RILEY M. DUREN
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CarbonMapper.org
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SUMMARY

I am the Chief Executive Officer of CarbonMapper.org, a Research Scientist at the University of Arizona, and an Engineering Fellow at NASA's Jet Propulsion Laboratory. For the previous decade I served as Chief Systems Engineer for JPL's Earth Science and Technology Directorate, with a broad portfolio of satellite and aircraft instruments and missions, research and analysis, applied science, and technology projects spanning NASA's earth science enterprise. I have worked for over 30 years at the intersection of science and engineering to deliver complex systems including satellite missions ranging from earth observations to telescopes in deep space.

My work applies earth system science and systems engineering to the challenge of climate change decision support. In 2020 I co-founded Carbon Mapper, a new non-profit organization leading a public-private partnership including philanthropies, a commercial aerospace company (Planet), NASA, the State of California, Arizona State University, U. Arizona and RMI to develop a constellation of satellites offering operational monitoring of methane and carbon dioxide emissions at high resolution to help accelerate greenhouse gas mitigation.

EXPERIENCE

CARBON MAPPER, Pasadena, California
- 2020-present, Chief Executive Officer

UNIVERSITY OF ARIZONA, Tucson, Arizona
- 2019-present, Research Scientist

JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, California
- 2017 – present, Engineering Fellow
- 2008 – 2019, Chief Systems Engineer, Earth Science & Technology Directorate
- 2002 – 2009, Chief Engineer & Project System Engineer, Kepler mission
- 2000 – 2002, Instrument System Engineer, Starlight mission
- 1996 – 2000, Metrology System Engineer, Shuttle Radar Topography Mission (SRTM)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, Kennedy Space Center, Florida
- 1988 – 1995, Payload Integration, Test and Operations Engineer (five space shuttle missions)

RESEARCH INTERESTS

My research extends the discipline of systems engineering to improving understanding of carbon emissions and working with diverse stakeholders to design and deploy decision support systems to help advance climate change mitigation and intervention efforts. I am currently Principal Investigator for five research projects involving observational systems and data analysis frameworks focused on methane and carbon dioxide emissions. My teams combine atmospheric measurements from satellites, aircraft and surface-based systems, tracer transport modeling, machine learning, and big data methods to detect, quantify and attribute emission sources. I have also co-organized studies of the observational challenges and risks of climate interventions (geoengineering) field research and briefed policy makers on these topics. My work supports programs at NASA, other federal and state agencies, and several non-governmental organizations.

EDUCATION

- Auburn University, Bachelor of Science, Electrical Engineering, 1991

HONORS

- JPL Mariner Award (2016)
- UN Climate Summit, Big Data Project to Watch: Megacities Carbon Project (2014)
- National Academy of Engineering Gilbreth Lecture (2013)
- Engineer's Council Distinguished Engineering Achievement Award (2012)
- NASA Exceptional Achievement Medals (2001 & 2010)
- NASA Systems Engineering Excellence Award (2010)
- NASA Group Achievement Awards (7 total, 1991-2013)

COMMITTEE SERVICE

- National Academy of Science: Committee on Developing a Research Agenda for Carbon Dioxide Removal and Sequestration (2017-2018)
- United States Carbon Cycle Science Program: 2nd State Of the Carbon Cycle Report – Writing Team, Decision Support and Urban Chapters (2016-2018)
- California Council on Science & Technology: Steering Committee for Long-term Viability of Natural Gas Storage Facilities (2017-2018)
- Integrated Global Greenhouse Gas Information System, Science Team (2015-present)
- NASA Plankton, Aerosol, Cloud, and ocean Ecosystem (PACE): Standing Review Board (2017 – 2018)
- External Advisory Board, NYU Center for Urban Science & Policy (2016-2018)
- External Advisory Board, Greenhouse Gas Management Institute (2012-2018)
- Multiple NASA ROSES review panels

OTHER AFFILIATIONS

- Adjunct Faculty, Center for Global Discovery and Conservation Science, Arizona State Univ.
- Visiting Researcher, UCLA Joint Institute for Regional Earth System Science & Engineering
- Member, American Geophysical Union

PEER-REVIEWED PUBLICATIONS

1. Lauvaux, T., C. Giron, M. Mazzolini, A. d'Aspremont, **R. Duren**, D. Cusworth, D. Shindell, P. Ciais, Assessment of Methane Mitigation Potential of Large Oil and Gas Leaks, *Science*, in press.
2. Ehret, Thibaud; De Truchis, Aurélien; Mazzolini, Matthieu; Morel, Jean-Michel; d'Aspremont, Alexandre; Lauvaux, Thomas; **Duren, Riley**; Cusworth, Daniel; Facciolo, Gabriele Global Tracking and Quantification of Oil and Gas Methane Emissions from Recurrent Sentinel-2 Imagery", *Env Sci & Tech.* in review.
3. John R. Worden, Daniel Cusworth, Zhen Qu[2], Yi Yin[3],Yuzhong Zhang A.Anthony Bloom, Shuang Ma, Brendan Byrne, Tia Scarpelli, Joannes D. Maasakkers, David Crisp, **Riley Duren**, and Daniel J. Jacob, The 2019 Methane Budget And Uncertainties At 1 Degree Resolution And Each Country, Through Bayesian Integration Of GOSAT Total Column Methane Data And A Priori Inventory Estimates, *Atmo. Chem. Phys.,* in review.
4. Logan E. Mitchell, John C. Lin, Lucy R. Hutyra, David R. Bowling, Ronald C. Cohen, Kenneth J. Davis, Elizabeth DiGangi, **Riley M. Duren**, James R. Ehleringer, Clayton Fain, Matthias Falk, Abhinav Guha, Anna Karion, Ralph F. Keeling, Jooil Kim, Natasha L. Miles, Charles. E. Miller, Sally Newman, Diane E. Pataki, Steve Prinzivalli, Xinrong Ren, Andrew Rice, Scott J. Richardson, Maryann Sargent, Britton B. Stephens, Jocelyn C. Turnbull, Kristal R. Verhulst, Felix Vogel, Ray F. Weiss, James Whetstone, Steven C. Wofsy, A Multi-City Urban Atmospheric Greenhouse Gas Measurement Data Synthesis, *Nature Sci. Data*, accepted.

5. Kourosh Vafi, Talha Rafiq, Sébastien Biraud, Andrew Thorpe, **Riley Duren**, Francesca M. Hopkins, Methane Super-Emitters in California's Oil Fields, *Nature Comm.,* in review.
6. Cusworth, D. H., **Duren, R. M.,** Thorpe, A. K., et al. (2021). Intermittent methane emissions in the Permian basin. *Env Sci & Tech Letters.*
7. Cusworth, D. H., **Duren, R. M.,** Thorpe, A. K., Pandey, S., Maasakkers, J. D., Aben, I., et al. (2020). Multi-satellite imaging of a gas well blowout enables quantification of total methane emissions. *Geophysical Research Letters*, 47. e2020GL090864. https://doi.org/10.1029/2020GL090864
8. Thorpe, A.K., O'Handley, C., Emmitt, G.D., DeCola, P.L., Hopkins, F.M., Yadav, V., Guha, A., Newman, S., Herner, J.D., Falk, M., Duren, R.M. (2021). Improved methane emission estimates using AVIRIS-NG and an Airborne Doppler Wind Lidar, *Remote Sensing of Environment.*
9. Cusworth, D.H., **Duren, R.M.,** Thorpe, Dennison, P.E., Frankenberg, C., Miller, C.E. (2021). Carbon dioxide emissions from power plants can be quantified globally using remote sensing, *AGU Advances*.
10. V. Yadav, S. Ghosh, K. Mueller, A. Karion, G. Roest, S.M. Gourdji, I. Lopez-Coto, K. R. Gurney, N. Parazoo, K. R. Verhulst, J. Kim, S. Prinzivalli, C. Fain, T. Nehrkorn, M. Mountain, R. F. Keeling, R. F. Weiss, **R. Duren,** C. E. Miller, J. Whetstone. The impact of COVID-19 on CO2 emissions in the Los Angeles and Washington DC/Baltimore metropolitan areas. *Geophysical Research Letters 48, e2021GL092744.*
11. Irakulis-Loitxate, I., et al Satellite-based Survey of Extreme Methane Emissions in the Permian Basin, *Science Advances*.
12. Cusworth, D. H., **Duren, R. M**., Yadav, V., Thorpe, A. K., Verhulst, K., Sander, S., et al. (2020). Synthesis of methane observations across scales: Strategies for deploying a multitiered observing network. *Geophys. Res. Let.*, *47*, e2020GL087869. https://doi.org/10.1029/2020GL087869
13. Miller, J.B., S.J. Lehman, K. Verhulst, C.E. Miller, **R.Duren**, V.Yadav, S. Newman, C. Sloop (2020), Large and seasonally varying biospheric CO_2 fluxes in the Los Angeles megacity revealed by atmospheric radiocarbon, *Proc. Natl Acad. Sci.*
14. Borchardt, J., Gerilowski, K., Krautwurst, S., Bovensmann, H., Thorpe, A. K., Thompson, D. R., Frankenberg, C., Miller, C. E., **Duren, R. M.,** and Burrows, J. P.: Detection and Quantification of CH_4 Plumes using the WFM-DOAS retrieval on AVIRIS-NG hyperspectral data, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2020-275, 2020.
15. Thorpe, A.K., **Duren, R.,** Conley, S., Prasad, K., Bue, B., Yadav, V., Foster, K., Rafiq, T., Hopkins, F., Smith, M. and Fischer, M.L (2020)., Methane emissions from natural gas storage in California, *Env. Res. Let*.
16. Borucki, W., J. Jenkins, **R. Duren**, Science Merit Function for the KEPLER Mission, *JATIS,* in press.
17. Rafiq, T., **R. Duren,** A. Thorpe, K. Foster, R.Patarsuk, C.E. Miller, and F.M. Hopkins (2020) ,Source Attribution of Methane Point Source Emissions using Airborne Imaging Spectroscopy and the Vista-California Methane Infrastructure Dataset, *Env. Res. Let*.
18. Guha, A., S. Newman, D. Fairley, T. M. Dinh, L. Duca, S.C. Conley, M. L. Smith, A. K. Thorpe, **R. M. Duren,** D.H. Cusworth, K. T. Foster, M.L. Fischer, S. Jeong, N. Yesiller, J.L. Hanson, and P. T. Martien, Assessment of Regional Methane Emission Inventories through Airborne Quantification in the San Francisco Bay Area, *Environ. Sci. & Tech.* **2020** *54* (15), 9254-9264 , DOI: 10.1021/acs.est.0c01212
19. Cusworth, D.H., **Duren, R.M.,** Thorpe, A.K., Tseng, E., Thompson, D.R., Guha, A., Newman, S., Foster, K., Miller, C.E. (2020). Using remote sensing to detect, validate, and quantify methane emissions from California solid waste operations. *Env. Res. Let.* **15**
20. **Duren, R.,** A. Thorpe, K.T. Foster, T. Rafiq, F. M. Hopkins, V. Yadav, B.Bue, D.R. Thompson, S. Conley, N. Colombi, C. Frankenberg, I.McCubbin, M.Eastwood, M.Falk, J. Herner, B. E. Croes, R. Green, C. Miller, California's Methane Super-emitters, *Nature* **575,** 180–184 (2019) doi:10.1038/s41586-019-1720-3.
21. Ware, J., E.A. Kort, **R. Duren**, K. Verhulst, V. Yadav, Detecting Urban Emissions Changes and Events with a Near Real Time Capable Inversion System, *J. Geophys Res – A.* (2019).
22. Yadav, V., **R. Duren**, K.Mueller, K.R. Verhulst , T. Nehrkorn, J. Kim, R.F. Weiss, R. Keeling, S.Sander, M. L. Fischer, S.Newman, M. Falk, T. Kuwayama, F. Hopkins, T.Rafiq, J. Whetstone, C. Miller, Spatio-

temporally resolved methane fluxes from the Los Angeles Megacity, *J. Geophy. Res. – A.* (2019).

23. Gurney, K. R., Patarasuk, R., Liang, J., Song, Y., O'Keeffe, D., Rao, P., Whetstone, J. R., **Duren, R. M.,** Eldering, A., and Miller, C.: The Hestia Fossil Fuel CO_2 Emissions Data Product for the Los Angeles Megacity (Hestia-LA), *Earth Syst. Sci. Data Discuss.,* https://doi.org/10.5194/essd-2018-162 (2019).
24. Cusworth, D., Jacob, D., Varon, D., Miller, C.C., Lu, X., Chance, K., Thorpe, A. , **Duren, R.,** Miller, C., Thompson, D., Frankenberg, C., Guanter, L., Randles, C., Potential of next-generation imaging spectrometers to detect and quantify methane point sources from space, *Atmos. Meas. Tech.* (2019).
25. Kuai, L., O.V. Kalashnikova, F. Hopkins, G. Hulley, H. Lee, M. J. Garay, **R. Duren**, J. Worden, S.Hook, Quantification of ammonia emissions with high spatial resolution thermal infrared observations from the Hyperspectral Thermal Emission Spectrometer (HyTES) airborne instrument, *JSTARS* (2019).
26. Cui., Y.Y, A. Vijayan, M. Falk, Y. Hsu, D. Yin, Z. Zhao, J. Avise, K. Verhulst, L. T. Iraci, M.S. Johnson, Y. Chen, K. Stroud, J.Herner, B. Croes, **R.Duren**, A multi-platform inversion estimation of statewide and regional methane emissions in California during 2014-2016, *Env. Sci. Tech* (2019).
27. He, L., Zhao-Cheng Zeng, T. Pongetti, C. Wong, J.Liang, K. Gurney, S Newman, V.Yadav, K. Verhulst, C.Miller, **R. Duren**, C. Frankenberg, P. Wennberg, R. Shia, Y. Yung and S. Sander, Leakage from natural gas usage correlates with seasonal methane emissions in Los Angeles, *Geophys. Res. Let.* (2019).
28. Jongaramrungruang, S., Frankenberg, C., Matheou, G., Thorpe, A., Thompson, D. R., Kuai, L., and **Duren, R**.: Towards accurate methane point-source quantification from high-resolution 2D plume imagery, *Atmos. Meas. Tech.,* doi: 10.5194/amt-2019-173, in review, 2019.https://www.atmos-meas-tech-discuss.net/amt-2019-173/
29. Ayasse, A.K., Dennison, P.E., Foote, M., Thorpe, A.K., Joshi, S., Green, R.O., **Duren, R.M**., Thompson, D.R. and Roberts, D.A. (2019). Methane Mapping with Future Satellite Imaging Spectrometers. *Remote Sensing*, 11(24), p.3054.
30. Carranza, V., Rafiq, T., Frausto-Vicencio, I., Hopkins, F. M., Verhulst, K. R., Rao, P., **Duren, R. M.,** Miller, C. E. (2018). Vista-LA: Mapping methane-emitting infrastructure in the Los Angeles megacity. *Earth System Science Data*. 10(1), 653-676. DOI: 10.5194/essd-10-653-2018
31. USGCRP, 2018: *Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report* [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. **R. Duren** contributing author to Chapter 4: Understanding Urban Carbon Fluxes and Chapter 18: Carbon cycle science in support of decision making, U.S. Global Change Research Program, Washington, DC, USA, 878 pp., https://doi.org/10.7930/SOCCR2.2018
32. CCST, 2018: Long-Term Viability of Underground Natural Gas Storage in California [Long, Jane C.S.; Birkholzer, Jens T.; Mace, Amber J.; Brady, Sarah E., eds]; Lead authors: Fischer, M., **Duren, R:** Section 1.5: Quantification of greenhouse gas emissions from underground gas storage in California, California Council on Science and Technology, https://ccst.us/reports/long-term-viability-of-underground-natural-gas-storage-in-california-an-independent-review-of-scientific-and-technical-information/
33. Thorpe, A.K., Frankenberg, C., Thompson, D.R., **Duren, R.M.,** Aubrey, A.D., Bue, B.B., Green, R.O., Gerilowski, K., Krings, T., Borchard, J., Kort, E.A., Sweeney, C., Conley, S., Roberts, D.A., Dennison, P.E. (2017). Airborne DOAS retrievals of methane, carbon dioxide, and water vapor concentrations at high spatial resolution: application to AVIRIS-NG. *Atmos. Meas. Tech.* (2017), doi: 10.5194/amt-2017-51.
34. Rao, P., R. Gurney, K., Patarasuk, R., Song, Y., E. Miller, C., M. **Duren, R**., Eldering, A. (2017). Spatio-temporal Variations in on-road CO2 Emissions in the Los Angeles Megacity. AIMS Geosciences. 3(2), 239-267. DOI: 10.3934/geosci.2017.2.239
35. Verhulst, K.R., J. Kim, P.K. Salameh, C. Sloop, A.Karion, T. Pongetti, F.M. Hopkins, C. Wong, P. Rao, J. Miller, R. F. Keeling, R. F. Weiss, C. Miller, and **R. Duren,** , In Situ Carbon Dioxide and Methane Measurements from a Tower Network in the Los Angeles Megacity , *Atmos. Chem. Phys.,* (2016), doi: 10.5194/acp-2016-850.

36. Thompson, D.R., A. K. Thorpe, C. Frankenberg, R. O. Green, **R. Duren**, L. Guanter, A. Hollstein, E. Middleton, L. Ong, S. Ungar, Space-based Remote Imaging Spectroscopy of the Aliso Canyon CH4 Super-emitter, *Geophys. Res. Let.* (2016), doi: 10.1002/2016GL069079
37. Hulley, G.C., **R. Duren,** S.J. Hook, F. Hopkins, N. Vance, et al. (2016), High spatial resolution imaging of methane and other trace gas sources with the airborne Hyperspectral Thermal Emission Spectrometer, *Atmos. Meas. Tech.*(2016)*,* doi:10.5194/amt-2016-8
38. Wong, K. W., Pongetti, T. J., Oda, T., Rao, P., Gurney, Kevin. R., Newman, S., **Duren, R**. M., Miller, C. E., Yung, Y. L., and Sander, S. P.: Monthly trends of methane emissions in Los Angeles from 2011 to 2015 inferred by CLARS-FTS observations, *Atmos. Chem. Phys.* (2016), doi:10.5194/acp-2016-232
39. Ware, J., E. Kort, P. Decola, **R. Duren** (2016), Aerosol Lidar Observations of Atmospheric Mixing in Los Angeles: Climatology and Implications for Greenhouse Gas Observations, *J. Geophys Res – A,* doi: 10.1002/2016JD024953, 2016*.*
40. Hopkins, F.M., J.R. Ehleringer, S.E. Bush, **R.M. Duren**, C.E. Miller, C.T. Lai, Y.-K. Hsu, V. Carranza, J.T. Randerson (2016). Mitigation of methane emissions in cities: how new measurements and partnerships can contribute to emissions reduction strategies, *Earth's Future* (2016), doi: 10.1002/2016EF000381
41. Bloom, A. A., Lauvaux, T., Yadav, V., **Duren, R.,** Sander, S., Worden, J., and Schimel, D., What are the greenhouse gas observing system requirements for reducing fundamental biogeochemical process uncertainty? Amazon wetland CH_4 emissions as a case study, *Atmos. Chem. Phys.,* doi:10.5194/acp-2016-325, 2016.
42. Kuai, L., G. Hulley, J. Worden, F. M. Hopkins, King-Fai Li, C. E. Miller, S. Hook, **R. Duren**, A. Aubrey (2016)**,** Characterization of anthropogenic methane plumes with the Hyperspectral Thermal Emission Spectrometer (HyTES): a retrieval method and error analysis, *Atmos. Meas. Tech.,* doi:10.5194/amt-2015-40
43. Feng, S., T. Lauvaux, S. Newman, P. Rao, R. Ahmadov, A. Deng, L.I. Diaz-Isaac, **R.Duren** et al. (2016) LA Megacity: a High-Resolution Land-Atmosphere Modelling System for Urban CO_2 Emissions, *Atmos. Chem. Phys.,* doi: 10.5194/acp-2016-143
44. Viatte, C., Lauvaux T., Hedelius J. K., Parker H., Chen J., Jones T., Franklin J. E., Deng A.J., Gaudet B., **Duren R.**, Verhulst K., Wunch D., Roehl C., Dubey M. K., Wofsy S., Wennberg P. O.,(2016) Estimating methane emissions from dairies in the Los Angeles Basin, *Atmos. Chem. Phys.*
45. Schimel, D., P. Sellers; B. Moore III; A. Chatterjee; D.Baker; J. Berry; K. Bowman; P. Ciais; D. Crisp; S. Crowell; S. Denning; **R. Duren**; P. Friedlingstein; M.Gierach; K. Gurney; K. Hibbard; R. Houghton; D. Huntzinger; G. Hurtt; K.Jucks; R. Kawa; R. Koster; C. Koven; Y. Luo; J. Masek; G. McKinley; C. Miller; J. Miller; P. Moorcroft; R. Nasser; C.O'Dell; L. Ott; S. Pawson; M.Puma; T. Quaife; H. Riris; A.Romanou; C. Rousseaux; A. Schuh; E. Shevliakova; C. Tucker; Y. Ping Wang; C. Williams; X. Xiao; T. Yokota, Observing the carbon-climate system, *B. Am. Meteorol. Soc.* (2016).
46. Gurney, K.R., P. Romero-Lankao, K. C. Seto, L. R. Hutyra, **R. Duren**, et al, **"**Track Urban Emissions on a Human Scale", *Nature* (2015)
47. Mullally, F., *et al*, Planetary Candidates Observed by Kepler VI: Planet Sample from Q1-Q16 (47 Months), *Astrophys. J. Suppl*. (2015), Volume 217, 2.
48. Keith, David W., **R. Duren,** and D. G. MacMartin (2014), Field experiments on Solar Geoengineering: An exploration of a representative research portfolio, *Phil Trans Royal Soc A, doi:* 10.1098/rsta.2014.0175
49. Hutyra, Lucy R., **R. Duren**, K.R. Gurney, N. Grimm, E. Kort, E.Larson, G. Shrestha, Urbanization and the carbon cycle: Current capabilities and research outlook from the natural sciences perspective, *Earth's Future* (2014), doi:10.1002/2014EF000255.

50. Romero-Lankao, P., K.R. Gurney, K.C. Seto, M. Chester, **R. Duren,** et al., A critical knowledge pathway to low-carbon, sustainable futures: Integrated understanding of urbanization, urban areas, and carbon, *Earth's Future* (2014), *2*, doi:10.1002/2014EF000258.
51. Wong, K.W., D. Fu, T. J. Pongetti, S. Newman, E. A. Kort, **R. Duren,** Y. Hsu, C. E. Miller, Y. L. Yung, S. P. Sander, Mapping CH_4:CO_2 ratios in Los Angeles with CLARS-FTS from Mount Wilson, California, Atmos Chem Phys. (2014) 14, 17037–17066, doi: 10.5194/acpd-14-17037-2014
52. West, T.O., M.E. Brown, **R. Duren,** S.M. Ogle, R. H. Moss, Definition, capabilities and components of a terrestrial carbon monitoring system, *Carbon Management,* (2013) 4(4), 413–422, doi: 10.4155/CMT.13.36
53. Robock, A., D.G.MacMartin, **R. Duren**, M.W. Christensen, Studying geoengineering with natural and anthropogenic analogs, *J. Clim. Change* (2013), doi: 10.1007/s10584-013-0777-5.
54. P. Ciais, A.J. Dolman, A. Bombelli, **R. Duren**, A. Peregon, P.J. Rayner et al., Current systematic carbon cycle observations and needs for implementing a policy-relevant carbon observing system, *Biogeosci* (2013), 10, 11447–11581, doi:10.5194/bgd-10-11447-2013
55. E. Kort, C. E. Miller, **R. Duren,** W. Angevine, Surface observations for monitoring megacity greenhouse gas emissions: minimum requirements for Los Angeles, *J. Geophys Res – A*, 2013. doi: 10.1002/jgrd.50135
56. **R. Duren** and C. Miller, Measuring the Carbon Emissions of Megacities, *Nature Climate Change* 2, 560–562 (2012). doi:10.1038/nclimate1629
57. **R. Duren** and C. Miller, Towards robust global greenhouse gas monitoring, *J. Greenhouse Gas Meas and Manag.* (2011). doi:10.1080/20430779.2011.579356
58. Farr, T.G., E. Caro, R. Crippen, **R. Duren,** S. Hensley, M. Kobrick, M. Paller, E. Rodriguez, P. Rosen, L. Roth, D. Seal, S. Shaffer, J. Shimada, J. Umland, M. Werner, The Shuttle Radar Topography Mission, *AGU Reviews of Geophysics* (2006).
59. **Duren, R.**, Verification and Validation of Deep-Space Missions, *AIAA J. Spacecraft and Rockets*, Vol. 41, No. 4 (2004)

SELECTED INVITED TALKS & PANELS

- *United Nations Framework Convention on Climate Change, Conference of Parties,* Glasgow, 2021
- *Methane Detection Technology Workshop*, US EPA, 2021
- *United States House Space & Aeronautics Subcommittee,* testimony on NASA's Earth Science and Climate Change Activities: Current Roles and Future Opportunities, 2021
- *CH_4 Connections,* Understanding Methane Emissions from NG Systems, Ft Collins, 2021
- *American Geophysical Union,* Methane emissions from oil, gas, coal operations, San Francisco, 2020
- *AAAS annual meeting,* California Methane Monitoring, Austin, 2018
- *Gas Technology Institute,* Methane monitoring, Ft Collins, 2018
- *Gordon Conference on Climate Engineering,* Engineering Aspects & Outdoor Experimentation, 2017
- *National Academy of Science - Polar Research Board,* Arctic Climate Interventions, Washington, 2016
- *DOE Workshop on Research Strategies on Oil and Gas Sector Methane Emissions*, Washington, 2016
- *AIAA Space Forum*, Earth Observations: Space and the Paris Agreement, Long Beach, 2016
- *American Geophysical Union,* Climate Intervention Research, San Francisco, 2015
- *AAAS annual meeting,* Geoengineering risks/challenges, San Jose, 2015
- *California Climate Symposium,* Megacities Carbon Project and CA methane, Sacramento, 2015
- *Bureau International des Poids et Measures meeting on Greenhouse Gas monitoring,* Megacities Carbon Project, Paris, 2015

- *United Nations Framework Convention on Climate Change, Conference of Parties,* Megacities Carbon Project, Lima, 2014
- *California Air Resources Board,* directors meeting, Megacities Carbon Project, Sacramento, 2014
- *Council on Foreign Relations,* Geoengineering risks, Washington, 2014
- *Bipartisan Policy Center,* Solar Radiation Management field research, Washington, 2014
- *American Geophysical Union,* Characterizing the carbon emissions of megacities, San Francisco, 2014
- *National Academy of Engineering,* Geoengineering, Irvine, 2013
- *Von Karman Lecture Series,* Geoengineering and Climate Intervention*,* Pasadena, 2013
- *Defense Science Board Task Force on Climate Change*, Arlington, 2011
- *AAAS*, Carbon Monitoring Systems, Washington, 2010 and 2009
- *Intergovernmental Panel on Climate Change (IPCC) Task Force on Inventories*, *Expert Meeting on Greenhouse Gas Inventory Validation and Uncertainties*, Utrecht, 2010
- *US Senate Science and Technology Caucus*, Washington, 2010
- *National Academy of Engineering Frontiers of Engineering*, Kepler mission, Irvine, 2009
- *International Council On Systems Engineering (INCOSE),* Keynote Speaker, Syracuse, 2005.

PUBLIC OUTREACH

- Print, television, and radio interviews with the *Associated Press*, *Los Angeles Times, NPR, KCRW, KQED, KCET, Nature* news, *NBC Nightly News*, *Bloomberg, PBS News Hour*, *Agence France-Presse*, *Climate Wire*, *Earth* magazine, *Science Now, Scientific American, Space News, Voice of America*, *The Weather Channel*, *Barron's, Blue Dot Report, Vox, Reveal, BBC, Washington Post,* others*.*
- Numerous public lectures 2000-present