R Subramanian **subu@cmu.edu**

Education

Ph.D., Mechanical Engineering, Carnegie Mellon University, Pittsburgh, PA, 2004. Doctoral Thesis: "Sampling, Analysis and Source-Apportionment of Ambient Carbonaceous Aerosols." Advisor: A.L. Robinson.

M. Tech., Energy Systems Engineering, Indian Institute of Technology–Bombay, Mumbai, India, 1999. Master's Dissertation: "Simulation of a Hybrid Electric Vehicle." Advisors: Professors U.N. Gaitonde and A. Ganesh.

B.E., Automobile Engineering, University of Mumbai (formerly Bombay), Mumbai, India, 1996.

Research Experience

2/2013 to date. Carnegie Mellon University, Pittsburgh, PA.
Research Scientist. Proposal development, leading teams, mentoring students. Characterization of methane and associated air pollutant emissions from the US natural gas sector. Studies of aerosol optical properties and BC mixing state through field experiments (SOAS, SOAS-2) and lab studies (SAAS-PNNL, SAAS-CMU.) Physicochemical characterization of cookstove soot emissions. Development of low-cost sensors for air quality monitoring, specifically the CMU Real-time, Affordable, Multi-Pollutant (RAMP) sensor package.

1/2012 to 1/2013. RTI International, Research Triangle Park, NC.
Research Environmental Scientist. Proposal development. Set up a new Atmospheric Chemistry Lab focused on aerosol chemical composition and optical properties. Studies of aerosol optical properties and BC mixing state. Characterized a nebulizer system to measure black carbon (BC) in liquid water. Instrumental in RTI's acquisition of a new Linux computing cluster for regional air quality modeling.

1/2007 to 12/2011. Droplet Measurement Technologies (DMT), Boulder, CO.
Research Scientist (2009 to 2011); Postdoctoral Research Scientist (2007 to 2009). Characterized BC emissions from combustion sources and studied the aging of BC during atmospheric transport and aerosol-cloud interactions using the DMT single particle soot photometer (SP2) in various field campaigns. These campaigns included the Megacity Initiative: Local and Global Research Observations (MILAGRO), Carbonaceous Aerosols and Radiative Effects Study (CARES), Ice in Clouds Experiment (Layer clouds, ICE-L, and Tropical clouds, ICE-T), and the Pacific Dust Experiment (PacDEx). Developed and characterized the SP2, the photoacoustic extinctiometer (PAX), and the fast-integrating mobility spectrometer (FIMS). Proposal development, sales and customer service, and software development for analysis of data from DMT instruments.

11/2004 to 12/2006. University of Illinois at Urbana–Champaign, Urbana, IL.
Postdoctoral Research Associate. Characterized diesel vehicle emissions in Thailand, and particulate emissions from biomass combustion. Studied morphology of organic aerosol collected on filter samples for subsequent optical and thermal analysis.

7/2000 to 9/2004. Pittsburgh Air Quality Study, Carnegie Mellon University, Pittsburgh, PA.
Graduate Research Assistant. Source-receptor modeling of ambient organic aerosol; instrument response of carbonaceous aerosol under different analytical protocols. Development of a denuder-based organic aerosol sampler, and evaluation of sampling artifacts associated with organic aerosol measurement.

4/1999 to 10/1999. Department of Mechanical Engineering, IIT-Bombay
Project Engineer. Design and initial development of a scaled model of the primary system of an Advanced Heavy Water Reactor, based on critical heat flux calculations.

7/1996 to 7/1997. Mahindra & Mahindra Ltd, Nashik, India.
Trainee Engineer, Transmission Systems R&D

Teaching Experience

Spring 2004 Department of Mechanical Engineering, Carnegie Mellon University
Graduate Teaching Assistant. Worked on developing and evaluating CyclePad, an intelligent tutor for thermodynamic cycles.
Fall 2003 Department of Mechanical Engineering, Carnegie Mellon University
Graduate Teaching Assistant. Thermodynamics: Grading, laboratory instruction, teaching.
Aug 1997–Jan 1999 Department of Mechanical Engineering, IIT-Bombay
Teaching Assistant. Sophomore thermodynamics and heat transfer: Grading, office hours, setting tests, laboratory instruction.

Current Grants as PI or Co-PI

Lead PI, "Collaborative Research: Aging of Black Carbon During Atmospheric Transport: Understanding Results From the DOE's 2010 CARES and 2012 ClearfLo Campaigns." US Department of Energy-ASR. $397,000 (CMU total $227,000; 2012-2016)
PI, "Development of a real-time, low-cost sensor package for distributed measurement of ambient air quality." Heinz Endowments, $15,000 (2016)
Co-PI, "Aerosol Optical Properties and Biogenic SOA: Effect on Hygroscopic Properties and Light Absorption." US Environmental Protection Agency, $141,000 (2012-2017, subcontract through DRI, Nevada)
Co-PI, "Measurement of Methane Emissions and Leakage from Natural Gas Extraction and Processing Facilities in Appalachia, the Rockies, and the Gulf Coast." NOAA. $600,000 (2014-2017)
Co-PI, "Measurements and modeling to quantify emissions of methane and VOCs from shale gas operations." Department of Energy-NETL. $1,000,000 (2013-2016)

Past Funding

"Measurement of Black Carbon from Associated Natural Gas Flaring." Clean Air Task Force (2014). $15,000
"Measurement of Black Carbon in and downwind of Sacramento, CA during CARES." US Department of Energy-ARM (2010-2011). $56,000
"Measurement of Black Carbon emissions from Combustion Sources using a Single Particle Soot Photometer (SP2) and a Photoacoustic Soot Spectrometer (PASS-3)." US Environmental Protection Agency, (2009-2010). $44,969
"ICE-T: In-cloud BC and dust over the Caribbean Sea." NSF (2011-2013). $204,000 (Co-PI)

Publications

1. Omara, M., M. R. Sullivan, X. Li, **R. Subramanian**, A. L. Robinson and A. A. Presto (2016). "Methane Emissions from Conventional and Unconventional Natural Gas Production

Sites in the Marcellus Shale Basin." Environmental Science & Technology, 50(4): 2099-2107

2. Weyant, C.L., P. B. Shepson, **R. Subramanian**, M. O. L. Cambaliza, A. Heimburger, D. McCabe, E. Baum, B. H. Stirm and T. C. Bond (2016). "Black Carbon Emissions from Associated Natural Gas Flaring." Environmental Science & Technology, 50(4): 2075-2081
3. Ellis, A.; R. Edwards, M. Saunders, R. K. Chakrabarty, **R. Subramanian**, A. van Riessen, A. M. Smith, D. Lambrinidis, L. J. Nunes, P. Vallelonga, I. D. Goodwin, A. D. Moy, M. A. J. Curran, and T. D. van Ommen (2015). "Characterizing black carbon in rain and ice cores using coupled tangential flow filtration and transmission electron microscopy." Atmospheric Measurement Techniques, 8(9): 3959-3969, doi:10.5194/amt-8-3959-2015
4. Marchese, A.J., T.L. Vaughn, D.J. Zimmerle, D.M. Martinez, L.L. Williams, A.L. Robinson, Mitchell, A.L., **R. Subramanian**, D.S. Tkacik, J.R. Roscioli, and S.C.Herndon (2015.) "Methane emissions from United States natural gas gathering and processing." Environmental Science & Technology, 49(17): 10718-10727. doi: 10.1021/acs.est.5b02275
5. Mitchell, A.L., D.S. Tkacik, J.R. Roscioli, S.C.Herndon, T.I. Yacovitch, D.M. Martinez, T.L. Vaughn, L.L. Williams, M.R. Sullivan, C. Floerchinger, M. Omara, A.L. Robinson, **R. Subramanian**, D.J. Zimmerle, A.J. Marchese, and A.L. Robinson (2015.) "Measurements of Methane Emissions from Natural Gas Gathering Facilities and Processing Plants: Measurement Results." Environmental Science & Technology, 49 (5), pp 3219–3227. DOI: 10.1021/es5052809.
6. Roscioli, J.R., T.I. Yacovitch, C. Floerchinger, A.L. Mitchell, D.S. Tkacik, **R. Subramanian**, D.M. Martinez, T.L. Vaughn, L.L. Williams, D.J. Zimmerle, A.L. Robinson, S.C. Herndon, and A.J. Marchese (2015.) "Measurements of methane emissions from natural gas gathering facilities and processing plants: measurement methods." Atmospheric Measurement Techniques, **8**, pp 2017-2035, DOI:10.5194/amt-8-2017-2015.
7. **Subramanian, R**., L.L. Williams, T.L. Vaughn, D.J. Zimmerle, J.R. Roscioli, S.C.Herndon, T.I. Yacovitch, C. Floerchinger, D.S. Tkacik, A.L. Mitchell, M.R. Sullivan, T.R. Dallmann, and A.L. Robinson (2015.) "Methane Emissions from Natural Gas Compressor Stations in the Transmission and Storage Sector: Measurements and Comparisons with the EPA Greenhouse Gas Reporting Program Protocol." Environmental Science & Technology, 49 (5), pp 3252–3261. DOI: 10.1021/es5060258.
8. Zimmerle, D.J., L.L. Williams, T.L. Vaughn, C. Quinn, **R. Subramanian**, G.P. Duggan, B. Wilson, J.D. Opsomer, A.J. Marchese, D.M. Martinez, and A.L. Robinson (2015.) "Methane emissions from the natural gas transmission and storage system in the United States." Environmental Science & Technology. 49(15): 9374-9383. doi: 10.1021/acs.est.5b01669
9. Takahama, S., L.M. Russell, C.A. Shores, L.C. Marr, J. Zheng, M. Levy, R. Zhang, E. Castillo, J.G. Rodriguez-Ventura, P.J.E. Quintana, **R. Subramanian**, M. Zavala, and L.T. Molina (2014.) "Diesel vehicle and urban burning contributions to black carbon concentrations and size distributions in Tijuana, Mexico, during the Cal-Mex 2010 campaign." Atmospheric Environment, 88:341-352, doi:10.1016/j.atmosenv.2013.09.057
10. Torres, A., T.C. Bond, C.M.B. Lehmann, **R. Subramanian**, and O.L. Hadley (2014.)

"Measuring Organic Carbon and Black Carbon in Rainwater: Evaluation of Methods." Aerosol Science and Technology, 48:3, 239-250, DOI: 10.1080/02786826.2013.868596

11. Phillips, V. T. J., P. J. Demott, C. Andronache, K. A. Pratt, K. A. Prather, **R. Subramanian** and C. Twohy (2013). "Improvements to an Empirical Parameterization of Heterogeneous Ice Nucleation and Its Comparison with Observations." Journal of the Atmospheric Sciences, 70(2): 378-409
12. Baumgardner, D., O. Popovicheva, J. Allan, V. Bernardoni, J. Cao, F. Cavalli, J. Cozic, E. Diapouli, K. Eleftheriadis, P. J. Genberg, C. Gonzalez, M. Gysel, A. John, T. W. Kirchstetter, T. A. J. Kuhlbusch, M. Laborde, D. Lack, T. Mueller, R. Niessner, A. Petzold, A. Piazzalunga, J. P. Putaud, J. Schwarz, P. Sheridan, **R. Subramanian**, E. Swietlicki, G. Valli, R. Vecchi and M. Viana (2012). "Soot reference materials for instrument calibration and intercomparisons: a workshop summary with recommendations." Atmospheric Measurement Techniques **5**(8): 1869-1887.
13. Cappa, C. D., T. B. Onasch, P. Massoli, D. R. Worsnop, T. S. Bates, E. S. Cross, P. Davidovits, J. Hakala, K. L. Hayden, B. T. Jobson, K. R. Kolesar, D. A. Lack, B. M. Lerner, S.-M. Li, D. Mellon, I. Nuaaman, J. S. Olfert, T. Petaja, P. K. Quinn, C. Song, **R. Subramanian**, E. J. Williams and R. A. Zaveri (2012). "Radiative Absorption Enhancements Due to the Mixing State of Atmospheric Black Carbon." Science **337**(6098): 1078-1081.
14. Setyan, A., Q. Zhang, M. Merkel, W. B. Knighton, Y. Sun, C. Song, J. E. Shilling, T. B. Onasch, S. C. Herndon, D. R. Worsnop, J. D. Fast, R. A. Zaveri, L. K. Berg, A. Wiedensohler, B. A. Flowers, M. K. Dubey and **R. Subramanian** (2012). "Characterization of submicron particles influenced by mixed biogenic and anthropogenic emissions using high-resolution aerosol mass spectrometry: results from CARES." Atmospheric Chemistry and Physics **12**(17): 8131-8156.
15. Zaveri, R. A., W. J. Shaw, D. J. Cziczo, B. Schmid, R. A. Ferrare, M. L. Alexander, M. Alexandrov, R. J. Alvarez, W. P. Arnott, D. B. Atkinson, S. Baidar, R. M. Banta, J. C. Barnard, J. Beranek, L. K. Berg, F. Brechtel, W. A. Brewer, J. F. Cahill, B. Cairns, C. D. Cappa, D. Chand, S. China, J. M. Comstock, M. K. Dubey, R. C. Easter, M. H. Erickson, J. D. Fast, C. Floerchinger, B. A. Flowers, E. Fortner, J. S. Gaffney, M. K. Gilles, K. Gorkowski, W. I. Gustafson, M. Gyawali, J. Hair, R. M. Hardesty, J. W. Harworth, S. Herndon, N. Hiranuma, C. Hostetler, J. M. Hubbe, J. T. Jayne, H. Jeong, B. T. Jobson, E. I. Kassianov, L. I. Kleinman, C. Kluzek, B. Knighton, K. R. Kolesar, C. Kuang, A. Kubatova, A. O. Langford, A. Laskin, N. Laulainen, R. D. Marchbanks, C. Mazzoleni, F. Mei, R. C. Moffet, D. Nelson, M. D. Obland, H. Oetjen, T. B. Onasch, I. Ortega, M. Ottaviani, M. Pekour, K. A. Prather, J. G. Radney, R. R. Rogers, S. P. Sandberg, A. Sedlacek, C. J. Senff, G. Senum, A. Setyan, J. E. Shilling, M. Shrivastava, C. Song, S. R. Springston, **R. Subramanian**, K. Suski, J. Tomlinson, R. Volkamer, H. W. Wallace, J. Wang, A. M. Weickmann, D. R. Worsnop, X. Y. Yu, A. Zelenyuk and Q. Zhang (2012). "Overview of the 2010 Carbonaceous Aerosols and Radiative Effects Study (CARES)." Atmospheric Chemistry and Physics **12**(16): 7647-7687.
16. Gysel, M., M. Laborde, J. S. Olfert, **R. Subramanian** and A. J. Groehn (2011).

"Effective density of Aquadag and fullerene soot black carbon reference materials used for SP2 calibration." Atmospheric Measurement Techniques **4**(12): 2851-2858.

17. Maimone, F., B. J. Turpin, P. Solomon, Q. Meng, A. L. Robinson, **R. Subramanian** and A. Polidori (2011). "Correction Methods for Organic Carbon Artifacts When Using Quartz-Fiber Filters in Large Particulate Matter Monitoring Networks: The Regression Method and Other Options." Journal of the Air & Waste Management Association **61**(6): 696-710.
18. Popovicheva, O., D. Baumgardner, **R. Subramanian**, G. Kok, R. Cary, E. Vlasenko, T. Khokhlova, N. Shonija and E. Kireeva (2011). "Tailored graphitized soot as reference material for EC/OC measurement validation." Atmospheric Measurement Techniques **4**(5): 923-932.
19. Pratt, K. A., S. M. Murphy, **R. Subramanian**, P. J. DeMott, G. L. Kok, T. Campos, D. C. Rogers, A. J. Prenni, A. J. Heymsfield, J. H. Seinfeld and K. A. Prather (2011). "Flight-based chemical characterization of biomass burning aerosols within two prescribed burn smoke plumes." Atmospheric Chemistry and Physics **11**(24): 12549-12565.
20. Cross, E. S., T. B. Onasch, A. Ahern, W. Wrobel, J. G. Slowik, J. Olfert, D. A. Lack, P. Massoli, C. D. Cappa, J. P. Schwarz, J. R. Spackman, D. W. Fahey, A. Sedlacek, A. Trimborn, J. T. Jayne, A. Freedman, L. R. Williams, N. L. Ng, C. Mazzoleni, M. Dubey, B. Brem, G. Kok, **R. Subramanian**, S. Freitag, A. Clarke, D. Thornhill, L. C. Marr, C. E. Kolb, D. R. Worsnop and P. Davidovits (2010). "Soot Particle StudiesInstrument Inter-ComparisonProject Overview." Aerosol Science and Technology **44**(8): 592-611.
21. Oanh, N. T. K., W. Thiansathit, T. C. Bond, **R. Subramanian**, E. Winijkul and I. Paw-armart (2010). "Compositional characterization of PM2.5 emitted from in-use diesel vehicles." Atmospheric Environment **44**(1): 15-22.
22. Pratt, K. A., A. J. Heymsfield, C. H. Twohy, S. M. Murphy, P. J. DeMott, J. G. Hudson, **R. Subramanian**, Z. Wang, J. H. Seinfeld and K. A. Prather (2010). "In Situ Chemical Characterization of Aged Biomass-Burning Aerosols Impacting Cold Wave Clouds." Journal of the Atmospheric Sciences **67**(8): 2451-2468.
23. **Subramanian, R**., G. L. Kok, D. Baumgardner, A. Clarke, Y. Shinozuka, T. L. Campos, C. G. Heizer, B. B. Stephens, B. de Foy, P. B. Voss and R. A. Zaveri (2010). "Black carbon over Mexico: the effect of atmospheric transport on mixing state, mass absorption cross-section, and BC/CO ratios." Atmospheric Chemistry and Physics **10**(1): 219-237.
24. Twohy, C. H., P. J. DeMott, K. A. Pratt, **R. Subramanian**, G. L. Kok, S. M. Murphy, T. Lersch, A. J. Heymsfield, Z. Wang, K. A. Prather and J. H. Seinfeld (2010). "Relationships of Biomass-Burning Aerosols to Ice in Orographic Wave Clouds." Journal of the Atmospheric Sciences **67**(8): 2437-2450.
25. Eidhammer, T., P. J. DeMott, A. J. Prenni, M. D. Petters, C. H. Twohy, D. C. Rogers, J. Stith, A. Heymsfield, Z. Wang, K. A. Pratt, K. A. Prather, S. M. Murphy, J. H. Seinfeld, **R. Subramanian** and S. M. Kreidenweis (2010). "Ice Initiation by Aerosol Particles: Measured and Predicted Ice Nuclei Concentrations versus Measured Ice Crystal Concentrations in an Orographic Wave Cloud." Journal of the Atmospheric Sciences **67**(8): 2417-2436.

26. **Subramanian, R**., E. Winijkul, T. C. Bond, W. Thiansathit, N. T. K. Oanh, I. Paw-Armart and K. G. Duleep (2009). "Climate-Relevant Properties of Diesel Particulate Emissions: Results from a Piggyback Study in Bangkok, Thailand." Environmental Science & Technology **43**(11): 4213-4218.
27. Baumgardner, D., **R. Subramanian**, C. Twohy, J. Stith and G. Kok (2008). "Scavenging of black carbon by ice crystals over the northern Pacific." Geophysical Research Letters **35**(22).
28. Shrivastava, M. K., **R. Subramanian**, W. F. Rogge and A. L. Robinson (2007). "Sources of organic aerosol: Positive matrix factorization of molecular marker data and comparison of results from different source apportionment models." Atmospheric Environment **41**(40): 9353-9369.
29. **Subramanian, R**., N. M. Donahue, A. Bernardo-Bricker, W. F. Rogge and A. L. Robinson (2007). "Insights into the primary-secondary and regional-local contributions to organic aerosol and PM2.5 mass in Pittsburgh, Pennsylvania." Atmospheric Environment **41**(35): 7414-7433.
30. **Subramanian, R**., C. A. Roden, P. Boparai and T. C. Bond (2007). "Yellow beads and missing particles: Trouble ahead for filter-based absorption measurements." Aerosol Science and Technology **41**(6): 630-637.
31. Polidori, A., B. J. Turpin, H.-J. Lim, J. C. Cabada, **R. Subramanian**, S. N. Pandis and A. L. Robinson (2006). "Local and regional secondary organic aerosol: Insights from a year of semi-continuous carbon measurements at Pittsburgh." Aerosol Science and Technology **40**(10): 861-872.
32. Robinson, A. L., **R. Subramanian**, N. M. Donahue, A. Bernardo-Bricker and W. F. Rogge (2006). "Source apportionment of molecular markers and organic aerosol. 3. Food cooking emissions." Environmental Science & Technology **40**(24): 7820-7827.
33. Robinson, A. L., **R. Subramanian**, N. M. Donahue, A. Bernardo-Bricker and W. F. Rogge (2006). "Source apportionment of molecular markers and organic aerosol. 2. Biomass smoke." Environmental Science & Technology **40**(24): 7811-7819.
34. Robinson, A. L., **R. Subramanian**, N. M. Donahue, A. Bernardo-Bricker and W. F. Rogge (2006). "Source apportionment of molecular markers and organic aerosols-1. Polycyclic aromatic hydrocarbons and methodology for data visualization." Environmental Science & Technology **40**(24): 7803-7810.
35. **Subramanian, R.**, N. M. Donahue, A. Bernardo-Bricker, W. F. Rogge and A. L. Robinson (2006). "Contribution of motor vehicle emissions to organic carbon and fine particle mass in Pittsburgh, Pennsylvania: Effects of varying source profiles and seasonal trends in ambient marker concentrations." Atmospheric Environment **40**(40): 8002-8019.
36. **Subramanian, R**., A. Y. Khlystov and A. L. Robinson (2006). "Effect of peak inert-mode temperature on elemental carbon measured using thermal-optical analysis." Aerosol Science and Technology **40**(10): 763-780.
37. Cabada, J. C., S. N. Pandis, **R. Subramanian**, A. L. Robinson, A. Polidori and B. Turpin

(2004). "Estimating the secondary organic aerosol contribution to PM2.5 using the EC tracer method." Aerosol Science and Technology **38**: 140-155.

38. **Subramanian, R**., A. Y. Khlystov, J. C. Cabada and A. L. Robinson (2004). "Positive and negative artifacts in particulate organic carbon measurements with denuded and undenuded sampler configurations." Aerosol Science and Technology **38**: 27-48.

Invited seminars and talks

American Meteorological Society's 18th Conference on Atmospheric Chemistry (Jan 2016.) "Emissions of Methane, Volatile Organic Compounds, and Black Carbon from Natural Gas and Oil Development, and an Examination of the Fat-Tail Problem (Invited Presentation)." New Orleans, LA

Applied Physics, Curtin University (Jan 2015.) "Research on black carbon and brown carbon at Carnegie Mellon University." Perth, Australia.

Centre for Environmental Science & Engineering, IIT-Bombay (May 2009.) "Carbonaceous aerosols at the source and in the atmosphere." Mumbai, India.

Atmospheric Sciences Division, Brookhaven National Laboratory (Jan 2009.) "Atmospheric aging and aerosol-cloud interactions of strongly-Light Absorbing Carbon (LAC) particles: Measurements with the Single Particle Soot Photometer (SP2)." Long Island, NY.

Environmental Engineering and Management, Asian Institute of Technology (Jan 2005.) "Sampling and analysis of ambient carbonaceous aerosols: Some results from the Pittsburgh Air Quality Study." Bangkok, Thailand.

Department of Mechanical Engineering, IIT-Bombay (Nov 2004.) "Source apportionment of ambient organic carbon: Results from the Pittsburgh Air Quality Study." Mumbai, India.

Professional activities and service

- Reviewer for *Aerosol Science & Technology*, *Atmospheric Chemistry & Physics*, *Atmospheric Measurement Techniques*, *Atmospheric Environment*, *Environmental Science & Technology*, *Journal of Aerosol Science*, *Journal of Geophysical Research-Atmospheres*, *Science of the Total Environment*, and *Atmospheric Research*.
- Proposal reviewer for NOAA.
- Co-chair of the AAAR Instrumentation Working Group (2007-2008) and member of the Technical Program Committee, AAAR Annual Conference 2008.
- Initiated, and co-organizer of, "Black carbon measurements in air, water and other media", a symposium at the 235th ACS National Meeting, New Orleans, LA (April 2008).
- Member of the American Association for Aerosol Research, the American Geophysical Union, and the American Meteorological Society.