Haagen-Smit Clean Air Awards
Sacramento, California
May 18, 2016

Donald H. Stedman
50 Years of Air Quality Instrument Inventions and Measurements

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UNIVERSITY of DENVER

Acknowledgments

- Bishop(s)
- State of Colorado
- State of California
- National Science Foundation
- University of Denver
- OPUS inspection
- Coordinating Research Council, R.D. Shell, Hirsch Foundation for Inspection Maintenance Review Committee and many other agencies and persons.

Chemistry Breakthrough

- Haagen-Smit, Bradley and Fox, Ind. Eng. Chem, 1953.
- LA smog is not London Smog (SO_2 and soot), it is highly oxidizing
- Mainly with OZONE
- It is counter intuitive to produce photochemically a strong oxidizing agent by adding two reducing agents, NO and VOCs to air.
- It is counter intuitive to create an interesting free radical chain reaction by adding two free radical quenchers, NO and VOCs to air
- It is counter intuitive that when the sun shines, the UV absorbing agent, NO_2, far from going away, actually increases with time.

Don

- Educated at Cambridge and met and married Hazel
- M.Sc./Ph.D., Univ. of East Anglia with Michael Clyne
- Post-Doc in Atmospheric Chemistry at K-State with Don Setser, 1967
- Ford Motor Company
- Professor University of Michigan, 1970
- Brainard Phillipson Professor University of Denver, 1983
  - Popular Science, The Best of What's New, 1991
  - Denver University Lecturer, 1994
  - AWMA Frank Chambers Award, 1996
  - ACS Advances in Environmental Science, 1996
  - ACS Colorado Professional Achievement, 1997
  - John Evans Professor 2000
  - ACS Thomas Midgley award, 2002
- Avid hiker and bird watcher / Singer / Woodworker / Beer maker / Watercolor painter / Poet

50 Years of Educating

Reactions of Atomic Hydrogen with Hydrogen Chloride and Nitrosyl Chloride, M.A.A. Clyne and D.H. Stedman, Transactions of the Faraday Society, 62:2164, 1966.

High-mileage Light-duty Fleet Vehicle Emissions: Their Potentially Overlooked Importance, G.A. Bishop, D.H. Stedman, D.A. Burgard and O. Atkinson, Environmental Science & Technology, DOI:10.1021/acs.est.6b00717 , 2016.

- 300+ refereed publications
- 35 patents to date
- 40+ M.Sc. And Ph.D. degree students
- Many more sabbatical faculty, post-doctoral students and undergraduates
- American Chemical Society traveling lecturer in retirement

50 Years of Inventing Instruments for Real World Measurements

- Involved in the early development of chemiluminescent NO detector.
- Published a measurement system for the photochemical rate of NO_2 dissociation j(NO_2).
- Invented a chemical amplifier for HO_2/RO_2 detection.
- Helped to develop a technique to measure ClO free radicals. (*Atomic Chlorine and the Chlorine Monoxide Radical in the Stratosphere: Three in-situ Observations*, J.G. Anderson, J.J. Margitan and D.H. Stedman, Science, 198, 501-503, 1977)
  - Subsequent measurements by this technique provided the “smoking gun” that helped decipher the Antarctic ozone hole
- Invented and commercialized chemiluminescence Nickel Carbonyl detector.
- Invented and commercialized chemiluminescence NO_2 detector.
- Invented and commercialized flame chemiluminescent Sulfur detector.
- Invented and commercialized on-road remote sensor for vehicle emissions
- Invented an on-road heavy-duty truck measurement system

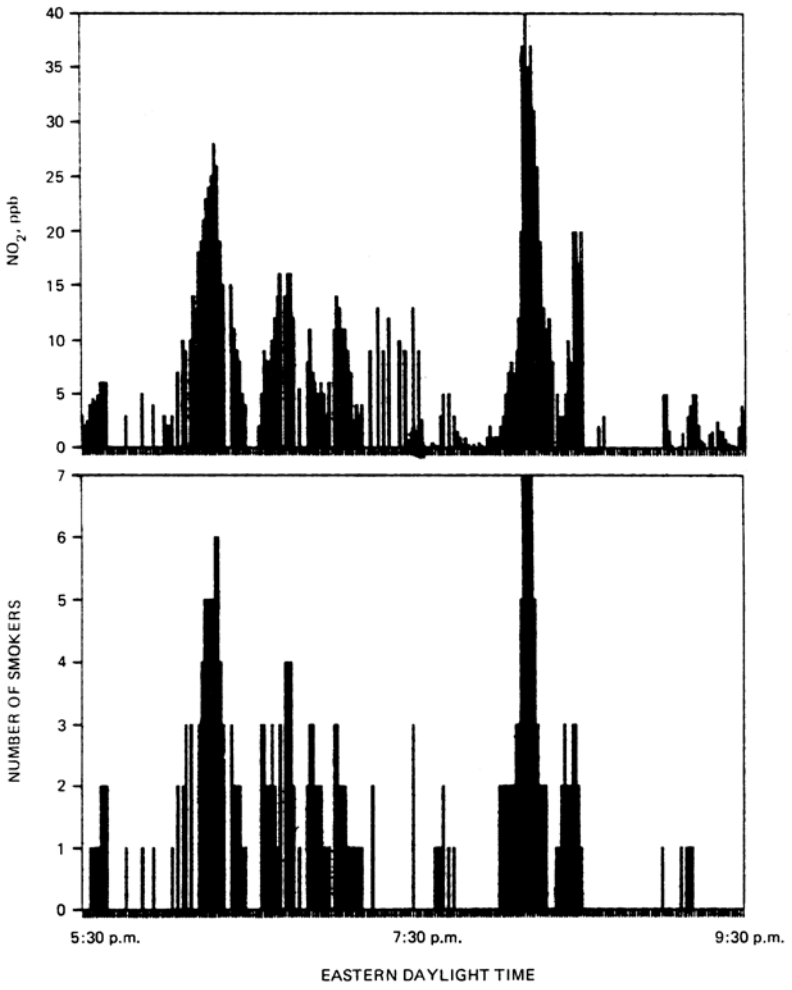


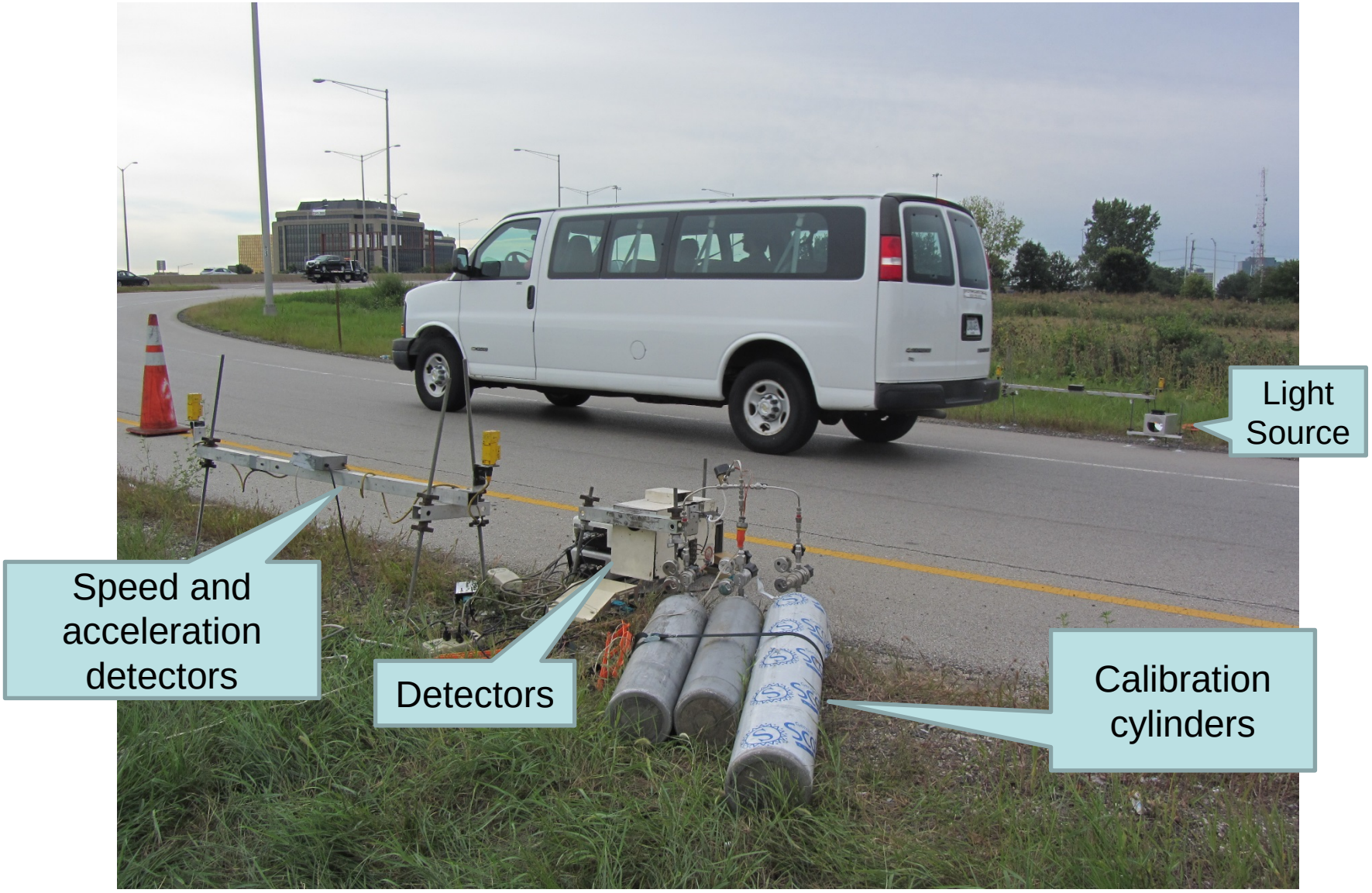
Figure 5-7 Top, NO_2 concentration vs. time during flight from Boston to Denver. Bottom, number of cigarettes smokers on same flight. NO_2 measured approximately once a minute; smokers (passengers with lighted cigarettes) counted approximately 15 s after NO_2 measurement. Data from D. H. Stedman (personal communication, 1985).

The Airliner Cabin Environment
Air Quality and Safety
Committee on Airliner Cabin Air Quality
National Research Council, 1986.

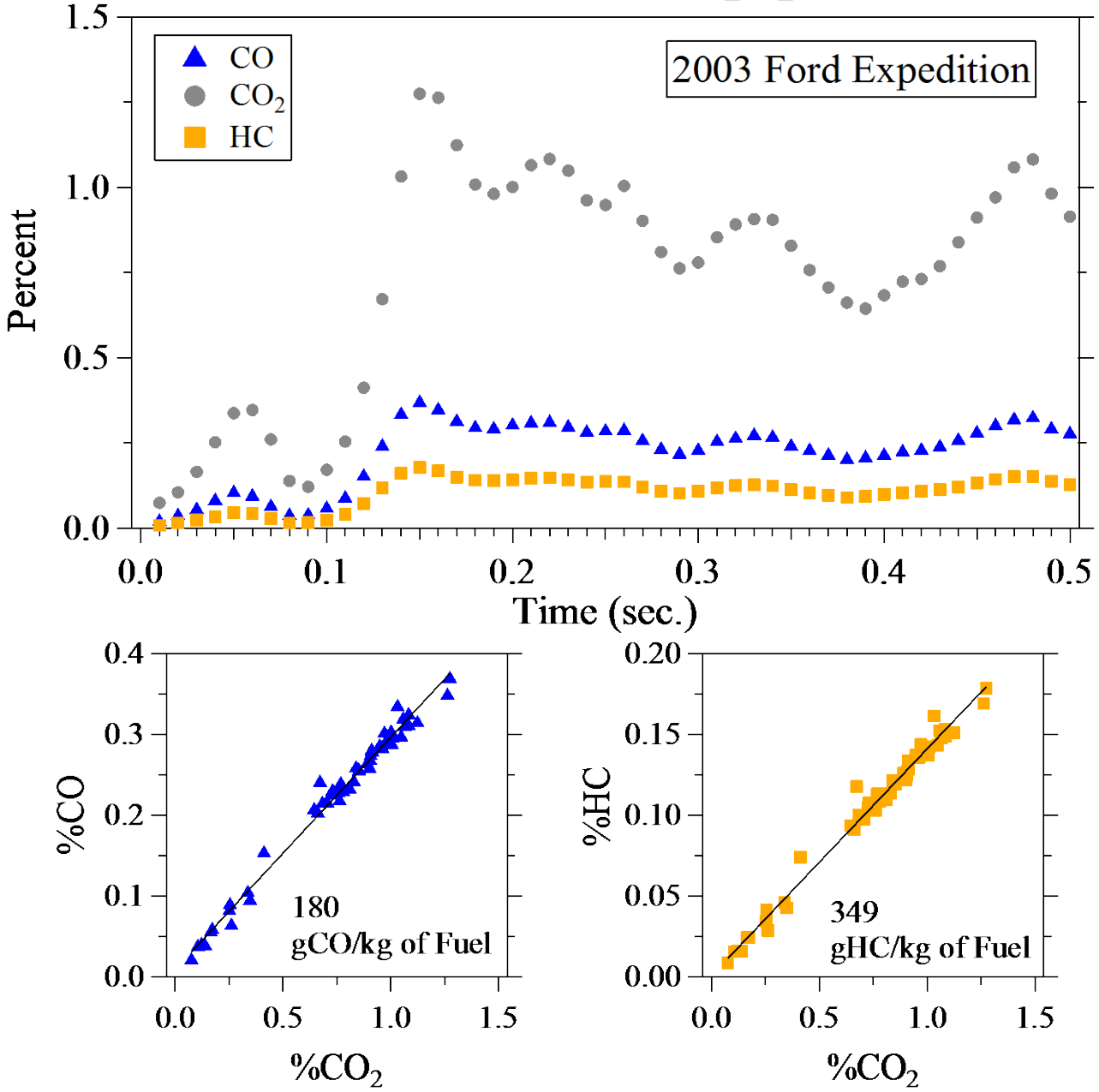
Apparatus for detection of certain nitrogen-containing gases using chemiluminescence.
US Patent No. 4,765,961,
H.I. Schiff & D.H. Stedman, 1988.

Don felt the work of this committee was his most important contribution to society.

On-road Remote Vehicle Exhaust Sensor (FEAT)



How FEAT Measures Tailpipe Emissions

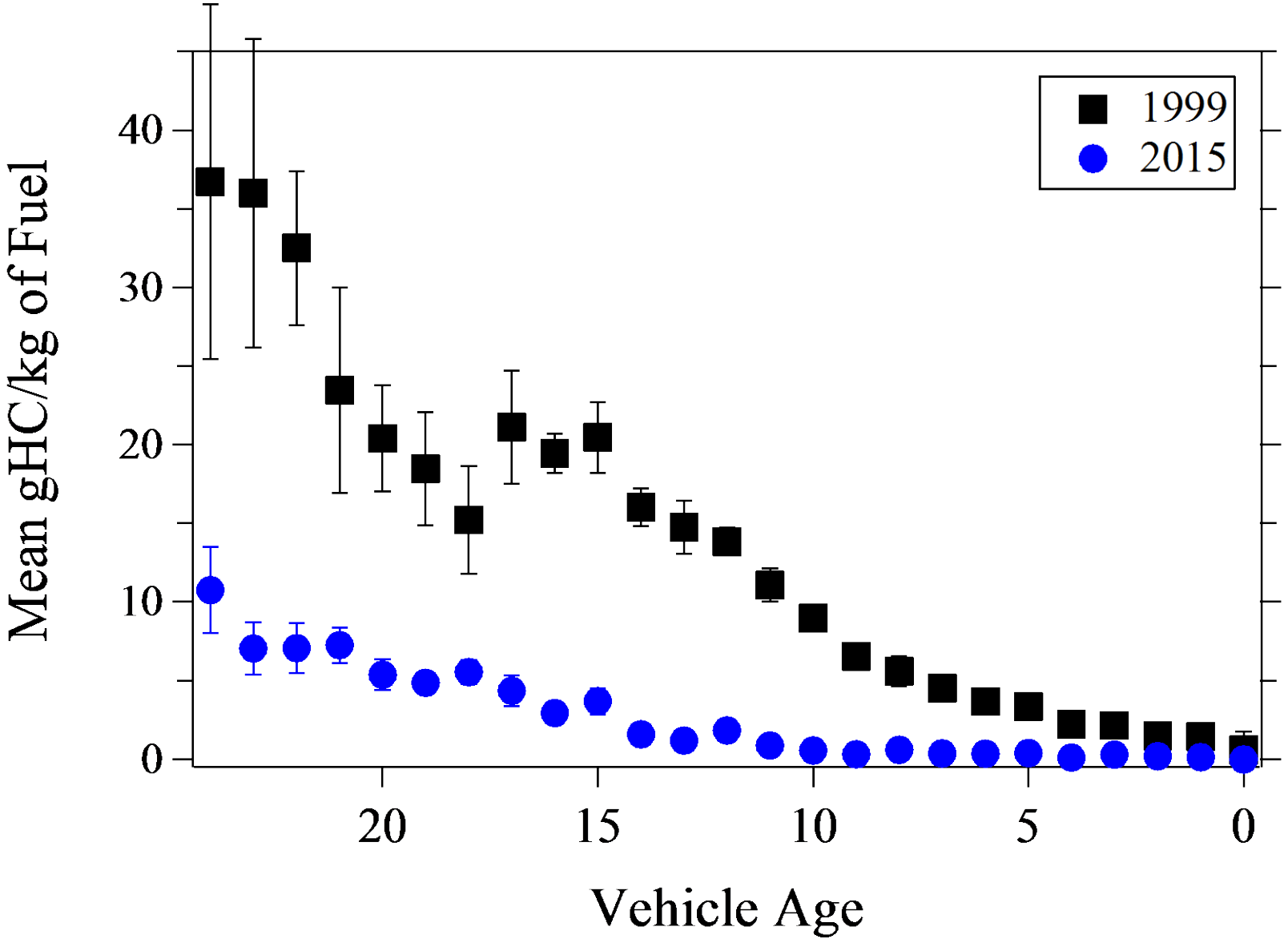



CANADA

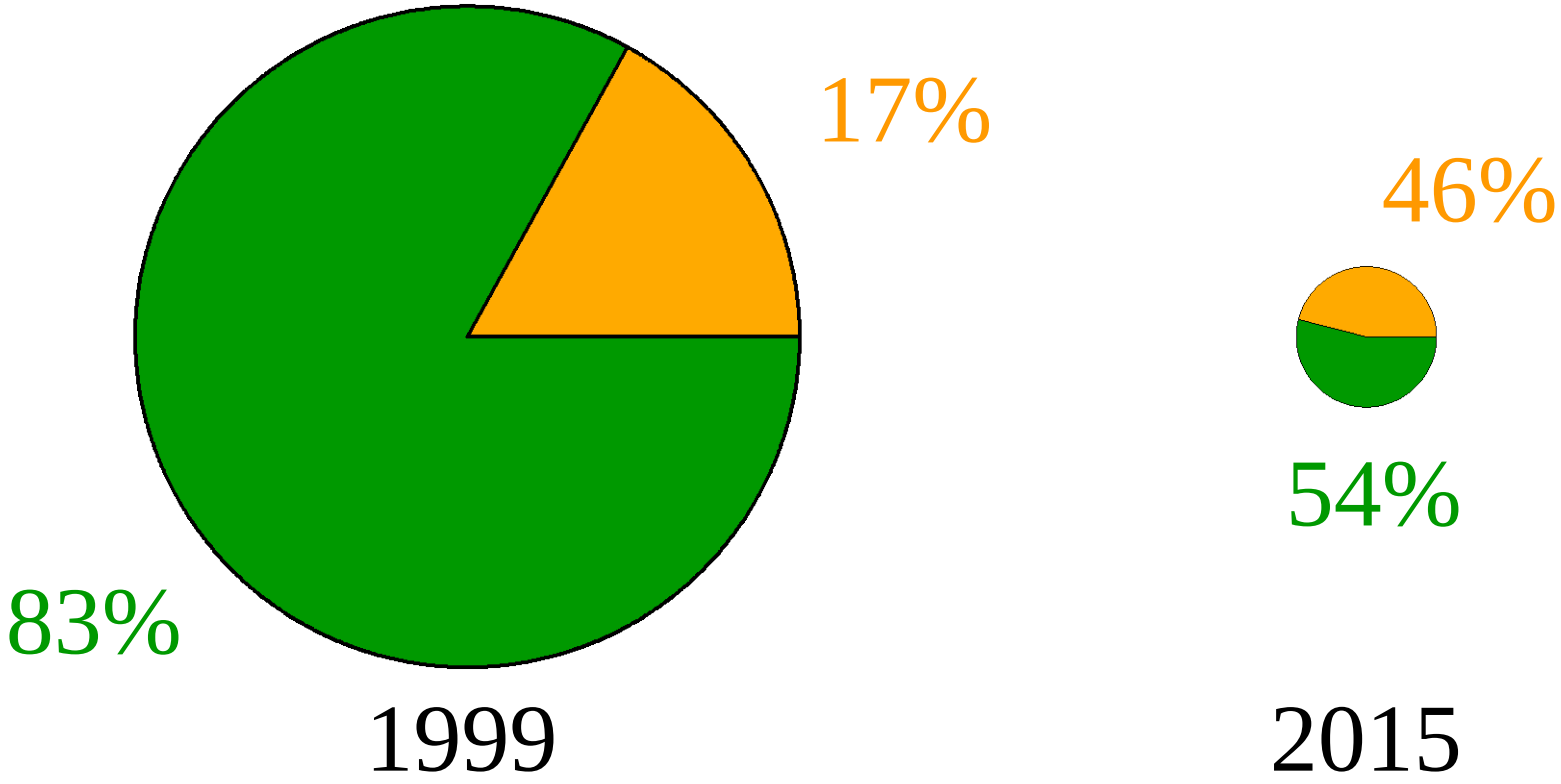
Ocean going Vessels Lion's Gate Bridge Vancouver BC

Bridge-based sensing of NO_x and SO_2 emissions from ocean-going ships
Daniel A. Burgard and Carmen R.M. Bria

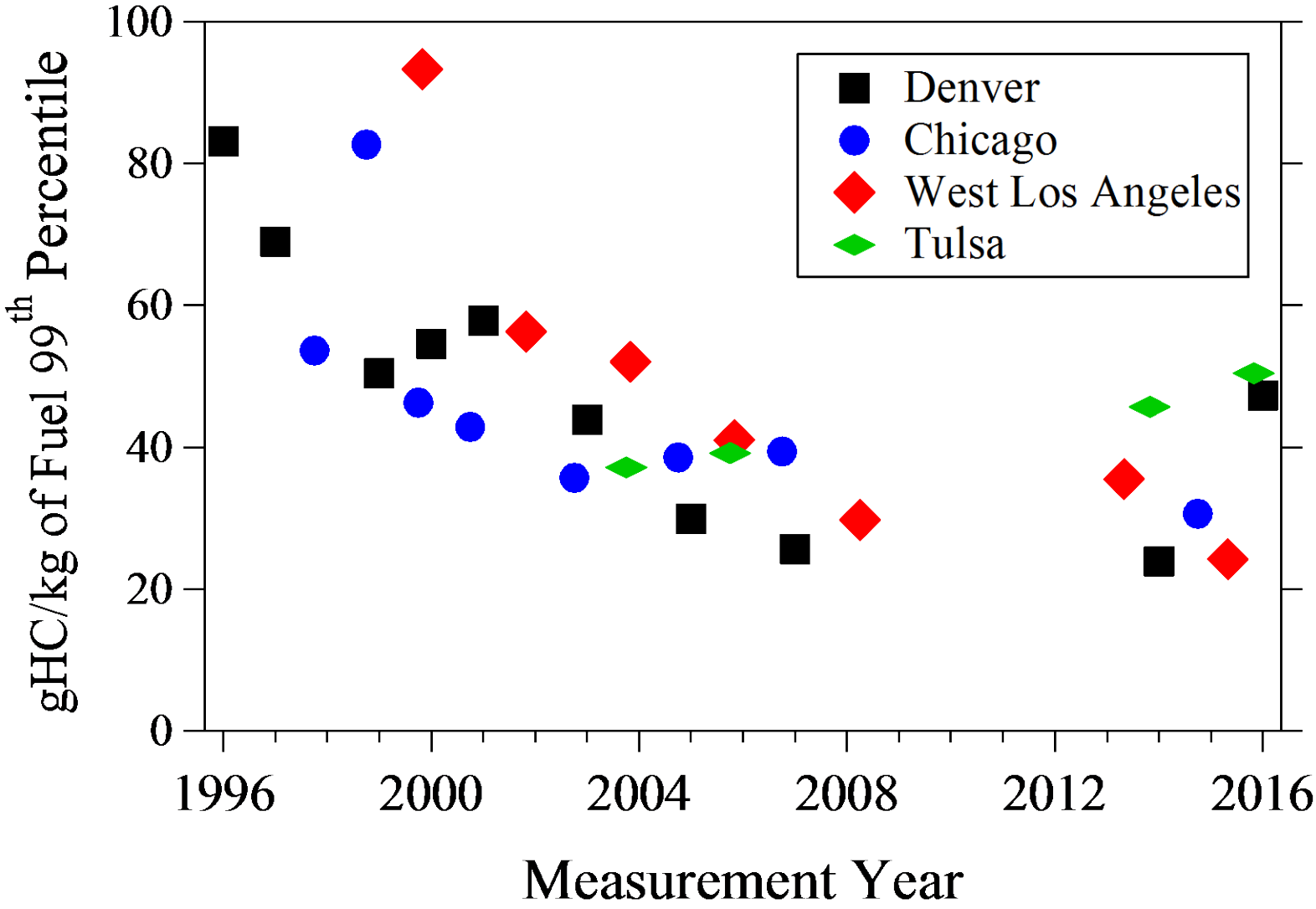
West Los Angeles HC Emission Comparison



West Los Angeles Percentage of HC Contributed by the 99th Percentile



Four City Historical HC 99th Percentiles

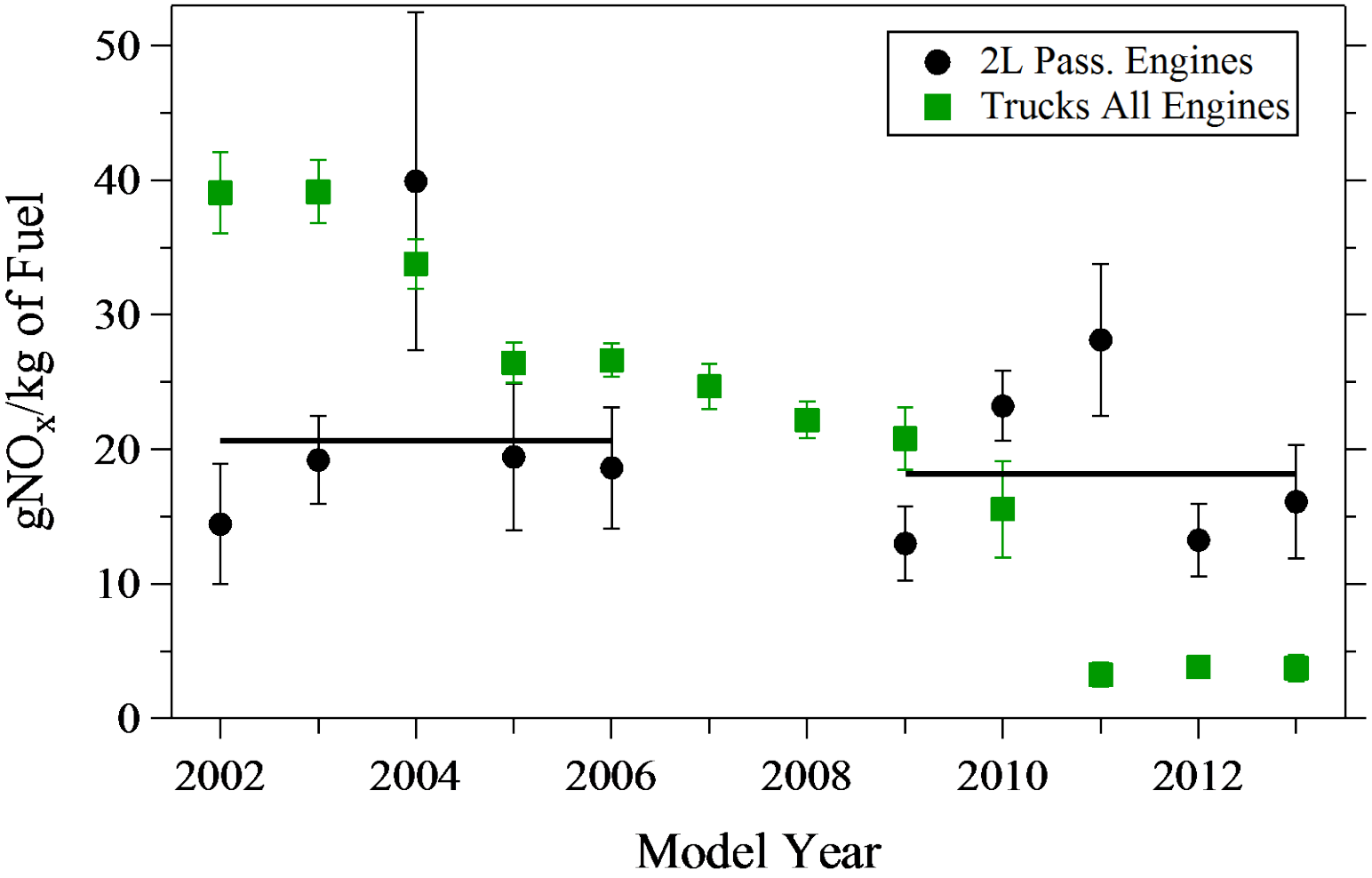


The Public Does Not Always Cooperate

On-Road Remote Sensing of CO and HC Emissions in California, D.H. Stedman, G.A. Bishop, S.P. Beaton, J.E. Peterson, P.L. Guenther, I.F. McVey and Y. Zhang, Final Report, Contract No. A032-093, California Air Resources Board, Feb., 1994.

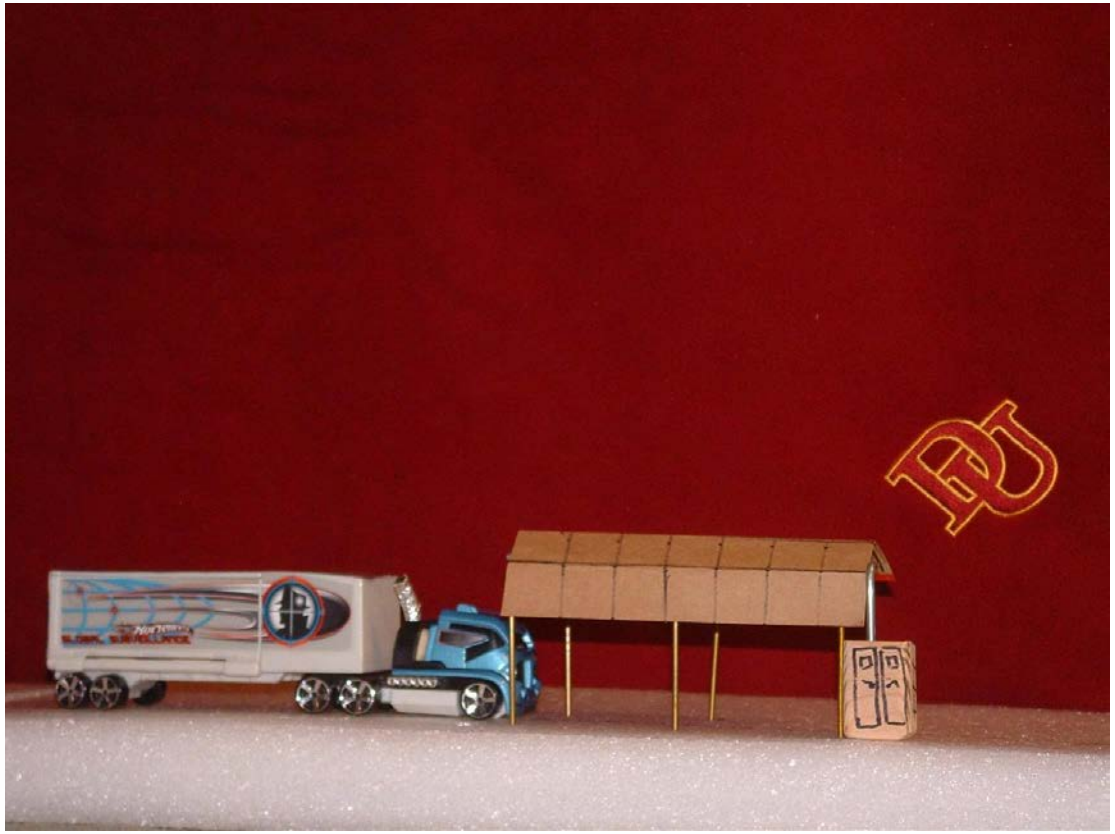
Regulations Don't Always Turn out as Envisioned

2013 LD Diesel Data from Denver, LA and Tulsa



Bishop and Stedman, Reactive Nitrogen Species Emission Trends in Three Light-/Medium- Duty United States Fleets. *Environ. Sci. Technol.* **2015,** 49, 11234-11240.

How one of Don's Ideas got Funding

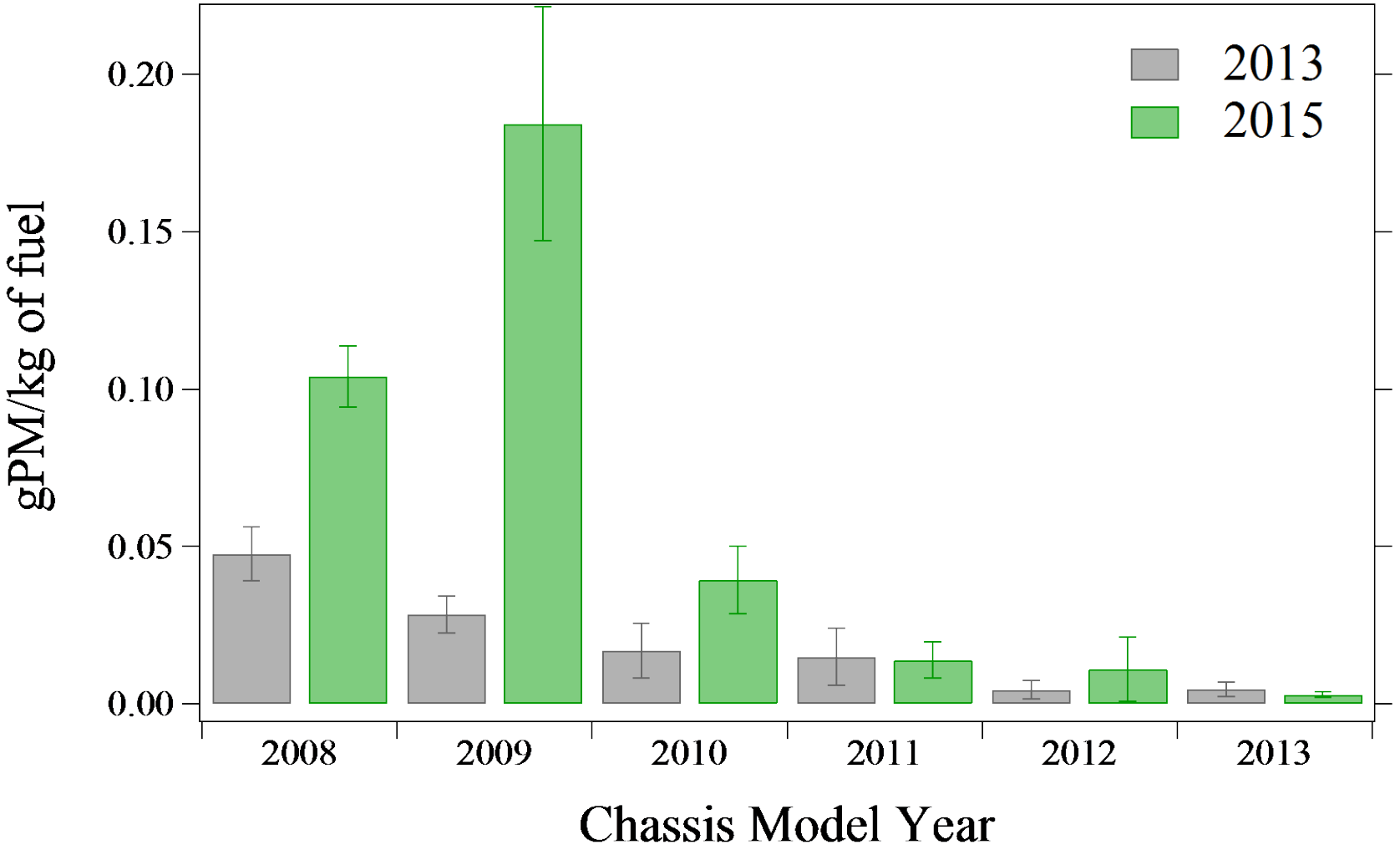


System and method for quantifying the presence of components in the exhaust of commercial and/or heavy-duty vehicles. US Patent 8,429,957, D.H. Stedman, 2013.

On-road Heavy-duty Measurement System

Bishop et al., On-road Heavy-duty Vehicle Emissions Monitoring System. *Environ. Sci. Technol.* **2015,** 49, (3), 1639-1645.

OHMS Measurements from the Port of Los Angeles



Don and Hazel, March 2016

References

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- Bishop, G. A.; Stedman, D. H., A decade of on-road emissions measurements. *Environ. Sci. Technol.* **2008,** 42, (5), 1651-1656, DOI: 10.1021/es702413b.
- Burgard, D. A.; Bishop, G. A.; Stadtmuller, R. S.; Dalton, T. R.; Stedman, D. H., Spectroscopy applied to on-road mobile source emissions. Appl. Spectrosc. **2006**, 60, 135A-148A, DOI: 10.1366/000370206777412185.
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- Vehicle Inspection Instrumentation, H. Hoshizaki, A. D. Wood and D. D. Kemp, Lockheed Palo Alto Research Laboratory, Final report to the California Air Resources Board, June 1973. http://www.feat.biochem.du.edu/assets/reports/LockHeed_ARB_1973.pdf
- Bishop, G. A.; Schuchmann, B. G.; Stedman, D. H.; Lawson, D. R., Multispecies remote sensing measurements of vehicle emissions on Sherman Way in Van Nuys, California. *J. Air Waste Manage. Assoc.* **2012,** 62, (10), 1127-1133, DOI: 10.1080/10962247.2012.699015.
- Bishop, G. A.; Stedman, D. H., The recession of 2008 and it impact on light-duty vehicle emissions in three western US cities. *Environ. Sci. Technol.* **2014,** 48, 14822-14827, DOI: 10.1021/es5043518.