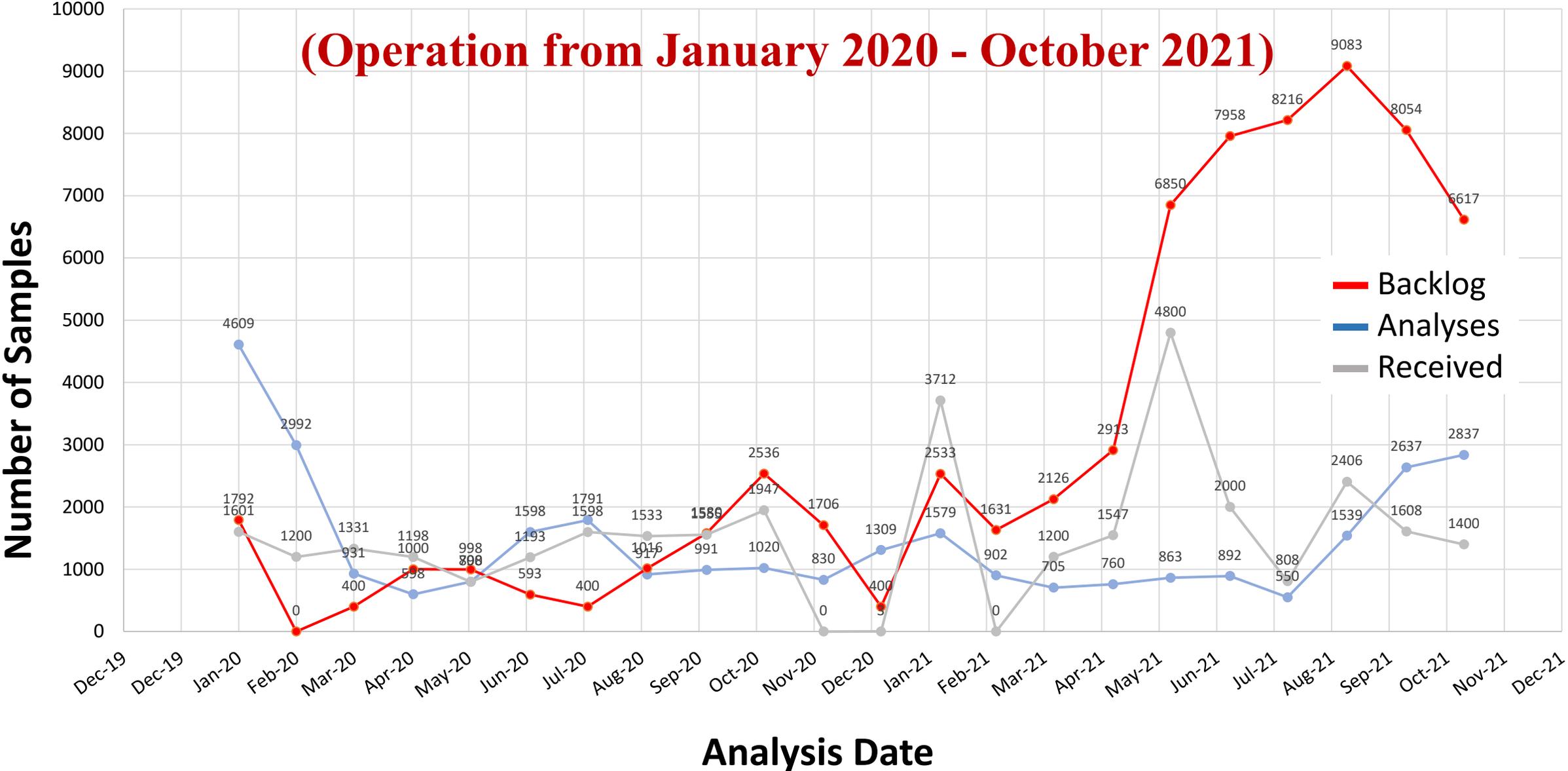# Carbon throughput averaged ~90 samples per day*

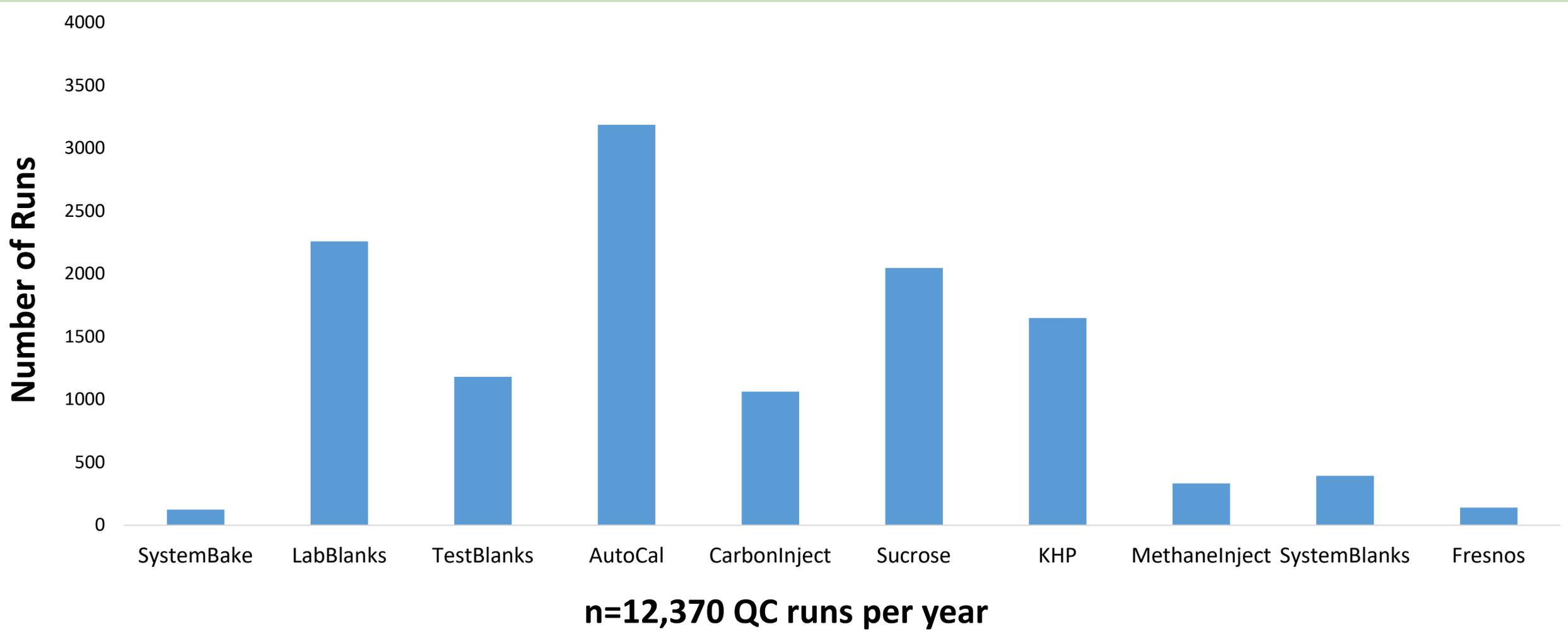

(January 2020 – October 2021)

*Excludes calibration runs and includes other projects
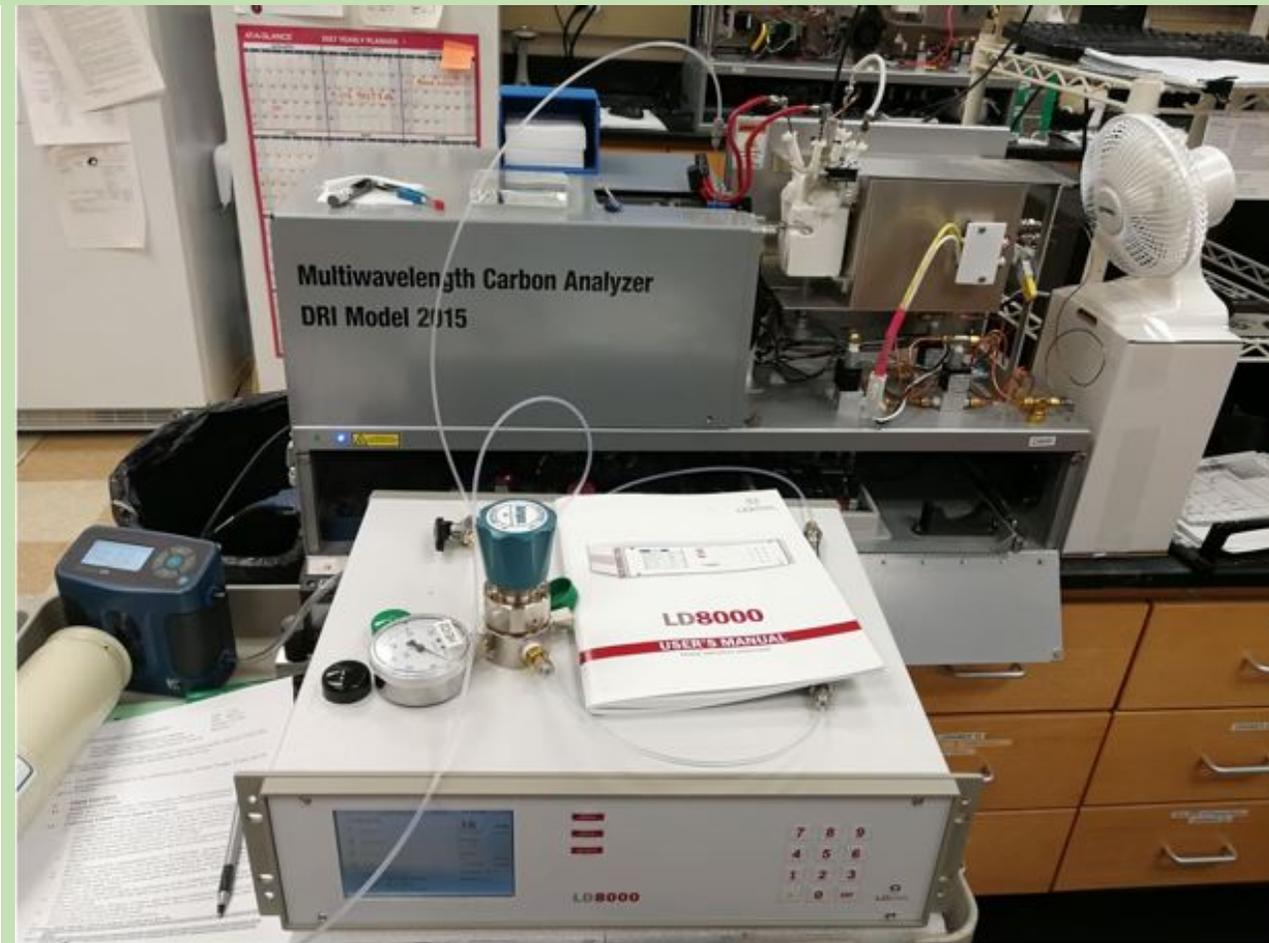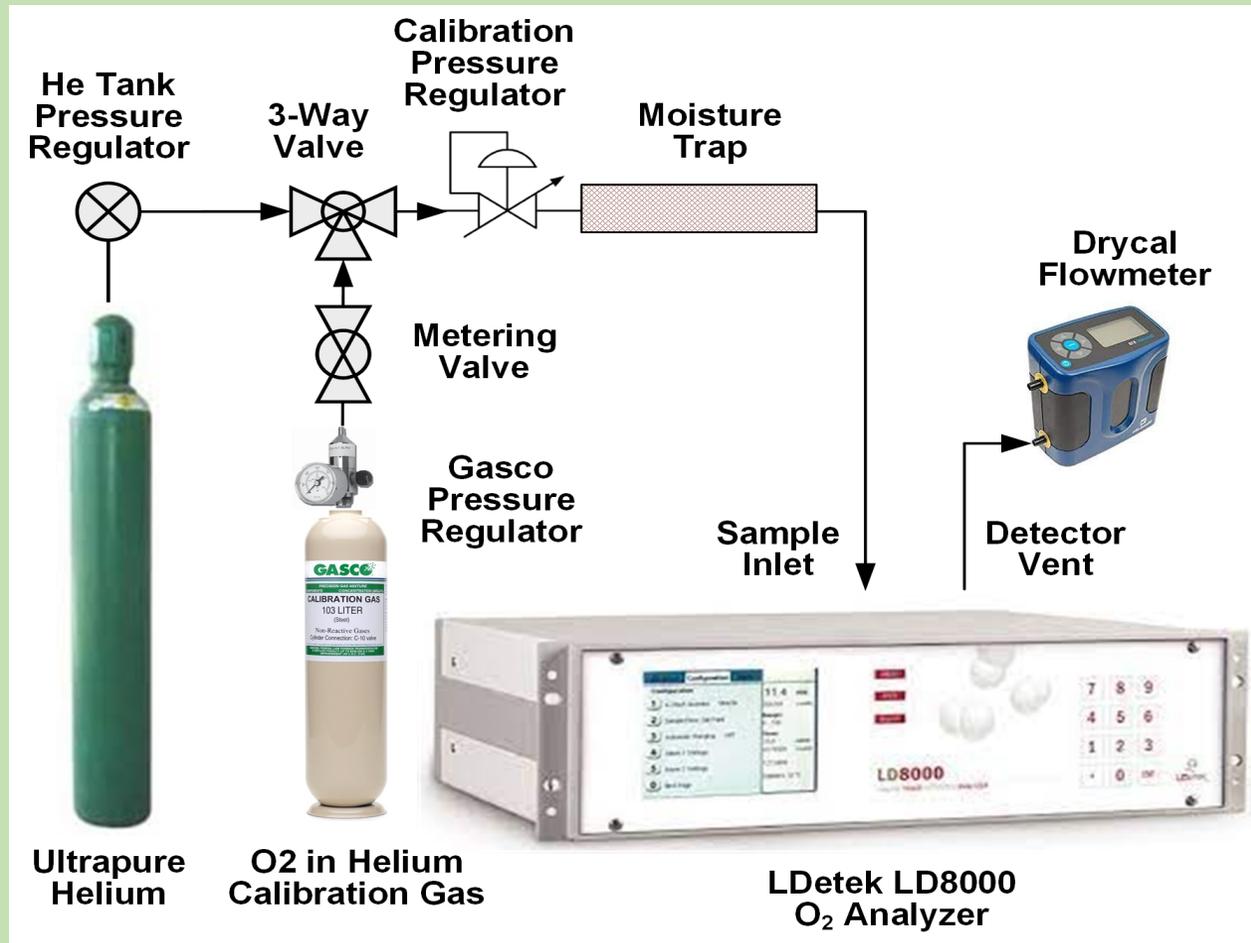
Average 34 runs per day are dedicated to multiple quality control (QC) checks
(October 2020 - September 2021)

A more efficient oxygen test was implemented to verify $O_2 < 100$ ppm in the He carrier gas (measured $O_2 < 60$ ppm)

All DRI Model 2015 Carbon Analyzers are tested for trace oxygen on a semi-annual basis

Established new protocols for data validation

- **Automated procedures to increase accuracy and efficiency**
  - Generate comparisons for replicates, reruns, and collocated samples
  - **Identify extreme values (e.g., high, low, zero, and negative)**
  - Monitor deviations from calibration peaks and sending alert to signal instrument malfunction
  - **Streamline data validation and reporting**

- **Created visualization tools**
  - Examine relationship between light attenuation and elemental carbon
  - **Evaluate temporal variation (e.g., comparison with historical medians)**

Sample rerun rates have been reduced from 8% to 3%
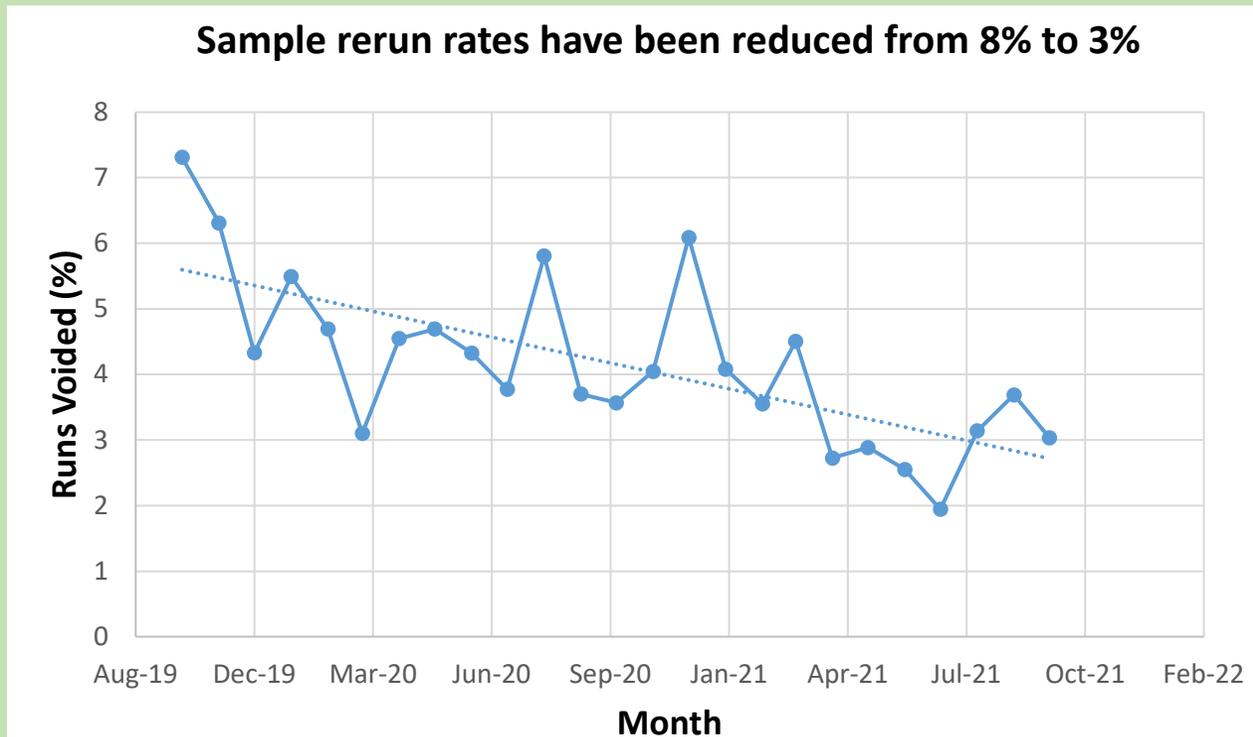
Additional protocols were added to facilitate efficient data validation

- **Implemented additional automated processes**
  - Find missing or mislabeled runs
  - **Inspect manual inputs for correctness**
  - Automate final report generation and replicate acceptance for uncertainty calculations

- **Use Machine Learning for future automation in data validation**
  - Apply large historical dataset for model training
  - **Rerun prediction is approaching 60% accuracy during testing**

Recent publications highlight the applications for multiwavelength data and brown carbon

Contents lists available at ScienceDirect

Particuology

ELSEVIER

Invited paper

Improved estimation of PM$_{2.5}$ brown carbon contributions to filter light attenuation

Judith C. Chow [a,b,c,*], L.-W. Antony Chen [a,d], Xiaoliang Wang [a,c], Mark C. Green [a,c], John G. Watson [a,b,c]

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ENVIRONMENTAL Science & Technology

Article

Brownness of Organic Aerosol over the United States: Evidence for Seasonal Biomass Burning and Photobleaching Effects

Lung-Wen Antony Chen,* Judith C. Chow, Xiaoliang Wang, Junji Cao, Jingqiu Mao, and John G. Watson

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Geophysical Research Letters

RESEARCH LETTER

Key Points:
- Model with whitening can largely reproduce spatial and temporal variability of brown carbon in US.
- Biogenic SOA appears to be of minor importance to BrC.
- BrC absorption direct radiative effects appear to be most significant over Arctic region during spring and summer.

Supporting Information:
- Supporting Information S1

Spatial and Temporal Variability of Brown Carbon in the United States: Implications for Direct Radiative Effects

Nicole A. June[1], Xuan Wang[2], L.-W. Antony Chen[3], Judith C. Chow[4], John G. Watson[4], Xiaoliang Wang[4], Barron H. Henderson[5], Yiqi Zheng[1], and Jingqiu Mao[1]

[1]Department of Chemistry and Biochemistry and Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA, [2]School of Energy and Environment, City University of Hong Kong, Hong Kong SAR, China, [3]Department of Environmental and Occupational Health, University of Nevada, Las Vegas, NV, USA, [4]Division of Atmospheric Sciences, Desert Research Institute, Reno, NV, USA, [5]Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA

Empirical adjustment factors of 2-4 may be needed to apportion light absorption to BC and BrC

Chow et al. 2021, Particuology
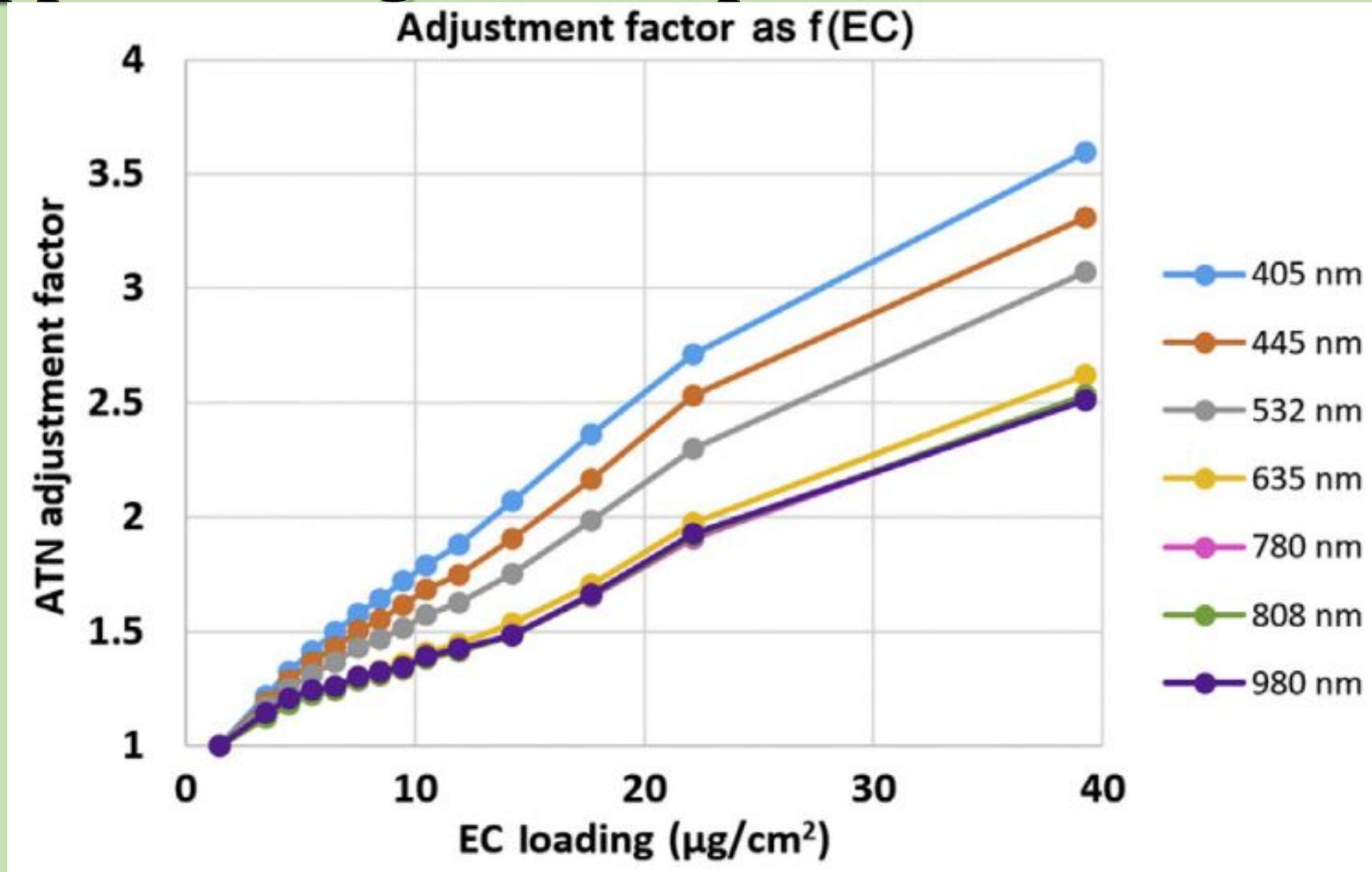
Filter loading adjusted ATN$_{BrC,405}$ tripled for CSN (3.6 to 10.7%) and 1.25 times for IMPROVE (23.7 to 29.5%)

Chow et al. 2021, Particuology
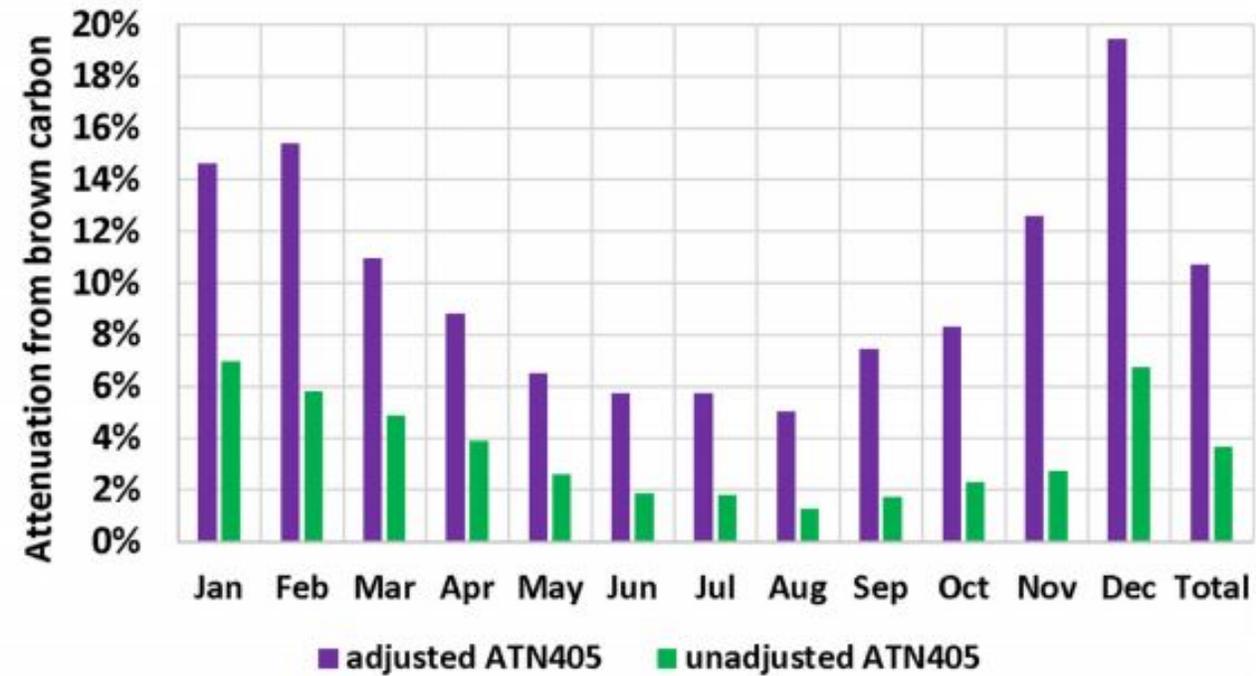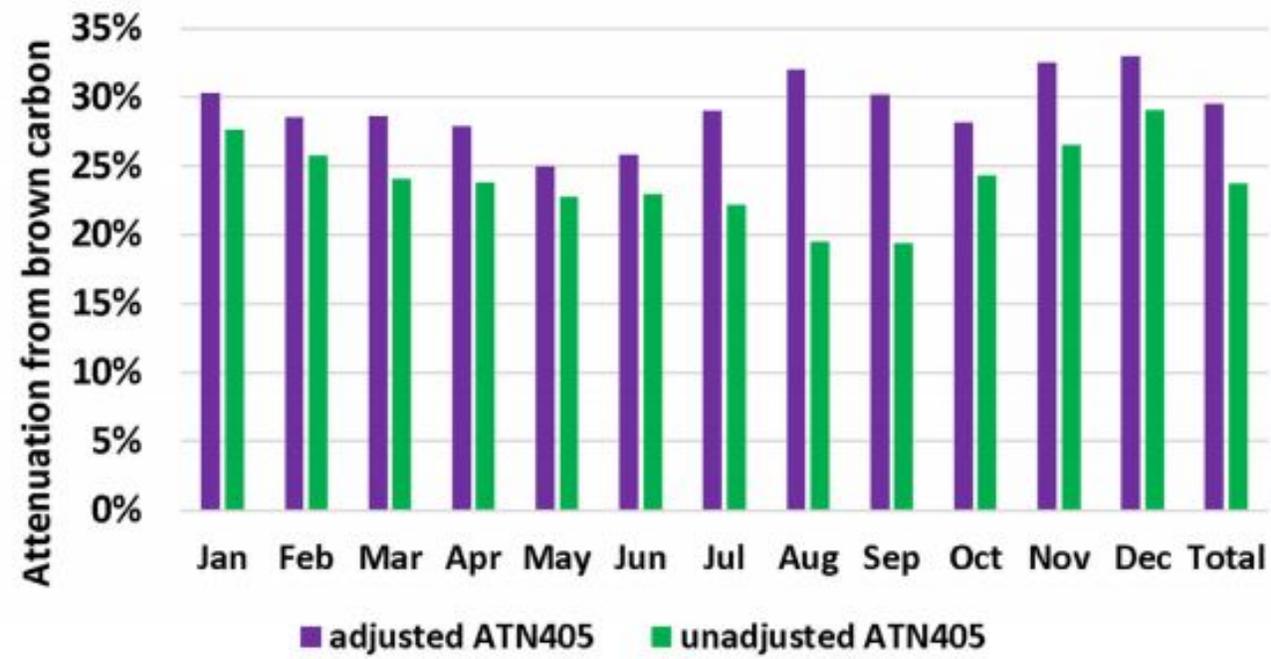
Using paired wavelength derived AAE$_{BC}$ increased BrC light attenuation for CSN by twofold (10.7 to 21.6%) and for IMPROVE by 11% (29.5 to 32.7%)

Chow et al. 2021, Particuology
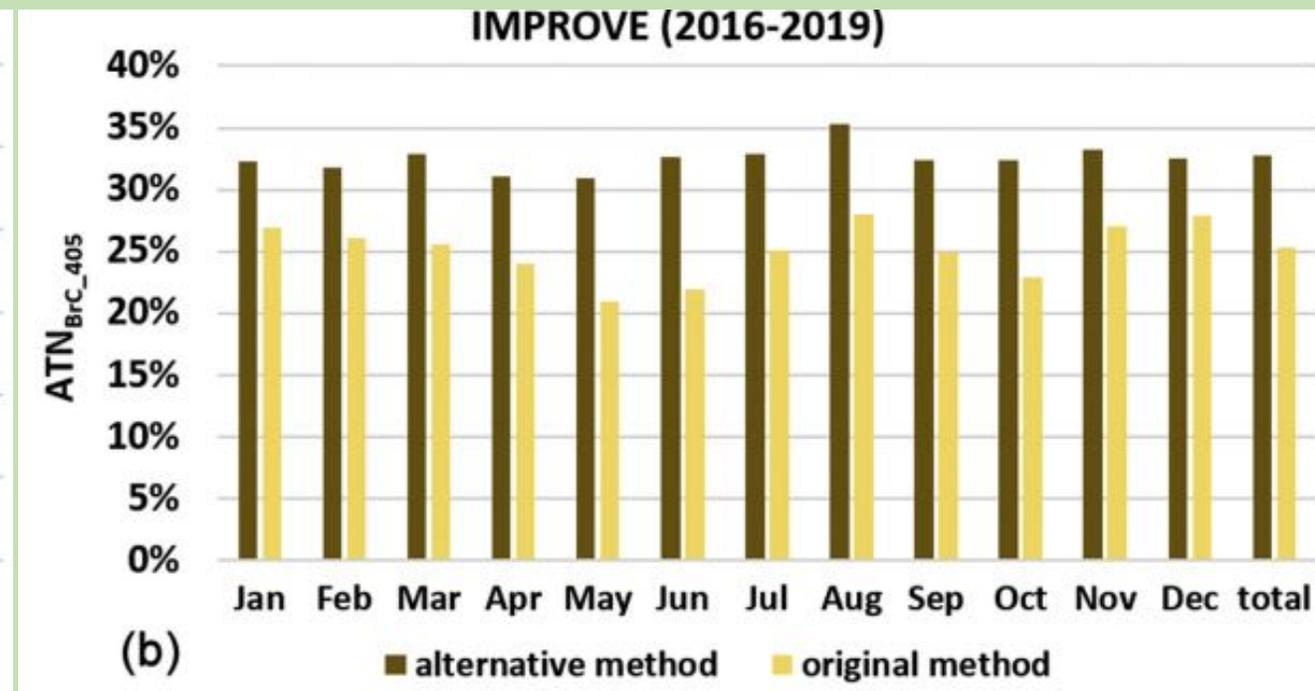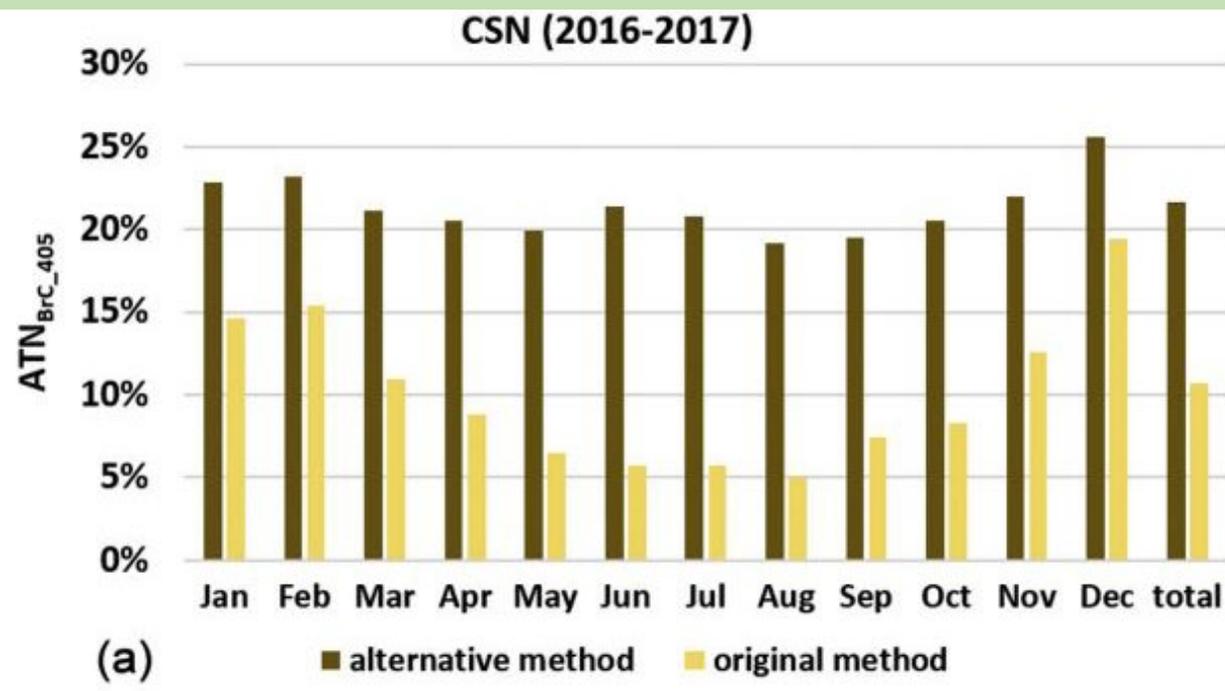
Large seasonal variations found in brownness of organic aerosol
(Higher brownness index during winter than summer months)

Chen et al., 2021, EST
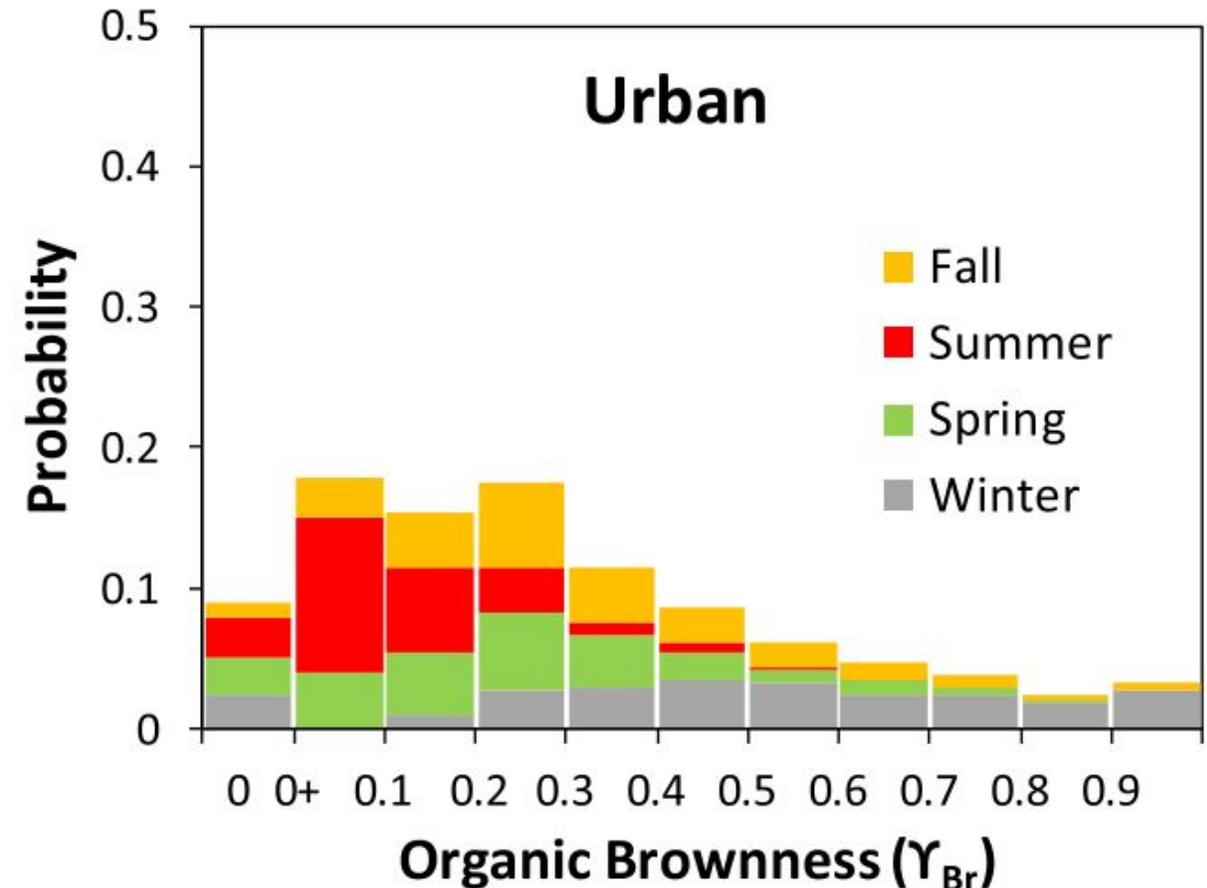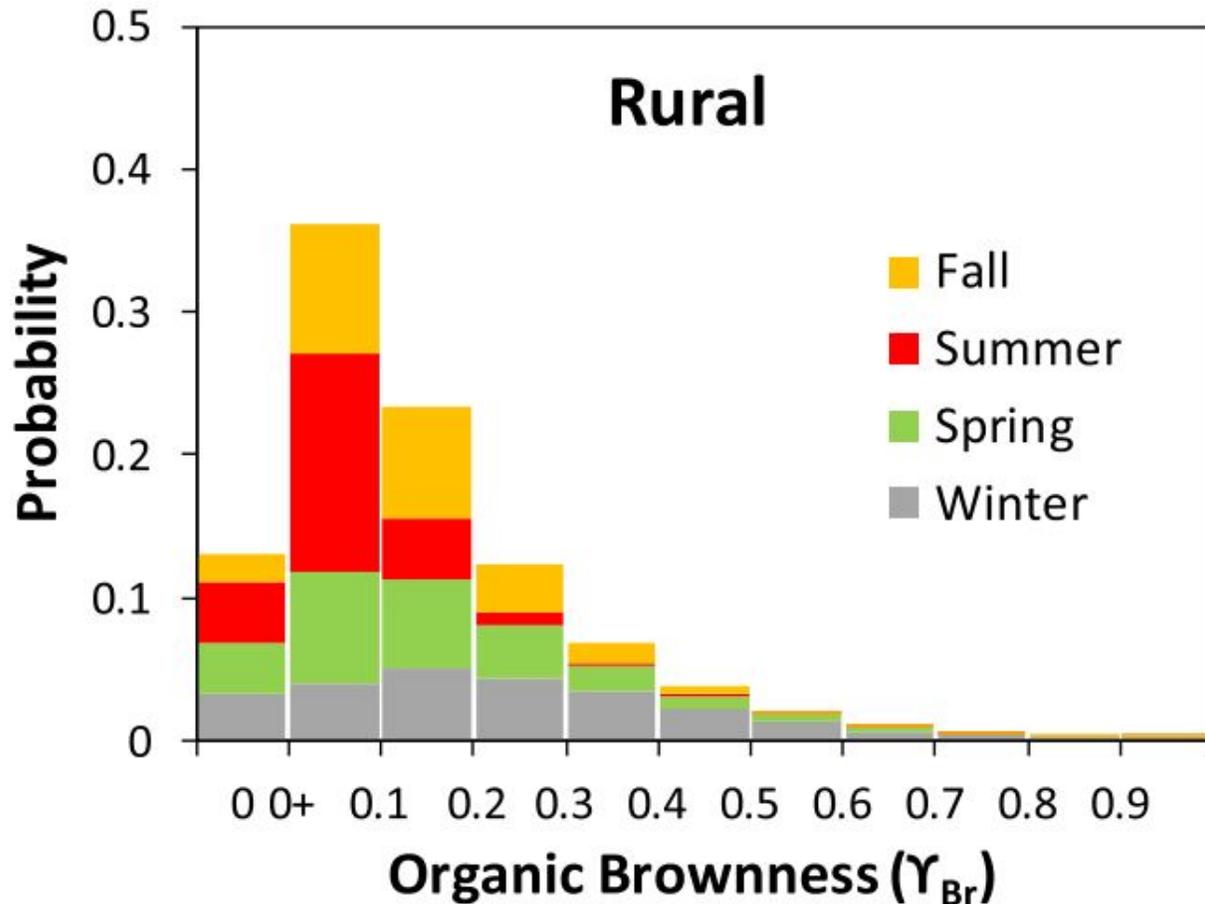
Higher brownness index during winter in the Northeastern and Midwest regions

(IMPROVE winter [June, Feb, & Dec] and summer [June, July, & Aug])

γ_{BrC}, brownness index= [BrC]/[OC*] with γ_{BrC} between 0 to 1

Chen et al., 2021, EST
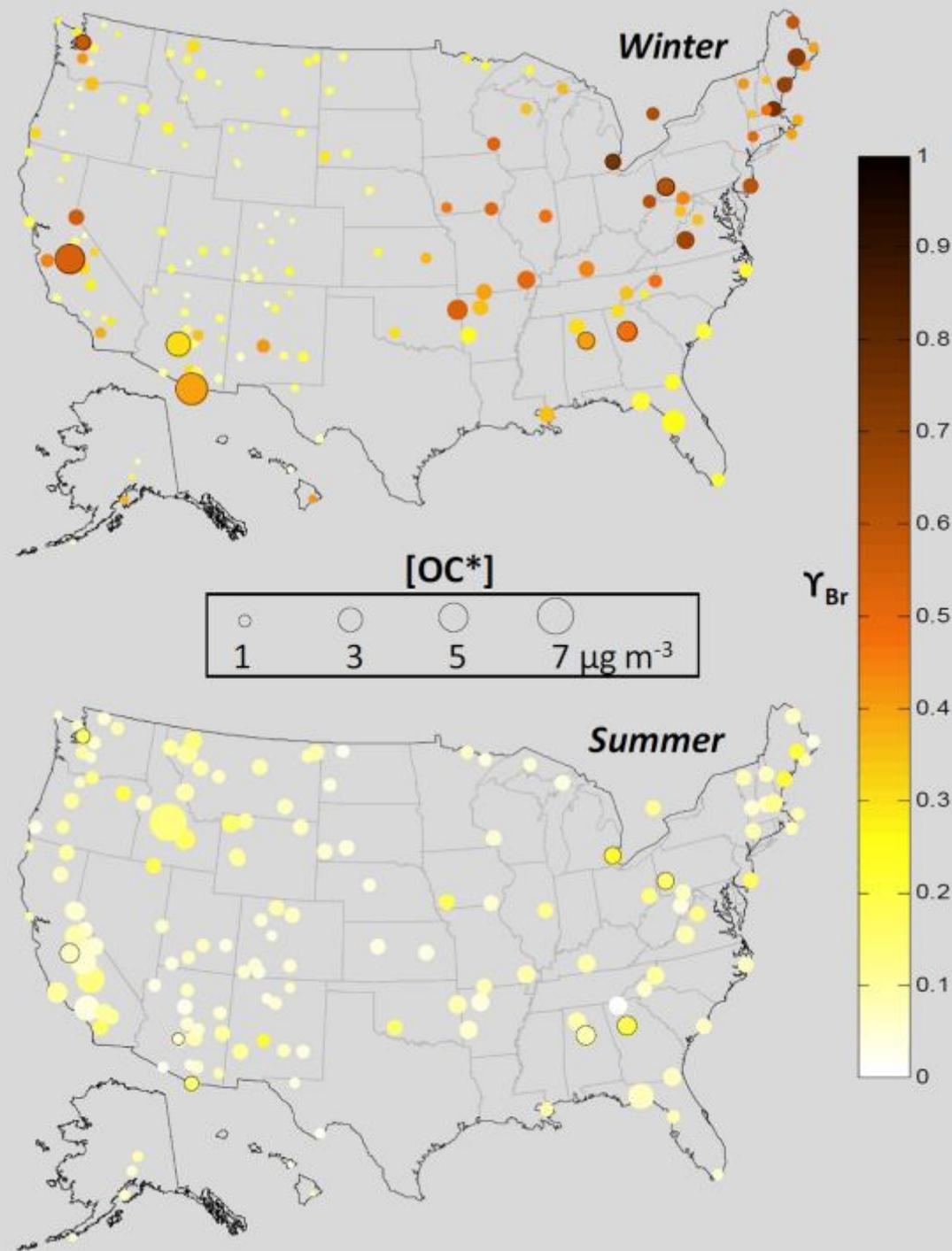
GEOS-Chem/GCM models reproduce the spatiotemporal pattern of BrC$_{AAOD}$*

(Circles are IMPROVE BrC)
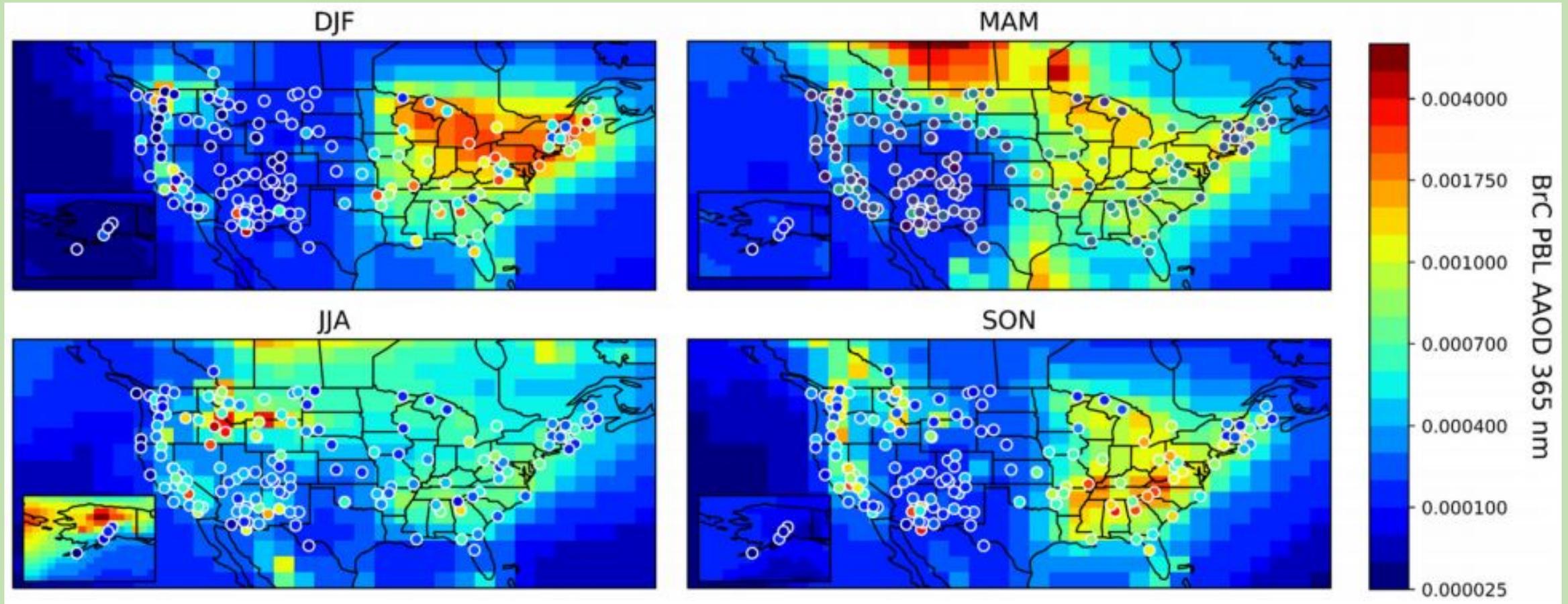
PBL AAOD: Planetary Boundary Layer Absorption Aerosol Optical Depth at 365 nm

$= MAC_{BrC\lambda} \times Mass_{BrC} \times PBL_{height}$

June et al., 2020, GRL

BrC absorption radiative effect (DRE) shows higher impacts over the Northern high latitude
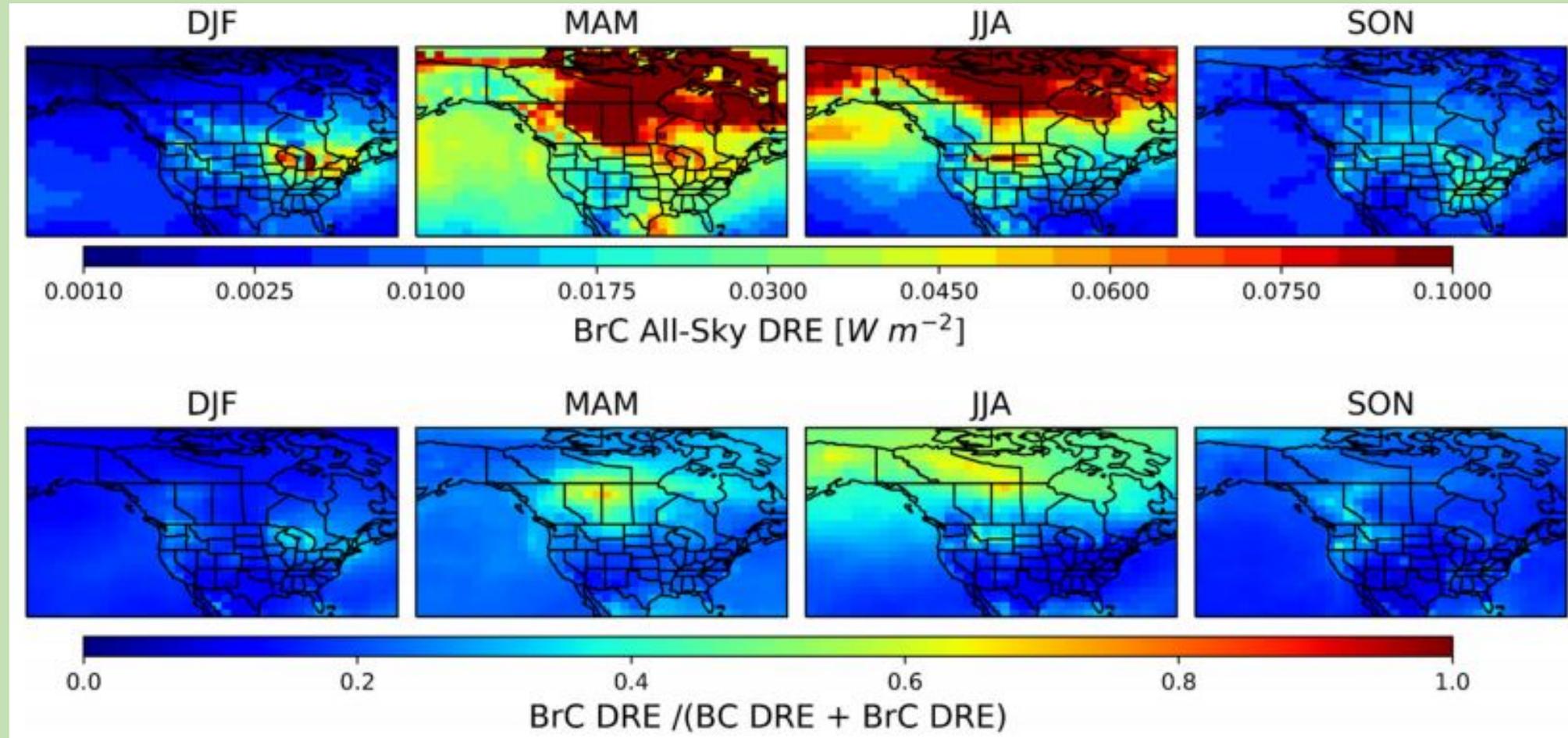
BrC can account for over 50% of BC+BrC warming in Northern high latitude during spring and summer

June et al., 2020, GRL

Example 2020-2021 publications and reports using the IMPROVE_A protocol (n= 45)

- Abbasi, B., Wang, X.L., Chow, J.C., Watson, J.G., Peik, B., Nasiri, V., Riemenschnitter, K.B., Elahifard, M., (2021). Review of respirable coal mine dust characterization for mass concentration, size distribution and chemical composition. Minerals, 11, 426. 10.3390/min11040426.

- Aldhaif, A.M., Lopez, D.H., Dadashazar, H., Sorooshian, A., (2020). Sources, frequency, and chemical nature of dust events impacting the United States East Coast. Atmospheric Environment, 231, 10.1016/j.atmosenv.2020.117456.

- Bian, Q.J., Ford, B., Pierce, J.R., Kreidenweis, S.M., (2020). A cecadal climatology of chemical, physical, and optical properties of ambient smoke in the western and southeastern United States. Journal of Geophysical Research-Atmospheres, 125, 10.1029/2019jd031372.

- Bürki, C., Reggente, M., M. Dillner, A., L. Hand, J., L. Shaw, S., Takahama, S., (2020). Analysis of functional groups in atmospheric aerosols by infrared spectroscopy: Method development for probabilistic modeling of organic carbon and organic matter concentrations. Atmospheric Measurement Techniques, 13, 1517-1538. 10.5194/amt-13-1517-2020.

- Carter, T.S., Heald, C.L., Jimenez, J.L., Campuzano-Jost, P., Kondo, Y., Moteki, N., Schwarz, J.P., Wiedinmyer, C., Darmenov, A.S., da Silva, A.M., Kaiser, J.W., (2020). How emissions uncertainty influences the distribution and radiative impacts of smoke from fires in North America. Atmospheric Chemistry and Physics, 20, 2073-2097. 10.5194/acp-20-2073-2020.

- Chen, D., Zhao, Y., Zhang, J., Yu, H., Yu, X.N., (2020). Characterization and source apportionment of aerosol light scattering in a typical polluted city in the Yangtze River Delta, China. Atmospheric Chemistry and Physics, 20, 10193-10210. 10.5194/acp-20-10193-2020.

- Chen, L.-W.A., Chow, J.C., Wang, X.L., Cao, J.J., Mao, J.Q., Watson, J.G., (2021). Brownness of organic aerosol over the United States: Evidence for seasonal biomass burning and photobleaching effects. Environmental Science & Technology, 55, 8561-8572. 10.1021/acs.est.0c08706.

- Chen, Y., Dombek, T., Hand, J., Zhang, Z., Gold, A., Ault, A.P., Levine, K.E., Surratt, J.D., (2021). Seasonal Contribution of Isoprene-Derived Organosulfates to Total Water-Soluble Fine Particulate Organic Sulfur in the United States. Acs Earth and Space Chemistry, 5, 2419-2432. 10.1021/acsearthspacechem.1c00102.

- Cheng, Y., Chow, J.C., Watson, J.G., Zhou, J.M., Liu, S.X., Cao, J.J., (2021). Decreasing concentrations of carbonaceous aerosols in China from 2003 to 2013 Scientific Reports, 11 5352. 10.1038/s41598-021-84429-w.

- Chow, J.C., Chen, L.-W.A., Wang, X.L., Green, M.C., Watson, J.G., (2021). Improved estimation of $PM_{2.5}$ brown carbon contributions to filter light attenuation. Particuology, 56, 1-9. 10.1016/j.partic.2021.01.001.

- Christiansen, A.E., Carlton, A.G., Henderson, B.H., (2020). Differences in fine particle chemical composition on clear and cloudy days. Atmospheric Chemistry and Physics, 20, 11607-11624. 10.5194/acp-20-11607-2020.

- Christiansen, A.E., Carlton, A.G., Porter, W.C., (2020). Changing nature of organic carbon over the United States. Environmental Science and Technology, 54, 10524-10532. 10.1021/acs.est.0c02225.

- Du, Y.Y., Chen, J., Zhang, J.L., Gan, G.C., Liu, Y.C., Su, M.X., Lou, S.R., Zhou, M., Tao, S.K., Qiao, L.P., (2020). Observation of aerosol optical properties and new particle formation in the Yangtze River Delta. Huanjing Kexue/Environmental Science, 41, 3932-3940. 10.13227/j.hjkx.201911271.

- Gantt, B., McDonald, K., Henderson, B., Mannshardt, E., (2020). Incorporation of remote PM2.5 concentrations into the downscaler model for spatially fused air quality surfaces. Atmosphere, 11, 10.3390/ATMOS11010103.

- Gonzalez, M.E., Garfield, J.G., Corral, A.F., Edwards, E.L., Zeider, K., Sorooshian, A., (2021). Extreme aerosol events at Mesa Verde, Colorado: Implications for air quality management. Atmosphere, 12, 10.3390/atmos12091140.

- Gorham, K.A., Raffuse, S.M., Hyslop, N.P., White, W.H., (2021). Comparison of recent speciated PM2.5 data from collocated CSN and IMPROVE measurements. Atmospheric Environment, 244, 10.1016/j.atmosenv.2020.117977.

- Guo, L., Cui, Y., He, Q., Gao, W., Pei, K., Zhu, L., Li, H., Wang, X., (2021). Contributions of aerosol chemical composition and sources to light extinction during haze and non-haze days in Taiyuan, China. Atmospheric Pollution Research, 12, 10.1016/j.apr.2021.101140.

- Hand, J.L., Prenni, A.J., Copeland, S., Schichtel, B.A., Malm, W.C., (2020). Thirty years of the Clean Air Act Amendments: Impacts on haze in remote regions of the United States (1990-2018). Atmospheric Environment, 243, 10.1016/j.atmosenv.2020.117865.

Example 2020-2021 publications and reports using the IMPROVE_A protocol (n= 45)

- June, N.A., Wang, X., Chen, L.-W.A., Chow, J.C., Watson, J.G., Wang, X.L., Henderson, B.H., Zheng, Y.Q., Mao, J.Q., (2020). Spatial and temporal variability of brown carbon in the United States: Implications for direct radiative effects. Geophysical Research Letters, 47, 10.1029/2020GL090332.

- Kumar, A., Singh, S., Kumar, N., Singh, N., Kumar, K., Chourasiya, S., (2021). Assessment of carbonaceous fractions in ambient aerosols at high altitude and lowland urban locations of Kumaon Province, Indian Himalaya. Sn Applied Sciences, 3, 10.1007/s42452-020-04010-4.

- Kumar, A., Singh, S., Kumar, N., Singh, N., Kumar, K., Mishra, A.K., Chourasiya, S., Kushwaha, H.S., (2021). Seasonal abundance and source attribution of carbonaceous aerosols at different altitude of mountainous locations in Uttarakhand Himalaya. Aerosol Science and Engineering, 5, 233-246. 10.1007/s41810-021-00098-2.

- Li, N., Wei, X., Han, W.H., Sun, S.Y., Wu, J.H., (2020). Characteristics and temporal variations of organic and elemental carbon aerosols in PM1 in Changchun, Northeast China. Environmental Science and Pollution Research, 27, 8653-8661. 10.1007/s11356-019-07494-9.

- Li, X., Xie, P., Li, A., Xu, J., Ren, H., Ren, B., Li, Y., Li, J., (2021). Study of aerosol characteristics and sources using MAX-DOAS measurement during haze at an urban site in the Fenwei Plain. Journal of Environmental Sciences (China), 107, 1-13. 10.1016/j.jes.2020.12.015.

- Liao, W.J., Zhou, J.B., Zhu, S.J., Xiao, A.S., Li, K., Schauer, J.J., (2020). Characterization of aerosol chemical composition and the reconstruction of light extinction coefficients during winter in Wuhan, China. Chemosphere, 241, 10.1016/j.chemosphere.2019.125033.

- Ma, Q.X., Wu, Y.F., Fu, S.L., Zhang, D.Z., Han, Z.W., Zhang, R.J., (2020). Pollution severity-dependent aerosol light scattering enhanced by inorganic species formation in Beijing haze. Science of the Total Environment, 719, 10.1016/j.scitotenv.2020.137545.

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- Malm, W.C., Schichtel, B.A., Hand, J.L., Prenni, A.J., (2020). Implications of organic mass to carbon ratios increasing over time in the rural United States. Journal of Geophysical Research-Atmospheres, 125, 10.1029/2019jd031480.

- Mardi, A.H., Dadashazar, H., Painemal, D., Shingler, T., Seaman, S.T., Fenn, M.A., Hostetler, C.A., Sorooshian, A., (2021). Biomass burning over the United States east coast and western North Atlantic Ocean: Implications for clouds and air quality. Journal of Geophysical Research-Atmospheres, 126, 10.1029/2021jd034916.

- Nava, V., Das, K.C., Amin, V., Gronstal, S., Wang, X.L., Chow, J.C., Watson, J.G., Yang, Y., (2021). Quantification of carboxyl-functionalized multiwall carbon nanotubes in plant tissues with programmed thermal analysis. Journal of Environmental Quality, 50, 278–285. 10.1002/jeq2.20180.

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- Niu, X.Y., Chuang, H.C., Wang, X.L., Ho, S.S.H., Li, L.J., Qu, L.L., Chow, J.C., Watson, J.G., Sun, J., Lee, S.C., Cao, J.J., Ho, K.F., (2020). Cytotoxicity of $PM_{2.5}$ vehicular emissions in the Shing Mun Tunnel, Hong Kong. Environmental Pollution, 263, 114386. 10.1016/j.envpol.2020.114386.

- Pan, L., Kim, H., Lee, P., Saylor, R., Tang, Y., Tong, D., Baker, B., Kondragunta, S., Xu, C., G. Ruminski, M., Chen, W., McQueen, J., Stajner, I., (2020). Evaluating a fire smoke simulation algorithm in the National Air Quality Forecast Capability (NAQFC) by using multiple observation data sets during the Southeast Nexus (SENEX) field campaign. Geoscientific Model Development, 13, 2169-2184. 10.5194/gmd-13-2169-2020.

- Peng, C., Tian, M., Wang, X.L., Yang, F.M., Shi, G.M., Huang, R.J., Yao, X.J., Wang, Q.Y., Zhai, C.Z., Zhang, S.M., Qian, R.Z., Cao, J.J., Chen, Y., (2020). Light absorption of brown carbon in $PM_{2.5}$ in the Three Gorges Reservoir region, southwestern China: Implications of biomass burning and secondary formation. Atmospheric Environment, 229, 10.1016/j.atmosenv.2020.117409.

- Peng, Y., Wang, H., Hou, M.L., Jiang, T., Zhang, M., Zhao, T.L., Che, H.Z., (2020). Improved method of visibility parameterization focusing on high humidity and aerosol concentrations during fog-haze events: Application in the GRAPES_CAUCE model in Jing-Jin-Ji, China. Atmospheric Environment, 222, 10.1016/j.atmosenv.2019.117139.

Example 2020-2021 publications and reports using the IMPROVE_A protocol (n= 45)

- Shen, J.Y., Zhao, Q.B., Cheng, Z., Huo, J.T., Zhu, W.F., Zhang, Y.H., Duan, Y.S., Wang, X.L., Chen, L.-W.A., Fu, Q.Y., (2020). Evolution of source contributions during heavy fine particulate matter ($PM_{2.5}$) pollution episodes in eastern China through online measurements. Atmospheric Environment, 232, 10.1016/j.atmosenv.2020.117569.

- Shimada, K., Takami, A., Ishida, T., Taniguchi, Y., Hasegawa, S., Chan, C.K., Kim, Y.P., Lin, N.H., Hatakeyama, S., (2021). Long-term measurements of carbonaceous aerosol at Cape Hedo, Okinawa, Japan: Effects of changes in emissions in East Asia. Aerosol and Air Quality Research, 21, 10.4209/aaqr.200505.

- Tao, J., Zhang, L.M., Wu, Y.F., Zhang, Z.S., (2020). Evaluation of the IMPROVE formulas based on Mie model in the calculation of particle scattering coefficient in an urban atmosphere. Atmospheric Environment, 222, 10.1016/j.atmosenv.2019.117116.

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- Verma, M., Pervez, S., Chow, J.C., Majumdar, D., Watson, J.G., Pervez, Y.F., Deb, M.K., Shrivas, K., Jain, V.K., Khan, N.A., Mandal, P., Chakrabarty, R.K., (2021). Assessing the magnitude of $PM_{2.5}$ polycyclic aromatic hydrocarbon emissions from residential solid fuel combustion and associated health hazards in South Asia. Atmospheric Pollution Research, 12, 101142. 10.1016/j.apr.2021.101142.

- Watson, J.G., Cao, J.J., Wang, X.L., Chow, J.C., (2021). $PM_{2.5}$ pollution in China's Guanzhong Basin and the USA's San Joaquin Valley mega-regions. Faraday Discussions, 226, 255-289. 10.1039/D0FD00094A.

- Wei, C., Bandowe, B.A.M., Han, Y.M., Cao, J.J., Watson, J.G., Chow, J.C., Wilcke, W., (2021). Polycyclic aromatic compounds (PAHs, oxygenated PAHs, nitrated PAHs, and azaarenes) in air from four climate zones of China: Occurrence, gas/particle partitioning, and health risks. Science of the Total Environment, 786, 147234. 10.1016/j.scitotenv.2021.147234.

- Zhang, Z.Z., Gao, Y., Yuan, Q., Tan, Y., Li, H.W., Cui, L., Huang, Y., Cheng, Y., Xiu, G.L., Lai, S.C., Chow, J.C., Watson, J.G., Lee, S.C., (2020). Effects of indoor activities and outdoor penetration on $PM_{2.5}$ and associated organic/elemental carbon at residential homes in four Chinese cities during winter. Science of the Total Environment, 739, 139684. 10.1016/j.scitotenv.2020.139684.

- Zhang, X.L., Trzepla, K., White, W.H., Raffuse, S., Hyslop, N.P., (2021). Intercomparison of thermal-optical carbon measurements by Sunset and Desert Research Institute (DRI) analyzers using the IMPROVE_A protocol. Atmospheric Measurement Techniques, 14, 3217-3231. 10.5194/amt-14-3217-2021.

- Zong, P., Zhu, Y., Wang, H., Liu, D., (2020). WRF-Chem simulation of winter visibility in Jiangsu, China, and the application of a neural network algorithm. Atmosphere, 11, 10.3390/atmos11050520.