

Hope Michelsen

Department of Mechanical Engineering, University of Colorado Boulder

Education

Stanford University Ph.D. major in Chemistry and minor in Physics 1/7/93
Dartmouth College A.B. with High Honors in Chemistry 6/10/84

Awards, appointments, and science team membership

Recipient, Adams Award, Combustion Research Facility, Sandia National Labs 11/18
 Tsuji Award Committee, Combustion Institute 9/18 - present
 Program Advisory Committee, 38th International Symposium on Combustion 9/18 - present
 Associate Editor, Proceedings of the Combustion Institute 1/18 - present
 Editorial Board, PeerJ Environmental Sciences 10/17 - present
 Fellow, The Optical Society (OSA) 9/17
 Linac Coherent Light Source (LCLS) Peer Review Panel (SLAC, Dept. of Energy) 5/17 - present
 Science Advisory Board, International Sooting Flame Workshop 2/17 - present
 Chair (Co-chair), Colloquium on Soot, 37th (36th) Int'l Symposium on Combustion 8/18 (8/16)
 Chair (Vice chair) Gordon Research Conference on Laser Diagnostics in Combustion 8/17 (8/15)
 Host, 7th International Workshop on Laser-Induced Incandescence of Soot 6/16
 Awardee, Outstanding Women at Sandia National Laboratories 2/14
 Inductee, Alameda County Women's Hall of Fame 1/13
 Advisory Committee, International Workshop on Laser-Induced Incandescence 9/05 - present
 Topical editor, Applied Optics (The Optical Society) 5/02 - 11/05
 Award for Excellence in Reviewing (American Geophysical Union) 12/03
 SPARC international water vapor assessment panel 3/99 - 3/00
 SAGE II (III) (satellite/space station instruments) science team (NASA) 1/96 - 4/99 (3/98 - 3/01)
 TOMS (Total Ozone Mapping Spectrometer instrument) science team (NASA) 1/98 - 10/01
 NASA Group Achievement Awards: POLARIS (ASHOE/MAESA) (ER-2 missions) 9/97 (11/94)
 ATMOS (space shuttle FTIR solar occultation instrument) science team (NASA) 3/94 - end
 Postdoctoral Research Fellowship in Chemistry (National Science Foundation) 2/93 - 3/95
 Global Change Distinguished Postdoctoral Fellowship (Dept. of Energy) - declined 6/92
 Student Award and Nellie Yeoh Whetten Award (American Vacuum Society) 11/92
 Chandler T. White 1916 Research Prize (Dartmouth College) 5/84

Papers or book chapters published, in press, or under review for publication

Atmospheric sci. 55; Combustion 43; Surface sci. 20; Total: 118; Google scholar *h*-index: 48

Work experience

University of Colorado 8/19 – present
 Associate professor, Department of Mechanical Engineering
Sandia National Laboratories 7/99 – 8/19
 Technical staff, Combustion Research Facility
Atmospheric and Environmental Research, Inc. 12/97 - 6/99
 Staff scientist
Harvard University 2/93 - 10/97
 Postdoctoral research fellow/research associate with Profs. James G. Anderson, Steven C. Wofsy
Stanford University and IBM Almaden Research Center 6/85 – 1/93
 Graduate research assistant to Prof. Richard N. Zare, Drs. Daniel J. Auerbach, Charles T. Rettner

Patents

R. P. Bambha and H. A. Michelsen, "Method and system for multi-pass laser-induced incandescence", *U. S. Patent Office*, Application no. 15239634 (August 17, 2016), Issued 2018.

Recent invited conference talks

H. A. Michelsen, "Solving the Mystery of Soot Particle Inception and Growth", *American Chemical Society Annual Meeting*, San Diego, CA (August 2019).

H. A. Michelsen, "Using VUV and X-Ray Tools to Solve the Mystery of Soot Formation", *The 40th International Conference on Vacuum Ultraviolet and X-Ray Physics*, Plenary talk, San Francisco, CA (July 2019).

H. A. Michelsen, "Soot Formation, Growth, and Global Impact: The Life Story of a Mass Murderer", *U. S. National Combustion Meeting*, Plenary talk, Pasadena, CA (March 2019).

H. A. Michelsen, "Mysteries of High-Temperature Particle Formation: Soot, Interstellar Dust, and Novel Materials", *LCLS-II-HE Workshop*, Menlo Park, CA (October 2018).

H. A. Michelsen, "Probing Soot Formation and Chemical Evolution During Combustion", *Fundamentals in Optics/Laser Science (OSA/APS)*, Washington, DC (September 2018).

H. A. Michelsen, "Soot Inception: What do we know, and where do we go from here?", *International Sooting Flames Workshop*, Keynote talk, Dublin, Ireland (July 2018).

K. O. Johansson and H. A. Michelsen, " Probing Soot Formation and Chemical Evolution During Combustion", *CLEO*, San Jose, CA (May 2018).

H. A. Michelsen, "Probing Combustion Chemistry Using Hard X-Rays: Needs, Challenges, and Opportunities", *LCLS-II-HE Workshop*, Menlo Park, CA (September 2016).

H. A. Michelsen, "Topical Overview: Probing Soot Formation, Chemical and Physical Evolution, and Oxidation: A Review of Diagnostic Techniques and Needs", *36th International Symposium on Combustion*, Seoul, South Korea (August 2016).

Publications

118. Q. Wang, P. Elvati, D. Kim, K. O. Johansson, P. E. Schrader, H. A. Michelsen, and A. Violi, "Spatial dependence of polycyclic aromatic compound growth in counterflow flames", *Carbon*, submitted (2018).

117. K. O. Johansson, M. P. Head-Gordon, P. E. Schrader, K. R. Wilson, and H. A. Michelsen, "Resonance-stabilized hydrocarbon-radical chain reactions may explain soot inception and growth", *Science* **361**, 997-1000 (2018) DOI: 10.1126/science.aat3417.

116. H. Graven, M. L. Fischer, T. Lueker, S. Jeong, T. P. Guilderson, R. F. Keeling, R. P. Bambha, K. Brophy, W. Callahan, X. Cui, C. Frankenberg, K. R. Gurney, B. W. LaFranchi, S. J. Lehman, H. A. Michelsen, J. B. Miller, S. Newman, W. Paplawsky, N. C. Parazoo, C. Sloop, and S. J. Walker, "Assessing fossil fuel CO₂ emissions in California using atmospheric observations and models", *Environ. Res. Lett.* **13**, 065007 (2018) DOI: 10.1088/1748-9326/aabd43.

115. M. F. Campbell, P. E. Schrader, A. L. Catalano, K. O. Johansson, G. A. Bohlin, N. K. Richards-Henderson, C. J. Kliwer, and H. A. Michelsen, "A small porous-plug burner for studies of combustion chemistry and soot formation", *Rev. Sci. Instrum.* **88**, 125106 (2017) DOI: 10.1063/1.5016212.

114. K. O. Johansson, F. El Gabaly, P. E. Schrader, M. F. Campbell, and H. A. Michelsen, "Evolution of maturity levels of particle surface and bulk during soot growth and oxidation in a flame", *Aerosol Sci. Technol.* **51(12)**, 1333-1344 (2017) DOI: 10.1080/02786826.2017.1355047.
113. K. O. Johansson, M. F. Campbell, P. Elvati, P. E. Schrader, J. Zádor, N. K. Richards-Henderson, K. R. Wilson, A. Violi, and H. A. Michelsen, "Photoionization efficiencies of five polycyclic aromatic hydrocarbons", *J. Phys. Chem. A* **121(23)**, 4447-4454 (2017) DOI: 10.1021/acs.jpca.7b02991.
112. K. O. Johansson, J. Zádor, P. Elvati, M. F. Campbell, P. E. Schrader, N. K. Richards-Henderson, K. R. Wilson, A. Violi, and H. A. Michelsen, "Critical assessment of photoionization efficiency measurements for characterization of soot-precursor species", *J. Phys. Chem. A* **121(23)**, 4475-4485 (2017) DOI: 10.1021/acs.jpca.7b02992.
111. Y. Y. Cui, J. Brioude, W. M. Angevine, S. A. McKeen, S.-W. Kim, J. Peischl, J. A. Neuman, D. Henze, N. Bousserrez, M. L. Fischer, S. Jeong, Z. Liu, R. P. Bambha, H. A. Michelsen, G. W. Santoni, B. C. Daube, E. A. Kort, G. J. Frost, T. B. Ryerson, S. C. Wofsy, and M. Trainer, "Top-down estimate of methane emissions in California using a mesoscale inverse modeling technique: The San Joaquin Valley", *J. Geophys. Res.* **122(6)**, 3686-3699 (2017) DOI: 10.1002/2016JD026398.
110. S. Jeong, X. Cui, D. R. Blake, B. Miller, S. Montzka, A. E. Andrews, A. Guha, P. Martien, R. P. Bambha, B. F. LaFranchi, H. A. Michelsen, C. Clements, P. Glaize, and M. L. Fischer, "Estimating methane emissions from biological and fossil-fuel sources in the San Francisco Bay Area", *Geophys. Res. Lett.* **44**, 486-495 (2017) DOI: 10.1002/2016GL071794.
109. S. Jeong, S. Newman, J. Zhang, A. E. Andrews, L. Bianco, J. Bagley, X. Cui, H. Graven, J. Kim, P. Salameh, B. F. LaFranchi, C. Priest, M. Campos-Pineda, E. Novakovskaia, C. D. Sloop, H. A. Michelsen, R. P. Bambha, R. F. Weiss, R. Keeling, and M. L. Fischer, "Estimating methane emissions in California's urban and rural regions using multi-tower observations", *J. Geophys. Res. Atmos.* **121**, 13,031-13,049 (2016) DOI: 10.1002/2016JD025404.
108. H. A. Michelsen, "Probing soot formation, chemical and physical evolution, and oxidation: A review of *in situ* diagnostic techniques and needs", *Proc. Combust. Inst.* **36**, 717-735 (2017) DOI: 10.1016/j.proci.2016.08.027.
107. K. O. Johansson, T. Dillstrom, P. Elvati, M. F. Campbell, P. E. Schrader, D. M. Popolan-Vaida, N. K. Richards-Henderson, K. R. Wilson, A. Violi, and H. A. Michelsen, "Radical-radical reactions, pyrene nucleation, and incipient soot formation in combustion", *Proc. Combust. Inst.* **36**, 799-806 (2017) DOI: 10.1016/j.proci.2016.07.130.
106. M. F. Campbell, A. Bohlin, P. E. Schrader, R. P. Bambha, C. J. Kliewer, K. O. Johansson, and H. A. Michelsen, "Design and characterization of a linear Hencken-type burner", *Rev. Sci. Instrum.* **87**, 115114 (2016) DOI: 10.1063/1.4967491.
105. K. O. Johansson, T. Dillstrom, M. F. Campbell, M. Monti, F. El Gabaly, P. E. Schrader, D. M. Popolan-Vaida, N. K. Richards-Henderson, K. R. Wilson, A. Violi, and H. A. Michelsen, "Formation and emission of large furans and oxygenated hydrocarbons from flames", *Proc. Natl. Acad. Sci. USA* **113**, 8374-8379 (2016) DOI: 10.1073/pnas.1604772113.

104. R. P. Bambha and H. A. Michelsen, "Effects of aggregate morphology and size on laser-induced incandescence and scattering from black carbon (mature soot)", *J. Aerosol Sci.* **88**, 159-181 (2015) DOI: 10.1016/j.jaerosci.2015.06.006.
103. H. A. Michelsen, C. Schulz, G. J. Smallwood, and S. Will, "Laser-induced incandescence: Particulate diagnostics for combustion, atmospheric, and industrial applications", *Progress Energy Combust. Sci.* **51**, 2-48 (2015) DOI: 10.1016/j.pecs.2015.07.001.
102. K. O. Johansson, J. Y. W. Lai, S. A. Skeen, D. M. Popolan-Vaida, K. R. Wilson, N. Hansen, A. Violi, and H. A. Michelsen, "Soot precursor formation and limitations of the stabilomer grid", *Proc. Combust. Inst.* **35**, 1819-1826 (2015) DOI: 10.1016/j.proci.2014.05.033.
101. A. Nanthaamornphong, J. C. Carver, K. Morris, H. A. Michelsen, and D. W. I. Rouson, "Building CLiIME via test-driven development: A case study", *Comput. Sci. Eng.* **16(3)**, 36-46 (2014).
100. X. López-Yglesias, P. E. Schrader, and H. A. Michelsen, "Soot maturity and absorption cross sections", *J. Aerosol Sci.* **75**, 43-64 (2014) DOI: 10.1016/j.jaerosci.2014.04.011.
99. N. Hansen, S. A. Skeen, H. A. Michelsen, K. R. Wilson, and K. Kohse-Höinghaus, "Flame experiments at the Advanced Light Source: New insights into soot formation processes", *Journal of Visualized Experiments (JoVE)* **87**, e51369 (2014) DOI: 10.3791/51369.
98. Z. Liu, R. P. Bambha, J. Pinto, T. Zeng, J. Boylan, M. Huang, H. Lei, C. Zhao, S. Liu, J. Mao, C. Schwalm, X. Shi, Y. Wei, and H. A. Michelsen, "Toward verifying fossil fuel CO₂ emissions from the CMAQ model: Motivation, model description, and initial simulation", *J. Air Waste Manage. Assoc.* **64(4)**, 419-435 (2014) DOI: 10.1080/10962247.2013.816642.
97. R. P. Bambha, M. A. Dansson, P. E. Schrader, and H. A. Michelsen, "Effects of volatile coatings on the laser-induced incandescence of soot", *Appl. Phys. B* **112(3)**, 343-358 (2013).
96. R. P. Bambha, M. A. Dansson, P. E. Schrader, and H. A. Michelsen, "Effects of volatile coatings and coating removal mechanisms on the morphology of graphitic soot", *Carbon* **61**, 80-96 (2013).
95. F. Goulay, P. E. Schrader, X. López-Yglesias, and H. A. Michelsen, "A dataset for validation of models of laser-induced incandescence from soot: Temporal profiles of LII signal and particle temperature", *Appl. Phys. B* **112(3)**, 287-306 (2013).
94. J. M. Headrick, P. E. Schrader, and H. A. Michelsen, "Radial-profile and divergence measurements of combustion-generated soot focused by an aerodynamic-lens system", *J. Aerosol Sci.* **58**, 158-170 (2013).
93. S. A. Skeen, H. A. Michelsen, K. R. Wilson, D. M. Popolan, A. Violi, and N. Hansen, "Near-threshold photoionization mass spectra of combustion-generated high-molecular-weight soot precursors", *J. Aerosol Sci.* **58**, 86-102 (2013).
92. S. A. Skeen, B. Yang, H. A. Michelsen, J. A. Miller, A. Violi, and N. Hansen, "Studies of laminar opposed-flow diffusion flames of acetylene at low pressures with photoionization mass spectrometry", *Proc. Combust. Inst.* **34**, 1067-1075 (2013).
91. H. A. Michelsen, P. E. Schrader, and F. Goulay, Erratum to "Wavelength and temperature dependences of the absorption and scattering cross sections of soot" [Carbon 48 (2010) 2175-2191], *Carbon* **50**, 740 (2011).

90. J. M. Headrick, F. Goulay, P. E. Schrader, and H. A. Michelsen, "High-vacuum time-resolved laser-induced incandescence of flame-generated soot", *Appl. Phys. B* **104**, 439-450 (2011).
89. H. A. Michelsen, P. E. Schrader, and F. Goulay "Wavelength and temperature dependences of the absorption and scattering cross sections of soot", *Carbon* **48**, 2175-2191 (2010).
88. F. Goulay, P. E. Schrader, and H. A. Michelsen, "Effect of the wavelength dependence of the emissivity on inferred soot temperatures measured by spectrally resolved laser-induced incandescence", *Appl. Phys. B* **100**, 655-663 (2010).
87. B. Zak, B. Bader, R. Bambha, H. Michelsen, M. Boslough, M. Moorman, and A. Jacobson, "Reduction of uncertainties in remote measurement of greenhouse gas fluxes", *2010 IEEE Aerospace Conference*, Accession # 11258446 (2010).
86. F. Goulay, L. Nemes, P. E. Schrader, and H. A. Michelsen, "Spontaneous emission from $C_2(d^3\Pi_g)$ and $C_3(A^1\Pi_u)$ during laser irradiation of soot particles", *Mol. Phys.* **108**, 1013-1025 (2010).
85. F. Goulay, P. E. Schrader, and H. A. Michelsen, "The effects of pulsed laser injection seeding and triggering on the temporal behavior and magnitude of laser-induced incandescence from soot", *Appl. Phys. B* **96(4)**, 613-621 (2009).
84. H. A. Michelsen, "Derivation of a temperature-dependent accommodation coefficient for use in modeling laser-induced incandescence of soot", *Appl. Phys. B* **94**, 103-117 (2009).
83. F. Goulay, P. E. Schrader, L. Nemes, M. A. Dansson, and H. A. Michelsen, "Photochemical interferences for laser-induced incandescence of flame-generated soot", *Proc. Comb. Inst.* **32**, 963-970 (2009).
82. H. A. Michelsen, M. A. Linne, B. F. Kock, M. Hofmann, B. Tribalet, and C. Schulz, "Modeling laser-induced incandescence of soot: Enthalpy changes during sublimation, conduction, and oxidation", *Appl. Phys. B* **93**, 645-656 (2008).
81. M. A. Dansson, M. Boisselle, M. A. Linne, and H. A. Michelsen, "Complications to optical measurements using a laser with an unstable resonator: A case study on laser-induced incandescence of soot", *Appl. Opt.* **46**, 8095-8103 (2007).
80. H. A. Michelsen et al., "Modeling laser-induced incandescence of soot: A summary and comparison of LII models", *Appl. Phys. B* **87**, 503-521 (2007).
79. L. Nemes, A. M. Keszler, C. G. Parigger, J. O. Hornkohl, H. A. Michelsen, and V. Stakhursky, "On spontaneous emission from the C_3 radical in carbon plasma", *Appl. Opt.* **46**, 4032-4040 (2007).
78. H. A. Michelsen, A. V. Tivanski, M. K. Gilles, L. H. van Poppel, M. A. Dansson, and P. R. Buseck, "Particle formation from pulsed laser irradiation of soot aggregates studied with a scanning mobility particle sizer, a transmission electron microscope, and a scanning transmission x-ray microscope", *Appl. Opt.* **46**, 959-977 (2007).
77. C. Schulz, B. F. Kock, M. Hofmann, H. A. Michelsen, S. Will, B. Bougie, R. Suntz, and G. Smallwood, "Laser-induced incandescence: Recent trends and current questions", *Appl. Phys. B* **83**, 333-354 (2006).

76. H. A. Michelsen, "Laser-induced incandescence of flame-generated soot on a picosecond timescale", *Appl. Phys. B* **83**, 443-448 (2006).
75. L. Nemes, A. M. Keszler, C. G. Parigger, J. O. Hornkohl, H. A. Michelsen, and V. Stakhursky, "The C₃ puzzle: Formation of and spontaneous emission from the C₃ radical in carbon plasmas", *Int. Elect. J. Mol. Design* **5**, 150-167 (2006).
74. P. O. Witze, M. Y. Gershenzon, and H. A. Michelsen, "Dual-laser LIDELS: An optical diagnostic for time-resolved volatile fraction measurements of diesel particulate emissions", *Proc. SAE*, SAE paper #2005-01-3791 (2005).
73. B. K. Pun, C. Seigneur, and H. A. Michelsen, "Atmospheric Transformations", in *Air Pollution Modeling: Theories, Computational Methods, and Available Software, 2nd edition, Vol. 2*, P. Zannetti, Ed., Van Nostrand Reinhold, New York, Chapter 12 (2005).
72. E.-W. Chiou, L. W. Thomason, S. P. Burton, and H. A. Michelsen, "Assessment of the SAGE II version 6.2 water vapor data set through intercomparison with ATMOS/ATLAS-3 measurements", *Geophys. Res. Lett.* **31**, L14101 (2004).
71. H. A. Michelsen, P. O. Witze, D. Kayes, and S. Hochgreb, "Time-resolved laser-induced incandescence of soot: The influence of experimental factors and microphysical mechanisms", *Appl. Opt.* **42**, 5577-5590 (2003).
70. H. A. Michelsen, "Understanding and predicting the temporal response of laser-induced incandescence from carbonaceous particles", *J. Chem. Phys.* **118**, 7012-7045 (2003).
69. F. W. Irion et al., "Atmospheric Trace Molecule Spectroscopy (ATMOS) Experiment Version 3 data retrievals", *Appl. Opt.* **41**, 6968-6979 (2002).
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66. H. A. Michelsen, "The reaction of Cl with CH₄: A connection between kinetics and dynamics", *Acc. Chem. Res.* **34**, 331-337 (2001).
65. H. A. Michelsen, "Carbon and hydrogen kinetic isotope effects for the reaction of Cl with CH₄: Consolidating chemical kinetics and molecular dynamics measurements", *J. Geophys. Res.* **106**, 12,267-12,274 (2001).
64. G. L. Manney, H. A. Michelsen et al., "Comparison of satellite ozone observations in coincident air masses in early November 1994", *J. Geophys. Res.* **106**, 9923-9943 (2001).
63. H. A. Michelsen and W. R. Simpson, "Relating state-dependent cross sections to non-Arrhenius behavior for the Cl+CH₄ reaction", *J. Phys. Chem. A* **105**, 1476-1488 (2001).
62. K. H. Rosenlof et al., "Stratospheric water vapor increases over the past half century", *Geophys. Res. Lett.* **28**, 1195-1198 (2001).
61. H. A. Michelsen, G. L. Manney, J. M. Russell III, P. N. Purcell, E. E. Remsberg, F. W. Irion, G. C. Toon, and M. R. Gunson, edited by D. Kley, *Stratospheric Processes and their Role in*

Climate: Water Vapor Assessment, World Climate Research Programme of WMO/ICSU/IOC, WCRP-113, WMO/TD-1043, Chapters 1.3.4, 2.3.4, and 2.4.1 (2000).

60. H. A. Michelsen, F. W. Irion, G. L. Manney, G. C. Toon, and M. R. Gunson, "Features and trends in Atmospheric Trace Molecule Spectroscopy (ATMOS) Version 3 water vapor and methane measurements", *J. Geophys. Res.* **105**, 22,713-22,724 (2000).
59. A. McIlroy, T. D. Hain, H. A. Michelsen, and T. A. Cool, "A laser and molecular beam mass spectrometer study of low-pressure dimethyl ether flames", *Proc. Combust. Inst.* **28**, 1647-1653 (2000).
58. G. L. Manney, H. A. Michelsen, F. W. Irion, G. C. Toon, M. R. Gunson, and A. E. Roche, "Lamination and polar vortex development in fall from ATMOS long-lived trace gases observed during November 1994", *J. Geophys. Res.* **105**, 29,023-29,038 (2000).
57. C. R. Webster, H. A. Michelsen et al., "Response of lower stratospheric HCl/Cl_v to volcanic aerosol: Observations from aircraft, balloon, space shuttle, and satellite instruments", *J. Geophys. Res.* **105**, 11,711-11,719 (2000).
56. H. A. Michelsen et al., "Maintenance of high HCl/Cl_v and NO_v/NO_y in the Antarctic vortex: A chemical signature of confinement during spring", *J. Geophys. Res.* **104**, 26,419-26,436 (1999).
55. G. L. Manney, H. A. Michelsen, M. L. Santee, M. R. Gunson, A. E. Roche, and N. J. Livesey, "Polar vortex dynamics during spring and fall diagnosed using trace gas observations from the Atmospheric Trace Molecule Spectroscopy instrument", *J. Geophys. Res.* **104**, 18,841-18,866 (1999).
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53. H. A. Michelsen et al., "Intercomparison of ATMOS, SAGE II, and ER-2 observations in Arctic vortex and extra-vortex air masses during spring 1993", *Geophys. Res. Lett.* **26**, 291-294 (1999).
52. H. Jost, M. Loewenstein, L. Pfister, J. J. Margitan, A. Y. Chang, R. J. Salawitch, and H. A. Michelsen, "Laminae in the tropical middle stratosphere: Origin and age estimation", *Geophys. Res. Lett.* **25**, 4337-4340 (1998); correction *Geophys. Res. Lett.* **26**, 479 (1999).
51. H. A. Michelsen, "A parameterization for the activity of H⁺ in aqueous sulfuric acid solutions", *Geophys. Res. Lett.* **25**, 3571-3573 (1998).
50. R. J. Barnes, A. Sinha, and H. A. Michelsen, "Assessing the contribution of the lowest triplet state to the near UV absorption spectrum of HOCl", *J. Phys. Chem. A* **102**, 8855-8859 (1998).
49. H. A. Michelsen, G. L. Manney, M. R. Gunson, and R. Zander, "Correlations of stratospheric abundances of NO_x, O₃, N₂O, and CH₄ derived from ATMOS measurements", *J. Geophys. Res.* **103**, 28,347-28,359 (1998).
48. H. A. Michelsen, G. L. Manney, M. R. Gunson, C. P. Rinsland, and R. Zander, "Correlations of stratospheric abundances of CH₄ and N₂O derived from ATMOS measurements", *Geophys. Res. Lett.* **25**, 2777-2780 (1998).
47. R. L. Herman et al., "Tropical entrainment time scales inferred from stratospheric N₂O and CH₄ observations", *Geophys. Res. Lett.* **25**, 2781-2784 (1998).

46. C. R. Webster et al., "Evolution of HCl concentrations in the lower stratosphere from 1991 to 1996 following the eruption of Mount Pinatubo", *Geophys. Res. Lett.* **25**, 995-998 (1998).
45. C. P. Rinsland et al., "ATMOS/ATLAS 3 infrared profile measurements of trace gases in the November 1994 tropical and subtropical upper troposphere", *J. Quant. Spectrosc. Radiat. Transfer* **60**, 891-901 (1998).
44. C. P. Rinsland et al., "ATMOS/ATLAS 3 infrared profile measurements of clouds in the tropical and subtropical upper troposphere", *J. Quant. Spectrosc. Radiat. Transfer* **60**, 903-919 (1998).
43. S. J. Gulding, A. M. Wodtke, H. Hou, C. T. Rettner, H. A. Michelsen, and D. J. Auerbach, "Alignment of D(v, J) desorbed from Cu(111): Low sensitivity of activated dissociative chemisorption to approach geometry", *J. Chem. Phys.* **105**, 9702-9705 (1996) DOI: 10.1063/1.472979.
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40. M. M. Abbas et al., "The hydrogen budget of the stratosphere inferred from ATMOS/ATLAS 3 measurements of H₂O and CH₄", *Geophys. Res. Lett.* **23**, 2405-2408 (1996).
39. M. C. Abrams et al., "On the assessment and uncertainty of atmospheric tracer gas burden measurements with high-resolution infrared solar occultation spectra from space by the ATMOS experiment", *Geophys. Res. Lett.* **23**, 2337-2340 (1996).
38. M. C. Abrams et al., "ATMOS/ATLAS 3 observations of long-lived tracers and descent in the Antarctic vortex in November 1994", *Geophys. Res. Lett.* **23**, 2345-2348 (1996).
37. M. C. Abrams et al., "Trace gas transport in the Arctic vortex inferred from ATMOS ATLAS 2 observations during April 1993", *Geophys. Res. Lett.* **23**, 2341-2344 (1996).
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